Exploitation of IASI thermal infrared observations for dust research applications

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Introduction

Applying Singular Vector Decomposition (SVD) to high resolution thermal infrared (8-12µm) spectra of the Infrared Atmospheric Sounding Interferometer (IASI) on the Metop satellite enables to observe airborne mineral dust over ocean, vegetation and deserts. Being independent of solar illumination (i.e. twice daily) the retrieval provides also information about dust particle size and dust layer temperature together with an estimation of the intrinsic retrieval error (Klüser et al., 2011).

Monitoring of dust episodes

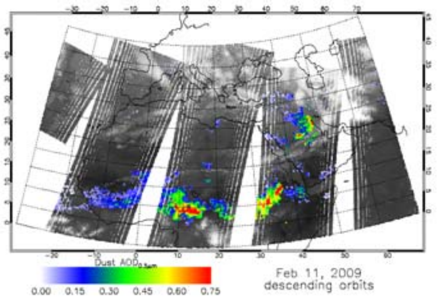

Fig. 1: IASI dust observation over Arabia and in the Sahel-Soudan belt (11 Feb 2009).

Monitoring of fast evolving dust events like the dust storm behind the Arabian cold front or the Sahelian dust event in Fig. 1 is possible due to twice daily observations (Fig. 3). The corresponding dust effective radius of 11 Feb 2009 is largest near dust source areas (Fig. 2).

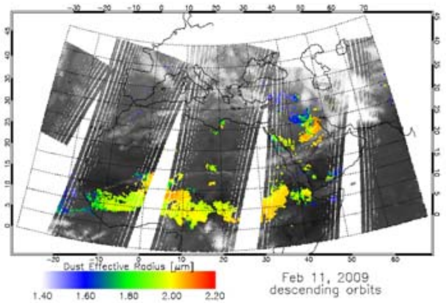

Fig. 2: Dust particle effective radius over Arabia and in the Sahel-Soudan belt retrieved from IASI (11 Feb 2009).

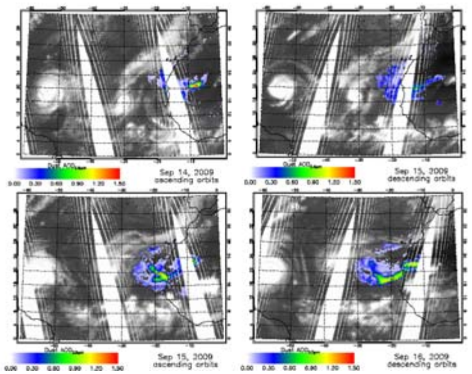

Fig. 3: Twice daily sampling of a dust outbreak off West-Africa in September 2009.

Diurnal cycles of dust activity

Monthly mean maps of the fraction of IASI observations showing airborne dust can be used to estimate the diurnal cycle of dust activity (Fig. 4). The example of February 2009 shows a southward shift in Sahelian dust observations from morning (descending orbits) to evening (ascending orbits) and significant dust activity in the Western Sahara in the evenings only. Over Arabia the diurnal cycle is less pronounced in terms of observation fraction. In June the Western Sahara dust source region is more active in the morning – as well as the active Arabian dust regions.

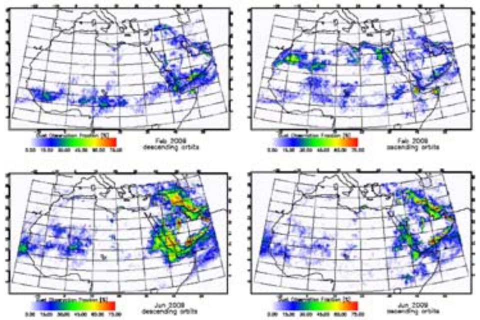

Fig. 4: Monthly dust observation fraction over Northern Africa and Arabia for February and June 2009 for morning (left) and evening (right) overpasses.

Dust AOD (representing dust load) and effective radius (largest near sources) observations can be used to infer dust source activation frequencies for morning and evening observations separately.

Dust impact on convective cloud cells

Studying the impact of aerosol on cloud properties has a strong demand for reliable aerosol type separation. Moreover morning overpasses of polar orbiting satellites are rather limited in estimating the impact on precipitation in convective regimes with strong diurnal cycles of the cloud state (Klüser and Holzer-Popp, 2010). Both requirements are fulfilled with IASI, from which also convective cloud properties such as e.g. cloud phase and estimates of effective ice particle size can be obtained.

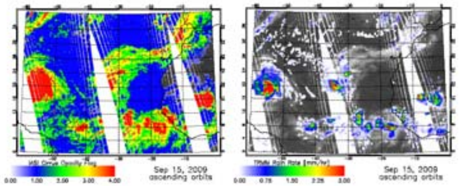

Fig. 5: Opaque cirrus mask (left) and corresponding TRMM rain rate (right) for ascending orbits of 15 September 2009.

IASI observations of dust and convective clouds together with three-hourly precipitation observations of the Tropical Rainfall Measuring Mission (TRMM) have been analyzed exemplarily for the tropical Atlantic Ocean dust and hurricane region (10°-30°N, 60°-18°W) for the period 12-20 September 2009, showing dust outbreaks and tropical cyclone activity (Fig. 3 and 5).

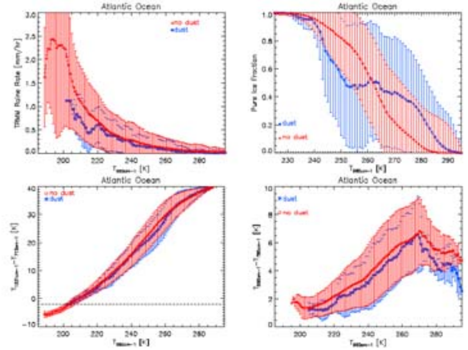

Fig. 6: Analysis of the impact of dusty environment on rain rate, ice fraction, convective overshooting and ice particle size.

Fig. 6 highlights exemplary results of the observed impact of dusty environment on convective clouds for the September 2009 case. Only observations within 1.5° of cloud boundaries are taken into account to guarantee comparability. These results are of case study character and are statistically neither significant nor representative.

Nevertheless for this case the precipitation is clearly reduced under the influence of mineral dust, especially for cold clouds (indicated by low temperatures). For low temperatures ice fraction is lower with dust, while it is higher for brightness temperatures above 265K. Ice fraction above 273K indicates semi-transparent cirrus.

$T_{1231cm^{-1}}$-$T_{712cm^{-1}}$<-2K is indicative for overshooting convection (Auman et al., 2011), which is not observed under dust influence in this episode. $T_{960cm^{-1}}$-$T_{790cm^{-1}}$ is sensitive to ice particle effective size. The systematically reduced values for ice phase clouds in dusty environments represent larger ice crystals compared to the dust free conditions.

Summary and outlook

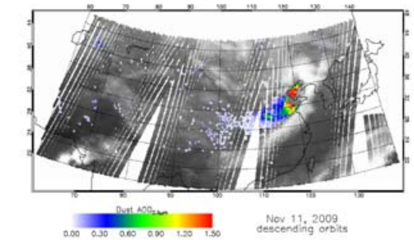

Fig. 7: IASI observation of airborne dust over China (11 November, 2009).

The SVD based dust retrieval for IASI provides twice daily mineral dust observations over land and ocean including bright desert areas, independent of solar illumination.

These observations, including dust particle effective radius and dust layer emission temperature, can be used for monitoring of fast evolving continental-scale dust events over the Atlantic Ocean, Northern Africa, Arabia and adjacent oceans and also over China (Fig. 7). The twice daily sampling enables to obtain information about the diurnal cycles of dust activity and dust source activation.

Together with cloud properties obtained form the same instrument, IASI dust observations of morning and afternoon overpasses provide detailed insights into dust-convection interactions and their impact on the convective state.

The IASI retrieval provides dust AOD together with a representation of the dust particle size distribution regardless of the underlying surface and of solar illumination. Moreover the dust emission temperature can be regarded as an estimate for the dust layer height. Every retrieval result is accompanied by an individual intrinsic retrieval error. Thus these observations meet (almost) all requirements for data assimilation into numerical models, allowing for a wide range of further higher level applications.

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