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Effect of satellite-derived insolation data on the accuracy of Performance Ratio Estimates

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MOTIVATION

- Irradiance sensors to measure received solar resources are not widely used in residential (or commercial/industrial) installations. For larger systems, these sensors are frequently reported to lack maintenance or regular recalibrations. Data from local meteorological ground stations are valuable and accurate since the instruments are usually well-maintained, but they are sparsely distributed and hence not a suitable data source for many PV systems.
- For these reasons, PV systems' short- and long-term performances have often been analyzed using satellite-derived insolation data. Despite the fact that higher uncertainties are associated with satellite-derived insolation data, no studies have been conducted to quantify this impact when assessing PV plant's performance ratio.

This work quantifies the **accuracy of satellite-derived insolation (open-source and paid service)** and then understands **the impact of satellite-derived insolation data on the accuracy of PR estimates**. In order to do that, ground-measured insolation data and PR time series computed using ground-mounted sensors are used as benchmarks.

GROUND-BASED AND SATELLITE-DERIVED DATA

- **Ground-based insolation:** GHI and the plane of array irradiance (G_{POA}) (20° tilt and 4° azimuth from the South) were monitored every minute for over three years (December 2015 - May 2019) by two secondary standard pyranometers mounted at SUPSI (Canobbio, Switzerland).
- **Satellite-derived CAMS insolation (open-source):** GHI, DHI and DNI components with 1-minute intervals for the same time period were retrieved.
- **Satellite-derived Solargis insolation (paid-service):** GHI, DHI, DNI and G_{POA} components were retrieved with a 5-minute frequency for the same period.

Table I. Ground-based and satellite-derived irradiance monitoring systems.

	Ground	CAMS	Solargis
Instrument	Pyranometer CM11 (UC = 2.7%, k=2)	Satellite (open-source)	Satellite (paid-service)
Time-step	1 minute	1 minute	5 minutes
GHI	✓	✓	✓
DHI	–	✓	✓
DNI	–	✓	✓
G_{POA}	✓	– (PVlib *Perez* [1])	✓

RESULTS & DISCUSSION

Uncertainty of Satellite-derived Insolation Data

$$UC_{Satellite}[\%] = k \times \pm \sqrt{\left(\frac{UC_{Pyra}}{k}\right)^2 + \left(\frac{MBE}{k}\right)^2 + \left(\frac{RMSE}{k}\right)^2}$$

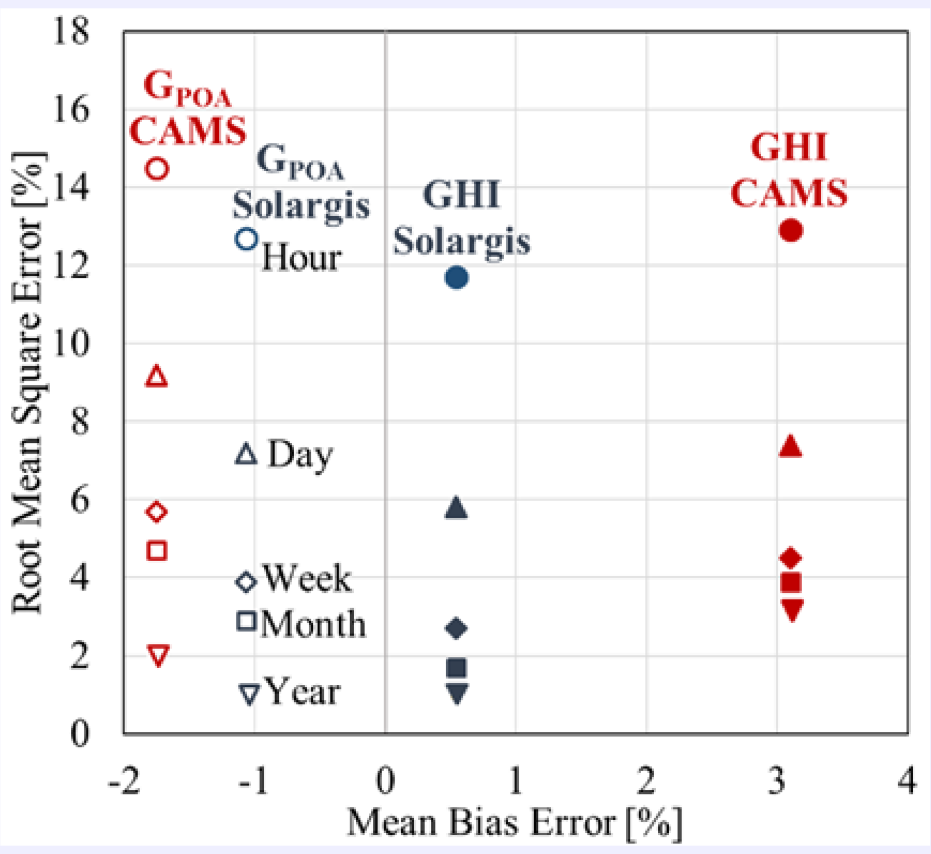

Fig. 1: MBE and RMSE of satellite-derived GHI and G_{POA} data from CAMS and Solargis with respect to ground-measured data.

Fig.1 shows that **Solargis GHI and G_{POA}** data have **better precision (lower RMSE)** and **accuracy (lower MBE)** than CAMS data. The precision of both satellite-derived data (RMSE) improves with lower temporal resolutions for both GHI and G_{POA}.

The uncertainty of satellite ($UC_{Satellite}$) data was calculated using the approach in the report of IEA PVPS Task 16 [2] (**Fig.2**). The **uncertainty of the pyranometer is 2.7%** (k=2) at 1000 W/m², considering the pyranometer specifications, calibration procedure, secondary calibration, maintenance, measurement, and environmental conditions [3].

- The **UC of G_{POA} decrease significantly with longer temporal intervals** as some errors cancel each other out, **similar to RMSE**.
- **Solargis G_{POA}** has, on average, **1.8% lower uncertainty** than **CAMS G_{POA}** for all temporal resolutions, except for the yearly resolution (**0.7%**).

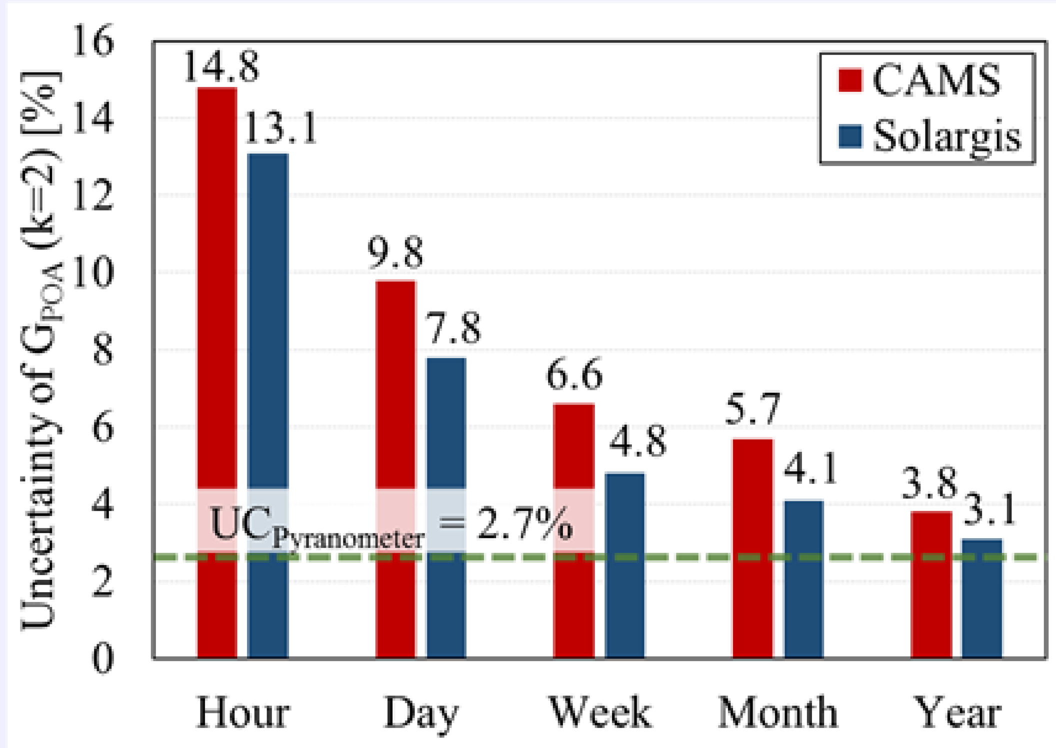

Fig. 2: Uncertainty (k=2) of G_{POA} for satellite-derived data for different temporal resolutions. The green dashed line is uncertainty (k=2) of pyranometer.

Uncertainty of Performance Ratio (PR)

The uncertainty of PR was calculated by propagating the **uncertainties of G_{POA}, P_{STC} by Pasan IIIb** at SUPSI PV-Lab(**1.6%**, k=2, spectrum corrected [3]) and **the outdoor P_{Meas} by maximum power point tracker** (**1.74%**, k=2, incl. uncertainty of tracker [4]) (see **Table II**).

- **$PR_{Solargis}$** has about **1.7% lower uncertainty than PR_{CAMS}** for all temporal resolutions, except for the yearly temporal resolution (0.6% lower).
- The **uncertainties of monthly and yearly $PR_{Solargis}$** are **1.1% and 0.3% higher than the best case** (**3.6%, uncertainty of $PR_{pyranometer}$**), respectively.

Table II. Uncertainties (k=2) of PRs computed using ground-based and satellite-derived CAMS and Solargis G_{POA} data.

Temporal res. / Insolation data	Uncertainty of PR (k=2): Day	Month	Year
Ground		3.6%	
CAMS	10.1%	6.2%	4.5%
Solargis	8.2%	4.7%	3.9%

CONCLUSION

- **Monthly and yearly PR values with an uncertainty below 5%** can be obtained **using satellite-derived insolation data** without having to deal with regular calibration and maintenance of an on-site pyranometer to check general status of a PV system. However, there is a **trade-off (saving cost and time vs accuracy)**.
- Depending on the purpose and requirements of use, one of the appropriate satellite-derived data sources (open-source or paid service) or ground-based measurement options can be preferred.
- Although **daily PR** has higher uncertainty than **monthly PR (8.2% vs 4.7%),** since it has about **thirty times more data points**, the **uncertainty arising from analysis to compute long-term performance change (PLR, %/year) may be less**. This **trade-off** will be investigated.

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