Three-dimensional pathways of dust over the summertime Sahara revealed by IASI

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1. Framework

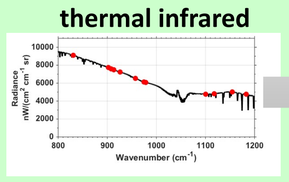
Desert dust plays a major role in the Earth system. The life cycle of desert dust and its numerous environmental impacts are closely related to its three-dimensional (3D) spatial distribution. Once uplifted from the surface over source regions, dust is transported to remote regions by the atmospheric circulation. Depending on the altitudes at which it is transported, dust impacts the Earth radiative budget, atmospheric stability, cloud properties as well as chemical and biogeochemical processes. When transported near the surface, dust causes poor air quality, low visibility and deposits on the ground. Accurate knowledge of the 3D pathways of desert dust transport and the associated dynamical processes is fundamental for assessing its major impacts on the environment.

In the current study, we present a new characterization of the three-dimensional (3D) distribution of dust over the Sahara during summertime, for June 2011.

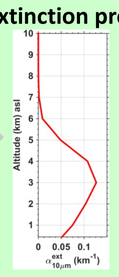
2. 3D distribution of dust from AEROIASI

Our approach called AEROIASI is based on the innovative retrieval of vertical profiles of dust extinction coefficient from daily cloud-free hyperspectral satellite observations of IASI.

Cloud-free IASI spectra in the thermal infrared

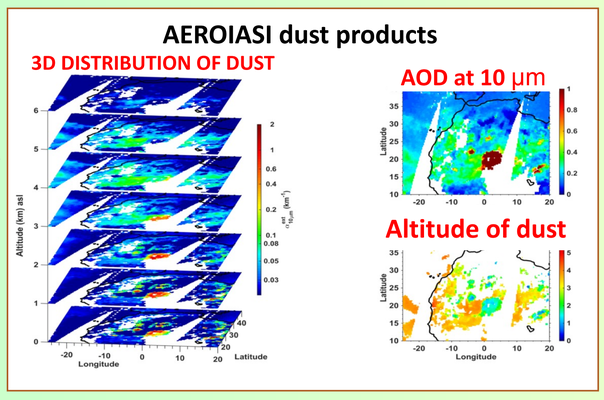


Dust vertical extinction profile



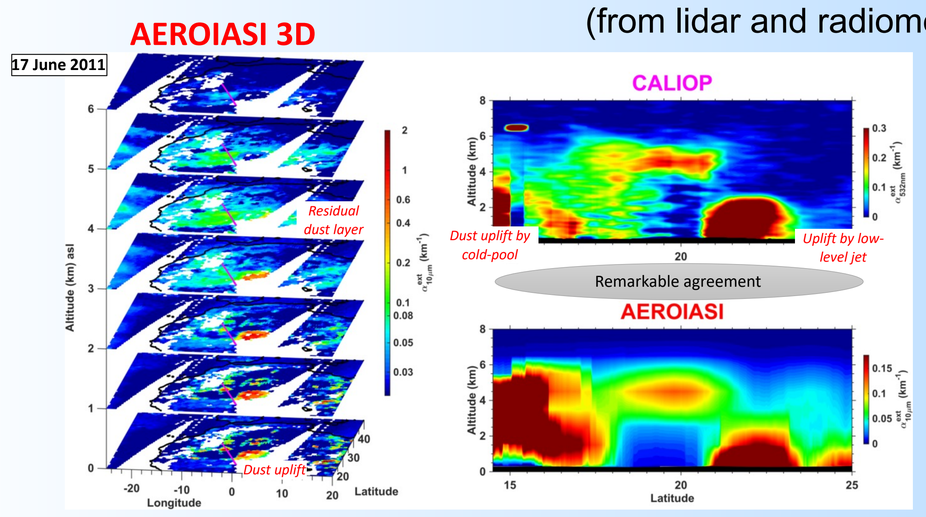
For each IASI pixel

AEROIASI dust products



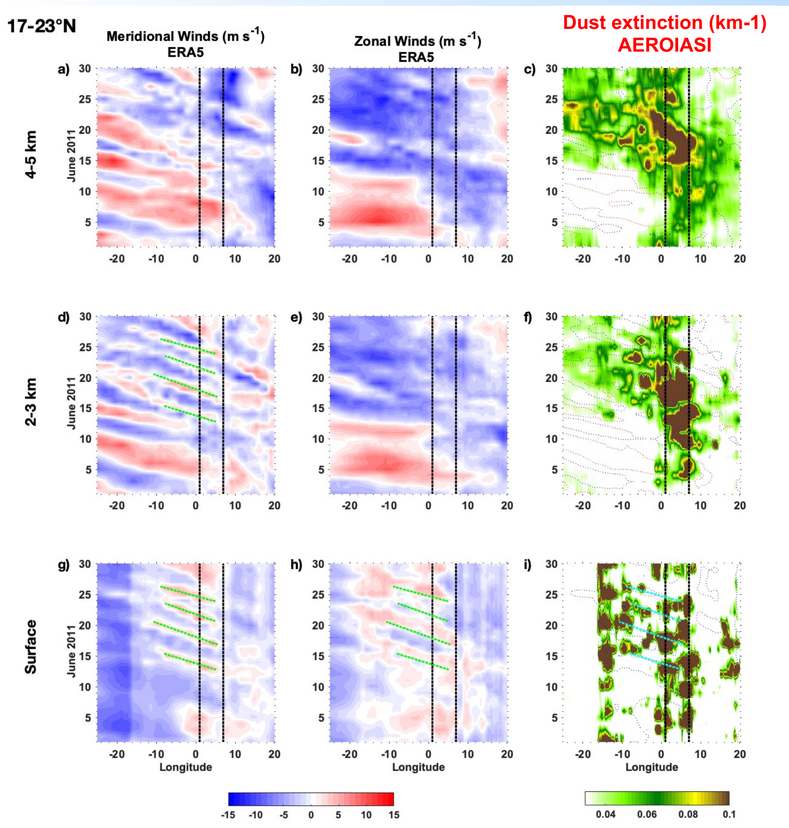
3. AEROIASI vs CALIOP

AEROIASI observations clearly agree with other widely used measurements (from lidar and radiometers)



4. Dynamical drivers of the 3D distribution of dust during June 2011

The 3D characterisation is focused on the dust maximum in June 2011, located in the central Sahara (17–23˚N 1–7˚E). AEROIASI shows near-surface dust load to be dominated by five major emission events occurring every 3–4 days. All these occur when the study region is under the influence of northward bursts of the WAM and convection-related cold pools, likely associated with orographic forcing by the Aïr Mountains. Convection over the hot spot also triggers wave-like disturbances that travel westwards (dashed green lines in the figure below).

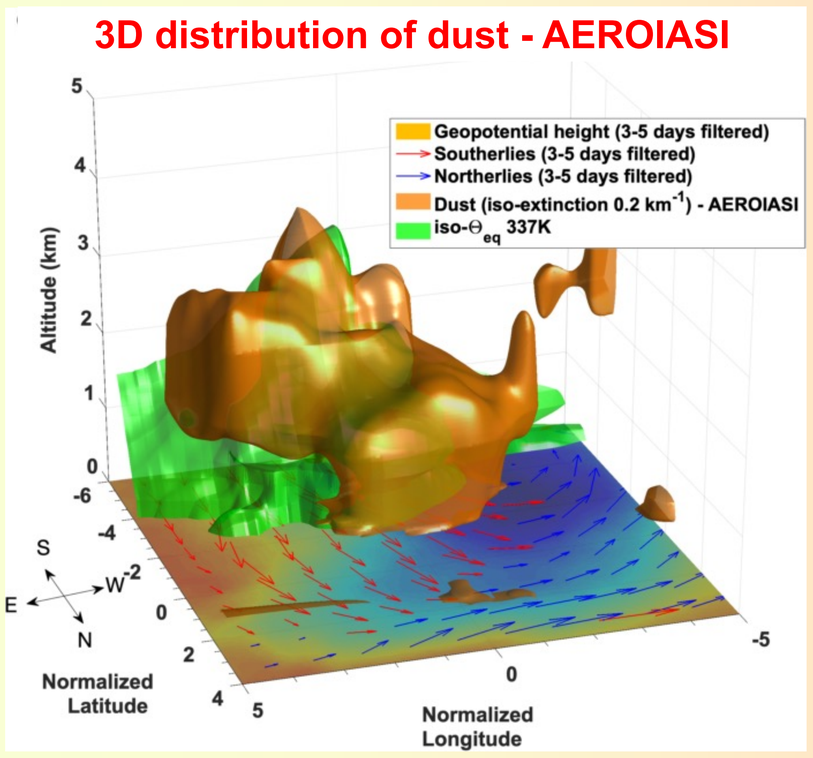


5. Genesis of major dust storms in Central Sahara during summer seen in 3D

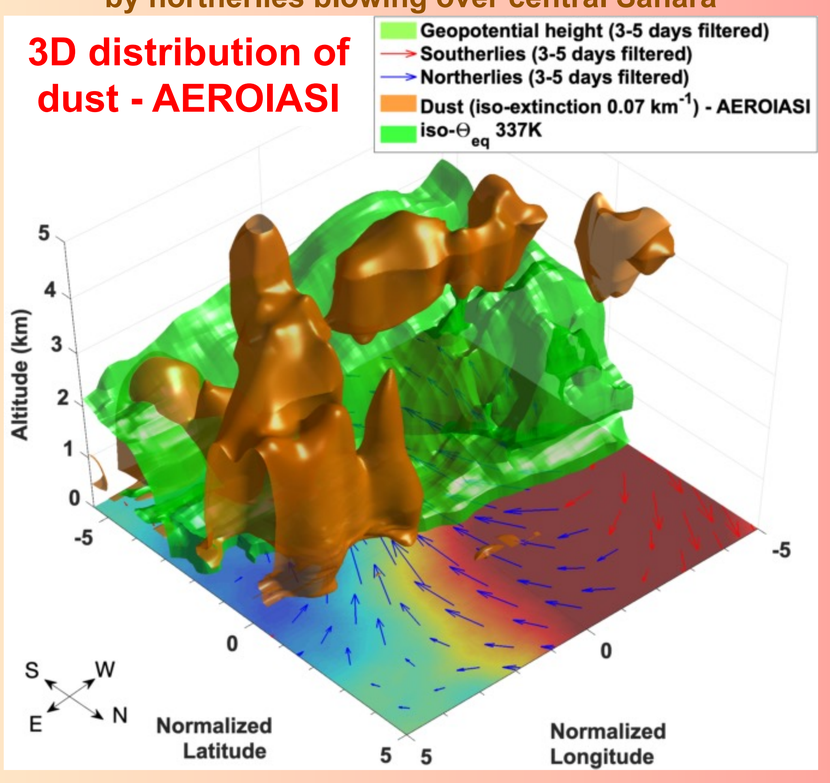
The three dustiest events are characterised by elongated dust fronts moving northwards, with a leading edge spanning 200–300 km horizontally and extending from the surface up to 2 km of altitude. Further south the dust layer progressively elevates to 3.5 km along the slanted isentropes at the interface of the monsoon and the harmattan, increasingly losing contact with the ground.

When northerlies blow over the study region, elevated dust layers at 3–5 km are observed, which are transported southwards within the Saharan air layer and westwards along the northern edge of the African easterly jet (after 13 June).

Dust storm genesis when southerlies blow over central Sahara



Dust uplifted to the free troposphere by northerlies blowing over central Sahara



See more details in

Cuesta, J, Flamant, C, Gaetani, M, et al. Three-dimensional pathways of dust over the Sahara during summer 2011 as revealed by new Infrared Atmospheric Sounding Interferometer observations . Q J R Meteorol Soc. 2020; 146: 2731– 2755. https://doi.org/10.1002/qj.3814

6. Summary

1. AEROIASI depicts a major hotspot of dust emission at 17-23˚N 1-7˚E, showing unprecedented details in 3D about the genesis of these dust storms
2. Over the hotspot, intense convection activity forms a succession of four haboobs every 3 or 4 days and and also generates wave-like perturbations that propagate westwards along the AEJ. These waves have periods of 3–5 days, as do those of typical AEWs, but they differ with respect to other properties. Both phenomena – haboobs and waves – contribute to the occurrence of concomitant northward bulges of the ITD over the hotspot, which then propagate westwards in concomitance with the southerlies behind the trough of the wave-like perturbations in the following 2 or 3 days.
3. The cyclonic circulation associated with the SHL is added as a third factor favoring the northward surge of the WAM over the hotspot.
4. Meanwhile, elevated dust layers between 2 and 5 km are visibly transported westwards by the AEJ.
5. These results show new observational evidence of the importance of the WAM, cold pools, extratropical disturbances and the SHL as drivers of the 3D distribution of dust over the central Sahara during summer.

Acknowledgements:

We are grateful for the support of CNES via the IASI TOSCA project, of PNTS via the project SYNAEROZON, ANR, the AERIS datacenter for providing satellite data, LERMA for the surface emissivity database and ECMWF for model data.