HIRISE OBSERVATIONS OF RECENT PHENOMENA IN THE NORTH POLAR REGION OF MARS. K. E. Herkenhoff[1], S. Byrne[2], C. M. Dundas[1], N. F. Baugh[2], and M. A. Hunter[1], and the HiRISE Science Team, [1]U. S. Geological Survey Astrogeology Science Center (2255 N. Gemini Dr., Flagstaff, AZ 86001; kherkenhoff@usgs.gov), [2]University of Arizona Lunar and Planetary Laboratory.

Introduction: The High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) has observed the north polar region of Mars during 8 summer seasons. Here we summarize analyses of the north polar data, focusing on active and recent processes including evolution of steep scarps in the north polar layered deposits (NPLD), bright and dark crossing streaks, and the north polar residual cap (NPRC).

Full-resolution HiRISE images are up to 20,000 monochrome pixels (~6 km) wide with color data in the central 4000 pixels [1]. Such HiRISE images of the north polar region at scales of ~30 cm/pixel show morphologic details and reflectance variations indicative of currently- or recently-active processes. The observations discussed here highlight the importance of both long- and short-term monitoring of north polar targets to further our understanding of time-variable phenomena in this region.

Steep Scarps: Initially recognized in Mars Global Surveyor data, steep scarps in the NPLD have been repeatedly observed by HiRISE. These scarps occur where the dark, basal unit is exposed to erosion, undercutting the more competent, overlying NPLD and causing mass wasting. Previous studies found that such rock falls occur primarily during late summer through early winter, and that the volume of wasted material is difficult to estimate [2]. Thermoelastic modeling indicates that extensional stresses are greatest in winter [3], generally consistent with the HiRISE observations.

Determination of the NPLD erosion rate at these steep scarps is complicated by differences in illumination and viewing geometry between HiRISE images of the rock falls. Planning repeat observations with nearly-identical observational geometry was difficult until we developed software to identify future opportunities for imaging targets with lighting and viewing geometry that is similar to a previously-acquired image. This new tool was used during the northern summer of Mars Year (MY) 34 to acquire images that, when paired with images taken earlier in the MRO mission with similar observational geometry, are better suited to measuring changes due to mass wasting. An example of such an "exact-match" image pair that includes clear evidence for wasting along a steep NPLD scarp is shown in Figure 1. The binned MY 28 (2006) image shows blocks at the base of the scarp that fell before the image was acquired; many of these blocks do not appear to have changed significantly in the 6 Mars years before the unbinned MY 34 (2018) image was taken, but blocks disappear in other areas.

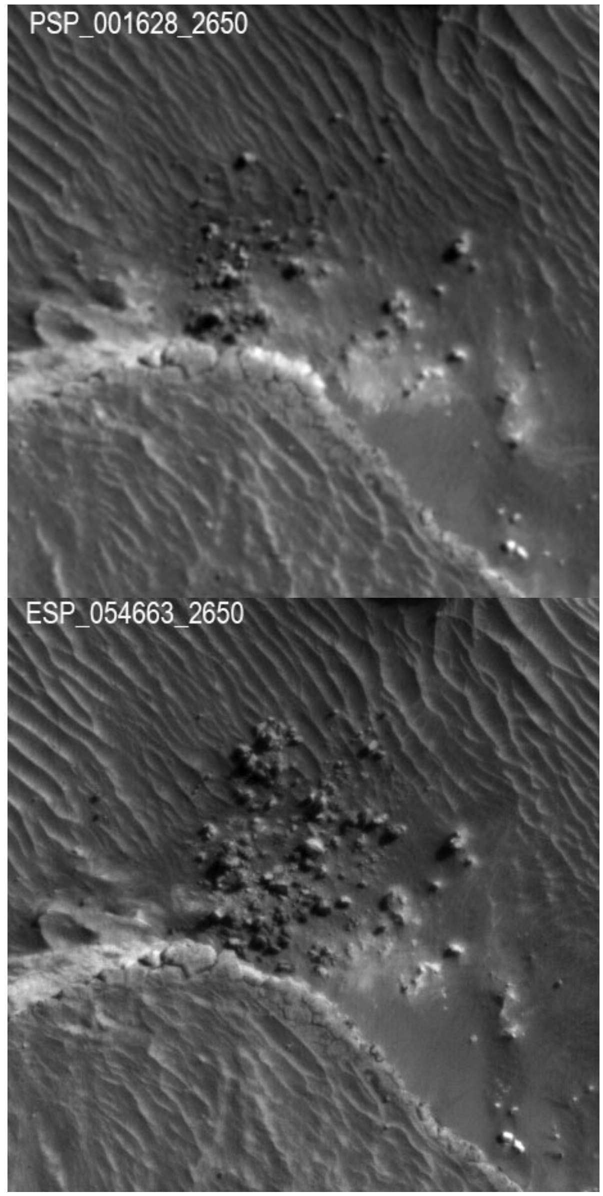

Figure 1. Subframes of red HiRISE images of a steep scarp in the north polar layered deposits at 85.1°N, 237°E. Illumination from upper right, area shown is about 147 m square. Top: PSP_001628_2650, acquired on 1 December 2006 (Mars Year 28, binned 2x2), L_s = 143.6°. Bottom: ESP_054663_2650, acquired on 25 March 2018 (Mars Year 34), L_s = 149.0°.

Another image of this scarp, ESP_019284_2650, was acquired in MY 30 at L_s = 144.6° and shows that a section of the scarp had already failed by that time. Blocks that appear near the base of the scarp in the MY 28 image were marked using ArcMap so that new blocks could be easily recognized in the later images: some of the older blocks have disappeared, as seen at other NPLD block falls. New blocks were outlined in each of the MY 30 and 34 images and their area measured. The lengths of shadows cast by 6 large blocks were measured in ESP_054663_2650 (solar incidence = 72.7°) and used to estimate the height of each block. The heights are similar to the radii of spheres having the same cross-sectional area as the blocks (standard deviation = 45 cm or 1.4 pixels), so we calculated the volume of each block as that of a half-sphere with the same radius as a circle having the same area as the block. The 0.02 to 37 m^3 range of block volumes derived using this approach is similar to that found along a similar NPLD scarp [4]. Ignoring unresolved blocks, the minimum volume of new blocks measured in ESP_019284_2650 is 538 m^3 and that of new blocks in ESP_054663_2650 is 1468 m^3. These volumes correspond to mass wasting rates of 0.08 and 0.1 m^3 per MY per meter along the NPLD scarp or 0.09 m^3 per MY over the 6 Mars Year span of these observations, somewhat less than the 0.3 m^3 per MY per meter rate found at another NPLD scarp [4]. We plan to make similar measurements at other locations where NPLD block falls have been observed in order to better constrain the average NPLD erosion rate.

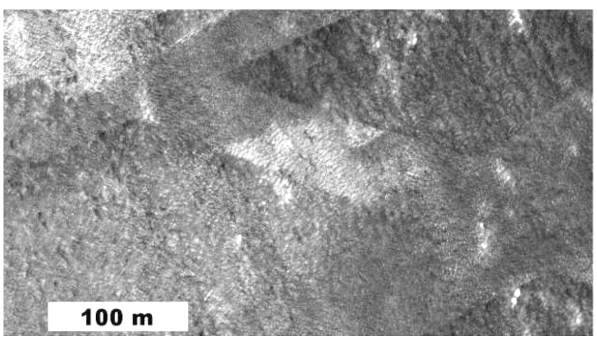

Figure 2: Subframe of red HiRISE image PSP_009273_2610, acquired at L_s = 100.3 in MY 29, showing complex streak superposition at 80.8°N, 330.6°E.

North Polar Streaks: Bright and dark streaks have been observed at the periphery of the north polar residual cap (NPRC) by previous Mars orbiters and were the target of repeated HiRISE observations. The complex interactions between overlapping bright and dark streaks in some of these HiRISE images (Fig. 2) indicate that formation of the streaks involves processes more complex than simply the emplacement of dark veneers. Bright and dark streaks are seen to evolve during the northern summer, evidence for active eolian redistribution of frost and perhaps darker (non-volatile) dust or sand. HiRISE color images do not include the area shown in Figure 2, but part of this area was imaged in color during MY 30. This and other color images of similar streaks show the red/blue ratio of the bright streaks is consistent with partial frost cover. While the color and albedo of the streaks are observed to change during the summer season and interannually, the surface texture does not, suggesting that mobility of dark, non-volatile material has a negligible effect on the underlying topography. The sharp boundaries of the streaks are similar to those seen along slope streaks in dust [5], perhaps formed by advancing clouds of saltating particles.

Residual Ice Cap: The NPRC on Mars has long been known to be composed of water ice [6]. Relatively dark patches observed within the NPRC during the summer indicate that the cap is thin or transparent in places. Counts of craters in MRO Context Camera (CTX) and HiRISE images indicate that the NPRC is accumulating at a rate that might result in observable changes in crater morphology during the MRO mission [7]. HiRISE and CTX images of the NPRC show few fresh craters. Therefore, a campaign of HiRISE observations of four NPRC targets near 87°N latitude (the maximum latitude of the MRO ground track) was initiated during the Martian northern summer of MY 29 (2008) and continued through the summer of MY 34. The images acquired during this campaign, with nearly nadir viewing geometry and similar solar azimuth, have been searched for evidence of current redistribution of NPRC material. Only minor albedo changes (no topographic changes) are observed in these areas. MY35 imaging is planned to continue to search for significant changes.

Summary: HiRISE and other MRO data show evidence for multiple types of ongoing activity in the north polar region, consistent with the apparent youth of the NPRC surface [7]. The latest HiRISE images of recently-active features will be shown and discussed at the conference.

References: [1] McEwen, A. S. *et al*. (2007) *JGR* **112**, doi:10.1029/2005JE002605. [2] Russell, P. S. *et al*. (2014) Eighth Internat. Conf. on *Mars,* abstract #1257. [3] Byrne, S. et al. (2014) Eighth Internat. Conf. on *Mars,* abstract #1373. [4] Fanara, L. *et al*. (2019) *Icarus* doi:10.1016/j.icarus.2019.113434 (in press). [5] Toyota, T. *et al*. (2011) *Planet. Space Sci*. **59**, 672-682. [6] Jakosky, B. M. and Haberle R. M. (1992) In *Mars* (H.H. Kieffer *et al.,* Eds.), pp. 969-1016. Univ. Arizona Press, Tucson. [7] Landis, M. E. *et al*. (2017) *LPSC* **XLVIII**, abstract #1588.