THE MARS THERMAL MODEL (MARSTHERM): A FORTRAN 77 FINITE-DIFFERENCE PROGRAM DESIGNED FOR GENERAL DISTRIBUTION. Stephen M. Clifford and Cheryl J. Bartels*, Lunar and Planetary Institute, 3303 NASA Road One, Houston, TX 77058. *University of Illinois, 1611 W. Green, Champaign, IL 61821.

Over the years, a variety of computer-based numerical models have been developed to examine the thermal characteristics and behavior of various planetary surfaces (e.g., 1-4). Unfortunately, despite the sophistication of these models, their utility to other investigators has been hindered by their limited distribution and often enigmatic code.

Such considerations have played a major role in the development of a recent software package called the Mars Thermal Model (MARSTHERM). Although lacking the power and refinement of some previous thermal models, MARSTHERM has been designed with the intent that its code be easily understood, well documented, readily modifiable, and essentially system-independent. As program development continues, greater sophistication and increased performance have also been established as primary goals. After initial testing is completed, copies of the software and documentation will be made available to all interested parties for the cost of duplication and shipping.

MARSTHERM is written in FORTRAN 77 and uses the method of finite differences to compute surface and subsurface temperature variations throughout the martian year. For the sake of computational efficiency, the program utilizes non-constant intervals for both depth and time (Figure 1), increasing program execution speed with only a small loss in numerical accuracy. Currently, compartmental thicknesses are calculated according to the simple relation

$$dz_i = 1.13*dz_{i-1} \tag{1}$$

where i is the compartment number; while the maximum time interval between calculations is established using the standard stability criteria

$$dt_i = \frac{0.25*\rho*c*dz_i^2}{k} \tag{2}$$

where ρ, c, and k, are the regolith density, specific heat, and thermal conductivity, respectively.

The transient heat conduction equation is solved using the finite-difference representation of the second derivative derived by Sundqvist and Veronis (5)

$$\frac{d^2T}{dz^2} = \frac{\frac{dT}{dz}_{i+1/2} - \frac{dT}{dz}_{i-1/2}}{0.5*(dz_i - dz_{i-1})} \tag{3}$$

where

$$\frac{dT}{dz}_{i+1/2} = \frac{(T_{i+1} - T_i)}{dz_i} \tag{4}$$

and

$$\frac{dT}{dz}_{i-1/2} = \frac{(T_i - T_{i-1})}{dz_{i-1}} \tag{5}$$

The performance of the current seasonal version of the program (35 compartments, with the surface temperature updated every 1/192 of a martian day) is such that a four-year simulation takes approximately 18 minutes of CPU time on a DEC VAX 11/780. When appropriately modified to take advantage of an Analogic AP 500 32 bit floating point array processor, a speed improvement of another order of magnitude is possible. At the other end of the performance spectrum, satisfactory results have been obtained using a Texas Instruments PC equipped with a 5 MHz 8088 and 8087 numerical co-processor; however, a four-year simulation on such a system takes anywhere from 3.5 to 6 hours under Microsoft FORTRAN, depending on the math library chosen when the program is compiled. The diurnal and seasonal temperatures that result from these calculations (e.g., Figures 2 & 3) appear to be in good agreement with those determined by previous martian thermal models (e.g., 4,6)

Through further development, it is our hope that MARSTHERM will become a useful educational and research tool. To this end, program corrections, extensions, and improvements, will be actively solicited from all users. Our current intent is to incorporate these changes in revisions of the software code and documentation on a roughly annual basis.

References: (1) Linsky, J. L. (1965) Harvard College Observatory Scientific Report No. 7. (2) Linsky, J. L. (1966) Harvard College Observatory Scientific Report No. 8. (3) Morrison, D. (1969) Smithsonian Astrophysical Observatory Special Report 292. (4) Kieffer et al. (1977) J. Geophys. Res. 82, 4249-4291. (5) Sundqvist, H. and G. Veronis (1969) Tellus 22. (6) Leighton, R. R. and B. C. Murray (1966) Science 153, 136-144.

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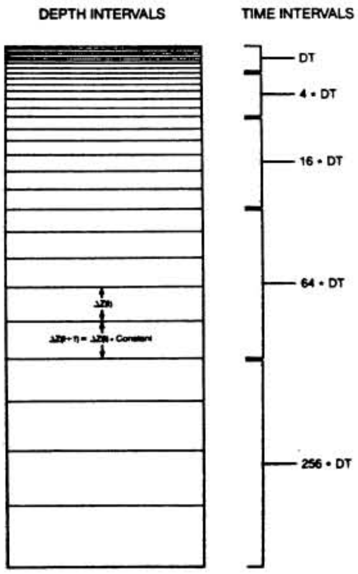

Figure 1. Relative compartment sizes and calculation intervals.

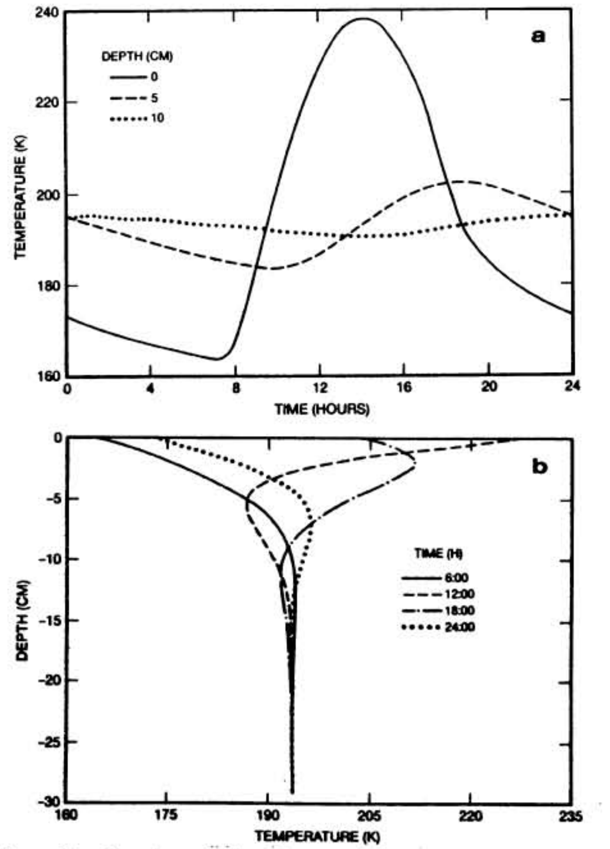

Figure 2. Examples of diurnal temperature output. Fig. 2a depicts diurnal temperature variations as a function of time at three different depths, while Fig. 2b illustrates the variation of temperature with depth for four different times during a typical martian day.

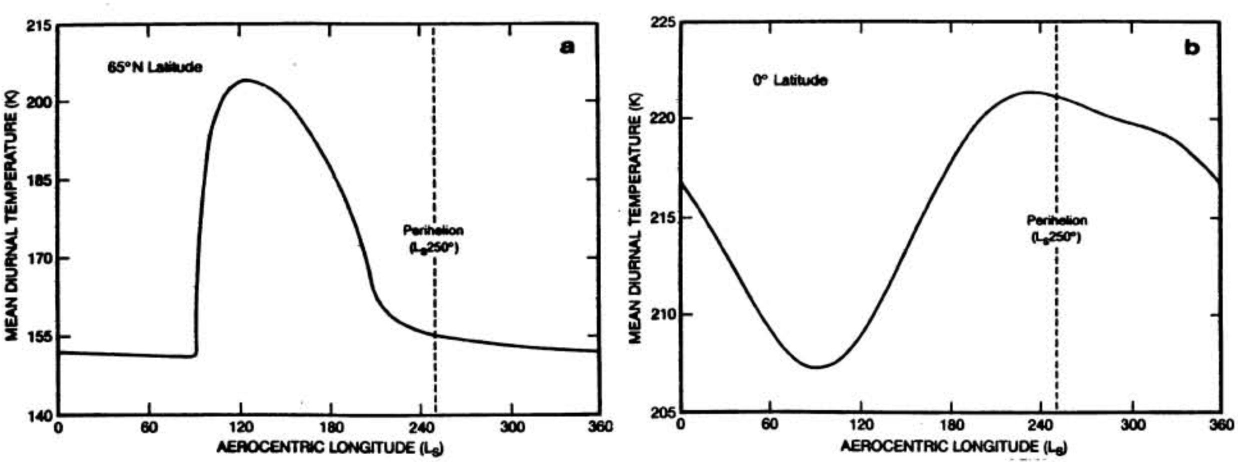

Figure 3. Seasonal variations in mean diurnal temperature for the latitudes of 65°N (Fig. 3a) and 0° (Fig. 3b). In Fig. 1a, the formation of the seasonal polar cap causes temperatures to level off for the L_s interval 198-90.