europlanet 2024 Research Infrastructure

H2020-INFRAIA-2019-1

Europlanet 2024 RI has received funding from the
European Union's Horizon 2020 Research and Innovation Programme under

Grant agreement no: 871149

# Deliverable D6.3

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| **Deliverable Title:** | GEM-Mars GCM products and tools |
| Due date of deliverable: | 31st March 2022 |
| Nature[1]: | Demonstrator |
| Dissemination level[2]: | Public |
| Work package: | WP6 |
| Lead beneficiary: | IASB-BIRA |
| Contributing beneficiaries: | |
| Document status: | Final |

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| Start date of project: | 01 February 2020 |
| Project Duration: | 48 months |
| Co-ordinator: | Prof Nigel Mason, University of Kent |

1. **Nature:** R = Report, P = Prototype, D = Demonstrator, O = Other
2. **Dissemination level:**

| PU | PP | RE | CO |
|---|---|---|---|
| Public | Restricted to other programme participants (including the Commission Service) | Restricted to a group specified by the consortium (including the Commission Services) | Confidential, only for members of the consortium (excluding the Commission Services) |

**Executive Summary / Abstract:**

This deliverable describes the products and tools related to the GEM-Mars General Circulation Model (GCM) provided to the VESPA project. The atmospheric fields from the simulations can be used as a reference, for inputs to retrieval codes and other models, and comparisons to observations from the surface or orbit. Properties and composition of the simulated atmosphere are given over the whole planet with seasonal and diurnal cycles represented. Two simulated years are provided, one of which includes the global dust storm of 2018 (Mars Year 34) and the next year with lower dust conditions.
As the dataset is very large, a web interface is used to provide the user with a way to access the data for user-defined point on the globe for a specified time.

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## 1. Explanation of D6.3 Work & Overview of Progress

### a) Objectives

Powerful and flexible atmospheric modeling capabilities are a vital and necessary tool in addition to an increasing observational dataset to enhance our understanding of the processes taking place in the Martian atmosphere.
The GEM-Mars three-dimensional general circulation model takes advantage of the cutting-edge efforts made by the numerical weather prediction (NWP) community by using the operational framework and dynamical core of the Global Environmental Multiscale (GEM) model from the Recherche en Prévision Numérique (RPN) division of Environment Canada (Côté et al., 1998a, 1998b; Yeh et al., 2002). The terrestrial model has been adapted for the simulation of the Mars atmosphere.
GEM-Mars is described and evaluated in Daerden et al. (2015), Neary and Daerden (2018), Smith et al. (2018), Daerden et al. (2019), Neary et al. (2020), Bouche et al. (2021), Newman et al. (2021) and Daerden et al. (2022).
The model is operated on a horizontal resolution of 4° × 4° (45 by 90 grid points) and on 103 hybrid vertical levels ranging from the surface to about 150 km altitude, with a time step of 30.8246 min (1/48th of a Mars solar day or sol). GEM-Mars contains routines for radiative transfer through an atmosphere containing $CO_2$ gas, dust, and water ice clouds, and also for subsurface heat transfer (including shallow subsurface ice at high latitudes), for turbulent convection in the Planetary Boundary Layer (PBL), for molecular diffusion and gravity wave drag. The model has a $CO_2$ deposition/sublimation cycle and an interactive surface pressure correction. The vertical distribution of dust can be either self-consistently calculated from dust that is lifted from the surface by shear wind stress and dust devils (Daerden et al., 2015, 2019; Musiolik et al., 2018; Neary & Daerden, 2018), or prescribed using a predefined vertical profile shape (Neary et al., 2020). In both cases, dust total optical depths and their spatiotemporal variation can also be chosen to be constrained by a dust optical depth climatology, such as those provided by Montabone et al. (2015, 2020).

### b) Explanation of the work carried in WP

The data provided are from simulations described in Daerden et al. (2022). Global coverage of a single Martian day (sol) is provided every 10 solar longitudes so that seasonal and diurnal cycles are represented. Two simulated years are provided, one of which includes the global dust storm of 2018 (Mars Year 34) and the next year with lower dust conditions.
Fields included are profiles of temperature, pressure, air density, mixing ratios of $CO_2$, $H_2O$ (vapor and ice) and $O_3$. Surface values of temperature, $CO_2$, and $H_2O$ ice are also given with the local time and solar zenith angle. The fields are provided on a 4x4 grid with 103 vertical levels, and at 48 time-steps per Martian day.

The GEM-Mars dataset is 66 GB and is too large to be gathered on a web server.

The interpolation methodology is very similar to the one documented in the MCD user manual. Based on the year, the routine finds the 4 Ls and LST pairs that bound the user-supplied geometry. For each pair, the GCM fields are interpolated to the target latitude and longitude using bi-spherical interpolation. These 4 pairs are then interpolated to the target Ls and LST using bi-linear interpolation. Finally, the surface topography is interpolated from the MOLA database, and the final atmospheric altitude and pressure grid are adapted to the change in surface topography.

To provide a user-friendly interface to this large dataset, we provide a web interface that interpolates the GEM-Mars dataset to user-supplied geometry. The user-supplied geometric fields are Mars Year, solar longitude, latitude, longitude, and local solar time. The interface decalls a routine that performs the interpolation and returns a VOTABLE (XML page).
The data service is set up with DaCHS software installed on Debian Buster. The metaparameters are EPN-TAP parameters. The "granule uid" parameter is of the form "GEM-Mars_myearA_latB_lonC_lsD_lstE" where A is the Martian year (34 or 35), B is the latitude (degree), C is the longitude (degree), D is the solar longitude (degree) and E is the local solar time (0-24). The data can be provided for any combination of those coordinates and time. The metaparameters are ingested in the database with the mixin tool. The "access_url" launches a python WSGI API that reads the parameters in the URL, processes the interpolation among the GEM-Mars data and returns a VOTABLE for reading with a VO tool like TOPCAT. An example of "access_url" is https://gem-mars.aeronomie.be/vespa-gem?myear=34&lat=-88&lon=328&ls=0&lst=2 and follows the same nomenclature as the "granule_uid" described previously. The VOTABLEs are generated "on the fly" at user request and take less than 3 seconds; this time can be further decreased. As the data is generated "on the fly", the only data storage required is for the table of metaparameters containing millions of examples of queries to the GEM-Mars dataset (4 GB).

The GEM-Mars data service is accessible through the VESPA portal (http://vespa.obspm.fr/planetary/data/display/?&service_id=ivo://bira-iasb/gem_mars/q/epn_core&service_type=epn) and other TAP clients by the IVOA registry of registries. The metaparameters are also accessible on the BIRA-IASB DaCHS (http://vespa-ae.oma.be/). (note: there are currently difficulties to generate the output VOTables in some configurations, which are being processed)

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