ANALYSIS OF PROPERTIES OF THE NORTH POLAR LAYERED DEPOSITS : THEMIS DATA IN CONTEXT OF MGS DATA.
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1 Introduction

One of the many questions of Martian exploration is to uncover the history of Mars, through analysis of the polar layered deposits (PLD). Martian polar ice caps hold most of the exposed water on the surface on Mars and yet their history and physical processed involved in their formation are unclear. We will attempt to contribute to our knowledge of the composition and stratigraphy of the polar deposits.

In this work we present the latest imaging data acquired by the Mars Odyssey THermal EMission Imaging System (THEMIS) [1] and place it into context of the Mars Global Surveyor (MGS) data. THEMIS provides capabilities for imaging in both thermal IR and visible color wavelengths. These observations are affected by atmospheric scattering and topography. The Mars Orbiter Laser Altimeter (MOLA) and Thermal Emission Spectrometer (TES) instruments [2, 3] on board of the MGS spacecraft can provide context information for THEMIS data. Of particular interest are Mars Orbiter Camera (MOC) images [4], which provide high-resolution data. We are primarily interested in the seasonal evolution of ice cap temperatures during the first northern summer of THEMIS observations. Morphology, stratigraphy and composition of the layered deposits can be addressed by THEMIS VIS color images, along with MOC high resolution data and MOLA Digital Elevation Models (DEM). This work is intentionally descriptive. Based on the knowledge obtained by the orbiting spacecraft and described here, we will attempt to expose major directions for modeling and further understanding of of the physical processes involved in the formation of the polar layered terrain

2 Available data

2.1 THEMIS IR

The THEMIS IR camera has 10 bands from 6 to 15 μm [5]. Due to to signal-to-noise restrictions the most useful band for polar observations is band 9 (12.57μm). Band 10 (14.88μm) data can be used for atmospheric calibration. An example of seasonal evolution observed by the THEMIS IR subsystem is shown in Figure 1. We have projected all IR images, covering a small area near 86N and 90E into a polar stereographic projection and then sampled "time" dimension in order to look at temperature evolution over the course of the summer. We are plotting averaged temperature data over two 1km^2 regions of interest: layered material inside the trough and the surface of the residual ice cap. High resolution THEMIS IR data allows us to distinguish properties of bulk of layered terrain and ice. We were not able yet to distinguish properties of individual layers.

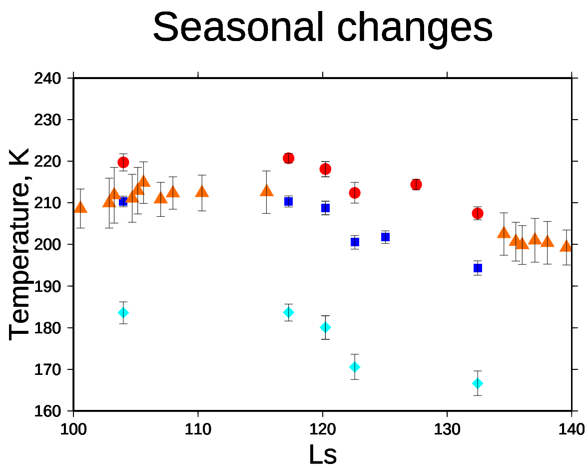

Figure 1: Seasonal temperature evolution of ice and trough material in the North Polar region. Red circles - layered material, blue squares - ice (THEMIS band 9), light blue diamonds - THEMIS band 10 data, orange triangles - TES surface temperature during first year of TES observations for the same region.

2.2 THEMIS VIS

The THEMIS Visible Imaging Subsystem (VIS) is a 5-color, 1024x1024 interline transfer CCD camera that acquires high spatial resolution 18 to 72 m/pixel multispectral images (425 to 860 nm) from Mars orbit ([5, 6]). In order to gain coverage most of the full-color images have a resolution of 36m/pixel. Figure 2 illustrates a fragment from the polar layered terrain. We were able to image this fragment at full resolution (18m/pixel). This image is a part of a larger mosaic and consists of two VIS images. Layers can be easily identified in this figure. Color calibration in underway right now [6] and in the future we plan to analyze true-color images.

2.3 Mars Global Surveyor data

Very interesting details of the polar layered deposits become evident in high resolution MOC Narrow Angle images [4]. These images are invaluable for interpreting details of the layered deposits observed with THEMIS. Narrow Angle MOC and THEMIS VIS images are ideal complements for each other : THEMIS provides extensive coverage and some color information, while MOC provides high resolution detail. An example of a MOC image from the same trough as in Figure 2 is shown in Figure 3.

It is very important to understand the state of the atmo-

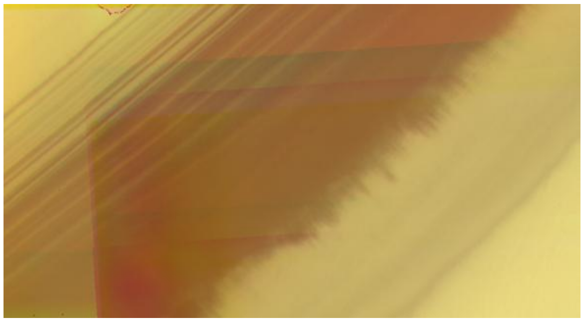

Figure 2: Fragment of false-color mosaic of THEMIS VIS images in the North polar region (near 86.7N and 60-70E). Camera bands 3, 2 and 1 are shown in this picture as Red, Green and Blue correspondingly. Resolution : 18m/pixel. Radiometric calibration of these images is still work in progress. Size of this THEMIS VIS image mosaic is 10.5×5.7km.

sphere (presence of dust, water ice), when the data were taken, as they can affect the observations described above. TES atmospheric data [7, 3] can provide dust and water ice opacities and many other parameters valuable for atmospheric analysis, as well as understanding large scale thermophysical properties. We compared TES surface temperatures (orange triangles in Figure 1) taken during the first year of TES mapping phase (two Martian years prior to presented THEMIS data). THEMIS and TES observations of surface temperatures are consistent. Note, however, that THEMIS data is not atmospherically corrected. Although the TES observation footprint (3×6km) does not allow to distinguish between ice and layered material, it is still possible to retrieve very useful spectral information from just one TES pixel, if the observed feature is large enough. MOLA, which has been working in radiometer mode since 2001 [8], can provide narrow-band radiometric information at $1\mu m$, in addition to wide-band TES bolometer measurements.

2.4 Discussion

Variations of thermophysical properties of surface materials are manifested in the thermal IR by various rates of heating up or cooling down. While this process is easy to observe in equatorial regions and mid-latitudes, it is very challenging to apply the same methods in the polar regions. For places in extreme polar latitudes, the sun is almost always over the horizon. Only during short periods in spring and fall can differences between day and night be observed. Further complicating matters in the spring time is CO_2 cover, which masks all possible thermal differences. We will look extensively at the fall time images, when thermal contrasts will become more apparent. We plan to continue analysis of seasonal trends for different geologic units inside the cap until CO_2 covers the surface of the ice cap. Our ultimate goal is to derive some measure of thermal inertia for the material in the troughs. TES atmospheric data from previous years is very helpful for planning this effort and for interpretation of the results.

The large spatial and relatively high-resolution coverage provided by the THEMIS visible camera can resolve individual layers in the northern polar layered deposits over long distances (See Figure 2). Higher resolution MOC narrow angle data can be used to characterize these individual layers. Comparing the trace of these layers to topographic data generated by the Mars Orbiter Laser Altimeter (MOLA) yields information in three dimensions about the position of the layer exposure. Strikes and dips of individual layers can be extracted allowing us to predict if this same layer will be exposed in troughs elsewhere in the layered deposits. Testing large-scale continuity of layers in this fashion may help us distinguish between a flowing or non-flowing ice cap. In addition the possibility of extracting a low-resolution version of the topography underlying the icecap from the three dimensional shape of many layers also exists.

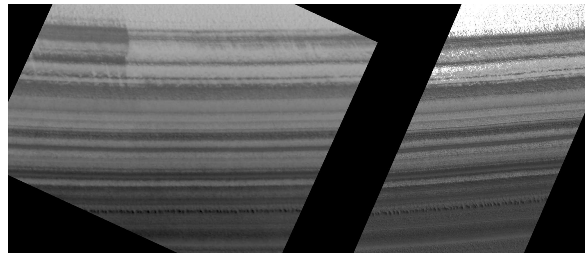

Figure 3: MOC image mosaic of the north polar layered terrain at 3 m/pixel resolution. MOC images M00/2100 and M01/3767 were used. Note variety and structure of layers in the trough. By precise registering of these images to THEMIS color images we will be able to deduce color information for some of the layer stacks. Size of this mosaic of MOC images is 12.3×5.3 km.

Requiring information from so many different datasets spread over various missions in a challenge. Geographic Information Systems (GIS) have been used to this end within the terrestrial remote sensing community for many years. We use the Arcmap software provided commercially by ESRI. It provides a convenient way to overlay different dataset of disparate resolutions and origins. It also allows for full three-dimensional viewing of any scene for which topography information exists (which is everywhere), which aids image interpretation by distinguishing slope and albedo effects on brightness.

3 Conclusions

In this work we present description of properties of the North Polar Layered Deposits in all available datasets, concentrating on data from Mars Odyssey's THEMIS investigation. Our approach is to 1) detect heating or cooling trends in THEMIS Thermal IR imagery for selected troughs in the NPLD and interpret these data in terms of thermophysical properties (e.g. thermal inertia) of the layers. The MGS TES atmospheric dataset will provide context and will be important for calibration of THEMIS data; 2) use THEMIS VIS images to investigate continuity of the layers in the layers deposits and their stratigraphic relationships using high-resolution MOLA topography. MOC images will provide important morphological detail. Our goal is to bring infrared and visible datasets together and suggest future directions for data analysis and modeling to improve our understanding of the composition of the layered deposits.

References

[1] P. R. Christensen, J. L. Bandfield, J. F. Bell, V. E. Hamilton, A. Ivanov, B. M. Jakosky, H. H. Kieffer, M. D. Lane, M. C. Malin, T. McConnochie, A. S. McEwen, H. Y. McSween, J. E. Moersch, K. H. Nealson, J. W. Rice, M. I. Richardson, S. W. Ruff, M. D. Smith, and T. N. Titus. Geology through temperature: Mars odyssey themis results. *submitted to Science*, 2003.

[2] D. E. Smith, M. T. Zuber, H. V. Frey, J. B. Garvin, J. W. Head, D. O. Muhleman, G. H. Pettengill, R. J. Phillips, S. C. Solomon, H. J. Zwally, W. B. Banerdt, T. C. Duxbury, M. P. Golombek, F. G. Lemoine, G. A. Neumann, and et al. Mars Orbiter Laser Altimeter: Experiment summary after the first year of global mapping of Mars. *JGR*, 106:23689–23722, October 2001.

[3] M. D. Smith, J. C. Pearl, B. J. Conrath, and P. R. Christensen. Thermal Emission Spectrometer results: Mars atmospheric thermal structure and aerosol distribution. *JGR*, 106:23929–23946, October 2001.

[4] M. C. Malin and K. S. Edgett. Mars Global Surveyor Mars Orbiter Camera: Interplanetary cruise through primary mission. *JGR*, 106:23429–23570, October 2001.

[5] P. R. Christensen, J. L. Bandfield, J. F. Bell, V. E. Hamilton, A. Ivanov, B. M. Jakosky, H. H. Kieffer, M. D. Lane, M. C. Malin, T. McConnochie, A. S. McEwen, H. Y. McSween, J. E. Moersch, K. H. Nealson, J. W. Rice, M. I. Richardson, S. W. Ruff, M. D. Smith, and T. N. Titus. Early Results from the Odyssey THEMIS Investigation. In *Lunar and Planetary Institute Conference Abstracts*, pages 1519–+, March 2003.

[6] J. F. Bell, T. McConnochie, B. Savransky, M. Stiglitz, M. J. Wolff, P. R. Christensen, G. Mehall, M. Malin, M. Caplinger, M. Ravine, L. L. Cherednik, K. C. Bender, K. Murray, and The Themis Science Team. High Spatial Resolution Visible Color Units on Mars from the Mars Odyssey THEMIS/VIS Instrument. this abstract volume.

[7] H. H. Kieffer and T. N. Titus. TES Mapping of Mars' North Seasonal Cap. *Icarus*, 154:162–180, November 2001.

[8] G. A. Neumann, J. B. Abshire, D. E. Smith, X. Sun, and M. T. Zuber. MOLA 1064nm Radiometry Measurements: Status and Prospects in Extended Mission. In *Lunar and Planetary Institute Conference Abstracts*, pages 1889–+, March 2002.