Restratification by Mixed Layer Eddies
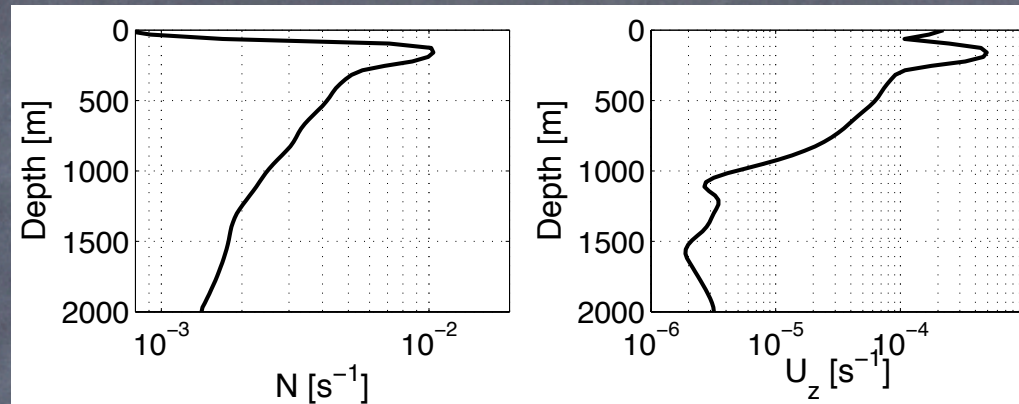
Baylor Fox-Kemper

Collaborators:
R. Ferrari, R. Hallberg, G. Flierl, G. Boccaletti and the CPT-EMiLIe team

AMS 16th Conference on
Atmospheric & Oceanic Fluid Dynamics
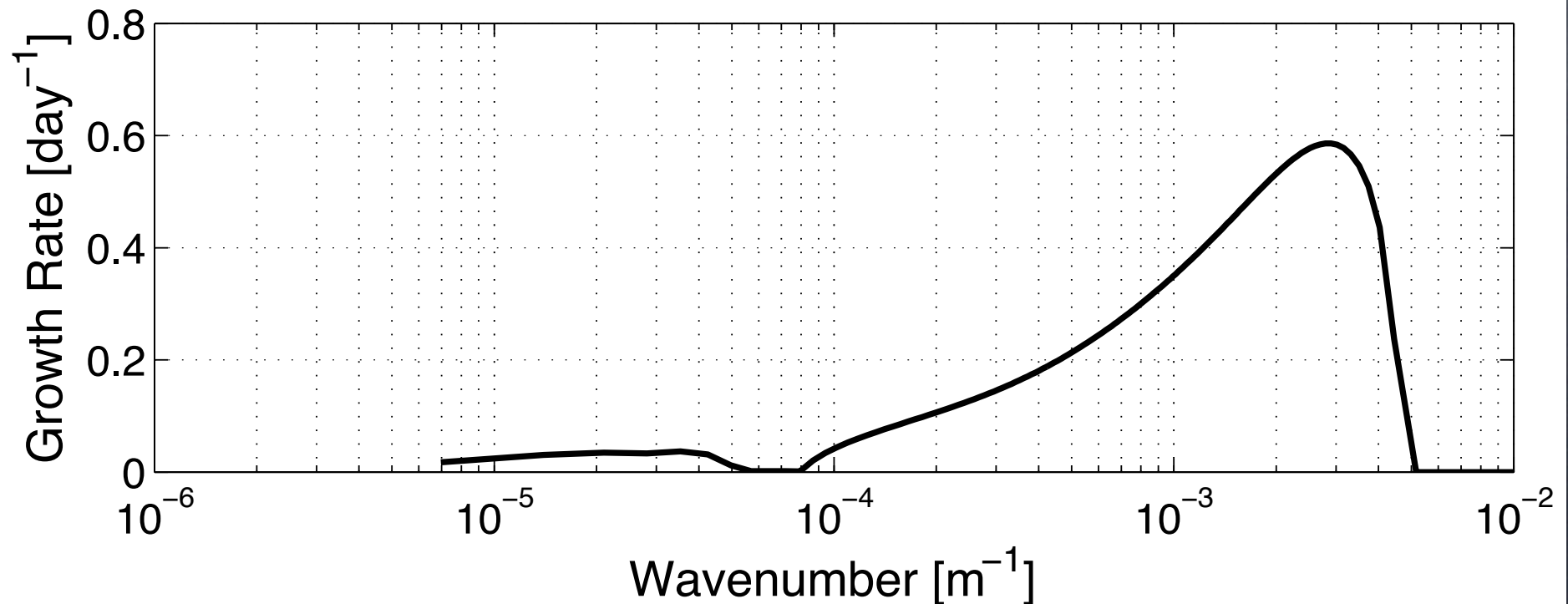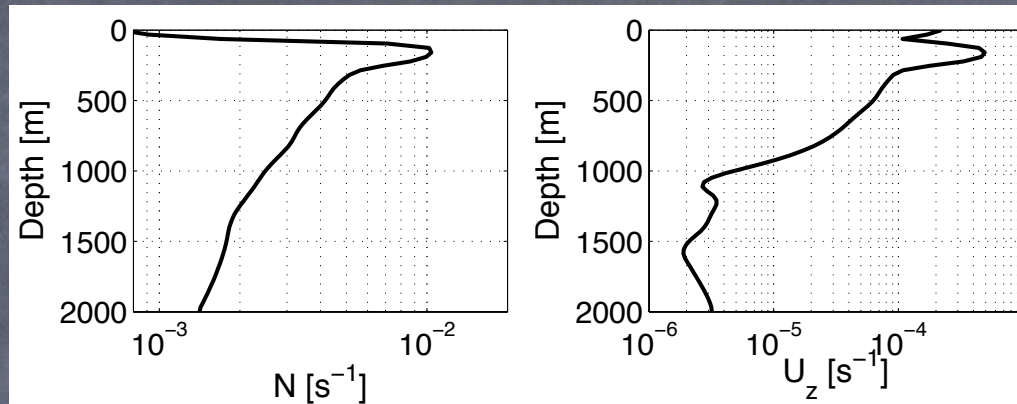Santa Fe, NM
Monday 6/25/07, 14:00-14:15

The Stratification Permits
Two Types of Baroclinic Instability:

Mesoscale and SubMesoscale (Boccaletti et al., 2006)

The Stratification Permits
Two Types of Baroclinic Instability:
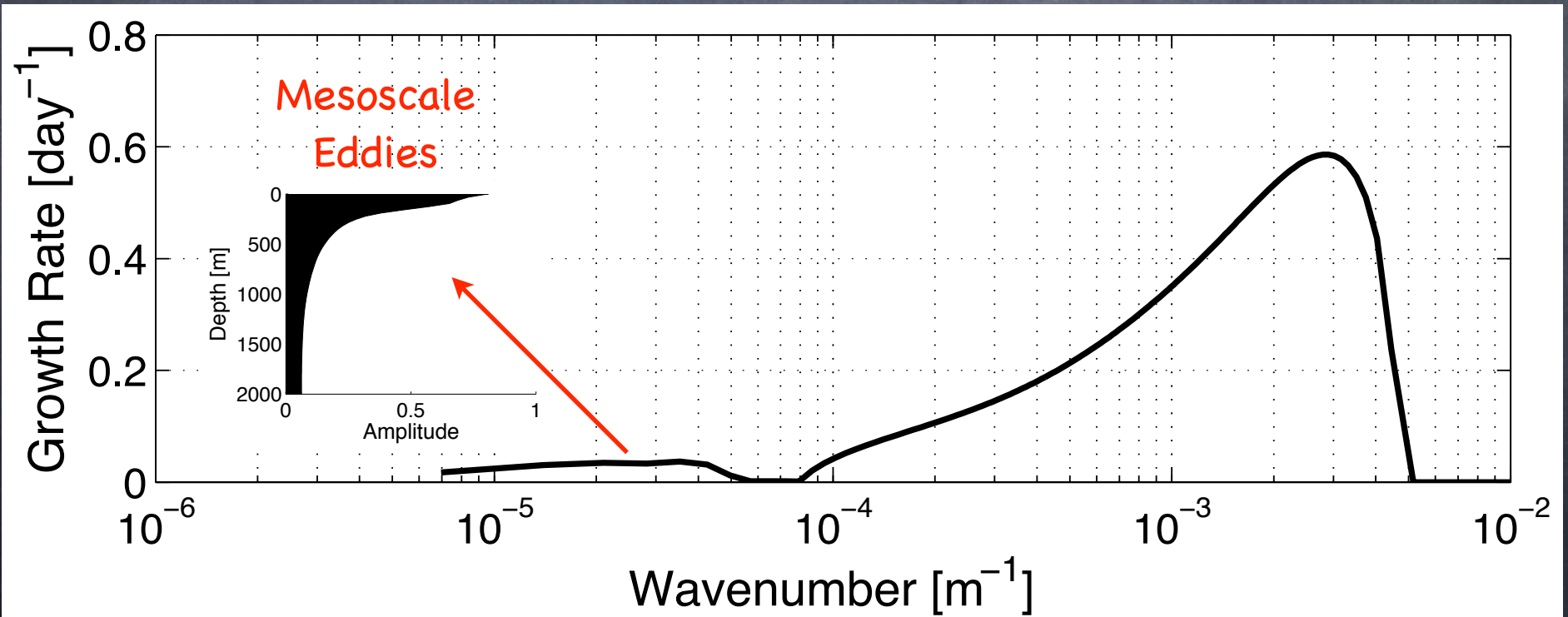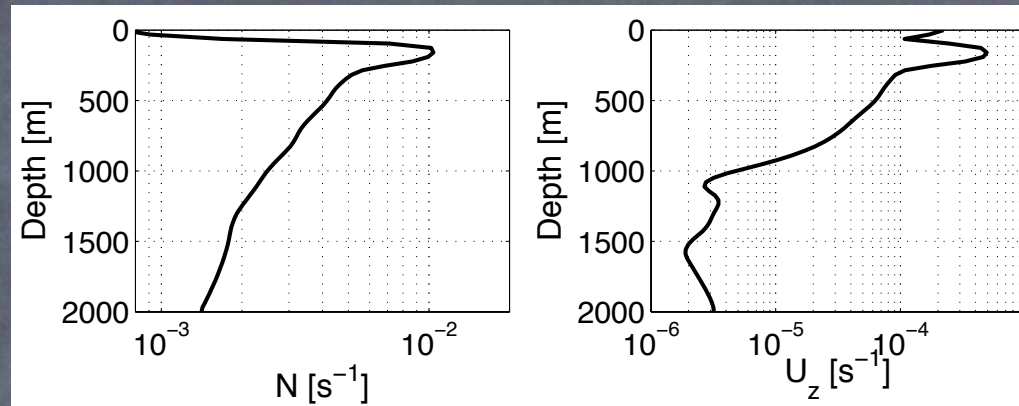
Mesoscale and SubMesoscale (Boccaletti et al., 2006)

The Stratification Permits
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The Stratification Permits
Two Types of Baroclinic Instability:
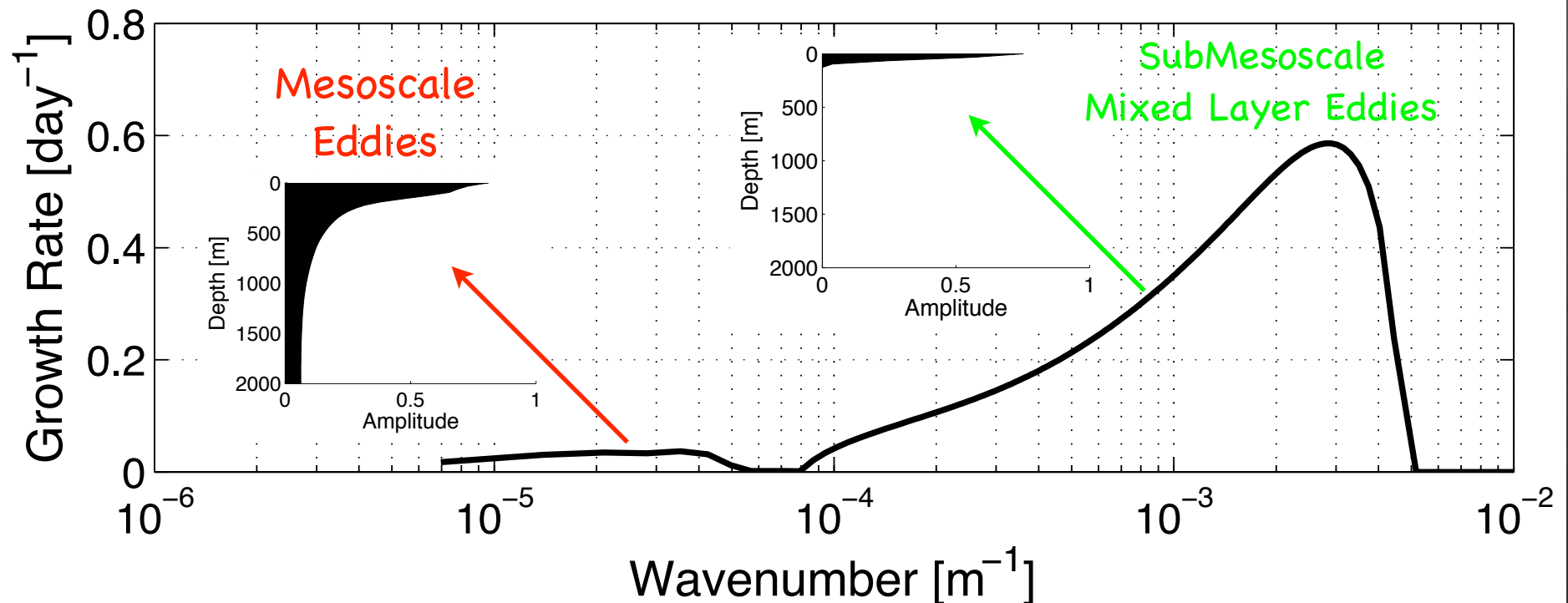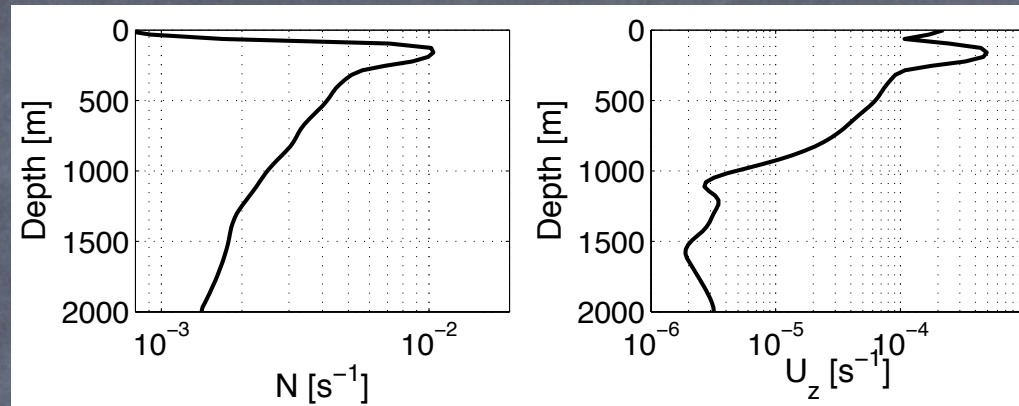
Mesoscale and SubMesoscale (Boccaletti et al., 2006)

The Stratification Permits
Two Types of Baroclinic Instability:
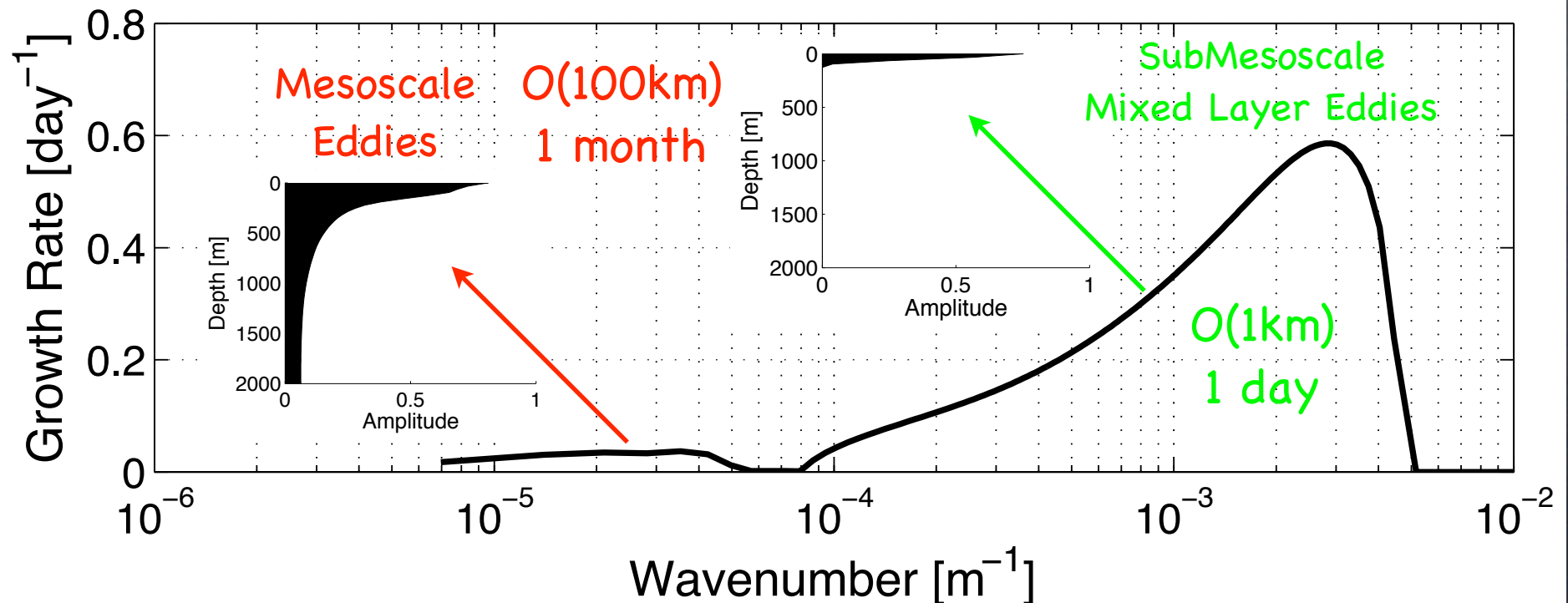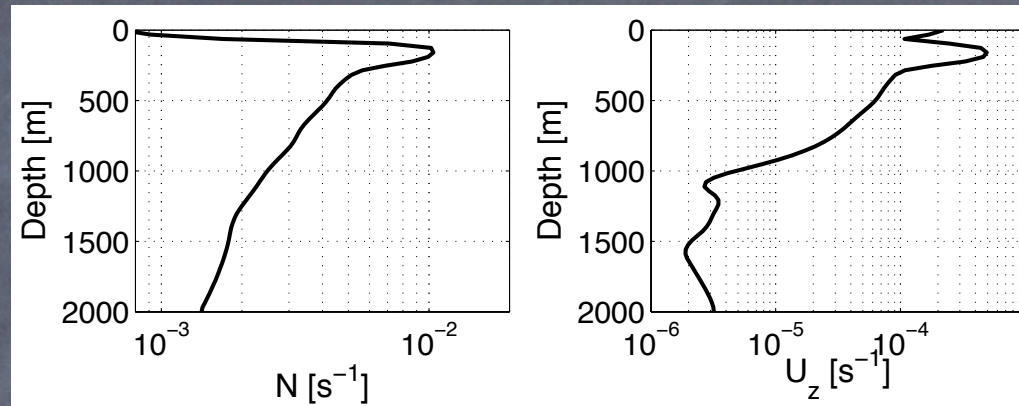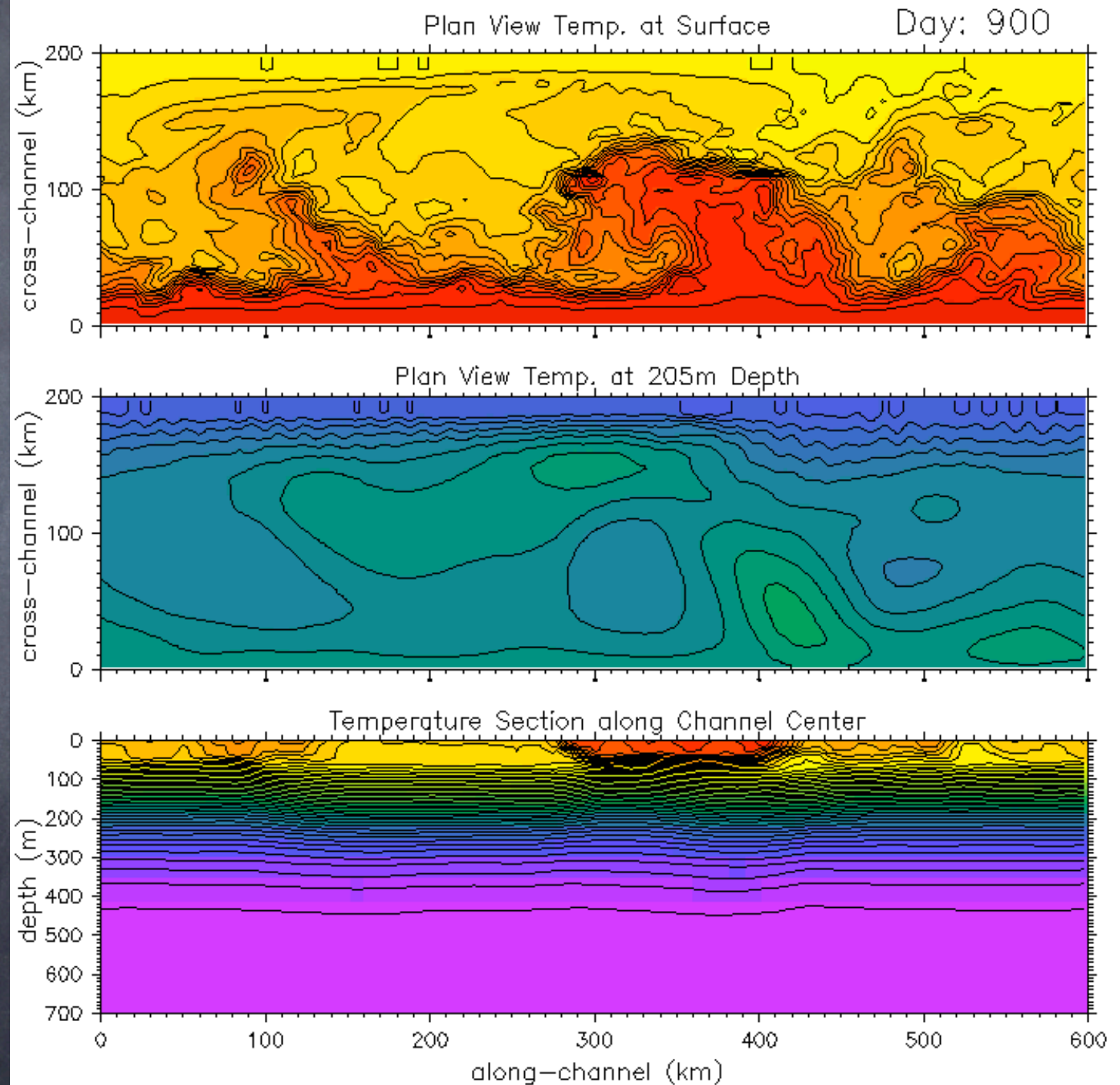
Mesoscale and SubMesoscale (Boccaletti et al., 2006)

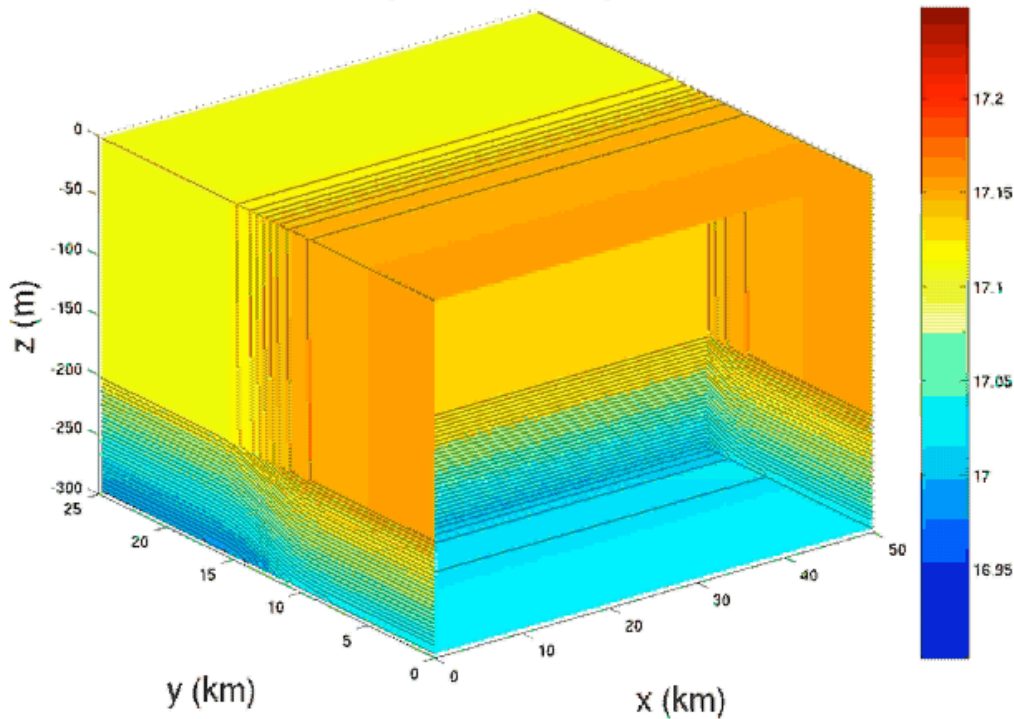Mesoscale and SubMesoscale are Coupled Together:

ML Fronts are formed by Mesoscale Straining.

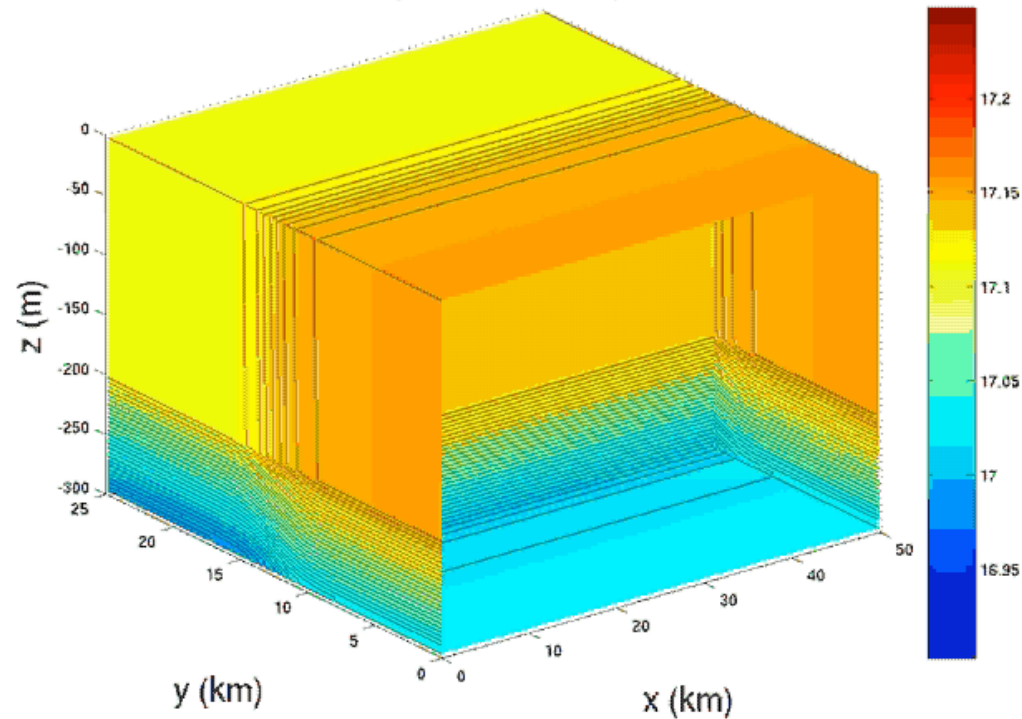Submesoscale eddies remove PE from those fronts.

Plan View Temp. at Surface   Day: 900

Plan View Temp. at 205m Depth

Temperature Section along Channel Center
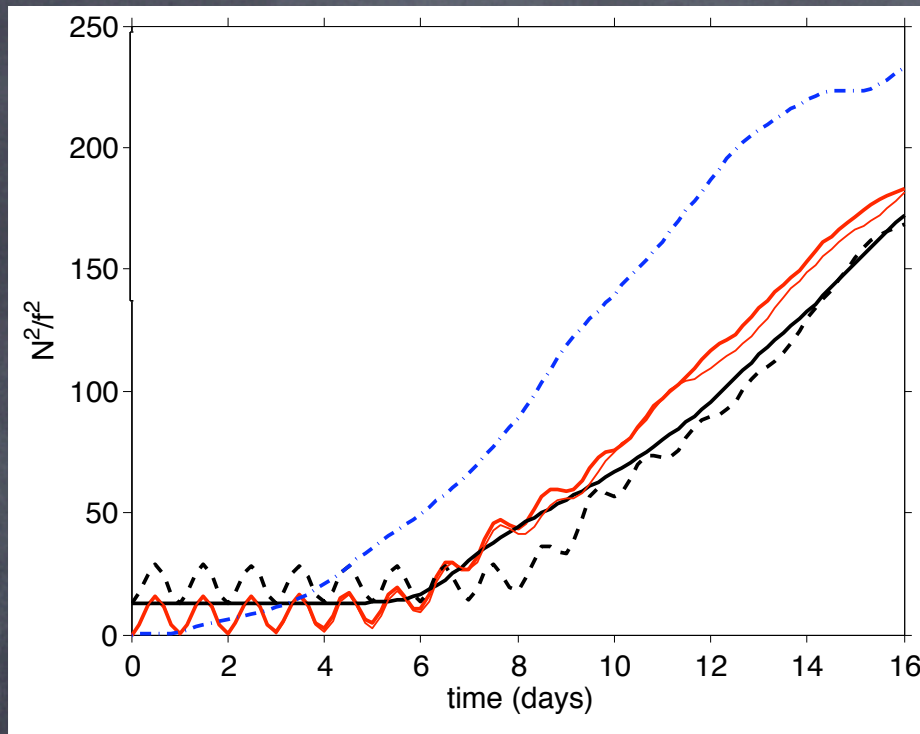
Prototype: Mixed Layer Front Overturning
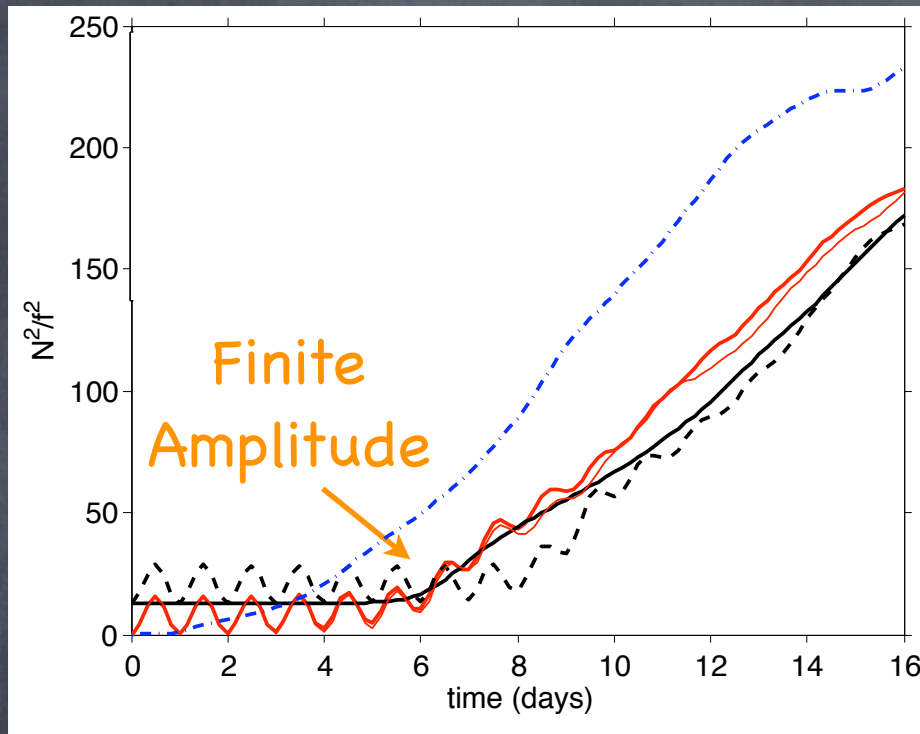

Simple Spindown

Plus, Diurnal Cycle and KPP

Note: initial geostrophic adjustment overwhelmed by eddy restratification

Parameterization of Finite Amp. Eddies: Ingredients

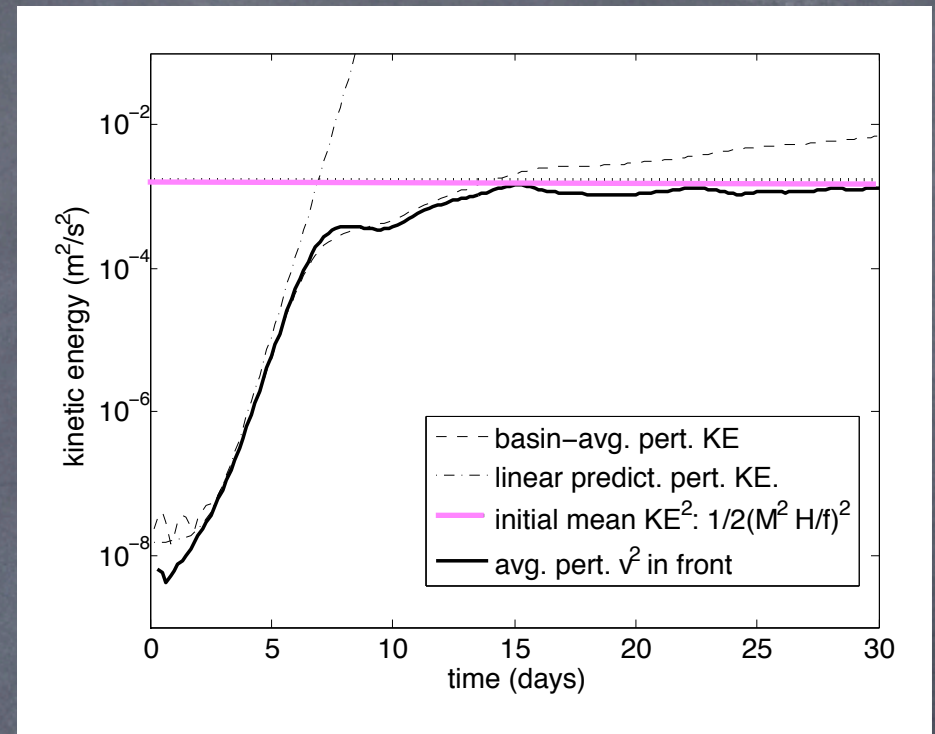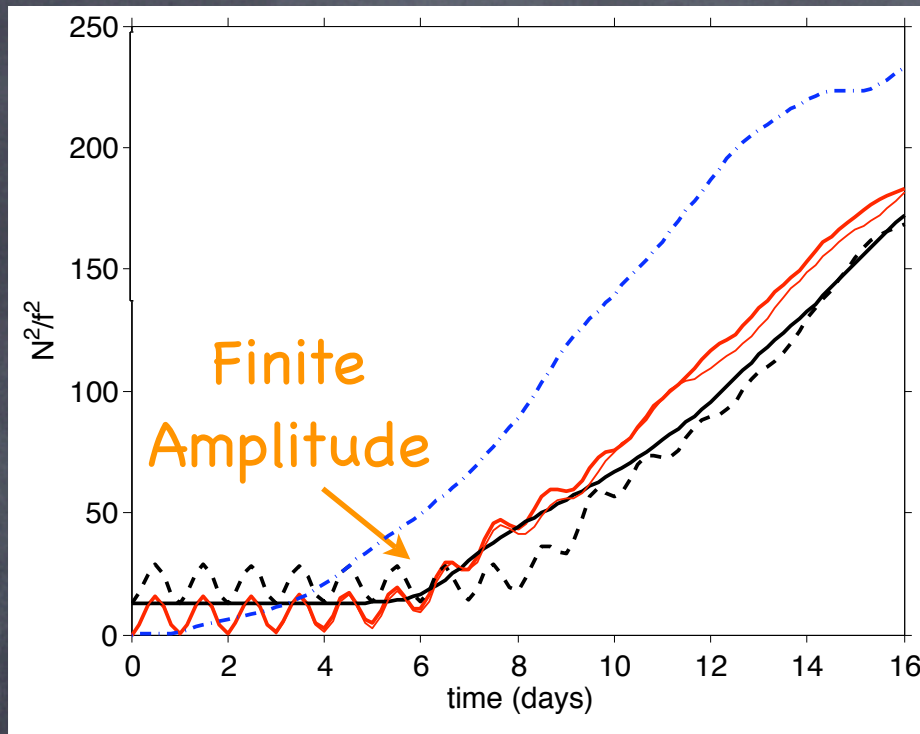Linear Solution <w′b′> for vert. structure.

Parameterization of Finite Amp. Eddies: Ingredients

Linear Solution <w'b'> for vert. structure.

Parameterization of Finite Amp. Eddies: Ingredients

Linear Solution <w'b'> for vert. structure.

Parameterization of Finite Amp. Eddies: Ingredients

Linear Solution <w'b'> for vert. structure.

Parameterization of Finite Amp. Eddies: Ingredients

Linear Solution <w'b'> for vert. structure.
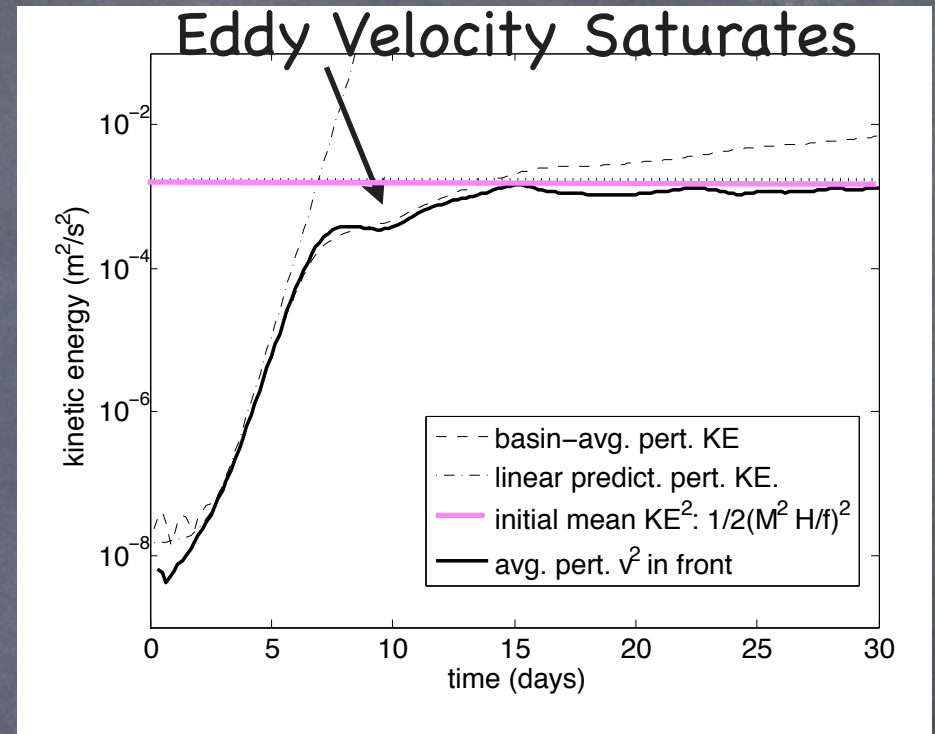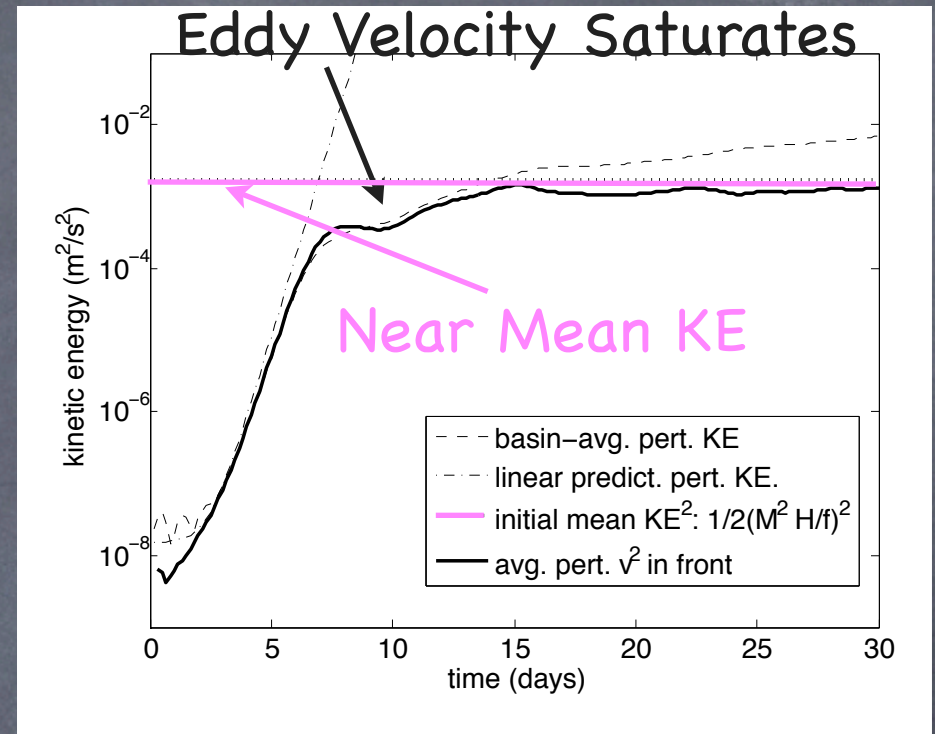
Parameterization of Finite Amp. Eddies: Ingredients

Finite Amplitude

Eddy Velocity Saturates

Near Mean KE

basin–avg. pert. KE
linear predict. pert. KE.
initial mean KE^2: $1/2(M^2 H/f)^2$
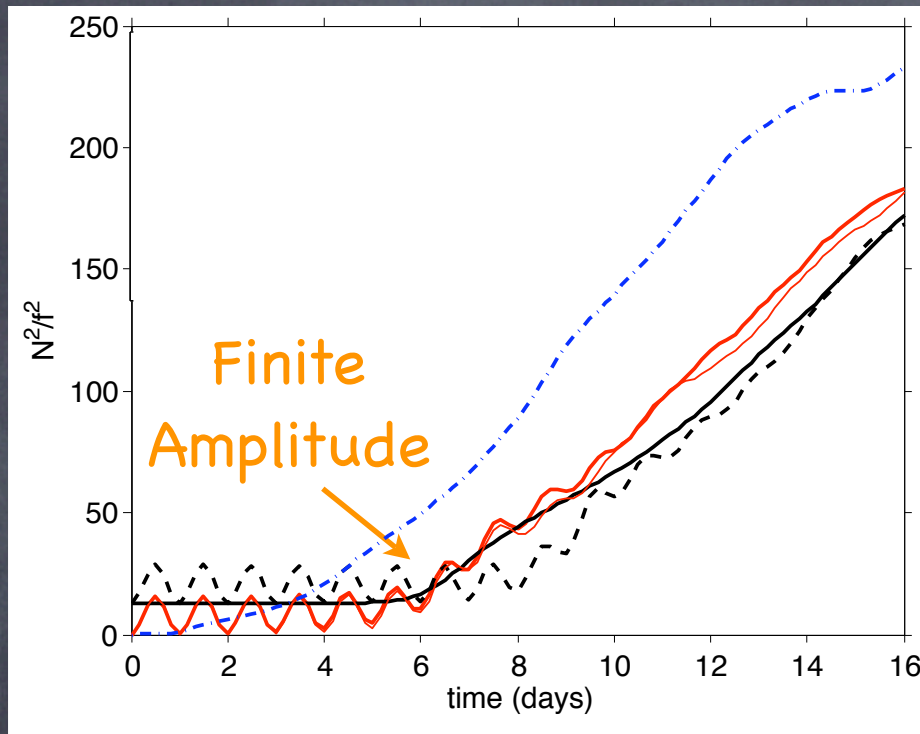avg. pert. v^2 in front

Vert. Excursions
(b'_{rms}/N^2)
scale with H
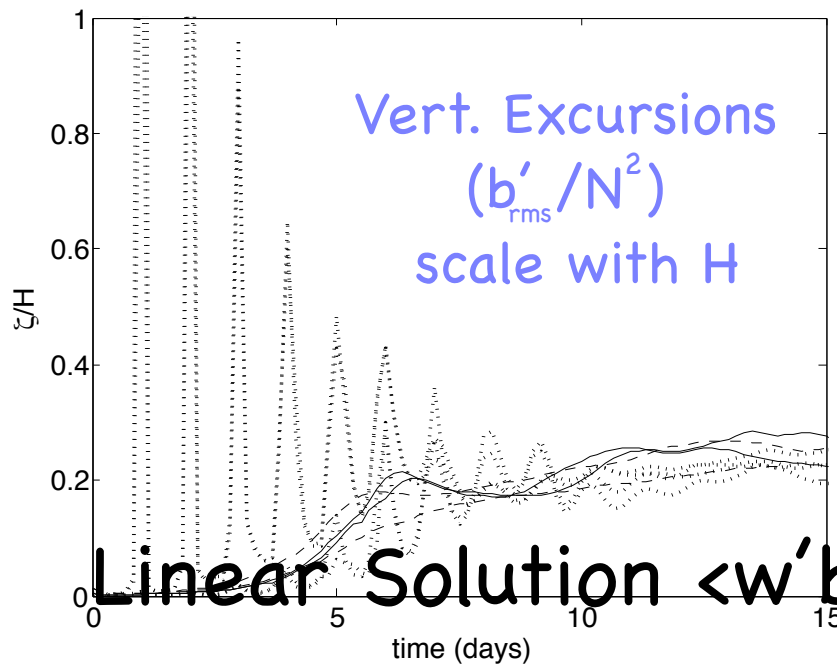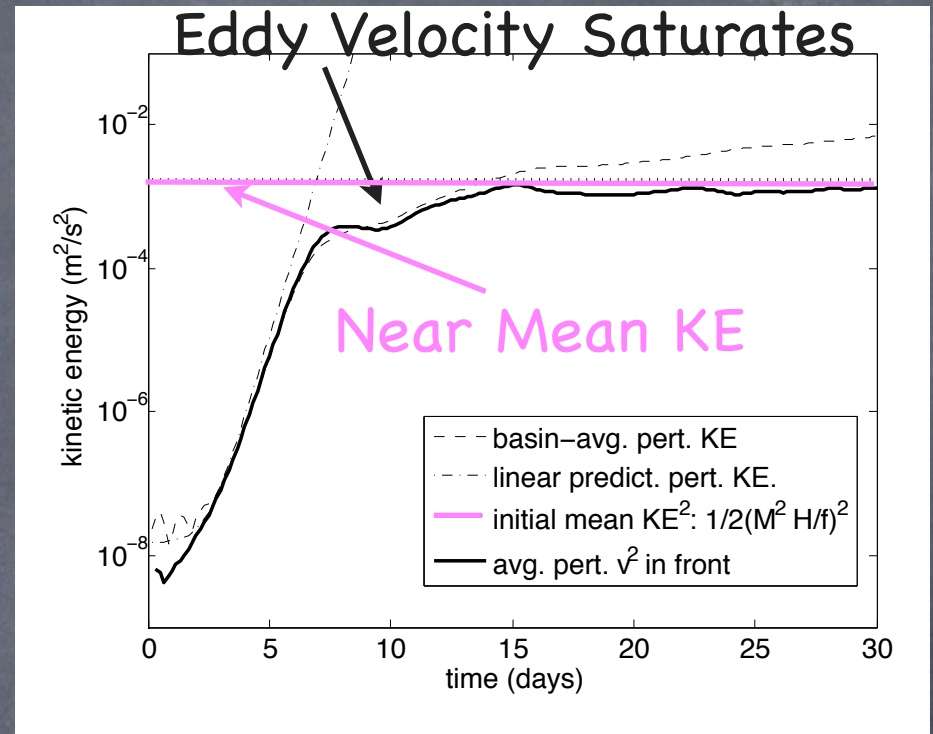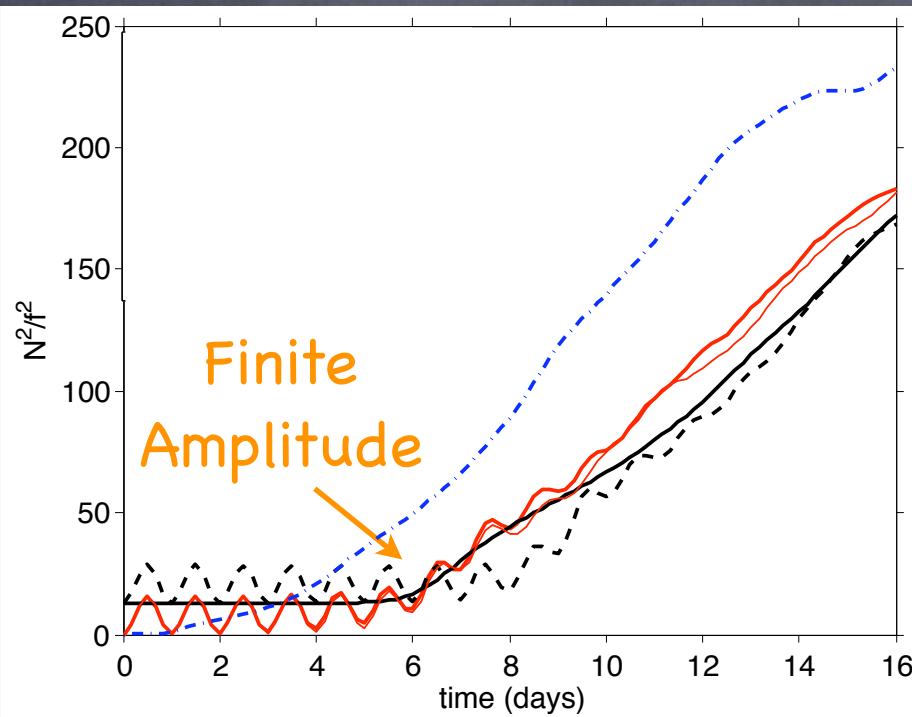
Linear Solution <w'b'> for vert. structure.

Parameterization of Finite Amp. Eddies: Ingredients

Finite Amplitude

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Near Mean KE

basin–avg. pert. KE
linear predict. pert. KE.
initial mean KE^2: 1/2(M^2 H/f)^2
avg. pert. v^2 in front

Vert. Excursions (b'$_{rms}$/N^2) scale with H
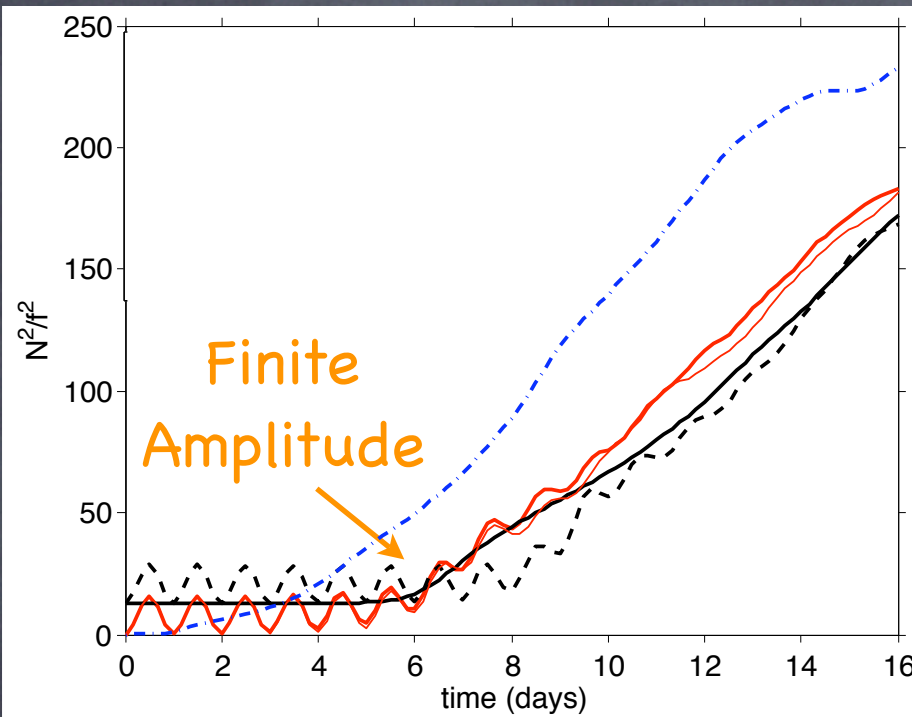
Eddy Fluxes are at nearly 1/2 the mean isopycnal slope
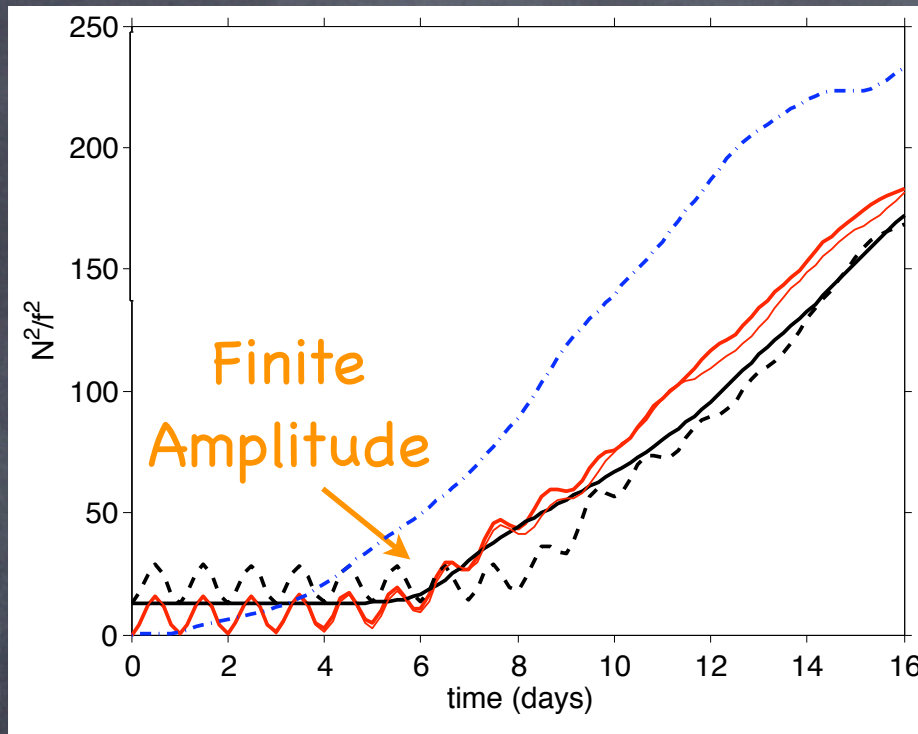
Linear Solution <w'b'> for vert. structure.

The Parameterization:

$$\mathbf{\Psi} = \frac{C_e H^2 \mu(z)}{|f|} \nabla \bar{b} \times \hat{\mathbf{z}}$$

$$\mu(z) = \left[1 - \left(\frac{2z}{H} + 1 \right)^2 \right] \left[1 + \frac{5}{21} \left(\frac{2z}{H} + 1 \right)^2 \right]$$

- The horizontal fluxes are downgradient:

$$\overline{\mathbf{u'_H} b'} = - \frac{C_e H^2 \mu(z) \frac{\partial \bar{b}}{\partial z}}{|f|} \nabla_H \bar{b}$$
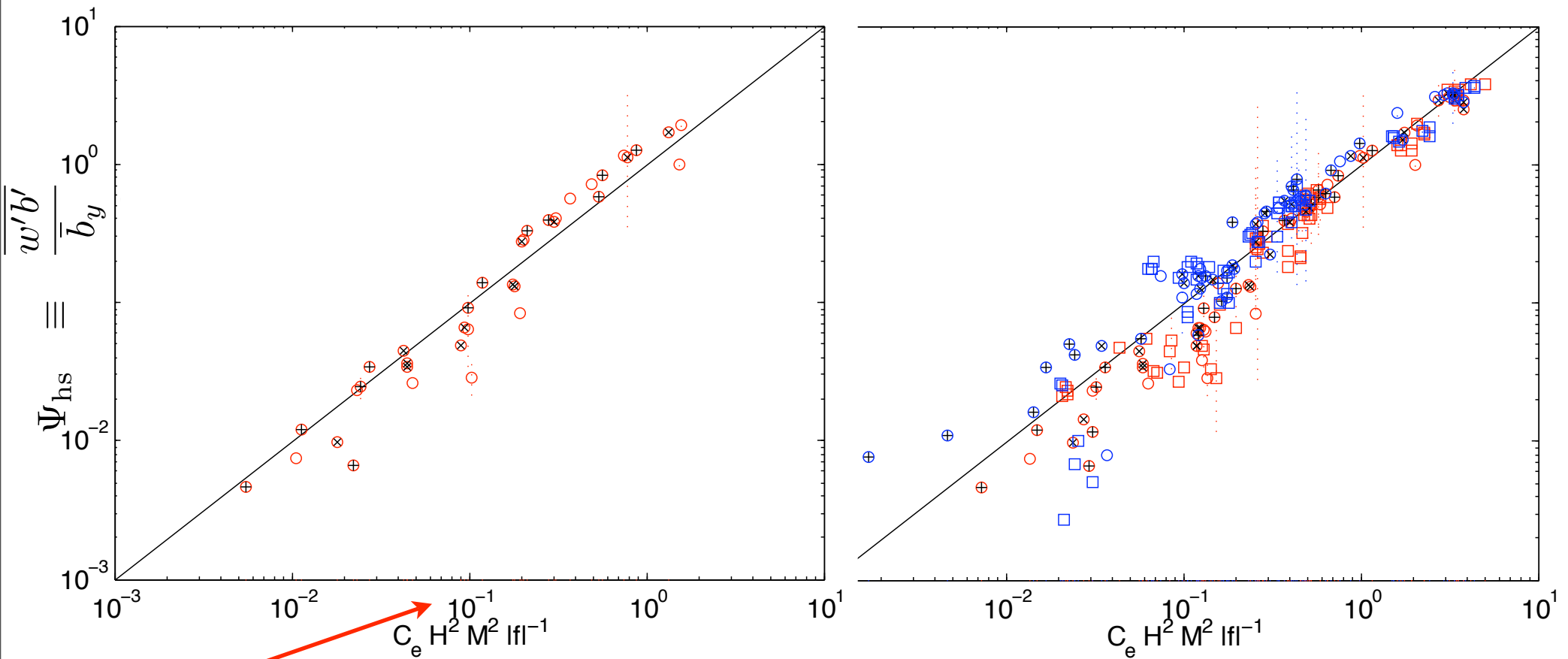
- Vertical fluxes always upward to restratify:

$$\overline{w' b'} = \frac{C_e H^2 \mu(z)}{|f|} |\nabla \bar{b}|^2$$

- Adjustments for coarse resolution and f->0 are known

It works for Prototype Sims:
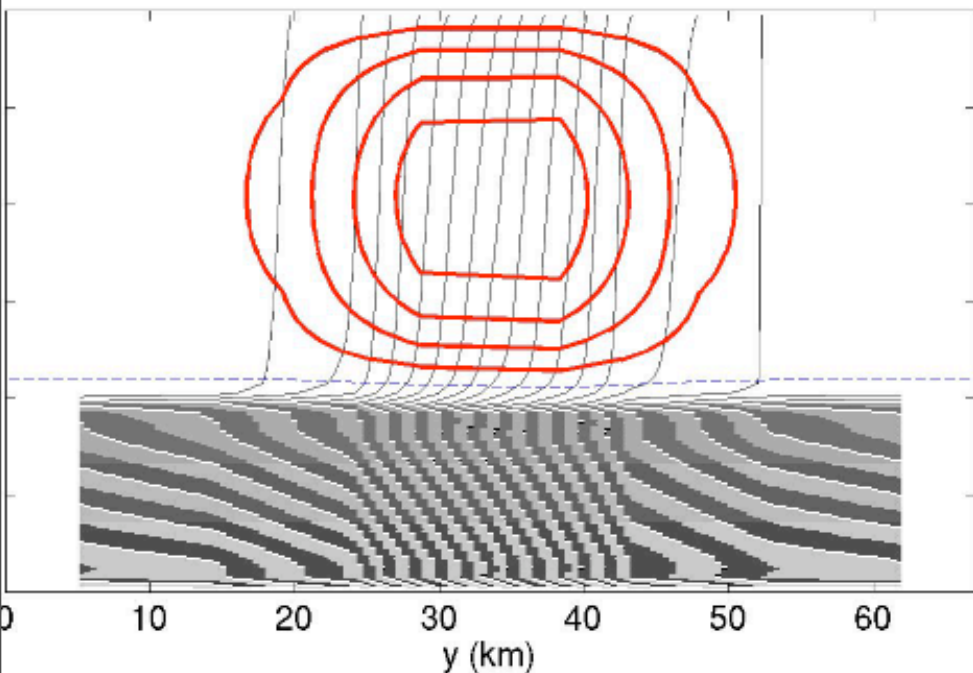

Circles: Balanced Initial Cond.
Squares: Unbalanced Initial Cond.

What does it look like?

Parameterization (2d, 10km grid)

Submesoscale-Resolving (3d,500m grid)
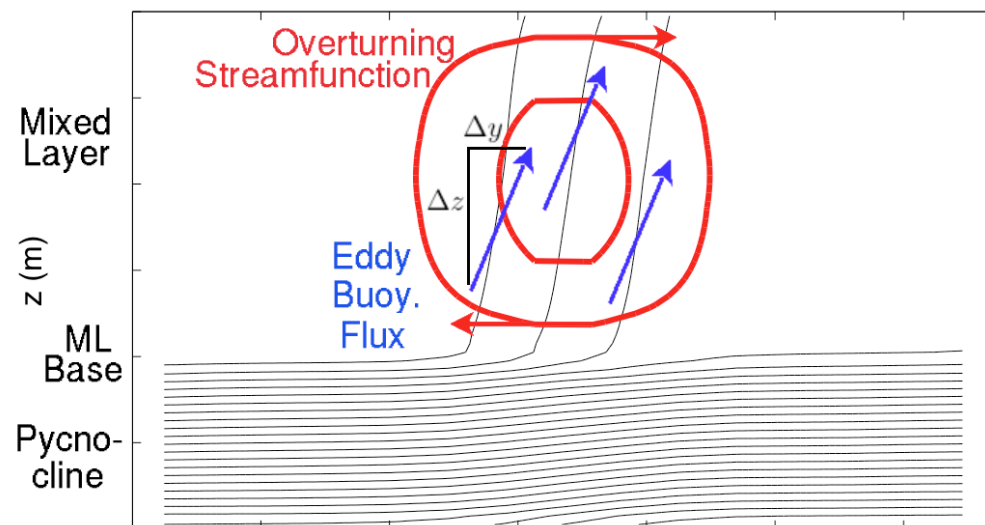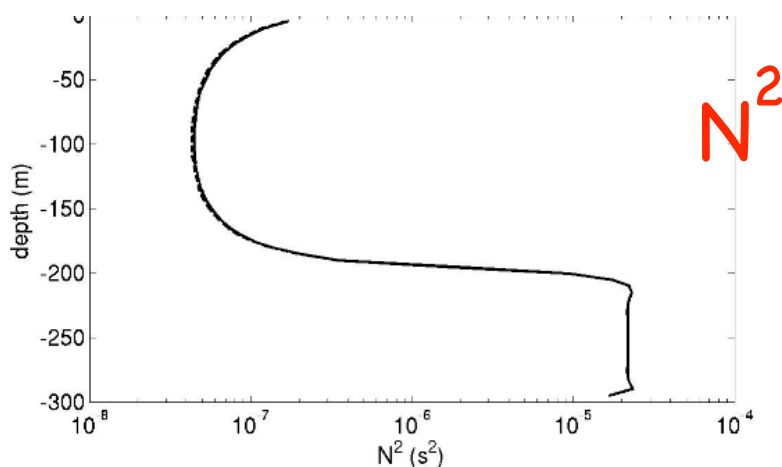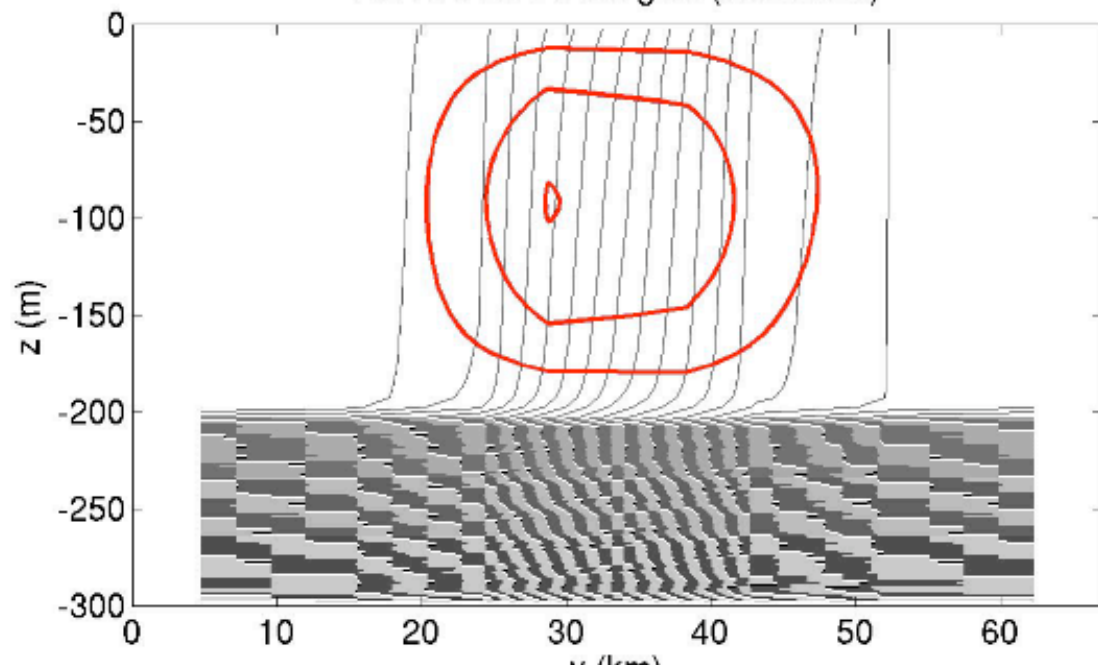
Changes To Mixing Layer Depth in Eddy-Resolving Southern Ocean Model
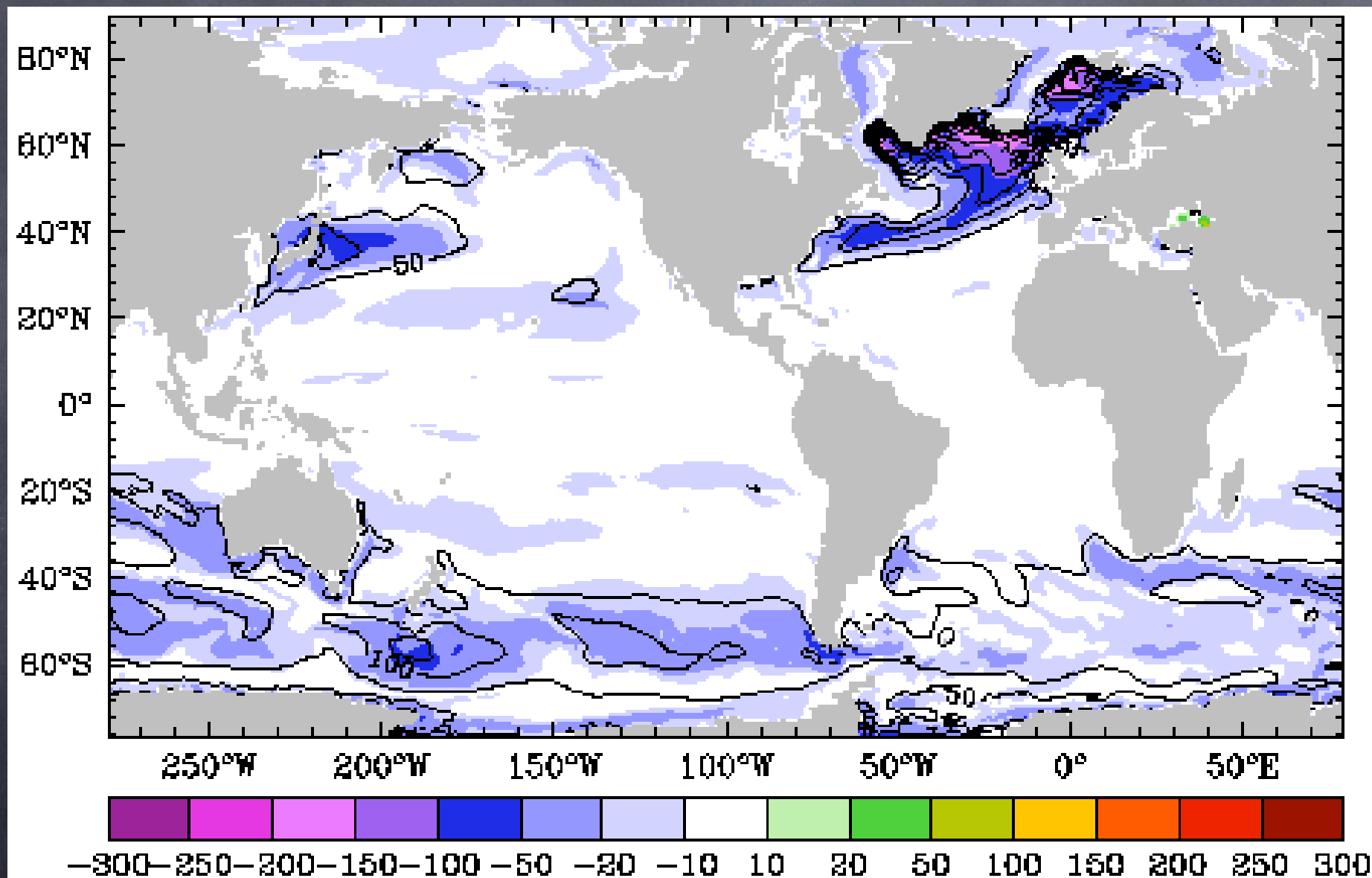

Mixed Layer Depth (m)
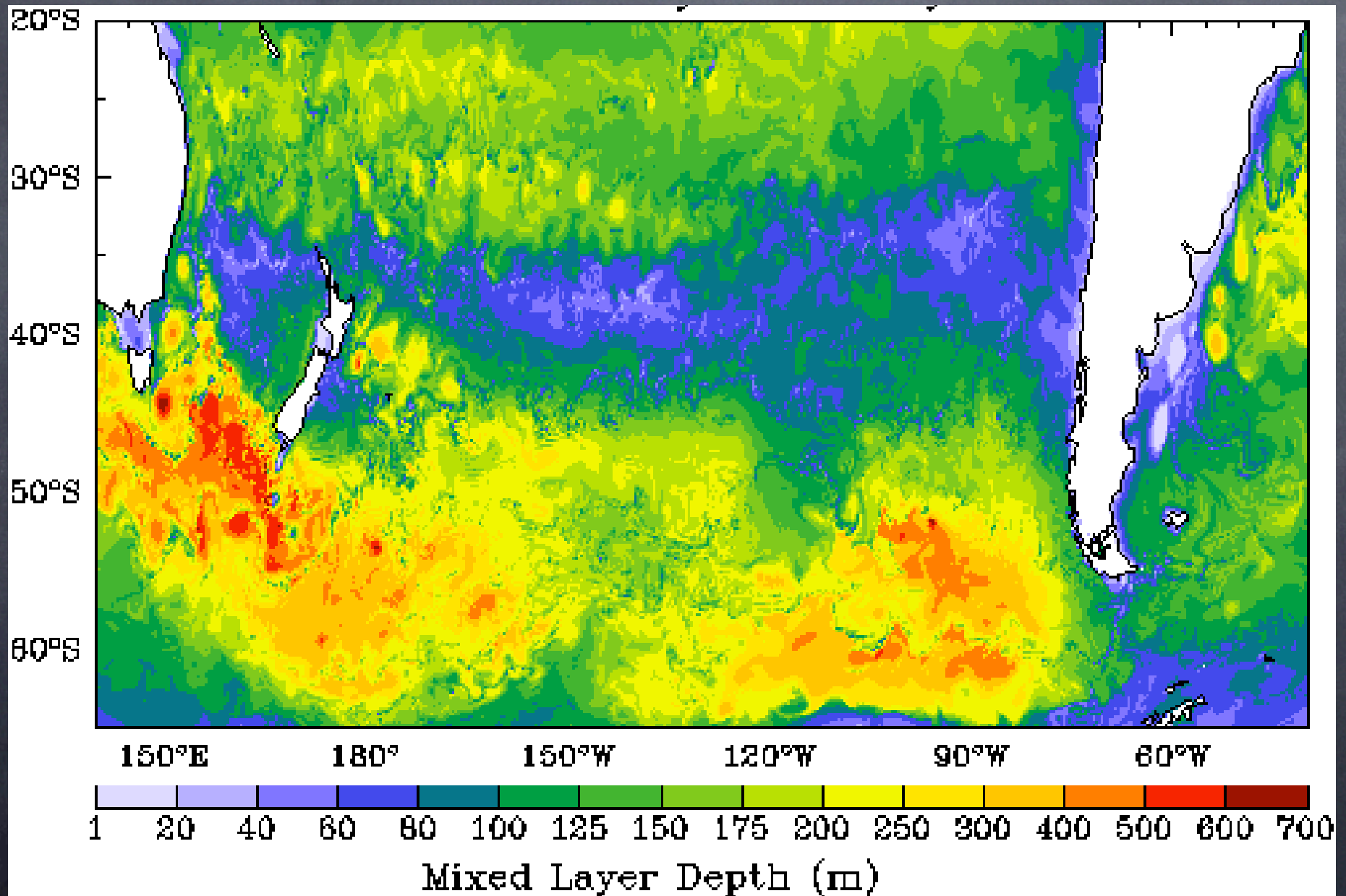
Changes To Mixing Layer Depth in Eddy-Resolving Southern Ocean Model
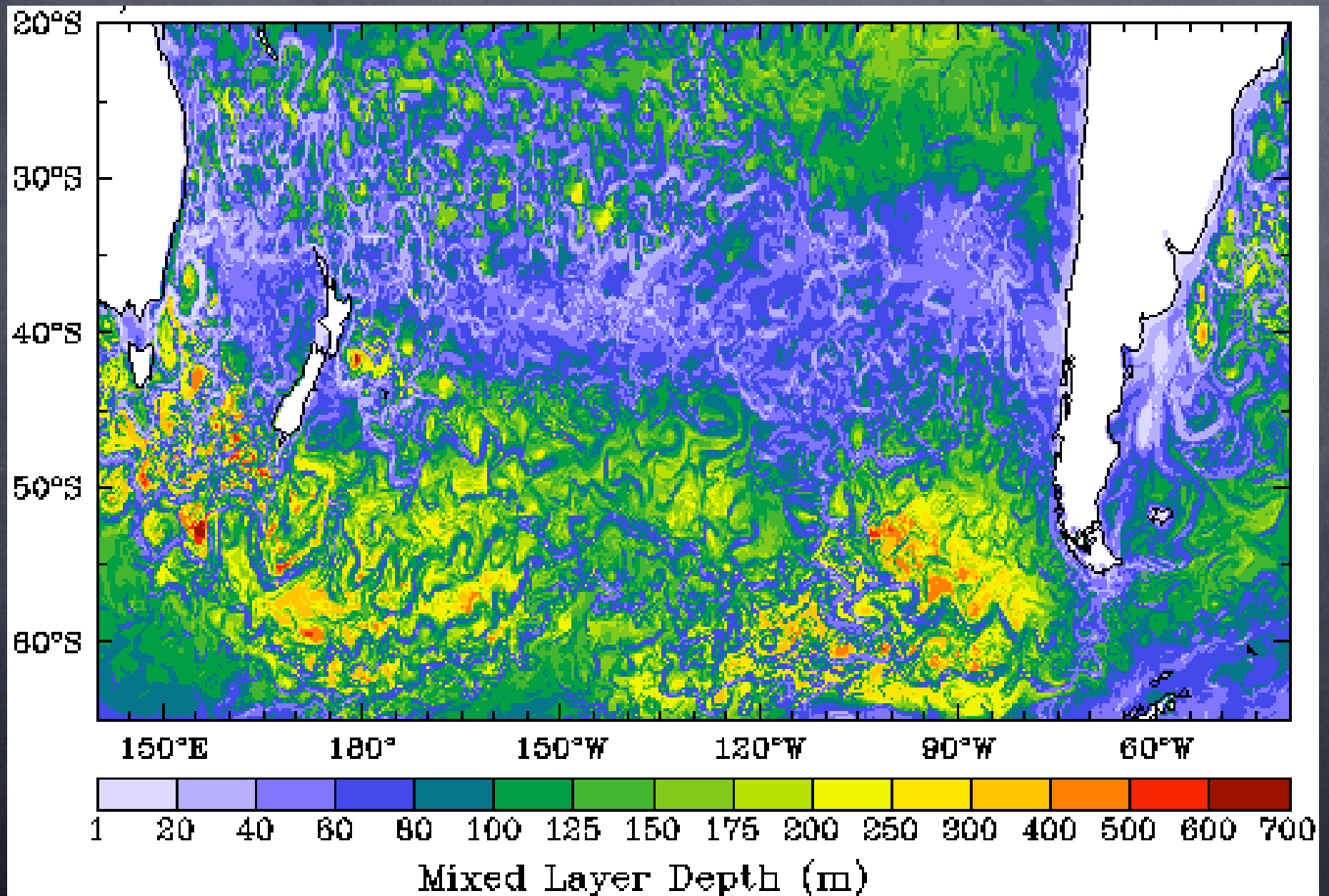
Equator (f->0) and coarse resolution (up to 1 deg) are manageable
Improves Restratification after Deep Convection
Note: param. reproduces Haine&Marshall (98) and Jones&Marshall (93,97)

Contoured: 5-yr mean mixing layer depth (m) in HIM.
Shaded: change (m) with parameterization

Conclusion:

- Submesoscale features, and mixed layer eddies in particular, exhibit large vertical fluxes of buoyancy that are presently ignored in climate models.

- A parameterization of mixed layer eddy fluxes as an overturning streamfunction is proposed. The magnitude comes from extraction of potential energy, and the vertical structure resembles the linear Eady solution.

- Many observations are consistent, and model biases are reduced. Biogeochemical effects are likely, as vertical fluxes and mixed layer depth are changed.

- In HIM, soon to be in MITgcm and CCSM.

- 3 Papers so far... Just ask me for them.