The Impact of the Sea State on the Typhoon Intensity in Atmosphere-wave coupled model

Nadao Kohno and Akihiko Murata
Meteorological Research Institute, JMA Tsukuba, Ibaraki 305-0052, Japan
E-mail: nkohno@mri-jma.go.jp

1. Introduction

It is necessary to estimate accurately the amount of momentum and heat exchanges, for evaluating the correct typhoon intensity. Especially, very rough sea condition under a typhoon, where high ocean waves are generated by storm wind and many sea sprays are flying, air-sea interaction is supposed to be influenced by the sea state (ocean waves).

However the flux dependency on sea state has not been solved satisfactorily yet, even though this knowledge shall give the important basis about the coupling mechanism between the ocean and the atmosphere. Recently several researches have been carried out with an integrated model (e.g. an atmosphere-ocean-wave coupled model), though the fundamental mechanism, how much impact will be given to a typhoon by including the wave dependency on flux, is seldom investigated intensively. Therefore, the impact on typhoon and wave intensity as a joint system with a atmosphere-wave coupled model is investigated, though there is still an uncertainty about the wave dependency itself.

2. Numerical Methods

The numerical model in our calculation is an atmosphere-wave coupled model: the atmospheric model Non-Hydrostatic Model (NHM) of the Meteorological Research Institute / Numerical Prediction Division of JMA (Saito et al., 2001) is coupled with the third generation wave model MRI-III (Ueno and Kohno, 2004). We define the horizontal grid scale as 5km in our calculation, and the NHM has 50 layers in vertical. The wave spectrum consists of 900 components; 25 in frequency and 36 in direction. The frequency of wave spectrum is divided logarithmically from 0.0375Hz to 0.3000Hz.

Since there are various formulae of roughness expression with wave dependency, we checked the performance by three characteristic types, (1) wave induced stress by Janssen (1989), (2) wave age by Smith et al. (1991), and (3) wave steepness by Taylor and Yelland (2001), and the results are inter-compared.

The simulated case is the developing stage of Typhoon Chaba (0416) during 03UTC on Aug 21 2004 to 00UTC on Aug 24. This typhoon slowly moved west and developed to a large and strong typhoon, the central pressure felled down to 910hPa from 985hPa in this period (69hours).

3. Calculation Results

Figure 1 depicts the scatter plot of C_d and U_{10}. The upper left is calculated by the formula of Kondo (1975), which has only wind dependency and used in standard NHM. It is easily recognized that the drag coefficients with wave dependency have large values in general. C_d values tend to be large in the strong wind, though C_d scatter is rather apparent in middle wind speed.

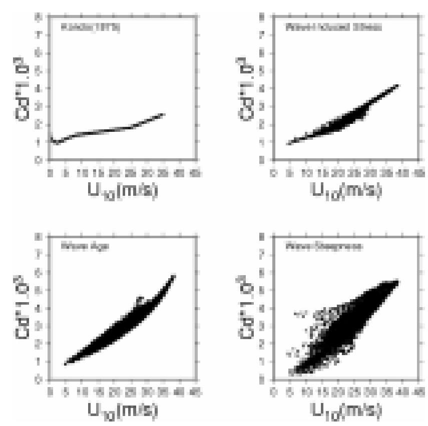

Fig. 1. The calculated drag coefficients

This large value decreases the lower wind speed as a strong resistance, and the typhoon were retarded to develop. In general, typhoon showed weak development in all calculations with the coupled model. However, the typhoon showed rapid intensification as the time goes on, and in some case typhoon intensity became rather stronger than that of uncoupled case in the last time. This impact also may come from the large C_d value: The large drag makes inflow in lower level larger by frictional effect. This means the enhancement of frictional convergence, and thus leads to the intensification of the primary circulation of typhoon. The radial wind around the typhoon at 18UTC on Aug 23 is shown in Fig. 2. (The typhoon center is 17.5N, 143.6E and moving westward.) In all cases of coupled calculation, the inflow in lower level is strong especially in the right-hand side of typhoon. The tangential wind speed at the same time is shown in Fig.3, which exhibits that wind speed in the right-hand side of typhoon is strong especially in the calculation with wave induced stress. The wind speed in the left-hand side of typhoon is rather weak, and asymmetry in tangential wind speed around typhoon is enlarged. It is also notable that the maximum wind at 850hPa is shifted inside in the coupled cases. This ‘shrunk’ typhoon structure seems be due to the enhancement of frictional convergence.

According to our results, the drag coefficients tend to have large values when wave dependency is included. This may leads to two impacts: one is the weakening of lower wind speed by the large drag values, and the other is that shrinking of typhoon size by large frictional convergence. The latter case sometimes led to a stronger typhoon than uncoupled one. This means there may be two opposite effect on typhoon intensity, and we are going to investigate the principal mechanism further.

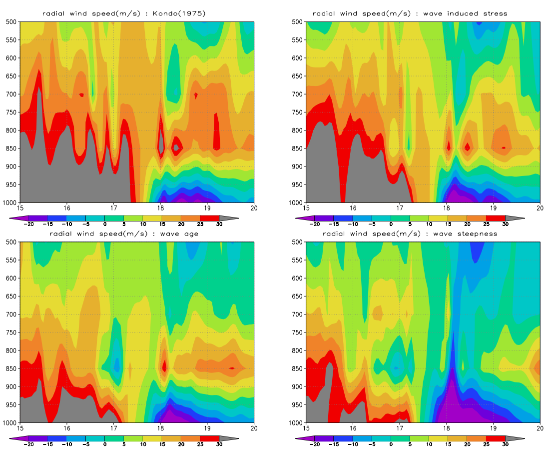

Fig. 2 The radial wind profile (m/s) at 143.6E

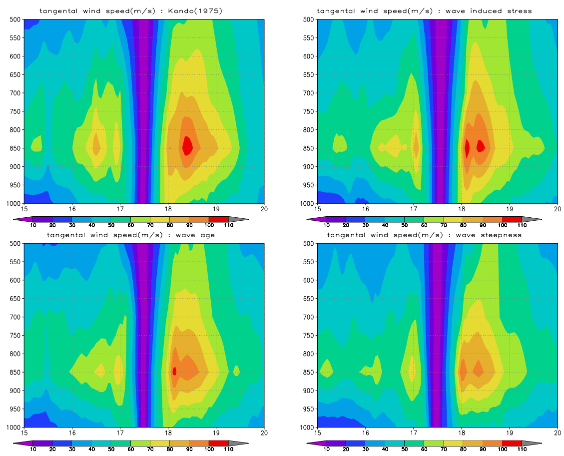

Fig.3 The tangential wind speed (m/s) at 143.4E

REFERENCES

Janssen, P. A. E. M., 1989: Wave-induced stress and the drag of air flow over sea waves. *J. Phys. Oceanogr.*, 19, 745-754.

Kondo, J., 1975: Air-sea bulk transfer coefficients in diabatic conditions. *Boundary-Layer Meteorol*., 9, 91-112.

Saito, K, T. Kato, H. Eito and C. Muroi, 2001: Documentation of the Meteorological Research Institute / Numerical Prediction Division unified nonhydrostatic model. *Tech. Rep. Meteorol. Res. Inst*., 42, 133pp.

Smith, S. D., R. J. Anderson, W. A. Oost, C. Kraan, N. Maat, J. DeCosmo, K. B. Katsaros, K. L. Davidson, K. Bumke, L. Hasse, and H. M. Chadwick, 1992: Sea surface wind stress and drag coefficients: The HEXOS results. *Boundary-Layer Meteorol*., 60, 109-142.

Taylor, P. K. and M. J. Yelland, 2001: The dependence of sea surface roughness on the height and steepness of the waves. *J. Phys. Oceanogr*., 31, 572-590.

Ueno, K. and N. Kohno, 2004: The development of the third generation wave model MRI-III for operational use. *in Proc. 8th Int. Workshop on Wave Hindcasting and Forecasting*, G2, 1-7.