Upgrade of JMA's Operational Global Model

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1. **Introduction**

In March 2020, the Japan Meteorological Agency (JMA) upgraded its operational Global Spectral Model (GSM; JMA 2019). The revision involved the refinement of parametrized surface drag processes, land surface processes, and surface albedo and stratocumulus on sea ice, which collectively resulted in better forecasting than with previous versions (Yonehara et al. 2018), especially in Northern Hemisphere middle and high latitudes. This report outlines individual components of the upgrade and related verification results.

2. **Major updates**

2.1 Parametrized surface drag processes

The subgrid-scale orography (SSO) scheme proposed by Lott and Miller (1997) replaced the previous scheme proposed by Iwasaki et al. (1989). The new version represents low-level blocked-flow drag produced by lateral flow that goes around subgrid-scale orography. The flow over such orography generates gravity waves, which vertically transport and deposit momentum where waves break. On top of this, the turbulent orographic form drag (TOFD) scheme (Beljaars et al. 2004) was also introduced. The introduction of the new set of schemes reduced forecast errors around troughs and ridges in the lower and middle troposphere over Northern Eurasia.

2.2 Land surface processes

The upgrade of land surface processes includes changes in the fraction of snow coverage (Roesch et al. 2001) and diagnostic schemes for soil thermal conductivity (Ek et al. 2003) to address various surface biases. The former appropriately reduced the diagnosed fraction of snow coverage, and the latter resulted in a relative suppression of excessive diurnal amplitude of soil heat flux. These updates resulted in a reduction of the excessive sensible heat flux seen in the previous land surface processes.

2.3 Surface albedo and stratocumulus on sea ice

To correct lower surface albedo biases in the Arctic, a new sea ice albedo scheme incorporating the effects of snow (Hunke and Lipscomb 2006) was introduced with a climatological snow cover fraction.

The diagnostic stratocumulus generation scheme (Kawai and Inoue 2006) was also disabled for sea ice areas to correct for excess cloud cover.

3. **Verification results**

Twin experiments were conducted to compare forecast scores of the previous (CNTL) and updated models (TEST) for July to September 2018 and December to February 2017/2018. Figure 1 shows root-mean-square error (RMSE) differences for 500-hPa geopotential height forecasts up to 5.5 days ahead verified against radiosonde observations averaged over the Northern Hemisphere (20 – 90°N) for both periods. Figure 2 shows mean errors (MEs) of 500-

hPa geopotential height at T+3d for CNTL and TEST. The upgraded system improved RMSE and ME values over forecasts of several days than previous GSM versions.

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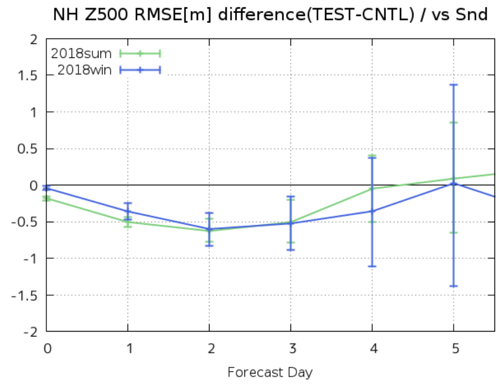

Figure 1. Root-mean-square error differences (TEST – CNTL) of 500-hPa geopotential height [m] against radiosonde (Snd) in the Northern Hemisphere extra-tropics (20 – 90°N) in the summer and winter experiments. The horizontal axis shows the forecast lead time [days], and the green and blue lines show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

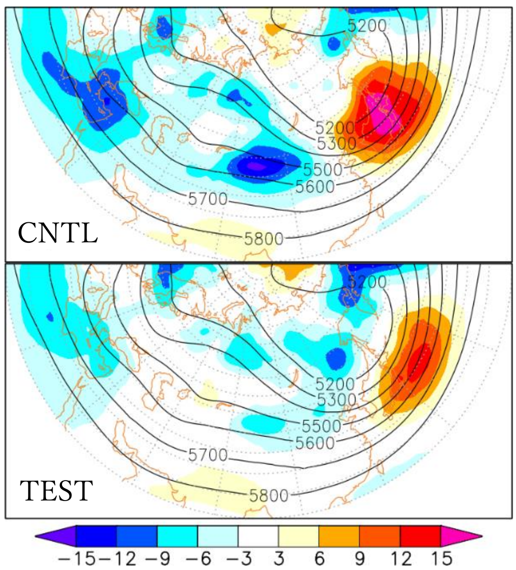

Figure 2. Mean errors of 500-hPa geopotential height [m] at T+3d in the 0 – 180°E, 20 – 90°N region for the winter experiment (shading). Contours represent time-averaged analysis.