Utilizing Mesoscale Atmospheric Modeling to Evaluate Forecasting Skill of Wind Ramp Events

Joseph F. Brodie
jbrodie@marine.rutgers.edu

Scott Glenn
glenn@marine.rutgers.edu

Travis N. Miles
tnmiles@marine.rutgers.edu

Center for Ocean Observing Leadership (RUCOOL)
Rutgers, The State University of New Jersey

Dana E. Veron
dveron@udel.edu

Center for Carbon-free Power Integration
University of Delaware

Rich Dunk
rdunk28@comcast.net

Aquawind, LLC

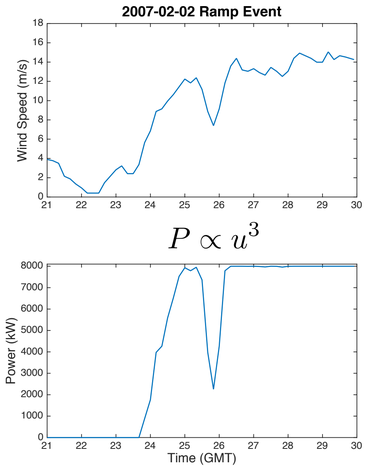
http://rucool.marine.rutgers.edu

Abstract

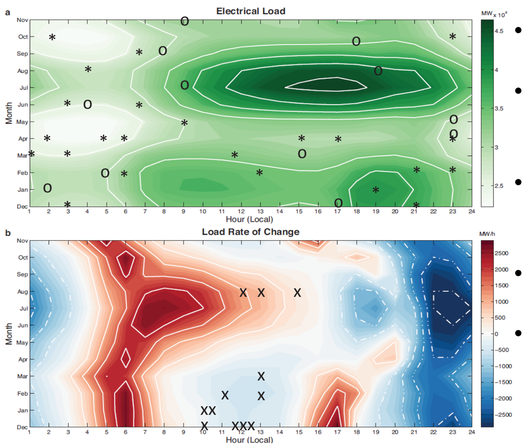
One significant challenge facing wind farm operators is the ability to correctly predict ramp events, which are rapid changes in wind speed that influence the power production of the farm. Errors in predicting these events can result in either surplus power generation that must be spilled or stored, or a shortage of expected power that requires the use of generation reserves. In this poster, we examine the forecasting skill of 24 case study ramp-up events for a hypothetical wind farm off of the Delaware coast using the Weather Research and Forecasting (WRF) model. Comparing the model data with observations from nearby buoy observations show errors in predicting ramp-up timing, magnitude, and shape. These case studies indicate that WRF tended to predict ramps too early, and often had wind speeds before the ramp higher than observed, or wind speeds after the ramp lower than observed. In order to further examine wind ramp forecasting skill in everyday operations, we discuss ongoing work to study ramps utilizing a multi-year dataset of daily real-time WRF forecasts available at RUCOOL.

What are Ramp Events?

- Large changes in wind speed over a short time duration
- Ramp-ups are rapid increases in wind speed; ramp-downs are rapid decreases
- Results in rapid and large changes in the power produced by wind turbines
- Challenging to predict accurately
- Different types of errors in prediction
  - Timing
  - Magnitude
  - Shape



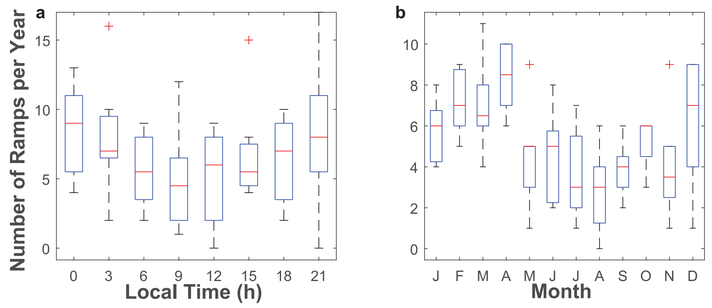
Why Are They Important?



- They take place dozens of times each year
- Timing of events can coincide with challenging load periods
- ✱ show times when 4+ ramps detected during hour/month over 7 years
- ○ and × show ramp event case studies modeled
- Ramp-up events can often take place during times of reducing demand!

Figure **(a)** above shows the average electricity load for PJM by hour of the day (x-axis) and month of year (y-axis), while Figure **(b)** shows the rate of change of that load. Most prominent are the single summertime peak in mid-afternoon, and the dual peaks during the winter at the start of the typical workday, and at the time many people return home from work.

Mid-Atlantic Ramp Events



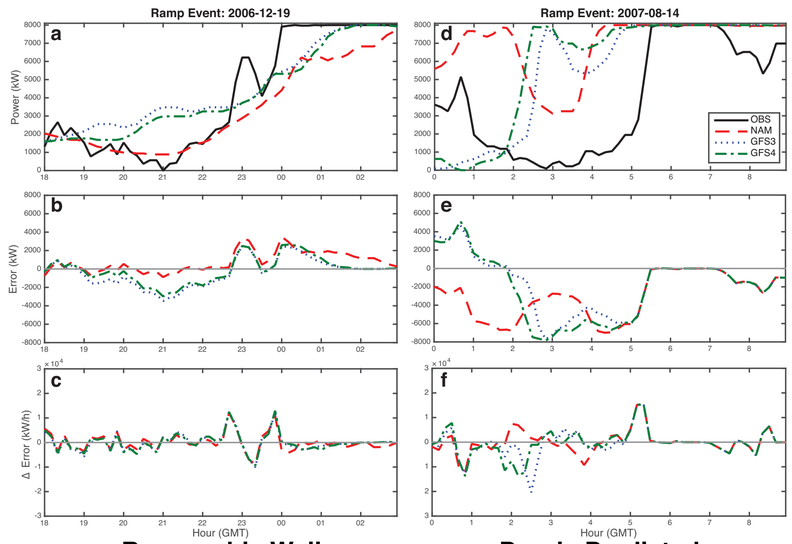
Ramp-up events detected using 7 years (2005-2012) of observations from buoy 44009 off the coast of Delaware, with threshold criteria of a ramp being a 50% increase in expected power production over a 1 hour time period. Figure **(a)** shows the median, range, and first and third quartiles of ramp events detected each year, by hour; and **(b)** by month.

Ramp events are more common:

In the Evening

During Winter and Early Spring

Modeling Case Study Ramp Events



Reasonably Well-Predicted Ramp

Poorly Predicted Ramp

These figures show two example case study ramp-up events, with the observed ramp from observations at 44009 in black, and three different WRF model runs in the colored lines.

- **(a), (d):** Estimated power based on the expected power production from an 8 MW wind turbine at the given wind speed
- **(b), (e):** Error in the WRF prediction, observed – modeled
- **(c), (f):** Predicted power error slope (PPES), which shows how the error is changing

Take Home:

- Spikes in PPES indicate when the model's performance suddenly changes; for example, going from underpredicting wind to overpredicting it!
- These can be particularly challenging for grid operations, since this results in sudden shift from overproducing power to underproducing, relative to what was forecast

Real-Time WRF at RUCOOL

The team at RUCOOL operates a unique configuration of the WRF model in real-time (RU-WRF) daily. It assimilates an RUCOOL sea surface temperature product that effectively captures coastal upwelling which is common off the NJ coast, and is important in effectively modeling wind speeds.

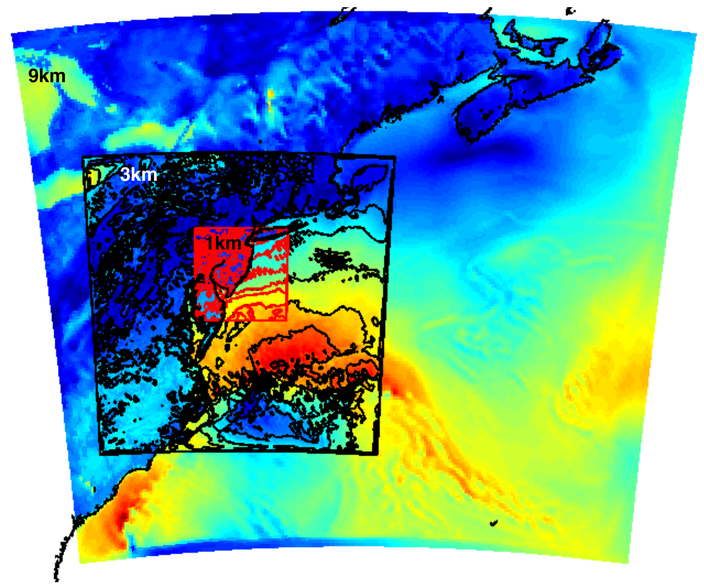
RU-WRF Uses Include:

- Hourly winds, used for wind power resource assessment
- Severe weather, for construction and O&M
- PJM grid management, including forecasting ramp events
- Energy market trading

Current Work:

- Continue ongoing daily modeling for wind resource assessment
- Mine archive of several years of RU-WRF output to evaluate the model's performance in predicting ramp events under real-time conditions

RU-WRF Domains



Next Steps

- Explore when RU-WRF does well at predicting ramps, and when improvement is needed
- Connect these performance statistics to overall synoptic-scale weather conditions at the time, to allow for future expectations of performance in real-time

Acknowledgements

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For Further Information

Veron, D. E., J. F. Brodie, Y. A. Shirazi, and J. R. Gilchrist, 2018: Modeling the electrical grid impact of wind ramp-up forecasting error offshore in the Mid-Atlantic region. *J. Renew. Sustain. Energy*, **10**, 13308, doi:10.1063/1.4990684.