THE VERTICAL STRUCTURE OF MARTIAN AEROSOLS EXPLORED USING A 3D SPHERICAL MONTE-CARLO MODEL AND OBSERVATIONS AT THE TERMINATOR BY OMEGA. Mathieu Vincendon[1], Y. Langevin[1], J-P. Bibring[1], T. Fouchet[2], B. Gondet[1], D. Jouglet[1], F. Poulet[1], [1]Institut d'Astrophysique Spatiale, CNRS/Université Paris Sud, Orsay, France (mathieu.vincendon@ias.u-psud.fr), [2]Observatoire de Paris-Meudon, 92195 Meudon, France.

Introduction: The OMEGA instrument onboard Mars Express has obtained several nadir observations of the surface of Mars at the boundary between day and night (the "terminator") since early 2004. Even under clear atmospheric conditions, the path length of photons in the aerosols layer is high for such observations. In the dayside, almost all solar photons heading toward the surface are stopped by aerosols. The surface is then lighted up by photons scattered high in the atmosphere, where the aerosol layer is thin enough. These aerosols also send photons toward the night side of the planet, which makes it possible to see the surface after the sunset. These observations are sensitive to the vertical structure of aerosols. Previous studies of the vertical distribution of aerosols have revealed that the particle size of atmospheric dust decreases with altitude [1] and that discrete layers of water ice are common [2].

A 3D spherical Monte-Carlo model: We have developed a 3D Monte-Carlo model of radiative transfer in an atmosphere populated by suspended particles. The Monte-Carlo approach includes multiple scattering without simplifying assumptions [3]. The model is used to populate look tables of reflectance seen from zenith both in the dayside and in the night side.

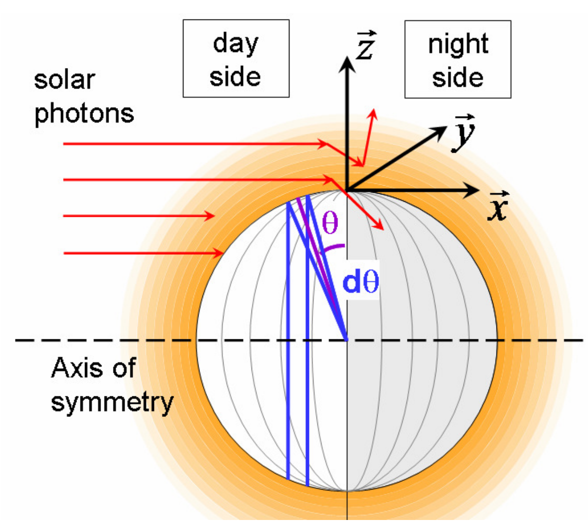

Figure 1: Scheme of the Monte-Carlo spherical radiative transfer model. The model takes advantage of the axis of symmetry that characterize spherical configuration. Solar photons are injected from one line (z axis) and can then evolve in a 3D environment.

Results of the model depend on the vertical structure of aerosols. The model can be used to study the origin of photons collected by the instrument (Figure 2). At the terminator, photons that light the surface and photons that are scattered by aerosols toward the instrument have been scattered at altitudes of 10 to 50 km (Fig. 2).

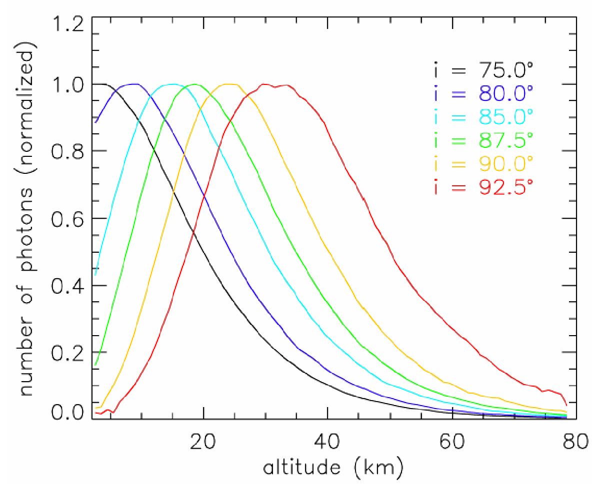

Figure 2: Altitude of interaction of photons with aerosols as a function the solar zenith angle i. The total optical depth is 0.5. On both sides of the terminator (i = 90°, yellow), photons that are collected by the instrument have been first scattered high in the atmosphere (15 – 40 km).

High altitude water ice aerosols: OMEGA has observed the south polar cap of Mars just before the southern spring equinox, when southern polar regions are not yet permanently lighted. At that time water ice condensation in the atmosphere is predicted by general circulation models [4]. Water ice signatures appear in the terminator observations of the southern latitudes when the solar zenith angle goes past 87°. At such incidence angles, most collected photons have been scattered at altitudes greater than 20 km (Figure 2). These water ice signatures are therefore due to thin water ice clouds that contribute to the observed signal only when the path length of photons inside is high enough, i.e. at the terminator.

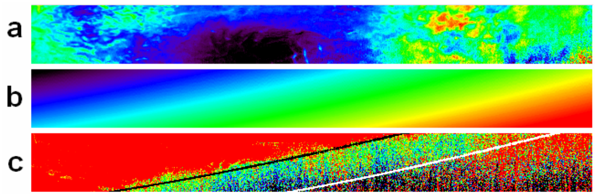

Figure 3: OMEGA observation obtained at L_S 175° above the south polar cap of Mars. (a) Map of the 1.43 µm band depth (surface CO_2 ice). (b) solar zenith angle, from black (80°, day side) to red (> 95°, night side). (c) 3.4 µm / 3.525 µm ratio showing small-grained water ice (red: no ice [5]); the black line is the "i = 87°" line, the white line is the terminator.

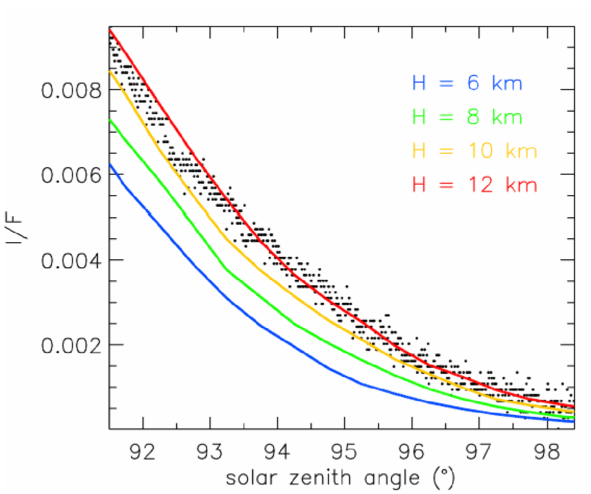

Figure 4: Black: reflectance at 1.1 µm measured by OMEGA in the night side of an observation at L_S 301° in august 2008. This part of the observation cover the region between 56°S and 64°S at 222°E. Model results are indicated in colors for a surface albedo of 0.19, an optical depth of 1.6 and different dust vertical scale heights H.

Dust scale height: When there is no ice clouds, each observation obtained at the terminator is characterized by three parameters in the model: the surface albedo, the aerosols optical depth, and the vertical distribution of this optical depth. The vertical structure of dust can be approximated at the first order by a decreasing exponential function with a fixed scale height. The real shape of the aerosols vertical profile is more complicated and change with time and position [6]. The surface albedo can be determined independently using observations obtained previously with moderate optical depths and low solar zenith angles. The range of optical depths at the time of the observation can be evaluated using simultaneous measurements performed from the ground by the Mars Exploration Rovers [7]. An observation at the terminator has been obtained at L_S 301° just after the maximum of the 2007 planet-encircling dust event (Figure 4). The optical depth at that time is high everywhere on the planet: both MER measurements indicate more than 2. This corresponds to an optical depth of about 1.6 once scaled to the elevation of our observation obtained at 60°S. The surface albedo is ~ 0.19 and roughly constant during all the observation. This observation is consistent with a dust scale height slightly lower than 12 but greater than 10, in agreement with the 11.5 km value derived in similar conditions ([7], [8]). Dust is expected to be mixed up high in the atmosphere as this observation is obtained during a dust storm when the atmosphere is warm. This result depends weakly on the assumptions about the surface albedo and the optical depth. Another observation is shown in Figure 5. It is obtained later in the season (L_S 338° in 2004) and close to the south pole (80°S). Atmospheric dust is confined close to the surface (H < 8 km) at that time and that place.

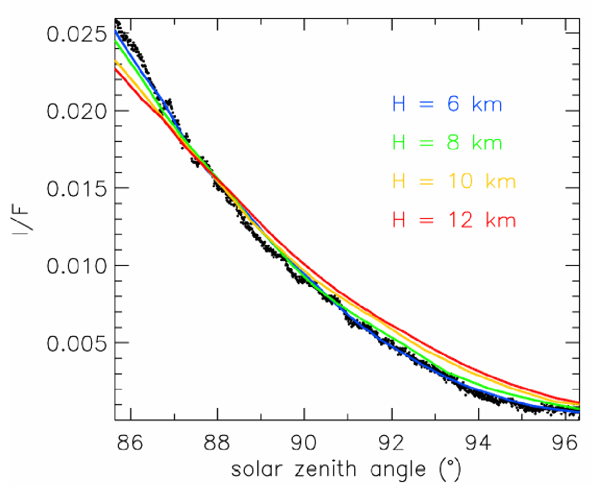

Figure 5: Same as Fig. 4 for an observation obtained at 80°S in 2004 (L_S 338°). The solar zenith angle range is wider and includes both day and night. All parameters (optical depth, surface albedo, dust scale height) are free. A smaller dust scale height is required to explain this observation obtained close to the south pole and autumn equinox.

References: [1] Chassefière, E., et al. (1992), Icarus 97, 1, 46-69. [2] Montmessin, F. (2006), J. Geophys. Res., 111, E09S09. [3] Vincendon, M., et al. (2007), JGR, 112, E08S13. [4] Forget F. et al. (1999), J. Geophys. Res., 104, E10, 24155-24175. [5] Langevin Y. et al. (2007), J. Geophys. Res., 112, E08S12. [6] Conrath, B. J. (1975), Icarus, 24, 36-46. [7] Lemmon, M. T., et al. (2004), Science, 306, 1753–1756. [8] Zazova, L., et al. (2005), Planet. Space Sci., 53, 10, 1065-1077.