Localized Effects of Wind Turbines on Weather Conditions

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MOTIVATION

- Minor research has been pursued in how wind turbine establishments affect local weather conditions
- Knowledge of how local wind farms affect weather around their vicinity is important to farmers in the area

Hypothesis:

- More turbulent rotation within the vicinity of turbines
- Mixing of air causes cooler day time temperatures and warmer night time temperatures
- Drier conditions downwind

BACKGROUND

Positive aspects of wind turbines:

- clean, efficient, abundant source of wind, wind is free
- Roy and Pacala (2004):
  - Nocturnal jet causes well mixed boundary
    - Early morning most prevalent
    - Changes temperature, humidity, and latent heat flux
- Frandsen and Emeis (1993):
  - States "momentum loss is due to an infinite cluster of obstacles, [in other words] wind turbines."
- Roy and Traiteur (2003):
  - Turbines change local weather by changing air flow patterns
  - Near-surface air temperatures downwind of the wind farm are higher than the upwind regions during night, and cooler during day
  - Nocturnal warming of the air helps protect crops from frosts

METHODS

Equipment:

- 4 WXT510s
- 1 MAWS101
- 3 evaporation containers
- Parameters measured: temperature, pressure, wind speed, wind direction, relative humidity, rain fall amount

Timeframe:

- 29 Oct – 17 Nov 2010
- 2 min intervals for 20 days
  - 29 Oct – 4 Nov: NE & SE sites
  - 4 Nov – 11 Nov: MAWS & NE sites
  - 11 Nov – 17 Nov: MAWS, SW, NW, & NE sites

RESULTS

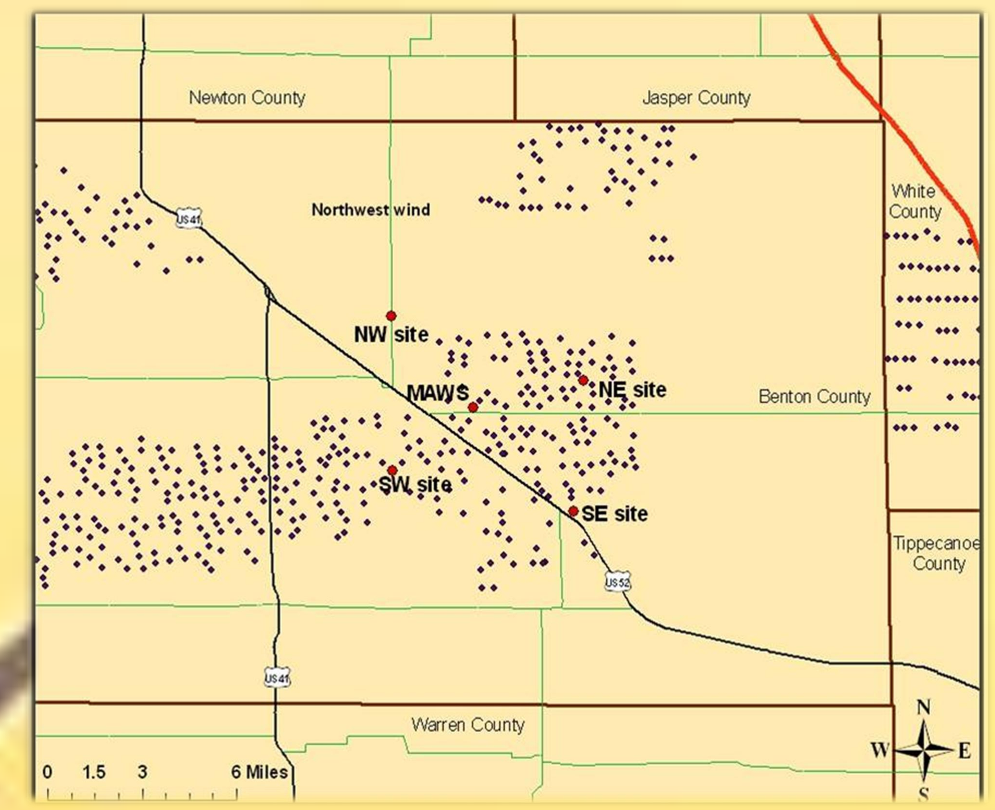

Figure 1: WXT-510 instruments were launched at 4 different sites within the wind farm. Each purple dot represents a designated wind turbine.

Weather during experiment:

29 October – 6 November
- Cold front went through between 4-5 November, causing higher wind speeds, lower barometric pressure, and lowered the temperatures slightly. Accumulating rain occurred 5 November.

6-13 November
- Dry cold front went through 8-9 November. On 13 November, the a cold front went through the area lowering pressure and temperature slightly. Wind speeds were between 5-10 mph. Little precipitation occurred with this front.

14-17 November
- No precipitation during 16-17 November. There was a brief drop in surface pressure with winds at 10 mph. Temperatures stayed steady throughout this time period.

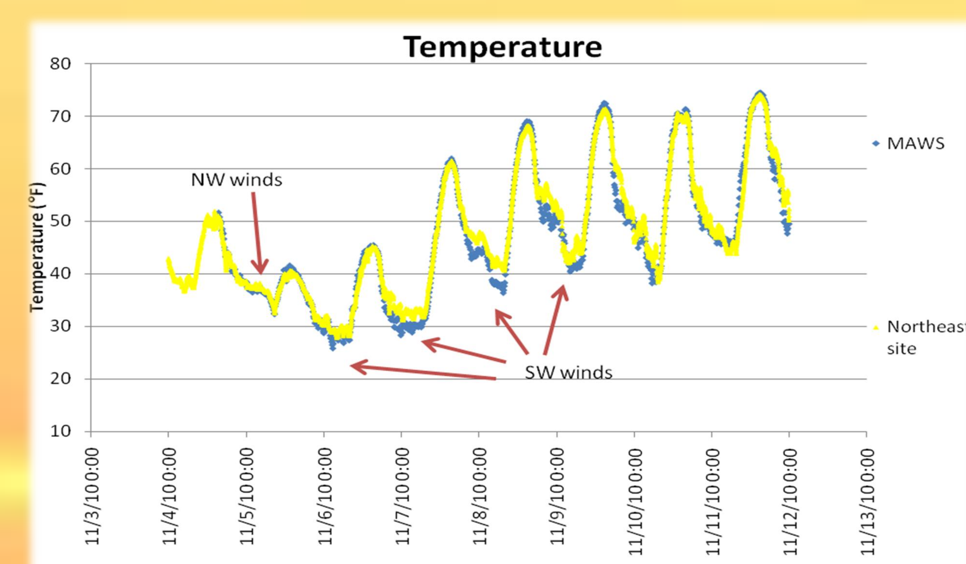

Figure 2: When the wind is simultaneously blowing perpendicular to the MAWS and NE site, i.e. from the northwest, the temperatures at both sites are relatively the same at night and during the day. When the wind is parallel to the two sites, such as a s with a southwest wind, the temperatures differ, both warming downwind overnight and cooling during the day.

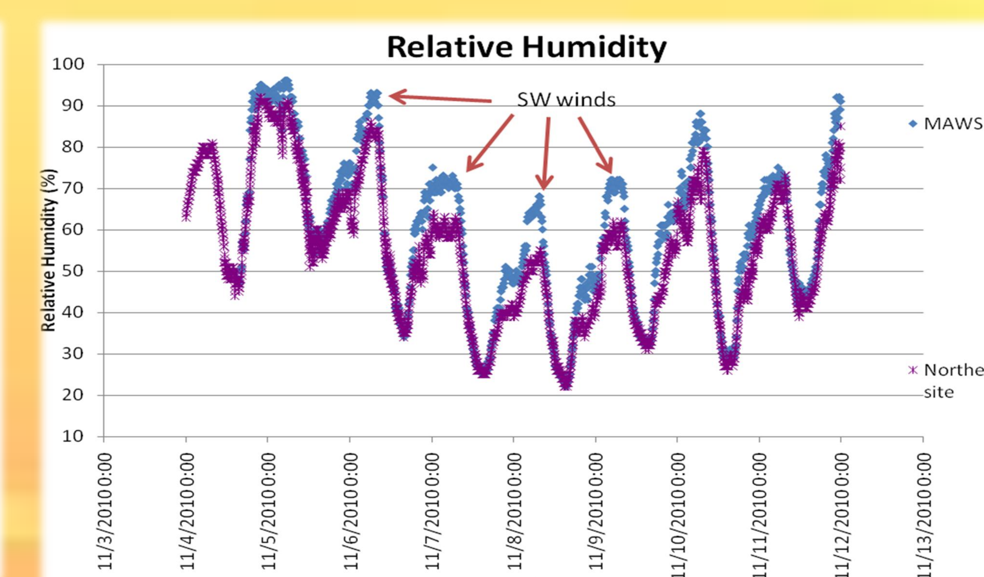

Figure 3: When the wind is blowing from the SW, there is a significant decrease in relative humidity downwind. At the MAWS site, the relative humidity values are approximately 10 percent higher than those further into the wind farm at the NE site. This phenomena is more noticeable during the nighttime to early morning hours.

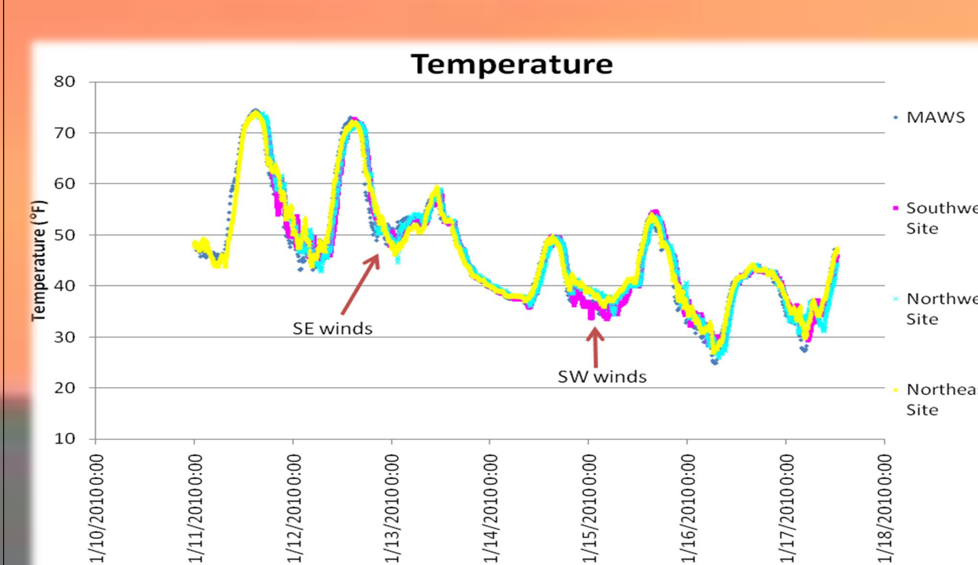

Figure 4: With a SE wind, the change in temperature was not as great due to the perpendicular path of the wind directed towards the wind farm. When SW winds prevailed, the difference in temperature from each site was much greater. The coldest temperatures during the night time hours were at the SW site, with the warmest temperatures at the same time frame being furthest away from the direct wind flow at the NW site.

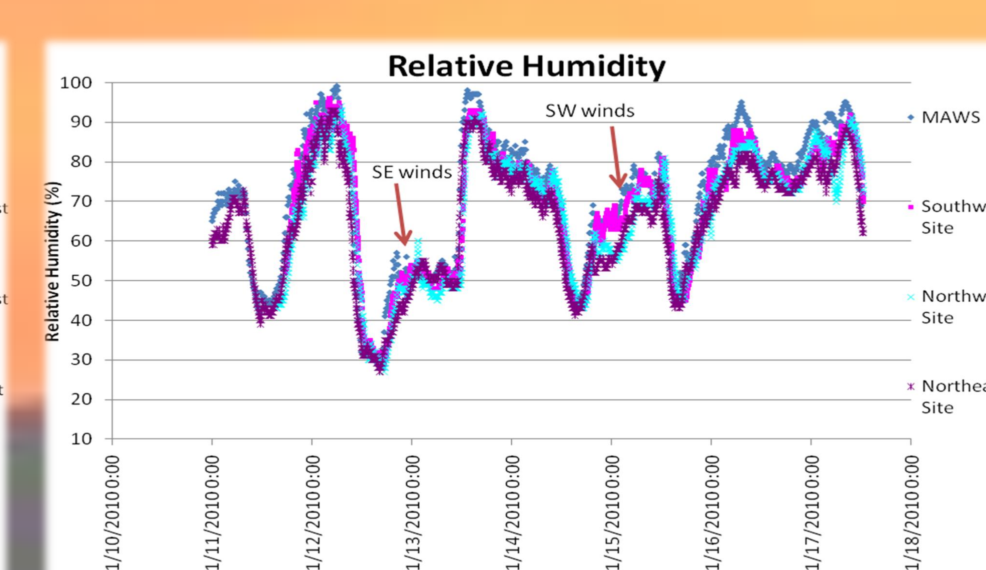

Figure 5: SE winds show RH values decrease moving into the wind farm. The further away from the direction of the wind, the drier the air. When SW winds were in effect, the SW site had the highest values of RH, and the NE/NW sites had much lower RH values, indicating drying moving in the direction of the wind due to mixing caused by rotation of wind turbines.

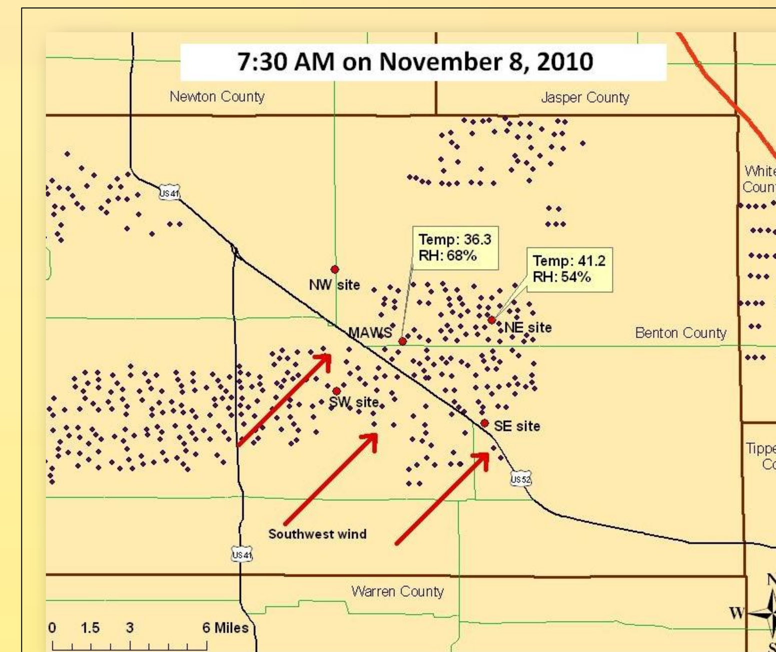

Figure 6: Using GIS programming, specific location of the wind turbines with correlation to the direction of the wind is identified at 7:30 AM for 8 November 2010. This time and date were chosen because of the maximal temperature gradient across the wind farm in the most favorable overnight to early morning hours.

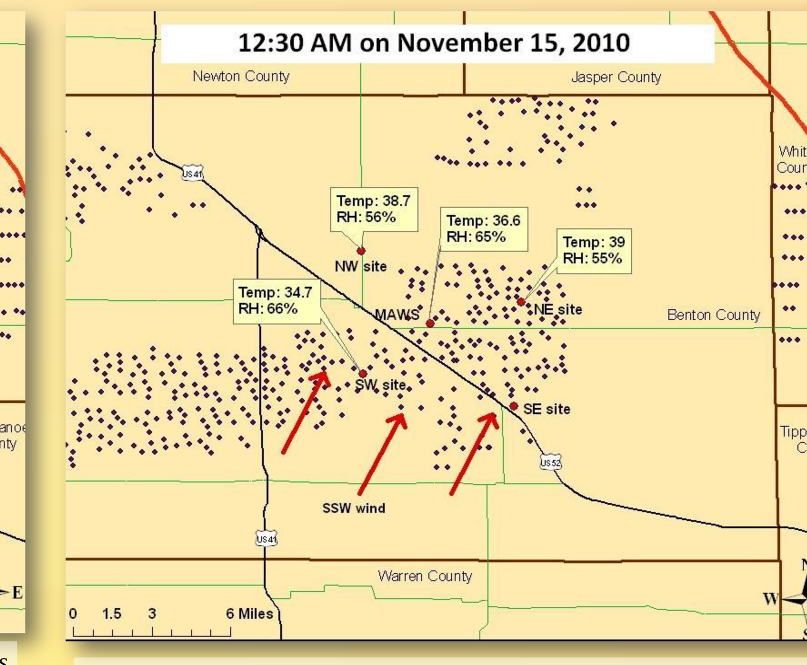

Figure 7: Using GIS programming, specific location of the wind turbines with correlation to the direction of the wind is identified at 12:30 AM for 15 November 2010.

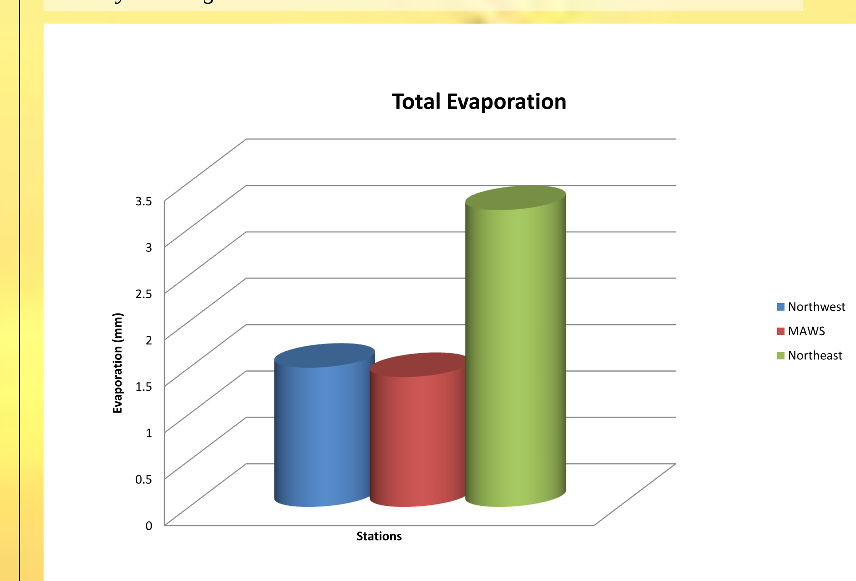

Figure 8: The NE site produced the greatest amount of evaporation, showing as the wind moved from the SW to NE in the wind farm area, the air became drier.

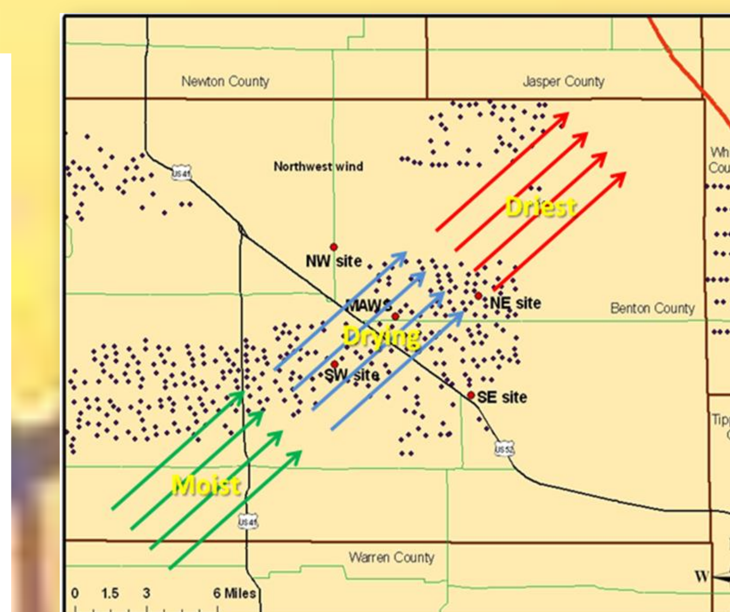

Figure 9: When SW winds prevailed, the air becomes progressively drier moving SW to NE in the designated wind farm area. Each purple dot depicted represents a specified wind turbine.

CONCLUSIONS and FUTURE WORK

Conclusions:

- Warmer temperatures occurred in localized areas downwind of turbines, especially late night/early morning
- Cooler temperatures were observed downwind of turbines during day time hours due to surface mixing caused by wind turbines
- Decrease in RH were found as winds progressed through wind farm
- As wind progressed through the wind turbines, higher evaporation rates occurred downwind

Future Work:

- Perform statistical analyses to delineate instrument error and biases
- Evaluation of soil moisture content of localized farm land
- Further experimentation to include cooler seasons to assess the decrease of frost down wind of wind turbines

References:

Roy, S.B., & Pacala, S.W. (2004). Can large wind farms affect local meteorology?. *Journal Of Geophysical Research, 109*. doi: 10.1029/2004JD004763.

Roy, S.B., & Traiteur, J.J. (2003). Impacts of wind farms on surface air temperatures. *PNAS, 107*(42), Retrieved from www.pnas.org/cgi/doi/10.1073/pnas.1000493107

Frandsen, S., & Emeis, S. (1993). Reduction of horizontal wind speed in a boundary layer with obstacles. *Boundary-Layer Meteorology, 64*.