Monday, October 13, 2003
Morning Session II
THE LATEST FROM MARS: THEMIS
10:30 a.m. Victoria Room

Plaut J. J. * Christensen P. Bender K. Bell J. Cherednik L. Ivanov A. Kieffer H. McConnochie T. Richardson M. Titus T. [INVITED]
THEMIS Visible Imaging of the South Polar Layered Deposits, Martian Southern Spring, 2003 **[#8130]**

Ivanov A. B. * Byrne S. Richardson M. I. Vasavada A. R. Titus T. N. Bell J. F. McConnochie T. H. Christensen P. R. THEMIS Science Team
Analysis of Properties of the North and South Polar Layered Deposits **[#8084]**

GENERAL DISCUSSION

THE NATURE AND EVOLUTION OF THE SEASONAL POLAR CAPS

Smith D. E. * Zuber M. T. [INVITED]
The Masses of Mars/Seasonal Polar Icecaps **[#8063]**

12:00 – 1:30 p.m. LUNCH

THEMIS VISIBLE IMAGING OF THE SOUTH POLAR LAYERED DEPOSITS, MARTIAN SOUTHERN SPRING, 2003.

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Introduction: The polar layered deposits (PLD) of Mars have attracted considerable attention since their identification in Mariner 9 images, largely due to the possibility that these finely layered, volatile-rich deposits hold a record of recent eras in Martian climate history. The PLD have been a target of imaging and other sensors in the last several decades, but only recently has it been possible to obtain a moderately high resolution image map, using the visible sensor on 2001 Mars Odyssey's Thermal Emission Imaging System (THEMIS). We report here on the acquisition of a 36 meter/pixel contiguous single-band visible image data set of the south polar layered deposits (SPLD), obtained during early southern spring in 2003. The data will undoubtedly be applied to many problems in Mars polar studies. We will discuss here, and in more detail at the Conference, the use of these images to further characterize the population of impact craters on the SPLD, and the implications of the observed population for the age and evolution of the SPLD.

Data: An imaging campaign with the goal of obtaining complete coverage of exposures of SPLD during early southern spring began in late April, 2003, just prior to the southern vernal equinox ($L_S = 180$). Most of the SPLD during this time of year is covered with CO_2 frost, giving a uniform albedo, and a view of the landforms that is dominated by local topographic slope. While this remained the case on surfaces close to the pole, higher latitude SPLD exposures showed surprisingly early changes in albedo, particularly in the so-called "cryptic" region [1,2]. The visible camera mode chosen was single band (0.654 microns) at 36 m/pixel resolution, which is twice the minimum pixel size of the visible camera. This allowed collection of a nearly contiguous data set in just two 30-sol Odyssey near-repeat orbital cycles. Each image is approximately 18 km by 260 km. Figure 1 shows the coverage after about 50 sols. The final data set consists of about 1000 images. Images were targeted at all longitudes between –78° and –87° latitude (areas poleward of –87° are inaccessible to THEMIS in the nadir-pointed attitude). The sector containing the Ultimi lobe, between longitudes 130° and 230° E was also targeted up to –70° latitude. At high latitudes, the Odyssey orbit track "walks" ~15 km every two sols, allowing collection of adjacent swaths closely spaced in time. Selected images are retargeted every 30 sols, to monitor changes associated with the retreat of the seasonal CO_2 frost. Simultaneous THEMIS infrared images are also acquired with selected visible images to monitor surface temperatures associated with the visible changes in surface albedo.

Impact Craters: One key objective of the SPLD imaging campaign was to obtain a new inventory of the population of impact craters on the SPLD. Studies using Viking orbiter images [3] and Mars Global Surveyor laser altimeter data [4] determined that the SPLD contained ~10 to 100 impact craters with diameters >800 m. These crater abundances are consistent with a surface age ~10s of My [5]. The THEMIS visible data set at 36 m/pixel allows identification of impact craters as small as about 200 m (~6 pixels). Many such craters have been identified in the THEMIS data. Current models of the size frequency distribution of martian impact craters predict that craters with D>200 m should be at least an order of magnitude more abundant than craters with D>800 m on a surface purely in crater production. Preliminary examination of the new SPLD images suggests that the small craters are not as abundant as expected for a production surface, implying efficient processes of small crater removal, as postulated by [4]. A complete inventory of impact craters on the THEMIS SPLD images will be presented at the Conference.

References: [1] Kieffer, H. et al. (2000) *JGR, 105,* 9653. [2] Titus. et al. (2003) this volume. [3] Plaut, J. J. et al. (1988) *Icarus 75,* 357-377. [4] Koutnik, M. et al. (2002) *JGR 107*, doi:10.1029/2001JE001805, [5] Herkenhoff and Plaut (2000) Icarus 144, 243-253.

(See next page for Figure 1)

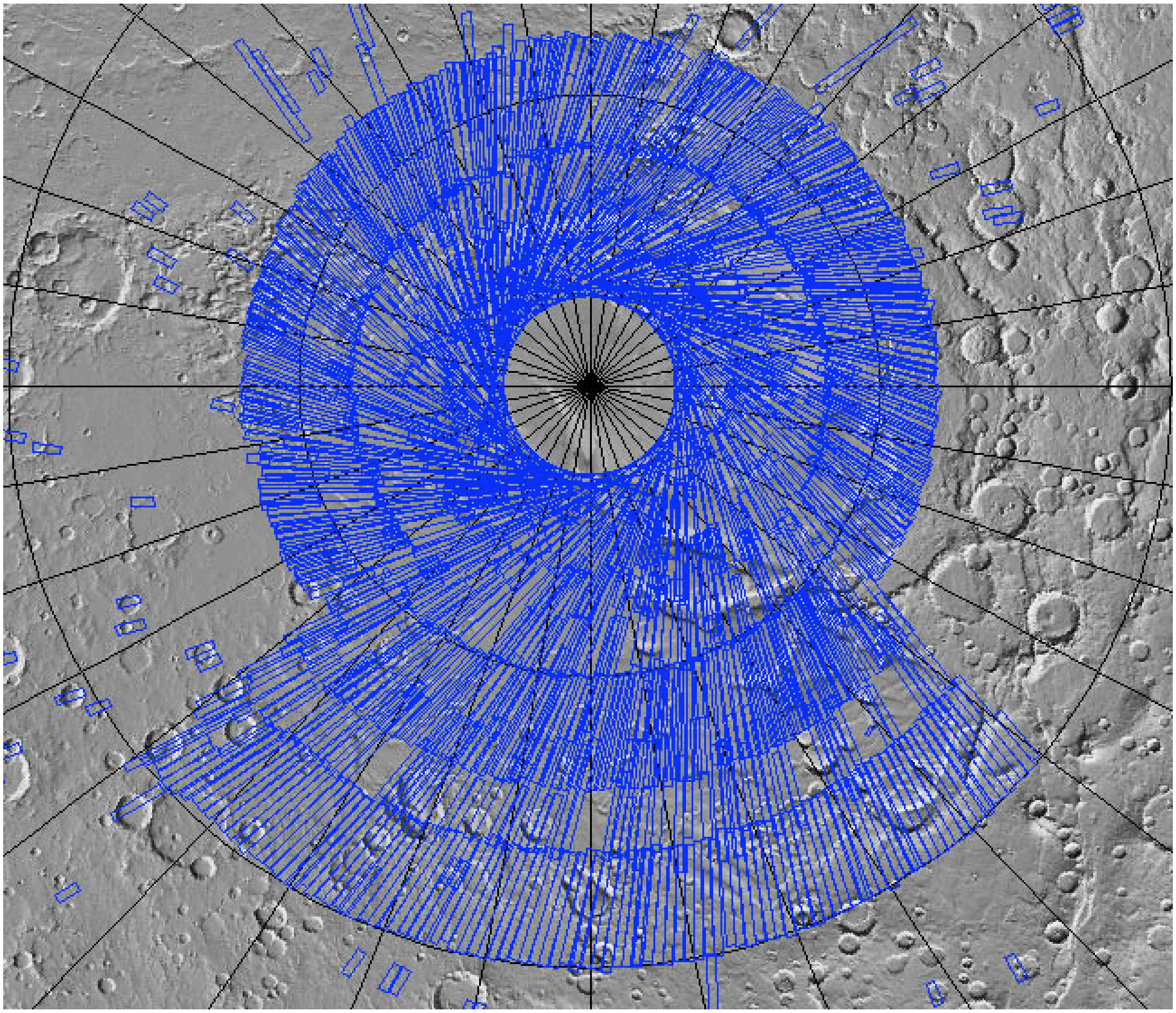

Figure 1. The south polar region of Mars, showing coverage of THEMIS visible images (blue outlines) after ~50 sols of the springtime imaging campaign. Background image is MGS MOLA topography. Latitude rings are 10 degrees. The area poleward of –87° is not accessible to THEMIS.

ANALYSIS OF PROPERTIES OF THE NORTH AND SOUTH POLAR LAYERED DEPOSITS. A. B. Ivanov[1], S. Byrne[2], M. I. Richardson[2], A. R. Vasavada[3], T. N. Titus[4], J. F. Bell[5], T. H. McConnochie[5], P. R. Christensen[6], THEMIS Science Team, [1]*Jet Propulsion Laboratory, MS168-416, Pasadena, CA, 91106; e-mail : anton.ivanov@jpl.nasa.gov*, [2]*California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, CA*, [3]*University of California, Los Angeles, CA*, [4]*U.S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ*, [5]*Cornell University, Department of Astronomy, Ithaca, NY*, [6]*Arizona State University, Tempe, AZ.*

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 ice on the surface of Mars and yet their history and physical processes involved in their formation are unclear. We will attempt to contribute to our knowledge of the composition and stratigraphy of the PLD.

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. We have discussed the North Polar data in [5]. This work concentrates on data acquired over the South pole of Mars and compares properties of North and South PLD.

We are primarily interested in properties of the layers in both ice caps : their continuity, morphology and stratigraphy. These questions can be addressed by THEMIS VIS color images, along with MOC high resolution data and MOLA Digital Elevation Models (DEM). We will investigate thermophysical properties of the layered deposits employing THEMIS IR images. Based on the data obtained by the orbiting spacecraft and described here, we will attempt to expose major directions for modeling and further understanding of the physical processes involved in the formation of the polar layered terrain

2 Available data

2.1 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 ([1, 6]). In order to gain coverage some images are downsampled to a resolution of 36m/pixel. This averaging mode was primarily employed to obtain full coverage of the South Polar Layered Deposits (SPLD) during early spring, when this area is still covered by seasonal frost. A fragment of THEMIS VIS mosaic is shown in Figure 1. This fragment shows a part of residual south polar ice cap between 270E and 320E. Layers are clearly seen in this figure. Since this area is all covered by seasonal frost at this time, brightness variations in this image are primarily due to changes in topography. The staircase structure of the layered deposits is clearly seen. Layers in the North PLD are much smoother and don't exhibit staircase structure. Figure 2 shows a THEMIS 36m/pix image and a MOC high-resolution image of a scarp in the SPLD. Layers are clearly visible in both THEMIS VIS and MOC images. Continuity of the layers can be easily analyzed from the one band THEMIS VIS mosaic, while color images can be taken in selected areas. MOC high-resolution images taken along the trough provide excellent high-resolution morphology.

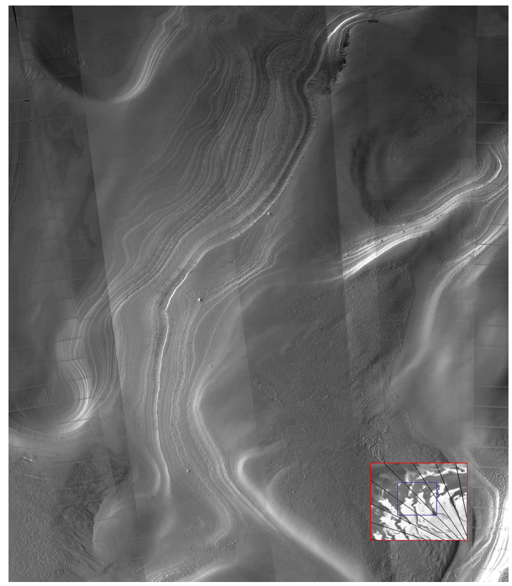

Figure 1: A fragment of THEMIS VIS mosaic of SPLD. The original image resolution is 36 m/pixel. Location of this fragment is shown in the lower right corner on top of the MOC image mosaic. Images were taken in early spring, while ground is still covered by CO_2 frost. Existence of frost on the ground is confirmed by the THEMIS IR data. Context image is shown in the lower-right corner (inside the blue box).

The high quality of the THEMIS VIS data and the high data rate available to download the images will allow us to complete mosaic of the SPLD. We plan to re-image this area during southern summer, when all the seasonal frost will be gone.

2.2 THEMIS IR

The THEMIS IR camera has 10 bands from 6 to 15 μm [1]. 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. High resolution THEMIS IR data allows us to distinguish bulk properties of of layered terrain and ice [5]. We were not able to distinguish between individual layers, however bulk thermophysical properties are under investigation.

2.3 Mars Global Surveyor data

Very interesting details of the polar layered deposits become evident in high resolution MOC Narrow Angle images [4].

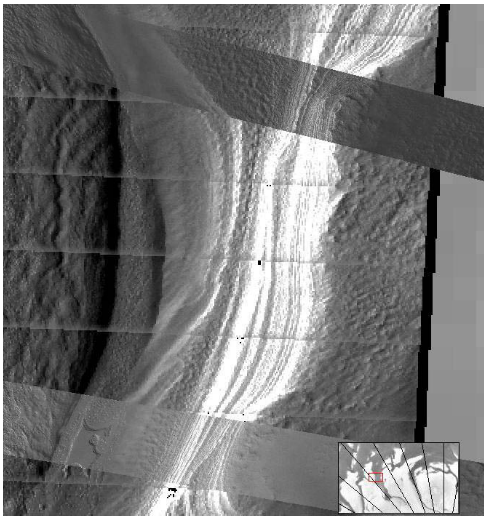

Figure 2: Mosaic of THEMIS VIS and two MOC NA images of a scarp in the SPLD. Images were taken during early southern spring with sun geometry is approximately the same for both MOC and THEMIS images. MOC NA images provide great morphological detail of the layers, while THEMIS VIS images allow to extrapolate this information over much larger areas of SPLD. Context area is shown in the lower-right corner of the figure. Pronounced stripes in the THEMIS image are due to scattered light from adjacent filter in the THEMIS camera.

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 An example of a MOC images mosaicked with THEMIS VIS is shown in Figure 2.

3 Discussion

Large spatial and relatively high-resolution coverage provided by the THEMIS visible camera can resolve individual layers in the NPLD over long distances [5]. 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.

The surface appearance of the layered deposits is distinctly different between the two poles [4]. However MOLA data [2] suggests that the general form of the ice caps is roughly the same and they are both composed of water ice mixed with dust [1]. A possible explanation for this difference lies in the timescale of the processes responsible for the formation of the layered deposits. Short-time scale processes are currently eroding the surface of the SPLD, while long-term (compared to obliquity cycle) formation processes are still the same for both caps. We will attempt to probe the internal structure of the cap by collecting vertical positions of selected layers in North and South PLDs.

We have successfully demonstrated the use of THEMIS VIS and MOC data in [5]. We were able to trace a marker bed through a trough and locate the same layer in other troughs.

4 Summary

In this work we present a description of the properties of the South Polar Layered Deposits and compare them with their North counterparts. We employ all available datasets, concentrating on data from Mars Odyssey's THEMIS investigation. Our ultimate goal is to characterize major properties of the polar layered terrains and suggest mechanisms and timescales for their formation. Our approach is to use THEMIS VIS images to investigate continuity of the layers in the layered deposits and their stratigraphic relationships using high-resolution MOLA topography. MOC images will provide important morphological detail. We will also attempt to detect heating or cooling trends in THEMIS Thermal IR imagery for selected troughs in the PLD 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.

References

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[5] A. B. Ivanov, and the Themis Science Team. Analysis of properties of the north polar layered deposits. In *Mars6 Conference Abstracts*, July 2003

[6] J. F. Bell, and the Themis Science Team. High Spatial Resolution Visible Color Units on Mars from the Mars Odyssey THEMIS/VIS Instrument. In *LPSC Conference Abstracts*, March 2003

THE MASSES OF MARS/SEASONAL POLAR ICECAPS.

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Introduction. Radio tracking of the Mars Global Surveyor spacecraft has revealed temporal changes in the long-wavelength gravity field of Mars that correlate, to first order, with the pattern expected for the seasonal redistribution of carbon dioxide between the atmosphere and surface. Detecting these gravity field changes requires isolating very small perturbations in the velocity of the spacecraft and estimating the very low degree zonal coefficients of the field. A comparison of these coefficients determined every 5 days for a period over 2 Mars years shows annual and semi-annual variations that are similar to those predicted by a General Circulation Model simulation [1]. These changes result from the redistribution of the mass of the planet by the exchange of carbon dioxide between the surface and the atmosphere through deposition and sublimation of CO_2 in the polar regions. A simple time-dependent model for the icecaps enables an estimate to be made of the mass of carbon dioxide at each pole as a function of the seasonal parameter, L_s.

Temporal Variations in Gravity. The gravity field of Mars is typically represented by a series of spherical harmonics [2] of which the largest are the low degree zonal terms. These terms represent the basic gravitational shape of Mars and, in combination with the rotational potential, largely define the long wavelength areoid. The redistribution of atmospheric material, particularly the pole-to-pole transport of carbon dioxide on the surface, causes these low degree terms in the description of the gravity field to change with time. In addition, when the CO_2 is deposited on the surface, the rest of the planet (mantle, core, etc. that is not changing in mass) moves slightly in position in order to maintain the center of mass of the whole planet in the same position in inertial space. This motion, and its gravitational effect, is a $C_{1,0}$ term in the gravity potential of the solid part of the planet. In addition, motion of material in the atmosphere that is deposited at the poles causes a change in the flattening of Mars that is manifest as a change in the $C_{2,0}$ gravitational coefficient. Similarly, there are changes in $C_{3,0}$ and all the higher degree and order terms, although the largest changes are in the first few low degree coefficients.

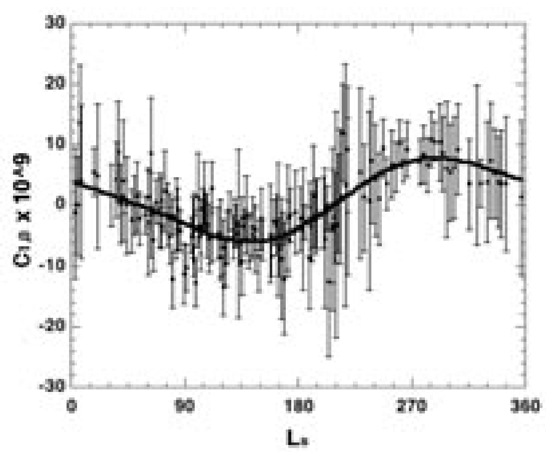

Fig. 1 *The variation in the degree 1 term of the solid part of the planet (core, mantle,* $C_{1,0}$*, e, crust) that arises because the deposition of carbon dioxide at the poles is balanced by a small motion of the rest of the planet.*

We have estimated the changes in the first 3 gravity coefficients by analyzing the small changes in the orbit of the MGS spacecraft [3]. Figure 1 shows the variation in the degree 1 coefficient of the gravity field of the solid part of the planet.

Note that the magnitude of the variation of the $C_{1,0}$ term is of order 10^{-9}, equivalent to a few centimeter movement of the solid component of the planet from its mean position.

Estimating the Seasonal Mass. If we make the assumption that the seasonal polar icecaps can, to first order, be represented as point masses at each of the poles, then it can be shown [4] that the mass of the north seasonal polar cap, *m(n),* can be written

$$m(n) = (1/2)(C_{1,0} + C_{2,0}) \times M,$$

and the mass of the south seasonal polar cap, *m(s),* as

$$m(s) = (1/2)(- C_{1,0} + C_{2,0}) \times M,$$

where $C_{1,0}$ and $C_{2,0}$ are the un-normalized first and second degree zonal coefficients in the expansion of the gravity field, and M ($=6.42 \times 10^{23}$ kg) is the mass of Mars.

The results for each pole for approximately two Earth years (one Mars year) are shown in Figure 2 where the mass in kg is plotted vs. L_s. Both datasets have been fit with annual (L_s), semi-annual ($2L_s$), and tri-annual ($3L_s$) periods. The annual period dominates for each pole as a result of the $C_{1,0}$ variation (Fig. 1) being much larger than the variation in the planetary flattening, $C_{2,0}$. Evident in Figure 2 is the suggestion of slow sublimation ($L_s \sim 270^o - 140^o$) and rapid deposition ($L_s \sim 180^o - 260^o$) in the northern hemisphere. In the south the accumulation and sublimation appear to be of equal length when measured against L_s. The pattern of mass exchange shows differences in comparison to the temporal pattern of latitudinal brightening due to the seasonal changes in frost deposition [5], suggesting that at least some aspects of reflectivity change are not associated with significant mass exchange.

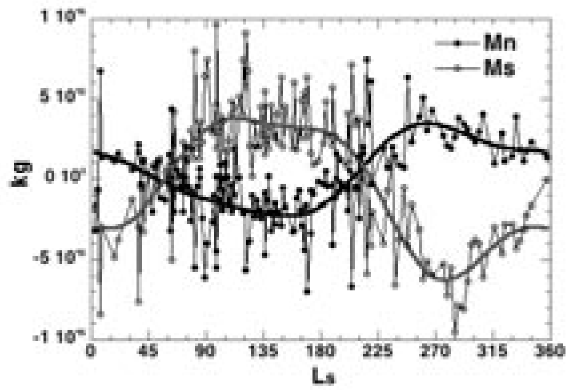

Fig. 2. *Estimated seasonal mass at each of the Martian poles based on a point mass model for the seasonal icecaps. Note that (1) sublimation begins in the southern hemisphere as soon as the sun reaches its maximum northerly latitude ($L_s=270^o$), and (2) the rapid rise and slow fall of deposition in the north.*

References. [1] Smith D. E. et al. (1999) *JGR, 104,* 1885-1899. [2] Lemoine F. G. et al. (2001) *JGR, 106*, 23,359-23,376. [3] Smith D. E. and Zuber M. T. (2003), submitted to *JGR*. [4] Zuber M. T. and Smith D.E. (2003) in prep. [5] Zuber M.T. and Smith D.E. (2003) this volume.