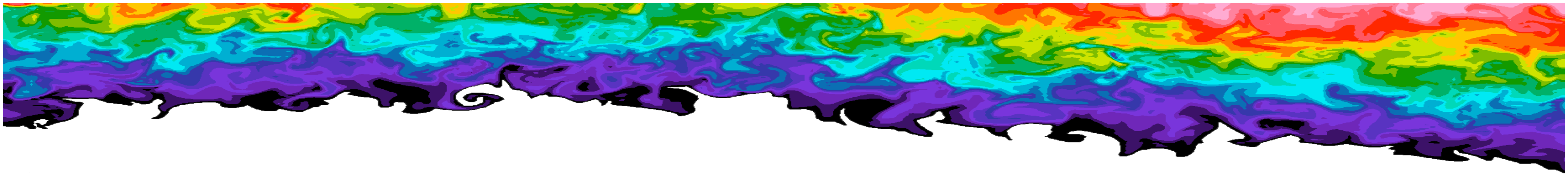
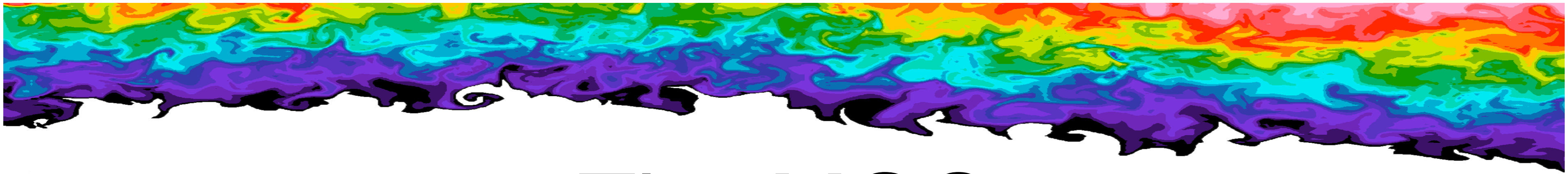


Diagnosing Eddy Mixing in the Southern Ocean from SOSE

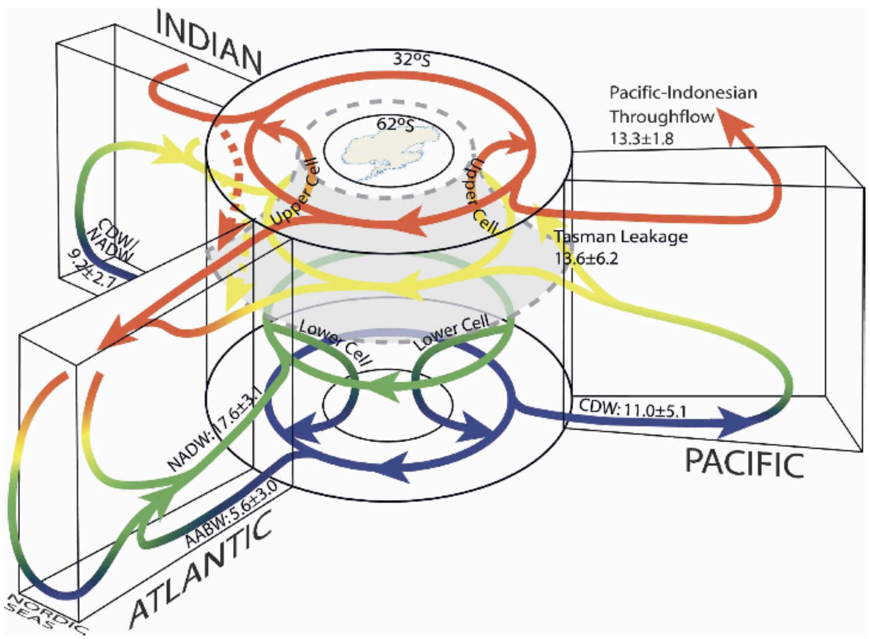
Ryan Abernathey

With

John Marshall, Matt Mazzloff and Emily Shuckburgh

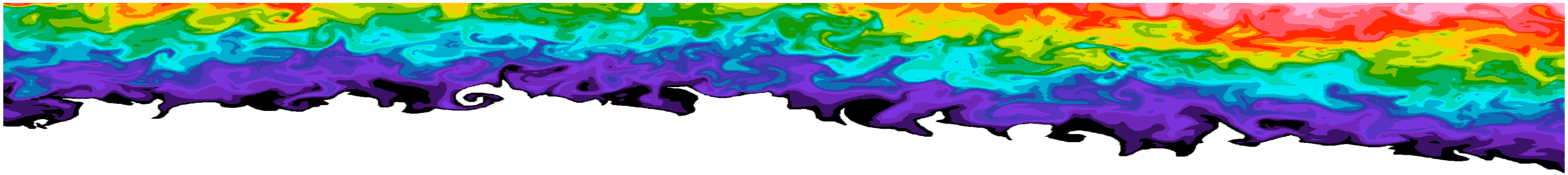


The MOC

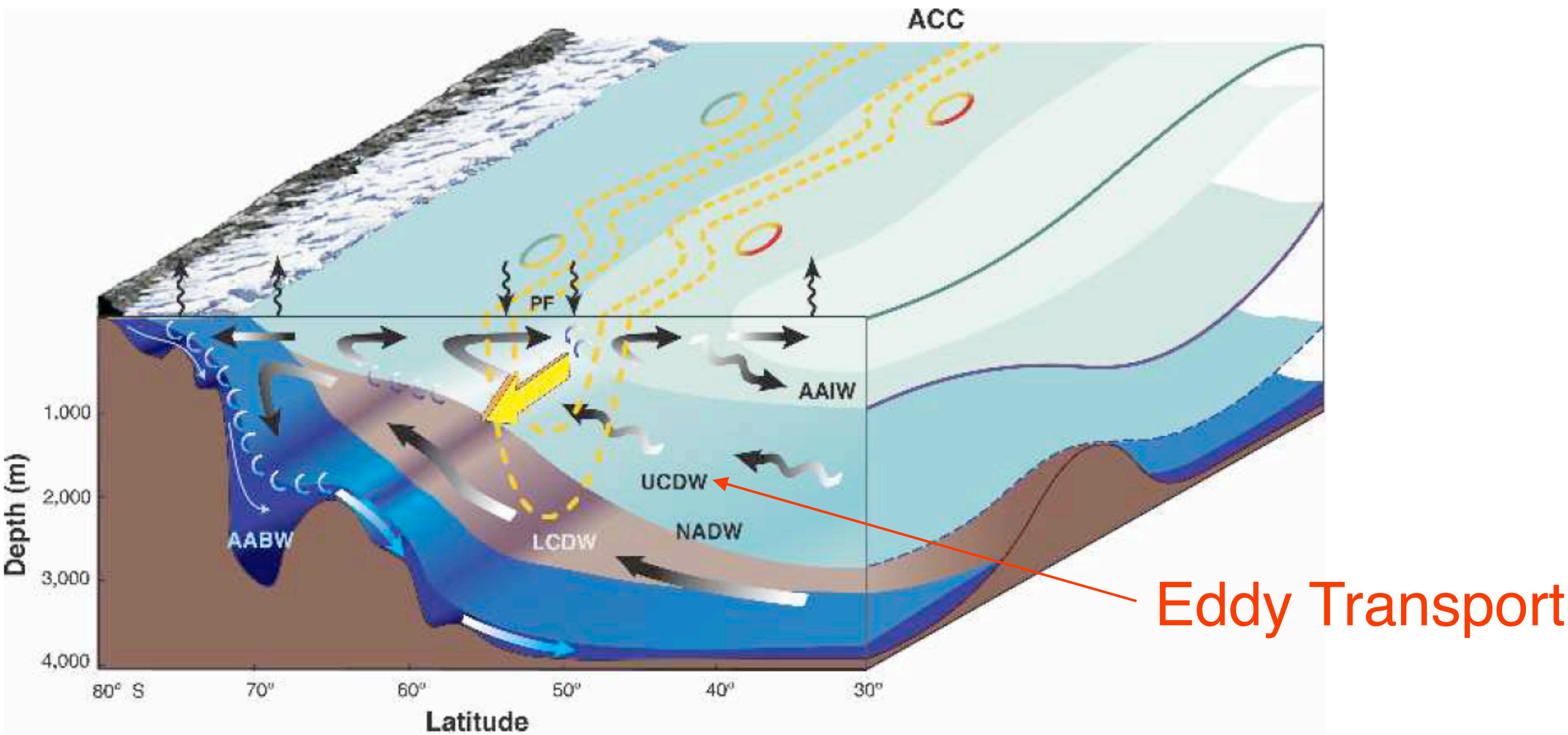


Lumpkin & Speer (2007)

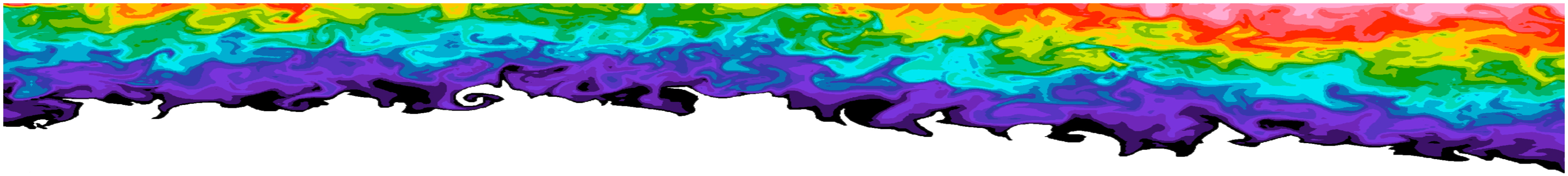
- Contributes to poleward heat transport
- Supplies surface biology with nutrients
- Determines rate of oceanic uptake of anthropogenic CO2
- Fundamental role in climate system!



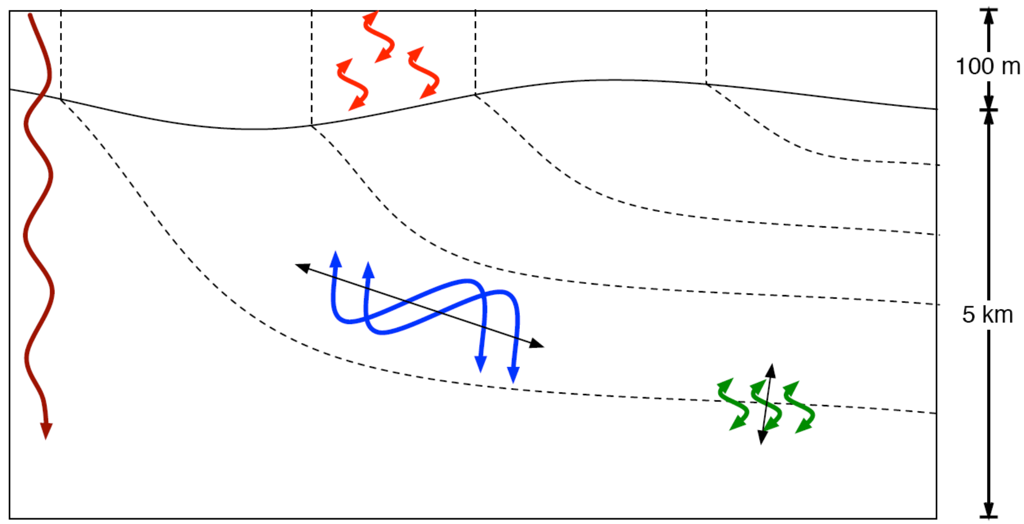
Southern Ocean Meridional Overturning



Speer Et Al. (2000) via Olbers and Visbeck (2005)



Unresolved Mixing Processes in Coarse Ocean Models



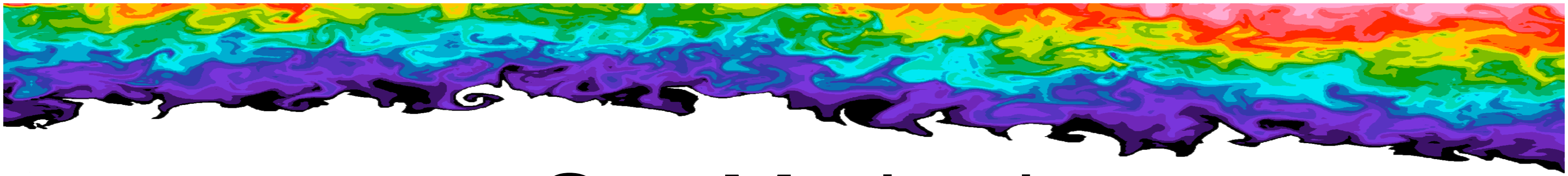
Mixed Layer Convection ~ 100 m

Deep Convective Plumes ~ 500 m

Isopycnal Transfer by Mesoscale Eddies ~ 10 km

Diapycnal Mixing in the Deep Ocean ~ 1 m

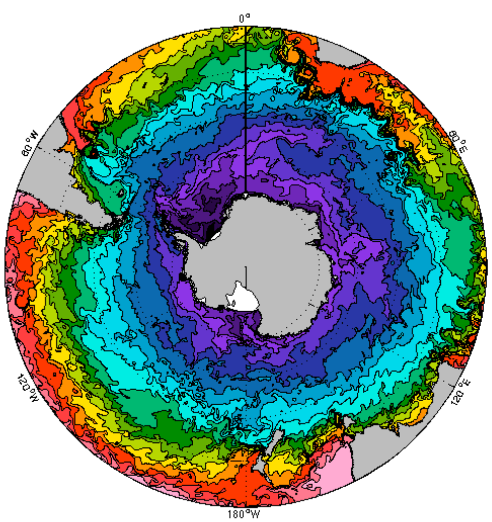
Eddy resolving “climate models” might still be far away.
Parameterization of mesoscale eddy transfer still important!



Our Method

- Simulate the advection of a passive tracer by the SOSE velocity fields
- Determine the “equivalent length” of a streched contour

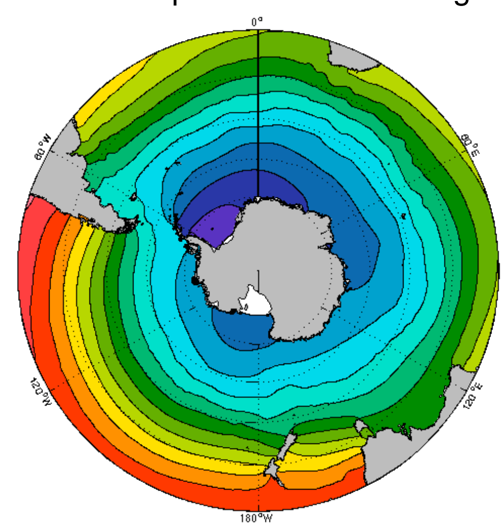
streched contours



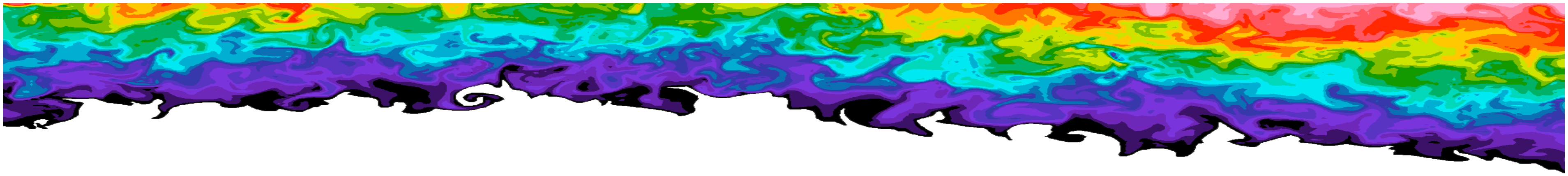
$\kappa = 50\ \mathrm{m^2 s^{-1}}$

$$K_{eff} = \kappa \frac{L_e^2}{L_{min}^2}$$

minimum possible contour length

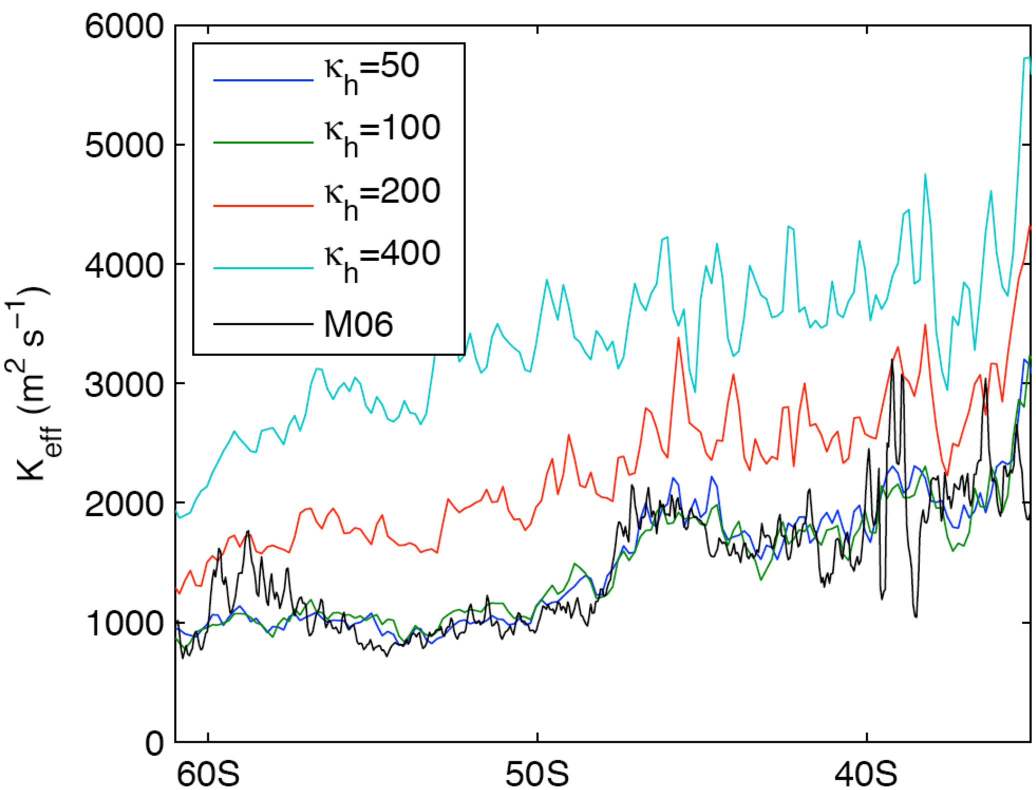


$\kappa = 40000\ \mathrm{m^2 s^{-1}}$



Comparison with Marshall et al. (2006)

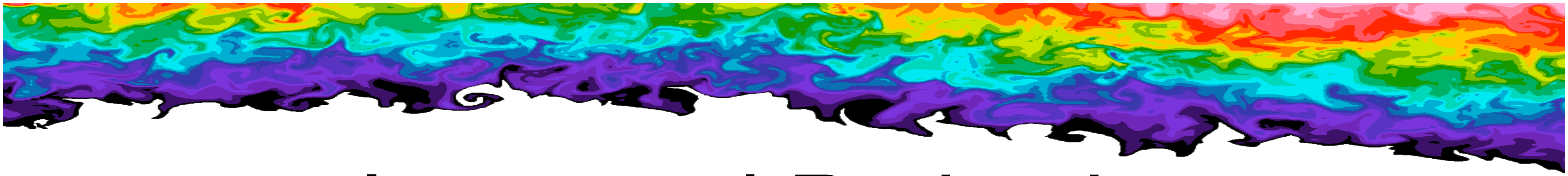
Horizontal effective diffusivity at 100 m depth



We are limited to the 1/6 degree grid of SOSE: numerical diffusion sets a lower bound on k. Too large k blurs fine-scale structure.

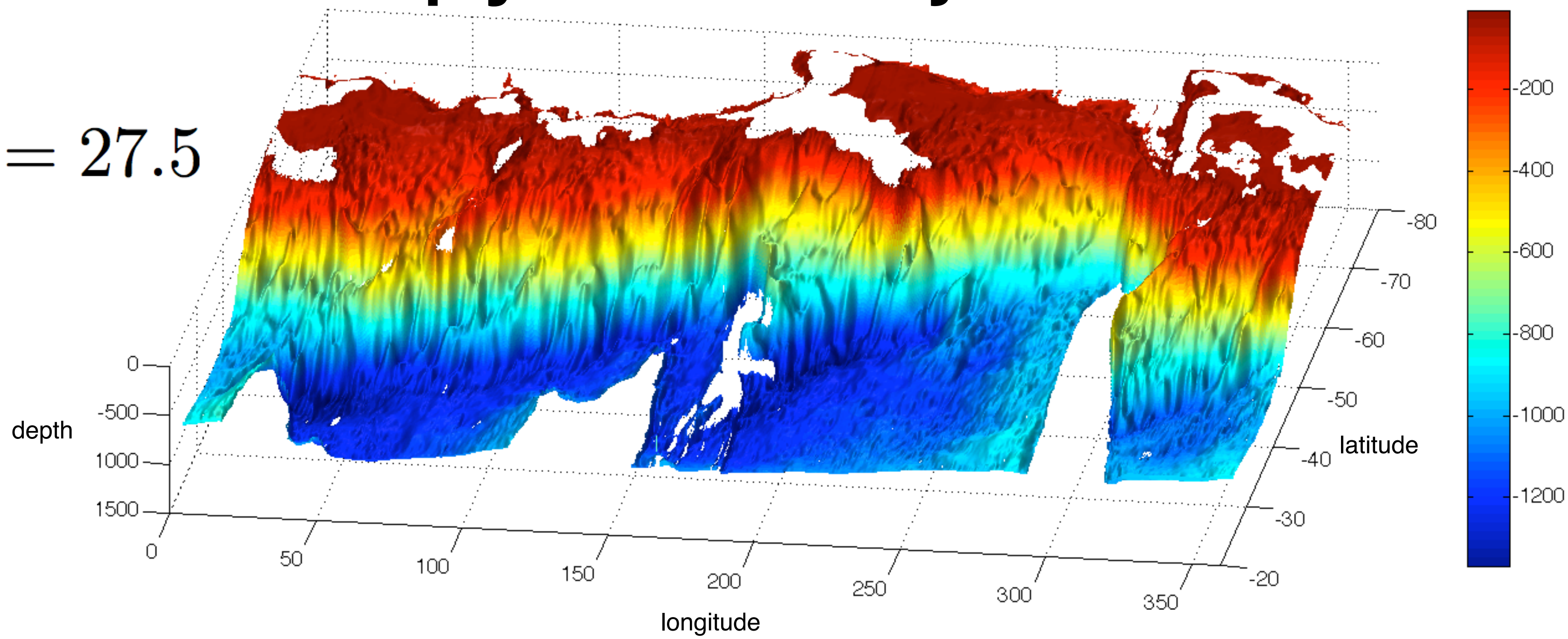
M06 investigated much finer grids. Our convergence with their results is encouraging.

Chose to analyze k = 100 case.



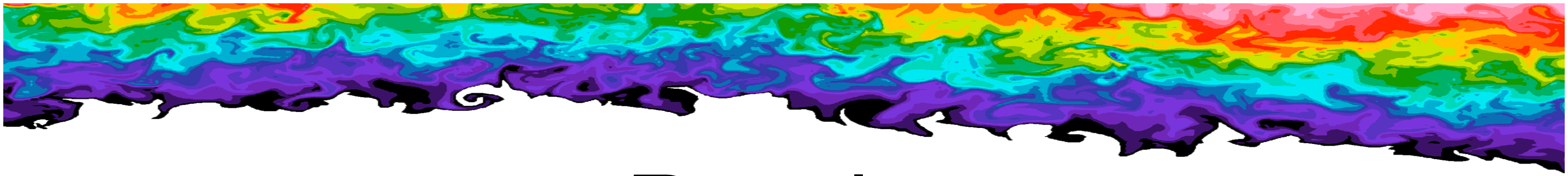
Isopycnal Projection

$$\gamma^n = 27.5$$

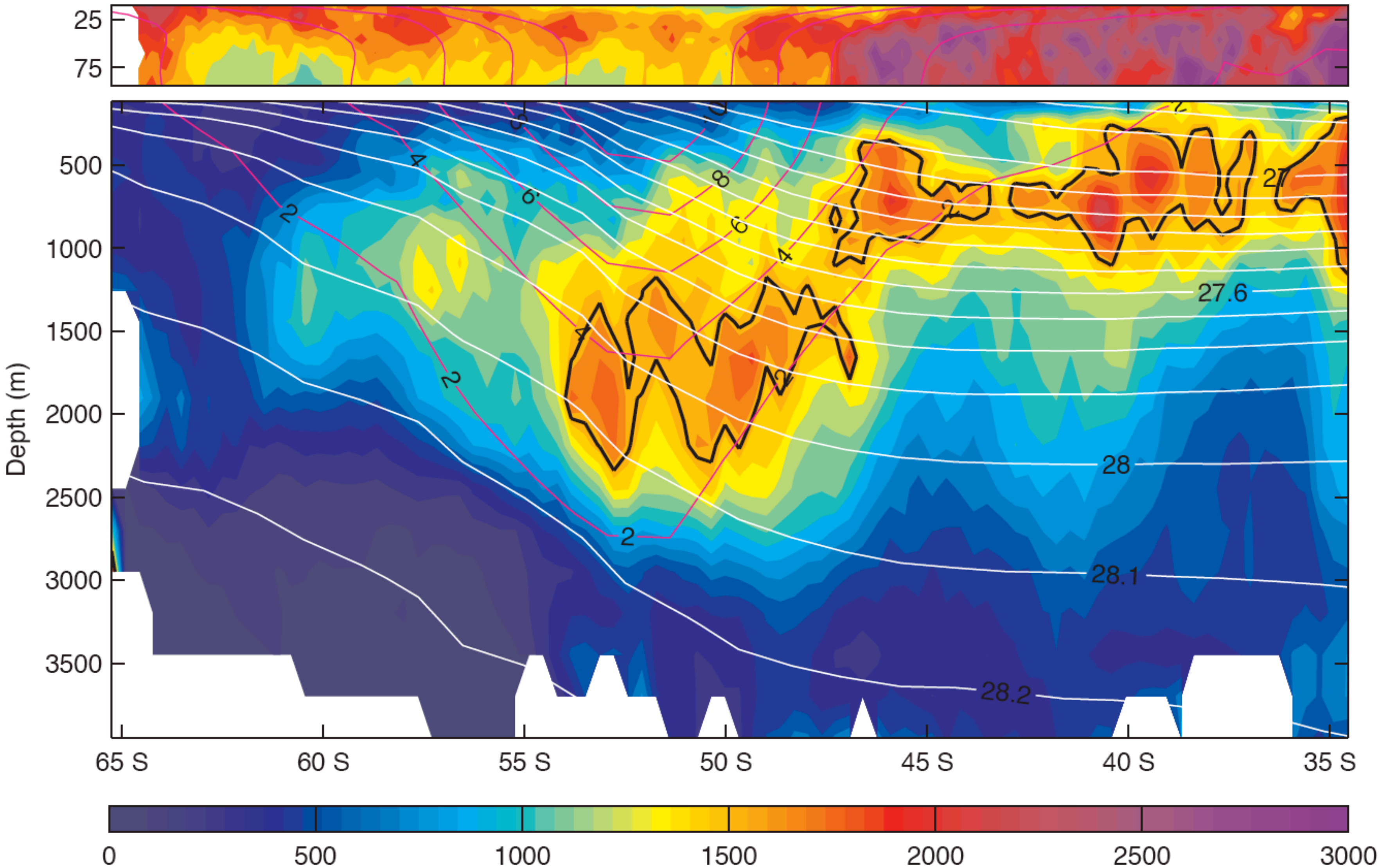


In the absence of diabaic processes (the ocean interior), water masses stay on isopycnal surfaces.

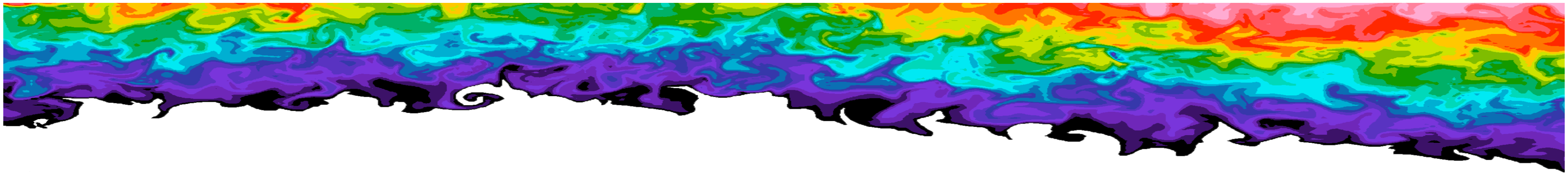
Calculated neutral density (Jackett & McDougal 1997). Interpolated tracer onto 35 neutral surfaces calculated from instantaneous T & S. These isopycnal tracer sheets were used for effective diffusivity calculation.



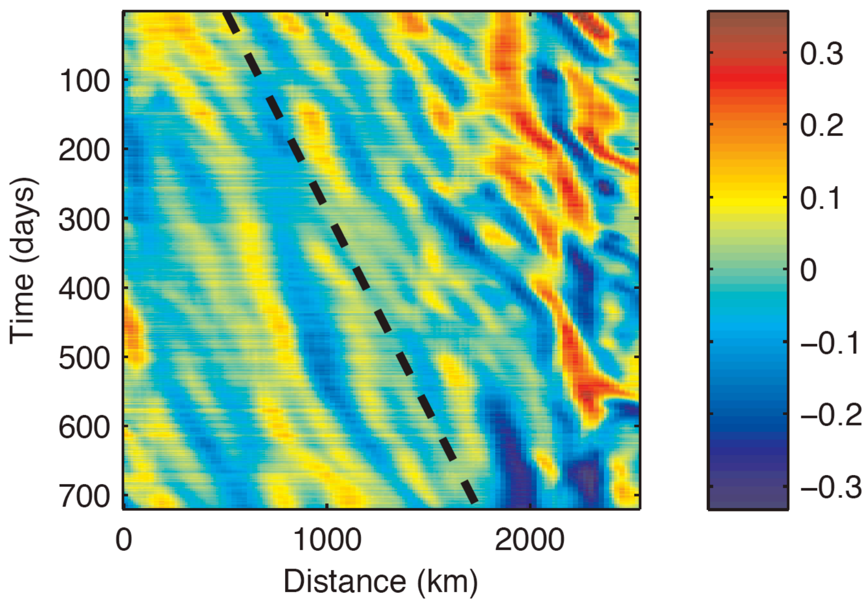
Results



25
75
500
1000
1500
2000
2500
3000
3500
Depth (m)
65 S
60 S
55 S
50 S
45 S
40 S
35 S
27.6
28
28.1
28.2
0
500
1000
1500
2000
2500
3000

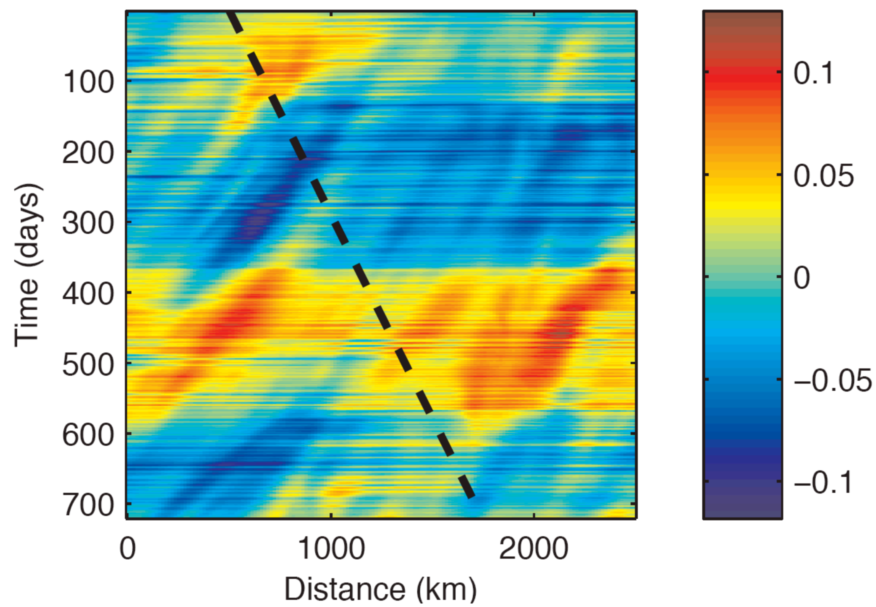


Hovmüller Diagram of Surface Height Anomaly in SOSE



Along a mean streamline centered around 53 S.

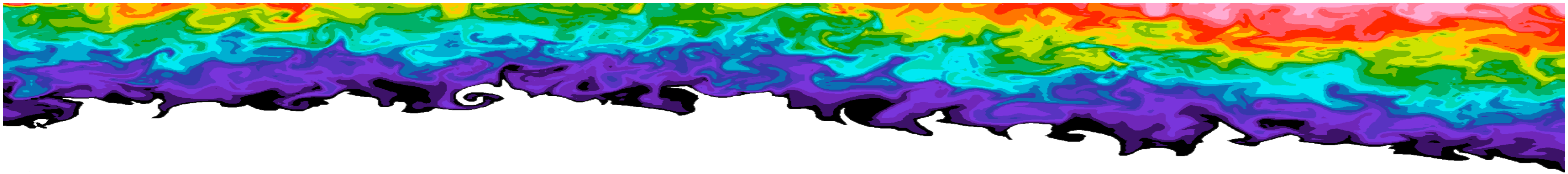
Dotted line is 2 cm/s westward.
Mean flow ~ 16 cm/2. Eddies propagating upstream.



Along 32S in Indian Ocean.

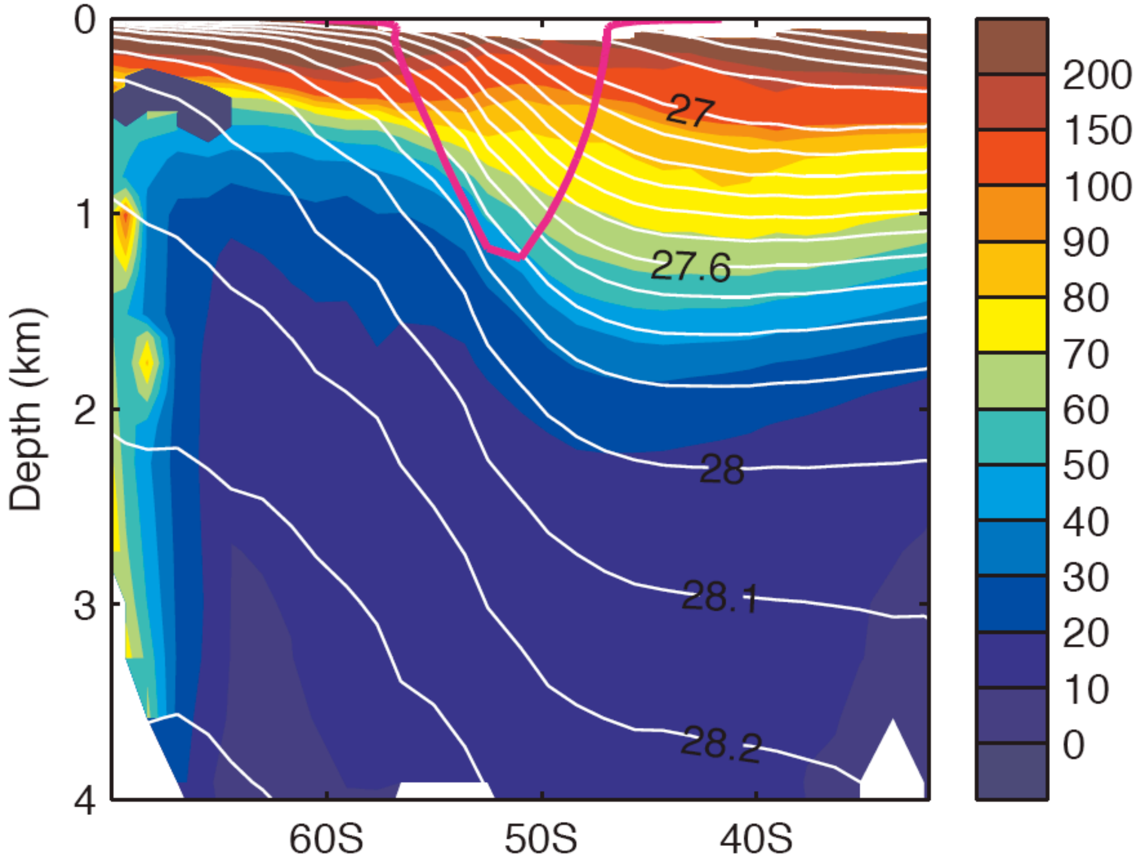
Eddies/waves propagating west.

Steering Level Somewhere Between!



Ertel / Isopycnal PV

(Note: PV is everywhere negative in southern hemisphere!)



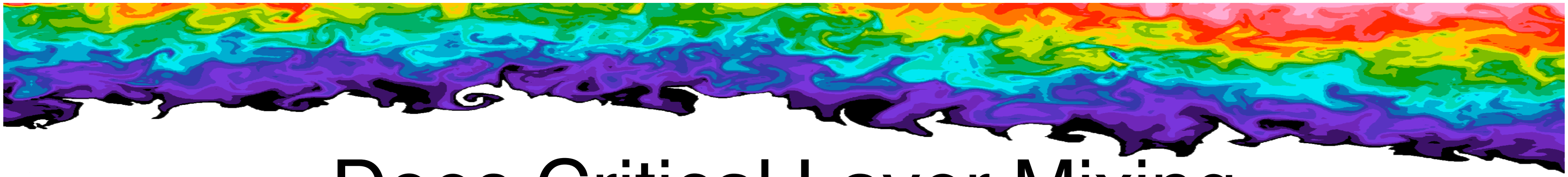
$$P = N^2(f+\zeta) = \frac{f+\zeta}{h}$$

$$h = \frac{\partial z}{\partial b}$$ Isopycnal layer thickness

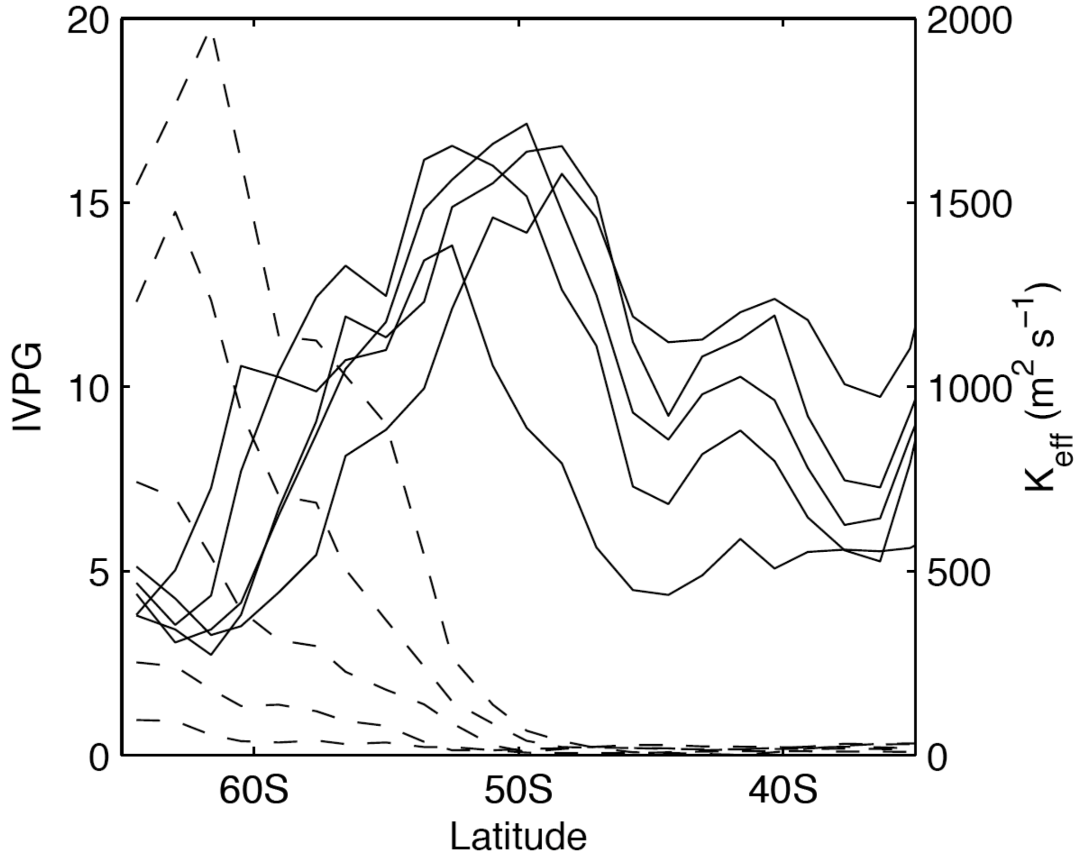
Averaged along streamlines and isopycnals.

Pink line: 5 cm/s streamwise flow (ACC)

Rhines & Young (1983): tracer (PV) homogenized inside closed streamlines



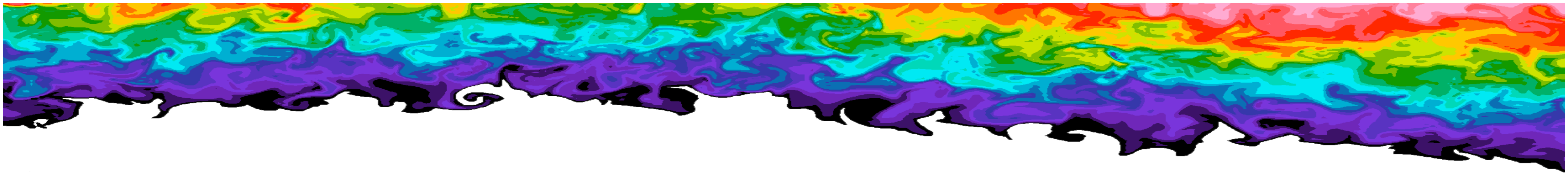
Does Critical Layer Mixing Homogenize PV?



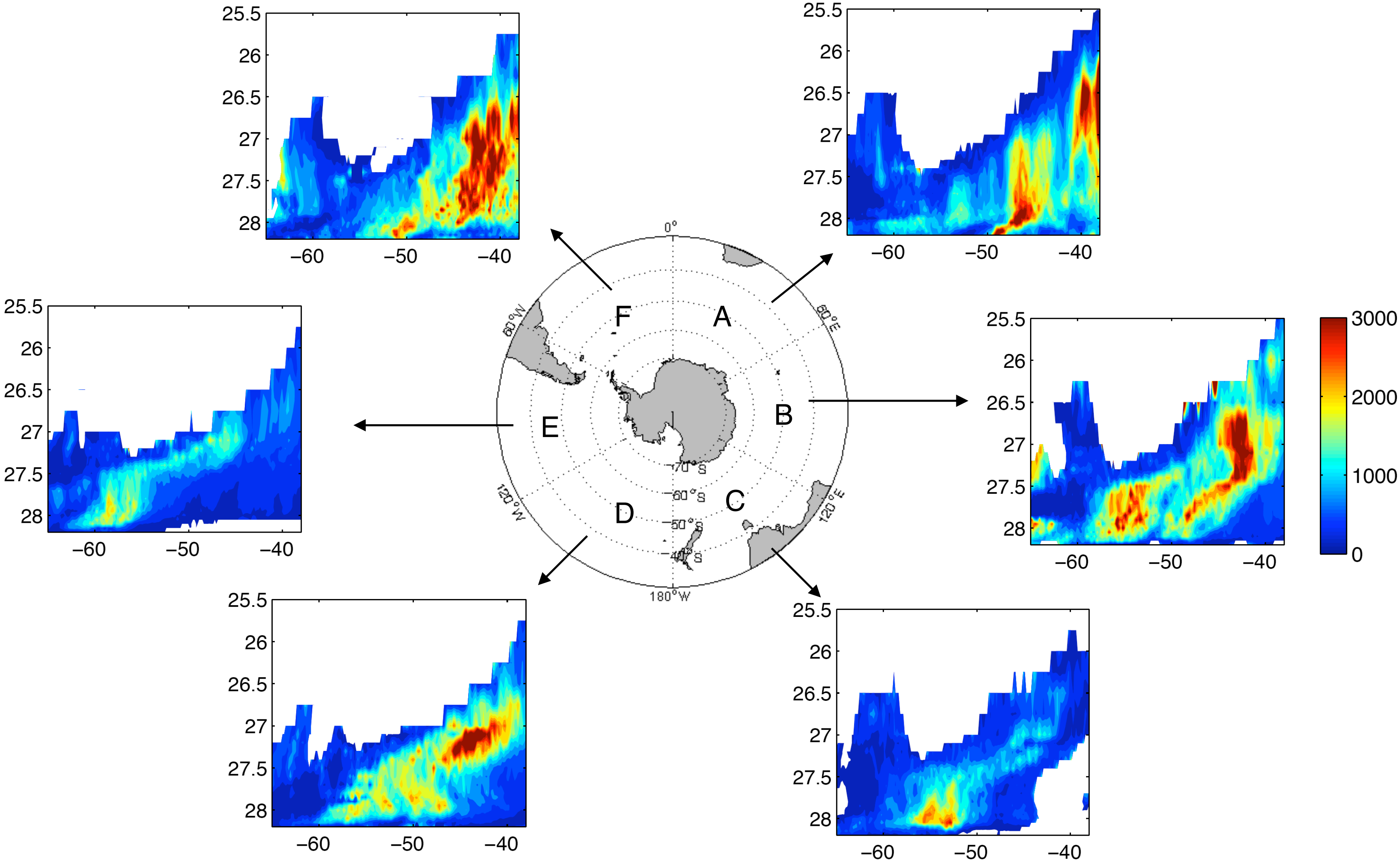
On neutral surfaces
28.1, 28.0 (NADW)
27.9, 27.8, 27.6 (UCDW)

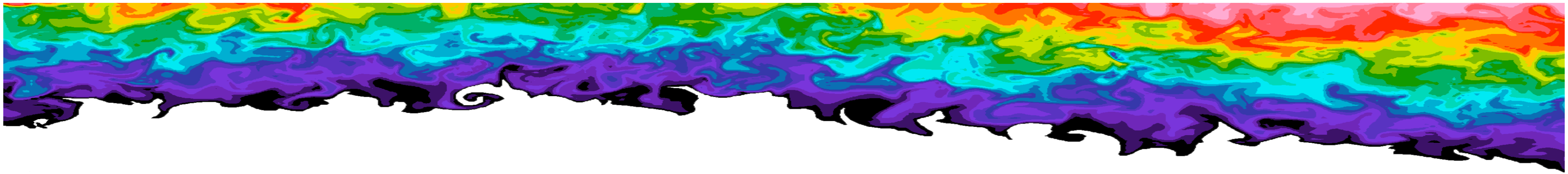
Strong mixing on the edge of a sharp PV gradient: reminiscent of stratospheric surf zone.

Advection of PV by residual flow can balance stirring: implies nonzero residual flow where both stirring and gradient are strong.

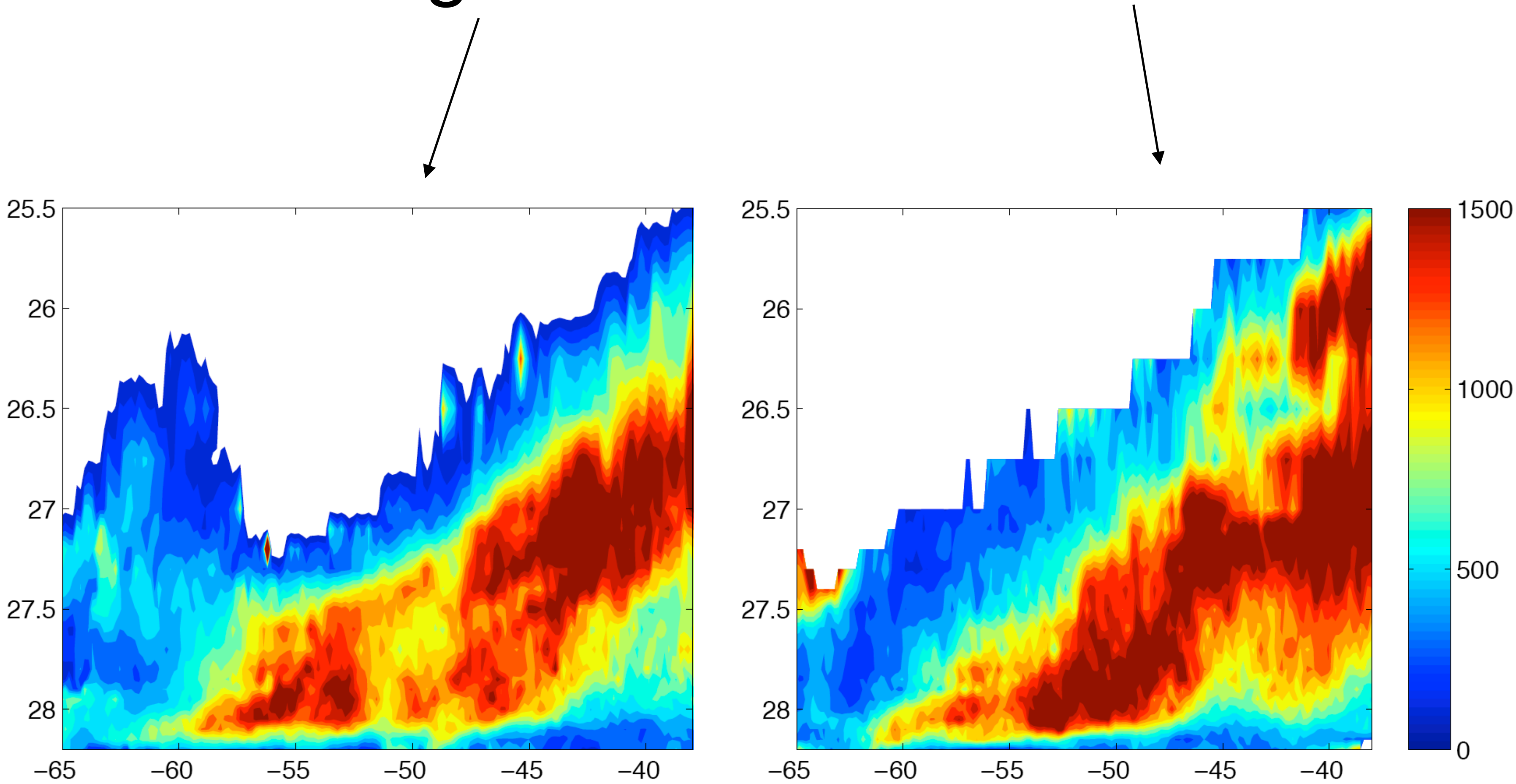


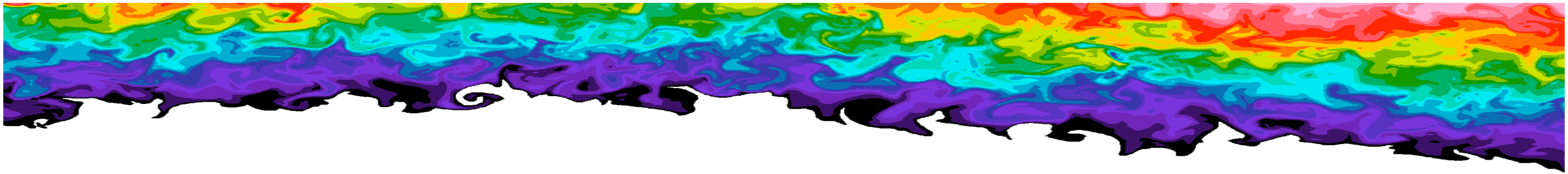
New Results: Sectors





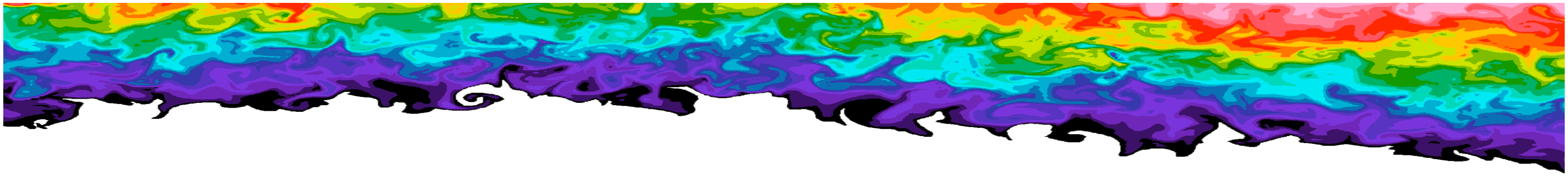
Average of Sectors vs. Global



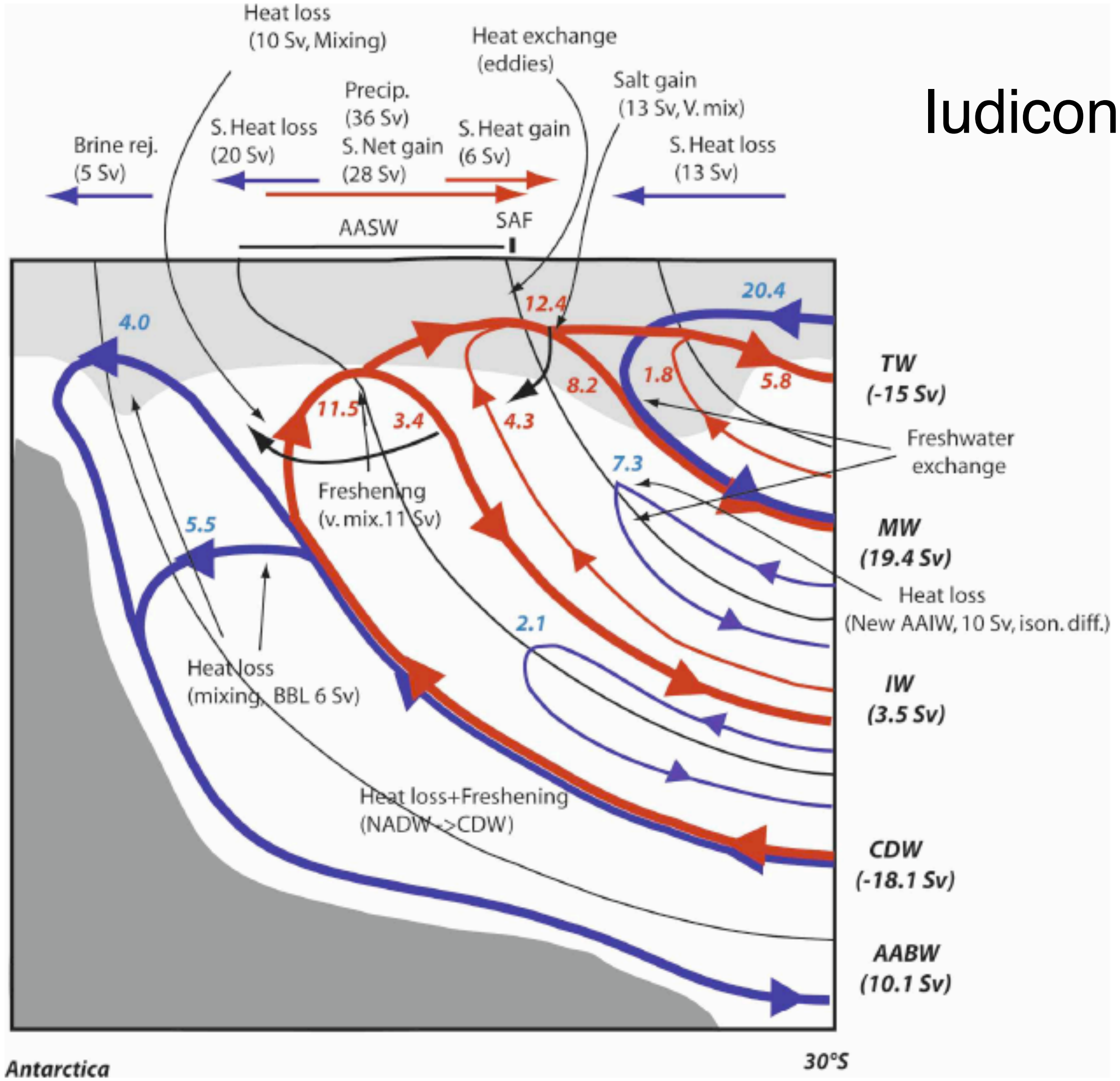


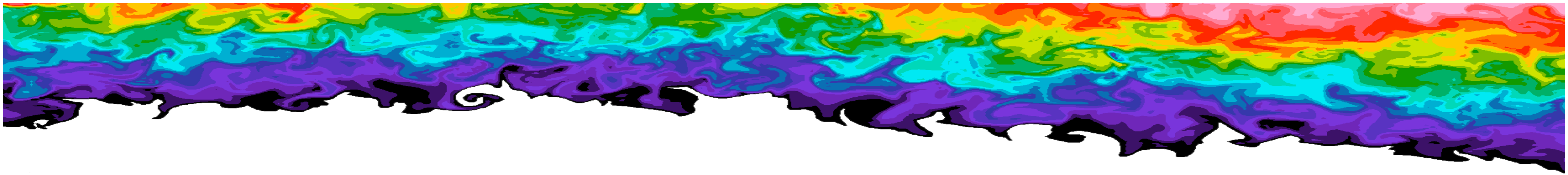
Future Work

- Explore using Keff in parameterizing eddy fluxes. Better than simple Gent-McWilliams?
- Examine the role of critical layer effects vs. topographic forcing. What really determines the spatial pattern of Keff?
- Do calculation in the global cs510 model!



Iudicone et al. 2008





How to quantify advective enhancement of diffusion?

$$\mathcal{A}\{X\} = \int\int^{Q} X(x,y,t)\,dx\,dy = \int^{Q} dq \oint X \frac{dl}{|\nabla q|}$$

Area contained within tracer contour Q: $A(Q,t) = \mathcal{A}\{1\}$

Modified Lagrangian Mean (MLM):

$$\widehat{X} = \frac{\partial}{\partial A}\mathcal{A}\{X\} = \left(\frac{\partial A}{\partial Q}\right)^{-1} \frac{\partial}{\partial Q}\mathcal{A}\{X\} = \frac{\oint X \frac{dl}{|\nabla q|}}{\oint \frac{dl}{|\nabla q|}}$$

Take MLM of tracer equation…

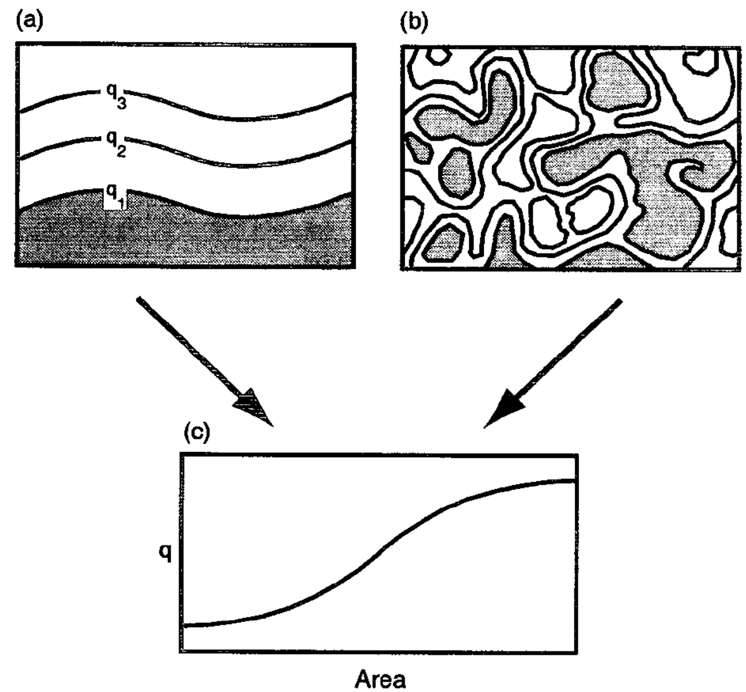
$$\frac{\partial Q}{\partial t} = \frac{\partial}{\partial A}\left(\kappa L_e^2 \frac{\partial Q}{\partial A}\right)$$

Looks sort of like diffusion.

$$L_e^2 = \widehat{|\nabla q|^2}\left(\frac{\partial Q}{\partial A}\right)^{-2}$$

“Equivalent length” of tracer contour Q

(following Alan Plumb’s stratosphere notes)



Nakamura (1996)