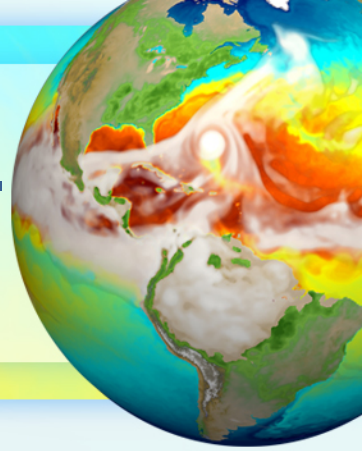
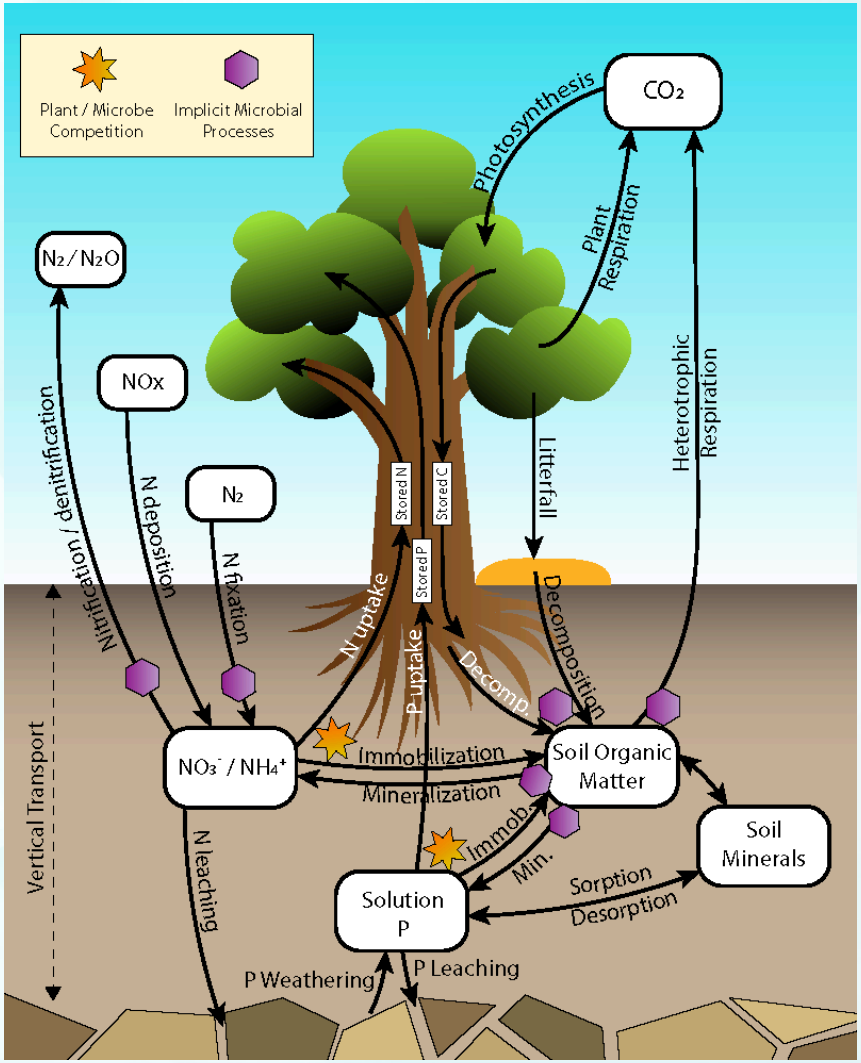
Global benchmarking of ELM v1 – ILAMB and beyond



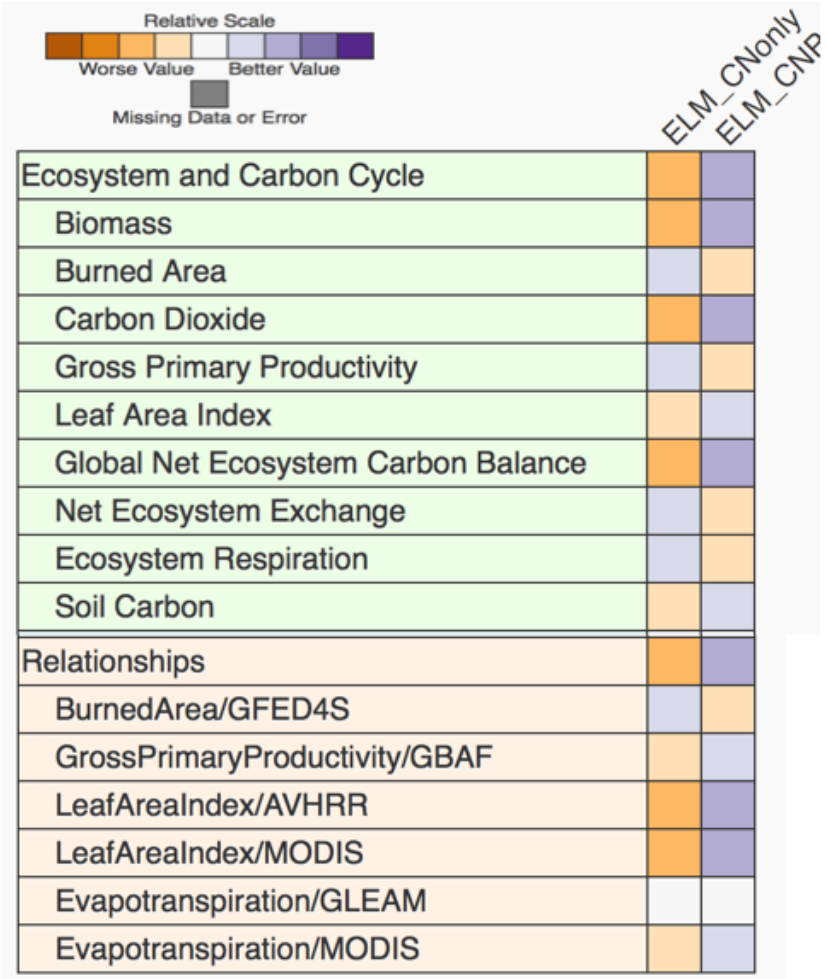
Xiaojuan Yang, Peter Thornton, Dan Ricciuto, Forrest Hoffman
Oak Ridge National Lab, Oak Ridge, TN 37831

E3SM Land Model v1

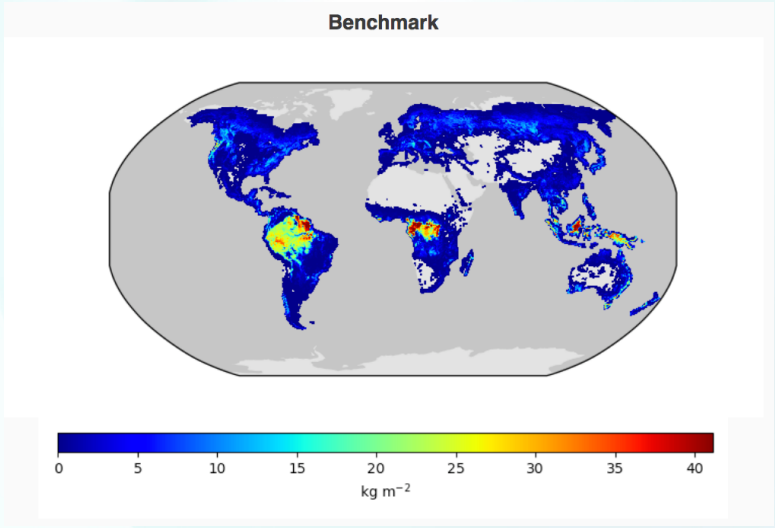


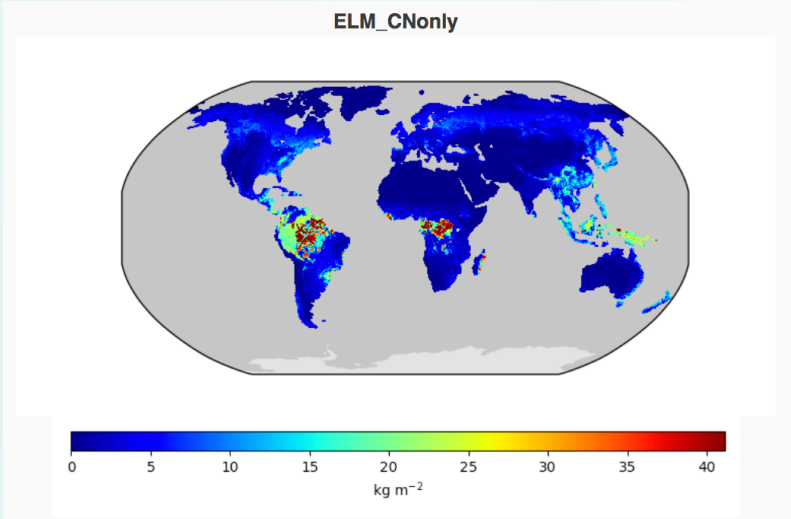
- Introduction of a prognostic phosphorus cycle and C-N-P interactions
- Representation of dynamic storage pools for C, N and P
- Global P maps for model initialization
- Representation of edaphic factors on mortality rate
- Representation of the competition between plants and microbial process for available soil N and P

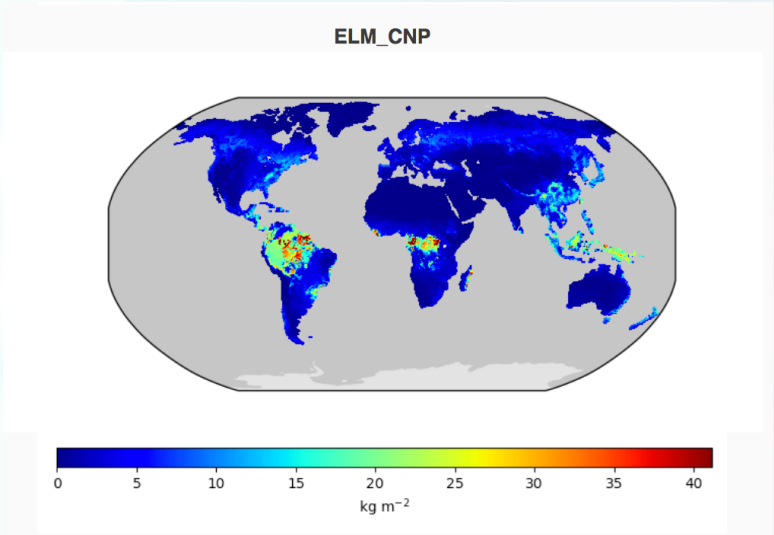
Implementation of P generally improves model performance



Implementation of P improves simulated spatial distribution of biomass

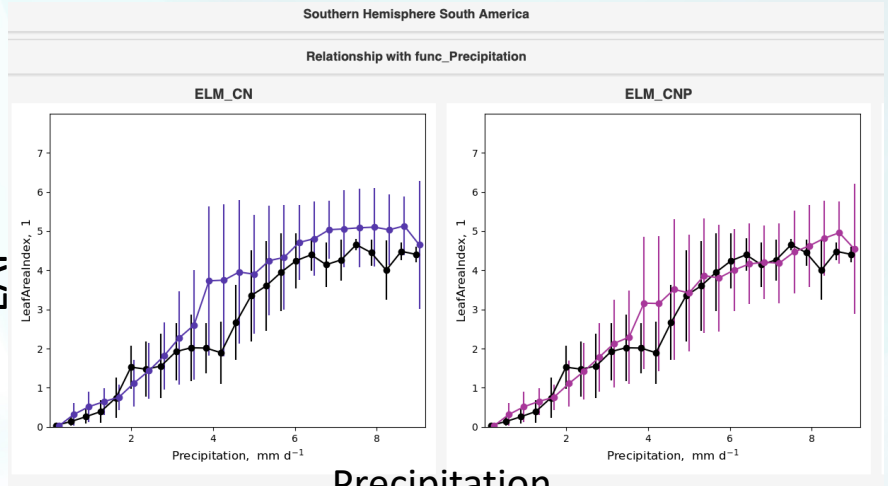






	Download Data	Period Mean (original grids) [Pg]	Model Period Mean (intersection) [Pg]	Model Period Mean (complement) [Pg]	Benchmark Period Mean (intersection) [Pg]	Benchmark Period Mean (complement) [Pg]	Bias [kg m-2]	Bias Score [1]	Spatial Distribution Score [1]	Overall Score [1]
Benchmark	[-]	451.								
ELM_CNonly	[-]	632.	612.	20.1	446.	4.91	1.87	0.655	0.917	0.786
ELM_CNP	[-]	578.	558.	19.3	446.	4.91	1.27	0.688	0.924	0.806

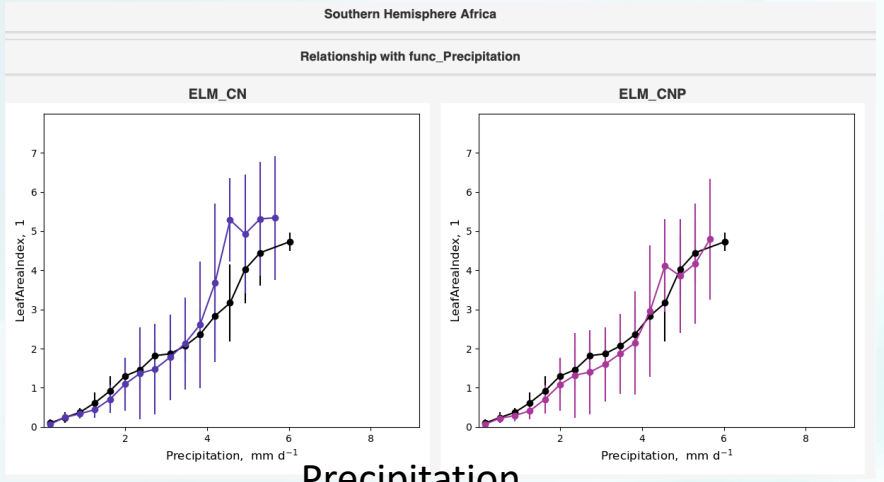
Implementation of P improves simulated functional relationships, particularly in tropical regions



LAI

Precipitation

South America

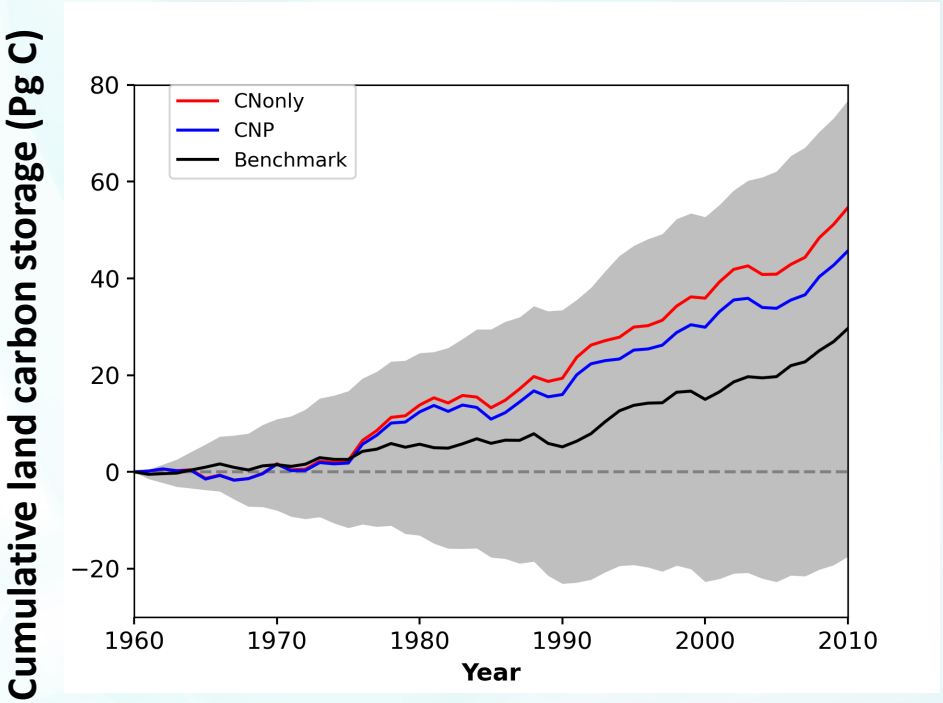


LAI

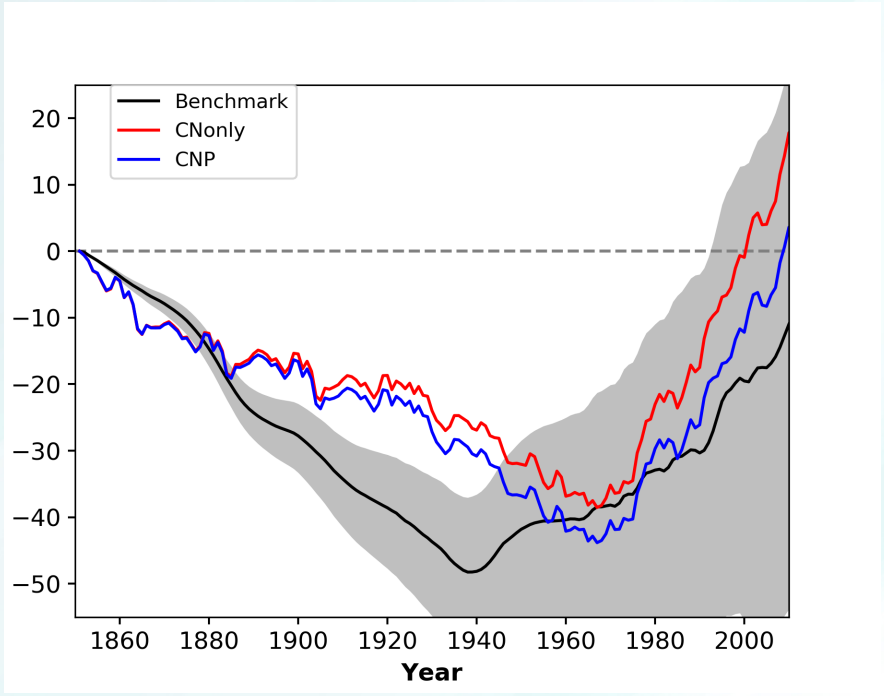
Precipitation

Tropical Africa

Implementation of P improves simulated historical land carbon accumulation

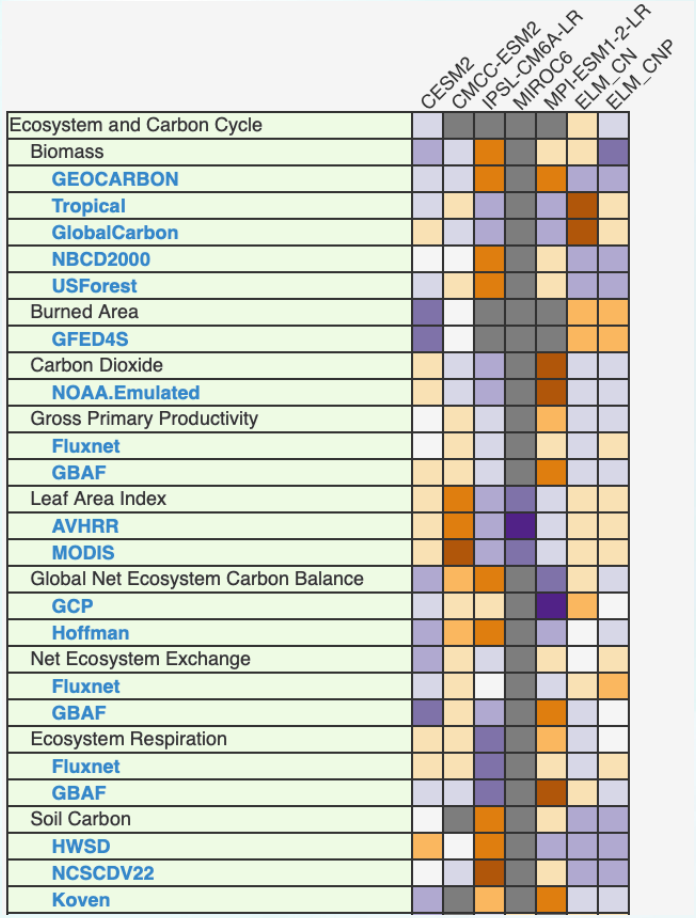


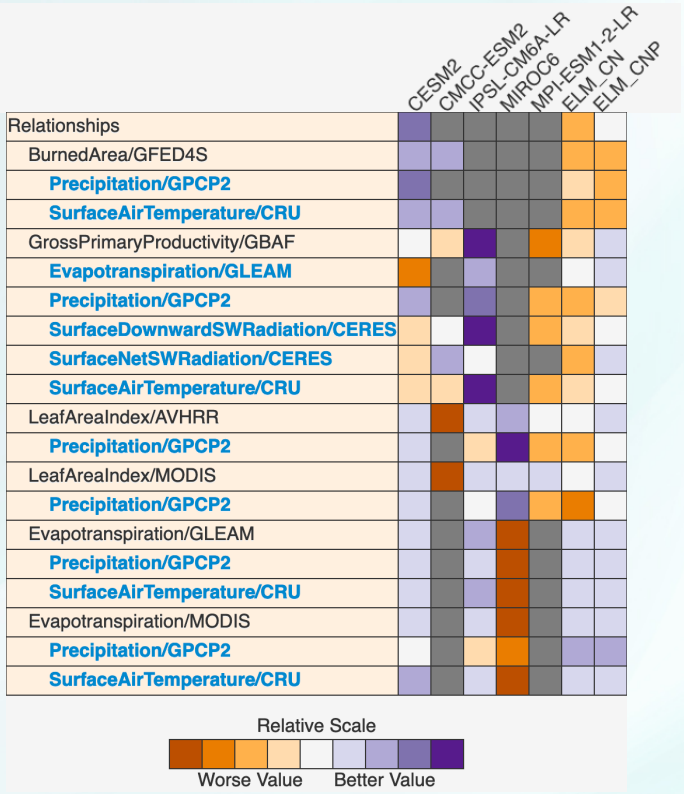
Benchmark: Le Quere et al., 2016
Global Carbon Project



Benchmark: Forrest Hoffman et al., 2014

ELMv1 and other land models in CMIP6

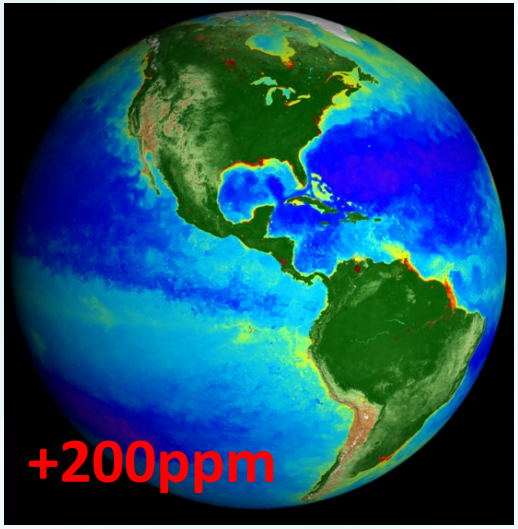




- **LS3MIP archive in CMIP6**
- **Offline global simulations**
- **0.5 degree resolution**
- **Same input data**

Benchmarking beyond ILAMB

FACE synthesis



A global FACE model experiment

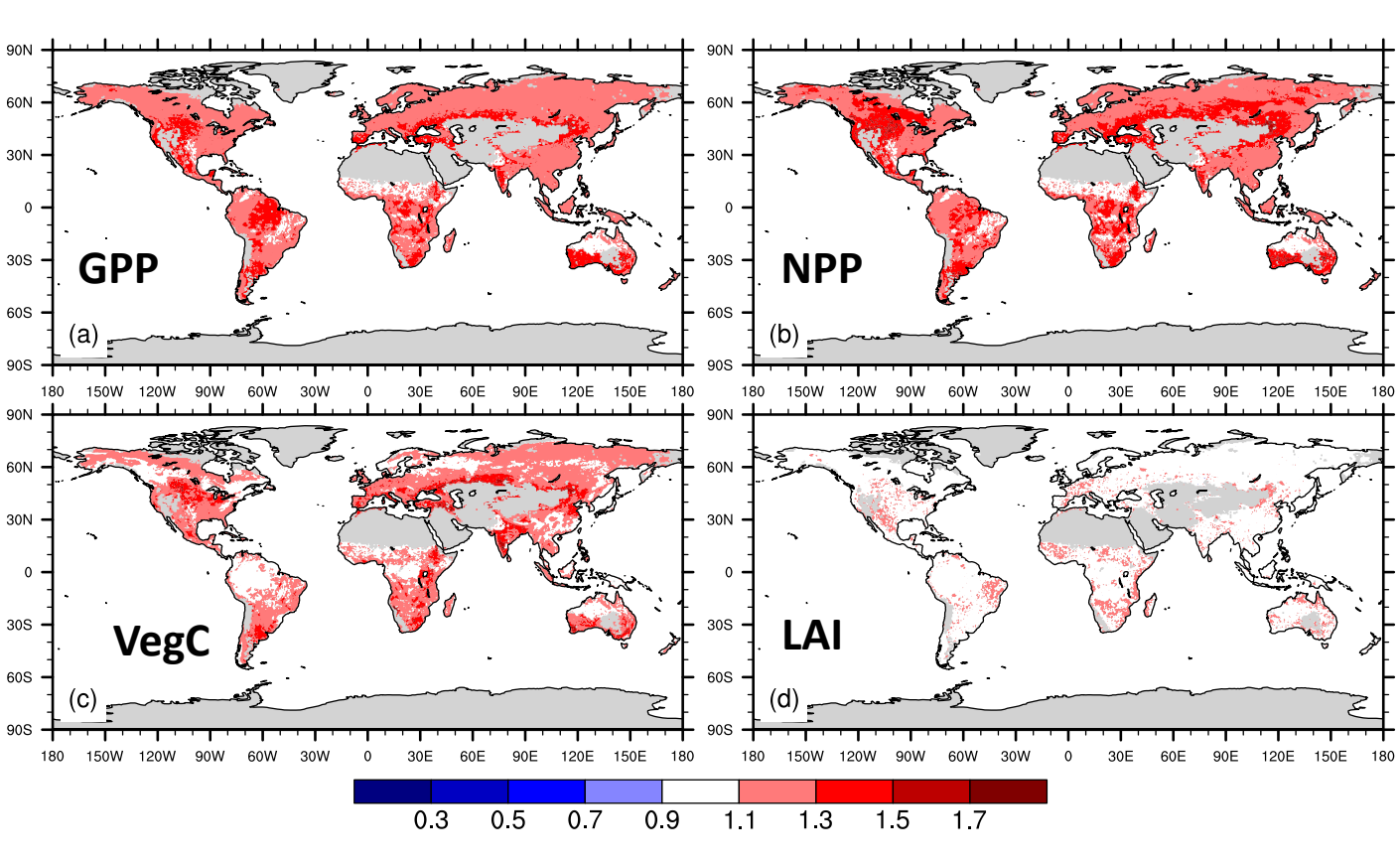
Picture credit: Oak Ridge FACE, Aspen FACE, Duke FACE, and EucFACE

Picture credit: NASA

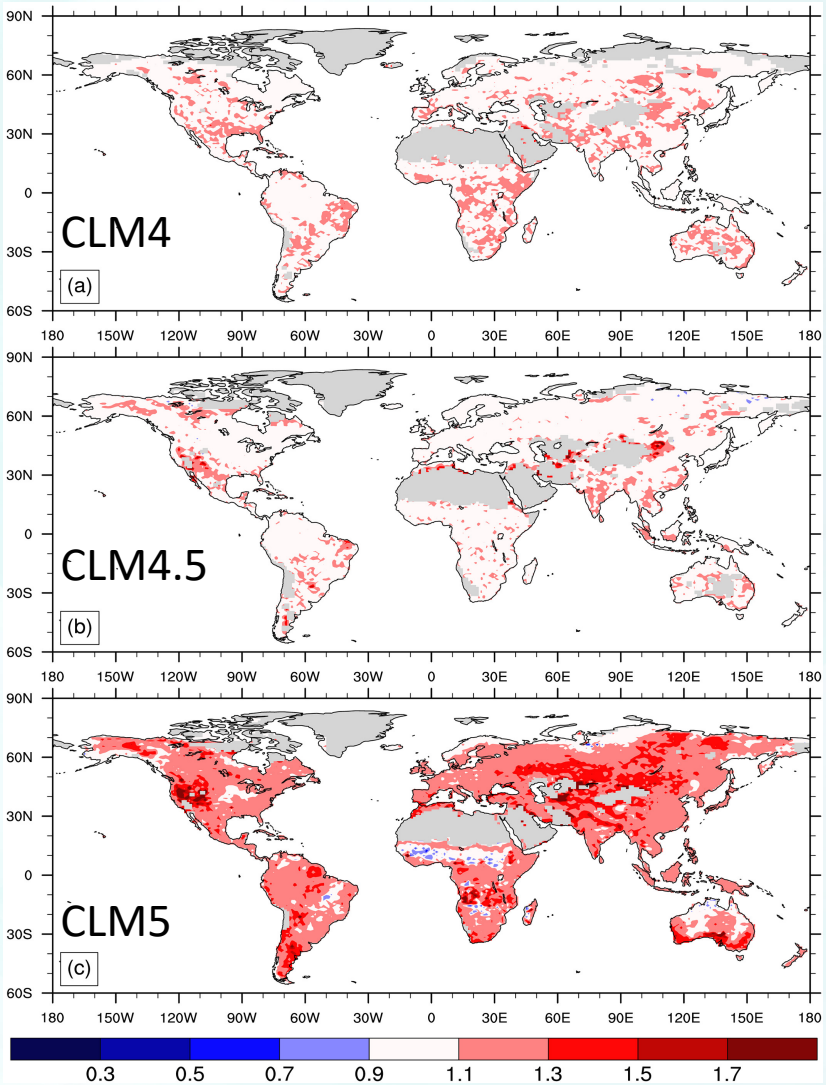
ELMv1 simulated effect size of CO_2 enrichment

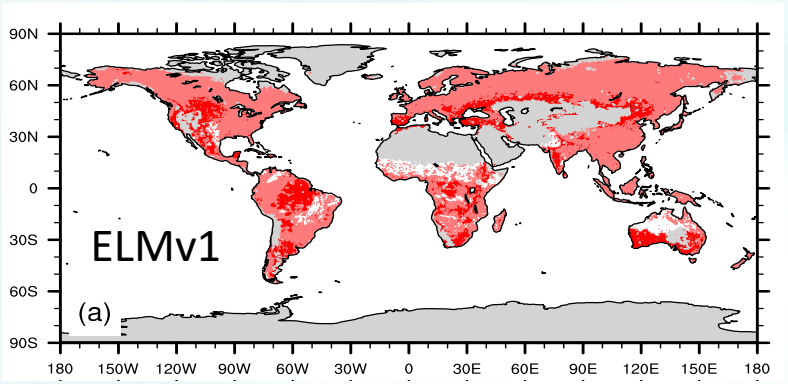
a

c



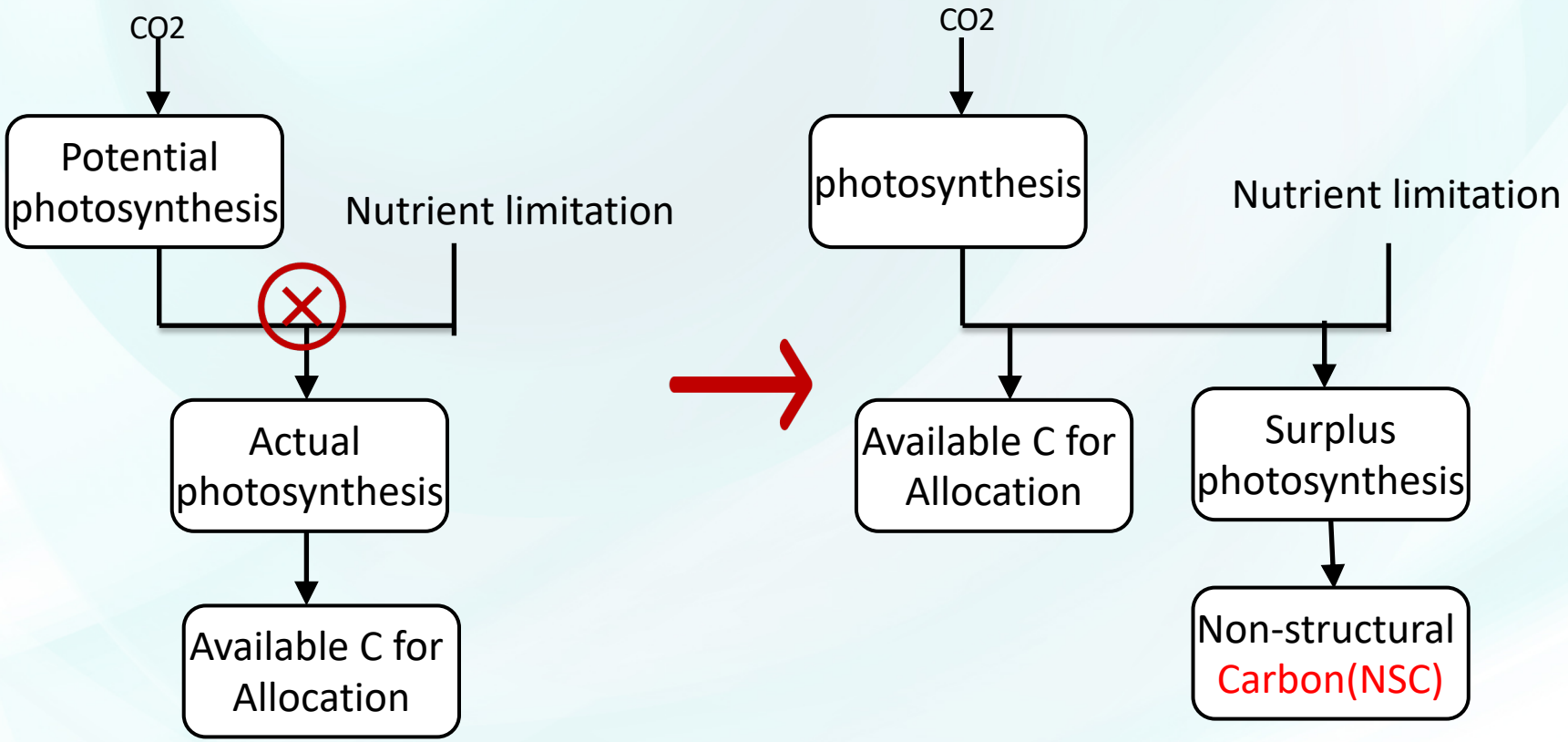
Simulated effect size of CO_2 enrichment on GPP





Wieder et al., 2019

Representation of nutrient limitation: from limitation on source activity to sink limitation



Trends in Ecology & Evolution

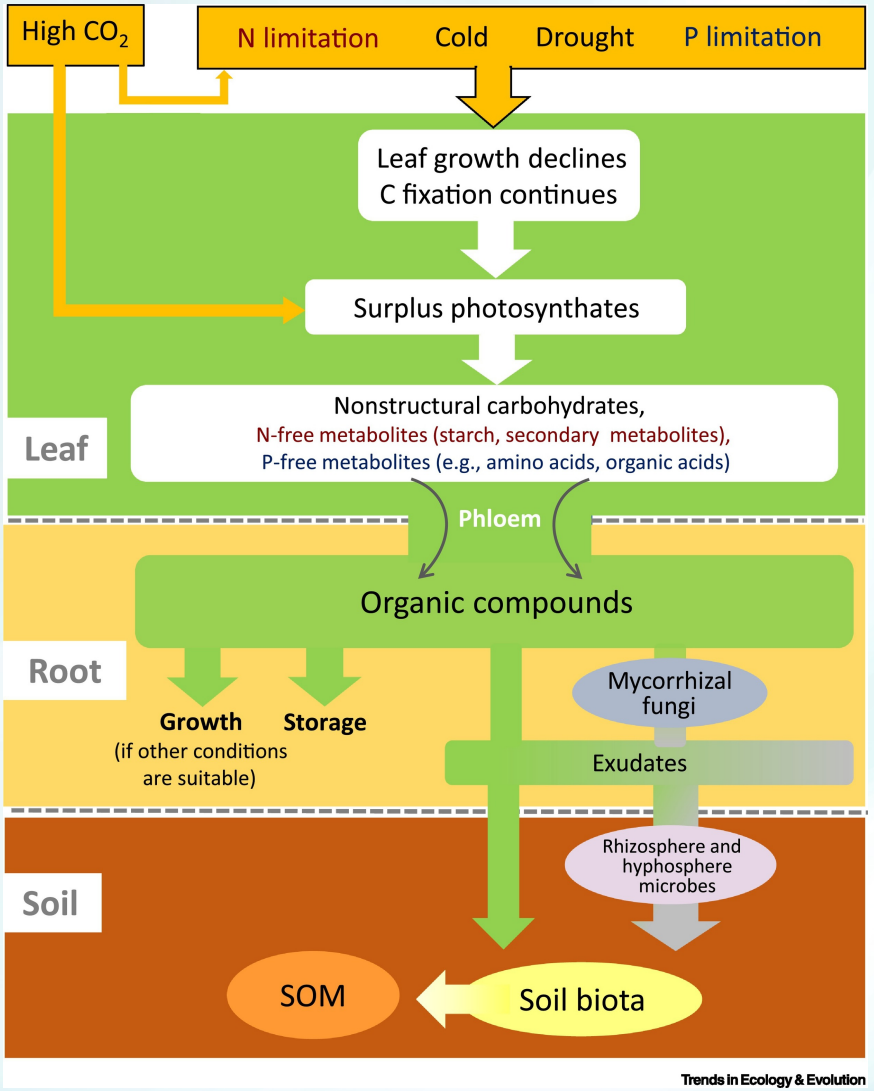
CellPress REVIEWS

Opinion

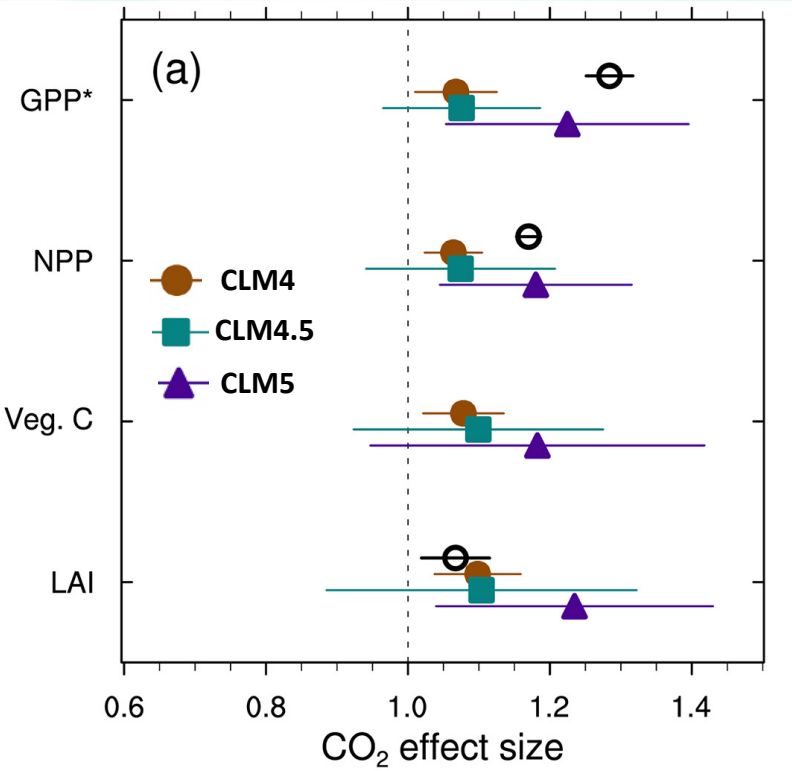
Surplus Carbon Drives Allocation and Plant–Soil Interactions

Cindy E. Prescott,[1,*] Sue J. Grayston,[1] Heljä-Sisko Helmisaari,[2] Eva Kaštovská,[3] Christian Körner,[4] Hans Lambers,[5] Ina C. Meier,[6] Peter Millard,[7] and Ivika Ostonen[8]

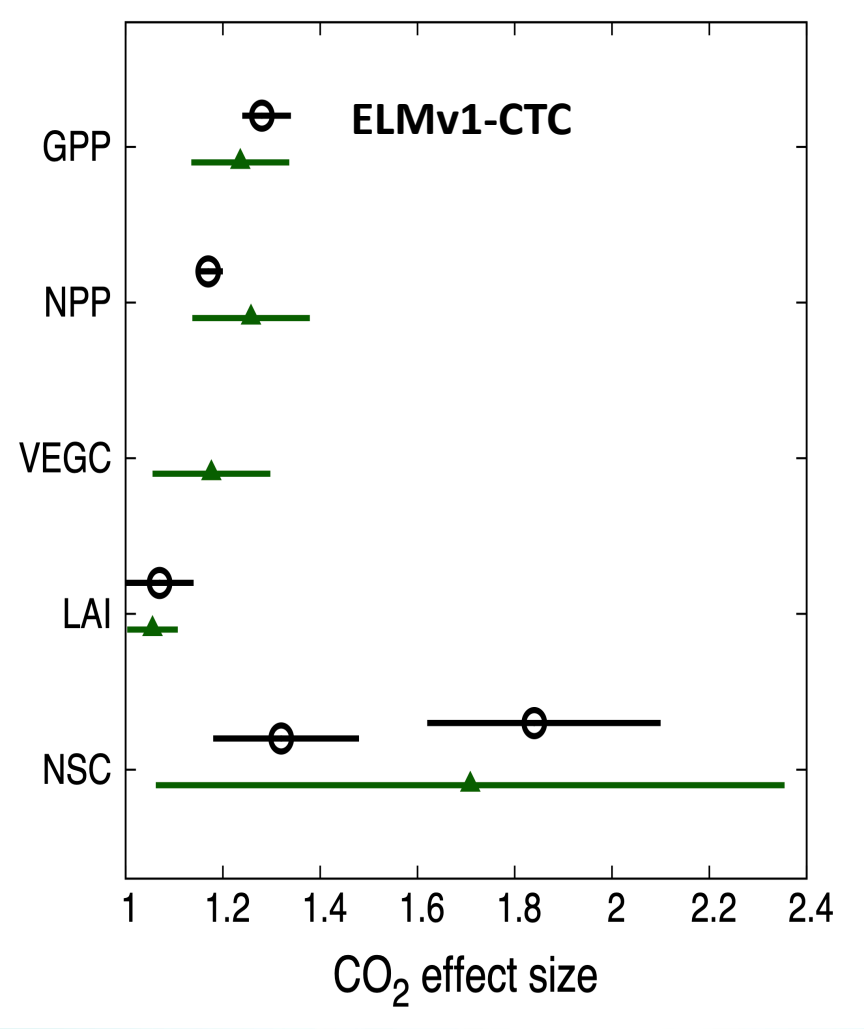
- Plant growth is usually constrained by the availability of nutrients, water, or temperature, rather than photosynthetic carbon (C) fixation
- In plants limited by nitrogen (N) or phosphorus (P), photosynthates are converted into sugars and secondary metabolites.
- Many interactions among above- and below- ground ecosystem components can be parsimoniously explained by the production, distribution, and release of surplus C under conditions that limit plant growth



Similar GPP responses to eCO2, but very different LAI responses



Wieder et al., 2019



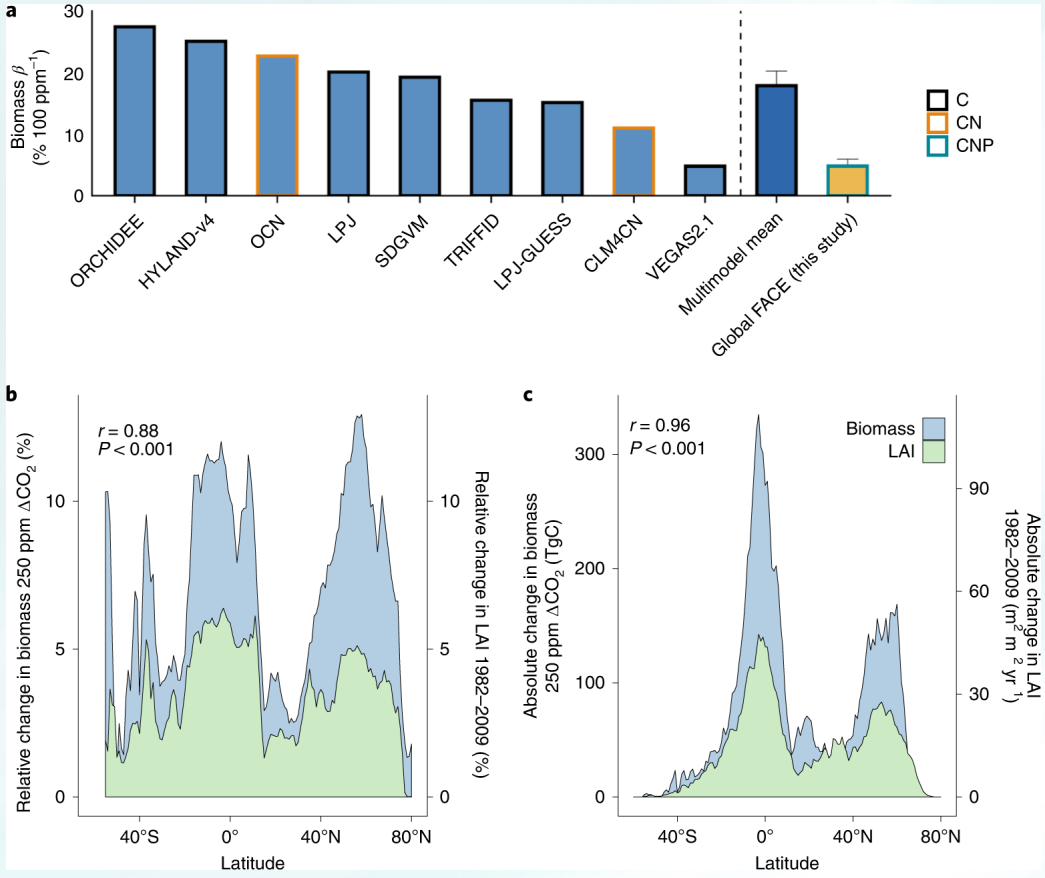
Observations are from Anisworth and Long 2005

A data-driven global quantification of the eCO2 effect

LETTERS
https://doi.org/10.1038/s41558-019-0545-2
nature climate change
There are amendments to this paper

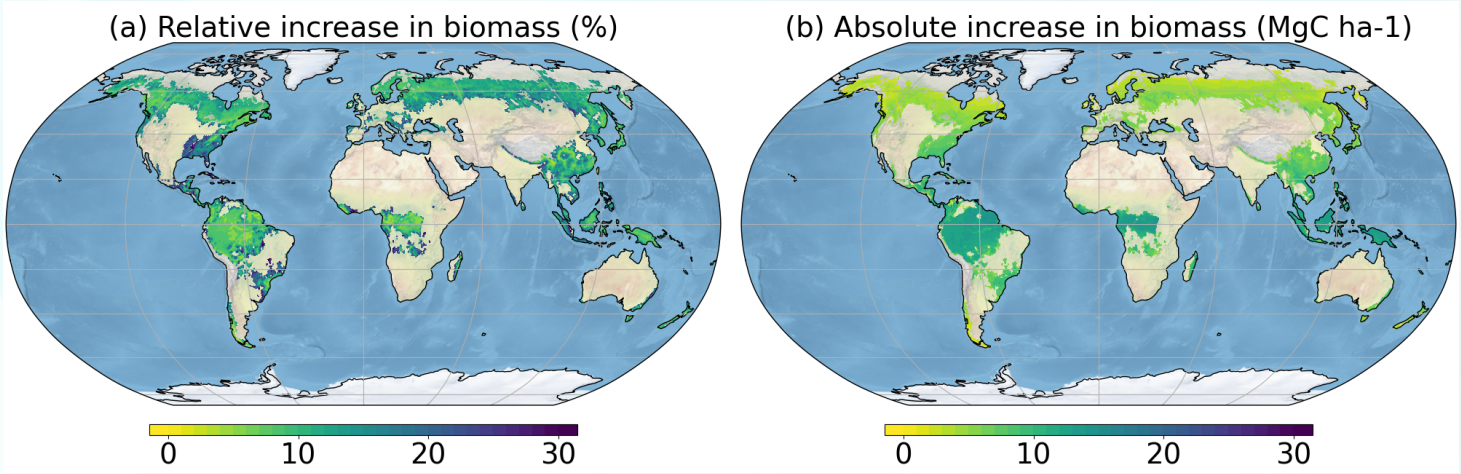
Nitrogen and phosphorus constrain the CO_2 fertilization of global plant biomass

César Terrer[1,2,3*], Robert B. Jackson[1,4], I. Colin Prentice[5,6,7], Trevor F. Keenan[8,9], Christina Kaiser[10,11], Sara Vicca[12], Joshua B. Fisher[13,14], Peter B. Reich[15,16], Benjamin D. Stocker[17], Bruce A. Hungate[18,19], Josep Peñuelas[17,20], Ian McCallum[3], Nadejda A. Soudzilovskaia[21], Lucas A. Cernusak[22], Alan F. Talhelm[23], Kevin Van Sundert[12], Shilong Piao[24,25], Paul C. D. Newton[26], Mark J. Hovenden[27], Dana M. Blumenthal[28], Yi Y. Liu[29], Christoph Müller[30,31], Klaus Winter[32], Christopher B. Field[4], Wolfgang Viechtbauer[33], Caspar J. Van Lissa[34], Marcel R. Hoosbeek[35], Makoto Watanabe[36], Takayoshi Koike[37], Victor O. Leshyk[18,19], H. Wayne Polley[38] and Oskar Franklin[3]

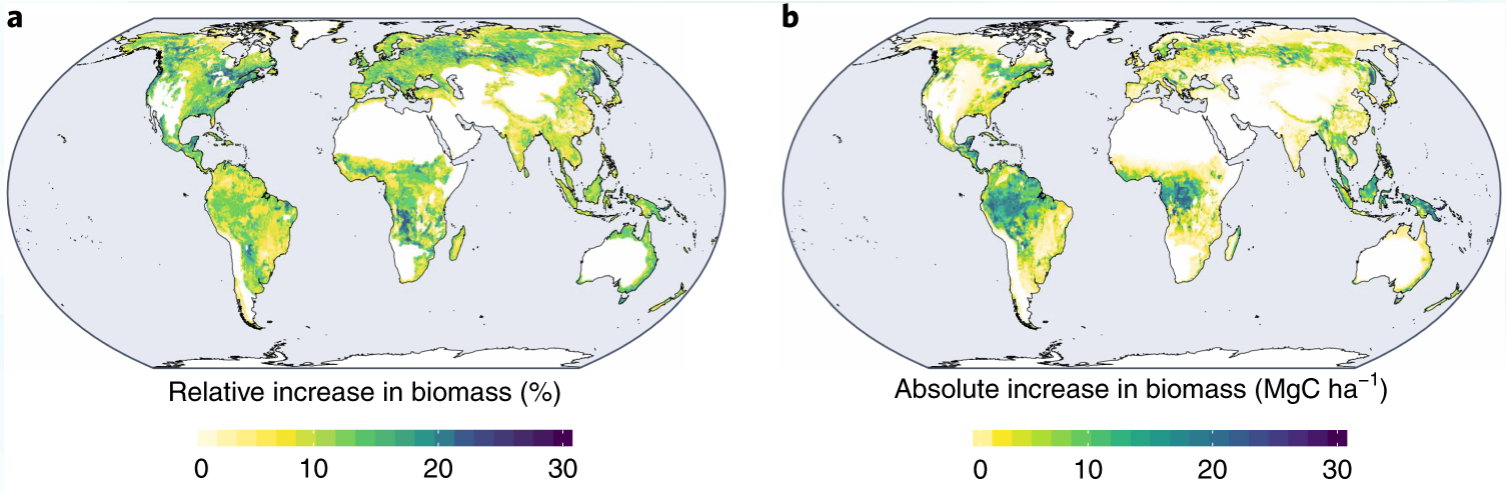


- A data-driven global quantification of the eCO2 effect on biomass based on 138 eCO2 experiments
- The derived eCO_2 effects is geographically consistent changes in greenness
- Lower than the previous model estimates

ELMv1 simulated biomass responses to eCO2 is consistent with the new data-derived estimate



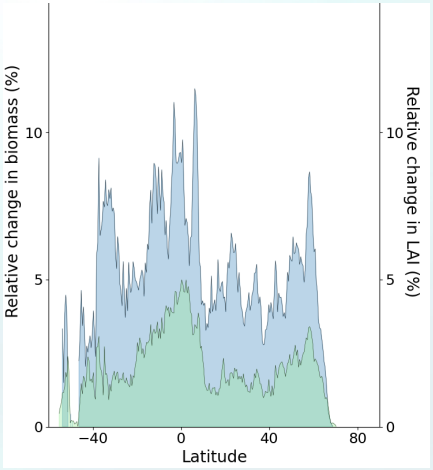
ELMv1

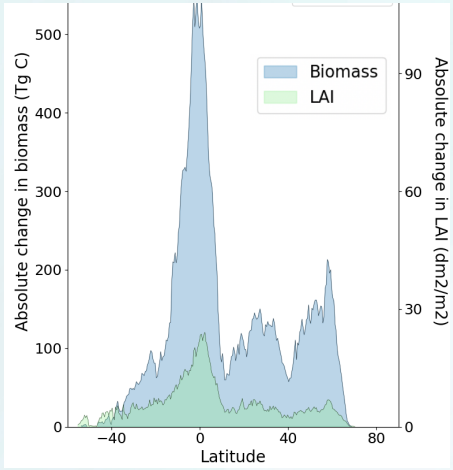


Terrer et al., 2020

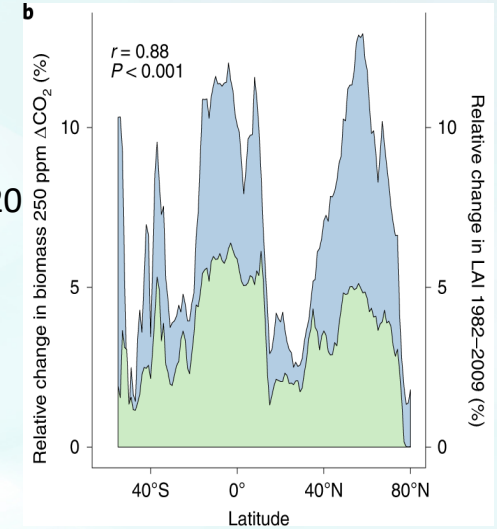
ELMv1 simulated biomass responses to eCO2 is consistent with the new data-derived estimate

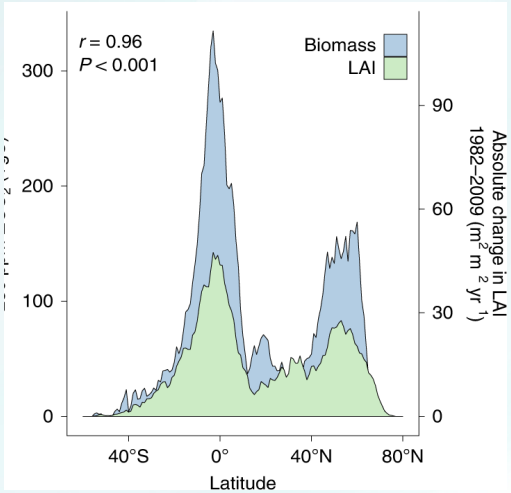
ELMv1





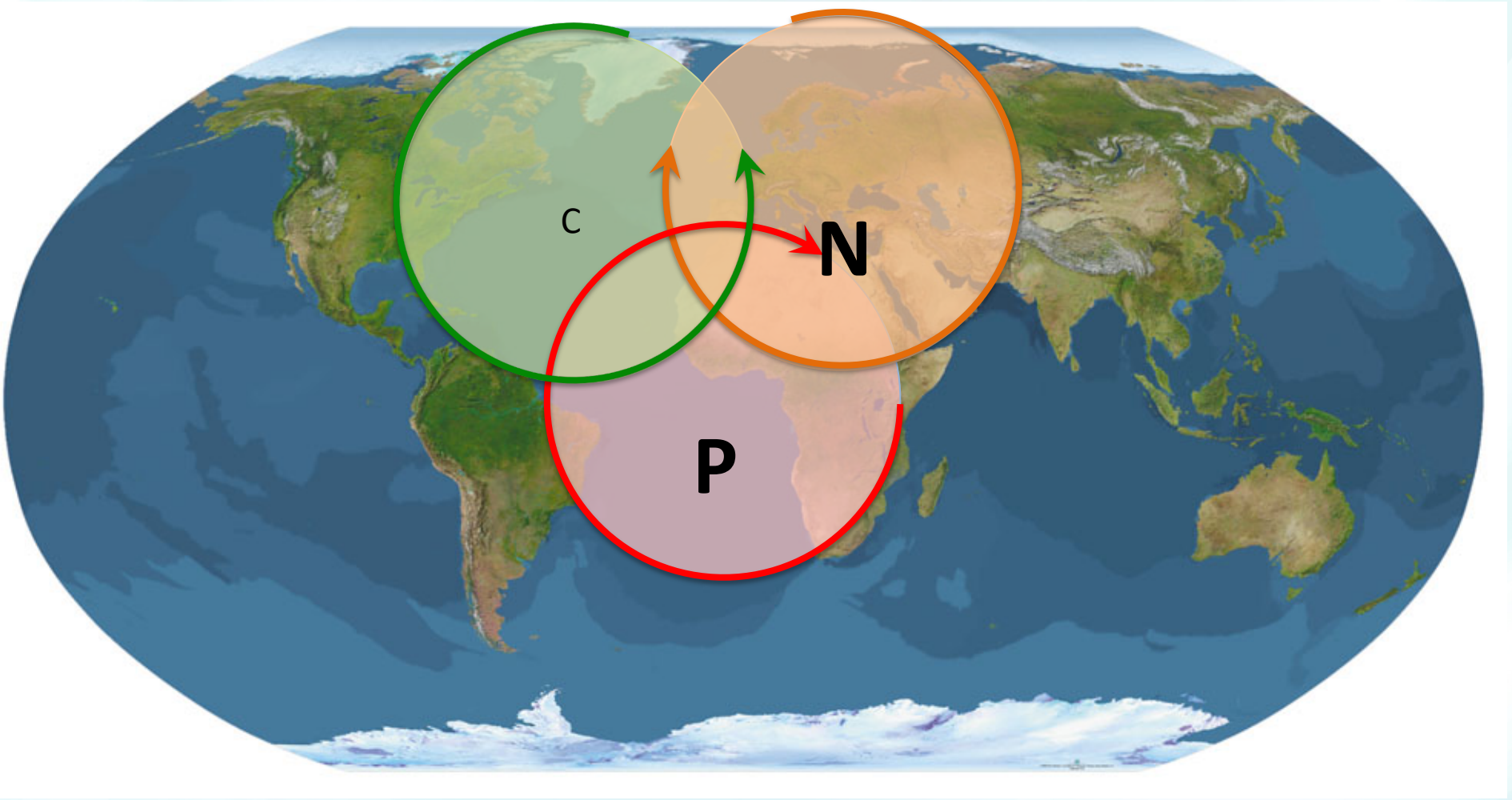
Terrer et al., 2020





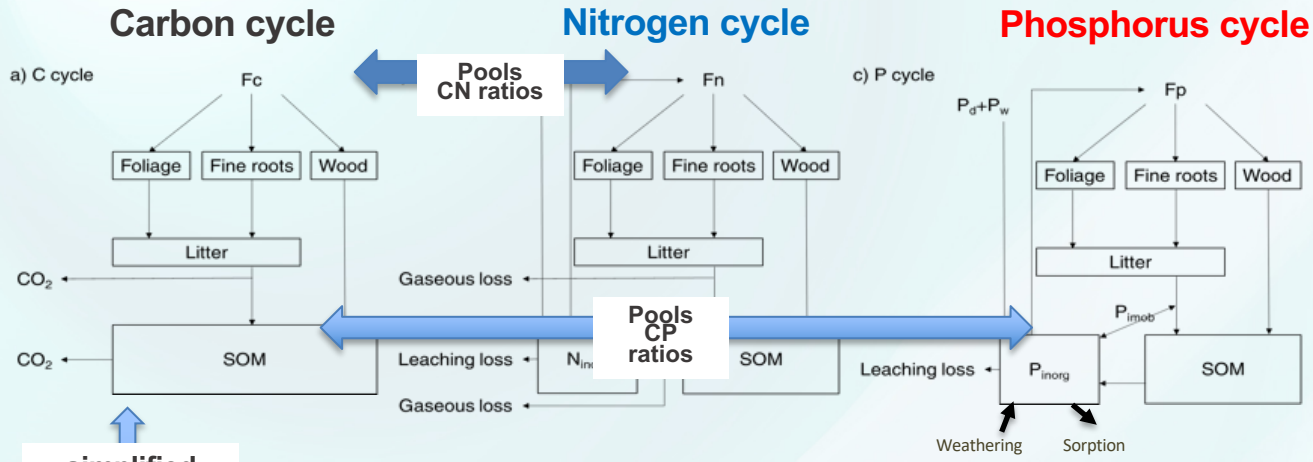
Benchmarking beyond carbon

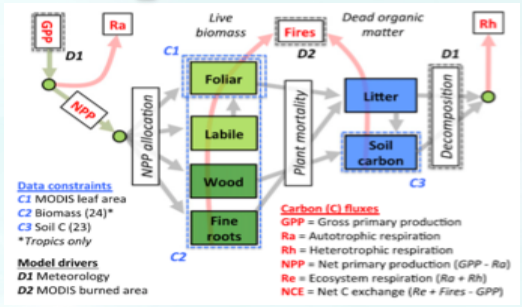
Evaluation of nutrient pools and fluxes on the global scale



GOLUM-CNP

An observational based global datasets





(Bloom et al., 2016)

Assumptions

- Mass conservation
- Steady state equilibrium

Input data

- External N and P inputs : BNF, deposition, weathering
- Biome-specific CN and CP of C pools

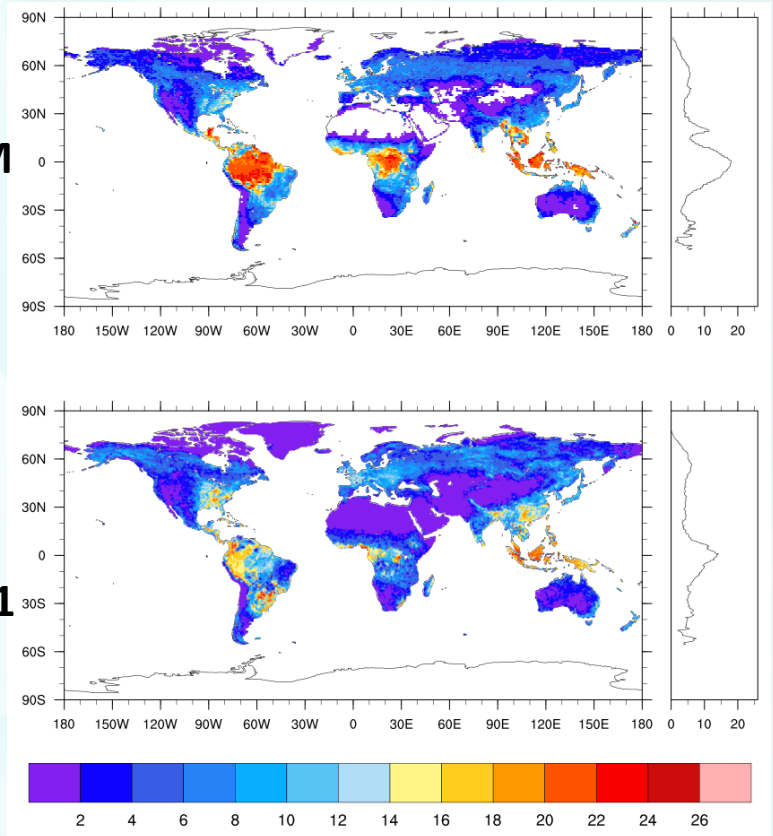
Comparison with GOLUM-CNP: nutrient uptake

N uptake

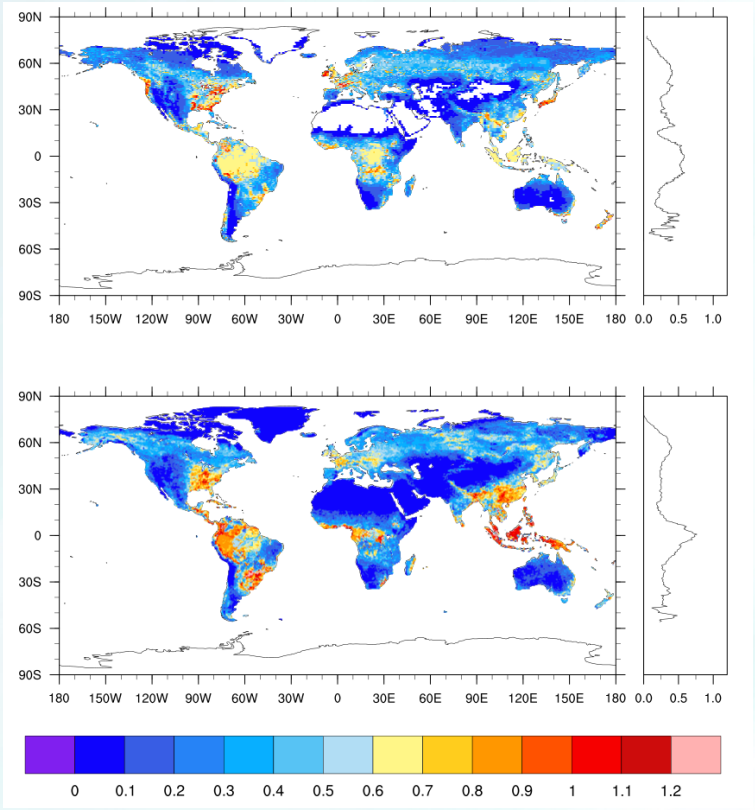
P uptake

GOLUM -CNP

ELMv1



Unit: g N m^{-2} yr^{-1}



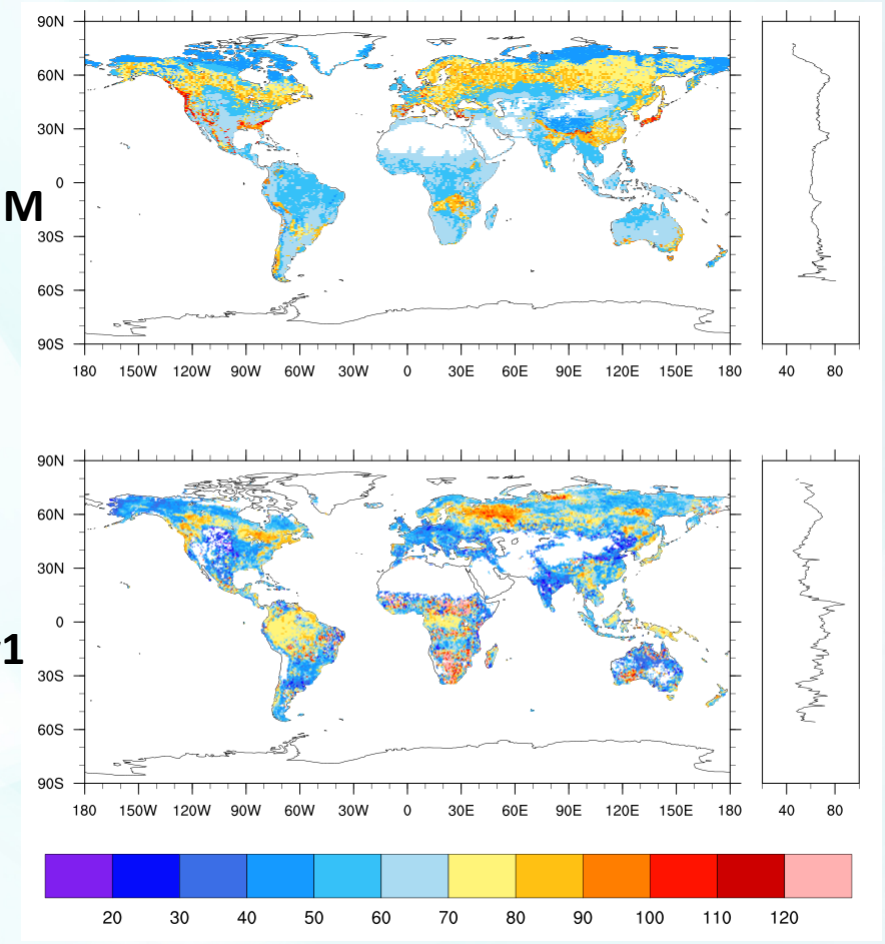
Unit: g P m^{-2} yr^{-1}

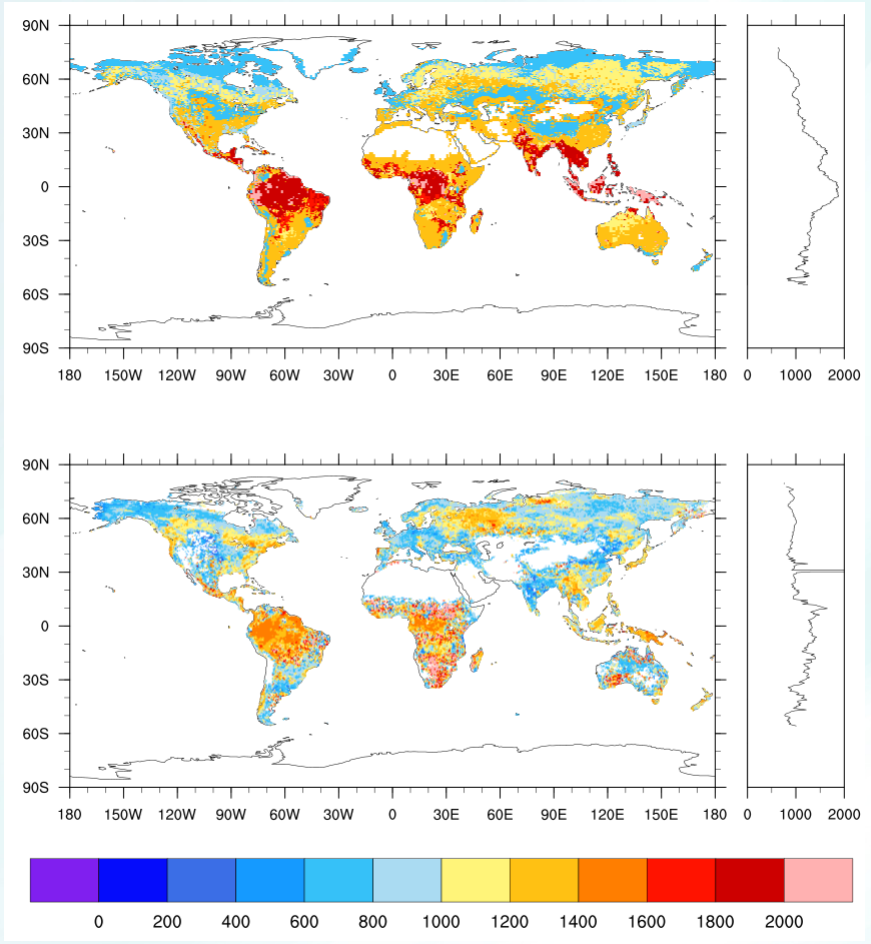
Comparison with GOLUM-CNP: Nutrient use efficiency

NUE

PUE

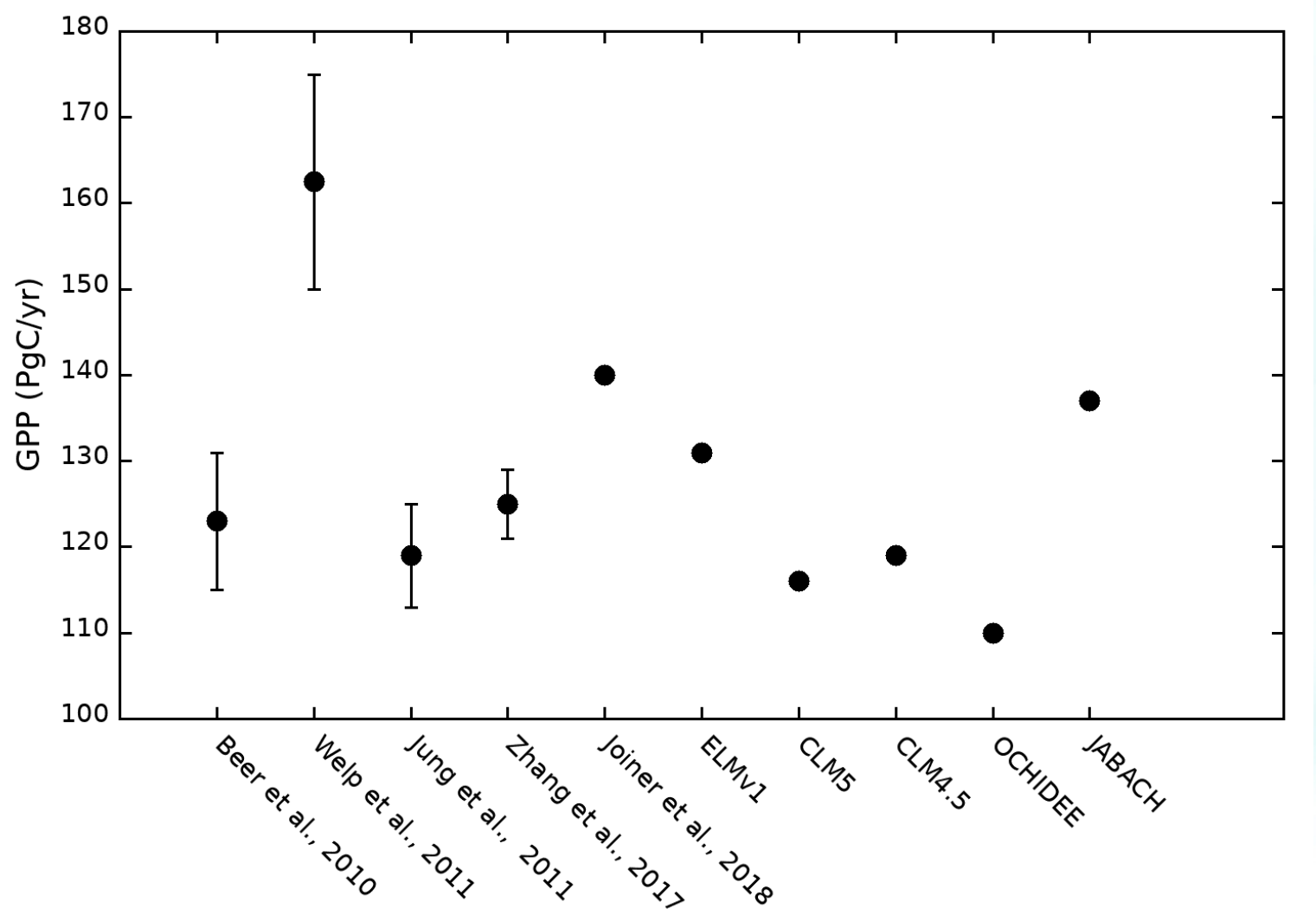
GOLUM -CNP





ELMv1

Other Literature values might be useful too!



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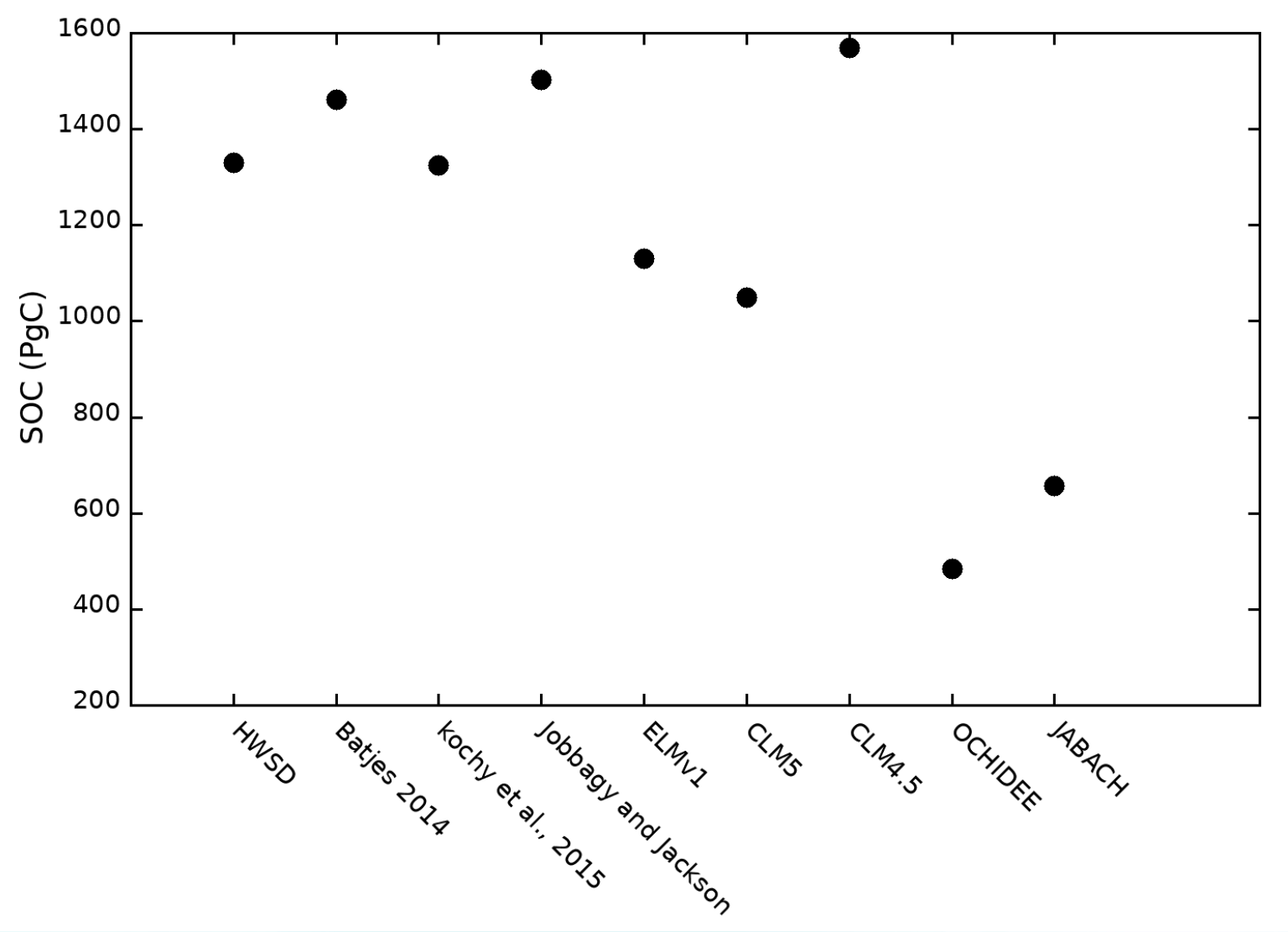

Summary and discussion points

- ILAMB is a great tool for systematic evaluation of land models, which can help identify improvement or degradation with the implementation of new processes
- Similar ILAMB scores between models that have very different process representations suggest process level evaluation is needed
- Comparison with a meta-analysis of FACE suggests ELMv1 assumptions of nutrient limitation is reasonable
- Benchmarks for nutrient cycle dynamics are needed as more land models are including N and even P limitation
- Other independently derived data product will be valuable addition to ILAMB