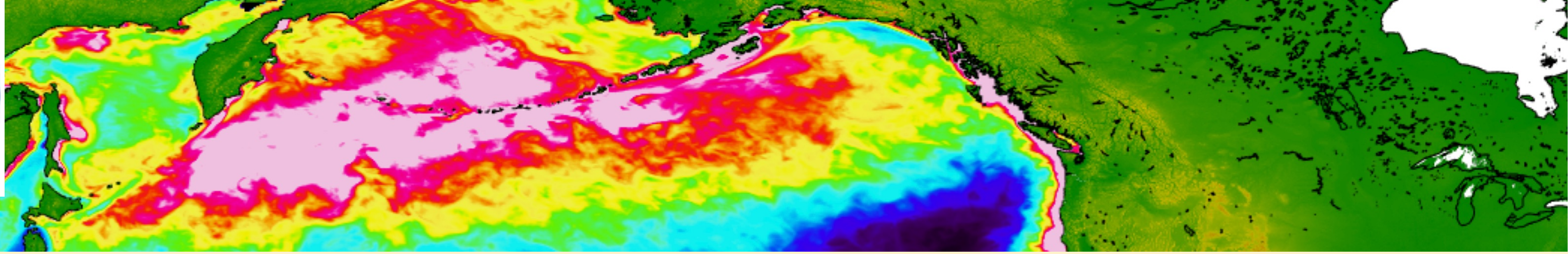
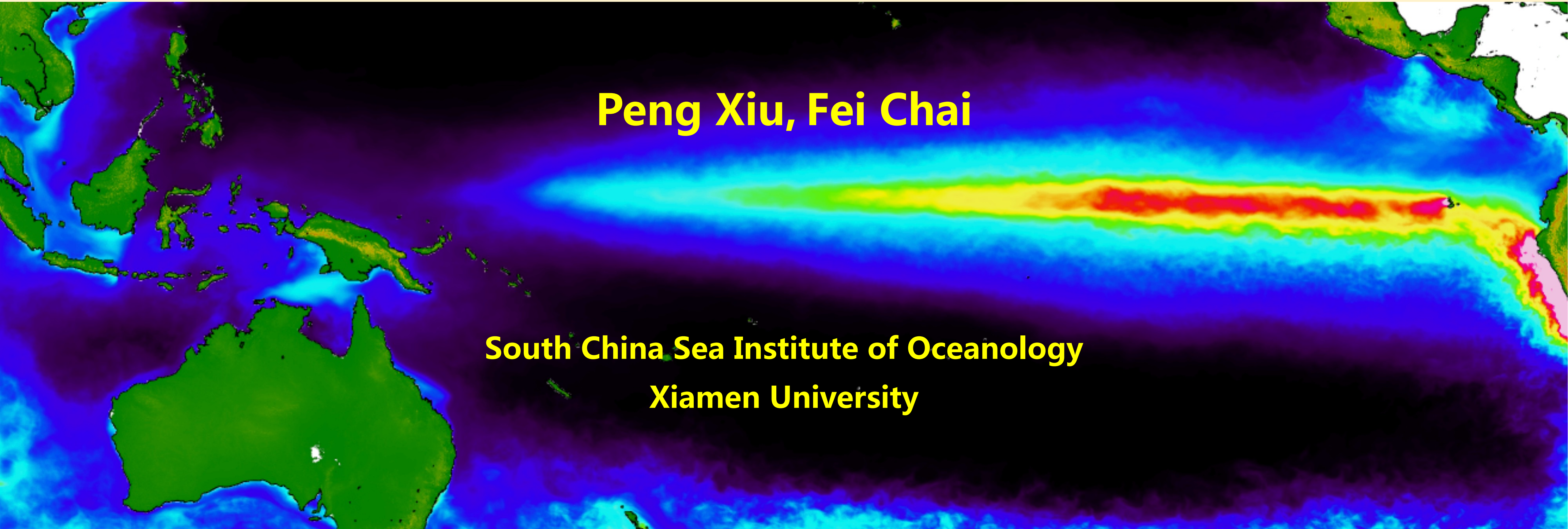


Modeling the impact of iron on carbon cycling in the Pacific Ocean

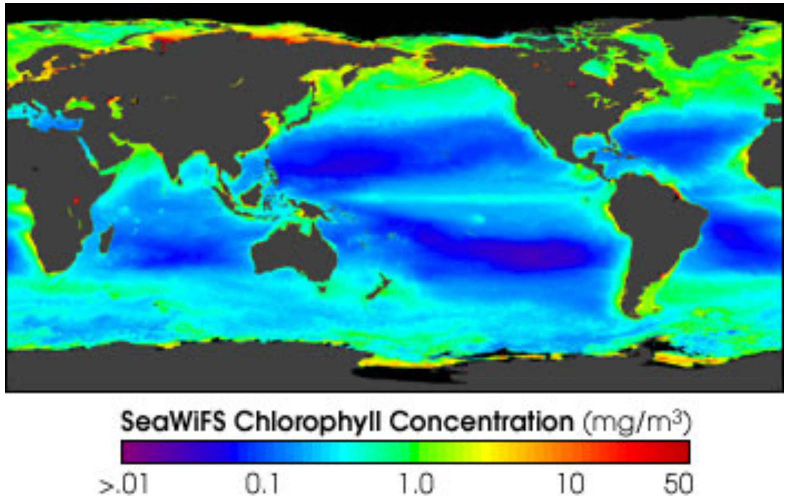


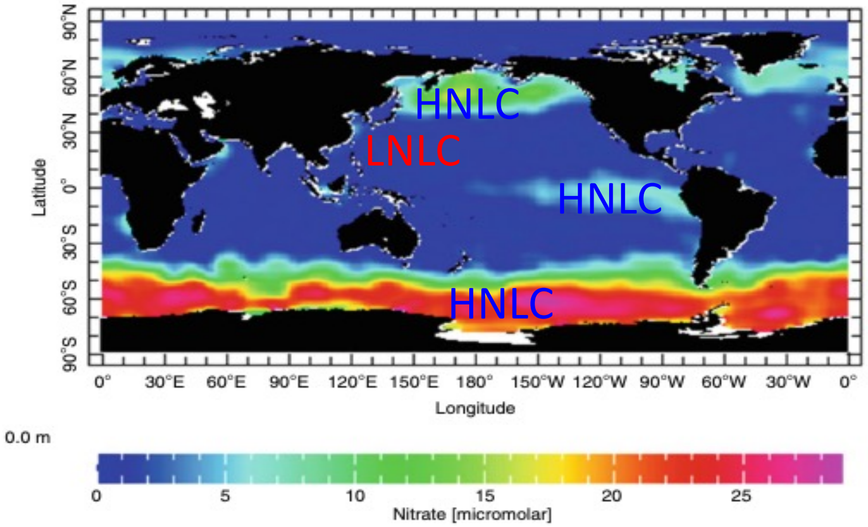
Peng Xiu, Fei Chai

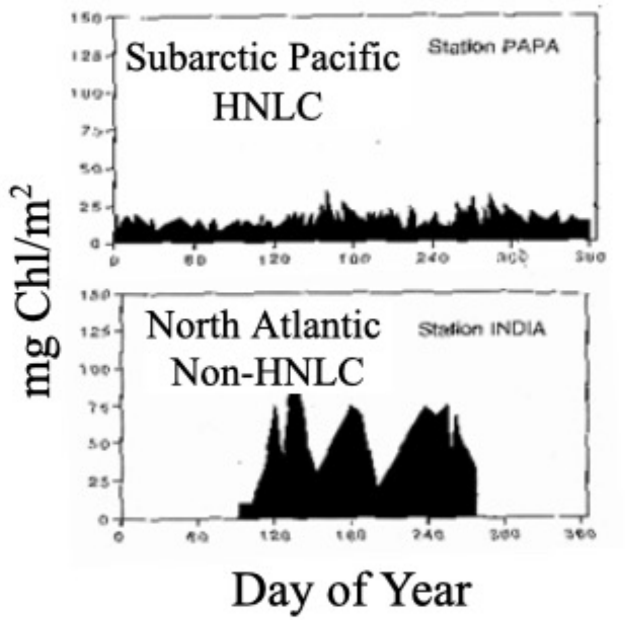
South China Sea Institute of Oceanology

Xiamen University

Phytoplankton chlorophyll and nitrate concentrations in the Pacific Ocean

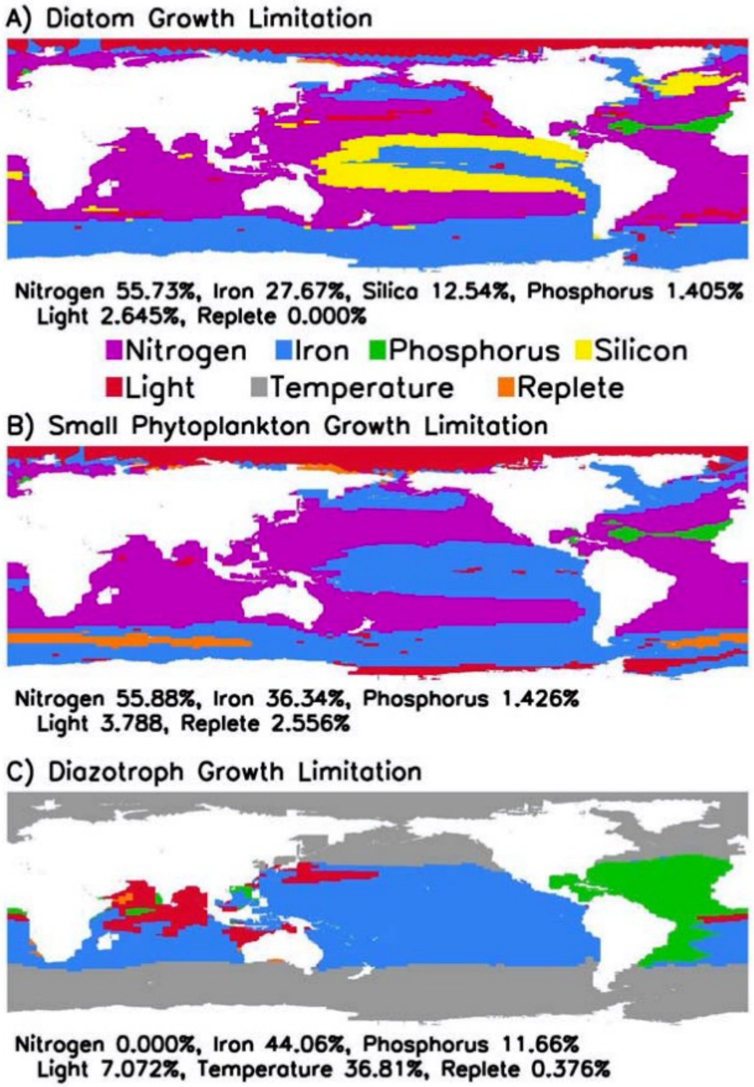




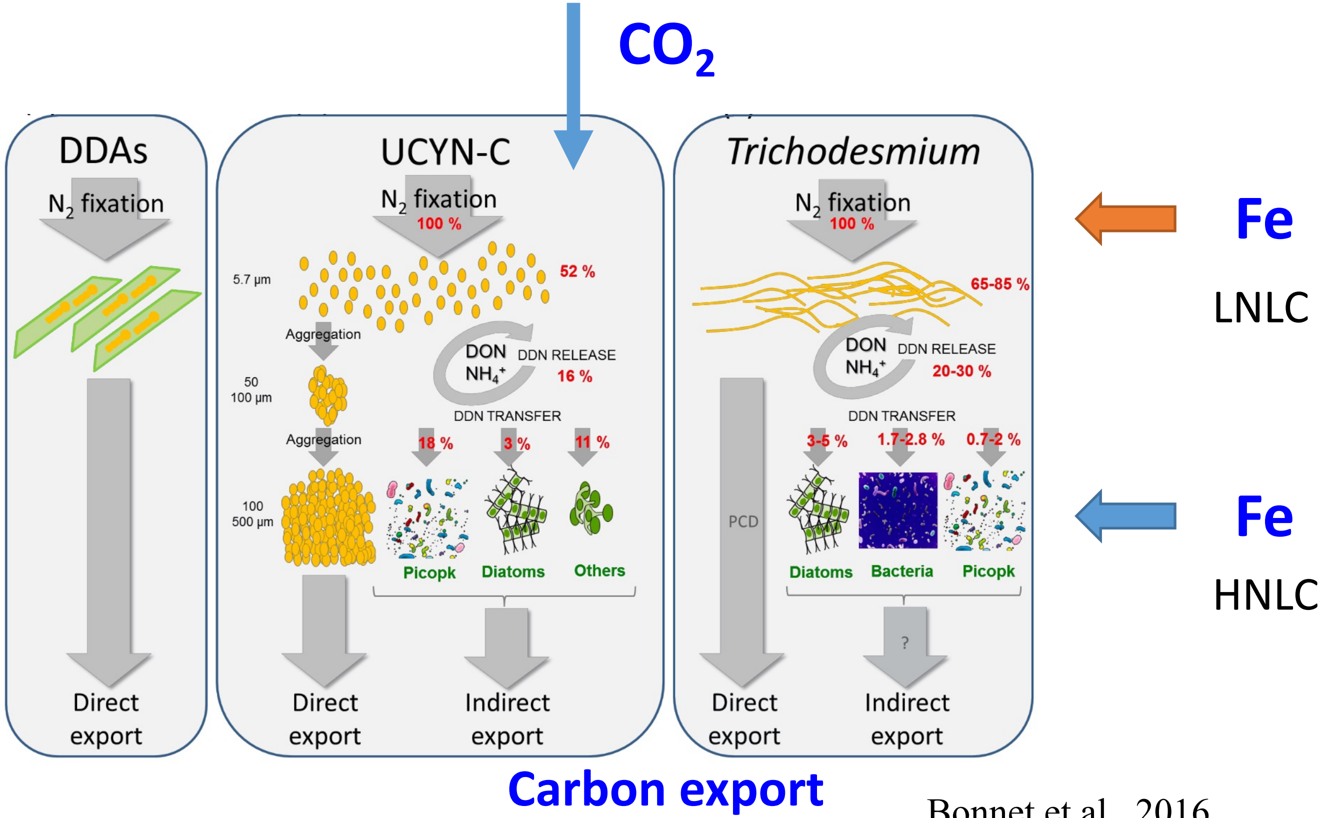


- **About 30% of the ocean are with excess nutrients while lower phytoplankton chlorophyll than expected (High-Nitrate-Low-Chlorophyll regions; HNLC)**
- **Another ~30% of the ocean, mostly in subtropical gyres, are with low nutrients and low phytoplankton chlorophyll (Low-Nitrate-Low-Chlorophyll regions; LNLC)**

Limiting nutrient for phytoplankton growth in the North Pacific



Moore et al., 2004

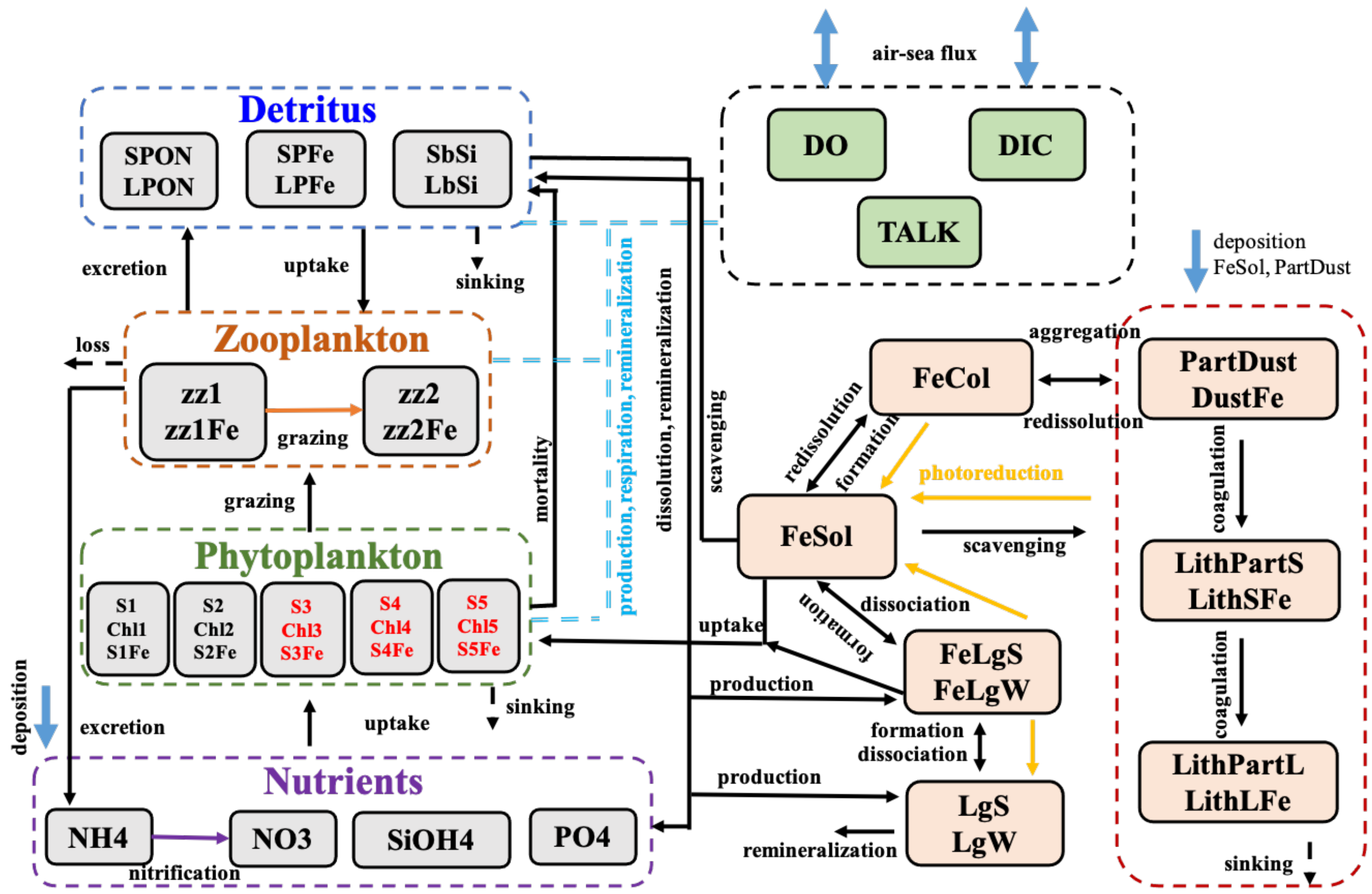


Bonnet et al., 2016

- **Iron is an essential nutrient for phytoplankton production across the North Pacific**
- **Variability in iron supply may lead to changes in the processes associated with biological carbon pump**

A new biogeochemical model, CoSiNE-Fe

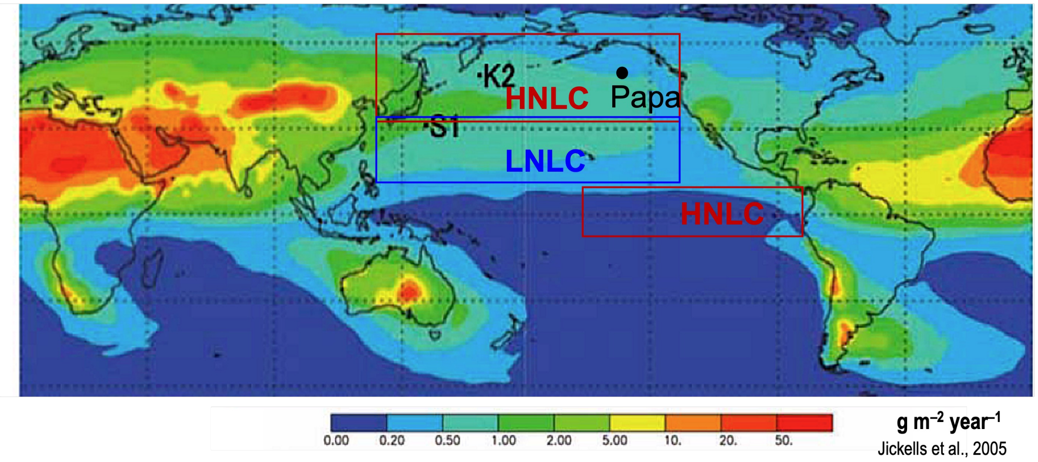
CoSiNE-Fe



- Five phytoplankton groups including picoplankton, diatom, and three diazotrophs (unicellular cyanobacteria, Trichodesmium, diatom-diazotroph associations (DDA))
- Iron cycles including soluble Fe, colloidal Fe, strong ligand Fe, weak ligand Fe, strong ligand, and weak ligand
- Atmospheric depositions of Fe, N, P, and lithogenic particles, and parameterized Fe sources from sediments and hydrothermal vents
- Three size classes of particles with different parameterizations
- A new light attenuation scheme with a dual-band model. Phytoplankton photoacclimation was parameterized

Xiu and Chai, 2021GRL; Xiu and Chai, in preparation

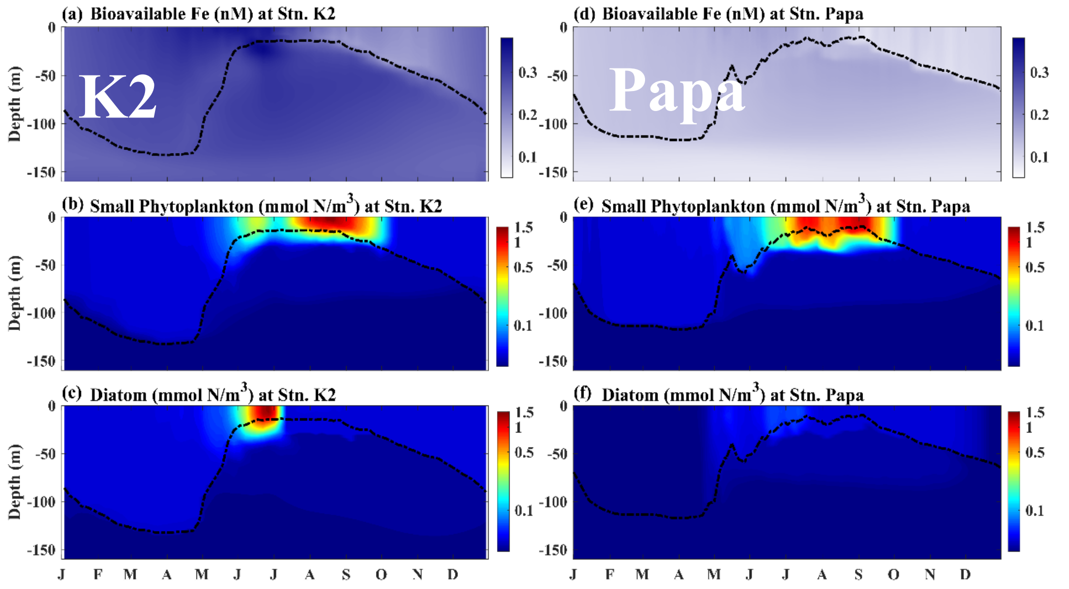
One-dimensional ROMS-CoSiNE-Fe model



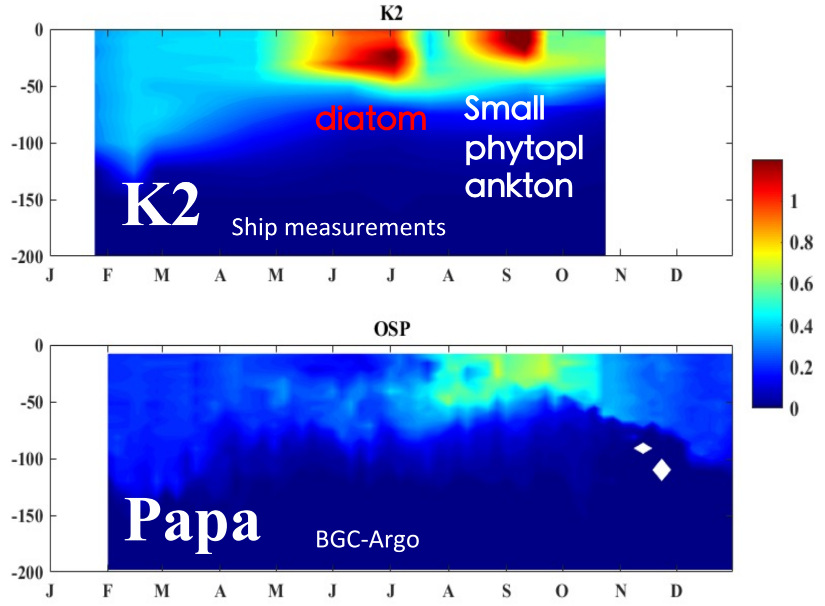
- Bioavailable Fe is higher in the western region (K2)
- Small phytoplankton peaks in late summer in both regions, with a relatively larger magnitude in the western region (K2) than the eastern region (Papa)
- Diatom in the the western region (K2) peaks from late spring to summer, while is constantly low in the eastern region (Papa)

The west-east gradient in dust Fe deposition shapes the difference of marine ecosystems between the western and eastern subarctic Pacific Ocean

Model

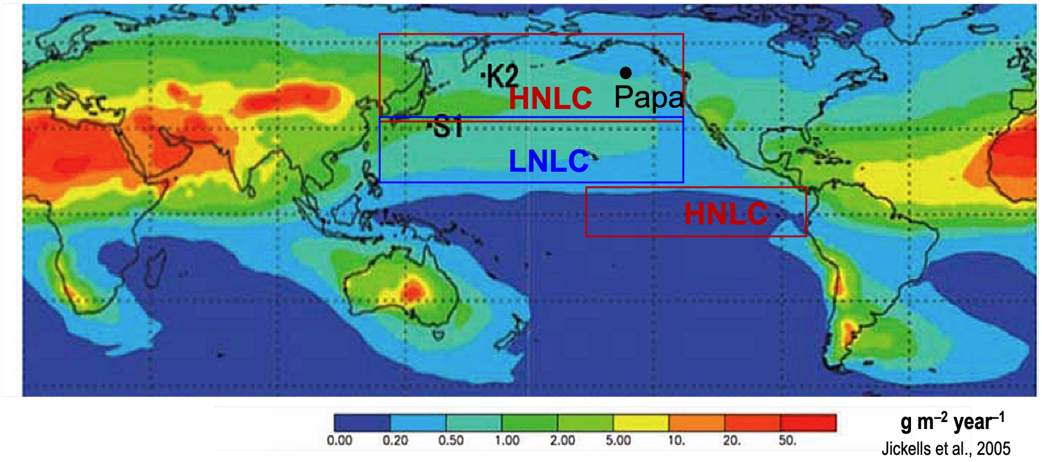


Observations

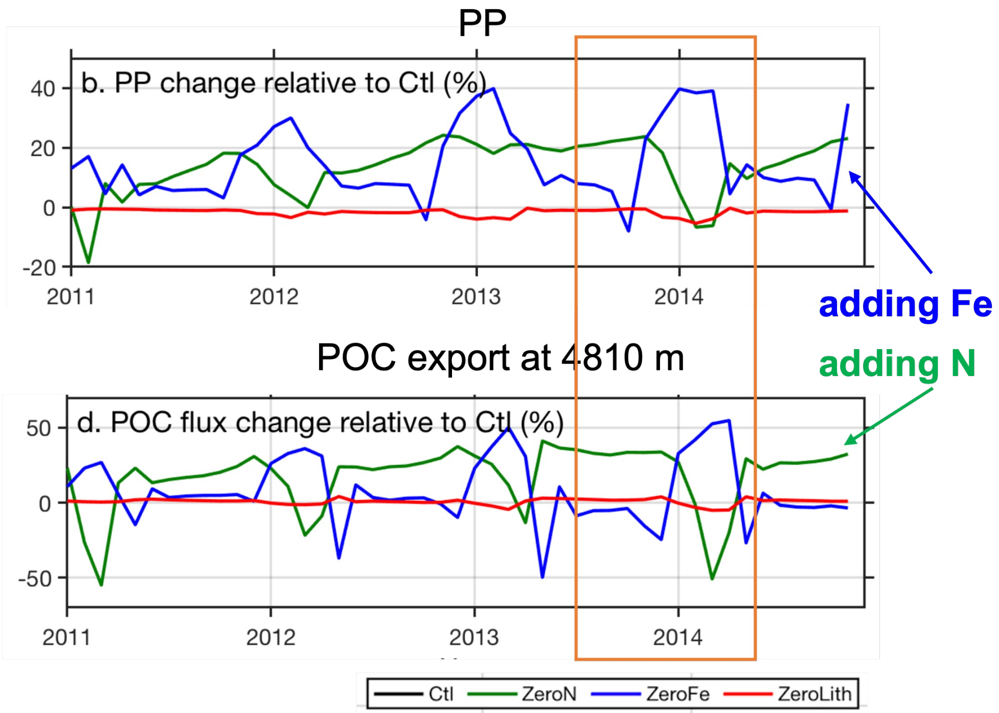


Zhang et al., 2021 FMS
Zhang et al., 2021 MEPS

One-dimensional ROMS-CoSiNE-Fe model



- **S1 (145°E, 30°N) is in the NPSG, but experiences strong winter mixing**
- **Phytoplankton is limited by nitrate in summer and fall, and nitrogen fixation is not strong in this region**
- **Atmospheric Fe deposition is still a significant input, especially from late winter to early spring**
- **A moored sediment trap at 200m, 500m, 4810m (Honda et al., 2002) from JAMSTEC**



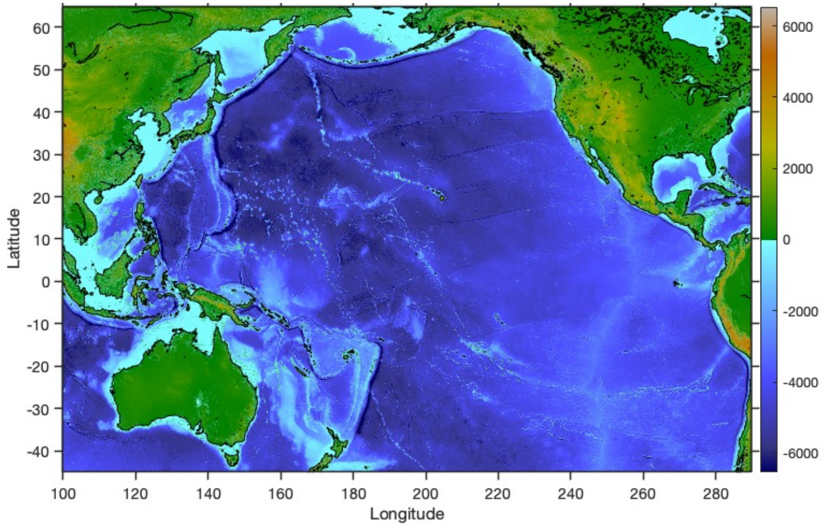
- Atmospheric deposition of N and Fe **increases 0-200m PP**
- Atmospheric **N** stimulates picoplankton growth in summer and fall with increased grazing pressure on winter diatoms and consequently **reduces deep ocean export in winter**
- Atmospheric **Fe** deposition matters in winter and **stimulates diatoms growth and deep ocean export**

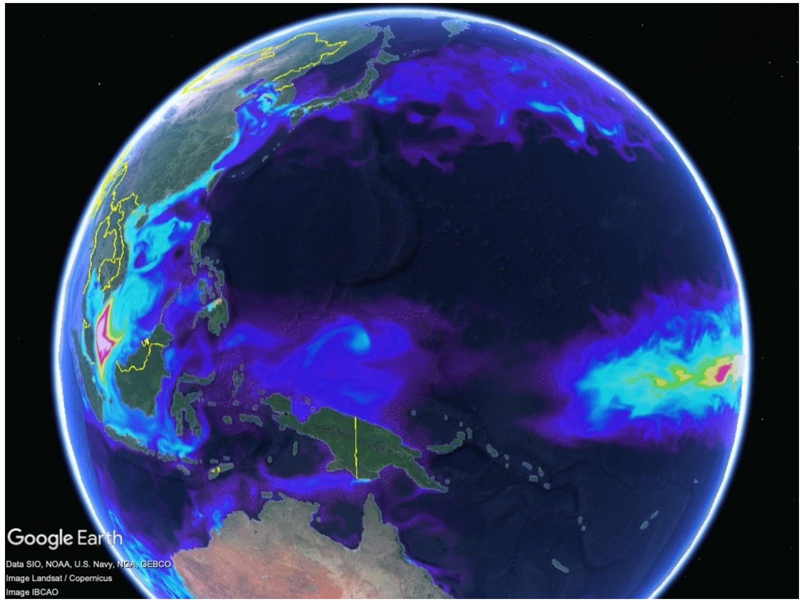
Xiu and Chai, 2021GRL

A high-resolution, three-dimensional ROMS-CoSiNE-Fe model for the Pacific Ocean

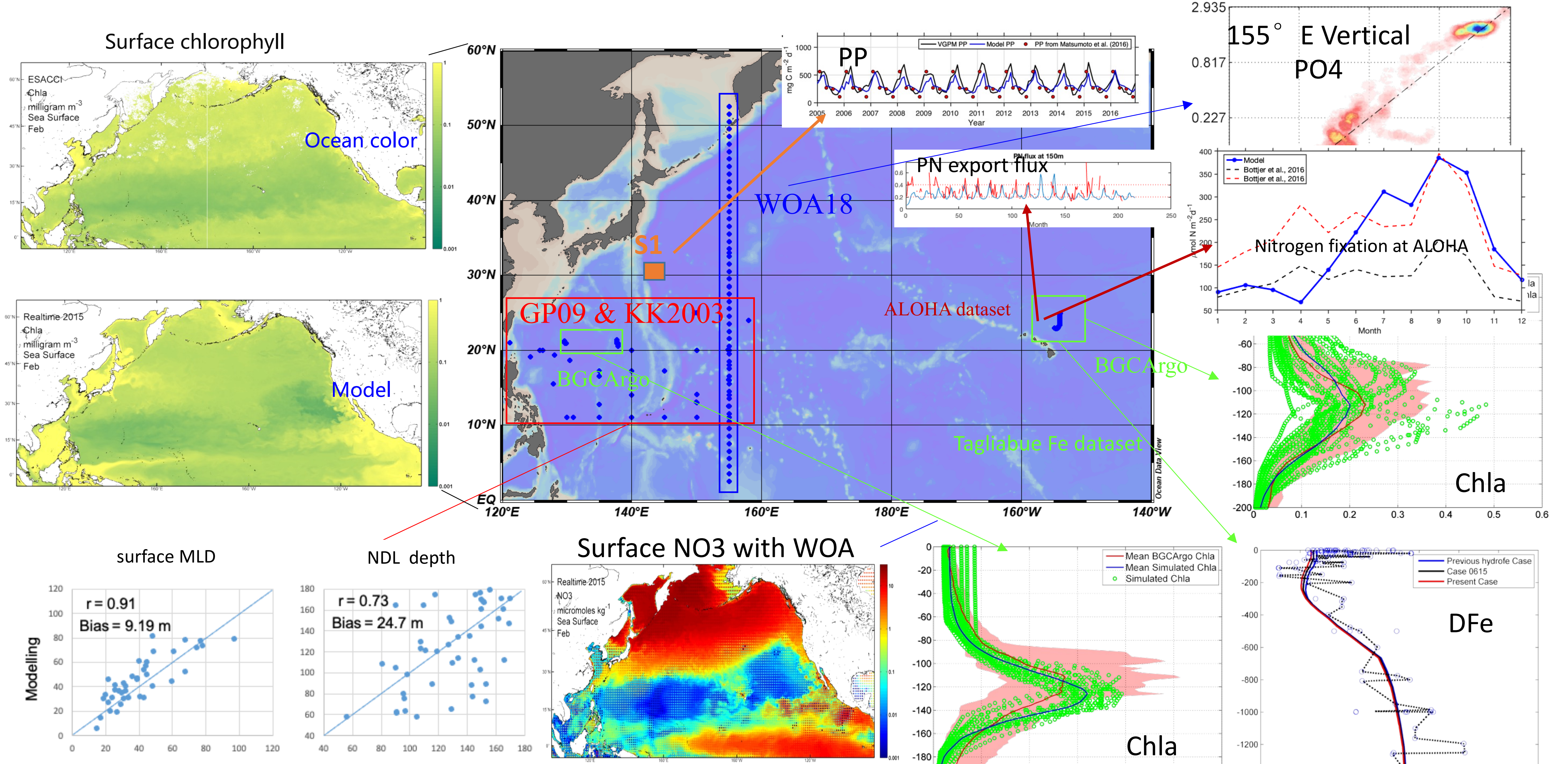
Pacific ROMS-CoSiNE-Fe

- ROMS model: 99~289.9^{o}E; -44~64.7^{o}N
- Horizontal resolution: 1/8^o (~10 km)
- Vertical layers: 60
- Topography data: SRTM30plus
- Lateral boundaries: HYCOM, WOA for biogeochemical variables
- Forcings: ERA5
- Rivers: Climatological monthly river discharge
- Tides: TPXO7.2 from OSU (M2, N2, S2, K2, K1, O1, P1, Q1)
- Vertical mixing: MY level-2.5 closure
- Atmospheric deposition: Monthly data from Chien et al. (2016)
- Hydrothermal vent Fe flux: Tagliabue et al. (2010)
- Sediment Fe flux: A function of depth (Moore et al., 2004; Aumont et al., 2015)





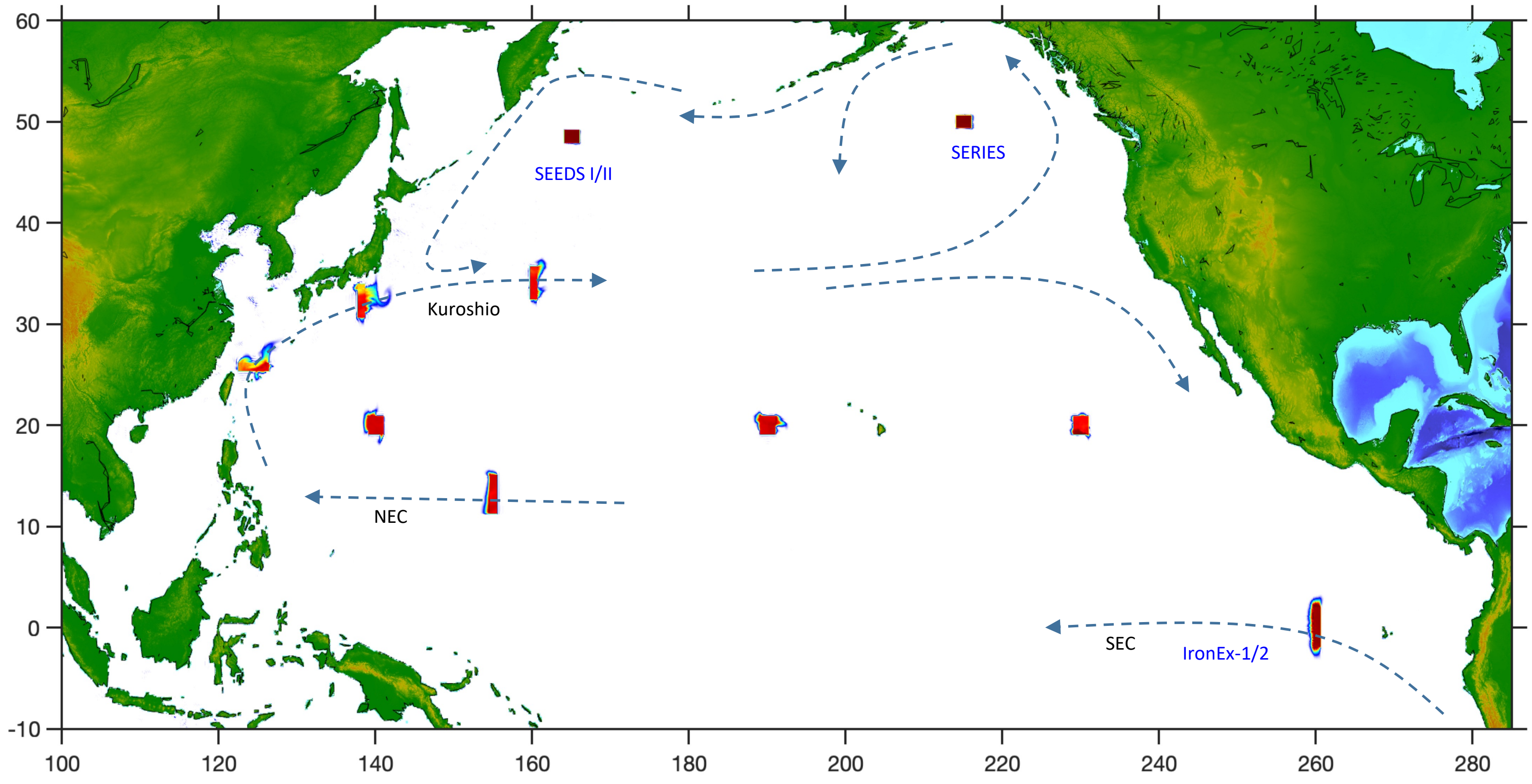
Model validations: Satellite derived products, BGC-Argo, WOA, in situ measurements



Ship measurements from Carbon-Fe led by Minhan Dai

Modeling OIF experiments

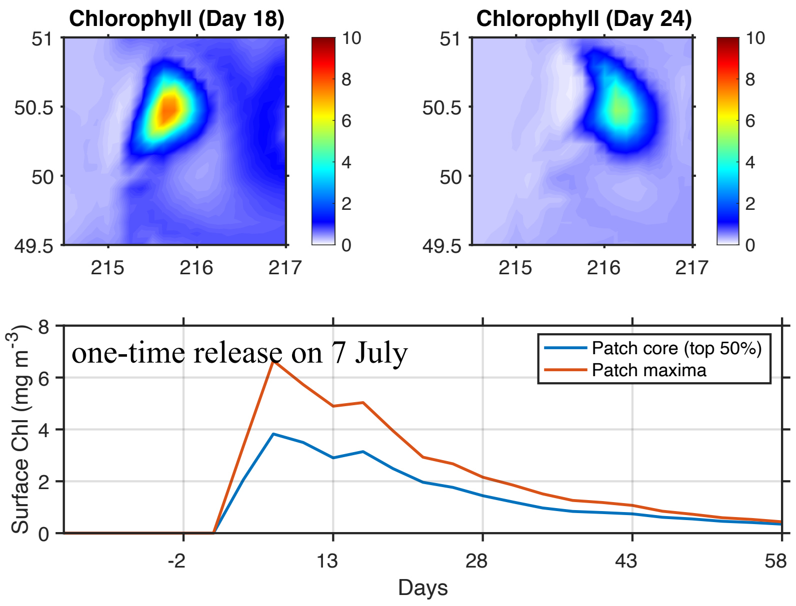
Ten locations in the Pacific Ocean

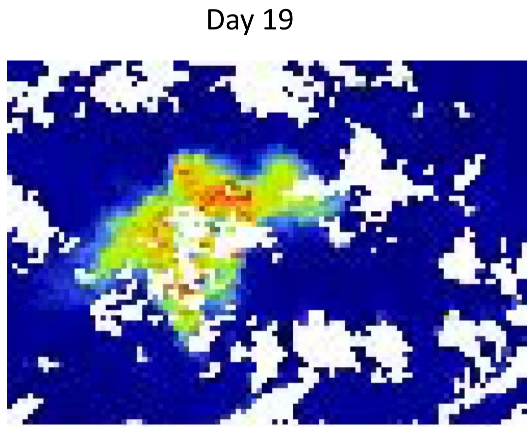


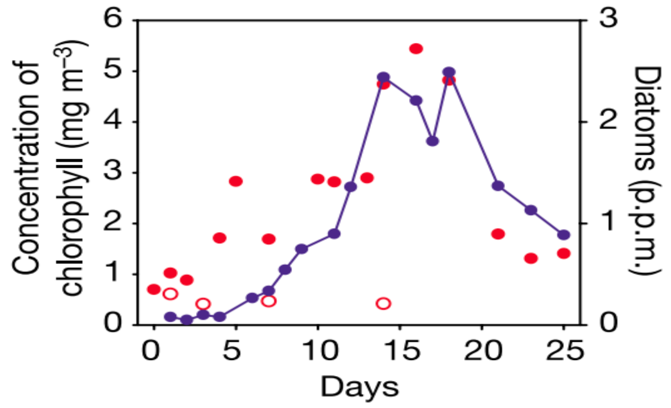
- **Season**
  - ➢ Two cases: starting from April 1 and from July 1 in 2017
  - ➢ Both cases run 3 months
- **Size**
  - ➢ For barges: 200 km long x 12.5 km wide, 400 km long x 100 km wide
  - ➢ For boxes: 50 km x 50 km, 200 km x 200 km
- **Depth**
  - ➢ In the upper 10 m
- **Iron amount**
  - ➢ Increase DFe concentration to 1.0 nM
  - ➢ Continuous release for 15 days

Modeling OIF experiments

- **Comparison with data during SERIES**

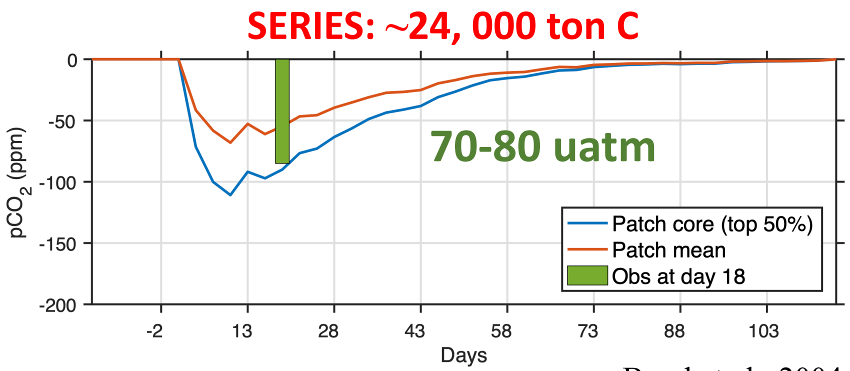




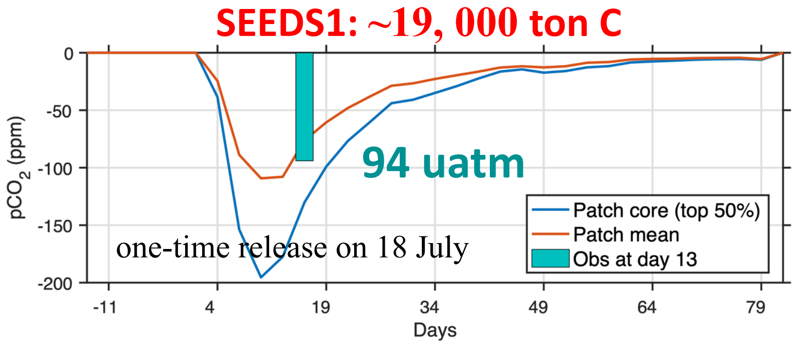


Boyd et al., 2004

- **Surface pCO_2 change**



Boyd et al., 2004

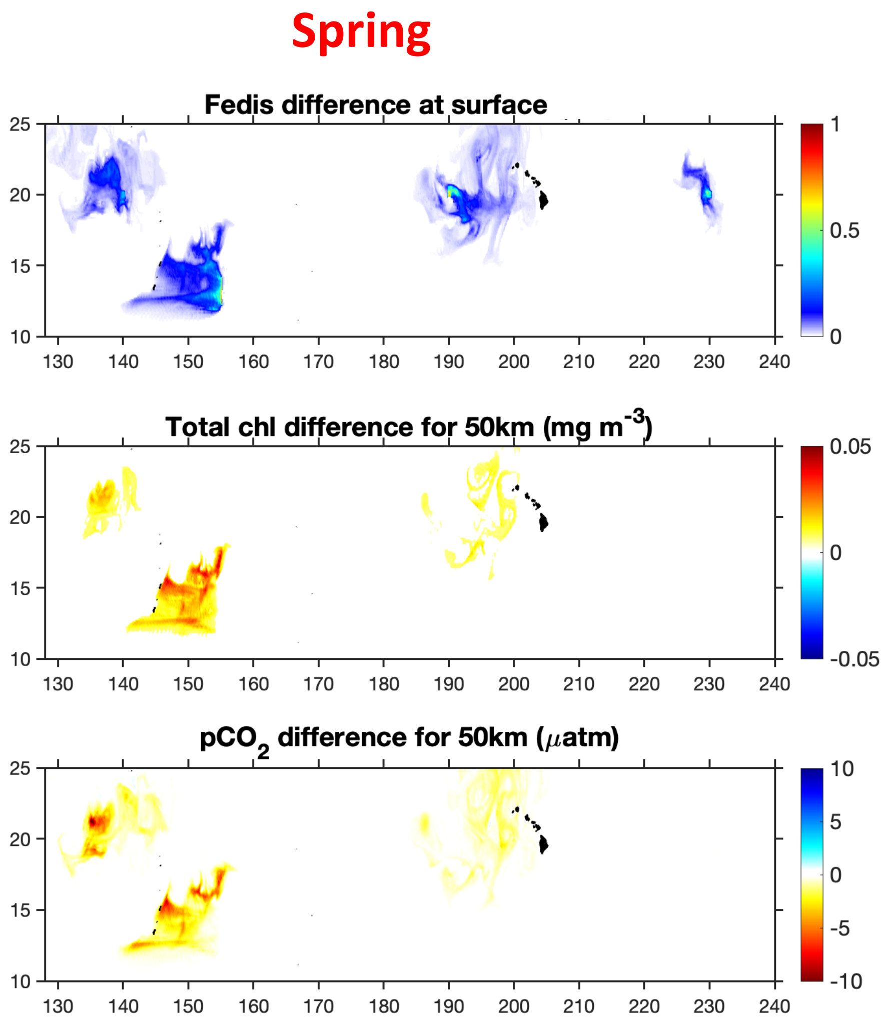


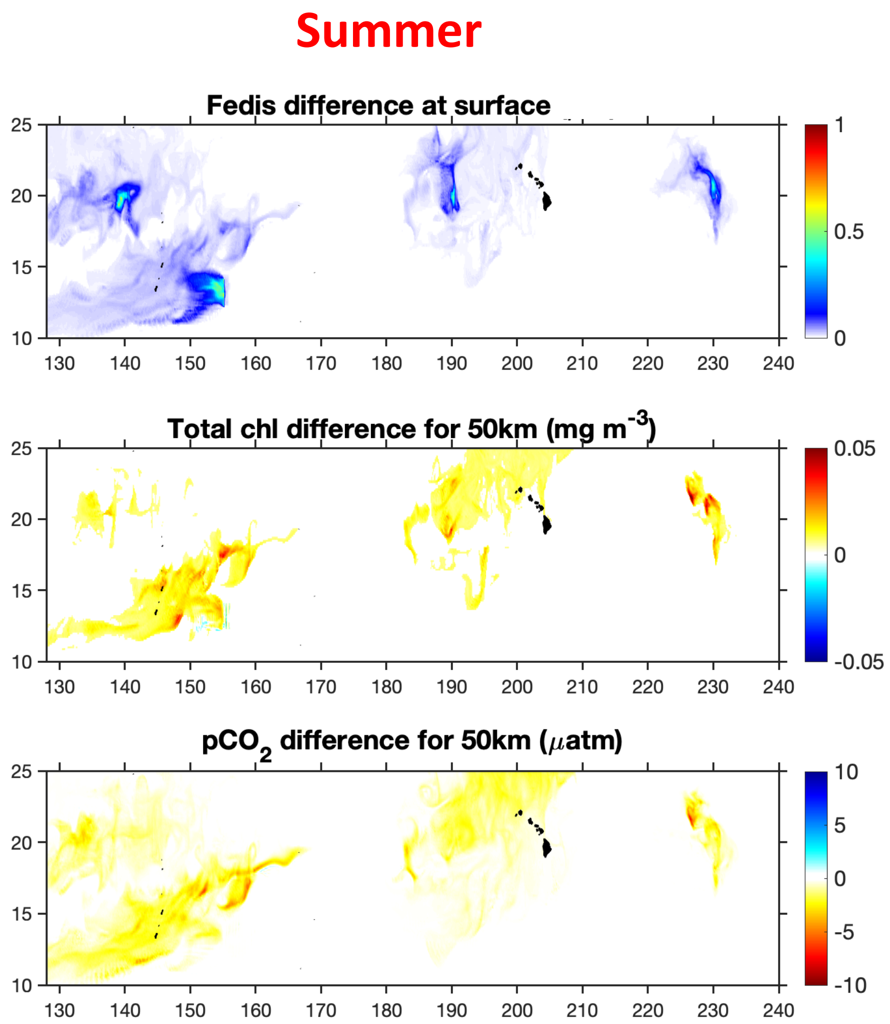
Tsuda et al., 2003

- **Model results are generally consistent with previous OIF experiments in subarctic region**
- **Adding Fe can drive surface pCO_2 drawdown**
- **The model can track the fertilized patch over its lifetime and estimate the integrated effect**

Modeling OIF experiments

- **Surface response averaged in three months**

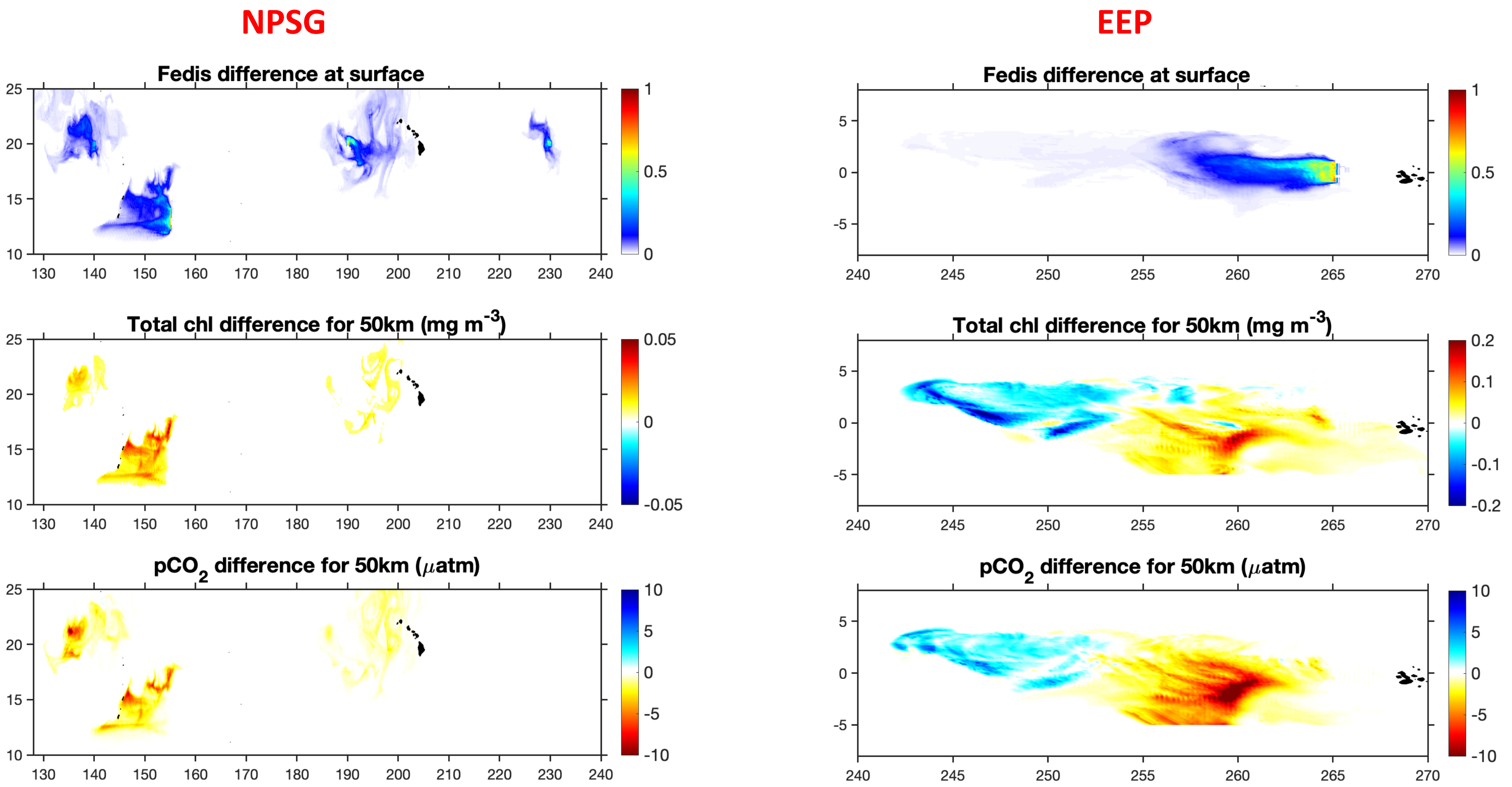




- **The eastern patch shows no biological response in spring, but shows response in summer**
- **Phyto response is relatively stronger in the western gyre than in the central gyre in spring**
- **During three months, the summer experiment covers more space than the spring experiment; the spring experiment is localized with high values**

Modeling OIF experiments

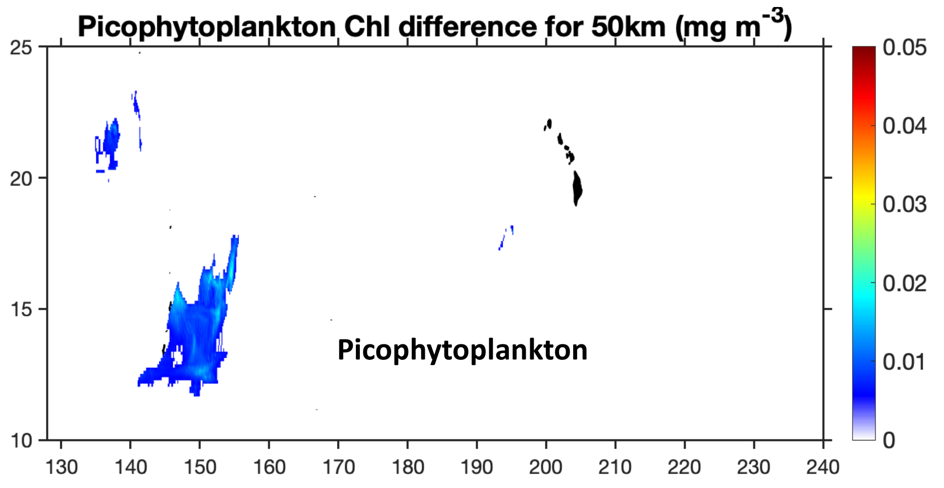
- **Surface response averaged in three months (April-June)**

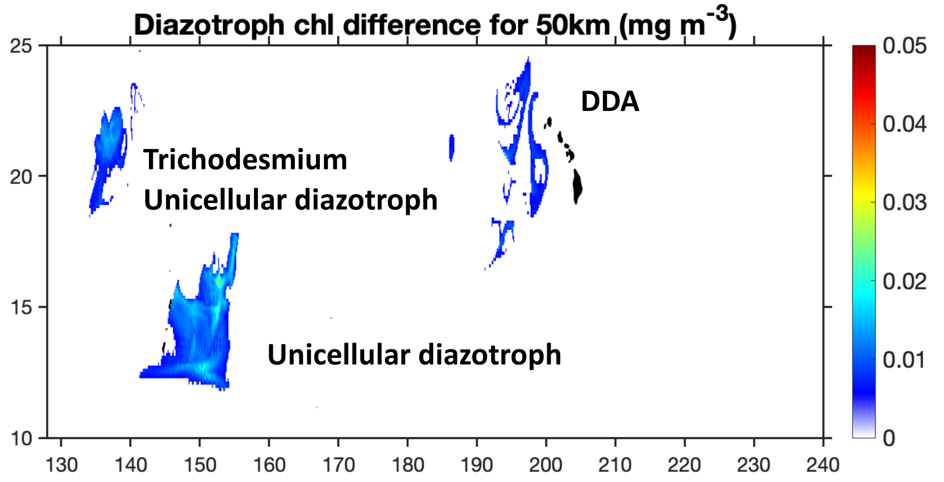


Modeling OIF experiments

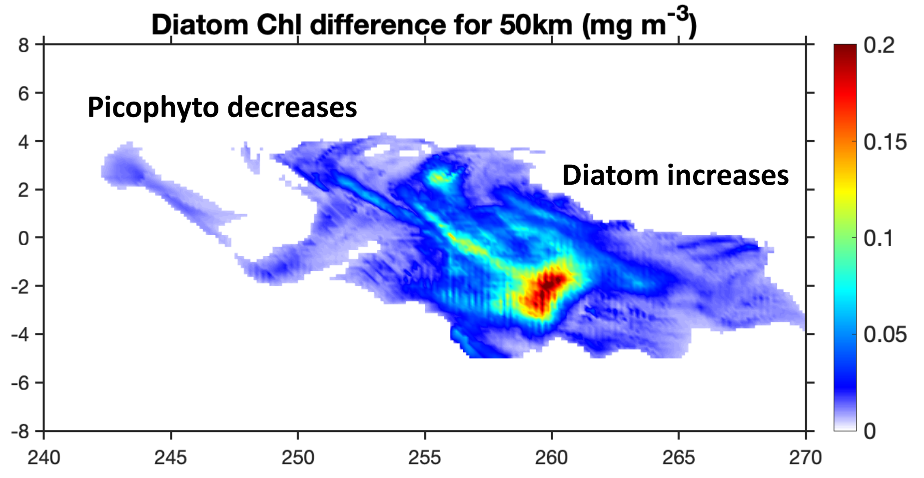
- **Surface response averaged in three months (April-June) : Related to different phytoplankton species**

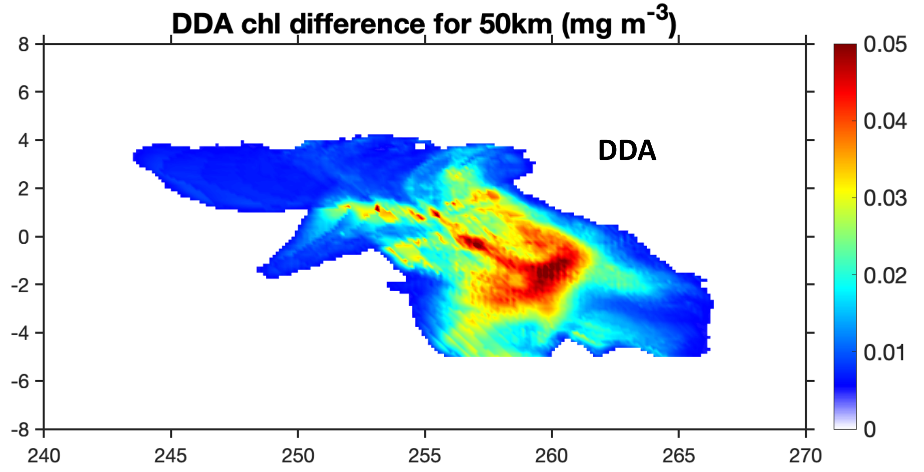
NPSG





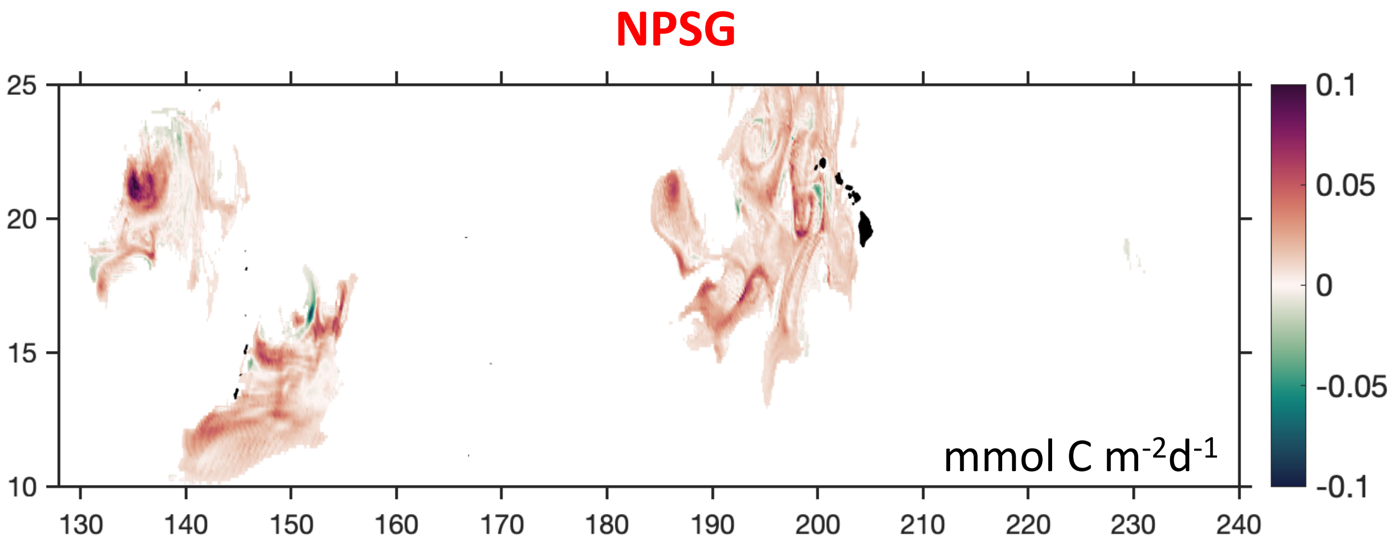
EEP

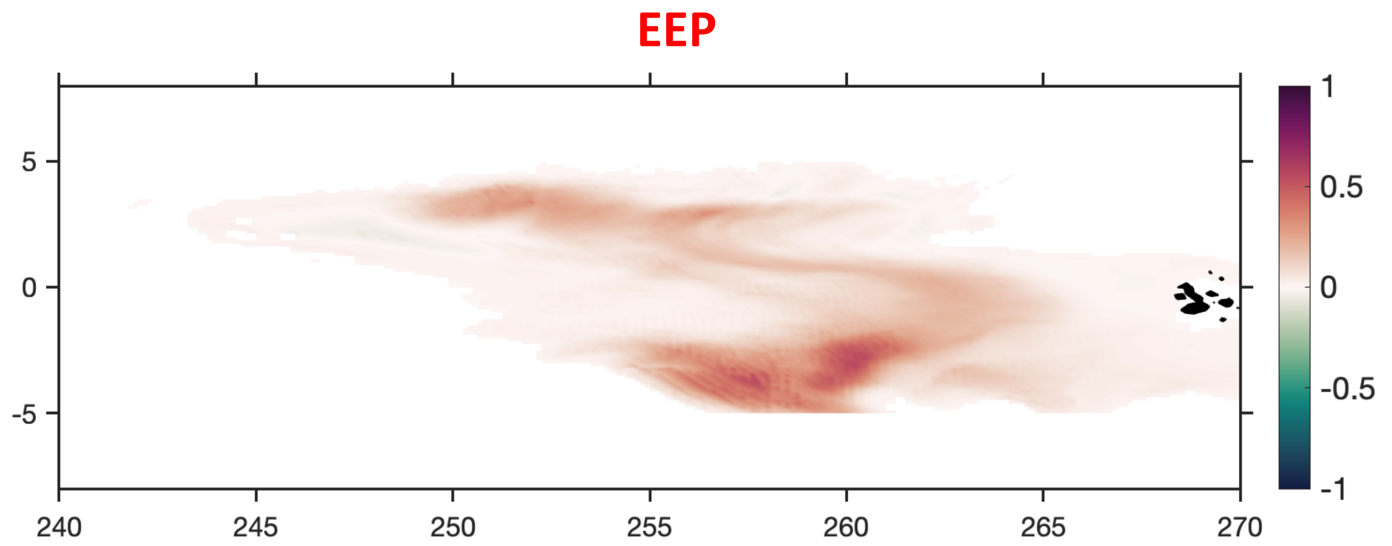




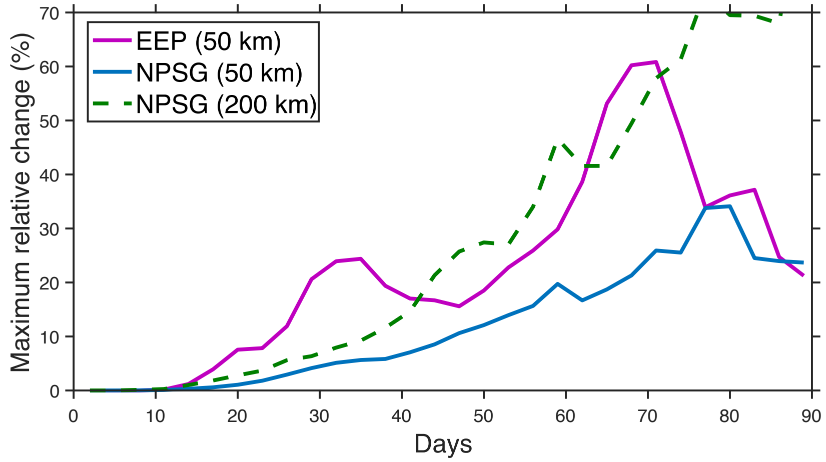
Modeling OIF experiments

- **POC export flux at 200 m averaged in three months (April-June)**





- **Both NPSG and EEP show changes in the POC export flux at 200 m**
- **The magnitude is larger in EEP than in NPSG**
- **The downstream change in EEP is not seen in the POC flux at 200 m, although it changes surface pCO_2**



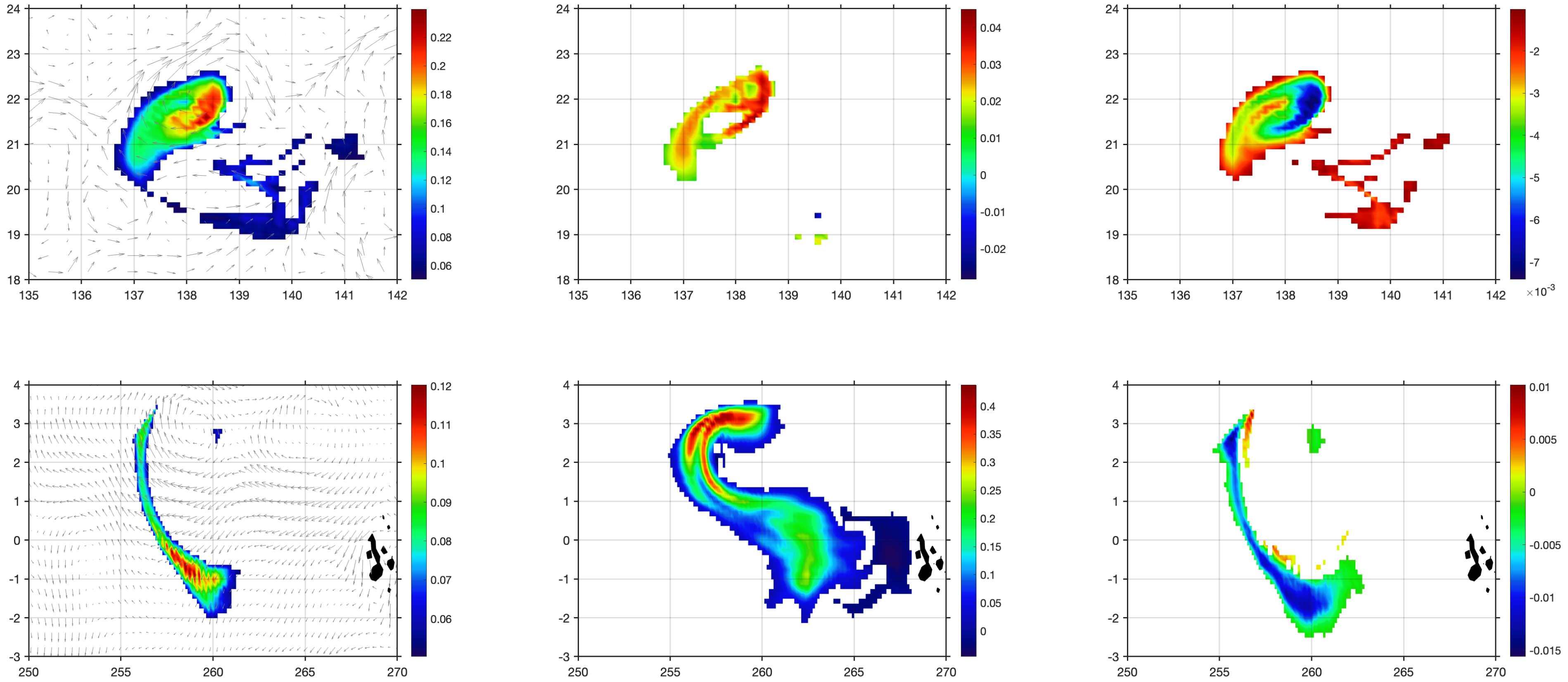
Modeling OIF experiments

- **Spatial distributions of patches on day 45**

Fe patch | POC flux patch | Air-sea CO_2 flux patch

Western gyre

EEP



- **In the western gyre, the Fe patch is in a similar shape as the POC flux patch and the air-sea CO_2 flux patch, regulated by a mesoscale eddy**
- **In the EEP, the shape of the Fe patch is similar to the air-sea CO_2 flux patch, but different from the POC flux patch**

Summary

- **A new biogeochemical model (CoSiNE-Fe) was built and coupled with the high-resolution ROMS model for the Pacific Ocean. The coupled model was validated against satellite data, BGC-Argo data and in situ measurements**
- **OIF experiments were simulated and evaluated by the coupled model in different regions and different seasons in the North Pacific Ocean**
- **In the western gyre, adding Fe may stimulate diazotroph (Trichodesmium and Unicell) and picophytoplankton growth, which can drawn surface pCO_2 and affect air-sea CO_2 flux. In the EEP, diatoms are simulated, which contributes to the POC export.**
- **The efficiency of OIF in changing air-sea CO_2 flux is comparable between the western gyre and the EEP, but is lower in exporting POC in the western gyre than in the EEP**
- **The Fe patch at the surface may be in different shapes and locations from the POC flux patch at 200 m (EEP)**