Assessment of the National Solar Radiation Database (NSRDB 1998–2016)

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Assessment of the National Solar Radiation Database (NSRDB 1998-2016)

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***Abstract* — Applying traceable and standardized uncertainty characterization for solar resource data provides confidence in the dataset for use by financiers, developers and site operators of solar energy conversion systems, and ultimately reduces deployment cost. Performance guarantees of solar energy conversion systems are based on the available solar resource from measurement stations or modeled dataset such as the National Solar Radiation Database (NSRDB). In this study we implemented a comprehensive uncertainty determination approach [1]. The study also analyzed how the NSRDB (1998-2016) – Version 3 compares with the previous NSRDB (1998-2015) – Version 2. The study also attempted to estimate the uncertainty differences derived by comparing the NSRDB data to the seven measurement stations from the National Oceanic and Atmospheric Administration's Surface Radiation Budget Network (SURFRAD) and University of Oregon Solar Radiation Monitoring Laboratory (SRML). The evaluation was conducted for hourly values, daily totals, monthly mean daily totals, and annual mean monthly mean daily totals and demonstrate the quality of the new datasets currently available from the NSRDB.**

I. Introduction

The NSRDB has been updated over the years, to meet the demand of solar resource for solar energy conversion systems. NREL released version 3, of the NSRDB (1998–2016) which contains gridded solar irradiance—global horizontal irradiance (GHI), direct normal irradiance (DNI), and diffuse horizontal irradiance at a 4-km by 4-km spatial resolution and half-hourly temporal resolution covering 19 years. Details of the dataset are available at https://nsrdb.nrel.gov. Additional details about the NSRDB are also described in [2], [3]. NREL implemented major meteorological input and processing changes in this update. MERRA-2 reanalysis data such as Aerosol Optical Depth and precipitable water vapor (PWV) were used in the NREL radiative transfer model, the physical solar model (PSM). Some downscaling methodologies such as interpolation and extrapolation used to align the multiple datasets to the same grid were changed in the version 3. Understanding the impacts of these changes on the solar resource and quantifying the uncertainty are essential for solar energy conversion systems. This study attempts to provide a comprehensive uncertainty estimate that demonstrates the performance characteristics of the NSRDB (1998–2016) by including all sources of uncertainty using observations at various time-averaged periods.

II. Method

As reported in [4], [5], a comprehensive uncertainty determination approach was implemented by incorporating the mean bias error (MBE) and root mean square error (RMSE) as statistical measures, and ground-based solar measurement uncertainty.

The ground-based solar measurement uncertainty was estimated at 5% and this estimate is consistent with previous studies estimations [6], [7], [8], [9]. These studies reported the uncertainty of the ground-based solar measurement using pyranometers and/or pyrheliometer includes sources of uncertainties such as the specifications of the instrument, calibration procedure, measurement conditions and maintenance, and environmental conditions. The reports mentioned above show the steps required to calculate the overall ground-based uncertainty using the GUM method, by incorporating these specifications.

To quantify the overall uncertainty of the modeled NSRDB data set, the approach applies RMSE, MBE, and the ground-based measurement uncertainties as sources of estimated combined uncertainty [4]. This approach provides uncertainty estimation on a 95% confidence interval representing two standard deviations (coverage factor of ~2.0) and assuming a Gaussian or normal distribution of the errors [4].

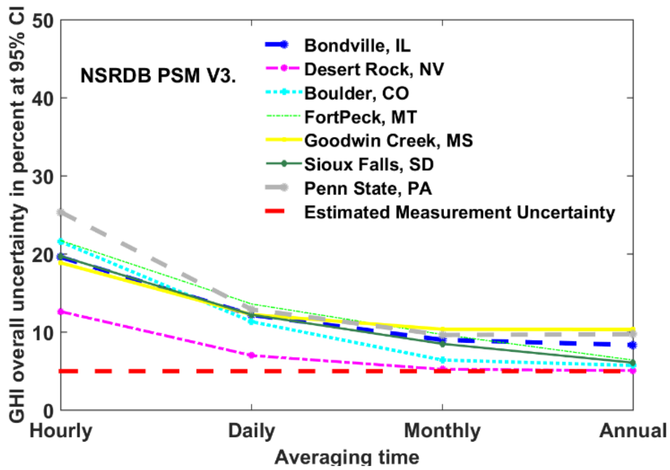
NSRDB 1998-2015 (version 2) and NSRDB 1998-2016 (version 3) were compared. The approach used to determine the uncertainty in both datasets is the same. Data from 1998-2015 from seven SURFRAD ground-based measurement were used to compare to the NSRDB version 2 and version 3. Further, four SRML measurement locations for 2015 were used to understand the differences between the GOES East and GOES West satellite irradiance values for the NSRDB version 3.

III. RESULTS AND DISCUSSION

A. NSRDB Version 2 and Version 3 Comparison and Uncertainty

Fig.1 shows uncertainties for varying time averages where the hourly dataset demonstrated higher uncertainty estimation of the NSRDB and as time averaging increased, the uncertainty decreased and approached the measurement uncertainty. The bias of the NSRDB data does not change from one-time average to another, on the other hand, the RMSE in the NSRDB (1998–2016) decreases significantly with the increase in the time average [4].

Further, as described in [4] the reason for the high uncertainty in the hourly dataset is due to the random error, RMSE and this in turn is due to the NSRDB pixel representing a 4-km by 4-km area, whereas a ground-based solar measurement represents only a small area above the measuring station. The subpixel variability in clouds appears to contribute to higher differences.



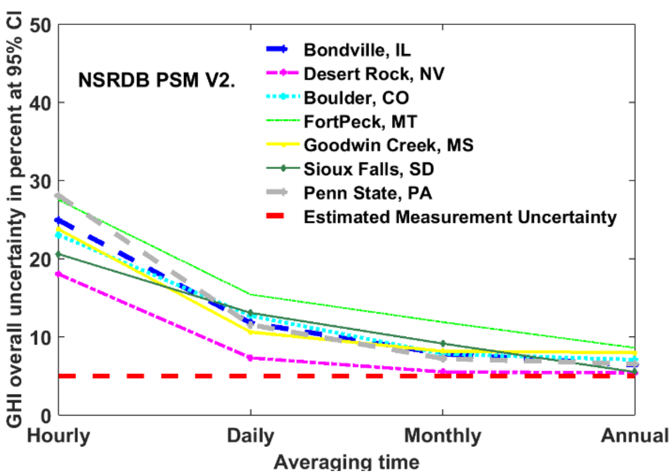
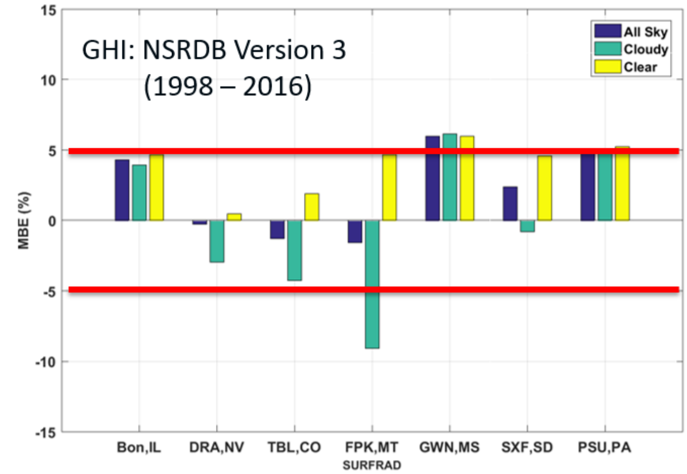


Fig. 1. GHI estimated overall uncertainty for seven ground-based solar measurement locations for NSRDB version 2 and 3.

Compared to version 2 of the NSRDB, version 3 has improved in overall measurement uncertainty (Fig.2). The improvement was noticeable on the hourly basis. For instance, at Desert Rock the uncertainty was ~18% in version 2; however, the uncertainty is reduced to about 12% in the NSRDB version 3. However, the monthly and annual averages for NSRDB version 2 appears to be better; this could be attributed to higher bias in NSRDB version 3 where the clear and cloudy condition biases are either both positive or negative. However, NSRDB version 2 appears to contain biases of opposing signs resulting in cancellation of biases (Fig. 2.).



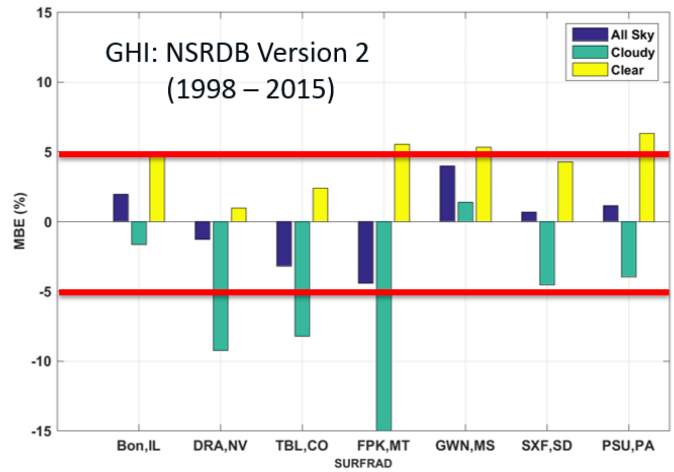


Fig. 2. estimated biases for seven ground-based solar measurement locations for NSRDB version 2 and 3.

B. Comparison of GOES East and GOES West

The satellite information that is used to produce NSRDB data originates from two satellites – GOES East and GOES West, with the dividing line between 105º and 110º west longitude. GOES East data has time-shift applied to cloud properties instead of solar radiation. The solar radiation data from both satellites is available at the top and middle of every hour. The data from both satellites were joined to provide a complete uninterrupted satellite image every half-hour at a 4 km resolution for the US as shown in Fig. 3.

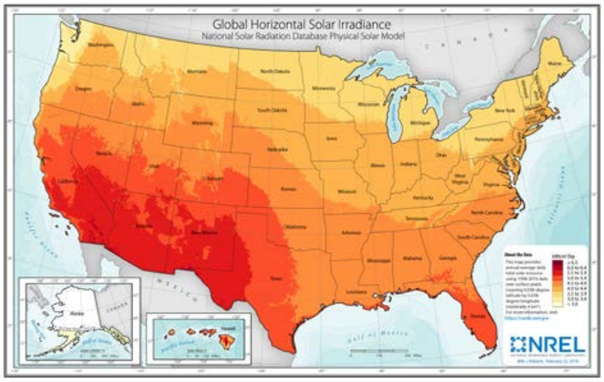


Fig. 3. NSRDB version 3 blended GHI dataset.

However, we noticed differences between the two version along the dividing line (105° longitude). To better understand these differences, we compared GHI estimates from the GOES-East and West satellites to four University of Oregon Solar Radiation Measurement Laboratory (SRML) ground measurement stations. Both satellites cover the state of Oregon where these stations are located. The result using 2014 data shows the GOES East satellite performs better than the GOES west satellite for this region (Table 1 and Fig 4.). Note that the GOES West satellite has a better viewing angle for the state of Oregon than the GOES East satellite.

Overall, the GOES East comparison shows zero bias for all sky condition and less than ±2% for clear and cloudy conditions for three out of four stations. However, the GOES West satellite shows higher biases in all, clear and cloudy skies, except for Ashland where all sky condition shows lower bias compared to GOES East; however, there is a cancellation of error because clear and cloudy have opposite signs of equal magnitude.

TABLE I
GOES EAST AND GOES WEST COMPARISON WITH SURFACE MEASUREMENTS (% MBE)

Station	Latitude	Longitude	GOES East			GOES West		
			All Sky	Clear Sky	Cloudy Sky	All Sky	Clear Sky	Cloudy Sky
Ashland	42.19	-122.7	4	5	2	1	6	-5
Burns	43.52	-119.02	0	2	-1	-1	2	-7
Eugene	44.05	-123.07	0	0	1	-1	2	-6
Silverlake	43.12	-121.06	0	0	-1	-2	1	-7

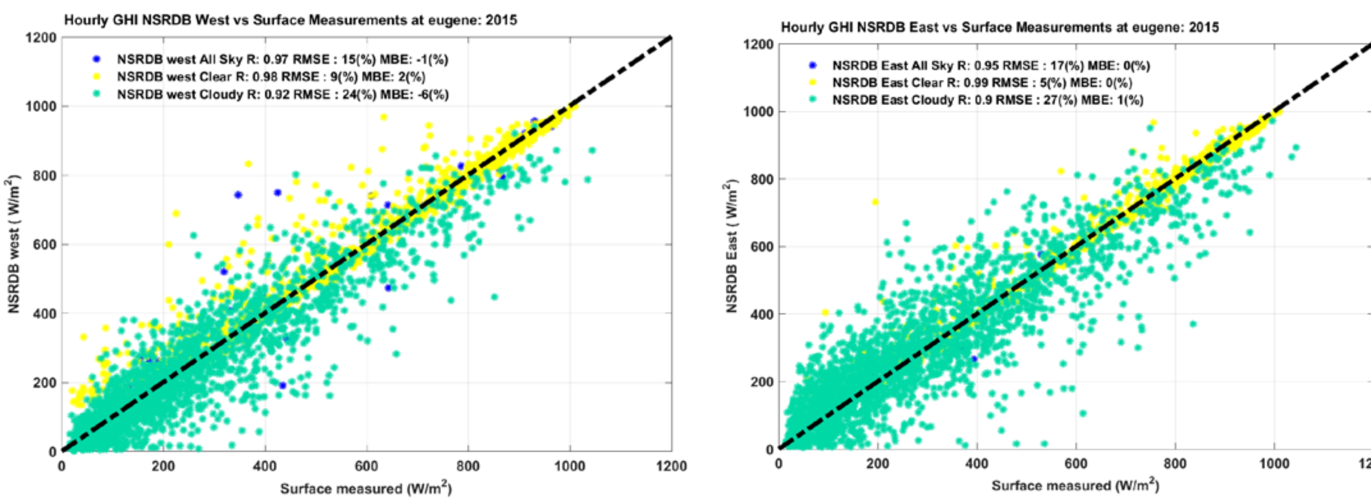


Fig. 4. Comparison for Eugene, Oregon (left) using GOES West satellite and (right) using GOES East satellite.

IV. Conclusion

Comparisons of the NSRDB (1998-2016) version 3 was assessed by comparing with selected ground-measured data under both clear- and cloudy-sky conditions and covered the period from 1998–2016. The result shows improvement compared to the previous version of NSRDB. The bias is ~ ±5% and the overall uncertainty reduced significantly on the hourly biases. Further the study analyzed the differences between the GOES East and GOES West satellites as they relate to irradiances and the result shows GOES East satellite provides a better solar radiation result compared to ground measurement for locations in the Oregon state. However, this needs further study to better understand the cause of the outcome.

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