Data assimilation experiments of Myanmar cyclone Nargis based on NHM-LETKF

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Nargis was a severe storm which formed in Bay of Bengal in April 2008 and made landfall in the Irrawaddy delta, resulting in massive damage and loss of life in Myanmar. After forming, Nargis followed the northwest direction until April 30th 2008 and turned to the east direction, intensified rapidly and made landfall with the estimated intensity of at least 165 km/h. All global forecasts missed this deflecting motion and rapid intensification. In this study, a data assimilation experiment based on the Local Ensemble Transform Kalman Filter (LETKF) and NHM model was performed to investigate this problem.

The NHM-LETKF system originally developed in JMA was adopted and modified in this study. The JMA nonhydrostatic model NHM (Saito et al., 2007) was used as the driving model in the system. The assimilation part followed the 4D-LETKF scheme as described by Hunt et al. (2007). This LETKF program supports adaptive inflation, adaptive vertical and horizontal localisation, and outer loop as options. Localisation is specified by two parameters: vertical and horizontal localisation scales, which when multiplied by $2\sqrt{10/3}$ yield the radii of vertical and horizontal scales. R-localisation was also implemented in the LETKF program. The control variable are u, v, t, qv, and ps. To apply the system to Nargis case, we introduced the Mercator projection into the system in addition to the default Lambert projection.

A domain with the resolution of 20km covering Bay of Bengal was chosen for the experiments. It has 201x161 grid points and 40 vertical levels. The domain and observations were used in the experiments are illustrated in Fig. 1. Forecasts from JMA's global deterministic model of the resolution of 0.5^0 were used as the boundary conditions. The boundary perturbations were interpolated from JMA's 1-week ensemble prediction system. The initial seeds for all members were also given by initial perturbations this system. SST perturbations were introduced by using SST analyses from 7 centers: FNMOC, JMA, JPL, NCDC, NCEP, REMSS, and UKMO.

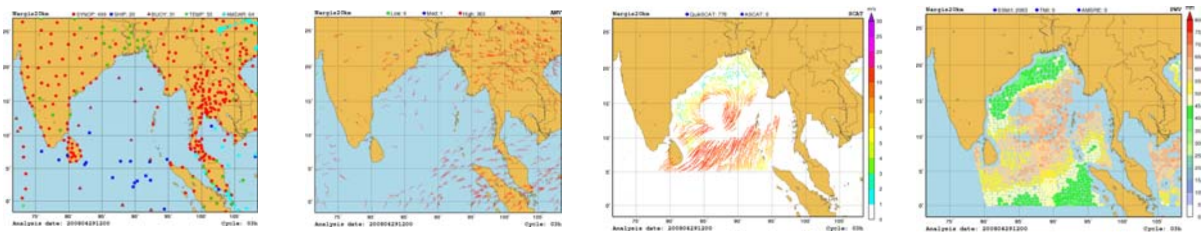

Fig. 1. Used observations at 18Z-20080429: conventional data, AMVs, sea winds, and retrieved precipitation water.

For all experiments here, we did not apply the outer loop or adaptive options. The configuration parameters were chosen as following: 50 ensemble members, the assimilation cycle of 3 hours, the horizontal localization scale of 5 (about 400 km radius). With two free remaining parameters: the multiplicative inflation factor (MIF) and the vertical localization scale (VLS), we performed sensitivity tests to find the appropriate values in Nargis case. In each experiment, the system was run from 12Z-28/04/2008 to 12Z-30/04/2004. Then the resulting analysis was used as the initial condition for 60-hour NHM forecast. To see the impact from NHM-LETKF, the forecast downscaling from JMA global model was also carried out.

First of all, the system was checked with MIF of 1.21 (10%) and VLS of 12. Fig. 2 shows the performance of the system with these parameters. This figure says that the system worked properly when analysis root mean square errors (RMSE) and spreads were less than those of forecasts, resulting from assimilation. However, it also points out that the system is under-dispersive with a large gap between RMSEs and spreads.

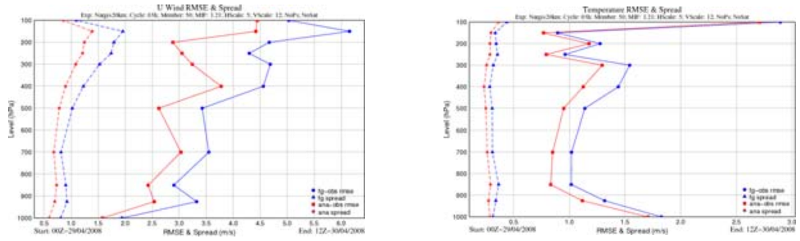

Fig. 2. Averaged RMSEs and spreads of forecasts and analyses at radiosonde stations with MIF of 10% and VLS of 12.

This under-dispersive property can be attributed to the sampling errors due to a limited number of ensemble member and the model errors, which was parameterized insufficient in the system. To alleviate this problem, MIFs should be increased. The impact of MIF increasing is illustrated in Fig. 3. It is clearly that the spreads increase while RMSEs slightly decrease with increasing MIF. In term of both Nargis track and intensity forecasts, MIF of 1.96 (40%) yields the best result.

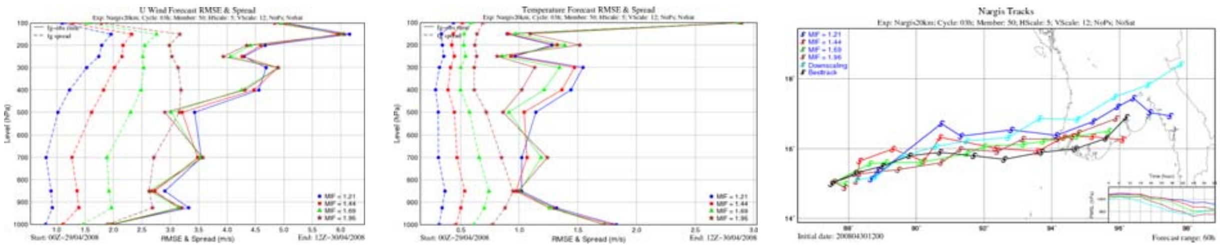

Fig. 3. Averaged RMSEs and spreads of u-wind (left) and temperature (center) forecasts at radiosonde stations, and Nargis track and intensity forecasts with different MIFs.

This under-dispersive property can also be cured by decreasing VLS. The sensitivity test of VLS was performed the same as the previous experiment with MIF (Fig. 4). As expected, spreads increased with decreasing VLS, however the impact on RMSEs is neutral. The interesting thing is that VLS increasing gives the better forecasted track and intensity, suggesting that in case of tropical cyclone, vertical localization scales should be large in LETKF.

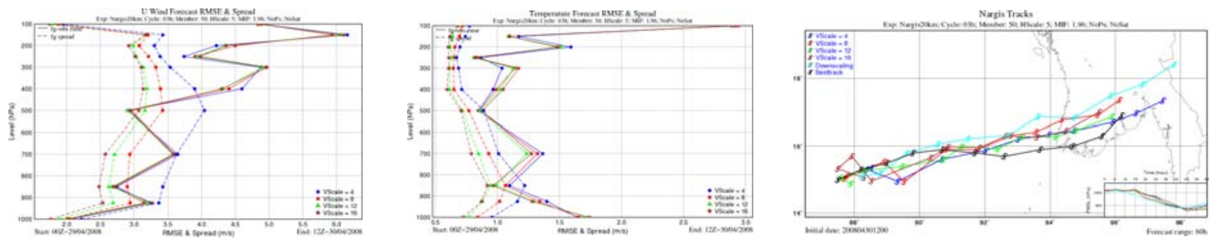

Fig. 4. Averaged RMSEs and spreads of u-wind (left) and temperature (center) forecasts at radiosonde stations, and Nargis track and intensity forecasts with different VLSs.

Reference

Hunt, B. R., E. J. Kostelich and I. Szunyogh, 2007: Efficient Data Assimilation for Spatiotemporal Chaos: A Local Ensemble Transform Kalman Filter. *Physica D*, **230**, 112-126.

Saito, K., Ishida J., Aranami K., Hara T., Segawa T., Narita M., and Honda Y., 2007: Nonhydrostatic atmospheric models and operational development at JMA. *J. Meteor. Soc. Japan.*, **85B**, 271–304.