Software requirement Document for the Martian Atmospheric General Circulation Model.

1 Introduction

The requirements specified in the URD will be met by bringing of number of improvements to the General Circulation Model (GCM) of the Martian atmosphere developed jointly at LMD and AOPP. These improvements will bear mostly on the physical parametrizations of the model. The present document lists the parametrizations which will be included in the GCM, as well as the necessary requirements in terms of computer facilities and input/output management.

2 Requirements for the GCM

The dynamical code is already included in the GCM. As mentioned in the URD, two different representations are used for the description of the atmospheric fields and of the adiabatic dynamics : a spectral representation (AOPP version) and a grid point representation (LMD version). Both representations will be used for the production of the database, but only the grid-point representation will be included in the version of the GCM to be delivered to ESA. The discretization will be made on a latitude-longitude grid horizontally and on σ levels (pressure normalized by its surface value) on the vertical. Both the horizontal and vertical discretizations are based on analytical functions and can be modified at will by the user of the model.

Both versions of the dynamical code include an operator for horizontal dissipation. This operator accounts for the interaction between resolved and unresolved scales. It also insures numerical stability of the model.

Radiative transfer is already present in the model. It includes the effect of CO_2 in the 15 μm CO_2 band, taking in particular into account the Doppler broadening of lines, which has a significant impact at altitudes above 50 km. Radiative transfer also includes the effect of dust, both in the infrared and in the visible. Scattering of thermal infrared radiation by dust, which is not included in the present model, will be included on the basis of a parametrization proposed by Toon et al. [7]. Although the effect of water vapor is probably significant during summer in tropical latitudes [6], its representation would require the computation of the entire atmospheric water cycle. This is out of reach of the available means, and will not be done. The effect of water clouds cannot be included for the same reasons. However, it must be stressed that both effects are generally negligible in comparison with the very strong effect of CO_2 in the infrared range, and of dust in both the visible and thermal infrared ranges. The near infrared CO_2 bands are also negligible [6], and will not be accounted for.

Planetary boundary layer: An accurate representation of turbulent mixing in the planetary boundary layer and of the subgrid scale turbulent variability is critical for a proper simulation of the atmospheric circulation, as well as for the determination of the environment of a probe located at the surface. The GCM will include a numerical scheme which, on the basis of the work by [4, 3], estimates the turbulent kinetic energy in the planetary boundary layer. Different degrees of approximation will be tested : in a first version, the turbulent kinetic energy is diagnostically computed as resulting from the balance between creation of turbulence by wind shear and destruction by stratification, while in a second version the time evolution of turbulent kinetic energy is explicitly computed in the model. In both versions, the efficiency of the turbulent mixing (the mixing coefficient) is directly related to the turbulent kinetic energy.

Whenever possible, the results of the model will be validated by comparison to available data.

Thermal conduction in the soil is already included in the model. It is based on a finite difference representation over 11 horizontal levels in the ground, and has been shown to correctly represent the response of the soil temperature to oscillations of the surface thermal flux over periods extending from a fraction of a Martian day up to more than one year.

A gravity wave drag scheme based on that of [5] will be introduced into the GCM. The scheme parametrises a single gravity wave that propagates vertically producing a stress profile. The vertical derivative of the stress gives the acceleration of the wind. The initial gravity wave amplitude is proportional to the dot product surface wind and the sub-grid scale orographic variance. The wave is then propagated vertically and Richardson number "felt by the wave" is then calculated. If the Richardson number drops below 0.25 the the wave is said to have broken and the saturation hypothesis is employed. This keeps the Richardson number at 0.25 by adjusting the wave amplitude. If the wave does not break until it reaches the model top all the momentum is deposited there.

Condensation and sublimation of CO_2 is already included in the GCM [2]. Atmospheric carbon dioxide can condense directly on the surface or up in the atmosphere. The atmospheric condensation of carbon dioxide is thought to reduce the upward thermal infrared emission (and thus the total condensation rate) by producing CO_2 clouds able to scatter the infrared radiation back to the ground, and by forming a fresh snow layer composed of small grains having a low emissivity [1]. This effect will be parametrized by lowering the surface emissivity when carbon dioxide condenses up in the atmosphere. We will also simulate the fact that the CO_2 snow falls wash the airborne dust particles out of the atmosphere by lowering the local atmospheric optical depth with the local atmospheric condensation rate. The subsequent decrease of the atmospheric radiation to space introduces a negative feedback on the atmospheric condensation.

3 Computer requirements

This concerns the version to be delivered to ESA.

The model will be written in FORTRAN-77.

The various parametrizations will be split into clearly documented small routines. The variables of the model will be passed to the routines as "arguments". Fortran commons will be used only for constants initialized at the beginning of the simulation.

The model will be managed under the UNIX operating system. It will use the standard "make" utility for compilation. The compilation will be tested on both HP-9000 and IBM-RISK processors.

4 Input/Output

The Inputs/Outputs of the model will be written in the format defined for the Data Retrieval System (DRS), developed at the Lawrence Livermore National Laboratory on the occasion of the Atmospheric Model Intercomparison Program (this is a major international program with participation of almost all groups involved in the development of General Circulation Models of the terrestrial atmosphere).

The DRS format will be used first for specifying the initial conditions of the simulations. For the use at ESA, a series of initial states, based on results of numerical simulations, will be provided for various times of the year (typically 12). The model will read this initial state and interpolate (or extrapolate) it to the grid chosen for the simulation.

As for the outputs, the model generates "history files" which contain a succession of complete sets of independent variables of the model at each grid-point. The output programs are written in a way which makes it very easy to introduce additional variables in the history file.

The DRS format is interfaced with different graphical packages so that it will normally not be necessary to develop specific graphical tools.

References

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