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Creating *a priori* atmospheres from GEM-Mars GCM for the investigation of Mars

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Abstract

We present a set of *a priori* atmospheric number densities for the atmosphere of Mars derived from the GEM-Mars GCM. The latitude, time of day, and season are binned in a way relevant to the Martian atmosphere and the nature of the retrieval geometries expected. We explore different statistical bin definitions, ways to incorporate the surface height (which vary much more on Mars than on Earth) and areoid, and the correct way to incorporate the mean and variance under the Bayesian framework used in the retrievals (i.e. Rodgers' methods [1]).

1. Bayesian Retrievals

Most of current retrieval algorithms, such as those based on Optimal Estimation Method [2, 3], do need a priori information on the variables to be retrieved. For example, BIRA-IASB will be using the in house developed ASIMUT program [4] to perform the spectroscopic retrievals of molecular and aerosol number densities. One aspect of these methods is the incorporations on *a priori* constraints of a mean and variance number densities profiles for each atmospheric species, including molecules and aerosols. For our purposes, we choose to construct a set of *a priori* states from the GEM-Mars GCM, developed at BIRA-IASB, since we can have full coverage geographical and temporally (time of day and year).

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 [5], and further details can be found in [6, 7, 8].

2. Methods

The data set from GEM Mars used in the construction of the *a priori* 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 provide sufficient enough coverage to be representative of the Martian atmosphere. Various combination of bins in L_s (e.g. seasons), Latitude (e.g. North-, South-, Mid-latitudes, etc), and Time of Day (e.g. Day, Night, Dusk, Dawn, etc.) are made available for individual applications.

The GEM-Mars uses a surface height at each grid point that is an averaged surface height derived from the well accepted MOLA data set [9], although the solutions themselves are given in terms of height above the surface. By adding the surface height before averaging, the altitude grid is given relative to the areoid. We compare three different options how to do this:

1. Interpolate onto a common grid.
2. Average into vertical bins, with each altitude given equal weight.

3. Average into vertical bins, with weighting proportional to altitude grid resolution.

Each of the above options has its trade-offs, which we will discuss in reference to the retrievals.

When reporting the mean and average, it is convenient to compute in terms of mixing ratio, because it is generally not exponential with altitude like number density. ASIMUT's forward model is to simulate spectra using the number density, which is computed using the mean mixing ratio times some representative total number density. But the variance of the mixing ratio under-represents the variance in the number density, especially for the the main constituents. We compute the relative standard deviation of the number density for each species, and use this with the mean mixing ratio for the species and a total atmosphere number density (which is derived separately, see our other presentation on *Interpolated Atmospheres*).

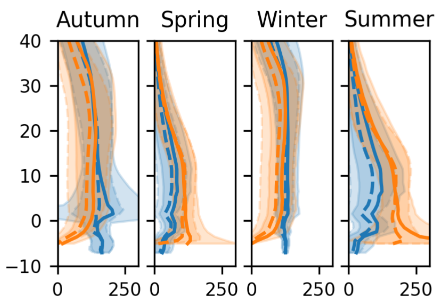

Figure 1: Example mean water vapor mixing with shaded standard deviation (in PPMV) versus z (in km). Northern hemisphere is blue, southern hemisphere is orange.

3. Summary and Conclusions

The *a priori* atmospheres derived from the GEM-Mars model will be used during the retrievals of NOMAD observations will be computed using ASIMUT. Our decision to incorporate the surface height and average each profiles into vertical bins with weighting proportional the altitude resolution (option 2c above) means that the altitude scale is relative to the areoid so that we can compare pressure levels easily across the planet. We decrease our bias towards the near surface atmosphere, which means the retrievals will be less constrained by the *a priori* in the lower atmosphere and more constrained by the data itself.

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