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Global distribution of clear-sky aerosol direct radiative forcing in the ultraviolet and visible using a long-term aerosol optical depth from TOMS observations

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A deterministic atmospheric spectral radiative transfer model, that uses comprehensive climatological data, was developed to compute the global distribution of mean monthly clear-sky total direct aerosol radiative forcing in the ultraviolet (UV) and visible, between 0.2 - 0.85 μm, at the top of the atmosphere (TOA), within the atmosphere and at the Earth's surface on a monthly mean basis. The aerosol data used in the model are taken from the Global Aerosol Data Set (GADS) and the Total Ozone Mapping Spectrometer (TOMS). The GADS aerosol data are given for various fixed relative humidity values and for 11 wavelengths within the UV-visible range, both for natural and anthropogenic aerosols. We first derive global climatologies of aerosol optical thickness (AOT), single scattering albedo (ω_{aer}) and asymmetry factor (g_{aer}), for actual relative humidity values within the aerosol layer, based on the National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) Reanalysis Project and the European Centre for Medium Range Weather Forecasts (ECMWF) datasets. We include the global distribution of cloud cover by using the D2 data from the International Satellite Cloud Climatology Project (ISCCP), to define the clear-sky fraction at the pixel level for each month. Supplementary 10-year climatological data for surface and atmospheric parameters were taken from NCEP/NCAR, ECMWF, ISCCP-D2, and TOVS. Given that GADS does not provide complete seasonal and interannual variability of aerosol properties, we use the long-term (1979-1993) monthly mean TOMS AOT data from Nimbus7-TOMS observations. The TOMS AOT data are given at two wavelengths, one at the

near infrared (0.38 μm) and another at the visible (0.5 μm). The spectral profile of GADS AOT was then scaled and adjusted to the TOMS AOT values. The resulted distributions of AOT data, along with the GADS ω_{aer} and g_{aer} data were used in the model to compute the temporal evolution of aerosol forcings over the period 1984-1993 at 2.5°x2.5° latitude-longitude resolution, on global scale. Our analysis allows the aerosol radiative properties and forcings to vary with space, time, and wavelength. The aerosols are found to decrease significantly the downward and the absorbed solar radiation at the surface, by up to 25 and 22 W m^{-2}, respectively, on a mean monthly basis, producing a surface cooling at all latitudes over all seasons. They are also found to generally increase the outgoing solar radiation at TOA (planetary cooling), by up to 12 W m^{-2}, while they increase the solar atmospheric absorption (atmospheric warming) by up to 14 W m^{-2}. However, the model results indicate that significant planetary warming, by up to 5 W m^{-2}, can occur regionally, over desert areas, due to strong aerosol absorption. A smaller, by up to 2 W m^{-2}, planetary warming is also found over highly reflecting ice- or snow-covered areas, such as such as northern continental regions during winter. In general, the aerosol-induced surface cooling exceeds the induced atmospheric warming, except for regions characterized by strong aerosol absorption (e.g. deserts). On a mean annual global basis, aerosols are found to cool the Earth by 1.7 W m^{-2}, to heat the atmosphere by 0.7 W m^{-2}, while they decrease the downward and net surface solar radiation (surface cooling) by about 2.8 and 2.4 W m^{-2}, respectively. Our model results reproduce well aerosol features associated with seasonal cycles such as the mineral cycle over Africa, or events such as the Pinatubo eruption in 1991.