Detecting High- Albedo Events in Craters in the Near- Polar Permanent Ice Cap of Mars Using Visible and Infrared Images from (THEMIS) onboard the Mars Odyssey Mission.

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ABSTRACT

THEMIS (thermal emission Imaging system) Images were observed for craters in the north polar cap. Infrared and visible Images from THEMIS were used to identify craters that contain water -ice and CO2 frost. The available THEMIS data both visible and infrared are spread throughout the Martian spring and summer with temperatures variation depending on the time and season image was taken. Images were downloaded to ENVI and various parameters and properties were obtained using analytical methods provided by ENVI. The result showed temperature variation spatially within and outside the crater and throughout the Martian years. The four Martian years available on the THEMIS were observed and discovered that year 2 and 3 are the years where water ice and CO2 frost can be clearly observed in the visible and infrared images. This project is based on observation of unknown craters at Latitude 73.0^0 N/ 164.5^0E, 70.5^0N/ 103.5^0E, 81^0N/ 77.21^0E, 77.4^0N/213.6^0E, 81.0^0N/ 190^0E and 73^0N/186.32^0E. These craters varies in size, latitude and morphology but appears to have a specific regional association on the surface that correlates with the distribution of subsurface regolith interpreted as an ice-rich layer observed on Mars.

INTRODUCTION

It has being said that water had played a great role in the evolution of Mars. So, If we want to make discoveries on Mars pertaining to the presence of life and that of other living things we need to explore for the presence of water which is essential for the life. So in order for Man to explore Mars, a source of water must be found and maybe eventually biological life.

The near–pole regions of Mars offers us an avenue to study the albedo changes of the craters and their associated carbon dioxide and water –ice / frost sublimation and condensation cycle. Understanding the annual, seasonal and daily circles of the craters in the near polar region in necessary to understanding the annual, seasonal and daily cycles of the craters in the near -polar region and this is necessary to understand the Martian atmosphere evolution, polar process and the current Martian hydrological cycle.

Recent advances in remote sensing technology have improved our understanding of the Martian surface significantly. There is now a scientific consensus that the north polar cap is rich in water- ice and covered with a carbon dioxide ice-veneer during the cold seasons, while the water -ice is exposed during the warmer times of the year after the CO2 ice sublimes away [Bibring, et al., 2004; Byrne, et al., 2003, Titus, et al,. 2003]. The carbon dioxide ice layer waxes and wanes with the seasons. During the Martian fall, winter and spring in the northern hemisphere when temperatures are cold enough (150k or lower), the CO2 ice/frost covers the polar region. As temperatures begin to rise from later spring to summer, CO2 ice/frost sublimates and uncovers water-ice in the polar permanent ice cap [Kieffer and Titus, 2001, Bibring et al., 2004, Zuber et al., 1998].

The seasonal polar ice caps are actively involved in the current climate and hydrological cycle of Mars. Many impact craters in the seasonal caps are found with high albedo events (HAEs) which are associated with sublimation and condensation of water –ice/frost and carbon dioxide ice/frost inside the crater (Armstrong et al. 2007 and Xie et al. in press). Craters or bowl-shape features in the seasonal polar caps with HAEs involved are of particular interest in this project study.

THEMIS Images were observed for six unnamed craters at Latitude 73.0^0 N/ 164.5^0E, 70.5^0N/ 103.5^0E,

81^0N/ 77.21^0E, 77.4^0N/213.6^0E, 81.0^0N/ 190^0E and 73^0N/186.32^0E. These are very interesting craters to study because they are in the North Pole and they are near- polar craters. Near polar craters are craters covered with seasonal CO_2 ice but located away from the permanent ice cap and this provides an opportunity to examine the polar processes in detail. Near polar craters have unique morphologies due in large part to their interaction with the seasonal polar cap [Gravin et al, 2000]. The first step in understanding these interaction is gathering information on the nature of the crater floor deposit. While circumpolar winds can deposit dust and sand visible in crater dune formations and CO_2 ice is seasonally deposited in the polar regions including polar craters, the interaction these craters have with water- ice deposits is largely unexplored. In previous work, Armstrong et al [2005] identified deposits within Korolev crater from Themis and TES observations that indicated water ice.

The aim and objectives of this class project is to investigate craters with HAEs in the northern seasonal or near- pole ice cap of Mars and to concretize the idea that visible images display very bright whitish image of the water- ice/ CO2 frost and in the Infrared Images provided by the THEMIS, water ice and CO2 frost appear black to dark color in crater and this will help us in identifying whether ice is actually present or not in craters. Also to know that In the visible Water ice/ CO2 frost have HAEs while and can be seen very brightly but the infrared images provides the temperature variation inside and outside the crater to further confirm the presence of water ice-frost in craters. The Solar longitude (Ls) tells us the relative distance of Mars with respect to the position of the Sun when the image was taken. Solar Longitude also tells us about the Martian season maybe it is in the spring, summer, fall or Winter season.

METHODOLOGY

Craters were selected or chosen based on their geographic locations. Craters chosen were outside of the permanent north polar cap and within the boundaries of the northern seasonal polar ice cap. The remote sensing data used are THEMIS visible and infrared data. THEMIS images retrieved from the NASA/ Arizona State University data archive were the primary data source used. Both visible Images (apparent brightness record) and infrared (brightness temperature record) images were used. THEMIS is an instrument aboard NASA's Mars Odyssey spacecraft that has being orbiting Mars since February 2002. THEMIS's high spatial resolution (20m) visual imaging system uses a 5-wavelength system and the infrared imaging system, with a resolution of 90m, uses a 9-wavelength systems [Christensen et al, 2004]. THEMIS visible images show the crater shape and interior along with the brightness of the crater interior and exterior. Infrared images show the surface temperature of craters. This surface temperature allows the comparison of temperature in a crater throughout the year, and also allows for the correlation of "bright areas" in the visible image with a temperature reading in the infrared.

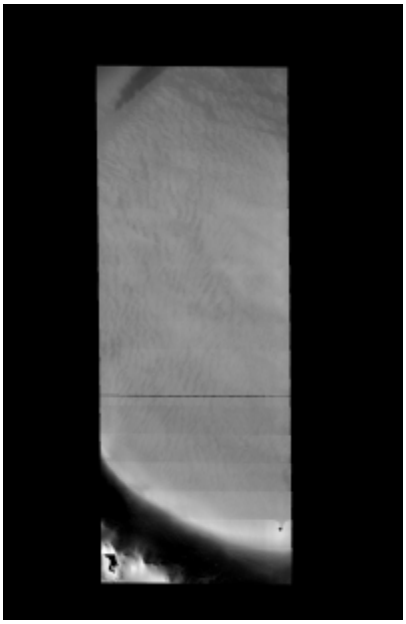
I focused on the northern part of Mars and obtained various visible and infrared images for different unknown craters at the different random locations. In all I obtained six visible images and Six infrared images. The visible images were easier to locate because of their high resolution compared to the infrared images which is quite difficult to locate. I also noticed that they were lots of distortions in most infra red images on the THEMIS compared to the visible. After I got the desired visible image, I pasted it onto my slide, searched and obtained the infrared image and did the same. For the visible, whitish appearance of the water –ice in the crater indicates an high albedo and an indication of water –ice. For the infrared images, presence of water-ice in crater must appear black or dark on the image.To compute the temperature variation to further clarify that water-ice is present in the crater, I downloaded the brightness temperature image and saved the image in a folder. Then I opened the folder using ENVI and displayed it on my computer monitor using the grey scale option. I then went back to the file where I saved the data and right clicked on it. I scrolled down and clicked on the "edit with vim option". This brought out all the image parameters and other information pertaining to the image. I then scrolled

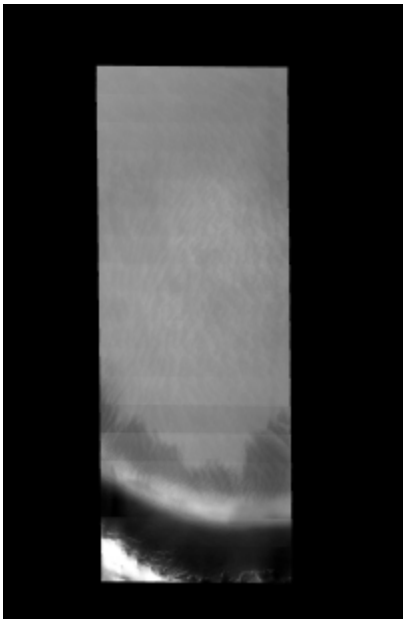
down to where I have the information for the scaling factor and the offset, am going to need the summation of the scaling factor and the offset for the Band Math function on ENVI. After I got these two values, I recorded them down. I then went on ENVI, clicked on basic tools, scrolled down to band maths and clicked on it. A new window popped up (Band Maths) where I have to enter an expression which is band 1* Scaling factor + Offset, clicked on add to list and then OK. The variable to bands pairing window popped up, I then clicked on the image band I needed, saved it into the memory and clicked OK. Replaced “scaling factor” with the values found in the .txt file and “offset” with the values found in the .txt file. Once this is completed for the infrared image, the file can be reopened and temperature readings in Kelvin are displayed. Cursor moved over crater ice (water-ice) and at other areas around the crater rim and beyond shows variation in temperature and temperature values were recorded. This further confirms the presence of water ice in this craters to compliment for the high albedo seen in the visible image where water ice is present.

Available THEMIS images for crater located at 73.0^0 N/ 164.5^0E visible (V) and thermal (I). Solar Longitude (Ls) image was taken corresponding to Martian season and local time and the Earth date of Image acquisition.

Image ID	LS, Martian season	Earth date	Local Martian time
1, V11796003	72.631, Spring	11/08/04	4.452
2, V12108003	83.862, Spring	06/09/04	4.530
3, I12926009	114.020, Summer	12/11/04	17.933

Temperature inside crater in Kelvin is 229 to further prove the presence of water-ice in crater.

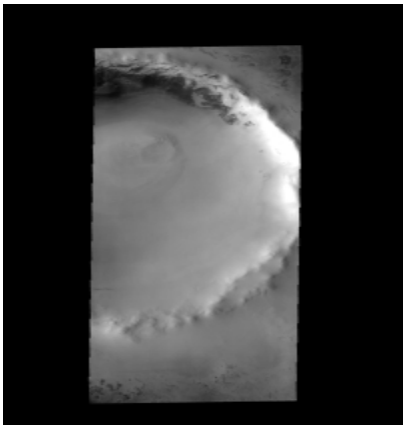


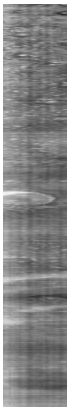


Available THEMIS images for crater located at 70.5^0N/ 103.5^0E visible (V) and thermal (I). Solar Longitude (Ls) image was taken corresponding to Martian season and local time and the Earth date of Image acquisition.

Image ID	LS, Martian season	Earth date	Local Martian time
1, V19430008	46.994, Spring	02/05/06	17.489
2, I22381002	158.943, Summer	31/12/06	5.127

Temperature inside crater in Kelvin is 271 to further prove the presence of water-ice.





Available THEMIS images for crater located at 81^0N/ 77.21^0E visible (V) and thermal (I). Solar Longitude (Ls) image was taken corresponding to Martian season and local time and the Earth date of Image acquisition.

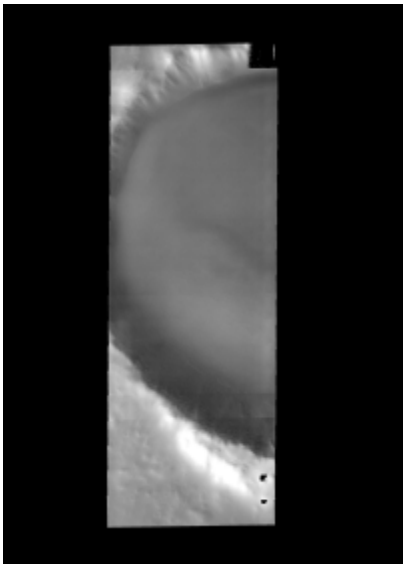
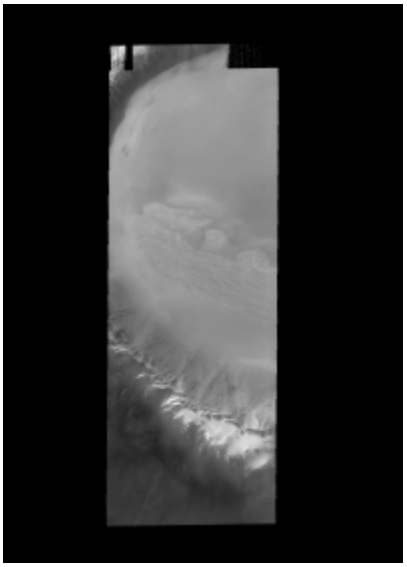
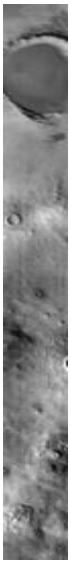
Image ID	LS, Martian season	Earth date	Local Martian time
1, V13878008	152.097, Summer	30/01/05	18.969
2, I13878007	152.098, Summer	30/01/05	18.222

Temperature of water-ice in crater is 216, this further confirms the presence of water-ice in crater.

Available THEMIS images for crater located at 77.4^0N/213.6^0E visible (V) and thermal (I). Solar Longitude (Ls) image was taken corresponding to Martian season and local time and the Earth date of Image acquisition.

Image ID	LS, Martian season	Earth date	Local Martian time
1, V10441006	22.860, Spring	22/04/04	17.413
2, V11976007	79.106, Spring	26/08/04	18.025
3, I12575003	100.893 Summer	14/10/04	18.021

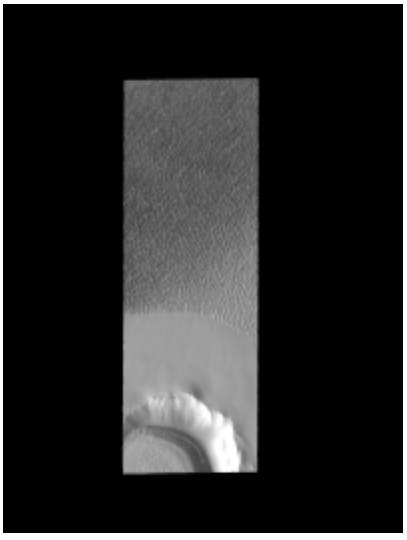
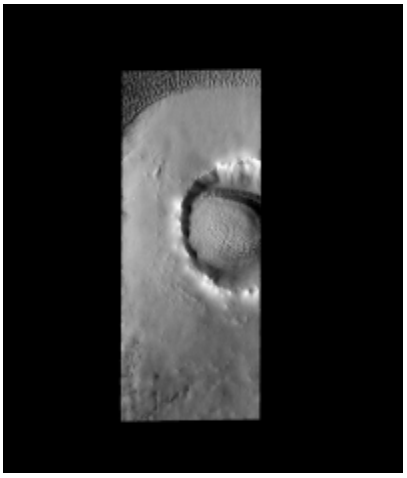
Temperature of water-ice in crater is 229, which further confirms the presence of water- ice in crater.

Available THEMIS images for crater located at 81.0^0N/ 190^0E visible (V) and thermal (I). Solar Longitude (Ls) image was taken corresponding to Martian season and local time and the Earth date of Image acquisition.

Temperature inside crater is 226, this is a further prove that water-ice exist in crater.

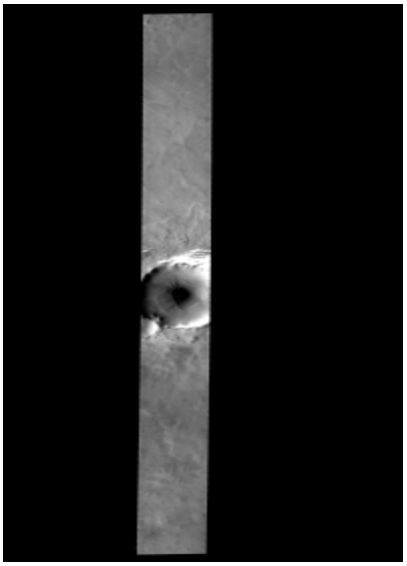
Image ID	LS, Martian season	Earth date	Local Martian time
1, V19103008	34.911, Spring	05/04/06	18.127
2, V19390006	45.528, Spring	04/28/06	18.336
3, I11715006	69.724, Spring	04/08/04	18.079

Available THEMIS images for crater located at 73^0N/186.32^0E visible (V) and thermal (I). Solar Longitude (Ls) image was taken corresponding to Martian season and local time and the Earth date of Image acquisition. This image has all its infrared images distorted so I could only get the visible image.

Image ID	LS, Martian season	Earth date	Local Martian time
1, V12788005	108.816, Summer	01/11/04	18.004

Temperature inside crater in Kelvin in 232, indicating the presence of water-ice in crater.



SUMMARY AND DISCUSSION

Computing the various visible and infrared images available and with the use of ENVI as the processing software, it can be clearly seen that when we have water ice in craters in visible images there is high albedo and the water-ice is seen as a whitish bright color on the image. In the infrared images, presence of water-ice in crater is seen as dark to black color and this image also gives us the temperature of the water-ice in the crater. This temperature of ice in crater is usually lower compared to the temperature of other areas outside the crater and this temperature is usually indicated in Kelvin. The albedo and temperature variation on crater surfaces fluctuates greatly both during the day and night and throughout the seasons. So daily time temperature on Mars is very critical to the temperature obtained in a crater at a particular day or time. I would like to compare the northern craters to craters located in the south to further clarify the presence of water ice in both polar regions and see what the southern polar region has to offer based on the fact that it is an older surface compared to the north and has an higher elevation compared to the northern polar cap.

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