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?

Conference or Workshop Item

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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° L_S
- 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[1,2]. We compare these data with our model results.

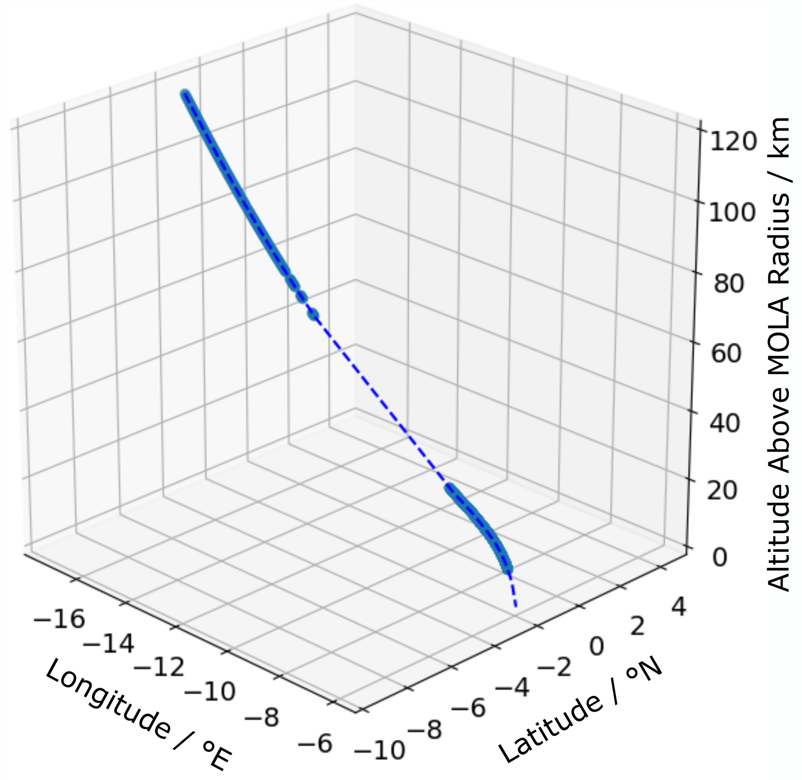

Figure 1: The reconstructed EDM descent trajectory, from an altitude of 100 km down to the surface. Markers indicate points in the descent for which data has been retrieved; dashed lines indicate the interpolated portions of the trajectory[1,2]. Data provided by the AMELIA team.

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[3].
  - 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.
  - We ran experiments for a simulated year, starting from initial conditions based upon prior atmospheric observations, thus providing an independent prediction of conditions through the period of this case study.
- **Mesoscale model:** the LMD Martian Mesoscale Model (MMM)[4], 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.

Previous comparisons of global-scale and mesoscale modelling have focused on areas containing small-scale topographical variation.

This work considers the relatively flat topography of the Schiaparelli site (Figure 2), which is more representative of most historical Martian landing sites.

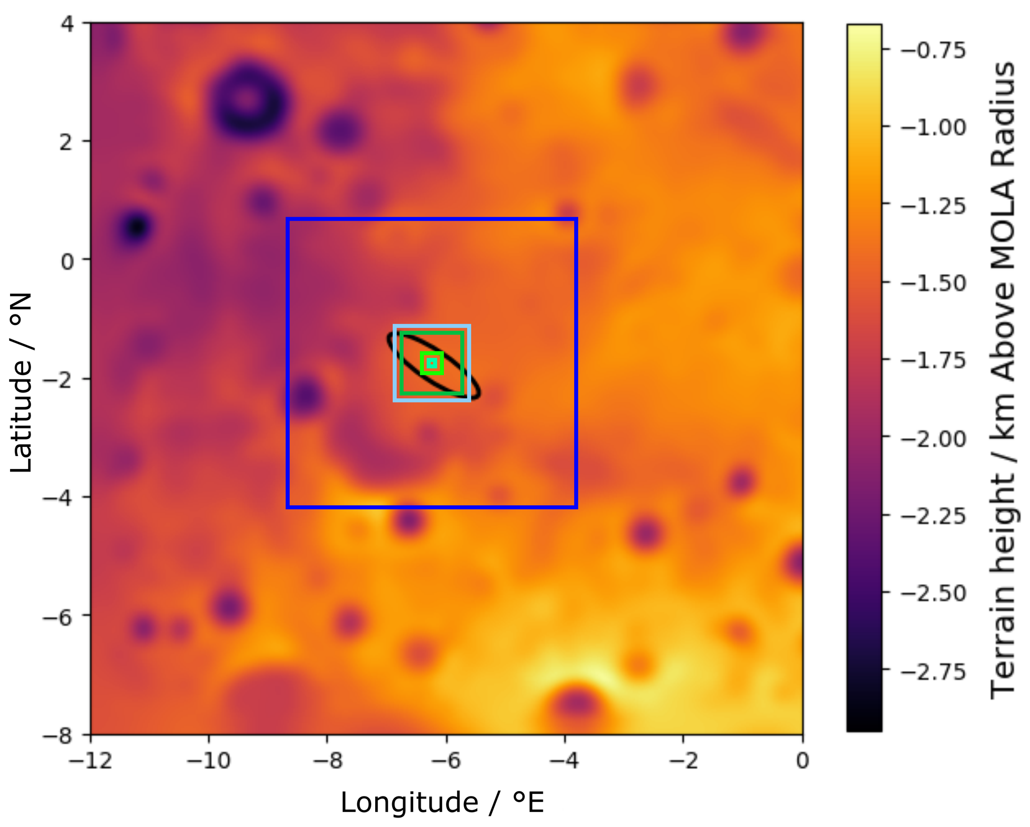

Figure 2: Terrain height map of a portion of Meridiani Planum. The Schiaparelli landing ellipse is marked, and the boxes illustrate the relative gridsizes used in the experiments: (*largest to smallest*) MGCM 5°x5°, MGCM 1.25°x1.25°, MMM 63 km, MMM 21 km, MMM 7 km.

3. Results

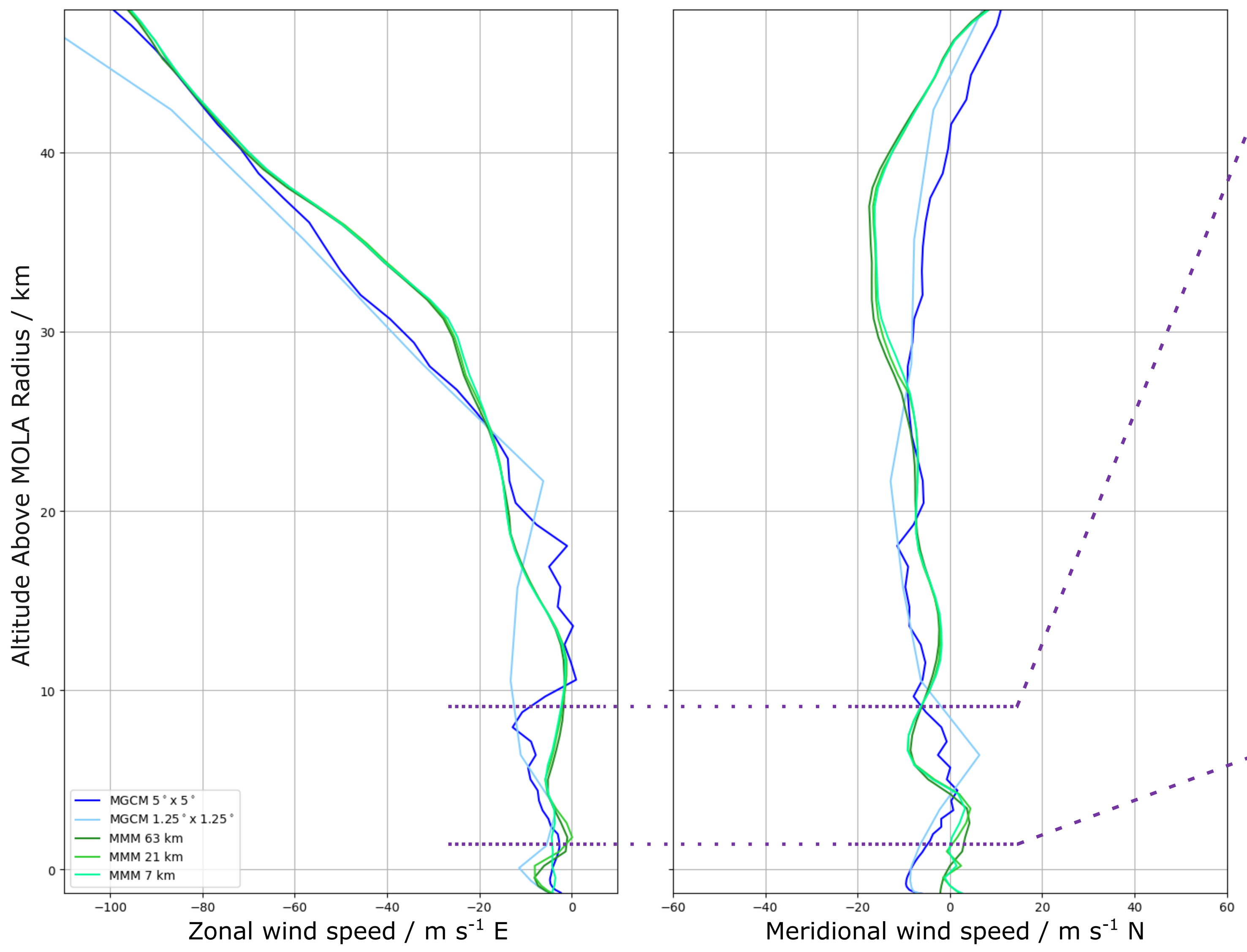

Figure 3 *(above)*: Vertical profiles of model zonal and meridional wind speeds, up to altitudes of 50 km. All experimental results exhibit similar large-scale trends: westward zonal winds reducing with decreasing altitude, and weak meridional winds that tend southwards. Lines show values averaged over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

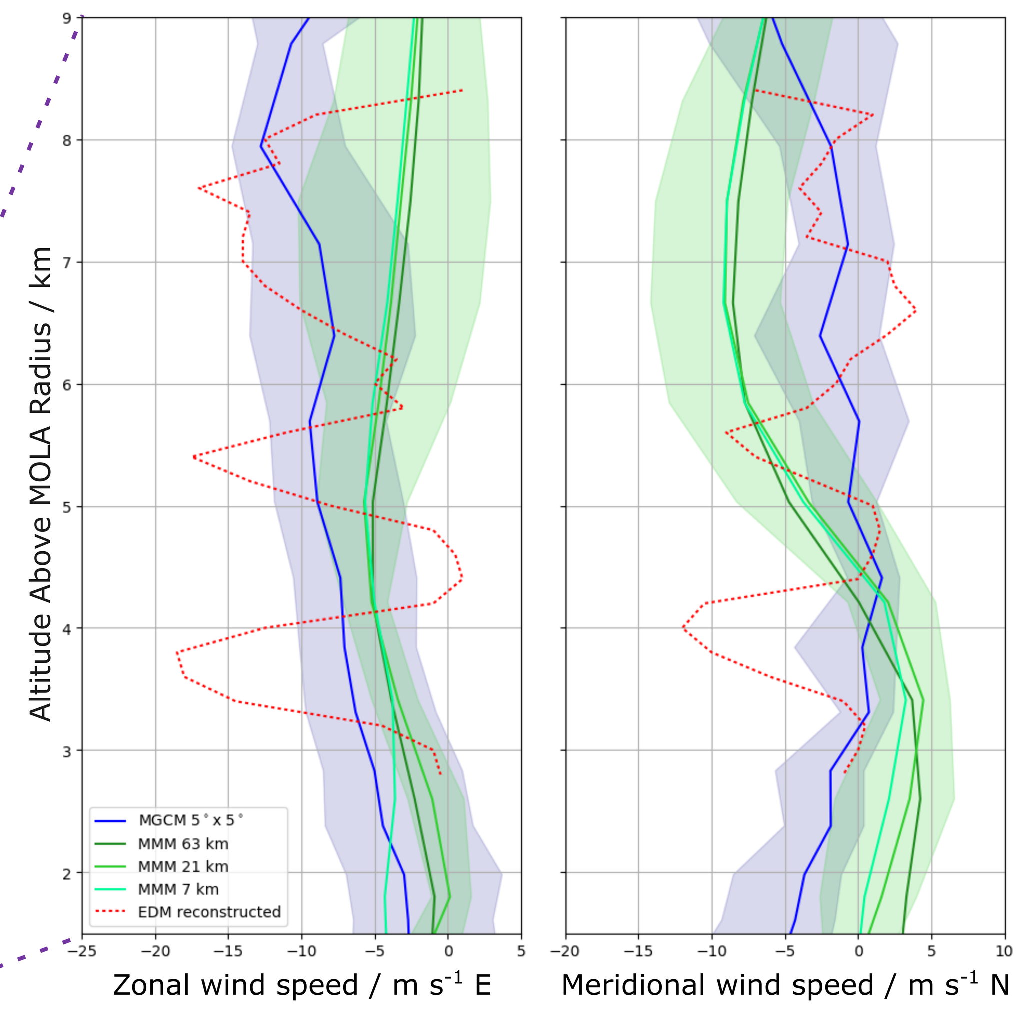

Figure 4 *(left)*: Vertical profiles of model and reconstructed EDM wind speeds[1,2], through the ~6 km of altitude available for comparison. Sol-to-sol profile variation is represented by shading; for clarity the MGCM 1.25°x1.25° line is not shown, and the MMM shading relates only to the 21 km resolution profiles. Neither the MGCM or the MMM data display the oscillation apparent in the reconstructed winds. The MGCM data are a better match to the general trend of the EDM data: westward zonal winds and weak meridional winds tending southwards with decreasing altitude. The MMM zonal winds are too weak and the meridional winds do not match the direction of the reconstructed wind speeds.

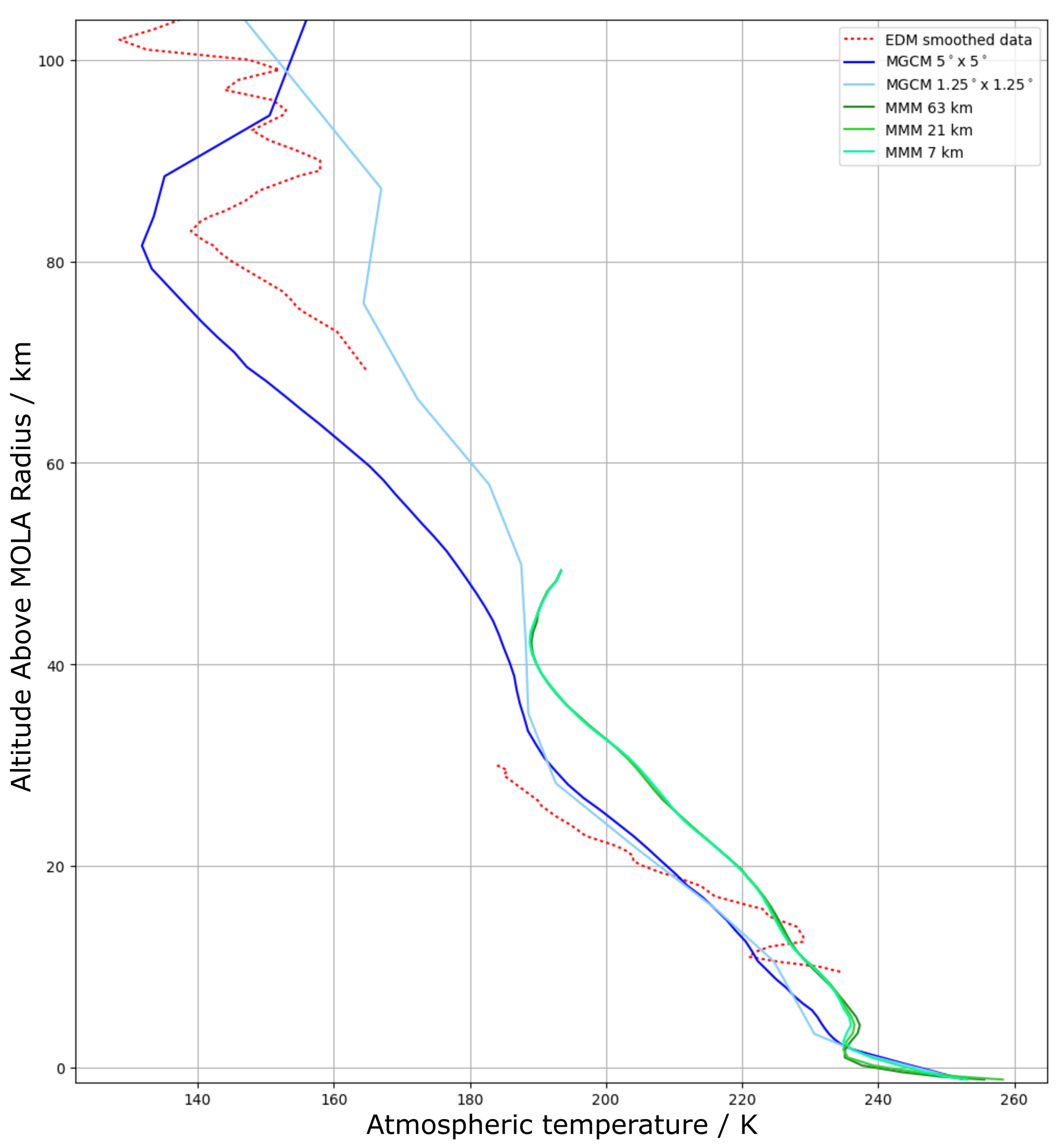

Figure 5 *(left)*: Vertical profiles of atmospheric temperature, comparing model results and data returned by the EDM during descent[1,2]. Through the lowest 50 km of the profiles the MGCM data show a closer match to the EDM data than the MMM profiles. At higher altitudes, the MGCM experiments deviate 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° L_S).
- In addition, none of the model results show the oscillation seen in the reconstructed EDM wind speeds.

References

[1] Aboudan et al., manuscript submitted, *SSR*. [2] Ferri et al. (2017) *IEEE Int. Wkshp. on Metrology for AeroSpace*. [3] Forget et al. (1999) *JGR*, 104, E10. [4] Spiga et al. (2009) *JGR*, 114, E2.

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