Restratification by Mixed Layer Eddies

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The Stratification Permits
Two Types of Baroclinic Instability:

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

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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.
Linear Solution $\langle w'b' \rangle$ for vert. structure.
Parameterization of Finite Amp. Eddies: Ingredients

Finite Amplitude

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

Finite Amplitude

Eddy Velocity Saturates

Linear Solution $\langle w'b' \rangle$ for vert. structure.
Parameterization of Finite Amp. Eddies: Ingredients

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Eddy Velocity Saturates Near Mean KE

Linear Solution $\langle w'b' \rangle$ for vert. structure.
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Vert. Excursions \( \left( \frac{b'_{\text{rms}}}{N^2} \right) \) scale with \( H \)

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

\[ u'_H b' = -\frac{C_e H^2 \mu(z) \frac{\partial \bar{b}}{\partial z}}{|f|} \nabla_H \bar{b} \]

- Vertical fluxes always upward to restratify:

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

- 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
Improves Restratafication after Deep Convection

Note: param. reproduces Haine&Marshall (98) and Jones&Marshall (93,97)

Equator (f->0) and coarse resolution (up to 1 deg) are manageable

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