Characterizing Wind Turbine Inflow and Wakes Through Comparison of SODAR and Met Tower Observations

A Part of TWICS: The Turbine Wake Inflow Characterization Study

Daniel Pollak (1)(2)(3)
Julie Lundquist(1)(2)(4)
Andrew Clifton(5), Matthew Aitken(4)

(1) National Center for Atmospheric Research, Boulder, Colorado, USA  (2) Significant Opportunities for Atmospheric Research and Science Program  
(3) Pennsylvania State University, University Park, Pennsylvania, USA  
(4) University of Colorado—Boulder, USA  
(5) National Renewable Energy Laboratory, Golden, Colorado, USA

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**Wind Energy: Turbine Wakes & Inflow**
- Wind turbines generate electricity by harnessing the wind's kinetic energy
- Turbines create wakes (waves) of wind speed deficits
- Wake characteristics depend on atmospheric inflow
- Inflow varies based on meteorological phenomena, topography and land use
- These wakes can reduce production to 60% in downstream turbines

**Increasing Efficiency of Wind Energy Generation**
- Why are wakes & inflow important to understand?
  - Improve meso-scale model performance for turbulence in complex terrain
  - Help engineers improve turbine design
  - Maximize energy efficiency
  - Pinpoint best wind farm sites
  - Increase turbine lifetime

**Project Goals & The National Wind Technology Center Site**
- The NWTC site is located downwind of Colorado's Front Range
- The Prevailing Wind is at ~292 degrees; ~the angle instruments in line along Long Term Trends:
  - April 1 ~ May 7, 2011

**Strong Correlations for Wind Speed**

**Methods & Filters**
- Data were 10 minute averages
- Comparing 50m and 80m Wind Speed & Direction Measurements
- Determine Correlations
- 37-day averages
- Compare measurements at 50, 80m for Intensive Observing Periods

**Wind Direction Bin Correlations & IOP Lineplot**
- Correlations highest from 270-120 degrees and when the sample size of points is highest
- Lower 80 meter R's could be from M2 errors or Triton instrument bias

**SODAR and Met Tower Have Strong Correlations for Wind Speed**
- Strong linear correlations of wind speed (R > 0.93) between M2 and Triton at 50m and 80m
- Flow usually homogeneous across NWTC, but occasionally inhomogeneous → slightly lower correlations
- Variation in # of data points due to data quality and filters
- Lower speed correlations in morning; highest before sunset
- M2 wind direction data may have had errors
- Smaller number of filtered data at 80m potentially behind lower R values

**TWICS: Turbine Wake Inflow and Characterization Study**

**Field Campaigns:**
- April - May 2011
  - The National Renewable Energy Laboratory's (NREL) National Wind Technology Center (NWTC) south of Boulder, Colorado

**Instruments Employed**
- NREL's M2 Metological Tower
- Second Wind's Triton Sodar
- NOAA's high resolution doppler lidar
- University of Colorado's Windcube Lidar

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**Conclusion & Next Steps**
- Triton data quality reduced above 80 meters
- Strong linear correlations of wind speed (R > 0.93) between M2 and Triton at 50 and 80m
- Flow usually homogeneous across NWTC, but occasionally inhomogeneous → slightly lower correlations → terrain effects
- Wind speed correlations vary with time of day (weaker in morning)
- Different conditions at Triton sodar and tower site from localized heating and turbulent mixing
- Changes in Triton performance with diurnal changes in atmospheric stability (decreased data quality → less data points available)

**Next Steps**
- Results from this research will feed into future analysis of data collected during TWICS and help our understanding of turbine performance in the atmospheric boundary layer
- Wind direction correlations are weak, require more quality control
- Examine larger data set (more time periods) to provide more robust conclusion results: looking at time of day and wind direction bins
- Examine metrics such as turbulence intensity & atmospheric stability
- Compare Triton and M2 data with the lidar data operated during TWICS

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Daniel A. Pollak
Email: dpollak216@gmail.com
Website: http://pollak.weebly.com

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