



**Uncertainty related to biological
nitrogen fixation increases terrestrial
carbon cycle uncertainty**

**Will Wieder, Cory Cleveland,
David Lawrence, Gordon Bonan**



N Inputs



96%

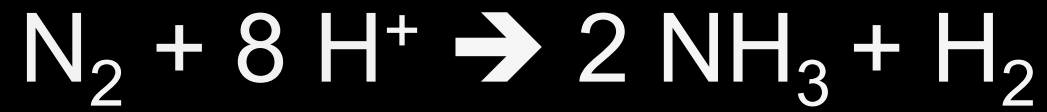
Cleveland *et al.* 2013

N Fixation

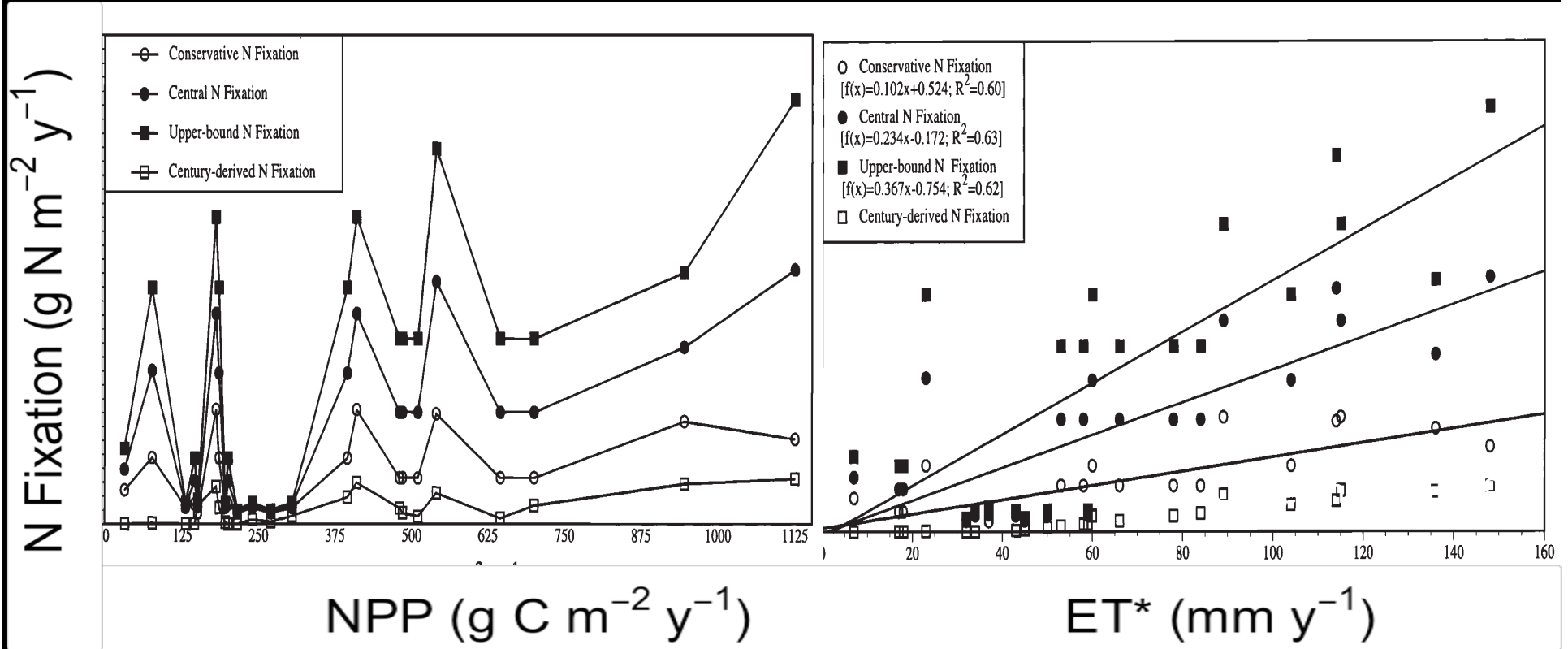


Photos: B. Sullivan

Why not everywhere?



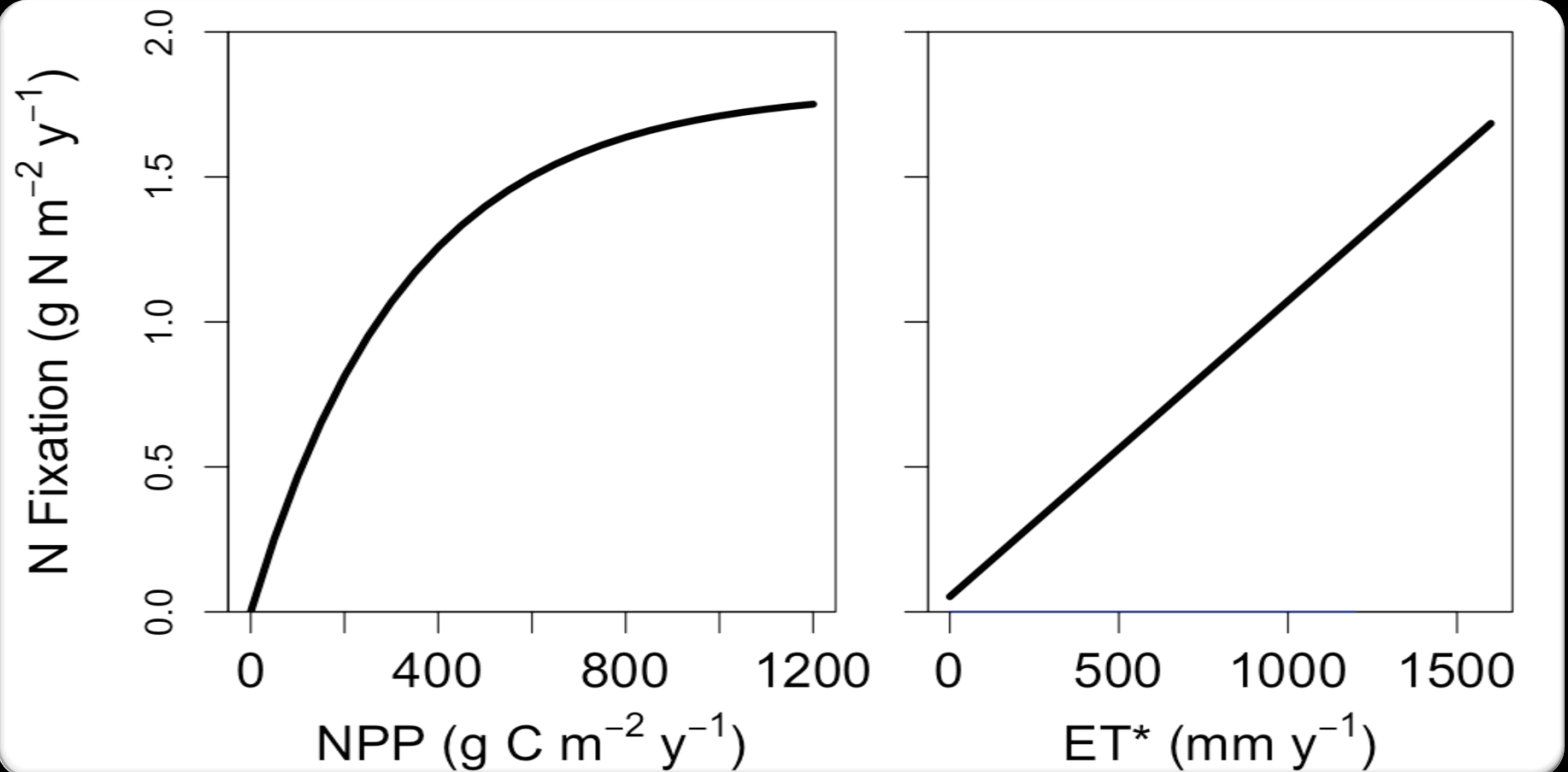
BNF observations



100 – 290 Tg N y⁻¹ Cleveland *et al.* 1999

40 – 100 Tg N y⁻¹ Vitousek *et al.* 2013

Structural Uncertainty

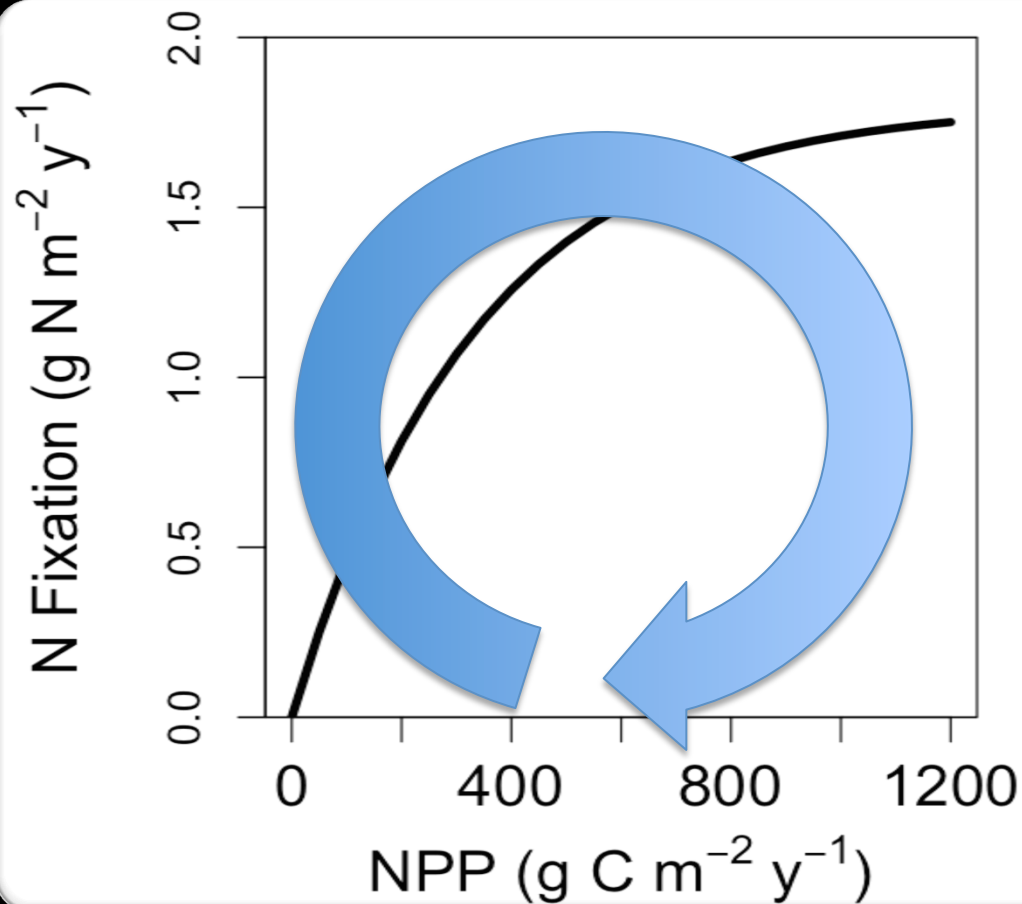


CLM4cn, CLM4.5bcg*
JSBACH*
UVic*

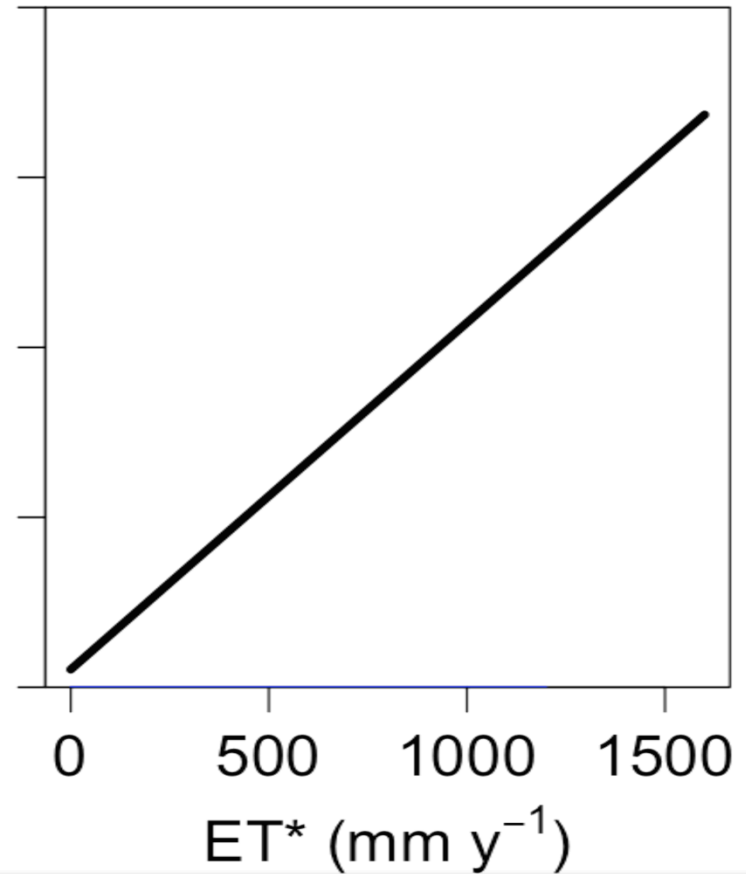
CENTURY*
ISAM*
OC-N*
UVic*

*Cleveland et al. 1999

Structural Uncertainty



CLM4cn, CLM4.5bcg*
JSBACH*
UVic*



CENTURY*
ISAM*
OC-N*
UVic*

*Cleveland et al. 1999

Motivation

“The current (CLM4cn) treatment of biological nitrogen fixation is entirely empirical... model response to increasing CO₂ is not particularly sensitive to the parameterization of this process (BNF)....”

Thornton et al. 2007

Is the same true in CLM4.5?

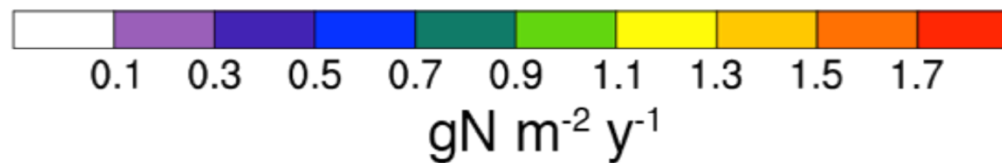
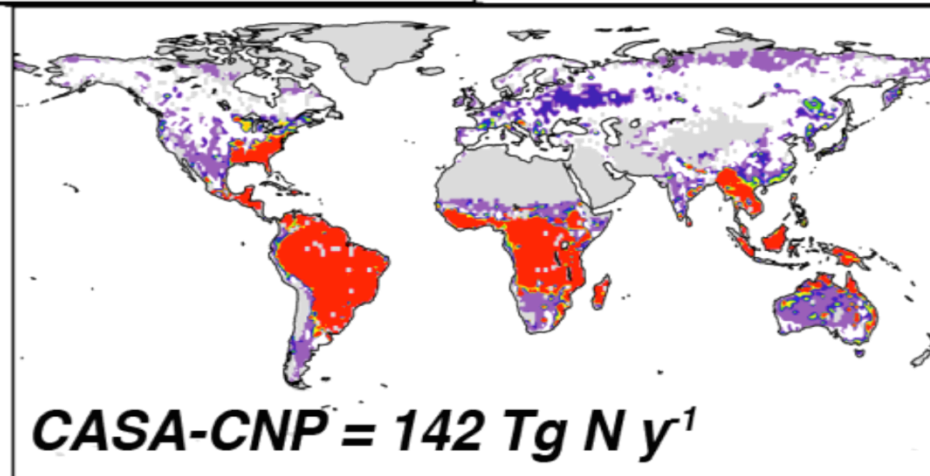
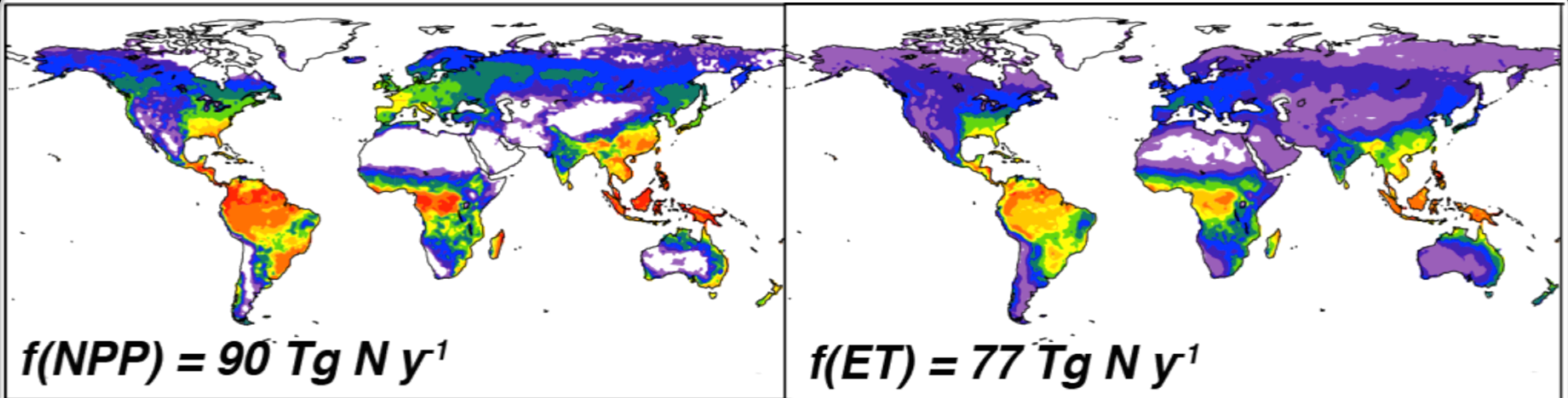
Methods

- “Spun-up” 1850 CLM4.5bgc
- + 500 years w/ $BNF = f(NPP | ET)$
- 1850-2005 Cru-NCEP
 - Transient land cover, CO₂, Climate
- 2006-2100 w/ RCP 8.5 anomaly forcing

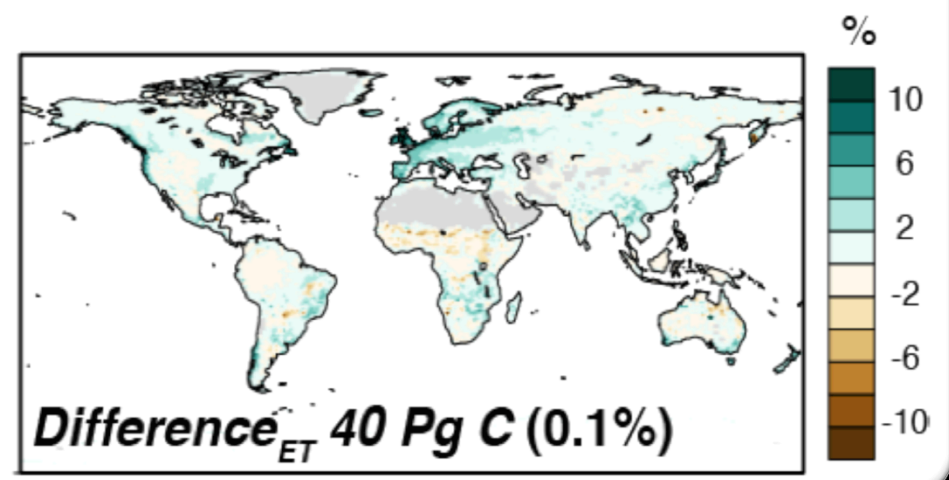
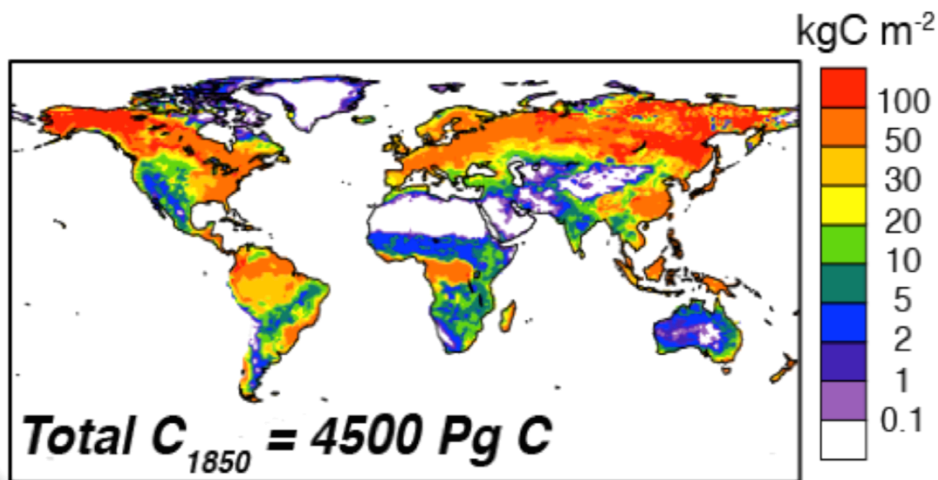
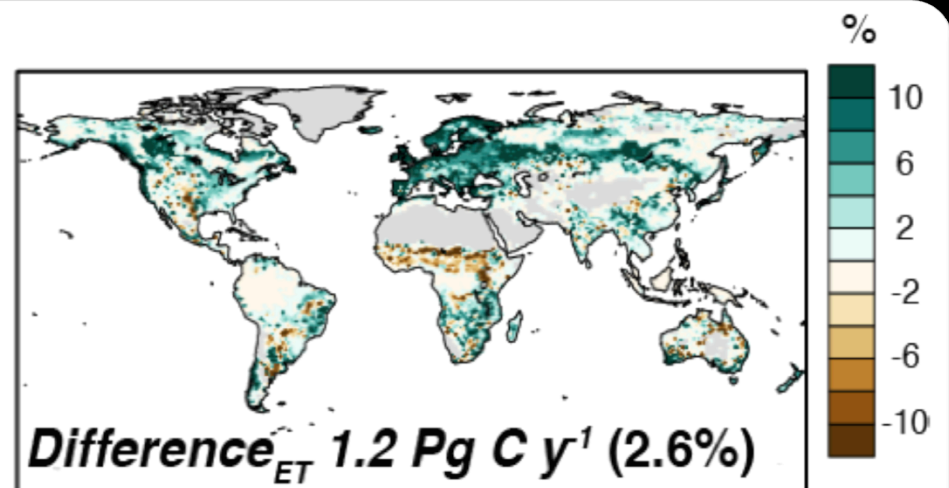
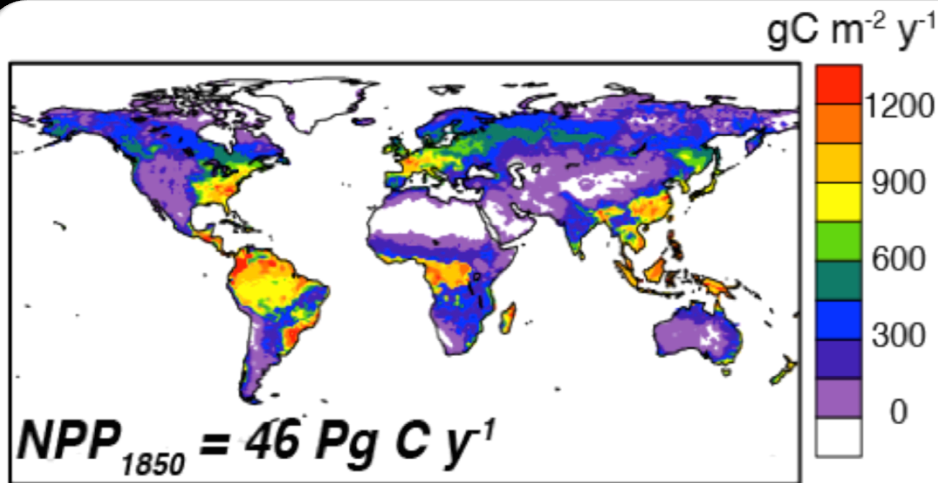
Koven *et al.* 2015

Spin-up

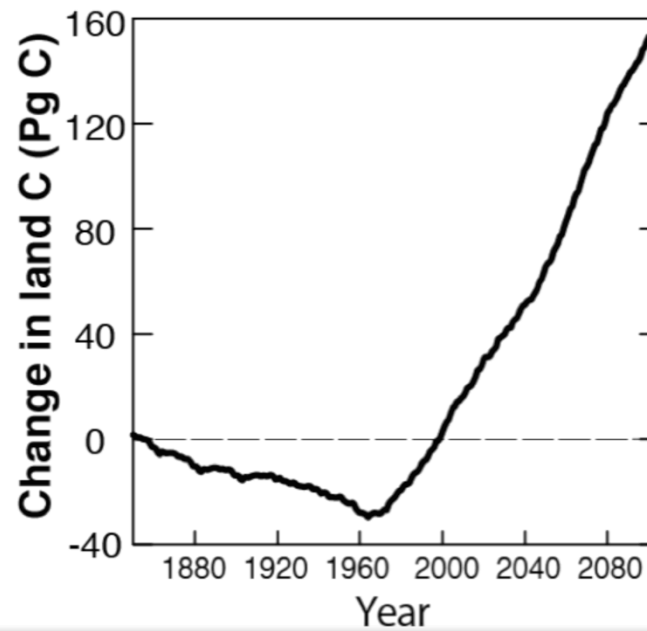
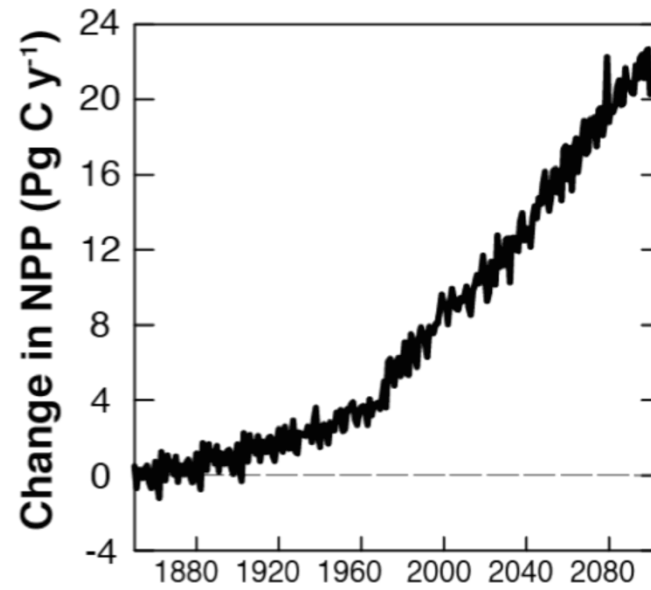
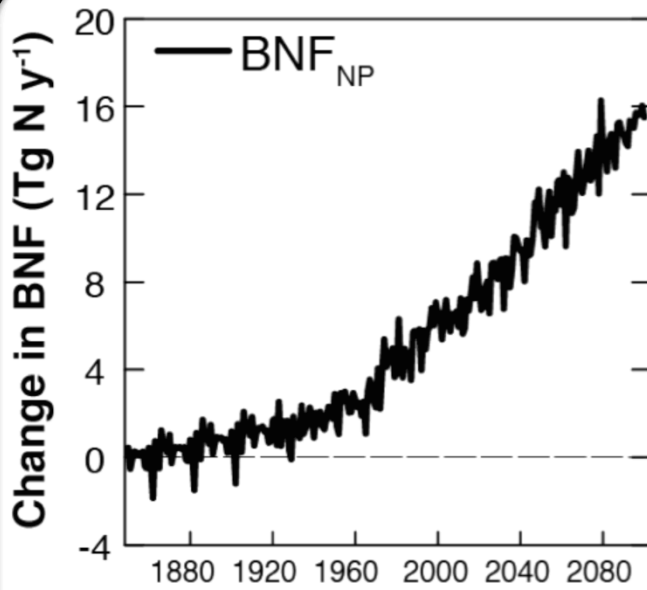
"obs" BNF= 40-290 Tg N y⁻¹



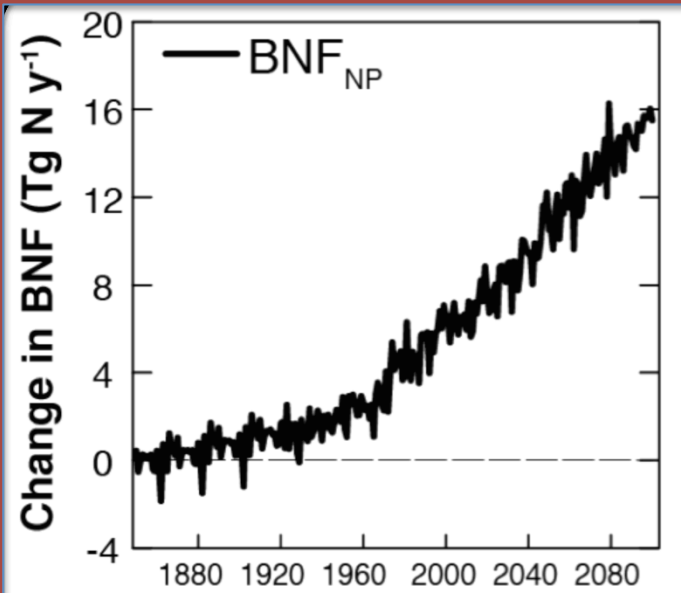
Spin-up



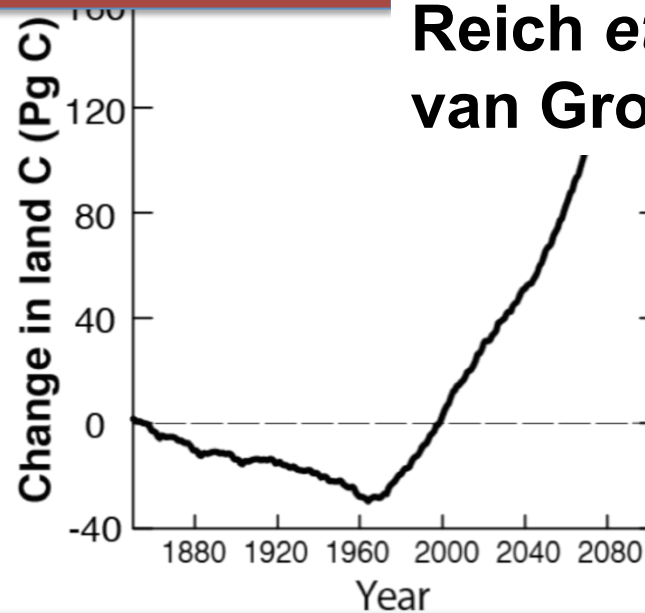
Transient



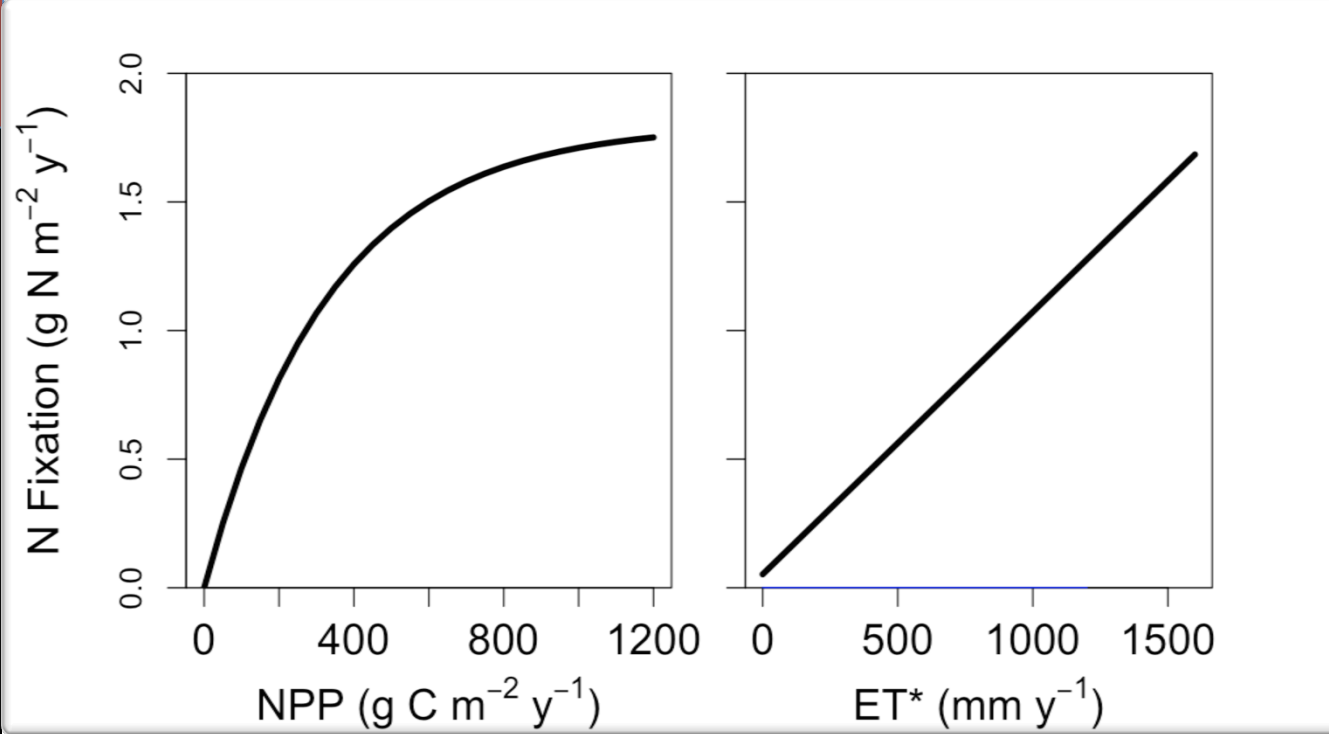
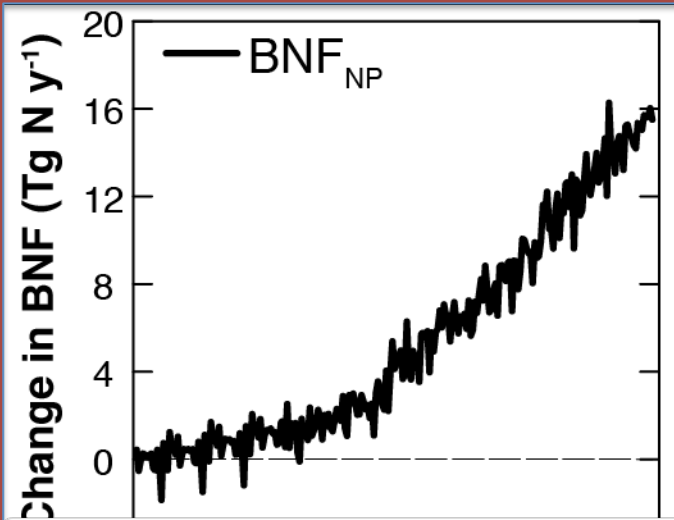
Transient



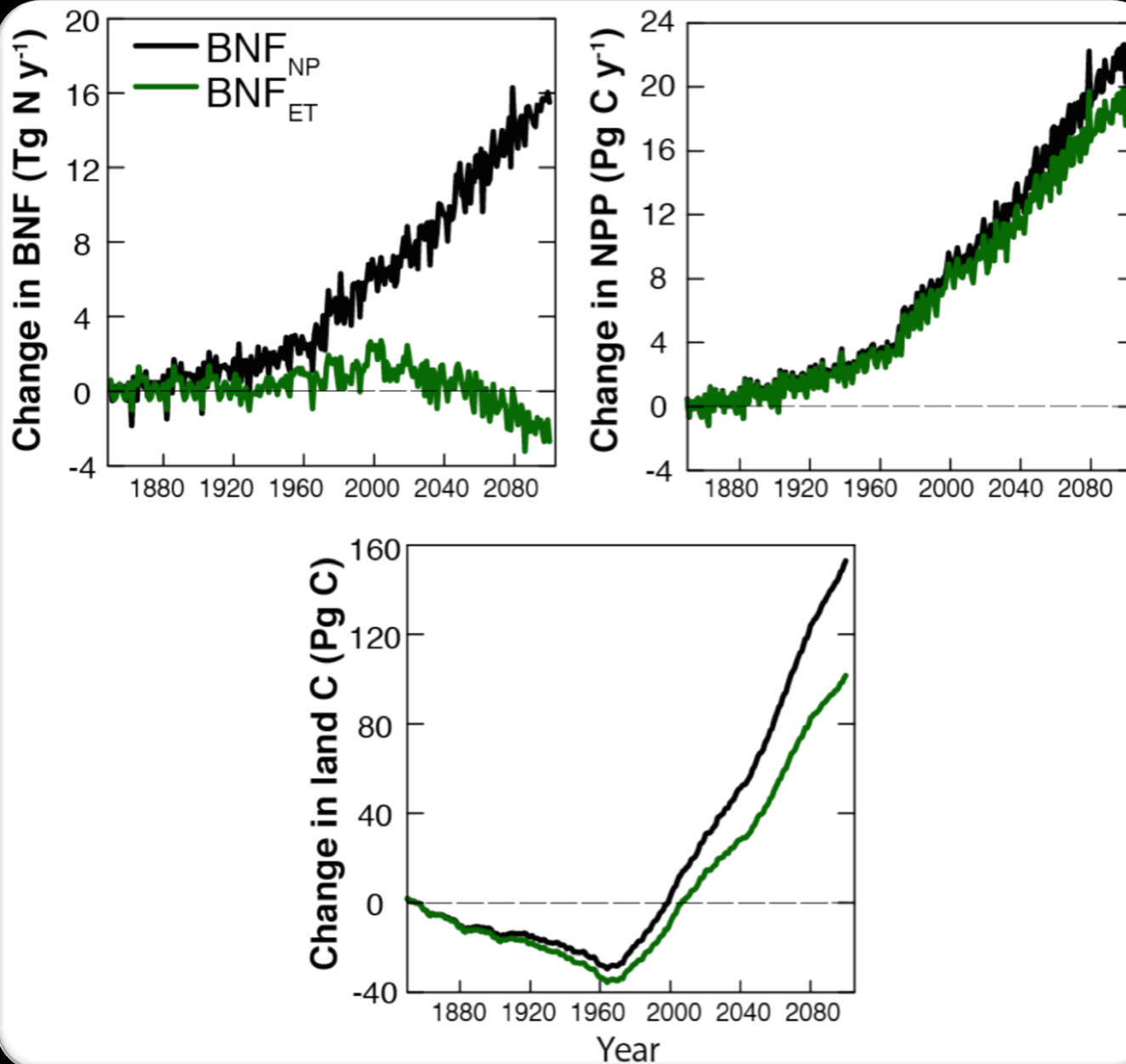
**Hungate *et al.*, 2004, 2013;
Reich *et al.*, 2006, 2013;
van Groenigen *et al.*, 2006**



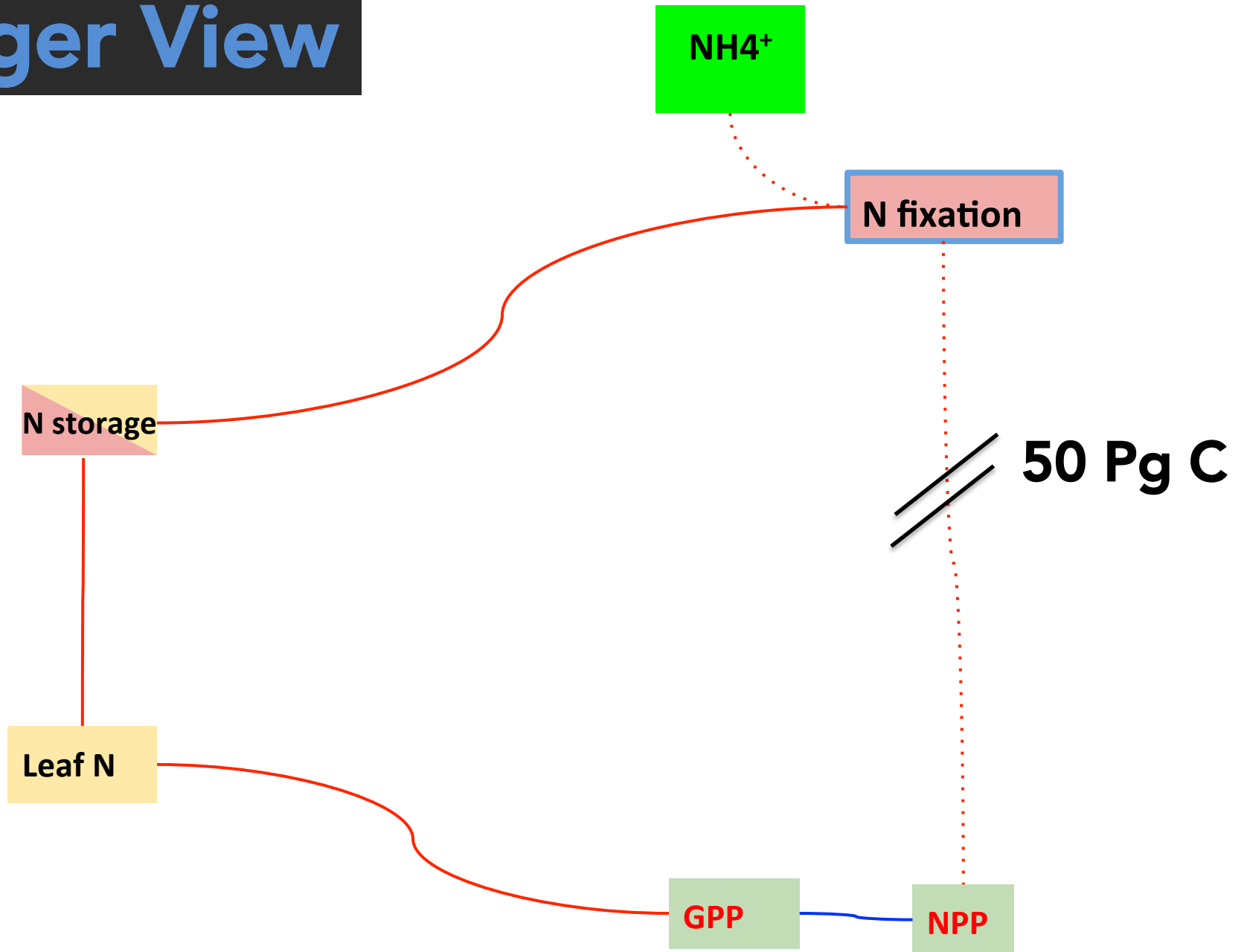
Transient

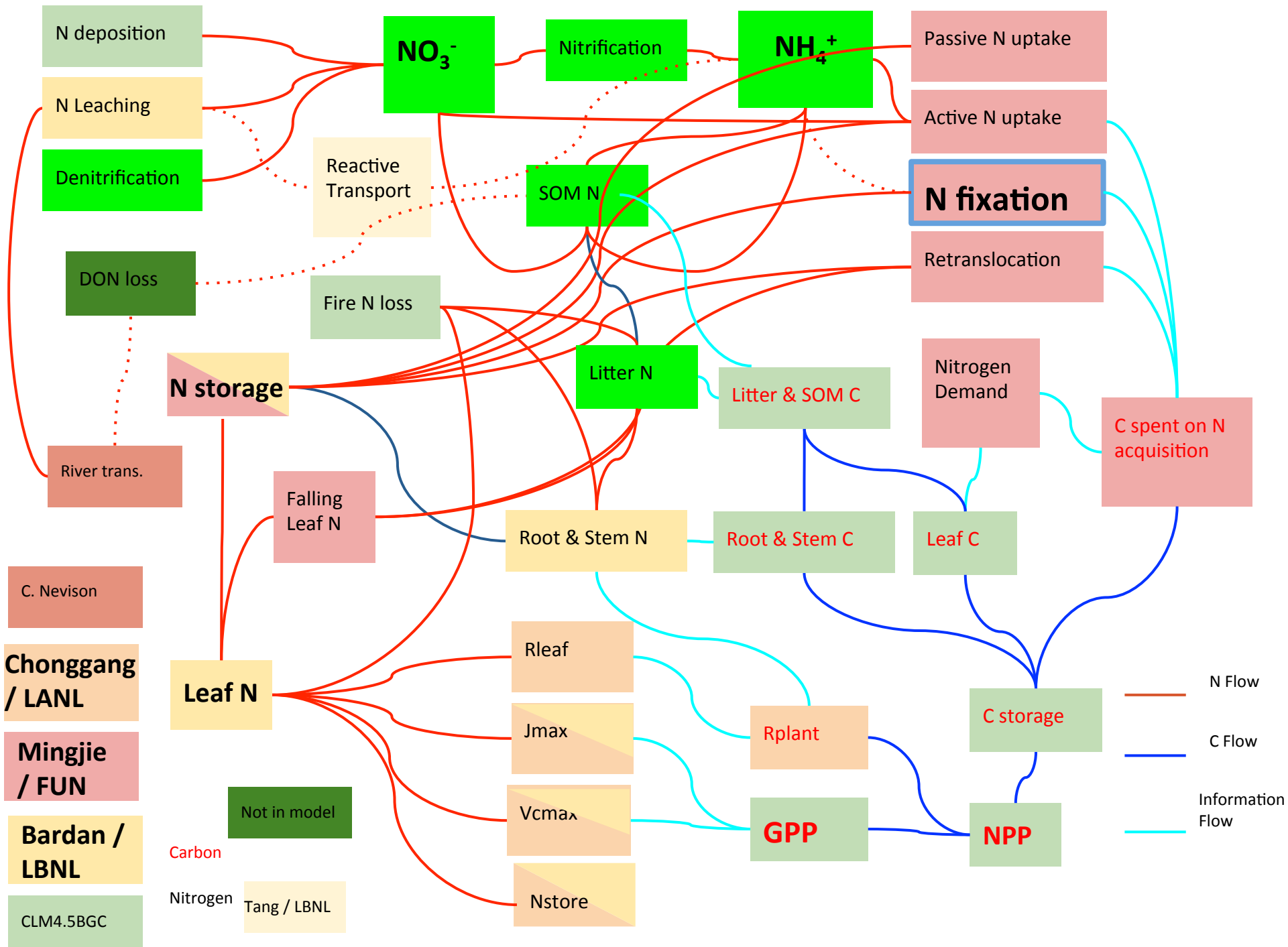


Transient

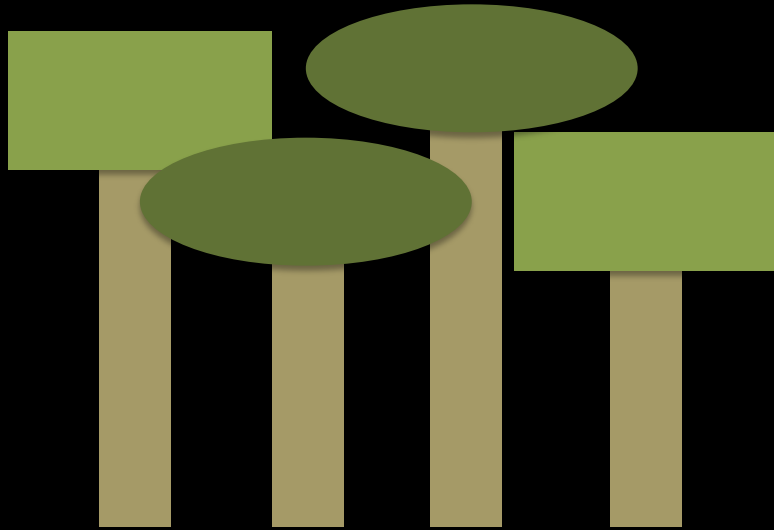


Larger View





CLM-FUN-ED



FUN.

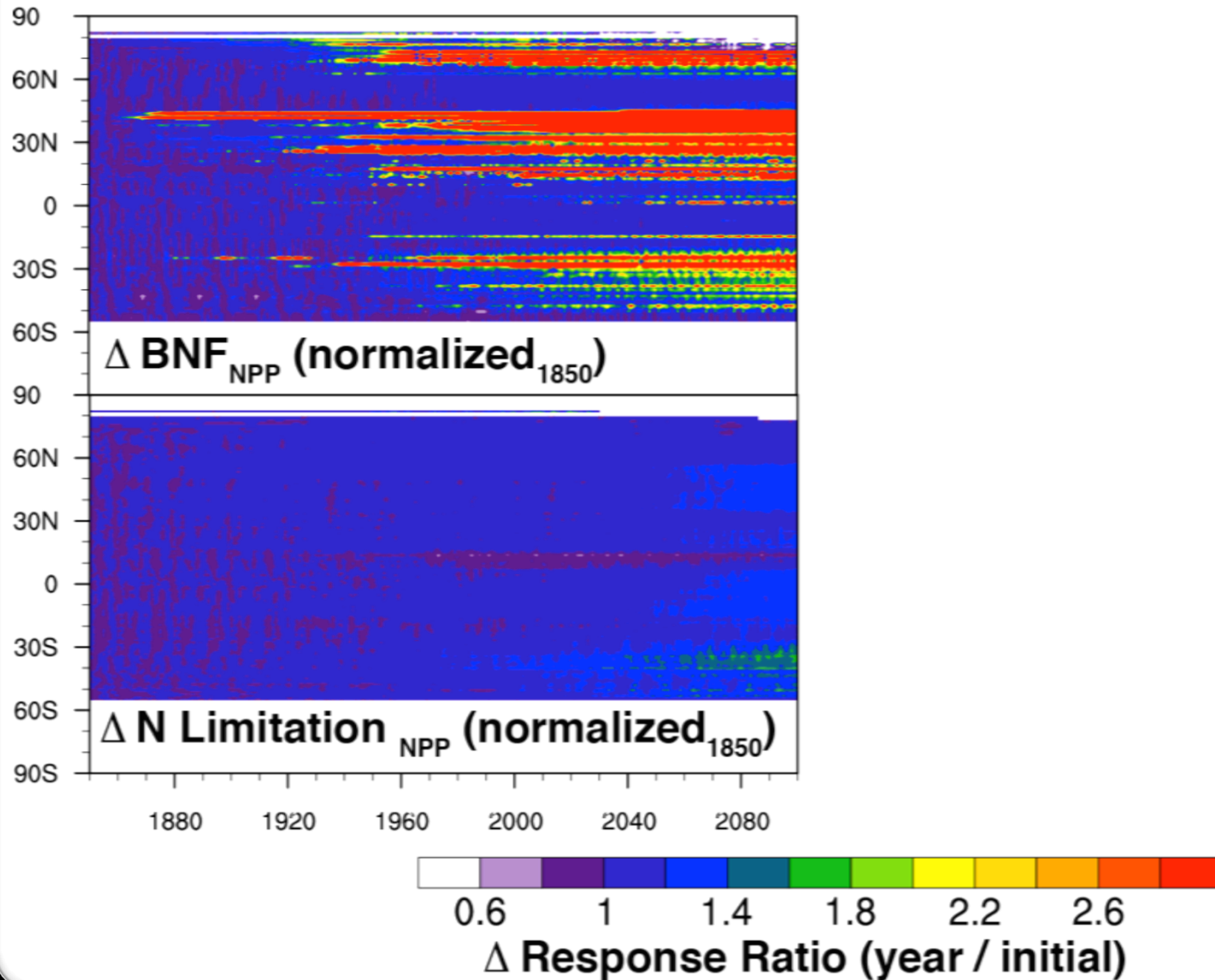


**BNF = $f(N,$
Light,
Disturbance,
Plants,
Microbes,
*P)***

N Losses?
N Transformations?
C to Soils?

N Limitation?

$$\text{BNF} = f(\text{NPP})$$



N Limitation?

$$\text{BNF} = f(\text{NPP})$$

$$\text{BNF} = f(\text{ET})$$

