Upgrade of JMA's Operational NWP Global Model

Hitoshi Yonehara, Masashi Ujiie, Takafumi Kanehama, Ryohei Sekiguchi, Yosuke Hayashi
Japan Meteorological Agency, Tokyo, Japan
(email: yonehara@naps.kishou.go.jp)

1. Introduction

In March 2014, the Japan Meteorological Agency (JMA) began operation of an upgraded Global Spectral Model (GSM: JMA 2013) with more vertical levels and a higher top level. The parameterization schemes for variables such as the boundary layer, radiation, non-orographic gravity waves and deep convection were also revised to improve the representation of atmospheric characteristics. This report briefly outlines the specifications of new vertical layers, parameterization improvements and verification results in relation to the upgrade.

2. Vertical layers

The number of vertical layers was increased from 60 to 100, and the pressure of the top level was raised from 0.1 hPa to 0.01 hPa. Table 1 compares the specifications of the new and old models, and Figure 1 compares their vertical layer distribution. The vertical resolution was increased at all elevations to reduce truncation errors caused by finite differentiation and to improve atmospheric vertical structure representation. In particular, more layers were applied mainly in the upper troposphere and the lower stratosphere to improve forecast accuracy for the troposphere and stratosphere, respectively. The main purposes of raising the model top were to allow the assimilation of more satellite observations with sensitivity for the middle atmosphere and to reduce the effect of pseudo-reflection from the model top in the stratosphere. In this connection, second-order linear horizontal diffusion was applied in the divergence equation and enhancement of fourth-order linear diffusion in the sponge layer around the model top was stopped.

3. Parameterization improvement

a. Boundary layer

Surface exchange coefficients based on the Monin-Obukhov similarity theory (Beljaars and Holtslag 1991) were introduced for bulk exchange formulation of land surface fluxes, and the vertical diffusive coefficients in the stable boundary layer were revised (Han and Pan 2011). These changes improved wind fields and diurnal cycles of temperature variation in stable conditions.

b. Radiation

A new long-wave radiation scheme based on a two-stream absorption approximation radiation transfer method (Yabu 2013) was introduced to improve the accuracy of the heating rate in the middle atmosphere and reduce computational cost. In the new long-wave radiation scheme, absorption relating to atmospheric molecules is calculated using a k-distribution approach. Despite the increased number of vertical levels, the computational cost of radiation was reduced.

Bare ground albedo parameter distribution was adopted instead of a globally uniform albedo, which substantially reduced mean errors of clear sky radiative fluxes near desert areas.

c. Gravity waves

Non-orographic spectral gravity wave forcing parameterization (Scinocca 2003) was introduced to replace Rayleigh friction in the forecast model in order to improve the middle atmospheric climate and representation of long-term oscillation (such as the quasi-biennial type) in the tropical lower stratosphere.

d. Deep convection

In the convection scheme, the energy correction method was adjusted to the new vertical levels. This mitigated extreme drying in the upper troposphere and improved large-scale circulation and precipitation distribution over the tropics.

4. Verification results

An experiment was conducted to evaluate the upgraded GSM's performance, including the impacts of improvements in data assimilation considerations such as the GNSS radio occultation bending angle (incorporating high-altitude data up to 0.1 hPa), AMSU-A 14 ch (with a sensitivity peak near 2 hPa) and ground-based GNSS zenith total delay. Although the revision of data assimilation and the increased number of vertical layers were not negligible, the parameterization improvements were the principal for forecast accuracy in the subsequent discussion.

Figure 2 shows profiles of mean errors (ME) and root mean square errors (RMSE) against the analysis for 11-day forecasting of geopotential height. The verification region is the whole globe, and the trial period is six months. The GSM improvements reduced ME and RMSE values for most pressure levels and all forecast times. Overall improvement was also found in forecasts of other elements such as global mean sea level pressure and 850/250-hPa vector wind in the extratropics.

Figure 3 shows that tropical cyclone track forecast errors for four regions are all reduced with the upgraded GSM. Further verification indicates that the new model's performance for cyclone identification is better than that of the old version.

References

Beljaars, A. C. M. and A. A. M. Holtslag, 1991: Flux parameterization over land surfaces for atmospheric models. *J. Appl. Meteor.*, **30**, 327 – 341.

Japan Meteorological Agency, 2013: Outline of the Operational Numerical Prediction at JMA.

Jongil Han, Hua-Lu Pan, 2011: Revision of Convection and Vertical Diffusion Schemes in the NCEP Global Forecast System. *Wea. Forecasting*, **26**, 520 – 533.

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

Simmons, A. J. and D. M. Burridge, 1981: An energy and angular momentum conserving vertical finite difference scheme and hybrid vertical coordinates. *Mon. Wea. Rev.*, **109**, 758 – 766.

Simmons, A. J. and R. Strufing, 1983: Numerical forecasts of stratospheric warming events using a model with a hybrid vertical coordinate. *Q.J.R. Meteorol. Soc.*, **109**, 81 – 111.

Yabu, S. 2013: Development of longwave radiation scheme with consideration of scattering by clouds in JMA global model. *CAS/JSC WGNE Res. Activ. Atmos. Oceanic. Modell.*, **43**, 04.07 – 04.08.

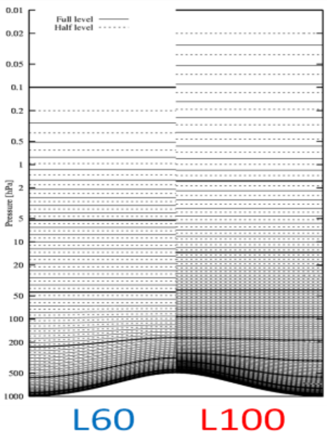

Fig. 1: Distribution of vertical layers: old model (left) and new model (right). The vertical coordinate system is based on Eta (sigma-p hybrid) coordinates (Simmons and Burridge 1981, Simmons and Strufing 1983) and the bottom half level is the surface. Solid and dashed lines show full and half levels, respectively.

Table 1: Model specifications

	Old	New
Horizontal resolution	TL959	
Vertical levels	60	100
Model top [hPa]	0.1	0.01
Time step [sec]	600	400

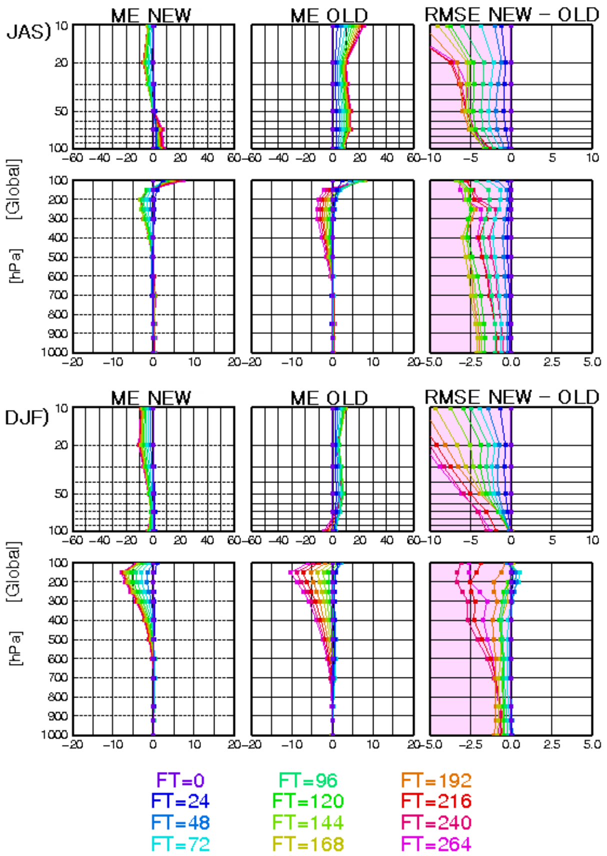

Fig. 2: Profiles of new MEs (left), old MEs (center) and RMSE differences (new – old, right) for geopotential height [m]. The reference values are the respective analysis results, and the verification region is the whole globe. The trial periods are six months for JAS 2013 (top) and DJF 2012/3 (bottom). Each line shows the result of a forecast time from FT = 0h to FT = 264h at 24-hour intervals.

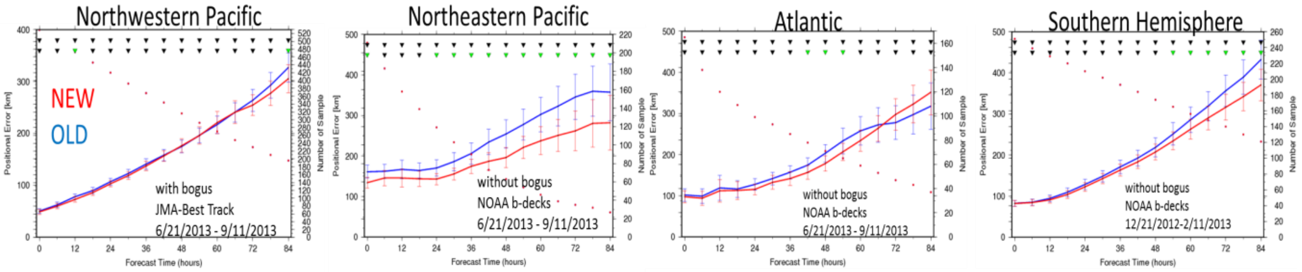

Fig. 3: Tropical cyclone track forecast errors for four regions (Northwestern Pacific, Northeastern Pacific, Atlantic, Southern Hemisphere). References are JMA best track and NOAA b-deck data. Red and blue lines show the track errors of the new and old models respectively (left axis), and each point shows the number of samples (right axis). Error bars indicate the two-sided 95% confidence interval.