Comment on "Drought-Induced Reduction in Global Terrestrial Net Primary Production from 2000 Through 2009"

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Zhao and Running (Reports, 20 August 2010, p. 940) reported that global net primary production has declined over the past decade and that this reduction was caused by drought. However, their findings are not direct measurements, but rather are based on outcomes from models in which a strong temperature dependence is assumed. I examine the assumptions underlying their results and show that their findings can be explained as logical consequences of these assumptions.

Zhao and Running (*1*), hereafter ZR10, reported that global terrestrial net primary production (NPP, the amount of atmospheric carbon fixed by plants and accumulated as biomass) has declined over the past decade and that large-scale droughts are responsible for the decline. However, their findings are based on outcomes from models in which a strong temperature dependence is assumed. A simple alternative explanation for their findings is that increased temperatures are driving modeled results.

NPP cannot be directly measured at large scales. Instead, the Moderate Resolution Imaging Spectroradiometer (MODIS) NPP algorithm used by ZR10 is a simple model that calculates NPP from remotely sensed data and climatic variables. The remote sensing input is the fraction of photosynthetically active radiation (FPAR) absorbed by the vegetation. Gross primary productivity (GPP) is estimated by multiplying this input data by the incoming radiation, a constant light-use efficiency, and two modifier terms. The two modifier terms represent assumptions that productivity is reduced by (i) low temperatures (T_{min} < 8° to 12°C) and (ii) high vapor pressure deficit (VPD > 0.65 – 0.8 kPa). Rising temperature can increase GPP through the effect of T_{min} where temperatures are low, but decreases GPP at higher temperatures through the effect of rising VPD, which is correlated with temperature.

NPP is then calculated from GPP by subtracting a respiration term that increases exponentially with temperature. The Supporting Online Material [SOM text for (*1*)] indicates that previous versions of the algorithm held the Q10 of this temperature dependence constant and equal to 2. For this paper, they state that a "temperature-acclimated Q10 equation" is used. However, the new temperature dependence they use is taken from a paper about variation in the short-term Q10 of respiration with measurement temperature (*2*). This function gives a stronger effect of temperature on respiration than previously, with a Q10 that ranges between 2 (at 25°C) and 3.22 (at 0°C). In contrast, temperature acclimation tends to reduce the basal rate of respiration, with the result that long-term Q10 values are considerably less than 2 (*3*–*5*). Measured temperature dependences are further reduced when high temperature is associated with drought because plant respiration rates are reduced by drought (*5*, *6*), an effect not accounted for by ZR10. Thus, ZR10 are assuming a strong temperature dependence of respiration and, consequently, a strong negative effect of temperature on modeled NPP.

Overall, therefore, NPP is assumed to increase with rising temperature in cold regions (< T_{min}) but to decrease with rising temperature in warmer regions. As one might expect from a model based on these assumptions, ZR10 report that modeled NPP has increased with rising temperature in the cooler Northern Hemisphere but decreased with rising temperature in the warmer Southern Hemisphere. The reported reduction in NPP is clearly a consequence of the chosen assumptions. If the respiration assumption were to be replaced with a weaker temperature dependence, the calculated reduction in NPP would decrease.

ZR10 argue that the reduction they observe in modeled NPP is induced by drought, demonstrating a correlation between NPP anomaly and the Palmer Drought Severity Index (PDSI) anomaly. Drought severity, like NPP, is not directly measurable at large scales, so model indices such as PDSI are commonly used to estimate it. The PDSI is calculated as a balance from precipitation inputs and evaporative losses. However, the PDSI also incorporates a strong temperature dependence, because potential evapotranspiration is calculated as a function of temperature (*7*). The PDSI therefore decreases (more severe drought) as temperatures increase (*8*). This temperature dependence of the PDSI provides a simple explanation for the correlation observed by ZR10 between NPP and PDSI in the Southern Hemisphere. It is not that drought is causing a reduction in NPP; rather, both NPP and drought severity are assumed to vary with temperature.

Models have a very important role to play in our understanding of terrestrial ecosystems. However, it is important to clearly present the assumptions underlying a modeling study, and correctly describe the conclusions. ZR10 have not shown, as claimed, that terrestrial NPP has decreased over the last decade. Rather, they have shown that if NPP is assumed to be affected by climate as specified in their model, then NPP would have declined over the past decade. It is important to make this distinction, because otherwise we run the risk of mistaking model outcomes for reality.

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