Evaluation of revised gravity wave parametrizations using statistics of first-guess departures

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1. Introduction

The effects of unresolved gravity waves, which significantly affect the accuracy of numerical weather prediction (NWP), are parametrized individually in subgrid-scale orography (SSO) parametrization and non-orographic gravity wave (NGW) parametrization in global models. Although such parametrization exhibits considerable uncertainty due to a lack of direct observation for momentum flux, it can be evaluated indirectly using the massive volume of various kinds of observation which is available through data assimilation in the NWP system. In this study, the performance of the revised NGW and new SSO parametrizations in the Japan Meteorological Agency Global Spectral Model (JMA GSM; JMA 2019) was individually examined in terms of statistics of fitting between first-guess (FG) and observation (i.e., FG departure (observation minus first guess in 3 – 9 h forecasts)) processed in data assimilation.

2. Non-orographic Gravity Waves (NGW)

The latitude-dependent function that reduces launch flux near the equator is incorporated into the source momentum flux in the NGW scheme (Scinocca 2003; ECMWF 2014). In addition, the vertical diffusion coefficient in the turbulent diffusion scheme is damped with the cubic function of pressure above the diagnosed tropopause in stable conditions.

This improves the representation of quasi-biennial oscillation in long integration over that of previous parametrization with uniform source momentum flux (not shown). The revised scheme also significantly reduces the standard deviations of FG departures in the tropical stratosphere, especially for microwave sounders and radiosondes as shown in Fig. 1, additionally providing positive impacts on short-range forecasts in data assimilation.

3. Subgrid-scale Orography (SSO)

A new set of parametrizations representing subgrid-scale orographic drag, including the effects of low-level flow blocking and orographic gravity wave drag (OGWD) as proposed by Lott and Miller (1997) and the turbulent orographic form drag proposed by Beljaars et al. (2004), is implemented. The performance of this set of parametrizations is compared with the OGWD scheme presented by Iwasaki et al. (1989), which was used in the GSM and incorporates two types of gravity wave drag affecting areas from the upper troposphere to the lower troposphere, and from the surface to the lower troposphere.

The revised SSO parametrization mitigates positive geopotential height biases around the East Asia in the Northern Hemisphere winter troposphere and improves medium-range forecasts skill. These impacts are also seen in the standard deviations of FG departures for the radiosonde zonal wind velocity shown in Fig. 2. However, this parametrization is also seen to cause a deterioration in FG departures for microwave sounding channels and radiosondes in the stratosphere over areas of steep orography (e.g., the Himalayas, the Southern Andes and the Antarctic Peninsula) in the winter hemisphere. This suggests that further improvement of gravity wave momentum flux generation and vertical profiles of orographic gravity wave breaking is required, particularly in regions with larger FG departure values.

References

Beljaars, A., A. R. Brown, and N. Wood., 2004: A new parametrization of turbulent orographic form drag. *Q. J. R. Meteorol. Soc.*, **130**, 1327-1347.

ECMWF, 2014: Part IV Physical Processes, Chapter 5 Non-orographic gravity wave drag. *IFS documentation – Cy40r1*, 67-72.

Iwasaki, T., S. Yamada, and K. Tada, 1989: A Parameterization Scheme of Orographic Gravity Wave Drag with Two Different Vertical Partitionings Part I: Impacts on Medium-Range Forecasts. *J. Meteor. Soc. Japan*, **67**, 11-27.

Japan Meteorological Agency 2019: *Outline of the operational numerical weather prediction at the Japan Meteorological Agency.* JMA.

Lott, F. and M. J. Miller, 1997: A new subgrid-scale orographic drag parametrization: Its formulation and testing. *Q. J. R. Meteorol. Soc.*, **123**, 101-127.

Scinocca, J. F. 2003: An Accurate Spectral Nonorographic Gravity Wave Drag Parameterization for General Circulation Models. *J. Atmos. Sci.*, **60**, 667-682.

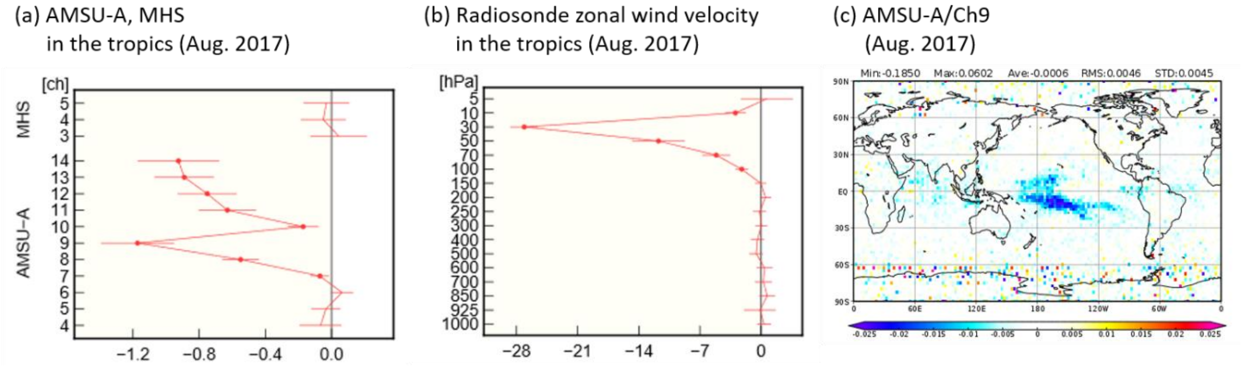
(a) AMSU-A, MHS in the tropics (Aug. 2017)
(b) Radiosonde zonal wind velocity in the tropics (Aug. 2017)
(c) AMSU-A/Ch9 (Aug. 2017)

Fig. 1 Normalized changes [%] in the standard deviation of FG departures in the tropics (20°N – 20°S) for (a) microwave temperature sounders and humidity sounders (AMSU-A, MHS), and (b) radiosonde zonal wind velocity. (c) Spatial distribution of changes in root mean square FG departures for AMSU-A/Ch. 9 brightness temperature [K]. The period is from Jul. 21 to Sep. 11 2017. Negative values show RMSE reductions with the revised scheme. Error bars and dots in (a, b) indicate 95% confidence intervals and statistically significant changes, respectively.

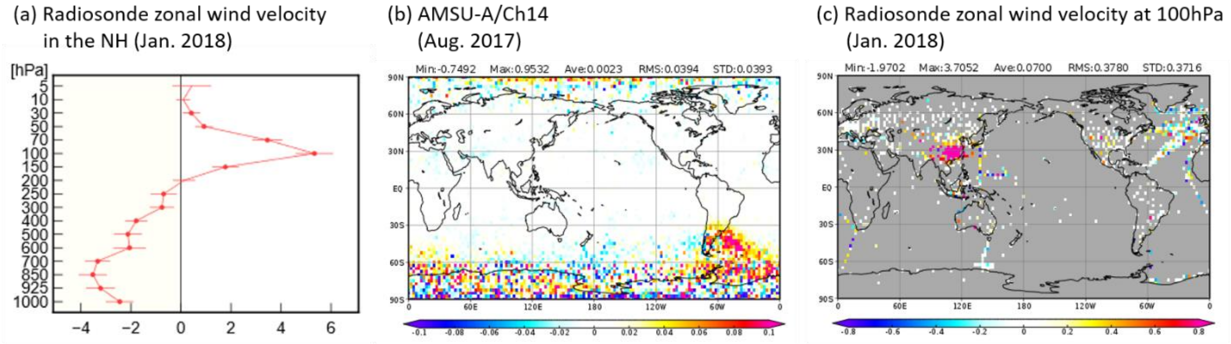
(a) Radiosonde zonal wind velocity in the NH (Jan. 2018)
(b) AMSU-A/Ch14 (Aug. 2017)
(c) Radiosonde zonal wind velocity at 100hPa (Jan. 2018)

Fig. 2 (a) Same as in Fig. 1 (b), but for the Northern Hemisphere (20°N – 90°N) from Dec. 21 2017 to Feb. 11 2018. (b, c) Same as in Fig. 1 (c), but for (b) AMSU-A/Ch. 14 brightness temperature [K] from Jul. 21 to Sep. 11 2017. (c) Radiosonde zonal wind velocity [m/s] at 100 hPa from Dec. 21 2017 to Feb. 11 2018.