Numerical simulations of shield-like precipitation pattern in the Eastern China Sea remotely enhanced by Typhoon Nepartak (2016)

*Akiyoshi Wada[1], Hiroshige Tsuguti[1] and Hiroyuki Yamada[2]

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

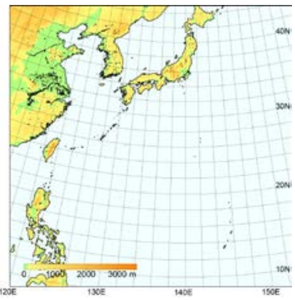
[2]University of the Ryukyus, Nakagami-gun, Okinawa, 903-0213 JAPAN

*awada@mri-jma.go.jp

1. Introduction

Typhoon Nepartak was the first tropical cyclone in the typhoon season of 2016. According to the Regional Specialized Meteorological Center (RSMC) Tokyo best track analysis, the typhoon was generated around 8.9˚N, 144.9˚E and reached the minimum central pressure of 900 hPa at 0600 UTC on 6 July in 2016. Then, the typhoon made landfall in Taiwan at 2150 UTC on 7 July (https://en.wikipedia.org/wiki/Typhoon_Nepartak_(2016)).

During the west northwestward translation of Nepartak, distant rainbands induced by the typhoon propagated toward the Amami Islands. The rainbands formed a shield-like precipitation pattern in the Eastern China Sea. Then the precipitation pattern formed a low pressure area that caused heavy rainfalls in the southern part of Kyusyu. In order to clarify the formation process of the precipitation pattern, numerical simulations were performed by using a nonhydrostatic atmosphere model coupled with ocean and ocean wave models (Wada, 2010). Hereafter, the atmosphere model is called NHM and the coupled model is called CPL.



2. Data and method

Figure 1 shows the computational domain. It covered a 4140 km x 4140 km area with a horizontal grid spacing of 3 km. The integration time was 120 hours with the time steps of 3 seconds in the NHM, 18seconds in the ocean model and 10 minutes in the ocean wave model. The initial time was 1800 UTC on 4 July in 2016. NHM had 55 vertical levels with variable intervals from 40 m for the near-surface layer to 1013 m for the uppermost layer. The top height was ~26 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 a horizontal grid spacing of 0.5˚. The control and sensitivity experiments were shown in Table 1. For sensitivity numerical experiments, the Kain-Fritsch cumulus parameterization was used in the KF experiment to perform numerical simulations by the NHM and CPL. The inhibition rate of evaporation of rain, snow and graupel was set to 0.3 (EVP03), 0.5 (EVP05) and 0.7 (EVP07), respectively.

Table 1 Control and sensitivity experiments. KF indicates the Kain-Fritsch parameterization scheme.

Experiment	KF	Inhibition rate (rain, snow, graupel)
CNTL	No	0.5
KF	Yes	0.5
EVP03	No	0.3
EVP07	No	0.7

3. Results

3.1 Track and central-pressure simulation

Figure 2 shows results of track and central pressure simulations for 120 hours started from 1800 UTC on 4 July. The simulated tracks had southward biases at an earlier integration time and then changed the direction northwestward so that the simulated typhoon made landfall in the northern Taiwan region. The peak intensity represented by minimum central pressure was well reproduced in the KF experiment (873 hPa) when the NHM was used for the simulation. However, the lowest minimum central pressure was 903.6hPa in the EVP03 experiment when the CPL was used. The cumulus parameterization did affect track and central pressure simulations even when the CPL was used. For Nepartak case, errors in the KF experiment became increased compared with those in the other three experiments (CNTL, EVP03 and EVP07). It should be noted that the time of the peak intensity of the RSMC best track analysis was later than that simulated by the NHM and CPL in all four experiments. In particular, the time of the peak intensity simulated by the CPL was fastest due to the effect of sea surface cooling induced by the simulated typhoon. The error associated with the intensity change was considered to affect the simulation of the shield-like precipitation pattern.

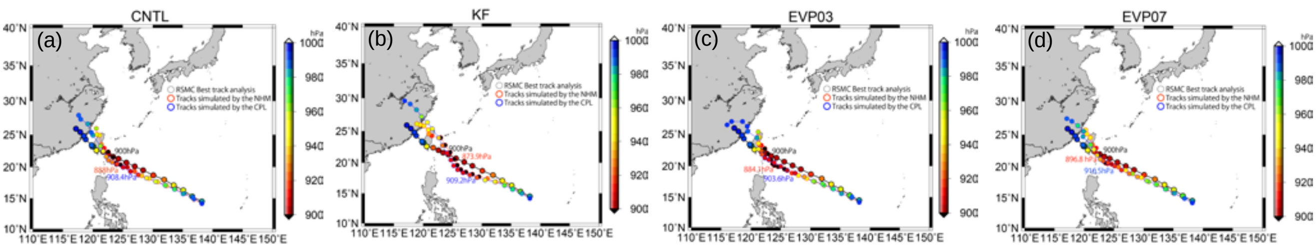


Figure 2 Results of track simulations of Nepartak with simulated central pressures in (a) CNTL, (b) KF, (c) EVP03 and (d) EVP07 simulated by the NHM and CPL, respectively. The RSMC best track was overlaid with black circles in the panels. Red circles indicated results by the NHM, while blue circles indicated those by the CPL.

3.2 Simulated shield-like precipitation pattern

Figure 3(a) shows the horizontal distributions of hourly precipitation at 1500 UTC on 7 July depicted from the Radar-Raingauge analyzed precipitation dataset estimated on the basis of radar observations calibrated with rain-gauge measurements from the Japan Meteorological Agency (JMA) Automated Meteorological Data Acquisition System (Makihara 1996). A shield-like precipitation pattern propagated northward far from the Nepartak existed around the Amami Islands. The CNTL experiment captured a shield-like precipitation pattern to some extent although the simulated pattern was located in the Eastern China Sea (Figure 3b). In the KF experiments, the precipitation pattern looked like a spiral distant rainband extending to the east and west (Figure 3c). The precipitation area was advected by southwesterly winds that were a part of the cyclonic circulation of Nepartak. The extent of the precipitation area was related to the inhibition rate of evaporation of rain, snow and graupel. In the EXP03 experiment, the area was relatively small (Figure 3d), while it was relatively large in the EXP07 experiment (Figure 3e). In Figures 3b-e, the impact of the KF parameterization on the precipitation pattern was outstanding.

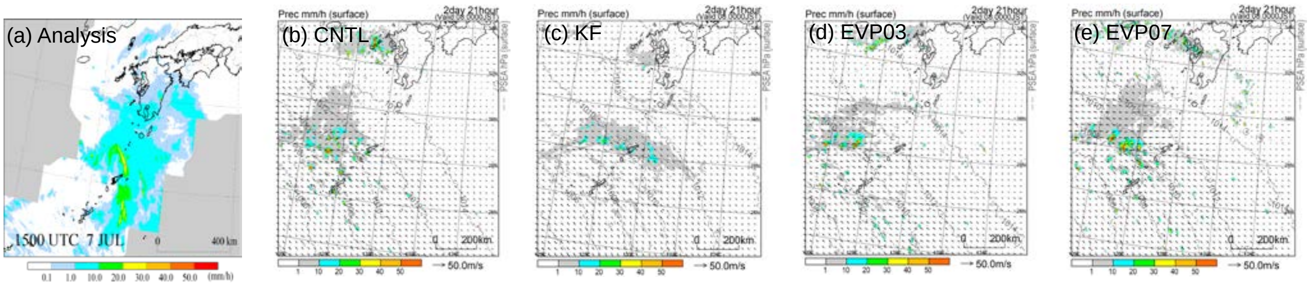


Figure 3 Horizontal distributions of hourly precipitation (shades) with sea-level pressures (contours) at 1500 UTC on 7 July in (a) the Radar-Raingauge analyzed precipitation dataset estimated on the basis of radar observations calibrated with rain-gauge measurements, (b) CNTL, (c) KF, (d) EVP03 and (e) EVP07 simulated by the CPL. Contour intervals are 2 hPa.

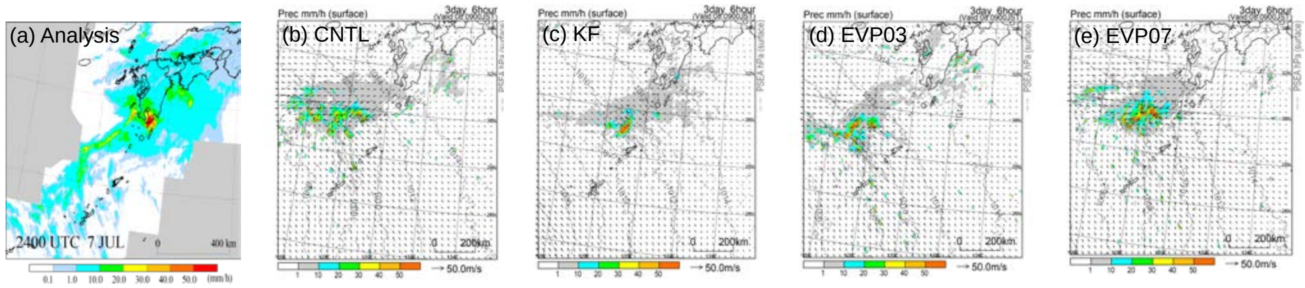


Figure 4 Same as Figure 3 except at 0000 UTC on 8 July.

As is shown in Figure 4a, the precipitation area moved eastward at 0000 UTC on 8 July. Local heavy rainfall included in a broad shield-like precipitation area was observed in the southern Kyusyu region. Results of numerical simulations indicated that the local heavy rainfall and a broad shield-like precipitation were reasonably simulated (Figures 4b-e) particularly in the KF experiment (Figure 4c) although the location quite differed between the analysis and the simulations. In addition, small low pressure analyzed in the weather map (not shown) was simulated in the simulations with the decrease in sea-level pressure of 1.5 hPa in the KF experiment (not shown).

4. Concluding remarks

Nepartak induced distant rainbands that propagated northward toward the Amami Islands. The behavior of the rainbands and resultant shield-like precipitation pattern were reasonably simulated by NHM (not shown) and CPL. This study demonstrated the sensitivity of the precipitation pattern to the cumulus parameterization and cloud physics. However, the location of the shield-like precipitation pattern was not successfully simulated. The effect of the track of simulated typhoon with exact moving speed on the location will be a future subject of this study although the effect was not substantially modified by alternation of the inhibition rate of rain, snow and graupel and the cumulus parameterization. In addition, formation processes of the shield-like precipitation pattern will be clarified by using the results of numerical simulations.

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