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

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<th>WRF-LES</th>
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Approach

• Numerical domain: $10.24 \times 10.24 \times 2 \text{ km}^3$
• 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

BRACE YOURSELF

TRADEOFFS ARE COMING