The Potential for Data Assimilation with the GEM-Mars GCM

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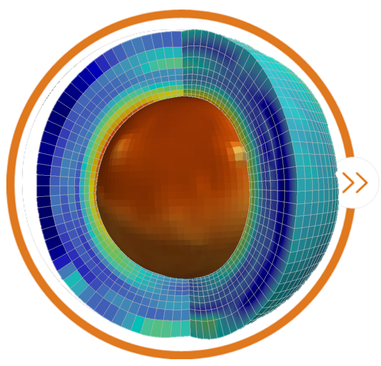
Introduction

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 (DA) for application to Mars. Our main objective would be process studies, i.e. to use DA to help gain insight into physical and chemical processes that may not be well represented in the model. At the same time, there is an interest in DA for terrestrial air quality applications with the GEM-AQ model. The modularity of the host GEM model and framework allows for the development of a system that will benefit both terrestrial and martian studies.



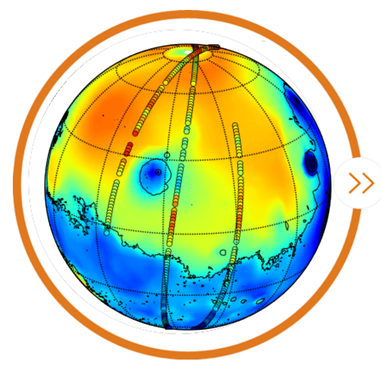
The GEM-Mars Model

The GEM-Mars GCM simulates the Martian atmosphere from the surface up to ~150 km. Physical parameterisations include an interactive CO_2 condensation/surface pressure cycle, a fully interactive water cycle including cloud radiative feedbacks, dust lifting schemes for saltation and dust devils, gravity wave drag and low-level blocking, molecular diffusion, and non-condensable gas enrichment.

As shown in Neary and Daerden (2018), the model reproduces the basic patterns in the Mars atmosphere and compares well to satellite and surface in-situ observations.

Key features:

- Multiscale: 1 modelling platform for global and mesoscale studies
- Parallelised code: MPI and OMP = fast, efficient
- Operational framework: used in data assimilation systems for Earth
- Chemical composition: flexible chemistry package



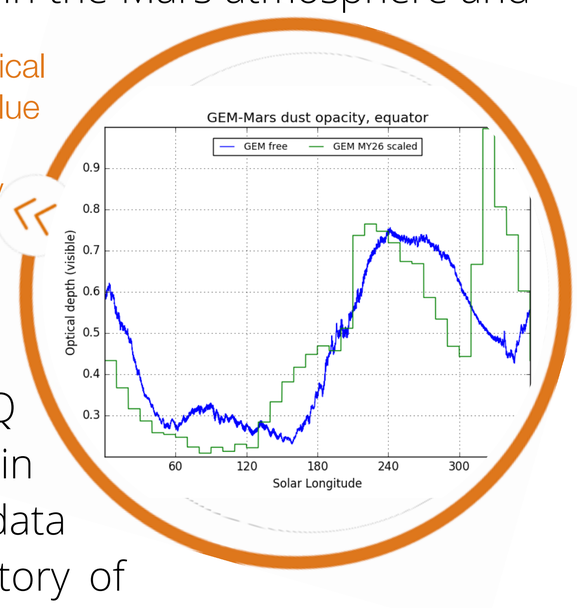


Figure 1: GEM-Mars dust optical depth at equator for MY26, blue is dust lifted freely by winds, green is scaled to climatology (Montabone et al, 2015).

Data Assimilation with GEM-Mars and GEM-AQ

The GEM weather forecast model is at the core of both GEM-Mars and GEM-AQ (Kaminski et al. 2008), a terrestrial air quality prediction model used extensively in Europe (e.g. Struzewska and Kaminski, 2012). There is a potential to develop a data assimilation system for both models in parallel based on the considerable history of work done for weather forecasting. GEM is currently used operationally in a four-dimensional ensemble-variational DA approach as well as an ensemble Kalman filter method. For our initial work, we may adopt a Gridpoint Statistical Interpolation (GSI) or 3DVar method as this has already been done with GEM in the past (e.g. De Grandpré et al., 2009) to assimilate stratospheric ozone.

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 (Vandaele et al., 2015) on ExoMars TGO, whose focus is on trace gases, clouds and dust. Through solar occultation, NOMAD will provide vertical profiles from the surface to 200 km 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 less than 10 km^2 and a revisit time of 30 martian days. For the study of dynamical processes, we can look at assimilating temperature and/or aerosols (dust, water ice).

Summary

The GEM model provides a good platform for data assimilation, but it is an ambitious undertaking. At present, we are reviewing 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 address stratospheric ozone with GEM, which could lend information to the question of assimilation of trace gases on Mars.

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More on **GEM-Mars modelling**: http://mars.aeronomie.be/en/modelling.htm

More on **TGO-NOMAD**: http://mars.aeronomie.be/en/exomars/nomad.htm

More on **GEM-AQ modelling**: http://ecoforecast.eu