High-altitude CO2 clouds on Mars: OMEGA and HRSC observations

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HIGH-ALTITUDE CO_2 CLOUDS ON MARS: OMEGA AND HRSC OBSERVATIONS. A. Määttänen[1], F. Montmessin[1], B. Gondet[2], H. Hoffmann[3], F. Scholten[3], E. Hauber[3], F. Gonzalez-Galindo[4], F. Forget[4], J.-P. Bibring[2], J.-L. Bertaux[1], and G. Neukum[5].
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Introduction: The Martian climate hosts a rare phenomenon of condensation of the bulk atmosphere. CO_2 condenses on the polar ice caps, but also forms clouds in the atmosphere. The existence of low-level, convective CO_2 clouds in the polar night was indirectly discovered by MOLA [1,2] and modeled in some studies [3-5]**.** Recently several satellite instruments [6-9] have observed CO_2 clouds also near the equator, but at high altitudes where the temperatures are low enough for CO_2 condensation. Montmessin et al. [7] identified spectroscopically from MEx/OMEGA observations these high-altitude clouds to be composed of CO_2 ice crystals by modeling the CO_2 ice spectral signature that was observed in a deep CO_2 gas absorption band at around 4.3 µm. In this work we have used the OMEGA [10] and HRSC [11] observations to map the occurrences of the high-altitude CO_2 clouds and their properties. We have also compared the observations to the predictions of the LMD Mars Global Climate Model (LMD-MGCM) [12] and in particular its improved version that extends to the upper atmosphere [13].

Instruments: OMEGA is an imaging spectrometer working in the wavelength range 0.4-5.1 µm. It can operate in nadir, limb and EPF modes: in this study only nadir observations have been used. The clouds can be seen in several wavelengths in the OMEGA data: visible (0.5 µm), slightly farther in the infrared (1.3 µm) and in the near-IR CO_2 absorption bands at 2.7 and 4.3 µm. The spectroscopic identification of the clouds was done using OMEGA data [7]. The HRSC is a camera imaging the Martian surface in stereo and color. It images the surface through several channels that are looking slightly off-nadir. When atmospheric features, like clouds, are imaged through two (or more) filters, the apparent parallax of the features enables very accurate determination of the cloud altitude. The possible across-track movement of the cloud in different images, taken at slightly different times, gives an estimate of the local winds.

Results: Mars Express has acquired already more than 2.5 years of data with varying spatial and temporal resolution. The OMEGA dataset has revealed about 60 occurrences of these high-altitude CO_2 clouds. These observations show that the clouds are mainly confined to the equatorial region (20°S – 20°N) and to a quite specific longitudinal band (-120°E – 30°E, between Tharsis Montes and Terra Meridiani). Only a handful of observations lie outside these limits, most notably two clouds at midlatitudes (one at 50°S, other at 45°N). The seasonal variations are notable, since the clouds appear mainly right after the spring equinox, disappear between Ls=60°-90°, and reappear after the summer solstice. The activity seizes rapidly after Ls=150°, but one cloud has been observed at Ls=250°. When observed from high altitudes (2500 to 4000 km), the clouds show convective morphologies (roundish shapes) in about 10 cases (15%). From lower altitudes (< 500 km), the width of the OMEGA image limits the interpretation: the narrow image reveals only a part of the cloud and any extrapolation would be very difficult. However, simultaneous HRSC observations may shed light on the morphologies.

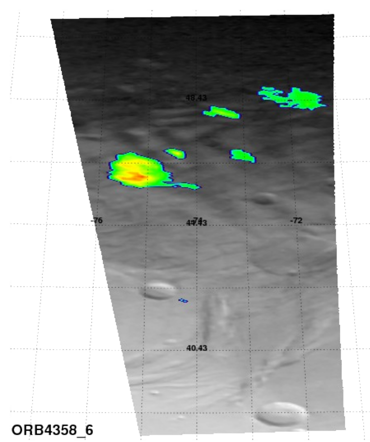

Figure 1: OMEGA observation of a convective-type cloud: the surface of Mars in grayscale and the analyzed cloud signal intensity in color.

Two shadow observations have been used to analyze the cloud optical thickness and particle size, as already mentioned by Montmessin et al. [7]. These authors also calculated the cloud altitude to be around 80 km. In our study we have also mapped the variations of these parameters inside the cloud by analyzing them pixel-by-pixel. These observations have confirmed the previous results of Montmessin et al. [7] as well as produced size distributions of the cloud particle effective radii and optical thickness. The effective radii vary mainly in the range 1-2 μm and the optical thickness between 0.2-0.7.

The HRSC has imaged clouds in several occasions and clearly two kinds of clouds can be separated from the HRSC dataset: the low- (< 40 km) and high-altitude clouds. The low altitude clouds are thoughts to be primarily H_2O rich, while the high altitudes ones are made of CO_2, as confirmed by a simultaneous observation by OMEGA. These clouds are observed close to the equator, show similar seasonal behavior, and the hygropause level should be at significantly lower altitudes thus limiting the amount of water vapor in the upper atmosphere.

The HRSC cloud altitudes vary from 53 km to 84 km (±2 km) and they exhibit mainly cirrus-like, filamented shapes instead of convective, round shapes (see Fig. 2). The East-West cloud speed (related to the local wind speeds) range is 15-105 m/s but mainly in the range 60-90 m/s (±13 m/s). One cloud, observed in southern midlatitudes, is actually moving from West to East with varying wind speeds of 5-40 m/s.

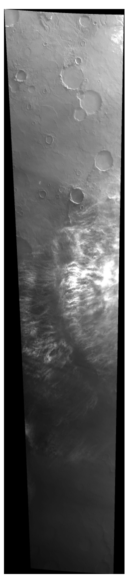

Figure 2: An example of a high-altitude cloud observed by HRSC (orbit 0567).

The cloud observations have been compared with the LMD-MGCM climatology. The MGCM shows strong diurnal temperature variations caused by the strong thermal tides in the mesosphere of Mars at the cloud altitudes. At the altitudes of our interest (60-80 km), the coldest temperatures are attained in the afternoon (16 local time) and the warmest temperatures in the morning hours (04 LT). Most of the clouds are observed in the afternoon, but in a few cases they have been observed before noon. The model reproduces the shutdown of cloud formation at Ls=60°-90°, but the reason for that is out of the scope of this study. The HRSC cloud altitude and wind observations show good general agreement with the MGCM results.

Implications: Formation of CO_2 ice clouds is known to affect the CO_2 cycle as a whole [3,4]. Although the cloud species reported here does not belong to the class of low-altitude clouds encountered in the polar night, it shares similar formation processes with the latter, and thus offers a unique opportunity to decipher the microphysical and dynamical processes at work. This in turn may help us derive a unified and robust theory for the formation of CO_2 clouds in the Martian atmosphere.

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