THERMAL STRUCTURE OF THE MARTIAN THERMOSPHERE: LMD-IAA GCM AND MTGCM INTERCOMPARISONS.

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Introduction

Several General Circulation Models for the study of the Martian atmosphere have been developed in the last decades, like the NASA Ames MGCM (*Pollack et al.,* 1990; *Haberle et al.,* 1993, 1999), the thermospheric MTGCM originally developed at the National Center for Atmospheric Research (*Bougher et al.,* 1990, 1999a, 2000), the GFDL Mars-GCM (*Wilson and Hamilton,* 1996) and the european model developed by the Laboratoire de Météorologie Dynamique (LMD, Paris) and the Atmospheric, Oceanic and Planetary Physics department (AOPP, Oxford University), LMD-AOPP GCM (*Hourdin et al.*, 1993; *Read et al.,* 1997; *Forget et al.,* 1999). With the exception of the MTGCM, all these models have been devoted to studies of the lowest layers of the Martian atmosphere. Recently, in collaboration with the Instituto de Astrofísica de Andalucía (IAA, CSIC, Granada) the LMD model has been extended to thermospheric altitudes, becoming thus the first GCM covering the whole Martian atmosphere (*Angelats i Coll et al.,* 2005; *González-Galindo et al.*, 2005).

For these models, the validation process can include comparisons with experimental data and comparisons with results from other models. Due to the scarcity of data in the Martian mesosphere and thermosphere, the comparisons between different models are specially important for thermospheric altitudes. This is specially useful for the newly developed extension to the thermosphere of the LMD-IAA GCM. The MTGCM has already been validated against several spacecraft datasets, including those from the MGS Accelerometer & Radio Science investigations (*Bougher et al.,* 1999b; 2001; 2003; 2004; 2005) and the recent Odyssey Accelerometer experiment (*Bougher et al.*, 2005). However, the MTGCM has not been tested in detail against other Mars thermospheric models. Here we present the first intercomparison between these two Martian thermospheric GCMs.

Models

MTGCM is a finite difference primitive equation model that solves for time-dependent neutral temperatures, neutral-ion densities, and three-component neutral winds. Prognostic equations for the major neutral species, selected minor species and several ions are included. These fields are simulated on 33 pressure levels above 1.32 μbar, using a log-pressure vertical coordinate. The MTGCM is presently coupled to the NASA Ames MGCM at the 1.32 μbar level (60-80 km). This coupling allows both migrating and non-migrating upward propagating tides to cross the MTGCM lower boundary and the effects of the thermal expansion and contraction of the Mars lower atmosphere to extend to the thermosphere. Energetic process incorporated include solar EUV, UV, and near-IR heating, a fast non-LTE CO2 15-micron cooling parameterization (*López-Valverde and López-Puertas,* 2001), and molecular and eddy thermal conduction. For more details on the MTGCM code and its coupling to the NASA Ames MGCM, see *Bougher et al.,* (2004; 2005).

The LMD-IAA model, evolved from a terrestrial model and including the relevant processes near the surface, extends now from the ground up to the thermosphere (0-250 km). The radiative processes considered include the effects of dust and CO_2 in the lower atmosphere, as well as the absorption of UV and EUV radiation by CO_2, O_2, $O(^3P)$, H_2, H_2O and H_2O_2. Non-LTE effects are considered using parameterizations for the solar near-IR heating, following *López-Valverde et al.,* (1998) and for the IR cooling by CO_2 at 15 μm following *López-Valverde and López-Puertas,* (2001). A photochemical model of the neutral atmosphere, as well as the effects of molecular diffusion, thermal conduction and a simple thermal scape scheme are also included. More details can be found in *Forget et al.*, (1999) and *Angelats i Coll et al.*, (2004; 2005).

The philosophy of this study is to keep the models essentially unchanged to see the differences between the "nominal" results. However, when some sources of discrepancy have been identified, modifications have been introduced to the models in order to study the effects of different ways of treating similar processes.

Scenarios

Some basic scenarios have been designed for this study. The basic idea was to keep the scenarios as simple as possible, but close to real scenarios. This will allow, in case of discrepancy between both models, to use some of the existing experimental data to see which of them is closer to reality. We also wanted to explore the different

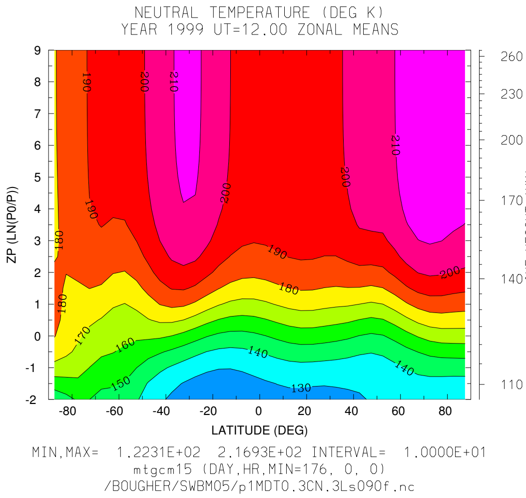

Figure 1: MTGCM zonal mean temperature structure for Ls=90

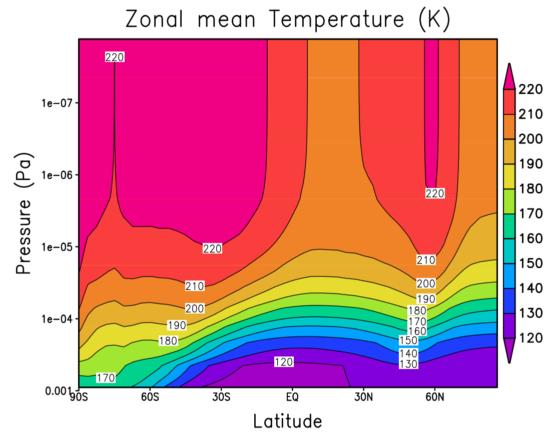

Figure 2: LMD-IAA zonal mean temperature structure for Ls=90

sources of variability between both models. So, scenarios for different seasons had to be designed. Keeping this is mind, we decided to use initially three different scenarios:

-Scenario #1: Ls=0, no dust

-Scenario #2: Ls=90, shallow dust distribution

-Scenario #3: Ls=270, heavy dust load

For the scenarios #2 and #3 the dust is homogeneously distributed in the horizontal, with a vertical distribution given by a Conrath distribution (*Conrath,* 1975) with $\tau = 0.3$ and $\tau = 1$ for the integrated optical dust opacity and values for the Conrath parameter of 0.3 and 0.03, respectively.

The same value for the UV and EUV heating efficiency, 18%, and for the CO_2-O deactivation rate, $3 \cdot 10^{-12} cm^3/s$ have been used in both models. When possible, similar spectroscopic data and solar flux values have been used. By keeping the inputs to both models as similar as possible, we make sure that the differences observed are not due to different input data.

Selection of results

A large number of maps from each model has been obtained for this comparative exercise. However, we will focus on this talk on a short selection on them, using zonal mean maps for a better display of the results.

Although this intercomparison exercise is focused on the thermal structure of the thermosphere, the temperature is not the only field that has been compared. The winds (zonal, meridional and vertical), the CO_2 and O number densities, and the main heating terms have also been analysed. This will be useful as a diagnostic tool, helping us to understand the reasons of the differences obtained in the thermal structure.

For a better visualization of the results, we decided to use zonal mean plots of those magnitudes. These plots allow us to capture both the latitude and altitude structure of the results (see Figs. 1 and 2; detailed discussions on these plots will be given in the presentation). However, in some cases, a more detailed inspection is needed. For this cases, we also use longitude-latitude maps at three different pressure levels: P=10^{-3} Pa, $1.2 \cdot 10^{-4}$ Pa, and $2.4 \cdot 10^{-8}$ Pa.

Additionally, a wave decomposition of the results at some fixed altitude levels has been also made. This decomposition provides a means to quantitatively understand the effects of tides propagating from the lower atmosphere upon thermospheric structures in both models.

Summary

The results of an intercomparison campaign between the only two Martian thermospheric GCMs operative nowadays will be shown. This will be a valuable exercise for both models, showing their strong and weak points. This will be useful to identify future improvements to be incorporated. For the LMD-IAA GCM this is only the beginning of a more extensive validation process, including comparisons with data from past and present Martian missions.

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