Preliminary Results of Mesoscale Ensemble Prediction with Stochastic Parameterization

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Since 2007, the Japan Meteorological Agency (JMA) has been developing a mesoscale ensemble prediction system (MEPS) using singular vector (SV) methods with the aim of providing probabilistic information for operational mesoscale forecasting (MSM). Recently, the MEPS was upgraded to have an ensemble size of 41 and a horizontal grid spacing of 10 km, assuming a configuration closer to that of the realistic pre-operation system. In addition, some case studies were conducted using this system. These results showed a deficiency of the increasing rate of ensemble spread compared to that of RMSE of the ensemble mean forecast, especially in the latter half of the forecast period in spite of the enhanced ensemble size (Figure 1). One of the reasons is that the uncertainty of the forecast model was not considered in the MEPS. Therefore, development of the stochastic parameterizations for the MEPS has been under way since 2011 to mitigate this deficiency.

In this study, two methods of stochastic parameterization were tested. One is a “random parameter to the Kain-Fritsch (KF) scheme” (RPKF) method and another is a “stochastically perturbed parameterization tendency” (SPPT) method. With RPKF, the sensitivity of the parameters used in the convection scheme (such as trigger function of KF initiation, radius of convective cloud, entrainment coefficient and removing ratio of CAPE) were investigated. The results revealed that only the trigger function showed significant sensitivity to the ensemble spread, and that the effects of the other parameters were small. Accordingly, we only investigate the sensitivity of trigger function in this paper. The random numbers were generated by the normal distribution $N(0, \sigma)$ with a standard deviation σ, and followed the first order Markov process. Spatial correlation was not considered. With SPPT, tendencies from the convection (KF scheme), diffusion and radiation processes were perturbed. Random numbers were also generated by $N(0, \sigma)$ with autocorrelation. Spatial correlation was considered by generating random numbers in the low resolution grid space. The details of the settings are shown in Table 1.

In order to examine the effects of the stochastic perturbations, a case study of ensemble forecasts was investigated in this paper. The MEPS with stochastic parameterizations had a horizontal grid spacing of 10 km and an ensemble size of 11 including control forecast. The initial and lateral boundary values were not perturbed to confirm only the effects of the stochastic parameterizations.

Figure 2 shows the ensemble spread of zonal wind velocity (U) and temperature (T) at 850, 500 hPa and 3 hourly accumulated precipitation (3hRA). The ensemble spread increases until around T+24 except for T at 850 hPa, showing a particular rapid increase in the first three hours. The amplitude of the ensemble spread for SPPT is larger than that for RPKF except with 3hRA, and the ensemble spread of 3hRA for RPKF is larger than that for SPPT in the first half of the forecast period. Figure 3 shows the horizontal distribution of forecasted 3hRA derived from the cloud physics scheme and the KF scheme, and the ensemble spread of each experiment. The spread for RPKF is large in the region where significant amounts of rain are seen from the KF scheme. On the other hand, the ensemble spread for SPPT covers the whole precipitation region. These results reflect that RPKF only perturbs KF precipitation directly via the perturbed trigger function, while SPPT perturbs all precipitation through the KF scheme, radiation and diffusion processes.

Further investigation is needed in regard to the adoption of stochastic perturbation for the MEPS using SV methods with 41 members and a 10-km horizontal resolution. For SPPT, ground variables should be included to perturb the lower atmosphere. In addition, for the random parameter method, other physical processes, such as radiation and diffusion, should also be perturbed, and spatial correlation pattern should be used like SPPT.

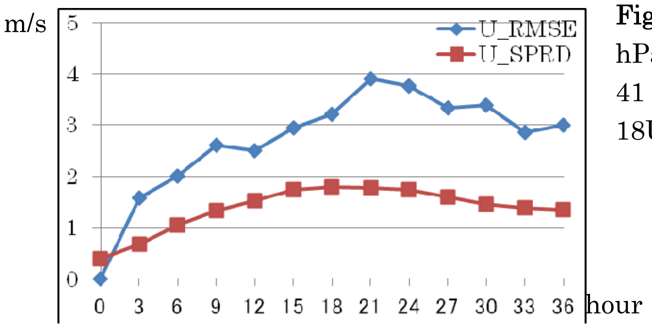


Fig1. Ensemble spread and RMSE of U at 850 hPa from the MEPS with a 10-km grid spacing, 41 members and perturbed by SVs. (initial time: 18UTC on June 10, 2010)

Table1. Details of the stochastic parameterizations.

	RPKF	SPPT
Target	KF trigger function	Tendency of radiation, diffusion and convection
Spatial cor.	None	dx = 500km
Autocorrelation	Markov process, cor.=0.97	e-folding time: 12 hour
σ	1 K	0.2
Limit of perturbation	3 K	0.8

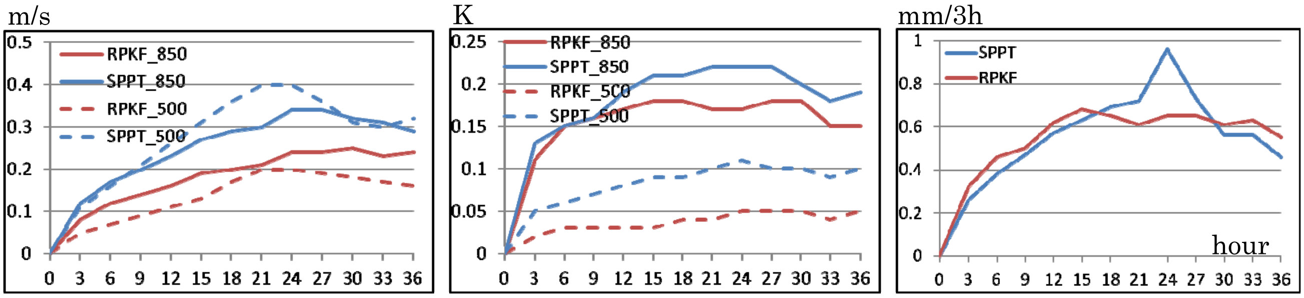
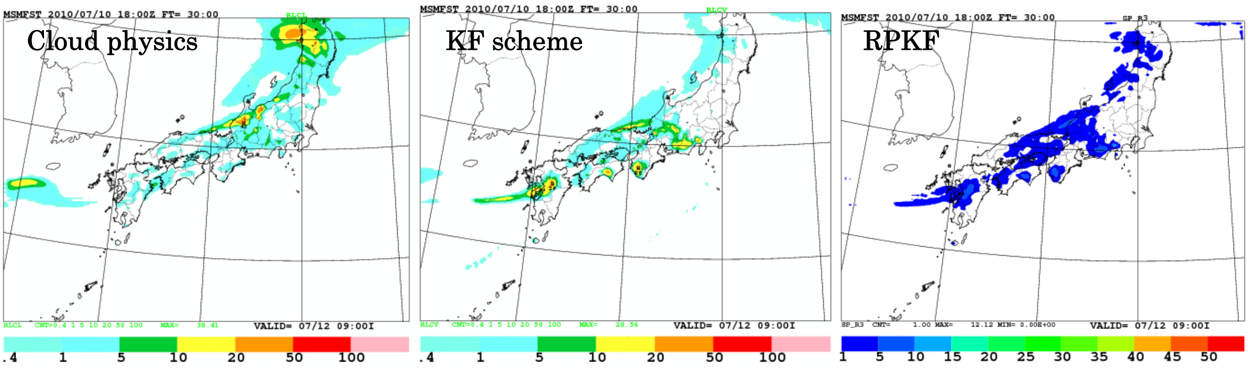


Fig2. Spread of U, T (850, 500) and three-hour accumulated rainfall. (initial time: 18 UTC on June 10, 2010)



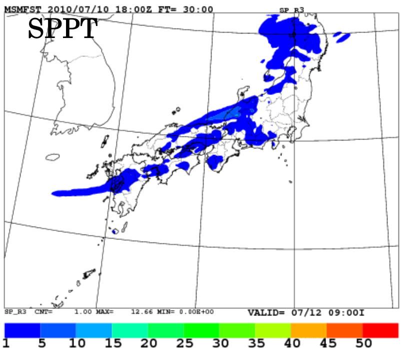


Fig3. Contribution to precipitation forecast from the cloud physics and the KF scheme, and ensemble spread of 3hRA derived from RPKF and SPPT. Valid at T+30. (initial: 18 UTC, June 10, 2010)