SEASONAL POLAR CAPS OF MARS IN SPRING: COLD JET ACTIVITY OBSERVED BY MRO'S HiRISE AND CRISM. G. Portyankina[1], C.J. Hansen[2], N. Thomas[3], K.-M. Aye[4], A. Pommerol[3], [1]Laboratory for Atmospheric and Space Physics, 3665 Discovery Dr., 80303, Boulder, Colorado, USA, [2]Physikalisches Institut University of Bern Sidlerstrasse 5, CH-3012 Bern, Switzerland, [3]Planetary Science Institute, St. George, Utah, USA, [4]UCLA, Los Angeles, CA, USA.

Introduction: There has been significant progress in recent years in the observation of the small scale seasonal phenomena on Mars. This is mainly associated with high resolution observations made using the Mars Reconnaissance Orbiter (MRO) instruments HiRISE [1] and CRISM [2]. Since its orbit insertion at the beginning of 2006, these instruments have conducted 4 southern and 4 northern polar spring observational campaigns. Each of these campaigns has provided information about temporal evolution of the seasonal volatile layer and its composition.

Seasonal polar caps extend from the poles equatorward to 55^o in latitude. The seasonal layer consists mainly of CO_2 ice mixed with H_2O and airborne dust in unknown and spatially and temporary varying proportions. The solid CO_2 forms a transparent slab of ice which coats conformally the surface. In early spring when, after a polar night, the Sun rises above the horizon, dark fans are visible on top of the seasonal layer. They consist of dark mineral dust and have high contrast against the underlying CO_2 layer. In many locations fans and so called spiders are seen in the same – dendritic features carved in the surface with 2-4 m scale depth. In some locations fans originate not from point sources but rather from linear sources. These are cracks in the slab ice through which the gas is able to escape. [3] described the hypothesis for the process that creates the fans and connects them to spiders. The working hypothesis is that the fans originate from cold jets of CO_2 powered by solar radiation via a solid-state greenhouse effect. The sunlight in visible wavelength range penetrates through a translucent CO_2 ice layer and warms up the underlying substrate. When the temperature reaches sublimation temperature of the ice, pockets of pressurized gas start to form and eventually the ice slab cracks or breaks when the gas pressure underneath it becomes too high compared to the ice yield strength. While moving underneath the ice slab escaping gas erodes away the surface little by little every year. After multiple repetitions this leads to the formation of the dendritic spider patterns.

Observations: We have investigated the details and general feasibility of this hypothesis in a series of papers that included modeling of the involved phenomena [4, 5], observations by high-resolution imaging [6, 7] and spectroscopy [8, 9]. Below we present a summary of the main finding of this work.

Spring evolution: Sets of observations taken weeks and sometimes days apart in early local spring have helped us clarify fan development and given clues about the outgassing process. The observations reported in [4,7] point to the very early onset of the first activity: for example at latitude of 82^{o}S dark fans are visible as early as at L_s = 171^o. This indicates that only a small energy input is needed to initiate activity. Computer modeling has been able to reproduce early onset of the activity using realistic parameters [4].

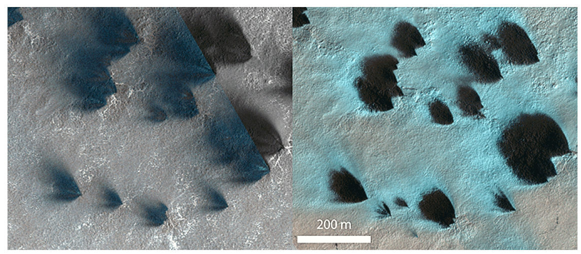

Fig 1: An example of early spring changes in appearance of fans in location Ithaca (lat = -85.2°, lon = 181.1°) at L_s = 181° and 194°. The colors are stretched to achieve maximum contrast for highlighting the bright fans.

Later in spring dark fans change: they often extend in length and width indicating either continuous or repeated outgassing. In several locations new fans appear later in spring starting from the common source with earlier fans but pointing to the different direction. The directions of fans are probably moderated by near-surface winds. The observed variability in fan directions offers some support for climate models that predict highly variable winds during local spring in polar areas.

The question if jet vents stay constantly open or can re-seal after an eruption is important for modeling of the jets. Several possible explanations for the observations of repeated or continuing outgassing alternateve to re-sealing were listed in [12]. Re-sealing can provide a possibility for the pressure underneath the ice to reach higher values and hence produce taller and more energetic jets. However the mechanism to create the seal is debated. Nighttime CO_2 condensation and sintering of the CO_2 slab at slightly higher than equilibrium temperature are the possibilities, however we have relatively poor understanding of the mechanical behavior of CO_2 slab ice under martian polar conditions. Experimental works towards measuring physical properties of this particular type of ice have been carried out, however they are in early stage. [10 and references therein].

Bright fans: Several of the locations exhibit bright bluish fans in addition to the dark dusty fans but only at particular times in spring. The creation mechanism of the bright fans remains somewhat uncertain. Observations showed that the bright fans appear later in spring and are fresh CO_2 ice. The initial hypothesis for their creation was that they are formed by the CO_2 snow deposited from adiabatically expanding gas after it exits a vent. However, jet modeling does not support snow deposition from the jets [5]. In addition the shapes of bright fans closely mimic shapes of the dark fans that existed at the same location before. This indicates some kind of surficial phenomena for the creation of the bright fans caused by interaction of the fan material and underlying CO_2 ice.

Surface reflectivity changes: Not only fans but also the surface in-between shows changes in spring. [9] showed that the surface reflectivity steadily increases in most observed areas until reaching the maximum sometime around Ls =240° depending on the location. CRISM data show that this brightening is correlated with the increased signal for surficial CO_2 ice. It indicates a process that cleans up the uppermost ice layer either by removing dust (e.g. by aeolian processes) or by dust being warmed up by the sunlight, sinking down into the ice layer and leaving behind clean CO_2 on the top, visible layer. Similar brightening of the volatile layer was also observed by the OMEGA instrument [11].

South-North differences: Somewhat surprisingly, the spring processes in the southern and northern seasonal polar caps are more similar than was at one time thought. Despite the differences in elevation, average pressure and substrate properties, both hemispheres exhibit dark and bright fans, cracks in the ice, and surface brightening. Seasonal activity in the north differs from that in the south in three main ways: 1) the fans are smaller in size, hinting at less powerful outgassing This may possibly be caused by a thinner slab layer. Alternatively, the northern hemisphere is wetter and hence has a lower proportion of CO_2 to H_2O ice in the seasonal layer compared to the south. This possibly adds to the surface brightening in the northern hemisphere, and inevitably increases the opacity of the ice layer. 2) The activity in the north is concentrated on the polar erg dunes. It is most probably connected to the low albedo of dunes that helps absorb more sunlight and thereby creating high enough basal gas pressure. 3) Spiders are only found in the south. The explanation for this is: in the north activity is concentrated on the dunes, in summer all the signs of erosion signs will themselves be erased by the movement of loose dune material. We have observed clearly the results of the CO_2 gas erosion on northern polar dunes in the shape of furrows (small channels) [6].

Small scale topography: The original view was that the main vent of each spider (and hence jets and fans) is created in the center of the spider, i.e. in the vicinity of where all its troughs come together and gas flows from all sides are directed towards this vent. After multiple observations of several years we are convinced this is not the case at least under current climatic conditions. Most vents (as evidenced by the source positions of fans) do not appear near spider centers. They tend to be located on/near the sides of spider troughs, around boulders or close to changes of slopes of dune (i.e. at the apexess or near the base). In [8] it was explained that small topographical features concentrate sunlight more efficiently in early spring and thus provide more energy for outgassing. They also provide weak points in the ice layer because they serve as disturbance for ice deposition.

Connection to surface erosion: We are routinely investigating summer images from different martian years in search for changes that might be the result of active erosion by the outgassing. After 4 years, we are yet to see one in the southern hemisphere. This must mean, that cumulative changes due to this erosion is smaller than the spatial resolution of HiRISE, i.e. less than 0.5 m per 4 years. However, in the northern hemisphere multiple furrows were detected and linked to solid state greenhouse phenomena. Most probably this is because mobile dune material in the north is much more easily to erode than the inferred cemented regolith in the south.

Conclusions: CRISM and HiRISE spring observations of the seasonal caps provide close-up views on active seasonal polar phenomena. The observations and the modeling results support the basic concept that geyser-like eruptions are driven by the solid-state green house mechanism acting on CO2 slab ice and have added many specific details about the processes involved.

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