MARS LIMITED AREA MODEL: STATUS REPORT.

T. Siili, *Finnish Meteorological Institute, Helsinki, Finland (Tero.Siili@fmi.fi)***, S. Järvenoja,** *Finnish Meteorological Institute***, J. Kauhanen, H. Savijärvi,** *University of Helsinki, Finland***.**

Introduction and background

Collaboration between the University of Helsinki (UH) and the Finnish Meteorological Institute (FMI) traces its roots back to the early 1990s. Adaptations of Earth 1-D Planetary Boundary Layer column model and a 2-D (vertical and one horizontal coordinate) mesoscale circulation model for Mars were initiated at UH around that time. FMI became involved in the modelling effort soon thereafter and the collaboration has been tight ever since. FMI has also contributed hardware to several (albeit so far unsuccessful) lander missions (Mars-96, Mars Polar Lander, NetLander, Beagle 2, Phoenix, Mars Science Laboratory / Rover Environmental Monitoring Station) relevant to Martian atmospheric science, bringing thus an observational dimension to the joint effort.

The 1-D model has since been used extensively both to develop and test computational schemes (perhaps most notably for radiative transfer and surface temperature prediction) suitable for Mars as well as simulate among others diurnal temperature & humidity cycles and vertical thermal structures with comparisons against Viking Lander (VL), Mars Pathfinder (MPF) and Mars Exploration Rover (MER) data[1–4].

The 2-D model in turn has been used to study primarily surface-induced circulations, such as those arising from topographical slopes, albedo and thermal inertia variations as well as CO_2 and H_2O ice coverage contrasts[5–7]. Polar water transport has also been investigated and a pilot study on use of *ensemble* approaches for Martian mesoscale simulations has been utilising the 2-D model[8, 9].

The Mars Limited Area Model

The Mars Limited Area Model (MLAM) is a regional or *mesoscale* (spatially) 3-D Mars Mesoscale Circulation Model implemented and developed as a joint effort between FMI and UH. The dynamical core of the MLAM is based on the HIgh Resolution Limited Area Model (HIRLAM) version 5.0.0 — a numerical weather prediction (NWP) model in operational use in, *e.g.*, several European countries [10]. The version we currently use is hydrostatic, although a non-hydrostatic version of the HIRLAM is also under development[11].

The model physics and parameterisations are comprehensive, including horizontal and vertical diffusion, convection as well as radiative transfer and soil processes. The radiative transfer scheme is based on the one implemented in our 1-D model [4]. The current MLAM version includes neither H_2O nor CO_2 condensation/sublimation processes. Surface temperature T_{surf} is predicted with a 2-level force-restore scheme, since HIRLAM's three-level and the five-level Crank-Nicholson scheme used in our 1-D model [1, 12] have exhibited instabilities in our tests, especially at low values of thermal inertia.

Initial and boundary conditions can currently be derived from either the European Mars Climate Database (MCD) or from the Oxford University Mars General Circulation Model (MGCM). Over the past few years only the Oxford MGCM results — both so-called *scenario* as well as assimilated Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) observations have been used.

HIRLAM and MLAM use hybrid vertical coordinates (terrain-following σ near the surface changing to p at higher altitudes). We have used 25–35 levels in the vertical with the lowest level at $\approx 1.5\,\mathrm{m}$ and the top level in the $40-50\,\mathrm{km}$ region.

The MLAM has nesting capability and the computational pole can be shifted to achieve approximately equidistant grid spacing in the computational domain irrespective of the domain's location on the globe. Typically 2-3 -level nesting has been used, but the pole shifting feature has not been utilised yet. Horizontal grid spacings used have been of the order of $10-60\,\mathrm{km}$.

The model can be run on either single- or multiprocessor (parallel) computing platforms. For testing purposes a workstation is normally used. The HIRLAM architecture (the operational NWP inheritance) favours short-duration (3-sol) runs, which can, however, be sequentially "chained" to create longer-duration runs. Our MLAM runs have until now been typically of the order of 3 sol and in any case less than 10 sol in duration, but this will change in the near future.

Simulations overview

A few of the investigations initiated with the MLAM are outlined below:

Comparisons with Viking and Pathfinder data Our initial tests were carried out in the VL-1 and MPF region at summer solstice — fairly close to the landing seasons of both spacecraft. This permitted comparisons with both observational data as well as previous 1-D and 2-D simulation results. We have made simulations with different size areas consisting of 66×50 to 194×140 gridpoints with $1 \ldots 0.2^\circ$ ($55 \ldots 11\,\mathrm{km}$) spatial resolution.

Orography was taken from MCD 3.0 dataset with coarse 5° resolution interpolated to our grid. Thermal inertia and albedo were taken from MGS/TES instrument with $2^\circ \times 2^\circ$ resolution for coarse run and $0.5^\circ \times 0.5^\circ$ resolution for nested runs. Initial and lateral boundary conditions were taken from MCD average data and Oxford MGCM continuous scenario data with 5° resolution.

The model has in these simulations produced, *e.g.*, realistic surface temperature and diurnal boundary layer behaviour, including nighttime inversions[11].

Summertime Hellas basin simulations Hellas' slope winds have been simulated previously with our 2-D MMCM [5], but the cylindrical shape of the feature limits the usefulness of 2-D models and renders use of a 3-D model a natural approach. Summertime and near-perihelion season for chosen to minimise the influence of the Southern polar cap — the H_2O and CO_2 processes remain incompletely implemented in the MLAM. The grids used have extended from slightly north of the equator to 70°S and from 20°E to 130°E with spacings of $1 \ldots 0.4^\circ$[13].

These simulations remain work in progress. However, even short 3-sol simulations show regular afternoon upslope, nocturnal downslope drainage winds and nocturnal along-slope low-level jets are predicted as well as drainage winds and jets especially over the southern slopes of the basin. Peak wind speeds are typically in the $10 - 20\,\mathrm{m/s}$ range.

Comparisons with Mars Exploration Rover (MER) Mini-TES results The MLAM has also been used recently to carry out simulations in the area of the MER-B (Opportunity) landing site to compare the predicted vertical temperature profiles with the Mini-TES observations. Simulation using our 1-D column model have been made already before. Here the assimilated Oxford MGCM data has been used for MLAM initial and boundary conditions. MLAM produces surface and lowest level temperatures nicely, but boundary layer temperatures need further work.

Future plans and possibilities

The MLAM remains under intense development and is nearing the freeze of what is regarded by us as the *reference version*. Consequently several simulations are slated for reruns in the near future for verification. In addition to the investigations outlined above future uses and applications of the model include simulations in support of the Phoenix mission (especially the ongoing landing site selection process) and similar tasks a bit later in support of the Mars Science Laboratory / Rover Environmental Monitoring Station (MSL/REMS) and potentially in support of the MetNet — the atmospheric science surface network being developed by FMI in collaboration with Russian partners. The MSL/REMS connection may provide opportunities for modelling collaborations as well, as the HIRLAM model is used also in Spain. The key capabilities to-be-added to the MLAM in the near-to-intermediate future include volatile and dust thermodynamical and transport processes.

References

[1] Hannu Savijärvi. Mars boundary layer modelling: diurnal moisture cycle and soil properties at the Viking Lander 1 site. *Icarus*, 117:120–127, 1995.

[2] Hannu Savijärvi. Radiative fluxes on a dustfree Mars. *Contrib. Atmos. Phys.*, 64:103–112, 1991.

[3] Hannu Savijärvi. A model study of the PBL structure on Mars and the Earth. *Contrib. Atmos. Phys.*, 64:219–229, 1991.

[4] Hannu Savijärvi, Anni Määttänen, Janne Kauhanen, and Ari-Matti Harri. Mars Pathfinder: new data and new model simulations. *Q. J. R. Met. Soc.*, 130(597):669–683, 2004. doi: 10.1256/qj.03.59.

[5] Tero Siili, Robert M. Haberle, James R. Murphy, and Hannu Savijärvi. Modelling of the combined late-winter ice cap edge and slope winds in Mars' Hellas and Argyre regions. *Planet. Space Sci.*, 47 (8-9):951–970, August 1999.

[6] Hannu Savijärvi and Tero Siili. The Martian slope winds and the nocturnal PBL jet. *J. Atmos. Sci.*, 50: 77–88, 1993.

[7] Tero Siili. Modeling of albedo and thermal inertia induced mesoscale circulations in the midlatitude summertime Martian atmosphere. *J. Geophys. Res.*, 101:14957–14968, 1996.

[8] Tero Siili, Hannu Savijärvi, Anni Määttänen, and Janne Kauhanen. Two-dimensional simulations of martian mesoscale circulation phenomena: a review and future role. In M. C. Desjean, F. Forget, M. Lopez-Valverde, and C. Newman, editors, *Proceedings of the workshop on Mars atmosphere modelling and observations*, pages 6–4. Centre national d'etudes spatiales, European Space Agency, Instituto de astrofisica de Andalucia, Laboratoire de meteorologie dynamique / Centre national de recherches scientifiques, University of Oxford, 2003-01-13–15 2003.

[9] Tero Siili and Anni Määttänen. Sublimation and condensation flows in Chasma Borealis: a sensitivity study using a 2-D ensemble mesoscale circulation model. In *Third international conference on Mars polar science and exploration*, number 1184 in

LPI Contributions, page Abstract 8046, 3600 Bay Area Boulevard, Houston, TX 77058-1113, October 13. . . 17 2003. Lunar and Planetary Institute. Poster presentation.

[10] Per Undén, Laura Rontu, Heikki Järvinen, Peter Lynch, Javier Calvo, Gerard Cats, Joan Cuxart, Kalle Eerola, Carl Fortelius, Jose Antonio Garcia-Moya, Colin Jones, Geert Lenderlink, Aidan McDonald, Ray McGrath, Beatriz Navascues, Niels Woetman Nielsen, Viel Ødegaard, Ernesto Rodriguez, Markku Rummukainen, Rein Rõõm, Kai Sattler, Bent Hansen Sass, Hannu Savijärvi, Ben Wichers Schreur, Robert Sigg, Han The, and Aleksander Tijm. HIRLAM-5 scientific documentation. Technical report, HIRLAM-5 Project, December 2002. Available at `http://hirlam.knmi.nl/open/publications/SciDoc\_Dec2002.pdf`.

[11] Janne Kauhanen. MLAM, three dimensional limited area modelling of the Martian atmosphere. In Laura Rontu, editor, *Proceedings of Baltic HIRLAM workshop, 2003-11-17–20*, pages 108–111, 2004.

[12] Hannu Savijärvi. On surface temperature and moisture prediction in atmospheric models. *Contrib. Atmos. Phys.*, 65:281–292, 1992.

[13] Tero Siili, Janne Kauhanen, Hannu Savijärvi, and Simo Järvenoja. 3-D simulations of mesoscale circulations in the Hellas region. In *Proceedings of the 35th COSPAR scientific assembly*. Committee on Space Research, 18–25 July 2004. Poster presentation, abstract nr. COSPAR04-A-04025, paper nr. C3.2/B0.8-0066-04.