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Thermal cracking of CO_2 slab ice as the main driving force for albedo increase of the martian seasonal polar caps

S. Philippe, B. Schmitt, P. Beck and O. Brissaud
Institut de Planétologie et d'Astrophysique de Grenoble, France, Université Grenoble-Alpes
sylvain.philippe@obs.ujf-grenoble.fr

Introduction

Understanding the microphysical processes occuring on the Martian seasonal cap is critical since their radiative properties can affect the martian climate. A well documented phenomenom is the albedo increase of the Martian seasonal caps during spring, Fig.1. There are a lot of hypotheses that have been proposed as an explanation for this observation : the decrease of the CO_2 grain size [2], a cleaning process of the CO_2 slab that would imply either the sinking or the ejection of the dust contained in its volume ([1], [2], [5]), a water-layer accumulation on the top of the slab [5], the role played by aerosols [2] etc ... So far, no experimental simulations have been realized to discriminate between these processes. We designed an experiment to investigate the hypothesis of CO_2 ice grain size decrease through thermal cracking as well as that of dust segregation as the possible reasons for albedo increase.

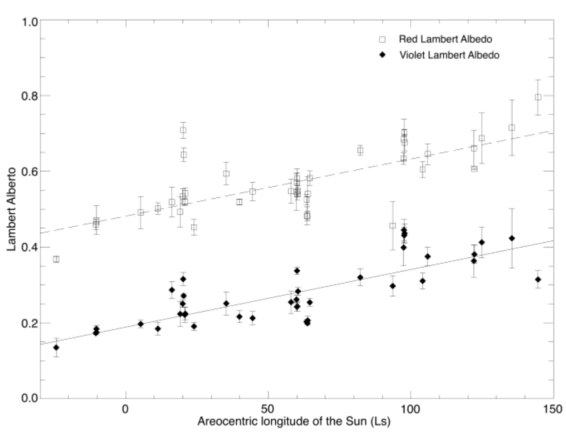


Figure 1: Albedo increase of the Northern seasonal cap seen by Hubble [1]

Experiment

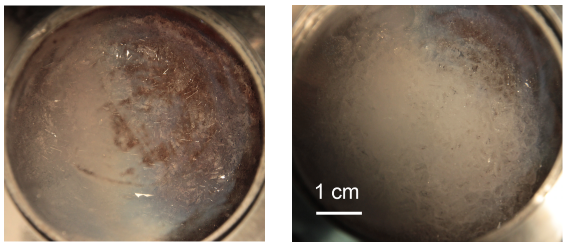
Protocol

To reproduce Martian seasonal deposits, an homogenous mix of CO_2 ice with dust was produced and introduced into the Carbo-NIR cell, which is a chamber developed at IPAG to simulate Martian environment. CO_2 ice is obtained in a granular form which is then 'slabised' (transformed into polycrystalline ice) in the cell using CO_2 gas injection. The entire experiment has been conducted at a temperature of -126^{o}C and a pressure of 6.5 mbar, characteristic of the martian environment during winter. The dust used in this experiment is a volcanic tuf that has been characterised in reflectance spectroscopy ([3], [4]) and which is used as an analog for martian dust in this experiment.

Reflectance spectra were acquired with the Spectrogonio-radiometer at IPAG laboratory. Our measurements span the range 0.5-4 μm with an acquisition step of 20 nm between 0.5 and 1 μm and 10 nm between 1 and 4 μm. Spectral resolution varies along the spectrum : from 19 nm between 0.5–3 μm to 39 nm between 3–4 μm. All the spectra were acquired with an incidence angle of 0°and emergence angle of 15°, azimuth of 0°.

Ice cracking could be potentially produced by 2 types of stresses induced by thermal gradient : the temperature gradient inside the slab could either be produced by the absorption of solar energy or, in atmospheric depression condition, by the rapid cooling of the surface due to CO_2 high sublimation enthalpy. Both hypotheses were tested with several experiments, including: illumination with stable pressure, decrease of pressure, illumination with pressure increase. The first situation represent a full martian analogy since we pumped into the volume limited cell to keep a stable CO_2 gas pressure all along the experiment to simulate the stable atmosphere. In the second case of decreasing pressure, we investigated typical ΔP experienced in Mars' atmosphere with baroclinic waves activity (typically 0.5-1 mbar). In our simulations, illumination is realized with an hallogen lamp and the flux brought to the sample is equal to the flux received by seasonal deposits in early spring (around 200 $W.m^{-2}$).

Results



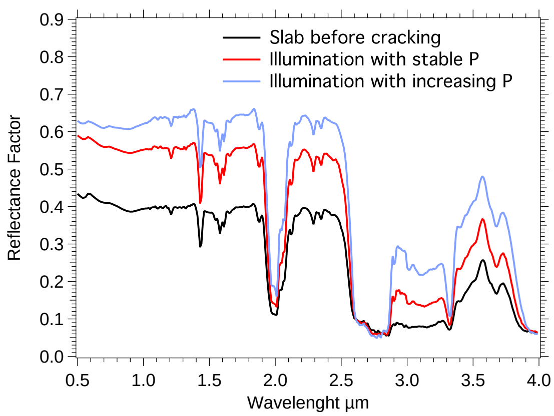


Figure 2: Bidirectional reflectance spectra of the CO_2 slab initial state (black), after thermal cracking (red) and after cracking only due to thermal stress (blue).

Fig.2 presents bidirectional reflectance spectra of the sample during the experiments. The black one is a typical slab spectrum as we can obtain it in our cell with deep CO_2 bands and a low reflectance. The blue and red spectra are obtained after thermal cracking of the slab ice with 2 different protocols : thermal cracking for the red spectrum was produced using illumination + pumping (stable P and surface T) while thermal cracking for the blue spectrum is realized with illumination only (i.e. the pressure increased inside the cell as the sample warmed up). Results associated with pumping only (ΔP = 1 mbar) are not displayed since we didn't observed any ice fracturing using this method.

At 1 μm, the reflectance is increased by 41% on the red spectrum and 58% on the blue spectrum. The difference of albedo increase between both cases is simply due to a longer illumination time for the second case (2h instead of 1h). This albedo increase can be compared to the one observed on Mars (see Fig.1).

The dust grain evolution into the slab was harder to get from these experiments. We can already say that dust contained into slab ice don't accumulate on the surface and would rather 'sink' into the slab since dust would preferably absorb light compared to CO_2 ice, warm and sublimate the ice around and sink with the same phenomenom that we observe on terrestrial glaciers.

Conclusions

This preliminary study showed that thermal cracking of CO_2 slab ice can produce a strong increase of the reflectance (as high as 60%) and mimic the Martian CO_2 photometric behaviour during spring. This value is consistent with the increase observed on Mars. We are currently developping a way to get a more quantitative estimation of the grain size variation of the polycristalline ice during sublimation with optical techniques and radiative transfer modeling. Furthermore, the evolution of dust into the slab will be reinvestigated.

References

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