

Restratification by Mixed Layer Eddies

Baylor Fox-Kemper

Collaborators:

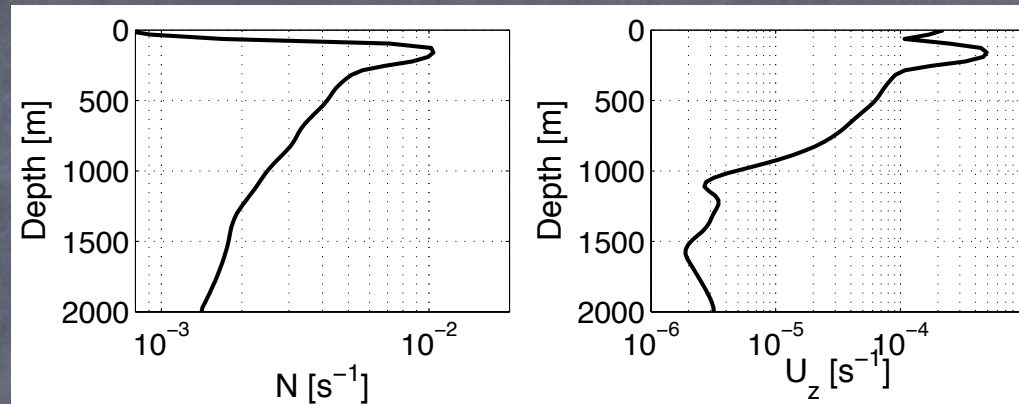
R. Ferrari, R. Hallberg, G. Flierl, G. Boccaletti and
the CPT-EMiLIE team

AMS 16th Conference on
Atmospheric & Oceanic Fluid Dynamics
Santa Fe, NM

Monday 6/25/07, 14:00–14:15

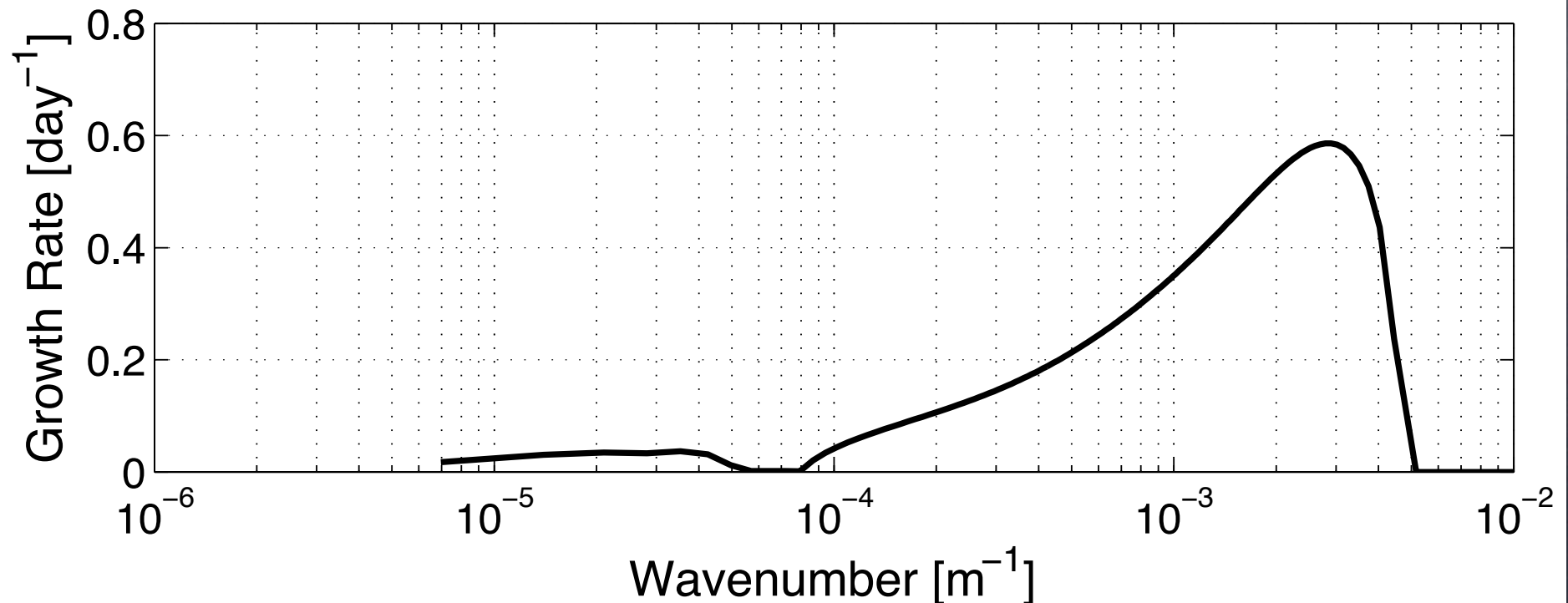
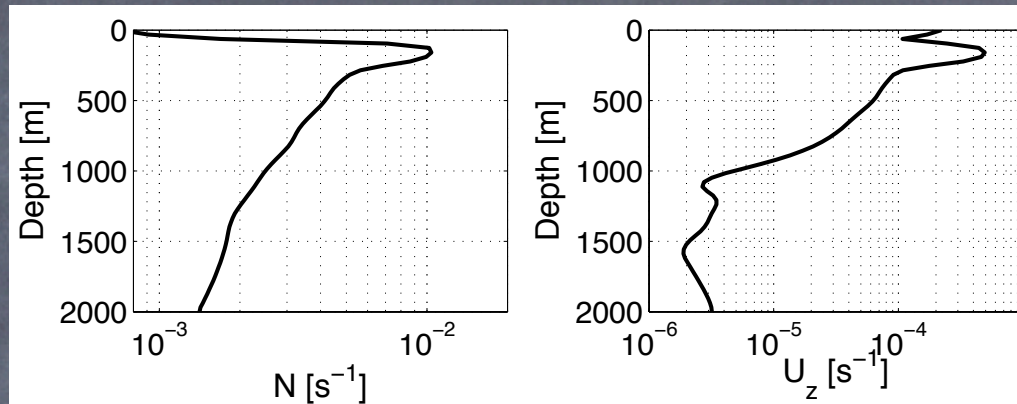
The Stratification Permits Two Types of Baroclinic Instability:

Mesoscale and **SubMesoscale** (Boccaletti et al., 2006)



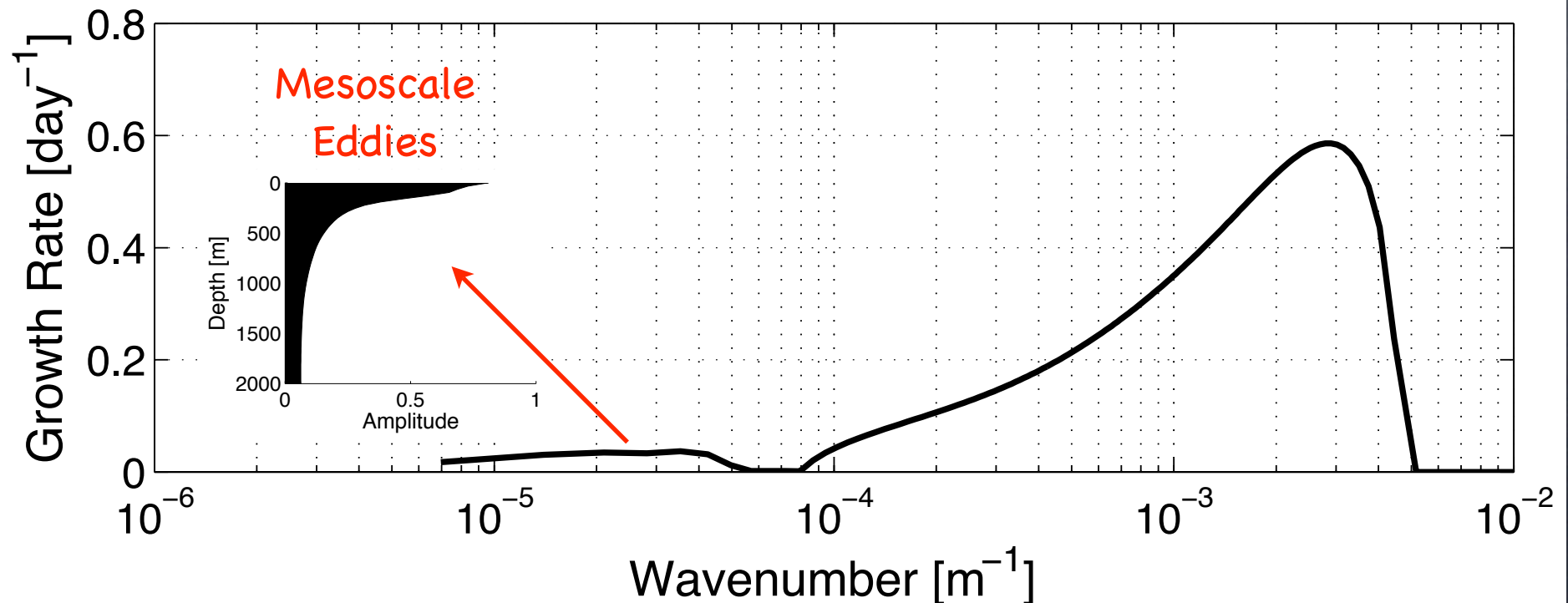
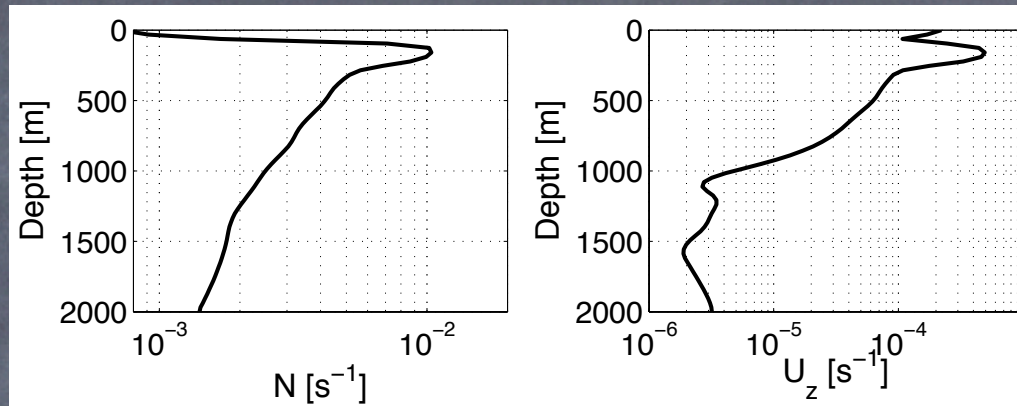
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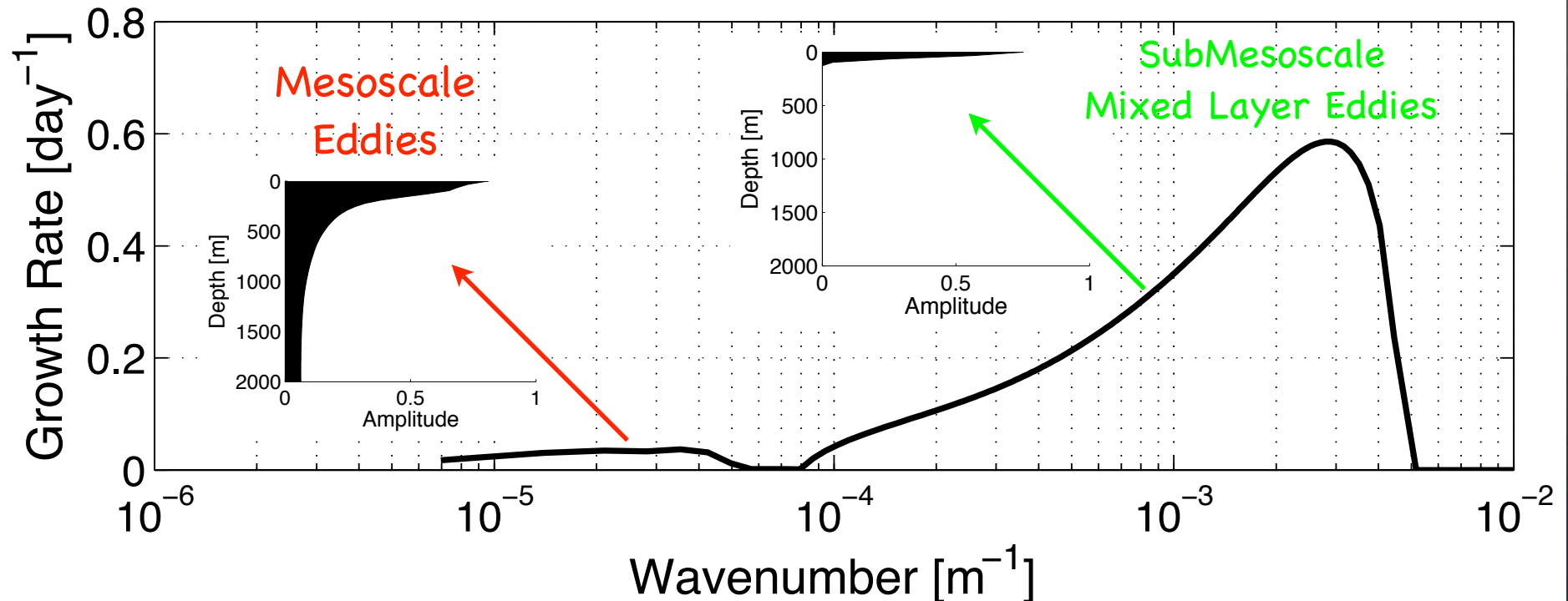
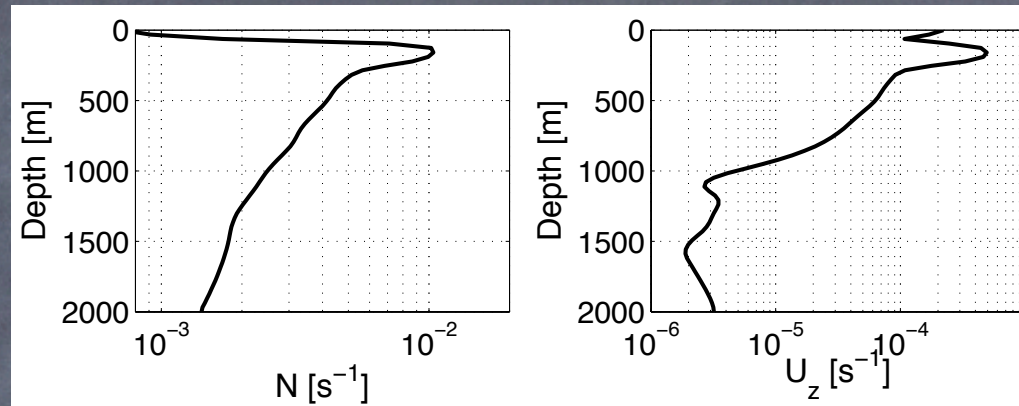
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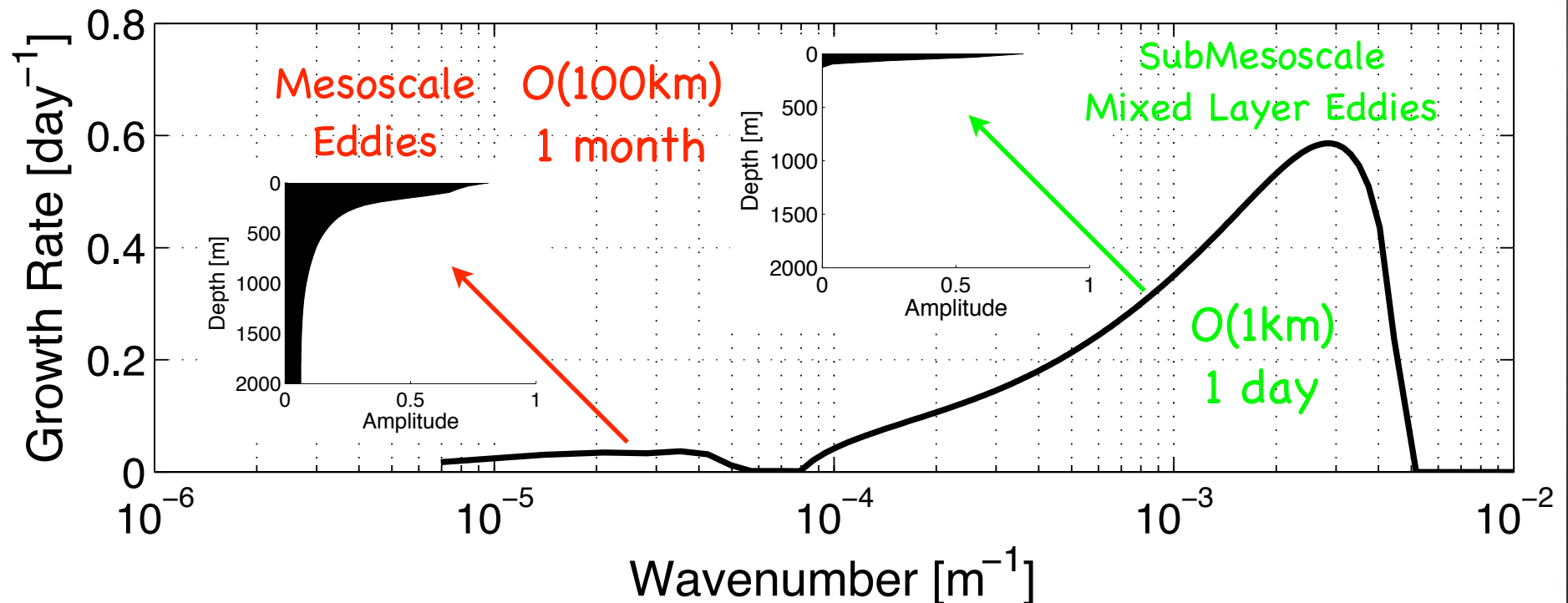
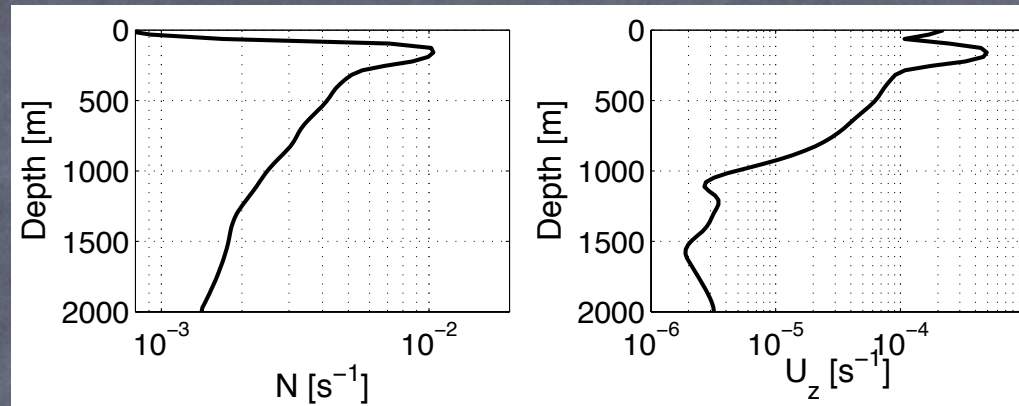
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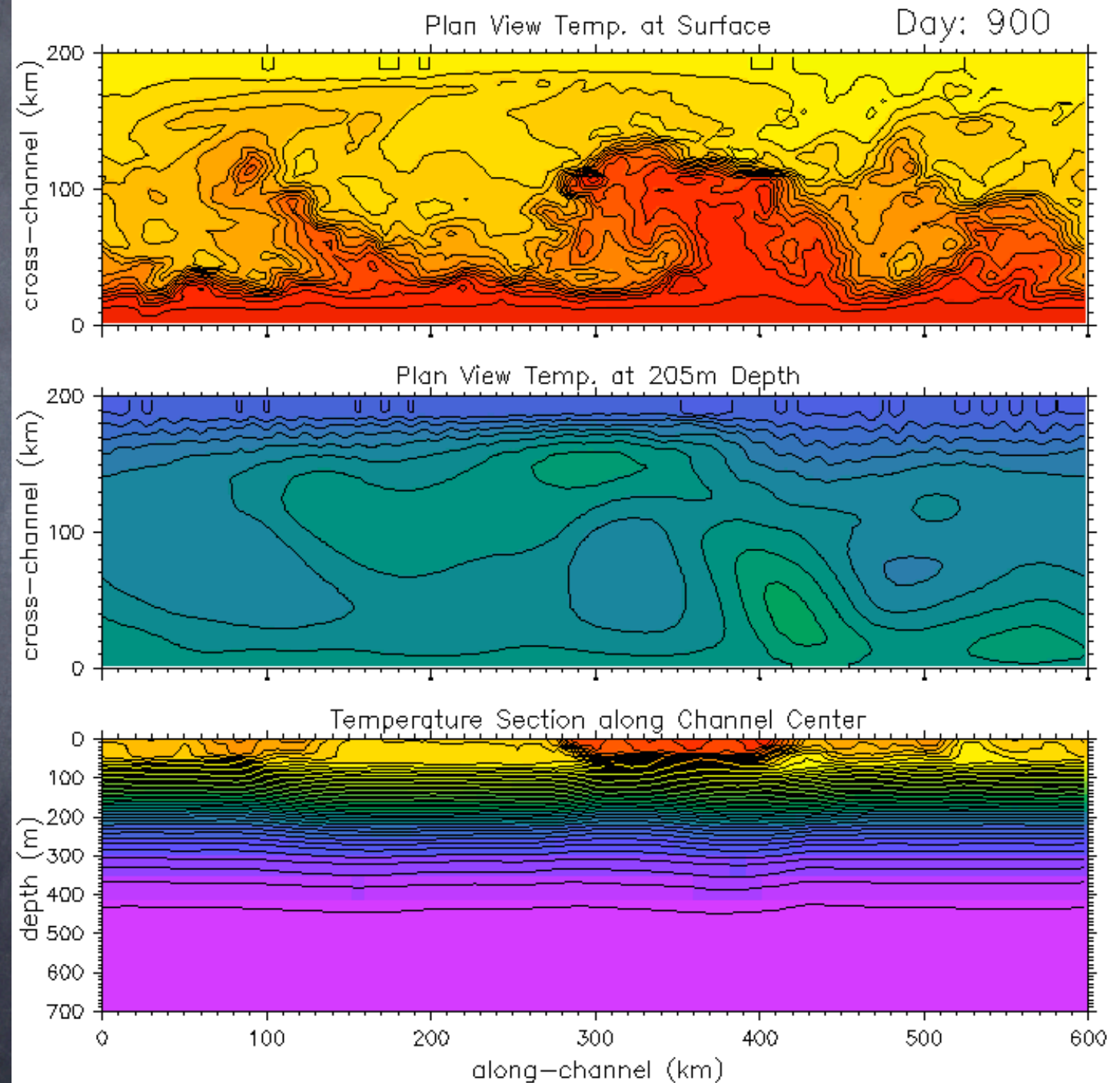
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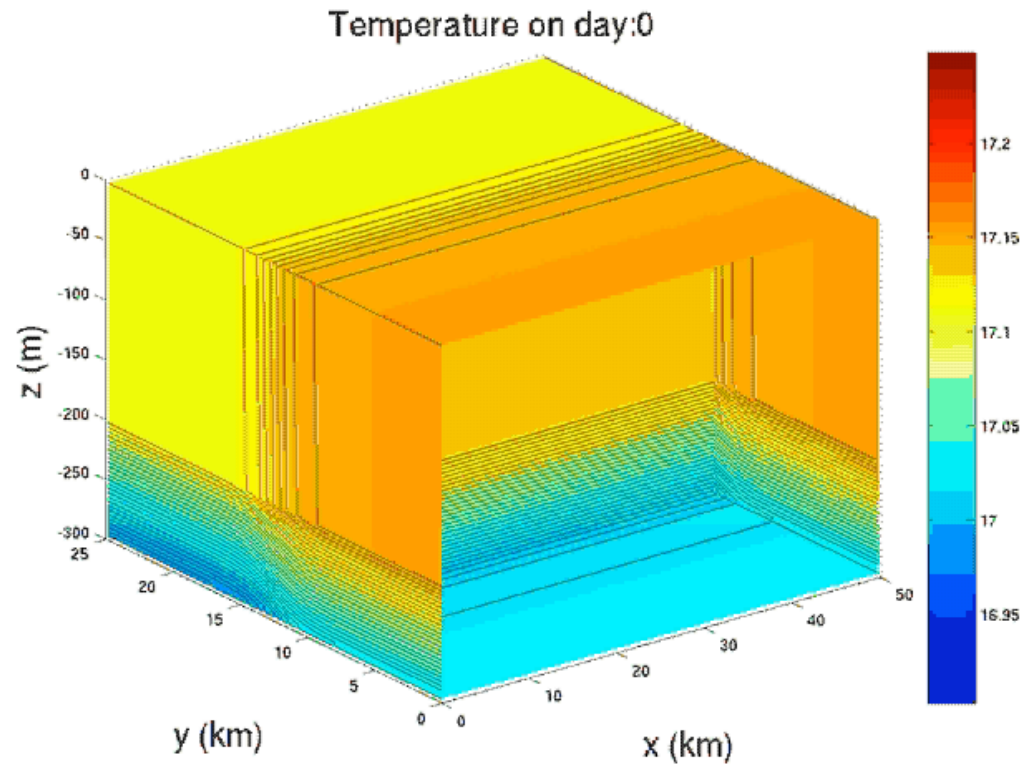
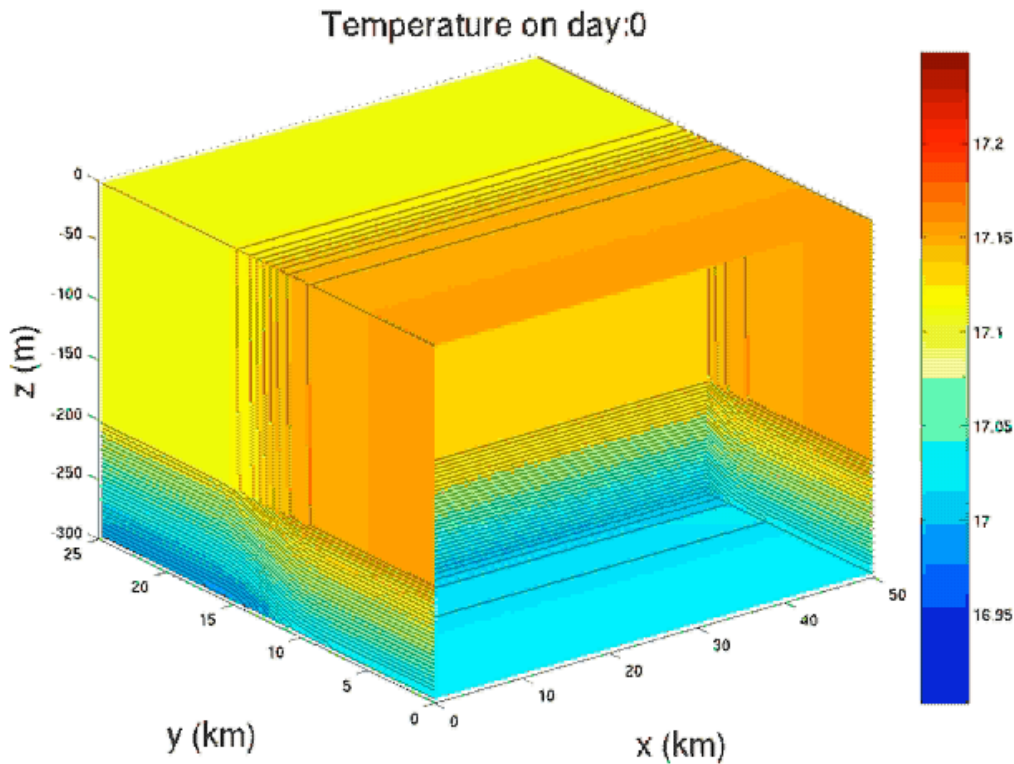
Mesoscale and
SubMesoscale
are
Coupled
Together:

ML Fronts are
formed by
Mesoscale
Straining.

Submesoscale
eddies remove
PE from those
fronts.



Prototype: Mixed Layer Front Overturning

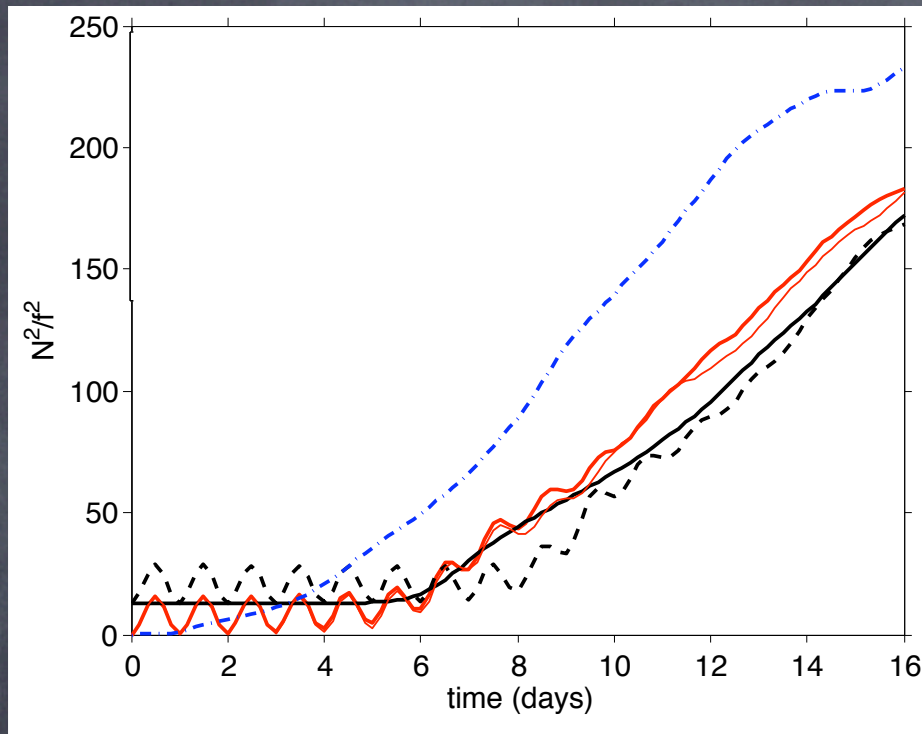


Simple Spindown

Plus, Diurnal Cycle
and KPP

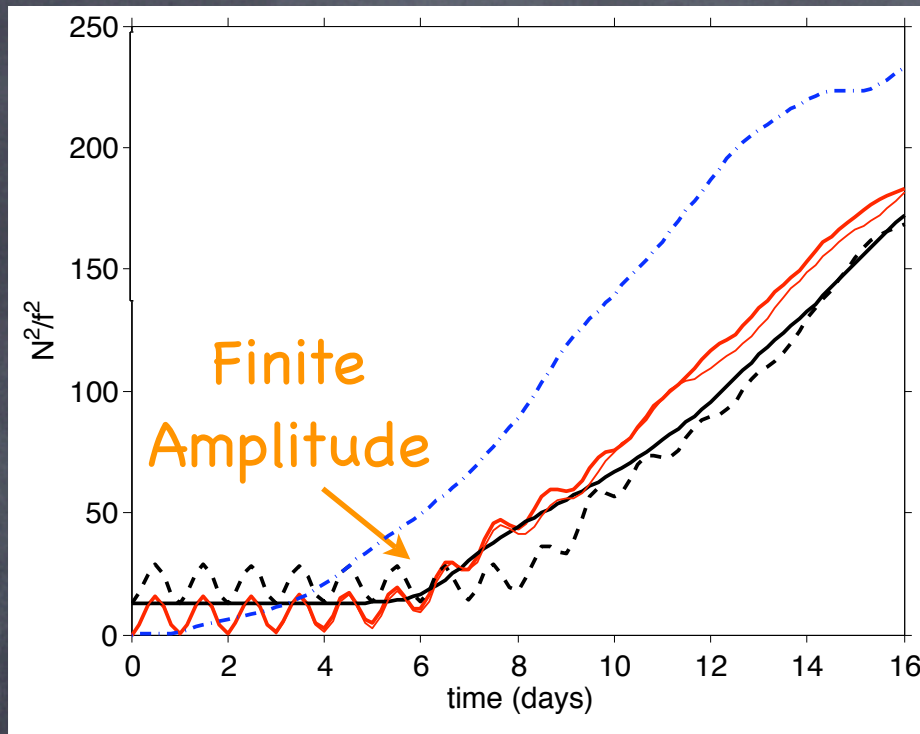
Note: initial geostrophic adjustment overwhelmed by eddy restratification

Parameterization of Finite Amp. Eddies: Ingredients



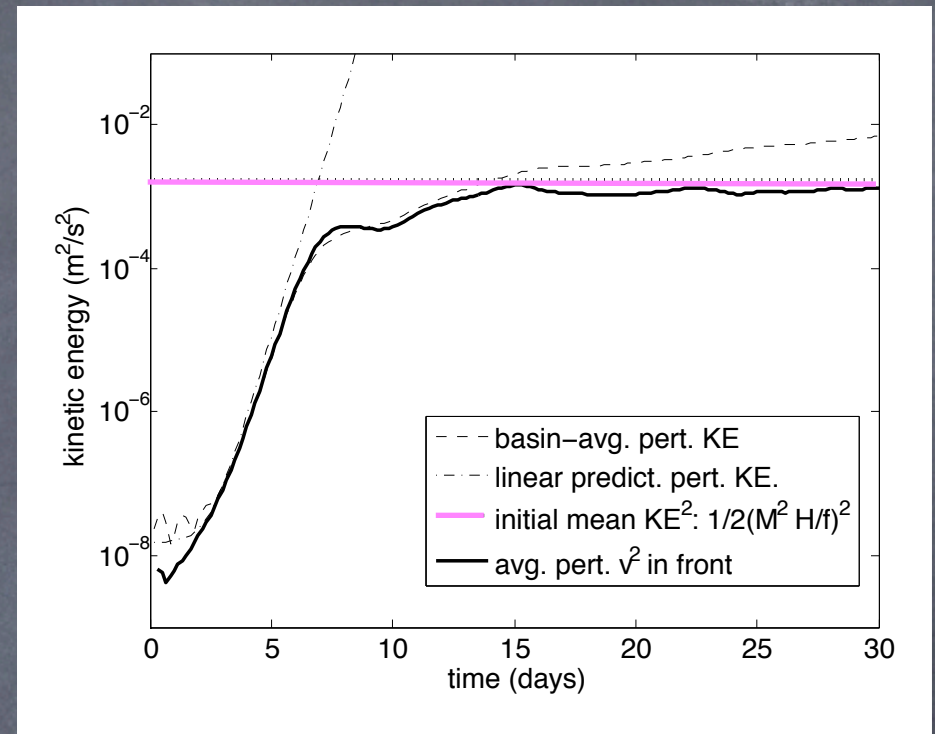
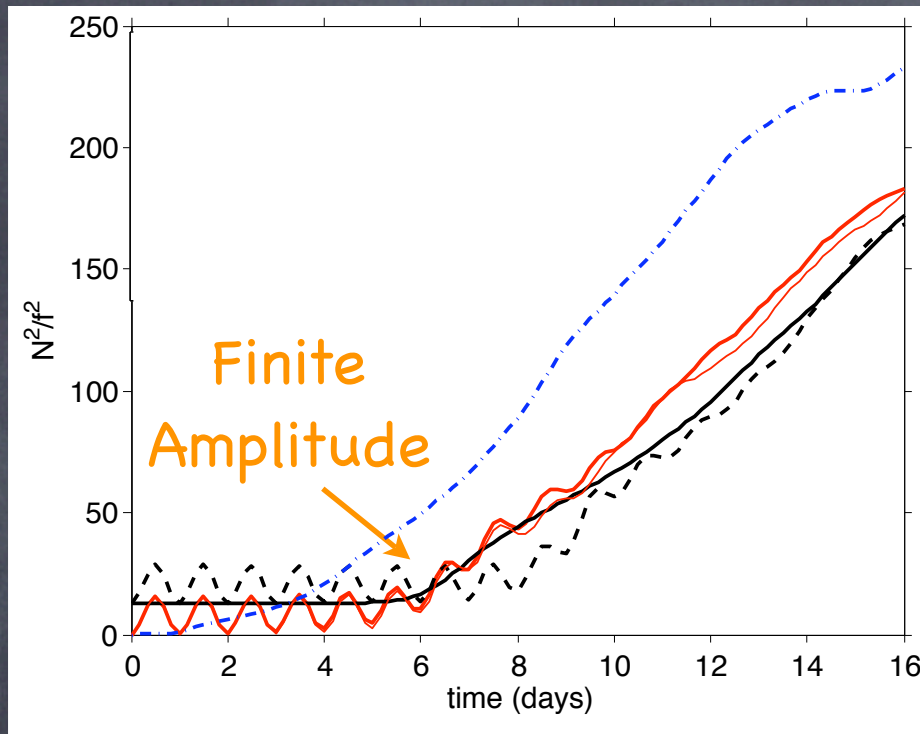
Linear Solution $\langle w'b' \rangle$ for vert. structure.

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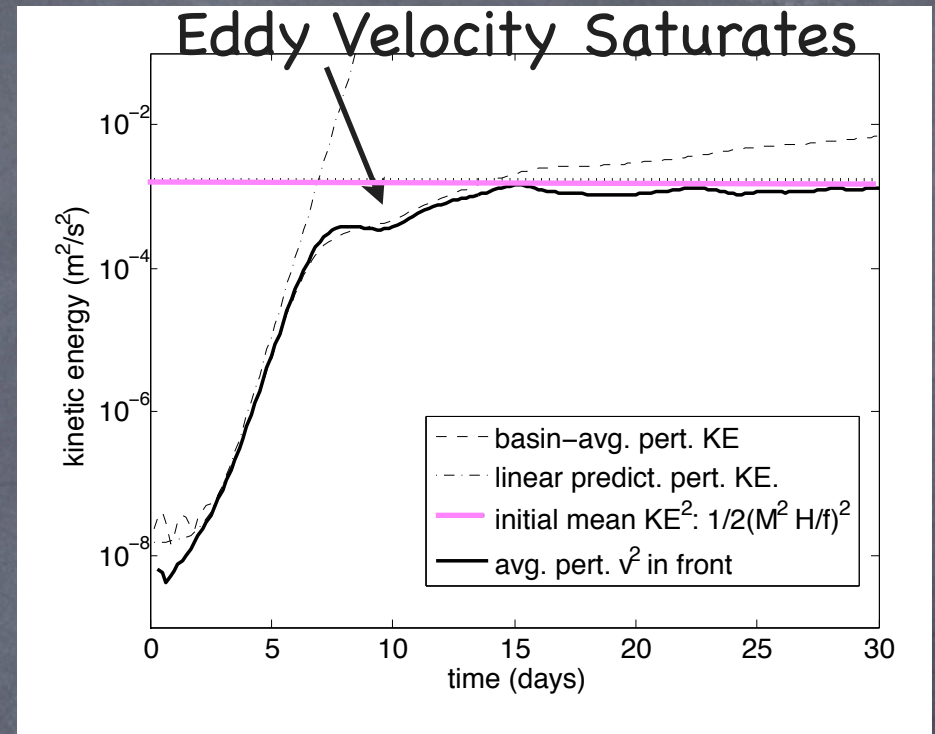
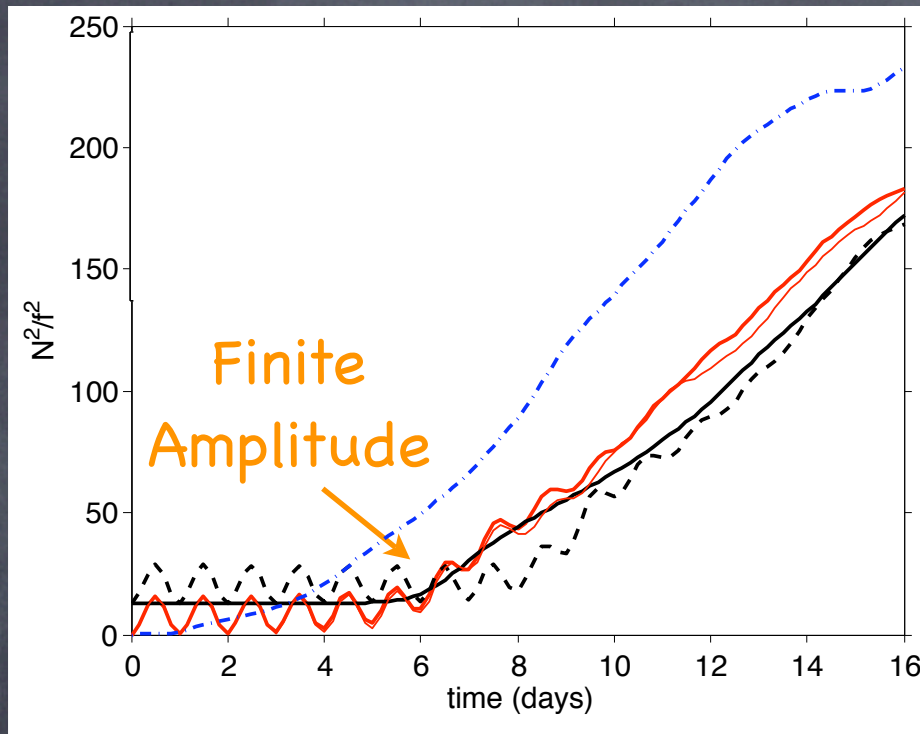
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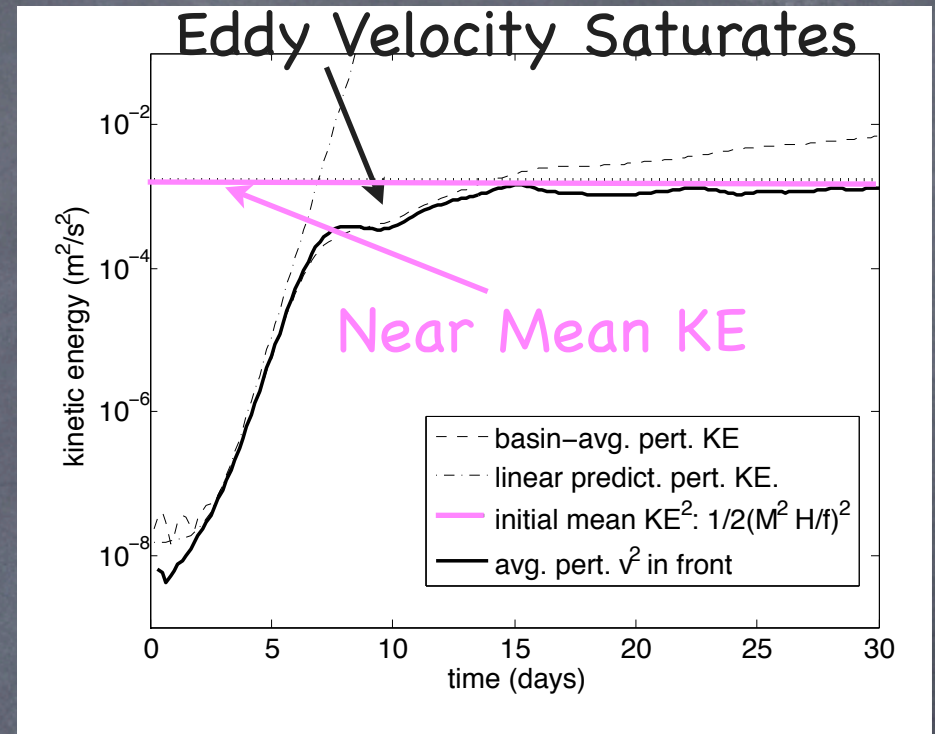
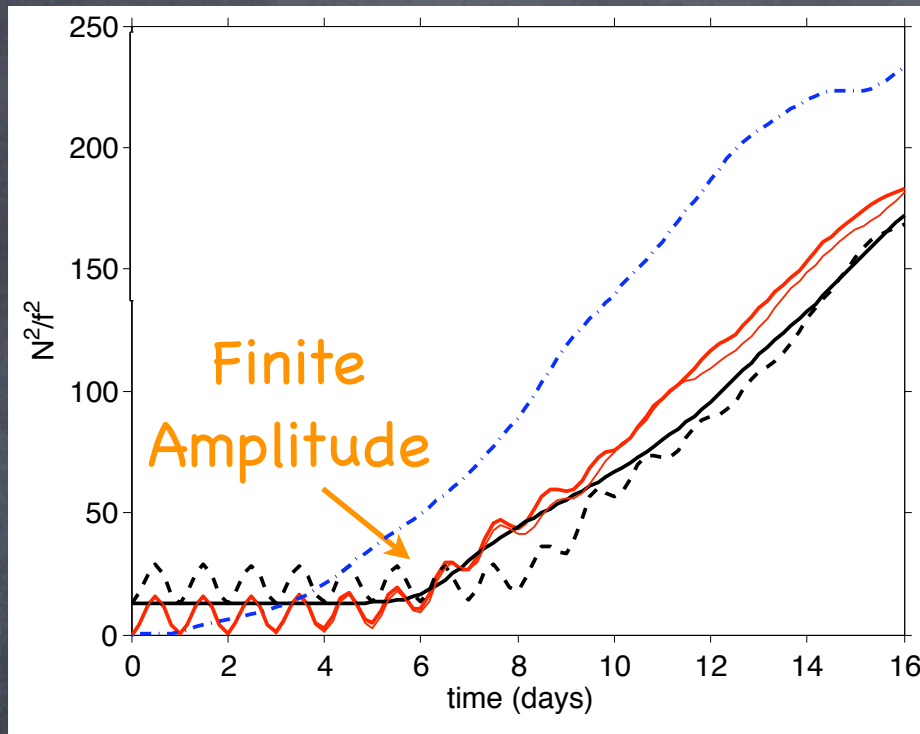
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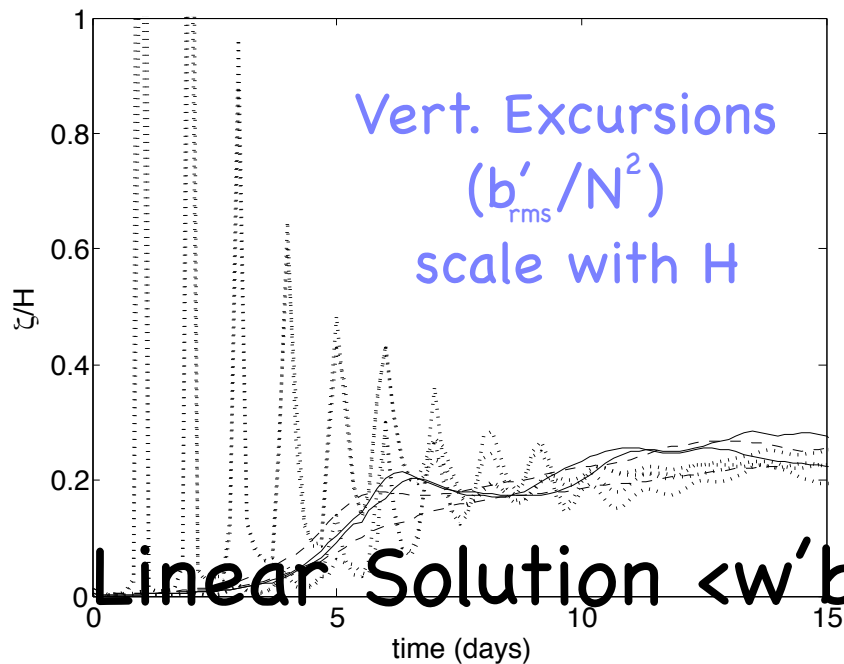
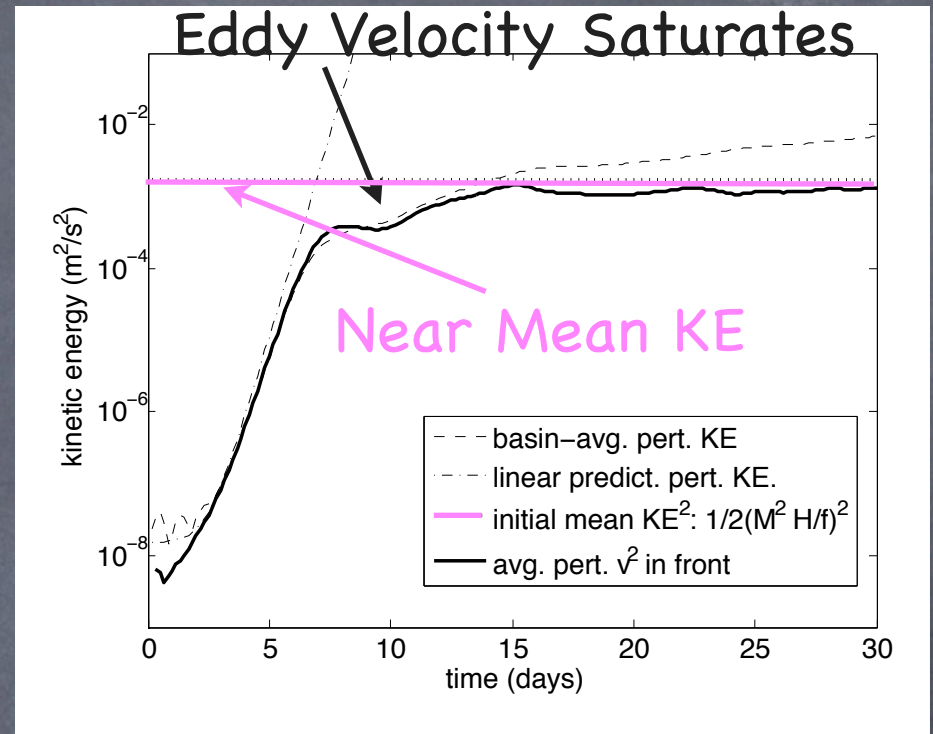
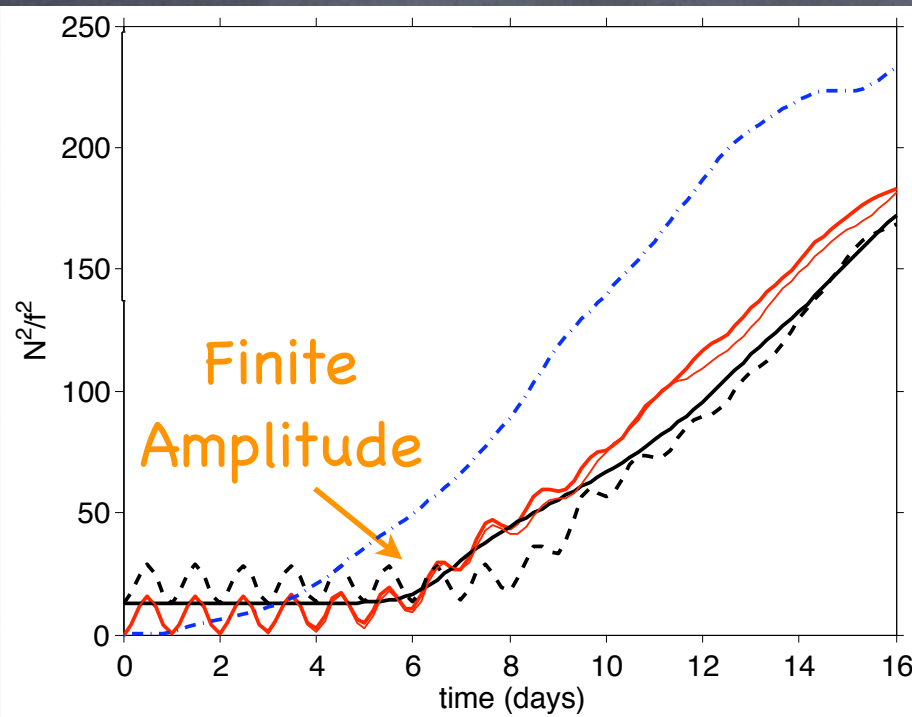
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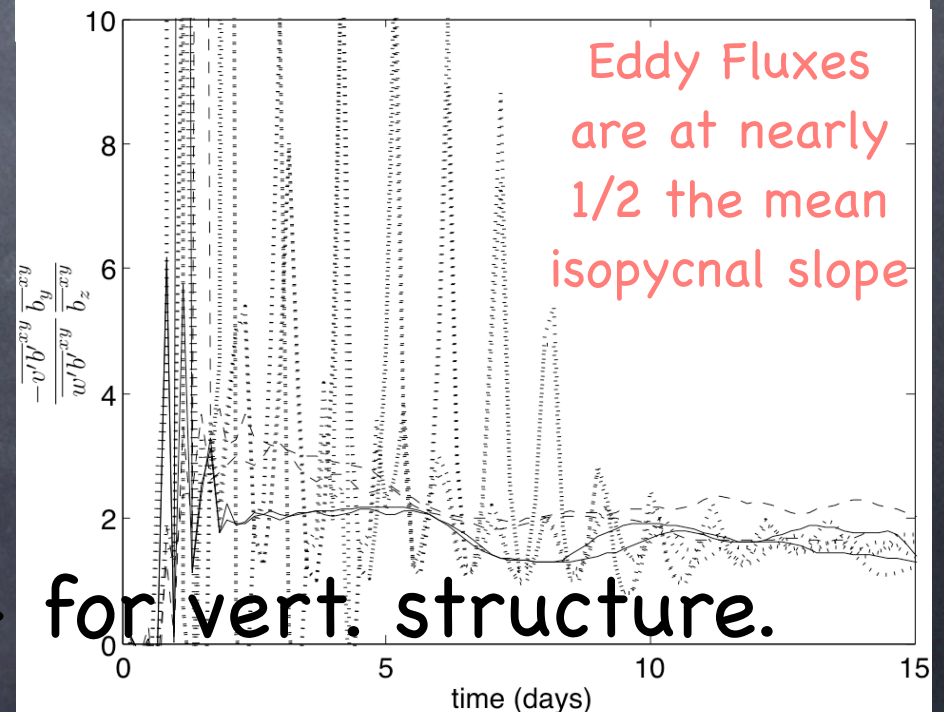
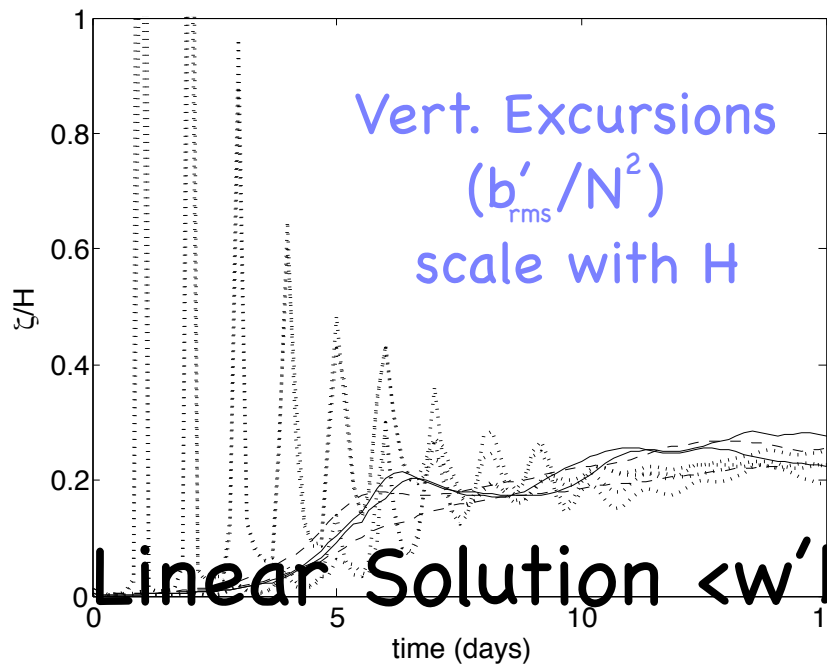
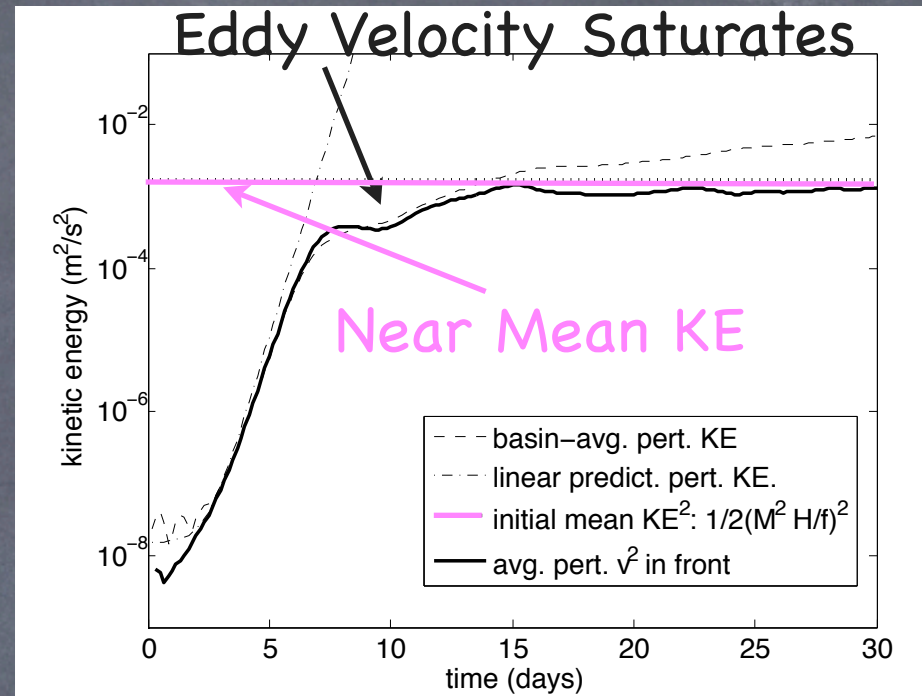
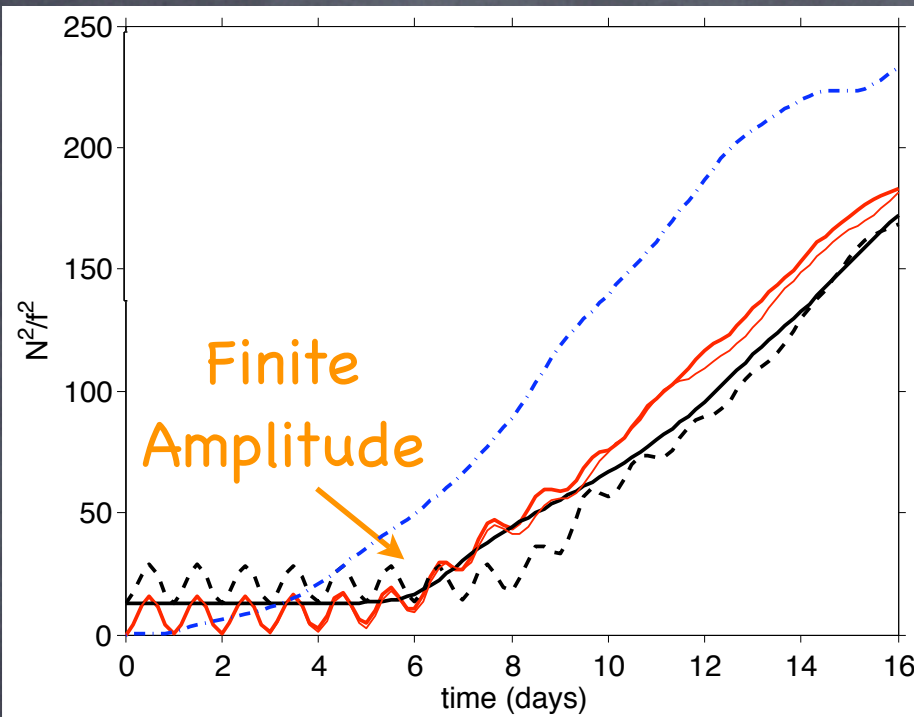
Linear Solution $\langle w'b' \rangle$ for vert. structure.

Parameterization of Finite Amp. Eddies: Ingredients



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Parameterization of Finite Amp. Eddies: Ingredients



The Parameterization:

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

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

- 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:

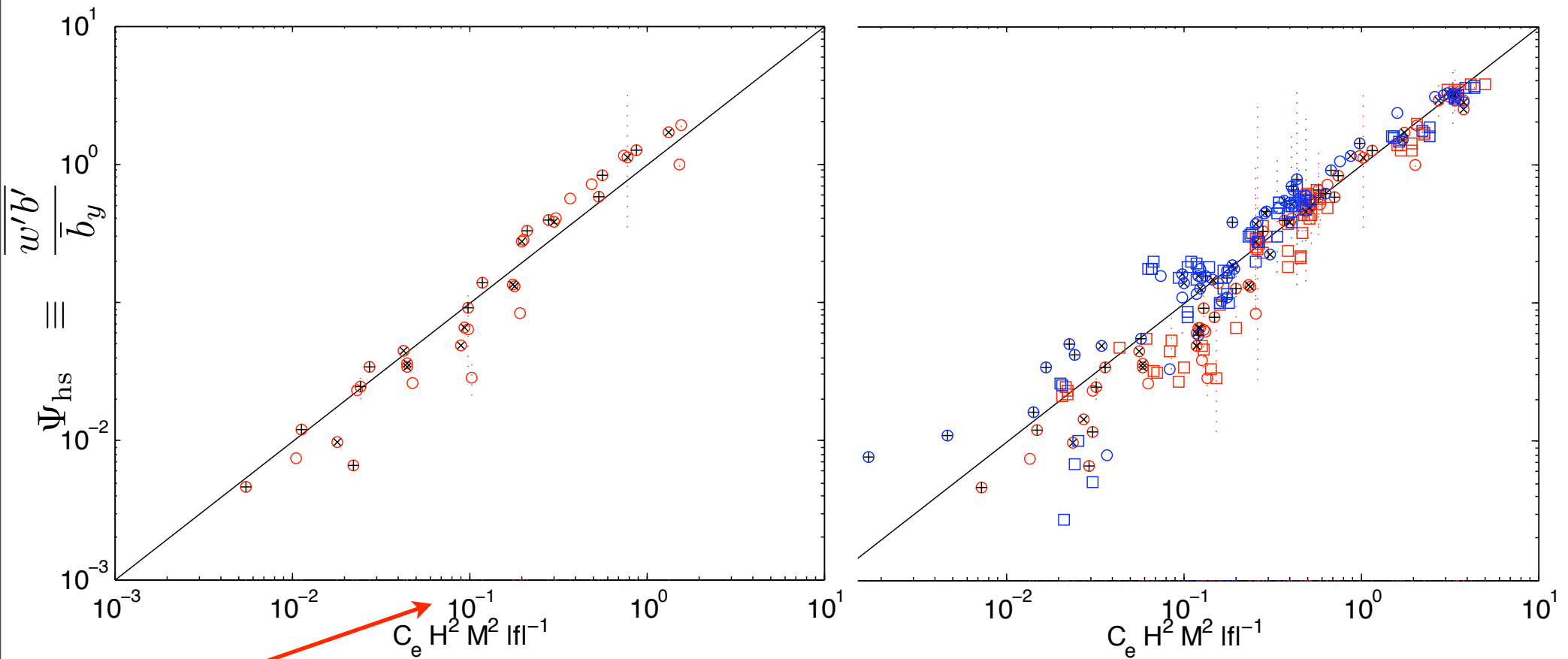
$$\overline{w' b'} = \frac{C_e H^2 \mu(z)}{|f|} |\nabla \bar{b}|^2$$

- Adjustments for coarse resolution and $f \rightarrow 0$ are known

It works for Prototype Sims:

Red: No Diurnal

Blue: With Diurnal



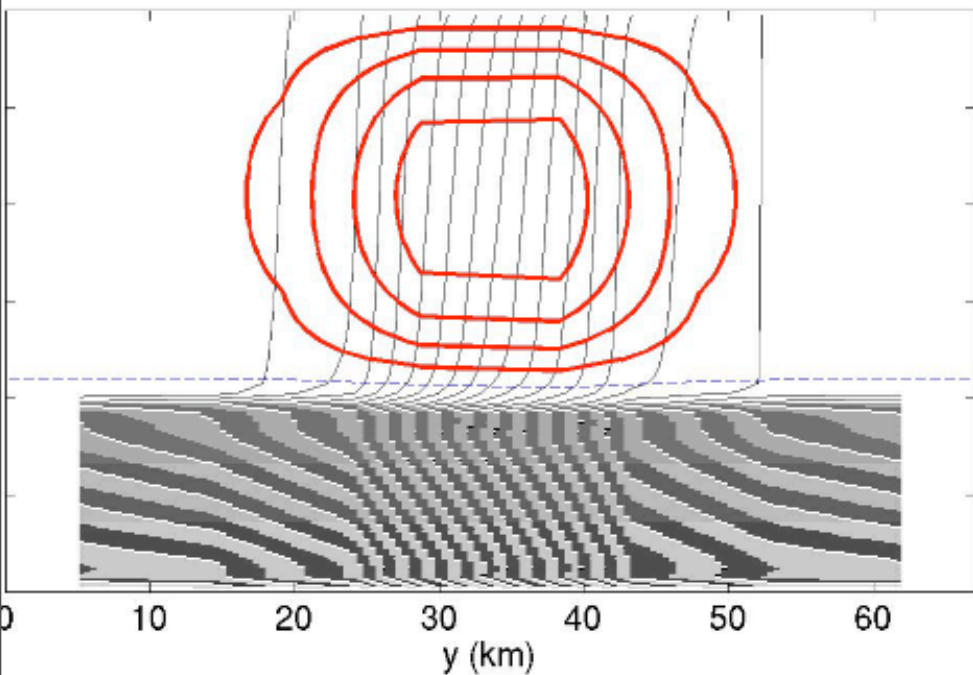
>2 orders of magnitude!

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

What does it look like?

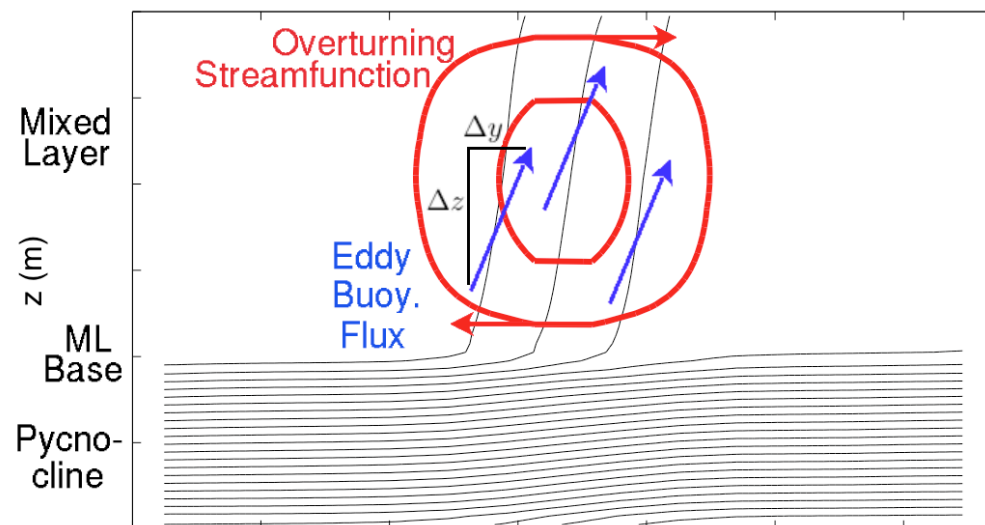
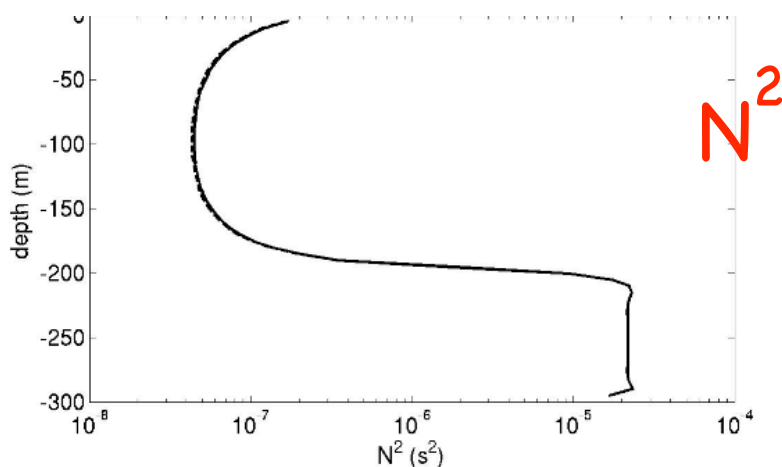
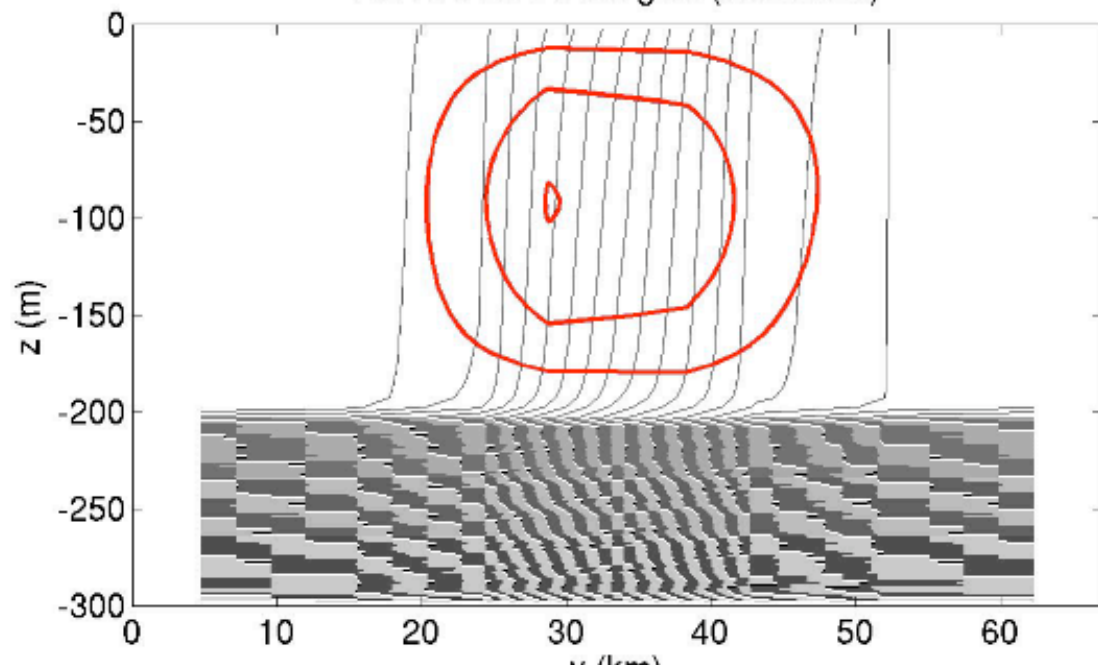
Parameterization (2d, 10km grid)

7d01h from 2d parameterization

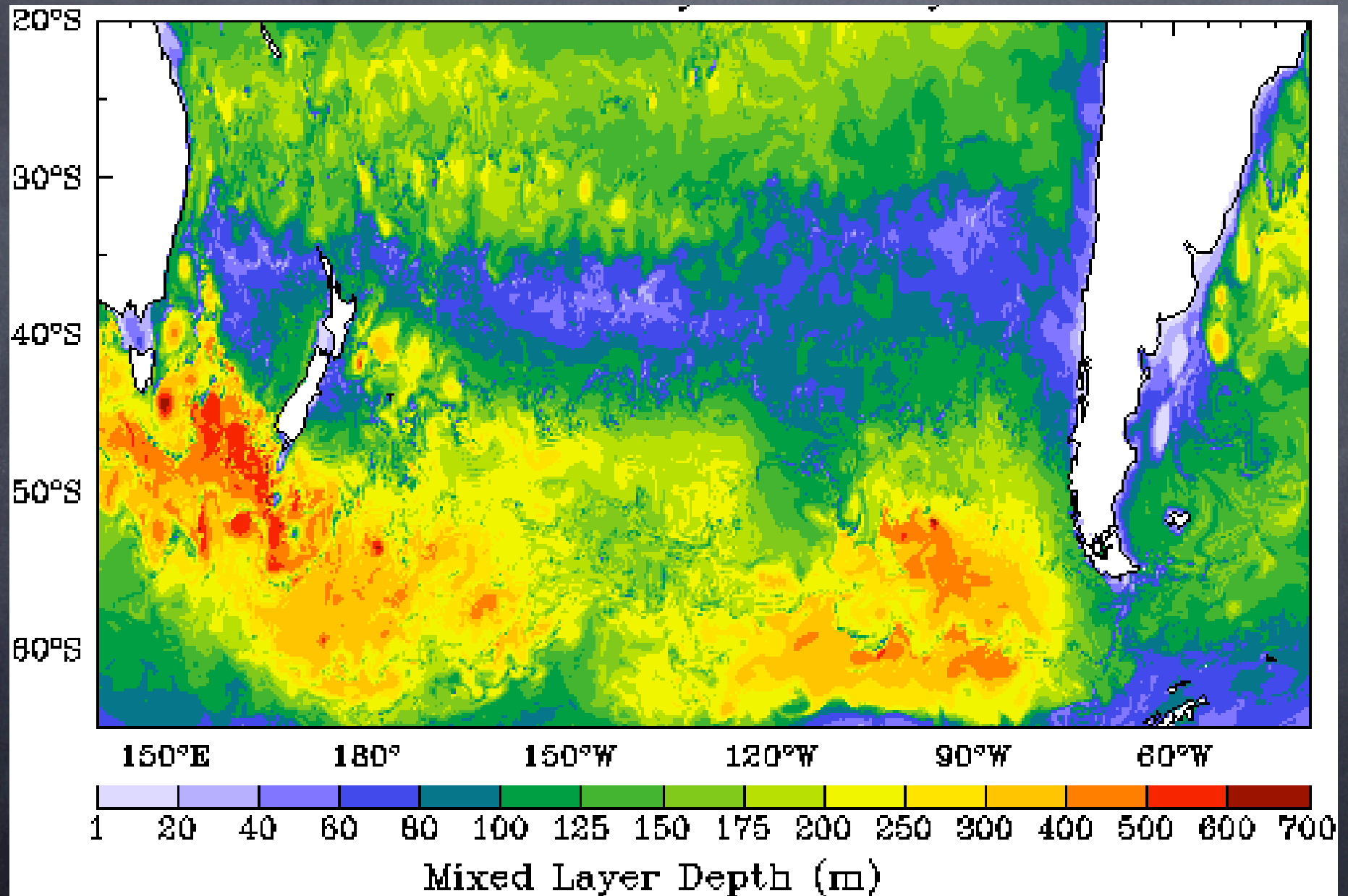


Submesoscale-Resolving (3d, 500m grid)

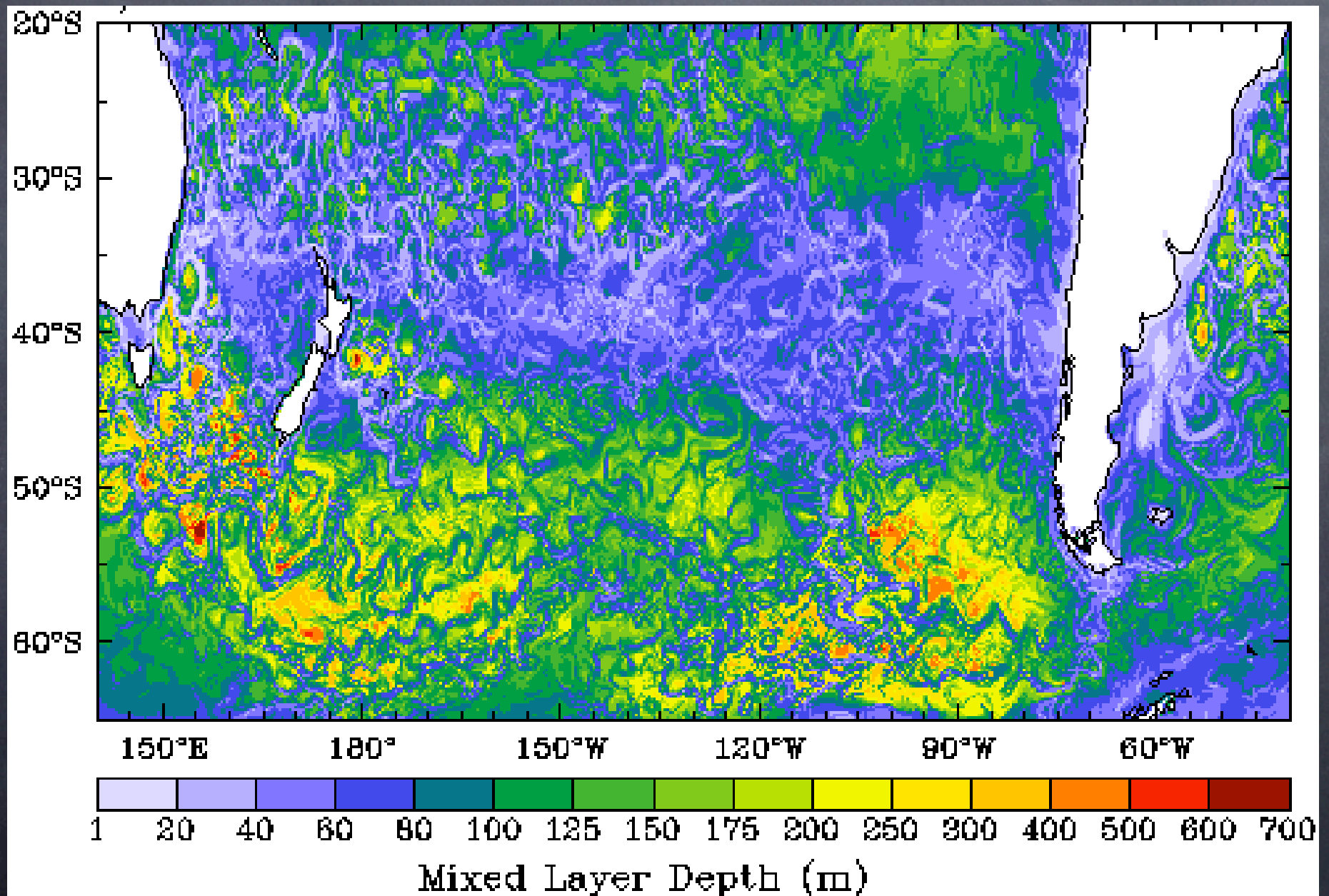
7d01h from 3d MITgcm (smoothed)



Changes To Mixing Layer Depth in Eddy-Resolving Southern Ocean Model



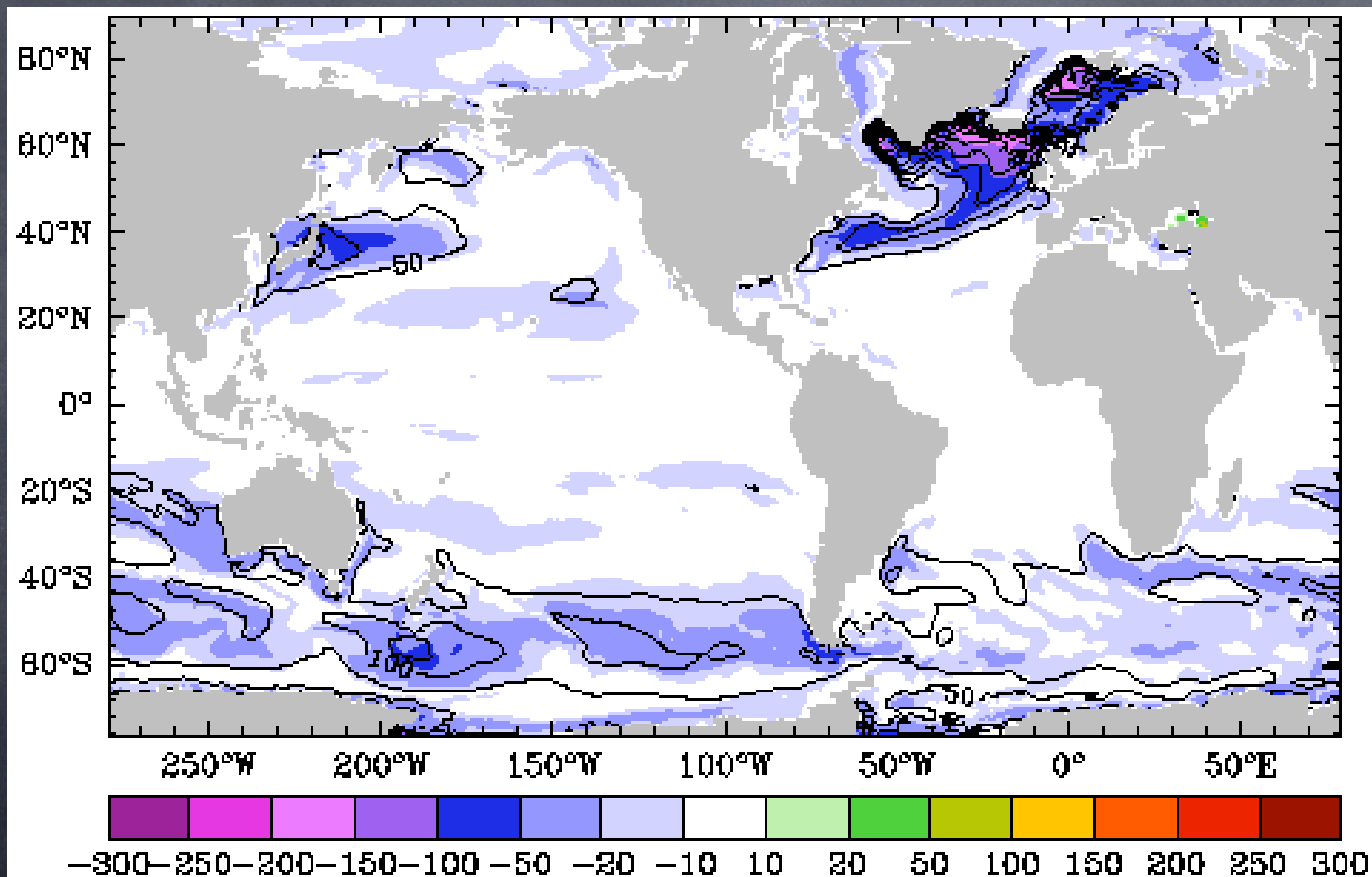
Changes To Mixing Layer Depth in Eddy-Resolving Southern Ocean Model



Equator ($f \rightarrow 0$) 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.