The importance of non-propagating wave drag in stratified flow over rough bathymetry

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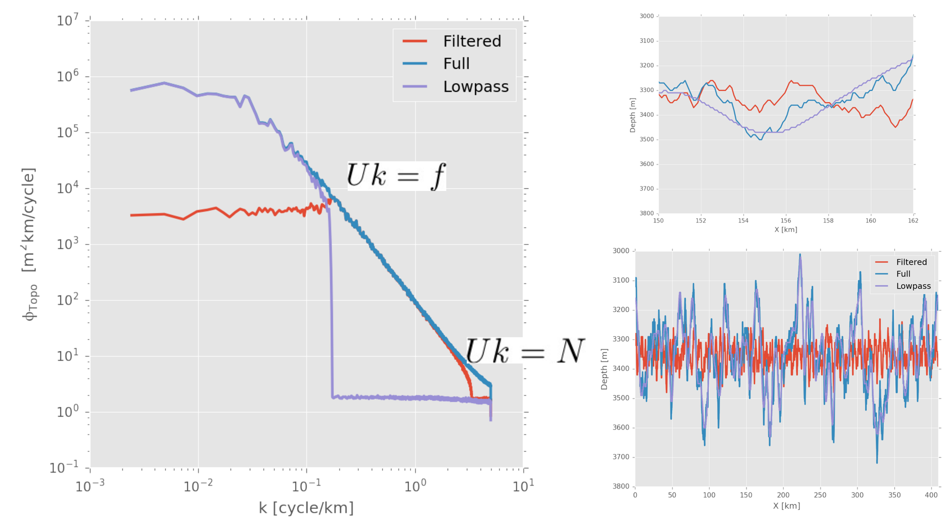
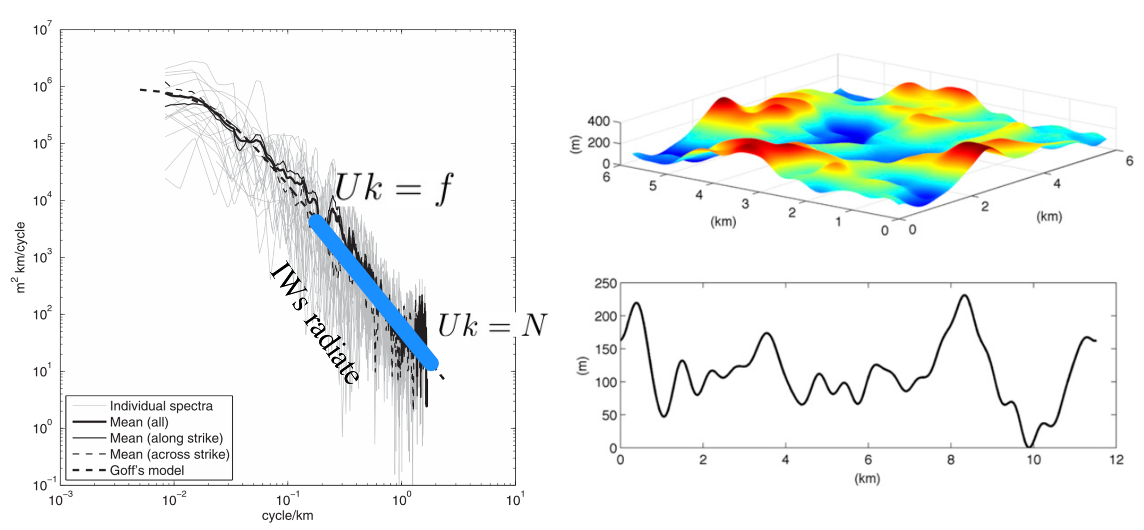
Introduction:

- Adding internal waves from rough bathymetry changes circulation in GCMs (i.e. *Trossman et al, 2013*).
- Use *Bell, 1975* assuming topographic spectrum, P(*k,l*), flow speed *U*, and stratification, *N.*
- Bell 1975 gives radiation from bathymetry in the "propagating regime": f > Uk > N.
- Tests (i.e. *Nikusahin & Ferrari, 2010;Nikurashin et al 2014*) bandpass bathy between 6 km and 600 m.



Left: Topographic spectra used in this work. Filtered is bandpass between 6 km and 600 m. Full is all topographic wavelengths, and Lowpass is just scales larger than 6km. Right: Example 1-d slices (zoomed, full domain)

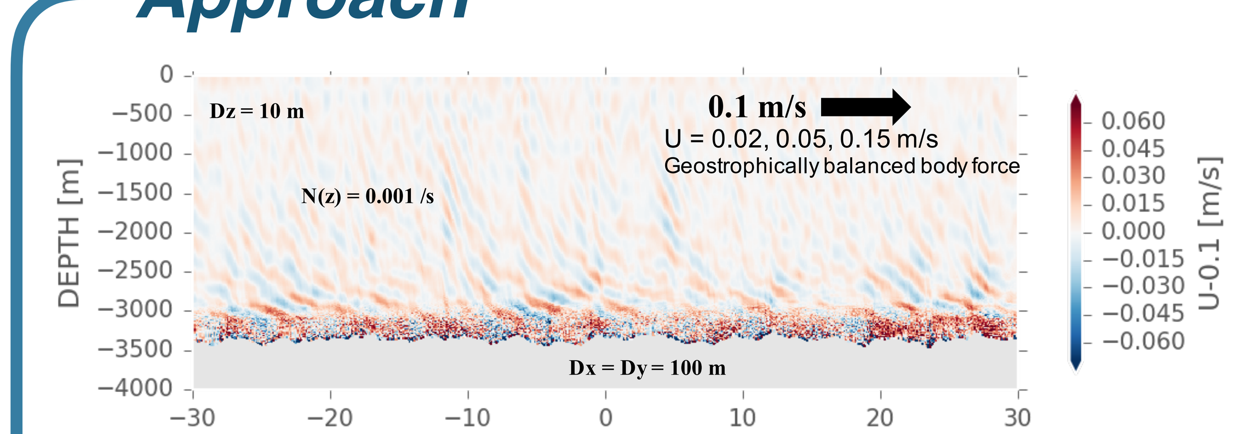


Abyssal Hill Topography (NikurashIn et al 2014). Left: portion of topography spectrum that allows propagating internal waves is shown in blue. Right: Examples of bathymetry used by Nikurashin et al. (2014).

Q: How important is large-scale bathymetry?

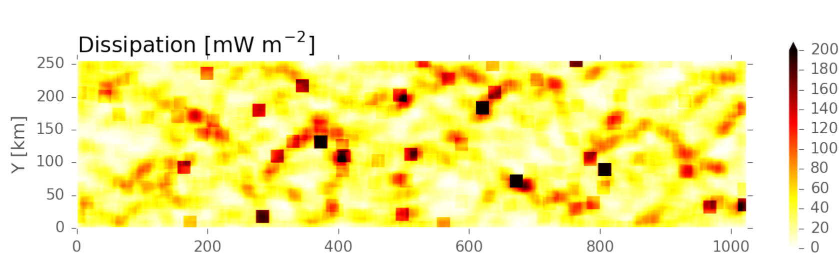
- How much energy lost?
  - theory says none, because not propagating, but *Nh/U>>1* for ocean applications, so hydraulic effects will dissipate non-propagating energy
- How patchy is energy loss?
  - Implications for observations
- How much of the large scale energy loss might be already included in GCM-scale models?

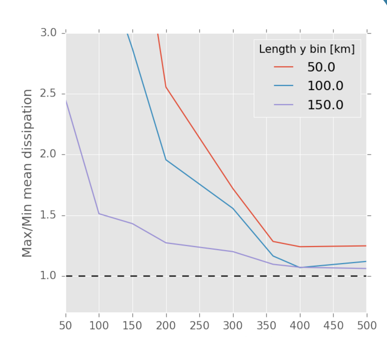
Approach



Why large domain?:

- Full turbulence very patchy.



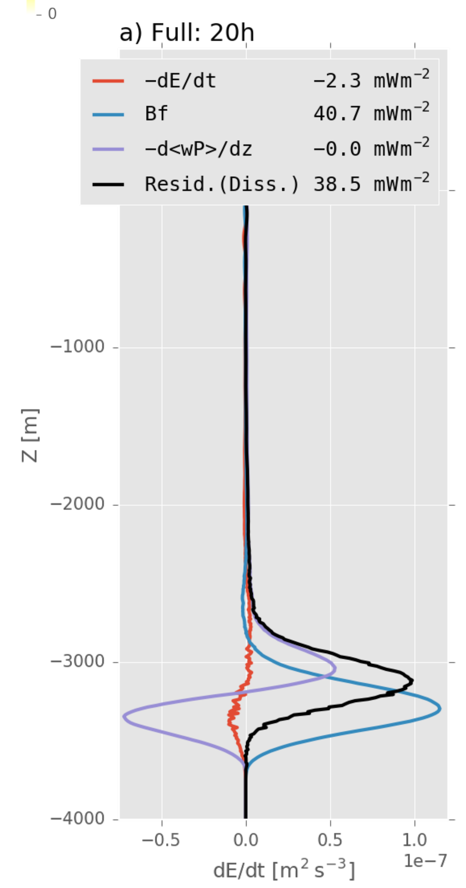


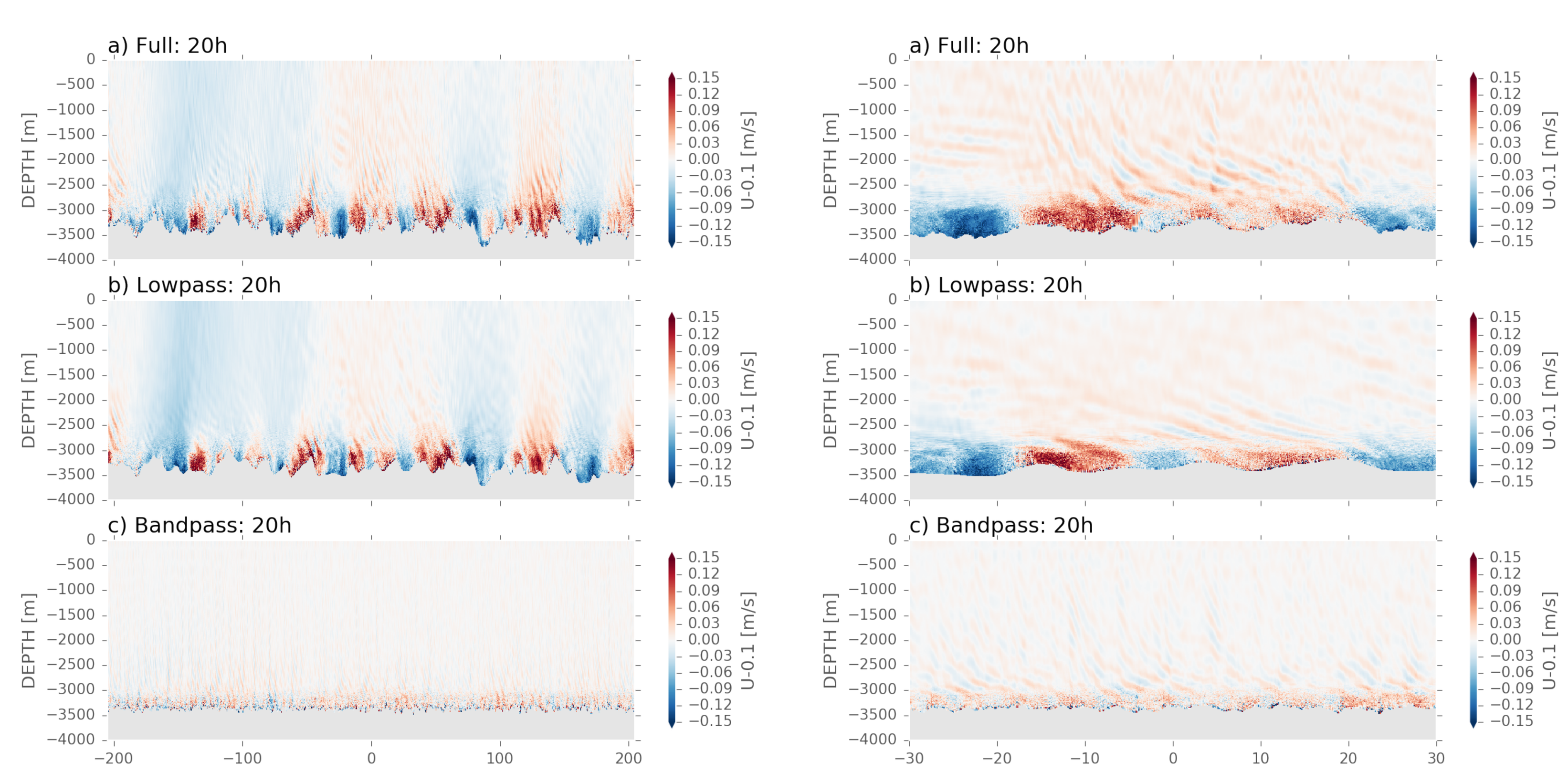
MITgcm:

- Three topographies: Filtered, Full, Lowpass
- 410x120 km domain (doubly periodic)
- 4000-m deep; *No* upper ocean absorber.
- Hydrostatic; *Klymak & Legg (2010)* overturning dissipation
- 200-h spinup (dx=dy=1km); 20 h at dx=100 m; Sensitivity runs at dx=1, 2, 4, 8 km.
- dz = 10 m (20-300 m sensitivity)

Energy Budget:

$$\overbrace{\epsilon}^{Dissipation} = -\overbrace{\frac{dE}{dt}}^{Unsteady} + -\overbrace{\frac{d}{dz}(w'p')}^{Wave\ flux\ divergence} + \overbrace{B}^{Body\ Force\ Work}$$

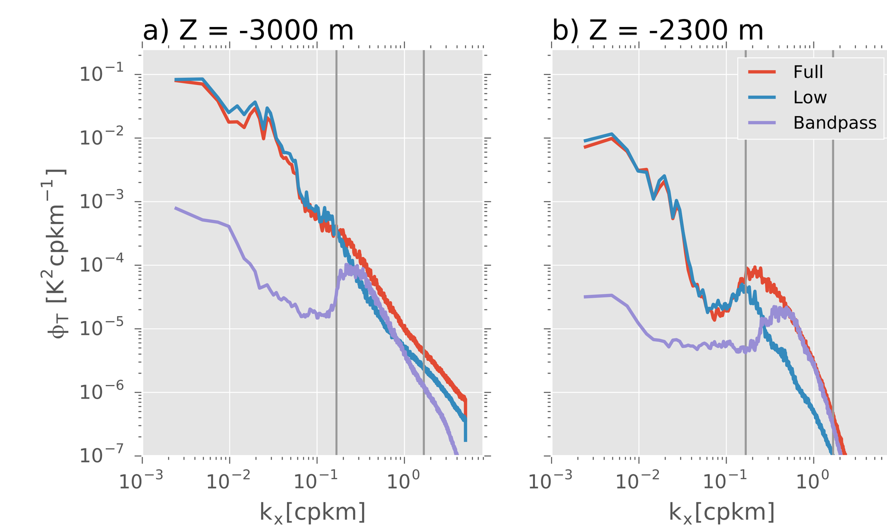




Velocity Slices

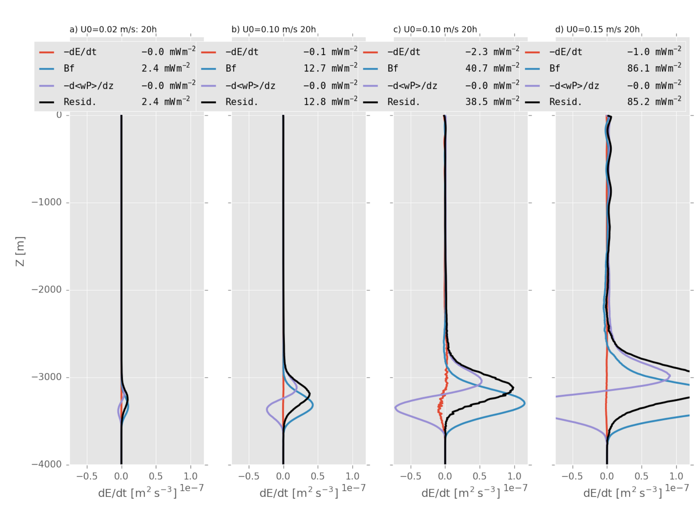
- Snapshots of U=0.1 m/s simulations. Left: Full domain; Right: Inner 60 km
- Time series of velocities are very steady except right near topography.

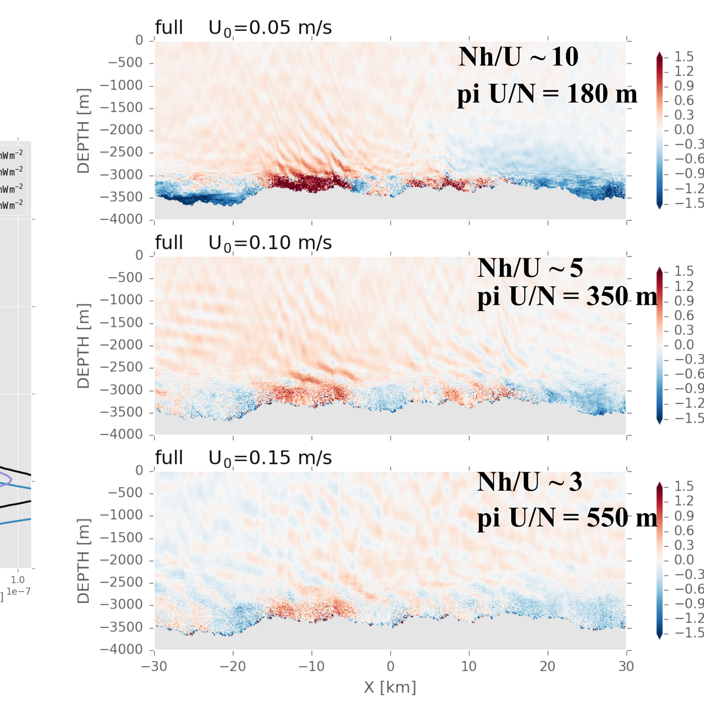
Results



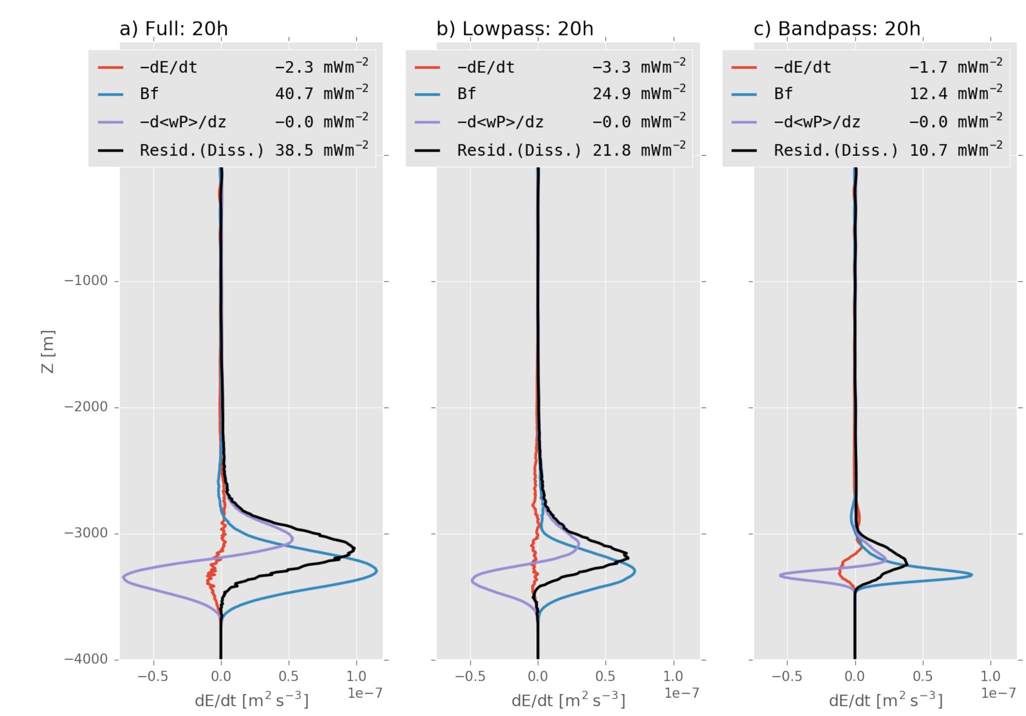
Temperature spectra show variance, even in the non-propagating band of wavenumbers.

Changing Forcing (U):





Changing Bathymetry:

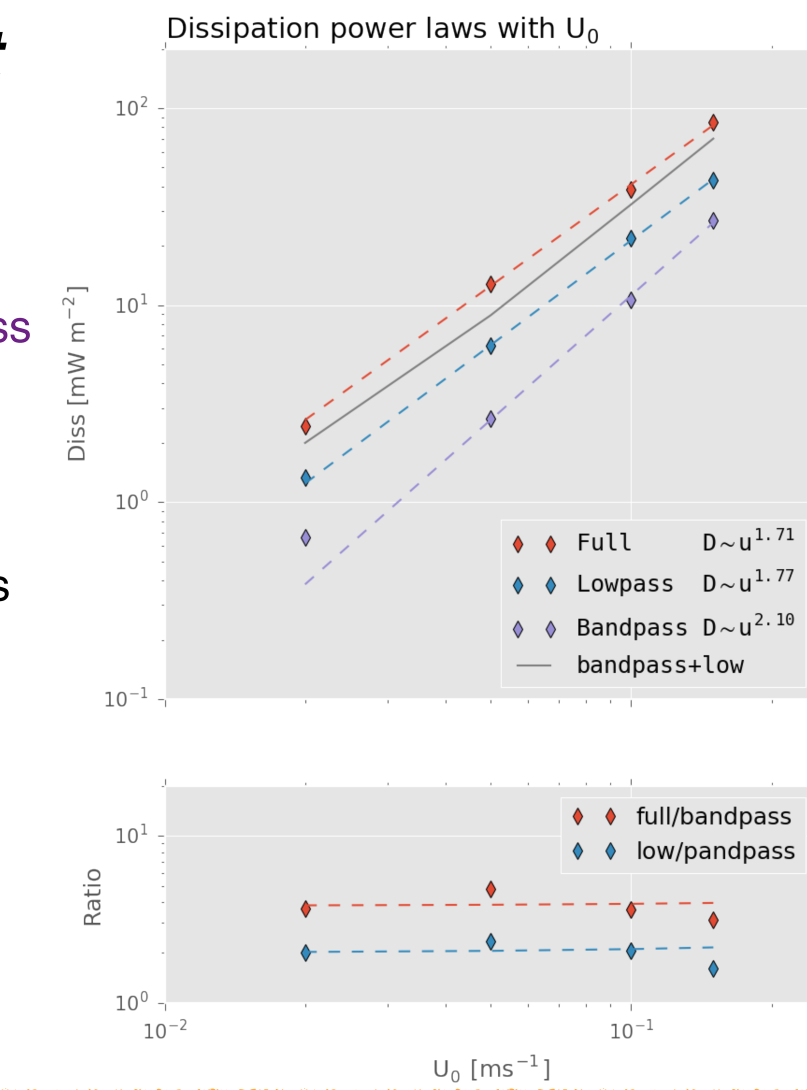


Much more energy lost in Full, and Lowpass bathymetries. Note:

- Bandpass+Low < Full
- Dissipation for large bathymetry extends >500m from seafloor

Main Result

- Full 3.5-4 x Bandpass
- Bandpass: ~U^2
- Lowpass and Full less steep
- Bandpass+Low less than Full



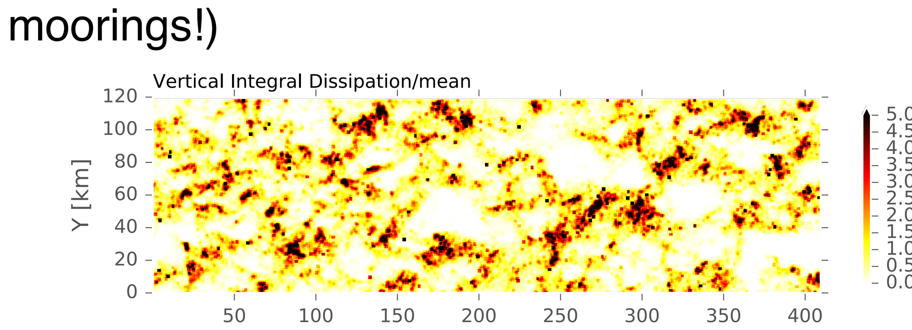
Discussion

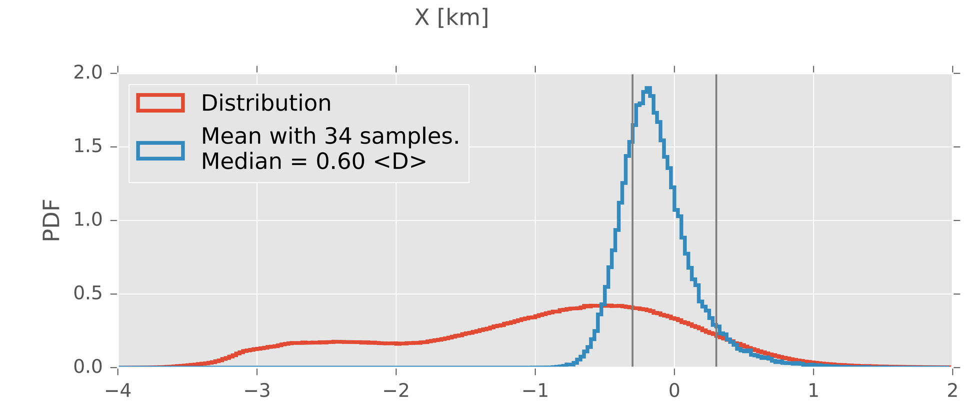
Non-propagating wave drag matters and dominates energy budget

Q: How spatially variable is dissipation?

A: Very!

- Small random samples will be biased low (beware moorings!)

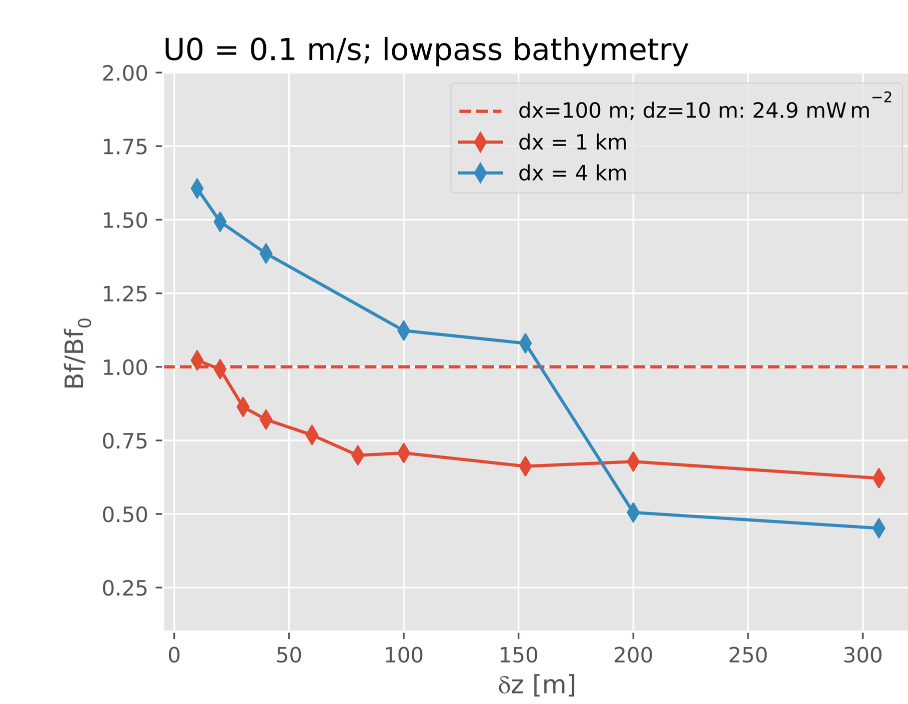




Q: Do GCM-scale models capture this drag already?

A: Complicated:

- larger dx (blue vs red below) leads to over-prediction
- larger dz (x-axis) leads to under-prediction



http://web.uvic.ca/~jklymak/MunkSymposium/