THE OPTICAL DEPTH SENSOR (ODS) ON NETLANDER AND PASCAL MISSIONS.

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Introduction

The ODS instrument (Optical Depth Sensor) goals are to measure the dust optical thickness and to give estimate of both particle effective radius and distribution width. ODS is part of ATMIS package on Netlander, and is also included in the proposed mission SCOUT/PASCAL (NASA). Because these missions are conceived as long term network stations (4 stations during at least 1 martian year for Netlander, 18 stations during 3 to 10 martian years for Pascal), the final aim of ODS is to produce a climatology of the global dust cycle. Dust is the main absorber and scatterer at visible wavelength, and thus has a strong impact on Mars meteorogy.
This instrument benefits of a precious heritage based on a previous version developped for MARS96 mission. The current design is shown on Figures 1 and 2

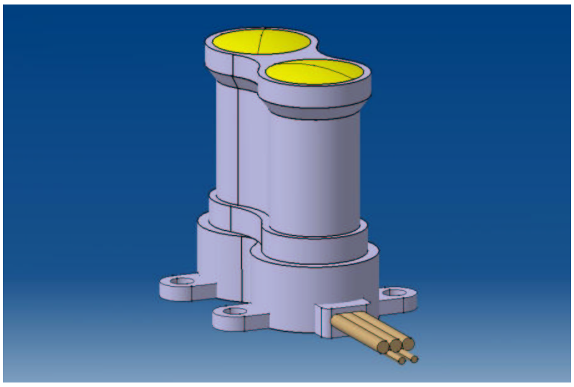
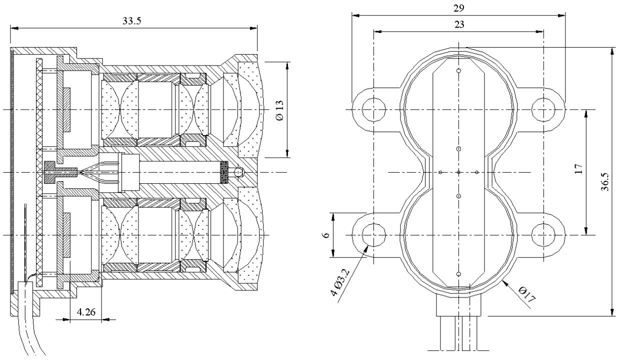


Figure 1: Design of ODS in a configuration with 2 channels (ODS/NETLANDER).

Scientific principle

ODS is an optical device which alternatively measures the direct and the scattered sunlight intensity on diurnal and annual basis using a silicon photodiode detector. The instrument has an annular field of view $FOV = \pm 50°$ with a central circular mask ($\pm 30°$). The optical thickness is retrieved by comparison between the sum of direct plus sctarred light intensity - when sun is inside the annular FOV (between $\pm 30°$ and $\pm 50°$) - and the scattered light intensity alone, when sun is outside the FOV.
Several configurations are possible for the spectral band of each channels, depending on the frequency of measurements.



(dimensions in mm)

Figure 2: Mechanical and optical design of ODS in the configuration with 2 filters.

Technical description (current design)

ODS is basically a fish eye optical system of lenses focussing incoming light on the sensitive surface of silicon photodiodes. Light can either be selected with colored filter or more simply collected over the whole spectrum transmitted by the optical system (Fig 2). The signal is transmitted through coax cables and amplified by an electronic. The amplifiers compare the current delivered by the detector ($5\ 10^{-10}$ to $5\ 10^{-5}$ A) to a reference source. The output signal is a 0 to 5 V (PASCAL) or -3 to 3 V (NETLANDER) analog signal digitalized, stored and transmitted in 10 bits. The electronic system successfully passed thermal tests down to $135K$ ($-140°C$), and could be thus installed in cold environment (as for ODS/Netlander).

The current estimate for ODS/NETLANDER mass and volume, with two channels, is $40\ g$ (14.15 cm^3) for optics, $70\ g$ (53.65 cm^3) for electronics and $30\ g$ for connectors and cables (total $140\ g$). Weight and volume is roughly proportionnal to the number of channel, and thus ODS/PASCAL is estimated to $75\ g$. Energy consumption is estimated to 25mW per channel and per

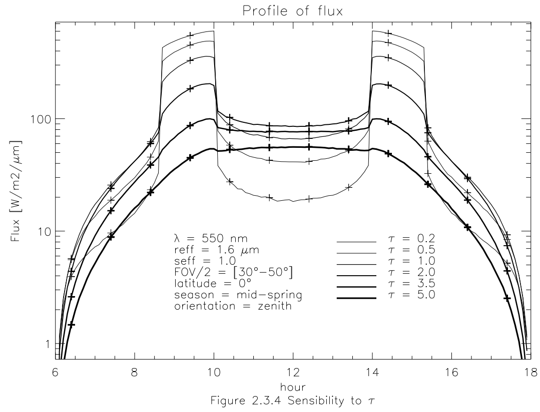


Figure 3: Sensitivity of the observed intensity to the total opacity (left). The crosses (+) show a sampling of one data per hour as in the future mission. Both direct and scattered contributions are mofified by τ

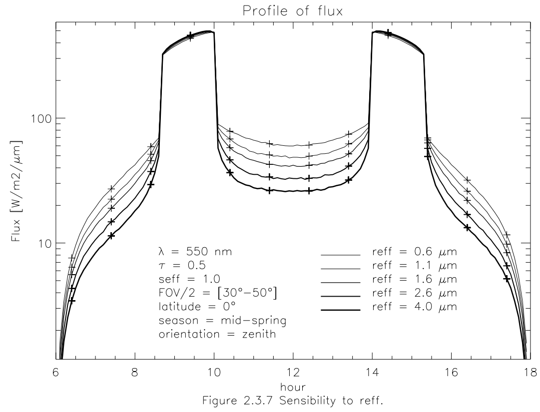


Figure 4: Sensitivity of the observed intensity to the effective radius of the distribution (right). Only the scattered contribution is strongly modified here. The direct contribution only depends on τ.

measurement (29 s warming + 1 s reading).

Model and retrieval

A preliminary study was carried with a simple parallel plane Monte-Carlo model of scattering by a uniform Martian dust layer. The scope of the model is to define options for the color and bandpass of filters, and to test retrieval procedures of dust propertyl.
For this preliminary test based on ODS/PASCAL configuration, we model direct flux and scattered flux as observed from the surface by ODS. We assume one measurement per hour, and from this data set, the retrieval procedure was tested to retrieve total opacity, effective radius r_{eff} and effective σ_{eff}. We tested several FOV configurations, spectral intervals and tilt of the instrument. It is important to note that only the shape of the light curve is used for the retrieval, not the absolute value of intensity. This is a strength of our system, since it overturns the difficulty induced by dust deposit [1] and ageing.

Main resuts

Figures 3, 4 and 5 show an example for the flux received by ODS during the day for several opacities, effective radius and effective variances.

In these figures, continue lines show the results of our model. With only one data per hour - as considered in our testes - only the crosses (+) can be used to retrieve the dust properties. The sensitivity to optical thickness (Fig 3) is such as this information can be retrieved with small uncertainties. On the other hand, the sensitivity

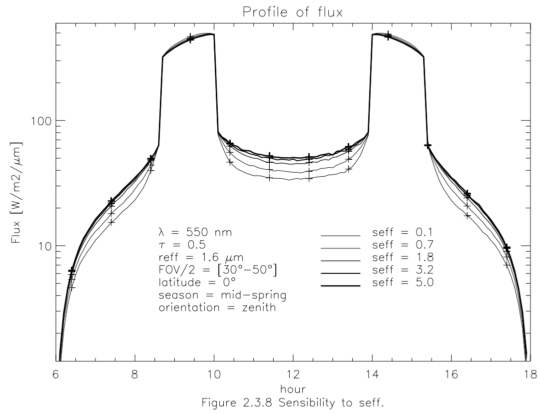


Figure 5: Sensitivity of the observed intensity to the effective variance of the distribution (left). Sensitivity to the effective variance is very similar to the sensitivity to the effective radius.

of the light curve with r_{eff} (Fig 4) and σ_{eff} (Fig 5) are quite similar. We can foresee that these two parameters will be more strongly correlated, and therefore harder to separate. However, if we bound the effective variance (is not willing to be larger than 1 [2,3]), we can obtain much more accurate results on r_{eff}.

Retrieval procedures

The retrieval procedure developped here is based on a database of lightcurves computed for several dust layer parameters (τ, r_{eff} and σ_{eff}). This data base is used to retrieve properties of fake observed data. The best agreement is selected with a χ^2 test. We also consider in this test that both the absolute intensity and the absolute time are not known. Thus our retrieval procedure also account for these unknown, and does not need absolute calibration of the optical system and of the clock system. For intermediate values of the parameters, we use a 3 degrees spline interpolation. The χ^2 test is performed on the interpolated data, and χ^2 maps can be edited as function of parameters.

We also want to estimate the impact of measurement uncertainties on the physical parameters. To do so, we include uncertainties due to digitalization and electronic drift due to temperature. Digitalization produces a relative uncertainty $\Delta I/I \simeq \pm 2.5 \times 10^{-3}$. The drift on the electronic signal due to temperature is known (from recent tests on ODS/MARS96) to be $\Delta U/\Delta T \simeq 5 \times 10^{-3}$. An uncertainty of $\pm 1K$ on temperature produces a relative uncertainty of $\Delta I/I \simeq \pm 5 \times 10^{-3}$. For this test, we use a total uncertainty $\Delta I/I \simeq \pm 7.5 \times 10^{-3}$. Uncertainties are included as a gaussian noise on intensity values with a 1-σ level characterized by $\Delta I/I \simeq \pm 7.5 \times 10^{-3}$. 50 retrieval tests are done on noisy data for each cases. This allow to estimate the uncertainties on the retrieved values of τ, r_{eff} and σ_{eff}

Our retrieval tests focused on several aspects: sensitivity to the spectral interval of detection, sensitivity to the FOV, and sensitivity to the fact that direct sun may or may not be seen by the detector depending on orientation or season. The retrieval tests have revealed that the best overall results are found for a quite narrow filter at $\lambda \simeq 550$ nm for small opacities, and is better in UV for large opacities. But this advantage is not really preponderant, and wider filter may be chosen as well to collect more light.

The table 1 shows the retrieval performance for three orientations for ODS, corresponding to -1- a direct solar light crossing twice the FOV (as in Fig 3) -2- a direct solar light not masked by the central mask as it may occurs due to seasonal courses and -3- a direct solar light which never crosses the FOV. The last situation may essentially occurs high in latitude or if ODS is unfortunately oriented toward the pole. We expect good estimates for optical thickness of the background dust (3% or less), and possibly degraded to 6% during dust storms. The effective radius will generally be retrieved within a 10% uncertainty, and ODS ligthcurves are rather less sensitive to σ_{eff} between 0 and 1.

Future developments and investigations

The modelling of the instruments ODS/NETLANDER and ODS/PASCAL will be continued for finalising the definition of the instruments as well as preparing and testing the retrieval algotithms. Among the main issues to be covered, there are:

- Impact of options for photodiodes detectors, optical and mechanical arrangements, electronics and bandpass of optical filters of ODS/NETLANDER.

- Detection of high altitude clouds ot rop altitude of dust layer from measurements enhanced frequency durinf twilight periods on Netlander (spherical shell radiative transfer model under developpement).

- Dust deposit can be overturned with ODS, since only the relative lightcurve is needed to retrieve dust properties. The dust deposition will be measured by comparing the long term evolution of absolute signal and the independant evaluation of atmospheric opacity (described above)

- Test the various designs and retrieval process in the Earth atmosphere by measuring Saharian dust at an African site also equiped with other operationnal aerosol monitoring instruments.

Uncertainties estimate (study for ODS/PASCAL)

Orientation	$\tau = 0.5$, $r_{eff} = 1.6\mu m$,$\sigma_{eff} = 0.3$		
Toward Pole	$\Delta\tau/\tau$	$\Delta r_{eff}/r_{eff}$	$\Delta\sigma_{eff}/\sigma_{eff}$
Nadir	2.2%	6.2%	30%
40°	2.7%	8.6%	40%
80°	3.0%	13.%	40%
Orientation	$\tau = 4.5$, $r_{eff} = 1.6\mu m$,$\sigma_{eff} = 0.3$		
Toward Pole	$\Delta\tau/\tau$	$\Delta r_{eff}/r_{eff}$	$\Delta\sigma_{eff}/\sigma_{eff}$
Nadir	1.9%	6.6 %	36%
40°	6.1%	8.6 %	50%
80°	7.0%	13. %	54%

Table 1: Uncertainties on three parameters for a circular FOV of $50°$ with a circular mask of $30°$, for three orientations of the sensor. Note that for the slant viewing $40°$, the mask does not appear on data but the alternance of direct + scattered and scattered light allows to retrieve accurate values. On the other hand, for the slant viewing $80°$, the direct light is never seen and no comparison is possible between the direct and scattered light. The performance are degraded but still meaningful. NB: For the retrieval, the value of σ_{eff} is bounded to 0.5

References

[1] Landis et al., J.G.R, **104**, E1,1855-1857, 2000.
[2] Tomasko et al., J.G.R, **104**, E4, 8897-9007, 1999.
[3] Markiewicz et al., J.G.R, **104**, E4, 9009-9017, 1999.