Could Instrumentation Drift Account for Arctic Sea Ice Decline?

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One of the key datasets used as evidence of anthropogenic global warming is the apparent decline in Arctic sea ice. Such weight is given to it that most scientists accept it unquestioningly and as such it has been used in numerous climate analyses and models. But might there be a problem with it? There was no significant trend in Arctic sea ice extent until the satellite era. Comparison of historic records and satellite measurements, and between satellite platforms with decaying orbits (Nimbus-7 SMMR and DMSP SSM/I) and a constant orbit system (AQUA AMSR-E), suggests there could be evidence of a long term drift in Arctic sea ice data obtained from SMMR & SSM/I. An estimate of the drift referenced to the AMSR-E system suggests the drift is enough to account for the apparent decline in Arctic sea ice over the satellite period. The possibility has been raised that inadequate correction has been applied to the temperature brightness data to account for orbital decay.

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Introduction

One of the key datasets used as evidence of anthropogenic global warming is the apparent decline in Arctic sea ice. Such weight is given to it that most scientists accept it unquestioningly and as such it has been used in numerous climate analyses and models. But might there be a problem with it? Could there be a long term system drift that has not been taken into account that may cause the apparent loss of Arctic sea ice? This study will briefly examine that possibility.

Discussion

Generally, only the Arctic sea ice data from satellite passive microwave sensors are presented by those using it as evidence of anthropogenic global warming and as such it only extends back to the 1970's when the first satellite-based measurements were made. However measurements and reconstructions extend back much further so why aren't these more widely disseminated? There must be good reason and that will be the starting point of this study.

One good example comes from Chapman & Walsh of the University of Illinois, who have created an Arctic sea extent reconstruction covering the era 1870 to 2008 based upon the following eight basic data sources:

1. Danish Meteorological Institute
2. Japan Meteorological Agency
3. Naval Oceanographic Office (NAVOCEANO)
4. Kelly ice extent grids (based upon Danish Ice Charts)
5. Walsh and Johnson/Navy-NOAA Joint Ice Center
6. Navy-NOAA Joint Ice Center Climatology
7. Temporal extension of Kelly data (see note below)
8. Nimbus-7 SMMR Arctic Sea Ice Concentrations or DMSP SSM/I Sea Ice Concentrations using the NASA Team Algorithm

They state that the more historical data should be treated cautiously and split the dataset into three sections, identifying fundamental changes in the sources:

- 1870-1952 Mostly climatologically determined but with increasing amounts of observations.
- 1953-1971 Mainly hemispheric observational data of varying reliability, but described as generally accurate.
- 1972-2008 Hemispheric satellite data with 'state-of-the-art' accuracy.

Notes:

1. Most of the direct observations (1870-1971) are from ships.

2. It would appear that Chapman and Walsh have extended the satellite data backwards in time, but for the purposes of this analysis let us stick to their definitions.

The University of Illinois northern hemisphere seasonal sea ice extent data can be found here: http://arctic.atmos.uiuc.edu/SEAICE/

More specifically, the data file used was: http://arctic.atmos.uiuc.edu/SEAICE/timeseries.1870-2008

Plotting the mean annual values from the time series gives the graph in Figure 1.

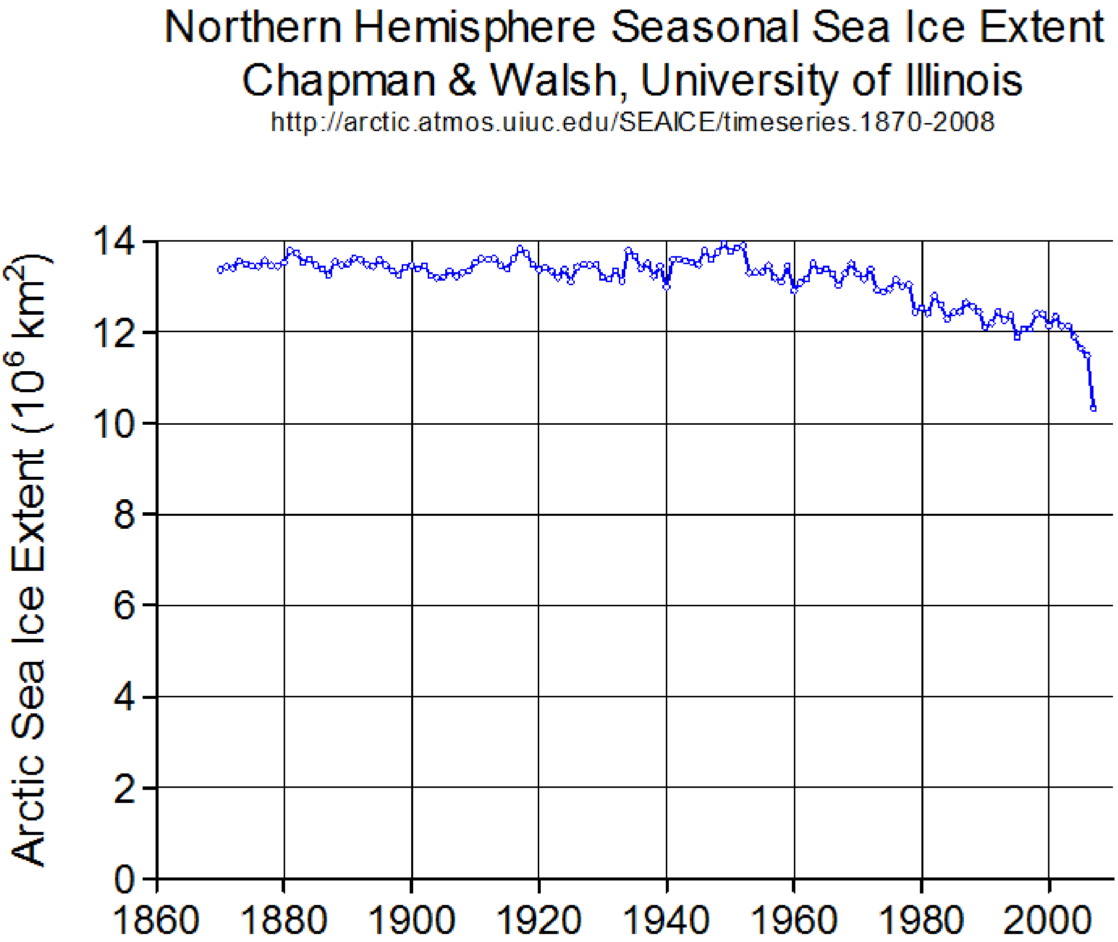

Figure 1: Chapman & Walsh northern hemisphere sea ice extent 1870-2008.

It should be noted that at the time that the dataset was downloaded it did not include a point for 2008 and that showed significant recovery in the sea ice extent.

As it stands, the Chapman & Walsh data does not seem to show anything particularly extraordinary, apart from a couple of obvious points; the first around 1952/3 and second at 2007. It merely shows relatively flat character at first, with maybe a slight downward slope that becomes much more rapid after about 1970.

Now if we look at the data split into the sections specified by Chapman & Walsh some interesting features appear, Figure 2. Least squares linear fits have been added to each section independently to highlight the trends.

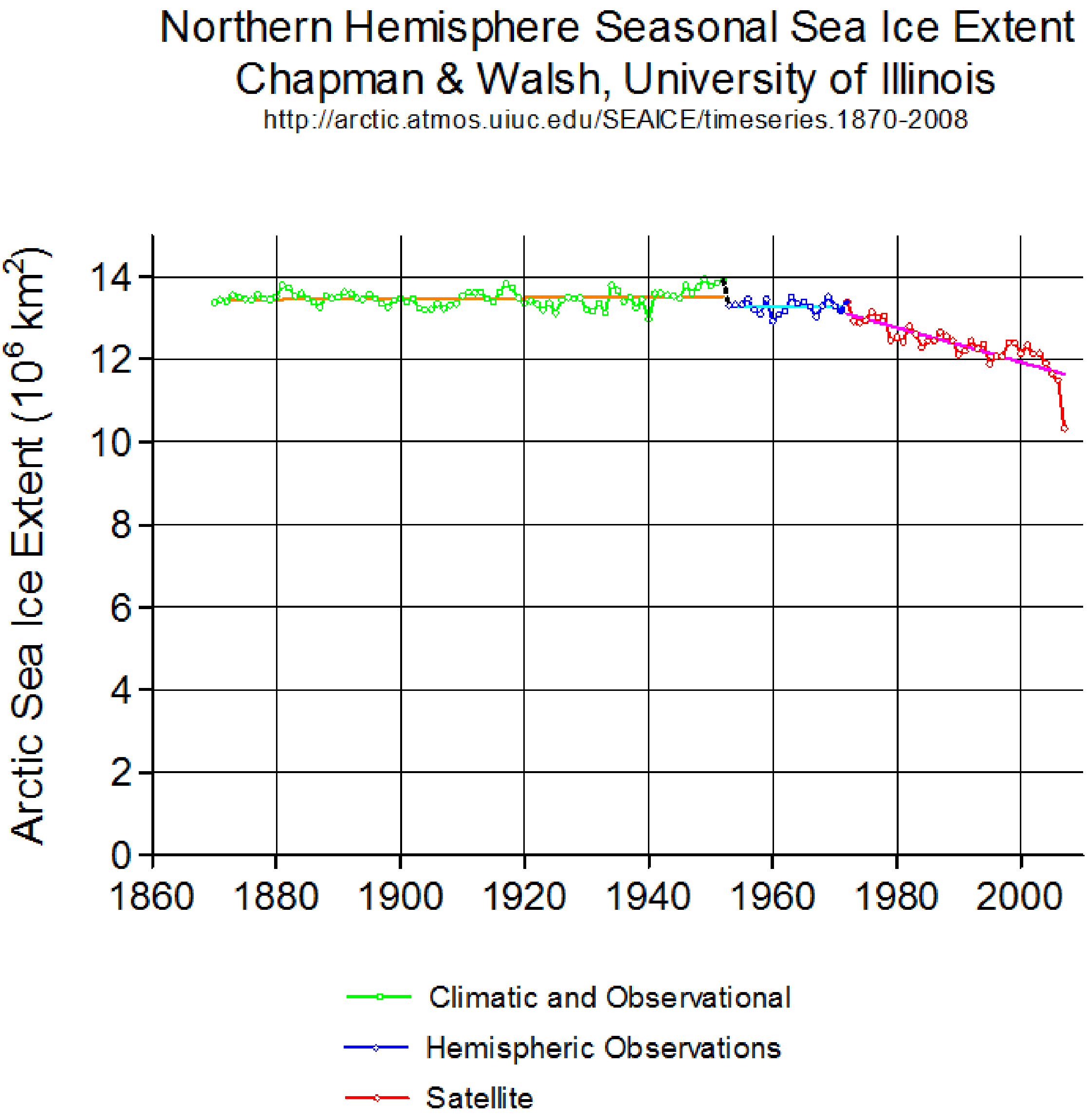

Figure 2: Chapman & Walsh sea ice extent split into measurement types by their definitions.

As can be seen, the two early eras have almost flat trends and there is a noticeable step in the data between them. That said, the step between trends appears to be within the variability. Now turning to the satellite era, it is clear that it joins the 1953-1971 data quite well. However, there is a very distinct difference in the trends with the satellite showing a rapid decrease in sea ice extent.

The calculated linear trends are:

1870-1952	0.00114 x 10^6 km^2/year
1953-1971	-0.00080 x 10^6 km^2/year
1972-2008	-0.04172 x 10^6 km^2/year
1870-1971 (mean)	0.00017 x 10^6 km^2/year

So when the measurement method swapped to satellite, the trend altered abruptly, from close to zero, to significantly declining. In fact, it is a factor of 52 greater than that of the 1953 to 1971 period. Is this just coincidental? It is difficult to say, but it is interesting that Chapman & Walsh consider the 1953 to 1971 data to be "generally accurate" and data for the 1972 to 2008 era as having "state-of-the-art accuracy". They also state that the pre-1953 reconstruction should be treated with particular caution.

If the first part of the set is rejected, it leaves two supposedly good, adjacent datasets showing significantly different trends. Which is correct, or more correct? This looks like a classic two clock problem.

It is thus instructive to compare another source and in this case the data from AMSR-E instrument which flies on the AQUA satellite platform. By all accounts this is presently the most accurate state-of-the-art system. The dataset is available from JAXA here: http://www.ijis.iarc.uaf.edu/en/home/seaice_extent.htm. Unfortunately this sensor has recently been shutdown, apparently due to a bearing failure. The actual dataset used in this document was dated 31/1/2009. This was compared to the SMMR & SSM/I series from the NASA team algorithm obtained here: ftp://sidads.colorado.edu/pub/DATASETS/seaice/polar-stereo/trends-climatologies/ice-extent/nasateam/. Specifically the following dataset: 'gsfc.nasateam.daily.extent.1978-2007.n' but which has since been updated.

Unfortunately, there was a relatively short overlap interval at the time this analysis was done; however, it is adequate for illustrative purposes. The data is plotted for comparison covering the overlapping period in Figure 3. This shows fairly good agreement but AMSR-E records significantly more ice in winter months. Calculating the ratio of them is more revealing and that is done in Figure 4 which includes a 365 point moving average to reveal the underlying trend, and a linear regression fit applied to the smoothed result.

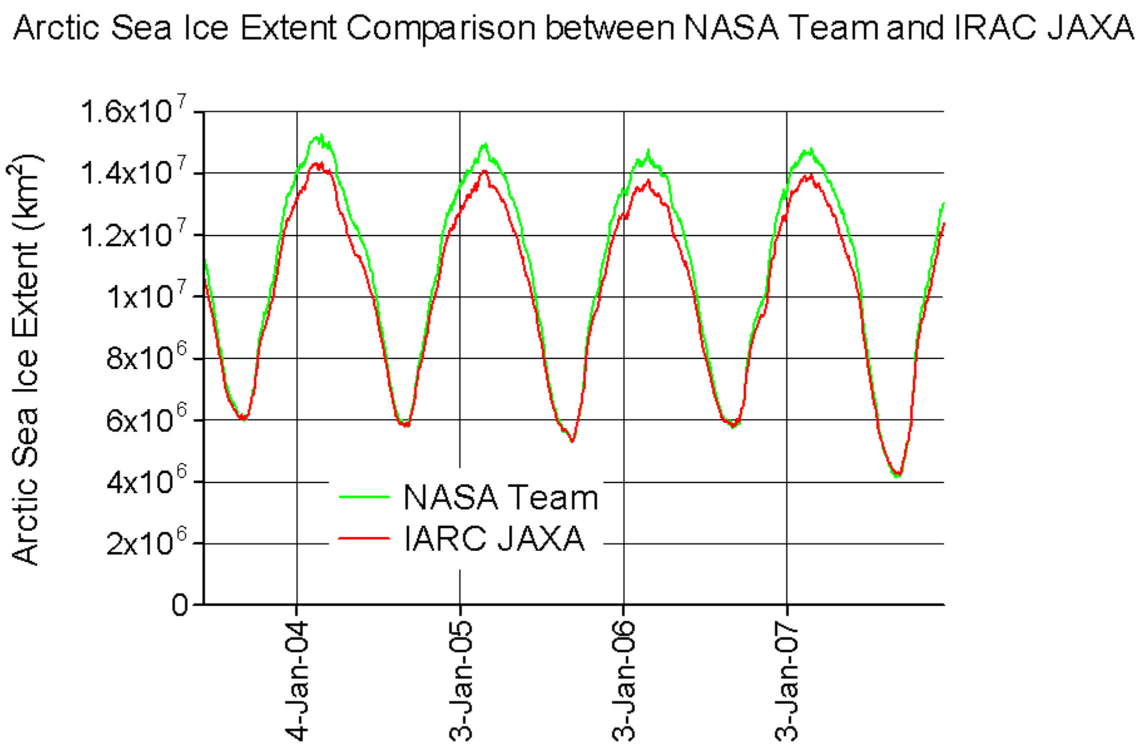

Figure 3: Comparison between NASA team SSM/I and JAXA AMSR-E sea ice extent.

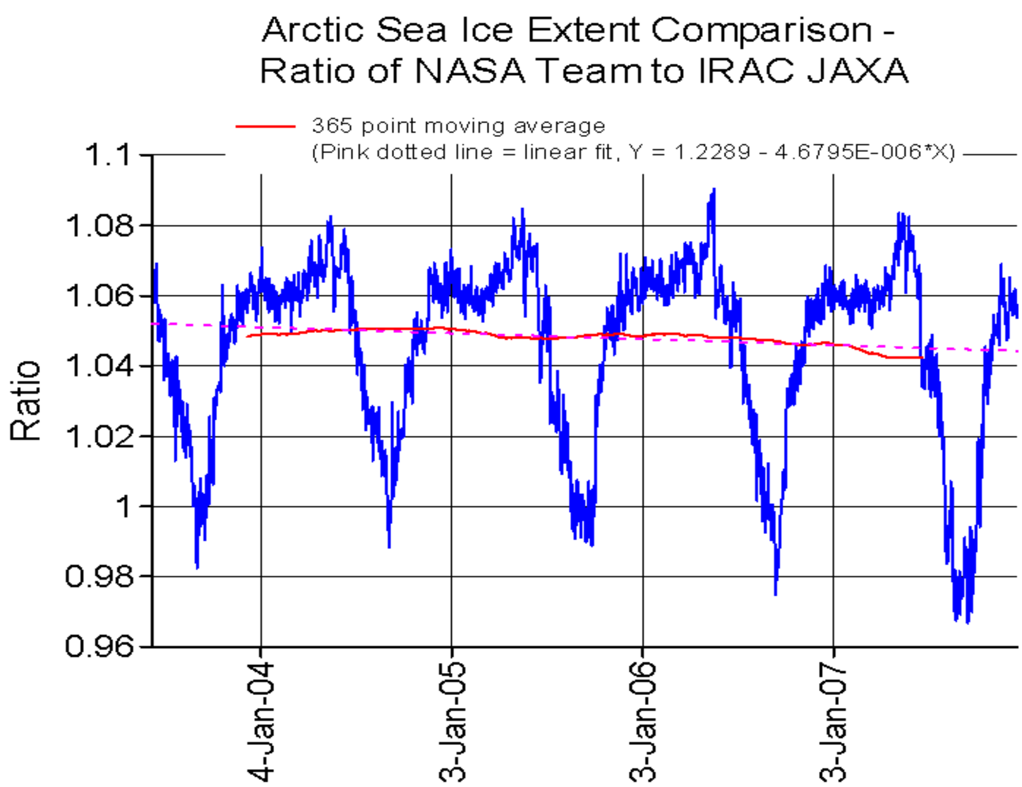

Figure 4: Ratio of NASA team and JAXA sea ice extent (blue) with 365 point moving average (red) and linear fit (dashed magenta).

The difference between the two varies seasonally; however, the trend is relatively smooth, and declining, as shown by the red line. From the linear fit to the trend, a decline of about 0.0017 per year relative to AMSR-E (JAXA) is evident. Assuming this trend is representative of the entire satellite era and that AMSR-E provides stable measurements, then the observed differences might account for a substantial proportion of the reported Arctic sea ice decline. In simple terms, this may be indicative of instrumentation or other drift.

Clearly, a ratio is not of great help when it is actual area (extent) that drives the scare stories in the media, and so the difference between the two satellite measurements was calculated making sure that complete annual cycles were used. This was done over the period 31 December 2003 to 31 December 2007, 4 cycles. A simple linear fit was applied to reveal the trend as shown in Figure 5.

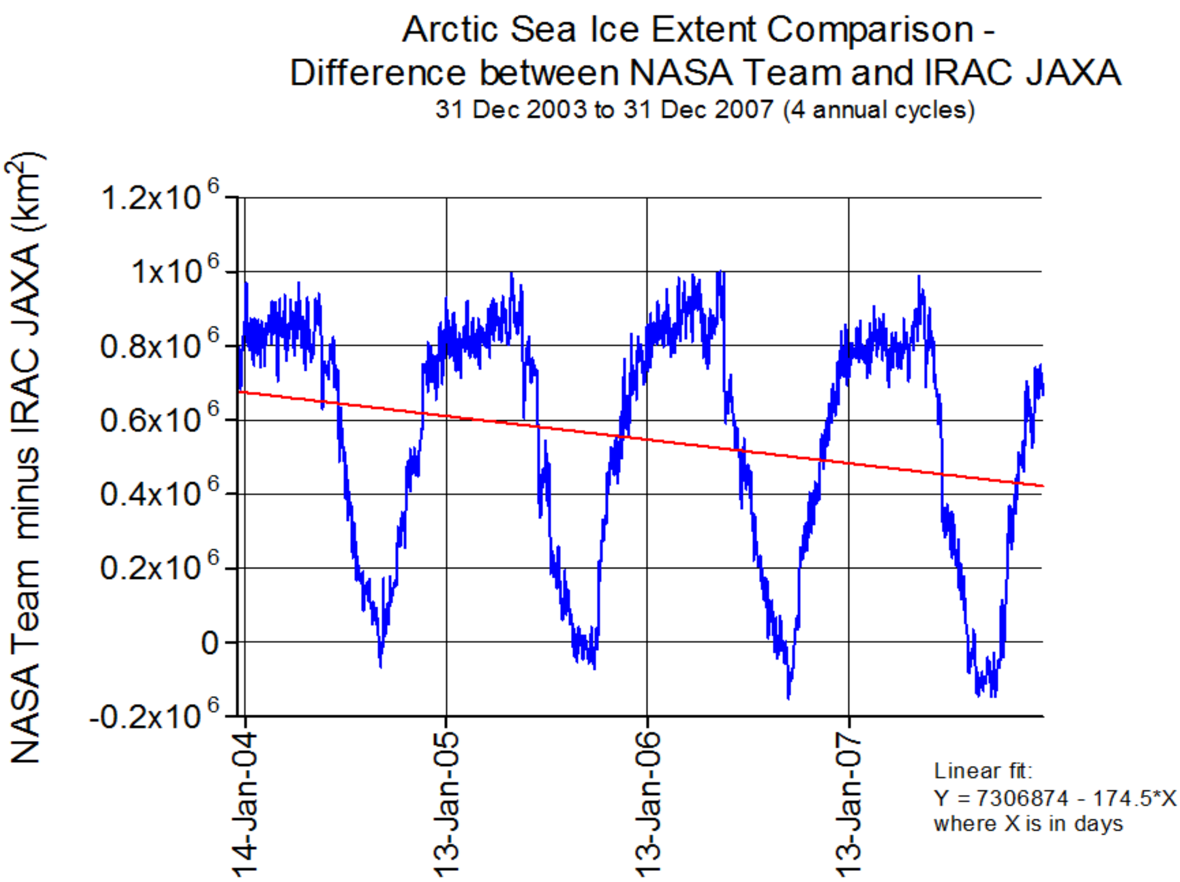

Figure 5: Difference is sea ice extent between NASA team and JAXA.

The linear fit was calculated as: Y = 7306874 – 174.5*X, where X is in days.

This corresponds to a change in Arctic sea ice extent of -63692 km^2 per year. Comparing it with the trend over the satellite period computed earlier of -41720 km^2 per year suggests it is larger than needed to explain the apparent decline. This overestimation can probably be accounted for by statistical variation over this period.

Hence, the apparent decline in Arctic sea ice extent since the 1970s could be the result of measurement drift in the SSM/I satellite data, assuming that AMSR-E is stable reference. This possibility will be examined further. In the meantime, for completeness, the Chapman & Walsh record has been plotted with the difference trend calculated above referenced to 2006, Figure 6.

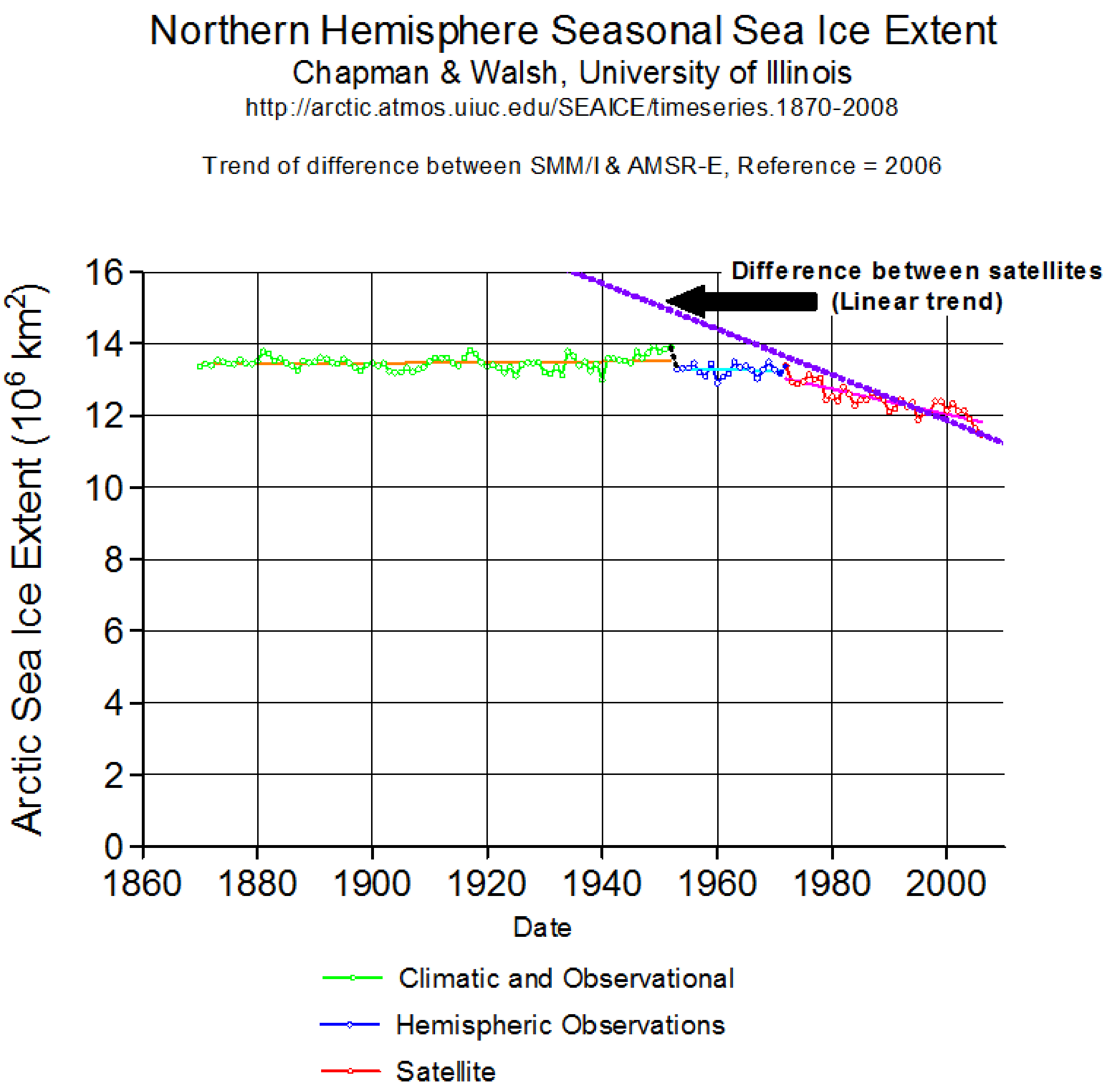

Figure 6: Northern hemisphere sea ice extent record from Chapman & Walsh with linear trend difference between NASA team and JAXA satellite records.

If this is a measurement drift, what could be causing it? Since stringent calibration is applied to all the sensors, the effect must be a difference in the systems that is not corrected by that process. Great care is taken to match the SSM/I data from the DMSP satellites as discussed by Frank J. Wentz in the Version-6 Calibration of SSM/I, RSS Technical Report 102210; October 22, 2010. Whilst this process appears to address inter-calibration of the instruments there does not seem to be much emphasis on the possibility of time dependent variations but the Earth Incidence Angle (EIA) is highlighted as an important variable. At the same time, it is acknowledged that altitude and attitude information are lacking.

With this in mind, researching the DMSP, NIMBUS and AQUA satellite platforms revealed that only AQUA is in a controlled orbit. All the others are in decaying orbits and their exact orbital parameters are poorly known. Therefore it is surmised that the stability of AMSR-E is probably, at least in part, due to its constant orbit and thus fixed EIA.

The importance of EIA is demonstrated in another document from Remote Sensing Systems (RSS): Decadal Trends and Variability in Special Sensor Microwave / Imager (SSM/I) Brightness Temperatures and Earth Incidence Angle by Hilburn, K. A. and C. L. Shie [RSS Technical Report 092811, 28 September 2011]. They explain how EIA affects the brightness temperature (T_B). T_B is used to establish sea ice parameters amongst other weather and climate parameters. Furthermore they state:

"Since the satellites are gradually falling over time, EIA has a trend of -0.14°/decade."

As such, EIA must be taken into account or a spurious trend will likely be present in the processed data. The effect of EIA on T_B is not constant but varies with meteorological conditions although the major influence is altitude. Since EIA is not explicitly known, it must be estimated from the data and used to correct T_B. Ideally this would be as near continuous correction.

Whilst RSS claim their retrieval algorithms parameterise for EIA there does not appear to be any indication that prime data users have corrected EIA for altitude change due to decaying orbit, at least not continuously. For example, National Snow and Ice Data Center (NSIDC) use the NASA team algorithm but appear to use constants for EIA, only changing them in response to system changes; i.e. inter-calibration:
http://home.earthlink.net/~tech_comm/SupportFiles/Portfolio/NSIDC/nsidc0051_gsfc_seaice.gd.pdf

Since the decays of satellites in similar orbits would be expected to be more or less common during over-lapping time frames, the application of a single EIA to inter-calibrate the satellites aligns the measurements; however it does not address the systematic errors resulting from the decaying orbits. Put simply, the differential correction has been applied to tie the time series together but the long term common-mode problem remains.

To get a feel for the potential magnitude of the problem it is instructive to refer back to Hilburn et al. They state that their proposed correction increases the trend seen in bottom-layer water vapour W_B by 3.1%/decade which reduces the negative trend considerably. Whilst W_B and sea ice are not directly related, it is interesting to note that the trend seen in the sea ice decline is similar at -3.3%, relative to the start of the satellite era. Determining whether this is coincidence is beyond the scope of this resource-limited study but may be circumstantial evidence that the issue is real. Note also, that even after the Hilburn corrections there is a small negative drift in W_B with time which does not appear to fit well with the notion of a warming planet and is questioned within the paper.

It would seem that research groups, for example NSIDC, are aware there is a problem, as is evident from a news report of 18th February 2009: Satellite Sensor Errors cause Data Outage: http://nsidc.org/arcticseaicenews/

> *"However, we do not use AMSR-E data in our analysis because it is not consistent with our historical data."*

No explanation was given as to why it was inconsistent and yet it is deemed state-of-the-art and more accurate than SMMR & SSM/I. Why would an apparently superior instrument be rejected from the record?

To finish, it should be noted that whilst the focus of this document is on the Arctic sea ice measurements, the underlying issues will have an effect on Antarctic sea ice. Other climatic measures are likely also affected to some degree.

Researchers are encouraged to investigate the possibility that a long-term systematic drift of the satellite instrumentation is being misinterpreted as a climatic signal – the decline in Arctic sea ice.

Conclusion

There was no significant trend in Arctic sea ice extent until the satellite era. Comparison of historic records and satellite measurements, and between satellite platforms with decaying orbits (Nimbus-7 SMMR and DMSP SSM/I) and a constant orbit system (AQUA AMSR-E), suggests there could be evidence of a long term drift in Arctic sea ice data obtained from SMMR & SSM/I. An estimate of the drift referenced to the AMSR-E system suggests the drift is enough to account for the apparent decline in Arctic sea ice over the satellite period. The possibility has been raised that inadequate correction has been applied to the temperature brightness data to account for orbital decay, although that should not rule out other potential causes.

Other researchers are encouraged to investigate the possibility that a long-term systematic drift of the satellite instrumentation is being misinterpreted as a climatic signal – the decline in Arctic sea ice.

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