MARTIAN H_2O ICE OUTLIERS IN THE NORTHERN PLAINS. C. Cornwall[1,2] and T. N. Titus[2], [1]Northern Arizona University, Flagstaff, AZ 86001 (cc269@nau.edu), [2]U.S.G.S., 2255 N. Gemini Dr., Flagstaff, AZ 86001 (ttitus@usgs.gov)

Introduction: Observations from Mars Reconnaissance Orbiter (MRO) Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) multispectral mapping data during the Martian northern summer (L_s = 130º-180º) have revealed small water ice deposits present throughout the northern plains, far from the residual cap [1, 2, 3]. These deposits typically form on the northward-facing slopes of craters or other elevated landforms, which suggests that their formation is related to dynamic atmospheric-surface interactions during the winter when the prevailing winds are out of the northwest. Occasionally, the ice deposits are located on the east and southeast-facing slopes of craters.

Hypothesis: Water ice deposits that are located on the east and southeast-facing slopes of craters may indicate wintertime deposition of bright, fine-grained CO_2 frost due to orographic lifting [4]. Since fine-grained CO_2 snow is usually brighter than the surrounding CO_2 ice, the snow sublimes more slowly during the spring than the ice. Eventually, only the snow remains, forming a late spring cold trap and inducing an accumulation of water ice. When the CO_2 snow finally sublimes, a temporary H_2O ice lag is left behind and can be observed in visible, near-infrared, and thermal-infrared images. This hypothesis is tested using instruments onboard Mars Global Surveyor (MGS), Mars Odyssey (ODY), Mars Express (MEX), and MRO.

Data: To locate possible water ice patches during the northern summer, we use Thermal Emission Imaging System (THEMIS) thermal infrared (TIR) and visible images acquired by the ODY mission over the last three years (2004-2007). We restricted our region of interest to latitudes between 60ºN and 75ºN. Temperatures of about 145 K indicate the presence of CO_2 ice, while temperatures between 160 K to 200 K suggest the presence of H_2O ice, especially when the intermediate temperatures correspond to visibly bright patches [5, 6]. When temperatures rise above 210 K, the presence of surface volatiles can be ruled out.

MRO CRISM was used to spectrally confirm the presence of H_2O or CO_2 ices and extend the temporal converage of the ice patches.

MGS Thermal Emission Spectrometer data was used to determine a relationship between ice patches in the summer and wintertime cold spot (CO_2 snow) formation [7, 8, 9, 10].

Analysis: THEMIS TIR images provide the highest spatial resolution (100m/pixel) as well as extensive regional and repeat coverage. THEMIS VIS provides additional temporal coverage and confirms that intermediate temperatures (170 K – 200 K) are also bright, thus indicating the presence of H_2O ice [5, 6]. Where there was CRISM coverage, the presence of water ice could be spectrally confirmed using the 1.5 µm absorption feature.

Results: The majority of water ice deposits have a repetitive behavioral pattern, where they form during early-to-mid spring then disappear late spring to summer and they often reoccur year after year in the same location [4]. There is also evidence that a few water ice patches reform after disappearing in late spring and summer.

We present data for one water ice patch that formed during mid-spring and disappeared in late summer then reformed before the autumn season. Figure 1 shows that CO_2 repeatedly forms at 267ºE, 70.3ºN year after year to the east of a crater during late winter. This location to the east is consistent with the prevailing winds.

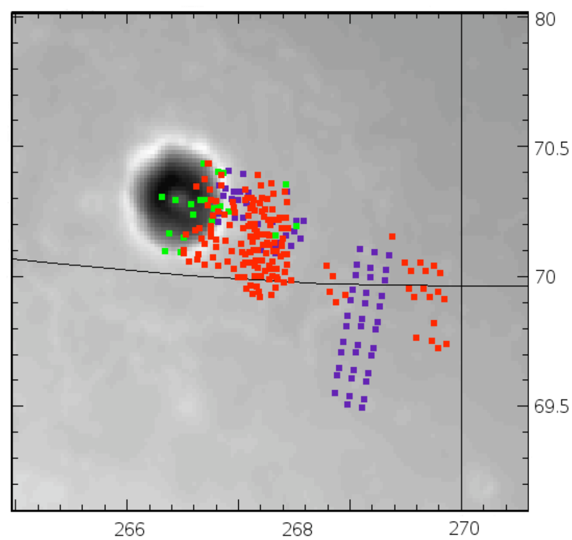

Figure 1. TES data showing CO_2 formation for three Mars Years (24, purple; 25, green, and 26, red). In all three years, CO_2 formation occurred during late winter between L_s 210 and 351.

Figure 2 shows the time evolution of the ice patch that formed in the same location during mid-spring with THEMIS TIR and VIS observations. Table 1 lists all THEMIS and CRISM coverage for MY 28 for the ice patch with temperature readings or a 1.5µm feature. The ice patch persists until mid-summer (around

L_s 141). CRISM data show that later in the summer season the ice patch reforms in the same location around L_s 160 and remains into the winter season around L_s 184 (Fig. 3).

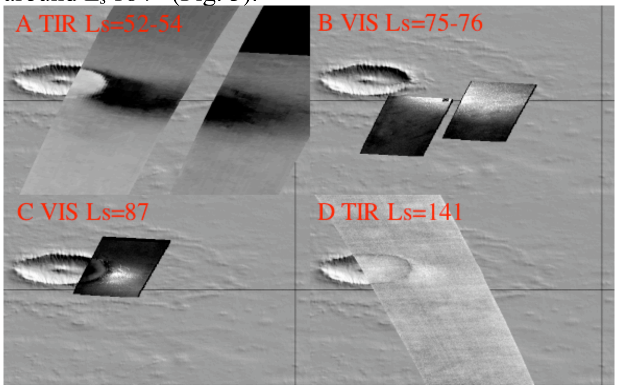

Figure 2. THEMIS Thermal-infrared and visible images showing the time evolution of an ice patch for MY 28 (May 2006). (A) TIR images I19574009 and I19624008, L_s 52 and 54, respectively. The dark (cool) area is ~190 K and the surrounding area is ~220 K. (B) Vis images V20223001 and V20248003, L_s 75 and 76, respectively, where the bright area is believed to be an ice patch. (C) Vis image V20560001, L_s 87, where the bright patch has significantly decreased in area and may indicate shrinking of the ice patch. (D) TIR image I21951002, L_s 141, where the ice patch is gone. The brighter area where the ice patch formally was is ~204 K and the surrounding area is ~200 K.

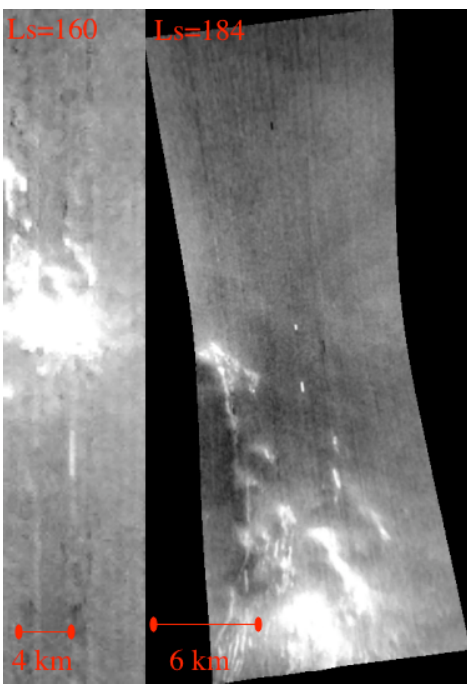

Figure 3. CRISM images MSP 3B84 and HRL 44AD for L_s 160 and 184, respectively. North is up. Images overlay 267°E, 70.3°N, where the CO_2 and mid-spring ice patch formation occurred. The bright areas indicate a positive identification for water ice at 1.5µm.

Table 1. All THEMIS and CRISM coverage of ice patch at 267°E, 70.3°N with Mars Year, L_s, and temperature data or presence of water ice.

Image ID	MY	L_s (°)	Ice patch (K)	Surroundings (K)
I19455034	28	47.9	149-154	165-172
I19480007	28	48.81	158-163	169-182
I19549010	28	51.33	195-198	201-213
I19574009	28	52.24	193-203	208-218
I19624008	28	54.05	181-183	197-217
V20223001	28	75.63	bright	
V20248003	28	76.53	bright	
V20560001	28	87.78	bright	
V20872003	28	99.17	bright	
I21396003	28	118.84	201-203	201-203
I21951002	28	140.82	203-205	198-205
I22238002	28	152.79	223-226	221-224
I22357005	28	157.91	221-226	221-226
I22407005	28	160.08	183-188	189-193
I22525002	28	165.26	171-174	171-174
I22550005	28	166.37	173-177	170-176
I22837008	28	179.4	160-167	160-167
MSP 3B84	28	160	H_2O ice	
HRL 44AD	28	184	H_2O ice	
MSP 7F69	28	273	no H_2O	

Summary: We have presented a time sequence using THEMIS and CRISM data for a single crater ice patch, showing the presence and later disappearance of water ice in late summer and subsequently the reappearance of the same water ice patch later in the season. We have also demonstrated with TES coverage the correlation between winter CO_2 activity and late-spring H_2O ice deposits. We will present a time sequence for other ice patches that form during late spring, disappear during the summer, and then reappear before autumn.

References: [1] Seelos, K. et al., (2007) Autumn AGU, Abs P24A-02. [2] Seelos, K. et al., LPSC XXXIX, Abs 1885. [3] W. M. Calvin et al., (2009) JGR, 114, CiteID E00D11 [4] Beitia et al., (2008) LPSC XXXIX, 1422. [5] Kieffer, H. H. and Titus, T. N., (2001) Icarus, 154, 162-180. [6] Titus, T. N., (2005) GRL, 32, L24204. [7] Titus, T. N. et al., (2001) JGR, 106, 23181-23196. [8] Gondet, B. et al., (2006) Autumn AGU, Abs P14A-02. [9] Cornwall, C. and Titus, T. N., (2007) LPSC XXXVIII, Abs 2391. [10] Cornwall, C. and Titus, T. N., (2009) JGR, 114, CiteID E02003.