HiRISE IMAGES AND INVESTIGATION OF NORTHERN SPRING ON MARS. C. J. Hansen[1] , S. Byrne[2], M. Bourke[1], A. McEwen[2], A. Pommerol[3], G. Portyankina[3], and N. Thomas[3], [1]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson 85719, cjhansen@psi.edu, [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, [3]University of Bern, CH-3012 Bern, Switzerland.

Introduction: Images have been collected by the High Resolution Imaging Science Experiment (HIRISE) on the Mars Reconnaissance Orbiter (MRO) of three northern spring seasons spanning Mars Year (MY) MY29 – MY31. The third northern spring campaign featured an earlier start and more complete temporal coverage than in earlier years at more than a dozen sites.

Most of the dynamic seasonal sublimation activity occurs on Mars' vast north polar erg. As the seasonal CO_2 ice cap sublimates a variety of phenomena are observed. The Kieffer model, developed to explain seasonal activity in the southern hemisphere cryptic terrain [1], appears to also form a good framework for our understanding of northern seasonal processes. In the Kieffer model penetration of sunlight through translucent CO_2 ice warms the surface below, which leads to basal sublimation of the ice layer. 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.

On northern dunes there are three weak spots where the ice typically ruptures, allowing gas to escape: a) Polygonal cracks form on broad expanses of ice such as stoss slopes [2, 3]; b) The crest of the dune is observed to be failure-prone - downhill shear stress from the weight of the dunes is usually balanced by friction with the underlying sand, however, if basal sublimation is occurring then the coefficient of friction may be reduced. At the top of the dune the weight of the ice acts downhill in diverging directions, which sets up tensional stresses in the ice at this location [4, 5]; c) The interface of the dune with the surface allows outbreaks around the edges, and the escaping gas carves shallow channels on the dune surface reminiscent of araneiform terrain in the southern hemisphere [4, 5].

Seasonal Phenomena: Figure 1 shows a classic sequence of sublimation on a barchan dune. Initially the dune is covered with a layer of CO_2 ice ~0.5m thick (Figure 1; L_s = 339 sub-image). Next the ice sheet shows polygonal cracking, and escaping gas carries material from the dune surface below (L_s = 7). Outbreaks of sand-laden gas occur around the edges of the interface with the dune to the ground (L_s = 7, 13, 31). Bright fans may form (L_s = 43). In some cases the slipface is destabilized and sand avalanching occurs [4]. We see this sequence repeated wherever there are barchan dunes, with a timing driven by the latitude and orientation of the dunes.

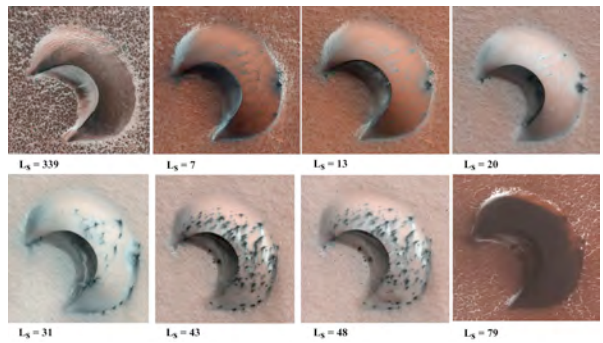

Figure 1. A classic barchan dune at 75.8N / 94.055E. South is up and illumination is from the upper right. [Figure is from reference 5]

Similarly Figure 2 shows a typical spring sequence on transverse dunes. The initial sub-image shows the scene covered with its layer of seasonal ice. Cracks form along the crest of the dune, releasing sand to slide to the foot of the dune, predominantly on the slipface but also on the stoss in this case. Polygonal cracks also develop in the less-sloped stoss sides of the dunes. When conditions are right bright fans form. The top of the dune is the first to defrost.

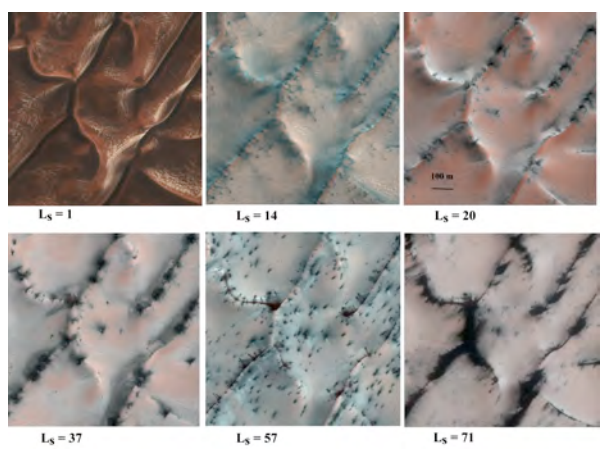

Figure 2. Transverse dunes at 80.22N / 217.1E. South is up and illumination is from the upper right [5].

Dune slipface orientation shows that winds blow primarily from the east at latitudes from 70N to 80N and from the west at latitudes from 80N to 85N [7, 8, 9]. We compare the sublimation sequence for these two dune field aspects. Since energy balance and the requirement of vapor pressure equilibrium drive volatile behavior through the season [6] it is informative to study insolation as a function of dune orientation (aspect angle relative to north). Insolation as a function of time depends on the slope and aspect of the terrain as shown in Figure 3.

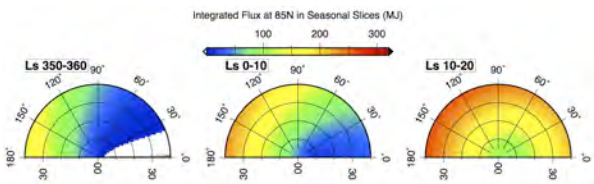

Figure 3. Integrated insolation is a function of slope (radial coordinate) and aspect (azimuthal coordinate, increasing to the east with north = zero). The time dependence of integrated flux is evaluated by comparing three periods in early spring. [5]

Model Predictions: Our energy balance model shows that when a dune becomes largely CO_2 ice-free turns out to be most dramatically dependent on orientation of the ~34^0 slipface. A dune with its slipface oriented north will defrost around L_s = 80-90, as shown in Figure 4, model predictions for when defrosting ultimately occurs. The whole dune defrosts in a narrow range of time. In contrast slipfaces oriented to the south may start to defrost as early as L_s = 45, while ice on the stoss side doesn't sublimate until L_s = 80. Most dunes in the north polar erg have an intermediate orientation.

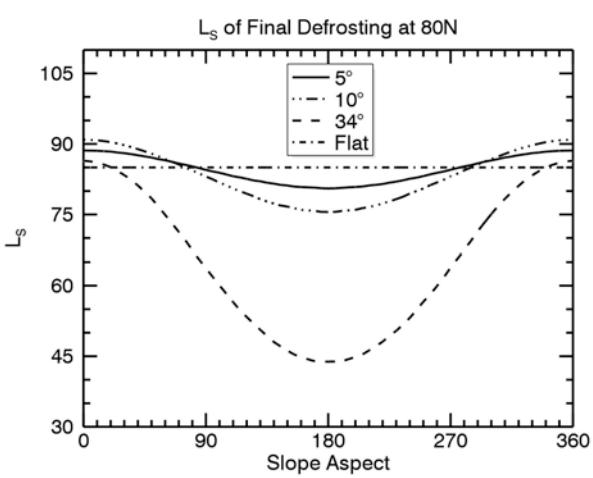

Figure 4. Model predictions for when final sublimation of the ice cover will occur show a large difference in time for dunes with slipfaces oriented to the south, while slopes on dunes with slipfaces oriented to the north tend to defrost almost all at once [5].

Comparison to data: Figure 5 shows a dune field with roughly southeast to southward-oriented slipfaces. The steep lee slopes and flat interdune expanses defrost before shallower north-facing stoss slopes.

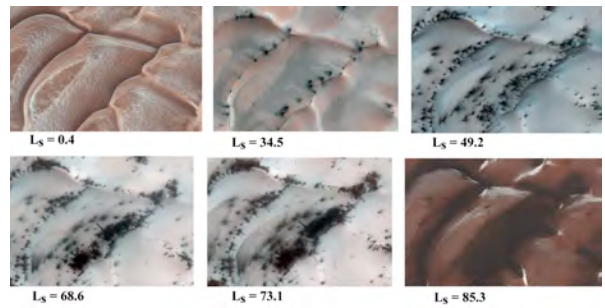

Figure 5. Dunes at 81.0N / 156.0E in a region known informally as "Zanovar". South is up and illumination is from the upper right. Each sub-image is 1.3 km across [5].

Interannual variability: A great deal of interannual variability has been observed across the three northern spring seasons, MY29 – MY31, observed. In particular, the second spring may have experienced "snowmageddon", with a thicker CO_2 layer, that featured a much later onset of seasonal sublimation activity. A different wind history as evidenced by fan length and direction is also observed between the three springs. Wind direction and depth of the seasonal ice layer may affect rates of morphological changes on the dunes such as shallow channel erosion and sand avalanches on the slipfaces, as well as when ice-free conditions are reached.

References: [1] Kieffer, H. (2007) *JGR, 112*, E08005. [2] Piqueux, S. and Christensen, P. R. (2008) *JGR, 113, (E8) 3-1*. [3] Portyankina, G. et al. (2011) *JGR, 117, E02006.* [4] Hansen, C. J. et al. (2011) *Science, 311, 575-578*. [5] Hansen, C. J. et al. (2012) *Icarus,* in press. [6] Leighton, R. B. and Murray, B. C. (1966) *Science, 153, 136-144*. [7] Tsoar, H. et al. (1979) *JGR, 84, 8167-8180*. [8] Ward, A. W. and Doyle, K. B. (1983) *Icarus, 55, 420-431*. [9] Coleman, S. J. and Hayward, R. K. (2011) *LPSCXXXXII, Abstract 1436*.

Acknowledgement: This research was supported by the MRO mission operated by JPL / CIT under a contract from NASA.