IOWA STATE UNIVERSITY
College of Engineering

Wind Energy Initiative (WEI)

Influence of Wind Turbines on Atmospheric Stability and Dew Duration

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Introduction

Using data from the Crop/Wind-energy Experiment 2011 (CWEX11) at a central Iowa wind farm, I will quantify the impact of wind turbines on both atmospheric stability and dew duration. As air passes through the turning blades of wind turbines, turbulence is generated, which in turn enhances the natural vertical mixing of the atmosphere[1]. These facts lead to two proposed hypotheses: 1) the turbine-enhanced mixing will lead to a decrease in surface-layer stability, and 2) if (1) is correct, then dew duration should be shortened. The stability change will be examined in terms of both the gradient Richardson number (*Ri*) and the Obukhov stability parameter (*z/L*). The motivation for this study is that crop vulnerability to diseases is enhanced by the presence of dew, so an impact of turbines on dew duration could indirectly impact crops.

Methods

CWEX11 data was collected by two flux stations provided by Iowa State University located in the southern region of an Iowa wind farm. One flux station, "ISU1", was located 160 m south of a line of turbines, and the other flux station, "ISU2", was located 260 m north of the same line of turbines. This line of turbines is referred to as the "B-line". Both ISU1 and ISU2 were positioned in corn fields, and recorded data in 10-min averages from 1 July 2011 – 16 August 2011. Furthermore, hub data from the B-line turbines were supplied for the period at 10-min intervals.

From these data, the gradient Richardson number *Ri* and Obukhov stability parameter *z/L* were calculated at the locations of ISU1 and ISU2 when ISU2 was in the wake of turbines B1-B4, as well as when neither flux station was in the wake of a turbine. Additionally, three sonic leaf wetness sensors were placed both north and south of the B-line. The sensors report values in mV that can then be interpreted to determine dew duration and intensity.

Figure 1. The B-line turbines and placement of CWEX11 field instruments.

Current Results

Hypothesis 1: The average *Ri* difference (ISU2-ISU1) was negative in the wakes of turbines B1, B2, B3, and B4. Likewise, the average *z/L* difference was negative in the wakes of B2, B3, and B4. The only increase was found for the *z/L* difference in the wake of B1. ISU1 and ISU2 datasets used a critical *Ri* of ±2 and critical *z/L* of ±10. Statistical analysis in the form of a paired t-test showed all results were statistically significant with the exception of the *z/L* increase in the wake of B1. For the non-wake case when winds were coming from the west, ISU2 reported a lower *Ri* and *z/L* than ISU1. This *Ri* decrease was found to be statistically significant; however, the *z/L* decrease is not significant.

Figure 2. *Ri* change (top) and *z/L* change (bottom) in west wind no-wake case. ISU2 *Ri* – ISU1 *Ri* (top). ISU2 *z/L* – ISU1 *z/L* (bottom).

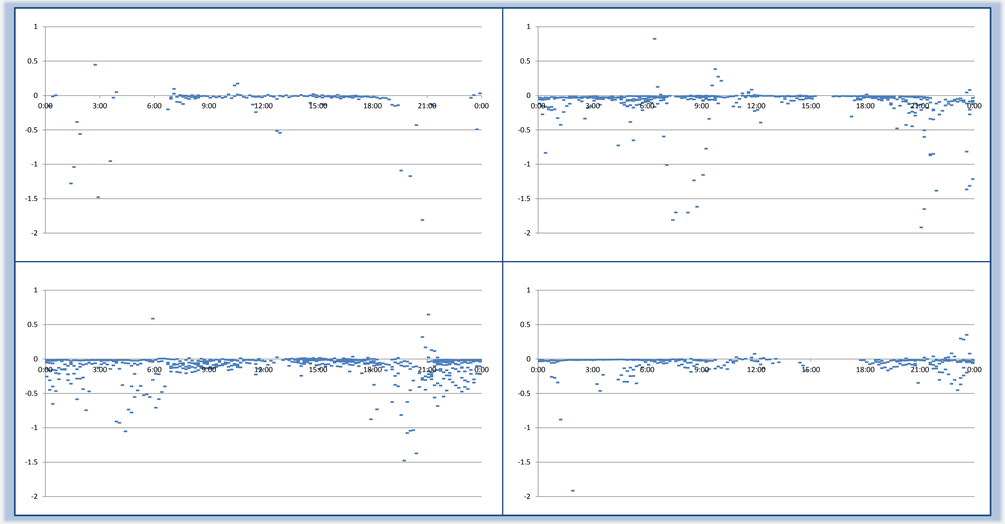

Figure 3. *Ri* change in the wake of B1 (top left), B2 (top right), B3 (bottom left), and B4 (bottom right). ISU2 *Ri* – ISU1 *Ri*.

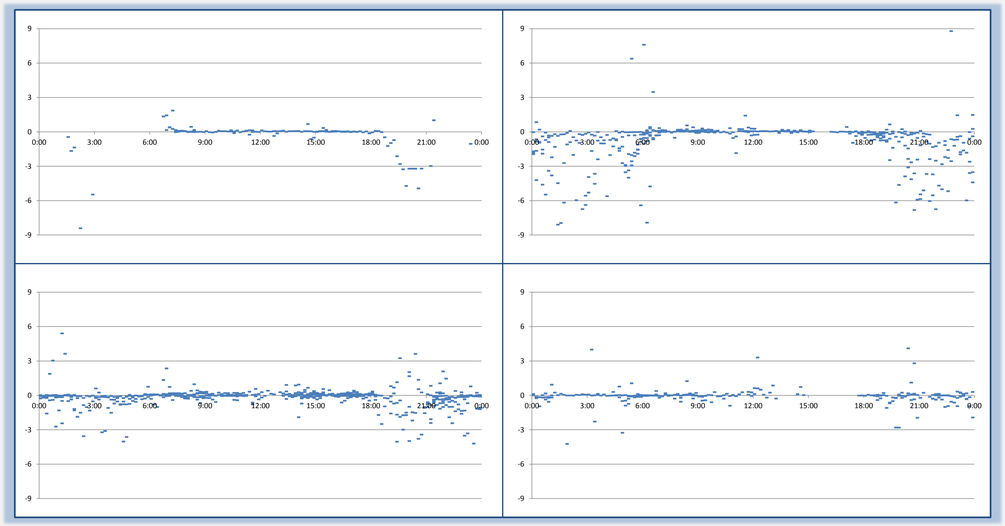

Figure 4. *z/L* change in the wake of B1 (top left), B2 (top right), B3 (bottom left), and B4 (bottom right). ISU2 *z/L* – ISU1 *z/L*.

Hypothesis 2: A quantification of dew duration proved inconclusive with the leaf wetness sensors, as the three sensors at each location all reported different durations. Precipitation, faulty sensor readings, and other factors also greatly limited the dataset of good dew duration reports.

Future Work

Data for the two stability parameters will be categorized (stable, neutral, unstable) from ISU1 data, and the *Ri* and *z/L* differences for each category will be examined for the same wake and no-wake cases. The paired t-test will again be used to determine the statistical validity of the results. Dew duration will be studied by other methods, such as the sign of moisture flux at ISU1 and ISU2.

References & Acknowledgements

[1] Baidya Roy, S., and J.J. Traiteur, 2010: Impacts of wind farms on surface air temperatures. *Proc. Natl. Acad. Sci.*, **107**, 17899-17904.

Support for this research was provided by a National Science Foundation Research Experience for Undergraduates site program in Wind Energy Science Engineering and Policy (WESEP) at Iowa State University. Data were provided by the Crop/Wind-energy EXperiment at Iowa State University (CWEX).