Summary:

This manuscript presents the characterization of radiative and optical properties of long-range transported dust events originating from Sahara Desert (SA) and Middle East (ME) region at the Agia Marina Xyliatou station (AMX), Cyprus. The study combines the use of multiple remote sensing instruments (ground based and satellite) to identify dust events at the site from 2015 to 2022.

Analysis focuses on the detailed dust-source identification by utilizing HYSPLIT model backward airmass trajectories and two methods analyzing optical properties relationship – AERONET-Dubovik method (aerosol optical depth AOD_{440nm} vs Ångström exponent $AE_{440-870nm}$ and LIDAR Depolarization-based method. The results of identified dust events were further confirmed by satellite measurements.

The identified dust events were investigated further (both sources separately), specifically their inter-annual variability, shortwave direct radiative effect (SW DRE) at different layers of the atmosphere, relationship between distinct optical properties as well as global horizontal irradiance (GHI) with implications for solar energy applications in the region.

General comments:

I see the strength of the manuscript in the effort to separate optical properties and radiative impacts of SA and ME originated dust events and validate outcomes by the combination of multiple reliable methods.

However, the title "Characterization of Dust Aerosol Source Types and Associated Shortwave Direct Radiative Effects Over Cyprus: A Seven-Year Study" can be a bit misleading. Although authors were analyzing seven-year long dataset, the work is missing the interannual variability of the events, which could provide valuable information on the change in frequency, intensity and occurrence of dust events together with their radiative impacts in medium-term period. Moreover, authors focus on four specific episodic dust events in Section 3.7 Analysis of dust events. I strongly suggest changing the title or incorporate interannual variability study.

More emphasis should be put on the manuscript novelty within text originating from combination of measurement techniques, advanced validation of methods or data processing as they are main scopes of the AMT journal.

In general, this work contains robust datasets, however, multiple information on representativeness and statistics is missing. Moreover, the information on overall solar irradiance and other meteorological variables (wind speed, wind direction, temperature, etc.) is missing to properly support certain claims in the manuscript. The additional comments can be found in Specific comments section.

I recommend cautious revision of the manuscript, as it contains inaccuracies, inconsistencies, formatting typos and false references within the text (See Technical comments section).

Therefore, I suggest major manuscript revisions to be made before publication.

Specific comments:

Whole manuscript: Since the analysis is restricted to dust-event periods, the reported statistics represent a conditional distribution characterized by strong episodic variability. In such cases, mean ± standard deviation may be sensitive to a small number of high-intensity events and may not represent the typical optical state during dust outbreaks. The authors are encouraged to assess the robustness of their results using additional statistical indicators (e.g., median and IQR).

L117-121: *"During DJF, an increase of approximately 50% in PM2.5 has also been documented, rising from approximately 10 μg m^{-3} in DJF to about 15 μg m^{-3} in JJA, attributed to enhanced photochemical activity, reduced precipitation prolonging aerosol lifetime, and the transport of fine-mode pollutants from regional sources, including Turkey and, to a lesser extent, Europe (Pikridas et al., 2018)."*
It is not clear if the increase of PM2.5 occurred in DJF or in transition from DJF to JJA, please rewrite.

L122: *"To further support the analysis of aerosol conditions over Cyprus, observations from a second site located in Limassol CUT TEPAK station in Limassol which is operated at the Cyprus Atmospheric Remote Sensing Observatory National Facility (CARO NF) of the Eratosthenes Centre of Excellence at Limassol (34.677ºN, 33.0375ºE) (Ene et al., 2024)."*
Please rewrite, the sentence is missing a verb.

L147: Do levels 1.0, 1.5 and 2.0 of data processing have the same time resolution?
Level 1.5 was used for SSA and ASYM while Level 2.0 for AOD, AE, FMF and TCWV. How were uncertainties resulting from different data levels handled?
What is the data availability after filtering out data for AOD (440nm) > 0.4?

Table 1: Were AOD and SSA measured at 675 nm used in the study? I can only identify results originating from 440 nm channel.
The asymmetry parameter is described in the Method section but is not displayed or commented on throughout the manuscript. This variable could introduce additional value on the morphology of the measured particles and direction of scattered light.

L220: It would be valuable to comment on the validation procedure (e.g. graph in the SM, uncertainty estimation, etc.).

L255-258: *"For days when lidar measurements were unavailable or inconclusive, MODIS true-colour imagery from the instruments aboard NASA's Terra and Aqua satellites,*

accessed via the NASA GIBS/Worldview platform, was used to visually confirm the presence of dust and to assess its spatial extent and transport patterns (section 2.2.2).”
The authors declare that LIDAR measurements were incorporated in 2017. However, the analysis was performed on datasets from 2015, so I assume 2 years of data were treated based on satellite measurements. Were LIDAR measurements compared against satellite retrievals to assess the comparability of used methods?

L268: The authors chose FMF < 0.4 for the threshold of coarse-mode dominance. Please comment on this choice.

L274-278: I suggest shortening the introductory part of 2.4.3 Estimation of dust direct radiative effects as it was explained in the 1. Introduction.

Figure 2: The percentages in Pie charts overlap and are not truly visible (b.iii, b.iv).
What is the time resolution of data points and what is the data availability after data processing in Figure 2a? Where do median/mean with IQR/std lay within classified aerosol types?

It may be valuable to calculate wind roses for different seasons (Figure 2b) to see the predominant wind direction.

L325-330: How did the frequency and intensity of dust events evolve over the years for SA and ME?

L339: *“Figure 2(iv) table of this classification by showing the median AOD_{440} for each aerosol type.”*
Please double check the sentence.

L342: Although marine and continental aerosols exhibit lower median AOD compared with dust and mixed aerosols, AOD alone does not fully characterize their radiative effects. Intensive optical properties (e.g., SSA, Ångström exponent, backscattering ratio or asymmetry parameter), which are independent of aerosol loading, determine aerosol scattering and absorption efficiency and may substantially influence radiative impacts even under lower AOD conditions.

L355: The authors are using 72-hour backward air mass trajectories computed with the HYSPLIT model to verify dust classification by AERONET-Dubovik method. However, later in text (L386), 96-hour backward air mass trajectories were used for LIDAR Depolarization-based method. Please comment on choice of the backward tracking periods.

Figure S1: This Figure in SM is valuable in terms of AMT scope as it clearly compares methods of dust origin identification. The authors may consider moving it into the main text. At the same time, I would suggest moving multiple plots into SM and keep max 10-11 Figures in the main text.

The method comparison from Figure S1 never agreed on the identification of ME, while it was very successful for SA. Please comment.

L415: SA is transported over the sea, thus can be mixed with sea salt as well.

L515: *"For a more compact and quantitative comparison of particle size between the two origins, because it summarizes the combined influence of the peak position and the coarse/fine partitioning."*
Please rephrase.

L570: The authors are often claiming that SA episodes are more frequent, but ME can have comparable impact based on individual high-loading episodes. How is the intensity of dust event evaluated/described in this study? Can authors estimate the averaged episodical intensity of SA compared to ME?

L577: The analysis of meteorological conditions including temperature or solar irradiance is missing to see the magnitude of variability in incoming solar radiation.

L581: Do authors want to refer to Figure 8 instead of Figure 5?

L575-589: Repetitive phrasing of the outcomes, please consider rewriting.

Figure 5: Despite almost identical AOD_{440nm} of SA and ME in MAM, SSA_{440nm} differs (irregular pattern for ME). Please elaborate on potential reason.

L633-634: *"For AOD at 440nm the surface cooling, reach values up to -204W/m^2 and -47 W/m^2 at the TOA and for the atmosphere reaching the 182 W/m^2 for Sahara dust."*
Please rephrase.

Figure 9: I suggest splitting SA and ME into separate plots (e.g. matrix 2x3) for better visibility of datapoints as well as the position of low SSA values.
The authors used Pearson correlation coefficient to evaluate correlation between DREs and AOD for each dust source and layer of the atmosphere. Were data tested for normal distribution? If data are not normally distributed, I would recommend using different non-parametric statistical indicators.

L708: Do authors want to refer to Figure 12 instead of Figure 11?

Figure 14b: The color-coding of datapoints with SSA values could provide information on aerosol absorption/scattering ability.

L760: Figure 15a instead of Figure 14a?

L777-778: *"January February and June July show weaker relative attenuation (typically below 10%), reflecting both reduced dust activity, and lower incoming solar radiation."*
Please provide evidence of decreased June July lower incoming solar radiation.

Figure 15: It may be interesting to see how the attenuation of radiation changes over years. Could authors investigate the influence of climate change on the frequency and intensity of dust events in this region?

L809: Figure 15 instead of Figure 14?

Technical comments:

Whole manuscript: Please pay attention to the consistency throughout the whole manuscript, namely: consistent spacing of wavelength and unit (e.g. 440 nm) and format of unit (W/m^2 vs $W\ m^{-2}$); space between the end and beginning of the new sentence; consistent usage of abbreviations (e.g. Ångström exponent (440–870 nm) vs AE vs 440-870 _AE); references to Figures (Fig. 2 vs Figure 2 or Figure 2b-i in text but Figure 2b.i in the plot); consistent decimal places; formatting of figure/table titles (bold vs regular or Figure 3. vs Figure 3:); please keep consistent line spacing.

L61: Excess dot before citation brackets.

L63: Previous studies (Dayan et al., 1991; Gkikas et al., 2018; Logothetis et al., 2021; Moustaka et al., 2024) revealed….

L64: Dayan et al., (1991), please remove comma.

L75: Regarding the surface DREs, Di Biagio et al. (2010) reported an instantaneous daily maximum…

L78: Additionally, dust aerosols can greatly affect energy production (Hansen et al., 1997; Kosmopoulos et al.,2017, 2018), …

L97: SSR is not defined in text.

L105: Please pay attention to spaces and brackets and keep the formatting consistent: (35.04º N; 33.06º E; 535 m a.s.l.)…

L199: …are used…

L285: …Moustaka et al. (2023), …

L364: …Figure 3…

L524: Undefined RTM, also, please keep the consistency of either RTM or RT models.

L638: *"This relationship is quantified further in Section 3.6 (Fig. 11)."*

L710: Please correct sentence from : *"At the surface, the selected Saharan dust events produce the strongest cooling, with DRE at surface values ranging from −168 to −126 W m $^{-2}$, compared to −126 to −96 W m $^{-2}$ for the selected ME cases."* to *"At the surface, the selected Saharan dust events produce the strongest cooling, with DRE at surface values ranging from −167 to −126 W m $^{-2}$, compared to −127 to −96 W m $^{-2}$ for the selected ME cases."*