THERMAL INERTIA OF THE ARSIA MONS CALDERA: A SITE FOR NIGHTLY CO_2 CONDENSATION.

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Introduction: Arsia Mons, the southernmost of three massive shield volcanoes in the Tharsis region, is a type of shield volcano distinct from most others with steep inner-margins, a broad flat caldera, and concentric ring-like graben and fractures. By either morphological or topographical comparison, Arsia Mons has no direct counterpart on Earth [1,2].

The caldera of Arsia Mons has one of the most extreme environments on Mars. At an elevation of 16.5 kilometers, the temperature varies by a factor of nearly two every day [3], and CO_2 frost is observed to form on the floor every night while not forming on the walls or rim. This suggests that the material on the floor has a lower thermal inertia, which, in turn, suggests that there are processes in the caldera that effectively sort aeolian material such as sand and dust [3]. This theory is supported by the presence of dust devil tracks, whose formation is crucially dependent on grain-size distribution and sorting of surface material [4].

The Mars Global Surveyor (MGS) has monitored the caldera temperatures over three martian years with temperatures derived from Thermal Emission Spectrometer (TES) bolometer data taken at roughly 2 a.m. and 2 p.m. (+/- 45 minutes). For this study, we restrict our analysis to observations of the caldera floor during the first year of TES mapping which occurred between February 1999 and January 2001 (TES orbits 1584-9991).

Previous regional thermal studies: The passing shadow of one of Mars' moons, Phobos, was used to determine thermal inertias on the southern flank of Arsia Mons. This was observed by the Termoskan instrument on board the Soviet Phobos '88 spacecraft. The thermal inertias were calculated to be 38-59 J m^{-2} $s^{-1/2}$ K^{-1} using a homogeneous model, but since the shadow passes a given location in about 20 seconds, only the few upper millimeters of surface thermal inertia were obtained [5]. At least two other investigations of this region were conducted using the Viking Infrared Thermal Mapper (IRTM) to determine diurnal thermal inertias in 2° x 2° bins. These studies gave regional thermal inertias to be 86-133 J m^{-2} $s^{-1/2}$ K^{-1} [6], and 92-147 J m^{-2} $s^{-1/2}$ K^{-1} [7]. Each of these derived thermal inertias help to support claims that the Tharsis region has a covering of dust and is currently an area of active dust deposition [5,6,7,8].

This investigation is conducted differently from those mentioned above. Previous thermal inertia studies looked at temperatures over a short range in time, while we determine best-fit thermal inertias based on observations over an entire martian year.

Data Analysis: Derived temperatures from the TES bolometer were compared with those generated by a multi-layer finite-difference thermal model called 'KRC' [9], which has been used extensively to study thermo-physical properties of Mars [9,10,11]. The model uses the Delta-Eddington radiative approximation to solve the subsurface thermal diffusion equation using a boundary condition of solar insolation on top of a single-layer gray atmosphere [10,11]. A typical martian atmospheric dust opacity of 0.2 was used. The model calculates surface temperatures for a specific set of slope, azimuth, latitude, elevation and albedo at up to ten different thermal-inertia values.

Homogeneous (single-layer) boundary conditions with zero-slope were investigated with four modeled cases: (1) afternoon and (2) nighttime observations with a fixed albedo of .26; (3) combined afternoon and nighttime observations with a fixed albedo; and (4) afternoon and nighttime data with a variable albedo.

Models were generated and the resulting temperatures were interpolated to times and dates corresponding to those on which measurements were taken. Best-fit thermal inertias were calculated by applying the downhill-simplex method of function minimization [12] to the observed and modeled data.

Results: The following values were determined for the four cases:

Case	Time	Fixed . albedo	Best-fit Thermal Inertia
1	Night	Yes	71 J m^{-2} $s^{-1/2}$ K^{-1}
2	Day	Yes	152 J m^{-2} $s^{-1/2}$ K^{-1}
3	Both	Yes	76 J m^{-2} $s^{-1/2}$ K^{-1}
4	Both	No	76 J m^{-2} $s^{-1/2}$ K^{-1}

Figures 1 and 2 show observed temperatures compared with those obtained from the model at best-fit thermal inertias of 71 and 152 J m^{-2} $s^{-1/2}$ K^{-1} for both nighttime and afternoon, respectively. Figure 3 shows both the nighttime and afternoon data fit simultaneously with a best-fit thermal inertia of 76 J m^{-2} $s^{-1/2}$ K^{-1}. Figure 4 shows the best fit for a.m. and p.m. observations with a variable albedo, giving the best simultaneous fit of 76 J m^{-2} $s^{-1/2}$ K^{-1} with a best-fit albedo of .29.

The difference in thermal inertia between the best fit a.m. and p.m. models, combined with the poor model fits when both afternoon and nighttime are combined, suggests that the observed data can't be modeled as a homogeneous material. Between L_s 120° and 240°, the afternoon observations are consistently 10-20K cooler than the model predicts. This could indicate the presence of a higher thermal inertia material beneath the top layer. Multi-layered cases are investigated, and the results presented at LPSC.

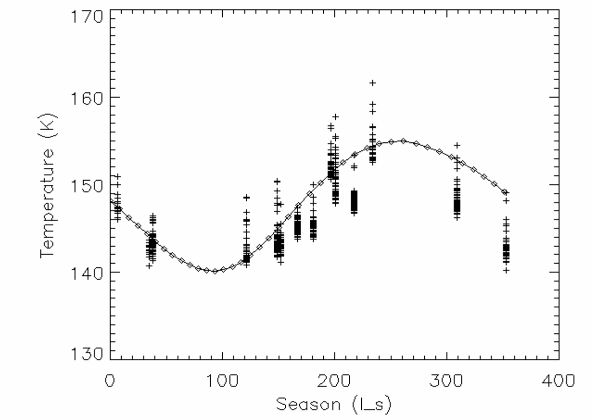

Figure 1: TES observed night temperatures compared with those from the best-fit thermal inertia of 71 J m^{-2} s$^{-1/2}$ K^{-1} calculated for an albedo of 0.26. The model closely follows observed phenomena.

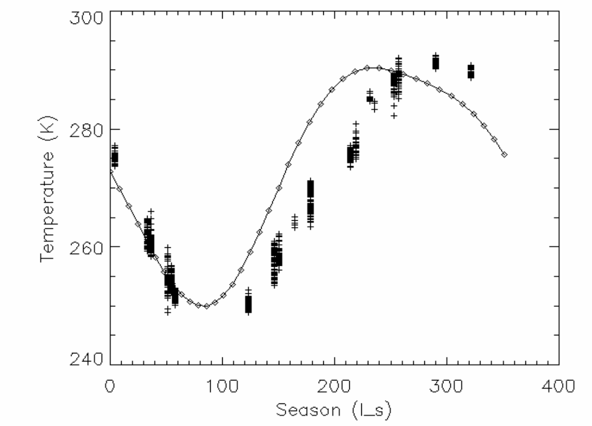

Figure 2: TES-observed afternoon temperatures compared with those from the best-fit thermal inertia of 152 J m^{-2} s$^{-1/2}$ K^{-1} calculated for an observed albedo of .26. The cooler temperatures between L_s 120° and 240° may indicate the presence of vertical layering with materials of higher thermal inertia beneath the surface.

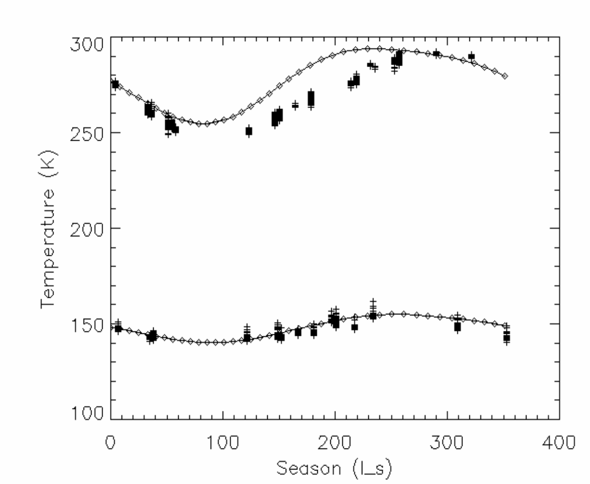

Figure 3: The model fit to TES-observed temperatures for night and afternoon simultaneously. The best-fit thermal inertia is 76 J m^{-2} s$^{-1/2}$ K^{-1}.

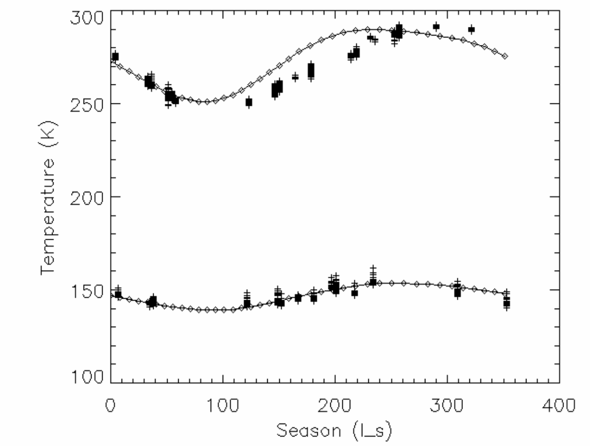

Figure 4: The model fit to TES-observed temperatures for night and afternoon simultaneously with variable albedo. The best fit gives a thermal inertia of 76 J m^{-2} s$^{-1/2}$ K^{-1} and an albedo of 0.29. The afternoon has a better fit with a variable albedo than with the observed albedo.

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