NEW ADVANCES IN UNDERSTANDING NORTHERN SEASONAL PROCESSES ON MARS. C. J. Hansen[1], S. Byrne[2], M. Bourke[1], N. Bridges[3], S. Diniega[4], C. Dundas[5], A. McEwen[2], M. Mellon[6], A. Pommerol[7], G. Portyankina[8], and N. Thomas[7], [1]Planetary Science Institute, 1700 E. Fort Lowell, Tucson, AZ, cjhansen@psi.edu, [2]University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ; [3]John Hopkins University/Applied Physics Lab, Maryland; [4]Jet Propulsion Laboratory/ California Institute of Technology, Pasadena, CA; [5]US Geological Survey, Flagstaff, AZ; [6]Southwest Research Institute, Boulder, CO; [7]University of Bern, Bern, Switzerland; [8]University of Colorado, Boulder, CO.

Introduction: Spring on Mars is a dynamic time at latitudes covered by seasonal CO_2 ice. Mars Reconnaissance Orbiter (MRO) instruments have observed four northern spring seasons, spanning Mars Year (MY) 29 – 32. With 4 years of MRO observations, we have learned that:

a. Sublimation activity is most dramatic on the north polar erg.
b. The Kieffer model developed for the south polar region works well as a framework also to understand spring sublimation-driven events in the north.
c. Morphological changes on the dunes happen in today's climate and are seasonally controlled; new alcoves and furrows form and are erased within time spans of 1 – 3 Mars years.
d. There is substantial interannual variability suggestive of regional storms.

Seasonal Sublimation Phenomena. The High Resolution Imaging Science Experiment (HiRISE) has imaged specific sites in the north polar erg with dense temporal coverage over spring and summer. As the seasonal CO_2 ice cap sublimates, a variety of phenomena are observed. Figure 1 shows a typical spring sequence [1]. Initially the dunes are covered by a layer of CO_2 ice ½ to 1 m deep. Polygonal cracks on the stoss side of the dune develop, allowing gas to escape. The interface between the dune and the ground below is also a weak spot that ruptures early in spring (L_s = 7 in this particular dune field). Dark dune sand entrained in the escaping gas falls in fan-shaped deposits on top of the seasonal ice layer.

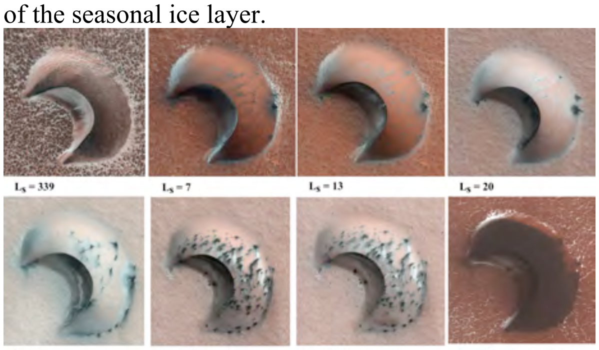

Figure 1. A classic barchan dune at 75.8N / 94.055E. South is up and illumination is from the upper right.

The Kieffer model, developed to explain seasonal activity in the southern hemisphere cryptic terrain [2], also forms a good framework for our understanding of northern seasonal processes. In this model penetration of sunlight through partially translucent CO_2 ice warms the surface below, which leads to basal sublimation of the ice layer. Polygonal cracking of the seasonal ice layer is predicted by models [3, 4], also lending support to the hypothesis of gas trapped under impermeable ice. The trapped gas escapes through ruptures at weak spots, entraining surface material which then settles out in fan-shaped deposits oriented by wind or slopes on top of the ice. Models show that escaping gas flow can produce fans 5–25 m in length [5].

A typical weak spot for ice to rupture is the crest of the dune, as shown in Figure 2. Slope streaks on dunes are dark sand that is mobilized and freed to slide down the slipface by the escaping gas associated with the basal sublimation of CO_2.

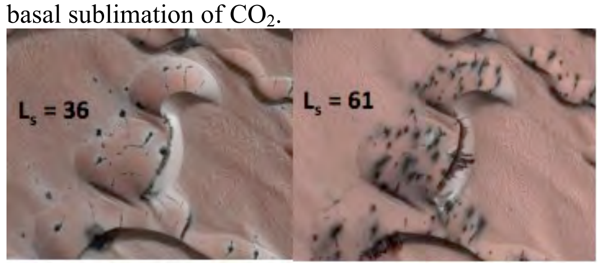

Figure 2. The ice at the crest of the dune thins rapidly, and when it ruptures sand is freed to slide down the slipface, as in this example from 84.7N / 0.7E. South is up.

Streaks are observed to appear and lengthen as the season progresses, guided by existing dune morphology. Figure 3 shows an example of these streaks of sand along with a dust cloud being raised by falling material. Dark streaks in both these examples occur very early in spring when CO_2 ice forms an uninterrupted cover, except at the localized vents where the ice has cracked allowing gas and sand to escape. The ambient surface and atmosphere temperature is buffered at ~145K, far too cold even for salt brines to flow.

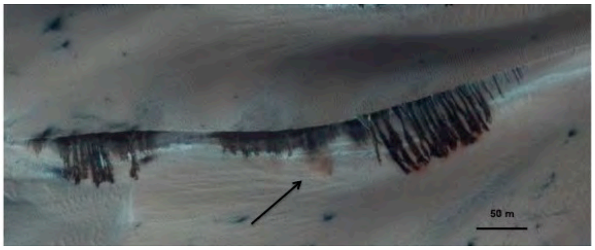

Figure 3. Slope streaks and a small cloud of dust (arrow) kicked up by falling material are captured in this sub-image of PSP_007962_2635, acquired at 83.5 / 118.6, L_s = 55.7. North is up.

Morphological changes on the dunes. Changes in dune morphology have been detected from one year to the next [6]. The sublimation process causes some of these changes, and the action of wind causes others. In the space of one Mars year we see new shallow furrows on the dunes (associated with seasonal gas flow), new alcoves (wind and mass-loading in the fall to winter), and alcoves being filled in with new ripples on aprons (wind).

Furrows. Furrows ~1 m wide [7] on dunes correlate to outbreaks of sand observed around the margins of dunes early in spring, as shown in Figure 4. The furrows act as conduits for the escaping gas. Some correspond to the location of the polygonal cracks on the stoss side of the dune. They are the northern equivalent of southern araneiform terrain ("spiders"), but they are ephemeral. Some can be identified in the same place from one year to the next, others are new. Sub-ice gas flow models predict speeds of 10 m/s, adequate to entrain 400 *u*m particles [8] and create the channels. Summer and autumn winds gradually fill the furrows back in.

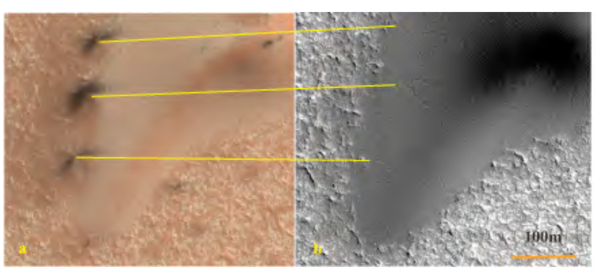

Figure 4. Furrows are shallow channels on the dune that terminate at the edge of the dune, and correlate to outbreaks of sand at the dune margin in the spring. This example from 80.0N / 122.5E compares (a) L_s 32.5, covered with ice, with (b) L_s 113.2, ice-free.

Alcoves. Comparison of ice-free images of the dunes between MY29 and MY30 revealed new alcoves that formed in one Mars year [6], shown in Figure 5. A campaign was undertaken in MY30-MY31 to identify when the new alcoves form, in order to establish whether they are wind-driven or caused by sublimation gas flow destabilization of the dune brink. The result, that large alcoves typically form in the fall-winter when we cannot image, suggests seasonal control. A possible scenario is that strong autumnal winds over-steepen the dunes, and then initial mass-loading of the crest as the condensed CO_2 builds up causes the sand to avalanche [9].

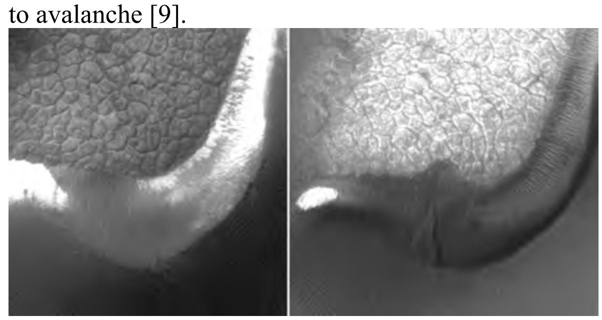

Figure 5. Comparison of PSP_008551_2830 and ESP_018275_2830 shows a new alcove and apron that formed in one Mars year.

Substantial interannual variability has been observed in alcove formation. At one study site 6x more alcoves formed in MY28-MY29 than between MY29 to MY30. At another study site 8x more alcoves formed from MY29-MY30 than from MY30 to MY31. Since the differences are in different Mars years it is likely that regional storms are implicated, rather than effects from the MY28 global dust storm [9].

Dune restoration, ripples and wind-blown frost. Ripples form on new debris aprons in less than a Mars year. Alcoves are erased in as little as 3 Mars years [1], indicating that wind plays an important role in transporting sand on the dunes and maintaining their pristine appearance. MRO's Compact Reconnaissance Imaging Spectrometer (CRISM) observations show that wind also re-distributes both CO_2 and H_2O frost in the spring [10].

References: [1] Hansen C. J. et al. (2012) *Icarus 225*, 881-897. [2] Kieffer H. H. (2007) *JGR, 112,* E08005. [3] Piqueux S. and Christensen P. (2008) *JGR, 113,* E06005. [4] Portyankina G. et al. (2011) *JGR*, *117*, E02006. [5] Thomas, N. et al. (2011) *GRL* 38, (8). [6] Hansen, C. J. et al. (2011) *Science, 331*, 575-578. [7] Bourke, M,. C. submitted for publication. [8] Thomas, N. et al., in preparation. [9] Hansen C. J. et al. (2014) submitted to Icarus. [10] Pommerol A. et al. (2013) *Icarus, 225,* 911-922.

Acknowledgement: This research was supported by NASA's Mars Reconnaissance Orbiter project.