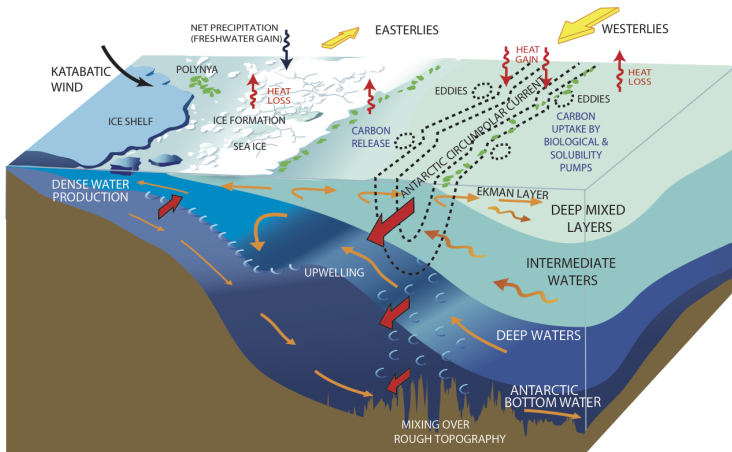


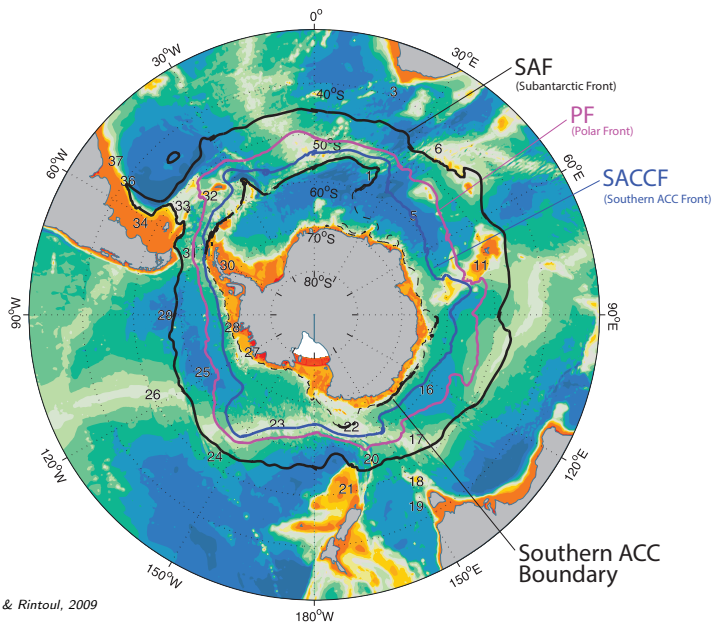
Goals of this talk

- ▶ Background overview of Southern Ocean oceanography.
- ▶ Prompt discussion about sampling strategies designed to target important regional features.

Southern Ocean circulation

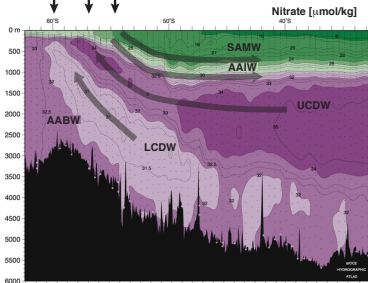
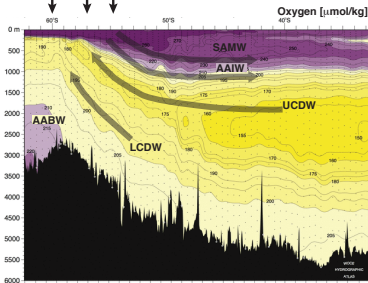
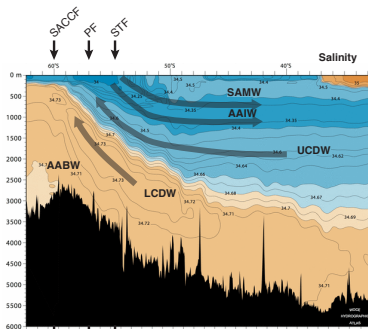
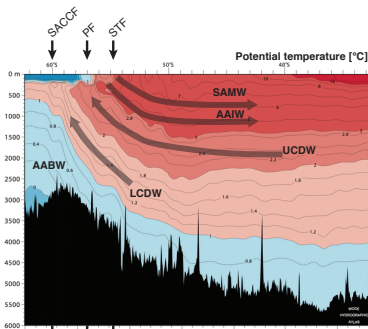


Frontal zonation in the Southern Ocean



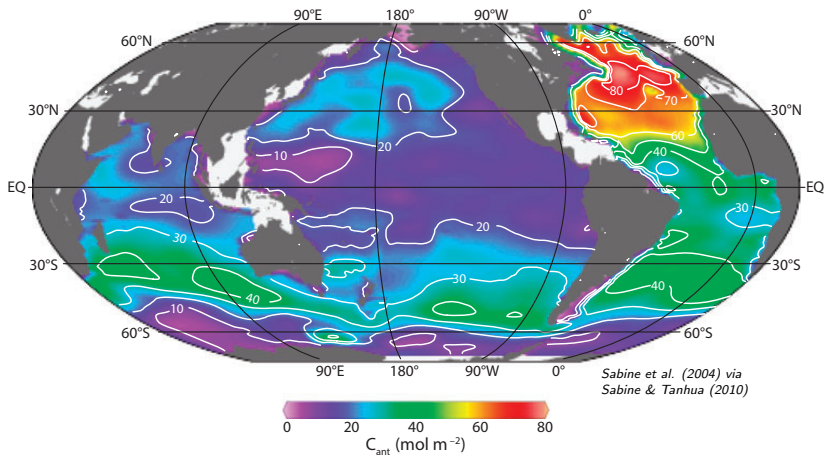
Sokolov & Rintoul, 2009

Properties along meridional section (P16; 150°W)

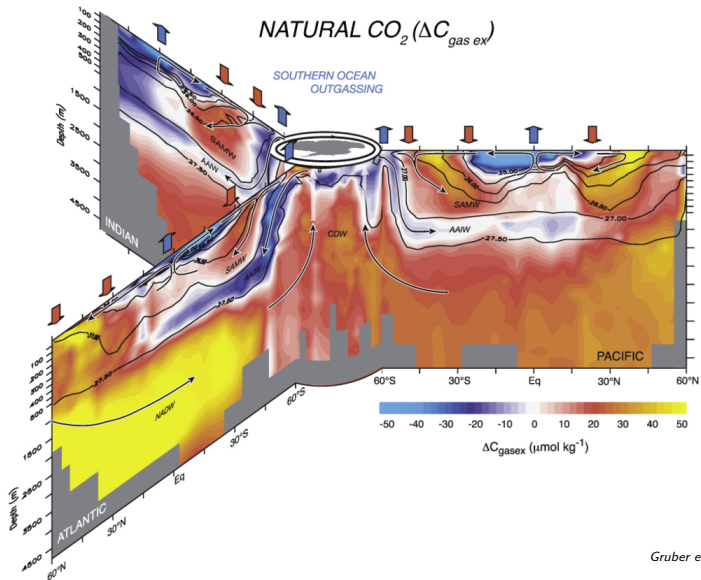


Anthropogenic CO₂ uptake is mediated by circulation

Ocean C_{ant} inventory (1990s)

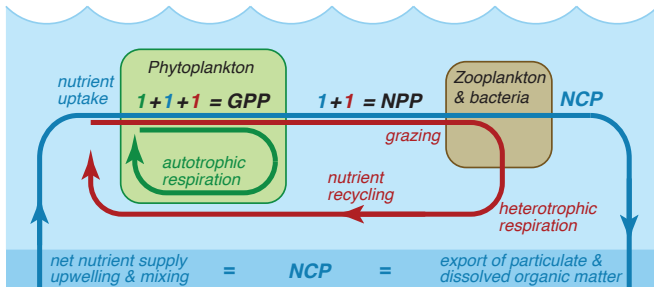


Natural carbon distributions



Gruber et al., 2009

Net community production



GPP: Gross primary productivity

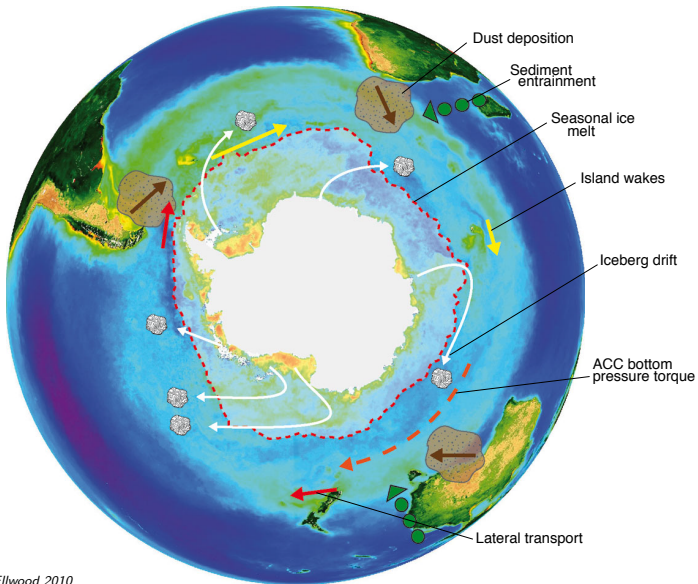
NPP: Net primary productivity

NCP: Net community production

after Sigman & Hain 2012

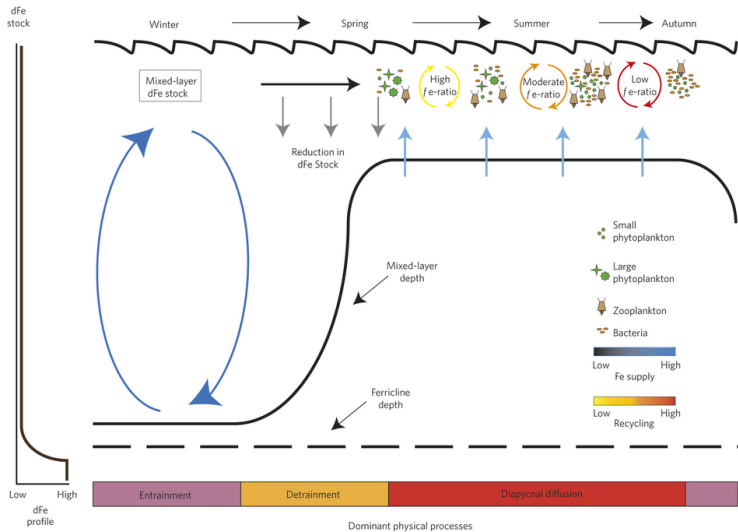
High nutrient, low chlorophyll region

Multiple sources of new iron to the Southern Ocean



Boyd & Ellwood 2010

Deep winter mixing sustains iron supply



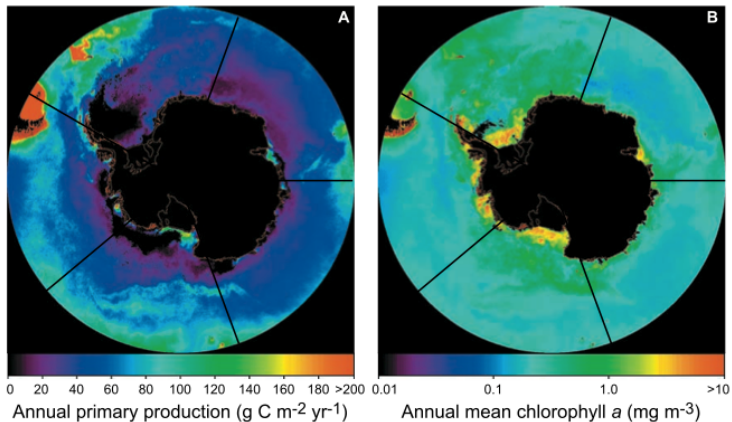
Tagliabue et al. 2014

Planning questions

At what regional scales are oceanographic processes accessible to observation in ORCAS?

Are there important environmental gradients across which we can sample and thereby improve opportunities for insight into system dynamics?

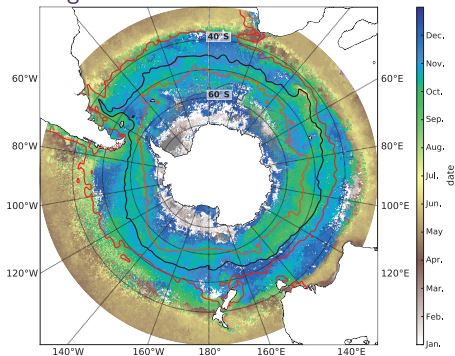
Satellite-based NPP: meridional gradient?



Arrigo et al., 2008

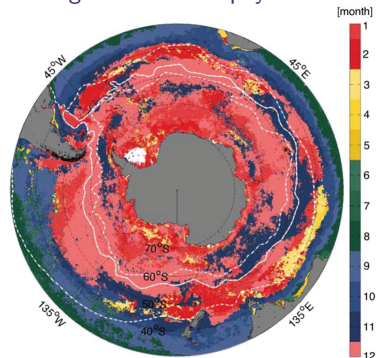
Spatial variation in bloom onset and peak (based on chlorophyll)

Timing of bloom onset



Thomalla et al., 2012

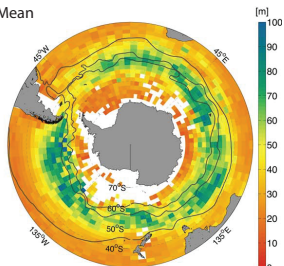
Timing of max chlorophyll



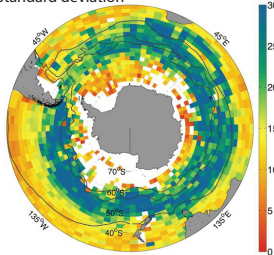
Carranza & Gille, 2015

Summer (DJF) mixed layer depth: mean and variability

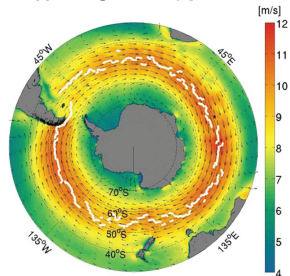
Mean



Standard deviation



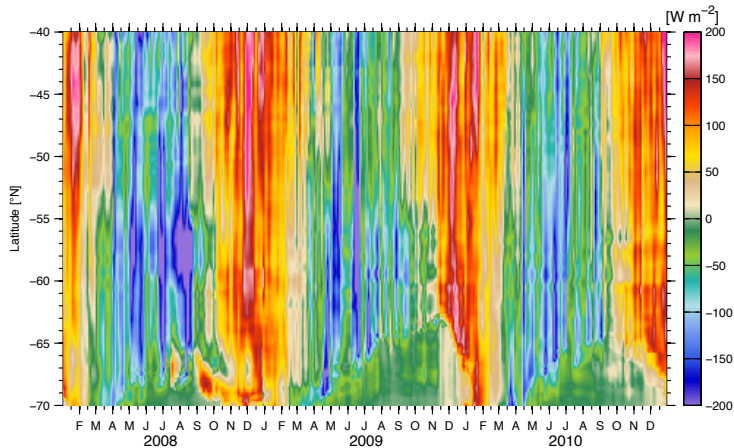
Mean DJF winds



Carranza & Gille, 2015

Surface heat fluxes

SOSE-derived, 5-day mean, surface heat fluxes (80°-90°W)

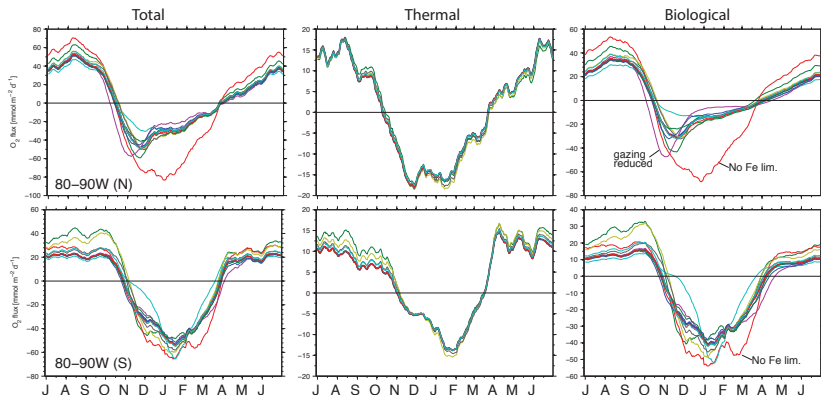


positive := downward

courtesy of M. Mazloff

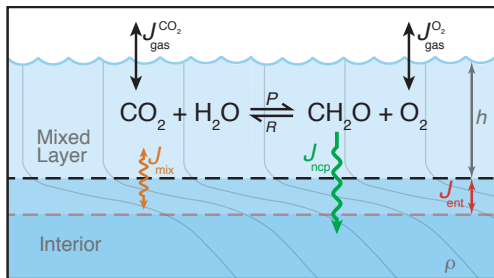
Simulated air-sea oxygen fluxes

CESM sensitivity experiments: O₂ fluxes N and S of ~PF (80°-90°W)



positive := downward

Conceptual framework: Mechanisms driving fluxes

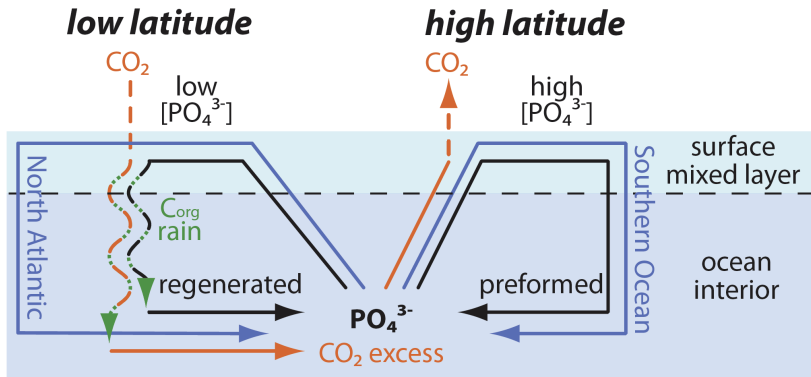


$$h \frac{dC}{dt} = \underbrace{k^{\text{CO}_2} \alpha (p\text{CO}_2^{\text{atm}} - p\text{CO}_2^{\text{ocn}})}_{\text{gas exchange}} + \underbrace{\Theta \left(\frac{dh}{dt} \right) \cdot (C_{\text{pyc.}} - C)}_{\text{entrainment}} + \underbrace{K_z \frac{dC}{dz} \Big|_{\text{pyc.}}}_{\text{vertical mixing}} + \underbrace{J_{\text{ncp}}}_{\text{biology}}$$

Entrainment formulation

$$C_{\text{pyc.}} = C + (h_{n+1} - h_n) \cdot \frac{dC}{dz} \Big|_{\text{pyc.}} \quad \Theta \left(\frac{dh}{dt} \right) = \begin{cases} 0, & dh/dt \leq 0 \\ 1, & dh/dt > 0 \end{cases} \quad (\text{Heaviside step function})$$

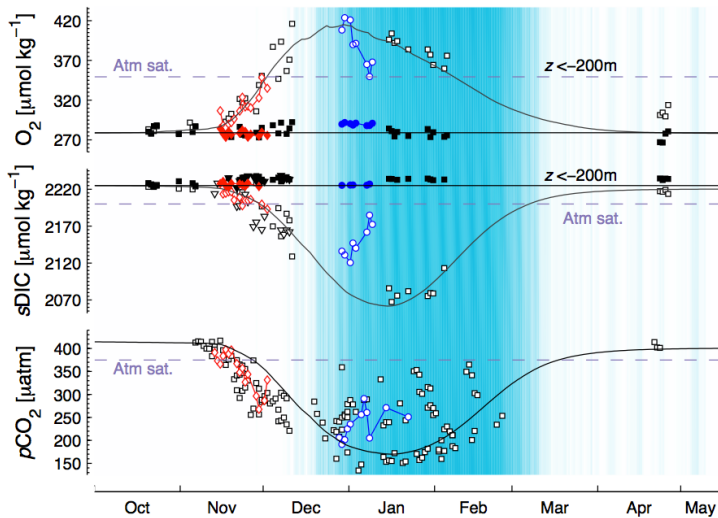
The Southern Ocean leak in the biological pump



Sigman et al., 2010

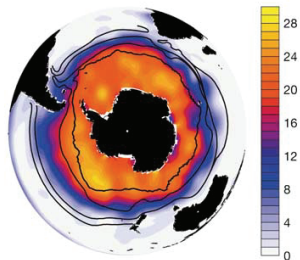
Seasonal rectification in the Antarctic zone

Properties in the Ross Sea

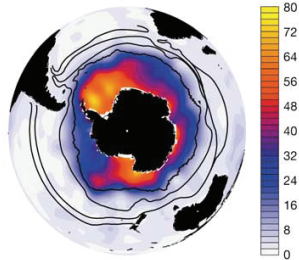


Long, 2010

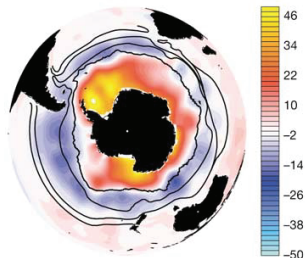
Annual mean surface properties



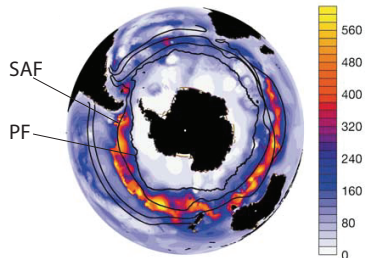
Nitrate ($\mu\text{mol kg}^{-1}$)



Si(OH)_4 ($\mu\text{mol kg}^{-1}$)



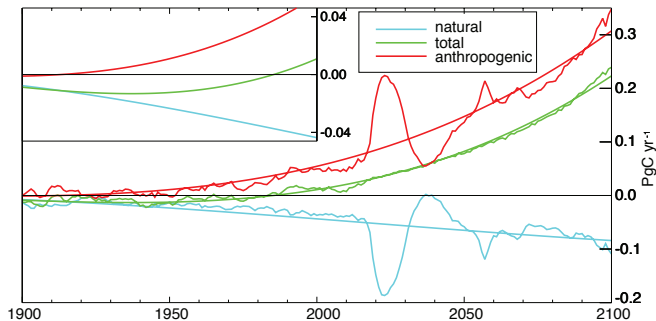
Si^* ($\mu\text{mol kg}^{-1}$)



Mixed layer thickness (m)

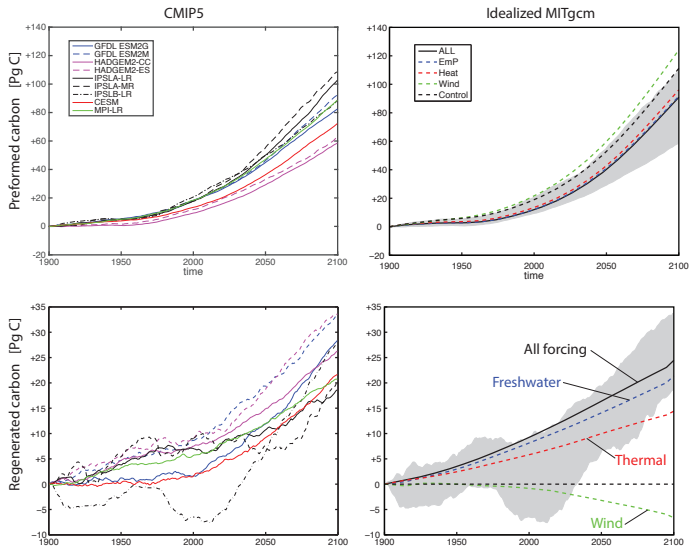
Net flux is a residual between C_{ant} uptake and C_{nat} outgassing

Southern Ocean air-to-sea fluxes



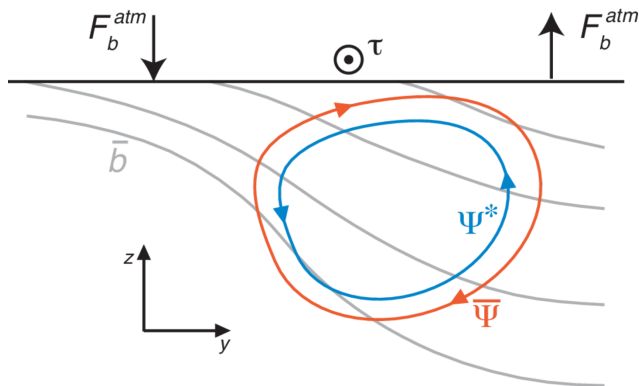
Zickfeld et al. 2008

Southern Ocean carbon inventory under RCP8.5 and idealized forcing



Southern Ocean overturning is strongly mediated by eddies

Eddy compensation



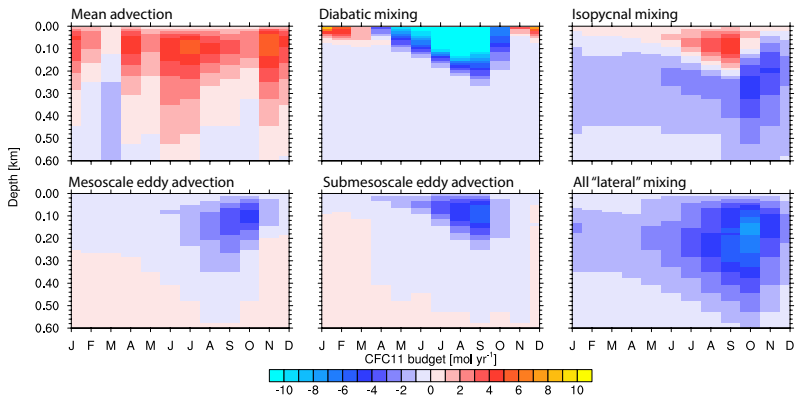
After Marshall and Radko, *JPO*, 2003

Eddy compensation: insensitivity of upper MOC to wind stress;

Eddy saturation: insensitivity of ACC transport to wind stress.

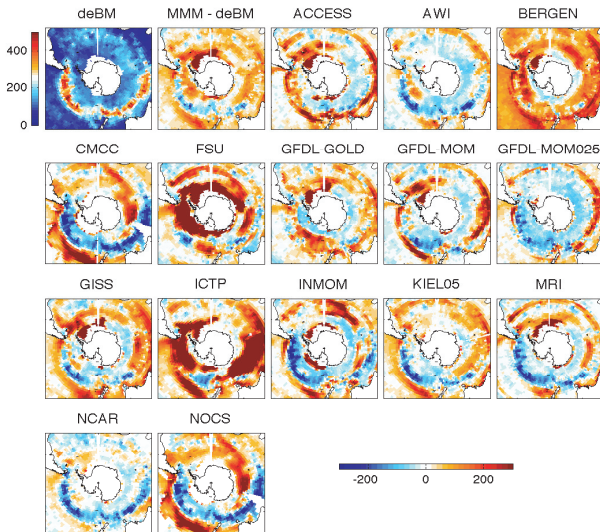
Vertical mixing mediates transient tracer uptake

Vertical fluxes in ACC



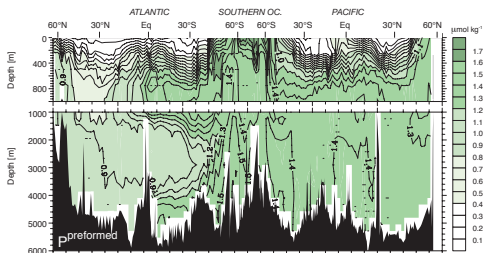
Missing physics?

September mixed layer depth: Obs and biases in CORE-forced runs



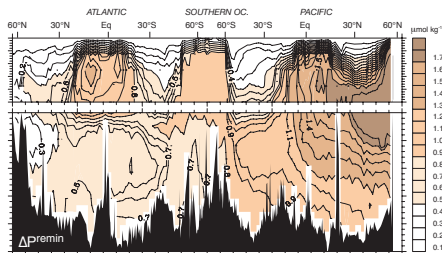
Southern Ocean leak in the biological pump

Preformed nutrient



(surface concentration advected to depth)

Regenerated nutrient



(produced in situ from sinking organic matter)

Sarmiento and Gruber, 2006

Freshly forming mode and intermediate waters

