Accounting for sub-hourly irradiance fluctuations in hourly performance simulations

40th European Photovoltaic Solar Energy Conference and Exhibition - September 18-22, 2023 - Lisbon, Portugal

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

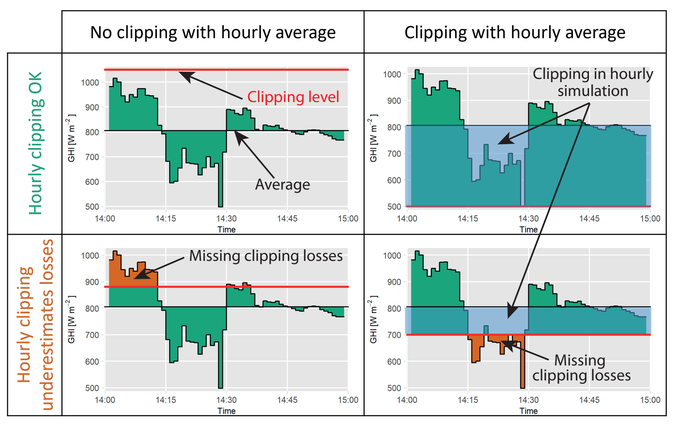
Abstract

Hourly performance simulations tend to report higher yields than sub-hourly performance simulations. One reason is that 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; it can be used to remove most of the yearly discrepancy between minute-level and hourly results.

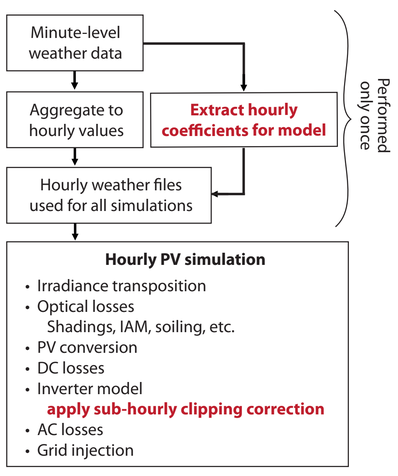
In this work we show how part of the remaining yearly discrepancies are an artefact from applying transposition models at the sub-hourly level. Taking as example the widely used Perez model, we propose a way to correct the diffuse decomposition coefficients in the minute simulation, which further reconciliates hourly- and minute-level simulations.

Sub-hourly fluctuations and impact on clipping

Clipping is always underestimated by the hourly simulation:

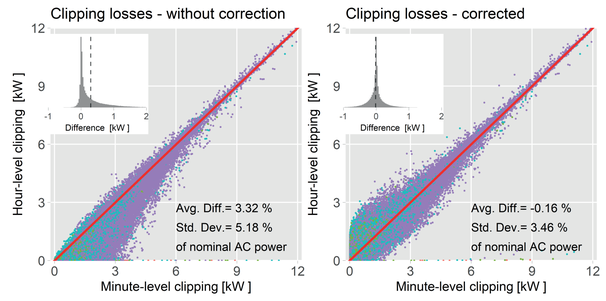


Our solution using minute data:

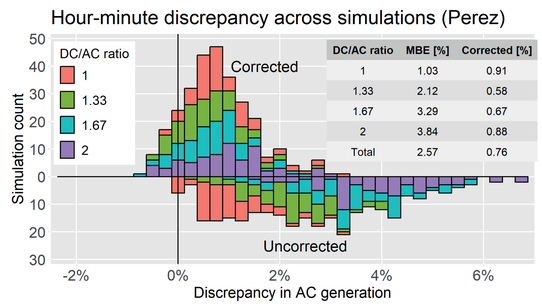


Results of the model

288 simulations: ➔ 4 sites - 2020 data
➔ 18 Orientations (1 SAT) ➔ 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 simulations.

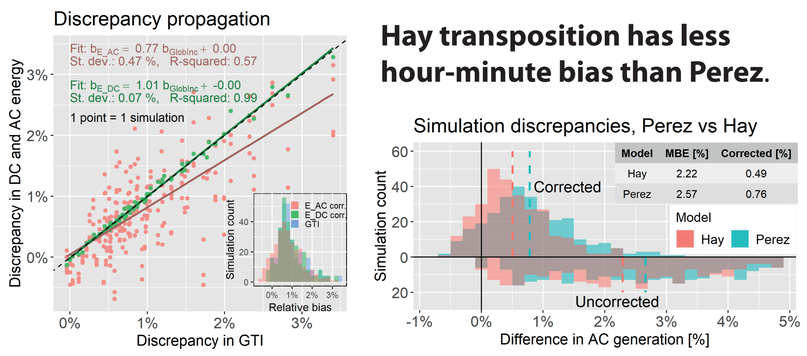
Question: where does the remaining discrepancy come from?

Transposition bias

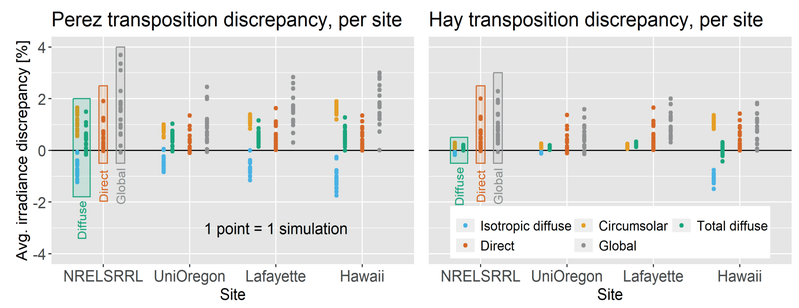
Discrepancy exists already after **transposition (GTI).**

Using a simpler transposition model reduces the bias.

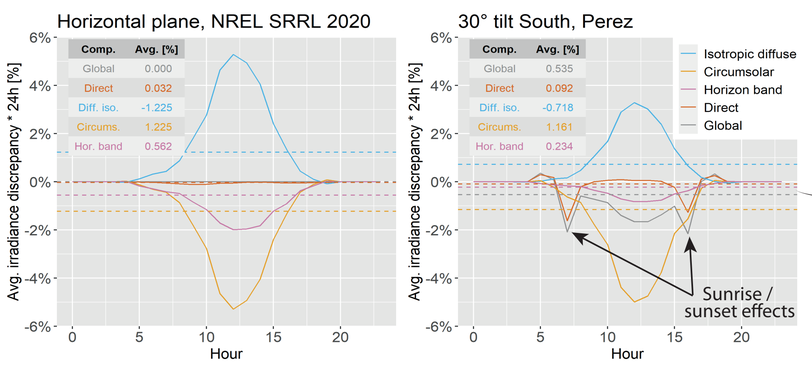
Hay transposition has less hour-minute bias than Perez.

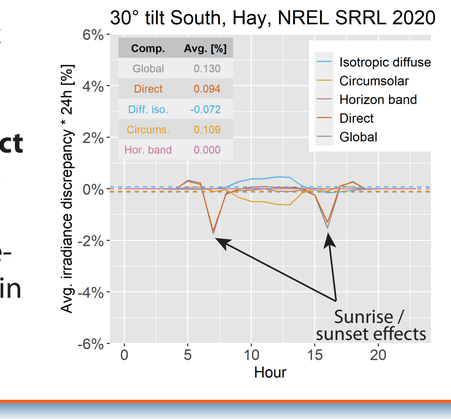


Hay transposition: the decomposition between diffuse components is less non-linear. This generates less discrepancies.



Average profile of discrepancies by irradiance components (avg. of 1 simulation)

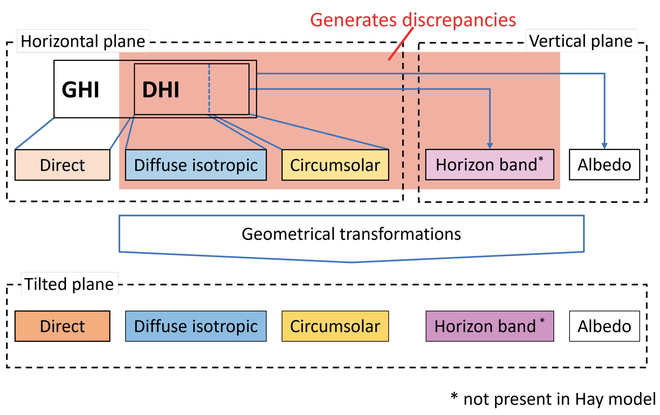




The main effect of the Perez **diffuse** decomposition is **in the middle of the day.**
The main effects of the **direct** transposition are **at sunrise and sunset**.
Transposing the direct generates the same discrepancy in Perez and Hay.

Non-linearity of the Perez diffuse decomposition

Perez transposition model



* not present in Hay model

The Perez diffuse decomposition is based on **48 coefficients:** 6 factors $\mathbf{F_{1j}(\epsilon)}$ and $\mathbf{F_{2j}(\epsilon)}$, **j=1,2,3** each for 8 Clearness **ϵ** bins.

$$F_1 = F_{11} + F_{12}\,\text{Brightness} + F_{13}\,\text{Zenith angle}$$

discriminates isotropic diffuse = $(1-F_1)$ DHI
from circumsolar = F_1 DHI

$$F_2 = F_{21} + F_{22}\,\text{Brightness} + F_{23}\,\text{Zenith angle}$$

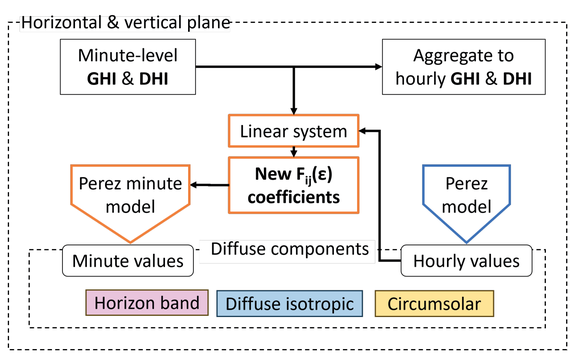
determines the horizon band = F_2 DHI

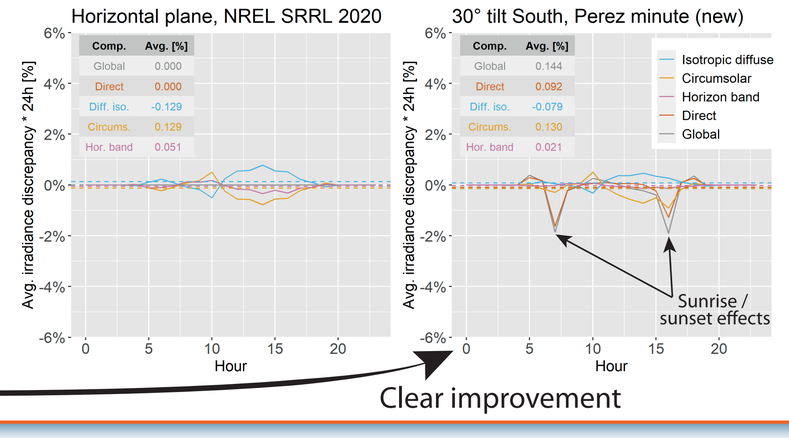
The **48** $\mathbf{F_{ij}(\epsilon)}$ coefficients were originally derived from hourly and 15-minute measurements. The coefficients are not adapted to minute-level data.

Can we find better Perez coefficients for the minute diffuse decomposition?

Fit coefficients with the **hourly horizontal diffuse values as a reference.**
Result : new Perez coefficients that can be applied to minute-level data.

Answer: Yes!





Clear improvement

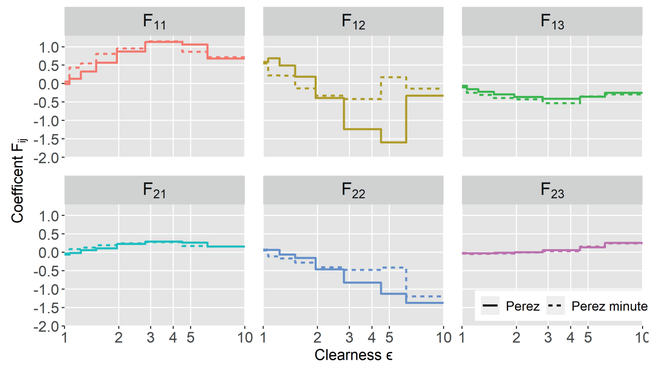
Discussion and outlook

New Perez coefficients:

- Procedure should be applied to larger minute datasets
- Largest differences for F_{12} and F_{22}, in 2 clearness bins

Remaining discrepancies:

- Direct component should be corrected in the hourly simulation, but has a small impact
- The clipping correction model (at DC to AC conversion) can still be improved



Summary

After applying the sub-hourly clipping correction [1]: hourly simulations still report higher yields than minute simulations, but by less than 1%.

- Non-linear steps in the Perez transposition model account for most of the remaining discrepancy. In particular, the diffuse decomposition step.
- The discrepancy from the diffuse decomposition step is an artefact of the Perez model on sub-hourly scales.

We propose a methodology to find **new Perez coefficients that can be used when transposing minute-level data**.

- It replicates the original Perez transposition applied on hourly data.
- Using the Hay transposition leads to a similar level of discrepancies

[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.