Determining Variabilities of Non-Gaussian Wind Speed Distributions using Different Metrics and Timescales

Joseph C. Y. Lee,[1] M. Jason Fields,[1] Julie K. Lundquist,[1,2] and Monte Lunacek[1]
[1]National Wind Technology Center, National Renewable Energy Laboratory, Golden, CO, USA
[2]Department of Atmospheric and Ocean Sciences, University of Colorado Boulder, Boulder, CO, USA

Motivation

- Quantifying the uncertainty of winds is critical for the wind resource assessment process. However, wind speed variations differ across averaging temporal scales.
- Standard deviation is a commonly used metric to quantify variability, yet it is not statistically robust or resistant (Wilks 2011).
- Our goal is to contrast the distribution spread and characteristics of wind speed at different averaging timescales, and to explore the value of using a robust and resistant method to assess variability.

Methodology

- We apply the horizontal wind speeds from the National Aeronautics and Space Administration's Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) reanalysis data set (Gelaro et al. 2017) from 1980 to 2017.
- We derive the wind speeds at 80 m above the surface using the power law and derived shear components. We compute the mean wind speeds at six time resolutions: hourly, daily, weekly, monthly, seasonal, and annual.
- We use a collection of spread metrics and distribution parameters, including:

Robust coefficient of variation

$$(\text{RCoV}) = \frac{\text{median}|x-\text{median}(x)|}{\text{median}}$$

Large RCoV represents high variability.

$$\text{Skewness} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2\right)^{\frac{3}{2}}}$$

Positive skewness means the distribution tends toward low values.

$$\text{Kurtosis} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^4}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2\right)^{2}} - 3$$

Positive kurtosis means the distribution tends to cluster near its center.

- A perfect Gaussian distribution has zero skewness and zero kurtosis.

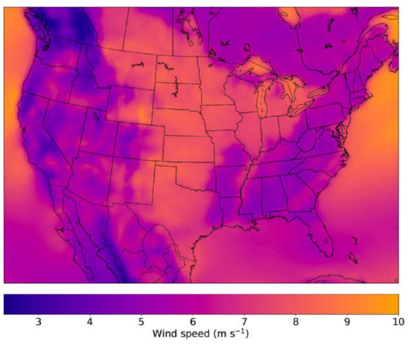

Figure 1. Hourly mean wind speed at 80 m above surface of the continental United States (CONUS) from 1980 to 2017

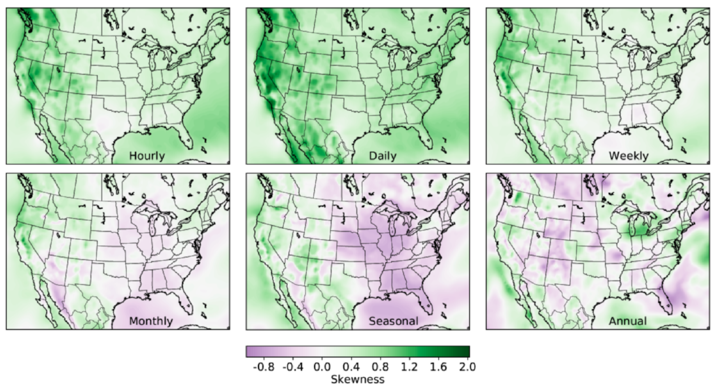

Figure 3. The skewness of mean wind speeds at different timescales of the CONUS over 38 years.

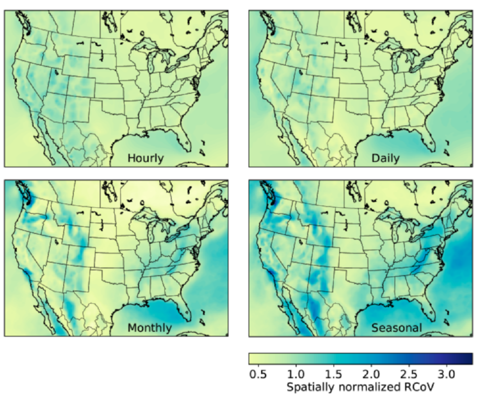

Figure 2. The RCoV calculated using mean wind speeds at different timescales of the CONUS over 38 years. For each timescale, the RCoV values are spatially normalized with the CONUS median of RCoV for that map.

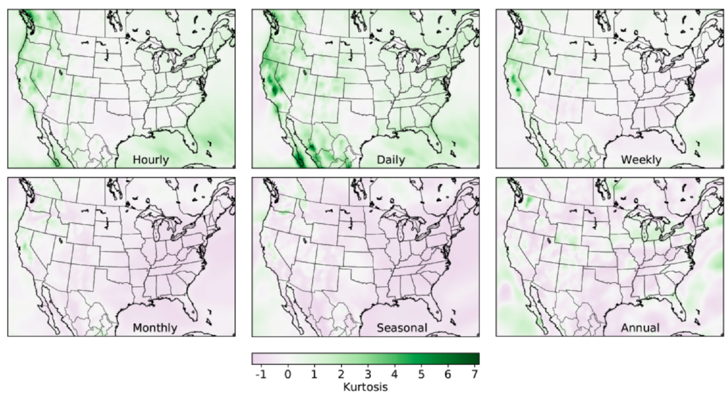

Figure 4.The kurtosis of mean wind speeds at different timescales of the CONUS over 38 years.

Results and Discussion

- RCoV effectively contrasts the wind speed variabilities of different regions, especially in monthly and seasonal mean data.
- RCoV indicates mountainous regions with high wind speed variabilities, regardless of the averaging timescales.
- Skewness and kurtosis drastically change with averaging time frames. Nonzero skewness and kurtosis illustrate that the Gaussian assumption is principally inadequate in most of the United States for all averaging time frames of wind speeds.
- Analysts should account for skewness and kurtosis when they use standard deviation to quantify long-term variability.
- Overall, using RCoV to evaluate wind speed variability is advantageous given its statistical robustness and resistance.

References

Gelaro, R., W. McCarty, M. Suarez, R. Todling, A. Molod, L. Takacs, C. Randles, A. Darmenov et al. 2017. "The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2)." *Journal of Climate*, 30, 5419–5454, doi:10.1175/JCLI-D-16-0758.1.

Wilks, D. S. 2011. *Statistical methods in the atmospheric sciences*. Academic Press, 676 pp.

The Alliance for Sustainable Energy, LLC (Alliance) is the manager and operator of the National Renewable Energy Laboratory (NREL). NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. This work was authored by the Alliance and supported by the U. S. Department of Energy under Contract No. DE-AC36-08GO28308. Funding was provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Wind Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the U.S. Department of Energy or the U.S. government. The U.S. government retains, and the publisher, by accepting the article for publication, acknowledges that the U.S. government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. government purposes.

The Science of Making Torque From Wind
Milano, Italy
June 20-22 2018
NREL/PO-5000-71713