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Evaluating the Methodologies of Assessing Long-Term Variability of Wind Speed

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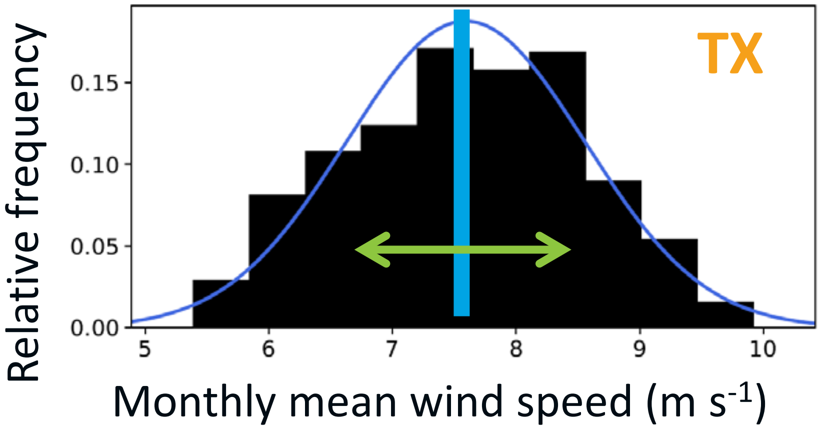
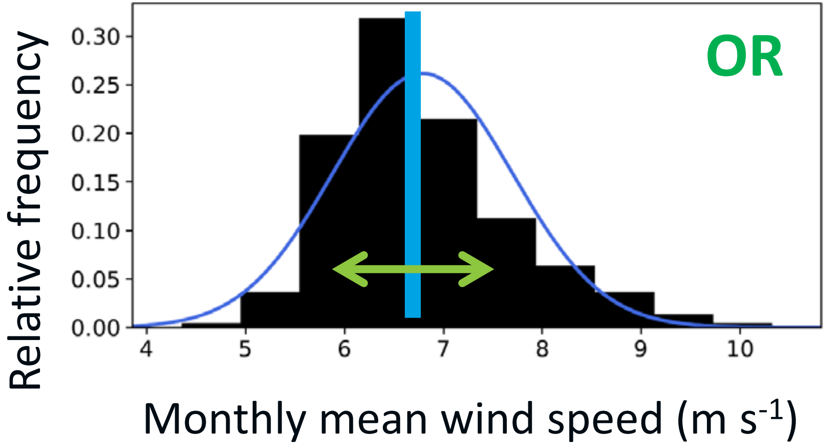
How Would One Quantify the Variability of Wind Speed?

- 37-year monthly mean wind speed at a sample site in Texas
- Close to Gaussian
- Using standard deviation (σ) seems appropriate
- 37-year wind speed at a sample site in Oregon
- Skewed distribution



65% data within 1 σ

Gaussian: 68% data within 1 σ



71% data within 1 σ

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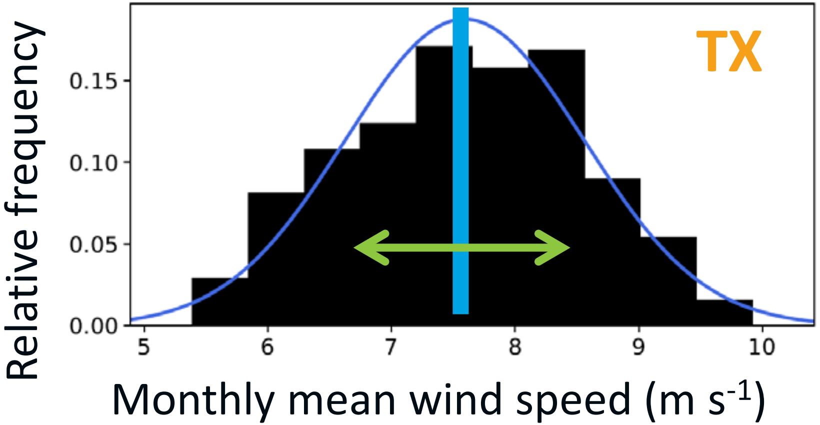

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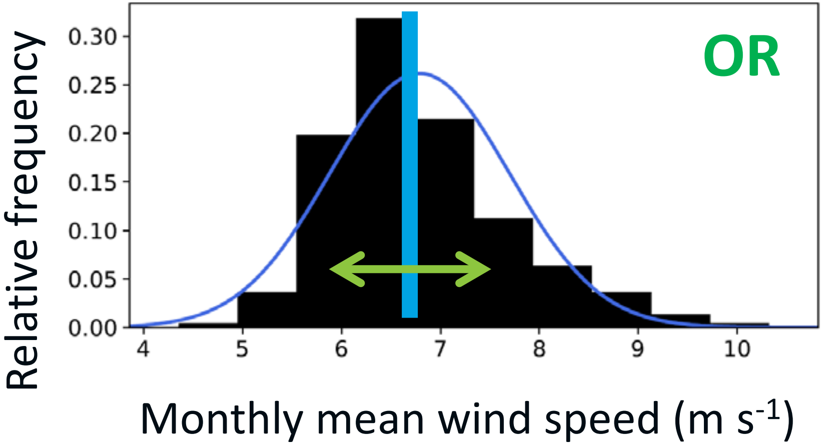
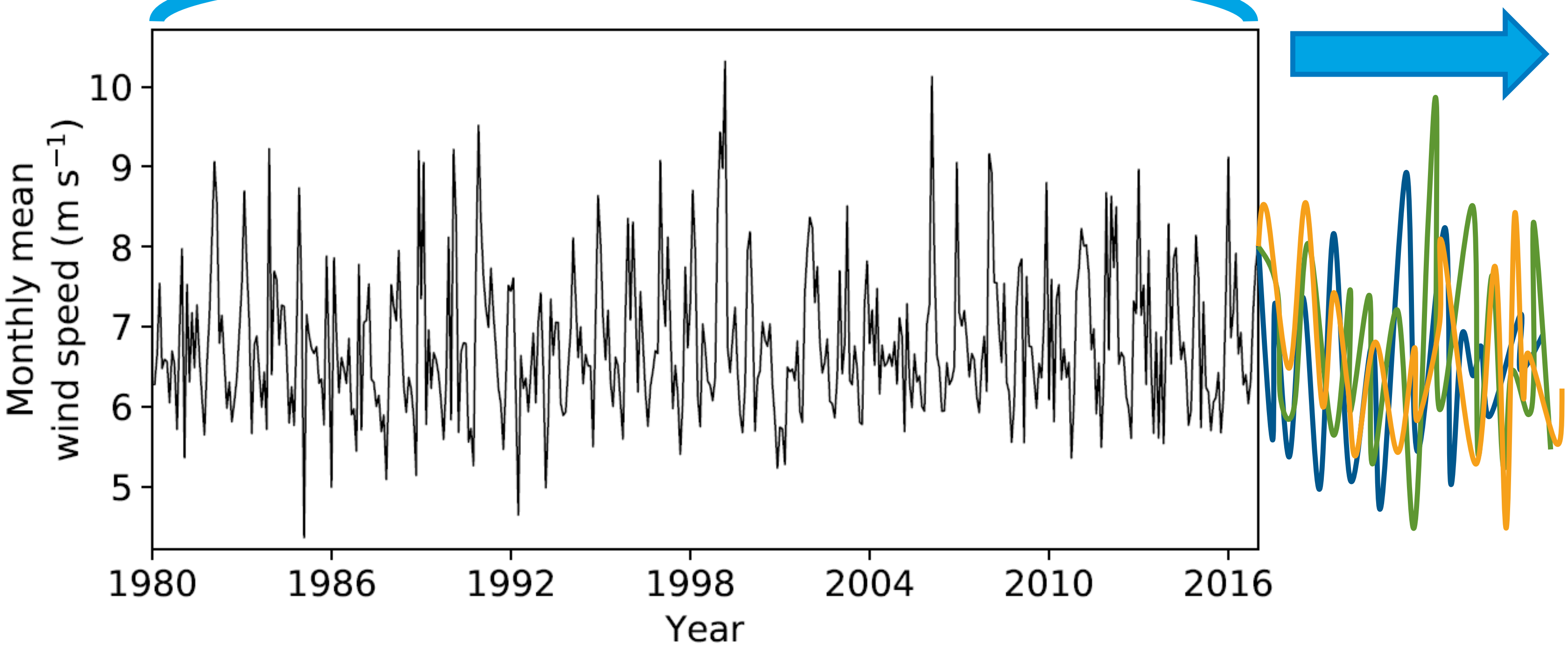


71% data within 1 σ

Need a statistically robust and resistant method

The Importance of Quantifying Variability

- Project lifetime variability can contribute 10% of total project uncertainty[1].



[1] Clifton, A., A. Smith, and M. Fields. 2016. *Wind Plant Preconstruction Energy Estimates: Current Practice and Opportunities* (Technical Report). TP-5000-64735. National Renewable Energy Laboratory (NREL), Golden, CO (US). https://www.nrel.gov/docs/fy16osti/64735.pdf.

The Importance of Quantifying Variability

- Project lifetime variability can contribute 10% of total project uncertainty[1]
- Representing variability as standard deviation is problematic
- Numerous spread metrics exist.

$$Interquartile\ range\ (IQR) = q_{0.75} - q_{0.25}$$

$$Standard\ deviation = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$Range = \max(x) - \min(x)$$

$$Coefficent\ of\ Variation\ (CoV) = \frac{standard\ deviation}{mean}$$

$$Weibull\ parameters$$

$$Mean\ deviation\ from\ mean = \overline{(x - \bar{x})}$$

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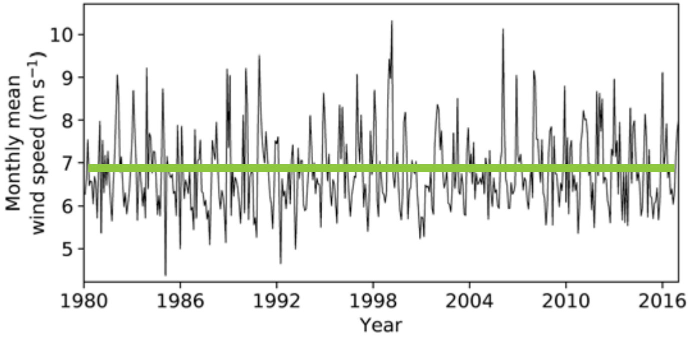
The Importance of Quantifying Variability

- Project lifetime variability can contribute 10% of total project uncertainty[1]
- Representing variability as standard deviation is problematic
- Numerous spread metrics exist
- We identified the robust coefficient of variation (RCoV), a statistically robust and resistant way to quantify variability.

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



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Goal: Compare Spread Metrics and Determine the Best One

MERRA-2[2] 80 m wind speed, 1980 – 2016 (37 years)

Variability

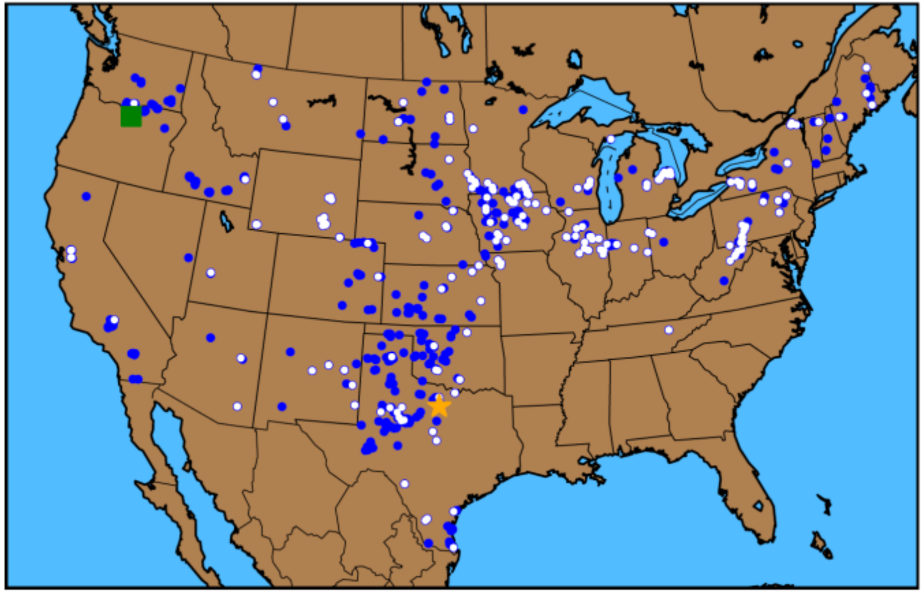
Energy Information Administration (EIA) net monthly generations (600+ sites)

[2]Gelaro, R. et al. 2017. "The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2)." *Journal of Climate*. https://doi.org/10.1175/JCLI-D-16-0758.1.

Site-specific linear regression, chose sites with $R^2 > 0.75$

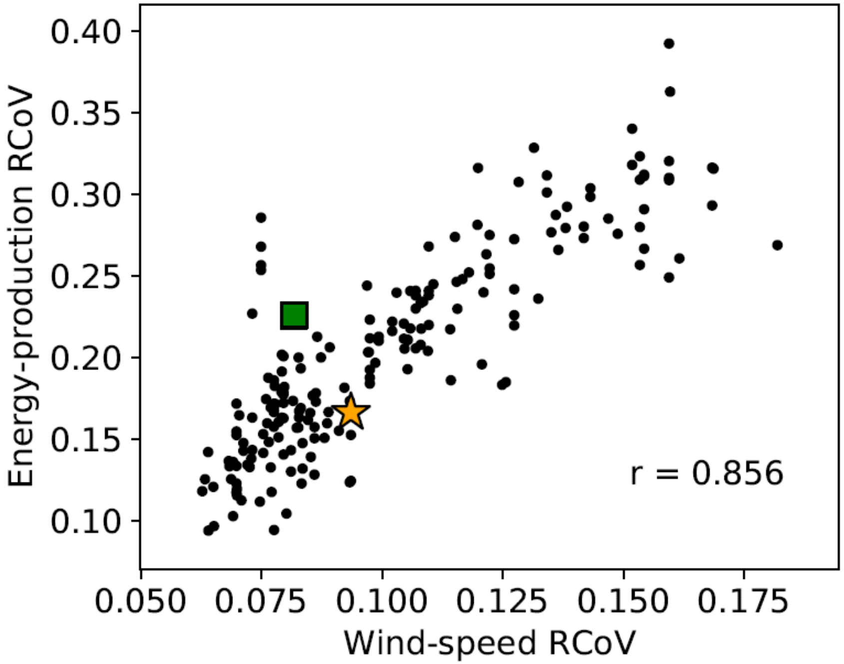
~200 sites chosen, including the Oregon and Texas sites

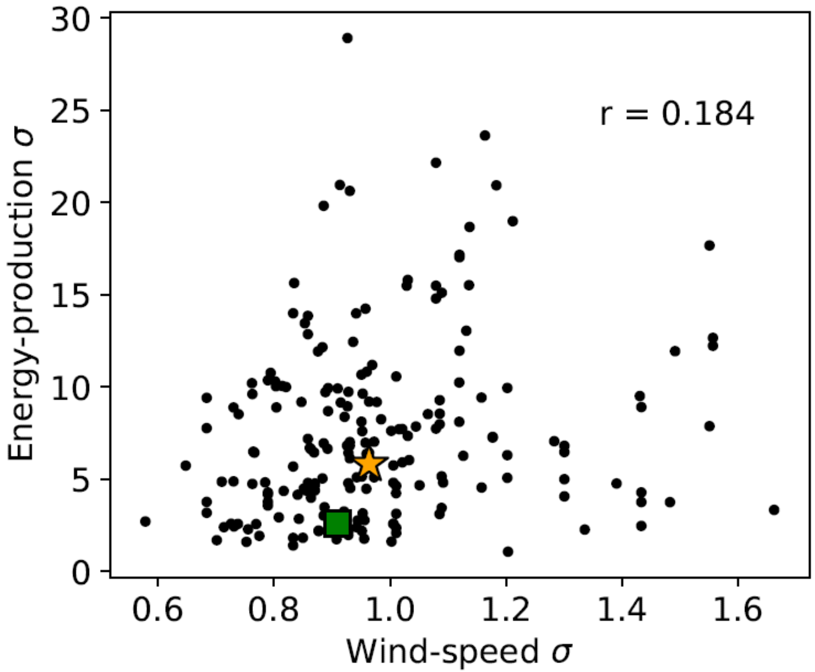
Tested 27 spread metrics and found **RCoV** is the most robust method



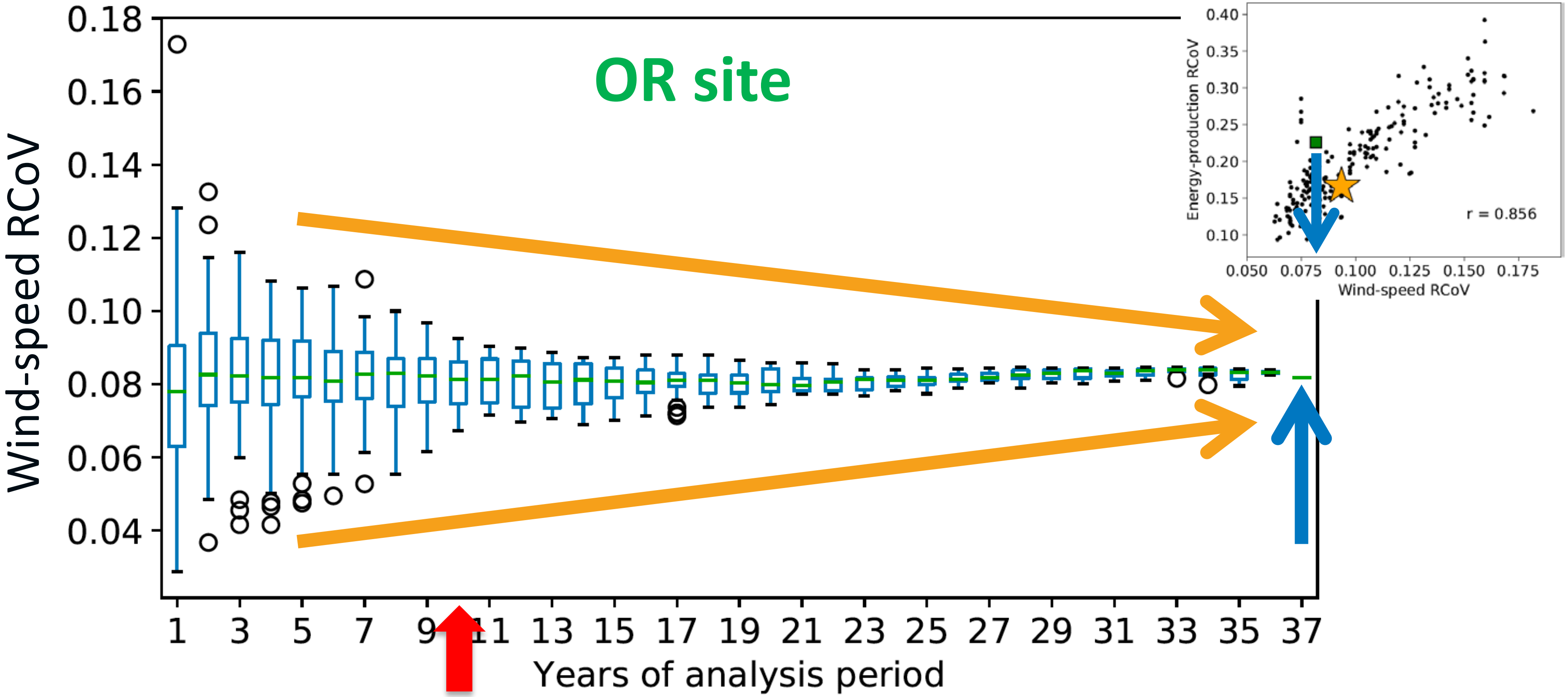
RCoV Has More Predictive Power Than Standard Deviation

- Correlate wind speed RCoV and energy production RCoV, r = 0.856
  - Strong r: high wind-speed variability translates into high-energy variability
- Using standard deviation only yields correlation of 0.184.



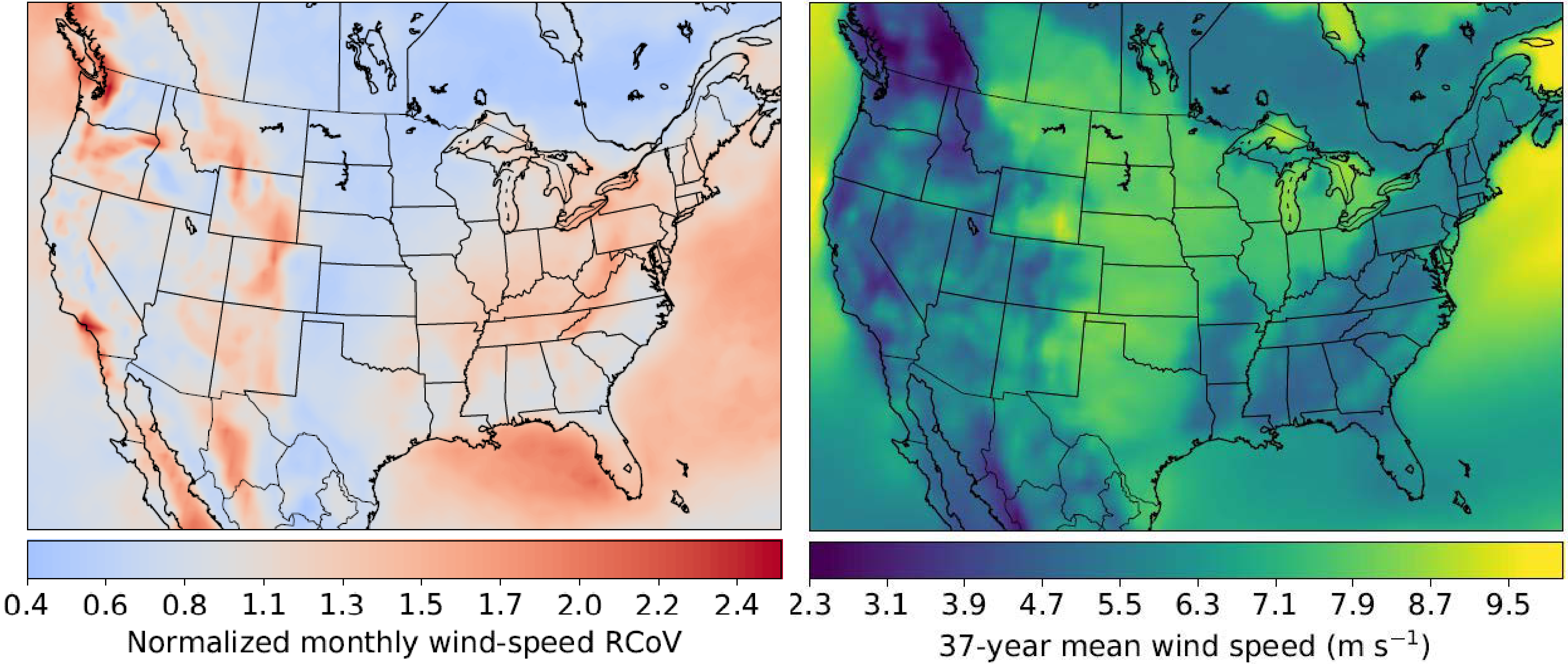


Including More Years in Estimating RCoV Reduces Variations



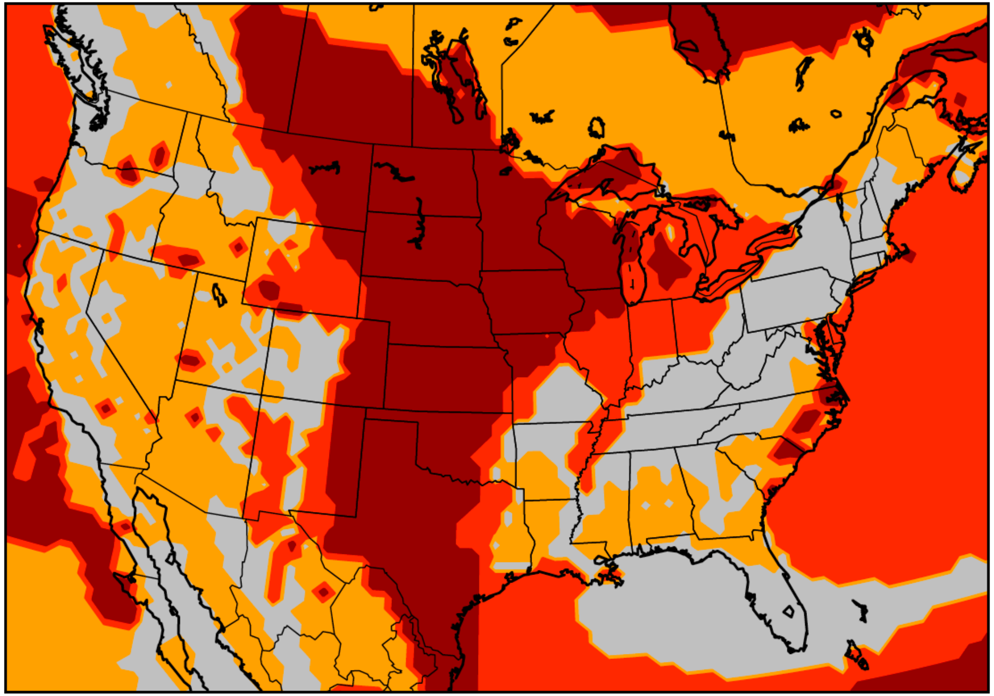
The period required to calculate wind-speed RCoV with 90% confidence is <u>10 ± 3 years.</u>

Ideal Wind Sites Possess Strong Winds with Low Variability



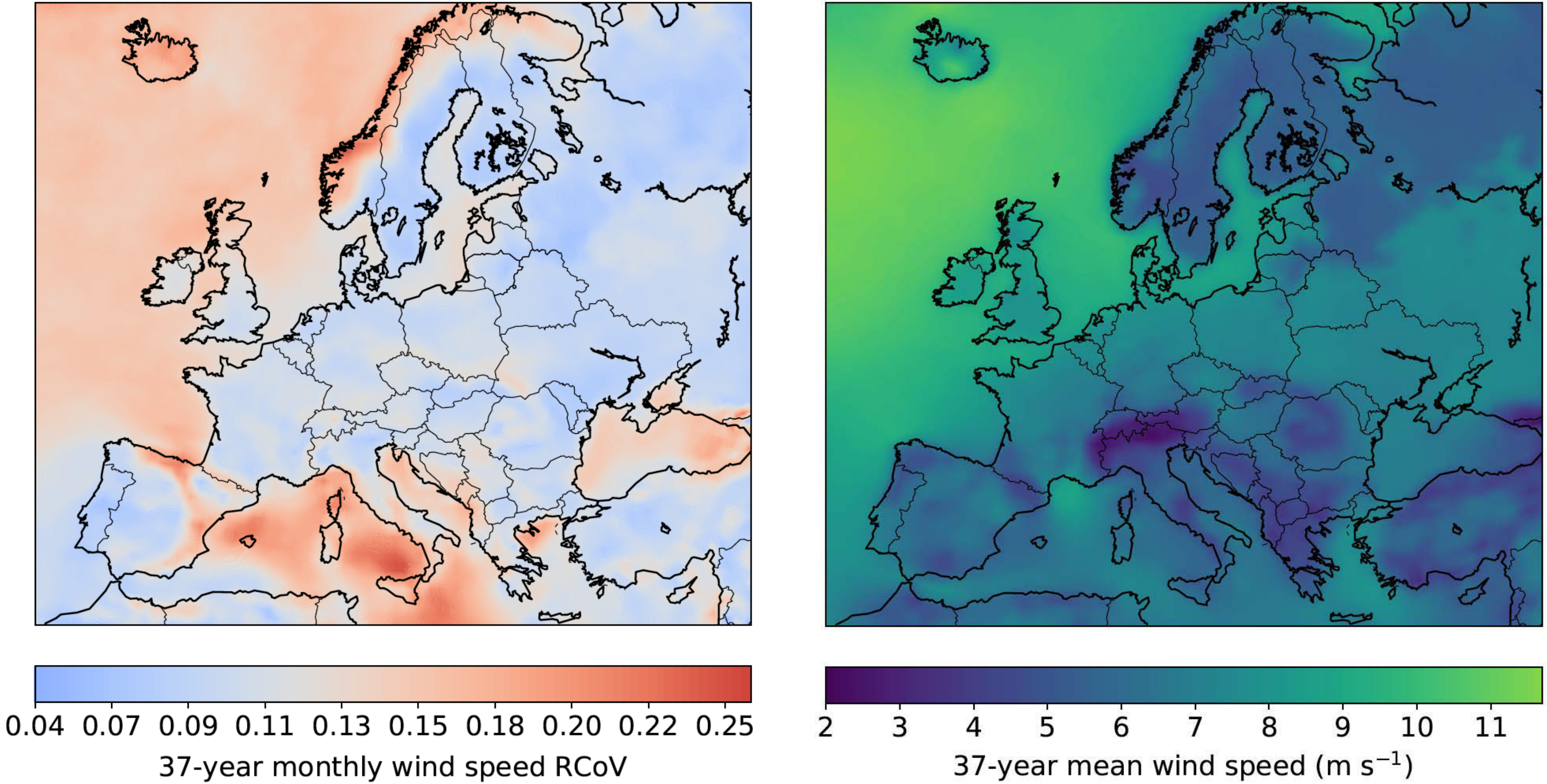
Low Variability High Variability Calm Windy

Ideal Wind Sites Possess Strong Winds With Low Variability



Below-median wind speed, above-median RCoV
Below-median wind speed, below-median RCoV
Above-median wind speed, above-median RCoV
Above-median wind speed, below-median RCoV

Ideal European Wind Locations Surround the North Sea



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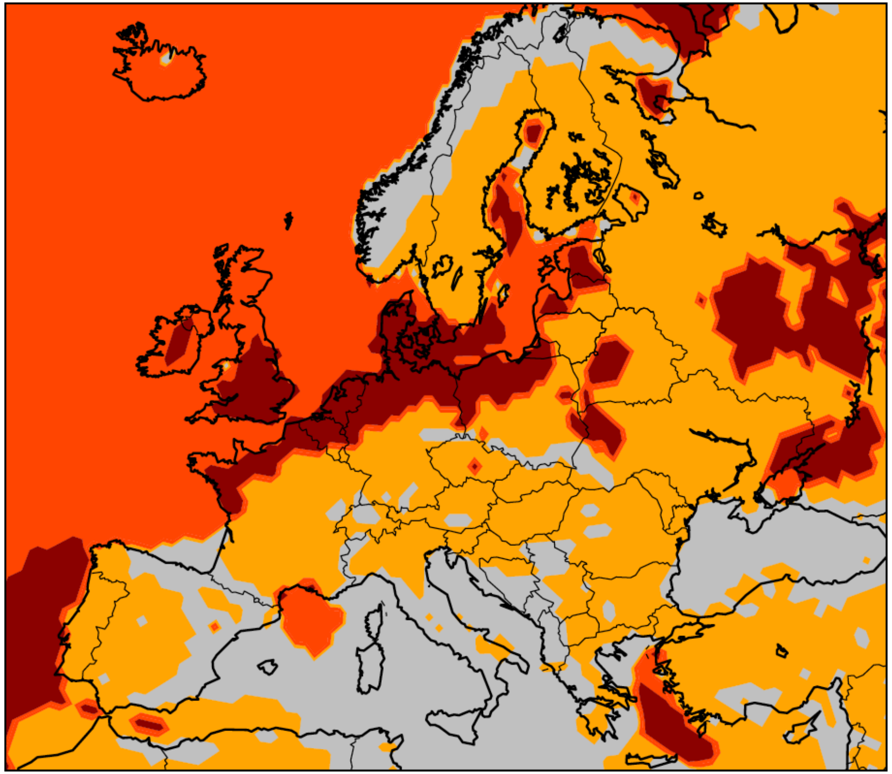


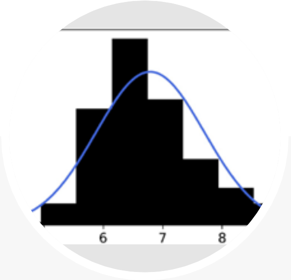
Below-median wind speed, above-median RCoV

Below-median wind speed, below-median RCoV

Above-median wind speed, above-median RCoV

Above-median wind speed, below-median RCoV

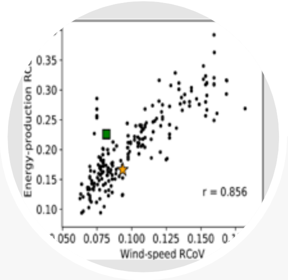
Recommended Best Practices



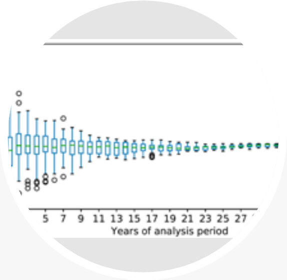
Non-Gaussian wind speed distributions require robust methods to quantify variability

After we challenged 27 spread metrics with 200 sites over 37 years, we recommend RCoV:

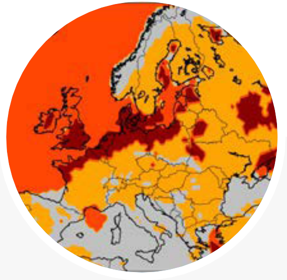
$$RCoV = \frac{median|x - median(x)|}{median(x)}$$



MERRA-2 winds and EIA energy data yield strong correlations between wind-speed RCoV and energy-production RCoV



Assessing variability via RCoV requires 10 ± 3 years of wind speed data



Windy regions with low variability produce stable generations, (e.g., areas around the North Sea)

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Lee, J.C.Y., M.J. Fields, and J.K. Lundquist. 2018. (In review). “Assessing Variability of Wind Speed: Comparison and Validation of 27 Methodologies.” *Wind Energy Science* discussion. https://doi.org/10.5194/wes-2018-49.

Lee, J.C.Y., M.J. Fields, and J.K. Lundquist. 2018. “Determining variabilities of non-Gaussian wind-speed distributions using different metrics and timescales.” The Science of Making Torque from Wind (TORQUE 2018). Doi: 10.1088/1742-6596/1037/7/072038.

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