Upgrade of JMA's Operational Global NWP system

UJIIE Masashi, HIGUCHI Mayuko, KADOWAKI Takashi, KUROKI Yukihiro, MIYAOKA Kengo, ODA Mayuko, OCHI Kenta, SEKIGUCHI Ryohei, SHIMIZU Hiroyuki, YOKOTA Sho, and YONEHARA Hitoshi

Japan Meteorological Agency, Tokyo, Japan

(email: ujiie@met.kishou.go.jp)

1. **Introduction**

The Japan Meteorological Agency (JMA) upgraded its operational global Numerical Weather Prediction (NWP) system (JMA 2019) in March 2021 to incorporate the enhanced vertical resolution of the JMA Global Spectral Model (GSM), improved land surface analysis and an upgraded atmospheric data assimilation system (Kadowaki et al. 2020). These improvements resulted in better forecasting (Yonehara et al. 2020), particularly for the Northern Hemisphere. This report outlines individual components of the upgrade and related verification results.

2. **Major Updates**

2.1 Number of Vertical Levels

The number of vertical levels of the GSM was increased from 100 to 128, with the uppermost level maintained at 0.01 hPa. Vertical grid spacing is now 1.2 – 1.3 times finer over the troposphere and stratosphere than before. The enhanced vertical resolution reduces discretization errors in the dynamical process and improves atmospheric representation.

2.2 Snow Depth Analysis

In the upgraded system, forecast snow depth corrected using satellite-estimated snow area data is employed as the first guess for snow depth analysis, as opposed to the climatological values employed with the previous system. Harnessing with the upgrade of the first guess, correlation length and magnitude of background error are optimized to increase the contribution of the first guess to analysis. These improvements mitigate excessive spread of snow analysis data over observation-sparse areas, and reduce systematic errors in shortwave radiative fluxes for snow-covered surfaces.

2.3 Soil Moisture Analysis

The upgraded system employs soil moisture analysis based on Ochi (2020) assimilating screen-level temperature and relative humidity analysis using a simplified Extended Kalman Filter. The system initializes soil moisture from the surface to a depth of 0.19 m, as opposed to the previous system's employment of climatological values.

This upgrade enables representation of soil moisture variations associated with daily weather conditions and reduces temperature errors for the lower troposphere.

2.4 Atmospheric Data Assimilation System

To optimize estimation of flow-dependent background error covariance (referred to here as **B**) in the four-dimensional variational data assimilation system, the number of ensemble members used to create ensemble-based **B** has been increased from 50 to 100, and the related weight has also been increased (Yokota et al. 2021). Climatological **B** has also been updated based on error statistics for the latest GSM.

These improvements result in better fitting of the first guess to observation data such as those from radiosondes and satellite radiances in the atmospheric data assimilation system.

3. **Verification Results**

Twin experiments conducted to evaluate the performance of the updated (TEST) system against the previous (CNTL) system for July to September 2019 (summer) and December to February 2019/2020 (winter) showed that the land surface analysis upgrade reduced systematic errors in the lower atmosphere. As an example, Figure 1 shows vertical profiles of mean errors (MEs) in temperature for CNTL and TEST averaged from September 2019 to February 2020. The upgraded system reduced cold biases in the lower troposphere, partially due to suppression of excessive spread in snow data. As a synthetic effect of these major forecast upgrades, TEST showed significantly reduced root-mean-square errors (RMSEs) for 500-hPa geopotential height over forecasts of several days (Figure 2).

References

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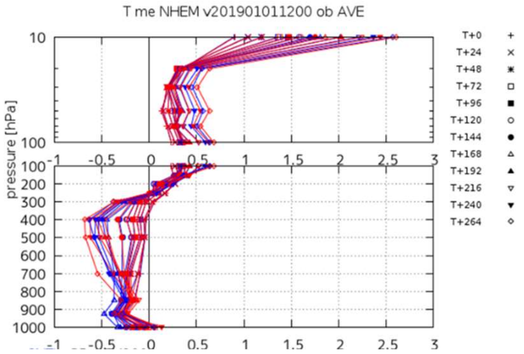

Figure 1. Vertical profiles of mean errors for temperature [K] in the 0 – 180°E, 20 – 90°N region for the winter experiment. Blue: CNTL; red: TEST. Lines represent ME at different forecast lead times for days 1 to 11.

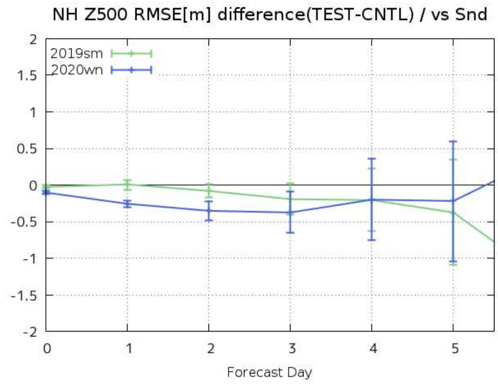

Figure 2. Root-mean-square error differences (TEST – CNTL) of 500-hPa geopotential height [m] against radiosonde (Snd) in the Northern Hemisphere extra-tropics (20 – 90°N) in the summer and winter experiments. The horizontal axis shows the forecast lead time [days], and the green and blue lines show the summer and winter experiments, respectively. Error bars indicate statistical significance with 95% confidence based on the bootstrap method.