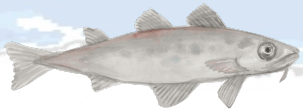


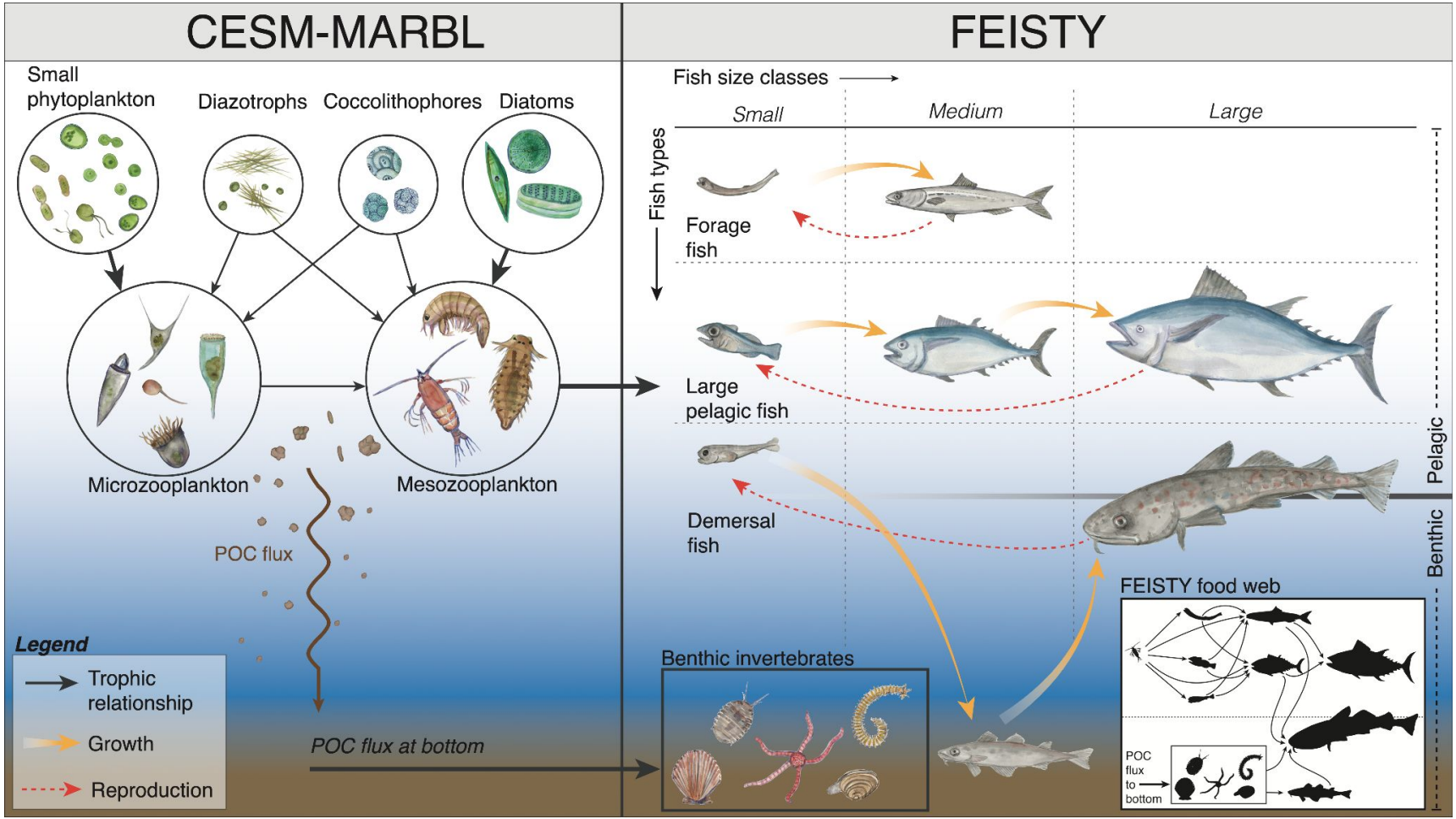
From nutrients to fish: Impacts of mesoscale processes in a global CESM-FEISTY eddying ocean model framework

Kristen Krumhardt

in collaboration with Matt Long, Colleen Petrik, Mike Levy, Fred Castruccio, Keith Lindsay, Lev Romashkov, Anna-Lena Deppenmeier, Rémy Denéchère, Zhuomin Chen, Laura Landrum, Gokhan Danabasoglu, Ping Chang

Overview

- Forced ocean sea ice (FOSI) high resolution (0.1°) CESM2 simulation run on Frontera
- Forced by Japanese Reanalysis, JRA-do (1958 to 2021), historical CO_2 forcing
- 4 phytoplankton, 2 zooplankton MARBL
- Fish model called FEISTY run “offline” from 1980 to 2021 (**F**ish**E**r**I**es **S**ize and functional **TY**pe model)
- Talk is an overview of the documentation paper:
    - Introduce 4p2z MARBL ecosystem + FEISTY fish model
    - Model evaluation compared to available observations
    - Preliminary analysis
    - Comparisons to 1° version of the run (“FOSI-HR” vs. “FOSI-LR”)


CESM-MARBL
FEISTY
Small phytoplankton
Diazotrophs
Coccolithophores
Diatoms
Microzooplankton
Mesozooplankton
POC flux
POC flux at bottom
Fish size classes
Small
Medium
Large
Fish types
Forage fish
Large pelagic fish
Demersal fish
Pelagic
Benthic
Benthic invertebrates
FEISTY food web
POC flux to bottom
Legend
Trophic relationship
Growth
Reproduction

Sea ice looks good!

- Important control on Antarctic and Arctic ecosystems
- Sea ice extents in both hemispheres match observations better than 1°

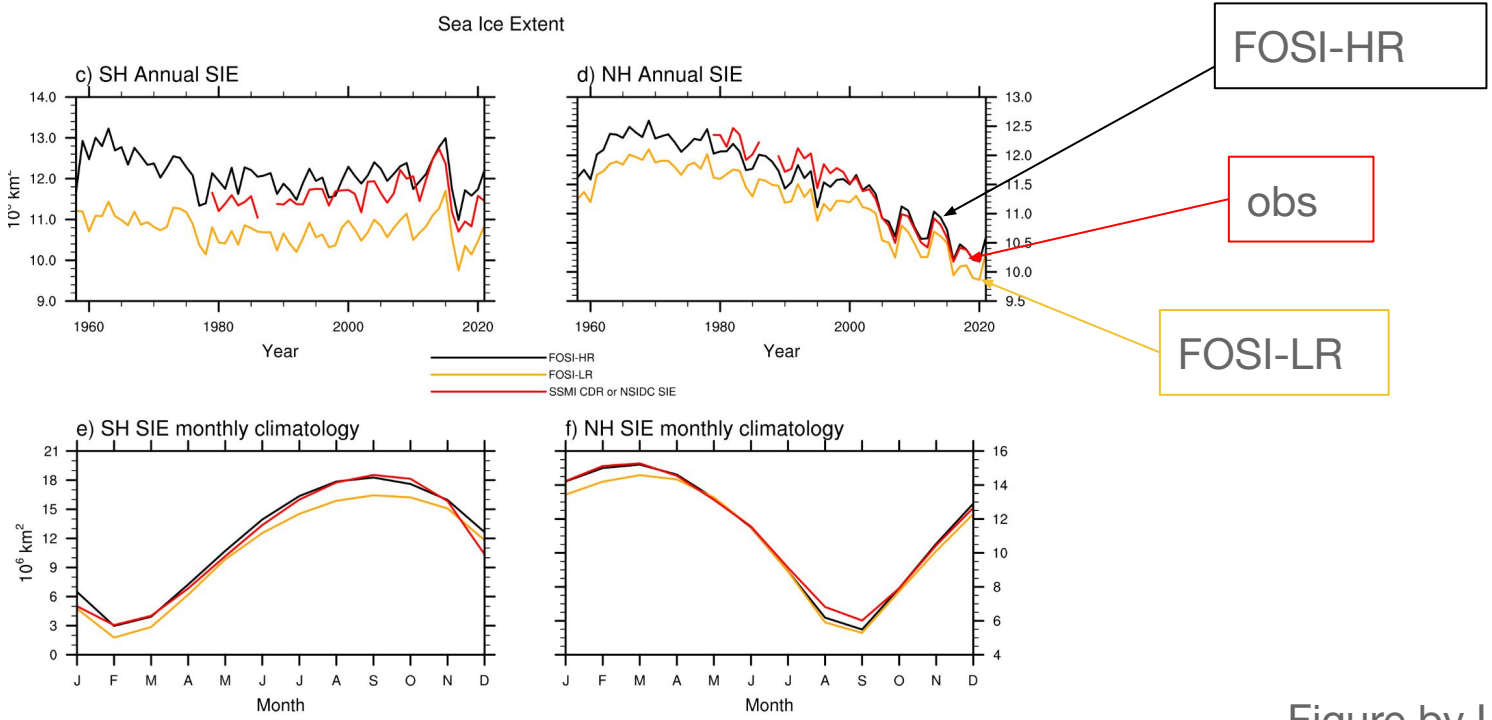


Figure by Laura Landrum

Oxygen compared to GOBAI-O2 observational product

- Difference maps at 400 m depth, highlights biases in model solution
- Negative biases in FOSI-LR are much reduced in FOSI-HR
- FOSI-HR was initialized with LR spinup

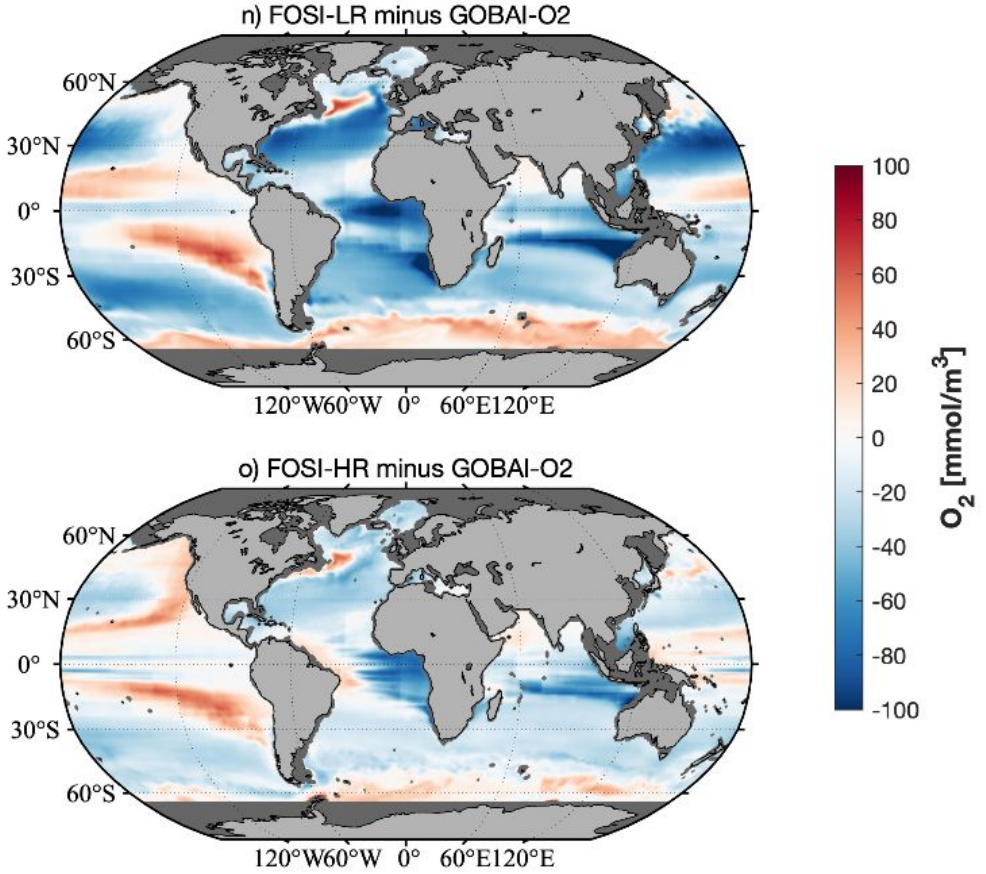
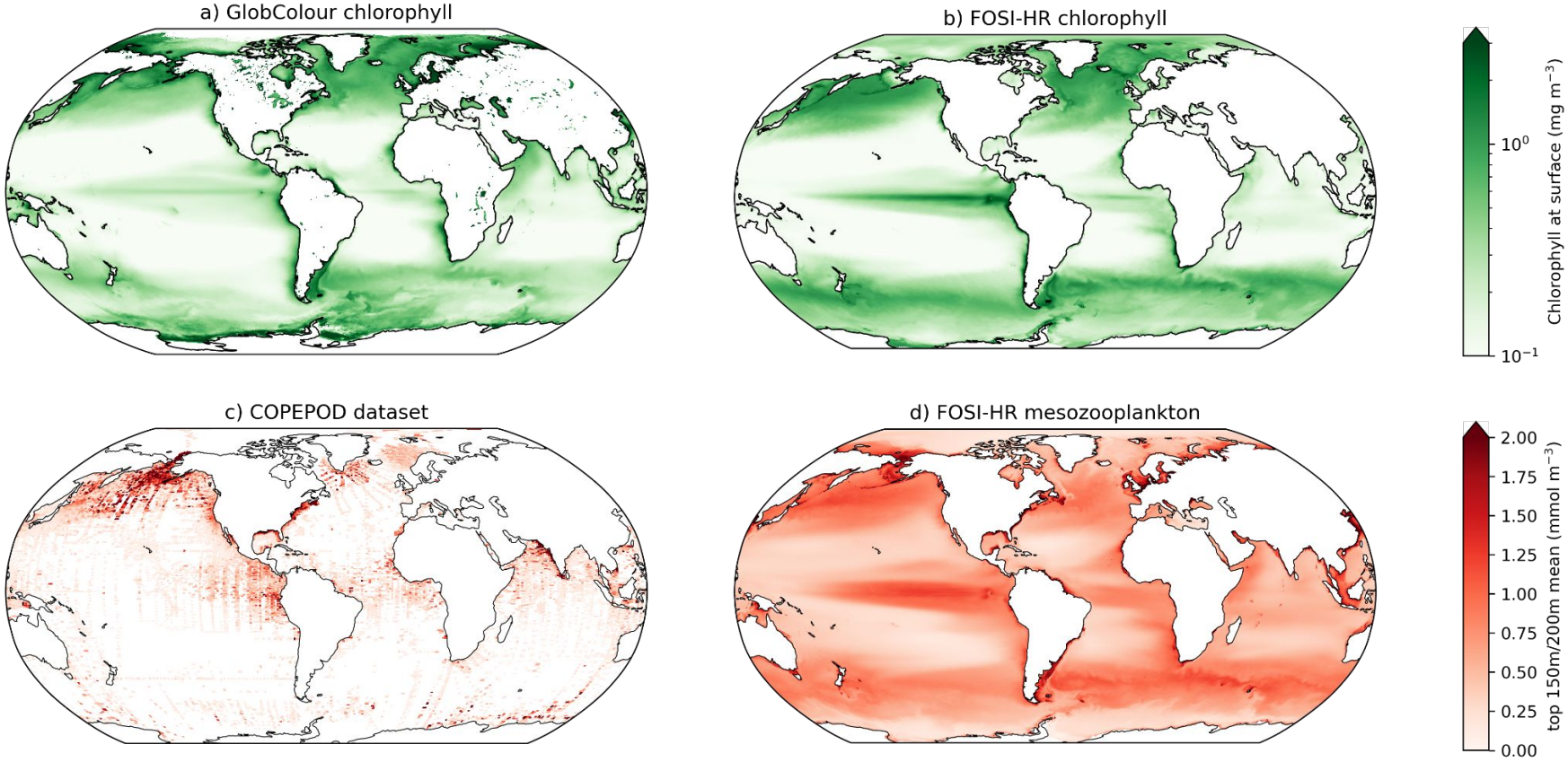


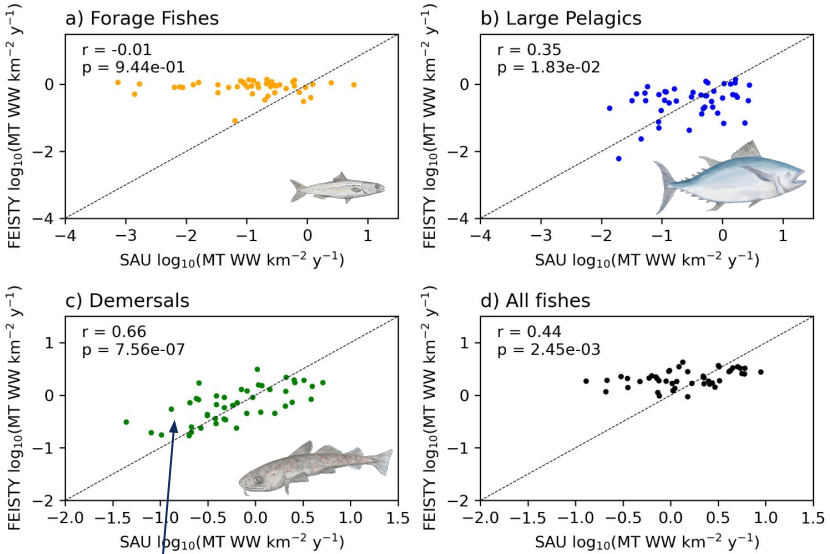
Figure by Zhuomin Chen

Large scale geographic patterns in plankton look reasonable



We compared FEISTY-HR fish "catches" to reported fish catches in Sea Around Us database

Mean state evaluation in Large Marine Ecosystems



Each dot represents mean fish biomass in one LME

Comparing time series of fish catch in a few LMEs

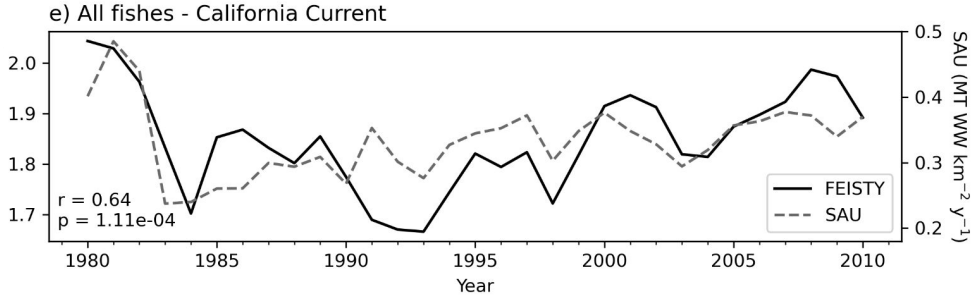
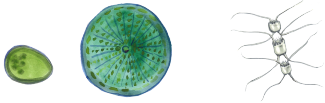


Figure by Lev Romashkov

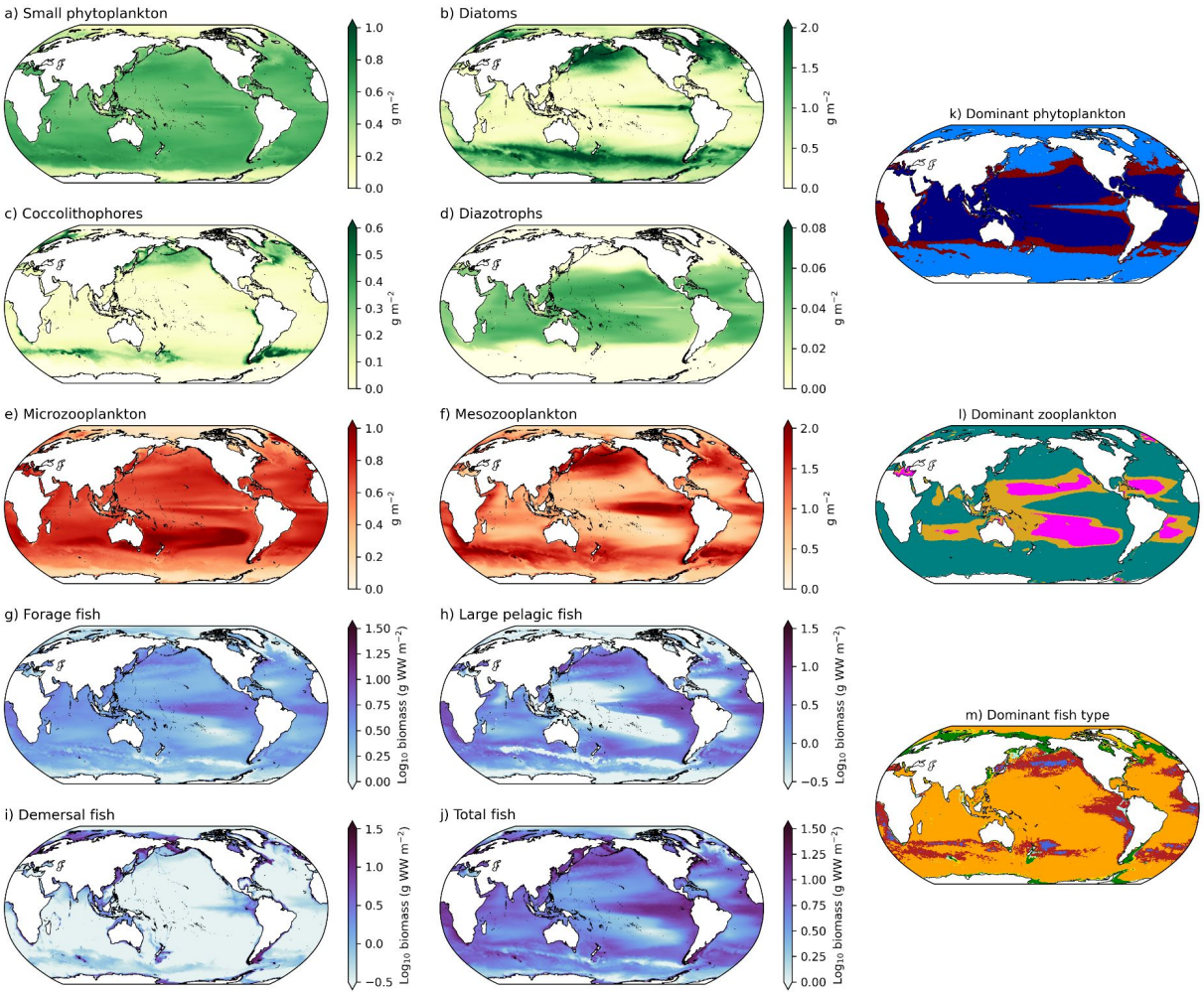
Large scale biogeography in FOSI-HR and FEISTY-HR

Phytoplankton



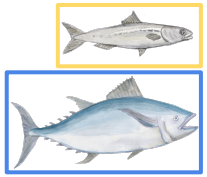
Zooplankton

Fish

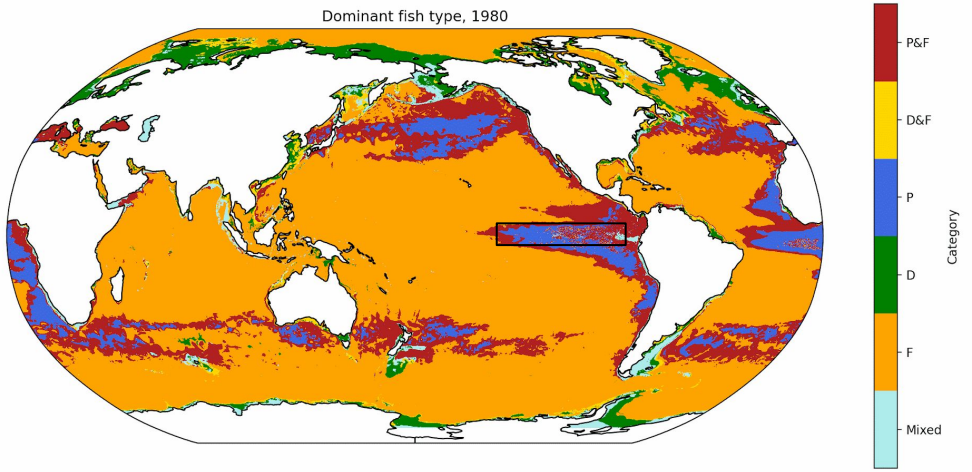


Fish biomass responds to climate forcing

- Both fish types drop during El Niño
- Forage fish recover faster



El Niños in purple



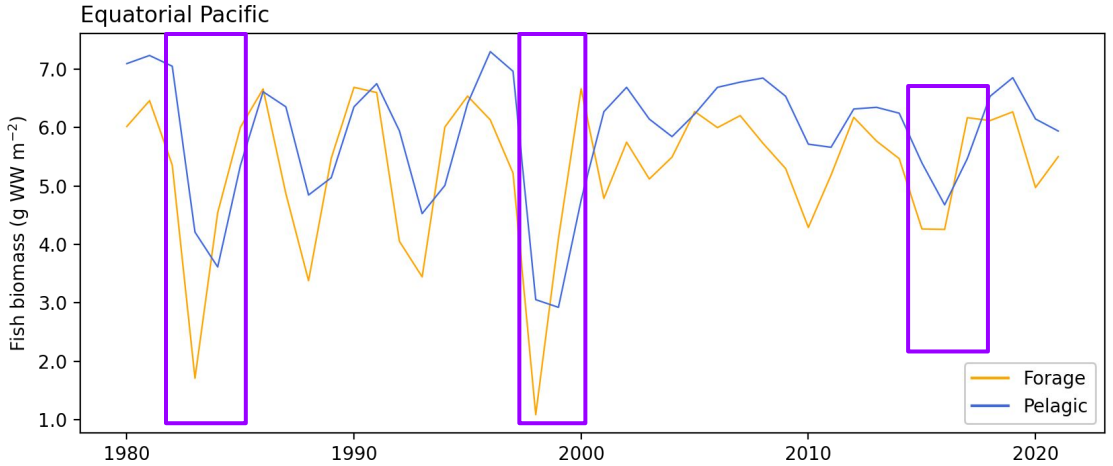
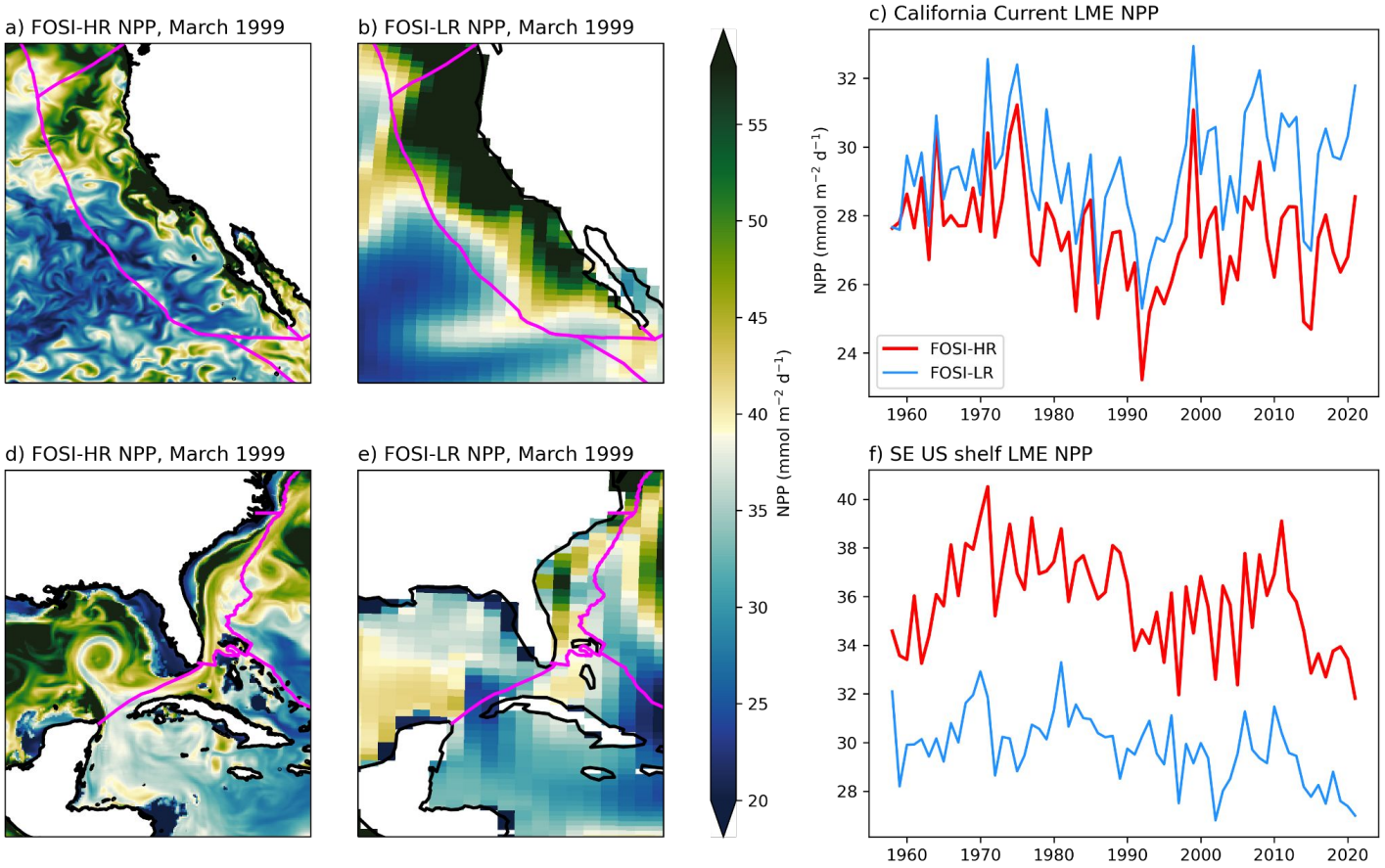


Figure and animation by Lev Romashkov

Comparing marine NPP in high resolution and low resolution

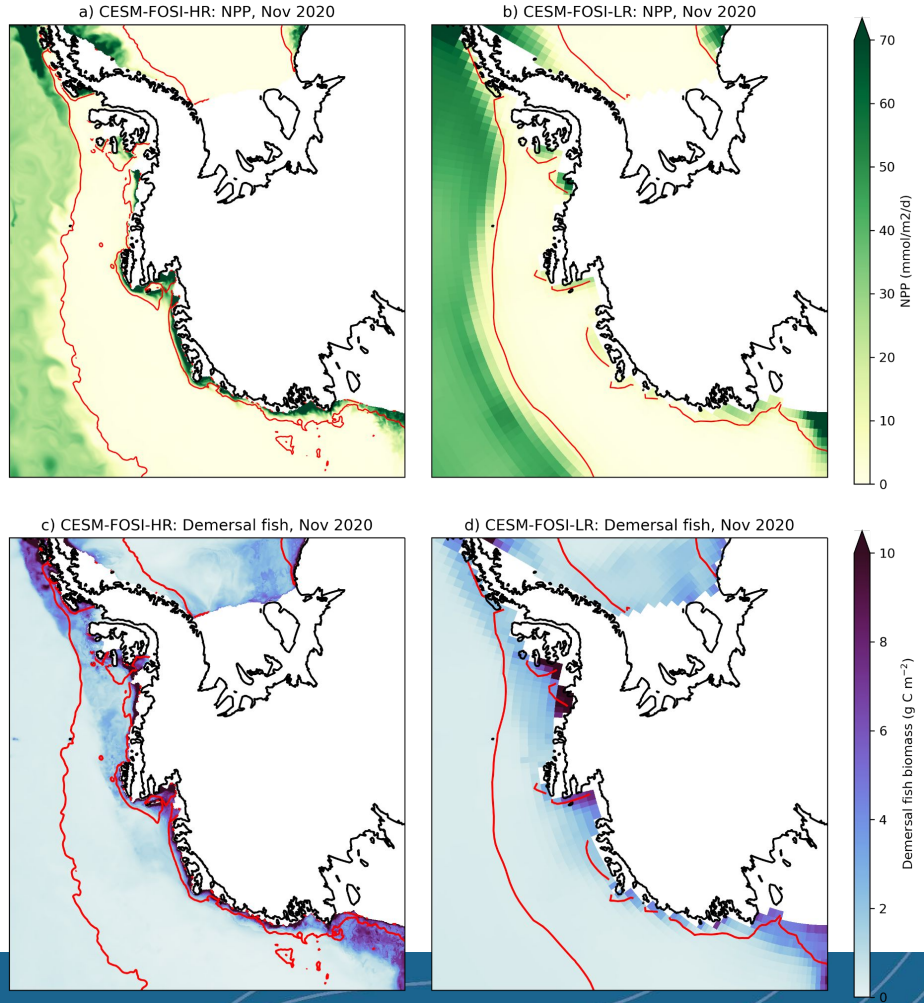
California current region

SE US Shelf



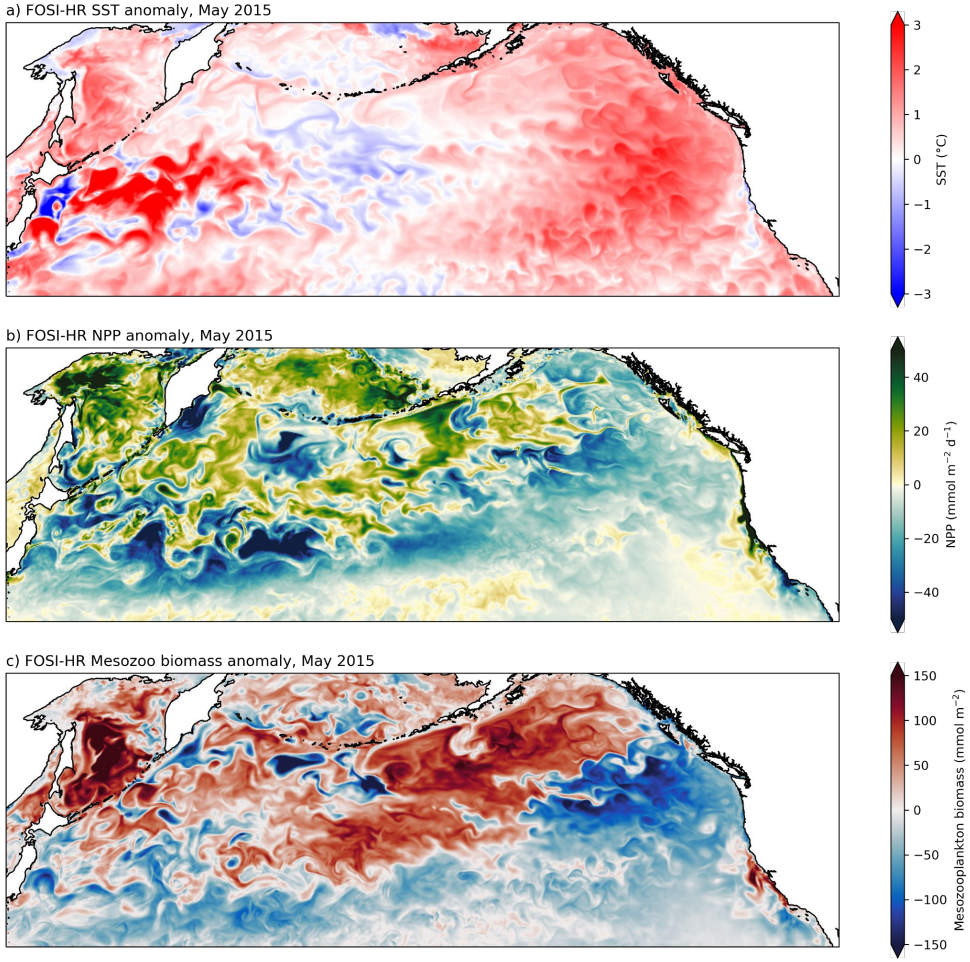
FOSI-HR and FEISTY-HR in the Antarctic

- Antarctic coastal current resolved in the CESM-HR in the Amundsen and Bellingshausen Seas
- Important during springtime, showing November snapshots
- Top plots: NPP
- Bottom plots: demersal fish
- Important food resource for Antarctic marine predators (seals, penguins)



Looking at the BGC/ecosystem response to “The Blob” MHW in the NE Pacific

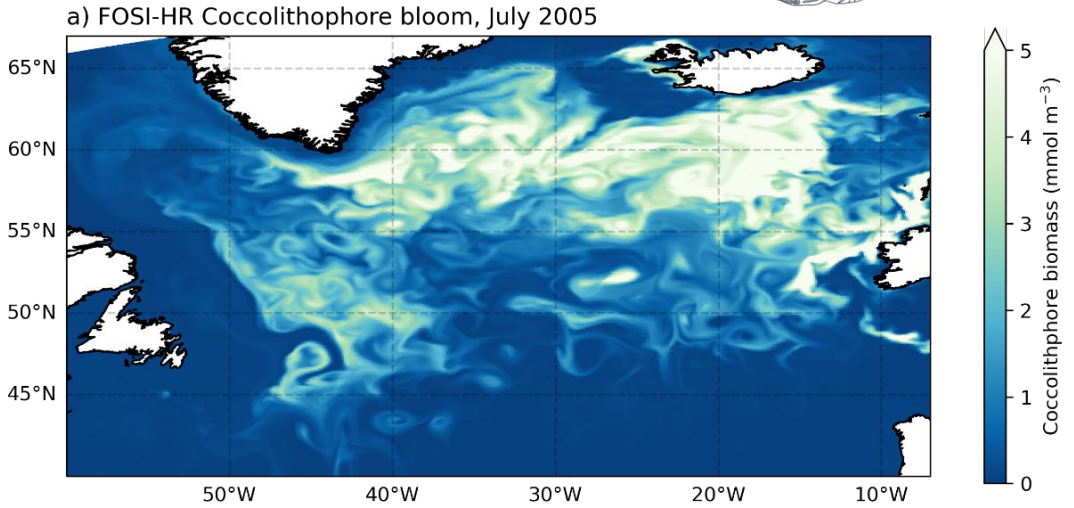
- May 2015 anomalies relative to 1980-2000 climatology
- Increases in NPP & mesozoo biomass to the north, decreases to the south
- Fish response?



Thank you for your attention!

- Just submitted manuscript documenting the run to ***Progress in Oceanography***
- Preprint will be soon available on earthArXiv.org (or just ask me for it)!
- Data from the FOSI-HR and FEISTY-HR is publicly available on a Globus Guest Collection
- And also readable on glade:
  /glade/campaign/cgd/oce/projects/FOSI_BGC/HR/g.e22.TL319_t13.G1850ECOIAF_JRA_HR.4p2z.001

Emiliania huxleyi coccolithophore



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NSF Convergence Accelerator Track E grant 2137684,
NSF AGS-2231237,
NSF OCE-1735846
NSF OCE-1948718.
NOAA-MAPP NA20OAR4310441 and NA20OAR4310442

Extra slides…

Tropical instability waves in the equatorial Pacific influence NPP

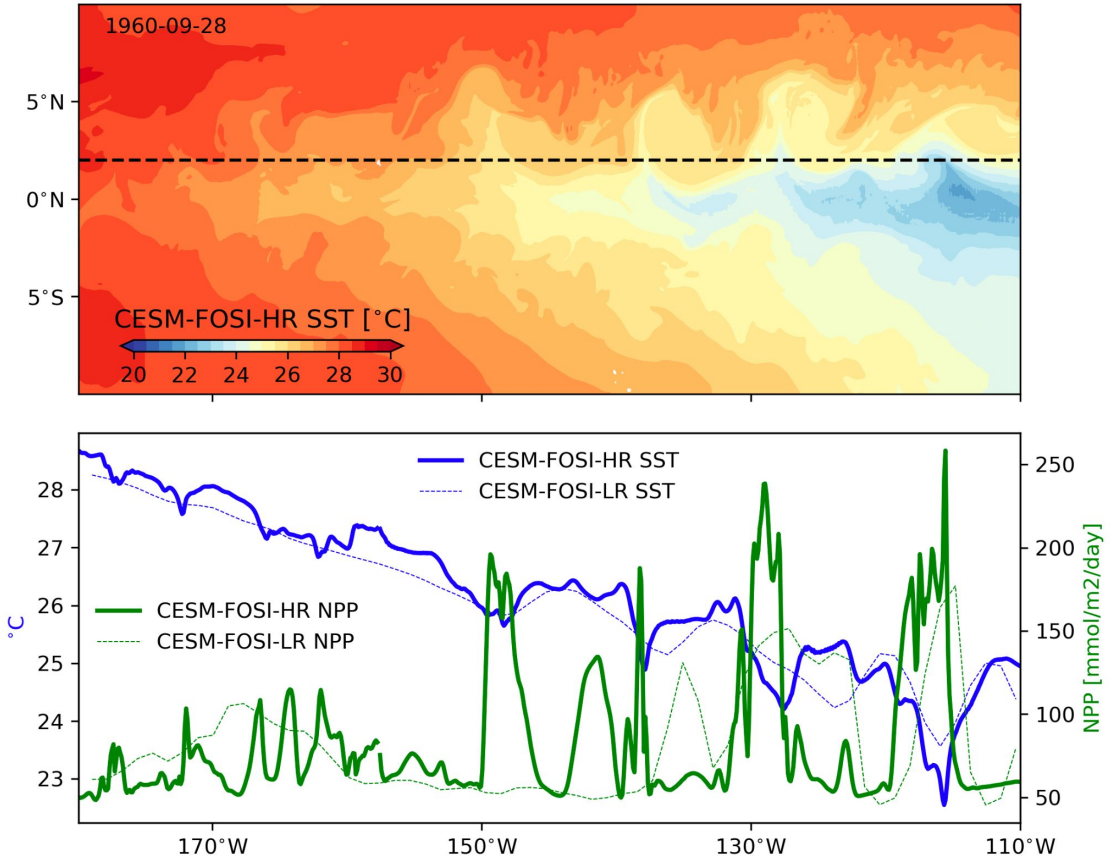
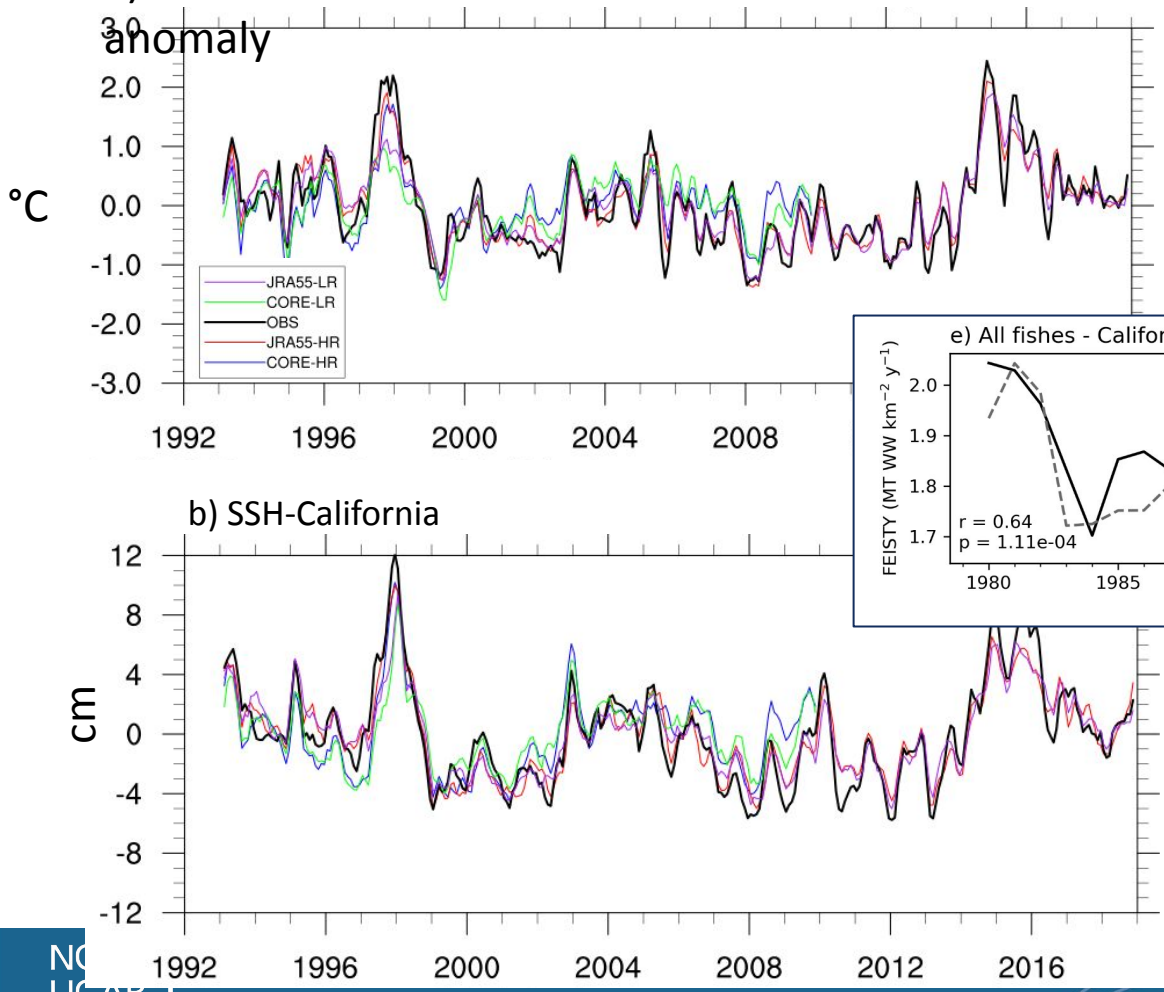
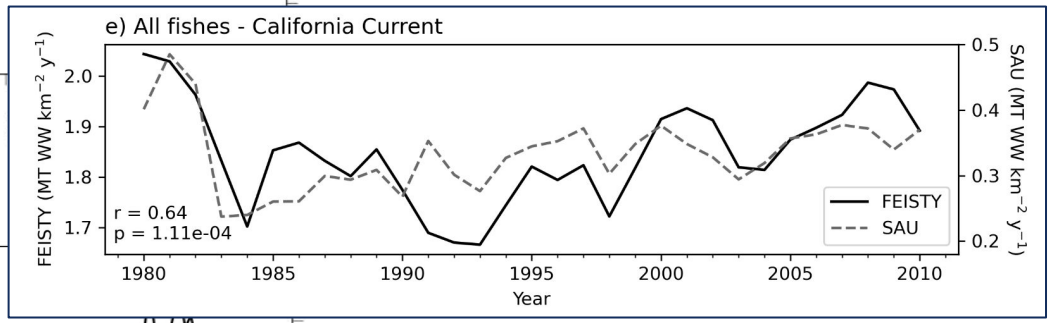


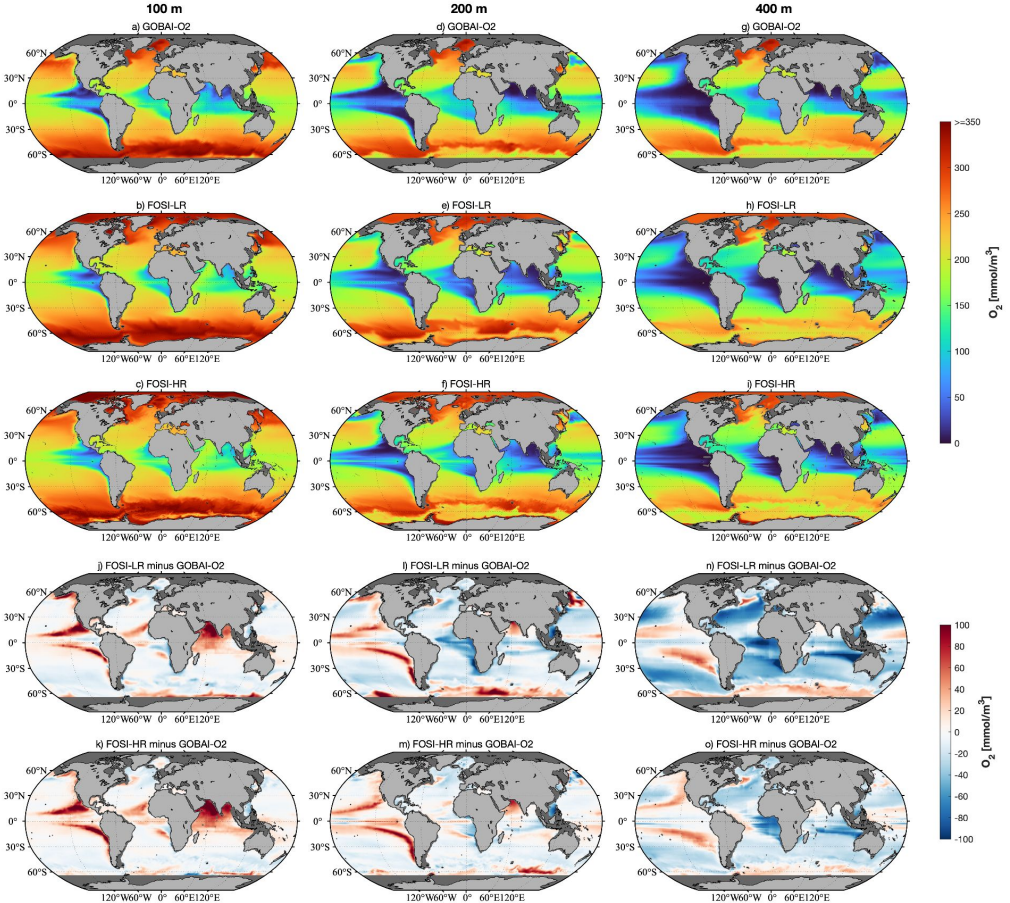
Figure by Anna-Lena Deppenmeier



a) SST and b) SSH anomaly averaged over the upwelling zone (100km westwards from coast: 36-44deg. N) from monthly-averaged data. Monthly long-term mean and linear trend has been removed and a 3-month running mean applied. The legend is shown in panel a). The black line (OBS) is data from a) OISST (Reynolds et al. 2007) and b) CMEMS/AVISO.



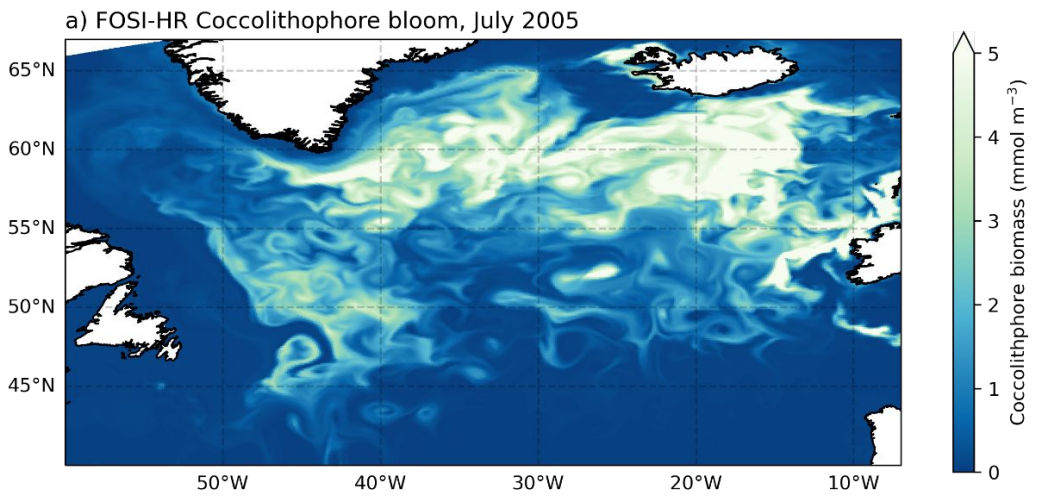
SST and SSH figures courtesy of Justin Small

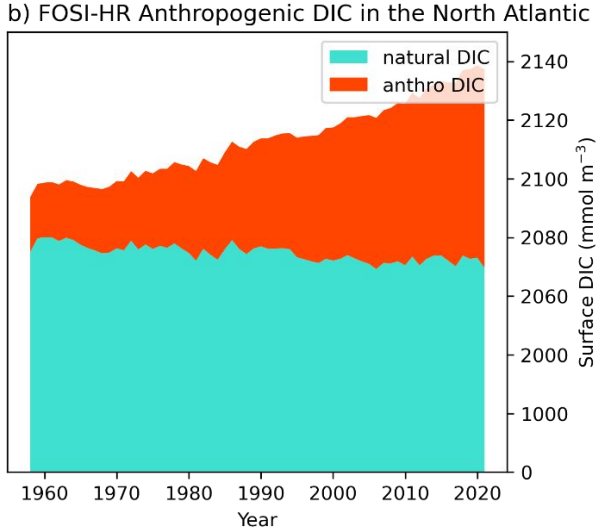


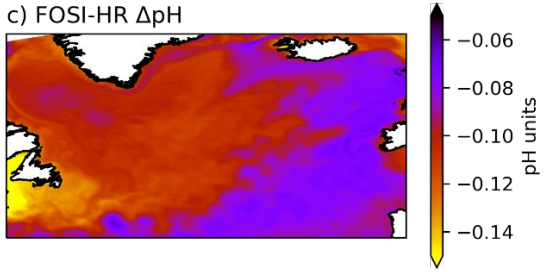
NCAR | UCAR

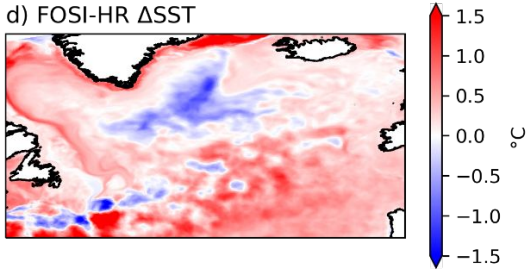
Fig 5: Oxygen validation and comparison to 1° (Zhuomin Chen)

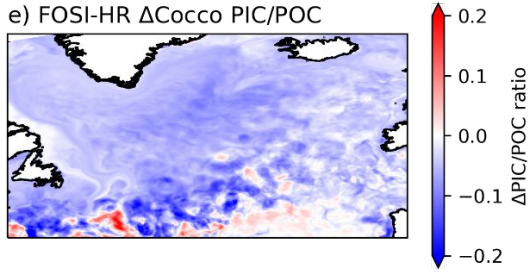
Coccolithophores and ocean acidification in the North Atlantic



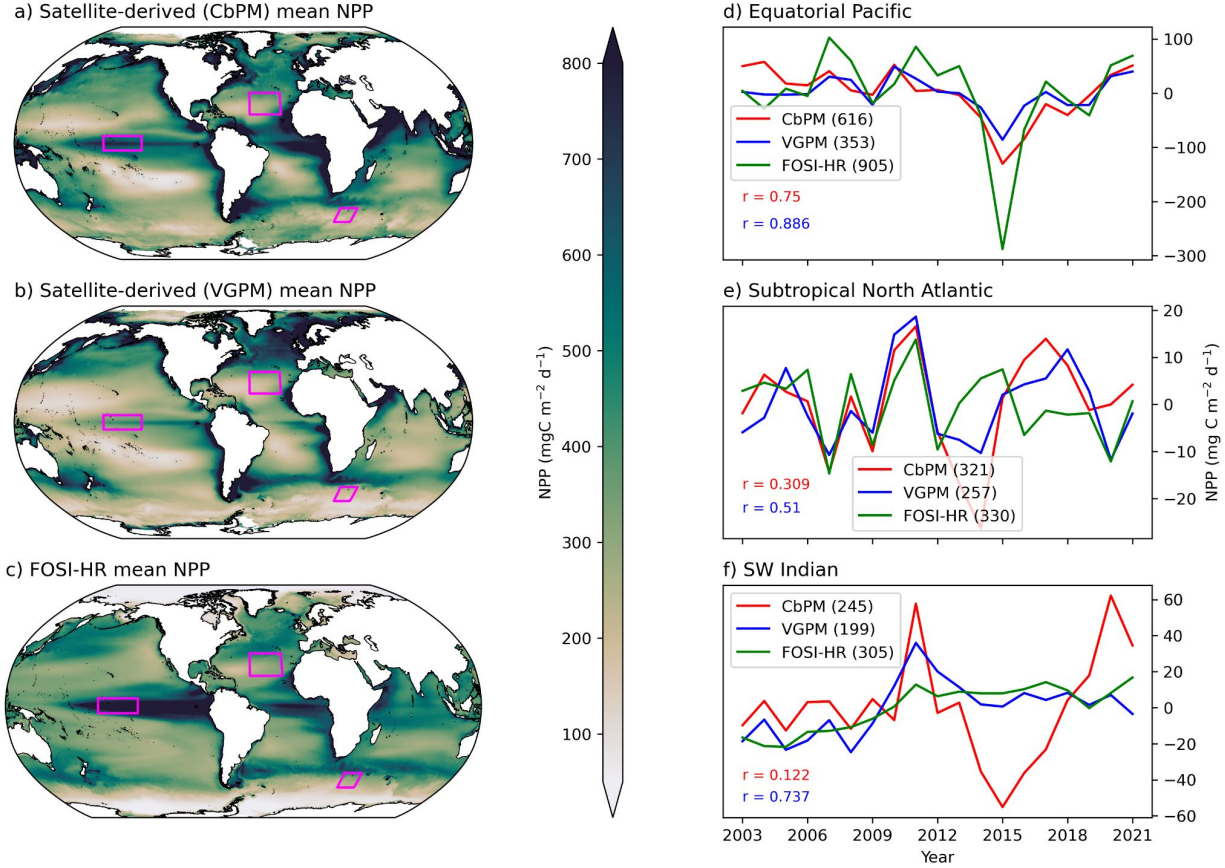






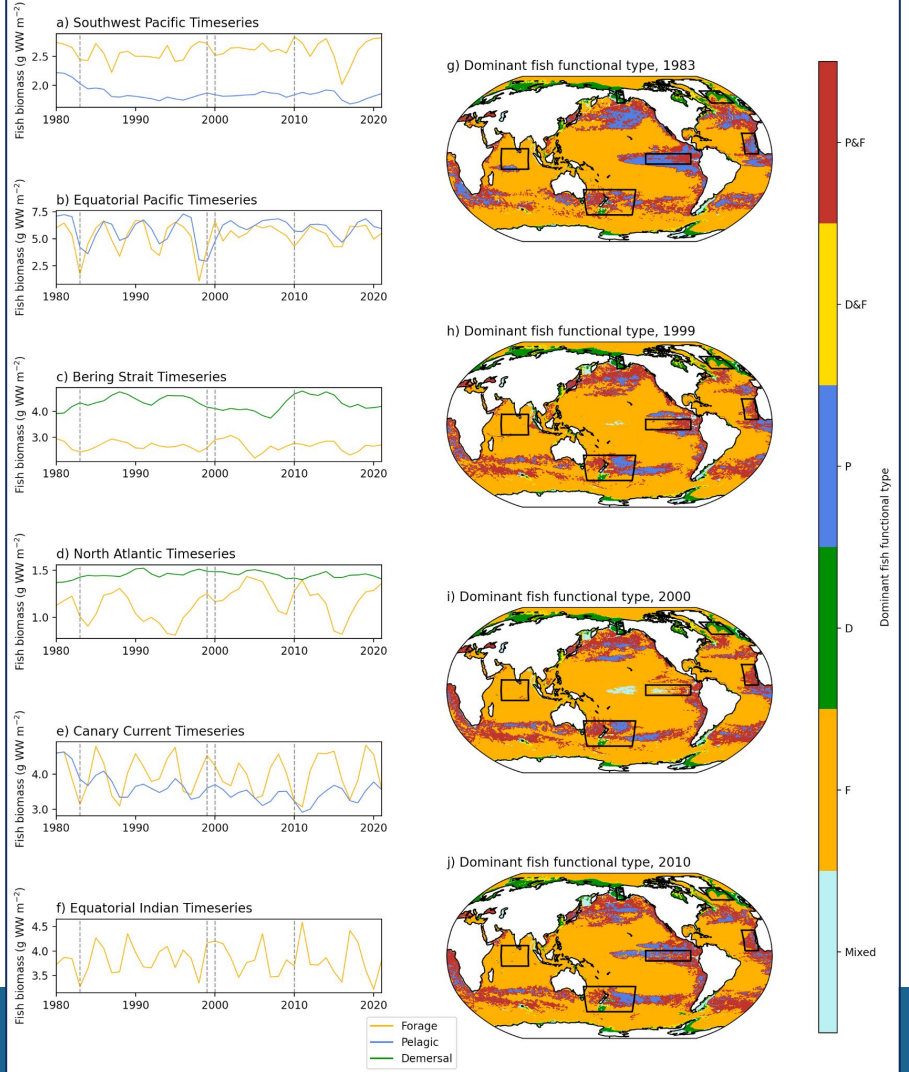


FOSI-HR NPP compares well to 2 NPP algorithms



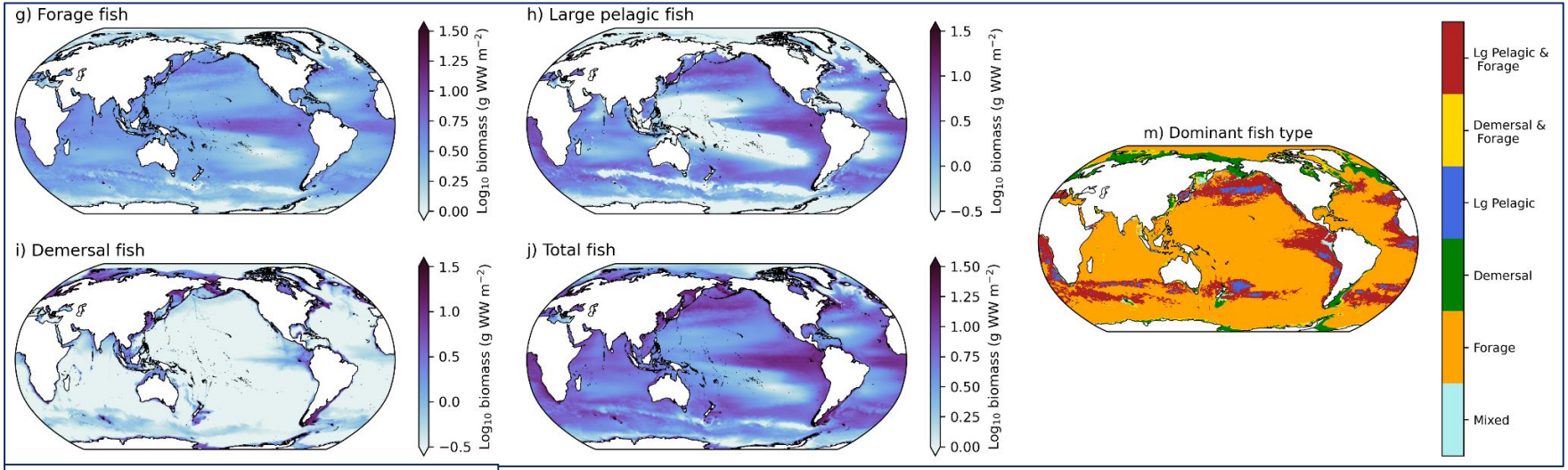
Visualizing variability in fish biomass from year-to-year

- Dominant fish types plotted in time-series plots
- Substantial variability in dominant fish type in regions we examined
- Focus on Equatorial Pacific region



Credit: Lev Romashkov

Large scale biogeography in CESM-HR and FEISTY-HR



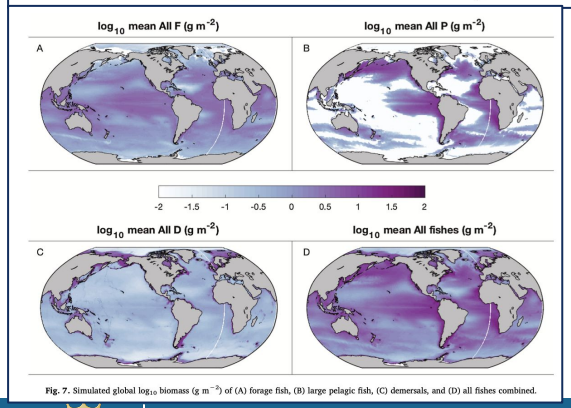
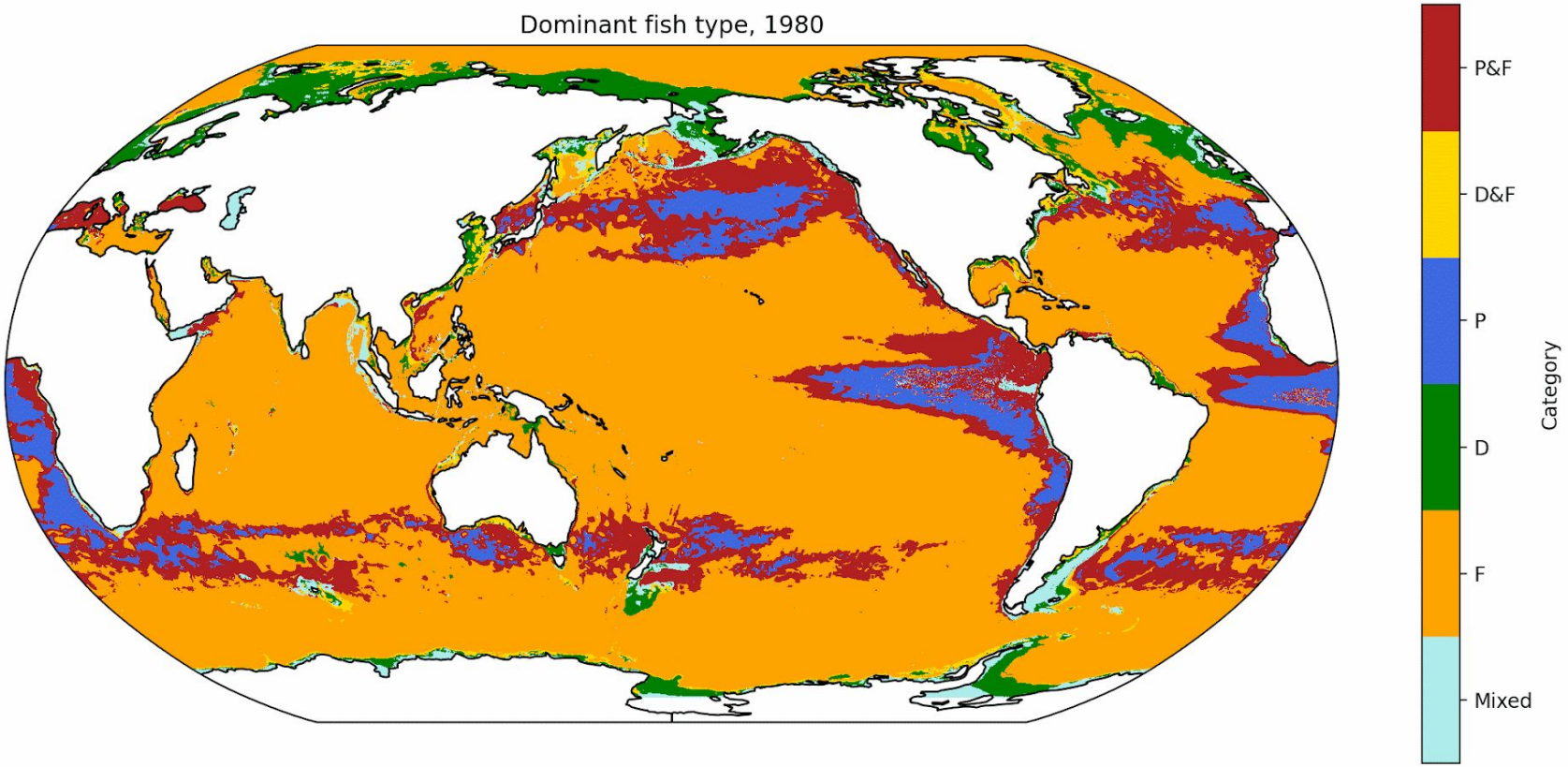


Fig. 7. Simulated global $\log_{10}$ biomass (g m^{-2}) of (A) forage fish, (B) large pelagic fish, (C) demersals, and (D) all fishes combined.

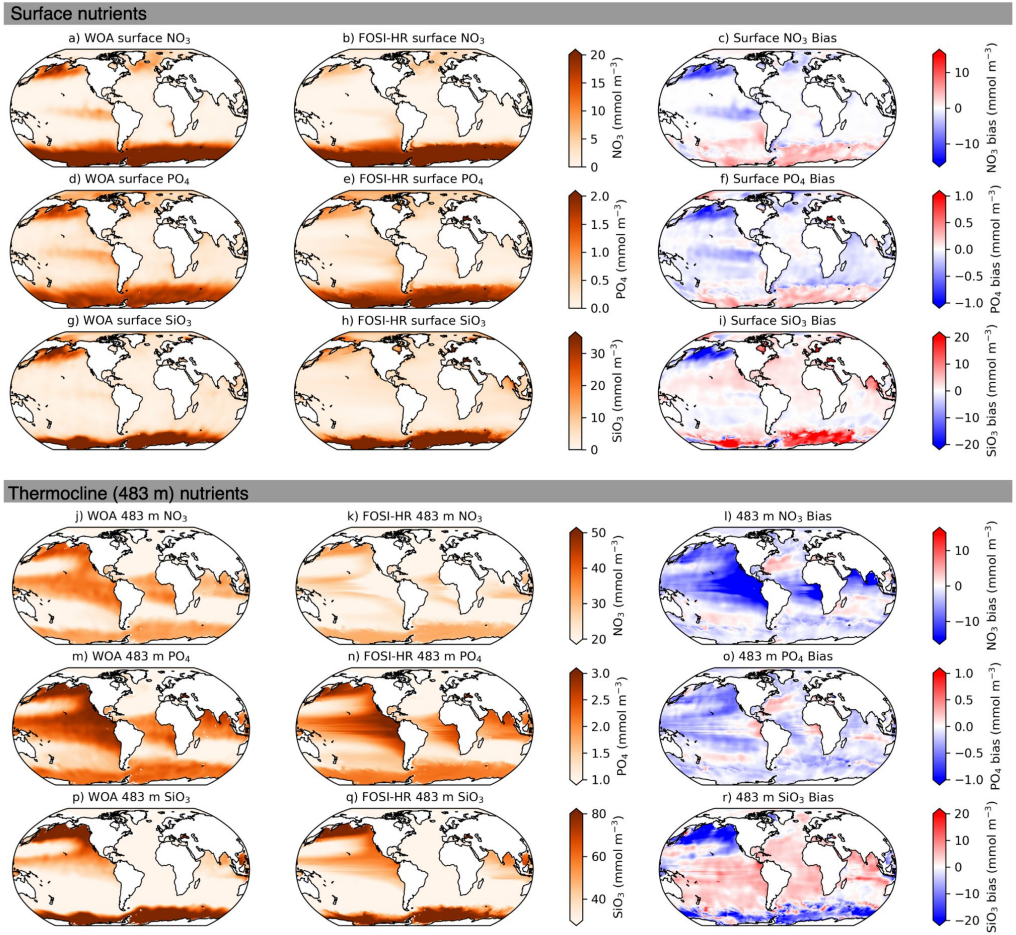
- Large-scale fish biogeography looks similar to Colleen's 2019 paper using GFDL model
- Forage fish dominate most places
- Demersal fish dominate in shelf regions
- Mixed fish assemblages in high productivity regions

Dominant fish type may vary from year to year

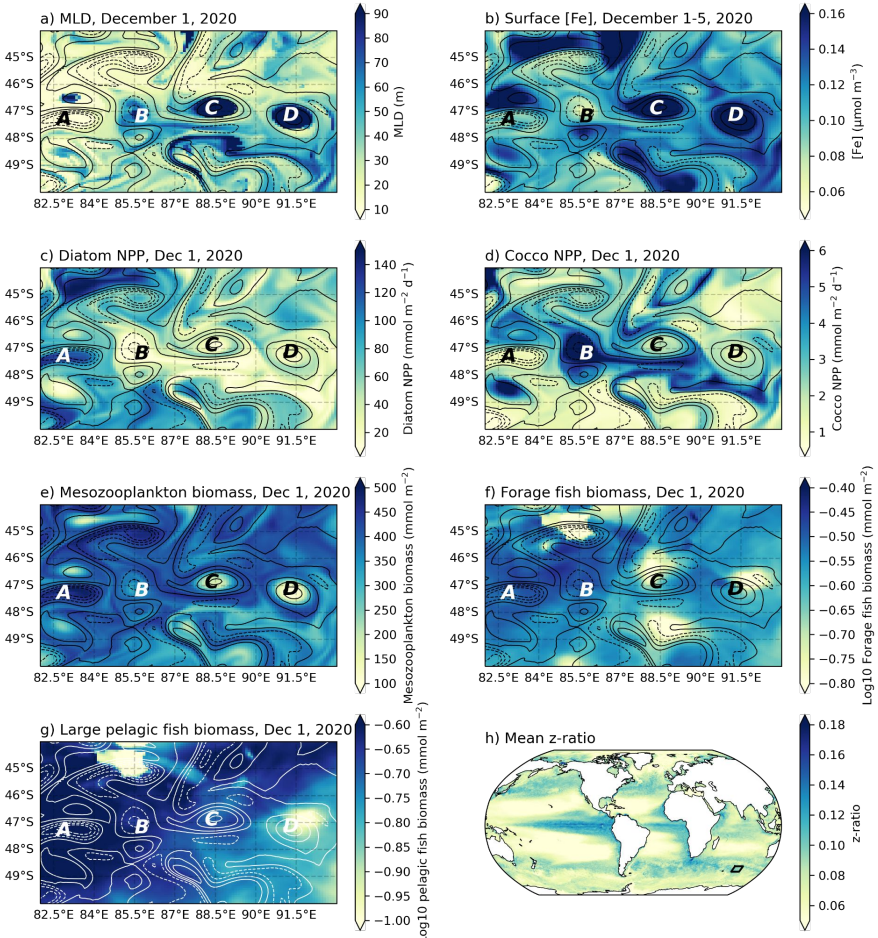
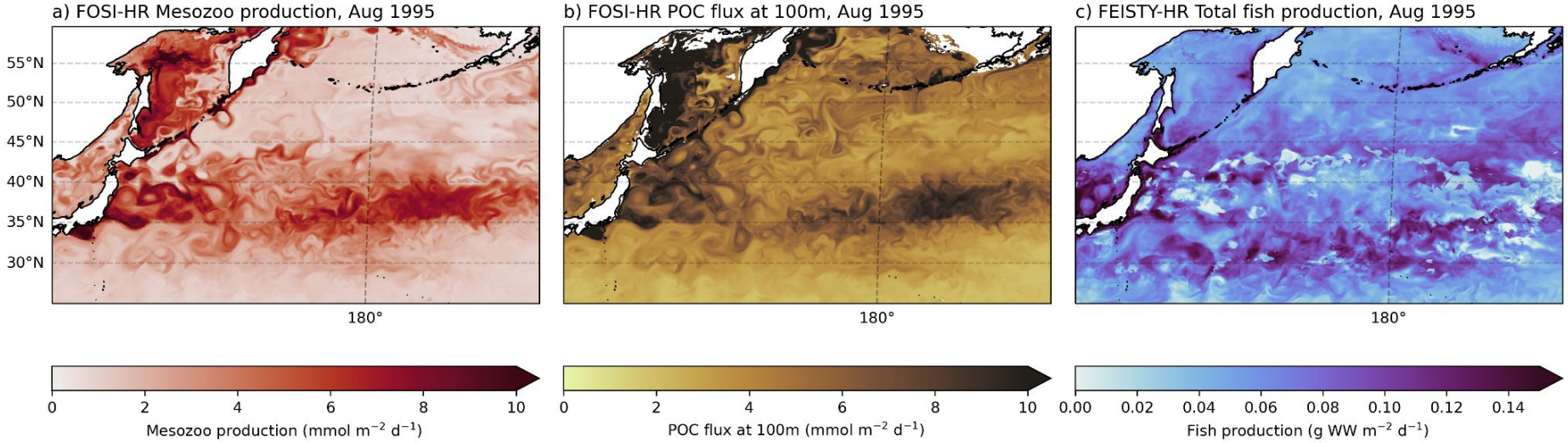


Credit: Lev Romashkov

Nutrient validation



Eddies influence trophodynamics



North Pacific snapshots