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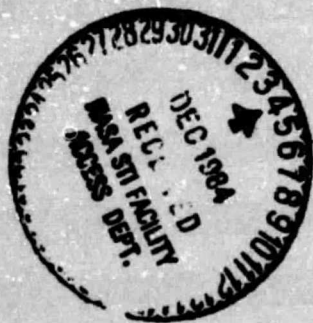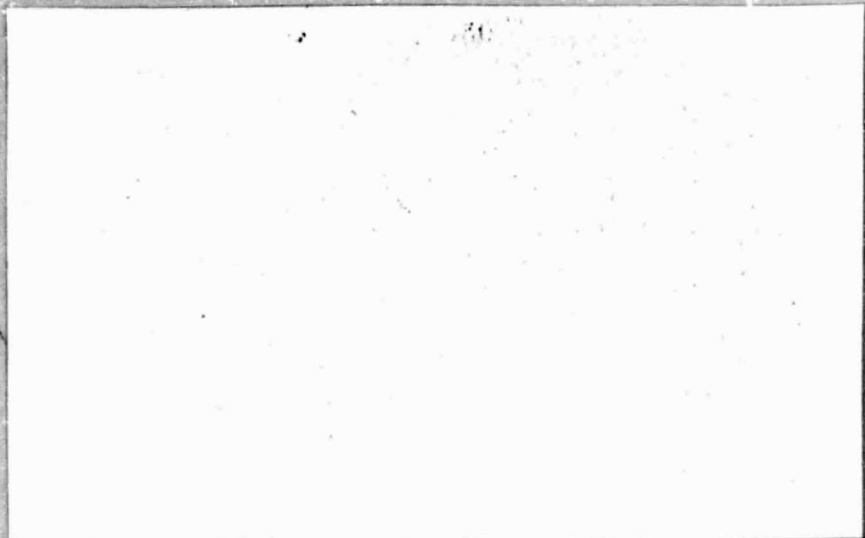
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NEW YORK UNIVERSITY

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

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NEW YORK UNIVERSITY

FACULTY OF ARTS AND SCIENCE

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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:

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

where

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

T_s, $<T_s>$ 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 $\epsilon = 1.0$ and $I = 272$ J/m^2-K-$s^{1/2}$, the seasonal variation of daily mean surface temperatures at latitudes of the VL-1

-2-

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 $\sim$ 70-200 J/m^2-K-$s^{1/2}$ 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°N for α=0.25. The agreement is generally quite good, with a seasonal amplitude of about 60°K. The model precedes the data in phase by about 10-20° 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°N, using α =0.32. Here the agreement is again quite good except in the vicinity of a temperature minimum during northern

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hemisphere winter near 300° aerocentric longitude. This is
likely due to an insolation cutoff by the dust storm occuring
between $275^O < L_s < 320^O$, which "thickened" the atmosphere to an
optical depth of 8 (James and North, 1982). Notice that L_s
$\simeq 275^O$ is where the model VL-1 temperature falls below the
model. There was also a dust storm between $205^O < L_s < 250^O$,
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
$157^O K$ 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

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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°N) during northern hemisphere winter, when
CO_2 is condensing into the southern polar cap, to precede the
corresponding minimum at VL-2 (48°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

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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.

FIGURE I

ALBEDO: 0.32

THERMAL INERTIA: 273 J M^{-2}S$^{-1/2}$K^{-1}

LATITUDE: 22°N
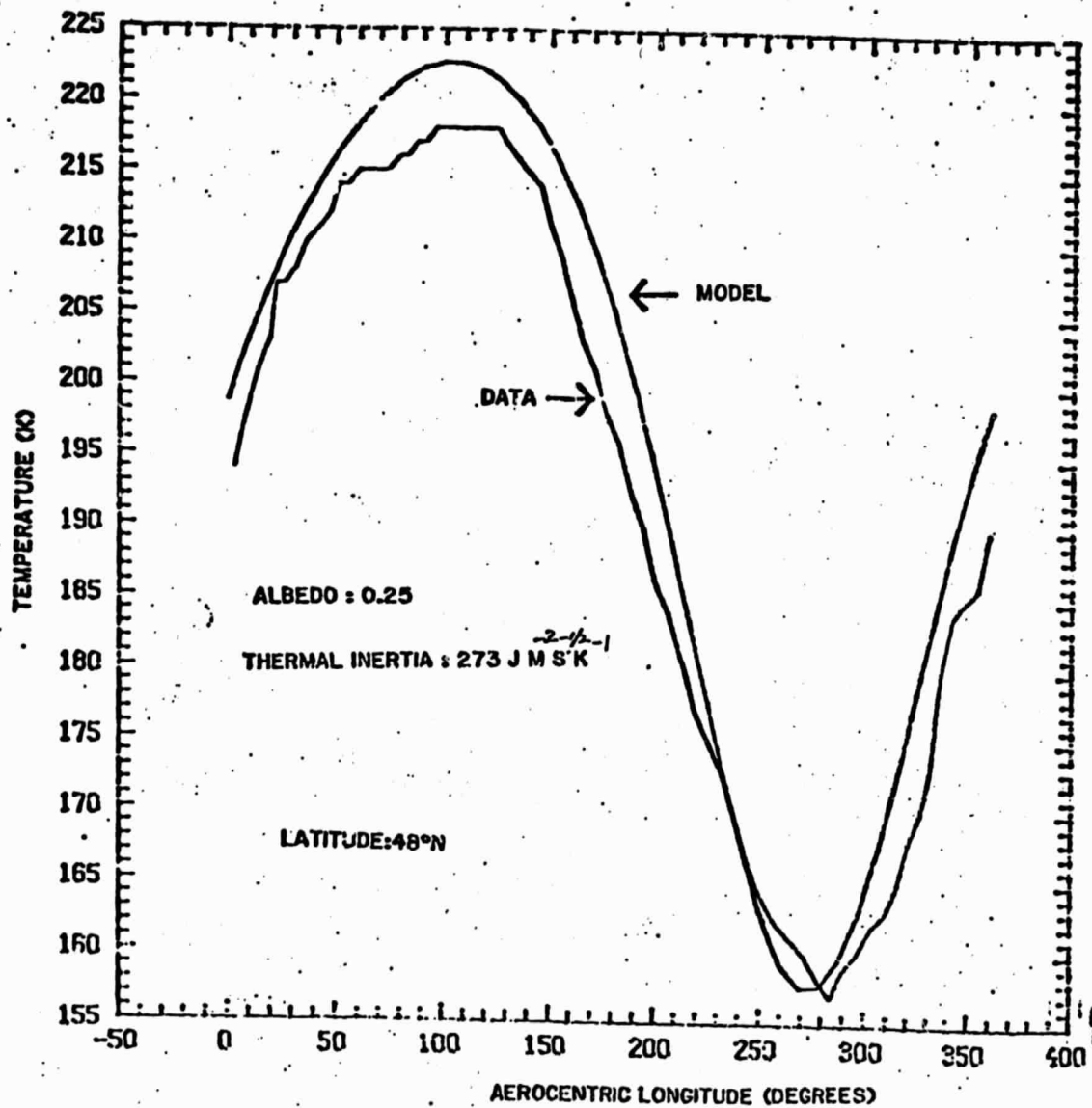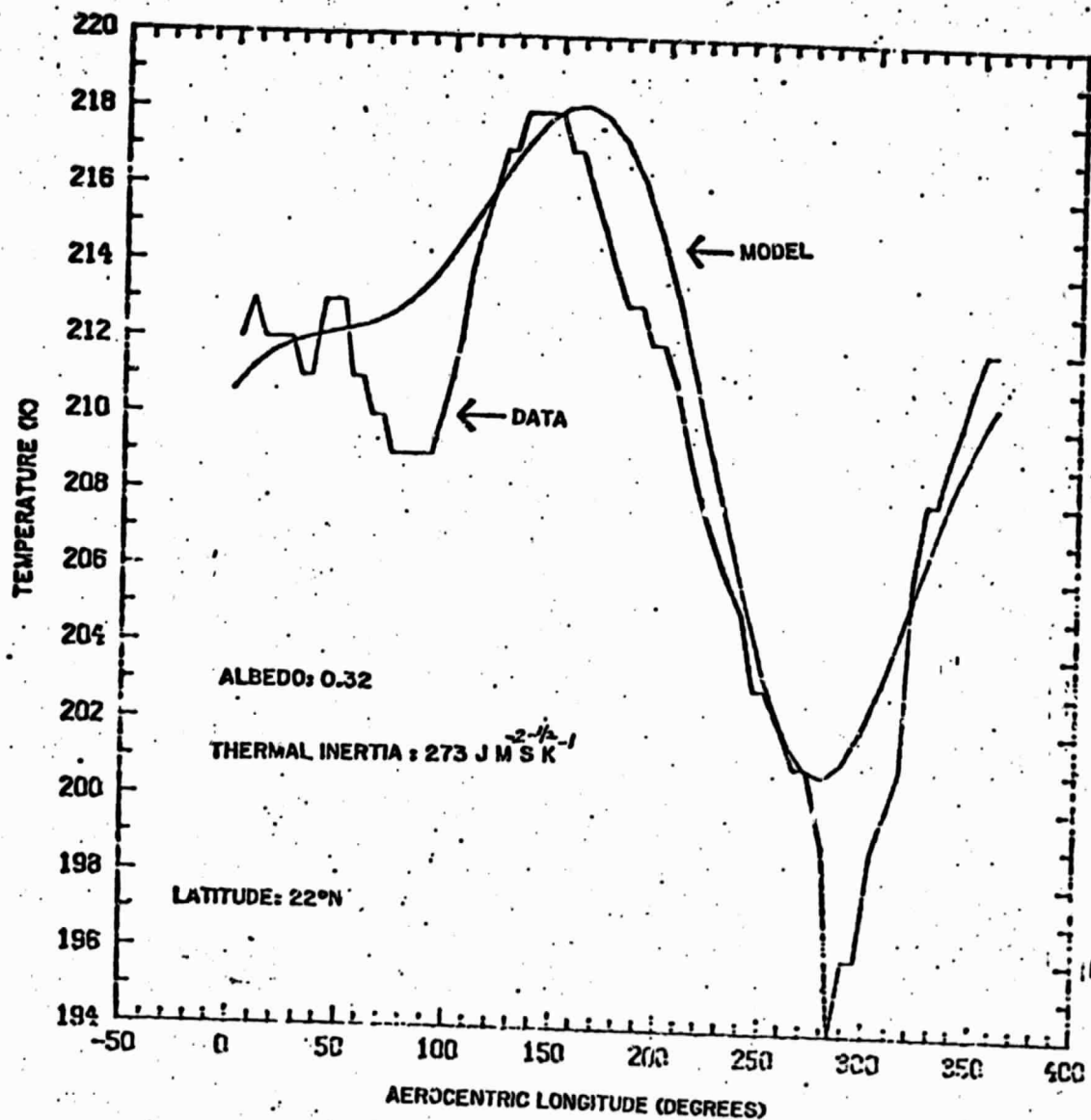
FIGURE 2

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