Experimental and model-based determination of mineral dust radiative effects in the short- and long-wave spectral range at a Central Mediterranean site

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Mineral dust aerosols play an important role in the Earth’s radiation budget and influence significantly the climate system through direct (scattering and absorption of solar and terrestrial radiation) and indirect effects (acting as cloud and ice condensation nuclei). The Mediterranean basin represents one of the most important areas for the study of mineral aerosols due to its proximity to the Sahara desert. Mineral dust outbreaks affect the Mediterranean region mostly in summer contributing to one of the highest radiative effects in the world [1]. The mineral dust direct radiative effect can be quantified by the Direct Radiative Forcing (DRF) and the Forcing Efficiency (FE). The DRF results strictly related to optical properties and concentration of aerosol particles, while the FE is mainly dependent on the particles composition and size. Mineral aerosols cause the decrease of the incoming short-wave (SW) radiation at the surface as a consequence of their scattering and absorption properties inducing a cooling effect and a negative value of the SW-DRF. Conversely, mineral dust particles enhance the greenhouse effect in the long-wave (LW) spectral range by trapping the outgoing terrestrial radiation and therefore the LW-DRF is positive at the surface. A moderate Saharan dust episode was observed over south-eastern Italy from 9 to 13 July 2012. The presence of dust particles was identified by using satellite MODIS images, analytical back trajectories, the BSC-DREAM8b model, AERONET sun/sky photometer aerosol products, and SW and LW radiative flux measurements at the surface. In particular, two Kipp & Zonen pyranometers (CMP 21 model) and two Kipp & Zonen pyrgeometers (CGR 3 model) were used to retrieve upward and downward radiative fluxes at the surface in the SW (0.31-2.8 μm) and in the LW (4.5-42 μm) spectral range, respectively. During the studied dust outbreak, the SW and LW downward fluxes decreased up to 9% and increased up to 13% at the surface, respectively, compared to a pristine dust-free day. This outcome is due to the cooling and warming effect by mineral dust in the SW and LW spectral range, respectively. Most of the previous works about mineral dust radiative effects over the Mediterranean area are based on radiative transfer models. Some papers have evaluated the mineral dust DRF by using experimental flux measurements and model simulations to determine the radiative fluxes with and without aerosol, respectively. Conversely, rather few studies have estimated the mineral dust radiative effects by only using experimental observations. This work presents a methodology to experimentally determine the instantaneous and clear-sky DRF by all aerosols (DRFt) and mineral dust particles (DRFd) during a desert dust event. To this end, the surface SW- and LW-FEs by all aerosols (FEt) have first been determined from the slope of the linear fit between the net radiative fluxes and the corresponding aerosol optical depths (AODs), according to the direct method by [2]. Note that SW- and LW-FEs have been calculated at fixed solar zenith angles (SZAs). The used AOD values have been determined from AERONET sun/sky photometer retrievals collocated in space and time with the radiative flux measurements. The experimental DRFt for different SZAs is then calculated by multiplying the estimated FEt value by the corresponding AOD. On the contrary, the experimental DRFd is estimated as the net flux difference between a dust and a pristine dust-free day. Note that the difference (DRFt - DRFd) has allowed evaluating the DRF by the background aerosol (DRFa), during the analyzed dust event. The DRFa may results relevant during desert dust outbreaks occurring few hundred kilometers away from the dust regions, as demonstrated by [3] by using model simulations. During the studied dust outbreak, we have found that the DRFd at the surface varied from -11 to -68 W m-2 and from +1.3 to +8.7 W m-2 in the SW and LW spectral domain, respectively. The SW- and LW-DRFa at the surface ranged between -1 and -22 W m-2 and between +0.2 and +1.9 W m-2, respectively. Hence, the mineral dust contribution has represented on average 82 and 81% of the SW- and LW-DRFt, respectively. A two-stream radiative transfer model (RTM) has then been used to test its ability to estimate DRFd and DRFa instantaneous values at the surface and to determine aerosol DRFs at the top of the atmosphere [4]. AERONET sun/sky photometer inversion products, LIDAR vertical profiles and meteo parameters from a radiosonde represent the main inputs of the RTM. It is shown that the used RTM can allow reproducing the experimental findings within the error range.

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