Parameterizations of Eddies: Fluxes and Lognormal Dissipation

Baylor Fox-Kemper & Brodie Pearson (Brown DEEP Sciences)
with Frank O. Bryan (NCAR), D. Menemenlis (JPL), and S. Bachman (NCAR)

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Satellite altimetry view of mesoscale flows

AVISO: log10(0.5 (u^2+v^2)) on 19940101
1963: Smagorinsky Scale & Flow Aware Viscosity Scaling, so the Energy Cascade is Preserved, but order-1 gridscale Reynolds #: \( Re^* = \frac{UL}{\nu_*} \)

\[
v_{*h} = \left( \frac{\gamma_h \Delta x}{\pi} \right)^2 \sqrt{\left( \frac{\partial u_*}{\partial x} - \frac{\partial v_*}{\partial y} \right)^2 + \left( \frac{\partial u_*}{\partial y} + \frac{\partial v_*}{\partial x} \right)^2}
\]
2D Turbulence Differs

Spectral Density of Kinetic Energy

Inverse Energy Cascade

Enstrophy Cascade

Re* = 1

$k^{-3}$

forcing

dissipation

$E(k)$

$k_0$  $k_1$  $k_D$  $k$

$\frac{2\pi}{\Delta x}$

1996: Leith Devises Viscosity Scaling, So that the Enstrophy (vorticity$^2$) Cascade is Preserved

$$v_* = \left(\frac{\Lambda \Delta x}{\pi}\right)^3 \left| \nabla h \left( \frac{\partial u_*}{\partial y} - \frac{\partial v_*}{\partial x} \right) \right|$$

Barotropic or stacked layers
What does it do?
Spectrally speaking in

Idealized Channel Tests
with an inverse energy and forward
potential enstrophy cascade

**QGLeith: Global Realistic Model**

Momentum uses Laplacian horizontal diffusion

Active & Passive Tracers use GM scheme w/ diffusivity/transfer coeff. matched to viscosity

\[ \nu_{qg} = \kappa_{Red} = \kappa_{GM} = \left( \frac{\Lambda_{qg} \Delta x}{\pi} \right)^3 |\nabla q_{qg}|. \]


There is a (weak) forward energy transfer that's sensitive to subgrid

Global KE Sinks

A (weak) dissipation of energy in enstrophy cascade...

Dissipation is lognormally distributed

90% of dissipation in 10% of ocean

Conclusions

A new scheme (QGLeith) has been developed for models resolving the deformation radius.

- It is adiabatic in tracers, more dissipative than 2DLeith and less dissipative than Smagorinsky.

For all high-res models, energy dissipation is extremely localized: lognormal distribution (90% of total in 10% of regions).

Subgrid scheme matters for leading order EKE budget and numerical stability. Even at 2km-10km resolution!

All papers at: Fox-Kemper.com
Lognormally distributed—AND knows where the Gulf Stream is!