Influence of phosphorus cycle coupling on land model response to CO2 fertilization and climate variability

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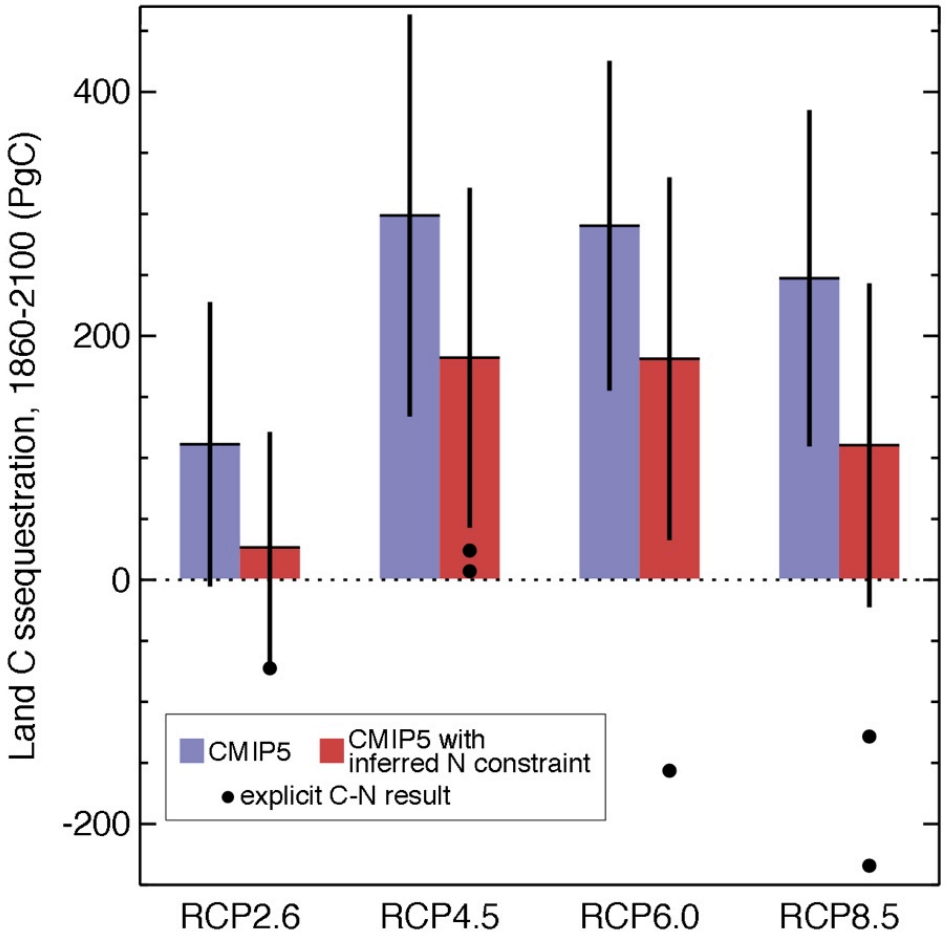
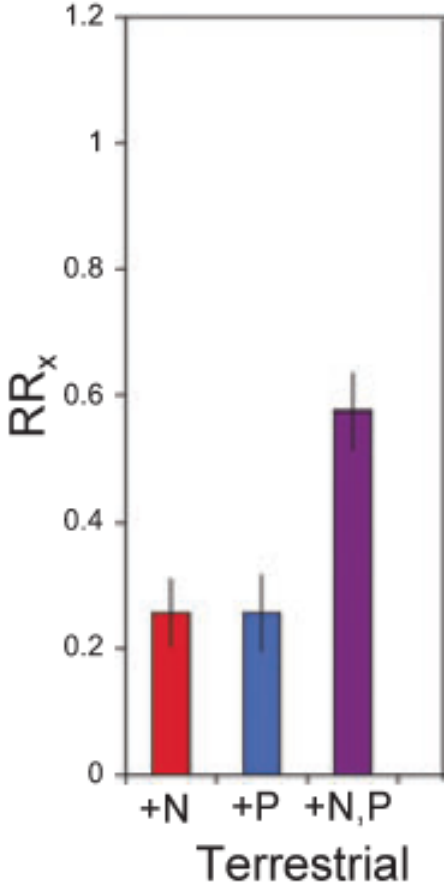
Nutrient limitation will very likely reduce the global land carbon storage projected by CMIP5 C-only models

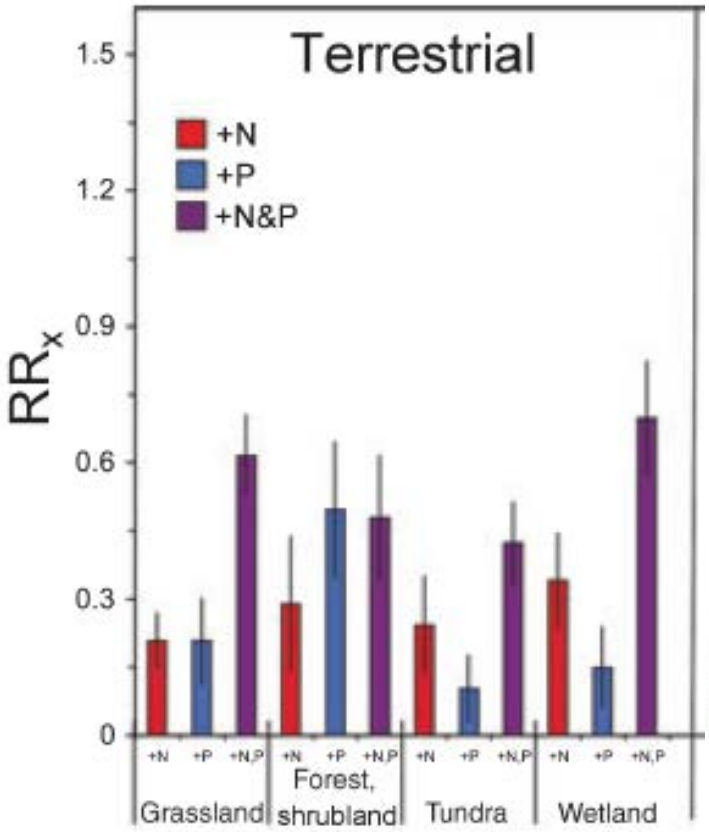


(IPCC,2013)

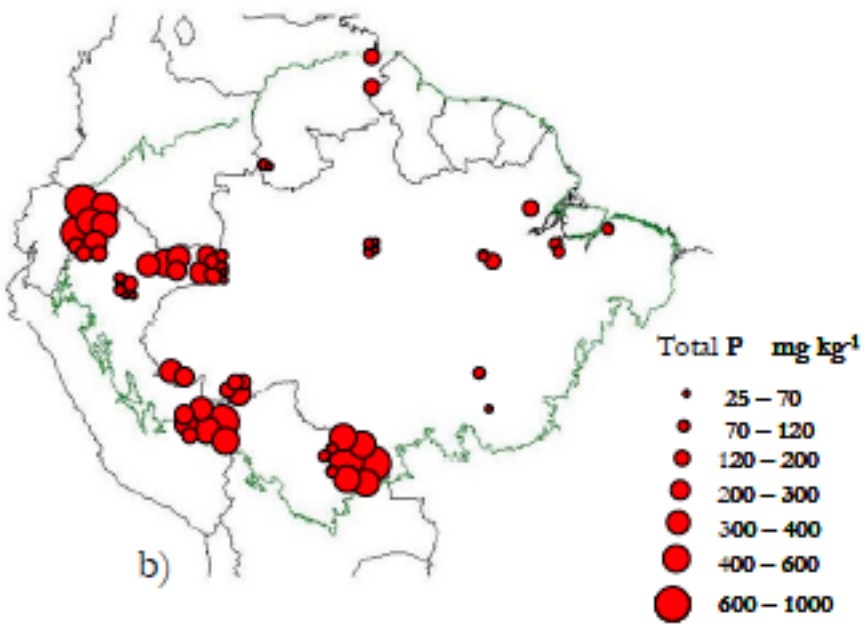
Widespread phosphorus limitation in terrestrial ecosystems, especially in lowland tropical forests

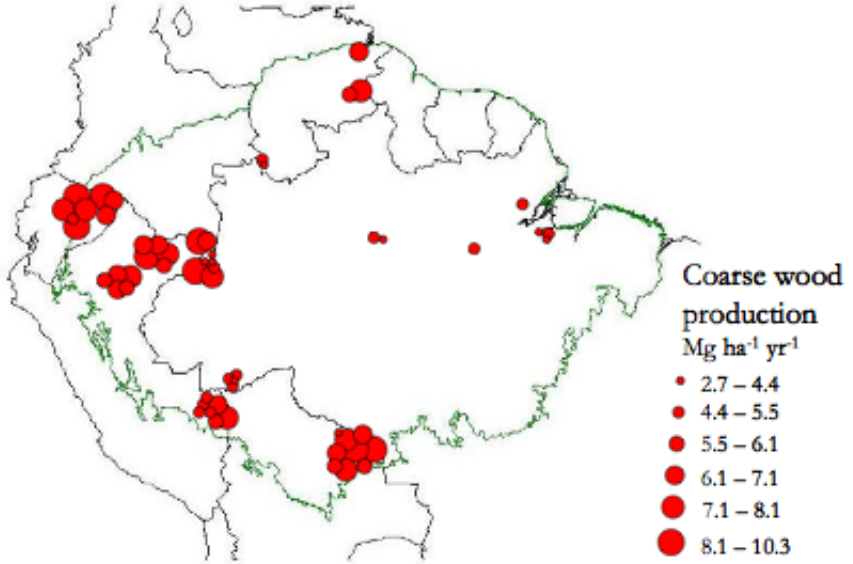
Elser et al., 2007





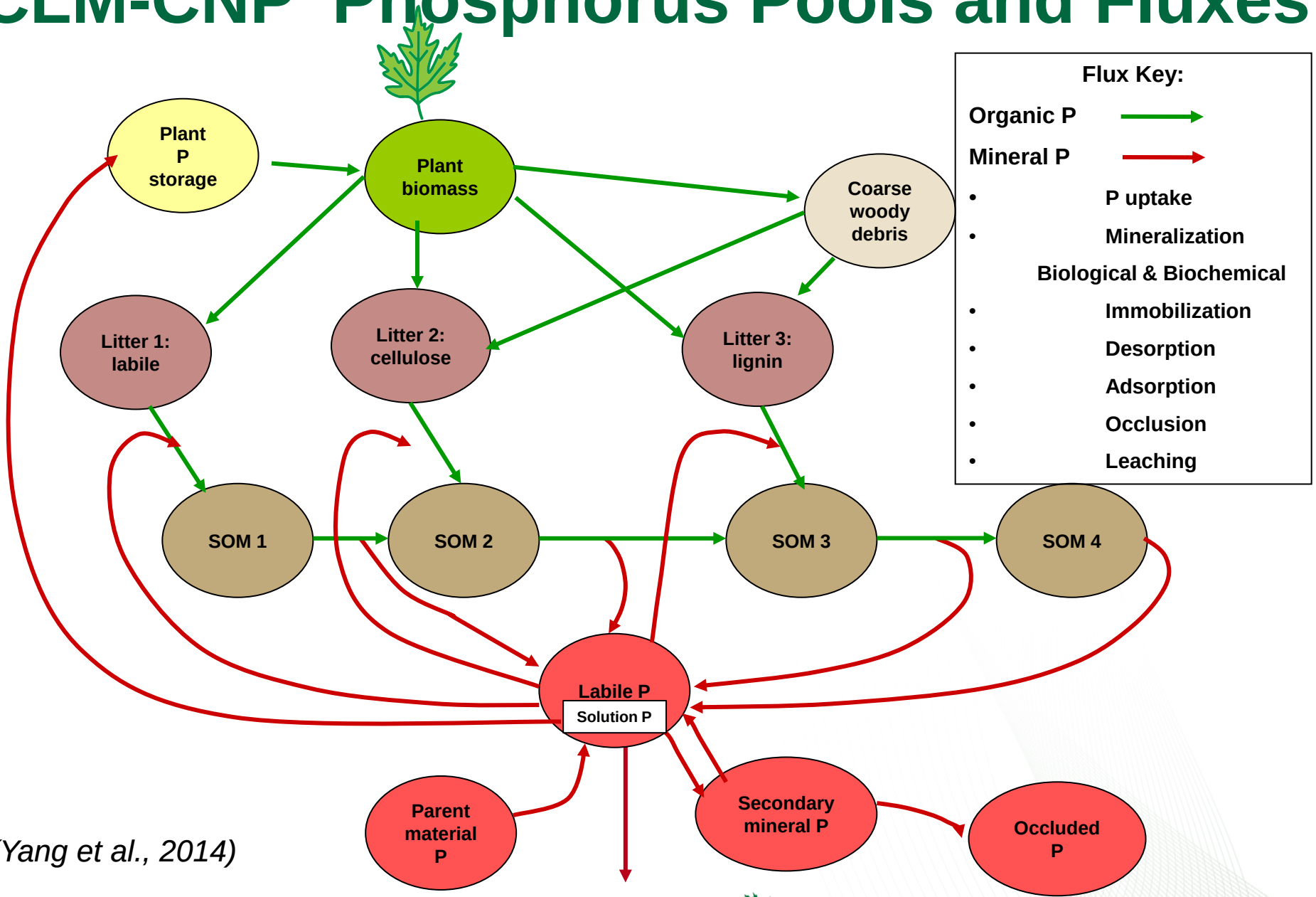
Forest stem growth rates mostly related to total soil P across the Amazon Basin





Quesada et al., 2012

CLM-CNP Phosphorus Pools and Fluxes

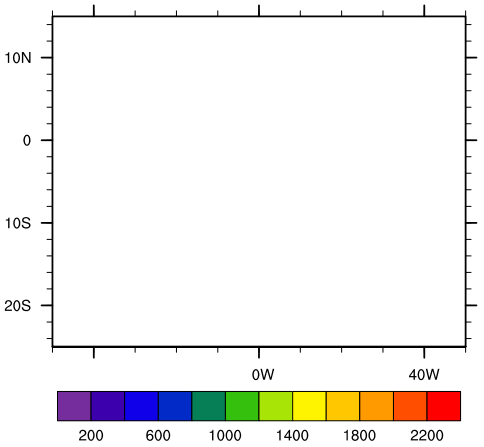


(Yang et al., 2014)

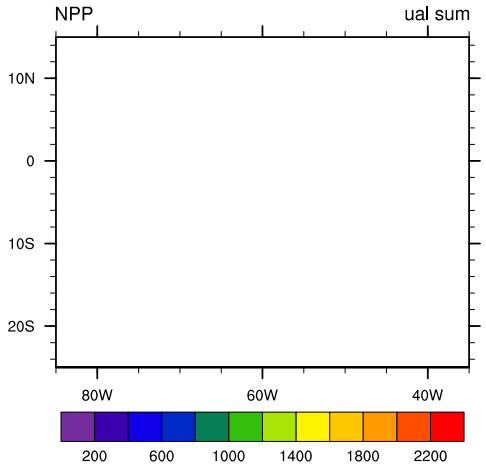
Mean annual simulated fluxes for the period 2000-2009

GPP NPP

CN



CNP



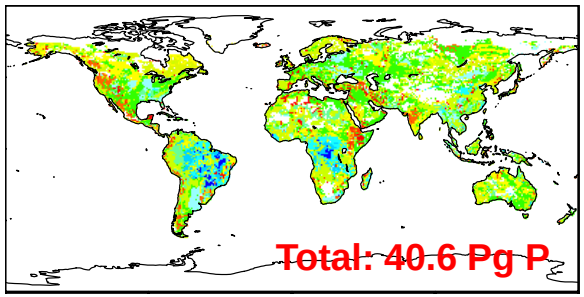
(Unit: g C m^{-2} a^{-1})

- Improved heterogeneity of simulated GPP & NPP in CNP model.
- NPP decreases from west to east across the Amazon basin following the gradient of total soil P.
- Spatial pattern of NPP consistent with field observations(Quesada et al., 2012; Aragão et al., 2011; Malhi et al., 2004).
- Comparison with satellite products in progress.

Global Simulations

- CLM4-CNP and CLM4-CN
- 0.5-by-0.5 degree
- Offline mode
- Steady-state simulations (Pre-industrial spinup)
- Transient simulations
  - CRU-NCEP reanalysis fields 1901-2009
  - historical [CO_2]

P maps for model initialization

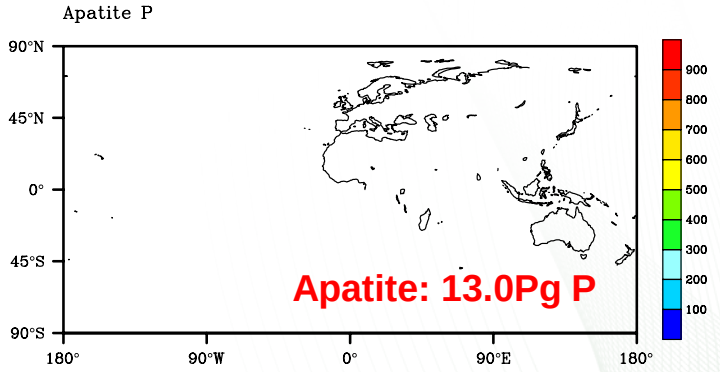


~~Total: 40.6 Pg P~~

Labile Inorganic: 3.6 Pg P

Organic: 8.6 Pg P

Secondary: 3.2 Pg P

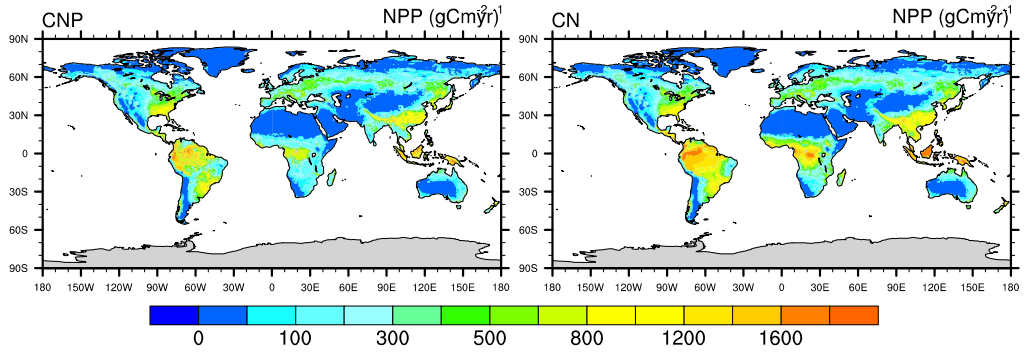


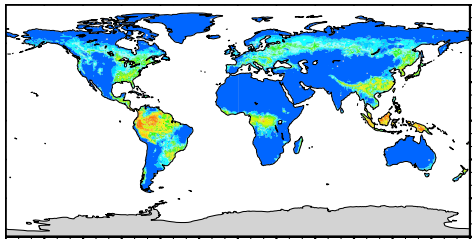
Occluded: 12.2 Pg P

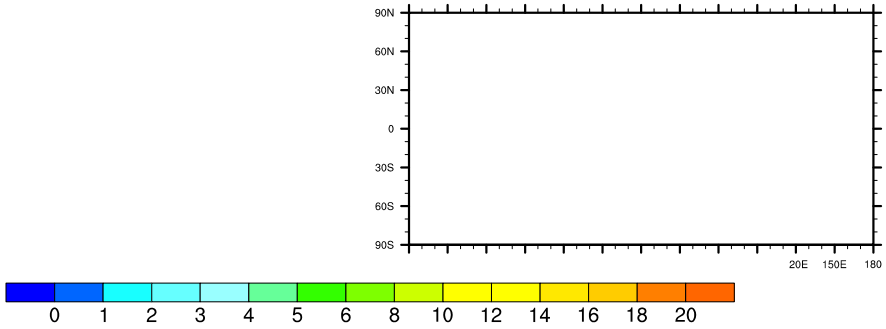
Apatite: 13.0Pg P

Yang et al., 2013

Introduction of P coupling reduces carbon stocks and fluxes at steady state

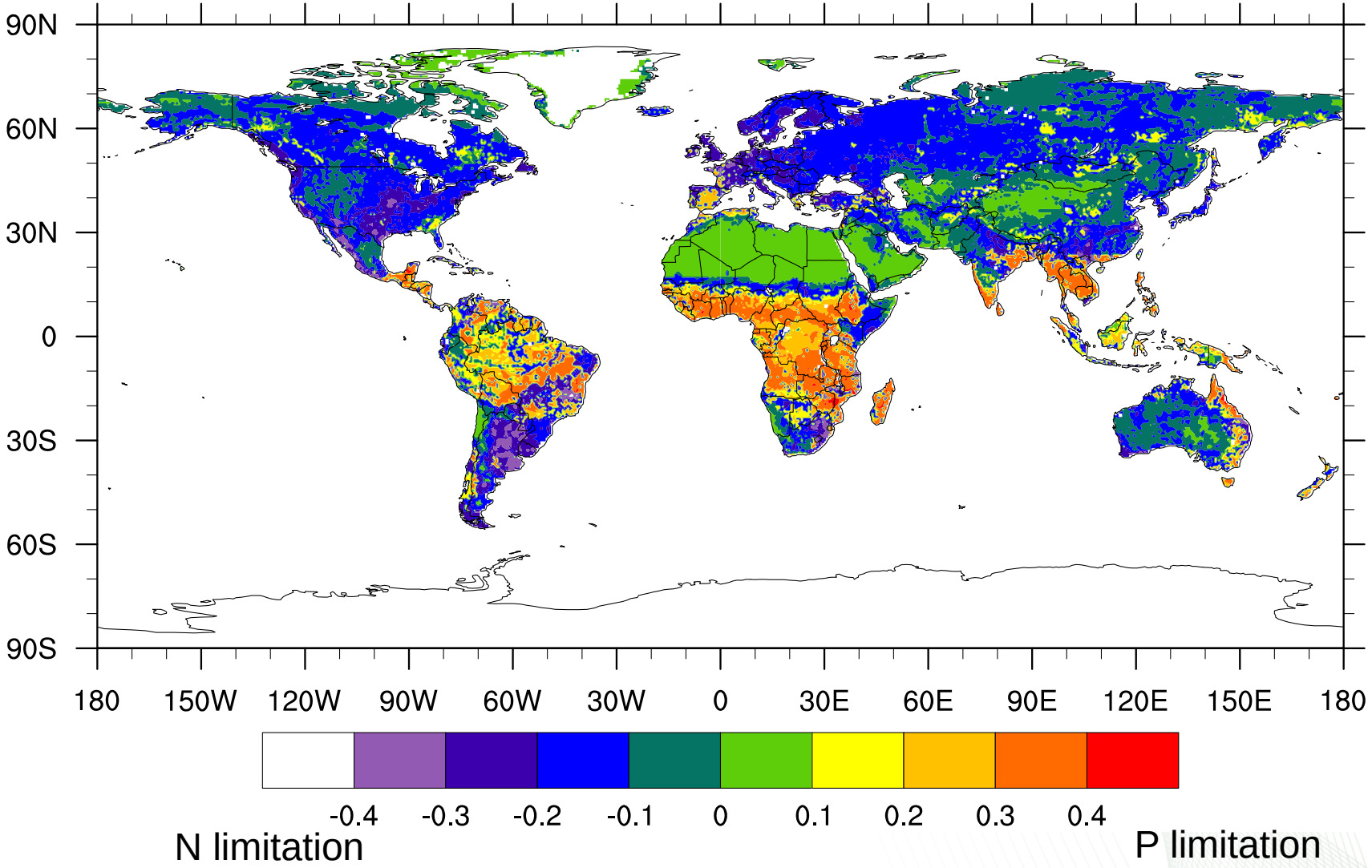






- P limitation reduces global GPP and NPP by 22% and 26% respectively, with the reduction concentrated in tropical regions
- Lower NPP translates to lower steady state carbon stocks in vegetation and in soils

Distribution of N vs. P limitation



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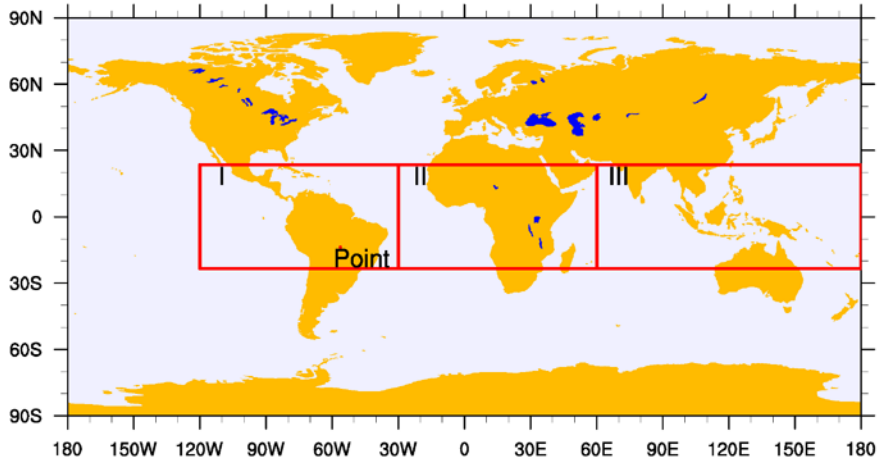
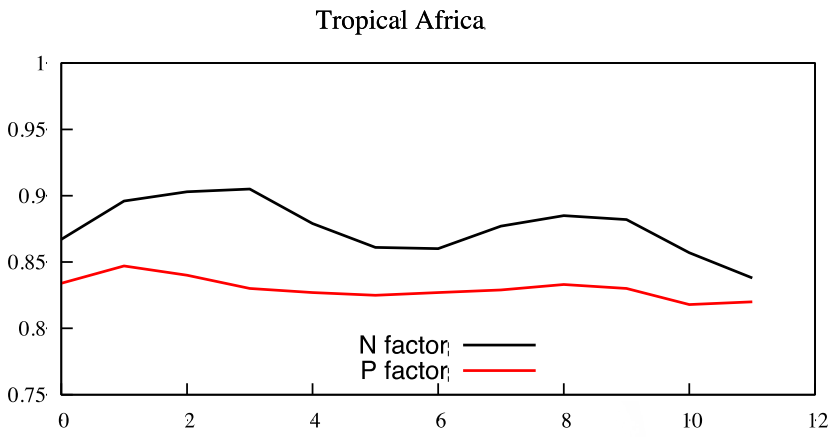
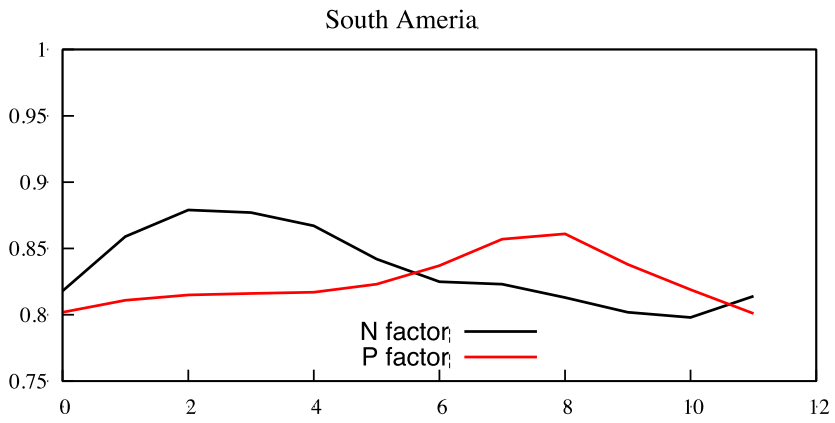
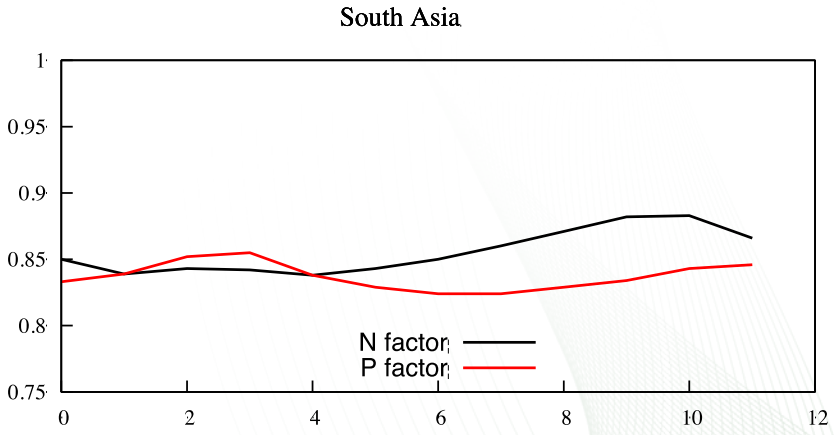
Seasonality of N vs. P limitation in three tropical regions

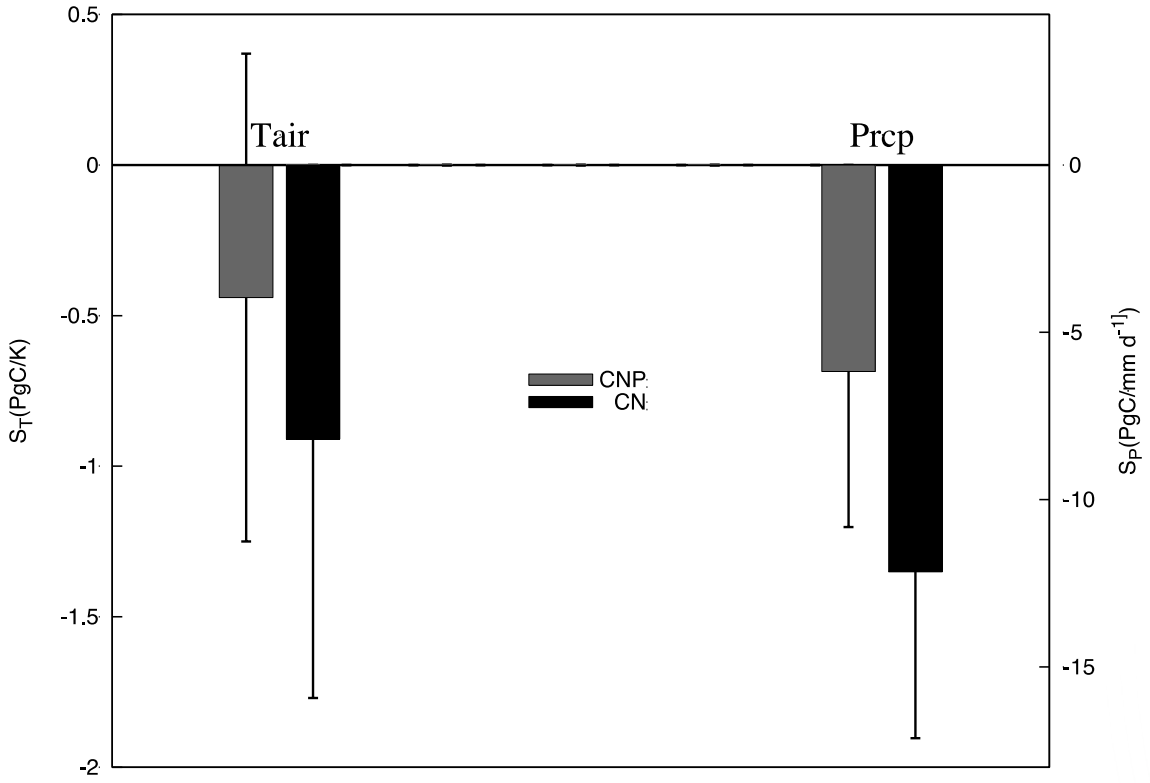






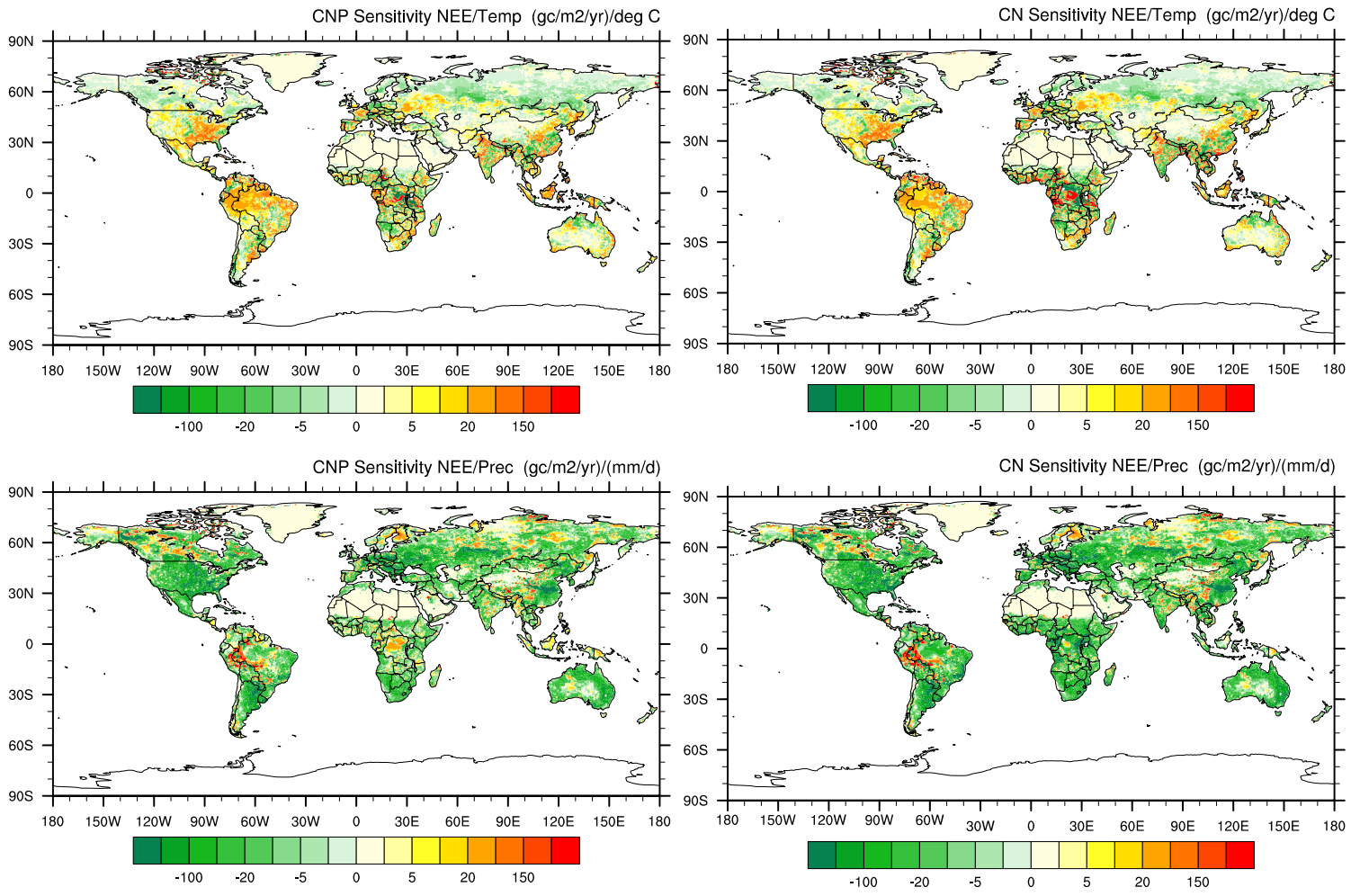


Phosphorus cycle dynamics reduce the sensitivity of global NEE to variations in temperature and precipitation

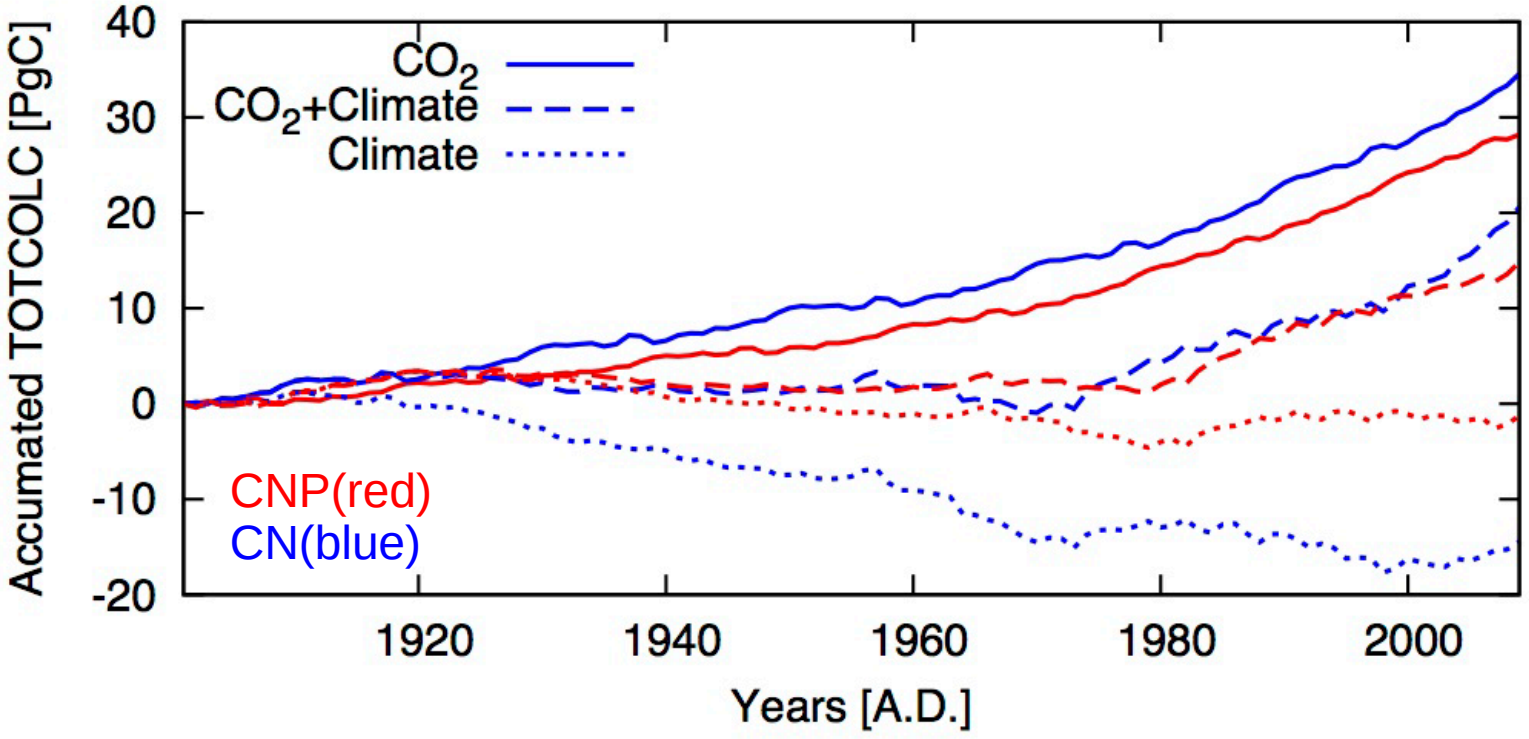


- Global integrated NEE against variations in global mean temperature and precipitation, assessed using multiple least-squares regression, following the methodology of Thornton et al.(2007)
- In particular, CN model shows significant negative relationship between NEE and precipitation, but slope is reduced for CNP model

NEE sensitivity to variations in temperature and precipitation (CLM-CNP vs. CLM-CN)

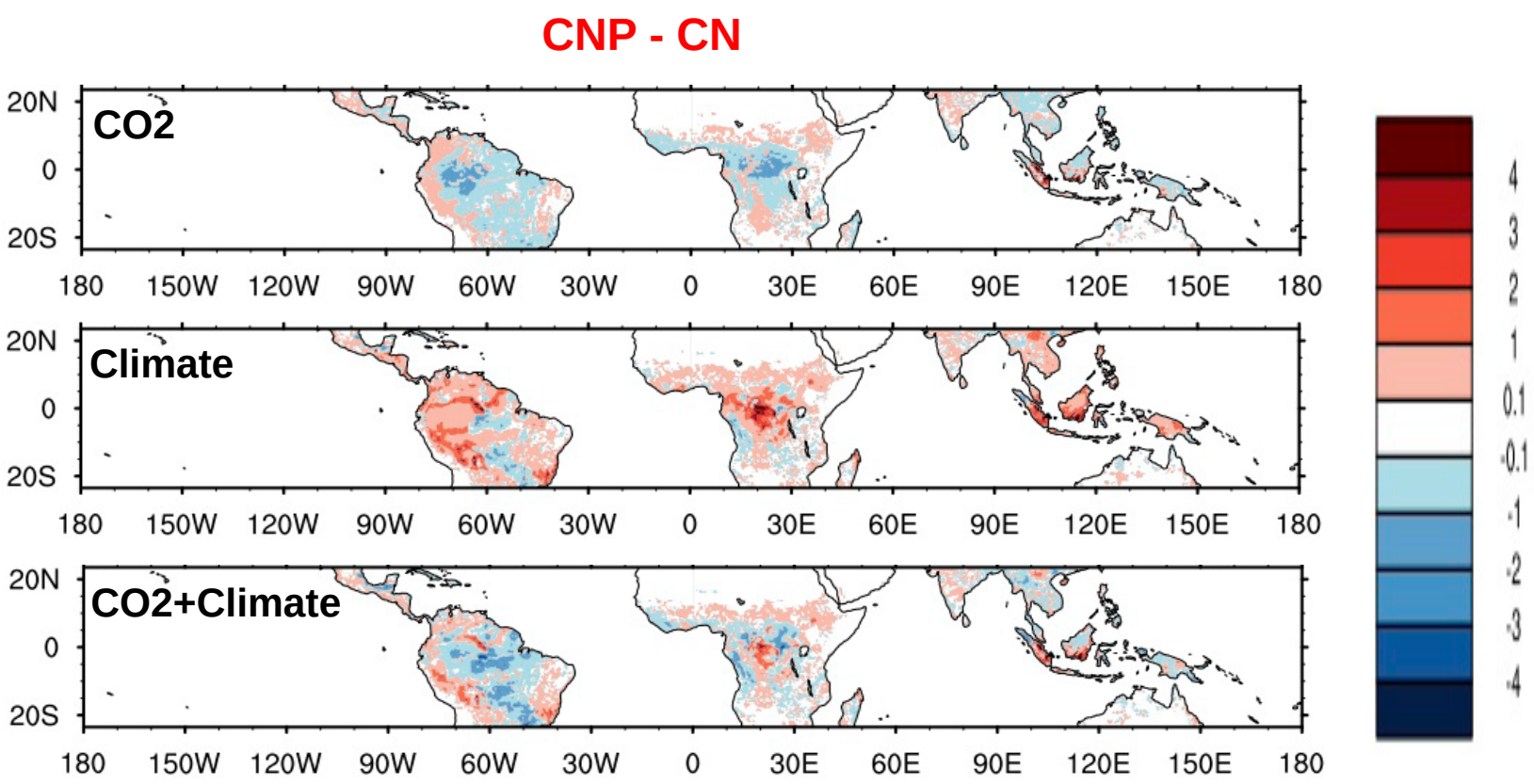


The role of phosphorus in tropical ecosystem responses to changes in [CO_2] and climate



- P limitation leads to a reduced CO2 fertilization effect
- Carbon release associated with historical climate change is reduced with P coupling, as warming induced mineralization may lead to indirect fertilization effect in P-limited ecosystems

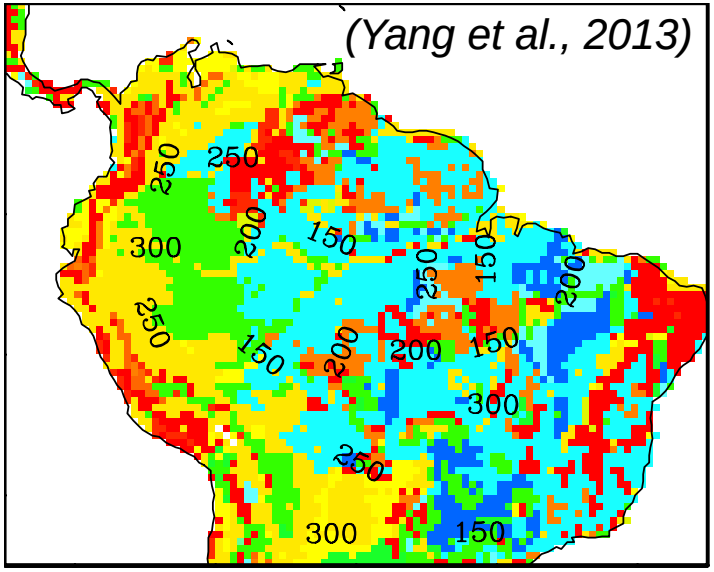
The role of phosphorus in tropical ecosystem responses to changes in [CO_2] and climate

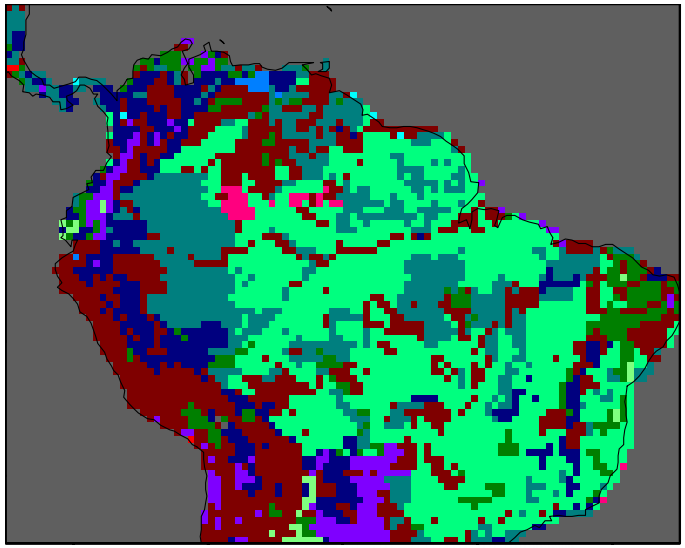


Summary

- Introduction of P coupling reduces carbon stocks and fluxes at steady state
- Phosphorus cycle dynamics tend to reduce the sensitivity of NEE to interannual variation in temperature and precipitation
- Introduction of phosphorus coupling leads to a smaller CO_2 fertilization effect and warming-induced CO_2 release from tropical ecosystems
- The offline simulations are a necessary first step toward exercising the C-N-P model in a fully-coupled Earth system simulation framework

Variations of soil P fertility in the Amazon region in relation to pedogenesis



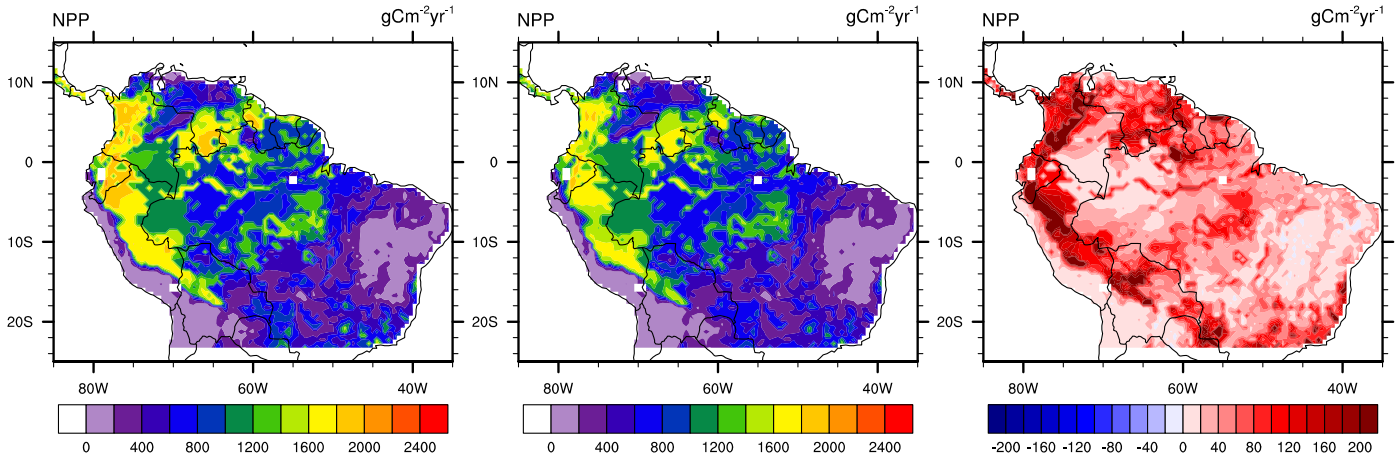


Total P varies with pedogenic development, with lower values found in older soils and higher total P found in younger soils

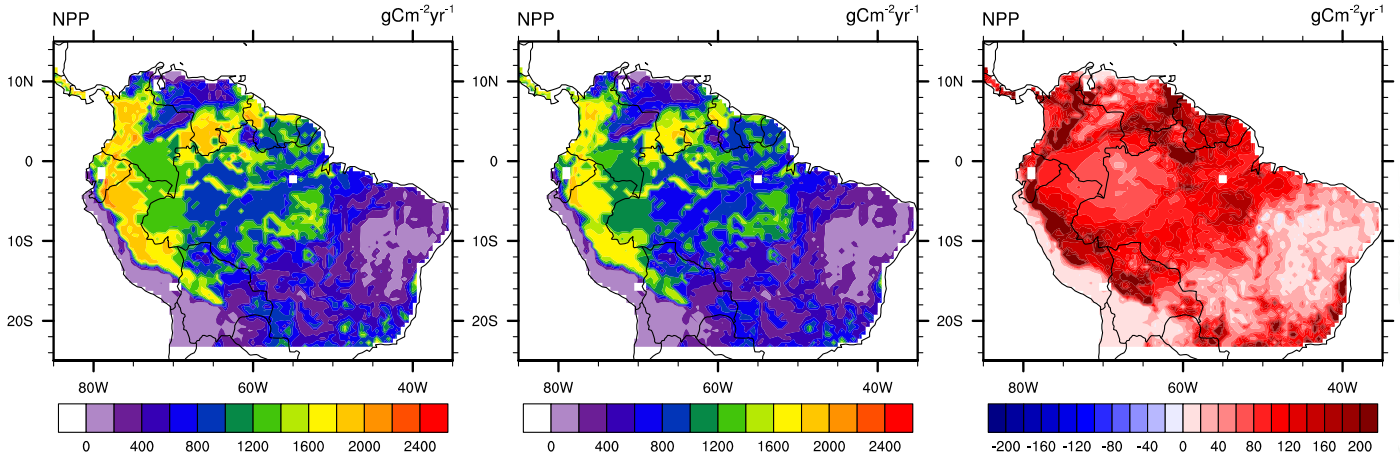
4 : Entisol 5: Inceptisol 6: Aridsol
7 : Vertisol 8: Mollisol 9: Alfisol
10: Spodosol 11: Ultisol 12: Oxisol

Enhanced phosphatase activity under elevated CO2 could alleviate P limitation

NPP(Default model parameters for phosphotase activity)



NPP(Enhanced phosphatase activity



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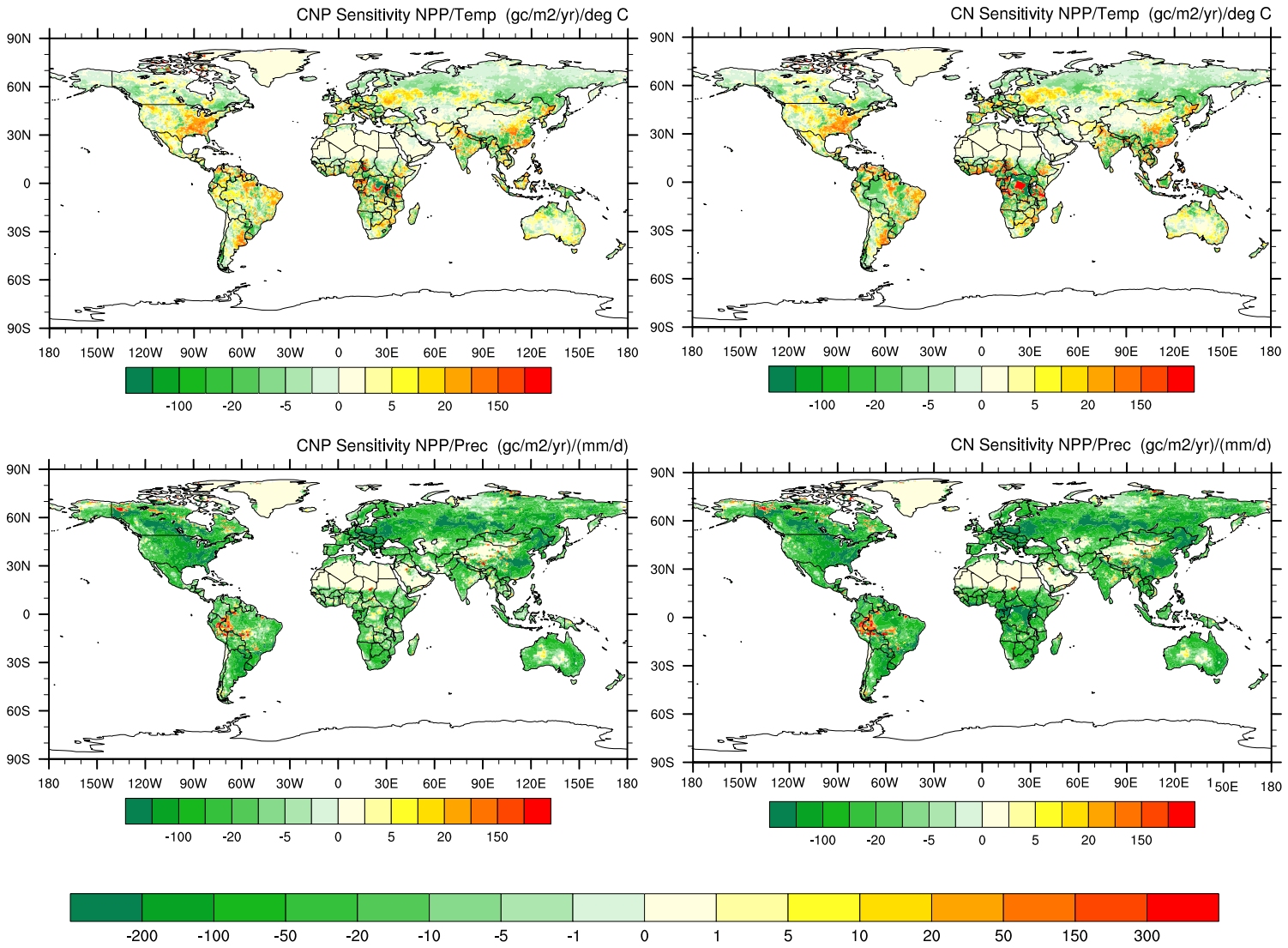
NPP sensitivity to Tair and Prcp (CLM-CN vs CLM-C)



TITUTE

HR sensitivity to Tair and Prcp (CLM-CN vs CLM-C)