STUDY OF A DUST STORM PROPERTIES FROM THE MARS EXPRESS OMEGA AND PFS DATA. A. Määttänen[1,2] T. Fouchet[3], P. Drossart[3], R. Melchiorri[3], T. Encrenaz[3], M. Combes[3], J.P. Bibring[4], Y. Langevin[4], B. Gondet[4], F. Poulet[4], D. V. Titov[5], O. Forni[6], V. Formisano[7], M. Giuranna[7] and the OMEGA team. [1]Division of Atmospheric Sciences, University of Helsinki (anni.maattanen@helsinki.fi) [2]Space Research, Finnish Meteorological Institute (P.O.Box 503, FI-00101 Helsinki, Finland), [3] Observatoire de Paris, Meudon, France,[4]Institut.d'astrophysique spatiale, Université Paris-Sud, Orsay, France, [5]Institut für Aeronomie, Katlenburg-Lindau, Germany, [6]CESR, Toulouse, France, [7] IFSI/INAF, Roma, Italy.

Introduction: Suspended dust is one of the key elements of the Martian climate, and information about its properties is crucial for modeling the atmosphere and data analysis. The dust is mainly lifted from the surface by winds, and is transported by the atmospheric circulation. In the thin Martian atmosphere dust affects strongly radiative transfer and heating in the atmosphere. The effect of dust depends on the altitude: at higher altitudes the temperatures rise and the amplitude of the daily variation increases. Near the surface the temperatures decrease as does the amplitude of the variation, because the dust shadows the surface.

The Martian atmosphere exhibits dust phenomena of very different scales from dust devils to global dust storms. The dust loading and activity is highly variable in both space and time, and thus the global storms are observed quasi-periodically starting mainly during the southern summer, but not every Martian year. A summary of dust storms has been provided by Martin and Zurek [1], and some general circulation model studies have aimed at understanding and explaining the variable dust cycle [2-4]. So far, with the exeption of reference [4], the models have not been able to predict the onset of dust storms and the year-to-year variability, and the models have needed observations of the dust cycle for constraining the atmospheric behavior.

Our study is aiming at providing new constraints on a local dust storm: dust particle properties, regional extent of the storm and its effect on the atmospheric temperature.

Methods: We base our study on the data of OMEGA (Observatoire pour la mineralogie, l'eau, la glace et l'activité), a spectro-imaging system aboard the Mars Express satellite, which has been on orbit of Mars since December 2003 [5]. Mars Express is a European Space Agency mission, and OMEGA has been built as collaboration of several laboratories, including LESIA in Observatoire de Paris, France, and Institut d'astrophysique spatiale in Orsay, France (P.I. Jean-Pierre Bibring). The instrument has so far collected nearly 4000 orbits of data in the spectral range of 0.35-5.1 micrometers. The spectral resolution is 0.01-0.02 microns and the spatial resolution can go down to 300m/pixel. The Planetary Fourier Spectrometer (PFS) provides spectra of the planet between 250 and 8000 cm-1 at a spectral resolution of 1.3 cm-1 and at a spatial resolution down to 12 km at periapsis [6]. It allows us to probe the atmospheric temperature from the surface up to 20 Pa and to retrieve the dust optical thickness at 9 micron.

Our topic was to study two orbits only 3 sols apart, 1201 and 1212, which fly over the same geographical area, but in which the atmospheric state is very different. The orbit 1201 is very clear and calm, and the dust optical depth is very small. This orbit can be used to retrieve the surface albedo and the surface pressure, which are important components of the following retrieval of dust properties. The orbit 1212 instead shows a very dusty region around the equator, and we use the data from the two orbits to retrieve the dust properties from the orbit 1212. The sample spectra from the two orbits are shown in Figure 1.

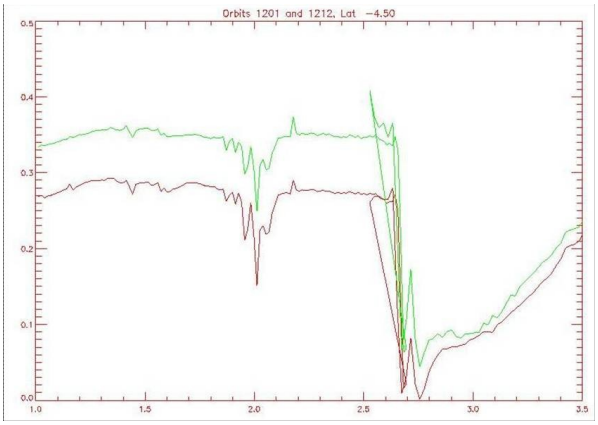


Figure 1. Reflectance versus wavelength for the orbits 1201 (red) and 1212 (green) at a 5-degree latitude bin centered over -4.5 degrees north.

We will use the ability of OMEGA to observe the atmospheric dust loading and the variations therein. Normally in nadir view it is difficult to separate the signal of the surface from that of the atmosphere, but

some methods are available. At some wavelengths the CO_2 atmosphere absorbs all the photons on their way through the atmosphere to the surface, so no reflection from the surface is seen. In this case any reflection seen must come from atmospheric scatterers, like dust. However, this method sees only above a certain altitude (15-20 km), and assumptions must be made considering the dust distribution below this altitude. Our previous results on mapping the dust optical depth using this method showed a bad correlation with the Thermal Emission Spectrometer of Mars Global Surveyor data, which implies that the assumed well-mixed dust distribution is not valid.

We retrieved the surface albedo from orbit 1201, and the surface pressure retrieved from OMEGA observations was provided by A. Spiga and F. Forget in Laboratoire de météorologie dynamique in Paris [7-8]. For the retrieval we used, however, the surface pressure from the Mars Climate Database, since the retrieved values and the database were in good agreement.

The retrieval is based on the very large dust optical depth observed in the dust storm region in orbit 1212. We fit the single-scattering properties of dust (single-scattering albedo and asymmetry parameter) using the spectrum of the highest observed reflectance on this orbit (implying quasi-infinite dust optical depth), after which we retrieve the dust optical depth from all of the observed dust storm spectra. The fits are made for the whole shortwave channel (1-2.7 micron). From the fitted parameters we can further deduce the extinction coefficient of dust for each wavelength.

We have also made an Independet Component Analysis (ICA) to compare the orbits. The method tries to find independent sources whose linear mixing produces the observed signal. The analysis was done using 4-5 components to distinguish different features from the data.

Results: The results show that the dust storm observed on orbit 1212 is very localized, possibly due to topography. It is also clearly seen in the ICA: the signal of the dust storm (from the 2.7 micron absorption band) is very clear and independent of the other components. The storm is located over a slope and close to a very steep boundary in albedo. Possibly the two effects of topography and albedo have had an influence on the formation of the storm via surface-induced circulations related to slopes and differential heating.

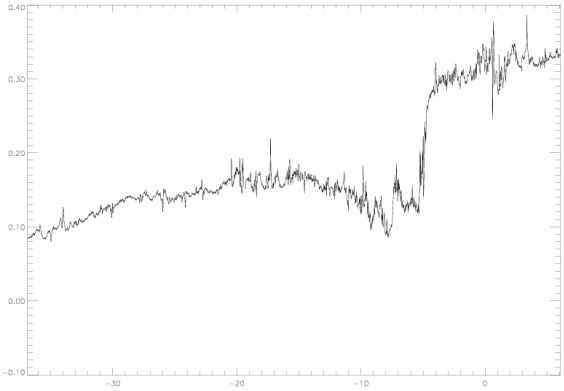


Figure 2. The albedo from orbit 1201: the x-axis goes from -40 degrees to +5 degrees north, and the y-axis goes up to 0.40. The sudden increase in albedo happens at around -7 degrees north.

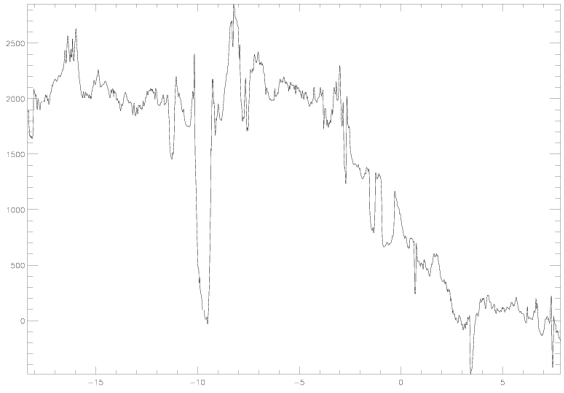


Figure 3. The topography from orbit 1212: the x-axis goes from -18 degrees to +8 degrees north, and the y-axis goes up to 2800 m. The slope seen in the plot resides between -7 and +3 degrees north.

The optical properties retrieved show discrepancies with the commonly used Ockert-Bell [9] values, which is not surprising, since already Fedorova et al [10] showed that the behavior of the scattering properties can differ from those of Ockert-Bell et al. [9].

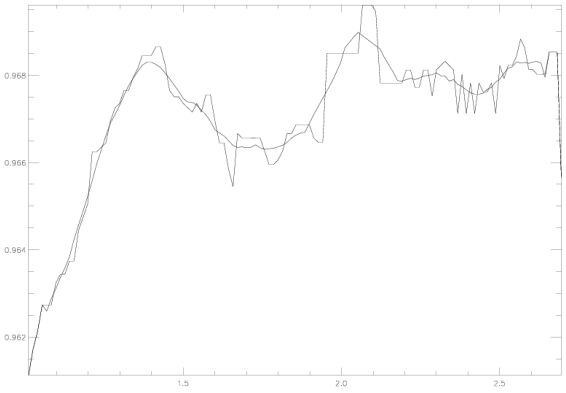


Figure 4. The fitted single-scattering albedo as a function of wavelength. The scale of the x-axis is 1.0-2.7 micron and the y-axis 0.962-0.972.

The dust optical depth retrieved is very high: going up to and above 8.0. Such high values of dust optical thickness can be perhaps related to the local nature of the storm, its temporal scale (developed in less than 3 sols) and the fact that this storm seems to be very strong and convective in nature.

We also checked for the surface pressure retrieval from OMEGA data, and interestingly enough the pressure field shows oscillations very near the dust storm area just 3 sols before the storm, so on orbit 1201 [8]. We have not yet done any modeling related to this observation, but it would be an interesting task to check for possible mechanisms that have initiated the storm formation. Perhaps the waves are topography-induced gravity waves, that have been amplified by slope winds, or the other way around, creating a downslope windstorm that has caused immense amounts of dust to be lifted and suspended in the atmosphere.

The effect of the dust storm is also seen in the temperature profile retrieved from PFS: the upper atmosphere is warming and the surface is cooling because of the thick suspended dust cloud.

One important refinement of the retrieval should be done by modeling the temperature profile with an atmospheric model, and using this profile for the retrieval. The temperature profile is very sensitive to high amounts of dust, and thus in this situation the standard atmosphere profile we have used is not a very good approximation. This work is still underway, and may change the results somewhat.

References:

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