CPT: Representing internal-wave driven mixing in global ocean models

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Harper Simmons (UAF)
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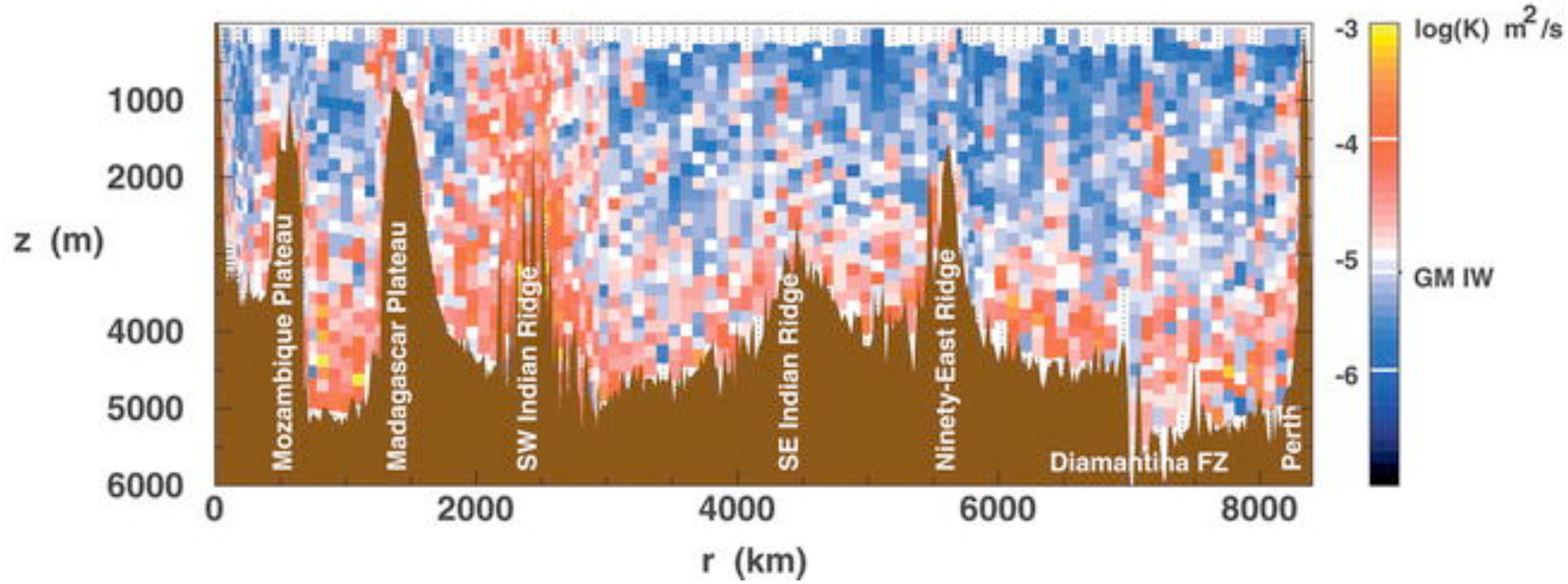
Patchy mixing in the Indian Ocean



Kunze et al 06

http://www-pord.ucsd.edu/~jen/cpt/

We're hiring 4 post-docs. Not too late to submit an application...

Overview

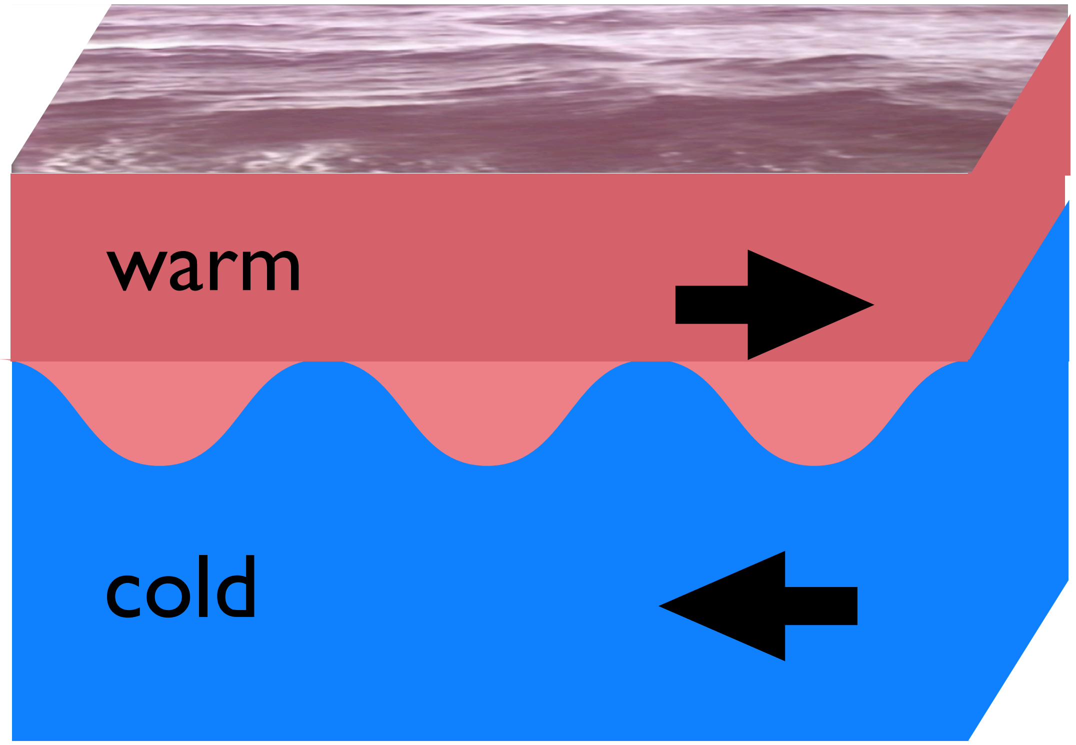
1. Most diapycnal (vertical) mixing in the ocean interior is due to breaking internal gravity waves

2. Mixing is patchy in space and time, reflecting the complex geography of internal wave generation, propagation, and dissipation.

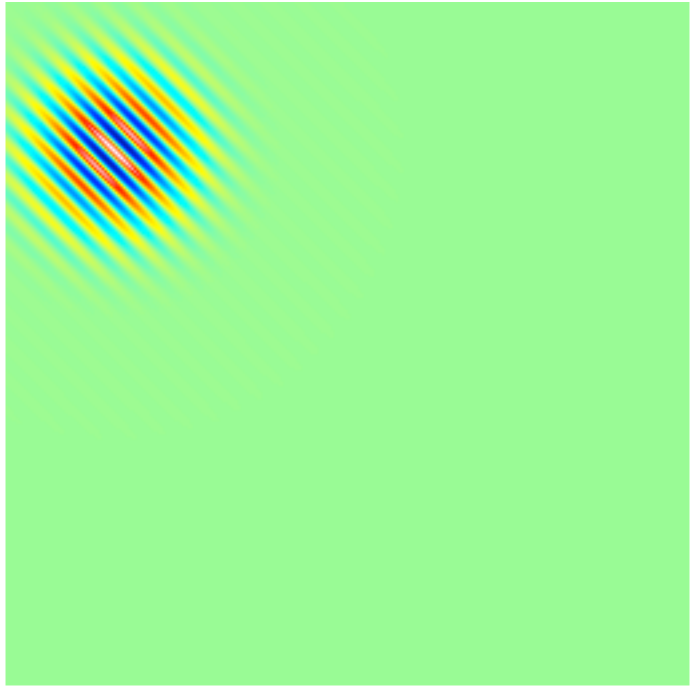
3. Patchy mixing matters for ocean circulation and fluxes. It's important to "get it right".

4. Our plan: use what we collectively know about internal wave physics to develop a dynamic parameterization of diapycnal mixing that can evolve in a changing climate.

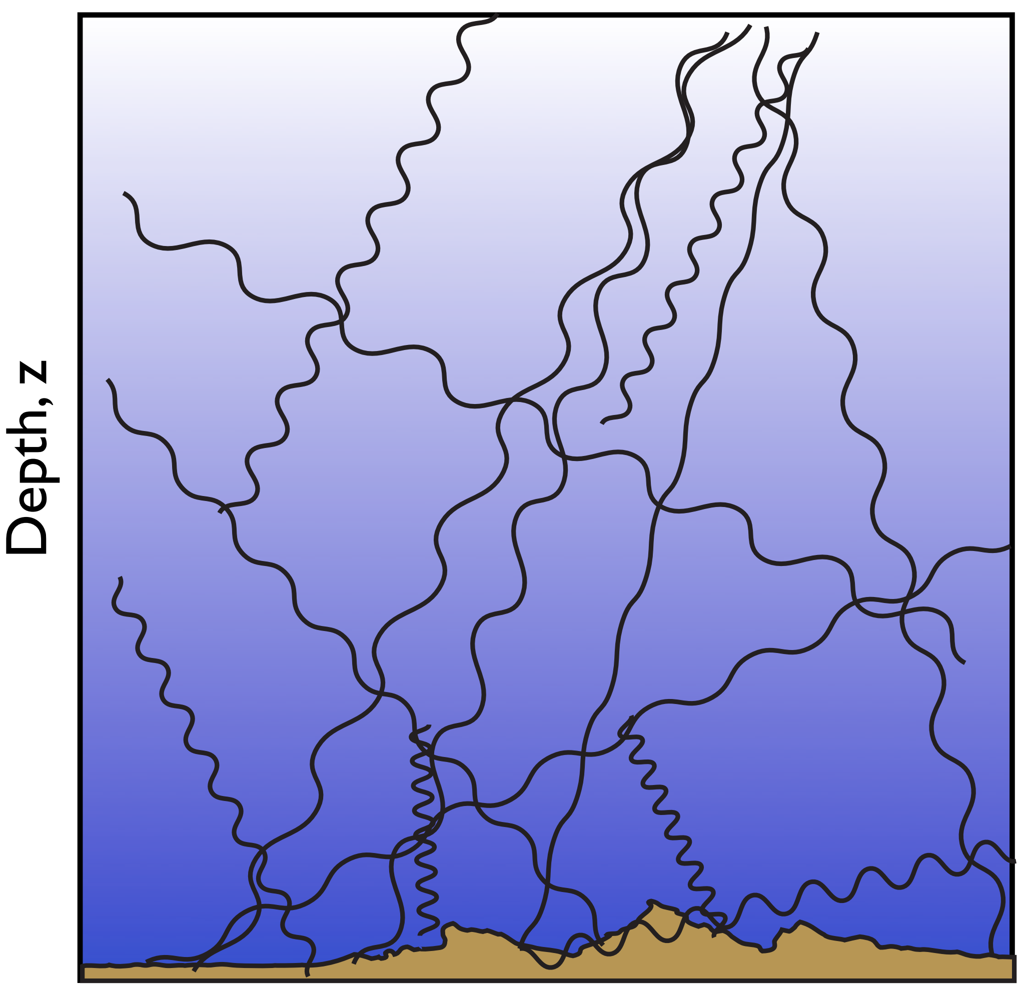
Internal wave primer



- Low-mode ~interfacial waves
- High-mode ~ plane waves
- Fast $f \leq \omega \leq N$
- Breaking waves are at small (1-10 m) scales

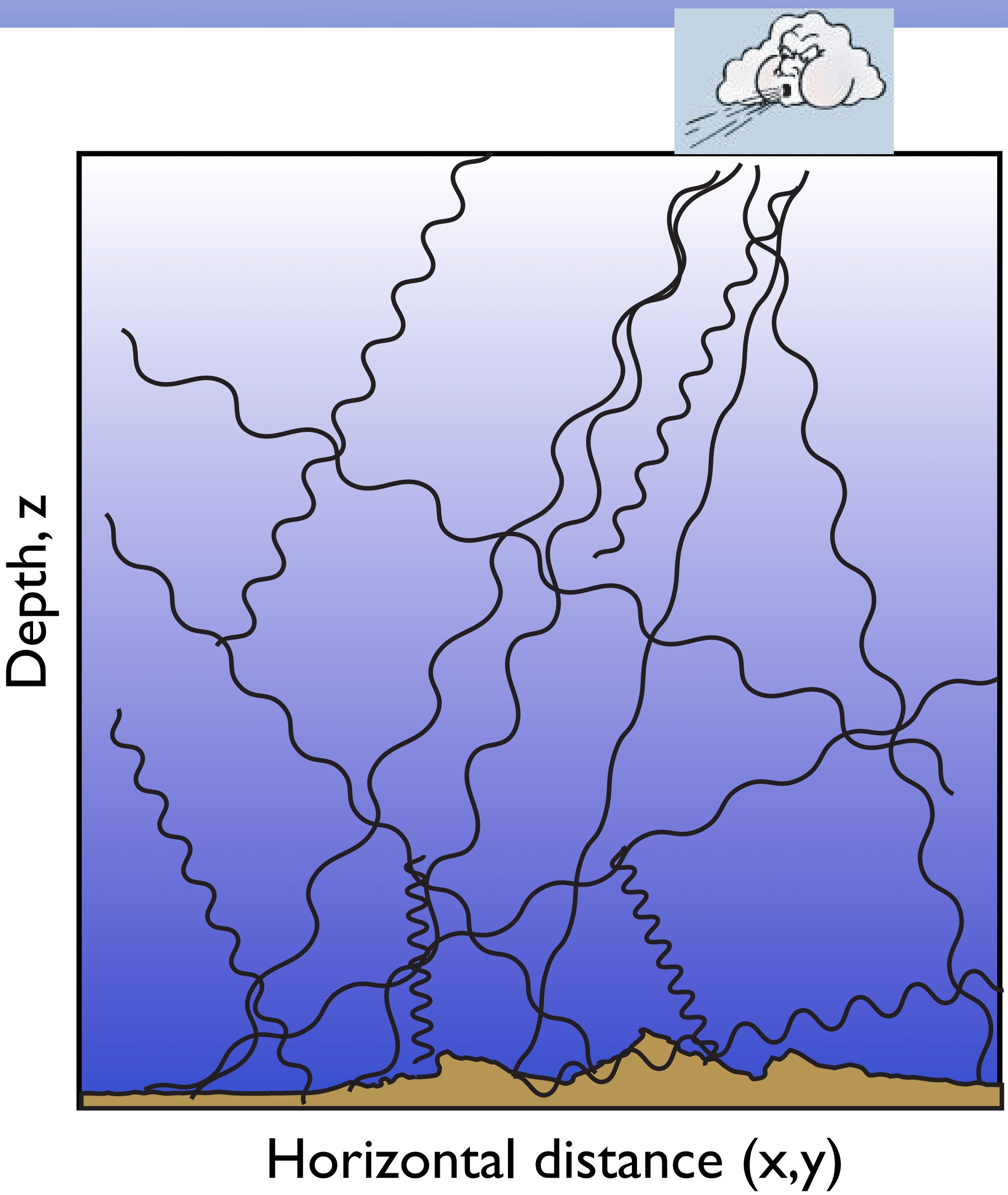


The zoo of internal waves in the ocean



Two frequencies dominate energetically

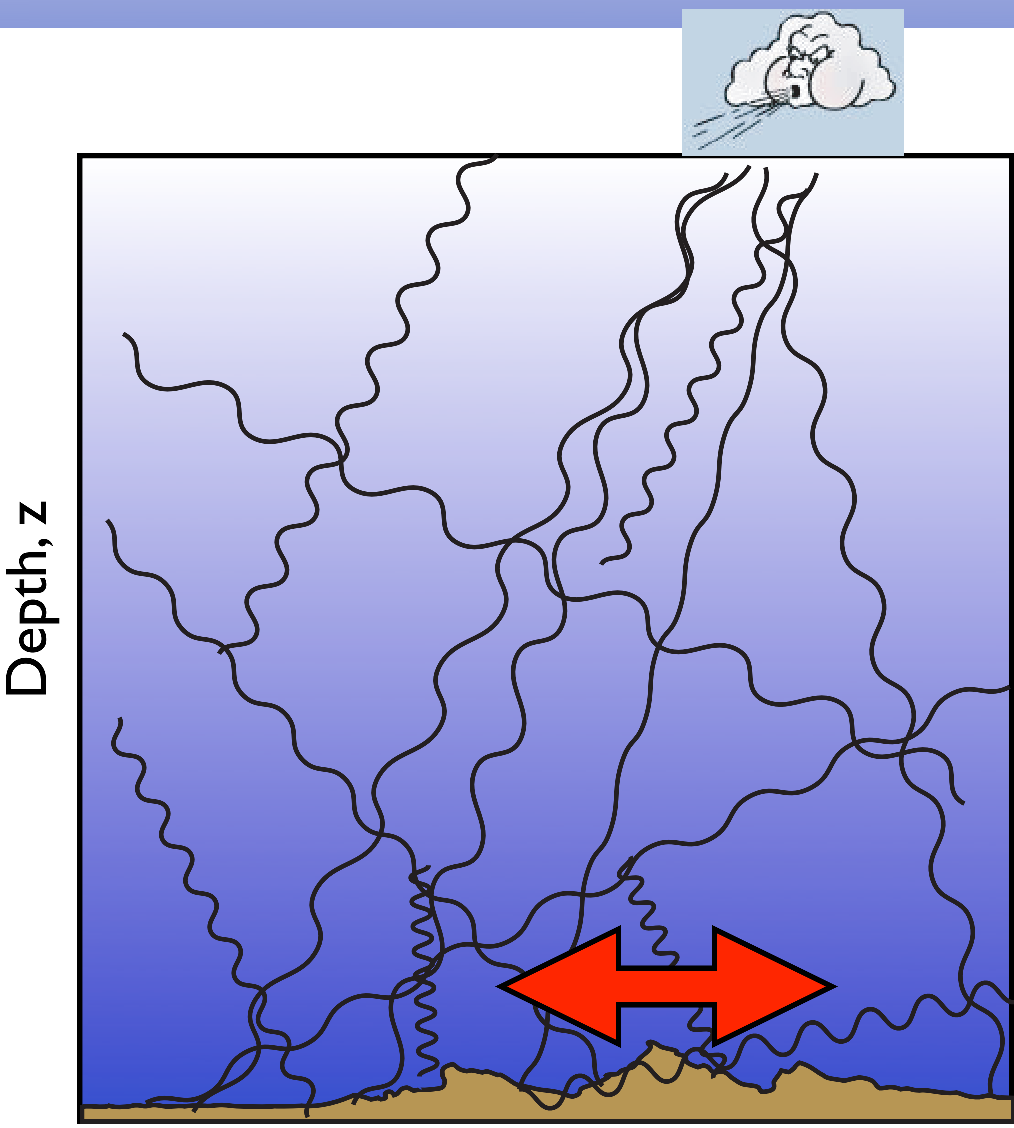
The zoo of internal waves in the ocean



Two frequencies dominate energetically

Near-inertial waves: often wind generated, have a frequency close to the local inertial frequency (latitude dependent)

The zoo of internal waves in the ocean



Two frequencies dominate energetically

Near-inertial waves: often wind generated, have a frequency close to the local inertial frequency (latitude dependent)

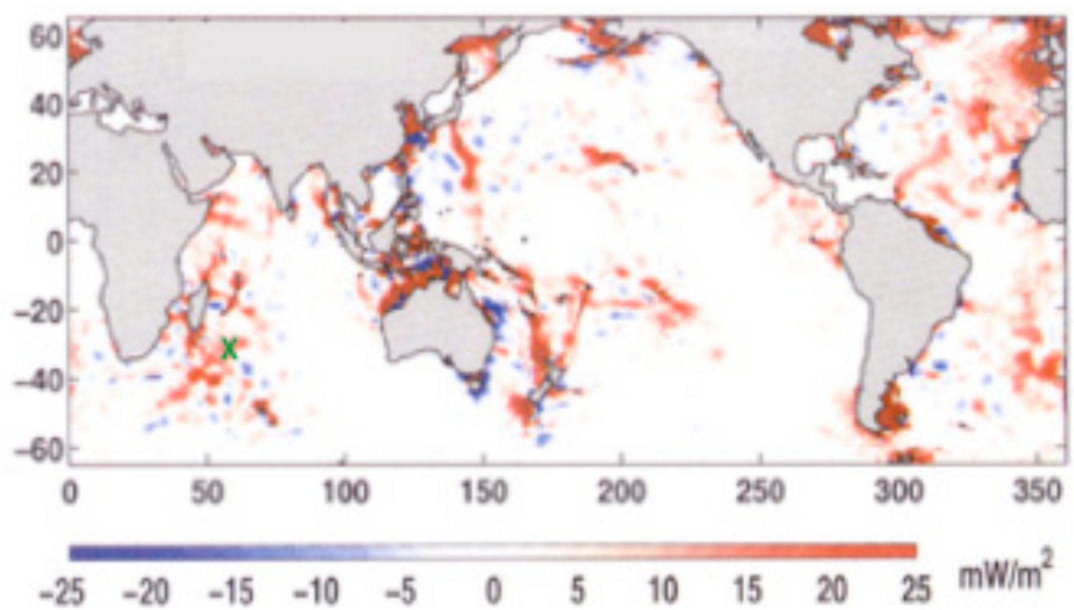
Internal Tides: generated by oscillatory tidal flow over topography. Waves have tidal (often M_2=12.4 hour) period

Parameterizing mixing

Cant' explicitly resolve internal waves in climate models.
3 steps to parameterize their role:

1) Wave generation

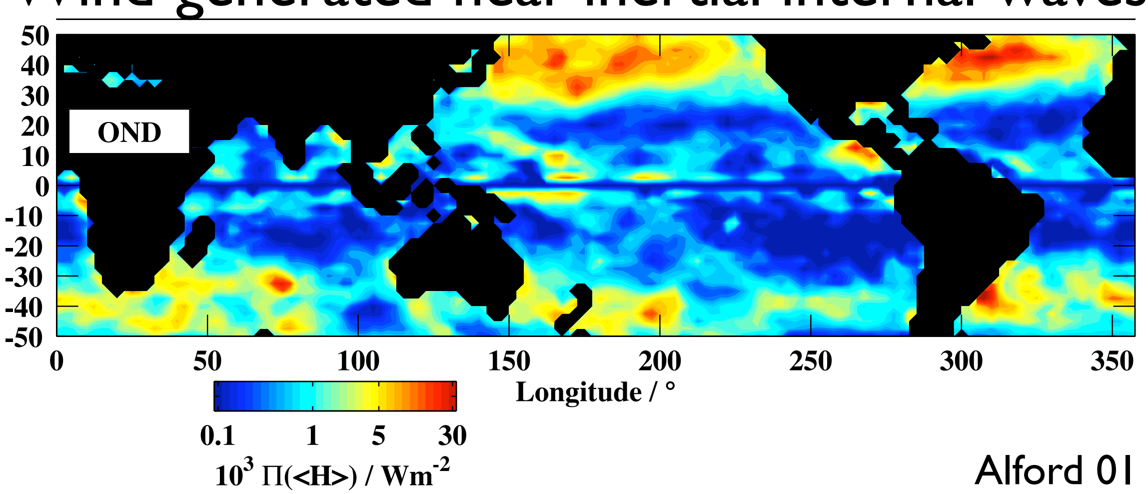
Internal-Tide Generation



Egbert and Ray 01

Generation where barotropic (astronomical) tides are large and topography is rough

Wind-generated near-inertial internal waves



Alford 01

Generation by rotating component of wind stress, mirrors storm tracks

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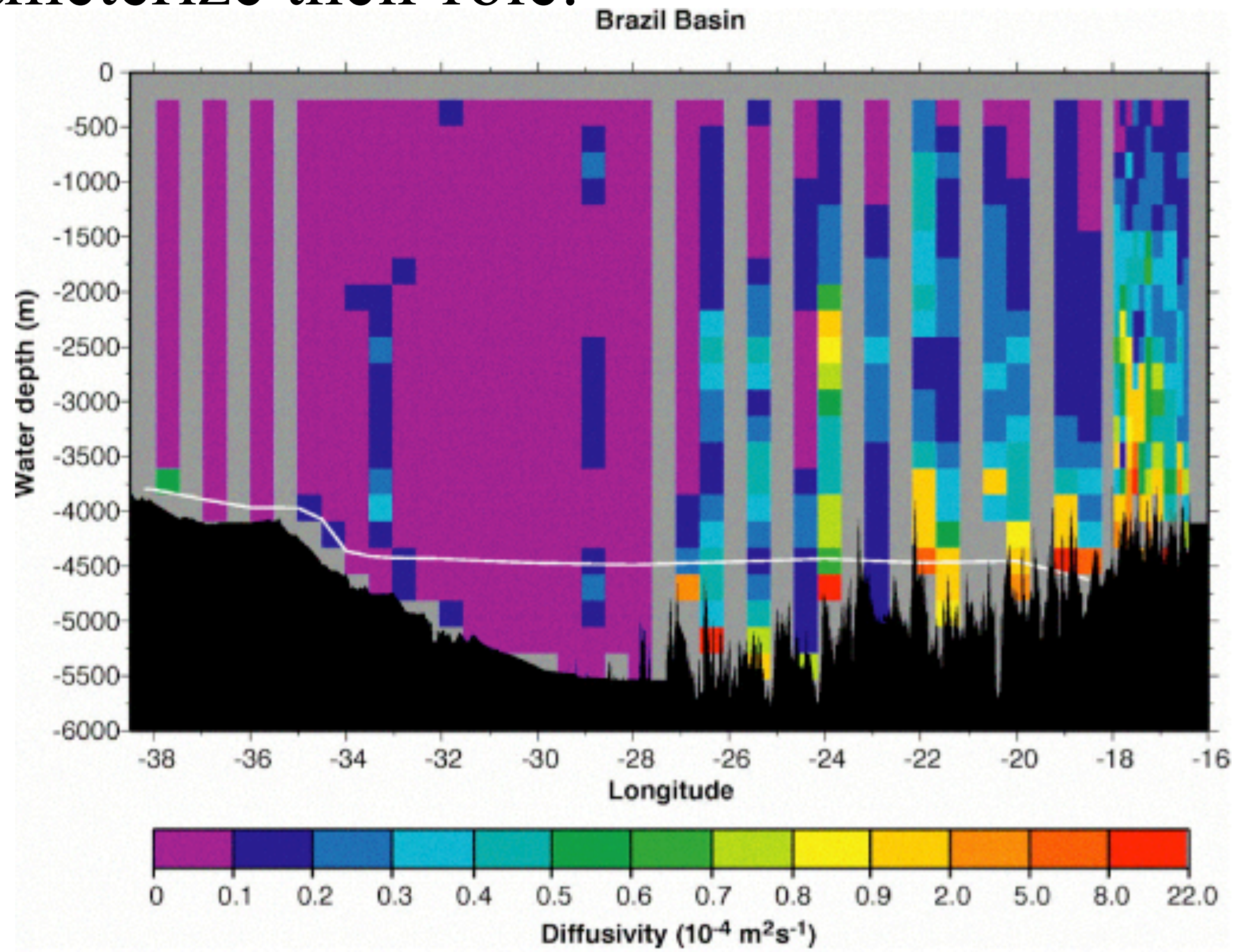
2) Some waves break "locally"

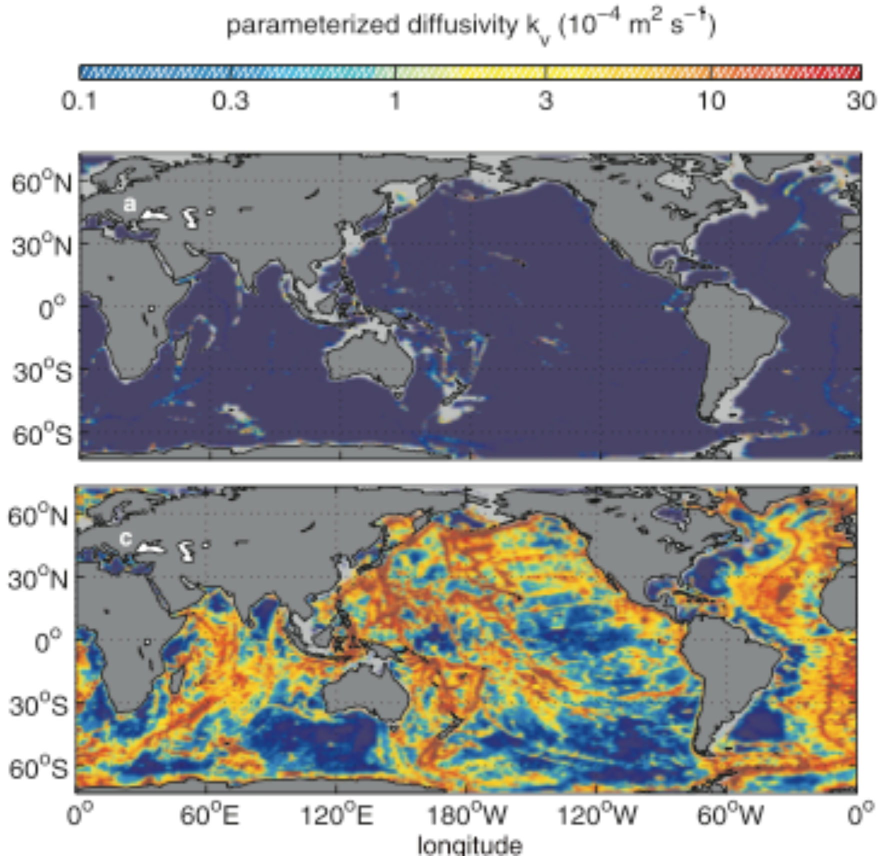


Internal tides propagating up from the rough (eastern) bathymetry steadily break, producing elevated mixing up into the main thermocline

Polzin et al. 97

Global pattern of mixing that mirrors wave generation

“Nearfield” tidal mixing



1000 meters

ocean bottom

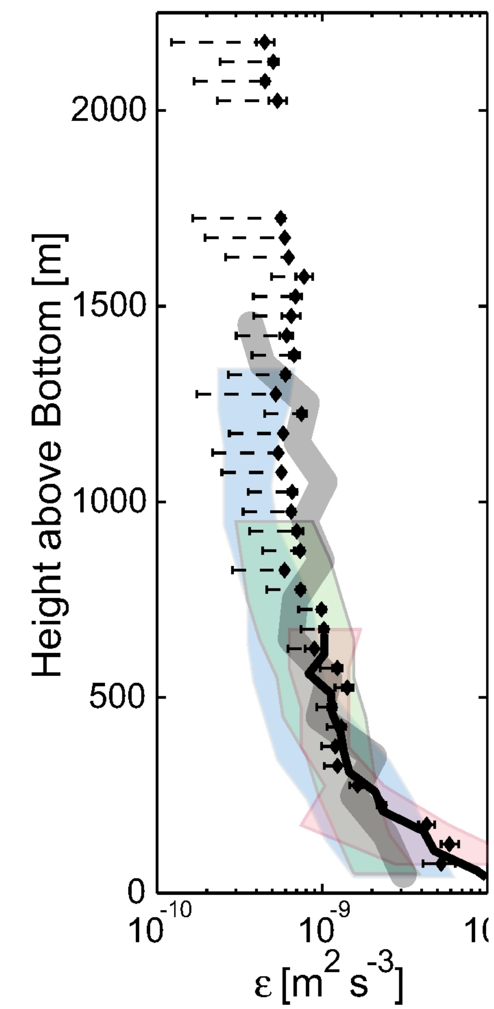
St Laurent et al 02

dissipation rate (related to diffusivity)

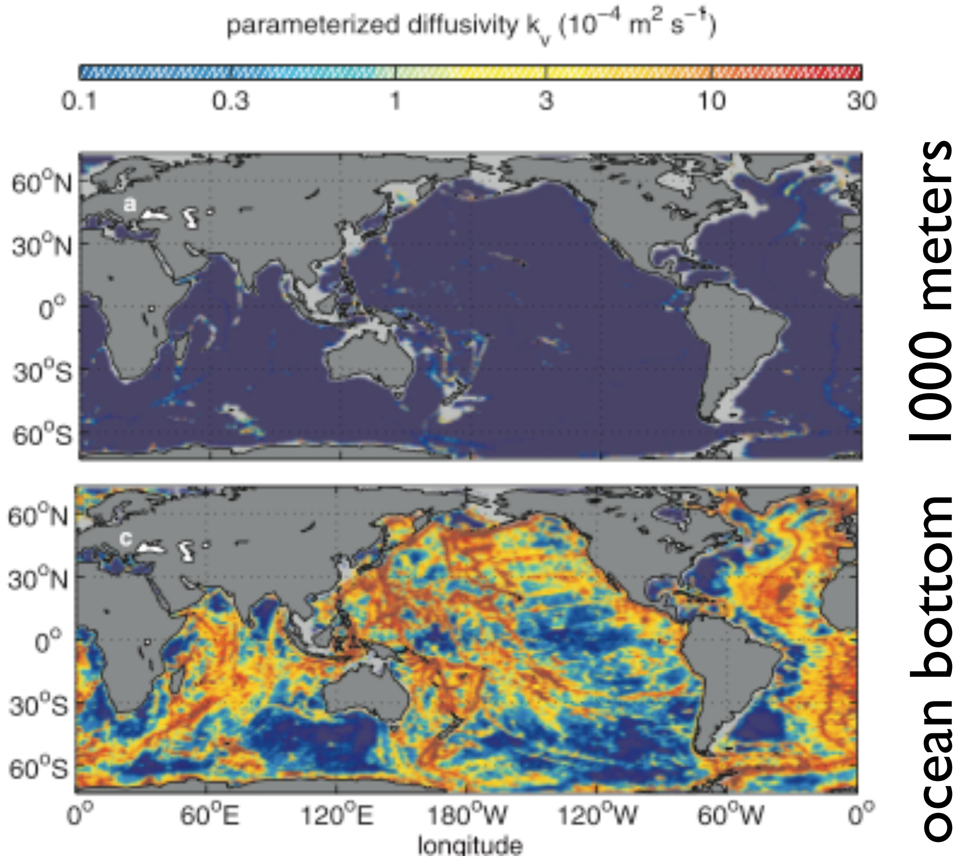
map of internal tide generation (U_{bt}, N)

vertical structure (exponential decay)

$$\epsilon = \frac{\mathbf{qE(x,y)F(z)}}{\rho}$$



"Nearfield" tidal mixing



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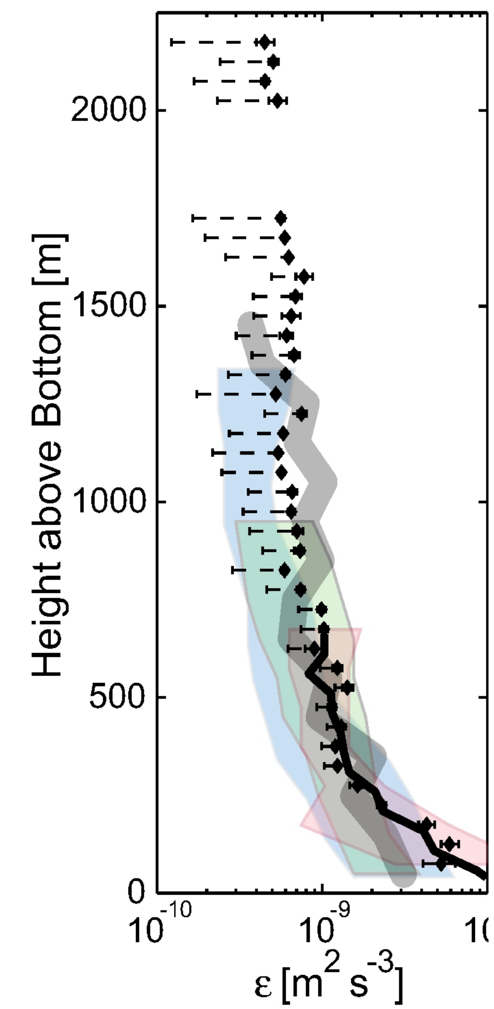
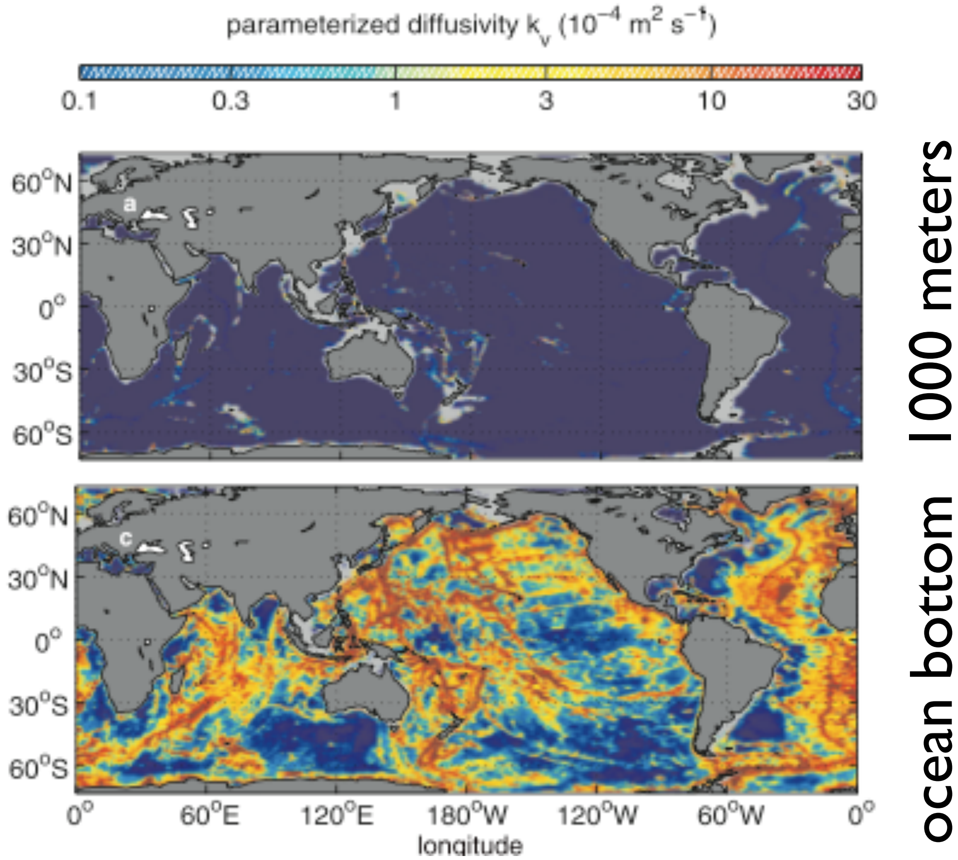


PLANNED WORK

Develop a vertical decay scale based on nonlinear dynamics of wave interaction and breaking

"Nearfield" tidal mixing



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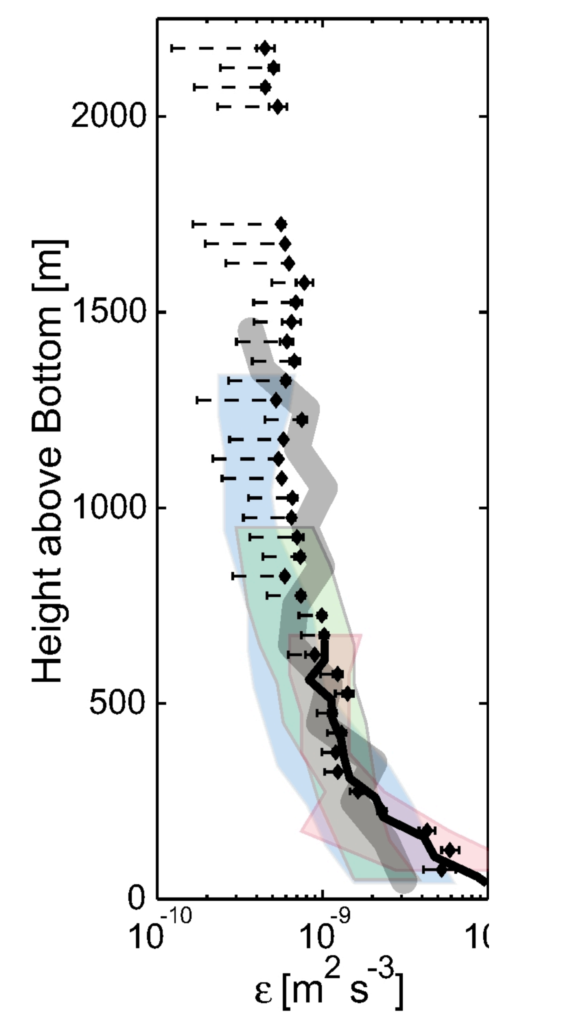


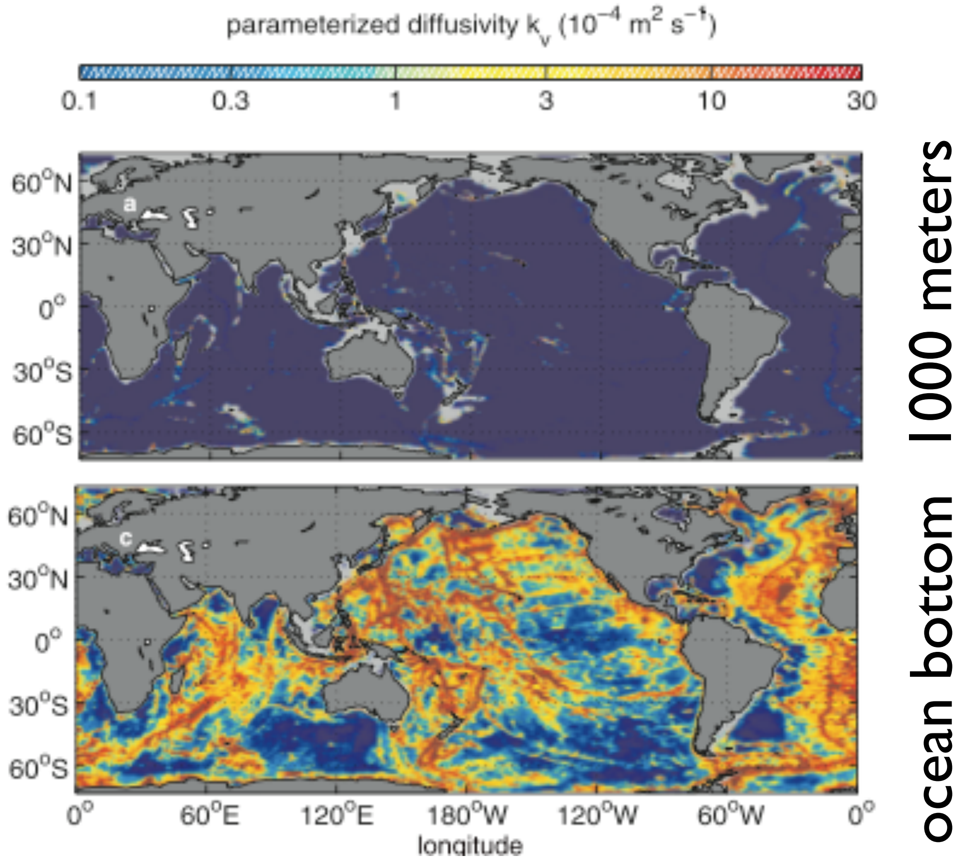
PLANNED WORK

Develop a vertical decay scale based on nonlinear dynamics of wave interaction and breaking

PLANNED WORK

Develop a similar representation for elevated mixing in the upper ocean under storm tracks

“Nearfield” tidal mixing



St Laurent et al 02

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% of energy that dissipates locally

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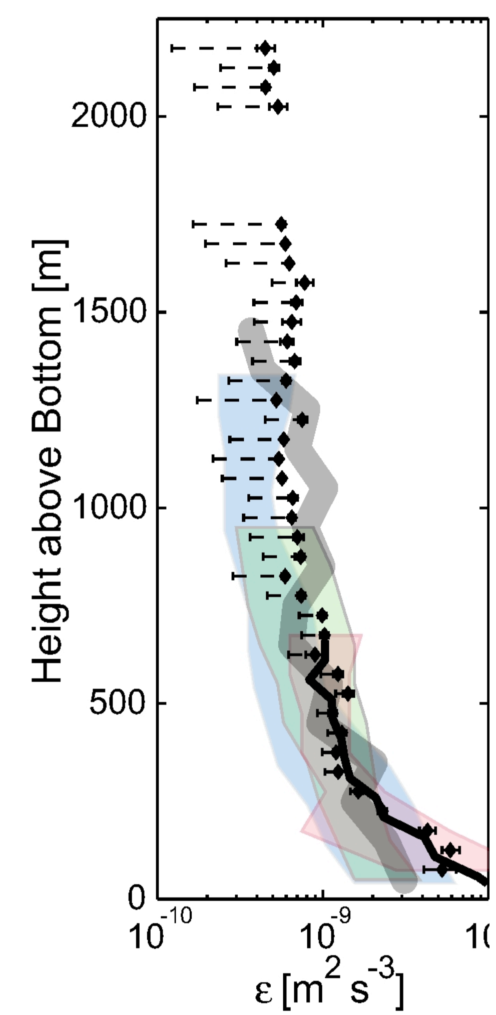


PLANNED WORK

Develop a similar representation for elevated mixing in the upper ocean under storm tracks

“Farfield” wave breaking / mixing

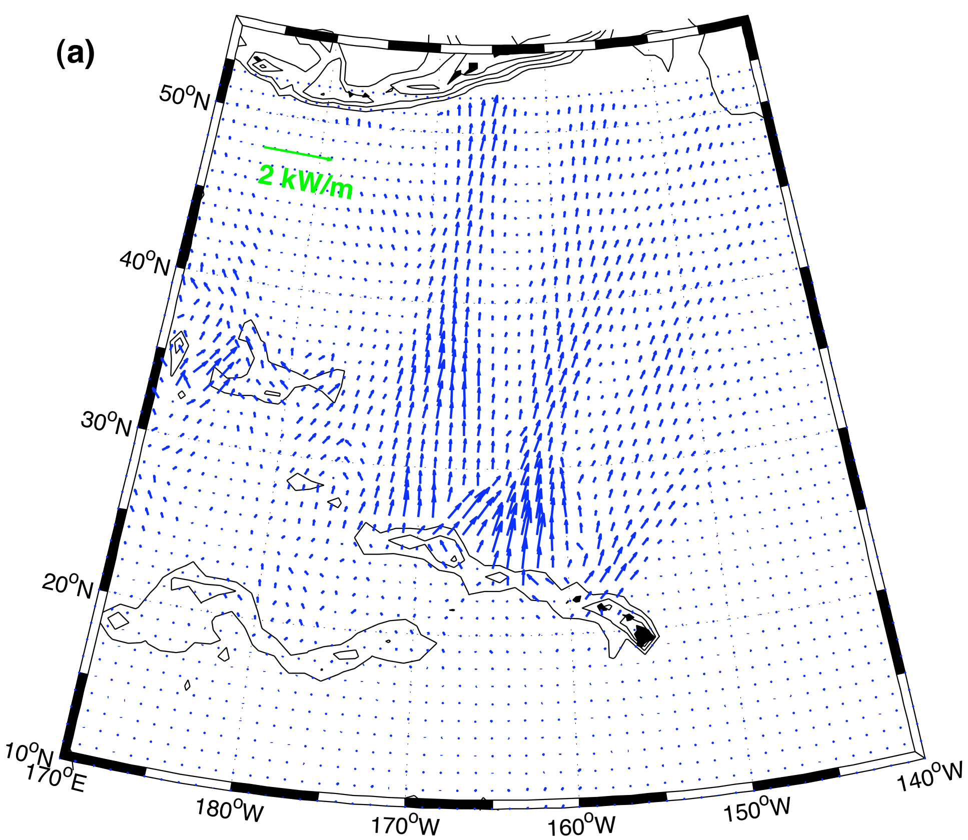
Most (70-90%) internal tide energy escapes to propagate thousands of km away.

Where do these waves break? [St. Laurent and Nash 04]

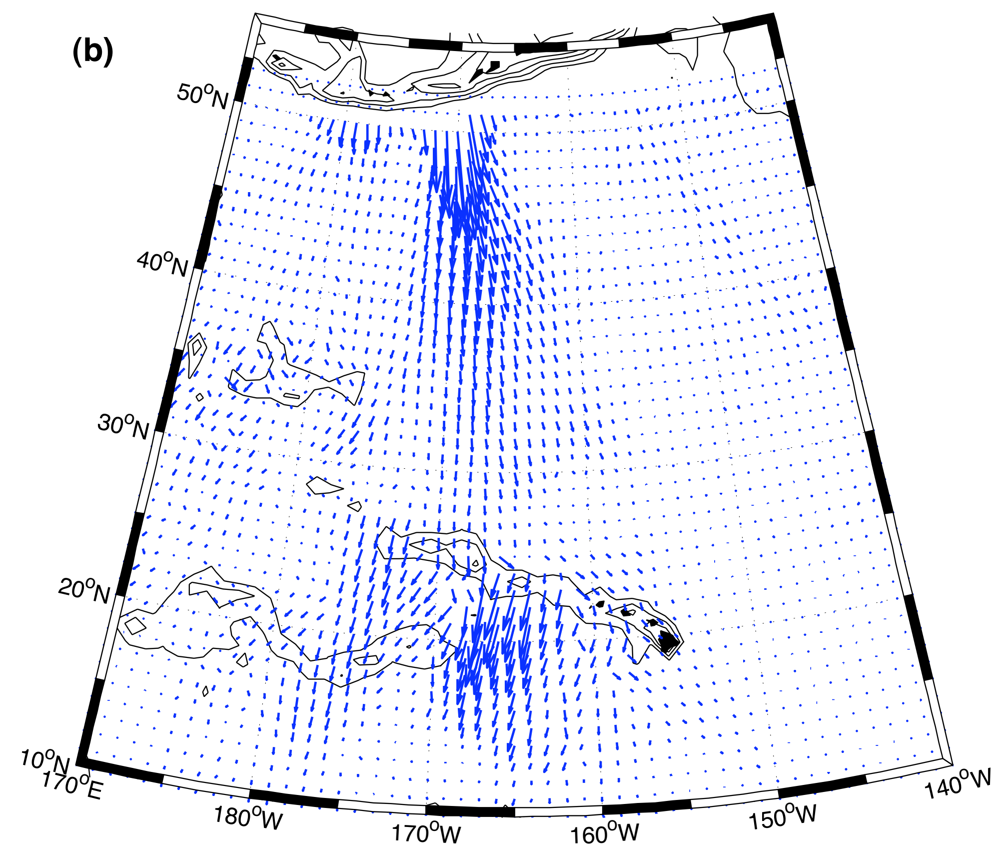
Altimetric tidal fluxes

Zhongxiang Zhao, UW

Northbound



Southbound



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Harper Simmons

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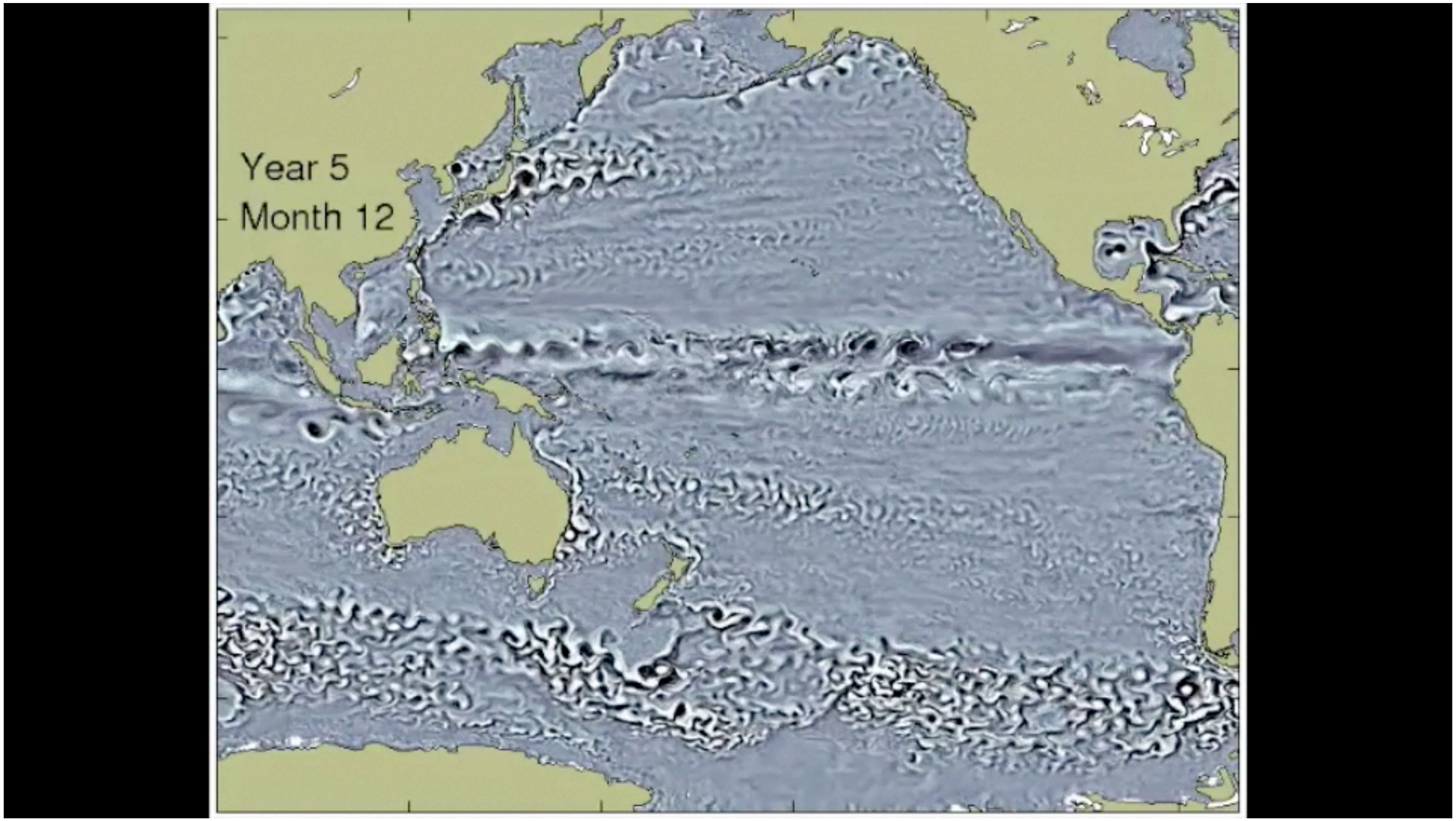

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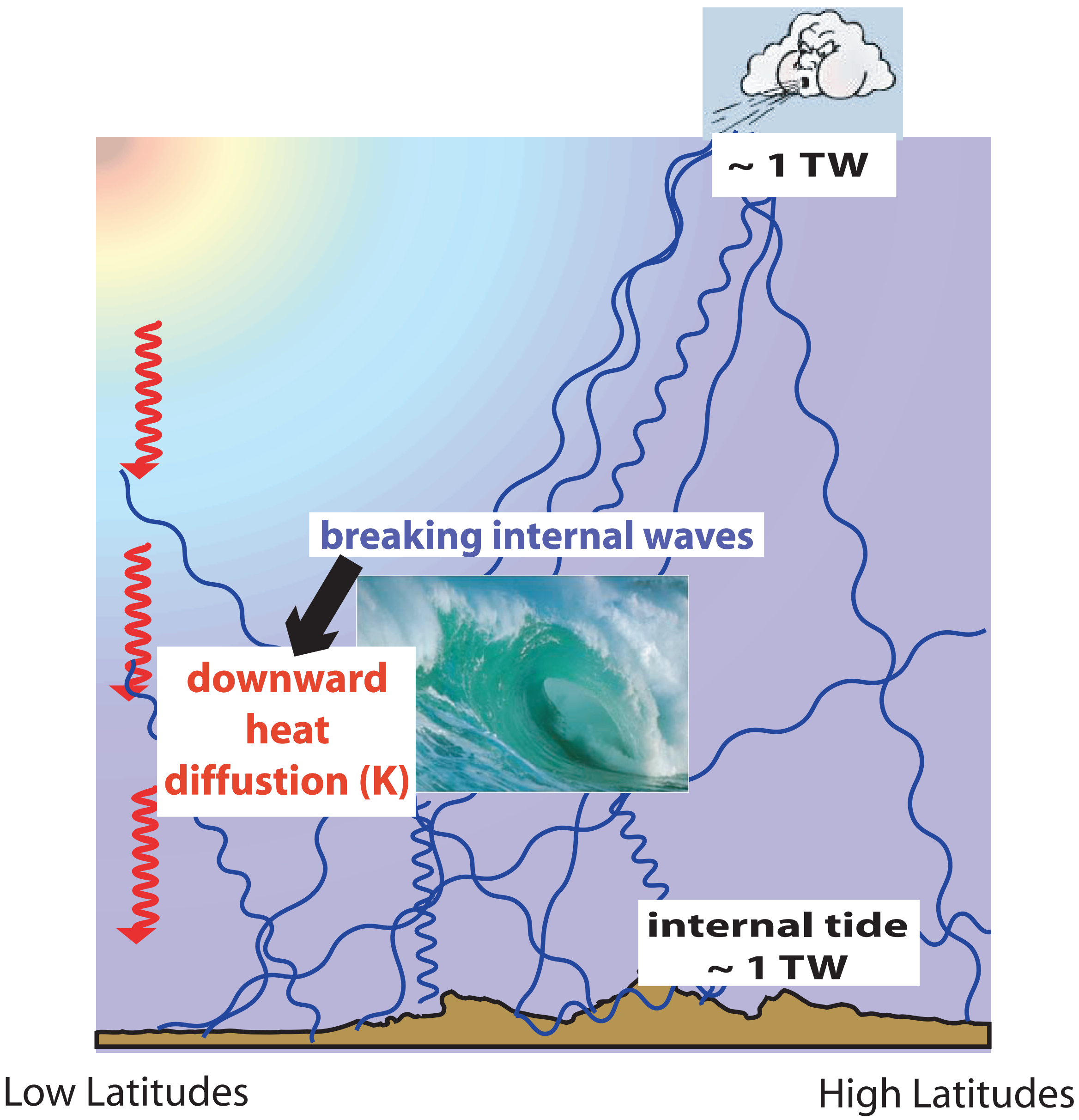
PLANNED WORK

Propagating waves steadily lose energy due to interaction with other internal waves and mesoscale eddies. Apply existing wave-wave interaction theory to develop a map of dissipation for low-mode internal waves

Turbulent mixing makes the ocean go round



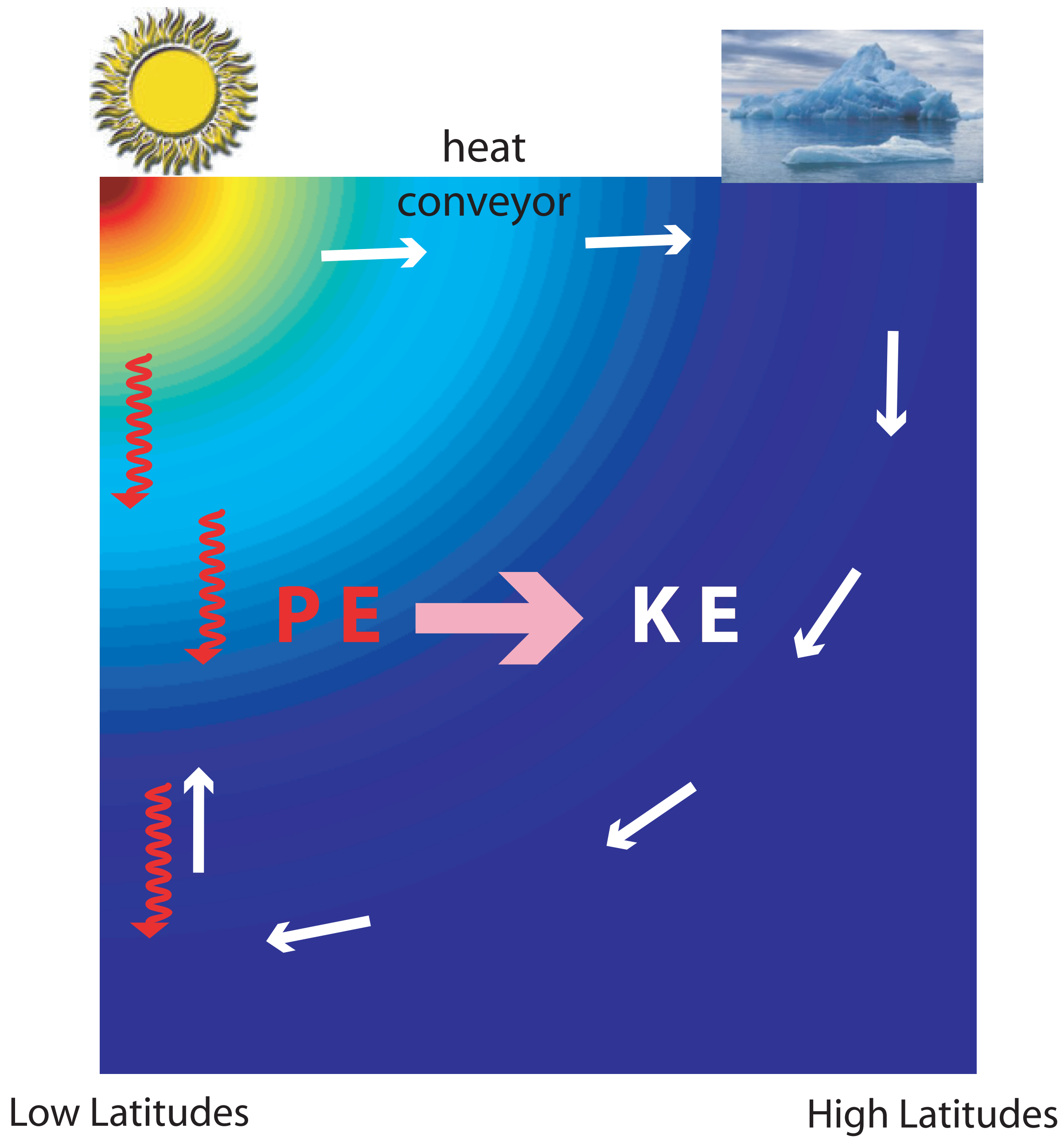
- Turbulence occurs at small scales: cm to m
- Determines large scale vertical transport of heat, C02, nutrients, etc.
- Drives meridional overturning circulation by creating potential energy.

nature (may 2007)

Churn, churn, churn

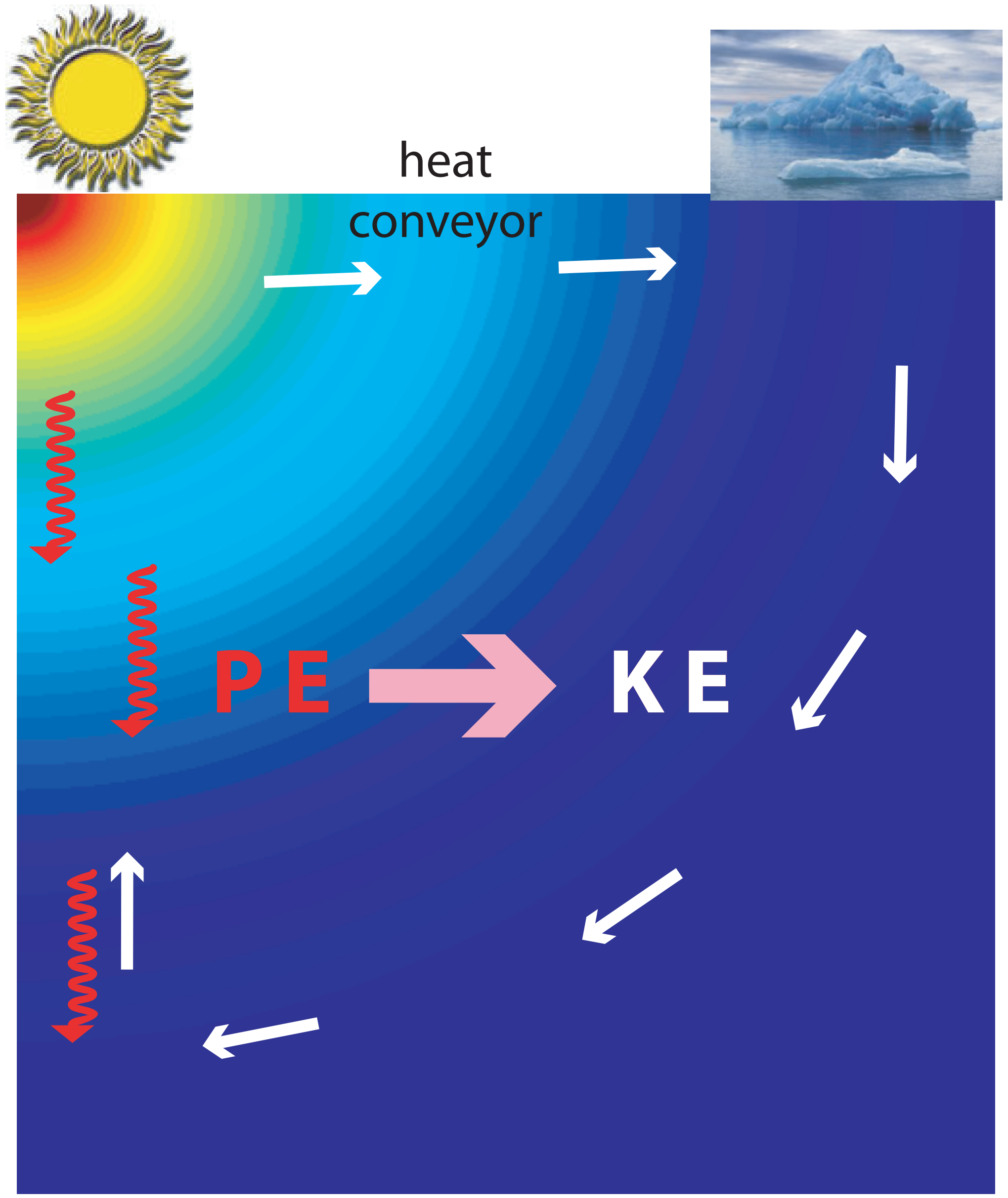
How the oceans mix their waters is key to understanding future climate change. Yet scientists have a long way to go to unravel the mysteries of the deep.

Turbulent mixing makes the ocean go round



simmons et al

Turbulent mixing makes the ocean go round



But patchy mixing changes the story

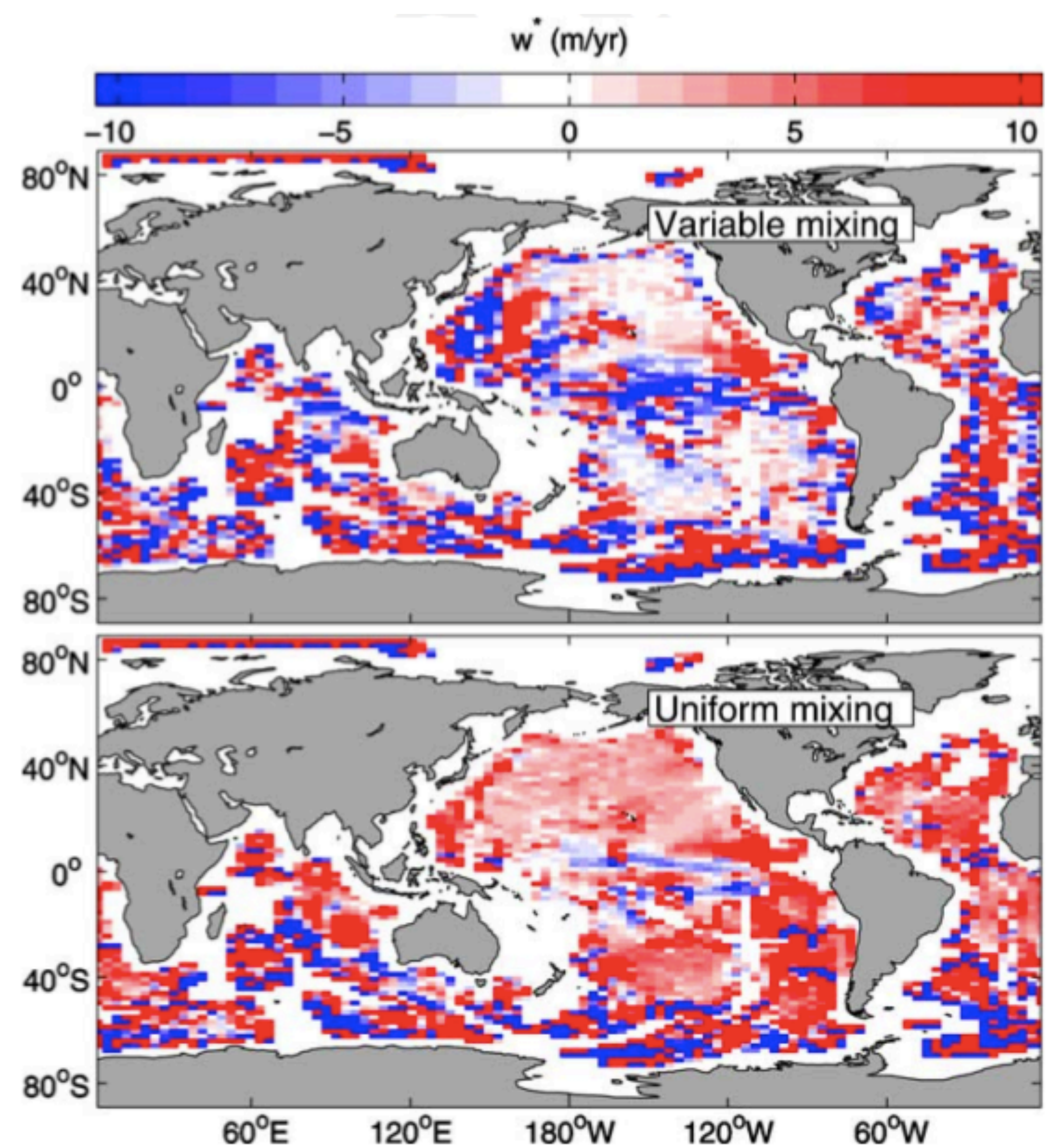
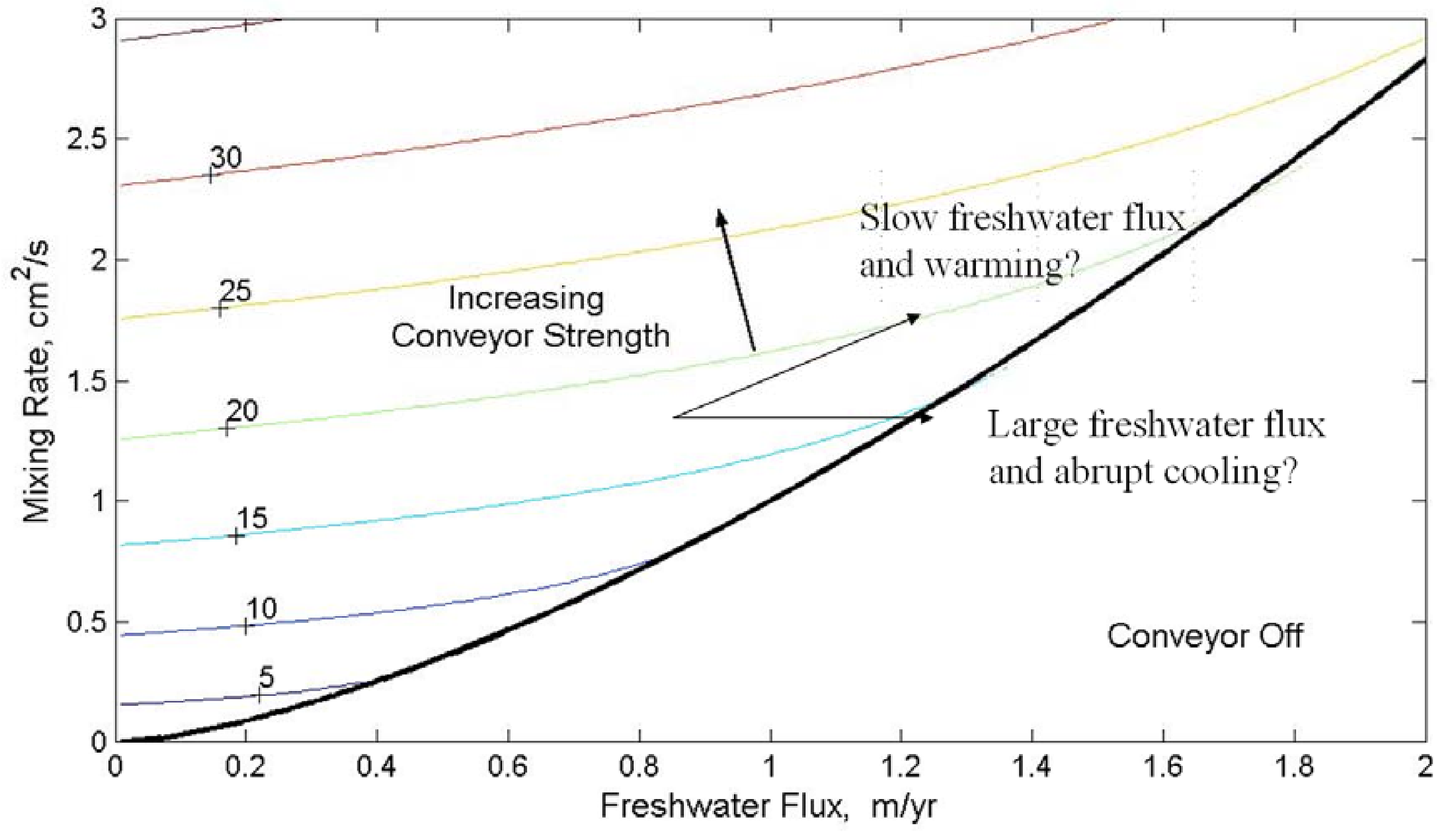


Fig. 5. Diapycnal mass flux (w^*) through the 3300 m depth level.

simmons et al

Changing strength of global overturning

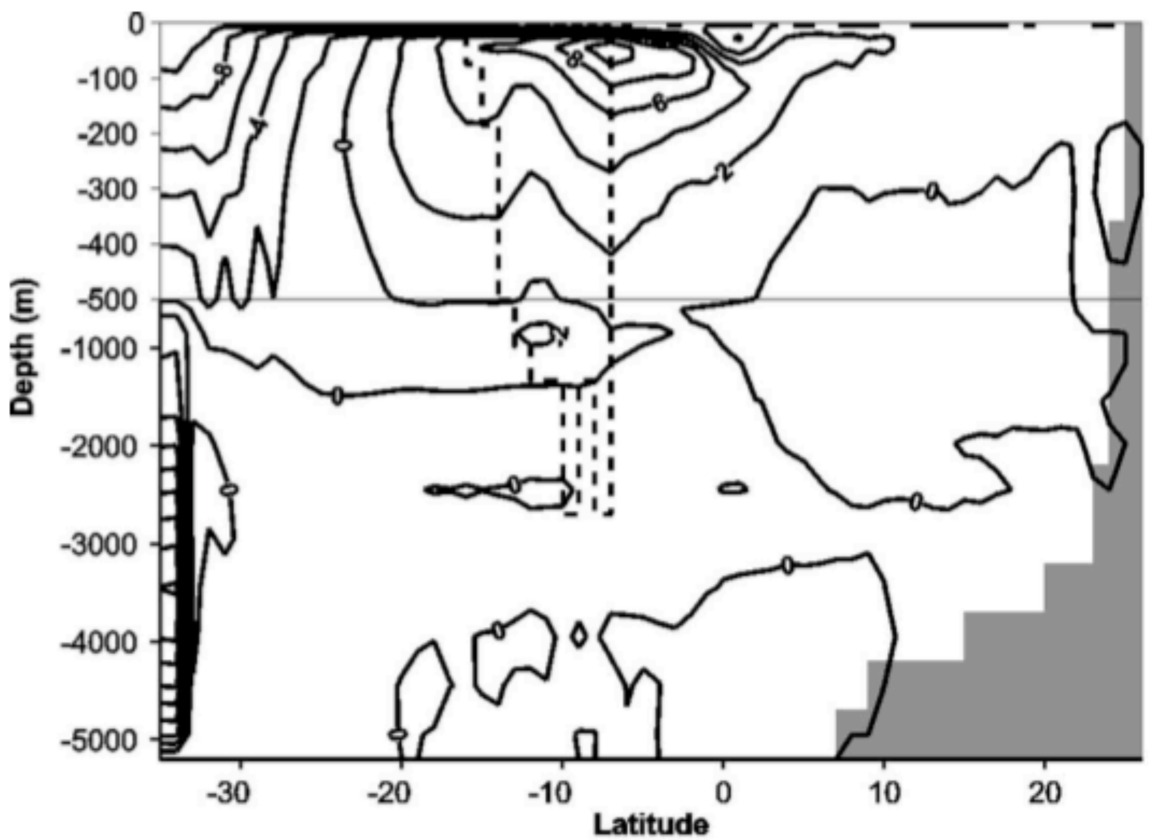
Expectation: freshwater flux will slow down MOC. But if mixing increases in a windier climate, maybe not (Schmitt et al, Ocean Obs)



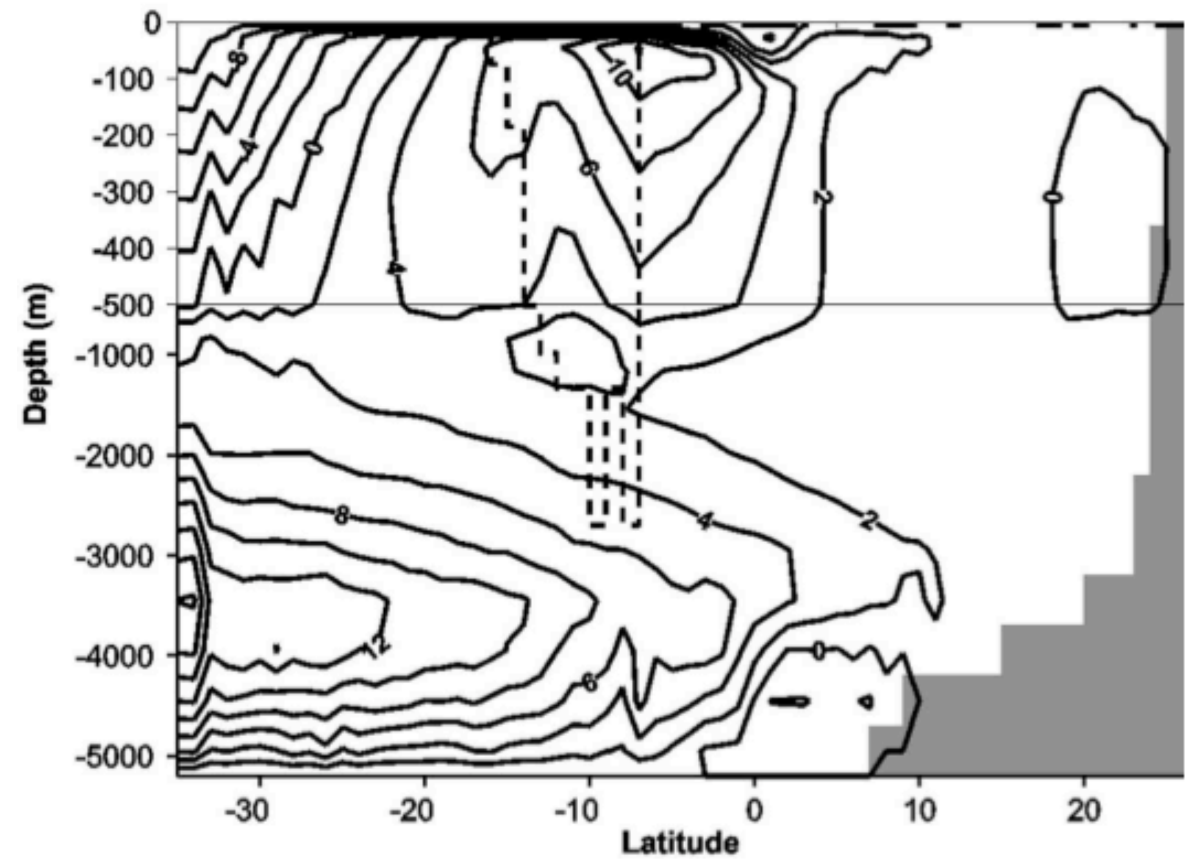
Changing strength of regional overturning

Palmer et al 07: Modeled Indian Ocean overturning streamfunction

Constant κ = 1.2 10^{-4}

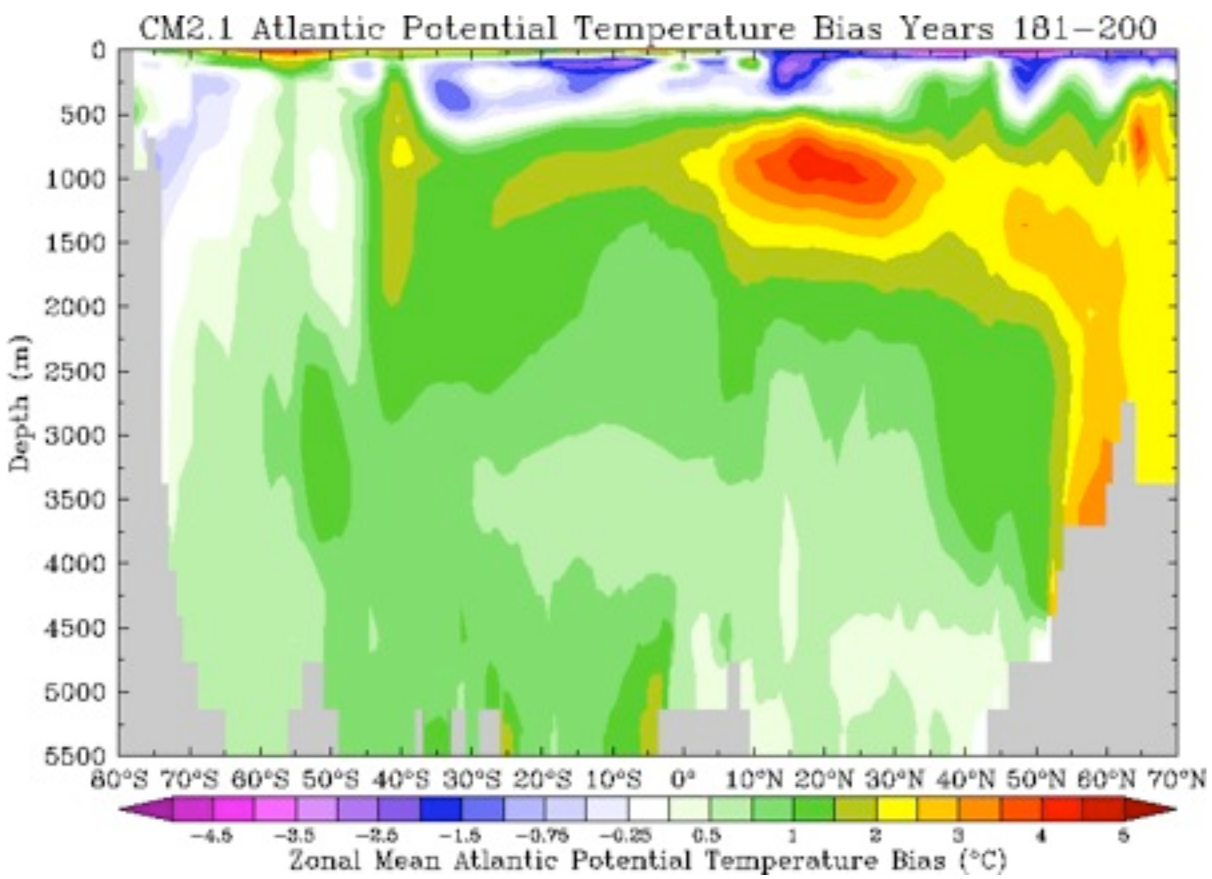


Bottom enhanced diffusivity

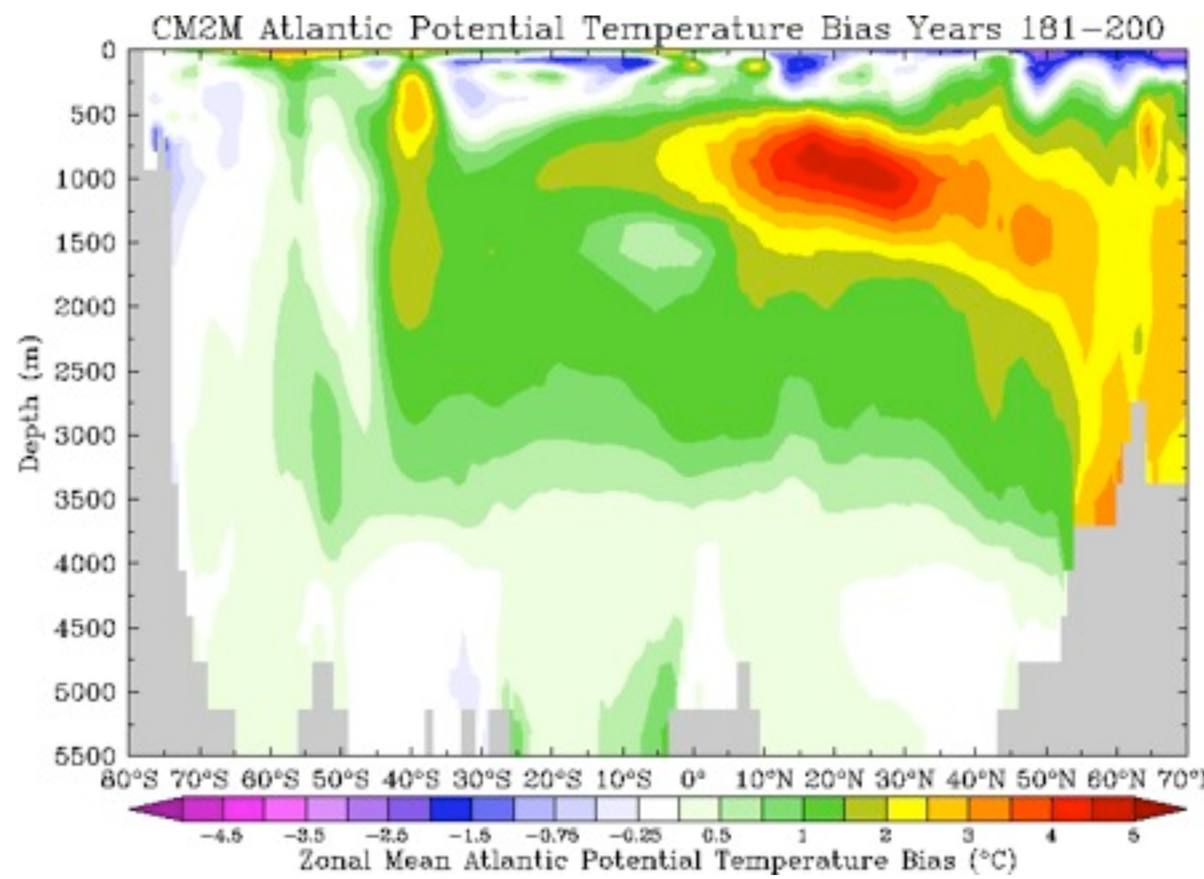


Patchiness of Deep Ocean Mixing matters

Zonal mean Atlantic temperature bias



CM2.1 (in AR4)



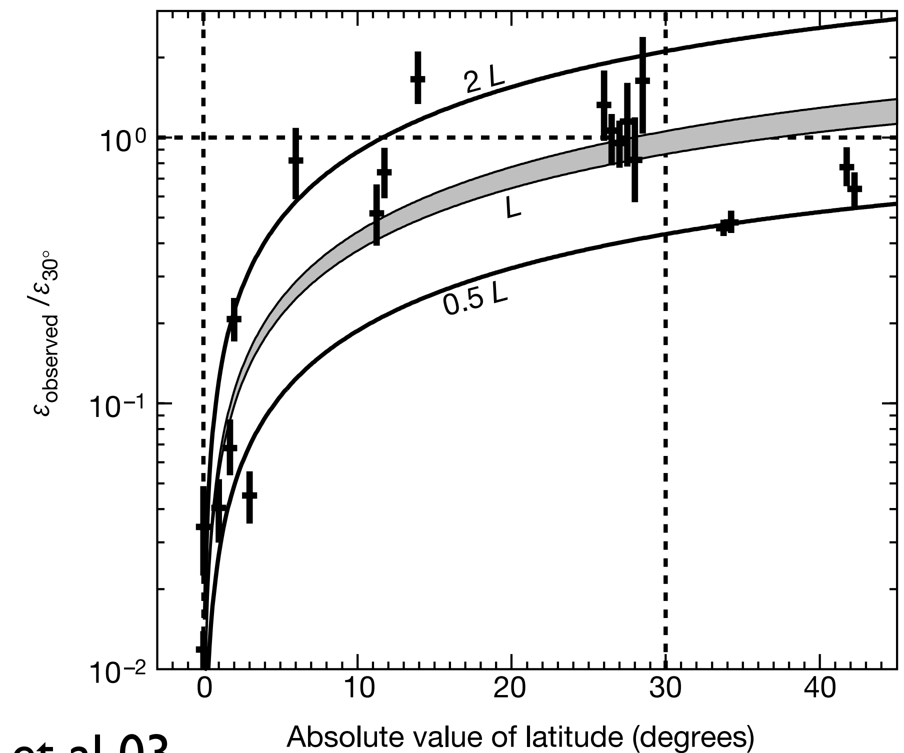
CM2M (in AR5)
Elevated mixing over rough topography

Hallberg

Patchiness of Upper Ocean Mixing matters

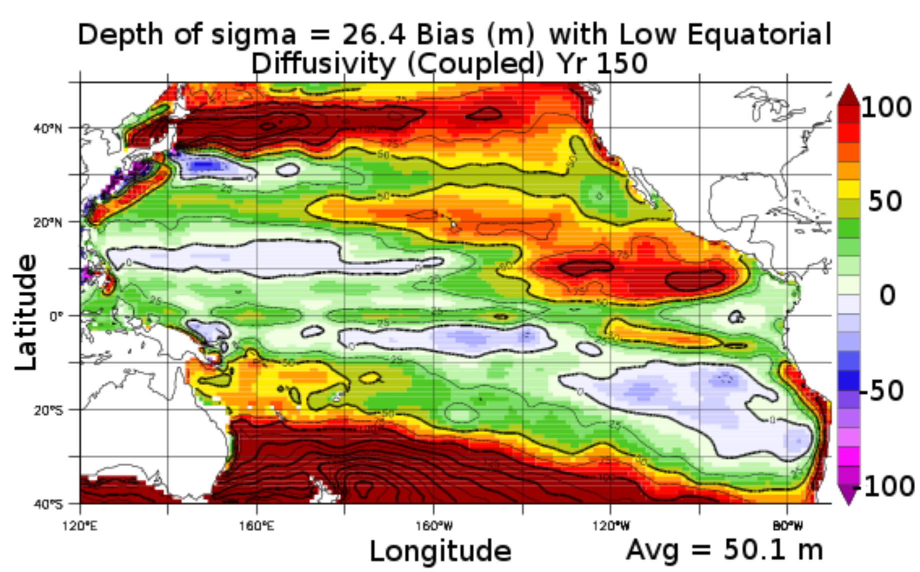
Successful application of wave-wave interaction theory: breaking of ambient internal wave field scales with latitude because of changing internal wave frequency band ($f<\omega<N$).

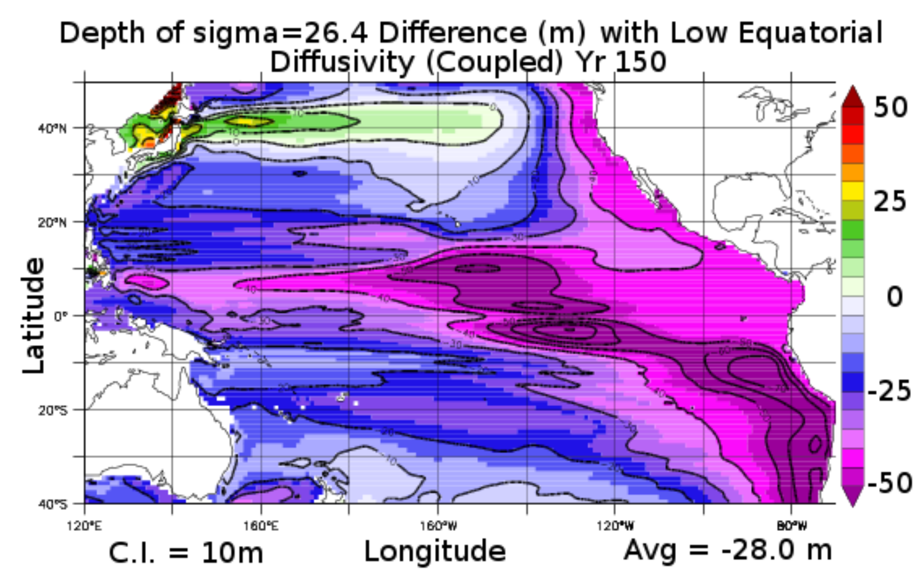
Observational confirmation



Gregg et al 03

Modeled implication





Harrison and Hallberg 08

Planned Work