Observations and models of oceanic macroturbulence:

meet the new bias same as the old bias

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with
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Old Bias–Reynolds Avg.–LowRes

Questionable eddy parameterizations
Not much data to assess them
Diversity of approaches, no cross-evaluation
Unclear relationship of key impacts to params.

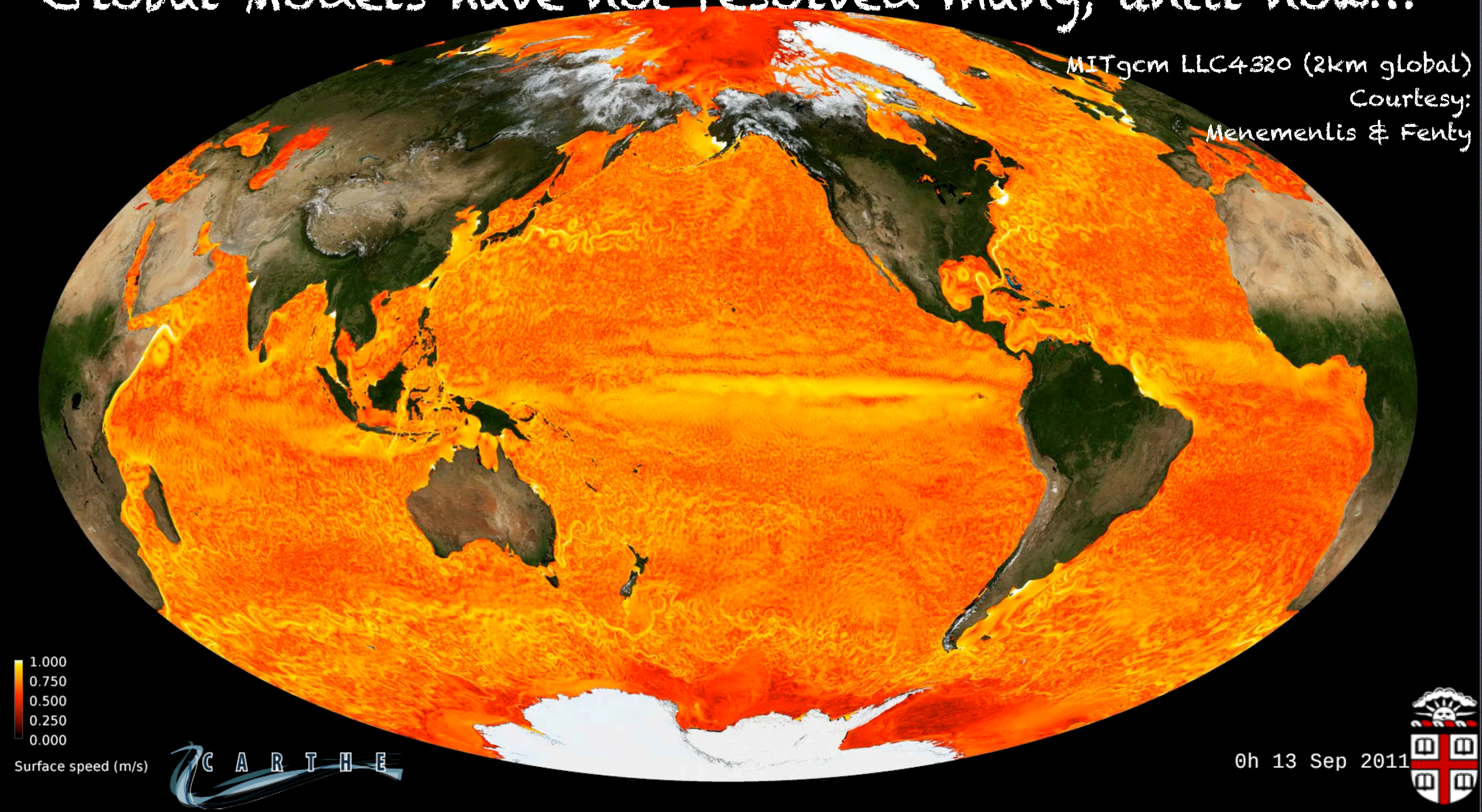
New Bias–Large Eddy Sims. (LES)

Questionable subgrid parameterizations
Not much data to assess them
Diversity of approaches, no cross-evaluation
Unclear relationship of key impacts to params.

Largest (Mesoscale) Ocean Eddies are Small vs. Earth

Regional Studies—Model & Obs—
like CARTHE LASER good for exploring

Global Models have not resolved many, until now...



Absent realistic global models, We studied "Cascade" Scalings

3D: Richardson/Kolmogorov/Smagorinsky/Corrsin

$$E \propto \epsilon^{2/3}\ell^{5/3}, \quad S_2 \propto \epsilon^{2/3} r^{2/3}, \quad \epsilon \propto \nu\alpha^2, \quad \nu = \mathrm{Pr}\,\kappa \propto \Delta x^2 |\alpha| \propto \epsilon^{1/3}\ell^{4/3}$$

2D: Barnier/Kraichnan/Leith

$$E \propto \eta^{2/3}\ell^3, \quad S_2 \propto \eta^{2/3} r^2, \quad \eta \propto \nu(\nabla\omega)^2, \quad \nu = \propto \Delta x^3 |\nabla\omega| \propto \eta^{1/3}\ell^2, \quad \kappa \propto ?$$

Quasigeostrophy: Barnier/Charney/QGLeith

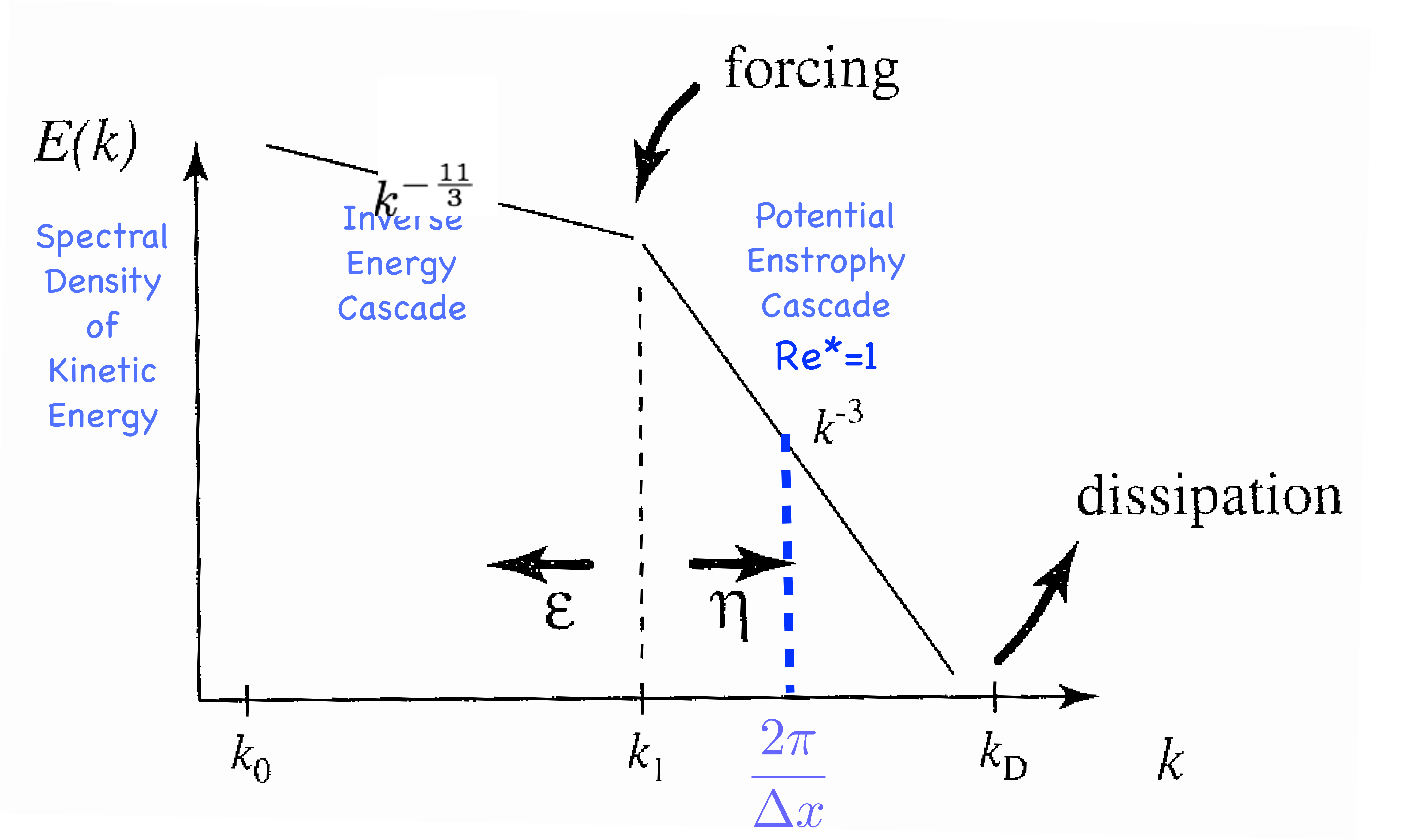
SQG?

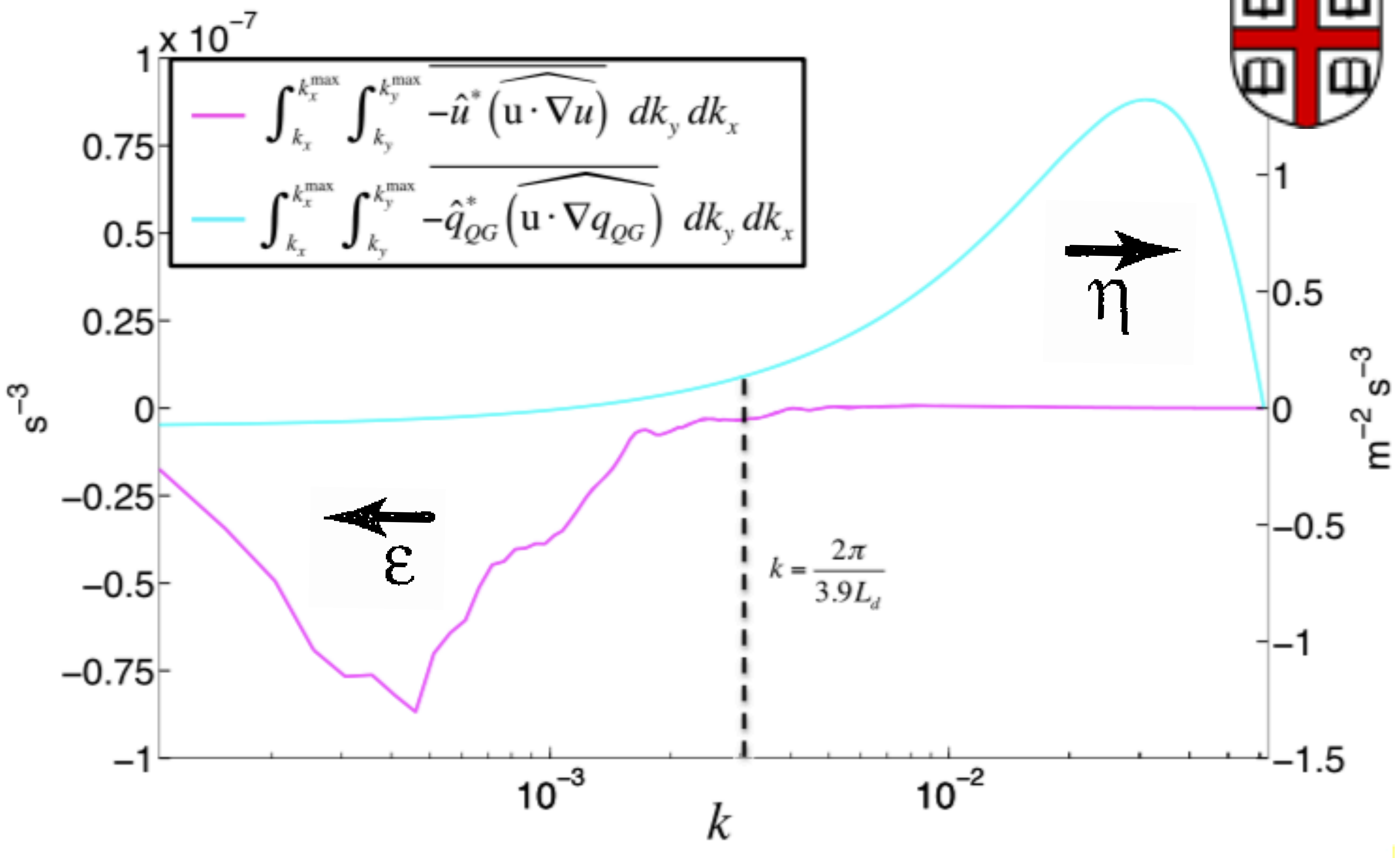
$$E \propto \eta^{2/3}\ell^3, \quad S_2 \propto \eta^{2/3} r^2, \quad \eta \propto \nu(\nabla q)^2, \quad \nu = \kappa_{Redi} = k_{GM} \propto \Delta x^3 |\nabla q| \propto \eta^{1/3}\ell^2$$

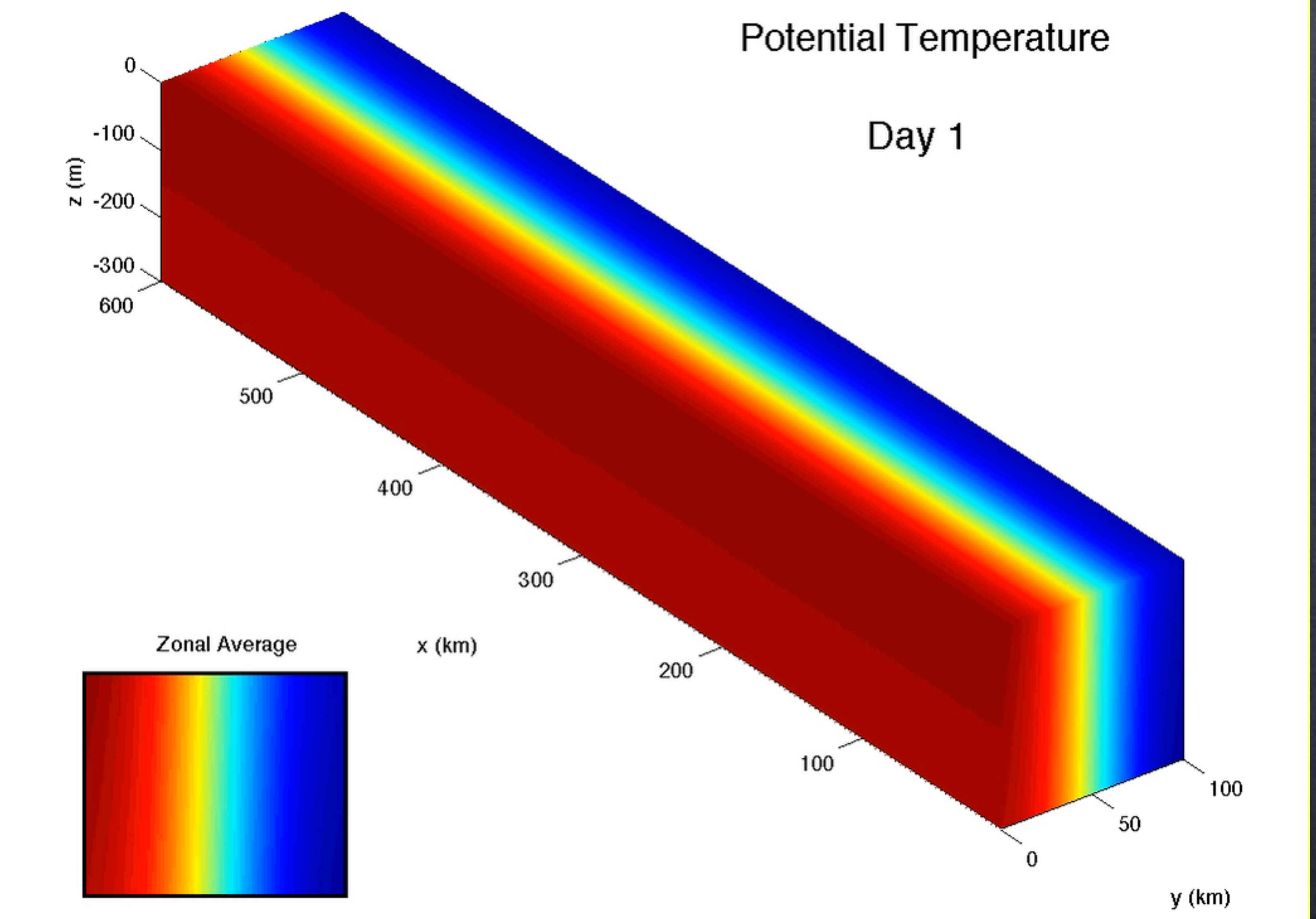
Submesoscale: McWilliams/?/?F-K?

$$E \propto \ell^2, \quad S_2 \propto r^1, \quad d/dt(PE + KE) = ??, \quad \nu = ?, \quad \kappa = ?$$

QG Turbulence: Pot'l Enstrophy cascade (potential vorticity²)





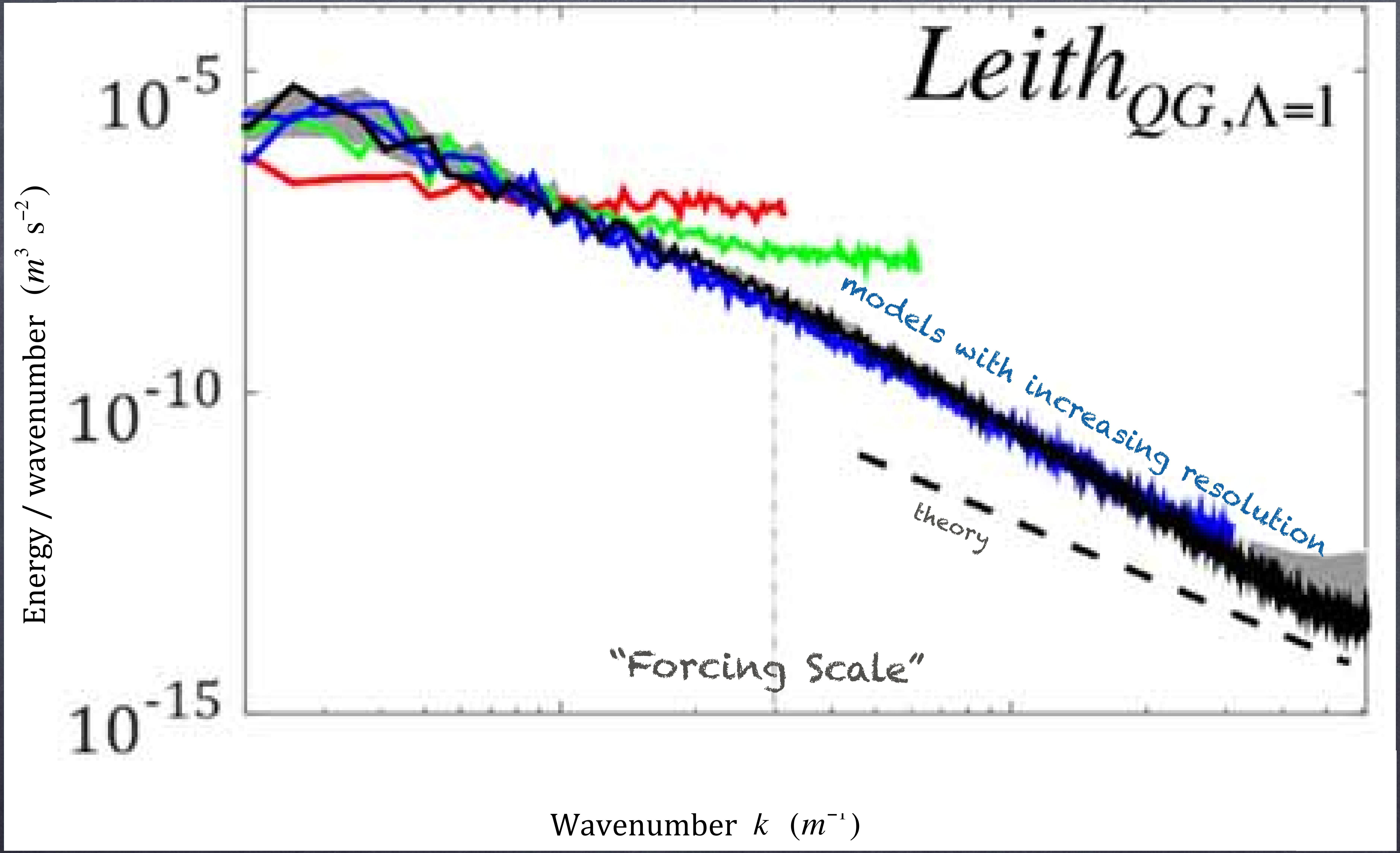


S. D. Bachman, B. Fox-Kemper, and B. Pearson. A scale-aware subgrid model for quasigeostrophic turbulence.Journal of Geophysical Research-Oceans, 122:1529-1554, March 2017.

BFK, D. D. Holm, W. Pan and V. Resseguier. Data-driven versus self-similar parameterizations for Stochastic Lie Transport and Location Uncertainty. In preparation.

Where does ocean energy go?

Spectrally speaking



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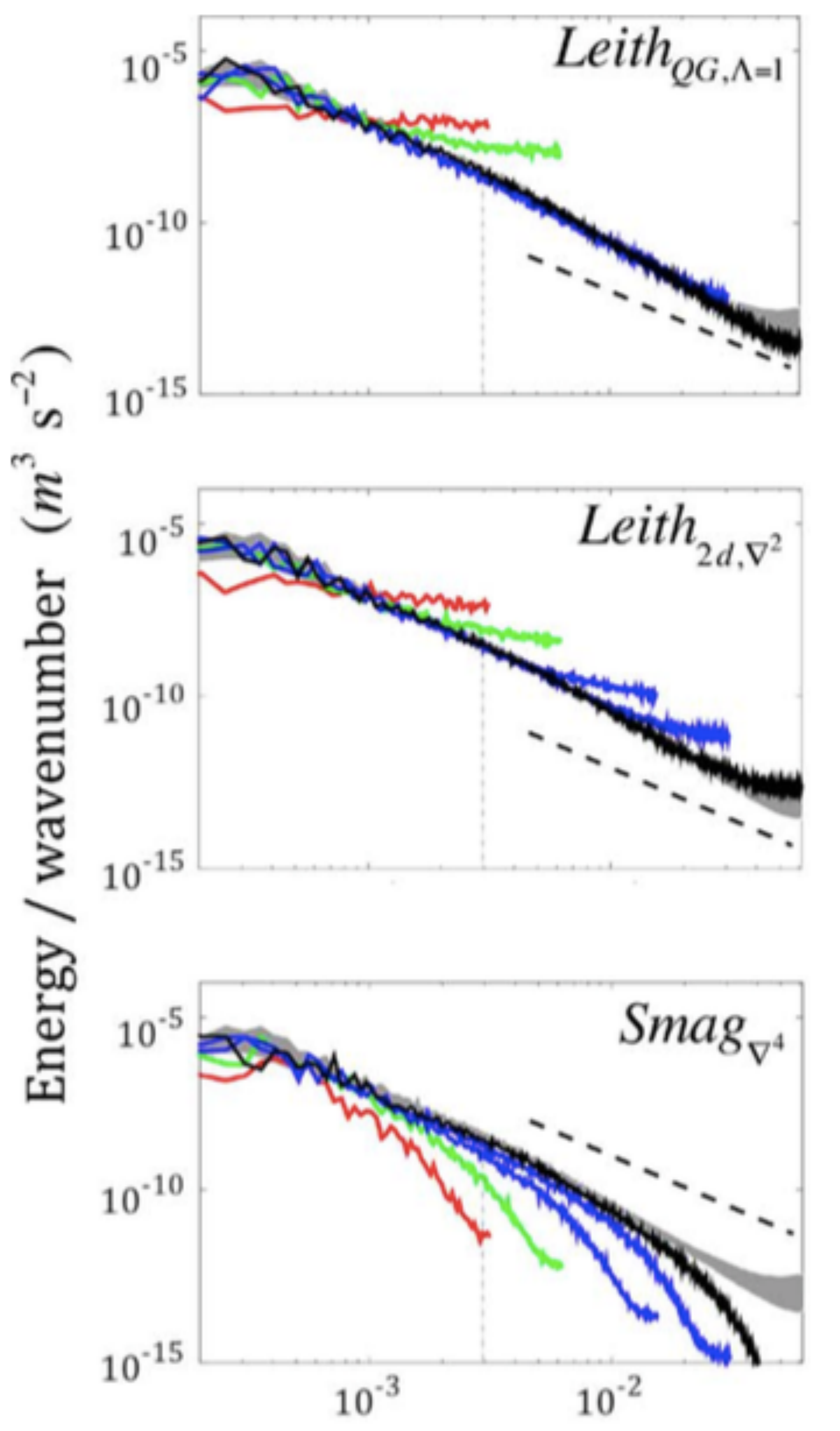
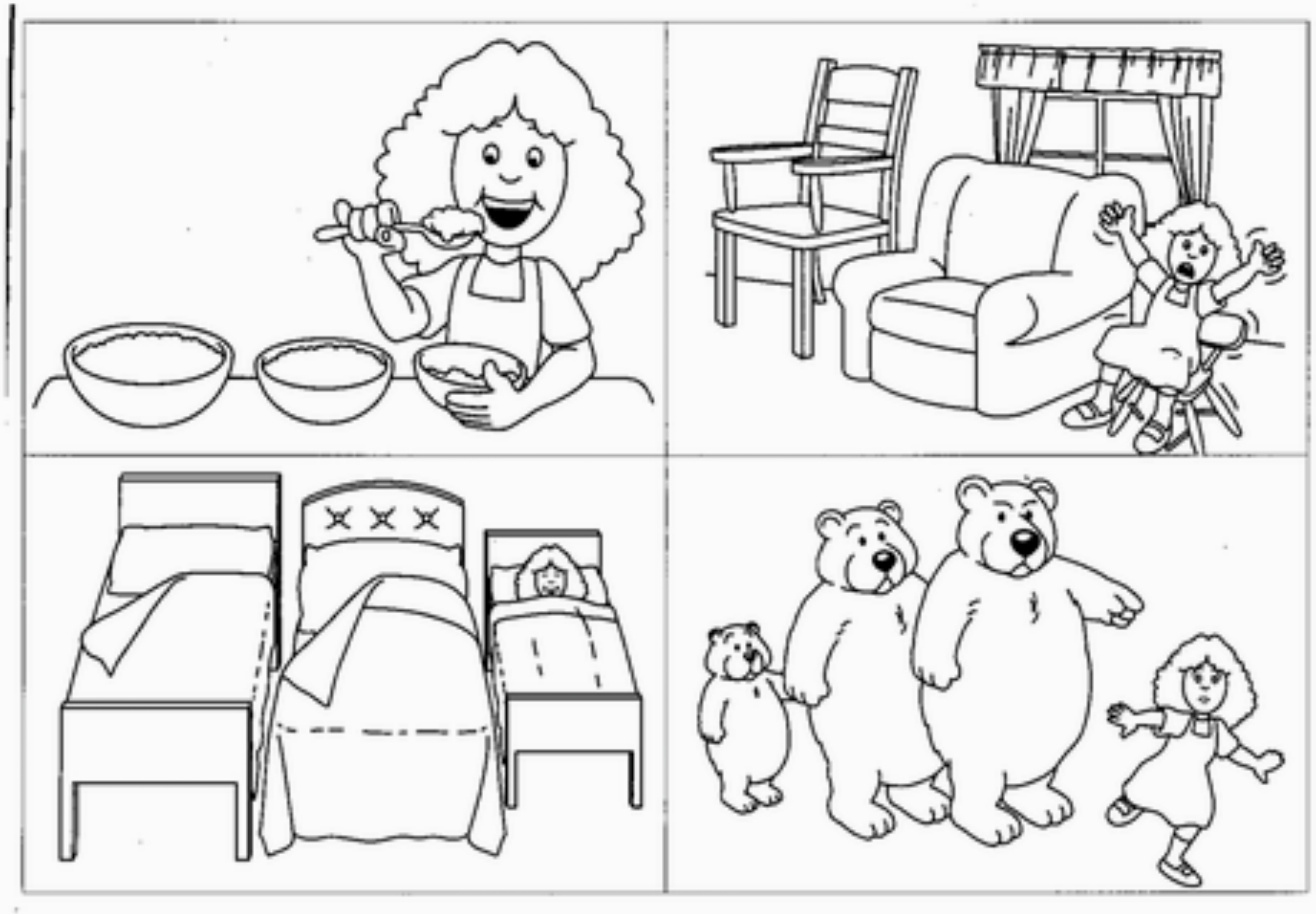


QG Leith:
Just Right!

2D Leith:
Too Noisy

3D Smagorinsky:
Too Smooth



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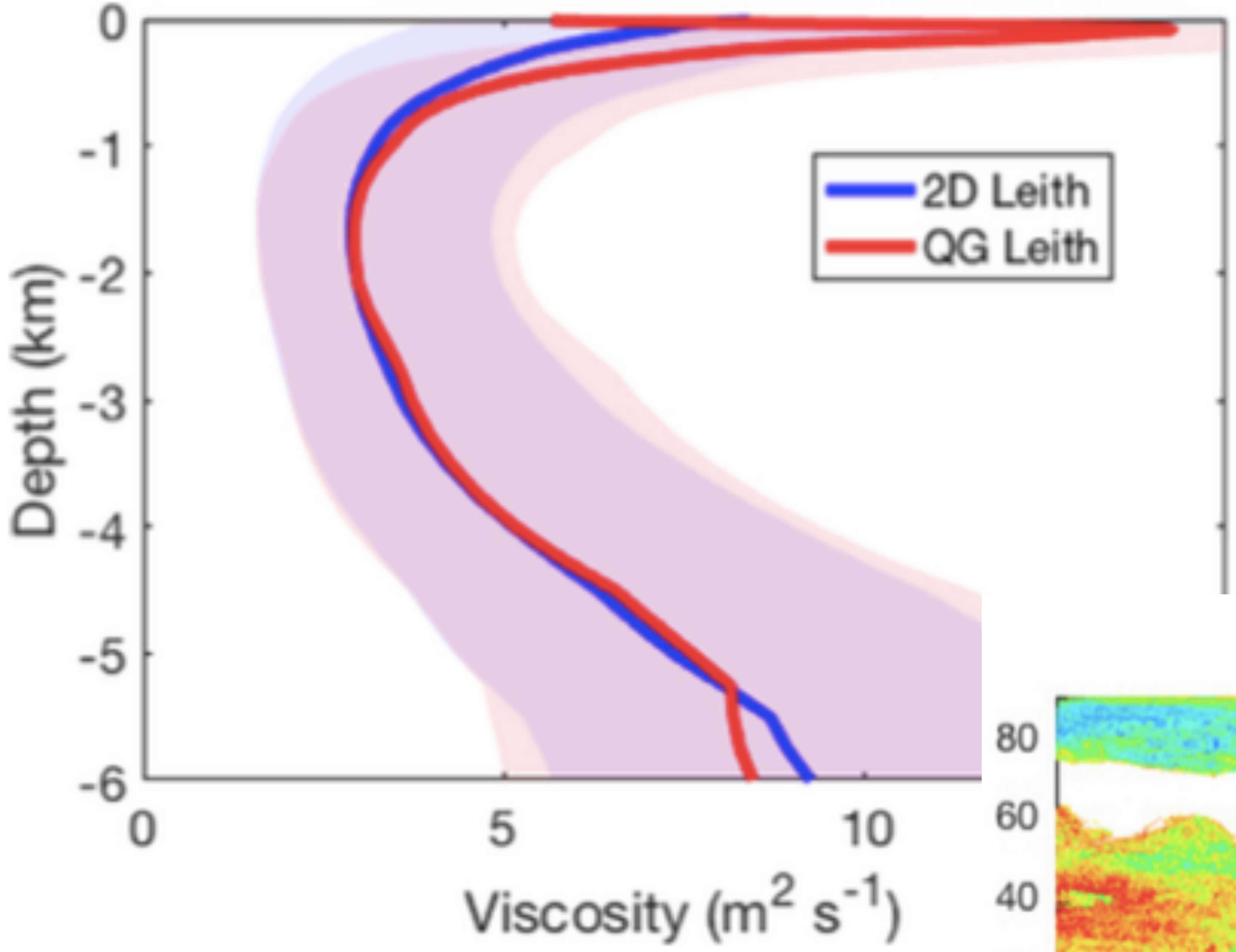
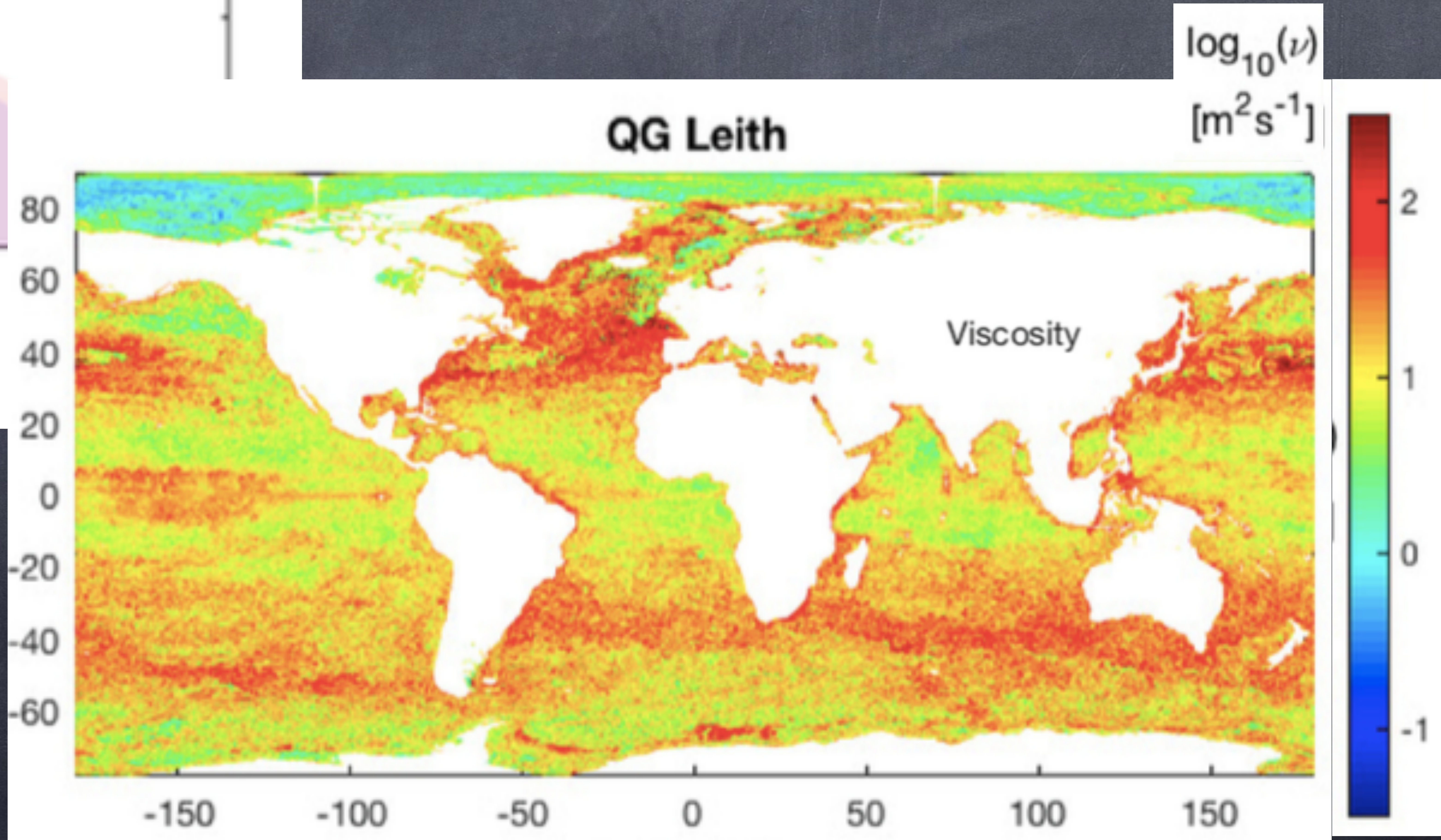
QG Leith:

Works OK in an idealized flow:
Let's try it in a realistic, global model!





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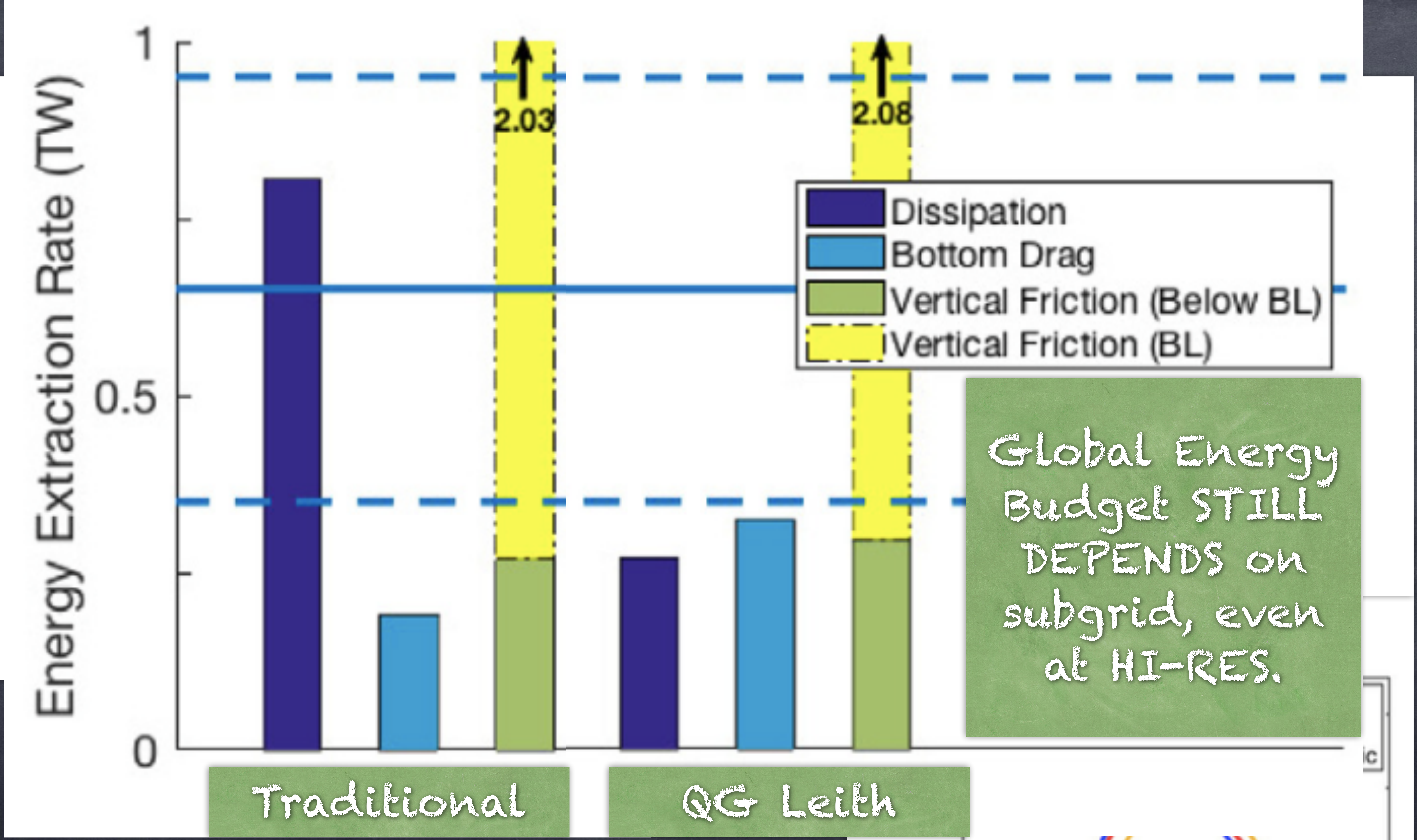
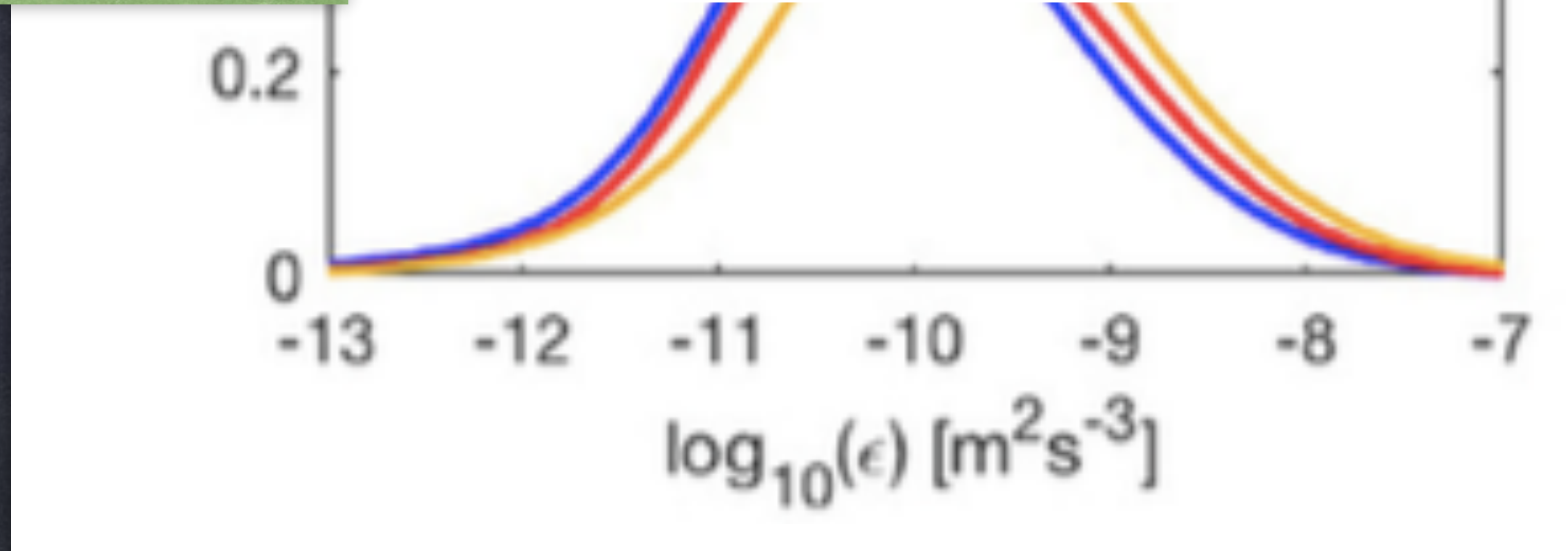


(most in upper 200m)



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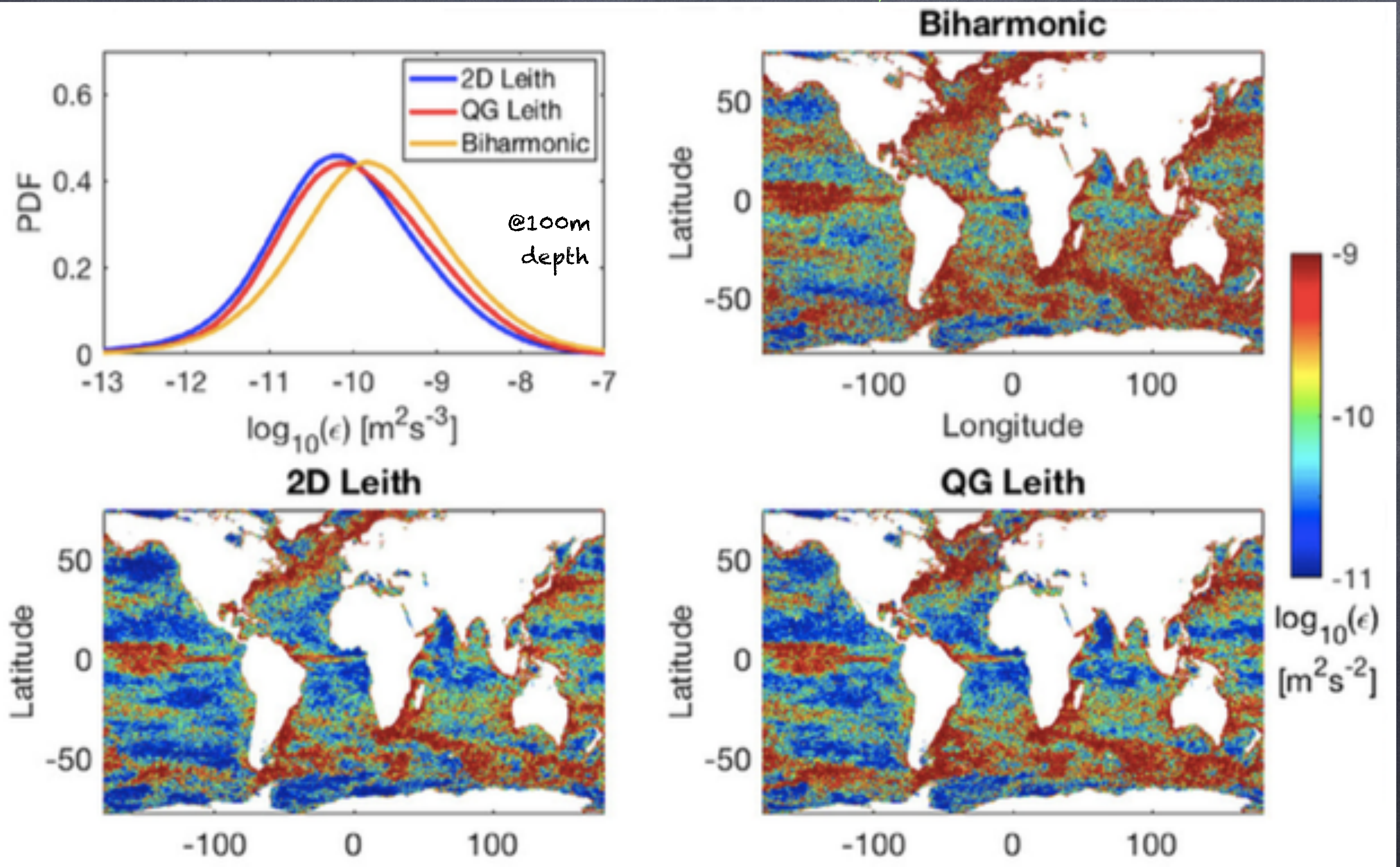
Energy Dissipation is Approx. Lognormally distributed–
AND knows where the Gulf Stream is!



Energy Dissipation Stats are Self-Similar

A (weak) dissipation of energy with pot'l enstrophy cascade

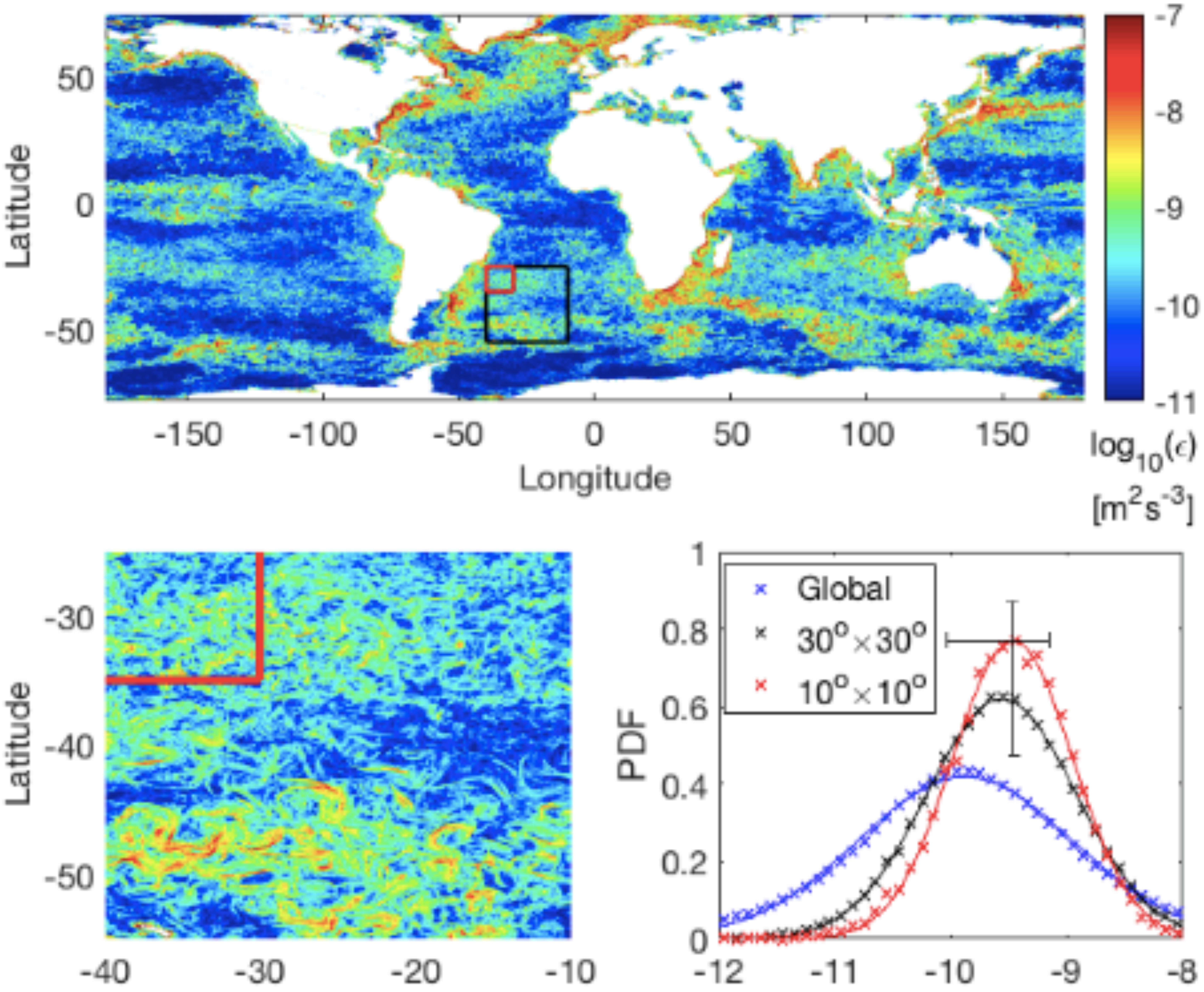
...

approx. lognormally distributed
(super-Yaglom '66)

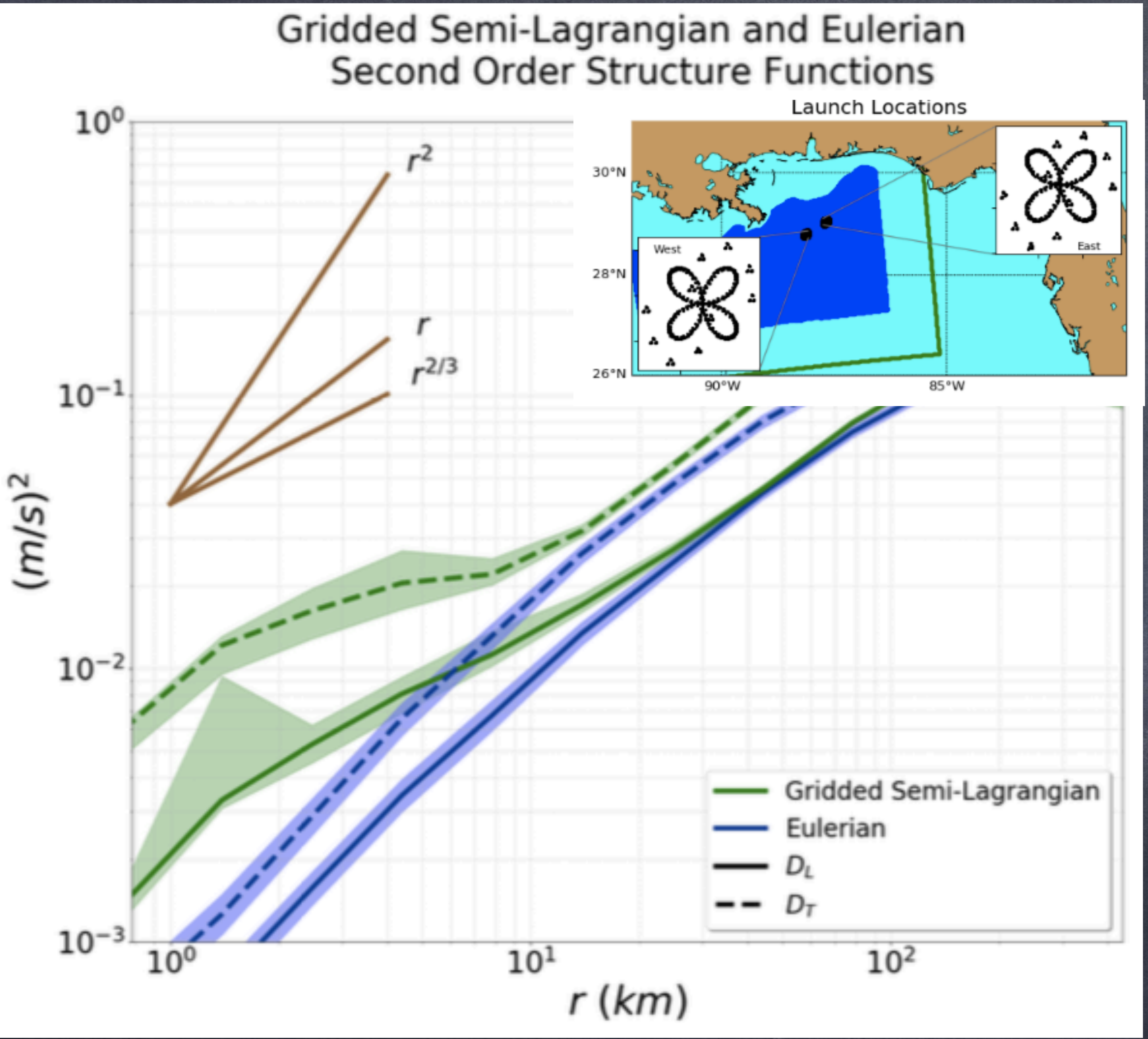
...

90% of KE dissipation in 10% of ocean

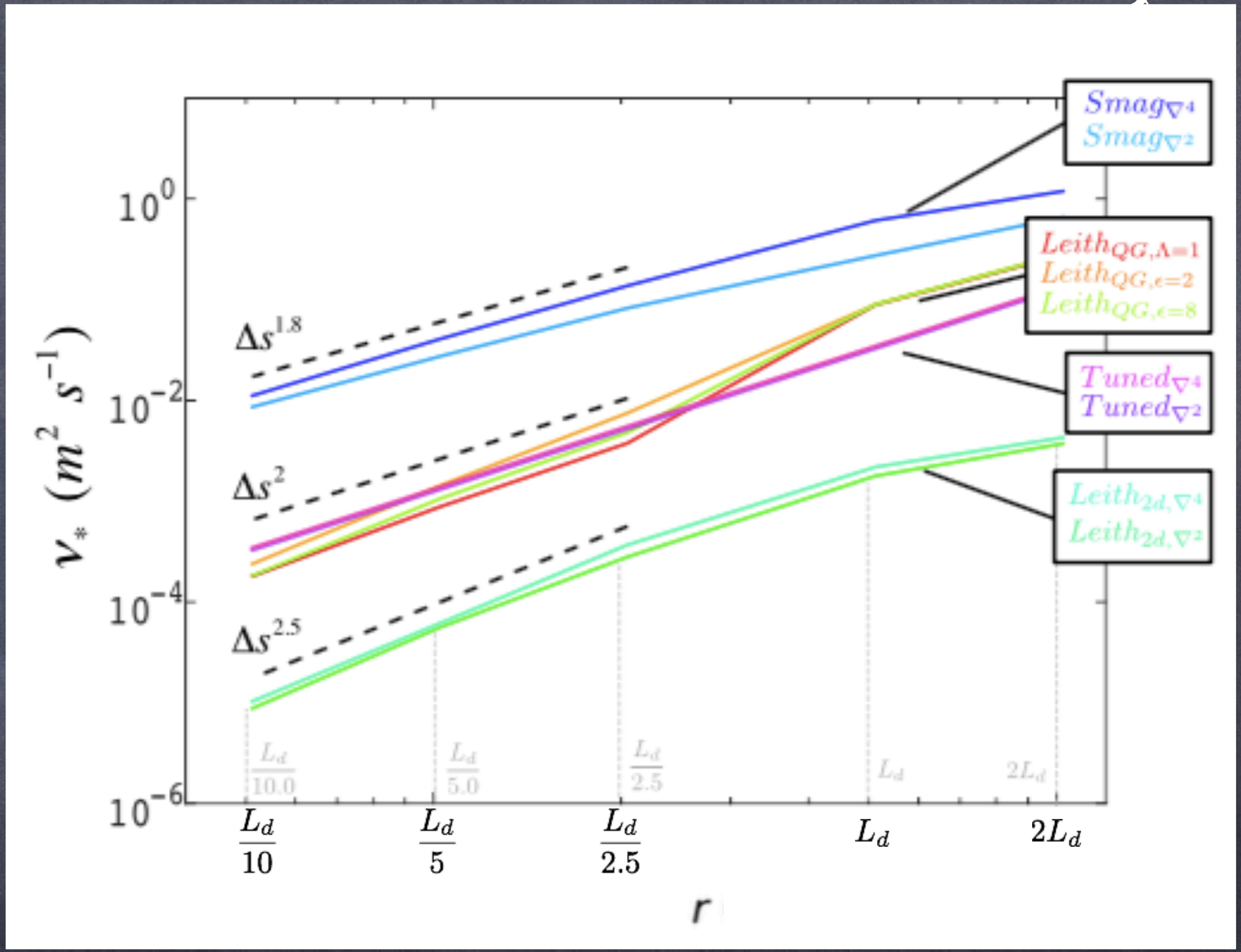
B. Pearson and BFK. Log-normal turbulence dissipation in global ocean models. Physical Review Letters, 120(9):094501, March 2018.



'Observed' scale-sensitivity?



J. Pearson, B. Fox-Kemper, R. Barkan, J. Choi, A. Bracco, and J. C. McWilliams. Impacts of convergence on Lagrangian statistics in the Gulf of Mexico. Journal of Physical Oceacnography, February 2018. Submitted.



Some Theory/Model combos are inconsistent (e.g., Smagorinsky in a QG regime)

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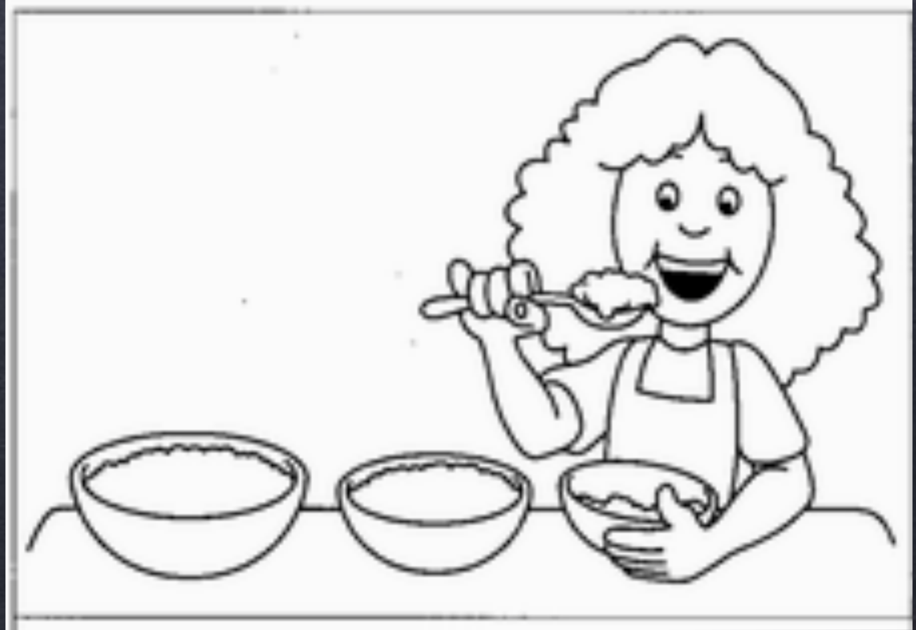

Under "Cascade" Scalings, new bias is a little different

Following Smagorinsky's 3D approach, we built schemes suitable for mesoscale-permitting ocean models, where 2D or QG cascades rule.

In these models, energy is dissipated nearly lognormally, like 3D turbulence, but for quite different reasons

Lognormal dissipation, together with limited observing platforms (e.g., drifters), makes observing dissipation & scalings challenging.

Some of the models & obs. don't obey a cascade–still work to do!