Comparison of Global-Scale and Mesoscale Modelling of Vertical Profiles in the Martian Atmosphere: How Does Model Resolution Impact Predictions of Conditions at Mission Landing Sites?

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Abstract

Detailed modelling of the Martian atmosphere is required for every planned landing on the planet’s surface. This facilitates planning of spacecraft atmospheric entry, descent and landing.

- We completed experiments using both a global-scale model and a mesoscale model, comparing the results against data returned from a recent European Space Agency spacecraft descent through the Martian atmosphere:
  - Location: 2°S, -6°E  Date: 244° Ls
  - For this specific descent, we find that the high resolution experiments do not provide a more accurate representation of atmospheric temperatures and wind speeds than the lower resolution experiments.

1. Introduction

Modelling of the Martian atmosphere provides a picture of the environment that a descending spacecraft will be travelling through, allowing detailed planning of the entry, descent and landing phase of the mission. The complexities of atmospheric modelling require models of different scales to best represent the behaviour of different scale atmospheric phenomena.

It is crucial to compare model results and in situ descent module data in order to improve the performance and accuracy of the models. Improved models enable better environmental predictions to be made for future missions landing on Mars. We describe how changes in model scale and resolution can impact experimental results, using the selected landing site of the European Space Agency (ESA) Schiaparelli Entry & Descent Module (EDM) as a case study.

The EDM was part of ESA’s ExoMars 2016 mission. It transmitted data during its descent through the Martian atmosphere, from which the AMELIA (Atmospheric Mars Entry and Landing Investigations and Analysis) team have reconstructed the module’s trajectory (Figure 1) and vertical atmospheric profiles. We compare these data with our model results.

2. Atmospheric Modelling

We completed experiments using a global-scale model and a mesoscale model.

- Global model: the UK version of the Laboratoire de Météorologie Dynamique (LMD) Mars Global Circulation Model (MGCM), a 3D multi-level spectral model of the Martian atmosphere up to an altitude of ~100 km
  - We varied experiment resolution from a typical Martian climate modelling resolution of ~5° latitude x ~5° longitude to a ‘high’ resolution of ~1.25° latitude x ~1.25° longitude.
- Mesoscale model: the LMD Martian Mesoscale Model (MMM), modelling up to an altitude of ~50 km
  - We completed a nested resolution set of MMM experiments, ranging from the outer, lowest resolution results at 63 km x 63 km, to the inner, highest resolution results at 7 km x 7 km.
  - Boundary and initial conditions for MMM experiments are drawn from MGCM results.

3. Results

Figure 3 (above): Vertical profiles of model zonal and meridional wind speeds, up to altitudes of 50 km. All experimental results exhibit similar large-scale trends: westward zonal winds reducing with decreasing altitude, and weak meridional winds that tend southwards. Lines show values averaged over multiple model profiles.

Figure 5 (left): Vertical profiles of atmospheric temperature, comparing model results and data returned by the EDM during descent. The lowest 50 km of the profiles the MGCM data show a closer match to the EDM data than the MMM profiles. At higher altitudes, the MGCM experiments deviate from the EDM data in opposite directions: the lower resolution experiment underestimates the temperature, while the higher resolution experiment overestimates it.

4. Conclusions

- We do not find that increasing the resolution of atmospheric modelling experiments improves the accuracy of the representation of atmospheric temperatures or wind speeds, for this specific situation.
- As high resolution experiments can require significant time to complete, this information should be considered in any future assessment of atmospheric modelling requirements during initial mission planning.
- It should be remembered that these results consider only one landing location (2°S, -6°E), at one point in time (244° Ls).
- In addition, none of the model results show the oscillation seen in the reconstructed EDM wind speeds.

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