Solar World Congress 2025

ASSESSING THE ACCURACY OF PUBLICLY AVAILABLE SPECTRAL IRRADIANCE DATA FROM NSRDB

Summary

This study presents the first validation of the National Solar Radiation Database (NSRDB) spectral irradiance data outside North America, focusing on sites in France, Brazil, and the USA. Ground-based measurements were used to assess the accuracy of modeled spectra and their suitability for estimating spectral mismatch modifiers (SMMs) in PV systems. Preliminary results from Palaiseau show that while raw NSRDB data underestimate broadband irradiance, rescaled spectra significantly reduce spectral bias and improve SMM-based energy yield estimates. The final paper will include full results across climates and compare NSRDB performance with simplified correction models for broader application in global PV modeling.

Keywords: spectral irradiance, spectral mismatch modifier, photovoltaic performance modeling, NSRDB

1. Introduction

High-resolution spectral irradiance data are essential for modeling photovoltaic (PV) performance, especially for technologies sensitive to spectral variability. Just as gridded broadband irradiance datasets enable PV yield predictions without ground measurements, gridded spectral datasets offer similar potential for estimating spectral effects, provided they are sufficiently validated.

As of May 2025, the National Solar Radiation Database (NSRDB), developed by NREL (Sengupta et al., 2018), remains the only publicly available source of gridded spectral irradiance, spanning major geostationary satellite footprints. Its latest all-sky product is based on the FARMS-NIT model, integrating radiative transfer simulations with satellite-derived inputs (Xie & Sengupta, 2018; Xie et al., 2018, 2019). The only published validation using ground data is by Pelland & Gueymard (2022), limited to North America.

This study extends NSRDB validation to three new sites: Palaiseau, France (temperate); Natal, Brazil (tropical); and Albuquerque, USA (dry). Using ground-based spectral data, we assess NSRDB accuracy and its impact on energy yield modeling in two modern PV configurations. Results are compared with methods that neglect spectral mismatch or apply simplified corrections. At this stage, only the spectral accuracy analysis for Palaiseau is complete; full PV performance evaluation is in progress.

2. Methodology

This section outlines the data sources (2.1), pre-processing steps (2.2), evaluation approach (2.3), and the method for estimating the impact of spectral data accuracy (2.4).

2.1. Data sources

Tab. 1 summarizes the ground-based spectral datasets. NSRDB estimates were retrieved as yearly Spectral On-Demand data (Sengupta et al., 2018; Xie et al., 2019, 2018; Xie & Sengupta, 2018). As of May 2025, data are available for 2017–2019 (Palaiseau) and 1998–2023 (Natal, Albuquerque). Timeframes reflect available overlap with ground measurements.

2.2. Data processing

Three pre-processing steps were applied: quality control and removal of flagged timestamps, temporal upscaling of minutely ground data, and spectral resampling with smoothing of modeled estimates.

Concurrent global horizontal irradiance (G) time series were used for quality control (Espinar et al., 2012) and to validate spectral integrals. Spectroradiometers typically cover up to 1650–1700 nm, missing much of the short-

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Tab. 1: Specifications of the ground-based spectral irradiance datasets used in this study.

Site	Latitude	Longitude	Climate	Spectral sensor	Spectral range	Timeframe	Reference
Palaiseau, France	48.712	2.208	Cfb	EKO MS-710	350-1050 nm	2017-2019 (continuous)	Haeffelin et al. (2005)
Natal, Brazil	-5.825	-35.227	Aw	EKO MS-711	300-1100 nm	2023 (continuous)	internal
Albuquerque, USA	35.055	-106.540	BSk	EKO MS-710 + MS-712	350-1700 nm	2021 (12 evenly spaced 15-day periods)	Driesse et al. (2023)

wave infrared (SWIR) spectrum, which thermopile pyranometers capture. Since atmospheric absorption lowers the SWIR proportion in surface irradiance, the top-of-atmosphere 8% contribution from 1650–2800 nm represents a theoretical ground-level maximum.

To assess spectral irradiance quality, we derived realistic bounds for each site's relevant spectral band using public datasets (e.g., Stoffel & Andreas, 1981; Driesse et al., 2023). For MS-700, Fig. 1 shows the ratio of WISER-only bands (290–350 + 1050–1650 nm) to broadband G as a function of 350–1050 nm irradiance, based on 2023 NREL data. Polynomial fits to the 1st and 99th percentiles (Eq. 1–2) define valid data ranges (Eq. 3).

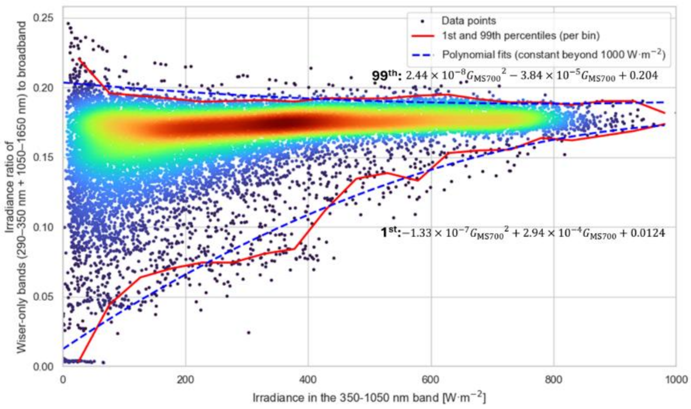

Fig. 1: Ratio of WISER-only bands (290–350 nm + 1050–1650 nm, i.e., $G_{UV+SWIR}$) to broadband irradiance (G) versus 350–1050 nm irradiance (G_{MS700}), measured at NREL SRRL in 2023. Polynomial fits to the 1st and 99th percentiles are shown, used for quality checks of EKO MS-700 measurements at other sites.

$$G_{\mathrm{UV+SWIR,max}} = G\left(2.44 \times 10^{-8} {G_{\mathrm{MS700}}}^2 - 3.84 \times 10^{-5} G_{\mathrm{MS700}} + 0.204\right) \quad \text{(eq. 1)}$$

$$G_{\mathrm{UV+SWIR,min}} = G\left(-1.33 \times 10^{-7} {G_{\mathrm{MS700}}}^2 + 2.94 \times 10^{-4} G_{\mathrm{MS700}} + 0.0124\right) \quad \text{(eq. 2)}$$

$$0.92\, G - G_{\mathrm{UV+SWIR,max}} < G_{\mathrm{MS700}} < G - G_{\mathrm{UV+SWIR,min}} \quad \text{(eq. 3)}$$

Hourly averaging was used to align minutely data with satellite resolution (per FARMS-NIT developer guidance), with timestamps centered and only full 60-minute intervals retained. Modeled spectra were smoothed using a Gaussian filter tailored to sensor resolution (e.g., 10 nm FWHM for MS-700) to reduce noise and improve comparability.

2.3. Performance evaluation

Wavelength-specific mean bias error (MBE) was used to assess model accuracy. Raw NSRDB data were evaluated, reflecting both broadband and spectral pattern errors. Rescaled data, matched to measured spectral integrals, were then analyzed to isolate spectral pattern bias. Seasonal and diurnal MBE variability were also examined.

2.4. Impact estimation

The effect of using NSRDB spectral data for estimating spectral mismatch modifiers (SMMs) was compared to methods that neglect spectral effects or use simplified corrections (e.g., King et al., 2004; Huld et al., 2009; Lee and Panchula, 2016; Caballero et al., 2018; Pelland et al., 2020). SMMs were computed for bifacial TOPCon and monofacial CdTe systems on horizontal single-axis trackers using SunSolve, based on internal and published module specifications. For this abstract, a generic crystalline silicon spectral response (Driesse & Stein, 2020) was used.

3. Preliminary results

This section presents results for the Palaiseau site. Analysis of the other two sites, seasonal and diurnal variability, and comparison with simplified correction models will follow in the final paper.

3.1. Performance evaluation

Fig. 2 shows that in Palaiseau, raw NSRDB spectral estimates underestimate irradiance across the full measured spectrum, mainly due to an 8.8% average underestimation of total irradiance over 2017–2019. However, the low bias in the rescaled data suggests that NSRDB spectral estimates hold promise for calculating SMMs and improving PV energy yield predictions compared to approaches that neglect spectral effects or use simplified correction models.

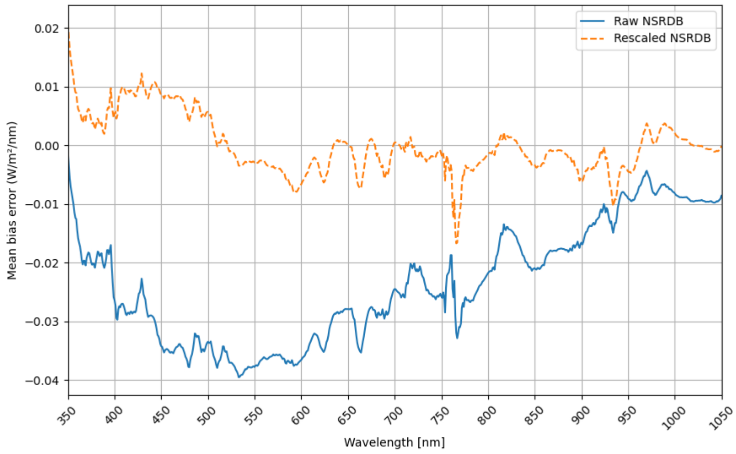

Fig. 2: Mean bias error of NSRDB spectral irradiance in Palaiseau (2017–2019), showing both raw estimates and rescaled estimates matched to measured spectral integrals.

3.2 Impact estimation

Fig. 3 shows that using NSRDB spectral data instead of assuming SMM=1 significantly reduces energy yield error for c-Si-based PV systems at Palaiseau-like sites. Over the 3-year average, the SMM=1 assumption leads to a 1.9% overestimation, while NSRDB data reduce the bias to –0.4%.

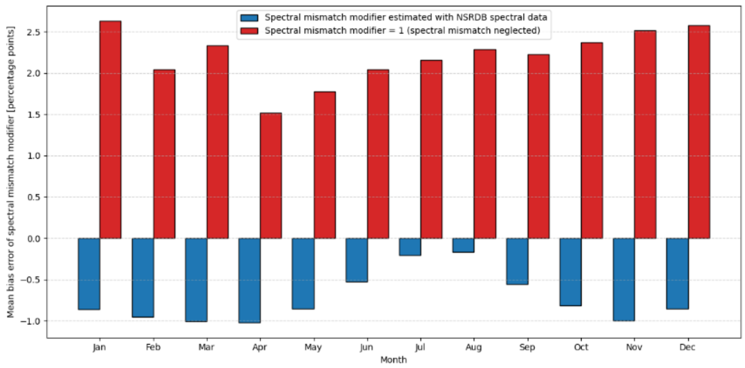

Fig. 3: Mean bias error (MBE) of spectral mismatch modifier (SMM) in Palaiseau (2017–2019), estimated using NSRDB spectral data and a reference spectral response (Driesse & Stein, 2020), compared to the MBE from assuming SMM = 1 (i.e., no spectral mismatch).

4. Conclusion

This study is the first to evaluate NSRDB spectral data outside North America. Preliminary results suggest that the data can be valuable for estimating spectral mismatch modifiers (SMMs). However, due to severe broadband underestimation, raw NSRDB spectral data are not recommended as a standalone replacement for solar data at Palaiseau-like sites within the Meteosat region. The final paper will present a more detailed analysis across three climate zones and compare NSRDB-based SMM estimation with simplified correction models.

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