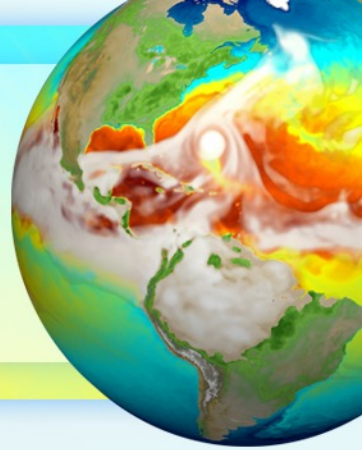

Mesoscale eddy parameterization affects the linearity of responses to increased CO2

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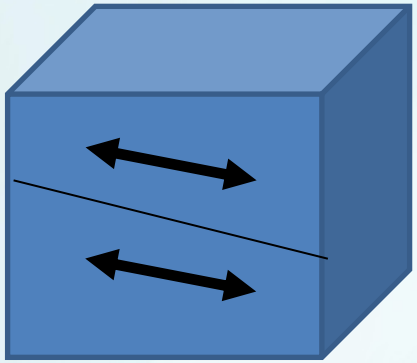
E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

What do eddies do?



Ocean is highly stratified, weakly stirred

Mixing coefficient along density surface is 8-9 orders of magnitude larger than mixing across density surfaces.

Parameterized by a “Redi” coefficient

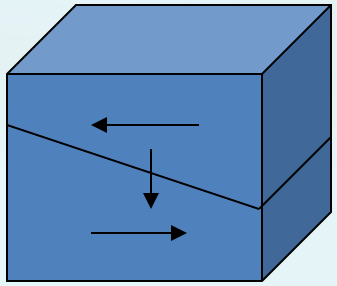
Value of this coefficient varies from <400 m^2/s to 2000 m^2/s in CMIP5

Was set to 0 in v1 (numerical issues)

Diffusion-stirs along isopycnal surfaces.

$$\langle uhC \rangle = -\langle h \rangle A_{Redi} \frac{\partial \langle C \rangle}{\partial x}$$

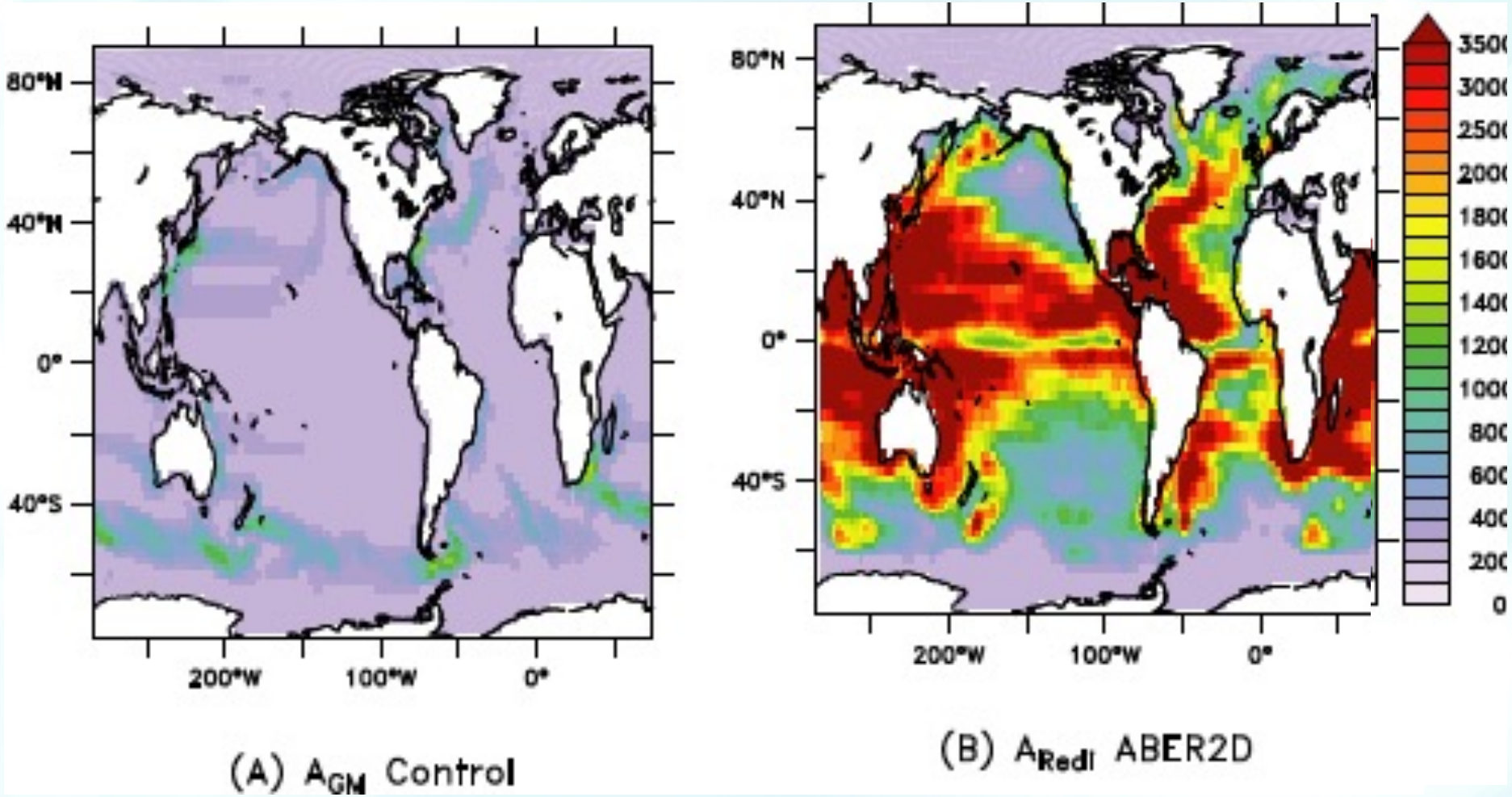
Complication: “Thickness” diffusion



- Basic idea is that eddies flatten layer interfaces.
- Corresponds to an advective effect…
- Or a vertical momentum transfer.
- Gent and McWilliams (1990)

$$F_C = -A_{GM} * C * \frac{\partial S}{\partial z}$$

Are coefficients these the same?



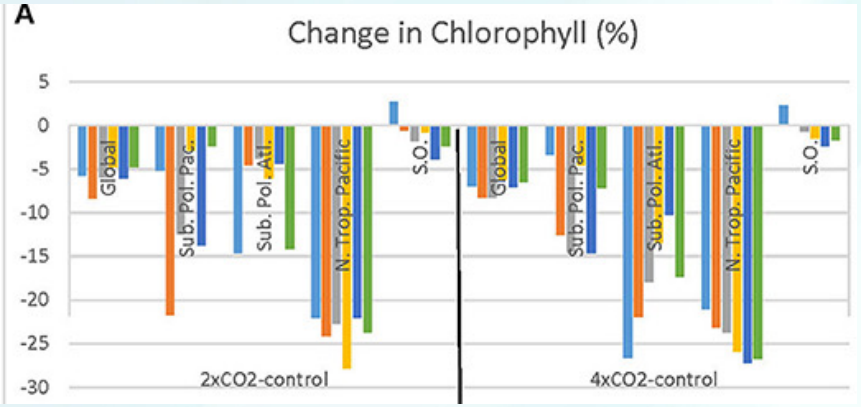
Why so different (?)

- GM parameterizes vertical momentum transport.
- Velocities involved are ageostrophic.
- Should be high in regions where we have baroclinic instability.
- Large in jet centers. (?)

- Redi parameterizes stirring along isopycnals
- Velocities involved are geostrophic.
- Can be suppressed if these velocities don't get to act over long periods of time (eddy advection)
- Smaller in jet centers (?)

Where does this make a difference?

In last year we've looked at the linearity of physical and biogeochemical responses to the parameterization.



Can we get fingerprint of historical changes by scaling large changes (4xCO2) to present-day radiative forcing.

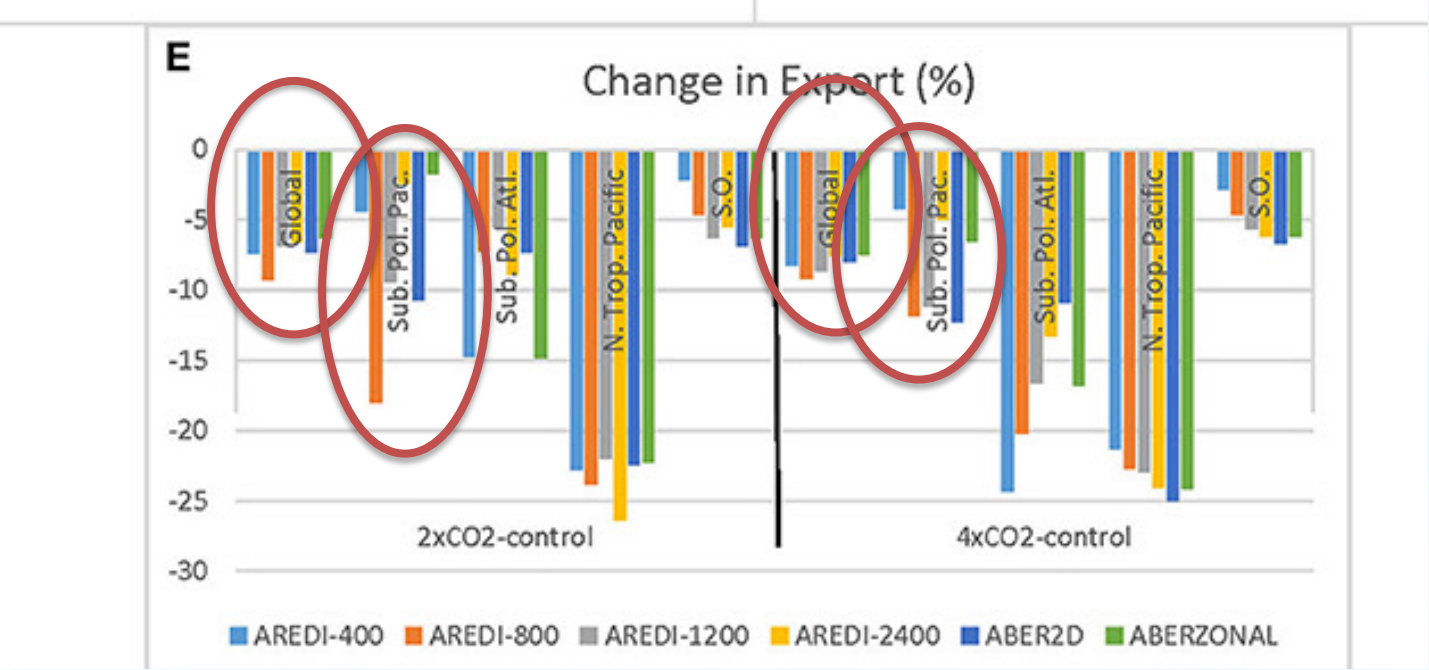
Compare 2xCO2/4xCO2 across different mixing schemes

Differences within clusters of bars show *sensitivity* to mixing.

Different clusters show different regions.

Differences between LHS and RHS sides of the plot show nonlinearity

Export of organic matter to deep

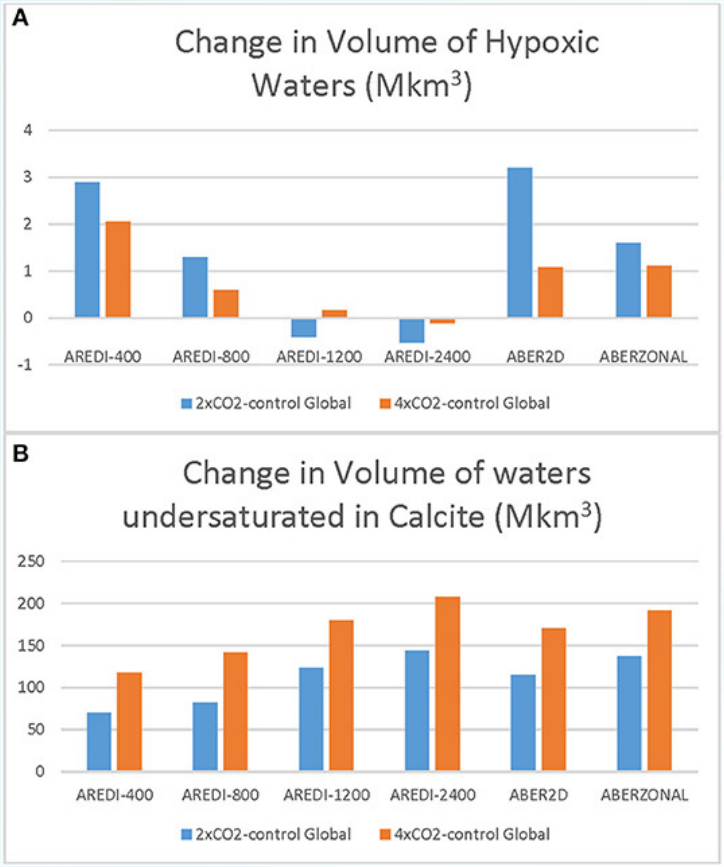


- Global productivity is relatively insensitive to mixing, relatively linear
- Regional productivity in N. Subpolar regions is to mixing, often nonlinear

Bahl et al., Front. Mar. Sci. 2020

Deep measures of ocean habitability are much more sensitive

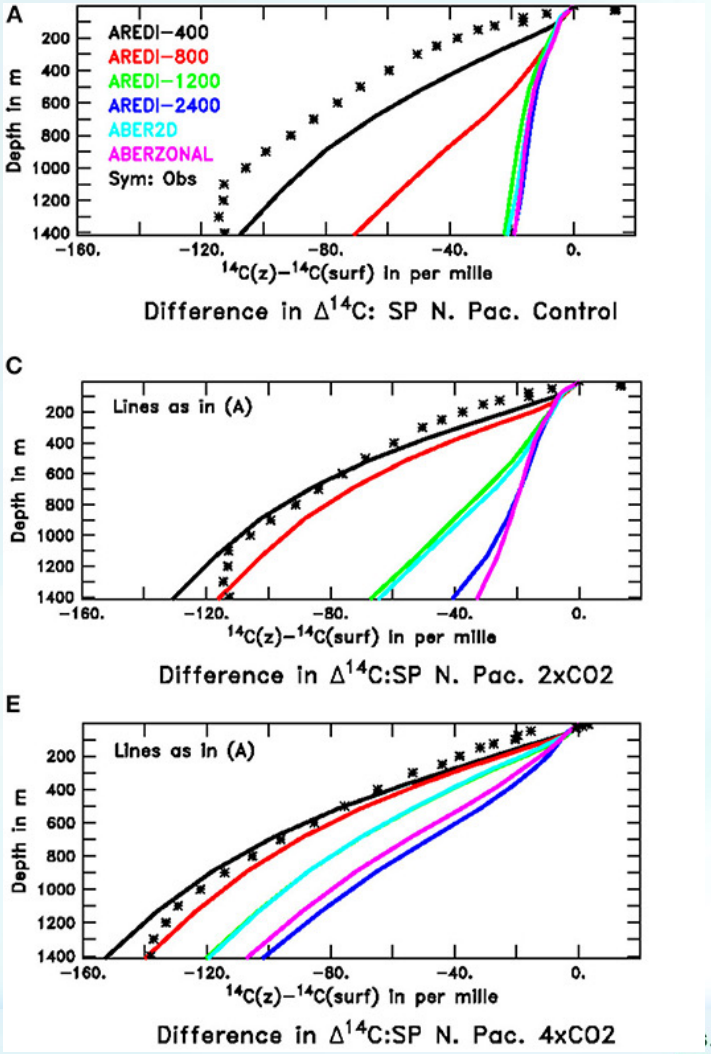
- Hypoxia can either grow or shrink depending on whether mixing is high or low.
- Change in water undersaturated in calcite is very different for different values of mixing.
- 4xCO2 does not predict 2xCO2!



Bahl et al., Front. Mar. Sci. 2020

Changes in subpolar gyre provide some of the explanation for this

- Consumption of oxygen, carbonate isn't all that different on a global scale.
- But convection in subpolar gyre regions is very sensitive to representation of mixing.
- More "realistic" mixing doesn't necessarily give more realistic convection.

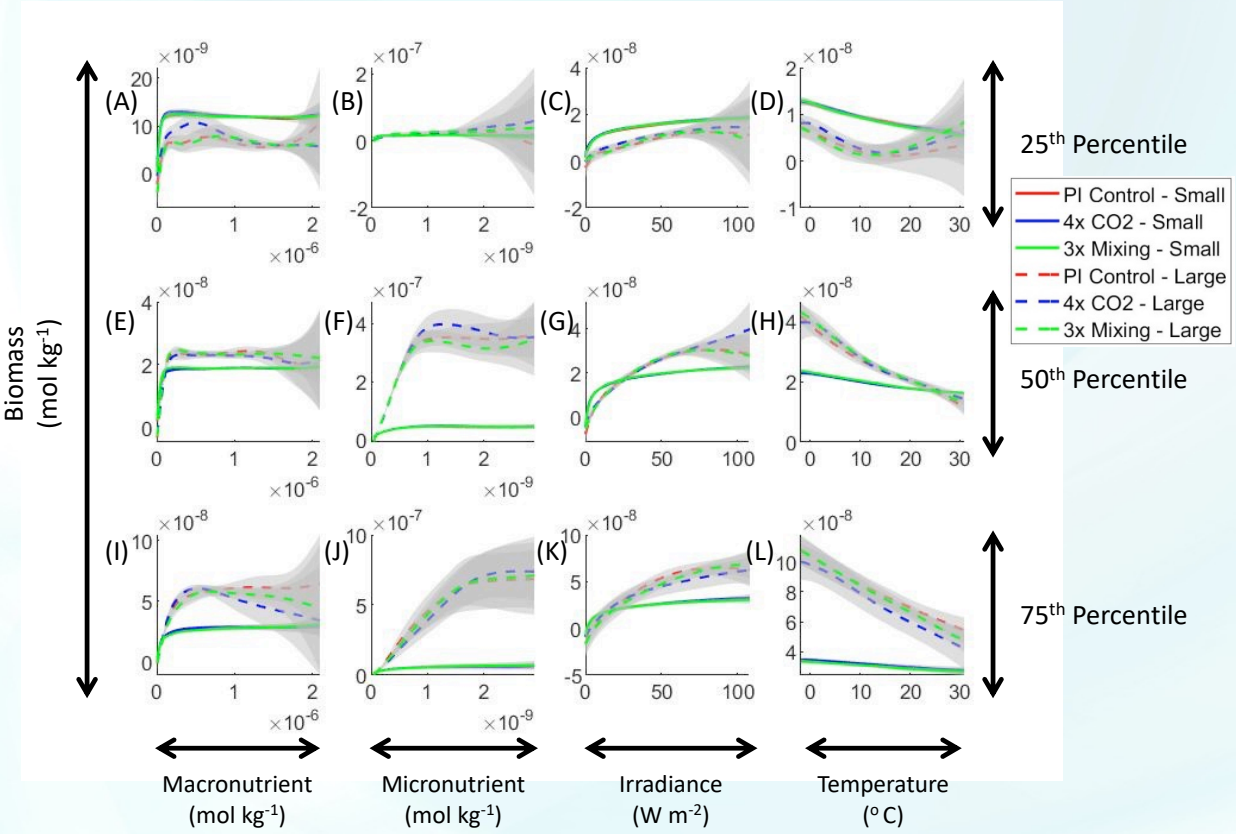


Bahl et al., Front. Mar. Sci. 2020

Implications for E3SM effort

- Don’t just assume Redi and GM are going to be the same.
- Differences matter in convective regions- focus attention there.
- Expect nonlinear biological responses in highly convective regions.
- Global diagnostics are insufficient for getting interior habilitability.
- Age tracers are going to be important to incorporate early.

Spinoff- using ML to see whether changing mixing moves us into new BGC regimes



See poster by Chris Holder