BOUNDARY LAYER/ SOIL MODEL FOR GLOBAL MARS MULTISCALE MODEL (GM3).

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Introduction:

Based on the observational data from the surface of Mars by the Mars Pathfinder and the Viking landers [3,9], the boundary layer turbulence and mean flow behaviour on Mars has been found to largely obey the same scaling laws as on Earth [5]. An alternate boundary layer model for Mars using the K-theory and similarity relations, within the framework of GM3 is described. Its results are also compared with Viking 1 and Mars Pathfinder landers temperature data.

Model Description:

The model is based on the dynamical core and the radiation scheme of GM3 [7]. The model grid configuration is designed for both a globally uniform grid and a limited area uniform grid system embedded within a global grid system. In the limited area configuration, the GCM can be used for mesoscale meteorology by zooming in the grid system on a local area of interest [8]. The boundary layer scheme described herein assumes that main effect of turbulence on the evolution of the layer is through the convergence of the vertical fluxes of heat and momentum. The scheme consists of a surface layer and the mixing parameterizations, combined with an underlying multilayer soil model. Because of its low density, the regolith acts as an important thermal sink and source for the atmosphere of Mars, and it also may be important in the control of meridional distribution of water vapour [3]

A multilayer soil scheme composed of 14 soil layers is used to calculate the thermal exchange within the regolith by solving the one dimensional heat diffusion equation for the time evolution of the sub-surface temperature. The ground temperatures are then computed by solving the surface energy budget. GM3 model uses the Mars Global Surveyor (MGS) TES thermal inertial and albedo data with the MOLA topography as the only input, assuming a constant value for the specific heat capacity and the regolith density.

The surface layer parameterization employs the Monin-Obhukov similarity theory to evaluate the turbulent surface fluxes of heat and momentum [6]. The mixed layer, lying above the surface layer is where the turbulent fluxes are parameterized based on the stability of the underlying layer. When the potential temperature gradient in the surface layer is greater than zero, the mixed layer is stably stratified and *K*-theory is used; the value of *K* (the eddy diffusion coefficient) is determined from the second-order closure theory. When the mixed layer is unstably stratified, the heat transport is countergradient [1]. The countergradient term proposed by Tijm et al. [10] is used to evaluate the eddy diffusion coefficient. At all levels above the boundary layer, a small but non-zero eddy coefficient proposed by Tijm et al. is used. The eddy diffusion coefficients are then applied to the energy and momentum equations in time, assuming horizontal homogeneity.

In addition, a new CO_2 sublimation/condensation scheme has been added to the model. The scheme is largely modeled after the CO_2 snow fall parameterization of Forget et al. (1998) which is both mass and energy conserving. Also, the attendant radiative effect of CO_2 ice is applied by decreasing the surface emissivity whenever fresh CO_2 ice is formed, and relaxes back to the old value of 0.95 after the ‘snowfall’. Local pressure changes as a result of the phase change of CO2 are also predicted by the model.

Model Results:

The surface temperatures produced by the model show little day-to-day variability but a strong diurnal variation in response to solar heating. The model performance has been evaluated by comparing with the Mars Pathfinder and Viking 1 landers observations. A model run with a global uniform grid at 9^0 by 9^0 resolution with a 30 minute time-step shows good agreement between the Mars Pathfinder’s ASI/MET sol 9 (Ls=147^0) data and the model results around the lander site. The atmospheric temperature at 1.6m predicted by the model however does under-predict the 1m sensor-level temperatures recorded by the ASI/MET instrument by ~5-6K. On the other hand, there exists a difference of about 10K in the nighttime temperatures predicted at the atmospheric height of 1.6m by the model and the Viking 1 lander data on sol 29 (Ls =110^0) of its mission. This is probably due to the model using a higher thermal inertia at that location compared to that observed by the lander. The daytime temperatures (especially when the sun is high) however were in good agreement. We hope to be able to publish detailed model comparison in a future article. Figures 3 and 4 shows the zonally averaged temperatures and zonal wind in the lower atmosphere during the northern hemisphere summer.

Figures:

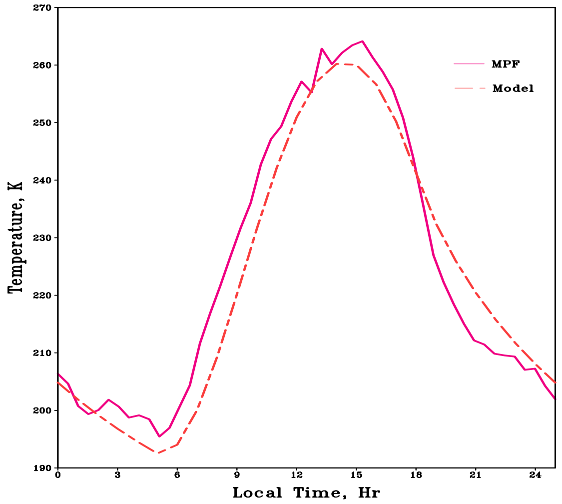

Figure1: Temperature at the 0.25m level of the MPF ASI/MET temperature sensor against the surface temperature predicted by the model on Ls=147^0.

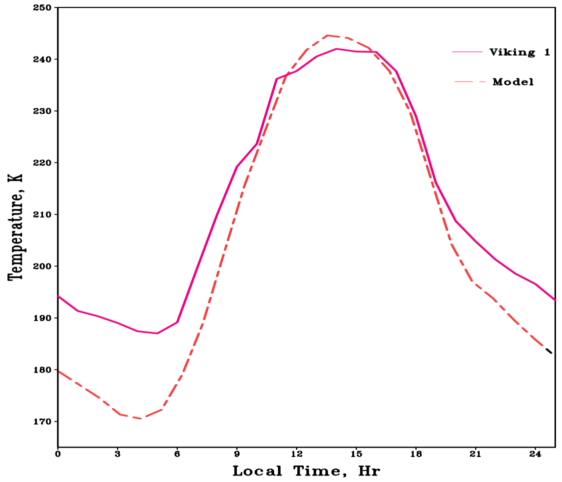

Figure2: Observed atmospheric temperature at 1.5m from Viking 1 lander compared to the model temperatures on Ls=110^0.

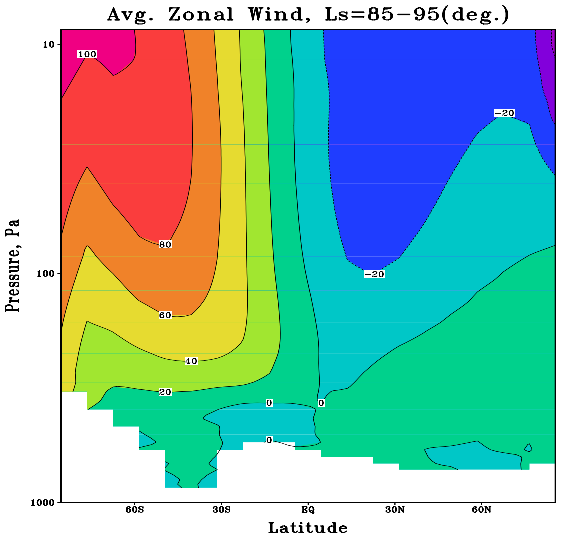

Figure 3: Averaged zonal wind in the lower atmosphere around Ls=90^0.

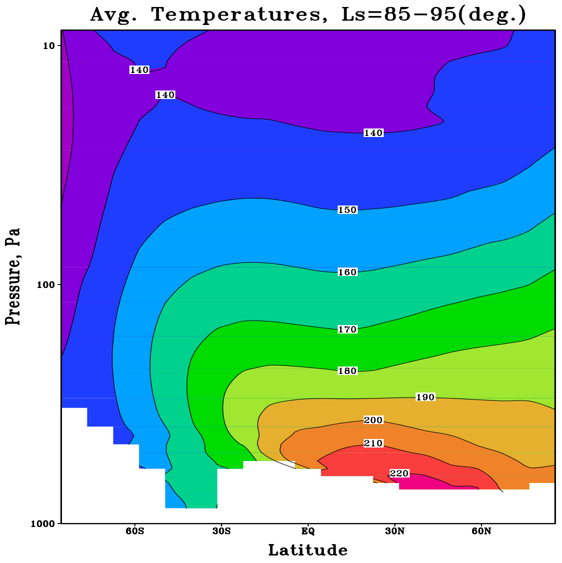

Figure 4: Zonally averaged temperatures of the lower atmosphere around the northern hemisphere' summer.

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