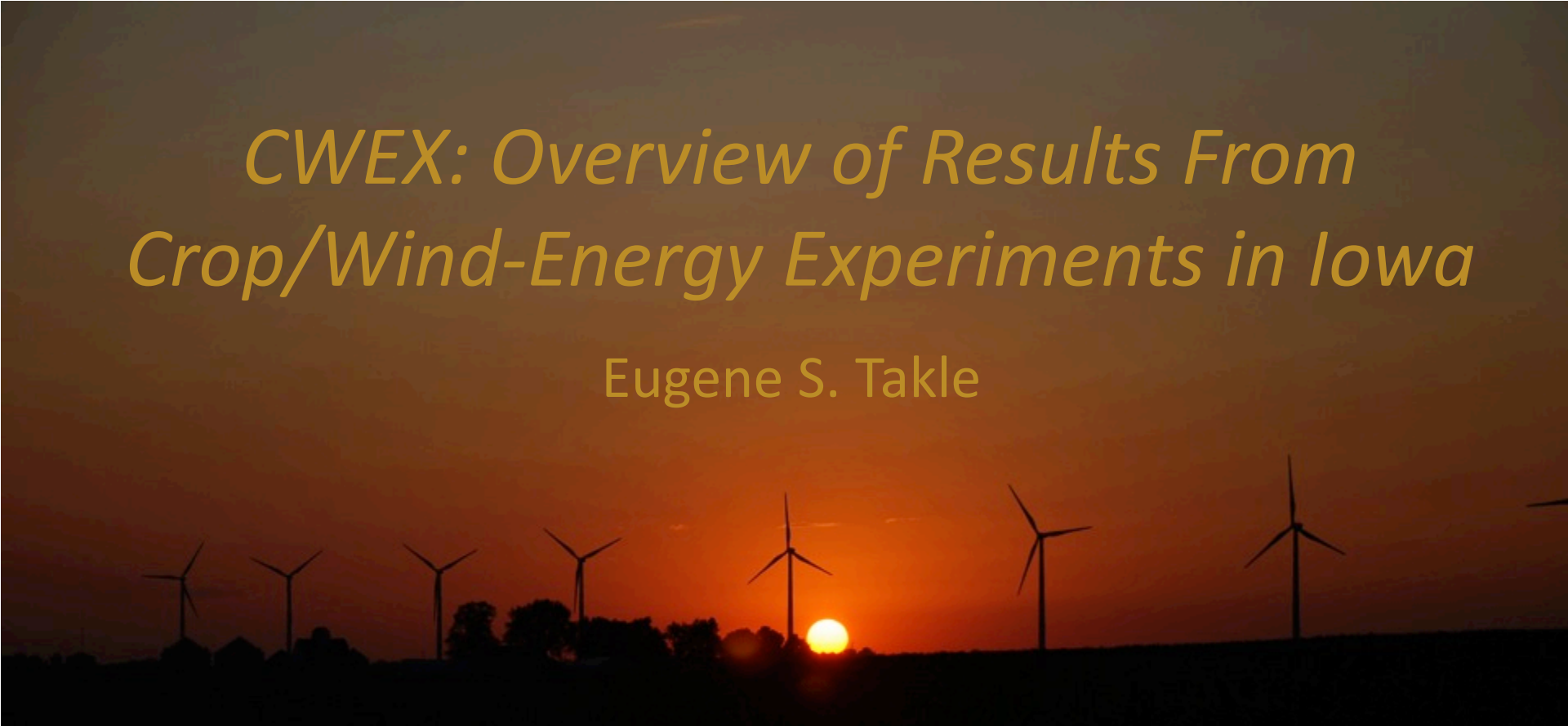
CWEX: Overview of Results From Crop/Wind-Energy Experiments in Iowa

Eugene S. Takle



Data and Analysis by Dan Rajewski, Erin Jackson, Renee Walton, and Russ Doorenbos

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Photo by Lisa Brasche

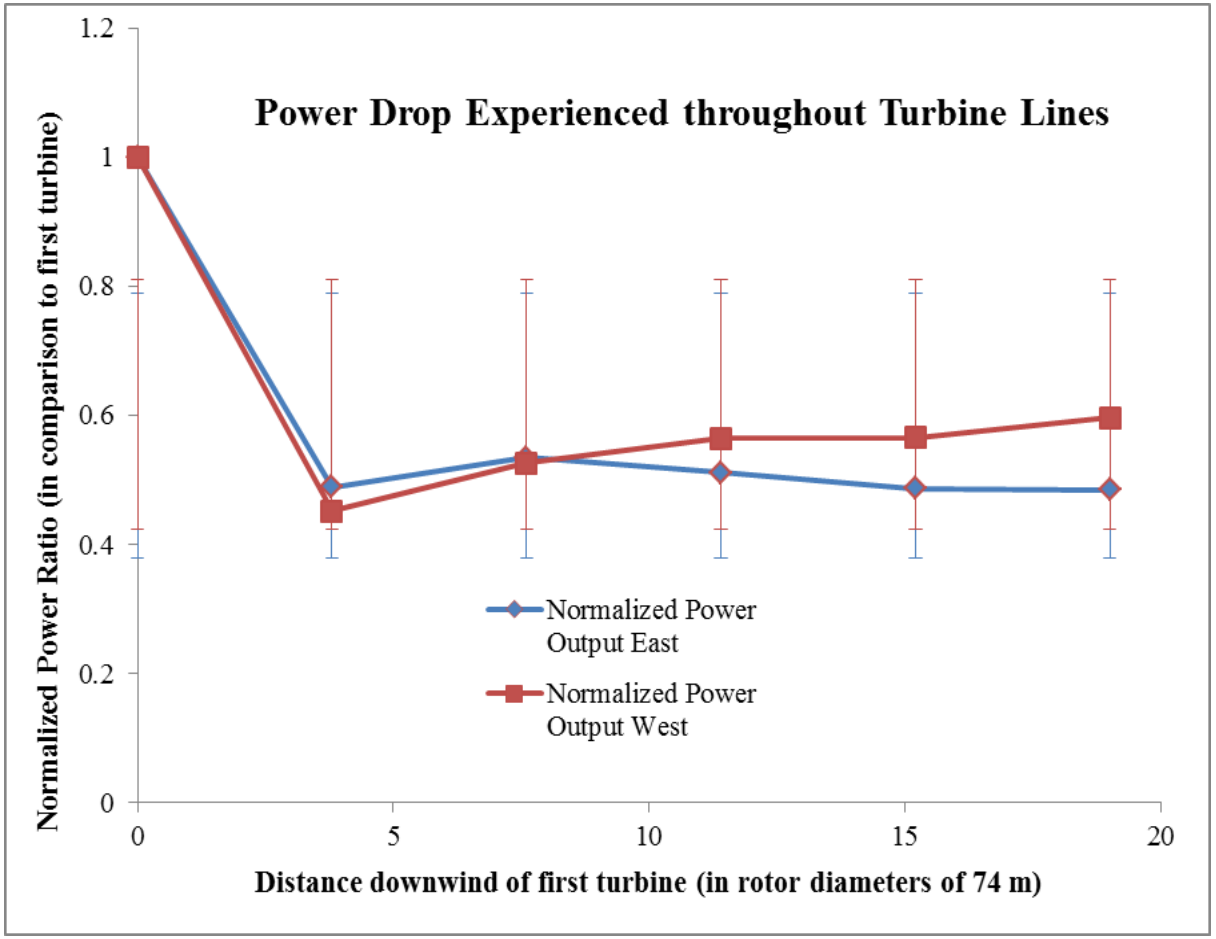
Outline

- CWEX overview
- Wakes
- Wind shear

CWEX Current Activities

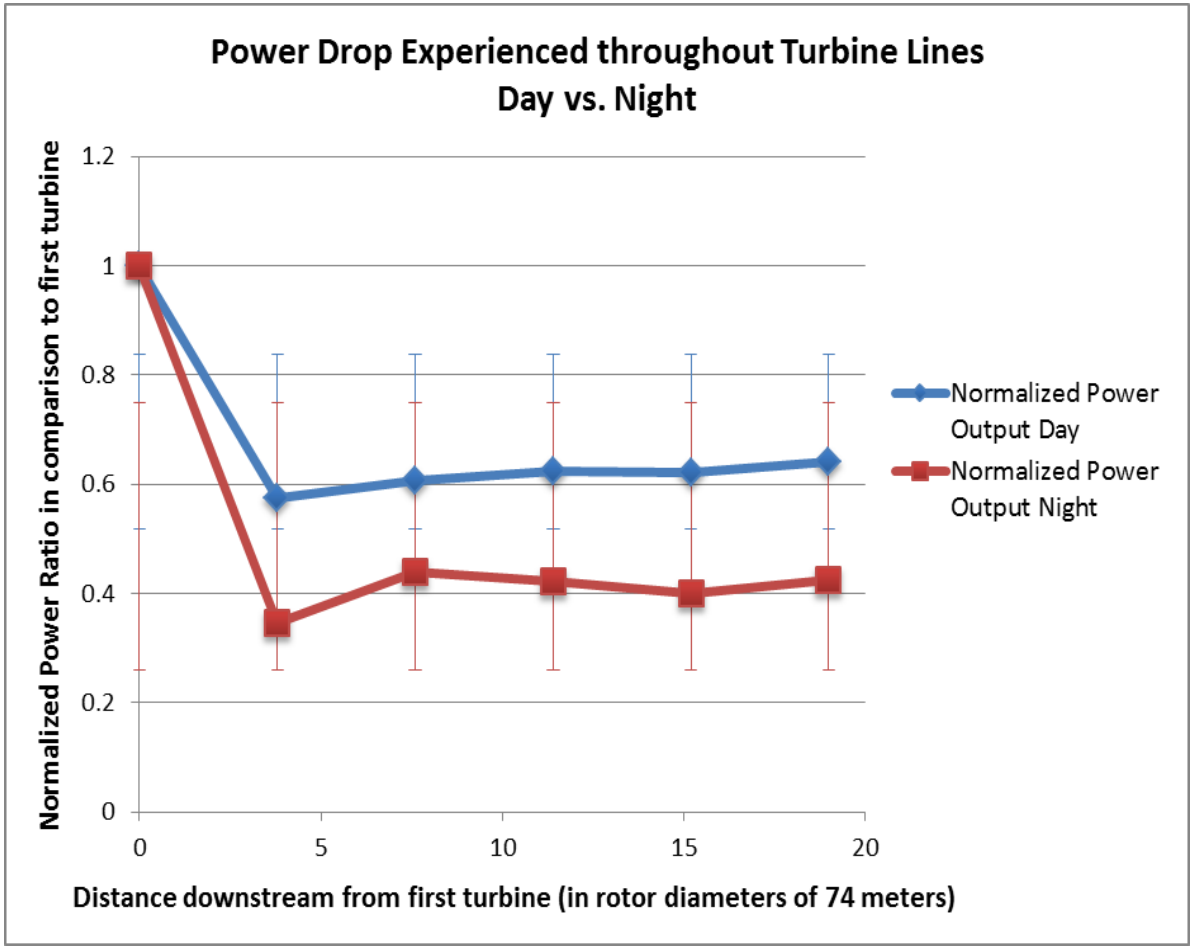
- Began as a study of crop-turbine interactions
  - Impact of individual turbines and lines of turbines on surface conditions
- Current measurements and data analysis focus on properties of the turbine layer and its near environment
  - Aerodynamics of the lowest 300 m: above-rotor layer, rotor (wake) layer, and sub-rotor layer
  - Mesoscale impact of the windfarm

Turbine Wakes



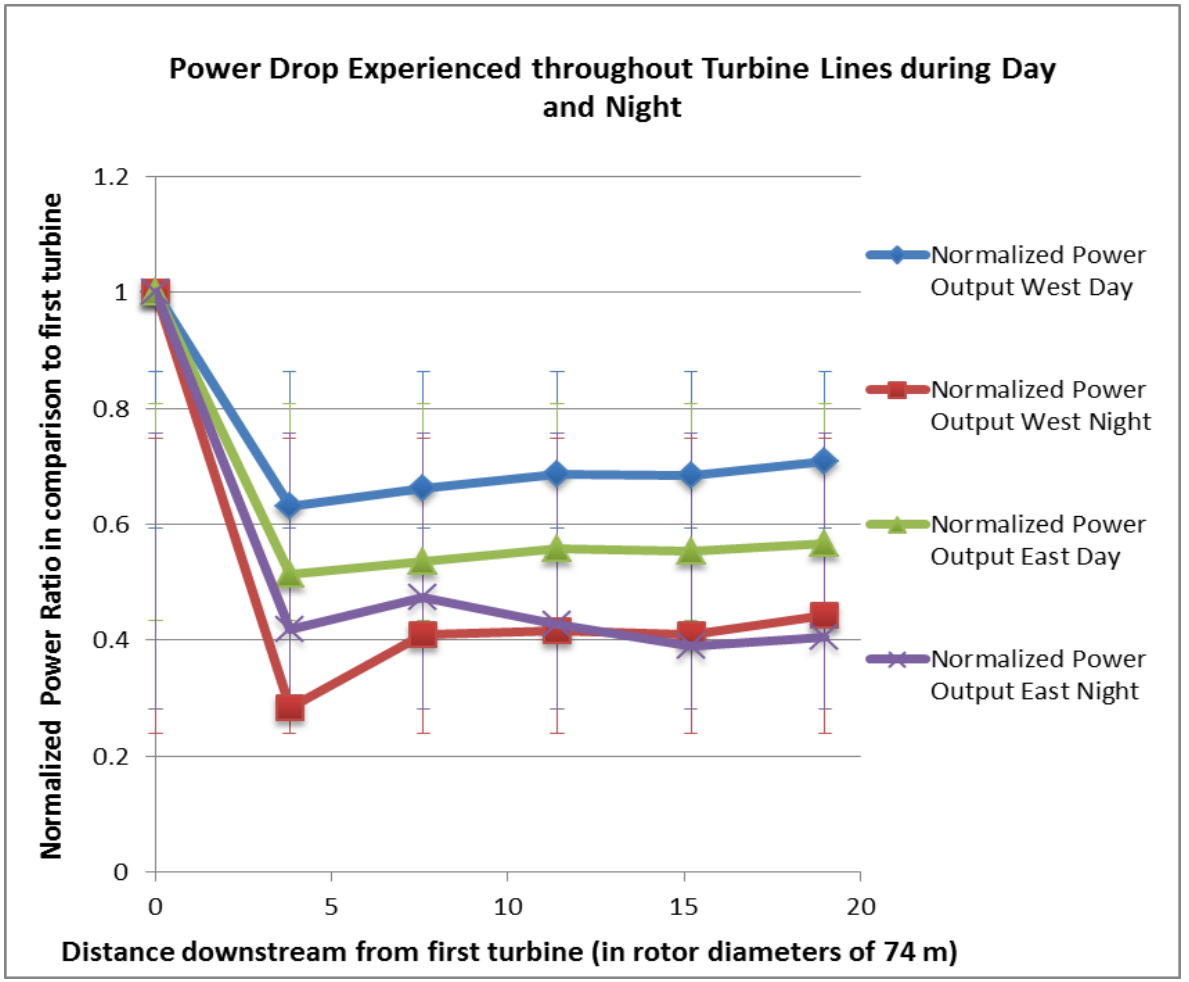
Power produced from a line of turbines under wake conditions. East (90° ± 10°) and west (270° ± 10°) wind events.

Turbine Wakes



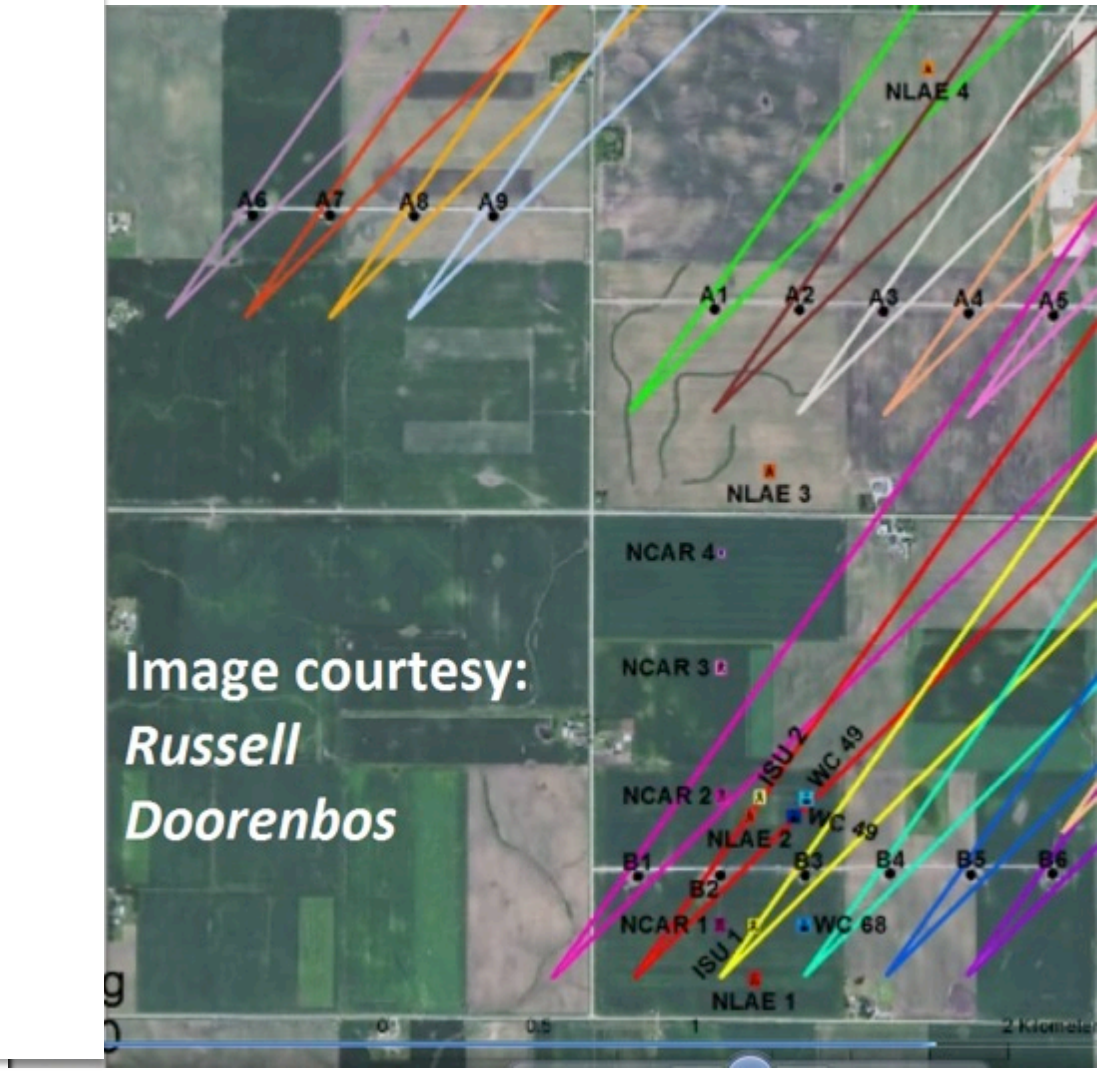
Power produced from a line of turbines under wake conditions - day vs. night.

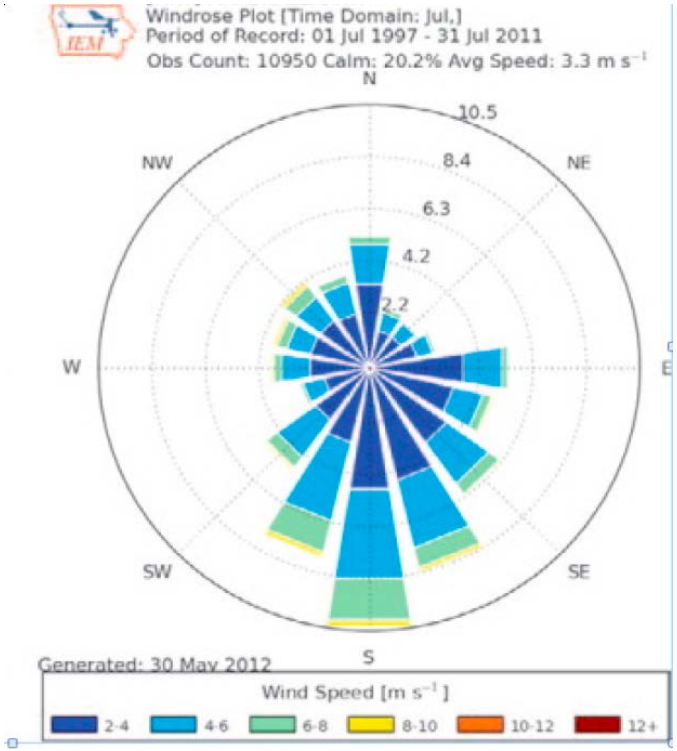
Turbine Wakes



Power produced from a line of turbines under wake conditions. East (90° ± 10°) and west (270° ± 10°) wind events – day vs night.

Single Tubine Wakes

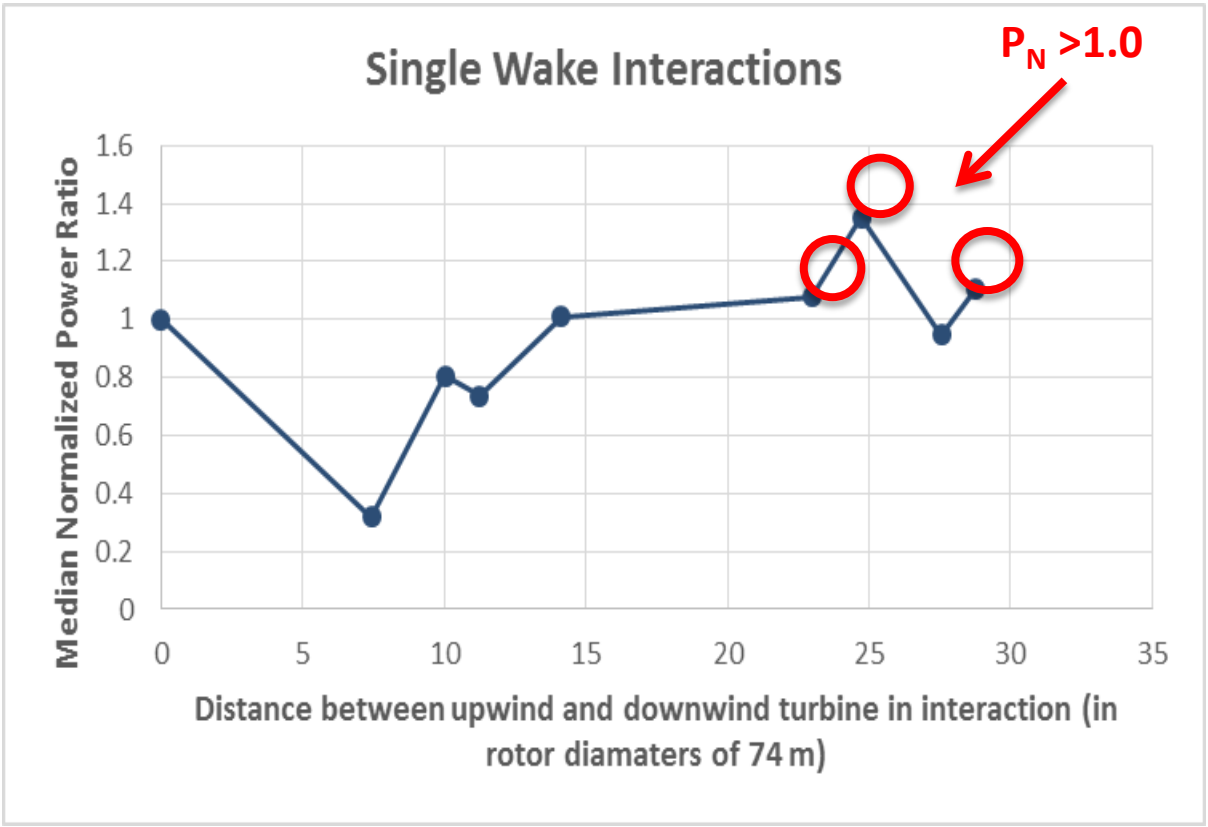




July – Aug 2011.

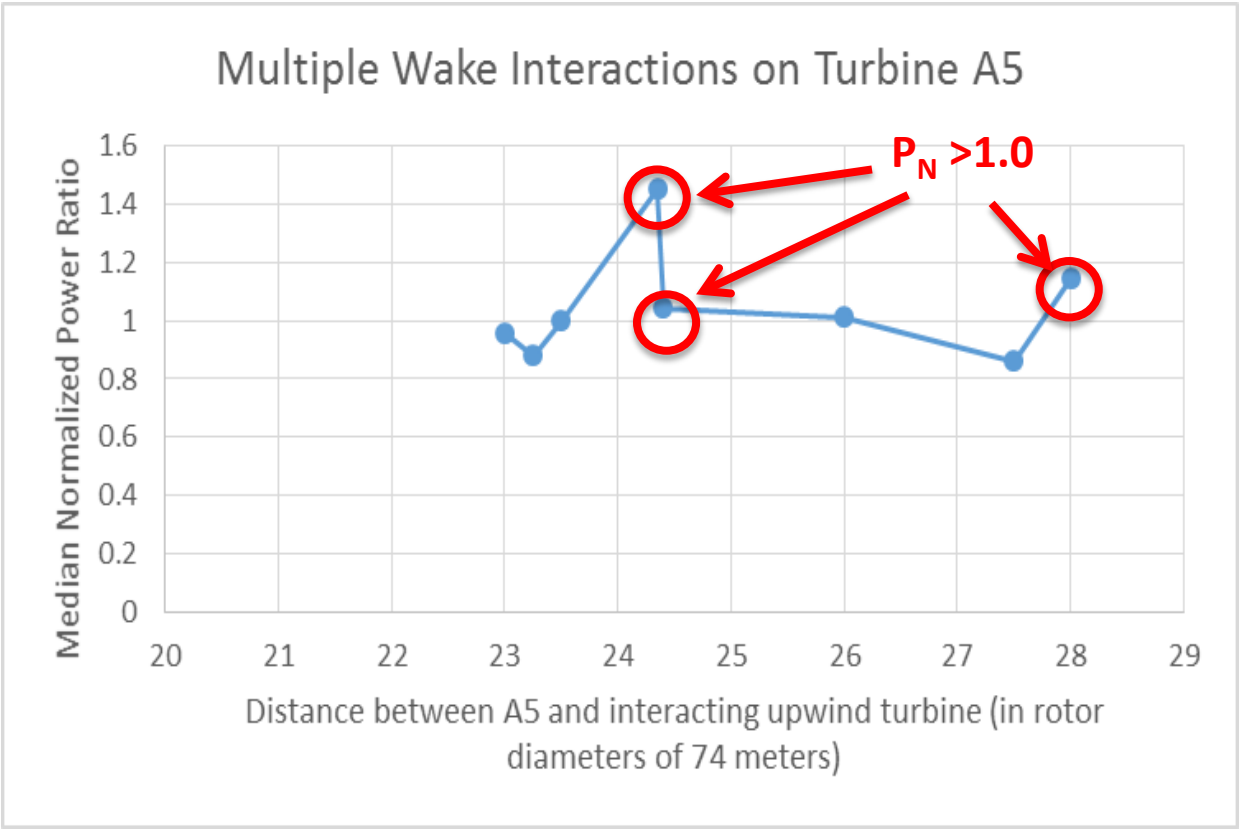
Assumed +/- 5^{o} wake expansion

Single Turbine Wakes



Mean normalized power as a function of downwind distance. All wind speeds were > 3 m/s. 56% of wake power ratios > 1.0 were at night (2000-0800 LST)

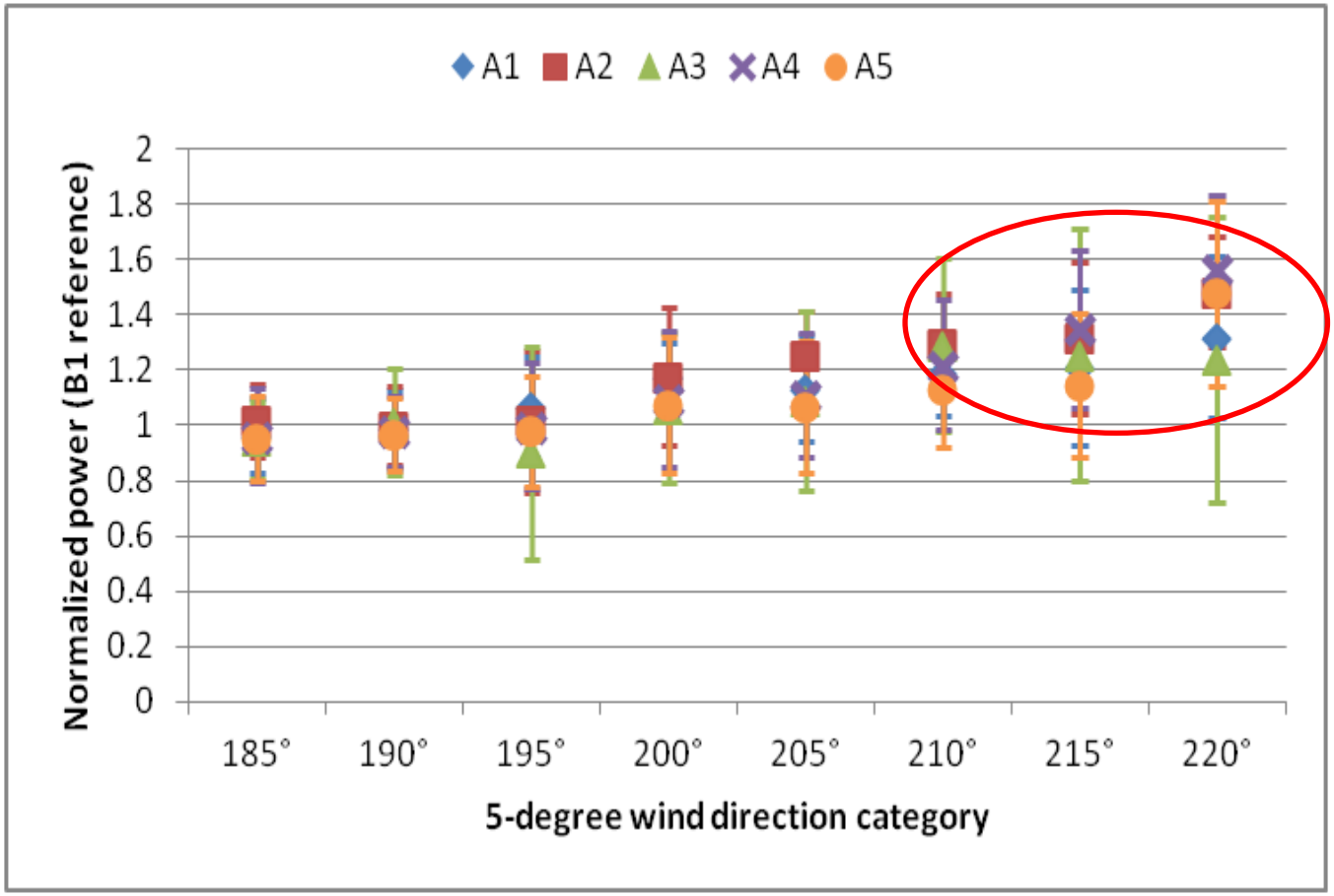
Multiple Turbine Wakes



Mean normalized power as a function of downwind distance for turbine A5. 48% of events with P>1.0 occurred at night (2000-0800 LST). Note: target turbine 7-10 m higher elevation than point of wake origin. Slope =10/1850= 0.0055.

Multiple Turbine Wakes

Stable surface conditions

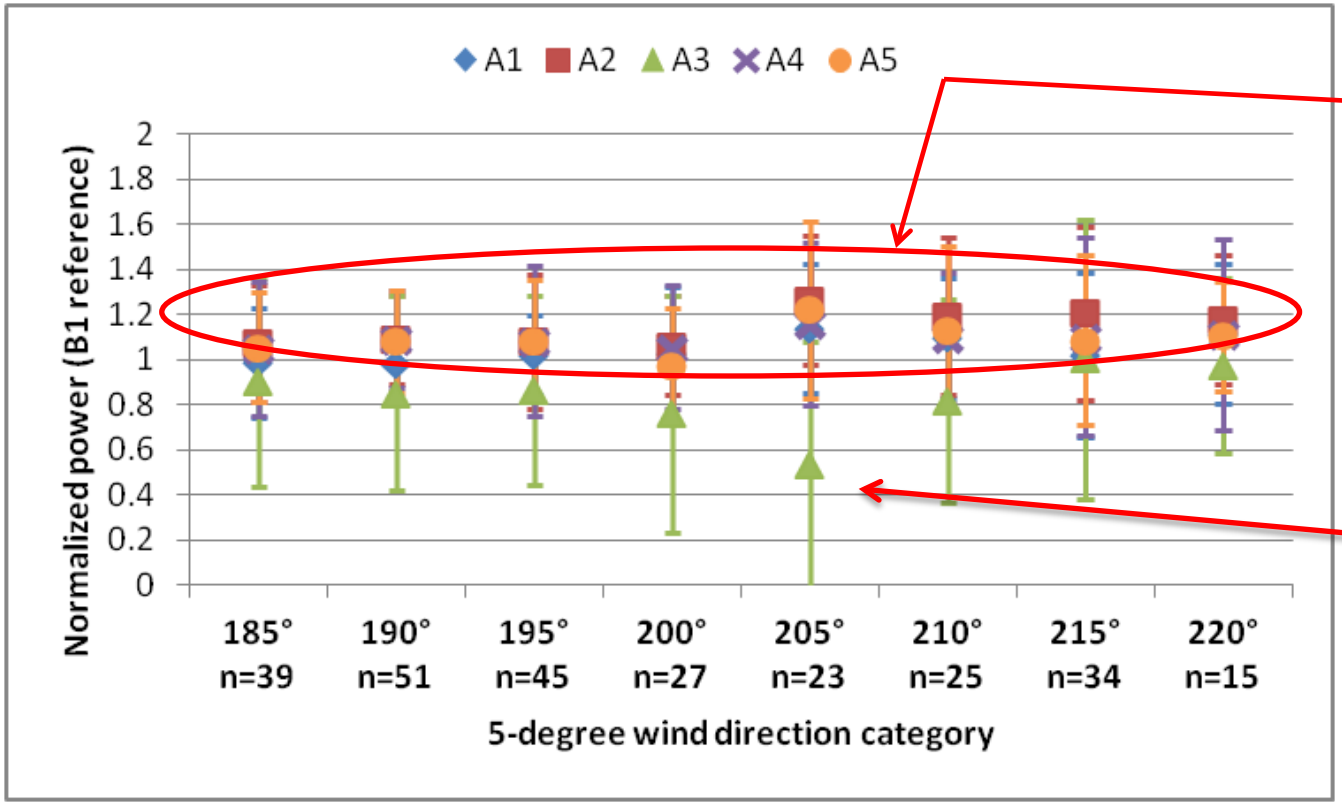


Stronger wind speeds on the outside of the B1-B6 wake aggregate for SW winds

Evidence of speed-up between/outside of turbine wakes (e.g. Hirsch and Schroeder 2013)

Multiple Turbine Wakes

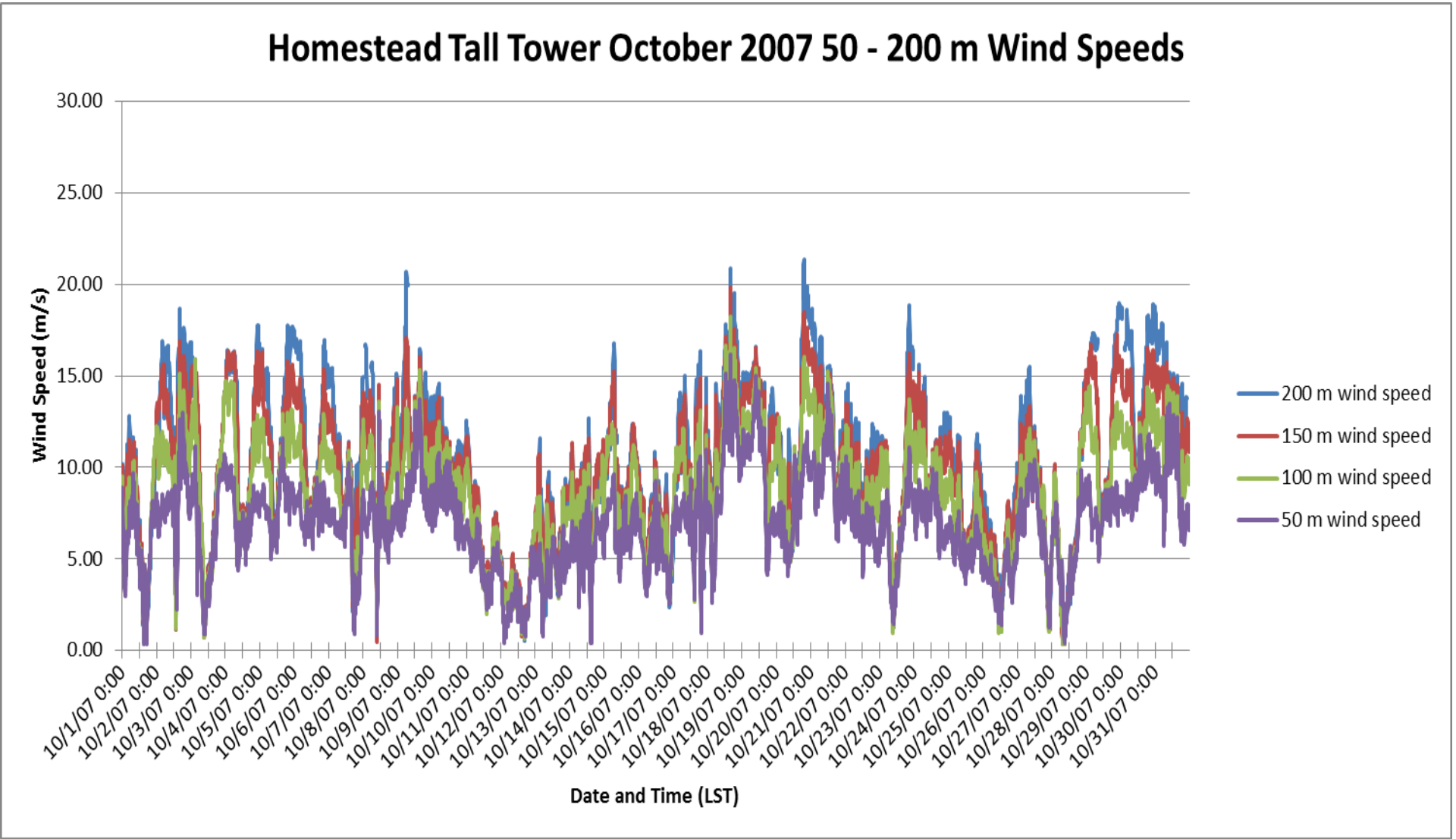
Neutral surface conditions



Weak overspeeding at most locations

Large speed deficit at A3 for SSW wind

High Wind Shear in Above-Rotor Layer



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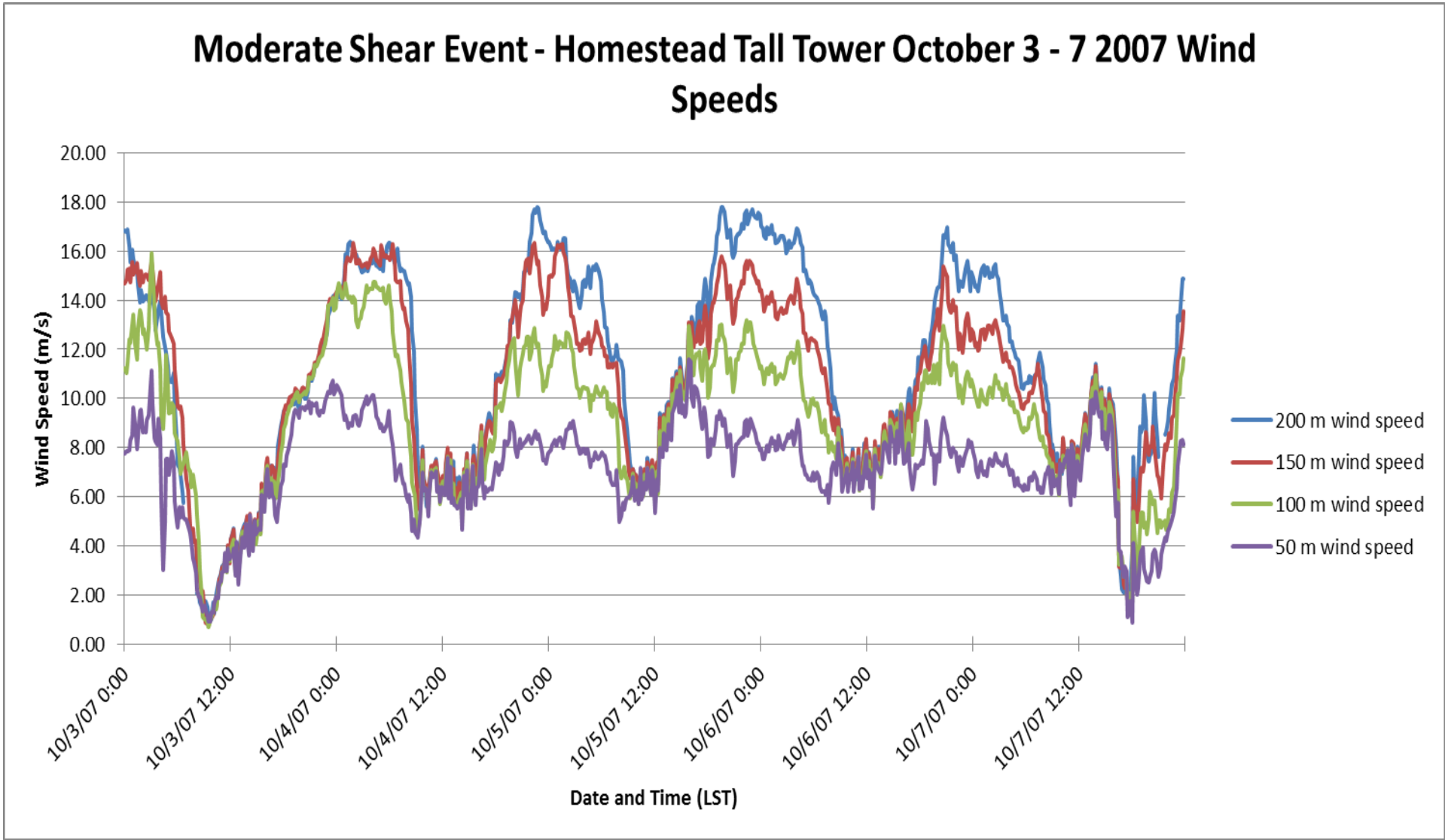

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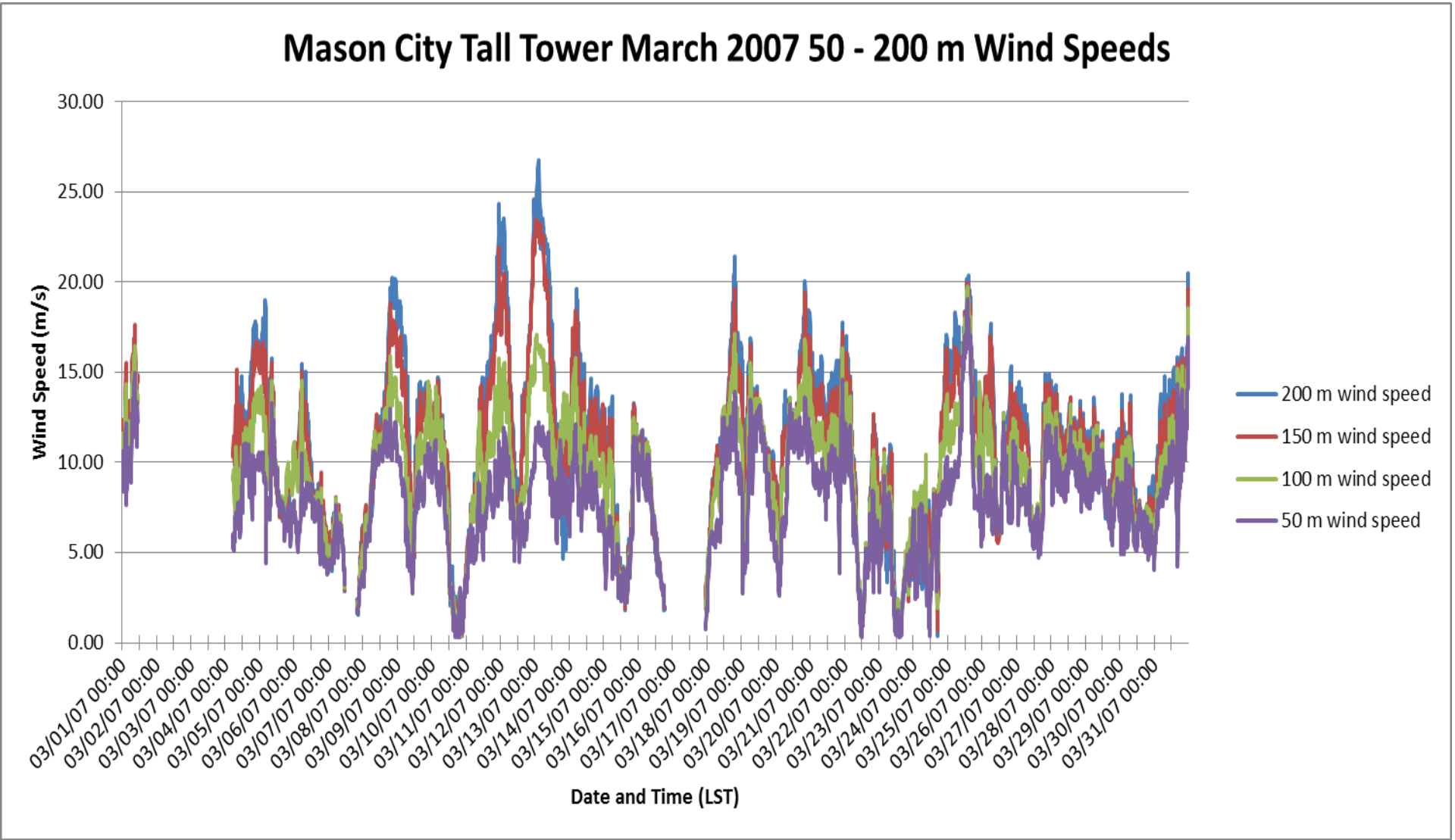

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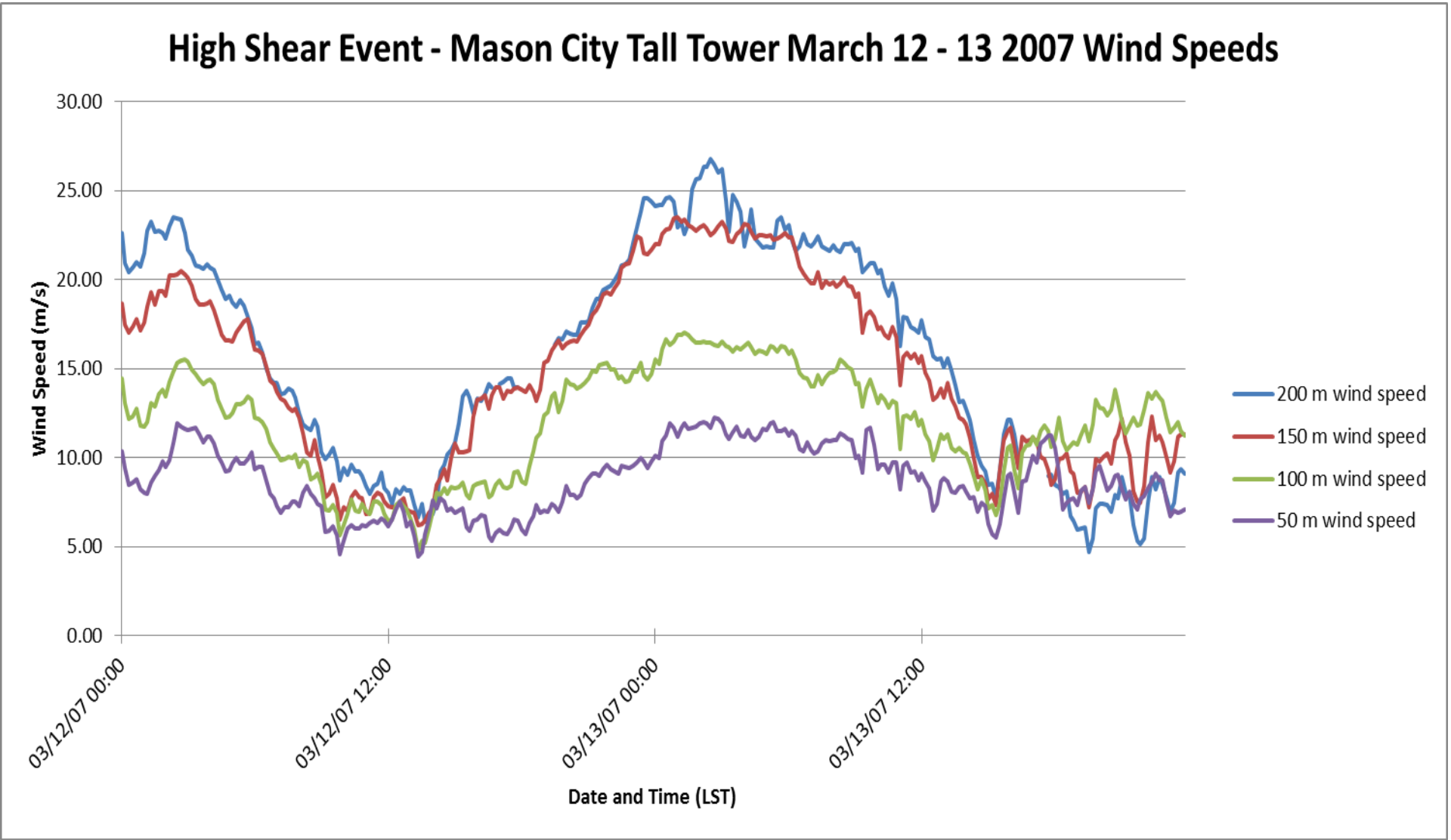

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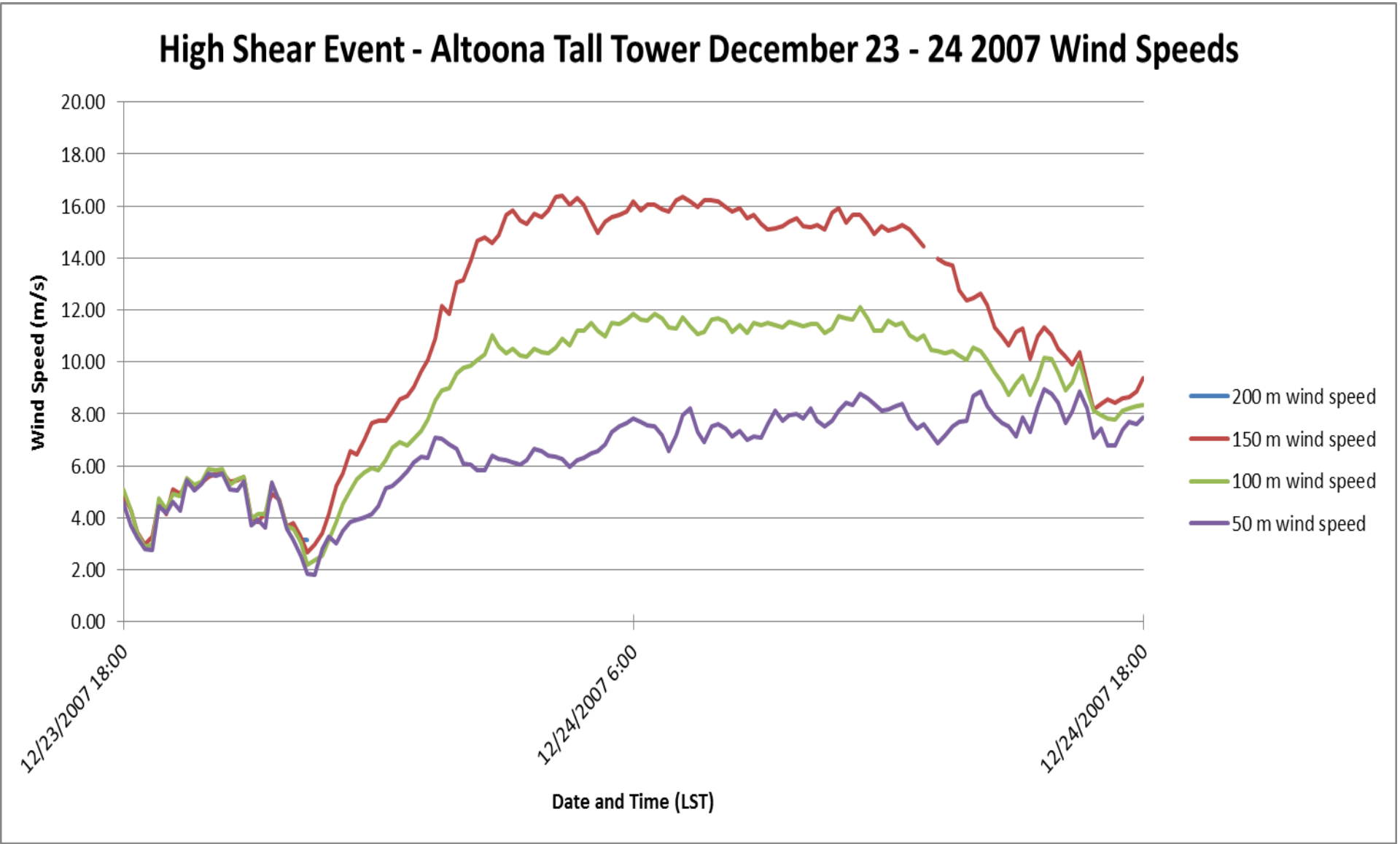

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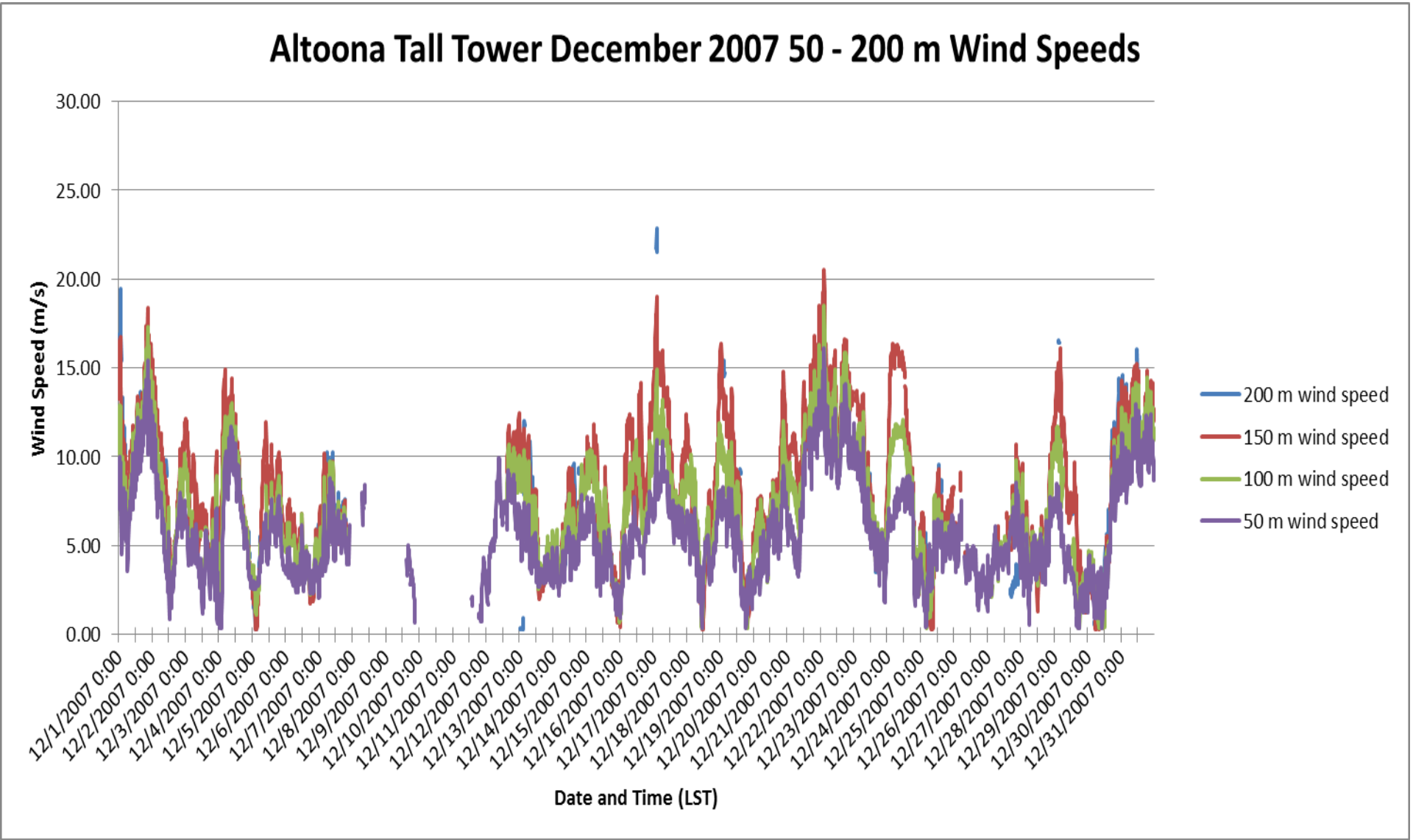

Summary

The near turbine wake (<5 D) for this Iowa wind farm shows characteristics similar to those reported by Barthelmie et al. for European off-shore conditions

Observations of the far turbine wake (>15 D) clearly show conditions where the turbine layer winds deeper in the wind farm are higher than at its upwind boundary

High wind speeds associated with the nocturnal low-level jet create high wind speeds and strong vertical wind shear in the above-rotor layer

There is some evidence that the wind shear created by the turbine wake may create sufficient turbulence to entrain high-speed wind from the above-turbine layer into the rotor layer