Extending Forecast Range and Introducing an Ocean Mixed Layer Model in JMA's Mesoscale NWP System

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1. Introduction

JMA operates a meso-scale model (MSM) to provide information for disaster prevention and aviation safety (JMA 2019). The model's physics parameterization was upgraded and the number of vertical layers was increased in March 2022, and an extension of the forecast range is planned for June 2022. This report provides summarizes the upgrade (MSM2203) from the previous system (MSM2003) with focus on sea surface processes for improved typhoon intensity forecasting.

2. Model updates

The number of vertical levels in MSM2203 is increased from 76 to 96 and the topmost level from 21.8 to 37.5 km to incorporate satellite data sensitive to temperature in the upper troposphere in meso-scale analysis.

The MSM forecast range is extended from 51 to 78 hours at 00 and 12 UTC to provide prefectural-scale precipitation information up to three days ahead, especially for potentially disastrous typhoons and heavy rainfall.

In MSM2003, mixing-length scale formulation for the planetary boundary layer scheme was modified based on Olson et al. (2019) to reduce excessive turbulent transport caused by turbulent kinetic energy in the free atmosphere. For the land surface scheme, evapotranspiration processes were also revised to represent a better diurnal cycle of surface temperature and moisture. A one-dimensional ocean mixed layer (OML) model based on Price et al. (1986) was additionally introduced to alleviate typhoon over-intensification, which relates to the use of a fixed SST as a boundary condition of the MSM so that the sea surface cooling induced by typhoons is not represented. The OML model represents ocean vertical mixing relating to static stability, mixed layer stability, shear flow stability associated with air-sea heat flux and wind stress. The vertical grid spacing of the OML is 5 m and the bottom depth is set as 100 m to save computational time. The initial sea surface temperature (SST) is determined from high-resolution merged satellite and in-situ SST data provided by JMA. The initial conditions for water temperature and salinity are obtained from World Ocean Atlas 2018 monthly mean climatology data (Locarnini et al. 2018, Zweng et al. 2018). Nudging is implemented in the OML model to avoid SST drift from a realistic state. The e-folding time for nudging is a function of distance from land and seafloor depth with a maximum of one day over open ocean.

3. Case study: Typhoon Krosa (2019)

Figure 1 exemplifies the effects of the OML model on SSTs and mean sea-level pressure for Typhoon Krosa (2019) with a lead time of 72 hours for MSM2003 and MSM2203. The latter shows sea surface cooling along the typhoon track, which was roughly consistent with SST analysis (not shown). The central pressure values were 949.3 hPa in MSM2003, 965.4 hPa in MSM2203 and 970 hPa in best-track analysis. MSM2203 significantly alleviated typhoon over-intensification, mainly due to typhoon-induced sea-surface cooling through OML and reduced latent heat flux due to sea salinity effect.

4. Verification

Figure 2 shows a statistical evaluation of mean errors and root-mean-square errors (RMSEs) of central sea-level pressure for MSM2003 and MSM2203 with regards to best track from 1 July to 15 September 2020 (summer). The negative bias and RMSE are significantly reduced in MSM2203 as compared with MSM2003, and there is little difference in typhoon track forecast errors between the two (not shown). The bias score is lower for the whole forecast range in MSM2203, and the equitable threat score (ETS) is also slightly higher for the forecast range between 30 to 78 h in MSM2203.

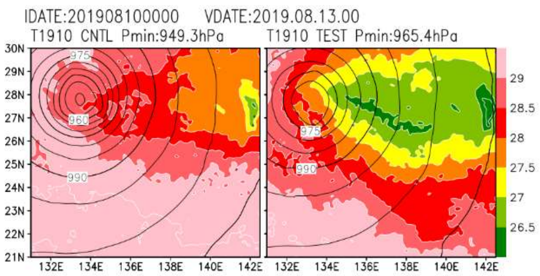

Figure 1: Horizontal pattern of mean sea-level pressure (contours: 5-hPa intervals) and SST (shading: degrees Celsius) for Typhoon Krosa (2019) with MSM2003 (left) and MSM2203 (right). Forecasts initialized at 00 UTC on 10 October 2019.

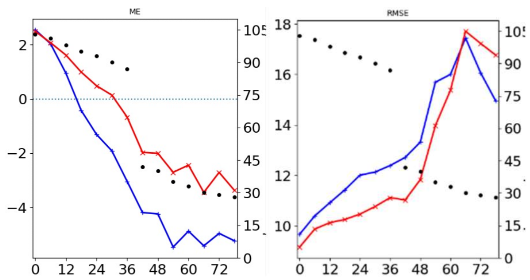

Figure 2: Time-series of mean errors (left) and RMSE (right) for central pressure (hPa) in summer with MSM2003 (blue) and MSM2203 (red). Dots represent the number of samples at each forecast lead time (right axis).

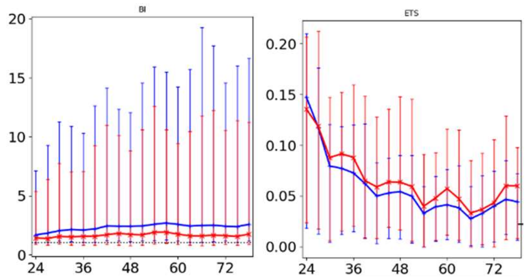

Figure 3: Bias score (left) and ETS (right) for 24-h cumulative precipitation forecasts at a 200 mm threshold for summer. Verification grid size: 20 km; blue: MSM2003; red: MSM2203.

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