Implementation of the SPPT scheme in JMA's Mesoscale Ensemble Prediction System

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1. **Introduction**

JMA's Mesoscale Ensemble Prediction System (MEPS; Ono et al. 2021) has provided uncertainty information for the Agency's Meso-Scale Model since June 2019. In the system, perturbed members are produced using initial and lateral boundary perturbations, for which the production method was upgraded in September 2020 (Kakehata et al. 2021). Model uncertainties are not considered in the system.

Against such a background, the Stochastically Perturbed Parametrization Tendencies scheme (SPPT; Buizza et al. 1999, Palmer et al. 2009) was introduced into MEPS in March 2023 to account for model uncertainties. This report outlines the implementation and related effects.

2. **SPPT scheme**

SPPT is intended to represent the uncertainty of physical processes based on perturbation of related tendencies. The perturbed tendency of the physical process, X_p, is

$$\mathrm{X_p} = (1 + r_X)X_c,$$

where r_X is a Gaussian random number correlated in space-time and X_c is the physical process tendency. The random number amplitude was set as 0.5, the correlation time as 6 hours, and the spatial correlation length as 500 km, and these parameters were tuned in preliminary experiments. For computational stability, only convection and radiation scheme tendencies were perturbed.

3. **Initial perturbation adjustment**

With the introduction of SPPT, the amplitude of the initial perturbation was readjusted. The previous MEPS ensemble spread (Figure 1, left) tended to be over-dispersive in relation to the ensemble mean RMSE (Figure 1, right), especially in the JPN area (25 – 45°N, 125 – 145°E). To optimize the spread-skill relationship, the amplitude of the initial perturbation was set to 95% of the related value in the previous MEPS.

4. **Verification results**

To verify the effects of these changes, comparative experiments were conducted using the previous (CNTL) and upgraded (TEST) versions for July 1 – 31 2020 and January 20 – February 25 2020.

The spatial distribution of the TEST spread decreased in the JPN area and increased near the lateral boundary (Figure 2, left) due to the dominant influence of initial perturbation in the JPN area, while the effect of SPPT extends to the entire forecast area. TEST results showed mitigation of the undesirable characteristics of over-dispersiveness in CNTL spread for the JPN area and under-dispersiveness near the lateral boundary as compared to the RMSE of the ensemble mean (Figure 2, right). The same results were obtained in the winter experiment (not shown). The time series of the spread-skill relationship (Figure 3) shows that over-dispersion up to the 15-hour forecast for the JPN area (left) and under-dispersion after the 12-hour forecast for the entire forecast area (right) were both reduced.

For precipitation probability forecasts, the Brier-Skill Score (BSS) shows improvement for the summer experiment at each threshold value (Figure 4, left). In the winter experiment, BSS is nearly neutral for thresholds at which it is more skillful than the climatological forecast (Figure 4, right). TEST precipitation distributions for each member were often not significantly different from those of CNTL (not shown). However, in some cases, TEST exhibited a higher probability of heavy rain where the convection scheme was activated (not shown). This may contribute to the improved probability seen in precipitation forecasts.

5. **Summary**

The results of the research showed that introduction of SPPT into MEPS and adjustment of the amplitude of initial perturbations improved ensemble spread and precipitation probability forecasts. JMA's operational system was updated accordingly in March 2023.

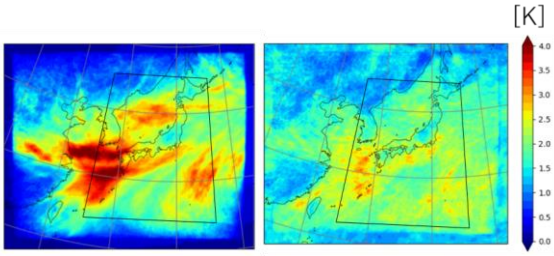

Figure 1. One-month (July 2020) average of ensemble spread (left) and RMSE of ensemble mean (right) for 850 hPa equivalent potential temperature (K) at T+9 for the previous MEPS (CNTL). Black frame: JPN area.

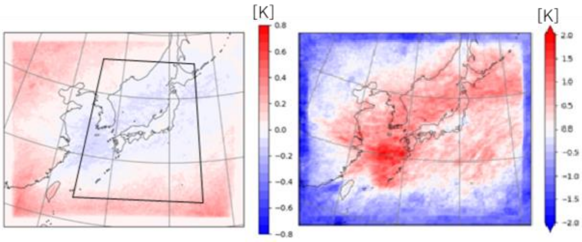

Figure 2. Spread difference between CNTL and TEST (left); difference between CNTLspread and RMSE of the ensemble mean of CNTL (right), both for 850 hPa equivalent potential temperature (K) at T+9 for the summer experiment. Right: differences between left and right in Figure 1.

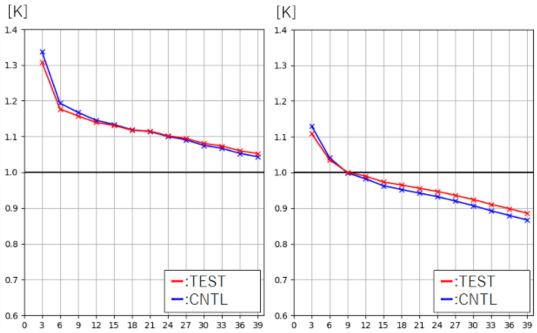

Figure 3. Time series (39 hours) of spread-skill relationship in the JPN area (left) and the entire forecast area (right) of 850 hPa equivalent potential temperature (K) for the summer experiment. Values are defined by the ratio of spread to RMSE, and are considered over-dispersive above 1 and under-dispersive below 1. The horizontal axis is the forecast range (hours).

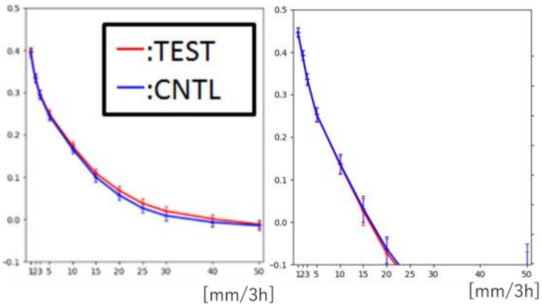

Figure 4. BSS of 3-hour cumulative precipitation probabilistic forecasting in CNTL (blue) and TEST (red) for the summer (left) and winter (right) experiments. Horizontal axis: threshold.

References

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