Rainfall simulations of Typhoon Mangkhut (2018) landfalling in the Philippines

Akiyoshi Wada

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

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

1. Introduction

Typhoon Mangkhut (2018) was generated around the Marshall Islands (12.7°N, 165.4°E) at 12 UTC on 7 September according to the Regional Specialized Meteorological Center (RSMC) Tokyo best track data. It moved westward and the central pressure reached 905 hPa at 12 UTC on 11 September. After that, Mangkhut had sustained the minimum central pressure for approximately three days and then made landfall in the Philippines province of Cagayan late on 14 September while keeping the central pressure of 905 hPa. Heavy rains caused by Mangkhut flooded Luzon Island, causing a lot of damage there. In order to investigate the predictability of precipitation caused by Mangkhut, numerical simulations were carried out using a 3-km mesh non-hydrostatic atmospheric model (NHM) and the atmospheric-wave-ocean coupled model (AWO) (Wada et al., 2010, 2018).

2. Experimental design

Table 1 shows a list of numerical simulations. The initial time was 1200 UTC on 9 September 27. As described in the introduction, the NHM and AWO were used for the numerical simulations. The computational domain was 4600 x 2500 km. The number of the vertical layer was 55. The top height was approximately 27 km. The integration time was 144 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 Kain-Fritsch cumulus parameterization (KF) (Kain and Fritsch, 1990) was used in order to simulate the precipitation more realistically (Wada and Gile, 2019).

Table1 List of numerical simulations

Name	*Model*	*Cumulus Parameterization*	*Typhoon case and initial time*
NHM	NHM	None	Mangkhut (2018/9/9/1200)
AWO	Coupled NHM-wave-ocean model	None	
NHMKF	NHM	KF	
AWOKF	Coupled NHM-wave-ocean model	KF	

In the experiments AWO and AWOKF, 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. The amount of 24-hour accumulated precipitation was calculated by adding up the 0.1°-mesh hourly precipitation obtained from the level-3 standard product of hourly global precipitation dataset of the Global Satellite Mapping of Precipitation (GSMaP: https://sharaku.eorc.jaxa.jp/GSMaP/index.htm) version 04G.

3. Results

3.1 Track and central pressure evolution

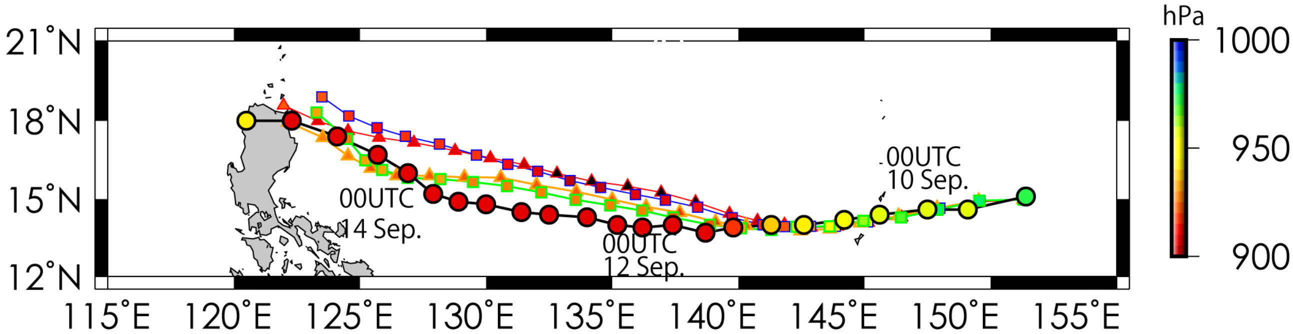

Figure 1 A thick black line with large circles indicates the best track of Mangkhut. Red and orange lines with small triangles indicate the simulation results in the experiments NHM (red) and NHMKF (orange). Blue and green lines indicate the simulation results in the experiments AWO (blue) and AWOKF (green). Colors within the circles indicate the value of central pressure obtained from the RSMC best track data or each experiment.

Figure 1 shows the results of track and central pressure simulations together with the RSMC best track data every 6 hours from 12 UTC on 9 September to 12 UTC on 15 September. The westward movement of Mangkhut analyzed in the best track data is reasonably simulated in all simulations although the northward deflection is obvious. Irrespective of ocean coupling, the northward deflection of simulated track becomes mitigated when the KF parameterization is used. Although the moving speed of simulated Mangkhut is relatively low compared with that in the best track data, the landfall location is well simulated in the NHMKF and AWOKF simulations

Figure 2 shows the RSMC best-track central pressure evolution together with the simulation results in all experiments. The effect of ocean coupling on the simulated central pressure starts to appear in the intensification phase of Mangkhut on 10 September. In the experiments NHM and AWO, the values of simulated central pressure are comparable to those of best-track central pressure. In the experiments NHMKF and AWOKF, however, the values of simulated central pressure are approximately 20 hPa higher at 12 UTC on 12 September than those in the experiments NHM and AWO although the track simulations become better in the experiments NHMLF and AWOKF.

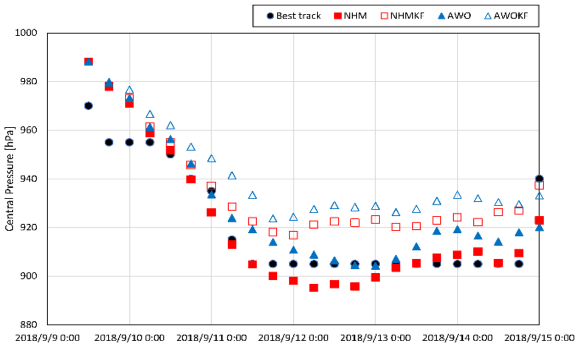

Figure 2 The evolution of RSMC best-track central pressure and simulated central pressures in the experiments NHM, AWO, NHMKF, and AWOKF.

3.2 24-h accumulated precipitation

Figure 3a shows a horizontal distribution of 24-hour accumulated precipitation on 12 September obtained from GSMaP data. The 24-hour accumulated precipitation was calculated by summation of hourly precipitation data. The amount of 24-h accumulated precipitation exceeds 200 mm near the track of Mangkhut. In addition, the area of 24-h accumulated rainfall exceeding 10 mm extends from north (~18°N) to south (~10°N). In the experiment AWO, the area over 200 mm shifts eastward because of slow translation of simulated Mangkhut (Fig. 3b). In addition, the area of 24-hour accumulated rainfall is meridionally narrower than that obtained from GSMaP. In the experiment AWOKF, the noise-like fine rainfall distribution is removed/smoothed due to the effect of KF (Fig. 3c). The eastward shift of the area over 200 mm caused by the slow translation in the experiment AWO is not seen in the experiment AWOKF. It is probably because of less northward shift of simulated track in the experiment AWOKF (Fig. 1).

It should be noted that the impact of ocean coupling on the horizontal distribution of 24-hour accumulated precipitation is small (not shown). This implies that excessive precipitation along the track of Mangkhut and relatively small precipitation in the surrounding indicate the necessity of the improvement of cloud physics and cumulus parameterization to simulate the precipitation distribution of the typhoon more accurately.

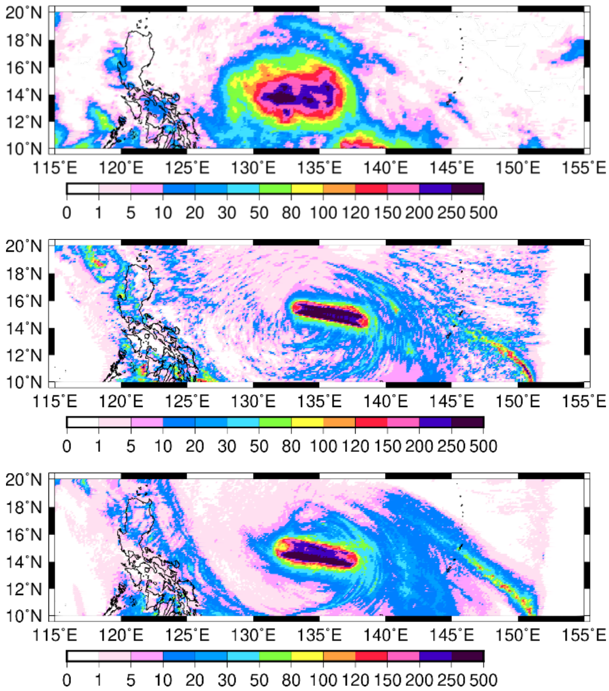

Figure 3 Horizontal distributions of 24-hour accumulated rainfall calculated by summation of hourly rainfall data from 00 UTC to 23 UTC on 12 September obtained from (a) GsMAP, (b) the experiment AWO, and (c) the experiment AWOKF.

4. Ongoing work

The final goal of this study is to improve the accuracy of simulation of precipitation when typhoons make landfall in the Philippines. In situ rainfall observations in the Philippines are needed to investigate the predictability of heavy precipitation caused by typhoons during the landfalling. Moreover, it is necessary to improve the track prediction of typhoons to validate simulation results with in-situ observations. The result in this report shows that the key physical process for both rainfall simulation and improvement of typhoon track prediction is a cumulus parameterization. Tuning the parameter in the cumulus parameterization will be one of the challenging works for simulating Mangkhut more accurately.

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

Wada, A. and R.P.Gile (2019). Roles of ocean coupling and cumulus parameterization in predicting rainfall amounts caused by landfalling typhoons in the Philippines. Research activities in atmospheric and oceanic modelling. CAS/JSC Working Group on Numerical Experimentation. Report No. 49. WCRP Report No.12/2019. WMO, Geneva, pp. 9.07-9.08.

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.