Annual Solar Irradiance Anomaly Features Over the USA During 1998–2017 Using NSRDB V3

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Abstract

- Annual solar irradiance anomalies (or departures from the long-term mean annual value) have a direct impact on various phases of solar energy projects, from prefeasibility studies to technical deployment decisions [1], [2], [3].
- Anomalies can happen because of normal climate variability or exceptional weather patterns.
- This study investigates such anomalies for both global horizontal irradiance (GHI) and direct normal irradiance (DNI) using Version 3 of the National Solar Radiation Database (NSRDB V3) and surface irradiance measurements at eight U.S. locations.
- At each site, the annual anomaly is analyzed here by evaluating the irradiance deviation from the long-term average for each specific year from 1998–2017.
- A positive/negative anomaly indicates that the solar resource was higher/lower than the long-term average during that specific year.
- The results show that in most cases the anomaly is within ±5% for GHI and ±10% for DNI using either ground-based irradiance measurements or modeled data from the NSRDB.

Methods

- In this study, the annual anomalies for the 1998–2017 period at seven National Oceanic and Atmospheric Administration Surface Radiation Budget Network (SURFRAD) stations and one station from the University of Oregon's Solar Radiation Measurement Laboratory are compared to those of the corresponding NSRDB pixels (Table 1).

Table 1. Locations Used in this Study During 1998–2017 (except 2003–2017 at Sioux Falls)

Station	State	Code	Latitude (◦)	Longitude (◦)
Bondville	IL	BON	40.052	-88.373
Boulder	CO	TBL	40.125	-105.237
Desert Rock	NV	DRA	36.624	-116.019
Fort Peck	MT	FPK	48.308	-105.102
Goodwin Creek	MS	GWN	34.255	-89.873
Penn. State Univ.	PA	PSU	40.720	-77.931
Sioux Falls	SD	SXF	43.734	-96.623
Burns	OR	BURNS	43.520	-119.020

- For any specific year, the anomalies are evaluated by calculating the percentage irradiance deviation from the long-term average—which constitutes the main characteristic of the solar resource at any solar project site. This method is consistent with what was used in earlier studies [2], [3].

Results

Fig. 1 shows the anomaly time series obtained for each year relative to the 1998–2017 long-term average at the eight test locations.

Fig. 1. Percentage annual anomaly of ground measurements (yellow bar) and NSRDB (green bar) for GHI (top row) and DNI (bottom row) at eight locations during the period from 1998–2017 (X-axis).

In general, the NSRDB and surface measurements capture similar positive or negative deviations as well as their magnitudes. This gives confidence that the NSRDB data are able to accurately predict long-term variability, even though exceptions do occur during some years, when the anomaly magnitudes differ for reasons still unclear.

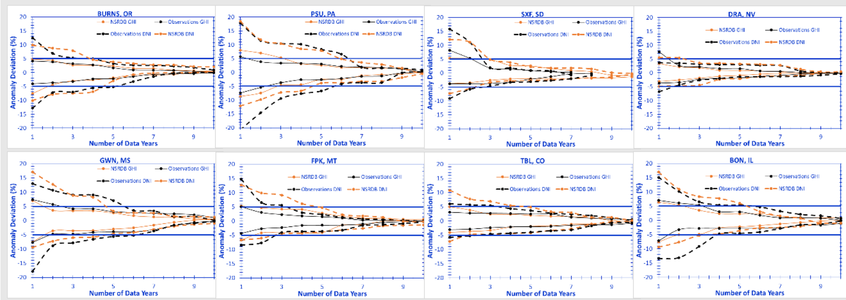

Fig. 2. Number of years required to stabilize GHI and DNI for the eight locations using NSRDB (orange) and observation data (black). The blue line represents the ±5% range. A period of 20 years of the NSRDB and observation data is assumed to represent the "true" climatological average.

- In Fig. 2, a hypothetical time series is constructed in a non-chronological order to identify the nominal period of record required to estimate the long-term "climatological" average at a given location.
- To construct Fig. 2, the observations and model predictions are sorted from the worst years showing the largest anomalies to the best years with smaller anomalies.
- This exemplifies the extreme cases when the period of irradiance record could, by chance, start during a very good year (maximum positive deviation) or during a very bad year (maximum negative deviation) relative to the long-term "climatological" average.
- As shown in Fig. 2, the selected 20-year period appears stable compared to the longer and different period used in [2], even though the latter's extremes were severely impact-ed by volcanic eruptions—especially in the case of the DNI's anomalies.

Conclusion

- Solar irradiance anomalies from one year to the next is an important source of uncertainty for solar energy projects.
- In most years at all locations, the results show deviations of up to approximately ±5% for GHI and ±10% for DNI.
- The present findings have clarified what the minimum period of irradiance records should be to correctly characterize the solar resource of PV plants.
- A minimum period of 5 years is recommended to approach the long-term average GHI within ±5%. In contrast, a 10-year period appears necessary to reach a more conservative risk of error of only ±1%.

References

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