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Aerosol direct radiative effect on solar radiation on planetary scale based on 7-year spectral aerosol optical properties from MODIS

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Atmospheric aerosols, both natural and anthropogenic, can cause climate change through their direct, indirect and semi-direct effects on the radiative energy budget of the Earth-atmosphere system. However, the quantification of the aerosol effects is difficult because aerosol physical, chemical and optical properties are highly variable in space and time. Another difficulty is the lack of continuous and long-term measurements of aerosol properties.

In the present study the mean monthly direct radiative effect (DRE) of aerosols on solar radiation is estimated on global scale for a 7-year period (March 2000 - February 2007), by using a deterministic spectral radiation transfer model and long-term satellite spectral aerosol data. The model uses climatological input data for various surface and atmospheric parameters, taken from the International Satellite Cloud Climatology Project (ISCCP-D2), the National Centers for Environmental Prediction – National Center for Atmospheric Research (NCEP-NCAR) Global Reanalysis project, and other global data bases. The aerosol DRE computations are performed in the ultraviolet, visible and near-infrared, spanning the total shortwave (SW) spectral range 0.2–10 μm. The model computes the aerosol effect on the SW radiation budget of the Earth-atmosphere system, namely at the top of atmosphere (TOA reflected solar radiation), within the atmosphere (absorbed solar radiation), and at the surface (incoming and absorbed solar radiation). The multiyear global distributions of spectral aerosol optical properties (aerosol optical depth, AOD, asymmetry parameter, g_{aer}, and single scattering albedo, ω_{aer}), which are of primary importance for aerosol DREs, are taken from the MODerate resolution Imaging Spectroradiometer (MODIS) of NASA (National Aeronautics and Space Administration) and they are supplemented by the Global Aerosol Data Set (GADS). More specifically, we use MODIS AOD and g_{aer} data at 7 wavelengths extending from 470 to 2130 nm, over land and ocean. The computations of aerosol DREs are performed at a spatial resolution of 2.5ºx2.5º latitude-longitude.

According to the model results, the 7-year global mean aerosol direct radiative effect on the outgoing (reflected) SW radiation at TOA (DRE_{TOA}) is equal -2.88 W/m2, indicating thus a significant planetary cooling. At the regional scale, however, the cooling effect is much stronger, while a planetary warming is found over highly reflecting surfaces like deserts. The global effect of aerosols on the atmospheric absorption of SW radiation (DRE_{atmab}) is equal to 3.94 W/m2, indicating an atmospheric warming due to aerosols. In addition, aerosols are found to decrease the downward SW radiation at the Earth's surface ($\Delta F_{SurfDown}$) by -7.97 W/m2, producing thus a very important surface radiative cooling. Based on the model computations, the inter-annual change of aerosol DRE from 2000 to 2007 is -3.7% for DRE_{TOA} (less aerosol planetary cooling), -13.4% for DRE_{atmab} (less aerosol atmospheric warming) and -10.4% for DRE_{surf} (less aerosol surface cooling). Our results indicate that a significant reduction in the magnitude of aerosol radiative effects has taken place from 2000 to 2007, which is primarily due to a corresponding decrease in aerosol loads over many world regions, Asian, European and American countries included.