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On the use of satellite remote sensing to determine aerosol direct radiative effect over land: A case study over China

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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 for cloud free sky 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 clear-sky TOA-fluxes and AODs. Using the linear regression an estimate for instantaneous monthly F_0 can be obtained by extrapolating the line to AOD=0, while F is the monthly mean of cloud free 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 between AOD and TOA fluxes. 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 the F_0 is also modeled using Libradtran. Comparison shows that the modeled aerosol-free fluxes are mainly 5-10 Wm^{-2} lower than the estimate obtained 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. 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.