Evaluating mesoscale WRF configurations for nested mesoscale-LES wind turbine wake simulations

Brian Vanderwende
Julie Lundquist
Eugene Takle
Steve Oncley

Presented 12 July 2012
Wind turbines produce wakes in the momentum field

LES simulation of wind turbine wake courtesy of Rod Linn, LANL

Barthelmie et al. 2010
When the wind farm is large, turbine wakes can combine into farm wake wake.

Christiansen and Hasager 2005

Offshore farm wake observed with Synthetic Aperture Radar
Wind farm wakes could have meteorological and societal impacts

Surface fluxes – crop impacts?

Low level jet strength?

Storm formation?

Long term climatology?
Observations of farm wakes are rare; modeling is used but is not verified!

15-year horizontal wind anomalies at 850 and 500mb

One day anomaly in precipitation amounts

Without observations, CFD modeling of wakes can be used to verify farm wake parameterizations

Kirk-Davidoff and Keith 2007

Fiedler and Bukovsky 2011
Outline of farm wake verification plan

• Evaluate WRF mesoscale skill at data site

• Compare large eddy simulation of turbine wakes using WRF inflow to observed data
  – Accurate mesoscale wind speed and direction critical to wake verification
  – Low-level jets often determine nocturnal winds

• Use LES to generate a wind farm wake and compare to WRF wind farm parameterization
Data from 2011 Crop Wind Experiment (CWEX) in Iowa used for evaluations

- Modern scale turbines
  - 5 in immediate row
  - ~80m hub heights, rotors
- Windcube Lidar (2)
  - 40-200m wind speed and direction
- NCAR ISFS Station (4)
  - Surface p, T, RH, SHF, LHF
  - Reynolds decomposed U
Model suite includes various input data and PBL schemes

- 3 domains
  - 30km, 10km, **3.3km**
- 60 vertical levels
  - $dz = O(10m)$ in PBL
- 3 boundary sets
  - NARR, GFS-FNL, ERA-Interim
- 5 PBL schemes
  - MYJ, MYNN2, YSU, ACM2, QNSE
- NOAH LSM, Thompson MP
9th-10th July case study includes multiple nocturnal low-level jets

- Jet acceleration begins 6-7pm
- Exists for 9-10 hrs
- Jet induced shear reaches turbine rotor ($\alpha > 0.4$)

As measured by south lidar

\[ U_2 = U_1 \left( \frac{z_2}{z_1} \right)^\alpha \]
WRF had less error with GFS analyses and ERA-Interim than NARR input data.

Similar for most statistics; NARR produces higher $\alpha$ values (stronger LLJs).
Farm wake parameterization requires MYNN, yet ranges too small with scheme.
Long run: Two synoptic regimes with differing WRF wind direction performance

Canadian high (better performance)

Frontal (poorer performance)

Windcube Lidar

MYNN WRF

NCEP HPC
Long run: Two synoptic regimes with differing WRF wind shear performance

Canadian high (weak LLJs common)

Frontal (much more variable)

Windcube Lidar

MYNN WRF

NCEP HPC
Conclusions

• In this particular case:
  – ERA-Interim and GFS input data are preferred over NARR
  – No PBL scheme is the obvious choice; use of MYNN scheme may limit outlier conditions

• Synoptically driven performance over longer periods illustrates importance of choosing appropriate time period for valid wake comparisons
Thank You!

Any questions?
Extra: Vertical Grids