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# Experiments of a Typhoon Bogussing Scheme in the MM5 3D-Var Cycling System

Qingnong Xiao*[1], Ying-Hwa Kuo[1], Ying Zhang[1], D. M. Barker[1] and D.-J. Won[2]

[1]National Center for Atmospheric Research, Boulder, Colorado
[2]Korean Meteorological Administration, Seoul, Korea

## 1. Introduction

One of the most challenging problems for the numerical prediction of typhoon is how to define its initial structures with insufficient observations over the ocean. Typhoon bogussing is still a necessary step toward an improved prediction of typhoon track and intensity (Kurihara et al. 1993). Based on the MM5 3D-Var cycling system (Barker et al. 2004), a typhoon bogussing and relocation algorithm is developed and tested with the Typhoon Rusa (2002) case. Similar to the MM5 4D-Var work by Xiao et al (2000), the bogus sea-level pressure and wind fields are assimilated into the MM5 3D-Var analyses in the cycling mode. Numerical simulations indicate that the typhoon 3D-Var initialization improves the subsequent track and intensity prediction.

## 2. Specification of typhoon bogus observations

In order to perform 3D-Var typhoon bogussing, a set of bogus observations are produced. In our study, the bogus observations are generated according to the method of Ueno (1989, 1995). It includes two components (symmetric and asymmetric) in the typhoon bogus data. The symmetric part is calculated based on the typhoon reports, and the asymmetric part is obtained from the 3D-Var background fields (MM5 forecasts in the 3D-Var cycling mode).

The typhoon bogus observations include sea level pressure and wind fields at 13 levels. The distribution of symmetric sea level pressure within the typhoon bogus area is calculated from Fujita (1952) empirical formula, and the bogus symmetric wind is based on the gradient wind relationship. The effect of surface friction is included by specifying smaller weightings for the lower levels. There are 13 levels (sea-level, 1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150 and 100 hPa) in the bogus wind profile. The weightings of the symmetric wind speed are 0.7, 0.8, 0.9, 1.0, 1.0, 1.0, 1.0, 0.0, 0.0, 0.0, 0.0, respectively.

The asymmetric components are extracted from the 3D-Var background fields (MM5 forecasts in the 3D-Var cycling mode). We relocate the asymmetric component, add them to the typhoon symmetric bogus fields, and create a set of bogus sea-level pressure and wind profiles within the typhoon bogus area. The errors of the bogus observations are empirically determined.

*Corresponding author address*: Qingnong Xiao, NCAR, MMM, P. O. Box 3000, Boulder, CO 80307-3000; Email: hsiao@ucar.edu

## 3. MM5 3D-Var with bogus data assimilation

There are mainly two modifications related to the bogus data assimilation in the MM5 3D-Var system. One is the maximum error check in the MM5 3D-Var system. The other is the addition of observation operators for the bogus observations, their tangent linear and adjoint to the 3D-Var system. The typhoon bogussing fields are treated as supplemental observations and are assimilated during the 3D-Var analyses.

Usually, the typhoon will be relocated to the correct position in the 3D-Var analyses unless the typhoon in the background is misplaced and is very strong. Otherwise a removal procedure for the misplaced typhoon in the background is performed in the developed algorithm.

## 4. Numerical experiments with Typhoon Rusa (2002) case

Three experiments are carried out with different typhoon initialization at 00 UTC 30 August 2002: 1) 3DVAR_BG, 3D-Var typhoon bogus data assimilation with one-day cycling (typhoon bogus data are assimilated from 00 UTC 29 August 2002, cycled at 12 hours interval), 2) BKG_BG, bogus typhoon into 3D-Var background (background bogussing), and 3) NO_BG, 3D-Var analyses without bogus.

### *4.1. Initial typhoon structure*

During the MM5 3D-Var bogussing process, the sea-level pressure and wind fields are adjusted toward the bogussed sea-level pressure and wind fields. Because MM5 3D-Var system contains dynamical and statistical balance constrains, the variables that are not assimilated (such as temperature) can respond to the assimilated sea-level pressure and wind fields and develop realistic typhoon structure under the 3DVAR constrains. As a result, not only the typhoon intensity and position in the 3D-Var typhoon bogussing analyses are closer to the observations than background bogussing, but also the initialization produces a sound typhoon vertical structure. Fig. 1 shows the cross sections of potential temperature and tangential wind along the north-to-south line cutting through the typhoon center. In the 3D-Var bogussing analysis, the potential temperature clearly shows a warm core structure. In addition, 3D-Var generated an asymmetric wind distribution compared with the background bogussing (Fig. 1).

### *4.2. Typhoon track*

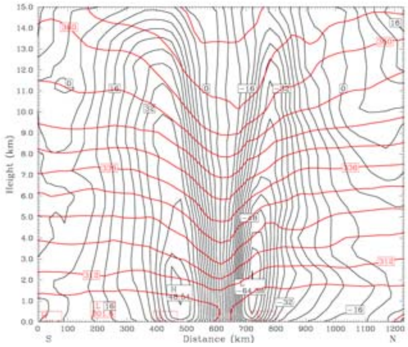


Fig. 1: 3DVAR_BG potential temperature and tangential wind speed at 00 UTC 30 August 2002 from 3D-Var bogussing initialization

Figure 2 shows the predicted tracks of Typhoon Rusa (2002) from three different initial conditions at 00 UTC 30 August 2002. The Tokyo Typhoon Center best track (OBS) is also plotted for comparison. The predicted track from 3D-Var bogussing (3DVAR_BG) follows the observed track, but moves faster than observations. The predicted track from background bogussing (BKG_BG) departs from the observed track in its early forecasting period (00-18 hour). There is a forecast spin-up process when the background bogussing analysis is used as initial conditions. Consequently, the predicted movement of the typhoon Rusa is slower than the observation. As expected, the track from experiment NO_BG is the worst.

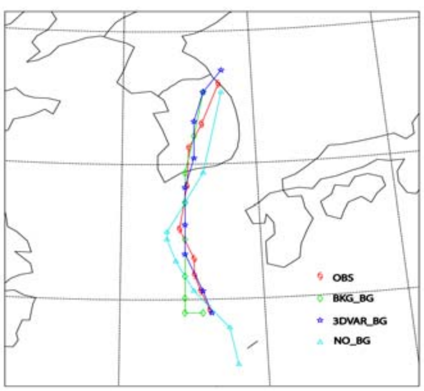


Fig. 2: Typhoon Rusa tracks (at 6 h interval, starting from 00 UTC 30 August 2002) for observation and three experiments (3DVAR_BG, BKG_BG and NO_Bg)

### *4.3. Intensity*

Fig. 3 shows the typhoon intensity change during the 48-h forecasts following the three different initializations. It is clearly shown that the 3D-Var bogussing (3DVAR_BG) produces better typhoon intensity change in the 48-h forecast, compared with the background bogussing (BKG_BG) and no-bogussing experiment (NO_BG). It is important to mention that the observed typhoon intensity is gradually reduced after landfall. This tendency is simulated in the 3D-Var bogussing experiment (3DVAR_BG), but it is not simulated in the background bogussing experiment (BKG_BG).

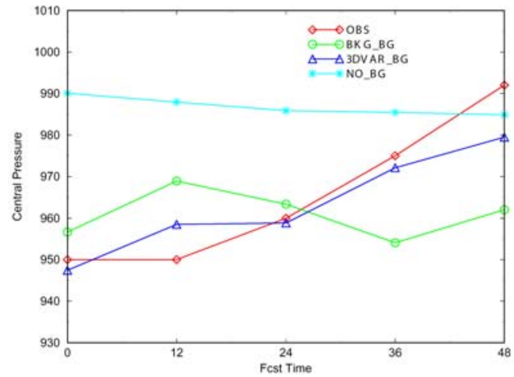


Fig. 3: The typhoon Rusa (2002) intensity change from 00 UTC 30 August through 00 UTC 1 September 2002

## 5. Summary and conclusions

MM5 Numerical simulations using the 3D-Var bogussing initialization showed a skillful forecast of Typhoon Rusa (2002) near landfall. The most important results are summarized as follows:

• The MM5 3D-Var typhoon bogussing algorithm is able to generate realistic warm-core temperature structure, through the dynamical and statistical balance constraints internal to the 3D-Var system, even though no thermal observations are assimilated. Studies show that the warm-core structure can be generated when only sea-level pressure is assimilated.

• Because the model initial conditions are dynamically balanced by 3D-Var, the one-day cycling assimilation of the typhoon bogus data produces improved track and intensity change of the typhoon prediction, compared with the background bogussing method.

• 3DVAR bogussing algorithm also improves the prediction of rainfall and typhoon landfall time. The typhoon intensity is very close to the observation at landfall in the 3D-Var bogussing experiment.

## Reference

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