The impact of oceanic initial conditions on the simulations of Typhoon Ma-on in 2011

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1. Introduction

Typhoon Ma-on was one of the three typhoons (Typhoons Ma-on, Talas, and Roke) that made landfall in Japan during the 2011 typhoon season. Ma-on was generated at 18.4°N, 156.6°E at 1800 UTC on 11 July 2011. Ma-on moved westward during its developing phase and changed to a northwestward track during its mature phase according to the Regional Specialized Meteorological Center (RSMC) Tokyo best-track data. This study addresses the sensitivity of the difference of oceanic initial conditions due to the difference of the horizontal resolution of oceanic reanalysis data to the simulations of the typhoon. This study also addresses the difference of the impacts between results of a single atmosphere model and an atmosphere-wave-ocean coupled model (Wada et al., 2010).

2. Experimental design

Summary of numerical simulations performed by the atmosphere-wave-ocean coupled model (Wada et al., 2010) is listed in Table1. The coupled model covered nearly a 2800 km x 2100 km computational domain with a horizontal grid spacing of 3 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 120 hours (120 h) with a time step of 8 seconds in the atmospheric part of the coupled model. The time step of the ocean model was six times that of the coupled model and that of the ocean wave model was 10 minutes.

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). Figure 1 displays horizontal distributions of sea surface temperature used in this study. The differences appeared at areas of warm temperature around 22°N, 140°E, south of Japan corresponding to the Kuroshio, and frontal temperature structure north of 30°N.

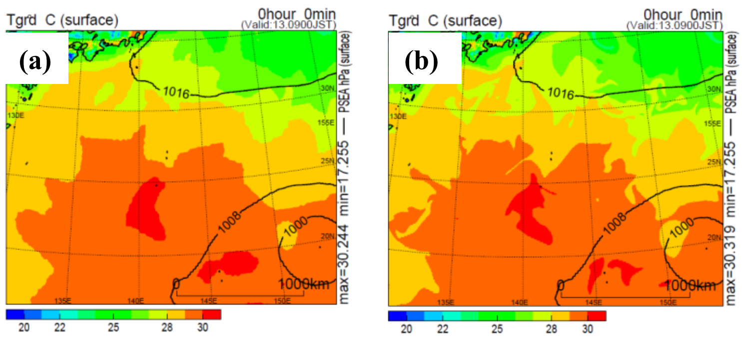

Figure 1 Horizontal distributions of sea surface temperature (shades) and sea-level pressure (contours) at the initial time in experiments (a) A5 and C5, and (b) A1 and C1. The contour interval is 8 hPa.

Table 1 Summary of ocean coupling/noncoupling and horizontal resolution of MOVE data

Experiment	Ocean coupling	Horizontal resolution of MOVE data
A5	NO	0.5°
C5	YES	0.5°
A1	NO	0.1°
C1	YES	0.1°

3. Results

Figure 2a indicates time series of the Regional Specialized Meteorological Center Tokyo (RSMC-Tokyo) best track central pressure and simulated central pressure of Ma-on in experiments A5, A1, C5 and C1 from 0000 UTC on 13 July to 0000 UTC on 19 July in 2011. In experiments A1 and A5, the simulated central pressures were lower than the best track central pressures after 1200 UTC on 14 July. In contrast, the simulated central pressures in experiments C1 and C5 were higher than the best track ones before 1500 UTC on 17 July.

Figure 2b depicts the time series of the central pressure deviations of C1-C5 and A1-A5 during the period of the integration. After 1500 UTC on 17 July, corresponding to the decaying phase (Fig. 2a), variations in the central pressure deviations between experiments A1 and A5 were similar to those between experiments C1 and C5. During the mature phase from 1800 UTC on 16 July to 1500 UTC on 17 July, the central pressure deviations between experiments C1 and C5 little changed, while the simulated central pressure in experiment A1 decreased more rapidly than that in experiment A5 during the time.

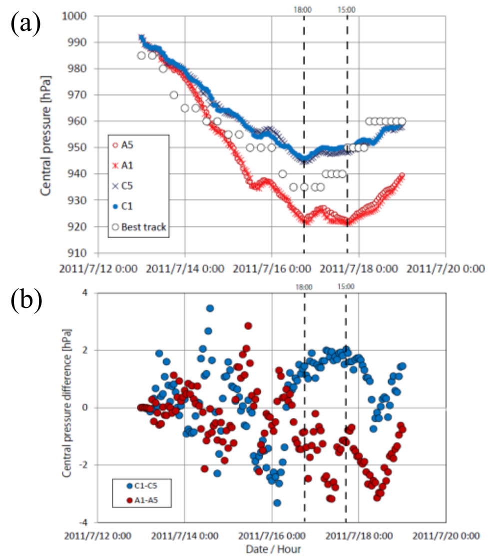

Figure 2 Time series of (a) the best track central pressure (open circles) and simulated central pressure of Ma-on in experiments A5 (red open circles), A1 (red asterisks), C5 (blue cross marks) and C1 (blue closed circles) and (b) central pressure deviations of C1-C5 (blue circles) and A1-A5 (red circles) from 0000 UTC on 13 July to 0000 UTC on 19 July in 2011.

Sea surface cooling induced by a TC can suppress intensification of the TC by delaying the merger of discrete mesovortices (Wada, 2009) indicated by a change in the horizontal distribution of potential vorticity. Figure 3 displayed the horizontal distributions of potential vorticity at 20 m height and sea-level pressure in experiments (a) A5, (b) A1, (c) C5 and (d) C1. In experiments A5 and A1, a ring-like potential vorticity pattern was well simulated at 90 h (1800 UTC on 16 July) with high potential vorticity exceeding 40 PVU (potential vorticity unit). In experiments C5 and C1, we can find a ring-like potential vorticity pattern although the maximum was lower than 30 PVU. All these patterns indicated that the simulated typhoon was mature (Wada, 2009). Compared with the difference between experiments by the atmosphere model alone and the coupled atmosphere-wave ocean model, the difference of the horizontal resolution of MOVE data between 0.5° (Figs. 3a and 3c) and 0.1° (Figs. 3b and 3d) resulted in little difference of the potential vorticity pattern.

Figure 4 depicted time series of mean horizontal specific-humidity (q_v) fluxes within a ring of 60 km widths centered at the radius of maximum wind speed averaged at 1460, 1770, and 2110 m heights, corresponding to 11-13 model levels in all experiments. These heights corresponded to the top of planetary boundary layer where the maximum wind speed appeared.

When Fig. 4 was compared with Fig. 2a, we could find that the variations of mean horizontal q_v fluxes shown in Fig. 4 appeared to be (negatively) correlated with those of simulated central pressures. This suggests that horizontal q_v fluxes could be regarded as a metric for diagnosing simulated central pressures. In particular, the horizontal q_v fluxes clearly decreased from the intensification phase on 15 July due to sea surface cooling. In addition, the deviation in horizontal q_v fluxes kept constant during the mature phase, which was the same characteristic as the deviations of simulated central pressures shown in Fig. 2b.

During the intensification phase, we could find a large variation in horizontal q_v fluxes in experiments C5 and C1 compared with that in experiments A5 and A1. The horizontal distribution of horizontal q_v fluxes showed a wave-number-one pattern and a ring-like pattern of potential vorticity was not formed (not shown). Mesovortices and associated convections within the core of the simulated typhoon may play a crucial role in increasing the q_v fluxes at the top of the planetary boundary layer, affecting the intensification of the simulated typhoon.

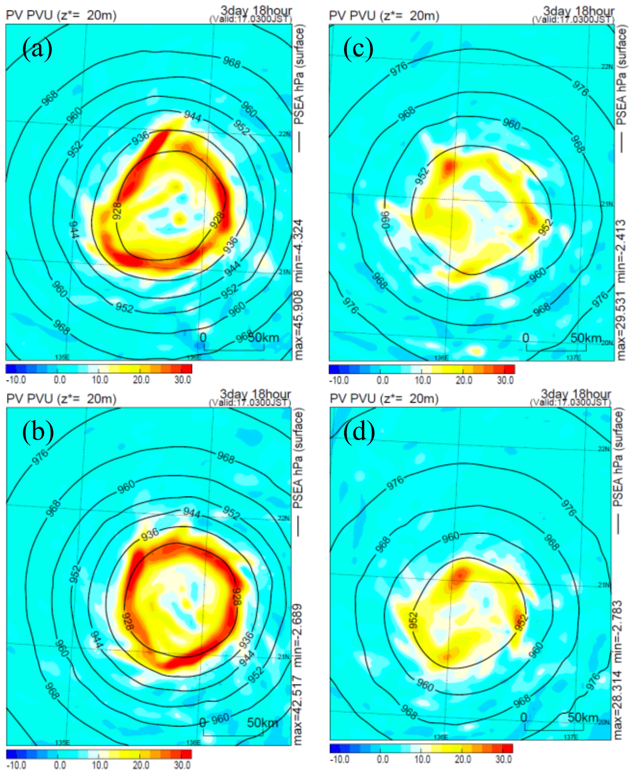

Figure 3 Horizontal distributions of potential vorticity at 20 m height (shades) and sea-level pressure (contours) in experiments (a) A5, (b) A1, (c) C5 and (d) C1. The contour interval is 8 hPa.

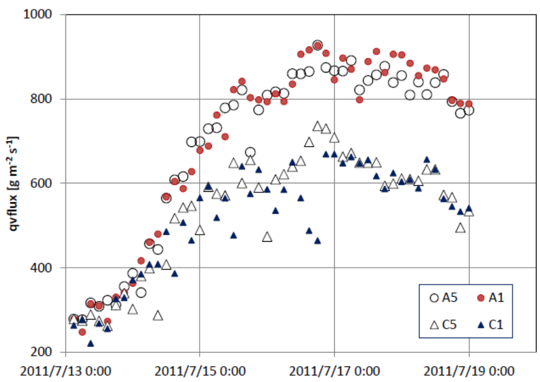

Figure 4 Time series of mean horizontal specific-humidity fluxes within a ring of 60 km widths centered at the radius of maximum wind speed averaged at 1460, 1770, and 2110 m heights, corresponding to 11-13 model levels in all experiments.

4. Discussion and conclusion

This study addresses the impact of the difference of the horizontal resolution of oceanic reanalysis data on the simulations of Ma-on. The impact differs between a single atmosphere model and an atmosphere-wave-ocean coupled model: A higher resolution of oceanic reanalysis data does not always results in a lower simulated central pressure when the coupled atmosphere-wave-ocean model was employed. This study also suggested that horizontal q_v fluxes well corresponds to simulated central pressures. How to determine horizontal q_v fluxes within the inner-core and the relation to oceanic initial conditions will be a subject in the future.

Acknowledgement

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