(NASA-CR-174073) THE MARTIAN CLIMATE: ENERGY BALANCE MODELS WITH CO2/H2O ATMOSPHERES Semiannual Status Report, 1 Mar. - 1 Sep. 1984 (New York Univ., New York.) 11 p HC A02/MF A01 CSCL 03B G3/91

N85-12849

Unclas
19781

NEW YORK UNIVERSITY

FACULTY OF ARTS AND SCIENCE

DEPARTMENT OF APPLIED SCIENCE

SEMI-ANNUAL STATUS REPORT

THE MARTIAN CLIMATE: ENERGY BALANCE MODELS WITH CO_2/H_2O ATMOSPHERES

Principal Investigator
Martin I. Hoffert

Prepared for
NASA GRANT NAGW-573
March 1, 1984 - September 1, 1984

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF APPLIED SCIENCE
26-36 Stuyvesant Street
New York, N.Y. 10003

The Martian Climate: Energy Balance Models with Carbon Dioxide/Water Atmospheres

Progress Thus Far

As described in our original proposal and work plan (including some modifications per the suggestions of the MDAP Review Panel), we are developing a multi-reservoir, time dependent energy balance climate model for Mars driven by prescribed insolation at the top of the atmosphere. The first approximately half-year of the program was devoted to assembling and testing components of the full model. Specific accomplishments have been made on a longwave radiation code, coupling seasonal solar input to a ground temperature simulation, and conceptualizing an approach to modeling the seasonal pressure waves that develop in the Martian atmosphere as a result of sublimation and condensation of CO_2 in polar regions. These steps are described below.

(1) Longwave radiation code

The previous study by Hoffert et al. (1981) of Mars' surface temperature distribution as a function of carbon dioxide and water vapor atmospheres utilized a 3-band longwave radiation code for the outgoing IR flux from the planet, i.e., the top-of-the-atmosphere (TOA) flux. The seasonal energy balance model (EBM) under development with separate atmosphere and surface temperatures requires the backradiation from the atmosphere to the surface at the bottom of the atmosphere, i.e., the BOA flux. A number of model runs using the longwave code integrated toward the surface have been made to develop BOA correlations as a function of surface pressure and temperature for use in the multi-reservoir EBM.

(2) Seasonal Ground Temperature Simulations: Current Mars

Expressions for the seasonal and latitudinal variation of solar radiation at the top of the atmosphere have been formulated as a function of orbital radius, eccentricity, obliquity and longitude of perihelion. This will allow consideration of the effects of astronomical long-period variations in orbital elements on insolation, and hence, on climate. This has been used to drive a "force-restore" model for ground temperature (neglecting at this point the influence of atmospheric and boundary layer heat transfer). The method is derived in Hoffert and Storch (1979), is computationally faster than a point-by-point integration of the 1D heat conduction equation into the ground; it involves a numerical solution of a ordinary (as opposed to a partial) differential equation:

$$(1/2)C_s dT_s/dt = S(t,\phi)(1-\alpha) - \varepsilon\sigma T^4 - (1/2)C_s\Omega(T_s - \langle T_s\rangle), \quad (1)$$

where

$C_s = (2/\Omega)I$, where I is the thermal inertia

T_s, $\langle T_s\rangle$ are the ground surface temperatures, instantaneously and annually averaged, respectively

t = time

α = solar albedo

ε = longwave emissivity

Ω = angular velocity of periodic forcing.

Using $\varepsilon = 1.0$ and $I = 272$ J/m^2-K-s$^{1/2}$, the seasonal variation of daily mean surface temperatures at latitudes of the VL-1 and VL-2 lander sites are shown and compared to lander anemeometer temperature data (from Seiff, 1982) in Figs. 1 and 2. The thermal inertia is within the range of Mars values $I \sim 70\text{-}200\ J/m^2\text{-}K\text{-}s^{1/2}$ cited by Jakosky (1979). These Mars surface values of I were derived by curve fits to a full integration of the unsteady heat conduction equation (in depth and time) by Kieffer et al. (1977). Equation (1) is exact for T_s for harmonic (sinusoidal)forcing and approximate when the forcing is periodic but nonharmonic; it avoids the numerical integration of PDEs at each surface point (an advantage for global climate models) and is more accurate than a slab model, since it calculates the temperature at the surface, as opposed to a mean slab temperature.

Fig. 1 shows the model versus data for the VL-1 site at 48^oN for $\alpha=0.25$. The agreement is generally quite good, with a seasonal amplitude of about 60^oK. The model precedes the data in phase by about $10\text{-}20^o$ of aerocentric longitude, indicating the possibility that I may be greater for this site than the Martian average. This can undoubtedly be improved by tuning the local I as described below.

Fig. 2 compares the model against data for the VL-1 site at 22^oN, using α =0.32. Here the agreement is again quite good except in the vicinity of a temperature minimum during northern hemisphere winter near 300° aerocentric longitude. This is likely due to an insolation cutoff by the dust storm occuring between $275^{\circ} < L_s < 320^{\circ}$, which "thickened" the atmosphere to an optical depth of 8 (James and North, 1982). Notice that $L_s \simeq 275^{\circ}$ is where the model VL-1 temperature falls below the model. There was also a dust storm between $205^{\circ} < L_s < 250^{\circ}$, but its effects on atmospheric transmissivity was about two orders of magnitude less than the storm at the temperature minimum. The dust storm effects do not show up in the model versus data comparison of Fig. 1; either the dust loading was less further north, or since the temperature minimum of about $157^{\circ}K$ was near the condensation frost point or CO_2, latent heat effects prevented the temperature from falling any lower. This is also to be investigated further.

To exploit Kieffer's (1977) computations of I and α for Mars, we have obtained from H. Kieffer the Mars Average Data Set (MADS) containing temperature and albedo data. Our intention is to check the seasonal surface temperature model against data for more latitudes than the two Viking lander sites. However, there are significant amounts of missing temperature data (Martin, 1981), and it is not yet clear the extent to which valid daily T_s values can be obtained for all latitudes and seasons. This investigation is underway. Nevertheless, it appears we can utilize the albedo data from MADS (for non-dusty times) as a function of latitude and possibly time of year as an input to our seasonal model, or possibly parameterize seasonal albedo change as a function of other properties (such as T_s). The distribution of I as a function of latitude is being obtained from the full Mars Consortium Data Set.

(3) Seasonal Pressure Waves

Despite the reasonable (present day) surface temperatures at middle latitudes neglecting atmospheric transport, it is necessary to include meridional mass transport of CO_2 in our seasonal model to account for seasonal pressure waves associated with CO_2 cap sublimation/condensation cycles. The James and North (1982) seasonal model assumes pCO_2 globally equilibrates over the duration of their numerical timestep of ~ 4 sols. Phil James (personal communication) cites Haberle's Mars GCM results indicating a relaxation time (by sublimation-driven winds) from the north pole to VL-1 as no more than ~ 8 sols. However, the pressure data for VL-1 and VL-2 (Sieff, 1982) show a minimum pCO_2 at VL-1 (22^{o}N) during northern hemisphere winter, when CO_2 is condensing into the southern polar cap, to precede the corresponding minimum at VL-2 (48^{o}N) by perhaps 0-30 sols. Similarly, the peak at VL-1 during southern hemisphere summer, when mass flux of CO_2 is entering the atmosphere from sublimation at the south polar region, precedes the maximum at VL-2.

To study this further, we are obtaining VL-1 and VL-2 pressure data from J. Tillman (2245 sols @ VL-1 and 1050 sols @ VL-2-- He expects to release this data to NSSDC in December, and we should receive it shortly). Our intent is to use it to estimate the meridional seasonal mass flux of CO_2 by examining the existence of phase lags between VL-1 and VL-2, and using their presence to calibrate equator-to-pole mass flux rates in the seasonal model. These considerations apply to meridional fluxes within the northern hemisphere only. Another effect which may impact the observed seasonal pressure waves is blocking by the intertropical convergence zone (ITCZ). Both Haberle's model and Kahn's data show a well-developed Hadley circulation in the tropics which could well effect interhemispheric transports. These effects, individually or in combination, could well effect the observed seasonal pressure waves, and will be studied in relation to our modeling of the current Martian climate.

ORIGINAL
OF POOR

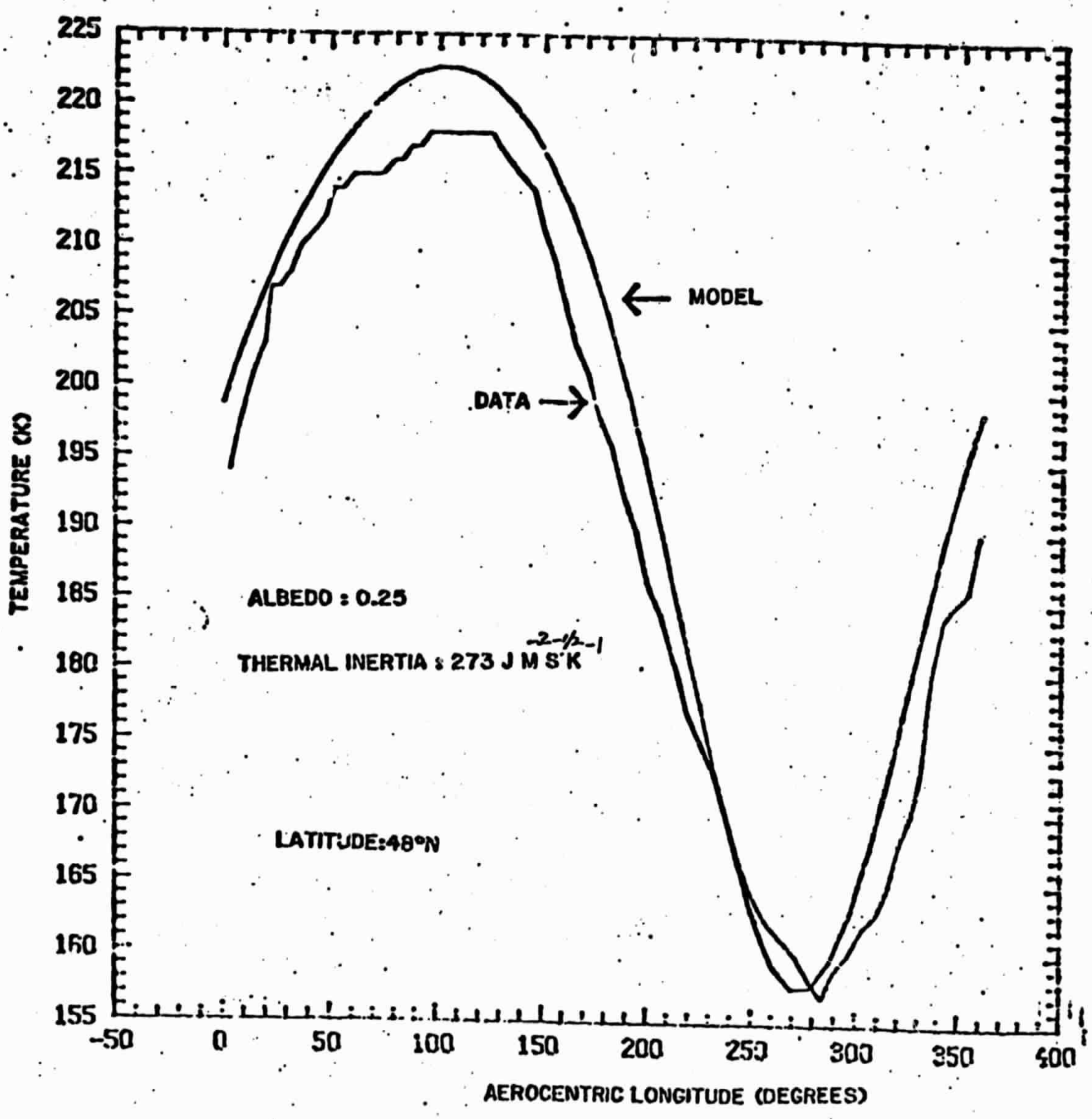

FIGURE 1

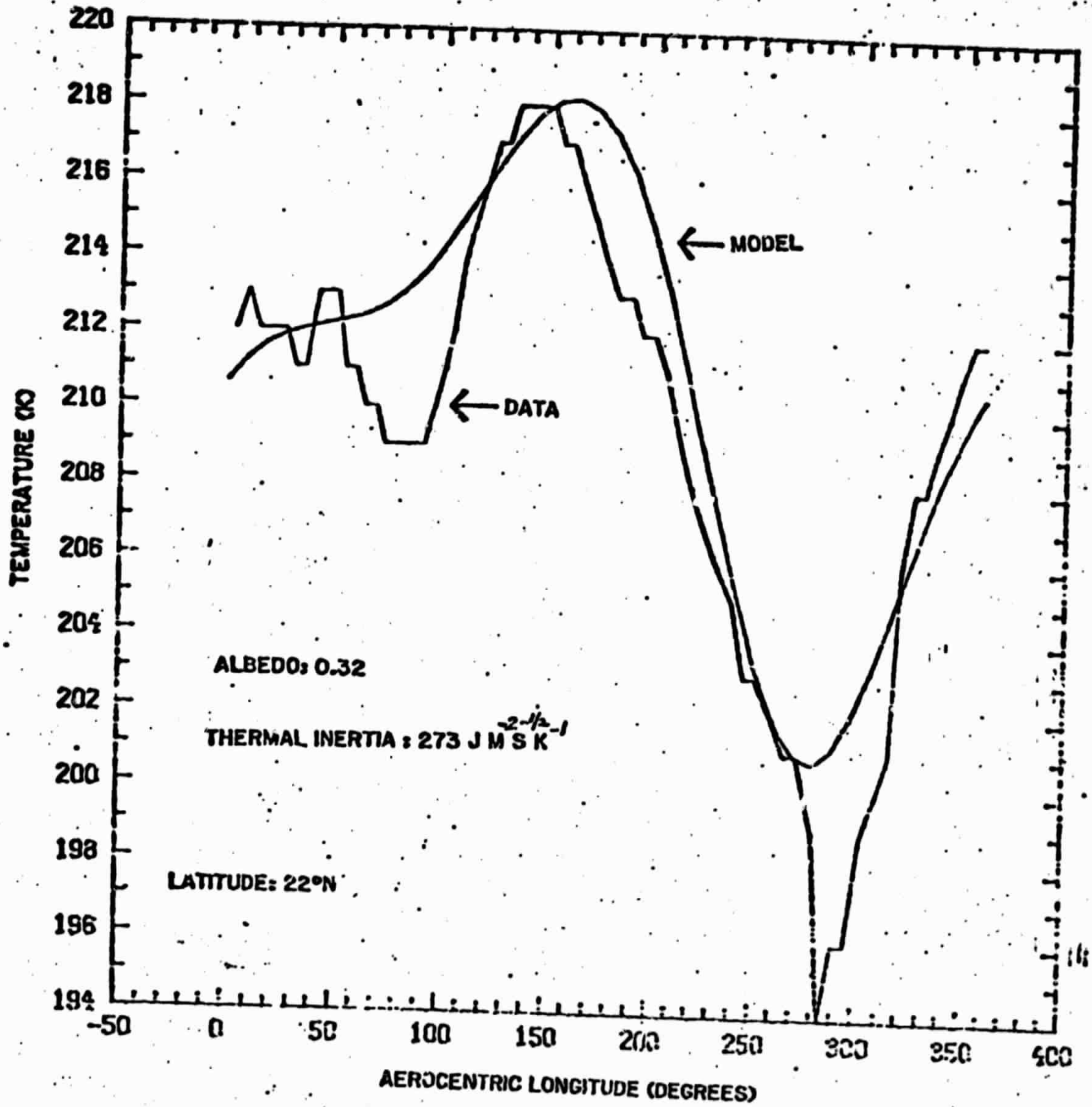
220
218
216
214
212
210
208
206
204
202
200
198
196
194
TEMPERATURE (K)
MODEL
DATA
ALBEDO: 0.32
THERMAL INERTIA : 273 J M-2 S-1/2 K-1
LATITUDE: 22°N
-50
0
50
100
150
200
250
300
350
400
AEROCENTRIC LONGITUDE (DEGREES)

FIGURE 2

References

Hoffert, M.I., and J. Storch (1979) A scheme for computing surface fluxes from mean flow observations., BOUNDARY LAYER METEOROLOGY, vol. 17, pp.429-442, D. Reidel Publishing, Dordrecht, Holland

Hoffert, M.I., A.J. Callegari, C.T. Hsieh, and W. Ziegler (1981) Liquid water on Mars: an energy balance model for CO2/H2O atmospheres. ICARUS, vol. 47, pp. 112-129

Jakosky, B.M. (1979) The effects of nonideal surfaces on the derived thermal properties of Mars., J. GEOPHYS. RES., vol. 84, pp. 8252-8262.

James, P.B., and G.R. North (1982) The seasonal CO2 cycle on Mars: an application of an energy balance climate model, J. GEOPHYS. RES., vol. 87, pp. 10271-10283.

Martin, T.Z. (1981) Mean thermal and albedo behavior of the Mars surface and atmosphere over a martian year., ICARUS, vol. 45, pp. 427-446

Seiff, A. (1982) Post-Viking models for the structure of the summer atmosphere of Mars., ADV. SPACE. RES., vol. 2, pp. 3-17.

ORIGINAL PAGE IS
OF POOR QUALITY