Acceptance test-plan for the General Circulation Model of the Martian Atmosphere

1 Introduction

As explained in the SRD, the requirement described in the URD for the Martian Atmospheric General Circulation Model (GCM) will be met by improving the physical package of the GCM of the Martian atmosphere developed jointly at LMD and AOPP.

The model in its present stage has already been largely validated by comparison to available data. When possible, the new developments must be validated : this concerns in particular the planetary boundary layer parametrization, the scattering of thermal infrared radiation by dust, the gravity wave scheme and the parametrization of the low emission zones in the polar regions.

The type of validation performed previously on the model as a whole must also be performed again since any modification of the model may improve or alter the global model performance.

In addition to these quality tests, the numerical performances of the model must be tested : this concerns the ability of the model to run on long periods on fine grids without numerical problems and its numerical efficiency.

2 Available data

The validation of the GCM is necessarily based on the available data which all come from spatial missions. For determination of the thermal and dynamical structure of the Martian atmosphere, the most important data are:

The in-situ measurements by the instruments aboard the Viking landers : the temperature measurements during the descent give a fine description of the vertical structure but in two points of the planet only and for a particular date and time [18, 17]; after landing, the Viking probes provided a very long coverage of the near surface (1.6 m) wind and temperature, as well as of the surface pressure and temperature.

Radio-occultations provide vertical temperature profiles with a very good vertical resolution (about 1 km) on a somewhat larger number of locations. Mars 2, 3 and 5 and Mariner 9 and Viking orbiters conducted such observations but no systematic compilation, usable for atmospheric purposes, seem to have been performed until now.

The Infrared Interferometer Spectrometer (IRIS) aboard Mariner 9 produced the most useful dataset on the atmospheric structure, combining a large spatial and time coverage (21,000 spectra over the whole duration of the mission) with a rather fine spectral resolution in the CO_2 15 μm band giving access to the vertical thermal structure up to about 45 km with a typical one-scale-height vertical resolution [5].

The InfraRed Thermal Mapper (IRTM) aboard viking orbiters gives the best spatial coverage (all the planet was covered during almost two Martian years) but in only five broad infrared channels centered at 7, 9, 11, 15 and 20 μm [10]. Four of those five channels were essentially unsensitive to the molecular absorption by the atmosphere and thus a direct signature of the emission by the surface. Only the 15 μm channel gave an information on the mean atmospheric temperature in the 20-35 km altitude range [11]. The four other channels, however contain a number of useful information on the dust amount in the atmosphere [13] and presence of snow in the atmosphere or on the surface in the polar night [3].

Erosion and cloud features give estimates of the wind direction at various locations and seasons [21]. However, those observations can generally not be used for more than a qualitative validation of the model results.

3 Global validation

Mean Thermal structure

The global mean thermal structure at a few number of seasons is given by the inversion of the Mariner 9 IRIS observations. The results of the GCM already compare very well to this observations [8]. However, this test will be performed again for the final acceptance of the GCM.

The typical agreement that must be achieved by the model is shown in Fig. 1.

An additional original validation will be added : the 15 μm temperature retrieved by the IRTM instrument [12, 11] aboard Viking will be explicitly simulated by applying a narrow band model developed for a study of the Martian atmospheric radiation [6] on the temperature profiles produced by the GCM.

Pressure variations

Among the meteorological observations at the Viking sites, the pressure measurements are especially interesting because they are less sensitive than others to local turbulent effects. They contain in fact informations on various components of the global atmospheric circulation of the planet.

The pressure records first exhibit large seasonal pressure variations which have been shown to result from the combined effect of condensation-sublimation of atmospheric CO_2 in the polar caps and large scale redistributions of the atmospheric mass by the general circulation [8]. It has been shown also [7] that it is possible to fit these large seasonal pressure oscillations of the surface pressure by tuning some very uncertain parameters of the model. This tuning and comparison will be performed on the final GCM version.

The global oscillation of the surface pressure has an amplitude of about 2 mbar for a mean 8 mbar pressure at Viking 1 site for instance. The accuracy

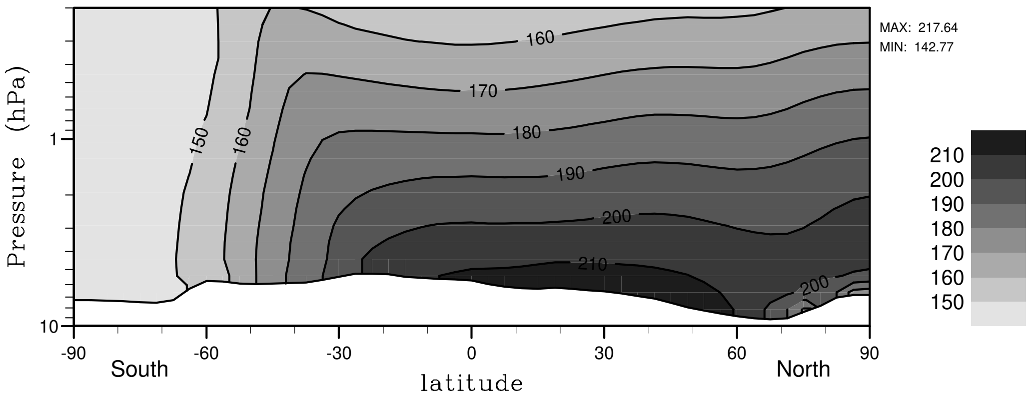

Figure 1: Comparison of observed and simulated temperature.
Upper panel : Mean temperature retrieved from Mariner 9 IRIS observations. The period, $L_s = 43 - 54$ corresponds to the northern mid-spring. At that time, the polar cap extends from the south pole up to about 60S. Lower panel : Simulated temperature for the same season with a 300 km horizontal resolution and 15 layers on the vertical using the LMD version of the GCM.

that must be achieved for the seasonal pressure cycle (after smoothing of the transient pressure variations) is of 0.2 mbar.

The pressure records also contain short term fluctuations with periods of a few days which are caused by eastward traveling planetary waves. Those waves exhibit a very interesting behavior, being much more regular than their terrestrial analogs [2]. The AOPP and LMD versions of the GCM have also been shown to reproduce very nicely the behavior of those transient pressure fluctuations [2, 7]. Once again, such tests must be performed once again on the final GCM.

The agreement that must be achieved in this run is that obtained in the studies by Collins et al. [2] for the frequency analysis and by hourdin et al. [7] for the amplitudes.

A qualitative comparison to available clouds and wind strikes will also be conducted.

4 Validation of the new parametrizations

Scattering and absorption of radiation by dust

The effect of dust in the radiative part needs specific validation both for the solar part which was already implemented in the model and for the thermal infrared part which is fully new.

For the infrared part the Martian observations can not be used for validation. The results of the model implemented in the GCM will be compared for the simple case of an isothermal profile with analytical and numerical results [20]. For those computations, maximal errors of about 20% on the radiative fluxes and cooling rates are acceptable.

The absorption and scattering of the solar radiation by dust will be done using radiative properties recently published [14, 15]. The choose of dust optical parameters in the visible and spectral discretization will be based on those recent results.

The parametrization of the planetary boundary layer

The parametrization will be compared to the results of various studies of the Martian planetary boundary layer [4, 16, 19]. In particular, the friction velocity, heating flux and Monin Obukhov length obtained in the GCM will be compared to published results. The GCM temperature profiles at the locations and seasons of the Viking entry will also be compared to descent temperature measurements. Finally, the standard deviations of the winds and temperature at various times of the day will be compared with the prediction of the planetary boundary layer scheme.

Polar low emissivities

The goal of the new parametrization of the condensation of the polar caps is to predict the CO_2 snow falls and to model their impact on the radiative budget.

This scheme will first be validated through its ability to reproduce the general forms of the cap seasonal evolution, which includes in particular the annual pressure variations recorded by the Viking Landers [7]. Locally, the simulated infrared emission will be compared to the radiative budget inferred from Viking infrared thermal mapper (IRTM) observations [3].

Since similar radiative budgets can be obtained with various kinds of clouds and snow (eg. thin and extensive CO_2 haze or scattered, but thick snow clouds), we will compare the simulated distribution of "low emission events" with the one observed by Viking [3]. In particular, the scheme shall not produce brightness temperatures colder than the lowest temperatures observed by Viking.

Gravity wave scheme

The gravity wave drag scheme should parametrise the modification of the wind and temperature field due to the breaking of gravity waves in the upper atmosphere. Unfortunately there are very few observations of the upper atmosphere to validate the scheme. Ideally one would need *in situ* wind measurements, however some progress may be made by iterating towards the IRIS temperatures and/or the IRTM observations by adjusting the 'tunable parameters' in the scheme. Also, as in [9], eddy diffusion coefficients can be calculated from the scheme and compared with those derived from ground based observations ([1]).

5 Numerical performances

Tests of the model stability will be performed by running the model, starting from a set of initial conditions and running it on one year with a 250 km horizontal resolution without any change of the parameters (such as time step) during the run.

The balance between the cost of various parametrizations will be tested. If needed, some parametrizations will be optimized (for instance the radiative transfer which may become too much expensive with a fine vertical grid and the representation of the full diurnal cycle). The model must be able to run at least 20 years of simulation (10 years for each of the two dust scenario) with an horizontal resolution better than 250 km on the computers available in both laboratories, in order to develop the climate database.

The model will be tested in a finer grid with a 150 km horizontal resolution on periods of typically 20 days, starting at four seasons from initial states extrapolated from the results of the one year simulation. This test is relevant for the version of the model to be delivered to ESA.

6 agenda

The global validation and tuning of the annual pressure cycle will be done just before the beginning of the long simulations required for the climate database (which must start in february).

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