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Direct effect of extreme aerosol episodes on atmospheric solar radiation in the broader Mediterranean basin and potential links with atmospheric dynamics

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Aerosols interact directly with solar radiation in the Earth-atmosphere system (aerosol direct radiative effect, DRE), perturbing thus its radiation budget. The aerosol direct radiative effect is particularly enhanced in cases of strong aerosol episodes, and therefore can potentially modify the atmospheric dynamics, for example by changing the atmospheric temperature lapse rates, thus affecting atmospheric processes like cloud and precipitation formation and the water cycle. Such potential links between aerosol DREs and atmospheric dynamics are investigated in the present study on the basis of a climatology of aerosol episodes for the greater Mediterranean basin over the 7-year period from 1 March 2000 to 28 February 2007.

First, an objective and dynamic algorithm was set up, in order to identify and classify the aerosol episodes, based on their physical and optical properties derived by satellite observations (Moderate resolution Imaging Spectroradiometer, MODIS, Earth Probe and Ozone Monitoring Instrument, OMI). More specifically, the aerosol properties used are: aerosol optical depth (AOD, τ), Ångström exponent (α), fine fraction (FF), effective radius (reff) and Aerosol Index (AI). The relevant data were gridded at 1ox1o degree geographical cells on a daily basis for the entire study period. The extreme aerosol episodes were then determined, and subsequently, specific types of episodes have been identified: biomass burning/urban (BU), desert dust (DD) and sea salt like (SS-like). In total, 10 BU, 57 DD and 14 SS-like extreme episodes were found.

Next, the aerosol solar DRE during the extreme aerosol episodes has been computed using the SBDART (Santa Barbara DISORT Atmospheric Radiative Transfer) model. The DREs were computed spectrally at 761 wavelengths from 0.2 to 4μm, and were then spectrally integrated to yield the total shortwave aerosol DRE at the top of the atmosphere (DRETOA), at the surface (DREsurf and DREsurfnet) and in the atmosphere (DREatmab). The structure of the atmosphere in the episodes' days has been determined using data from SBDART standard atmospheres, the Optical Properties of Aerosols and Clouds (OPAC), AeroCom and MODIS databases, and the NCEP Reanalysis Project.

The spectral profile of aerosol DREs pretty matches that of the solar radiation, regardless of episodes type radiative effect component (DREi), with clear maximum values (up to 5.5 Wm-2μm-1) near 0.5μm, with the exception of DRETOA. The maximum DRE values are found for extreme DD episodes over maritime regions, because of the highest AOD values in such cases, and they are equal to 85.3Wm-2, -518.9Wm-2, -492.9Wm-2, 407.6 Wm-2, for DRETOA, DREsurf, DREsurfnet and DREatmab, respectively. On the other hand, the aerosol radiative efficiency (ARE) takes maximum values for BU episodes, equal to -210.8 Wm-2/AOD550nm, -200.3 Wm-2/AOD550nm and 170.2 Wm-2/AOD550nm, for AREsurf, AREsurfnet and AREatmab, respectively, while maximum ARETOA values (80.7 Wm-2/AOD550nm) are found for extreme SS-like episodes. It is found that solar atmospheric warming can be significantly enhanced under extreme BU and DD episodes, by 80% and 220% respectively, whereas the planetary cooling can be enhanced under extreme SS-like conditions by 100%. Strong atmospheric heating rates, up to 5 K/day and 10 K/day, are computed under extreme BU and DD episodes, respectively, while the corresponding rates for SS-like episodes are very small. Moreover, the computed vertical profiles of atmospheric heating rates show that during extreme BU episodes, the maximum heating occurs in the low boundary layer (between 0.5 and 1.5 km) while under extreme dust episodes the maximum warming is observed at 2.5 km. Such atmospheric temperature changes produced by aerosol episodes can have important implications for atmospheric dynamics and the hydrological cycle.