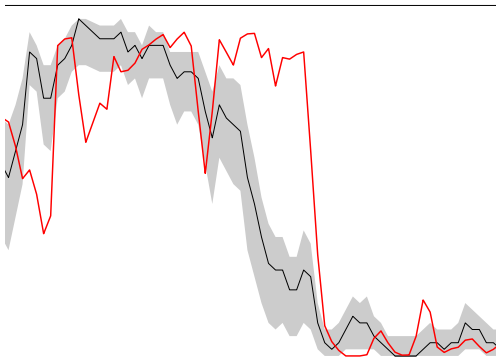
Exceptional service in the national interest

SAND2016-11708C

Sandia National Laboratories



Predicting Wind Power Ramp Events

Andrea Staid

INFORMS Annual Meeting

November 15, 2016

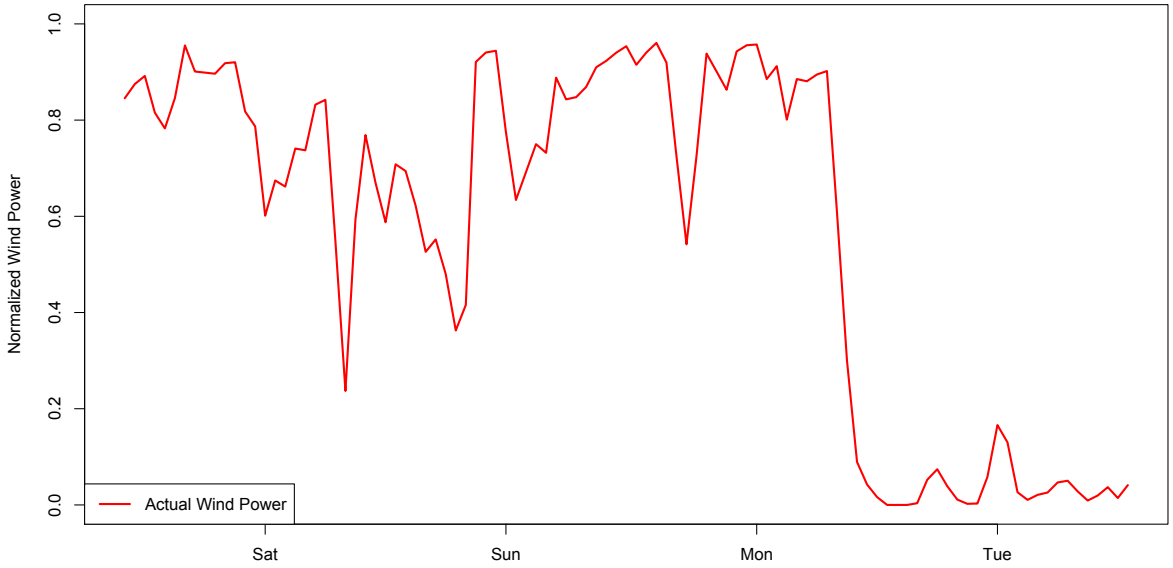
U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-mission laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Wind Power Ramp Events

- Rapid loss or gain of wind production
- Sharp ramp rate makes it difficult to manage in real time
  - Need fast-ramping generation to make up the difference, usually at a high cost
  - Can we better predict ramps by incorporating additional data sources?
- Any advance warning is advantageous – costs can be lowered



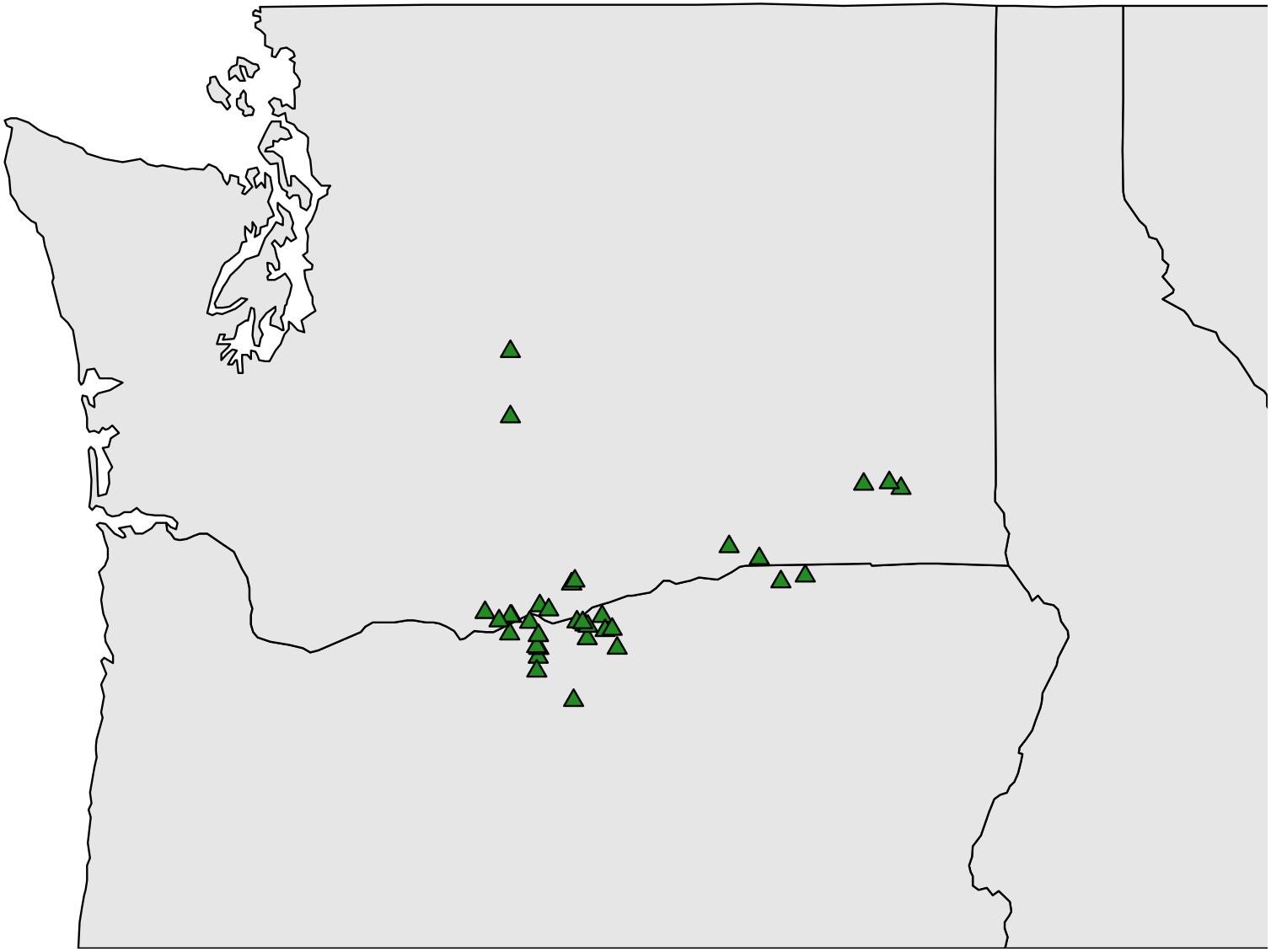
Data Used

Sandia National Laboratories

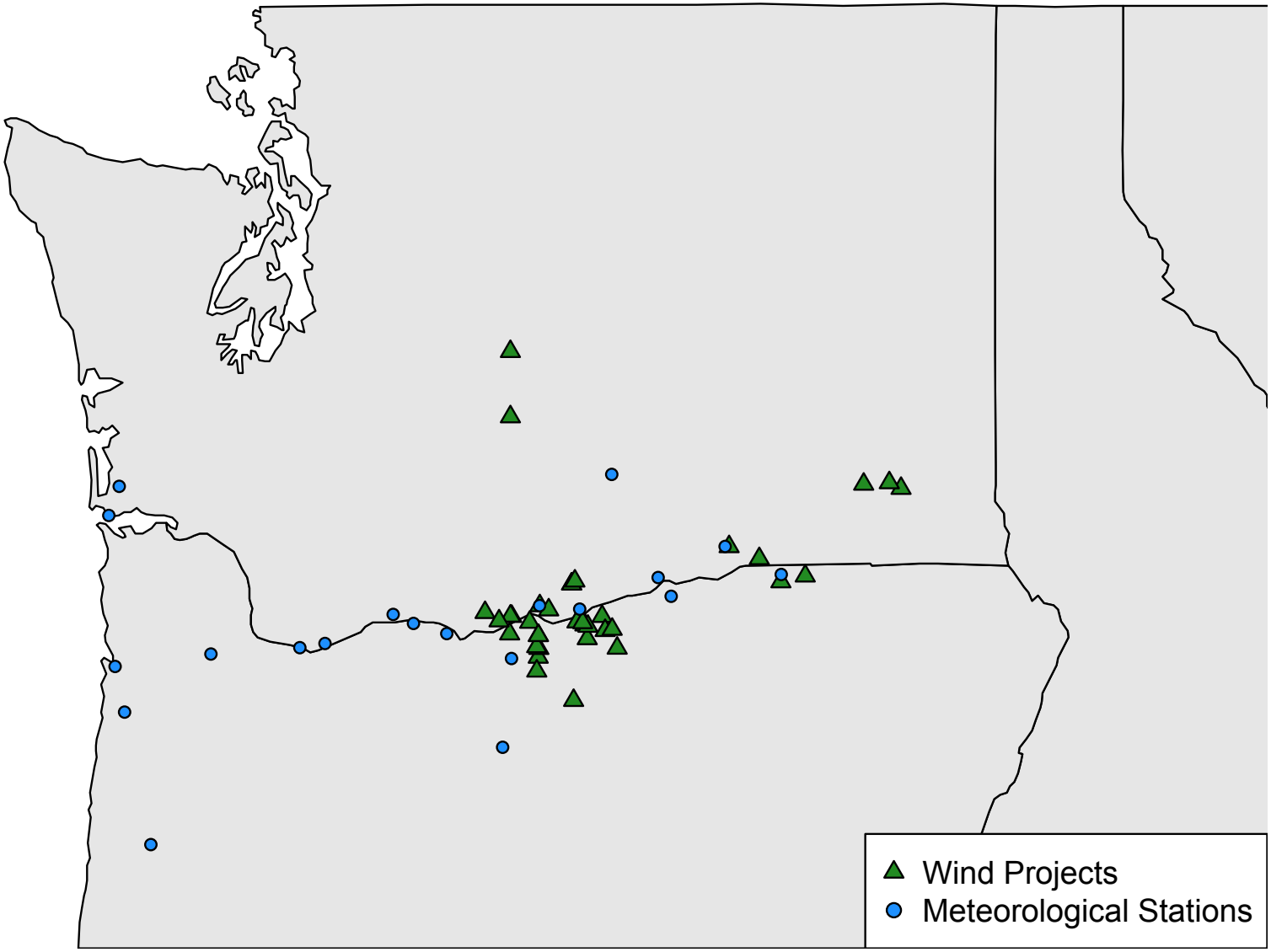
- Bonneville Power Administration (BPA) wind data
  - 33 wind projects in Washington and Oregon, mostly along the Columbia River
  - 20 meteorological towers, collecting weather data throughout the region
    - Not always co-located with wind projects, several towers have collections at multiple heights
- BPA purchases wind power forecasts from vendors
  - Forecasts issued for each individual wind project – mean value, plus upper and lower bound from ensemble runs
  - Forecasts are updated hourly and cover one week

Wind Project Locations

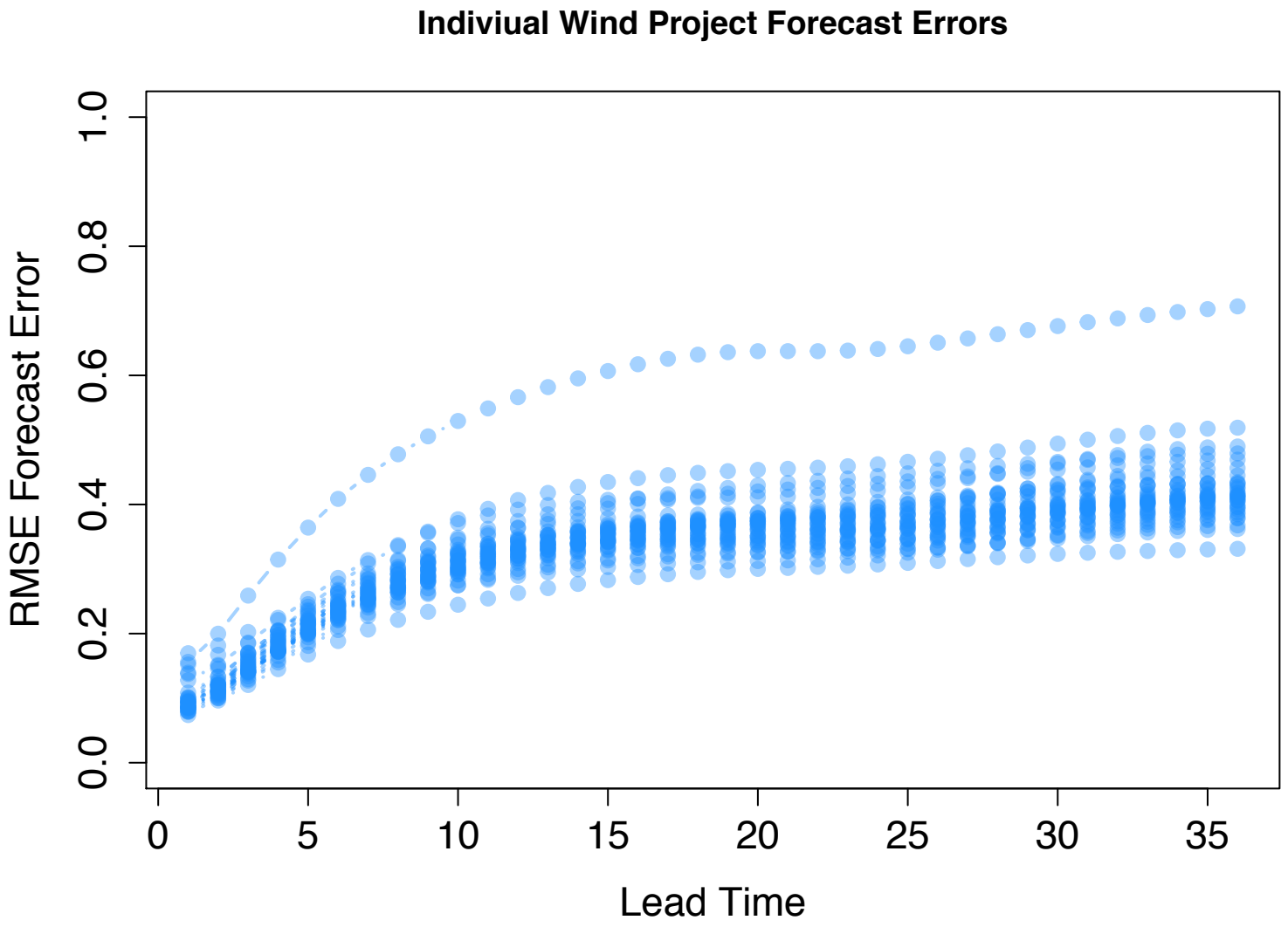
Sandia National Laboratories



Wind Projects and Met Towers



How Good are the Forecasts?



Research Questions

Sandia National Laboratories

- Can we improve ramp event predictions?

- What is the most promising approach?
  - Focus on individual projects and aggregate?
  - Assess aggregated wind data as a whole?
  - Improve forecasts generally?
    - Assume that ramps will be better predicted as a result?
  - Focus only on predicting occurrence of ramp events?
    - Requires a definition to define an event – could be limiting
    - Ramps occur for different reasons, we shouldn't group them without understanding the physical processes behind them

Attempts so Far

Sandia National Laboratories

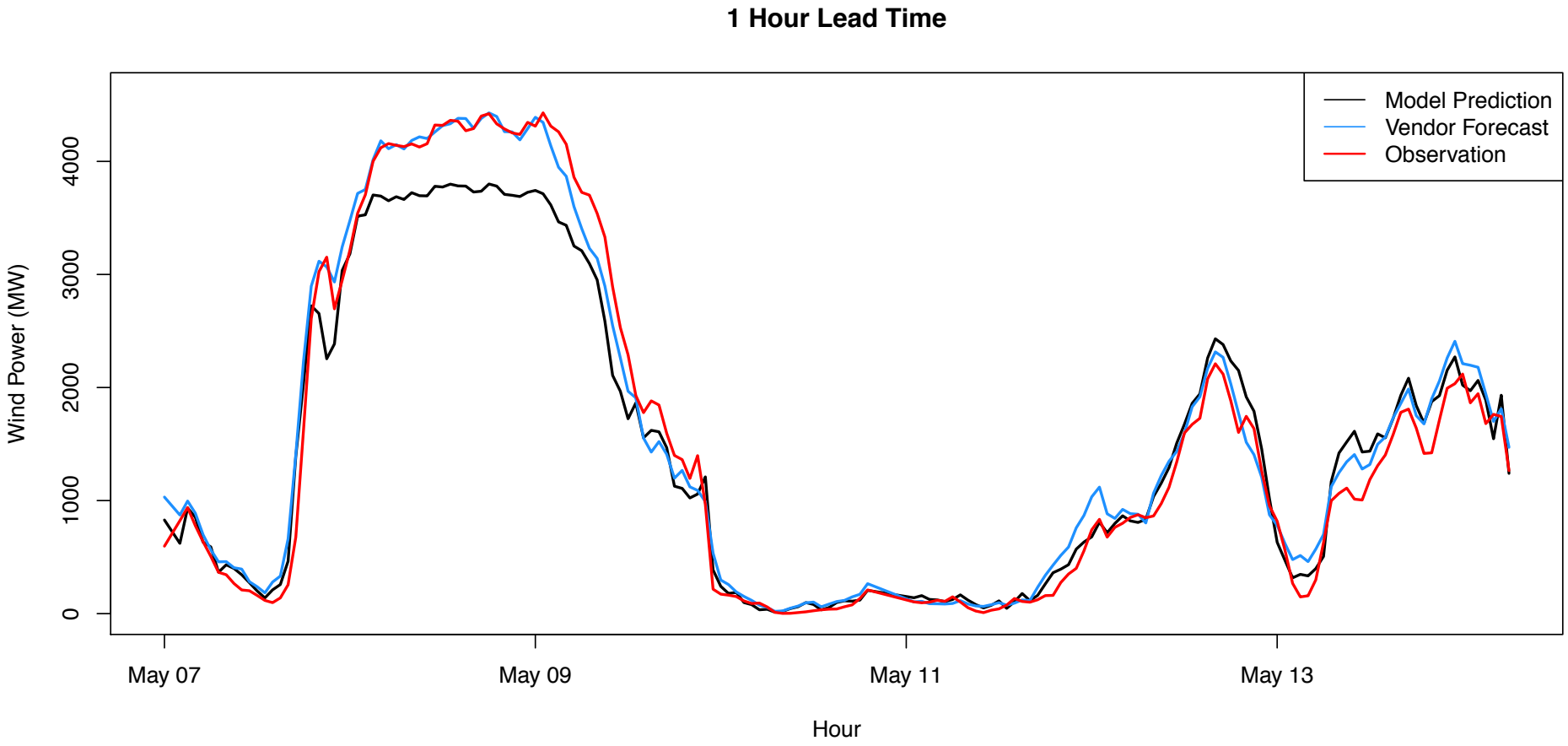
- Understanding physical processes
  - Large scale weather patterns
    - Are these indicative of forecast errors?
  - Relationships between individual wind sites and nearby met towers
    - Not very useful for wind sites without met towers nearby
- Study relationships in entire system
  - Correlations among wind sites, among met towers
  - Correlations across time
    - Potential for leading indicators?
  - Some interesting stuff, but no smoking guns
- Vendors are good, improvements are not easy
  - They capture physical processes better than I ever will
  - Is there room for improvement?

A Bit of Promise…

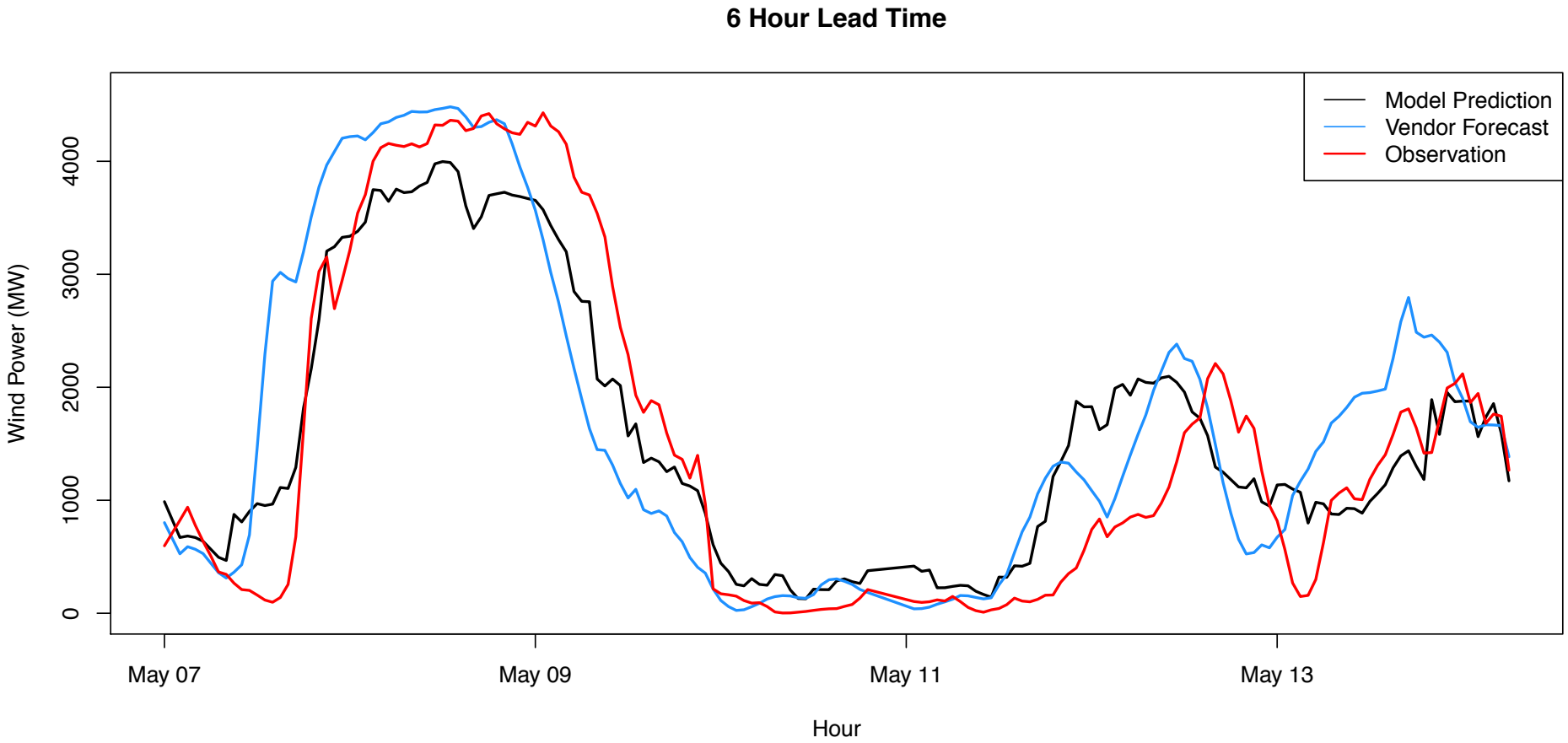
- Relationships are complex, difficult to model directly
- Instead use Non-Parametric methods: Neural Nets and Random Forests
- Tested models on dataset of all forecast data (mean, min, max per wind site) and met tower data for a given lead time
  - Tested a few variations, but more thorough evaluation needed*
  - Trained on first 60% of data, tested on remaining 40%
    - Only 1 year of data total, but BPA does not have strong seasonal variation/patterns
  - Looking at lead times from 1-12 hours
    - Improvements in this time period could directly influence operational decisions and reduce costs
  - High degree of collinearity, but ignoring for now for the sake of interpretability
- Random Forest model looked most promising

*Still in early stages, much left to do. Suggestions welcome!

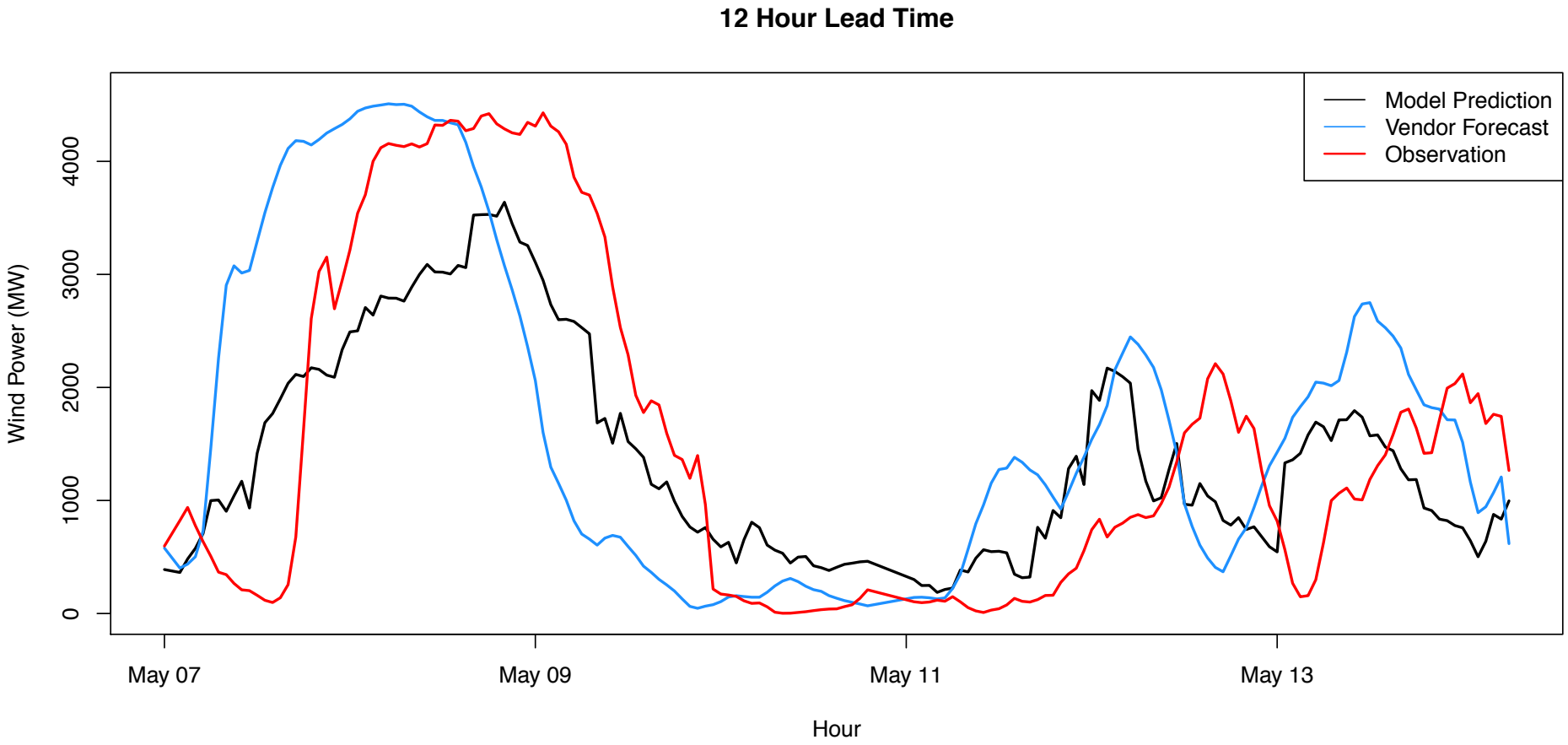
Model vs Vendor Forecasts



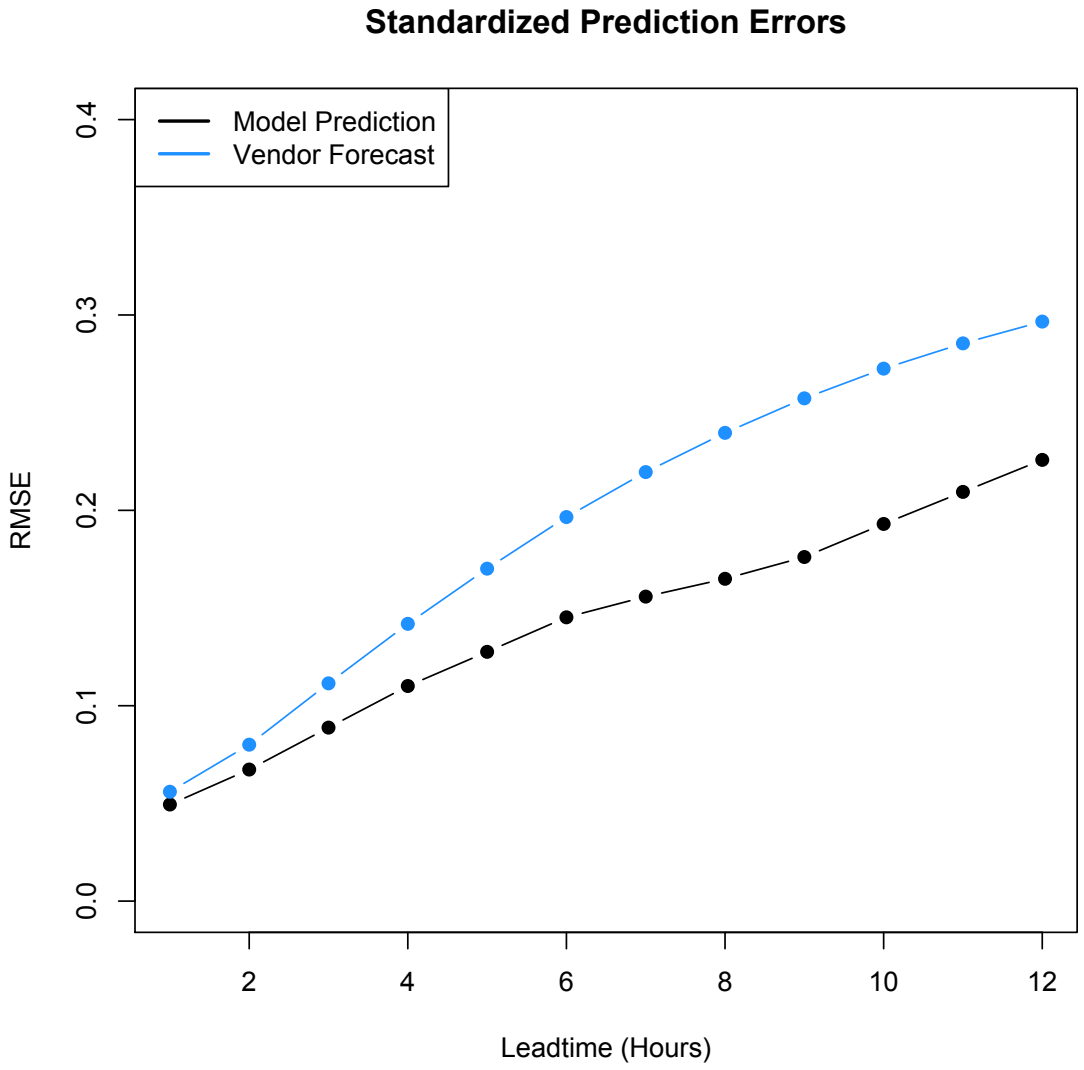
Model vs Vendor Forecasts



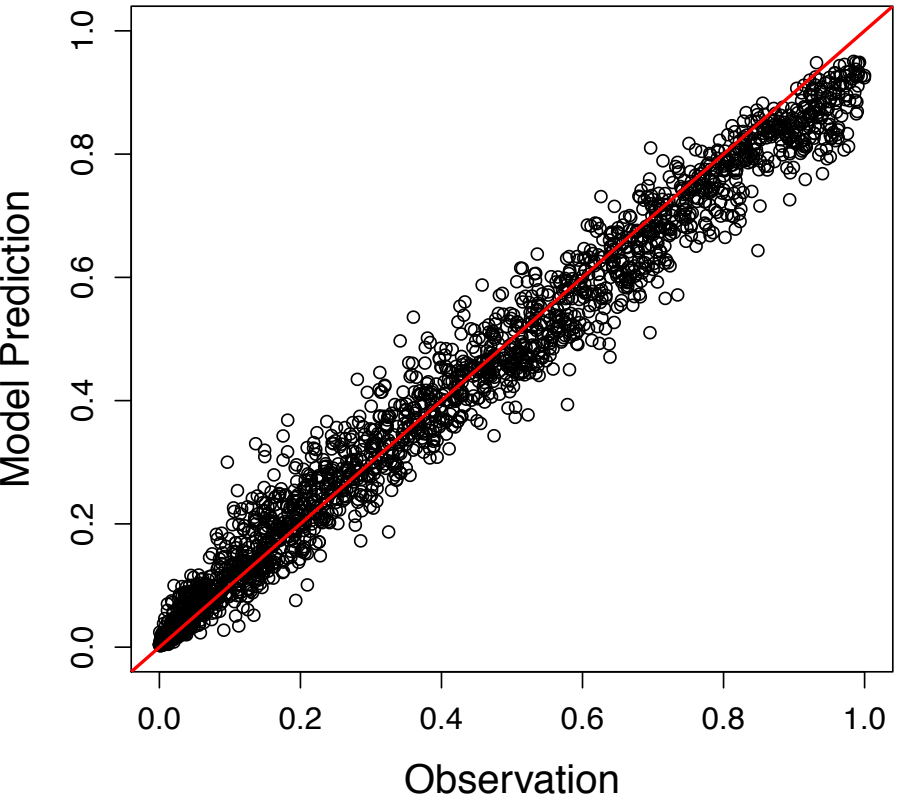
Model vs Vendor Forecasts

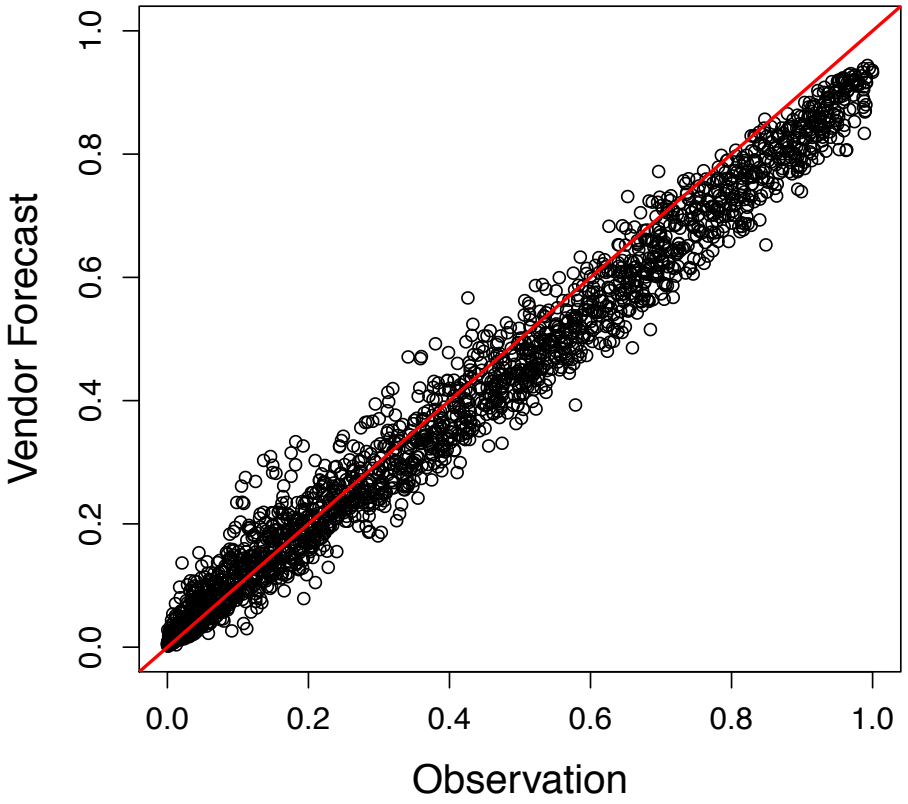


Normalized Prediction Errors

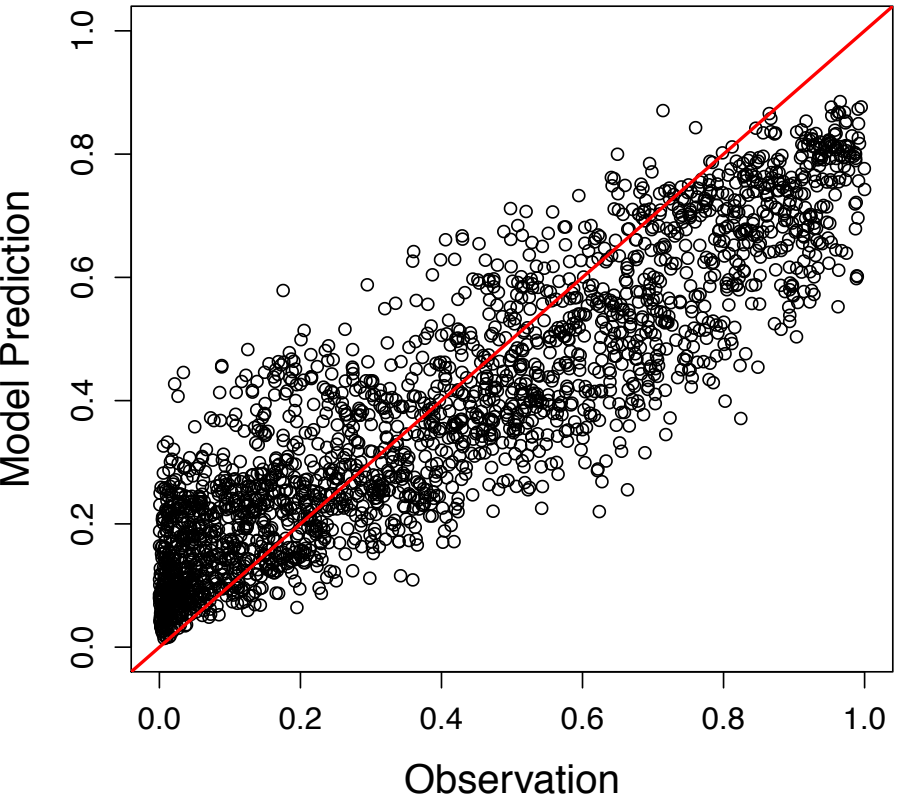


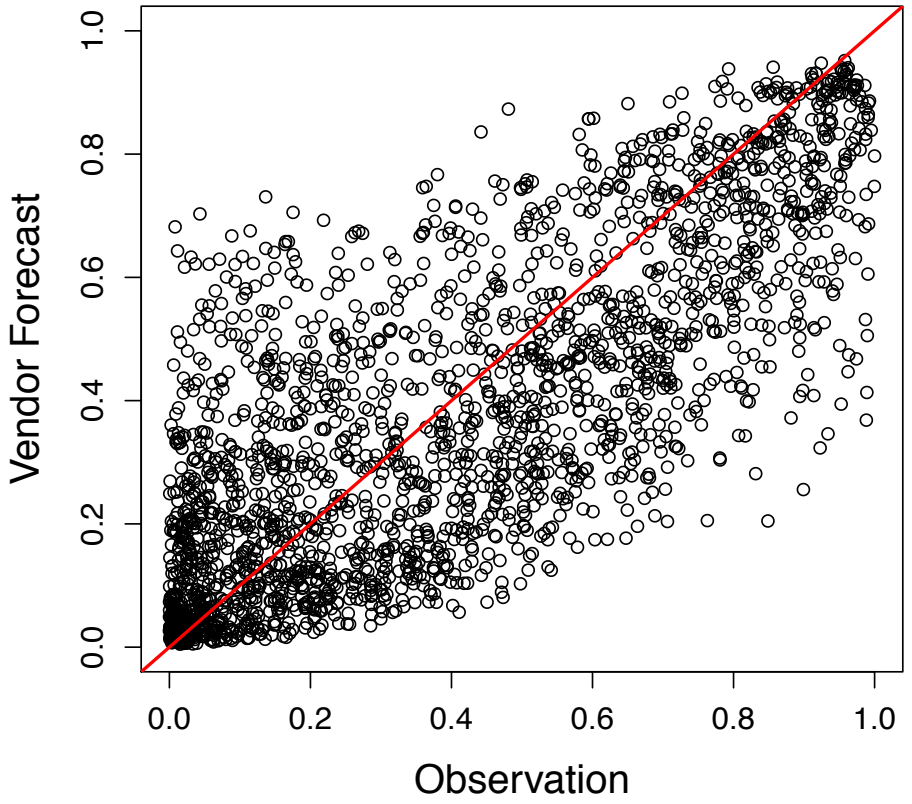
Individual Lead Time – 1 Hour





Individual Lead Time – 6 Hours

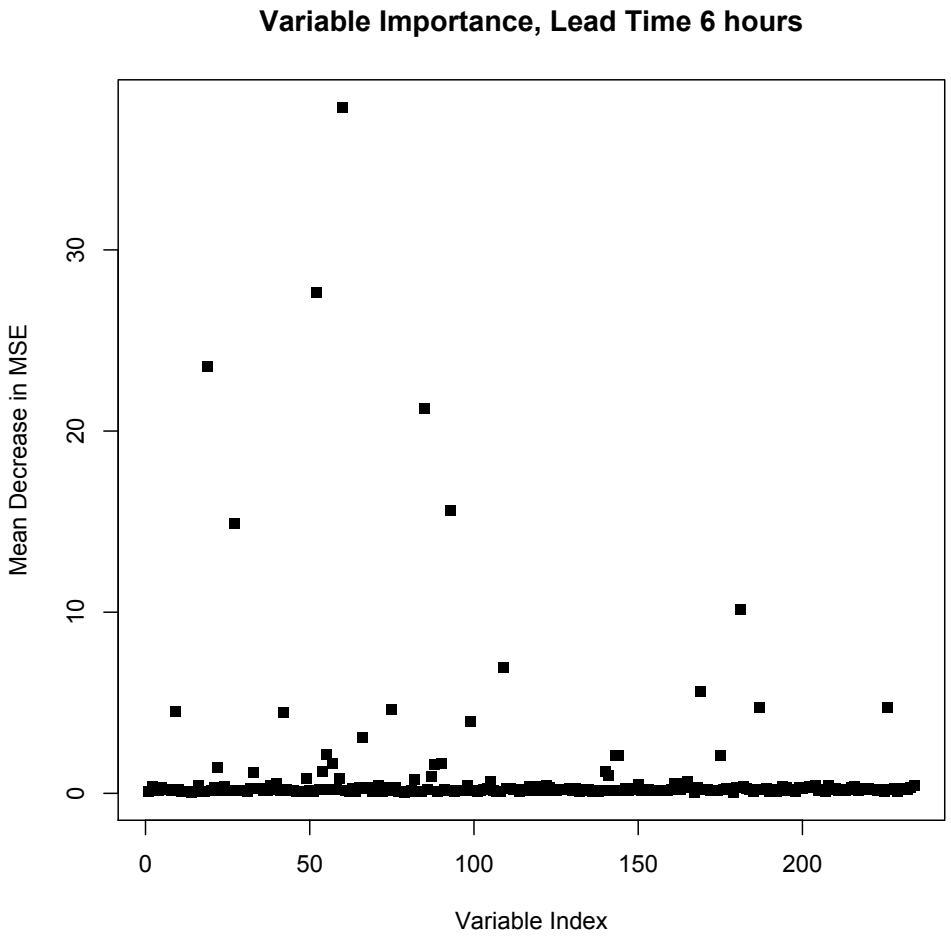




Variable Importance

- Are there bellweather wind sites?
- What is driving the improvement in forecast?

- Focusing on Importance Measures > 10:
  - Variables from only two wind sites appear – min, mean, and max values
    - Both have large capacities (but not the largest)
  - One met tower wind direction



Some Final Thoughts

Sandia National Laboratories

- More analysis needed to understand where the forecast improvements are coming from
- May lead to more insights that point to more promising focus areas
- While not predicting ramps specifically, aggregated models that incorporate all available forecast data result in lower errors
  - Benefit appears to come mostly in terms of phase-shift errors (as opposed to magnitude errors); These are likely more critical for operational planning

Questions?

Sandia National Laboratories

Contact:

Andrea Staid

astaid@sandia.gov