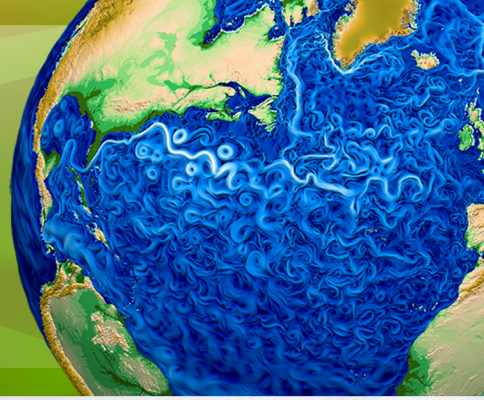
E3SM
Energy Exascale
Earth System Model



Impacts of nitrogen and phosphorus co-limitation on global carbon cycling

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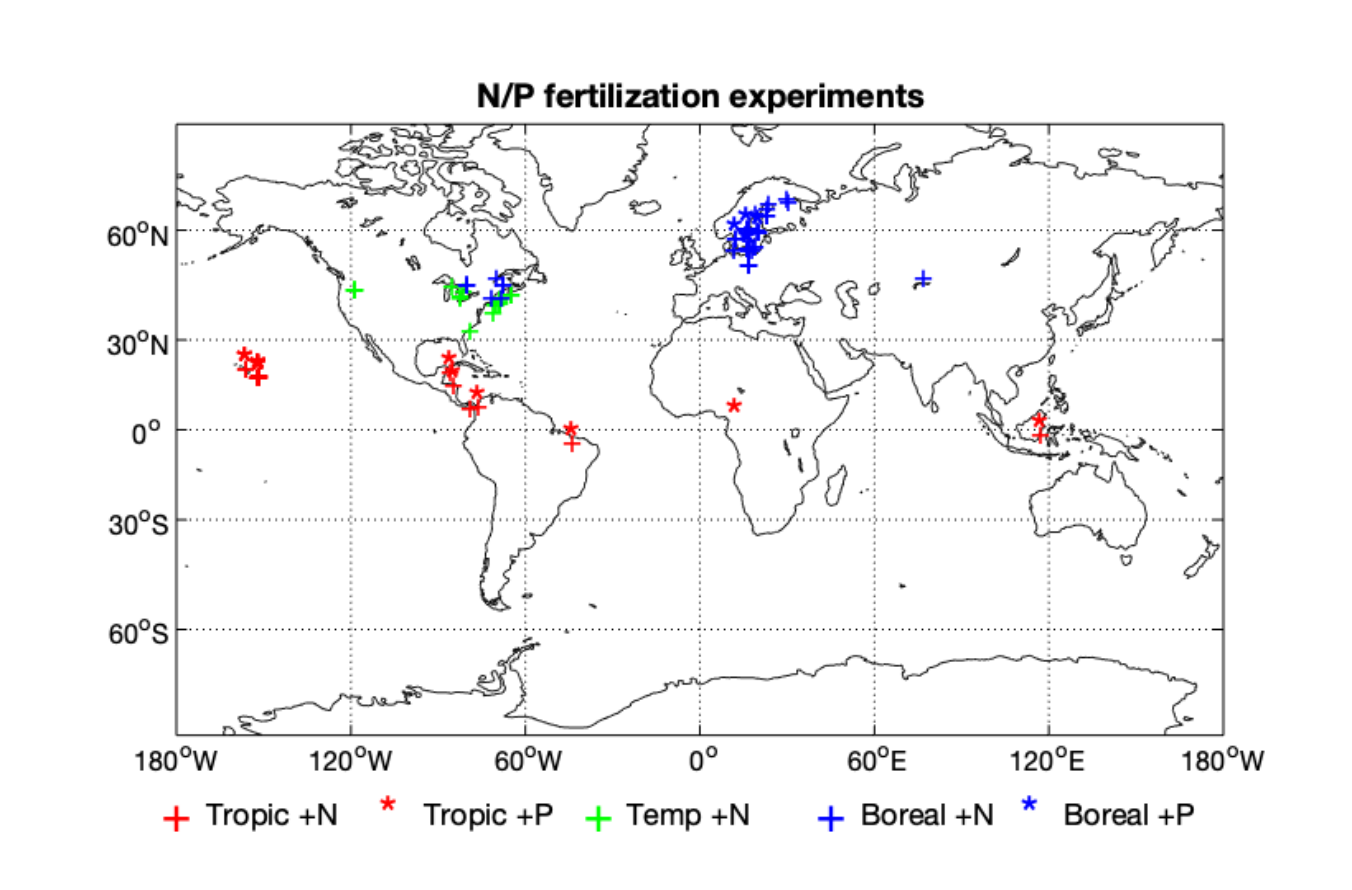
Introduction

- Soil Nitrogen (N) and Phosphorus (P) availability strongly modulate the terrestrial ecosystem carbon cycle
- Two concepts have been widely supported in the literature to represent nutrient limitations:
  - Liebig's Law of the Minimum (LLM) and the Multiple Element Limitation (MEL)
- We first benchmarked ELMv1 against 98 nutrient perturbation field experiments
- We then evaluated the 21st century global C cycle responses to nutrient limitations

Nutrient Limitation Hypotheses

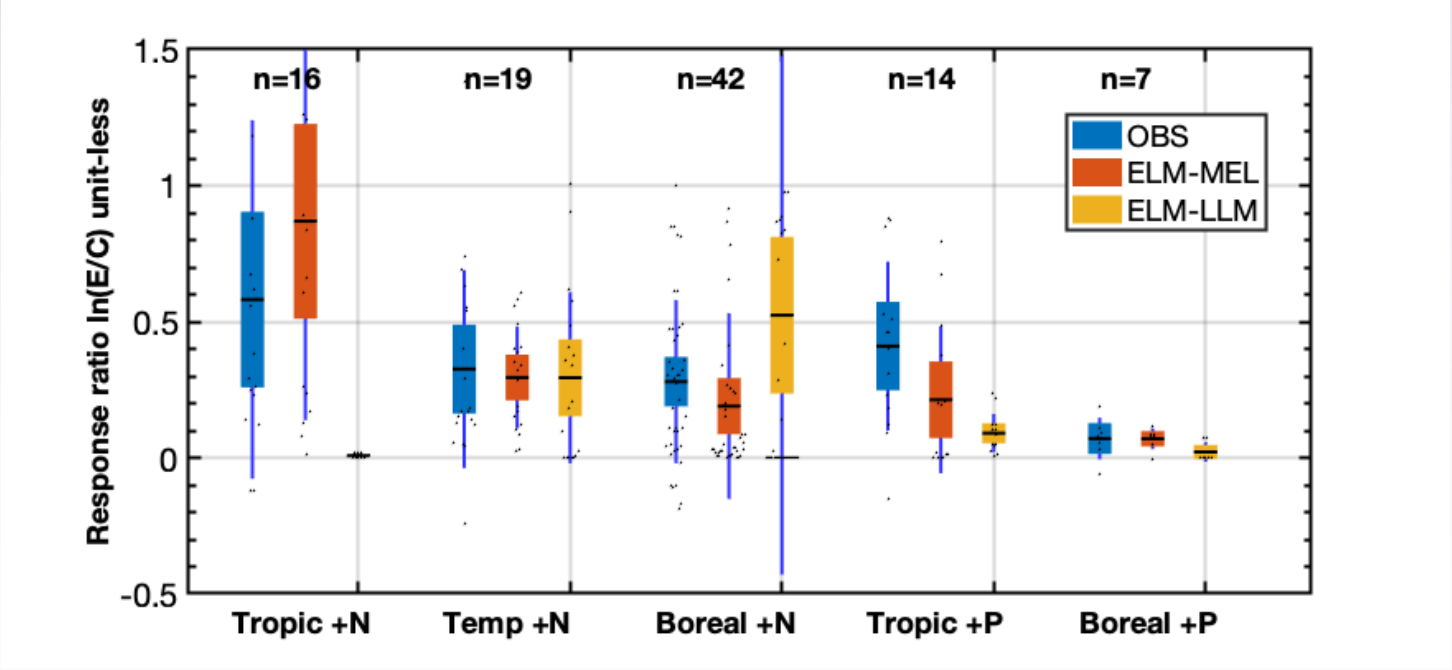
- Liebig's Law of the Minimum (LLM) hypothesis
  - Determines the effect of N and P separately at each time point, and applies that limitation to GPP and growth
- Multiple Element Limitation (MEL) hypothesis
  - Plants possess multiple pathways to overcome transient and uneven N and P co-limitation by
    - Adjusting photosynthesis rates based on leaf N and P concentrations
    - Adjusting whole plant carbon allocation to balance carbon versus nutrient limitation
    - Investing resources to enhance phosphatase or nitrogenase activity
    - Exudation, etc.

Synthesized 98 N & P Fertilization Experiments



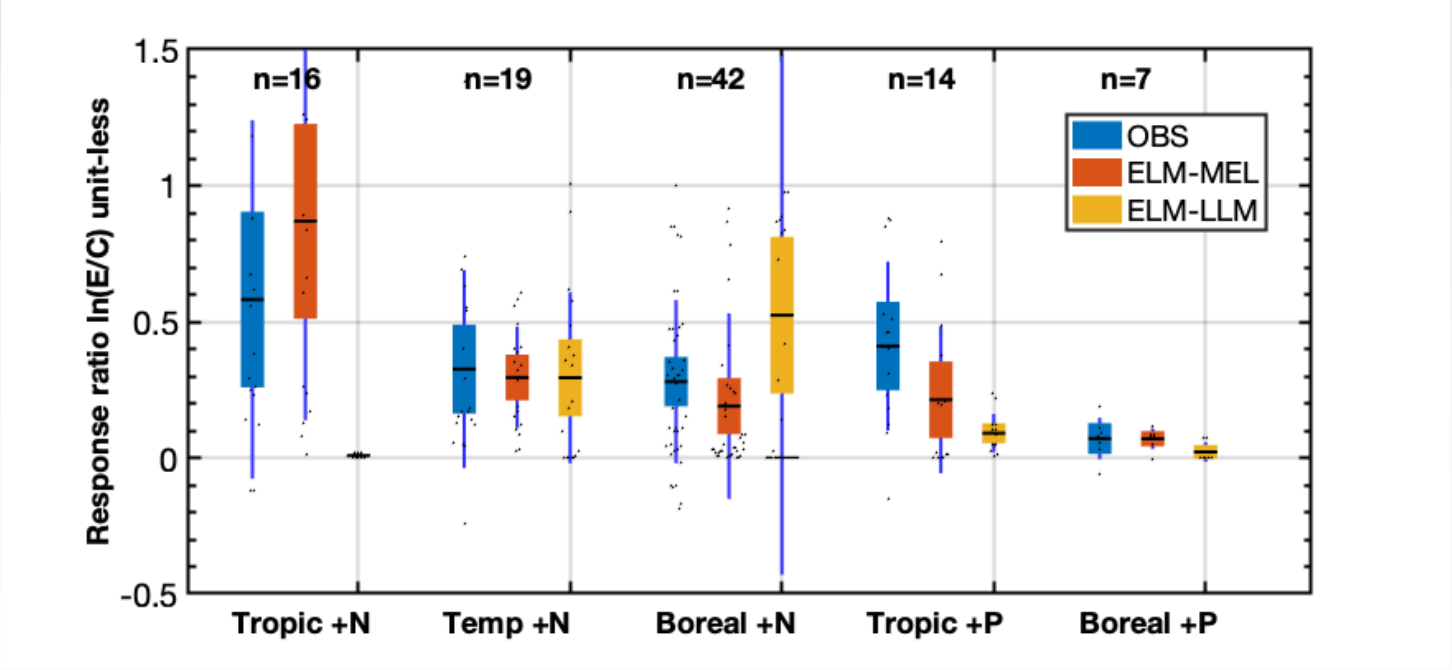
Observed Fertilization Responses

- Observed N and P limitations are largest in Tropics
- Low P limitation in boreal forests



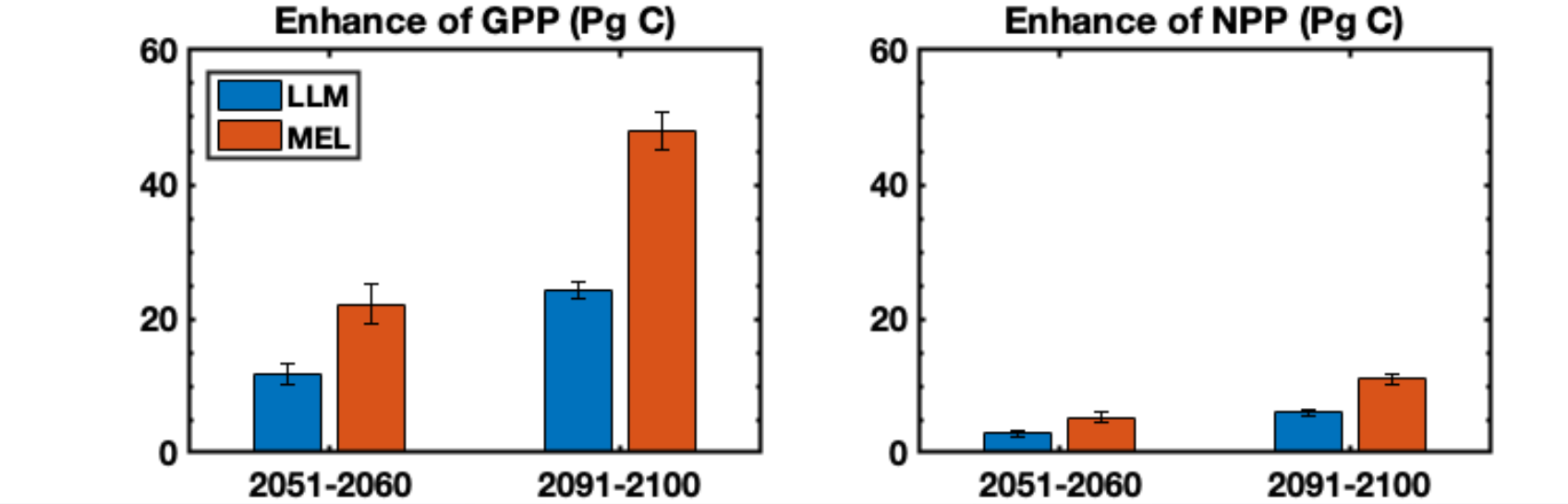
Modeled Fertilization Responses

- MEL approach more closely matches the observed responses, particularly in the tropics and boreal zones
- The LLM approach
  - Strongly underestimates N & P limitations in the Tropics
  - Over- and under-estimates N and P responses in the Boreal zone



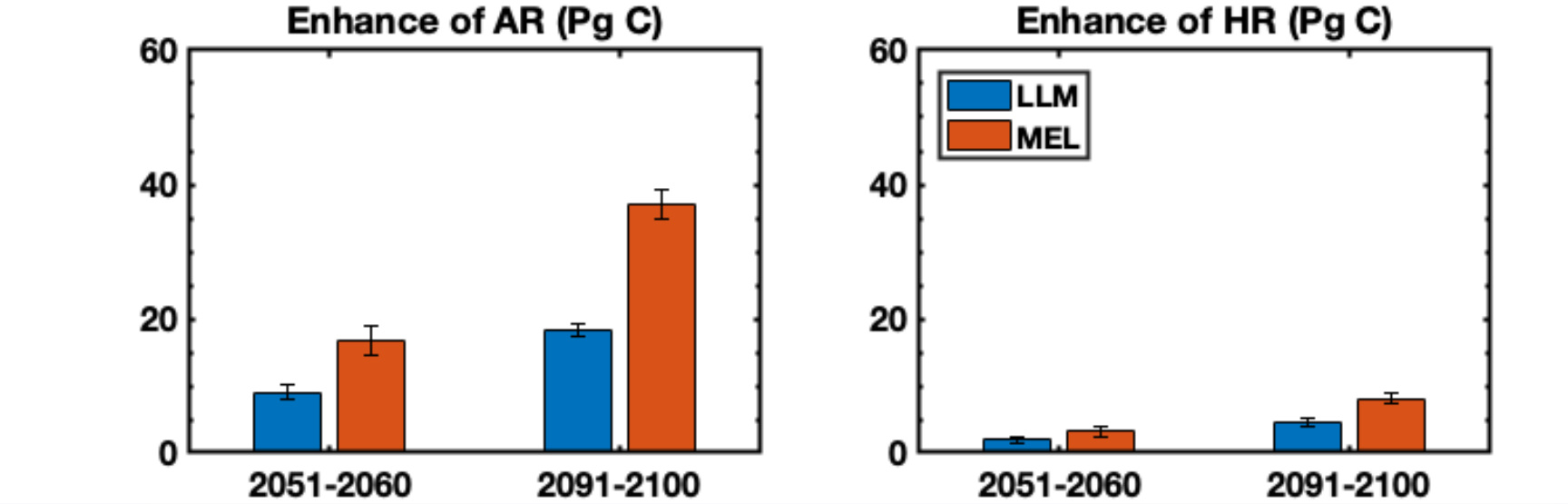
RCP8.5-CO_2 scenario: Relative impacts of MEL and LLM hypotheses

- The MEL hypothesis results in larger GPP and NPP enhancements at mid-century and by year 2100



RCP8.5-CO_2 scenario: Relative impacts of MEL and LLM hypotheses

- Autotrophic respiration is enhanced more under the MEL hypothesis (than under the LLM hypothesis)
- Autotrophic respiration enhancement is much larger than HR enhancement



RCP8.5-CO_2 scenario: Relative impacts of MEL and LLM hypotheses

- Vegetation biomass increases more with the MEL hypothesis under 21st century RCP8.5-CO_2
- Soil carbon is less responsive to elevated CO_2 compared with vegetation carbon
- Temperate ecosystem have high potential to accumulate vegetation biomass due to relatively balanced N and P co-limitation