MARTIAN H_2O ICE OUTLIERS MAY RESULT FROM WINTERTIME NEAR-SURFACE CO_2 SNOWS.

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Introduction: Analysis of MRO CRISM multispectral mapping data obtained during the late northern summer season on Mars (L_s = 130º-180º) has revealed small water ice deposits distributed throughout the northern plains at latitudes quite distant from the residual polar cap [1]. These outliers range in size from a few hundred meters to several kilometers, and are generally associated with the northward facing slopes of crater rims or other elevated landforms. In a few instances the ice deposits are located on the leeward (southeast-facing) sides of craters. The locations of these ice outliers suggest that their formation is linked to dynamic atmospheric-surface interactions during a season when the prevailing winds are out of the northwest, i.e. during the winter.

Hypothesis: The presence of these "ice patches" may indicate the presence of autumn or wintertime near-surface CO_2 snow formation from orographic lifting, which forms fine-grained CO_2 which then falls downwind from the craters. Since fine-grained CO_2 snow is typically brighter than the surrounding CO_2 ice, the snow sublimes more slowly during the spring than the surrounding CO_2 ice. Ultimately, only the CO_2 snow patch remains, forming a late spring cold trap and inducing an accumulation of water ice. The CO_2 snow finally sublimes, leaving a temporary H_2O ice lag, which can be observed in visible, near-infrared, and thermal infrared imaging. We test this hypothesis using observations from the Mars Global Surveyor (MGS), the Mars Odyssey (ODY), the Mars Express (MEX), and the Mars Reconnaissance Orbiter (MRO).

Data: This research primarily uses Thermal Emission Imaging System (THEMIS) thermal infrared (TIR) and visible images acquired by the Mars Odyssey Mission over the last three years (2004-2007) to locate possible H_2O ice patches during the northern summer. Our region of interest is the latitude band between 60ºN to 75ºN. Temperatures of ~145K indicate the presence of CO_2 ice, while temperatures between ~160 to ~200 are suggestive of H_2O ice, especially when the intermediate temperatures correspond to visibly bright patches [2,3]. The presence of surface volatiles can be ruled out when temperatures rise above 210K.

The MEX infrared imaging spectrometer (OMEGA) and the MRO Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) are used to spectrally confirm the presence of H_2O or CO_2 ices and to extend the temporal coverage of the ice patches.

MGS Thermal Emission Spectrometer (TES) observations are used to determine whether the summer H_2O ice patches correlate to locations of wintertime cold spot (CO_2 snow) formation [4, 5, 6].

Analysis: THEMIS TIR imaging provides the highest spatial resolution (10m/pixel) while still maintaining both nearly complete regional and repeat coverage. Visible imaging systems, such as THEMIS VIS often provide additional temporal coverage as well as confirming that intermediate temperatures (170K-200K) are also bright – indicating the presence of H_2O ice [2,3]. In the regions with CRISM coverage, the presence and composition of ices can be spectrally confirmed from absorption features at 1.435 µm (CO_2 ice) and 1.5 µm (H_2O ice) [7]. OMEGA observations, which are typically lower spatial resolution than either CRISM or THEMIS, also add additional spectral confirmation of ice composition and temporal coverage [8]. The combination of these data sets allows the identification and monitoring of these "ice patches" from the polar night, to their formation as outliers, and finally to their complete sublimation.

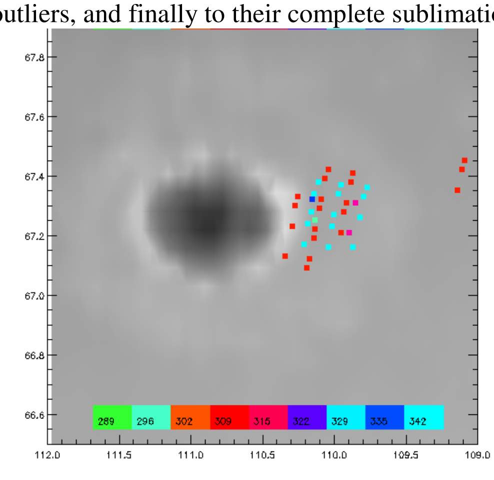

Figure 1: TES observations of cold spot activity downwind from the crater. The background image is a MOLA DEM while the colored squares indicate TES observations. The color indicates the season when the cold spot activity occurred.

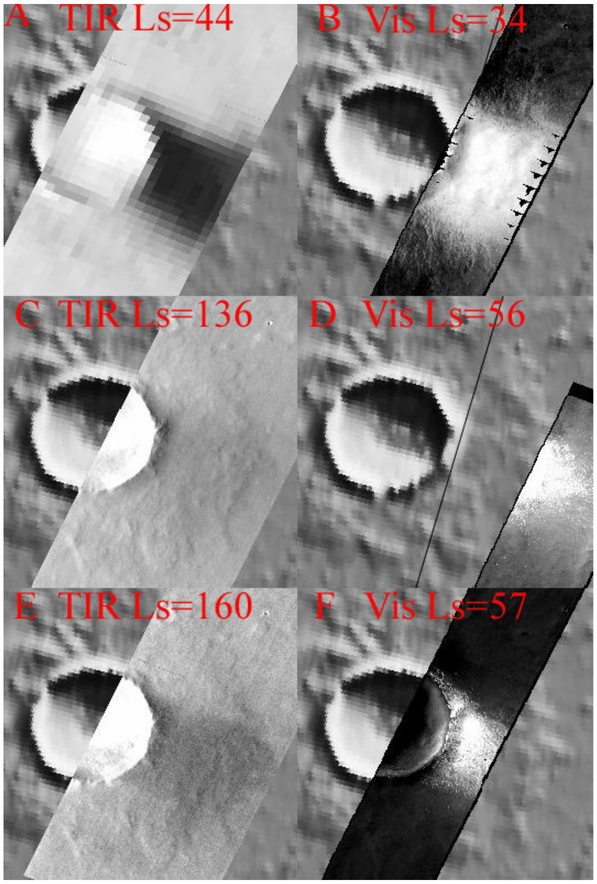

Figure 2: THEMIS Thermal infrared and visible time sequence for the ice patch located at 250.19ºE, 67.14ºN. (A) Thermal image I19350002, L_s 44 (April 2006) The dark (cool) area is at ~180 K and the surrounding area is at ~220K. (B) Vis Image V10739005, L_s 34.157, (May 2004), where the bright area is believed to be a patch of ice. (C) Thermal image I13497002, L_s 136.333 (Dec 2004). The dark (cool) area is at 205K while the surrounding warmer area is at 215K. No ice is present. (D) Vis Image V11338010, L_s 56.147 (July 2004). (E) Thermal Image I22420005. Dark area is at 190K and surrounding area is at 195K at L_s 160.646, date of the image is Jan 2007. (F) Vis Image V11363006, L_s 57.051 (July 2004).

Results: Our initial analysis clearly indicates a repetitive behavioral pattern for the “ice patches” found in the northern polar cap. Several “ice patches” can be seen forming during early to mid-spring and then disappearing in late spring to summer. Many of the “ice patches” that form near craters reoccur year after year.

The results for one ice patch are presented here. THEMIS observations of a crater located at 250ºE, 67ºN consistently show the formation of the “ice patch.” Figure 1 shows that CO_2 repeatedly forms east of the crater during the autumn-winter season. This (east) is the direction one expects for the prevailing winds. THEMIS observations (Fig 2) show the presence of an H_2O ice outlier as early as L_s 34°. This outlier persists at least until L_s 57°, but is gone by L_s 94° (Fig 3). While the ice is gone by early summer, a faint spectral signature remains, suggesting the possibility of interaction between the annual ice and the local regolith.

Summary: Here we have presented the time sequence of a single crater-ice-patch pair, demonstrating the correlation between winter CO_2 activity and late-spring H_2O ice patches. We will present the time sequence of several other crater-ice-patch pairs distributed throughout the northern polar region. We will compare our results to the Ames Mars General Circulation Model (GCM) in order to understand why some craters have ice patches and others do not.

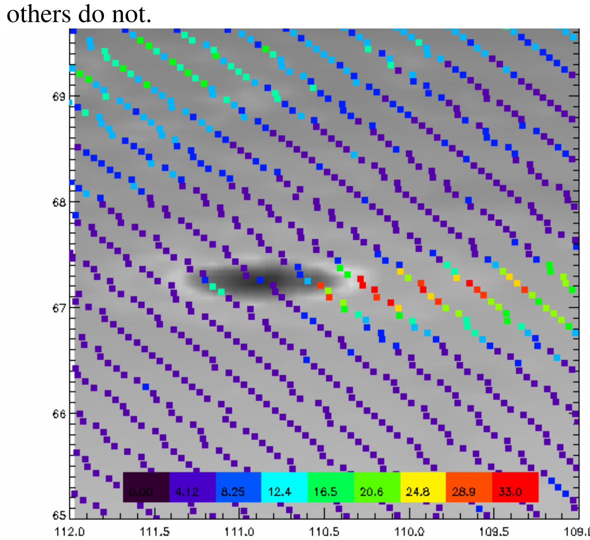

Figure 3: 1.5 µm banddepth OMEGA observations. There is a very weak spectral feature associated with the location of both the TES observations of cold spots and the THEMIS observations of the ice patch. Because the spectral feature is extremely weak, the ice is gone. However, the correlations between the various data sets suggest there is evidence that the annual ice patch has interacted with the surface regolith.

References: [1] Seelos, K. et al. (2007) *Fall AGU*, Abstract P24A-02. [2] Kieffer, H. H. and Titus, T. N. (2001) *Icarus, 154*, 162-180. [3] Titus, T. N. (2005) *GRL, 32*, L24204 [4] Titus, T.N. et al (2001) *JGR, 106*, 23181-23196 [5] Cornwall, C. and Titus, T.N. (2007) *LPSC XXXVIII*, 2391 [6] Cornwall, C. and Titus, T.N. (Fall AGU, Abstract P14A-02 [8] Schmitt, B. et al. (2005) Fall AGU, abstract P23C-02 2008), *GRL, submitted*
[7] Gondet, B. et al. (2006)