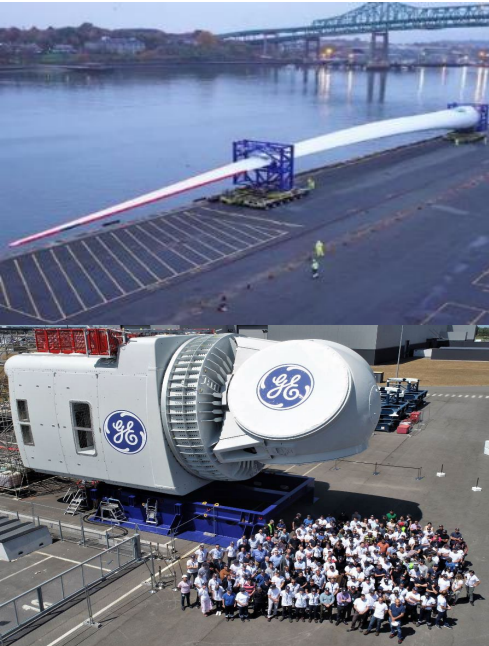# T15 – WFIP II Extended Analysis

Tech RD&T/Atmosphere to Electrons

Will Shaw

Pacific Northwest National Laboratory

4 August 2021

FY21 Peer Review - Project Overview

Project Summary:

- Extraction of further value from the rich data set collected during the second Wind Forecast Improvement Project (WFIP2)
    - Expansion of scope to analyze cloud impact on hub-height winds
    - Expansion of scope to analyze impacts of land surface models
    - Extension of prior WFIP2 work that developed a new 3D turbulence model
    - Dissemination of uncertainty quantification and verification and validation, including development of a community tool.
- Key project partners: ANL, LLNL, NREL, PNNL, NOAA

Project Start Year: FY19
Expected Completion Year: FY FY22
Total expected duration: 3 years

FY19 - FY20 Budget: $2.92M

Key Project Personnel: Will Shaw, PNNL; Rao Kotamarthi, ANL; Bobby Arthur, LLNL; Caroline Draxl, NREL; David Turner and James Wilczak, NOAA

Key DOE Personnel: Shannon Davis

Project Objective(s) 2019-2020:
- Evaluation and improvement in modeling boundary-layer turbulence and surface energy exchange
- Improved model treatment of cloud impacts on turbine-level winds
- Further improvement for modeling atmospheric horizontal variability
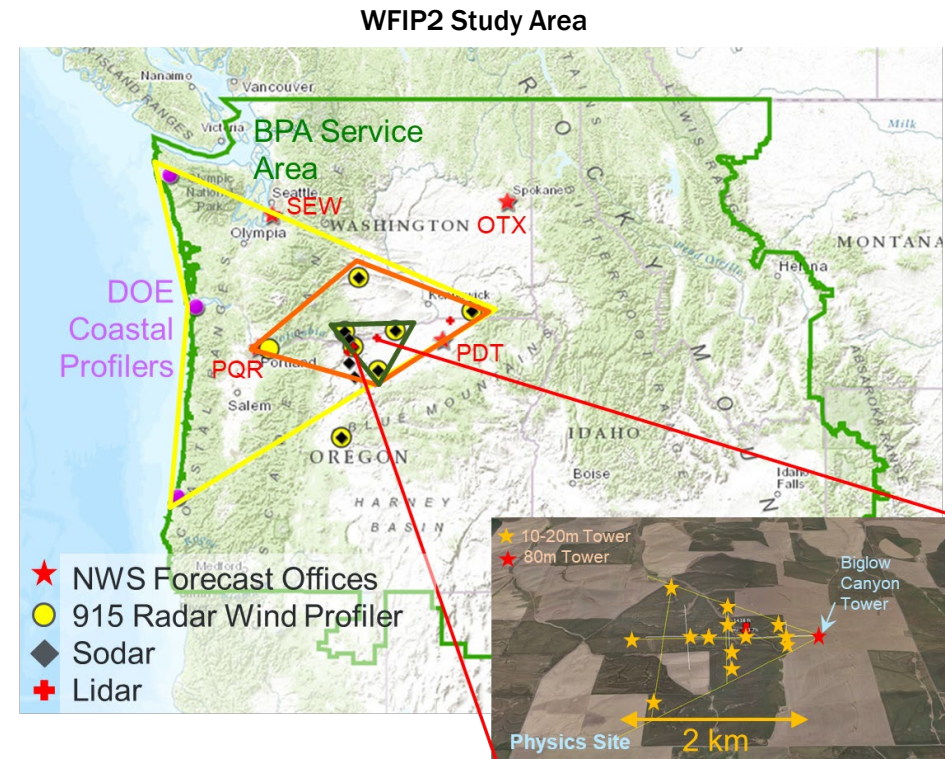- Application of systematic model verification and validation and quantfication of model uncertainties

Overall Project Objectives (life of project):
- To further improve the ability of numerical weather prediction models to accurately calculate winds at hub height in complicated environments

Project Impact

- **Anticipated Project Outcomes**
  - Substantially improved understanding of atmospheric physics affecting hub-height winds with fuller utilization of WFIP2 data set
  - Better numerical techniques for modeling in steep terrain
  - Significant extension of verification and validation formalism for improved forecast models
- **Benefits to the Wind Industry**
  - Advances in understanding will lead to better models
  - Model improvement will apply to widely used models
    - NOAA: High-Resolution Rapid Refresh (HRRR) for operational forecasting
    - Wind industry and research community: Weather Research and Forecasting (WRF)
  - Model validation methodology
    - Benchmark exercise will illustrate methodology
    - Validation tool will offer commonality of approach

WFIP2 Study Area

BPA Service Area

SEW
OTX
DOE Coastal Profilers
PQR
PDT

★ NWS Forecast Offices
🟡 915 Radar Wind Profiler
◆ Sodar
✚ Lidar

★ 10-20m Tower
★ 80m Tower
Biglow Canyon Tower
Physics Site
2 km

Program Performance – Scope, Schedule, Execution

FY2019 Execution (Project Start: April 1)

- Mountain wave report delivered
  - Basis of later data set for international forecast model validation exercise
- Extended analysis initiated under all four project objectives
  - Turbulence/surface exchange, cloud impacts, numerical methods, model validation
- Two journal articles published on WFIP2
- Milestones and progress measures
  - Annual report (milestone) provided to DOE on time
  - One cloud impacts project measure delayed

FY2020 Execution

- Data set delivered for forecast model validation
  - Data from mountain wave case; participants recruited from U.S. and Europe
  - A U.S. contribution to IEA Wind Task 36 on forecasting for wind energy
- Case studies selected
  - For turbulence, surface exchange, cloud impacts and model validations
- Three journal articles published on WFIP2 analyses
- Milestones and progress measures
  - Annual report (milestone) provided to DOE on time; cloud progress measure delayed for technical issues

Project Management

- Multi-lab project with ANL, LLNL, PNNL, and NREL in active collaboration with NOAA
- Management occurs primarily through biweekly team calls and shared cloud drive
  - Calls include both management and technical discussions

Power Impacts of Gravity Waves
- WRF simulation (right) of winds at 100 m above ground. Color scale is wind speed, vectors are direction.
- Observations from wind turbine (above) of wind speed (black, solid) and power (red) for the same time period

Location
- Columbia Basin of eastern Oregon
- Symbols, left side north to south: Mt. Hood, Mt. Jefferson, Sisters/Broken Top in Cascades
- Symbols, right side north to south: Wasco, OR and Prineville, OR

Program Performance – Accomplishments & Progress

Truly Horizontal Gradients in Complex Terrain

- Forecast model (WRF) uses terrain-following coordinates (right)
- In steep terrain this complicates calculation of truly horizontal gradients, forcing crossing of vertical levels
- Lower figure shows the maximum number of vertical levels that must be crossed to obtain truly horizontal gradient

Impact of Truly Horizontal Gradients

- Reduction of vertical mixing in cold pool events
- 20% reduction in near-surface wind speed bias compared to observations

Program Performance – Accomplishments & Progress

HRRR Improvement
- Version 3 (2018, bottom) vs. Version 4 (2020, top)
- Later version has WFIP2 improvements

Location: north-central OK
- Improvements in Columbia Basin should not break the model elsewhere

Down Ramp at Day 11.5
- Observations in black
- HRRR v.3 mostly misses, with only 6-hr and 12-hr forecasts seeing the ramp
- HRRR v.4 much more accurate out to 24 hr

Project Performance - Upcoming Activities

- **IEA Wind Task 36**
  - Application of verification and validation formalism to benchmark using WFIP2 case
  - Python tool developed as community resource for validation

- **Additional Evaluation**
  - 3D PBL parameterization
  - Numerical methods
  - Potential additions to NOAA models

- **Cloud Impacts**
  - Resumption of schedule for this analysis

- **Model Sensitivities to Land Surface Module**
  - Continuation of analysis underway

- **Communication of Findings**
  - Five journal articles published since FY20
  - Additional manuscripts in preparation

The Verification and Validation Strategy Within the Second Wind Forecast Improvement Project (WFIP 2)

Caroline Draxl,[1] L. K. Berg,[2] L. Bianco,[3] T. A. Bonin,[3,8] A. Choukulkar,[3,8] A. Clifton,[4] J. W. Cline,[5] I. V. Djalalova,[3,8] V. Ghate,[7] E. P. Grimit,[6] K. Holub,[3] J. S. Kenyon,[3,8] K. Lantz,[3,8] C. Long,[3] J. K. Lundquist,[1,9] J. McCaa,[6] K. McCaffrey,[3,8] J. F. Newman,[10] J. B. Olson,[3,8] Y. Pichugina,[3,8] J. Sharp,[11] W. J. Shaw,[2] N. H. Smith,[12] and M. D. Toy[3,8]

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11 Sharply Focused, LLC
12 Texas Tech University

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Technical Report
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This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

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Stakeholder Engagement & Information Sharing

- **Stakeholder Engagement**
  - Professional meetings, such as those of the Energy Systems Integration Group and American Clean Power
  - Technical meetings, such as those of the American Meteorological Society, the North American Wind Energy Academy, and the European Wind Energy Academy

- **Information Sharing**
  - Numerous conference presentations
  - Publications in peer-reviewed journals
  - Algorithm transfer to NOAA for code improvements that, if successful, appear in subsequent NOAA operational forecast models
  - Transfer of significant derived data products to the Data Archive and Portal to become part of the overall WFIP2 data archive