Rainfall simulations of Typhoons Kammuri and Phanfone landfalling in the Philippines

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1. Introduction

In the Philippines, 4-5 typhoons make landfall in a year on average. In 2019, five typhoons made landfall in the Philippines. Heavy rain and strong winds associated with the typhoons often cause natural disasters in the Philippines. Wada and Gile (2019) showed that cumulation parameterization in a nonhydrostatic atmospheric model (NHM) is required to accurately simulate the distribution of rainfall associated with a typhoon. However, other factors affecting rainfall simulations such as the mutual effect between ocean coupling and cloud physics have not been investigated so far. The purpose of this study is to investigate the effects of ocean coupling and inhibition rates of evaporation of rain, snow and graupel included in the cloud physics on the rainfall simulation in the cases of Typhoon Kammuri and Phanfone using the NHM coupled with the multilayer ocean model and the third-generation ocean surface wave model (CPL) (Wada et al., 2010, 2018).

2. Experimental design

The list of numerical simulations is shown in Table 1. Each initial time was 0000 UTC on November 27 for Kammuri and 0000 UTC on December 23. The computational domain was 4800 x 2400 km for Kammuri’s simulation and 2700 x 2400 km for Phanfone’s simulation. The number of the vertical layer was 55. The top height was approximately 27 km.

Table1 List of numerical simulations

Name	*Model*	*Evaporation Inhibition Rate*	*Typhoon cases*
NHM EVP0	NHM	0	Kammuei (2019/11/27/0000)
CPL EVP0	Coupled NHM-wave-ocean model	0	Phanfone (2019/12/23/0000)
NHM EVP1	NHM	1	
CPL EVP1	Coupled NHM-wave-ocean model	1	

The integration time was 168 hours for Kammuri and 72 hours for Phanfone. 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) global objective analysis with horizontal resolution of 20 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. Tropical Cyclone Database (https://sharaku.eorc.jaxa.jp/TYP_DB/index_e.html) is used to obtain the Global Precipitation Measurement (GPM) Microwave Imager (GMI) and the Dual-frequency Precipitation Radar (DPR) data,

3. Results

3.1 Kammuri

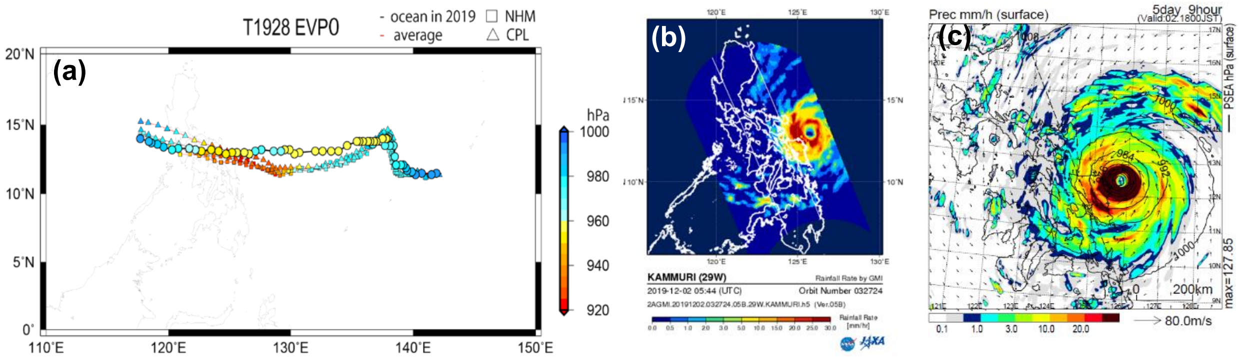

Figure 1 (a) Early analysis on the track and central pressure (hPa) of Typhoon Kammuri and simulation results. (b) Horizontal distribution of hourly rainfall obtained from GMI. (c) Horizontal distribution of simulated hourly rainfall at the 129-hour integration time in the CPL EXP0 experiment.

Figure 1a shows the results of track and central pressure simulations together with the results of early analysis. The tracks in the four experiments with the inhibition rate of 0.0 are reasonably simulated compared with the early analysis. However, the simulated central pressures are relatively low around 125-130˚E before making landfall in the Philippines. In fact, the hourly rainfall distribution obtained from GMI shows the robustness of the eyewall (Fig. 1b). In addition, a primary rainband is remarkable along the eastern coast of the Samar island. The simulation result in the CPL EXP0 experiment captures these features to some extent (Fig. 1c). The effect of oceanic initial conditions on the intensity and rainfall distribution is relatively small compared with that of ocean coupling (not shown).

3.2 Phanfone

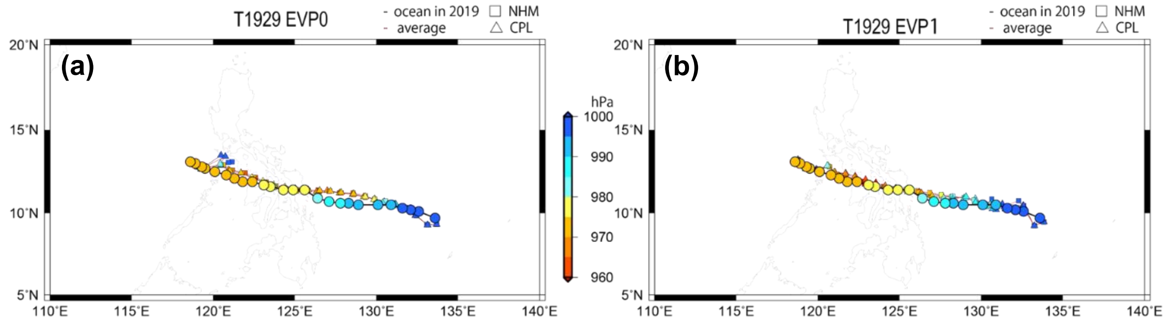

Figure 2 Early analysis on the track and central pressure (hPa) of Typhoon Phanfone and simulation results (a) in the EVP0 experiments and (b) in the EVP1 experiments.

Figure 2 shows the results of track and central pressure simulations together with the results of early analysis in the EVP0 (Fig. 2a) and EVP1(Fig. 2b) experiments. The difference of the inhibition rate slightly affects the simulated track. The change in the track simulation also affects the evolution of central pressure simulations. In this case, the effect of oceanic initial conditions on the intensity and rainfall distribution is also relatively small compared with that of ocean coupling (not shown). This suggests that ocean coupling is the most crucial process for improving the simulation of hourly rainfall distribution.

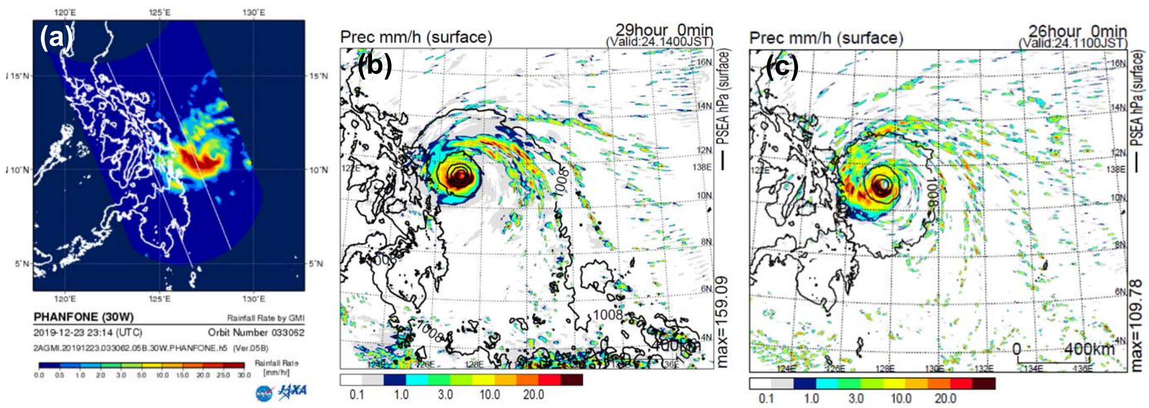

Figure 3 (a) Horizontal distribution of hourly rainfall of Typhoon Phanfone obtained from GMI. (b,c) Horizontal distribution of simulated hourly rainfall (B) at the 29-hour integration time in the CPL EXP0 experiment and (c) at the 26-hour integration time in the CPL EXP1 experiment .

Figure 3 shows the horizontal distribution of analyzed and simulated hourly rainfall. The pattern consists of broad primary rainband south of the typhoon center and relatively narrow spiral rainbands north of the center. When the inhibition rate of evaporation is set to be 0.0, these two features are not clear, and the pattern becomes more concentric. The two features are reasonably simulated when the inhibition rate of evaporation is set to be 1.0. The results suggest that the setting of the inhibition rate is important to simulate the hourly rainfall distribution in addition to ocean coupling.

4. Future study

It is possible to specify the optimal parameters regarding the inhibition rate of evaporation by verifying the simulation results with the DPR data in a 3-dimentional view. This is one of the plans in the future.

References

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