Introduction of a JMA-type typhoon bogus scheme into MM5 to improve hindcasting of coastal sea surface winds

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ABSTRACT: A typhoon bogus scheme is developed for the NCAR/PSU mesoscale model MM5, by imitating the ANL-Bogus scheme operationally used in Japan Meteorological Agency. Performance of the scheme is tested with 5 typhoons hitting Japan in 2004. As a result, it is found that the hindcast accuracy of coastal sea surface winds is improved by using the developed typhoon bogus scheme together with four-dimensional data assimilation option.

KEYWORDS: Typhoon bogus scheme, MM5, Sea surface winds.

1 INTRODUCTION

In the analysis of coastal disasters and maritime accidents by typhoons, information of sea surface wind fields is needed with a high horizontal resolution, e.g., several hundred meters to a few kilometers. When such high-resolution wind fields are estimated with a mesoscale model, it is very important to accurately initialize typhoon structures in the model. The initial conditions in the mesoscale model are usually created by interpolating regional objective analysis data. However, in the regional objective analysis, typhoon structures are often too smooth to represent the actual intensity due to its coarse horizontal resolution, e.g., a few tens of kilometers.

One solution to this problem is using a typhoon bogus scheme, which can embed bogus data into the objective analysis data so that typhoon structures are close to reality. In the fifth generation Mesoscale Model MM5 (Dudhia et al.\textsuperscript{1}), developed by National Center for Atmospheric Research (NCAR) and Pennsylvania State University (PSU), a tropical cyclone bogussing scheme has been already installed (Davis & Low-Nam\textsuperscript{2}). However, the scheme has some shortcomings; for instance, central pressure of the typhoon can not be specified explicitly. Thus, this study develops a new typhoon bogus scheme for MM5, by imitating the typhoon bogus scheme operationally used in Japan Meteorological Agency (JMA).

2 TYPHOON BOGUS SCHEME FOR MM5

The new typhoon bogus scheme is designed for the use in the preprocessing of MM5 and coded in FORTRAN according to descriptions of the JMA ANL-Bogus scheme (Ohnogi & Ueno\textsuperscript{3}, Ueno\textsuperscript{4}). In the code, typhoon bogus data is created and finally embedded into objective analysis data, by taking the following five steps.

1) Calculation of surface pressure distribution using the Fujita\textsuperscript{5}'s equation
2) Calculation of geopotential heights using a function based on the analysis by Frank\textsuperscript{6}
3) Calculation of gradient winds based on axisymmetric pressure fields
4) Addition of asymmetric components into the axisymmetric bogus data
5) Embedding the typhoon bogus data into objective analysis data
Figure 1. Surface wind speed and pressure fields before and after embedding typhoon bogus data into RANAL.

Specifically, the code is executed in the MM5 preprocessing named “regridder” and needs two input files. One is REGRID_DOMAINn, which is gridded analysis data created from the JMA Regional Analysis RANAL (20 km grid). The other is the Best Track data provided from the Regional Specialized Meteorological Center (RSMC) Tokyo – Typhoon Center. According to typhoon parameters written in the Best Track data, the code creates proper typhoon bogus data, embeds it into REGRID_DOMAINn, and finally outputs REGRID_DOMAINn_BOGUS.

Figure 1 compares surface wind speed and pressure fields between before and after embedding typhoon bogus data into RANAL. The central pressure of T0421 at this time is actually 965 hPa, but it is 989 hPa in RANAL (Figure 1(a)). As shown in Figure 1(b), the central pressure is well improved by embedding typhoon bogus data. After the addition of typhoon bogus data, the central pressure is found to be deepened down to 965 hPa with intensified winds around the typhoon center.

3 VALIDATION OF THE TYPHOON BOGUS SCHEME

The developed JMA-type typhoon bogus scheme is tested with 5 typhoons hitting Japan in 2004 (T0416, T0418, T0421, T0422 and T0423). First, the typhoon bogus scheme is used only for model initialization so as to examine its effects on subsequent intensity and track hindcasting. Next, the typhoon bogus scheme is used with four-dimensional data assimilation (FDDA) option, which can “nudge” the model state toward gridded analyses. In the case without the typhoon bogus scheme, nudging is performed with 6-hourly gridded analysis data. In the case with the typhoon bogus scheme, MM5 is run two times and 3-hourly gridded analysis data including typhoon bogus data are used for FDDA in the second run. This is for the sake of making extensive use of 3-hourly typhoon information available in the RSMC Best Track data. Thus, in all, 4 kinds of simulation (with or without the typhoon bogus scheme and FDDA) are carried out for each typhoon. All the domains used for the simulations consist of 140×140 grids with horizontal grid spacing of 13.5 km and 32 vertical layers. The simulation period is 24 hours, and its central time roughly corresponds to the landfall time of each typhoon.

In general, disastrous winds caused by a typhoon are closely related to the intensity and track of typhoon. Thus, first of all, prediction errors in central pressure and position of typhoon
are compared among the 4 simulations. The results are shown in Figures 2-3. Comparison of two no-FDDA cases shows that the typhoon bogus scheme effectively reduces central pressure errors, especially in the former period (Figure 2). Moreover, it is also found that position errors decrease with use of the typhoon bogus scheme (Figure 3), although the improvement is slightly compared to that of central pressure errors. In short, only using the typhoon bogus scheme for model initialization, the subsequent intensity and track hindcasting is found to be improved.

Next, effects of FDDA on the accuracy of simulation are evaluated. It is interesting in Figure 2 that FDDA tends to increase central pressure (i.e., weaken the intensity of typhoon) regardless of using the typhoon bogus scheme. This result is most likely related with the fact that FDDA nudges the central pressure toward higher pressure as the predicted typhoon center departs from the actual position. In contrast, position errors dramatically decrease in the case with both FDDA and the typhoon bogus scheme (Figure 3). These contrasting results imply the difficulty to keep intensity and track of typhoon in the simulation simultaneously. According to Figures 2-3, the combination of the typhoon bogus scheme and FDDA seems to work the best among the 4 simulations, as a whole.

Finally, accuracy of simulated coastal surface winds is shown in Figure 4. The accuracy is evaluated using 10 observations per each typhoon. All the data are obtained from Japan Coast

![Figure 2](image1.png)  ![Figure 3](image2.png)

Figure 2. Average and RMS errors in central pressure for 5 typhoons.

Figure 3. Average position errors for 5 typhoons.
Guard and the stations are mostly lighthouses located along coast lines. Although the order of the accuracy varies according to typhoons, Figure 4 clearly shows that the combination of the typhoon bogus scheme and FDDA yields the smallest RMS error for 3 typhoons (T0421, T0422 and T0423) and the highest correlation coefficient for 3 typhoons (T0416, T0422 and T0423). Furthermore, in terms of the averages for 5 typhoons, it is shown that the combination case exhibits the smallest RMS error and the highest correlation coefficient among the 4 cases.

4 CONCLUSIONS

A JMA-type typhoon bogus scheme has been developed for MM5, and its performance was tested with five typhoons. In the validation, 4 kinds of simulation (with or without the typhoon bogus scheme and FDDA) were carried out and compared each other. In cases without FDDA, the typhoon bogus scheme, used only for model initialization, was found to improve the subsequent intensity and track hindcasting. Among the 4 simulations, the case with both the typhoon bogus scheme and FDDA exhibited the best performance as a whole. These results indicate that introduction of the JMA-type typhoon bogus scheme into MM5 is effective in improving the hindcast accuracy of coastal sea surface winds.

5 REFERENCES