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

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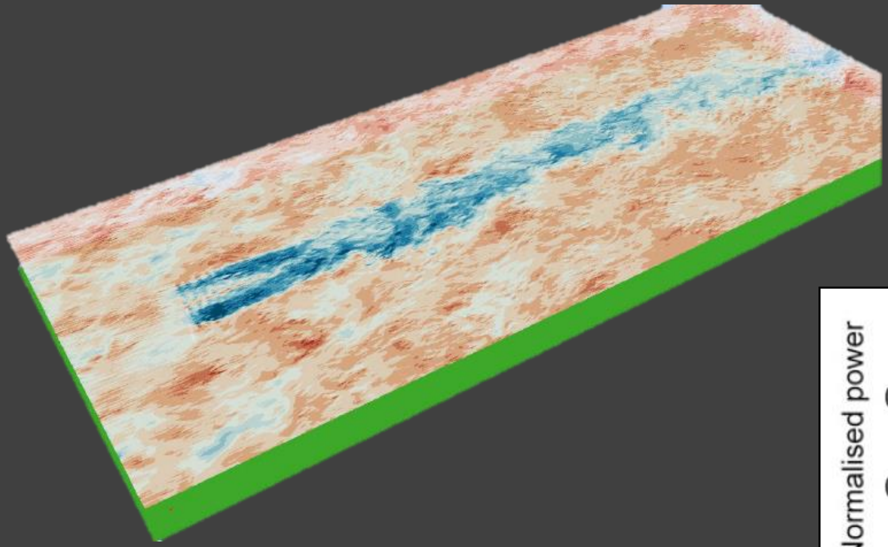
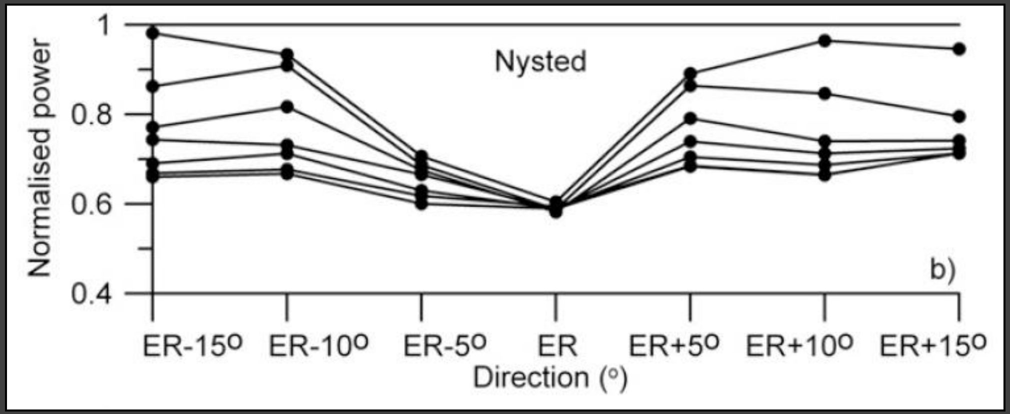
Wind turbines produce wakes in the momentum field



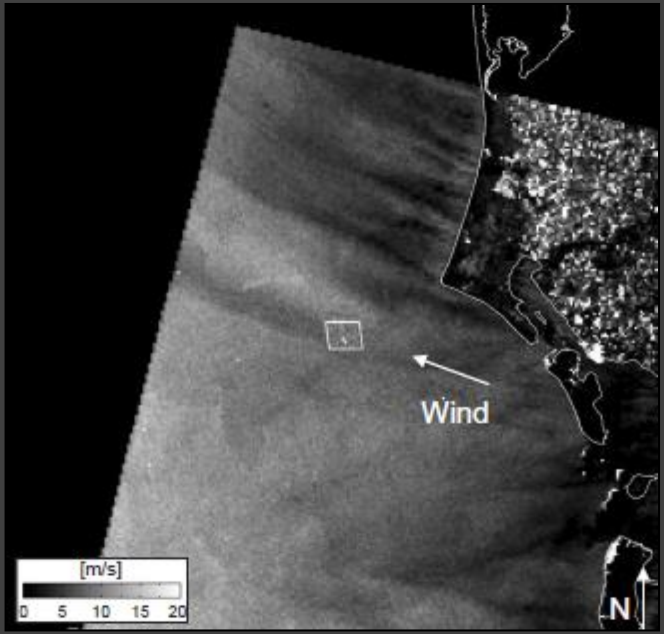
LES simulation of wind turbine wake courtesy of Rod Linn, LANL

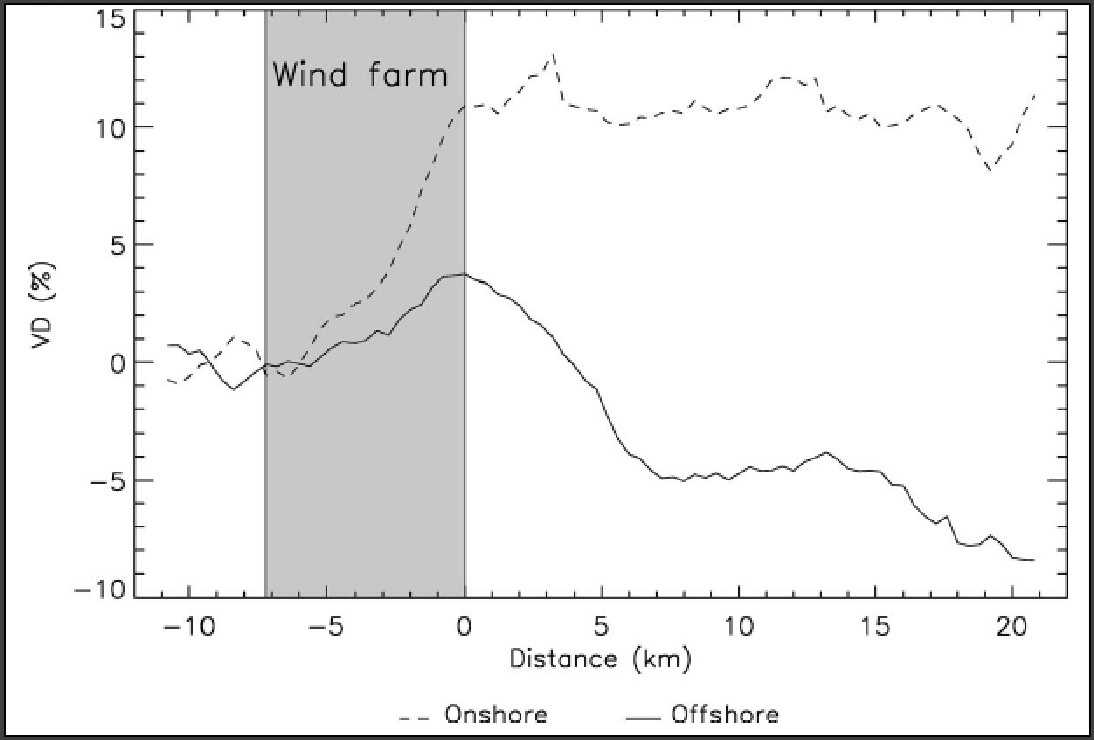


Barthelmie et al. 2010

When the wind farm is large, turbine wakes can combine into farm wake

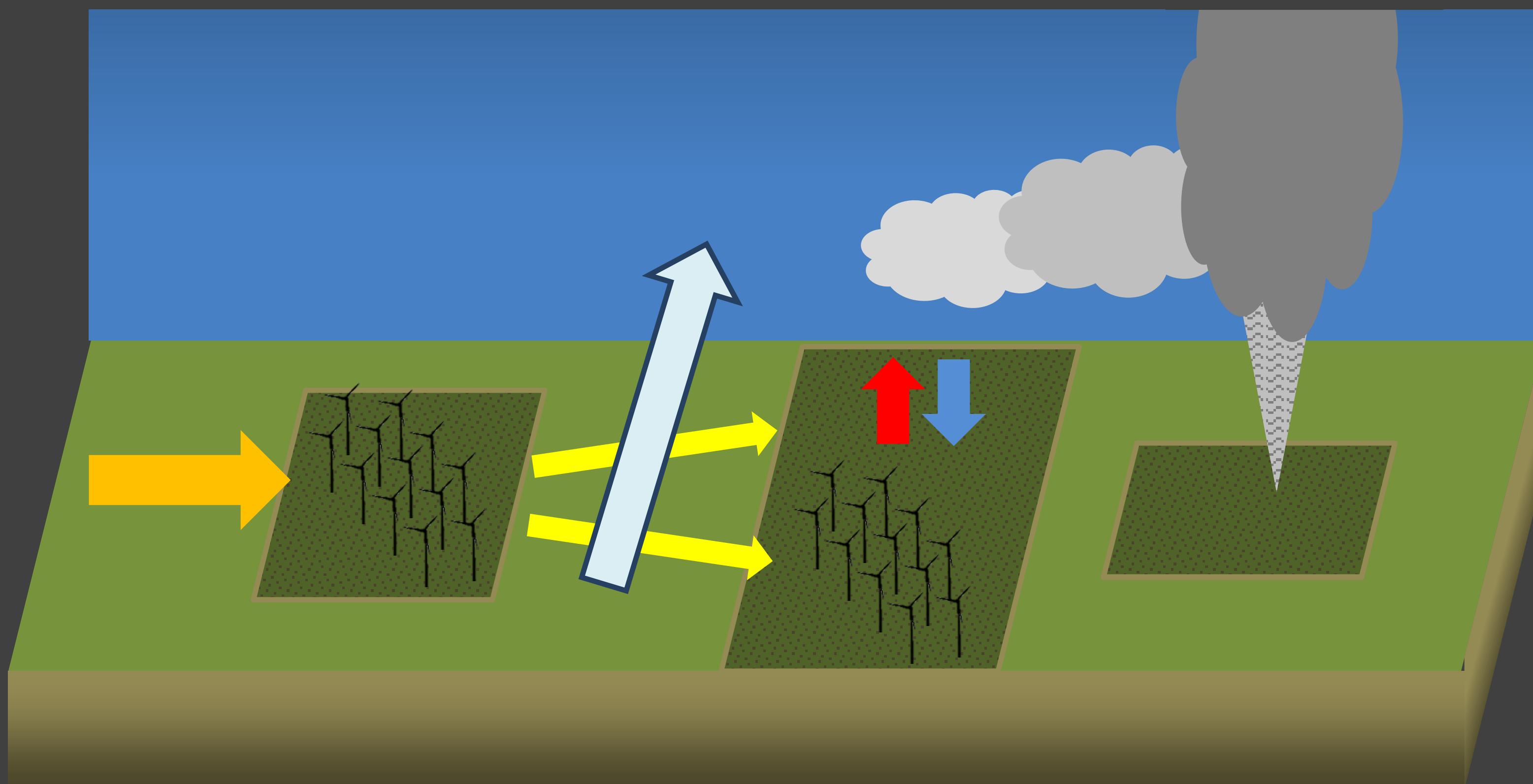
Christiansen and Hasager 2005





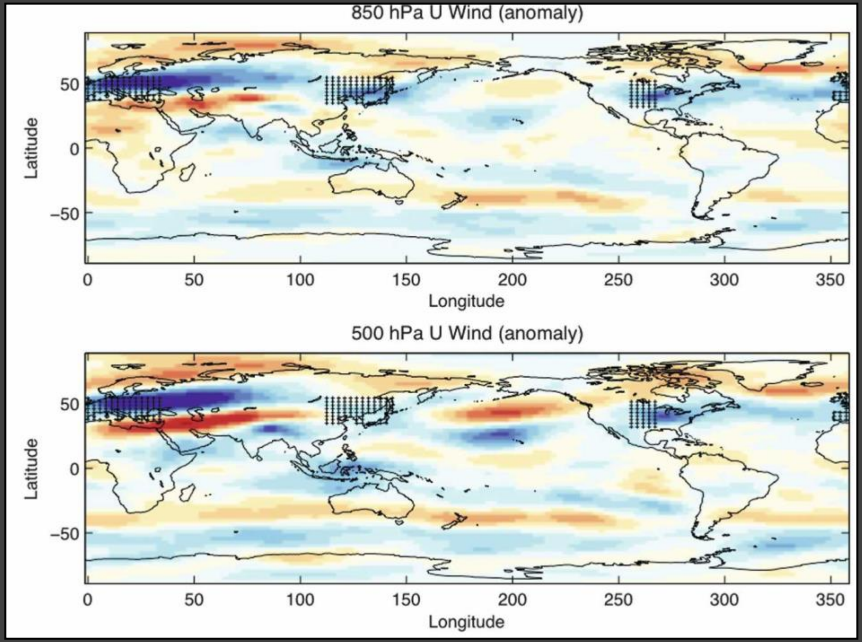
Offshore farm wake observed with Synthetic Aperture Radar

Wind farm wakes could have meteorological and societal impacts



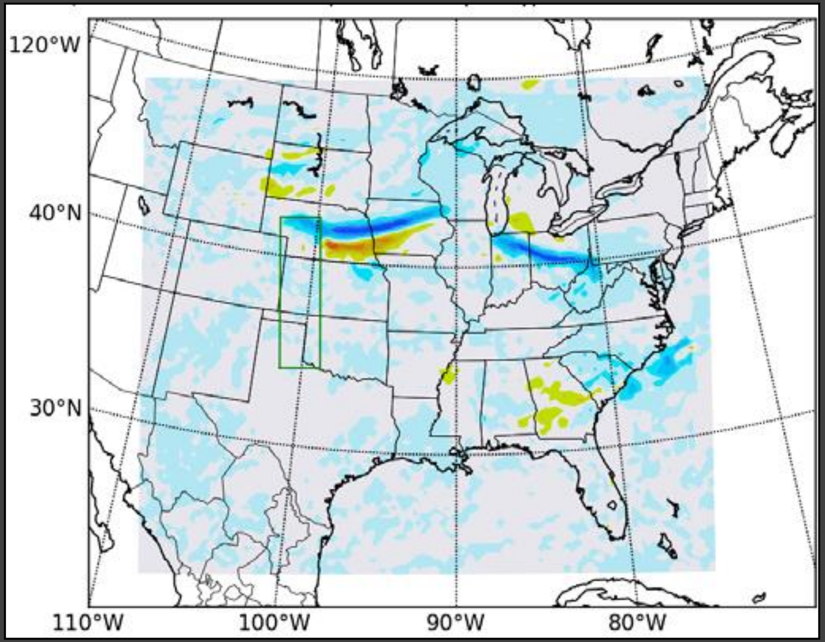
Observations of farm wakes are rare; modeling is used but is not verified!

15-year horizontal wind anomalies at 850 and 500mb



Kirk-Davidoff and Keith 2007

One day anomaly in precipitation amounts



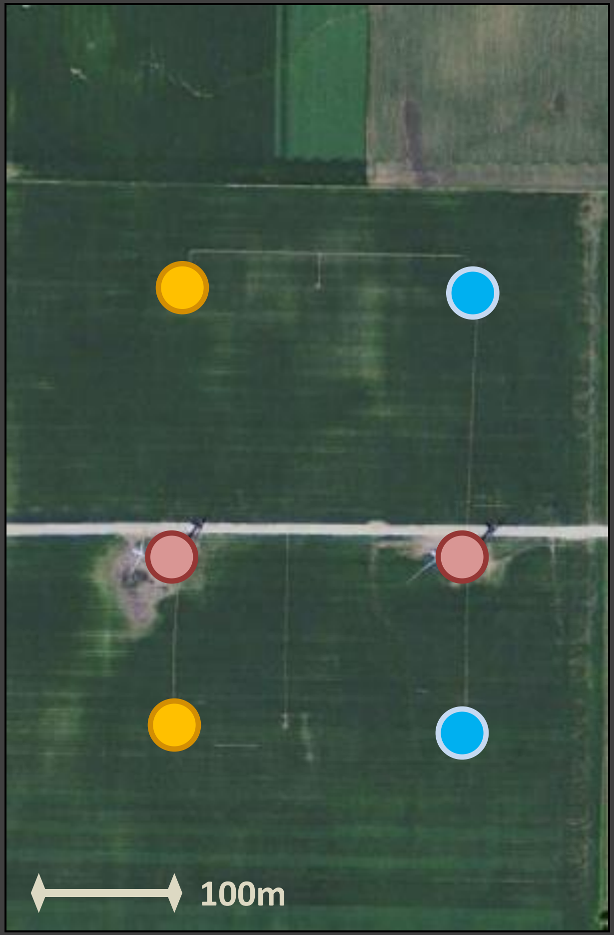
Fiedler and Bukovsky 2011

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

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

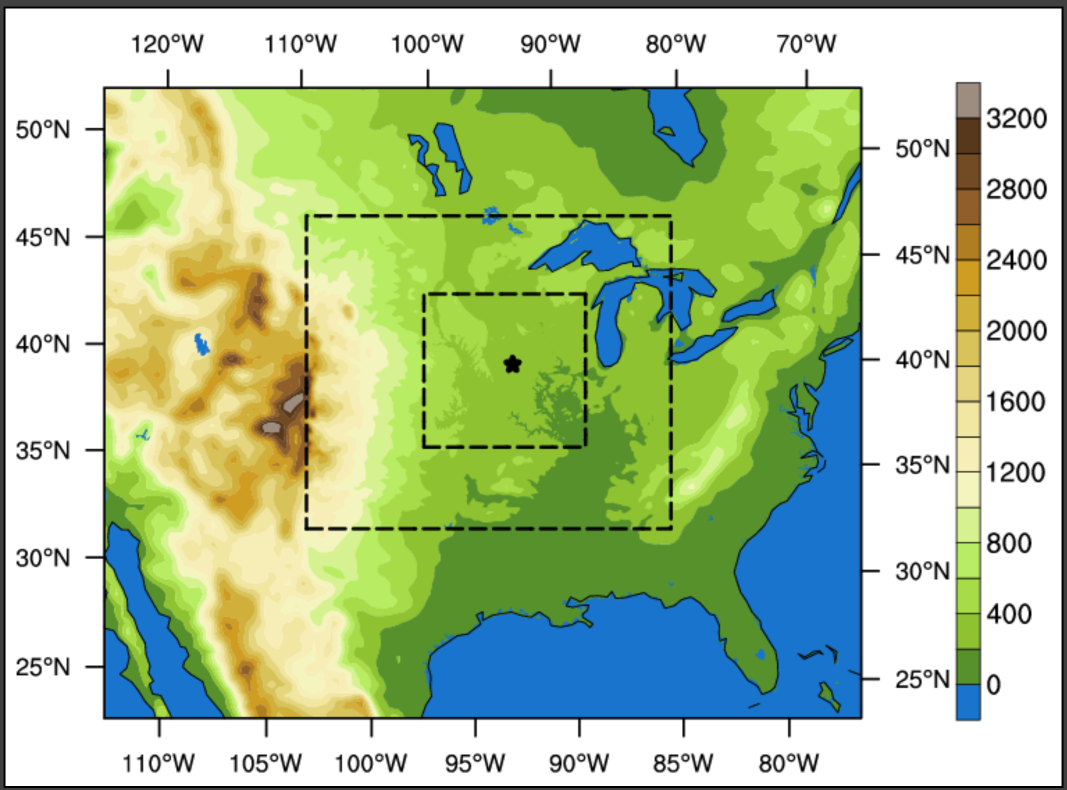
Data from 2011 Crop Wind Experiment (CWEX) in Iowa used for evaluations



Google Maps

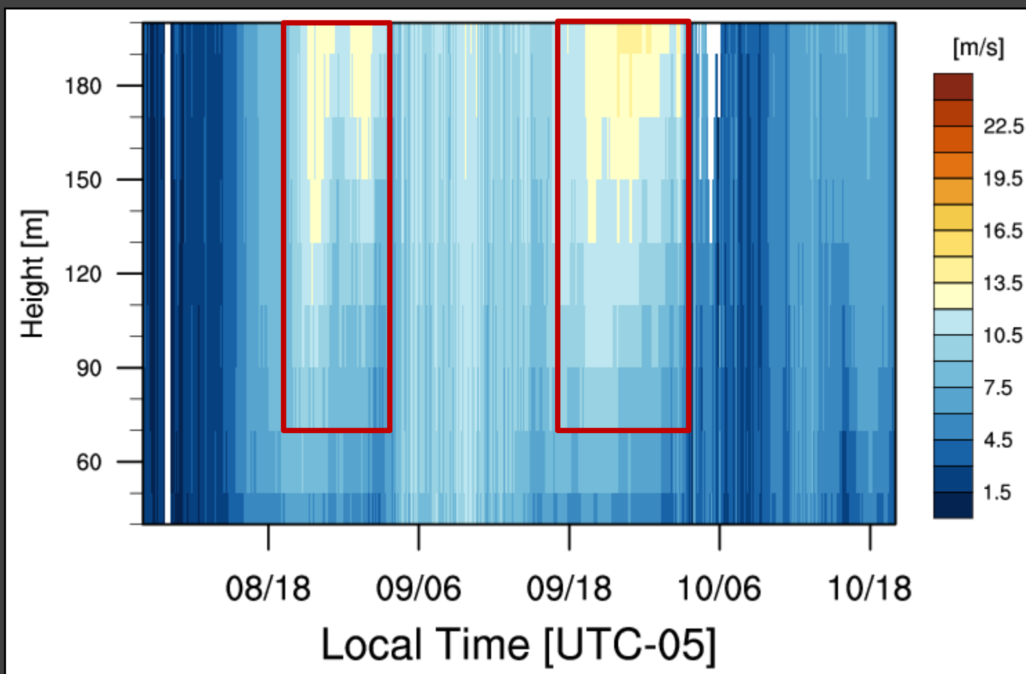
- Modern scale turbines
  - 5 in immediate row
  - ~80m hub heights, rotors
- Windcube Lidar (2)
  - 40-200m wind speed and direction
- NCAR ISFS Station (4)
  - Surface p, T, RH, SHF, LHF
  - Reynolds decomposed U

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

9^{th}-10^{th} July case study includes multiple nocturnal low-level jets

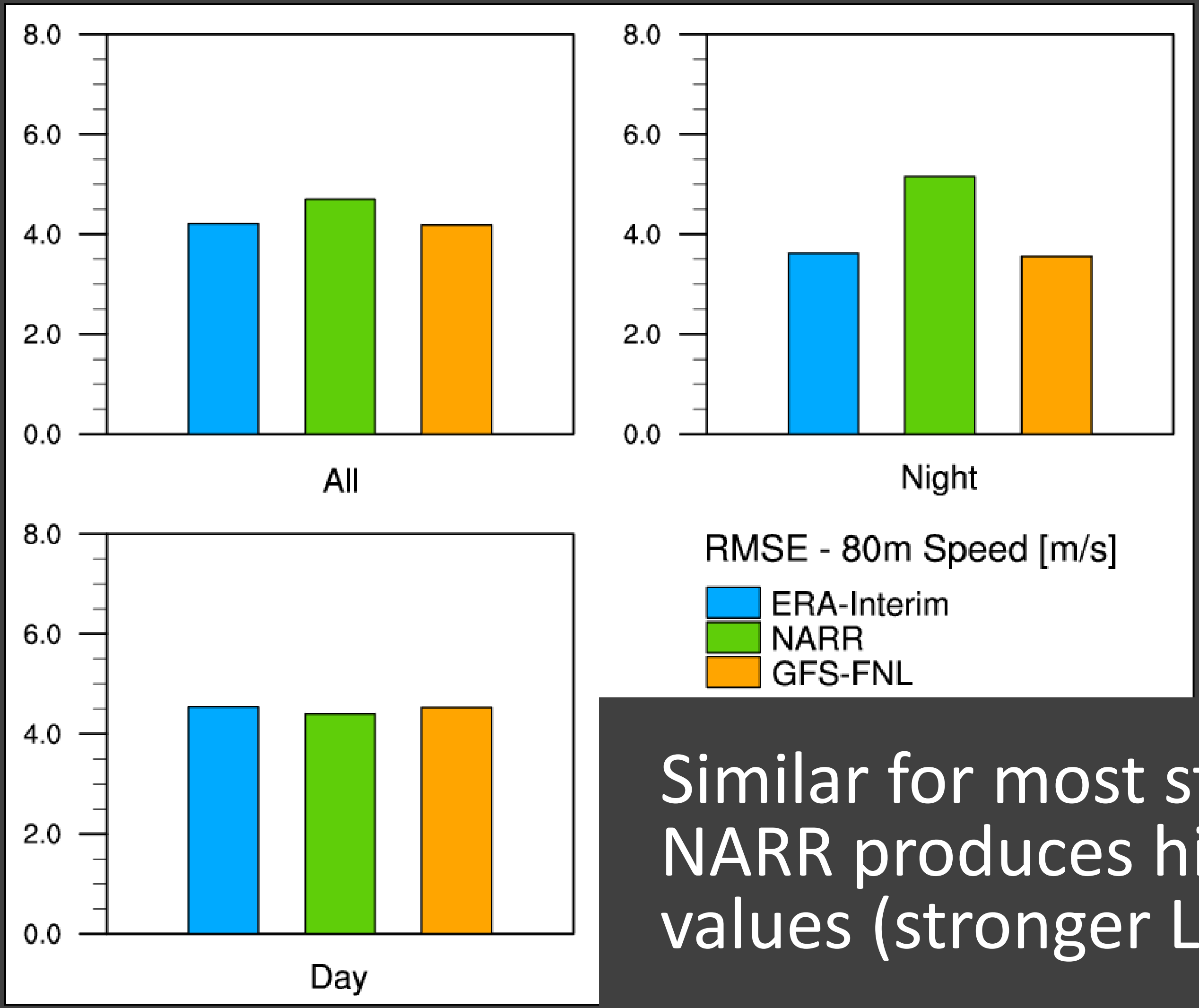


As measured by south lidar

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

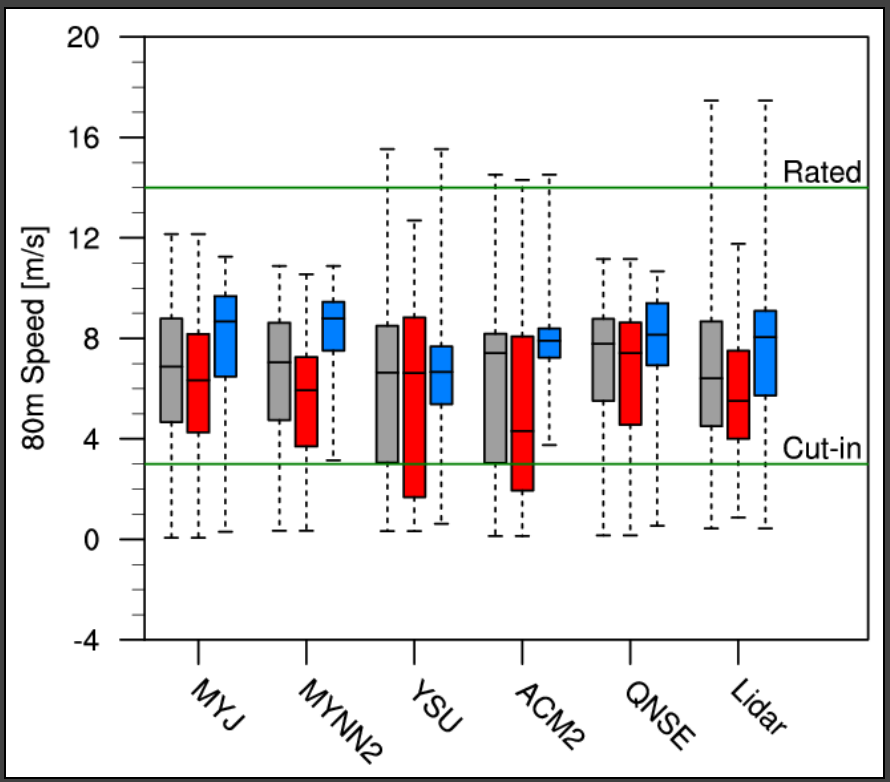
$$U_2 = U_1 \left(\frac{z_2}{z_1}\right)^{\alpha}$$

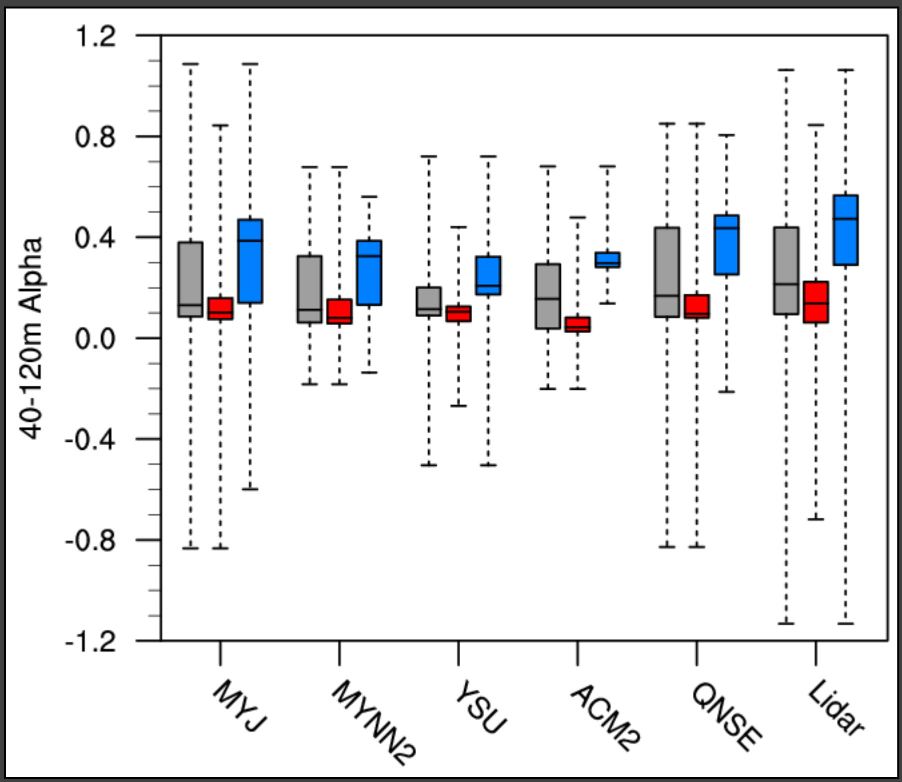
WRF had less error with GFS analyses and ERA-Interim than NARR input data



Similar for most statistics; NARR produces higher α values (stronger LLJs)

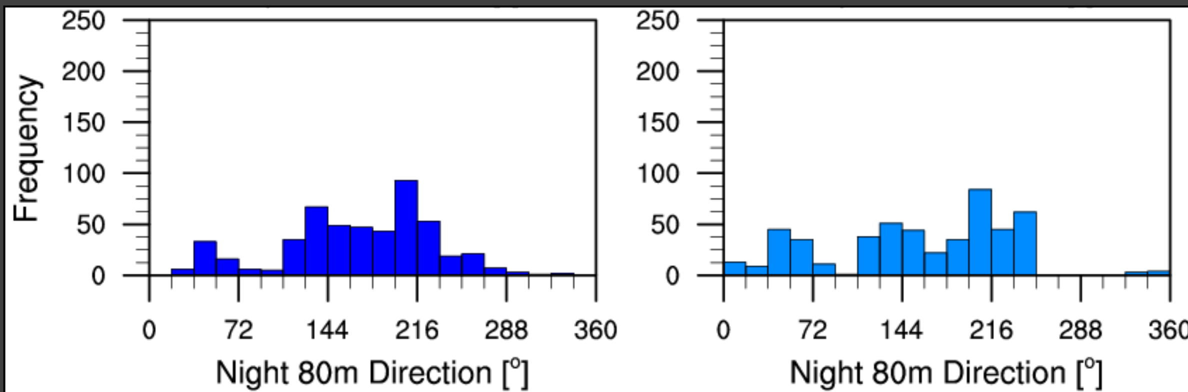
Farm wake parameterization requires MYNN, yet ranges too small with scheme

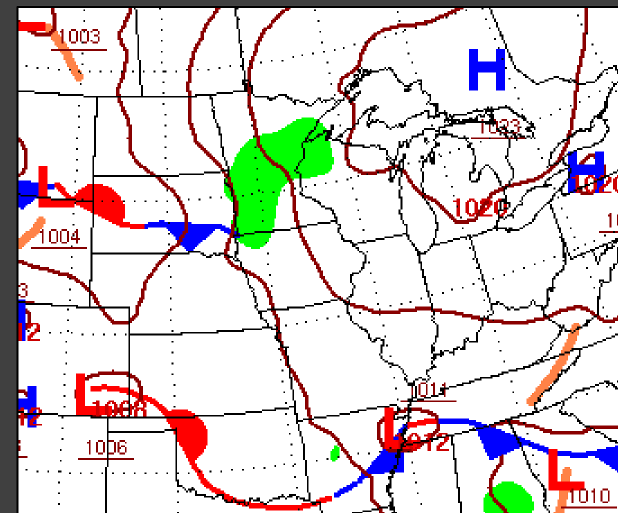




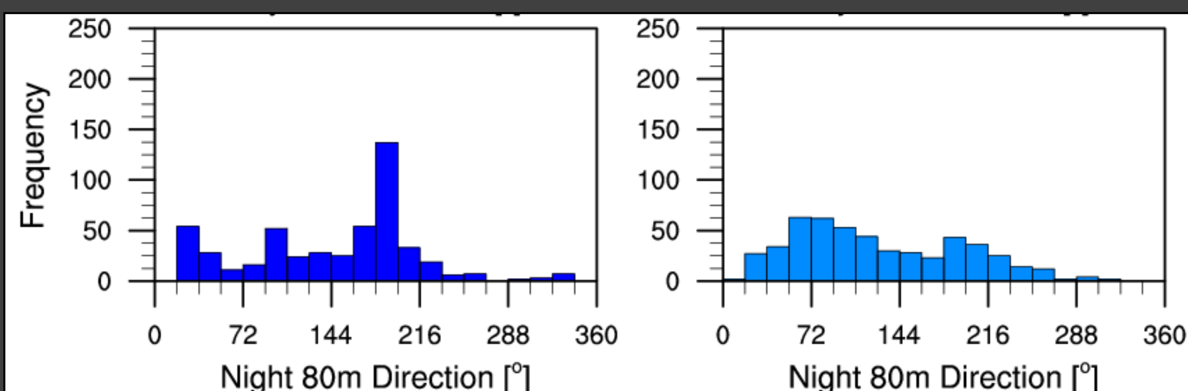
Long run: Two synoptic regimes with differing WRF wind direction performance

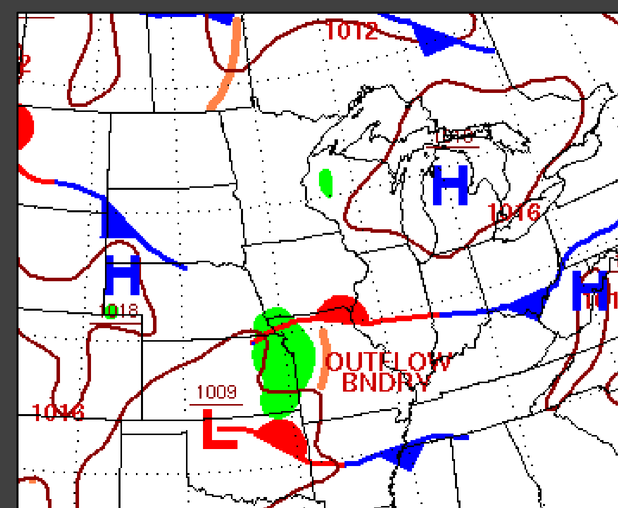
Canadian high (better performance)





Frontal (poorer performance)



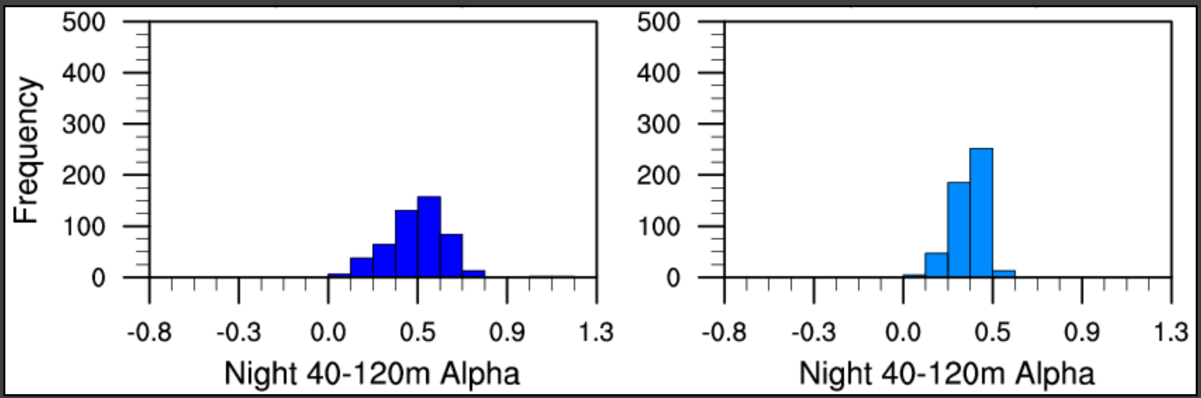


Windcube Lidar MYNN WRF

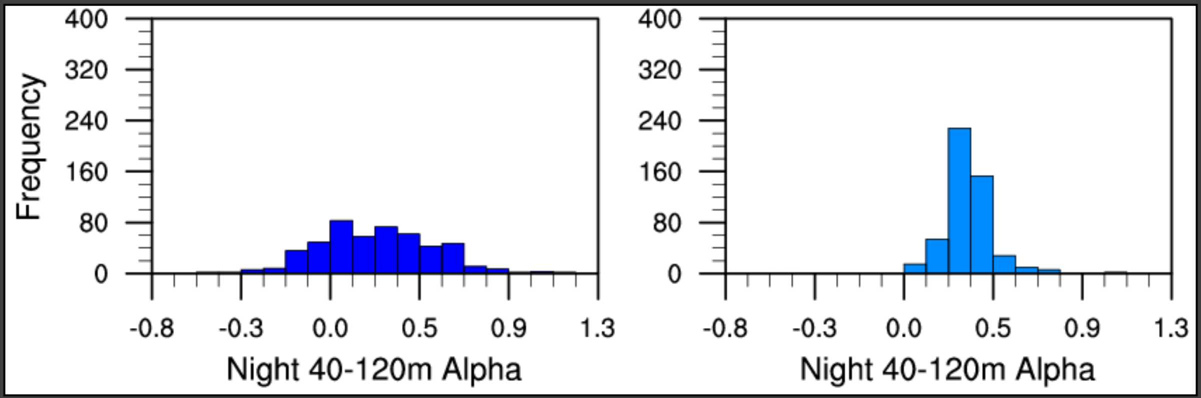
NCEP HPC

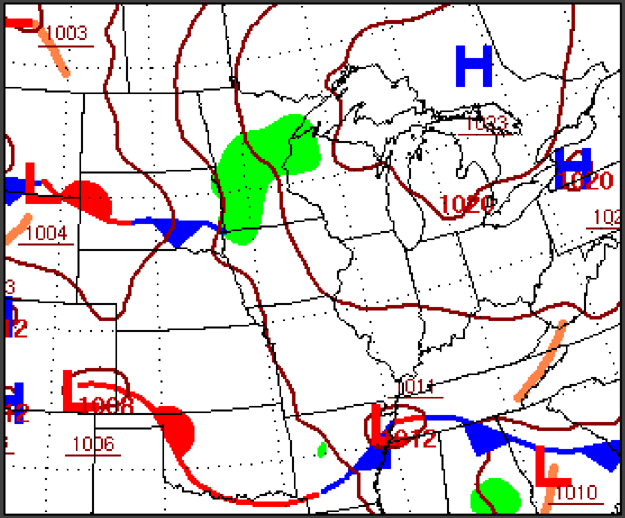
Long run: Two synoptic regimes with differing WRF wind shear performance

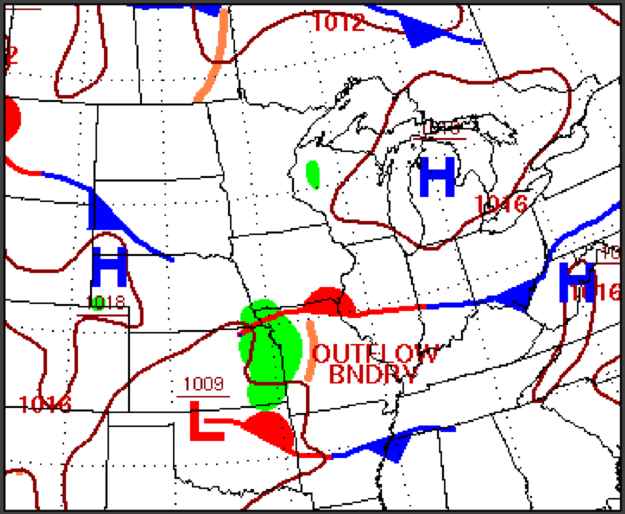
Canadian high (weak LLJs common)



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