THE POTENTIAL FOR DATA ASSIMILATION WITH THE GEM-MARS GENERAL CIRCULATION MODEL

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Introduction: GEM-Mars is a grid point general circulation model (GCM) of the Mars atmosphere [1]. The dynamical core of the model [2,3] was developed by Environment Canada for weather forecasting (Global and Regional Deterministic Prediction Systems). The GEM model can employ the four-dimensional ensemble-variational data assimilation (4DEnVar) approach [4] as well as an ensemble Kalman filter (EnKF) method [5].

With the influx of new observational data from the ExoMars Trace Gas Orbiter (TGO) mission, we plan to explore the possibility of using the GEM operational framework with data assimilation for applications to Mars.

On Earth, one of the main objectives of data assimilation is to increase the accuracy of weather predictions. This can be useful for future Mars missions or short-term observational planning with current missions. Also, we can employ data assimilation to highlight atmospheric processes not well described in the model and use the information to make improvements to physical parameterisations.

Model Description: At the time of writing, the GEM-Mars model is using the dynamical core of GEM version 4.2.0 while work is underway to implement version 4.8LTS13. With this update, the grid definition can be changed to a "Yin-Yang" grid configuration [6] (Figure 1).

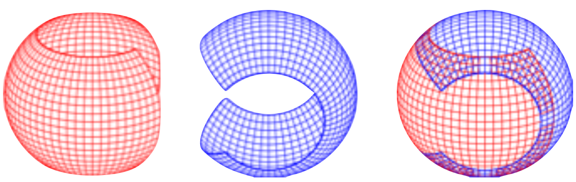

Figure 1 GEM v4.8 Yin-Yang grid configuration, consisting of two limited-area domains.

For application on Mars, physical parameterisations of the terrestrial model are replaced with those appropriate for the Mars atmosphere. Also, we include basic gas phase and photochemistry for the study of trace gases in the Martian atmosphere. A full description and evaluation are given in [1], and applications of the model are presented in [7, 8, 9].

GEM-Mars is able to take advantage of the speed requirement in weather prediction and is fully parallelised with MPI and OpenMP. The model is run on IASB-BIRA's high-performance cluster, as well as other machines.

As shown in [1], the model can reproduce the basic patterns in the Mars atmosphere and compares well to satellite observations and surface in-situ measurements. One of the main objectives of GEM-Mars is to better understand the distribution, seasonal cycles and processes of trace gases in the Martian atmosphere. For example, Figure 2 shows a comparison of zonal mean column ozone from the Mars Color Imager (MARCI) [10] with GEM-Mars. The major features of the seasonal cycle are reproduced, with maxima seen at high latitudes in fall, winter and spring.

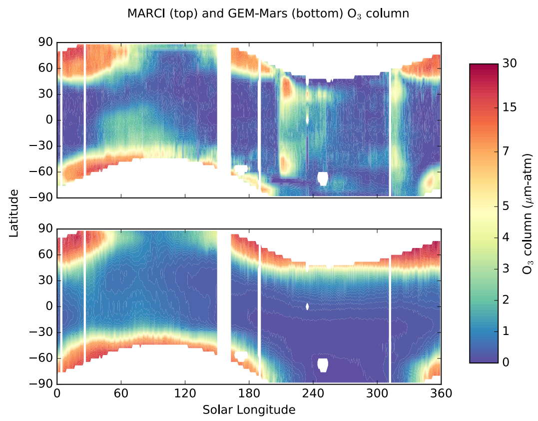

Figure 2 MARCI (top) zonal mean daytime column ozone compared with GEM-Mars (bottom). In the second part of the year, MARCI retrievals are contaminated by dust, leading to unrealistic peaks between 60° N/S latitude.

Data Assimilation with GEM: Significant advances have been made over the last decades with both the GEM model and the assimilation methods used in the operational analysis system at Environment Canada. The assimilation technique has moved from a statistical interpolation analysis to 3DVAR, then to 4DVAR and in parallel, an EnKF system. The current 4DEnVar method uses the ensemble to estimate the background-error covariances, which eliminates the need for the tangent linear and adjoint version of the model and increases computational efficiency.

The GEM model was also used to study the radiative impact of stratospheric ozone assimilation [11] using 3DVAR [12, 13]. As one of the main focuses of GEM-Mars is on the behaviour of trace gases, we may be able to gain insight from this work.

Potential datasets: With the chemistry package included in GEM-Mars, we have the possibility to use observations from the NOMAD ("Nadir and Occultation for MArs Discovery") spectrometer suite [14] on ExoMars TGO, whose focus is on trace gases, clouds and dust. The instrument is composed of 3 spectrometers: SO – (Solar Occultation) operating in the infrared (2.3-4.3 μm), LNO (Limb Nadir and solar Occultation) also in the infrared (2.3-3.8 μm) and an ultraviolet/visible spectrometer (UVIS – UV visible, 200-650 nm). Through solar occultation, NOMAD will provide vertical profiles from the surface to 200 km altitude at a resolution of less than 1 km with a sampling rate of 1 s. In nadir mode, mapping of several constituents can be performed with a footprint of 0.5 x 17 km^2 (LNO) and 5 km^2 (UVIS), with a revisit time of 30 Martian days. Species of particular interest are water vapour and simultaneously HDO (providing D/H), ozone and carbon monoxide.

Summary: The GEM model provides a good platform for data assimilation, but it is an ambitious undertaking. At present, we are reviewing the options and hope to take advantage of the extensive work done with the application of GEM in the terrestrial operational analysis systems.

The EnKF and 3DVAR methods are more appealing as they do not require the adjoint model and 3DVAR has already been applied to the problem of stratospheric ozone, which could lend information to the problem of assimilation of trace gases on Mars.

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