中央氣象局TWRF模式使用Blending analysis技術對颱風預測能力之效應

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Taiwan’s Central Weather Bureau has implemented a TWRF (Typhoon WRF) modeling system for operational typhoon prediction since 2010. The TWRF model consists of triple nested grids at the resolution of 45-km, 15-km and 5-km, respectively. The two finer grids are centered over Taiwan. The TWRF employs a partial cycling data assimilation scheme based on the WRF 3DVAR system. The partial cycling begins with a cold start at 12 h prior to the analysis time based on the NCEP GFS analysis. This is followed by two subsequent data assimilation cycles at 6-h intervals using the TWRF forecast as the first guess. The TWRF partial cycling analysis suffers two deficiencies. First, with the existence of lateral boundaries, the observations outside the model domain could not influence the analysis within the model domain. Second, the TWRF does not assimilate satellite radiance observations. Consequently, systematic biases (due to model physics errors) can develop over the ocean and influence the typhoon prediction.

With an objective to improve the initial conditions for TWRF, we adopt the blending scheme of Yang (2005) to merge the NCEP GFS global analysis with the TWRF regional analysis with a cut-off length of 1,200 km. For circulations with length greater than 1200 km, the blended analysis is increasingly weighted toward the NCEP global analysis. For circulations with lengths less than 1200 km, the blended analysis is increasingly weighted toward the TWRF partial cycling analysis. At the length of 1,200 km, these two analyses are weighted evenly. The impact of analysis blending is tested on 19 typhoons over the western Pacific in 2013.

The blended analysis is shown to be superior to either the NCEP GFS global analysis or the original TWRF regional analysis. When verified against the independent high-resolution (25 km) ECMWF global analysis, the TWRF regional analysis is shown to possess sizeable systematic errors over the ocean. This systematic error is largely removed in the blended analysis. It is apparent that the TWRF regional analysis suffers significant deficiency on the large-scale, which is well remedied by the introduction of NCEP GFS analysis through blending. Comparison of 279 forecasts on the 45-km grid for the 19 typhoons shows that the TWRF model initialized with the blended analysis gives a much improved typhoon track forecast (Fig. 1). The difference in mean track forecast error, which is statistically significant, can be as big as 80 km at 72 h forecast.

Weighted toward the TWRF regional analysis for scales less than 1,200 km, the blended analysis is shown to possess superior mesoscale structure than that of the NCEP GFS global analysis. For track forecast on the 15-km grid (where mesoscale analysis becomes important), TWRF initialized with the blended analysis gives more accurate track forecast than that initialized with the NCEP GFS global analysis (Fig. 2). The difference, which is also statistically significant, is about 20 km at 72-h averaged over 143 cases.

The superior mesoscale analysis in the blended analysis over the NCEP GFS analysis is well reflected in typhoon's wind, temperature and pressure structure at the model initial condition as well as rainfall prediction over the 5-km grid centered over Taiwan. Using Typhoon Soulik as an example, which was the only typhoon that made landfall over Taiwan in 2013, we showed that the cycling analysis using TWRF forecast as the first guess clearly has its advantages in capturing the mesoscale vortex wind and pressure structure at the surface associated with the typhoon circulation as well as the local topographically induced circulations (Fig. 3). The superior mesoscale structure retained in the blended analysis, which includes a mesoscale vortex circulation, a robust warm core (Fig. 4), and a stronger upslope flower, led to a much more accurate rainfall forecast both in terms of peak rainfall amount and rainfall distribution (Fig. 5).

Our study shows that the blended analysis indeed has the best of both worlds. On one hand, it takes advantages of the accurate large-scale fields from the NCEP GFS global analysis. This significantly reduces the systematic errors over the ocean and greatly improves the track forecast. On the other hand, it takes advantages of the superior mesoscale fields provided by the TWRF partial cycling analysis. This improves the track forecast on the 15-km grid, as well as producing a much more accurate rainfall forecast on the 5-km grid over Taiwan.

With these encouraging results, the blended analysis is recommended for operational implementation with TWRF at the Central Weather Bureau starting in 2013.

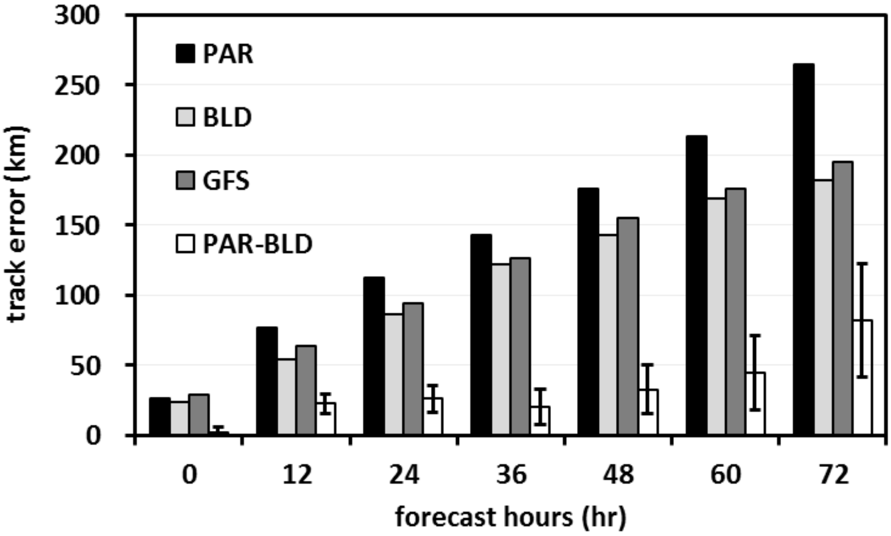

Fig. 1 Mean typhoon track errors for PAR (black bars), BLD (light gray bars), GFS (dark gray bars) experiments. Error bars denote the 95% confidence interval of the mean difference between PAR and BLD (PAR-BLD; white bars).

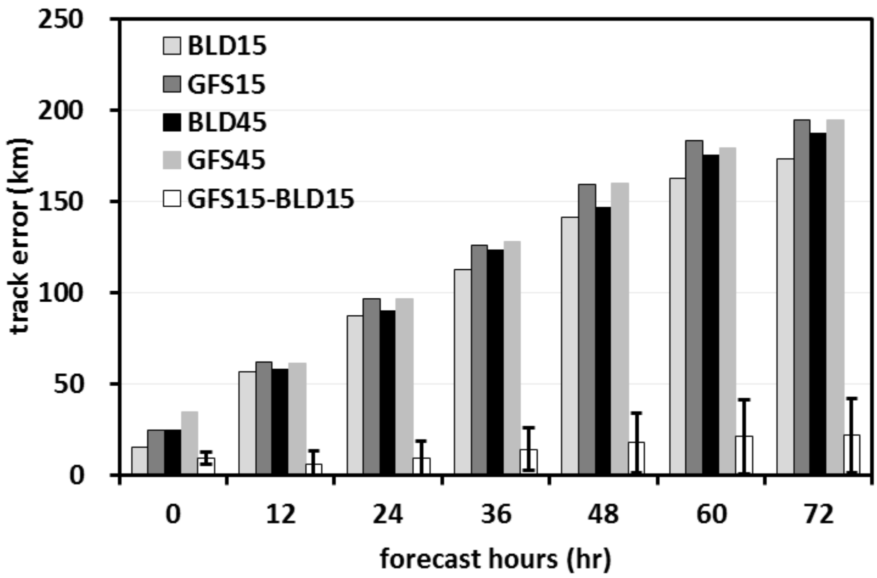

Fig. 2 The comparison of mean track errors between 45- and 15-km resolutions in the BLD and GFS experiments for a total of 143 cases within the 15km domain. Error bars denote the 95% confidence interval of the mean difference for 15km resolution between GFS and BLD (GFS-BLD; white bars).

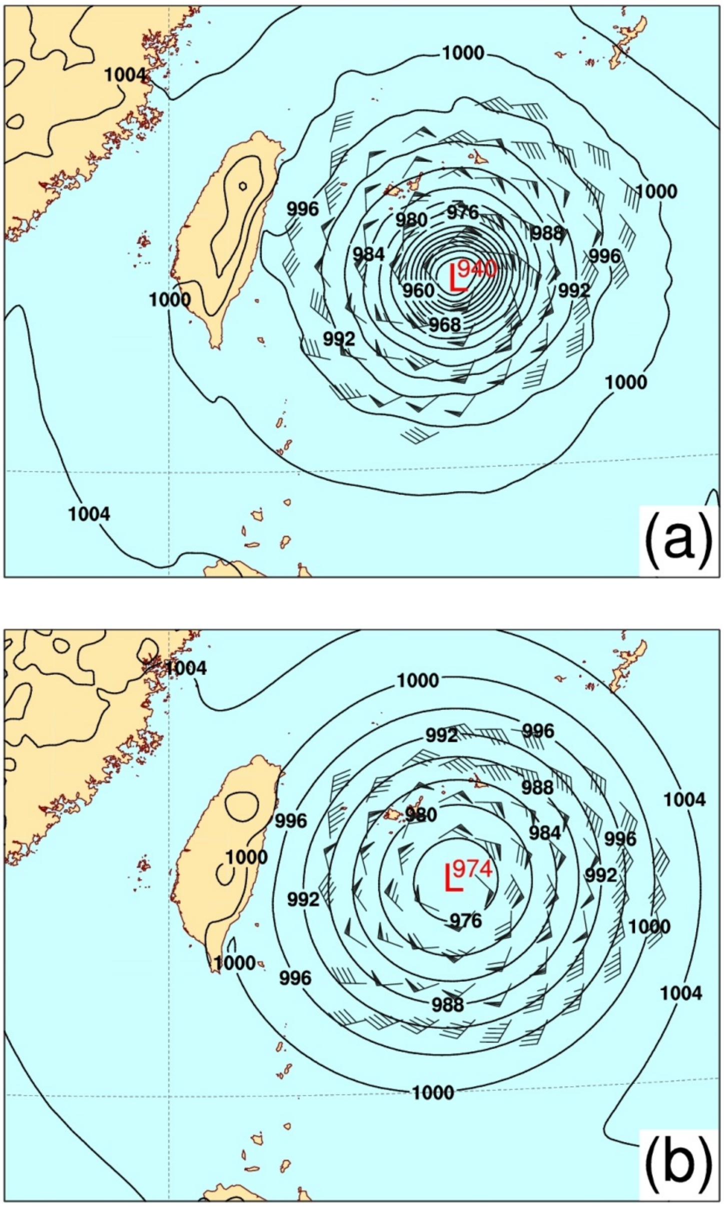

Fig. 3 The sea level pressure analysis from (a) BLD and (b) GFS experiment at 0600 UTC 12 July 2013.

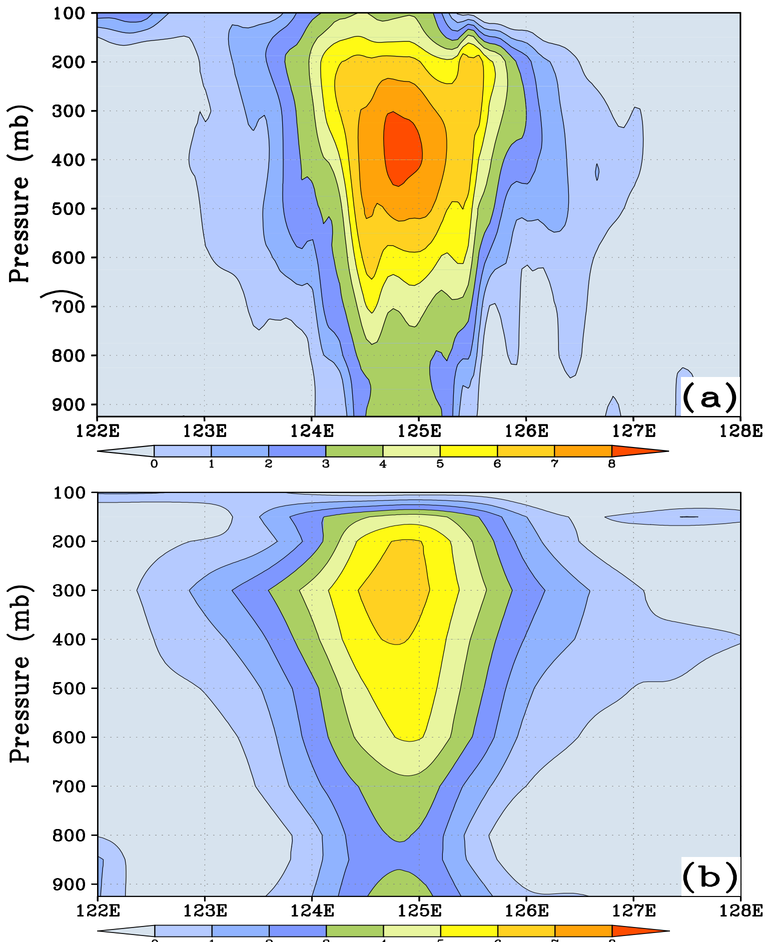

Fig. 4 Zonal cross section of anomaly temperature cutting through typhoon center from (a) BLD and (b) GFS experiments for model initial condition at 0600 UTC 12 July 2013.

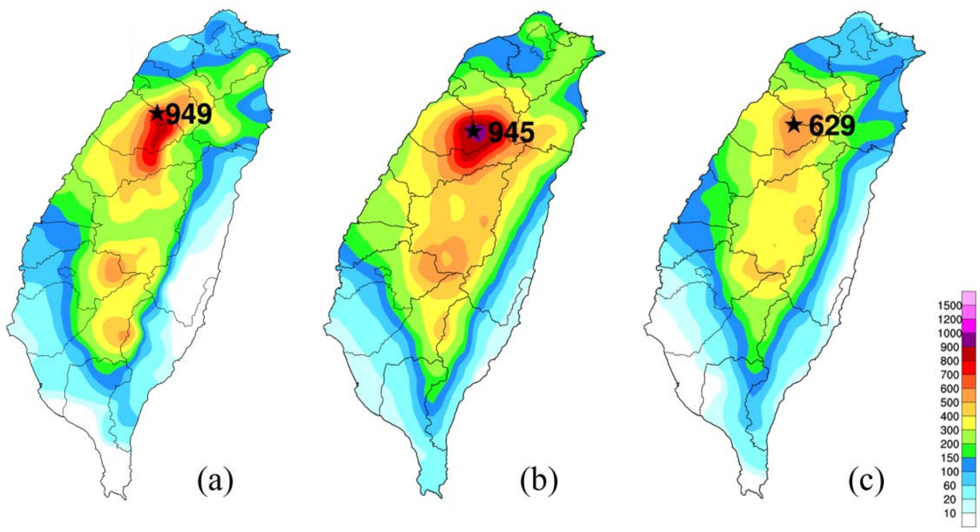

Fig. 5 The 24 h accumulated rainfall from the forecast initiated at 0600 UTC 12 July: (a) observed rainfall, (b) BLD and (c) GFS experiments.