OBSERVATIONS BY OMEGA/MEX OF CO_2 AND H_2O FROSTS IN THE SEASONAL CAPS DURING A FULL MARTIAN YEAR (01/2004 – 11/2005)

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Introduction:

Condensation and sublimation of CO_2 and H_2O frosts in circumpolar regions down to mid latitudes play a critical role in the seasonal evolution of the martian atmosphere. Together with the deposition and transportation of aerosols, they represent the most important processes for surface atmosphere interactions. The OMEGA VIS/IR imaging spectrometer on board Mars Express is able to unambiguously identify water and CO2 frosts as they present strong specific absorption features in the near IR. OMEGA has now been observing the surface of Mars during more than one martian year, starting shortly before the northern spring equinox. Image cubes have been obtained over a wide range of Ls, with pixel sizes ranging from 500 m to 10 km. These observations provide important constraints on general ciculation models, the role of water vapor and ice in surface atmosphere interaction processes and the North-South asymmetry.

Instrument characteristics:

OMEGA is an imaging spectrometer which provides VIS-IR spectral cubes at 352 wavelengths ranging from 0.4 to 5.1 µm. Example spectra (Fig. 1) demonstrate the capability to identify regions dominated by dust, CO2 ice and H2O ice. Information can also be obtained on the brightness temperature from the radiance at wavelengths close to 5 µm. The temperature of ice free regions can exceed 300 K at noon close to perihelion, while that of frost covered regions cannot exceed the sublimation temperature.

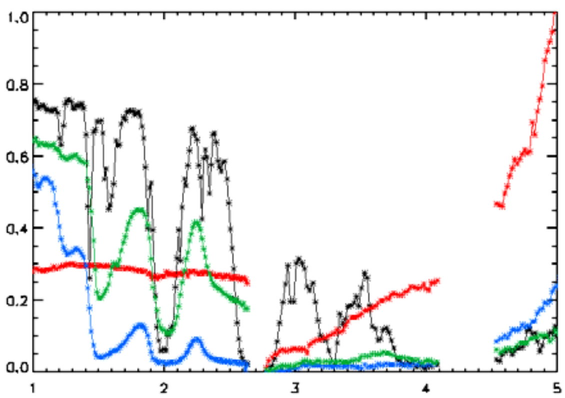

Fig. 1 Example spectra obtained by OMEGA from ice free regions (red), CO2 frost (black), water ice frost (green, size < 100 µm) and water ice on the permanent North cap (blue, size ~ 1 mm).

As discussed in other contributions, OMEGA can also monitor H2O in the gas phase, in particular over ice free regions. OMEGA obtained extensive coverage of the recess of the northern seasonal cap during early spring (Ls 0° to 50°) and a few observations before the Northern summer solstice in early to mid 2004. Extensive coverage of the recess and stabilization of the Southern seasonal cap was obtained From Ls 120° to Ls 335° in late 2004 and 2005. The last phases could be compared to a few observations obtained at Ls 335° in early 2004 (Bibring et al., 2005).

Results:

OMEGA observations on the Northern seasonal and permanent cap confirm that the intermediate temperature ring with a width of 5° to 10° in latitude observed by TES (Kieffer and Titus, 2001) is constituted by water ice frost lagging behind CO2 frost during the recess (Fig. 2). The late stages of the recess are dominated by water ice frost, and CO2 frost disappears after the solstice (Bibring et al, 2005). The permanent cap remains partly covered by water ice frost until early northern summer. The sublimation of the frost one to two months after solstice reveals the coarser grained water ice of the permanent cap (Langevin et al., 2005).

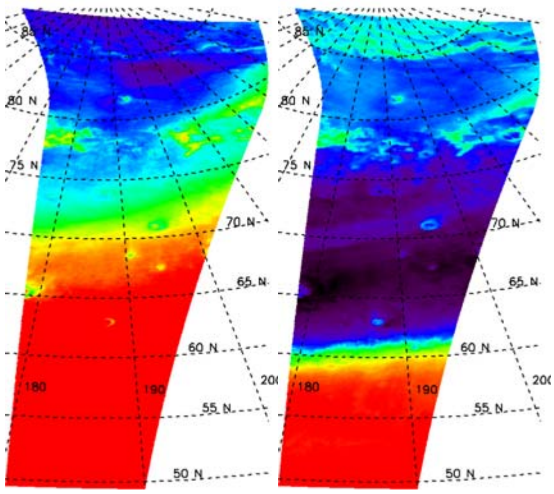

Fig. 2: depth of characteristic bands of CO2 frost (1.425 µm, left) and H2O frost (1.5 µm, right). The color scale ranges from 0% absorption (red) to 40% absorption (black) during the recess of the northern seasonal cap (Ls = 8.6°)

The recess of the southern seasonal cap appears markedly different from that of the northern seasonal cap. The seasonal cap is dominated by CO2 ice during the whole period. Slab CO2 ice (several 10 cm in thickness) is observed over most outer areas during the first stages of the recess (Ls 130° - 160°). At later stages (Ls 200°-250°), this recess is very asymmetrical, as previously observed by TES (Titus, 2005). OMEGA confirms the important role of the so-called "cryptic region" (60° to 210° E, 75° to 85° S) observed by Viking and TES in this process. Quite surprisingly, the "slab CO2 ice" hypothesis which had been proposed for this relatively dark and cold region has not been substantiated by OMEGA, which observes very shallow CO2 spectral features in this area.

Contrarily to the situation in the North, there is no H2O ice ring lagging behind the recess of the CO2 cap. Before the spring equinox (Ls 130° - 160°), the seasonal cap is extremely dry except for a region from Hellas eastwards (initially 60°E – 120°E, extending to 150° later in the period). This observation is consistent with the ice cloud formation and deposition models of Montmessin et al. (2004) based on GCM models (e.g. Forget et al., 1999). H2O frost is present as a contaminant of most of the CO2 frost after the local spring equinox (Ls 180° - 200°, Fig. 3). Models show that a very small fraction per volume (< 0.1 %) is consistent with the observed band strengths. The observed spectra are consistent with either an intimate mixture of small ice grains (< 50 µm) and larger CO2 grains (1 to 10 mm) or a dispersion of small ice grains into slab CO2 ice such that the mean free path in CO2 is in the 1 – 10 mm range.

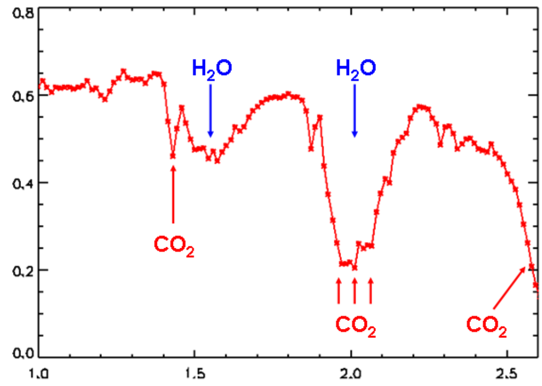

Fig.3 Example spectrum of a region at 207°E, 71°S for Ls = 187°. The major broad signatures of water ice around 1.5 µm and 2 µm are superimposed on the narrower characteristic CO2 absorption bands.

From Ls 220° to Ls 240°, only a few water ice rich patches remain close to the boundary of the CO2 cap, mostly concentrated in topographic lows. From Ls 240° to Ls 275°, the seasonal cap is nearly free of water ice signatures, which means that the volume concentration is well below 0.01%.
The most recent observations overlap that obtained with OMEGA in early 2004, around Ls 335°. At this stage, the outer boundaries of the cap nearly perfectly match the observations of early 2004 (Bibring et al., 2004) and the boundaries of the cap observed in the visible by MGS and Viking. Similarly to early 2004, OMEGA observes an apparent albedo in the continuum of 60% to 65% on the cap (the actual albedo may be higher due to aerosol extinction at incidences exceeding 75°). The cap exhibits a significant contamination by water ice bands with regional variations.

Again similarly to 2004, small regions with intermediate albedo (40 to 45%) are dominated by water ice features at the boundary of the CO2 cap. They show no significant variation in extent from early 2004 to late 2005. This supports the interpretation of Bibring et al., which consider these regions as outcrops of permanent water ice. It should however be noted that the ice grain size in these regions (in the range of 100 µm) is much smaller than that of the northern permanent cap, hence they could correspond to the minimum extend of water ice patches in a seasonal frost deposit. An interesting issue is whether the CO2 and H2O ice-rich regions observed by OMEGA shortly before the southern fall equinox does correspond to a "permanent" cap with thick deposits of water ice overlain by a thin layer of CO2 ice. Observations by MARSIS should provide important information on this issue.

Conclusion:
Overall, the southern cap appears much dryer than the northern cap, which is consistent with circulation models. The first martian year of OMEGA observations provides new insight on the stability of seasonal cap features from martian year to martian year, the nature of the cryptic region, the strong geographic variability and time dependence of water ice contamination. These results strongly constraint general circulation models in terms of the distribution of water vapor, water ice clouds, water ice condensation and sublimation.

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