Satellite observations of aerosol-cloud interactions

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Introduction

Aerosols contribute to the climate system in many ways. Besides altering the heat balance of atmosphere and surface, the interaction of aerosols with the radiation field in the atmospheric column (known as direct aerosol effects) changes the initial conditions for cloud formation and growth. Also already formed clouds are influenced by aerosols due to microphysical effects (indirect aerosol effects). These effects, well established in cloud microphysical theory, are still unknown in magnitude, in regional distribution and also in overall sign of resulting radiative forcing. The reason for this lack of knowledge is the large variety of existing aerosol species and different pathways of interaction with clouds. Known effects of aerosols suitable as cloud condensation nuclei (CCN) are reduction of cloud droplet size and thus increasing the cloud albedo (referred to as Twomey effect) and resulting from the reduced droplet size a reduction of precipitation efficiency especially in warm-top clouds (referred to as drizzle supression effect). Another suggested result form the drizzle reduction is a decrease of cloud top temperatures (CTT) resulting from the increased release of latent heat due to non-precipitating droplets. Also this CTT effect then influences the radiation balance and thus the climate system.

The indirect effects of aerosols depend not only on the properties of the cloud fields, but also on aerosol type. Thus aerosol type information is an essential paramter in statistical analysis of aerosol cloud interactions.

Data

Observations from the geostationary Meteosat Second Generation (MSG) and the polar-orbiting ENVISAT satellites are used for analysis. Cloud products are derived from MSG-SEVIRI and ENVISAT-AATSR observations through the Avhrr Processing sCheme Over Land, cLouds and Ocean (APOLLO, Kriebel et al., 2003). An aerosol retrieval using synergetic effects from AATSR and SCIAMACHY observations (SYNAER) provides aerosol optical depth (AOD) and aerosol type information (40 predefined aerosol types) for ENVISAT (Holzer-Popp et al., 2008). A similar AOD retrieval incorporating only two aerosol types is applied to MSG observations together with a new mineral dust index from infrared observations.

Mineral dust detection from bitemporal MSG IR observations

At DLR-DFD a new method has been developed to detect mineral dust over land from bitemporal MSG infrared observations. This *Bitemporal Mineral Dust Index* (BMDI) is composed from day- (12:00 UTC) and nighttime (03:00 UTC) observations of 10.8μm and 12.0μm brightness temperatures and their differences (BTD). As this index does only incorporate IR observations, dust retrieval is also possible over bright surfaces such as the Sahara or Namib and Kalahari deserts. Fig. 1 shows the number of days with dust detected by BMDI in 2006 (a) and the mean total AOD determined with SYNAER (b) for the same period. Notice, that with SYNAER no AOD retrieval is possible over bright surfaces such as the Sahara .

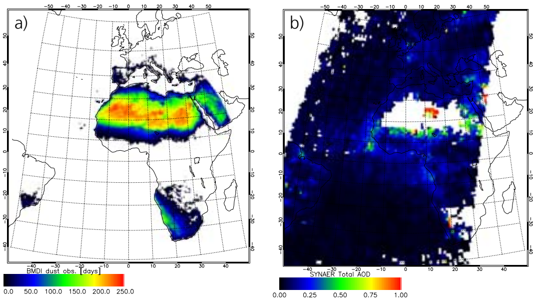

Figure 1: number of days with dust detected by BMDI from Jan-Dec 2006 MSG observations (left) and mean AOD as determined with SYNAER (ENVISAT) for the same period (right)

Comparisons of this new mineral dust index with the Aerosol Robotic Network AERONET (Holben et al., 1998), MODerate resolution Imaging Spectrometer (MODIS) „Deep Blue" AOD (Hsu et al., 2004) and Ozone Monitoring Instrument (OMI) Aerosol Index (Torres et al., 1998) show good results in detecting mineral dust with BMDI and also highlight the possibility to gain information about the atmospheric dust load.

Clouds and aerosol in the Sahel region

The Sahel as part of the West African Monsoon region (WAM) is characterised by strong annual cycles of cloud cover and precipitation and by advection or local emission of different aerosol types (mainly mineral dust and biomass burning aerosol) into the intertropical discontinuity. Also mixing of those aerosol types (both external mixing and advection in seperated layers) occurs during WAM drytime. Fig. 2a shows the temporal evolution of BMDI (blue), AOD (orange) and cloud cover (red) for the Sahelian sector as defined in fig. 2b. The dust season, being winter and spring in the Sahel, is evident in both, BMDI and AOD observations, while the monsoon onset in June is indicated by rising cloud cover in the region.

In the presence of dust, cloud optical depth and cloud top temperature distributions are changed significantly (fig. 2 c and d).

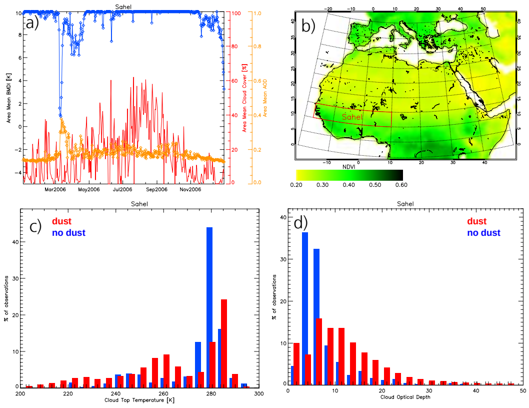

Figure 2: Cloud cover and BMDI annual cycles of the Sahel region (a) as defined in the map (b) and effect of dust onto cloud properties (c and d)

Influence of mineral dust on cloud properties over the tropical Atlantic Ocean

The *Main Development Region* (MDR) for Atlantic tropical cyclones (TC) is defined as the area 6N - 18N and 18W - 50W (fig. 3a). Mineral dust, exported from the *Dust Export Region* (DER) to the Atlantic Ocean, has been reported to decrease TC intensities or to suppress TC formation from easterly waves and tropical disturbances at all. The physical effects resulting in TC suppression are not yet fully understood. Besides entrainment of wind shear into the cyclone at the edge of dust fronts effects of mineral dust aerosol onto cloud microphysics are thought to be of relevance for dust-hurricane interactions. First results of the hurricane season (Jun-Nov) 2006 reveal an increase of cloud optical depth in presence of mineral dust (4°-box mean AOD > 0.2), which might be indicative for microphysical interactions of the dust with cloud clusters (fig. 3b).

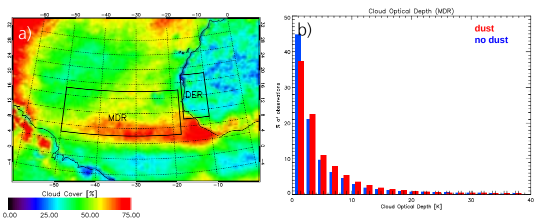

Figure 3: North Atlantic mean cloud cover together with definitions of MDR and DER regions (left) and cloud optical depth (right) vhistograms for dusty and dustfree conditions during the hurricane season 2006

Conclusions and outlook

A new approach of mineral dust remote sensing MSG IR observations has been developed. From this Bitemporal Mineral Dust Index, the influence of mineral dust on Sahelian cloud properties can be inferred. AOD analyses reveal some influence of mineral dust on cloud optical depth in the Main Development Region for atlantic tropical cyclone.

Further analysis will also include contributions of biomass burning aerosol as inferred from ENVISAT observations. Also larger datasets including more years of observations will be available soon, so that interannual variability can be accounted for.

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