Comparison of convective boundary layer velocity spectra calculated from large eddy simulation and WRF model data

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TORNADOES!!!!!

Introduction

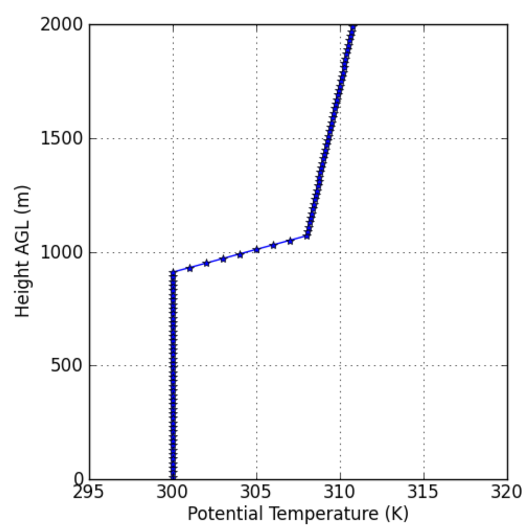
- The WRF model is evolving toward a self-contained NWP system, capable of modeling atmospheric motions encompassing global to fine scales.
- The promise of such capability is appealing to both operational and research environments.
- CBL flows were reproduced using a traditional LES code (OU-LES; Fedorovich et al. 2004a,b) and the WRF model applied in an LES mode (WRF-LES).
- Velocity spectra and other statistics compared

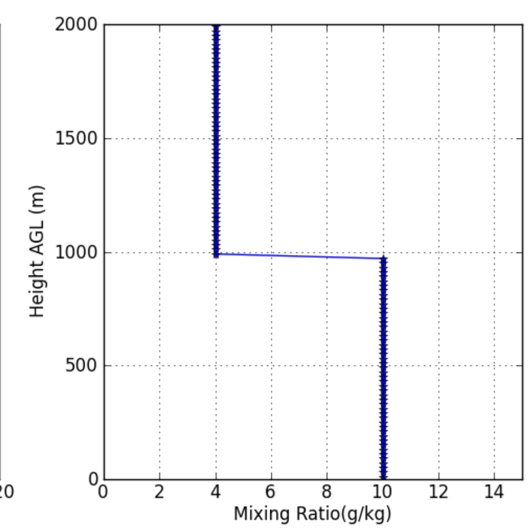
Model Descriptions

	OU-LES	WRF-LES
Governing Equations	Incompressible, Boussinesq	Compressible, Non-hydrostatic
Finite Difference Scheme	2^{nd}-order centered	5^{th}-order upwind
Integration Scheme	3^{rd}-order Runge-Kutta	3^{rd}-order Runge-Kutta (time-split)
Subgrid Scheme	1.5-order TKE	
Boundary Conditions	Periodic	

Approach

- Numerical domain: 10.24×10.24×2 km^3
- Initialized with same idealized profiles
- CBL forcings were set equal and held constant
- Effects of flow types (with/without shear) and of varying isotropic grid spacing (**20**/40/80 m) were investigated

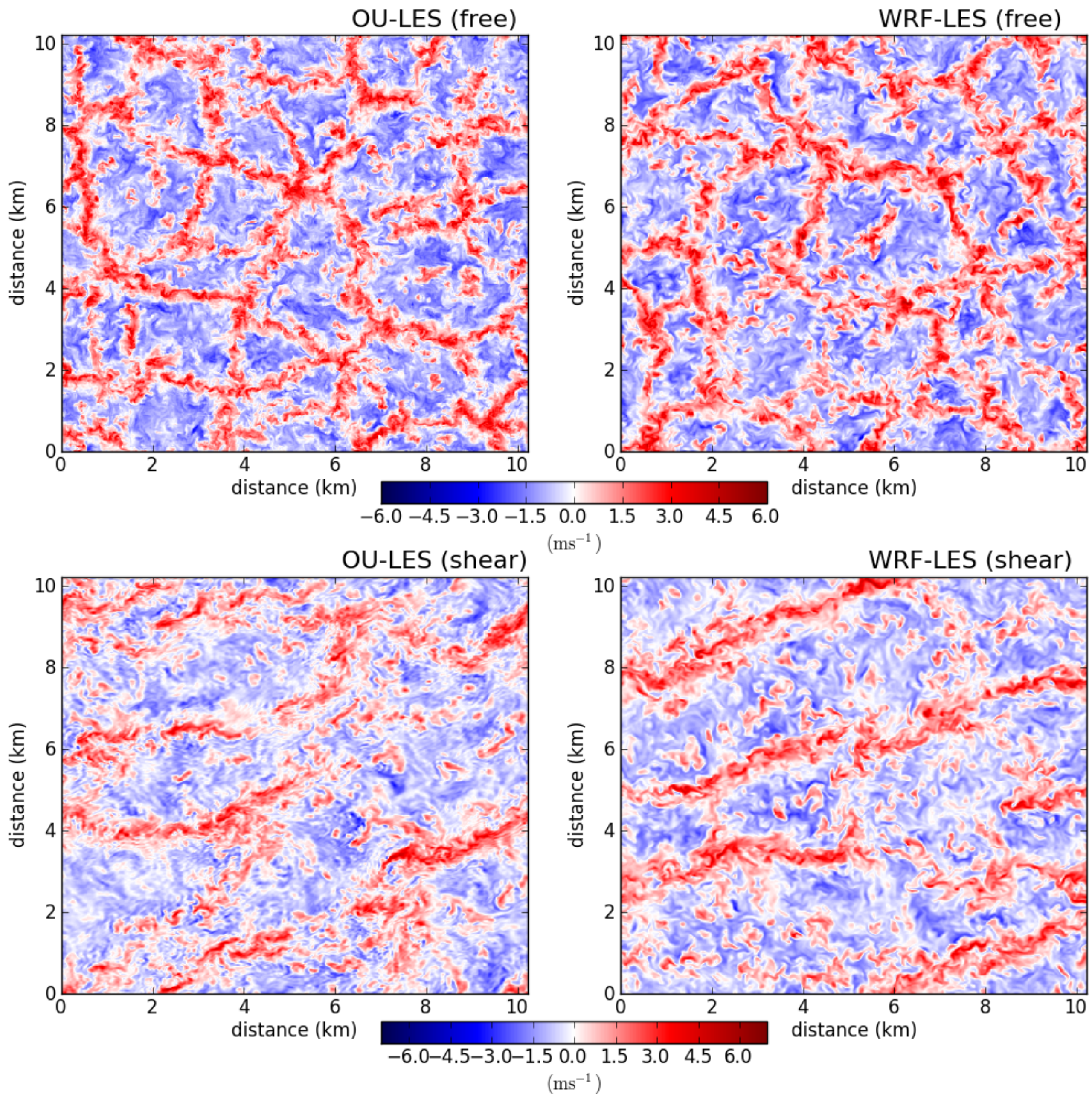




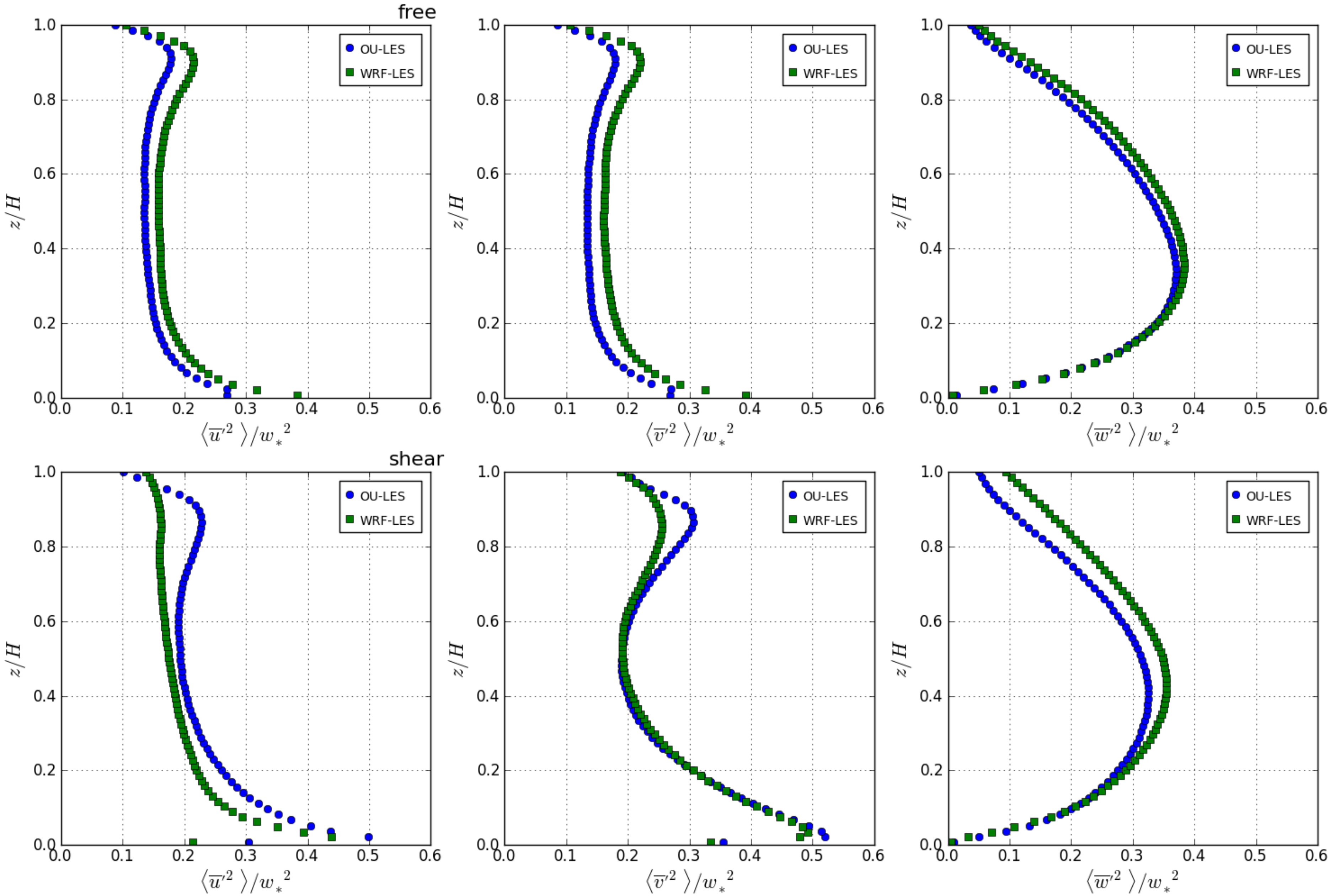
Why Spectra?

- Non-traditional validation measure, why use it?
- Lack of verification data at these scales
- Can indicate whether a model produces expected energy statistics
- This in turn indicates whether a model produces features consistent with realistic atmospheric dynamics
- Further allows investigation of model numerics and assessment of effective resolution

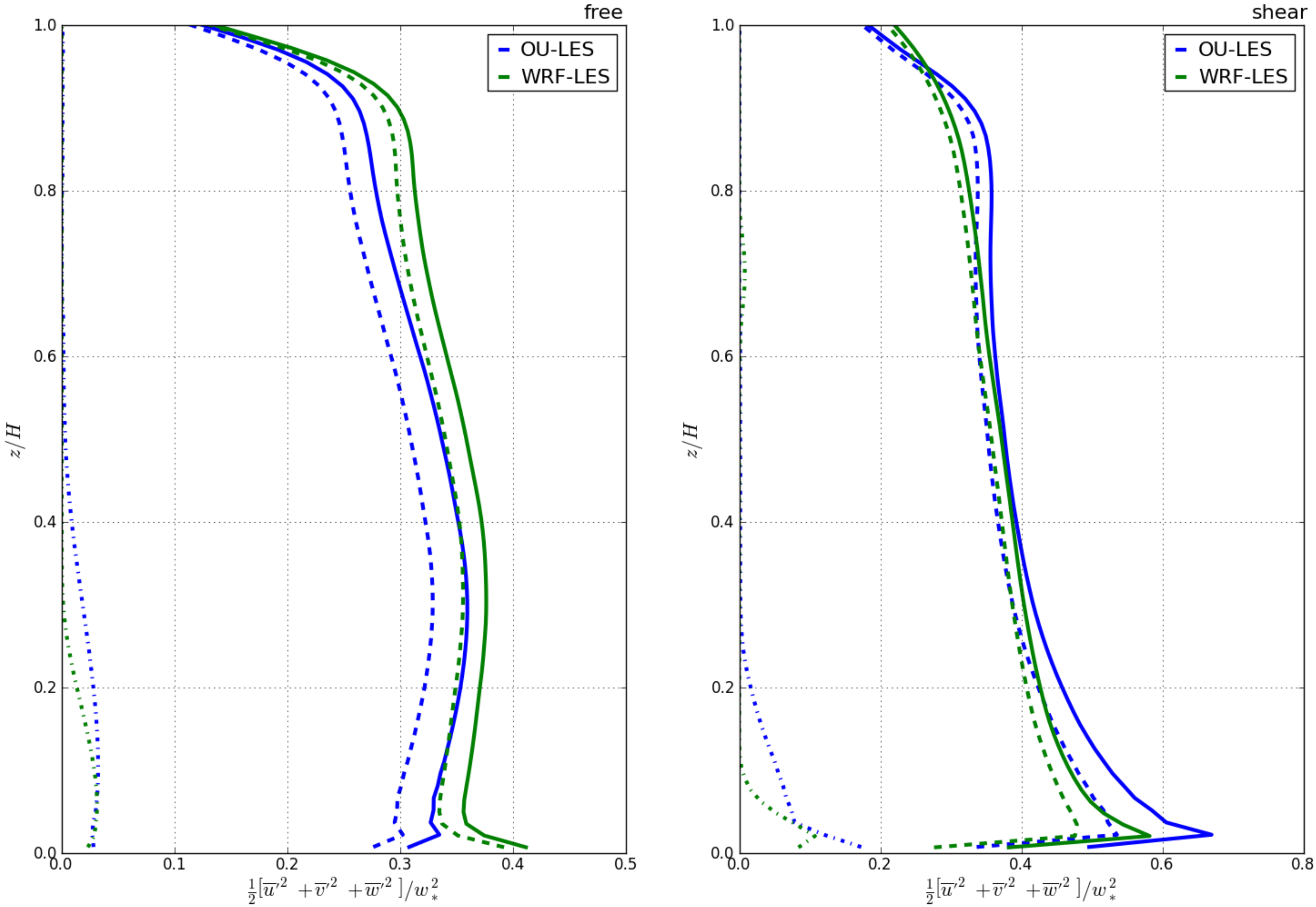
w-component velocity (z/z_i=0.25)



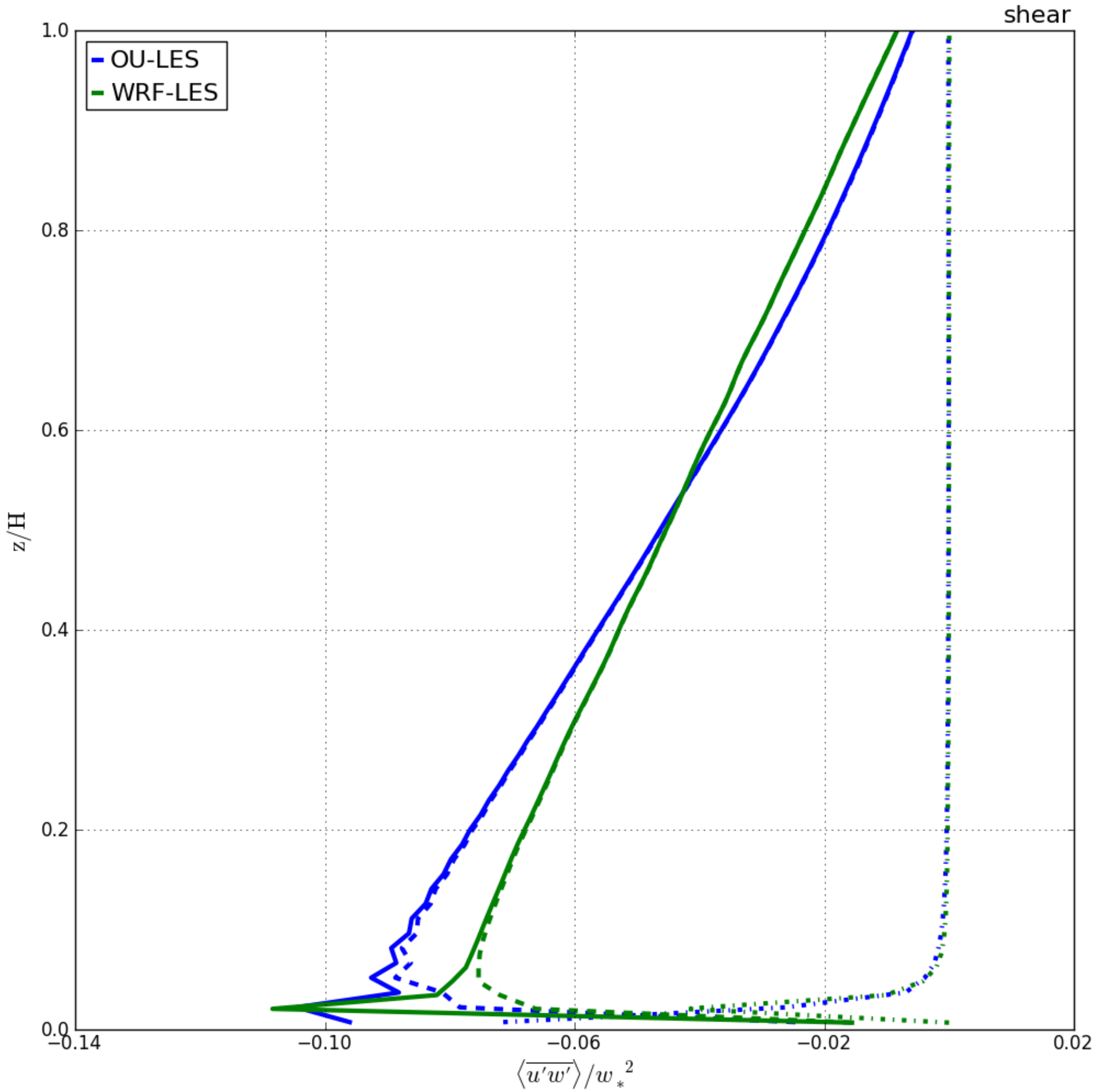
normalized velocity variance



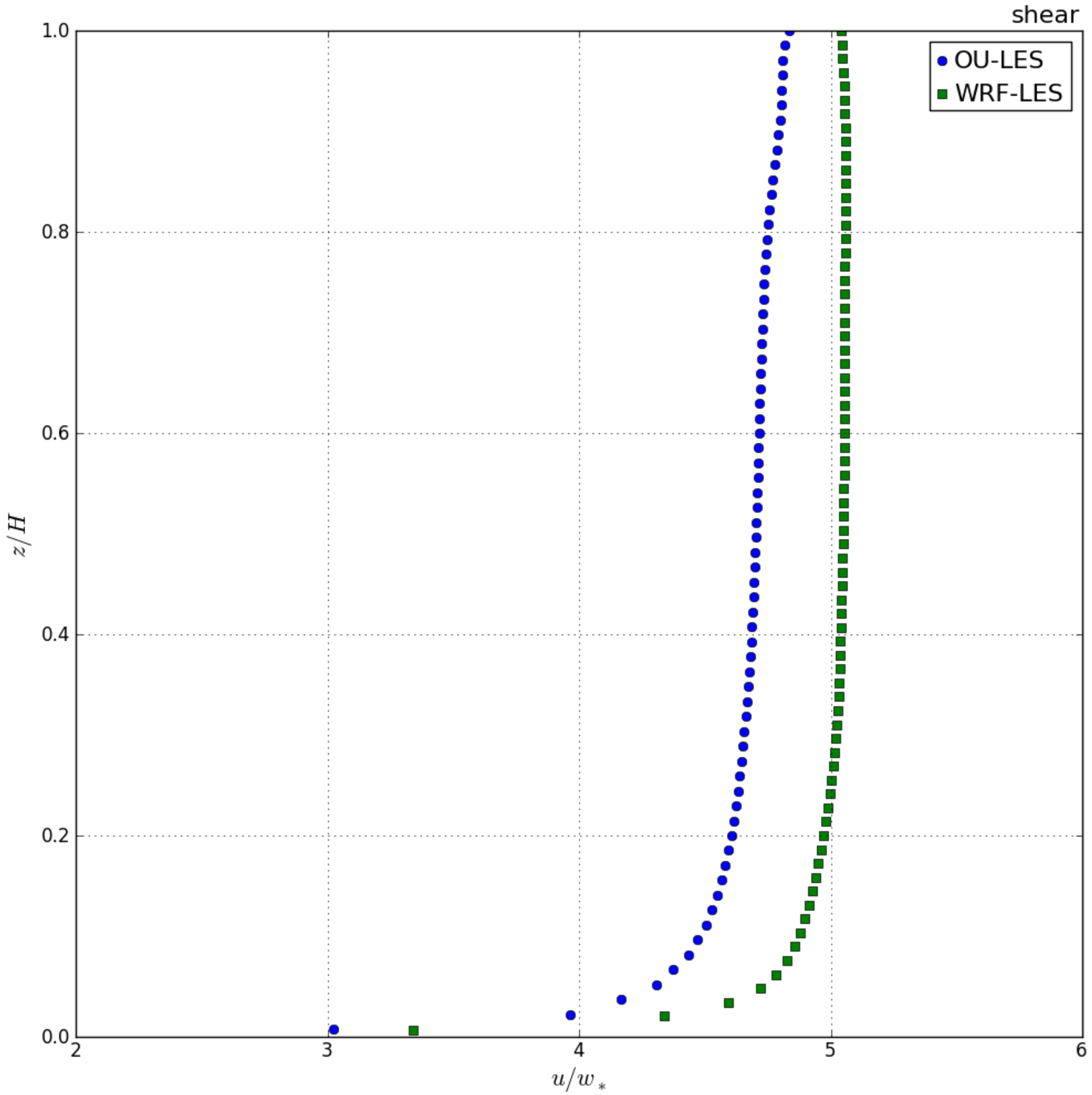
normalized turbulence kinetic energy



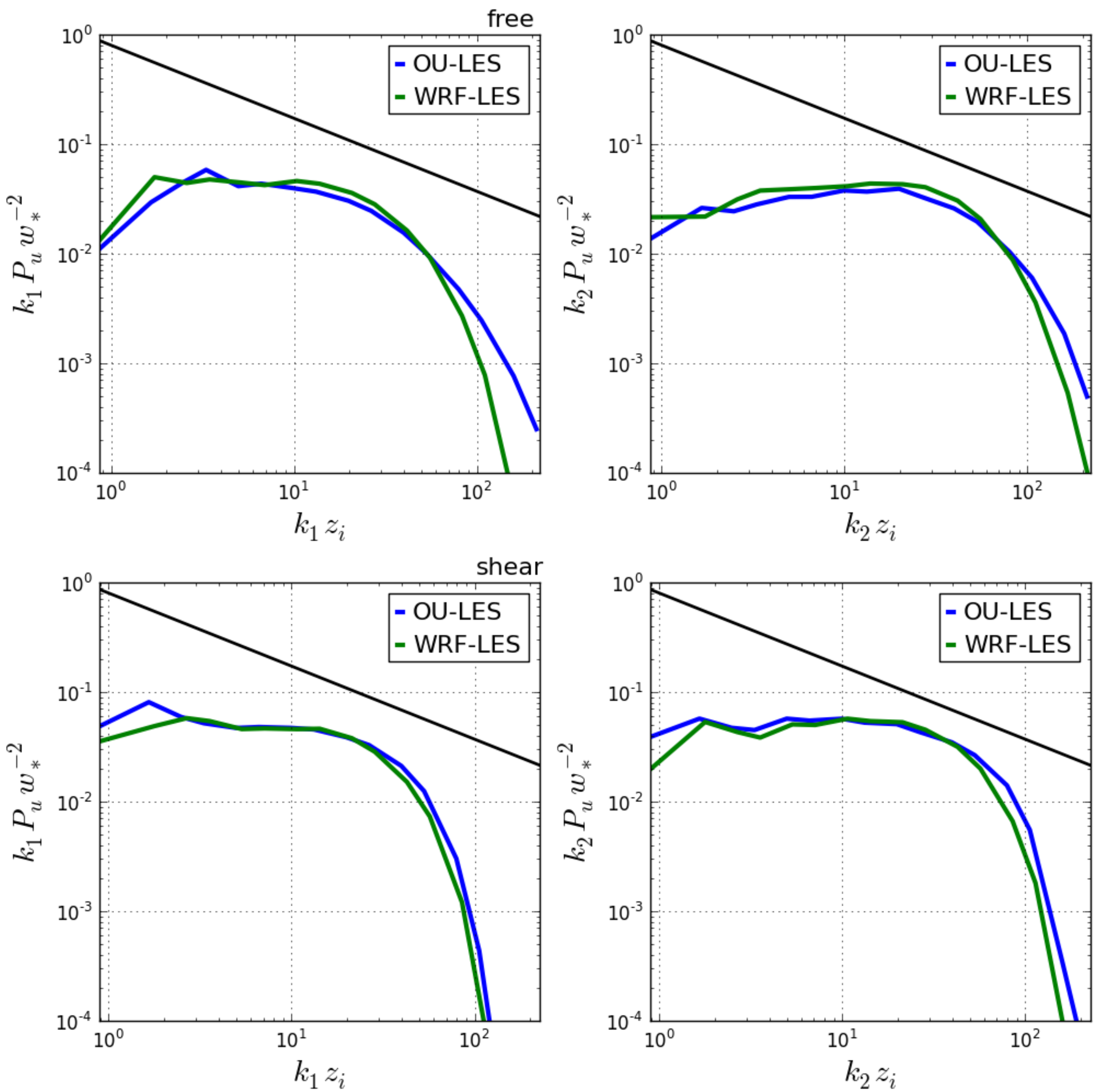
normalized vertical momentum flux



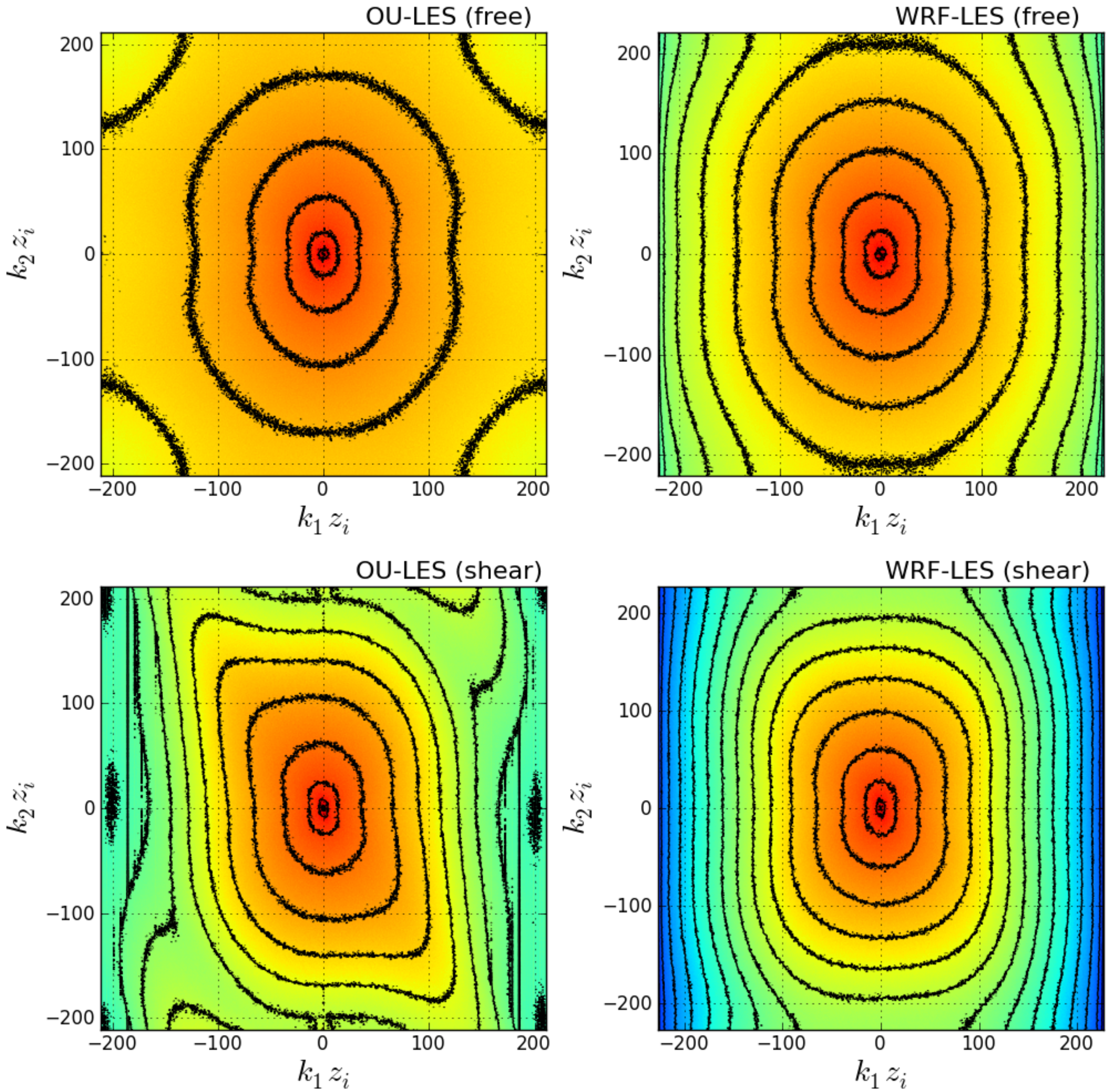
normalized *u*-component velocity



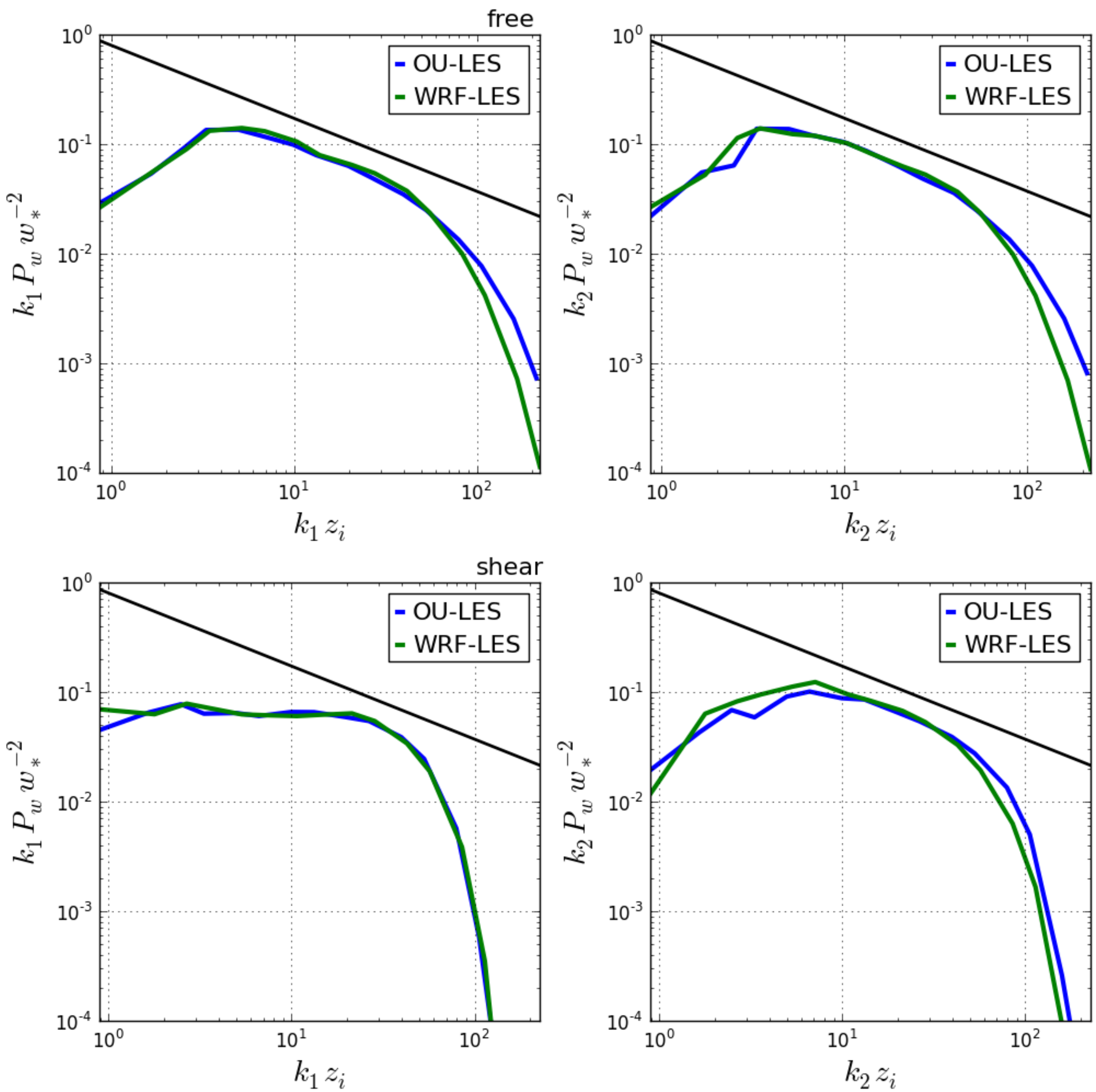
u-component: 1D spectral density (z/z_i=0.25)



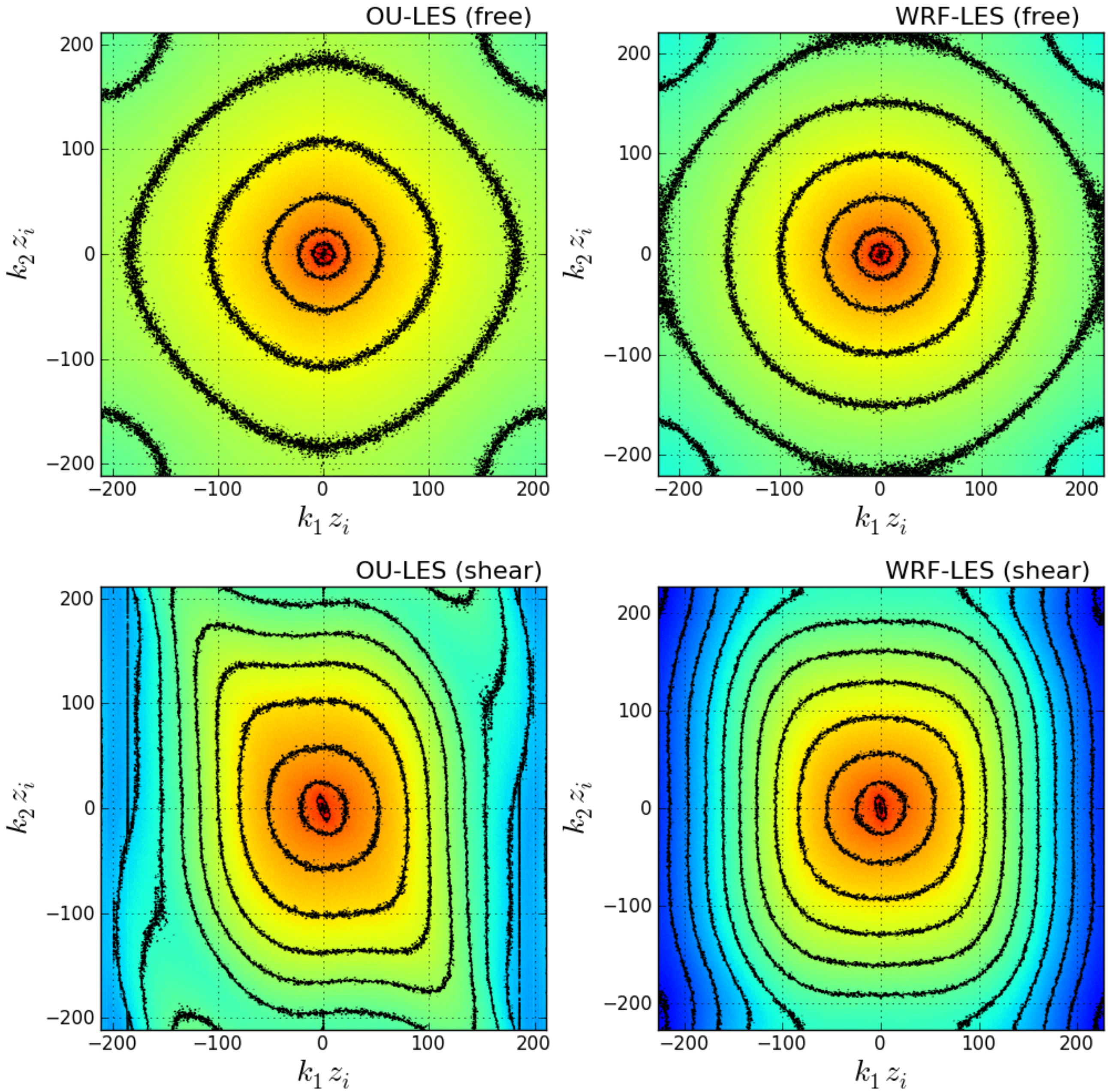
u-component: 2D spectral density (z/z_i=0.25)



w-component: 1D spectral density (z/z_i=0.25)



w-component: 2D spectral density (z/z_i=0.25)



Discussion: Shear-Free

- Visually, data look fairly similar
- WRF-LES produced larger velocity variances, larger TKE
- Spectra show that energy seemingly attributed to larger scales in WRF-LES as compared to OU-LES
- Spectra also show that WRF-LES had a slightly narrower inertial sub-range, slightly less effective resolution, and a sharper drop-off at high frequencies as compared to OU-LES

Discussion: Shear-Driven

- Visually, data look fairly similar
- WRF-LES produced smaller variances, TKE, and turbulent momentum flux - larger velocities
- Spectra show that energy only slightly (if at all) skewed toward larger scales in WRF-LES as compared to OU-LES
- Spectra show that k_1 spectra match closely, but for k_2, same behavior seen as in shear-free
- 2D spectra indicate that shear-induced, smaller-scale anisotropic effects are smudged out in WRF-LES.

Discussion

- Why? Perhaps numerical filters.
  - Implicit diffusion term in advection scheme
  - Time-splitting requires filters to maintain stability
- Could reduce accuracy of finite-difference scheme to remove diffusion term
  - Just did this for 80m run, spectra looked “better”, but still same behavior at small scales
  - Okay for traditional LES with periodic LBCs, but probably not a good idea for real-data where there are more complex fronts, boundaries, and spatial accuracy is important
- WRF-LES with realistic LBCs have troubles

Discussion

- Do we care? (I see you shaking your heads)
- Skamarock noted in 2004 that filters effect scales that aren't of meteorological importance
- Probably true on mesoscale or larger, but WRF-LES?
- In air pollution applications, dispersive role of small-scale motion may be very important
- Or in wave propagation business, where structure-function parameter will be wrong if small-scale motions are affected by numerical dissipation.

Summary