ASYMMETRIC RELEASE OF CO_2 DURING SOUTHERN SPRING.
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Introduction: The polar condensation/sublimation of CO_2, that involve about one fourth of the atmosphere mass, is the major Martian climatic cycle. Early observations in visible and thermal infrared have shown that the sublimation of the Seasonal South Polar Cap (SSPC) is not symmetric around the geographic South Pole [1]. Therefore the asymmetric release of CO_2 in the atmosphere may lead to special atmospheric features.

Method: We use observations by OMEGA in the near-infrared to unambiguously detect the presence of CO_2 at the surface, and to estimate albedo. Second, we calculate the asymmetric release of CO_2 using a sublimation model. Finally we discuss some implications for the Martian atmosphere. All calculations has been done with time bins of 5°Ls and spatial bins of 0.3° in latitude and 10° in longitude.

Field estimation. For a spatial bin we define the inner crocus date - respectively the outer crocus date – as the dates when the first - resp. the last – pixel within this spatial bin ends to present any CO_2 ice signature. We estimate both inner and outer crocus dates using the OMEGA dataset and a method previously described in [2]. This method uses an automatic detection algorithm [3] and a dedicated algorithm to extract the crocus line. In this paper, we propose to interpolate the measured crocus dates to get a map of both the inner and outer crocus dates.

We extract CO_2 ice albedo after removing the contribution of the the aerosol layer using the method provided by [4]. Then we average all pixels inside a bin and perform an empirical spectral integration of albedo over the solar spectrum in the visible and near-IR. Finally, we estimate the albedo field over the whole area covered by seasonal deposits using an interpolation method based on convolution.

Sublimation model. First we use the D-frost model to estimate the daily average mass surface balance [2] for each space-time bin. We estimate altitude and slopes for each bin averaging a map in stereographic south projection of MOLA data at 920 m resolution.

We propose two extreme cases for the time of the end of integration (crocus date) : the inner or the outer the crocus dates. A more realistic case is a decreasing proportion of surface covered by CO_2 ice inside each bin from the inner to the outer crocus dates. We assume a linear decrease with time (quoted as "linear surface proportion") and integrate it.

Results: The total sublimated mass calculated from Ls=90° to the end of the year is about 7.7 10^{15} kg (fig. 1) which is slightly higher than the gravity [5] and the GRS and HEND measurements [6, 7]. The time evolution of the total sublimated mass (fig 1) is compatible with the GCM and GRS measurements [4] although sublimation seems to start slightly earlier with the D-frost model. These discrepancies are due to differences in the integration method. In contrary to the measurements, with our D-frost model the total mass integrates all sublimating CO_2 aera except the aera where accumulation occurs. Thus the deviation of the model around Ls=90°, is due to CO_2 accumulation still acting in the polar region - which effectively counter–balance sublimation at lower latitudes. Nevertheless, there is a good agreement of the end of sublimation around Ls=270°.

Figure 2 shows the integration of the SPPC sublimation splits into two sectors : the cryptic region from longitude 50°E to 230°E, and the anti-cryptic region from longitude 130°W to 50°E (the complementary sector). For the more realistic case (linear decrease), the main conclusion is that despite the asymmetry of crocus lines and albedo, the total sublimated mass at the end of the recession seems to be symmetric around the geographic pole. This conclusion confirms the statement done by [2] based only on four latitude points for both cryptic and anti-cryptic sectors. But the difference, less than 2.2 %, could be higher in cases of non-linear decreases. The extreme case of the outer crocus date give an inter-sector difference of 15%.

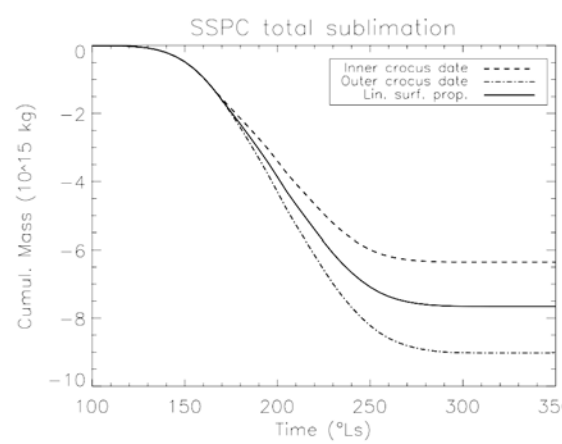

Fig 1: Evolution of the total sublimated mass with time.

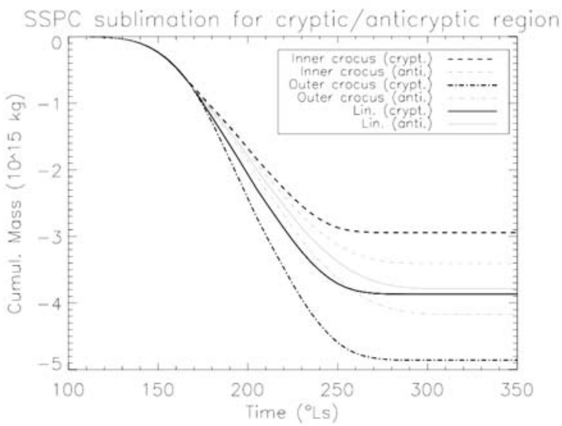

Fig 2: Total sublimated mass for both cryptic and anticryptic regions.

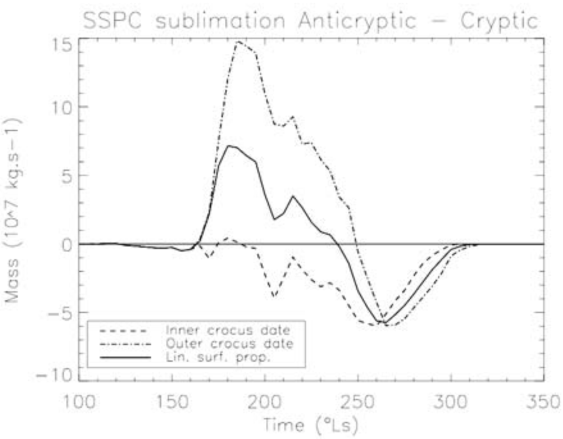

Fig. 3: Difference of sublimation mass rates between the cryptic and the anti-cryptic sectors. The sublimated mass is a negative quantity so that positive values correspond to a faster sublimation in the cryptic region.

The difference of the sublimation mass rates for the two sectors is increasing after Ls=160° (fig 3). From this date to Ls=240°, CO_2 ice in the cryptic sector sublimates faster, with a maximum difference of 7.2 10^7 $kg.s^{-1}$ due a relatively lower albedo in this sector. Then from Ls=240° to 310°, the situation is reversed in favor of the anti-cryptic region, with a peak at 5.7 10^7 $kg.s^{-1}$. This behavior is due to the fact that the SSPC recession is asymmetric, i.e.: the recession stops earlier in the cryptic region compared to the anti-cryptic region.

This difference in sublimation rates is completely balanced over the season and produces a two stages regime. This statement seems to be robust because it is independent of the sublimation scenario. During the first stage (from Ls=160° to 240° for the linear decrease), the release of CO_2 is stronger in the cryptic region and the net atmospheric flux should be from the cryptic to the anti-cryptic region.

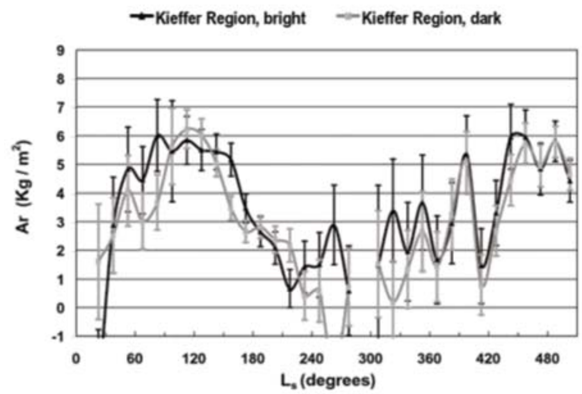

Fig. 4: Ar measurements in both cryptic (dark, in grey) and anti-cryptic region (bright, in black) provided by the GRS instrument (adapted from Sprague et al. (2007)).

During that period, atmospheric Argon - which is a non-condensible gas and thus depleted in the southern hemisphere - should be less depleted in the anti-cryptic region. During the second regime (from Ls=240° to 310°), the release of CO_2 is stronger in the anti-cryptic region and the net atmospheric flux is reversed. Ar should then be less depleted in the cryptic region. The Ar measurements (fig. 4) seems to indicate a change of Ar dilution between the two sectors around the same time period [8], but the other way around. This could show that there is effectively an atmospheric transition around Ls=240°, but the physical processes controling the possible associated change in Ar dilution is not well understood.

Conclusion: At present time, this asymmetry of CO_2 sublimation is not included in any atmosphere modeling because the albedo is set to a constant value for the whole hemispheric condensates. The first implication of this lack is the absence in the atmospheric simulations of possible dynamical effects induced by this two stages regime. In particular, it could produce some asymmetry of winds and their reversal may explain the measured change in Ar depletion. This asymmetry could also play a role in the stability of the permanent layer of CO_2 ice (swiss cheese) and it may control its offset position from the south geographic pole.

References: [1] Veverka, J. & Goguen, J. (1973) J. Royal Astron. Soc. Can., 67, 273-+. [2] Schmidt F., et al., (2008) Icarus (submitted) [3] Schmidt F., et al., Geosci. Rem. Sens. IEEE Transactions, 45(5):1374–1385, 2007. [4] M. Vincendon, et al., (2008), Icarus (in press) [5] Karatekin, T. et al. (2006), JGR E, 111, 6003 [6] N. J. Kelly, et al., (2006) JGR E , 111, 3 [7] M. L. Litvak, et al., (2007) JGR E, 112, 3 [8] Ann L. Sprague, (2007), JGR E, 112, 15