11th International Meeting on Statistical Climatology
July 12-16, 2010
Edinburgh, Scotland

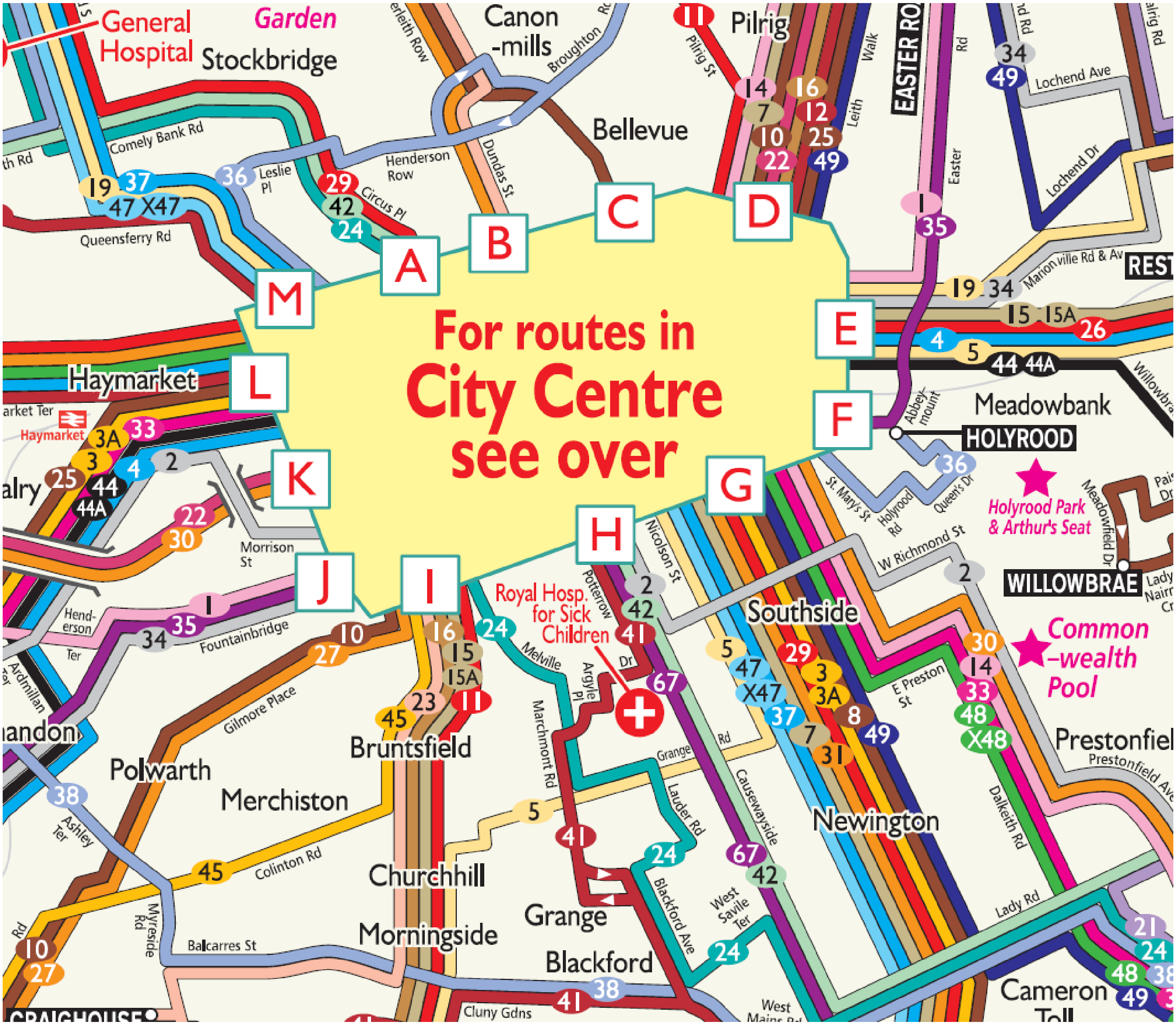
Program & Abstracts

Organized by
University of Edinburgh and
International Meetings on
Statistical Climatology Steering Committee

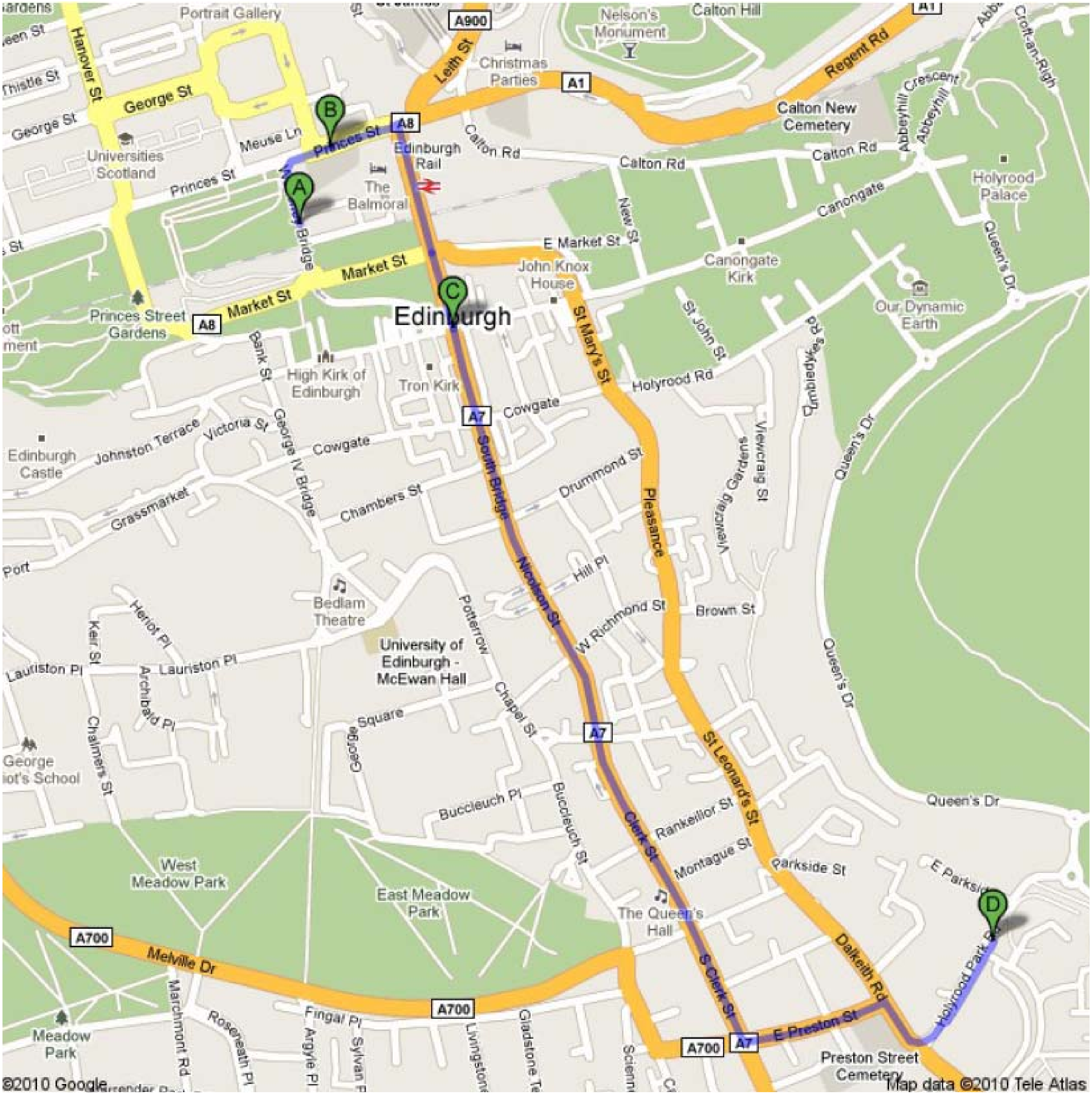
SAGES ICMS Centre for Earth System Dynamics National Centre for Atmospheric Science NATURAL ENVIRONMENT RESEARCH COUNCIL

Bus map of city centre

Bus map of outside the city

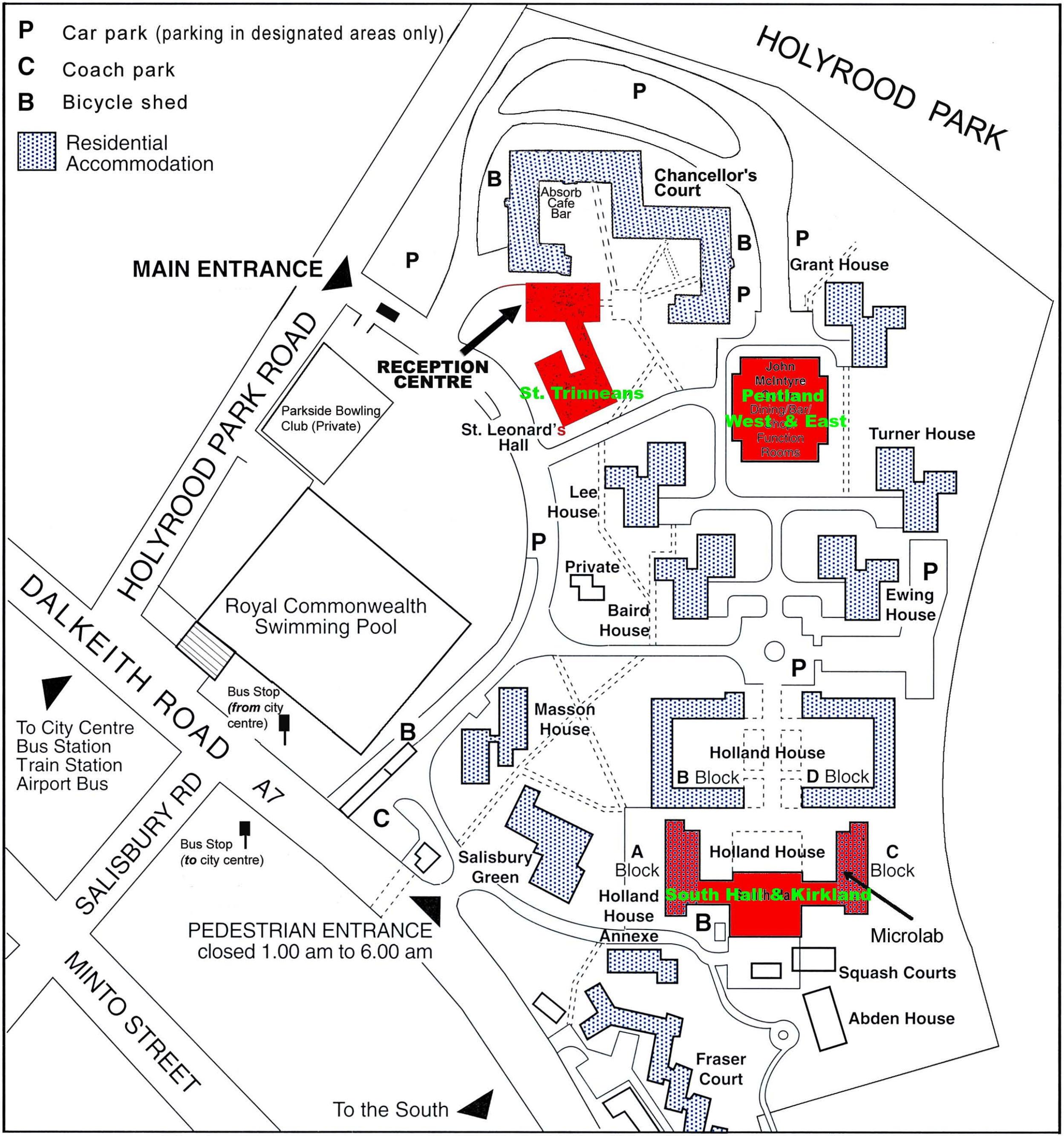


Edinburgh Centre to Pollock Halls



A. Waverly Train Station AND stop of the AIRLINK
B. Tourist Information
C. Royal Mile
D. Conference Center Pollock Halls

Airlink leaflet


P Car park (parking in designated areas only)
C Coach park
B Bicycle shed
Residential Accommodation
HOLYROOD PARK
Chancellor's Court
Absorb Cafe Bar
Grant House
MAIN ENTRANCE
RECEPTION CENTRE
St. Trinneans
St. Leonard's Hall
John McIntyre
Pentland West & East
Dining/Bar/
Function Rooms
Turner House
Parkside Bowling Club (Private)
HOLYROOD PARK ROAD
Lee House
Private
Baird House
Ewing House
Royal Commonwealth Swimming Pool
DALKEITH ROAD
Bus Stop (*from* city centre)
Masson House
Holland House
B Block
D Block
To City Centre
Bus Station
Train Station
Airport Bus
A7
SALISBURY RD
Bus Stop (*to* city centre)
Salisbury Green
A Block
Holland House
C Block
South Hall & Kirkland
Microlab
Holland House Annexe
PEDESTRIAN ENTRANCE
closed 1.00 am to 6.00 am
Squash Courts
Abden House
MINTO STREET
Fraser Court
To the South

Tips and advice for travelling in Edinburgh

1. The emergency number of the UK is **999**.
2. It is safest to call a taxi by phone. In some cases, you might be lucky to wave one but that does not always work. Taxi telephone numbers are, for example, **0044 131 229 2468** and **0044 131 272 8000**.
3. From the airport, the airlink bus service is relatively fast, and quite cheap. It drops downtown next to the Waverley Railway Station, and leaves frequently.
4. If you are at a bus stop waiting for a bus, it can be necessary to wave to the approaching but to make it realize you are interested in boarding it. Bus numbers **14**, **30**, **33** and **48** stop closest to Pollock Halls. Bus maps for the city centre and outside the city are provided below.
5. There is a map with the most important places, the Pollock Halls, train station, Royal Mile and the Airlink stop, are marked. A more detailed Airlink map provided as well.
6. Lastly www.visitscotland.com is a great homepage for tourist attractions.

Places to eat near Pollock Halls of Residence, Edinburgh

Absorb Café (within Pollock Halls)	Serves a variety of snacks and drinks
JMCC Restaurant (within Pollock Halls)	Open for breakfast, lunch and dinner (until 19.30)
The Sandwich Shop Old Dalkeith Road	Opposite the Commonwealth Pool Take-away sandwiches etc
Reverie Bar 1-5 Newington Road http://thereverie.co.uk/	Lunches, snacks, evening meals Live music some evenings Worth a visit
Yak and Yeti 13 Newington Road http://www.yak-yeti.co.uk/	Nepalese restaurant and take-away Good food!
Wild Elephant Restaurant 21 Newington Road	Thai restaurant with a good reputation
Metropole Café 29-33 Newington Road	Coffee shop, open for lunches and snacks Relaxed atmosphere and 'shabby chic'
Il Positano Pizzeria 85-87 Newington Road http://www.ilpositanorestaurant.co.uk/	Italian restaurant, open for lunch and dinner
Voujon 107 Newington Road http://www.voujonedinburgh.co.uk/	Bengali and Indian Restaurant Popular Bangladeshi and Northern Indian cuisine
Gabbro at the Salisbury Hotel 43-45 Salisbury Road http://www.the-salisbury.co.uk/gabbro-restaurant/	Café style menu, open for 'Quick Bites' Lunches and evening snacks
Olive Café and Take-away 18 South Clerk Street	Small, popular Mediterranean café Vegan and vegetarian meals, fair-trade
Hellers Kitchen 15 Salisbury Place http://www.hellerskitchen.co.uk/	Great for lunches. Also does evening meals
Vincent Café 5 Salisbury Place	Coffee shop and snacks. Ideal for quick lunch.
Hanedan Turkish 41 West Preston Street http://www.hanedan.co.uk/	Authentic Turkish cuisine. Open for lunches and dinner.

Information for Presenters:

for poster presenters:

*) We would like the posters to be printed in DIN A0 landscape (1189mm (width) x 841mm (height))

*) The posters are to be hung up in the morning PRIOR to the invited session

*) The poster presenters will be asked to come on stage together during a brief introduction of the poster titles by the session organizer/ chair at the end of the morning session. (NO presentation needed)

*) We plan to make posters available online as pdfs after the meeting if you provide a pdf of your poster during the meeting.

for oral presenters:

*) Please upload your presentation to the computer in the presentation room well before your session starts at the very latest, IDEALLY, on the day before. Upload t*o the central computer in South Hall*

*) Please name your presentation *'yourname_sessionx.ppt or pdf* eg smith_session4.pdf if you are allocated to session 4–, and 'yourname_sessionx_invited.ppt if you are an invited speaker. This will help us a lot. DONT name it imsc.ppt please – we can rename, but time is tight.

*) Your presentation should be no more than 80% of the allotted timeslot (eg 12 minutes if slot is 15 minutes, ~15 if 20 minutes, 20 if 25 minutes, we recommend no more than 15 slides for contributed presentations).

*) Please leave the remaining time for questions. We are not able to let talks run over time, so if you use all the time, there will be no time for questions, which would be a pity.

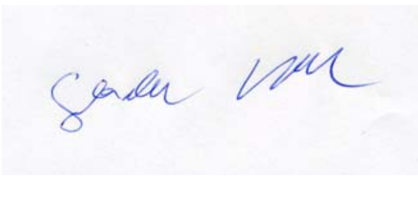
*) We plan to make presentations available online as pdfs after the meeting. If you would rather not have your presentation available online, we will give you an opportunity to object later, but it would be helpful to know on upload (for example, you could name your presentation as Jones_noupload.ppt if your name is Jones in that case.)

Dear Participants,

Welcome to the 11^{th} International Meeting on Statistical climatology, which is the 11^{th} meeting since the first IMSC meeting in 1979 in Tokyo, Japan. Since then, meetings have been held at intervals of about 3-4 years in many locations worldwide, with the goal of ‘promotion of good statistical practice in the atmospheric and climate sciences and in maintaining and enhancing the lines of communication between the atmospheric and statistical science communities.’ This goal has been served very well by interdisciplinary IMSC meetings over the years, and the importance of this goal, if anything, has increased since. We have all witnessed the call for stronger interaction between statistics and climate science, and not all calls seem to have been aware of this long tradition of collaboration and cross-fertilization. Climate science needs statistics, since climate is per se a statistical description of weather variability and means. Close interaction with statistics helps using the most appropriate tools, and particularly helps to use modern tools to describe uncertainty fully, rigorously and elegantly. On the other hand, statistics benefits from exposure to interesting questions coming from climate science. At this meeting, you will hear, for example, about questions of reconstructing past climate, and the statistical tools suitable to describe noisy proxy-climate relationships; about methods to reconstruct patterns of climate variations in instrumental times, methods to homogenize and quality control climate data; to use multi-model data fully and rigorously for predictions; to design experiments, methods to evaluate predictions; describe changes in extremes; low-frequency climate variability; and methods to base predictions on observed changes.

I wish to thank the International Centre for Mathematical Sciences (ICMS) for their support of the session on reconstructing Holocene climate, and particularly Audrey Brown and Irene Moore for their help with logistics and their extremely useful advice. I also thank the National Center of Atmospheric Science (NCAS), and the Center for Earth System Dynamics, which is part of the Scottish Alliance for GeoSciences, the Environment and Society, SAGES, for support in many important ways (not least underwriting). The meeting could not have happened without the organizational skills of my graduate student, Simone Morak, and without Stephanie West at SAGES, Edinburgh, and co-op student Rodney Chen at Environment Canada, Toronto. Thanks also to the session organizers, who helped make this a really exciting program, and apologies to everybody for the errors in program drafts– many found, but I am sure there are remaining ones.

Last not least, I hope you have an opportunity to see a bit of beautiful Edinburgh, and have a chance to go out to the Highlands and the west coast. Having moved myself here only recently, I am amazed by Scotland’s beauty, and its long scientific tradition. *Failte gu Alba, tha mi 'n dochas gum bidh spors againn*. (Phonetically - Falche goo Alba, ha me n dochas goom be spors ackainn); which I am told (by my kids’school, thanks!) means welcome to Scotland, I wish you a good time!



Gabi Hegerl, Edinburgh, June 29, 2010

11 IMSC Session Program Overview

	Monday	Tuesday	Wednesday	Thursday	Friday
08:00-08:30	Registration - South Hall Foyer Welcome by program chair, at 8:50 Gabi Hegerl	Registration - South Hall Foyer	Registration - South Hall Foyer	Registration - South Hall Foyer	Registration - South Hall Foyer
08:30-09:00		3 - South Hall	10 - South Hall	1 - South Hall	6 - South Hall
09:00-09:30	4 - South Hall				
09:30-10:00					
10:00-10:30		Coffee Break - Pentland			Coffee Break - Pentland
10:30-11:00	Coffee Break - Pentland	3 - South Hall 8 - South Hall	Coffee Break - Pentland	Coffee Break - Pentland	7 - South Hall
11:00-11:30	9 - South Hall		5 - South Hall	2 - South Hall	
11:30-12:00		Poster Introduction - South Hall			
12:00-12:30		Lunch			
12:30-13:00	Lunch		Lunch	Lunch	Poster Introduction - South Hall
13:00-13:30					Lunch
13:30-14:00	Poster 4, 9 - Pentland with coffee and desserts	Poster 3, 8, 10 - Pentland with coffee and desserts	5b South Hall / 2 Kirkland / 11 St Trinneann	2 Kirkland / 7 South Hall / 10 St Trinneann	
14:00-14:30					Poster 7 - Pentland with coffee and desserts
14:30-15:00	4 South Hall / 9 Kirkland / 3 St Trinneann	3 Kirkland / 5 South Hall / 8 St Trinneann		Pentland	
15:00-15:30			Coffee Break - Pentland	Coffee Break - / 6 St Trinneann	7 South Hall / 6 Kirkland / 1 St Trinneann
15:30-16:00			5b South Hall / 2 Kirkland / 11 St Trinneann	2 Kirkland / 7 South Hall	
16:00-16:30	Coffee Break - Pentland	Coffee Break - Pentland			
16:30-17:00	4 South Hall / 5 Kirkland / 3 St Trinneann	3 Kirkland / 5 South Hall / 8 St Trinneann	Poster Introduction - South Hall	Poster Introduction - South Hall	Coffee Break - Pentland
17:00-18:30			Poster 5, 11 - Pentland with drinks and nibbles	Poster 1, 2, 6 - Pentland with drinks and nibbles	7 South Hall / 6 Kirkland
17:30-18:00					
18:00+	Sponsored dinner for Session 3 ICMS only	IMSC dinner and Ceilidh	Royal Society meeting on Holocene		

Note – Late abstracts may not have been included in the Session Program yet

Session 1
Ensemble techniques: design (*Richard Chandler, Marian Scott*)

Session 2
Evaluation and uncertainty estimation from multimodel and perturbed physics ensembles (*Reto Knutti*)

Session 3
International Centre for Mathematical Sciences Special Session: Reconstructing and understanding climate over the Holocene (*Gabi Hegerl, Jonathan Rougier, Juerg Luterbacher*)

Session 4
Historical reconstructions of climate fields based on instrumental observations (*Alexey Kaplan and members of GCOS SST/SI Working Group*)

Session 5
Predictions of climate change relevant for impacts (*Xuebin Zhang, Bruce Hewitson*)

Session 6
Using observations to constrain and verify climate predictions (*Francis Zwiers, Nathan Gillett, Peter Guttorp*)

Session 7
Extreme events and event attribution (*Matilde Rusticucci, Peter Stott, Doug Nychka*)

Session 8
Climate Data Homogenization and Climate trend/Variability Assessment (*Xiaolan Wang*)

Session 9
Bayesian statistics for climate research (*Seung-Ki Min, Jonathan Rougier*)

Session 10
Long term memory (*Peter Guttorp and Peter Craigmile*)

Session 11
Forecast Verification (*David Stephenson, Ian Jolliffe*)

Monday, July 12, 2010

Plenary Session

08:50 – 09:00 **Welcome by program chair, Gabi Hegerl**

09:00 – 10:40 **Session 4 - South Hall** (20 min talk + 5 min discussion)

Historical reconstructions of climate fields based on instrumental observations (*Alexey Kaplan and members of GCOS SST/SI Working Group*)

Chair: Alexey Kaplan

09:00 – 09:25 *N. A. Rayner* - Practical implementation of statistical reconstruction methods in a non-ideal world

09:25 – 09:50 *Michael N. Evans* - Are there lessons for historical climate field reconstruction from paleoclimatology?

09:50 – 10:15 *Mark A Bourassa* - Issues regarding the construction of satellite and in situ gridded data sets for ocean surface winds and fluxes

10:15 – 10:40 *Ricardo T. Lemos and Bruno Sansó* **-** HOMER: A hierarchical ocean model for extended reconstructions

10:40 – 11:00 **Coffee Break - Pentland**

11:00 – 12:30 **Session 9 - South Hall**

Bayesian statistics for climate research (*Seung-Ki Min, Jonathan Rougier*)

Chair: Seung-Ki Min

11:00 – 11:30 *Pao-Shin Chu* - Bayesian analysis for extreme events

11:30 – 12:00 *Armin Haas* - Softcore and hardcore Bayesianism in climate research

12:00 – 12:30 *Jonathan Rougier* - A new statistical framework for analysing multi-model ensembles

12:30 – 13:45 **Lunch**

Poster Session

13:45 – 14:45 - Poster Session (15)

Poster Session 4 - Pentland

Historical reconstructions of climate fields based on instrumental observations (*Alexey Kaplan and members of GCOS SST/SI Working Group*)

1. *John Kennedy and Nick Rayner* - Towards the new version of the Hadley Centre SST and sea ice data set - HadISST2
2. *David I. Berry and Elizabeth C. Kent* - New approaches to the construction of gridded datasets for air-sea interaction
3. *B. Meyssignac, A. Cazenave, R. Morrow, F. M. Calafat, M. Marcosa and W. Llovel presented by M.* Becker- Past sea level reconstruction and variability of

sea level trend patterns over 1970-2001 in the Mediterranean Sea basin derived from Altimetry and 2 long OGCM runs

4. *Jean-Philippe Vidal, Eric Martin, Laurent Franchistéguy, Martine Baillon and Jean-Michel Soubeyroux* - Uncertainties in the Safran 50-year atmospheric reanalysis over France
5. *Lucie Pokorná and Radan Huth* - Different definitions of the North Atlantic oscillation index: A comparison of their effects on surface climate elements in Europe
6. *Sayaka Yasunaka, Masayoshi Ishii, Masahide Kimoto, Takashi Mochizuki and Hideo Shiogama* - Impact of XBT depth bias correction on decadal climate prediction
7. *Xiaoshu Lu and Esa-Pekka Takala* - Structural modelling of nonlinear exposure-response relationships for longitudinal data
8. *Xiaoshu Lu* - A functional relationship model for simultaneous data series

Poster Session 9 - Pentland

Bayesian statistics for climate research (*Seung-Ki Min, Jonathan Rougier*)

1. *Edward P. Campbell and Mark J. Palmer* - Modeling and forecasting climate variables using a physical-statistical approach
2. *T. Hauser, L. Tarasov, A. Keats and E. Demirov* - Artificial neural network assisted Bayesian calibration of the planet simulator general circulation model
3. *Steve Jewson, Dan Rowlands and Myles Allen* - Probabilistic forecasts of future climate based on an objective Bayesian approach using Jeffreys' Prior
4. *Malaak Kallache, Elena Maksimovich, Paul-Antoine Michelangeli and Philippe Naveau* - Multi-model combination by a Bayesian hierarchical model: Assessment of ice accumulation over the oceanic Arctic region
5. *Jenny Lannon* - A hierarchical model for Hydrologically Effective Rainfall and Soil Moisture Deficit
6. *Lindsay Collins and Clive Anderson* - Climate variability and its effect on the terrestrial biosphere

Parallel Session (4 parts)

14:45 – 18:00 Part 1 - Session 4 - South Hall

Historical reconstructions of climate fields based on instrumental observations (*Alexey Kaplan and members of GCOS SST/SI Working Group*)

Chair: Bruno Sansó

14:45 – 15:00	*Jonah Roberts-Jones, Emma Fiedler and Matthew Martin* - OSTIA reanalysis: A high resolution SST and sea-ice reanalysis
15:00 – 15:15	*Aida Alvera-Azcárate, Alexander Barth and Jean-Marie Beckers* - Reconstruction of missing data in satellite and in situ data sets with DINEOF (Data Interpolating Empirical Orthogonal Functions)

15:15 – 15:30	*Alicia R. Karspeck, Alexey Kaplan and Stephan Sain* - Modeling and prediction of mid-scale spatial variability in historic Northern Hemisphere Atlantic sea surface temperatures
15:30 – 15:45	*Alexander Ilin and Jaakko Luttinen* - Variational Gaussian-process factor analysis for modeling spatio-temporal data
15:45 – 16:00	*Sayaka Yasunaka and Kimio Hanawa* - Intercomparison of historical sea surface temperature datasets
16:00 – 16:15	*John Kennedy, Robert Smith and Nick Rayner* - Assessing the relative importance of bias uncertainty, structural uncertainty and random errors in SST data sets

16:15 – 16:45 Coffee Break - Pentland

Chair: Nick Rayner

16:45 – 17:00	*Jean-Marie Beckers, Charles Troupin, Mohamed Ouberdous, Aida Alvera-Azcárate and Alexander Barth* - Gridding of in situ data using DIVA to produce climatologies
17:00 – 17:15	*Yoshikazu Fukuda, Shoji Hirahara and Masayoshi Ishii* - An approach for reconstructing historical global monthly sea surface temperatures
17:15 – 17:30	*R. D. Ray and B. C. Douglas* - Reconstruction of global sea levels over the 20th century
17:30 – 17:45	*Thomas M. Smith and Phillip A. Arkin* - Reconstruction of near-global precipitation variations based on gauges and correlations with SST and SLP
17:45 – 18:00	*Achan Lin and Xiaolan L. Wang* - A new algorithm for blending satellite precipitation estimates with in-situ precipitation measurements over Canada

14:45 – 16:45 Part 2 - Session 9 - Kirkland

Bayesian statistics for climate research (*Seung-Ki Min, Jonathan Rougier*)

Chair: Jonathan Rougier

14:45 – 15:05	*S. Mieruch, S. Noël, M. Reuter, H. Bovensmann, J. P. Burrows, M. Schröder and J. Schulz* - A Bayesian method for the comparison of trend data and application to water vapour
15:05 – 15:25	*Markus Huber and Reto Knutti* - Assessing climate system properties and projections within the perfect model approach using a statistical emulator
15:25 – 15:45	*A. M. Fischer, C. Buser, A. P. Weigel, M. A. Liniger and C. Appenzeller* - Climate change projections for Switzerland: A Bayesian multi-model combination using ENSEMBLES regional climate models
15:45 – 16:05	*Martin P. Tingley* - Bayesian ANOVA for the calculation of climate anomalies

16:15 – 16:45 **Coffee Break - Pentland**

14:45 – 17:52 **Part 3 - Session 3 - St Trinneann** (15 minutes talk + 3 minutes discussion)

International Centre for Mathematical Sciences Special Session: Reconstructing and understanding climate over the Holocene (*Gabi Hegerl, Jonathan Rougier, Juerg Luterbacher*)

Chair: Gabi Hegerl

14:45 – 15:03 *Caitlin Buck* - Changing the focus: Studying uncertainty in palaeoclimate reconstruction

15:03 – 15:21 *Andrew C. Parnell and John Haslett* - The use of chronologies in Holocene palaeoclimate reconstruction

15:21 – 15:39 *Christian Schoelzel and Eugene Wahl* - Probabilistic model for palaeo temperature reconstructions based on pollen ratios

15:39 – 15:57 *Susan E. Tolwinski-Ward, Michael N. Evans, Malcolm K. Hughes and Kevin J. Anchukaitis* - Mechanistic modeling of proxy data for Bayesian climate reconstructions

15:57 – 16:15 *Vincent Garreta and Joël Guiot* - Process-based reconstruction of palaeoclimate from pollen data

16:15 – 16:45 **Coffee Break - Pentland**

Chair: Juerg Luterbacher

16:45 – 17:03 *Ailie Gallant, Joelle Gergis and Karl Braganza* - Quantifying uncertainties associated with calibrating proxy data against instrumental records – an ensemble approach

17:03 – 17:21 *Thomas Crowley* - An unforced decadal-scale oscillation in the 1400s

17:21 – 17:39 *Frank Kwasniok and Gerrit Lohmann* - Deriving dynamical models of glacial millennial-scale climate variability from ice-core records: parameter estimation, model performance and model selection

16:45 – 18:00 **Part 4 - Session 5 - Kirkland**

Predictions of climate change relevant for impacts (*Xuebin Zhang, Bruce Hewitson*)

Chair: Xuebin Zhang

16:45 – 17:00 *Bryson C. Bates, Richard E. Chandler, Stephen P. Charles and Edward P. Campbell* - Assessment of apparent non-stationarity in time series of annual inflow, daily precipitation and atmospheric circulation indices: A case study from Southwest Western Australia

17:00 – 17:15 *Juan Feng, Jianping Li and Yun Li* - A new monsoon-*like* Southwest Australian circulation index explains rainfall decline in Southwest Western Australia

17:15 – 17:30	*Wenju Cai and Tim Cowan* - Using CMIP3 multi-models simulations to understand the relationship between large-scale climate drivers
17:30 – 17:45	*Daniel Mitchell* - Extreme variability of the stratospheric polar vortex
17:45 – 18:00	*Tim Cowan and Wenju Cai* - Recent unprecedented skewness towards more positive Indian Ocean Dipole occurrences and its impact on regional climate

Evening

Sponsored dinner for Session 3 ICMS only

Tuesday, July 13, 2010

Plenary Session

08:30 – 10:10 **Session 3 - South Hall** (20 mins talk + 5 mins discussion)

International Centre for Mathematical Sciences Special Session: Reconstructing and understanding climate over the Holocene (*Gabi Hegerl, Jonathan Rougier, Juerg Luterbacher*)

Chair: Jonathan Rougier

08:30 – 08:55 *Heinz Wanner* - Holocene climate change – facts and mysteries

08:55 – 09:20 *John Haslett* - Uncertainties in palaeoclimate reconstruction – sampling ensembles for the younger dryas

09:20 – 09:45 *Michael E. Mann* - Global signatures of the "Little Ice Age" and "Medieval Climate Anomaly" and plausible dynamical origins

09:45 – 10:10 *Timothy J. Osborn, Douglas Maraun, Sarah C.B. Raper and Keith R. Briffa* - How good do palaeoclimate reconstructions of last 1000 years need to be to usefully constrain climate model parameters?

10:10 – 10:40 **Coffee Break - Pentland**

10:40 – 11:20 **Session 3 - South Hall** (20 mins talk + 5 mins discussion)

International Centre for Mathematical Sciences Special Session: Reconstructing and understanding climate over the Holocene (*Gabi Hegerl, Jonathan Rougier, Juerg Luterbacher*)

Chair: Gabi Hegerl

10:40 – 11:05 *Mary Edwards and Heather Binney* - Use of pollen data to investigate past climates: Spatial and ecological sources of uncertainty

11:05 – 11:20 *Francis Zwiers* - Discussion of use of statistical methods in palaeoreconstructions (15 minutes discussion)

11:20 – 11:50 **Session 8 - South Hall**

Climate Data Homogenization and Climate trend/Variability Assessment (*Xiaolan Wang*)

Chair: Xiaolan Wang

11:20 – 11:50 *Reinhard Böhm* - Bridging the gap from indirect to direct climate data – experience with homogenizing long climate time series in the early instrumental period

11:50 – 12:00 **Introduction to posters - South Hall**

Introduction to poster sessions 3, 10 and 8 (session chairs to give list of posters with titles, grouped by topic; and poster presenters to go on stage, raising hand when their title mentioned).

12:00 – 13:30 **Lunch**

Poster Session

13:30 – 14:30 **Poster Session** (27)

Poster Session 3 - Pentland

International Centre for Mathematical Sciences Special Session: Reconstructing and understanding climate over the Holocene (*Gabi Hegerl, Jonathan Rougier, Juerg Luterbacher*)

1. *Christoph Matulla, Roland Psenner and Roland Schmidt* - Climate change within the Eastern European Alps through the past 20ka as derived from different data
2. *Stig Uteng, Dmitry Divine, Håvard Rue and Fred Godtliebsen* - A Bayesian approach to the reconstruction of surface air-temperature from ice-core data
3. *Richa Vatsa, Simon Wilson and John Haslett* - The Variational Bayes approximation for the palaeoclimate reconstruction problem
4. *Per Arnqvist, Christian Bigler, Amitava Mukherjee, Ingemar Renberg and Sara Sjöstedt-de Luna* – A statistical method to analyse varved lake sediments with respect to reconstruction of past environment and climate change
5. *Peter Green* - Calibrating pseudoproxies
6. *James Sweeney and John Haslett* - Approximate joint statistical inference for large spatial datasets
7. *Vladimir A. Lobanov, Svetlana A. Gorlova and Anton Ye. Shadursky* - Analysis of past climate fluctuations and comparison with modern climate change
8. *Daniel Peavoy* - Statistical analyses of the abrupt temperature increases of the last interglacial
9. *Michael Salter-Townshend and John Haslett* - Fast inversion of a flexible regression model for multivariate pollen counts data
10. *Mathew Schofield* - No title provided
11. *Peter Thejll* - Considering the effect of residual structure on the performance of climate reconstruction methods - the Cochrane-Orcutt method

Poster Session 8 - Pentland

Climate Data Homogenization and Climate trend/Variability Assessment (*Xiaolan Wang*)

1. *Mojgan Afshar and Fardin Saberi Louyeh* - The survey of the weather quality frequencies and determining the heat islands in Tehran
2. *Fardin Saberi Louyeh and Mojgan Afshar* - The effect of climate change on bioclimatic in the north and west of Iran
3. *Peter Domonkos and Rafael Poza* - Detecting seasonal cycle of inhomogeneities in observed temperature time series

4. *David Hanslian* - Measure-correlate-predict (MCP) methods used for extension of the short-term wind data series
5. *Marco Marinelli, Karl Braganza, Dean Collins, David Jones, Shoni Maquire, Catherine Ganter, Pandora Hope and Glenn Cook* - Improved climate data and monitoring for Western Australia to support the understanding of past, present and future climate
6. *S. Mieruch, S. Noël, H. Bovensmann and J. P. Burrows* - Trend evaluation including level shifts and overlapping data
7. *P. Stepanek* - Various methods for correction of inhomogeneities in daily time series on example of Central European datasets
8. *Tamás Szentimrey, Mónika Lakatos and Zita Bihari* - Methodological questions of data series comparison for homogenization
9. *Lucie A. Vincent and Ewa J. Milewska* - Bias in minimum temperature due to a redefinition of the climatological day at synoptic stations in Canada
10. *Enric Aguilar and Lucie A. Vincent* - Trends in daily and extreme temperature and precipitation indices for the countries of the Western Indian Ocean, 1975-2008

Poster Session 10 - Pentland

Long term memory (*Peter Guttorp and Peter Craigmile*)

1. *Albert R. Boehm* - Quantification of the effect of auto correlation and climate trends on record observations
2. *Alicia R. Karspeck, Caspar Ammann and Doug Nychka* - Assimilation of low-resolution paleo-proxies for spatial reconstruction of North American summertime climatology
3. *Vladimir A. Lobanov and Svetlana A. Gorlova* - Space-time stochastic modeling of climate changes
4. *Y. Markonis, D. Koutsoyiannis and N. Mamassis* - Orbital climate theory and Hurst-Kolmogorov dynamics
5. *Oleg Pokrovsky* - Non-linear trend technique to analyze non-stationary climate series
6. *Denis Gilbert* - Serial correlation in the water mass properties of the Gulf of St. Lawrence

Parallel Session (3 parts)

14:30 – 18:00 **Part 1 - Session 3 - Kirkland** (15 minutes talk)

International Centre for Mathematical Sciences Special Session: Reconstructing and understanding climate over the Holocene (*Gabi Hegerl, Jonathan Rougier, Juerg Luterbacher*)

Chair: Juerg Luterbacher

14:30 – 14:45 *Jonathon Rougier* - What can we learn about palaeo-biomes from pollen?

14:45 – 15:10	*Brian Huntley* - Reconstructing palaeoclimates from biological proxies: Some biological and chronological sources of uncertainty (20 minutes talk + 5 minutes discussion)
15:10 – 15:25	*Bo Christiansen* - Constructing a reconstruction method that does not underestimate low-frequency variability
15:25 – 15:40	*Alexey Kaplan, Jason E. Smerdon and Michael N. Evans* - Skill of climate field reconstruction methods in the context of optimal interpolation estimates
15:40 – 15:55	*Julie M. Jones, Ryan L. Fogt and Martin Widmann* - Historical Southern Hemisphere Annular Mode variability from statistical reconstructions and the IPCC AR4 simulations

16:00 – 16:30 Coffee Break - Pentland

Chair: Jonathan Rougier

16:30 – 16:45	*Michael N. Evans and Alexey Kaplan* - Coral-based, multiproxy, multicentury, ensemble climate field reconstructions of Pacific basin sea surface temperatures
16:45 – 17:00	*Julien Emile-Geay, Tapio Schneider, Diana Sima and Kim Cobb* - Variance-preserving, data-adaptive regularization schemes in RegEM. Application to ENSO reconstructions
17:00 – 17:15	*David Hirst* - A Bayesian hierarchical modelling approach to reconstructing past climates
17:15 – 17:30	*Elizabeth Mannshardt-Shamseldin, Peter Craigmile and Martin Tingley* - Paleoclimate extremes in proxy data
17:30 – 18:00	General discussion of statistical challenges in reconstruction methods (30 minutes)

14:30 – 18:00 Part 2 - Session 5 - South Hall

Predictions of climate change relevant for impacts (*Xuebin Zhang, Bruce Hewitson*)

Chair: Bruce Hewitson

14:30 – 15:00	*Colin Jones* - CORDEX: Developing an ensemble of high-resolution Regional Climate Change projections for the majority of land regions on the globe (**invited**, 30 minutes)
15:00 – 15:15	*E. Hertig and J. Jacobeit* - Downscaling future climate change using statistical ensembles
15:15 – 15:30	*Martin Widmann and Jonathan M. Eden* - Downscaling of GCM-simulated precipitation using Model Output Statistics
15:30 – 15:45	*Radan Huth, Stanislava Kliegrov and Ladislav Metelka* - Constructing ensembles of climate change scenarios based on statistical downscaling

15:45 – 16:00 *Aloke Phatak, Harri Kiiveri, Carmen Chan and Bryson Bates* - Statistical downscaling and modelling using sparse variable selection methods

16:00 – 16:30 Coffee Break - Pentland

Chair: Bruce Hewitson

16:30 – 16:45 *Edmondo Di Giuseppe, Giovanna Jona Lasinio, Stanislao Esposito and Massimiliano Pasqui* - A functional data approach for climate zones identification

16:45 – 17:00 *Arthur M. Greene* - Downscaling climate change projections of Indian summer monsoon rainfall using a nonhomogeneous hidden Markov model

17:00 – 17:15 *Chiara Ambrosino, Richard E. Chandler and Martin C. Todd* - Controls on rainfall variability on Southern Africa: An analysis based on generalized linear model

17:15 – 17:30 *Guilong Li, Xuebin Zhang and Francis Zwiers* - Construction of high resolution monthly temperature scenarios for North America

17:45 – 18:00 *Xiaogu Zheng, James Renwick and Anthony Clark* - Simulation of multisite precipitation using an extended chain-dependent process

14:30 – 17:45 Part 3 - Session 8 - St Trinneann

Climate Data Homogenization and Climate trend/Variability Assessment (*Xiaolan Wang*)

Chair: Xiaolan Wang

14:30 – 14:50 *Olivier Mestre, Victor Venema and COST-ES0601 "HOME" Task Force* - Intercomparison of homogenization procedures: Results of COST ES0601 HOME experiment (**invited**, 20 minutes)

14:50 – 15:10 *Richard Cornes* - The London and Paris daily pressure series, 1692-2007: The development and analysis of long pressure series (**invited**, 20 minutes)

15:10 – 15:30 *Manola Brunet* - Detecting and minimising the *screen bias* from long temperature series recorded over Western Mediterranean climates (**invited**, 20 minutes)

15:30 – 15:45 *Paula Brown and Art DeGaetano* - The influence of weather conditions on daily/hourly inhomogeneity adjustments

15:45 – 16:00 *Xiaolan L. Wang, Hanfeng Chen, Yuehua Wu, Yang Feng and Qiang Pu* - New techniques and software package for detection and adjustment of shifts in daily precipitation data series

16:00 – 16:30 Coffee Break - Pentland

Chair: Xiaolan Wang

16:30 – 16:45	*Peter Domonkos* - Short-term, platform-like inhomogeneities in observed climatic time series
16:45 – 17:00	*Alexis Hannart* - Homogenization of Argentinean temperature series with an automated Bayesian procedure
17:00 – 17:15	*Lucie A. Vincent and Xiaolan L. Wang* - New developments on the homogenization of Canadian daily temperature data
17:15 – 17:30	*Claudie Beaulieu and Jorge L. Sarmiento* - A change point approach for applications to atmospheric carbon dioxide time series
17:30 – 17:45	*Mercedes Andrade-Bejarano, Edinson Andrés Zuluaga, John Jairo Millán Hernández and Gabriel Conde Arango* - Generalised linear mixed models, for the modeling of monthly average temperature in a tropical weather

Evening

IMSC dinner and Ceilidh

Wednesday, July 14, 2010

Plenary Session

08:30 – 10:30 Session 10 - South Hall

Long term memory (*Peter Guttorp and Peter Craigmile*)

Chair: David Hirst

08:30 – 09:00 *Peter F. Craigmile* - The analysis of long memory climate series

09:00 – 09:30 *Armin Bunde, Sabine Lennartz and Mikhail Bogachev* - Linear and non linear persistence in climate and its effect on the extremes

09:30 – 10:00 *Demetris Koutsoyiannis* - Memory in climate and things not to be forgotten

10:00 – 10:30 *Peter Guttorp* - Discussion

10:30 – 11:00 Coffee Break - Pentland

11:00 – 12:30 Session 5 - South Hall

Predictions of climate change relevant for impacts (*Xuebin Zhang, Bruce Hewitson*)

Chair: Xuebin Zhang

11:00 – 11:30 *Dan Cooley* - A comparison study of extreme precipitation from six regional climate models via spatial hierarchical modeling

11:30 – 12:00 *B. Hewitson, W. Gutowski and R. Crane* - Blending analyses for building robust regional predictions

12:00 – 12:15 *Nicola Ranger, Falk Niehoerester and Leonard A. Smith* - Understanding the relevance of climate model simulations to informing policy: An example of the application of MAGICC to greenhouse gas mitigation policy (15 minutes)

12:15 – 12:30 *L. DeWayne Cecil, Alex C. Ruane, Radley M. Horton, Cynthia Rosenzweig, Peter A. Parker, Brian D. Killough, Ray McCollum and Doug Brown* - Expressing uncertainty in climate analysis – A pilot of climate impacts on Panamanian Maize (15 minutes)

12:30 – 13:30 Lunch

Parallel Session (3 parts)

13:30 – 16:45 Part 1 - Session 5b - South Hall

Statistical models for analysis of circulation (*Xuebin Zhang, Bruce Hewitson*)

Chair: Bruce Hewitson

13:30 – 13:45 *Heiko Paeth* - Statistical postprocessing of simulated precipitation – perspectives for impact research

13:45 – 14:00 *Jean-Philippe Vidal and Eric Sauquet* - Multimodel ensemble climate projections for the Garonne river basin, France

14:00 – 14:15 *A. Hannachi, T. Woollings and B. J. Hoskins* - Nonlinear circulation regimes and jet variability in the North Atlantic

14:15 – 14:30 *Radan Huth and Monika Cahynová* - Classifications of circulation patterns from the COST733 database: An assessment of synoptic-climatological applicability by two-sample Kolmogorov-Smirnov test

14:30 – 14:45 *Iratxe González and Julia Hidalgo* - A RCM bias correction method for climatic indices expressed in a daily based frequency applied to temperature projections of the North Iberian Peninsula

14:45 – 15:00 *Zuvelao Aloise Maja, Matulla Christoph, Lexer Manfred J., Scheifinger Helfried, Anders Ivonne, Auer Ingeborg and Böhm Reinhard* - Downscaling climate change simulations for impact assessment studies within the Alpine region

15:00 – 15:30 Coffee Break - Pentland

Chair: Xuebin Zhang

15:30 – 15:45 *Sebastian Wagner, Janina Koerper and Jonas Berking* - Statistical downscaling of precipitation of two transient Holocene AOGCM simulations for central Sudan

15:45 – 16:00 *Barbara Früh, Meinolf Kossmann and Marita Roos* - Impact of climate change on the heat load in Frankfurt am Main, Germany

16:00 – 16:15 *Charles Cuell* - Statistical support for ad-hoc observations in atmospheric synoptic typing

16:15 – 16:30 *Radley Horton, Alex Ruane and Cynthia Rosenzweig* - Comparison of downscaling methods for stakeholder applications in the urban Northeast U.S.

16:30 – 16:45 *Chris Lennard* - Statistical challenges for the Co-ordinated Regional Downscaling Experiment (COREX)

13:30 – 16:45 Part 2 - Session 2 - Kirkland

Evaluation and uncertainty estimation from multimodel and perturbed physics ensembles (*Reto Knutti*)

Chair: Reto Knutti

13:30 – 13:45 *Leonard A. Smith* - When is a model relevant?

13:45 – 14:00 *Wendy S. Parker* - Ensembles, metrics & probabilities

14:00 – 14:15 *Dan Rowlands, Steve Jewson and Myles Allen* - Objective approaches to probabilistic climate forecasting

14:15 – 14:30	*Amy Braverman, Noel Cressie, and Joao Teixeira* - A likelihood-based scoring method for the evaluation of climate model predictions
14:30 – 14:45	*Jouni Räisänen* - Weighting of model results for improving projections of climate change

15:00 – 15:30 Coffee Break - Pentland

Chair: Paul Northrop

15:30 – 15:45	*Natalia Andronova* - Climate scenario forecasting and related uncertainties
15:45 – 16:00	*Leonard A. Smith* - Are current flaws in Bayesian approaches to climate projection fatal?
16:00 – 16:15	*Qinqyun Duan and Thomas J. Phillips* - Bayesian estimation of local signal and noise in CMIP3 simulations of climate change
16:15 – 16:30	*Hideo Shiogama, Seita Emori, Naota Hanasaki, Manabu Abe, Yuji Masutomi, Kiyoshi Takahashi and Toru Nozawa* - Uncertainty propagation from climate change projections to impacts assessments: Water resource assessments in South America
16:30 – 16:45	*Lorenzo Tomassini, Jan O. Härter and Jin-Song von Storch* - Perturbed physics ensembles of GCM simulations: From slab ocean to coupled model experiments

13:30 – 16:30 Part 3 - Session 11 - St Trinneann

Forecast Verification (*David Stephenson, Ian Jolliffe*)

Chair: David Stephenson

13:30 – 13:50	*Christopher A. T. Ferro* - Verifying extreme weather events
13:50 – 14:10	*Laura Huang, George Isaac and Grant Sheng* - Generating verification metrics for optimal model selection from different NWP models in real time
14:10 – 14:30	*Ian Jolliffe and David Stephenson* - The metaverification minefield
14:30 – 14:50	*Thordis L. Thorarinsdottir and Tilmann Gneiting* - Ensemble model output statistics using heteroskedastic censored regression

15:00 – 15:30 Coffee Break - Pentland

Chair: Ian Jolliffe (General session on forecasting)

15:30 – 15:45	*Caio Coelho* - An intercomparison of multivariate regression methods for the calibration and combination of seasonal climate predictions
15:45 – 16:00	*Steve Jewson and Ed Hawkins* - Uncertain climate forecasts: When to use them, when to ignore them, and when and how to adjust them

16:00 – 16:15 *Richard W. Katz, Yongku Kim and Balaji Rajagopalan* - Use of hidden Markov models to assess predictability on annual to decadal time scales

16:15 – 16:30 *Ed Hawkins, A. N. Other, Len Shaffrey and Fiona Underwood* - Developing statistical climate forecasts for the coming decade

16:45 – 17:00 Introduction to posters - South Hall

Introduction to poster sessions 5 and 11 (session chairs to give list of posters with titles, grouped by topic; and poster presenters to go on stage, raising hand when their title mentioned).

Poster Session

17:00 – 18:00 Poster Session (29)

Poster Session 5 - Pentland

Predictions of climate change relevant for impacts (*Xuebin Zhang, Bruce Hewitson*)

1. *Judit Bartholy, Rita Pongrácz, Ildikó Pieczka and Csaba Torma* - Analysis of RCM simulations for the Carpathian basin for the 21st century
2. *Alessio Bozzo, Gabriele Hegerl and Simon Tett* - Volcanoes and climate: modelling the atmospheric circulation's response to volcanic aerosol forcing
3. *Zuzana Chládová* - Analysis of real data and data from regional climate models according to linear and non-linear statistical techniques in the Czech Republic and in Europe
4. *Aline de Holanda Nunes Maia and Emerson M. Del Ponte* - Statistical forecasting approaches to improve risk management in a changing climate
5. *Ruth Doherty* - No title provided
6. *Carlos Gaitan* - No title provided
7. *A. Hannachi* - Intermittency, autoregression and censoring: Application to daily precipitation
8. *Stanislava Kliegrova, Jiří Mikšovský, Petr Štěpánek and Ladislav Metelka* - Daily precipitation in the Czech Republic: Different methods for statistical correction of model results
9. *Ken-Chung Ko and Huang-Hsiung Hsu* - Statistical and dynamical impacts of the tropical cyclones on the summertime submonthly wave patterns over the Western North Pacific
10. *Ganna Leonenko* - TBA
11. *Gustavo Naumann and Walter M. Vargas* - Joint diagnostic of the surface air temperature in South America and Madden-Julian Oscillation
12. *Charles Ngenda* - No title provided
13. *Andreas Paxian, Gernot Vogt and Heiko Paeth* - Dynamical downscaling of future climate change in the Mediterranean region

14. *Jana Pechková, Petr Štěpánek, Jiří Mikšovský and Ladislav Metelka* - Statistical correction of daily precipitation from RCM in the Czech Republic and results for precipitation indices
15. *Eva Plavcová and Jan Kyselý* - Evaluating links between indices of atmospheric circulation and surface air temperature in control climate model simulations
16. *Felix Pollinger and Heiko Paeth* - Enhanced evidence in climate models for changes in extratropical atmospheric circulation
17. *Jacqueline Potts and Claus Dieter-Mayer* - Assessing the similarity between time series of two meteorological fields using the RV coefficient
18. *Radan Huth, Jiří Mikšovský, Petr Štěpánek, Zuzana Chládová and Lucie Pokorná* - A comparative extended validation of statistical downscaling and regional climate models
19. *Richard E. Chandler, Stephen P. Charles and Bryson C. Bates* - Water resources in South-west Western Australia: model uncertainty in climate change adaption
20. *F.Taghavi and A.Neyestani* - Wavelet and spectral analysis of precipitation variability over Iran
21. *Yun Li and Ian Smith* - A statistical downscaling model for Southern Australia winter rainfall
22. *Anton Ye. Shadursky and Vladimir A. Lobanov* - Understanding recent climate change in key regions of Russia
24. *Oleg M. Pokrovsky* - Impact of SST slow oscillations in North Atlantic and North Pacific on trends in global surface air temperature and Arctic ice extent for last 150 years
25. *Hofstatter Michael, Matulla Christoph* and *Wang Jiafeng* - Scenarios of daily extreme precipitation under climate change
26. *Heikki Haario, Erkki Oja, Alexander Ilin, Heikki Järvinen and Johanna Tamminen* - Novel advanced mathematical and statistical methods for understanding climate (NOVAC)

Poster Session 11 - Pentland

Forecast Verification (*David Stephenson, Ian Jolliffe*)

1. *Raymond W. Arritt for the MRED Team* - Skill in large ensembles of downscaled seasonal forecasts
2. *Elisabeth Orskaug, Ola Haug, Ida Scheel and Arnoldo Frigessi* - A validation suite for downscaled climate model data
3. *Theodoros Mavromatis and Ioannis Pytharoulis* - Evaluating the skill in predicting crop yield using an ensemble climate forecast by a regional climate model

Evening

Royal Society meeting on Holocene

Thursday, July 15, 2010

Plenary Session

08:30 - 10:30 **Session 1 - South Hall**

Ensemble techniques: design (*Richard Chandler, Marian Scott*)

Chair: Richard Chandler

08:30 – 09:00 *Reto Knutti* - The CMIP multi model ensemble and IPCC: lessons learned and questions arising

09:00 – 09:30 *Paul Northrop* - Using statistics to assess climate uncertainty

09:30 – 10:00 *Peter Challenor* - Designing ensembles for climate prediction

10:00 – 10:30 *Steve Sain* - NARCCAP: Design and analysis of a regional climate model experiment

10:30 - 10:50 **Coffee Break - Pentland**

10:50 - 12:30 **Session 2 - South Hall** (25 minutes **invited** talk each)

Evaluation and uncertainty estimation from multimodel and perturbed physics ensembles (*Reto Knutti*)

Chair: Reto Knutti

10:50 – 11:15 *Andreas P. Weigel* - Multi-model combination on seasonal and multi-decadal time-scales

11:15 – 11:40 *Alex Hall* - A strategy to improve projections of Arctic climate change

11:40 – 12:05 *David Sexton, Ben Booth, Mat Collins, Glen Harris and James Murphy* - Using a perturbed physics ensemble to make probabilistic climate projections for the UK

12:05 – 12:30 *Ben Sanderson* - Perturbed physics and multimodel ensembles: How can we use them together to constrain future climate response?

12:30 - 13:30 **Lunch**

Parallel Session (4 parts)

13:30 - 16:30 **Part 1 - Session 2 - Kirkland**

Evaluation and uncertainty estimation from multimodel and perturbed physics ensembles (*Reto Knutti*)

Chair: Steve Sain

13:30 – 13:45 *Simon C. Scherrer* - Present-day interannual variability of surface climate in CMIP3 models and its relation to the amplitude of future warming

13:45 – 14:00 *F. Niehörster, M. Collins, U. Cubasch* - Comparing cloud feedbacks in perturbed-physics ensembles from two different GCMs

14:00 – 14:15 *Nathalie Schaller, Jan Cermak and Reto Knutti* - Model evaluation of the hydrological cycle in the present and future climate

14:15 – 14:30 *M. C. Cuellar and A. Lopez* - Extraction of information from a global climate model perturbed physics ensemble

14:30 – 14:45 *D. Masson and R. Knutti* - Constraining climate sensitivity by natural interannual variability in the CMIP3 ensemble

14:45 – 15:00 *David Stainforth* - The inapplicability of traditional statistical methods in climate ensembles

15:00 – 15:30 Coffee Break - Pentland

Chair: Reto Knutti

15:30 – 15:45 *Robert Fildes and Nikos Kourentzes* - Forecast encompassing testing of statistical time series climate forecasts of global temperature and their implications for global circulation models

15:45 – 16:00 *H. W. Rust, M. Vrac, M. Lengaigne and B. Sultan* - Quantifying differences in circulation patterns with probabilistic method

16:00 – 16:15 *T. Halenka, P. Skalak, P. Huszar and M. Belda* - How can RCMs reproduce the annual cycle and what we can learn from it

16:15 – 16:30 *Dan Rowlands, Dave Frame, Tolu Aina, Nicolai Meinshausen and Myles Allen* - Quantifying uncertainty in climate forecasts from climate*prediction*.net

13:30 - 16:45 Part 2 - Session 7 - South Hall

Extreme events and event attribution (*Matilde Rusticucci, Peter Stott, Doug Nychka*)

Chair: Matilde Rusticucci

13:30 – 13:45 *Leila M. V. Carvalho and Charles Jones* - Extreme variations in the American Monsoon Systems: An integrated overview based on a multivariate index

13:45 – 14:00 *Barbara Casati, Louis Lefaivre and R. De Elia* - Analysis of regional climate projections of extreme precipitation and temperatures by using an Extreme Value Theory non-stationary model

14:00 – 14:15 *Defu Liu, Huajun Li, Liang Pang and Fengqing Wang* - Extreme value prediction of typhoon events – Models and applications

14:15 – 14:30 *Jonathan M. Eden and Martin Widmann* - Estimating future changes in daily precipitation distribution from GCM simulations

14:30 – 14:45 *Hayley J. Fowler, Daniel Cooley, Stephan R. Sain and Milo Thurston* - Detecting change in UK extreme precipitation using results from the climate*prediction*.net BBC Climate Change Experiment

14:45 – 15:00 *Ailie Gallant and David Karoly* - Variations of climate extremes in Australia during 1911-2008

15:00 - 15:30 Coffee Break - Pentland

Chair: Peter Stott

15:30 – 15:45 *Alexander Gluhovsky* - Subsampling inference for trends and extremes in climate data

15:45 – 16:00 *Malcolm R. Haylock* - European extra-tropical storm damage risk from a high-resolution multi-model ensemble of dynamically downscaled global climate models

16:05 – 16:15 *Frank Kwasniok* - Predicting extremes in the midlatitudinal atmospheric circulation using regime-dependent modelling

16:15 – 16:30 *Won-Tae Kwon, Hee-Jeong Baek and Hyo-Shin Lee* - Characteristics of extreme events in Korea: Observations and projections

16:30 – 16:45 *Seung-Ki Min, Xuebin Zhang, Francis W. Zwiers and Gabriele C. Hegerl* - Detection of human influence on extreme precipitation

13:30 - 15:00 Part 3 - Session 10 - St Trinneann

Long term memory (*Peter Guttorp and Peter Craigmile*)

Chair: Peter Craigmile

13:30 – 13:45 *H. W. Rust, O. Mestre and V. Venema* - Inhomogeneities in temperature records deceive long-range dependence estimators

13:45 – 14:00 *T. Schmith, S. Johansen and P. Thejll* - Statistical analysis of global surface temperature and sea level using nonstationary methods

14:00 – 14:15 *Sabine Lennartz and Armin Bunde* - Estimation of the anthropogenic trend in temperature records

14:15 – 14:30 *Christian Franzke* - On the statistical significance of climate trends

14:30 - 15:00 - Coffee Break - Pentland

15:00 - 16:45 Part 4 - Session 6 - St Trinneann - South Hall

Using observations to constrain and verify climate predictions (Francis Zwiers, Nathan Gillett, Peter Guttorp)

Chair: Francis Zwiers

15:00 – 15:15 *Lauren E. Padilla, Geoffrey K. Vallis and Clarence W. Rowley* - Combined effects of forcing uncertainty and natural

	variability for present and future estimates of transient climate response future estimates of transient climate response
15:15 – 15:30	*Stephen S. Leroy, Yi Huang and Richard M. Goody* - A relaxes Bayesian approach to climate projection and attribution
15:30 – 15:45	*Siddharth Arora, Max A. Little and Patrick E. McSharry* - Probabilistic surface air temperature predictions: comparing global climate models with nonlinear time series models
15:45 – 16:00	*Nathan Gillett and Peter Stott* - The limited contribution of model uncertainty to the uncertainty in observationally-constrained estimates of anthropogenic warming
16:15 – 16:30	*Gareth S Jones, Mike Lockwood and Peter Stott* - What influence will future solar activity have on projected global climate changes?
16:30 – 16:45	*M.C. Cuellar, A. Svedin and E. A. Spiegel* - Prediction of the sunspot activity using the shadowing filter

16:45 – 17:00 **Introduction to posters**

Introduction to poster sessions 1 and 2 (session chairs to give list of posters with titles, grouped by topic; and poster presenters to go on stage, raising hand when their title mentioned).

Poster Session

17:00 - 18:00 **Poster Session** (27)

Poster Session 1 - Pentland

Ensemble techniques: design (*Richard Chandler, Marian Scott*)

1. *Hee-Jeong Baek, Won-Tae Kwon and E-Hyung Park* - Probabilistic regional climate change projections using Bayesian model averaging over East Asia
2. *Omar Bellprat, Daniel Lüthi, Sven Kotlarski and Christoph Schär* - Towards systematic calibration of comprehensive climate models
3. *Tom Carrieres, Kyle Allison and Greg Crocker* - An ensemble model for predicting iceberg drift
4. *J. Fernández, S. Herrera, J.M. Gutiérrez and M.A. Rodríguez* - The MVL diagram: A diagnostic tool to characterize ensemble simulations
5. *Ed Hawkins and Rowan Sutton* - Decadal predictability of the Atlantic: estimation of optimal perturbations
6. *F. Niehörster, E. Tredger and L.Smith* - SVD on ICE - On the linearity of climate change simulation with GCMs
7. *Christian Schoelzel and Andreas Hense* - Probabilistic assessment of regional climate change by ensemble dressing
8. *Tony Sit* - Crossing critical thresholds

Poster Session 2 - Pentland

Evaluation and uncertainty estimation from multimodel and perturbed physics ensembles (*Reto Knutti*)

1. *Susanne Brienen, Barbara Früh and Andreas Walter* - Evaluation of high-resolution regional climate simulations for the use in climate impact studies
2. *Richard E. Chandler, Stephen P. Charles and Bryson C. Bates* - Water resources in south-west Western Australia: model uncertainty in climate change adaption
3. *M. Dubrovsky* - Stochastic climate change scenario generator for use in probabilistic climate change impact assessments
4. *Alexis Hannart* - The spread and skewness of climate sensitivity: revisiting some commonplace assumptions
5. *Jara Imbers and Ana Lopez* - Climate model evaluation and models of natural variability
6. *A. Lopez, Milena C. Cuellar, Gil Lizcano and Mark New* - Analysis of long term persistence in a perturbed physical ensemble
7. *Gamil Gamal* - Future climate in tropical Africa
8. *Lindsay Collins, Ken Carslaw, Graham Mann and Dominick Spracklen* - Towards an improved understanding of aerosol effects on the climate

Poster Session 6 - Pentland

Using observations to constrain and verify climate predictions (*Francis Zwiers, Nathan Gillett, Peter Guttorp*)

1. *Monika Cahynová and Radan Huth* - Links between atmospheric circulation and recent climatic variability and trends in Europe – A comparative approach using the COST733 classifications database
2. *A. M. Chiodi and D. E. Harrison* - Trends in ENSO and tropical Pacific surface winds and SST
3. *Cathrine Fox Maule and Peter Thejll* - The Palmer Drought Severity Index considered in Europe with an ensemble of models - present day, and future expectations
4. *J.A. Freund, S. Mieruch, S. Noël, H. Bovensmann and J.P. Burrows* - Climate change detected through a Markov chain analysis – an application to the Iberian Peninsula
5. *Fernando Sebastião and Irene Oliveria* - Independent component analysis for extended time series in climate data
6. *Milan Paluš and Dagmar Novotná* - Shift of seasons at the European mid-latitudes: Natural fluctuations correlated with the North Atlantic oscillation
7. *Nipa Phojanamongkolkij, Marty Mlynczak and Xu Liu* - Sensitivity of measurement uncertainty to the detection of climate feedbacks
8. *Kory Priestley and G. Louis Smith* - Implications of systematic and random errors on observational capability for the Earth radiation budget climate data record

9. *Daithi Stone* - Bottom-up versus top-down: An evaluation of historical trends in climate model performance
10. *Katsumasa Tanaka and Brian C. O'Neill* - Learning about the climate sensitivity
11. *Stan Yip* - Attributing uncertainty in climate predictions

Friday, July 15, 2010

Plenary Session

08:30 - 10:40 **Session 6 - South Hall**

Using observations to constrain and verify climate predictions (*Francis Zwiers, Nathan Gillett, Peter Guttorp*)

Chair: Nathan Gillett

08:30 – 09:00 *Myles Allen* - Quantifying and communicating the robustness of estimates of uncertainty in climate predictions: implications for uncertainty language in AR5 (30 minutes)

09:00 – 09:15 *Peter Stott* - Discussant (15 minutes)

09:15 – 09:45 *Peter Guttorp, Magne Aldrin and Marit Holden* - Bayesian estimation of the climate sensitivity based on a simple climate model fitted to global temperature observations

09:45 – 10:00 *Bruno Sansó* - Discussant (15 minutes)

10:00 – 10:10 General discussion (10 minutes)

10:10 - 10:40 **Coffee Break - Pentland**

10:40 - 12:40 **Session 7 - South Hall** (Each talk 25 mins plus 5 for questions plus 10 mins at end for discussion.) (**invited** session)

Extreme events and event attribution (*Matilde Rusticucci, Peter Stott, Doug Nychka*)

Chair: Matilde Rusticucci

10:40 – 11:20 *Albert Klein Tank* - Monitoring information on weather and climate extremes in support of climate change attribution studies

11:20 – 12:00 *A. C. Davidson* - Statistical inference for space-time extremes

12:00 – 12:40 *Pardeep Pall, Tolu Aina, Dáithí A. Stone, Peter A. Stott, Toru Nozawa, Arno G.J. Hilberts, Dag Lohmann and Myles R. Allen* - Anthropogenic greenhouse gas contribution to UK Autumn flood risk

12:40 – 12:50 **Introduction to posters - South Hall**

Introduction to poster sessions 6 and 7 (session chairs to give list of posters with titles, grouped by topic; and poster presenters to go on stage, raising hand when their title mentioned).

12:50 - 14:00 **Lunch**

Poster Session

14:00 - 15:00 **Poster Session** (35)

Poster Session 7 - Pentland

Extreme events and event attribution (*Matilde Rusticucci, Peter Stott, Doug Nychka*)

1. *Anderlan Henrique Batista Siqueira, Cristiano da Silva Cardoso, Nayara Arroxelas dos Santos and Luiz Carlos Baldicero Molion* - Analysis of extreme rainfall events in May of 2006 on the east coast of Northeast Brazil and its impacts
2. *Iracema FA Cavalcanti* - Extreme monthly precipitation over northern and southern sectors of La Plata Basin in South America- observations and model simulations
3. *Charles Jones and Leila M. V. Carvalho* - Variability of extreme precipitation events in the United Stated during winter
4. *Cheng-Ta Chen and Yu-Shiang Tung* - Projecting high-resolution high-impact weather extremes with observational constrain
5. *Ksenija Cindrić and Zoran Pasarić* - Spatial patterns and variability of dry spells in Croatia
6. *Paul M. Della-Marta and Malcolm R. Haylock* - Long-term variability and changes in North East Atlantic and European winter storminess
7. *Thomas Deutschländer, Achim Daschkeit, Susanne Krings and Heiko Werner* - An analysis of changes in the extremes of temperature, precipitation and wind speed based on regional climate projection for Germany
8. *M. D. Frías, R. Mínguez, J. M. Gutiérrez and F. J. Méndez* - Changes on extreme temperatures over Europe from regional climate models
9. *M. Gajic-Capka* - Temporal changes in precipitation extremes since the beginning of the 20th century in Croatia
10. *S. Herrera, J. M. Gutiérrez, R. Ancell, M. Pons, M. D. Frías and J. Fernández* - Can gridded data represent extreme precipitation events?
11. *Mari Jones, C. G. Kilsby, H. J Fowler, S. Blenkinsop* - Changes in the annual largest daily rainfall totals
12. *Jan Kyselý, Jan Picek, Romana Beranová* - Estimating extremes in climate change simulations using the peaks-over-threshold method with a non-stationary threshold
13. *Lelys Guenni* - Evaluation of extreme precipitation changes in the north central coast of Venezuela using time-varying extreme value models
14. *Andreas Lustenberger and Reto Knutti* - The limits of pattern scaling
15. *Tiziano Colombo, Vinicio Pelino and Filippo Maimone* - Historical records in a constant climate: comparison with the observations from Italian weather network
16. *Douglas Maraun, Timothy J. Osborn and Henning .W. Rust* - Variability of extreme daily precipitation in the United Kingdom. Observed and simulated relationships with the synoptic scale atmospheric circulation
17. *Morak Simone, Gabriele Hegerl* - Warm and cold spells – their changes and causes

18. *Markus Neuhäuser* - Nonparametric testing for change in the frequency of extreme events

19. *O. C. Penalba, V. Pántano, J. Rivera and F. A. Robledo* - Temporal variability of the extreme rainfall events and water balance in Northeastern Argentina

20. *Sarah E. Perkins* - Comparisons of extreme parameter estimation between observed and modelled data, and implications for future projections

21. *Rita Pongrácz, Judit Bartholy, Gabriella Kovács, Csaba Torma* - Analysis of simulated trends of extreme climate indices for Central/Eastern Europe using RegCM outputs

22. *Lukáš Pop* - Estimation of extreme wind speeds based on different types of measured data

23. *Concepcion Rodriguez-Puebla, Ana Casanueva and Nube Gonzalez-Reviriego* - Change in temperature extremes over Europe

24. *Anne Schindler, Douglas Maraun and Jürg Luterbacher* - The annual cycle of intensity and frequency of extreme precipitation events across the UK in observations and future projections

25. *Jana Sillmann* - Statistical modeling of winter temperature extremes in Europe including Euro-Atlantic atmospheric blocking as covariate

26. *Peter Szabo* - Using observations to verify climate predictions and the evaluation of models used at Hungarian Meteorological Service through statistical methods

27. *Bárbara Tencer and Matilde Rusticucci* - Comparison of observed daily extreme temperature events in Southeastern South America and RCM simulations

28. *Jessica Turner, Katie Coughlin, Thomas Laepple, Steve Jewson, Enrica Bellone and Dan Rowlands* - Incorporating sea-surface temperature trends in a stochastic hurricane model

29. *Natalia Vyazilova* - Storm activity in North Atlantic and precipitation anomalies over Europe

30. *Weilin Chen and Zhihong Jiang* - Projection and evaluation of climate extremes over the Yangtze and Huaihe River Basins (China) using a Statistical Downscaling Model

31. *Joanna Wibig* - Comparison of selected measures of drought events in Poland

32. *Ksenija Zaninovic* - Temporal changes in temperature since the beginning of 20th century over Croatia

33. *Christopher J. White, Stuart Corney, Michael Grose, Greg Holz, James Bennett and Nathaniel L. Bindoff* - Modelling extreme events in a changing climate using regional dynamically-downscaled climate projections

34. *Helen Hanlon* - An investigation of causes of the 2003 heatwave in Europe using large ensembles of the ECMWF IFS

35. *Helen Hanlon and the EQUIP consortium* - Probablisitic predictins of heatwaves, drought, crops and fisheries (TBA)

Parallel Session (3 parts)

15:00 - 18:00 Part 1 - Session 7 - South Hall

Extreme events and event attribution (*Matilde Rusticucci, Peter Stott, Doug Nychka*)

Chair: Peter Stott

15:00 - 15:15 *G. Nikulin, E. Kjellström, U. Hansson, G. Strandberg and A. Ullerstig* - European weather extremes in an ensemble of regional climate simulations

15:15 - 15:30 *Mark Palmer and Carmen Chan* - Spatial-temporal modelling of extreme rainfall

15:30 - 15:45 *Jan Picek, Martin Schindler and Jan Kyselý* - Regression quantiles methodology for choosing the optimal threshold of the 'peak- over- threshold' method in climate change simulations

15:45 - 16:00 *L. Speight, J. Hall, C. Kilsby and P. Kershaw* - An application based approach to modelling the spatial dependencies of extreme flood risk

16:00 - 16:15 *David B. Stephenson, Chun K. Ho, Mat Collins, Chris Ferro and Simon Brown* - Calibration strategies for inferring future changes in extreme events from climate simulations

16:30 - 17:00 - Coffee Break - Pentland

Chair: Peter Stott

17:00 - 17:15 *Blair Trewin* - New indices for monitoring changes in heatwaves and extended cold spells

17:15 - 17:30 *Michael Wehner* - Sources of uncertainty in the extreme value statistics of climate data

17:30 - 17:45 *Dörte Jakob, David Karoly and Alan Seed presented by David Karoly* - Recent changes in sub-hourly and daily intense rainfall events in South-East Australia

17:45 - 18:00 *Daithi Stone, Chris Lennard and Mark Tadross* - An operational weather risk attribution system for Africa

15:00 - 18:00 Part 2 - Session 6 - Kirkland

Using observations to constrain and verify climate predictions (Francis Zwiers, Nathan Gillett, Peter Guttorp)

Chair: Peter Guttorp

15:00 - 15:15 *David Karoly, Frank Drost and Karl Braganza* - Communicating global climate change using simple indices

15:15 - 15:30 *Michael Beenstock and Yaniv Reingewertz* - Polynomial cointegration tests of the anthropogenic theory of global warming

15:30 - 15:45	*Simon Tett* - Detection and attribution of changes in European temperature and precipitation
15:45 - 16:00	*Gabriele Hegerl, Juerg Luterbacher, Fidel Gonzalez-Rouco, Simon Tett and Elena Xoplaki* - Influence of external forcing on European temperatures
16:00 - 16:15	*Aurélien Ribes and Serge Planton* - Comparing the spatial features of observed and simulated climate change over the Mediterranean basin
16:15 - 16:30	*Francis W. Zwiers, Xuebin Zhang and Yang Feng* - Anthropogenic influence on long return period daily temperature extremes at regional scales

16:30 - 16:45 - Coffee Break - Pentland

Chair: Francis Zwiers

16:45 - 17:00	*Paulo Ceppi, Simon C. Scherrer and C. Appenzeller* - Spatial characteristics of gridded Swiss temperature trends: Local and large-scale influences
17:00 - 17:15	*Snigdhansu Chatterjee* - Statistical evidence of recent climate change: An analysis of Arctic seawater data
17:15 - 17:30	*Irina Mahlstein and Reto Knutti* - Ocean heat transport as a key process for model spread in Arctic warming
17:30 - 17:45	*Bettina C. Lackner, Gabi C. Hegerl, Andrea K. Steiner and Gottfried Kirchengast* - The radio occultation record for atmospheric climate change detection
17:45 - 18:00	*Daniel Feldman, Chris Algieri, Jonathan Ong, William Collins* - Observational system simulation experiments of CLARREO shortwave reflectance spectra

15:00 - 17:00 Part 3 - Session 1 - St Trinneann

Ensemble techniques: design (*Richard Chandler, Marian Scott*)

Chair: Marian Scott

15:00 - 15:30	*Ed Hawkins and Rowan Sutton* - The potential to narrow uncertainty in regional climate predictions
15:30 - 16:00	*Yaeji Lim, Seongil Jo, Jaeyong Lee, Hee-Seok Oh and Hyun-Suk Kang* - Multi-model ensemble forecasting of rainfall over East Asia region using regularized regression
16:00 - 16:30	*C. McSweeney* and *R. G. Jones* - PRECIS + QUMP: Experimental design of small-ensemble regional modelling experiments for developing regions of the world

16:30 - 17:00 - Coffee Break - Pentland

Practical implementation of statistical reconstruction methods in a non-ideal world

Monday - Plenary Session 4

N.A. Rayner

The reconstruction, using statistical techniques, of useful globally complete fields of irregularly and often sparsely sampled climate variables for the last century is complicated by the real-world's refusal to conform to theoretical ideals. This presentation will consider the application of these techniques to various variables, e.g. sea surface temperature, ocean temperature and salinity, land and marine air temperature, sea level pressure, precipitation, etc and use practical examples to illustrate some of the main challenges, including:

- Estimation of covariance between observations;
- Reconstruction of long-term changes;
- Reconstruction of adequate levels of variability;
- Ensuring homogeneity in the face of changing observational sampling;
- Production of comprehensive uncertainty estimates, including accommodation of correlated errors in reconstruction techniques;
- Reconstruction of historically data-poor regions;
- Meaningful presentation of uncertainty estimates.

Are there lessons for historical climate field reconstruction from paleoclimatology?

Monday - Plenary Session 4

Michael N. Evans

Dept. of Geology and Earth System Science Interdisciplinary Center, University of Maryland, College Park, USA

The comparatively severe issues in reconstruction of global gridded climate fields from high resolution paleoproxy data throw the challenges facing historical reconstructions based on instrumental data into sharp relief. When observations are scarce, irregularly distributed in space and/or time, and contain large random errors and biases, stiff tests for methodological innovations are provided.

In developing observational inputs, we should redouble data archaeological efforts in underobserved regions, and improve subgrid-scale replication using multiple measurement systems and data archives. We may need to focus on resolution of the most energetic syntopic patterns, but avoid reliance on demonstrably unstable teleconnection patterns. We should also use multiple direct and indirect means to derive observational uncertainty estimates based on external precision at the grid scale, and employ the subgridscale distribution of observations in the reconstruction framework.

At the stage of analysis and infilling of climate fields, we can use efficient joint spatiotemporal covariance recognition algorithms to identify and exploit tightly coupled aspects of the climate system. We should employ simple process models as physical constraints on the results, and data-level models to identify and incorporate gridscale observational uncertainties into the reconstruction algorithm. As products we should emphasize the statistical distribution of analyses over central measures as end products. Finally, we should seek out all possible validation exercises spanning the satellite, historical and late Holocene eras.

Issues regarding the construction of satellite and in situ gridded data sets for ocean surface winds and fluxes

Monday - Plenary Session 4

Mark A Bourassa

Dept. of Meteorology & Center for Ocean-Atmospheric Prediction Studies, Florida State University, Tallahassee, USA

There are remarkable similarities and differences in the statistical problems associated with creating regularly gridded data sets from satellite and in situ observations. For applications of a single variable (e,g, wind speed or a vector wind component), the many of sampling related issues with gridding roughly a day of satellite data are similar to gridding one month of in situ data for Volunteer Observing Ships (VOS). In both cases, the sampling is non-homogeneous, with data concentrated in tracks: either following satellite orbits or major shipping routes). In contract, some gridded products are products of multiple types of observations (e.g., wind speed, air temperature, sea surface temperature, and humidity). The observations used to create the gridded product can be limited to those where all variables are measured simultaneously; however, this approach greatly reduces the quantity of available data and consequently increases the gaps in coverage. The quantity of observations can be increased by combining data gathered at different times (e.g., from different ships or satellites); however, natural variability and the smoothing of this variability both can then contribute to substantial errors.

A wide variety of statistical techniques have been employed to fill the gaps in coverage in a manner that results in a credible product. But what is meant be credible? These products are typically developed for an in-house application, and then released for wider use. The qualities desired for one application (e.g., the global energy balance; minimum bias) are quite different many other applications (e.g., estimating the depth of the ocean's mixed layer, which is non-linearly dependent on the wind speed). Furthermore, the spatial smoothing applied to the data decreases the resolution. Products are release with clear information on the grid spacing, which many users confuse with resolution.

Approaches to filling gaps in gridded data will be discussed, with examples of pros and cons of the techniques. Problems with the estimation of some types of error in these products will also be demonstrated, as will the impacts on resolution.

HOMER: A hierarchical ocean model for extended reconstructions

Monday - Plenary Session 4

Ricardo T. Lemos[1,2] **and Bruno Sansó**[3]

[1]*Instituto de Oceanografia, Universidade de Lisboa, Portugal*

[2]*Maretec - Instituto Superior Técnic, Universidade Técnica de Lisboa, Portugal*

[3]*University of California Santa Cruz, USA*

We consider the problem of fitting a statistical model to data sets of ocean temperature and salinity measurements. With the model we pool the sparse available observations into smooth, three dimensional monthly fields. Long term trends and transient non-linear fluctuations are parameterized explicitly. We consider data from different sources, including the NODC, REMSS and ICOADS, incorporating information on different measurement errors in the observation equation. The model imposes constraints on density to ensure vertical stability, making post hoc corrections unnecessary. Discrete process convolutions are constructed with kernels that have flexible location-dependent shapes and compact support. To enable the estimation of parameters on large spatio-temporal domains, we develop a distributed-memory Markov chain Monte Carlo method and provide tests on computational speedup and efficiency.

Bayesian analysis for extreme events

Monday - Plenary Session 9

Pao-Shin Chu

Department of Meteorology, School of Ocean and Earth Science and Technology, University of Hawaii, USA

Bayesian analysis for extreme events will be reviewed in the context of detecting abrupt shifts in the series of extreme events. I will first introduce the Bayesian change-point analysis applied to detect abrupt shifts in the time series of tropical cyclone (TC) counts (Chu and Zhao, 2004). Specifically, a hierarchical Bayesian approach involving three layers – data, parameter, and hypothesis – is formulated to derive the posterior probability of the shifts throughout the time. For the data layer, a Poisson process with gamma distributed intensity is presumed. For the hypothesis layer, a "no change in the TC intensity" and a "single change in the intensity" hypotheses are considered. In Chu and Zhao (2004), the method was only applicable to detecting a single change in the extreme event series. To overcome this deficiency, Zhao and Chu (2006) developed a scheme which extends from the two-hypothesis to three-hypothesis (i.e., from a no change to a double change in the Poisson intensity). Also new was the use of the Markov chain Monte Carlo (MCMC) method to solve for complex integral quantities of posterior distributions. Moreover, Zhao and Chu (2006) also devised an empirical approach, called the informative prior estimation (IPE), for setting appropriate prior of Poisson rates. Results indicate that hurricane activity in the eastern North Pacific has undergone two shifts since 1972 with three climate regimes.

Although the MCMC imbedded with IPE method was demonstrated to be viable for a multiple hypothesis model, it suffers from a shortcoming. That is, because parameter spaces within different hypotheses are varying from each other, a simulation has to be run independently for each of the candidate hypotheses. If the hypotheses have higher dimension, this strategy is not efficient and is computationally prohibitive. In principle, a standard MCMC algorithm is not appropriate for a model selection problem because different candidate models or hypotheses do not share same parameter sets. To address this issue, a reversible jump MCMC (RJMCMC) algorithm is introduced to detect potential multiple shifts within an extreme event count series (Zhao and Chu, 2010). Results of a simulated sample and some real-world cases (e.g., heavy rainfall, summer heat waves) will be given.

Chu, P.-S., and X. Zhao, 2004: Bayesian change-point analysis of tropical cyclone activity: The central North Pacific case. *J. Climate*, 17, 2678-2689.

Zhao, X., and P.-S. Chu, 2006: Bayesian multiple changepoint analysis of hurricane activity in the eastern North Pacific: A Markov Chain Monte Carlo approach. *J. Climate*, 19, 564-578.

Zhao, X., and P.-S. Chu, 2010: Bayesian change-point analysis for extreme events (Typhoons, Heavy Rainfall, and Heat Waves): A RJMCMC approach. *J. Climate*, 23, 1034-1046.

Softcore and hardcore Bayesianism in climate research

Monday - Plenary Session 9

Armin Haas

In many cases, climate researchers have sufficient data for applying strictly mathematical Bayesian learning routines. In my terms, they perform hardcore Bayesianism. In many other cases, researchers face a lack of sufficient data. In this case, their judgment rests on their understanding of the system or process under investigation.

Nevertheless, they are able to come up with probability judgments and make decisions. The non-mathematical routines they use for making these judgments and taking these decisions I conceptualise as softcore Bayesianism.

I will give examples of hardcore and softcore Bayesianism in climate research and argue that both approaches are intimately interwoven in our daily research.

A new statistical framework for analysing multi-model ensembles

Monday - Plenary Session 9

Jonathan Rougier

University of Bristol, UK

In climate science, the standard approach for combining evaluations from different climate models is to treat them similarly to climate observations. This is tractable, but does not accord with the way that climate scientists interpret climate model output. At issue is whether there is a 'right' factorisation of the joint distribution of climate model evaluations, climate, and climate observations. Our factorisation is based on the notion that a subset of the climate models may be treated as second-order exchangeable, and that climate respect this exchangeability

Towards the new version of the Hadley Centre SST and sea ice data set - HadISST2

Monday - Poster Session 4

John Kennedy and Nick Rayner

Met Office Hadley Centre, UK

The sea-surface temperature component of the new version of the Hadley Centre sea ice and SST data set (HadISST) is based on a two step reconstruction process. In the first step an expectation maximisation (EM) algorithm is used to generate a large scale reduced space optimal interpolation of the SST fields. In the second step, a local interpolation scheme is used to analyse the residual differences between the reconstruction and the observations.

The method is tested using model data sub-sampled to be representative of the historical observational coverage with regard to three particular points:

1. How well is the long term trend in global and regional SSTs reconstructed.
2. Do the calculated uncertainties correspond to the actual errors in the reconstruction.
3. How well are small scale features captured in the analysis.

New approaches to the construction of gridded datasets for air-sea interaction

Monday - Poster Session 4

David I. Berry and Elizabeth C. Kent

National Oceanography Centre, Southampton, UK

Any air-sea flux dataset must combine observations of different variables using parameterisations of air-sea exchange. For example the estimation of surface heat flux requires information on wind speed, air temperature, sea surface temperature and humidity. There are two common approaches to such dataset construction. The first makes flux estimates for sets of observations using collocated observations of all the required parameters from a single ship or buoy. These flux estimates are then used to construct a gridded dataset. An alternative approach is to construct gridded datasets of each individual parameter and calculate fluxes for each grid-box from these. Each method has its advantages and disadvantages and the best approach is dependent on the characteristics of the input data, including the covariance of the different input variables and the error structure of the data.

Lessons learnt from the construction of a gridded air-sea flux dataset (NOCS Flux Dataset v2.0) will be presented. This dataset is the first air-sea flux dataset to be characterised with estimates of random and bias uncertainty. The dataset was constructed using the best available information on data bias and uncertainty and can be demonstrated to better represent variability than datasets based on the same data which are constructed without consideration of data uncertainty. Problems remain, especially in data sparse regions and plans to improve the dataset will be outlined.

Past sea level reconstruction and variability of sea level trend patterns over 1970-2001 in the Mediterranean Sea basin derived from Altimetry and 2 long OGCM runs

Monday - Poster Session 4

B. Meyssignac, A. Cazenave, R. Morrow, F. M. Calafat, M. Marcosa and W. Llovel

LEGOS/GOHS, UMR5566/CNES/CNRS/UPS/IRD, Toulouse, France

IMEDEA (CSIC-UIB), Esporles, Spain

For the past decades, there are no direct basin-scale sea level observations concerning the spatial sea level patterns and their evolution in the Mediterranean Sea. In order to understand physical processes driving sea level variability it is important to know the dominant modes of regional variability on interannual/decadal/multidecadal time scale in the Mediterranean basin. It is also of interest for assessing ocean circulation models dedicated to the Mediterranean Sea. For these purposes, we have developed a reconstruction method of past Mediterranean sea level (since 1970) that combines long tide gauge records of limited spatial coverage and 2-D sea level patterns based on the AVISO altimetry dataset and on runs from two different Ocean General Circulation Models (OGCMs). In the latter case, we use runs from the ORCA05 model (without data assimilation) over 1958-2005 available from the DRAKKAR project and the SODA reanalysis over 1958-2005 available from GODAE (Carton et al., 2008), assimilating all available in situ temperature, salinity and sea level data. We also perform the past sea level reconstruction over the Mediterranean Sea using 2-D spatial patterns from satellite altimetry.

The three sea level reconstructions are inter-compared, together with results from a published study (Calafat and Gomis, 2009). The dominant modes of temporal variability are discussed and sea level hindcasts at tide gauge sites not used in the analysis are compared to actual observations. Comparisons with steric sea level patterns based on in situ hydrographic data are also presented and discussed with regard to the conclusions of past studies based on tide gauge records analysis.

Uncertainties in the Safran 50-year atmospheric reanalysis over France

Monday - Poster Session 4

Jean-Philippe Vidal1[1,2], Eric Martin[2], Laurent Franchistéguy[3], Martine Baillon[3] and Jean-Michel Soubeyroux[3]

[1]*Cemagref, Lyon, France*

[2]*CNRM/GAME, Météo-France and CNRS, Toulouse, France*

[3]*Direction de la Climatologie, Météo-France, Toulouse, France*

Long-term retrospective meteorological datasets at high spatial and temporal resolution are of critical use in regional climate change assessment. Safran is a gauge-based analysis system that combines atmospheric profiles from ECMWF global scale reanalyses with ground observations to provide time series of seven variables – solid and liquid precipitation, air temperature, specific humidity, wind speed, visible and infrared radiation – for climatically homogenous zones. Within the ClimSec1 project, Safran has here been applied over France to build a 50-year meteorological dataset with a 8 km spatial resolution (Vidal et al., in press). This study focuses on the uncertainties identified in this long-term reanalysis.

Several tests were conducted in order to investigate three different sources of uncertainty. The intrinsic uncertainty of the analysis system, due to the spatial and temporal interpolation steps, is first assessed over the whole period 1958-2008 by comparing Safran outputs with observations at 83 high-quality validation stations included in the analysis (dependent data). The second source of uncertainty is related to the significance of the ground network density and its evolution over the 50-year period. This type of uncertainty has been studied throughout three experiments: (1) four years sampling the rise in available observations were selected for running the Safran analysis after having discarded observations from the validation stations (independent data); (2) the Safran analysis has been run again for a recent year by considering only stations available in the early 1960s; and (3) the analysis was finally run for the same recent year by considering no ground observation at all. The last studied source of uncertainty results from the non-homogeneity in time series of surface observations and is here assessed by comparing long-term trends computed from reanalysis outputs and from homogenized time series.

Results first show that Safran intrinsic bias and error are relatively low and fairly constant over the 50-year period. The dramatic rise in the number of observations that occurred in the 1990s results in a large decrease of the uncertainty between the late 1950s and the early 2000s for all variables expect precipitation for which a dense network of observations was already available at the beginning of the period. Large-scale information only appears not to be sufficient for adequately representing spatial patterns of visible and infrared radiation and wind speed fields. Adding observations from stations available in the early 1960s improves significantly the results for all variables except visible radiation and wind speed, whose field correlation remain low. Finally, trend estimates from the Safran reanalysis compare well to homogenized series for precipitation, but show very scattered values for minimum and maximum temperature that are not found in trends from homogenized series.

Vidal, J.-P., Martin, E., Baillon, M., Franchistéguy, L., and Soubeyroux, J.-M. (in press). A 50-year high-resolution atmospheric reanalysis over France with the Safran system, *Int. J. Clim*.

Impact of climate change on soil moisture and droughts in France", founded by the Fondation MAIF and Météo-France

Different definitions of the North Atlantic oscillation index: A comparison of their effects on surface climate elements in Europe

Monday - Poster Session 4

Lucie Pokorná and Radan Huth

Institute of Atmospheric Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic

The aim of this work is to compare various definitions of the North Atlantic Oscillation (NAO) index that have frequently been employed in recent studies. The period used for the comparison is 1958-1998 and only winter and summer seasons are analyzed. We examine seven definitions of the monthly NAO indices and scores (scores were derived from rotated solutions of principal component analysis):

- Index based on normalized sea level pressure (SLP) anomaly between Ponta Delgada, Azores, and Stykkisholmur, Iceland,
- Index based on SLP anomaly between Gibraltar and Reykjavik, Iceland,
- Index based on SLP anomaly between the centres of the Azores High (AH) and Icelandic Low (IL),
- The first principal component of 4 characteristics of the NAO centres: SLP anomalies in the centres of the AH and IL and their latitudes,
- Rotated principal component score of the NAO mode for the field of the 500 hPa geopotential heights in the CDAS dataset (produced by the National Weather Service, NOAA),
- Rotated principal component score of the NAO mode for the 500 hPa height field in the NCEP/NCAR reanalysis,
- Rotated principal component score of the NAO mode for the SLP field in the NCEP/NCAR reanalysis.

The correlations of indices with four climatic elements over Europe are used for comparison: mean monthly maximum and minimum surface temperature, the number of days with precipitation $\geq$0.1 mm, and monthly precipitation amounts. The climate elements are defined at 82 stations across whole Europe and are taken from the ECA&D database.

Correlation among the indices and scores range from 0.64 to 0.86 in winter, while from 0.50 to 0.87 in summer; correlations of all pairs of indices and scores are statistically significant. The NAO is clearly defined in winter, the location of the centres varying only little among different definitions. The differences in the surface climate response between the indices and scores in winter are small and statistically insignificant for the major part of Europe. The character of the subtropical centre is sensitive to the definition of the NAO in summer. It shifts westward and northward for the definition based on SLP, the western, central, and northern Europe being influenced by a weak positive anomaly during the positive phase of NAO. For the definition based on 500 hPa heights, the southern centre of the NAO splits into two cells, all Europe except the Mediterranean being influenced by a strong positive anomaly. The correlations of the NAO indices with surface temperature and precipitation are generally weak and insignificant in summer except for the station-based NAO indices. The largest and statistically significant differences between indices and scores were found for western and central Europe, while on the Iberian peninsula, in the Mediterranean and northwestern Europe all indices produce similar correlations (mostly weak and statistically insignificant except northwestern Europe).

Impact of XBT depth bias correction on decadal climate prediction

Monday - Poster Session 4

Sayaka Yasunaka[1], Masayoshi Ishii[2,4], Masahide Kimoto[1], Takashi Mochizuki[2] and Hideo Shiogama[3]

[1]*Center for Climate System Research, University of Tokyo, Japan*

[2]*Japan Agency for Marine-Earth Science and Technology, Japan*

[3]*National Institute for Environmental Studies, Japan*

[4]*Meteorological Research Institute, Japan Meteorological Agency, Japan*

An impact of the expendable bathythermograph (XBT) depth bias correction introduced by Ishii and Kimoto (2009) on decadal climate prediction is presented. Using a coupled atmosphere-ocean climate model, we perform two sets of 10-member data assimilation runs and ensemble hindcast experiments with two different observational data sets of ocean temperature; one is the data set with the bias correction and the other is that without it. Differences between the two sets of assimilated ocean temperatures appear prominent along the thermocline in the tropics and the subtropics where the depth biases are large. Root-mean-square errors of ocean temperature in the hindcasts are reduced thanks to the correction especially in the central-to-eastern tropical Pacific and the central North Pacific, which might be caused by an improvement of the initialization. The hindcasts of the Pacific Decadal Oscillation are also better agreement with bias-corrected observations than those without the correction.

Structural modelling of nonlinear exposure-response relationships for longitudinal data

Monday - Poster Session 4

Xiaoshu Lu and Esa-Pekka Takala

Finnish Institute of Occupational Health, Helsinki, Finland

Exposure–response relationships are of interest in many epidemiological, medical, meteorological, climatological, and many other applications. Once exposure information is obtained, following outcomes over time would provide the information needed to complete the risk assessment. The widespread use of exposure and risk assessment procedures has produced a diversification and specialisation of different methodologies, depending on the case under consideration. However, a critical review reveals that linear model has been widely used in examining exposure-response relationships. In many applications, data often show a remarkable dynamic and nonlinear characteristic, which requires a structure-based approach to elucidate the nonlinear exposure-response relationship behind the data. Standard statistical methods provide few theories on how to study nonlinear patterns. In this paper, we develop a new model for longitudinal data to address these challenges. The performance of the model is demonstrated using the hypothetical data. In the hypothetical data, the response responds to the exposure only by a phase shift with random errors. Hence the response is positively correlated with the exposure. A longitudinal analysis with a standard linear mixed-effects model, for example through SAS's PROC MIXED procedure, shows that the parameter estimate is statistically discernible at 5% level, indicating that response is negatively associated with exposure ($p<0.005$) which is obviously incorrect. A linear analysis can lead to wrong results for such kind of data. The results show that response is positively associated with exposure ($p<0.001$) from the developed model, which demonstrates that the proposed model can indeed uncover the real association between exposure and response. Furthermore, the developed model is computationally attractive as various software packages and routines exist to perform the final obtained mixed-effects model with no extra programming effort. The model has a logical structural interpretation for the relationship between exposure and response over time. In a general framework for multivariate analysis, such relevant exposure-response patterns are common to different longitudinal data, which represent the driving forces or mechanism of the study systems. Therefore, this approach has strong relevance for the interpretation of structures of cyclic systems which are important in meteorological and climatological applications. Most importantly, the model parameters correspond to characterising the dependence patterns of exposure and response as the complexity of the data or pattern curves increase.

A functional relationship model for simultaneous data series

Monday - Poster Session 4

Xiaoshu Lu

Finnish Institute of Occupational Health, Helsinki, Finland

Modelling the relationship between simultaneous data series is important for a wide variety of applications. Despite apparently wide application, methodologies are at present still inadequate. The well-known modelling technique is longitudinal data analysis. Longitudinal data analysis mainly focuses on how to handle the within-person correlations among the repeated measurements. Data are often obtained with few measures per subject and the models are formulated as linear. For two longitudinal data with large-scale measures for subjects, the dimensionality is high, hence there are few robust alternatives that can successfully address the unique features characterised by the data. As such, another technique, referred to as functional data analysis, is often employed. Various smoothing techniques are introduced and applied for analysing functional data sets, such as curves and shapes. A sufficiently large amount of data is needed to adequately approximate the function. However, many data series are short, hence functional data model may not be able to simulate with reasonable accuracy. In addition, a significant characteristic of real life's data is their nonlinear nature. It is thus desirable to devise a method able to discover and identify the nonlinear structure of the relationship between the data series. The purpose of this study is to present a new mathematical methodology for addressing all these issues. We extend the literature to both periodic time series and longitudinal data. The main difference of the proposed model from other methods is its capability for identifying complex nonlinear structure of the relationship behind the simultaneous data series. We use singular value decomposition technique to extract and model the dominant relationship between two data series. The functional relationship can be used to explore complex interplay among the mechanical and physical factors which govern the targeting system. The dataset of measured computer-related workload and health outcome was used to test the proposed model with promising results even though the data suffer from a number of limitations such as collection of time series of the data is short. In addition, computation algorithms are relatively simple which are easily computed by computers with available commercial software.

Modeling and forecasting climate variables using a physical-statistical approach

Monday - Poster Session 9

Edward P. Campbell and Mark J. Palmer

CSIRO Mathematical & Information Sciences, Wembley, Australia

In climatology it is common for studies to use either process models derived from physical principles or empirical models, which are rarely combined in any formal way. In part this is because it is difficult to develop process models for climate variables such as monthly or seasonal rainfall that may be thought of as outputs from complex physical processes. Models for these so-called climate outputs therefore typically use empirical methods, often incorporating modelled data as predictors. Our application is concerned with using simplified models of the El Niño- Southern Oscillation to drive forecasts of climate outputs such as monthly rainfall in south-east Australia. We develop a method to couple an empirical model with a process model in a sequential formulation familiar in data assimilation. This allows us to model climate outputs directly, and offers potential for building new seasonal forecasting approaches drawing on the strengths of both empirical and physical modelling. It is also easy to update the model as more data become available.

Artificial neural network assisted Bayesian calibration of the planet simulator general circulation model

Monday - Poster Session 9

T. Hauser, L. Tarasov, A. Keats, E. Demirov

Memorial University of Newfoundland, St. John's, Canada

Earth systems models that attempt to make long-term climate predictions are sensitive to the approximations they employ. These approximations crucially depend upon model parameters whose values and uncertainties ought to be defined using objective and repeatable methods. In this study we approach this problem by using observational data to generate Bayesian posterior probability distributions for the model parameters. This allows us to determine high-probability parameter values along with their credible intervals, and accounts for the observational uncertainties related to the calibration data. However, for complex climate models, evaluating the posterior can require a prohibitive degree of computational expense. In the experiments presented here, artificial neural networks (ANNs) are trained with output from a general circulation model (GCM) to emulate the model response to different parameter sets. The ANNs are used as surrogate models to allow a computationally efficient Markov chain Monte Carlo (MCMC) sampling of the Bayesian posterior of the GCM calibrated against seasonal climatologies of temperature, pressure, and humidity. To reduce complexity, for these initial investigations we vary only five model parameters, which influence temperature and radiation transport. We validate the methodology with the results of a calibration against a default model run with added noise. These experiments serve as benchmark tests, and allow us to determine sensitivity to noise in the constraint data. Using observational climatologies, we also examine calibration sensitivity to the spatial resolution of the constraint data. Increasing the number of data points used eventually increases the complexity of the emulation problem, to the point where the ANNs are no longer accurate enough to effectively direct the MCMC sampling. To reduce the complexity of the emulation we experiment with using constraint data produced by empirical orthogonal function (EOF) analysis of the observations. Finally, we summarize remaining issues to address in order to create a fully validated operational methodology for objective model calibration.

Probabilistic forecasts of future climate based on an objective Bayesian approach using Jeffreys' Prior

Monday - Poster Session 9

Steve Jewson[1], Dan Rowlands[2] and Myles Allen[2]

[1]*Risk Management Solutions*

[2]*Oxford University, UK*

Bayesian statistical methods can be divided into 'subjective' and 'objective' approaches, the difference being whether the prior is based on judgement, or on some kind of rule. Several authors have used subjective Bayesian statistics to convert numerical climate model runs into probabilistic forecasts of future climate. We believe that there are three particular weaknesses of such an approach. Firstly, that since the prior is based on judgement rather than on repeatable scientific methodology it is perfectly reasonable to disagree with the resulting predictions. This is fine if the predictions are for the personal use of the modellers, but less appropriate if the predictions are to be used to try and achieve wider consensus about likely future climates. Secondly, predictions based on subjective priors can never be subjected to credible evaluation by hindcasting. Thirdly, the prediction produced from such an analysis cannot be usefully compared with predictions from other models, since any differences may simply be due to differences in the judgements included in the prior.

To avoid these problems we believe that it would also be useful to produce probabilistic climate forecasts from numerical climate models using objective Bayesian statistics. In particular, we believe that it would be useful to use the (non-location version of) Jeffreys' Prior, since (a) it is the most commonly used and most widely discussed objective prior, (b) it has various attractive mathematical properties, and (c) it is already used in probabilistic predictions of future climate based on pure statistical models. We argue that the calculation of Jeffreys' Prior for complex numerical climate models can be made feasible by making the reasonable assumption that model errors are normally distributed. Based on this assumption we show how expressions for the Jeffreys' Prior can be derived, and present some results from application to very simple climate models. We discuss some of the issues that are likely to arise when applying Jeffreys' Prior to fully complex numerical climate models, discuss whether similar ideas could or should be applied to seasonal and decadal forecasts, and mention some aspects of experimental design, including the possible benefits of using initial condition ensembles of size one.

Finally we propose that the time has come for seasonal forecasts, decadal forecasts, and climate predictions to be tested using rigourous out-of-sample hindcasting. To achieve that the model parameters should be fitted using either maximum likelihood or (preferably) objective Bayesian inference. We believe that computer power has reached the point where the complexity of the models should no longer be an excuse for not testing them in this way. Such testing would yield invaluable information about model skill, would increase the confidence in projections of the future, and would open the door to the development of much better methods for calibration and model combination.

"A New Method for Making Objective Probabilistic Climate Forecasts from Numerical Climate Models Based on Jeffreys' Prior" (2009), Jewson S., Rowlands D. and Allen, M., http://arxiv.org/abs/0908.4207

Multi-model combination by a Bayesian hierarchical model: Assessment of ice accumulation over the oceanic Arctic region

Monday - Poster Session 9

Malaak Kallache[1,2], **Elena Maksimovich**[3], **Paul-Antoine Michelangeli**[2] **and Philippe Naveau**[1]

[1]*Laboratoire des Sciences du Climat et de l'Environnement (LSCE-IPSL), Paris, France*

[2]*CLIMPACT, Paris, France*

[3]*Laboratoire d'Océanographie et du Climat (LOCEAN-IPSL) Paris, France*

The performance of general circulation models (GCM) varies across regions and periods. When projecting into the future it is therefore not evident to reject or prefer a certain GCM. Combining the outputs of several GCM models may enhance results. We present a method to merge multi-model GCM projections via a Bayesian hierarchical model similar to Tebaldi et al. (2005). Here, the influence of each GCM is weighted according to its performance in a training period, with regard to observations. As outcome predictive distributions for yet unobserved observations are obtained.

Technically, GCM outputs and observations are assumed to vary randomly around common means, which are interpreted as the actual target values under consideration. Posterior parameter distributions of our Bayesian hierarchical model are obtained by a MCMC method. Advantageously all parameters, such as bias and precision of the GCM models, are estimated together. Potential time dependence is accounted for by integrating a Kalman filter (cf. Harvey et al., 2007). The significance of trend slopes of the common means is evaluated by analysing the posterior distribution of the parameters.

Our method is applied to assess the evolution of ice accumulation over the oceanic Arctic region in cold seasons. The observed ice index is created out of NCEP reanalysis data. Outputs of seven GCM models are merged by using the training period 1962–1999 and prediction periods 2046–2065 and 2081–2100 with SRES scenarios A2 and B1. A continuing decrease of ice accumulation is visible for the A2 scenario, whereas the index stabilises for the B1 scenario in the second prediction period.

Tebaldi, C., R. L. Smith, D. Nychka, and L. O. Mearns, 2005: Quantifying uncertainty in projections of regional climate change: A Bayesian approach to the analysis of multi-model ensembles. *Journal of Climate*, 18 (10), 1524–1540.

Harvey, A. C., T. M. Trimbur, and H. K. Van Dijk, 2007: Trends and cycles in economic time series: A Bayesian approach. *Journal of Econometrics*, 140 (2), 618–649, doi:10.1016/j.jeconom.2006.07.006.

A hierarchical model for Hydrologically Effective Rainfall and Soil Moisture Deficit

Monday - Poster Session 9

Jenny Lannon

University of Reading, UK

The purpose of this work is the development of a new hierarchical statistical model designed to simulate Hydrological Effective Rainfall (HER) and Soil Moisture Deficit (SMD) for use in the assessment of the impacts of climate change on water quality. In essence, this model is a new rainfall-runoff model derived from a statistical analysis of observed data. In addition, the simulation of HER and SMD is required for the application of a catchment-scale water quality model to assess how future changes in land-use management and climate will affect streamwater nitrate concentrations (Whitehead et al, 2006, Wilby at al, 2006). Quantifying the likely future changes in streamwater nitrate concentrations is important because over-enrichment of surface waters leads to problems of eutrophication. The statistical model takes into account rainfall and temperature (which are required as input) as well as Actual Evapotranspiration and flow. All model fitting is performed in a Bayesian framework using WinBUGS. The model is designed parsimoniously and ensures that all parameters are physically interpretable.

Whitehead, P., Wilby, R., Butterfield, D. and Wade, A, 2006, Impacts of climate change on in-stream nitrogen in a lowland chalk stream: An appraisal of adaption strategies. *Science of the Total Enviroment*, 365: 260-273.

Wilby, R. et al., 2006 Integrated modelling of climate change impacts on water resources and quality in a lowland catchment: River Kennet, UK. *Journal of Hydrology*, 330: 204-220.

Climate variability and its effect on the terrestrial biosphere

Monday - Poster Session 9

Lindsay Collins and Clive Anderson

University of Sheffield, UK

Climate change is the most important environmental issue of the 21st century, with profound societal impacts. International strategies to mitigate climate change rely on predictions on the fluxes of greenhouse gases (especially carbon dioxide) between atmosphere, oceans and the terrestrial biosphere. Of these fluxes, that between the atmosphere and vegetation and soils is the most complex and the least well quantified. A central strategy for estimating and predicting terrestrial carbon dynamics encapsulates knowledge of ecological and soil processes in a computer model, known as dynamic global vegetation model (DGVM), and uses the model to synthesise data and process understanding to predict carbon fluxes. Climate variables are major drivers of DGVMs and potentially a major source of uncertainty in derived carbon flux estimates.

Here we bring together carbon modelling and statistical methods to identify the sources of uncertainty in the DGVM carbon fluxes with respect to the climate and the weather. The Sheffield Dynamic Global Vegetation Model (SDGVM) is used in this study. Dynamic linear models are used to measure the variability in the climate across the UK according to the SDGVM driving data. Bayesian sensitivity analysis is then used in the framework of Gaussian process emulation to estimate the uncertainty in the UK carbon flux estimates with respect to the climate and weather variability.

OSTIA reanalysis: A high resolution SST and sea-ice reanalysis

Monday - Parallel Session 4

Jonah Roberts-Jones, Emma Fiedler and Matthew Martin

A high resolution SST and sea-ice reanalysis is being produced using the Operational SST and sea Ice Analysis (OSTIA) system which runs at the UK Met Office. The output will be a daily, global coverage 1/20° (~6km) combined foundation SST and sea ice concentration product of at least 20 years duration. Observational data sources used in the reanalysis are the AVHRR Pathfinder archive, (A)ATSR multi-mission archive, ICOADS in-situ archive and sea-ice data from the OSI-SAF archive. Input data is passed through an automatic quality control system and a bias correction on the AVHRR data using the in-situ and (A)ATSR data (where available) as a reference is carried out. OSTIA then uses a multi-scale optimal interpolation scheme to assimilate in-situ and satellite SST observations onto a first guess field provided by the previous analysis.

An overview of the OSTIA system will be presented in the context of the reanalysis. Validation results of a preliminary version of the OSTIA reanalysis will be shown, including comparisons to other reanalysis products and to the operational OSTIA system where there is an overlap with the reanalysis period.

Reconstruction of missing data in satellite and in situ data sets with DINEOF (Data Interpolating Empirical Orthogonal Functions)

Monday - Parallel Session 4

Aida Alvera-Azcárate, Alexander Barth and Jean-Marie Beckers

GHER-AGO, University of Liège, Belgium

DINEOF (Data Interpolating Empirical Orthogonal Functions), a method to reconstruct missing data in geophysical data sets, is presented. Based on a truncated Empirical Orthogonal Functions (EOF) basis, DINEOF uses an iterative procedure to calculate the values at the missing locations. A clear advantage of DINEOF is that no aprioriate knowledge about the statistics of the data set being reconstructed is needed (such as covariance or correlation length): the EOF basis is used internally to infer necessary information about the data, so no estimation of those parameters is needed. This characteristic is specially interesting for heterogeneous data distributions for which is difficult to derive this information. Also obtained are estimations of the error covariance of the reconstructed field, and outliers, i.e. data that present anomalous values with respect to the surrounding information in the original data, for which the residuals are larger than the statistically expected misfit calculated during the analysis.

When very few data is available, the estimated covariance between two successive images used in the EOF calculation might not sufficiently robust. As a consequence, spikes appear in the temporal EOFs, which result in unrealistic discontinuities in the reconstruction. A temporal filter has been applied to the covariance matrix used to determined the EOFs, which effectively enhance temporal continuity. This has been applied to a SST data set of the Black Sea and the reconstruction error is estimated by cross-validation.

On-going work includes the development of a merging capability within DINEOF that will allow to blend data from different platforms (satellite and in situ data).

Modeling and prediction of mid-scale spatial variability in historic Northern Hemisphere Atlantic sea surface temperatures

Monday - Parallel Session 4

Alicia R. Karspeck[1], **Alexey Kaplan**[2] **and Stephan Sain**[1]

[1]*National Center for Atmospheric Research, USA*

[2]*Lamont Doherty Earth Observatory, Columbia University, USA*

Existing historical records of sea surface temperature extending back to the mid 1800's are a valuable source of information about climate variability at interannual and decadal time-scales. However, the temporal and spatial irregularity of these data make them difficult to use in climate research, where gridded and complete data fields are expected both for statistical analysis and forcing numerical models.

Infilling methods based on constraining the solution to the linear space spanned by the leading eigenvectors of the global-scale covariance have proven very successful in creating gridded estimates of sea surface temperature. These methods are especially useful for infilling the vast regions of unobserved ocean typical of the earliest segments of the data record. Regional variability, on the other hand, is not well represented by these methods, especially in data-poor regions. Here we present a method for augmenting the established large-scale reconstruction methods with a statistical model of the regional scale variability. Using high quality sea surface temperature data from the last 30 years, including satellite-derived records, we specify a spatially non-stationary, non-isotropic covariance model for the regional scale sea surface temperature variability. With the covariance model estimated from the modern record, historical observations are used for estimating the expected value and correlated uncertainty of the regional scales.

While this work focuses on a limited domain in the mid-latitude North Atlantic Ocean, the method employed here can be extended to global reconstructions.

Variational Gaussian-process factor analysis for modeling spatio-temporal data

Monday - Parallel Session 4

Alexander Ilin and Jaakko Luttinen

Adaptive Informatics Research Center, School of Science and Technology, Aalto University, Finland

We present a new probabilistic model which can be used for studying spatio-temporal datasets [1]. The method is based on the factor analysis model $\mathbf{Y} = \mathbf{WX}$ + noise = $\Sigma^{D}_{d=1} \mathbf{w}_{:d}\mathbf{x}^{\mathrm{T}}_{d:}$ + noise, where $\mathbf{Y}$ is a matrix in which each row contains measurements of some quantity in one spatial location and each column corresponds to one time instance. Each vector $\mathbf{x}_{d:}$ (the d-th row of $\mathbf{X}$) represents the time series of one of the D factors whereas $\mathbf{w}_{:d}$ (the d-th column of $\mathbf{W}$) is a vector of loadings which are spatially distributed. Matrix $\mathbf{Y}$ may have missing values as the samples can be unevenly distributed in space and time.

The said model for $\mathbf{Y}$ yields standard principal component (or empirical orthogonal functions, EOF) analysis when both factors $\mathbf{x}_{d:}$ and noise are normally distributed and the noise variance is the same for each measurement. In our approach, we assume that factors $\mathbf{x}_{d:}$ and corresponding loadings $\mathbf{w}_{:d}$ have prominent structures such as, for example, slowness or periodicity for $\mathbf{x}_{d:}$ and spatial smoothness for $\mathbf{w}_{:d}$. We model such regularities using Gaussian processes (GPs), which is a flexible tool for smoothing and interpolating non-uniform data [2]. Applying the GP methodology directly to observations $\mathbf{Y}$ can be unfeasible in real-world problems because the computational complexity of the inference scales cubically w.r.t. data dimensionalities. Using separate GP models for $\mathbf{x}_{d:}$ and $\mathbf{w}_{:d}$ facilitates analysis of large spatio-temporal datasets because we perform GP modeling only either in the spatial or temporal domain at a time.

The model is identified using the framework of variational Bayesian learning. The true posterior distribution of the unknown variables $\mathbf{x}_{d:}$ and $\mathbf{w}_{:d}$ is approximated using a probability density function which has a tractable form. The parameters defining the GP priors are found by maximizing the lower bound of the respective likelihood. The computational complexity of GP modelling is reduced by using sparse approximations.

In the experimental part the model is used to compute reconstructions of historical sea surface temperatures. The global temperatures are computed for the period 1856-1991 using the data from the MOHSST5 dataset containing monthly sea surface temperature anomalies. We compare the proposed method with existing reconstruction techniques [3]. The advantage of the presented technique is that it incorporates the assumptions of the standard reconstruction systems in a single model, which allows for optimal use of all available data.

The proposed technique can be seen as a combination of such techniques as EOF analysis, kriging and temporal smoothing. The elegancy of the model is that it is completely symmetrical w.r.t. space and time. The model has good interpretability, which makes it easy to explore the results in the spatial and temporal domains and to set priors reflecting the modeling assumptions.

[1] J. Luttinen and A. Ilin. Variational Gaussian-process factor analysis for modeling spatiotemporal data, *NIPS* 2009.

[2] C. E. Rasmussen and C. K. I. Williams. *Gaussian Processes for Machine Learning*, MIT Press, 2006.

[3] A. Kaplan, M. Cane, Y. Kushnir, A. Clement, M. Blumenthal and B. Rajagopalan. Analysis of global sea surface temperatures 1856–1991, *Journal of Geophysical Research*, 103:18567– 18589, 1998.

Intercomparison of historical sea surface temperature datasets

Monday - Parallel Session 4

Sayaka Yasunaka[1] **and Kimio Hanawa**[2]

[1]*Center for Climate System Research, University of Tokyo, Japan*

[2]*Department of Geophysics, Graduate School of Science, Tohoku University, Japan*

Seven historical sea surface temperature (SST) datasets are compared with each other: the Hadley Center sea ice and SST (HadISST) dataset, version 1; the centennial in situ observation-based estimate of SSTs (COBE); the extended reconstruction of global SST (ERSST), version 3; the optimal smoothing analysis by the Lamont-Doherty Earth Observatory (LDEO); the monthly summaries of the International Comprehensive Ocean-Atmosphere Data Set Release 2.1 (ICOADS); the second Hadley Center SST (HadSST), and SSTs by the authors at Tohoku University (TOHOKU). Differences in 30-year climatologies and standard deviations of anomalies from the climatologies exist, especially in observation-sparse areas and periods. Correlation among the datasets mainly depends on the number of observational data. Global means from all datasets are consistent with each other except for those from ICOADS. Signals of the El Niño/Southern Oscillation (ENSO) correlate highly with each other after 1880, although the durations and intensities of each event are different. Temporal variations of the Pacific Decadal Oscillation (PDO) correspond well after 1950, become gradually worse backward in time, and are scattered before 1880. These differences are ascribed to the use of different interpolation methods for missing grids, treatments of satellite-derived data, instrumental bias correction methods, and other factors.

Assessing the relative importance of bias uncertainty, structural uncertainty and random errors in SST data sets

Monday - Parallel Session 4

John Kennedy, Robert Smith and Nick Rayner

Met Office Hadley Centre, UK

Recent improvements in the analysis of SST data – including the development of bias adjustments, more sophisticated error models and the free availability of a range of SST analyses – mean that it is now possible to assess the relative importance of uncertainties arising from each of these components.

The uncertainties in the bias adjustments are largest when there are large changes in the database of observations in the way the recorded measurements were made because relevant metadata are lacking. Two periods stand out in this respect: 1939-1960, and the period from 1990 to the present. During the former period, there was a poorly documented change from making SST measurements using canvas buckets to making measurements using insulated rubber buckets and engine room thermometers. Since 1990, the SST observing system has come to be dominated by observations from drifting buoys.

Structural uncertainties arise when different, but equally valid methods are used to derive a particular quantity such as the global average SST. The spread in such quantities derived from different data sets is a measure of this uncertainty. Structural uncertainties are largest at times when there are few observations but they also project strongly onto long-term trends.

Since 1979, bias uncertainty is a larger contributor to the uncertainty in global-average SST trends than structural uncertainty. However the uncertainty in the trends at longer time scales show that structural uncertainty is perhaps the larger component.

Gridding of in situ data using DIVA to produce climatologies

Monday - Parallel Session 4

Jean-Marie Beckers, Charles Troupin, Mohamed Ouberdous, Aida Alvera-Azcárate and Alexander Barth

GHER-MARE, University of Liège, Liège, Belgium

A Data Interpolating Variational Analysis tool (DIVA) is widely used as a reference tool for computing climatologies for regional seas around Europe. Though the mathematical formulation is based on a spline approach and hence different from classical optimal interpolation, it can be shown that under some hypotheses it leads to the same analysed fields. However with DIVA, boundaries of the ocean (coastlines and bottom topography) are naturally taken into account. As the tool also allows to deal efficiently with very large data sets and to take into easily account anisotropic covariances introduced by advection fields, it is a good candidate for climatology production. For climate change analyses, it is however important to address two points: When data are distributed inhomogeneously in space and time, bias can be introduced into the analysis. We show an approach that allows to conjointly provide an average spatial climatology and interannual variations of the mean taking into account the data distribution. Also seasonal or daily cycles can be estimated directly with this approach. A second problem is the estimation of the error of integrals of the analysis, for example when calculating the heat content of a basin, one would need also the associated error bars. Normally this demands the calculation of the full error covariance matrix of the analysis, but we will show a way to circumvent this and calculate the error on integrals with reasonable cost.

We will show these different aspects on the example of the Mediterranean Sea climatology based on historical data.

An approach for reconstructing historical global monthly sea surface temperatures

Monday - Parallel Session 4

Yoshikazu Fukuda[1], **Shoji Hirahara**[1] **and Masayoshi Ishii**[2,3]

[1]*Climate Prediction Division, Japan Meteorological Agency, Japan*

[2]*Meteorological Research Institute, Japan Meteorological Agency, Japan*

[3]*Japan Agency for Marine-Science and Technology, Japan*

Reconstructed sea surface temperatures (SSTs) on a centennial scale are needed for climate model initialization and prediction as well as long-term climate monitoring. The reconstruction analysis produces SSTs with a homogenized quality in space and time. According to our cross-validation studies made so far, errors in global mean SSTs and other areal averages are reduced by conducting reconstruction significantly in cases of data sparse, in comparison with straightforward analysis such as optimal interpolation.

A newly developed scheme for reconstruction of historical global monthly SSTs is introduced. In our latest reconstruction analysis, monthly SSTs are estimated from separated analyses of long-term trends and interannual variations. When reconstructing SSTs, we consider additional variations on a shorter time scale than a month, in order to avoid a statistically simple structure inherently in the reconstructed monthly SSTs and to compensate a part of SST variability ignored in the reconstruction due to truncation. The quality of the reconstructed SSTs is evaluated by using a cross validation method. Uncertain features of the reconstructed SST are also discussed, comparing with counterparts produced by other centers.

Reconstruction of global sea levels over the 20th century

Monday - Parallel Session 4

R. D. Ray[1] and B. C. Douglas[2]

[1]*NASA Goddard Space Flight Center, Greenbelt, USA*

[2]*Florida International University, Miami, USA*

Global sea level rise over the past century has usually been determined by analyzing long time series of measurements from a small number of coastal tide gauges. That task is considerably complicated by large interannual and decadal variability in the records, which is unrelated to global sea-level rise. Large variability at isolated stations also frustrates accurate determination of the much smaller decadal variability in global mean sea level; the existence of the latter is now well established by two decades of precise satellite altimetry. One approach to overcome these issues is to form a time series of near-global sea-level maps, whose individual global means are less sensitive to the isolated variability at single stations. This can be done by combining—hopefully in some optimal sense—the spatial structure of sea level, as determined by satellite altimetry, with the temporal structure from tide gauges. Kaplan and colleagues have used this approach to reconstruct global sea-surface temperatures and pressures since 1850, and Church and colleagues have adopted the method for historical sea levels. We here reexamine several aspects of the sea level reconstruction. Of primary concern is that the reconstruction methods assume the spatial structures and correlations recently observed by altimetry remain stationary throughout the whole reconstruction period. We have strong doubts that this can be the case. The altimeter time series is now long enough that the this can be partially explored by realistic modifications of the spatial interpolation functions. We also explore the sensitivity to the number and distribution of tide gauges. The tide-gauge sea level trends are potentially biased by vertical land motion, which is induced by both glacial rebound and by tectonic processes near the sites. We explore the sensitivity of the sea-level reconstruction to realistic errors in the landmotion corrections.

Reconstruction of near-global precipitation variations based on gauges and correlations with SST and SLP

Monday - Parallel Session 4

Thomas M. Smith[1,2] and Phillip A. Arkin[2]

[1]*NOAA/NESDIS/STAR/SCSB, University of Maryland, College Park, USA*

[2]*CICS/ESSIC, University of Maryland, College Park, USA*

Over the last 15 years a number of methods were developed for reconstructing near-global temperature and surface pressure variations using historical data and reconstruction statistics. Reconstruction statistics are based on the more dense modern data, and satellite data are especially valuable because of their more nearly complete sampling. Those reconstructions help to more clearly show climate variations over more than a hundred years. Reconstructions are especially valuable over the oceans where data are limited, and both sea-surface temperature (SST) and sea-level pressure (SLP) variations have been reconstructed using mostly for historical ship observations. Oceanic precipitation is another important climate variable, and a reconstruction of that would also be of value. However, historical oceanic precipitation data are limited because historical ship reports are typically only qualitative if they exist at all. In addition, individual precipitation events have smaller time and space scales than SST or SLP, making the available ocean-area records less representative of large-scale monthly or longer-term variations.

Using satellite-based precipitation estimates for reconstruction statistics, several groups have attempted to reconstruct monthly-average historical precipitation over oceans from land and island gauge variations. Those studies use the largest land-sea spatial modes to estimate ocean-area variations associated with the modes. A weighted sum of the modes is formed using the land and island historical gauge data to determine the best weights for the modes. This method works best for precipitation associated with large-scale modes accounting for large parts of the variance, such as ENSO or NAO. In our experiments we first tested this gauge-based method, making improvements where possible. We found that this method can resolve much of the oceanic interannual precipitation variation. For multi-decadal variations we found this method to be less reliable. Those variations account for less overall variance than interannual modes like ENSO, and may need more sampling to be reliably reconstructed. Therefore we developed a second reconstruction method that indirectly estimates precipitation from SST and SLP. This indirect method does not use the gauge data, but it is able to reconstruct large-scale land variations where gauges are available. Over the oceans the indirect method shows increasing interannual variations, consistent with theoretical estimates for a warming world. These two reconstructions, one direct from land and island gauges and the other indirect for correlations with SST and SLP, are combined to form a monthly reconstruction of historical precipitation beginning 1900.

A new algorithm for blending satellite precipitation estimates with in-situ precipitation measurements over Canada

Monday - Parallel Session 4

Achan Lin and Xiaolan L. Wang

Climate Research Division, Science and Technology Branch, Environment Canada, Canada

This study proposes a new algorithm for blending satellite precipitation estimates with in-situ gauge precipitation measurements over Canada, which is to be used to produce a blended monthly total precipitation dataset for Canada with a 50 km resolution on an oblique stereographic projection (CanGrid). The input satellite data used in this study include SSMI GPROF and SSMI UMORA (from 1987 to present), TVOS (from 1979 to 2002) and AIRS (from 2003 to present). The field of satellite precipitation estimates was adjusted against the field of gauge data based on the moving averages of both satellite field and gauge field before being used on the blending analysis. The blending (merging) technique is a combination of ordinary kriging and statistical interpolation with gauge data as observation field and multiple satellite precipitation estimates as the background field. A preliminary assessment of the performance of this algorithm is presented in this study.

A Bayesian method for the comparison of trend data and application to water vapour

Monday - Parallel Session 9

S. Mieruch[1], S. Noël1, M. Reuter[1], H. Bovensmann[1], J. P. Burrows[1], M. Schröder[2] and J. Schulz[2]

[1]*Institute of Environmental Physics (IUP), University of Bremen, Bremen, Germany*

[2]*Satellite Application Facility on Climate Monitoring, German Weather Service (DWD), Offenbach, Germany*

Global total column water vapour trends from 1996 to 2007 have been derived from GOME (Global OzoneMonitoring Experiment) and SCIAMACHY (SCanning Imaging Absorption spectrometer for Atmospheric CHartographY) satellite data by IUP and from globally distributed radiosonde measurements, archived and quality controlled by DWD.

In this presentation we address the question if observed water vapour trends from independent instruments are equal or not. This is in principle the Behrens-Fisher problem (comparison of samples with different means and different standard deviations) applied to trends from time series.

First we solve the Behrens-Fisher problem approximately using frequentist standard hypothesis testing by performing the Welch-test. Second, a Bayesian model selection is applied to solve the Behrens-Fisher problem exactly by integrating the posterior probabilities numerically by the algorithm Differential Evolution Markov Chain (DEMC). Additionally we derive an analytical approximative solution of the Bayesian posterior probabilities by a quadratic Taylor series expansion, which can be applied computationally efficient to large data sets.

The results from the frequentist and Bayesian approaches are discussed from a statistical view and a climatic view.

Assessing climate system properties and projections within the perfect model approach using a statistical emulator

Monday - Parallel Session 9

Markus Huber and Reto Knutti

In terms of climate model evaluation, the IPCC‘s Third Assessment Report (TAR) states two different approaches. On one hand, the degree of realism of the representation of physical processes is considered. On the other hand, model errors are quantified and the origins of these errors are analyzed. The crucial issue in this context is the use of observations of the real climate system in both model development and model evaluation.

The observed temperature, ocean heat uptake and radiation fields have been extensively used to constrain climate sensitivity and future temperature projections. However, both radiative forcing and ocean heat uptake show large uncertainties (e.g. despite measuring the same climate system, two projects recently came up with different observations of the ocean heat uptake). In general, the latter effect results from differences in observational methods and assumptions in postprocessing the data. Hence, it is a demanding task to assess what the independent information constitutes across the different data sets and dependencies among the data sets have to be considered.

The perfect model approach overcomes many observational issues by considering a fully-coupled general circulation model (AOGCM) as a comprehensive representation of the true climate system. This approach allows to test the current statistical methods such as the use of Bayes Theorem to update probability density function of climate system properties. Moreover, it offers a framework to quantify the value of different observational quantities (e.g. ocean heat uptake) in terms of constraining climate model properties and projections.

We use the Bern2.5 climate model of intermediate complexity together with the Random Forest statistical emulator to evaluate the likelihoods of different climate model set-ups by taking the climate models of the CMIP3 Project as observational references. A second goal is to analyze different covariance structures of climate parameters and internal variability in the covariance matrix of the likelihood function. A key point in our analysis is to test subsequent climate projections since we take the CMIP3 climate models as the true climate trajectory.

Climate change projections for Switzerland: A Bayesian multi-model combination using ENSEMBLES regional climate models

Monday - Parallel Session 9

A. M. Fischer[1], C. Buser[2], A. P. Weigel[1], M. A. Liniger[1] and C. Appenzeller[1]

[1]*Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland*

[2]*Seminar for Statistics ETH Zurich, Zurich, Switzerland*

The assessment of different future climate pathways is a highly challenging task due to the cascade of uncertainties ranging from emission uncertainties, model uncertainties over natural fluctuations down to uncertainties arising from downscaling approaches. The latter is particularly challenging over complex terrains such as the Alpine region. However, it is climate change information on these spatial scales, which is most relevant for end-user needs. Here, we focus on model uncertainty. A pragmatic and well-accepted approach to address model uncertainty is given by the concept of multi-model combination. The key challenge in this context is the derivation of a probability density function (pdf) from a finite set of discrete ensemble members. Given that any climate projection needs to be conditioned on an array of unprovable assumptions (e.g. assumptions concerning the future behavior of systematic model biases), it is conceptually reasonable to determine such a multi-model pdf within a Bayesian framework.

Here, we discuss the recently developed Bayesian multi-model combination algorithm of Buser et al. (2009) with regard to its applicability for regional climate scenarios. This Bayesian methodology combines observations of the control period with the output of control and scenario runs from multiple climate models. The algorithm considers both the change of the mean signal as well as changes in inter-annual variability and quantifies the systematic model biases. Due to an identifyability problem between the climate change signal and model-induced projection errors, an informative prior needs to be applied to constrain the projection error tolerance. Using synthetic data, mimicking real model data, it can be shown that the posterior distribution in the mean climate shift is largely dominated by the underlying assumptions of this prior: the more informative the prior is chosen, the smaller is the uncertainty in the mean shift and vice versa. This also has implications on how an outlier in the different model projections is contributing to the posterior distribution. Different approaches to define this informative prior are discussed.

As the main application, the Bayesian methodology is then applied to seasonally averaged regional climate scenarios for Switzerland under the A1B emission scenario, taking 2021-2050 as scenario and 1961-1990 as control period. The data basis for these projections stems from a new generation of high-resolution (25 km) regional climate model (RCM) simulations provided by the European project FP6-ENSEMBLES. The magnitudes of internal variability are quantified, and a proposal is made on how these may be included into the prior specifications. Applying these specifications, the projections indicate a temperature increase over Switzerland within the range of plus 0.5 – 3.0 °C, similar to previous estimates of climate scenarios derived from a pattern scaling approach of PRUDENCE models. However, unlike this earlier study, the transient ENSEMBLES model simulations do not reveal a significant decrease in summer and autumn precipitation. This points to the importance of analyzing transient model simulations for projecting future precipitation changes.

Bayesian ANOVA for the calculation of climate anomalies

Monday - Parallel Session 9

Martin P. Tingley

SAMSI, USA

Harvard University, USA

For the purposes of studying climate, space-time variables such as temperature are generally analyzed only after the the mean over some reference time interval has been removed from each time series. For example, the Climate Research Unit's temperature compilation is composed of a grid of monthly time series of deviations from a 1961-90 base period. While climate fields will generally display complex structures, including strong dependencies on latitude and orography, the anomalies might reasonably be expected to be dominated by larger scale spatial features, which facilitates the identification of trends and patterns.

Given the underlying assumption that the field is changing through time, a common interval must be used to calculate the mean of each time series. In general, the time series under analysis have different amounts of missing data, resulting in a reference interval shorter than the length of the data set. As a result, the variance across the estimated anomaly time series (i.e. spatial variance) is reduced within the reference interval, and inflated elsewhere.

We present an alternative approach to calculating climate anomalies, based on maximizing the length of the reference period and accounting for the increased uncertainty that results from the missing values. In this context, the standardization problem is framed as a Bayesian multi-factor ANOVA analysis, with the factors being location and year. The climate anomalies then result from removing the location effects from each time series. Within the Bayesian framework, the missing values in the data set are treated as additional parameters that must be estimated, while the posterior distributions of the year and location effects account for the uncertainty introduced by the missing observations.

We apply the Bayesian ANOVA scheme to two well known data sets: the northern hemisphere temperature reconstructions over the last 1.3ky plotted in Figure 6.10 of the IPCC Fourth Assessment report, and the Climate Research Unit's gridded instrumental compilation. These data sets are both presented as anomalies from a 1961-1990 reference period, and we discuss the impact that extending the reference period to the length of each data set has on each.

Changing the focus: Studying uncertainty in palaeoclimate reconstruction

Monday - Parallel Session 3

Catlin Buck

Current understanding of Holocene climate is largely based on study of preserved environmental indicators (known as climate proxies). Until recently those seeking to reconstruct palaeoclimate on the basis of proxies have typically used simple, correlation-based statistical methods which map directly from proxy observations to statements about past climate without providing formal statements about the link between climate and the proxy in question. Such research has focused on obtaining point estimates of past climate and has not placed much emphasis on associated uncertainties. With increased interest in comparing and combining reconstructions, however, the key role of high quality uncertainty estimates is now becoming clear. In this talk, we will focus on these uncertainties, providing an overview of recent work by members of a Leverhulme Trust funded International Research Network that is Studying Uncertainty in Palaeoclimate Reconstruction (SUPRAnet). We will discuss the limitations of the statistical methods currently in routine use and then outline a probabilistic research framework that is allowing us to a) better understand the nature and scale of uncertainties associated with proxy-based reconstructions and b) provide a modular, multi-proxy approach to past climate reconstruction. Several of the other talks in this session are given by members of SUPRAnet and will describe modelling, implementation and computational developments that are taking place withing the broad framework outlined here.

The use of chronologies in Holocene palaeoclimate reconstruction

Monday - Parallel Session 3

Andrew C. Parnell and John Haslett

UCD and TCD, Dublin, Ireland

In estimating the timing of past environmental changes we always require a chronology. That is, ages with associated uncertainty for a set of depth slices at which a palaeoenvironmental indicator is found in a sediment core. Chronologies are used in a variety of palaeoclimate sciences:

- In estimating the ages of past climatic events from pollen samples (eg Parnell et al 2008)
- In reconstructing past Holocene climate (eg Haslett et al 2006)
- In creating records of past sea level change from foraminiferal-based transfer functions (eg Horton et al 1999)
- In calculating oceanic offsets to the radiocarbon calibration curve.

The chronologies are created from uncertain dates taken from a much smaller sample of slices, the number depending on factors such as availability of dateable material and cost, amongst others. The statistical challenge is to combine the uncertain dates with a suitable monotonic stochastic process which defines the chronological process.

Recently, a number of proposals for the nature of sedimentation changes over time have been proposed in the statistical literature (eg Blaauw and Christen, 2005; Haslett and Parnell, 2008) for radiocarbon-dated chronologies. The monotonic processes used here are necessarily simple to balance the complexity of calibrating radiocarbon determinations.

In this talk, I will discuss the stochastic processes behind chronology construction, and how they may be enhanced with the further use of additional data and sophisticated computational techniques.

Probabilistic model for palaeo temperature reconstructions based on pollen ratios

Monday - Parallel Session 3

Christian Schoelzel[1] **and Eugene Wahl**[2]

[1]*Meteorological Institute, University of Bonn, Bonn, Germany*

[2]*NOAA/NESDIS/NCDC/Paleoclimate Branch, Boulder, USA*

Past climate reconstructions based on proxy data help to understand natural climate variability. It is essential that palaeoenvironmental transfer functions between climate and proxy variables take in to account the stochastic nature of the climate system. Especially pollen based reconstructions are a complex issue, since pollen counts do not show direct relation to climatological parameters, for example due to plant competition or land cultivation. The idea is to access the background knowledge from classical, more empirically based methods in order to develop statistical transfer functions between vegetation and climate.

In this context, a taxonomically reduced-space climate-pollen forward model is developed, expressed formally as ratios of pollen types (or groups of types) that vary inversely in relation to the climate variable(s) of interest. The ratios are formulated as a/(a+b), where a and b are counts of the pollen taxa (or groups of taxa) selected, insuring that the value of the ratios varies between 0 and 1. Such ratios can be modeled as a binomial random variate, conditional on the total count sum (a+b). A large set of candidate pollen types (n=63) has been examined for forward model validation in temperate northeastern North America (lat=41-50N, lon=60-92W), using strength of the pollenclimate correlation as the initial screening criterion. After this screening step, a power set analysis of all possible combinations of the selected taxa was done, inputting these into a bionmial-logistic generalized linear model with temperature climatology as the explanatory variable. The final ratio model(s) chosen were identified based on joint criteria of high explained deviance and ecological simplicity and meaningfulness.

For example, the ratio model employing oak+hickory vs. spruce+birch (Quercus+Carya vs. Picea+Betula) yields explained variability in fit-vs.-observed tests that slightly exceeds the comparable explained variability obtainable using the modern analog technique ("MAT", employing all 63 pollen types) to reconstruct July temperature climatology at the same sites across the study region. Thus, the climate-pollen forward models used for Bayesian reconstruction represent more than an order-of-magnitude reduction in the pollen taxonomic information assimilated relative to current state-of-the-art in MAT-based climate reconstruction. Additionally, the formulation of the forward models in terms of binomial random variates greatly simplifies this part of the Bayesian formulation, in contrast to specification of the mat in terms of the multinomial distribution, with no reduction in model explanatory power.

The reconstruction is given in a Bayesian framework, in terms of the posterior probability density for palaeoclimate conditional on both the recent calibration data and the palaeo proxy data. Statistical inference is obtained via MCMC integration, which allows to estimate the uncertainty due to both limited representation of pollen counts as well as model limitation. Uncertainty estimates are hence non-homogeneous in time.

Mechanistic modeling of proxy data for Bayesian climate reconstructions

Monday - Parallel Session 3

Susan E. Tolwinski-Ward, Michael N. Evans, Malcolm K. Hughes and Kevin J. Anchukaitis

Paleoclimate reconstructions may benefit from the inclusion of information on the mechanisms that form climate proxy data{ signatures of past climate variability imprinted on natural archives through biological, physical or chemical processes. We present a simple forward model of tree ring width formation, called VS-Lite, which is efficient enough to be integrated into Bayesian climate reconstructions. VS-Lite runs on monthly temperature and precipitation inputs, and accounts for the nonlinear inuences of temperature and moisture availability on annual growth through the principle that the more limiting factor will control the proxy response. The model simulates two networks of North American ring width chronologies with comparable or better skill than regression of the proxy series on the principal components of monthly climate data. VS-Lite also performs more consistently with its calibration-interval skill in verification exercises.

In an analogue of classical pseudoproxy climate field reconstructions, we also evaluate the results of a Bayesian hierarchical modeling experiment that conditions past climate on synthetic tree-ring series. The target variables are the known temperature and precipitation fields generated by a General Circulation Model. VS-Lite generates the \observed" ring width data from the target fields, and also relates past climates to these proxy series at the data level of the Bayesian hierarchy. We compare our results to those from a more standard approach based on extrapolation of statistical- empirical climate-ring width relationships.

Process-based reconstruction of palaeoclimate from pollen data

Monday - Parallel Session 3

Vincent Garreta and Joël Guiot

CEREGE, Aix-Marseille Universités, Aix en Provence, France

Abstract Pollen assemblages sampled in sediment cores provide local (in space and time) and noisy images of the past vegetation dynamics. Assuming that the main driver of this dynamics is climate, palaeoclimatologists use pollen for past climate reconstruction. The majority of the methods used for palaeoclimate reconstructions are based on models of the species `niches'. In these approaches, the pollen is assimilated to the plant and its local response to a small number of climate variables is modelled. The `niche', as a core structure, complicates new developments because (i) it hides the known sources of noise in an unintuitive structure, (ii) it precludes the use of the every growing knowledge on processes driving the climate-plant-pollen system and, (iii) it is intrinsically local and static (in time and space).

We propose a process-based approach using a dynamic vegetation model to simulate vegetation dynamics from climate, combined with a hierarchical model of the processes patially linking vegetation and its pollen records. This combination defines a spatiotemporal model whose parameters are inferred using a modern dataset of climate and pollens across Europe. Reconstruction then consists in the inference of a state-space model partly composed of a computer simulator. We managed to obtain the smoothing distribution for climate dynamics parameters and the filtering distributions for past climate and vegetation states.

We present the main steps of the Bayesian statistical modelling and inference before applying it to the reconstruction of the Holocene climate in South-East Sweden from four close cores. We conclude on the potential of this approach for palaeo-sciences, including climatology, and indicate a major point for further work: statistical inference for computer models.

Quantifying uncertainties associated with calibrating proxy data against instrumental records – an ensemble approach

Monday - Parallel Session 3

Ailie Gallant[1], Joelle Gergis1 and Karl Braganza[2]

[1]*School of Earth Sciences, University of Melbourne, Australia*

[2]*Australian Bureau of Meteorology, Australia*

One of the goals of rigorous scientific analysis is to quantify the uncertainty associated with the data. In palaeoclimate reconstructions, uncertainty can arise from a variety of sources including in the measurement of the climate proxy and the assumptions of stationarity and linearity between the palaeodata and the climate variable. It is important to address these uncertainties when aiming to produce reliable estimates of the range of past climate variability. When developing palaeoclimate reconstructions, proxy data is often tested and/or calibrated using an instrumental record. Present practice normally identifies a single calibration period against which the record is 'tuned' and subsequently tested against an independent verification period. If the reconstruction shows skill in representing the instrumental data during this verification period, it is often recalibrated using the entire period of overlap with the instrumental data.

We argue that there is a trade off between improving the performance of the proxy transfer function and potentially over-fitting reconstructions to the instrumental record. Therefore, we propose a methodology whereby the uncertainty associated with calibrating the proxy data to the instrumental record is included in the final reconstruction by using a simple bootstrapping technique to create an ensemble of reconstructions based on a suite of randomly selected calibration periods.

The technique is demonstrated using a newly developed multi proxy rainfall reconstruction for southeast Australia (1796–1989) with 80 overlapping years of instrumental data. Using a Monte-Carlo approach, n years within this overlap period were randomly sampled to provide a series of years for calibration, while the remaining years were used for validation. This was performed 10,000 times to produce an ensemble of reconstructions. The final rainfall reconstruction was calculated as the mean of the 10,000-member ensemble, with the 95th and 5th percentiles of the distribution used to provide robust uncertainty estimates.

By using multiple, randomly selected calibration periods, we argue that the potential of over-fitting the reconstruction to one period from the instrumental record is reduced. As rainfall displays more stochastic variability than temperature, we suggest that this approach helps minimise calibration biases associated with the assumption of linearity. Using this technique, we found that the suite of reconstructions showed variations of over one standard deviation from the ensemble mean, proving that the contribution of the differences associated with the choice of the calibration period is not insignificant.

An unforced decadal-scale oscillation in the 1400s

Monday - Parallel Session 3

Thomas Crowley

Previous work has demonstrated that much of mid-high latitude northern hemisphere variability from about 1350-1850 is a linear response to (primarily) volcanic and CO2 forcing. The most prominent exception to this relationship involves an abrupt 0.2-0.3 C warming beginning about 1403 and lasting about four decades. None of this warming can be related to any external forcing; the warming must be an unforced oscillation in the system. The warming seems quite widespread across the northern mid-latitudes, so no obvious local source of variability (N Atlantic Oscillation) seems invocable. Other explanations will be discussed.

Deriving dynamical models of glacial millennial-scale climate variability from ice-core records: parameter estimation, model performance and model selection

Monday - Parallel Session 3

Frank Kwasniok[1] **and Gerrit Lohmann**[2]

[1]*University of Exeter, Exeter, UK*

[2]*Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany*

Simple conceptual nonlinear dynamical models are derived from ice-core data, thus integrating models and theories with palaeoclimatic records. The method is based on parameter estimation using the unscented Kalman filter, a nonlinear extension of the Kalman filter. Unlike the conventional linear Kalman filter and the widely used extended Kalman filter, the unscented Kalman filter keeps the full system dynamics rather than linearising it, leading to a superior treatment of nonlinearities. The unscented Kalman filter truncates the filter probability density to a Gaussian in each iteration by only propagating first and second moments but neglecting higher-order moments. The method is applicable to both deterministic and stochastic models. It offers a practical and computationally cheap alternative to more complete but also considerably more cumbersome approaches like particle filters or Markov chain Monte Carlo methods.

Different conceptual models for glacial millennial-scale climate transitions (the so-called Dansgaard-Oeschger events) are considered and their parameters estimated from a North Greenland ice-core record: (i) stochastically driven motion in a bistable potential; (ii) a stochastic oscillator in a bistable potential; (iii) a stochastic van der Pol-type oscillator. Model performance is evaluated against the ice-core data using various statistical quantities. An approach to model selection is proposed based on information-theoretic measures.

Assessment of apparent non-stationarity in time series of annual inflow, daily precipitation and atmospheric circulation indices: A case study from Southwest Western Australia

Monday - Parallel Session 5

Bryson C. Bates[1], Richard E. Chandler[2], Stephen P. Charles[1] and Edward P. Campbell[1]

[1]*Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, Wembley, Australia*

[2]*Department of Statistical Science, University College London, London, UK*

The southwest region of Western Australia has experienced a sustained sequence of low annual inflows to major water supply dams over the last 30 years. Until recently, the dominant interpretation of this phenomenon has been predicated on the existence of one or more sharp breaks (change or jump points), with inflows fluctuating around relatively constant levels between them. This paper revisits this interpretation. To understand the mechanisms behind the changes, we also analyze daily precipitation series at multiple sites in the vicinity, and time series for several indices of regional atmospheric circulation that may be considered as drivers of regional precipitation (Figure 1). We focus on the winter half-year for the region (May to October) as up to 80% of annual precipitation occurs during this 'season'. We find that: the decline in the annual inflow is in fact more consistent with a smooth declining trend than with a sequence of sharp breaks; the decline is associated with decreases both in the frequency of daily precipitation occurrence and in wet-day amounts; and the decline in regional precipitation is strongly associated with a marked decrease in moisture content in the lower troposphere, an increase in regionally-averaged sea-level pressure in the first half of the season, and intraseasonal changes in the regional north-south sea-level pressure gradient. Overall, our approach provides an integrated understanding of the linkages between declining dam inflows, declining precipitation and changes in regional atmospheric circulation that favor drier conditions.

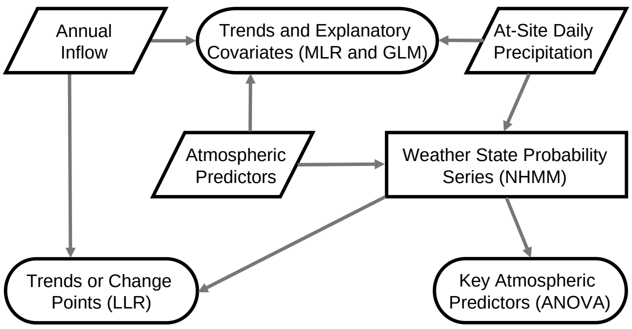


Figure 1. Data flow diagram for the analysis. ANOVA = analysis of variance; GLM = generalized linear model; LLR = local linear regression; MLR = multiple linear regression (joint mean-variance models); NHMM = non-homogeneous hidden Markov model.

A new monsoon-*like* Southwest Australian circulation index explains rainfall decline in Southwest Western Australia

Monday - Parallel Session 5

Juan Feng[1]**, Jianping Li**[1] **and Yun Li**[2]

[1]*Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China*

[2]*CSIRO Mathematical and Information Sciences, Wembley, Australia*

Using the NCEP/NCAR, ERA-40 reanalysis, and precipitation data from CMAP and Australian Bureau of Meteorology, the variability and circulation features influencing southwest Western Australia (SWWA) winter rainfall are investigated. It is found that the climate of southwest Australia bears a strong seasonality in the annual cycle and exhibits a monsoon-*like* atmospheric circulation, which is termed as the southwest Australian circulation (SWAC) for its several distinct features characterizing a monsoonal circulation: the seasonal reversal of winds, alternate wet and dry seasons, and an evident land-sea thermal contrast. The seasonal march of the SWAC in extended winter (May to October) is demonstrated by pentad data.

An index based on the dynamics normalized seasonality was introduced to describe the behavior and variation of the winter SWAC. It is found that the winter rainfall over SWWA has a significant positive correlation with the SWAC index in both early (May to July) and late (August to October) winter. In weaker winter SWAC years there is an anti-cyclonic anomaly over southern Indian Ocean resulting in weaker westerlies and northerlies which are not favorable for more rainfall over SWWA, and the opposite combination is true in the stronger winter SWAC years. The SWAC explains not only a large portion of the interannual variability of SWWA rainfall in both early and late winter, but also the long term drying trend over SWWA in early winter. The well-coupled SWAC-SWWA rainfall relationship seems to be largely independent of the well-known effects of large-scale atmospheric circulations such as the Southern Hemisphere Annular Mode (SAM), El Niño/Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) and ENSO Modoki (EM). The result offers qualified support for the argument that the monsoon-*like* circulation may contribute to the rainfall decline in early winter over SWWA. The external forcing of the SWAC is also explored in this study.

This work was supported by the Australia-China Bilateral Climate Change Partnerships Program of the Australian Department of Climate Change.

Using CMIP3 multi-models simulations to understand the relationship between large-scale climate drivers

Monday - Parallel Session 5

Wenju Cai and Tim Cowan

CSIRO Marine and Atmospheric Research, Aspendale, Australia

Using models from the Third Coupled Model Inter-comparison Project (CMIP3) simulations of individual global climate drivers have been examined, however the relationship among them has not been fully assessed in a model framework. This is carried out to address several important issues, including the possibility of the Southern Annular Mode (SAM) forcing Indian Ocean Dipole (IOD) events, and the likely impact of the IOD on El Niño-Southern Oscillation (ENSO) events and/or vice-versa.

Several conclusions emerge from statistics based on multi-model outputs. Firstly, ENSO signals project strongly onto the SAM, although ENSO-forced signals tend to peak before ENSO. This feature is similar to the situation in the Indian Ocean, where the IOD-induced signal over southern Australia peaks before the IOD itself, through the emergence of steady equivalent barotropic wavetrains. Secondly, there is no control by the SAM on the IOD, in contrast to what has been suggested previously. Indeed, none of the CMIP3 models produces a SAM-IOD relationship that supports a positive SAM driving a positive IOD event (Cai et al. 2010a). Thirdly, the IOD does impact on ENSO, however in the majority of models this coherence is quite weak, lower than has been observed (Cai et al. 2009). However, the ENSO's influence is boosted by a spurious oceanic teleconnection, whereby ENSO discharge/recharge signals transmit to the Sumatra-Java coast, generating thermocline anomalies resulting in changes in IOD properties. Without this spurious oceanic teleconnection, the influence of the IOD on ENSO is comparable to the impact of ENSO on the IOD.

Also discussed is the well-known ENSO cold tongue, which leads to a complete ‘‘nonresponse to ENSO’’ in terms of rainfall along the central and eastern equatorial Pacific in the majority of CMIP3 models. Climatological SSTs, which are far too cold along the Pacific equator and extend too far west, have linkages to a weakness in the teleconnection with Hawaii boreal winter rainfall and an inducement of an unrealistic teleconnection with rainfall over west Papua New Guinea and northwest Australia in austral summer (Cai et al. 2009, Cai et al. 2010b). Similar IOD-rainfall teleconnections will also be discussed.

Cai, W., A. Sullivan, and T. Cowan (2009), Rainfall Teleconnections with Indo-Pacific Variability in the WCRP CMIP3 Models. *J. Climate*, 22, 5046–5071.

Cai, W., A. Sullivan, and T. Cowan (2010a), Interactions of ENSO, the IOD, and the SAM in CMIP3 models. *J. Climate* (submitted).

Cai, W., T. Cowan, J. Ribbe, G. Shi, and A. Sullivan (2010b), Summer rainfall over Northwest Australia: will the observed increase continue? *Geophys. Res. Lett*. (under review).

Extreme variability of the stratospheric polar vortex

Monday - Parallel Session 5

Daniel Mitchell

University of Reading, UK

During extreme events in the Stratosphere the Northern Hemisphere polar vortex can break down in an event known as a Stratospheric Sudden Warming (SSW). The structure and evolution of the vortex during winter is analysed with special regard towards such events. Initially the traditional methods of zonal mean zonal wind and polar cap temperature are employed to study the vortex, the analysis then proceeds using a novel technique known as elliptical diagnostics to provide an in-depth look at how the vortex is evolving. Elliptical diagnostics calculate the centre, aspect ratio and strength of the vortex on different isentropic surfaces, this allows the structure of the vortex to be captured in more detail than the traditional methods would alone. Distributions of the diagnostics are then build and examined using extreme value theory, this gives a view of the vortex during its rare states which often refer directly to SSW events.

The elliptical diagnostics are then composited in time and height for different external climate forcings. Such forcings include ENSO, large volcanic eruptions, the solar cycle and different phases of the quasi-biennial oscillation. The analysis shows that under some of these forcings the vortex is more disturbed, warmer and more equatorward than usual. Where as for other forcings the vortex becomes more poleward, stronger and colder. The use of elliptical diagnostics to produce these results tie in well with the current understanding of each forcing, but also provides more information on how the vortex is evolving during these periods.

Recent unprecedented skewness towards more positive Indian Ocean Dipole occurrences and its impact on regional climate

Monday - Parallel Session 5

Tim Cowan and Wenju Cai

CSIRO Marine and Atmospheric Research, Aspendale, Australia

During 2006-2008 a rare realization of three consecutive positive Indian Ocean Dipoles (pIODs) occurred, including an unusual occurrence with a La Niña in 2007 (Luo et al. 2008). These consecutive pIODs contributed to the prolonged drought (termed the “Big Dry”) over southeastern Australia (SEA), preceding the devastating “Black Saturday” bushfires near Melbourne that killed over 170 people and devastated many communities. Is the recent high frequency of pIOD events a consequence of global warming? Is there a linkage between recent major bushfires over SEA and the recent skewness toward more frequent positive events?

From available observations and reanalyses, there has been a pIOD frequency increase from about four per 30 years early in the 20th century to about 10 over the last 30 years (Cai et al. 2009a). By contrast, the number of negative Indian Ocean Dipole (nIOD) events (that are associated with above average rainfall in SEA) has decreased from about 10 to two over the same periods. These changes in the IOD account for about 40% of the observed austral spring rainfall reduction since 1950 across SEA. Out of the 16 pIODs since 1950, 11 have been followed by a major bushfire event (Cai et al. 2009b), relating to the fact that pIODs lead to lower rainfall totals and higher temperatures during the rainy season for SEA.

As a means of undertaking a statistical assessment into the rarity of such events, we take 50 years from 19 climate model simulations submitted for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). The simulations without climate change produce only two occurrences of three-consecutive pIOD events, whilst those with climate change the occurrence increases to 8, comparable to the observed frequency of one per century (Cai et al. 2009c). Although we cannot attribute the trigger of the observed events in 2006-2008, climate change ***is*** increasing the frequency of pIODs. This could ultimately mean an increased bushfire risk for much of SEA in the future as global warming persists.

Luo, J.-J., S. Behera, Y. Masumoto, H. Sakuma, and T. Yamagata (2008), Successful prediction of the consecutive IOD in 2006 and 2007, *Geophys. Res. Lett.*, 35, L14S02, doi:10.1029/2007GL032793.

Cai, W., T. Cowan, and A. Sullivan (2009a), Recent unprecedented skewness towards positive Indian Ocean Dipole occurrences and its impact on Australian rainfall, *Geophys. Res. Lett.*, 36, L11705, doi:10.1029/2009GL037604.

Cai, W., T. Cowan, and M. Raupach (2009b), Positive Indian Ocean Dipole events precondition southeast Australia bushfires, *Geophys. Res. Lett.*, 36, L19710, doi:10.1029/2009GL039902.

Cai, W., A. Sullivan, and T. Cowan (2009c), Climate change contributes to more frequent consecutive positive Indian Ocean Dipole events, *Geophys. Res. Lett*., 36, L23704, doi:10.1029/2009GL040163.

Holocene climate change – facts and mysteries

Tuesday - Plenary Session 3

Heinz Wanner

Institute of Geography and Oeschger Centre for Climate Change Research, University of Bern, Switzerland

At the millennial timescale the key mechanisms determining climate variability and change during the recent interglacial, the Holocene, are satisfactorily understood. Most likely due to the high summer insolation in the Northern Hemisphere (NH) a warmer mid-Holocene period, called Hypsithermal, Altithermal or Holocene Climate Optimum, followed the cooler periods of the Preboreal and Boreal after about 9000 yr BP. With the decreasing summer insolation in the NH and the slightly increasing winter insolation in the Southern Hemisphere the Intertropical Convergence Zone shifted progressively southward after about 5000 yr BP, causing a weakening of the summer monsoon systems in Africa and Asia, and an increasing dryness and desertification on both continents. Due to the summer cooling in the NH a series of glacier advances took place. Therefore this period, which ended with the recent global warming, was mainly called Neoglacial.

The spatiotemporal structure and the corresponding processes which caused multi-decadal to mult-century scale climate variability are less well understood. Firstly, precise reconstructions of the two important natural forcing factors (volcanic eruptions, solar activity) for the whole Holocene period are still under debate. Secondly, the so-called Bond cycles, which were often called the Holocene equivalent of the glacial Dansgaard-Oeschger cycles, show interesting correlations with climate fluctuations in the North Atlantic – Eurasian area, e.g. with glacier dynamics in the European Alps. But a plausible mechanism for the transmission of their signal to the Southern Hemisphere was not found. Thirdly, despite existing evidence for simultaneous rapid shifts in climate records from different areas of the globe, their spatiotemporal pattern is very complex and shows, at least during certain periods, the character of a quasi-stochastic behaviour. This fact is also confirmed by ensembles of long-term simulations with ESMs (Earth System Models), which can even reproduce decadal to multi-century scale cold or warm events even the natural forcing factors are kept constant.

Uncertainties in palaeoclimate reconstruction – sampling ensembles for the younger dryas

Tuesday - Plenary Session 3

John Haslett

Palaeoclimate reconstruction involves the joint use of multiple sources of uncertain data to make joint inference on the stochastic space-time system that is the palaeo-climate. Current methodologies are crude but fast; the literature on uncertainty is completely undeveloped. In a proof-of-concept paper, Haslett et al (2006) proposed an ambitious Bayesian formulation for pollen-based reconstruction, illustrated by a single core that covered the past 15,000 years. More recently, SUPRAnet authors (2010) have discussed a larger framework, arguing that multi-proxy space-time reconstructions can be cast as Bayesian inversion of forward process models. Algorithms are the practical challenge; that proposed in Haslett et al was completely infeasible in practice. We report here on the overall framework and on considerable progress with the algorithms.

The overall framework sees a multivariate space-time stochastic process $\mathcal{C} = C(s, t)$ - defined everywhere in a continuous region of space-time. This drives other systems such as vegetation $\mathcal{V} = V(s, t)$ which in turn drive proxy-deposition in archive systems $\mathcal{A}$ and ultimately generate data Y – of which we have a single instance y. Archive systems - eg sedimentation - have their own dynamics and other inputs; these include absorption and subsequent decay of radio-carbon.

We propose a joint model F for the data generating system. Viewed as computer code F is simply a network of input-output sub-models, with external inputs such as known forcing and numerical values for some system parameters – jointly $\mathcal{X}$ - and with very many stochastic outputs - being proxy data Y, as well as the states of the many sub-systems. It may also be viewed as implicitly specifying the joint likelihood. Then the posterior probability distribution is $\pi(\mathcal{C} \mid Y = \mathrm{y})$, for the palaeoclimate given the data, is proportional to $F(y \mid \mathcal{C}, X, \Theta)\ \pi(\mathcal{C})\ \pi(\Theta)$ (these latter being priors) marginalised with respect both to such states and the internal system parameters Θ. Palaeoclimate reconstruction - with due allowance for the many uncertainties - is achieved by sampling ensembles from the posterior. Post- processing these permits focus on specific aspects of the palaeoclimate. There are of course many practical challenges to such a broad framework.

We illustrate the general framework and the challenges with modular algorithms, replacing and extending those in Haslett et al (2006). These can be seen as sampling climate ensembles that are probabilistically consistent with sediment based proxies of uncertain date. We focus on the Younger Dryas, the rapid changes in which provide a demanding test.

Haslett, J et al (2006) Bayesian Palaeoclimate Reconstruction, Journal of the Royal Statistical Society (A)169, 395-430

SUPRAnet project (2010) Studying Uncertainty in Palaeoclimate Reconstruction: a Framework for Research; in draft, March 2010

Global signatures of the “Little Ice Age” and “Medieval Climate Anomaly” and plausible dynamical origins

Tuesday - Plenary Session 3

Michael E. Mann

Pennsylvania State University, University Park, USA

I will review recent work aimed at establishing the nature of, and factors underlying, patterns of large-scale climate variability in past centuries. Evidence is compared from (1) recent proxy-based reconstructions of climate indices and spatial patterns of past surface temperature variability, (2) ensemble experiments in which proxy evidence is assimilated into coupled ocean-atmosphere model simulations to constrain the observed realization of internal variability, and (3) ensemble coupled model simulations of the response to changes in natural external radiative forcing. Implications for the roles of internal variability, external forcing, and specific climate modes such as ENSO and the NAO will be discussed. Implications for long-term variations in Atlantic tropical cyclone activity will also be discussed.

How good do palaeoclimate reconstructions of last 1000 years need to be to usefully constrain climate model parameters?

Tuesday - Plenary Session 3

Timothy J. Osborn, Douglas Maraun, Sarah C.B. Raper and Keith R. Briffa

Recent work has used reconstructions of past temperature variability to estimate or constrain climate model parameters such as climate sensitivity (e.g., Hegerl *et al.*, 2006) or carbon cycle feedback (Frank *et al.*, 2009). Our study takes a step back and uses synthetic data, constructed using output from climate model simulations, to explore how the *potential* constraints on climate model parameters depend on the uncertainty associated with temperature reconstructions. We also consider the influences of internally-generated climate variability, which tends to mask the response to external climate forcings, and of the uncertainty associated with past climate forcings. The results are likely to be optimistic compared with our ability to constrain equivalent parameters of the real climate system, because the experimental design makes a number of assumptions about prior knowledge of the synthetic climate, though the influence of these assumptions can be quantified.

Synthetic temperature reconstructions were generated by combining a simulation of externally-forced climate change (produced using an energy balance climate model) with several hundred realizations of internal climate variability (diagnosed from a multi-century control simulation with a GCM-based climate model). An iterative optimisation algorithm, involving thousands of simulations with the energy balance climate model, was adopted to obtain a maximum-likelihood estimate of unknown model parameters (climate sensitivity and parameters that determine the timescale-dependence of ocean effective heat capacity). The approach was also extended to estimate the amplitudes of past forcings to explore the relative importance of accurate temperature reconstructions and uncertainty in estimates of climate forcings.

These experiments reveal a range of results: (i) climate reconstructions for the pre-instrumental period have the potential to provide additional constraints upon climate model parameters (and hence future climate predictions) but this potential is limited by the need for accurate estimates of past forcing factors; (ii) the response to past volcanic eruptions appears to provide some constraint upon the lower values of climate sensitivity, but less so for the higher values; (iii) observing the response to forcings that operate across multiple time scales (e.g., volcanic and solar variations together) is necessary if both the climate sensitivity and ocean heat uptake need to be estimated, especially if the strengths of the forcings are also uncertain.

Use of pollen data to investigate past climates: Spatial and ecological sources of uncertainty

Tuesday - Plenary Session 3

Mary Edwards and Heather Binney

University of Southampton, UK

Pollen data are the most abundant form of information about past terrestrial environments. Many hundreds of localities have been studied, particularly across North America and Europe. For the period 21,000 yr BP to present, tens of thousands of individual pollen spectra are recorded, many linked to a radiocarbon chronology. This considerable archive of pollen data, both modern and fossil samples, provides the basis of continental-scale reconstructions of past vegetation, and, either directly or indirectly, climate. Various algorithms link current patterns of pollen distribution with climate variables and are used to infer past climate conditions for different points in time at each locality. These all suffer from a so-called 'no-analogue' situation when fossil pollen spectra do not closely resemble any modern counterparts and the climate-pollen relationship breaks down. The 'biomization' approach circumvents this problem by basing pollen classification on functional types, which are physiologically linked to climate and which characterize various 'biomes' or major vegetation units. Vegetation models can use the same vegetation units driven by the same bioclimatic relationships. This paves the way for an inverse approach to climate reconstruction in which a climate simulation drives a vegetation model, and the resultant vegetation map is compared with pollen-based biomes to assess the effectiveness of the simulation.

Two main types of spatial error or bias characterize the use of arrays of pollen data. First, the relationship between abundance of a pollen taxon at a locality and the abundance of the plants that produced it for a given source area is not linear, and, for a number of physical and ecological reasons, the relationship varies for each pollen type. The theory behind this is well developed; while it is difficult to implement corrections in detail, a simple algorithm can be applied to reduce this kind of bias. Second, pollen data comprise information points in a largely unpopulated space, and the extrapolation of taxon abundances, biome extent, or reconstructed climate variables away from the measured points remains a considerable challenge.

Bridging the gap from indirect to direct climate data – experience with homogenizing long climate time series in the early instrumental period

Tuesday - Plenary Session 8

Reinhard Böhm

Central Institute for Meteorology and Geodynamics, Climate Research Department, Vienna, Austria

Climate data from weather services are usually regarded as kind of "official" data of great quality and are used as "ground-truth" against which the skill of models and/or paleo-proxies have to be tested. Working in a weather service I am glad about this and I can approve it. We spend much time and invest much money, manpower and savvy in our quality controls. But the aim is to produce data of internal and spatial physical consistence according to the current state of the respective measuring site. It is these data which are stored in the databanks, exchanged all over the globe, and published in yearbooks. It does not belong to the principal canon of the duties of weather services to have a look at the longterm stability of their data. But we have to be aware that "original climate time series" in no case contain climate information exclusively. In fact there is much random noise in them and (even worse) also systematic breaks or (the worst of all) trends or other things not representing climate but growing cities, trees, technological progress in measuring instruments, data processing, quality control mechanisms and an number of other non climatic things.

Some basic findings from the experience of our group:

- No single longterm climate time series is a priori homogeneous (free from non climatic noise)
- At average each 20 to 30 years a break is produced which significantly modifies the series at an order comparable or exceeding the real climate signal
- Many but not all of these single breaks are random if the regional (global) sample is analyzed - even regionally or globally averaged series contain biases in the order of the real climate signal
- There are a number of mathematical procedures which - preferably if combined with metadata information from station history files – are able to detect and remove (or at least reduce) the non climatic information
- This is much work so it should preferably be done by specialized regional groups close to the metadata – this produces the best results, is more effective and saves the time of research groups wanting to analyze the data

The instrumental period in climatology usually is regarded to have started shortly after the mid 19th century. Respective benchmarks are the starting point of the global mean temperature timeseries in the 1850s or the founding of many of the national meteorological services in the following two to three decades. But there is a considerable and valuable amount of measured climate data decades to a century earlier. But the demands on these early instrumental data in terms of their comparability with modern data are increasingly difficult to fulfil progressively back in time. Decreasing network density makes mathematical homogeneity testing and adjusting less reliable and the equipment as well as the measuring and data processing philosophy were in some aspects rather different to the recent one.

One of these “early instrumental” (EI) problems is taken as an example here for the possibilities and the requirements to reduce such EI-problems in long temperature series.

Instrumental temperature recording in the Greater Alpine Region (GAR, 4-19°E, 43-49°N) began in the year 1760. Prior to the 1850-1870 period, after which screens of different types protected the instruments, thermometers were insufficiently sheltered from direct sunlight so were normally placed on north-facing walls or windows. It is likely that temperatures recorded in the summer half of the year were biased warm and those in the winter half biased cold, with the summer effect dominating. Because the changeover to screens often occurred at similar times, it has been difficult to determine the scale of the problem through relative homogeneity testing, as all neighbour sites were likely to be similarly affected. This study uses simultaneous multiannual comparative recordings at a still preserved historic and an onsite modern installation to assess the issue. The temperature differences between the two locations (screened and unscreened) have caused a change in the diurnal cycle, which depends on the time of year. Using the orientation angle of the buildings (sites across the GAR in the range from NE to NW) different adjustments to the diurnal cycle have been developed for each location of the other EI-series in the region. The effect on the 32 sites across the GAR varies due to different formulae being used by NMSs to calculate monthly means from the two or more observations made at each site each day. These formulae also changed over the years, so considerable amounts of additional metadata have had to be collected to apply the adjustments across the whole network.

Overall, the results of the additional EI-corrections indicate that summer (April to September) average temperatures had to be cooled by about 0.4°C before 1850, with winters (October to March) staying much the same. The effects on monthly temperature averages are largest in June (a cooling from 0.21° to 0.93°C, depending on location) to a slight warming (up to 0.3°C) of some sites in February.

The presented EI-correction example intends to confirm that - in spite of the additional problems compared to the situation in the fully developed instrumental period – homogenization in the 1750-1850 period is feasible and should be tried wherever such early data exist. There is a considerable and valuable amount of measured climate data decades to a century earlier of mid 19^{th} century. The added value of having another century of directly measured climate information is great: these data bridge the pre-anthropogenic to anthropogenic forcing eras and they considerably lengthen the potential calibration period for proxies.

Climate change within the Eastern European Alps through the past 20ka as derived from different data

Tuesday - Poster Session 3

Christoph Matulla[1], Roland Psenner[2] and Roland Schmidt[3]

[1]*Central Institute for Meteorology and Geodynamics (ZAMG), Vienna, Austria*

[2]*Institute for Limnology, Mondsee, Austria*

[3]*Institute for Ecology, University of Innsbruck, Innsbruck, Austria*

Recently we were in the contended position to publish a book on the evolution of the climate throughout the past 20ka within the Eastern Alpine region. The book states an assemblage of contributions from different scientific fields that contribute to the reconstruction of the past climate. This involves lake sediment and tree ring research as well as the analysis of glacier changes. The allocation of tested instrumental data that covers the past 255 years within the European Alps is another very important source of information. In total more than 20 scientists contributed to the book. We would like to give a brief overview on the evolution of the climate in the Alpine region and comment the accordance/discrepancy between different scientific data sources that describe the climate evolution of the Holocene.

A Bayesian approach to the reconstruction of surface air-temperature from ice-core data

Tuesday - Poster Session 3

Stig Uteng[1], Dmitry Divine[1,2], Håvard Rue[3] and Fred Godtliebsen[1]

[1]*The University of Tromsø, Tromsø, Norway*

[2]*The Norwegian Polar Institute, Tromsø, Norway*

[3]*NTNU, Trondheim, Norway*

We present a Bayesian approach to the constructing of the probability- density function of surface air temperature conditional on instrumental δ^{18}O- profile data. Effects of various post-depositional alterations of the initial δ^{18}O-profile and errors in timescale are also accounted for. The aim is to quantify the uncertainties in the reconstruction of past climate conditions with a particular focus on surface air temperature. The errors in timescale will be accounted for through the use of an ensemble of depth-time transformations generated by Markov Chain Monte Carlo-methods and calibrated by fix points (age-markers), i.e. ^{14}C-dating and past volcanic outbursts. The goal is to estimate the initial depositional δ^{18}O-profile which is obtained through an inversion of the various post-depositional alterations. In the presentation of the results we will employ scale space techniques (SiZer) which shows the significant features of the surface air temperature. As a case study we will be using Svalbard ice core data from the Lomonosovfonna ice sheet.

The Variational Bayes approximation for the palaeoclimate reconstruction problem

Tuesday - Poster Session 3

Richa Vatsa, Simon Wilson and John Haslett

Trinity College Dublin, Dublin, Ireland

In the reconstruction problem, past climate is inferred using pollen data. The inference on climate is carried out in two stages. At the first stage, a regression model of pollen response to climate is built using modern data on pollen. At the second stage, the knowledge of responses of pollen is used to infer past climate from data on ancient pollen prevalence.

We implement a Bayesian approach to the reconstruction problem. The inference problem is highly multivariate and computationally challenging. We present Variational Bayes approximation for the inference on past climate. The Variational Bayes (VB) Method, a functional approximation, is quick and easy to implement. The VB method permits more dimensions of climate, and fit the data with more types of pollen taxa, than has been possible with MCMC. However this is at the expense of approximating independence assumptions. We explore the consequence of these approximations on the inference.

The pollen data exhibit zero-inflated behaviour and should be modeled with a zero-inflated distribution. The VB method is restricted to posterior distributions that factorize in a certain ways and standard zero-inflated models do not fit into that category. We discuss ways in which the VB method can be adapted to work in these situations.

We also discuss the application of multiscale modelling with the VB method for a quick and its successful approximation for the model with many unknown climates variables.

A statistical method to analyse varved lake sediments with respect to reconstruction of past environment and climate change

Tuesday - Poster Session 3

Per Arnqvist[1], Christian Bigler[2], Amitava Mukherjee[1], Ingemar Renberg[2] and Sara Sjöstedt-de Luna[1]

[1]*Department of Mathematics andMathematical Statistics, Umeå University, Umeå, Sweden*

[2]*Department of Ecology and Environmental Science, Umeå University, Umeå, Sweden*

A statistical method to analyze historical archives consisting of yearly profiles, such as annually laminated (varved) lake sediments and tree rings, is here presented, with the aim of reconstructing past environment and climate change. The pattern of a yearly profile is expected to contain valuable information about past climate, with similar profiles corresponding to similar climatic conditions. The method we propose classifies the yearly profiles into groups that are translated (by experts) to different climatic scenarios. The occurrences of these climatic scenarios over time can then be further studied and interpreted. Penalized splines and hierarchical cluster analysis are tools used in the classification process, which is not obvious due to several reasons: a) the yearly profiles are of different lengths, i.e. varve thickness varies, b) the average level, range and form of the profile can all be potentially important factors influencing the climatic interpretation and thus the way classification should be performed, c) the degree of smoothing for the splines used to capture the forms of the profiles need be determined and is related to the uncertainties in the observed data.

In particular we analyze a varved lake sediment core from the lake Kassjön (N. Sweden). The sediment record consists of ~6400 varves, each varve around 0.5-1 mm thick. Image analysis was used to generate the observed data of yearly profiles (in terms of grey-scale variation) and varve thickness was measured as the number of pixels within a varve (year). We present the classification and some interpretation of the Kassjön data.

Calibrating pseudoproxies

Tuesday - Poster Session 3

Peter Green

The performance of a palaeoclimate reconstruction method can be tested in a pseudoproxy experiment. The method is used to reconstruct a model climate from simulated proxies, and then the result can be compared to the known target.

The results of these experiments depend on the properties of these pseudoproxies; a higher signal to noise ratio will result in a better score for the reconstruction, or a more complicated noise structure will result in a lower score. In order to get an accurate assessment of the relative strengths and weaknesses of the various methods it is important that the properties of the pseudoproxies are as realistic as possible. But to facilitate interpretation the proxy model should also be as simple as possible.

Many pseudoproxy models add random errors – often either independent normal or AR(1) errors – to a gridbox temperature series. A pseudoproxy may record temperature information via a number of climate variables, and so the total climate signal in a proxy record may be significantly underestimated if we limit the pseudoproxy's climate signal to a single gridbox temperature.

In fact 'temperature plus noise' pseudoproxies, with realistic correlations between the proxy and the local temperature, produce pseudo-reconstructions with unrealistically low calibration and validation performance. This suggests that more climate information needs to be included in pseudoproxy models.

Approximate joint statistical inference for large spatial datasets

Tuesday - Poster Session 3

James Sweeney and John Haslett

Trinity College Dublin, Ireland

We propose an approximate sequential approach for inferring the correlation matrix in large multivariate spatial regression problems. This enables the decomposition of the computationally intensive, multivariate, ”joint” problem, into a set of independent univariate problems with possible correlation structure inferred sequentially. Omission of correlation structure(where not appropriate) in potential models will lead to increased uncertainty in the degree of confidence at the reconstruction stage of an associated inverse problem.

The results from the proposed sequential approach are compared to those obtained using a (correct) full joint approach through the comparison of bias and predictive properties for simulated and palaeoclimate data. Inference procedures used are Empirical Bayes(EB) based where the hyperparameters governing a given model are considered as unknown fixed constants.

Analysis of past climate fluctuations and comparison with modern climate change

Tuesday - Poster Session 3

Vladimir A. Lobanov, Svetlana A. Gorlova and Anton Ye. Shadursky

Russian State Hydrometeorological University, St.Petersburg, Russia

Main problem of modern (anthropogenic) climate change is the assessment of its contribution in general climatic fluctuations and separation of “anthropogenic” and “natural” components. Instrumental data only is not suitable for this aim, because the anthropogenic impact started with the beginning of observations on gauged stations practically. Therefore paleodata together with the longest instrumental records have been used for decision of this problem. Paleodata have been chosen for different time periods:

- 803 KYrBP – present (European Project for Ice Coring in Antarctica (EPICA) with a high-resolution deuterium profile and temperature reconstruction);

- 45 KYrBP – present (a late-glacial and Holocene high-resolution site and source temperature record derived from the EPICA Dome C isotope records);

- reconstructed records of the North Hemisphere temperature for last 1000-1300 years with annual step (6 different reconstructions).

Among the gauged data the longest time series of temperature and precipitation have been chosen on some European stations (from the beginning of the 18th century), as well as, the Russian stations to 2009 and global observed temperature.

New effective statistical methods, such as truncation method of decomposition and separation of different-scale components and method of smoothing of cycles amplitudes have been applied for processing, analysis and temporal modelling. The following main results have been obtained:

- different frequency of paleo-reconstructions impacts on the periods and amplitudes of obtained cycles for processes of different time scale, therefore time series need divide into quasi-homogeneous temporal parts;

- for 803 KYr record four time scale processes have been separated: centural, millennial, 10thousand-year and 100thousand-year with average amplitudes of cycles 1.6-1.7^{0}C and maximum amplitudes 3.0-3.5^{0}C for centural scale and 4.0-5.0^{0}C for other scales;

- a late-glacial and Holocene periods average amplitudes of cycles for processes of centural and millennial scales equal 1.0-1.5^{0}C and average centural changes are 2.0-3.0^{0}C under superposition of the cycles of different scale processes;

- analysis of annual reconstructions of the North Hemisphere temperature allowed to obtained two groups of data: 3 records with closed information (parameters of cycles) and 2 records with extreme results and for homogeneous group the average periods of cycles are equal 4 year (interannual scale), 24-28 years (decadal scale) and 140-190 years (centural scale) and average amplitudes of cycles are 0.16-0.27^{0}C for interannual and decadal scales and 0.20-0.21^{0}C for centural scale with maximum amplitudes 0.4-0.5^{0}C for interannual scale, 0.3-0.4^{0}C for decadal scale, 0.2-0.3^{0}C for centural scale;

- the longest observed time series contain 3 different-scale components: interannual, decadal and centural and the model of step-changes or “jumps” is more suitable for interpretation of decadal variations and it caused by non-linear climate system and atmospheric circulations epochs.

Statistical analyses of the abrupt temperature increases of the last interglacial

Tuesday - Poster Session 3

Daniel Peavoy

The North Atlantic, during the last glacial period, was subject to large and sudden climate changes known as Dansgaard-Oeschger (DO) events. These large increases in temperature, occuring within one hundred years or less, are clearly visible in the North Greenland Ice core Project (NGRIP) $\delta^{18}O$ record, which is a proxy for temperature dating back to the previous interglacial (110 Kyr before present). It is important to analyse these events in order to understand their pattern of recurrence and to determine whether similar features are present in the Holocene climate. Previous conclusions regarding the periodic or random ocurrence of DO events have been based upon their identification by eye or by using thresholding methods. Since the climate background temperature changes over the period due to Milankovitch forcing and the DO events vary in magnitude, it is difficult to distinguish them unambiguously.

Here we propose to identify DO events by their distinct dynamics rather than their magnitude. For this we introduce an unobserved climate state, corresponding to either usual fluctuations or DO event dynamics. Conditional on this hidden state the data is assumed to evolve according to one of two independent AR(1) processes. We make no assumptions about the parameters in this model, instead they are estimated from the NGRIP data using Bayesian methods. Consequently, we are able to present the posterior probability of an event as a function of time, displaying our uncertainty in their occurence. We find that there is considerable agreement between times of high probability in our model and the original identification of DO events.

We consider two different models for the evolution of the hidden state. The first, assumes the events are a random Poisson Process with unknown rate, the second, that they occur periodically with unknown phase, period and probability. The two models are compared in a Bayesian framework using Monte Carlo methods. Finally, we assess the likelihood of the purported 1450 year period with regards to the second model.

Fast inversion of a flexible regression model for multivariate pollen counts data

Tuesday - Poster Session 3

Michael Salter-Townshend and John Haslett

We introduce a rich class of models $\pi(y|c;\theta)$ for multivariate zero-inflated count data. We use the recently introduced Integrated Nested Laplace Approximation (INLA) methodology for fast Bayesian inference on θ given training data $D = \{(y_i, c_i) ; i = 1, . . . , n\}$ and propose a new algorithm for fast inversion as $\pi(c|y^f)$.

Such models arise in palaeoclimate reconstruction, where y represents a possibly high dimensional vector of counts of a proxy such as pollen and c represents a low dimensional climate. In the context of our motivating application, D represents a modern data set used to calibrate the forward relationship in which (spatially) varying values of c drive varying vegetative responses, whence variation in the composition of the pollen rain, reflected in count data in samples of (eg lake) sediment.

Subsequently y^f is a vector of counts in a sample taken from a sediment core, thus reflecting ancient pollen rain and ancient climate – the palaeoclimate. The methodology applies in principle to palaeoclimate reconstruction from many other proxy types found in lake and ocean sediment; eg chironamids, diatoms, testate amoebae. However, the generic issue - the statistical inversion of a multivariate relationship - is found in many areas of application; e.g. clustering, supervised classification, medical imaging, oil shale modelling.

The principle novelty of the paper is a new class of multivariate models based on nested Dirichlet-Multinomial distributions with zero inflation.

No title provided

Tuesday - Poster Session 3

Mathew Schofield

Statistical calibration is the process of predicting partially observed covariate values, x, from outcome data y. Here we discuss the calibration procedure in view of current reconstruction methods. In particular, we show that current methods can be viewed as particular forms of a hierarchical model. We explore the implications of such assumptions on reconstructions of climate and explore the sensitivity of the reconstructions when these assumptions are relaxed.

Considering the effect of residual structure on the performance of climate reconstruction methods - The Cochrane-Orcutt method

Tuesday - Poster Session 3

Peter Thejll

Danish Climate Centre, DMI, Copenhagen, Denmark

In classical regression theory it is well known that the residuals, formed as the difference between target and model, must be "i.i.d" - independent and identically distributed - for the results (the regression coefficients as well as their formal error estimates) to be bias free. In reality the residuals often do not comply with this requirement, and therefore, in such cases, the results are not optimal. Residual structure can occur for many reasons - e.g. "missing variables" or "autocorrelated noise". Some of these conditions can occur easily in the field of climate reconstructions where regressions play a central role. Tools exist for ameliorating the effects of non-iid-ness, such as the classical and simple "Cochrane Orcutt" method. In this poster we describe an analysis of how regression-based climate reconstruction methods fare when the CO method is applied instead of e.g. the ordinary least squares method. Modest but significant improvements can be found. Recent new reconstruction insights (see Christiansen, this conference) as well as older approaches will be analysed and compared using a model climate dataset in which, e.g. the global mean temperature is known and can be used for method inter-comparisons.

The survey of the weather quality frequencies and determining the heat islands in Tehran

Tuesday - Poster Session 8

Mojgan Afshar[1] **and Fardin Saberi Louyeh**[2]

[1]*Azad University - Central Branch, Tehran, Iran*

[2]*Payam e Noor University, Tehran, Iran*

The development of industry and the increase of the population during the last 100 years have caused a lot of environmental problems and damages to the nature in different areas of the world including Iran. Tehran with the population of over 12 million people as a metropolitan city, unfortunately because of special geographical situations and not considering the environmental problems in planning the urban spaces (residential, commercial, industrial, cultural, educational and transportation) has faced a lot of problems in the above research, the influence of unreasonable development and planning the urban on the urban climate and the quality of its unsuitable climate has been surveyed and with the use of the most and the least temperature differences obtained from the stations located in Tehran in comparison with different stations in the suburb of the heat Islands in different urban areas has been specified in order to do this, the arithmetic of the period of 10 years of the daily temperature in under study stations for determining the heat island and temperature and the intensity of daily rainfall and the wind direction in order to determining the quality of the weather has been surveyed so after doing these surveys, some suggestions have been considered.

The effect of climate change on bioclimatic in the north and west of Iran

Tuesday - Poster Session 8

Fardin Saberi Louyeh[1] **and Mojgan Afshar**[2]

[1]*Payam e Noor University, Tehran, Iran*

[2]*Azad University - Central Branch, Tehran, Iran*

The present article tries to survey the effect of climate elements on Bioclimatic in the North and North West of Iran as an important population pole with high density. The key to understanding the possible effect of climate change, is the study of the relations of the phenomena and heat regime. In this research, the data of the climate temperature and the relative wetness in the arithmetic period of 1990 -1999 and 2000-2009 has been compared and it has been defined that during the last ten years the bioclimatic ability of the region in comparison to the first decade has considerable changes this fact has caused change in the comfort zone and has caused the delay or the quickness of it. As the result, the populations centers need revising in predicted definitions in the use of energy and choosing the place and city pollution and so on. On the other hand the trees, births) blooming (and their death) fall (an the region wild animal birth and their migration time have changed.

Detecting seasonal cycle of inhomogeneities in observed temperature time series

Tuesday - Poster Session 8

Peter Domonkos and Rafael Poza

Centre for Climate Change (C3), Geography Dept., University Rovira i Virgili, Campus Terres de l'Ebre, Tortosa, Spain

Any change in technical or environmental conditions of observations may result in bias from the precise values of observed climatic variables. The common name of these biases is inhomogeneity (IH). IHs usually appear in a form of sudden shift in the time series of variable, and the timing of the shift indicates the date of change in the conditions of observation. The seasonal cycle of radiation intensity often causes marked seasonal cycle in the IHs of observed temperature time series, since a substantial portion of temperature IHs has direct or indirect connection to radiation changes in the micro-environment of the thermometer. Therefore the magnitudes of temperature IHs tend to be larger in summer than in winter.

A new homogenisation method, the Adapted Caussinus-Mestre Algorithm for Networks of Temperature series (ACMANT) has recently been developed. The ACMANT explores seasonal cycles of IHs in an advanced level applying two IH-detection methods, namely the main detection and the secondary detection. Both methods are developed from the Caussinus-Mestre detection algorithm, but they differ markedly from the source algorithm and also from each-other. While the main detection is for detecting long-term IHs, and uses annual characteristics of observed temperatures, the secondary detection is for identifying short-term IHs, and examines monthly mean temperatures. The secondary detection is applied only in certain parts of time series where the accumulated anomalies remained high after the corrections derived from the main detection.

In the main detection two variables, namely the annual mean temperature and the difference of summer temperature – winter temperature are examined together. Step functions are fitted to the series of both variables, and a combined optimisation of the sum of squared errors is fulfilled. Monthly corrections from the main detection are set calculating harmonic function from the detected mean shift and mean seasonal difference. Advantages of the new method are a) when annual characteristics are used the noise rate is lower, than using monthly or seasonal characteristics, b) when homogenisation is applied one-by-one for series of individual months or seasons of the year independently from each-other, it is often not easy to find the relations between monthly, seasonal and annual biases, due to the random characteristic of detection results, c) the combined examination of two variables reduces randomness when the examined variables have shifts with the same timings.

In the secondary detection 60 months subperiods around the maximum in accumulated anomalies are examined, if the maximum exceeds a predefined threshold. The Caussinus-Mestre algorithm is changed in a way that for constant sections of step-functions harmonic curve (wavelength = 12 months, extreme values are in January and July) substitutes the section-mean if the section is longer than 9 months. For one subperiod no more than two additional IHs are accepted from secondary detection.

The introduced changes are recommended for homogenisation of temperature datasets of mid- and high-latitudes, where the quasi-harmonic annual cycle of IH-size is frequent and dominant.

Measure-correlate-predict (MCP) methods used for extension of the short-term wind data series

Tuesday - Poster Session 8

David Hanslian

Institute of Atmospheric Physics, Academy of Sciences, Prague, Czech Republic

Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

The knowledge of local wind conditions is essential in the process of developing a wind energy project. However, the high quality long-term wind measurement is rarely available in the vicinity of the site and the accuracy of numerical models is not satisfactory to meet the needs of responsible economical decision. Therefore the on-site wind mast measurement is necessary in most cases. For practical reasons, the length of such a wind measurement is typically one year, which makes the results biased from the long-term conditions due to year-to-year variations of average wind speed. As a result, it is essential to expand the wind series to longer period of typically 10 years or more. A variety of methods, usually called as "measure-correlate-predict" or "MCP", has been developed, including various types of regression, matrix methods, the neural networks or complex systems incorporating diverse sources of input data. The simple, most commonly used approach, is to use one reference long-term wind data series (or more of them, each separately) that is overlapping with the short-term measurement. The most important factors that determine the accuracy of results are: i) the level of correlation between the short-term and reference data set, ii) the homogeneity of reference data set, iii) the length of overlapping period. Because of homogeneity issues, the reanalysis data are most often used as a reference, even in the case any meteorological station with wind measurements is not too far from the measuring site. In the presentation, the key issues concerning MCP approach will be discussed, as well as the performance of the common MCP methods practically used.

Improved climate data and monitoring for Western Australia to support the understanding of past, present and future climate

Tuesday - Poster Session 8

Marco Marinelli[1 2], Karl Braganza[1], Dean Collins[1], David Jones[1], Shoni Maquire[1], Catherine Ganter[1,3], Pandora Hope[3] and Glenn Cook[2]

[1]*National Climate Centre, Australian Bureau of Meteorology, Melbourne, Australia*

[2]*West Australian Regional Office, Australian Bureau of Meteorology, Perth, Australia*

[3]*CAWCR, Australian Bureau of Meteorology, Melbourne, Australia*

Recent observed climate change in Western Australia has been well documented. Specifically, significant rainfall declines have occurred in the south-west of Western Australia during autumn and winter since the mid-1970's. In the north-west of the state, significant increases in summertime rainfall have more recently been observed, associated with a more active Australian monsoon. An important component of the third stage of the Indian Ocean Climate Initiative (IOCI 3) will be the improvement of the historic climate dataset for Western Australia. The study regions for IOCI 3 are characterised by diverse climates and often sparse meteorological networks. These networks have undergone large changes over the past century (for example a marked expansion during the early and mid-20th century). Significant effort is required to develop datasets that can form a sound basis for analyses of observations (e.g., trend and change point detection), model validation, adaptation studies and downscaling. The National Climate Centre (NCC), at the Australian Bureau of Meteorology, is in the process of preparing a range of improved climate datasets for Western Australia. These include high-quality daily rainfall data, extended high-quality temperature data, surface solar-radiation and cloud data, and tropical cyclone data. These datasets will be developed with the specific aim of supporting other areas IOCI 3 research, and will include sector relevant climatologies and trend analyses.

One component of this work involves the application of scientific and statistical methods to develop an extended high-quality daily rainfall dataset. Methods used include analysis of temporal patterns at each station, statistical tests to assess agreement between stations (correlation, covariance, regression and intercept) in similar regions and disaggregation of multi-day rainfall totals. Special focus has been given to the north of Western Australia, where there are no stations that contribute to the current high-quality daily rainfall dataset. In this region, the low number of stations, the large variation in the tropical rainfall and the often large distances between each station, require a high degree of scrutiny when deciding if a station passes the selection criteria. In the south-west of Western Australia there is a higher density of stations across a smaller area in the "wheatbelt" region of the state, making the quality of these stations somewhat easier to test.

Trend evaluation including level shifts and overlapping data

Tuesday - Poster Session 8

S. Mieruch, S. Noël, H. Bovensmann and J. P. Burrows

Institute of Environmental Physics (IUP), University of Bremen, Germany

The detection of trends is difficult and depends on the length of the time series, the magnitude of variability and autocorrelation of the data. The trends can be influenced by level shifts inside the time series from instrument changes or new instrumental calibration etc. Short time series as well as high variability, autocorrelation and level shifts in the data increase the uncertainty of trend detection. Weatherhead et al. (1998) showed how to consider autocorrelations of the noise and level shifts in time series. In this presentation we extend the methods from Weatherhead et al. (1998) in three ways. First, an amplitude change is considered at the position of the level shift (Mieruch et al., 2008) to reliably estimate the seasonal component of the time series. Second, the introduction of level shifts for homogenisation is expanded by allowing the data to overlap. Instead of removing level shifts from data, they are considered as a source of uncertainty during the trend analysis and error estimation. Third, we apply the method to a combined data set consisting of three segments of data, hence demonstrating the potential of implementing multiple level shifts for overlapping data.

The method is applied to monthly global satellite observations of water vapour total column data from the Global Ozone Monitoring Experiment (GOME) (since 1995), SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) (2002–now) and GOME-2 (since 2006). Hence we have to implement 3 level shifts to combine the data for the subsequent trend analysis.

Mieruch, S., Noël, S., Bovensmann, H., and Burrows, J. P.: Analysis of global water vapour trends from satellite measurements in the visible spectral range, *Atmos. Chem. Phys.*, *8*, 491–504, 2008.

Weatherhead, E. C., Reinsel, G. C., Tiao, G. C., Meng, X.-L., Choi, D., Cheang, W.-K., Keller, T., DeLuisi, J., Wuebbles, D. J., Kerr, J. B., Miller, A. J., Oltmans, S. J., and Frederick, J. E.: Factors affecting the detection of trends: Statistical considerations and applications to environmental data, *Journal of Geophysical Research*, 103, 17,149–17,161, 1998.

Various methods for correction of inhomogeneities in daily time series on example of Central European datasets

Tuesday - Poster Session 8

P. Stepanek

Czech Hydrometeorological Institute, Brno, Czech Republic

During the last decade, software package consisting of AnClim, ProClimDB and LoadData software for processing climatological data has been created. This software offers complex solution in processing climatological time series, starting from loading data from a central database (e.g. Oracle, software LoadData), through data duality control and homogenization to time series analysis, extreme values evaluation and model outputs verification (ProClimDB and AnClim software). Further methods, if available under R, can be easily linked with the software and then the whole processing can benefit from user-friendly environment in which all the most commonly used functions for data handling and climatological processing are available (read more at www.climahom.eu).

In recent years tools for correction of inhomogeneites in daily data was introduced. Partly methods already programmed in R (e.g. by Christine Gruber, ZAMG) like HOM of Paul Della-Marta and SPLIDHOM method of Olivier Mestre or own methods are available, some of them being able to apply multi-element approach (using e.g. weather types). Available methods can be easily compared and evaluated (both for inhomogeneity detection or correction in this case). Comparison of the available correction methods is also current task of ongoing COST action ESO601 (www. homogenisation.org).

Performance of the available correction methods (on daily scale) is shown on example of Central European series of various meteorological elements (air temperature, precipitation, relative humidity, sunshine duration). Comparisons among the methods as well as its various modifications (parameters settings) were investigated.

Methodological questions of data series comparison for homogenization

Tuesday - Poster Session 8

Tamás Szentimrey, Mónika Lakatos and Zita Bihari

Hungarian Meteorological Service, Budapest, Hungary

The aim of the homogenization procedures is to detect the inhomogeneities and to correct the series. In general the relative homogeneity principle is used to remove the unknown climate change signal since we have no information about the shape of this signal. During the relative procedures the series can be compared mutually and the role of series – that may be candidate or reference ones – is changing in the course of procedure. The reference series are not assumed to be homogeneous at the sophisticated examinations! The significance and the power of the procedures can be defined according to the probabilities of type of errors. Type one error means the detection of false or superfluous inhomogeneity while type two error means neglecting some real inhomogeneity.

The methodology of comparison of series is related to the following questions: reference series creation, difference series constitution, multiple comparisons of series etc. This topic is very important for detection as well as for correction, because the efficient comparison of series can increase both the significance and the power. The development of efficient comparison methods can be based on the examination of the spatial covariance structure of data series. Consequently the spatial mathematical modelling is also a key question of data series homogenization and it is a basic part of our homogenization method MASH (Multiple Analysis of Series for Homogenization) as well.

During our presentation we intend to focus on the above mentioned topic with special regard on the activity within the COSTES0601 HOME action.

Bias in minimum temperature due to a redefinition of the climatological day at synoptic stations in Canada

Tuesday - Poster Session 8

Lucie A. Vincent and Ewa J. Milewska

Climate Research Division, Science and Technology Branch, Environment Canada, Toronto, Canada

When a homogeneity procedure was initially applied to the annual means of the daily maximum and minimum temperatures at 210 stations in Canada (Vincent and Gullett 1999), a decreasing step of about 0.6° to 0.8°C was found in 1961 in the minimum temperatures. This step accentuated the cooling trend observed in Eastern Canada over the past 50 years. In Western Canada, a significant step was not detectable. It was concluded that the step could have been caused by a redefinition of the climatological day in 1961 and needed further investigation.

Recently, this cold bias was closely examined (Vincent et al. 2009). Hourly temperatures taken at 121stations for 1953-2007 were used to determine its magnitude and spatial variation. It was found that its annual mean varies from -0.2 in the west to -0.8°C in the east. However, not all days were affected by the change in the observing time. The annual percentage of affected days ranges from 15% for stations in the west to 38% for stations in the east. An approach based on hourly temperatures is proposed to adjust daily minimum temperatures. Overall, with the adjustments, the trends are becoming either more positive or are reversing from negative to positive over 1950-2007, and they have changed by as much as 1°C in numerous locations in Eastern Canada.

Vincent, L.A., E.J. Milewska, R. Hopkinson and L. Malone, 2009: Bias in minimum temperature introduced by a redefinition of the climatological day at the Canadian synoptic stations. *J. Appl. Meteor. Climatol.*, *48*, 2160-2168. DOI: 10.1175/2009JAMC2191.1.

Vincent, L.A., and D.W. Gullett, 1999: Canadian historical and homogeneous temperature datasets for climate change analyses. *Int. J. Climatol.*, *19*, 1375-1388.

Trends in daily and extreme temperature and precipitation indices for the countries of the Western Indian Ocean, 1975-2008

Tuesday - Poster Session 8

Enric Aguilar[1] **and Lucie A. Vincent**[2]

[1]Center for Climate Change, Geography Department, Universitat Rovira i Virgili, Tarragona, Spain

[2]Climate Research Division, Environment Canada, Toronto, Canada

In the framework of the project "Renforcement des Capacités des Pays de la COI dans le Domaine de l'Adaptation au Changement Climatique (ACCLIMATE)" (Comission de l'Ocean Indien, COI), a workshop on homogenization of climate data and climate change indices analysis was held in Mauritius in October 2009, using the successful format prepared by the CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices. Scientists from the five countries in Western Indian Ocean brought daily climatological data from their region for a meticulous assessment of the data quality and homogeneity, and for the preparation of climate change indices which can be used for analyses of changes in climate extremes. Although the period of analysis is very short, it represents a seminal step for the compilation of longer data set and allows us to examine the evolution of climate extremes in the area during the time period identified as the decades where anthropogenic warming is larger than natural forcing.

This study first presents some results of the homogeneity assessment using the software package RHtestsV3 (Wang and Feng 2009) which has been developed for the detection of changepoints in climatological datasets. Indices based on homogenized daily temperatures and precipitations were also prepared for the analysis of trends at more than 50 stations across the region. The results show an increase in the percentage of warm days and warm nights over 1975-2008 while changes in extreme precipitations are not as consistent.

Quantification of the effect of auto correlation and climate trends on record observations

Tuesday - Poster Session 10

Albert R. Boehm

Retired Climatologist

Consider a set of observations Xi i=1 to N, for example daily temperature readings typically taken at one site at fixed time intervals. But in general could be simultaneous measurements taken at N sites along a line in space.

Define a record measurement, Xr as exceeding all prior measurements that is, Xr> Xj for all j <r. There are many historical references that have consider Xr in thecae An ex tream measurement exceeds all measurements in the set. Thus an extreme is always a record, a record may or may not be an extreme since a larger value may be measured later. when the measurements are independent i.e. have zero aut correlation and come from identical distributions a variety of measurements have been considered including size of animals and rocks, salaries and others However weather data is known to have considerable auto correlation and to come from seasonal and climate trends The goal of this paper is to describe a normative (theoretical) model that explicatively shows the results of these effects on record observations.

With weather data autocorrelation ca be very complex what with positive and negative feedbacks and seriall correlation induced by hyerarchica, downscaking, effects and by spatial "teliconnections TO CLARIFY RESULTS, WE LIMIT AUTOCORRELATION her to the degree of linear relation (product moment correlation between Xj and Xj+1. Thus we select the simple first order aut regressive model Xj+1=Xj +Br wher r is relatively small randome variable and A= ro the auto correlation parameter and B=SQRT(1-ro ro) This simple model is easy to simulate and is mathematically tractable and leads directly to insight between autocrelation and record observations

We again note this is a normative model not validated yet with real weather observations.But since I Boehm (1873)and I Gringorten have found it to have similar temporal statistic to observed data, I believe the normative insights have relevance to real data. Found in nature.

Boehm(1973)EVALUATION OF MODELED CONDITINAL PROBABILITY IN OPERATIONAL FORECASTING AMS Preprint third conferece on probability and statistics in atmpsheriv science p259, AMS Boston.

Assimilation of low-resolution paleo-proxies for spatial reconstruction of North American summertime climatology

Tuesday - Poster Session 10

Alicia R. Karspeck, Caspar Ammann and Doug Nychka

National Center for Atmospheric Research, USA

Unlike high-resolution paleo-proxies that might provide information about the annually resolved climate, low-resolution proxies, such as pollen assemblages, provide information on decadal-scale climate variability. Ideally, reconstructions would use both high- and low-resolution proxies to create reconstructions with corresponding multi-scale uncertainty estimates.

Toward this goal, we focus here on the question of how best to assimilate pollen ratios representative of 30-yr average summertime temperatures into a spatial reconstruction of North American surface temperatures. Using an 1150 yr integration of the NCAR Community Climate System Model (CCSM), we form a prior distribution of the seasonal climatology (a variable that is not typically a probabilistic quantity). Although point-proxies of 30 yr means can tell us very little about the instantaneous annual state, we explore here what they may be able to provide in terms of adjustments to the temporally evolving seasonal climatology.

Second, we form a statistical autocorrelation model that will allow us to predict how innovations at discrete time points impact temporally distant state variables. A realistic network of proxy locations is used to condition the posterior distribution. We operate within a standard Bayesian framework in which we are able to generate both the expected value and uncertainties associated with the reconstruction.

Space-time stochastic modeling of climate changes

Tuesday - Poster Session 10

Vladimir A. Lobanov and Svetlana A. Gorlova

Russian State Hydrometeorological University, St.Petersburg, Russia

Time series of any climate characteristic in present and past can be represented as a statistical ensemble of different time scales fluctuations. The general space-time modeling includes a generalization of information in three main directions: intra-year, inter-year and space. Description of all fluctuations includes the following steps:

- description of intra-annual fluctuations in form of the parameters of seasonal function or averaged values;

- extraction of interannual, decadal, centural, millennia and other time-scale components, connected with different factors of climate change, and their presentation in the form of stochastic or deterministic-stochastic model;

- spatial classification and determination of homogeneous regions;

- development of spatial statistical models of different forms for homogeneous regions.

Statistical methods and the particular tools have been developed for realization of each step of development of such joint model. Among them are:

- two parameters linear model of seasonal function as a number of relationships between averaged data for long-term period and data of each year;

- robust statistical methods of decomposition and smoothing for extraction of interannual, decadal, centural and other time-scale components from observed time series, which do not misrepresent the properties of fluctuations;

- application of new dynamic characteristics, which characterize abrupt climate change and other dynamic properties (period and amplitude of cycles, speed of increasing and decreasing of fluctuations and their durations, etc.);

- identification of random events and their generalization into the time model as probable distribution function (pdf) or time function for modeling and forecast;

- tool for classification and regionalization of climate change components, which takes into account a spatial correlation and threshold index of intersection of the same sites in each class;

- linear spatial model, which connects mean historical climatic field with each year field and includes two main coefficient: gradient and level of the field (external properties) and a parameter of space-time non- homogeneity (internal properties).

Application of each technique is shown in form of the particular case studies and they are:

- processing of time series of palaeodata for the last 17-20 thousand years;

- time model for more than 3 centural instrumental record of air temperature for the Central England and precipitation records in the same region and a couple model of extracted climate change components;

- monthly air temperature at sites over European continent, their time models, determination of homogeneous regions with the same climate change and spatial modelling into homogeneous regions.

Orbital climate theory and Hurst-Kolmogorov dynamics

Tuesday - Poster Session 10

Y. Markonis, D. Koutsoyiannis and N. Mamassis

Department of Water Resources and Environmental Engineering, Faculty of Civil Engineering, National Technical University of Athens, Zographou, Greece

Orbital climate theory, based mainly on the work of Milankovitch, is used to explain some features of long-term climate variability, especially those concerning the ice-sheet extent. The paleoclimatic time series, which describe the climate-orbital variability relationship, exhibit Hurst-Kolmogorov dynamics, also known as long-term persistence. This stochastic dynamics provides an appropriate framework to explore the reliability of statistical inferences, based on such time series, about the consistency of suggestions of the modern orbital theory. Our analysis tries to shed light on some doubts raised from the contradictions between the orbital climate theory and paleoclimatic data.

Non-linear trend technique to analyze non-stationary climate series

Tuesday - Poster Session 10

Oleg Pokrovsky

Main Geophysical Observatory, St. Petersburg, Russia

A smoothing procedure to acquire non-linear trend (NLT) for a non-stationary time series was developed. It is based on a combination of piecewise local polynomial data approximation and smoothing by means of the regularization mechanism of Tikhonov. A selection rule for impact nodes and data is governed by means of cross-validation criterion Wahba. The NLT provides a unbiased feature fulfillment similar to those for linear trend (LT): estimates. Besides the NLT estimates delivers some novel statistical benefits: (1) “white noise”-like behavior of the NLT deviations from the observing data (2) delta-type of autocorrelation function for the deviation time series in contrast to those for the LT; (3) lesser corresponding variances and widths for confidential intervals with the same statistical significance levels than these for the LT. Global annual surface air temperature (SAT) CRUTEM3 data set for 1850-2009 years was used for illustration of this method efficiency with account to LT and moving average (MA) technique. The NLT smoothing permits to reveal SAT wavelike oscillations with quasi-periodicity of 65-70 years. Independent wavelet analysis confirms existence of this quasi-periodicity in data. Similar study for Atlantic Multidecadal Oscillation (AMO) for winters in 1856-2009 years has proved that there is a coherency between the AMO and the de-trended global SAT series. Autocorrelation function for time series of the LT deviations from the SAT and AMO data demonstrates pair wise swings just in intervals of its non-stationary behavior, e.g. 65-70 years. Autocorrelation functions responded to the NLT have a delta-like structure. That means that corresponding NLT deviations from observations are close to model of “white noise”. Wavelet analysis of the NLT SAT and AMO displays a single anomaly in 2-D spectrum scales of 65-70 years, which looks like those in spectrum for original data. Similar analysis carried out with the MA smoothing procedure could not be so helpful in revealing of slow temporal data oscillation and provides more blurred 2-D wavelet spectrums. Examples of NLT for other climate parameters (solar activity, sea ice extent, sea surface temperature, Pacific Decadal Oscillation, etc.) will be presented.

Serial correlation in the water mass properties of the Gulf of St. Lawrence

Tuesday - Poster Session 10

Denis Gilbert

Maurice-Lamontagne Institute, Dept. of Fisheries and Oceans, Mont-Joli, Canada,

The water masses of the Gulf of St. Lawrence, as well as most of the world ocean, exhibit strong serial correlation in interannual time series of temperature, salinity, dissolved oxygen and other properties. In spite of this, oceanographers and fisheries scientists often ignore serial correlation in estimations of the mean or the trend of univariate time series, thus overestimating the number of degrees of freedom and underestimating the uncertainties for the test statistics. Another area of research suffering from the neglect of serial correlation is fisheries oceanography. For example, a large proportion of fish recruitment studies claim significant relationships between a given environmental variable time series and the recruitment time series of a particular species, completely ignoring the fact that one or perhaps both time series are serially correlated to begin with. I will be reviewing some of the most popular techniques for taking into account serial correlation in oceanography and fisheries science.

What can we learn about palaeo-biomes from pollen?

Tuesday - Parallel Session 3

Jonathan Rougier

Dept. of Mathematics, University of Bristol, UK

Biomisation' is the process of reconstruction biomes from pollen taxa assemblages. The dominant method is to choose the biome with the highest affinity score. This is a non-statistical method, and it is interesting to see whether a statistical method can be derived which uses the same information. Such a method would open the door to quantitative assessment of biome uncertainty, and a comparison of competing biomes on the weight of evidence, ie hypothesis testing. We derive such a method, and show that it is a special case of a more general method that can allow for differential contamination and counting errors across biomes and pollen taxa, and differential productivity and dispersal across taxa.

Reconstructing palaeoclimates from biological proxies: Some biological and chronological sources of uncertainty

Tuesday - Parallel Session 3

Brian Huntley

Durham University, UK

The various biological proxies used as the basis for palaeoclimatic reconstructions respond principally to different climatic variables. Biologists' knowledge of which variables are of primary importance to a given proxy is often limited or even lacking. Furthermore, even when known, these primary variables often are not those directly recorded by meteorologists. Further complexity arises from the observations that climatic, and sometimes also other environmental, variables often have interacting effects upon orgamisms, and that the primary climatic variable generally differs in different parts of the geographical / climatic range of the taxon providing the proxy. Reconstructing the 'wrong' variable(s), or reconstructing individual variables in isolation, represents a large, but often overlooked, source of uncertainty in the reconstructed values obtained.

One approach to reducing such uncertainties is to attempt to make concurrent palaeoclimatic reconstructions from different proxies sampled in different localities, requiring that the spatial and temporal relationships between the reconstructed values are consistent with physical understanding of the climate system. The use of different methods to estimate the chronology for these different records, along with the limitations of each of these methods, however, generates an additional source of uncertainty when attempting to develop this approach.

Constructing a reconstruction method that does not underestimate low-frequency variability

Tuesday - Parallel Session 3

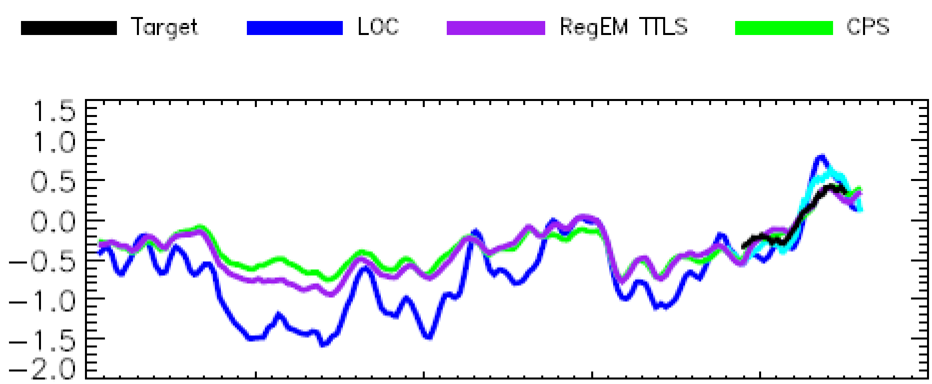
Bo Christiansen

Danish Meteorological Institute, Denmark

Many reconstructions of the Northern Hemisphere mean temperature in the last millennium show a hockey-stick signature: A mean temperature that does not vary much before the rapid increase in the last century. However, there has been an increasing awareness of the fact that the applied reconstruction methods underestimate low-frequency variability and trends (e.g., Christiansen et al. 2009). It has also been found that reconstructions contain a large element of stochasticity which is revealed as broad distributions of skills. This means that it is very difficult to draw conclusions from a single or a few realizations.

Climate reconstruction methods are based on variants of linear regression models relating temperatures and proxies. In this contribution we review some of the theory of linear regression and error-in-variables models to identify the sources of the underestimation. Based on the gained insight we formulate a reconstruction method supposed to minimise this problem. The new method (LOC) is tested with a pseudo-proxy approach by applying it to an ensemble of surrogate temperature fields based on two climate simulations covering the last 500 and 1000 years, respectively. Compared to the RegEM TTLS method and a composite plus scale method (CPS) - two methods recently used in the literature - the new method strongly improves the behaviour regarding the low-frequency variability and trends.

The importance in real world situations is demonstrated by implying the methods to different sets of real proxies. Here the new method (LOC) shows much larger low-frequency variability and a much colder pre-industrial temperature level than the other reconstruction methods. The figure shows an example based on the proxies from Hegerl et al. 2007. The proxies cover the period 1505-1960, the calibration period is 1880-1960, observed temperatures are from HadCRUT2v. The average temperature north of 30± N is reconstructed.



Christiansen, B., T. Schmith, and P. Thejll, A surrogate ensemble study of climate reconstruction methods: Stochasticity and robustness, *J. Climate*, *22*, 951–976, 2009.

Hegerl, G. C., T. J. Crowley, M. Allen, W. T. Hyde, and H. N. Pollack, Detection of human influence on a new, validated 1500-year temperature reconstruction, *J. Climate*, *20*, 650–666, 2007.

An intercomparison of the SAM index in the 20th century reanalysis, HadSLP2 and statistical SAM index reconstructions

Tuesday - Parallel Session 3

Julie M. Jones[1], Ryan L. Fogt[2] and Martin Widmann[3]

[1]*Department of Geography, University of Sheffield, UK*

[2]*Department of Geography, Ohio University, USA*

[3]*School of Geography, Earth and Environmental Sciences, University of Birmingham, UK*

The Southern Hemisphere Annular Mode (SAM) is the main mode of atmospheric circulation variability in the Southern Hemisphere. It characterises changes in the strength and position of the eddy-driven jet, with a positive index representing negative high latitude and positive midlatitude pressure anomalies, and hence stronger westerly circumpolar flow. Recent observational records indicate positive trends during austral summer and autumn, a number of modelling studies suggest that this is a response to stratospheric ozone depletion and increased atmospheric greenhouse gas concentrations. It is difficult to put these changes into a longer-term context, due to the lack of a long, homogeneously spaced network of meteorological stations to provide SLP estimates, largely due to the large ratio of ocean to land in the Southern Hemisphere, and that the largest continent, Antarctica, did not have regular meteorological measurements until 1958.

This study compares the SAM in the four standard seasons as calculated from the twentieth century reanalysis, as calculated from a statistical reconstruction of gridded SLP (HadSLP2), and from SAM index reconstructions derived using principal component regression with station sea level pressure (SLP) data as predictors (Jones et al. 2009). Initial analysis shows differences between the reconstructions and HadSLP2 between the 1920s and the 1940s, which may be linked to a lack of pressure data in the southeastern Pacific during this period.

Jones, J. M., R. L. Fogt, M. Widmann, G. Marshall, P. D. Jones, and M., Visbeck, 2009: Historical SAM Variability. Part I: Century Length Seasonal Reconstructions, *J. Climate*, 22, 53195345.

Skill of climate field reconstruction methods in the context of optimal interpolation estimates

Tuesday - Parallel Session 3

Alexey Kaplan[1], **Jason E. Smerdon**[1] **and Michael N. Evans**[2]

[1]*Lamont-Doherty Earth Observatory of Columbia University, USA*

[2]*Department of Geology and Earth System Science Interdisciplinary Center, University of Maryland, USA*

Well-known pseudoproxy tests that were previously used for such methods of climate field reconstruction as Regularized Expectation-Minimization (RegEM) and Canonical Correlation Analysis (CCA) are now repeated for Optimal Interpolation and its reduced space approximation (RSOI). The actual RSOI skill and the reliability of its theoretical error estimates for reconstructed values are evaluated. Their dependence on the observational network, length of the calibration period and the homogeneity of “true” climate record are analyzed. These results are then used for the interpretation of the skill exhibited by RegEM and CCA.

Historical Southern Hemisphere Annular Mode variability from statistical reconstructions and the IPCC AR4 simulations

Tuesday - Parallel Session 3

Julie M. Jones[1], **Ryan L. Fogt**[2] **and Martin Widmann**[3]

[1]*Department of Geography, University of Sheffield, UK*

[2]*Department of Geography, Ohio University, USA*

[3]*School of Geography, Earth and Environmental Sciences, University of Birmingham, UK*

Reconstruction of Southern Hemisphere climate presents a challenge due to the smaller land-surface area than the Northern Hemisphere, and the lack of measurements from the largest continent (Antarctica) before the mid twentieth century.

Seasonal reconstructions of the Southern Hemisphere Annular Mode (SAM) index back to 1865 using principal component regression with station sea level pressure (SLP) data as predictors, have been derived. Two reconstructions using different predictands were obtained, one (JW) based on the first principal component (PC) of extratropical SLP from the ER40 reanalysis, and the other (Fogt) on the index of Marshall (2003).

As the predictors are based on observational data, this provides an opportunity to investigate reconstruction issues in a case where the predictors have a purely climatic response to the variable being reconstructed, but as for many proxy-based reconstructions, are based on a spatially inhomogeneous network.

The spatial structure of the SAM differs between seasons, and this influences the structure of the statistical model and the reconstruction uncertainty. The spatial structure of SLP anomalies in periods of strong positive and negative SAM index was investigated, to determine how well the spatially inhomogeneous predictors capture the SLP anomaly in each season. Many cases, such as the most recent peak in austral summer, represent a full hemispheric SAM pattern. However a number of periods project onto the SAM but are not canonical SAM-events. For example a number have positive SLP anomalies in mid-latitude regions known to be preferential to blocking, but not a zonally symmetric SAM signature. How well these events are captured then depends on the location of predictor stations in relation to the anomaly regions. Hence some events will be captured more realistically than others by a sparse predictor network.

The reconstructed SAM indices were used to evaluate the SAM in simulations from 17 IPCC Fourth Assessment Report models from 1865-2005. The models capture the recent (1957-2005) positive SAM trends in austral summer, which reconstructions indicate is the strongest trend during the last 150 years; ozone depletion is the dominant mechanism driving these trends. The models simulate too strong recent trends in SON, indicating low ozone and greenhouse forcing on the SAM or that natural variability overrides any trends.

Coral-based, multiproxy, multicentury, ensemble climate field reconstructions of Pacific basin sea surface temperatures

Tuesday - Parallel Session 3

Michael N. Evans[1] **and Alexey Kaplan**[2]

[1]*Dept. of Geology and Earth System Science Interdisciplinary Center, University of Maryland, College Park, USA*

[2]*Lamont-Doherty Earth Observatory of Columbia University, Palisades, USA*

We report skill characteristics and features of an ensemble of optimal interpolation, reduced space, climate field reconstructions (OI-CFR) of annually-averaged Pacific Basin SST. Reduced space OI-CFR finds the target climate field estimate that is the least-squares fit to error-weighted, calibrated proxy observations and an error-weighted, truncated estimate of variability in the known modern target climate field. The OI-CFR approach is modified to produce an ensemble of CFRs, assuming the reduced space reconstruction has normal multivariate error. In this framework, the sum of signal and error variance are constant over time, even if declining numbers of proxy observations over time require that the ratio of signal to error variance changes dramatically over time. The CFRs are developed from 96 annual and higher-resolution coral data series obtained from the World Data Center-A for Paleoclimatology and PANGAEA databases, which extend with discontinuities back to the 10th century. Similar to earlier efforts, we find two EOF patterns, possibly a third, are reliably reconstructed: these appear to describe ENSO-related variability, with the third pattern a homogeneous trend. Skill is improved due to better spatial coverage and reaches 50% of target field variance in the central equatorial Pacific. Analysis and applications of the results include (1) probability and frequency of very strong ENSO events and decadal-timescale features over time; (2) development of forcing functions for ensemble atmospheric GCM experiments for testing hypotheses linking ENSO cold phase activity to drought episodes in North America over the past several centuries.

Variance-preserving, data-adaptive regularization schemes in RegEM. application to ENSO reconstructions

Tuesday - Parallel Session 3

Julien Emile-Geay[1], Tapio Schneider[2], Diana Sima[3] and Kim Cobb[4]

[1]*University of Southern California, USA*

[2]*California Institute of Technology, USA*

[3]*Katholieke Universiteit Leuven, Belgium*

[4]*Georgia Institute of Technology, USA*

The Regularized Expectation-Maximization algorithm (RegEM) has been abundantly used in recent years to estimate past climate variability from proxy data (e.g. *Mann et al* [2005,2007a, 2008, 2009], *Rutherford et al.*, [2005, 2007]; *Emile-Geay et al*, 2010). Paleoclimate problems offer three important challenges to this particular imputation method:

(a) the amount of missing values is very large, typically > 50%

(b) proxy networks are noisy, so only few modes (<5) can be reliably estimated

(c) the proxy series have very different noise levels, calling for adaptive regularization schemes

Smerdon & Kaplan [2007] and *Smerdon et al* [2008] have showed how RegEM can underestimate past variability when the ridge regression scheme is used; this is due to the smoothing effect of the procedure, which turns out to damp the amplitude of even the leading eigenmode of the covariance matrix when few degrees of freedom are available. Regularization by truncated total least squares (TTLS), has proven more robust [*Mann et al* 2008, 2009] but is no longer data-adaptive, hence necessitating a subjective truncation choice. Thus, one needs to devise new regularization schemes that are data-adaptive, perserve leading eigenvalues, and perform well even with large amounts of missing data.

In this work, we compare 3 regularization methods TTLS (as used by *Mann et al*, 2009), a new adaptive TTLS method (iTTLS) which finds optimal solutions by Bayesian Model Averaging; and a standard, l_1 based regularization method (LASSO). The performances of the three methods are compared on a synthetic SST imputation problem as well as a pseudoproxy-based reconstruction problem. Using these 3 schemes, ENSO variability is then reconstructed from a network of paleoclimate proxies over the past 1000 years (*Emile-Geay et al* 2010). We discuss the impacts and biases of each method, as well as implications for other paleoclimate reconstructions.

Emile-Geay, K. Cobb, M. Mann, S. Rutherford, and A. T. Wittenberg. Low-Frequency Tropical Pacific Sea-Surface Temperature over the Past Millennium: Reconstruction and Error Estimates. *J. Clim*., submitted.

Mann, M. E., S. Rutherford, E. Wahl, and C. Ammann (2005), Testing the Fidelity of Methods Used in Proxy-Based Reconstructions of Past Climate., *Journal of Climate*, *18*, 4097–4107.

Mann, M. E., S. Rutherford, E. Wahl, and C. Ammann (2007), Robustness of proxy-based climate field reconstruction methods, *Journal of Geophysical Research* (*Atmospheres*), *112*(D11), 12,109–+, doi:10. 1029/2006JD008272.

Mann, M. E., Z. Zhang, M. K. Hughes, R. S. Bradley, S. K. Miller, S. Rutherford, and F. Ni (2008), Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia, Proceedings of the National *Academy of Sciences*, 105(36), 13,252–13,257, doi:10.1073/pnas. 0805721105.

Mann, M. E., Z. Zhang, S. D. Rutherford, R. S. Bradley, M. K. Hughes, D. T. Shindell, C. M. Ammann, G. Faluvegi, and F. Ni (2009), Global Signatures of the "Little Ice Age" and "Medieval Climate Anomaly" and Plausible Dynamical Origins, *Science*, 326(5957):1256–1260.

Smerdon, J. E., and A. Kaplan (2007), Comments on "Testing the Fidelity of Methods Used in Proxy-Based Reconstructions of Past Climate": The Role of the Standardization Interval, *J. Clim*., pp. 5666–5670.

A Bayesian hierarchical modelling approach to reconstructing past climates

Tuesday - Parallel Session 3

David Hirst

Norwegian Computing Center, Norway

Using proxy data to estimate past temperature has a number of inherent problems: Individual proxies have different time spans and resolutions, they have a complex relationship to temperature, and in some cases may have no relationship at all, they rarely have good instrumental data for calibration, and usually can only reflect local conditions. I will attempt to address some of these problems by developing a Bayesian hierarchical model to relate proxy data to an underlying true temperature.

The model assumes a temperature field T which has a spatio-temporal structure. The data (both proxy and instrumental) are then regarded as observations, with error, of this field. A simple example could be that T is autoregressive order 1 with no spatial variability, ie $T_t \sim N\left(\beta_T T_{t-1}, \sigma_T^2\right)$. This could represent a regional or global mean temperature.

Each observation series $O_{y,t}$ is then a function g_y of this series, plus temporally (and possibly spatially) correlated error $h_y(t)$, plus iid measurement error $\varepsilon_{y,t}$:

$$O_{y,t} = g_y(T_{y,t}) + h_y(t) + \varepsilon_{y,t}$$

The model can be fitted using a Bayesian approach, which in principle allows almost any proxy series to be included in the analysis, since g can take whatever form is necessary. For example if the proxy is considered to represent an average temperature over some (known) period, this can easily be incorporated. Also missing data cause no problems, and multiple proxies of different lengths can be included. The uncertainty in the reconstruction is automatically calculated as the posterior distribution of T.

The talk will be illustrated with and example using multiple proxies and instrumental records.

Paleoclimate extremes in proxy data

Tuesday - Parallel Session 3

Elizabeth Mannshardt-Shamseldin, Peter Craigmile and Martin Tingley

There is often interest in determining which year in a proxy reconstruction was warmest, coldest, or otherwise extreme. For example, using proxy data to address questions such as “Were the 1990s the warmest decade of the last millennium?”, “Is there evidence that the extreme events of recent decades are more extreme than previous decades?” The methodology of extreme value theory has not been widely applied to this problem. What can the statistics of extremes offer? Are there temporal trends among the extreme temperature values in proxy data? What can be learned by examining the behavior of the extreme value distributions for proxies themselves versus those for reconstructions and observed data? There is also interest in determining how these reconstructions compare to the observed climate. This leads to possible calibration with climate model output, with models run under different greenhouse gas assumptions.

CORDEX: Developing an ensemble of high-resolution Regional Climate Change projections for the majority of land regions on the globe

Tuesday - Parallel Session 5

Colin Jones

Rossby Centre, SMHI, Sweden

CORDEX (Coordinated Regional Downscaling Experiment) is a WCRP sponsored activity whereby the international downscaling community is coming together in order to generate a coordinated set of Regional Climate projections based on the CMIP5 GCM simulations. This presentation will motivate the need for an ensemble approach to Regional Climate Change Assessment, explain the main aims of the CORDEX initiative and present some initial results from Regional Climate Simulations made for the present day climate over the CORDEX Africa domain.

Downscaling future climate change using statistical ensembles

Tuesday - Parallel Session 5

E. Hertig and J. Jacobeit

Institute of Geography, University of Augsburg, Augsburg, Germany

Different types of techniques to regionalize global climate model output have been developed: variable resolution GCMs, high resolution time-slice experiments, nested regional climate models, and various statistical downscaling approaches mostly using synoptical analysis or transfer functions.

Statistical downscaling is a computationally inexpensive technique which can be adapted for a wide range of applications. It is based on statistical relationships linking a set of large-scale atmospheric variables (predictors) to regional climate variables (predictands) during an observational period. The established statistical relationships have to be verified during a period independent from the calibration period and are subsequently used to predict the future response of regional climate to simulated climate model changes of the large-scale variables. In the scope of this approach careful attention has to be given to the choice of predictors. Also different techniques should be applied to a range of several AOGCM simulations. To further consider uncertainties which arise from the use of statistical downscaling techniques, nonstationarities in the predictor-predictand-relationships should also be addressed.

An appropriate approach to take into account such non- stationarities in the circulationclimate- relationships is the use of a statistical ensemble method which is based on several different calibration periods. Predictor- predictand- relationships are established in each of these different calibration periods, thus covering a larger range of natural variability. The differing performance of the statistical models in the verification periods can be used to further examine the underlying non-stationarities. Additionally, future projections of regional climate change can be specified with a particular quantification of uncertainties.

Downscaling of GCM-simulated precipitation using Model Output Statistics

Tuesday - Parallel Session 5

Martin Widmann and Jonathan M. Eden

School of Geography, Earth and Environmental Sciences, University of Birmingham, UK

Regional or local-scale precipitation changes can not be directly inferred from precipitation simulated by General Circulation Models (GCMs) because of the limited spatial resolution of GCMs, but also because of systematic errors even on the resolved scales. One possibility to overcome the problem is to estimate regional precipitation through statistical downscaling. For climate change studies the statistical links between large and small spatial scales are usually derived from real-world observations and then applied to the output of GCM simulations for the future climate. This approach requires the large-scale predictors from the GCM to be realistically simulated and is therefore known as 'Perfect-Prog(nosis)' (PP) downscaling.

An alternative approach, which is known as and which is routinely used in numerical weather prediction, is to derive empirical corrections for simulated variables, for instance by formulating statistical models that correct simulated precipitation. MOS usually combines a correction and a downscaling step. The use of MOS for climate change simulation is hampered by the fact that standard GCM simulations for historic periods do not represent the temporal evolution of random variability. If MOS corrections were fitted based on such simulations, there would be a risk that differences in simulated and observed variables, such as biases, scaling factors or more general differences in distribution parameters, would be falsely attributed to model errors and thus would be falsely modified by the MOS approach, when they are actually caused by random differences in the simulated and observed distribution of large-scale weather states. Moreover, in such a setting the type of statistical models that can be formulated to link simulated and observed variables is strongly restricted. As a consequence the MOS approach has not yet been used for estimating precipitation changes directly from GCM climate change simulations.

In order to derive MOS corrections for simulated GCM precipitation we have conducted a simulation for the period 1958-2001 with the ECHAM5 GCM in which key circulation and temperature variables are nudged towards the ERA-40 reanalysis. This simulation thus is consistent with reality with respect to the large-scale weather variability, and MOS corrections that link simulated precipitation with regional observed precipitation can be derived from it. For this approach it is crucial that the simulated precipitation is not nudged towards observations and is calculated purely by the precipitation parameterisations in the GCM.

We have used simple local scaling as well as different regression-based MOS downscaling methods that use non-local predictors (Maximum Covariance Analysis, PC multiple linear regression) to estimate regional monthly precipitation (1958-2001) from the nudged ECHAM5 simulations. The observations to fit and validate the methods have been taken from the global GPCC gridded dataset, which has a spatial resolution of 0.5° x 0.5°. Cross-validation shows that ECHAM5 precipitation is in many areas a very good predictor for the real precipitation given realistic synoptic-scale atmospheric states. Correlations of the MOS estimates for monthly means with GPCC observations are as high as 0.9 in parts of the Northern Hemisphere and Australasia. Reconstructions of European winter (summer) precipitation show a mean correlation with observations of 0.72 (0.51). We have compared the MOS approach with conventional PP downscaling using geopotential height and humidity as predictors and found a substantially better performance of MOS. For instance the best PP estimates for European winter (summer) precipitation a mean correlation with observations of 0.54 (0.34).

Application of the best methods to ECHAM5 simulation for the 21 century used in the IPCC Fourth Assessment Report (AR4) are currently underway and estimates for future precipitation changes as well as for the spatially varying skill of these estimates will be presented.

Constructing ensembles of climate change scenarios based on statistical downscaling

Tuesday - Parallel Session 5

Radan Huth[1], **Stanislava Kliegrová**[2] **and Ladislav Metelka**[2]

[1]*Institute of Atmospheric Physics, Prague, Czech Republic*

[2]*Czech Hydrometeorological Institute, Regional Office, Hradec Králové, Czech Republic*

Probabilistic framework is now accepted as a standard for formulating future climate change scenarios based on global climate model (GCM) outputs. However, the use of statistical downscaling (SDS) as a tool for transferring climate information from large to local scales introduces additional uncertainties that should be taken into account in climate change scenarios. The SDS-related uncertainties arise from a considerable sensitivity of SDS outputs to the selection of the statistical model and its parametres, as well as of the set of predictors. In this contribution, we aim to assess the SDS uncertainty alone, that is, for a single emission scenario of a single GCM, thereby keeping most of the other uncertainty factors constant. We calculate climate change response for daily temperature at a network of European stations (data coming from the ECA&D database) by various SDS methods, including linear regression and neural networks, and for different sets of predictors. We discuss whether the individual SDS outputs forming the ensemble should be weighted, and which weights should be used. We argue that the weights of a particular SDS-based scenario should reflect (i) the ability of the SDS model to reproduce the predictand, (ii) the ability to reproduce past climatic trends, (iii) the ability of the driving GCM to reproduce the SDS predictors, (iv) the multiplicity (or mutual dependence) of SDS models, and (v) the stability of the predictor-predictand relationship. The final pdf of anticipated temperature change is constructed bz the Gaussian kernal algorithm. Examples of the probabilistic climate change scenarios constructed in this way are shown.

Statistical downscaling and modelling using sparse variable selection methods

Tuesday - Parallel Session 5

Aloke Phatak[1], **Harri Kiiveri**[2], **Carmen Chan**[1] **and Bryson Bates**[1]

[1]*CSIRO Climate Adaptation Flagship, CSIRO Mathematics, Informatics and Statistics, Wembley, Australia*

[2]*CSIRO Transformation Biology Platform, CSIRO Mathematics, Informatics and Statistics, Wembley, Australia*

In many statistical downscaling and modelling methods in climatology, the atmospheric predictors used to model variables such as rainfall are often chosen by a combination of expert knowledge and empirical measures such as correlations or partial correlations. To date, little work has been done on automatic variable selection from a large ensemble of potential predictors arising from atmospheric fields. In this work, we describe the use of a fast, sparse variable selection technique known as RaVE (**Ra**pid **V**ariable **E**limination) (Kiiveri, 2008) for selecting atmospheric predictors, and illustrate its use on rainfall occurrence and amounts at stations in Australia.

RaVE is a generalization of *L*1-norm methods such as the LASSO (Tibshirani, 1996); however, because it is also a general engine for imposing sparsity on a wide range of models, it can be used to select variables in simple models for modelling rainfall occurrence, such as logistic regression, but also in more complex models in which we wish to model either the location or scale parameter of a generalized extreme value distribution for modelling trends in rainfall extremes. Using examples drawn from different regions in Australia, we show that RaVE generates parsimonious models that are both sensible and interpretable, and whose results compare favourably to those obtained by existing methods.

1. Kiiveri, H. (2008). *BMC Bioinformatics*, **9**, 195.

2. Tibshirani, R. (1996). *Journal of the Royal Statistical Society*, Ser. B, 267–288.

A functional data approach for climate zones identification

Tuesday - Parallel Session 5

Edmondo Di Giuseppe[1], **Giovanna Jona Lasinio**[2], **Stanislao Esposito**[1] **and Massimiliano Pasqui**[3]

[1]*CRA-Cma, Roma, Italy*

[2]*Uniroma1, Roma, Italy*

[3]*CNR-Ibimet, Roma, Italy*

In order to correctly describe atmospheric variability and clear trends, homogeneous climate regions should be identified. A combination of Functional Data Analysis (FDA) and Partioning Around Medoids (PAM) clustering technique is applied in Italy for surface temperature and precipitation fields. The analysed dataset is composed of daily precipitation and daily minimum and maximum temperature data collected for the period 1961-2007 from 96 Italian stations. First, minimum and maximum temperatures were averaged to obtain medium temperature. Then Monthly Mean of Medium Temperature (Tmed-MM) and Monthly Cumulated Rainfall (Prec-MC) were calculated. Thus, 96 time series of 564 monthly values concerning a set of 2 climatic variables form the basis for the classification.

FDA is a collection of techniques to model data from dynamic systems in terms of some set of basis functions, which are a linear combination of known functions. FDA consists of converting observations gathered at discrete time into functional data.

Tmed-MM and Prec-MC time series can be considered as realizations of continuous processes recorded in discrete time. As each time series is representative of station location climate variability, they are converted into functional data through the estimation of spline coefficients. The main advantage of functional data is the reduction of many observations to few coefficients, preserving the information about temporal pattern of the time series. B-splines system of basis with a fixed number of knots is adopted for functional data conversion, which guarantees a comparability of responses from 96 time series. Fixed interior knots are 45 plus 2 knots corresponding to the edges of observations interval, piece-wise polynomials degree is 3 for a total number of 51 estimated coefficients. A Generalized Cross Validation (GCV) procedure is applied for determining the λ weight of penalty matrix. Finally the number of estimated coefficients is reduced by means of Principal component analysis (PCA). Thus, the Pc's of estimated coefficients are partitioned by PAM classification technique to obtain climate zones.

PAM algorithm clusters objects around k medoids where k is specified in advance. Medoids are chosen at each iteration as representative items rather than calculate the mean of the items in each cluster. As an alternative the coordinates of k medoids can be established as initial medoids. A comparison between the average distance of object i from all other objects in the same cluster and the minimum distance of object i from all other objects not in the same cluster composes an index defined as *silhouette*. A plot of silhouettes for all objects is a method both to determine the number of clusters and also to determine which objects lie well within their clusters and which do not.

Once a final grouping of the stations is established, a cross validation procedure is applied in order to quantify those stations correctly classified. An assessment based on climatic mechanisms is also presented to judge the quality of the clustering obtained. Besides, classical method for climate zone delineation, like S-mode and T-mode procedures, were performed and a comparison of results obtained with different method is worth evaluating the functional data approach.

Downscaling climate change projections of Indian summer monsoon rainfall using a nonhomogeneous hidden Markov model

Tuesday - Parallel Session 5

Arthur M. Greene

Downscaled rainfall projections for the Indian summer monsoon are generated using information from both a dense observational dataset and an ensemble of general circulation models (GCMs), with estimation carried out in the framework of a nonhomogeneous hidden Markov model (NHMM). Simulations, produced at daily resolution, are both constrained by observed spatiotemporal variability and conditioned by changes in large-scale fields from the GCMs, drawing from each class of information those attributes it is best suited to provide. Warming of the planet brings about an increase in lower tropospheric moisture, while a weakening of the large-scale monsoon circulation shifts the balance in favor of drier states. The NHMM assimilates both of these tendencies, projecting distributions that respect GCM-inferred changes in the circulation and moisture fields while retaining the fine-scale structure implicit in the observational record.

Controls on rainfall variability on Southern Africa: An analysis based on generalized linear model

Tuesday - Parallel Session 5

Chiara Ambrosino[1], **Richard E. Chandler**[2] **and Martin C. Todd**[3]

[1]*University College London, Department of Geography, London, UK*

[2]*University College London, Department of Statistical Science, London, UK*

[3]*University of Sussex, Department of Geography, Brighton, UK*

Southern Africa is particularly prone to adverse effects of changes in the climate system. In particular global warming may cause intensification of the hydrological cycle, with changes in frequencies and amplitudes of periods of below normal rainfall and associated scarcity in water availability and drought compromising the availability of water for rain-fed agriculture.

To reduce the vulnerability advancement in the climate research needs to be advocated and provision of climate information is necessary for planning adaptation and mitigation measures.

As a first step towards the provision of such information, it is helpful to understand the important climatological controls of rainfall variability in the region. There is already an extensive literature investigating the association between rainfall in southern Africa and individual climate indices such as ENSO, ... However, as far as we are aware there has been little work done to date that attempts to quantify how the various indices work in combination to control the rainfall variability of the region. This talk will describe an analysis based on generalised linear models (GLMs) that aims to address this issue. The GLM-based framework is being used increasingly in climatology: here, it has been employied to identify a small number of key climate indices from a large list of candidates taken from the literature, and to quantify the seasonal and regional effects of these indices upon southern African precipitation.

GLMs are fitted to 20th century observational gridded datasets to characterise the dependence of precipitation upon geographical and climate indicators of interest . As well as characterising the effect of the covariates upon precipitation, GLMs are explicitly probabilistic and therefore provide the opportunity to simulate continuous multiple precipitation sequences useful for impact study applications that are consistent with any given set of atmospheric drivers while recognising that the dependence is not deterministic.

The relationships revealed by the GLM analysis can be exploited in principle to downscale large-scale output from general circulation models (GCMs) to scales that are suitable for use in studies that aim to assess the hydrological impacts of climate change. However, such procedures are based on an assumption the relationships will continue to hold in the future. Although this assumption is untestable, some reassurance may be gained by comparing equivalent relationships obtained from GCM simulations for the 20th and 21st centuries. If these relationships are similar (and regardless of whether the GCMs are able to reproduce the observed relationships), one can reasonably infer that their stability is at least consistent with our best available knowledge of climate dynamics. The talk will conclude by presenting some preliminary work in this direction.

Construction of high resolution monthly temperature scenarios for North America

Tuesday - Parallel Session 5

Guilong Li[1], Xuebin Zhang[2] and Francis Zwiers[2]

[1]*Atmospheric Science and Application Unit — MSC Ontario Region, Environment Canada, Canada*

[2]*Climate Research Division — ASTD, Environment Canada, Canada*

This presentation provides a framework in which dynamical and statistical downscaling methods are combined to construct monthly temperature scenarios over North America at 45x45 km resolution. Monthly temperatures from outputs of three GCMs are dynamically downscaled by three regional climate models (RCMs) participating the North America Regional Climate Change Assessment Program. The dynamically downscaled high resolution temperature and low resolution GCM outputs for the periods 1968-2000 and 2038-2070 are then used to establish statistical models to link small scale and large scale temperatures. These statistical models are then applied to GCM projected future temperature changes available from the CMIP3 database, to construct high resolution monthly temperature scenarios for North America. Uncertainties due to difference in GCMs, in emission scenarios, and internal variability are analyzed. The end product provides projected monthly temperature changes in the future at 45 km resolution with different uncertainty ranges.

Simulation of multisite precipitation using an extended chain-dependent process

Tuesday - Parallel Session 5

Xiaogu Zheng[1], James Renwick[2] and Anthony Clark[2]

[1]*College of Global Change and Earth System Science, Beijing Normal University, Beijing, China*

[2]*National Institute of Water and Atmospheric Research, Wellington, New Zealand*

The chain-dependent process is a popular stochastic model for precipitation sequence data. In this paper, the effect of daily regional precipitation occurrence is incorporated into the stochastic model. This model is applied to analyze the daily precipitation at a small number of sites in the upper Waitaki catchment, New Zealand. In this case study, the probability distributions of daily precipitation occurrence and intensity, spatial dependences, and the relation between precipitation and atmospheric forcings are simulated quite well. Specifically, some behaviors which are not well modeled by existing models, such as the extremal behavior of daily precipitation intensity, the lag-1 cross correlation of daily precipitation occurrence, spatial intermittency, and spatial correlation of seasonal precipitation totals, are significantly improved. Moreover, a new and simpler approach is proposed which successfully eliminates the overdispersion, i.e. underestimation of the variance of seasonal precipitation totals.

Intercomparison of homogenization procedures: Results of COST ES0601 HOME experiment

Tuesday - Parallel Session 8

Olivier Mestre[1], **Victor Venema**[2] **and COST-ES0601 "HOME"**[3] **Task Force**

[1]*Ecole Nationale de la Météorologie, Toulouse, France*

[2]*University of Bonn, Bonn, Germany*

[3]*COST-ES0601 Task Force composed of: Enric Aguilar, Ingeborg Auer, José A. Guijarro, Petr Stepanek, Claude.N.Williams, Matthew Menne, Emilie Lebarbier, Franck Picard, Alexis Hannart, Peter Domonkos, Julien Viarre, Tamas Szentimrey, Monika Lakatos, Dubravka Rasol, Elke Rustemeyer, Gregor Vertacnik, Kostas Kolokythas, Tania Marinova, Fiorella Acquaotta, Lars Andersen, Tanja Likso, Matija Klancar, Michele Brunetti, Christine Gruber, Marc Prohom Duran, Theo Brandsma*

Long instrumental climate records are the basis of climate research. However, these series are usually affected by inhomogeneities (artificial shifts), due to changes in the measurement conditions (relocations, instrumentation and others). As the artificial shifts often have the same magnitude as the climate signal, such as long-term variations, trends or cycles, a direct analysis of the raw data series can lead to wrong conclusions about climate change. In order to deal with this crucial problem many statistical homogenisation procedures have been developed for detection and correction of these inhomogeneities.

We present here the results of European COST Action ES0601, whose objectives are to compare existing procedures and achieve a general method for homogenising climate and environmental datasets.

http://www.homogenisation.org/

http://www.meteo.uni-bonn.de/venema/themes/homogenisation/

The London and Paris daily pressure series, 1692-2007: The development and analysis of long pressure series

Tuesday - Parallel Session 8

Richard Cornes

Over the last ten years, daily series of mean sea-level pressure (MSLP) have been constructed for several sites across Europe that extend back into the mid-eighteenth century. These series have allowed more detailed analyses of the variability of the atmospheric circulation in the North Atlantic/Western European area than have previously been possible with monthly resolution data. However, long *daily* series of MSLP have not been constructed for the cities of London and Paris. While MSLP series have previously been developed for these two sites at the *monthly* resolution, many of the daily barometer observations have never been extracted from the original sources and have remained uncorrected and unhomogenized. To rectify this situation, the barometer observations recorded by several scientists and organisations based in the cities of London and Paris have been recovered and corrected. By joining these data with previously corrected short series, daily series of MSLP have been constructed for the two sites that extend back to the late seventeenth century (1692 in the case of London and 1670 for Paris). Given that these series consist of the instrumental readings from several observers and extend over a considerable length of time, the homogenization of the data has been an important and major component of the project. This process has been helped by the fact that many of the observations were recorded by leading scientists or scientific institutions, and a remarkable amount of information about the observations is available, even for the seventeenth and eighteenth centuries. Through the application of suitable corrections, these pressure data are able to yield important information about the state of the atmospheric circulation in previous times, and how the circulation has varied over the past 300 years. Most notably, the MSLP series permit the construction of a westerly index on a near-continuous basis back to 1748 and on a more fragmented basis back to 1692.

Detecting and minimising the *screen bias* from long temperature series recorded over Western Mediterranean climates

Tuesday - Parallel Session 8

Manola Brunet

Centre for Climate Change, University Rovira I Virgili, Tarragona, Spain

Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK

It is known that the exposure of thermometers, and the shelters that protect them, at land stations have changed over time. These changes have compromised the homogeneity of century-long air temperature records and their adjustment is difficult to estimate by applying most state-of-the-art homogenisation techniques, as the changeover to new screens took place at similar times in the past at most sites in the national meteorological networks. Relative homogeneity testing techniques in such cases are of little use.

In this solicited talk it will be, first, reviewed the effects induced by the so-called *screen-bias* in long temperature series, which has incorporated a warm (cold) bias in maximum (minimum) temperature records and whose magnitude is dependent on the latitude, the moment of the year/day and on the meteorological conditions of the measurement. This impact will be particularly addressed for the Mediterranean climates. It will be also shown and discussed an exploratory statistical analysis, aimed at the minimisation of this bias from the affected Western Mediterranean long-temperature records. The approach lies in the statistical analysis of about 6 years (5 years as calibration and 1 year as validation periods) of daily paired maximum and minimum temperature observations taken under a replicated ancient MONTSOURI shelter (one of the open stands used in the past to protect thermometers from direct or indirect radiation and wetting) and the modern STEVENSON screen installed in two experimental sites, the meteorological gardens of La Coruña and Murcia, Spain. The generation of a parsimonious regression model based on the data from both experimental sites will be discussed. The model takes into account polynomial terms of lower order for the predictor variables (Tx and DTR recorded under the ancient shelter) and harmonic terms, in order to represent the seasonal cycle of the screen bias.

The influence of weather conditions on daily/hourly inhomogeneity adjustments

Tuesday - Parallel Session 8

Paula Brown and Art DeGaetano

Northeast Regional Climate Center/Department of Earth and Atmospheric Science, Cornell University, Ithaca, USA

Hourly temperature and dewpoint observations have been recorded in the US since the early 20th century. Homogeneity tests have identified that instrument and site changes have affected these long-term records and as a result adjustments are required to account for these changes. Most homogeneity adjustments are based on the relative change on monthly or annual averages between a station and one or many reference stations, with the influence of different weather conditions having received little attention. An investigation of the effects of rain, cloud and wind on temperature and dewpoint adjustments is made using nearby neighbour stations that are part of a different hourly observation network. Time of day and time of year (monthly, seasonal and annual) are also assessed as to the effect of weather conditions on temperature and dewpoint adjusmtents on different timescales. Based on these analyses potnetial methods to adjust hourly observations are determined.

New techniques and software package for detection and adjustment of shifts in daily precipitation data series

Tuesday - Parallel Session 8

Xiaolan L. Wang[1,2], Hanfeng Chen[3], Yuehua Wu[2], Yang Feng[1] and Qiang Pu[2]

[1]*Climate Research Division, Science and Technology Branch, Environment Canada, Toronto, Canada*

[2]*Department of Mathematics and Statistics, York University, Toronto, Canada*

[3]*Department of Mathematics and Statistics, Bowling Green State University, Bowling Green, USA*

This study integrates a Box-Cox power transformation procedure into a common trend two-phase regression model based test (the PMFred algorithm) for detecting changepoints, to make the test applicable to non-Gaussian data series, such as non-zero daily precipitation amounts. The detection power aspects of the transformed method (transPMFred) were assessed using Monte Carlo simulations, which show that this new algorithm is much better than the corresponding untransformed method for non-Gaussian data series. The transPMFred algorithm was also shown to be able to detect three changepoints in a non-zero precipitation series recorded at a Canadian station, with the detected changepoints being in good agreement with documented times of changes.

A set of functions for implementing the transPMFred algorithm to detect changepoints in non-zero daily precipitation amounts were developed and made available online free of charge, along with a quantile matching (QM) algorithm for adjusting shifts in non-zero daily precipitation series, which should work well in absence of any discontinuity in the frequency of precipitation measured (i.e., frequency discontinuity) and should work well for continuous variables such as daily temperature series.

However, frequency discontinuities are often inevitable, especially in the measurement of small precipitation due to changes in the measuring precision etc. Thus, it was recommended to use the transPMFred to test the series of daily precipitation amounts that are larger than a threshold, using a set of different small thresholds, and to use the PMFred algorithm to check the homogeneity of the series of monthly or annual frequency of precipitation occurrence (or non-occurrence, i.e., zero precipitation days) and of various small precipitations measured. These would help gain some insight into the characteristics of discontinuity and attain better adjustments. It was also noted that, when a frequency discontinuity is present, adjustments derived from the measured daily precipitation amounts, regardless of how they were derived, could make the data deviate more from the truth. In this case, one must adjust for the frequency discontinuities before conducting any adjustment to the measured precipitation amounts.

Short-term, platform-like inhomogeneities in observed climatic time series

Tuesday - Parallel Session 8

Peter Domonkos

Centre for Climate Change (C3), Geography Dept., University Rovira i Virgili, Campus Terres de l'Ebre, Tortosa, Spain

Any change in technical or environmental conditions of observations may result in bias from the precise values of observed climatic variables. The common name of these biases is inhomogeneity (IH). Large IHs of the candidate time series can easily be identified with appropriate statistical tools when other time series from neighbouring observing stations are available, and they have high correlation with the candidate series. Improving data quality applying homogenisation is an important step towards revealing the real characteristics of climate change and climate variability in the last one-two centuries. In the recent decades big efforts have been put to develop better and better homogenisation methods, and the effectiveness of these methods was tested using artificial datasets with known IH characteristics.

There still exists a serious problem that has hardly been considered yet, i.e. characteristics of artificial datasets seem to markedly differ from those of observed datasets at least in case of temperature data. A comparison of real and simulated characteristics of detected temperature IHs using Central European datasets showed that observed datasets contain large number of short-term, platform-like IHs. (Platform means a pair of sudden shifts with the same magnitude and opposite direction). These IHs usually have small direct impact on the time series characteristics, and they cannot be distinguished from the random noise. However, the presence of short-term IHs markedly changes the efficiencies of homogenisation methods. For instance, when 100 year long series include standard white noise process plus randomly situated shifts with 0.05 frequency and mean magnitude of 3.5 standard deviation, the efficiencies of the widely used IH-detection methods (Standard Normal Homogeneity Test, Easterling-Peterson method, Wilcoxon Rank Sum test, etc.) are quasi uniformly high. When instead of solely shifts platforms of 1-10 years duration are included leaving the mean frequency and magnitude unchanged, all the efficiencies drop dramatically, and the Caussinus - Mestre method, the Multiple Analysis of Series for Homogenization and the Multiple Linear Regression perform clearly better, than the other detection methods examined.

Some statistics show that this problem is not specific for Central Europe, and has not been treated well even in the ongoing COST project (COST ES0601: Advances in homogenisation methods of an integrated approach). In the COST project a huge benchmark dataset was built including real and artificial networks for temperature and precipitation data series. In an own-developed, fully automatic homogenisation method (ACMANT = Adapted Caussinus-Mestre Algorithm for Networks of Temperature series) two detection segments were applied, one is for long-term IHs with minimum 3 years duration (main detection), and another one (secondary detection) for detecting the relatively large but short-term biases remained after the correction derived from the main detection. Though the overall frequency of detected IHs is 0.05-0.07 for both the real and simulated networks, only 6% of the IHs was detected with the secondary detection in the simulated networks, while the same rate is 19% for real networks of observed temperature datasets.

Homogenization of Argentinean temperature series with an automated Bayesian procedure

Tuesday - Parallel Session 8

Alexis Hannart

We describe a new automatized homogenization procedure. Inhomogeneities are detected on pairwise difference series between correlated neighbours, using a recent Bayesian changepoint algorithm which provides breakpoints posterior distributions. Then, a set of rules which take advantage of these posteriors in the framework of Bayesian decisioning theory is created to attribute the detected inhomogeneities to their culprit series and to group them, in lieu of the time consuming visual inspection used by most existing procedures involving pairwise difference series. The procedure is illustrated on Argentinean temperature data, leading to enhanced warming trends after homogenization.

New developments on the homogenization of Canadian daily temperature data

Tuesday - Parallel Session 8

Lucie A. Vincent and Xiaolan L. Wang

Climate Research Division, Science and Technology Branch, Environment Canada, Toronto, Canada

Long-term and homogenized surface air temperature datasets had been prepared for the analysis of climate trends in Canada (Vincent and Gullett 1999). Non-climatic steps due to instruments relocation/changes and changes in observing procedures were identified in the annual mean of the daily maximum and minimum temperatures using a technique based on regression models (Vincent 1998). Monthly adjustments were derived from the regression models and daily adjustments were obtained from an interpolation procedure using the monthly adjustments (Vincent et al. 2002).

Recently, new statistical tests have been developed to improve the power of detecting changepoints in climatological data time series. The penalized maximal t (PMT) test (Wang et al. 2007) and the penalized maximal F (PMF) test (Wang 2008b) were developed to take into account the position of each changepoint in order to minimize the effect of unequal and small sample size. A software package RHtestsV3 (Wang and Feng 2009) has also been developed to implement these tests to homogenize climate data series. A recursive procedure was developed to estimate the annual cycle, linear trend, and lag-1 autocorrelation of the base series in tandem, so that the effect of lag-1 autocorrelation is accounted for in the tests. A Quantile Matching (QM) algorithm (Wang 2009) was also developed for adjusting Gaussian daily data so that the empirical distributions of all segments of the detrended series match each other.

The RHtestsV3 package was used to prepare a second generation of homogenized temperatures in Canada. Both the PMT test and the PMF test were applied to detect shifts in monthly mean temperature series. Reference series was used in conducting a PMT test. Whenever possible, the main causes of the shifts were retrieved through historical evidence such as the station inspection reports. Finally, the QM algorithm was used to adjust the daily temperature series for the artificial shifts identified from the respective monthly mean series. These procedures were applied to homogenize daily maximum and minimum temperatures recorded at 336 stations across Canada.

During the presentation, the procedures will be summarized and their application will be illustrated throughout the provision of selected examples.

Vincent, L.A., X. Zhang, B.R. Bonsal and W.D. Hogg, 2002: Homogenization of daily temperatures over Canada. *J. Climate*, 15, 1322-1334.

Vincent, L.A., and D.W. Gullett, 1999: Canadian historical and homogeneous temperature datasets for climate change analyses. *Int. J. Climatol*., 19, 1375-1388.

Vincent, L.A., 1998: A technique for the identification of inhomogeneities in Canadian temperature series. *J. Climate*, 11, 1094-1104.

Wang, X. L., 2009: A quantile matching adjustment algorithm for Gaussian data series. Climate Research Division, Atmospheric Science and Technology Directorate, Science and Technology Branch, Environment Canada. 5 pp. [Available online at http://cccma.seos.uvic.ca/ETCCDMI/software.shtml].

Wang X. L. and Y. Feng, 2009: RHtestsV3 User Manual. Climate Research Division, Atmospheric Science and Technology Directorate, Science and Technology Branch, Environment Canada. 26 pp. [Available online at http://cccma.seos.uvic.ca/ETCCDMI/software.shtml].

Wang, X. L., 2008a: Accounting for autocorrelation in detecting mean-shifts in climate data series using the penalized maximal *t* or *F* test. *J. Appl. Meteor. Climatol.*, 47, 2423-2444.

Wang, X. L., 2008b: Penalized maximal F-test for detecting undocumented mean-shifts without trend-change. *J. Atmos. Oceanic Tech.*, 25 (No. 3), 368-384. DOI:10.1175/2007/JTECHA982.1.

Wang, X. L., Q. H. Wen, and Y. Wu, 2007: Penalized maximal *t* test for detecting undocumented mean change in climate data series. *J. Appl. Meteor. Climatol.*, 46 (No. 6), 916-931. DOI:10.1175/JAM2504.1

A change point approach for applications to atmospheric carbon dioxide time series

Tuesday - Parallel Session 8

Claudie Beaulieu and Jorge L. Sarmiento

Atmospheric and Oceanic Sciences, Princeton University, Princeton, USA

Long-term changes in climate variables can exhibit step-like changes in the mean, in the variance and/or in the trend. Change point methods allow detecting and quantifying these changes. Change point methods have been used in atmospheric and oceanic sciences to detect artificial or natural discontinuities and regime shifts.

Most change point approaches were designed to detect a specific type of shift (e.g. either a change in the mean, in the variance or in the parameters of a regression model, but rarely a combination of several types of changes at the same times). Furthermore, most change point methods rely on the independence hypothesis while the presence of autocorrelation is a common feature of climate time series (especially at the short time scales). A positive autocorrelation can lead to the detection of false shifts if it is not taken into account in the analysis. Recently, several studies have started to take into account the autocorrelation in change point detection by assuming that it can be represented by a lag-1 autoregressive model (AR(1)). The autocorrelation structure in climate time series can be more complex that that.

In this work, the informational approach is used to discriminate between several types of changes (shift in the mean, shift in the variance, shift in the trend, shift in the relation with a covariable or a combination of these different types of changes) though the application of a hierarchy of models. The informational approach is also used to identify the auto correlation structure in each models (not restricted only to an AR(1)) and it is taken into account in the change point analysis. The usefulness of this approach to detect change points in atmospheric CO_2 concentration, in the growth rate of atmospheric CO_2 and in the sources and sinks of atmospheric CO_2 is demonstrated through applications.

Generalised linear mixed models, for the modeling of monthly average temperature in a tropical weather

Tuesday - Parallel Session 8

Mercedes Andrade-Bejarano, Edinson Andrés Zuluaga, John Jairo Millán Hernández and Gabriel Conde Arango

School of Industrial Engineering and Statistics, Universidad del Valle, Cali, Colombia

Andrade (2009) modelled monthly average temperature by using lineal mixed models, with spatial and temporal correlated errors. However, the errors did not show normal behaviour, the tails show departures from the fitted line and from the bands at α= 0:05 of the normality plots and also the Anderson Darling Test (A_2) show small p-values (< 0.005). These heavy tails of residuals are determined because of the extreme values of monthly average temperature in years when the "El Niño" and "La Niña" phenomena occur (Pabón *et al*. 2002).

In this research, we modelled monthly average temperature by using generalised linear mixed models (McCullagh and Nelder 1989; Lin 1997), as an alternative to solve the lack of normality in models fitted for monthly average temperature by Andrade (2009). Data for this research come from time series of monthly average temperature from 28 sites, collected over the period 1971 to 2002. Due to the geographical location of the study zone (Valle del Cauca, Colombia, South America); monthly average temperature is affected by the altitude and the "El Niño" and "La Niña" phenomena. Time series for some of the sites show a tendency to increase. Also due to the two dry and wet periods in the study zone, a seasonal behaviour in monthly average temperature is seen. A random effect for year is included in the models and the trends of the time series are modelled through random coefficients. The altitude variable is included in the fixed part of the models and the "El Niño" and "La Niña" phenomena are modelled by including the Southern Oscillation Index. The seasonal patterns are eliminated by fitting models by month. Geographical position (in the valley and mountains) is also included in the modelling. Variograms are used to explore the spatial and the temporal correlation in the errors. Spatial and temporal covariance structures are modelled individually using isotropic models. Maps of predicted temperatures throughout the study area for the "El Niño", "La Niña" and normal conditions are drawn.

Andrade, M. (2009). *Monthly average temperature modelling for Valle del Cauca* (Colombia). (Unpublished PhD. Thesis. The University of Reading, United Kingdom).

Lin, X. (1997), 'Variance component testing in generalised linear models with random effects', Biometrika 84(2), 309-326.

McCullagh, P. and Nelder, J. F. (1989), Generalized Linear Models, second edn, Chapman and Hall. Great Britain.

Pabón, J., Zea, J., León, G., Hurtado, G., González, O. and Montealegre, J. (2002), La Atmósfera, el Tiempo y el Clima, Instituto de Hidrología, Meteorología y Estudios Ambientales IDEAM. Colombia.

The analysis of long memory climate series

Wednesday - Plenary Session 10

Peter F. Craigmile

Department of Statistics, The Ohio State University, Columbus, USA

Long memory processes are a class of stochastic models that exhibit a slowly decaying autocorrelation sequence or equivalently a spectral density function with a pole at zero frequency. Starting with its application in hydrology by Hurst (1951), long memory processes have been used in many applications including atmospheric and climate sciences. It is very common for example to model temperature time series observed at a single location using a long memory process.

In this talk we will review the properties of such processes and will discuss methods that are commonly employed in their statistical analysis. We will discuss the impact of long memory dependence upon trend estimation, and will extend our discussion to the analysis of long memory dependence observed in space-time series. We will motivate this topic via an analysis of temperature series taken from a number of different monitoring stations.

Linear and non linear persistence in climate and its effect on the extremes

Wednesday - Plenary Session 10

Armin Bunde, Sabine Lennartz and Mikhail Bogachev

Institut fuer Theoretische Physik, Universitaet Giessen, Germany

We discuss the occurrence of long-term memory in climate. We show that long-term memory leads to a clustering of extreme events, a phenomenon which is well known from the reported floods in central Europe over the last 6 centuries. We also consider the effect of nonlinear memory that is particularly important in precipitation data, and discuss how it can be used for risk estimation.

Memory in climate and things not to be forgotten

Wednesday - Plenary Session 10

Demetris Koutsoyiannis

Department of Water Resources and Environmental Engineering, Faculty of Civil Engineering, National Technical University of Athens, Zographou, Greece

Forgetting some fundamental issues related to climate may have detrimental effects in its research. A first issue that need not be forgotten is the fact that the very notion of climate relies on statistics. For example, according to a popular definition (U.S. Global Change Research Program: Climate Literacy, The Essential Principles of Climate Sciences, 2009), climate is the long-term average of conditions in the atmosphere, ocean, and ice sheets and sea ice described by statistics, such as means and extremes. In turn, long-term average conditions cannot be assessed correctly if inappropriate statistical models and assumptions are used. For example, statistical methods commonly used in climate research are based on the classical statistical paradigm that assumes independence of processes in time, or on the slightly modified model of Markovian dependence. However, substantial evidence has been accumulated from long time series, observed or proxy, that climate is characterized by long-term persistence, also known as long memory or long-range dependence. Such behaviour needs to be described by processes of Hurst-Kolmogorov type, rather than by independent or Markovian processes. Consequently, it should be remembered that the Hurst-Kolmogorov dynamics implies dramatically higher uncertainty of statistical parameters of location and high negative bias of statistical parameters of dispersion. It also implies change at all scales, thus contradicting the misperception of a static climate and making redundant the overly used term “climate change”. The fundamental mathematical properties of Hurst-Kolmogorov processes is another issue that must not be forgotten, in order to avoid incorrect or misleading results about climate.

A comparison study of extreme precipitation from six regional climate models via spatial hierarchical modeling

Wednesday - Plenary Session 5

Dan Cooley

Department of Statistics, Colorado State University, USA

We analyze output from six regional climate models (RCMs) via a spatial Bayesian hierarchical model. The primary advantage of this approach is that the model naturally borrows strength across locations via a spatial model on the parameters of the generalized extreme value distribution. This is especially important in this application as the data we analyze have great spatial coverage, but have a relatively short data record for characterizing extreme behavior. The hierarchical model we employ is also designed to be computationally efficient as we analyze data from nearly 12000 locations. The aim of this analysis is to compare the extreme precipitation as generated by these RCMs. Our results show that, although the RCMs produce similar spatial patterns for the 100-year return level, their characterizations of extreme precipitation are quite different. Additionally, we examine the spatial behavior of the extreme value index and find differing spatial patterns for the point estimates from model to model. However, these differences may not be significant given the uncertainty associated with estimating this parameter.

Blending analyses for building robust regional predictions

Wednesday - Plenary Session 5

B. Hewitson[1], W. Gutowski[2] and R. Crane[3]

[1]*University of Cape Town, South Africa*

[2]*Iowa State University, USA*

[3]*Pennsylvania State University, USA*

The demand for regional climate change information continues to grow rapidly as users grapple with the realities of developing response strategies tailored to their specific climate exposure, and with due consideration of relevant spatial and temporal details. However, the paucity of clear defensible and actionable information at the scales of importance is now a leading constraint in adaptation decision making. There remains a heavy reliance on Global Climate Model (GCM) native grid resolution data, even though such data is largely inadequate at local scales and presents a significant danger of over-interpretation.

This presentation uses case studies to explore the principles and issues involved in developing robust regional climate change information, drawing on parallel analyses to build a robust understand of regional scale change. The construction of regional climate change messages, defensible and relevant to users, is a nuanced task more complex than simple dissemination of model data derivatives. The robustness of any regional climate change message requires consideration and integration of four principal information sources; a) the past record, b) the controlling large scale circulation, c) the indications of change from multi-model GCM simulations, and d) the detail of local scale projected change derived through downscaling methods.

The historical trend is assessed with an evaluation of the distribution function of past changes. The large scale governing circulation draws on Self Organizing Maps to explore the changes in processes driving the regional climate. The multi-model GCM data is examined in terms of the envelope of projected changes. Finally the local scale projections are assessed with statistical downscaling. The collective of analyses allows for the construction of a more complete understanding of regional changes, and leads to enhanced robustness of the derived information for those working in the impacts and adaptation community.

Understanding the relevance of climate model simulations to informing policy: An example of the application of MAGICC to greenhouse gas mitigation policy

Wednesday - Plenary Session 5

Nicola Ranger, Falk Niehoerester and Leonard A. Smith

The Centre for Climate Change Economics and Policy (CCCEP), London School of Economics and Political Science, London, UK

The Centre for Time Series Analysis (CATS), London School of Economics and Political Science, London, UK

A central debate in international climate change policy over the last decade has been around the question of: how rapidly must global greenhouse emissions be reduced to avoid “dangerous anthropogenic interference” (DAI) with the Earth’s systems. Over the past few years, consensus has begun to form around the goal to limit global warming to two degrees above pre-industrial levels. This was reflected in the ‘Copenhagen Accord’, which was noted by parties to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2009. Partly in response to this increased recognition, a growing number of studies have explored what global emissions reductions would be required to meet such a goal with a defined probability of success. Here, we explore to what extent current climate models are adequate to provide such information and how climate model output might be robustly used in decision-making.

We take the example of Bowen and Ranger (2009). Bowen and Ranger evaluated a ‘plausible envelope’ of global emissions paths that would secure at least a 50 per cent chance of limiting global warming to two degrees above pre-industrial levels. Probabilistic climate projections for twenty paths were evaluated using a version of “MAGICC”, a simple climate model. The resultant temperature distributions aimed to represent parameter uncertainty in the model. The study concluded that, under a low aerosol scenario, global emissions would need to peak in the next five to ten years and then be reduced to less than 48 GtCO2e in 2020 to give at least a 50 per cent chance of limiting warming to two degrees. Under a high aerosol scenario, the upper limit was 54 GtCO2e in 2020. We explore the extent to which such information can be considered informative to policy, given the uncertainties inherent in the approach; an evaluation framework based on ‘necessary, not sufficient’ tests of model adequacy is presented for discussion.

An important aspect of Bowen and Ranger (2009), and its partner Stern (2009), was the use of economics to facilitate decision-making under uncertainty. It together considered the uncertainties in the level of DAI, the science of a global emissions target and the economics of mitigation and from this presented a number of options and recommendations. The conclusions centred on the need to maintain future flexibility. We discuss the relationship between the economics and science in this example and how the lessons learnt translate to the interpretation of climate model information for adaptation and the design of model experiments to better inform decision-making.

Bowen, A. and N. Ranger (2009) "Mitigating climate change through reductions in greenhouse gas emissions: the science and economics of future paths for global annual emissions" Grantham/CCCEP Policy Brief No. 2, http://www2.lse.ac.uk/GranthamInstitute/publications/PolicyBriefsandPapers/PBMitigatingBowenRangerDec09.pdf

Stern, N. (2009) "Deciding our future in Copenhagen: will the world rise to the challenge of climate change?", http://www2.lse.ac.uk/GranthamInstitute/publications/PolicyBriefsandPapers/PBActionSternDec09.pdf

Expressing uncertainty in climate analysis – A pilot of climate impacts on Panamanian Maize

Wednesday - Plenary Session 5

L. DeWayne Cecil[1], Alex C. Ruane[2], Radley M. Horton[2], Cynthia Rosenzweig[2], Peter A. Parker[3], Brian D. Killough[3], Ray McCollum[4] and Doug Brown[4]

[1]*U.S. Geological Survey, Idaho Falls, USA*

[2]*NASA Goddard Institute for Space Studies, New York, USA*

[3]*NASA Langley Research Center, Hampton, USA*

[4]*Booz, Allen, and Hamilton, Hampton, USA*

Decision makers often sift through multiple analytical model results in an effort to determine the best course of action. In the area of climate analysis, the problem is complicated with uncertainty in the data measurements and input provided from an array of Global Climate Models (GCMs) that each show different results. The uncertainty from model to model is often a key consideration for decision makers and provides a gauge of reliability in the simulated projections.

The objective of this presentation is to create a standard process to analyze and express uncertainty in climate impacts analysis such that decision makers can better understand the role it plays in decision support.

The project analyzed uncertainty involved in the analysis of 5 GCMs used to produce scenarios for agricultural decision support on a climate change time scale (the 2030s). To ensure that the results were relevant, the model was based on a location in Panama with an extensive climatological record. Data were analyzed and displayed to provide policy makers with the means to mitigate and adapt to projected climate changes in this challenging region.

To date, the GISS team has constructed climate change model projections for the uncertainty analysis. Probability functions were derived from the climate model data. Cumulative density functions were derived for Maize yield and conditional probability functions were derived for hot and cold climate conditions. The conditional functions helped explain the impact of temperatures rising above, or falling below, specified levels. All answers were specified in terms relevant to a decision maker so that one clear picture of the future could be presented to the decision maker based on the inputs from multiple models.

The outcome of the project has demonstrated that variability from model to model was insignificant compared to the variability in the predicted climate patterns at the Panamanian location. Model-to-model variability was actually much smaller and all models give similar results when compared to overall prediction uncertainties.

The next step in the process is to classify and express uncertainty throughout the climate prediction process. Preliminary analysis of the data has shown that CO2 level variation plays a greater role in the sensitivity of the existing maize yield model than anticipated. This revelation and other study findings point to the importance of understanding and classifying uncertainty throughout the process of climate prediction.

Statistical postprocessing of simulated precipitation – perspectives for impact research

Wednesday - Parallel Session 5b

Heiko Paeth

Institute of Geography, University of Würzburg, Germany

Rainfall represents an important factor in agriculture and food security, particularly, in the low latitudes. Climatological and hydrological studies which attempt to diagnose the hydrological cycle, require high-quality precipitation data. In West Africa, like in many parts of the world, the density of observational data is low and climate models are needed in order to perform homogeneous and complete data sets. However, climate models tend to produce systematic errors, especially, in terms of rainfall and cloud processes, which are usually approximated by physical parameterizations.

A 25-year climatology of monthly precipitation in West Africa is presented, derived from a regional climate model simulation, and evaluated with respect to observational data. It is found that the model systematically underestimates the rainfall amount and variability and does not capture some details of the seasonal cycle in sub-Saharan West Africa. Thus, in its present form the precipitation climatology is not appropriate to draw a realistic picture of the hydrological cycle in West Africa nor to serve as input data for impact research. Therefore, a statistical model is developed in order to adjust the simulated rainfall data to the characteristics of observed precipitation. Assuming that the regional climate model is much more reliable in terms of atmospheric circulation and thermodynamics, model output statistics (MOS) is used to correct simulated rainfall by means of other simulated parameters of the near-surface climate like temperature, sea level pressure and wind components. Monthly data is adjusted by a cross-validated multiple regression model. The resulting adjusted rainfall climatology reveals a substantial improvement in terms of the model deficiencies mentioned above.

In addition, many applications like for instance hydrological models require atmospheric data with the statistical characteristics of station data. A dynamical-statistical tool to construct virtual station data based on regional climate model output for tropical West Africa is developed. This weather generator incorporates daily gridded rainfall from the model, an orographic term and a stochastic term, accounting for the chaotic spatial distribution of local rain events within a model grid box. In addition, the simulated probability density function of daily precipitation is adjusted to available station data in Benin. The resulting virtual station data are in excellent agreement with various observed characteristics which are not explicitly addressed by the algorithm. This holds for the mean daily rainfall intensity and variability, the relative number of rainless days and the scaling of precipitation in time.

Multimodel ensemble climate projections for the Garonne river basin, France

Wednesday - Parallel Session 5b

Jean-Philippe Vidal and Eric Sauquet

Cemagref, Lyon, France

This study presents a method for deriving high-resolution multimodel transient climate projections, that builds on the bias-corrected local scaling (BLS) method (Vidal and Wade, 2008a). This statistical downscaling method makes use of General Circulation Model (GCM) information on large-scale near-surface variables (precipitation and temperature) as well as a high-resolution meteorological dataset to build transient projections at the monthly time scale. The BLS method is based on disaggregation and bias-correction schemes initially developed for seasonal forecasting, and later used for climate change impact assessment. The downscaling framework previously applied to the UK with IPCC TAR GCMs consists of the following steps: (1) building appropriate precipitation time series from land areas covered by GCM sea or mixed cells; (2) quantile-quantile correction of GCM outputs inherent biases; and (3) disaggregation of bias-corrected outputs to a finer scale by using monthly spatial anomalies. This method has been found to compare well with other statistical and dynamical downscaling techniques (Vidal and Wade, 2008b).

This study aims at presenting improvements implemented in the Bias-corrected Local Mapping (BLM) method and its application over the Garonne river basin located north of the Pyrenees mountain range in France, within the Imagine2030 project1. The objective was to take account not only of mean monthly discrepancies between the regional and local scales already provided by the BLS method, but also of differences in the distributions due to the orography and to local-scale meteorological features. The third step is thus here replaced by a quantile-quantile transformation between interpolated GCM present- day fields and the 8 km resolution Safran reanalysis data over France (Vidal et al., in press). The BLM method thus enables (1) to preserve the monthly temporal pattern of the transient simulations; (2) to take account of GCM ranked categories of large-scale spatial patterns; (3) to preserve the fine-scale local variations of statistical distributions; and (4) to consider multiple projections as equiprobable thanks to the quantile mapping steps.

The BLM method is here applied over the Garonne river basin with an ensemble of IPCC AR4 GCMs run under the A2, A1B and B1 emissions scenarios. Results show an increase in temperature over the basin that is more pronounced in summer. The inter-model dispersion is much higher for precipitation, but all GCMs show a decrease in summer over the 21st century. Multimodel ensemble mean values suggest that temperature changes will be higher in the north-east of the basin, and that reductions in precipitation will affect more specifically the Pyrenees. Within the Imagine2030 project, the downscaled projections have been subsequently disaggregated temporally in order to drive hydrological models for assessing the impact on river flows.

Vidal, J.-P., and Wade, S. D. (2008a) A framework for developing high-resolution multi-model climate projections: 21st century scenarios for the UK. *Int. J. Clim.*, 28, 843-858.

Vidal, J.-P., and Wade, S. D. (2008b) Multimodel projections of catchment-scale precipitation regime. *J. Hydrol*., 353, 143-158.

Vidal, J.-P., Martin, E., Baillon, M., Franchisteguy, L., and Soubeyroux, J.-M. (in press). A 50-year high-resolution atmospheric reanalysis over France with the Safran system, *Int. J. Clim*.

http://imagine2030.lyon.cemagref.fr

Nonlinear circulation regimes and jet variability in the North Atlantic

Wednesday - Parallel Session 5b

A. Hannachi, T. Woollings and B. J. Hoskins

Department of Meteorology, Reading University, Reading, UK

Atmospheric dynamics on planetary and regional scales constitute an important topic in climate variability and change, which is an ongoing discussion in climate research. The eddy-driven jet stream is a robust feature that controls much of the dynamics in the extratropics. Nonlinear circulation regimes have been around for sometime but no clear link to jet variability was discussed. Here diagnostics of the latitude and speed of the eddy-driven jet stream are presented and compared with conventional diagnostics of the North Atlantic Oscillation (NAO) and the East Atlantic (EA) patterns. The jet stream analysis suggests three preferred latitudinal positions of the North Atlantic winter eddydriven jet stream in very good agreement with a Gaussian mixture model applied to the NAO-EA state space. Changes in regimes and jet positions are also examined and discussed.

Classifications of circulation patterns from the COST733 database: An assessment of synoptic-climatological applicability by two-sample Kolmogorov-Smirnov test

Wednesday - Parallel Session 5b

Radan Huth and Monika Cahynová

Institute of Atmospheric Physics, Prague, Czech Republic

A large number of classifications of circulation patterns have been produced within the international COST733 Action "Harmonization and Applications of Weather Types Classifications for European Regions." The classifications are produced by about 15 different classification methods, including cluster analysis, principal component analysis, leader algorithm methods, and threshold-based methods for unified data: sea level pressure and 500 hPa heights over the ERA-40 period (1957-2002) for 12 domains covering Europe. Here we examine the synoptic-climatological applicability of classifications, which is defined as their ability to stratify surface climate elements. The degree of stratification is quantified by conducting the two-sample Kolmogorov-Smirnov test between the distribution conditioned by a particular circulation type and the unconditional distribution. As the climate data, temperature and precipitation station series from the ECA&D database and gridded dataset produced in the ENSEMBLES project have been used. The results are sensitive to the number of classes (classifications with a lower number of classes tending to yield a better stratification) and depend on season. Although the overall 'best' method (or a group of optimum methods) cannot be identified, methods with generally better and worse performance can be determined.

A RCM bias correction method for climatic indices expressed in a daily based frequency applied to temperature projections of the North Iberian Peninsula

Wednesday - Parallel Session 5b

Iratxe González and Julia Hidalgo

Environment Unit., LABEIN – Tecnalia, Spain

This study focuses on the fundamental aspect of the Regional Climate Models (RCM) temperature validation. Current bias correction methods are discussed and a methodology is proposed for the indices based on a daily frequency as heat and cold waves, or frost episodes. The methodology proposed is applied to the two meters temperature projections in the North Iberian Peninsula from six RCM of the EU-FP6 ENSEMBLES project. Several standardized indices from the EU-FP5 STARDEX project are used to depict the extremes events during summer and winter seasons for present (1961-1990) and future projections (1991-2100). Using Empirical Orthogonal Function analysis regional historic series, from observations and models, and projections from RCM are obtained for the Basque Country Region situated in the north of Spain. The selected models generally overestimate the observed extreme temperatures, both in summer and in winter seasons, with a big influence depending on the Global Climate Model that drives the RCM. Once the correction methods applied the standard deviation between models is 4ºC in wintertime and 5ºC in summertime. The overall tendency due to maximum and minimum threshold temperature indicates an increase of 3ºC up to 2100. Moreover, from 2020 the temperature grows faster showing more frequent and longer-term duration heat waves, from 10% of the days in summer up to 50% days at the end of the century, while the number of frost days decreases and cold waves become more rare until their disappearance in the first third of the century.

Downscaling climate change simulations for impact assessment studies within the Alpine region

Wednesday - Parallel Session 5b

Zuvela-Aloise Maja[1], Matulla Christoph[1], Lexer Manfred J.[2], Scheifinger Helfried[1], Anders Ivonne[1], Auer Ingeborg[1] and Böhm Reinhard[1]

[1]*Central Institute for Meteorology and Geodynamics (ZAMG), Vienna, Austria*

[2]*University of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria*

The projects mentioned in the following are to be seen as a close cooperation between climate modeling and impact modeling. We are deriving regional scale climate change datasets for the Alpine region that are used in applications of different impact assessment studies. One of our current projects focuses on the sensitivity of Austrian forest to changes in meteorological parameters that are required to simulate forest-disturbances such as damages by storms, droughts, bark beetles attacks etc. We aim to provide consistent climatic information on a high resolution to be used for forest sensitivity studies and our focus is on the climate change scenarios in the 21st century. Another field of research involves the investigation of observed changes in phenological occurrence dates which are, as well, closely tied to meteorological parameters (in this case mainly the daily mean temperature). We design regional climate model experiments which are feasible to differentiate between the climate signal including to the human influence and natural forcing alone. The scenarios provided by the regional climate model will be used in phenological modelling to test the sensitivity of the occurrence dates of phenophases to different forcings throughout the past 60 years.

Statistical downscaling of precipitation of two transient Holocene AOGCM simulations for central Sudan

Wednesday - Parallel Session 5b

Sebastian Wagner[1,4]**, Janina Koerper**[2,4] **and Jonas Berking**[3,4]

[1]*GKSS Research Center, Institute for Coastal Research, Geeshacht, Germany*

[2]*Department of Meteorology, Free University of Berlin, Berlin, Germany*

[3]*Department of Physical Geography, Free University of Berlin, Berlin, Germany*

[4]*TOPOI Excellence Cluster, Free University of Berlin, Berlin, Germany*

In the present analysis a statistical downscaling of the large scale circulation of two transient simulations of the global coupled climate model ECHO-G for the Holocene for a region in central Sudan [Naga, Nubic desert] is carried out to assess precipitation. Results will help colleagues from historical sciences investigating the rise and fall of ancient cultures in this region.

In the first part of the presentation the basic climatological features of the region under investigation and the calibration and validation of the statistical downscaling models are presented. An important part forms the physical plausibility of the statistical downscaling models calibrated with recent observational data. It will be shown that using principal component regression it is possible to investigate physical processes in the climate-circulationship that are implicitly used by the statistical model.

The second part will present results based on these models for precipitation. An interesting result pertains to the added value of the application of statistical downscaling compared to the raw model precipitation output on centennial-to-millennial timescales. For instance, the downscaled model results show a non-linear decrease in precipitation in the Nubic desert during July in the course of the Holocene. This decrease, also evident in many proxy data time series and with climate models using interactive vegetation, can be reproduced by the downscaling model despite i) constant vegetation patterns used in the transient Holocene simulations and ii) the absence of the decline in precipitation in the raw model output.

Finally potential driving mechanisms controlling precipitation variability in the Nubic desert during the Holocene based on changes in external forcings [orbital, solar, greenhouse gases] are discussed.

Impact of climate change on the heat load in Frankfurt am Main, Germany

Wednesday - Parallel Session 5b

Barbara Früh, Meinolf Kossmann and Marita Roos

Deutscher Wetterdienst, Offenbach, Germany

For the 21st century a significant rise of near surface air temperature is expected from IPCC global climate model simulations. The additional heat load associated with this warming will profoundly affect cities since it adds to the well-known urban heat island effect. With already more than half of the world's population living in cities and continuing urbanization highly expected, managing urban heat load will become even more important in future. To support urban planners in their effort to maintain or improve the quality of living in their city, detailed information on future urban climate on the residential scale is required. To pursue this question the 'Umweltamt der Stadt Frankfurt am Main' and the 'Deutscher Wetterdienst' (DWD, German Meteorological Service) built a cooperation. This contribution presents estimates of the impact of climate change on the heat load in Frankfurt am Main, Germany, using the urban scale climate model MUKLIMO_3 and climate projections from different regional climate models for the region of Frankfurt.

A computationally inexpensive method (called cuboid method) has been developed to limit the number of necessary high resolution MUKLIMO_3 runs to only eight different simulations for each relevant wind direction. The conditions of these eight simulations were chosen to cover the range of all potential heat load conditions. Ten different building structures were considered to realistically represent the spatial variability of the urban environment. The evaluation procedure combines the urban climate model simulations and the regional climate projections to calculate several heat load indices based on the exceedance of a temperature threshold.

The range of potential future heat load in Frankfurt is statistically evaluated using an ensemble of four different regional climate projections. Furthermore, the applicability of the new cuboid method is tested. Future work will examine the options of urban planning to mitigate the enhanced heat load expected from climate change.

Statistical support for ad-hoc observations in atmospheric synoptic typing

Wednesday - Parallel Session 5b

Charles Cuell

Aquatic Ecosystems Impacts Research Division, Environment Canada, Saskatoon, Canada

Atmospheric synoptic typing is used to relate large scale atmospheric circulation to small scale climate variables, such as local temperature and precipitation. Often, the results of such a study are ad-hoc explanations of how certain characteristic circulation patterns influence the climate variables. The ad-hoc explanations require the linkages to be obvious and usually one dimensional.

This talk demonstrates how canonical correlation analysis can be implemented to provide support for the ad-hoc linkages, and to find more complicated, multi-dimensional linkages.

Comparison of downscaling methods for stakeholder applications in the urban Northeast U.S.

Wednesday - Parallel Session 5b

Radley Horton, Alex Ruane and Cynthia Rosenzweig

As stakeholder engagement in climate change impacts and adaptation increases, there is a growing need for downscaled climate projections that map specific climate hazards to sector-specific impacts and potential adaptation strategies. Borrowing upon lessons learned through New York City's climate change adaptation process (involving 40 city and state agencies, regional planning associations, and private companies) and other stakeholder-driven projects around the globe, this presentation will compare how four different downscaling approaches may inform decision-making in the urban Northeast U.S. Potential advantages and disadvantages of each method will be described from a stakeholder perspective, and sample preliminary results for the region will be presented.

The four downscaling approaches are the delta method, in which global climate model changes through time are projected onto observed station data, regional climate model simulations from the North American Regional Climate Change Assessment Program (NARCCAP), and two statistical downscaling methods (the Statistical Downscaling Model (SDSM) and the Bias Corrected and Downscaled WCRP CMIP3 Climate Projections

(http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/)

The extent to which each downscaling technique lends itself to the following stakeholder-favored characteristics will be discussed: 1) inclusion of multiple GCM and emissions scenarios, 2) emphasis on extreme events, and 3) user-defined climate risk metrics.

Statistical challenges for the Co-ordinated Regional Downscaling Experiment (COREX)

Wednesday - Parallel Session 5b

Chris Lennard

Climate modelling groups around the world have started work on the CORDEX initiative (Co-Ordinated Regional Downscaling Experiment) with the aim of generating regional climate change information for most inhabited regions of the globe. It is envisaged that CORDEX will be a leading contributor of regional climate change information for support of adaptation activities and policy decisions. Africa, a region for which there is until now relatively little regional climate information, has been identified as the priority region for the initial stages of the experiment.

Such an experiment poses many methodological and analytical challenges. In particular, the downscaling models include regional dynamical models which may or may not be nudged (spectral or grid), nudged/non-nudged variable resolution global dynamical models, and statistical downscaling models. There are fundamental differences between these various approaches which pose major challenges to collective analysis. The huge volumes of data the experiment will produce pose further challenges for African studies.

This presentation provides an overview of the CORDEX initiative, some early output, and solicits input from the statistical climatology community in addressing some of the challenges listed above.

When is a model relevant?

Wednesday - Parallel Session 2

Leonard A Smith

London School of Economics and Pembroke College, Oxford, UK

Many if not most of the questions stated in this session's description assume that at least one model in hand (e.g. one model in the ensemble of models being analyzed) is adequate for quantitative predictive purposes of interest. This assumption is investigated. How might we tell whether a collection of models (a) consists entirely of models that are inadequate for purpose, (b) includes one, or a few, adequate models amongst many inadequate models, or (c) consists entirely of models that are adequate for purposes of interest?

A key distinction is made between a "best" model and a "decision-relevant" model, and the question is asked whether today's best model is indeed relevant for quantitative decision support, or is better used "merely" for insight and understanding. We consider lessons learned in actual applications of medium-range weather forecasts and of seasonal forecasts to decision support questions. Fundamental differences between these weather-like applications and decision support in the context of climate change are stressed; these differences include distinguishing interpolation and extrapolation, and the need to evaluate a model and its climate distributions given only a single realization of the system's weather time series under transient forcing.

Avenues for scientific support of policy and decision making in the case where state-of-the-art models best provide insight and understanding, thereby underpinning the science and exposing unknown risks and processes, are considered. The design and interpretation of multi-model and perturbed physics experiments are examined in this light, and questions posed in the session description are recast.

Ensembles, metrics & probabilities

Wednesday - Parallel Session 2

Wendy S. Parker

Department of Philosophy, Ohio University, USA

Ensemble studies raise a number of methodological questions: On what basis should a model be included in or excluded from an ensemble study? Should results from some models be given more weight than others? If so, how should they be weighted? Should ensemble results be transformed into probability distributions? These questions are the focus of this paper.

A minimum requirement for including a model in an ensemble study is: it is plausible that the model can provide at least some of the information that is sought in the study. Judgments of plausibility should consider a number of factors, including: the construction of the model (e.g. whether/how it represents processes that significantly influence the variables of interest), its spatiotemporal resolution, and its performance in simulating those aspects of past climate that seem particularly relevant (given the predictive goals at hand) in light of process-based thinking or for other reasons. These factors can be considered informally or with the help of metrics.

At least three types of metrics may be of use when carrying out ensemble studies. A **metric of model performance** defines a measure of the difference between model output and one or more observational datasets. A **metric of model quality** defines a measure of the quality or “goodness” of a model, given the purposes for which the model is to be used, and may take into account all of the factors mentioned above in connection with plausibility: model construction, spatiotemporal resolution, and scores on relevant metrics of performance. Finally, a **metric of ensemble diversity** defines a measure of the extent to which the members of a set of models, each of which scores sufficiently well in terms of model quality, differ from one another in ways that are expected to expand the range of outcomes produced by their simulations. Such metrics of diversity might take into account the provenance of the models, the extent to which they rely on similar parameterizations, the extent to which particular errors in their simulations of past climate have been correlated, and other factors.

Metrics of model quality can be used to rank or weight results from different models. Weighting is sometimes used to produce probability density functions (PDFs). But while it is easy to produce a PDF, it is another question whether that PDF can be said to reflect our uncertainty about future climate. Methods used so far to produce PDFs – even complex Bayesian methods that employ “discrepancy” terms – have not been implemented in such a way that they take into account all of the available evidence that bears on conclusions about future climate. As a consequence, it is unclear whose probabilities (i.e. degrees of belief) they can be said to represent.

When it comes to offering depictions of uncertainty to decision makers, it may be that a PDFs often is not the best choice, because the shape and/or width of the PDF is itself recognized to be rather uncertain. (This can mean, for instance, that the PDF assigns different probabilities to outcomes when in fact they should be judged indistinguishable.) In such cases, depiction of uncertainty should take a different form – e.g. a range of values in which the outcome is judged to have (approximately) a specified probability of falling, or a statement about the expected sign of the change.

Objective approaches to probabilistic climate forecasting

Wednesday - Parallel Session 2

Dan Rowlands[1], Steve Jewson[2] and Myles Allen[1]

[1]*AOPP, Oxford University, UK*

[2]*Risk Management Solutions*

Observations of the climate are one of the primary tools for assessing the performance of climate models, the assumption being that if a climate model performs well in simulating the present day climate we should place greater faith in future predictions from the same model.

However there is currently little consensus on how to weight ensembles of climate model simulations together in such a way for making future forecasts, and role of prior assumptions has received much attention. While the Detection and Attribution (D&A) community has often relied on Likelihood based statements, the Climate Prediction community has often embraced subjective prior assumptions, thus resulting in inconsistencies when one compares hind casts from the two approaches – should we believe a model hind cast that is biased with respect to the very observations used to constrain it?

In this work we seek to unite the two detailing three approaches, namely: Likelihood Profiling, Transfer functions and Reference Priors, where observational constraints can be used in Objective Probabilistic Forecasting. The key feature is that prior assumptions are based on the observational constraints used, rather than climate model parameters, which often do not correspond to any real world quantities.

We show that for a simple Energy Balance Model example the three converge in terms of the uncertainty estimates produced, and discuss extensions to more complex models using the climate*prediction*.net ensemble.

A likelihood-based scoring method for the evaluation of climate model predictions

Wednesday - Parallel Session 2

Amy Braverman[1], **Noel Cressie**[2], **and Joao Teixeira**[1]

[1]*Jet Propulsion Laboratory, California Institute of Technology, USA*

[2]*Department of Statistics, The Ohio State University, USA*

Like other scientific and engineering problems that involve physical modeling of complex systems, climate models can be evaluated and diagnosed by comparing their output to observations of similar quantities. Though the global remote sensing data record is relatively short by climate research standards, these data offer opportunities to evaluate model predictions in new ways. For example, remote sensing data are spatially and temporally dense enough to provide distributional information that goes beyond simple moments. For time periods during which remote sensing data exist, comparisons against multiple models can provide useful information about which models, and therefore which physical parameterizations and assumptions, most closely match reality. In this talk, we propose a method for scoring climate models according to the relative likelihood that a model's time series of predictions arises from the true process generating the observations. Our approach is based on a given summary statistic, computed for the observations and for resamples from the output of each of the models being compared. To respect temporal-dependence characteristics, the resamples are based on a moving-block bootstrap method. Relative scores are formed as the ratio of each candidate model's likelihood to the largest likelihood. We demonstrate our methodology by scoring several models' predictions of the pressure at the planetary boundary layer, with reanalysis output standing in for observations.

Weighting of model results for improving projections of climate change

Wednesday - Parallel Session 2

Jouni Räisänen

Department of Physics, University of Helsinki, Finland

Climate projections from multi-model ensembles are commonly represented by the multi-model mean climate change. As an alternative, various subjectively formulated schemes for performance-based weighting of models have been proposed. Here we introduce a more objective framework for model weighting. A key ingeredient of this scheme is a calibration step quantifying the relationship between intermodel similarity in observed climate and intermodel similarity in simulated climate change. Models that simulate the observed climate better are only given higher weight where and when such an intermodel relationship is found, and the difference in weight between better and worse performing models increases with the strength of this relationship. The method is applied to projections of temperature change in the CMIP3 ensemble. First, cross-validation is used to study the potential of the method to improve the accuracy of climate change estimates and to search for suitable predictor variables. The decrease in cross-validation error allowed by the weighting is found to be relatively modest, but it might be increased if better predictor variables were found. Second, observations are used to weight the models, to study the differences between the weighted mean and multi-model mean estimates of 21st century temperature change.

Climate scenario forecasting and related uncertainties

Wednesday - Parallel Session 2

Natalia Andronova

University of Michigan, USA

Climate projection uncertainties are not solely related to the uncertainties in the projection of human activities in terms of changing atmospheric composition and models' structural inaccuracies, but also in terms of the uncertain behavior of natural climaterelated factors. Through the use of a combination of observations and existing model simulations, this paper investigates ways of compiling climate scenario for attribution of the future climate change.

Are current flaws in Bayesian approaches to climate projection fatal?

Wednesday - Parallel Session 2

Leonard A Smith

London School of Economics, London, UK

Pembroke College, Oxford, UK

Bayesian approaches to the statistical analysis of observational data relevant to climate science offer tremendous advantages both to the science and to decision makers. When applied to climate projections with an eye to supplying conditional probabilities for adaptation or mitigation, on the other hand, in-practice Bayesian approaches can be expected to yield false confidence and poor decision support. Fatal flaws in currently deployed methods, such as the estimation of an irrelevant "discrepancy" term, are illustrated in a simple celestial mechanics example. Here an ensemble of Newtonian models is deployed in an application solvable given the theory of general relativity, but in which the discrepancy term estimated from an ensemble of Newtonian models yields false over-confidence and poor decision support. A relevant point here is that one may be able to identify the estimated discrepancy as irrelevant long before one can rectify the physics. The empirical inadequacy of the Newtonian model was identified 50 years before the proposal of general relatively; similarly we do not expect the empirical inadequacy of today's climate models to be rectified for decades.

The general prospects of the Bayesian approach in the context of physical science questions involving extrapolation of systems best modeled as nonlinear, with access only to empirically inadequate models, are discussed. Bayes' rule is, of course, never called into question; the heart of the matter here does not lie in a divide between competing tribes of statisticians, but rather with the rational interpretation and in-practice interpretation of physical models by physical scientists. For risk management in climate-like problems, ambiguity (second order uncertainty) can limit the relevance of Bayes' rule to the questions on the table: can we find a Bayesian path relevant to decision makers in the time available?

Bayesian estimation of local signal and noise in CMIP3 simulations of climate change

Wednesday - Parallel Session 2

Qinqyun Duan[1] and Thomas J. Phillips[2]

[1]*Beijing Normal University, Beijing, China*

[2]*Lawrence Livermore National Laboratory, Livermore, USA*

The Bayesian Model Averaging (BMA) algorithm of Raftery et al. is employed to estimate local probability distributions of projected changes in continental surface temperature T and precipitation P, as simulated by some 20 CMIP3 coupled climate models for two 21st century greenhouse emissions scenarios of different severity. Bayesian-weighted multi-model consensus estimates of the local climate-change signal and noise are determined from the statistical agreement of each model's historical climate simulation with observational estimates of T and P, and of its 21st century climate projection with suitably chosen T or P target data. The multi-model consensus estimate of the local climate-change signal and noise proves to be surprisingly insensitive to different methods for choosing these future-climate target data.

It is found that the Bayesian-estimated local climatic changes in continental T are universally positive and statistically significant under either future emissions scenario. In contrast, changes in continental P vary locally in sign and are statistically significant only in limited regions under the more severe scenario. Bayesian estimation of 21st century climate change that jointly considers more than one climate variable or statistical parameter is also explored in the BMA framework. A bi-variate approach allows estimation of the probability distribution of the joint projected climate change in T and P which differs qualitatively by region, while inclusion of both first- and second-moment statistics of either T or P results in a greater differentiation of the Bayesian weightings of the individual simulations and a general enhancement of the estimated signal-noise ratio of the projected climate change.

We gratefully acknowledge the support provided by Beijing Normal University. A portion of the work also was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Uncertainty propagation from climate change projections to impacts assessments: Water resource assessments in South America

Wednesday - Parallel Session 2

Hideo Shiogama[1], Seita Emori[1,2], Naota Hanasaki[1], Manabu Abe[1], Yuji Masutomi[3], Kiyoshi Takahashi[1] and Toru Nozawa[1]

[1]*National Institute for Environmental Studies, Tsukuba, Japan.*

[2]*Center for Climate System Research, University of Tokyo, Kashiwa, Japan*

[3]*Center for Environmental Science in Saitama, Kisai Town, Japan.*

Generally, climate change impact assessments are based on climate change projections from coupled Atmosphere Ocean General Circulation Models (AOGCMs). Therefore, uncertainties of climate change projections propagate to impact assessments, and affect subsequent policy decisions. This study examined uncertainty propagation from climate change projections to water resource assessments in South America (SA). We applied Maximum Covariance Analysis (dubbed Singular Value Decomposition analysis) to examine relationships between global-scale uncertainties of climate changes and continental-scale uncertainties of impact assessments. It was found that annual mean runoff in SA are sensitive to changes in the Walker circulation (1st mode) and the Hadley circulation (2nd mode). The 1st and 2nd modes of runoff changes are associated with intensities of the Walker circulation and the Hadley circulation in the present climate simulations, respectively. We also proposed a method to determine metrics associated with the leading runoff modes. It was suggested that the ensemble mean water resource assessment (wetting in the most of SA) is not the best estimate. Drying in the Amazon basin and wetting in the La Plata basin are more reliable. Our finding may have great implications for likelihood assessments of the dieback of the Amazon rainforest. This study would be a good practice of interdisciplinary studies between IPCC WG1 and WG2.

Perturbed physics ensembles of GCM simulations: From slab ocean to coupled model experiments

Wednesday - Parallel Session 2

Lorenzo Tomassini, Daniel Klocke, Jan O. Härter and Jin-Song von Storch

Max Planck Institute for Meteorology, Hamburg, Germany

The working group on uncertainty at the Max Planck Institute for Meteorology plans to perform perturbed physics ensemble simulations with the coupled atmosphere-ocean general circulation model ECHAM5/MPI-OM. In the atmospheric part, mainly parameters related to cloud properties are varied, while in the ocean the focus is on variables that determine the vertical mixing. This leads to the simulation of a wide range of climates with different sensitivities.

The use of a fully coupled global climate model implies the possibility of investigating the sensitivity of atmosphere-ocean interactions and spatial distributions of energy, momentum, and mass on different parameter settings. One of the research questions will be related to non-linearities in the dependence of climate model integrations on parameters. This is important for the conceptual understanding of interactions within the climate system.

We will discuss details of the experimental design and present some results of preliminary slab ocean experiments. They suggest that the perturbed physics ensemble indeed samples a wide range of model behaviors in many respects.

Verifying extreme weather events

Wednesday - Parallel Session 11

Christopher A. T. Ferro

University of Exeter, UK

Evaluating the quality of forecasts of extreme weather events is important for both producers and consumers of forecasts. Producers need to know how changes to the forecasting system affect forecast quality, while consumers need guidance on how to incorporate forecasts into their decisions. Verifying forecasts of extreme events is complicated by the typically small amount of data available and by the fact that most common verification measures necessarily degenerate to trivial values as event rarity increases. We shall review some recent developments in tools for verifying forecasts of extreme events. This will include a description of new measures for quantifying the relationship between forecasts and observations of extreme events and a demonstration of the advantages that accrue from characterising this relationship with models derived from extreme-value theory.

Generating verification metrics for optimal model selection from different NWP models in real time

Wednesday - Parallel Session 11

Laura Huang1, George Isaac1 and Grant Sheng2

[1]*Science and Technology Branch, Environment Canada, Toronto, Canada*

[2]*Faculty of Environmental Studies, York University, Toronto, Canada*

This paper presents a system that generates dynamic verification metrics for selecting an optimal model from different numerical weather prediction (NWP) models for nowcasting. Each NWP model has its own strengths and limitations, and the forecast performance often varies in relation to time, location and other forecasting variables. The data from traditional verification may not fully reflect the current model performance. Many researchers found that the nearest past model performance is strongly correlated with the model performance in the nowcast period (0 to 6 hours). By combining the performance of dynamic modeling with historical performance, forecasters are provided with more reliable information with which to select optimal models for nowcasting. We are developing a novel system that can generate dynamic verification metrics for pre-selected periods in real time. The system can also continuously calculate cumulative verification metrics from start time to current time. The verification metrics include: 1) mean error, 2) bias, 3) mean absolute error, 4) root mean square error, 5) mean square error, 6) correlation coefficient, 7). confidence intervals, and 8) mixed contingency tables relevant to events hits and optimal model hits. The metrics can be generated with respect to models, locations, parameters and time.

The metaverification minefield

Wednesday - Parallel Session 11

Ian Jolliffe and David Stephenson

University of Exeter, UK

A common approach in forecast verification is to construct a numerical score that measures the relative quality of different forecasts. For a given type of forecast data there are typically a number of possible scores or measures that can be used. A question that then arises is how to choose between candidate scores. For this purpose a number of properties of scores were defined in the 1980s and 1990s, by Allan Murphy and others, which it is deemed that ‘good’ scores should possess. This exercise of looking at properties of scores is known as *metaverification*.

It has become increasingly apparent that metaverification is a complex topic, with properties such as *propriety, equitability* and *consistency* having a number of hidden subtleties. Some of these are explored in this presentation, including the incompatibility of propriety and equitability, and the non-equitability of the ‘equitable threat score’.

Ensemble model output statistics using heteroskedastic censored regression

Wednesday - Parallel Session 11

Thordis L. Thorarinsdottir and Tilmann Gneiting

University of Heidelberg, Germany

We propose a novel way of statistically post-processing ensemble forecasts by using heteroskedastic regression which allows for cencoring and/or asymmetry in the resulting predictive distribution in correspondence with the weather quantity of interest. The location and the spread of the probabilistic forecast derive from the ensemble while the method can substantially improve the calibration of the ensemble system and correct for possible biases. We discuss both how to obtain the probabilistic forecasts as well as the verification process and show that these two are linked in that using a scoring rule such as the continuous rank probability score for parameter estimation may lead to significant improvement of the predictive performance. We apply the ensemble model output statistics method to 48-h-ahead forecasts of maximum wind speed and maximum gust speed over the North American Pacific Northwest by using the University of Washington mesoscale ensemble. The statistically post-processed density forecasts turn out to be calibrated and sharp, and result in a substantial improvement over the unprocessed ensemble or climatological reference forecasts.

An intercomparison of multivariate regression methods for the calibration and combination of seasonal climate predictions

Wednesday - Parallel Session 11

Caio Coelho

Centre for Weather Forecats and Climate Studies (CPTEC), National Institute for Space Research (INPE), Brazil

Seasonal climate predictions are currently produced by a number of coupled ocean-atmosphere climate models. The predictions deviate from the real world climate mainly because these models have imperfect representation of physical processes that lead to the observed climate. For this reason climate model predictions need to be calibrated by comparing past observations with retrospective predictions (i.e. predictions produced after the event was observed). Different climate models have slightly different physical formulation, which lead to different predictions for the same climate event. Given the availability of seasonal climate predictions from different climate models one can combine these predictions aiming to obtain the best probabilistic estimate of the future climate. This study compares three multivariate regression methods for the calibration and combination of austral summer (December-February) rainfall predictions over South America produced by five coupled ocean-atmosphere climate models as part of the EU-ENSEMBLES project. The five models are: ECMWF, Meteo-France, INGV, IFM-KIEL and UK Met Office. The three investigated methods are principal component regression, multivariate regression based on maximum covariance analysis and ridge principal component regression. These methods are used to overcome the problem of multicollinearity common when dealing with large dimensional datasets as is the case in multi-model seasonal climate predictions. Retrospective predictions for the period 1960-2005 of all five models are used in the application of the calibration and combination regression methods. The intercomparison is performed in cross-validation leave one out mode, where the year to be predicted is removed from the sample of data prior to estimating the multivariate regression parameters. Both deterministic and probabilistic skill measures are examined and compared for investigating the performance of all used methods.

Uncertain climate forecasts: When to use them, when to ignore them, and when and how to adjust them

Wednesday - Parallel Session 11

Steve Jewson[1] and Ed Hawkins[2]

[1]*Risk Management Solutions*

[2]*Reading University, UK*

Suppose that we have a forecast for a change in a climate variable (perhaps derived from an ensemble mean), and that we also have a reasonable estimate of the uncertainty around that forecast (perhaps derived from an ensemble spread). If the ratio of the size of the change to the size of the uncertainty is large then it makes sense to use the forecast. If, however, the ratio of the size of the change to the size of the uncertainty is small, then, when minimizing expected mean squared error is the goal, the forecast would be better ignored. In between these two extremes there is a grey area where it may make sense to make a compromise between using and ignoring the forecast by reducing the forecast towards zero.

First, we discuss this problem and its relation to standard statistical ideas of overfitting, model selection, bias-variance tradeoff, shrinkage and biased estimation. We then discuss the application of standard model selection rules (including BIC and Bayes Factors) to decide between using a forecast and ignoring it.

Secondly, we discuss the development of new minimum mean squared error shrinkage estimators that attempt to do the best we possibly can in the grey area (see [3]). We call the new adjusted forecasts that result "damped" forecasts.

Thirdly, we apply these ideas to AR4 rainfall projections. We inflate the spread of the AR4 ensemble to account for positive correlations due to common errors between different models using the method described in [1]. We then test whether it would be best to use, ignore, or „damp" the predictions, as a function of lead time. We find that at short lead times it would be best to ignore the forecasts, at intermediate lead-times it would be best to damp the forecasts, and at long lead times it would be best to use the forecasts as is (see [2]).

Finally we discuss the relevance of these ideas to other kinds of forecasts such as seasonal forecasts and decadal forecasts.

[1] "CMIP3 Ensemble Spread, Model Similarity, and Climate Prediction Uncertainty" (2009), Jewson S. and Hawkins E., http://arxiv.org/abs/0909.1890

[2] "Improving the Expected Accuracy of Forecasts of Future Climate Using a Simple Bias-Variance Tradeoff" (2009), Jewson S. and Hawkins E., http://arxiv.org/abs/0911.1904

[3] "Improving Uncertain Climate Forecasts Using a New Minimum Mean Square Error Estimator for the Mean of the Normal Distribution" (2009), Jewson S. and Hawkins E., http://arxiv.org/abs/0912.4395

Use of hidden Markov models to assess predictability on annual to decadal time scales

Wednesday - Parallel Session 11

Richard W. Katz[1], Yongku Kim[1] and Balaji Rajagopalan[2]

[1]*National Center for Atmospheric Research, Boulder, USA*

[2]*University of Colorado, Boulder, USA*

A hidden Markov model (HMM) is a technique that allows for a mixture of distributions to be temporally dependent. In the climate context, the components of the hidden mixture could be viewed as reflecting different "regimes." Because the hidden state variable is Markov dependent, these regimes can persist on annual or longer time scales. The approach is fully probabilistic, with the output of the fitted model including the posterior probability of being in a particular hidden state at a given time (termed "local decoding") or the sequence of hidden states that is most likely a posterior (termed "global decoding"). In other words, the technique recognizes that in practice one never knows for sure which hidden state has occurred.

To demonstrate the proposed approach for assessing predictability, we fit HMMs to annual and seasonal time series of total precipitation and mean minimum and maximum temperature for two locations, Pergamino and Pilar, in the Argentine Pampas. In this region, there are well established teleconnections between the El Niño–Southern Oscillation (ENSO) phenomenon and precipitation and temperature. Nevertheless, the source of certain variations in precipitation on annual to decadal time scales, especially an unusually prolonged wetter than normal period in recent decades, remains unknown. Using local and global decoding, the hidden states identified by the fitted HMMs can be related to observed circulation indices.

Remaining challenges include devising parsimonious ways to introduce seasonality and trends into the HMM. An ordinary HMM may not be capable of producing sufficient variation on a decadal time scale, in which case a non-homogeneous hidden Markov model (NHMM), involving use of both hidden states and observed circulation indices, could be used instead. Another extension concerns using a common hidden state variable for multiple sites, a plausible constraint if the hidden state variable is intended to reflect large-scale circulation patterns and a chance mechanism by which to indirectly induce spatial dependence.

Our ultimate goal is to generate time series of daily weather, at least minimum and maximum temperature and precipitation amount, consistent with the identified hidden states or regimes on a seasonal or annual time scale. This downscaling technique combines the HMMs for seasonal or annual precipitation and minimum and maximum temperature with a stochastic weather generator based on a generalized linear model (GLM).

Furrer, E.M., and R.W. Katz, 2007: Generalized linear modeling approach to stochastic weather generators. *Climate Research*, **34**, 129–144.

Kim, Y., R.W. Katz, B. Rajagopalan, and G.P. Podestá, 2010: Reduced overdispersion in stochastic weather generators for temporal statistical downscaling of seasonal forecasts. Submitted for publication.

Developing statistical climate forecasts for the coming decade

Wednesday - Parallel Session 11

Ed Hawkins[1], A. N. Other[1], Len Shaffrey[1] and Fiona Underwood[2]

[1]*NCAS - Climate, University of Reading, Reading, UK*

[2]*Department of Applied Statistics, University of Reading, Reading, UK*

Predicting the climate on regional scales for the coming decade would be of considerable value to a wide range of decision makers. Two main factors influence the climate of the next decade; firstly, the continuing response of the climate system to greenhouse gas emissions and other external factors such as volcanoes and solar activity, and secondly, natural fluctuations in the ocean which can offset, or enhance, anthropogenic changes for a decade or two.

Until recently, climate models were only used to predict the externally forced component. However, there is now a major international effort underway to add information about the present state of the ocean into climate models in order to consider both factors and hence improve predictions – so called ‘decadal prediction’. Initial results from global climate models (GCMs) are encouraging, but it is essential to critically assess prediction skill to determine their ability to inform decision makers, especially given the decadal prediction multi-model intercomparison (CMIP5) planned for the next IPCC assessment report (AR5). We propose to provide a benchmark against which to measure decadal prediction skill, and future progress, by assessing the ability of simple statistical models to retrospectively predict climate, with a particular focus on historical sea surface temperature (SST) observations of the Atlantic Ocean and the separation of the forced trend from the residual internal variability. The latest results will be discussed.

Analysis of RCM simulations for the Carpathian basin for the 21st century

Wednesday - Poster Session 5

Judit Bartholy, Rita Pongrácz, Ildikó Pieczka and Csaba Torma

Department of Meteorology, Eötvös Loránd University, Budapest, Hungary

The regional climate models (RCMs) nested into global climate models (GCM) are expected to improve the regional climate change scenarios for the European subregions. For analyzing the possible regional climate change in the Carpathian Basin (located in Eastern/Central Europe), we have adapted the models PRECIS and RegCM at the Department of Meteorology, Eotvos Lorand University. (1) The model PRECIS is a hydrostatic regional climate model HadRM3P developed at the UK Met Office, Hadley Centre, and nested in HadCM3 global climate model (GCM). It uses 25 km horizontal resolution transposed to the Equator and 19 vertical levels with sigma coordinates. (2) The model RegCM is also 3-dimensional, sigma-coordinate, primitive equation model originally developed by Giorgi et al. Currently, it is available from the ICTP (International Centre for Theoretical Physics). RegCM uses 18 vertical levels and its horizontal resolution is 10 km. The initial and lateral boundary conditions of the fine-resolution experiments were provided by the ECHAM-driven RegCM simulations using 25 km horizontal resolution.

Expected future changes (i.e., mean values, distributions and empirical probabilities) are analyzed for the period 2071-2100 (compared to 1961-1990, as a reference period).

According to the results of PRECIS simulations, the following main findings will be presented: (i) In all the four seasons significant warming is projected at 0.05 level for both A2 and B2 cenarios, the largest warming is expected in summer. (ii) Not only the mean will change, but also the distribution of daily mean temperature implying more frequent warm and hot periods and larger record hot conditions than in the 1961-1990 reference period. (iii) By the end of the century the annual precipitation in the Carpathian Basin is likely to decrease by about 20% for both A2 and B2 scenarios. (iv) Significant drying is projected in the region, especially, in summer (the seasonal precipitation is expected to decrease by 43% and 58% on spatial average in Hungary in case of B2 and A2, respectively) while in winter the precipitation is expected to increase in the region of Transdanubia. (v) Based on the PRECIS simulations the annual distribution of monthly mean precipitation is also expected to change. In the 1961-1990 reference period the wettest months in Hungary occurred from April to July, and the driest months were January and February. In the 2071-2100 future period, the driest months are projected to be July and August, while the wettest April, May and June.

In the frame of the CECILIA EU-project, RegCM experiments for three different time slices (1961-1990, 2021-2050, and 2071-2100) have been accomplished for the selected Eastern/Central European subregion. The initial and lateral boundary conditions of the fine-resolution experiments have been provided by the ECHAM-driven RegCM simulations using 25 km horizontal resolution for the A1B emission scenario. The results suggest that the seasonal mean temperature in the selected domain is likely to increase by about 0.6-1.8°C, and 2.4-3.1°C by the middle, and the end of the 21st century, respectively (relative to the 1961-1990 reference period).

Frequency of cold temperature extremes is projected to decrease significantly while warm extremes tend to occur more often in the future. Precipitation in the Carpathian basin is generally projected to decrease, especially, in summer, when the expected drying by 2071-2100 is about 18% on spatial average.

Volcanoes and climate: modelling the atmospheric circulation's response to volcanic aerosol forcing

Wednesday - Poster Session 5

Alessio Bozzo, Gabriele Hegerl and Simon Tett

School of Geosciences, University of Edinburgh, UK

Winters closely following explosive volcanic eruptions tend to show warm anomalies, for example, in Northern Europe. The mechanism involved and the ability of models to simulate this mechanism fully, is still uncertain. There is reasonable certainty that large volcanic eruptions generate a dynamic response in the global circulation, but the magnitude of the response and the mechanisms involved are yet not clear. Recent studies show that current climate models generally appear to underestimate the observed magnitude of the circulation changes due to stratospheric volcanic aerosol. Studies with simplified global circulation models have shown that temperature forcings applied to the lower equatorial stratosphere are able to generate a coupled stratospheric-tropospheric response that resembles the one observed after major tropical volcanic eruptions. Eddy fluxes play a major role in driving the anomalies. Ensemble simulations with the Unified Model HadGEM2 with improved stratospheric dynamics are analysed in order to study the model's response to the forcing induced by volcanic aerosol injected in the lower equatorial stratosphere. Both the low top (40km) and high top (84km) version of HadGEM2 will be employed, in order to verify the effect of the stratospheric dynamics in the model's response.

Analysis of real data and data from regional climate models according to linear and non-linear statistical techniques in the Czech Republic and in Europe

Wednesday - Poster Session 5

Zuzana Chládová

Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Institute of Atmospheric Physics, Academy of Sciences, Prague, Czech Republic

Regional climate models (RCMs) are currently one of regularly applied tools for localization of global climate models (GCMs) outcomes. The analysis compares recent and future runs of regional climate models RCAO and HIRHAM. Observed data were compared with model data as well with CRU data in the Czech Republic. Firstly, mean annual courses of daily mean temperature and precipitation for 48 grid points of the regional climate models HIRHAM and RCAO and 29 meteorological stations of the Czech Republic were compared for reference period 1961 – 1990. Secondly, mean annual courses of mean daily temperature and precipitation in the period 2071–2100 were analyzed at selected HIRHAM and RCAO grid points for A2 and B2 scenarios. The results show that model temperatures are overestimated, mostly in winter months, and annual mean course of precipitation is dramatically flattened. Generally, the models simulate the temperature better than the precipitation due to the effects of model topography and inaccurate modeling of convective precipitation events. Both models showed an all round year increase of mean daily temperatures in the period 2071–2100 compared to 1961–1990. This increase was most pronounced in August, July, September and January. Concerning precipitation, both models showed increase in February, March, December and October and decrease in August in the period 2071–2100. Dependence on the scenario was not significant for precipitation. Finally, nonlinear technique of analysis was compared with linear technique (autocorrelation function). Average mutual information (AMI) was used as the suitable nonlinear technique. AMI has been calculated for one selected time series of each grid point of the models and real data of the Europe concentrate on the Czech Republic with a time lag varying from 1 to 10 days. According to the results, values of AMI are lower at sites more exposed towards western winds from Atlantic Ocean.

Statistical forecasting approaches to improve risk management in a changing climate

Wednesday - Poster Session 5

Aline de Holanda Nunes Maia[1] and Emerson M. Del Ponte[2]

[1]*Laboratório de Geotecnologias e Métodos Quantitativos, Embrapa Meio Ambiente, São Paulo, Brazil*

[2]*Laboratório de Epidemiologia de Plantas, Departamento de Fitossanidade, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil*

Based on case studies from two contrasting Brazilian environments, we discuss statistical approaches for probabilistic seasonal forecasting of climate-related response variables that capture climatic variability and trends via atmospheric and oceanic indices (AOI). Such methods are widely used in other fields of science but yet underutilized in climate science (Kim et al 2003; Maia and Meinke, 2009). Here we show their usefulness for near future prediction of climate-related risks and associated uncertainties using long-term climate data and AOI GCM projections. These methods can be applied to aid decision-making within all climate sensitive sectors of our societies. Specifically, we discuss: i) conditional empirical distribution functions estimation (CEDF, Kaplan and Meier, 1958), ii) logistic regression (LREG, Nichols, 1984), iii) Cox proportional hazards model (CPHM, Cox, 1972), iv) weighted Cox model (WCM, Schemper, 1992) and v) nonparametric CDF estimation (NPCDF, Li and Racine, 2008). Although empirical distributions derived from AOI categorization are used widely due to their simplicity, CEDF constitutes only a crude, exploratory approach, that does not fully account for the predictor's influence on the resulting probability of exceeding functions (POE, POE(y)=P(Y>y)) or the uncertainties surrounding these functions. LREG allows assessing the predictors influence on POEs for fixed y thresholds. This constitutes a limitation when multiple thresholds need to be evaluated. Furthermore, LREG does not account for non-proportional AOI influences on response variables of interest, a common pattern for El Niño/Southern Oscillation (ENSO) derived indices (Power, 2006). Through the construction of conditional CDFs, methods (i), (iii) and (iv) enable POE estimations across the entire range of the response variable. Of all the methods we considered, WCM and NPCDF are the most flexible because they do not require an often unrealistic assumption of proportionality of hazards (PH). While WCM focus on unbiased estimation of average predictors influence on risks under non-PH conditions (which is appropriate for exploratory spatial studies), NPCDF constitutes a flexible inferential framework for kernel-based estimation of conditional CDFs. A possible weakness of all methods discussed here is the assumption that a stable relationship holds between prognostic and predictor variables over time. However, for long time series, indicators for different time slices could be incorporated into the models as dummy variables, thereby providing an objective and quantitative means for assessing stability of the relationship. We conclude that using innovative, theoretically sound statistical approaches in combination with cutting-edge climate science has to potential to considerably improve risk management of climate sensitive systems.

Cox DR. 1972. Regression models and life-tables (with discussion). *Journal of the Royal Statistical Society* 34B: 187-220.

Kaplan EL, Meier P. 1958. Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association* 53: 457-481.

Kim T, Valdés, J B, Yoo C. 2003. Nonparametric approach for estimating return periods of droughts in arid regions, *Journal of Hydrologic Engineering*, ASCE 8(5):237–246.

Li Q, J S Racine. 2008. Nonparametric estimation of conditional CDF and quantile functions with mixed categorical and continuous data, *Journal of Business and Economic Statistics* 26(4): 423-434.

Nicholls N. 1984. A system for predicting the onset of the North Australian wet-season. *Journal of Climatology* 4: 425-435.

Maia A H; Meinke, H. 2009. Probabilistic methods for seasonal forecasting in a changing climate: Cox-type regression models. *International Journal of Climatology.Available* on line: http://www3.interscience.wiley.com/journal/122677357/abstract

Power S, Haylock M, Colman R, Wang X. 2006. The predictability of interdecadal changes in ENSO activity and ENSO teleconnections. *Journal of Climate* 19: 4755-4771.

Schemper, M.1992. Cox analysis of survival data with non-proportional hazard functions. *The Statistician* 41, 455-465.

No title provided

Wednesday - Poster Session 5

Ruth Doherty

We explore the impact of climate model uncertainty upon predictions of future vegetation carbon stocks, for the period up to 2100, generated by a dynamic global vegetation model (DGVM) under a particular emissions scenario (SRES A2). Deterministic simulations are generated from the Lund-Potsdam-Jena (LPJ) model using climatic inputs derived from nine general circulation models (GCMs). Simulated changes between 1961-1990 and 2070-2099 range from +26 to +133 gtC, and are in broadly good agreement with those obtained in a recent previous study using the LPJ model. Simulated values for the 20th century are also obtained by running LPJ with observed climate data, and this provides a baseline against which the other runs can be compared. Time series regression models are used to analyse the discrepancies between each of the GCM-based simulations and the baseline simulation, and a form of model averaging - in which we average across GCM-based simulations and across models for each discrepancy - is then used to combine these into a probabilistic projection for global stocks of vegetation carbon.

No title provided

Wednesday - Poster Session 5

Carlos Gaitan

The coarse-resolution Canadian Coupled General Circulation Model (CGCM 3.1) running the SRES A2, and the SRES A1B simulations (Nakicenovic, N. et al, 2000) was downscaled using a variety of linear and nonlinear machine learning/statistical methods (e.g. linear regression, principal component analysis, artificial neural networks) to obtain daily station values of maximum temperature (TMAX), and minimum temperature (TMIN) for five weather stations located on Vancouver Island. The downscaled data were analyzed for variability and extremes events. In addition, based on previous work by STARDEX (Climatic Research Unit, 2005), extreme indices were calculated, and comparisons in variability were made between values of these indices observed in the base climate period (1961-2000), and values projected for the 21st century. The results show that the downscaled data series were able to capture higher variances than the NCEP/NCAR Reanalysis, although these variances are smaller than weather station/observed ones.

Intermittency, autoregression and censoring: Application to daily precipitation

Wednesday - Poster Session 5

A. Hannachi

Department of Meteorology, Reading University, Reading, UK

Statistical modelling of intermittent geophysical processes is a challenging problem. Various models have been proposed with differing complexities. One of the characteristics of these processes, the serial autocorrelation, tends in general not to be fully accounted for by these models. Here, a simple methodology is presented which makes use of the plethora of availables tools from continuous time series based on autoregressive models combined with censoring to model the zero values. The methodology can be used as a weather generator. The theory of the methodology is presented and application to daily precipitation is discussed.

Daily precipitation in the Czech Republic: Different methods for statistical correction of model results

Wednesday - Poster Session 5

Stanislava Kliegrova[1], Jiří Mikšovský[2], Petr Štěpánek[1] and Ladislav Metelka[1]

[1]*Czech Hydrometeorological Institute, Czech Republic*

[2]*Faculty of Mathematics and Physics, Charles University, Czech Republic*

The climate characteristics simulated by regional model ALADIN/Climate/CZ (with GCM ARPEGE-Climat as the lateral forcing) are compared to the data observed for the period 1961-1990 in the Czech Republic to assess the model's ability to reproduce the main patterns of the climate in the area. The model's results were compared to a newly developed gridded dataset of station observations. As seen, regional model simulations are not perfect reproductions of the reality and some correction methods should be used to adjust the simulated values according to the observed ones. The daily precipitation values simulated by regional model and the values corrected by the variable correction methods (neural networks, method designed and validated by Piani et al.) were compared to the data observed with the help of quantile- quantile plots. Some precipitation indices (for example mean climatological precipitation, mean wet-day precipitation, percentage of wet days,…) were computed and investigated for the Czech Republic as a whole.

Statistical and dynamical impacts of the tropical cyclones on the summertime submonthly wave patterns over the Western North Pacific

Wednesday - Poster Session 5

Ken-Chung Ko[1] **and Huang-Hsiung Hsu**[2]

[1]*Department of Geography, National Kaohsiung Normal University, Kaohsiung, Taiwan*

[2]*Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan*

The importance of the impacts of the tropical cyclones (TCs) on the sub-monthly wave pattern near East Asia-Pacific area during July-September season was examined. Those TCs were removed from the large scale circulation and the resultant circulation features were compared with the original circulation patterns. The 7-30 day filtered wave pattern was also examined and compared with those no-TC patterns. The results indicate that the kinetic energy was significantly reduced after the TCs were removed. The barotropic conversion term also shows significant changes between the TC and no-TC fields as well as the extreme intraseasonal phases. It was believed that the TCs could have an impact on the circulation fields not only in the strength but also in the wave patterns.

Joint diagnostic of the surface air temperature in South America and Madden-Julian Oscillation

Wednesday - Poster Session 5

Gustavo Naumann and Walter M. Vargas

National Scientific and Technological Research Council (CONICET), Department of Atmospheric and Oceanic Sciences, University of Buenos Aires, Argentina

The objective of this research is to explore the relationship between maximum and minimum temperatures, daily precipitation, and the Madden-Julian Oscillation (MJO). It was found that the different phases of the MJO show a consistent signal on winter temperature variability and precipitation in southeastern South America. Additionally, this paper explores the spatial-temporal variations of mutual information and joint entropy between temperature and the MJO. A defined spatial pattern was observed with an increased signal in northeastern Argentina and southern Brazil. In the local mutual information analysis, periods in which the mutual information doubled the average values were observed over the entire region. These results indicate that these connections can be used to forecast winter temperatures with a better skill score in situations where both variables covary.

No title provided

Wednesday - Poster Session 5

Charles Ngenda

Zambia Meteorological Department, Lusaka, Zambia

Wind energy is a variable resource caused by the differential solar heating of the earth. Topography and nature of the surface are some of the local/regional factors responsible for substantial differences between local/regional and global wind patterns.

This resource is largely untapped in Zambia hence its exclusion from the overall national energy balance. Zambia seems to have a huge wind potential which could be exploited for energy applications. This could lessen the dependance on the forest resource base largely used by the poor rural population who account for the larger propotion of the entire population.

This study attempts to highlight parts of the country which are viable for energy installations. Results from Statistical analysis with respect to variabiliy and reliability of the wind regime in Zambia indicate that much of the areas south of Mongu/Isoka line are generally reliable at greater than 80 percent and 6 m/s.

Dynamical downscaling of future climate change in the Mediterranean region

Wednesday - Poster Session 5

Andreas Paxian, Gernot Vogt and Heiko Paeth

Geographical Institute, University of Würzburg, Würzburg, Germany

The German KLIWEX-MED project aims to analyse the regional characteristics and intensity of climate change in the Mediterranean Basin with special focus on extreme events like heavy precipitation, heat waves and droughts. Corresponding uncertainties are quantified in a probabilistic sense.

For the investigation of dynamical downscaling, we consider simulations of the global climate model ECHAM5/MPI-OM (1.875°) as well as simulations of the high-resolution (0.5°) regional climate model REMO which is nested in ECHAM5/MPI-OM for the time period 1961-2050. As forcing we consider observed GHG emissions for 1961-2000 and A1b and B1 emission scenarios for 2001-2050.

We present means and trends of seasonal temperature and precipitation of both REMO and ECHAM5/MPI-OM for the time periods 1961-2000 and 1961-2050. For the present-day time period the findings are validated with observational data from CRU TS 2.1 and ENSEMBLES WP5.1. The whole time period presents a projection of decadal future climate change in the Mediterranean region. In comparing regional and global climate model results we reveal the added value of high-resolution regional climate modelling.

To prove if the forcing global climate model ECHAM5 is a representative member of the multi-model ensemble of the IPCC AR4, its long-term mean and trend for the time period 1961-2050 are compared to the corresponding multi-model mean values of the AR4 global climate models interpolated on a common 3°x3° model grid.

In turn, to quantify and test the signal-to-noise ratio of the climate change projection of the whole multi-model ensemble, the resulting total temperature and precipitation variability is subdivided by means of two-way analysis of variance into external, as imposed by radiative forcing, and internal variability, as imposed by different model parameterisations and initial conditions.

Furthermore, certain differences between present-day REMO and observational trends can be explained by a deviation of the temporal evolutions of few main large-scale circulation patterns, mainly the winter NAO, simulated by the forcing model ECHAM5/MPI-OM from those of recent observations. This deviation has been found in a seasonal principal component analysis and can be correlated to the mentioned temperature and precipitation trend differences.

Statistical correction of daily precipitation from RCM in the Czech Republic and results for precipitation indices

Wednesday - Poster Session 5

Jana Pechková[1], Petr Štěpánek[1], Jiří Mikšovský[2] and Ladislav Metelka[1]

[1]*Czech Hydrometeorological Institute, Czech Republic*

[2]*Dep. of Meteorology and Environ. Protection, Charles University, Czech Republic*

Regional climate model ALADIN-Climate/CZ (with GCM ARPEGE-Climat as the lateral forcing) has been used to simulate daily precipitation values in period 1961 – 1990 in the Czech Republic. As the validation showed, some postprocessing methods should be used for correcting climate output according to the observed ones. The precipitation data from ALADIN-Climate/CZ were corrected with the help by two statistical methods (neural networks and method designed by Piani et al.) and all simulated and corrected precipitation datasets from the RCM were compared to gridded dataset of station observations. Some precipitation indices (climatological precipitation, mean wet-day precipitation, percentage of wet days, mean dry-day persistence, percentage of wet days above 10 mm per day and percentage of wet days above 20 mm per day) were calculated with RCM's simulated and corrected precipitation datasets and compared to precipitation indices of observation data on maps of the Czech Republic to investigate the spatial distribution of the differences.

Evaluating links between indices of atmospheric circulation and surface air temperature in control climate model simulations

Wednesday - Poster Session 5

Eva Plavcová[1,2] **and Jan Kyselý**[1]

[1]*Institute of Atmospheric Physics AS CR, Prague, Czech Republic*

[2]*Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic*

Regional climate models (RCMs) driven by outputs from global climate models (GCMs) are the most widely used tools for simulating regional scenarios of climate change. Since their control outputs suffer from deficiencies in the reproduction of recent climate conditions, it is important to identify sources of these errors and to address them in further development of the models.

The study examines links between atmospheric circulation represented by circulation indices (flow direction, strength, and vorticity; derived from gridded mean sea level pressure) and surface air temperature (daily maximum, minimum and mean temperatures) in recent climate (1961-1990) as simulated by an ensemble of RCMs over central Europe. We make use of RCM simulations with high resolution (around 25 km) carried out within the ENSEMBLES project. The RCM dataset is split in two parts: we examine i) a set of different RCMs driven by a single GCM (ECHAM5), and ii) a set of single RCM (RCA) simulations driven by different GCMs and the ERA-40 re-analysis. This allows for evaluating the role of the RCM formulation and the driving model. Observed data are represented by the ERA-40 re-analysis (mean sea level pressure fields) and two datasets of daily temperatures gridded onto the RCM grids: E-Obs, provided within ENSEMBLES and calculated from a low-density station network, and GriSt, data gridded from a high-density station network in the Czech Republic.

The aims of the work are (i) to identify errors in RCM-simulated distributions of the circulation indices in individual seasons, (ii) to identify errors in simulated distributions of daily maximum, minimum and mean temperatures under particular circulation conditions, (iii) to evaluate whether the results depend on the dataset used to represent observed temperatures, and (iv) to identify the added value of the RCMs, by comparing the links between atmospheric circulation and surface air temperatures in the RCMs and the driving GCMs.

Enhanced evidence in climate models for changes in extratropical atmospheric circulation

Wednesday - Poster Session 5

Felix Pollinger and Heiko Paeth

Institute of Geography, University of Wurzburg, Wurzburg, Germany

We investigate changes in extratropical atmospheric circulation during the winter season as derived from the most recent multi-model ensemble of global climate projections. This internationally coordinated systematic data base allows for an accurate assessment of climate change signals against the background of model uncertainty. A total of 133 individual climate change simulations from 24 different climate models are used in this study.

The multi-model mean time series of the northern-hemisphere (NAM) and southern-hemisphere (SAM) annular modes and of the North Atlantic Oscillation (NAO) are in line with the observed positive trends during the second half of the 20th century and project a further strengthening until the end of the 21st century. For the North Pacific index (NPI) the multi-model mean time series also indicate future strengthening but with no correlation with the time series derived from the HadSLP2 data set.

To identify and quantify the impacts of prescribed radiative forcing against model uncertainty we use a spectral approach based on a two-way analysis of variance.

For SAM and NAM the simulated changes are unambiguously related to anthropogenic forcing and outperform the level of model uncertainty. This result enhances the probability for severe regional impacts of climate change, in particular over extratropical land masses. The climate change signals are noticeably weaker under the B1 mitigation scenario than under the A2 business-as-usual scenario.

Furthermore we investigate the influence of two basic inhomogeneities of the AR4 multi-model ensemble relevant to atmospheric dynamics. The different treatment of observed ozone depletion and assumed recovery has a significant impact on the amplitude of future circulation changes on both hemispheres, whereas no systematic effect is found with respect to the models' top-of-atmosphere.

Assessing the similarity between time series of two meteorological fields using the RV coefficient

Wednesday - Poster Session 5

Jacqueline Potts and Claus Dieter-Mayer

Biomathematics and Statistics Scotland, UK

The technique of singular value decomposition of the covariance matrix, also known as maximum covariance analysis, has been widely used in the atmospheric sciences to compare time series of two meteorological fields. Similarity between the ordinations is often assessed by means of the correlation between the data points on two corresponding axes. Maximum covariance analysis is also used in the biological sciences, where it is known as co-inertia analysis. In the biological literature the RV coefficient is often reported as a measure of the overall similarity between two data sets. This statistic could also be used to assess the overall similarity between time series of two meteorological fields. The significance of the RV coefficient may be assessed by means of a permutation test. If the two meteorological fields are completely independent, a value of the RV coefficient close to zero would be expected. However, where there are more grid points or observing stations than the number of observations at each, values of the RV coefficient may be misleadingly high. An adjusted RV coefficient is presented, which is unbiased in the case of independent fields.

A comparative extended validation of statistical downscaling and regional climate models

Wednesday - Poster Session 5

Radan Huth[1], **Jiří Mikšovský**[2], **Petr Štěpánek**[3], **Zuzana Chládová**[1] **and Lucie Pokorná**[1]

[1]*Institute of Atmospheric Physics, Prague, Czech Republic*

[2]*Dept. of Meteorology and Environment Protection, Charles University, Prague, Czech Republic*

[3]*Czech Hydrometeorological Institute, Regional Office, Hradec Králové, Czech Republic*

Although both statistical and dynamical downscaling methods have been validated thoroughly, comparisons of their performance are still rather scarce, especially for non-trivial statistical measures, other than bias or explained variance. Nevertheless, a correct reproduction of such properties may be essential in specific applications and impact studies. In this contribution, we subject several statistical downscaling methods (both linear and non-linear) and outputs from high-resolution (~10 km) regional climate models (Aladin-Climate/CZ and RegCM3) to the same validation procedures. The validation characteristics include temporal and spatial autocorrelations and higher-order statistical moments for daily temperature. The validation is conducted on a dense grid with the approximate resolution of 10 km in central Europe. We show that neither statistical downscaling nor dynamical downscaling simulate the non-trivial statistical measures correctly and that each of them has its specific drawbacks, which may affect the applicability of their outputs in climate change impact studies.

Water resources in South-west Western Australia: model uncertainty in climate change adaption

Wednesday - Poster Session 5

Richard E. Chandler[1], **Stephen P. Charles**[2] **and Bryson C. Bates**[3]

[1]*Department of Statistical Science, University College London, UK*

[2]*CSIRO Land and Water, Wembley, Australia*

[3]*CSIRO Climate Adaptation Flagship, Wembley, Australia*

Southwest Western Australia (SWWA) is currently experiencing an extended period of drought and, according to the IPCC Fourth Assessment Report, winter precipitation in the region is "very likely" to decrease over the coming century. Since 70-80% of the region's rainfall falls in winter, this has serious water resource implications. Water resource managers therefore face the challenge of putting in place the mechanisms and infrastructure to cope with reduced water availability in the future. The decisions they make will be informed by projections of future climate based on deterministic atmosphere-ocean general circulation models (GCMs). However, these projections can vary widely between GCMs, with differences becoming more pronounced at the relatively fine spatial and temporal scales relevant for hydrological applications. It is therefore natural to ask how best to combine information from different GCMs.

Here we present a transparent, logically coherent and interpretable framework that formalises the issues involved and provides the opportunity to frame the relevant questions in an unambiguous manner. The framework uses a hierarchical statistical model to represent features that account for inter-GCM differences, shared biases and outlying GCMs; it is in principle sufficiently general that it could be applied in any climate impacts study. To develop projections for use in SWWA water resource planning, the methodology is applied in conjunction with a statistical downscaling tool to develop projections of winter (May-October) rainfall for a network 30 sites in the region. The results suggest that naïvely combining the projections from different GCMs and treating the resulting ensemble as a probability distribution may substantially underestimate the uncertainty involved.

Wavelet and spectral analysis of precipitation variability over Iran

Wednesday - Poster Session 5

F.Taghavi and A.Neyestani

Institute of Geophysics, University of Tehran, Iran

Spectral decomposition is an appropriate tool for analysis frequency contents of climatologically data. Spectral analysis provide frequency contents of climatic signal in base stationary supposition of time series, but it is not indicate the exact time of frequency contents, while Wavelet transform is a useful technique for analyzing localized variation on time-scale space. In this study, the rainfall variability over Iran is investigated using wavelet and spectral analysis. It is concluded that the wavelet provides a superior representation of rainfall variability when compared with spectral analysis method.

A statistical downscaling model for Southern Australia winter rainfall

Wednesday - Poster Session 5

Yun Li[1] **and Ian Smith**[2]

[1]*CSIRO Mathematical and Information Sciences, Wembley, Australia*

[2]*CSIRO Marine and Atmospheric Research, CSIRO Water for a Health Country Flagship, Aspendale, Australia*

A technique for obtaining downscaled rainfall projections from climate model simulations is described. This technique makes use of the close association between mean sea level pressure (MSLP) patterns and rainfall over southern Australia during winter. Principal components of seasonal mean MSLP anomalies are linked to observed rainfall anomalies at regional, grid point and point scales. A maximum of 4 components is sufficient to capture a relatively large fraction of the observed variance in rainfall at most locations. These are used to interpret the MSLP patterns from a single climate model which has been used to simulate the both present day and future climate. The resulting downscaled values provide (a) a closer representation of the observed present day rainfall than the raw climate model values and, (b) provide alternative estimates of future changes to rainfall that arise due to changes in mean MSLP. While decreases are simulated for later this century (under a single emissions scenario), the downscaled values, in percentage terms, tend to be less.

Understanding recent climate change in key regions of Russia

Wednesday - Poster Session 5

Anton Ye. Shadursky ,Vladimir A. Lobanov

Russian State Hydrometeorological University, St.Petersburg, Russia

Russian area gives the main contribution in raise of global temperature in present as well as in the nearest future. Scenarios lead to increasing of temperature up 10-120C on the north of Siberia under increasing of the global temperature on 40C and the most modern regional warming take place in the center part of the East Siberia. For understating of modern situation the longest climate records of monthly temperature and precipitation have been chosen on the Russia area. Whole Russia has been divided into 22 homogeneous regions and sub-regions where the close relationships between average regional temperature and the temperature records at the particular stations take place. Three main competition time series models have been used for records of average regional temperature: stationary sample, linear trend and "jumping" model. Efficiency of each model has been obtained by standard error of remainders and Fisher's test. As a result, the "jumping" model gave the minimum of standard deviation of errors in 55% cases and the same results as other models for rest regions. Statistical significance of conclusions under Fisher's test takes place for 3 regions of the East Siberia only. For understanding of such situation more detailed analysis has been realized in two key regions of Russia: north of West Siberia (the most future increasing) and the center part of the East Siberia (the most present increasing).

Inside the north of West Siberia, 16 stations have been chosen with records of maximum daily precipitation, monthly precipitation and temperature. Dixon, Fisher and Student statistical tests have been applied for assessment of homogeneity and stationarity. There hypothesis have been accepted in all cases practically for maximum daily precipitation and two exclusion cases connect with maximum extremes of empirical probable distributions. The obtained non-stationarity in time series of monthly precipitation is displayed as a step increasing in the 1960s and for cold period only and for the stations near the Polar Ocean, where the strong winds are observed. The cause of such non-stationarity is a change of register devises, after that the precipitation have not a systematic decreasing under wind blow out. Monthly temperature have stationary regime in the most cases and the exclusion observed for the March month only as a step increasing in 1970s and caused by change of atmospheric circulations epochs. The main conclusion that the temperature regime is stable and no any reason to wait a great changes in the nearest future for this region. In the center part of the East Siberia some long-term records of annual temperature with information up to 2009 have been processed. The main result, if information of all 12 months has been used for calculation of annual temperature, that there is a step raising temperature on 0.7-2.00C for the particular stations of this region from 1990s.

Impact of SST slow oscillations in North Atlantic and North Pacific on trends in global surface air temperature and Arctic ice extent for last 150 years

Wednesday - Poster Session 5

Oleg M. Pokrovsky

Main Geophysical Observatory, St. Petersburg, Russia

Atlantic Multidecadal Oscillation (AMO) and Pacific Decadal Oscillation (PDO) monthly time series (Ernfield, et al, 2001) were investigated for last 150 years by implementation of a comprehensive smoothing technique controlled by cross-validation procedure, which provided more statistically significant nonlinear trend evaluation than moving average or linear trend techniques. It was found that there is a winter sea surface temperature (SST) oscillation of around the 64-69 year scale behind a known SST fluctuation of decadal scale for winter months. The AMO trend demonstrates waters warming in the first part of twentieth century, cooling period in 50-th and 60-th, and warming in 80-th – 90-th years. The PDO nonlinear trend has similar periodicity, but it is shifted in 17 years by phase. It was proved by means of cross-correlation and cross-wavelet analysis. This result partly confirms the global ocean conveyer theory of Broker. Weak AMO and PDO linear trends respond to the greenhouse warming effect related to carbon dioxide concentration increasing. It demonstrates a slow warming behind a more strong (in amplitude) oscillation responded to still not well understood world ocean features. This result was confirmed by independent research based on wavelet analysis of the same time series. Decadal and multidecadal scales were detected at wavelet power spectrum as a statistically significant with account to 95% probability level. Similar study was carried out for paleoclimate proxy data related to the AMO and PDO for last six centuries. Nonlinear trends and wavelet spectrum confirm above conclusions on existence of the SST natural oscillations in the Atlantic and Pacific Oceans with a periodicity of 60-70 years. Global annual surface air temperature (SAT) CRUTEM3 data set for 1850-2009 years was used in similar study. De-trended (when liner trend was excluded) and SAT series demonstrated slow oscillations, which looks like AMO. Auto and cross correlation functions for pair AMO and global SAT was investigated. Hurrell's data on monthly the North Atlantic Oscillation (NAO) index with account for SST since 1856 were also used and provided very close conclusions with respect to decadal and multidecadal oscillations and its phases. Similar study was carried out for the 20-th century ice extent (IE) time series obtained in Arctic and Antarctic Research Institute (St. Petersburg) for Russian margin seas: Kara, Laptev and East-Siberian during late summer and early autumn (Polyakov, et al, 2002). The IE smoothed curve in Barents and Kara Seas shows a coherent behavior: two minimums (in 20-th –30-th and in 80-th – 90-th) and one maximum in the middle of 20-th century. Wavelet analysis provided similar anomalies in power spectrum. It turned out that the atmospheric sea level pressure (SLP) climate series for Northern Siberia demonstrated fluctuations of decadal and multidecadal scales. The surface atmosphere temperature (SAT) series for North Asia sites displayed analogical time and spectral structures. Coherency of the AMO/PDO/NAO/IE trends, on one hand, and SLP/SAT trends, on other hand, proved a close relationship existed in various modules of the climate system (atmosphere-ocean-glacial cover) in the Northern Hemisphere. Another issue of this study was an investigation of the phase delay detected under analysis of the smoothed

curve signatures responded to above climate parameters. Considered phase delays in decadal and multidecadal oscillations were also explored by means of a cross wavelet analysis tool. To quantitative evaluate a linkage between above parameters we carried out a cross wavelet analysis (Grinsted, et al, 2004) and revealed some ranges in power spectrum, which are statistically significant with account for 95% probability level.

Scenarios of daily extreme precipitation under climate change

Wednesday - Poster Session 5

Hofstatter Michael[1], Matulla Christoph[1], and Wang Jiafeng[2]

[1]*Central Institute for Meteorology and Geodynamics, Vienna, Austria*

[2]*Department of Math and Statistics, York University, Toronto, Canada*

Daily extreme precipitation events under climate change conditions are the focus of research in our study. Such events can have considerable impacts on wealth and society by causing floodings or mudslides for example. In our study we used daily records of precipitation at 50 stations over Austria covering the period 1963-2006. To calculate the adequate timeseries for the future considering IPCC's climate change scenarios A1B and B1 we applied the analog method. Daily fields of sea level pressure from the NCAR/NCEP1 Reanalysis within the region of Europe (20W35E/ 30S65N), served as the prime predictor between local scale observations and climate simulations out of the MPIECHAM5 model. Several return values were determined by fitting a general extreme value distribution to the timeseries consisting of the three most extreme, declustered events per year. Results reveal that future changes of 20yreturn values are within ±20% for most stations, whereby the signal of change is stronger for the first period (20072050) as compared to the later one (20512094). This is valid for both IPCC scenarios. We conclude, that even for the relatively small area of Austria both the sign and rate of change in future extreme precipitation, offers a clear diversity among climatological regions. This implies an important aspect for forthcoming studies.

Novel advanced mathematical and statistical methods for understanding climate (NOVAC)

Wednesday - Poster Session 5

Heikki Haario[1], Erkki Oja[2], Alexander Ilin[2], Heikki Järvinen[3] and Johanna Tamminen[3]

[1]*Lappeenranta University of Technology, Finland*

[2]*Aalto University, School of Science and Technology, Finland*

[3]*Finnish Meteorological Institute, Finland*

Climate models contain closure parameters which can act as effective "tuning handles" of the simulated climate. These appear in physical parameterization schemes where unresolved variables are expressed by predefined parameters rather than being explicitly modeled. In the current climate model tuning process, best expert knowledge is used to define the optimal closure parameter values, based on observations, process studies, large eddy simulations, etc. In fact, closure parameters span a low-dimensional space, and the parameter probability densities should be objectively estimated simultaneously for all relevant parameters.

The authors have just started a project called "Novel advanced mathematical and statistical methods for understanding climate" (NOVAC, 2010-2013) which is funded by the Academy of Finland. Several research problems addressed during the project are discussed here.

The uncertainties of climate model closure parameters are estimated to improve understanding of reliability of climate predictions. We focus on the ECHAM5 model closure parameter distribution, and study the impacts on the reliability of future climate predictions. The methodology is, however, generic and applicable in any multi-scale problem with similar closure parameters.

Efficient Markov chain Monte Carlo (MCMC) sampling techniques are developed to tackle computationally challenging problems. MCMC simulations is an attractive tool for solving complex inverse problems. However, they are computationally very expensive and only efficient and maximally optimized MCMC techniques make the approach realistic in practice. We develop new tools based on adaptive algorithms, multiple computational grids, parallel chains as well as methods based on early rejection. Also, methodologies for collecting and archiving information for future runs is developed.

Novel statistical methods are developed to analyze very large observed and modeled data sets involved in climate research. For compression and for finding underlying spatio-temporal factors, methods such as empirical orthogonal functions (principal components) and related techniques are commonly used. The objective here is to develop advanced statistical data mining methods that surpass these well-known techniques, to more effectively detect the most significant multidimensional signals from the data. This enables us to find efficient cost function criteria for the application of the sampling methods for closure parameter estimation. Also, it enables us to visualize climate and to detect known climate phenomena, as well as to discover unknown ones in the observed climate and to detect consistent climate modes and anomalous features in simulated climates. We will focus on the formulation of efficient cost function criteria for the application of the sampling methods for closure parameter estimation.

Skill in large ensembles of downscaled seasonal forecasts

Wednesday - Poster Session 11

Raymond W. Arritt for the MRED Team

Iowa State University, Ames, USA

The Multi-Regional climate model Ensemble Downscaling (MRED) project is producing large ensembles of downscaled seasonal forecasts from coupled atmosphere-ocean seasonal prediction models. Eight regional models each are downscaling 15-member ensembles from the National Centers for Environmental Prediction (NCEP) Climate Forecast System (CFS) and the new NASA seasonal forecast system based on the GEOS5 atmospheric model coupled with the MOM4 ocean model. This produces 240-member ensembles (8 regional models x 15 global ensemble members x 2 global models) for each winter season 1982-2003. Preliminary results show that the combined global-regional downscaled forecasts show skill for seasonal precipitation anomalies in strong El Niño events such as 1982-83 and 1997-98. In these cases the regional models add useful spatial detail to the global forecasts, mainly due to better resolution of terrain in the regional models. Skill for weakly forced or ENSO-neutral conditions is lower and is much more difficult to evaluate. Our results emphasize that an ensemble approach is essential to realizing the added value from the combined global-regional modeling system, and that the minimum ensemble size to obtain useful ensemble skill varies with the climate regime (e.g., El Niño, La Niña or neutral). Our project also points to the challenge of finding appropriate statistical methods to extract maximum value from large multi-model ensembles.

A validation suite for downscaled climate model data

Wednesday - Poster Session 11

Elisabeth Orskaug[1,2], Ola Haug[1,2], Ida Scheel[3,2] and Arnoldo Frigessi[4,2,1]

[1]*Norwegian Computing Center, Oslo, Norway*

[2]*Statistics for Innovation, (sfi)*[2]

[3]*Department of Mathematics, University of Oslo, Oslo, Norway*

[4]*Department of Biostatistics, University of Oslo, Oslo, Norway*

The intensification of climate research over the past decade produces a steadily increasing number of data sets combining different climate models, CO2 emissions scenarios and downscaling techniques. For impact studies, but also as an issue of separate interest, the quality of these data need to be verified. Hence, there is an apparent demand for validation of past and present climate projections against real observations at different spatial scales.

In our work we report on a systematic approach to identify discrepancies in downscaled climate data. Based on methods suggested in the literature, we propose a comprehensive validation suite of global as well as local measures. Our concern is twofold: To identify the location of distributional differences, and to assess the seriousness of these diverences by appropriate effect measures.

We illustrate our methods using precipitation data for Norway. Downscaled ERA40 data are compared with triangulated and aggregated station measurement data on a 25x25km^2 grid nationwide. This is work in progress, and we will include some preliminary results.

Research is carried out in collaboration with people from the Norwegian Meteorological Institute (Eirik Førland, Jan Erik Haugen, Ole Einar Tveito), and Peter Guttorp (University of Washington and Norwegian Computing Center).

Evaluating the skill in predicting crop yield using an ensemble climate forecast by a regional climate model

Wednesday - Poster Session 11

Theodoros Mavromatis and Ioannis Pytharoulis

Department of Meteorology – Climatology, School of Geology, Aristotle University of Thessaloniki, Thessaloniki, Greece

Advances in climate prediction, at multi-week lead-time, offer the potential: i.- to reduce human vulnerability to agricultural impacts of climate variability, through improved agricultural decision making, and ii.- either prepare for expected adverse conditions, or take advantage of expected favourable ones. The main objective of this study is to assess the value of multi-week forecasts, with increasing spatial resolution on the lead-time, for successful prediction of simulated wheat, in the Mediterranean basin and mainly in Greece. Nine ensemble members are developed using the WRF-ARW regional atmospheric numerical model, at two different horizontal resolutions (from about 50km x 50km to almost 15km x 15km). The WRF model is applied, at forecast mode, every June for the years 2000-2009. To assess the value of the forecasts, two sets of site-specific daily weather scenarios (of incoming solar radiation, maximum and minimum air temperature and precipitation) are compared with one, based on the existing historical climatic data. The daily weather scenarios are created with a stochastic weather generator and correspond to the abovementioned two different horizontal resolutions. The CERES-Wheat crop model is used to simulate distributions of wheat yield at selected locations.

The CMIP multi model ensemble and IPCC: Lessons learned and questions arising

Thursday - Plenary Session 1

Reto Knutti

Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

Recent coordinated efforts, in which numerous general circulation climate models have been run for a common set of experiments, have produced large datasets of projections of future climate for various scenarios. Those multi-model ensembles sample initial condition, parameter as well as structural uncertainties in the model design, and they have prompted a variety of approaches to quantifying uncertainty in future regional climate change. International climate change assessments like IPCC rely heavily on these models and often provide model ranges as uncertainties and equal-weighted averages as best-guess results, the latter assuming that individual model biases will at least partly cancel and that a model average prediction is more likely to be correct than a prediction from a single model. This is based on the result that a multi-model average of present-day climate generally out-performs any individual model. However, there are several challenges in averaging models and interpreting spread from such ensembles of opportunity.

Among these challenges are that the number of models in these ensembles is usually small, their distribution in the model or parameter space is unclear and the fact that extreme behavior is often not sampled when each institution is only developing one or two model versions. The multi model ensemble should probably be interpreted as a set of 'best guess' models from different institutions, all carefully tuned to the same datasets, rather than a set of models representing the uncertainties that are known to exist or trying to push the extremes of plausible model response.

Model skill in simulating present day climate conditions is often weakly related to the magnitude of predicted change. It is thus unclear how the skill of these models should be evaluated, i.e. what metric should be used to define whether a model is 'good' or 'bad', and by how much our confidence in future projections should increase based on improvements in simulating present day conditions, a reduction of intermodel spread or a larger number of models. Metrics of skill are also likely to depend on the question and quantity of interest.

In many probabilistic methods, the models are assumed to be independent and distributed around the truth, which implies that the uncertainty of the central tendency of the ensemble decreases as the number of models increases. Because all models are based on similar assumptions and share common limitations, this behavior is unlikely to be meaningful at least for a large number of models. Indeed the averaging of models and the correlation structure suggest that the effective number of independent models is much smaller than the number of models in the ensemble, and that model biases are often correlated.

The bottom line is that despite of a massive increase computational capacity and despite of (or maybe because of) an increase in model complexity, the model spread in future projections is often not decreasing. Even on the largest scale, e.g. for climate sensitivity, the range covered by models has remained virtually unchanged for three decades. Probabilistic projections based on Bayesian methods that determine weights

for each model strongly depend on the assumptions made for the likelihood, i.e. the metric chosen to define model performance. Future model intercomparisons and methods to quantify uncertainties will face additional challenges when combining perturbed physics ensembles (a single model run with multiple parameters sets) and structurally different models, and when trying to incorporate structural error, i.e. the fact that many models tend to have common biases. Whether and how to weight models in multi model projections seems unclear at this stage. Some recent studies have proposed ways to do so while others have shown that the pitfalls may be larger than the potential benefits.

Using statistics to assess climate uncertainty

Thursday - Plenary Session 1

Paul Northrop

UCL, UK

Projections of future climate are often based on deterministic models of the earth's atmosphere and oceans. However, the projections can vary greatly between climate models, the socio-economic scenario envisaged for the future, and realisations based on different initial conditions. We use a simple random effects model, and data from the IPCC AR4, to assess which of these three sources of uncertainty are of greatest importance, taking as examples global temperature and rainfall in Northern China. In light of the fact that the design of the IPCC AR4 experiments are far from optimal for our purposes, we consider how best to estimate the parameters of the random effects model. We find that the relative importance of the three sources of uncertainty varies depending on the climate variable and the time horizon of interest.

Designing ensembles for climate prediction

Thursday - Plenary Session 1

Peter Challenor

The key to the analysis of data is in the design of the experiment, yet climate model experiments are often badly designed making analysis difficult. I will outline the principles of experimental design as applied to computer experiments. Starting with experiments with a single climate model I will review space filling designs and outline new approaches to sequential design and how you might cope with non-quantitative variables. Here an initial space filling design is augmented by further model runs to improve the design in the light of the initial experiment. The more difficult problem of how to design multi-model experiments will then be considered.

NARCCAP: Design and analysis of a regional climate model experiment

Thursday - Plenary Session 1

Steve Sain

The North American Regional Climate Change Assessment Program (NARCCAP) is an international program focused on delivering high-resolution climate fields over North America by using 6 regional climate models nested within 4 global models as well as two time-slice experiments. In this talk, we will discuss the motivation and features of the design of the NARCCAP experiment as well as the implications of the design for analysis of the ensemble. In particular, analysis will be presented that focuses on understanding the different sources of variation as well as interactions between the global models and the regional models.

Multi-model combination on seasonal and multi-decadal time-scales

Thursday - Plenary Session 2

Andreas P. Weigel

Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland

During the past decade, seasonal forecasting has become a well-established technique, and dynamical seasonal prediction systems are now in operational use at a range of climate prediction centers. In the wake of these developments, an enormous data-base of climate model simulations has been created, which has not only advanced our knowledge about seasonal predictability per se. Given that these data allow for systematic and statistically robust verification, plenty has also been learnt about technical and conceptual issues with relevance to other time-scales, e.g. questions regarding the interpretation and post-processing of ensemble forecasts.

This presentation focuses on the issue of multi-model combination – an issue which is also highly relevant in the context of climate change projections. From the evaluation of seasonal forecasts, it has been demonstrated that multi-models on average outperform any single model strategy. Moreover, seasonal forecasts have helped us to understand the underlying mechanisms and reasons for the success of multi-model combination. In particular, it has been possible to resolve the seeming paradox as to why, and under what conditions, a multi-model can outperform the best participating single model.

While the potential benefits of multi-models are now widely accepted on essentially all time-scales, there is so far no consensus on what is the best way to construct a multi-model. The simplest way is to give one vote to each model ("equal weighting"), while more sophisticated approaches suggest to apply model-weights according to some measure of performance ("optimum weighting"). Seasonal forecasts have revealed that model weighting indeed can improve the forecasts, but only if the optimum model weights are accurately known and truly represent the underlying model uncertainties. Otherwise, equal weighting on average yields better results.

These findings have major implications for the context of climate change, where – mainly due to the long time-scales involved - the determination of optimum weights is still an unresolved issue, and the "risk" of inadvertently applying wrong weights is high. In fact, with a conceptual model of climate change it can be shown that more information may actually be lost by wrong weights than could potentially be gained by optimum weights, particularly if internal variability is high. These results do not imply that the derivation of performance-based weights for climate projections is impossible by principle. However, they do imply that a decision to weight climate models should be taken with great care, and that for many applications equal weighting may well be the better and more transparent way to go.

A strategy to improve projections of Arctic climate change

Thursday - Plenary Session 2

Alex Hall

Here we describe our recent efforts to constrain the simulated response of the Arctic to anthropogenic forcing with observations. In the AR4 models, we show that the spread in simulated Arctic climate response is determined by the longwave component of an Arctic-specific climate feedback parameter. This negative longwave feedback is in turn controlled by the strength of the wintertime temperature inversion in the current climate, with strong (weak) inversions giving large (small) negative feedback. A comparison with reanalysis and satellite data reveals that the atmospheric temperature inversion is unrealistically strong in most models, indicating that these models simulate excessive negative longwave feedback in the Arctic. Further analysis of the observed and simulated relationships between sea ice concentration and inversion strength shows that many models mishandle the effects of atmosphere-to-ocean heat fluxes through the ice pack on the atmospheric boundary layer, generating systematic errors in inversion strength. The conclusion of this research is that model development efforts to improve the models' Arctic response to anthropogenic forcing should focus on the polar atmospheric boundary layer.

Using a perturbed physics ensemble to make probabilistic climate projections for the UK

Thursday - Plenary Session 2

David Sexton, Ben Booth, Mat Collins, Glen Harris and James Murphy

Met Office, UK

UKCP09, the latest set of climate projections for the UK were released on June 18th 2009. For the first time the climate projections for the UK are probabilistic, so that it is an appropriate tool for people who are taking a risk-based approach to policy and decision making. We will give a brief overview of how the probabilities were estimated using a) a combination of a number of 'perturbed physics ensembles' that explore parameter uncertainty in different components of the Earth System and b) a Bayesian framework which combines this climate model output with observations and multi model output to provide probabilities that are relevant to the real world and therefore relevant to risk-based decision making. The importance of factoring in structural error will be demonstrated and its contribution to the overall uncertainty will be compared with other sources of uncertainty.

Perturbed physics and multimodel ensembles: How can we use them together to constrain future climate response?

Thursday - Plenary Session 2

Ben Sanderson

Various studies have attempted to produce constraints on future climate response using the results of ‘Perturbed Physics Ensembles’ (PPEs), which explore the parameter uncertainty in a particular GCM. In recent work, we have demonstrated how constraints on future climate response based upon ensemble correlations within a PPE may not be robust when applied to a different GCM. However, by using additional information from a multimodel ensemble such as CMIP-3, together with a sound understanding of the feedback processes that vary within the PPE itself, we can create a more meaningful constraint on the likely future response of the real world. We demonstrate how a relatively small selection of features in the base climate of a perturbed model can be used to predict the large-scale future response of that model to greenhouse gas forcing and how constrained regression techniques can be used to eliminate unphysical correlations from a multivariate predictor of future climate response.

Present-day interannual variability of surface climate in CMIP3 models and its relation to the amplitude of future warming

Thursday - Parallel Session 2

Simon C. Scherrer

Climate Services, Federal Office of Meteorology and Climatology MeteoSwiss, Zürich, Switzerland

Interannual variability (IAV) of 2m temperature (T), sea level pressure (SLP) and precipitation (P) in the CMIP3 20th century model simulations is compared with IAV in observational and reanalysis data sets. Further the relation between the representation of T IAV and the amplitude of future warming is investigated.

In the Northern Hemisphere (NH) extratropics, T and SLP IAV are (in contrast to P) in general well represented although a few models perform much worse than others. General problem regions are i) sea ice boundary regions, where well known biases in the mean states exist and ii) the Pacific Ocean and Central Africa where SLP IAV is consistently underestimated. T and SLP IAV discrepancies are often found in similar regions and are large in well known bias problem regions in the tropics and subtropics and high mountain regions. “Bad” IAV representation also occurs in regions with small biases. T IAV is in general better reproduced on land than on sea and in the extratropics than in the tropics. Among the “good” IAV models there is no robust relation between the tropics (sea only) and the extratropics (land only).

The relation between the model’s ability to correctly represent T IAV and projected temperature changes is slightly negative (more warming for better IAV representation) but except for the NH summer season not significant when the worst models in terms of IAV representation are omitted. With exception of NH summer, this suggests that no robust relations are found between the model’s ability to correctly represent T IAV and the projected temperature change.

Comparing cloud feedbacks in perturbed-physics ensembles from two different GCMs

Thursday - Parallel Session 2

F. Niehörster[1,2], M. Collins[3], U. Cubasch[1]

[1]*Freie Universität Berlin, Germany*

[2]*London School of Economics, UK*

[3]*MetOffice - Hadley Center, UK*

In order to quantify uncertainties in cloud feedbacks arising from cloud parameterization schemes a 32-member perturbed-physics ensemble is generated by perturbing the values of key parameters in the corresponding cloud schemes of the fully coupled climate model EGMAM. To analyse parametric uncertainty, climate change experiments are carried out for the ensemble of models. To estimate cloud feedbacks, it is important to simulate the change in sea surface temperature in a physically consistent way. Thus, a key development for this study is an effective method to estimate the equilibrium change due to a doubling of the CO_2 concentration for an ensemble of climate models with a comprehensive ocean component. Results of these climate change experiments are presented for quantities indicative for cloud feedbacks and parametric uncertainty for different climate signals are quantified. Two main drivers for the simulated cloud feedbacks can be identified: (i) an increase in cloud height enhances the greenhouse effect of clouds (a positive feedback) and (ii) an increase in liquid water content especially of marine low-clouds in the tropics results in an increase of cloud albedo (a negative feedback).

An analysis of the contribution of individual perturbation parameters to parametric uncertainty shows that the entrainment rate for turbulent entrainment and the conversion rate from cloud water to rain in updrafts play an important role in determining the simulated cloud feedbacks. Nevertheless, independent of the choice of parameter values, all ensemble members show positive longwave and negative shortwave cloud feedbacks. As an important result, an anti-correlation between longwave and shortwave cloud feedbacks is found within the ensemble of model versions which leads to low variance in (negative) total cloud feedback and a low climate sensitivity in the EGMAM ensemble.

A comparison of results from perturbed physics ensemble with the HadSM3 climate model shows substantial differences in the simulation of climate feedbacks as well as the relationships between them. These differences to the EGMAM results lead to different estimates of climate sensitivity. This indicates a model dependence of perturbed physics results and leads to the conclusion that parametric uncertainty is different from structural uncertainty in climate models. Therefore, a comprehensive quantification of uncertainties in simulations of future climate change has to include the analysis the analysis of multi-model and perturbed-physics ensembles.

Model evaluation of the hydrological cycle in the present and future climate

Thursday - Parallel Session 2

Nathalie Schaller, Jan Cermak and Reto Knutti

Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

The intensification of the hydrological cycle is expected to have major impacts on human societies and ecosystems, which is why reliable statements about future changes in the precipitation patterns are urgently needed. Unfortunately, the model spread for precipitation is particularly broad. Another source of concern is the disagreement in trends between observations and model simulations of precipitation. While both climate models and observations predict an increase of the total amount of water in the atmosphere of 7% per Kelvin of surface warming, all climate models indicate a precipitation increase between only 1 to 3%/K, which is lower by a factor 2 or more than the observed increase in precipitation during the last decades.

Here we explore new ways of evaluating and understanding the intensification of the hydrological cycle in the climate models along with, as background motivation, the identification of potential reasons for the discrepancy between models and observations.

A common way to evaluate the model simulations is to use statistical measures to quantify their biases with respect to observations on the global scale. However, since precipitation is highly variable on both the spatial and temporal scales, metrics representing regional features of the modeled precipitation response to climate change might be more suitable to identify the good models. Three different ways of ranking the climate models are therefore compared, considering: a) biases in a broad range of climate variables, b) only biases in global precipitation and c) regional features of modeled precipitation in areas where future changes are expected to be pronounced. A surprising result is that the multimodel mean performs only average for the feature-based ranking, while it outperforms all single models in the two biasbased rankings. It is further shown that many models have similar biases and that the observation datasets are often located at one end of the model range. This outcome indicates that instead of using the “one model, one vote” approach, weighting the models according to their ability to simulate the present climate on a regional scale might lead to more reliable projections for precipitation.

Extraction of information from a global climate model perturbed physics ensemble

Thursday - Parallel Session 2

M. C. Cuellar and A. Lopez

Centre for Time Series Analysis, London School of Economics, London, UK

We analyze sets of runs of the climateprediction.net project, the largest perturbed physics climate model ensemble available to date. This ensemble is specifically designed to sample climate-model uncertainty in HadCM3 and has stored different climate variables as global and regional monthly means between 1920 and 2080.

We explore different methodologies to obtain empirical probability distributions of climate variables and/or ranges of potential impacts of climate change. A set of model runs within the perturbed physics ensemble is selected by checking their ability to reproduce detectable correlations in climate observations and their forecasting skill. This first selection of model runs is performed by checking (i) distance to climatology and (ii) natural model variability. The model runs that had passed THESE checks are combined to produce a forecasting probability density function whose predictability skill is evaluated using the Ignorance Skill Score.

The final goal is to investigate whether the Perturbed Physics ensemble can provide information potentially useful to assess impacts of climate change, with some quantifiable predictability skill.

Constraining climate sensitivity by natural interannual variability in the CMIP3 ensemble

Thursday - Parallel Session 2

D. Masson and R. Knutti

Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

The climate sensitivities of the CMIP3 climate models used in the IPCC AR4 report cover a range from about 2 to 5 K. Although much of the information contained in observation datasets has already been used to calibrate these models, it is difficult to find an observational constraint to get a more accurate uncertainty estimate of the true climate sensitivity. Such a problem can partly be circumvented by using a large ensemble of perturbed physics climate models where parameters have not been calibrated to mimic observation. This technique estimates the parametric uncertainty of a model but not the structural uncertainty. Because CMIP3 is the only ensemble that samples structural uncertainty, it is important to derive confidence interval based on it using observable constraints.

Wu and North (JGR, 2003) found a possible relationship between internal variability and climate sensitivity in an older set of global climate models. Its application to the present CMIP3 ensemble predicts a climate sensitivity between 2.45 and 3.95 K (95% confidence interval) using the ERA40 observation data. The constraint on climate sensitivity relies on the interannual variability surface temperature of individual calendar months. The internal variability of each 12 calendar months is first computed at the grid-point scale on a common T42 resolution and then globally averaged. Summer months are less variable than winter months and the ratio of these two variances correlates positively with climate sensitivity. The origin of this correlation is still not fully clear, but understanding why internal variability correlates to climate sensitivity may provide a new constraint to improve climate models and reduce their spread in the future.

The inapplicability of traditional statistical methods in climate ensembles

Thursday - Parallel Session 2

David Stainforth

Grantham Research Institute, London School of Economics, London, UK

There is growing demand for predictions of future climate to support planning efforts to adapt to 21st century climate change. At the same time there has been growing effort expended in the quantification of uncertainty in model based climate predictions at all scales. This has led to a number of large ensembles of complex climate models; ensembles exploring emissions uncertainty, initial condition uncertainty and model uncertainty. These ensembles do not, of course, explore any of these sources of uncertainty comprehensively.

There is a continuing challenge to expand these ensembles and to better design them for a variety of different purposes. However, perhaps the greatest challenges at present relate to their interpretation. Given the lack of any clear definition of “model space” and given the ad hoc nature of the shape of model parameter space the sampling of model uncertainty can not be treated as IID (Independent and Identically Distributed). This lack of independence between ensemble members critically undermines the application of many common statistical methodologies. The challenges here will be discussed and illustrated using a 40,000 member GCM ensemble from climateprediction.net. Differences in the treatment of initial condition uncertainty and model uncertainty will be highlighted along with some discussion of how they may be combined.

Forecast encompassing testing of statistical time series climate forecasts of global temperature and their implications for global circulation models

Thursday - Parallel Session 2

Robert Fildes and Nikos Kourentzes

Lancaster Centre for Forecasting, Lancaster University, UK

This paper first considers the validation of long term climate global circulation models as used by the IPCC in their forecasts of global warming. This paper presents an appraisal of various extrapolative time series benchmarks forecasts of annual average temperature, both global and local. Methods include non-linear univariate neural nets and benchmark smoothing models. Nonlinear multivariate models relating carbon emissions to globally averaged atmospheric carbon dioxide are also considered. These models are compared for their accuracy against 10-year ahead forecasts produced from a global circulation model. By examining forecast encompassing tests it is shown that the global circulation model is mis-specified and its forecasts can be improved on by including forecasts from the time series models. 20-year ahead forecasts are improved by including information on CO2 emissions.

Quantifying differences in circulation patterns with probabilistic methods

Thursday - Parallel Session 2

H. W. Rust[1], M. Vrac[1], M. Lengaigne[2] and B. Sultan[2]

[1]*Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Gif-sur-Yvette, France*

[2]*Laboratoire d'Océanographie et de Climatologie par Experimentation et Approche Numérique (LOCEAN), Paris, France*

The comparison of circulation patterns (CP) obtained from reanalysis data to those from general circulation model (GCM) simulations is a frequent task for model validation, downscaling of GCM simulations or other climate change related studies. Here, we suggest a set of measures to quantify the differences between CPs. A combination of clustering using Gaussian mixture models with a set of related difference measures allows to take cluster size and shape information into account and thus provides more information than the Euclidean distances of cluster centroids. The characteristics of the various distance measures are illustrated with a simple simulated example. Subsequently, we use a Gaussian mixture model to define and compare circulation patterns obtained for the North Atlantic region among reanalysis data and GCM simulations. The CPs are independently obtained for NCEP/NCAR and ERA-40 reanalyses, as well as for 20th century simulations from several GCMs of the IPCC-AR4 database. The performance of GCMs in reproducing reanalysis CPs strongly depends on the CPs looked at. The relative performance of individual GCMs furthermore depends on the measure used to quantify the difference, e.g., if size and shape information are considered or not. Especially the latter highlights the complementarity of the suggested measures to the classical Euclidean distance.

How can RCMs reproduce the annual cycle and what we can learn from it

Thursday - Parallel Session 2

T. Halenka[1], **P. Skalak**[2], **P. Huszar**[1] **and M. Belda**[1]

[1]*Dept. of Meteorology and Environment Protection, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic*

[2]*Czech Hydrometeorological Institute, Prague, Czech Republic*

The annual cycle is analyzed by means of Taylor score to assess the ability to reproduce annual cycle in regional climate models (RCMs) used in EC FP6 project ENSEMBLES. The objective of this effort is to provide rather simple, but still convenient method with one figure output for further weighting of the RCMs ensemble simulations. The application of Taylor score directly to the original results averaged to monthly time series for individual so-called PRUDENCE regions can provide first guess of this annual cycle performance, especially for temperature where annual cycle is a main source of variation and correlation, although for precipitation there are clear deficiencies in this assumption. More comprehensive technique applying multiple linear regression analysis on the time series to extract a pure annual cycle is used to assess the differences in the both method of evaluation. It is shown that the results of both methods coincide reasonably well. However, as the original technique provides basically the overall performance of the model, the quality of annual cycle description in the models can be one of the important factors affecting its precision on monthly scale. The comparison with driving fields is presented as well.

Quantifying uncertainty in climate forecasts from climate*prediction*.net

Thursday - Parallel Session 2

Dan Rowlands[1], Dave Frame[2], Tolu Aina[3], Nicolai Meinshausen[4] and Myles Allen[1]

[1]*AOPP, Oxford University, UK*

[2]*Smith School, Oxford University, UK*

[3]*OeRC, Oxford University, UK*

[4]*Department of Statistics, Oxford University, UK*

Perturbed physics ensembles have been run to explore the uncertainty in climate forecasts by systematically varying physics parameters in a single base model. Here we discuss some results from the transient HadCM3L ensemble run as part of the climate*prediction*.net project.

In particular we detail the approach taken in evaluating the level of model-data discrepancy in each ensemble member, based on methods used in Detection & Attribution studies. In particular we advocate comparing model output and observations only at a level where the residual is indistinguishable from our best estimate of natural variability – this avoids ignoring the irreducible error or the need for a subjective “discrepancy” term.

Further, we consider the question of what observations are relevant for making a particular climate forecast: should the set that we use depend on the question that we are asking, or does it make sense to have a broad set over which we evaluate the model performance? Can the inclusion of transient and climatological information together help us rule out particular future climates?

We finally discuss how one may incorporate all of this information together into a single probabilistic forecast, and advocate objective approaches based on testable information rather then subjective, often untestable, prior assumptions on climate model parameters.

Extreme variations in the American Monsoon Systems: An integrated overview based on a multivariate index

Thursday - Parallel Session 7

Leila M. V. Carvalho[1,2] **and Charles Jones**[2]

[1]*Department of Geography, University of California Santa Barbara, USA*

[2]*Earth Research Institute, University of California Santa Barbara, USA*

The presence of a monsoonal type of circulation involving intense convective activity and heavy precipitation is a common climatic feature in the Americas during the respective summer seasons. The seasonal migration of the monsoons in the Americas has been extensively investigated and important mechanisms on intraseasonal to interannual (ISI) time scales controlling their variability have been identified. In this study we show a unified view of the American Monsoon Systems (AMS) by developing a multivariate index based on combined Empirical Orthogonal Function (CEOF) Analysis. To derive this index, long-term annual means are first removed from 5-day averages (pentads) of precipitation (P), zonal and meridional wind components (U, V), specific humidity (Q) and temperature (T) at 850-hPa. Precipitation from the Global Precipitation Climatology Precipitation (GPCP) and atmospheric variables from the National Centers for Environmental Prediction/National Center for Atmospheric Research reanalysis (NNR) are used. We show that the first, second and third combined EOFs represent different phases of the migration of convection over the Americas and characterize the transition of the monsoon systems from the Southern to Northern Hemisphere and vice-versa. The first combined EOF (henceforth Large-Scale Index for the American Monsoon – LIAM-1) shows high correlation with opposite sign between the Mexican and South American Monsoons. The second combined EOF (EOF-2) shows high correlation with convection and circulation over Equatorial South America. Wavelet analysis of LIAM-1 shows clear decadal variability of the amplitude of the AMS, with large amplitudes from 1995-2008 compared with the previous decades. Large variability on interannual time-scales is observed for LIAM-2, consistent with the influence of ENSO and corresponding teleconnections over Equatorial South America. Large variability in both indexes is observed on intraseasonal timescales. In this study we explore extreme variations in the AMS by investigating extreme anomalies in LIAM-1 and LIAM-2 indexes on ISI time-scales. Both indexes are band-filtered and extremes are defined as the upper and lower quartiles of the respective anomalies. We investigate the relationships between the extreme anomalies and global sea surface temperature, precipitation, moisture fluxes and circulation on ISI time-scales. We show that the enhancement convection over tropical continental South America during December-February on intraseasonal timescales is associated with the organization of the Pacific North American Pattern (PNA) and with the strengthening of the Northern Hemisphere subtropical jet. Variations on interannual timescales are examined along with variations in the South Atlantic and Pacific SST patterns.

Analysis of regional climate projections of extreme precipitation and temperatures by using an Extreme Value Theory non-stationary model

Thursday - Parallel Session 7

Barbara Casati[1], **Louis Lefaivre**[2] **and R. De Elia**[1]

[1]*Consortium Ouranos, Montreal, Canada*

[2]*Canadian Meteorological Center, Dorval, Canada*

Future climate projections of extreme events can help to forewarn society of high-impact events and develop better adaptation strategies. Extreme Value Theory (EVT) provides a well established and robust statistical framework to analyze the behaviour of extreme events for the present climate and future projections. In this study a non-stationary model for Generalized Extreme Value (GEV) distributions is used to analyze the trend of the distributions of extreme precipitation and temperatures, in the context of a changing climate.

The analysis is performed for the climate projections of the Canadian Regional Climate Model (CRCM), under a SRES A2 emission scenario, over North America. Annual and monthly extremes of 24h accumulated precipitation and daily minimum and maximum temperatures are analyzed. Significant positive trends for the location of the distributions are found, indicating an expected increase in extreme value intensities, whereas the scale (variability) and shape (tail values) of the extreme distributions seem not to vary significantly.

The trends have been tested for three different behaviours: linear, parabolic and logistic, the latter representing an abrupt change between a present and a future equilibrium states. Linear trends best fit the changes in the extremes, for both temperatures and precipitation; temperature maxima exhibit sometimes also parabolic trends; temperature minima exhibit logistic behaviours in the Arctic regions, possibly due to a more ice-free future polar environment.

Extreme value prediction of typhoon events – Models and applications

Thursday - Parallel Session 7

Defu Liu, Huajun Li, Liang Pang and Fengqing Wang

Ocean University of China, Qingdao, China

Since 1972 typhoon No.12 induced extraordinary storm surge attacked Dalian port in Bohai sea of China, causing severe damage in this port, and 1975 typhoon Nina induced storm inundation led to 25,000 death and effected 12,000,000 people, we found that traditional extrapolation by asymptotic distributions from annual maxima data sampling method can not determine the design return period for such extraordinary typhoon events. By compounding a discrete distribution (typhoon frequency) and a continuous extreme distribution of typhoon events, the Compound Extreme Value Distribution (CEVD) was derived and published in US at 1980 and CEVD used to predict hurricane characteristics along Gulf of Mexico and Atlantic coasts in 1982. The predicted results by CEVD were higher than NOAA proposed SPH and PMH in West and East Florida regions, and they are close to the 2005 Katrina and Rita hurricane characteristics.

During the past years CEVD has been developed into Multivariate Compound Extreme Value Distribution (MCEVD) and applied to prediction of typhoon induced sea hazards for coastal, offshore structures and estuarine cities. Both of CEVD and MCEVD have advantages: instead of traditional annual maximum data sampling, the typhoon process maximum data sampling is used, and typhoon frequency involved in the model.

Based on the MCEVD, the Double Layer Nested Multi-objective Probability Model(DLNMPM) is proposed in which the joint probability prediction of different typhoon characteristics are taken as the first layer and typhoon induced disaster factors (such as strong wind, storm surge, huge wave, heavy rain, inundation, landslide and so on) are taken as the second layer. This model was adopted by the Office of State Flood Control and Drought Relief Headquarters of P.R. of China for typhoon disaster prediction, prevention and mitigation.

Proposed models are successfully used to study on the New Orleans and Shanghai prevention criteria; joint probability study of combined extreme sea environmental loads criteria and deck clearance for fixed platform; long term prediction of sedimentation for sea port and waterway; reliability analysis and risk assessment for some important coastal defense structures by MCEVD.

Estimating future changes in daily precipitation distribution from GCM simulations

Thursday - Parallel Session 7

Jonathan M. Eden and Martin Widmann

School of Geography, Earth and Environmental Sciences, University of Birmingham, UK

Precipitation changes are an important aspect of climate change and impact assessment often requires not only estimates for future mean precipitation but also for changes in daily precipitation, for instance in the frequencies of extreme events or in the length of dry spells. However, the limited spatial resolution and the systematic errors of precipitation simulated in General Circulation Models (GCMs) make direct estimates of future daily precipitation from GCMs unrealistic.

So-called ‘Perfect-Prog(nosis)’ (PP) downscaling methods, which apply statistical links between large and small spatial scales derived from observation to simulated large-scale predictors, are often used to estimate mean precipitation on small spatial scales, but quantifying expected changes in the intensity and temporal characteristics of daily precipitation events remains a challenge.

An alternative approach to statistical downscaling is ‘Model Output Statistics’ (MOS), where statistical corrections for simulated variables are formulated. We have performed simulations with the ECHAM5 GCM nudged towards the circulation and temperature in the ERA-40 reanalysis as a basis for fitting MOS models and have found MOS corrections of simulated monthly mean precipitation for the period 1958-2001 to be substantially better than conventional PP estimates (see abstract by Widmann and Eden).

Here we extend this work to daily timescales and investigate the performance of MOS corrections for simulated daily precipitation over the same 1958-2001 period. Whilst potentially global in application, corrections will be made only for regions where high-quality daily observational products are available. Candidate MOS methods are direct empirical corrections of simulated frequency distributions (quantile mapping), regression-based methods (Maximum Covariance Analysis, PC multiple linear regression) with non-local daily simulated precipitation as predictor and daily precipitation as predictand, as well as corrections of distribution parameters. The potential for estimating changes in the real world extreme value distribution from the simulated precipitation will also be discussed. Skill assessment will be based on cross-validation and include the analysis of estimated distribution parameters, of threshold exceedance and of temporal characteristics.

Detecting change in UK extreme precipitation using results from the climate*prediction*.net BBC Climate Change Experiment

Thursday - Parallel Session 7

Hayley J. Fowler[1], Daniel Cooley[2], Stephan R. Sain[3] and Milo Thurston[4]

[1]*School of Civil Engineering and Geosciences, Newcastle University, Newcastle upon Tyne, UK*

[2]*Department of Statistics, Colorado State University, Fort Collins, USA*

[3]*Institute for Mathematics Applied to Geoscience, National Center for Atmospheric Research, Boulder, USA*

[4]*Oxford e-Research Centre, Oxford University, Oxford, UK*

We investigate a question posed by policy makers, namely, "when will changes in extreme precipitation due to climate change be detectable?" To answer this question we use climate*prediction*.net (CPDN) model simulations from the BBC Climate Change Experiment (CCE) over the UK. These provide us with the unique opportunity to compare 1-day extreme precipitation generated from climate altered by observed forcings (time period 1920-2000) and the SRES A1B emissions scenario (time period 2000-2080) (the Scenario) to extreme precipitation generated by a constant climate for year 1920 (the Control) for the HadCM3L General Circulation Model (GCM).

We fit non-stationary Generalized Extreme Value (GEV) models to the Scenario output and compare these to stationary GEV models fit to the parallel Control. We define the time of detectable change as the time at which we would reject a hypothesis at the $\alpha = 0.05$ significance level that the 20-year return level of the two runs is equal. We find that the time of detectable change depends on the season, with most model runs indicating that change to winter extreme precipitation may be detectable by the year 2010, and that change to summer extreme precipitation is not detectable by 2080.

We also investigate which climate model parameters affect the weight of the tail of the precipitation distribution and which affect the time of detectable change for the winter season. We find that two climate model parameters have an important effect on the tail weight, and two others seem to affect the time of detection. Importantly, we find that climate model simulated extreme precipitation has a fundamentally different behavior to observations, perhaps due to the negative estimate of the GEV shape parameter, unlike observations which produce a slightly positive (~0.0–0.2) estimate.

Variations of climate extremes in Australia during 1911-2008

Thursday - Parallel Session 7

Ailie Gallant and David Karoly

University of Melbourne, Australia

A modified version of the Climate Extremes Index (mCEI) of Karl *et al.* (1996) has been developed for Australia to identify changes in climate extremes on interannual, decadal, and longer time scales. The mCEI is based on a suite of non-parametric indices measuring the spatial extent of the areas experiencing extremes of daily and annual temperature, rainfall and soil moisture each year from 1911 – 2008. Though interannual and decadal variability are present, trends showing increases in the extent of warm temperature extremes and decreases in the extent of cool extremes are evident over the period of record. There have also been increases in the areas experiencing extreme numbers of wet days and extreme soil moisture surplus during this time and some changes to heavy daily precipitation.

The extremes indices used for this study are non-parametric and percentile-based. This makes it easier to combine indices for different climate variables, such as for temperature and rainfall. It is also easier to compare indices from observations and climate model simulations, as changes in the indices are compared to their own frequency distributions, avoiding some of the problems that climate models may have in simulating extremes.

The causes of annual to century-long variations of these extremes indices are investigated. The influence of large-scale natural climate drivers, such as El Niño – Southern Oscillation (a strong interannual driver of mean Australian rainfall and temperature) is assessed, as is the contribution from random climate variability. The influence of anthropogenic forcing on the long-term trends is determined using comparisons of the observations and coupled climate model simulations from the CMIP3 multi-model archive. The observed variations in extremes are compared with those from model simulations for the period 1911-2008 forced by natural forcings (*e.g.* solar and volcanic eruptions) and anthropogenic forcings (greenhouse gas and sulfate aerosols), as well as from control model simulations with no changes in external forcing. A deviation outside the range given by the control experiments implies that anthropogenic forcing is likely to have contributed to the trends in Australian climate extremes from 1911 – 2008.

Subsampling inference for trends and extremes in climate data

Thursday - Parallel Session 7

Alexander Gluhovsky

Department of Earth & Atmospheric Sciences, Purdue University, West Lafayette, USA

Department of Statistics, Purdue University, West Lafayette, USA

Standard statistical methods involve strong assumptions that are rarely met in climate data, whereas resampling methods permit obtaining valid inference without making questionable assumptions about the data generating mechanism. Among these, subsampling works under the weakest assumptions, which makes it particularly applicable for climate data analyses.

In the talk, two problems will be handled by subsampling techniques. One is the construction of simultaneous confidence bands for the unknown trend in a time series that can be modeled as a sum of two components: deterministic (trend) and stochastic. The stochastic one is a zero-mean stationary process (not necessarily an iid noise as is often assumed). The other problem is the tail index estimation for heavy tailed time series. Subsampling procedures will be illustrated with modeled and observed data.

This work is supported by the National Science Foundation Grant ATM-0756624.

European extra-tropical storm damage risk from a high-resolution multi-model ensemble of dynamically downscaled global climate models

Thursday - Parallel Session 7

Malcolm R. Haylock

PartnerRe Reinsurance Company, Zurich, Switzerland

A set of European wind storms was derived from twenty-two 25km regional climate model runs driven by either the ERA40 reanalyses or one of four coupled atmosphere-ocean global climate models. Storms were identified using a model-dependent storm severity index based on maximum daily 10m sustained wind. We calibrated the storm set of each model to a set of high resolution 7km historical storm windfields using the 70 storms with the highest severity index in the period 1961-2000, employing a two stage calibration methodology. First we downscaled the 25km daily maximum sustained to our 7km historical model grid using the 7km surface roughness and elevation, also applying an empirical gust parameterisation. Secondly we statistically calibrated wind speeds to our historical storms to match the geographically-dependent cumulative density distribution.

The greatest downscaling challenges were to produce a storm set from each 25km model that showed similar statistical properties to the historical sets, in particular similar intensity attenuation across the set, and to combine the 22 individual models into a single homogenous millennium-scale storm set.

The final combined historical-regional model event set of storms was run through an operational catastrophe reinsurance pricing model to determine the return level of loss to a Europe-wide population derived portfolio of residential property. The model showed close agreement between the combined storm set and the historical storm set with the added benefit of more detail at higher return periods.

Predicting extremes in the midlatitudinal atmospheric circulation using regime-dependent modelling

Thursday - Parallel Session 7

Frank Kwasniok

University of Exeter, Exeter, UK

Prediction and predictability of extreme events in the midlatitudinal atmospheric circulation are studied using a mixture of empirical statistical models. Estimation of the model parameters is combined with a clustering algorithm; each model is conditional on the flow regime the system is in. Prediction and predictability of extreme events are investigated as a function of initial condition, event rarity and event magnitude. The contribution aims to introduce the methodology into the statistical climatology community; the ideas are explored in a quasigeostrophic atmospheric low-order model.

Characteristics of extreme events in Korea: Observations and projections

Thursday - Parallel Session 7

Won-Tae Kwon, Hee-Jeong Baek and Hyo-Shin Lee

Climate Research Laboratory, National Institute of Meteorological Research, Korea Meteorological Administration, Seoul, Korea

According to the IPCC's fourth assessment report (2007), warming of the global climate system is unequivocal and the rate of global warming is expected to increase during the 21st century. Recently, regional changes in extreme events (heavy rainfall, drought, heat wave, typhoon, etc.) became one of the most demanding issues among the impact and adaptation communities. The impacts on human and natural systems are more severely hit the least developed regions and also more vulnerable groups even in the developed regions.

The objective of this study is to understand the characteristics of regional climate change over the Korean Peninsula using observations and future projections (based on SRES A1B). We have analysed changes in mean, variability, and extremes of temperature and precipitation. It is found that the mean temperature over Korea is increased by 1.7^{O}C for 1912-2008. Indices related to warmer climate have been increased while indices related to colder climate show decreasing trends. Precipitation amount is also increased by 19% during the same period. The frequency of heavy rainfall increased but number of rainy day decreased, resulting rain rate intensified. In order to understand future climate change over Korea, we have produced multi-decadal simulations based on SRES A1B scenario with 27-km horizontal resolution. It is found that the projected mean temperature show more warming in the northern land area than the southern coastal area, and precipitation show increasing trend over the Peninsula. The variability and trend over Korea is larger than global averages. The results indicate a significant change in frequency and intensity of extreme climate events. Indices related to warmer temperature show increasing trend, and vice versa. Frequency of heavy rainfall is expected to increase in the future. Detailed analysis results will be presented at the conference.

Detection of human influence on extreme precipitation

Thursday - Parallel Session 7

Seung-Ki Min[1], Xuebin Zhang[1], Francis W. Zwiers[1] and Gabriele C. Hegerl[2]

[1]*Climate Research Division, Environment Canada, Toronto, Canada*

[2]*School of GeoSciences, University of Edinburgh, Edinburgh, UK*

Heavy precipitation events have become more intense over a large part of the Northern Hemisphere (NH) land area. It has been suggested that human influence may be partly responsible for the intensification of extreme precipitation in line with the increased water holding capacity of atmosphere due to global warming. However, because of the limited availability of daily observations, most previous studies have examined only the potential detectability of extreme precipitation through model-model comparisons. Here we compare observed and multi-model simulated extreme precipitation using an optimal fingerprinting method, and provide the first evidence that human-induced increase in greenhouse gases and sulphate aerosols have contributed to the observed intensification of heavy precipitation events during the latter half of the 20th century. The anthropogenic signal is found to be detectable over large NH land areas. Models, however, under-simulate the observed increase in heavy precipitation trend, indicating that model projected changes in extreme precipitation and their impacts may also be underestimated.

Inhomogeneities in temperature records deceive long-range dependence estimators

Thursday - Parallel Session 10

H. W. Rust[1], O. Mestre[2] and V. Venema[3]

1Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Gif-sur-Yvette, France

2Ecole Nationale de la Météorologie, Toulouse, France

3Meteorological Institute, University of Bonn, Bonn, Germany

We investigate the effect of inhomogeneities in data temperature records on the estimation of a long-range dependence (LRD) parameter. hort-range dependent processes are characterised by an exponential tail of the autocorrelation function (ACF) and a finite area under the ACF, whereas LRD processes show an algebraic tail and the area under the ACF is infinite. It is crucial to reliably determine this characteristic because these slowly decaying correlations are responsible for an increase in confidence intervals for statistics derived from the data. Furthermore, they alter significance levels for tests, as, e.g., trend tests. Examples of inhomogeneities in observed temperature data are sudden jumps caused by a relocation of the measurement station, or a new type of shelter. Homogenisation procedures are able to detect and correct for such jumps by considering the signal of multiple nearby measurement stations and can thus reduce the bias in estimating the LRD parameter. We analyse a set of temperature time series before and after homogenisation with respect to LRD and find that the average LRD parameter is clearly reduced for the homogenised series. In order to test whether the homogenisation artificially reduces LRD, we create sets of simulated data from a LRD stochastic process and artificially introduce jumps. These sets are then corrected using a homogenisation procedure. This test provides evidence that the homogenisation procedure is able to remove biases introduced by artificial changes, leaving the LRD parameters unchanged.

Statistical analysis of global surface temperature and sea level using nonstationary methods

Thursday - Parallel Session 10

T. Schmith[1], S. Johansen[2] and P. Thejll[1]

[1]*Danish Meteorological Institute, Denmark*

[2]*University of Copenhagen, Denmark*

Global averages of both surface temperature and sea level have increased through the past century. The relationship between these two non-stationary series is however quite complicated. For instance: the warming period in the 1940es is not very evident in mean sea level. This would also be expected a priori, due to the complicated physical cause-effect relationships involved: Surface temperature has increased primarily due to external radiative forcing, but is affected by the large heat capacity of the ocean. Mean sea level in turn has risen due to the effect of rising temperatures t partly hrough thermal expansion and partly through glacier melt-off.

We analyse this relationship using a bivariate Vector Error Correction Model (VECM) approach. This is a well-known method within the field of econometrics and can with advantage be applied to climate time-series analysis. The method is well-suited for revealing cause-effect relationships (in a statistical sense) between time series.

We find that the two series are cointegrated, i.e. inter-related in the long run which confirms our a priori expectation. But the VAR analysis tells us more: namely that changes in the sea-level influences changes in the surface temperature while the opposite is not the case. This is in accordance with the notion that the major part of the heat capacity of Earth's climate system resides in the ocean. By adding historical estimates of long- and short-wave forcing as external explanatory variables we are able to explain the differences in temperature and sea level behaviour in terms of the radiative budget.

These results have application in the field of forecasting sea-level rise, given greenhouse gas emission scenarios.

Estimation of the anthropogenic trend in temperature records

Thursday - Parallel Session 10

Sabine Lennartz and Armin Bunde

Institute for Theoretical Physics, University of Giessen, Giessen, Germany

It is well accepted that the global mean surface air temperature has been rising in the 20th century, with a more pronounced increase in the last 50 years. The open question is how much of this increase can be attributed to natural fluctuations, and how much is of anthropogenic origin, caused, for example, by the increasing greenhouse gas (GHG) emission. To treat this detection problem, we do not use climate simulations, but assume as statistical null hypothesis that monthly temperature records are long-term correlated with a Hurst exponent H >0.5 (including also nonstationary records with H values above 1). We are interested in the probability W(D) that an observed trend D occurs naturally, and in the anthropogenic part A(Q, D) of the temperature increase within a given confidence interval Q. We show that for confidence intervals with Q above 80% analytical expressions for W(D) and A(Q, D) can be derived, which request as input solely the Hurst exponent, as well as the temperature increase D obtained from the linear regression line and the standard deviation around it [1]. We apply this methodology to a large number of global and local stations, and find that in general, the trends in the global data are more significant than in the local data. In addition, our analysis yields the surprising result that the comparatively strong temperature increase in the last 50 years is a weaker indicator for an anthropogenic trend than the lower annual increase in the last 100 years.

[1] Lennartz, S., and A. Bunde, Geophys. Res. Lett. 36, L16706 (2009)

On the statistical significance of climate trends

Thursday - Parallel Session 10

Christian Franzke

British Antarctic Survey, Cambridge, UK

One of the major problems in climate science is the prediction of future climate change due to anthropogenic green-house gas emissions. The earth's climate is not changing in a uniform way because it is a complex nonlinear system of many interacting components. The overall warming trend can be interrupted by cooling periods due to natural variability. Thus, in order to statistically distinguish between internal climate variability and genuine trends one has to assume a certain null model of the climate variability. Traditionally a short-range, and not a long-range, dependent null model is chosen. Here I show evidence for the first time that temperature data at 8 stations across Antarctica are long-range dependent and that the choice of a long-range, rather than a short-range, dependent null model negates the statistical significance of temperature trends at 2 out of 3 stations. These results show the short comings of traditional trend analysis and imply that more attention should be given to the correlation structure of climate data, in particular if they are long-range dependent.

In this study I use the Empirical Mode Decomposition (EMD) to decompose the univariate temperature time series into a finite number of Intrinsic Mode Functions (IMF) and an instantaneous mean. While there is no unambiguous definition of a trend, in this study we interpret the instantaneous mean as a trend which is possibly nonlinear. The EMD method has been shown to be a powerful method for extracting trends from noisy and nonlinear time series. I will show that this way of identifying trends is superior to the traditional linear least-square fits.

Combined effects of forcing uncertainty and natural variability for present and future estimates of transient climate response future estimates of transient climate response

Thursday - Parallel Session 6

Lauren E. Padilla, Geoffrey K. Vallis and Clarence W. Rowley

Princeton University, USA

With interest increasing in the near term risks of climate change, we seek to improve our understanding of uncertainty in transient climate response by constraining the parameters of very simple stochastic climate models with past observations of the climate. We compare the relative importance of uncertainty in forcing and natural variability of the observed signal in their impact on overall temperature response uncertainty. We introduce a novel method using a Sigma-point Kalman filter, which is essentially a computationally efficient recursive Bayesian estimation method for nonlinear systems. The recursive filter allows us to easily track the evolution of uncertainty as it is updated dynamically and with observational data over time. With data projected out to the year 2030, we are able to show how quickly we can expect transient climate uncertainty to decline as additional observations are made. We validate our method using 'observational' data from the CM2.1 climate model of GFDL with known transient climate response. We then apply the method to real temperature observations. We also explore how our results would vary with changes in the assumptions made to initialize the filter.

A relaxes Bayesian approach to climate projection and attribution

Thursday - Parallel Session 6

Stephen S. Leroy, Yi Huang and Richard M. Goody

We will present an approach to climate projection and climate signal detection and attribution that is based in Bayesian statistics. It is derived in the same fashion as the equations of optimal detection but without the assumptions of a prior separable in signal shape and signal trend and of uninformed signal trend. In it, a probability density function is formed in the space of observed variables and predicted variables from an ensemble of runs of a climate model that spans both a historical period and a future period. Every model is equally weighted, and only a single realization of each model is included. This way, the joint PDF includes the uncertainties introduced by natural variability and model uncertainty. Then, by inserting data into the data variables in the PDF, the section in the space of the prediction variables is the posterior PDF for climate projection. The normalization constant for the posterior PDF is the joint probability of the ensemble of climate models used to formulate the PDF and the data, a quantity that can be used to test the ensemble of climate models. A hypothesis testing approach to attribution is obtained when the joint probabilities of ensemble and data are determined using (1) an ensemble of “all” climate forcings is generated for the historical variables, and (2) and ensemble of “natural” climate forcings is generated for the historical variables.

We apply the method to 20th century surface air temperature using the CMIP3 ensemble. The data vector contains historical trends in eight different regions. The prediction vector contains the evolution of temperature change for a particular region over the coming century. Because of the limited number of independent models that contributed to CMIP3, it is valid to approximate the joint prior distribution as normal. The resulting equations require the inversion of the covariance matrix in the space of the data variables only, and this matrix is ill-determined because of the paucity of models used to construct it. Consequently, only two eigenmodes are permitted in decomposition according to the North criterion, and four are permitted using a statistical F-test on the post-fit residuals. Our effort points toward the need to use a perturbed physics ensemble of runs of a climate model because they typically provide far more independent runs, historical and prediction, than an ensemble of best-judgment climate model runs.

Probabilistic surface air temperature predictions: comparing global climate models with nonlinear time series models

Thursday - Parallel Session 6

Siddharth Arora[1,3], Max A. Little[2] and Patrick E. McSharry[1,3]

[1]*Department of Mathematics, University of Oxford, Oxford, UK*

[2]*Department of Physics, University of Oxford, Oxford, UK*

[3]*Smith School of Enterprise and the Environment, Oxford, UK*

Climate variability can be attributed to either internal dynamics or external forcing. Internal dynamics are the unforced natural changes in our environment, such as the El Nino cycles or anomalies of ocean heat content, which usually account for short-term regional changes in the climate [1]. External forcing caused by human activity, such as increasing CO2 emissions, account for recent global climatic changes [2]. Long term projections for global climatic change are undertaken using Global Climate Models (GCMs). Government policy and decision-making in the private sector over the coming decades relies heavily on accurate long term projections of surface air temperatures. As these policies will in turn have a large effect on global climate change, the need for rigorous evaluation of projections from GCMs is of utmost importance. The focus of our study is to assess surface air temperature predictions obtained from the Decadal Climate Prediction System (DePreSys), a dynamical GCM based on the Hadley Center Coupled Model. We investigate the potential of parsimonious nonlinear time series models, with only a few parameters, to compete with the GCM both in terms of point and density forecasts over varying horizons. Comparisons between GCM projections, appropriate benchmarks, and proposed nonlinear models is undertaken using different performance scores, including root mean square error (RMSE), mean absolute error (MAE), and the continuous ranked probability score (CRPS).

[1] P. A. Stott, S. F. B. Tett, G. S. Jones, M. R. Allen, J. F. B. Mitchell, G. J. Jenkins, “External Control of 20th Century Temperature by Natural and Anthropogenic Forcings”, Science, 2000, **290**, 2133 – 2137.

[2] D. M. Smith, S. Cusack, A. W. Colman, C. K. Folland, G. R. Harris and J. M. Murphy, “Improved Surface Temperature Prediction for the Coming Decade from a Global Climate Model”, Science, 2007, **317**, 796-799.

The limited contribution of model uncertainty to the uncertainty in observationally-constrained estimates of anthropogenic warming

Thursday - Parallel Session 6

Nathan Gillett[1] and Peter Stott[2]

[1]*Canadian Centre for Climate Modelling and Analysis, Environment Canada, Canada*

[2]*Met Office Hadley Centre, UK*

Output from multiple climate models is often used in studies which attempt to constrain past and future anthropogenic warming using observational constraints. Recent studies have used output from multiple models first to obtain a less noisy estimate of the anthropogenic response, since it is anticipated that different models will exhibit different errors in their response patterns. Second, these studies have used inter-model differences to account for model uncertainty in estimates of the uncertainty in anthropogenic warming, using the Error in Variables approach. Here we show that explicitly accounting for model uncertainty in this way only marginally inflates the uncertainty in estimates of anthropogenic warming. We find that this is because inter-model differences in the magnitude of the anthropogenic response are disregarded in the analysis, since the magnitude is constrained by observations; and overall uncertainty in observationally-constrained anthropogenic warming is dominated by internal variability in the observations, with model uncertainty in the pattern of the response making only a small contribution. These results imply that observationally-constrained projections of 21st century warming are relatively insensitive to the model used. We discuss the extent to which these results apply to other variables, such as precipitation.

What influence will future solar activity have on projected global climate changes?

Thursday - Parallel Session 6

Gareth S Jones[1], **Mike Lockwood**[2] **and Peter Stott**[1]

[1]*Met Office Hadley Centre, Exeter, UK*

[2]*Dept Meteorology, University of Reading, Reading, UK*

During the 20th century solar activity increased in magnitude to a so called "grand maximum". Since the last solar cycle maximum in 2002, activity has decreased to levels lower than any solar minimum since 1937. Some measures of Earth's global near surface temperature over the same period show a decrease in the rate of warming. Whilst this is consistent with climate model projections and knowledge of climate internal variability there have been claims that the drop in solar activity may be partially responsible. Indeed further claims suggest that future solar variations will have significant impacts on climate that could partially offset projected anthropogenic warming. Observations and reconstructions of solar activity over the last 9000 years have been used as a constraint on possible future variations to produce probability distributions of total solar irradiance over the next 100 years. Using this information, with a simple climate model, we will present results of the potential implications for future projections of climate on decadal to multi-decadal timescales.

Prediction of the sunspot activity using the shadowing filter

Thursday - Parallel Session 6

M.C. Cuellar[2], A. Svedin[1] and E. A. Spiegel[1]

[1]*Department of Astrophysics, Columbia University, New York, USA*

[2]*Centre for Time Series Analysis, London School of Economics, London, UK*

We study how the shadowing filter applies for a low dimensional dynamical model of the solar cycle by Platt, Spiegel, and Tresser (PST model), and available observations of the sunspots number to generate forecast of future solar activity. This model sees variations of the solar activity as a result of the coupling of the nonlinear oscillation and a chaotic oscillator. Each of these oscillations are interpreted as the motion in the convection zone and the tachocline dynamo.

This case study constitutes a perfect example for assessing the predictability of the variations of the sunspot number, where the model available (e.g. the PST model) is an imperfect model of the complex dynamics of the sun, and at the same time is a tractable mathematical representation of the physics that features the same intermittency shown in the sunspot number observational data.

The solar activity prediction problem is in many ways similar to the problem of verification and prediction of climate. In both cases, it is important to better constrain predictions to observations and to measure the quality and reliability of predictions, either to inform the physics of the model or decision making.

Probabilistic regional climate change projections using Bayesian model averaging over East Asia

Thursday - Poster Session 1

Hee-Jeong Baek, Won-Tae Kwon and E-Hyung Park

National Institute of Meteorological Research, KMA, Korea

Recently Bayesian approaches have been applied to model evaluation and multi-model ensemble averaging for weather and climate predictions. We employed similar method used by Min et al. (2007) for regional-scale climate change projections using IPCC AR4 multi-model data set and regional climate model data. The objective of this study is to calculate a probabilistic climate change projection over East Asia using Bayesian Averaging Model (BAM) and to estimate uncertainties of regional climate projections. This information on the uncertainty is useful for decision-makers.The BMA technique is applied to the twenty-first century climate variables simulated by the models of IPCC AR4 and regional climate models to produce probabilistic predictions of regional climate over East Asia. In case of temperature change, Bayesian training was applied to temperature data over land derived from the Climate Research Unit and model data for the period of 1950-1999. The results from weighted PDFs were compared with unweighted PDFs for future climate change projection over East Asia. Comprehensive measure of model skills based on multiple climate variables might be useful to produce more robust weighting factors and hence more reliable probabilistic predictions of regional climate changes.

Towards systematic calibration of comprehensive climate models

Thursday - Poster Session 1

Omar Bellprat, Daniel Lüthi, Sven Kotlarski and Christoph Schär

Institute of Atmospheric and Climate Science, ETH Zürich, Switzerland

The calibration of climate models is a subject of constant debate and strongly diverging opinions. There is no clear consensus whether the models should reproduce most accurately past and present sets of observations or rather be exlusively based upon physical laws. When should a model or a parameter set be rejected? Do the available observations actually allow for rejection in the sense of the ability to make a prediction? Which are the relevant characteristics of the model that should constrain the parameter sets and which are the important statistical measures? Even though these questions are fundamental, the efforts of model calibration in climate science are often concealed. In particular physicallybased global and regional climate models, which also are subject to some degree of calibration, show a lack of transparency of their optimization.

From the calibration of intermediate complexity climate models, which is a far more openly discussed topic, we have improved our understanding of the parameter uncertainty and the structural errors of the climate models. In addition it provided some estimates on how much of the model projection uncertainty can be constrained by reducing the parameter uncertainty and led to the application of many efficient statistical frameworks for model calibration. Unfortunately most these methods are still inappropriate for costly high resolution climate models, but still relevant information on parameter interrelations and model uncertainty can be inferred.

Here we present preliminary results of an ongoing project on the systematic calibration of the regional climate model COSMOCLM. The COSMOCLM is a nonhydrostatic limited area climate model originally developed by the German Weather Service. An optimal performance framework on the variables of interest, available and useful reference datasets, statistical measures of skill and spatial and temporal averaging is discussed. We show the effects of training period length on the measures, implications for the consideration of interannual variability and relate the measures to estimates of the internal variability of the model for the years 1990 – 2000.

Furthermore a perturbed physics ensemble is shown for about 50 poorly confined parameters in the convection, turbulence, radiation, microphysics, dynamical and surface flux scheme for the year 1990. Parameters of the soil model are not tested, since long simulations are required to assess the model sensitivity to these parameters. The results of the model sensitivity and its pattern correlation are related to the calibration of the model.

An ensemble model for predicting iceberg drift

Thursday - Poster Session 1

Tom Carrieres[1], **Kyle Allison**[1] **and Greg Crocker**[2]

[1]*Canadian Ice Service – Environment Canada, Canada*

[2]*Ballicater Consulting, Canada*

Icebergs present the most significant hazard to shipping and oil and gas production off the east coast of Canada. Although routine monitoring for local areas is feasible, it is also extremely costly. For large scale monitoring, the Canadian Ice Service and the International Ice Patrol use a combination of infrequent observations and state of the art iceberg model forecasts. The model forecasts are often quite accurate but occasionally are startlingly bad. One approach to providing additional information on the expected quality of the forecast is to use ensemble techniques. Ensembles have been constructed using a single model with perturbations within estimated uncertainties in the initial iceberg observations, environmental driving forces and model parameters. Prototype probability of occurrence products require an ensemble size of 250 members. These results and future plans towards a more refined approach will be presented.

The MVL diagram: A diagnostic tool to characterize ensemble simulations

Thursday - Poster Session 1

J. Fernández[1], S. Herrera[2], J.M. Gutiérrez[2] and M.A. Rodríguez[2]

[1]*Universidad de Cantabria, Spain*

[2]*Instituto de Física de Cantabria, Spain*

This work illustrates the usefulness of some recent spatiotemporal analysis tools in the field of weather and climate simulation. To this aim we present a recent characterization of spatiotemporal error growth (the so called mean-variance logarithmic (MVL) diagram, Primo et al. 2005, Gutiérrez et al. 2008). Behind a simple calculation procedure, the MVL diagram comes from a sound theoretical basis borrowed from the growth of rough interfaces (López et al. 2004), and has several applications as a diagnostic tool in the characterization of ensemble prediction systems. Namely, it is useful in characterizing (1) the initial perturbations applied in a simulation, (2) the model dynamics, acting as a fingerprint for different models and (3) the climatological fluctuations of the perturbations specific of each model. As opposite to the standard temporal analysis (spatially-averaged or single-point), the MVL spatiotemporal analysis accounts for the nontrivial localization of fluctuations, thus allowing disentangling the effects of the different initialization procedures (random, lagged, singular vectors) and the different model formulations.

We show an application of this diagram using a coupled ocean-atmosphere Ensemble Prediction System (Fernández et al. 2009); in particular we consider the DEMETER multimodel seasonal hindcast and focus on both initial conditions (three different perturbation procedures) and model errors (seven coupled GCMs). We show that the shared building blocks of the GCMs (atmospheric and ocean components) impose similar dynamics among different models and, thus, contribute to poorly sampling the model formulation uncertainty. We also illustrate how multiple scales in dynamical systems impose non-trivial effects on the growth of perturbations.

Decadal predictability of the Atlantic: estimation of optimal perturbations

Thursday - Poster Session 1

Ed Hawkins and Rowan Sutton

NCAS - Climate, University of Reading, Reading, UK

Future decadal climate forecasts are likely to rely on ensembles initialised using small perturbations to ocean and atmosphere conditions. In order to design efficient ensembles there is a need to identify those perturbations that grow most rapidly. Such perturbations may also be useful to identify where new ocean observations could improve forecast skill. We have employed two different methods to estimate such optimal perturbations, or 'singular vectors', for decadal predictions of the Atlantic Ocean.

Firstly, we use linear inverse modelling (LIM) to find the initial condition anomalies which grow most rapidly under a particular norm of interest. We have utilized a wide range of different GCMs to explore the sensitivity of the results. The regions consistently identified as most sensitive to small perturbations are located in the far North Atlantic. Significant non-normal amplification is found, and the mechanisms of amplification generally involve a basin-wide overturning circulation response to the small perturbations. We also demonstrate multi-decadal predictability of the overturning strength, and of basin-wide temperature and salinity fields.

Secondly, we are using an ensemble based technique – Climatic Singular Vectors (CSVs) - which, unlike the LIM approach, enables optimal perturbations to be estimated for specific initial conditions, e.g. a high or low overturning strength. Reliable CSVs can be obtained in the HadCM3 GCM, although the methodology is computationally very expensive. Amplification again occurs in the far North Atlantic, indicating that these regions are optimal for additional ocean observations to improve decadal climate predictions.

For more details:

Hawkins & Sutton, 2009, Journal of Climate, **22**, p3960

Hawkins & Sutton, 2010, Journal of Climate, submitted

SVD on ICE - On the linearity of climate change simulation with GCMs

Thursday - Poster Session 1

F. Niehörster1, E. Tredger1,2 and L.Smith1,3

[1]*Grantham Institute of the London School of Economics, UK*

[2]*Department for the Environment, Food and Rural Affairs, UK*

[3]*Pembroke College, Oxford, UK*

This poster focuses on questions of linearity in general circulation model (GCM) simulations of global warming as a function of a increasing atmospheric CO_2 concentration. The assumption that climate response is "linear" is widely used and multiply defined. Indeed, the assumption of linearity is crucial for several applications of climate science including pattern scaling. After noting several different interpretations of what "linear" might mean in the case of climate simulations, the extend to which these approximations hold is evaluated in large (~2^9) initial condition ensembles (ICE). These simulations consider the equilibrium response of HadSM3 to three different levels of CO_2 concentration increase. By comparing the singular value decomposition (SVD) and the leading singular vectors of the three initial condition ensembles we evaluate not only the relevance of the linearity assumption, but also the robustness of the principal pattern of temperature change.

Probabilistic assessment of regional climate change by ensemble dressing

Thursday - Poster Session 1

Christian Schoelzel and Andreas Hense

Meteorological Institute, University of Bonn, Germany

Since single-integration climate models only provide one possible realisation of climate variability, ensembles are a promising way to estimate the uncertainty in climate modelling. A statistical model is presented that combines information from an ensemble of regional and global climate models to estimate probability distributions of future temperature change in Southwest Germany in the following two decades. The method used here is related to kernel dressing which has been extended to a multivariate approach in order to estimate the temporal autocovariance in the ensemble system. It has been applied to annual and seasonal mean temperatures given by ensembles of the coupled general circulation model ECHAM5/MPI-OM as well as the regional climate simulations using the COSMO-CLM model. The results are interpreted in terms of the bivariate probability density of mean and trend within the period 2011–2030 with respect to 1961–1990. Throughout the study region one can observe an average increase in annual mean temperature of approximately 0.6 K in and a corresponding trend of +0.15 K/20a. While the increase in 20-years mean temperature is virtually certain, the 20-years trend still shows a 20% chance for negative values. This indicates that the natural variability of the climate system, as far as it is reflected by the ensemble system, can produce negative trends even in the presence of longer-term warming. Winter temperatures are clearly more affected and for booth quantities we observe a north-to-south pattern where the increase in the very southern part is less intense.

Crossing critical threshold

Thursday - Poster Session 1

Tony Sit

Climate models forced with increased concentrations of carbon dioxide project a gradual change in variables, such as temperature and precipitation, which are of consequence to society. Planners and decision-makers use such projections for developing strategies for adaptation and/or mitigation. For this purpose, it is often important to ”predict” when the change in a specific climate variable will cross a critical threshold and to attach a measure to such information of uncertainty. Given a range of future projected climate trajectories taken from a multitude of models or scenarios and assuming that they span the range of future possibilities, we argue that the best way to determine the threshold crossing time is to calculate the average of all crossing times. In particular, we compare the proposed estimator to the more commonly used method of calculating the crossing time of the average of all trajectories (the mean paths) and show that the former method is superior with respect to the mean square error between the estimate and the true crossing time. Moreover, using the former approach also allows us to provide a measure of uncertainty as well as other properties of the crossing times distribution. As a demonstration of our method, we look at the projected reduction in rainfall in two subtropical regions: the US Southwest and the Mediterranean.

This is a joint work with V. H. de la Pena, Y. Kushnir and A. Ravindranath.

Evaluation of high-resolution regional climate simulations for the use in climate impact studies

Thursday - Poster Session 2

Susanne Brienen, Barbara Früh and Andreas Walter

Deutscher Wetterdienst, Offenbach, Germany

Contemporary climate and environmental consulting need to consider the impact of climate change. For this purpose, past and future climate projections at spatially high resolution and high quality are mandatory. Although regional climate models evolved largely in the last years, model deficiencies, which are too high to be acceptable in policy and climate advice, still remain. To improve the regional climate projections of the regional climate model COSMO-CLM and, thus, enable a subsequent climate impact research we work on the optimization of the physical parameterization for climate purposes.

In a first step, we examine an ensemble of sensitivity simulations using COSMO-CLM with 7km grid spacing, forced by operational global model analyses, in comparison to surface observations in Germany. We find that important differences occur especially in the 2m relative humidity, but also in the 2m air temperature, and that changes in the configuration of all parts of the model (e.g. physics, numerics, model domain…) can influence the results.

Here, we present and discuss our first results.

Water resources in South-west Western Australia: model uncertainty in climate change adaption

Thursday - Poster Session 2

Richard E. Chandler[1], **Stephen P. Charles**[2] **and Bryson C. Bates**[3]

[1]*Department of Statistical Science, University College London, UK*

[2]*CSIRO Land and Water, Wembley, Australia*

[3]*CSIRO Climate Adaptation Flagship, Wembley, Australia*

Southwest Western Australia (SWWA) is currently experiencing an extended period of drought and, according to the IPCC Fourth Assessment Report, winter precipitation in the region is "very likely" to decrease over the coming century. Since 70-80% of the region's rainfall falls in winter, this has serious water resource implications. Water resource managers therefore face the challenge of putting in place the mechanisms and infrastructure to cope with reduced water availability in the future. The decisions they make will be informed by projections of future climate based on deterministic atmosphere-ocean general circulation models (GCMs). However, these projections can vary widely between GCMs, with differences becoming more pronounced at the relatively fine spatial and temporal scales relevant for hydrological applications. It is therefore natural to ask how best to combine information from different GCMs.

Here we present a transparent, logically coherent and interpretable framework that formalises the issues involved and provides the opportunity to frame the relevant questions in an unambiguous manner. The framework uses a hierarchical statistical model to represent features that account for inter-GCM differences, shared biases and outlying GCMs; it is in principle sufficiently general that it could be applied in any climate impacts study. To develop projections for use in SWWA water resource planning, the methodology is applied in conjunction with a statistical downscaling tool to develop projections of winter (May-October) rainfall for a network 30 sites in the region. The results suggest that naïvely combining the projections from different GCMs and treating the resulting ensemble as a probability distribution may substantially underestimate the uncertainty involved.

Stochastic climate change scenario generator for use in probabilistic climate change impact assessments

Thursday - Poster Session 2

M. Dubrovsky

Institute of Atmospheric Physics ASCR, Prague, Czech Republic

The volume of GCM simulations available for climate change impact studies continually increases. This allows for better representation of uncertainties (inter-GCM and intra-GCM, between emission scenarios, between parameterizations, etc.), but, simultaneously, the volume of available GCM output data has become so large such that it poses a strong requirement for more effective organization of climate change impact analyses. In implementing the multi-model information for a given impact analysis, only scenarios from a subset of all available GCMs are mostly employed. Less frequently, the impact analysis is based on scenarios processed from all of the GCMs. However, this is not applicable in cases where an ensemble of GCM simulations is too large (for example, when dealing with the perturbed-physics ensemble available from climateprediction.net project). In such cases, one may use scenario emulators/generators, which may produce a large set of climate change scenarios representing the whole multivariate probability distribution function of the scenarios. The present contribution introduces a new stochastic climate change scenario generator.

In the first part, the underlying model of the scenario generator is presented. The generator is based on a multivariate parametric model whose parameters are derived from a set of GCM-based scenarios (no limit on the size of the learning set, the model may also be calibrated with a very large perturbed-physics ensemble). Once calibrated, the generator may produce an arbitrarily large set of climate change scenarios. These scenarios consist of changes in monthly means and variabilities, and are easily linked with the stochastic weather generator M&Rfi, which produces weather series (with an optional number of variables and optional time step) to be used as an input to the impact models.

The second part is focused on validation of the scenario generator. The generator is used to make a probabilistic assessment of climate change impacts on annual averages and extremes of temperature, precipitation and two Palmer drought indices (Z, PDSI) in 10 European and 11 US stations. The monthly weather series, from which the characteristics are derived, are generated by M&Rfi weather generator, whose parameters are derived from observed weather series and then modified according to climate change scenarios coming from two sets: (i) scenarios derived from individual GCMs (IPCC-AR4 database), and (ii) scenarios generated by the stochastic climate change scenario generator calibrated by the set of GCM-based scenarios. The validation of the scenario generator is then based on comparison of the probabilistic distribution functions (in individual stations) of impacts obtained with the two sets of scenarios.

The study is supported by the GAAV Grant Agency (project IAA300420806).

The spread and skewness of climate sensitivity: revisiting some commonplace assumptions

Thursday - Poster Session 2

Alexis Hannart

Both models and observations yield probability distributions for climate sensitivity – the global mean temperature expected for a doubling of CO_2 – that exhibit two main characteristics: they are widespread (likely range of 2°C-4.5°C) and positively skewed (small but finite probabilities of very large values). Both of these characteristics have recently received attention in order to determine their causes and implications. Several authors have proposed a simple framework to explain these characteristics based on the uncertainty on feedback and on the inverse relationship between feedback and sensitivity.

Introducing more formal statistical definitions and concepts within this framework, explicit relationships between the spread and the skewness of the PDFs of sensitivity and feedbacks are derived. Based on these relationships, we discuss the implications on sensitivity PDFs spread and skewness of further reducing the spread on feedback. We also discuss the validity of the assumption of a non-skewed PDF for feedback, which is commonplace. We show that this assumption is not supported by AR4 multimodel ensemble data and that it is questionable based on this evidence.Note : A limited part of this study has been published (Hannart, A., J.-L. Dufresne, and P. Naveau (2009), Why climate sensitivity may not be so unpredictable,Geophys. Res. Lett.) but the scope of this proposed talk is a bit broader and does not merely restrict to a comment on a specific article.

Climate model evaluation and models of natural variability

Thursday - Poster Session 2

Jara Imbers[1] and Ana Lopez[2]

[1]*Department of Mathematics, Oxford University, UK*

[2]*Grantham Research Institute, London School of Economics, UK*

Nonlinearities in the climate system induce strong interactions among separated space and time scales. However, there is no climate model that encompasses all temporal and spatial scales, includes all the components and processes and therefore explains the climate phenomena at once. As a result Global climate models (GCM) often exhibit significantly lower variability. In general GCMs concentrate the modelling on a particular frequency band. Variables that evolve on slower timescales can be modelled as quasi-adiabatic parameters and variables evolving more rapidly can be modelled as random fluctuations. Therefore, when looking at climatic records we should ask which is the relevant frequency band, and which features of such a record are the ones a model of the behaviour within that band should capture. In this work we analyse these issues in the context of climate model evaluation. When validating climate models with observations the standard assumption is that fast variables can be described as uncorrelated random variables, neglecting strong correlations between different time-scales. Using the CMIP3 models and climateprediction.net perturbed physics ensemble, we investigate whether correlations between different time scales are relevant for the model runs' evaluation and the consequences of taking them into account in the metrics to evaluate models.

Analysis of long term persistence in a perturbed physical ensemble

Thursday - Poster Session 2

A. Lopez, Milena C. Cuellar, Gil Lizcano and Mark New

Global climate model perturbed physics ensembles are currently being created with the goal of quantifying the uncertainty in climate change projections due to uncertain model parameterisations.

The perturbed physics ensemble (PPE) consists of typically hundredths of model runs obtained by setting the parameters to alternative values considered physically plausible by experts in the relevant parameterisation schemes. However, not necessarily all the regions in parameter space correspond to model runs that are consistent with physically sensible climates.

It is clear that a simple comparison between the mean state of the atmosphere of a single model run and the observed climate does not guarantee that its dynamical properties are consistent with those of the climate system.

In this work we focus on the analysis of the long term persistence of the ensemble model runs, comparing it with the observed long term correlations, and discuss the viability of this approach as a tool to validate model runs within the ensemble.

Future climate in tropical Africa

Thursday - Poster Session 2

Gamil Gamal

I studied the future climate of the tropical Africa by comparison the output from five models from 1979 to 2000 to compare with the available National centers for environmental prediction (NCEP) reanalysis data of the ten stations which started from 1979. The Climate Systems Analysis Group (CSAG) at the University of Cape Town provides services in support of climate change data analyses as well as the assessment of impacts and adaptation strategies. Outputs from five different AOGCMs are represented, all of which are available for downloading from the CSAG Data Dissemination Centre (DDC).

The five GCM models are: Geophysical and Fluid Dynamical Laboratory (GFDL) model, NASA Goddard Institute for Space Studies (GISS) model, Max Planck Institute for Meteorology, Germany (ECHAM5) model, Commonwealth Scientific and Industrial Research Organization (CSIRO-MK3_5) model and Canadian Center for Climate Modeling and Analysis (CCCMA) model.

We choose ten stations in the tropical Africa as a case study for the comparison between observed and output results for five GCM models are:

Dakar- Tambacounda- Abidjan- Odienne- Ndjamena- Kinshasa- Jimma- Mandera- Zanzibar- Musoma.

From the previous comparisons we constructed that the CCCMA and ECHAM5 models have the least root mean square error (RMSE) and mean bias (MB) compare with the other models. So the CCCMA model is the highest performance model using for predicting the maximum temperature and precipitation and ECHAM5 model for predicting minimum temperature in the future.

For this we used CCCMA and ECHAM5 models to show the future climate of the selected stations during the period 2045-2065, we found that the trends of maximum temperature are positive for Dakar and Musoma stations and stations (Tambacounda, Abidjan, Odienne, and Zanzibar) have negative trends. While for minimum temperature we found positive trends in Dakar, Ndjamina, Jimma, and Mandera, and the stations that have the negative trends are Tambacounda, Abidjan, Odienne, Kinshasa, Zanzibar and Musoma. Most of stations give a positive trend of precipitation except for two stations gave us a negative trend. The stations that have positive trend are Dakar, Tambacounda, Abidjan, Odienne, Ndjamina, Jimma, Mandera and Zanzibar. The stations that have the negative trends are Kinshasa, and Musoma.

GCMs models, CSAG, DDC, GFDL, GISS, ECHAM5, CSIRO-MK3_5, CCCMA, Dakar, Tambacounda, Abidjan, Odienne, Ndjamena, Kinshasa, Jimma, Mandera, Zanzibar, Musoma.

Towards an improved understanding of aerosol effects on the climate

Thursday - Poster Session 2

Lindsay Collins, Ken Carslaw, Graham Mann and Dominick Spracklen

University of Leeds, UK

The AErosol model RObustness and Sensitivity study (AEROS) aims to provide improved climate and air quality prediction through an improved understanding of the uncertainties in aerosol effects on the climate. Aerosol has persistently been assessed as the largest radiative forcing uncertainty (IPCC, 2007) with its effects being of comparable magnitude but with opposite sign to the greenhouse gases (a cooling effect on the atmosphere). The best current knowledge of aerosol processes is encapsulated in the GLObal Model of Aerosol Processes (GLOMAP), Spracklen (2005). GLOMAP is the aerosol module of the UK climate model and the aerosol scheme for the UK's Earth System model. Complex aerosol microphysics have enhanced model realism and improved reliability of predictions but model uncertainties remain high. The computational demands of GLOMAP mean that uncertainty at the process level has not yet been quantified. GLOMAP has participated in model-intercomparison studies in which a large diversity between models is seen. This has shown that more complex models do not necessarily perform best in comparison to observations and it is not yet known whether they have greater explanatory power or whether parameter uncertainty dominates.

The aim of AEROS is to establish comparable process-level diagnostics across a diverse range of models, developed using the GLOMAP model. Uncertainty and sensitivity analysis offers great potential in aerosol modelling due to the wide range of uncertain parameters and model structures. The process-level model uncertainty is to be quantified and the major sources with respect to model parameters and model structure to be identified. Initially, Gaussian Process emulation is employed with respect to GLOMAP's uncertain parameters working closely with the model developers. Early results and intentions for future research are presented here.

Spracklen, D.V, Pringle, K.J, Carslaw, K.S, Chipperfield, M.P, Mann, G.W. A global off-line model of size-resolved aerosol microphysics: I. Model development and prediction of aerosol properties. Atmos. Chem. Phys., 5, 2227–2252, 2005

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Links between atmospheric circulation and recent climatic variability and trends in Europe – A comparative approach using the COST733 classifications database

Thursday - Poster Session 6

Monika Cahynová[1,2] **and Radan Huth**[1]

[1]*Institute of Atmospheric Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic*

[2]*Department of Physical Geography and Geoecology, Charles University, Prague, Czech Republic*

In this study we evaluate and compare 24 circulation classifications from the COST733 inventory according to their ability to stratify daily station climatic data into circulation types, and assess the magnitude of seasonal temperature and precipitation trends in Europe in the period 1961-2000 that can be linked to changing frequency of circulation types in these classifications (as opposed to changing climatic properties of individual circulation types). The selected classifications were created using eight methods, each applied in three variants with fixed numbers of types (9, 18, and 27), which enables us to study how the number of types influences our results. Furthermore, we examine the effect of spatial scale of atmospheric circulation on the links between individual circulation catalogues and local climatic variability and trends, i.e. we compare the results obtained with classifications derived from a large European domain and from smaller sub-domains representing European regions. The skill to stratify climatic data into types (measured by explained variance index) is the highest for maximum temperature, lower for minimum temperature, and the lowest for precipitation. The highest values are generally obtained in winter for classifications with 27 types that are computed on the small spatial domains. Seasonal climatic trends in the period 1961-2000 can be only partly explained by the changing frequency of circulation type, the link being the strongest in winter. In the other seasons, within-type climatic trends are responsible for a major part of the observed trends. Circulation changes in the small domains are usually more tightly connected with climatic trends than those in the large domain except for Icelandic and Scandinavian stations where circulation over the whole Europe explains a larger part of the observed trends. There are large differences between results obtained with individual classifications, which suggests that a comparative approach is highly desirable in such synoptic-climatological studies.

Trends in ENSO and tropical Pacific surface winds and SST

Thursday - Poster Session 6

A. M. Chiodi and D. E. Harrison

There has been considerable interest over the past decade in the extent to which global warming may bring a change in the characteristics of marine surface conditions in the tropical Pacific and whether the statistics of ENSO variability also will change. There are only a limited number of direct measurement time series to address these questions. We here use the Darwin SLP record, near-surface winds and SST data from the TAO array when possible, and reconstructed SST products to provide a contemporary summary of what the observations reveal about these questions. The very strong amplitude of ENSO variability, together with the large multi-decadal changes in frequency and amplitude, make trend estimation of both ENSO statistics and surface condition trends challenging. We suggest that the null hypothesis should remain that ENSO statistics have not changed over the past 1850 years and that even over the post-1980 period when global warming has been unequivocal, tropical Pacific SST and surface wind trends generally also are not significant.

The Palmer Drought Severity Index considered in Europe with an ensemble of models - present day, and future expectations

Thursday - Poster Session 6

Cathrine Fox Maule and Peter Thejll

Danish Climate Centre, DMI, Copenhagen, Denmark

The Palmer Drought Severity Index (PDSI) has recently been reformulated in a self-calibrating framework to address problems related to local effects in the original PDSI. The PDSI depends on (lack of) precipitation, evapotranspiration, and water holding capacity of the soil at a given place, and how the two first parameters vary with time. We investigate the performance of the new index with an ensemble of regional climate models from the ENSEMBLES project - all driven by the ERA40 reanalysis. The quality of extreme drought predictions made by the new index will be investigated by comparison to observations, and the validated method is then applied to a set of models forced in accordance with the future emissions scenario A1B. Using a suite of models allows us to evaluate which model predictions of drought are robust.

Climate change detected through a Markov chain analysis – an application to the Iberian Peninsula

Thursday - Poster Session 6

J.A. Freund[1], S. Mieruch[2], S. Noël[2], H. Bovensmann[2] and J.P. Burrows[2]

[1]*Institute for Chemistry and Biology of the Marine Environment, University of Oldenburg, Germany*

[2]*Institute of Environmental Physics, University of Bremen, Germany*

The fingerprint of climate change can be seen in many regions across the globe. In Europe, the Iberian Peninsula is most susceptible to climate change. Trend studies indicate that glaciers are melting, droughts and storms are increasing and beaches get lost. In contrast, significant changes of climate variables are harder to detect on shorter time scales, e.g. for the last decade being the relevant time range for climate data acquired by modern satellites. We show how signs of climate change can also be observed on shorter time scales when analysing the interplay of climate variables. To this end we describe the interplay using dynamic descriptors such as persistence, recurrence time and entropy. These descriptors are based on anomaly statistics derived from a coarse-grained categorical representation of multivariate time series and a subsequent Markov chain analysis. We apply the method to a multivariate data set of temperature (GISS), water vapour (GOME/SCIAMACHY) and vegetation (SPOT), recorded for Europe on a 0.5° by 0.5° grid and spanning the time range from 1999 to 2005. As a result, for the Iberian Peninsula we find a pronounced change in persistence around the year 2003 and discuss the possibility of a climatic regime shift.

Independent component analysis for extended time series in climate data

Thursday - Poster Session 6

Fernando Sebastião[1,2] and Irene Oliveria[2,3]

[1]*Department of Mathematics, School of Technology and Management, Polytechnic Institute of Leiria, Portugal*

[2]*CM-UTAD, Portugal*

[3]*Department of Mathematics, University of Trás-os-Montes and Alto Douro, Portugal*

Various techniques of multivariate data analysis have been proposed for sets of time series, including Multi-channel Singular Spectrum Analysis (MSSA). This technique is Principal Component Analysis (PCA) (Jolliffe, 2002) of extended matrix of initial lagged series, hence also designated in the climatological context as Extended Empirical Orthogonal Function (EEOF) Analysis (von Storch and Zwiers, 1999).

The aim of this work is to present Independent Component Analysis (ICA) (Hyvärinen *et al*., 2001) to study the extended matrix of time series, as an alternative to the method MSSA. ICA is a technique widely used in areas such as image processing, biomedical signals, telecommunications and econometric time series among others. In this decade ICA is beginning to be applied in climatology in cases where the classical PCA does not extract all the essential information underlying a data set in space and time. Sometimes, ICA is more appropriate than PCA to analyse time series, since the extraction of Independent Components (ICs) involves higher order statistics. ICs reveal more useful information than the usual Principal Components (PCs) since PCA only uses the second order statistics conditioned on the PCs are no correlated, and which are not necessarily independent. We present an example of time series for meteorological data and some comparative results between the techniques under study, particularly with regard to different methods of ordering ICs, which influence the quality of the reconstructions of the original data.

1. Cheung, Y. and Xu, L. (2001). Independent component ordering in ICA time series analysis. *Neurocomputing*, 41, 145-152.

2. Hannachi, A., Jolliffe, I. T. and Stephenson, D. B. (2007). Empirical orthogonal functions and related techniques in atmospheric science: a review. *Internaional Journal of Climatology*, 27, 1119-1152.

3. Hyvärinen, A., Karhunen, J. and Oja, E. (2001). *Independent Component Analysis*. John Wiley &Sons, Inc., U.S.A..

4. Jolliffe, I.T. (2002). *Principal Component Anlysis* (2nd Edition). Springer-Verlag, New York.

5. von Storch, H. and Zqiers, F. W. (1999). *Statistical Analysis in Climate Research*. Sprinfer-Verlag, New York.

Shift of seasons at the European mid-latitudes: Natural fluctuations correlated with the North Atlantic oscillation

Thursday - Poster Session 6

Milan Paluš[1] **and Dagmar Novotná**[2]

[1]*Institute of Computer Science, Academy of Sciences of the Czech Republic (CAS), Prague, Czech Republic*

[2]*Institute of Atmospheric Physics, CAS, Prague, Czech Republic*

Daily mean near surface air temperature series from several European locations were processed in order to obtain reliable estimates of instantaneous phases of the annual cycle as an objective measure of timing the seasons. Four methods for estimating the phase were compared. The estimates have been found robust, mutually consistent and correctly capturing shifts in the temperature cycles of different years. The recent changes in the phase of the annual cycle do not depart from the range of natural phase fluctuations observed in the historical temperature records during the studied period 1775 – 2007. No significant trends were detected using the wavelet and SSA decompositions of the instantaneous phases. Significant, geographically dependent correlations of the phase fluctuations with the North Atlantic Oscillations index have been observed.

Sensitivity of measurement uncertainty to the detection of climate feedbacks

Thursday - Poster Session 6

Nipa Phojanamongkolkij, Marty Mlynczak and Xu Liu

NASA Langley Research Center, Hampton, USA

NASA is developing the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission to provide accurate measurements to substantially improve understanding of climate change. CLARREO will measure spectral reflected solar and emitted infrared radiances, and Global Positioning System (GPS) Radio Occultation refractivities. To demonstrate the utility of such measurements, earlier studies (Leroy et al. 2008; Huang et al., 2009) have applied optimum detection methods to derive climate change fingerprints using climate model runs from the Cloud Feedback Model Intercomparison Project (CFMIP) as surrogates for climate change. In this study we follow the work of Huang et al. (2009) and use all-sky infrared spectra of the difference between the mean equilibrium states in a doubled (280 to 560 ppmv) CO_2 experiment. The optimum detection method is used to derive climate feedback fingerprints that are statistically significant above the known uncertainties that include natural variability, signal shape uncertainty, and the climate uncertainty. We then extend the earlier work to include measurement uncertainty in addition to the aforementioned uncertainties and assess the impact on the derived fingerprints. Further sensitivity analysis on this measurement uncertainty is also performed to determine the uncertainty level at which the optimum detection method will no longer be able to provide statistically significant climate change and climate feedback fingerprints.

Huang, Y., Leroy, S., Gero, P., Dykema J., and Anderson, J., 2009: Separation of longwave climate feedbacks from spectral observations. *Manuscript*.

Leroy, S., J. Anderson, J. Dykema, and R. Goody, 2008: Testing climate models using thermal infrared spectra. *J. Climate*, **21**, 1863-1875.

Implications of systematic and random errors on observational capability for the Earth radiation budget climate data record

Thursday - Poster Session 6

Kory Priestley[1] **and G. Louis Smith**[2]

[1]*NASA Langley Research Center, Hampton, USA*

[2]*National Institute for Aerospace, Hampton, USA*

Space based observations of the Earth's radiative budget commenced more than 30 years ago. The resulting Earth Radiation Budget Climate Data Record (ERB CDR) has been assembled from a series of NASA/NOAA (NIMBUS-ERB, ERBE, CERES) instruments whose radiometric performance and capability have evolved by a factor of 3 to 5 over this period. Thus, the observational record is of uneven radiometric quality, the consequence being a trade-off between the accuracy and length of the record. Also, the record consists of observations from various fields-of-view, ranging from wide field-of-view radiometers with resolutions of 10 to 15 degrees ECA to 20km nadir FOV's.

The known interannual, or natural, variability in the record includes, but is not limited to, ENSO, NAO, Arctic and Antarctic Oscillations, PNA, as well as volcanic effects. While Smith et al. studied ENSO with Nimbus 6 and 7 ERB WFOV data; Minnis et al. investigated the radiation effects of the eruption of Mt. Pinatubo, the magnitude of radiation variation associated with many of these phenomena have not yet been investigated. Globally averaged interannual variations are small compared to both the regional/zonal annual variations outside the Tropics and the annual mean. As the difference between two large numbers, interannual variations are sensitive to errors.

The interannual variability of reflected solar radiation and of Earth emitted radiation has been computed for the period 2000 through 2007 by Mlynczak and Smith (2010), providing a starting point for investigations of interannual variability.

The major question regarding climate is global warming due to greenhouse gas emission, such as CO2. The greenhouse parameter G is taken to be the longwave radiative flux at the top of the atmosphere divided by the longwave radiative flux at the surface. The effect of increased CO2 is to decrease G. A value of $G < 1$ indicates an increase in the surface temperature. If the global average albedo does not change, then for the energy flows to and from the Earth to balance, the global average TOA longwave radiative flux will not change. Thus the global average TOA longwave flux is not an indicator of global warming. However, the higher latitudes are expected to warm more quickly than the rest of the planet, such that zonally/regionally averaged TOA LW flux at high latitudes may demonstrate variability.

The question then is how long it will take to rigorously demonstrate an increase of zonally averaged TOA LW at high latitudes in the presence of natural variability. An analysis is presented in which the annual mean regional average TOA LW is assumed to be the natural variation plus an exponentially increasing effect of unknown growth rate and initial magnitude. For this study the interannual variations are assumed to be uncorrelated. Expressions are derived for the best estimators (in the sense of least squares) of initial magnitude and growth rate. Simulations are performed to find the length of record required to compute the initial magnitude and growth rate with a given probability that these parameters are at least the estimated value.

Measurement errors, consisting of errors from the instrument, computation of the instantaneous fluxes from the radiance measurements and computation of the time averaged parameter from the instantaneous values are included in the present study. These measurement errors will be of the same magnitude, and thus indistinguishable, from the natural variations of fluxes and will simply add to the variations. The question of how much longer will it take to detect the effect of CO2 due to measurement errors is treated with these simulations.

Bottom-up versus top-down: An evaluation of historical trends in climate model performance

Thursday - Poster Session 6

Daithi Stone

Climate Systems Analysis Group, University of Cape Town, South Africa

It is often asserted that increasingly accurate and precise predictions of future climate require further development of complicated dynamical models. This talk will present a test of that assertion by analysing historical trends in predictions of climate change made over the past few decades with the bottom-up approach of using state-of-the-art dynamical climate models. It will also present a comparison with predictions made with the top-down approach of using observational constraints on a simple curve-fitting model. While the bottom-up approach provides little indication on accuracy and does not appear to be providing increased precision, the top-down approach both provides a defensible measure of accuracy and shows evidence of increased precision with increased monitoring. Furthermore, it will be argued that the model/monitoring hierarchy behind the bottom-up approach, of predicting with dynamical models and evaluating with observational monitoring, makes little sense considering data availability. Instead, data availability favours the reversal of this hierarchy implicit in the top-down approach.

Learning about the climate sensitivity

Thursday - Poster Session 6

Katsumasa Tanaka[1,2] **and Brian C. O'Neill**[2,3]

[1]*CICERO (Center for International Climate and Environmental Research – Oslo), Oslo, Norway*

[2]*IIASA (International Institute for Applied Systems Analysis), Laxenburg, Austria*

[3]*NCAR (National Center for Atmospheric Research), Boulder, USA*

"Learning" is defined as a change in the estimate of an uncertain parameter and its uncertainty with the acquisition of new observations. How the estimate in climate sensitivity might change in the future is an important input to current decision-making on climate policy. To gain insights into this problem, we look into how the best estimate of climate sensitivity and its uncertainty range change over the historical period 1930-2000 as derived through our data assimilation setup described below:

The data assimilation approach has been developed from the inverse estimation setup for the reducedcomplexity climate and carbon cycle model ACC2 (Aggregated Carbon Cycle, Atmospheric Chemistry, and Climate model) (Tanaka, 2008; Tanaka et al., 2009). In the inversion approach for ACC2, the best estimates of uncertain parameters are obtained by optimization against various historical observations since 1750 – i.e. we minimize the cost function consisting of the squared misfits between the model projection and observations as well as those between the parameter estimates and their prior weighted by respective prior uncertainties. The uncertainty range for climate sensitivity is indicated by a cost function curve, which consists of the values of cost function for a series of inversions in which climate sensitivity is fixed at values between 1°C and 10°C at intervals of 0.25°C. By progressively feeding historical observations (e.g. temperature records) to this data assimilation setup, we study how the estimates and uncertainty ranges of parameters (e.g. climate sensitivity) are updated over time.

Our preliminary results show that how we learn about climate sensitivity is significantly influenced by how we account for the uncertainty in radiative forcing. Furthermore, regardless of how radiative forcing uncertainty is represented, the evolution of the best estimate of climate sensitivity contains periods of both rising and falling values. This indicates that no matter what the true value turns out to be, there have been periods in which learning proceeded in the wrong direction. Better prediction skills of the decadal and multi-decadal variability in temperature would allow a faster convergence of the estimate of climate sensitivity in the future.

Tanaka, K. (2008) Inverse estimation for the simple earth system model ACC2 and its applications. Ph.D. thesis. Hamburg Universität, Germany. International Max Planck Research School on Earth System Modelling, Hamburg, Germany. 296 pp. http://www.sub.uni-hamburg.de/opus/volltexte/2008/3654/

Tanaka, K., T. Raddatz, B. C. O'Neill, C. H. Reick (2009) Insufficient forcing uncertainty underestimates the risk of high climate sensitivity. *Geophysical Research Letters*, **36**, L16709, doi:10.1029/2009GL039642.

Attributing uncertainty in climate predictions

Thursday - Poster Session 6

Stan Yip

University of Exeter, UK

Quantification of various sources of uncertainty to the total uncertainty in global climate predictions is essential for environmental policy decision. In this paper, a general review on the partitioning sources of uncertainty is presented. Motivated by the problem of attributing uncertaintyrelated to the deviation of climate models emission scenario and natural variability, some existing approaches and their improvement possibilities are discussed.

Bayesian estimation of the climate sensitivity based on a simple climate model fitted to global temperature observations

Friday - Plenary Session 6

Peter Guttorp, Magne Aldrin and Marit Holden

Norwegian Computing Center, Norway

Our aim is to estimate the climate sensitivity by modeling the relationship between (estimates of) radiative forcing and global temperature observations in post-industrial time. Complex general circulation models are computationally expensive for this purpose, and we use instead a simple climate model of reduced complexity. This climate model is deterministic, and we combine it with a stochastic model to do proper inference.

Our combined model can be written as

$$\mathbf{y}_t = \mathbf{m}_t(\mathbf{x}_{t-},\theta) + \mathbf{f}(z_t) + \mathbf{n}_t$$

Here, $\mathbf{y}_t$ is the observed temperature in year t and $\mathbf{m}_t$ the corresponding output from the simple climate model. Furthermore, the model input $\mathbf{x}_{t-}$ is the unknown radiative forcing in year t and previous years back to pre-industrial time. θ is a vector with time-constant model parameters, whereof the climate sensitivity is the parameter of main interest. The function $\mathbf{f}(z_t)$ is an empirical motivated term added to the model to account for the El Niño effect and z_t is an El Niño indicator. Finally, $\mathbf{n}_t$ is an autoregressive error term representing model and measurements errors.

The output from the climate model $\mathbf{m}_t$ is three-dimensional, consisting of the air temperature on the northern and southern hemispheres and the global ocean heat content. The temperature observations $\mathbf{y}_t$ consist of three different time series of global temperature observations from around 1850, and one series for the ocean heat content from 1955. The three temperature time series are all based on observations at various measurement stations around the earth, but differs by how these are weighted.

The "true" radiative forcing is unknown, but we use the most recent (temperature-independent) estimates with specified uncertainties as prior distribution. We also have informative prior distributions for all parameters in θ except for the climate sensitivity, for which we use a flat prior.

This work is done in cooperation with Center for International Climate and Environmental Research in Oslo (CICERO).

Monitoring information on weather and climate extremes in support of climate change attribution studies

Friday - Plenary Session 7

Albert Klein Tank

Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands

Changes in weather and climate extremes are among the most serious challenges to society in coping with a changing climate. The sustainability of economic development and living conditions depends on our ability to manage the risks associated with extreme events. According to the latest IPCC report, ‘confidence has increased that some extremes will become more frequent, more widespread and/or more intense during the 21st century’. But what changes in weather and climate extremes do we observe already over recent decades, how certain are we about these changes, and are our monitoring systems adequate to address these questions?

In this talk, some examples of available observational evidence for changes in extremes will be shown from the European Climate Assessment & Dataset project (ECA&D; http://eca.knmi.nl). This project provides vital ingredients for successful monitoring of weather and climate extremes across Europe, even reporting online during emerging extreme events. ECA&D is embedded in worldwide activities that monitor extremes on the basis of station data using standardized descriptive indices. Each index describes a particular characteristic of climate change, both changes in the mean and extremes. Observed changes in mean state inevitably affect extremes. Moreover, the extremes themselves may be changing in such a way as to cause changes that are larger or smaller than would simply result from a shift of variability to a different range.

The core set of temperature and precipitation indices in ECA&D follows the definitions recommended by the joint CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI). This team has helped to design and implement a system of indices and tools that enable a consistent approach to the monitoring, analysis and detection of changes in extremes of temperature and precipitation by countries and regions across the globe. An additional set of indices in ECA&D highlights other characteristics of climate change in Europe (including snow depth, sunshine duration, etc.). Latest developments include the use of extreme value theory to complement the descriptive indices of extremes, in order to evaluate the intensity and frequency of more rare events. Changes in return values for events that occur up to once in 50 years are compared to the trends in the indices for more moderate extremes.

Statistical inference for space-time extremes

Friday - Plenary Session 7

A. C. Davison

EPFL, Switzerland

Statistical inference for extremes of univariate time series is now well-established and widely used in climate applications. However many problems involve extremes that are dependent in space or time or both, and inference for these is much less well developed. In this talk I shall describe approaches to modelling such extremes, illustrated with rainfall and with temperature data. The ingredients are composite likelihood, Gaussian processes, max-stable models, peaks over thresholds and block maxima models for extremes, and of course data. The work is joint with Mehdi Gholamrezaee, Raphaël Huser, Simone Padoan and Mathieu Ribatet, and is supported by the Swiss National Science Foundation and the Competence Centre for Environmental Sustainability. (http://www.cces.ethz.ch/projects/hazri/EXTREMES)

Anthropogenic greenhouse gas contribution to UK autumn flood risk

Friday - Plenary Session 7

Pardeep Pall[1,2], Tolu Aina[3], Dáithí A. Stone[1,4], Peter A. Stott[5], Toru Nozawa[6], Arno G.J. Hilberts[7], Dag Lohmann[7] and Myles R. Allen[1]

[1]*Atmospheric, Oceanic & Planetary Physics, Department of Physics, University of Oxford, Oxford, UK*

[2]*Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland*

[3]*Oxford e-Research Centre, University of Oxford, Oxford, UK*

[4]*Tyndall Centre Oxford, Oxford University Centre for the Environment, Oxford, UK*

[5]*Met Office Hadley Centre, Exeter, UK*

[6]*National Institute for Environmental Studies, Tsukuba, Japan*

[7]*Risk Management Solutions Ltd., London, UK*

Interest in attributing the risk of damaging weather-related events to anthropogenic climate change is increasing[1]. Yet climate models typically used to study the attribution problem do not resolve weather at scales causing damage[2]. Here we present the first multi-step study that attributes increasing risk of a damaging regional weather-related event to global anthropogenic greenhouse gas emissions. The event was the UK flooding of October and November 2000, occurring during the wettest autumn in England & Wales since records began in 1766[3] and inundating several river catchments[4]. Nearly 10,000 properties were flooded and transport services and power supplies severely disrupted, with insured losses estimated at £1.3bn[5,6]. Though the floods were deemed a 'wake up call' to the impacts of climate change[7], were anthropogenic drivers to blame? Typically offered thermodynamic arguments do suggest increased precipitation extremes in a warming climate, but are too simple[8,9] to fully account for the complex hydrometeorology[4,10] associated with the flooding. Instead we use a Probabilistic Event Attribution framework to more rigorously estimate the contribution of anthropogenic greenhouse gas emissions to England & Wales Autumn 2000 flood risk. This involves comparing an unprecedented number of daily river runoff realisations for the region – under Autumn 2000 scenarios both with and without the emissions. These realisations are produced using publicly volunteered distributed computing power to generate several thousand seasonal-forecast resolution climate model simulations[11,12] that are then fed into a precipitation-runoff model. Autumn 2000 flooding is characterised by realisations exceeding the highest daily river runoff for that period, derived from the observational-based ERA-40 re-analysis[13]. Our model results indicate 20th century anthropogenic greenhouse gas emissions significantly (at the 10% level) increased England & Wales flood risk in Autumn 2000 and most probably about trebled it.

1. Hegerl, G.C. *et al*. Understanding and attributing climate change. In *Climate change* 2007: *The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [eds Solomon, S. *et al*.] (Cambridge University Press, United Kingdom and New York, NY, USA) (2007).

2. Stott, P.A. *et al*. Detection and attribution of climate change: a regional perspective. *Wiley Interdisciplinary Reviews: Climate Change*, submitted.

3. Alexander, L.V. & Jones, P.D. Updated precipitation series for the U.K. and discussion of recent extremes. *Atmos. Sci. Lett*. **1**, 142-150 (2001).

4. Marsh, T.J. & Dale, M. The UK floods of 2000-2001 : A hydrometeorological appraisal. *J. Chartered Inst. Water Environ. Manage.* **16**, 180-188 (2002).

5. Association of British Insurers. Flooding: A partnership approach to protecting people.
http://www.abi.org.uk/Display/File/301/Flooding_-_A_Partnership_Approach_to_Protecting_People.doc (2001).

6. Department for Environment, Food and Rural Affairs. To what degree can the October/November 2000 flood events be attributed to climate change? DEFRA FD2304 Final Report, London, 36 pp. (2001).

7. Environment Agency. Lessons learned: Autumn 2000 floods. Environment Agency, Bristol, 56 pp. (2001).

8. Lenderink, G. & Van Meijgaard, E. Increase in hourly precipitation extremes beyond expectations from temperature changes. *Nature Geosci*. **1**, 511-514 (2008).

9. O'Gorman, P.A. & Schneider, T. The physical basis for increases in precipitation extremes in simulations of 21st-century climate change. *Proc. Natl. Acad. Sci. U.S.A.* **106**, 14773-14777 (2009).

10. Blackburn, M. & Hoskins, B.J. Atmospheric variability and extreme autumn rainfall in the UK. http://www.met.rdg.ac.uk/~mike/autumn2000.html (2001).

11. Allen, M.R. Do-it-yourself climate prediction. *Nature* **401**, 642 (1999).

12. Massey, N. et al. Data access and analysis with distributed federated data servers in climateprediction.net. Adv. *Geosci*. **8**, 49-56 (2006).

13. Uppala, S.M. et al. The ERA-40 re-analysis. *Quart. J. Roy. Meteor. Soc.* **131**, 2961-3012 (2005).

Analysis of extreme rainfall events in May of 2006 on the east coast of Northeast Brazil and its impacts

Friday - Poster Session 7

Anderlan Henrique Batista Siqueira[1], Cristiano da Silva Cardoso[2], Nayara Arroxelas dos Santos[1] and Luiz Carlos Baldicero Molion[1]

1 Institute of Atmospheric Sciences, Federal University of Alagoas, Brazil

2 Federal University of Pelotas, Brazil

On days 01 and 16 May 2006 the stations located on the east coast states in Northeast Brazil showed total accumulated precipitation above the climatological normal. In Maranhão, Piauí, Tocantins, Bahia, Alagoas, largely of Ceará and the western sector of the states of Rio Grande do Norte, Paraíba and Pernambuco such events cause loss of human life and major socioeconomic damage. In this study, such events were analyzed using, Review of data from National Center for Envorimental Prediction /National Center Atmospheric Research, the Sistema de Radar Meteorológico de Alagoas (SIRMAL), satellite images from GOES-8 and GOES + Meteosat (Centro de Previsão de Tempo e Estudos Climáticos/Instituto Nacional de Pesquisas Espaciais) and precipitation data (Proclima). The weather and severe flooding resulted from two factors, these are the disturbances in the field of trade winds that are associated with the penetration of a System Front.

Extreme monthly precipitation over northern and southern sectors of La Plata Basin in South America- observations and model simulations

Friday - Poster Session 7

Iracema FA Cavalcanti

Center for Weather Forecasting and Climate Studies- National Institute for Space Research (CPTEC/INPE), Brazil

The La Plata Basin in South America comprises a large region of four countries: Brazil, Uruguay, Argentina and Paraguay, which extends from subtropical to extratropical latitudes. Therefore, the precipitation regimes are different in the northern and southern sectors. This region undergoes large interannual variability, with floodings and droughts occurrences which causes social and economic problems, besides the destructions and deaths. The objective of this study is to analyze the monthly/interannual variability and frequency of extreme precipitation and associated features in observed data and model results from an AGCM (CPTEC/COLA AGCM) and two CGCM (HADCM3 and GFDL). The extreme monthly precipitation in the two sectors are selected based on the SPI (standardized precipitation index), which identify extreme wet/dry cases (SPI >=2.0/ SPI<=-2.0); severe wet/dry cases (1.5 <=SPI<= 2.0)/ (-1.5 <=SPI<= -2.0) and moderate wet/dry cases (1.0<=SPI<=1.5)/ (-1.0<=SPI<=-1.5). The frequency of extreme wet cases are larger than the extreme dry cases in both sectors in the observed data. In 23 years (1979-2001), 6 years were identified as extreme wet in the northern sector and 8 years in the southern sector, while 3 years were identified as extreme dry in the northern sector and 4 years in the southern sector. The monthly anomalies precipitation are analyzed in these cases and the global atmospheric conditions are discussed. Although the frequencies obtained in the model analysis are different from the observations, similar behavior of precipitation anomalies and atmospheric characteristics are identified in the simulations.

Variability of extreme precipitation events in the United Stated during winter

Friday - Poster Session 7

Charles Jones[1] **and Leila M. V. Carvalho**[1,2]

[1]*ICESS, University of California Santa Barbara, USA*

[2]*Dept. of Geography, University of California Santa Barbara, USA*

Although extreme precipitation events occur infrequently in time, they are usually associated with significant impacts for the society and economy. This paper investigates the variability of extreme precipitation over the contiguous United States during winter. Gridded observed precipitation is used to identify extreme events and variations in the large-scale are examined with National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis from 1948-2009. Novel statistical methods are employed to characterize the temporal and spatial occurrences of extreme precipitation. The presentation will focus on the importance of the Madden- Julian Oscillation (MJO) and El Niño/Southern Oscillation (ENSO) in modulating the spatiotemporal variability of extreme precipitation.

Projecting high-resolution high-impact weather extremes with observational constrain

Friday - Poster Session 7

Cheng-Ta Chen and Yu-Shiang Tung

Department of Earth Sciences, National Taiwan Normal University, Taiwan

Changes in the frequency or intensify of extreme weather and climate events could have profound impacts on both human society and the natural environment. The IPCC 4th assessment concludes that frequency (or proportion of total rainfall from heavy falls) of heavy precipitation events are very likely to increase over most areas as the climate warms. These future projections are mainly reply on the simulation of extreme rainfall distribution in the current generation of climate model. It is often argued that relatively low resolution climate model can't properly reproduced the high-impact weather extremes. This raises issues on the reliability of their future projections on extremes. In response to the question, very high resolution version of climate models run under the time-slices experiment design or fine-scaled regional climate models forced by global model result from lateral boundaries are used to explore the problem. Although it generally matched better with station rainfall data or high-resolution gridded observational analysis, the cost of such high resolution model runs are excessive to be affordable to create multi-models and multiple-member ensembles that better sample the uncertainty in future projections.

Recently high temporal and spatial resolution ground station analysis and satellite estimates are available for climate study. The length of data record are starting to provide enough sampling on the extreme weather events. It is well know that there is spatial scaling issue concerning on the study on the extreme weather events. By studying the statistical properties that link the different spatial scale in the observational data. One can develop statistical downscaling method for the extreme weather and climate indices. Applying the methodology to the CMIP3 climate models, it is possible to derive very high resolution extreme statistics based on observational relationship. The result should be welcomed by the community working on the impact and adaptation study that need more local projection on the extreme events.

Spatial patterns and variability of dry spells in Croatia

Friday - Poster Session 7

Ksenija Cindrić[1] and Zoran Pasarić[2]

[1]*Meteorological and Hydrological Service of Croatia, Zagreb, Croatia*

[2]*Department of Geophysics, Faculty of Science, University of Zagreb, Zagreb, Croatia*

Seasonal and annual dry spells are analysed employing daily precipitation data from 25 meteorological stations in Croatia. The analysis is based on four precipitation-per-day thresholds (0.1, 1, 5 and 10 mm) and covers the time period 1961-2000. The climatology of dry spells indicates three main climatic regions: mainland, highland and coastal region. Attempting to find the joint spatial and temporal variations of mean and maximum dry spells in Croatia, the Empirical Orthogonal Function (EOF) analysis is performed. In order to fit the empirical frequency distributions of dry spells the goodness of fit of several statistical distributions is tested. A comprehensive analysis of time trends of mean and maximum dry spells is performed including a piecewise estimation of local trends by means of Kendall's tau slope estimator.

Long-term variability and changes in North East Atlantic and European winter storminess

Friday - Poster Session 7

Paul M. Della-Marta and Malcolm R. Haylock

Partner Reinsurance Company, Switzerland

In this study we utilize the EMULATE daily mean sea level pressure (MSLP) dataset to analyze the variability and change in North East Atlantic and European storminess since 1880. We derive geostrophic wind speed from the MSLP and use this to define a number of extreme wind indices (EWI), sensitive to different aspects of storm size and intensity. We then apply extreme value analysis techniques to these storminess series and investigate both long-term trends and variability of storminess as a function of various covariates such as time and large-scale climate indices. Each daily EMULATE MSLP field comes with an interpolation error field which we use to estimate the error in the derived EWIs and the error in trend and variability analyses. Results generally agree with previous studies which show that the there is no significant trend in storminess since 1880 to present and that the storminess climate is dominated by decadal and multi-decadal variability. However, a number of new insights result from this analysis, such as a long-term decline in both storm frequency and intensity from 1880~1910. Again, as in previous studies the 1990s are a decade with frequencies and intensities of storminess that are comparable to those in the late 19th Century. Only when we consider western European land areas separately to the North east Atlantic-European domain do we see that the decadal peak in storminess in the 1990s as being unprecedented since 1880. Decadal modulation of the scale parameter of the Generalized Pareto Distribution (GPD) shows that the 99th percentile can change by up to 15% which we show has implications for the pricing of wind storm related loss risk of loss.

An analysis of changes in the extremes of temperature, precipitation, and wind speed based on regional climate projections for Germany

Friday - Poster Session 7

Thomas Deutschländer[1], Achim Daschkeit[2], Susanne Krings[3] and Heiko Werner[4]

[1]*German Meteorological Service (DWD), Department of Climate and Enviromental Consultancy, Offenbach am Main, Germany*

[2]*Federal Enviroment Agency (UBA), Dessau-Rosslau, Germany*

[3]*Federal Office of Civil Protection and Disaster Assistance (BBK), Bonn, Germany*

[4]*Federal Agency for Technical Relief (THW), Bonn, Germany*

Besides earthquakes, weather catastrophes have by far the greatest societal effect of all natural disasters in terms of civil damages. Therefore, changes in the climatic extremes are definitely one of the most important aspects of climate change. However, while an increase in the frequency of hot days and warm nights over land masses can be regarded as highly probable, e.g. regional projections of heavy summer precipitation events in Central Europe vary from a slight decrease up to an increase of 30%. Generally, changes in frequencies and intensities of climatic parameters particularly affecting the general public are still very uncertain on a regional and especially local scale. Consequently, the Alliance of German Federal Agencies comprising the Federal Environmental Agency (UBA), the Federal Office of Civil Protection and Disaster Assistance (BBK), the Federal Agency for Technical Relief (THW), and the German Meteorological Service (DWD) has recently commenced a research project aiming to analyze regional climate projections for Germany focussing on weather extremes and their changes.

The project is subdivided into tow major parts. In the first stage the data will be examined by means of a selection of climate monitoring and climate change indices as recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI) and used within the European Climate Assessment & Dataset (ECA&D) project. The selected indices were primarily chosen according to their importance for risk and emergency management. Furthermore, statistical robustness was taken into accounts, i.e. indices too far into the tail of the distribution are not employed (typically, the 10th or 90th percentiles are used). For the examination of extreme wind speed changes we principally follow Beniston at al. (2007) [1], who works with 10-m winter wind speed percentiles, winter sea-level pressure percentiles, and Beaufort thresholds.

In the second stage we will employ extreme value statistics for the determination of the modelled changes in return values/return periods for the meteorological parameters temperature, precipitation, and wind speed. As a great variety of – in our belief equally promising – approaches for fitting theoretical distributions to empirical or modelled data exists, we intend to compute several different methods in order to compare the results. One of the most important issues we will focus our attention on is the question of what part of the data is best to be used for the fits. Besides the typically employed block maxima and peak over threshold (POT) approaches, a study by Jones et al. (2005) [2] proposes that the use of the entire sample (i.e. not only the data which is extreme in some kind of way like, for instance, annual maxima) guarantees the most robust results. In addition, the authors have developed a method for the derivation of continuous time-dependent probability density functions called structure-oriented time-series analysis which we will also explain.

In addition to the above mention methods, the project will focus on two other important aspects. First of all, the quality of the climate projection data will be investigated thoroughly with the aid of DWD's comprehensive climate data archive. For the inference of future changes only those statistics will be used for which the control runs of the individual climate projections have been successfully evaluated before. Furthermore, geostatistical methods will be applied in order to determine the smallest spatial scale on which results are still statistically significant.

[1] Beniston, M., D. Stephenson, O. Christensen, C. Ferro, C. frei, S. Goyette, K. Halsnaes, T. Holt, K. Jylhä, B. Koffi, J. Palutikof, R. Schöll, T. Semmler, and K. Woth, 2007: Future exteme events in European Climate: an exploration of regional climate models. Climatic Change, **81**, 71-95. DOI 10.1007/s10584-006-9226-z

[2] Umweltbundesamt, 2005: Climate Change 07/05 – Berechnung der Wahrscheinlichkeiten für das Eintreten von Extremereignissen durch Klimaänderungen – Schwerpunkt Deutschland – Aurthors: Jonas, M., T. Staeger, C. D. Schönwiese

Changes on extreme temperatures over Europe from regional climate models

Friday - Poster Session 7

M. D. Frías[1], R. Mínguez[2], J. M. Gutiérrez[3] and F. J. Méndez[2]

[1]*Department of Applied Mathematics and Computer Science, Universidad de Cantabria. Santander, Spain*

[2]*Environmental Hydraulics Institute "IH Cantabria", Universidad de Cantabria. Santander, Spain*

[3]*Instituto de Fisica de Cantabria, Santander, Spain*

Extreme temperatures and heat waves had a big impact in European socioeconomic activities during the last years (e.g. the 2003 heat wave in France). Climate change has the potential to alter the prevalence and severity of extremes giving rise to more severe impacts with unpredictable consequences. Changes on frequency and intensity of these events have increased the interest in studying the impacts of climate extremes in different sectors (agriculture, energy, insurance, etc.). Regional climate models offer the opportunity to analyze and project in different future scenarios the variability of extremes at regional scales. In the present work, we estimate changes of maximum temperatures in Europe using two state-of-the-art regional climate models from the EU-funded project ENSEMBLES. Regional climate models are used as dynamical downscaling tools to provide simulations on smaller scales than those represented for global climate models. Extremes are expressed in terms of return values derived from a time-dependent generalized extreme value (GEV) model for monthly maxima. The study focuses on the end of the 20th century (1961-2000), used as a calibration/validation period, and analyzes the changes projected for the period 2020-2050 considering the A1B emission scenario.

Temporal changes in precipitation extremes since the beginning of the 20th century in Croatia

Friday - Poster Session 7

M. Gajic-Capka

Meteorological and Hydrological Service, Zagreb, Croatia

This analysis deals with time-series of precipitation amounts (annual and seasonal) and six indices of precipitation extremes indicating intensity and frequency of extreme rainfall events. They are proposed by World Meteorological Organization-Commission for Climatology (WMO-CCl) and the Research Programme on Climate Variability and Predictability (CLIVAR), and calculated after daily precipitation amounts. The data are from the period 1901-2008 for the five meteorological stations in Croatia covering different climate regions: continental, mountainous and maritime.

Trends are calculated by a simple least squares fit of the linear model, and tested for statistical significance at the 95% confidence level using a non-parametric Mann-Kendall rank statistics *t*. For the series showing the significant trend identified by the Mann-Kendall coefficient *t*, a Sneyers progressive analysis of the time series was performed by means of the statistic *u(t)* in order to determine the beginning of this phenomenon. In order to eliminate short-term fluctuations and show the longer time scale changes more clearly, the noise was taken out of the data series by means of the weighted 11-year binomial moving average filter, which is often used for the analysis of climate variability. A search for change in variability has been performed by time series analysis of coefficients of variation (c_v) in consecutive 30-year periods (1901-1930, 1902-31,·······, 1979-2008).

During the 20th century annual amounts of precipitation showed a downward trend in all parts of Croatia, thus joining the trend of drying across the Mediterranean. Decadal trends in annual and seasonal precipitation amounts have not been significantly changed according to data series prolonged by 2008. Precipitation amounts have large interannual variability, both on annual and seasonal scales. Therefore, in order to find out position of 10 driest years in the observed 108-year period, it could be seen that they did not occur grouped in some period. Variability of annual precipitation amounts in the period 1901-2008, indicates a decrease in NW Croatia, mountainous region and northern littoral. Such a decrease was present in the eastern lowland by the end of the 20th century as well, but the changes since the beginning of the 21st century contribute to an increase of variability. Dalmatian islands experienced an increase of variability in a period from the middle of the 20th century.

In the area of drying such as Croatia there is no signal of major secular changes in extremes related to the high amounts of precipitation (fraction of annual total precipitation due to very wet days (R95%T) and annual 1-day and 5-day maxima) and frequency of wet (Rd≥R75%) and very wet (R95%T) days over the larger part of Croatia. The reduction in the annual amounts of precipitation can be attributed to changes in the frequency of low-intensity rain days and significant increase in incidence of dry days (R_d<1.0 mm) all over Croatia.

Can gridded data represent extreme precipitation events?

Friday - Poster Session 7

S. Herrera[1], J. M. Gutiérrez[1], R. Ancell[2], M. Pons[2], M. D. Frías[3] and J. Fernández[3]

[1]*Instituto de Fisica de Cantabria, Santander, Spain*

[2]*Agencia Estatal de Meteorología (AEMET), Santander, Spain*

[3]*Department of Applied Mathematics and Computer Science, Universidad de Cantabria. Santander, Spain*

The analysis and characterization of extreme precipitation at regional scale requires data at high temporal and spatial resolution due to the abrupt variations of this variable in time and space. In recent years there has been an increasing demand for comprehensive regular high-resolution (both in time and space) gridded datasets from different sectors, including hydrology, agriculture and health which are severely affected by extreme events. One of the main shortcomings of gridded datasets is that extreme events can be smoothed during the interpolation process. Heavy rainfall events can be very local and, hence, interpolation with neighboring stations may lead to an underestimation of the precipitation amounts.

In this work we study the capability of a high-resolution daily precipitation gridded dataset over Spain (we refer to this dataset as Spain02, Herrera et al 2010) to characterize extreme precipitation. A dense network of 2756 quality-controlled stations was selected to develop the Spain02 grid with a regular 0.2º horizontal resolution covering the period from 1950 to 2003. We study both upper percentiles and the extreme indicators commonly used to characterize extreme precipitation regimes. We also show the performance of the gridded dataset to capture both the intensity and the spatial structure of severe precipitation episodes which constitute characteristic ephemerides of extreme weather in the Iberian peninsula. The results are compared to the 25 Km E-OBS grid (Haylock et al 2008) developed in the ENSEMBLES project, which is the best daily dataset for the whole Europe to date.

- Haylock, M., N. Hofstra, A. Klein-Tank, E. J. Klok, P. Jones, and M. New, 2008: A european daily high-resolution gridded data set of surface temperature and precipitation for 1950–2006. Journal of Geophysical Research, 113, D20 119.

- Herrera S., J. M. Gutiérrez, R. Ancell(2), M. Pons(2), M. D. Frías(3) and J. Fernández 2010. Development and Analysis of a 50 year high-resolution daily gridded precipitation dataset over Spain (Spain02). Submitted to International Journal of Climatology.

Changes in the annual largest daily rainfall totals

Friday - Poster Session 7

Mari Jones, C. G. Kilsby, H. J Fowler, S. Blenkinsop

School of Civil Engineering and Geosciences, Newcastle University, Newcastle upon Tyne, UK

Many studies have considered severe rainfall in terms of metrics expressing extremity such as peaks over threshold, or quantiles of the observations, to maximise the data available. However, the selection of a base period for these thresholds can have a significant impact on the perceived trends. On the other hand, partial duration series can limit the scope of any investigation by removing key information, and completely ignore “drier” years.

A common method used in sea surge and, occasionally, wind storm analysis is that of the “r-largest” events per year. We find this to be a statistically unbiased measure which does not unduly reduce the available data, and which has not yet been explored in great depth for extreme rainfall. The distribution of “r-largest” daily rainfall accumulations in each year offers a unique representation of how extreme precipitation patterns are changing, while also accounting for changes in “dry” years.

We establish the optimum number of events to include so that more regular rainfall does not skew the data. After ranking the observations, we fit a multivariate EVD to the top r events. From the event date, it is possible to approximate the seasonality and, hence, likely controlling influences.

Estimating extremes in climate change simulations using the peaks-over-threshold method with a non-stationary threshold

Friday - Poster Session 7

Jan Kyselý[1], **Jan Picek**[2], **Romana Beranová**[1]

[1]*Institute of Atmospheric Physics, Prague, Czech Republic*

[2]*Technical University, Liberec, Czech Republic*

We present a methodology for estimating high quantiles of distributions of daily temperature in a non-stationary context, based on the peaks-over-threshold analysis with a time-dependent threshold expressed in terms of regression quantiles. The extreme value models are applied to estimate tails of distributions of maximum daily temperature over Europe in transient GCM simulations for the 21st century. A comparison of scenarios of changes in 20-yr return temperatures based on the non-stationary peaks-over-threshold models with a conventional stationary model and a non-homogeneous Poisson process model is performed. It is demonstrated that the application of the stationary extreme value model in temperature data from GCM scenarios yields results that may be to a large extent biased, while the non-stationary models lead to spatial patterns that are robust and enable one to detect areas where the projected warming in the tail of the distribution of daily temperatures is largest. The method also allows splitting the projected warming of extremely high quantiles into two parts that reflect a change in the location and scale of the distribution of extremes, respectively. Spatial patterns of the two components differ significantly in the examined climate change projections over Europe. The study is supported by the Czech Science Foundation under project P209/10/2045.

Evaluation of extreme precipitation changes in the north central coast of Venezuela using time-varying extreme value models

Friday - Poster Session 7

Lelys Guenni

Departamento de Cómuto Científico y Estadística, Universidad Simón Bolívar, Caracas, Venezuela

Exceptional rainfall events occurred during mid-December 1999 produced floods and landslides along the north central coast of Venezuela with extended damages and fatalities. Similar events occurred also in February, 1951 and February 2005. Many of the severe events documented in the region have occurred during the period November-February which is supposed to be the dry season. When the North Tropical Atlantic (NTA) and the Equatorial Pacific (Niño 3 region) is used in this analysis and it is called the Atlantic-Pacific Index or API. By fitting a dynamic generalized extreme value (GEV) model to station based daily rainfall at different locations and to the Xie and Arkin precipitation data set for the north central coast of Venezuela, we found a significant and varying time dependence of extreme precipitation to the API index. Dependence between the Atlantic-Pacific index and the probabilistic behavior of extreme rainfall was also explored for simulations from two global coupled General Circulation Models for the 20th century climate (20C3M experiment) and the 21st century climate (SRES A2 experiment): the Echam5 model and the HadCM3 model. The Echam5 20C3M experiment model outputs show a similar dependence of extreme precipitation to the API index, while the HadCM3 model output de not show such dependence. When looking at future climates under SRES A2 experiment from the Echam5 model simulations, the dependence of extreme rainfall from the API index is still significant for the middle part of the 21st century (2046-2064), while the dependence fades off for the latest part of the century (2081-2099).

The limits of pattern scaling

Friday - Poster Session 7

Andreas Lustenberger and Reto Knutti

Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

For the assessment of future climate scenarios and the associated impacts, it is important to have reliable projections based on future emission scenarios. However, for an appropriate statistic there are more scenarios necessary than can be simulated by a global climate model (GCM) or regional climate model (RCM). Additional scenarios may be generated by scaling a response pattern simulated by a GCM or RCM. We investigate the limits of scaling temperature and precipitation patterns using different statistical approaches for the pattern scaling. The pattern scaling technique will be applied to the 27 extreme indices suggested by the joint CCI/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI). The different statistical approaches will be developed and tested with the aid of the recent RCM transient runs of the ENSEMBLES project covering the time period from 1950 to 2100. The areas of interest are Switzerland and Europe. The higher spatial resolution of the RCMs is often associated with the presence of more nonlinear processes. In addition, extremes also exhibit nonlinear behaviour. Therefore, this project investigates the inuences of the potential nonlinearity on the pattern scaling and attempts to answer the question if the pattern scaling technique is a reasonable method for the development of scenarios of extreme events. Especially in case of scaling precipitation patterns, it is expected that the use of predictors other than temperature should increase the accuracy of a scaled pattern. Effects of a complex topography and site-specific conditions on the scaling of RCM response patterns may also lead to a spatially dependent scaling.

Historical records in a constant climate: comparison with the observations from Italian weather network

Friday - Poster Session 7

Tiziano Colombo, Vinicio Pelino and Filippo Maimone

In this work we have considered the behaviour of historical record updates of monthly temperatures, as measured by a network of 50 weather stations, quite uniformly distributed over Italian territory, for a period of the last 49 years. Firstly, the sum of update numbers over all the stations is considered, and the result is confronted against the null statistical hypothesis of a constant climate given by the average climatological distributions relative to the whole period considered. Subsequently, partial summation over particular station clusters are considered. It is found that, while the resulting (monotonically growing in time) update numbers for all the stations does not seem to allow for absolute rejection of null hypothesis, at least at 95% confidence level, single clusters of them, on the contrary, permit this rejection, at the same confidence level. Asymptotic behaviour for constant climate null hypothesis is then linked to the predictions of extreme value theory, while the limits of its applicability are discussed in the light of analyzed data. It is shown, in particular, the existence of 'stationarity islands' conerning the months of December and January, also with respect to the employed clustering, in such a way that application of extreme value theory on these months seems more appropriate and justified.

Variability of extreme daily precipitation in the United Kingdom. Observed and simulated relationships with the synoptic scale atmospheric circulation

Friday - Poster Session 7

Douglas Maraun[1,2], Timothy J. Osborn[2] and Henning .W. Rust[3]

[1]*Department of Geography, University of Giessen, Germany*

[2]*Climatic Research Unit, School of Environmental Sciences, University of East Anglia, UK*

[3]*Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur- Yvette, France*

Extreme precipitation is a major natural hazard in the United Kingdom. To assess likely future impacts of extreme precipitation on local scales it is important to understand changes in the intensity of extreme precipitation on decadal and multidecadal time scales. Ultimately, this also requires to (1) understand the natural variability of local precipitation extremes and the relationship to its large scale driving processes, and (2) how regional climate models reproduce variability and relationships respectively.

First, we investigate the relationship between synoptic scale airflow and local extreme daily precipitation, measured at 689 rain gauges in the United Kingdom. To this end, we model the monthly maxima of daily precipitation using a generalised extreme value distribution (GEV), and the airflow influence using a vector generalised linear model, that links airflow strength, vorticity and direction to the GEV parameters. The relationships show pronounced spatial patterns related to the interaction between airflow, orography and the surrounding seas. On regional scales, synoptic scale airflow explains about 20% of the variability on sub-annual to decadal time scales.

Second, we evaluate the representation of precipitation extremes and its relationship with large scale atmospheric flow in a set of 18 25km-resolution regional climate models (RCMs) used in the ENSEMBLES project. Instead of investigating the representation of extreme precipitation and its variability alone, investigating the representation of the relationships with the synoptic scale atmospheric circulation provides additional insight. This analysis increases confidence in the RCMs ability to correctly simulate changes in rainfall extremes due to changes in the atmospheric circulation caused by climate change.

Warm and cold spells – their changes and causes

Friday - Poster Session 7

Morak Simone, Gabriele Hegerl

This study deals primarily with the changes in warm and cold spells during the winter months January and February, showing changes in the duration of those spells and their return time. The study attempts to determine if these changes are related to the climate change signal or if they could be explained by teleconnection patterns or general global circulation.

Nonparametric testing for change in the frequency of extreme events

Friday - Poster Session 7

Markus Neuhäuser

Department of Mathematics and Technique, RheinAhrCampus, Koblenz University of Applied Sciences, Remagen, Germany

The detection of a change in the frequency of extreme events in a time series is of particular interest in climatology. Lopez-Diaz (*Journal of Climate* 203; **16**, 2602-2614) proposed to apply the nonparametric Wilcoxon-Mann-Whitney test. Here it is shown that, when the climate is becoming more extreme, the positions that the events occupy in the series have a smaller variance than the positions without the event. In addition, there are obviously more observations without than with an extreme event. In such a scenario another rank-based test, the test introduced by Brunner and Munzel (*Biometrical Journal* 2000; **42**, 17-25) is much more powerful than the Wilcoxon-Mann-Whitney test. This difference in power is demonstrated here using simulated data and three real time series on climate change.

Temporal variability of the extreme rainfall events and water balance in Northeastern Argentina

Friday - Poster Session 7

O. C. Penalba[1], V. Pántano[1], J. Rivera[2] and F. A. Robledo[1,2]

[1]*Departamento de Ciencias de la Atmósfera y los Océanos, FCEN - UBA, Buenos Aires, Argentina*

[2]*Consejo Nacional de investigaciones Científicas y Tecnológicas (CONICET), Buenos Aires, Argentina*

Global mean temperatures began an upward trend during the second half of the twentieth century, which could be attributed to increases in greenhouse gas concentrations in the atmosphere. In the future years a heating due to anthropogenic greenhouse gas emissions is very likely to happen. Higher atmospheric temperatures affect the hydrological cycle, leading, at global scale, to higher moisture content and an increased evapotranspiration. Regionally the relation between the different involved factors, thermodynamics and dynamics, is not so direct. This interaction leads to a geographically complex response of mean precipitation to global warming. Assess the temporal fluctuation of hydrological processes and most especially rainfall, which constitutes the main source of water input and estimation of the regional water balance, is of great importance. The region under study, southern South America, is part of the La Plata Basin. This region is a densely populated one where agriculture and hydrology have serious social and economic ramifications.

The aim of this study is to examine the inter-annual, inter-decadal and low frequency variability of rainfall in different time scale jointly with the water balance in the soil, with special emphasis in extreme events.

Daily rainfall and temperature data used in this study were provided by different national institutions or Weather Services, in the longest period 1900-2008. In this research, we define extreme event when surpass a defined threshold (tails of the distribution). To assess the different rainfall characteristic in the region, the following indices or variables are analyzed a) total monthly rainfall; b) percentage of extreme events of rain; c) percentage of daily intensity of extreme rainfall; d) annual amount of dry days and e) percentage of months with deficit and surplus, estimated by water balance. The indices were calculated per each austral season: summer (December, January and February, DJF), autumn (March, April and May, MAM); winter (June, July and August, JJA), spring (September, October and November, SON), and the year as a whole. Different statistical methodologies were applied to analyze the temporal variability of the indices, such as a non-parametric Kendall-Tau test, an 11-year running mean with distributed weights, spectrum and wavelets analysis.

The results of the annual indices show a regional variability highly non-stationary. The most outstanding feature is the difference before and after the 1950s or 1960s. The interdecadal variability is particularly well defined in the west, with a “jump” or discontinuity around the mentioned decades. In the eastern zones, a gradual increase can be observed starting in the 1950s. The interdecadal and interannual variations affect the behavior of extreme rainfall in the annual scale and during the months with maximum rainfall in the region. In summer, autumn and spring, the region has a marked spatial coherence in the positive sign trends of rainfall indices. Winter is the

exception, with negative trends. The temporal variability of the annual amount of dry days is in accordance with these results. In addition, this index identified the development and evolution of the most important dry and wet periods throughout the study region. The temporal analysis of this index shows that an increase in the amount of dry days dominated much of the country during the recent years. The decadal analysis of deficit and surplus reveals the complexity of the different factors involved. Moreover, the results show the different hydrological behavior in the region. The most outstanding results were that 1960s and 2000s were the decades with greater amount of deficit for all seasons.

Comparisons of extreme parameter estimation between observed and modelled data, and implications for future projections

Friday - Poster Session 7

Sarah E. Perkins

CSIRO Marine and Atmospheric Research, Melbourne, Victoria, Australia

Extreme value theory in terms of the Generalized Extreme Value (GEV) distribution has been used comprehensively to estimate climatic extremes at the global and continental scale using both global climate model (GCM) and observed daily datasets (Wehner, 2004; Schaeffer et al., 2005; Kharin et al., 2007; Coelho et al., 2008; Rusticucci and Tencer, 2008; Perkins et al., 2009). Fitting an extreme value distribution such as the GEV to future projections by GCMs gives an indication as to how the frequency and magnitude of extreme events may change in the future, which is imperative to adaptation studies and policy. Evaluating GCMs on their ability to simulate observed extreme events is therefore warranted to give *some* level of confidence of their future reliability (Perkins and Pitman 2009, Perkins et al., 2009).

To explore this idea, Perkins et al. (2009) modified the evaluation metric introduced by Perkins et al. (2007) to examine the difference in the daily observed and modeled Probability Density Function (PDF) tail. This metric uses an arbitrary threshold of the 95th (5th) percentile of the observed maximum (minimum) temperature PDF. This metric therefore always includes at least observational data which is superfluous when fitting the GEV, and does not quantify the difference in observed and modeled extremes if the tails do not overlap in the prescribed range. A new question consequently arose; how well do GCMs replicate the observed GEV parameters?

This study will compare by ratios each of the observed and modeled GEV parameters (the location, scale and shape) estimated by the method of L-moments for minimum temperature, maximum temperature and precipitation. Models evaluated include CMIP3 models with daily data for the climate of the 20th century simulation and are compared to the Australian Bureau of Meteorology observational dataset for a number of regions over Australia defined by Perkins et al. (2007). The use of these regions will allow for an evaluation of the GCMs over various climatic types.

Although somewhat simplistic, calculating the observed to modeled ratio of each GEV parameter quantitatively informs us whether the model is under or over approximating the distribution and by how much (i.e. the model bias), and is not just focused on the return levels which are the end product of fitting the GEV. Further, the resulting ratios may be used in future scenarios to obtain extreme value projections which may be more realistic than the actual GCM projections, assuming that the relationship between the model and observations is consistent throughout time. This is demonstrated by scaling the model-estimated GEV parameters by their respective ratios for the SRES A2 scenario and comparing the consequential return values from the scaled and non-scaled data.

Analysis of simulated trends of extreme climate indices for Central/Eastern Europe using RegCM outputs

Friday - Poster Session 7

Rita Pongrácz, Judit Bartholy, Gabriella Kovács, Csaba Torma

Department of Meteorology, Eötvös Loránd University, Budapest, Hungary

High resolution regional climate model results are essential for the generation of national climate change scenarios, as it is recommended by the United Nations Development Programme (UNDP). For analyzing the possible regional climate change in the Carpathian Basin (located in Central/Eastern Europe), we have adapted the model RegCM at the Department of Meteorology, Eotvos Lorand University. This regional climate model is a 3-dimensional, sigma-coordinate, primitive equation model originally developed by Giorgi et al. Currently, it is available from the ICTP (International Centre for Theoretical Physics). RegCM uses 18 vertical levels and its horizontal resolution is 10 km. The initial and lateral boundary conditions of the fine-resolution experiments were provided by the ECHAM-driven RegCM simulations using 25 km horizontal resolution.

First, we evaluate the model capabilities of reconstructing the present climate (1961-1990) using two different sets of boundary conditions, (i) from the European Centre for Medium Range Weather Forecast ERA-40 reanalysis database, (ii) from GCM output data. Then, we compare the results for the periods 2021-2050, 2071-2100 (using the HadCM3/ECHAM GCM outputs as boundary conditions taking into account the SRES A1B emission scenario) and 1961-1990 (as the reference period).

Not only the mean climate conditions play an important role in determining the climate of a particular region, but also, several extreme conditions, which are represented by extreme climate indices. These indices are defined on the basis of simulated daily temperature and precipitation values using different threshold values. Thus, our statistical trend analysis includes the evaluation of several climate indices, e.g., the numbers of severe cold days, winter days, frost days, cold days, warm days, summer days, hot days, extremely hot days, cold nights, warm nights, the heat wave duration, the number of wet days (using several threshold values defining extremes), the maximum number of consecutive dry days, the highest 1-day precipitation amount, the greatest 5-day rainfall total, the annual fraction due to extreme precipitation events, etc.

Analysis of the simulated daily temperature datasets suggests that the detected regional warming is expected to continue in the Carpathian Basin in the 21st century. Frequency of warm (cold) temperature extremes is projected to increase (decrease). Expected changes of annual precipitation indices are small in the Carpathian Basin, but generally consistent with the detected trends of the 20th century. Based on the simulations, extreme precipitation events in the target region are expected to become more intense and more frequent in winter, while a general decrease of extreme precipitation indices is expected in summer.

Estimation of extreme wind speeds based on different types of measured data

Friday - Poster Session 7

Lukáš Pop

Institute of Atmospheric Physics, Academy of Sciences, Prague, Czech Republic

Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Two basic types of wind data are commonly used to estimate extreme winds: average wind speeds with typical averaging period of 10 minutes and maximum wind gusts. The most common single-value outputs from distribution fitting are maximum average wind speed and maximum wind gust with the return period of 50 years. Theoretical relation between these two variables - in a very simplified manner - is described in the international standard IEC 61400-1. However, the practical application of theoretical methods is connected with many constraints. The most significant one is the lack of reliable and homogenous long-term series of wind data. Nevertheless, there are also some issues concerning varying sensor characteristics and data collection standards. At first, the values of wind gusts are affected differently by inertia of various measuring equipment. Even the average wind speed can be affected by the overspeeding effect of cup anemometers. Additionally, wind measurements are often recorded in an averaging interval longer than standard 10 minutes. Then the extreme values of wind speed are lower than in the case of 10-min averaging interval. In the Czech Republic, 15 minutes represents the present standard in use, while the historical data are usually available in hourly interval. In some cases the situation gets even more complicated when historical wind series use disjunct sampling (e.g. last 10 minutes in an hour). In order to approach unbiased estimation of extreme wind values as much as possible, the above-mentioned issues are investigated. Various types of wind measurements taken over the area of the Czech Republic are used for this purpose.

Change in temperature extremes over Europe

Friday - Poster Session 7

Concepcion Rodriguez-Puebla, Ana Casanueva and Nube Gonzalez-Reviriego

Department of Atmospheric Physics, University of Salamanca, Spain

The purpose of this study is to present results about the variability of temperature extremes based on threshold exceedance: warm days (tx90), warm nights (tn90), cold days (tx10), cold nights (tn10), cold wave duration index (cwdi) and heat wave duration index (hwdi) for different seasons December-January-February (DJF), March-April- June (MAM), June-July-August (JJA) and September-October-November (SON) over Europe. One important motivation to perform this study is the greater vulnerability of ecosystems to climate extremes than to mean climate changes. We use the daily gridded datasets derived through interpolation of station data (E-OBS) version 2.0 (Hofstra et al. 2009). The variability of the indices would be analysed by means of probability density function (PDF), Singular Spectral Analysis (SSA) and different procedures to derive the significance of the trend. The changes in the extreme temperature indices would be explained by obtaining correlation analysis and composite maps of large-scale variables for the most extreme values of the indices by taking into account the atmospheric teleconnection indices and Sea Surface Temperature (SST). We will discuss results for the four seasons and provide additional details with respect to a previous study where temperature extremes of annual time series were analyzed over the Iberian Peninsula (Rodriguez-Puebla et al. 2010). One application of this study is to propose statistical models to characterize the extreme temperature indices and to learn how slow climate changes would affect the variability of temperature extremes.

Hofstra, N; Haylock, M; New, M; Jones, PD (2009) Testing E-OBS European highresolution gridded data set of daily precipitation and surface temperature. *Journal of Geophysical Research-Atmospheres*, 114, D21101, 21101-21101

Rodriguez-Puebla C., Encinas A.H., Garcia-Casado L.A. and Nieto S. (2010) Trends in warm days and cold nights over the Iberian Peninsula: Relationships to large-scale variables. *Climatic Change*. DOI 10.1007/s10584-009-9721-0

The annual cycle of intensity and frequency of extreme precipitation events across the UK in observations and future projections

Friday - Poster Session 7

Anne Schindler[1], **Douglas Maraun**[1,2] **and Jürg Luterbacher**[1]

[1]*Department of Geography, University of Giessen, Germany*

[2]*Climatic Research Unit, School of Environmental Sciences, University of East Anglia, UK*

To assess possible future impacts of extreme precipitation it is necessary to study intensity and frequency of extreme events together with their spatial and temporal occurrence throughout the year. Especially in a downscaling process it is important to model intensity and occurrence frequency independently to use large-scale predictors for daily extreme events.

We design a statistical model based on extreme value statistics (EVS). We formulate the extreme precipitation process as a point process as the block maxima and the peak over threshold approach both cannot model occurrence and intensity combined. By fitting it to data from 689 british rain gauges we study the spacial pattern of the annual cycle of intensity and frequency respectively.

Furthermore we evaluate the representation of the annual cycle of frequency and intensity in the 25km resolution ENSEMBLES RMCs. With the help of these climate models we investigate changes of the annual cycle for the SRES scenario A1B.

Statistical modeling of winter temperature extremes in Europe including Euro-Atlantic atmospheric blocking as covariate

Friday - Poster Session 7

Jana Sillmann

Max Planck Institute for Meteorology, Hamburg, Germany

In this study, we apply a parametric approach to identify winter (DJF) temperature extremes in Europe using global climate model data. In particular, we fit the Generalized Extreme Value distribution (GEV) to monthly minima (maxima) of DJF minimum (maximum) temperatures in Europe. The behavior of the distribution's parameters and the 20-year return values are analyzed for 20th century and future climate ensemble simulations (represented by the SRES A1B emission scenario) using the ECHAM5/MPI-OM climate model. Furthermore, we test the hypothesis that climate extremes are influenced by certain large-scale atmospheric circulation patterns. We make an attempt to improve the fit of the GEV distribution to winter temperature extremes by conditioning the distribution's parameters on a covariate. In this respect atmospheric blocking acts as a prominent feature explaining parts of the European winter climate variability. We demonstrate that relating particularly the location parameter of the GEV distribution to atmospheric blocking improves the fit to the minimum temperature data in large areas of Europe with considerable impact on the 20-year return values. This relation remains robust under future climate conditions, however with less magnitude due to decreasing blocking frequency in A1B.

Using observations to verify climate predictions and the evaluation of models used at Hungarian Meteorological Service through statistical methods

Friday - Poster Session 7

Peter Szabo

Observational studies showed that changes in precipitation and temperature are amplified at the tails of the probabilty distribution function. One of our objective is to show whether there have been remarkable changes in the frequency of observed extreme events through Hungarian observations available from 1961, and also while focusing on the extremes is to compare our model outputs (ALADIN-Climate and REMO) with this gridded data set. The model outputs have also been analyzed for the projections: we have time slices in case of ALADIN-Climate (from 1961 to 2100) and the REMO has a transient run for the period of 1951-2100.

The ALADIN-Climate model was developed by Meteo France (based on the short range numerical weather prediction model ALADIN) and has both 10 km and 25 km of horizontal resolution (the latter is used only for the experiments for the past). The REMO model developed by Max Planck Institute for Meteorology is available on 25 km horizontal grids. The validation experiments are performed with perfect lateral boundary forcings (ERA-40), or driven by GCMs (ARPEGE-Climat for ALADIN-Climate and ECHAM for REMO). In this study we analyze several climate extreme indices (included complex indices) for the Carpathian Basin. We try to determine the spread and the average of the model outputs, though they differ in resolution, forcings and in terms of the observations as well.

The results are complemented with significance tests using t-test, Welch-test and Mann-Kendall-test: these indicate that there have been a trend in the past events or whether the model deviations from observed climate and with respect to the future simulations are considered to be significant or not. However, it requires more sophisticated mathematical analysis, a bivariate distribution is the most common method for modeling extreme events.

Comparison of observed daily extreme temperature events in Southeastern South America and RCM simulations

Friday - Poster Session 7

Bárbara Tencer and Matilde Rusticucci

Laboratorio de Extremos Climáticos en Sudamérica, Departamento de Ciencias de la Atmósfera y los Océanos, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina

CONICET, Buenos Aires, Argentina

Extreme temperature events have a huge impact on the environment and the society. Changes in the frequency of occurrence and the intensity of extremes have greater influence on the ecosystem than changes in mean values. The purpose of this study is to evaluate the skill of some Regional Climate Models (RCMs) in representing daily extreme temperature events in Southeastern South America.

Within the framework of the EU FP6 project CLARIS, four regional modelling groups have coordinated simulations of South American present climate (1992-2000). The models' domains cover the entire continent and are driven at the lateral boundaries by ERA40 reanalysis with a horizontal resolution of 50 km. Observed data belongs to a new daily high-resolution gridded data set developed during the EU FP7 project CLARIS LPB for Southeastern South America based on the available observed data at meteorological stations from Argentina, Brazil, Uruguay and Paraguay.

The empirical distribution of daily temperature simulated by each of the RCMs is compared to the distribution obtained from the observational data set on a monthly basis for the region and period common to all models and the observations, 20º-40ºS 45-70ºW, 1992-2000. With the objective of study both cold and warm extremes, 5^{th}, 10^{th}, 25^{th}, 75^{th}, 90^{th}, and 95^{th} percentiles are compared. 50^{th} percentile is computed as a measure of RCMs to represent mean values.

All models overestimate minimum temperature percentiles, especially over the northern part of the studied domain. In the case of maximum temperature, almost all models also overestimate percentiles, but some models give an underestimation of percentiles over the Cordillera de los Andes, southeastern Brazil and the southern part of the domain. An overestimation of the temperature percentiles leads to an overestimation of mean values and warm extremes, but an underestimation of cold extremes.

Incorporating sea-surface temperature trends in a stochastic hurricane model

Friday - Poster Session 7

Jessica Turner[1], Katie Coughlin[1], Thomas Laepple[2], Steve Jewson[1], Enrica Bellone[1] and Dan Rowlands[3]

[1]*Risk Management Solutions, U.K.*

[2]*Alfred Wegner Institute, Germany*

[3]*University of Oxford, UK*

The estimation of hurricane risk is of life-and-death importance for millions of people living on the West Coast of the Atlantic. Risk Management Solutions (RMS) provides products and services for the quantification and management of many catastrophe risks, including the risks associated with Atlantic hurricanes. Of particular importance in the modeling of hurricane risk, is the estimation of future hurricane rates. We are interested in making accurate estimates of the underlying rates associated with Atlantic Hurricanes which make landfall.

We discuss our methodology – combining physical and statistical modeling – for estimating the hazard and correlated risk associated with landfalling hurricanes in the Atlantic. Of particular importance is incorporating trends in Atlantic and Pacific tropical sea-surface temperature. A validation of the method is performed using out-of-sample hindcasting over the period 1900-2007 with bias-corrected sea-surface temperatures from the IPCC 20th century ensemble runs.

Storm activity in North Atlantic and precipitation anomalies over Europe

Friday - Poster Session 7

Natalia Vyazilova

Extratropical storm activity and the extreme weather events are linked. There is no standard measure of storm (cyclone) activity because cyclones may exhibit changes in intensity, duration, location and frequency. The purpose of this paper is to show the storm activity influence on the formation of wet and dry zone in North Atlantic and European region [30°N-80°N, 50°W-70°E] during some selected winter seasons (1994/95, 2006/07 and 2007/08 years with positive mode of North Atlantic Oscillation, 1995/96, 2000/01 and 2005/06 years with negative mode of NAO). Precipitation anomalies for this seasons were calculated from CMAP archive.

The study of storm activity in this paper based on automated cyclone tracking algorithm and the 6-hourly MSLP from the NCEP/NCAR re-analyses from 1979 to 2009. The analyses includes the calculation of two kind of storm activity indices. The first two were calculated for each grid point of region and includes average for winter season the number of cyclone centers (NCC) and integral cyclone intensity (sum of cyclone centers MSLP anomalies -CCMA). The second two were Integral regional storm activity indices and they were calculated as standartizide anomalies of integral CCMA for selected latitude zones [30°N-55°N, 50°W-70°E; 55°N-80°N, 50°W-70°E].

Study had shown that winter seasons with positive NAO mode Nord Europe were outstanding by strong positive precipitation anomalies and strong cyclonic intensity, and during winter seasons with negative NAO mode in this region were observed negative precipitation anomalies and weak cyclonic activity. Calculated Integral regional storm activity indices had shown the intensification of cyclonic activity over North Atlantic and North European region in last years.

Projection and evaluation of climate extremes over the Yangtze and Huaihe River Basins (China) using a Statistical Downscaling Model

Friday - Poster Session 7

Weilin Chen and Zhihong Jiang

Key Laboratory of Meteorological Disaster of Minisry of Education, Nanjing University of Information Science &Technology, China

The regression-based downscaling method (Statistical Downscaling Model, SDSM) has been used to test its ability to simulate indices of climate extremes and construct the future scenarios of the extremes over the 29 meteorological stations which locate at the Yangtze and Huaihe River Basins. Empirical relationships are first derived among selected variables from the daily NCEP reanalyses and daily observed daily maximum temperature and precipitation data, by which the climate extremes is computed .Subsequently the statistical downscaling model is applied to construct scenarios of the climate extremes for the end of the 21st century using predictor sets simulated by two GCMs (i.e.HadCM3 and CGCM3) forced by the special report on emission scenarios(SRES) A2. The evaluation of simulated extreme indices of temperature and precipitation for the current climate shows that the downscaled temperature-related indices match the observations well for all seasons, and Statistical Downscaling Model (SDSM) can modify the systematic cold biases of the AOGCMs; For indices of precipitation, the performance is not attractive as the corresponding performance of temperature-related indices, but still perform well than the raw AOGCMs. The inter-annual variability of all indices in all season is under-estimated by the SDSM. Overall , compared to the AOGCMs, the downscaling model really has "added value". Scenario results using A2 emissions show that in all seasons there is a significantly increase for mean daily-maximum and minimum temperature in the 29 meteorological stations, associated with a decrease in the number of frost days and with an increase in the heat wave duration. There is good agreement for the direction and magnitude of the projected changes of temperature-related indices between the two driving AOGCMs. A warming environment will also give rise to changes in extreme precipitation events such as the maximum 5-day precipitation and the heavy rainfall proportion R95t . Precipitation extremes are projected to increase over most of the 29 meteorological stations in a quite consistent manner among the two global scenarios.

Comparison of selected measures of drought events in Poland

Friday - Poster Session 7

Joanna Wibig

Department of Meteorology and Climatology, University of Lodz, Poland

Contemporary climate change with well established warming exerts a strong impact on hydrological regime. In many areas changes in hydrological extremes, e.g. droughts and floods are observed as is indicated by many studies (Trenberth et al, 2007; Bates et al, 2008). Public awareness of drought events is high because drought affects a very large number of people through the impact it exerts on water availability and agriculture.

This study focuses on the meteorological drought in Poland defined as a prolonged lack of precipitation over a region. A few drought indices are tested and compared. Among them are:

- ✓ simply number of dry days, defined as a days without precipitation or with precipitation lower than 1 mm per day during month, season or the whole year,
- ✓ the standardized precipitation index (SPI; McKee et al. 1993; 1995; Hayes et al. 1999) calculated based on monthly, seasonal and annual scales,
- ✓ the effective drought index (EDI; Byun and Wilhite, 1999) calculated based on monthly, seasonal and annual scales.

The daily precipitation dataset covering the period from 1st January 1951 to 31st December 2006 was collected from 18 rain stations in Poland (data from IMWM in Warsaw, Poland). On the basis of this dataset the series of indices were established.

For trend detection the Mann-Kendall test was used, because the distributions of indices were far from the Gaussian one. It was recommended (Mitchell et al. 1966) that Mann-Kendall test is more robust than the t-Student test of linear regression in time in such cases.

The values and trends of presented indices were compared and their sensitivity on different features of drought events was discussed.

Temporal changes in temperature since the beginning of 20th century over Croatia

Friday - Poster Session 7

Ksenija Zaninovic

Meteorological and Hydrological Service, Croatia

The temperature variability and changes in different climatic regions of Croatia during the 20th century as well as the changes at the beginning of the 21st century were analysed by means of trends in mean annual temperatures and trends in indices of temperature extremes based on the daily series. Five meteorological stations were chosen as the representatives of different climates in Croatia. The positive mean annual temperature trends are evident from the beginning of the period, and became more expressed in last 50 and especially in last 25 years. The greatest contribution to positive trends in annual values at the coast gave the trends in warm season, while in the continental part the warming is more pronounced in the cold season. Most from the 10 warmest years belongs to the last 10 years period. The analysis of temperature indices, as the indicator of temperature extremes, and defined as the days with minimum and maximum air temperature exceeding the thresholds defined by means of percentiles, showed the positive trends of warm and negative trends in cold indices. The trends of temperature indices are greater at the coast than in the continental part. The warming in the capital of Croatia Zagreb, evident in mean temperatures as well as in indices might be the result of urbanization.

Modelling extreme events in a changing climate using regional dynamically-downscaled climate projections

Friday - Poster Session 7

Christopher J. White[1], Stuart Corney[1], Michael Grose[1], Greg Holz[1], James Bennett[1,2] and Nathaniel L. Bindoff[1,3]

[1]*Climate Futures for Tasmania, Antarctic Climate & Ecosystems Cooperative Research Centre, University of Tasmania, Hobart, Australia*

[2]*Hydro Tasmania Consulting, Cambridge, Australia*

[3]*Centre for Australian Climate and Weather Research, CSIRO Marine and Atmospheric Research, Aspendale, Australia*

The ability of regional dynamically-downscaled global circulation models (GCMs) to assess changes to future extreme climatic events and the likely impacts was investigated. A collaborative research initiative generated projections on a high-resolution 0.1° (~14km) grid across Tasmania, an island state of Australia, using the CSIRO Conformal Cubic Atmospheric Model (CCAM). Two future emission scenarios and multiple GCMs were used for the period 1961-2100. Extreme value methods were employed for the analysis of temperature and precipitation extremes and a bias-adjustment procedure was developed to correct extreme magnitudes against observed data. Changes to the magnitude, intensity, frequency and duration of extreme events were modelled and analysed using a suite of indices to demonstrate evolving changes to extremes. Estimates of precipitation return periods were calculated using events fitted to a Generalized Pareto distribution through a robust extreme value threshold selection procedure developed for gridded precipitation datasets. Results were correlated against mean trends, both seasonally and annually, and compared to station and gridded observations. Future trends in individual and multi-model projections were compared with existing Australia-wide and global scale results calculated from GCMs. Increases in both daily maxima and minima temperature associated with climate change were noted, resulting in fewer cold nights, more heat waves and increased bushfire weather occurrences. Projections of future precipitation extremes were found to correlate closely with changes to regional climate drivers and spatial variance was also found across the state that closely matched observations. Results demonstrate that dynamical downscaling captures regional climate variability (particularly relevant for precipitation) and displays significant ability in modelling future changes to extreme events at the local scale for use in adaptation and emergency planning applications.

An investigation of causes of the 2003 heatwave in Europe using large ensembles of the ECMWF IFS

Friday - Poster Session 7

Helen Hanlon

School of Geosciences, University of Edinburgh, UK

Summer 2003 saw the most extreme temperatures in Southern and Central Europe since records began. Many regions experienced a large number of deaths due to the elevated temperatures; and attribution studies have determined that human activity has at least doubled the risk of such a heatwave, compared to a non-industrial scenario. It was suggested that, other, non-linear process could also have amplified Summer 2003 temperatures; feedbacks between reduced cloud cover and soil moisture may have prevented the usual convective disruption of the high pressure system, leading to a prolonged bout of high temperatures. Previous attribution studies were built upon by attempting to quantify further the change in risk of a heatwave due to anthropogenic influences. A large ensemble of the ECMWF IFS model was performed at higher resolution than previous studies with improved simulation of land surface processes.

The results support the theory that a feedback between soil moisture and temperature acted to amplify the already excessive temperatures in Summer 2003. Also, the relationship between the variables involved in the feedback are sensitive to certain land-surface properties, which implies that if the same factors that caused the 2003 event occurred in a different location a different event could have been seen. The temperature seen in 2003 were also shown to be sensitive to Atlantic sea surface temperatures; had the Atlantic not been so warm, this event may not have occurred.

It was also found that the attributable risk due solely to anthropogenic greenhouse gas emission for this event is very high. Scaling this risk to account for the cooing effect of aerosols gives an attributable risk due to anthropogenic forcing that agrees well with other studies. It shows the risk of such event has increased considerably under the effort of anthropogenic greenhouse gas emissions.

European weather extremes in an ensemble of regional climate simulations

Friday - Parallel Session 7

G. Nikulin, E. Kjellström, U. Hansson, G. Strandberg and A. Ullerstig

Rossby Centre, Swedish Meteorological and Hydrological Institute, Sweden

Statistics of temperature, precipitation and wind extremes (in terms of the 20-year return values) over Europe are examined in an ensemble of climate simulations performed with the Rossby Centre Regional Climate Model - RCA3 driven by six different GCMs under the A1B emission scenario. Such an ensemble of six members allows us to estimate uncertainties in the simulated extremes related to driving GCMs.

In the control period (1961-1990), a degree of dependency of all simulated extremes on a driving GCM is very large. Differences among the individual simulations can reach 20 °C for temperature extremes, several tens of percents for precipitation extremes and 10 m s^{-1} for wind extremes. Nevertheless, the projected future (2071-2100) changes in temperature extremes show coherent spatial patterns among the simulations with different magnitude. The corresponding changes in precipitation extremes have much less consistent geographical patterns with many regional details, though a common tendency can be indentified. The projected future changes in wind extremes are strongly different among the simulations and we can hardly say that there is any common tendency.

For the present ensemble of regional climate simulations the future changes in temperature extremes are more robust to a choice of a driving GCM than ones in precipitation extremes while we have almost no confidence on the projected changes in wind extremes.

Spatial-temporal modelling of extreme rainfall

Friday - Parallel Session 7

Mark Palmer and Carmen Chan

CSIRO Mathematics, Informatics and Statistics, Climate Adaptation Flagship, Australia

Extreme rainfall over the south-west of Western Australia and the Sydney region of NSW over the last fifty years has been modelled using a Bayesian hierarchical approach. A Gaussian process, derived from a convolution kernel approach, is incorporated to model spatial variability of the rainfall distribution. This is a flexible approach, accommodating rainfall measured over different durations (from sub- to super-daily) and also allowing for the possibility of linking the extremes to external drivers.

The approach can be used to characterize the behaviour of extremes under present day and projected future conditions. It can be used to derive intensity-duration-frequency curves together with estimates of their associated uncertainties, for specific locations that can be either gauged or ungauged, which provides information for the design of engineering structures such as culverts, bridges, and stormwater and sewerage systems. Further extensions to model extremes of areal rainfall are being developed.

Regression quantiles methodology for choosing the optimal threshold of the 'peak- over- threshold' method in climate change simulations

Friday - Parallel Session 7

Jan Picek[1], **Martin Schindler**[1] **and Jan Kyselý**[2]

[1]*Technical University, Liberec, Czech Republic*

[2]*Institute of Atmospheric Physics, Prague, Czech Republic*

The widely used statistical methods of the extreme value analysis, based on either 'block maxima' or 'peaks-over-threshold' representation of extremes, assume stationarity of extreme values. Such assumption is often violated due to existing trends or long-term variability in the investigated series. This is also the case for climate model simulations carried out under variable external forcings, originating e.g. from increasing greenhouse gas concentrations in the atmosphere. Applying the POT approach involves the selection of an appropriate covariate-dependent threshold. Koenker and Basset in 1978 introduced regression quantiles as a generalization of usual quantiles to a linear regression model. The key idea in generalizing the quantiles is that one can express the problem of finding the sample quantile as the solution to a simple optimization problem. The covariate-dependent threshold set as a particular regression quantile yields exceedances over the whole range of years whereas for a constant threshold, exceedances occur more frequently (or almost exclusively) in later years, which violates assumptions of the extreme value analysis. Several variants of the regression quantiles are compared; the choice of the order is based on the quantile likelihood ratio test and the rank test based on regression rank scores.

The study is supported by the Czech Science Foundation under project P209/10/2045.

An application based approach to modelling the spatial dependencies of extreme flood risk

Friday - Parallel Session 7

L. Speight[1], J. Hall[1], C. Kilsby[1] and P. Kershaw[2]

[1]*School of Civil Engineering and Geosciences, Cassie Building, Newcastle University, Newcastle upon Tyne, UK*

[2]*Catlin, London, UK*

The floods of summer 2007 caused widespread disruption across the UK. Temporary flood defences could not be deployed and national resources were stretched to their limits. For those involved in risk assessment and emergency planning it highlighted the need for greater understanding of extreme events to answer questions such as, "if town A is flooded, what is the probability of town B also flooding?", or "what is the probability of an extreme event affecting more than 50% of the country?". We develop an application based approach to modelling the spatial dependencies of extreme flood risk in the UK to address these issues.

Traditional methods of extreme event analysis recommend the use of peaks over threshold data. However when looking at large spatial scales it is unlikely that all gauges in the network will be extreme at the same time. An alternative is to extract continuous flow data for all gauges when one or more gauges are extreme. Taking an example gauge with 20 years of 15 minute flow data this equates to over 700,000 data points to analyse. Scaling this up to a moderate network of gauges soon results in an unmanageable amount of data. The third option is to use daily mean flow data which provides daily data for all gauges regardless of the extremeness of the event. This is the dataset which is used in the following methodology.

Spatial dependencies in extreme flow events are characterised using the Heffernan and Tawn[1] model for conditional dependence as used in a recent study of flood risk by Keef et al[2,3]. The methodology also enables simulation of large scale events that are more extreme than anything that has been observed in the gauged data.

However for risk assessment these results are of limited use since daily mean flow data is not able to capture the full details of extreme events. In particular the flood peak, which is likely to be most significant in terms of flood defence overtopping, is not reproduced. To overcome this problem we use the ratio between daily mean flow and flood peaks to estimate peak flows.

The strength of this methodology is that it can be used for flood risk assessment at site specific locations nested within the national framework, for example an electricity company may wish to know the risk across their network of substations or an insurance company may wish to know the risk to a particular portfolio. This final stage of the methodology involves transferred the flow estimates from gauges to sites of interest while maintaining the spatial distribution of the extreme event.

1 Heffernan, J., and Tawn, J. (2004) A conditional approach for multivariate extreme values, Journal of the Royal Statistical Society, Series B, 66 (3), p497-546

2 Keef, C., Svensson, C., Tawn, J. (2009) Spatial coherences in extreme river flows and precipitation for Great Britain, Journal of Hydrology, 378, p240-252

3 Keef, C., Lamb, R., et al (2009) Spatial coherences of flood risk, Environment Agency Science Report SC060088/SR

Calibration strategies for inferring future changes in extreme events from climate simulations

Friday - Parallel Session 7

David B. Stephenson[1], Chun K. Ho[1], Mat Collins[1,2], Chris Ferro[1] and Simon Brown[2]

[1]*University of Exeter, Exeter, UK*

[2]*Met Office/Hadley Centre, Exeter, UK*

The extremal properties simulated by climate models (even the highest resolution ones) are not expected to be identical to those of observed real world processes. The numerical models have limited spatial and temporal resolution, missing physical processes, etc. and so it is not physically unreasonable to expect differences between simulated extremal properties and those observed in the real world.

This discrepancy needs to be accounted for if one is to use climate change models to make predictive statements about the behaviour of observable extreme events in the future. This talk will present various calibration strategies for tackling this problem. It will be demonstrated that different reasonable calibration strategies yield different predicted probability distributions.

The strategies will be illustrated using daily summer temperature extremes over Europe inferred from ensembles of regional climate simulations. The different approaches will be shown to produce radically different estimates (e.g. 10 year return values) for future extremely hot days.

New indices for monitoring changes in heatwaves and extended cold spells

Friday - Parallel Session 7

Blair Trewin

National Climate Centre, Australian Bureau of Meteorology, Melbourne, Australia

Changes in temperature extremes have attracted considerable attention in recent years, and numerous analyses have been published of changes in the occurrence of single-day extremes. While the impact of multi-day extreme events, such as the European heatwave of 2003, is well-known, there have been limited analyses of changes in such events. A major contributor to this gap in analyses has been the lack of suitable, widely-applicable indices which can be used to define multi-day heatwaves (or cold spells), with most indices proposed either specific to a particular location, subject to qualities which make them difficult to analyse (e.g. many years with zero or null values), or both. The percentile-based approach widely used for indices of single-day extremes breaks down for multi-day events as the probability of the number of consecutive days above (below) a threshold is a product of the autocorrelation structure of the daily time series as well as the frequency distribution of daily values.

A new suite of indices is proposed to address this question. These indices are defined in each year, for a period of N days, as:

(a) the highest (lowest) temperature T such that there are at least N consecutive days above (below) T in the year concerned;

(b) the mean temperature of the N-day period defined by (a) above; and

(c) the highest (lowest) value of the N-day running mean of temperature during the year.

These indices are defined in every year which satisfy data completeness criteria, and as they are defined in terms of °C, changes in their values can be readily compared with changes in mean temperatures at the same location. They can be applied to daily maximum, minimum or mean temperatures. An analysis of data from a range of regions, including Australia, Europe, Canada and Antarctica, found that, in addition to the absence of null values, the frequency distribution of these indices did not significantly differ from the normal (Gaussian) at a substantial proportion of stations, with only 7-15% of stations (depending on the index) showing skewness significant at the 95% level, compared with 25-100% for other indices previously used in the literature. The new indices also appear to be effective in identifying the most extreme events such as the August 2003 heatwave in France. One drawback of the new indices is that their definition is relatively complex and difficult to communicate to a lay audience.

An analysis of trends over the period 1961-2007 for 5-day periods for index (a) found strong positive trends in most cases. For Australian stations, trends ranged from +0.05°C/decade for high maxima to +0.25°C/decade for low minima, while for European stations trends ranged from +0.33°C/decade for high maxima to +0.60°C/decade for low minima.

These indices may also be used to investigate the relationship between extended heatwaves (or cold spells) and broad-scale drivers of climate variability. An interesting example exists in eastern Australia, where the probability of extended heatwaves is significantly higher in El Niño years in New South Wales and Queensland (which matches the ENSO signal in mean seasonal temperatures), but significantly lower in Tasmania and the south of Victoria and South Australia (which does not). This may indicate a greater mobility of synoptic-scale systems in El Niño summers.

Sources of uncertainty in the extreme value statistics of climate data

Friday - Parallel Session 7

Michael Wehner

Lawrence Berkeley National Laboratory, Bekeley, USA

We investigate three sources of uncertainty in the calculation of extreme value statistics for observed and modelled climate data. Inter-model differentces in formulation, unforced interval variability and choice of statistical model all contribute to uncertainty. Using fits to the GEV distribution to obtain twenty year reutrm values, we quantify these uncertainties for the annual maximum daily mean surface air temperatures of pre-industrial control rtuns from fifteen climate model in the CMIP3 dataset. We find that uncertainty resulting from differing model formulations is much larger than that due to both unforced internal climate variability and the fit of the statistical model. A consistent spatial pattern of higher uncertainty over land than over ocean is true for all three types of uncertainties. The uncertrainties due to unforced internal climate variability and the fit of the statistic model are similar in both magnitude and spatial pattern with both exhibiting a strong poleward gradiant over land, especaily in the northern hemisphere.

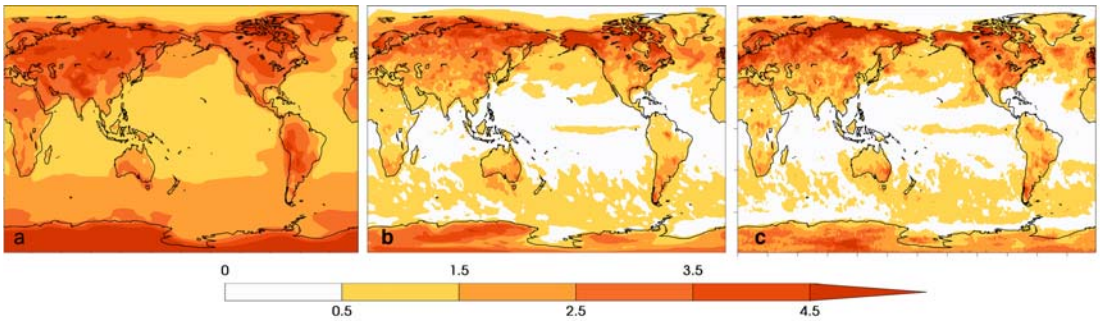


Figure: Measures of uncertainty of calculated 20 years return values of annual maximum daily mean surface ait temperature from the CMIP3 archieve. A) from intermodal differences b) from unforced internal variability c) from the fit of the statistical model. (Expressed as a standard deviation in kelvins)

Recent changes in sub-hourly and daily intense rainfall events in South-East Australia

Friday - Parallel Session 7

Dörte Jakob[1,2], David Karoly[1] and Alan Seed[2]

[1]*School of Earth Sciences, Melbourne University, Melbourne, Australia*

[2]*Bureau of Meteorology,, Melbourne, Australia*

There is little information in the published literature on potential changes in the magnitude and frequency of intense rainfall events at sub-daily and sub-hourly durations for Australia. This is partially due to the lack of suitable observational and model data. Potential changes in both the frequency and intensity of rainfall at short durations are particularly relevant for urban applications. Given the potential for significant economic loss and severe social implications, it is prudent to explore changes in the frequency and magnitude of these rainfall events.

This paper attempts to address this gap by analysing rainfall data for parts of the densely populated south-east of Australia. Intense rainfall events were identified using a peaks-overthreshold (POT) approach. Thresholds were defined in terms of the average number of exceedances per year and three different thresholds were considered (20, 10 and 3 events per year). A range of durations (from 6 minutes to 72 hours) was considered to explore contrasting changes at sub-hourly and daily durations.

Based on historical data for one station (Sydney Observatory Hill, New South Wales) for the period 1921 to 2005, a methodology was developed for investigating changes in frequency and magnitude of intense rainfall events for durations ranging from 6 minutes to 72 hours. Non-parametric approaches were used to assess changes in frequency, magnitude and quantile estimates as well as the statistical significance of those changes. Deviations from the longterm average vary with season, duration and threshold. The effects of climate variations are most readily detected for the highest thresholds. Deviations from the long-term average tend to be larger for frequencies than for magnitudes, and changes in frequency and magnitude may have opposite signs. Significant deviations from the long-term average frequency are found for only the highest threshold. Quantile estimates for the period 1976 to 2005 show significant decrease for the 6 and 72-hour durations.

Using data for a common period (1976-2005) for a set of 31 sites located in New South Wales and Victoria (south-east Australia), it was possible not only to explore how changes in the frequency and magnitude of rainfall events vary with season and geographical location but also whether such changes are consistent across groups of sites, giving greater confidence that changes identified as statistically significant are indeed climate driven and not due to, e.g., poor data or changes in site characteristics.

Analysis of seasonality in the frequency and magnitude of events revealed considerable variation across the set of sites, implying different dominating rainfall producing mechanisms and/or interactions with local topography. Both these factors are relevant when assessing the potential effects of climate on intense rainfall events and the set of sites was therefore split into groups according to the characteristics of intense rainfall events. While sites in the north of the study area typically exhibit a decrease in frequency, particularly in autumn and at medium and longer durations, sites in the south experience an increase in the frequency of events in summer (particularly for short durations) but also for spring (across the range of durations).

An operational weather risk attribution system for Africa

Friday - Parallel Session 7

Daithi Stone, Chris Lennard and Mark Tadross

Climate Systems Analysis Group, University of Cape Town, South Africa

"Was this weather event caused by our emissions of greenhouse gases?" Unfortunately, the climate change research community has focussed more on the past and future rather than the present, and thus the popular attribution questions have remained unanswered. Adaptation activities have had to make do with products designed for informing mitigation activities.

Here we will present the world's first real-time product to examine whether and how human greenhouse gas emissions have contributed to our weather. Some results will be presented from analysis of the first year of operation, including sensitivity to model selection, sensitivity to time of year, and sensitivity to forecast method. Some neglected issues which must be addressed for an operational product, most particularly the selection effect, will also be discussed. While this product has its roots in seasonal forecasting, it is quite clear that it differs in crucial ways from a standard seasonal forecast and thus must be treated accordingly.

Communicating global climate change using simple indices

Friday - Parallel Session 6

David Karoly[1], Frank Drost[1] and Karl Braganza[2]

[1]*University of Melbourne, Melbourne, Australia*

[2]*Bureau of Meteorology, Melbourne, Australia*

The most common indicator of global-scale climate change is the global mean surface air temperature, of which graphs are shown in almost every report and talk on climate change and its causes. There are several additional indices of global-scale temperature variations that are useful for distinguishing natural internal climate variations from anthropogenic climate change (Karoly and Braganza 2001, Braganza et al. 2003). These include the contrast between the average temperatures over land and over oceans, the meridional temperature gradient in the Northern Hemisphere, and the magnitude of the annual cycle of average temperatures over land. These indices are nearly independent of the global mean temperature for natural internal climate variations at decadal time scales and represent different aspects of the climate system, yet they show common responses to anthropogenic climate change (Braganza et al, 2004). Hence they are useful for assessing recent observed climate variability and change, as well as evaluating climate model simulations. Their simplicity also aids in the communication of different aspects of global climate change.

The earlier results that have evaluated these indices using observations and model simulations until 1999 are updated using a further decade of observational data, until 2009. In addition, the performance of some of the CMIP3 climate models in simulating recent climate variability and change is assessed using these indices. Finally, the indices are used to evaluate climate model performance in the large CPDN perturbed physics multi-model ensemble in order to constrain the ensemble and projections of future global-scale climate change.

Braganza, K., D. J. Karoly, A. C. Hirst, M. E. Mann, P. A. Stott, R. J. Stouffer, and S. F. B. Tett, 2003: Simple indices of global climate variability and change: Part I - variability and correlation structure. Climate Dynamics, 20, 491-502.

Braganza, K., D. J. Karoly, A. C. Hirst, P. A. Stott, R. J. Stouffer, and S. F. B. Tett, 2004: Simple indices of global climate variability and change Part II: attribution of climate change during the twentieth century. Climate Dynamics, 22, 823-838.

Karoly, D. J. and K. Braganza, 2001: Identifying global climate change using simple indices. Geophysical Research Letters, 28, 2205-2208.

Polynomial cointegration tests of the anthropogenic theory of global warming

Friday - Parallel Session 6

Michael Beenstock and Yaniv Reingewertz

Department of Economics, the Hebrew University, Isreal

We use statistical methods designed for nonstationary time series to test the anthropogenic theory of global warming (AGW). This theory predicts that an increase in greenhouse gases concentrations increases global temperature permanently. Specifically, polynomial cointegration methodology is used to test AGW when global temperature and solar irradiance are stationary in 1st differences, whereas greenhouse gas forcings (CO_2, CH_4 and N_2O) are stationary in 2nd differences. We show that greenhouse gas forcings share a common stochastic trend, but the latter is empirically independent of the stochastic trend between temperature and solar irradiance. Therefore, greenhouse gas forcings, global temperature and solar irradiance are not polynomially cointegrated, and AGW is refuted. This result is not sensitive to the inclusion of aerosols in the analysis. Although we reject AGW, we find that greenhouse gas forcings have a temporary effect on global temperature. Because the greenhouse effect is temporary rather than permanent, predictions of significant global warming in the 21st century by IPCC are not supported by the data.

Detection and attribution of changes in European temperature and precipitation

Friday - Parallel Session 6

Simon Tett

Recent heat waves and flooding events have generated popular views that European climate is changing due to human influences. We compare simulated and observed changes in warm and cold season temperature and precipitation for two European regions. We find that combined human and natural influences are robustly detectable in temperature and in Northern European cold season precipitation changes. Natural only influences on European climate are not robustly detected. This work also suggests that changes in winter precipitation are under estimated in current climate models.

Influence of external forcing on European temperatures

Friday - Parallel Session 6

Gabriele Hegerl[1], Juerg Luterbacher[2], Fidel Gonzalez-Rouco[3], Simon Tett[1] and Elena Xoplaki[4]

[1]*GeoSciences, University of Edinburgh, UK*

[2]*University of Giessen, Giessen, Germany*

[3]*Universidad Complutense Madrid, Spain*

[4]*Cyprus Institute, EEWRC, Nicosia, Cyprus*

We use results from a reconstruction of seasonal European temperature and several climate model simulations of the last millennium to show that external forcing has influenced European past seasonal temperature variations . We use fingerprints for external forcing that are averaged from the simulations as well as fingerprints from simple climate models to attribute reconstructed seasonal changes to forcing. Results show that regional reconstructed winter and spring temperatures have significantly responded to external forcing. Approximately 25% of the variance of decadal winter and spring temperatures can be attributed to external forcing over the entire time period. A best estimate of 88% of the winter warming since the early 19th century is attributable to greenhouse gas and aerosol forcing. The winter season also shows a significant, but noisy, short term response to volcanic eruptions, with warming in Northern Europe both in ensembles of GCM simulations and observations a bit long sentence. In contrast, the contribution of forcing to decadal variability of summer and fall temperatures is small, making the most recent rate of warming in summer highly unusual. Highly significant short term summer cooling can be detected immediately after individual volcanic eruptions, and there may be a detectable response to solar forcing in decadal variations in summer. These differences between the seasons suggest that sub-annual information is needed to reliably predict impacts.

Comparing the spatial features of observed and simulated climate change over the Mediterranean basin

Friday - Parallel Session 6

Aurélien Ribes and Serge Planton

Studies regarding the regional features of climate change have known a growing interest over the last decades, due to the need for improved projection at such scales. The main goal of this study is to assess the ability of the climate models to properly simulate the spatial distribution of anthropogenic climate change at the regional scale, focusing on the Mediterranean basin. We propose to compare the outputs of a statistical detection technique applied respectively to climate model runs and observed data.

In a first step, we introduce briefly the Temporal Optimal Detection (TOD) method for climate change detection. This method involves looking for a climate change signal in the observations, assuming that the temporal pattern of change is known. In addition to assess the significance of the climate change signal, this method allows to infer the spatial distribution of the change directly, from the observed data.

In a second step, we apply the TOD method to both observed and simulated temperature datasets covering the 1900-2010 period over the Mediterranean basin. The climate change signal is significant in all cases and we can compare the evolution of the test p-value over the period, between observed and modeled climate. In each case, the method provides an evaluation of the spatial distribution of change. The main focus of this work is to compare these different spatial patterns, after having proved their significance. The comparison is done with respect to several metrics, discussing their respective benefits. In particular, we will illustrate results obtained with the euclidean metric and the ones given by using the “optimal fingerprint” metric, often used in detection-attribution studies.

Anthropogenic influence on long return period daily temperature extremes at regional scales

Friday - Parallel Session 6

Francis W. Zwiers, Xuebin Zhang and Yang Feng

Climate Research Division, Environment Canada, Toronto, Canada

Observed annual extreme temperatures, namely annual maximum daily maximum (TXx) and minimum (TNx) temperatures and annual minimum daily maximum (TXn) and minimum (TNn) temperatures, are compared with those from climate simulations of multiple model ensembles with historical anthropogenic (ANT) forcing and with combined anthropogenic and natural external forcings (ALL) for the period 1961-2000 at both global and regional scales using a technique that allows us to infer changes in long return period extreme temperatures. We fit generalized extreme value (GEV) distributions to the observed extreme temperatures using a time-evolving pattern of location parameters obtained from model simulated extreme temperatures under ANT or ALL forcing. Evaluation of the parameters of the fitted GEV distributions shows that both ANT and ALL influence can be detected in TNx, TNn, TXn, and TXx at the global scale over the land areas for which there are observations, and also regionally over many large land areas, with detection in more regions in TNx. We therefore conclude that the influence of anthropogenic forcing has had a detectable influence on extreme temperatures that have impacts on human society and natural systems at global and regional scales. External influence is estimated to have resulted in large changes in the likelihood of extreme annual maximum and minimum daily temperatures. Globally, waiting times for events that were expected to recurred once every 20 years in the 1960s are now estimated to exceed 30 years for extreme annual minimum daily maximum temperature and 35 years for extreme annual minimum daily minimum temperature, and to have decreased to less than 10 or 15 years for annual maximum daily minimum and daily maximum temperatures respectively.

Spatial characteristics of gridded Swiss temperature trends: Local and large-scale influences

Friday - Parallel Session 6

Paulo Ceppi, Simon C. Scherrer and C. Appenzeller

Climate Services, Federal Office of Meteorology and Climatology MeteoSwiss, Zürich, Switzerland

Temperature is an essential variable in monitoring the impact of global climate change. Here we perform a detailed regional trend analysis of Swiss Alpine temperatures in the period 1959 to 2008 using a newly available gridded data set based on homogenised observations from 91 MeteoSwiss stations. The aim is to quantify possible large-scale and local-scale contributions to the local trends. It is shown that the yearly trends are all positive and highly significant, with an average warming rate of 0.35 °C/decade, consistent with results from earlier studies. The values show fairly little spatial variability, with 90% of all gridpoint trends between 0.30 and 0.39 °C/decade. This indicates that the warming in Switzerland has exceeded the NH extratropical mean trend by a factor of 1.6 over the last 50 years. On a seasonal scale, the analysis also reveals overall positive temperature trends, but seasonal and spatial variability are pronounced. The weakest trends (mostly insignificant at the 5% level) are observed in autumn (SON, 0.17 °C/decade on average) and early summer features the strongest warming rates, peaking at 0.48 °C/decade in May-June-July. A pronounced altitude dependence is found from late summer to early winter (ASO to NDJ), where the trends decrease with elevation.

We investigate the impact of large-scale versus local-scale influences on seasonally-averaged temperatures using a regression model with atmospheric circulation patterns and northern hemispheric temperatures as explanatory variables. The analysis reveals that 45 (summer) to 80% (winter) of the interannual variability of Swiss gridpoint temperatures can be explained by largescale influences. In spring, summer and autumn, a fraction of up to 20% of the temperature trends remains unexplained by the model. In spring, a positive trend anomaly close to the zero-degree isotherm is not detected by our model, while the largest unexplained trend magnitudes are found at low elevations in autumn and winter.

Our results suggest that snow-albedo feedback effects might be responsible for the unexplained 10% higher spring trends near the altitude of the zero degree isotherm and snow line. In autumn, the observed decrease in mist and fog frequency may be a key process explaining the 20% higher Swiss autumn temperature trends at low elevations. Changes in soil-atmosphere interactions could explain part of the difference between observed and modelled trends in summer. For the unexplained lower than modelled temperature trends in late winter at low altitudes the physical mechanisms remain to be determined.

Statistical evidence of recent climate change: An analysis of Arctic seawater data

Friday - Parallel Session 6

Snigdhansu Chatterjee

School of Statistics, University of Minnesota, Canada

We perform a statistical analysis on a dataset on seawater pattern over the last few decades. For specificity, we restrict attention to temperature measures in the Arctic Ocean region for this talk. Our goal is to investigate whether there is a significant change of pattern in the Arctic Ocean seawater temperature, thus detecting recent climate change, after accounting for the systematic factors like location, depth, season, and the temporal and spatial dependence pattern of the observations. In a major departure from many climate data modeling studies, we do not explicitly model the spatio-temporal dependency pattern of the observations, but treat it as an extremely high dimensional nuisance parameter, and use techniques for estimation and inference that are insensitive to it. We use nonparametric curve fitting for weakly dependent observations, sequential tests, complex resampling-based robustness studies, block bootstrap based two-regime analysis as a part of our statistical approach. The methodology used in this paper is applicable for any sequence of dependent observations on the climate, and does not rely on climate models or reanalysis, nor on indirect historical data, nor on technical assumptions like linearity, Gaussian nature of random variables, specific dependency patterns, and so on. This is joint work with Qiqi Deng and Jie Xu.

Ocean heat transport as a key process for model spread in Arctic warming

Friday - Parallel Session 6

Irina Mahlstein and Reto Knutti

Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

The Arctic region is characterized by a very large variability and complex physical processes which govern its climate. Global warming caused by anthropogenic greenhouse gases impacts this region severely by changes in sea ice cover which have strong implications for the heat budget. Numerous physical processes account for the strength of the ice albedo feedback which is mainly responsible for polar amplification. Simulating future temperature increase in this region is challenging due to the complexity of this particular climate system. Atmosphere Ocean Global Circulation Models (AOGCM) show large uncertainties in their projections for this region. The range of simulated future temperatures until 2100 across the different AOGCMs covers 2.5-7.5K compared to 0.5-4K for the global temperature increase. However, models showing a large warming in the Arctic project a larger global warming, as well. Understanding the Arctic climate system with all its feedbacks is therefore indispensable in order to reduce uncertainty in global climate projections.

In this study we show that the main differences in the pattern of the simulated surface temperatures of the AOGCMs are localized over the Barents Sea. This is a region where surface temperature depends on ocean currents, namely the North Atlantic Drift Stream bringing warm surface water to high latitudes. The strength of the northward ocean heat transport on the other hand impacts the sea ice cover in this region. Less sea ice leads to a stronger warming. Comparisons with observations reveal that those models which have a stronger northward ocean heat transport simulate the sea ice extent more accurately than those which have a weaker ocean heat transport. Transporting less energy to the north induces more sea ice in the Arctic and consequently the future polar warming is less pronounced in these projections. Constraining climate simulations of the northward ocean heat transport with observations offers one possibility to reduce uncertainty in future projections. However, obtaining accurate observations of the ocean heat transport is very challenging.

The radio occultation record for atmospheric climate change detection

Friday - Parallel Session 6

Bettina C. Lackner[1], **Gabi C. Hegerl**[2], **Andrea K. Steiner**[1] **and Gottfried Kirchengast**[1]

[1]*Wegener Center for Climate and Global Change, University of Graz, Austria*

[2]*School of GeoSciences, University of Edinburgh, UK*

The detection of climate change signals in rather short satellite datasets is a challenging task in climate research and requires high quality data with good error characterization. Global Navigation Satellite System (GNSS) radio occultation (RO) provides a novel record of high quality measurements of atmospheric parameters of the upper troposphere-lower stratosphere (UTLS) region. Due to characteristics such as self-calibration, long-term stability, and a good height-resolution, RO retrieved parameters are highly qualified to investigate atmospheric climate change. In our study we aim at the detection of a forced climate change signal by means of a monthly mean zonal RO data record using ordinary least-square fingerprinting. UTLS trends of RO refractivity, geopotential height, and temperature within two periods (1995–2008 intermittently and 2001–2008) are investigated. Furthermore, characteristics of the data as well as QBO and ENSO based variability within the record period are discussed. Results show that a climate change signal consistent with the projections of three representative global climate models of the IPCC 4th Assessment Report (CCSM3, ECHAM5, HadCM3) can be detected for temperature at a 90% confidence level. Lower confidence levels are achieved for the refractivity record, while for geopotential height the results are questionable as to the consistency of variances between models and observations.

Observational system simulation experiments of CLARREO shortwave reflectance spectra

Friday - Parallel Session 6

Daniel Feldman[1], **Chris Algieri**[2], **Jonathan Ong**[1], **William Collins**[1,2]

[1]*University of California-Berkeley, USA*

[2]*Lawrence Berkeley National Laboratory, USA*

The reflected solar spectrum contains information about climate forcings and feedbacks and will likely change as a result of changes in the Earth's climate. Therefore, we have developed and extensively validated an Observational System Simulation Experiment (OSSE) framework in order to analyze changes in reflectance spectra over seasonal, annual, and decadal time-scales. OSSEs have been widely utilized with infrared spectra, but are a novel approach to exploring the utility of visible and near-infrared measurements. This OSSE couples the NCAR CCSM climate model with the MODTRAN radiative transfer code to calculate spectra that simulate IPCC AR4 emissions scenarios. We have found that the spectral signature of aerosol forcing changes are substantial relative to natural variability and are confined to lower latitudes. The signatures of low-cloud feedbacks and snow and ice-albedo changes are also readily detectable from the reflectance spectra. We also tested the reflectance spectra residuals associated with CCSM runs with different cloud feedback strengths to gauge the magnitude of the signal. The results of the OSSE suggest that the proposed NASA CLARREO mission to record highly-calibrated infrared and shortwave spectra from a satellite platform may help detect climate forcings and feedbacks more quickly than conventional satellite instruments.

The potential to narrow uncertainty in regional climate predictions

Friday - Parallel Session 1

Ed Hawkins and Rowan Sutton

NCAS - Climate, University of Reading, Reading, UK

Faced by the realities of a changing climate, decision makers in a wide variety of organisations are increasingly seeking quantitative predictions of regional and local climate. An important issue for these decision makers, and for organisations that fund climate research, is what is the potential for climate science to deliver improvements - especially reductions in uncertainty - in such predictions?

Uncertainty in climate predictions arises from three distinct sources: internal variability, model uncertainty and scenario uncertainty. Using data from a suite of climate models (CMIP3), we separate and quantify these sources for predictions of both surface air temperature and precipitation.

For predictions of changes in temperature on decadal timescales and regional spatial scales, we show that uncertainty for the next few decades is dominated by sources (model uncertainty and internal variability) that are potentially reducible through progress in climate science. Furthermore, we find that model uncertainty is of greater importance than internal variability. For precipitation projections we find that the potential to narrow uncertainty is far lower than for temperature. We also consider the sources of uncertainty in predictions of stratospheric ozone recovery and Amazonian dieback.

Our findings have implications for managing adaptation to a changing climate. Because the costs of adaptation are very large, and greater uncertainty about future climate is likely to be associated with more expensive adaptation, reducing uncertainty in climate predictions is potentially of enormous economic value. Our study also highlights the importance of targeting climate science investments on the most promising opportunities to reduce prediction uncertainty.

For more details:

Hawkins & Sutton, 2009, BAMS, **90**, p1095

Hawkins & Sutton, 2010, Climate Dynamics, in review

Multi-model ensemble forecasting of rainfall over East Asia region using regularized regression

Friday - Parallel Session 1

Yaeji Lim[1], Seongil Jo[1], Jaeyong Lee[1], Hee-Seok Oh[1] and Hyun-Suk Kang[2]

[1]*Department of Statistics, Seoul National University, Seoul, Korea*

[2]*National Institute of Meteorological Research, Korea Meteorological Administration, Seoul, Korea*

In this study, a statistical ensemble forecasting method is proposed for the prediction of rainfall over the East Asia region based on regularized regression approach. The proposed method consists of two steps, preprocessing step and ensemble step: (1) In the preprocessing step, we generate predicted values by applying a method to each individual GCM model output. The preprocessing step can be implemented using various methods such as EOF/CCA, regularized CCA and regularized regression methods including LASSO and ridge regression. (2) The ensemble step combines the results from the preprocessing step by using regularized regression methods and provides the final prediction. Key features of the proposed method are as follows: (1) it can evaluate ontribution of models for prediction by selecting some models rather than considering all models, (2) using regularized regression allows to use high-dimensional data, so that we can consider all locations as well as various climate variables, and (3) it is computationally effcient, and hence, various climate data including observations and model output can be analyzed. The proposed method is applied to monthly outputs of nine GCM models on boreal summer (June, July, and August) from 1983 to 2002. The prediction skill of the ensemble forecast is examined against observations and corresponding outputs of each constituent model. The result shows that the proposed method is capable to improve the forecast by adjusting each model before combing and taking the strength of each model.

PRECIS + QUMP: Experimental design of small-ensemble regional modelling experiments for developing regions of the world

Friday - Parallel Session 1

C. McSweeney and R. G. Jones

Met Office Hadley Centre, UK

PRECIS was developed at the Met Office Hadley Centre to make available a system for generating high resolution climate change information for any region of the world by providing, free of charge, a regional climate modelling system with a simple user interface and appropriate training to climate centres in developing countries.

A recent development in the PRECIS modelling system allows users to downscale 17 members of the Hadley Centre's QUMP (Quantifying Uncertainty in Model Predictions) perturbed physics ensemble (HadCM3Q0-Q16) with either the standard HadRM3 regional model, or the corresponding perturbed physics regional models (HadRM3Q0-Q16). Limitations in the computing facilities available to many climate centres mean that in many cases a 17-member ensemble is not feasible, and we look at criteria that might be used for selecting 'sub-sets' of three or more models from the ensemble.

We describe here the approach taken in recommending a sub-set of around 7 members from the 17 for modelling experiments for South East Asia at Vietnam's Institute for Meteorology, Hydrology and Environment (IMHEN). In this case study, we use analyses of the QUMP GCM simulations to:

1) Eliminate any ensemble members that perform poorly in their simulations of the major features of south east Asian climate (specifically, the Asian summer monsoon);
2) Select from those remaining, a sub-set that capture a broad range of responses in temperature, monsoon characteristics and precipitation;
3) Assess whether the complete, or subset of, QUMP ensemble represents the range of responses from the multi-model CMIP3 ensemble.

We find that, in this case, the QUMP models perform similarly well in replicating the key characteristics of the onset, position and strength of the Asian summer monsoon. We therefore do not find strong grounds for elimination of any models, and base our selection solely on sampling the range of responses, in terms of magnitude and spatial patterns. We demonstrate that the QUMP ensemble capture a range of magnitude of response that is wide than that of CMIP3, but simulates much more homogeneous spatial patters of precipitation change.

Finally, we discuss the implications for the implementation of similar methodologies for different regions, and interpretation of the systematically-sampled small-ensemble simulations of regional climate.