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Creating high-spatial resolution atmospheric profiles from the GEM-Mars GCM for the investigation of Mars

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Abstract

It is necessary for GCMs to operate on a coarse resolution grid, especially when simulating an entire planet for long durations. But there are many circumstances when one desires the solution at much higher resolutions. In this work, we present our methods to interpolate the GEM-Mars GCM solution to higher resolutions in Latitude and Longitude, as well as time of day and time of year. A principle motivation of this work it to provide high-resolution approximations of the Martian atmosphere to be used during spectroscopic retrieval for the investigation of Mars.

1. GEM-Mars

GEM-Mars is a General Circulation Model for the atmosphere of Mars with online atmospheric chemistry. The model is operated on a grid with a horizontal resolution of 4°x4° and with 103 vertical levels reaching from the surface to ~150 km. It calculates atmospheric heating and cooling rates by solar and IR radiation through atmospheric CO and dust and ice particles and solves the primitive equations of atmospheric dynamics. Geophysical boundary conditions are taken from observations. Physical parameterizations in the model include an interactive condensation/surface pressure cycle, a fully interactive water cycle including cloud radiative feedbacks, a thermal soil model including subsurface ice, interactive dust lifting schemes for saltation and dust devils, turbulent transport in the atmospheric surface layer and convective transport inside the planetary boundary layer (PBL), subgrid scale vertical mixing in the free troposphere, a low level blocking scheme, gravity wave drag, molecular diffusion, non-condensable gas enrichment, and atmospheric chemistry. A detailed description of the model, its formulation, grid, dynamical core and physical parameterizations, together with extensive validation against multiple datasets, was given in [4], and further details can be found in [5, 6, 7].

2. Methods

BIRA-IASB will be using the in house developed ASIMUT program [1] to perform the spectroscopic retrievals of molecular and aerosol number densities based on the Optimal Estimation Methods [2, 3]. In addition to using mean atmospheric compositions as *a priori* constraints (see presentation by Erwin et al. on "Creating *a prior* atmospheres from GEM-Mars"), the retrieval process requires vertical temperature and pressure profiles on which to compute cross sections. For each observation, we need to compute vertical profiles which corresponds to the geographical and temporal circumstances of each observation.

2.1. Geographic Interpolation

The data set from GEM Mars used in the construction of the interpolated atmospheres is comprised of 48 time steps per day, 36 days per year (every 10° L_s). Every day of the year is available, but the above subset is already 500GB, and is should be sufficiently representative of the Martian atmosphere.

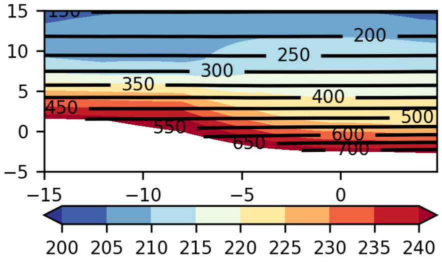

Figure 1: Gale crater using geographic interpolation. Temperature is colored contours (in Kelvin) and pressure levels are the contour lines (in Pascal).

For a particular Latitude and Longitude, a bi-linear spherical interpolation is performed to interpolate the bounding GCM grid points to the particular value.

Next, for a particular L_s and Local Solar Time (LST), we must interpolate in time using the time steps in a day, and days in L_s. First, we use a 4 point Lagrange interpolation in LST for each day. Second, we use a 4 point Lagrange interpolation in L_s (effectively using 16 points in a split, 2D interpolation).

2.2. Surface Height Correction

The interpolation from GEM produces a linear variation in surface height between GEM-Mars grid points. The surface of Mars has much more structure over this range, and we can use the MOLA data set [8] to get an improved value for the surface height. Yet, a simple offset or extrapolation using this new height would incorrectly interpret the upper or lower atmosphere.

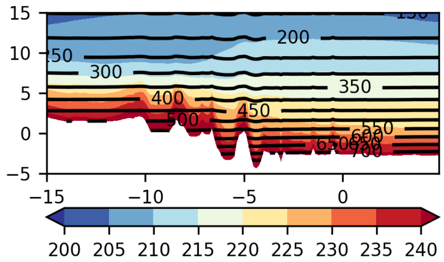

Figure 2: Gale crater with surface height correction.

Instead, we use a pressure scaling similar to the one discussed with in the MCD User's Guide [9]. Potentially, this correctly estimates the surface pressure, near surface structure, and upper atmosphere pressure relative to the areoid.

An additional step is to adjust the near surface pressure to adapt for the change in surface height. One option is to use the adiabatic lapse rate to adapt for the change in altitude, or we can instead use an averaged temperature profile (i.e. the *a priori* atmosphere) to interpret a change in temperature.

3. Summary and Conclusions

The interpolation detail in this work can be used to interpolate the GEM-Mars GCM solutions to any geometric or temporal parameters, extending the usefulness of the model. Correcting the surface height and pressure scaling produce a desirable vertical profile that ASIMUT can use to compute spectra.

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