SEASONAL VARIATION IN VOLATILE ICES IN THE NORTH POLAR REGION OF MARS.

W. M. Calvin[1], P. B. James[2], and C. J. Hansen[3], [1]Dept. Geological Sci. MS 172, University of Nevada, Reno, NV (wcalvin@unr.edu), [2] Space Science Institute, Boulder, CO. [3]Planetary Science Inst., Tucson, AZ.

Introduction: Observations using the Mars Reconnaissance Orbiter (MRO) instruments have occurred over three martian years (MY) 28, 29, and 30, with MY31 just beginning. We have observed the seasonal cap recessions in both the north and south using MARCI daily global images and have examined the composition of selected units of the polar layered deposits using CRISM. CTX and HiRISE allow us to relate the composition to surface geomorphology of the deposits. Observations over multiple Mars years allows comparison between years, a detailed examination of exposed volatile ices and their variability, as well as exploration of longer term evolution of the high albedo deposits at the poles.

Northern Spring Recession: Spacecraft observations of the northern cap recession have been made using MOC, THEMIS, OMEGA, MARCI, and CRISM [e.g. 1-5]. Calvin et al. [4] presented seasonal cap recession movies as observed in both MY 29 and 30. Recession patterns observed in MY 30 are similar to those described for MY 29 [6]. Significant variability in the early season is noted in both years and the retreating seasonal cap edge is extremely dynamic. However, details of the high albedo deposit cover are variable between mars years. A related abstract at this conference [7] compares the cap recession curves from MARCI with previous observations.

As has been noted in both OMEGA [3] and CRISM [5] the retreating north seasonal cap has signatures of both water and carbon dioxide ices. The appearance of both frosts is spatially and seasonally dynamic, with some spatial patterns associated with surface topography or trough systems. In general, there is a water ice collar around the retreating seasonal cap edge that has been observed based on both temperature [2] and near-infrared ice features [3] and similar to that observed in the south [8] though larger in latitude extent. Appéré et al. [3] presented a simplified model to describe the evolution of water and CO_2 frosts in the retreating cap, but there is a good deal of spatial heterogeneity, suggesting local factors such as elevation, albedo, slope aspect and winds are all contributing to the mobility and evolution of polar volatiles.

CRISM has acquired a number of repeated observations of locations to monitor spring and summer changes. We here present results from examination of selected locations where multiple full-resolution targeted (FRT) observations have occurred. Figure 1 shows the location of these repeat spots and Table 1 summarizes the number of FRT images available and the range of Ls values at each site.

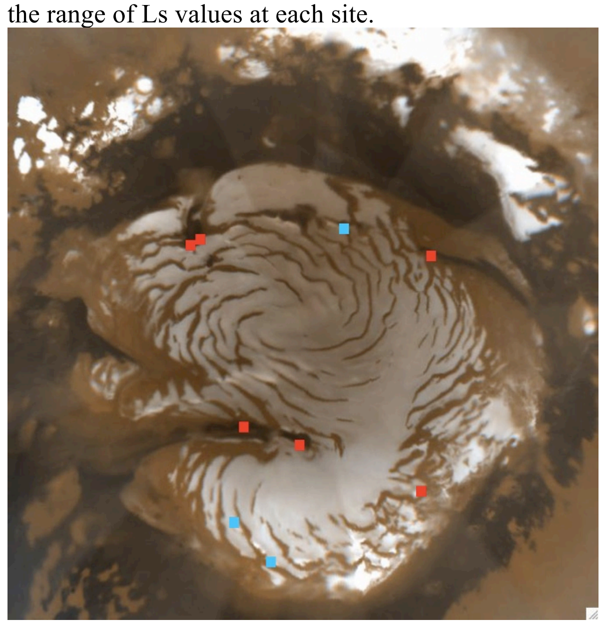

Figure 1. Locations of repeated CRISM FRT observations as outlined in Table 1. Red squares denote areas monitored from spring into summer and blue squares are areas monitored primarily for summer change.

Sites i through vi were selected for multiple observations spanning the spring recessional time frame. Several have observations in both MY 29 and 30. All sites were selected for reasonably clear atmospheric conditions, and the MARCI daily mosaics allow us to view average conditions during the time of acquisition. Only the very earliest Ls observations (before Ls 20) show uniform spectral coverage by CO_2 ice. Multiple locations show that mid-spring volatiles are a combination of CO_2 and water ice signatures, which may be a water layer over CO_2 as proposed by Appéré et al [3] or might be a thoroughly mixed surface of the two frosts together. These observations are dominated by small scale variation in albedo and band depth and don't exhibit strong band depth changes in any one scene. Mid to late spring observations are predominantly water ice in several locations, but suppression and flattening of the spectrum from 3 to 3.5 μm and subtle features near 2.3 μm suggest the presence of CO_2 ice. Site ix, chosen as a summer monitoring location shows only water ice (Ls 49.5) but later in the season (Ls 67) shows CO_2 ice in restricted locations. This suggests cold trapping based on slope aspect and possibly elevation. Retreating frost at site iii shows

CO_2 dominantly in defrosting dune regions (Figure 2). This would support the model that retreating H_2O exposes an underlying layer of CO_2, however, the CO_2 signature is only on one side of the defrosting dunes and in the highest albedo regions, again possibly suggesting cold trapping due to slope aspect. HiRISE image data exist for a number of these sites which will contribute to understanding the spatial distribution of various frosts.

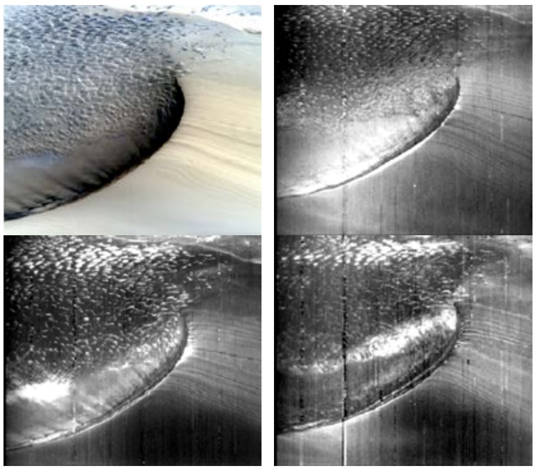

Figure 2: Evolution of CO_2 ice feature strength at site iii. Upper left: Visible false color at Ls 59.5, correspoding to the CO_2 band strength image in the lower left. CO_2 ice is not the brightest surface but appears somewhat bluer than other surfaces. B/W images are CO_2 ice strength after the method of [3]. Upper right: Ls 47.7, lower left: Ls 59.5, lower right: Ls 67.1

Northern Summer Variability: Calvin and Titus [9] first noted several sustained bright patches that repeated over multiple mars years as observed by TES. One of these patches dubbed "Vostok" was noted to erode in MY 28 [6], though the underlying, somewhat lower albedo surface still showed the strong signature of water ice. Additional locations were identified, primarily at the lower elevation margins of the high albedo deposits. These sites were monitored in MY 29 and 30 using FRT and HR(S,L) CRISM observations. Sites vii, viii and ix were selected to explore the summer variation in these locations as they have also been associated with fine-grained water ice late in the season [10]. Site vii shows variation in ice band depth (a proxy for grain size) over the summer and development of new thin deposits over the dark lanes. The last in the series shows a curious albedo inversion, and this was determined to be due to a thin atmospheric dust cloud seen in the MARCI image for the day of acquisition. CTX ride alongs for this series show albedo patterns similar to CRISM and potentially highlight sastrugi or other wind related forms on the upper mesas. The ice band depth appears to be an independent measure of ice content and is relatively independent of atmospheric conditions. Figure 3 shows evolution of ice band depth over time at this site.

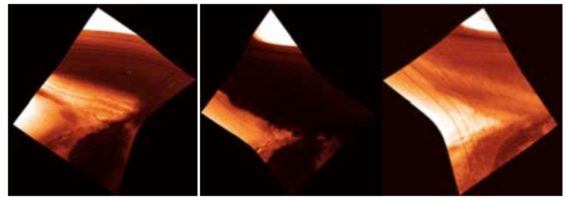

Figure 3: Evolution of ice band depth at site vii. Left: Ls 97, Middle: Ls 118, Right: Ls 152. Band depth of the 2.0 μm water ice feature. Brighter colors are stronger features in each frame, but the absolute scale is different in each scene. Ls 152 was acquired through a thin dust haze that inverts the optical albedo seen in both CRISM S and CTX images.

References: [1] James, P. B. and B. A. Cantor, Icarus, 154, p. 131. 2001. [2] Kieffer, H. H. and T. N. Titus, Icarus, 154, p. 162, 2001. [3] Appéré et al. JGR 116, doi:10.1029/2010JE003762, 2011. [4] Calvin, W. M. et al. 5th Mars Polar Conf #6077. [5] Brown, A.J. 5th Mars Polar Conf. #6060. [6] Cantor, B. A. et al. Icarus, 208 (1), pp. 61-81, 2010. [7] Dixon, E. M. et al. (this conference). [8] Calvin, W.M. and T. Z. Martin, JGR, 99 (E10) p. 21143, 1994. [9] Calvin, W. M. and T. N. Titus, PSS, 56, p. 212, 2008. [10] Langevin et al., Science, 307, p. 1581, 2005.

Table 1: CRISM FRT sites examined in this study.

Site	Location (lat, lon)	Description	FRTs	MY: Ls Range
i	83.77, -123.87	Olympia Rupes – Mesa Point	9	29: 14 – 123
ii	83.99, -126.55	Olympia Rupes – Scarp+Dunes	9	29: 29 – 95, 30: 46-77
iii	83.50, 118.69	Olympia Planum "Tail" – Scarp+Dunes	7	29: 29 – 64, 30: 51- 77
iv	84.81, -26.19	Chasma Boreale Dunes	4	29: 28 – 83
v	84.65, 1.0	Tenuis Cavus Dunes	10	29: 17 – 102, 30: 47- 79
vi	81.59, 37.36	Gemini Scopuli Scarp face	3	29: 20 – 141
vii	85.27, 156.73	Olympia Rupes	20	29: 87 – 152
viii	80.19, -17.73	Gemini Scopuli Mesa	4	29: 88 – 133
ix	79.00, -4.68	Gemini Scopuli Scarp Face	4	29: 85 – 89, 30: 49 – 67