Dust effects on ground-based irradiance measurements

M. Rita Perrone [1] , S. Romano[1]

[1]Dipartimento di Matematica e Fisica, Università del Salento, Lecce, 73100, Italy

The dust role in the Earths radiation budget is widely recognized and several experiments have been undertaken to investigate the impact of mineral dust on the Mediterranean radiation budget (e.g. Perrone *et al.*, 2012 and references therein). The radiative impact of dust particles is rather complex since they are of large size and exert a significant direct radiative effect in both the short- (SW) and long-wave (LW) radiation. SW and LW direct radiative effects (DREs) by dust particles are generally opposite. In particular, the absorption and scattering by dust particles in the LW-domain enhance the greenhouse effect and consequently aerosol LW-DREs are positive at the surface, while SW-DREs are negative. Hence, it is important to look at the interaction of dust particles with LW and SW radiation, to properly define how they alter the energy budget. Ground-based irradiance measurements performed from December 2011 up to November 2012 at a costal site of south-eastern Italy (40.33°N, 18.11°E) have been used in this study to investigate dust effects at the surface in both the SW and LW spectral range. Two Kipp and Zonen pyranometers (CMP 21) and pyrgeometers (CGR 3) have been used to measure upward and downward radiative fluxes in the SW (0.31-2.8 μm) and LW (4.5-45 μm) domain, respectively. The monthly analysis of the dust effect on ground-based SW and LW irradiance measurements has been performed in clear-sky days, selected by satellite images. Satellite MODIS images (http://modis.gsfc.nasa.gov/), analytical back trajectories (http://ready.arl.noaa.gov/), the BSC-DREAM model (http://www.bsc. es/), and aerosol microphysical properties retrieved from AERONET sun/sky photometer measurements (http://aeronet.gsfc.nasa.gov/), co-located in space and time with irradiance measurements, have been used to determine and evaluate the presence of mineral dust at the monitoring site. The dust effect on ground-based downward flux measurements are shown in Figure 1a and 1b for the SW and the LW range, respectively. It has been found that from March to September, the mean SW downward flux F↓ is equal to 590±80 W m^{-2} and 570±80 W m^{-2} in dust-free and dust days, respectively. The mean LW-F↓ is equal to 360±40 W m^{-2} and 370±40 W m^{-2} in dust-free and dust days, respectively. These results reveal the cooling and warming effect by mineral dust in the SW and LW spectral range, respectively. The direct radiative effect of mineral dust particles is quantified by the dust Direct Radiative Forcing (DRF) and the Aerosol Forcing Efficiency (AFE). The DRF results strictly related to radiative properties and concentration of aerosol particles, while AFE is mainly dependent on the particle composition and size (Tafuro et al., 2007). The use of measured net fluxes with aerosols to

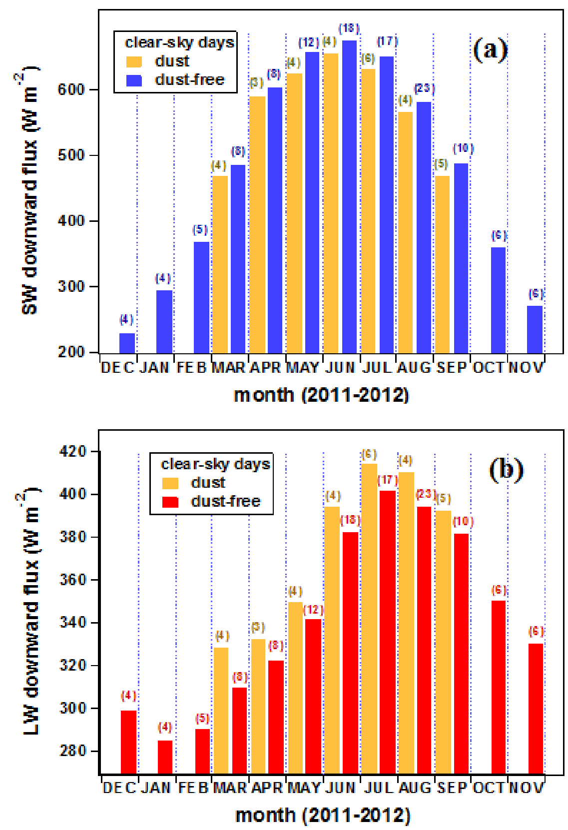

Figure 1. Monthly mean values of ground-based (a) short- and (b) long-wave downward flux for dust and dust-free days during the period December 2011 November 2012. The value in parentheses represents the number of dust or dust-free days during the related month.

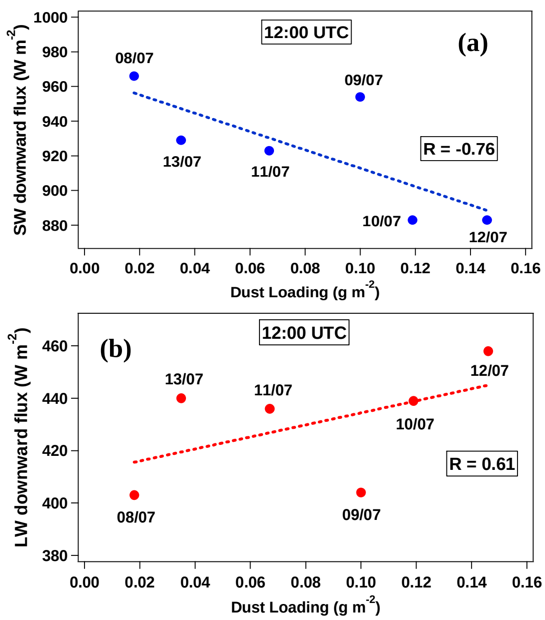

Figure 2. Scatterplot of the measured downward fluxes in (a) the SW and (b) the LW spectral range versus the dust loading estimated by the BSC-DREAM8b model, from 8 to 13 July 2012 at 12:00 UTC. The dotted line represents the linear fit. The date (dd/mm) and the correlation coefficient R are also reported.

evaluate dust DREs and AFEs represents a peculiarity of this study: net fluxes are strongly dependent on the assumed surface albedo, the vertical distribution of the aerosol load, and the optical and microphysical aerosol properties. Results on the dust impact on ground-based SW and LW irradiance measurements, during the Saharan dust outbreak that has affected South-Eastern Italy from 9 to 13 July, 2012, are reported in this study as an example. We have found that the dust loading was equal to 0.02 g m^{-2} at 12:00 UTC of 8 July and increased up to 0.15 g m^{-2} at 12:00 UTC of July 12. Then, we can observed in Figure 2a and 2b that the dust loading increase of 0.13 g m^{-2} was responsible for the SW- F↓ decrease from 966 to 883 W m^{-2} and the LW- F↓ increase from 403 to 458 W m^{-2}, respectively. The significant effect of the dust loading on the ground-based irradiance measurements is also confirmed by the correlation coefficient (R) of the best-fitting lines (dotted lines) which is equal to -0.76 and 0.61 in the SW and LW spectral range, respectively.

The surface SW- and LW-AFE at a fixed SZA have been determined from the slope of the linear fit between the net radiative fluxes and the corresponding Aerosol Optical Depth AOD, according to Satheesh and Ramanathan (2000). As

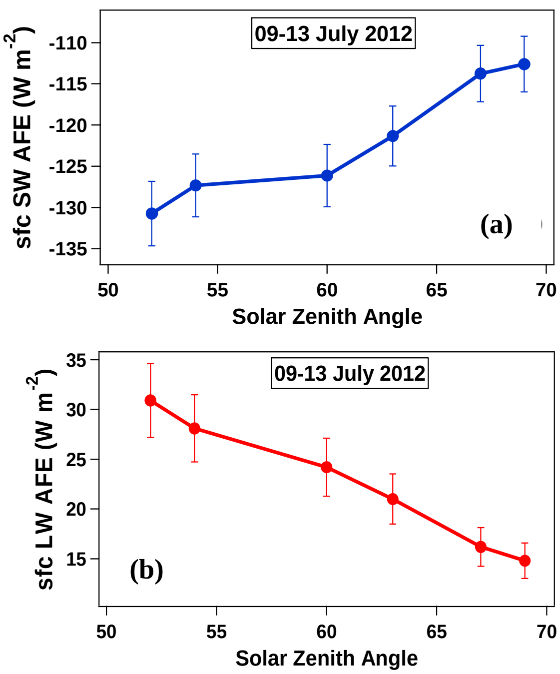

Figure 3. Scatterplot of the estimated instantaneous (a) SW and (b) LW aerosol forcing efficiencies at the surface versus the related solar zenith angles in 52-69 range, from 9 to 13 July, 2012.

revealed by Figure 3a and 3c, we have found that from 9 to 13 July, 2012, the instantaneous SW-AFE increased of 18 Wm^{-2} AOT_{440} $^{-1}$ and the instantaneous LW-AFE decreased of 16 Wm^{-2} AOT_{440} $^{-1}$, respectively, for SZA angles varying within the 52-69° range.

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