Optimization of orographic drag parametrizations in the JMA operational global model using COORDE-type experiments

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1. Introduction

The orographic drag inter-comparison project recently proposed and conducted under the auspices of the Working Group for Numerical Experimentation (WGNE) and the Global Atmospheric System Studies (GASS), the COnstraining ORographic Drag Effects (COORDE; van Niekerk et al. 2020), offers new insights on orographic drag parametrizations in global numerical weather prediction models. The Japan Meteorological Agency (JMA) Global Spectral Model (GSM) exhibits greater deceleration of zonal wind due to overly strong orographic gravity wave drag (OGWD) at lower altitudes among participated models. Zonal wind field deterioration in the winter stratosphere was evident when the orographic drag parametrizations described below were incorporated into the GSM, while significant improvement of short- to medium-range forecast skill in the Northern Hemisphere winter troposphere was also achieved (Yonehara et al. 2020). We consider the deterioration in the winter stratosphere to be associated with increased gravity wave forcing at lower altitudes than in other models. In this study, orographic drag parametrizations were optimized in COORDE experiments.

2. Parametrizations and Experimental design

The GSM employs sub-grid scale orographic (SSO) drag parametrization for consideration of low-level flow blocking and OGWD based on Lott and Miller (1997) and the turbulent orographic form drag (TOFD) of Beljaars et al. (2004) (JMA 2022). To mitigate excessive parametrized OGWD in the lower stratosphere, generation of gravity wave stress at the surface is adjusted by decreasing the tunable parameter n_{eff} from 2.4 to 1.0 to multiply effective gravity wave amplitude. The gravity wave drag coefficient G was increased from 0.25 to 0.6, resulting in greater upward propagation and peaking at higher altitude. The parameter α in TOFD was doubled to compensate for reduced gravity wave drag and related deterioration of forecast accuracy in the lower troposphere.

The COORDE experiments of van Niekerk et al. (2020) were conducted using the GSM with current and new orographic drag configurations (Table 1) at low-resolution (LR: TL159 (~110 km)). All forecasts were initialized from JMA's own analysis at 00 UTC from 1st to 14th January 2015. Forecasts at T+24 were evaluated via averaging over 14 cases.

3. Results

The impacts of parametrized orographic drag on zonal wind (i.e., LR_CNTL − LR_NOSSO, LR_REVISED − LR_NOSSO) were compared with those of resolved drag (i.e., HR_CNTL − HR_LROR) (Fig. 1). While the impacts of OGWD in LR_CNTL are stronger at lower altitudes than resolved as pointed out in van Niekerk et al. (2020), the revised orographic drag represents impacts closer to those of resolved drag in the lower stratosphere due to lower generated gravity wave stress and increased vertically propagating gravity waves with the new parameters. As a result, the noticeable negative zonal wind biases in LR_CNTL are significantly alleviated in LR_REVISED (Fig. 2).

References

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Table.1 Experiments.

Experiment	Description
LR_CNTL	Low-resolution (LR: ~110 km) control experiment with SSO drag turned on
LR_NOSSO	Low-resolution (LR: ~110 km) control experiment with SSO drag turned off
LR_REVISED	Low-resolution (LR: ~110 km) experiment with parameter-revised SSO drag turned on
HR_CNTL	High-resolution (HR: ~10 km) control experiment with SSO drag turned off
HR_LROR	High-resolution (HR: ~10 km) control experiment with low-resolution (~110 km) mean orography with SSO drag turned off

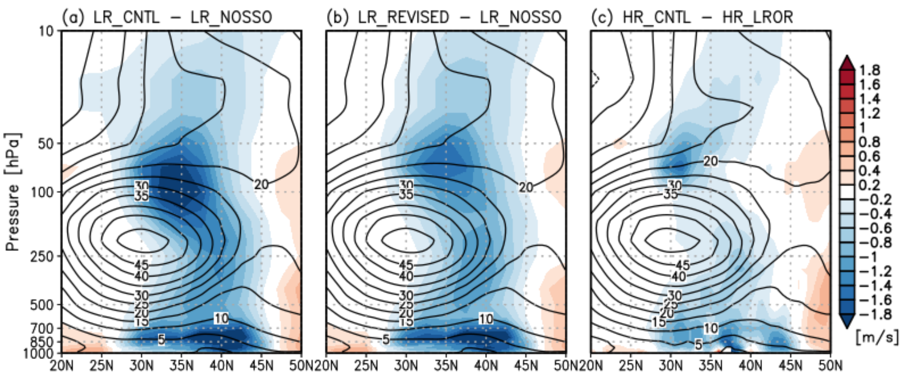

Fig. 1 Latitude-height cross section showing impacts of SSO drag on zonal wind [m/s] averaged over the Middle East (28 – 68°E). (a) LR_CNTL minus LR_NOSSO; (b) LR_REVISED minus LR_NOSSO; (c) HR_CNTL minus HR_LROR. Contours represent mean zonal wind in each experiment.

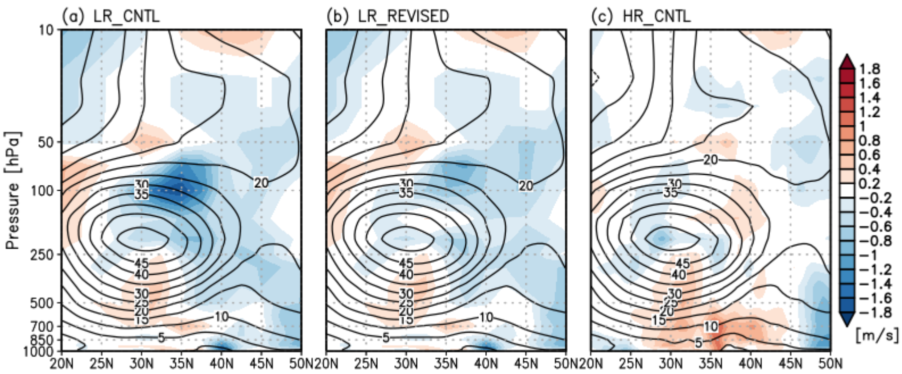

Fig. 2 Latitude-height cross section of zonal wind mean error against analysis [m/s] averaged over the Middle East region (28 – 68°E). (a) LR_CNTL; (b) LR_REVISED; (c) HR_CNTL. Contours represent mean zonal wind in each experiment.