Quantifying soiling using operational data

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Abstract

Soiling significantly affects PV plant performance. Soiling sensors require constant maintenance, and their discrete nature can also result in a misrepresentation of the overall plant condition. To overcome these challenges, GPM has developed its own algorithm to predict soiling and has compared it to the established Humboldt State University (HSU) soiling model [1]. While the HSU soiling model is based on meteorological parameters, GPM approach leverages devices power signals to detect cleaning events and estimate daily soiling.

Methodology

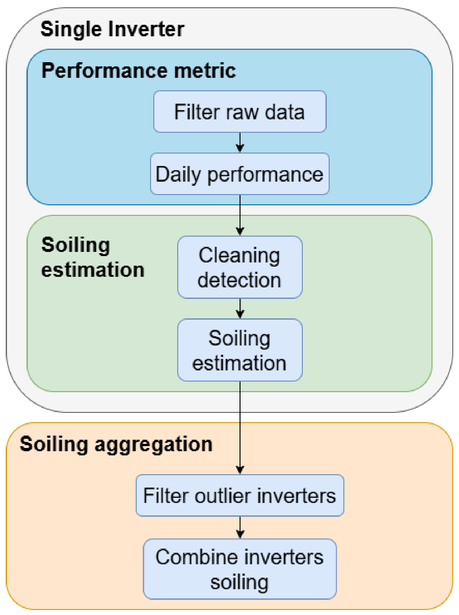

Figure 1 GPM estimator summary

To estimate the site soiling, soiling of each of the inverters is estimated daily and aggregated to provide a robust site-level soiling estimation.

The required inputs are:

- Irradiance
- Temperature
- Inverters power

Initially, outliers and sampling times with other losses are filtered. Remaining data are normalized by temperature and aggregated into a daily performance metric (PM).

Cleaning events are identified from sudden increases in PM, their magnitude is quantified, and the data are segmented into soiling intervals. Within a soiling interval, a representative PM slope between all the days is obtained using two different statistical methods. The difference between both methods and additional checks on the soiling interval shape and data quality ensure a robust inverter-level soiling estimation.

The soiling aggregator filters outlier inverters and combines the rest in a single site-level soiling.

A detailed flowchart of the overall algorithm is presented in Figure 2.

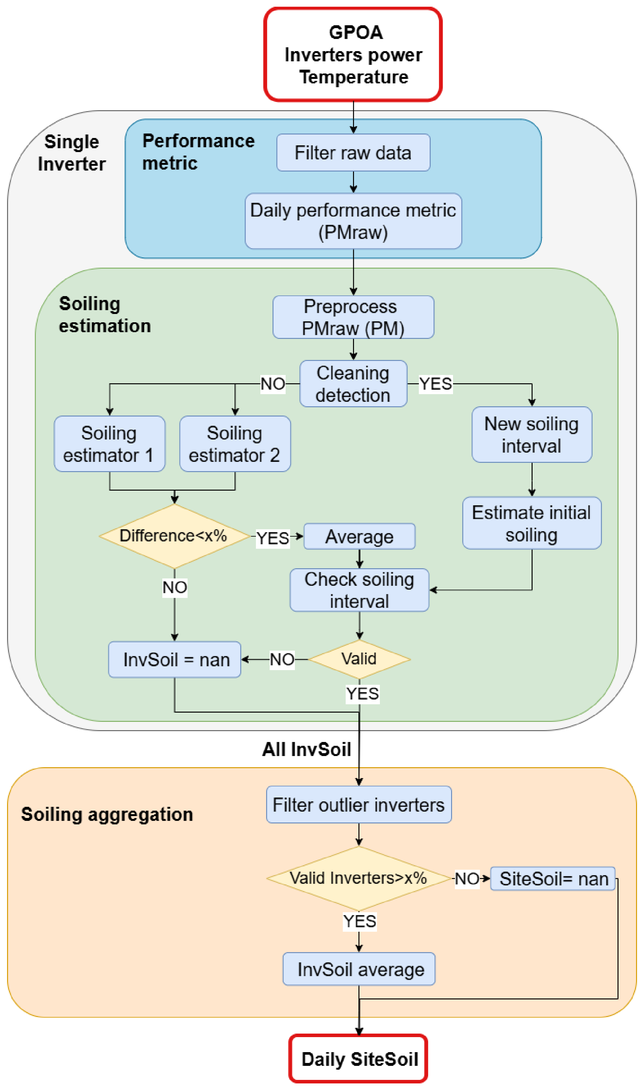

Figure 2 GPM estimator flow diagram

Results & Conclusions

Validation campaigns included:

- 20 sites over periods ranging from 1 to 3 years
- GPM's algorithm
- HSU model
- Soiling station data

Figures 3 and 4 illustrate these comparisons across two Middle Eastern sites over six-month periods for visual clarity. Registered cleaning events are used to assess the accuracy of the soiling measurements or estimations.

In Figure 3, the soiling station signals differ from both GPM and HSU model which correlate better with the daily site performance ratio (PR).

Cleaning event in Figure 3 in mid-July 2024:

	Site PR	Soiling stations	HSU	GPM
Change	~8%	<1%	4-5%	6-7%

Figure 3 also highlights inaccuracies in the assumptions of the HSU model:

- Meteorological data represents site conditions
- Perfect cleaning following rainfall above a threshold

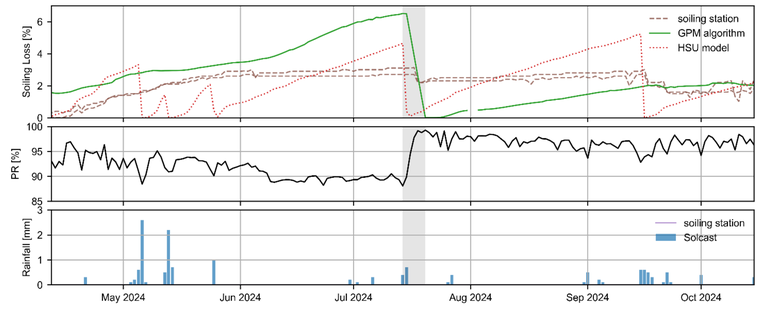

Figure 3 Validation site 1

Figure 4 highlights the potential pitfalls of relying solely on soiling stations or meteorological models

Manual cleaning event in Figure 4 in August 2023:

- No recorded rainfall in the Solcast ® data
- Fully cleaned panels expected

	Site PR	Soiling stations	HSU	GPM
Change	~12%	4%	0%	12%
Remaining soiling	-	9%	9%	0%

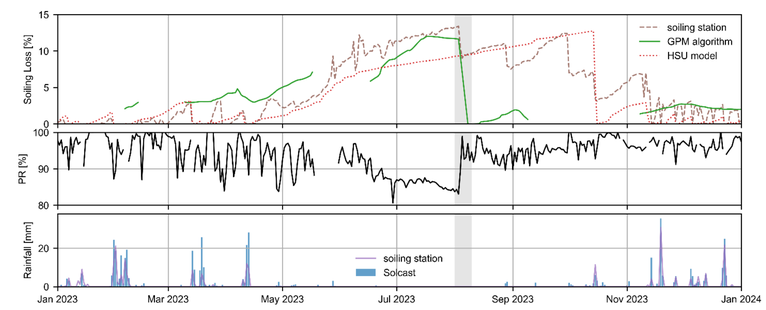

Figure 4 Validation site 2

In conclusion, soiling is far from trivial. Traditional sensors, while useful, often fall short due to their maintenance demands. By harnessing the plant itself soiling can be estimated automatically, enabling smarter and faster decision-making.

References

[1] HSU Soiling Model – PV Performance Modeling Collaborative (PVPMC)