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

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Introduction

- The effects of unresolved gravity waves which play a crucial role for accurate numerical weather prediction (NWP) are parametrized as subgrid-scale orography (SSO) parametrization and non-orographic gravity waves (NGW) parametrization in global models.
- These parametrizations are known for large uncertainties due to lack of direct observations of gravity wave flux. However, it is still possible to indirectly evaluate these parametrizations using a massive volume of various kinds of observation which is available through data assimilation in an NWP system.

Overview of Parametrizations and Evaluations

1. Non-orographic Gravity Waves (NGW)

- In order to improve the representation of the quasi-biennial oscillation (QBO), a latitudinal dependent function \( F \) is introduced into the source momentum flux in an NGW scheme (Scinocca 2003) and vertical diffusion coefficient is damped with a cubic function of pressure above the diagnosed tropopause in stable conditions in a turbulent diffusion scheme, and \( F \) is given by

\[
F(\alpha) = 1 - (1 - A)\exp\left(-\frac{\alpha}{2}\right)
\]

where \( A \) and \( \alpha \) are tunable parameters (ECMWF 2014; \( A = 0.55, \alpha = 10 \) [deg]; hereafter LATD+VAMP).

- Compared to old parametrization (i.e. uniform source momentum flux; hereafter UNIFORM), LATD+VAMP significantly decreases the standard deviation of FG departures (observation minus first guess (3h-9h forecasts)) in the tropical stratosphere, especially for microwave sounders, GNSS radio occultation and radiosonde, which indicates positive impacts also on short-range forecasts in data assimilation.

2. Subgrid-Scale Orogaphy (SSO)

- A new set of parametrizations (hereafter LMTOFD) representing sub-grid scale orographic draging including the effects of low-level flow blocking and orographic gravity wave drag (OGWD) by Lott and Miller (1997), and the turbulent orographic form drag by Beljaars et al. (2004) is implemented.

- The performance of this set of parametrizations is compared with the OGWD scheme by Iwasaki et al. (1989) (hereafter IW), which is currently used in the GSM and incorporates two different types of gravity wave drag affecting on upper troposphere to lower stratosphere, and surface to lower troposphere. Note that no parametrization scheme accounting for the form drag is used in IW runs with OGWD scheme.

- LMTOFD runs remarkably improve medium-range forecasts skills in the NH winter in the troposphere, and the improvement especially manifests itself in mitigation of the positive geopotential height bias around the East Asia, which has been one of the major issues to be addressed in the GSM for a long time.

- However, in the stratosphere the deterioration of the root mean square FG departures for model runs with OGWD soundings in the regions with larger FG departures (not shown), and IW also indicates relatively large root mean square FG departures in the upper stratosphere in the Southern Andes.

- The median FG departures for AMSU-A/Ch14 shows overall negative departures over the Southern Andes and Antarctic Peninsula in the winter hemisphere.

Future Plans

- Improving stratospheric representation in orographic gravity wave parametrization particularly over the regions, where LMTOFD shows worse fit of the FG departures with observations than IW, through the evaluation using the statistics of FG departures
- Evaluating gravity wave parametrizations using direct/indirect observations and partitioning into orographic and non-orographic gravity wave drag, blocked flow drag, and turbulent orographic form drag parametrizations

Background:

- The performance of the new SSO and revised NGW parametrizations in the Japan Meteorological Agency Global Spectral Model (JMA GSM; JMA 2019) is individually examined in terms of the statistics of fit between first guess (FG) and observation processed in data assimilation.