Accounting for sub-hourly irradiance fluctuations in hourly performance simulations

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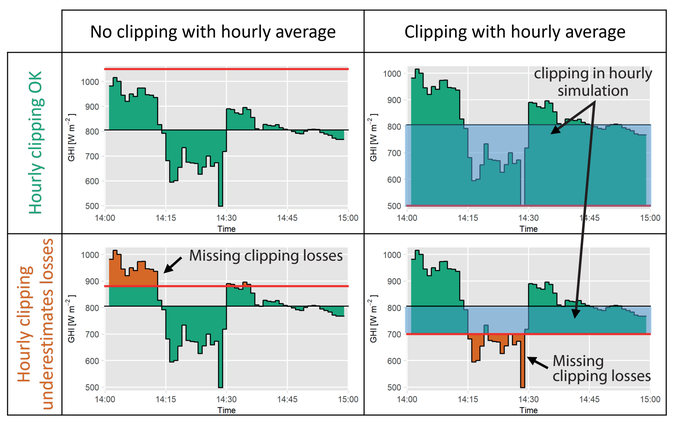
Agnès Bridel-Bertomeu, André Mermoud, Michele Oliosi, Bruno Wittmer
PVSYST SA, route de la Maison-Carrée 30, CH 1242 Satigny - Switzerland

Abstract

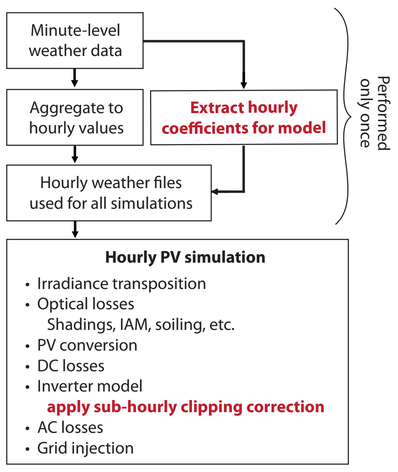
On average, hourly performance simulations report higher yields than sub-hourly performance simulations. Notably, the clipping losses due to sub-hourly irradiance fluctuations will be underestimated in hourly simulations. In a previous work [1], we developed a model to estimate these extra clipping losses. This model removes most of the discrepancies between minute-level and hourly clipping losses, but a small bias component of less than 1% remains in the yield estimate.
Here we show that most of the remaining bias stems from the transposition of the diffuse irradiance components, mainly from the estimate of the circumsolar, horizon band, and isotropic diffuse components in the Perez model. This bias, though it may be fixed in the hourly transposition values, is rather to be understood as an artefact from applying the transposition models at the sub-hourly level. Sub-hourly simulations should address this issue by adapting the transposition models to sub-hourly datasets. The transposition of the direct component, may however warrant a correction in the hourly simulations.

Sub-hourly fluctuations and impact on clipping

Clipping is always underestimated by the hourly simulation:

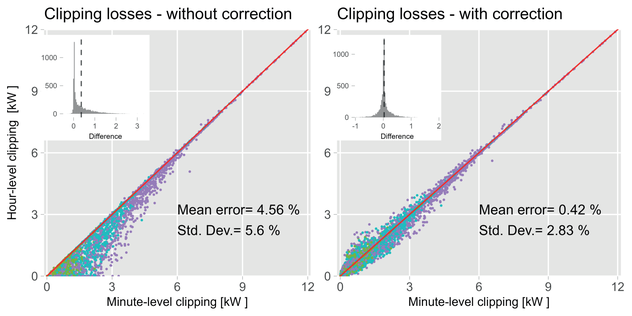


Our solution using minute data:

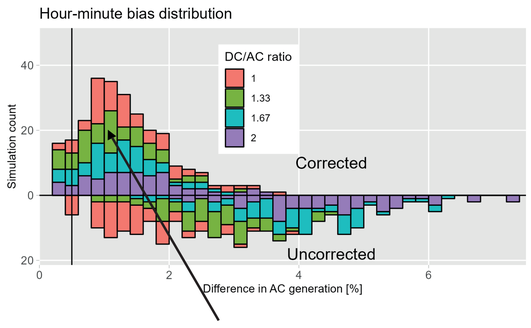


Results of the model

272 simulations:
➔ 4 sites ➔ 17 Orientations ➔ 4 DC:AC ratios



The clipping correction model largely removes the bias on the clipping losses.



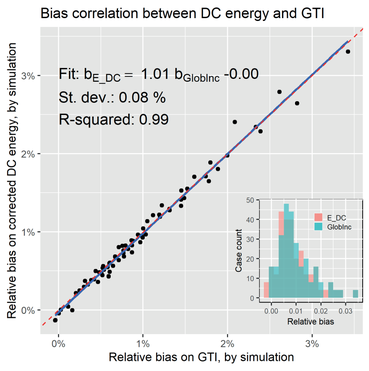
The corrected hourly simulations still yield on average 0.8 % more than the minute-level simulation results.

Question: where is the remaining bias coming from?

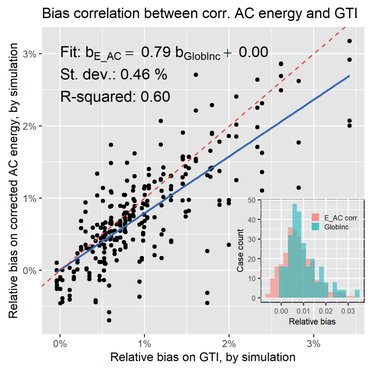
Transposition bias

Results of 272 simulations

DC energy bias exists already in **transposition**

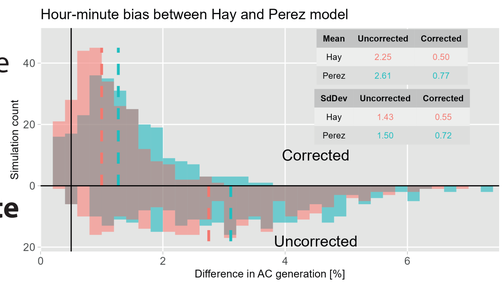


Following simulation steps increase spread but almost **do not change bias**

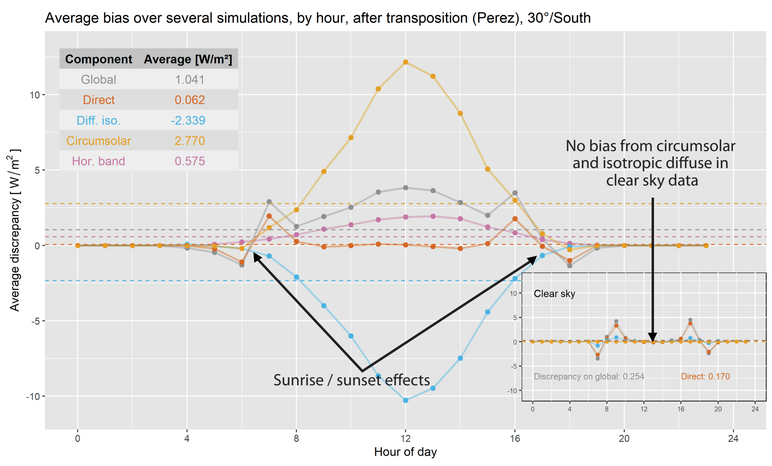


Using a simpler transposition scheme reduces the bias

Hay transposition has less hour-minute bias than Perez



Bias behavior differs by irradiance components:

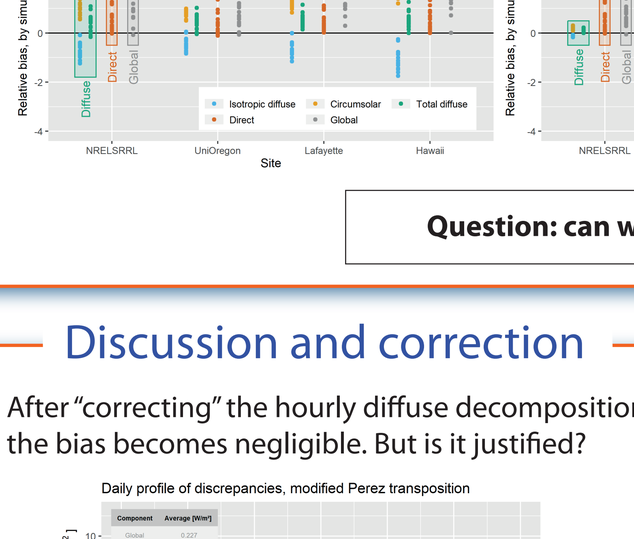


Major sources of bias : transposed diffuse components
- Horizon band (55% of the bias over all simulations)
- Separation of circumsolar and isotropic diffuse (41%)

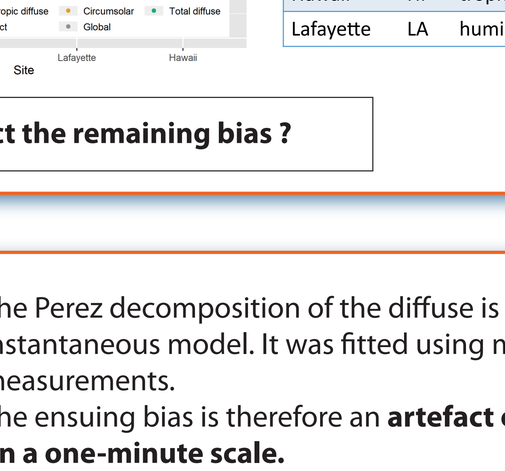
The remaining bias is mostly due to transposing the diffuse irradiance

Non-linearity of the diffuse decomposition

Perez and Hay transposition models

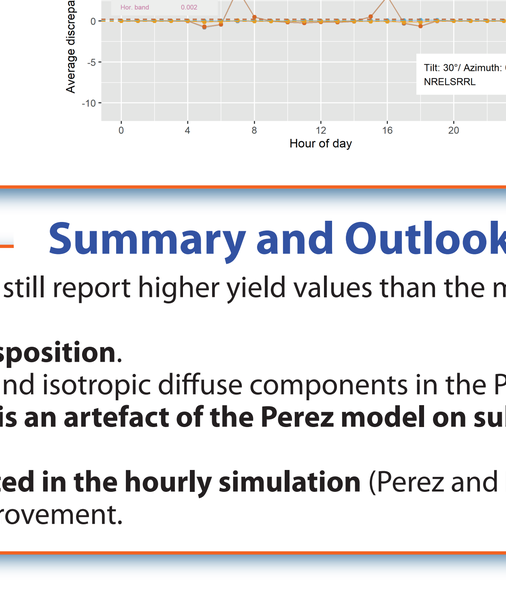


Factors F1 and F2 are determined non-linearly in Perez
- F1 : discriminates isotropic diffuse from circumsolar
- F2 : horizon band evaluation

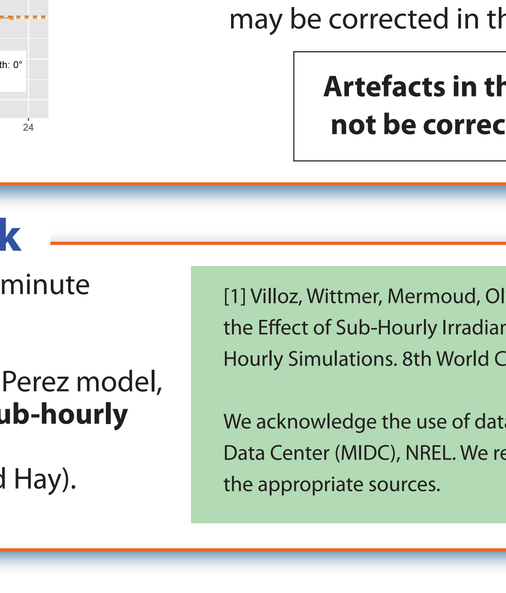


The discrepancy correlates well with F1 non-linearity

Perez transposition



Hay transposition



In the **Hay** transposition, the decomposition between circumsolar and isotropic diffuse is less non-linear.

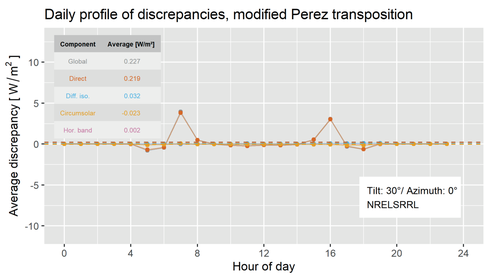
The direct component is transposed in the same way in Perez and Hay. It generates non-negligible bias for some plane orientations.

Site label	St.	Climate (Köppen)
NRELSRRL	CO	semi-arid continental (BSk)
UniOregon	OR	warm-summer Medit. (Csb)
Hawaii	HI	tropical semi-arid (BSh)
Lafayette	LA	humid subtropical (Cfa)

Question: can we correct the remaining bias ?

Discussion and correction

After "correcting" the hourly diffuse decomposition, the bias becomes negligible. But is it justified?



The Perez decomposition of the diffuse is not an instantaneous model. It was fitted using mostly hourly measurements.
The ensuing bias is therefore an **artefact of using Perez on a one-minute scale.**
The transposition of the direct component, however, may be corrected in the hourly simulation.

Artefacts in the minute simulation should not be corrected in the hourly simulation

Summary and Outlook

After applying the sub-hourly clipping correction [1], hourly simulations still report higher yield values than the minute simulations, albeit by less than 1%.
We find that **the main source of remaining bias is the irradiance transposition**.
Non-linear steps such as the estimate of the circumsolar, horizon band, and isotropic diffuse components in the Perez model, account for most of the remaining bias. **The diffuse transposition bias is an artefact of the Perez model on sub-hourly scales.** It should not be corrected in the hourly simulation.
However, the transposition of **the direct component should be corrected in the hourly simulation** (Perez and Hay).
The sub-hourly clipping model correction [1] does not need further improvement.

[1] Villoz, Wittmer, Mermoud, Oliosi, Bridel-Bertomeu, 2022. A Model Correcting the Effect of Sub-Hourly Irradiance Fluctuations on Overload Clipping Losses in Hourly Simulations. 8th World Conference on Photovoltaic Energy Conversion.

We acknowledge the use of data from the Measurement and Instrumentation Data Center (MIDC), NREL. We refer the reader to [1] or to the MIDC website for the appropriate sources.