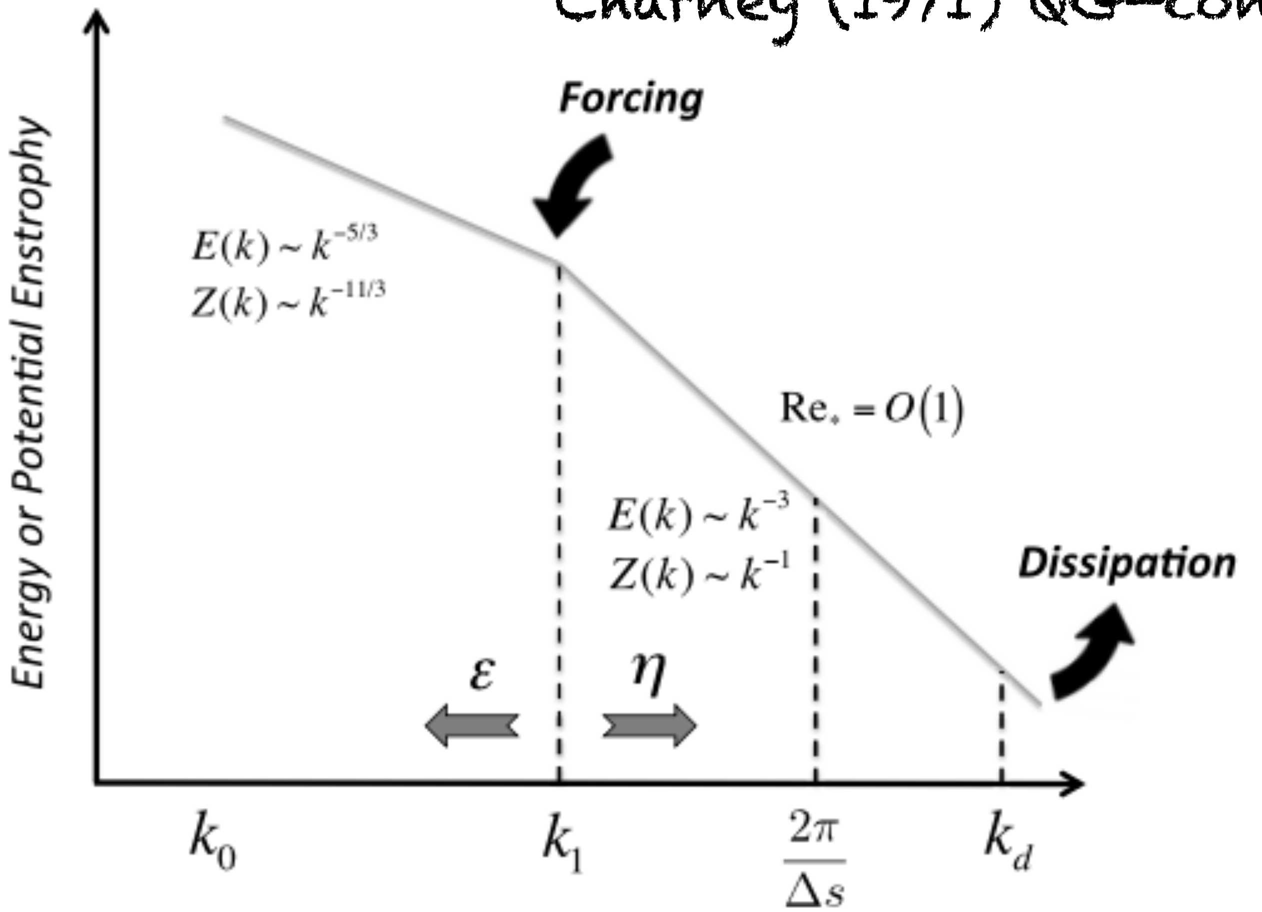
Linking Scale-Aware Eddy Parameterizations and Observed Fluxes Across Scales

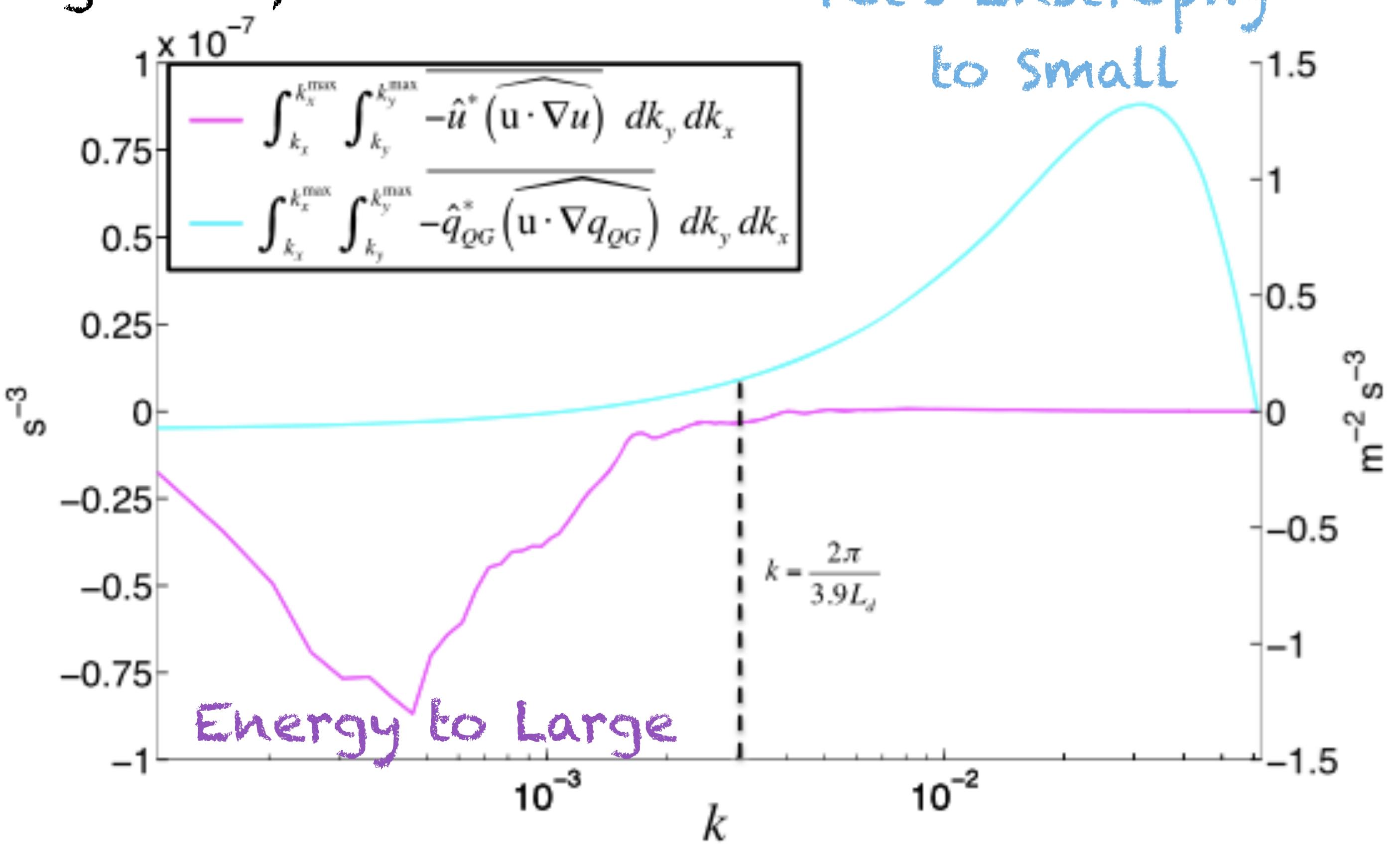
Contributions from: Brodie Pearson, Jenna Palmer (Brown), Scott Bachman & Frank O. Bryan (NCAR), Roy Barkan & J. McWilliams (UCLA), Jun Choi & Annalisa Bracco (GaTech), E. D'Asaro (UW)

Baylor Fox-Kemper
Brown University

PS33A-01

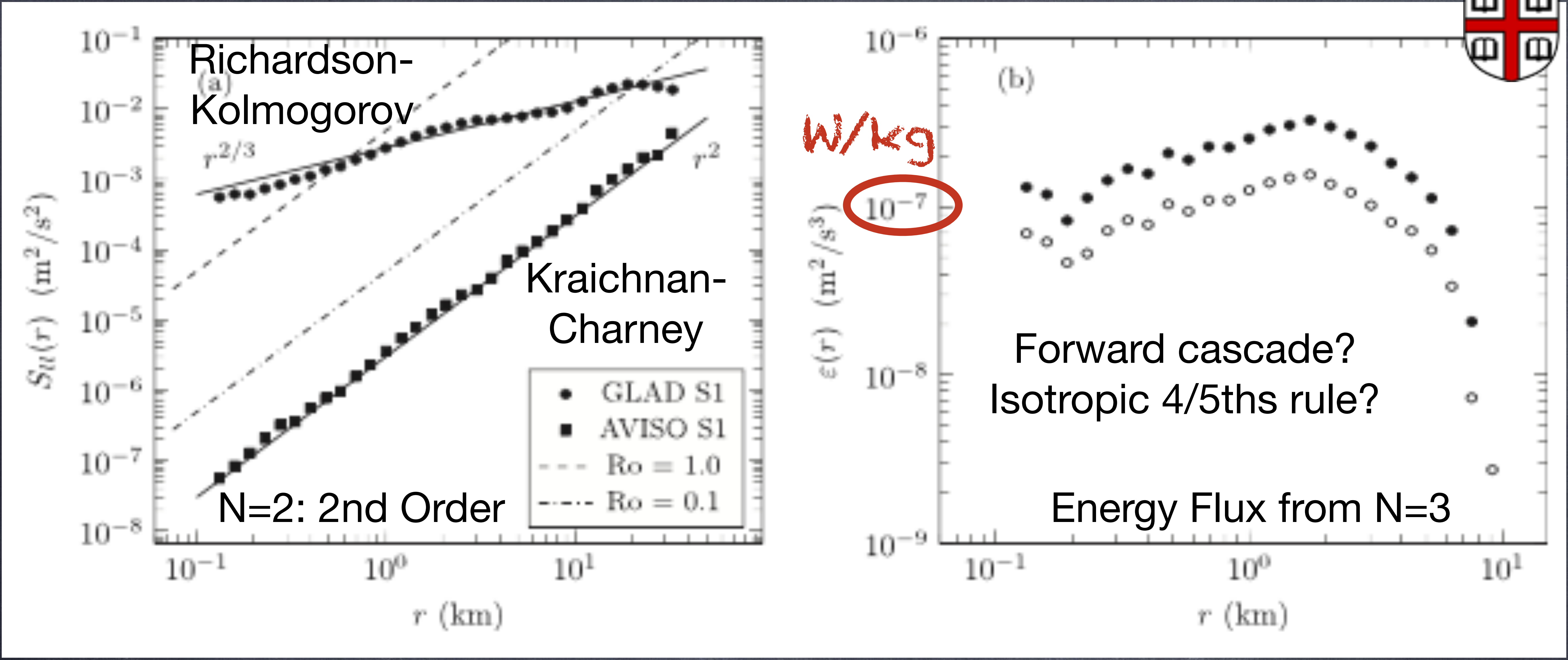
Charney (1971) QG-convergence-free cascade





Support: CARTHE (GoMRI), Key Research Program of China (2017YFA0604100), NSF OCE-1350795 and ONR N00014-17-1-2963

GLAD Observations of Forward Energy Cascade from 30km?



Richardson-Kolmogorov

Kraichnan-Charney

N=2: 2nd Order

W/kg

Forward cascade?
Isotropic 4/5ths rule?

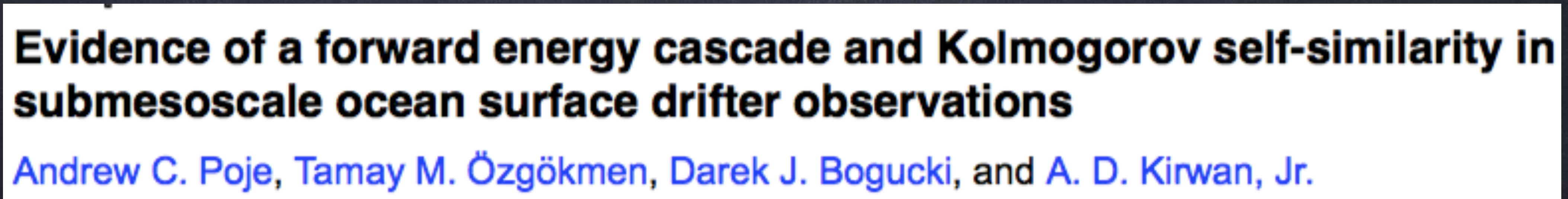
Energy Flux from N=3

$$\text{Structure Fct} = (u[\mathbf{x}+\mathbf{r}] - u[\mathbf{r}])^N$$

140TW (global)/(1.4 10^{21} kg)=10^{-7} W/kg

>>Winds: ~20TW global + Tides: 3.5TW global

<D'Asaro et al (2011): Enhanced @ Fronts: 10^{-5} to 10^{-6} W/kg

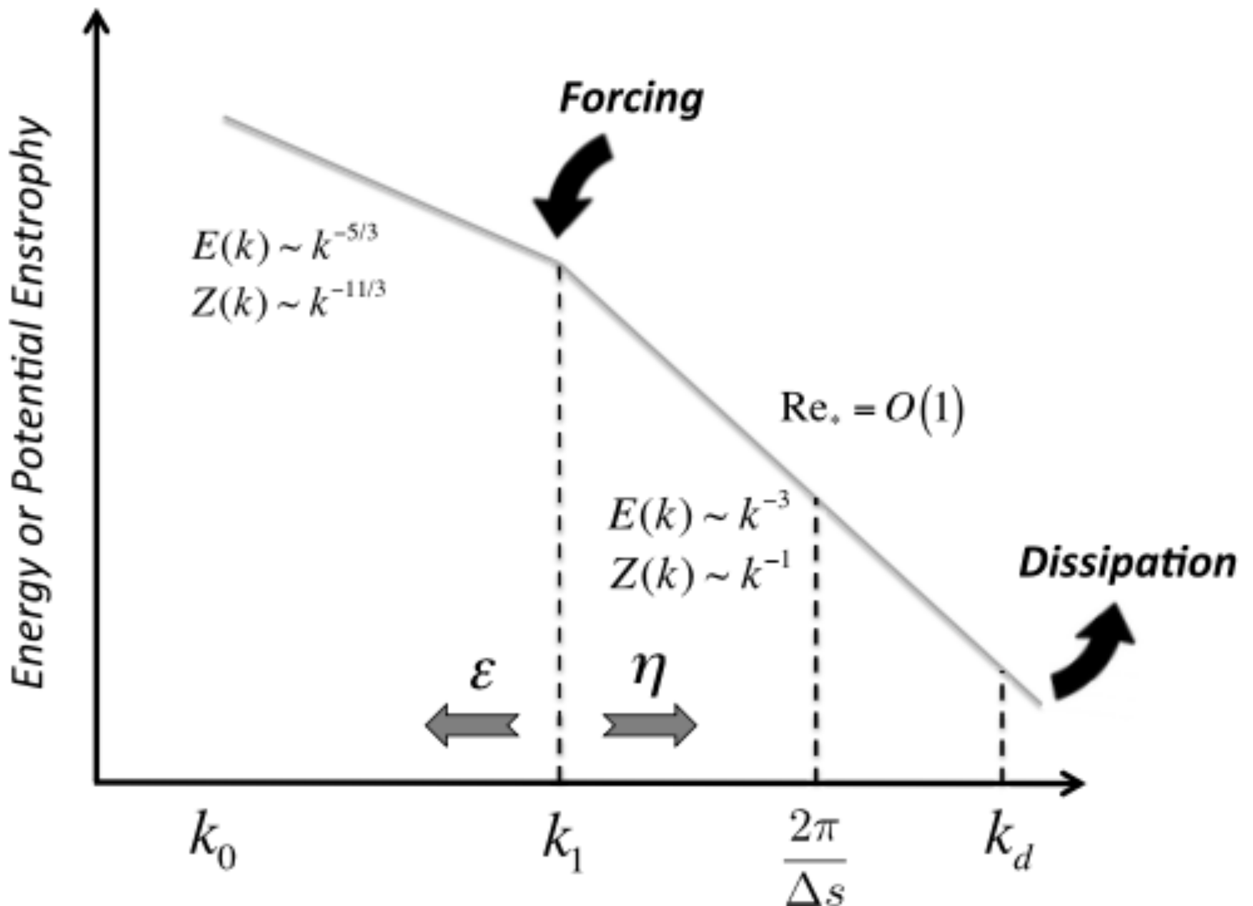


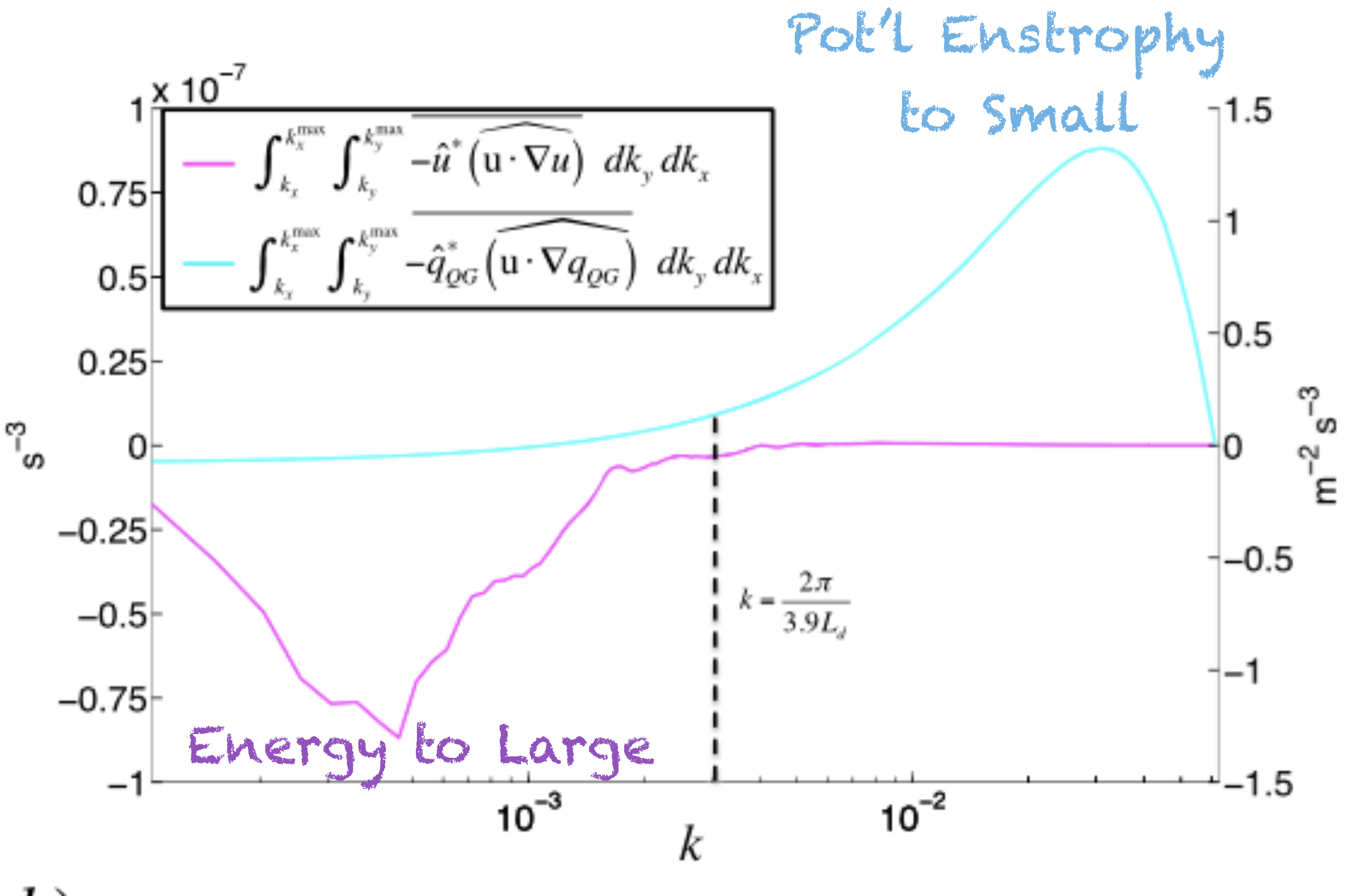
Evidence of a forward energy cascade and Kolmogorov self-similarity in submesoscale ocean surface drifter observations

Andrew C. Poje, Tamay M. Özgökmen, Darek J. Bogucki, and A. D. Kirwan, Jr.

Fluxes Across Scales: 3 Ideas

1) Param. for Mesoscale Ocean Large Eddy Sims. (MOLES): QG Leith
2) Intermittency of the cascades: log-normal mesoscale stats.
3) Structure functions for observations, drifters, and models



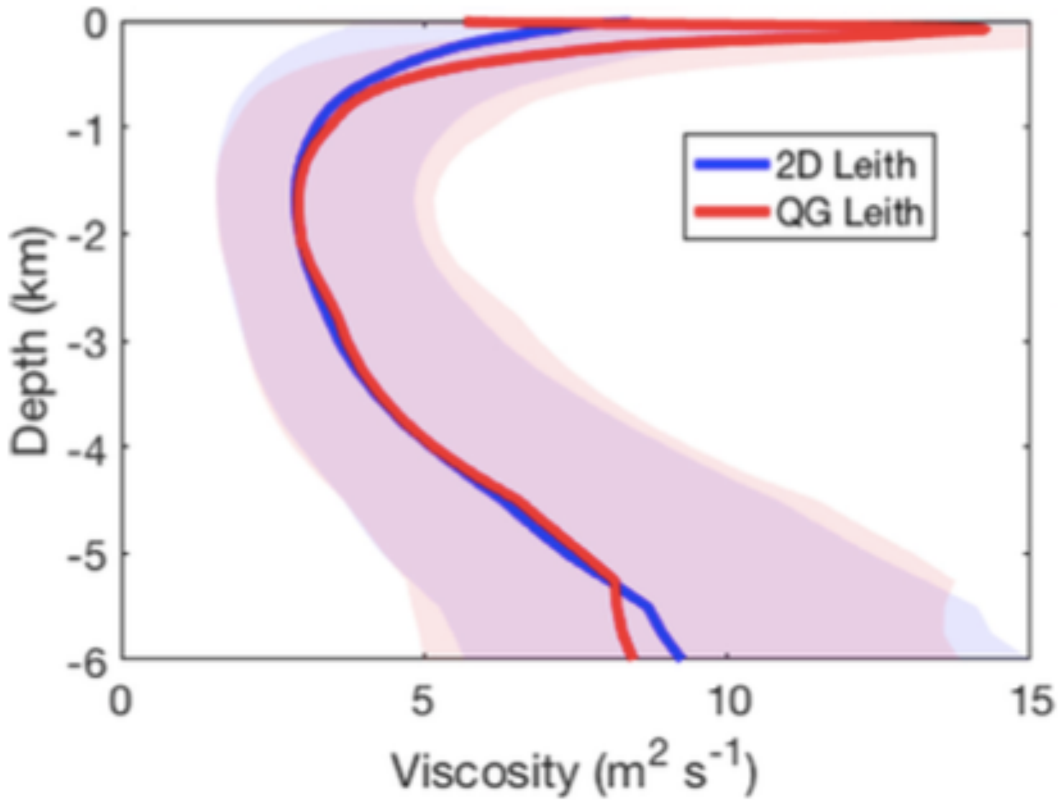


QGLeith: A Pot'l Enstrophy-Based MOLES Closure

$$\nu_{qg} = \left(\frac{\Delta_h \Lambda_{qg}}{\pi}\right)^3 \sqrt{|\nabla_h q_{qg}|^2 + |\nabla_h \left(\nabla_h \cdot \mathbf{u}\right)|^2}$$

Momentum uses Laplacian horizontal viscosity

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



S. D. Bachman, BFK, and B. Pearson, 2017: A scale-aware subgrid model for quasi-geostrophic turbulence. Journal of Geophysical Research–Oceans, 122:1529–1554.

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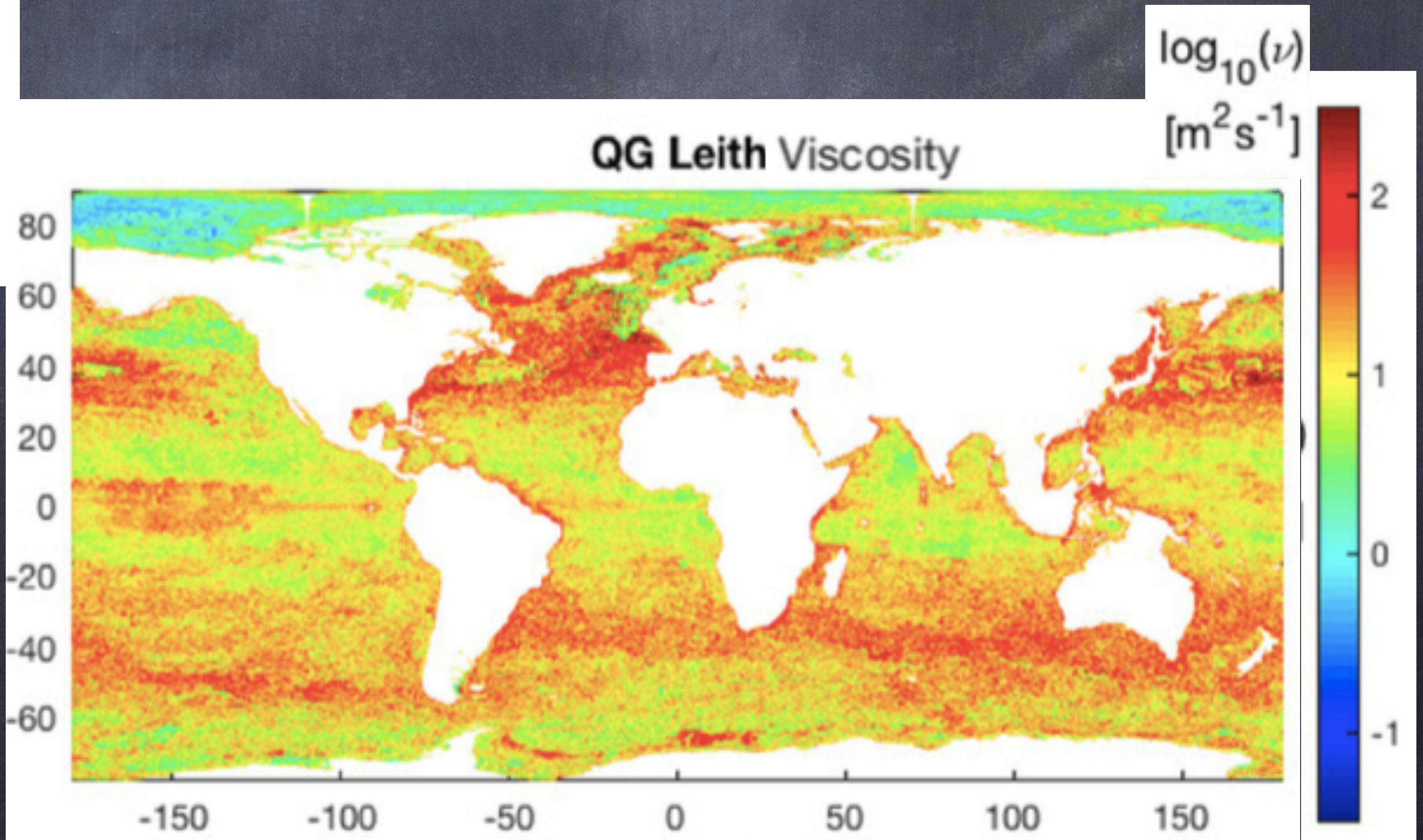

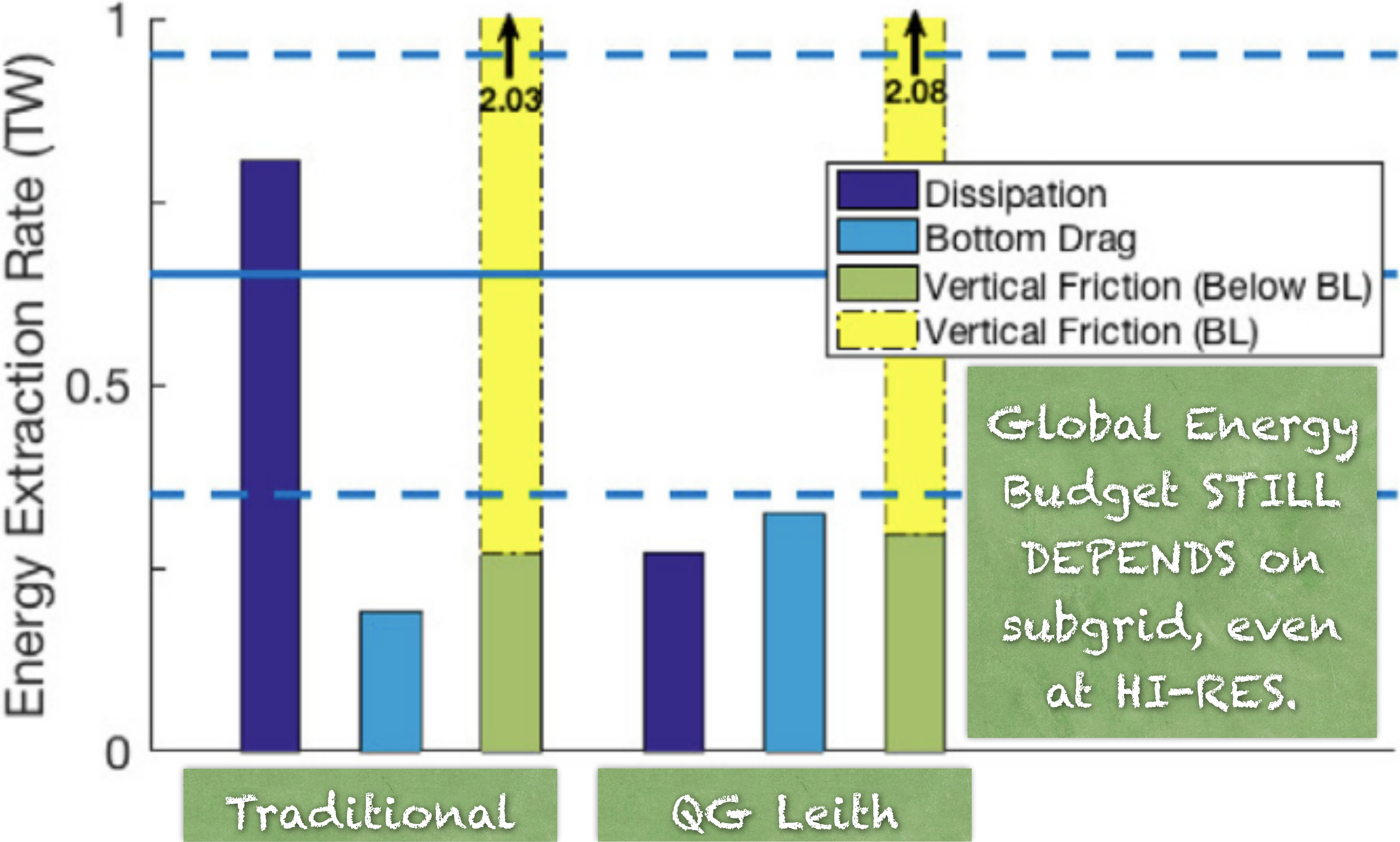

Global Energy Budget STILL DEPENDS on subgrid, even at HI-RES.

(most in upper 200m)

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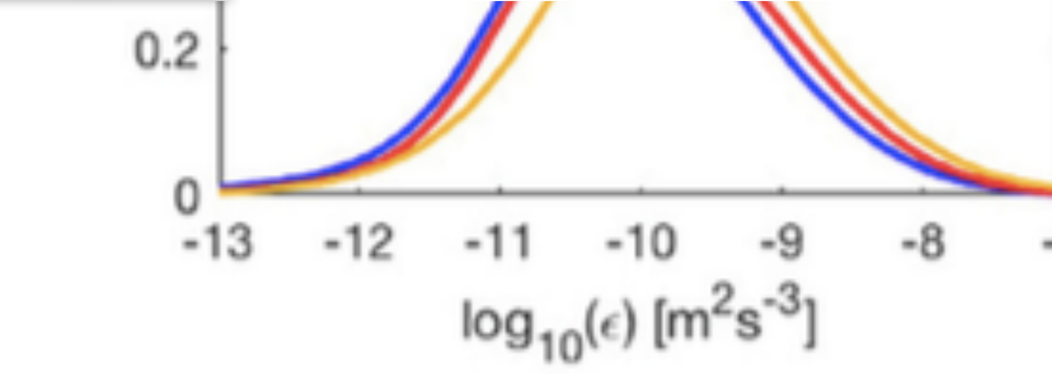
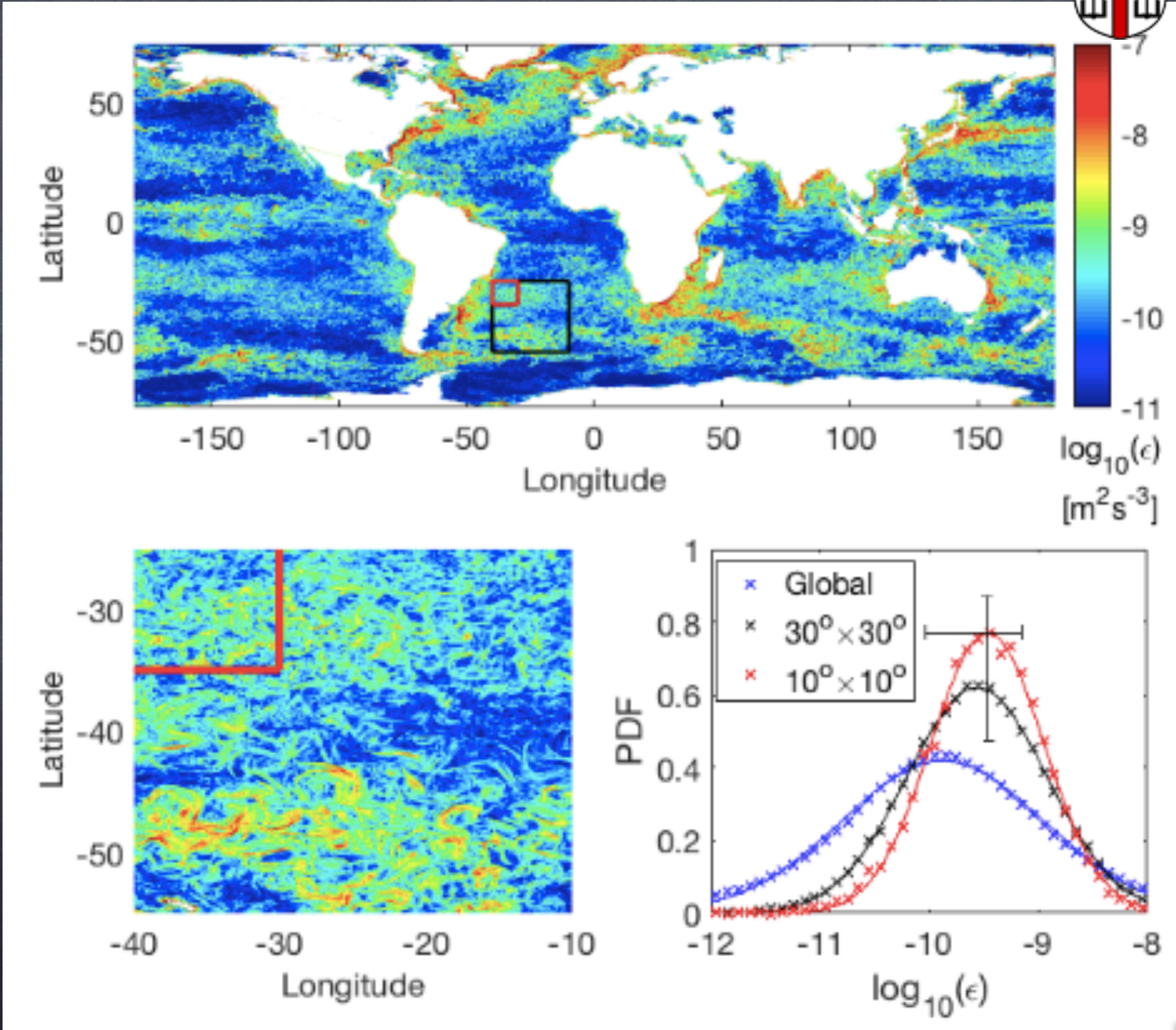


MOLES: Log-Normal Dissipation Intermittency

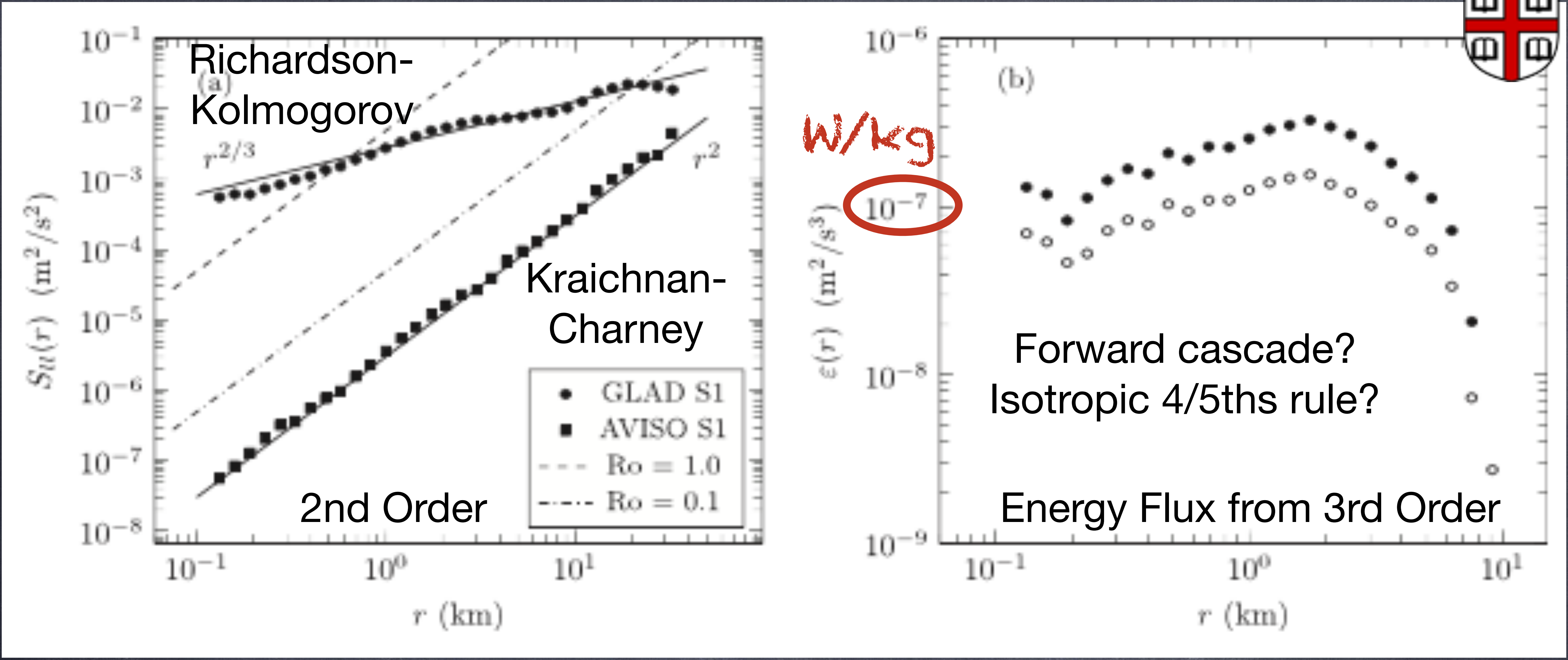
A (weak)
dissipation of
energy
with pot'l
enstrophy
cascade
...
that's
lognormally
distributed
(super-Yaglom '66)

90% of KE
dissipation in
10% of ocean

B. Pearson and BFK, 2018: Lognormal turbulence dissipation in global ocean models. Physical Review Letters. In press.



Drifter Obs. ns of Forward Energy Cascade from 30km?



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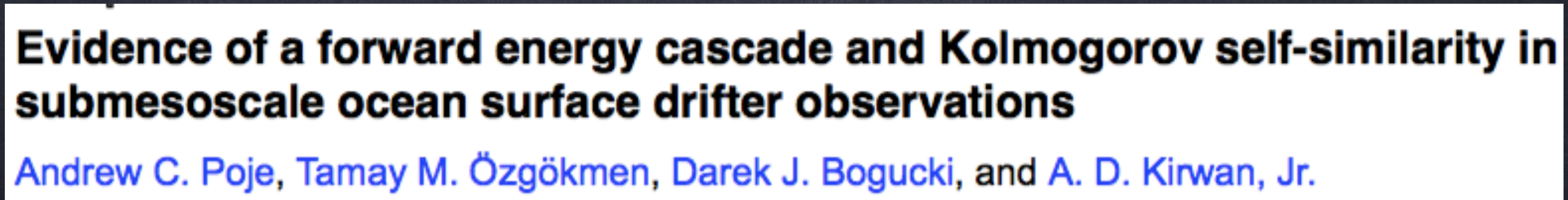

Evidence of a forward energy cascade and Kolmogorov self-similarity in submesoscale ocean surface drifter observations

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GLAD/LASER, CARTHE:
Consortium for Advanced Research on the Transport of Hydrocarbons in the Environment

See: “Ocean convergence and the dispersion of flotsam”
Eric A. D’Asaro et al. PNAS 2018


Image: D’Asaro

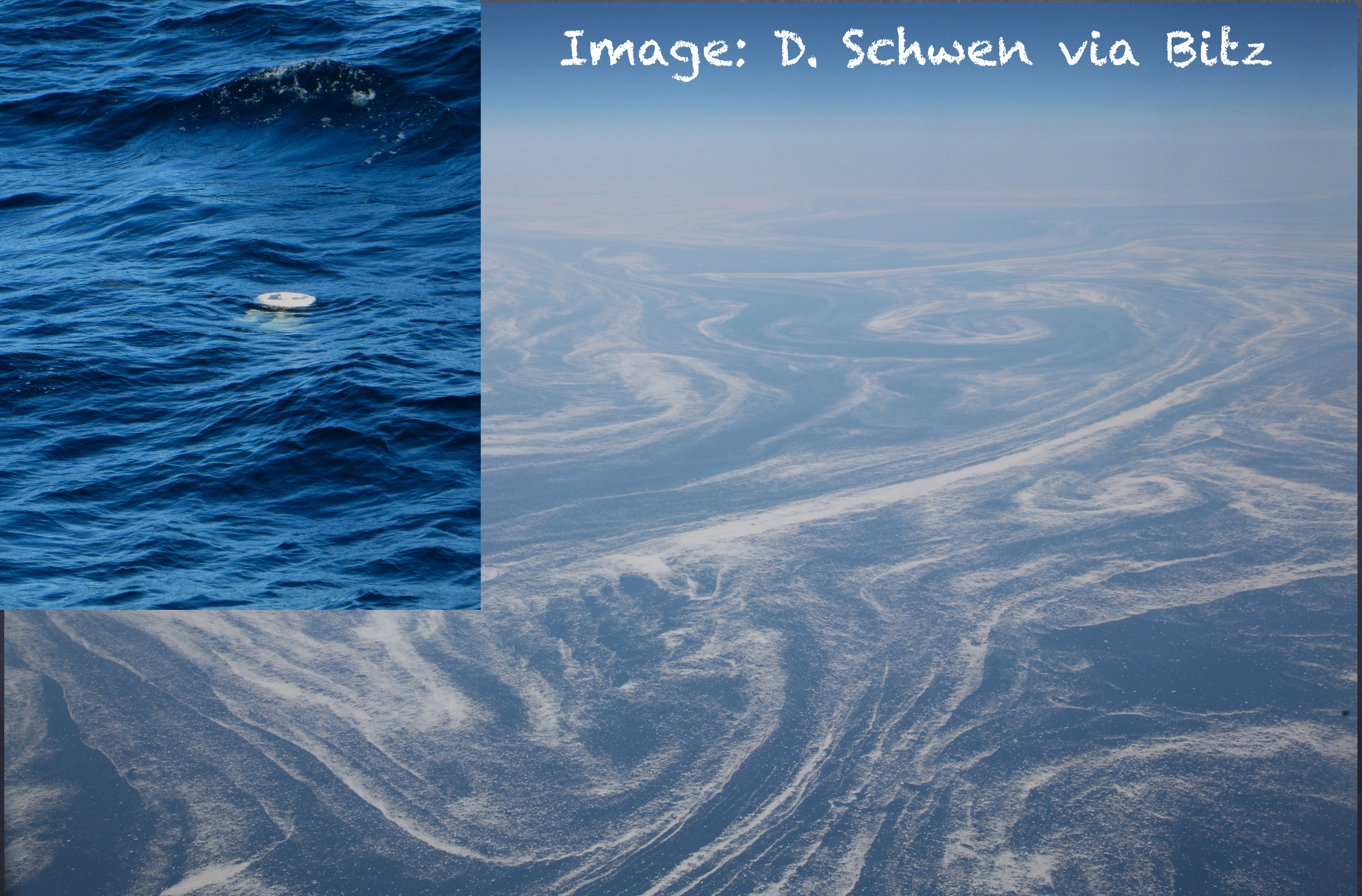
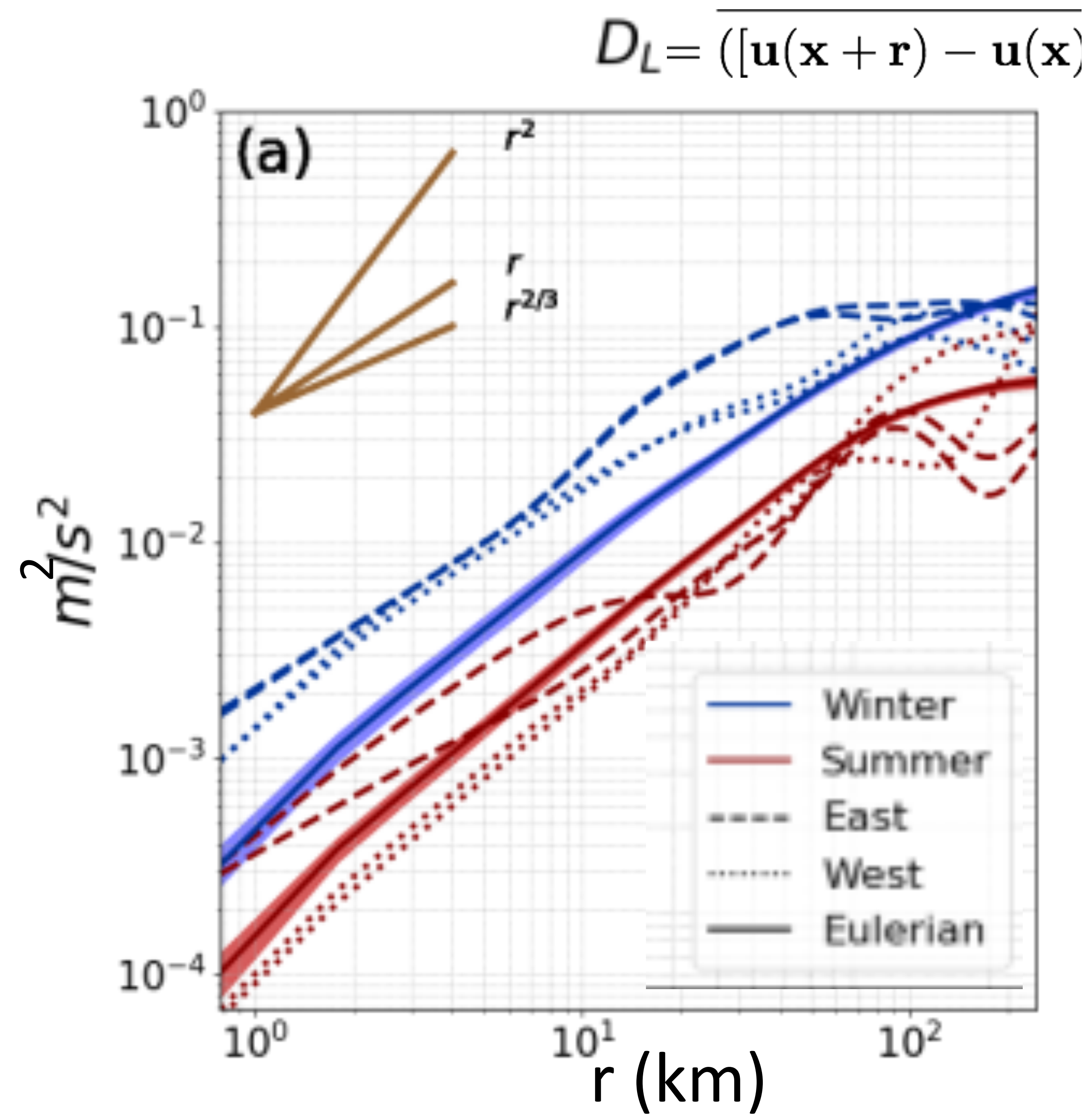
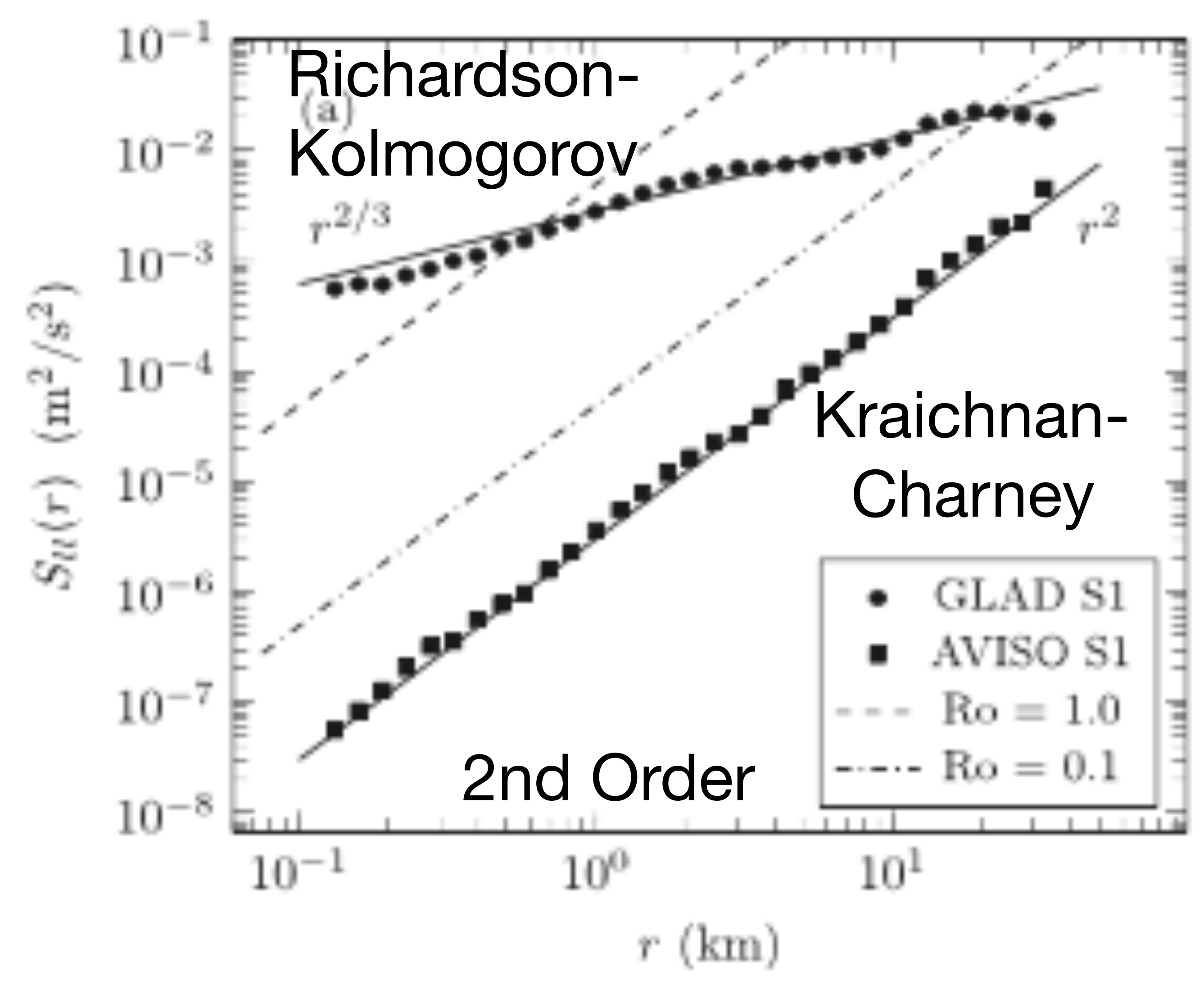


Image: D. Schwen via Bitz

Submesoscale Eulerian vs. Lagrangian:

L. is biased toward sampling convergent fronts &tc.—See the 2nd Order Structure Function!





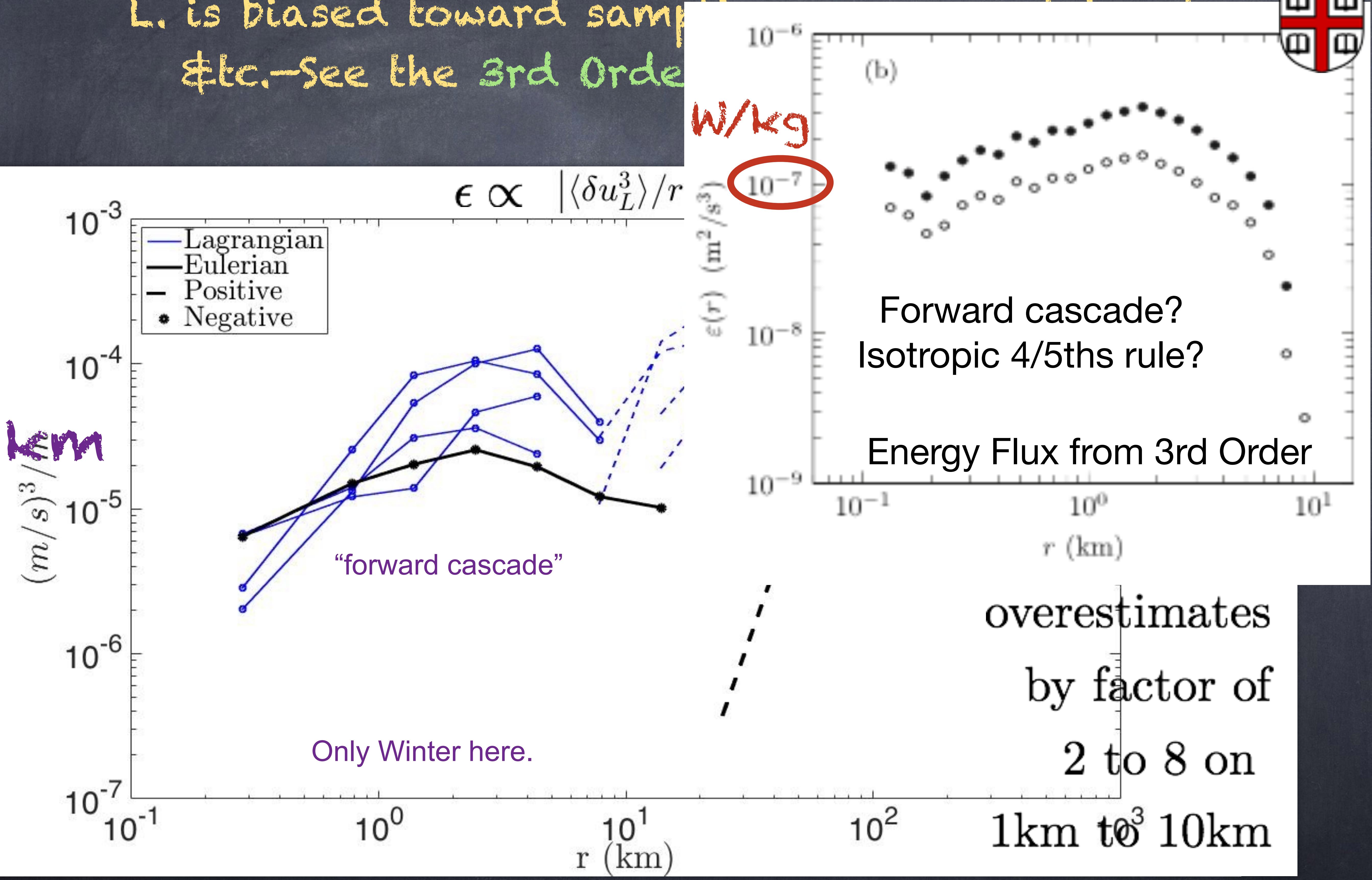
Lagrangian slope is shallower—
More like Kolmogorov-Richardson
than unbiased Eulerian version.

J. Palmer, BFK, R. Barkan, A. Bracco, J. Choi, J. C. McWilliams, 2018: Impacts of convergent zones on structure function statistics in the Gulf of Mexico. JPO. Submitted.

Submesoscale Eulerian vs. Lagrangian:

L. is biased toward samp

&tc.—See the 3rd Orde



"forward cascade"

Only Winter here.

Forward cascade?
Isotropic 4/5ths rule?

Energy Flux from 3rd Order

overestimates
by factor of
2 to 8 on
1km to 10km

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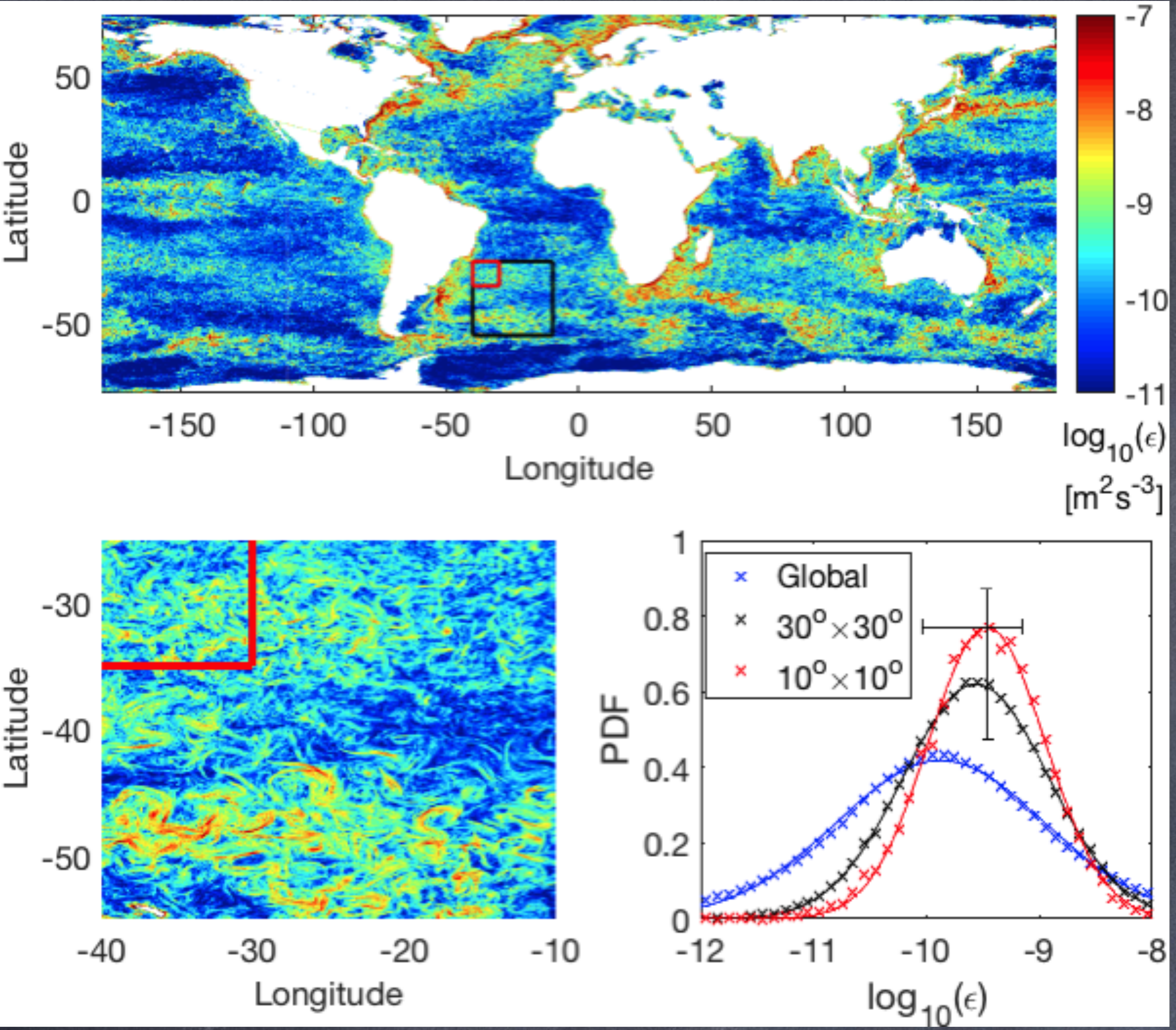


2) Dissipation of KE and QGPE is extremely localized (90% of total in 10% of regions)

2) EKE is dissipated (weakly) within QG Pot’l Enst. Cascade

Poje et al. estimate EKE cascade:
2) Lognormal: +1.5 st.dev.,
3) Drifter bias large > 2x to 8x

Conclusions:

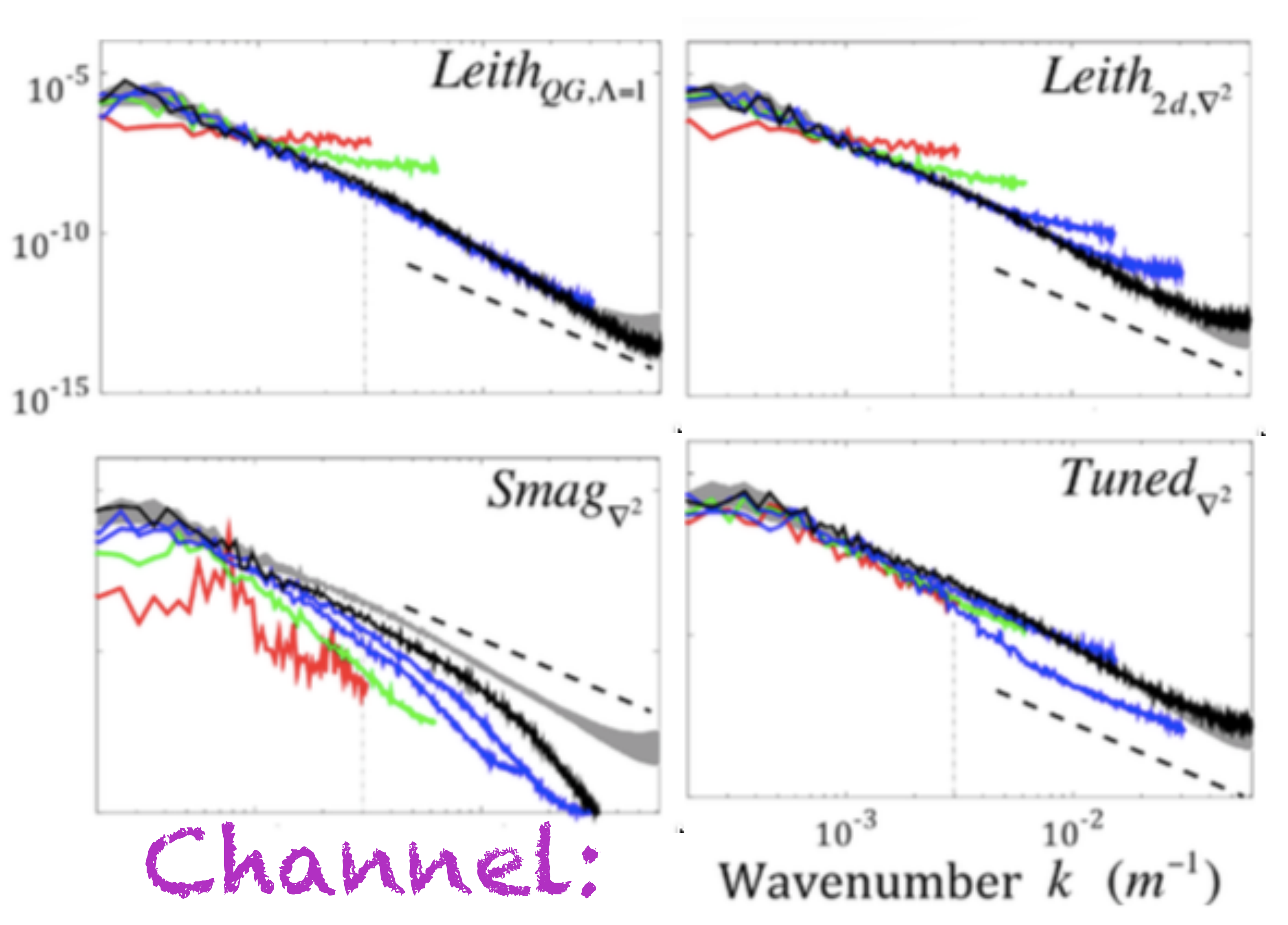
1) Even at high-res. subgrid scheme affects leading order EKE budget!

1) Cascades can inform subgrid, but should be the right cascade

Known Unknowns:
2) Lognormality tail.
3) Drifters biased toward fronts.
1,2,3) Subgrid matters.

Ideas: 1) Cascade Params.,
2) Intermittency,
3) Structure Fcts.

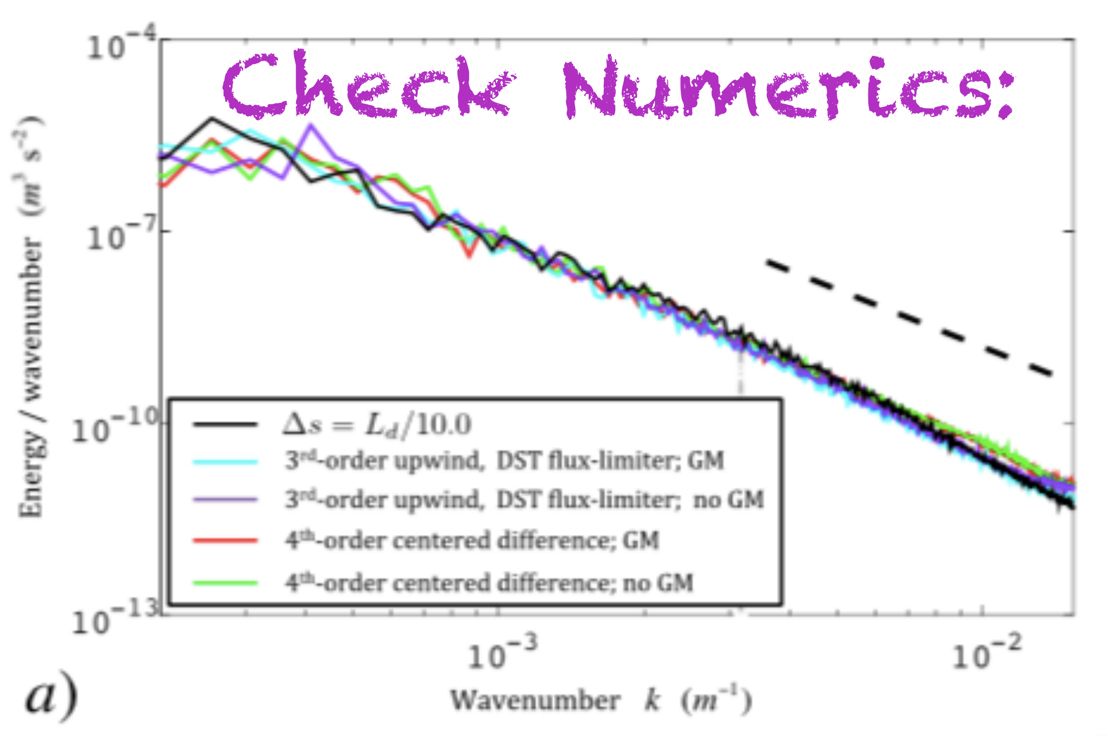
Mesoscale Ocean LES (MOLES): QGLeith



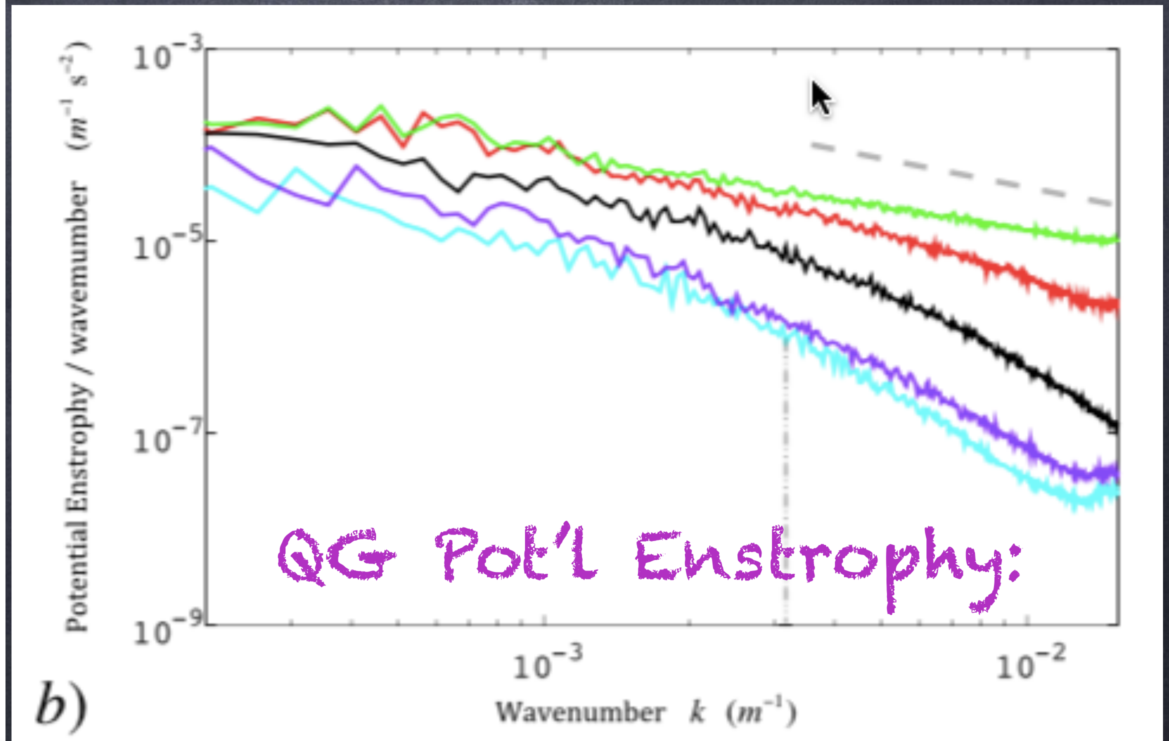
Channel:

MITgcm in
Idealized Domain.
Resolutions from coarse to
very fine
in terms of resolving
deformation radius
High vert. resolution

S. D. Bachman, BFK, and B. Pearson, 2017: A scale-aware subgrid model for quasi- geostrophic turbulence. Journal of Geophysical Research–Oceans, 122:1529–1554.



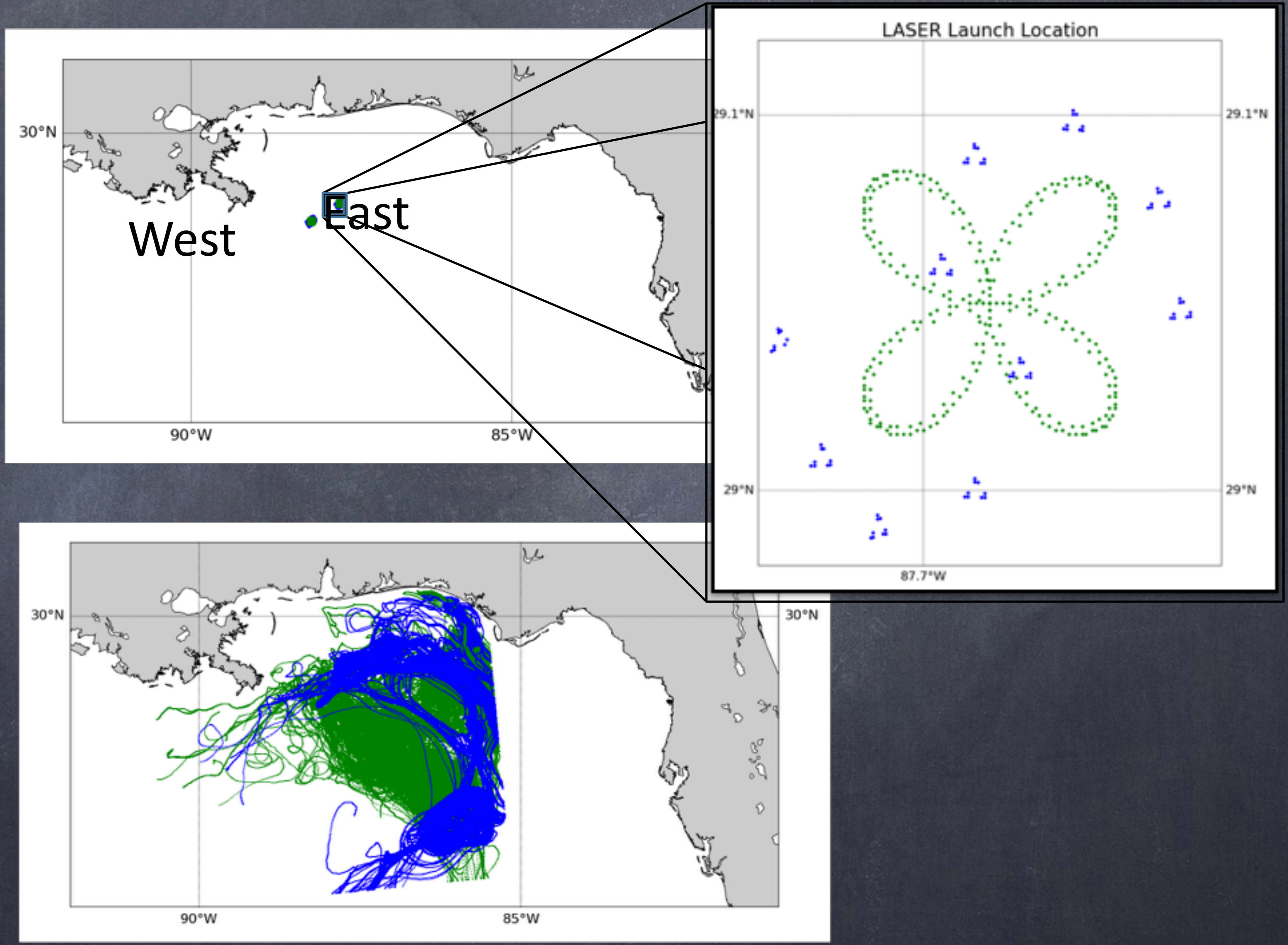
Check Numerics:



QG Pot'l Enstrophy:

Lagrangian vs. Eulerian Cascades

- Regional Ocean Modeling System (ROMS) operating at 500m resolution (climatology)
- Synthetic trajectories were launched within and advected using the Lagrangian TRANSport Model (LTRANS) v.2b
- The launch patterns, locations of deployment, and time of year all mimic GLAD (summer, West) and LASER (winter, East)
- Here Eulerian=model grid sampling & Lagrangian=sampling at trajectory locations



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