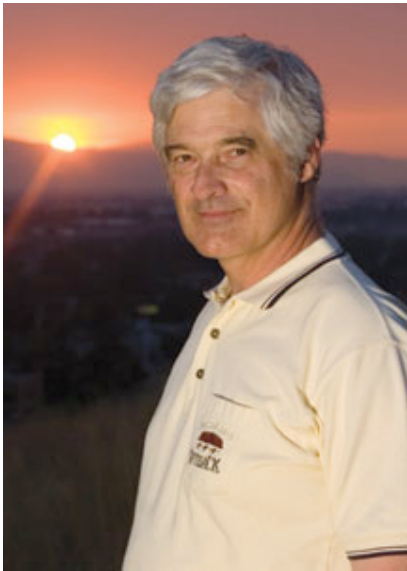


**Critique of**  
**“Drought-Induced Reduction in Global Terrestrial**  
**Net Primary Production from 2000 through 2009”**

**by**  
**Zhao and Running**  
**Science, Vol. 329, p. 940, August 2010**



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**Technical Comment Material Reviewed “positively” - good chance of being published in the next couple of months (hopefully).**

## The Set Up

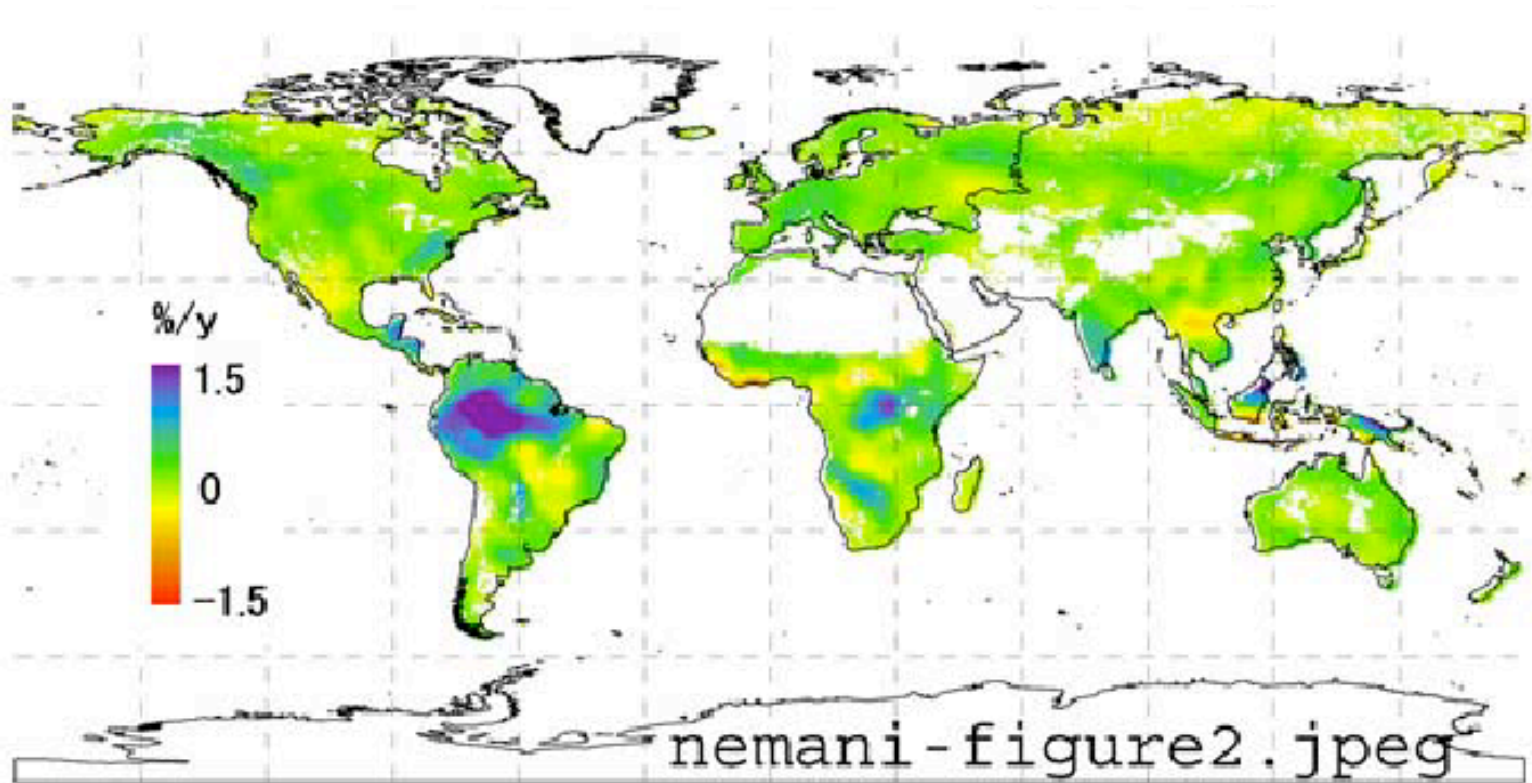
**“Terrestrial net primary production (NPP) quantifies the amount of Atmospheric carbon fixed by plants and accumulated as biomass.**

**Previous studies have shown that climate constraints were relaxing with increasing temperature and solar radiation, allowing an upward trend in NPP from 1982 through 1999.**

**The past decade (2000 to 2009) has been the warmest since instrumental measurements began, which could imply continued increases in NPP; however, our estimates suggest a reduction.**”

**Text taken ad verbatim from ZR10's abstract**

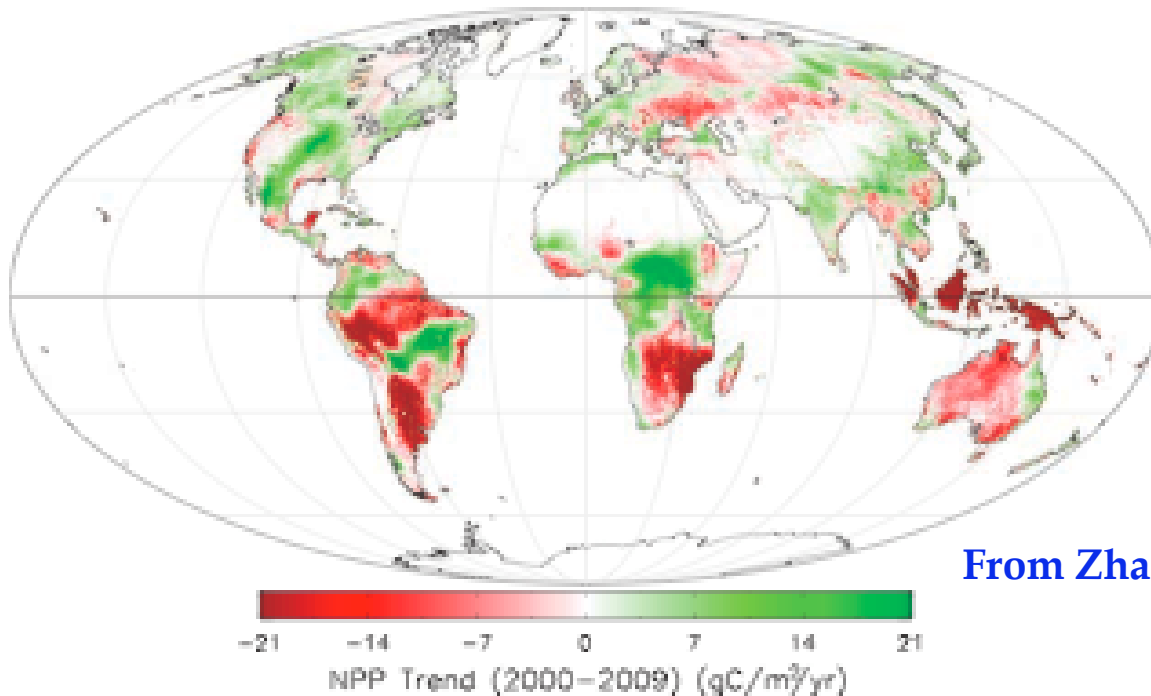
## Changes in Vegetation Net Primary Production: 1982-1999



From Nemani et al., (*Science*, 2003)

- Trends in NPP are [positive over 55%](#) of the global vegetated area and are statistically more significant than the [declining trends observed over 19%](#) of the vegetated area
- Due to [relaxation of climatic controls](#) on plant growth (radiation, temperature and precip)

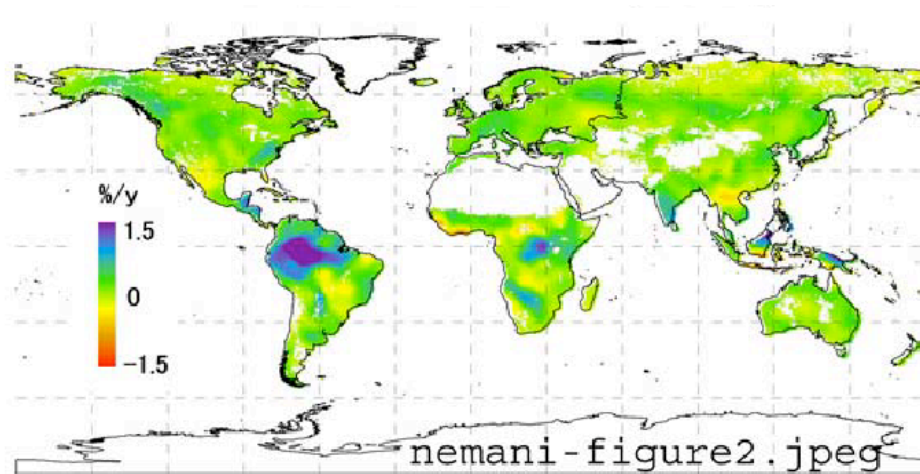
## Changes in Vegetation Net Primary Production: 2000-2009



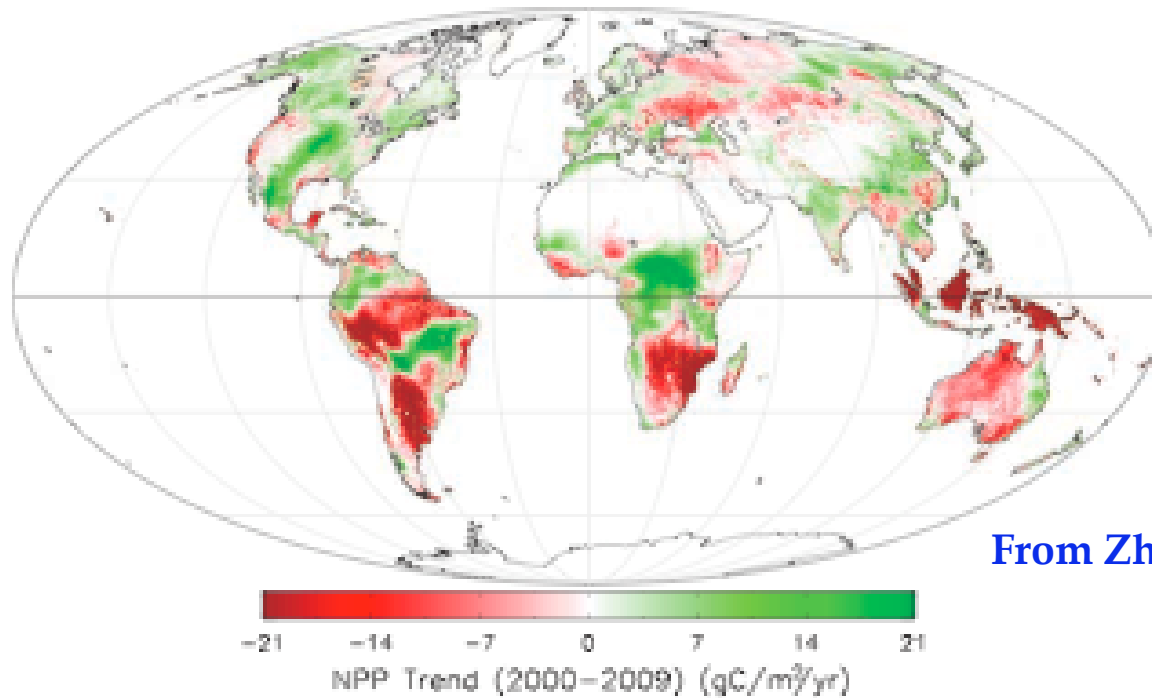
From Zhao and Running, (*Science*, 2010)

- Reduction in NPP of 0.55 billion tons of Carbon during 2000-2009
- Large droughts have reduced regional NPP (see, Amazon region for example)
- A drying trend in the Southern Hemisphere has decreased NPP there
- There was slight increasing trend in Northern Hemisphere

## Changes in Vegetation Net Primary Production



From Nemani et al., (*Science*, 2003)



From Zhao and Running, (*Science*, 2010)

## The Gossip

- Six Technical Comments were submitted to *Science*
- The authors responded to each of them separately
- The Technical Comments and Author's Responses were peer-reviewed
- Based on the peer-review, the Author's Responses were deemed adequate in case of three Technical Comments - end of story.
- The other three Technical Comments were asked to be “finalized” in light of peer review reports
- These three “Final” versions of the Technical Comments were sent to the authors along with peer review reports of their initial response
- The Authors were asked to finalize their Response as one piece
- All of this is now at *Science*, awaiting a final decision

## General Critique of Zhao and Running

- Zhao and Running reported an extremely small reduction, 0.55 petagrams of carbon (Pg C), in global terrestrial net primary production of 535.21 Pg C over a ten-year period, or **0.1%**
- This decline is due to a drying trend in the **Southern Hemisphere** that decreased NPP by 1.83 Pg C (**0.34%**), and which was counteracted by increased NPP in the **Northern Hemisphere** by 1.28 Pg C (**0.24%**).
- These small changes raise the obvious question – how credible are these numbers and the reported regional patterns?
- The Amazonian forests present a good test case to assess Zhao and Running because of some field NPP measurements scaled to test the NPP model are available and the dominant role these forests play in reported NPP trends and interannual variability (66%).

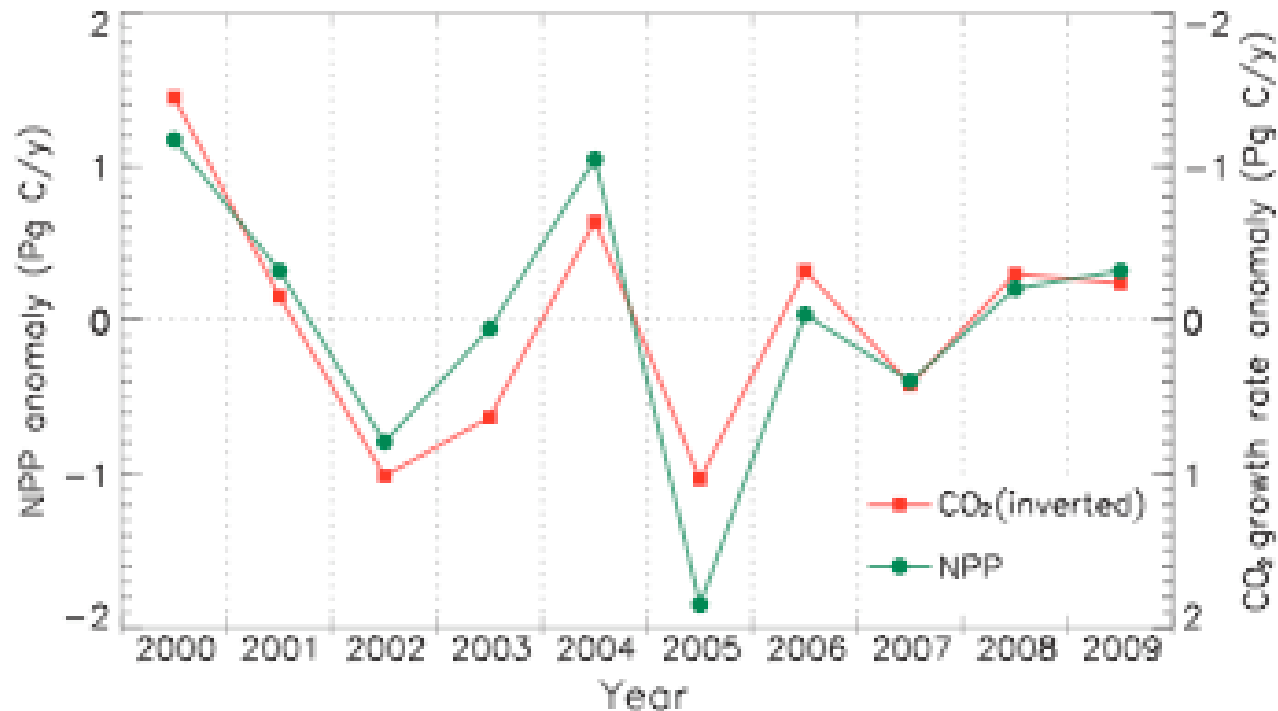


## Comparison of Model and “Field NPP Measurements”

Site	Period	Observed NPP	Zhao and Running (1)	
		(kg-C m <sup>-2</sup> yr <sup>-1</sup> )	(kg-C m <sup>-2</sup> yr <sup>-1</sup> )	Error (%)
KM67	2001	1.230	0.832	-32.36
KM67	2004	1.055	0.733	-30.52
ZF-2	2001	1.063	0.779	-26.72
ZF-2	2002	1.356	0.703	-48.16
UFAC	2001	1.343	0.997	-25.76
UFAC	2002	1.299	0.925	-28.79
BA712	2006	1.366	1.519	11.20
AGP (AGP-01 and AGP-02)	2004-2006	1.148	1.000	-12.28
CAX (CAX-06 and CAX-08)	2004-2006	1.396	0.737	-47.21
TAM (TAM-05 and TAM-06)	2005	1.534	2.028	32.20
ZAR-01	2004-2006	0.930	1.042	12.04

- Zhao and Running’s NPP estimates **differ** from field measurements by **28%**
- They generally **underestimate by 31%** and **overestimate** in a few cases by **18%**
- This does **not give confidence** in their modeled NPP estimates

## Correlation between NPP and CO2 Growth Rates



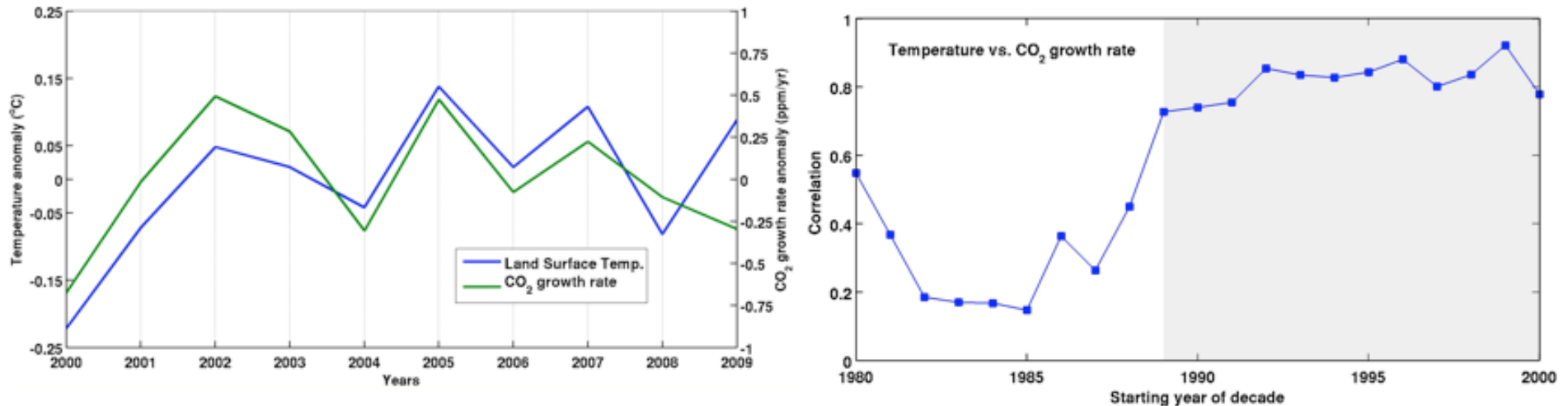
- Zhao and Running report a [spectacular correlation](#) between interannual variations in their modeled net primary production and atmospheric CO2 growth rate ( $r = -0.89$ ,  $p < 0.0006$ ).
- They argue that this correlation suggests that global vegetation net primary production is a [major driver](#) of the interannual CO2 growth rate.
- **Is this true?**

## Correlation between NPP and CO2 Growth Rates

Evergreen Needle Forests	-0.29
Evergreen Broadleaf Forests	-0.59** (p<0.1)
Deciduous Needle Forests	-0.71* (p<0.05)
Deciduous Broadleaf Forests	-0.42
Mixed Forests	-0.63* (p<0.05)
Closed Savannas	-0.11
Open Savannas	-0.78* (p<0.05)
Woody Savannas	-0.71* (p<0.05)
Savannas	-0.92* (p<0.05)
Grasslands	-0.85* (p<0.05)

- In fact, we observe statistically significant correlation between interannual variations in net primary production of several vegetation classes and atmospheric CO2 growth rate
- This correlation is observed even in the case of vegetation types that contribute very little to global net primary production (grasslands or deciduous needle forests, for example)
- So, it is not net primary production but some variable driving net primary production that is really correlated with atmospheric CO2 growth rates at interannual scales!

## Correlation between Temperature and CO2 Growth Rates



- Interannual variations in temperature are significantly correlated with interannual variations in atmospheric CO<sub>2</sub> growth rate (left panel;  $r = 0.73$ ;  $p < 0.05$ )
- The 10-year correlation was low during the early 1980s but began to increase after mid 1980s reaching a high value in late 1980s and stayed high thereafter (right panel)
- Zhao and Running's model is highly sensitive to temperature. When temperature goes up, net primary production goes down (higher respiration rates) and vice versa, especially in warmer regions.
- The model faithfully translated interannual variations in temperature to variations in net primary production. Thus, **the suggestion that interannual variations in net primary production are a major driver of atmospheric CO<sub>2</sub> growth rate variations is not true!**

## Dr. Belinda Medlyn's Comments

$GPP\_OPTIMAL = FAPAR * INCIDENT\_PAR * LIGHT\_USE\_EFFICIENCY$

$GPP\_ACTUAL = GPP\_OPTIMAL * TEMP\_SCALAR * VPD\_SCALAR$

TEMP\_SCALAR and VPD\_SCALARS are NUMBERS BETWEEN 0 and 1

“The two modifier terms represent assumptions that productivity is reduced by

(i) low temperatures ( $T_{min} < 8 - 12 \text{ }^{\circ}\text{C}$ ) and

(ii) high vapour pressure deficit ( $VPD > 0.65 - 0.8 \text{ kPa}$ ).

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.”

## Dr. Belinda Medlyn's Comments

$$\text{NPP} = \text{GPP\_ACTUAL} - \text{AUTOTROPHIC RESPIRATION}$$

“The supplementary material (Text S1) 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 which compared the short-term (not acclimated) Q10 of respiration across biomes (Tjoelker et al. 2001). This function gives a stronger effect of temperature on respiration than previously, with a Q10 that ranges between 2 and 3.22.

In contrast, work on temperature acclimation indicates that long-term Q10 values are considerably less than 2 (Atkin et al. 2005, 2008).

Thus, ZR10 are assuming a strong temperature dependence of respiration, and consequently, a strong negative effect of temperature on modelled NPP.”

## Dr. Belinda Medlyn's Comments

“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 modelled 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.”

## Amazon Forests NPP Changes: 2000-2009

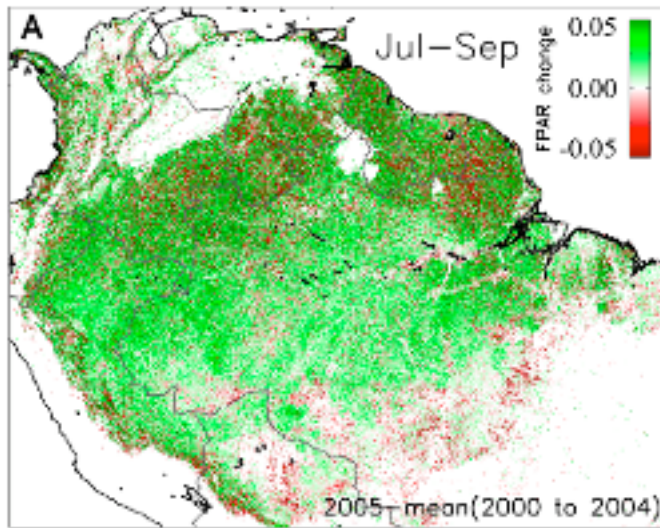
Table S4. 10-year (2000-2009) NPP (PgC/yr) for the globe, tropics, tropical rainforests and three major regional tropical rainforests [Amazon, Africa and Asia (Figure S11)].

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Globe	54.692	53.841	52.727	53.465	54.565	51.672	53.557	53.123	53.725	53.841
Tropics	30.089	28.850	28.153	28.423	29.249	26.419	28.615	27.890	28.708	29.090
Tropical rainforests	16.207	15.525	15.677	15.808	15.963	14.625	15.138	14.915	15.319	15.608
Amazon rainforests	7.984	7.363	7.439	7.530	7.621	6.883	7.117	7.096	7.489	7.518
African rainforests	2.566	2.720	2.625	2.722	2.672	2.513	2.624	2.732	2.766	2.868
Asian rainforests	4.134	3.986	4.216	4.167	4.249	3.863	3.977	3.639	3.628	3.809

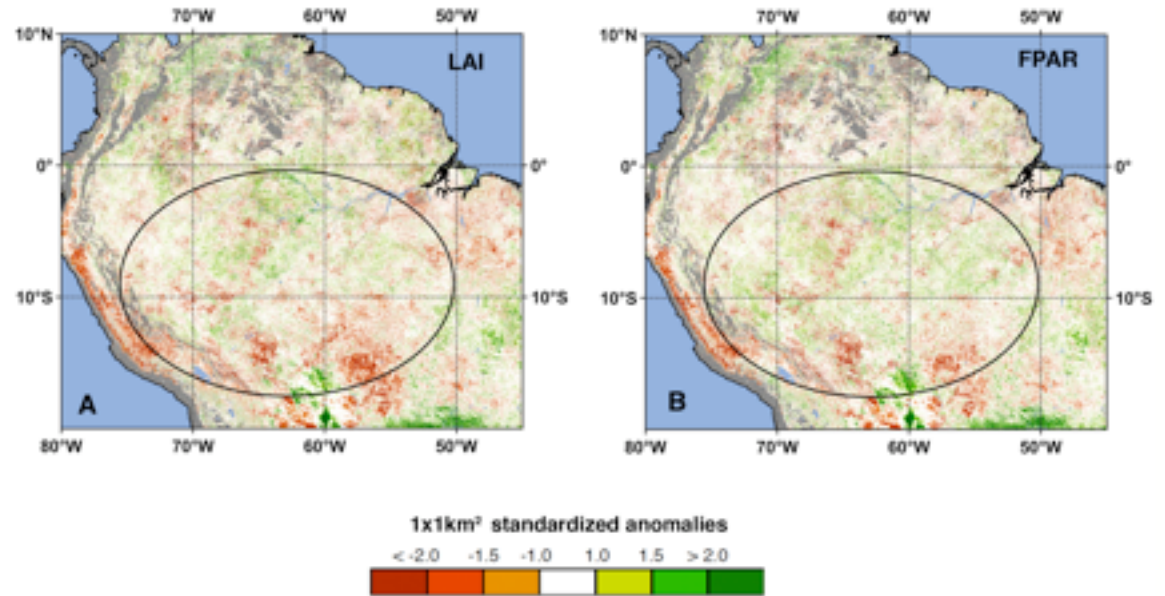
- **Low NPP in 2005** - attributed to drought (cite Phillips et al. (2009) as evidence)
- **Also low NPP in 2006 and 2007** - why? No reasons given (lingering drought effects)
- Difference in NPP between 2000 to 2004 and 2008 to 2009 is only 1.1% which suggests the forests have **recovered** from the impacts of 2005 drought
- Zhao and Running present this short term (3 year) low NPP anomaly (-6%) as a **ten year declining trend** - this is the kind of **misleading** results one can obtain when working with short term data sets



## Amazon Forests FPAR Changes

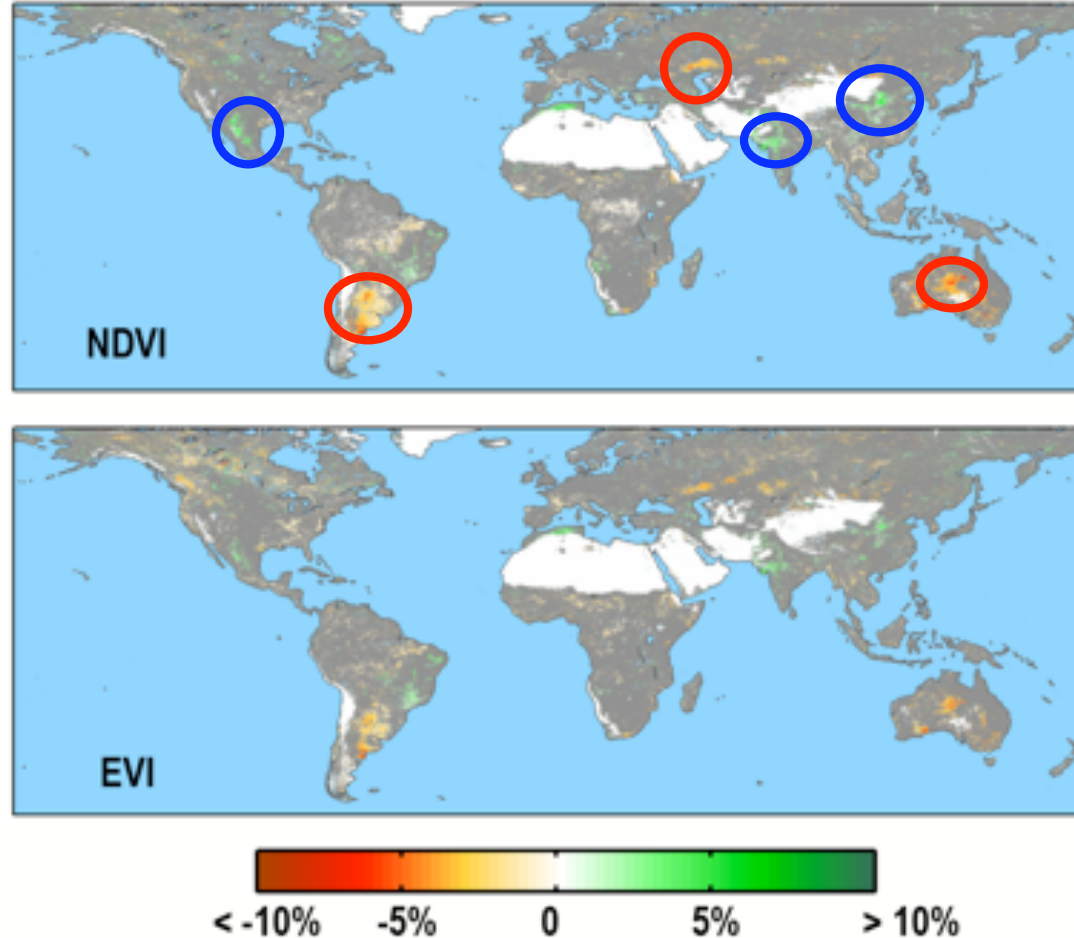


(Zhao and Running, 2010)



- The NPP model uses MODIS [LAI and FPAR](#) products as inputs
- Zhao and Running report [greening](#) of the Amazon region during the drought of 2005!
- However, our analysis of the same data, filtered for atmospheric corruption due to clouds and aerosols shows [no greening](#)
- We believe that Zhao and Running's NPP estimates are [incorrect](#) due to using [unfiltered and/or gap-filled](#) LAI and FPAR data as inputs

## Direct Evidence of Changes: 2000-2009



- 86% of all vegetated land south of 70°N shows no trends
- About 8 to 9% show declining trends, in three non-forested regions - the Eurasian steppes, Argentina and central Australia
- The remaining 3 to 4% show a slight greening trend, visible consistently in Mexico, Northwest India and North central China
- Direct observations of vegetation activity do not show any large-scale declines

## Dr. Belinda Medlyn's Comments

- “ZR10 have not shown, as claimed, that terrestrial NPP has decreased over the last decade.
- Rather, they have shown that, if NPP was affected by climate in the way specified by the model, then NPP would have declined over the last decade.
- It is **important** to make this distinction, because otherwise we run the risk of mistaking model outcomes for reality.”

## FINAL REMARKS

- Papers published in *Science*, *Nature*, *PNAS*, etc. are **NOT** necessarily “better” than those published in **technical journals**
- Be **critical** of any scientific work
- Science is **fun** - your 100th paper is as **likely to be refused** for publication as your 1st paper