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Modelling the direct effect of aerosols on solar radiation based on satellite observations, reanalysis datasets, and spectral aerosol optical properties from Global Aerosol Data Set (GADS)

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In this study, we estimate the seasonal direct radiative effect (DRE) of natural plus anthropogenic aerosols on solar radiation on a planetary scale. The aerosol DRE computations are obtained at the top of atmosphere (TOA, ΔF_{TOA}), in the atmosphere (in terms of atmospheric absorption of solar radiation, ΔF_{atmab}), and at the Earth's surface (in terms of surface downward and absorbed solar radiation, ΔF_{surf} and $\Delta F_{surfnet}$, respectively), under all-sky conditions by combining satellite measurements and reanalysis data with a spectral radiative transfer model. The detailed spectral model computations separate the aerosol DREs in the ultraviolet (UV), visible and near-infrared wavelengths, and finally the total SW radiative effects are computed, which matter for the radiative energy budget and climate. The global distribution of spectral aerosol optical properties was taken from the Global Aerosol Data Set (GADS) whereas data for clouds, water vapour, ozone, carbon dioxide, methane and surface albedo were taken from various satellite and reanalysis datasets. Using these aerosol properties and other related variables, climatological (for the 12-year period 1984-1995) monthly mean aerosol DREs were generated at 1ºx1º resolution on a global scale. The global annual mean DRE on the outgoing SW radiation at the top of atmosphere (ΔF_{TOA}) is 1.62 W m^{-2} (with a range of -10 to 15 W m^{-2}, positive values corresponding to planetary cooling), the effect on the atmospheric absorption of SW radiation (ΔF_{atmab}) is 1.6 W m^{-2} (values up to 35 W m^{-2}, corresponding to atmospheric warming), and the effect on the surface downward and absorbed SW radiation (ΔF_{surf}, and $\Delta F_{surfnet}$, respectively) is -3.93 and -3.22 W m^{-2} (values up to -45 and -35 W m^{-2}, respectively, corresponding to surface cooling). According to our results, aerosols decrease/increase the planetary albedo by -3 to 13% at the local scale, whereas on planetary scale the result is an increase of 1.5%. Aerosols can warm locally the atmosphere by up to 0.98 K day^{-1}, whereas they can cool the Earth's surface by up to -2.9 K day^{-1}. Both these effects, which can significantly modify atmospheric dynamics and the hydrological cycle, can produce significant planetary cooling on a regional scale, although planetary warming can arise over highly reflecting surfaces. The aerosol DRE at the Earth's surface compared to TOA can be up to 15 times larger at the local scale. The largest aerosol DRE takes place in the northern hemisphere both at the surface and the atmosphere, arising mainly at ultraviolet and visible wavelengths.