MARS CO_2 ICE CLOUDS PROPERTIES FROM OMEGA/MEX OBSERVATIONS COUPLED TO RADIATIVE TRANSFER MODELING

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Introduction: Observations have revealed the presence of CO_2 ice clouds in the Martian atmosphere [1-5]. These clouds, with no analog on Earth, form at high latitudes during the polar night, but also at equatorial latitudes in the martian mesosphere (50-100 km) in the 0-140° Ls range. A few occurrence of CO_2 ice clouds have also been observed at midlatitudes during local autumn. These CO_2 ice clouds are of particular importance as they may be one of the keys to understand Mars past climate [6]. Assessing their actual impact, however, require precise constraints about their physical properties and formation mechanisms which still remain unclear.

Here we perform a systematic analysis of previously detected CO_2 ice clouds on Mars, combining OMEGA/MEx observations and radiative transfer modeling in order to determine their physical properties (composition, opacity, grain size).

Radiative transfer modeling: Simulations of CO_2 ice clouds reflectance and transmission spectra over the VIS-NIR spectral range (0.5-4.5 µm) were performed using a Mie code [7] coupled to a radiative transfer model from [8]. In particular, this Mie code has the capability to compute single particles photometric properties (single scattering albedo, phase function, extinction cross section), both homogeneous in composition or with a stratified structure (coating), thus giving us the opportunity to explore a large panel of potential scenarios with particles made of CO_2 ice, H_2O ice and/or dust, and assess our capability to detect them in available VIS-NIR spectral datasets. Particles are considered here of spherical shape for simplicity. CO_2 and H_2O optical constants are taken from [9], whereas dust optical constants come from a combination of [10] and [11].

These photometric properties were computed over specific grain size distribution and then used as inputs to a radiative transfer model of the martian atmosphere based on a Monte-Carlo scheme [8]. In particular, this latter is capable of computing the reflectance and transmission spectra of clouds of particles with a given composition and particle size, for specific cloud opacities and illumination/viewing geometries (Figure 1).

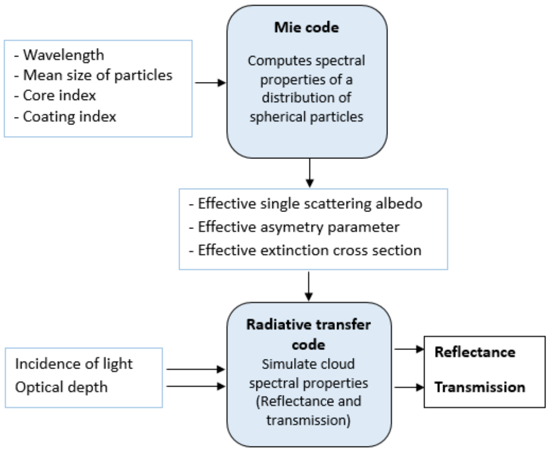

Figure 1: *Functional diagram of the main program to compute the spectral properties (both reflectance and transmission spectra) of CO_2 ice clouds*

Observations and comparison with simulation results: More than 80 OMEGA/MEx observations of CO_2 ice clouds have been made so far. Compositional identification was based on the detection of a diagnostic spectral feature around 4.26 µm which is produced by resonant scattering of solar photons by mesospheric CO_2 ice particles in a spectral interval otherwise dominated by saturated gaseous absorption.

For a first run, we selected about 20 of these observations where the cloud shape was clearly defined, so that the spectral signature of the ground close to the cloud could be easily analyzed. For each cloud observation, we have extracted their spectral signature following the procedure and the assumptions described in Figure 2, similar to [5]. This signal was then compared to the results of the simulations made with our radiative transfer model to assess their composition, grain size and opacity.

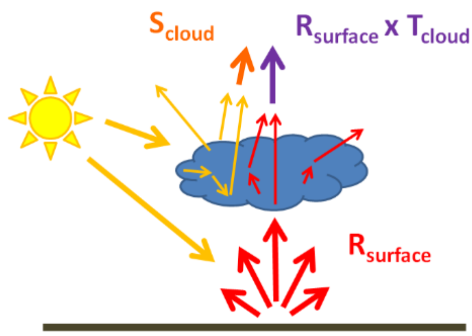

Figure 2: *Radiative transfer scheme considered. The ground below the cloud is illuminated by "direct" sunlight (no attenuation by the cloud itself) as*

we consider small clouds. The reflectance R_{cloud} measured above the cloud is thus composed of the scattered reflectance of the cloud S_{cloud} (orange arrow, composed of single and multiple scattering by cloud particles without interaction with the surface), plus the reflectance coming from the surface (red arrow) modulated by the cloud transmission factor which account for multiple scattering between cloud particles: $R_{surface} \times T_{cloud}$ (purple arrow).

Results:

- Results show that equatorial CO_2 ice clouds studied here have always an effective mean grain size (diameter) between 1 and 4 µm.
- Their opacity in the visible remains relatively low with values from 0.1 to 0.4.
- Results also show that particles of homogeneous composition (CO_2 ice) does not always provide the best fit to the observations and that other configurations might also be permitted. This is currently under investigation and could provide new insights into Mars CO_2 ice clouds formation (nucleation sites) and evolution process.

References: [1] Montmessin et al. 2006, *Icarus*, 183 403-410, [2] Montmessin et al. 2007, *JGR*, 112 E11S90, [3] Gondet et al. 2008 *abstract 9046 from the 3rd International Workshop on Mars Atm.*, [4] Määttänen et al. 2010, *Icarus*, 209 452-469, [5] Vincendon et al. 2011, *JGR*, 116 E00J02, [6] Forget and Pierrehumbert 1997, *Science*, 278 1273-1276, [7] Toon and Ackerman, 1981, *Applied Optics*, 20 3657, [8] Vincendon et al. 2007, *JGR*, 112 E08S13, [9] Schmitt et al. 1998, *Solar System Ices* p199, [10] Wolff et al. 2009, *JGR*, 114 E0D004, [11] Ockert-Bell, 1997, *JGR*, 102