EPSC Abstracts
Vol. 12, EPSC2018-680, 2018
European Planetary Science Congress 2018

Gravity wave drag parameterization for the new generation of Mars Global Circulation Models

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Abstract

We investigate the prevailing role of the sub-grid scale parametrization for the gravity wave drag in the Martian atmosphere using the NASA Ames Legacy General Circulation Model and the high performance Geophysical Fluid Dynamics Laboratory (GFDL)'s FV3 dynamical core running at high (sub-degree) resolution.

1. Introduction

Gravity waves are vertically propagating waves that can propagate over tens of kilometers, break, and deposit momentum that changes the mean atmospheric flow afar from their sources. Gravity waves can be orographic, that is, excited by the topography, or non-orographic when the source of the perturbation is dynamic (e.g. convection, front systems). On Mars, orographic gravity waves, in particular, have been studied with Global Circulation Model (GCMs). They are known to have a significant influence on the Hadley circulation and to dynamically alter the thermal structure of the atmosphere in the polar regions [2]; [4]

Oftentimes with GCMs, the horizontal scales of the topographic features that are exciting the orographic gravity waves are smaller than the grid spacing of the model. Therefore, these waves can not be adequately resolved within a numerical simulation and must be parameterized as a sub-grid scale process.

2. Method

We port the implementation of the Palmer et al. gravity wave drag scheme [6] for the NASA Ames Legacy GCM to the GFDL's FV3 dynamical core. The implementation includes wavelength-dependant thermal damping rates from Eckermann et al. [3] and also requires some degree of tuning to correctly match orbiter observations. The NASA Legacy Ames GCM uses a baseline resolution of 5 degree in latitude by 6 degree in longitude and 24 vertical levels. Within the FV3 framework though, sub-degree horizontal resolution is obtained and additional vertical layers are added in a computationally efficient manner. Therefore, the model now reaches a resolution where some of the topography features and dynamics that are exciting the gravity waves start to be resolved explicitly. Simulations are run at different horizontal resolutions, vertical resolutions and the tuning of the scheme is adapted consequently to investigate the impact of the spatial discretization on the waves' propagation and breaking.

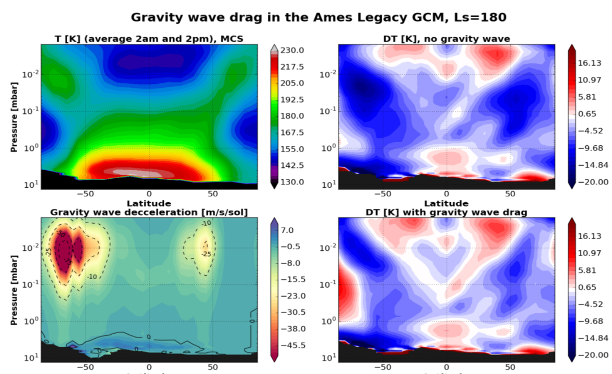

Figure 1: (Top left) MCS temperature retrievals. (Top right) Temperature difference GCM-MCS with no gravity wave. (Bottom left) Deceleration on the mean flow induced by the gravity wave drag. (Bottom right) Temperature difference GCM-MCS with gravity waves. The fields are zonally -averaged and the solar longitude is 180.

3. Preliminary Results

Figure 1 shows predictions for the temperature structure of the atmosphere from the NASA Ames Legacy GCM without (top right), and with (bottom right) sub-grid scale orographic gravity wave drag. The results are presented as difference plots with Mars Climate Sounder (MCS) temperature retrievals (top left) at a solar longitude of Ls =180. With gravity wave drag, the deceleration applied to the mean flow (bottom left) induce warming above the 1 mbar level at high latitudes.

4. Summary and ongoing work

The orographic gravity wave scheme improves the temperature structure of the atmosphere in the polar regions. [2] We are currently attempting to characterize the sensitivity of the spatial discretization for the tuning of the Palmer et al. [6] gravity wave drag scheme using FV3's high resolution capabilities. We also intent to test other gravity wave schemes, namely the orographic scheme from Garner et al. [5], and the non-orographic scheme from by Alexander and Dunkerton [1] which have been used in the GFDL terrestrial model.

References

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