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Satellite observation of aerosol - cloud interactions over semi-arid and arid land regions

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Satellite observations from three different sources are used to study the interactions between aerosol and ice clouds in five semi-arid and arid land regions over Africa and Asia, reaching from the South-African Kalahari to the Taklimakan and Gobi in Mongolia. (1) Six years of Aqua MODIS cloud and aerosol observations (including "Deep Blue" retrievals) which contain a qualitative separation into coarse and fine mode aerosol are analysed. (2) Five years of APOLLO cloud observations and SYNAER aerosol retrievals which allow discriminating between mineral dust and soot dominated cases from AATSR and SCIAMACHY on ENVISAT are exploited. (3) Moreover IASI provides one year of ice cloud and mineral dust observations over land retrieved with a newly developed method based on singular vector decomposition. Cloud top temperature observations are used to asses the state of convection and to statistically re-project observation distributions of cloud properties to background conditions. Then the difference between observation density distributions of background and re-projected aerosol-contaminated samples can be evaluated. By such way of analysis the influence of different cloud development stages, which also manifest in seasonal cycles of cloud properties, can be minimised.

The analysis of the various observation density distributions shows that liquid water and ice effective radius is mainly decreased for increased total aerosol content for both aerosol types, biomass burning aerosols and mineral dust, separately.

Two different modes of aerosol impacts on cloud optical depth can be shown. Optical depth is mainly increased, directly following the theory of the so-called "Twomey effect". In the West African Sahel a decrease of cloud water path (for both liquid water and ice) under the influence of absorbing aerosols results also in decreased optical depth. As at the same time the cloud fraction does not decrease under aerosol influence, the statistical decrease of mean optical depth and ice water path points towards an invigoration of cirrus clouds, which is also supported by the very high fraction of low ice cloud optical depth observations in the Sahel.

Ice cloud cover is increased by up to 25% for almost all observations, the impact is stronger for mineral dust than for fine mode aerosol. The ice cloud fraction as ratio between ice cloud cover and total cloud cover is also increased for all regions and aerosol regimes. Also here the strongest impact is observed for mineral dust, reflecting the good suitability of dust particles as ice nuclei.

The effects seen by the three satellite datasets are overall consistent. The analysis clearly shows that for ice clouds the Twomey effect also can be observed as for liquid water clouds, but that also other effects impact on optical depth variation. Ice water path is generally increased by aerosol, but in the Sahel also a decrease is observed which can be attributed to a higher cirrus fraction at low CTT.