OMEGA-PFS OBSERVATIONS OF A LOCAL DUST STORM ON MARS. F. Altieri[1], G. Bellucci[1], G. Carrozzo[1], L. Zasova[2], J. P. Bibring[3], V. Formisano[1], [1]INAF-IFSI (Via Fosso del Cavaliere 00133 Rome, Italy, francesca.altieri@ifsi-roma.inaf.it), [2]IKI (Moscow, Russia), [3] Institut d'Astrophysique Spatiale, Université Paris-Sud, Orsay, France, (University of Paris-Sud, Orsay Paris, France).

Introduction: Dust plays an important role in current martian climate. The particulate component of the Mars atmosphere is composed of micron-sized particles, which are products of soil weathering, and water ice clouds. In the absence of a dust storm, a so-called permanent dust haze with opacity $\tau \approx 0.05$–0.2 in the atmosphere of Mars determines its thermal structure. Dust loading varies substantially with the season and geographic location. Opacity may reach several units during a dust storm.

Having a relatively low single scattering albedo in the visible-NIR spectral range, dust particles provide the efficient heating of atmosphere by direct absorption of solar radiation. In turn, in the IR the dust determines the ability of the atmosphere to radiate heat into space by IR emission. Dust may be responsible for atmospheric instability, as global dust storms are believed to be caused by the positive feedback between the dust content and the intensity of atmospheric motion [1]. In the following, we report on the observation of a dust storm in the Atlantis Chaos region on Mars, observed by the OMEGA instrument on board of Mars Express. The observation was done on March 2nd, 2005 at 11.00 LT and Ls = 168° (end of southern winter). At the same time, also the PFS instrument took high resolution spectra over the region, thus allowing to retrieve the pressure and thermal profiles with the altitude. These joint observations constitute a unique data set which allows to study both the physical and scattering properties of the suspended dust and the mechanism of formation of dust storms on Mars. Moreover, the study of airborne dust can allow to better constrain its spectral behaviour in order to decouple its effect from the surface mineralogy. A similar study is also presented in another paper in this conference [2].

The instruments: The OMEGA imaging spectrometer [3] acquires 352 monochromatic images of the Martian surface in the 0.36 – 5.1 μm spectral range. It is composed of two bore-sighted spectrometers covering, respectively, the 0.36 – 1.05 μm [4] and 0.89 – 5.1 μm spectral ranges. This wavelength domain is diagnostic of iron mineralogy, pyroxene composition, water H_2O-OH bound in minerals, H_2O-CO_2 ice in the soils and water vapour in the atmosphere. PFS (Planetary Fourier Spectrometer, [5]) is a high resolution Fourier spectrometer covering the 1 – 50 μm spectral range, with a resolving power of ~2500 at 2 μm, particularly suited to study the atmospheric minor compounds, the thermal and pressure fields.

Discussion: Figure 1a shows a true color image of the dust storm as observed by the OMEGA visual channel. The dust storm appears as a very bright albedo feature (I/F = 0.43 at 0.75 μm, compared to I/F= 0.24 on the surface). In the image, the surface contrast is also reduced, due to the suspended dust. This is better seen in figure 1b, showing a RGB composite image (see the context image shown in figure 2 for comparison). It can be seen also that a region in the lower part of the image is heavly contaminated by airborn dust, appearing as a bluish tint. The scattering properties of the dust, as single scattering albedo and optical depth are not reported here since this is a working progress report. However, it can be seen that the optical depth is very high since the dust storm obscures completely the surface details. From the OMEGA measurement we derive the brightness temperature, by assuming a dust emissivity at 5 μm $\varepsilon = 1 - R_f$, where R_f is the radiance factor at 5 μm obtained by the formula $R_{f\,5\mu m} = R_{f\,2.4\,\mu m} / 2.178$ and $R_{f\,2.4\,\mu m}$ is the radiance factor at 2.4 μm. This assumption provides an over estimation of the derived temperature because the radiance factor at 2.4 μm is affected also by the dust scattering behavior. Figure 2 shows the temperature map superimposed to a Viking image for the context. It can be seen that the bright albedo feature seen in figure 1a exibhits the lowest temperature, about 220 K, to be compared with an average surface temperature of 240 K. Moreover, also the region which correlates with the suspended dust seen in figure 1b exibhits temperatures lower than the average. In order to infer about the dust storm altitude, we have assumed the dust storm as reflecting completely the solar radiation at 2 μm. With this assumption, the CO_2 absorption seen in the OMEGA spectra is inversely proportional to the altitude. Moreover, by using the MOLA topography, we have calibrated the OMEGA derived altitude for some surficial topographic features. figure 3 shows the dust storm altitude-temperature profiles, together with the MOLA surface topography along the segment shown on figure 2. It can be seen that the dust storm lyies about 0.5 km above the surface and follows the surface topography; this fact suggests that it is really blown wind dust (with the wind direction from south-west) and not a just a dust

cloud. It is interesting to note the behaviour of the dust temperature. The dust lying at low altitude, between -0.5 and 1 km, shows a temperature of about 220 K. This can be easily interpreted as due to the dust thermalization at the local atmospheric temperature. However, as soon as the altitude increases, from 1 to 3 km, the dust temperature increases to about 240 K. We do not exclude that at 5 µm there is also some radiance contribution coming from the surface, in other words, the dust storm is not infinitely optically thick at that wavelength. However, the effect seems real, even if for some reason, overestimated. The right part of the temperature profile is mostly the surface temperature since in this region, the dust storm is optically thin. PFS measurement provide usefull information about the temperature field over the region. In fact, by inverting the CO_2 band absorption at ~15 µm it is possible to retrieve the temperature-altitude profile. Figure 4 shows three temperature profiles taken by PFS over the study region. Note that the PFS footprint in this observation is about 170 km, compared to the 4.2 km/pixel of OMEGA. It can be seen that two of these profiles show a temperature inversion at about 42 km. Moreover, one of them exibiths the lowest atmospheric temperature, generally about 20 K less that the others. This profile shows also that the temperature inversion starts at 30 km, with the maximum occurring at 42 km. The surface temperature is also the lowest, about 190 K. This could be due to the shadowing effect of the suspended dust with respect to the solar radiation, causing cooling of the surface. Since the three PFS profiles pratically coincide in space, the variations we are seing on the profiles are mainly temporal effects. PFS takes one measurement every ~10 sec. So the variations we see in the thermal profiles are of this order of magnitude.

Figure 5 shows the apparent ozone abundance derived by the 1.27 µm emission od O_2 [6-7]. It can be seen that the ozone abundance correlates with the atmospheric dust content, the maximum being on the brightest part of the dust storm. This map shows the ozone abundance above 20 km altitude. Below this level, the ozone is quenched by CO_2 and dust collisions. Moreover the O_3 is expected to be anticorrelated with water vapour [8], because athomic hydrogen also reacts with O_2 to form HO_2. Some authors have reported an anticorrelation between dust and water vapour (e.g. [9]). We interpret the observation reported in figure 5 as possibly due to substantial lack of water vapour in the region, thus allowing the ozone accumulation. We will verify this by using the high resolution spectra of PFS to measure the water vapour abundance over the dust storm.

Finally, in figure 6 we show the spectrum of the dust storm (for the location see fig. 1a), compared to that of a dust free region nearby, and their ratio. The dust spectrum exibhits a negative IR slope, due to the light scattering by dust grains. Both spectra show an absorption edge between 0.4 and 0.75 µm associated to ferric iron. The most striking feature is that the suspended dust is less hydrated than the surface, as can be seen by the 3 µm absorption in the spectral ratio. This, in turn, can be interpreted as a dehydration of the dust once suspended in the dry atmosphere. The ratio shows also absorptions at ~0.55 and 1 µm which are stronger in the soil spectrum than in the dust one. This suggests that the dust deposited on the surface masks its spectral features and this effect must be taken into account when surface mineralogy is derived by remote spectroscopy.

Additional information: The work presented here is a preliminary study, and we plan to go into more depth study in the near future.

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References:

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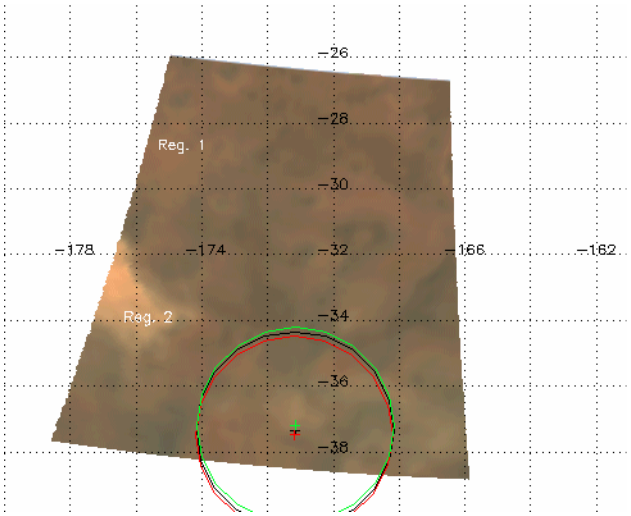

Figure 1a: True color OMEGA image showing the dust storm as a very bright albedo feature.

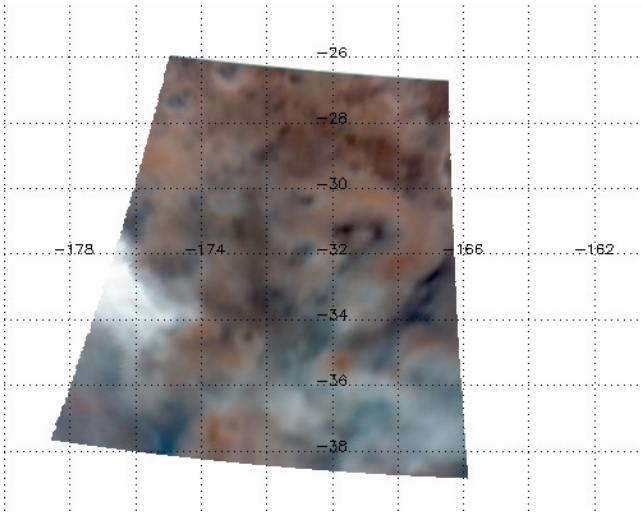

Figure 1b: RGB composite image (R = 0.68 µm, G = 0.53 µm, B = 0.43 µm). Suspended dust can be seen in the bottom part of the image.

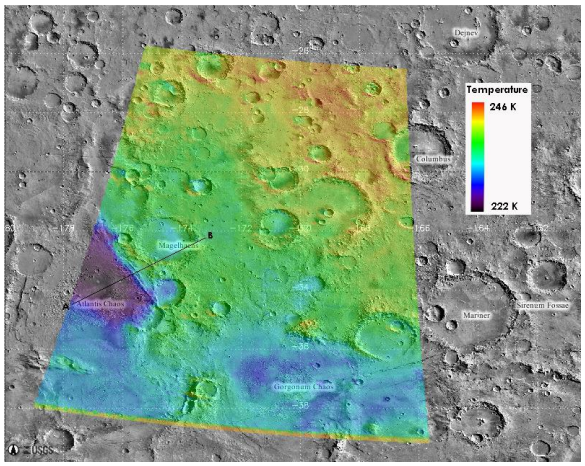

Figure 2: Temperature map derived from the 5 µm OMEGA radiance. The dust storm exibhits the lowest temperature in the scene.

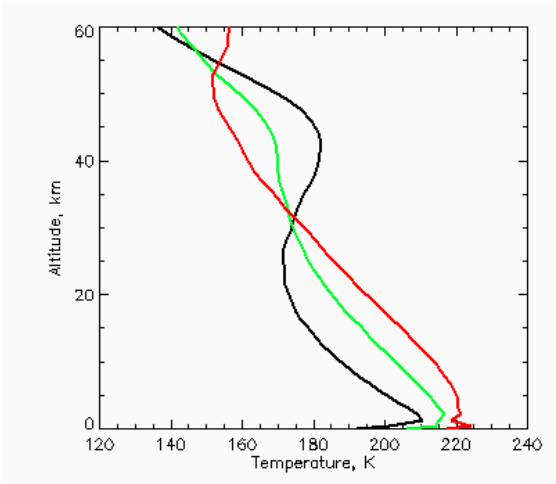

Figure 4: PFS temperature profiles over the study region. The location is shown on fig. 1a.

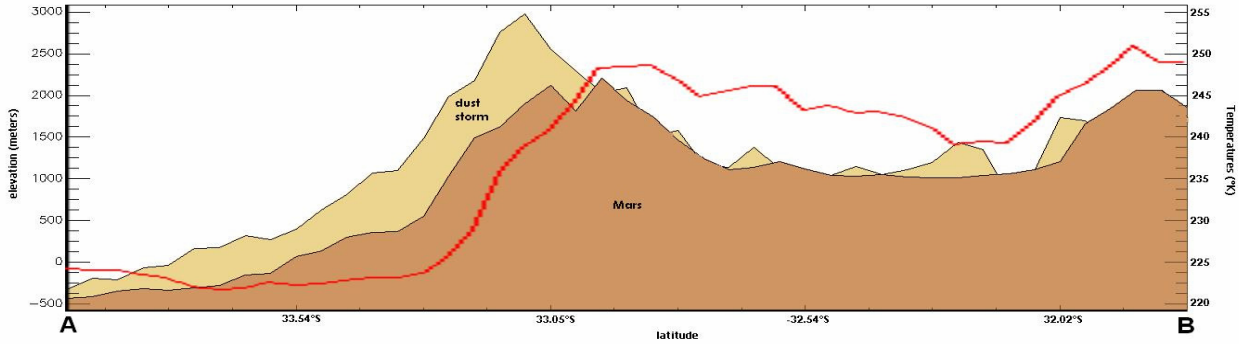

Figure 3: Altitude of the dust storm compared to the surface topography. The temperature along the segment shown in fig. 2 is also plotted (in red).

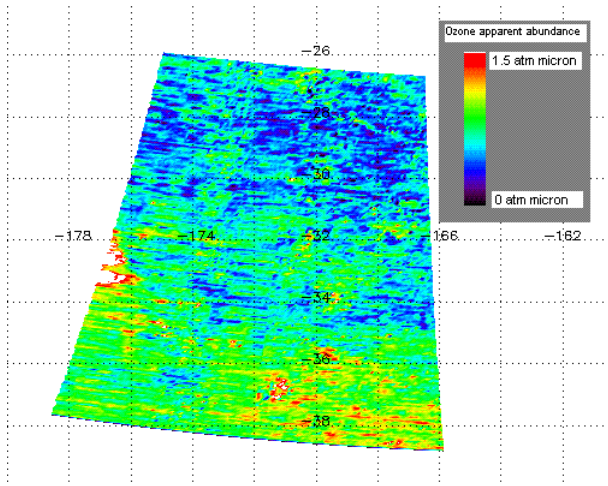

Figure 5: Ozone apparent abundance map. It shows the column abundance above 20 km. Ozone emission correlates with the suspended dust.

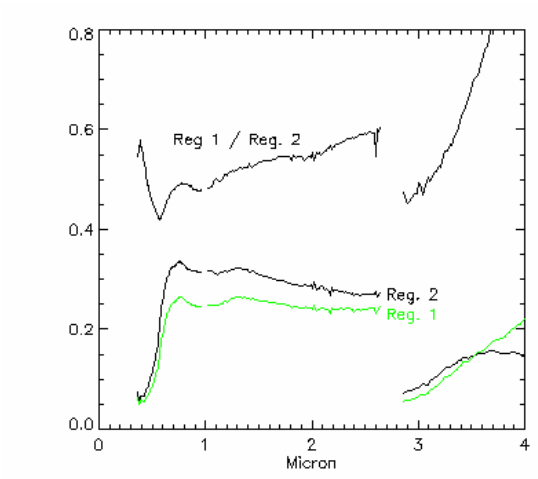

Figure 6: OMEGA mean spectra of the dust storm, the surface and their ratio. The dust/surface ratio is offset by 0.3 reflectance units for clarity. The location is shown in fig. 1a.