Quantifying the Impact of Quality Control on PV Applications

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Introduction

Ground-based solar radiation measurements play a key role in PV project development and operation. They provide site-specific data essential for resource assessment, energy yield estimation, system design, and performance monitoring. Rigorous quality control (QC) is crucial when using ground-measured solar radiation data for any downstream application. We quantify how retaining flawed measurements propagates errors into downstream applications and show the resulting inaccuracies across common data-quality issues. Finally, we emphasize the importance of regular, proactive QC throughout measurement campaigns. Early and continuous QC ensures timely issue detection, preserves data quality, and maximizes the integrity of long-term datasets relied on in PV applications.

The Risk of Neglecting Quality Control (QC)

Table 1 presents statistics for selected quality issues identified in 154 one-year GHI datasets (with 1- or 5-minute time resolution). It quantifies the relative increase in bias and RMSD between measurements and Solargis solar resource model when specific quality issues remain uncorrected. All datasets were evaluated using Solargis automatic and manual QC procedures.

Key takeaways:

- **All datasets are affected by quality issues.** None of the analyzed time series were completely free of error QC flags.
- **Most common issues:** Exceeding **physical minimum/maximum (91%), shading (85%), soiling (57%), maintenance events (53%), and dew/frost (49%)** of datasets. In 66% of datasets, detected anomalies could not be clearly attributed to a specific cause.
- **Occurrence patterns vary.** Shading typically dominates (median 5% of dataset). Other issues, such as sensor misalignment, may appear sporadically (a few days) or persist throughout the entire dataset depending on maintenance quality.
- **Impact on data accuracy:** Leaving issues unflagged increases bias by up to **1.3% (90th percentile)** and RMSD by up to **3.2% (90th percentile).**
- **Conclusion:** Even small residual issues can significantly affect data uncertainty, highlighting the need for consistent, well-defined QC procedures.

Issue Type	Proportion of Affected Datasets [%]	Proportion of Affected Data Points - Median [%]	Proportion of Affected Data Points - p90 [%]
Static values, Logger issues	47,40	0,15	1,38
Shading	85,06	5,03	13,54
Misalignment	9,09	13,48	98,37
Calibration	1,95	0,90	13,29
Dirt, Soiling	57,14	0,76	6,83
Multi-component tests	35,71	0,32	6,89
Snow	3,90	0,15	1,74
Not-specified	65,58	0,07	0,63
Dew, Frost	49,35	0,13	1,32
Physical Minima and Maxima	90,91	0,09	1,17
Postfiltering	94,16	0,12	0,90
Maintenance	52,60	0,04	0,41
Reflection	3,90	0,00	0,03
Any issue	100,00	8,31	23,68

Table 1: Proportion of affected datasets and data-points by selected quality issues.

Issue Type	Proportion of Affected Data Points Maximum [%]	Absolute Effect on Relative Bias – Maximum [%]	Absolute Effect on rRMSD – Maximum [%]
Static values, Logger issues	14,24	52,88	116,68
Shading	38,40	6,36	7,36
Misalignment	99,85	0,71	2,52
Calibration	16,39	0,37	1,27
Dirt, Soiling	49,72	2,28	3,21
Multi-component tests	20,70	1,65	2,63
Snow	2,30	0,24	0,23
Not-specified	94,66	2,37	3,19
Dew, Frost	4,50	0,33	0,47
Physical Minima and Maxima	9,49	16,66	39,98
Postfiltering	8,11	0,18	1,30
Maintenance	2,86	0,07	0,20
Any issue	100,00	50,65	113,67

Table 2: Most common issues identified in compromised datasets of Global Horizontal Irradiance and the maximal effect on the Relative Bias and RMSD found in the sample.

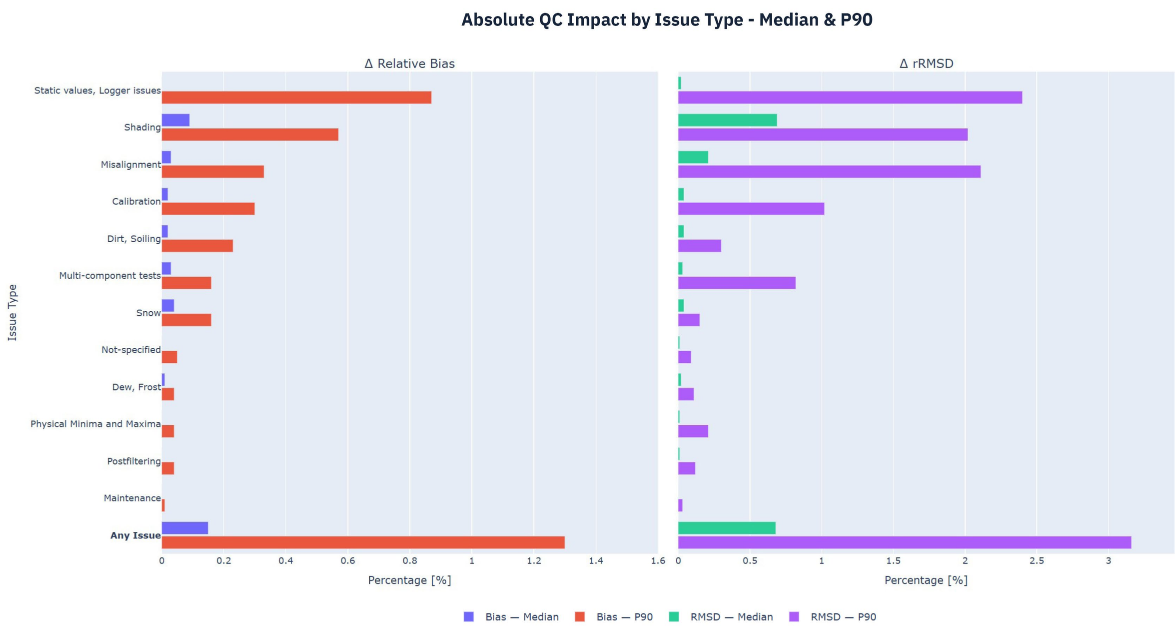

Figure 1: Most common issues identified in compromised datasets of Global Horizontal Irradiance and their absolute effect on the median and 90th percentile Relative Bias and RMSD.

Variable Impact of Quality Issues on Uncertainty — Soiling/Dirt Case Study

The statistics in Table 1 illustrate the typical occurrence and effect of various quality issues. In general, it is not advisable to derive general uncertainty or correction factors from the presented statistics, as it would represent a significant oversimplification. In reality, most issues exhibit high variability in both occurrence and severity, as demonstrated in this **soiling/dirt case study** performed on 108 one-year GHI datasets.

Key takeaways:

- **No consistent correlation** exists between the occurrence of soiling/dirt and the resulting bias or RMSD.
- **Any part of the day** — or even the **entire day** — may be affected by soiling or dirt accumulation.
- **Impact severity varies widely:** soiling can cause either a **minor reduction** or a **severe drop** in measured GHI values.
- In some cases, **soiling can artificially increase** the measured irradiance signal
- **Conclusion:** The highly variable nature of soiling effects highlights the importance of event-specific professional assessment

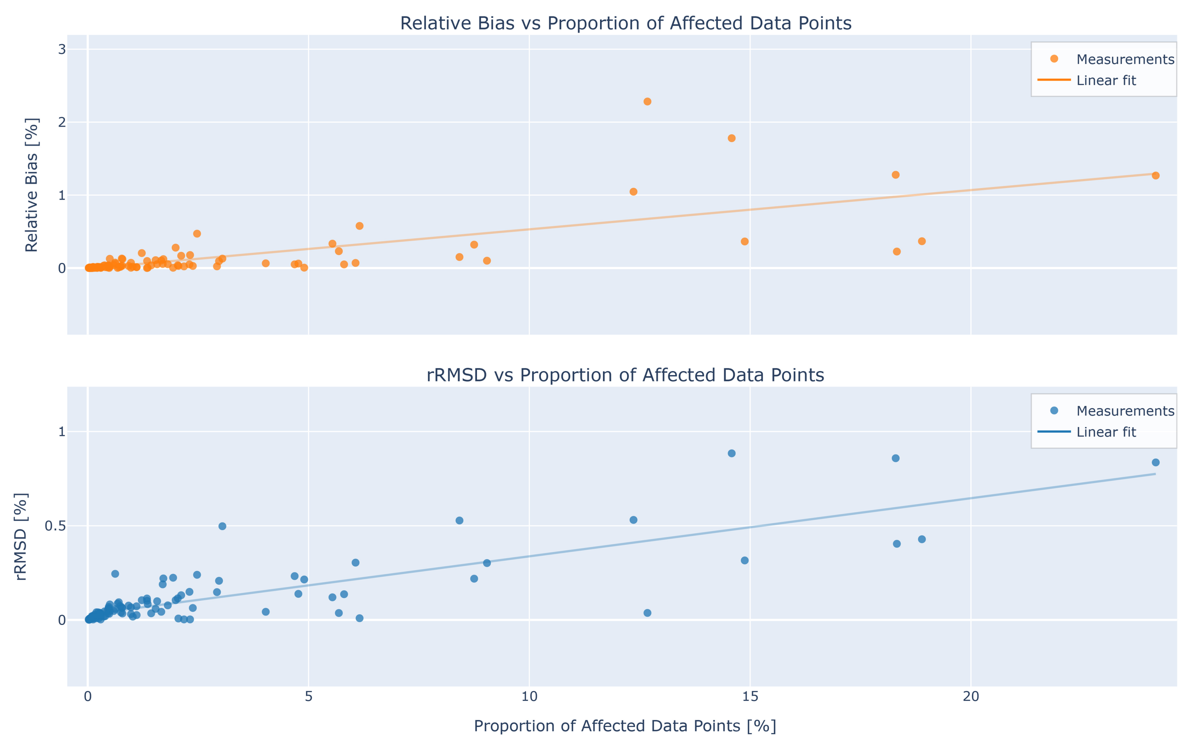

Figure 2: The Scatter Plots showing the relation between occurrence of soiling/dirt and resulting increase in bias and RMSD.

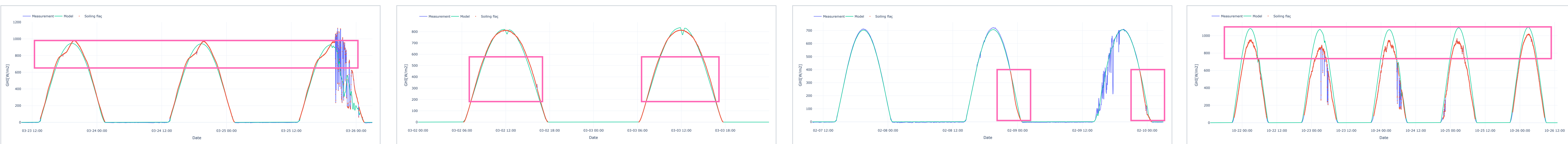

Figure 3: Time Series showcasing the effect of soiling/dirt on measured data and comparison with Solargis solar resource model.

Reducing uncertainty by regular and proactive QC - misalignment case study

In current industry practice, quality control (QC) is often performed only at the end of a measurement campaign, if at all. On average, **15% of GHI measurement data** are affected by quality issues — a value that can reach **up to 100%** in cases of persistent soiling, calibration drift, or sensor misalignment.

In this case study, we simulate one year of GHI measurements and introduce controlled misalignments with random azimuth and tilt angles ranging from **0.2° to 10°**. The resulting bias and RMSD are then compared against correctly aligned datasets. The analysis is performed for **five distinct geographic locations (results for two of them are show in Table 3)**.

Key takeaways:

- **Growing impact:** The bias and RMSD increase rapidly with both the **tilt angle of misalignment** and the **distance of the site from the equator.**
- Even a **1° tilt misalignment** can cause an **bias of up to 1.6%** in absolute value at higher latitudes.
- **Regular QC and timely corrective actions** can prevent such systematic errors, substantially reducing measurement uncertainty and data loss.
- **Conclusion:** Proactive QC throughout the campaign is far more effective than end-of-campaign validation, ensuring higher data reliability and availability.

	location	(-8.846,-77.769)			(58.078,-67.764)		
	stat	Min	Max	Range	Min	Max	Range
Metric	Tilt [°]						
Effect on Relative Bias [%]	0,2	-0,15	0,10	0,25	-0,40	0,20	0,60
	0,6	-0,40	0,35	0,76	-1,00	0,79	1,80
	1	-0,66	0,60	1,26	-1,61	1,39	3,00
	2	-1,33	1,20	2,52	-3,13	2,86	5,99
	3	-2,00	1,78	3,77	-4,67	4,32	8,99
	4	-2,66	2,34	5,00	-6,18	5,75	11,93
	5	-3,30	2,88	6,18	-7,62	7,17	14,79
	6	-3,93	3,40	7,33	-8,99	8,57	17,56
	7	-4,55	3,90	8,45	-10,28	9,95	20,23
	8	-5,16	4,38	9,54	-11,48	11,32	22,80
	9	-5,75	4,84	10,60	-12,59	12,67	25,26
	10	-6,34	5,28	11,62	-13,59	14,01	27,60
Effect on rRMSD [%]	0,2	0,45	0,69	0,24	0,89	1,20	0,31
	0,6	0,59	1,41	0,82	1,91	2,39	0,48
	1	0,79	2,19	1,39	3,15	3,72	0,56
	2	1,43	4,18	2,75	6,35	7,12	0,77
	3	2,10	6,09	3,99	9,57	10,42	0,85
	4	2,80	8,01	5,21	12,46	13,75	1,29
	5	3,48	10,02	6,53	14,94	17,06	2,12
	6	4,15	12,02	7,87	17,23	20,32	3,10
	7	4,79	14,01	9,22	19,37	23,61	4,24
	8	5,42	15,99	10,57	21,39	26,87	5,47
	9	6,04	17,96	11,92	23,30	30,09	6,80
	10	6,64	19,92	13,28	25,08	33,29	8,21

Table 3: The minimal, maximal and range of bias/RMSD of misaligned data compared to the reference model GHI for 2 different locations.

Conclusion

This analysis quantifies the impact of retaining compromised measurements on bias, RMSD, and overall data uncertainty. For GHI measurements, the **median effect** is **0.2%**, while the **90th percentile bias** reaches **1.3%**. The maximal value of bias in the sample reaches to **50.7%**.

The results demonstrate that **similar quality issues can manifest very differently**, depending on local conditions and operational factors. Consequently, **regular and proactive QC**, combined with timely maintenance, is essential. Early detection and mitigation of measurement issues significantly **reduce uncertainty, prevent data loss**, and ensure **reliable measurements** for further PV applications.