Sensitivity experiments on axisymmetrization of Typhoon Faxai (2019) just before landfalling in Japan simulated by atmosphere-ocean coupled model

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1. Introduction

Typhoon Faxai (2019) made landfall in Chiba Prefecture on September 9, causing a serious disaster mainly in the Boso Peninsula. When the typhoon entered Tokyo Bay from Sagami Bay, the 1-hour rainfall distribution analyzed every 10 minutes showed the structural change from the symmetric to axisymmetric pattern (Fig. 1). In fact, rainfall increased from 16 UTC to 18 UTC on September 8 over Sagami Bay, corresponding to the eyewall or primary rainband formation south of the typhoon center. In general, it is known that a typhoon changes its structure from an axisymmetric to an asymmetric pattern in mid-latitude, and then it is often transited into an extratropical cyclone. In this regard, the axisymmetrization of Faxai is an unusual phenomenon. In order to understand the role of the ocean and the topography in the axisymmetrization, sensitivity numerical experiments were performed by using a coupled atmosphere-wave-ocean model (Wada et al., 2018).

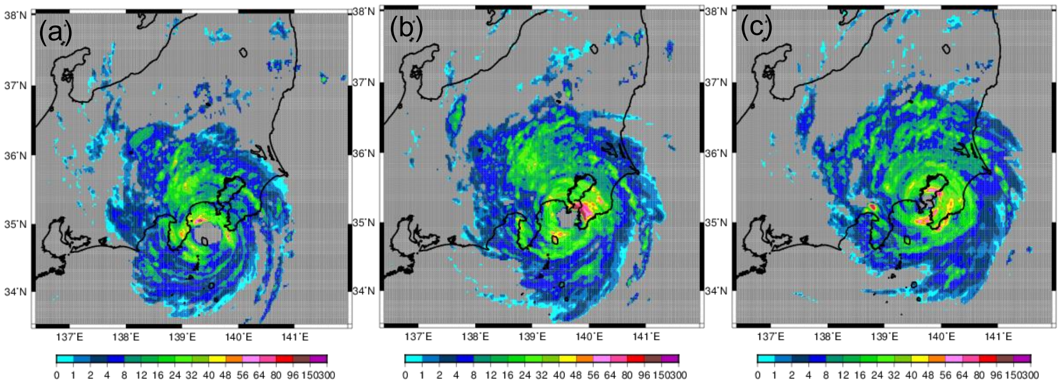

Figure 1 The 1-hour rainfall distribution analyzed every 10 minutes (mm/hour) at (a) 16 UTC, (b) 17 UTC and (c) 18 UTC.

2. Experimental design

Table1 List of numerical simulations

Name	*Model*	*Ocean*	*Topography*
CPL	Coupled NHM-wave-ocean model	2019	Default
CPLAVE	Coupled NHM-wave-ocean model	Climatology	Default
CPL100m	Coupled NHM-wave-ocean model	2019	100m in the Kanto area
CPLizu2	Coupled NHM-wave-ocean model	2019	Twice in the Izu Peninsula

The list of numerical simulations is shown in Table 1. Each initial time was 0000 UTC on September 8. The computational domain was 960 x 1260 km. The number of the vertical layer was 55. The top height was approximately 27 km. The integration time was 36 hours. The time step was 3 seconds for NHM, 18 seconds for the ocean model, and 6 minutes for the ocean surface wave model.

The physical components were exchanged between NHM, the ocean model, and the ocean surface wave model every time step of a model with a longer time step. 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. In addition, climatological oceanic averaged data are calculated by using the oceanic reanalysis data from 1982 to 2018 (Usui et al., 2017). When the climatological data are used in the simulation, 'AVE' is added to the end of the experiment name shown in Table 1. In addition, two sensitivity numerical experiments were performed on topography. One was to set the altitude in the Kanto area to 100m, and the other was to set the altitude double in the Izu Peninsula.

3. Results

3.1 Radius of maximum wind speed

Figure 2 shows the time series of simulated maximum surface wind speed and its radius. After around 12UTC on September 8, the simulated maximum surface wind speed greatly increased compared with the Regional Specialized Meteorological Center Tokyo best track maximum surface wind. It should be noted that the time representativeness of simulated surface winds is less than 1 hour because instantaneous values are used for the analysis of the simulations. Another reason for the large difference in maximum surface winds at the initial time is that there is a large difference between early anasysis and confirmed best track data. While the simulated maximum surface wind increased, the radius certainly reduced in all the four simulations.

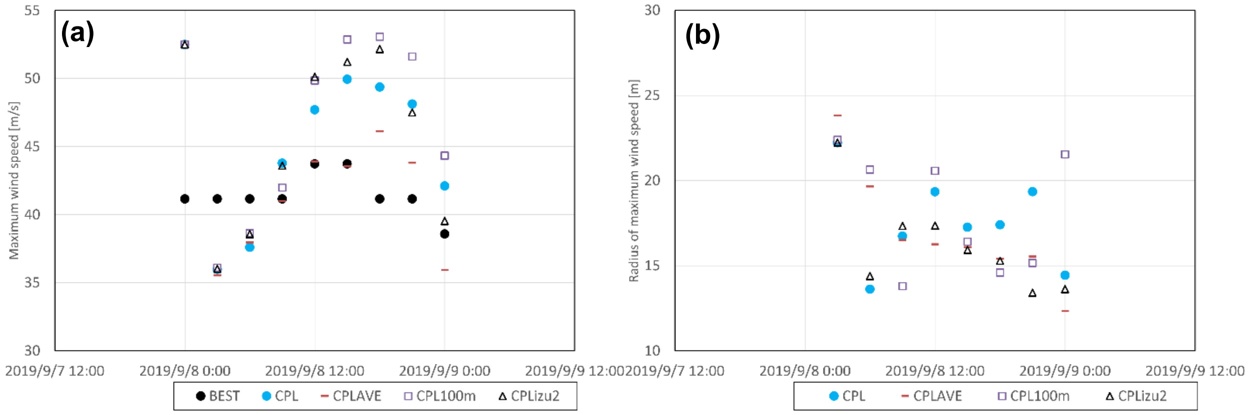

Figure 2 Time series of (a) simulated maximum surface wind speed and (b) simulated radius of the maximum surface wind speed.

3.2 Rainfall distribution

Figure 3 shows the horizontal distributions of 1-hour accumulated rainfall in the four experiments simulated by the coupled model. Rainfall at the eyewall west of the typhoon center ('A') was simulated much more than the analysis shown in Fig. 1. A primary rainband south of the typhoon center ('B') was simulated in the CPLAVE and CPLizu2 experiments although it was not analyzed in Fig. 1a. A rainfall shield northwest of the typhoon center ('C') was not simulated in the CPL100m experiment. These results indicate the effect of oceanic environment represented by the difference between real and climate oceanic conditions on the rainfall amount and that of topography on the rainfall distribution. Without the topography, axisymmetrization of the rainfall pattern in the CPL100m experiment would be more concentric than that in the other experiments. It should be noted that there is a difference in the horizontal distribution of simulated sea surface temperature in between CPLAVE and the other experiments: in the CPLAVE experiment, sea surface cooling was induced by Faxai along the typhoon track, while another sea surface cooling was salient west of Sagami Bay in the other experiments (not shown).

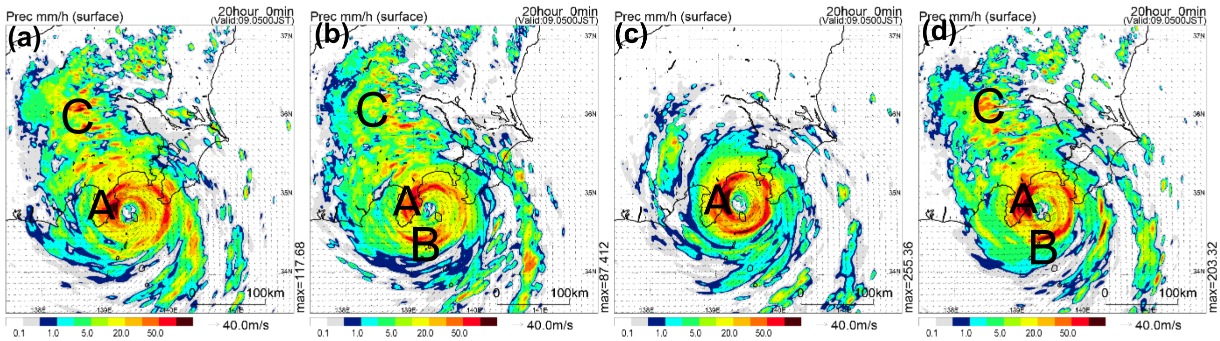

Figure 3 The 1-hour accumulated rainfall distribution simulated by the atmosphere-wave-ocean coupled model in the (a) CPL, (b) CPLAVE, (c) CPL100m and (d) CPLizu2 experiments.

4. Concluding remarks

The coupled model can simulate axisymmetrization regardless of the oceanic initial conditions and topographical setting. In other words, factors that cause the axisymmetrization may be related to another factor such as atmospheric environmental condition and its associated typhoon track.

References

Usui, N, T. Wakamatsu, Y. Tanaka, N. Hirose, T. Toyoda, S. Nishikawa, et al, (2017), Four-dimensional variational ocean reanalysis: a 30-year high-resolution dataset in the western North Pacific (FORA-WNP30). Journal of Oceanography, 73, 205-233.

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