EPSC Abstracts
Vol. 12, EPSC2018-548, 2018
European Planetary Science Congress 2018

CO_2 ice morphologies under Martian conditions

G. Portyankina (1), J. Merrison (2), J. J. Iversen (2), Z. Yoldi (3), C. J. Hansen (4), K.-M. Aye (1), A. Pommerol (3), N. Thomas (3)
(1) Laboratory for Atmospheric and Space Physics, University of Colorado, USA, (2) University of Aarhus, Denmark, (3) University of Bern, Switzerland, (4) Planetary Science Institute, Arizona, USA

Abstract

We have used the Aarhus Wind Tunnel Simulator II (or AWTSII [1]) in the framework of Trans-National Access opportunities within the EuroPlanet Research Infrastructure to experimentally study CO_2 ice deposition under conditions similar to those expected in the Martian polar areas. We have found that under Martian conditions, CO_2 ice most readily deposits as slab ice while under slightly lower temperatures ($T <= 125$ K), CO_2 ice deposited as crystals. The type of the substrate (machined aluminum or regolith) did not significantly alter the morphologies of the deposited ice.

1. Introduction

CO_2 is the main constituent of the Martian atmosphere and the main component of the seasonal polar caps on Mars. Martian climate is controlled by the state of CO_2. More specifically, the areas where the seasonal cap forms every fall and sublimes every spring are directly affected by the CO_2 ice and how it interacts with the surface and atmosphere. For understanding physics of these interactions and to adequately analyze remote-sensing data of CO_2-covered surfaces, knowledge of CO_2 ice properties is essential. However, important properties are unknown either completely or partially.

Among others, the crystalline structure and morphologies of CO_2 ice formed under Martian conditions are currently poorly investigated. CO_2 crystalline structure is known to be cubic, thus the possible range of morphologies of the CO_2 crystals can be hypothesized. However, which of these are to be realized on the Martian surface or in the atmosphere must be determined experimentally.

2. Experimental setup

AWTSII is a large cylindrical vacuum chamber (2.1 m inner diameter, 10 m length, volume 38 m^3) housing a recirculating wind tunnel. For this project we have developed and used a specialized cooling plate (35 × 50 cm) cooled by liquid nitrogen, separately from the chamber cooling system, for improved thermal uniformity and stable temperature of the upper surface.

We monitored temperatures inside the chamber and on and around the cooling plate by a set of thermoresistive temperature sensors. We used 2 USB microscopes inside the AWTSII to image the structure of CO_2 ice.

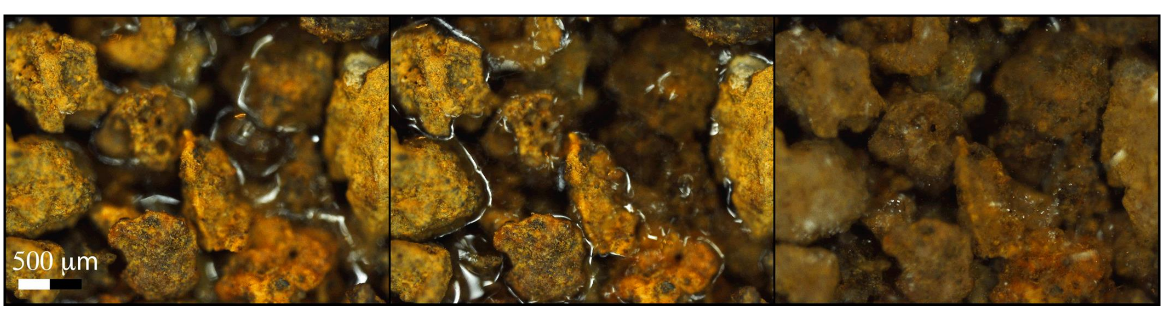

Figure 1: Sequence of microscopic images taken while CO_2 ice deposits in a form of slab ice under Martian conditions. From the left to middle frames CO_2 fills in the voids between the regolith particles. The right frame shows regolith completely covered by the ice.

During the experimental runs, AWTSII was first evacuated to below 0.5 mbar. Then the cooling plate was cooled to a selected target temperature, and then CO_2 gas was introduced into the chamber. We investigated ranges of temperatures and pressures similar to those in Martian polar areas and observed the physical state of the created CO_2 ice layer. Previously, we had reported on the results of experimental runs when CO_2 ice was deposited directly on the top surface of the cooling plate, i.e. on the machined aluminum substrate [2]. During the most recent campaign in April 2018, we aimed to investigate how (if at all) the substrate on which ice deposits influences the crystalline structure of CO_2 ice. We have used Martian regolith simulant (JSC Mars-1) as the surface to deposit CO_2 ice on instead of the surface of the cooling plate. We spread 2 monolayers of JSC on the top of the cooling plate and monitored deposition of CO_2 under the same conditions that were previously investigated and reported in [2].

3. Results

During our experimental runs we have observed several different textures of CO_2 ice. In previous tests, during the deposition directly on the brushed aluminum surface, we have identified that under Martian conditions the CO_2 ice deposited preferably as slab ice – continuous highly translucent polycrystalline form of the ice. In the most recent tests, we have confirmed that this stays true when CO_2 deposits on the regolith (Fig. 1). The ice starts depositing in-between regolith grains and fills in the pores in upward motion. The ice formed over the regolith layer is highly translucent and retains its translucency better than the ice formed on the aluminum surface because it is less prone to thermal cracking. We attribute this either to the decreased scale of thermal expansion and contraction of the regolith layer compared to the aluminum plate or to regolith acting as an insulating layer and reducing temperature variations that reach the ice layer from below.

Additionally, we have investigated P-T conditions slightly outside of typical Martian surface ranges. For example, at T = 120-125 K and P = 1 – 30 mbar we have previously observed unconventional "triangular" CO_2 crystals not previously reported in the literature. It is possible that we have observed preferential growth of one of the crystallographic planes of the more complex CO_2 crystalline structures, like hextetrahedral. Our most recent tests showed that the regolith substrate did not considerably alter the deposition pattern under these P-T. We have observed occasional cubic and octahedron crystals, but the most prevailing shape is shown in Fig. 2. These crystalline forms of CO_2 are thicker, i.e. less dense and opaque.

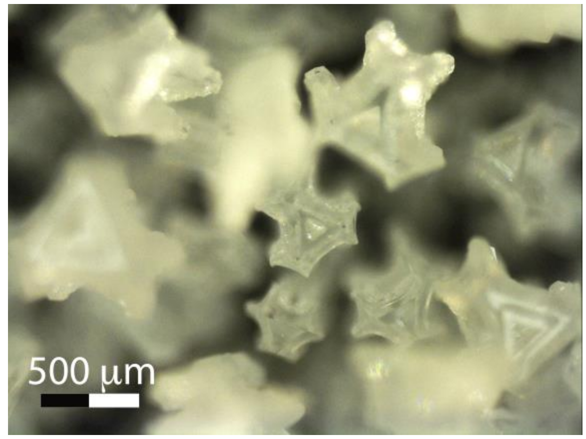

Figure 2: Microscopic view of CO_2 crystals shapes deposited at T = 120-125 K and P = 1 – 30 mbar.

4. Conclusions

The substrate did not considerably alter the deposition morphologies of CO_2 observed in our previous work. CO_2 deposits as a slab under Martian conditions. Under colder temperatures and lower pressures, CO_2 crystals assume shapes that we best can describe as hollow triangular prisms. These CO_2 crystalline morphologies require further investigation, because of their relevance to Martian CO_2 cloud formation.

Acknowledgements

This project is supported by the Trans-National Access opportunities within the EuroPlanet Research Infrastructure grant agreement No 654208. The team from the University of Bern is supported through the Swiss National Science Foundation and through the NCCR PlanetS.

References

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