Georgia Tech Earth and Atmospheric Sciences
College of Sciences

LOCEAN

Anthropogenic iron deposition alters the ecosystem and carbon balance of the Indian Ocean over a centennial timescale

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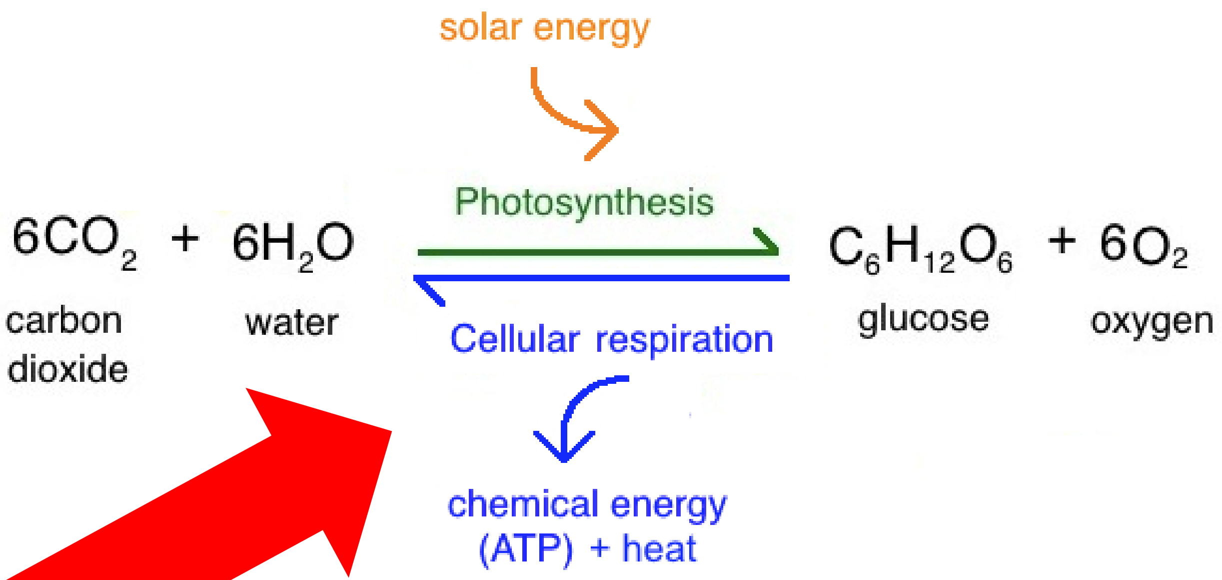
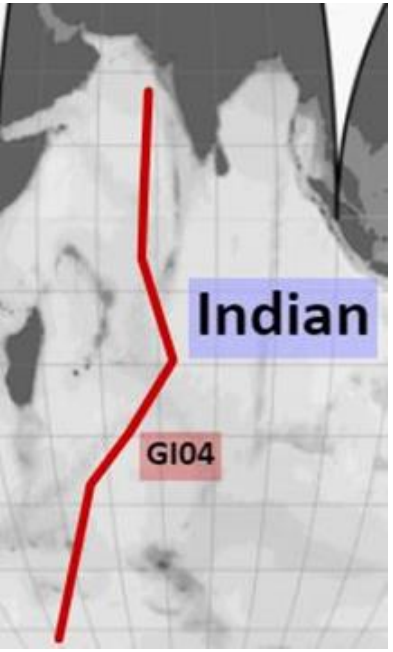
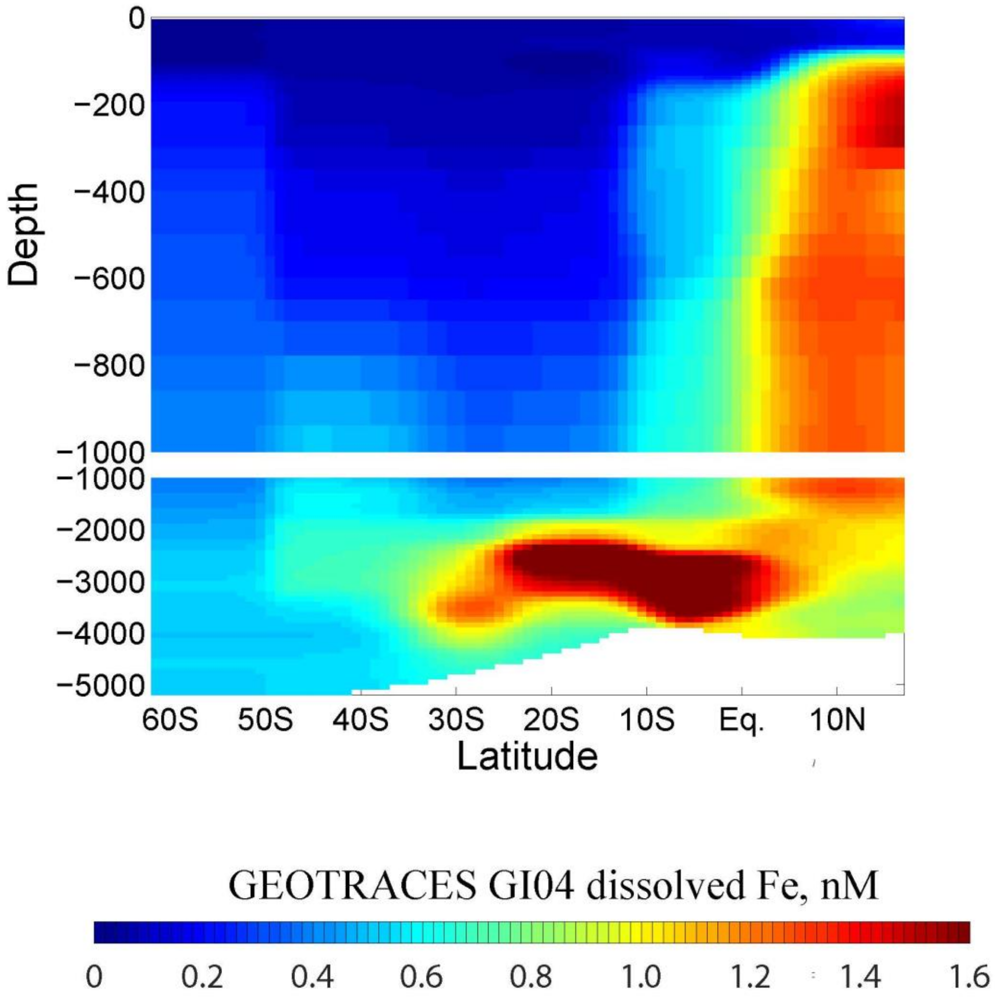
Marine phytoplankton need iron for photosynthesis

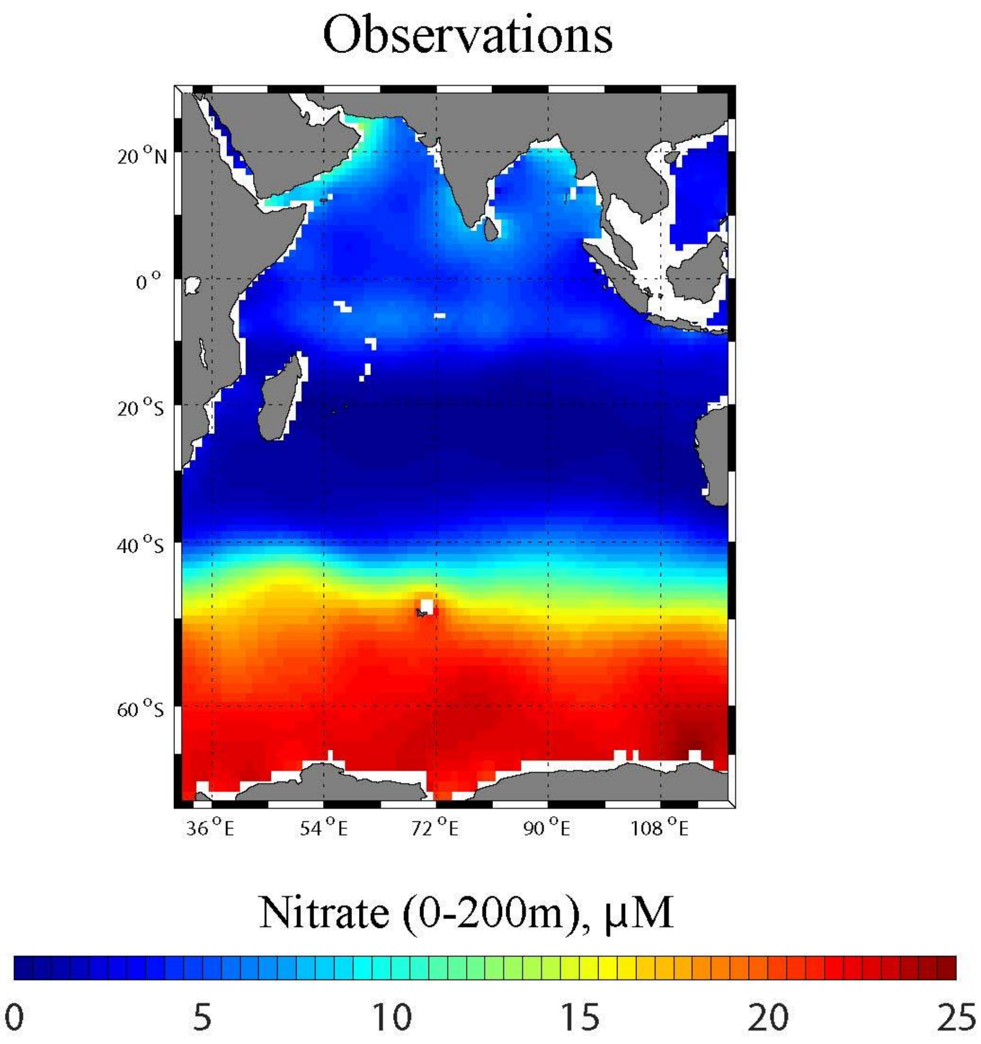




Nishioka et al., 2013

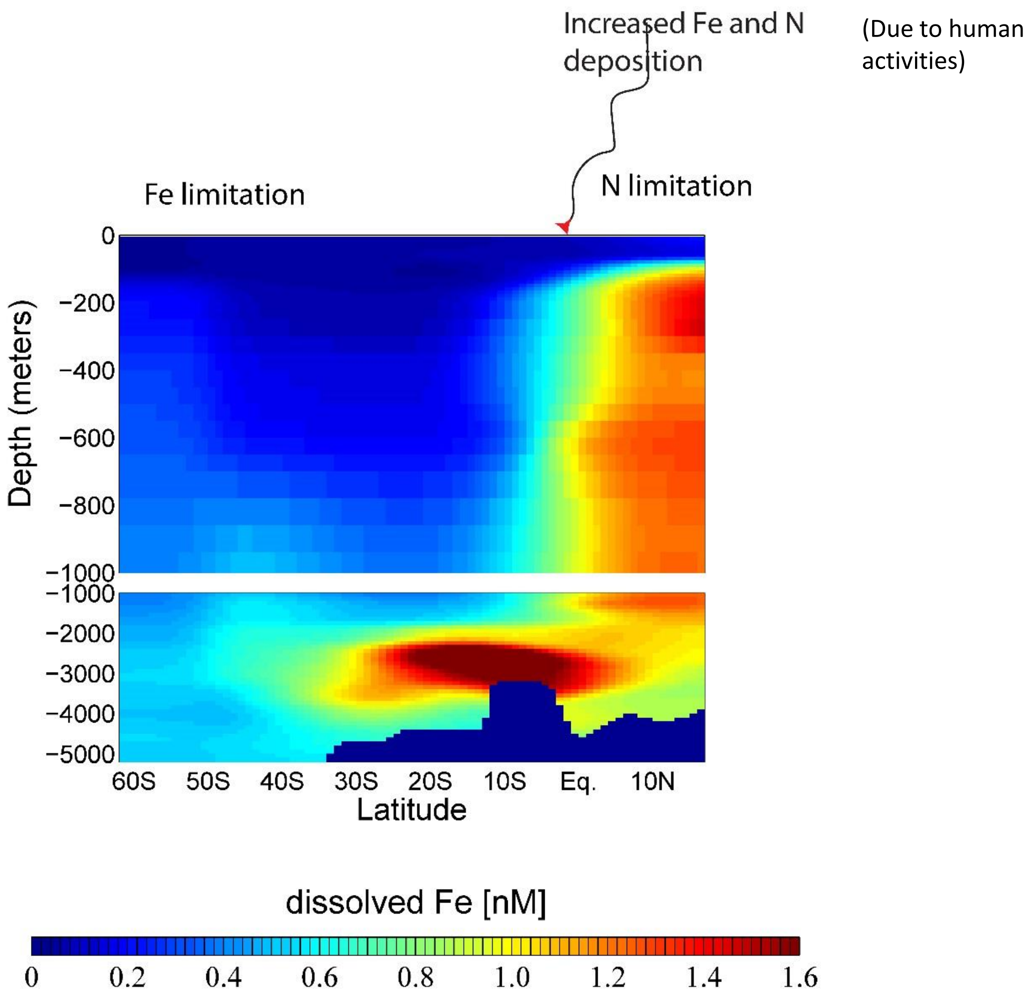


Ocean dissolved Fe (dFe) concentration is very low in the southern Indian Ocean



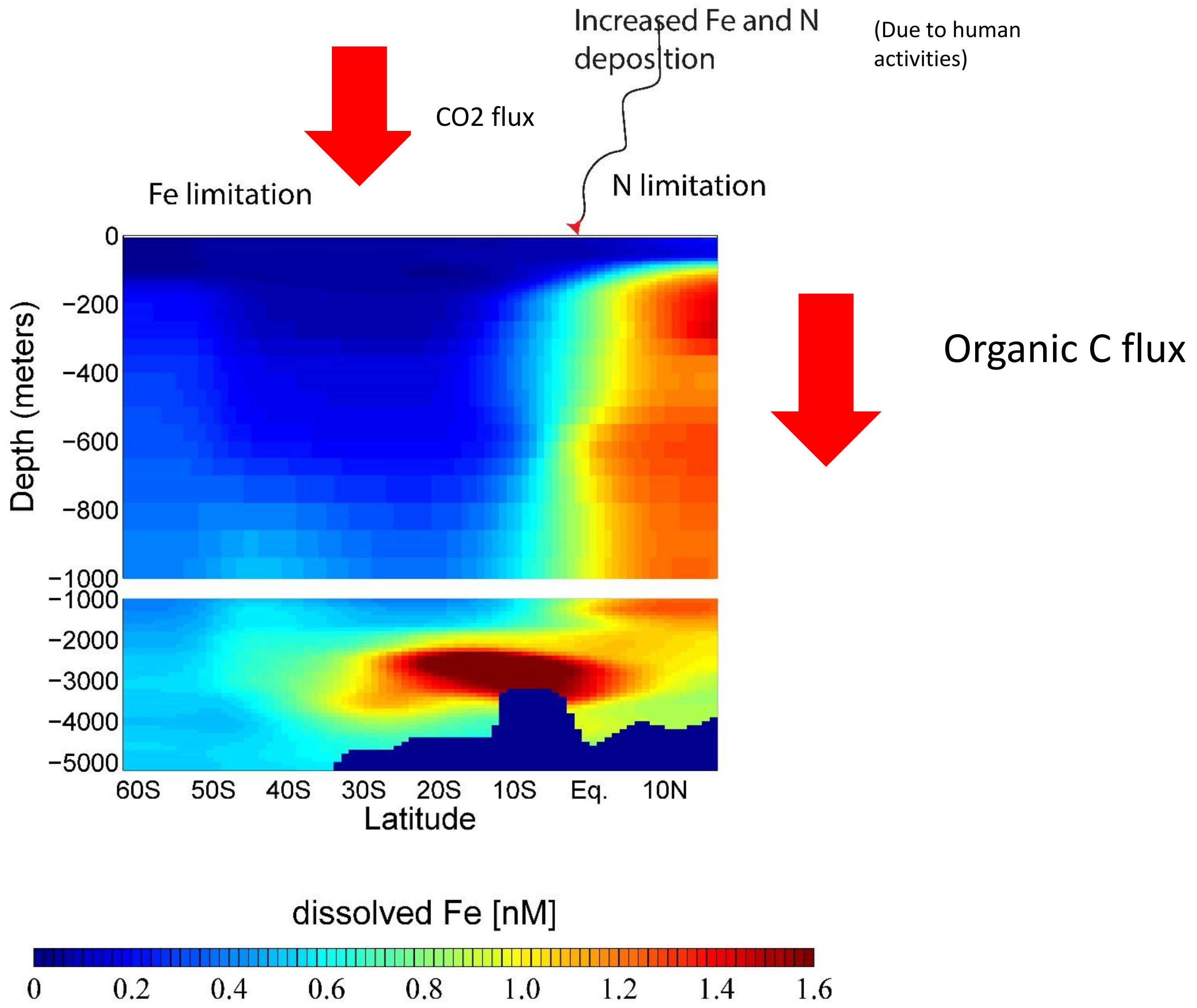
World Ocean Atlas 2018

Macronutrient concentration is low in the northern Indian Ocean



Q: How the phytoplankton community and carbon balance in the Indian Ocean will respond to an increase in the Fe and N atmospheric deposition on a centennial timescale?

Previous modeling studies used a simple Fe cycling scheme and did not focus on the Indian Ocean



Hypotheses: increased organic carbon flux ? Increased ocean carbon dioxide uptake?

Goal:

- Examine the response of phytoplankton community and carbon uptake in the Indian Ocean over a centennial timescale

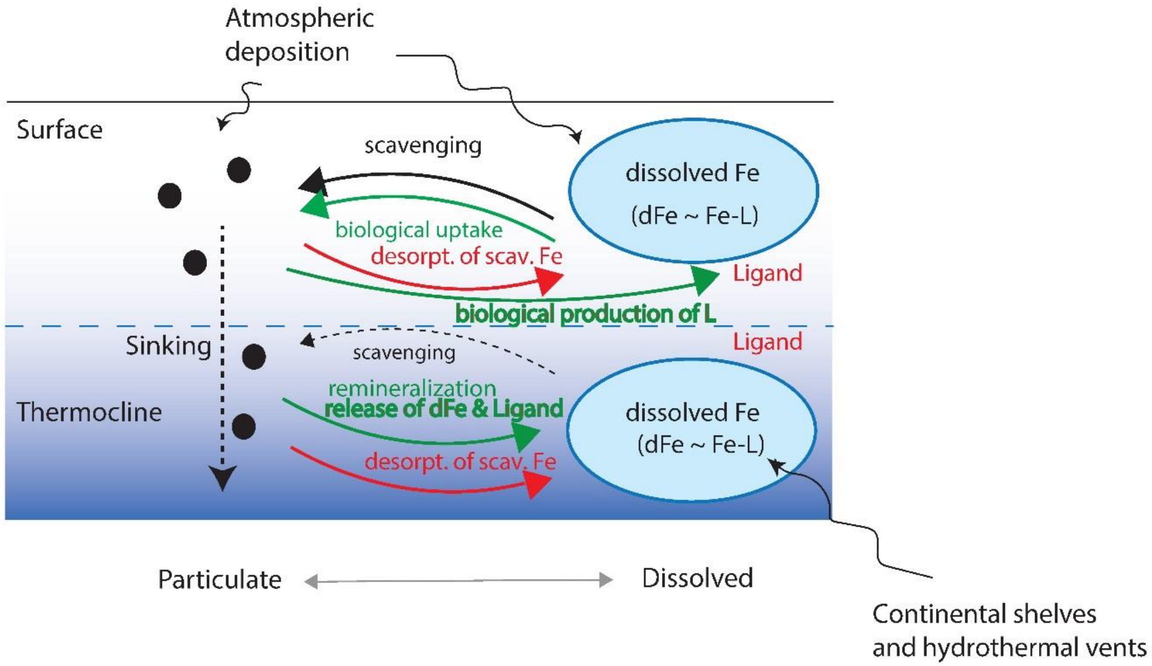
Method:

- An ecosystem model (Dutkiewicz et al. 2014) includes diatom, diazotrophs, coccolithophores, pico- and large plankton with **an improved Fe cycling**

- **Two equilibrium simulations** with high and low atmospheric deposition of Fe and N

Ocean Biogeochemistry Model

- A simple ocean biogeochemistry model with **iron cycling parameterizations** included:

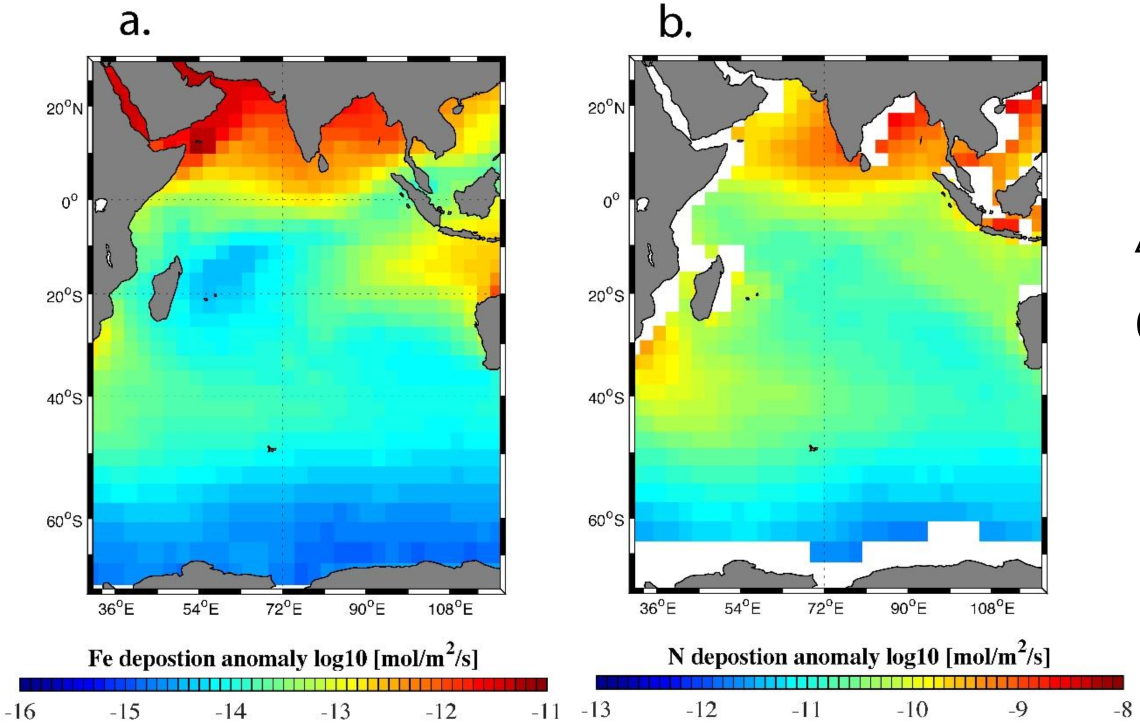


1. Fe sources: dust, sediment, and hydrothermal
2. Particle-dependent scavenging
3. **Complex with three ligand classes**
4. **$L_2 = \alpha$ AOU, representing remineralization sources of ligand**
5. Spatially and temporally varying pFe dissolution

Sensitivity simulations

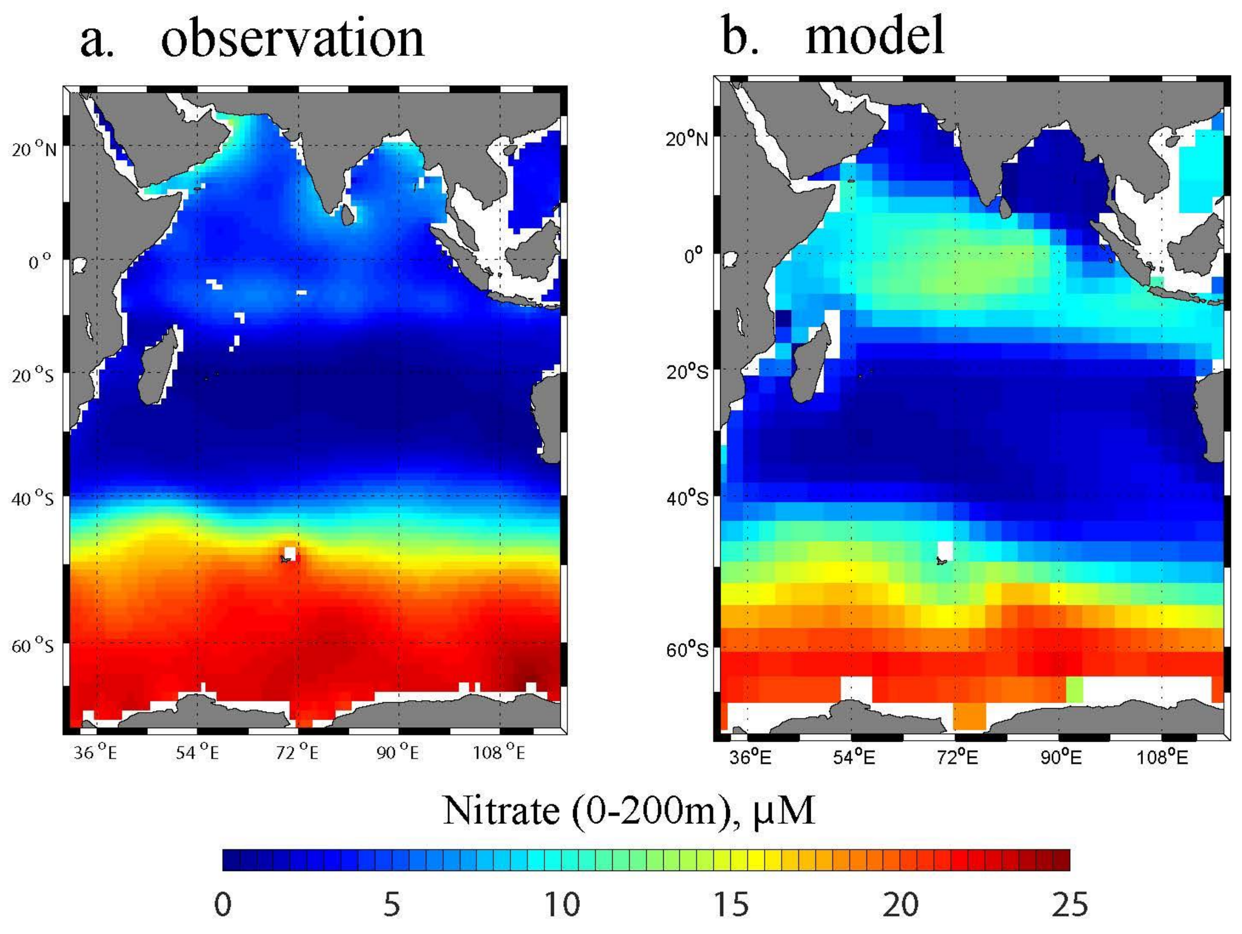
- Pre industrial deposition for Fe and N (PreIn run)
- Industrial deposition for Fe and N (Ind run)
- Analyzing the difference in nutrient fields, phytoplankton structure, and carbon uptake of the Ind run relative to the PreIn run (Ind - PreIn) over the first one hundred years

ΔFe deposition



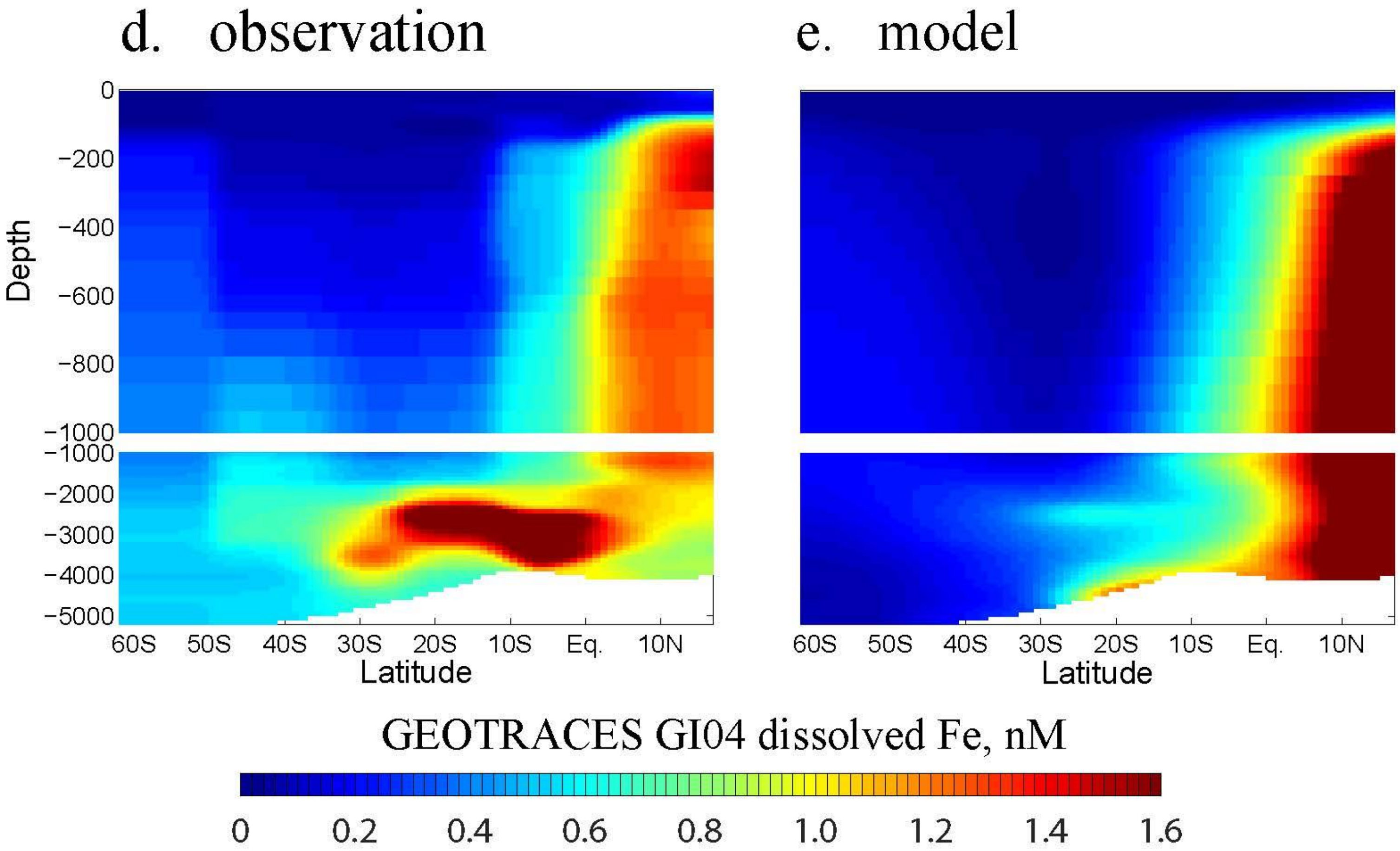
ΔN deposition

Model validation



Macronutrient concentrations
World Ocean Atlas (left) vs. Ind run (right)

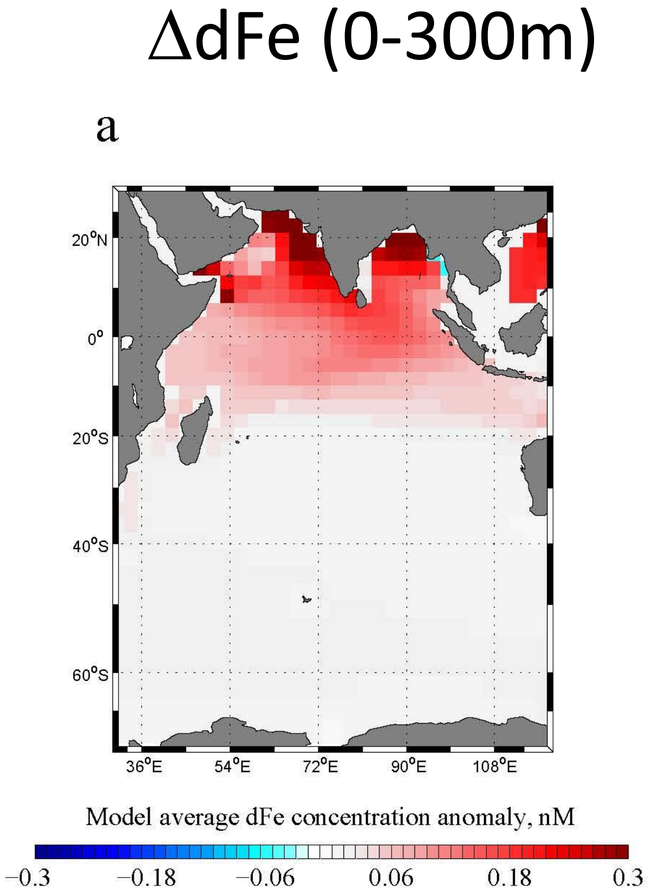
Model validation

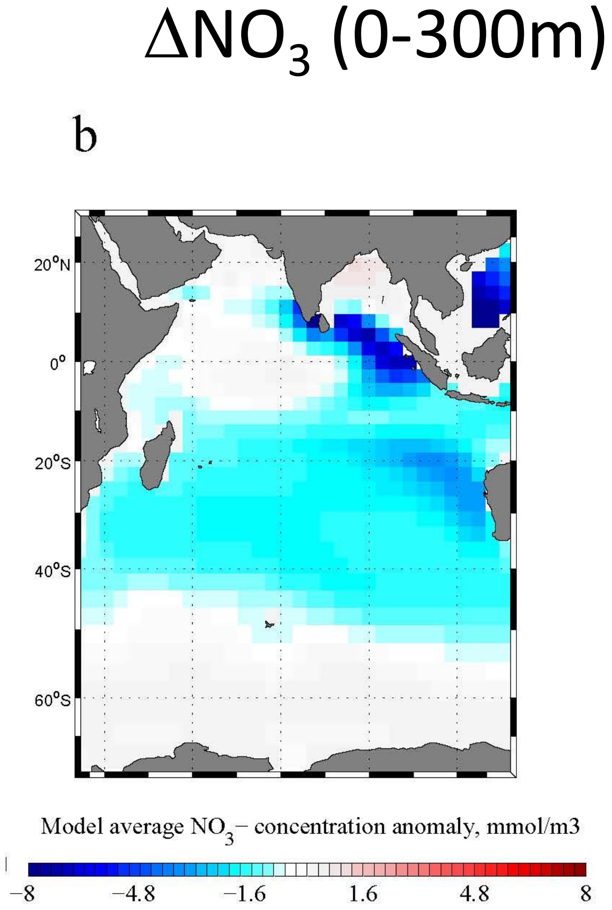


dFe concentration in the Indian Ocean
GEOTRACES measurements (left) vs. Ind run (right)

Sensitivity simulations

Ind - PreIn



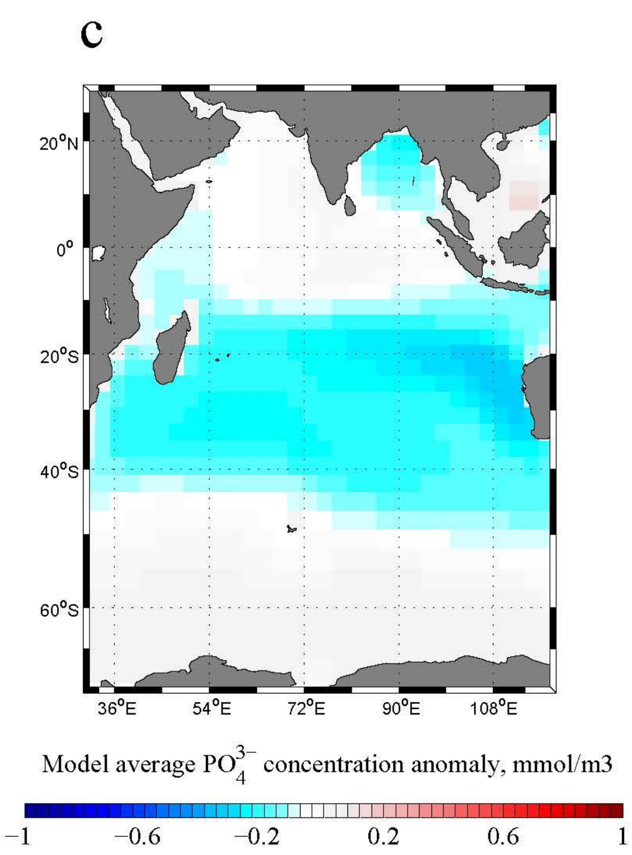


- Fe concentration increases ~ 0.3nM in the upper water column of the northern Indian Ocean
- NO3 decreases in the subtropical gyres

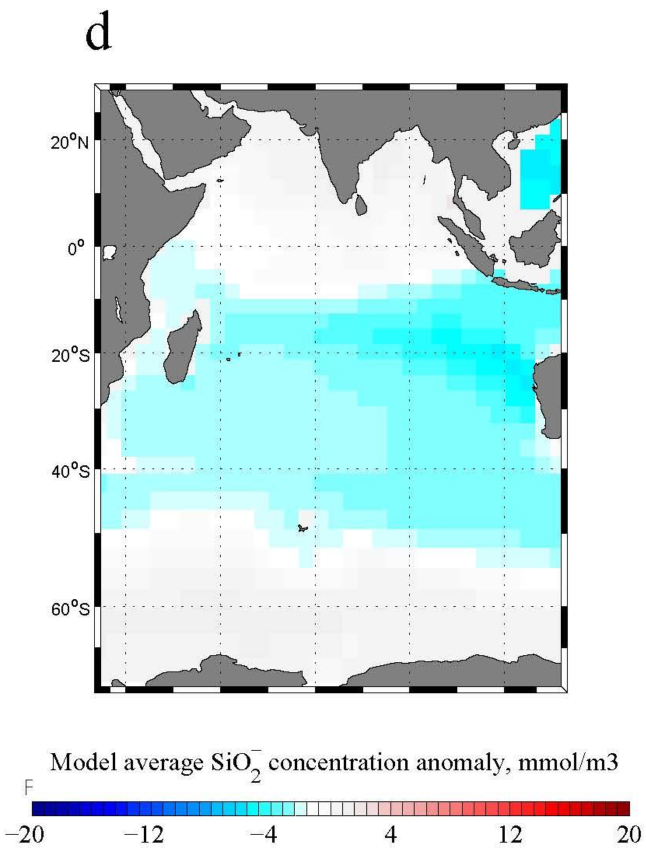
Sensitivity simulations

Ind - PreIn

ΔP (0-300m)



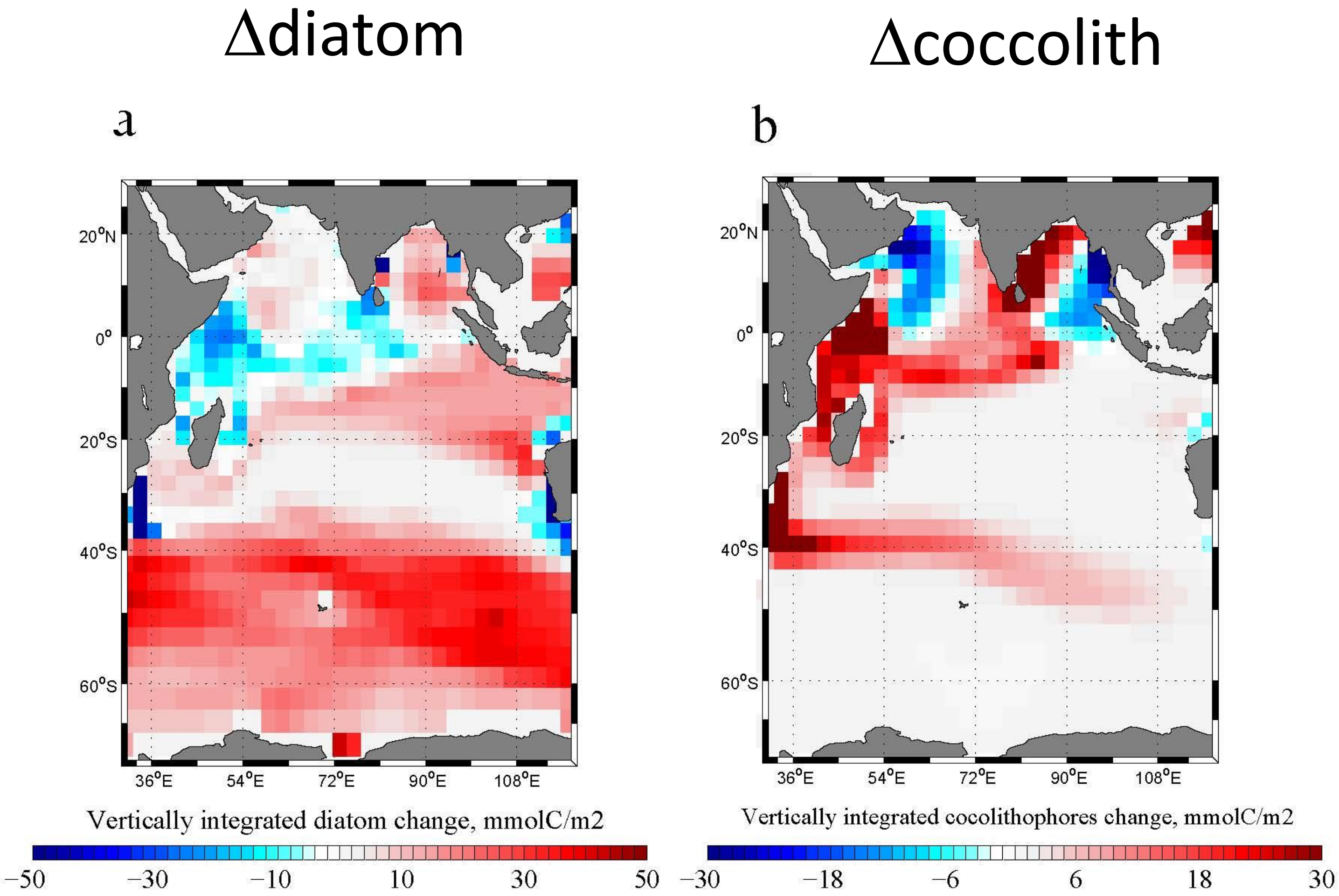
ΔSi (0-300m)



- Phosphate and silicate decrease in the subtropical gyres

Sensitivity simulations

Ind - PreIn

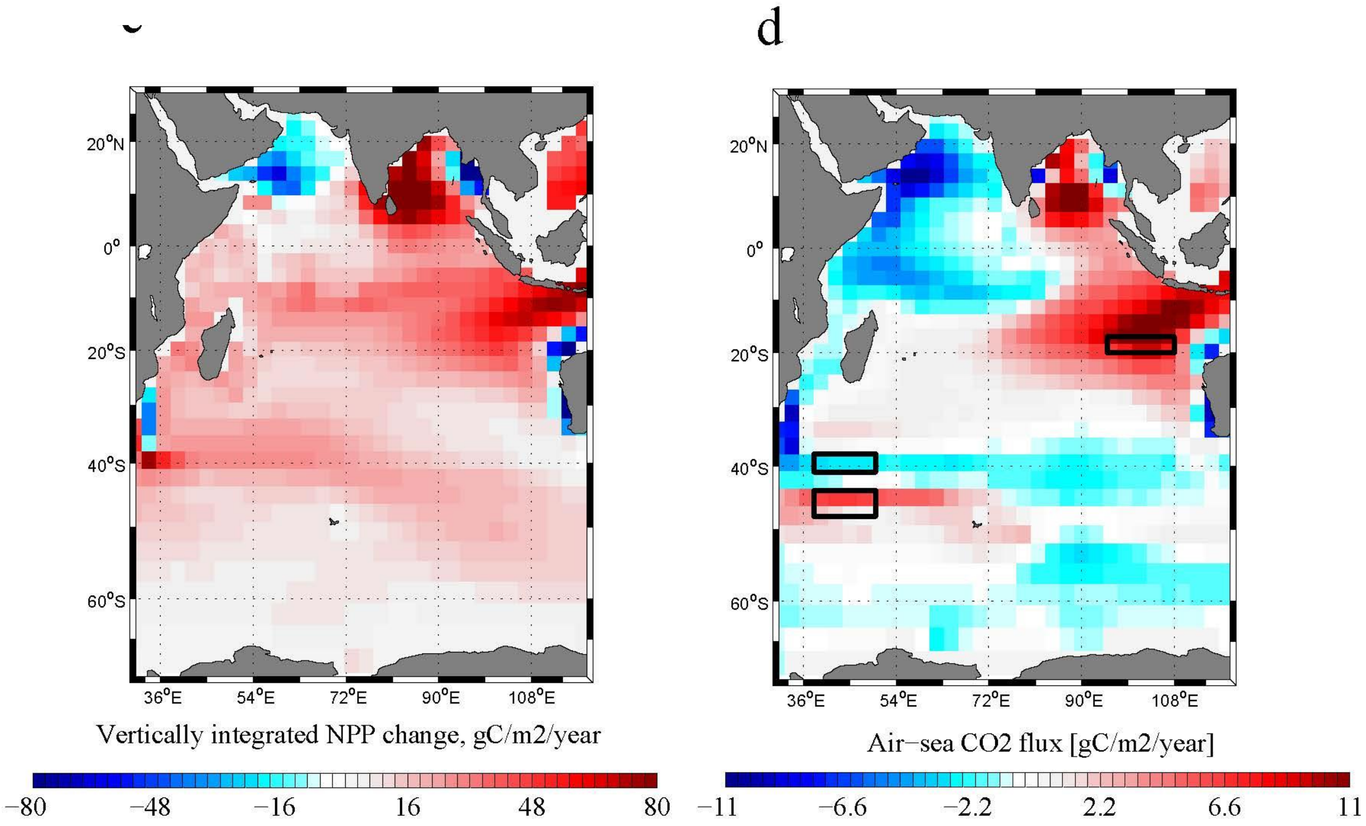


- Diatoms increased in the south of 40°S , in the Bay of Bengal, and in the southeastern tropics
- Coccolithophores increase along 40°S and in the southern part of the Arabian Sea
- Coccolithophores have a lower demand for phosphate than diatom

Sensitivity simulations

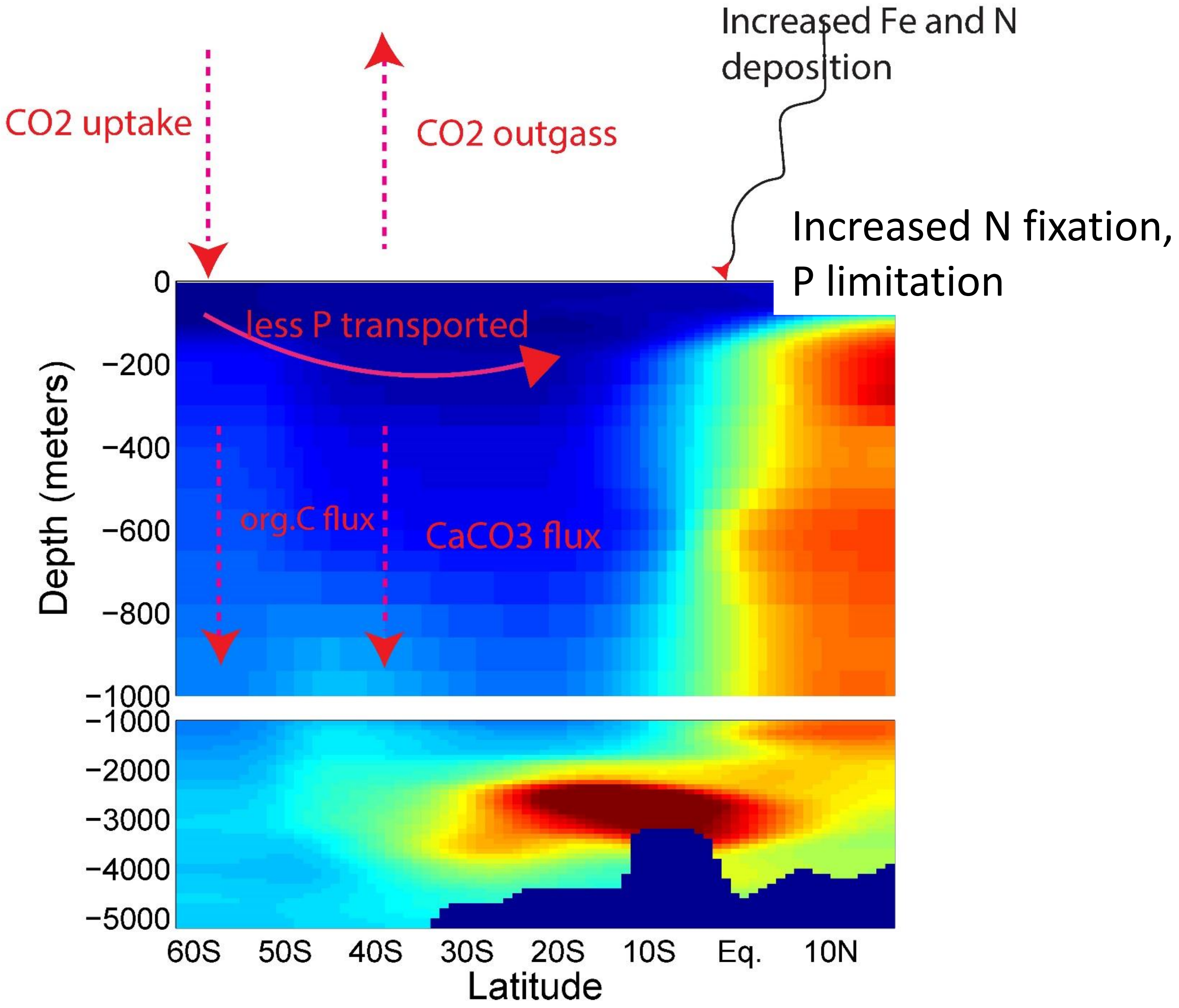
Ind - PreIn

ΔNPP ΔF_{CO2}



- CO2 uptake increases in the south of 40°S, the Bay of Bengal, and the southeastern tropical Indian Ocean but decreased along 40°S and in the Arabian Sea

Conclusions



The ecosystem response is complex with non-local features.

Changes in diatoms and coccolithophores modulated the biological carbon and carbonate pumps, ultimately altered the air-sea CO_2 exchange in the Indian Ocean.