

ATMD-2026-306

Interactive comment on “Impact of Spectral Aerosol Radiative Forcing at the Izaña Observatory during the August 2023 Extreme Wildfires” by Rosa D. García et al.

Referee #1

Reviewer recommendation: Accept with minor revisions

General comment:

The study by Garcia et al. captures a rare near-source wildfire event at a well-instrumented high-altitude observatory, providing valuable spectral radiative forcing data that is scarce in the literature. Due to the wide range of columnar, vertical, in situ aerosol and trace gas instrument at the Izaña Observatory (IZO) it is a comprehensive multi-instrument approach with rigorous methodology and significant results.

Specific comments

Missing aerosol absorption properties: The authors note (line 122) that AERONET inversion products (SSA, asymmetry parameter) were unavailable. This is a significant limitation since: SSA is crucial for distinguishing scattering vs. absorption effects. Without SSA, the conclusion that "scattering processes" dominate relies primarily on the positive diffuse forcing rather than direct measurement. Recommendation: Discuss this limitation more explicitly and consider whether MAAP absorption data could partially compensate.

Authors: The authors thank the referee for this comment. In order to provide useful information for the discussion on the predominance of the scattering capacity of the aerosols studied from spectral observations during the events selected in this work, the time series of the Single Scattering Albedo (SSA) at 637 nm has been included. This parameter was derived from data obtained with two surface instruments already described in this study: the Integrating Nephelometer and the MAAP. This information has been added to the final manuscript, as follows:

Lines 161-168:

“The Single Scattering Albedo (SSA; ω_0) was calculated following Valenzuela et al. (2015), by combining the total scattering coefficient ($\sigma_{scat}(\lambda)$) from the nephelometer and the absorption coefficient ($\sigma_{abs}(\lambda)$) derived from the MAAP measurements. The absorption coefficient was obtained by multiplying the eBC mass concentration by the mass absorption cross-section of $6.6 \text{ m}^2 \text{ g}^{-1}$, with a correction factor of 1.05 applied to account for the shift in the MAAP light source wavelength (Müller et al., 2011). SSA was then computed at 637 nm using:

$$\omega_0(\lambda) = \frac{\sigma_{scat}(\lambda)}{\sigma_{scat}(\lambda) + \sigma_{abs}(\lambda)}$$

where $\sigma_{scat}(\lambda)$ was interpolated to 637 nm from the nephelometer measurements using the SAE, in order to match the MAAP absorption wavelength.”

Lines 332-334:

“...This enhanced scattering capacity is consistent with the high SSA values obtained from the surface measurements (Fig. 5 in Sect. 4.1)...”

Besides, this information has been added as an additional time series in Fig. 5(c)

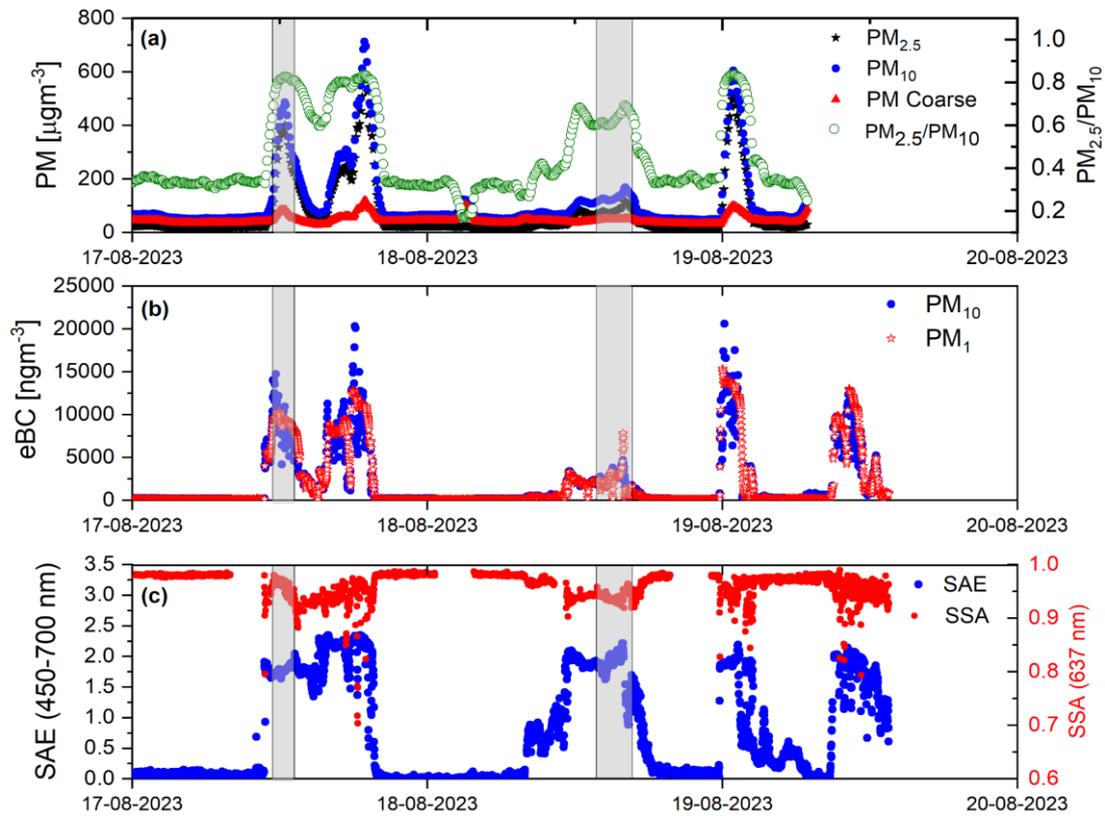


Figure 5.- Time series of in situ aerosol measurements at IZO from 17 to 20 August 2023. (a) Mass concentrations of PM_{10} (black stars), $\text{PM}_{2.5}$ (blue circles), coarse-mode PM (red triangles) and $\text{PM}_{2.5}/\text{PM}_{10}$ ratio (green dots, right axis). (b) Equivalent Black Carbon (eBC) concentrations for PM_{10} (blue circles) and PM_1 (red stars) (c) SAE (450–700 nm; blue circles) and SSA (at 637 nm; red circles, right axis). Shaded areas indicate the periods corresponding to the maximum AOD values observed on 17 and 18 August.

Limited temporal coverage: Analysis mostly focuses on two specific times (11:56 and 15:46 UTC). While understandable for detailed spectral analysis, a diurnal evolution of radiative forcing would strengthen the analysis. **Recommendation:** Consider adding a figure showing temporal evolution of integrated radiative forcing throughout the two days.

The comparison between 17 and 18 August would probably benefit from an analysis of measurement variability during each event.

Authors: Following the reviewer’s recommendations, we have added the temporal evolution of the integrated radiative forcing throughout 17 and 18 August in Section 4.2 of the final manuscript.

Lines 367-373:

“In addition to the instantaneous spectral and band-integrated forcing values discussed above, the temporal evolution of the broadband shortwave radiative forcing was analysed over the two smoke-affected days in order to evaluate the diurnal behaviour of the aerosol perturbation (Figure 9). The time series shows a clear enhancement in the magnitude of the forcing during periods of strongest smoke influence, with the largest cooling occurring around local noon, when solar irradiance is at its maximum. On 17 August, the forcing exhibits a pronounced peak between approximately 11:30 and 13:30 UTC, coinciding with the period of highest aerosol loading observed at the station. On 18 August, the forcing remains significant over a broader time interval, with a maximum around 15:30 UTC, consistent with the later arrival of the densest smoke plume (Figure 4a).”

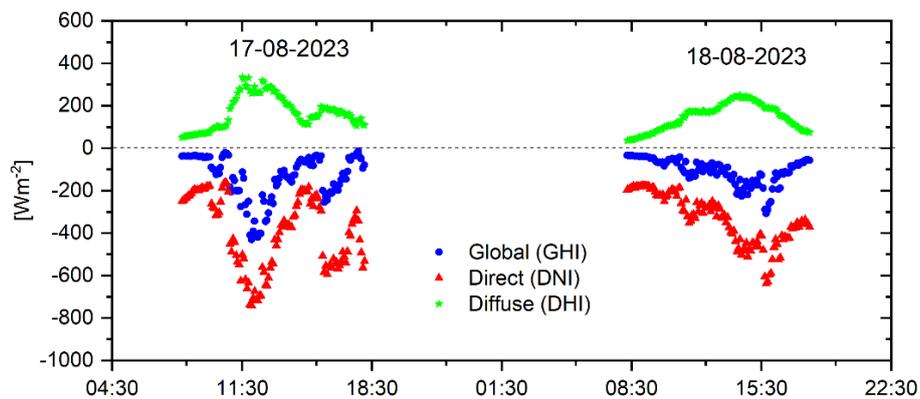


Figure 9.- Temporal evolution of the radiative forcing components (blue: global (GHI), red: direct (DNI) and green: diffuse (DHI) radiation) at Izaña Observatory during the wildfire smoke events of 17 and 18 August 2023.

Minor comments:

1. **Date/Time format:** format of date/time varies between figures (e.g. Fig. 3 and 4), consider aligning the format

Authors: Following the reviewer’s recommendations, we have standardized all the figures using the same date/time format in the final manuscript.

2. **Add one or two more wildfire studies** and the values mentioned therein?

Authors: Yes, we have included several studies on wildfires that show results consistent with ours results:

Lines 241-244:

“...Figure 4c confirms this dominance, with data points from 17 and 18 August clustering in the region of high AE (> 1.5) and high FMF (> 0.8) (Figure 4c), indicative of fine-mode aerosols from biomass burning (Eck et al., 2001; O’Neill et al., 2023). These values are similar to those reported by Masoom et al. (2023); Michailidis et al. (2024) for the extreme wildfires that occurred in Greece in August 2021 and 2023, respectively, as well as to those reported by Filonchik and Peterson (2024) at the El Arenosillo site in southern Europe as a result of the 2023 Canadian forest fires.”

3. **Line 100:** “at the 4th position the shadow band stops at +5° **after** the solar disk” - Should this be “beyond” rather than “after”?

Authors: Corrected

4. **Line 222 and 232 – reference to Masoom seems** somewhat repetitive, maybe add FMF value of Masoom to increase information value of second mention.

Authors: Following the reviewer’s recommendations, we have added the FMF values reported in Masoom et al. (2023) in the final manuscript as follows:

Line 232:

*“Simultaneously, $AE > 2$ on both days (2.06 on 17 August and 2.04 on 18 August) (see Table 1), indicating a predominance of fine-mode particles. These features are characteristic of biomass-burning aerosol intrusions and are comparable to those reported by Masoom et al. (2023) during the extreme wildfire episode in Greece in August 2021, where AOD values up to 3.6 at 500 nm, AE up to 2.4 (440–870 nm), **and fine-mode fraction (FMF) values around 0.98 were observed.** Therefore, the following study focuses on the events recorded on 17 and 18 August.”*

5. **Table 1 and lines 259/260:** The PM2.5/PM10 ratio shows 0.81 for 17/08 and 0.66 for 18/08, but text (line 260) states “0.83 and 0.69”, why is that?

Authors: The data in Table 1 correspond to the two events analysed in this study, during which the maximum AOD values were observed (grey-shaded areas in Fig. 4), whereas the values reported in the text (lines 255–260) correspond to the maximum in situ measurements (grey-shaded areas in Fig. 5). In any case, the paragraph has been updated as follows:

Lines 265-274:

*“...The peaks on 17 August morning and 18 August afternoon (**shaded areas in Figure 5**) coincided with fire events identified from columnar properties (Figure 4). The elevated PM10 and PM2.5 concentrations within these periods indicate direct impacts from wildfire smoke plumes at the observatory, reaching maximum values of 485.19 and 167.80 $\mu\text{g m}^{-3}$ for PM₁₀ and 401.53 and 116.26 $\mu\text{g m}^{-3}$ for PM2.5 (17 and 18 August). The eBC concentrations reached record values for the station (González et al., 2025) with **peaks** of 14.74 and 10.31 $\mu\text{g m}^{-3}$ for the PM10 and PM1 size cuts on 17 August, and 4.69 and 7.81 $\mu\text{g m}^{-3}$ on 18 August. Correspondingly, **the SAE, PM2.5/PM10 ratio, and SSA, which provide complementary information on aerosol size and optical properties, reached maximum values of 1.93, 0.83, and 0.98 on 17 August, and 2.21, 0.69, and 0.96 on 18 August, respectively. These values collectively confirm the dominance of fine, light-scattering wildfire originated particles during the selected events.**”*

6. **Reference list:** several times doi link wrong format: “https://doi.org/https://doi.org..” (remove one <https://doi.org>)

Authors: Corrected

Overall Assessment:

This is a valuable contribution documenting an extreme biomass burning event with rare spectral detail. The main scientific conclusions are sound, but the paper would benefit from a clearer discussion of limitations, particularly regarding missing SSA data. The multi-instrument approach is a major strength that validates the findings across independent measurement techniques. With the revisions outlined above the manuscript should be suitable for publication.

Authors: We acknowledge the referee's comments.