

Rapid intensification of Typhoon Roke in 2011

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1. Introduction

Typhoon Roke moved anticyclonically around the South Borodino Island from 16 to 19 September in 2011 and then turned to move northeastward. During the northeastward translation, Roke reached a central pressure minimum of 940 hPa. A decrease of central pressure was 30 hPa in a day just before the typhoon reached the central pressure minimum. The rapid decrease of central pressure indicates that the typhoon rapidly intensified south of Japan, around the Kuroshio region.

In 2011 typhoon season, sea surface temperature (SST) continued to be low east of the Okinawa Island from the normal value due to the subsequent passages of typhoons (for example, Ma-on, Muifa and Talas). When the typhoon passed around the low SST area, the typhoon intensified less. In addition, the typhoon rapidly intensified around the Kuroshio region where the ocean was warm. Therefore, the oceanic environment is considered to play a crucial role in the rapid intensification of Roke.

In order to understand roles of the ocean in Roke, particularly its rapid intensification, numerical simulations were performed using a nonhydrostatic atmosphere model coupled with ocean wave model and a multi-layer ocean model (Wada et al., 2010). The surface roughness length calculated by the coupled model is derived from the formulation based on wave steepness (Taylor and Yelland, 2001).

2. Experimental design

Summary of numerical simulations performed by the atmosphere-wave-ocean coupled model is listed in Table 1. The coupled model covered nearly a 1600 km x 1600 km computational domain with a horizontal grid spacing of 2 km. The coupled model had 40 vertical levels with variable intervals from 40 m for the near-surface layer to 1180 m for the uppermost layer. The coupled model had maximum height approaching nearly 23 km. The integration time was 84 hours (84 h) with a time step of 6 s in the coupled model. The time step of the ocean model was six times that of the coupled model. Oceanic initial conditions were obtained from the oceanic reanalysis datasets with horizontal resolutions of 0.1° and 0.5° (Table 1) calculated by the Meteorological Research Institute multivariate ocean variational estimation (MOVE) system (Usui, et al., 2006).

Table 1 Summary of ocean coupling/noncoupling, and horizontal resolution of MOVE reanalysis of the coupled model.

Experiment	Ocean coupling	Horizontal resolution of MOVE reanalysis
A1_2km	NO	0.1°
C1_2km	YES	0.1°
A5_2km	NO	0.5°
C5_2km	YES	0.5°

3. Results

Figure 1 illustrates the results of track simulations and the best track of Roke. Simulated Roke moved north-northwestward to westward (anticyclonically) from 0 h to 36 h, whereas the best track of Roke indicates the northward translation along 131° E and then turn to northeastward from 1200 UTC 19 September (36 h integration time). According to the best track, Roke made landfall at Hamamatsu, Shizuoka Prefecture, whereas simulated typhoons made landfall in the Izu Peninsula. A difference of the track simulation caused by a difference of the initial oceanic condition is small (Fig. 1).

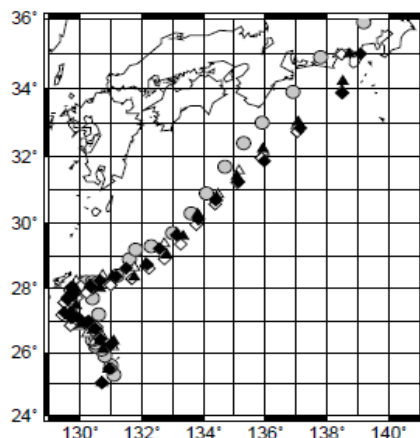


Figure 1 (Best track (gray circle) and simulated tracks in A1_2km (close diamonds), C1_2km (close triangles), A5_2km (open diamonds), and C5_2km (open triangles).

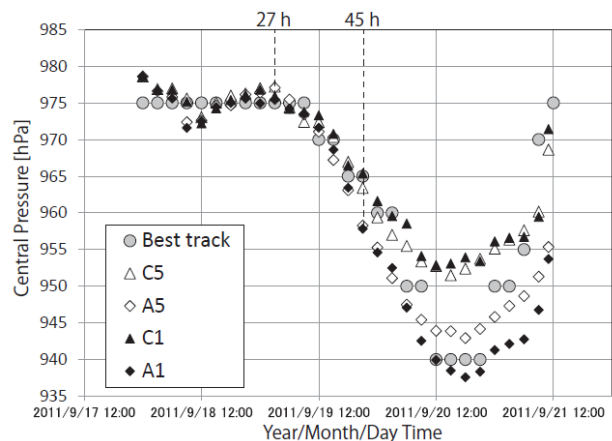


Figure 2 Time series of central pressures in A1_2km (close diamonds), C1_2km (close triangles), A5_2km (open diamonds) and C5_2km (open triangles).

Figure 2 indicates the time series of best-track central pressure and simulated central pressures. The 30 hPa rapid decrease in central pressure in a day was successfully simulated in A1_2km, whereas the rapid decrease was poorly simulated in C1_2km and C5_2km. In addition, there is a clear difference in the simulated central pressure between the oceanic reanalysis datasets of 0.1° and 0.5° horizontal resolutions. The numerical results suggest that sea surface cooling due to a passage of Roke hardly contribute the rapid intensification of Roke. In addition, oceanic environments play a crucial role in the rapid intensification.

Figures 3a-d illustrates the horizontal distribution of wind speeds at 20 m height and hourly precipitation at 27 h and 45 h, respectively. At 27 h, a low wind-speed area within a radius of maximum wind speed was clearly seen. The horizontal distribution of the wind speed was asymmetric like a wave-number 1 pattern. Hourly precipitation was high in the eastern phase of the simulated typhoon.

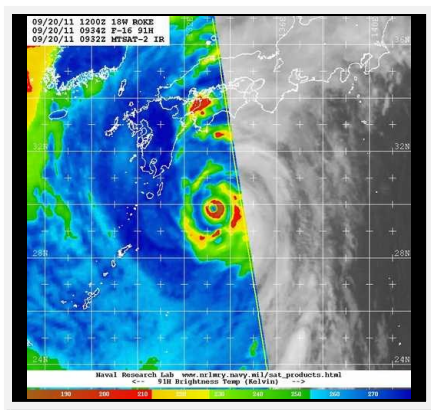


Figure 4 Horizontal distributions of 91GHz brightness temperature observed by SSMIS at 0934 UTC on 20 September (This panel is cited by http://www.nrlmry.navy.mil/tc-bin/tc_home2.cgi).

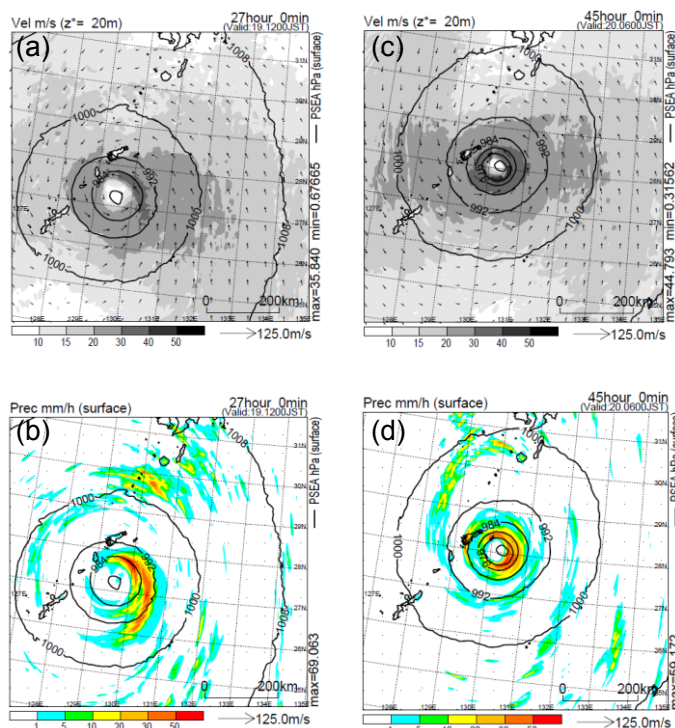


Figure 3 Horizontal distributions of (a) wind speeds at 20 m height at 27 h, (b) hourly precipitation at 27 h, (c) wind speeds at 20 m height at 45 h and (d) hourly precipitation at 45 h.

At 45 h, a low wind-speed area within a radius of maximum wind speed was narrower than that at 27 h. The horizontal distribution of the wind speed became close to the axisymmetric pattern. The maximum wind speed appeared in the southern phase of the simulated typhoon. The horizontal distribution of hourly precipitation indicates that the typhoon was shrinking during its rapid intensification. However, SSMIS microwave observation (Fig. 4) indicates secondary eyewall formation outside the primary (axisymmetric) eyewall. Moat between primary and secondary eyewalls clearly appeared in Fig. 4. This implies that finer horizontal resolution is needed to resolve the inner core dynamics of Roke. Higher horizontal resolution than 2 km is expected to develop the simulated Roke more excessively. The ocean coupling may contribute the suppression of the excessive development.

4. Discussion and conclusion

The results of the numerical simulations for Roke suggest that the horizontal resolution of 2 km is insufficient to simulate the intensity and structural change of Roke although the nonhydrostatic atmosphere model without ocean coupling well reproduce a rapid decrease of central pressure, 30 hPa in a day. We need to perform numerical simulations for Roke with a horizontal resolution less than 2 km. One of interesting themes for Roke is secondary eyewall formation and formation of concentric eyewall. In this study, an westward track error at an early integration may interrupt the secondary eyewall formation due to topography at the Amami Islands.

Acknowledgement

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