SEASONAL EVOLUTION OF SURFACE CO_2 ICE ON MARS: PHYSICAL PROCESSES AND IMPACTS ON SURFACE PROPERTIES. C. Pilorget[1], F. Forget[2], C.S. Edwards[1] and B.L. Ehlmann[1,3], [1]California Institute of Technology, 1200 E. California Blvd., MC150-21, Pasadena CA 91125 USA, [2]Laboratoire de Météorologie Dynamique, CNRS/UPMC/IPSL, Paris Cedex 05 France, [3]Jet Propulsion Laboratory, Caltech, Pasadena CA USA (cpilorge@caltech.edu).

Introduction: Every year in fall/winter, atmospheric CO_2 condenses on the surface of Mars, forming seasonal polar caps that gradually sublime in spring. This process involves up to 30% of the atmosphere and covers large areas, poleward of ~45° of latitude (and even closer to the equator on pole facing slopes). Therefore the caps' seasonal/long-term evolution (and stability) has a large impact on the radiative budget of the planet and on the atmosphere dynamics and pressure.

Over the last few years, critical results obtained from observations and numerical models have revealed that cap evolution is governed by complex and exotic physical processes with no equivalent on Earth [1-8].

Controls on CO_2 ice condensation and sublimation processes: CO_2 condenses on the martian surface through radiative cooling, resulting in the formation of a CO_2 ice slab, with potential inclusions like dust, water ice and CO_2 snow. The condensation/sublimation processes and quantities are governed by energy deposition/emission in the CO_2 ice as well as in the underlying regolith. The fraction of light reflected vs. absorbed (in the ice and the underlying regolith) is hugely dependent on variation in CO_2 ice properties, with inclusions exerting a strong influence, even at the ppm level (Fig 1). In particular CO_2 ice transparency in the visible spectral range results in the transmission of a large fraction of the incident light when the CO_2 ice slab is very clean (Fig 1 and [2,5]).

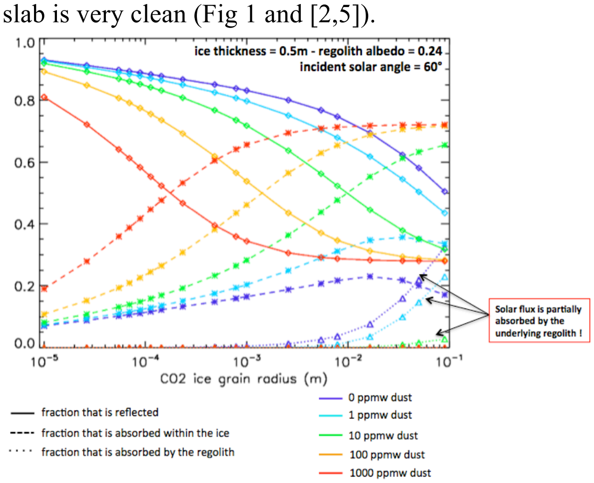

Fig 1. Evolution of the interaction between a CO_2 ice layer and the solar flux as a function of CO_2 grain radius and dust contamination. The overall albedo of the ice changes a lot with the ice properties.

Remote sensing data show these properties are both spatially and temporally variable [3,8], which leads to a rich variety of evolutionary paths.

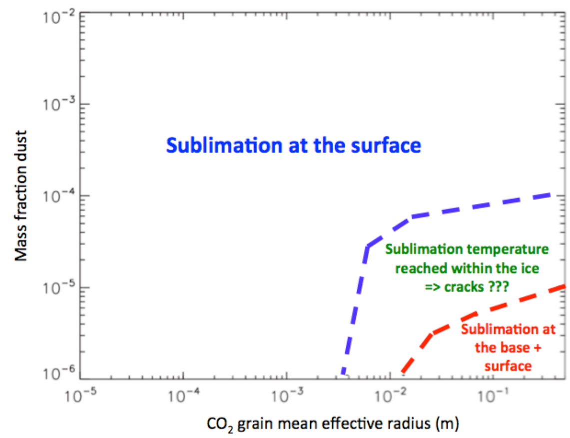

Fig 2. Different behaviors of the CO_2 ice depending on effective grain size and dust content. Simulations were run on a flat terrain at -85°lat.

Cold jets and the formation of dark spots: Models have shown that when the CO_2 ice has specific properties (ice grain size greater than ~1 cm and low dust content, see Fig 2), a large fraction of the solar light is absorbed by the underlying regolith, which warms up and basal sublimation occurs [5]. Clean CO_2 slab ice, leading to basal sublimation, is quite common on Mars [3,9,10] and leads to dramatic surface features. When the sublimated CO_2 gas trapped under the ice finds a path to the surface, it is ejected and can carry with it regolith-type material. Dark spots then form on top of the CO_2 ice slab. These exotic features have been detected in large areas of the seasonal polar caps at various latitudes, both in the northern and in the southern hemispheres [11-14]. The timing of material ejection initiation depends mostly on the ice properties and the incident solar flux (through latitude and slope) [5]. These ejections appear to occur at multiple occasions during a first phase that results in the darkening of the surface. In a second phase, no significant regolith-type material is ejected, until complete defrosting occurs [7]. During winter, CO_2 ice condenses again on atop the regolith, repeating the cycle of basal sublimation and ejection during spring.

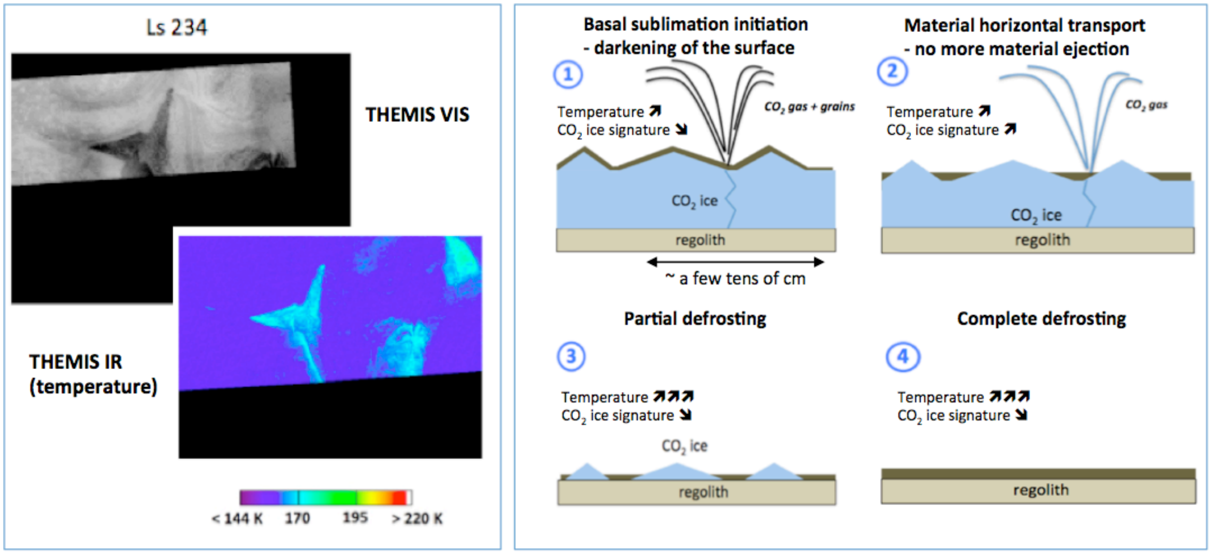

Fig 3. Left: THEMIS visible image of the Starfish area at Ls 234 (top) and corresponding THEMIS temperature map (bottom). The dark areas correspond to high concentration of dark spots and the "warm" areas on the temperature map. This result is consistent with the presence of material on top of the CO_2 ice. The thickness of the material can be estimated by coupling these observations to numerical thermal models. Right: sequence of material ejection/ defrosting during spring, inferred from THEMIS/CRISM observations [7].

CO_2 ice related processes and their impact on the Martian surface: Coupled NIR and TIR observations (e.g. Fig 3) have revealed that a few hundreds of microns to a few mm of regolith-type material cover the CO_2 ice around the ejection points [7]. Part of this material can also be spread over larger areas, with a potential impact on the defrosting rate.

This important annual material transport can have an important impact on surface properties. Numerous depressions (a.k.a "spiders", see Fig 4) over the polar areas have been reported [13-15]. A potential mobilization and redeposition of the finer fraction of the regolith has also been suggested by [7], which would lead to surface homogeneization and possibly hiding bedrock surface at high latitude.

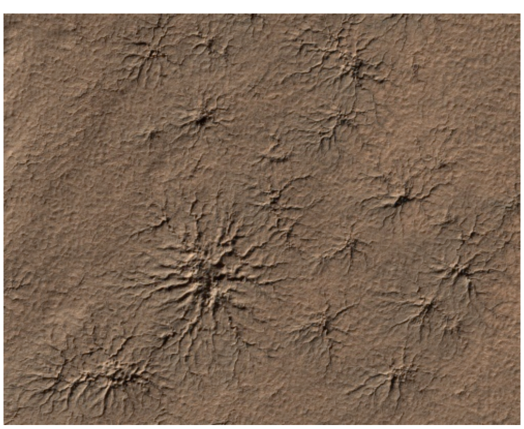

Fig 4. HiRISE visible image of an area situated at 87°S lat, 86.5°E. Depressions (a.k.a "spiders") cover the entire area.

Conclusion and open issues: The CO_2 ice seasonal and long-term evolution is a critical aspect of the evolution of Mars, with important implications for the atmospheric and the surface properties. Exotic processes have been highlighted here and could be involved in various geological as well as climatic processes. Future work should include experimental study to better understand the physics of the different processes, coupled to numerical modeling and observations analysis.

Understanding the present-day processes will help us to better assess the processes at stake during the evolution of Mars. In particular, the question of the long-term evolution and stability of the CO_2 ice reservoirs (at the surface or buried), with critical implications for the evolution of the surface pressure, remains open.

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