

WATER ICE AND CARBON DIOXIDE ICE INTERACTIONS: CRATER INVESTIGATIONS IN RESIDUAL NORTH POLAR ICE CAP. M.A. Thueson and H. Xie, Earth and Environmental Science, The University of Texas at San Antonio, San Antonio, TX 78249, U.S.A. (misti.thueson@gmail.com) (Hongjie.xie@utsa.edu).

Introduction: The evolution of Mars is deeply tied to water. The Martian polar caps and their seasonal fluctuations are of great importance when trying to understand the Martian atmosphere. The CO₂/H₂O interaction is important to understanding the geological processes near the pole as well as the overall Martian hydrological cycle and climate. The Northern polar cap of Mars is covered with a seasonal ice cap. This ice cap is a mixture of water ice and carbon dioxide ice. The carbon dioxide ice layer waxes and wanes with the seasons. During the Martian winter and spring in the northern hemisphere the temperatures are cold enough that the CO₂ ice is solid. As the summer emerges the temperatures begin to rise, allowing the CO₂ ice to sublimate and uncover water ice in some areas [1, 2, 3]. The water ice that is found at the surface of the Martian planet is of great interest because it is the water that readily participates in the Martian water cycle and can be easily sampled by future robotic missions and later human missions [4]. These seasonal ice fluctuations and the associated high albedo deposits are the basis of this study, as seen in an unnamed crater located at 81°N/190°E and Inuvik crater at 79°N/331°E.

Methodology: THERmal EMISSION Imaging System (THEMIS) images retrieved from the NASA/Arizona State University data archive were the primary data source used. Both visible images and brightness temperature images were used. THEMIS is an instrument aboard NASA's Mars Odyssey spacecraft that has been orbiting Mars since February 2002. THEMIS's high spatial resolution (20 m) visual imaging system uses a 5-wavelength system and the infrared imaging system, with a resolution of 90 m, uses a 9-wavelength system [5,6]. Craters investigated were previously identified high albedo craters north of 70° N [7].

Results: The craters examined in this study are located at 81°N/190°E and 79°N/331°E. Both the unnamed crater and Inuvik crater are found outside of the perennial north polar cap.

One of the craters examined in this study is located at 81°N/190°E. This unnamed crater is found within the *Olympia Planitia* dune fields. This impact feature has a diameter of ~19 km and a depth of 0.92 km as measured using MOLA images [6]. The crater

cavity has a central peak that is equal in height to the area surrounding the crater (see Image1).

Available THEMIS data, both infrared and visible, is shown in Table 1. Images available spread throughout the Martian spring and summer. Visible images show a distinct center plateau. The visible THEMIS images (shown in Figure 1) show a decreasing albedo in the center plateau of the crater as the seasons progress from early spring ($L_s=12.690$) to summer ($L_s=126.509$). The first crater image in Figure 1 (ID 5) shows a very high albedo feature. As the seasons progress to early summer the carbon dioxide ice in the center begins to sublime, revealing the plateau foundation and leaving a small ice patch in the center. The valley of the crater becomes more distinct as the CO₂ ice sublimates. As summer progresses the walls of the crater, though above the temperature of CO₂ sublimation (as seen in figure 2), keep a high albedo. This would imply that the walls are water ice.

Inuvik crater has a diameter of 20 km and a depth of 850 m as measured using MOLA images. The crater cavity, as seen in the elevation profiles in Figure 1, has no significant central peak but more of a U-shaped cavity [7] with a small peak to the northwest.

Available THEMIS data, both infrared and visible, is shown in Table 2. Images available spread throughout the Martian spring and summer. The visible THEMIS images shown in Figure 2 are heavily shadowed. In the first image, image ID 2, the sun is coming from high in the southwestern sky. This leaves the crater well illuminated with the exception of the northern valley which is shadowed by the higher southern wall (see Figure 1 for elevation maps). In this image the center peak is white with CO₂ ice. The second image (ID 3) has the sun coming from low in the west. This low western sun is illuminating the outer western wall and the inner eastern wall. The area surrounding the peak is shadowed on all sides by the higher elevation areas. In this spring image the CO₂ is still covering the central peak. The third image shown (ID 4) is later in the spring. Here you can see the sun is coming from the west a little higher than in the previous image. The outer west and inner east walls are illuminated and the inner ring is lightly shadowed. Here there is still some CO₂ ice seen on the central peak. Image ID 6 from Figure 1 is during the mid-summer. Here the sun is coming from high overhead to the east. The CO₂ ice has now sublimated as can be seen by the lack of white CO₂ deposits on the central peak. The

water ice to the south, north, and east is now clearly visible. In the last image of Figure 1 (ID 7) the sun is coming from the northeast. Here the water ice is still clearly visible and the center peak is still free from the white CO₂ ice deposits. THEMIS IR image ID 8 shown in Figure 1 is from mid-summer, also. The water ice areas that are visible in Figure 1, ID 8 are seen in the THEMIS IR image. The water ice areas are lower in temperature than all of the surrounding areas (as would be expected with an area of water ice) as indicated by the lighter coloration of these areas compared to the surrounding areas.

Discussion and summary: Our survey of the unnamed crater at 81°N/190°E and Inuvik crater indicates that there is water-ice present in both impact features. THEMIS visible images support the trend that is known to occur between CO₂ and water ice on Mars with the decrease of overall crater albedo as the year progresses from spring to summer. In the spring CO₂ ice is present and as summer approaches and the temperatures rise the CO₂ sublimates, allowing us to see what is below the CO₂. Visible ice can be seen during the summer months and the infrared data from THEMIS shows that the temperature of the water-ice is much lower than the surroundings, supporting further that it is indeed water. Further analysis of other observations (from HRSC and OMEGA aboard Mars Express) of this and other area craters will give us further information on the presence of water ice in the northern residual polar region of Mars.

References: [1] H. H. Kieffer and T. N. Titus, *Icarus* 154, 162-180 (2001). [2] J.-P. Bibring et al., *Nature* 428, 627 (2004). [3] M. T. Zuber et al., *Science* 282, 2053-2060 (1998). [4] T. N. Titus et al., *Science* 299, 1048-1050 (2003). [5] J. C. Armstrong et al., *Icarus* 174, 360-372 (2005). [6] P. R. Christensen et al., *Space Science Reviews* 110, 85-130 (2004). [7] J.B. Garvin et al., *Icarus* 144, 329-352 (1999). [8] P. R. Christensen et al., *THEMIS Public Data Releases*, Planetary Data System node, Arizona State University, <http://themis-data.asu.edu>.

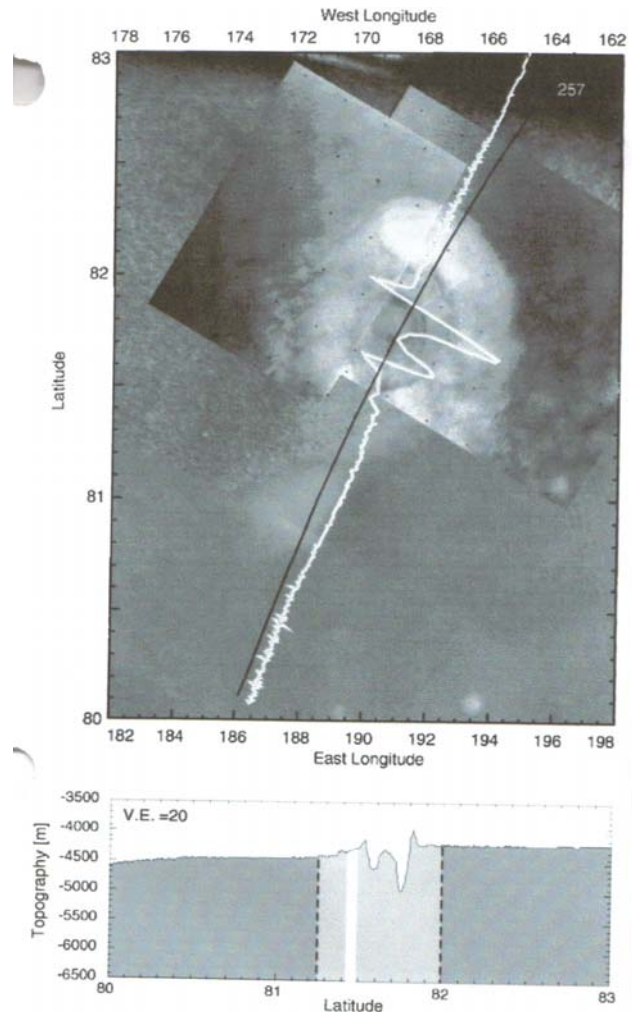


Image 1: Unnamed crater at 81°N/190°E MOLA image over laying Viking image with MOLA cross section (from Garvin et al).

Table 1: Available THEMIS images for crater at 81°N/190°E visible (V) and thermal (I)

Image ID	LS, Martian season	Earth date
1, I04251002	101.648, summer	11/29/02
2, I04563009	113.313, summer	12/25/02
3, V04563010	113.313, summer	12/25/02
4, I04950005	128.521, summer	01/26/03
5, V10180005	12.690, spring	03/31/04
6, I11715006	69.724, spring	08/04/04
7, V12314008	91.330, summer	09/23/04
8, I12938005	114.475, summer	11/13/04
9, V13250007	126.509, summer	12/09/04

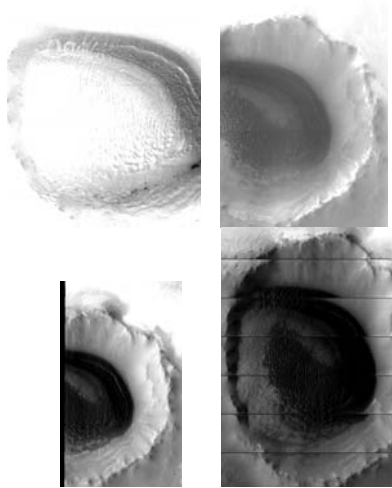


Figure 1: Visible THEMIS images for unnamed crater #1 (top panel left to right image ID 5 and 7, bottom left to right is ID 3 and 9 of Table 1).

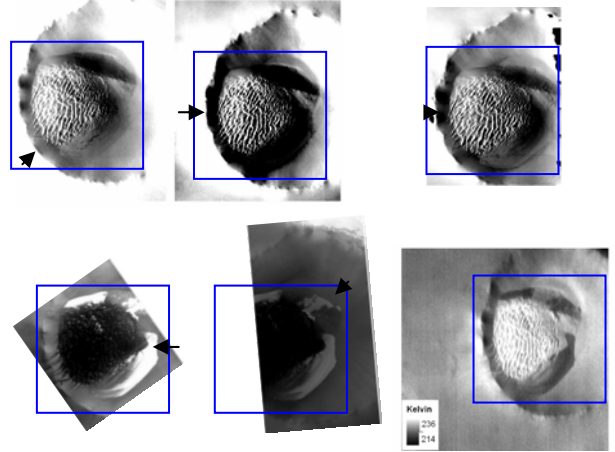


Figure 2: Visible THEMIS images of 2,3,4 (top, left to right) 6,7 (bottom from left to right) and the bottom far right image is THEMIS thermal image 8 (image number corresponds to Image ID from Table 1). Arrows indicate the direction the sun is coming from.

Table 2: Available THEMIS images for Inuvik crater at 79°N/331°E visible (V) and thermal (I) [8].

Image ID	LS, Martian season	Earth date
1, I04121002	96.863, summer	11/18/02
2, V10724001	33.594, spring	05/15/04
3, V11036032	45.162, spring	06/10/04
4, V11348002	56.507, spring	07/05/04
5, I11972005	78.962, spring	08/26/04
6, V12883002	112.392, summer	12/02/04
7, V13170002	123.386, summer	11/09/04
8, I13195002	124.359, summer	12/04/04
9, I13974004	156.197, summer	02/06/05

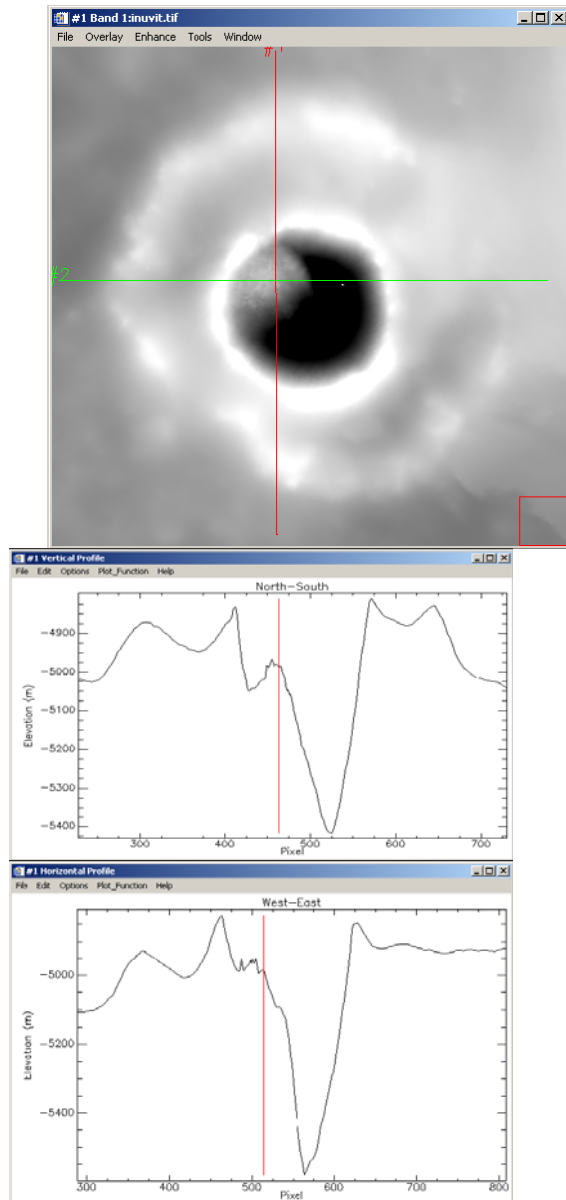


Figure 3: MOLA DEM of Inuvik crater (top) elevation cross-sections running north to south (middle) and west to east (bottom).