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The direct effect of aerosols on the radiation budget and climate of the Earth-atmosphere system: its variability in space and time

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Atmospheric aerosols, these tiny particles suspended in the air, play a very important role for the Earth-atmosphere climate system on both global and regional scales through various mechanisms and physical processes. The climatic effects of aerosols are determined by modifications they induce on the various components of the Earth's radiation budget. Despite the progress that has been made lately, there is still much to learn about the climatic role of aerosols in various aspects. One of the most important issues that has to be addressed is the spatial and temporal variability, especially the temporal variability of aerosol properties and their consequent radiative effects. For example, there is uncertainty with regard to aerosol radiative properties and whether or not aerosol loads are increasing or decreasing with time, and what the consequences are. Moreover, the extent to which aerosols cool or warm the planet is not clear, as well as the contribution to this cooling/warming by aerosols of natural and anthropogenic origin. Given that the aerosol radiative effects, especially on radiation reaching the Earth's surface and in the atmosphere, cannot be directly measured/observed, models are necessary to overcome this problem. Specifically, radiative transfer models (RTMs) are able to calculate the radiation fluxes within the entire Earth-atmosphere system from regional to planetary scale, and the flux changes caused by aerosols. Yet, what is more interesting for models is that they allow us to study in detail the space and time resolved aerosol radiative effects and their sensitivity to various physical parameters. Using RTMs the aerosol direct effect on solar radiation can be determined at the top of the atmosphere (DRE_{TOA}) in the atmosphere (DRE_{atm}) and at the Earth's surface (DRE_{surf}).

Using a detailed radiative transfer model together with climatological input data for surface and atmospheric variables, the direct radiative effects of aerosols (DREs) were determined over the globe for a period of more than two decades, covering the eighties (1980s), the nineties (1990s) and the early 20^{th} century (2000s). The climatological input data are representative for each region of the globe (2.5˚x2.5˚ latitude-longitude resolution) and for each month and year, and were taken from various satellite databases (e.g. International Satellite Cloud Climatology Project, ISCCP, Total Ozone Mapping Spectrometer, TOMS, Moderate Resolution Imaging Spectroradiometer, MODIS) and reanalysis datasets (e.g. National Centers for Environmental Prediction, NCEP, National Center for Atmospheric Research, NCAR). The inter-annual variability of aerosol DREs was then estimated and subsequently tendencies and trends of DREs were determined. These trends were considered with regard to current discussions on global dimming and brightening (GDB) to assess the effects of aerosols on these climatic processes. An attempt was made to quantify the overall changes in surface solar radiation (i.e. GDB) to compare them against quality surface measurements (Baseline Surface Radiation Network, BSRN, Global Energy Balance Archive, GEBA) and to identify their causes. In addition, the effect of aerosols on the thermal dynamics of the Earth-atmosphere system was investigated and possible effects on clouds and precipitation were also examined.