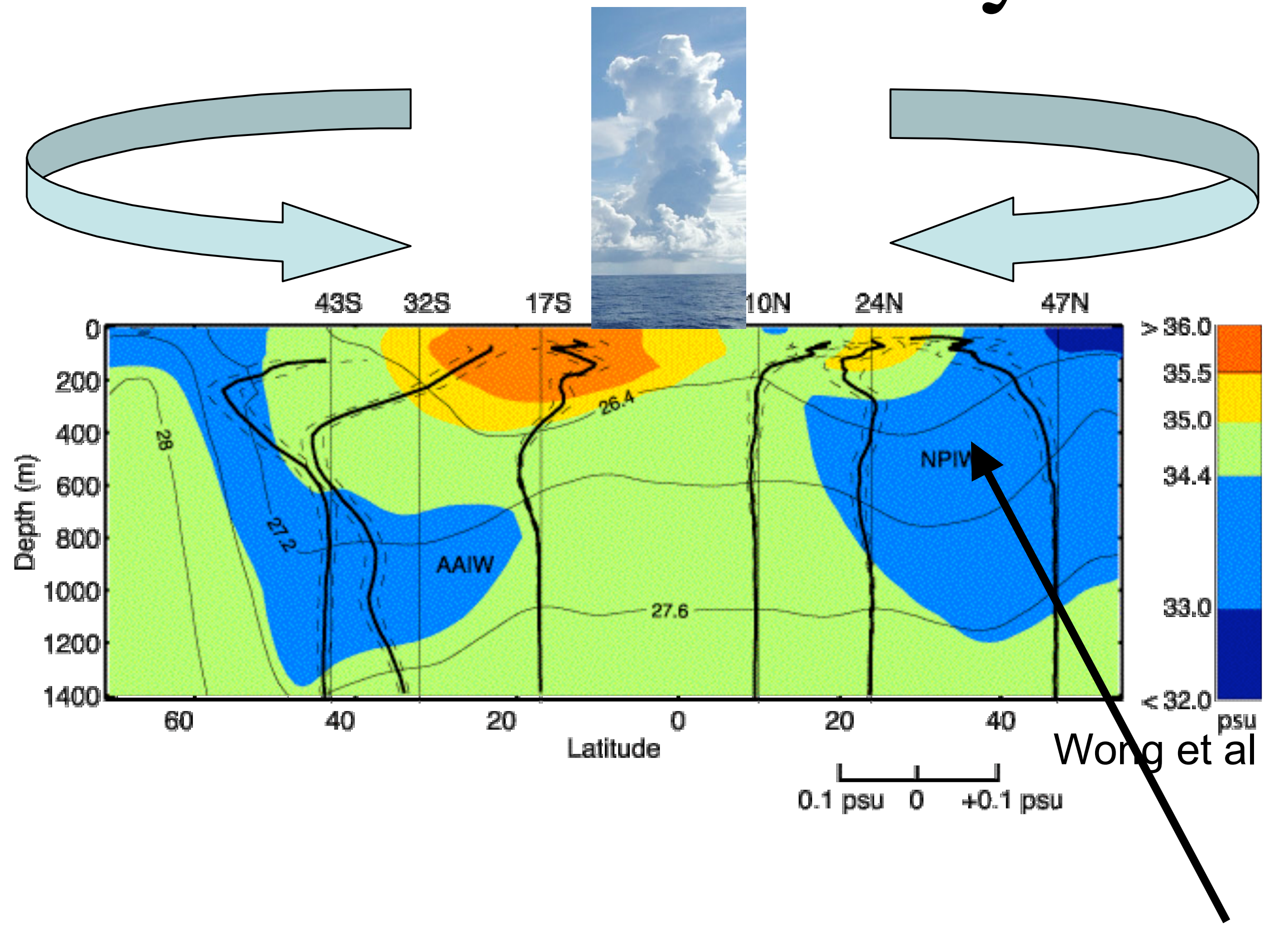
The Upper Cell

1. Climate change illuminates processes operating in the basic state

2. Link between interior and mixed layer key

3. Role of eddies complex - much vertical structure hidden by net results

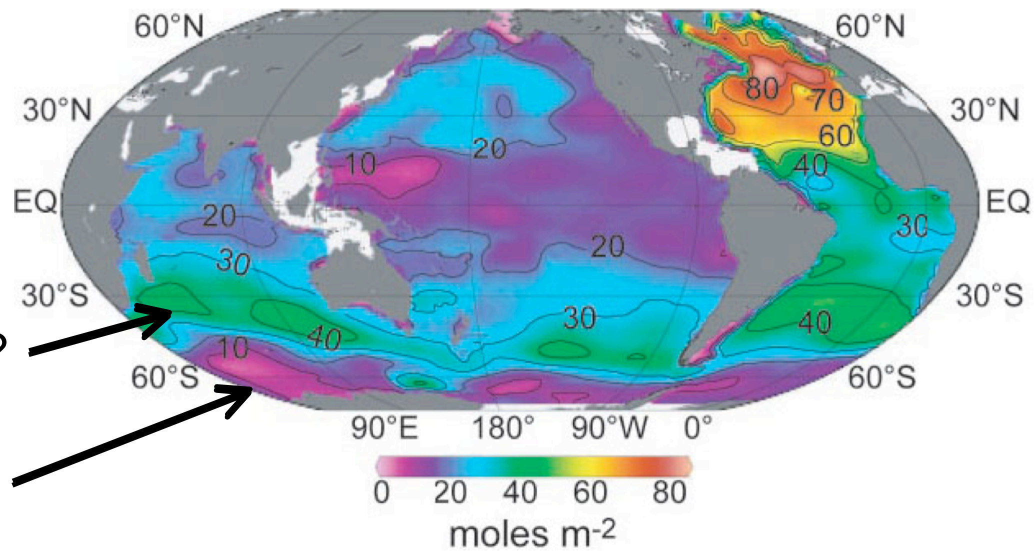
Enhanced Water Cycle



Salinity suggests intermediate freshwater “cell” but interior climate signal is strongest in mode waters

mean advection versus diffusion from source region

Subduction and the Upper Cell

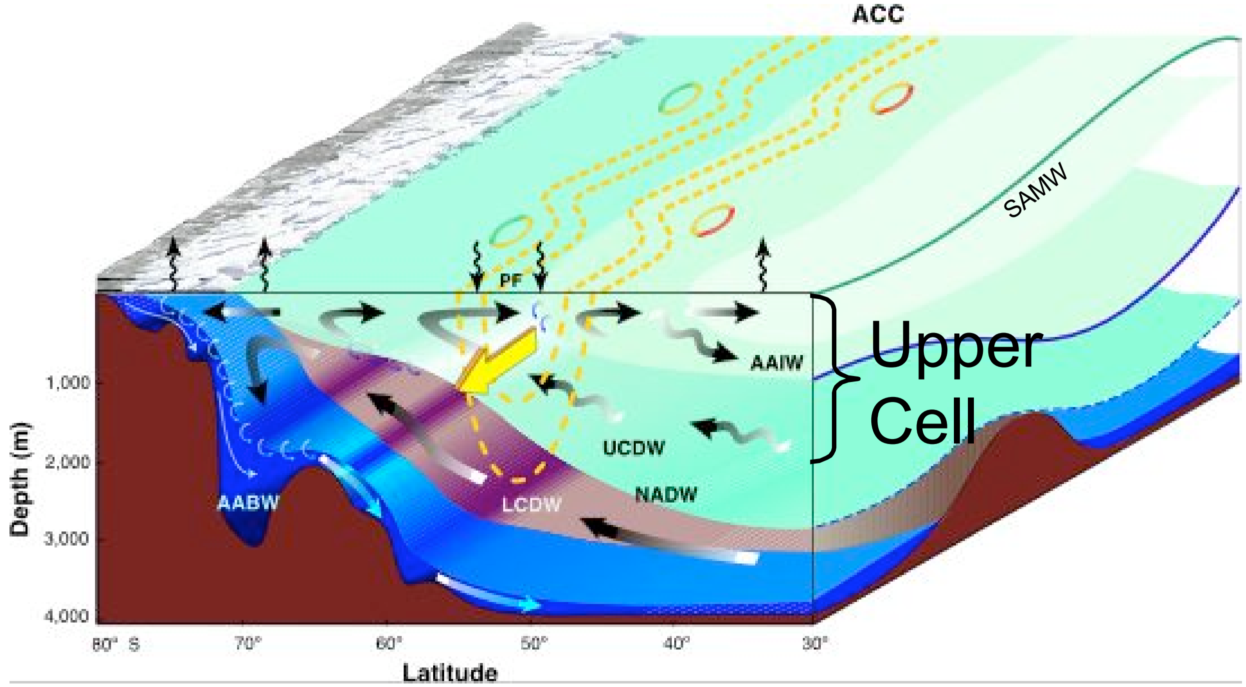


Going down?

Going up?

Ekman transport
Mean flow
Eddy transport

Southern Ocean

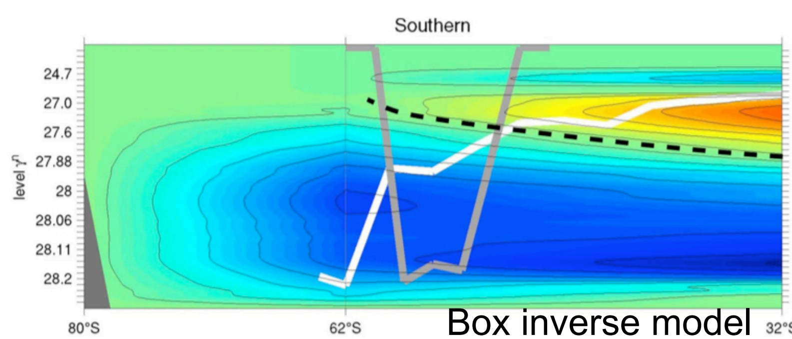


The Upper Cell

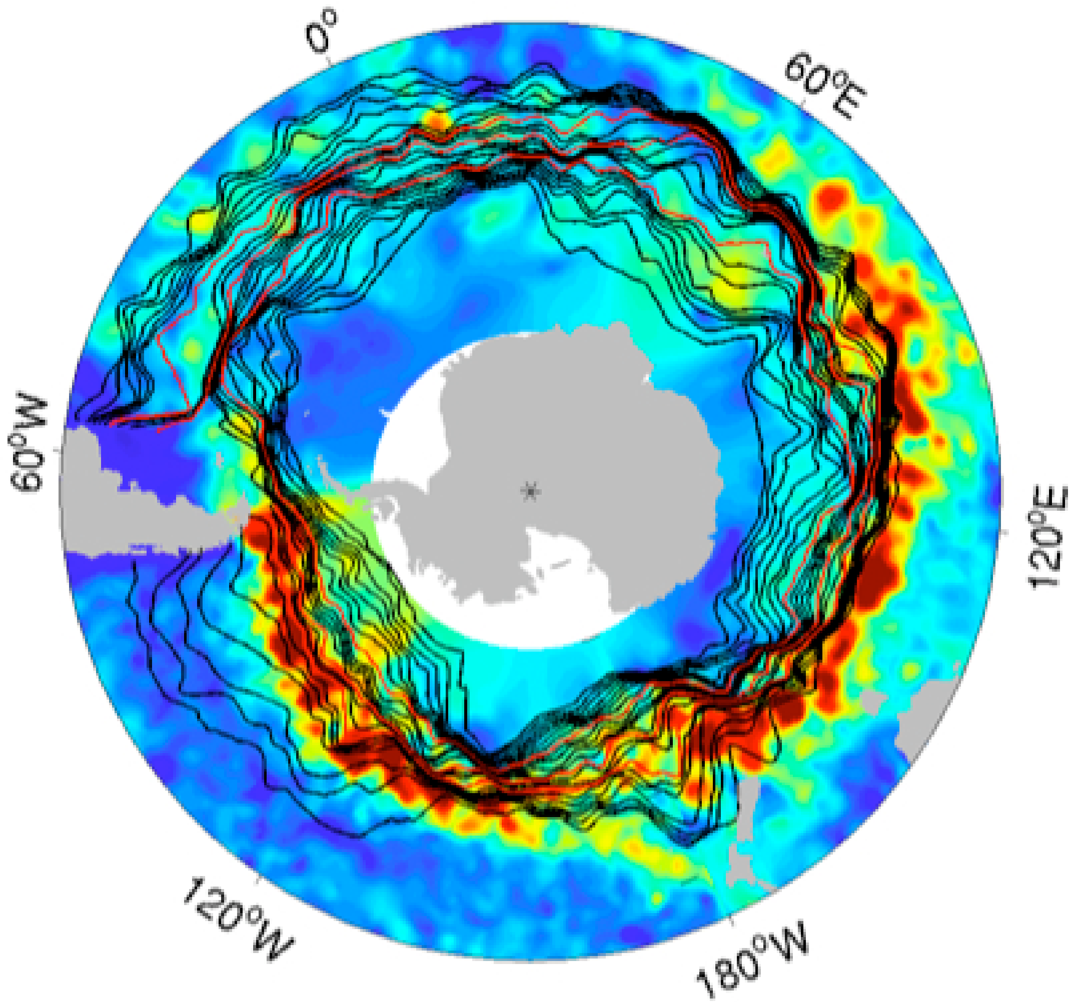
Brings warm UCDW up
Brings natural carbon up
Brings low oxygen up

Takes surface carbon down
Takes surface freshening down

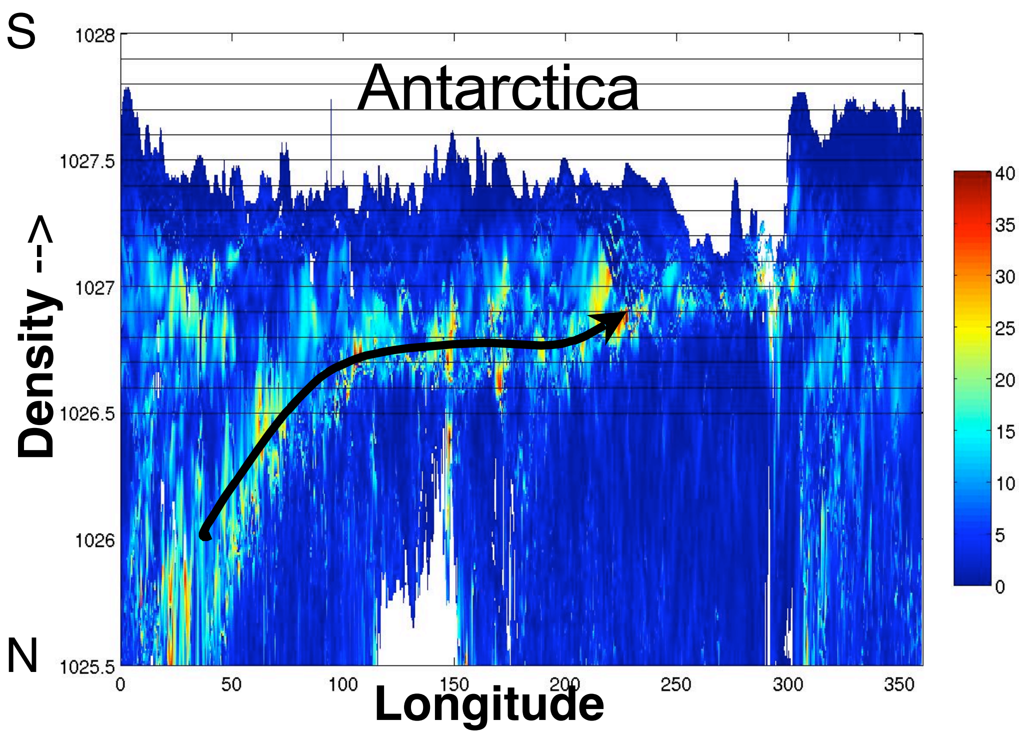
Has mixed layer processes imbedded



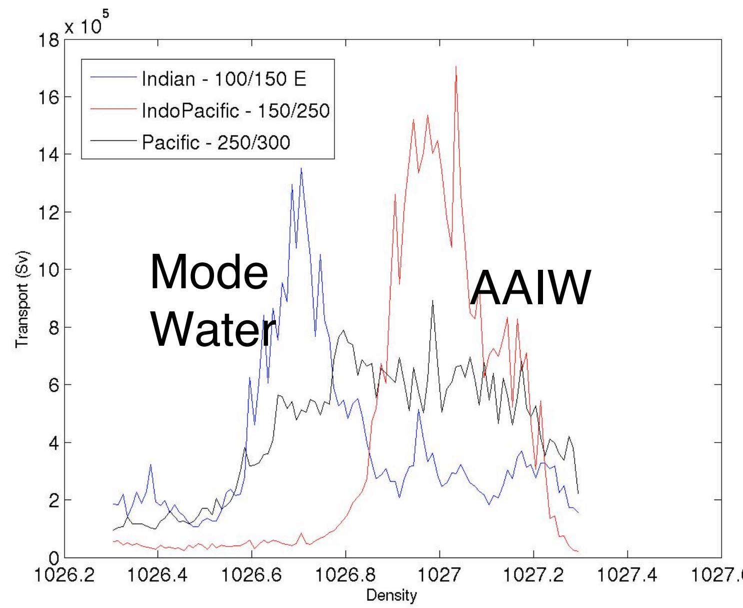
Mean Flow and MLD



ACC
and mixed layer mass transport

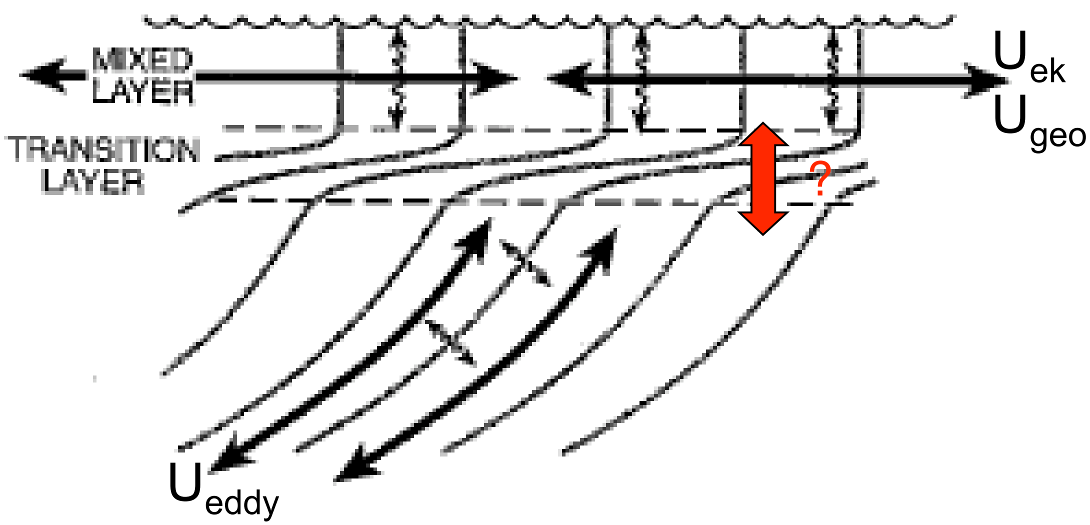


Geostrophic transport/length *in mixed layer* density classes -> accumulation in denser deeper mixed layers



Net ML transport by density: 20 Sv transferred from mode water to AAIW *in ML*

Mixed Layer Transports



Ekman transport

Geostrophic transport

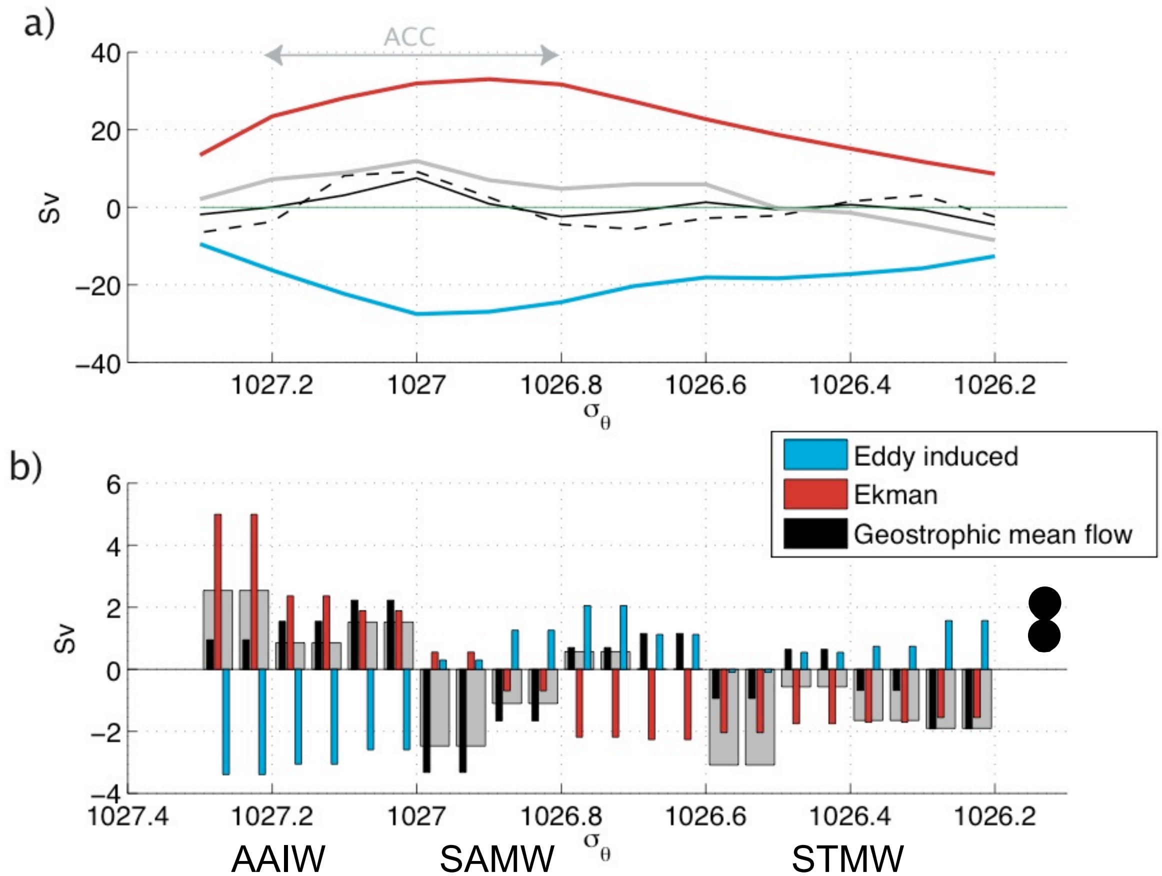
Eddy transport

Gent McWilliams interior (sub-mixed layer) eddy parameterization

Treguier et al. (97) everything spreads into the ML.

Ferrari & McWilliams (08): only a portion of the transition layer transport spreads into the ML.

Zonal Average View of Subduction



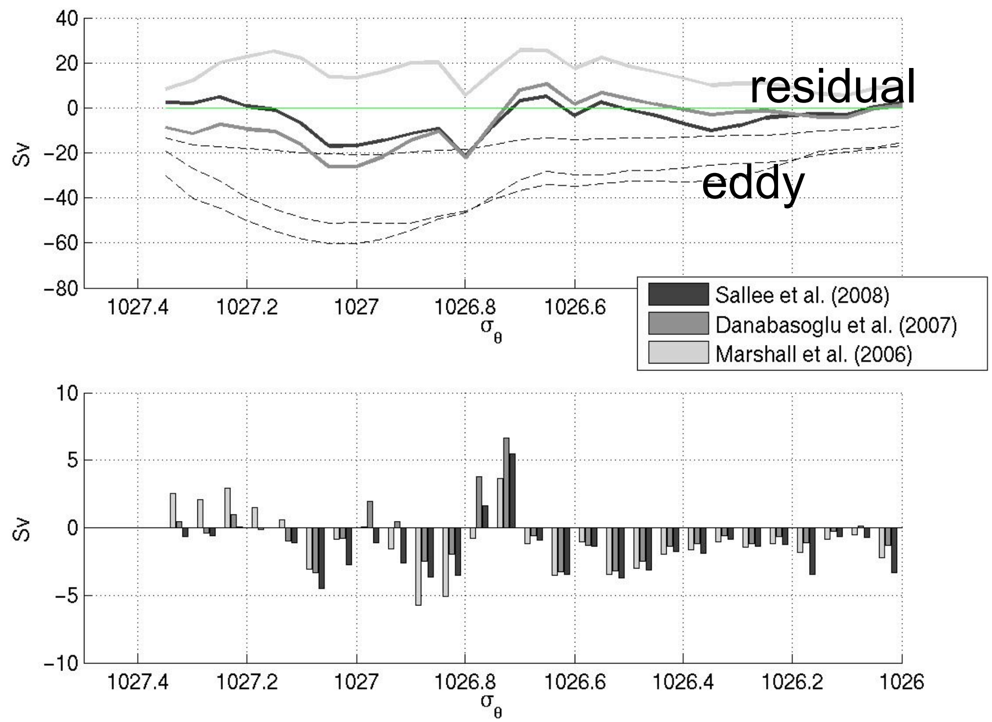
Subduction = $\nabla \bullet (U_{eddy} + U_{ek} + U_{geo})$

Sensitivity to lateral mixing coefficient K

U_{eddy} = K *x* isopycnal slope

Use K from Sallee et al (2008), compare to others

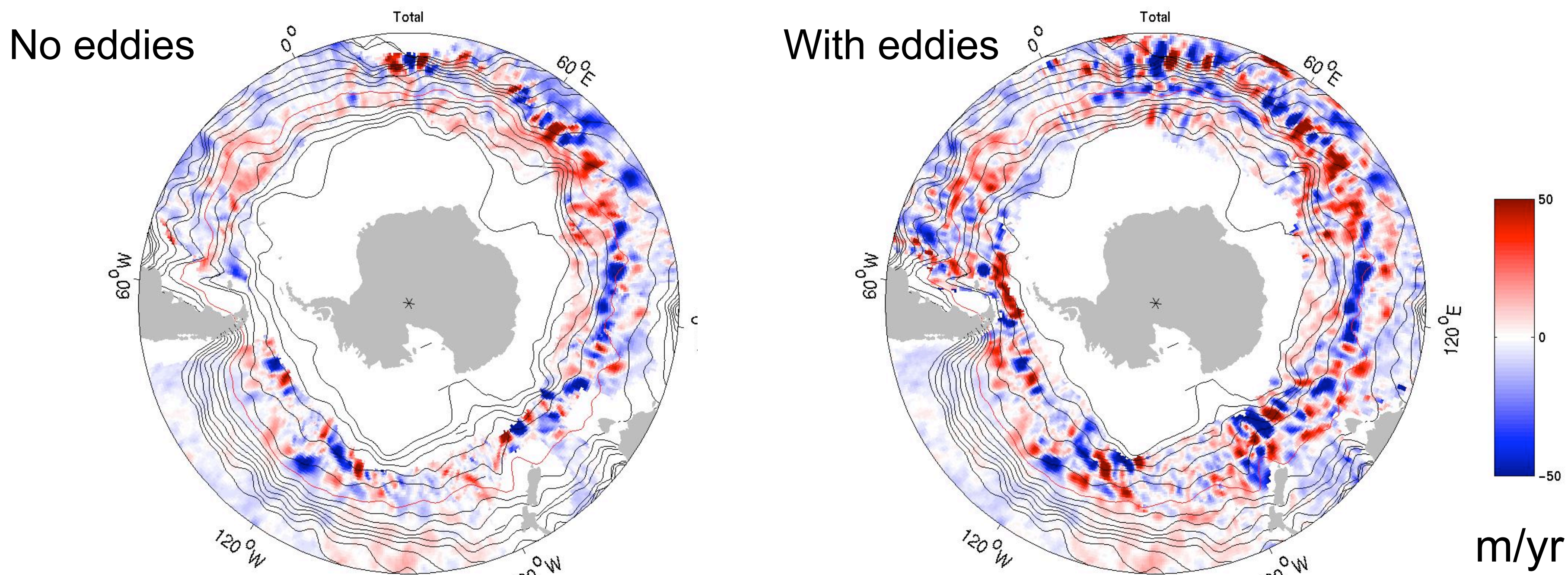
- surface estimate, projected throughout seasonal ML



Net cross-isopycnal flow very different

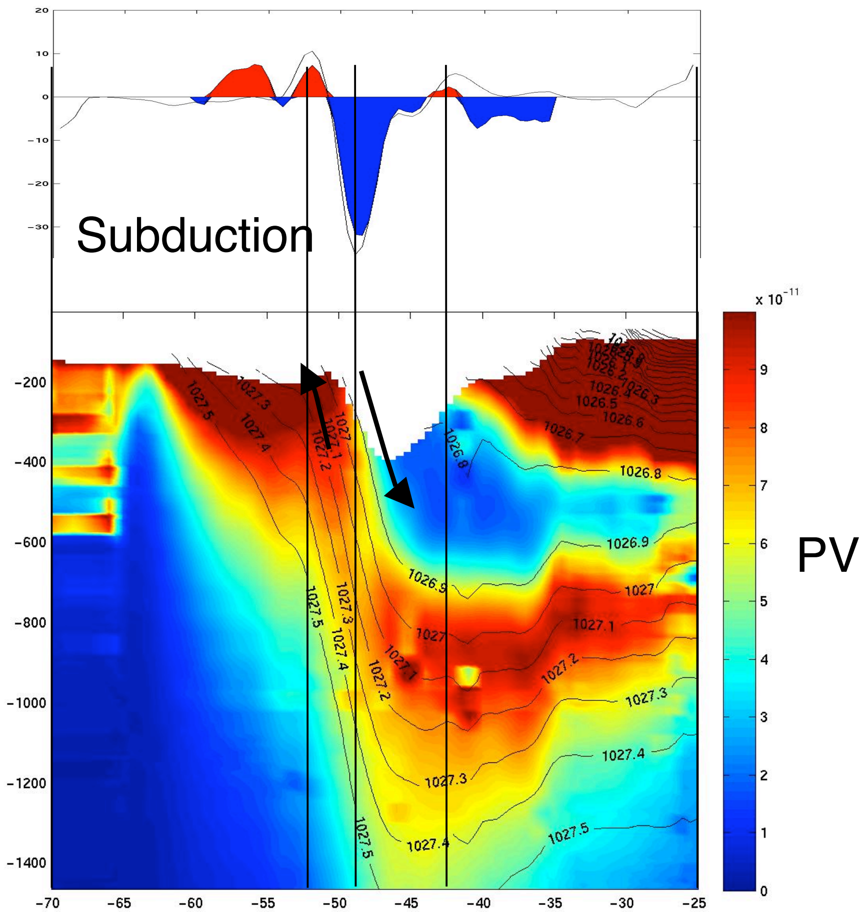
Net subduction not very different (shape is dominated by slope of isopycnal)

Maps of Subduction

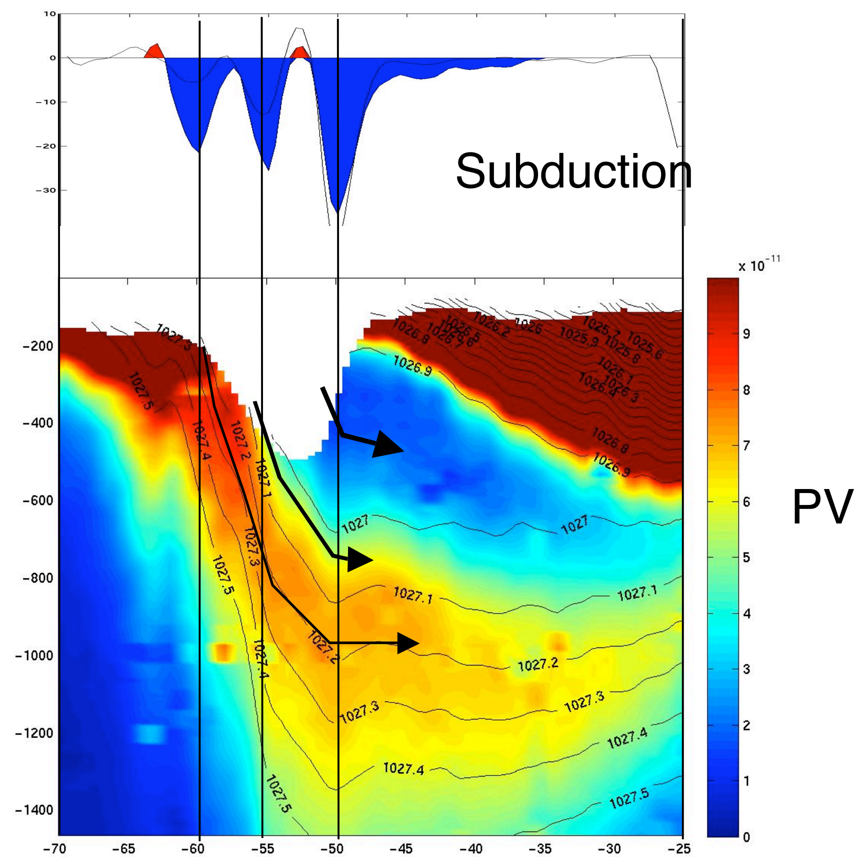


Sections of Subduction

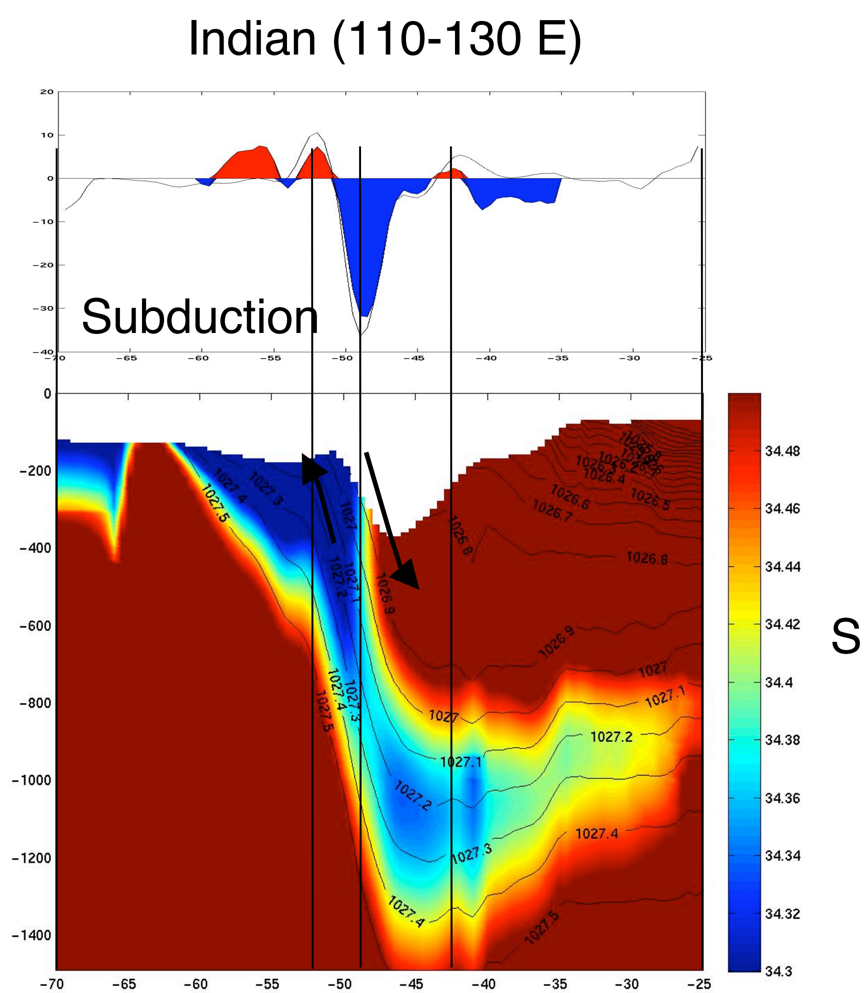
Indian (110-130 E)

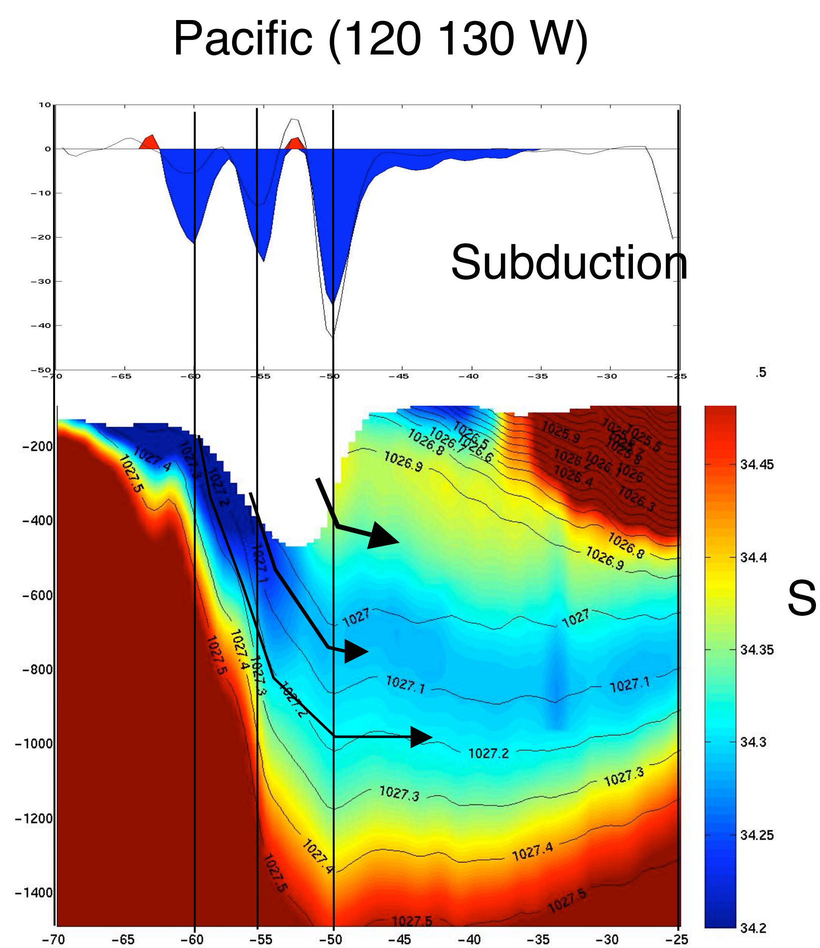


Pacific (120 130 W)

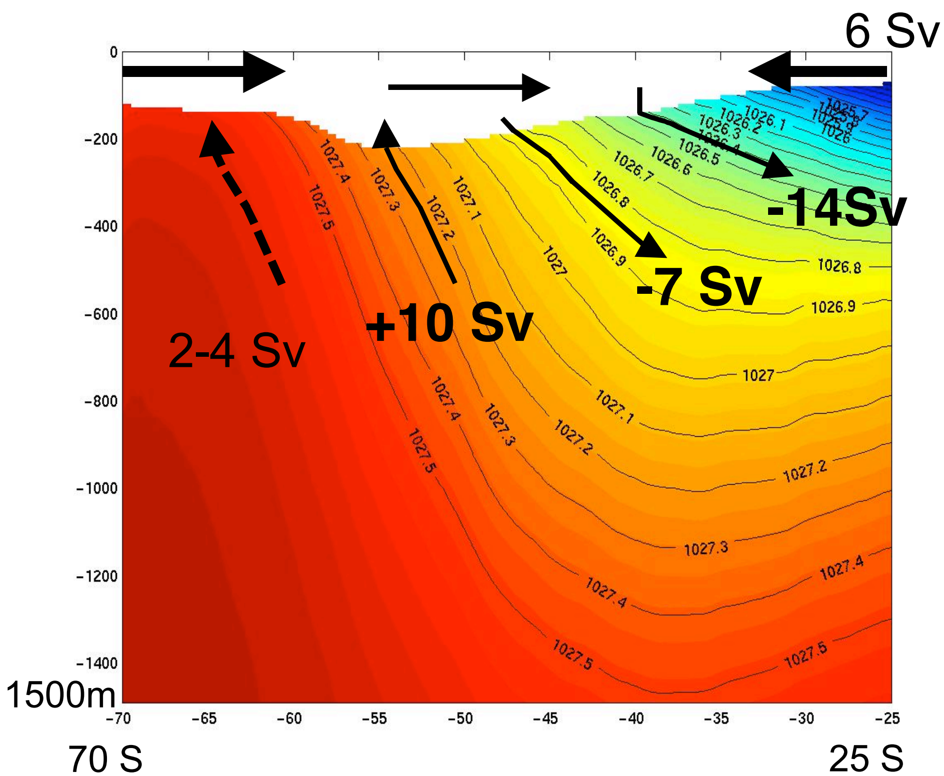


Sections of Subduction





Summary



The upper Upper Cell

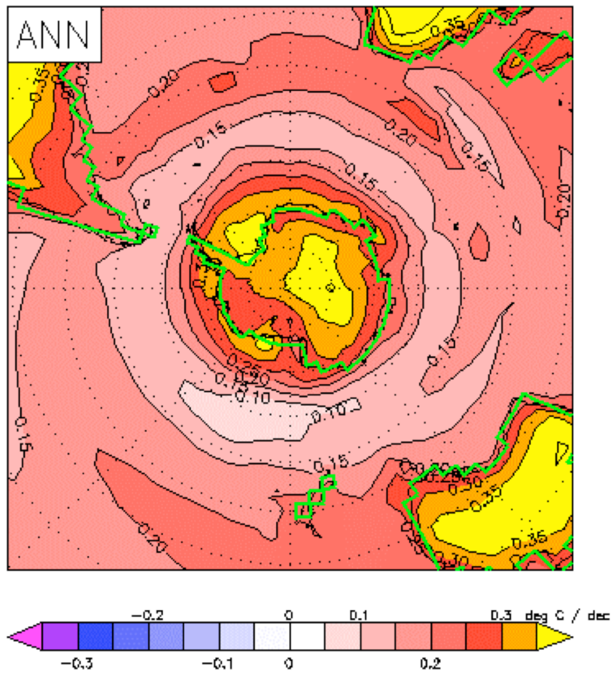
20 Sv coming up + south, 20 Sv going down, creating mode waters

Eddies tend to cancel mean flow at high and low densities

Eddies tend to concentrate subduction at fronts

Sallee, Rintoul, Matear (2009) find carbon fluxes associated with these subduction estimates.

ML Evolution
Predicted trends in ST



Predicted trends in surface temperatures over the next 100 years from a weighted average of the 20 coupled models used in IPCC AR4 (Bracegirdle et al., 2008).

Mixed Layer Response: SST

Driven by modified atmosphere-ocean heat fluxes and Ekman flow

FAST

•SST responds to the SAM within 1 month

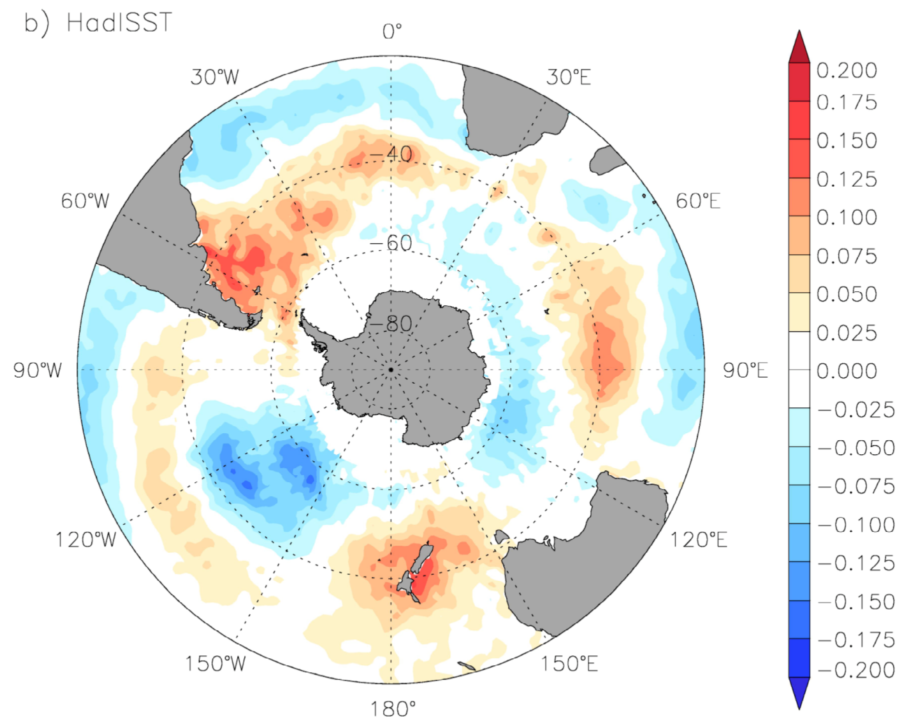
•Between 50-65°S cooling due to enhanced northward Ekman transport

•Between 30-45°S warming due to anomalous southward Ekman transport

SLOW.

•2-3 yr lagged warming in eddy-resolving models in south, *outweighs* initial cooling

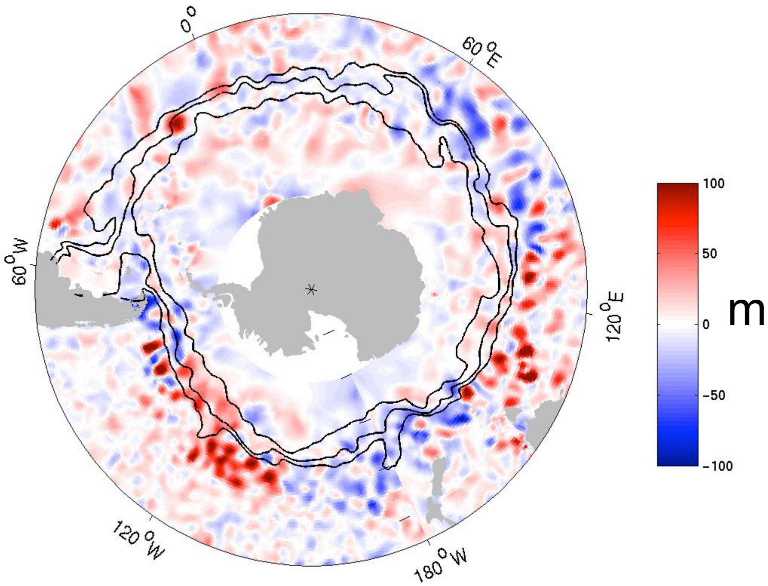
SST regressed on SAM



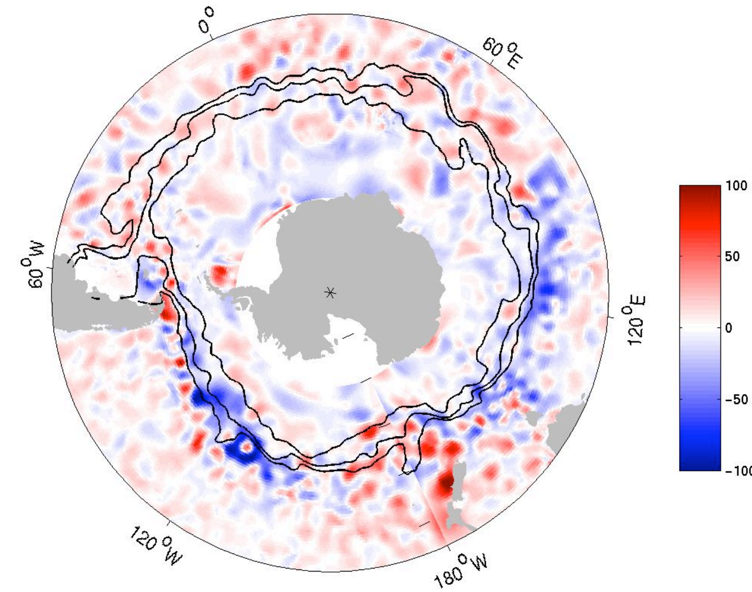
Screen et al J. Climate 2009

Mixed Layer Response: MLD

SAM+



SAM-



MLD Trends may be important for subduction, productivity

Sallee et al. 2009

Questions

Is there an "oceanic SAM"?
•Most variability is associated with meandering fronts
•Most meandering is a response to SAM or ENSO
•Internal EKE variations are ~ EKE variations forced by wind

Is overturning adiabatic or diabatic below the ML?
•Nonlocal fluxes
•Nonlinear EOS
•Highly intermittent processes

How are natural carbon, warm deep water brought to the surface?
•Ekman upwelling
•Recirculation in the TL and ML
•Upper Cell eddy-driven upwelling

What do we need a SOOS for?
•Freshwater fluxes
•Acidification