High-resolution simulation of wind structure in the inner-core of Typhoon MA-ON (2004) and sensitivity experiments of horizontal resolution

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1. Introduction

The record-breaking number 10 of tropical cyclones made landfall on Japan in 2004 and caused a lot of damage throughout Japan due to strong winds, severe flooding, and storm surges. Among them, Typhoon MA-ON (2004) was characterized that it had strong winds in the left-rear quadrant during its passage over the southern portion of Kanto Plain. The primary purpose of the present study is to elucidate the structure and the generation mechanism of strong winds by using the high-resolution cloud resolving model. Moreover, sensitivity tests were conducted to study the impact of horizontal resolution of the numerical model on this event.

2. Characteristics of the strong winds observed during the passage of Typhoon MA-ON in the southern part of Kanto plain occupied by cold air at the low-level

On 9 October 2004, a strong typhoon MA-ON hit Izu peninsula in Eastern Japan and passed through the southern Kanto region. When MA-ON landed, the central pressure was 950 hPa. A strong wind in the left-rear quadrant near the inner-core characterized MA-ON. In the Kanto Plain, about 20 ms^{-1} northerly sustained winds (10-min average) were observed at the north and the west side of the typhoon (Figure 2). Moreover, maximum instantaneous wind of 39.9 ms^{-1} was observed at Yokohama local meteorological observatory after the center of the typhoon passed by (Figure 3), and 1-minute averaged wind of 38.4 ms^{-1} was recorded at the coast of Hiratuka City. Another noteworthy characteristics of MA-ON are as follows. Kanto plain was broadly occupied by cold air at the low-level which was sustained during the passage of MA-ON. The wind directions in the cold air mass under the translating cyclone were quite different from the general feature of tropical cyclones swirling around the typhoon center with some inflow angle.

3. Numerical model and description

Numerical reproduction of the strong wind events in the southern Kanto plain was attempted using a two-way double-nested model (Mashiko and Muroi 2003). This model is based on Meteorological Research Institute/Numerical Prediction Division unified nonhydrostatic model of JMA (MRI/NPD-NHM; Saito et al. 2001). The model domain of the outer mesh with a 6 km horizontal grid size is 3000 km x 2400 km. The inner domain with a 2 km horizontal grid size is designed to explicitly resolve the inner core of the Typhoon and strong wind structure. The vertical grid of both models contains 50 levels with variable grid intervals of 40 m (near the surface) to 904 m (at the top of the domain), and the model top is located at 22.7 km. The initial and boundary conditions were produced from the MANAL and forecasts of the JMA Regional Spectral Model, respectively. In both domains, microphysics with the ice phase is used as precipitation processes, and no convective parameterization scheme is used. The initial time of the outer domain was 21 JST 08 October 2004. The inner domain was initialized at 6-hour forecast by interpolating output from the outer domain, and it was integrated for 18 hours. The sensitivity tests were also conducted by using the single domain run (6 km horizontal resolution) and the triple nested run (0.667 km horizontal resolution in the innermost mesh).

4. Results

Strong winds observed in a narrow area in the left-rear quadrant of MA-ON during its passage over the southern portion of the Kanto Plain were simulated fairly well. Figure 4 shows the simulation result of the equivalent potential temperature at a height of 250 m from the inner domain. The typhoon with high equivalent temperature moved over the cold air mass at the low-level in the Kanto plain. The flow of the cold air mass at the low-level formed just like 'gap flow' between the typhoon center and the mountains in the west of the Kanto plain. A strong wind area greater than 60 ms^{-1} is seen over Sagami Bay, where is corresponding to the gap outflow region. The cold air mass flow decreased in depth in the left-rear quadrant of Typhoon. Trajectory analysis from the model output shows that the parcels associated with the strong winds descended with diffluent flows and accelerated. Figure 5a and 5b show the vertical cross-sections of equivalent potential temperature and horizontal wind, respectively. They show that the strong wind area can be seen only at the low level on the western side of the storm and it corresponds to the cold air mass quite well. This feature of the strong winds was not observed before the landfall. The experiment eliminating the mountains on the western side of the Kanto plain shows that the strong winds of the left-rear quadrant decreased by about 25 ms^{-1} (not shown).

Figure 6 shows the result of the single run with a horizontal grid length 6 km. The strong winds in the left-rear quadrant of the storm were not well reproduced. This experiment was conducted with the same topography as the double nested run, therefore it indicates that the inner core of the typhoon need to be resolved enough in this event. The triple nested run could resolve the detailed structure well, such as the disturbances on the shear line of the cold air mass flow, but the feature of the strong winds in the left-rear quadrant were not so different from those of the double nested run (not shown).

REFERENCES

Mashiko, W. and C. Muroi, 2003: Development of a two-way multiply-nested movable mesh typhoon model using the cloud resolving nonhydrostatic model. CAS/JSC WGNE No.33, 5.22-5.23.

Saito, K., T. Kato, H. Eito and C. Muroi, 2001: Documentation of the Meteorological Research Institute / Numerical Predic-tion Division Unified Nonhydrostatic Model. Technical Re-ports of the MRI, 42, 133pp

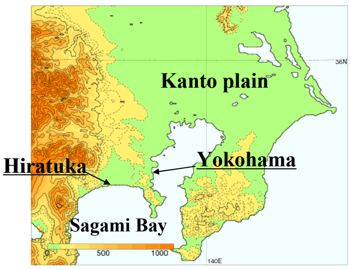

Fig. 1. Geographical map around Kanto plain.

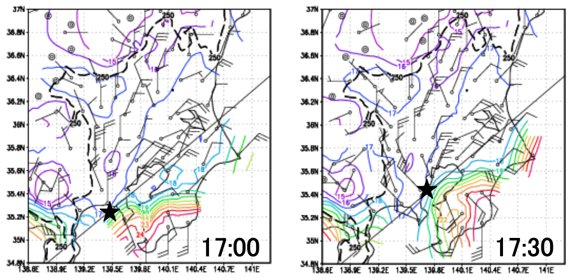

Fig. 2. Distribution of surface winds and temperature from AMeDAS stations (a) at 1700 JST and (b) at 1730 JST 9 Oct. Wind barb and flag represent 5ms^{-1} and 25ms^{-1}, respectively. Solid line shows the track of MA-ON with the estimated center of the storm.

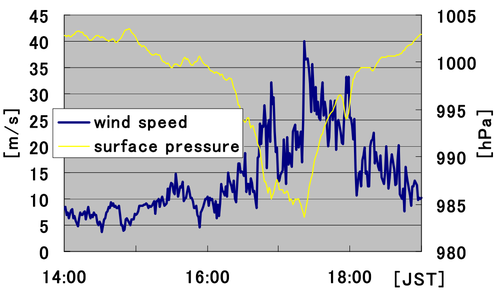

Fig. 3. Time sequence of instantaneous wind speed, sea surface pressure at Yokohama local meteorological observatory between 1400 and 1900 JST.

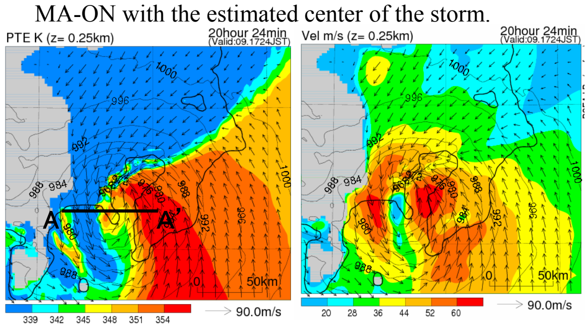

Fig.4. Horizontal distribution of (a) equivalent potential temperature and (b) wind speed at a height of 250 m. Vectors denote the horizontal winds. The area above 250 m height is masked with the gray color.

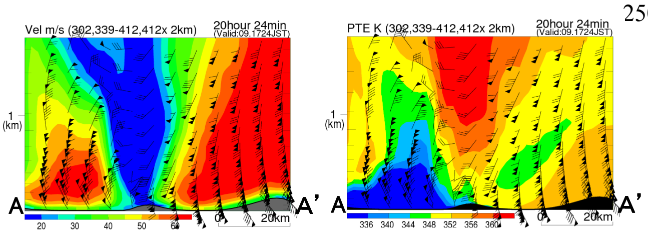

Fig.5. The east-west vertical cross sections of (a) the equivalent potential temperature and (b) the wind speed along the line A-A' in Fig.4a. Full wind barb and flag indicate the horizontal wind speed of 5 ms^{-1} and 25 ms^{-1}, respectively.

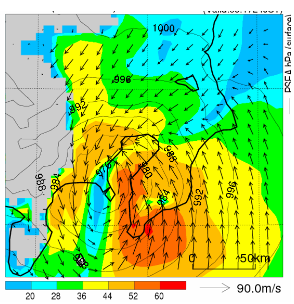

Fig.6. Same as Fig 3a, but the single run with a 6 km horizontal grid length.