

CONSTRAINTS ON THE WITHIN SEASON AND BETWEEN YEAR VARIABILITY OF THE NORTH RESIDUAL CAP FROM MGS-TES. W.M. Calvin¹, T.N. Titus², and S.A. Mahoney¹. ¹Dept. of Geological Sciences, MS172, University of Nevada, Reno, NV 89557, wcalvin@unr.edu, ²U.S. Geological Survey, Flagstaff, AZ 86001, ttitus@usgs.gov.

INTRODUCTION: There is a long history of telescopic and spacecraft observations of the polar regions of Mars. The finely laminated ice deposits and surrounding layered terrains are commonly thought to contain a record of past climate conditions and change. Understanding the basic nature of the deposits and their mineral and ice constituents is a continued focus of current and future orbited missions. Unresolved issues in Martian polar science include a) the unusual nature of the CO₂ ice deposits (“Swiss Cheese”, “slab ice” etc.) b) the relationship of the ice deposits to underlying layered units (which differs from the north to the south), c) understanding the seasonal variations and their connections to the finely laminated units observed in high-resolution images and d) the relationship of dark materials in the wind-swept lanes and reentrant valleys to the surrounding dark dune and surface materials.

Our work focuses on understanding these issues in relationship to the north residual ice cap. Recent work using Mars Global Surveyor (MGS) data sets have described evolution of the seasonal CO₂ frost deposits [1-5]. In addition, the north polar residual ice cap exhibits albedo variations between Mars years and within the summer season [4-6]. The Thermal Emission Spectrometer (TES) data set can augment these observations providing additional constraints such as temperature evolution and spectral properties associated with ice and rocky materials. Exploration of these properties is the subject of our current study.

MGS-TES DATA SET: Mars Global Surveyor began systematic mapping of the planet in March of 1999. The Mars season was early northern summer, L_s=104. As Kieffer and Titus [2] noted, the seasonal CO₂ frost had disappeared by that time and they observed the growth of higher albedo regions (onset of winter frosting) beginning at L_s ~ 164. James and Cantor [4] monitored the seasonal cap recession of 2000 and found the signature of the residual cap emerging under the seasonal CO₂ frost between L_s 60 and 70. We somewhat arbitrarily mark our timeframe of interest as L_s 65 to 165. This allows study of the albedo, temperature and spectral properties of the residual cap through the seasonal cap and the “bare” residual cap. In this regard we can compare variations within the summer season to properties observed under thin or sparse CO₂ frost coverage. The table below illustrates that there are two full and one partial north-

ern summer seasons of data acquired. The data from the first two summers are available via the PDS and the second full summer’s data are being released over the next several months.

Northern Summer	L _s 65	L _s 165	Mission Phase
1-partial	4-Dec-98 (pre-mapping)	5-Jul-99	Map
2-full	20-Oct-00	22-May-01	Map/Ext
3-full	8-Sept-02	9-Apr-03	Ext-Ext

PREVIOUS OBSERVATIONS: Earlier workers noted the change in albedo in a number of north pole bright outliers and in the overall coverage by bright ice deposits both between Viking summers and between Viking and Mariner 9 [6-8]. This was possibly attributed to the affects of global dust storms [8]; however Bass et al. [6] showed that significant within season variation occurred among Viking imagery. Cantor et al. [5] also explored this variation in MOC images and noted brightening at the edges within a given Mars summer season and changes in the cap appearance at the same L_s between MGS years (1 and 2 as defined in the table above). The early season appearance was possibly attributed to the occurrence of a large dust storm the previous year, and it was noted that late season ice extent recovers to Viking levels but exhibits small-scale inter-year variations that may not be related to globally repeated weather events [5].

These brightness variations are most extensively observed in the quadrant from 0 to 120 east longitude (lower right) on a polar stereographic projection (see Figures 1 and 2). Typically the large “tail” below the Chasma Boreale and its associated plateau (see Zuber et al. [9] for topography) remain bright while highly sloped cap edges and valleys are defrosted in the early season. Malin and Edgett [10, Figure 76] also call out variations on the end of the southern “tail” (-15 to -40 longitude) and in spiral structures above the Chasma Boreale observed at the same L_s in different Mars years. We note there also appears to be substantial frost variation at the “source” of Chasma Boreale (10 to 25E) from Viking to recent years, being darker in the present epoch in MOC and TES albedos than it was during Viking (Figures 1 and 2).

PRELIMINARY RESULTS: We are examining these seasonal and interannual variations of the north cap in the TES data set. This includes comparison of TES albedo with visible appearance in MOC imagery, merging TES, MOC and Viking data with high-resolution topography, and mapping spectral properties associated with seasonally varying and more constant units within the north residual cap. Figure 2 shows initial results for the early season of MGS “Summer 2” acquired from 12/20/00 to 1/03/01 or $L_s \sim 92$ to 98. Early season “defrosted” units are seen quite similar to the MOC and Viking results [5, 6, and 10] described in the preceding section. We will present the evolution of TES albedos within this MGS northern summer and the ability to use temperature and slope as a proxy for units which are susceptible to summer and annual changes.

TES spectra are notoriously difficult to work with for these cold polar temperatures. Kieffer et al. [1] show representative examples, but typically use large regional averages to improve the signal-to-noise, especially at higher wavenumbers ($>1200 \text{ cm}^{-1}$) where the radiance is dropping rapidly. In an effort to examine seasonal trends they developed several multichannel “bands” and used brightness temperatures (T_b) of these broadband averages and their differences to define surface units. Kieffer and Titus [2] presented data either longitudinally averaged or using these broadband temperatures. We are currently developing methods of handling the spectral variations including use of 2-temperature models to fit mixed pixels of warm rock and cold ice as well as cold surfaces under a warmer atmosphere (e.g. [11]). We will report on the status of various methods and their comparison to previous approaches. We will present preliminary spectral characteristics of ice units that are seasonally variable, seasonally stable and of non-ice units both within and surrounding the residual north cap.

REFERENCES: [1]Kieffer et al, *JGR*, **105**(E4), 9653-9699, 2000. [2]Kieffer and Titus, *Icarus*, **154**, 162-180, 2001. [3]Titus et al. *JGR*, **106**(E10), 23181-23196, 2001. [4]James and Cantor, *Icarus*, **154**, 131-144, 2001. [5]Cantor et al. *JGR*, **107**(E3), 10.1029/2001JE001588, 2002. [6] Bass et al. *Icarus*, **144**, 382-396, 2000. [7] Kieffer, *JGR*, **96**, 1481-1493, 1990, [8] Paige et al. *JGR*, **99**, 25959-25991,1994. [9] Zuber et al. *Science*, **282**, 2053-2060, 1998. [10] Malin and Edgett, *JGR*, **106**(E10), 23429-23570, 2001. [11] Hanel et al., *Exploration of the Solar System by Infrared Remote Sensing*, 1992.

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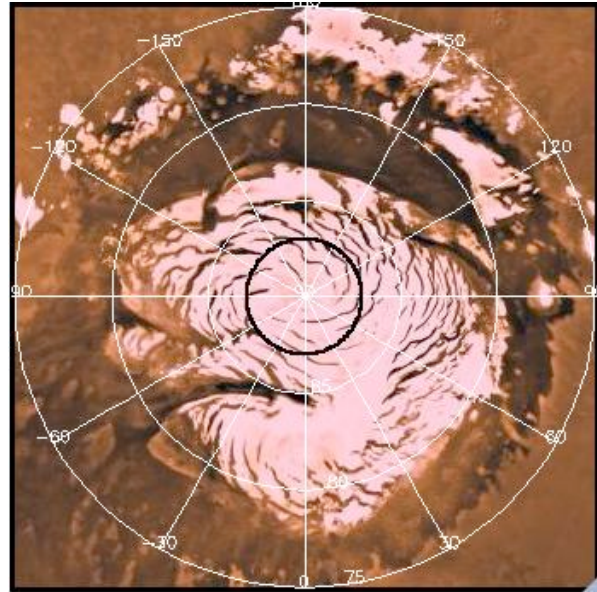


Figure 1: North residual cap as observed by Viking. Black ring denotes area within which TES does not acquire data.

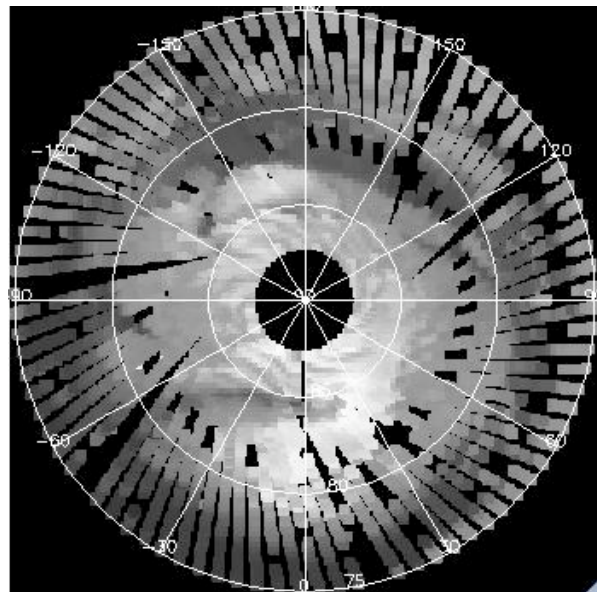


Figure 2: TES albedo map $L_s \sim 95$ (Dec00/Jan01). Note the lack of bright areas from 30 to 120 E longitude, the extent of Chasma Boreale and the shape of ice surfaces below the Chasma compared with Viking. Squares do not model TES pixel size.