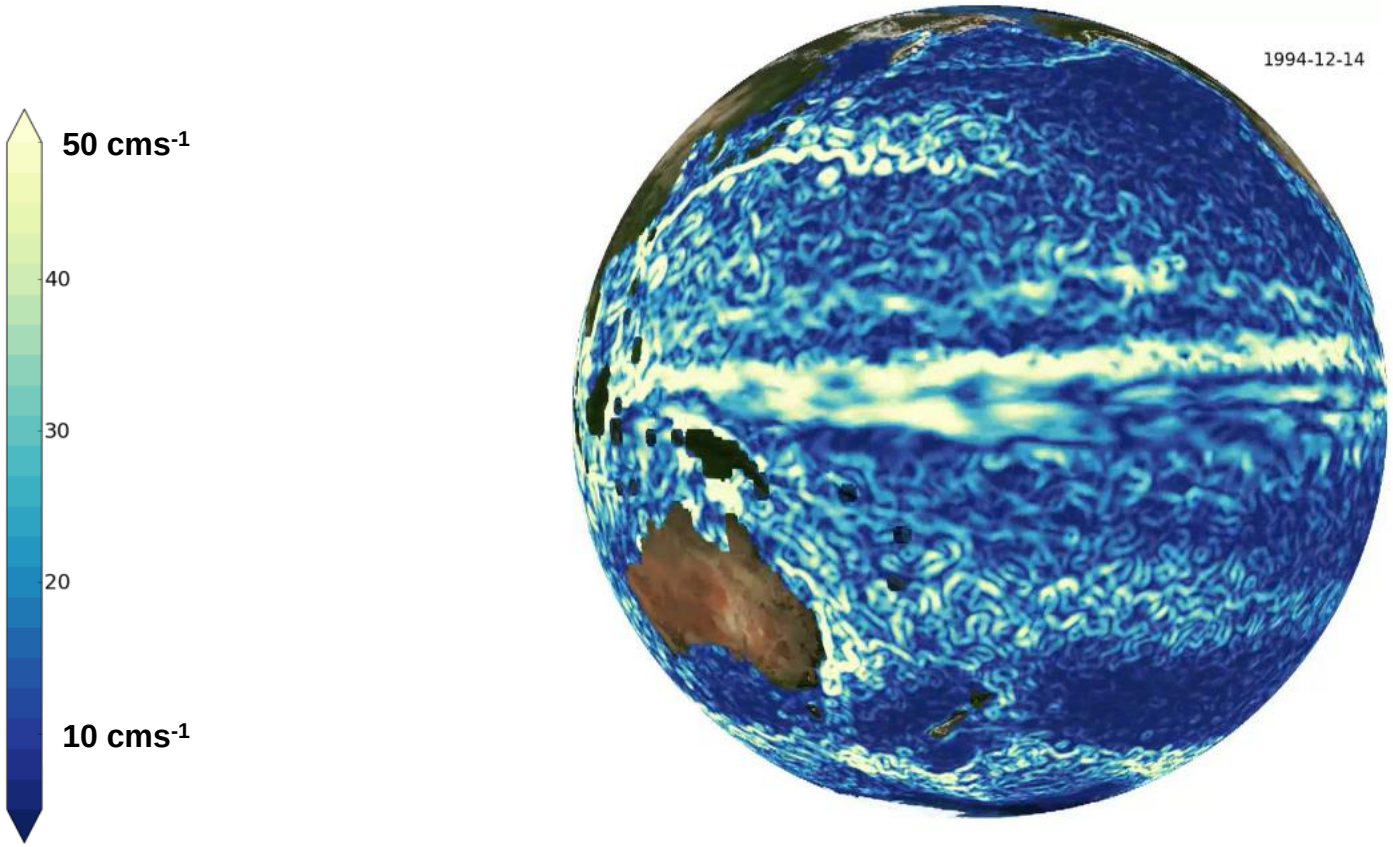
Observed surface ocean currents

20 years of observations

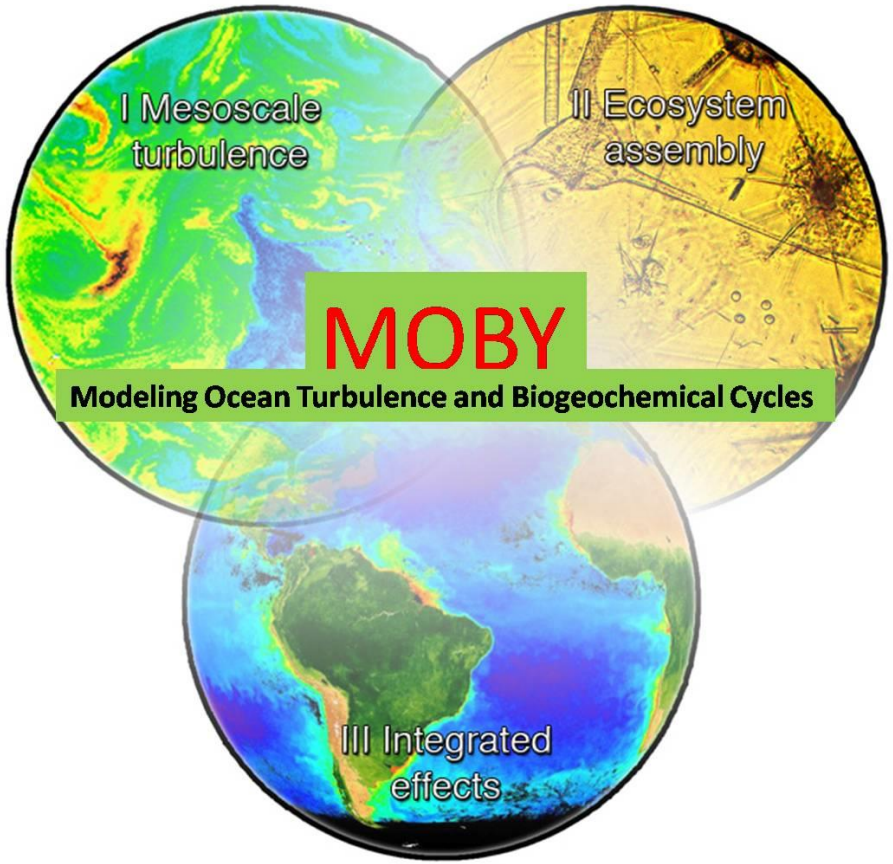
Satellite altimetry



- Ocean is a ‘living fluid’ – full of turbulence across myriad space and timescales
- Turbulence mediates the physical and chemical environment of phytoplankton
- Ocean is constantly exchanging heat, water, carbon etc with the atmosphere

Modeling Ocean Turbulence and Biogeochemical Cycles

Key questions

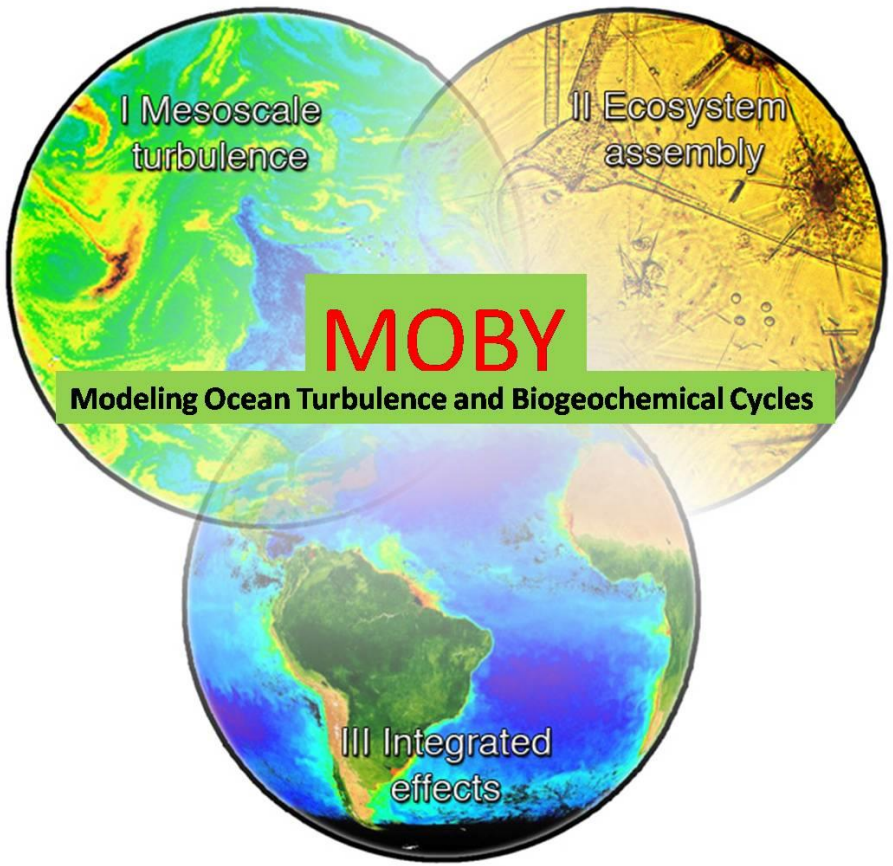


1. How do intermittent perturbations due to the mesoscale affect ocean ecosystems and their BGC?

2. What is the role of physical variability on the diversity of phytoplankton communities?

3. What is the integrated effect of the mesoscale and how can it be captured in models that do not resolve the mesoscale?

Modeling Ocean Turbulence and Biogeochemical Cycles



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Dennis McGillicuddy

NCAR
Gokhan Danabasoglu, Bill Large and Matt Long.

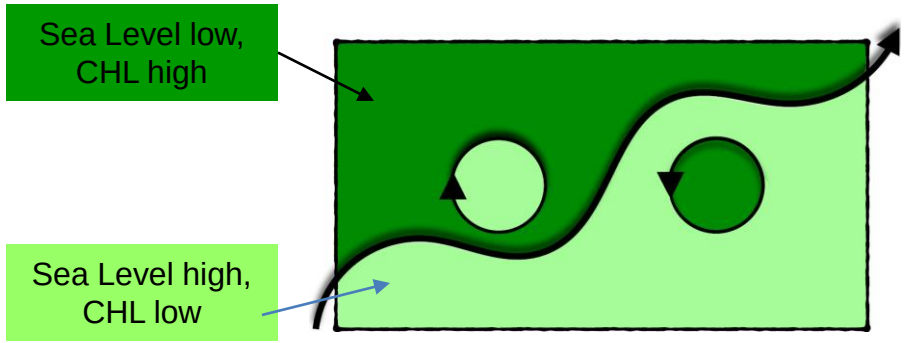
Post-docs
Ross Tulloch, Hajoon Song, Pete Gaube, Matt Long

Students
Sophie Clayton, Elise Olson, Emily Zakem

Two key mechanisms

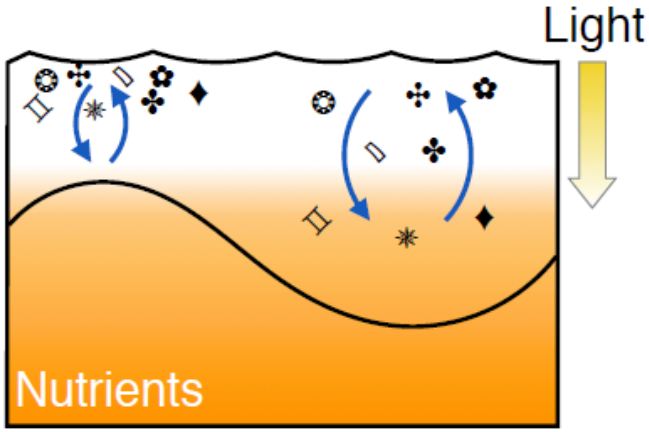
Mesoscale influences biogeochemical cycles through:

1. Lateral mixing (trapping and stirring)



Typically leads to negative sea-level/ CHL correlations

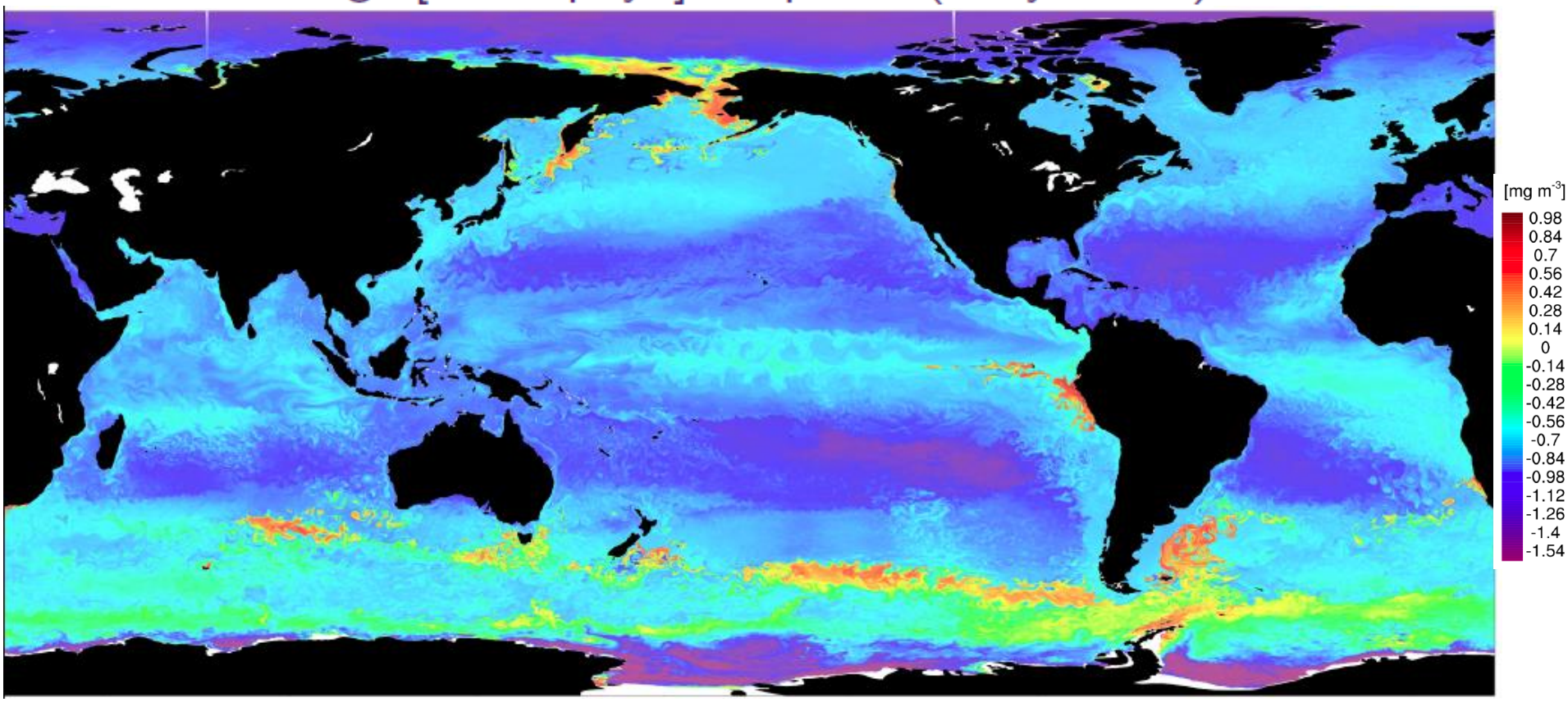
2. Vertical mixing (modulation of mixed layer depth)



Can lead to both negative and positive sea-level/CHL correlations

Explore in model world…

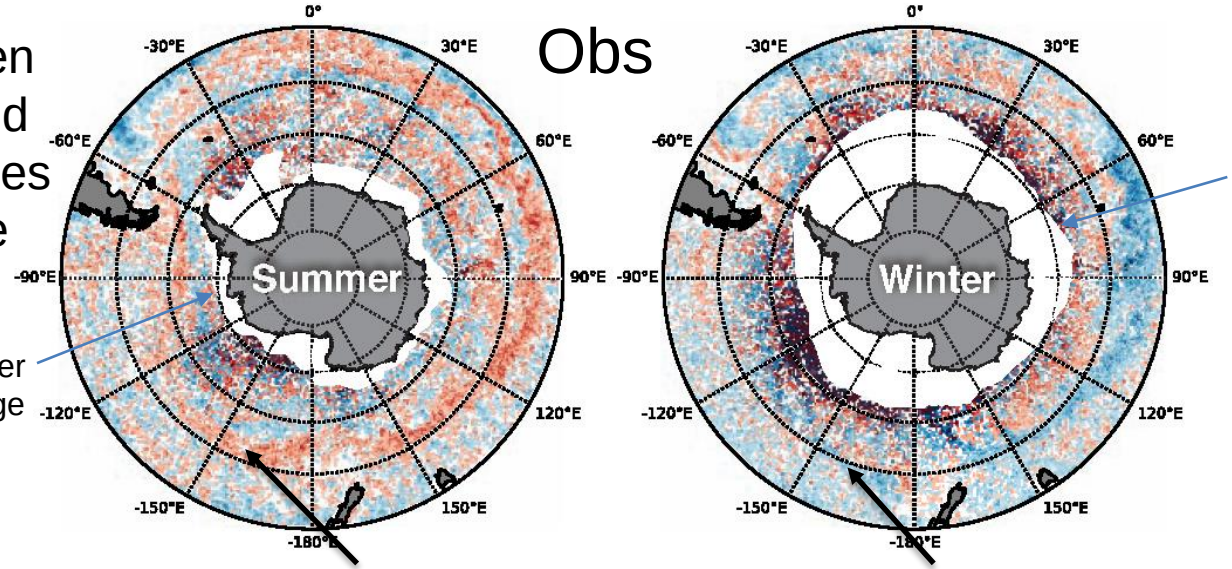
Surface $\log_{10}$[chlorophyll] snapshot (daily mean)



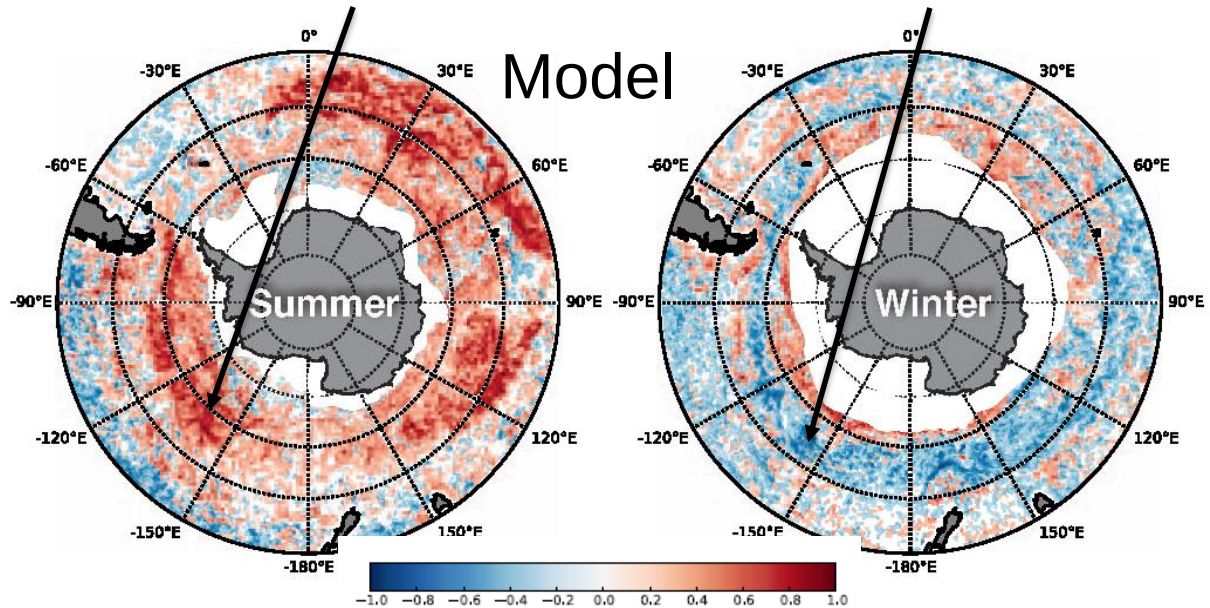
0.1° BGC coupled run (CESM)

…and compare with observations

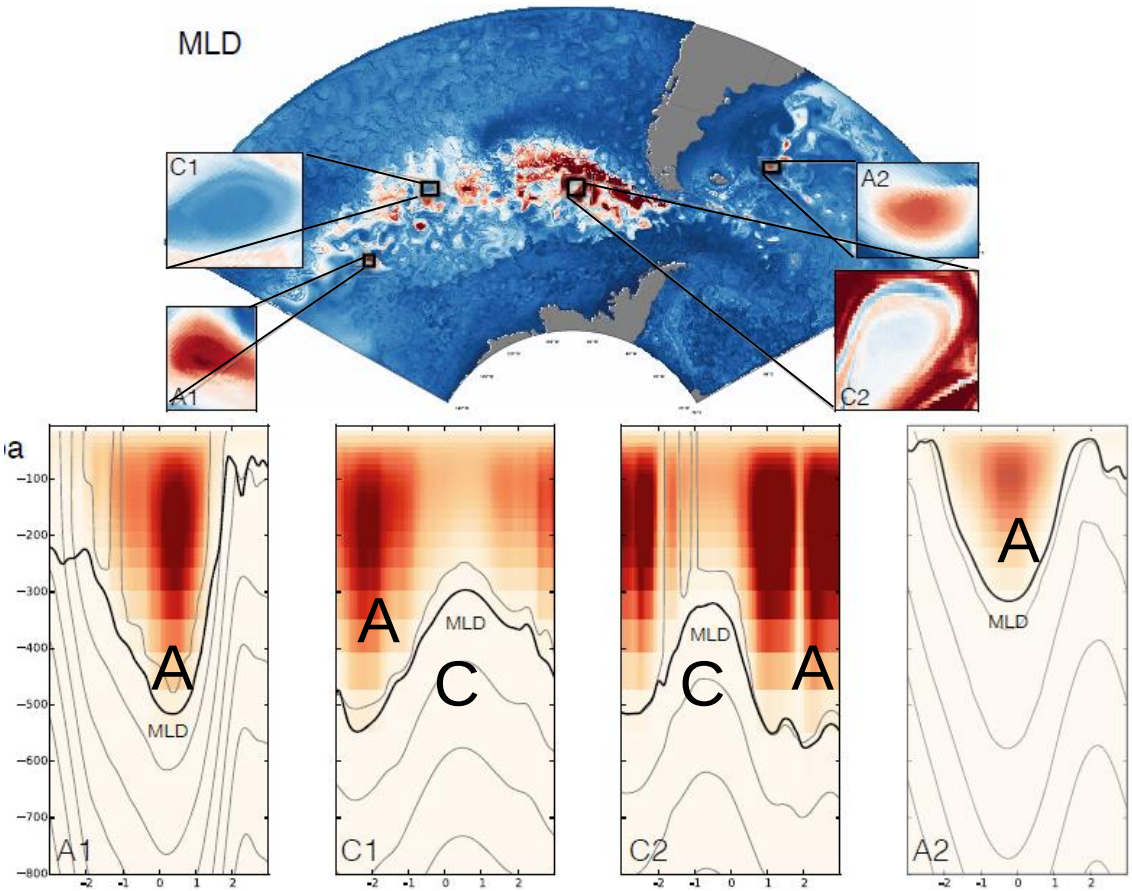
Correlation between dynamic height and chlorophyll anomalies on the mesoscale

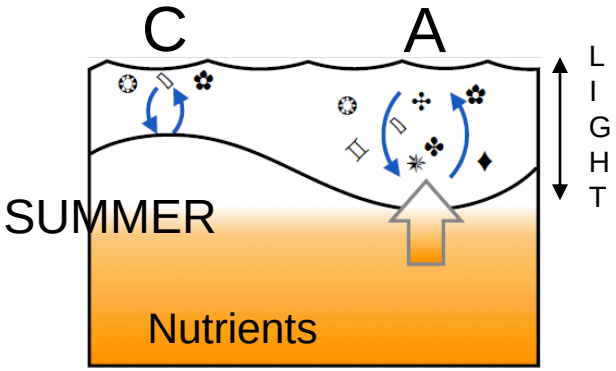


Corr (SLA, CHL) (+ ve in summer) (- ve in winter)



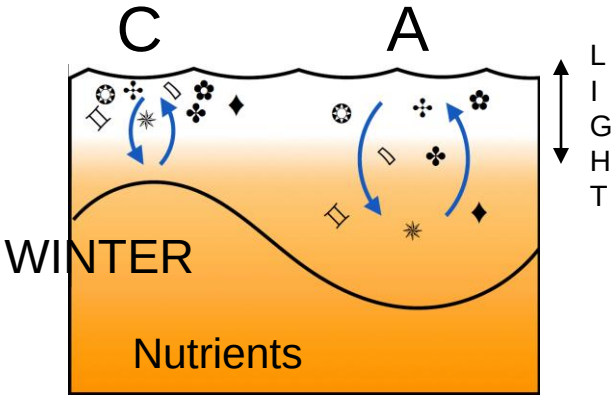
Modulation of mixed-layers by eddies





Lots of light, anticyclones 'dig deeper', drawing up nutrients from depth

+ ve Corr (SLA, CHL)



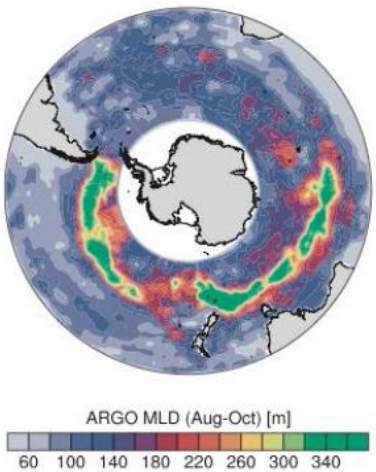
anticyclones sweep phytoplankton to depth, out of light layer

- ve Corr (SLA, CHL)

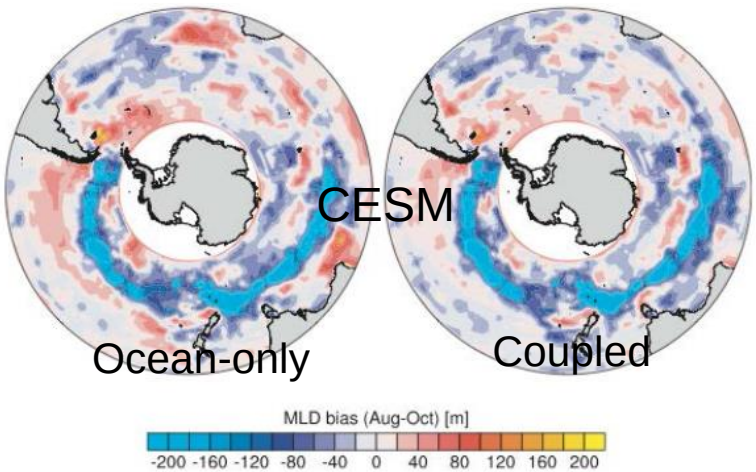
Biases in models that do not resolve eddies

Ocean models used in climate research do not resolve the mesoscale

Observed winter mixed-layer depth

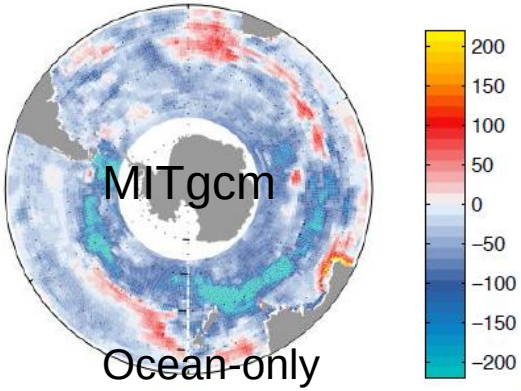


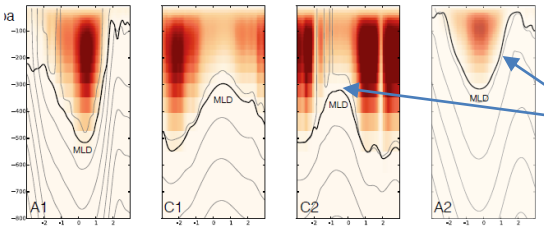
Model - Obs



Modeled mixed layer depth is too shallow with consequences for BGC

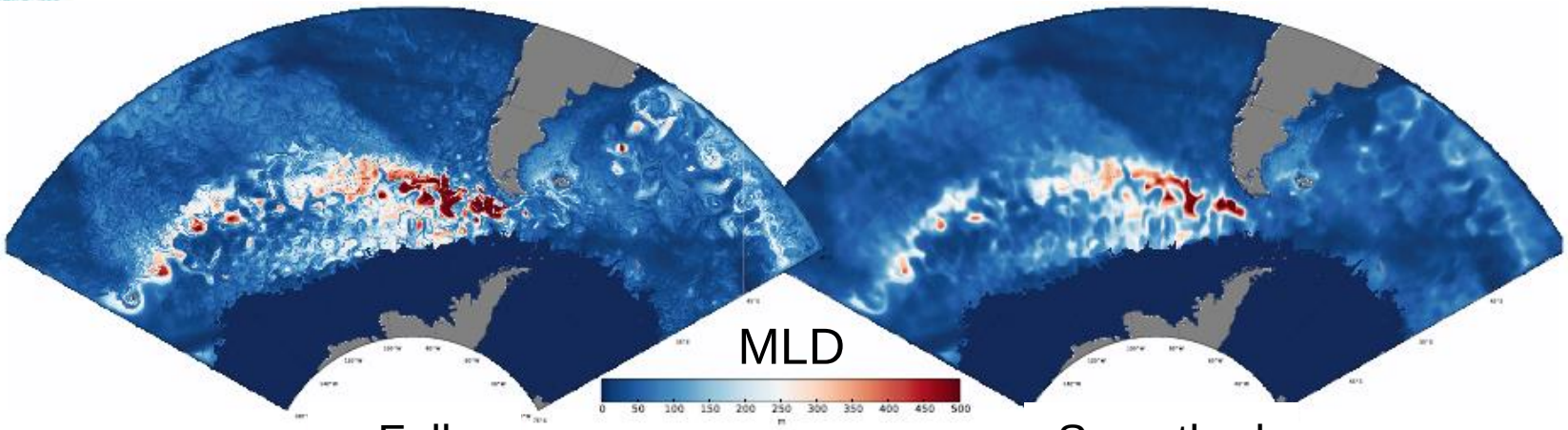
Bias is largely due, we believe, to modulation of the mixed-layer depth by eddies.





Average mixed-layer depth is deeper with eddies than without

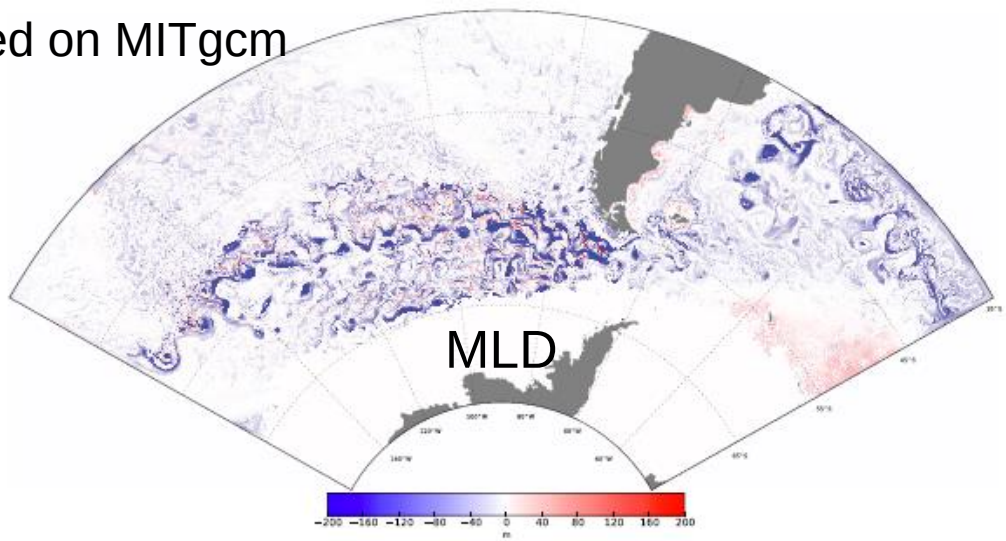
Mixed-layer shallows as eddies smoothed



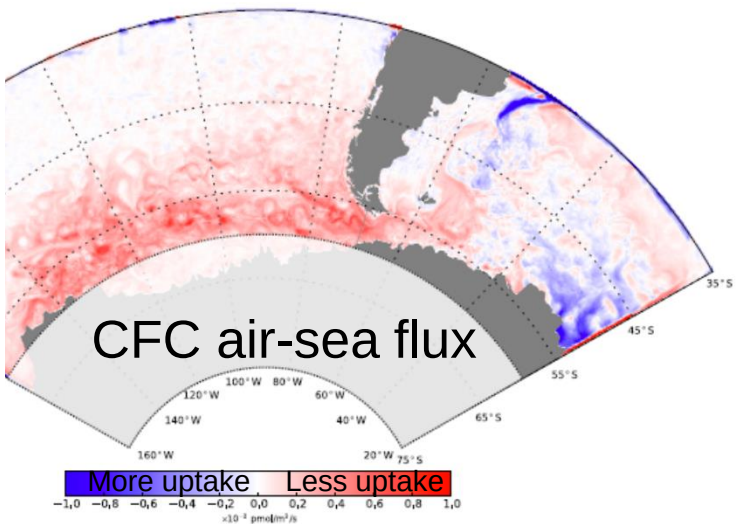
Full

Smoothed

Off-line model based on MITgcm

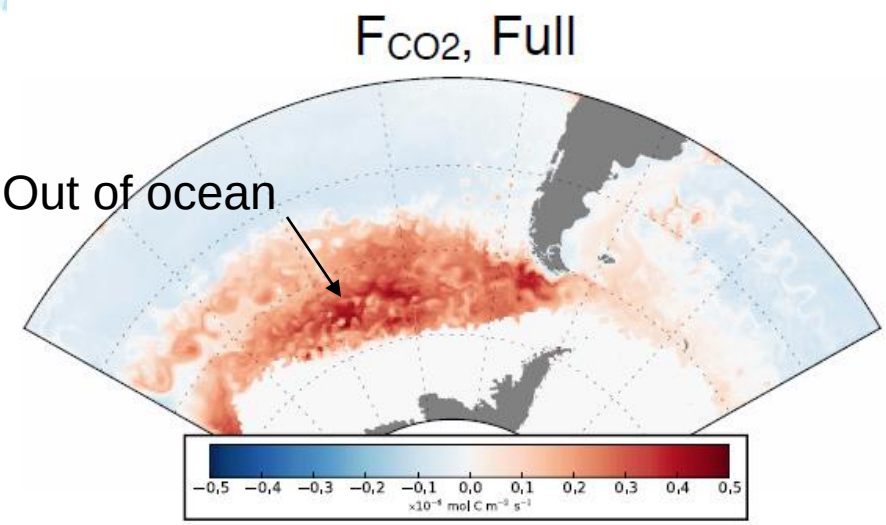


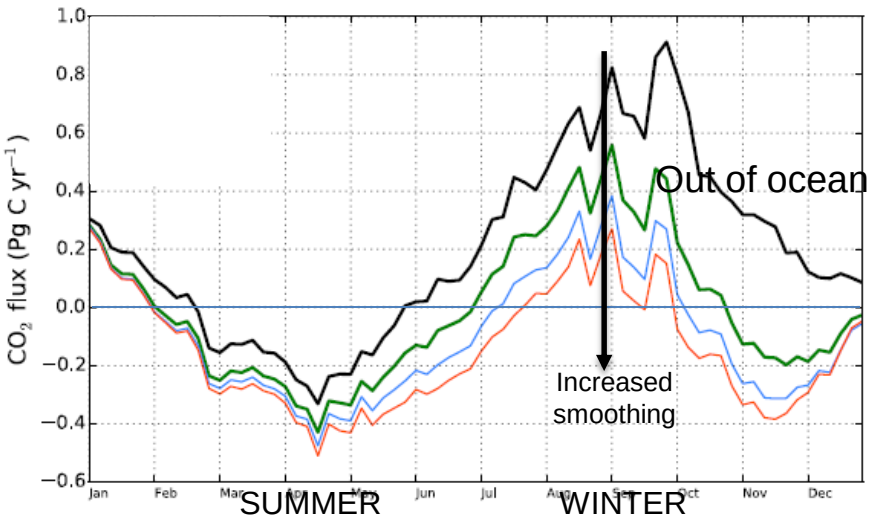
Smoothed - Full



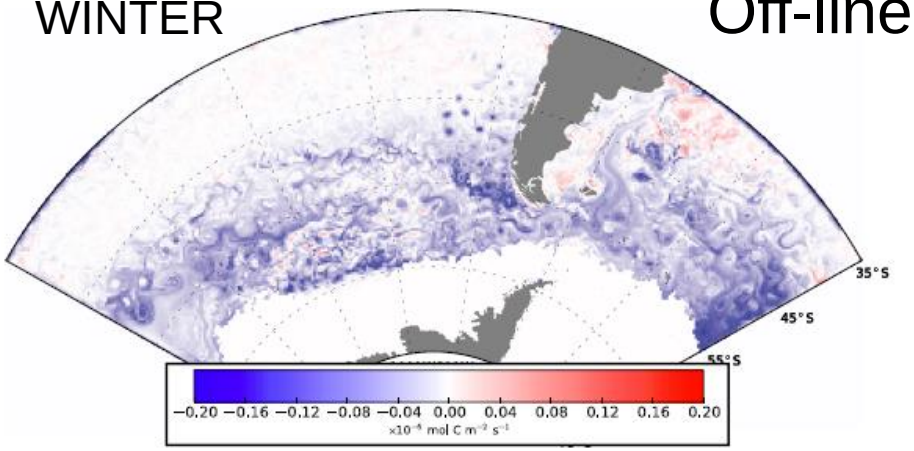
Smoothed - Full

Air-Sea CO2 flux reduced as eddies smoothed



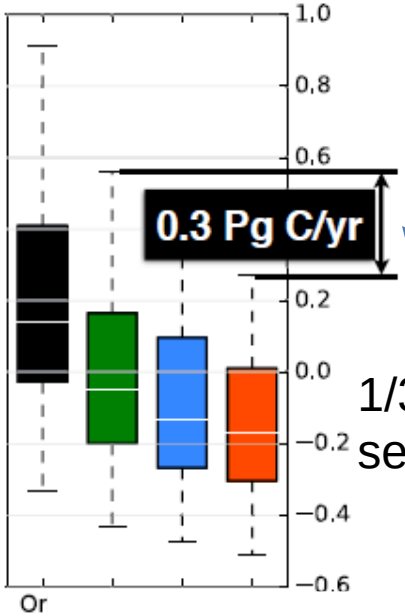


WINTER



Smoothed - Full

Off-line model



1/3 amplitude of seasonal cycle

Cross-talk:

Parameterizing the interaction between diapycnal and mesoscale mixing in the ocean

John Marshall, MIT

Bill Large and Gokhan Donabasoglu, NCAR

Subgridscale physical processes in ocean models are typically prioritized, tackled, implemented and evaluated one at a time. However, there is often important ‘cross-talk’ between different processes and if this interaction is not represented, model fidelity can be compromised. For example, the modulation of the mixed-layer depth by mesoscale eddies is currently not represented in coarse-resolution models. This has important consequences for, e.g.,

(i) the air-sea fluxes of heat and soluble gases such as CO2 and CFCs, resulting in a systematic under-estimate of ocean uptake and

(ii) by inference, the rate at which heat and carbon are sequestered in the interior ocean.

Although the association of enhanced diapycnal mixing with a more turbulent ocean is not surprising, this important effect has yet to be parameterized in our models.

‘Cross-talk’, then, proposes to link diapycnal and mesoscale mixing processes together. It would involve:

(a) diagnosing biases in mixed-layer/ subduction processes and air-sea gas fluxes in current models in the framework provided by observations and our current understanding of the processes involved

(b) appropriately 'hooking' diapycnal and mesoscale schemes together and

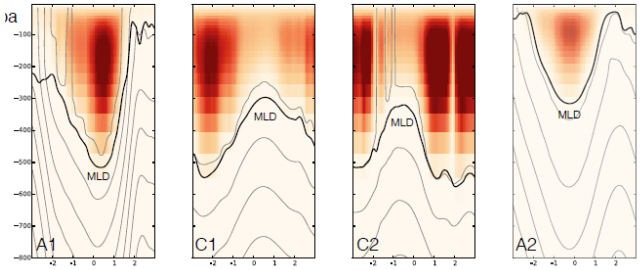
(c) evaluating the resulting closure.

Conclusions and plans

Interaction between eddies and mixing is likely critical to understanding mixed layer biases and key to how we might correct them.

Cyclone + Anticyclone ≠ zero

≈ Anticyclone



Offers a ‘simple’ explanation for mixed-layers being too shallow in coarse resolution models

MOBY: major accomplishments

1. Technical development

   a. 1/10 degree global coupled model with BGC (CESM)
   b. offline BGC model based on MITgcm
   c. ported MIT's DARWIN model to CESM

2. Scientific

   a. elucidated role of lateral & vertical mesoscale transports on BGC
   b. quantified the importance of eddy-mixed layer interactions in mediating MLD and air-sea fluxes of CO2, CFCs.
   c. evaluated role of the mesoscale in phytoplankton diversity.

3. People

   Provided a framework for education of students and postdocs

4. Large 'review' being planned and public meeting next summer

5. Ongoing and future

   'Cross-Talk'

   parameterizing the interaction between diapycnal and mesoscale mixing in the ocean.