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Estimating the direct aerosol radiative effect over China using multi-sensor satellite remote sensing measurements

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The quantification of aerosol radiative effects is complex and large uncertainties still exist, mainly due to the high spatial and temporal variation of the aerosol concentration and mass as well as their relatively short lifetime in the atmosphere. In this work a multi-sensor satellite based approach is studied for defining the direct short wave aerosol radiative effect (ADRE) over China. ADRE at the top of the atmosphere (TOA) is defined as the difference between the net solar flux with (F) and without (F_0) aerosols. The negative values of ADRE correspond to increased outgoing radiation and planetary cooling, whereas positive values correspond to decreased outgoing radiation at TOA and increased atmospheric warming.
To derive instantaneous ADRE from the satellite observations, the challenge is to estimate the value for F_0. In this work F_0 is derived using the colocated observations of CERES (Clouds and the Earth's Radian Energy System) short wave broad band TOA-flux and MODIS (Moderate Imaging Spectroradiometer) aerosol optical depth (AOD). Assuming that aerosol type does not change systematically within a 0.5 deg. grid cell over a month, a linear relationship is established between the TOA-flux and AOD when AOD < 2.0. Using the linear fit an estimate for F_0 can be obtained and F is the monthly mean of CERES observations. However, there are several other parameters affecting the observed TOA flux than the aerosol loading and aerosol type, such as solar zenith angle, water vapour, land surface albedo and Earth-Sun distance. Changes in these parameters within a grid cell over a month inflect the correlation. To minimize the effect of zenith angle, water vapour, and Earth-Sun distance the CERES fluxes are normalized before the linear fitting using reference fluxes calculated with a radiative transfer code (Libradtran). The normalization, especially to a fixed zenith angle increases the correlation between TOA flux and AOD significantly. For a comparison theF_0 is also modeled using Libradtran. Comparison shows that the modeled aerosol-free fluxes are mainly $5 - 10Wm^{-2}$ lower than the estimate from the linear fitting, but on the other hand over bright surfaces the satellite based estimate is lower than the modeled F_0. Nevertheless, the fitting method in most of the cases produces qualitatively similar results for instantaneous ADRE than what is obtained with modeled F_0 over the region of interest. In some cases, the satellite based method gives positive ADRE over areas where it is expected to be negative. This is most probably a method failure, related to either subvisible cirrus contamination, systematic change of aerosol type or both.