Characterization of aerosols properties from a synergy of 2nd generation vertical sounders and imagers (AIRS, IASI, MODIS) observations.

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Introduction

Dust aerosols contribute for the main part to the total load of aerosols in the atmosphere and they have an effect on atmospheric radiation **both at visible and infrared wavelengths**.
Until recently, most of the studies have focused on the visible wavelengths or in-situ measurements.
Nevertheless, it has been shown that the **optical and microphysical properties** (i.e. optical depth, mean altitude, effective radius) **of dust aerosols** can be retrieved from the observations of 2nd generation vertical sounders, in the **infrared spectrum** *[3].*

Dust Optical Depth at 10 µm – Comparison with MODIS –

We study mean AOD time series over **12 regions in the tropical Atlantic**.

Although some regions cover land, only **night** data over **ocean** are considered here.

Fig. 1 : 12 regions of study in the tropical Atlantic

AOD Time series :

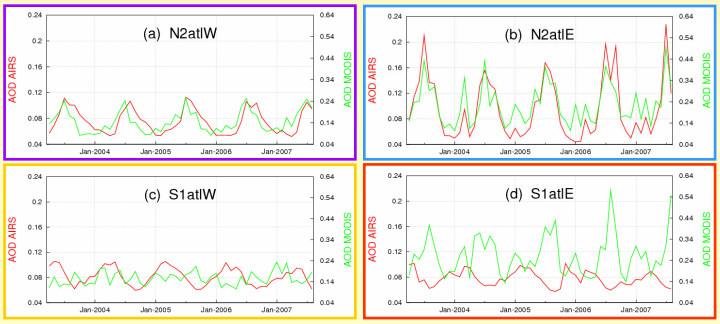


Fig. 2 : AIRS 10 µm (red) and MODIS 0.55 µm (green) optical depth time series over 4 regions of study in the Atlantic (see Fig. 1).

(a) (b) Northern regions : Good agreement between AIRS and MODIS : dust episodes happen during summer (May–Sept). Both instruments are in phase.
(c) (d) Southern regions : AIRS and MODIS do not appear to be in phase but during dust episodes (Dec-Apr, as seen by AIRS), the two instruments do agree quite well. Besides, MODIS observes peaks of AOD during the fire season.

Ratio IR AOD / VIS AOD : the quantitative ratio between visible and infrared AOD is **variable** in time : we can show that during significant dust episodes (correlation coefficient r>0.7) the value of this ratio can vary from 0.2 to 0.5.

AOD 4-year climatology :

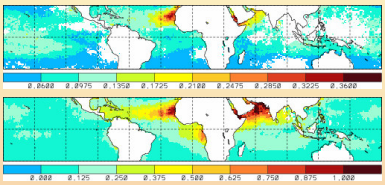


Fig. 3 : AIRS (top) and MODIS (bottom) AOD 4-year climatology for July. AIRS AOD varies from 0.06 to 0.36. MODIS AOD varies from 0 to 1.

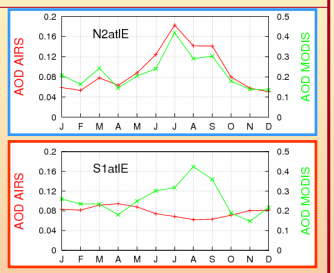


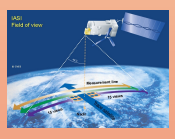
Fig. 4 : Climatology of AIRS (red) and MODIS (green) AOD calculated from 4 years of observations, for two regions : N2atlE (top) and S1atlE (bottom) (see Fig. 1).

AIRS and MODIS both retrieve dust plumes over the eastern Atlantic and Arabic peninsula. MODIS also detects smaller particles and aerosols from biomass burning in southern Africa and pollution in Asia.

For the first time, we show a climatology of the AOD retrieved with AIRS based on 4 years of observations. The climatology enhances the seasonality of dust aerosols and highlights the complementarity between AIRS and MODIS.

- N2atlE: AIRS and MODIS are in very good agreement and observe the same seasonality of dust.
- S1atlE : Quite good agreement during dust season but the main result is that MODIS climatology is more representative of aerosols from fire (see *[1]* for fire climatology)

Studying aerosols with IASI



The **Infrared Atmospheric Sounding Interferometer (IASI)** is developed by the Centre National d'Etudes Spatiales in cooperation with EUMETSAT and is already scheduled to fly on 3 METOP platforms.

The first IASI instrument was launched onboard Metop-A on October, 2006, together with other instruments : AMSU, MHS, HIRS, AVHRR…

High spectral resolution sounders like AIRS show that it is possible to retrieve aerosol optical properties in the infrared spectrum by carefully selecting channels based on their sensitivities to variables such as aerosols, water vapor, ozone… The **Infrared Atmospheric Sounding Interferometer (IASI),** with its important **number of channels** and **very high spectral resolution**, will allow selecting channels only sensitive to particular components of the atmosphere. This will allow **finer determination of aerosols properties** in the infrared spectrum.

30 channels have already been selected at LMD for their aptitude to measure the signal of aerosols.
Compared to the 8 AIRS channels used in this study, IASI should improve our knowledge of aerosols in the infrared spectrum.

Data and method

We analyze **53 months of observations** from the 2nd generation high spectral resolution infrared sounder AIRS over the tropical belt (30°N-30°S) for the period April 2003 to August 2007.
Using a **radiative transfer code (4A)** coupled with a **discrete ordinate algorithm (DISORT)**, and a **Look-Up Table** approach, we retrieve the **optical depth at 10 µm** and the **altitude** of dust aerosols *[3,4].*
A 4-year global climatology of these products is established.
These results in optical depth (10 µm) are compared to those obtained from the MODerate Imaging Spectrometer at 0.55 µm.

Data obtained for this study :

	AIRS 10 µm		MODIS 0.55 µm	
	Land	*Ocean*	*Land*	*Ocean*
AOD	*In progress*	Available	Available except on deserts	Available
Altitude	*In progress*	Available		
Period	April 2003 to August 2007		February 2000 to August 2007	

AIRS and MODIS both fly on the same platform NASA/Aqua in the A-Train.

Dust Altitude

The **mean altitude of the aerosol layer** can be retrieved from **infrared vertical sounders**, due to their ability to separate the contributions to the incoming radiation of the various atmospheric layers.
However, the retrieved altitude is a **mean altitude** and we are not able to determine whether there are **one or several layers**.

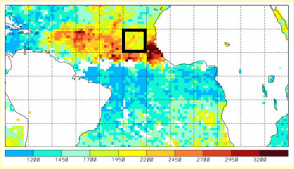


Fig. 5 : Map of June 2006 AIRS-retrieved altitude over the tropical Atlantic ocean. The black box represents the limits of a region centered over Cape Verde Islands.

On this map we can see a dust plume escaping from Western Africa at altitudes reaching over 3200 m. The altitude of dust slowly decreases during the transport towards the Caribbean.

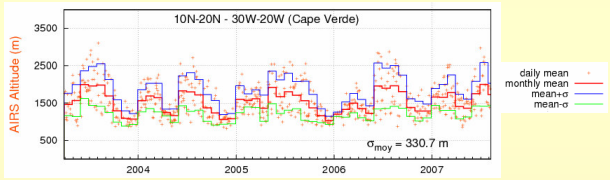


Fig. 6 : Time series of the altitude retrieved from AIRS over the Cape Verde region. Small orange crosses are daily means. The red steps represent monthly mean altitude. The blue and green steps show the standard deviation around the mean. The value of the mean standard deviation is 330.7 meters for this period.

This plot shows the variation of dust altitude in time. Seasonal variations show high altitudes, up to 2500 m in summer (June-September) and also quite high altitude in January-March. The minimum of altitude occurs generally around the end of the year (November-December). This cycle of dust altitude is in agreement with other studies *[2].*

Validation :

In order to validate our results, it will be very interesting to use the **synergy of the different platforms of the A-Train** (i.e. Aqua and CALIPSO). Very soon we will be able to colocate our altitude products to **active remote sensing data** obtained from CALIOP onboard CALIPSO since April 2006.
The Laboratoire de Meteorologie Dynamique has already developed a technique to compare AIRS and CALIPSO data *[Stubenrauch, personal communication]* for the cirrus clouds and this technique is now being applied to aerosols.

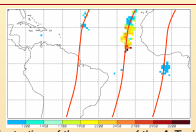


Fig. 7 : Illustration of the synergy of the A-Train. The map represent daily altitude retrievals over the Atlantic on June 6, 2006. The red curves represent some ground tracks of CALIOP.

Conclusion and perspectives

Aerosols play an important role in the climate system and have an **impact on radiative transfer** in the atmosphere, both at visible and **infrared wavelengths**.
We show that **aerosols properties can be retrieved from infrared sounders observations**, such as **optical depth** and **altitude**. We present an analysis of **4 years of AIRS observations** and the first **4-year global climatology** of aerosol optical depth at 10 µm and altitude.
Our results in optical depth over the tropical Atlantic ocean show a regular **seasonal cycle**, with maximum 10 µm optical depth reaching 0.25 in some regions during dust events (generally between June and September). The comparison with MODIS AOD shows **good agreement** between the two instruments ; in some regions it is even possible to **separate dust aerosols signal from biomass burning** aerosols signal. Moreover, we show that the **ratio between visible and infrared optical depth** is not constant during a dust episode.
Our results in terms of altitude are in good agreement with other studies and show high altitudes around July-September and at the beginning of the year. Although we are not able to distinguish one or several layers of dust, we present **results of the mean altitude of dust aerosols**. **Validation is in process** with **active data** acquired by CALIOP onboard **CALIPSO**.

Analysis of AIRS data will continue with the **treatment of land and day data** : land data treatment is in process and benefits from the use of **surface emissivity maps** obtained from AIRS at LMD *[4].*
An important improvement would be to refine **refraction indices** and to calculate **new Look-Up Tables** in order to better constrain the type of aerosol.

This method is easily **adaptable to the very high spectral resolution brought by IASI**. On the basis of the AIRS retrieval scheme, channels will be carefully selected and algorithms adapted to **retrieve even more accurately optical properties of aerosols : optical depth**, **altitude**, **effective radius** and even composition…

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