MARS CHARACTERIZATION FOR FUTURE MISSIONS

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FINAL REPORT

Professor Alison F.C. Bridger
Meteorology Department
San Jose State University
San Jose CA 95192-0104
bridger@hellas.arc.nasa.gov

Dr. Robert M. Haberle
NASA Ames Research Center
MS 245-3
Moffett Field, CA
haberle@humbabe.arc.nasa.gov

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OVERVIEW

The purpose of this research project was to create statistical products which could be of use to the engineering and scientific communities planning future missions to Mars. This has been accomplished. Using simulations of Mars' atmosphere under a variety of conditions, we have created statistical databases quantifying the behavior of Mars' atmosphere under a variety of conditions expected to be encountered on forthcoming missions. These data are now being incorporated into a new version of Mars-GRAM.

EXPERIMENTS AND ANALYSIS

To generate the desired data products, we utilized the NASA Ames Mars General Circulation Model (MGCM), a sophisticated computer model of Mars' atmosphere. The MGCM is capable of simulating the atmosphere from pole-to-pole up to elevations of about 80 km. Simulations can be for short periods [O(10's of days), simulating "weather"], or for annual or even multiannual periods ("climate").

The MGCM incorporates sophisticated physics, including: radiative driving of the atmosphere (visible and IR); realistic distributions and effects of suspended atmospheric dust; allowed condensation of CO_2; realistic topographical, albedo, and thermal inertia distributions; a sophisticated boundary layer scheme; and an improved soil scheme. Results of simulations under a variety of conditions have appeared in the literature.

For the purposes of this study, we utilized results from a set of annual simulations of the model. In these, the dust is assumed to be uniformly distributed in the horizontal, and is not allowed to vary in time. In the vertical, dust is mixed uniformly up to a certain height, above which its amount decays exponentially with height. Two such simulations have been used, having dust opacities of $\tau=0.3$ (low dust) and $\tau=1.0$ (moderate dust; a high dust $\tau=3.0$ simulation is pending, and results will be added to the database). These choices were agreed upon following consultation with Dr. Jere Justus, and are in part driven by values observed during the Viking mission and by recent MGS-TES observations.

It was decided that an appropriate measure of the variability of the atmosphere would be given by amplitudes and phases of atmospheric diurnal (one cycle per sol) and semidiurnal (two cycles per sol) thermal tides. These tides are excited by the sun's radiative driving, and can attain substantial amplitudes during dusty conditions. Their amplitudes generally increase with altitude, and thus they might sufficiently perturb the higher atmosphere to impact aerobraking and aerocapture activities.

After some experimentation, it was decided to develop the following products:

1. zonally-averaged and time-averaged fields (temperatures, densities, horizontal wind components, pressures on geopotential surfaces)
2. zonally-averaged tidal amplitudes of the above fields
3. zonally-averaged tidal phases
4. distributions of tidal amplitudes and phases at the two lowest levels in the MGCM, to provide near-surface temperature information

RESULTS

The products outlined above have been developed, and are accessible via anonymous ftp from mintz.arc.nasa.gov (/pub/mgcm/justus and directories below). At this stage, it has not been decided to put the data on the web (as had been proposed), since it can be readily accessed via ftp by those who immediately need it. However, since other products from these MGCM simulations will be made available on the web as part of the MGCM Climate Catalog, the products generated here may be added to that site (in the form if gifs and/or ascii data files).

The zonally-averaged fields are computed based on an average over 30 sols. In part, this is determined by the structure of files archived from the annual simulations. Twelve "mini-seasons" are defined for each simulation, each lasting 30 sols, and spaced every 30° of areocentric longitude (Ls). The top panel of Fig. 1 shows an example of the latitude-height distribution of zonally averaged temperatures at Ls 270° (northern mid-winter). The distribution shows the warm, summer pole, and the cold winter polar atmosphere, with a sharp north-south thermal gradient, indicative of an active baroclinic zone in the north at this season.

For tidal fields, after experimentation it was decided to compute amplitudes based on 5-sol composite fields, centered on the middle five sols of the 30 sol records mentioned above. The chief reason for this is that there can be significant variation of tidal amplitudes and phases over 30 sols, rendering 30-sol averages somewhat difficult to interpret. In addition, and especially with tidal phases, we have encountered significant longitudinal variations, again making averaging difficult (since products 1-3 are zonally-averaged). To overcome this, a special zonal averaging procedure was developed for phase fields. Taking the cosine and sine portions of the tidal field, we first form zonal averages of these, and then form a final zonally-averaged phase from the ratio of these.

The lower two panels of Fig. 1 show the amplitudes (zonally-averaged) of the diurnal and semidiurnal temperature tide for the low dust case at Ls 270°. They indicate a diurnal tidal wave with amplitudes over 12.5 K (i.e., 25 K peak-to-peak temperature swings). The semidiurnal wave has a somewhat smaller amplitude at this season.

A second set of products we proposed to create pertain to data for a near-surface temperature model. This was accomplished again using the annual MGCM simulations mentioned above. The products discussed above were provided following interpolation to z-surfaces. The MGCM simulations however produce results on σ-surfaces, where σ is related to the ratio p/ p_s, with p = actual pressure and p_s = surface pressure. It was decided to extract temperature information on the model's lowest two σ surfaces, corresponding to altitudes of approximately 5m AGL and 30m AGL. From these temperature fields, diurnal and semidiurnal tidal amplitudes and phases were again computed and stored in data files. From these, together with the temperature products mentioned above, we can get a fairly detailed view of near-surface temperatures and their variation through the day (as a function of season).

Figure 2 shows the latitude-longitude distribution of mean temperatures (upper panel), as well as diurnal and semidiurnal tidal amplitudes in the temperature field at the lowest σ-level in the model, again at Ls 270° and for the low dust case. In the mean field, we see the north-south temperature gradient, as well as evidence of stationary wave activity in the sub-tropics. Both tidal amplitude fields show considerable longitudinal structure. This is indicative of the presence of non-migrating tides (sun-synchronous tides propagate westwards, "following the sun". If these alone are present, we would expect no longitudinal variations in amplitude. However, longitudinal variations of topography, albedo, and thermal inertia can produce non-sun-synchronous tidal oscillations, yielding a complicated horizontal structure).

As mentioned above, all products have thus far been generated for both low and moderate dust cases (144 files per annual simulation). Data from a third, high dust case is pending. We may also choose to include (in consultation with Dr. Jere Justus of MSFC) data from a shorter simulation (e.g., 30-50 sols) of a dust storm. For example, we may include a simulation of the Noachis dust storm observed during MGS aerobraking (simulation performed by Dr. Jim Murphy at NMSU), or simulations from Viking-era dust storms.

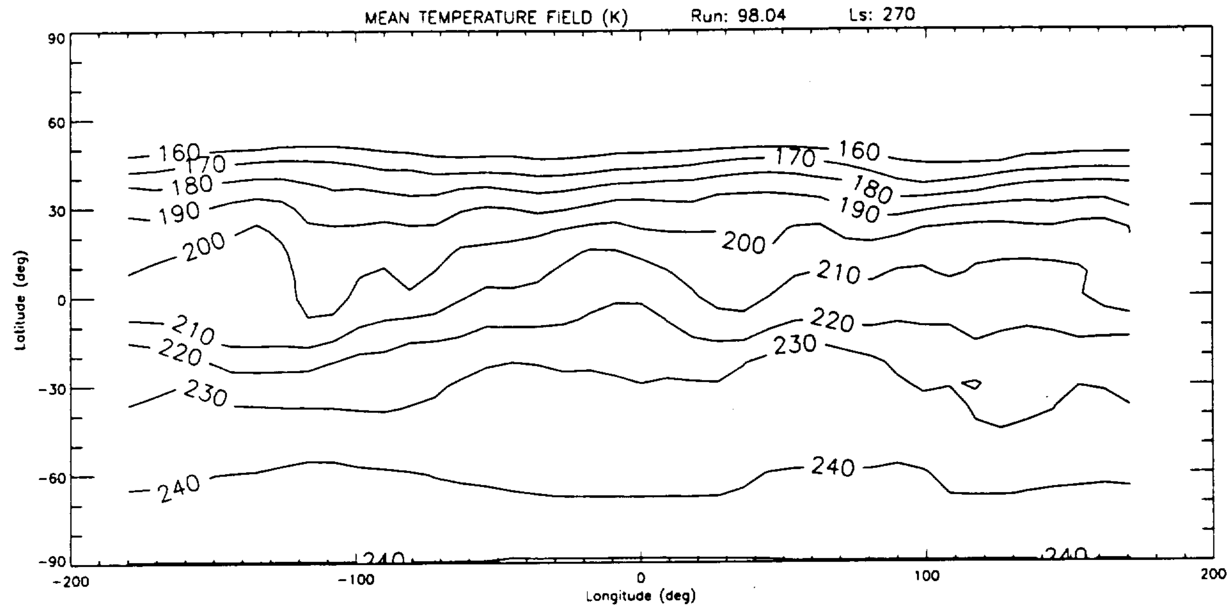
SUMMARY

Annual simulations of Mars' atmosphere made with the NASA Ames Mars General Circulation Model have been used to extract and generate products to provide statistical products that detail the variability of Mars' atmosphere on fairly short time scales. These products are needed for the creation of a new version of Mars-GRAM, due for completion in June, 1999. The updated Mars-Gram, in turn, will provide guidance for forthcoming aerobraking and aerocapture activities.

We have created files containing zonally-averaged fields (temperatures, densities, pressures, and winds, all on z-surfaces), as well as zonally-averaged diurnal and semidiurnal tidal amplitudes and phases. All fields represent a time averaged state (over either 5 or 30 sols), and all fields are available at each of 12 seasons for a Mars year (the seasons being 30° of Ls apart). Files for low and moderate dust loading cases are available via anonymous ftp. Files for a high dust case will be in place shortly.

FUTURE WORK

Two extensions from this work are possible. In the first (being funded through the second year of this effort), we will provide products from these same simulations as input to the Mars Thermospheric General Circulation Model (MTGCM, in consultation with Dr. Steve Bougher at UA). We will provide data on tidal oscillations that are needed to "drive" that model (i.e., Hough function amplitudes and phases). In a second possible extension, it is clear that there are large-amplitude stationary waves in Mars' atmosphere. These are expected, given Mars' large amplitude topography at large-scales. Evidence of high-altitude stationary wave activity emerged during MGS aerobraking. It may prove worthwhile to include a parameterization of this into Mars-GRAM. Again, products would be created from simulations of the MGCM.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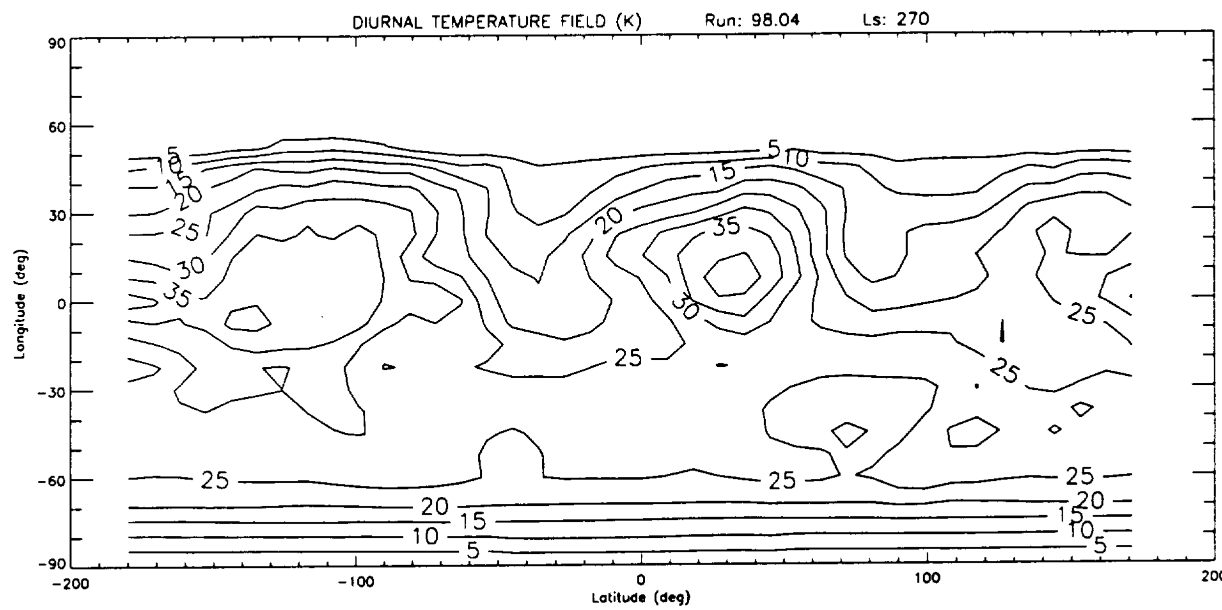
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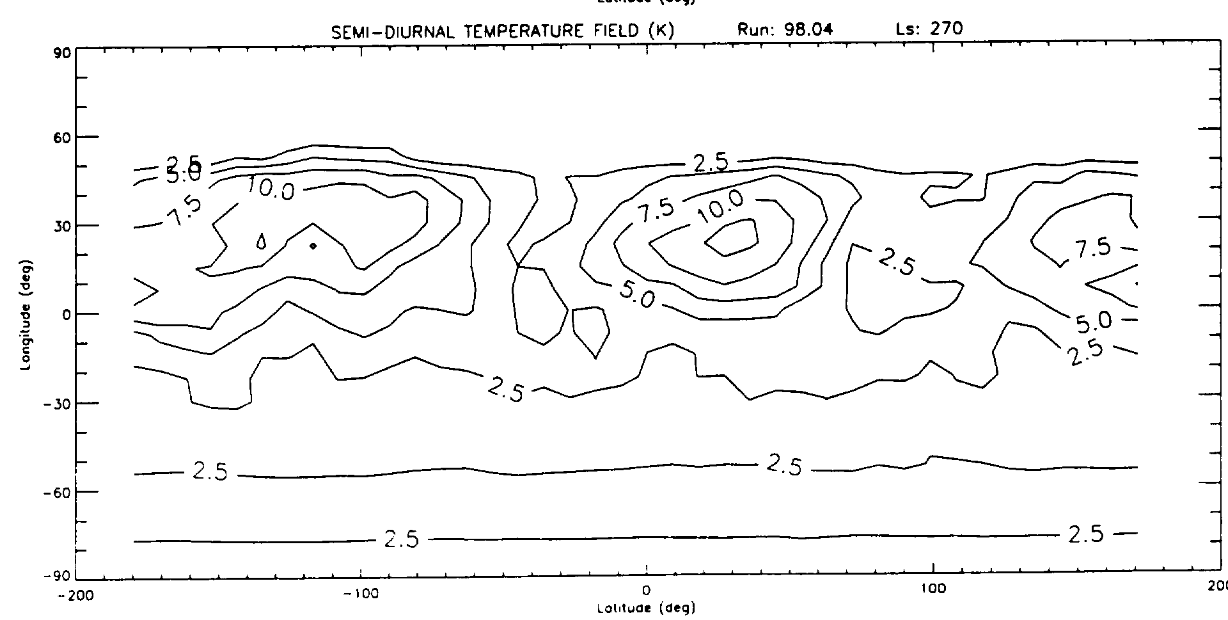
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