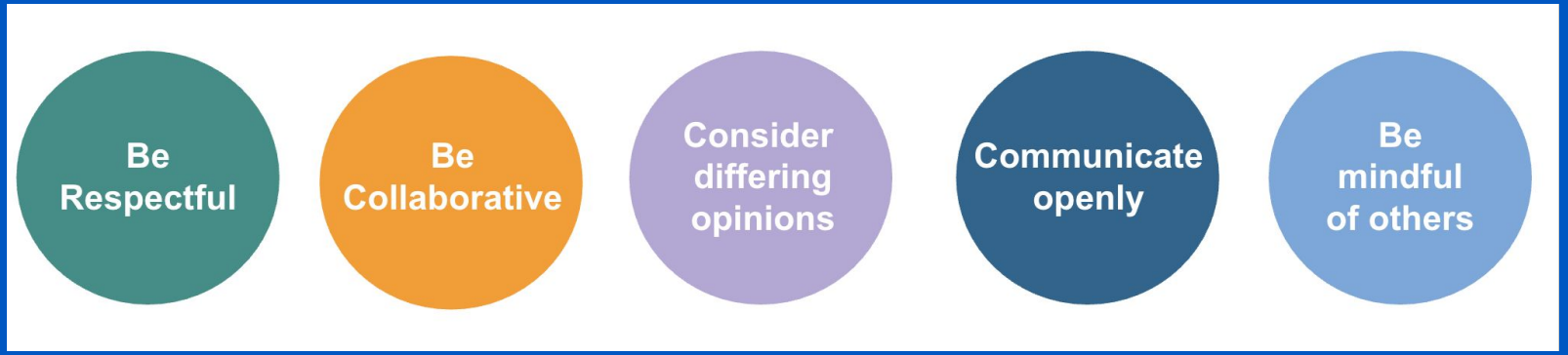

Be Respectful
Be Collaborative
Consider differing opinions
Communicate openly
Be mindful of others

NCAR OPERATED BY UCAR Community Earth System Model

CESM Communications:

https://www.cesm.ucar.edu/communications

Subscribe to the CESM Newsletter :

www.cesm.ucar.edu/news/newsletters

@ncar_cgd

@NCAR_CGD

NSF NCAR CGD

@ncar-cgd.bsky.social

Updates on ocean biogeochemistry in CESM3

Kristen Krumhardt
NSF NCAR
BGCWG co-chair

Contributions from Keith Lindsay, Mike Levy, Nicola Wiseman,
Keith Moore, Jun Yu, Gustavo Marques, Ian Grooms

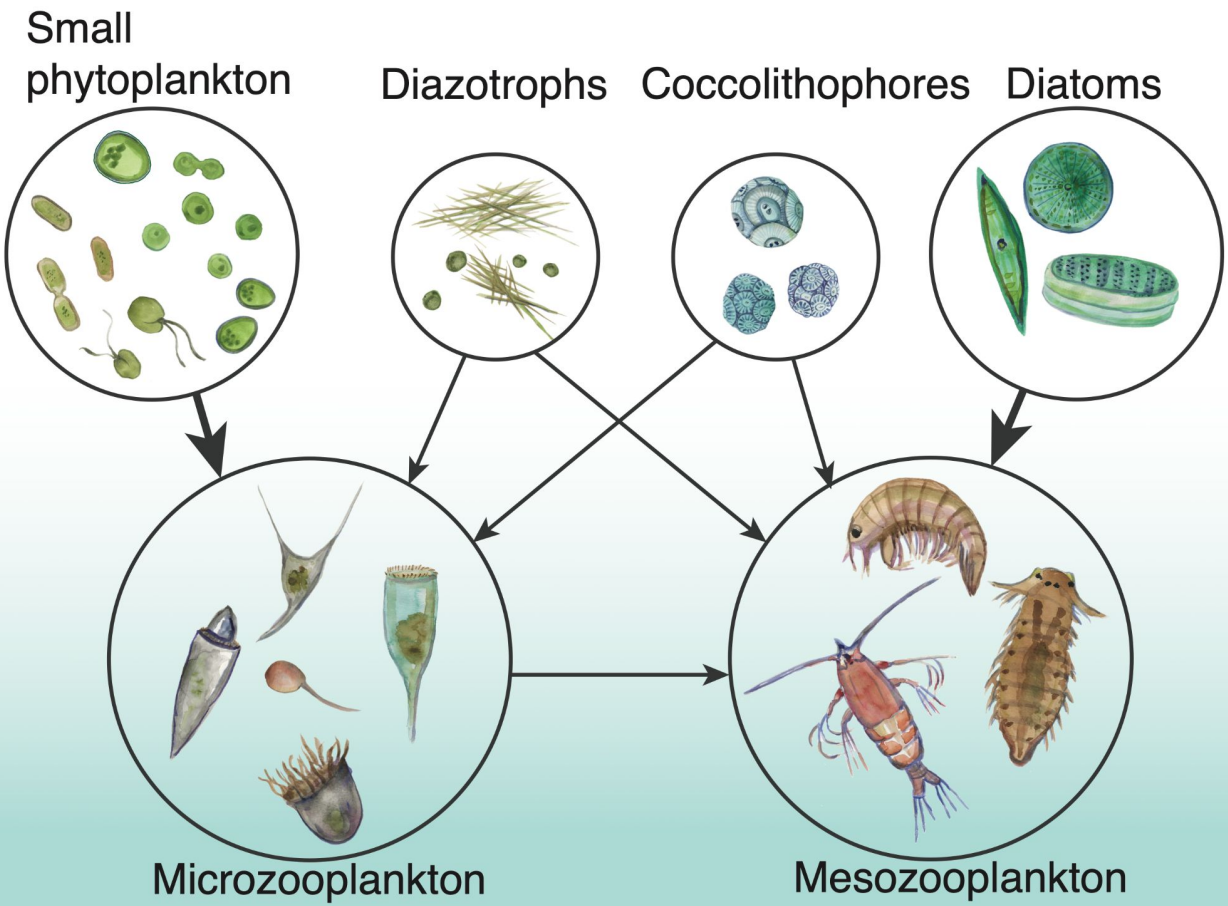
Overview of CESM3 MARBL developments

- New planktonic ecosystem
- Coccolithophores
- Fully variable phytoplankton stoichiometry
- New iron cycle updates
- Fixing OMZ problem

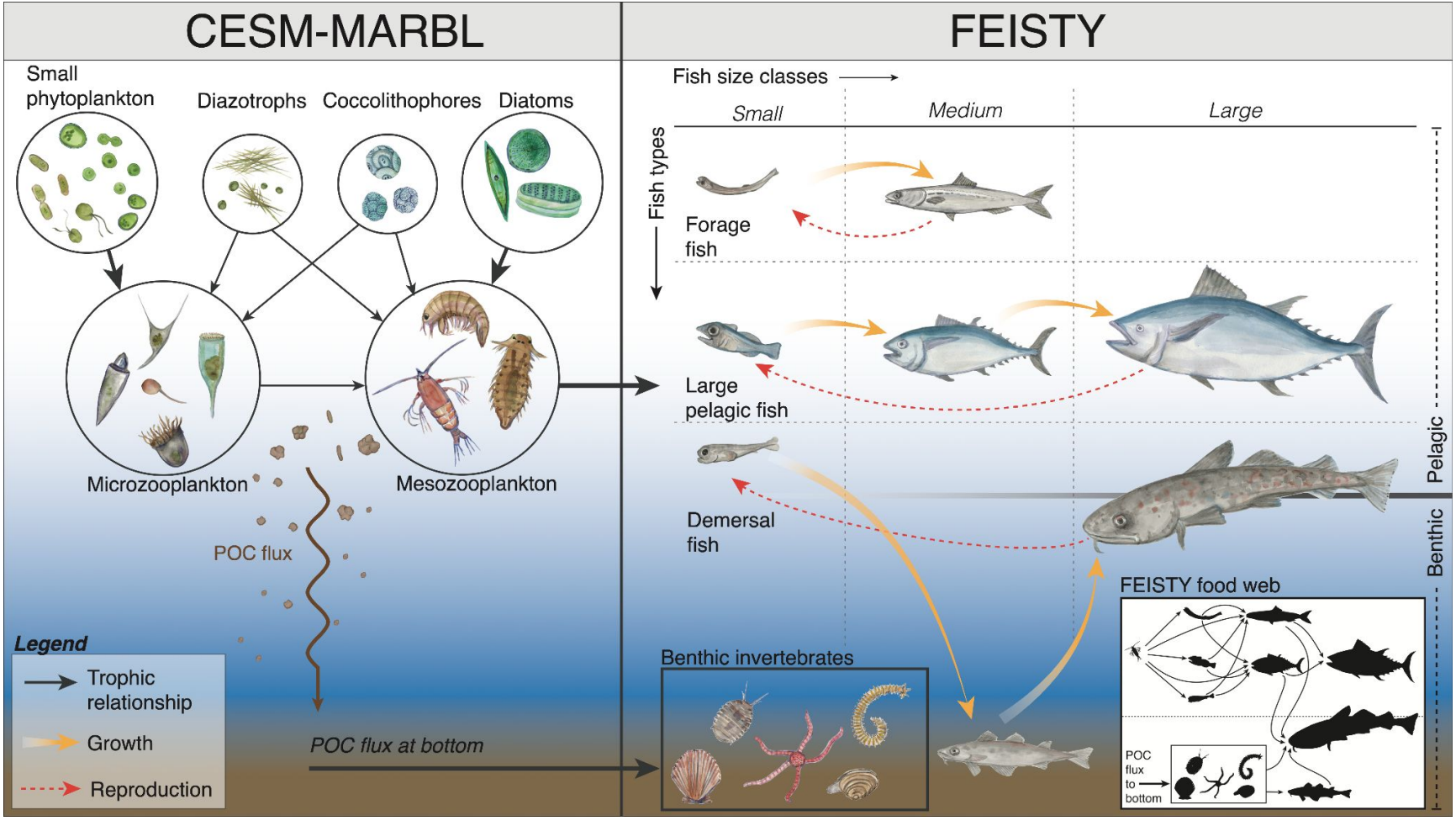
4 Phytoplankton / 2 Zooplankton (“4p2z”) MARBL

- CESM2 had 3p1z plankton
- Small phytoplankton and diatoms do most ocean NPP
- Coccolithophores and diazotrophs have important BGC roles
- 2 zooplankton types allows offline coupling to a fish model

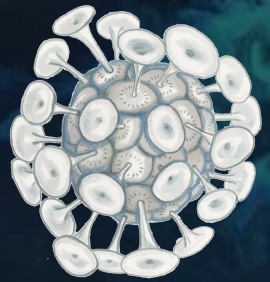
CESM-MARBL-4p2z planktonic ecosystem



4p2z ecosystem allows offline coupling to fish model



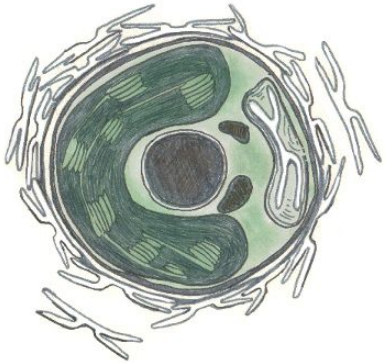
Coccolithophore phytoplankton functional type & ocean acidification



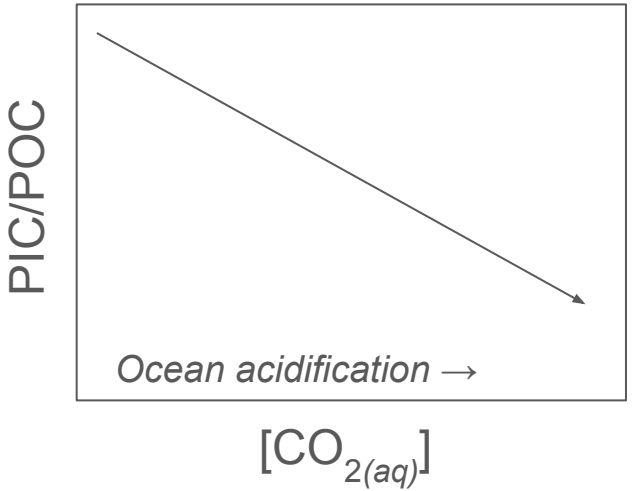
- Coccolithophore importance to carbon cycle
  - Affect air-sea CO_2 uptake via calcification
  - $CaCO_3$ shell ballasts organic matter to deep ocean
- Ocean acidification impacts coccolithophore calcification and growth

https://visibleearth.nasa.gov

As more CO_2 absorbs into the ocean, cocco calcification decreases



$CaCO_3$ → Particulate Inorganic Carbon (PIC) shell / Particulate Organic Carbon (POC) inside = $\frac{PIC}{POC}$

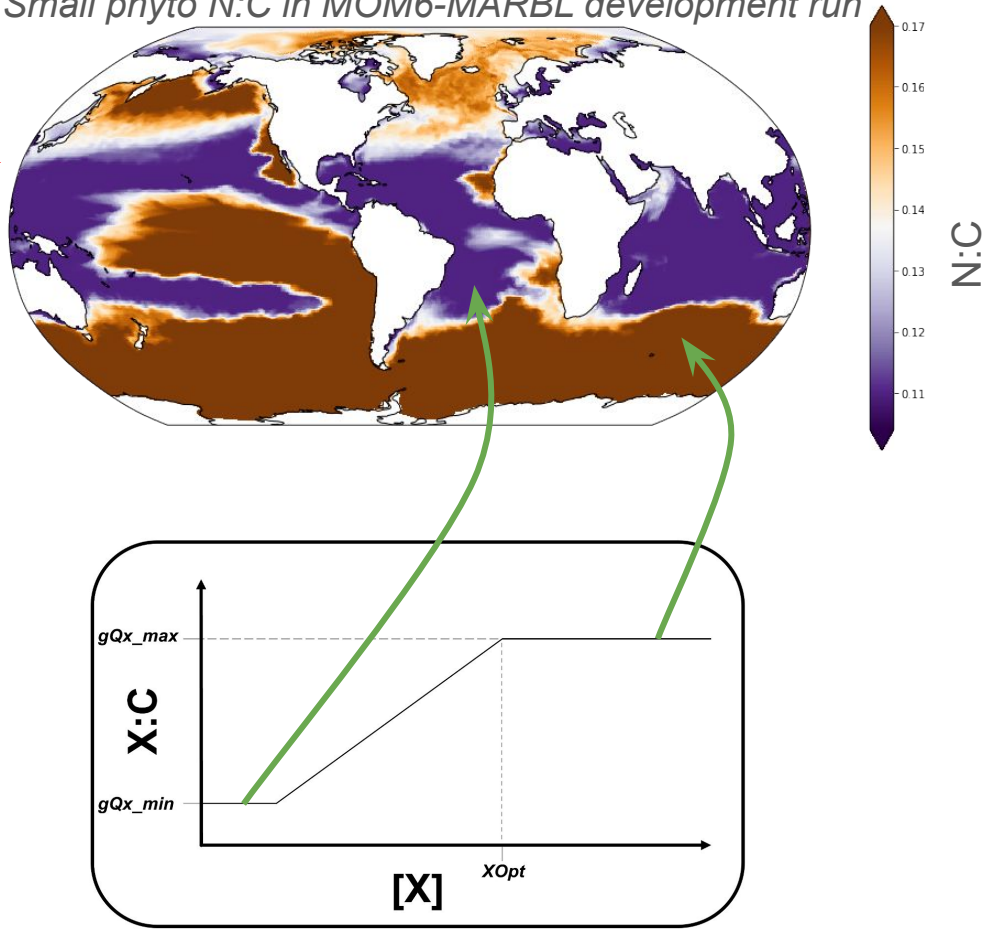


- Based on a large meta-analysis of laboratory experiments (Krumhardt et al., 2017, *Progress in Oceanography*)
- Less calcification → more alkalinity stays in the surface ocean → more CO_2 uptake/less ballasting of carbon to deep ocean

Fully variable C:N:P:Fe:Si stoichiometry in phytoplankton

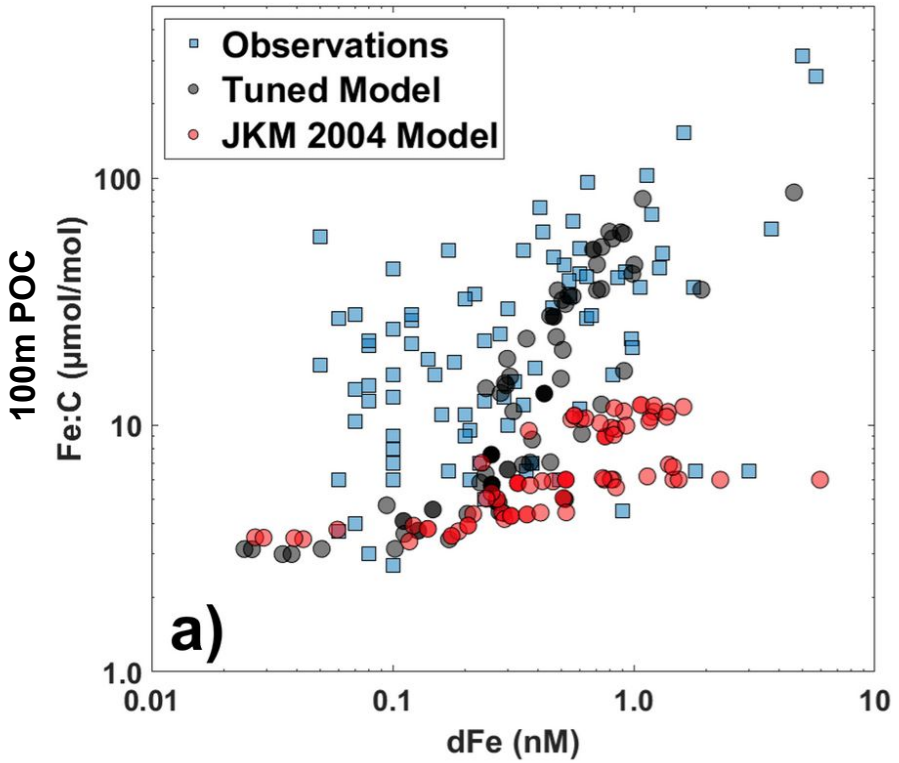
- Variable phytoplankton N:C new in CESM3
- Each PFT has min/max of X:C

Small phyto N:C in MOM6-MARBL development run



Fully variable C:N:P:Fe:Si stoichiometry in phytoplankton

- Variable phytoplankton N:C new in CESM3
- Each PFT has min/max of X:C
- Improved match to particulate organic matter stoichiometry
- Strong implications for ocean biological carbon pump to climate change

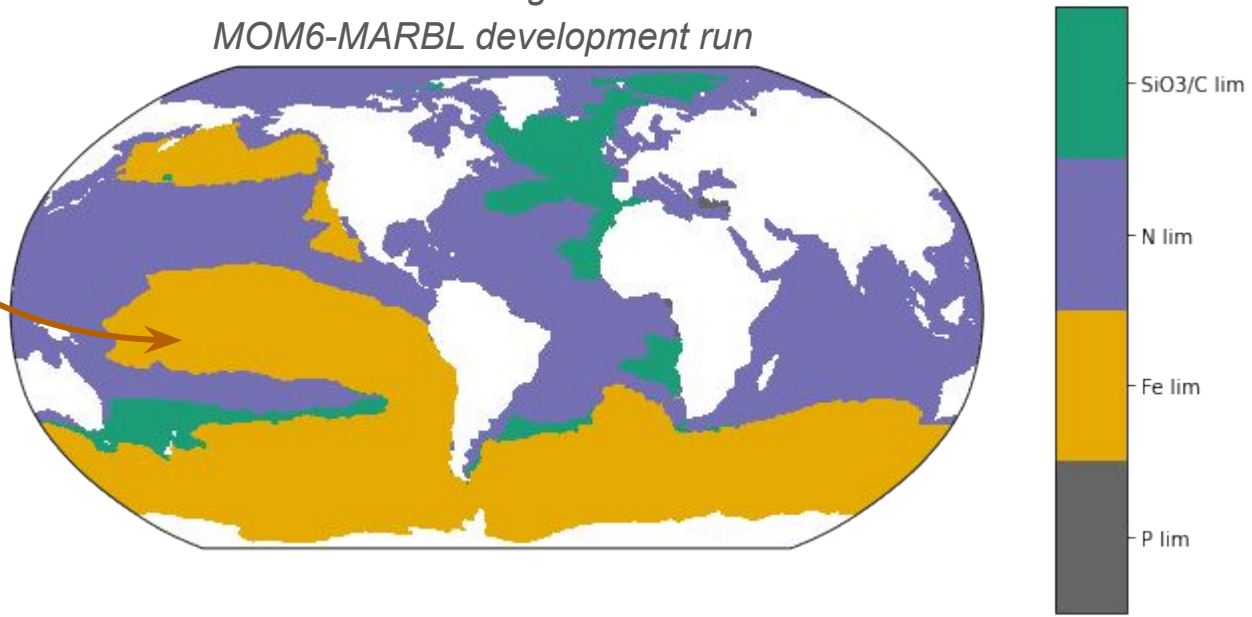


Iron cycle updates

(Keith Moore & Jun Yu, UCI)

- Iron is an important control on phytoplankton growth in many regions

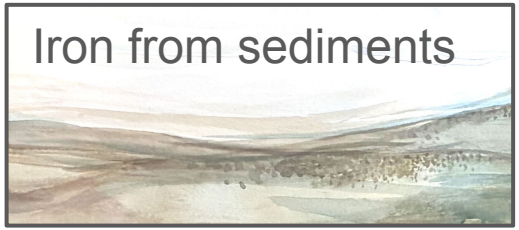
Diatom most limiting nutrient in MOM6-MARBL development run



Iron cycle updates

(Keith Moore & Jun Yu, UCI)

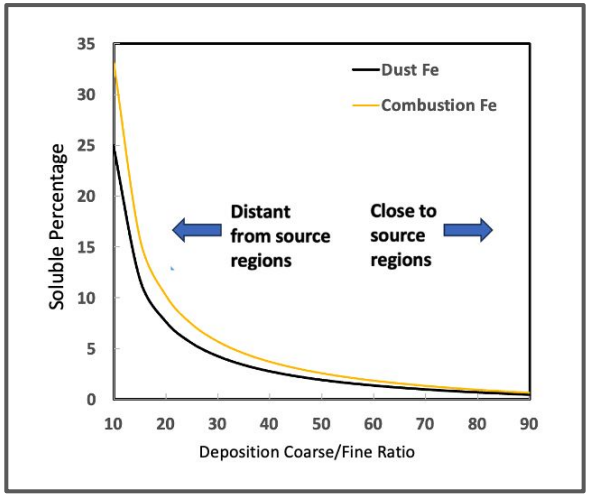
- Iron is an important control on phytoplankton growth in many regions
- Iron comes from many sources, updated in CESM3

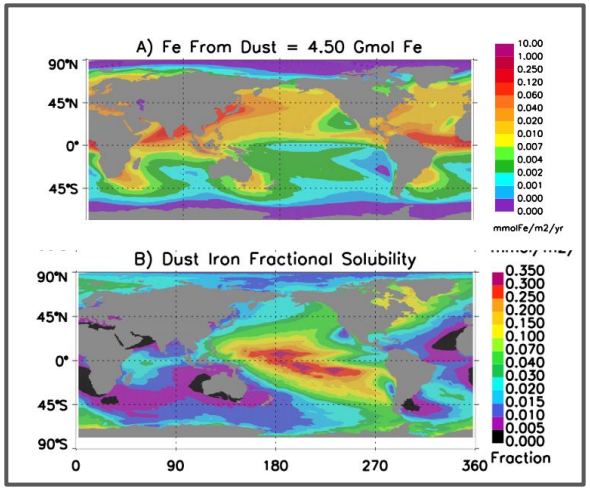


Iron cycle updates

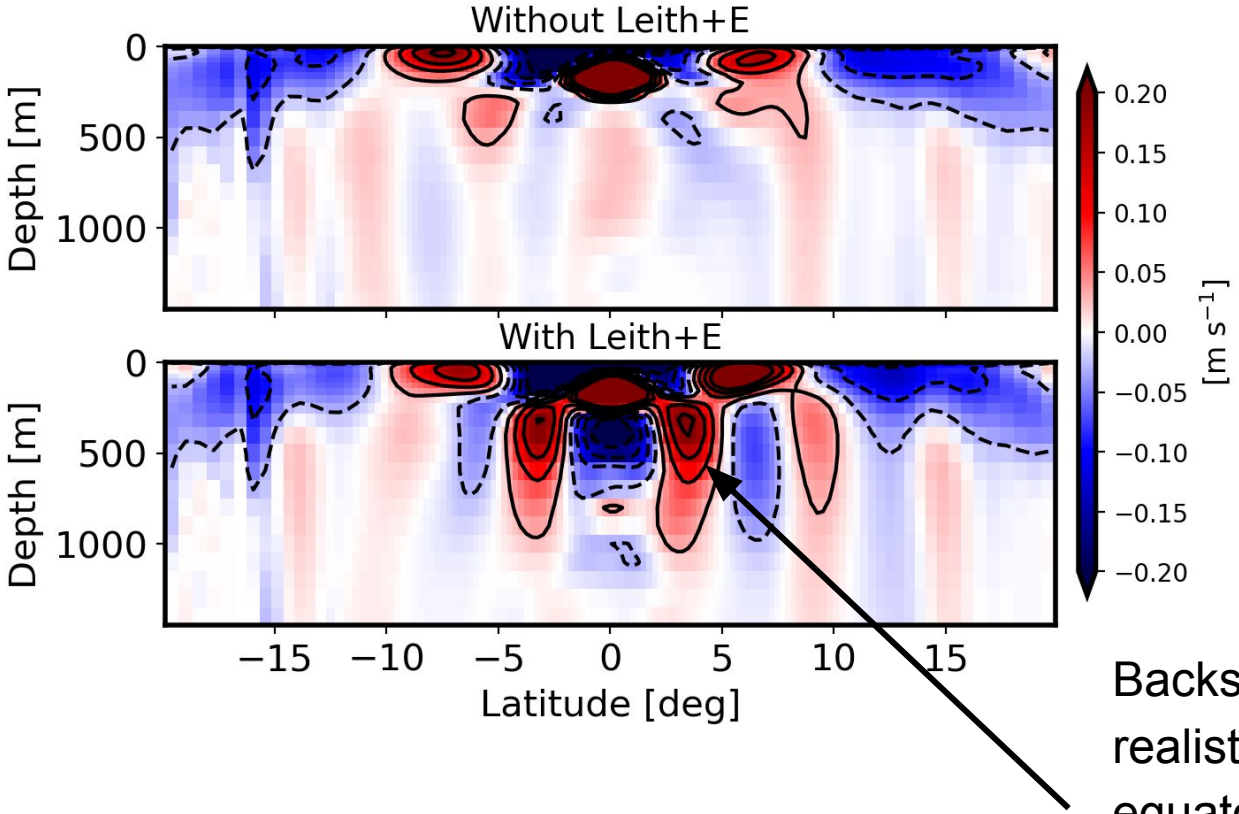
(Keith Moore & Jun Yu, UCI)

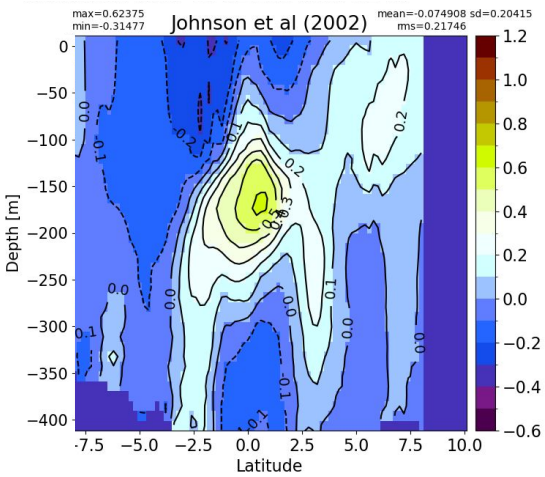
- Iron is an important control on phytoplankton growth in many regions
- Iron comes from many sources, updated in CESM3
- For atmospheric deposition, Coarse/Fine ratio determines soluble %
- Scavenging of iron in the ocean also updated for CESM3





Leith-E backscatter helps equatorial OMZs





Backscatter generates more realistic zonal jets: stacked at the equator, with Tsuchiya jets on the flanks

Figures courtesy of Ian Grooms & Gustavo Marques

Effect of using Leithy backscatter on OMZs

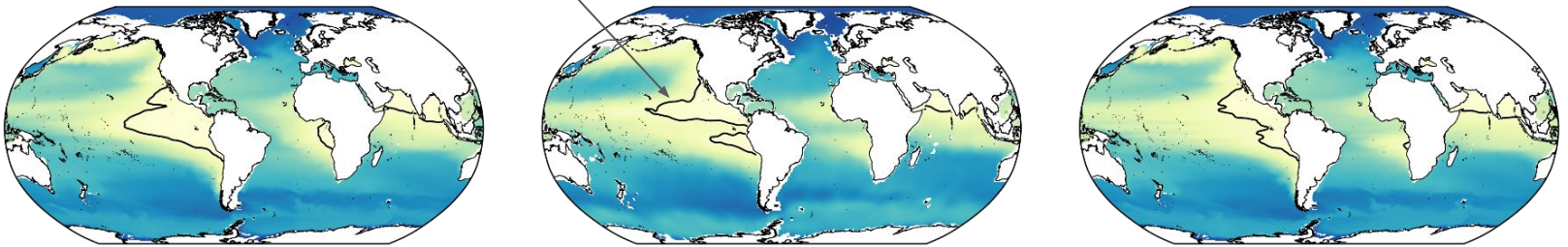
O_2 at 500m

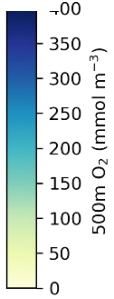
20 mmol m^{-3} O_2 contour

CESM Control

Observations

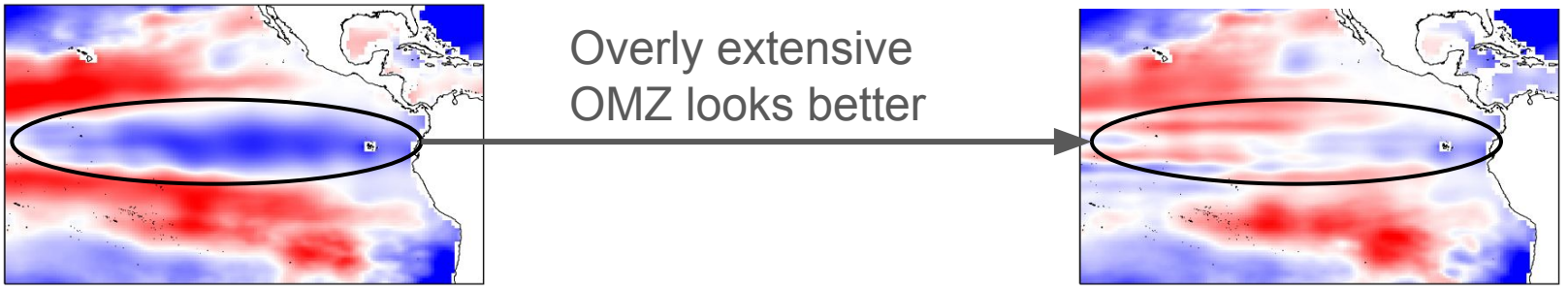
CESM with backscatter



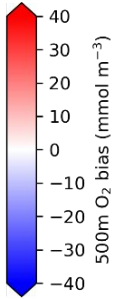


CESM Control O_2 bais

CESM Backscatter O_2 bais

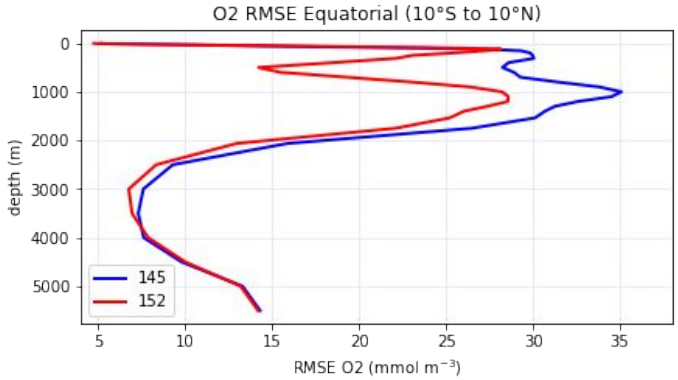


Overly extensive
OMZ looks better

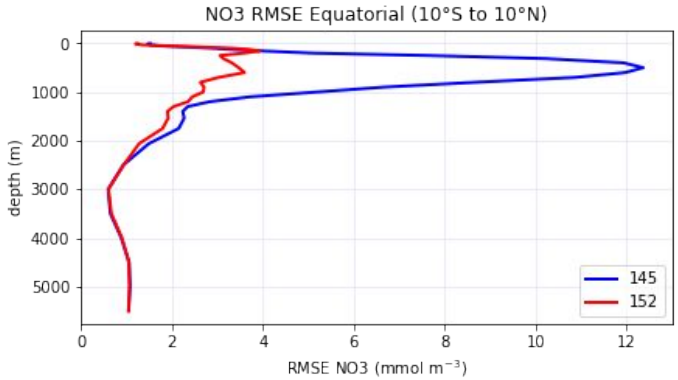


Leith-E backscatter helps equatorial O_2 and NO_3 biases

O_2 →



NO_3 →

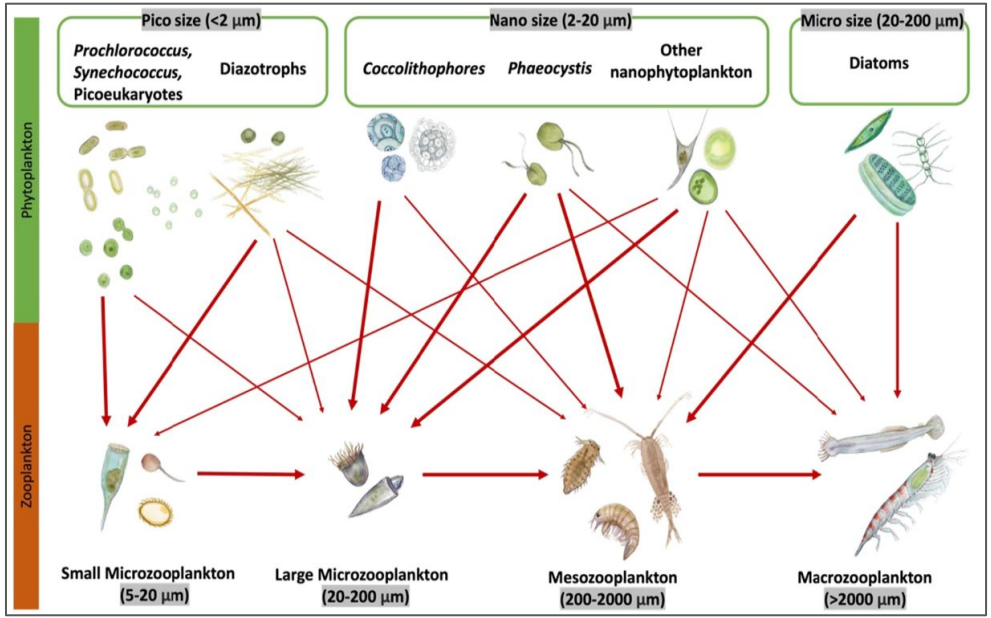


145: no backscatter
152: backscatter

- Low O_2 triggers denitrification - remineralization of POC that consumes NO_3

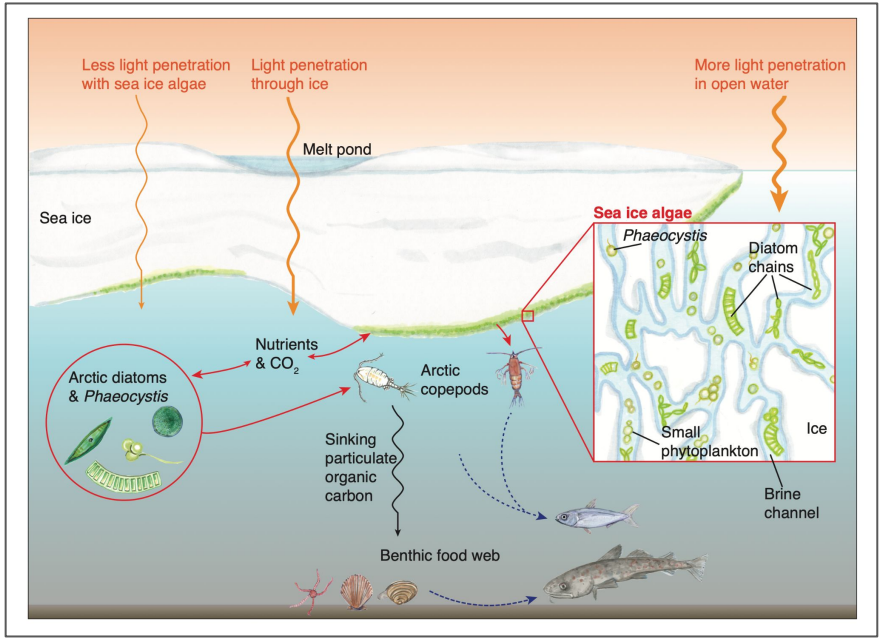
Future plans for subsequent versions of CESM3

- 8 phytoplankton / 4 zooplankton MARBL



Yu et al., 2025, JAMES

- Ocean biogeochemistry coupling with sea ice



Thank you! Any questions?

Email: kristenk@ucar.edu

NSF

NCAR
OPERATED BY UCAR