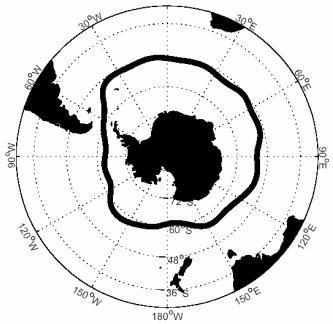
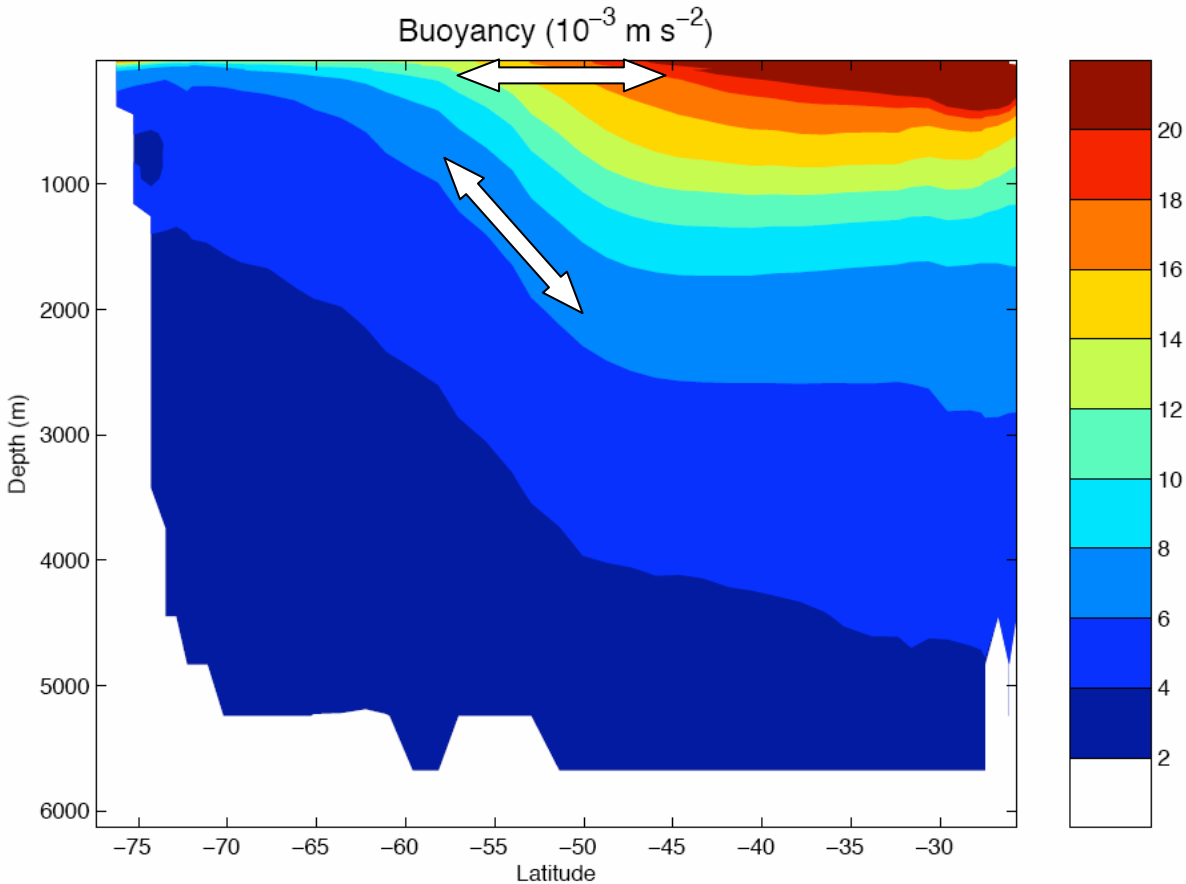
Eddy stirring and mixing in the southern ocean

John Marshall, Ryan Abernathey, MIT

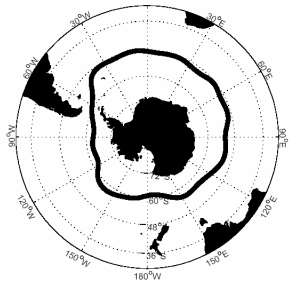
Shafer Smith, Courant, NYU

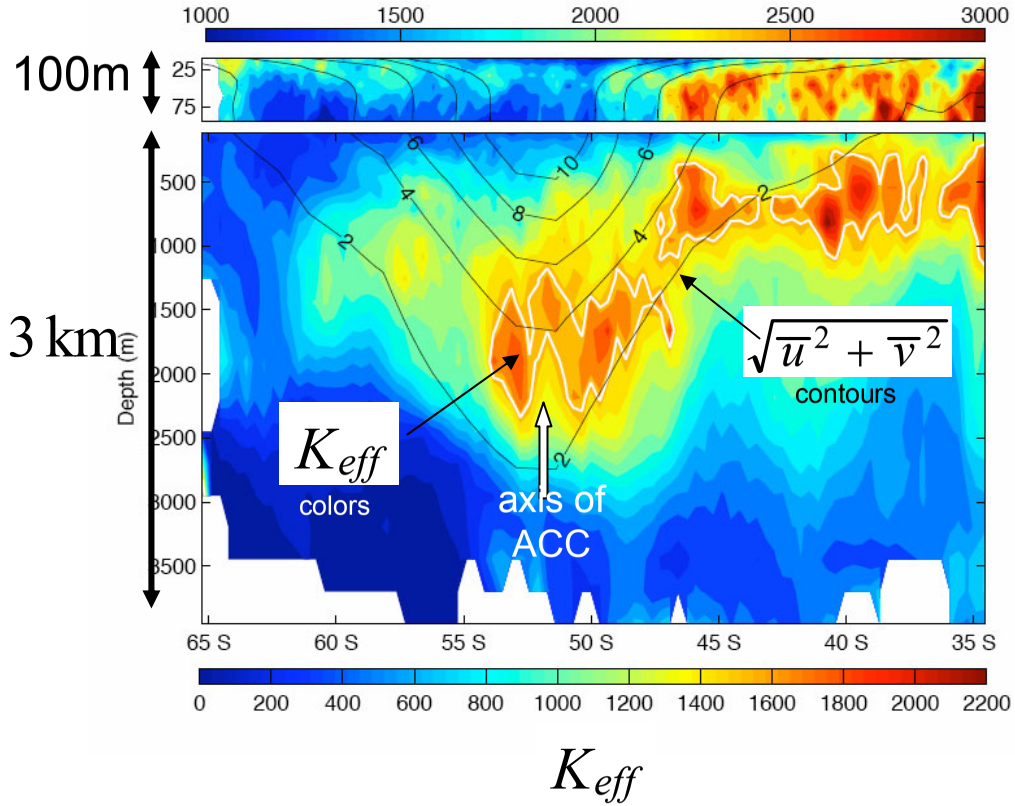
Emily Shuckburgh, BAS





Likely meridional structure of K_{eff}





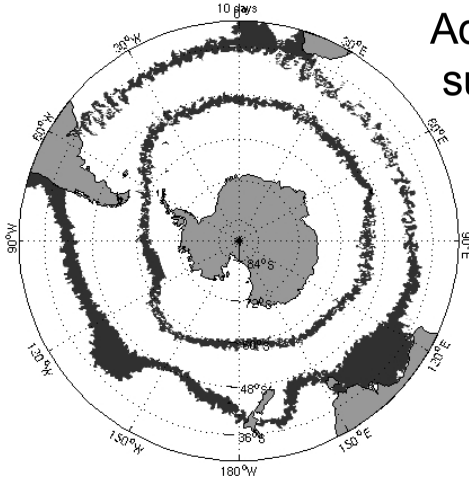
How did we obtain this distribution?

Does it make sense dynamically?

What are the implications for the dynamics of the southern ocean and the overturning circulation?

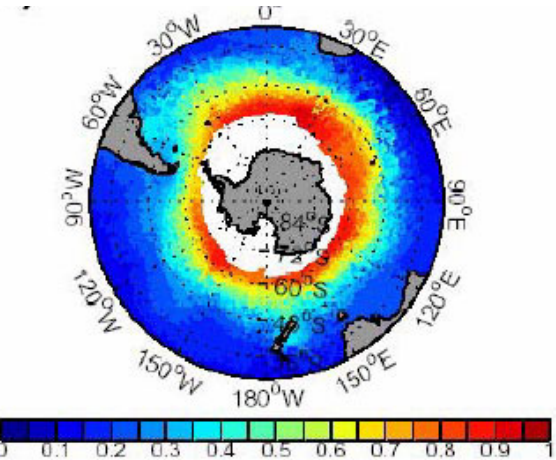
Implications for DIMES?

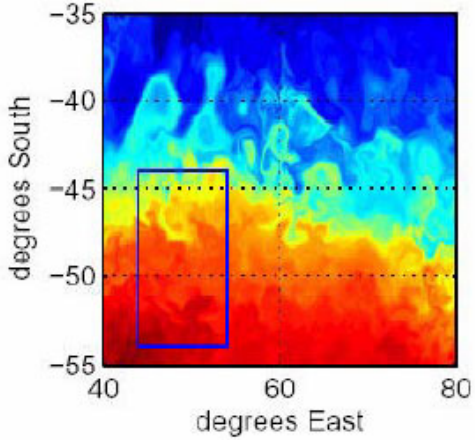
Inferring surface eddy diffusivities from altimetry

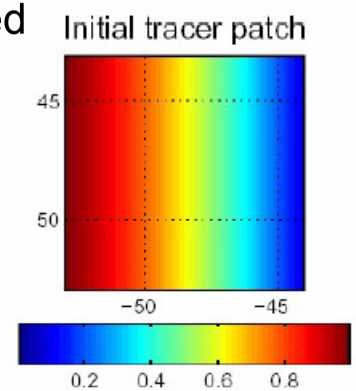


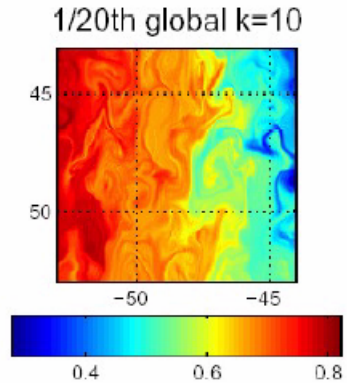
Advect tracer with altimetric-derived surface velocities

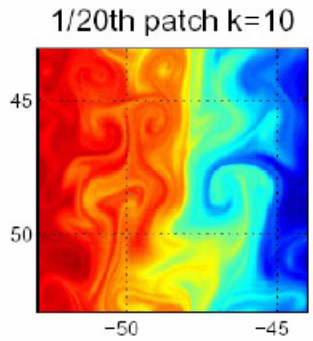
$$\frac{\partial q}{\partial t} + \mathbf{v} \cdot \nabla q = k \nabla^2 q$$

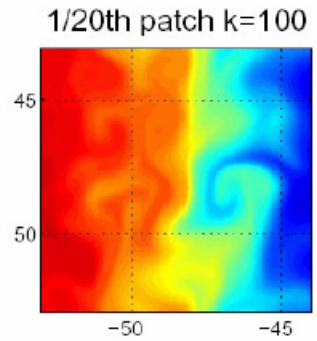


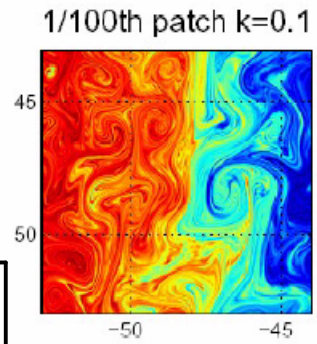


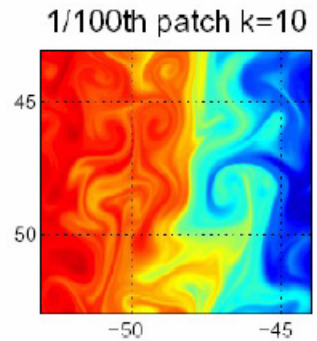










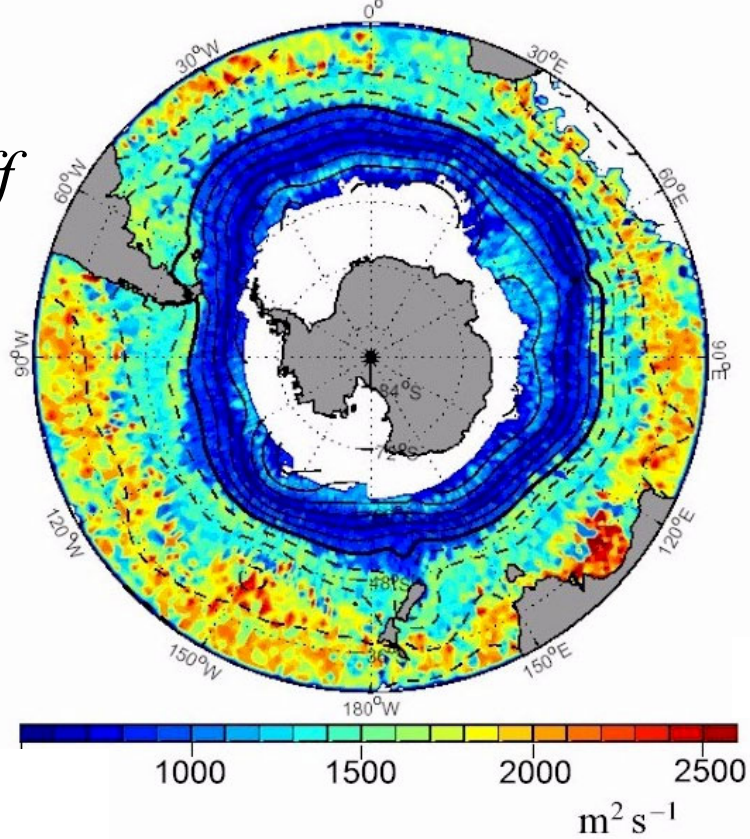


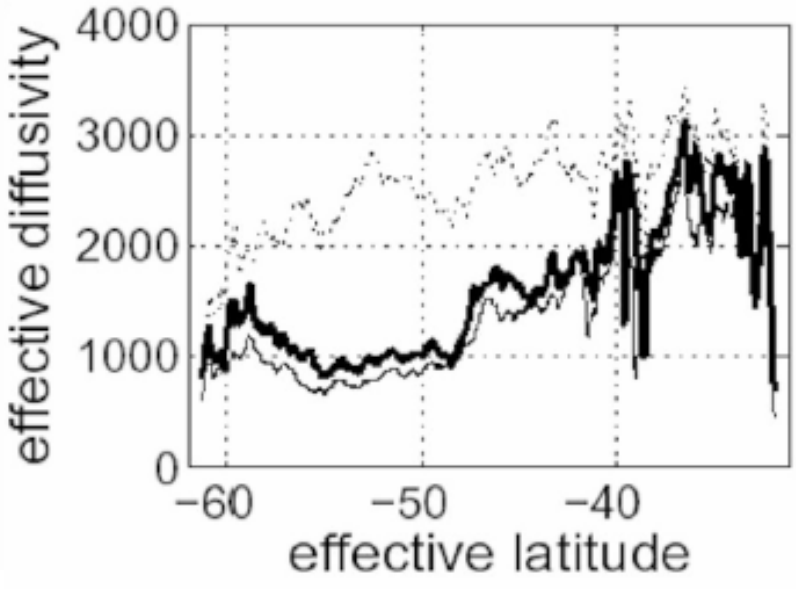
Nakamura, 1996

Marshall, Shuckburgh et al 2006

$$K_{eff} = k \frac{L_{eq}^2}{L_{\min}^2}$$

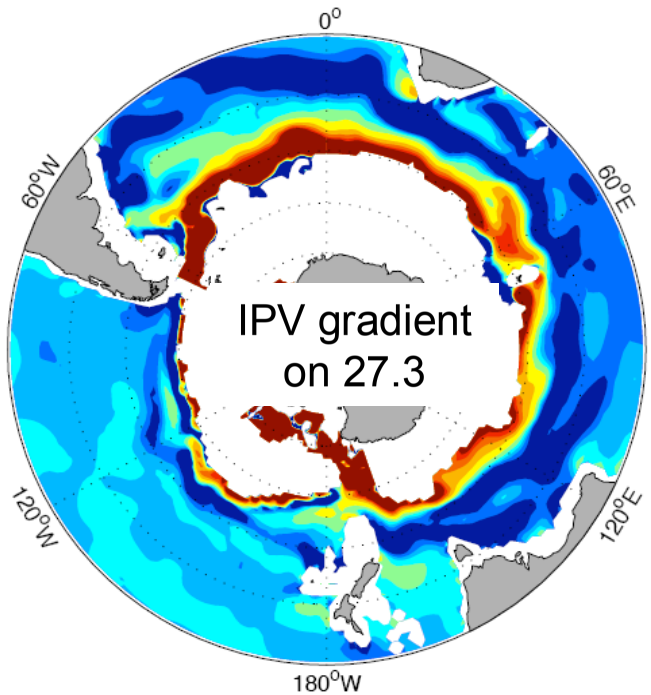
K_{eff}



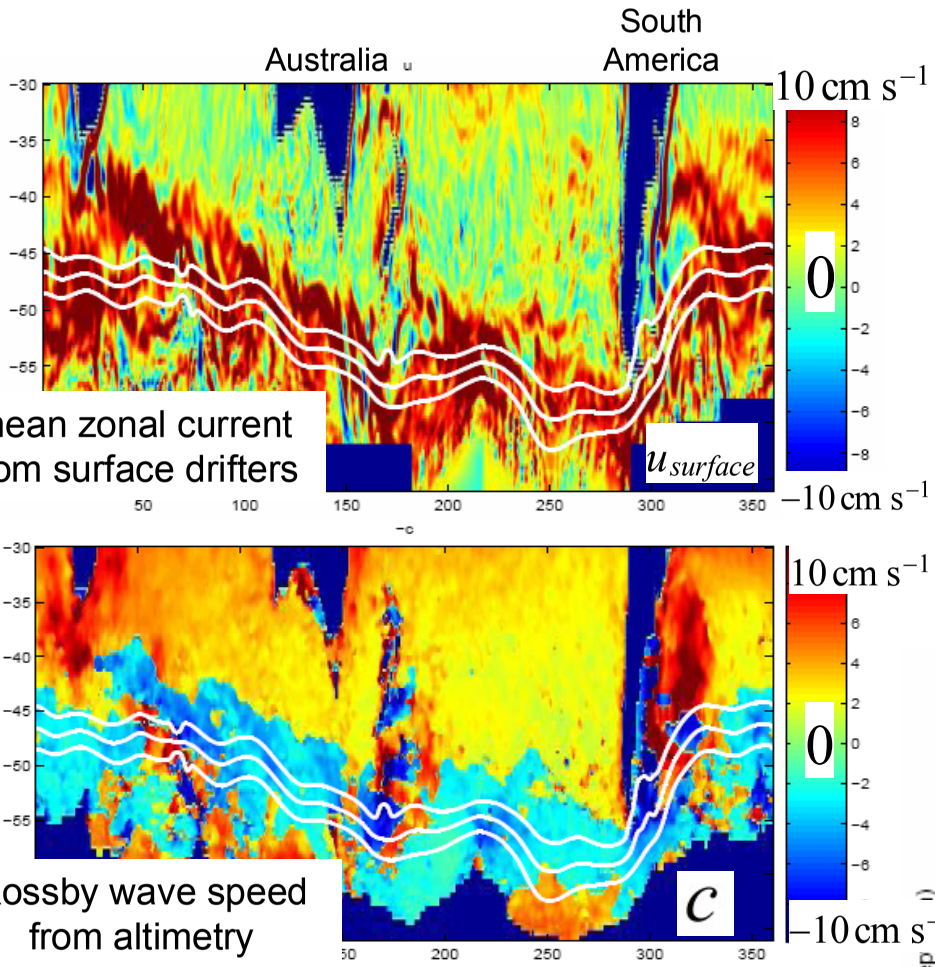


Marshall, Shuckburgh et al, 2006, JPO

What about the subsurface distribution?



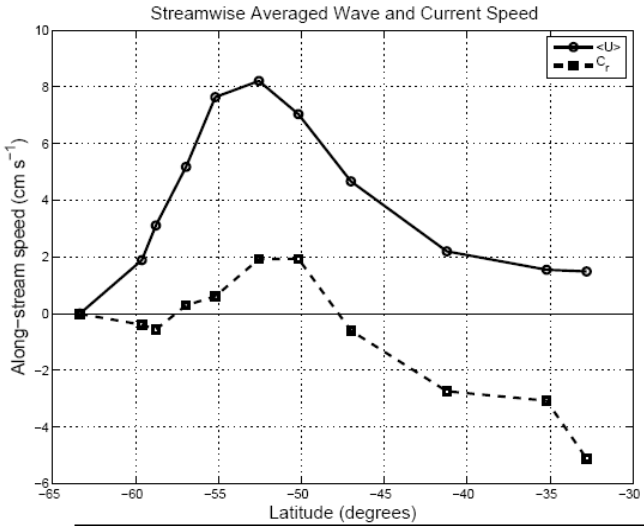
Hints from satellite altimetry



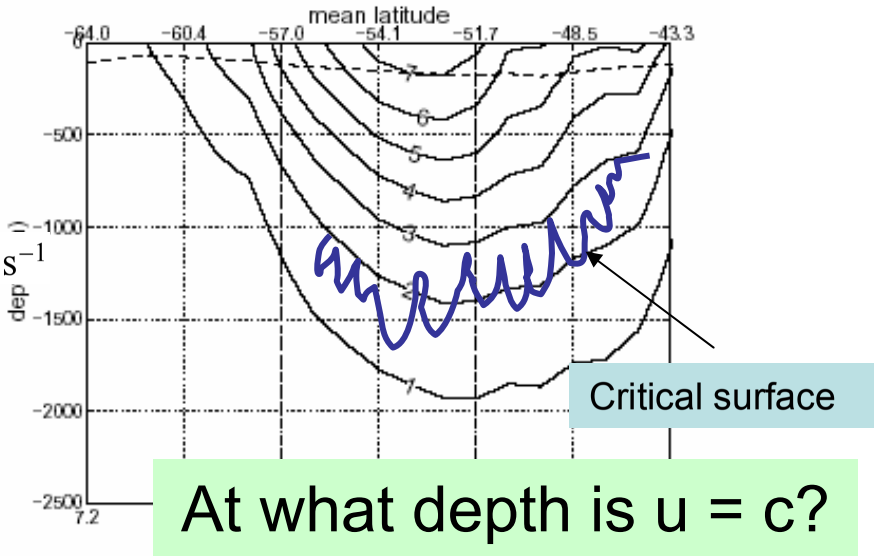
mean zonal current from surface drifters

Rossby wave speed from altimetry

Chris Hughes



What might these observations suggest about eddy mixing?



Smith and Marshall, 2008

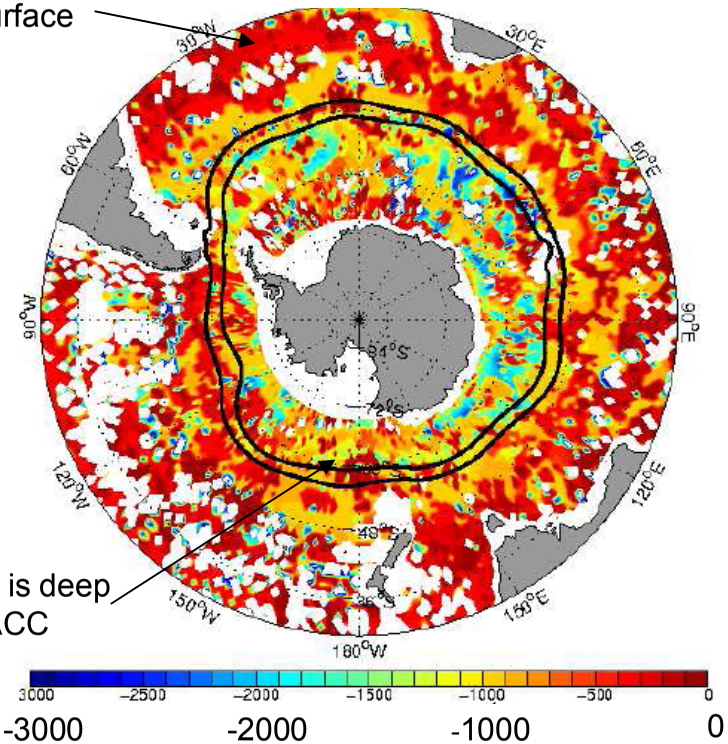
At what depth is u = c?

Linear stability analysis of WOCE climatology

Shafer Smith (2008)

Critical level rises up toward the surface

Critical layer depth



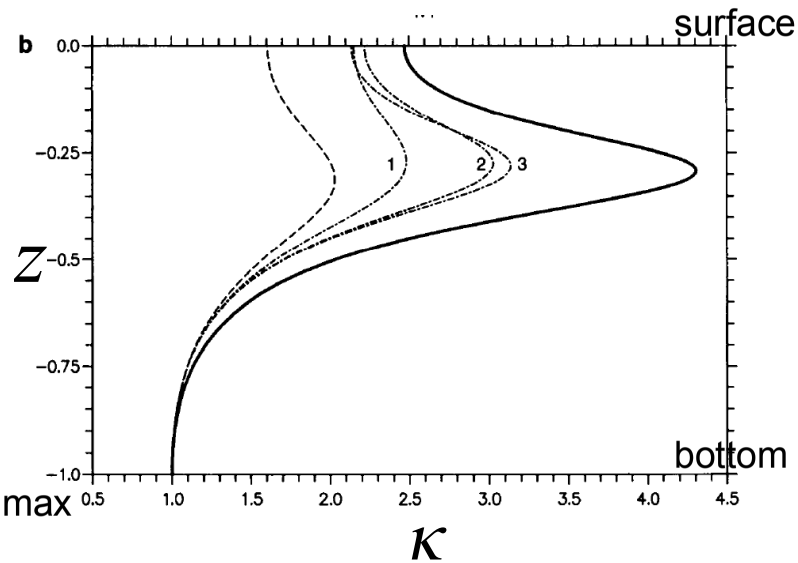
Critical level is deep in 'core' of ACC

Linear baroclinic instability theory suggests

Green, 1970, Marshall, 1982, Killworth, 1997

Diffusivity

$$\kappa(x, y, \rho) = \frac{kc_i}{2f^2\rho_0^2}\left|\frac{B}{\tilde{u} - c}\right|^2$$



- Linear theory → - Critical surface
  - level at which APE release is max
- Strongly non-linear → - Strongest mixing where PV gradients are smallest and visa-versa

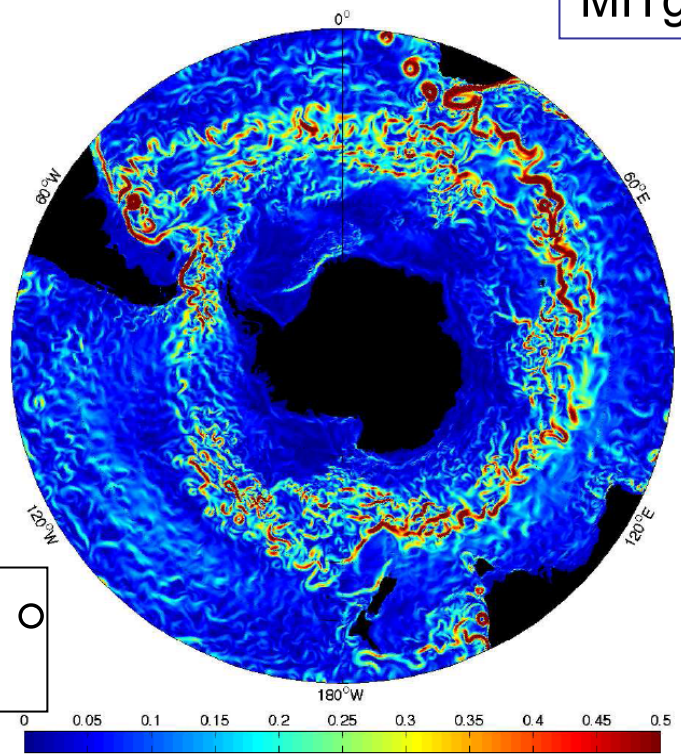
expect to observe enhanced stirring by eddies at mid-depth in core of ACC

Effective diffusivities estimated from an eddy resolving model constrained by observations

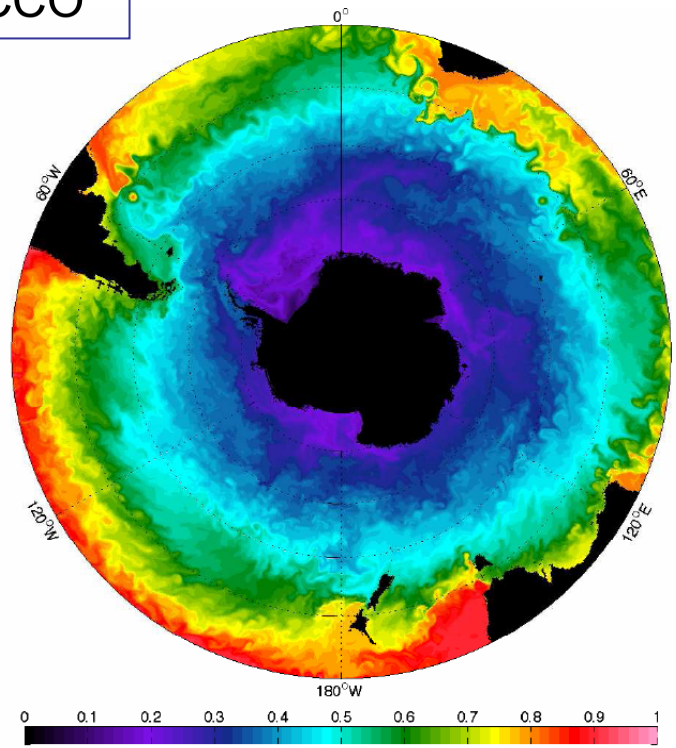
Gael Forget

MITgcm + ECCO

$\frac{1}{6}^\circ \times \frac{1}{6}^\circ$



Surface current speed

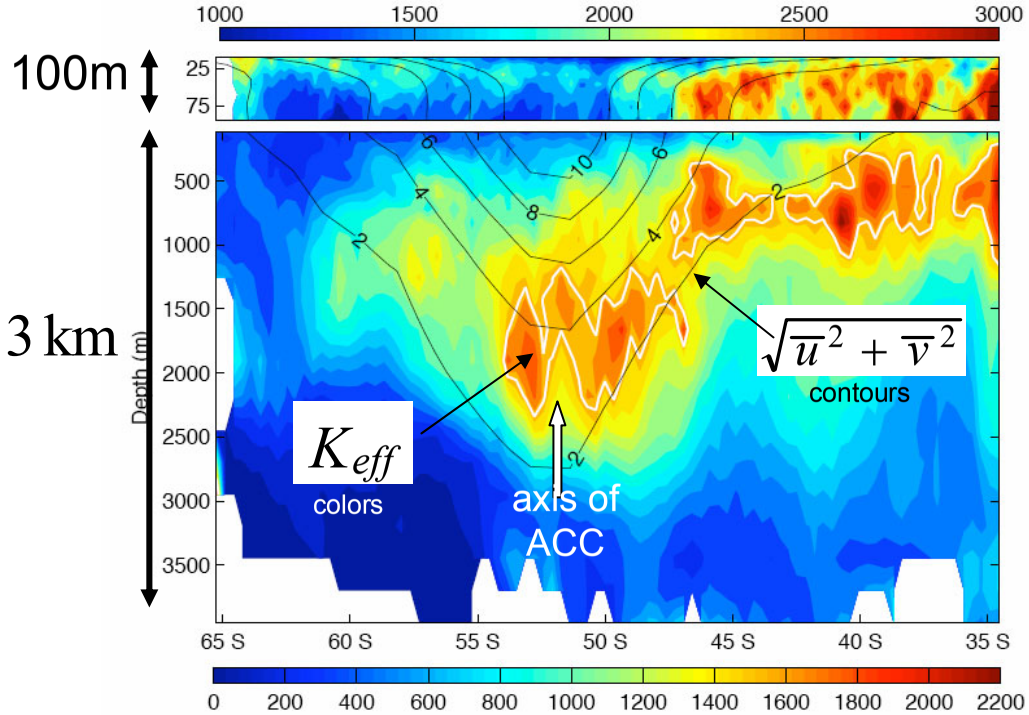


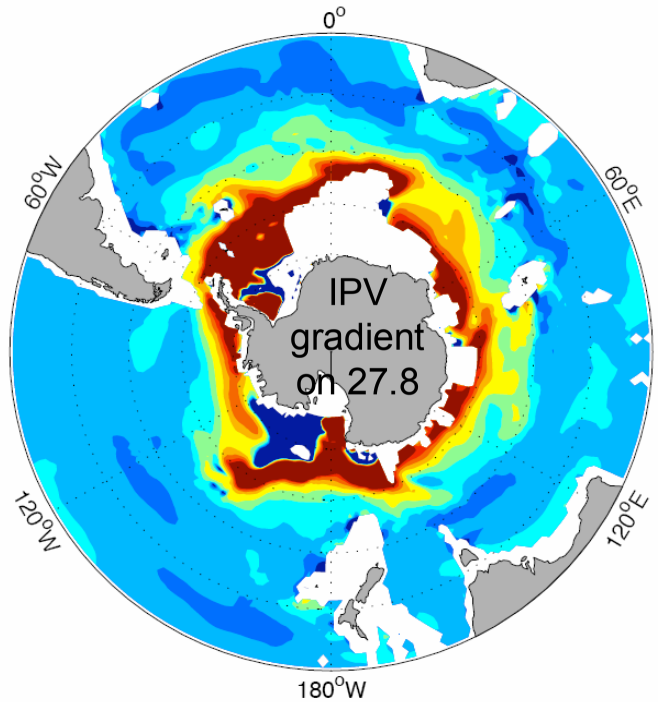
Surface tracer distribution

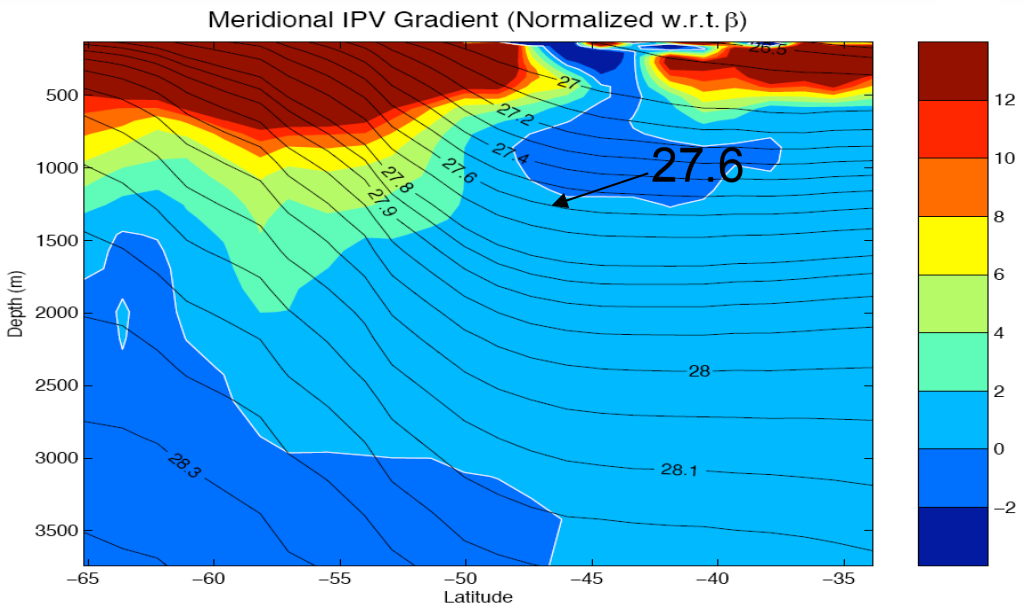
$$\frac{\partial q}{\partial t} + \mathbf{v} \cdot \nabla q = k \nabla^2 q$$

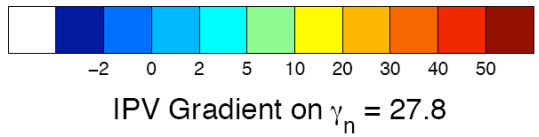
carry out calculation
in 3-dimensions

Ryan Abernathey
Matt Mazloff









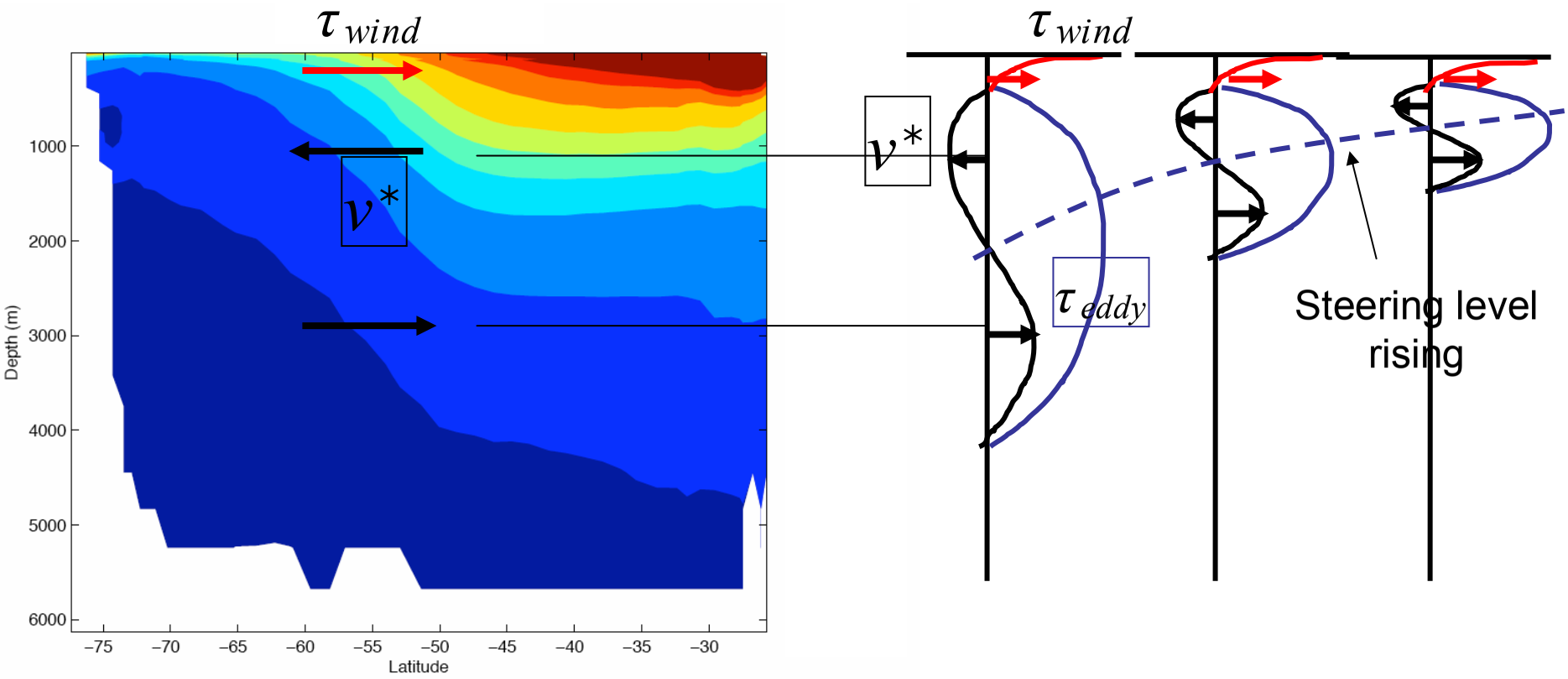
IPV gradient normalized wrt $\beta\langle N^2 \rangle$

Diffusivity is small in regions of high gradients of IPV

Idealized schematic of eddy-driven circulation

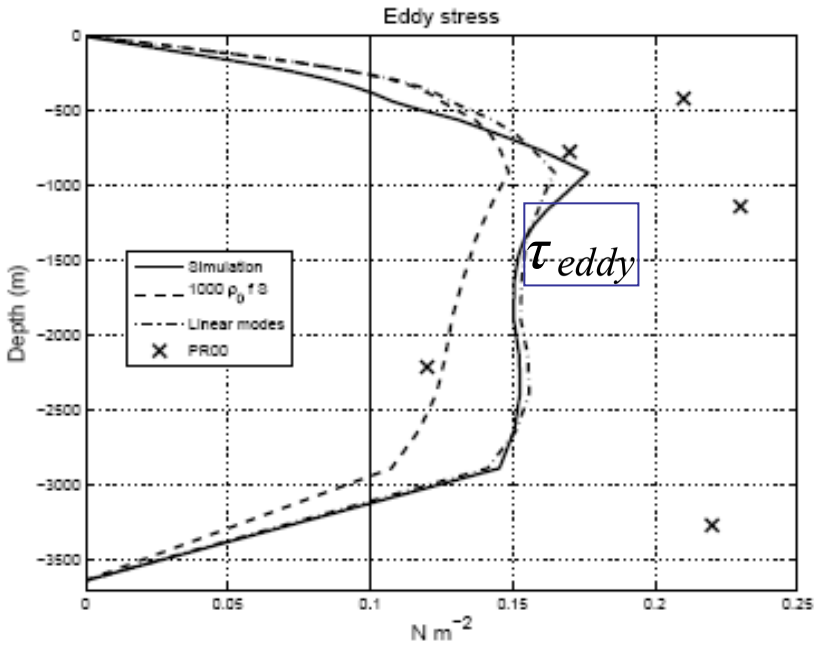
Eddy driven circulation

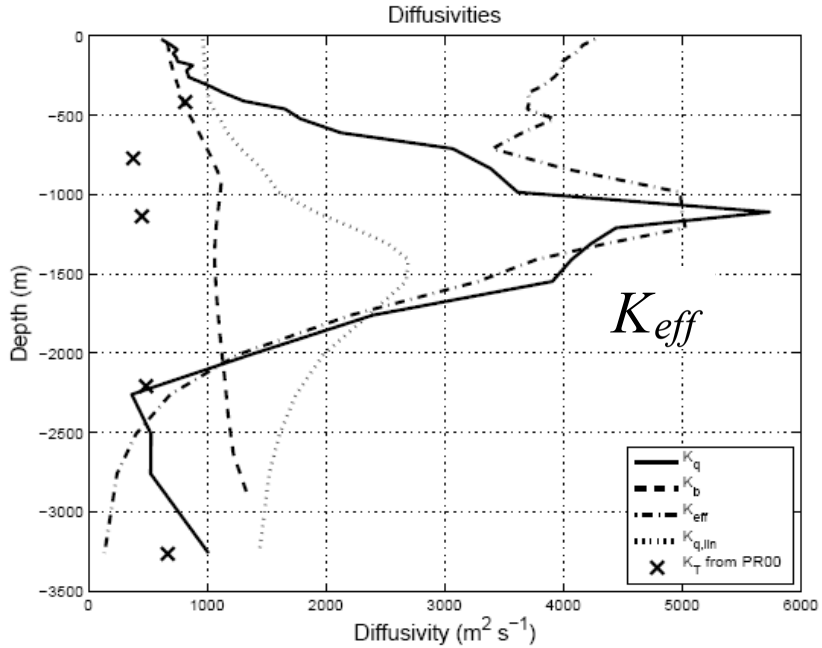
$$-fv^* = \overline{v'q'} = \frac{\partial \tau_{eddy}}{\partial z}$$



Detailed study of vertical structure at one location

Smith and Marshall (2008)





141E, 51S mooring site

Phillips and Rintoul 2000

Calculations of turbulent fluxes from a local 'process' quasi-geostrophic model constrained by observations

Conclusions

Multiple viewpoints lead one to the conclusion that eddy mixing is peaked at depth in the ACC

1. Steering level considerations
2. Depth of baroclinic conversion
3. Geography of PV gradients and gradient reversals
4. Brute calculations from an eddy resolving model constrained by observations
5. Detailed calculations of turbulent fluxes from a ‘process’ quasi-geostrophic model constrained by observations

Important implications for the dynamics of the ACC

What next?

Regional patterns must be mapped out

DIMES provides ground truth in one region