The impact of a non-orographic gravity wave drag parameterization scheme on the middle atmosphere in JMA's Global Spectral Model

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1. Introduction

The Japan Meteorological Agency (JMA) plans to raise the top level of its operational Global Spectral Model (GSM) from 0.1 hPa to 0.01 hPa to include the whole stratosphere and place a model lid on the mesopause. The total number of vertical layers will be increased from 60 to 100 according to the tentative plan. One of the aims of these developments is to improve the representation of the middle atmosphere (i.e., the stratosphere and mesosphere), where gravity waves play a key role as a driving force for meridional circulation and long-term oscillations such as QBO (quasi-biennial oscillation). As gravity waves have smaller horizontal and vertical scales than the model's resolutions, their effects need to be parameterized in the GSM. To this end, a non-orographic gravity wave drag scheme [1] was tested in the vertically extended GSM.

2. Experiment Configuration

A six-year integration was conducted for the period 1995 – 2000 to clarify the impact of the non-orographic gravity wave drag scheme with the vertically extended low-horizontal-resolution GSM TL95L100. The model physics used were the same as those of the operational GSM in the control experiment (hereafter referred to as CNTL). In the test experiment (hereafter referred to as TEST), Rayleigh friction in the current operational GSM was replaced with the non-orographic gravity wave drag scheme. The parameters of the test scheme were different from those described in the original paper.

3. Results

Figure 1 shows zonally averaged zonal winds in the tropical lower stratosphere. Compared to ERA-Interim data [2], the TEST experiment outcome successfully shows QBO-like periodic changing zonal winds. However, the period is shorter than that of ERA-Interim. Additionally, the amplitude of the westerly wind phase is over 10 ms^{-1} weaker. No signs of QBO were captured in the CNTL experiment.

Model climatologies for zonal mean temperature and zonal wind fields in January are shown in Figure 2. Compared to the SPARC [3] climatology, the weak easterly jet bias in the middle atmosphere of the summer hemisphere in CNTL was alleviated in TEST. However, both experiments failed to reproduce the closed structure of the westerly jet in the mesosphere. In addition, temperatures in the upper mesosphere were over 20 K warmer than those of SPARC. The main cause of this bias is the excessive mesospheric ozone climatology used in the short-wave radiation scheme. Although the upper mesosphere in summer is cooler than the lower mesosphere in winter for SPARC, neither experiment reproduced such a structure. This suggests that both experiments were unable to represent meridional circulation leading to upward (downward) motion of the air producing adiabatic cooling (heating) in the summer upper (winter lower) mesosphere. The climatologies for July have features similar to those for January (not shown) even though the seasons are opposite.

The results described here are preliminary in nature, and further investigation is being conducted by

NPD/JMA. Some parameters of the non-orographic gravity wave drag scheme in TEST are also being tuned to improve its representation of the middle atmosphere in consideration of the accuracy and biases of other parameterizations such as long- and short-wave radiation schemes.

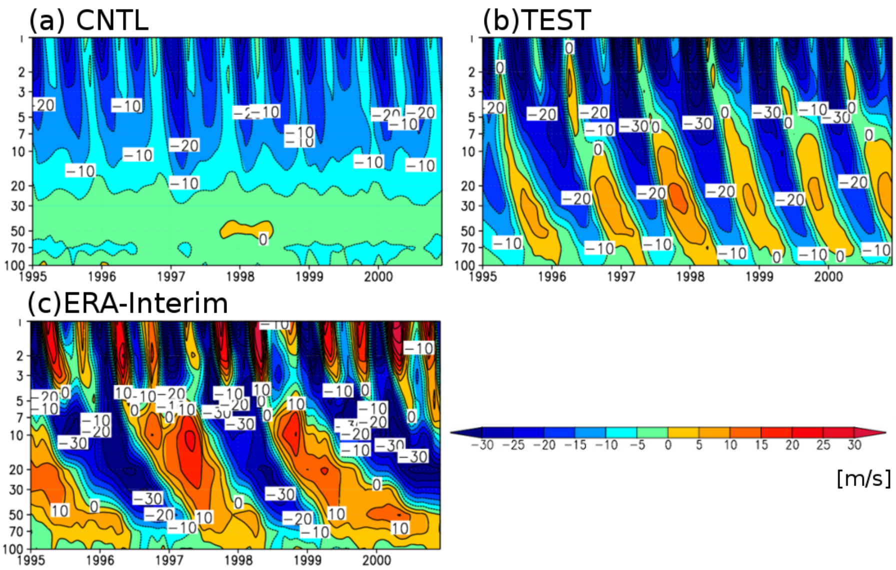

Figure 1. Time evolution of zonally averaged zonal winds (ms^{-1}) averaged over the 5°S – 5°N region. Positive values indicate westerly winds. (a) Control experiment: TL95L100 with Rayleigh friction; (b) test experiment: TL95L100 with a non-orogaphic gravity wave drag scheme; (c) ERA-Interim.

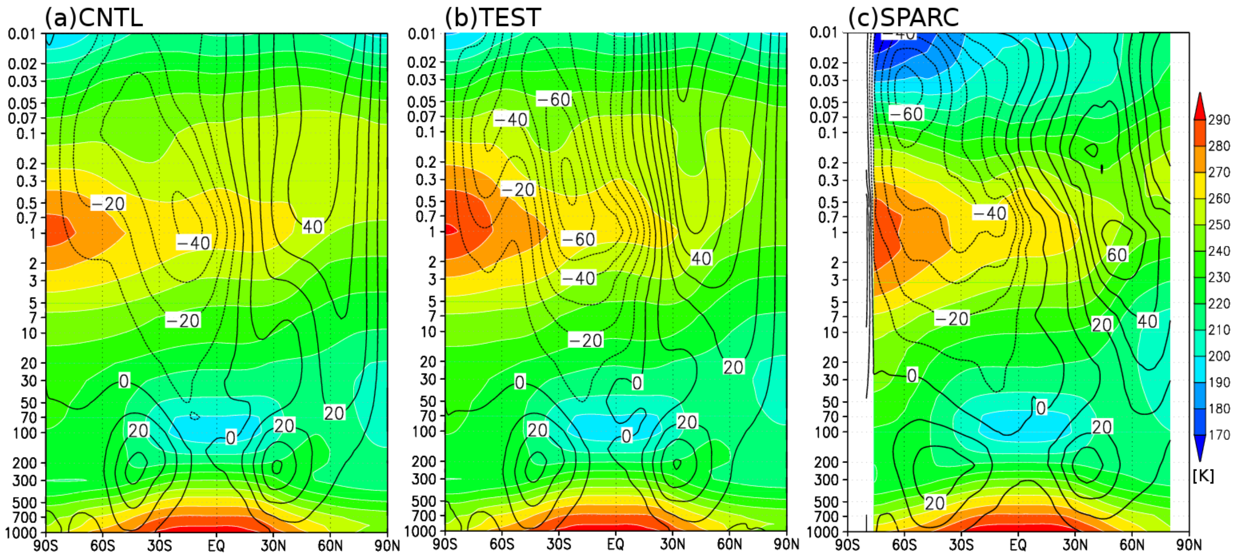

Figure 2. Zonal mean climatologies of zonal wind (contours, ms^{-1}) and temperature (shaded, K) for January. The contour intervals are 10 m/s. (a) Control experiment: TL95L100 with Rayleigh friction; (b) test experiment: TL95L100 with a non-orographic gravity wave drag scheme; (c) SPARC climatology. SPARC climatology for the 90°S – 75°S and 80°N – 90°N regions is not shown due to a lack of data.

References

[1] Scinocca, J. F., 2003: An accurate spectral nonorographic gravity wave drag parameterization for general circulation models. *J. Atmos. Sci.*, **60**, 667 – 682.

[2] Dee, D. P. et al., 2011: The ERA-Interim reanalysis: configuration and performance of the data assimilation system. *Quart. J. Roy. Meteor. Soc.*, **137**, 553 – 597.

[3] Randel, W. et al., 2004: The SPARC intercomparison of middle-atmosphere climatologies. *J. Climate*, **17**, 986 – 1003.