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Experimental simulation of the condensation and metamorphism of seasonal CO_2 condensates under martian conditions.

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Abstract

An experimental set-up, CARBON-IR, has been developed in order to perform the condensation and metamorphism of CO_2 condensates in various controlled martian conditions at, or out of, equilibrium. The sample texture is monitored and near-infrared reflectance spectra are recorded. We present a first set of experiments aimed to simulate the formation of compact translucent slabs by condensation of CO_2 gas, the metamorphism of CO_2 snow, as well as their sublimation.

1. Introduction

The understanding of the microphysical processes occurring during the condensation, metamorphism and sublimation of the seasonal condensates is requisite to correctly interpret their spectral and photometric evolutions during their whole cycle, as recorded by numerous in-orbit instruments. GCMs also need to include these processes to better represent their effects on Mars's climate and on the spatio-temporal ices distribution. Bright CO_2 snow/frost as well as compact and translucent layers (slabs) have been detected in the seasonal deposits by spectro-imagers (OMEGA, CRISM). The later are suspected to be at the origin of geysers and spiders. How solid CO_2 form and evolve at the surface of Mars is still an open question. It can form as snow in the atmosphere and precipitate, or directly as frost or ice at the surface, with varying grain sizes, texture as well as thermal and radiative properties. The possible evolution pathways between these forms are even less understood.

2. CarboN-IR setup

An experimental set-up, CarboN-IR, has been developed in order to better understand the conditions of formation and evolution of the different seasonal condensates on Mars, their associated textures as well as their spectral and radiative properties. This setup allows us to simulate the condensation and metamorphism of CO_2 condensates in various controlled martian conditions at, or out of, equilibrium.

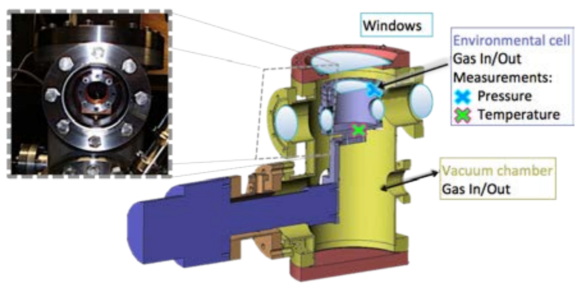

Figure 1: Schematic of the CarboN-IR setup. Insert: picture of the cell from the side window.

It is mostly made of a large (6 x 8 cm) and almost isothermal environmental cell cooled by a temperature controlled closed cycle cryostat (40-300K). The temperature and pressure inside the cell are controlled and accurately measured. Composition, amount and flux of gases are controlled by a thermodynamic system (pressure gauges and flux controller). Top and lateral windows allow us to observe the sample texture. The whole system is placed inside our spectro-gonio radiometer to allow bi-directional spectral measurements from 0.4 to 4.8 µm.

Different types of samples can be formed either ex-situ and placed in the call or in-situ with different substrates (ice, minerals, …).

3. CO_2 snow metamorphism

A CO_2 snow sample with ~50% porosity and 10µm grain size was formed ex-situ and placed in the cell at -125°C. Its evolution was monitored during 6 weeks.

A progressive formation of compact and translucent slab from the bottom was observed. It occurred by sublimation-recondensation of CO_2 through the snow porosity due to the weak vertical thermal gradient.

Figure 2: Progressive evolution of the slab after 13, 17, 21 and 43 days.

The slab is made of compact polycrystalline ice with rounded grains less than 1mm in size.

4. CO_2 condensation

In-situ formation of CO_2 ice was obtained by direct condensation under pure CO_2 atmosphere and a flow of about ≤ 6 cm^3/min, typical of Mars winter condensation rate. The progressive growth of a compact, transparent slab with large columnar grains (few mm wide) was observed. Its final thickness was 24 mm in 26 days.

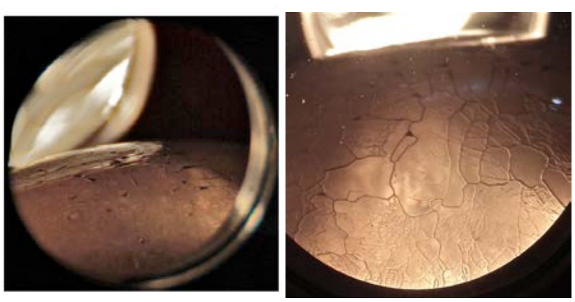

Figure 3: CO_2 slab formed by direct gas condensation.

When non-condensable gas (air) is injected in the cell the formation of transparent and compact ice stops and coarse grained frost (few mm grains) starts to grow. After removal of the non-condensable gas CO2 condense in the porosity of the frost and the slab formation restart.

Figure 4: coarse grained CO_2 frost formation under a non-condensable atmosphere

5. Thermal stresses

When subjected to thermal stresses the compact slabs cracks. Contraction generate random cracks, while dilatation trigger the opening of grain boundaries, thus strongly increasing the scattering behaviour of the slab.

Figure 5: effects of positive (left) and negative (right) thermal stresses on a CO_2 slab.

5. Application to Mars

These different formation and evolution processes can be applied to Mars observation to try to understand the formation and microphysical evolutions of CO2 ice/snow on Mars during the various stage of condensation/sublimation of the seasonal deposits.

Acknowledgements

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References

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