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High-Quality Data for Grid Integration Studies

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I. Introduction

Energy from wind and solar resources is now among the cheapest new sources of energy, leading to a rapid increase in the amount of wind and solar generators installed in the United States and internationally. The power output from these generators varies with site characteristics (Fig. 1).

Grid integration studies predict the response of the grid to different generation mixes and test future technologies and market structures.

Fig 1. How does energy from wind and solar resources vary over time and space? Photo by Dennis Schroeder, NREL

II. What Data Do We Need?

A grid integration study needs:

- Resource time series
- Time series of other factors that impact generators (air density, air temperature, etc.)
- High temporal resolution (10 minutes at least)
- High spatial resolution (order of kilometers)
- Consistent physics for different resources
- Known accuracy and clear limits to use
- Easy access to data.

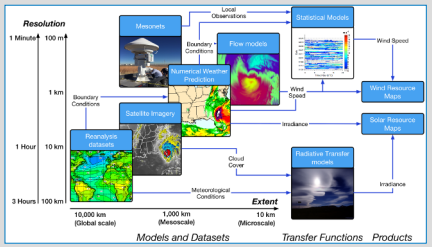

Fig. 2. Grid integration data sets are produced by downscaling data to the highest possible temporal and spatial resolution

III. The Wind Integration National Dataset (WIND) Toolkit

What Is the WIND Toolkit?
In prior studies, false ramps resulted in unrealistic power system impacts when the data were used in power systems modeling (Fig. 3, 4). The WIND Toolkit project was launched to mitigate these problems.

The WIND Toolkit used the WRF to create meteorological data for the United States for 2007–2013 [1].

What's in the WIND Toolkit?

- 2-km by 2-km, 10-minute meteorological data for the continental United States
- Power time series for most likely sites from meteorological data, site-specific power curves, and a wake-loss model
  - 110,000 sites on land
  - 10,000 sites offshore (Fig. 5).
- Forecasts for 24 hours
- Web GUI and API.

How Good Is the WIND Toolkit?
Data were validated from a meteorological point of view (e.g., diurnal and annual cycles, frequency distributions, error metrics of wind speed) and from a grid integration perspective (e.g., ramps and variability of power output). The validation shows no obvious systematic biases (Fig. 6). More information can be found in [2] and [3].

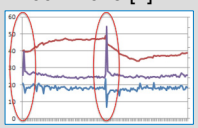

Fig. 3. Prior data sets had false jumps and ramps from restarts or data assimilation issues.

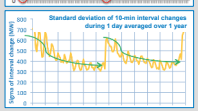

Fig. 4. Artifacts remained even after aggregating over multiple sites.

Fig. 5. The location of sites in the WIND Toolkit

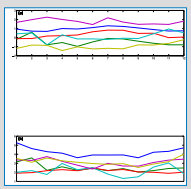

Fig. 6. (a) Monthly cycle of bias, (b) CRMSE, and (c) RMSE of six different locations

IV. The National Solar Radiation Database (NSRDB)

What Is the NSRDB?
The 2017 NSRDB is a time series of solar resource data, available online (Fig. 7).

The NSRDB is created from satellite data products and weather reanalysis data using physical models (Fig. 8).

What's in the NSRDB?

- 4-km by 4-km, 30-minute data for the continental United States
- Global horizontal irradiance (GHI) and direct normal irradiance (DNI)
- Meteorological data
- Web GUI (Fig. 7) and API
- Updated every year
- Regularly validated (Fig. 9).

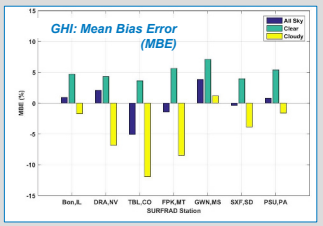

Fig. 9. NSRDB validation results against NOAA SURFRAD stations

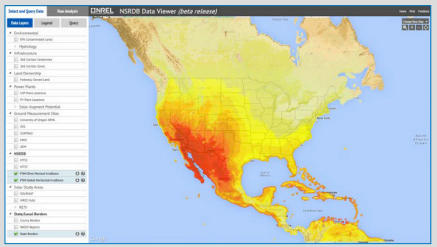

Fig. 7. The NSRDB can be accessed online at http://nsrdb.nrel.gov.

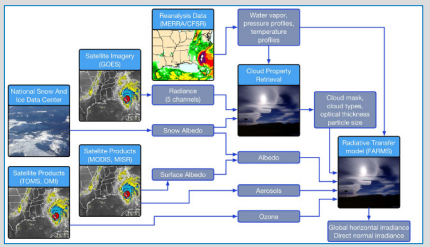

Fig. 8. The NSRDB is produced using a combination of observations and models from many sources.

V. Observations Lead the Way

The theme of the 2017 AMS Annual Meeting is "Observations Lead the Way." In our experience:

Observations and networks that are needed:

- Resource and production summaries for wind and solar plants at subhourly scales
- Simplified data discovery and extraction.

Instruments needed to make these observations:

- Research grade wind and solar resource measurements with metadata
- Wind measurements at multiple heights
- Resource measurements of GHI and DNI.

The greatest observational needs for wind and solar energy integration:

- A way to share data but protect commercial interests, e.g., through delays, aggregation
- More demonstrations to industry of the value of data sharing.

The information in this panel is in response to a request from the AMS and is based on the authors' experiences.

VI. What's in the Future?

Grid integration studies will need to be updated to reflect new generator technologies and new site selection criteria. This means new data sets.

We anticipate:

- Higher resolution in time and space
- Unified model chain, e.g., WRF solar
- More challenges storing and distributing tens of Petabytes of data
- On-demand machine-learning approaches.

References and More Information

Access the data:

- WIND Toolkit: http://www.nrel.gov/grid/wind-toolkit.html
- NSRDB: https://nsrdb.nrel.gov.

References:

1. C. Draxl, B.-M. Hodge, A. Clifton, and J. Mc Caa, "The Wind Integration National Dataset (WIND) Toolkit," *Applied Energy* (2015), doi:10.1016/j.apenergy.2015.03.121.
2. C. Draxl, A. Clifton, and B.-M. Hodge, *Overview and Meteorological Validation of the Wind Integration National Dataset Toolkit* (Technical Report NREL/TP-5000-61740) (Golden, Colorado: National Renewable Energy Laboratory, 2015).
3. J. King, A. Clifton, and B.-M. Hodge, *Validation of Power Output for the WIND Toolkit* (Technical Report, NREL/TP-5D00- 61714) (Golden, Colorado: National Renewable Energy Laboratory, 2014).

For more information:

- A. Clifton, B.-M. Hodge, C. Draxl, J. Badger, and M. Sengupta, "Wind And Solar Resource Mapping," *Wiley Interdisciplinary Reviews (WIREs) Energy and Environment* (forthcoming).
- M. Sengupta, Y. Xie, A. Habte, A. Lopez, and A. Clifton, *The National Solar Radiation Data Base* (forthcoming).

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