

# Coupled biogeochemistry experiments: progress to-date and future analysis of the experiments

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## Science Questions

### Biogeochemistry (BGC) science question

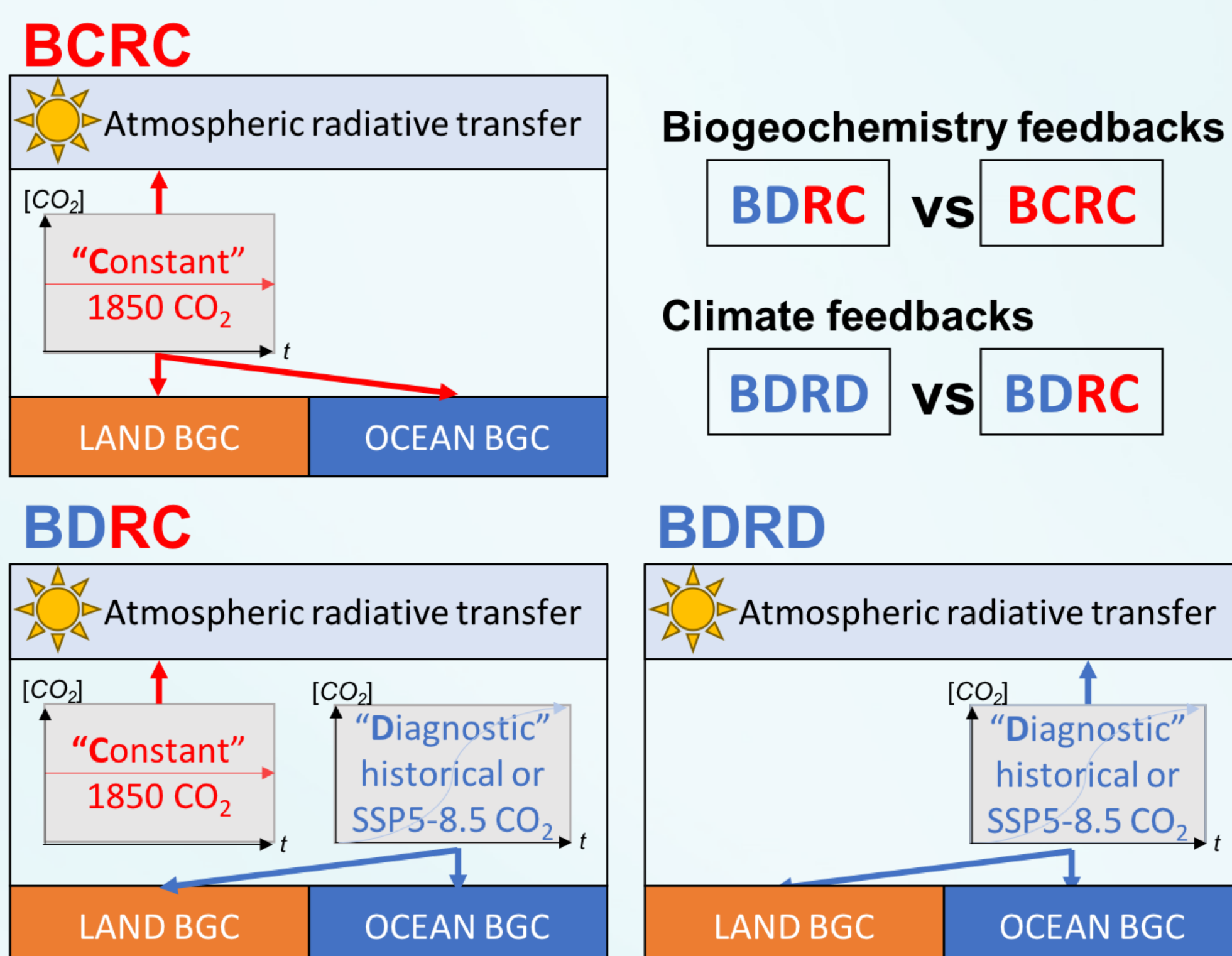
How do the biogeochemical cycles interact with other Earth system components to influence energy-sector decisions?

### V1 science question

What are the effects of nitrogen (N) and phosphorous (P) on climate-biogeochemistry interactions, and how sensitive are these interactions to model structural uncertainty?

## v1 Experiment Plan

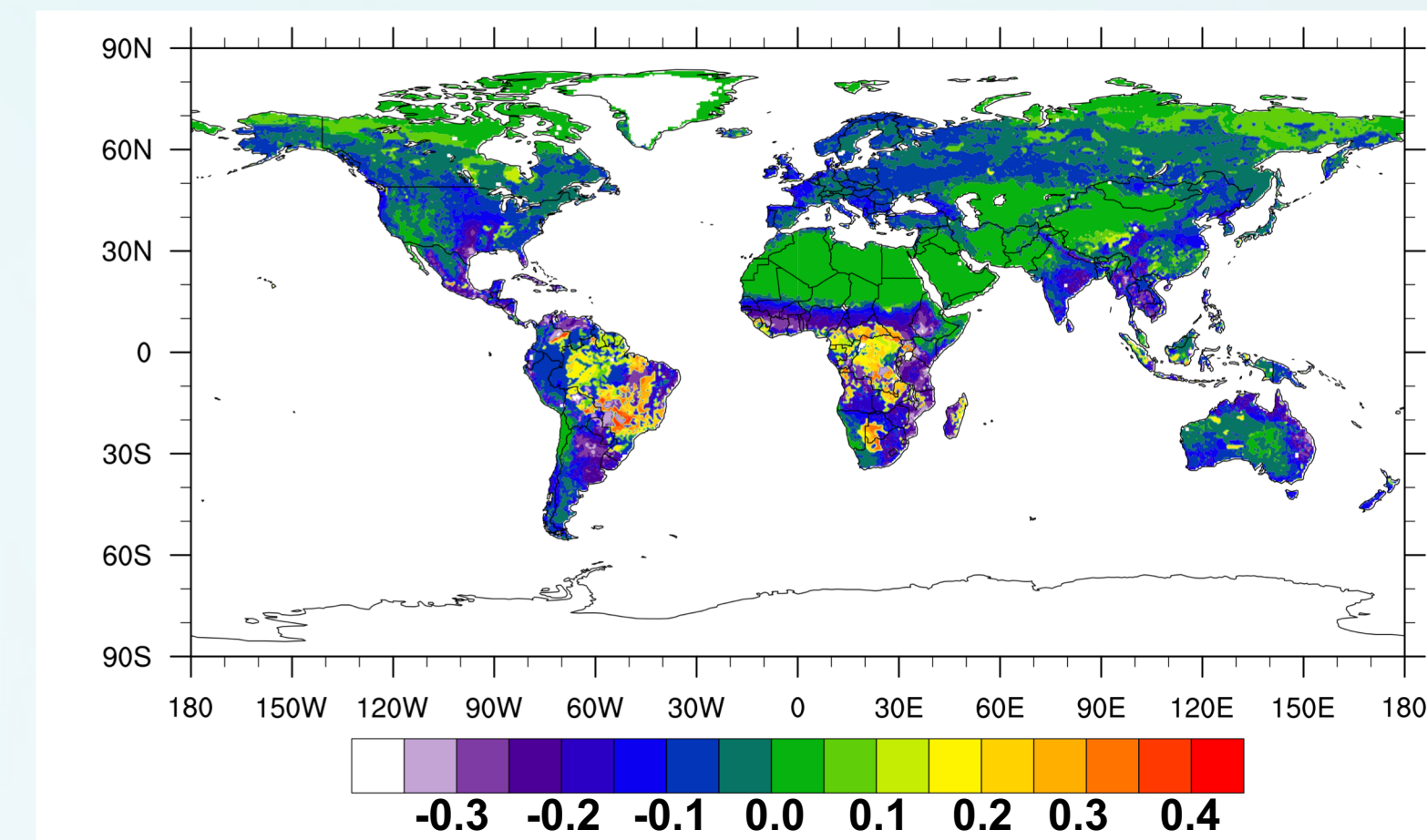
### Planned simulations



Alternative couplings of CO<sub>2</sub> will allow **Biogeochemical (B)** and **Radiative (R)** responses to be separately quantified in each model configuration. The atmosphere's radiation code, and the surface models, will see either **Constant (C)** or **Diagnostic (D)** prescribed historical or future CO<sub>2</sub> pathways.

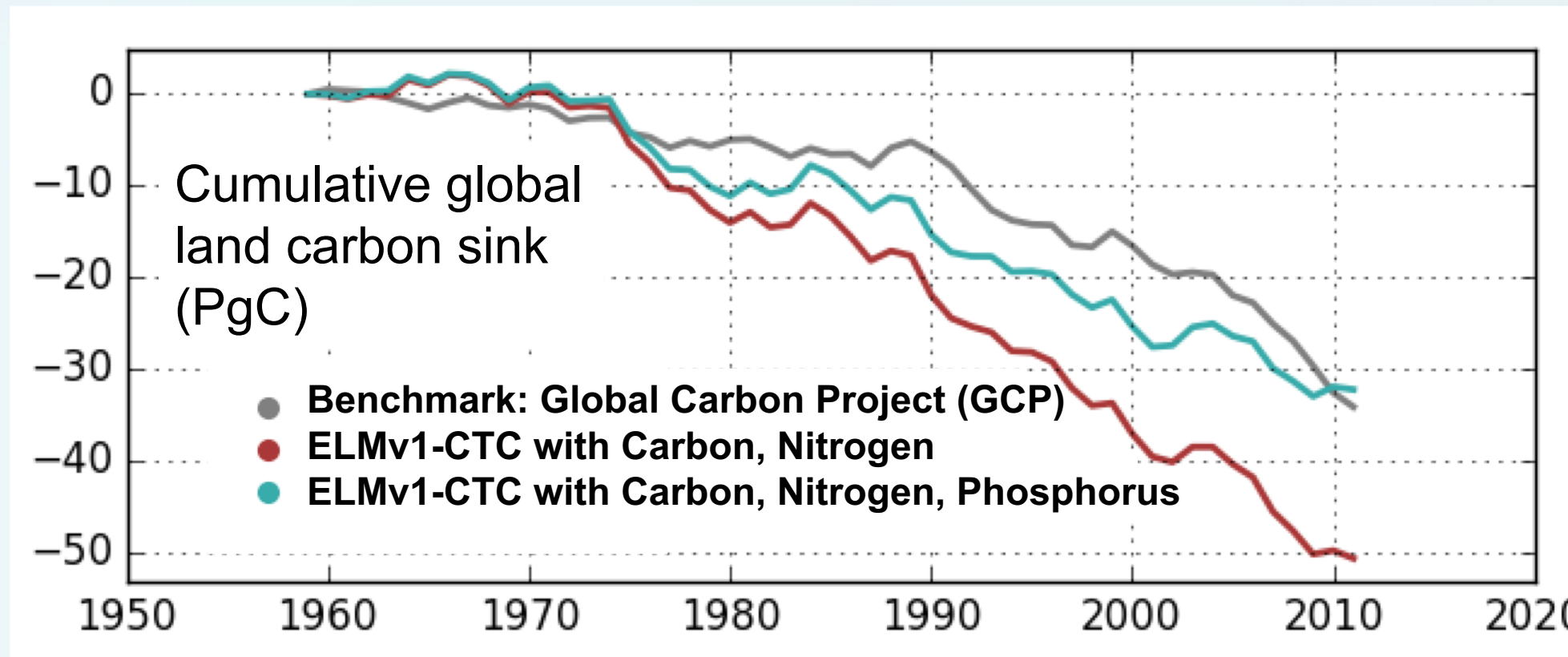
## Land nutrient limitation

### Converging Trophic Cascade (CTC)



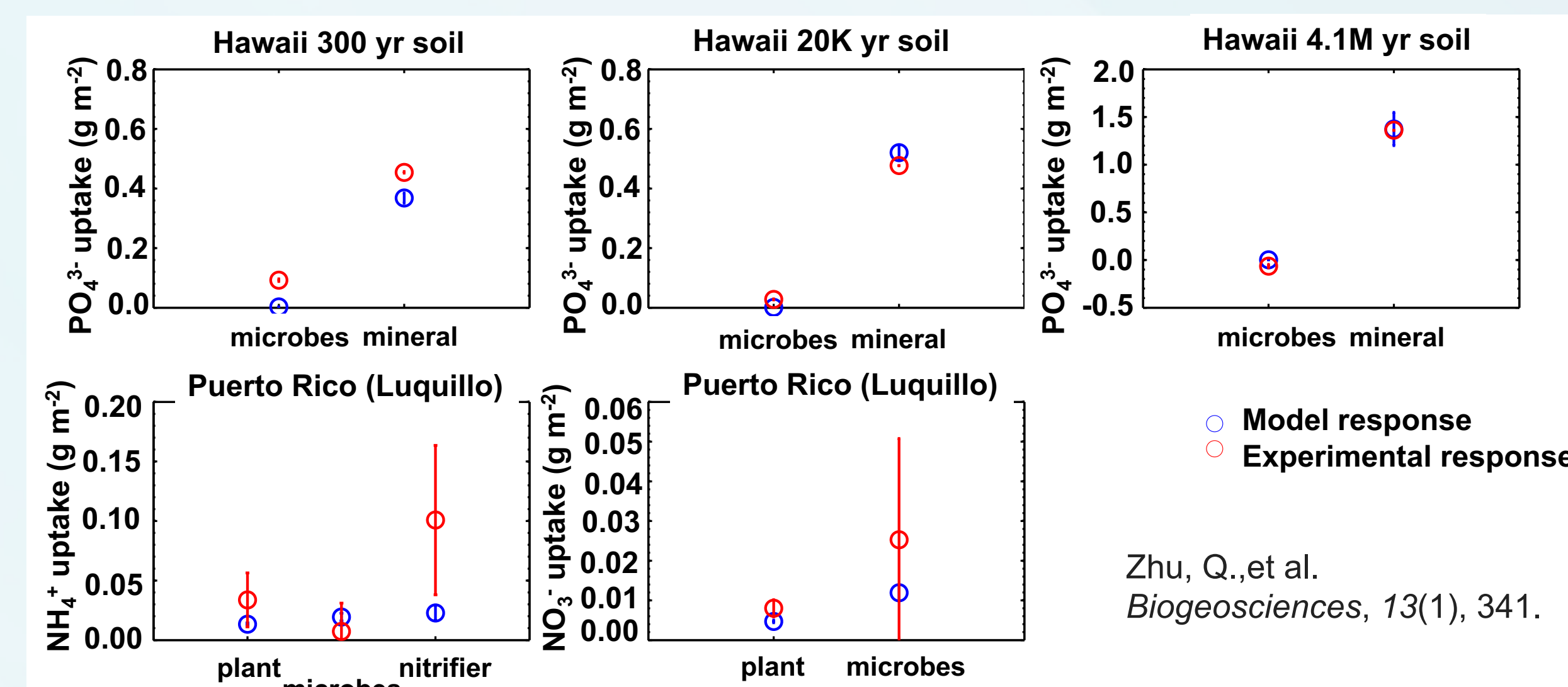
Spatial variation of the extent of nutrient limitation in the ELMv1-CTC-CNP model. Values shown are:  $1-f_p$  when  $f_p < f_n$ ;  $f_n-1$  when  $f_n < f_p$ .  $f_p$  and  $f_n$  are limitation factors for plant growth when considering only N or P limitation, respectively. Regions with a negative value are more limited by N, while regions with a positive value are more limited by P. Greater absolute values indicate stronger nutrient limitation.

Historical simulations of the cumulative global land carbon sink (PgC) in the ELMv1-CTC land model.



The introduction of P dynamics and P limitation improves the simulated carbon sink.

### Equilibrium Chemistry Approximation (ECA)

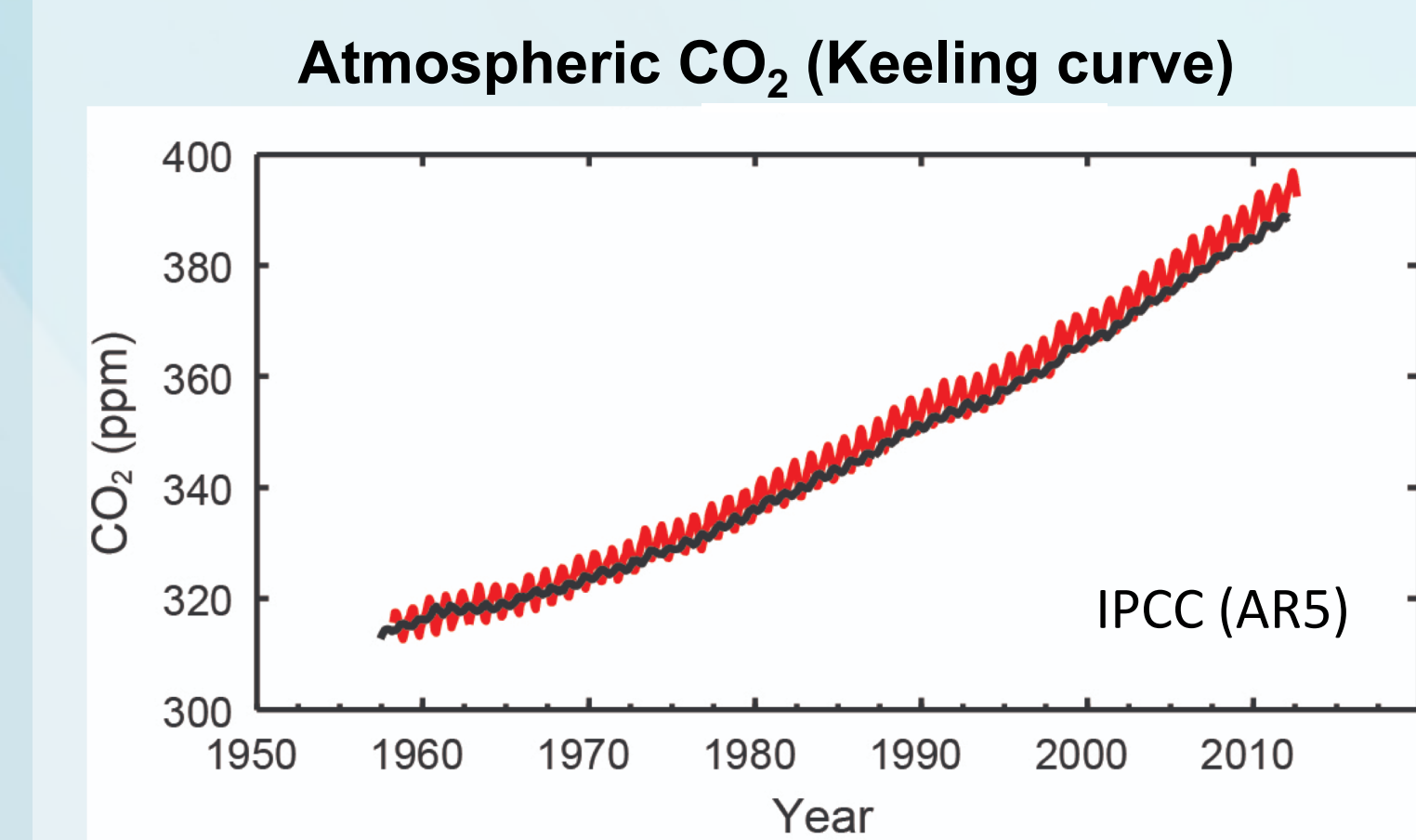


Evaluation of ELMv1-ECA-CNP land model simulations using N/P fertilization experiments at various tropical sites. According to resource use theory, if an ecosystem (e.g., tropical forest) responds positively to fertilization by a particular nutrient (e.g., phosphorus), this indicates that the system is resource-limited by that nutrient.

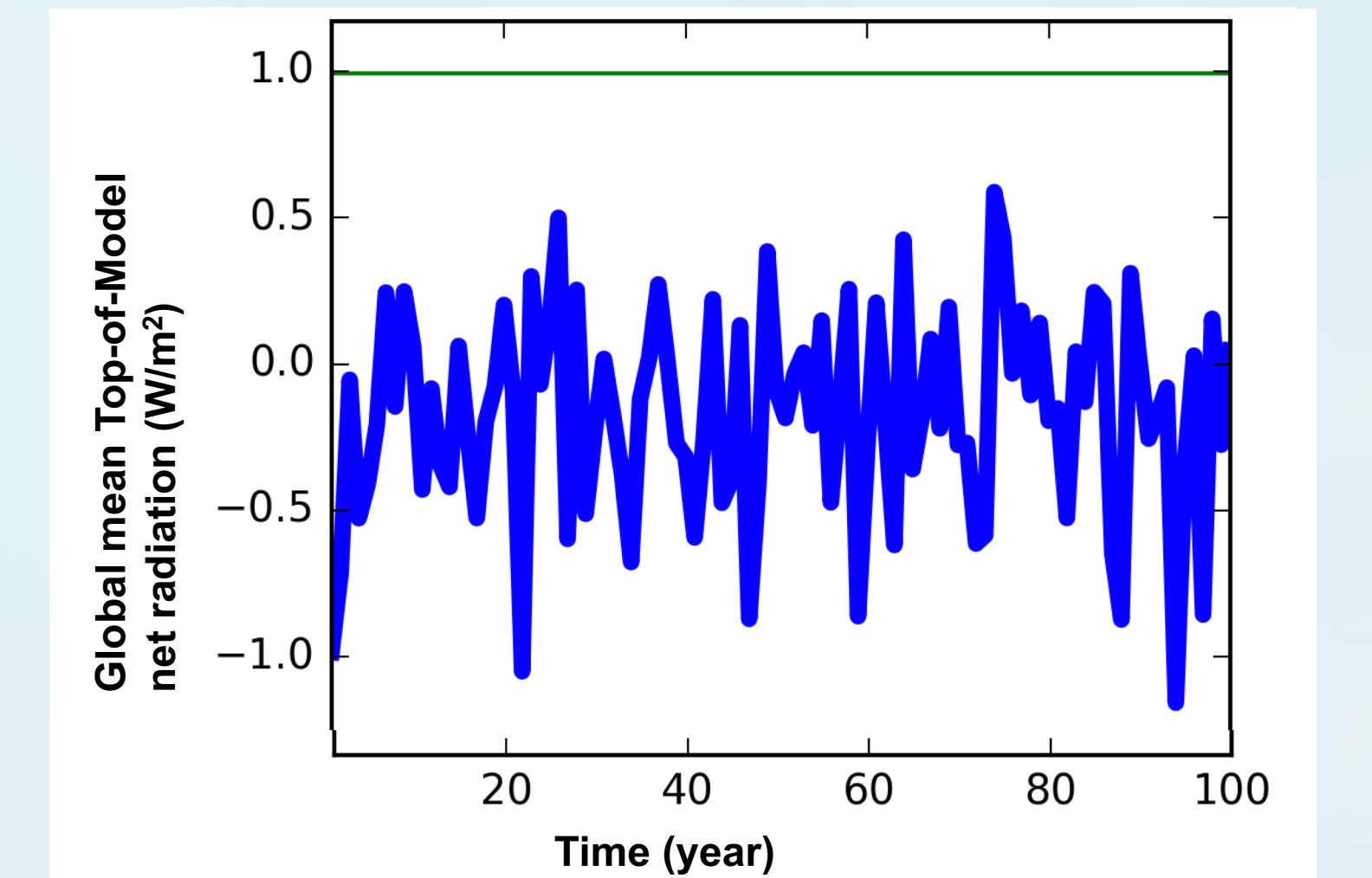
## E3SM v1 coupled BGC spin-up

### Coupled biogeochemistry metrics and diagnostics

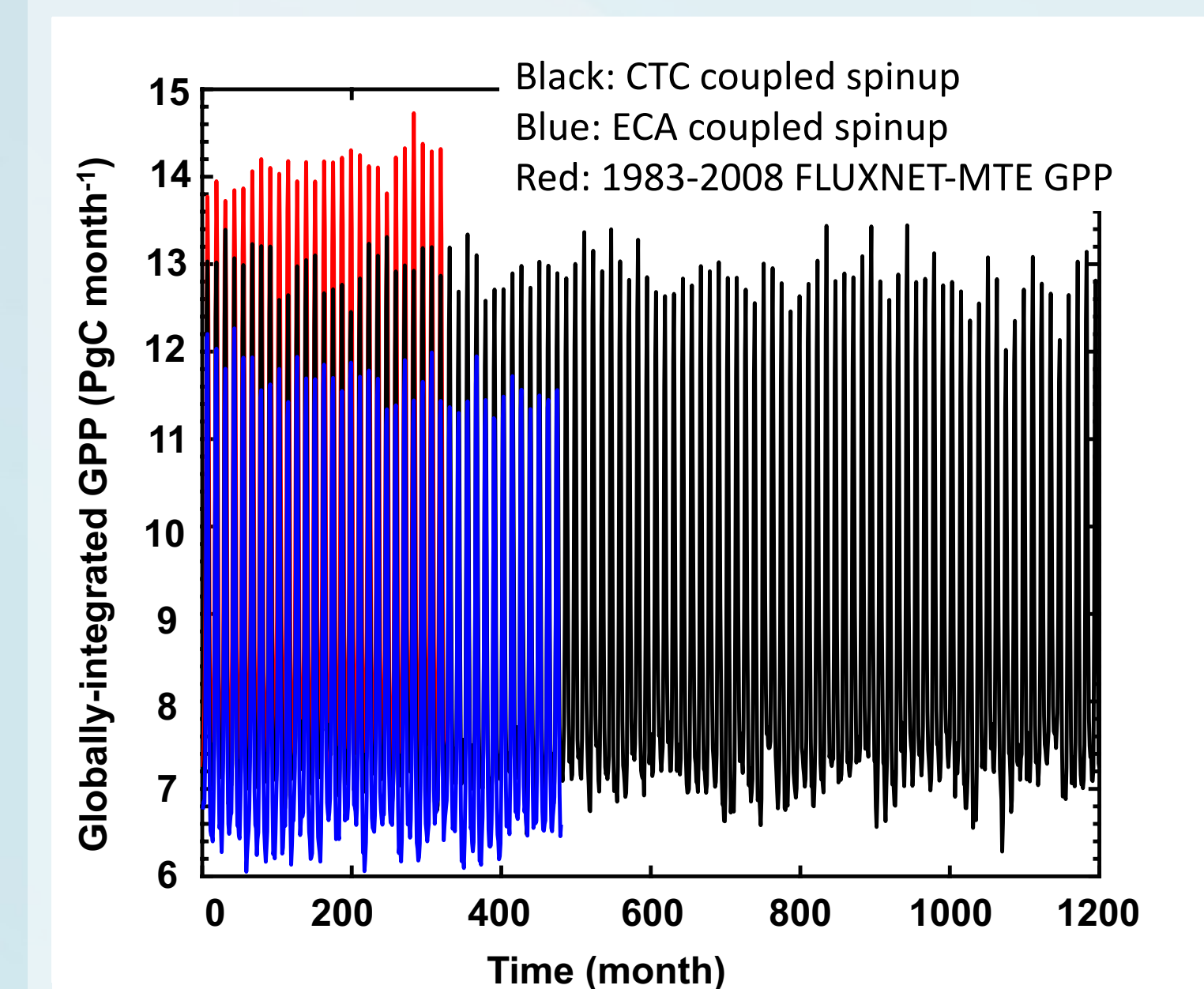
Ocean and land biogeochemistry each take up about 30% of anthropogenic CO<sub>2</sub> emissions.



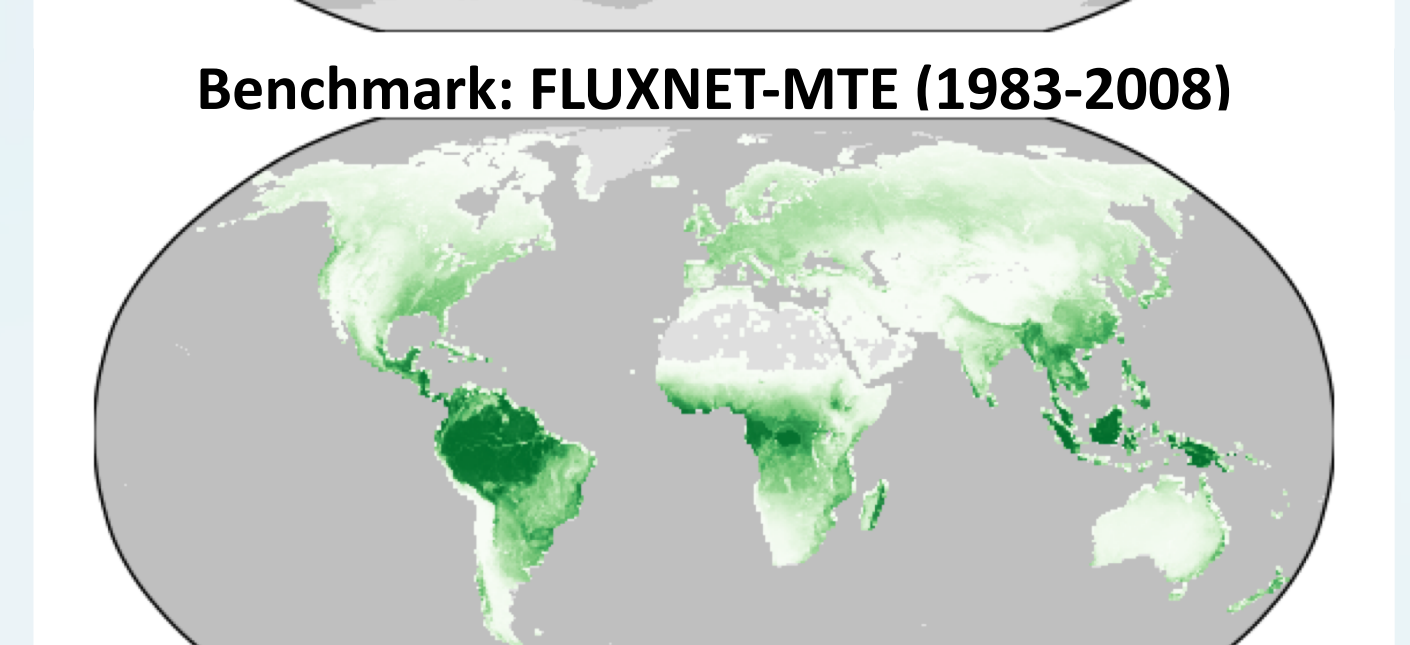
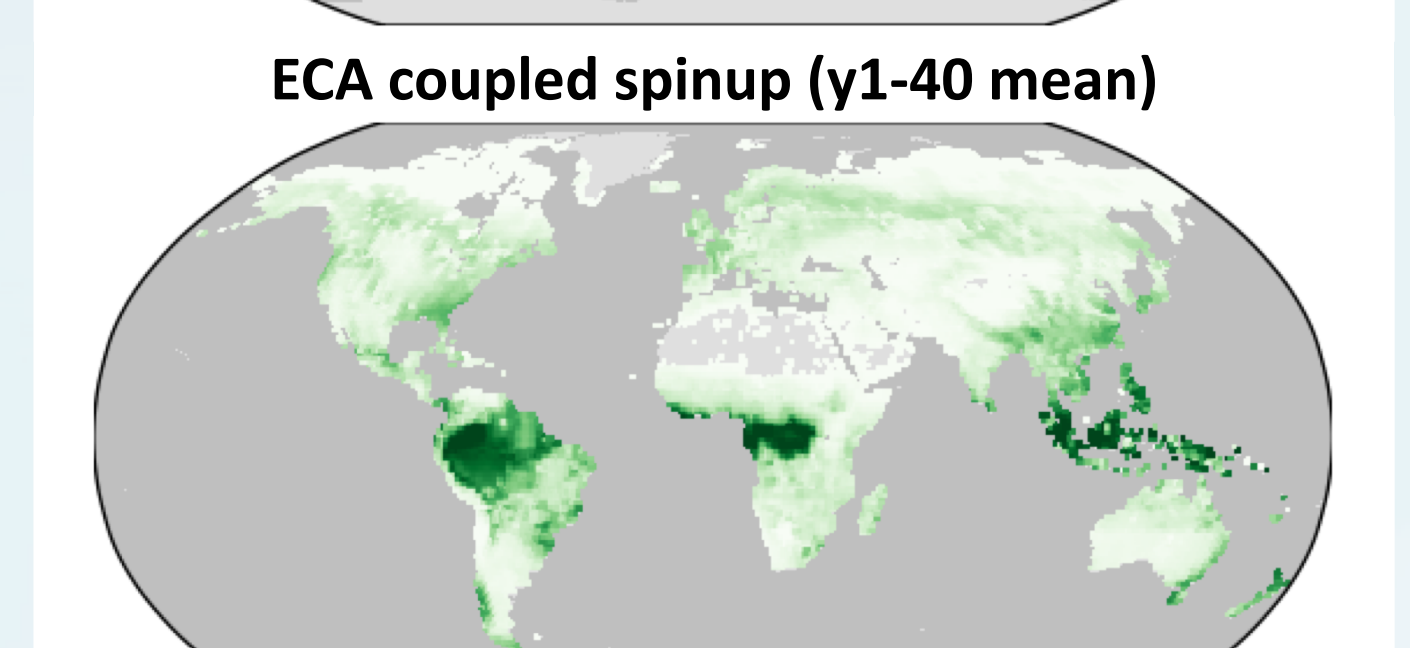
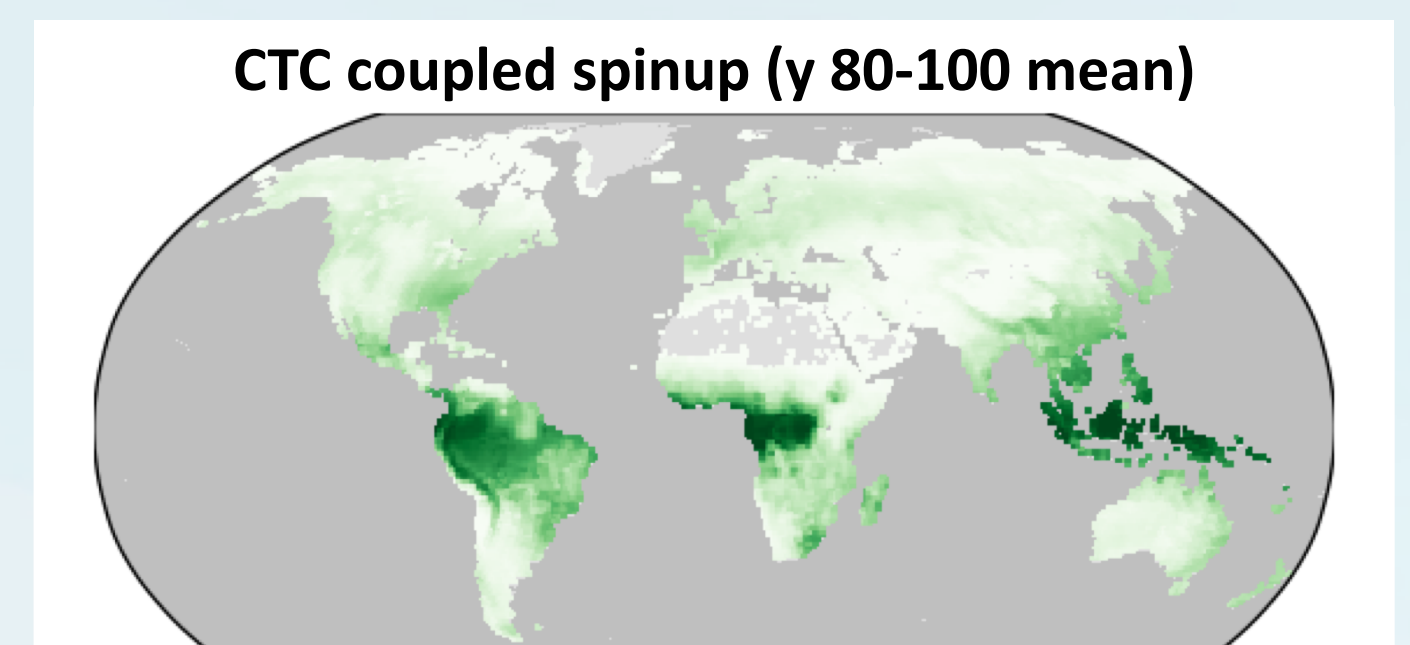
Global mean Top-of-Model net radiation (W/m<sup>2</sup>)



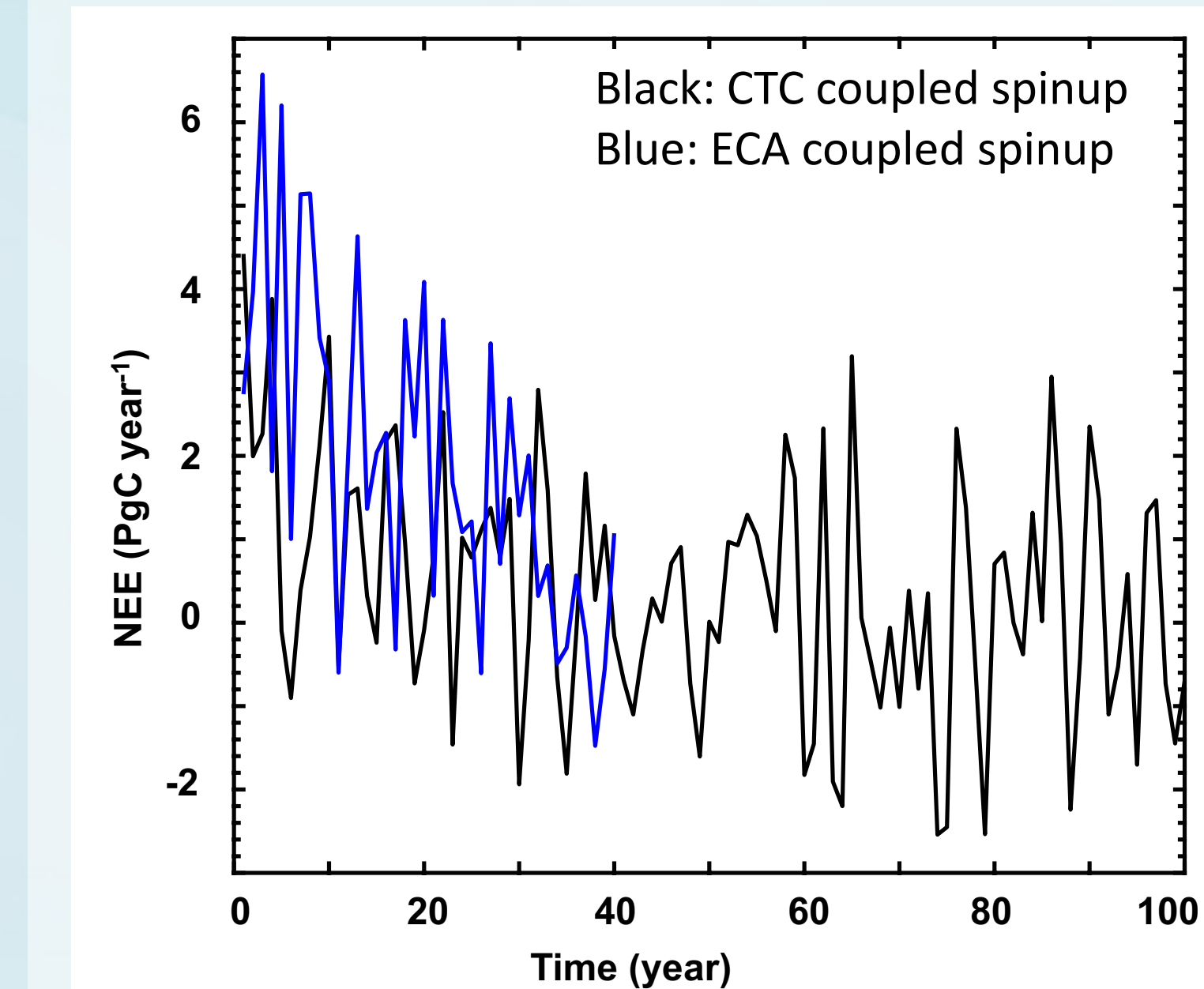
### Monthly mean globally-integrated GPP



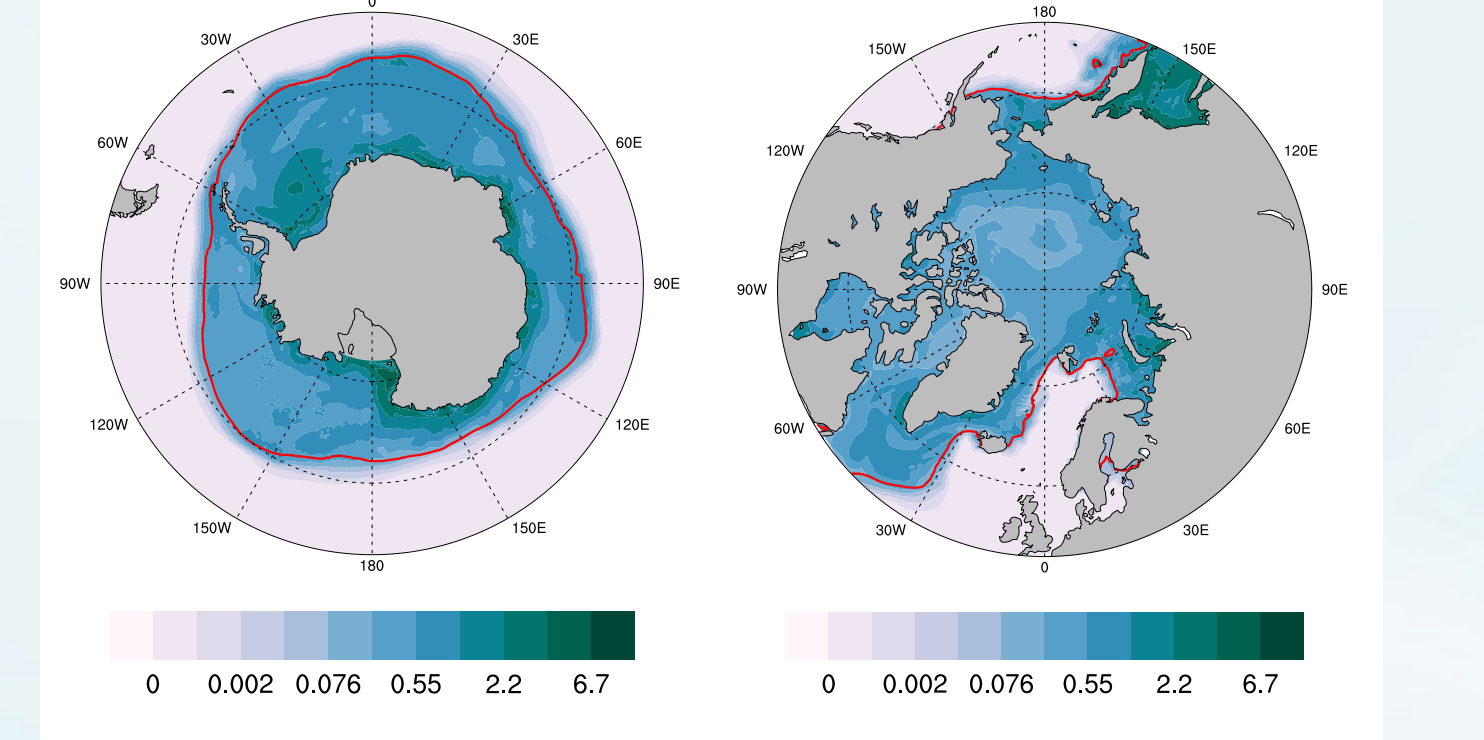
### Gross Primary Production (GPP)



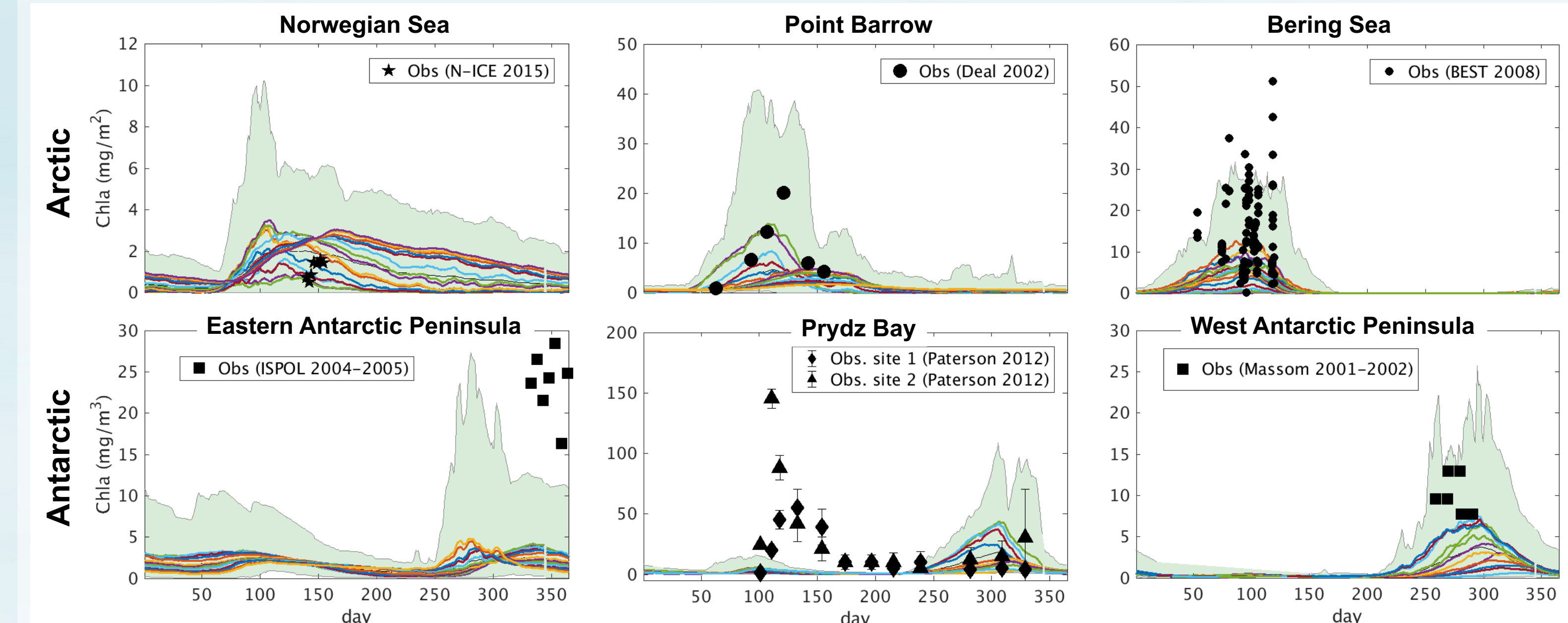
### Annual mean Net Ecosystem Exchange (NEE)



### Annual mean Ice Primary Production (gC/m²) Arctic



Sea ice chlorophyll concentrations from 15 years of fully-coupled E3SM v1 1850 spin-up, compared with in situ measurements from sea ice cores (points). Colored lines are 15-year mean seasonal cycles, for each grid point within 2° of the field location. Green shaded region indicates the range of simulated daily means.



## Planned analyses

### Land model biogeochemistry

- Analyze impacts of P limitation using differences between on/off experiments
- Analyze impacts of P limitation using spatiotemporal relationships in single simulation
- Interactions between BGC and water cycle

### Ocean-sea ice biogeochemistry

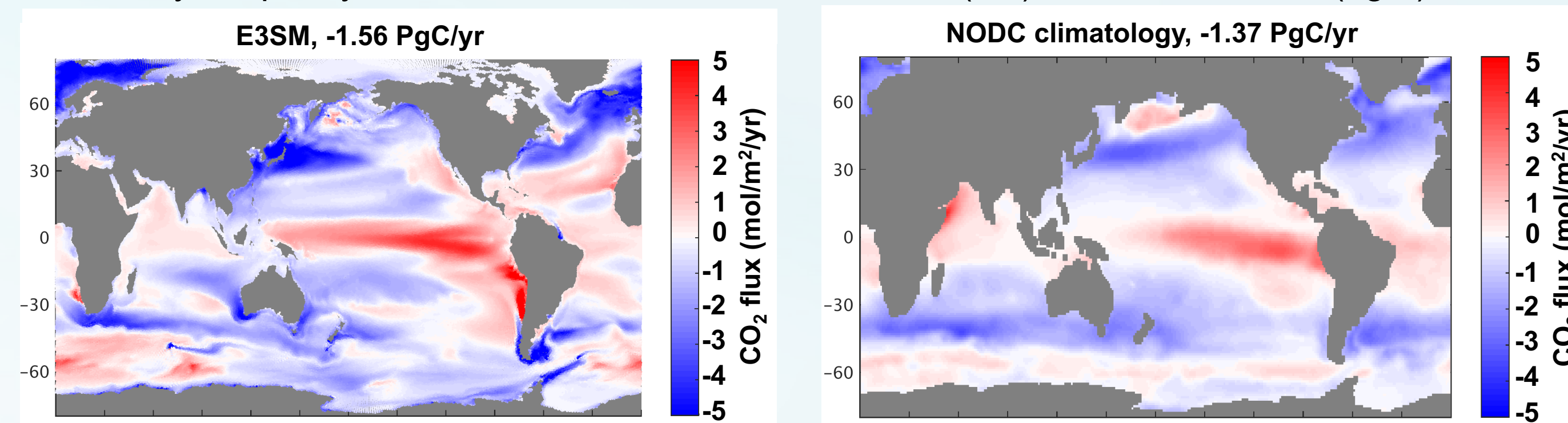
- Multiple tracers to understand impacts of biotic and abiotic processes on ocean carbon uptake

### Coupled biogeochemistry

- Linear analysis to estimate feedbacks due to biogeochemical and climate forcing effects

## Ocean-ice biogeochemistry

CO<sub>2</sub> flux between ocean and atmosphere (negative values denote flux out of the atmosphere) from a fully coupled year 2000 time slice E3SM simulation (left) and observations (right).



Concentration of surface chlorophyll-a from a fully coupled year 2000 time slice E3SM simulation (left) and observed climatology from the SeaWiFS satellite (right).

