



Validation of Numerical Model Improvements through Public Data Sets and Code

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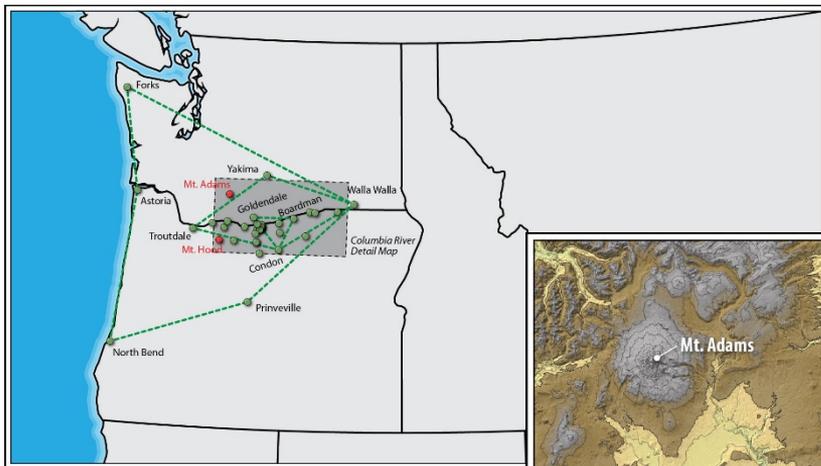
Virtual Wind Integration Workshop, November 11–12, 2020



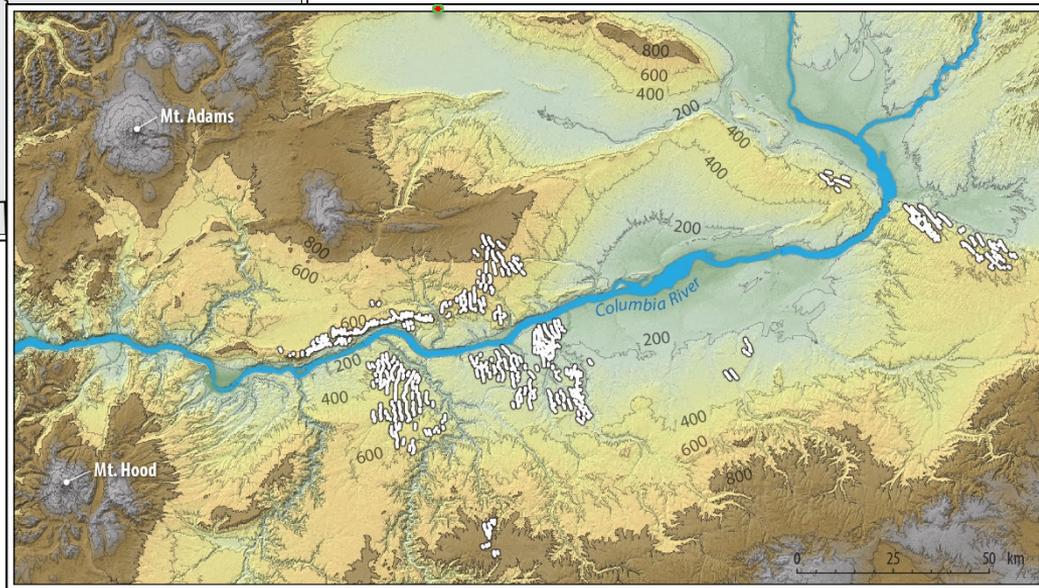
Content

- Verification and Validation (V&V) process of the Second Wind Forecast Improvement Project (WFIP2)
- Introduction to a validation framework developed for IEA Wind Task 36 (Subtask 1.3)
- Solicit feedback regarding:
 - Dissemination of framework
 - Approach, case selection, and usefulness
 - Engaging partners in this effort.

Improve Wind Speed Forecasts in the Turbine Rotor Layer in Complex Terrain



Maps by Billy Roberts, NREL



WFIP2 Verification and Validation Goals

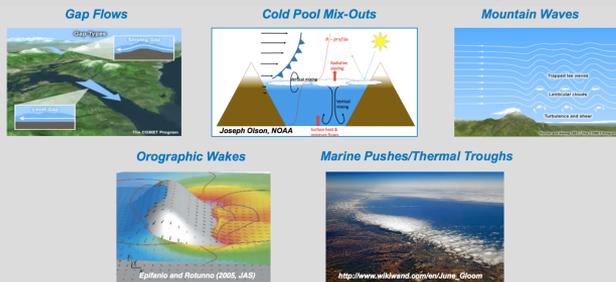
Provide tools, methods, and guidance to enable **repeatable, metrics-based assessment** of Weather Research and Forecasting (WRF) and High-Resolution Rapid Refresh (HRRR) models for analysis and forecasting of **mesoscale weather phenomena that are important for wind energy** in the Columbia River Gorge and the continental United States.

Verification: Verification is concerned with checking the mechanics of the software code rather than checking that the model's physics are correct.

Validation: Validation is determining the degree to which the model represents the real world for a particular application.

Validation Approach

WFIP2 weather taxonomy:



Event log

Key variables and metrics:

- 80-m wind speed
- Wind power
- Bulk rotor layer statistics (RMSE, bias, MAE, percentage improvement)
- Wind ramp metric.

Regular V&V meetings to discuss and coordinate results

Experiment to Model Analysis Table (EMAT):

- What, where, when?
- What are the dominant physics?
- How do we see this in measurements?
- What are the metrics we should use?

Workshops to compare validation results and test EVS tool

Common case study data set to test validation code

Validation tool and database:



Verification and Validation Summary and Conclusion



Publications



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. Gritmit,⁹ K. Holub,² J. S. Kenyon,^{3,8} K. Lantz,^{3,8} C. Long,³ J. K. Lundquist,^{1,8} J. McCaa,⁴ K. McCaffrey,¹⁰ 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^{1,8}

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Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC
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Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08G028308

Technical Report
NREL/TP-5000-72563
November 2019

Olson, J. B., and Coauthors, 2019: Improving Wind Energy Forecasting through Numerical Weather Prediction Model Development. *Bull. Amer. Meteor. Soc.*, **100**, 2201–2220,
<https://doi.org/10.1175/BAMS-D-18-0040.1>.

William L. Oberkamp and Christopher J. Roy. 2010. *Verification and Validation in Scientific Computing* (1st. ed.). Cambridge University Press, USA.

Public Validation Code

Experience:

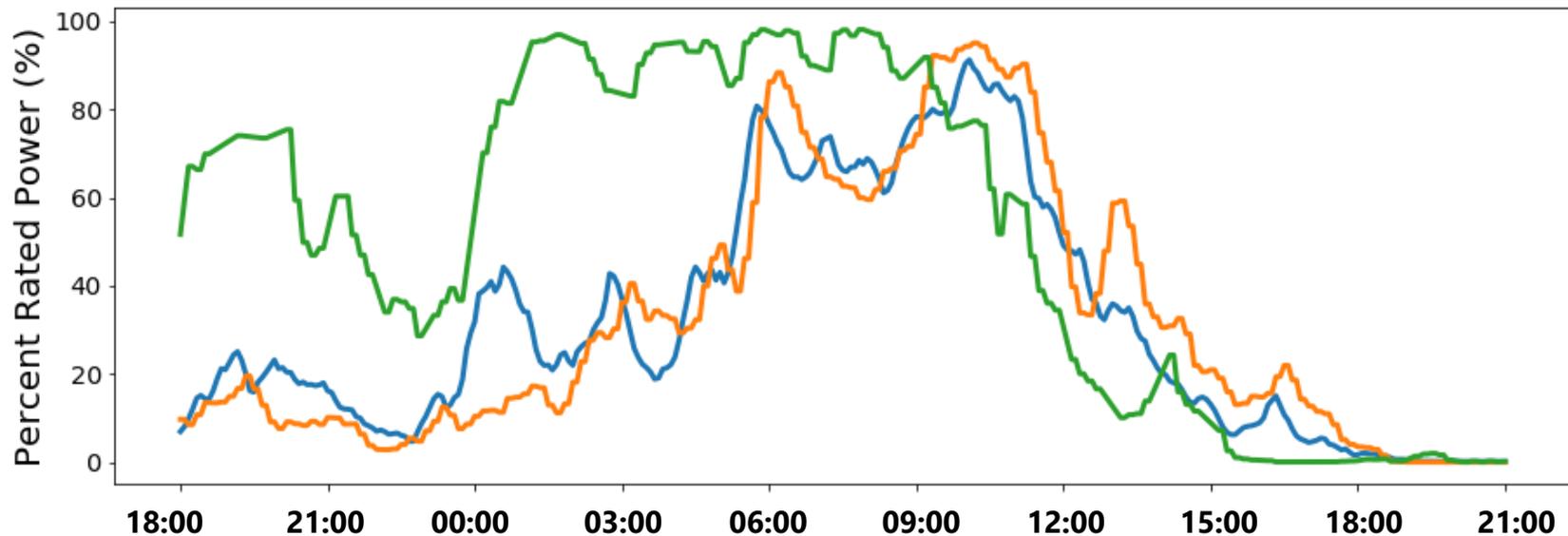
We tested a case study in WFIP2:

- We provided a model time series with hourly time stamps.
- We told the group the observation location and where to find the observations.
- Everyone used their own scripts to calculate root mean square error (RMSE) and bias.
- Results were provided.
- Different results were obtained because of wrong interpretations of the time stamp.
- And different averaging techniques were used in the horizontal and vertical.

Proposed validation framework:

- Offer a code that can be used by anyone.
- Use data from simulations and observations and use phenomena that are relevant for wind energy.
- Ensure that data are freely available.
- Can be reproduced (use WRF model), but it is also extendable for other NWP model output.
- Evaluate improvement: Provide two model simulations and observations.
- Document the case in the literature.

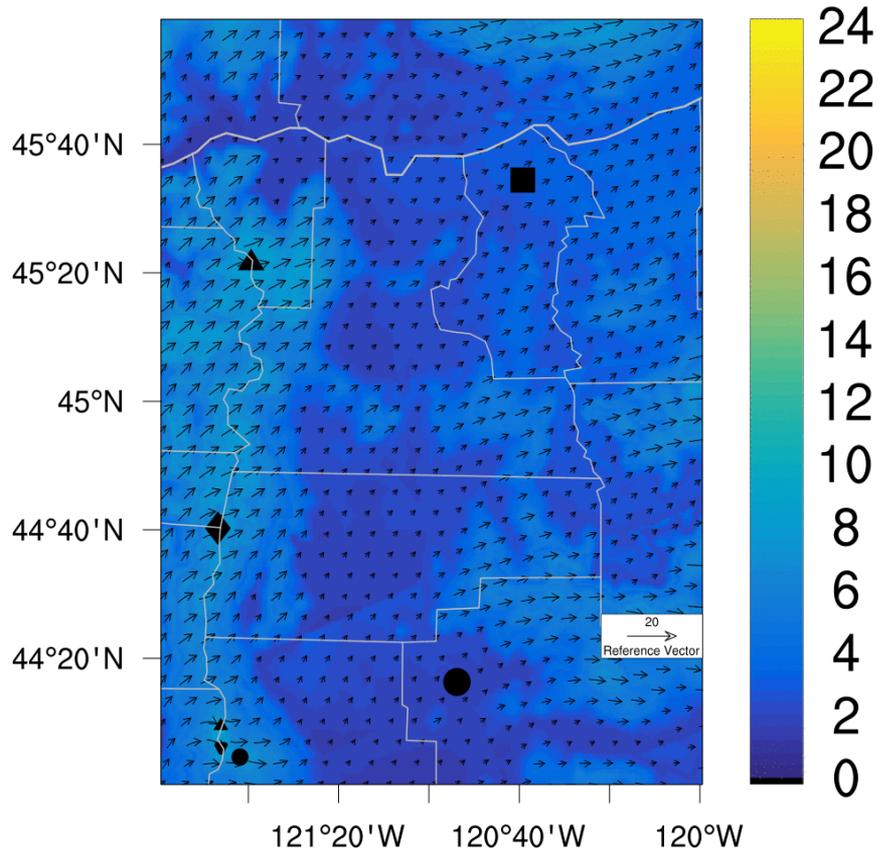
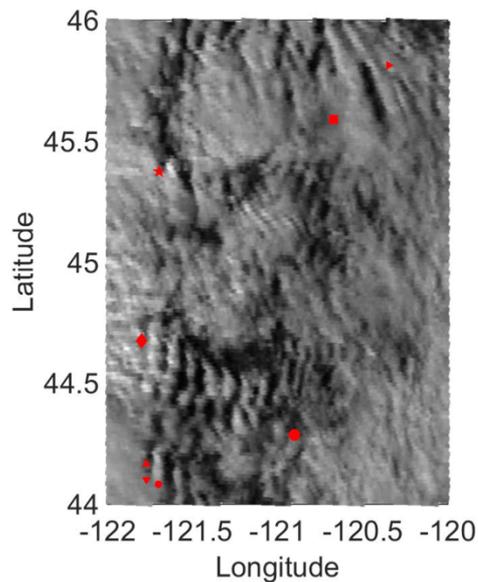
Fluctuations in Power Output from Wind Power Plants



Simulated Waves

Init: 2016-09-23_12:00:00

Valid: 2016-09-23_12:00:00



Draxl, C., et al, Mountain waves impact wind power generation, *Wind Energ. Sci. Discuss.*, <https://doi.org/10.5194/wes-2020-77>, in review, 2020.

iValidate

- 1) Install Python 3
- 2) Clone GitHub repository to your machine.
- 3) Edit config.yaml
- 4) Put data sets in the specified path.
- 5) Run.

<https://github.com/joejoeyjoseph/nwtc-ivalidate/tree/dev>

joejoeyjoseph add trimmed wrf data		56e268b 7 days ago	🕒 History
..			
ex1	Add example data (oof---big)	4 years ago	
ex2	Add example data (oof---big)	4 years ago	
mw_data_sodar	add sodar data	7 days ago	
mw_data_wrf	add trimmed wrf data	7 days ago	

Directory where your data live

Directory with scripts that extract data
(e.g., WRF; can be changed to your data set)

Directory with scripts that calculate metrics

Directory with scripts that perform
quality control

Join GitHub today
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[Sign up](#)

🔗 dev 2 branches 0 tags [Go to file](#) [Code](#)

This branch is 22 commits ahead of somerandomsequence:master. [Pull request](#) [Compare](#)

joejoeyjoseph add sodar py file		47f6b2f 7 days ago	🕒 43 commits
data	add trimmed wrf data	7 days ago	
inputs	add sodar py file	7 days ago	
metrics	add wrf vs sodar mw case	4 months ago	
notebooks	update nb	7 days ago	
plotting	validate at different heights	4 months ago	
prepare	add wrf vs sodar mw case	4 months ago	
.gitignore	add gitignore	5 months ago	
README.md	Update docs	4 years ago	
TODO.md	Separate file for todo	4 years ago	
compare.py	validate at different heights	4 months ago	
config.yaml	add comments in yaml	3 months ago	
i-validate_user_guide_2020-07.pdf	add user guide	3 months ago	
output.json	debug compare.py	5 months ago	
requirements.txt	add requirements.txt	3 months ago	

Metrics Directory

dev - nwtc-ivalidate / metrics /

Go to file

This branch is 22 commits ahead of somerandomsequence:master.

[Pull request](#) [Compare](#)

 **joejoeyjoseph** add wrf vs sodar mw case

25e99fb on Jun 17 [History](#)

..		
 README.md	Update docs	4 years ago
 __init__.py	Initial version	5 years ago
 bias.py	add wrf vs sodar mw case	4 months ago
 bias_pct.py	add other metrics	5 months ago
 mae.py	add demo nb	5 months ago
 mae_pct.py	add other metrics	5 months ago
 rmse.py	add other metrics	5 months ago

README.md

Metrics

This directory contains algorithms to compute timeseries comparison metrics.

To add your own, simply copy an existing file or use this interface (template):

```
# foobarbaz.py
#
# The best metric.
#
# Your Name <your.name@someplace.gov>

class foobarbaz:

    # This function takes two datetime-indexed pandas dataframes as input
    # and returns a single float value
    def compute(self,x,y):
        return None
```

Prepare Directory: Quality Control

Branch: master ▾ nwtc-ivalidate / prepare / Create new file Find file History

Caleb Phillips Update docs Latest commit fc88d8f on Jun 9, 2016

..

 README.md	Update docs	11 months ago
 __init__.py	Rename qa/qc to prepare	11 months ago
 linear_interp.py	Implement and test time windowing and trimming	11 months ago
 trim.py	Convert the internal format from list of tuples to pandas dataframe	11 months ago

 README.md

Preprocessing

This directory contains quality assurance and quality control (QA/QC algorithms), including outlier detection and cleaning as well as interpolation and other pre-processing routines.

To add your own, simply copy an existing file or use this interface (template):

```
# foobarbaz.py
#
# Translate the data somehow.
#
# Your Name <your.name@someplace.gov>

class foobarbaz:

    # Do something with the given configuration
    def __init__(self,config):
        self.config = config

    # Input & output is a datetime-indexed pandas dataframe
    def apply(ts):
        return ts
```

Config.yaml:

Defines what you would like to compute

```
python compare.py  
config.yaml > output.json
```

Grid point/
location

QC criteria

Time series

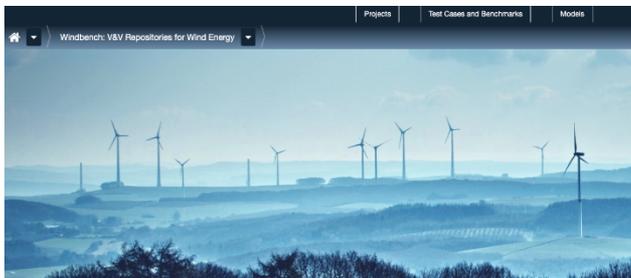
Which metrics
should be computed

Basic data set 1

Data set 2 to which
data set 1 is compared

```
58 lines (52 sloc) | 1.11 KB  
1 # validation location  
2 location:  
3 # latitude and longitude in degrees  
4 lat: 45.57451  
5 lon: -120.74734  
6  
7 prepare:  
8 # align the length of validation period of two data sets  
9 - trim:  
10   lower: -1000.0  
11   upper: 1000.0  
12 - linear_interp:  
13   #n: 23  
14   # resolution of input data  
15   period: 300 # every 300 second, according to WRF output's 5-minute resolution  
16  
17 time:  
18 window:  
19 # validation period start time  
20 lower: 2016-09-23 12:00:00  
21 # validation period end time  
22 upper: 2016-09-25 12:00:00  
23 trim: left # can be left or right  
24  
25 # validation metrics to be calculated and plotted  
26 metrics:  
27 - rmse  
28 - bias  
29 - bias_pct  
30 - mae  
31 - mae_pct  
32  
33 levels:  
34 # height level of validation above ground level  
35 height_agl:  
36 - 40  
37 - 80  
38 - 120  
39  
40 # "truth" data input  
41 left:  
42 name: sodar  
43 # data directory  
44 path: data/mw_data_sodar  
45 format: sodar_netcdf  
46 # variables to validate  
47 var: wind_speed  
48  
49 # data input to be compared with the "truth" data input  
50 right:  
51 - name: wrf  
52 # data directory  
53 path: data/mw_data_wrf  
54 format: wrf_netcdf  
55 # variables to validate  
56 var:  
57 - u  
58 - v
```

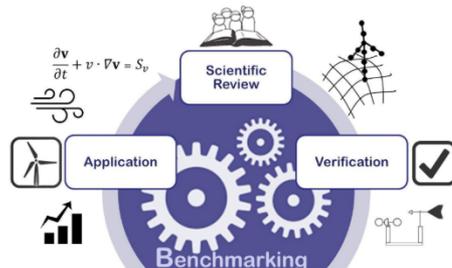
Collaborations and Synergies



Windbench: V&V Repositories for Wind Energy

The WINDBENCH verification and validation (V&V) platform is developed to guide wind energy model developers and end-users on best practices for the evaluation of models. To this end, the platform offers an updated inventory of models, a repository of quality checked test cases for model evaluation and documentation to orient the user. Best practice guidelines are built from model intercomparison benchmarks with different levels of complexity.

V&V benchmarks are typically developed in the frame of a research project. Windbench offers hosting for a project space from which test case (experiment description) and benchmark (model intercomparison) instances are produced. Contents in windbench can be open-access or restricted by access control ruled by an associated manager.



IEA Wind Task 31 Wakebench

The screenshot shows the **SOLAR FORECAST ARBITRATOR** website dashboard. The navigation bar includes: Key Topics, About, Publications, Stakeholder Committee, Email List, Blog, Documentation, and Dashboard. The main content area is titled **Solar Forecast Arbitrator** and features a central hub with several interconnected nodes and data visualizations:

- Standardized Objective Open source** (connected to GitHub)
- Safe, secure, private Data rights management**
- Stakeholder Informed**
- Graphical reporting Automated workflow**
- Many-vendor Trial Anonymization Realtime and retroactive**
- Data quality control Reference data & forecasts**
- Deterministic, Event Probabilistic**
- Solar Forecast Arbitrator API**

The dashboard also displays various charts and graphs, including a bar chart for 'Table Mountain Boulder CO Current Day NAEI gWh MBE', a line graph for 'Observed (2016-2022)', and a scatter plot for 'Solar Resource Boulder CO'. A 'Share with collaborators' dialog box is visible in the top left corner.

The Solar Forecast Arbitrator is an open source tool to enable evaluations of solar irradiance, solar power, and net-load forecasts that are impartial, repeatable and auditable. The Solar Forecast Arbitrator supports the [U.S. Department of Energy Solar Energy Technologies Office Solar Forecasting 2](#) program and the broader solar forecast community. Please [sign up for the mailing list](#) to receive quarterly project updates.

See the [funding page](#) for more information on the project's DOE SETO funding.

We continue to seek members of the solar forecast community to provide guidance on project development. Please see our [Stakeholder Committee](#) page for more information on how you can join the committee and help guide the project development.

This project page contains reference materials describing project use cases, metrics, reference data, and more under the Key Topics menu. Visit the [Solar Forecast Arbitrator Dashboard](#) to browse data and evaluate forecasts. Documentation is available under the Documentation menu.

We Need Your Input!

We propose a validation framework that is reproducible, can be adapted by many users, includes metrics that are state of the art and stakeholder focused, can be extended, can be used for any numerical model output, and is freely available.

- Is this tool useful?
- What applications would you use it for?
- Is it straightforward to use? Which issues did you run into?
- Are there any applications that you would need it for that it currently cannot address?
- Which additional metrics would you want to see in this tool?
- Would you use the tool in the future with the additional metrics? Why, why not?
- How should we disseminate it?

Messner, JW, Pinson, P, Browell, J, Bjerregård, MB, Schicker, I. Evaluation of wind power forecasts—An up-to-date view. *Wind Energy*. 2020; 23: 1461– 1481.

<https://doi.org/10.1002/we.2497>



iea wind

www.IEAWindForecasting.dk

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The IEA Wind TCP agreement, also known as the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of IEA Wind do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

THANK YOU!