SPATIAL, SEASONAL AND VERTICAL DISTRIBUTION OF WATER ICE CLOUD PARTICLE SIZE INFERED FROM OMEGA LIMB DATA.

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Introduction: The OMEGA imaging spectrometer has acquired hundreds of limb vertical profiles of the Martian atmosphere at various solar longitude and location. Here we report a new approach that can be used to rapidly estimate the mean particle size of water ice layers observed in these vertical profiles.

Method: The attenuation coefficient of water ice strongly increases for wavelengths about 3 µm: while it is characterized by a moderate value of 0.01 at 2.8 µm and 3.6 µm, it approaches unity at 3.1 µm [1, 2]. This strong attenuation of incoming solar radiations going through ice grains results in a strong 3 µm absorption feature observed in water ice spectra. As the attenuation coefficient increases near 3.1 µm, the refractive index also increases from 1.3 to 1.8. This attribute results in a strong increase of the quantity of light scattered by water ice grains at 3 µm to 3.6 µm compared to surrounding wavelengths (Figure 1). A similar effect is observed for CO_2 ice at wavelengths about 4.3 µm [3]. We have performed Mie [4] and radiative transfer modeling [5] of the scattering properties of water ice clouds using the optical constants of [1, 2] to simulate cloud reflectance properties as observed by OMEGA for various cloud types. Examples of results are presented in Figure 1.

In nadir viewing geometries, the absorption dominates and the 3 µm region appears as an absorption feature in near-IR spectra of water ice clouds [6]. This is due to the fact that collected light have passed through the cloud to reach the surface and then to reach the instrument. In limb viewing geometries, most of light collected from the cloud has been only scattered by ice particles. Hence, limb profiles are expected to be mainly sensitive to the scattering properties of water ice particles, i.e. they will show an emission peak between 3 µm to 3.6 µm instead of an absorption feature.

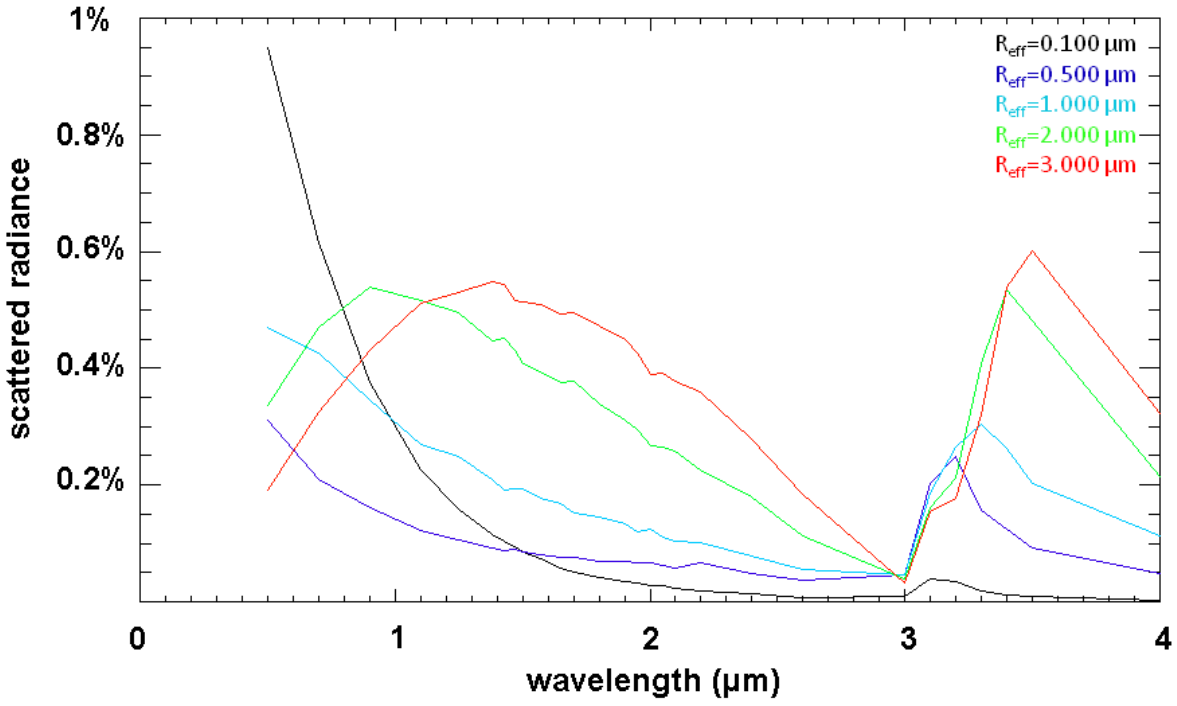

Figure 1: % of incoming solar radiations scattered by a water ice cloud with a vertical optical depth of 0.1. Five mean particle sizes are represented, from 0.1 µm to 3 µm. The light scattered by water ice clouds presents a distinctive emission peak between 3 and 3.6 µm. The exact position of this maximum strongly depends on the mean grain size: it is located at about 3.1 µm for small, 0.1 µm grain size and shifts to 3.5 µm for larger 3 µm grain size.

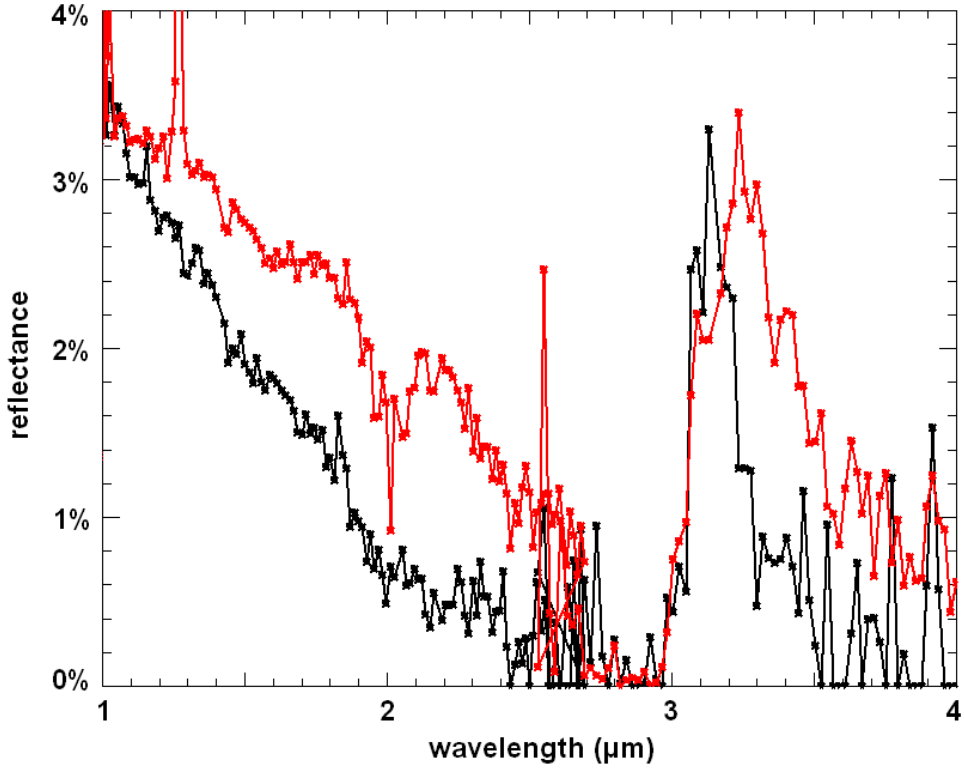

Figure 2: OMEGA limb spectra extracted from 2 different limb observations. The black spectrum corresponds to a bright layer located at 45 km altitude, while the red spectrum correspond to a bright layer located closer to the surface, at about 13 km. The maximum at 3 to 3.6 µm is sensitive to the mean particle size of the ice cloud (see Figure 1). The relatively high altitude cloud (black) has a maximum at 3.13 µm: it corresponds to small grains in the 0.1 to 0.3 µm range. On the contrary, the low altitude cloud (red) corresponds to larger grains (typically 1 µm) as the water ice emission maximum is located at longer wavelengths (3.25 µm).

Results: In Figure 2, we present 2 examples of OMEGA spectra showing the distinctive water ice emission maximum between 3 and 3.6 µm. The black spectrum has been observed at a relatively high altitude of 45 km at 13°E and 44°S. The solar longitude is 18° and the local time about 10.00. This cloud is characterized by an emission peak located at 3.13 µm, which correspond to small particles of about 0.1 to 0.3 µm according to Figure 1. The red spectrum is extracted from another OMEGA observation at 240°E and 65°S. The solar longitude is 35° and the local time is also about 10.00. In that case particles are larger, typically about 1 µm, as indicated by the shift of the maximum toward 3.25 µm. The decrease of the scattering efficiency of the cloud between 1 µm and 2.5 µm are also consistent with these particle sizes.

Conclusions: Water ice particles located in the Martian atmosphere are characterized by a strong scattering maximum located at wavelengths near 3.2 µm. The exact position of this maximum depends on the mean particle size of the cloud. It shifts from 3.1 µm for small submicron particles to 3.5 µm for several micrometers particles. This maximum thus provides a rapid estimate of the mean particle size of water ice aerosols observed in OMEGA limb data. Considering the large OMEGA limb dataset, we aim at constructing spatial, seasonal and vertical maps of water ice particle size which will complete existing database [7]. This rapid approach will supplement more sophisticated methods under development for the analysis of OMEGA limb data [8].

Reference: [1] Warren 1984, Applied Optics, vol 23, 1206-1225. [2] Grundy & Schmitt 1998, J. Geophys. Res. E11, 103, 25809-25822. [3] Montmessin et al. 2007, J. Geophys. Res. 112, E11S90. [4] Mishchenko & Travis 1998, J. Quant. Spectrosc. Radiat. Trans. 60, 309-324. [5] Vincendon et al. 2007, J. Geophys. Res. 112, E08S13. [6] Madeleine et al., 2010, submitted to J. Geophys. Res. [7] McConnochie & Smith 2008, 3rd M.A.M.O. workshop, 9114. [8] Vasilyev et al. 2009, Solar System Research 43, 5, 392–40.