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Optical Depth Sensor (ODS) for the measurement of dust and clouds properties in the Mars atmosphere

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Abstract

A small and sophisticated optical depth sensor (ODS) has been designed to work in both Martian and Earth environments. The principal goal of ODS is to carry out the opacity due to the Martian dust as well as to characterize the high altitude clouds at twilight, crucial parameters in understanding of Martian meteorology. The instrument was initially designed for the failed MARS96 Russian mission, and also was included in the payload of several other missions [1]. Until recently, it was selected (NASA/ESA AO) in the payload of the atmospheric package DREAMS onboard the MARS 2016 mission. But following a decision of the CNES, it is no more included in the payload.
In order to study the performance of ODS under a wide range of conditions as well as its capable to provide daily measurements of both dust optical thickness and high altitude clouds properties, the instrument has participated in different terrestrial campaigns. A good performance of ODS prototype (**Figure 1**) on cirrus clouds detection and in dust opacity estimation was previously archived in Africa during 2004-2005 and in Brasil from 2012 to nowadays. Moreover, a campaign in the arctic is expected before 2016 where fifteen ODSs will be part of an integrated observing system over the Arctic Ocean, allowing test the ODS performance in extreme conditions.
In this presentation we present main principle of the retrieval, the instrumental concept, the result of the tests performed and the principal objectives of ODS in Mars.

1. Motivations and objectives

On Mars, dust and clouds are primary elements for studying the interactions of solar radiation with the atmosphere and surface and their influence on the radiation balance. In the absence of massive condensed water and precipitation, dust lifted by storms are the unique condensation nuclei available at the Mars atmosphere. This fact highlights the importance of dust in the vertical structure of the Mars lower atmosphere.
Therefore a capability of modelling the dust and clouds is vital for understanding of meteorology and climate on Mars. The capacity of ODS is the monitoring of dust optical thickness and size distribution on a daily basis as well as the detection of the altitude and opacity of high altitude sub-visible cirrus at twilight.
For validation purpose, ODS prototypes were deployed in West Africa sahel region in Ouagadougou, Burkina Faso next to a AERONET station and now ODS is in Bauru in Brazil. Analyses of the signal returned by ODS are part of the preparation of the instrument for spatial missions.

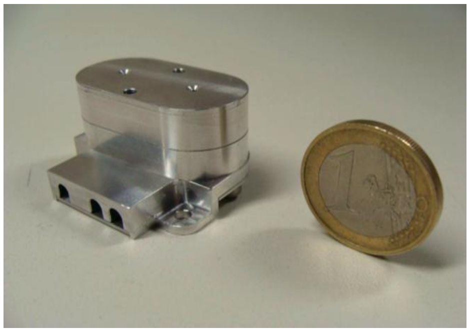

Figure 1: *Optical head of the ODS instrument. The total weight of the instrument for two channels is 63 g: 28 g for the optical head and 35 g for the electronics.*

2. Principle of the measurement

ODS is always oriented to zenith, with an annular field of view between ±25 and ±50 solar zenith angle, and two channels are selected by using different filters (375 nm and 780 nm). The scattered flux is observed from sunrise to sunset and the total flux, given by the direct + scattered flux, only when the sun passes in the ODS field of view. Dust opacity is retrieved by comparing the flux scattered by the atmosphere, and the sum of the scattered + direct solar flux. The ratio of these two fluxes depends on the aerosol load. The retrieval procedure is base on the use of look-up tables of intensities reproducing the signals that should be observed by ODS, as a function of the aerosol optical depth (AOD). Look-up tables of intensities are obtained by using radiative transfer simulations. **Figure 2** shows ODS measurements for a dusty day archived at Ouagadougou, and ODS signals simulated for different AOD. The shapes of theoretical signals are then compared to observations and the best fit is selected with a goodness test.

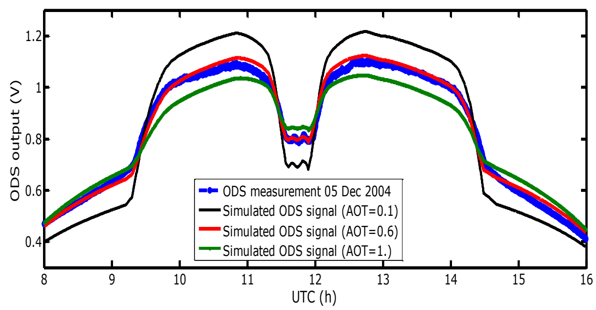

Figure 2: *ODS output voltage for the blue channel (blue) and ODS signal modelled, for different dust optical depth.*

A notable characteristic of ODS is that its retrievals are indeed independent of any absolute calibration. This fact is essential for ensure its performance in Mars. **Figure 3** shows ODS daily average AOD at 375 nm at Bauru. The results show the capability of ODS to identify the burning biomass season at Brazil. For the cloud detection, the index colour (CI) is used, defined as the ratio between the scattered light at red and blue wavelengths. If a cloud is present during twilight, then a peak must be observed in the time variation of CI [2]. Clouds properties are retrieved by simulating the CI signal as a function of the cloud optical depth (COD) and the altitude of the cloud, by using a radiative transfer model, but in this case during twilight. Hence, look-up tables of intensities should be built by using a model in spherical geometry. **Figure 4** shows a twilight simulation with MONTE CARLO model in spherical geometry where an ice cloud with different altitudes and COD values, is present.

In this work, we will present the procedures used to retrieve the AOD and the cloud properties. Such procedures were used to analyse the data taken during the terrestrial field campaign mentioned above.

We then show our results concerning cloud properties and the dust optical depth. We will also show the type of observation that are possible to obtain in Martian environment, concerning the dust and cloud layers.

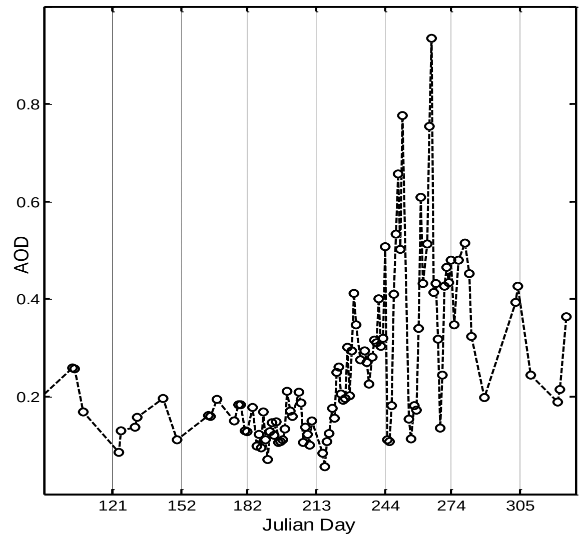

Figure 3*: ODS optical depth at 375 nm at Bauru during 2012.*

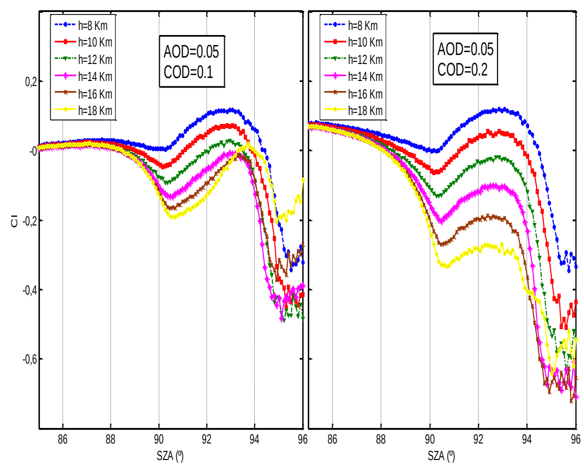

Figure 4: *Simulated ODS CI during twilight for different values of both, cloud height and cloud optical depth.*

References

[1] Maria et al., "Technical aspects of the optical depth sensor", Adv. Space Res., 38, 726-729, (2006)

[2] Tran et al., "Scientific aspects of the optical depth sensor", Adv. Space Res., 36, 2182-2186, (2005)