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

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Introduction

Nargis was a severe tropical cyclone (TC) that 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 then turned to the east direction, intensified rapidly and made landfall with the estimated intensity of at least 165 km/h. All global models forecasted Nargis' landfall time early and underestimated its intensity. This entailed some studies (Kuroda et al., 2010; Kunii et al., 2010) using high-resolution limited-area models to predict Nargis's track and intensity. The point here is how to produce the best initial condition for model running. In this study, some data assimilation experiments based on the Local Ensemble Transform Kalman Filter (LETKF) and NHM model was performed to investigate this problem.

NHM-LETKF

The NHM-LETKF system originally developed in JMA was adopted and modified in this study. The JMA non-hydrostatic model NHM (Saito et al., 2007) was used as the driving model. 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, R-localisation, and outer loop as options. Localisation is specified by two parameters: vertical and horizontal localisation scales, which yield the radii of vertical and horizontal scales when multiplied by $2\sqrt{(10/3)}$. The control variables are u, v, t, qv, and ps.

For the purpose of TC forecast, some new features were incorporated into the system. Firstly, the Mercator projection, which was applied in Nargis case, was introduced in addition to the default Lambert projection. Secondly, the Running In Place (RIP) algorithm was implemented to reduce the spin-up time of system when TCs exist in the analysis domain. Random perturbations added to reanalyses were drawn from Gaussian distributions with standard deviations of 1.8 m/s, 0.7 K, 15 % for wind, temperature and relative humidity, respectively. All perturbations were scaled by 0.01. Finally, an assimilation module of TC advisories including locations and minimum mean sea level pressures was added. Since LETKF enable observation operators to be nonlinear, this module realised an observation operator as a program that finds the location and magnitude of the minimum of pmsl field.

Experiments

A domain with the resolution of 20km covering Bay of Bengal was chosen for the experiments (Fig. 1). It has 201x161 grid points and 40 vertical levels. Forecasts from JMA's 0.5° global deterministic model GSM were used as the boundary conditions. The boundary perturbations were interpolated from JMA's 1-week ensemble prediction system. The initial seeds for 50 members were also given by this system. SST perturbations were introduced by using SST analyses from 7 centers: FNMOC, JMA, JPL, NCDC, NCEP, REMSS, and UKMO. The assimilated observations included conventional data (SYNOP, SHIP, BUOY, TEMP, PILOT, AMDAR), satellite-derived winds (AMV), sea winds (QuikSCAT and ASCAT), and retrieved precipitable water.

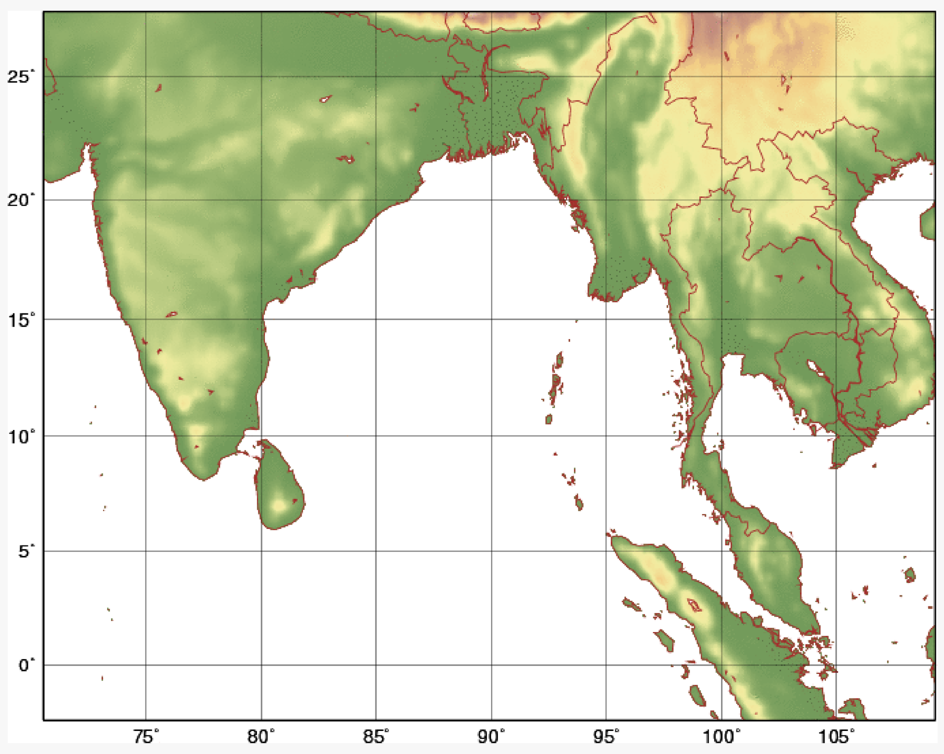

Figure 1. Analysis domain for all NHM-LETKF experiments

We performed 4 experiments: LETKF as is (LETKF), LETKF with RIP (LETKF-RIP), LETKF with the assimilation of TC advisories (TCAssim) and LETKF using both RIP and assimilation of TC advisories (TCAssim-RIP). For each experiment, NHM-LETKF was run from 12Z-28/04/2008 to 12Z-30/04/2008 with a 3-hour assimilation cycle. The resulting analysis was then used as the initial condition for 60-hour NHM deterministic forecast. This extended forecast was carried out at 10 km resolution. Verification was performed using the best track data from RSMC, New Delhi.

After performing sensitivity tests with different free parameters in LETKF, the following parameter set was used in all experiments: horizontal localization scale of 5, and vertical localization scale of 12. All experiments applied the adaptive inflation option with the initial inflation factor of 10%, except for LETKF. When using LETKF as is, the initial inflation factor was increased to 40%.

Results

Fig. 1 shows the track and intensity forecasts initialized with analyses from 4 experiments. To see the impact from NHM-LETKF, the forecast downscaling from GSM was also plotted in addition to the actual track and intensity. It is clear that GSM's track has a northern bias with the landfall time of 12-hours before the actual time. LETKF forecasts the landfall time better when the timing error is reduced to nearly zero, although LETKF's track is still close to GSM's track. When RIP was applied, LETKF-RIP's track now has a southern bias and the TC velocity even is faster than one of GSM's forecast. The fall of LETKF and LETKF-RIP in producing a better forecast track can be attributed to the lack of observations over the Bay of Bengal.

The information from TC advisories are valuable in this case and can be assimilated into the model. When this special kind of observation was assimilated, the initial location of Nargis was improved considerably. The forecasted tracks thus are closer to the best track. Especially, when combined with RIP, TCAssim produced the best result among 4 experiments both in track and intensity forecast.

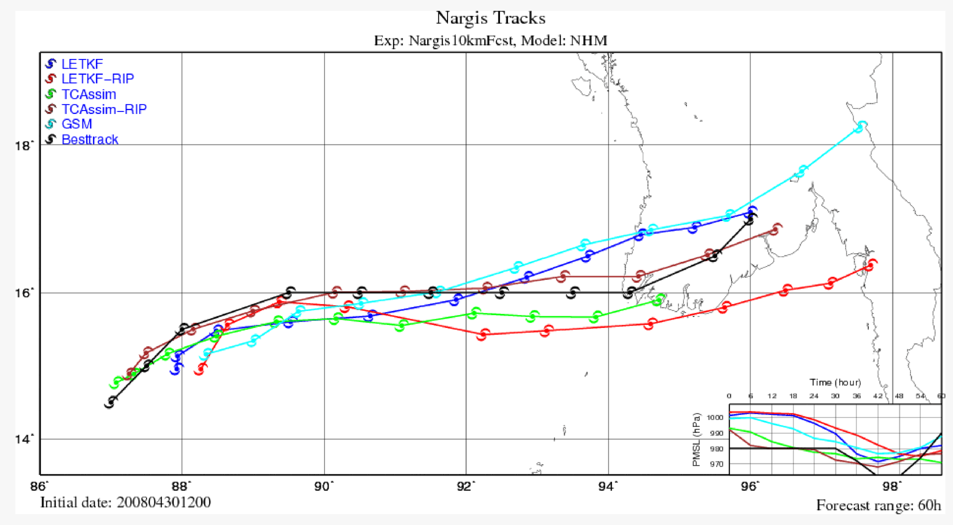

Figure 2. Deterministic forecasts of Nargis track and intensity.

To further examine the extended forecast based on TCAssim-RIP's analysis, we performed an ensemble forecast based on ensemble analyses of TCAssim-RIP at 12Z-30/04/2008. Fig. 2 shows the track and intensity forecasts by 50 members. The shaded area represents the probability that a point will be affected by TC within a radius of 50 km. The ensemble mean forecasted track and intensity are quite close to the ones of control.

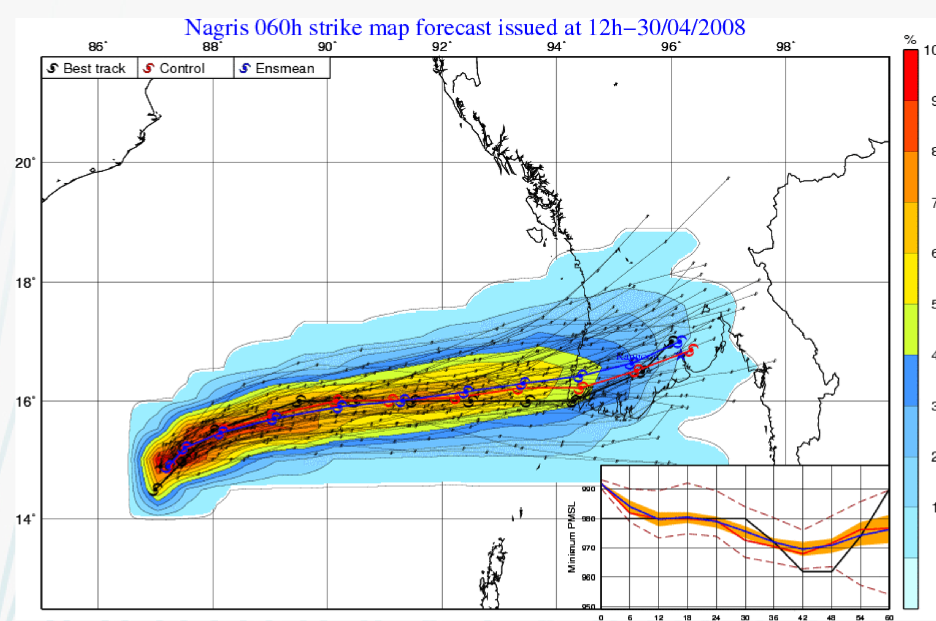

Figure 3. Ensemble forecast of Nargis track and intensity.

Conclusion

A data assimilation experiment based on NHM-LETKF was conducted to investigate the severe storm Nargis track and intensity forecast. The system were improved both in computational and scientific aspect for the purpose of tropical cyclone forecast. The result showed a better forecast both in tracks and intensities in comparison with the one downscaling from JMA global model or the one initialized by LETKF only.

References

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