A NEW GENERAL CIRCULATION MODEL OF THE MARTIAN ATMOSPHERE: DESCRIPTION AND FIRST RESULTS.

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Introduction

We present a new general circulation model which was developed under the aegis of the Mars Atmosphere Observation and Modeling project (MAOAM) as part of the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) research priority program “Mars and the Terrestrial Planets". The model represents a deeply re-designed version of the Cologne Model of the Middle Atmosphere (COMMA) [e.g., *Berger and von Zahn*, 1999], a terrestrial GCM which was extensively used for studies of the dynamics and photochemistry in the Middle atmosphere for more than 20 years. The Martian GCM was recently described in more details in [*Hartogh et al.*, 2005].

General description and model dynamics

The dynamical core of the model is the finite-difference (grid point) solver for the hydrostatic primitive equations of the hydrodynamics on the sphere. The equations for the horizontal momentum, the thermodynamic equation as well as the continuity and the hydrostatic equations [e.g., *Andrews et al.*, 1987] are discretized on a regular grid in the flux form. The vertical discretization is based on the log-pressure coordinates. The model has a variable resolution in both horizontal and vertical. It is run most often in the “lower resolution" mode (32 x 36 grid points in the longitude and latitude directions, respectively), and in the “higher resolution" version (64 x 36) for some experiments. The time step at this resolution is $\Delta t = 2$ min. In vertical, 118 vertical staggered levels cover the atmosphere from the deepest point on the Martian surface (depends on the horizontal resolution of the model) to approximately 130 km with a vertical grid step of about 1.14 km. We use the Mars digital elevation model derived from the Mars Orbiter Laser Altimeter (MOLA) profiles [*Delacourt et al.*, 2003]. The topography was spectrally truncated according to the spatial model resolution, no additional smoothing was performed.

The model utilizes the centered (“leapfrog") time-differencing scheme with the Asselin time filter (coefficient 0.05 below 100 km, followed by the tangential rise to 0.15 at 130 km). In horizontal, Shapiro filter is applied to the wind and temperature fields. The stability of the model in high latitudes is maintained with a “near-pole" filter, which truncates all zonal harmonics (wind, atmospheric and surface temperature) greater than 2 at latitudes higher than 82.5°.

Radiation schemes

The model employs a new CO_2 15-μm non-LTE cooling scheme, CO_2 near-infrared heating parameterization, and the dust radiation scheme.

The CO_2 IR non-LTE cooling scheme is described in the accompanied talk [*Feofilov et al.* New technique for calculating...] This scheme can be used for computing both the CO_2 15-μm cooling and the IR CO_2 heating. Alternatively, the formulae from [*Forget et al.*, 1999] can be used instead of detailed calculations.

The dust scheme is borrowed from [*Kuroda et al.*, 2005], and will be presented in an accompanied talk as well. The major update since publication of [*Hartogh et al.*, 2005] is the implementation of the 19 spectral band version.

Surface energy budget

On the surface, a slab model is used to calculate the energy budget. The energy balance is determined by the sensible heat flux from the surface to the atmosphere, by the flux into the soil, and by the net radiative flux (including the solar and thermal components). The thermal flux is the output of the CO_2 and dust radiation schemes, the solar flux is computed from the black body emissivity of the Sun, the geometry, and the absorption and scattering by the atmospheric dust. The surface albedo [*Christiansen et al.*, 2001] and the surface inertia maps are used in the model.

Subgrid-scale dynamics

The model employs a standard local diffusion parameterization for the free atmosphere based on the Richardson number with the parameters adapted from the terrestrial atmospheric NCAR–CAM3 (National Center for Atmospheric Research–Community Atmospheric Model) GCM. Coefficients of the turbulent diffusivity and thermal conduction are taken proportional to the stability functions F_c:

$$F_c(Ri) = (1 - 18Ri)^{1/2}, \qquad Ri < 0$$

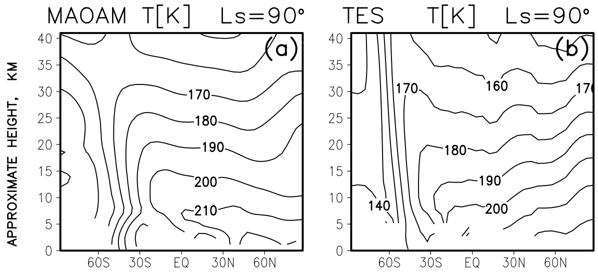

Figure 1: Zonal mean temperature for $L_s = 90°$ (a) simulated with the model, (b) obtained from the TES measurements. The contour interval is 10 K.

$$F_c(Ri) = [1 + 10Ri(1 + 8Ri)]^{-1}, \qquad Ri \geq 0 \quad (1)$$

where Ri is the Richardson number. Prandtl number equal to 1 is assumed.

The lack of wind measurements in the middle atmosphere provides little information about the effects of broad-spectrum GWs. Therefore, we employ only the parameterization of effects of gravity waves excited by the subgrid-scale orography. The source magnitudes of GW harmonics with zero phase velocity above the resolved topography is estimated after from subgrid scale variance of the topography. The vertical propagation including effects of the refraction, nonlinearities, and ultimately breaking and dissipation near critical levels is calculated using the parameterization of *Medvedev and Klaassen* [2000]. This spectral scheme was adapted for one harmonic also calculates the thermal effects of dissipating and breaking gravity waves. The only tunable parameter is the characteristic horizontal wavelength was taken equal 200 km.

The model employs a standard energy conserving convective adjustment scheme. The Rayleigh friction (a "sponge layer") is imposed near the top of the domain to substitute for the missing damping effects in the upper atmosphere and, perhaps, for the drag from broad-spectrum gravity waves. The Rayleigh friction coefficient grows exponentially with height above 100 km, and reaches 9 sol^{-1} at 130 km.

Only thermal (and no mass) effects of CO_2 condensation and sublimation are considered in the present version of the model.

Comparison with MGS–TES

The global zonally averaged temperature is available from MGS–TES nadir measurements. Figures 1–3 compare the simulated temperature in the corresponding domain for $L_s = 90°$, $180°$, and $270°$. According to the adopted dust scenario, the optical depth at the equator was 0.05, 0.05, and 0.2, respectively. The model fields were averaged over $\Delta L_s = 6°$ centered around the indicated aerocentric longitude.

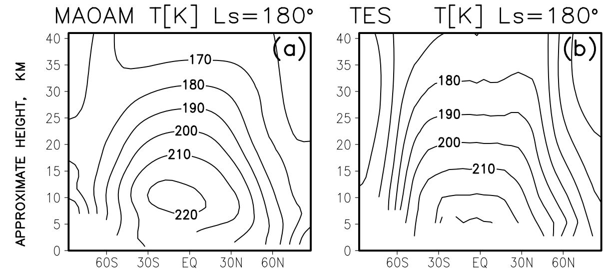

Figure 2: Same as in Fig. 1 but for $L_s = 180°$.

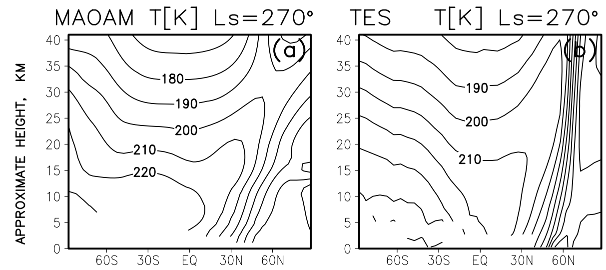

Figure 3: Same as in Fig. 1 but for $L_s = 270°$.

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