

## Reply to Reviewer#1

Citation: <https://doi.org/10.5194/egusphere-2026-2775-RC1>

### ➤ Major comments

- **#1:** Please include a clear definition of the reported losses, preferably including the corresponding equation. The reference used to compute the percentage losses should be explicitly stated. Some related definitions appear later in the manuscript (line 375), but this concept should be introduced earlier and described in greater detail.

**Answer:** The corresponding equation regarding the reported losses was included in section 3.1 – Results and discussion and linked to the figures including the respective results, as follows:

Lines 388-392:

“The resulting irradiance and PV energy losses are expressed relative to aerosol-free atmospheric conditions. More specifically, the afore-mentioned losses were calculated based on the following formula:

$$\text{Losses (\%)} = \frac{(R_{\text{clear-sky}} - R_{\text{all-sky}})}{R_{\text{all-sky}}} * 100 \quad (3)$$

Where R denotes the respective parameter in each case; DNI and GHI for radiation losses (presented in Fig.3) and solar energy for PV losses (presented in Fig. 4)”

- **#2:** A map showing the geographical distribution of the considered sites would help the reader better understand the study area and the analysis presented in Section 2.

**Answer:** A map presenting the stations in which this study was based was included along with the following description in Section 2.3.

Lines 184-189:

“The selected stations under study are shown in Fig. 1 (also see Fig.1 in Papetta et al., 2026 for the different cases in detail).”

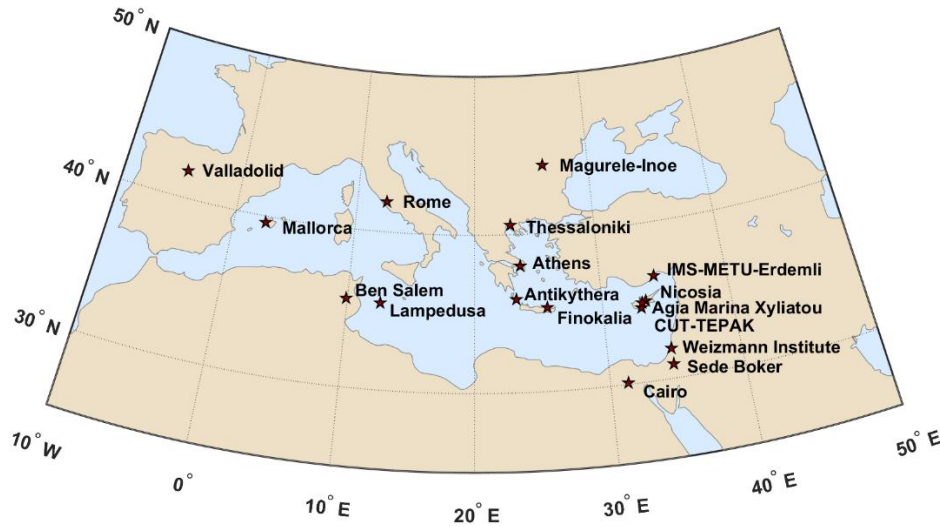


Figure 1: Spatial distribution of all AERONET stations across the Mediterranean Basin used in this study during the different dust events.”

- **#3: Methodology:** *a description of the broadband radiation measurements is missing. Please provide information on the measurement sites, instruments/sensors, measured variables, quality-control procedures, and any other relevant details.*

**Answer:** A sub-section was added in Section 2, “2.2 Solar radiation measurements” including a description of the broadband radiation measurements as follows:

Lines 163-170:

#### “2.2 Solar radiation measurements

Broadband solar radiation measurements from ground-based pyranometers were also used in the frame of this study, providing timeseries of global (GHI) and diffuse (DHI) surface solar irradiance. More precisely, the afore-mentioned observations were used to identify the cloudy and clear-sky conditions (for  $SZA < 80^\circ$ ,  $GHI - DHI < 120 \text{ W/m}^2$  denoted the presence of clouds) during two selected events for two different stations, Lampedusa and Agia Marina Xyliatou. In addition, they were used to directly validate the model-derived radiation parameters, GHI and DHI, as well as to calculate the produced PV energy. The specific sensors provide high-quality measurements, with uncertainties not exceeding 2% for hourly totals and 1% for daily totals over the wavelength range 280-2800 nm at a 1-minute temporal resolution.”

- **#4:** *How is GTI obtained from SSR? Please clarify the procedure used for this conversion, as this step can introduce significant uncertainties. If this calculation is performed internally within GSEE, please state so and briefly describe the methodology in Section 2.*

**Answer:**

GSEE requires the GHI as input, and optionally the diffuse fraction (DHI) to calculate  $k_d = \frac{DHI}{GHI}$ . If DHI is not available, the GSEE includes an implementation of the BRL diffuse fraction model. Next, GSEE internally calculates the plane-of-array irradiance, by applying trigonometric calculations, which also account for the surface albedo and the ground-reflected component of irradiance. While under moderate aerosol conditions the parameterization of the diffuse component is quite accurate, under high dust loads, BRL underestimates DHI. Under very high dust loads ( $\sim 1$ ), the underestimation of the diffuse SSR fraction can result in errors in the simulated energy production of the order of 2% and 5% for fixed and solar-tracking panes respectively (Papadimitriou et al., 2026).

A respective description has been added to the manuscript as follows (lines: 294-305):

“Transposition to the PV plane is done considering the GSEE default optimal tilt angle model (<http://www.solarpaneltilt.com/#fixed>) and the BRL output (direct and diffuse components calculated considering solar angles), internally by GSEE. GSEE requires the GHI as input, and optionally DHI to calculate the diffuse fraction ( $k_d$ ):

$$k_d = \frac{DHI}{GHI} \text{ (Equation 2)}$$

If DHI is not available, the GSEE includes an implementation of the BRL diffuse fraction model. As a next step, GSEE internally calculates the plane-of-array irradiance, by applying trigonometric calculations, which also account for the surface albedo and the ground-reflected component of irradiance. While under moderate aerosol conditions the parameterization of the diffuse component is quite accurate, under high dust loads, BRL underestimates DHI. Under very high dust loads ( $\sim 1$ ), the underestimation of the diffuse SSR fraction can result in errors in the simulated energy production of the order of 2% and 5% for fixed and solar-tracking panes respectively (Papadimitriou et al., 2026). More uncertainties are introduced due to uncertainties in the GSEE input parameters (SSR, surface albedo, temperature), as well as on uncertainties in the parameterization of losses on the panels and the inverter system, and uncertainties related to dust deposition on the panels.”

- **#5:** *The description of the GSEE implementation is not sufficiently detailed. Please specify explicitly which irradiance components (GHI, DHI, DNI and/or plane-of-array irradiance) were provided as inputs to GSEE for each simulation setup (measurements, libRadtran and METAL-WRF) and clarify whether the transposition to the PV plane was performed internally by GSEE. Also include some details in the PV generation model.*

**Answer:**

GSEE is a widely used open-access model designed for rapid calculations of PV energy production. It considers the position of the sun, as well as the panel's tilt angle and orientation. Transposition to the PV plane is done considering the GSEE default optimal tilt angle model (<http://www.solarpaneltilt.com/#fixed>) and the BRL output (direct and diffuse components calculated considering solar angles), internally by GSEE.

To clarify the model implementation, we have expanded the description in Section 2.7 together with the additions made to address the previous comment. We now explicitly state that GHI is used as the primary input to GSEE, while DHI can optionally be provided. The irradiance components used for each simulation setup (measurements, libRadtran, and METAL-WRF) are also explicitly specified in the corresponding sections of the manuscript and are also indicated in the relevant figures (e.g., Fig. 14).

- **#6:** *Figure 4: please clarify what is meant by "solar energy loss". Does it refer to tilted irradiance, PV energy production, or another quantity? Also indicate the reference used for the normalization and percentage calculations.*

**Answer:**

Solar energy loss refers to the decrease in PV energy production. Calculations have been performed with respect to the PV output under aerosol-free skies, with all other conditions kept the same.

A clarification was added in lines 407-408 as follows:

“Solar energy losses refer to the decrease in PV energy production. The percentage losses have been calculated relative to the PV output under aerosol-free skies (Eq.3), with all other conditions kept identical.”

In addition, the term “PV” was added before “solar energy” in Fig. 5 (previously Fig.4) caption, to clearly indicate that the figure presents PV energy losses.

- **#7:** *Please include the optimum fixed tilt angle used at each site.*

**Answer:**

The tilt angles have been calculated using the default GSEE function. The equation used for the calculations was included in the manuscript, as follows (lines: 288-293):

“For fixed panels, the tilt angles were calculated using the default, built-in latitude linear function included in the GSEE model, considering also a south orientation of the PV panels.

More precisely, the optimum tilt angles (OTAs) of the fixed-tilt systems were calculated using the following function (for latitudes  $> 25^\circ$  and latitudes  $< 50^\circ$ ):

$$\text{OTA} = (\text{Lat.} * 0.76) + 3.1 \text{ (1)}''$$

Additionally, a table where all the stations, their coordinates and the respective angles are listed in detail, was included in Appendix C.

- **#8:** *Please provide more details on the clear-sky selection procedure.*

**Answer:** An additional comment was included in Sect. 2.2 where the ground-based solar radiation measurements are described, and in Sect. 3.3 to define the clear-sky selection procedure.

Lines 502-503:

“More precisely, days were identified as clear-sky when GHI and DHI components exceeded  $120 \text{ W/m}^2$  for SZAs  $< 80^\circ$  and exhibited a smooth diurnal curve with no rapid fluctuations.”

➤ **Minor comments:**

- **#1:** *L35 - Please clarify that the sensitivity analysis is performed under clear skies conditions*

**Answer:** A clarification was added in the following sentence between lines 34-37: “The results ... under clear-sky conditions... between 5% and 25%.”

- **#2:** *Fig.1. the figure is difficult to interpret. Is the color coding important for the analysis? If so, please clarify its meaning and improve readability.*

**Answer:** The colors in Fig.2 correspond to the different combinations of inputs and outputs regarding the Radiative Transfer simulations. We understand it might cause some confusion and, therefore, we added the following description in Sect. 2.4, right before the figure.

Lines 235-242:

“On the left side, the inputs representing the realistic atmospheric conditions (AOD, AE, SSA, ASY and PW) are listed for the two spectral regions as described in (a), allowing the RT simulations to account for the spectral dependence of aerosol radiative effects. On the right side, the parameters (AOD, AE, SSA, ASY, and SZA) used in the frame of a sensitivity analysis described in (b) are presented. A more detailed description of the sensitivity analysis is

provided in Section 2.6. Finally, the dark and light grey colours indicate the different wavelength ranges of the RT model inputs that were used to calculate the corresponding GHI and DNI, whose integration over the respective spectral intervals yielded the total broadband BOA irradiances. The sensitivity analysis (shown in dark blue) was performed over the full 280-3000 nm wavelength range.”

- **#3:** *There is a mismatch between figure numbering and the figure references in the text. (e.g. Figures 5, 6 and 7). Please check figure numbering throughout the manuscript. Also, use a consistent format when referring to figures. For example Fig. X.*

**Answer:** The numbering and format of the figure references has been revised to ensure consistent use of “Fig. X” format throughout the manuscript.

- **#4:** *Sec 3.3 Please refer to figures in order of appearance. For example, Fig. 11 appears referenced before Fig. 9.*

**Answer:** The reference to (previously) Fig. 11 was removed from the beginning of the Section, and introduced later, right before the respective figure.

- **#5:** *L260: fixed tilt: which angle?*

**Answer:** This comment was addressed in our response to Major comment #7; The fixed tilt angle refers to the optimum fixed-tilt angle used for each PV system, which was calculated using the default GSEE function for the applicable latitude range.

- **#6:** *Fig. 9 and Fig. 11: please indicate which days are considered clear-sky cases.*

**Answer:** The specific clear-sky days were mentioned in the manuscript (lines: 502-504) but, to avoid confusion, they were also specified in the respective figure’s caption as follows:

Caption of Fig. 10 (previously Fig. 9):

“...In the case of AMX, during days 2, 3, 5 and 7 clear-sky conditions dominated, while in the case of Lampedusa, days 1, 6, 7, 8 and 9 indicated cloudy conditions.”

In Fig. 12 (previously Fig.11), where the comparison between model and measurements are presented, the cloudy sky days were removed completely to avoid confusion.

- **#7:** *In the sensitivity analysis, please specify the wavelength associated with the reported AOD values.*

**Answer:** The wavelength associated with the reported aerosol properties values was included in Sect. 2.6, lines 272-274 as follows:

“... (AOD at 500 nm, AE for 440-670 nm, SSA at 675 nm, ASY at 675 nm, and SZA)...”

And also denoted in Table 2, as follows:

| Parameter                   | Range     | Step |
|-----------------------------|-----------|------|
| <b>AOD<sub>500</sub></b>    | 0-1.6     | 0.1  |
| <b>AE<sub>440-670</sub></b> | 0-0.4     | 0.2  |
| <b>SSA<sub>675</sub></b>    | 0.84-0.99 | 0.03 |
| <b>ASY<sub>675</sub></b>    | 0.62-0.82 | 0.04 |
| <b>SZA</b>                  | 0-75°     | 15°  |

- **#8:** *Fig. 11 and Fig. 1 comparing outputs from a clear sky radiative transfer model (libRadtran in this case) with measurements affected by cloudiness is difficult to interpret and does not provide a meaningful assessment of model performance.*

**Answer:** The authors agree, the comparison under cloudy-sky conditions was excluded and the respective figures have been replaced. The updated figures 12 and 14 (previously 11 and 13, respectively) are the following, where the results presented correspond to comparisons only during clear-sky days:

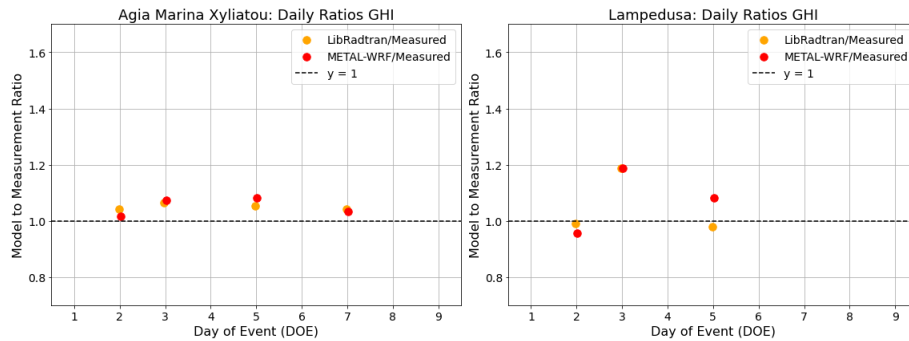


Figure 12: Ratios of GHI from libRadtran (orange) and METAL-WRF (red) to measured GHI at Agia Marina Xyliatou (left) and Lampedusa (right) for clear-sky days.

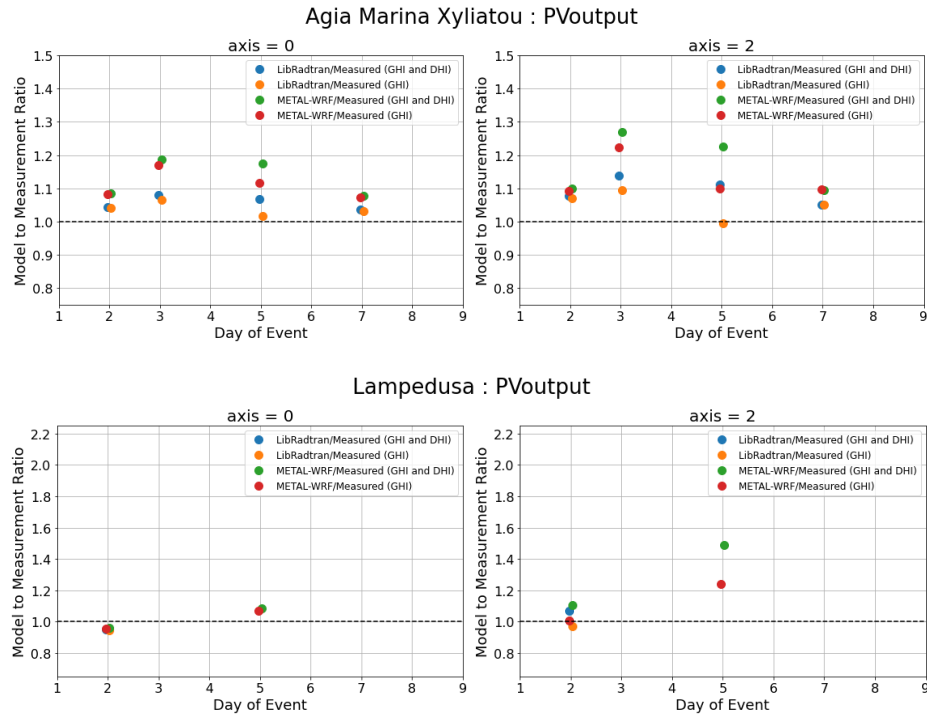


Figure 1: Ratios between  $PV_{lbr}$  and  $PV_{wrf}$  for Agia Marina Xyliatou (upper panels) and Lampedusa (lower panels), for clear-sky days and for two panel setups: optimally inclined PVs (left panels), and 2-dimensional solar tracking PVs (right panels).

- **#9:** conclusions: consider removing "Under cloudy conditions, the comparisons lead to greater differences and an overall overestimation in the case of libRadtran", as this result is expected when comparing clear-sky simulations with cloudy-sky observations.

**Answer:** The authors agree, the sentence was removed from the conclusions.

#### ➤ Suggestions:

- **#1:** Consider including a glossary of the main acronyms and variables used throughout the manuscript.

**Answer:** We thank the reviewer for the suggestion. A table with abbreviations was included at the end of the manuscript.

- **#2:** L120: is there any estimate of the annual energy losses associated with dust events over the study region? Although outside the main scope of this work, such information could help place the reported event-scale impacts into a broader context.

**Answer:** A reference to another study by Verga et al. (2026) was already included in the introduction of the manuscript, which discusses the annual energy losses associated with dust events over the study region. To improve clarity, we have slightly rephrased the relevant sentence (Lines 121-122):

“In a more recent study, Varga et al. (2026) showed that Saharan dust events reduce PV output across the Mediterranean countries by an average of 25–40% on an annual basis, with losses exceeding 50% during extreme events.”

- **#3:** *Since completely clear days are relatively scarce, the authors could consider using clear-sky periods selected from different days (even when a full day is not entirely cloudless) through the application of a clear-sky detection algorithm. This could potentially increase the amount of data available for the final analysis.*

**Answer:** In Figure 13 our intention is to quantify differences in the simulated daily integrals of the PV output when simulations are based on METAL-WRF or libRadtran instead of measurements. Giving a more analytical graph with individual measurements is out of the scope of this figure. Thus, we decided to keep daily integrals for cloudless days.