IMPACT ON LONG-TERM WIND SPEED PREDICTIONS FOR WIND DEVELOPMENT PROJECTS DUE TO INTERANNUAL VARIATION OF ERA5 AND MERRA-2 DATASETS

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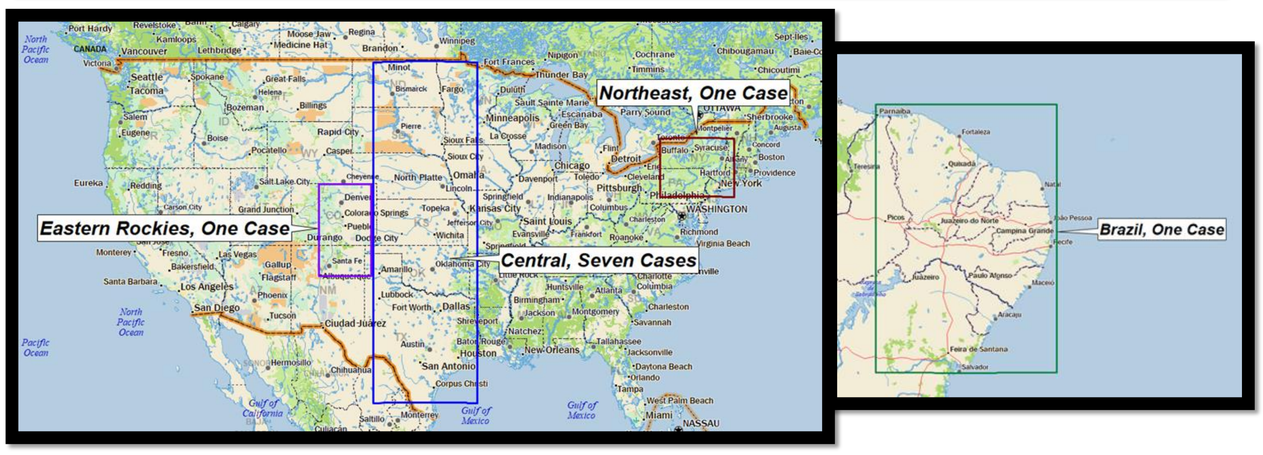
Introduction

ERA5 and MERRA-2 wind speed time series data are commonly used in a measure-correlate-predict (MCP) fashion to predict long-term wind speeds in modern wind energy resource assessments. Differences in time series data are inherent for nodes with similar coordinates from each dataset based on the individual model assumptions and underlying reanalysis data utilized. Recent ArcVera technical work on projects in the United States suggests potential discontinuity in the interannual variation exhibited long-term for ERA5 and MERRA-2 datasets simulated for the same node or nodes within proximity of one another. These differences may drive notable impact on predicted wind speed and associated net energy production in preconstruction and operational wind resource assessments depending on the lookback period used.

Results from 10 total preconstruction and operational analyses are considered in these comparisons, nine in the United States, and one in Brazil. Trends are examined for wind speed predictions based on a lookback period beginning January 2002 compared to a 10-year lookback period relative to the period of record for the preconstruction or operational dataset. Estimated impacts on net MWh energy production are also provided.

Objectives are to determine whether or not clear discontinuity signals exist between ERA5 and MERRA-2 datasets used for specific node pairs, and if there are regional or temporal trends to consider.

General Overview Maps



Methodology

To assess the potential impacts of applying different lookback periods for ERA5 and MERRA-2 reference data, a pool of ten projects were chosen from ArcVera's internal results database where net energy production was forecast in either a preconstruction or operational data analysis. Specific project data is redacted in this presentation to remain confidential. Data from ERA5 and MERRA-2 data nodes with a shared coordinate or coordinates in proximity to one another were selected for study, with the datasets extending back to January 2002, a point associated with higher-quality data used in the reanalysis model process.

Two lookback periods are established to investigate the difference in predicted wind speed for each project: 1) using the full reference data record extending back to 2002, and 2) using a 10-year lookback period relative to the period of record used in the assessment. Using each lookback period, the period of record composite mean annual wind speed estimate is adjusted to long-term using the ratio of the project period of record composite mean annual wind speed for the reference data node over its long-term mean annual wind speed for the period of interest.

$$MCP\ Ratio = \frac{Reference\ WS_{L-T}}{Reference\ WS_{POR}}$$

For projects based on operational data, wind speed is converted to estimated net MWh energy using a simple linear regression. For preconstruction projects, forecasted wind speeds are adjusted based on a ratio calculated from the MCP Ratios associated with each lookback period. Gross energy is predicted based on the adjusted wind speeds, and project-specific gross-to-net loss factors are applied to arrive at a net MWh energy prediction.

$$10-Year\ Lookback\ MCP\ Ratio = \frac{MCP\ Ratio_{10-Year}}{MCP\ Ratio_{Starting\ 2002}}$$

In both scenarios, the differences in predicted long-term wind speed and net MWh production are then compared to the baseline predictions.

Additional comparisons are performed based on the interannual wind speed variation bias between ERA5 and MERRA-2 datasets to determine if any trend exists.

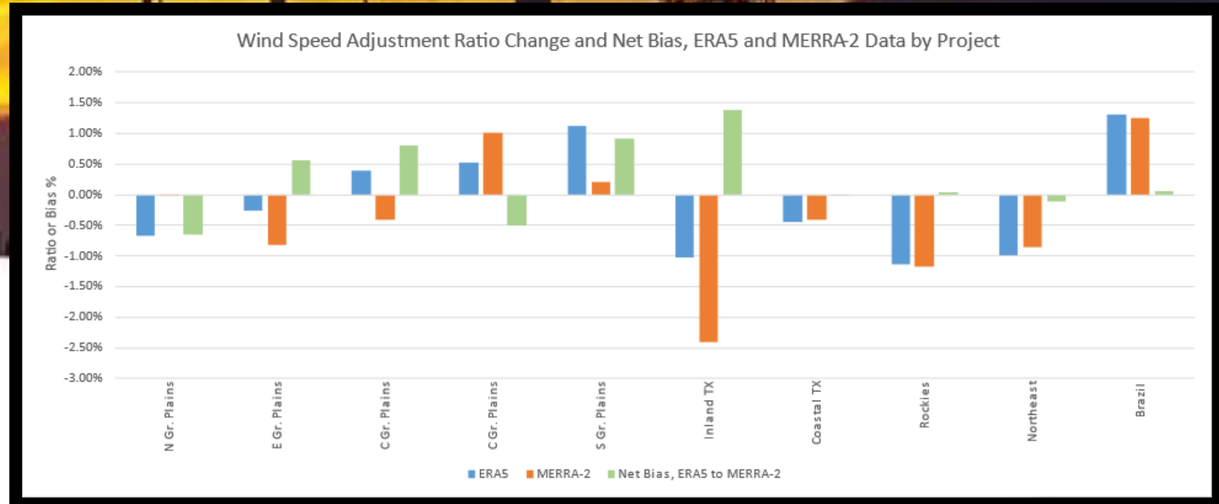
Results

Comparison of the associated differences in wind speed adjustment ratios and ratio bias illustrates significant variation, which is expected due to the inherent interannual variability of wind speed for a given location.

Wind Speed Adjustment Ratio, Period of Record to Long-Term Based on Lookback Period

	Northern Great Plains	Eastern Great Plains	Central Great Plains	Central Great Plains	Southern Great Plains	Inland Texas	Coastal Texas	Eastern Rockies	Northeast	Brazil
Full ERA5	1.008	1.004	0.996	0.983	0.994	1.004	1.005	1.006	1.013	0.987
10-Yr ERA5	1.002	1.001	1.000	0.988	1.005	0.994	1.001	0.995	1.003	1.000
Difference	-0.68%	-0.26%	0.40%	0.52%	1.12%	-1.02%	-0.44%	-1.14%	-0.98%	1.31%
Full MERRA-2	1.003	1.009	1.010	0.986	1.006	1.028	1.004	1.005	1.004	0.988
10-Yr MERRA-2	1.003	1.001	1.006	0.996	1.008	1.003	1.000	0.993	0.995	1.000
Difference	-0.02%	-0.83%	-0.41%	1.02%	0.21%	-2.41%	-0.42%	-1.18%	-0.86%	1.24%
Bias, ERA5 to MERRA-2	-0.65%	0.56%	0.81%	-0.49%	0.91%	1.39%	-0.03%	0.04%	-0.12%	0.06%

Results Cont'd



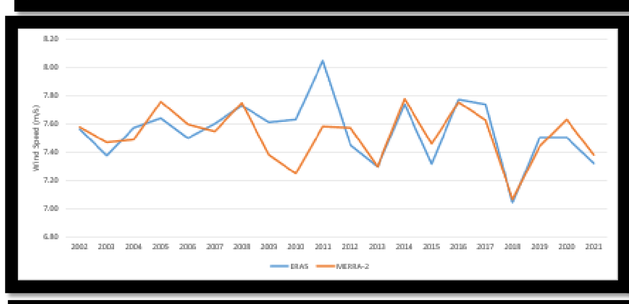
Differences in predicted net MWh energy production track similarly to the wind speed ratio differences.

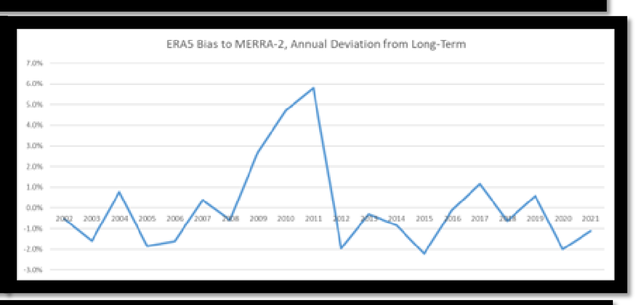
Overall consistency of the interannual variation between the ERA5 and MERRA-2 datasets is judged using the resulting bias in the change in wind speed ratio between the full lookback period beginning January 2002 and the project-relative 10-year lookback period. In theory, if there is no inherent bias between the ERA5 and MERRA-2 lookback periods, then the resulting bias will be quite low since the prediction will not change.

Based on the tabular results and graph, near-zero bias is exhibited for the Coastal Texas, Eastern Rockies, Northeast, and Brazil projects. Relatively moderate bias is observed at the Northern Great Plains, Eastern Great Plains, and Central Great Plains projects, and significant bias is evident at the Southern Great Plains and Inland Texas projects.

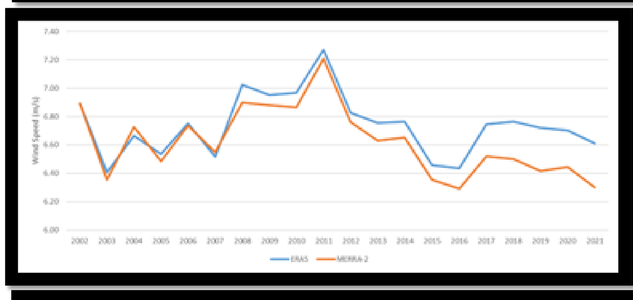
Investigating select Great Plains projects provides additional detail on why such biases exist.

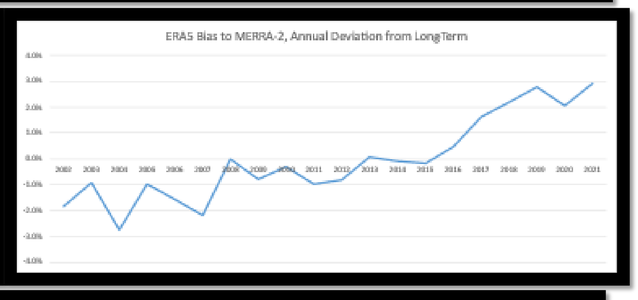
For the Northern Great Plains project, the change in ERA5 prediction drives much of the net prediction bias. Reviewing the annual wind speed patterns between the ERA5 and MERRA-2 datasets for this project shows a potential discontinuity in the data records in 2009-2011, with significant bias between the annual wind speeds. Further reviewing the bias in annual wind speed deviation relative to long-term wind speed between ERA5 and MERRA-2 shows an abnormal high spike during these years.





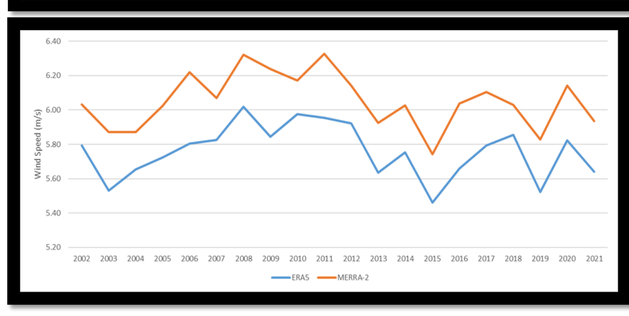
Review of the Inland Texas project indicates notable negative change in using a 10-year lookback period relative to the full period of record for either dataset, with MERRA-2 having a higher magnitude of change.

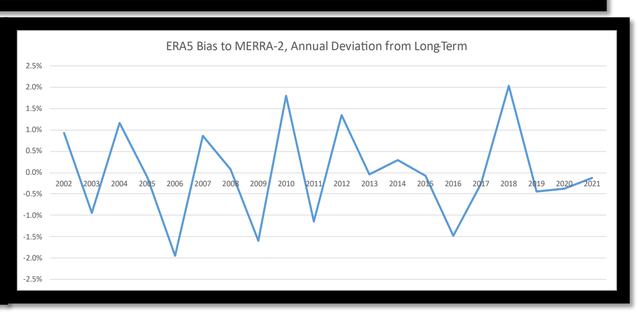




These graphs show a deviation between the two datasets in 2008, and again in 2017. Review of the bias in annual wind speed deviation from long-term shows a gradual increase in relative variation in the ERA5 dataset over time, which may suggest a bias in the ERA5 dataset.

For comparison, the Eastern Rockies project, with a near-zero bias, shows ERA5 and MERRA-2 datasets that track well with one another for the entire period of record, and that while net bias between interannual deviations from long-term vary by year, they tend to be normalized about the zero axis equally.





Conclusions

Based on the outcomes of this preliminary study using ten example projects, long-term wind speed predictions in a measure-correlate-predict method for preconstruction or operational wind energy projects using ERA5 or MERRA-2 reference data may be significantly impacted depending on the lookback period utilized.

No clear universal signal is present across the datasets investigated, though three potential trends are noted:

1. Observed differences in prediction based on lookback period were stronger in the Great Plains than other areas.
2. The magnitude of difference in prediction and associated bias in interannual variation relative to long-term change depending on the latitude of the project within the Great Plains, with increasing bias moving from north to south.
3. Potential discontinuities may be present in the ERA5 data for select nodes, with gradually increasing bias relative to MERRA-2 and patterns that also vary on a site-specific basis.

At a minimum, these qualitative outcomes provide evidence that the interannual deviation from long-term of a reference dataset should be reviewed against other sources to determine the overall consistency of the data and inform potential site-specific lookback period strategies to employ for the project analysis.

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