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WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Observations and Simulations of a Wind Farm Modifying a Thunderstorm Outflow Boundary" *by* Jessica M. Tomaszewski and Julie K. Lundquist

Anonymous Referee #1

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General comments:

This case study, apparently the first evaluation of how a parameterized wind farm affects the speed of a simulated gust front, is a useful addition to the literature. The figures and text are polished and generally free of mistakes. This is the start of a good paper, but it will benefit from substantial improvements to the scientific approach, analysis, and interpretation. The focus of my review is on major comments and substantive minor comments. A comprehensive list of technical corrections does not seem useful at this stage because much of the text is likely to change between this and future versions.

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Discussion paper

Specific comments:

1. One of my foremost concerns appears in the manuscript as a seemingly minor comment: “Such delays in the WFP outïňĆow evolution could be artifacts of the 3-km model resolution” (lines 232-233). The same thought occurred to me, and it seems like a fundamental issue. A large fraction of the analysis in the manuscript is about the speeds of the simulated outflow with and without the wind farm’s influence, and comparisons to observations. If the simulated speed’s sensitivity to the computational grid is first order, then doesn’t this call into question many of the manuscript’s conclusions? At a minimum, other grid intervals should be tested to characterize this sensitivity. If the sensitivity is high, then the study needs to be redone based on simulations at a resolution for which results converge.

2. In the abstract, the stated goal of the manuscript is to “address the extent to which wind farms can modify thunderstorm outflow boundaries” (line 5). The actual analysis of results in the main body of the text is more modest than this statement suggests. The outflow’s speed and some near-ground conditions are evaluated, but not its kinematic nor thermodynamic structures in the vertical. These also could exhibit important modifications, and the 4-D fields from the model, configured to provide high resolution in the lowest levels of the troposphere, should provide the opportunity to evaluate vertical structure.

3. The terms “propagate,” “propagation,” “propagating,” etc. are used throughout the manuscript. However, I think the authors do not intend to refer to propagation velocity, but rather to velocity of the gust front relative to the ground. Velocity relative to the ground is the vector sum of two velocities: 1) velocity of the gust front’s propagation through the air and 2) velocity of the air relative to the ground.

4. References to “resolution” in the manuscript should be corrected to “grid spacing,” “grid interval,” “model cell size,” or something similar (there are many possible terms). It is an important distinction. The information that can actually be resolved with reason-

able numerical accuracy is at a scale larger (coarser) than the grid interval. Specifically, the WRF Model's effective resolution is approximately 7x the grid interval (Skamarock, MWR, 2004). This means simulations on a grid with dx = 3 km have an effective resolution of approximately 21 km.

5. Lines 113-114 ("provides the initial visual of the outflow"): "Visual" is an adjective, not a noun. Also, I'm not sure what "initial visual" means. Is this just the initial (first) figure you are presenting in the manuscript?

6. Line 119 ("observation period of 5 minutes"): Does this mean that data were reported as a 5-minute average of samples taken every #? minutes or #? seconds? Is the reporting time centered on the 5-min period?

7. Line 121 ("located 5 km southwest of the wind farm"): The farm looks big. Is this distance of 5 km from the center of the farm, the southwestern edge, or to some other point?

8. Line 157 ("top-down view"): Consider a different adjective. This is an odd use of "top-down."

9. Lines 161-162 ("However, the outflow event in the simulation occurs too early"): The issue of timing deserves several sentences of additional explanation. Does the simulated moist convection occur too early overall, or does the timing seem about right except that the outflow is produced too early? Does the simulated outflow move too quickly at first?

10. Line 167 ("from the corresponding point"): Do you interpolate or choose the closest point?

11. Lines 172-173 ("possibly an artifact of the 5-min sampling in the observations as opposed to the 1-min sampling in the simulation"): Can you determine whether this is an artifact by averaging the model output in the same way the observations are averaged?

12. Lines 175-176 ("These model biases could be due to inaccuracies in the soil moisture that stem from differences in precipitation that occurred earlier in the day"): This is an interesting point. Can you check by running another simulation with higher soil moisture?

13. Lines 183-184 ("Regions of cooler temperatures (blue) indicate that the temperature in the WFP simulation is cooler than in the NWF simulation, suggesting faster movement of the outflow bringing cooler temperatures"): It might also be useful to show a plot of the difference in 10-m wind depicted as vectors.

14. Lines 185-186 ("Early in the outflow event, only subtle differences exist between the simulations upwind from the wind farm"): Do these differences surprise you? What do you think is causing them? Although it is true that the upwind differences are smaller than the largest differences on figs 5b,c where the gust front is most affected by the wind farm, the upwind differences are roughly the same as in many other parts of the domain in fig 5c. It would be helpful to reduce or completely eliminate the differences in simulations before the gust front nears the wind farm. Have you considered running the first part of the WFP simulation without the wind farm, writing a restart file at the output time just before the gust front reaches the farm, turning on WFP, then resuming the simulation by initializing with the restart file? I'm not sure if that is possible, but you might check.

15. Lines 191-192 ("The wind farm also appears to act as a barrier around which the outflow channels and accelerates, most notably immediately following passage over the wind farm"): Can you provide figures that support this interpretation? Can such channeling even be resolved at dx = 3 km? That equates to resolving features with a characteristic length scale of 21 km or so, which seems too coarse to depict channeling. (Please see the major comment about grid resolution.)

16. Line 199 ("suggesting the modified outflow in the wind farm case recovers after the initial disruption by the wind farm"): I am having trouble following this interpretation. The

analyisis of the data is not Lagrangian, it does not follow the gust front as it moves away from the wind farm and, presumably, is less influenced by it. Rather, the time series is at a point that does not move relative to the farm. That's why I don't know what to make of the term "recovery." Do you mean that changes in the moist convection and outflow with time at the observing station cause time series to appear more as they were before the gust front arrived?

17. Lines 210-212 ("wind speeds, the longer delay for the mixing ratio response indicates that the wind farm-modified outflow impacts absolute moisture more, suggesting that the change in moisture due to the outflow lags the change in temperature."): Maybe I am misreading, but isn't this a circular argument? Here is my interpretation: greater delay indicates greater impact, which suggests greater delay (i.e., lag). Also, I don't follow how you calculate what is a greater or lesser impact. The units of temperature and humidity are not the same. It's like trying to evaluate whether a flower is more colorful than a sprinter is fast. Would it clarify your point if you normalize changes in temperature and humidity by calculating standard deviations from sufficiently long temporal means? What is the physical explanation for why a greater lag can be interpreted to indicate a greater impact?

18. Lines 214-216 ("We measure the observed outflow propagation speed by tracking the reflectivity fine-line along a transect and recording its distance traveled every data update"): In the radar data, is the fine line at a consistent altitude at all times of your calculations? If not, then if the gust front is not vertical all the way to the top of the outflow (or at least to the highest altitude represented in the radar scans), wouldn't slope influence your calculations of location at fixed times and therefore your calculations of speed?

19. Lines 218-219 ("Both simulation and radar outflow are measured against a 5x5 km grid"): What does this mean?

20. Lines 220-221 ("Three separate measurement examinations are conducted for

each case”): That’s an effective technique. Please explain this more. Three different people? The same person three different times? Something else?

21. Caption to figure 7 (“with the gradients in 10-m wind speed providing the position of the boundary to track”): Do you place the boundary where the gradient is highest? At the leading edge of the greatest change in the gradient? Somewhere else?

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