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# Critique of Zhao and Running's Technical Response to Technical Comments

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

by

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**Summary**

The "Technical Response" by Zhao and Running (ZR10-TR, hereafter) is unconvincing and sidesteps the criticisms in the "Technical Comments" by Samanta et al (Samanta-TC) and Medlyn (Medlyn-TC).

First, the trends in MODIS satellite observations presented in Fig. 1 of ZR10-TR have not been tested for statistical significance (as in Samanta-TC) and even the maximum trend is smaller than the average error of the measurement (example panel A in Fig. 1 of ZR10-TR).

Second, changing the Q10 paramter in their respiration model to a more realistic value of 1.4, as recommended in Medlyn-TC, reduces the already extremely small NPP trend reported in their original paper (0.1% per decade) by a factor of 10 (Table 2 in ZR10-TR).

Third, Fig. 2 in ZR10-TR which purports to present the validity of their NPP model excludes tropical forests, especially the Amazon rainforests, where NPP ranges between 1000 to 1500 gC/m$^2$/yr.

Finally, the interannual variability in modeled NPP is highly sensitive to temperature (Fig. 3 in ZR10-TR). The strong correlation between NPP anomalies and atmospheric CO2 growth rates shown in Fig. 1 of their original report is only possible through unrealistic sensitivity of their model to temperature, as argued in Medlyn-TC and Samanta-TC.

**Abbreviations:**
**ZR10**: Zhao and Running, Science, Vol. 329, Page 940, August 20, 2010
**ZR10-TR**: Technical Response of Zhao and Running, Science, August 26, 2011
**Samanta-TC**: Technical Comment on ZR10 by Samanta et al., Science, Aug 26, 2011
**Medlyn-TC**: Technical Comment on ZR10 by Medlyn, Science, August 26, 2011
**NPP**: Net Primary Production
**NDVI**: Normalized Difference Vegetation Index
**EVI**: Enhanced Vegetation Index
**FPAR**: Fraction of Photosynthetically Active Radiation Absorbed by Vegetation
**LAI**: Leaf Area Index

## Satellite Data Results

(1) ZR10 claimed drought-induced reduction in global terrestrial NPP during the period 2000 to 2009 principally from the Southern Hemisphere, and especially due to Amazon rainforests. In ZR10-TR, they claim that Samanta-TC use of annually averaged satellite observations of vegetation indices, vegetation leaf area and radiation absorption as incorrect. They argue that growing season averages should be used instead.

> (a) As is well known, *the growing season in the tropics is 12 months long*. There is no dormancy period, as claimed by ZR10-TC. There is also no snow in the Amazon region. Thus, *it does not change the gist of Samanta-TC whether annual averages or growing season averages are used*.
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> (b) Defining growing season period as snow-free period as in ZR10-TR is more or less equivalent to using a NDVI threshold value of 0.1 as in Samanta-TC.

(2) ZR10-TR claim that Samanta-TC used coarser resolution (5x5km) satellite data and this may have somehow corrupted the results reported in Samanat-TC. They then start with higher resolution (1x1km) pixel observations and filter cloud and aerosol corrupted data in the same manner reported in Samanta-TC and obtain results from similarly coarse resolution (5x5 km) data sets that are different than those in Samanta-TC.

> (a) The coarser-resolution (5x5km) satellite data used in Samanta-TC are higher-quality official data sets *produced by experts* selected by NASA through a peer-review process.
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> (b) ZR10-TR repeated the same process, as these experts, in deriving the 5x5 km data sets from 1x1 km data sets. *This is a meaningless exercise on the part of ZR10-TR*.

(c) The difference between Samanta-TC (Fig. 1) and ZR10-TR (Fig. 1) is the following. In Samanta-TC, *only pixels with statistically significant trends were reported*. In ZR10 (Fig. 2) and in ZR10-TR (Fig. 1), the *pixel-level trends were not tested for statistical significance*.

(d) *Why show statistically significant trends in Fig. S2 (in SOM) of ZR10-TR but show all trends in Fig. 1?* That is misleading the reader. All further analysis should have been restricted to only those pixels showing statistically significant trends. Only 7% of the tropical forests and 6% of the Amazon forests show statistically trends in FPAR – one of the input variables to their mode - by their own calculation (Table S1 in SOM of ZR10-TR). *The minuscule NPP reductions they report should therefore not come as a surprise.*

(e) Moreover, the reported trends in NDVI, EVI, FPAR and NPP are extremely small (Fig. 2 in ZR10 and Fig. 1 in ZR10-TR). For example, the maximum negative trend in growing season vegetation absorbed photosynthetically active radiation (FPAR) is -0.009 per decade. The uncertainty of the MODIS FPAR data is 0.1 (absolute). Thus, *their maximum trend is lower than the error of the measurement*. That means that *measurement errors are greater than all the trends shown in Fig. 1 (Panels A) of ZR10-TR*. Probably the same is true in the case of NDVI and EVI.

(f) Coloring statistically insignificant and extremely small trends in bold red and blue colors (Fig. 2 in ZR10 for NPP and Fig. 1 for FPAR, NDVI and EVI in ZR10-TR), *convinces no one*.

**Temperature Sensitivity of ZR10 Model**

(1) *ZR10-TR agree with arguments in both Medlyn-TC and Samanta-TC* that their NPP model is overly sensitive to temperature – VPD, respiration and the Palmer Drought Severity Index – are all dependent on temperature.

(a) ZR10-TR however evade the point made in Samanta-TC (Supplementary Fig. S1) that *the relationship shown in Fig. 1 in ZR10 is essentially an artifact of this temperature sensitivity*. That is, the correlation between NPP anomalies and atmospheric CO2 growth rates at interannual scales is really a relationship between temperature and atmospheric CO2 growth rates. *Therefore, the claim in ZR10 that "global terrestrial NPP is a major driver of interannual CO2 growth rate" remains contested as per Samanta-TC*.

(b) *Table 2 in ZR10-TR supports arguments in Medlyn-TC that a more realistic representation of respiration dependence on temperature, one that is based on observations, greatly reduces the NPP trends*. For example, changing the Q10 from that used in their original report (ZR10; Control entry in Table 2 in ZR10-TR) to a more realistic value of 1.4 reduces the already minute NPP trend by factor of 10! Moreover, the percent of bootstraps with negative slopes decreases from 76.5% to 54.9%. That means, a realistic modeling of respiration alone would have produced half the vegetated pixels with declining NPP trends and the other half with increasing trends. Given that NPP varies greatly by vegetation type, and that the declining trend in their control run is already extremely small and statistically insignificant (0.1% per decade), *it is quite likely that they may have actually found a small increase, not decreasing, trend*. ZR10-TR concede as much, but claim, rather absurdly, that "However, none of these parameter combinations produce a positive NPP trend through our time period (Table 2)."

(c) ZR10-TR evade the issue of how changing the respiration dependence on temperature affects the relationship between NPP anomalies and atmospheric CO2 growth rates (Fig. 3). If anything, Fig. 3 shows rather dramatic changes in the interannual variability of NPP anomalies with changing respiration dependence on temperature. Moreover, the data stream from MODIS started only in late February 2000. So, at the very least, two months of critical data for the tropical and Southern Hemisphere vegetated lands were missing. Had they not used 2000 as the starting year, Fig. 3 in ZR10-TR would look quite different. In any case, *by not contesting the arguments in Medlyn-TC and Samanta-TC, they accept that their declining NPP trend is a consequence of their NPP model assumptions and that it does not reflect reality*.

**Validity of the NPP Model**

(1) The declines in terrestrial NPP reported in ZR10 were largely due to decline in Amazon rainforest NPP. Therefore, Samanta-TC tested the modeled NPP values against the best set of available field measurements from the Amazon region – the same data set that has been used by many investigators (Ref. 6 in ZR10-TR, for example). The ZR10 NPP model fared very poorly in this comparison (Table 1 in Samanta-TC).

(a) ZR10-TR rather than acknowledging the poor performance of their model in Amazon rainforests, raise irrelevant issues to confuse the discussion and try to argue that the field data are limited and of poor quality. This is a classic example of "*when the model compares poorly to data, then the data should be bad"*.

(b) ZR10-TR then embark on testing their model against another data set (Fig. 2). *But all the NPP values are less than 800 gC/m$^2$/yr – while tropical forests typically have NPP values greater than 1000 gC/m$^2$/yr. The Amazon forests in particular have NPP values between 1200 to over 1500 gC/m$^2$/yr.* If their drought-induced decline in NPP is due to Amazon rainforests, then they should test how well the model performs in those forests. That is exactly what Samanta-TC did and found that the model performed very poorly.

**Amazon Droughts**

(1) ZR10-TR perfunctorily dismiss Phillips's et al. careful analysis of field data from several long-term plots and conclusions published in "Science" (2009; Ref 6 in ZR10-TR) regarding the 2005 drought.

> (a) When it suited them, as in their original report (ZR10), however, *they leaned heavily on Phillips et al.'s results to support their model predictions* of Amazon rainforest NPP in 2005 and ascribing it to the 2005 drought.
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> (b) But, Samanta-TC showed that the reasons for NPP reductions in two studies as very different. *While not contesting Samanta-TC, ZR10-TR now twist Phillips et al's findings in an absurd manner* – The (biomass) losses driven by occasionally large mortality increases and by widespread but small decline in growth as "a signal more likely quantified by the satellite data than by isolated plot data."
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> (c) ZR10-TR evade the issue raised in Samanta-TC about how a short term anomaly due to a drought in 2005 can be interpreted as a declining trend. Instead, *ZR10-TR keep invoking temperature increases to explain declines in both drought (2005) and non-drought years (2006 and 2007)*.
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> (d) These arguments are contradictory. If temperature and VPD increases due to the 2005 drought are the mechanisms for the decline in NPP of Amazonian forests, then, in non-drought years, 2006 and 2007, how can the same mechanisms produce lower NPP. As argued in Medlyn-TC and Samanta-TC, this is precisely why their modeled NPP decline is an artifact – *an overwhelming sensitivity to temperature, which overrides other important dynamics (soil moisture, for example).*
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> (e) ZR10-TR mention the 2010 Amazon drought. All reports about this drought thus far suggest it to be more severe than the 2005 drought. ZR10-TR reports a 1.2% decline in global NPP in 2010 relative to 2009 (0.65 PgC). Again, this minute decline raises the same questions as their original report – *how credible is this number?*
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> (f) In Fig. S3 (in SOM) of ZR10-TC, they again show FPAR anomalies during the dry season of 2005 relative to 2000 to 2004. Samanta-TC shows both LAI and FPAR anomalies during the same dry season of 2005 but relative to the entire 2000 to 2009 period of the study (excluding 2005; SOM Fig. S2). *The results in Samanta-TC are thus mor rigorous.*

**NPP Reduction and Drought**

(1) In their original report, ZR10 argue that the declining NPP trend is due to droughts, demonstrating a correlation between NPP anomaly and the Palmer

Drought Severity Index (PDSI) anomaly.

(a) Medlyn-TC argued that the PDSI also incorporates a strong temperature dependence, because potential evapotranspiration is calculated as a function of temperature. The PDSI therefore decreases (more severe drought) as temperatures increase. 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*. ZR10-TR evade addressing this issue and cite various unrelated articles that purport to support their results (References 18 and 21 in ZR10-TR), just as they had cited Phillips et al.'s work in their original report when it suited them, but when contested, promptly changed the tune (see above under "Amazon Droughts").

**Gap Filling**

(1) ZR10-TR state that gap-filling is a common and accepted method to fill corrupted or missing satellite observations.

(a) However, they do not address the comments in Samanta-TC regarding the limitation of their simple linear interpolation method for gap filling, the accuracy of which varies with respect to the distance between the two valid values.

(b) The acceptance in ZR10-TR that gap-filled data were used to drive their NPP model, without an explicit analysis of errors/uncertainties *diminishes the scientific validity of the reported NPP trends*.