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A Numerical Prediction System for Wind and Sea Wave: A Typhoon Case

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ABSTRACT: A numerical model system is constructed to predict surface conditions over the open oceans for a typhoon case. Its atmospheric and oceanic components are the Weather Research and Forecasting (WRF) model and the NOAA WaveWatch version 3 (NWW3) model, respectively. The initial condition of the WRF is obtained from the NCEP aviation forecast, while the WRF-predicted surface winds serve as the boundary conditions for sea wave prediction of the NWW3.The capability of this model system is evaluated in terms of the predictions of surface wind and sea waves associated with the typhoon Bilis (No. 0604). This typhoon formed over the west side of Guam (141?E, 12?N) on July, 9, 2006, and moved northwestward across Taiwan to decay over southeast China on July, 15, 2006. Its moving track is reasonably predicted by the WRF with an averaged error of 99 km in 24-hr forecast and of 233 km in 48-hr forecast. These errors are in comparable ranges with the official typhoon forecasts conducted by weather services in the countries around the Pacific. The circulation pattern and intensity of surface winds and height of sea waves can be adequately portrayed by this prediction system in advance by 48 hrs. The dangerous and navigable semicircles of the typhoon are also clearly delineated. As such, the spatial domains of high wind and high sea are identified, providing potentially useful information for navigation safety.

1 INTRODUCTION

The global surface observation network is dense over lands and sparse over oceans. The missing data over oceans is often filled with satellite observations, but still to some limits. The satellite observations are in good quality during the clear-sky day, but easily distorted by severe weather. Ship observations are another important data source. However, they are restricted within the routine commercial routes to cover certain parts of the ocean. Moreover, ship observations fail to provide detailed surface information for severe weather due to its detour for safety. The real surface conditions underneath a severe storm over ocean (e.g., typhoon or hurricane) are still mysterious to us so far.

To overcome this problem, one may take advantage of the state-of-the-art atmospheric and oceanic numerical models developed in the recent years. In other words, a numerical atmosphere-ocean model system may be constructed for simulating/predicting the atmospheric and oceanic conditions associated with the severe weather event. Such a numerical model simulation/prediction, although not perfect, can at least provide us a reasonable guess for surface conditions underneath and near the storm over the open oceans. The purpose of this study is to report the construction of an atmosphere-ocean numerical model system. Its performance in typhoon prediction is investigated.

2 THE PREDICTION SYSTEM

The model system constructed in this study aims at predicting surface wind and sea wave in the western North Pacific. This system consists of two models. The atmospheric component is the Weather Research and Forecasting (WRF) model (Skamarock et al. 2005), while the oceanic component is the NOAA WaveWatch version 3 (NWW3) model (NOAA 2002). Given the NCEP aviation forecast as the initial boundary condition, the WRF with the 145-km grid is first executed to make prediction for the 80°-160°E, 10°S-50°N domain. Its predictions are then dynamically downscaled by the second WRF with a higher spatial resolution, 15-km grid, in the 100°-150°E, 0°-35°N domain. Later, the 10-m winds predicted by the second WRF are used as the boundary conditions for the NWW3 model to simulate sea wave, focusing on its height and propagation. This NWW3 model is in a 0.2° grid and has a spatial domain of 110°-145°E, 5°-35°N. The model system is designed for predicting typhoon activities over the western North Pacific.

3 THE MODEL PERFORMANCE

The prediction of Typhoon Bilis (No. 0604) is selected as the case for examining the model performance. Bilis formed over the west side of Guam (141°E, 12°N) on July, 9, 2006, and moved northwestward across Taiwan to decay over southeast China on July, 15, 2006. Such a track is reasonably predicted by the WRF (Fig. 1) in its 24- and 48- hr forecasts.

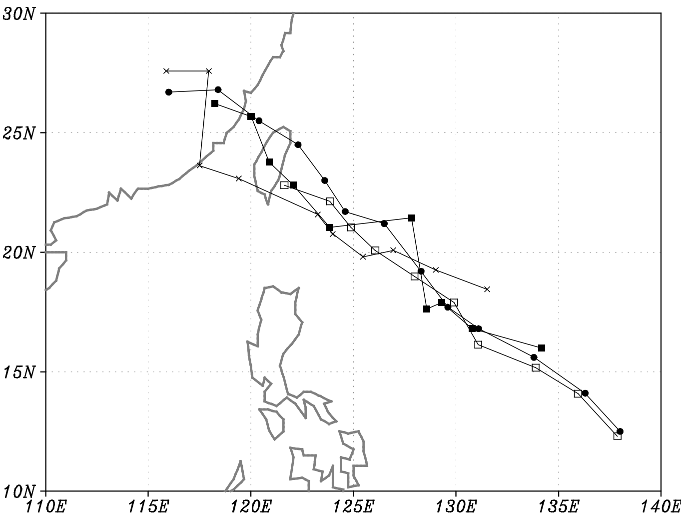

Fig. 1. The central position of Typhoon Bilis from observed, initial condition, 24-hr prediction, and 48-hr prediction.

The averaged error in the spatial position of typhoon center is 99 km in 24-hr forecast and 233 km in 48-hr forecast. These errors are in comparable magnitudes with the official typhoon forecasts conducted by weather services in Taiwan, Japan, China, and USA, which range 94-110 km for 24-hr forecast and 173-191 km for 48-hr forecast. The prediction errors in the magnitude of 10-m winds along the 125°E longitude (15°N, 20°N, 25°N, and 30°N) are evaluated against observations represented by the NCEP Reanalysis data (Kalnay et al. 1996). Table 1 reveals that prediction error in wind magnitude is largest near the center of typhoon track (20°N), followed by the dangerous semicircle (typhoon's right-hand side at 25°N and 30°N), and smallest in the navigable semicircle (typhoon's left-hand side at 15°N).

Table 1. The averaged errors of 10-m wind magnitude for the initial condition (0 hr), 24-hr prediction, and 48-hr prediction at 4 different meridional locations along the 125°E longitude (unit: m/s).

bilis(125E)	0hr	24hr	48hr
15N	2.52	1.44	5.00
20N	5.60	4.75	9.35
25N	4.33	4.09	6.95
30N	4.85	3.02	4.57

The spatial pattern of 10-m winds delineate clearly that wind speed is apparently larger in the dangerous semicircle than in the navigable semicircle (Fig. 2).

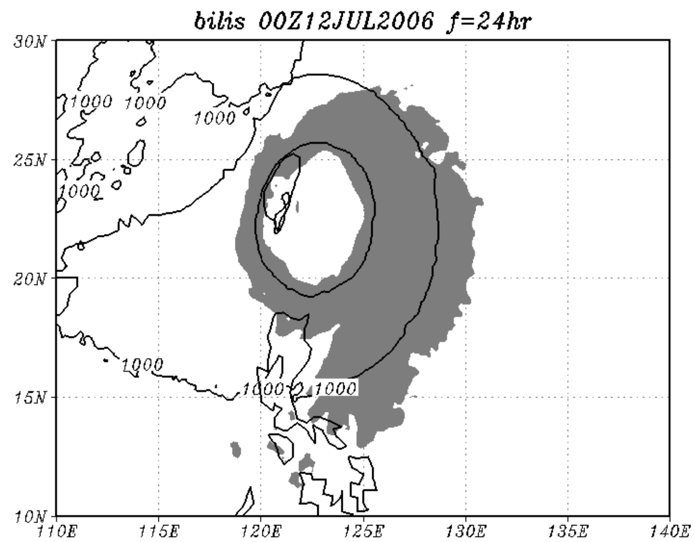

Fig. 2. The spatial pattern of predicted high wind (≧ 30 knots, shading) at 10 m from the 24-hr prediction of the WRF model. Sea level pressure is plotted in contours

Regarding the sea wave, the predicted height of sea wave is validated against the wave analysis issued by the Japan Meteorological Agency (JMA). Its prediction errors (Table 2) are largest in the dangerous semicircle, followed by the typhoon center, and smallest in the navigable semicircle.

Table 2. As in Table 1, except for the averaged errors of the height of sea wave (unit: m).

bilis(125E)	0hr	24hr	48hr
15N	0.98	1.02	1.61
20N	1.11	0.75	2.07
25N	1.83	2.69	3.46
30N	1.33	1.87	2.69

The prediction shows that the height of wave (Fig. 3) in the dangerous semicircle can be twice as large as that in the navigable semicircle (9 m vs. 4 m).

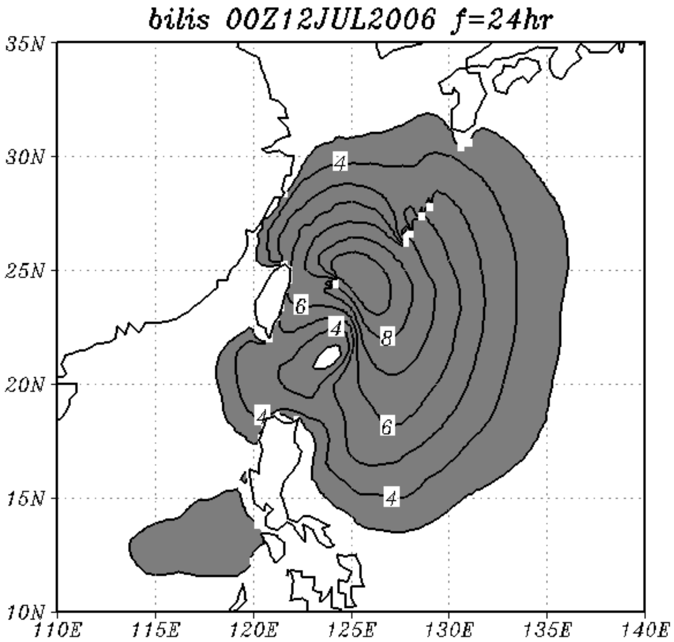

Fig. 3. The spatial pattern of predicted sea wave height (shading) from the 24-hr prediction of the NWW3 model

4 SUMMARY

By investigating the temporal and spatial patterns of the predicted 10-m winds and sea wave, general performance of this model system in typhoon prediction is summarized as follows:

- The numerical model system is able to reasonably capture typhoon track in advance by 24 to 48 hrs.
- The dangerous regions with high wind (≧ 30 knots) and high sea (≧ 4 m) can be identified. The spatial range of the prediction error (about 100-240 km) in typhoon center should be added to broaden the spatial domain of dangerous regions when the predictions are employed in navigational plan.
- Contrast between the dangerous and navigable semicircles of the typhoon are clearly portrayed by this model system. The model prediction reveals that spatial domain of high wind is much larger in the dangerous semicircle than that in the navigable semicircle, while the maximum height of sea wave is about twice in magnitude in the former than in the latter.
- The model prediction is able to largely simulate the surface winds and sea wave over the oceans underneath and near the typhoon. These surface conditions are potential useful inputs for (1) constructing the database for a navigational simulator, (2) making evacuating plan for ship from the harbor, and (c) issuing early warning for navigation safety.

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