Interacting nutrient cycles in tropical forest ecosystems : a case study in the Amazon region

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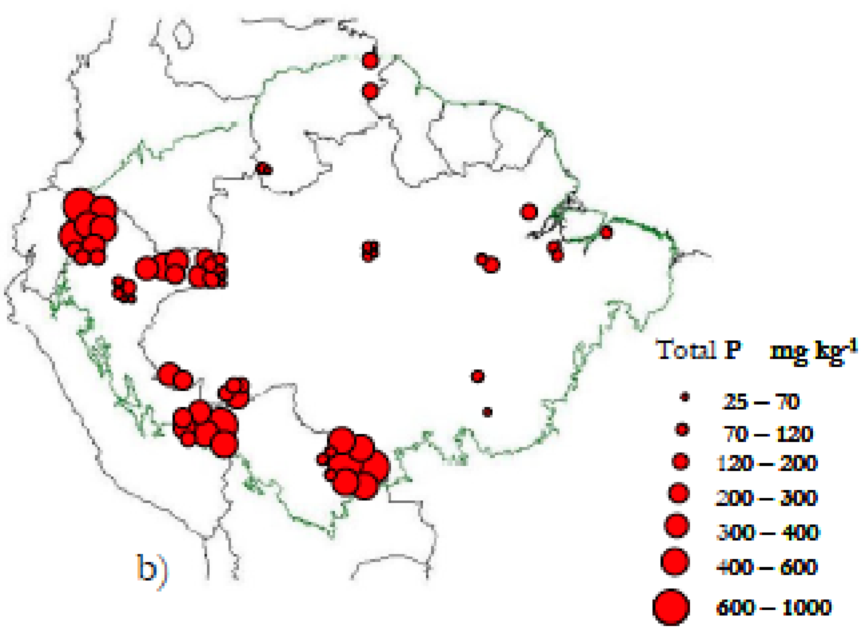
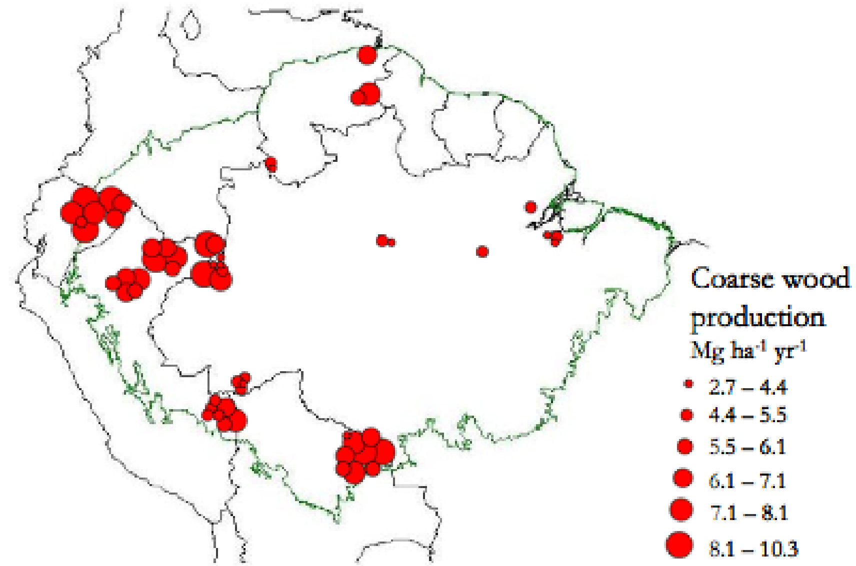
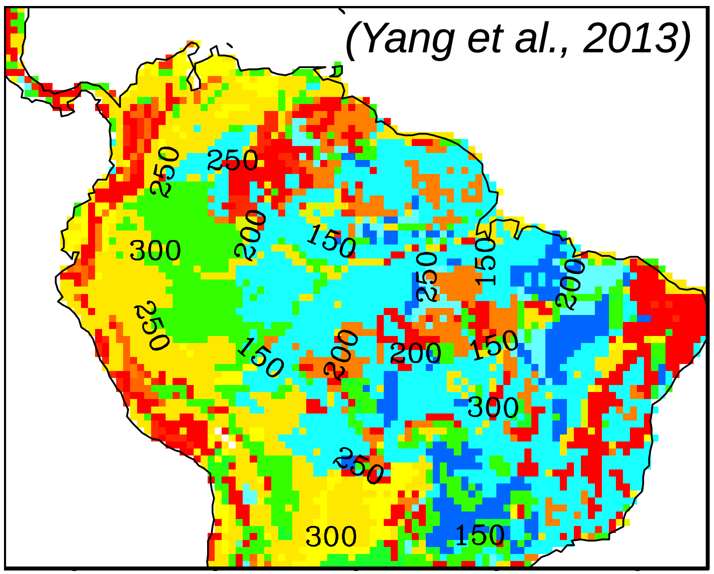
Forest stem growth rates mostly related to total soil P across the Amazon Basin

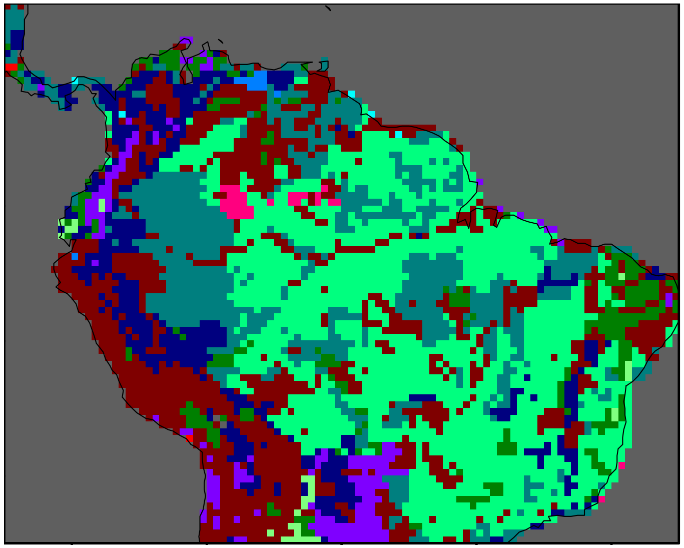




Quesada et al., 2012

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

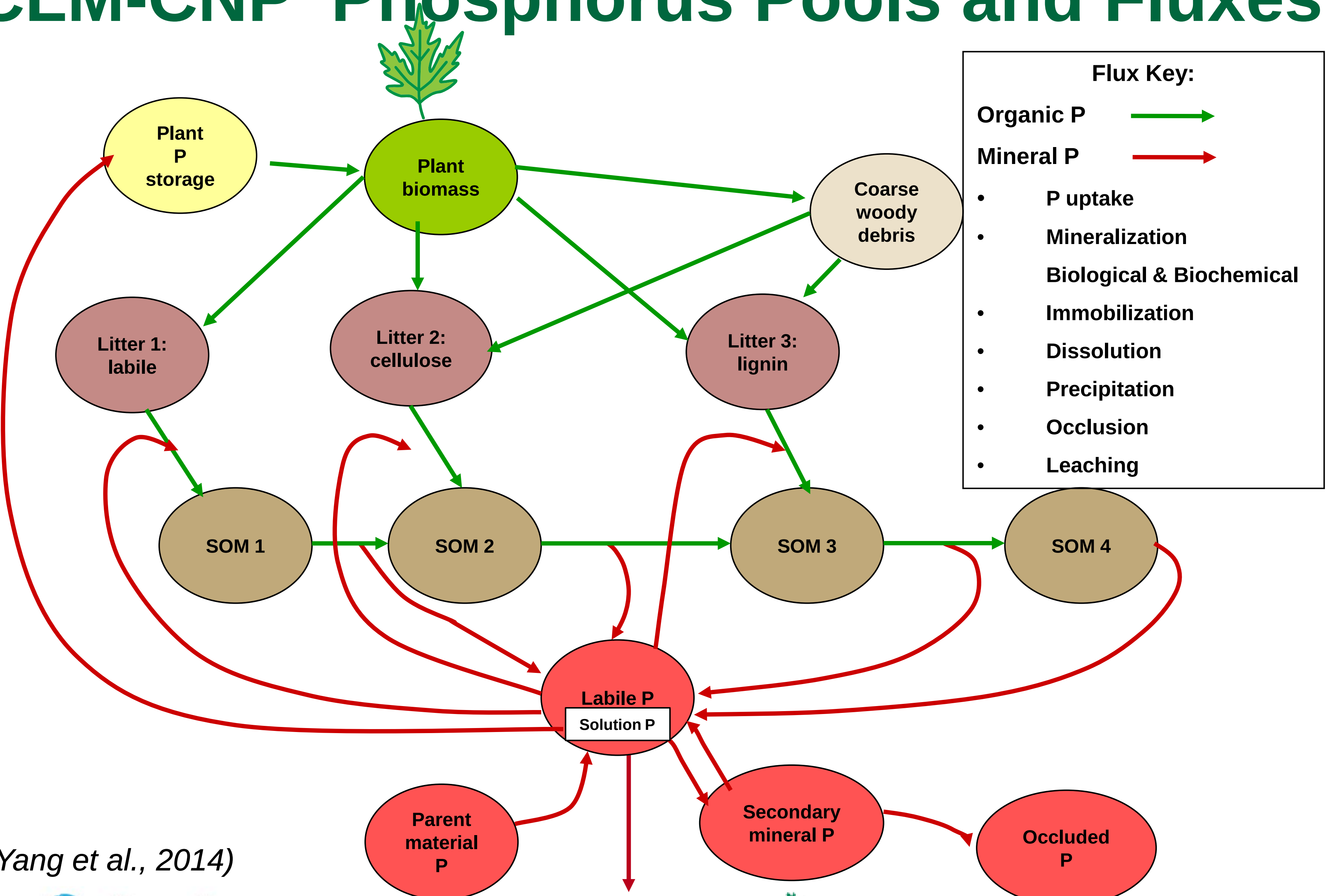




Total P varies with pedogenic development, with lower values found in older soils and higher total P found in younger soils

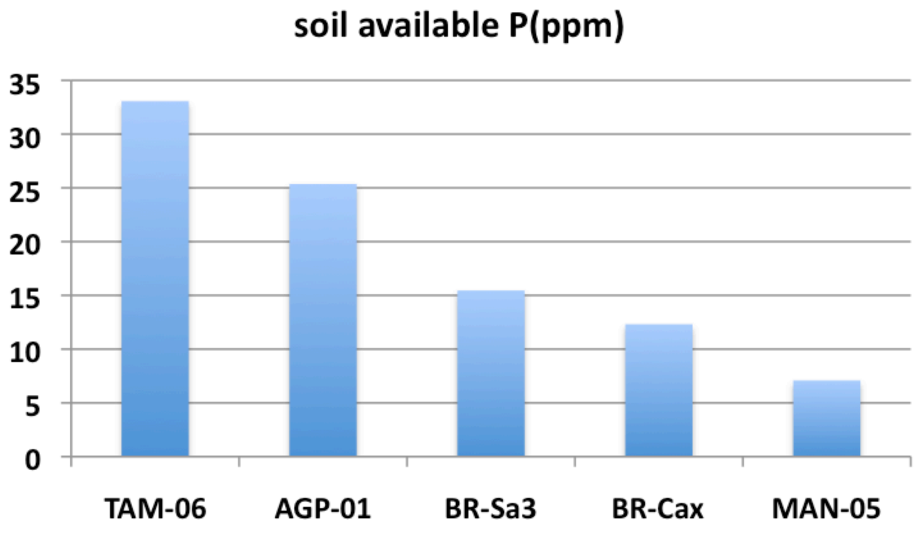
4 : Entisol 5: Inceptisol 6: Aridsol
7 : Vertisol 8: Mollisol 9: Alfisol
10: Spodosol 11: Ultisol 12: Oxisol

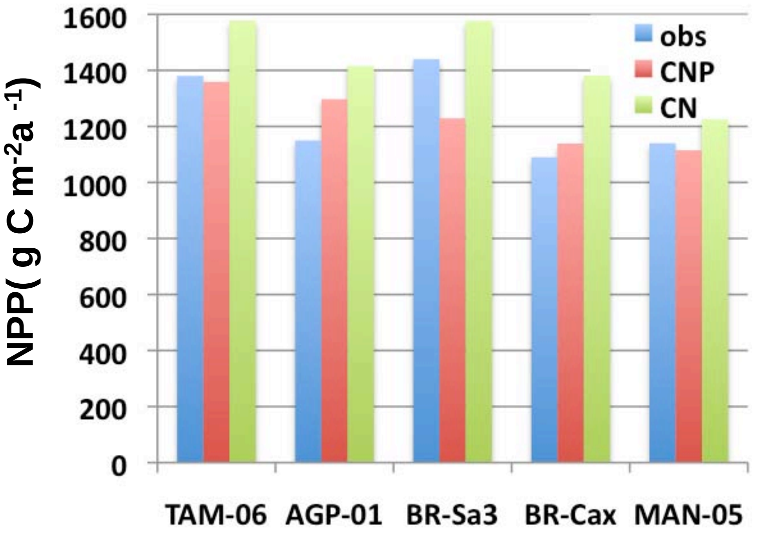
CLM-CNP Phosphorus Pools and Fluxes



(Yang et al., 2014)

Introduction of P limitation improved model simulated NPP in tropical forests





- Observations show that NPP tends to decrease with decreasing soil P availability
- Model simulations using CNP model capture the overall trend in NPP along the P availability gradient
- Site characteristics and land use history need to be considered to explain the discrepancy between models results and observations

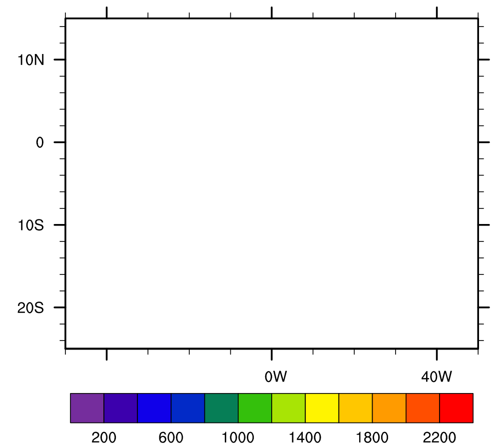
(Yang et al., 2014)

Mean annual simulated fluxes for the period 2000-2009

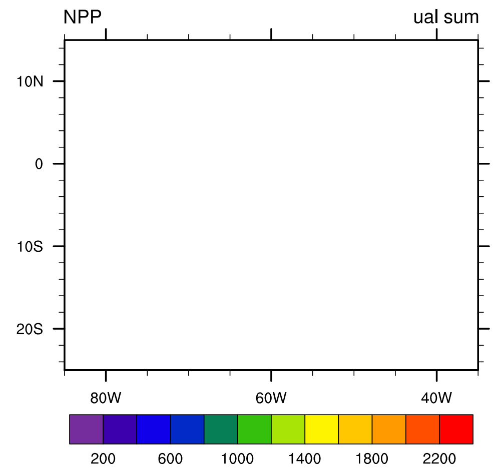
GPP

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.

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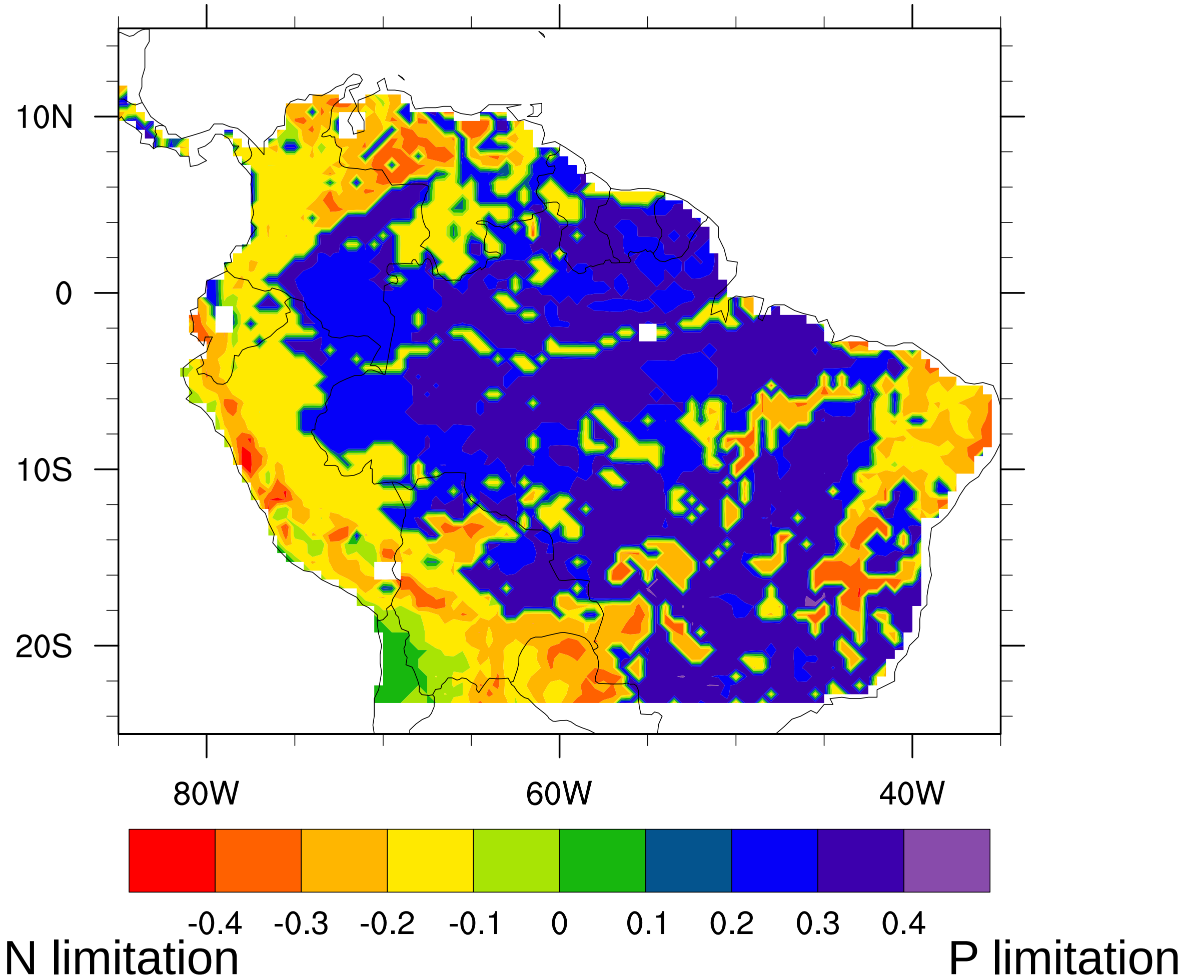
The type and extent of nutrient limitation in the Amazon region



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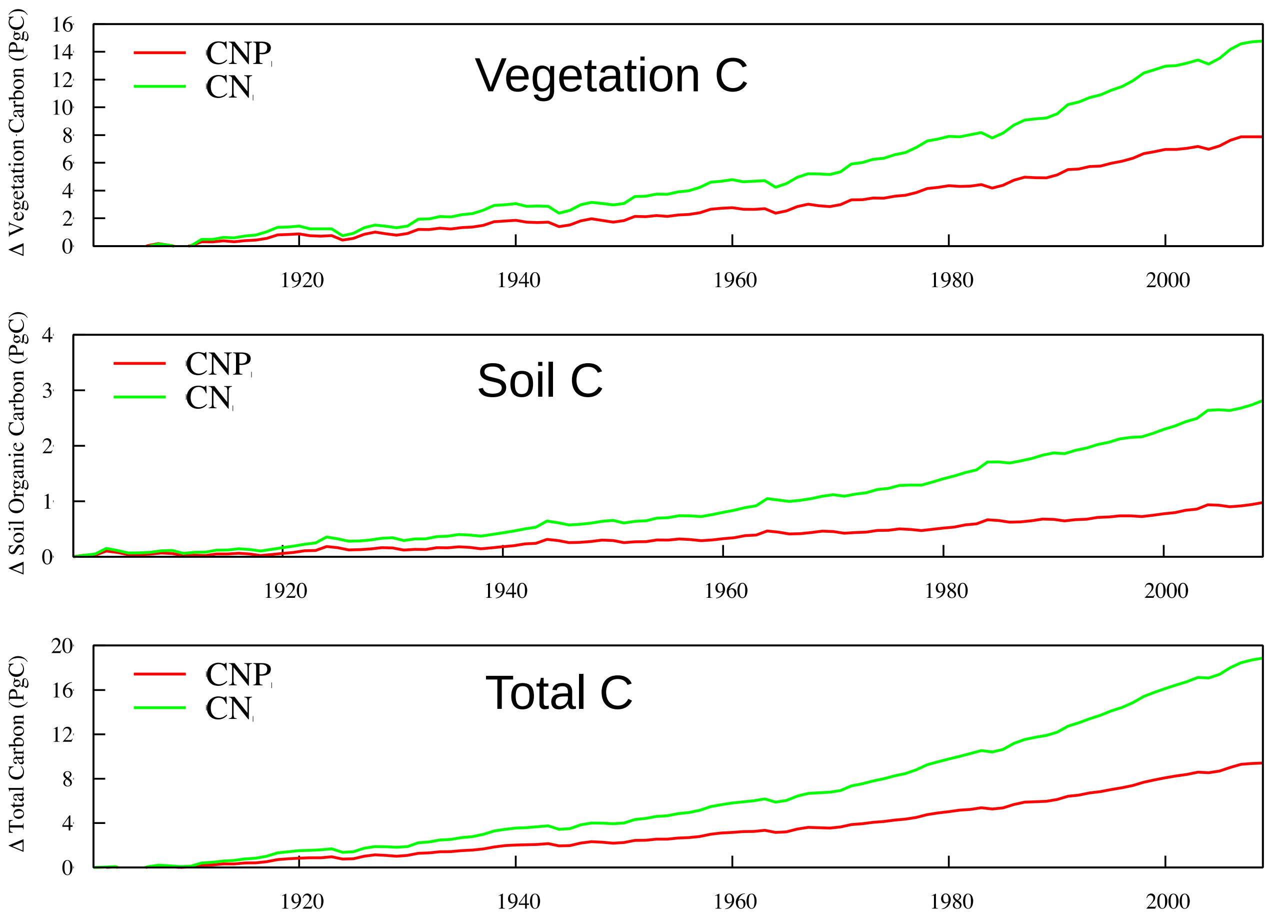
Introduction of P limitation significantly reduces the C uptake response to historical increase in [CO_2]

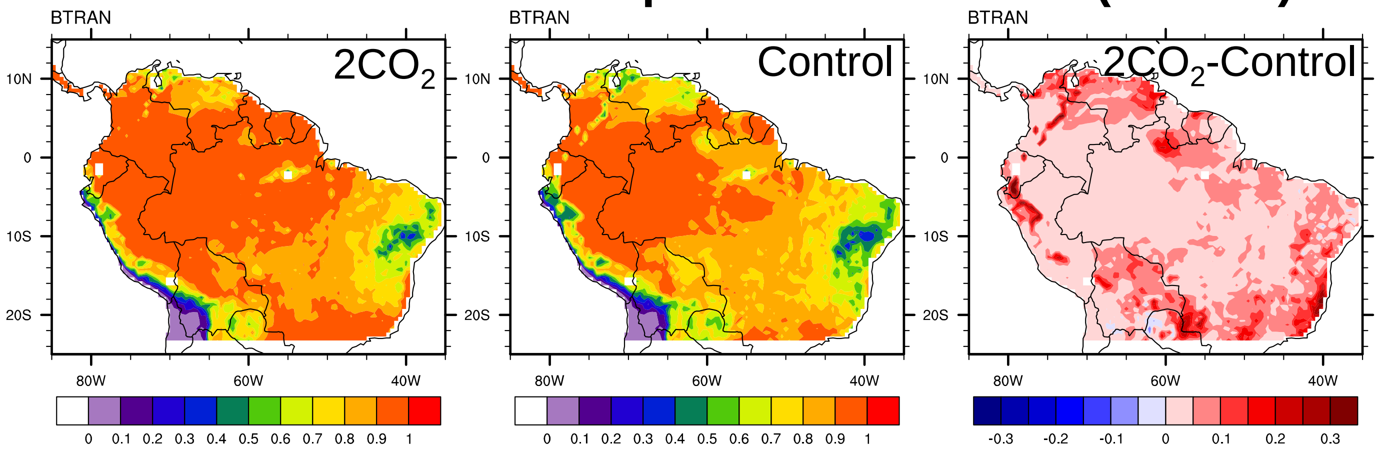


Model experiments

- Explore how nutrient cycling interacts with increasing [CO_2] and warming to affect future C uptake in the Amazon region
- Two exploratory simulations (2010-2050)
  - #1 : 2xCO_2
  - #2 : +4 °C

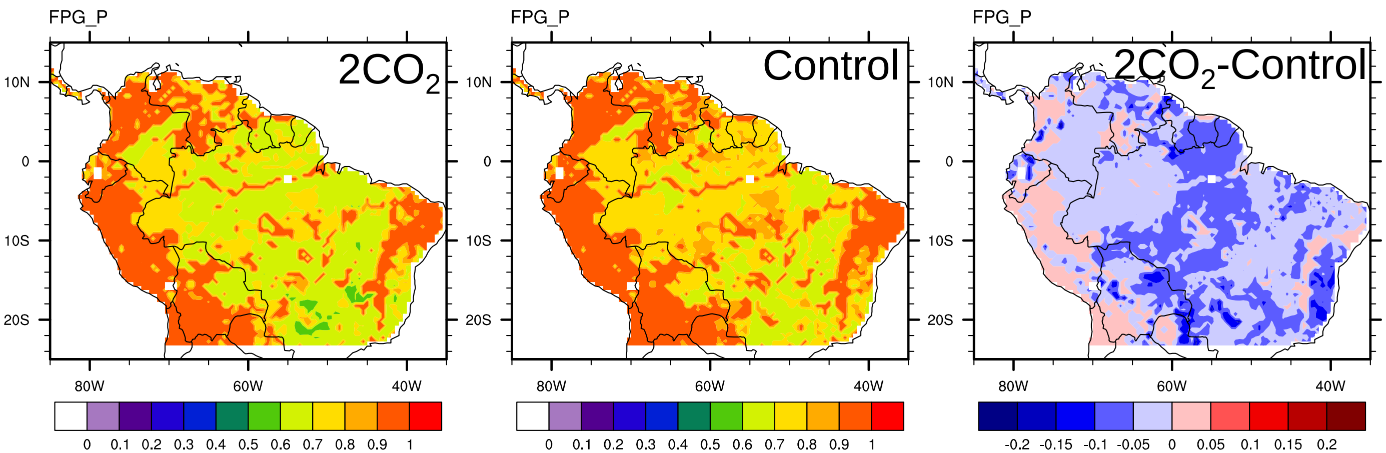
2CO2

Annual Means of Transpiration Beta Factor(BTRAN)



- Elevated CO_2 increases WUE and reduces water stress, especially in drier areas.

P limitation factor



- Phosphorus becomes more limiting under elevated CO_2 condition.

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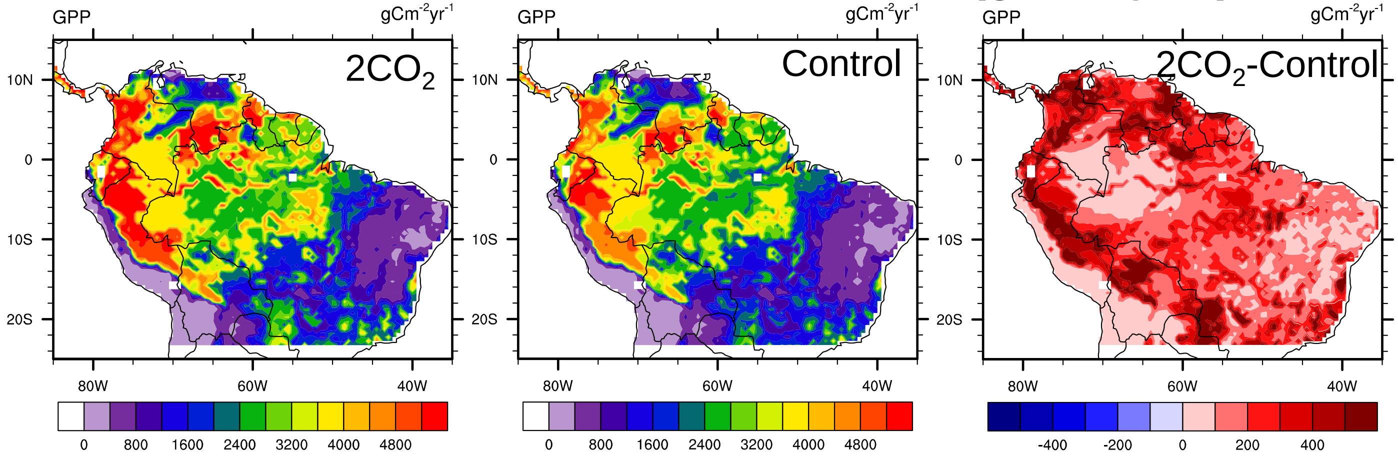
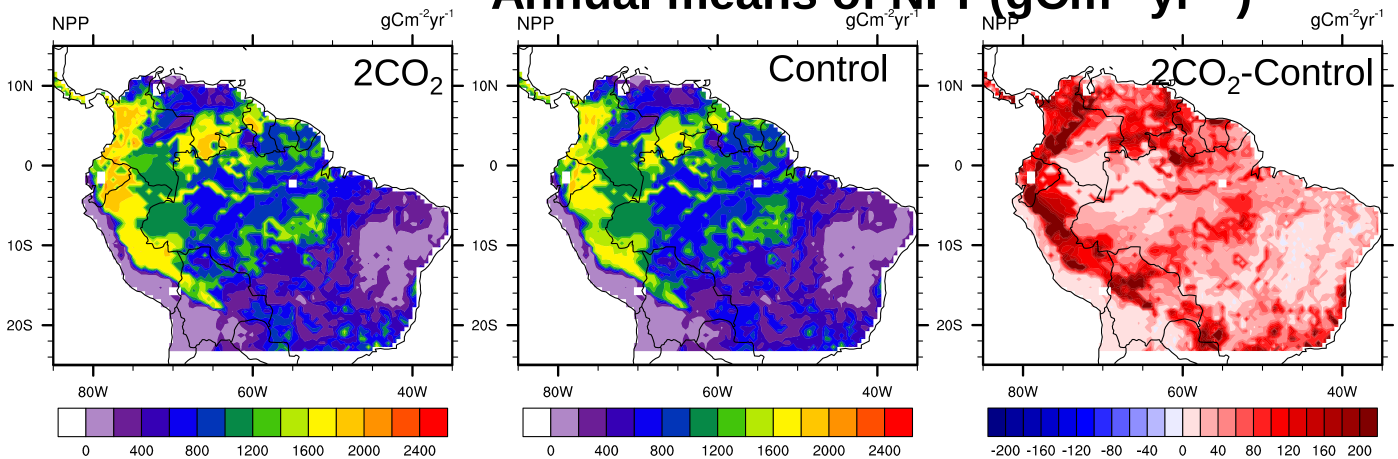
2CO2

Annual means of GPP($gCm^{-2}yr^{-1}$)



- Productivity is enhanced with elevated CO2, especially in drier regions because of improved WUE.

Annual means of NPP($gCm^{-2}yr^{-1}$)



- CO2 fertilization effect is constrained by P availability in lowland tropical forests on highly weathered soils.

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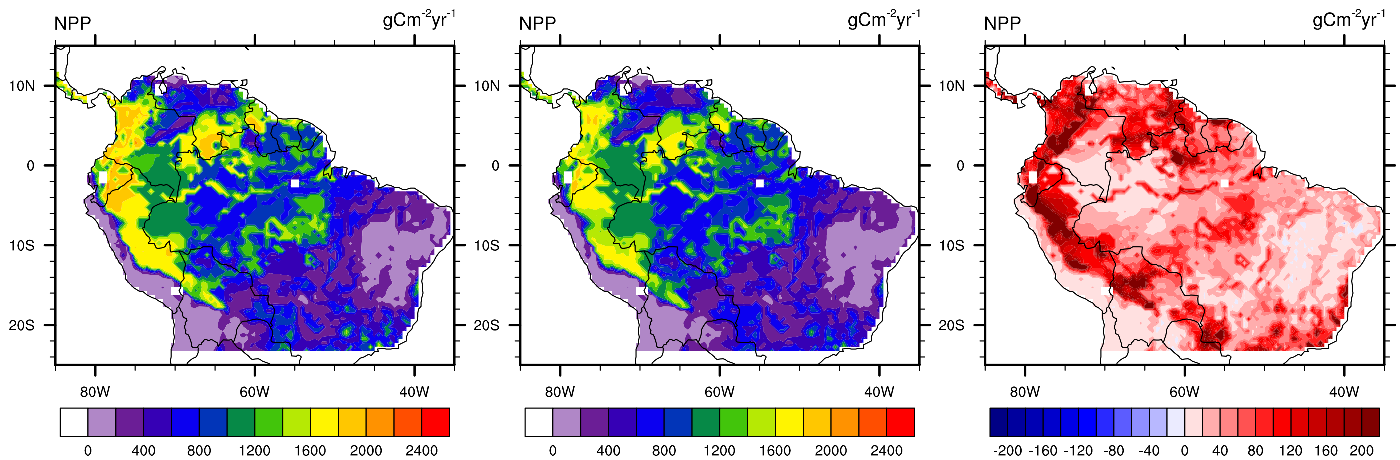
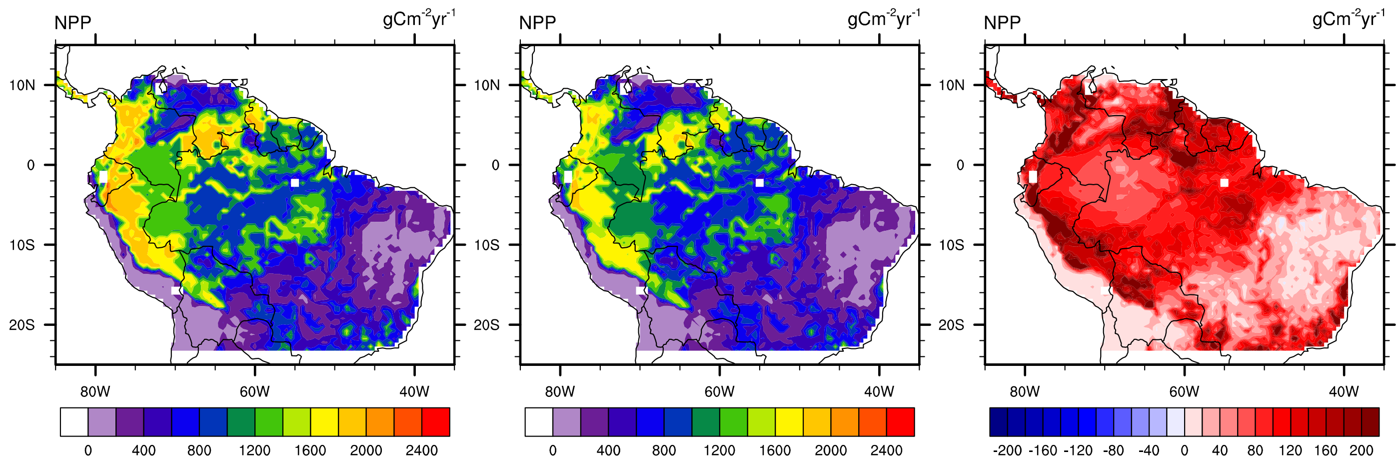
Enhanced phosphatase activity under elevated CO_2 could alleviate P limitation

NPP(Default model parameters for phosphotase activity)



NPP(Enhanced phosphatase activity)



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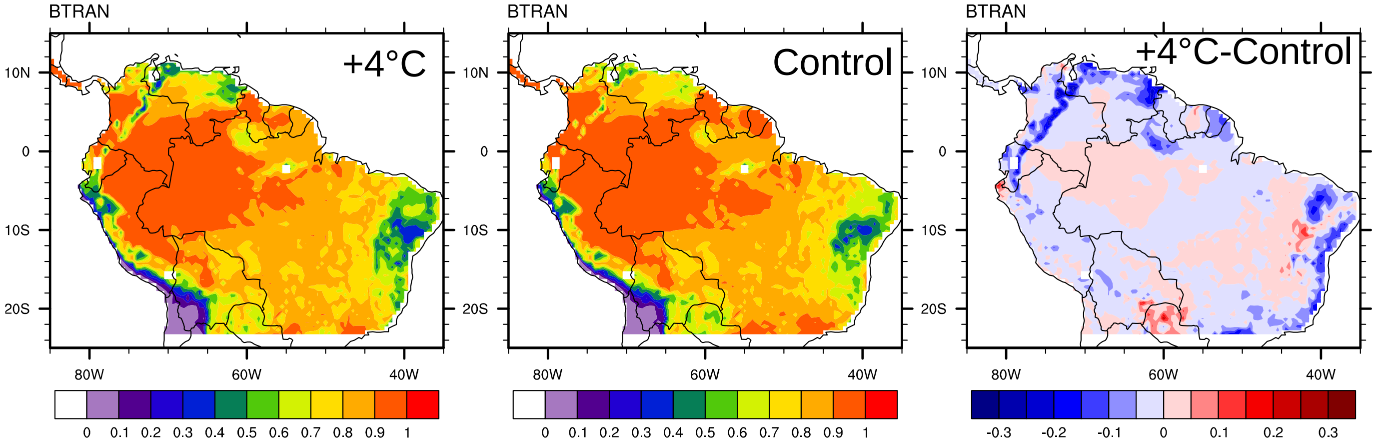
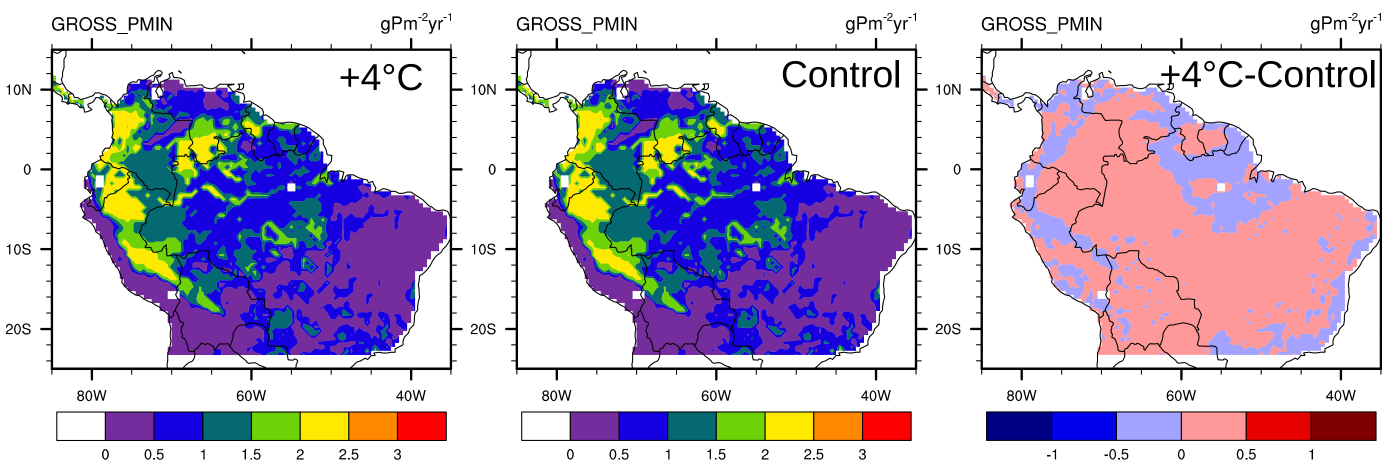
Warming(+4°C)

Annual Means of Transpiration Beta Factor(BTRAN)



- Higher temperature leads to deepening of dry season water stress.

Annual Means of P mineralization($gPm^{-2}yr^{-1}$)



- Warming leads to increased nutrient mineralization.

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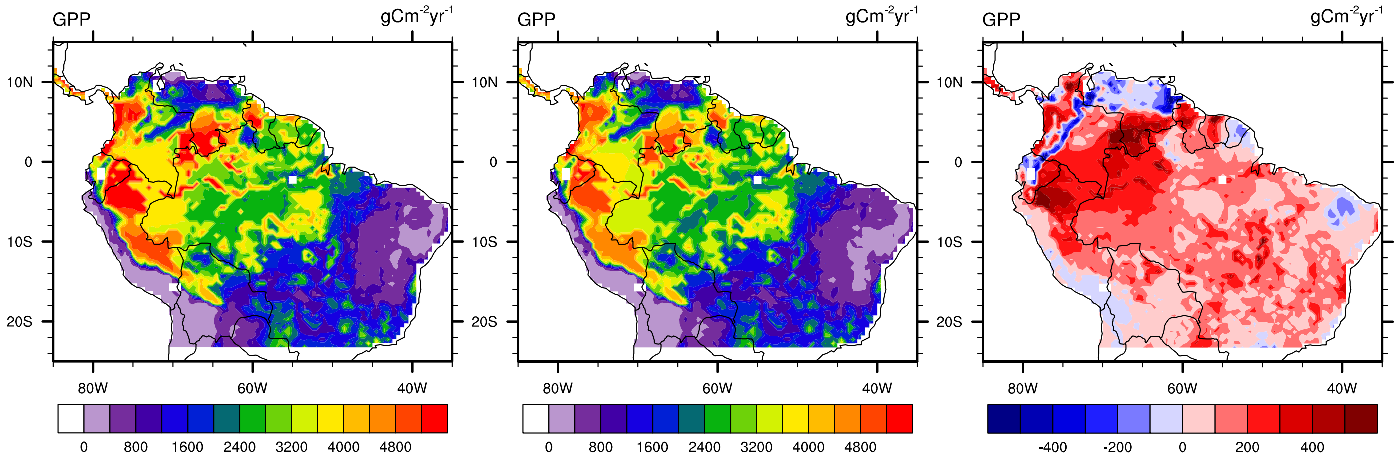
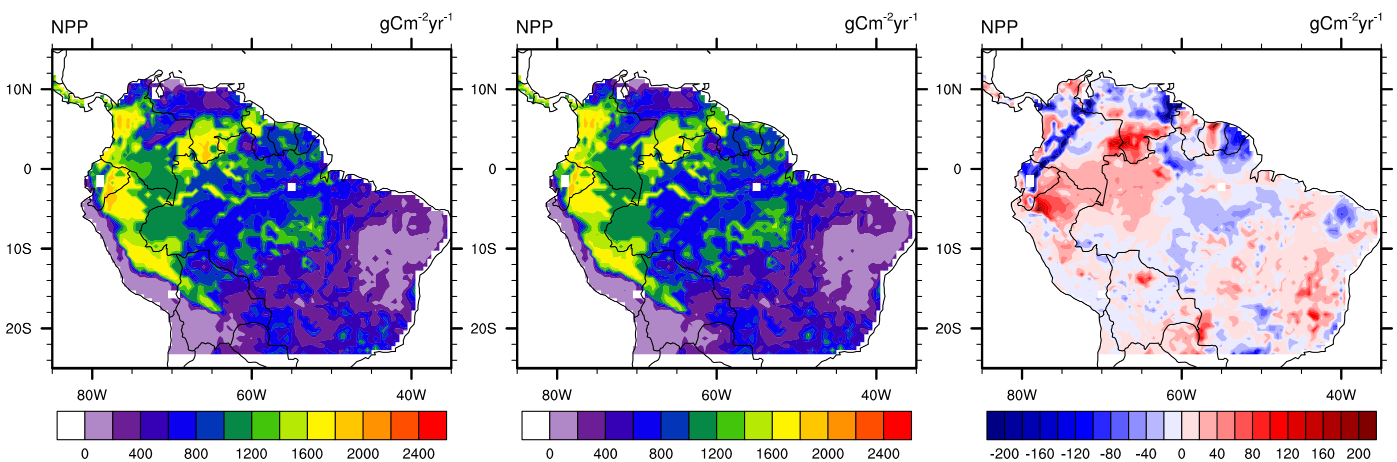
Warming(+4°C)

Annual means of GPP($gCm^{-2}yr^{-1}$)



- Wet season GPP is increased due to enhanced nutrient mineralization.

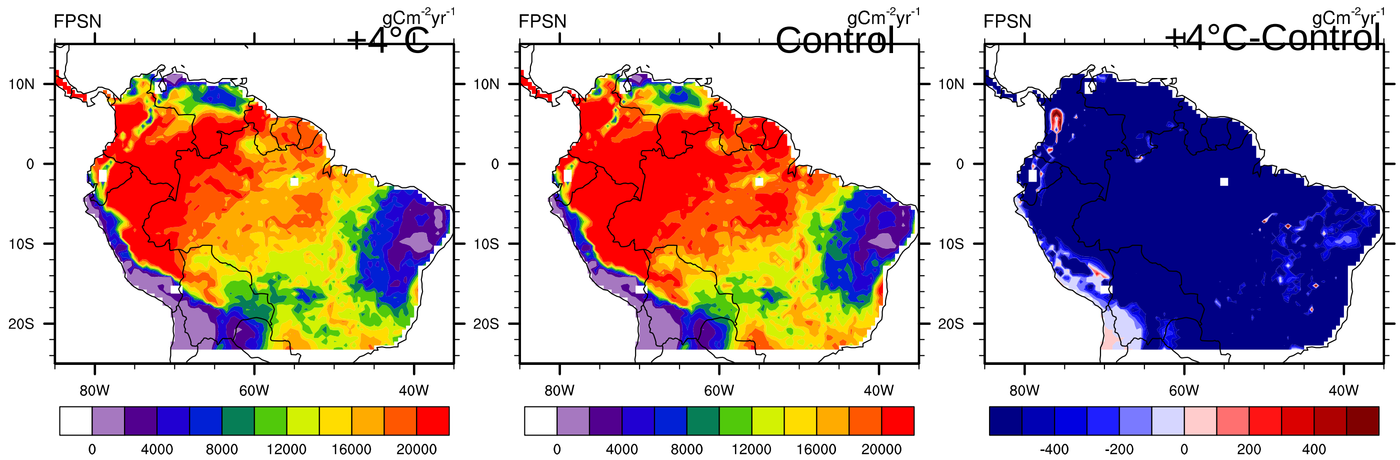
Annual means of NPP($gCm^{-2}yr^{-1}$)



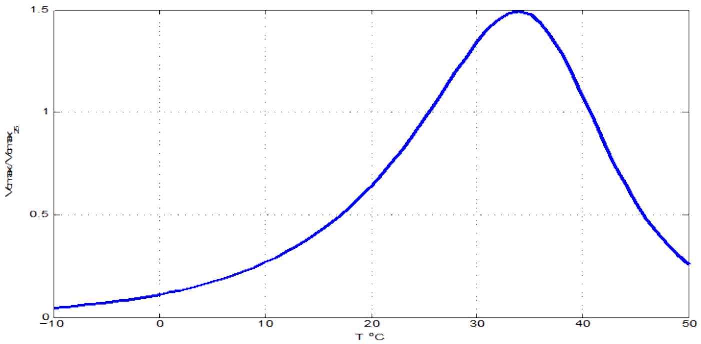
- Autotrophic respiration response to warming greatly limits NPP response.

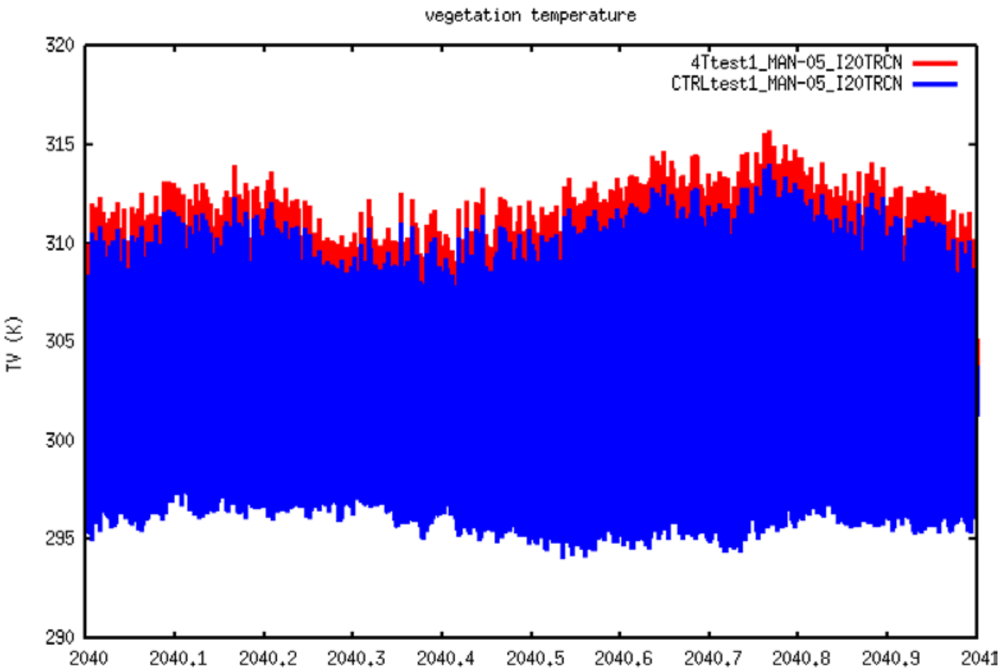
Warming(+4°C)

FPSN



T-sensitivity of Vcmax





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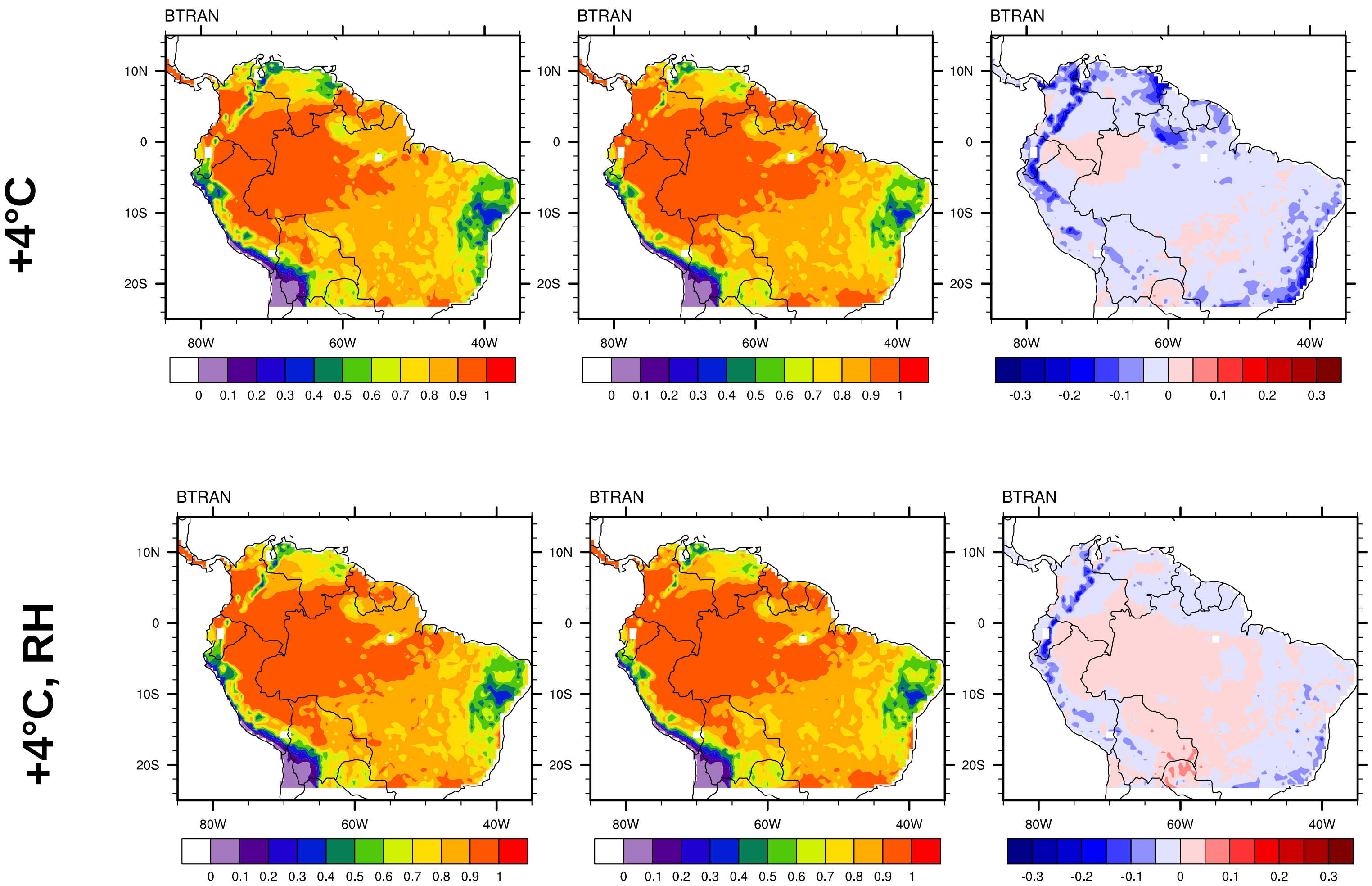
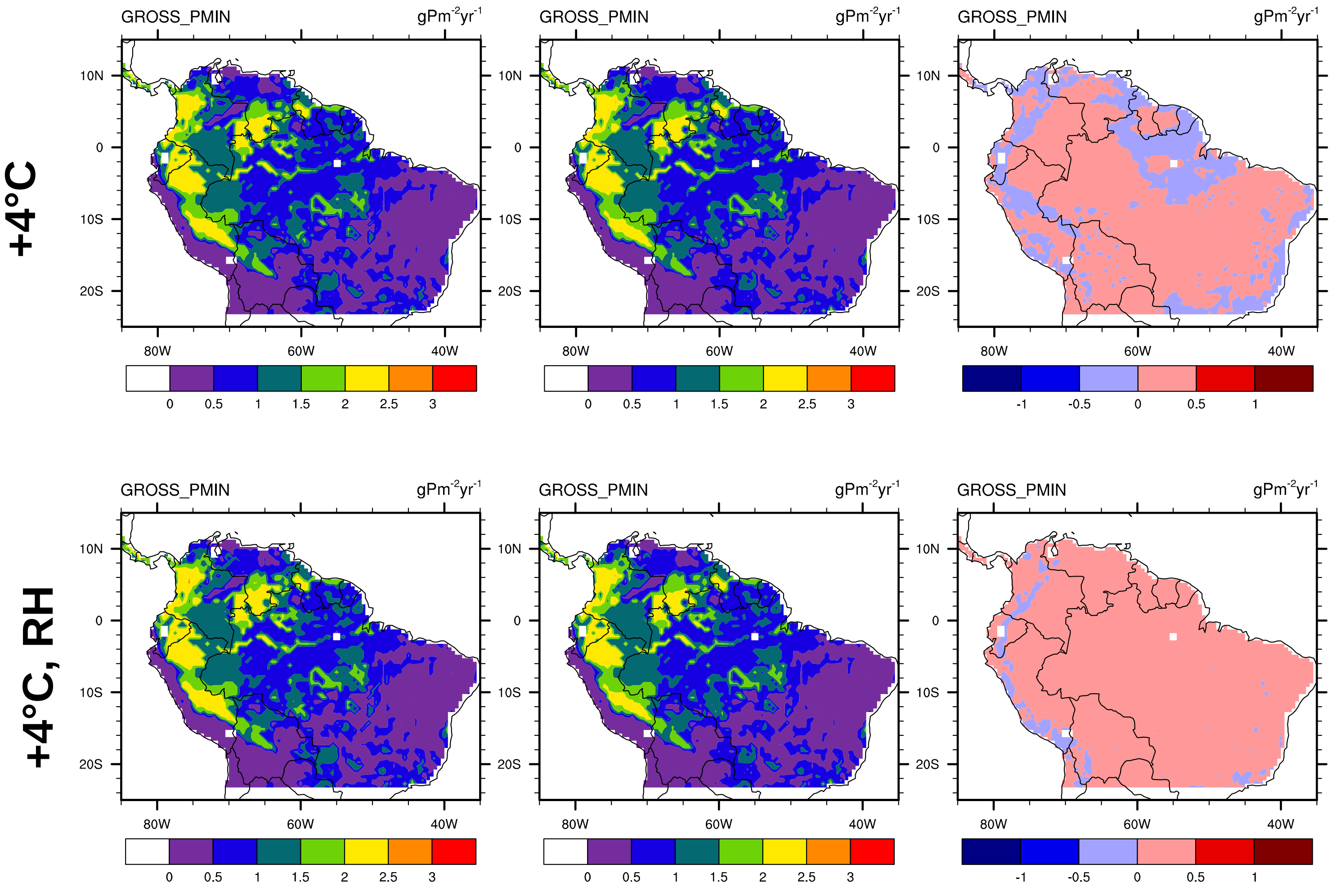
The effect of maintaining constant RH

Water stress



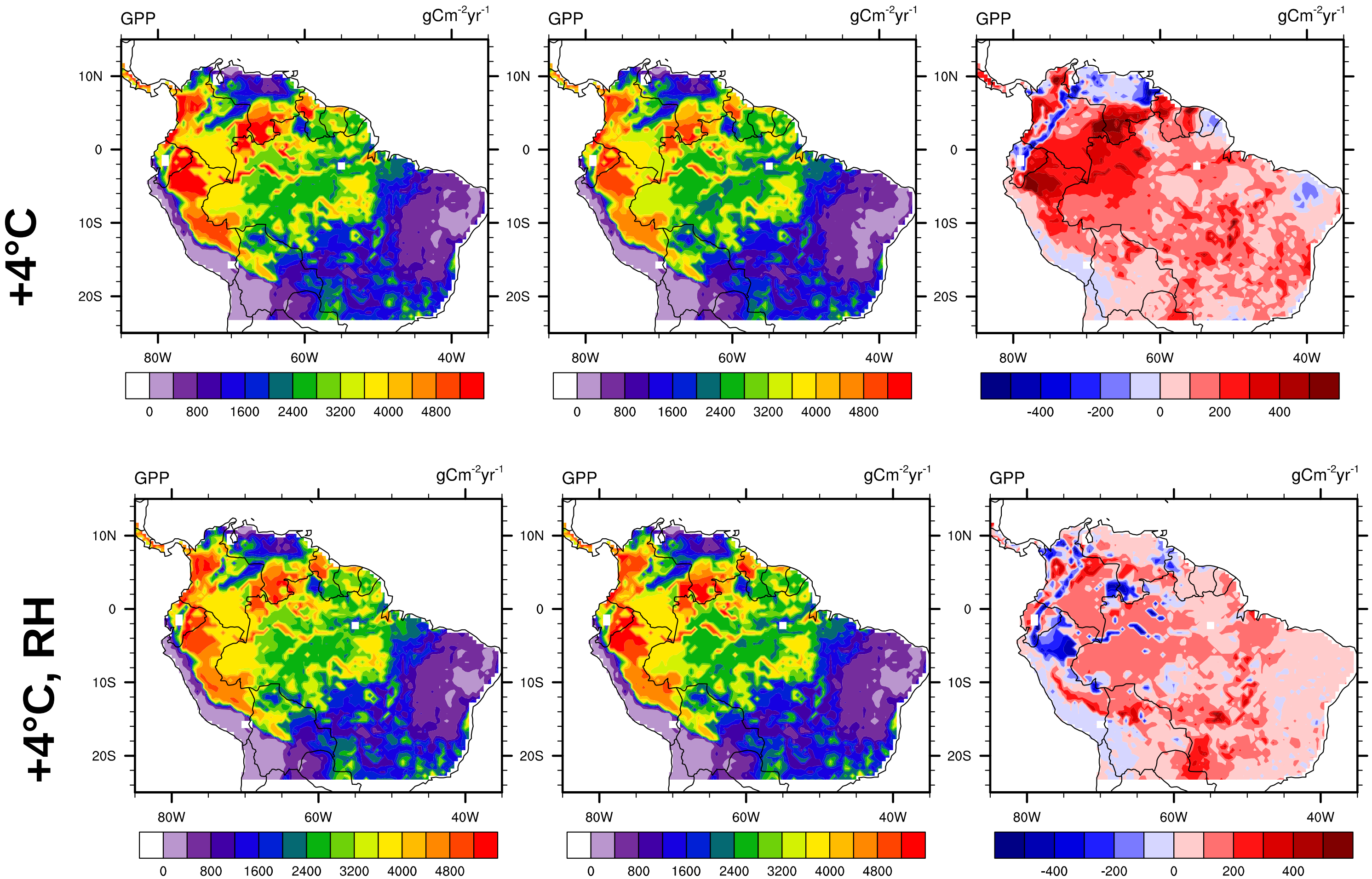
The effect of maintaining constant RH

Gross P mineralization



The effect of maintaining constant RH

GPP



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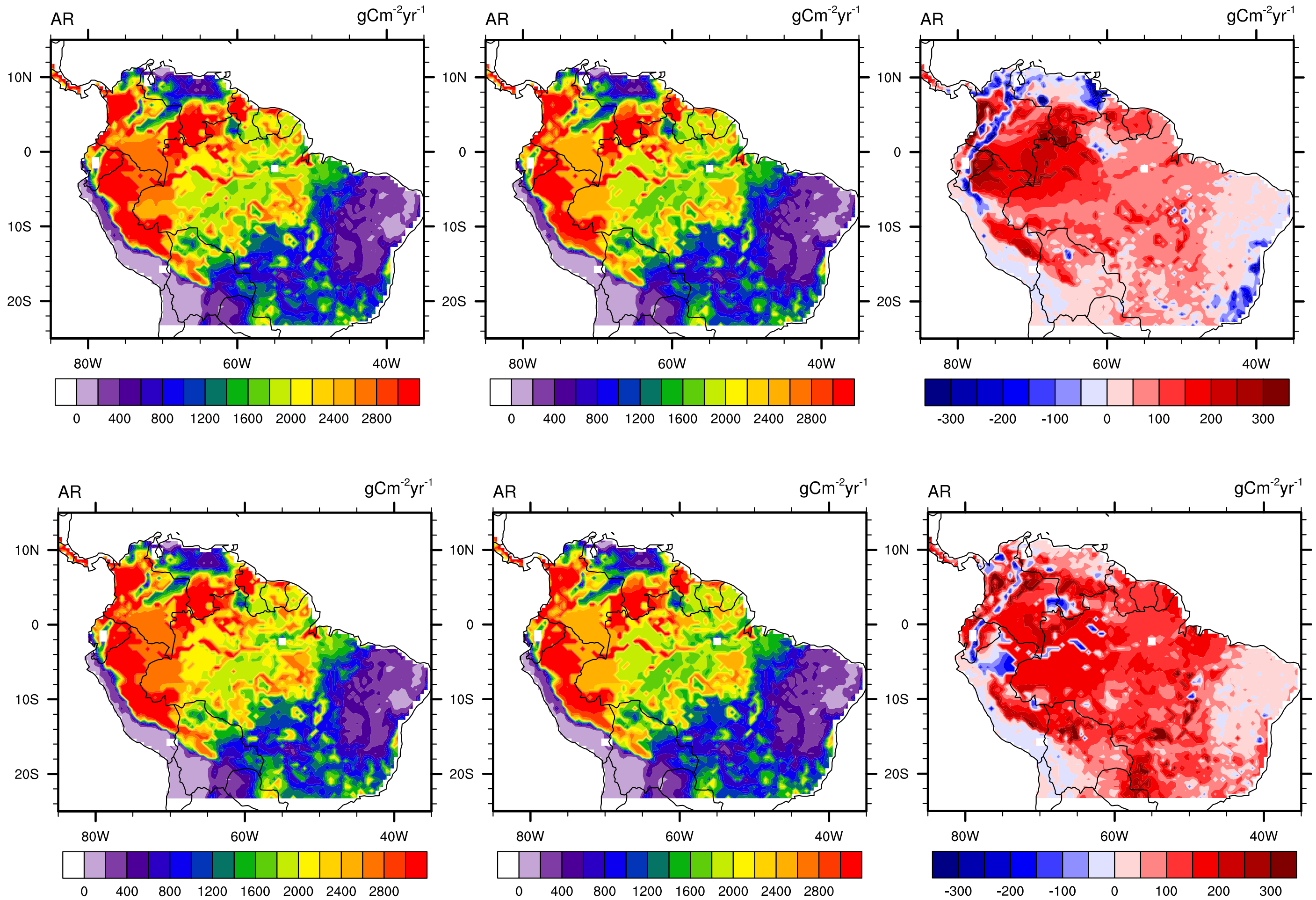
The effect of maintaining constant RH

AR

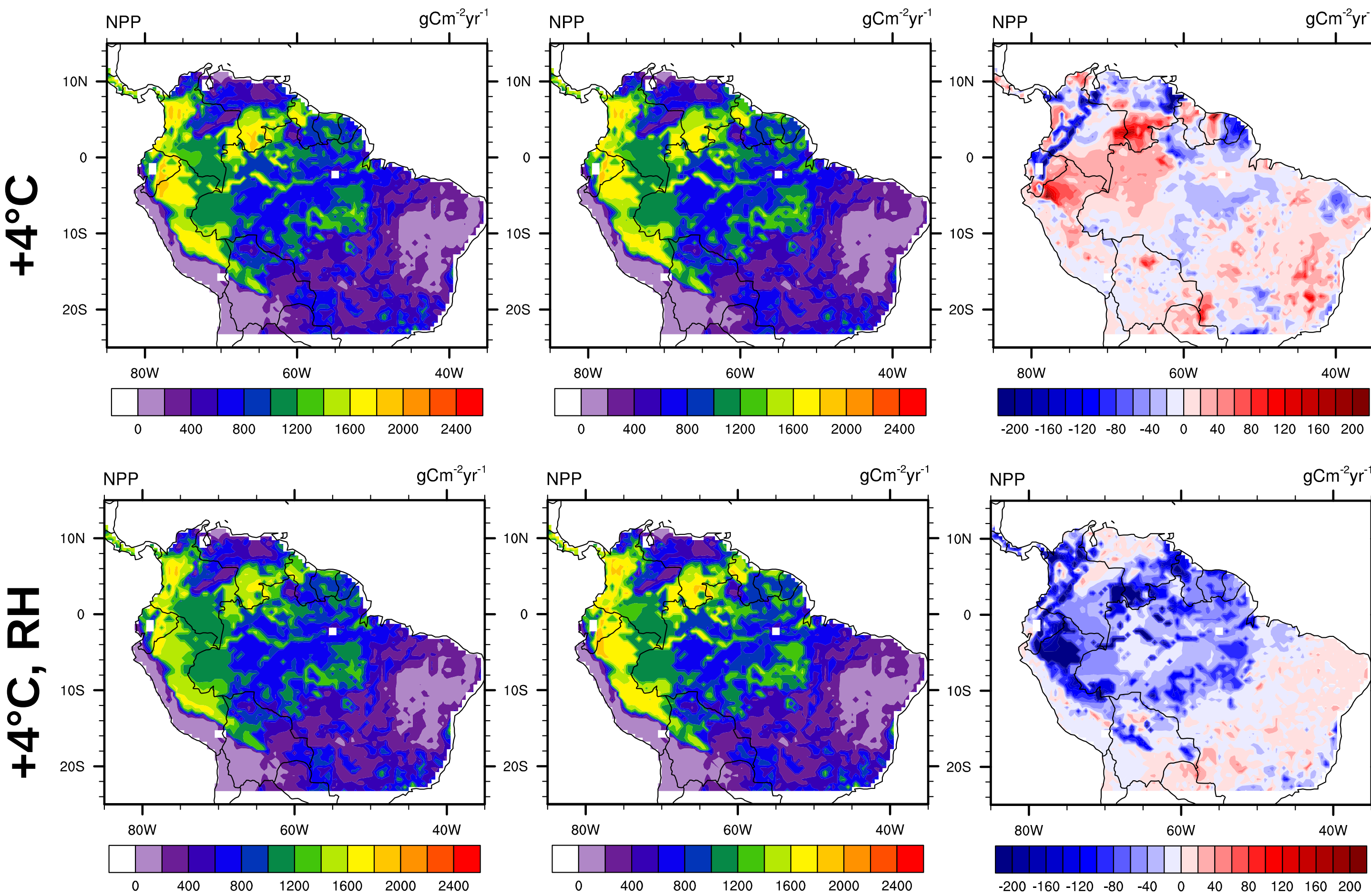
+4°C

+4°C, RH



The effect of maintaining constant RH

NPP



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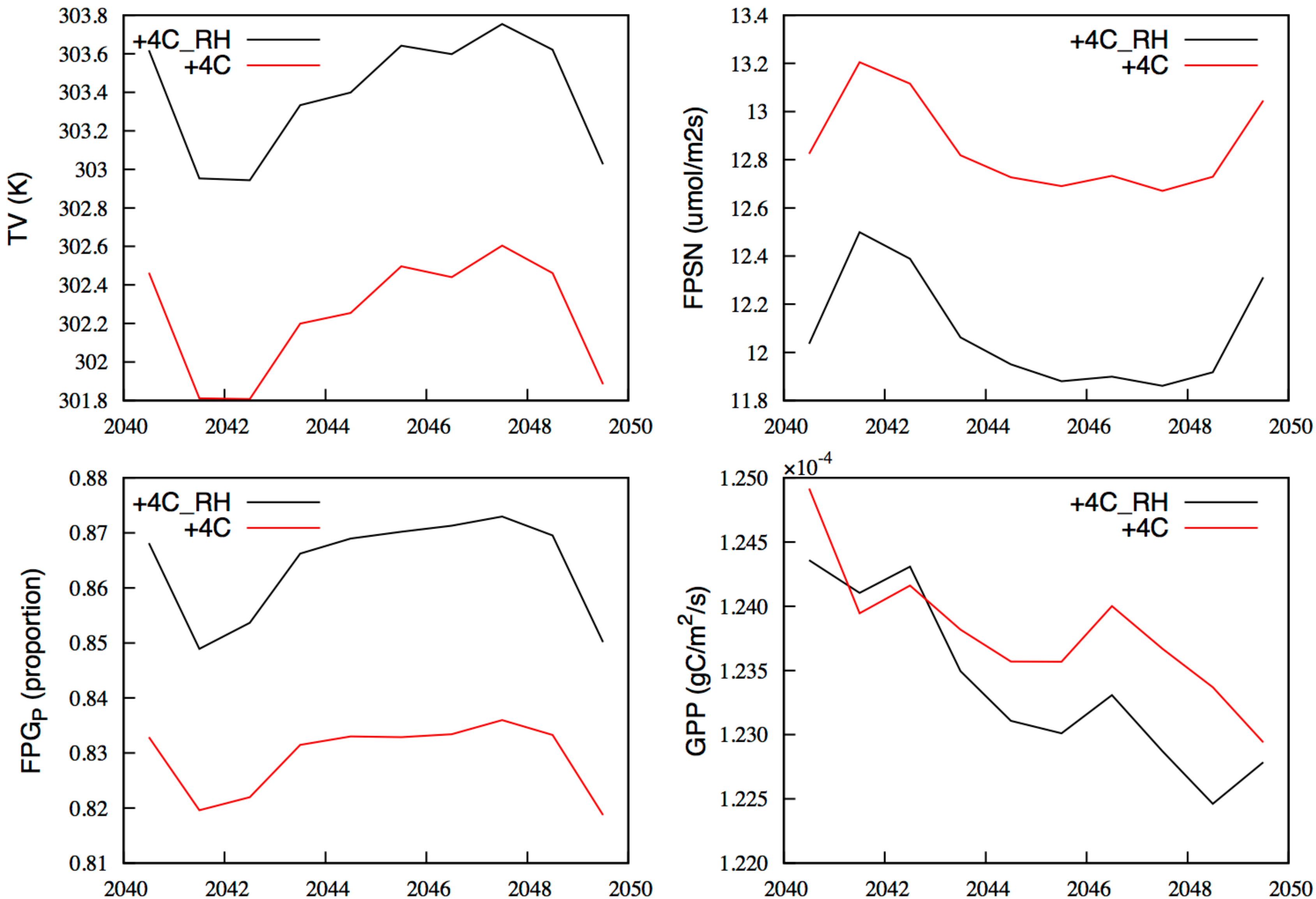
Effects of Leaf temperature dominate



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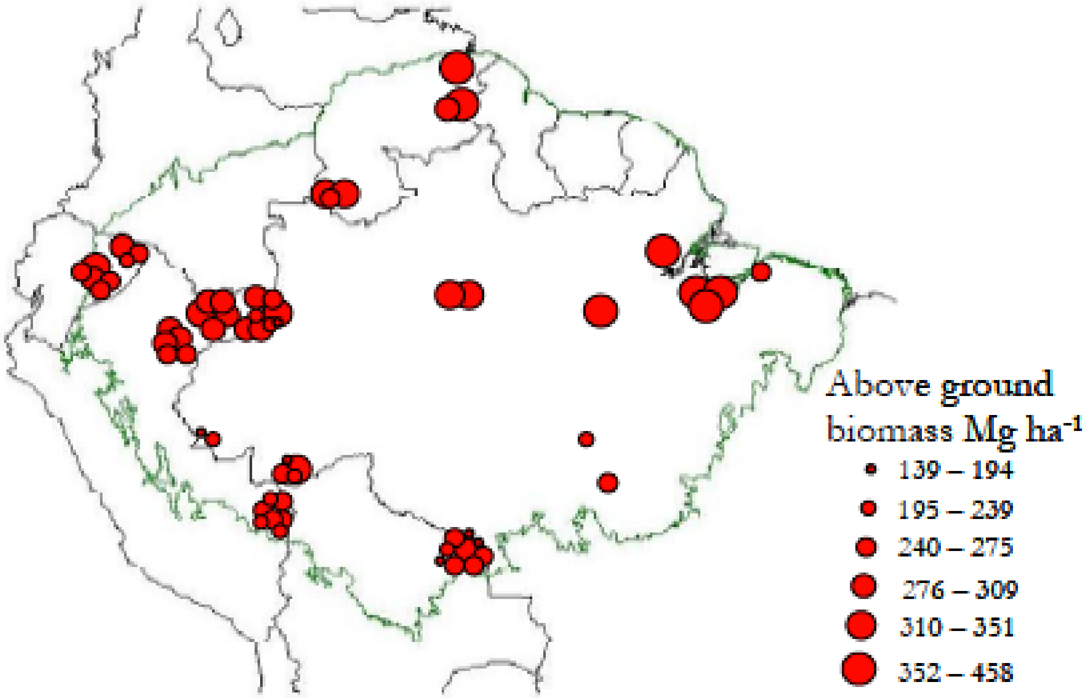
Summary

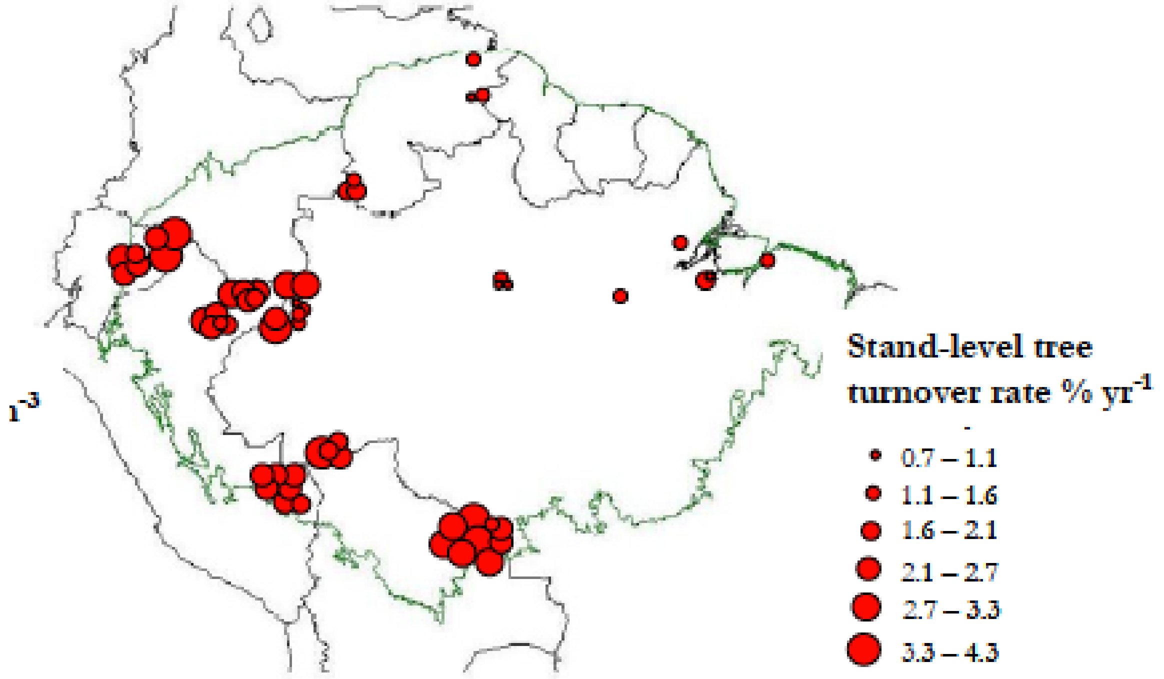
- The introduction of P cycling and limitation improved heterogeneity of simulated GPP & NPP across the Amazon region, relative to the original CLM-CN model.
- Phosphorus coupling reduces simulated historical CO_2 fertilization effect.
- Tropical ecosystem responses to CO_2 increases and warming interact strongly with drought and nutrient dynamics.
- Growth-chamber or free-air CO_2 enrichment (FACE) experiments and warming experiments in tropical forests are needed to test the model predictions.

Above ground biomass



Quesada et al., 2012

Stand-level tree turnover rate



Quesada et al., 2012