CONSTRAINING THE MARTIAN DUST PROPERTIES FROM THE MARS EXPRESS/OMEGA DATA.

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The Martian atmosphere is a very peculiar meteorological and dynamical object. It is essentially composed of CO_2, but its average surface pressure, 610 Pa, is less than a percent of the mean terrestrial surface pressure of 1013 hPa. As the Earth, Mars presents a strong seasonal cycle (its obliquity is 26°) reinforced by a large orbital eccentricity (e=1.1). The northern summer receives 40% more solar energy than the southern summer, but is much shorter in duration. On both hemispheres, during winter, the atmospheric temperature at the poles decreases below the CO_2 condensation temperature: the atmosphere condenses out to form a seasonal polar ice cap, bound to sublime the following summer. This condensation/sublimation cycle induces large, periodic, surface pressure variation with an amplitude of 100 Pa. This cycle is associated with a strong meridional transport of air from the subliming polar cap to the condensing one. An H_2O cycle is superimposed on this CO_2 cycle: water sublimes from the summer cap, is transported through the equator in Hadley cell circulation, and condenses on the winter cap.

A third cycle, the dust cycle, exists. A variable amount of aerosols, essentially dust, is present in the Martian atmosphere. The dust is lifted by the winds from the dry, desert, solid surface of the planet, and transported, both horizontally and vertically, by the atmospheric circulation. Dusty episodes come in different forms. Dust devils are small vortices, which are present all over the planet. During spring, local or regional dust storms affect both the Northern and Southern hemispheres, but are more intense in the Southern hemisphere. Finally, dust storms can erupt in late southern spring from the Southern hemisphere, and evolve into global, planet-encircling dust storms. The spatial dust activity and the atmospheric loading greatly vary from year to year. For example, global dust storms are not observed each Martian year, but rather with a quasi-period of three years. A good summary of dust storms and their occurrence can be found in *Martin and Zurek* (1993), and GCM simulations aiming to understand the variability and formation mechanisms of dust storms have been presented in *Newman et al.* (2002a,b). In a thin atmosphere like the one of Mars, the dust optical depth strongly affects the radiative budget and the atmospheric heating rates. For example, when a global dust storms reach an optical depth of one, the atmospheric temperature can rise by as much as 40 K. On the other hand, the boundary layer of Mars turns more neutrally stratified, because the dust also shadows the surface, which does not heat up so dramatically as with a dust-free atmosphere, and convection will not form so easily (*Määttänen and Savijärvi*, 2004).

Global numerical atmospheric models, the so-called General Circulation Models (GCMs) are able to reproduce qualitatively the CO_2 and H_2O cycles. However, neither GCMs (*Newman et al.*, 2002a,b) nor other atmospheric models (for example, atmospheric boundary-layer and limited-area models), are able to reliably predict the amount of the dust lifted, and especially the interannual variations of the dust activity. Therefore, in order to make quantitative predictions of the meteorological parameters (temperature, surface pressure, winds), in GCMs and other atmospheric models, the dust atmospheric loading needs to be forced to the observed values. This requirement precludes any meteorological forecast for the future, but also hampers the reliability of GCMs to investigate past Martian climates.

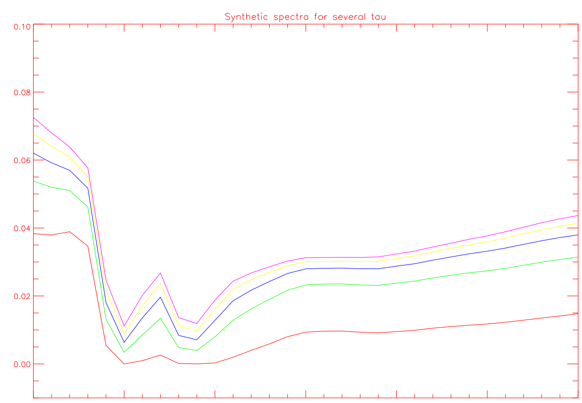

Figure 1: Examples of the synthetic spectra used for fitting. For all the plotted spectra surface pressure is 6 hPa and the cosine of the incidence angle is 0.2. The albedo is our "reference albedo" and the lines represent different values of τ. The red line is for τ=0.0, the green for τ=0.5, the blue for τ=1.0, the yellow for τ=1.5 and the purple for τ=2.0.

Our project aims at providing new constraints on the Martian dust. We will base our study on data gathered by the spectro-imaging system OMEGA (Observatoire pour la mineralogie, l'eau, la glace et l'activite) aboard the Mars Express spacecraft. The Mars Express mission is operated by the European Space Agency (ESA), while the OMEGA instrument has been designed and built by several laboratories including the LESIA (P.I. Jean-Pierre Bibring, Institut d'astrophysique spatiale, Orsay, France). Since the successful Mars Express insertion into orbit on December 25th, 2003, the instrument has been performing routinely, and has already acquired some 300 million spectra. The OMEGA spectral range includes the visible and near infrared (0.35-5.1 μm), with a spectral resolution of 0.01-0.02 μm. In terms of spatial resolution, the pixel can be as small as 300 meters. OMEGA allows us to retrieve the surface mineralogy, the chemical and physical state of ices, and the atmospheric chemical composition. We will use its ability to determine the atmospheric dust loading, its spatial, seasonal and interannual variations. Our retrievals will be used in association with Martian meteorologists to improve the dust modelling in GCMs and other atmospheric models.

In nadir viewing, it is difficult to distinguish the solar light reflected on dust from the solar light reflected on the surface. But some methods can be used to disentangle surface reflection from dust reflection. At 2.7μm and 4.3 μm, where CO_2 absorbs the solar light, no photons can reach the surface. If some light is reflected, it is from dust particles located above 20 km at 2.7 μm and above 70 km at 4.3 μm. This method (see, e.g. *Fedorova et al.* (2002)) allows us to map the dust optical depth during the whole the Mars Express mission, and will provide insights into spatial and temporal variations of the dust loading. We have developed at the LESIA a radiative transfer code that allows us to treat both the multiple scattering induced by the particles, and the gaseous absorptions. The radiative transfer code can be used in nadir or limb pointing geometry. The synthetic spectra calculated with the code (see examples in Figure 1) are interpolated with respect to known variables as incidence angle, which we get from the OMEGA data itself, and surface pressure, for which we use the Mars Climate Database (*Lewis et al.*, 1999). In principle the surface pressure could be extracted from the CO_2 2.0 μm band, as described in *Haus and Titov* (1999), and we may try this approach in the next phase. The synthetic spectra need to be interpolated also with respect to surface albedo (not known), which we have evaluated (*Erard*, 2001) and fit with the interpolation. The last parameter, naturally, is the dust optical depth, which we fit both throughout the whole spectral window used (2.6-3.2 μm) and in the bottom of the absorption band. The two fits are compared, and generally the fit in the bottom of the band gives more reliable results, since the albedo estimation is very difficult and uncertain.

We are mapping the dust atmospheric content during the Mars Express mission using the 2.7μm CO_2 band with the technique described above. The results can be compared with mapping done by another Mars Express Instrument (Planetary Fourier Spectrometer, PFS) and survey from the NASA spacecrafts (Mars Odyssey and Mars Global Surveyor). The high spatial resolution provided by the OMEGA instrument will allow us to search for short scale features in the dust cover, such as lee or orographic waves induced by the interaction between the mean wind field and the surface. Such waves, in predictions of the meteorological models, play an important role in the angular momentum transfer between the deep equatorial atmospheric layers to the rest of the planet. Unfortunately, observations of such waves are scarce. The full mapping of these waves provided by OMEGA, would hence be of great interest to meteorological models. A collaboration with the Laboratoire de Meteorologie Dynamique (LMD) will follow the data analysis period to interpret the results within the Martian meteorological frame.

We will present analyzed example orbits from different seasons and locations and discuss the observed behaviour of dust.

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