Aerosol effects on the cloud albedo

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Aerosols have an impact on the radiation budget of the earth, directly through interaction with radiation and indirectly via interaction with clouds. The net effective radiative forcing of both aerosol-radiation interactions and aerosol-cloud interactions is negative which means they have a cooling effect on the climate. But there is still a huge uncertainty in the magnitude of the negative forcing. One factor contributing to this uncertainty is the different effects of aerosol types. Some aerosols (e.g. sulfate) reflect solar radiation which leads to a cooling while other aerosols absorb solar radiation and hence induce a warming.

A linear relation between albedo and cloud fraction was determined in five main regions of low marine stratocumulus clouds on the monthly time scale (Bender et al., 2011), indicating a constant cloud albedo. The climatic effects of various aerosol types can be studied by use of this relation. In this study the Twomey effect, which is referred to as aerosol-cloud interactions in the AR5 terminology (IPCC AR5, Boucher et al., 2013) is investigated by linking the AOD (Aerosol Optical Depth) to the albedo and cloud fraction. The AOD is a measure how much direct solar radiation is reflected and absorbed by aerosols. The concentration of aerosols determines the number of cloud condensation nuclei (CCN) available and thereby the cloud droplet number and size. Considering the same liquid water content, a polluted cloud has more smaller droplets and therefore a higher albedo. Model results have shown a positive AOD gradient in the five main regions (Bender et al., 2015), which means higher albedo occur for a higher AOD at a given cloud fraction.

We have used model output of four experiments provided by CMIP5 to study the climatic effects of sulfate and BC (black carbon) aerosols. The historical experiment 'sstClim' was forced with a control SST climatology while the aerosol emissions are on a preindustrial level. This simulation serves as a reference. Three sensitivity experiments are forced with the same SST climatology, but have a different aerosol forcing. In the first experiment 'sstClimAerosol', the model is forced with all aerosol emissions on the level of the year 2000, in the second experiment 'sstClimSulfate' with sulfate aerosols on the level of 2000 and the third experiment with an increased BC aerosol forcing.

The focus is on the five main regions of low marine stratocumulus clouds, according to Klein and Hartmann (1993) and Bender et al. (2011). The climatic effects of the aerosol types will be determined by changes of the AOD gradient in the albedo-cloud fraction space. An increase of the aerosol emissions to the level of year 2000 causes an increase of available CCNs and therefore cloud droplets. This should lead to a cloud brightening.

Our results coincide with earlier studies analyzing model output and confirm discrepancies between model output and satellite observations. We will investigate reasons for these differences between models and observations and furthermore investigate in the representation of aerosols in the different CMIP5 models.

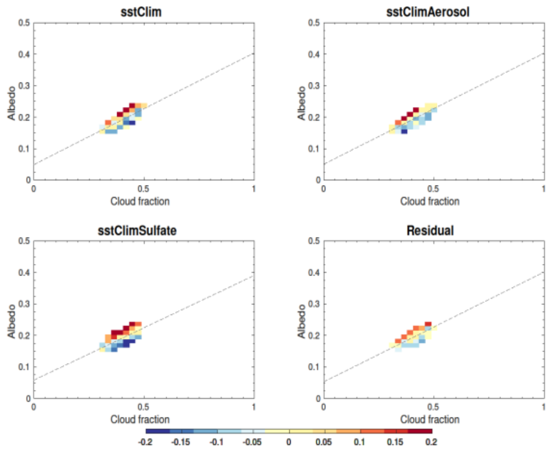

Figure 1. Normalized AOD anomaly in the albedo-cloud fraction space for the CMIP5 climate model NorESM for the Australian region (one of the five main regions of marine startocumulus clouds). From the upper left to the lower right, the results of the three different experiments sstClim, sstClimAerosol and sstClimSulfate are shown.

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