HiRISE Views of the Sublimation of Mars' Southern Seasonal CO_2 Cap. C. J. Hansen[1] , C. Okubo[2], A. McEwen[2], Shane Byrne[3], E. DeJong[1], K. Herkenhoff[3], M. Mellon[4], P. Russell[5], and N. Thomas[5], [1]Jet Propulsion Lab, Pasadena, CA 91101, [2]University of Arizona, Department of Planetary Sciences, Tucson, AZ 85721, [3]USGS, 2255 N. Gemini Dr., Flagstaff, AZ 86001, [4]University of Colorado, Boulder, CO, [5]Physikalisches Institut, Universitaet Bern, Schweiz.

Introduction: Southern spring on Mars has just come to an end. The High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconaissance Orbiter (MRO) carried out a major observing campaign to image the sublimation of the seasonal CO_2 cap. High resolution snapshots of a number of different types of south polar terrain were collected. The ability of MRO to point off-nadir enabled repeated temporal coverage with a variety of frequencies of a number of locations. The selected locations supported investigations judged to benefit in particular from the high resolution and high signal to noise ratio of the HiRISE camera.

Science questions investigated: What is the nature of the spots and fans observed by MOC [1] on the surface of the seasonal cap? Do the dust fans (clearly blown by the wind) start from a patch of bare ground or is the dust lofted from below a translucent ice layer by "geysers" similar to those observed on Neptune's moon Triton? Are the spider-like channels conduits for escaping gas? How does the nature of the terrain affect the sublimation process? What is the timing of CO_2 defrosting on different terrains at HiRISE resolution?

Campaigns: HiRISE studies of the seasonal sublimation of the southern cap began in December 2006, winter in the southern hemisphere. Southern spring started February 8, however sublimation of the seasonal cap begins even before local sunrise. HiRISE imaged a variety of locations repeatedly to study the evolution of the spots and fans that develop as the cap sublimates. A number of locations in the cryptic terrain, a region of the southern cap that remains cold enough that CO_2 ice must be present, in spite of the relatively dark albedo [2,3], were imaged. The areas of the seasonal cap studied by HiRISE have been given in some cases colloquial names: Inca City, Manhattan Island, Ithaca, Oswego, four "spider targets", Giza and Starfish.

Eight targets were selected to look for geysers. These eight targets are in the cryptic terrain in locations where spidery channels and fans of dust have been observed by MOC, and THEMIS coverage has shown rapid changes [3]. The "geyser" hypothesis that we wanted to test with HiRISE was originally proposed by Kieffer [2] and is summarized as follows: a layer of translucent CO_2 ice forms during southern winter. In the spring sunlight penetrates the clear ice, warms the CO_2 underneath, trapping gas under pressure, which then is explosively released, entraining fine dust particles. The dust is sprayed up into the atmosphere and carried downwind by the prevailing winds. Our approach was to attempt to detect dust plumes by acquiring stereo images separated by a very short time interval. Near the pole the orbit groundtracks are closely spaced allowing us to image a given location with just one orbit (~2 hour) separation. Any geyser-like activity should be detectable in stereo images as a plume rising above the surface. The hypothesis that every spot is a site of gas jets [3,4] implies that the probability of catching a geyser in action is very high.

The goal of studying the sublimation process in a variety of terrains and in particular understanding the role of seasonal volatiles on landscape evolution drove other imaging campaigns to observe the Russell Crater dunes, Richardson dunes, Finger Lake, and an area called the caterpillar, repeatedly through the season. Images were taken of gullies in craters to discern the location and role of seasonal volatiles in gully modification.

Results: The sublimation process of Mars' southern seasonal cap is not a simple gradual disappearance of ice. The sublimation process is quite active and dramatic changes are seen on very short timescales.

Every spring fan-shaped wind streaks appear on Mars' seasonal cap. Their overall orientation is determined by the seasonal wind field and local topography. During this season the wind direction is driven by the sublimation mass flux and Coriolis effects in the Ekman layer [5]. Theoretically the dominant direction changes rapidly from east to west between Ls = 180 and Ls = 220. Changes in wind direction are illustrated in Figure 1a and Figure 1b in a region known as Ithaca.

These two images were taken 106 hours apart. Fans are seen to start and lengthen. Fans from a single point go in multiple directions, reflecting the changes in direction of the local wind. Bright streaks are observed, and may be condensed frost rather than dust. Water vapor would be expected to condense immediately when it encounters the cold ambient atmosphere. CO_2 could be the frost, however then all plumes should be bright.

Figure 1. Ithaca images PSP_002622_0945 and PSP_002675_0945, acquired 106 hours apart, show dramatic changes in the color, morphology, and extent of the fans. Images were taken on Ls = 185 and 187.

Channels are ubiquitous and exhibit a variety of morphologies. They appear bright relative to their surroundings in early images, then darker as the season progresses and the overlying frost sublimates. It could be that bright frost deposited early in winter interior to the channels is covered by, but does not anneal into, the translucent ice layer covering the cryptic terrain. Based on MOC images it has been suggested that complex channels emanating from a central depression, dubbed ”spiders”, could be formed by escaping CO_2 vapor being channeled to a vent [6]. Our high resolution images only partially support this hypothesis. Figure 2 shows a “classic” spider with a dark center source of dust.

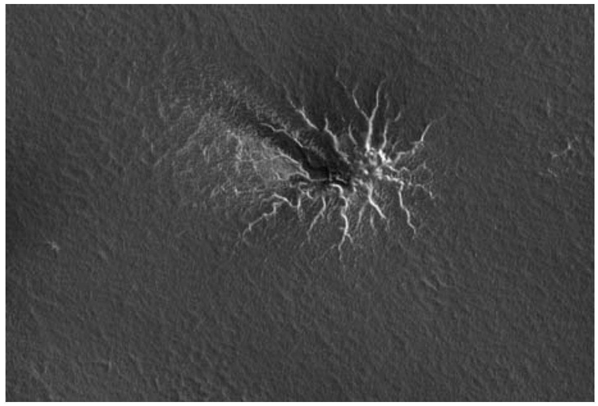

Figure 2. Spider target PSP_003087_0930 is a “classic” example of a cluster of channels radiating out with a dark spot emanating from the center and dust blown downwind.

Generally however at high resolution the channels are seen to be interwoven much more than simply radially. Regions known to have spidery channels are observed at HiRISE resolution to have channels so dense that they look more like lace than spiders, as shown in Figure 3, taken in a region known as “Manhattan Island”.

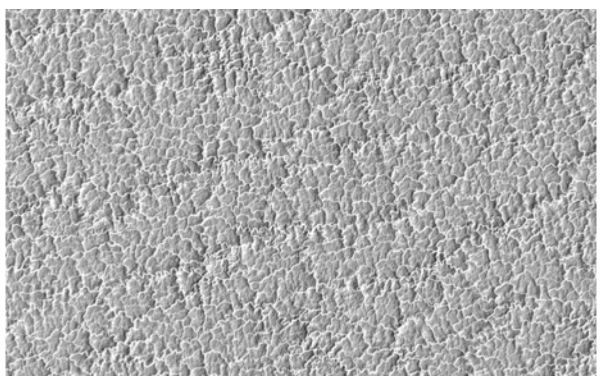

Figure 3. A subset of image PSP_002651_0930 taken in “Manhattan Island” shows a thicket of channels, more like lace, not radially organized.

Figure 4 shows that dust fans do not necessarily emanate from the center of radially organized channels. It may be that in the regions exhibiting the most dense tangle of channels the pressure of escaping CO_2 does not build up but rather hisses out along a number of cracks. Entrained dust is then spread out along a wider area. This thin layer of dust lowers the overall albedo of the cryptic terrain. The quantity of dust in some places is enough to cover the channels fairly deeply. In Figure 4 fans are observed to obscure the underlying channels, sometimes as a very thin layer, sometimes very thick.

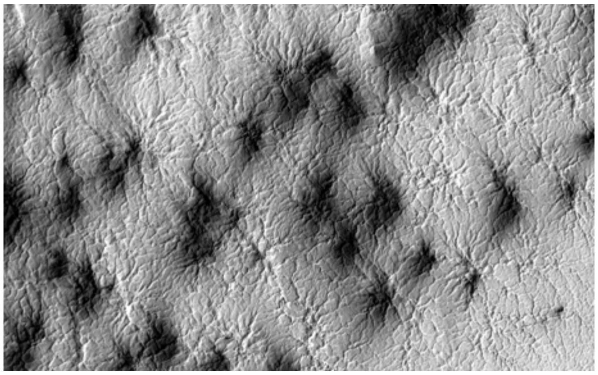

Figure 4. A subset of image PSP_002651_0930 taken in "Manhattan Island" shows dust obscuring the underlying channels with varying degrees of thickness.

At one location in the Manhattan Island region, using our stereo imaging technique, we may have captured a geyser in the process of eruption. It is a tenuous detection at best, very near the limits of the camera capability. The putative plume is not high above the surface (< 10m high) and is optically very thin. In stereo small bumps on the surface can be observed that may be the site of other gas jets. Figure 5 shows the bumps and small fans that may be the initiation of the gas release. They show up in stereo as small localized slightly elevated areas on the surface. Figure 6 shows the fan we believe may be actively venting.

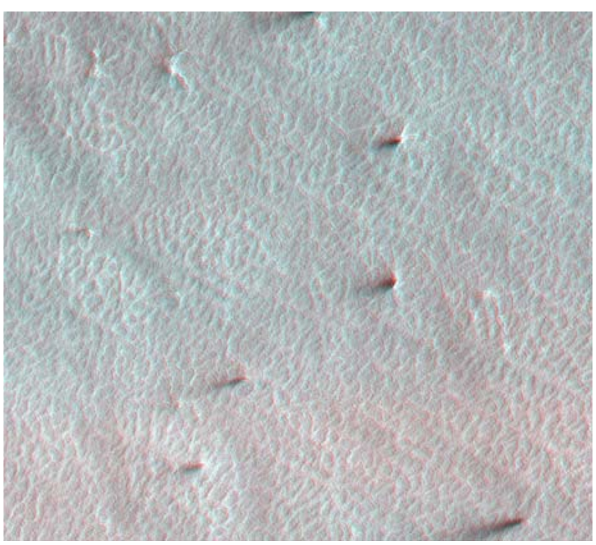

Figure 5. Bumps and small fans in this anaglyph of images PSP_002758_0945 and PSP_002759_0855 (taken 2 hours later) may show the initiation of gas jets releasing pressure built up below a layer of translucent seasonal ice.

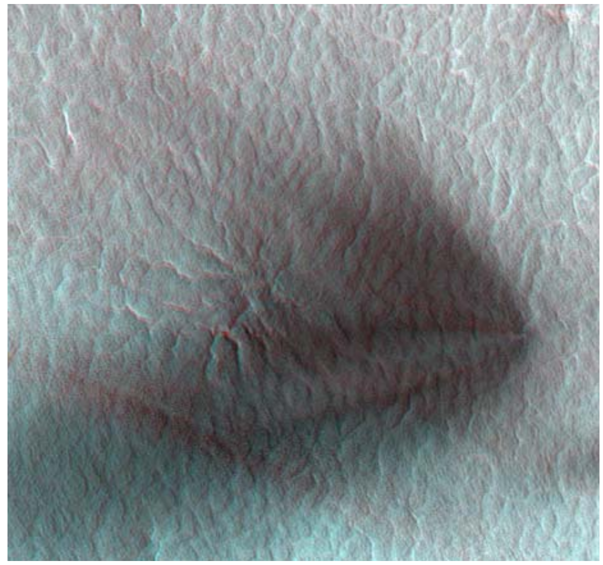

Figure 6. A possible geyser is captured in this anaglyph of images PSP_002758_0945 and PSP_002759_0855 (taken 2 hours later). Features on the surface match between the two images, while parallax will cause a plume above the surface to shift, visible as a very narrow red streak and a very narrow blue streak both emanating from the same point. This is still a tentative identification at this time, with more work to be done to verify this interpretation.

The region known as Inca City exhibits a variety of phenomena, which evolve through the spring season. In Figure 7 fans and spots are seen to be associated with boulders, implying that boulders warm their immediate surroundings and initiate sublimation.

Figure 7. Image PSP_002868_0985 of Inca City shows boulders associated with the onset of sublimation, thermally affecting their immediate surroundings.

Russell Crater dunes. The Russell crater dune field at -54 latitude features a large "megadune" ~500 m high, with slopes of 8 – 10 deg. The existence of gully-like channels is not consistent with the more general hypothesis for gully origins which invokes subsurface aquifers. Other theories include meltwater from ground ice or CO_2 liquid flow, at high martian obliquity [7, 8].

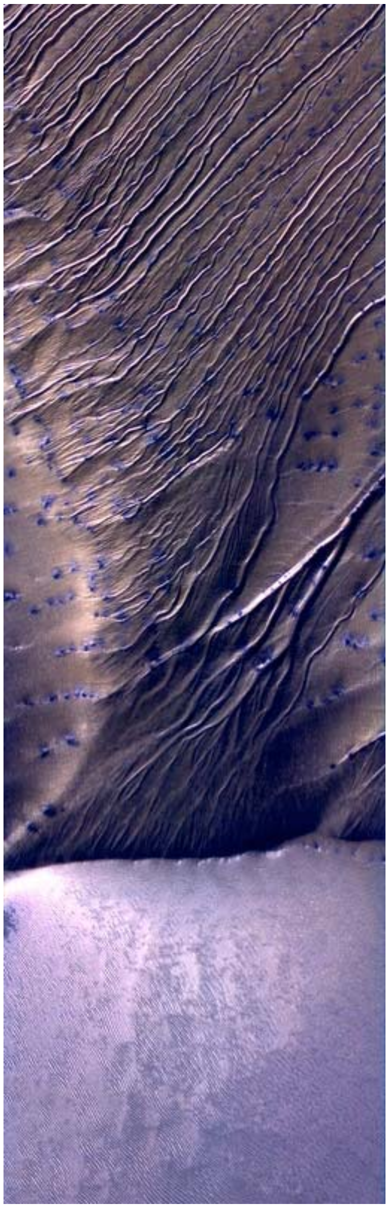

Figure 8. The Russell crater megadune imaged in PSP_001440_1255.

HiRISE high resolution color data suggest another possibility: seasonal CO_2 jets associated with sublimation of the seasonal frost which covers the dunes yearly. If the dunes experience the same explosive release of CO_2 gas as seems to be the case in the cryptic terrain, this may be enough force to dislodge loose sand grains on a steep slope. As shown in Figure 8 the HiRISE color data show "geyser spots" on the Russell crater megadune, associated with the alcoves of many of the gullies, and dotted along their downhill path. This could also explain the lack of a fan at the termination of the channels.

Note: HiRISE has 10 red CCDs in a row, to image a swath 6 km wide at 300 km altitude. Two blue-green (~536 nm) and two near-IR (~874 nm) CCDs are offset just above and below the two center red (~692 nm) CCDs. (See McEwen [9] for a detailed description of the camera.)

References: [1] Malin, M. and K. Edgett, (2001) JGR 106:23429-23570. [2] Kieffer, H., (2000) LPI Contribution #1057. [3] Christensen, P., (2005) EOS Trans. AGU 86(52) P23c-04. [4] Kieffer, H., (2006) accepted for publication in JGR. [5] French, R., and P. Gierasch, (1979) JGR 84:4634-4642. [6] Piqueux, S., S. Byrne, and M. Richardson, (2003) JGR 108(E8):3-1. [7] Mangold, N., F. Costard, and F. Forget (2003) JGR 108(E4):8-1. [8] Musselwhite, D., T. Swindle, and J. Lunine, (2001) GRL 28:1283–1285. [9] McEwen, A., *et al*, (2006) JGR, in press.