

# MLAM - Mars HIRLAM

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## 1 Introduction

The increased amount and accuracy of observational data from planet Mars due to successful missions has enhanced modelling of the general circulation as well as mesoscale phenomena of the Martian atmosphere. The global coverage of observational data from Mars orbiters has made it possible to validate the general circulation simulations of present Mars. There are five different Mars general circulation models (MGCM) with advanced parameterization schemes at present. Already a decade ago, among the very first, Savijärvi (1991a,b, 1999) and Savijärvi and Siili (1993) modified the University of Helsinki 1-D and 2-D mesoscale models to simulate locally Martian small scale weather phenomena.

The 3-D mesoscale Mars limited area models are a natural step forward to simulate local phenomena. There are three mesoscale models for Mars presently, all already in an advanced stage. These are: 1) MRAMS (Rafkin et al., 2001), 2) OSU MMM5 (Tyler et al., 2002) and 3) The Cornell/CalTech Mars MM5 (Toigo and Richardson, 2002). A fourth model, MLAM - M(ars) (HIR)LAM - is being developed in co-operation between the Division of Atmospheric Sciences of University of Helsinki and the Finnish Meteorological Institute. MLAM is still at an early stage. The HIRLAM 4.7.3 version has been modified for Mars and test runs have been carried out. Results have been presented in an international Mars modelling workshop in Granada, Spain, in January 2003.

This report describes briefly the modifications needed in HIRLAM as well as the preparations of input data needed by the model. Some preliminary results from Mars simulations are also shown.

## 2 Changes in the model

The HIRLAM 4.7.3 version is the basis of MLAM. Conversion for Mars requires, firstly, the change of all Earth's physical constants to the Martian ones. These include e.g., the gas constants, gravity, radius of the planet, rotation speed, soil properties, solar constant and reference pressure. These constants are in principle given in common blocks, but, unfortunately, some constants (gas constant, gravity and reference pressure) were hard-coded in several subroutines (here is a message for future overhaul). Also these had to be found and changed. The average surface pressure on Mars is 6.1 hPa and average surface temperature (210 K) is lower than that

on the Earth. The reference pressure and temperature for Mars were set to 450 Pa and 210 K, respectively.

The length of the Martian day is 24 h 40 min, which is close to the length of the Earth's day. Mainly for this reason the "Earth's clock", i.e., time handling routines, is kept as such. The file naming of history files is thus kept unchanged as well.

The radiation routine (RADIA) was rewritten for Martian conditions. The routine takes into account the different day length, relevant orbital parameters and different composition of the Martian ( $CO_2$ ) atmosphere compared to the Earth's. The effects of dust are also included in the radiation parameterization.

The basics of the surface scheme (SURF) are kept unchanged, but an additional variable - thermal inertia - has been introduced. This spatially varying variable describing in a condensed form the much variable thermal properties of Mars' surface substance, regolith, has been added into the climate file.

### 3 Preparation of input data

The HIRLAM environment and scripts are retained unchanged in the MLAM system as much as possible. There are, however, two new "home made" packages that are run outside the HIRLAM system. These are the climate and boundary generations.

The climate files, including the surface fields for Mars, are constructed from several different datasets with different resolutions and data formats. Therefore the original HIRLAM climate generation was completely re-structured. The following surface fields are created from various Mars datasets: orography, surface and subsoil temperatures, albedo and thermal inertia. Some variables are simply set to constant values. Fraction of land is set to 1, since there are no oceans on Mars. The snow cover is set to 0, in the first experiments at least, and the soil moisture is set to 0. Furthermore, the roughness length is set to 0.01 m.

For boundary generation, a GRIB converter was written. It creates a HIRLAM standard type GRIB file needed for the HIRLAM system. At present, data from the Mars Climate Database (MCD) are used for boundaries as well as initial conditions. MCD provides temperature and wind components at 25  $\sigma$ -levels plus the surface pressure. The MCD data does not include humidity, which is very small on Mars anyway. Therefore the specific humidity is set to zero in the boundary files. We are expecting to have MGCM data for our next simulations because the MCD data is "monthly" averaged. The MCD data is generated from "European" Mars GCM run over one Mars year of 687 sols, one sol being the Mars day of 24 h and 40 min.

### 4 Experiments

Mars provides a demanding test bench for the model. The diurnal temperature range at the planet's surface can be as much as 100 K.

No "real data", i.e., actual daily data have been used in the first experiments. The MCD data used as initial conditions and boundary data are a description of average hourly conditions from a longer period (Martian month, about 60 Earth days) and are available at 2 h temporal and 3.75° spatial resolution. Therefore, for a longer simulation the same average boundary conditions are repeatedly used from day to day.

The first longer simulations proved to be unstable resulting in a model blow-up on the second day. The reason for this blow-up was traced back to spurious, partly tidally driven, large-amplitude waves in temperature and wind fields at the uppermost levels (90 km), partly reflected from boundaries. An ad hoc cure for damping these spurious waves was to enhance the horizontal diffusion (sponge layer) for the uppermost five levels.

So far experiments have been run for two Mars regions, those of Viking Lander 1 and 2 (VL1, VL2) sites. For the VL2 site also a doubly nested system has been used.

#### 4.1 VL1 and PathFinder

For the first test runs, the simulation area to cover the VL1 and Pathfinder landing sites was chosen. The reason for this is the availability of real observations that can be used for verifying the model results. In addition, there exist model results from previous 1-D and 2-D experiments to compare with. The simulation area consists of  $194 \times 140$  gridpoints with a  $0.2^\circ$  resolution (about 11 km in Mars). Time for the simulations was the Martian summer solstice, close to the actual landing time of VL1 and Pathfinder. For simplicity, the same 25  $\sigma$ -levels were used as in the MCD boundary fields. Orography was taken from the MCD 2.3 dataset with its coarse  $3.75^\circ$  resolution. Thermal inertia and albedo were taken from NASA consortium dataset with a  $1.0^\circ$  resolution for albedo and with a  $2.0^\circ$  resolution for inertia. Initial and lateral boundary conditions were taken from MCD with a  $3.75^\circ$  resolution. Figure 1 shows the complex orography of the simulation area (from high resolution NASA data; smoother  $3.75^\circ$  orography was used in the experiments).

Figure 2 demonstrates the diurnal soil surface temperature cycle as produced by MLAM (full line), 1-D model of University of Helsinki (UH/1D, dashed line) and MCD (dotted line). The sandy surface is "hot" during the day and very cold during the night, as in Sahara, for instance.

#### 4.2 VL2

The simulations of Viking Lander 2 landing site were carried out for the Mars Mesoscale Model Intercomparison Project that was arranged in connection of the Mars atmosphere modelling and observations workshop in Gradana, Spain, 13-15 January 2003. The idea was to compare different mesoscale model results against averaged VL2 meteorology cycles in late NH summer condition, VL2 latitude is  $48^\circ\text{N}$ . Surface fields were again initialised from different data sources. Orography as well as surface pressure were taken from the MCD 2.3 dataset with a  $3.75^\circ$  resolution. Surface temperature was also taken from MCD, deep soil temperature being the average of the previous month. Albedo and thermal inertia are based on the Thermal Emission Spectrometer on board Mars Global Surveyor.  $2^\circ$  dataset for  $1.0^\circ$  runs and  $0.5^\circ$  dataset for  $0.2^\circ$  runs were adopted.

In these simulations a nested system was used. Outer area was  $66 \times 50$  points in a  $1.0^\circ$  latitude/longitude grid. In the vertical, 25  $\sigma$ -levels were used with the lowest level at 1.5 m. Time step was set to 30 s. Initial and lateral boundary conditions were taken from the MCD  $3.75^\circ$  dataset. The boundaries were available with a 2 h temporal resolution. The inner area consists  $194 \times 140$  points in a  $0.2^\circ$  latitude/longitude grid. The same 25  $\sigma$ -levels as in the outer area were used. Time step was set to 15 s. For the inner area runs initial and lateral boundary conditions were taken from outer area runs. The boundaries were with a 2 h temporal resolution.

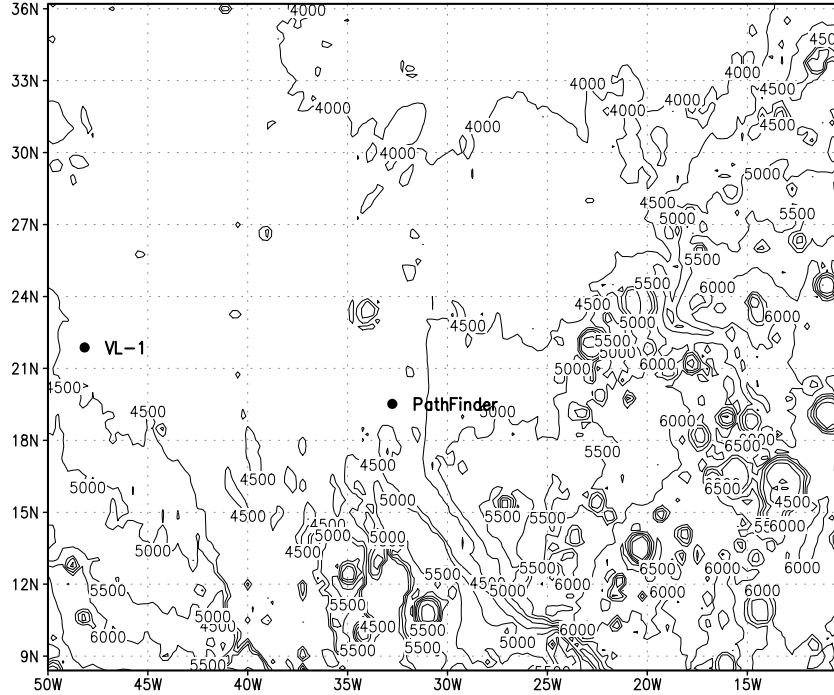


Figure 1: The simulation area (50.0 to 11.4°W, 8.4 to 36.2°N) consisting of 194×140 gridpoints. High resolution orography is shown with contour interval of 500 m. VL1 and Pathfinder sites are marked as well.

MLAM managed to simulate NH late summer conditions fairly well. The diurnal temperature cycles were very similar to those produced by the other groups. The winds were simulated also nicely. The diurnal cycle of the  $v$  component of wind is shown in Fig. 3.

The Martian conditions can be quite extreme compared to the Earth's. Figure 4, showing the predicted lowest model level temperature, provides an example of a sizeable temperature gradient in the west-east direction during the sunrise. Local time at the western border of Fig. 4 (115°W) is 07.30.

## 5 Summary

Development and application of HIRLAM (MLAM) to the extreme Martian conditions has been demanding and challenging. We have managed to do that initially well, as the results show. Even if the model is in the early stages of its development, it has shown potential. The development will continue and we have many ideas to improve and apply MLAM. The work may help also Earth HIRLAM in various ways.

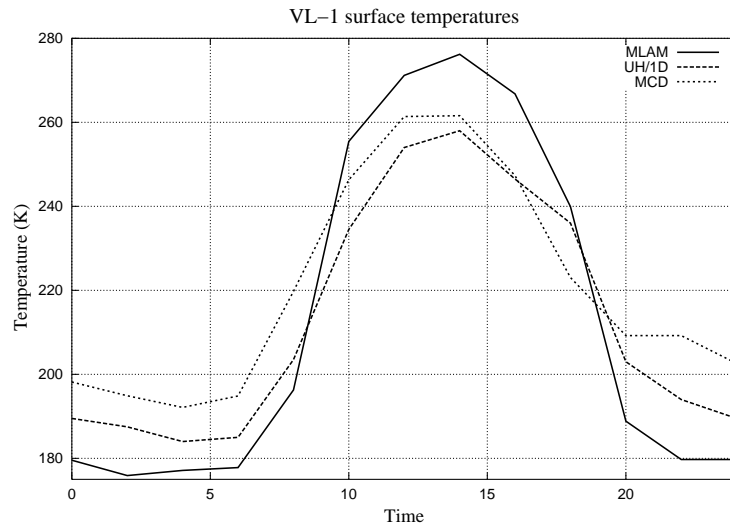


Figure 2: Diurnal surface temperature cycle as produced by MLAM (solid line), UH/1D (dashed line) and MCD (dotted line).

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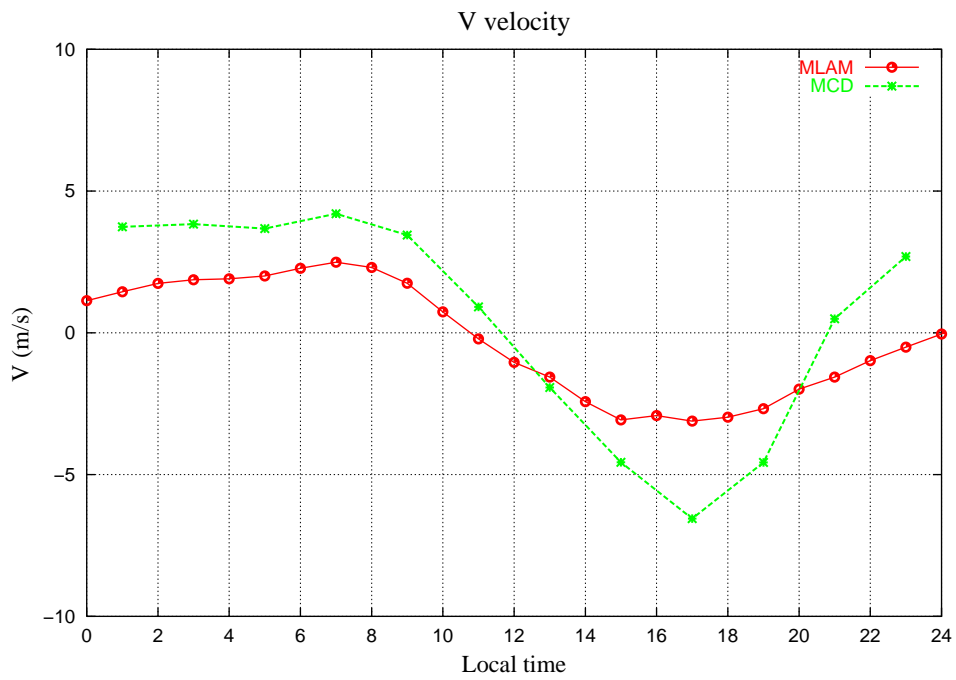


Figure 3: Simulated diurnal cycle of v component of the wind (full line with dots) in the VL2 landing site compared against MCD data (dashed line with crosses).

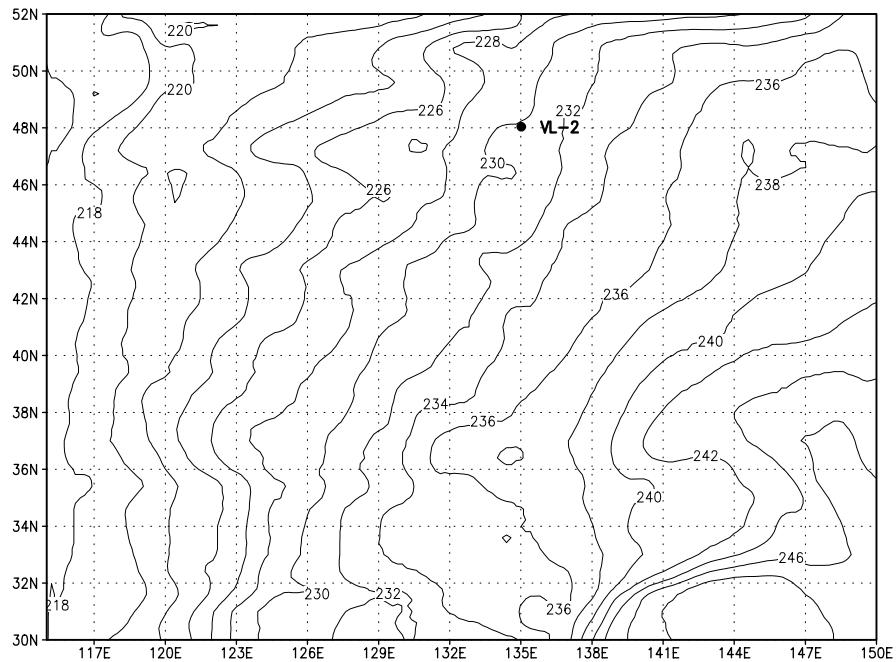


Figure 4: Predicted (+27h) lowest model level (1.5 m) temperature during sunrise. Contour interval: 2 K. VL2 site is marked as well.