Impact of a non-orographic gravity wave drag parameterization on the middle atmosphere in the Global Spectral Model of the Japan Meteorological Agency

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Introduction

The Japan Meteorological Agency (JMA) has a plan to raise the topmost level of operational Global Spectral Model (GSM) from 0.1 hPa to 0.01 hPa, which makes GSM include whole stratosphere and place the model lid on the mesopause. Therefore, the total number of vertical layers will be increased from 60 to 100, with the aim of improving the representation of the middle atmosphere. In the middle atmosphere, gravity waves play a key role as a driving force of meridional circulations and long-term oscillations like QBO (Fritts and Alexander 2003). Because of insufficient vertical resolution of GSM, their effects need to be parameterized. For this purpose, non-orographic gravity wave drag (NGWD) scheme by Scinocca (2003) (hereafter referred to as S03) was tested in GSM.

Experiment Configurations

As gravity wave drag parameterizations, the operational GSM includes the orographic gravity wave drag scheme by Iwasaki et al. (1989) and the simple non-orographic gravity wave drag scheme as known as Rayleigh friction (RF) by Boville (1986). To study the impact of NGWD scheme, two experiments that one used RF and the other used NGWD instead of RF were conducted using low horizontal resolution GSM (T195) with the extended vertically resolution (L100) and the GSM with the operational vertical resolution (L60). Parameters of S03 were as follows: $s = 1, p = 1.5$, launch level $= 450$ [hPa], number of azimuths $= 4$, [N, S, E, W], number of phase speeds $= 50$, launch E-P flux density $= 3.5 \times 10^{-3}$ [Pa], $m = 2000$ [m], $c_{\text{min}} = 0.25$ [m/s], $c_{\text{max}} = 2000$ [m/s], $\gamma = 0.6$. Time step was $3600$ seconds. Other model descriptions of GSM were as same as described in Nakagawa (2009). The integration period was $6$ years for 1995-2000 and initial conditions were JRA-25 (Onogi et al. 2007). Analyzed SST and climatological ICE field were given. The model climatologies of the experiments are compared to the SPARC climatology (Randel et al. 2003) and ERA-Interim (Dee et al. 2011).

Zonal Mean Climatologies

- Winter polar lower stratosphere temperature (50hPa) of L60-RF (Fig. 1a, 3a) is about $10$ K colder than SPARC (Fig. 1c, 3c). This bias is alleviated in L60-NGWD (Fig. 1b, 3b), L100-RF (Fig. 1c, 3c) and L100-NGWD (Fig. 1d, 3d). In addition, the summer stratopause temperature in L60-NGWD and L100-NGWD are much closer to SPARC.
- Considering that winter stratopause temperature of L60-NGWD (Fig. 2b, 4b) and L100-NGWD (Fig. 2d, 4d) are much colder than SPARC (Fig. 2c, 4c) and winter mesosphere temperature are much warmer than SPARC, NGWD has a weak thermal circulation. Therefore, temperature bias alleviations seen in the summer stratopause in NGWD experiments may be compensating errors between weak heating bias of short wave radiation scheme and lack of upwelling cooling of meridional circulation in NGWD experiments.
- L100-RF and L100-NGWD have less latitudinal temperature gradient in the mesosphere, so that the winter westerly jets are too strong and are not closed in the mesosphere. Possibly this may be caused by O3 climatology error and radiation scheme bias (Sekiguchi at JMA/NPD, personal communication) in the mesosphere. Development to tackle the issues is undergoing at JMA/NPD.
- In the summer hemisphere, zonal mean of zonal wind for L100-NGWD (Fig. 2d, 4d) shows good agreement with SPARC (Fig. 2e, 4e), which indicates that RF excessively deaccelerates easterly winds in the region.

Tropical Winds

- L60-NGWD (Fig. 5b) and L100-NGWD (Fig. 5d) have zonal wind oscillations, but the amplitudes and periods are weaker and shorter than ERA-Interim. In contrast, L60-RF (Fig. 5a) and L100-RF (Fig. 5c) do not show such periodic oscillation.
- Comparing L60-NGWD with L100-NGWD, NGWD scheme impacts are not identical for L60 and L100 with the same parameter. This suggests the need of different optimal tunings depending on the model levels and the layer thicknesses. Vertical resolution is thought as a key factor of QBO modeling since model resolved waves depend on it.

References

Boville (1986), JAS ; Dee et al. (2011), QJRMS ; Fritts and Alexander (2003), R. Geophysical ; Iwasaki et al. (1989), JMA ; Nakagawa (2009), JMA ; Nakajima (2009), JMA ; Takasai et al. (2007), J. Clim ; Scinocca et al. (2003), JAS ; Sekiguchi at JMA/NPD, personal communication)

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