Developments of a local ensemble transform Kalman filter with JMA global model

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Miyoshi and Sato (2007) reported their successful implementation of the local ensemble transform Kalman filter (LETKF, Hunt et al. 2007) with the JMA global model (GSM). They also succeeded in assimilating satellite radiances, which indicated positive impact. After the report by Miyoshi and Sato (2007), the following major upgrades have been made to the GSM-LETKF system:

1) Removing local patches as in Miyoshi et al. (2007)
2) Applying an additive covariance inflation method as in Whitaker et al. (2007), but using JRA-25 (Onogi et al. 2007) instead of NCEP/NCAR reanalysis (Kalnay et al. 1996)
3) Applying an efficient parallel algorithm
4) Applying an adaptive bias correction for satellite radiances to simulate the operational variational bias correction within 4D-Var (Sato 2007)

The details are described in a separate paper, which is in preparation at the moment. This short report presents recent results of the comparison between LETKF and the JMA operational 4D-Var (Kadowaki 2005) and ensemble prediction system (EPS).

LETKF performed well in typhoon track forecast. The typhoon Rananim case in 2004 showed an excellent performance of LETKF (Fig. 1). LETKF captured the westward movement successfully, although most operational systems at that time predicted the northward movement, leading to false caution to Japan. Even with JMA's latest operational EPS with singular vectors centered at 4D-Var analysis (Sakai et al. 2008), just a few ensemble members out of 51 captured the westward movement. Not just in this case but on average over many cases, we obtained improvements of the track forecast.

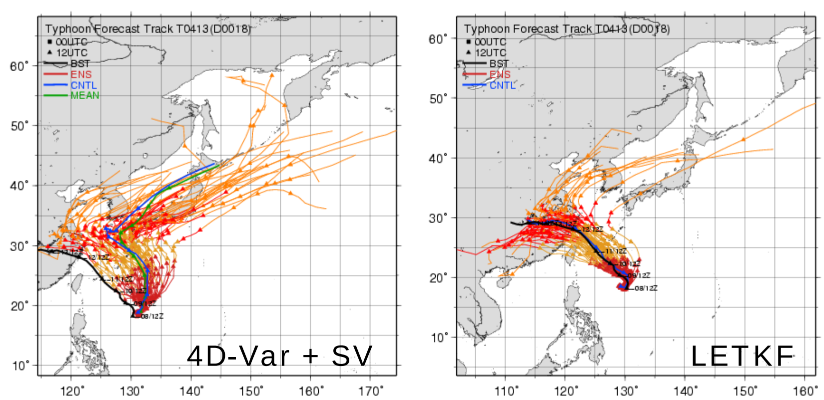

Fig. 1. 51-member typhoon track ensemble forecast in the typhoon Rananim case initialized at 12 UTC 8 August 2004. Left and right panels indicate operational singular-vector ensemble prediction system centered at 4D-Var analysis and LETKF, respectively. The thick black line indicates the best track. The red/orange lines indicate ensemble members. The blue and green lines show control forecast and ensemble mean, respectively.

To make an overall comparison between LETKF and 4D-Var, forecast anomaly correlations are compared; Figure 2 shows the relative improvements of LETKF over 4D-Var. Without the adaptive bias correction for satellite radiances, high temperature bias existed in the LETKF analysis, which leads to large degradation of forecasts. This problem was found to be caused by the fact that RTTOV-8 has been applied to LETKF rather than RTTOV-7 which is used in the operational 4D-Var and quality control systems. It turned out that the surface emissivity model FASTEM-2 of RTTOV-7 contained some known bugs causing spurious positive bias in the calculated surface emissivity. As a result, radiances are computed to be spuriously large for satellite sensors sensitive to the surface emissivity such as AMSU-A ch.4, which are also sensitive to the lower tropospheric temperature. Therefore, the observations are too

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low compared to the computed radiances; the variational bias correction scheme in 4D-Var adds positive value to the observation to remove the biased differences. Without the adaptive bias correction within LETKF, the same bias correction has been applied. However in LETKF, RTTOV-8 does not contain the bugs in FASTEM-2. Therefore, the observations after the “wrong” bias correction are too high, which results in the high temperature bias in the lower troposphere.

After applying the adaptive bias correction, the estimated bias was drifted rapidly away from the optimal value for 4D-Var; it happened only to the satellite channels sensitive to the surface emissivity. Then, we obtained much improvement as shown in Fig. 2 (b). However, the positive bias in the analysis was not completely removed. We still need to improve the SH and extratropical surface pressure forecasts.

LETKF indicated advantages in probabilistic forecasts compared to the operational EPS. LETKF showed better brier skill scores than the singular-vector or bred-vector EPS centered at 4D-Var analysis in shorter leads up to 72 hours (Fig. 3). This tendency that LETKF probabilistic forecast is advantageous in shorter leads is true for other verification measures including ROC area.

Several major upgrades have been made to the LETKF system and resulted in steady improvements. Now it is said that overall LETKF performs comparable to 4D-Var. LETKF outperforms 4D-Var in the Tropics, and slightly outperforms in the NH in general. However, further improvements are desired for extratropical surface pressure forecasts and general performance in the SH. We will continue the development to improve the LETKF performance, so that it becomes a possible operational choice in near future.

(a)

	PseaSurf	T850	Z500	Wspd850	Wspd250
Global	−9.00	−10.45	−10.64	2.38	0.13
N. Hem.	−4.47	−2.95	−1.72	3.74	0.66
Tropics	0.48	−11.66	−17.60	11.69	9.88
S. Hem.	−10.90	−14.51	−13.00	−1.52	−3.81

(b)

	PseaSurf	T850	Z500	Wspd850	Wspd250
Global	−5.21	−2.33	−4.21	3.94	1.73
N. Hem.	−3.89	2.06	1.32	4.30	1.30
Tropics	7.05	6.49	7.44	13.58	9.57
S. Hem.	−6.35	−6.47	−6.20	0.39	−1.14

Fig. 2. Relative improvements (%) of 1- to 9-day forecast anomaly correlations of LETKF over 4D-Var, averaged over 31 days in August, 2004. Positive values indicate that LETKF outperforms 4D-Var. (a) and (b) show the cases without and with the adaptive bias correction for satellite radiances, respectively.

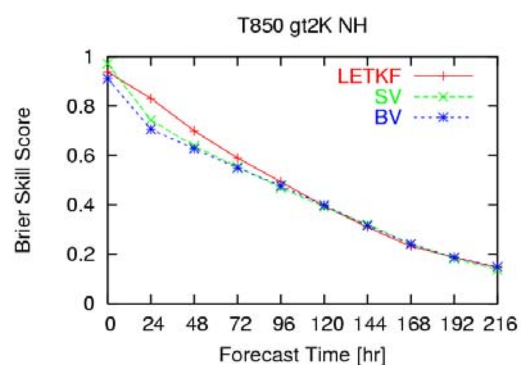

Fig. 3. Brier skill scores of LETKF (red), SV (green), and BV (blue) for the event that temperature at 850 hPa is greater than 2 K than climatology.

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