

Benchmarking PASE Backward Ray Casting Light Model with bifacial_radiance and Experimental Data

Bruhwyler R.¹, Sanchez H.², De Cock N.¹, Meza C.^{2,3}, Gottschalg R.^{2,3}, Lebeau F.¹

¹ DEAL, BioDynE, Gembloux Agro-Bio Tech (f.lebeau@ulg.ac.be), Université de Liège, ² Hochschule Anhalt University of Applied Sciences, ³ Fraunhofer-Center for Silicon Photovoltaics CSP

Light modelling for agrivoltaics

- Key challenge in agrivoltaics (AV): properly modelling light pattern dynamics underneath PV modules to assess crop yield.
- An open-source tool exists to assess light and PV productivity with ray tracing: bifacial_radiance [1]
- Lack of a tool to assess light on both components: crop and PV modules
- Productivity of AV systems should be modelled over multiple years to integrate the inter-annual variability of crop yield [2]
- The open-source Python Agrivoltaic Simulation Environment (PASE), developed by DEAL, meets those needs
- The efficient ray casting-based light model of PASE has been presented previously in [3], it avoids calculation repetitions and allows different levels of precision and resolution depending on the user needs to get fast computations
- This poster presents the validation of PASE's light model with 2 experimental datasets and a benchmark with a bifacial_radiance simulation

Material and methods

1. Light data from the Siguesol AV prototype at Werbomont (Belgium, latitude: 50.37 and longitude: 5.68)

- Irradiance data collected from 10th to 27th August 2023 with Davis 6450 pyranometers at a 15 min time step
- One pyranometer located in full sun conditions and another in AV conditions (Figure 1.a)
- The AV pyranometers was in the middle of the 56 cm gap between the central PV modules
- Geometric features have been measured on site to reproduce the scene in both tools (PASE and bifacial_radiance)



Fig. 1: Siguesol agrivoltaic prototype and experimental set up with full sun condition pyranometer in purple and agrivoltaic pyranometer in red (a) and experimental set up reproduced in PASE (b)

2. Light data from the AV system of the NREL at Golden (Colorado, USA, latitude: 39.74 and longitude: -105.18)

- Light data and technical features of the AV system are available in open-access here: [4]
- 5 pyranometers (Ap_1 to Ap_5) collected light data along the transect of the AV facility from 7th September to 2nd November 2023 (Figure 2.a, 2.b) at a 1 min time step
- The scene has been reproduced in PASE

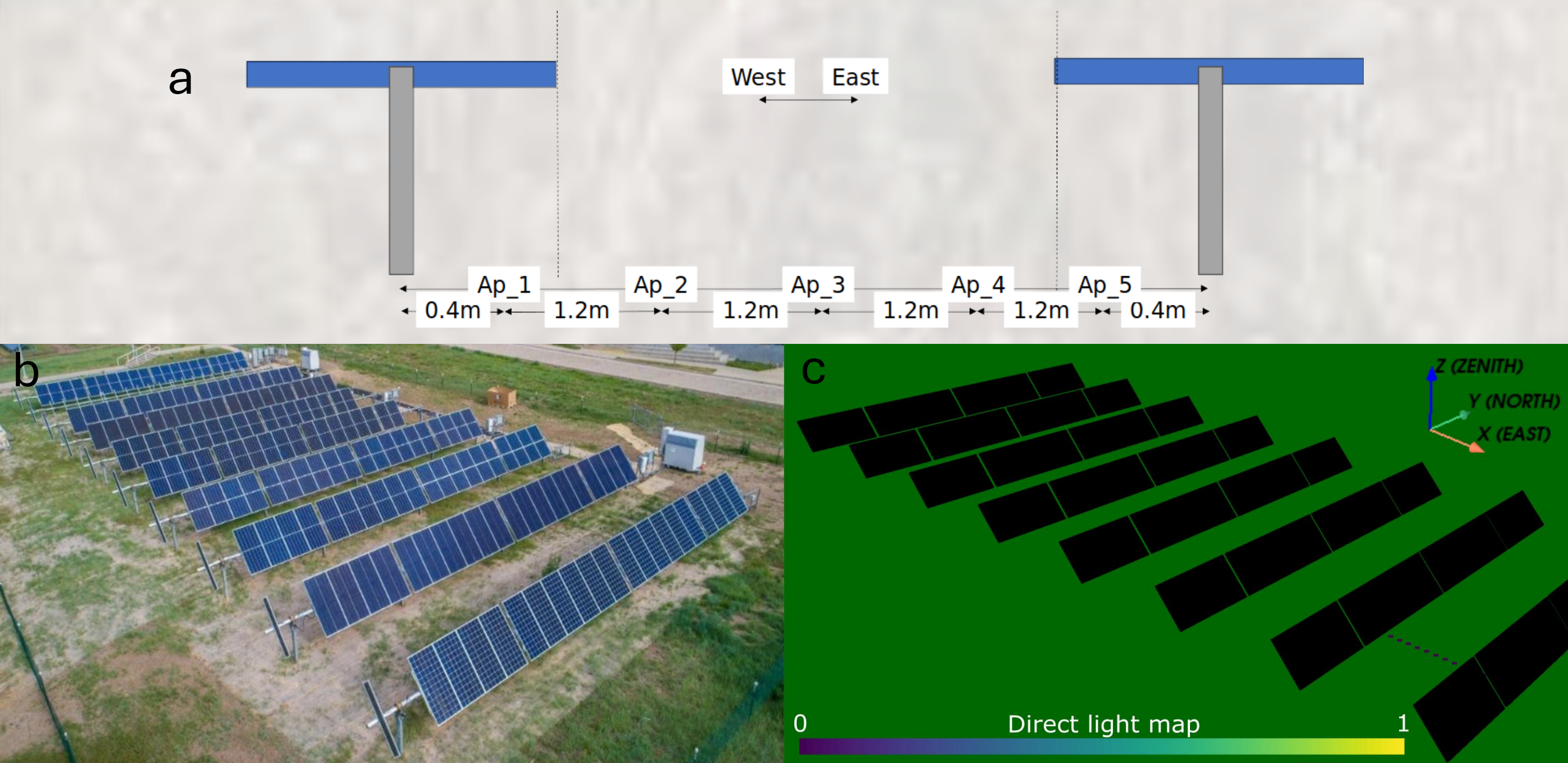


Fig. 2: Location of agrivoltaic pyranometers (a) in the NREL agrivoltaic system at Golden, Colorado (b) and reproduction of this system in PASE (c)

Results

1. Validation with Siguesol AV prototype and benchmarking with bifacial_radiance

- Figure 3 presents the irradiance reaching the full sun and AV in situ pyranometers as well as virtual sensors from PASE and bifacial_radiance (BR) for a clear sky and a cloudy day

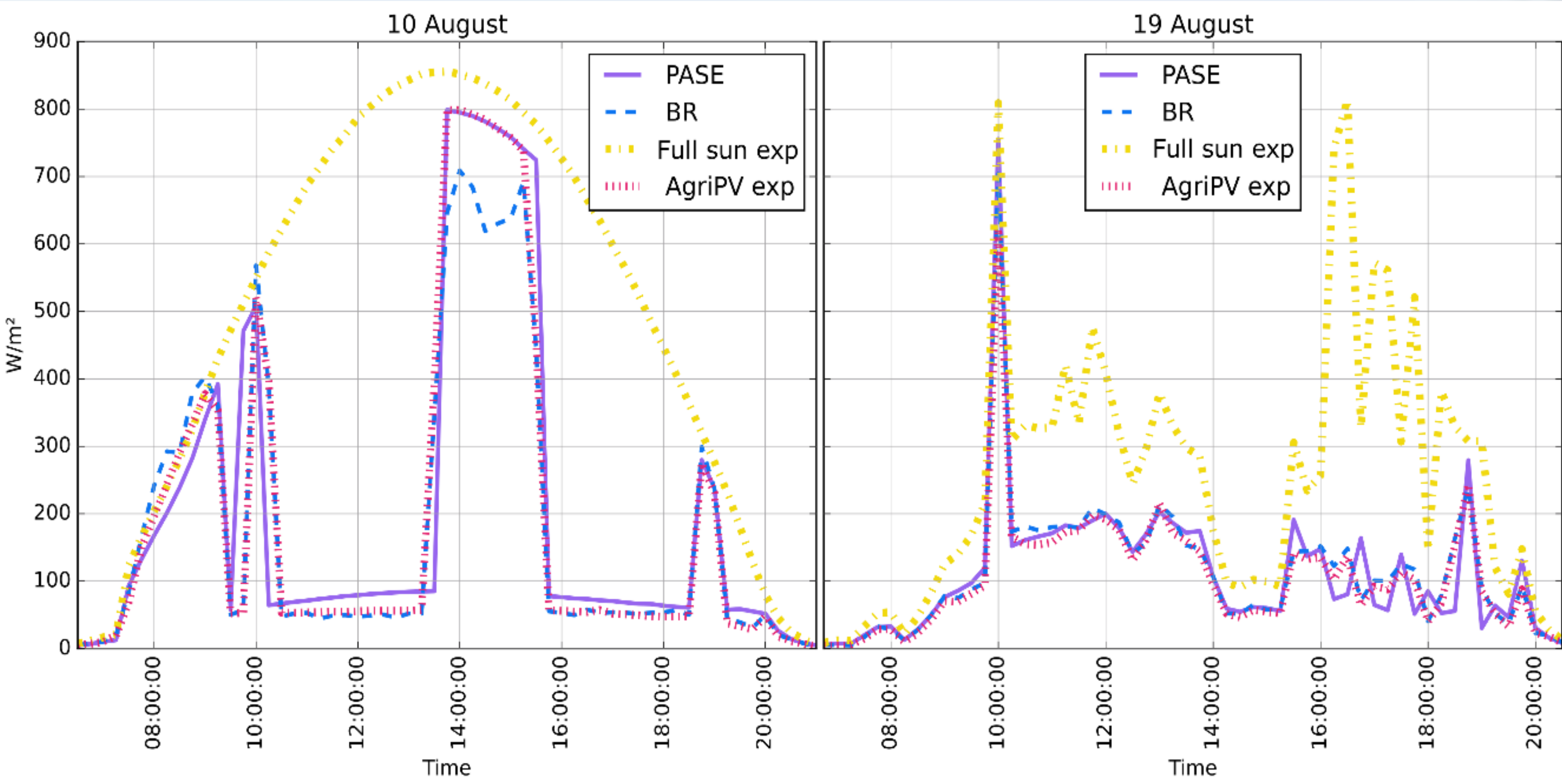


Fig. 3: Comparison between experimental and simulation data with PASE and bifacial_radiance (BR) on a clear sky day (10th August) and a cloudy day (19th August)

	PASE	Bifacial_radiance
Clear sky day RMSE	90.1 W/m ²	45.2 W/m ²
Cloudy day RMSE	33.1 W/m ²	14.6 W/m ²
Clear sky daily irradiation error	2.4 %	11.3 %
Cloudy daily irradiation error	0.5 %	1.0 %
Measurement period error on irradiation	1.0 %	0.5 %

2. Validation with the AV system of the NREL

- Figure 4 presents the irradiance reaching 3 of the 5 *in situ* and *in silico* pyranometers located along the AV transect compared with full sun reference data on the 16th September 2023
- Results have been generated with a monthly sampling on solar position: sun positions from the 15th day of the month are considered for all the days of the month

	Ap_1	Ap_2	Ap_3
RMSE 16 th Sept.	108.2 W/m ²	83.8 W/m ²	74.8 W/m ²
16 th Sept. daily irradiation error	6.6 %	0.4 %	1.6 %
Error on irradiation over the period from 8 th Sept. to 31 st Oct.	4.7 %	0.2 %	1.8 %

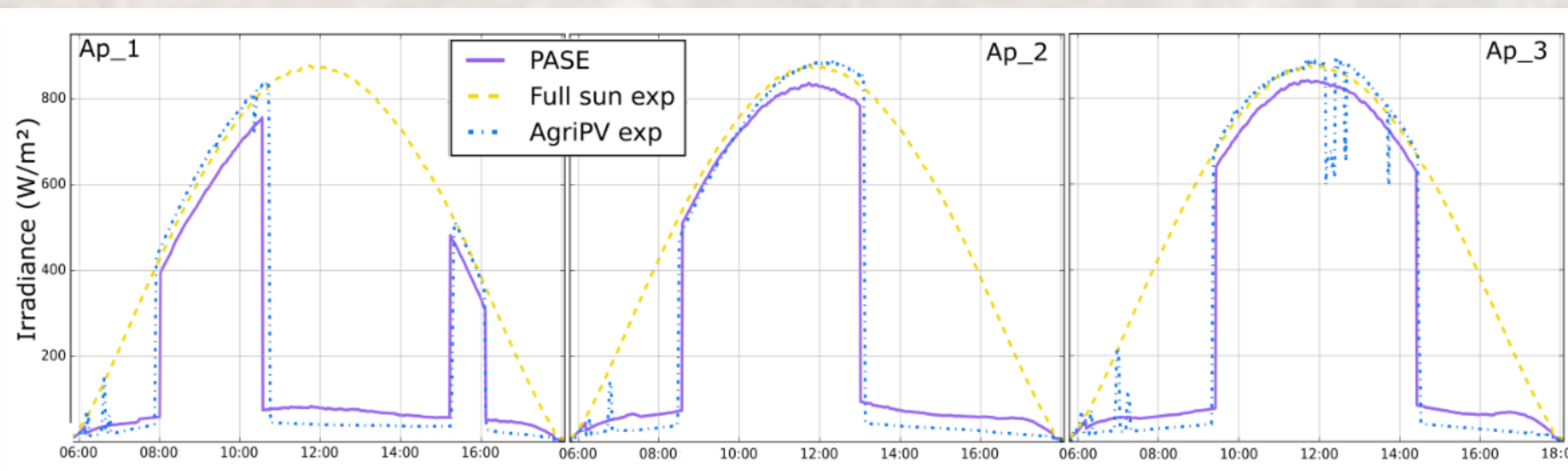


Fig. 4: Comparison between experimental from the AV system of the NREL and simulation data with PASE on the 16th September 2023 for 3 locations of pyranometer along the AV transect (Ap_1, Ap_2 and Ap_3)

Aknowledgments to the NREL for the access to their data

References

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- [4] <https://datahub.duramat.org/dataset/best-field-data>