The effects of ocean coupling and sea spray on the simulated track for Typhoon Muifa in 2011

Akiyoshi Wada
Meteorological Research Institute, Tsukuba, Ibaraki, 305-0052, JAPAN
awada@mri-jma.go.jp

1. Introduction

Previous studies have pointed out that the effect of ocean coupling on the simulated track of tropical cyclones was negligibly small compared with the effect of steering flow in the atmosphere. However, Wada (2014) demonstrated from the results of numerical simulations by using an atmosphere-wave-ocean coupled model that storm-induced sea surface cooling significantly affected the simulated track for Muifa in 2011 when the atmospheric steering flow was southwesterly and relatively weak. The question is whether the effect is caused by changes in the steering flow or by changes of the inner-core structure of a storm due to changes in turbulent heat fluxes near the air-sea interface from the ocean to the atmosphere.

The purpose of this study is to compare the simulated storm among different numerical experiments and to understand the effect of ocean coupling and increases in turbulent heat fluxes due to sea spray on the simulated track for Typhoon Muifa in 2011.

2. Model and experimental design

Numerical simulations were conducted by both a regional nonhydrostatic model (NHM) and a regional atmosphere-wave-ocean coupled model (CPL) developed by Wada et al. (2010). In addition, the sea spray parameterization (Bao et al. 2000) was incorporated into NHM (NHMSP) and CPL (CPLSP). The models covered a ~2200 km x ~2200 km computational domain with a horizontal grid spacing of 2 km. The models had 40 vertical levels with variable intervals from 40 m for the near-surface layer to 1180 m for the uppermost layer. The top height was ~23 km.

The simulations used the Japan Meteorological Agency global objective analysis data for atmospheric initial and boundary conditions (with a horizontal grid spacing of ~20km) and the daily oceanic reanalysis data calculated by the Meteorological Research Institute multivariate ocean variational estimation (MOVE) system (Usui, et al. 2006) with the horizontal grid spacing of 0.1˚. The initial time was 0000 UTC on 30 July in 2011. The integration time was 84 hours. The model and experimental design were the same as Wada et al. (2014) except for the sea spray parameterization.

3. Results and concluding remarks

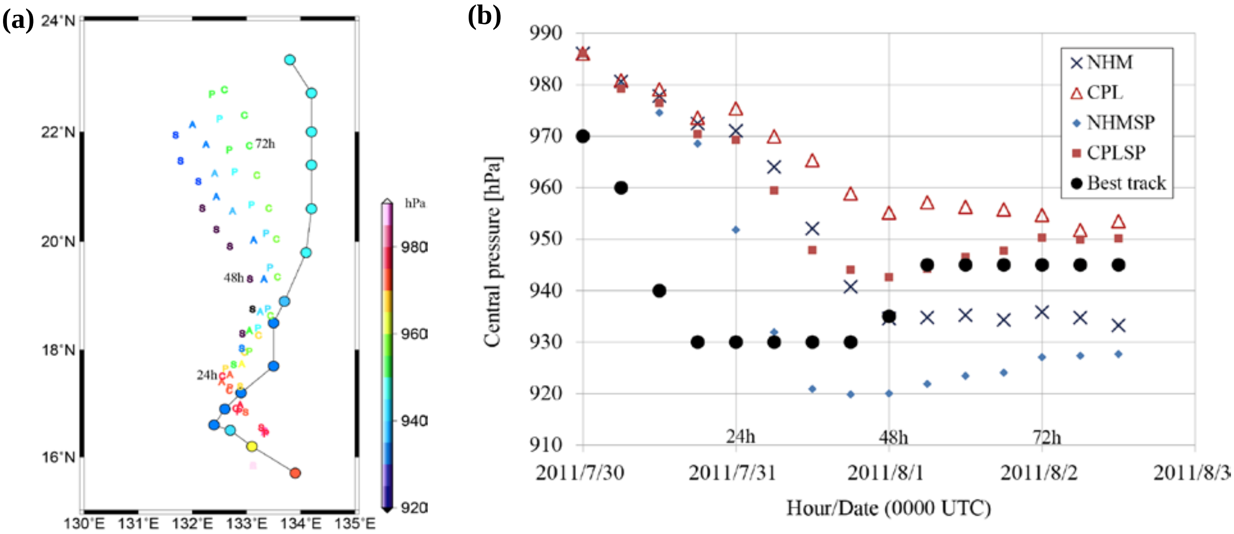

Figure 1 (a) Results of simulated tracks (A: NHM, C: CPL, S:NHMSP, P: CPLSP) and Regional Specialized Meteorological Center-Tokyo best track (b) Results of simulated central pressures and the best-track central pressure.

Figure 1 shows the results of simulated tracks (Fig. 1a) and central pressures (Fig. 1b) in the NHM, CPL, NHMSP and CPLSP experiments. The results of track simulations indicated that the track tended to shift westward as the simulated central pressure became low. All experiments poorly simulated rapid intensification of the storm occurred from 30 to 31 July in 2011. During the period, the simulated track showed the northward bias against the Regional Specialized Meteorological Center-Tokyo best track. Not only the ocean coupling but also sea spray parameterization did affect the simulated track through the change in turbulent heat fluxes near the air-sea interface.

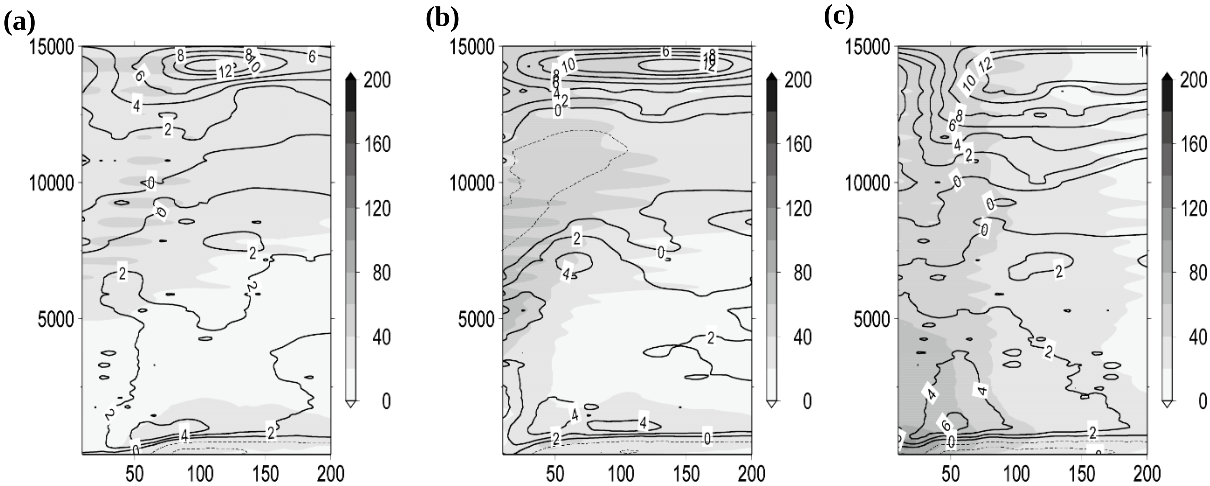

Figure 2 Axisymmetrical mean vertical profiles of radial flow (m/s: contours) and the standard deviation (m/s shades) in (a) NHM, (b) CPL and (c) NHMSP at 24 h, at 0000 UTC on 31 July. Soild contours indicate outflow, whereas dashed contours indicate inflow. Vertical axis shows heights (m) and horizontal axis shows a distance (km) from the storm center.

Figure 2 displays axisymmetrical mean radial-height profiles of radial flow and the standard deviation in the NHM, CPL and NHMSP experiments. In the tropical-cyclone boundary layer, the inflow became weak due to the effect of ocean coupling and resultant sea surface cooling (Wada et al. 2014). In addition, the location of the maximum outflow shifted outward from the radius of 120 km to that of 150 km. Even though the effect of the ocean coupling on the steering flow was small (Wada et al. 2014), the effect of ocean coupling on the inner-core structure of the simulated storm was remarkable.

The effect of sea spray parameterization on the inner-core structure of the simulated storm appeared not only in the tropical-cyclone inflow layer but also above the edge of the inflow layer and the outflow layer around the height of 14000 m. The effect of sea spray parameterization resulted in the asymmetry of the inner-core structure of the simulated storm. Above the edge of the inflow layer, the updraft became strong. The strong updraft was connected with the structure of the outflow layer. In this case, the location of the maximum outflow shifted inward compared with that in the NHM and CPL experiments.

Figure 2 also indicates that the amplitude of vertical shear was smallest in the CPL experiment, whereas that was greatest in the NHMSP experiment. However, the difference of the vertical shear on the simulated track was relatively small at 24 h and then became great after 24 h. Thus, the result of this study suggests that the changes of the inner-core structure resulted from the difference of turbulent heat fluxes lead to the changes of the steering flow and associated simulated tracks under the relatively weak atmospheric environmental flow.

As described in the introduction, this study addresses a rare case that storm-induced sea surface cooling significantly affected the simulated track. However, the result will contribute to improvement of “busts” of tropical cyclone track forecasts under a relatively weak steering flow. Further studies are needed to understand the role of ocean coupling and sea spray parameterization in track predictions.

Acknowledgement

This work was supported by MEXT KAKENHI Grant Number 25106708.

References

Bao, J.-W., J. M. Wilczak, J.-K. Choi and L. H. Kantha (2000). Numerical simulations of air-sea interaction under high wind conditions using a coupled model: A study of hurricane development. Mon. Wea. Rev., 128, 2190-2210.

Usui, N., S. Ishizaki, Y. Fujii, H. Tsujino, T. Yasuda and M. Kamachi (2006). Meteorological Research Institute multivariate ocean variational estimation (MOVE) system: Some early results. Advances in Space Research, 37(4), 806-822.

Wada, A., N. Kohno and Y. Kawai (2010). Impact of wave-ocean interaction on Typhoon Hai-Tang in 2005. SOLA, 6A, 13-16.

Wada, A, T. Uehara and S. Ishizaki (2014). Typhoon-induced sea surface cooling during the 2011 and 2012 typhoon seasons: observational evidence and numerical investigations of the sea surface cooling effect using typhoon simulations. Prog. Earth Planet. Sci. 1:11