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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Introduction: Detailed modelling of the Martian atmosphere is completed for every spacecraft designed to land on the planet's surface. This provides the most complete picture of the environment that the descending module will be entering and travelling through, and facilitates planning of the Entry, Descent and Landing (EDL) phase of the mission.

The selected resolution of an atmospheric model can impact the results of the experiments performed. The complexities of atmospheric modelling also require models of different scales to best represent the behaviour of different scale atmospheric phenomena. Comparisons between multiple model results and *in situ* data are crucial for improving future environmental predictions for missions landing on Mars.

This work describes how changes in model scale and resolution (horizontal and vertical) can impact experimental results, using as a case study the selected landing site of the European Space Agency (ESA) Schiaparelli module. Schiaparelli was part of ESA's ExoMars 2016 mission; the module descended through the Martian atmosphere on 19th October 2016.

Method: Experiments were completed that encompassed the period of Schiaparelli's descent, using both a global-scale and a mesoscale model. The global model used in this work is the UK version of the LMD (Laboratoire de Météorologie Dynamique) Mars Global Circulation Model ("the MGCM"), a 3D multi-level spectral model of the Martian atmosphere up to an altitude of ~100 km [1]. The mesoscale model used in this work is the LMD Martian Mesoscale Model (MMM) [2]; in these experiments an altitude of ~50 km was modelled in the mesoscale.

Multiple resolution experiments were completed using the MGCM; results range from a 'low' resolution ~5° latitude x ~5° longitude (a resolution typically used for Martian climate modelling) to a 'high' resolution ~1° lat x ~1° lon. The vertical dimension is modelled using a set number of vertical layers; in these experiments the number of vertical layers selected was between 23 and 100. Experiments were run 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. The MMM experiments were completed in a set of nested resolutions, 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. MMM experiments were completed using 60 vertical layers.

Previous comparisons of global-scale and mesoscale modelling have focused on areas containing small-scale topographical variation that is not present in the global scale models. This work considers the relatively flat topography of the Schiaparelli site – a location that is more representative of the majority of historical Martian landing sites than areas that contain severe, small-scale topographical variation.

Results: Initial analysis has focused on constructing vertical profiles from the model output at both experimental scales, following preliminary information on the descent trajectory of the Schiaparelli module.

Figure 1 shows an example comparison of atmospheric profiles constructed from MGCM results at different model resolutions. The plot displays atmospheric temperature obtained from experiments completed at different vertical resolutions: 23 and 100 vertical levels. There is a good match between the results, with a root mean square deviation (RMSD) of 9.83 K between the results for the full height of the profiles; the RMSD reduces to 2.05 K when considering only the lowest ~10 km of the profiles (approximately one scale height).

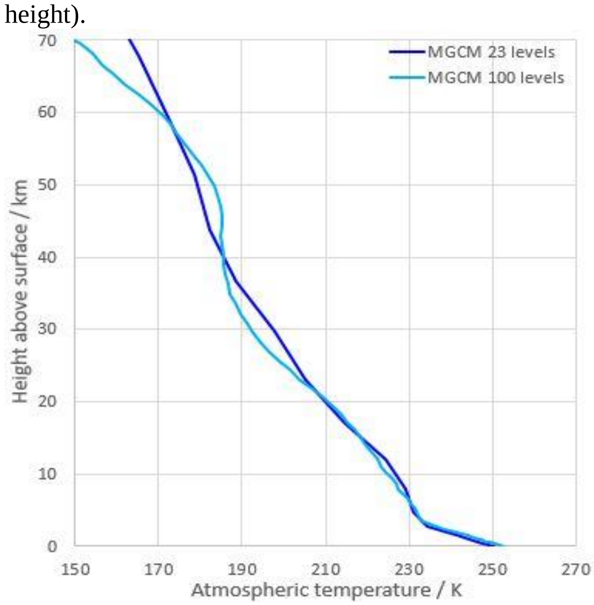

Figure 1: Vertical temperature profile of the Martian atmosphere at the Schiaparelli site during the period of the module's descent, from MGCM experiments of different vertical resolutions: 23 and 100 levels.

Figure 2 compares vertical atmospheric temperature profiles from MGCM and MMM results. While the trend in the results is similar, the results differ by ~10 K between the models through most of the profile, down to a height of ~3 km above the surface. Between 50 and 3 km above the surface the RMSD of the profiles is 9.79 K; below 3 km (down to the lowest MGCM model layer) the match is closer, with an RMSD of 2.59 K.

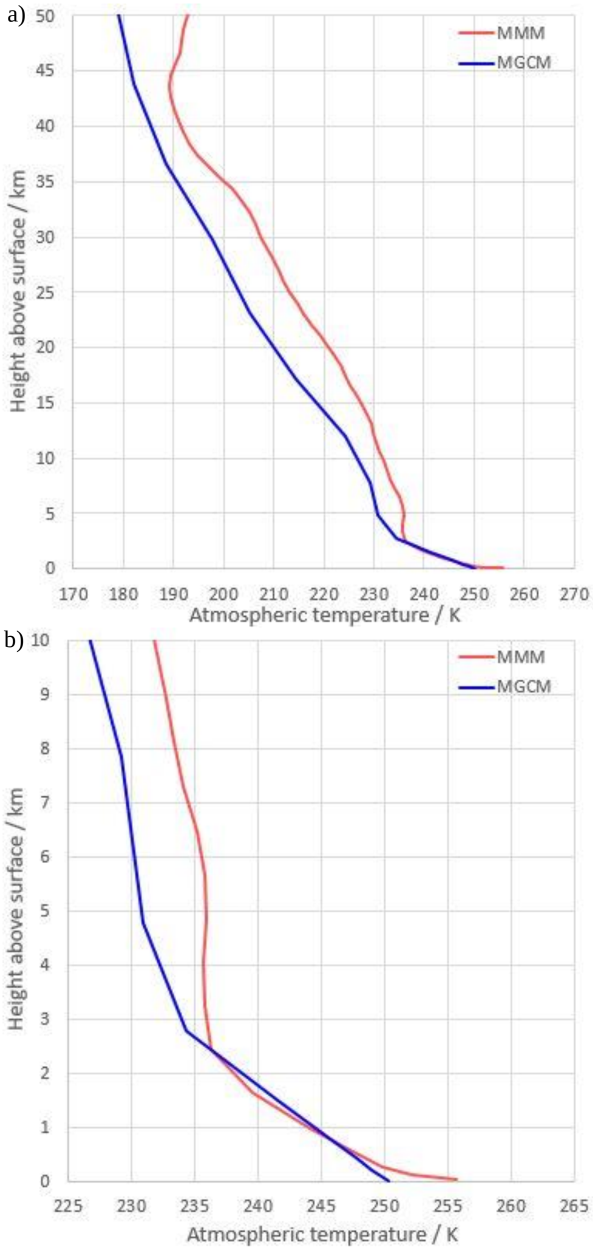

Figure 2: MGCM (23 layers) and MMM vertical profiles of atmospheric temperatures; a) up to 50 km above the surface, which is the full vertical extent of the mesoscale experiment, b) the lowest 10 km of the profiles.

Further comparisons have been completed between the MGCM and MMM results, such as wind speed and direction, including consideration of the wider topographical and atmospheric context of Schiaparelli's landing site and EDL period.

These results show that, for the region considered within this case study, changing the horizontal or vertical resolution used in MGCM experiments does not greatly impact the results obtained. Similarly, the MMM results do not vary more than ~4 K with changing horizontal resolution. In both cases, lower resolutions results (which are quicker and less computationally expensive to complete) are a good approximation of higher resolution results. Additionally, the similarity of the trends seen in the results from the different scale models suggests that global-scale model results are a reasonable approximation for mesoscale model results, for a number of potential landing locations on Mars.

Future work: Figure 3 shows a portion of the Meridiani Planum region, Schiaparelli landing ellipse superimposed. The module successfully transmitted some data that was captured during its descent, primarily from engineering sensors; this data includes the module's trajectory and attitude during the mission's EDL phase. The ExoMars AMELIA (Atmospheric Mars Entry and Landing Investigations and Analysis) team aim to use the data returned by Schiaparelli during descent, combined with dynamic modelling of the module's motion, to reconstruct atmospheric profiles of density, pressure, temperature and wind speed [3].

Upon the release of the Schiaparelli data, the results from both the MGCM and MMM experiments will be compared with the data, supporting the work of the AMELIA team.

References: [1] Forget et al. (1999) *JGR, 104,* E10. [2] Spiga et al. (2009) *JGR, 114,* E2. [3] Ferri et al. (2012) *9th International Planetary Probe Workshop*.

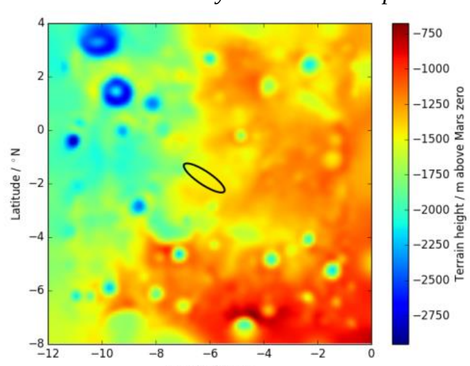

Figure 3: Terrain height map of a portion of Meridiani Planum as modelled in the mesoscale experiments. The Schiaparelli landing ellipse is marked; the relatively flat topography of the site even at this scale is evident.