Quality Control Methods for Global Tilted Irradiance Measurements

Anton Driesse
PV Performance Labs, Freiburg, Germany
anton.driesse@pvperformancelabs.com

Niklas Blum
German Aerospace Center (DLR), Almería, Spain
niklas.blum@dlr.de

Motivation and objectives

- Most solar energy applications use a tilted surface rather than horizontal one in order to collect **more solar energy**, therefore system performance is evaluated using global tilted irradiance (GTI) measurements.
- Most weather stations measure global horizontal irradiance (GHI) and also often the beam (DNI) and diffuse (DHI), therefore quality control (QC) methods developed for these stations do not consider GTI specifically.
- Measurement and quality control challenges:
  - It is difficult to adjust the **azimuth and tilt** of a sensor accurately, or to measure these angles accurately after it is installed
  - It is difficult to check **consistency** of GTI measurements with GHI, DNI and DHI measurements
- In this work we propose methods to address both these challenges.
- The focus is on one-minute average values, but the approach can also be applied to data collected at shorter or longer intervals.

Modelling a range of expected values

- An expected value for GTI can be calculated by using a **transposition model** together with known or modelled values of GHI, DNI, DHI, tilt, orientation, and albedo (ground reflectance).
- Traditionally, a **static empirical tolerance** value would be used to change this into an interval representing plausible values of GTI, but a static interval can never be optimal for all conditions.
- In this work we generate an **interval of plausible GTI values** by expressing all inputs to the (Perez-Driesse) transposition as intervals. This leads to a GTI interval that **varies with operating conditions**.

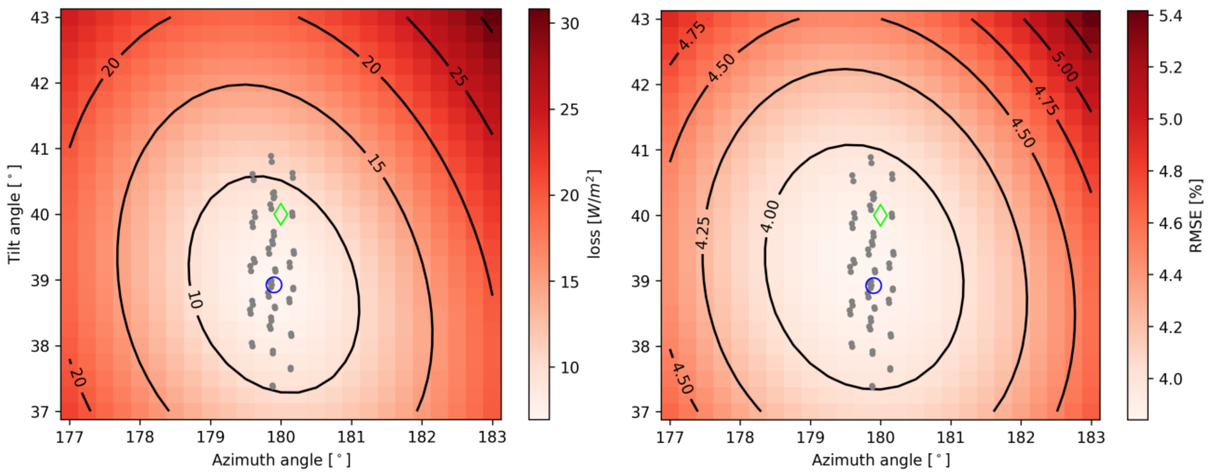
GTI component (selected)	Transposition calculation step	Input variable intervals
Beam	$\mathrm{DNI}\cdot\cos(\theta)$	$DNI \pm 1\% \pm 5W$ $\theta \pm 2.5°$
Horizon brightening	$f_{hor} \cdot \mathrm{DHI} \cdot \sin(\beta)$	$DHI \pm 2\% \pm 10W$ $f_{hor} = f_{2,Perez-Driesse} \pm 0.1$
Circumsolar brightening	$f_{circ} \cdot \frac{\mathrm{DHI}}{\sin(Z)} \cdot \cos(\theta)$	$DHI \pm 2\% \pm 10W$ $f_{circ} = f_{1,Perez-Driesse} \pm 0.1$
Isotropic sky	$(1 - f_{circ}) \cdot \mathrm{DHI} \cdot \left(\frac{1+\cos(\beta)}{2}\right)$	

Note: To propagate intervals through any calculation, the calculation is repeated for all combinations of the interval limits of the inputs. From the results, the largest and smallest values constitute the output interval.

Detecting radiometer tilt and azimuth

- Sensor orientation is detected by **minimizing the deviation** between modelled and measured GTI within a range of tilt/azimuth angles
- The minimization is repeated using all combinations of the interval limits of the inputs to give an indication of the test's **uncertainty**
- If the documented angle falls outside this ensemble result, a significant error is flagged and must be investigated

- In the example, GTI is measured in a nominally south-facing plane with 40° tilt (green diamond).
- The check detects the sensor's orientation (blue circle) and an ensemble of orientations representing the check's uncertainty using input variable intervals (cloud of grey dots).
- The resulting tolerance interval of the check is -1.6° to +2.0° for the tilt and –0.3° to +0.3° for the azimuth angle (left figure), therefore the sensor is accurately mounted within the tolerance interval/accuracy of the check.

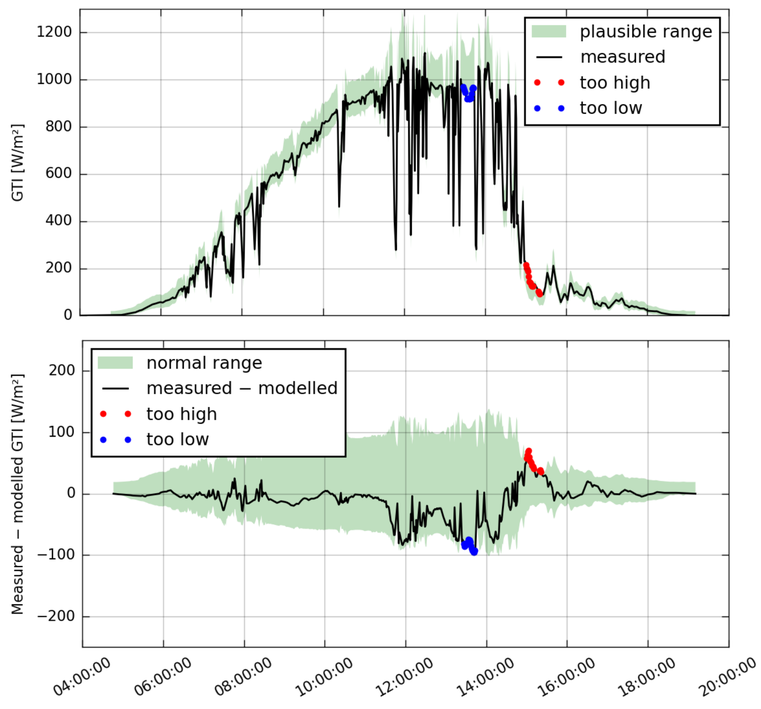


Detecting sporadic outliers

- Outliers are detected by comparing against the limits of the plausible range. Values outside this range are flagged as **too high or too low**.
- During highly variable conditions the plausible range is expanded:
  - using a **new variability index** based on beam irradiance (DNI)
  - using the thresholds of the preceding/following time intervals

(details on these two aspects provided in the proceedings article)

- The graphical example at the right shows a day with highly variable conditions
- The expanding plausible range in the middle of the day accommodates most of the measurements
- Two clusters of outliers are flagged, but they are only slightly out of range
- Assumptions about the input variable intervals can be adjusted to tune the sensitivity of the test based on knowledge of the site climate and quality of the instrumentation



Supported by the German Federal Ministry for Economic Affairs and Climate Action via Grant number 03EE1195B

PV Performance Labs provides a range of services in support of PV system R&D and operations including planning, measurements, simulation and analysis