Numerical simulations of the rapid weakening of Typhoon Haishen (2020) by a coupled atmosphere-wave ocean model

Akiyoshi Wada and Wataru Yanase

[1]Meteorological Research Institute, Tsukuba, Ibaraki, 305-0052, JAPAN

[1]awada@mri-jma.go.jp

1. Introduction

Wada (2021) investigated the effect of the ocean on Typhoon Haishen (2020) using the results of numerical simulations conducted by a nonhydrostatic atmosphere model (NHM) and the coupled atmosphere-wave-ocean model (CPL, Wada, et al., 2018). Wada (2021) concluded that the simulation result by CPL with the KF cumulus parameterization seems to be better for the intensity change in the weakening phase. In fact, Haishen was a relatively compact typhoon with a concentric eyewall. Haishen had a multiple eyewall structure at 15 UTC on 5 September (Fig. 1a) in the mature phase, but the innermost eyewall collapsed at 03 UTC on 6 September (Fig. 1b) in the weakening phase.

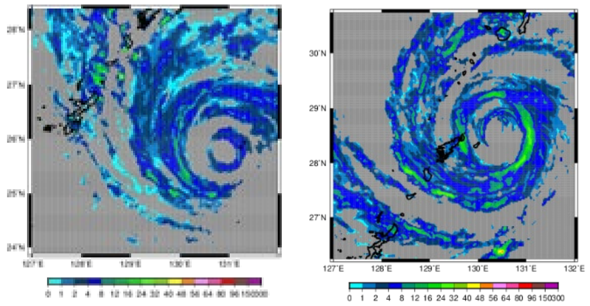

Figure 1 The 1-hour rainfall distribution analyzed every 5 minutes (mm/hour) at (a) 15 UTC on 5 September and (b) 03 UTC on 6 September.

To investigate the effect of the ocean coupling and sea surface temperature (SST) at the initial integration time on the inner-core structural change and thereby intensity change of Haishen, numerical simulations were conducted by using the 1-km mesh NHM and CPL.

2. Experimental design

Table 1 shows a list of numerical simulations. The initial time of integration was 0000 UTC on 5 September. The computational domain was 1500 x 2040 km with a grid spacing of 1 km. The number of the vertical layer was 50. The top height was approximately 21 km. The integration time was 48 hours. The cumulus parameterization of Kain and Fritsch (1990) (KF in Table 1) was used for comparison.

Table1 List of numerical simulations

Name	*Model*	*SST at the initial time*	*Cumulus Parameterization*
NHMKF	NHM	OISST on 5 September	Kain and Fritsch (1990)
CPLKF	CPL	OISST on 5 September	Kain and Fritsch (1990)
NHMKF3DB	NHM	OISST on 2 September	Kain and Fritsch (1990)
CPLKF3DB	CPL	OISST on 2 September	Kain and Fritsch (1990)

The time step was 1 second for NHM, 6 seconds for the ocean model, and 6 minutes for the ocean surface wave model. The Japan Meteorological Agency (JMA) mesoscale objective analysis with horizontal resolution of 5 km and the JMA North Pacific Ocean analysis with horizontal resolution of 0.5° were used for creating atmospheric and oceanic initial conditions and atmospheric lateral boundary conditions (every 3 hours). As for the initial condition of SST, the Optimally Interpolated SST (OISST) daily product with horizontal resolution of 0.25°, obtained from the site: http://www.remss.com, was used. The dates of OISST used to create the initial condition of SST are not only 5 September but also 2 September (3DB, see Table 1).

3. Results

3.1 Simulated track and intensity

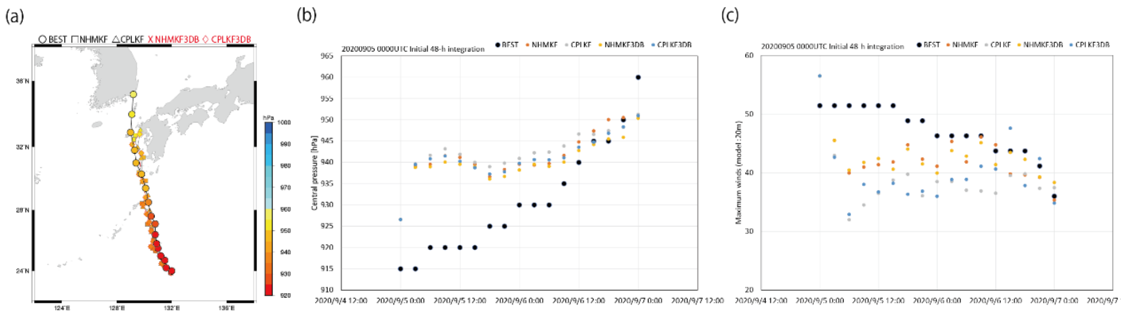

Figure 2 (a) Simulated tracks together with the Regional Specialized Meteorological Center (RSMC) Tokyo best track. (b) Simulated central pressures together with the RSMC best track central pressure. (c) Simulated maximum wind speeds at the height of 20 m together with the RSMC best track maximum wind speed at the height of 10 m. The interval of plots is 3 hours.

Figure 2a shows the results of track simulations together with the Regional Specialized Meteorological Center

(RSMC) Tokyo best track (https://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/besttrack.html). All simulated tracks are reasonable to the best track although the moving speed of simulated Haishen is relatively slow. There is no impact of ocean coupling and different SST distribution at the initial time on the track simulation. Figures 2b and 2c show the result of Haishen's intensity simulations. Differently from the result in the intensification phase (Wada, 2021), there is less impact of ocean coupling and different SST distribution at the initial time on the simulated central pressures (Fig. 2b). However, the effect of ocean coupling on the simulated maximum wind speed is obvious (Fig. 2c). In other words, a simulated wind-pressure relationship is changed due to ocean coupling.

3.2 SST and Inner-core structural change

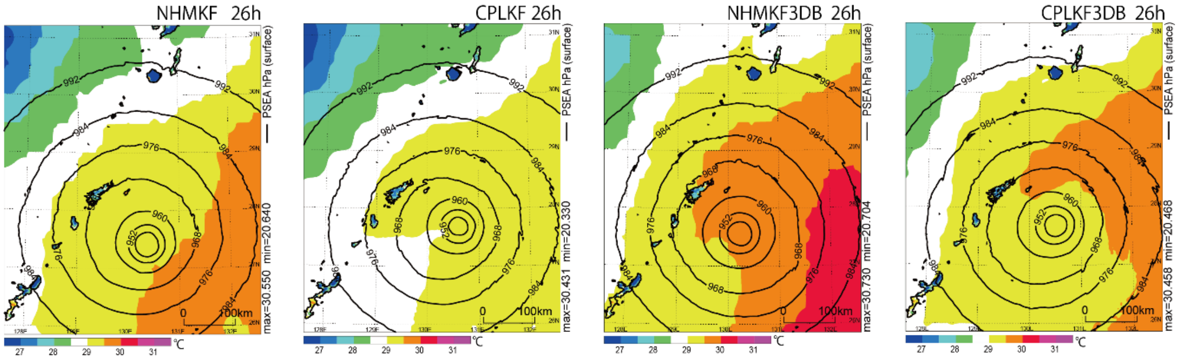

Figure 3 The horizontal distribution of SST in the experiments NHMKF, CPLKF, NHMKF3DB and CPLKF3DB at the 26-h integration time.

Figure 3 shows the horizontal distribution of SST at the 26-h integration time in the experiments NHMKF, CPLKF, NHMKF3DB and CPLKF3DB. In the experiments NHMKF and NHMKF3DB, the SST distribution is fixed during the integration. In the experiments CPLKF and CPLKF3DB, sea surface cooling is simulated by the passage of simulated Haishen. However, the SST in the vicinity of the center of Haishen keeps 29~30 °C at the 26-h integration time in all experiments.

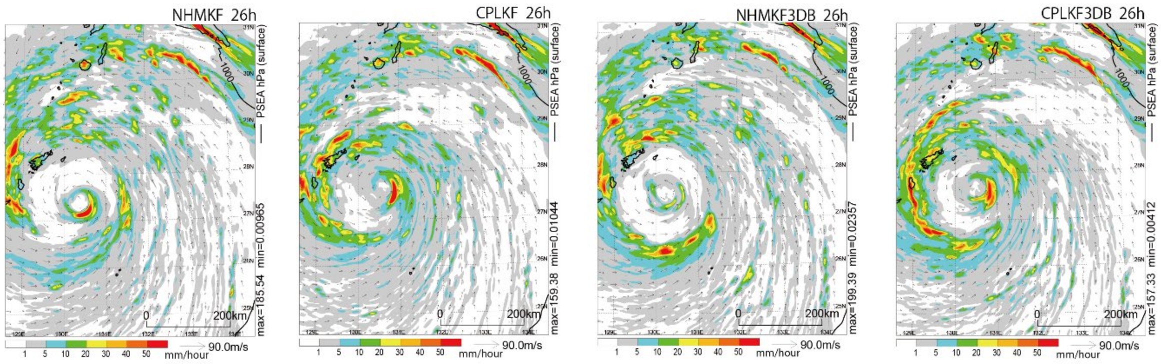

Figure 4 The horizontal distribution of hourly rainfall (shades), sea-level pressure (contours) and surface winds (vectors) in the experiments NHMKF, CPLKF, NHMKF3DB and CPLKF3DB at the 26-h integration time.

Figure 4 shows the horizontal distribution of hourly precipitation around the center of simulated Haishen at the 26-h integration time in the experiments NHMKF, CPLKF, NHMKF3DB and CPLKF3DB. Concentric eyewall in the vicinity of the center of simulated Haishen is clearly simulated at the 26-h integration time in the experiments NHMKF and NHMKF3DB. However, the innermost eyewall collapses at the 26-h integration time in the experiments CPLKF and CPLKF3DB. The result suggests that ocean coupling may be related to the corruption of the innermost eyewall as is shown in Fig. 1b. In addition, the difference in the initial SST distributions also affects the distribution of hourly precipitation particularly in the outer concentric rainband even though the impact of the simulated central pressure is small.

4. Concluding remarks

The 1-km mesh atmosphere-wave-ocean coupled-model simulation with KF cumulus parameterization enables to simulate a multiple eyewall structure and the corruption of the innermost eyewall in the case of Haishen. However, the result of intensity simulation is not realistic. To simulate more accurate intensity of Haishen, the simulation at an earlier integration time should be improved. The model top height (~21km) may be too low for Haishen.

References

Kain, J. S., and J. M. Fritsch (1990). A one-dimensional entraining/detraining plume model and its application in convective parameterization. Journal of the Atmospheric Sciences, 47, 2784-2802.

Wada, A. (2021). Numerical simulations of Typhoon Haishen by a coupled atmosphere-wave ocean model with two different oceanic initial conditions. Research Activities in Earth System Modelling, Submitted.

Wada, A., S. Kanada, and H. Yamada (2018). Effect of air–sea environmental conditions and interfacial processes on extremely intense typhoon Haiyan (2013). Journal of Geophysical Research: Atmospheres, 123, 10379-10405.