Consistent Initial and Lateral Boundary Perturbations in Mesoscale Ensemble Prediction System at JMA

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1. Motivation

The Japan Meteorological Agency (JMA) started pre-operation of the regional ensemble prediction system (Mesoscale Ensemble Prediction System: MEPS) in March 2015 with the aim of providing uncertainty information for operational deterministic regional model (Meso-Scale Model: MSM). MEPS is based on the JMA non-hydrostatic model (JMA-NHM; Saito. et al. 2006) with 5 km grid spacing, 48 vertical layers and the ensemble size of 11 including a control run (CTL)[1].

The initial perturbations (IPs) of MEPS members are generated by blending singular vectors (SVs) at different scales; global SV (GSV) based on JMA global model (Global Spectral Model: GSM), and mesoscale SV (MSV) based on JMA-NHM (Ono et al. 2011[2]). However, the lateral boundary perturbations (LBPs) are derived from JMA global ensemble prediction system (Global EPS: GEPS). This combination of individually generated IPs and LBPs brings inconsistencies between them, including artificial anomalies from the CTL forecast in perturbed runs. Figure 1 shows an example of such inconsistencies. One of perturbed runs (member 09: M09) forecasts heavy precipitation over China (see dashed black circle in Figure 1) at T+12. This precipitation is heavier than that from CTL, corresponding to the positive perturbation of equivalent potential temperature (EPT) at 925 hPa originating from IP. At T+18, heavy rain is still forecast with CTL near the same region. However, the precipitation forecast with M09 is weaker because the negative perturbation of EPT at 925 hPa from the western lateral boundary is dominant in this region. As this example shows, inconsistencies between IP and LBP can change the tendency of perturbed forecasts artificially. It can be an obstacle to the use of ensemble members as different scenarios from CTL.

To maintain consistency between IP and LBP, a new LBP generation method has been developed. This approach is based on the integration of GSV (a large-scale component of IP), using the tangent linear model (TLM).

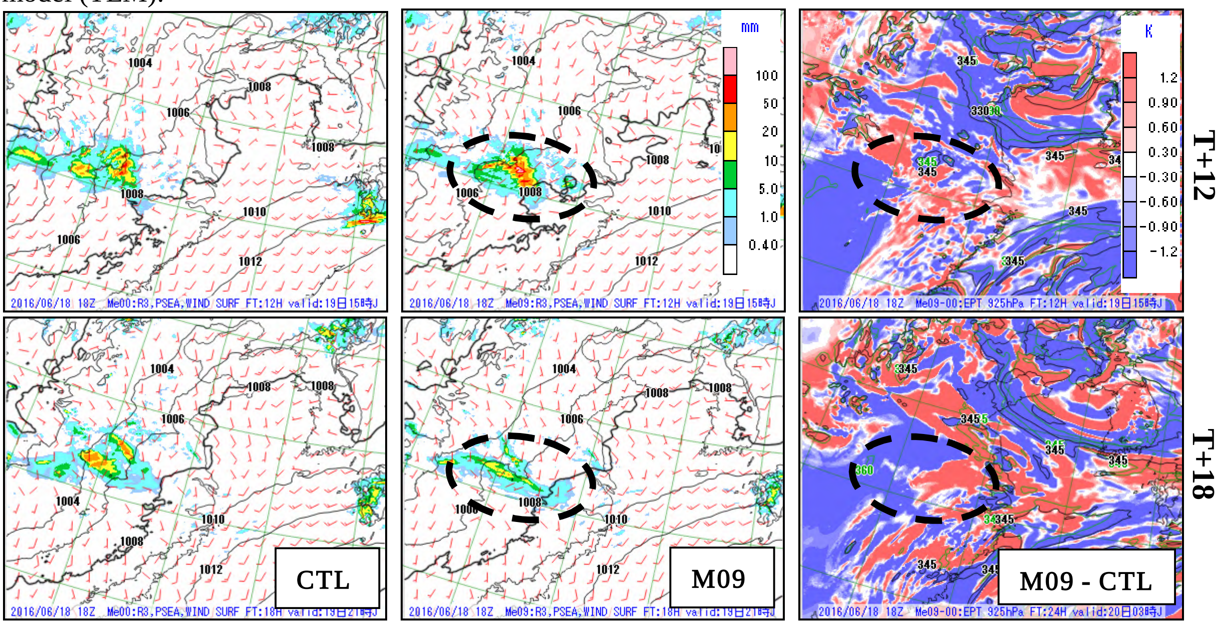

Figure1: Sea level pressure, surface wind and three hour accumulated rainfall foreacast with CTL (left) and M09 (center). M09 perturbation of EPT at 925 hPa is also shown (right). The initial time is 18 UTC on 18 June 2016.

2. New Configurations of GSV in Consideration of LBP

The use of GSV for both IP and LBP requires coverage of the whole forecast domain over the 39-hour forecast period by GSV. Accordingly, the GSV target region was extended to exceed the forecast domain

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[1] A new non-hydrostatic model ASUCA (Aranami et al. 2015) with 76 vertical layers has replaced JMA-NHM as the MSM forecasting model since Feb. 2017. Therefore, JMA plans to also switch the forecasting model of MEPS to ASUCA soon.

[2] Water vapor perturbation from GSV is not used in the current system.

(Figure 2 (a)). Its optimization interval was also extended from 24 to 39 hours in line with the forecast range. For LBP generation, all GSVs are integrated over a period of 39 hours using the TLM, and combined linearly with the coefficients used in IP generation for each forecast time. The LBP amplitude is adjusted using the climatological root mean square error (RMSE) of the lateral boundary value (same as GSM forecast) against the MSM initial value. Figure 2 (b) illustrates the relationship between SVs and perturbations.

Figure 3 highlights the consistency between IP and LBP structures at T+3. The LBP from GEPS induces discontinuity in the perturbation pattern shaped like a ‘frame’ near the lateral boundary. Meanwhile, the GSV-based LBP exhibits clear continuity with IP. To determine the impact of enhanced consistency, deterministic forecast skill scores were calculated for all ensemble members, and compared with those of CTL and each member using LBP from GEPS. However, no clear advantage from the new system was found, suggesting that consistency does not improve the statistical forecast skill score of each member.

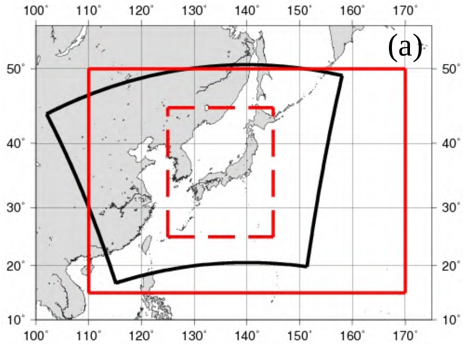
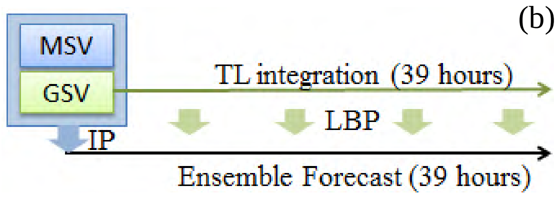


Figure 2: (a) Forecast domain (black line), and target region (red lines; dashed: old region; solid: new region). (b) Relationship between SVs and perturbations.



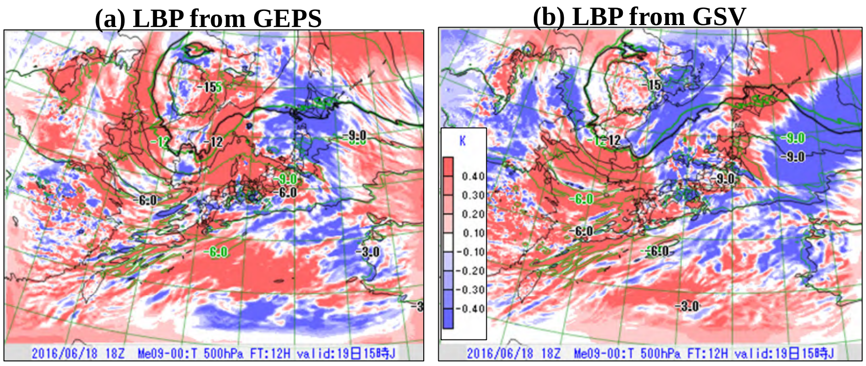


Figure 3: 500-hPa temperature perturbation at T+3 (initial time: 18 UTC on 18June 2016 (a) LBP from GEPS. (b) LBP from GSV.

3. Probabilistic Forecast Skill Scores for the New GSV System

The changes in GSV influence IP, and the performance of MEPS as an ensemble prediction system. The spread-skill relationship and Brier skill score (BSS) for precipitation forecasting are shown in Figure 4. The excessive spread of LBP with the old GEPS system is suppressed in LBP with the new GSV system. BSS is also improved by suppressing excessive dispersion in rain forecasts. This LBP method was incorporated into the pre-operational system in January 2017.

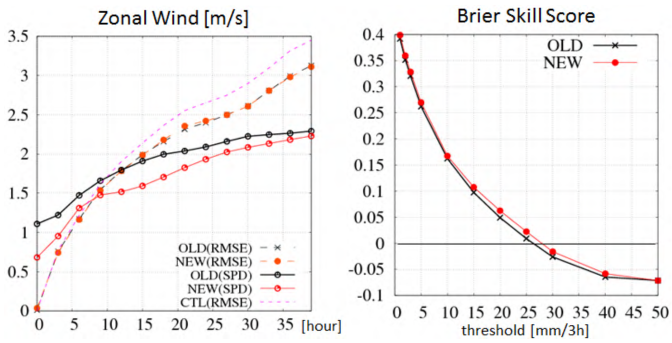


Figure 4: Ensemble spread (SPD) and RMSE against MSM initial value of zonal wind at 500 hPa (left) and BSS of three-hour accumulated rainfall against rain gauge data (right). The black line shows the LBP with the old GEPS system, and the red line shows that with the new GSV system. The pink line shows the RMSE of CTL. The verification period is 17 - 26 June 2016 with every 18 UTC initial forecast (10 cases).

References

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Saito et al. (2006): The operational JMA Nonhydrostatic Mesoscale Model. *Mon. Wea. Rev*. **134**, 1266-1298.