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Analysis and Prediction of Winds at the Wind Farms in Westcentral US: Modeling Tools and Challenges

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Accurate wind and severe-weather forecasts are crucial for wind-energy production and grid-load management. Most of the prevailing wind power forecast methods rely heavily on statistical approaches that typically do not deal directly with weather processes. Currently employed numerical weather prediction (NWP) models are deemed insufficiently accurate by many industry stakeholders for wind power prediction, even though they have been used for such applications. The reason is partly because the NWP products used for power forecasting are typically produced by the coarse-resolution models at the major operational weather centers. Although a few of high-resolution models are run by some wind energy industries, most of these model do not contain advanced data assimilation capabilities that are required to initialize the model prediction with the important high-resolution weather information.

In this presentation, we introduce the NCAR Real-Time Four Dimensional Data Assimilation (RTFDDA) and forecasting system that has been developed to specifically analyze and predict meteorological conditions over small regions. Operational RTFDDA systems have been implemented across the United States and other global regions to support tens of other weather-critical applications in the last nine years. The system provides rapidly updated, multi-scale weather analyses and forecasts with the fine-mesh domain having a 0.5 - 3 km grid increment. The presentation will focus on the modification and improvements to the NWP technologies in RTFDDA for wind energy applications. The technologies include the use of a) an advanced mesoscale weather model (WRF, Weather Research and Forecasting model) with a continuous 4-D data assimilation scheme, b) an effective data quality-control procedures that handles the ingestion of diverse weather data sources, c) special algorithms for the assimilation of wind-farm measurements including met-tower and turbine nacelle wind speeds, d) ensemble-based probabilistic data analysis and forecasting, e) a sophisticated land-surface model and land-surface data assimilation system, f) model nests from the synoptic scale to the intra-farm microscales, and g) advanced model post-processing for prediction-error correction and power-generation calibration.

These technologies are being utilized as part of a research and development partnership with Xcel Energy Services, Inc., which purchases power from wind farms across the US. Results for a large wind farm (with 274 wind turbines) in northern Colorado are analyzed in detail to illustrate the capabilities of each of the technologies described above. Inherent challenges in wind modeling and the predictability of intra-farm-scale weather processes and the high priority research directions for wind forecasting will also be discussed.