Upgrade of JMA's Operational Global Numerical Weather Prediction System

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1. Introduction

In March 2023, the Japan Meteorological Agency (JMA) upgraded its operational global Numerical Weather Prediction system (JMA 2023) to incorporate the enhanced horizontal resolution of the JMA Global Spectral Model (GSM). The upgrade also involved refinements such as parametrized surface drag, non-orographic sub-grid gravity waves, and radiation, resulting in better forecasting than the previous versions (Ujiie et al. 2021), particularly in Northern Hemisphere middle latitudes. New source datasets are used for orographic ancillary files (Kanehama et al., 2023). Global snow depth analysis was also improved.

This report outlines individual components of the upgrade and related verification results.

2. Main Updates

2.1 Horizontal resolution

Truncation for spectral dynamics was changed from linear to quadratic to reduce noise on smaller scales with spectral blocking, and grid spacing was enhanced from around 20 km to around 13 km. Effective horizontal resolution was also enhanced by sharpening the model mean topography and weakening fourth-order horizontal spectral numerical diffusion.

2.2 Surface drag

Subgrid-scale orographic drag parameterization (SOD) parameters were revised to reduce stress distribution in the lower stratosphere to improve the weak westerly wind bias in the lower stratosphere. Additionally, the effects of turbulent orographic form drag were strengthened to complement the drag in the mid-lower troposphere weakening due to the SOD revision (Matsukawa et al. 2022).

2.3 Non-orographic gravity wave

In non-orographic gravity wave parameterization, latitudinal dependence of launch momentum flux was improved for reduction at all latitudes, with particularly small fluxes at higher latitudes. This reduced zonal wind and temperature biases in the stratosphere.

2.4 Radiation

The effective size diagnostic scheme for ice clouds in the radiation scheme was changed from that proposed by Wyser (1998) to that of Sun (2001), which applies to tropical and mid-latitude regions. The change resulted in a smaller diagnostic cloud ice effective size and mitigated excess bias in outgoing long-wave radiation flux at the top of the atmosphere due to increased ice cloud optical depth.

Ozone concentration monthly climatology was updated with the 1981–2010 average based on the latest MRI CCM2 reanalysis (Deushi and Shibata 2011) to reduce temperature biases in the stratosphere.

A set of correction schemes for surface downward shortwave radiation (Hogan and Bozzo 2015, Hogan and Hirahara 2016) was incorporated to improve surface radiation fluxes.

2.5 Snow Depth Analysis

The frequency of global snow depth analysis was increased from once a day to four times a day and the analysis method was modified for effective use of satellite snow-cover data.

3 Verification

Two experiments were conducted to compare forecast scores of the previous (CNTL) and updated (TEST) models for July to September 2021 and December 2021 to February 2022. Figure 1 shows root-mean-square error (RMSE) differences for 500-hPa geopotential height forecasts up to 5.5 days ahead verified against own analysis averaged over the Northern Hemisphere (20 – 90°N) for both periods. The upgraded system improved RMSE values of 500-hPa geopotential height and other variables over forecasts of several days as compared to previous GSM versions. The improved accuracy of these forecasts in the troposphere is mainly due to the enhanced accuracy of initial atmospheric conditions resulting from the above improvements in the atmospheric analysis.

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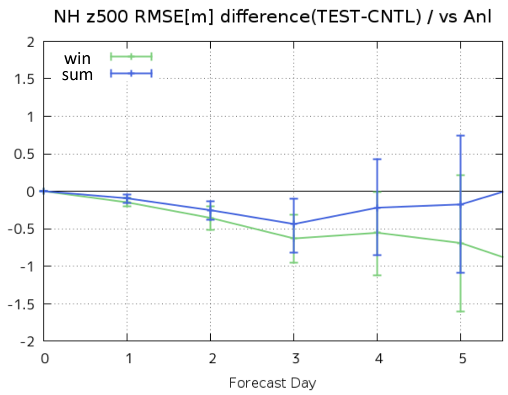

Figure 1. Root-mean-square error differences (TEST – CNTL) of 500-hPa geopotential height [m] against analysis (Anl) in the Northern Hemisphere extra-tropics (20 – 90°N) in the winter and summer experiments. The horizontal axis shows the forecast lead time [days], and the green and blue lines show the winter and summer experiments, respectively. Error bars indicate statistical significance with 95% confidence based on the bootstrap method.