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Direct radiative effects induced by intense desert dust outbreaks over the broader Mediterranean basin

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Throughout the year, under favorable conditions, massive loads of mineral particles originating in the northern African and Middle East deserts are transported over the Mediterranean basin. Due to their composition and size, dust aerosols perturb the Earth-Atmosphere system's energy budget interacting directly with the shortwave (SW) and longwave (LW) radiation. The present study aims to compute the Mediterranean dust outbreaks' direct radiative effects (DREs) as well as to assess the effect of including dust DREs in numerical simulations of a regional model. To this aim, 20 intense dust outbreaks have been selected based on their spatial coverage and intensity. Their identification, over the period 2000-2013, has been achieved through an objective and dynamic algorithm which utilizes as inputs daily satellite retrievals derived by the MODIS-Terra, EP-TOMS and OMI-Aura sensors. For each outbreak, two simulations of the NMMB/BSC-Dust model were made for a forecast period of 84 hours, with the model initialized at 00 UTC of the day when the dust outbreak was ignited, activating (RADON) and deactivating (RADOFF) dust-radiation interactions. The simulation domain covers the northern Africa, the Middle East and Europe at 0.25º x 0.25º horizontal resolution, for 40 hybrid sigma pressure levels up to 50 hPa. The instantaneous and regional DREs have been calculated at the top of the atmosphere (TOA), into the atmosphere (ATMAB), and at surface, for the downwelling (SURF) and the absorbed (NETSURF) radiation, for the SW, LW and NET (SW+LW) radiation. The interaction between dust aerosols and NET radiation, locally leads to an atmospheric warming (DREATMAB) by up to 150 Wm-2, a surface cooling (DRENETSURF) by up to 250 Wm-2 and a reduction of the downwelling radiation at the surface (DRESURF) by up to 300 Wm-2. At TOA, DREs are mainly negative (down to -150 Wm-2) indicating a cooling of the Earth-Atmosphere system, although positive values (up to 50 Wm-2) are encountered over desert areas. The mean regional NET DREs, under clear-sky conditions, vary between -10 to 2, -3 to 25, -35 to 3 and -22 to 3 Wm-2 for TOA, ATMAB, SURF and NETSURF, respectively. According to our results, dust outbreaks can cause a decrease of temperature at 2 meters by 4 ºC during daytime while an increase of a similar magnitude is found at night. Moreover, negative feedbacks on dust emissions and aerosol optical depth are observed when dust-radiation interactions are activated. Our analysis clearly shows that taking into account the dust radiative effects in numerical simulations (RADON) the model's ability to reproduce the temperature fields as well as the downwelling radiation fluxes at the surface is improved. The former is confirmed by the evaluation of the model's outputs against ERA-Interim reanalyses datasets and weather stations observations (Integrated Surface Database, ISD) while the latter is justified through the comparison of model's downwelling SW/LW radiation fluxes at the surface with ground measurements from 6 Baseline Surface Radiation Network (BSRN) stations. A similar analysis is also attempted for the dust aerosol optical depth at 550 nm using the AERONET ground retrievals as reference measurements.