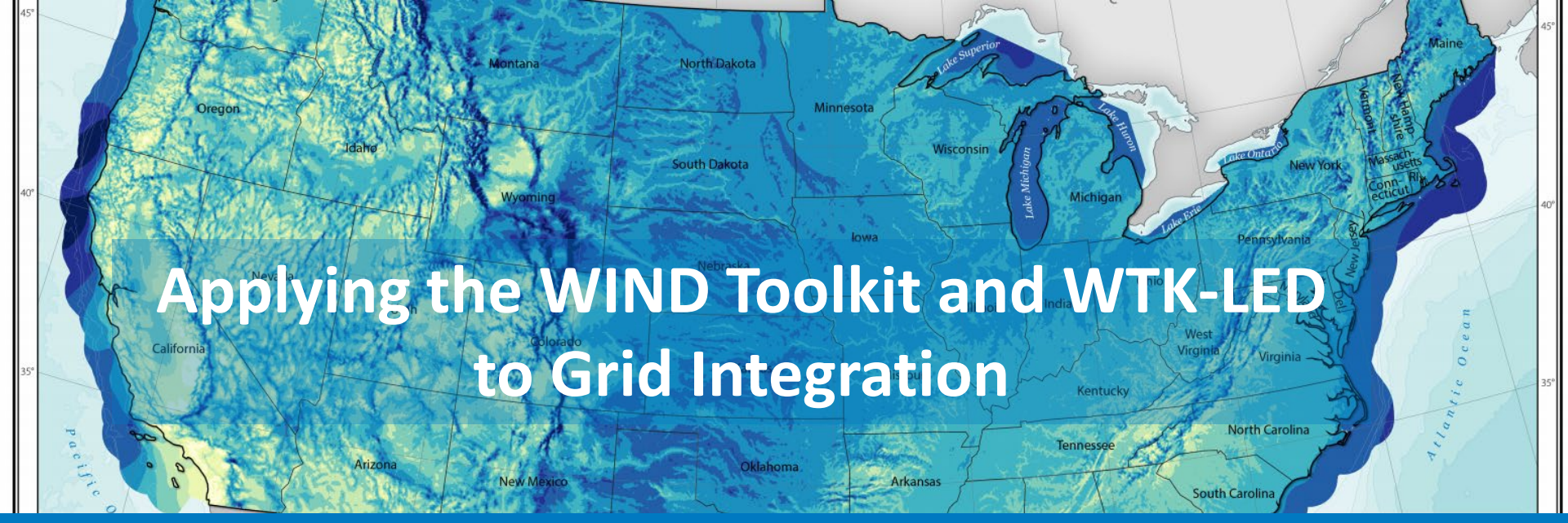

Applying the WIND Toolkit and WTK-LED to Grid Integration

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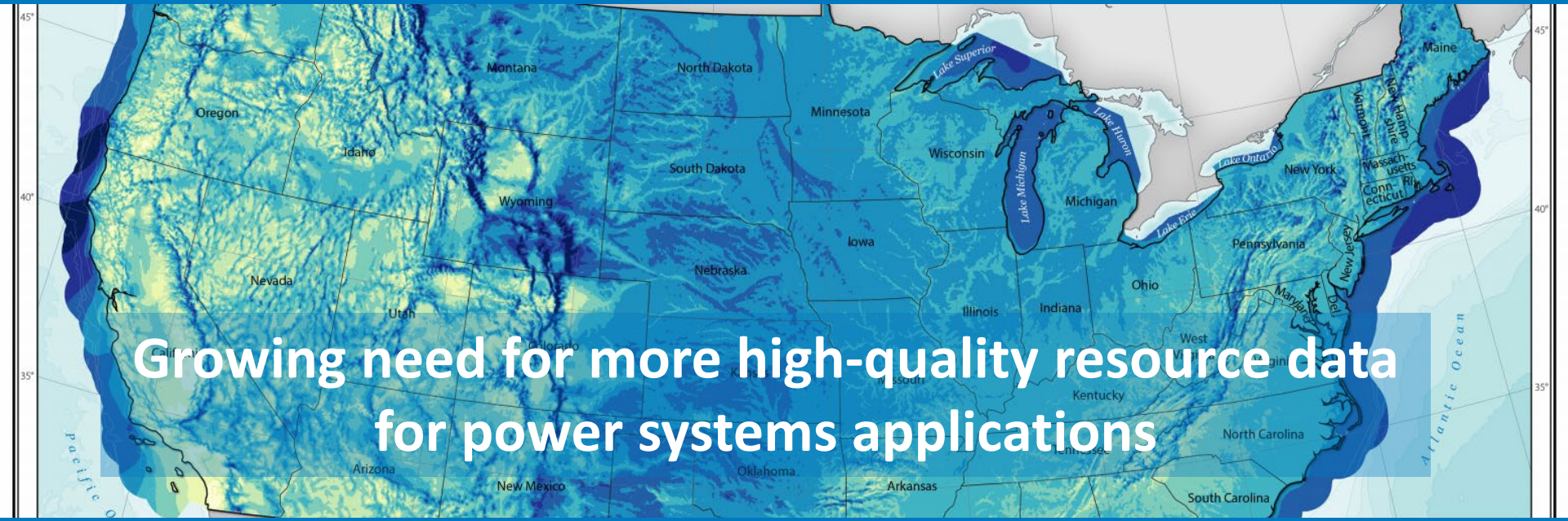
Caroline Draxl
Greg Brinkman

National Renewable Energy Laboratory (NREL)

June 11, 2024

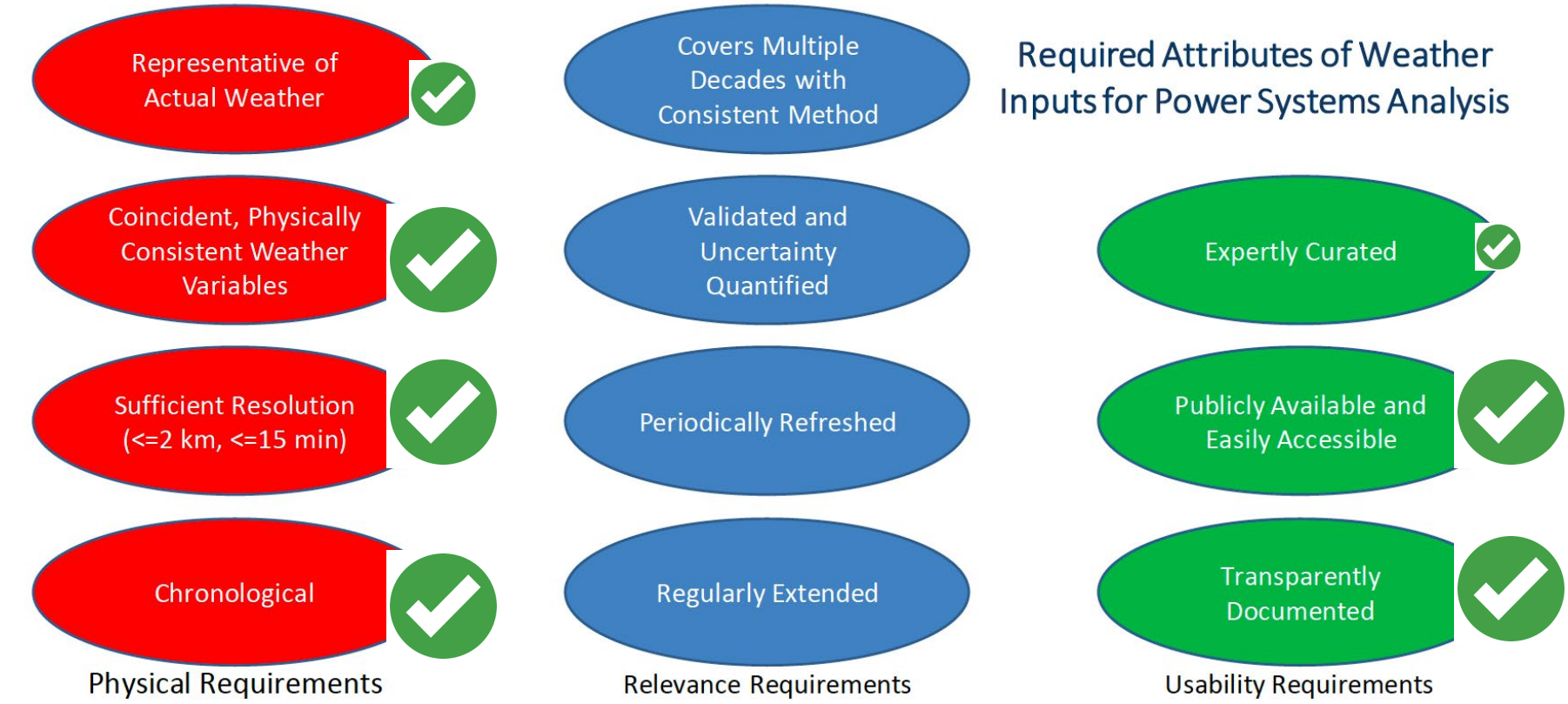
NREL
Transforming ENERGY

With thanks to
Trieu Mai
Dave Corbus
Grant Buster
Becca Fuchs
Victor Igwe
And our March 2024 workshop participants!



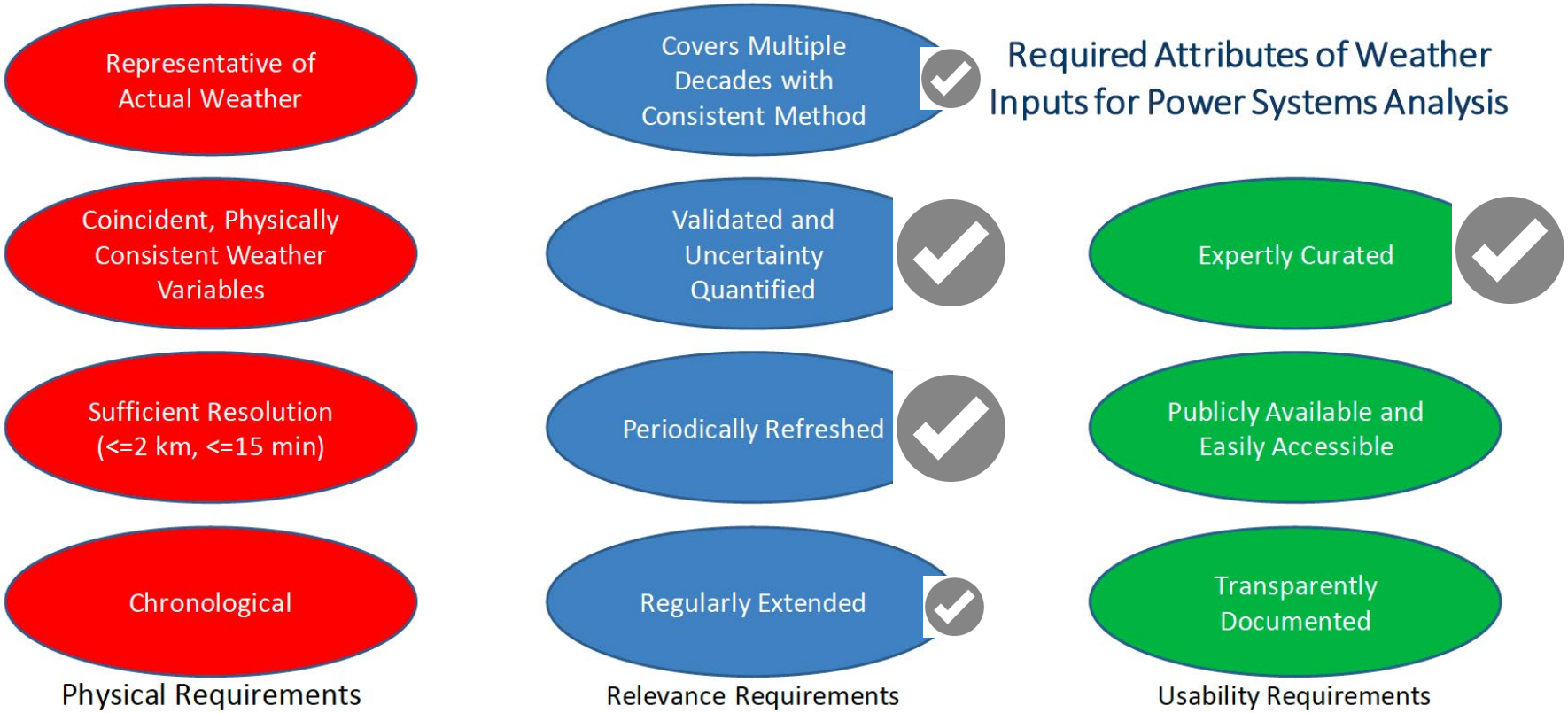
Growing need for more high-quality resource data for power systems applications

New WIND Toolkit Long-Term Ensemble Dataset covers many physical and usability requirements for grid integration

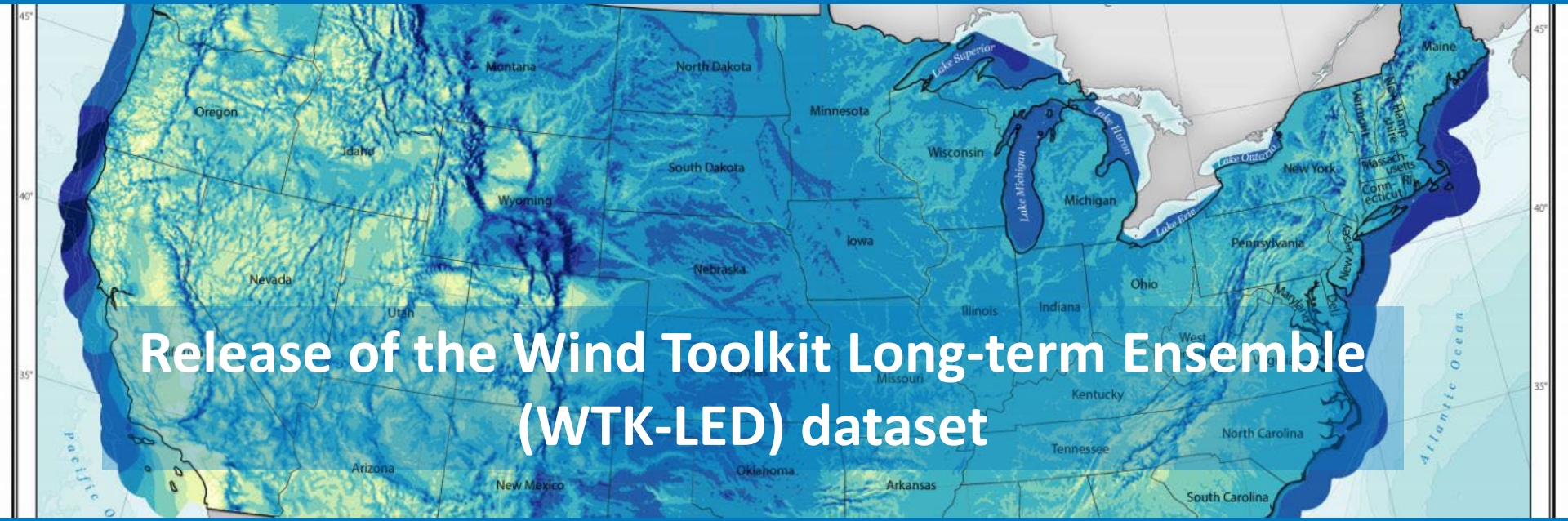


Green checkmarks represent the performance of the WIND Toolkit Long-Term Ensemble Dataset (WTK-LED)

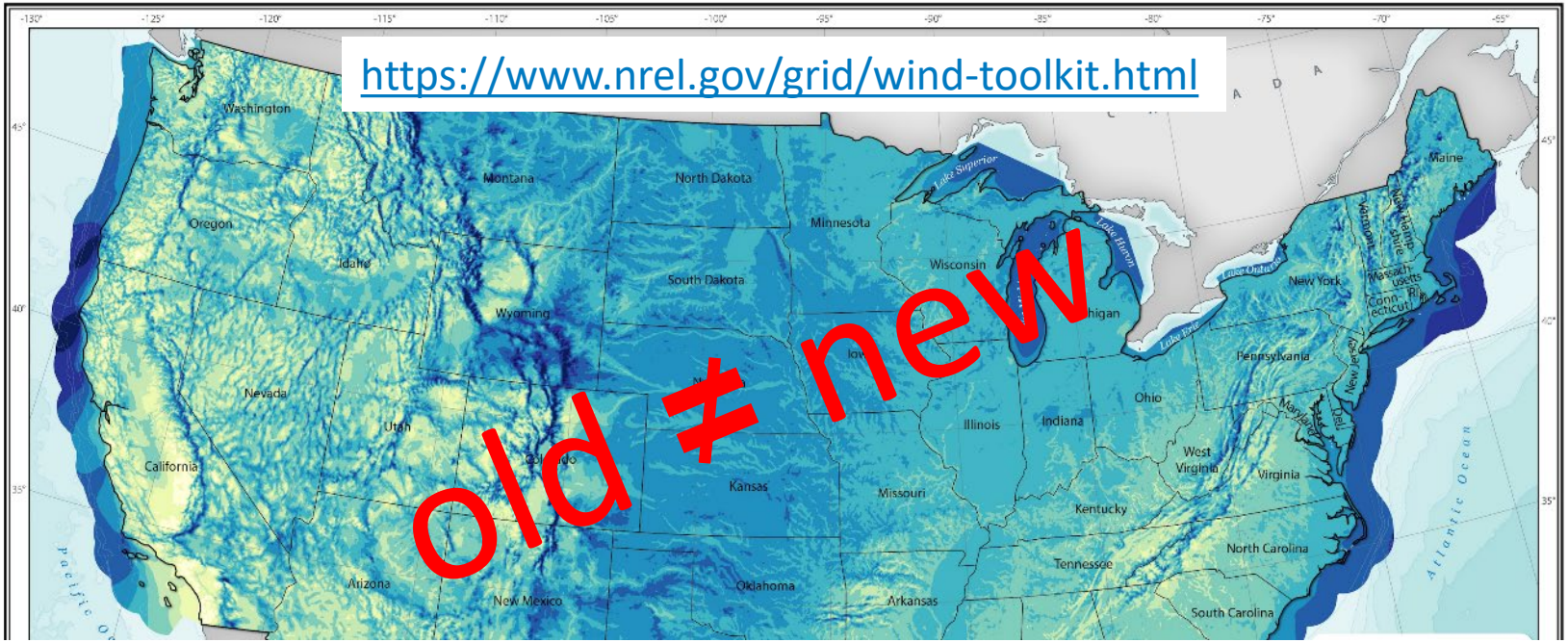
Ongoing NREL work will address curation and validation



Gray checkmarks represent ongoing work with WTK-LED and NREL-adjusted HRRR data to be discussed



Release of the Wind Toolkit Long-term Ensemble (WTK-LED) dataset



Original WIND Toolkit:

- 7 years (2007–2013) at 2 kilometers (km), 5 minutes (min)
- Deterministic dataset containing meteorological and power data
- Contiguous United States (CONUS)
- **Developed as a grid integration dataset to mimic forecast errors.**

WIND Toolkit LED:

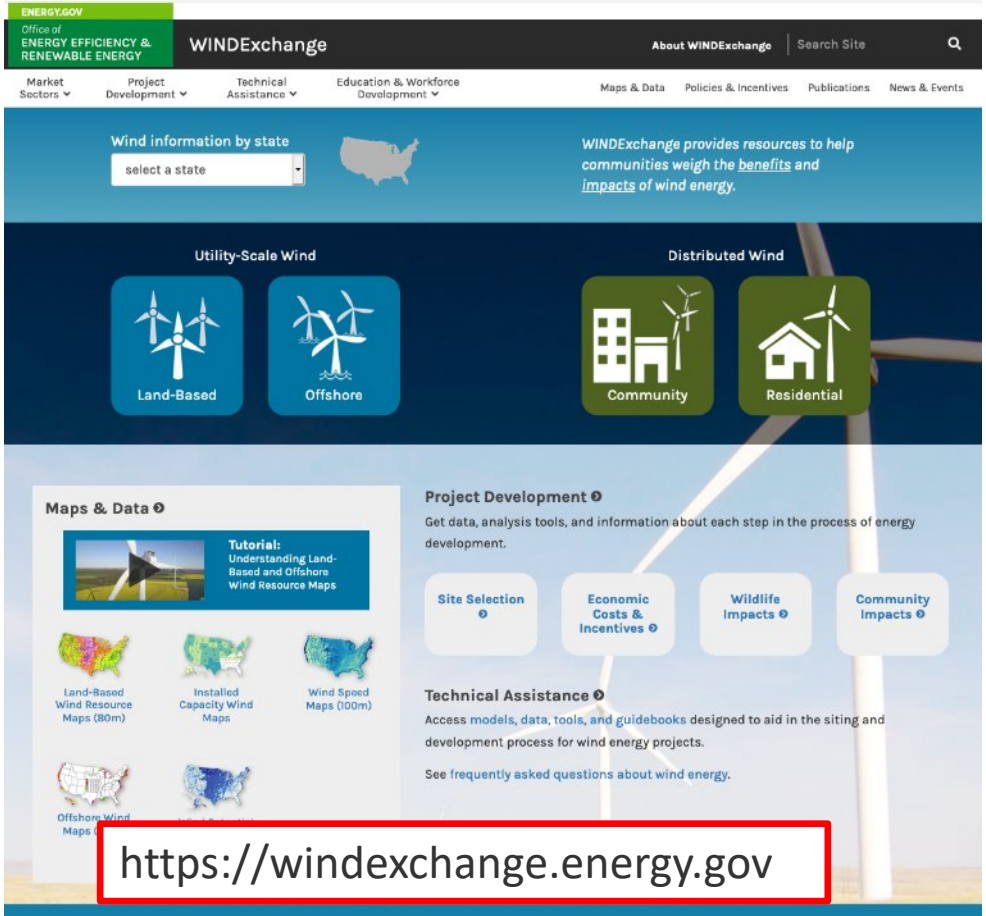
- Updated Weather Research and Forecasting version (4.1.3)
- CONUS, Alaska, and Hawaii for 2018, 2019, and 2020 at 2 km, 5 min
- North America Climate dataset covering 20 years (2001–2020) at 4 km, hourly
- Model uncertainty quantified (ensembles)
- *NO power forecasts.*

WTK-LED comprised of three available datasets

Recall: No power forecasts this time!

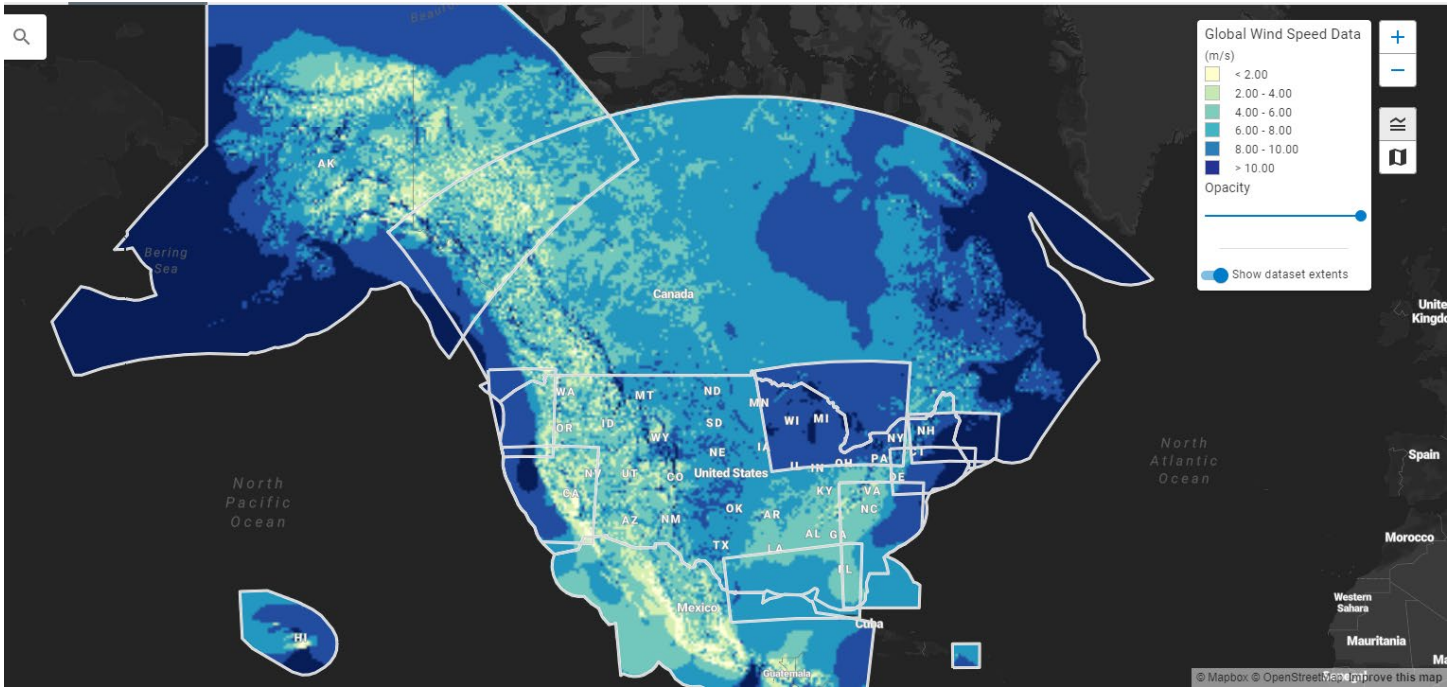
	1 CONUS Alaska/Hawaii	2 North America	3 NOW-23 *Offshore*
Time resolution	**5 minutes**	**1 hour**	**5 minutes**
Spatial Resolution	**2 kilometers**	**4 kilometers**	**2 kilometers**
Years covered	**2018-2020**	**2001-2020**	**20+ years**

Maps and data is available online



https://windexchange.energy.gov

Maps and **data** is available online



wrdb.nrel.gov (also on AWS)

Uncertainty estimates included, but no full validation for grid integration

Intended stakeholders:

- distributed and utility scale wind industry
- airborne wind energy
- grid integration
- power systems modeling
- environmental modeling

1 CONUS Alaska/Hawaii

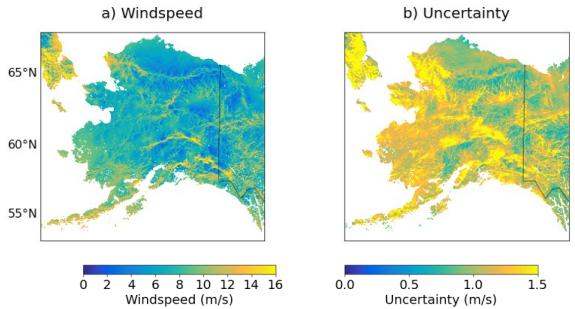
2 North America

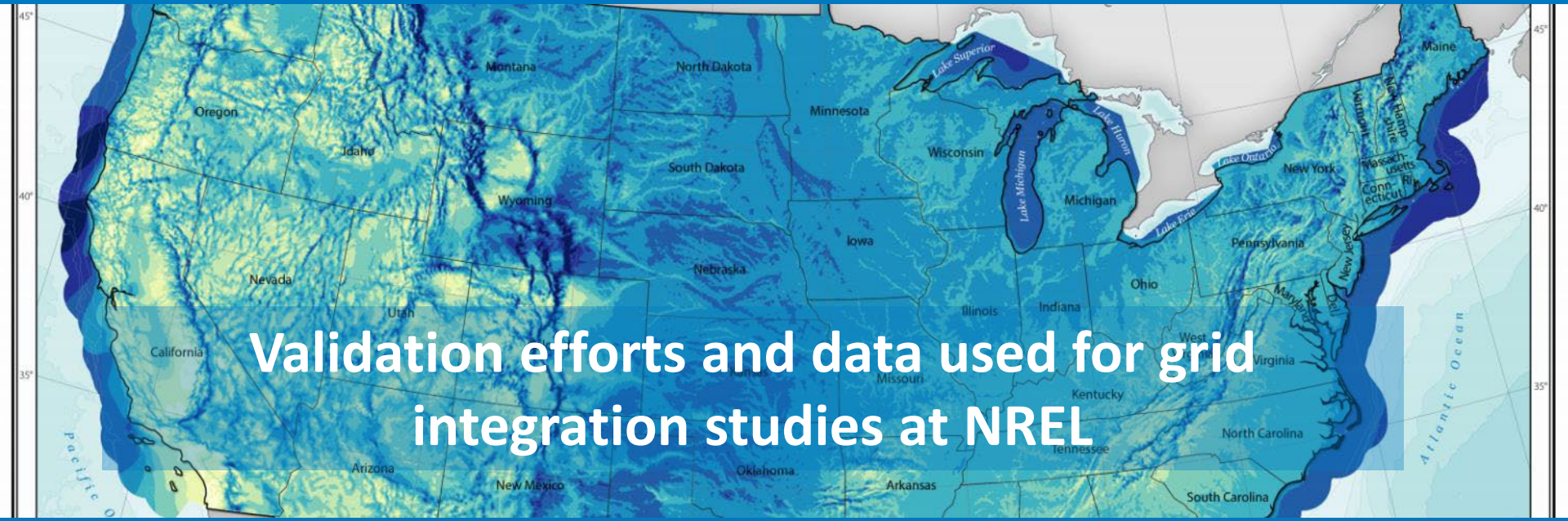
3 NOW-23 *Offshore*

Authors' intended use statements

grid integration studies ***(a priori validation required)***	wind resource estimates (interannual variability, seasonal variability); annual, monthly, diurnal signals	offshore grid integration studies ***(a priori validation required)***

Uncertainty estimates





Validation efforts and data used for grid integration studies at NREL

Datasets used at NREL

Validation focused on 2019-2020

2007-2013 // 2014 2015 2016 2017 2018 2019 2020 **2021**

High Resolution Rapid Refresh (HRRR) (NOAA)

2 km over CONUS; hourly

BCHRRR (bias-corrected HRRR) (NOAA/NREL)

2 km over CONUS; hourly

WIND Toolkit Long-Term Ensemble (WTK-LED) (NREL)

2 km over CONUS+HI+AK; 5min

Historical WIND Toolkit (NREL)

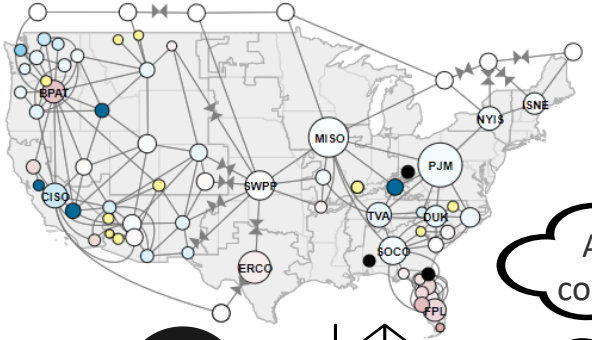
2 km over CONUS; 5min

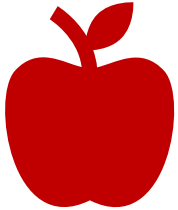
EIA-930 Generation Observations

EIA Regions, hourly

However, validating against EIA-930 requires trying to compare apples to a… similar variety of apple

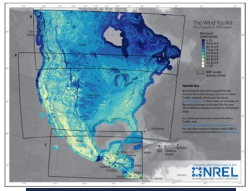
EIA observed wind generation *only* available hourly by EIA region





Are these comparable?

1



NOAA

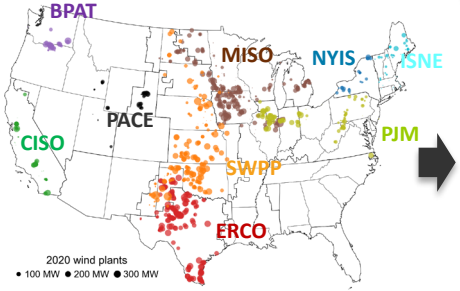
Synthetic windspeed data

2

rev

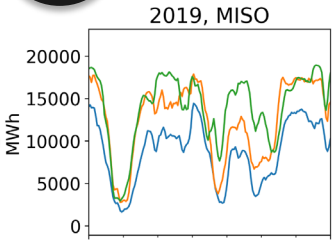
Estimate wind generation with 2018 turbine across CONUS

3

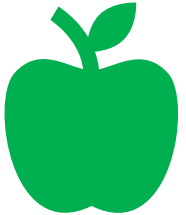


Map to existing wind sites in comparison year

4

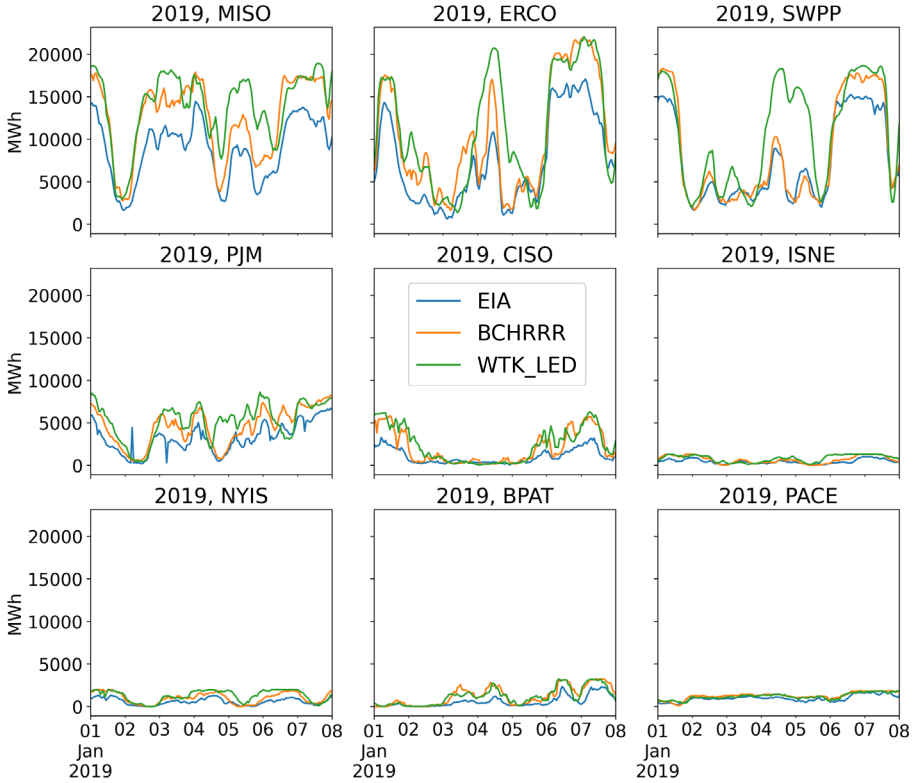


Aggregate to compare generation at EIA-930 region



Adjacent NREL validation effort shows both new WTK-LED and bias-corrected HRRR correlate with regional generation observations

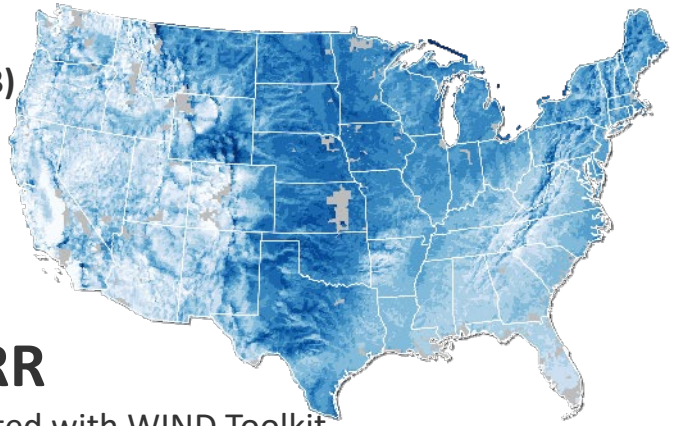
- WTK-LED and BCHRRR generation estimates higher than EIA-930
- Non-harmonized assumptions could drive overestimation, including:
  - High wind resource
  - Curtailment not included in reV
  - Wake losses (internal)
  - Installed capacity differences
  - Technology vintage inconsistencies between model and EIA
  - Inconsistent boundaries



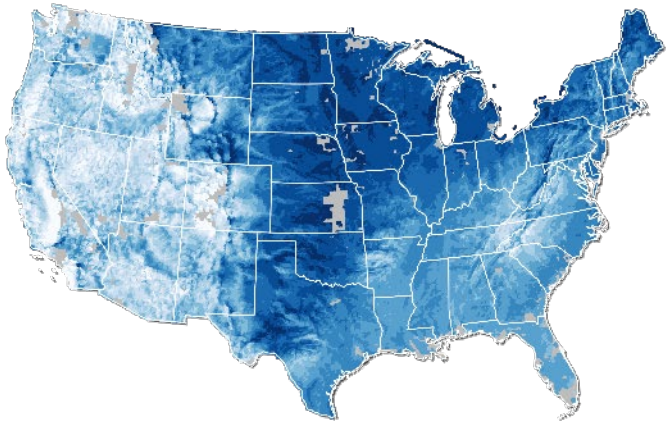
*All timestamps Coordinated Universal Time (UTC)

Wind capacity factors higher in WTK-LED

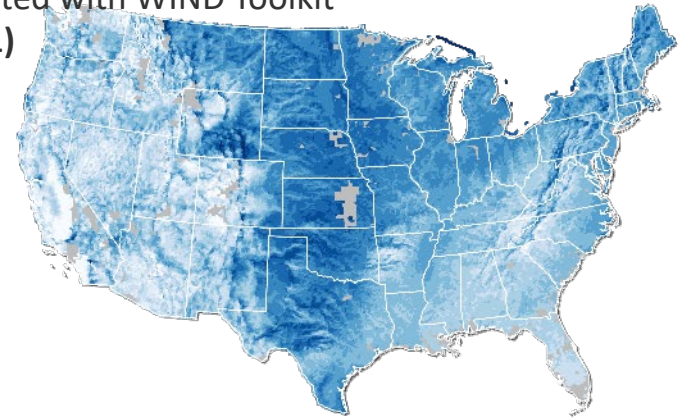
WTK
(2007-2013)



WTK-LED
(2018-2019)



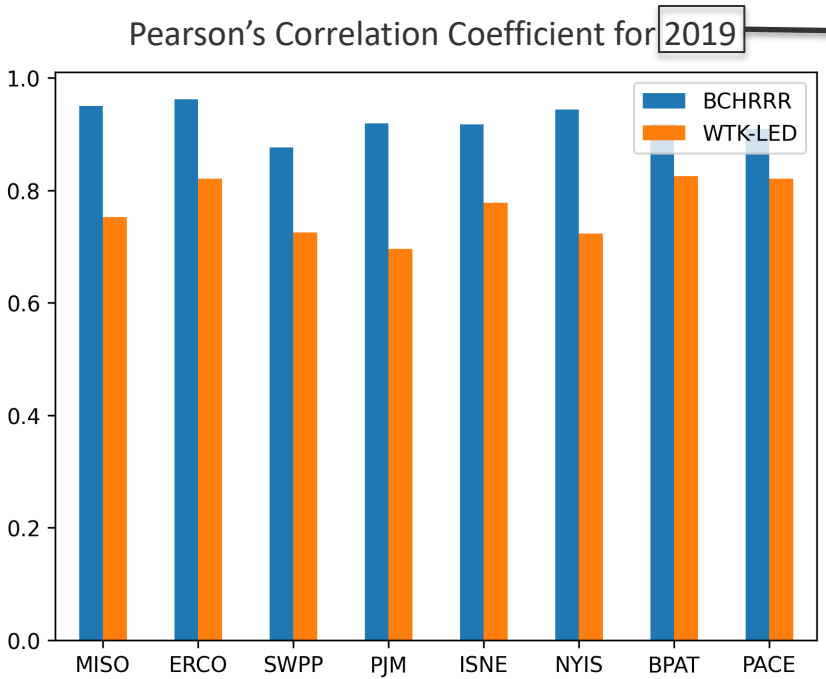
BCHRRR
Bias corrected with WIND Toolkit
(2015-2021)



Capacity Factor

- 0 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35
- 0.35 - 0.4
- 0.4 - 0.45
- 0.45 - 0.5
- 0.5 - 0.55
- > 0.55

Correlation shown in timeseries is present across full year of hourly wind data



Shows correlation over a longer time period than previous plots (Year vs Week)

Higher correlation of BCHRRR with EIA-930

HRRR data are taken from the analyses, not the forecasts.

Conclusion of validation efforts and appropriate use of WTK-LED

Without a clearly defined end-use standard for grid integration studies it is challenging to say what “appropriate use” is, or what improvements would bridge a gap to making a specific atmospheric dataset the **gold standard**.

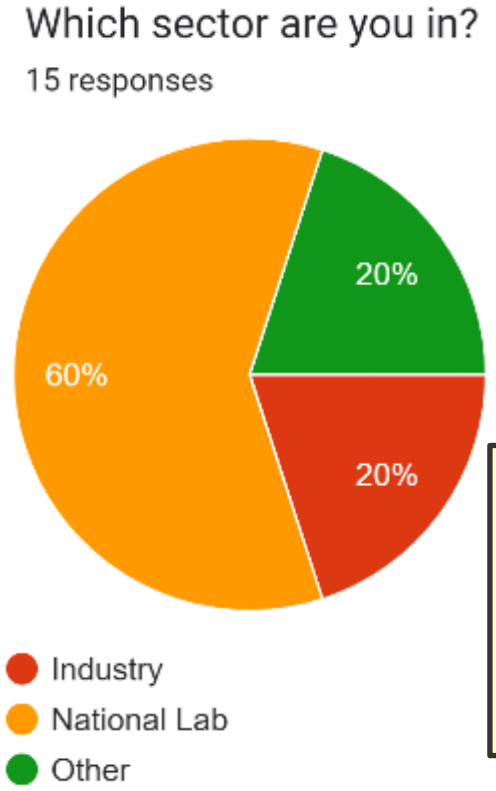
Recent workshop and survey to better align on what’s most useful

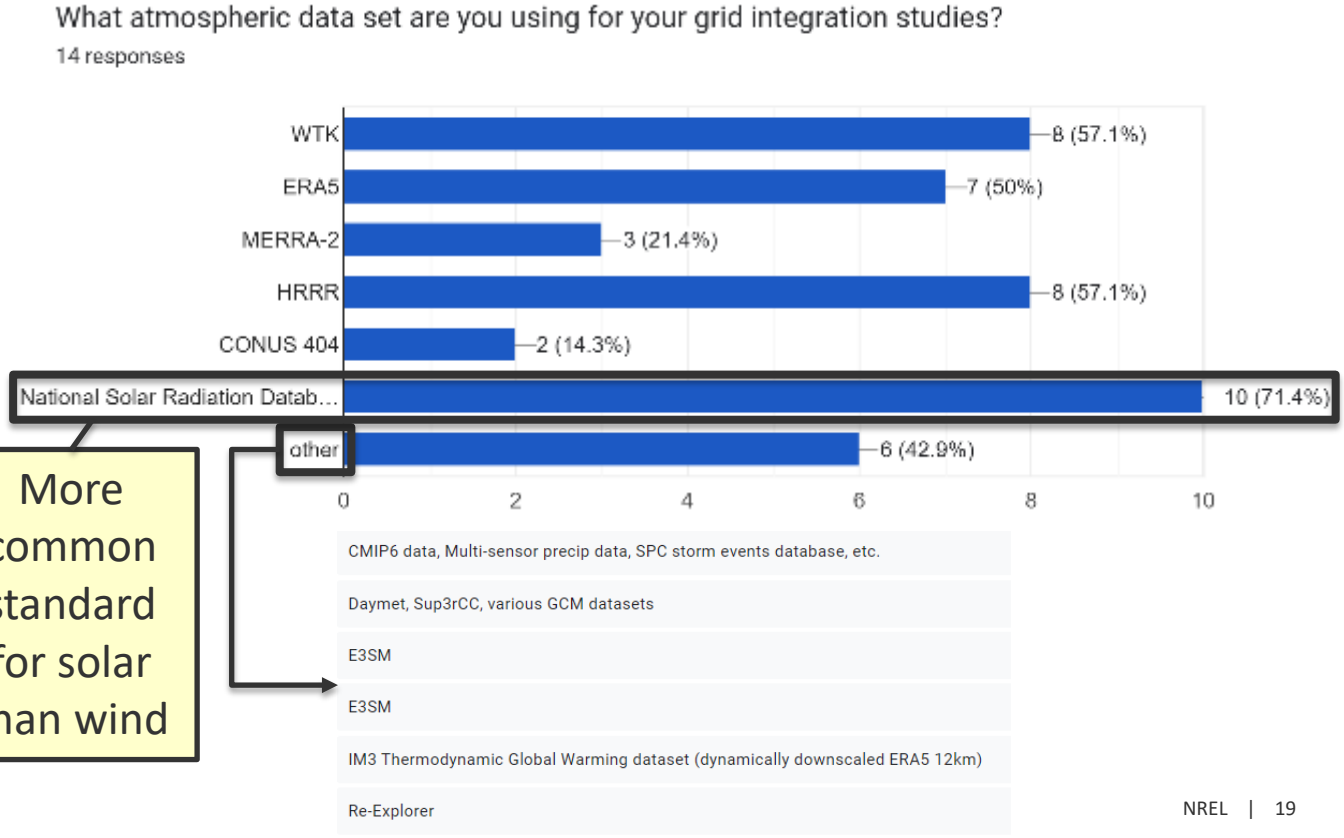
YOU CAN WEIGH IN SOON!

Recent workshop highlights further gaps
… and, you can also take a survey!

Workshop participants touring the Flatirons Campus
Photo from Justin Sharp

Grid integration practitioners use many atmospheric datasets



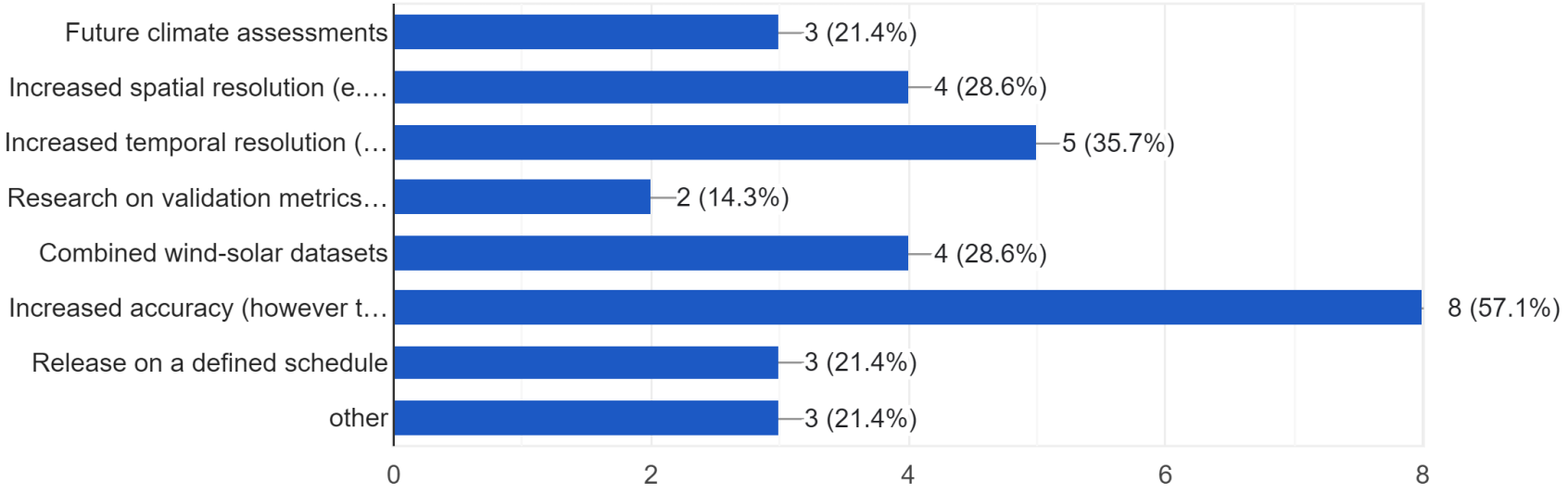


More common standard for solar than wind

Accuracy stands out among high-priority needs for future datasets

Which of these should have the highest priority for future atmospheric datasets for grid integration studies? (Choose one)

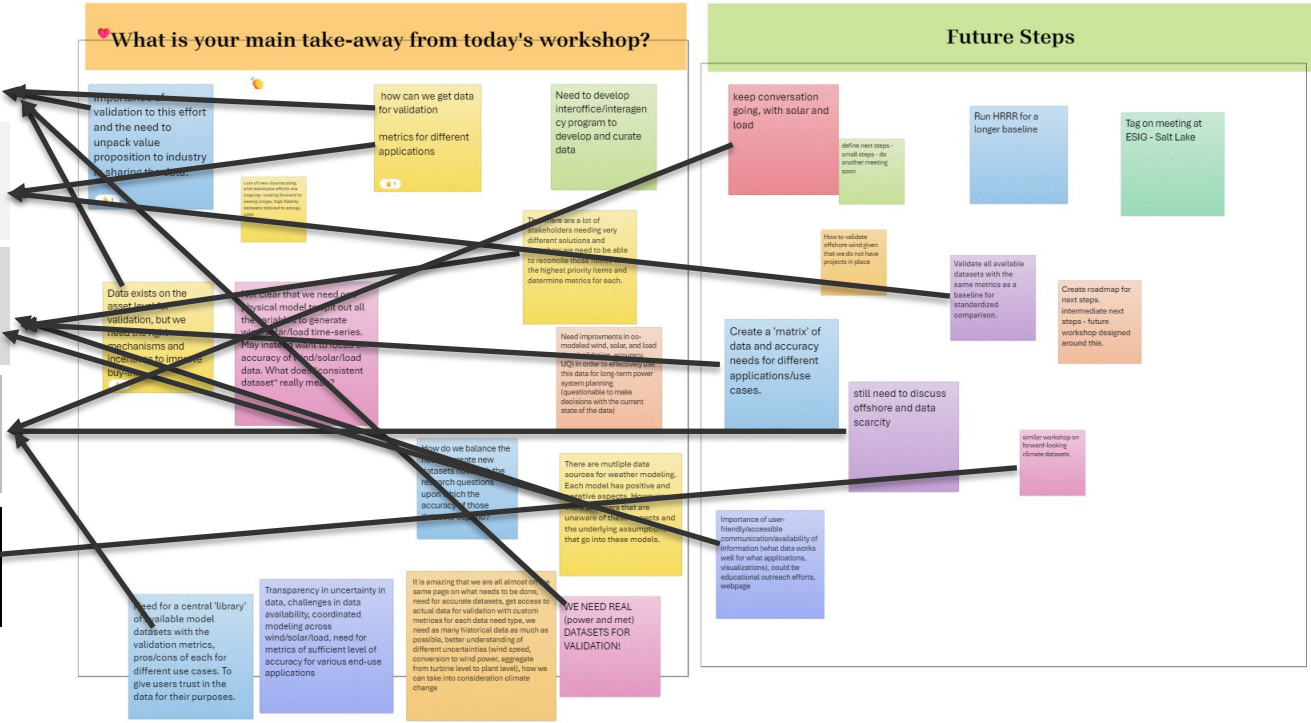
14 responses



Increased accuracy could be achieved with better validation and combined wind/solar/load/hydropower data.

Workshop whiteboard identifies five key focus areas

1. Validation is missing
2. No common set of metrics for usability
3. Clear definition of use cases needed
4. Relevant datasets not linked
5. What about the future?

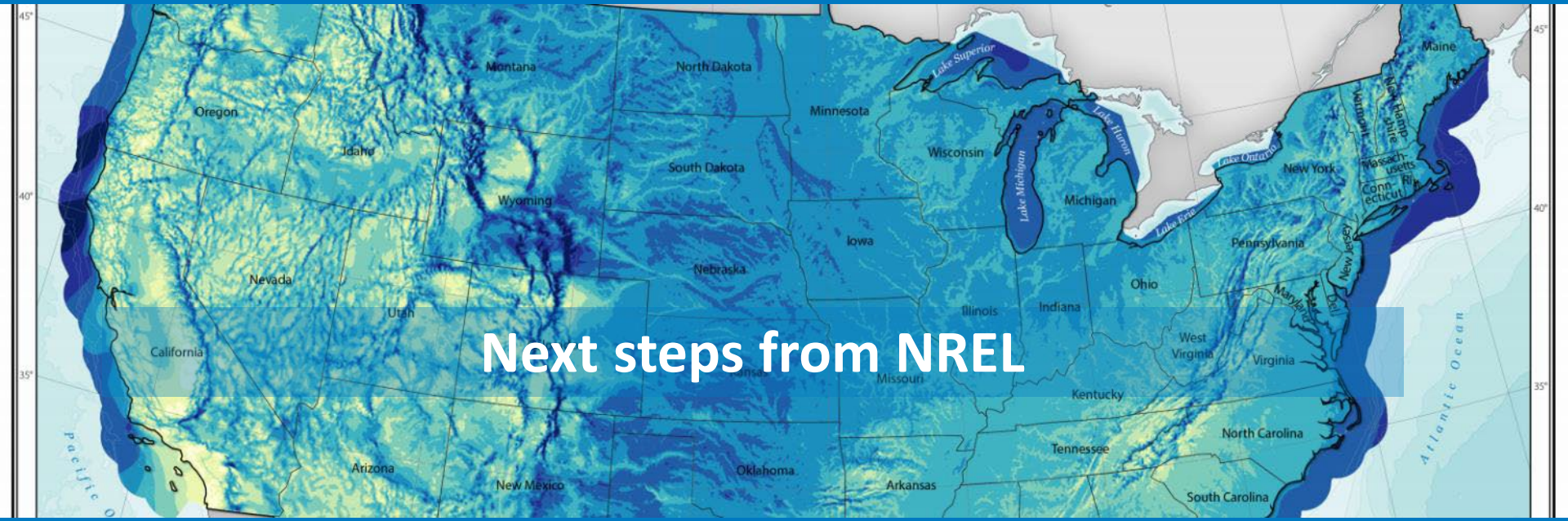


These five key areas will inform next steps

Add your thoughts to help inform next steps!

National Scale Wind Data for Grid Integration - Survey (google.com)

https://bit.ly/3Xel2PC


Next steps from NREL
Montana
North Dakota
Minnesota
Oregon
Idaho
South Dakota
Wisconsin
Wyoming
Michigan
Nebraska
Iowa
Nevada
Utah
Illinois
Indiana
Ohio
California
Missouri
West Virginia
Virginia
Kentucky
Tennessee
North Carolina
Arizona
New Mexico
Oklahoma
Arkansas
South Carolina
Pennsylvania
New York
Maine
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
Atlantic Ocean
Pacific Ocean

NREL team continues to validate and release data; open to feedback!

Wind validation according to the use case, distributions, and tails → Release validation metrics and code from earlier analysis

Combined wind/solar/load datasets → Release of more historical years of datasets alongside NREL's power system planning tools

Address climate variability and quantify uncertainty of climate change models → Stay for Grant Buster's talk on SuperCC?!

Comprehensive, industrywide data transparency and sharing of meteorological measurements, and generation and availability data → How to make operational data more widely available?

Thank You!

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Wind lead: dave.corbus@nrel.gov

www.nrel.gov

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