Typhoon Man-yi in 2013 simulated by an atmosphere-wave-ocean coupled model with 1.2-km horizontal resolution

Akiyoshi Wada

Meteorological Research Institute, Tsukuba, Ibaraki, 305-0052, JAPAN

awada@mri-jma.go.jp

1. Introduction

Previously, Wada (2015a) concluded for simulations on Typhoon Man-yi (2013) that deep warm water and a steep horizontal water-temperature gradient around the Kuroshio Current region were responsible for excitation of a mesovortex where the horizontal gradients of sea-level pressure and those of tangential winds were steep between the circulation center and the radius of the maximum surface wind. In addition, Wada (2015a) mentioned that rapid intensification of the mesovortex was triggered by the shift of the location of the mesovortex to inside the radius of the maximum surface wind. In order to verify the mechanism, numerical simulations are needed to be conducted by a nonhydrostatic atmosphere model with a horizontal resolution finer than 2 km (Wada, 2014, 2015a). The numerical model with the horizontal resolution less than 2 km is expected to more realistically reproduce a behavior of mesovortices excited inside the radius of the maximum wind speed and associated convective bursts. To that end, numerical simulations were performed by an atmosphere-wave-ocean coupled model (CPL) developed based on the Japan Meteorological Agency (JMA) nonhydrostatic atmosphere model (NHM) with a horizontal resolution of 1.2 km.

2. Model and experimental design

Numerical simulations for Typhoon Man-yi (2013) were conducted by both a regional nonhydrostatic model (NHM) and a regional atmosphere-wave-ocean coupled model (CPL) developed by Wada et al. (2010). Both models covered a ~2000 km x ~2400 km computational domain with a horizontal grid spacing of 1.2 km. Hereafter, 'A' indicates the results by NHM, whereas 'AWO' indicates the results by CPL. Both NHM and CPL had 55 vertical levels with variable intervals from 40 m for the near-surface layer to 1180 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 the horizontal grid spacing of 0.1˚. The initial time was 0000 UTC on 14 September in 2013. The integration time was 54 hours.

3. Results and concluding remarks

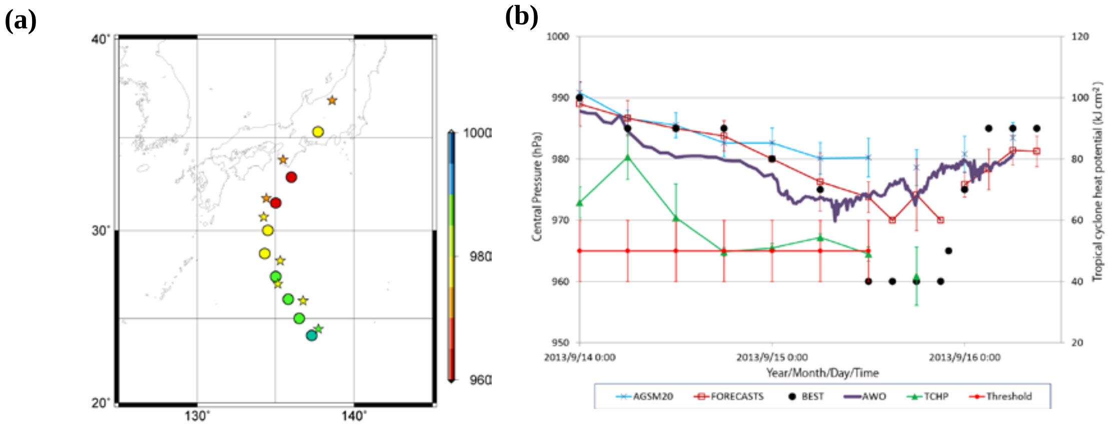

Figure 1 (a) The simulated track by CPL(◊) and the Regional Specialized Meteorological Center Tokyo best track (◯) and (b) time series of simulated central pressure by CPL, the best-track central pressure, predicted central pressure by JMA global spectral model and forecast of central pressures together with tropical cyclone heat potential and the threshold.

Figure 1 shows the simulated track and the Regional Specialized Meteorological Center (RSMC) Tokyo best track positions every 6 hours (Fig. 1a) and the time series of central pressures simulated by CPL (Fig. 1b, AWO) . Figure 1b also presents time series of the best-track central pressures(BEST), central pressures predicted by JMA global spectral model (AGSM20), and forecast of central pressures (FORECASTS) together with tropical cyclone heat potential (TCHP) and the threshold for intensification of a typhoon (Threshold) passed around 26˚-32˚N (Wada, 2015b). It should be noted that the output intervals increase to 10 minutes after 24 h integration time from an 1-hour interval in order to capture the behavior of mesovortices.

The simulated track shows the westward bias with respect to the RSMC Tokyo best track. Simulated central pressures are relatively low compared with the best-track central pressures, central pressures predicted by JMA global spectral model and forecast of central pressures when the typhoon was south of 30˚N over warm ocean with relatively high TCHP exceeding the threshold. In contrast, CPL could not simulate rapid intensification around 1200 UTC 15 September even though a local deepening occurred (Fig. 2).

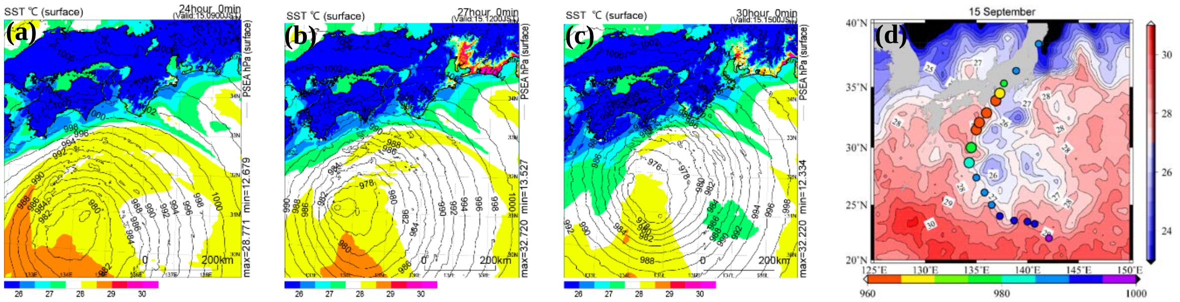

Figure 2 Horizontal distributions of sea surface temperatures (shades) with sea-level pressures (contours at 1-hPa intervals) at (a) 24 h, (b) 27 h and (c) 30 h integration times and (d) horizontal distribution of daily satellite sea surface temperature with a horizontal resolution of 0.25°(http://www.remss.com/measurements/sea-surface-temperature) with RSMC Tokyo best track with central pressures.

Figure 2 displays the horizontal distribution of sea surface temperature simulated by CPL from 24 h to 30 h every three hours with simulated sea-level pressures. On the right side of the simulated track, sea surface cooling is induced by the passage of the simulated typhoon Man-yi. The feature is also captured by daily satellite sea surface temperature (Fig. 2d). The inner core of the simulated typhoon passes over relatively warm ocean where the sea surface temperature exceeds 28˚C, which is also similar to the relation of the best track to the horizontal distribution of daily satellite sea surface temperature. However, mesovortices within the inner core of the simulated typhoon are not exciting.

In order to understand why mesovortices within the inner core of the simulated typhoon are inactive, back trajectory analysis is conducted with 30 particles. The start point is at 31.35˚N, 134.50˚E, corresponding to the location of central pressure at 33 h integration time. The result is shown in Fig. 3. Near 31.35˚N, 134.50˚E, upward motion is analyzed. However, downward motion is also found on the south-eastern side from the center of the typhoon. The location corresponds to upshear-right side of the moving typhoon, not to down-shear sides. The relative location of the production of mesovortices to the vertical shear would be responsible for inactive mesovortex activities and resultant mesoscale convection.

This result suggests that high resolution less than 2 km is not always necessary to simulate a behavior of mesovortices. Fast translation compared with the best track would affect the simulation of the mesovortex behavior and thus typhoon intensity prediction.

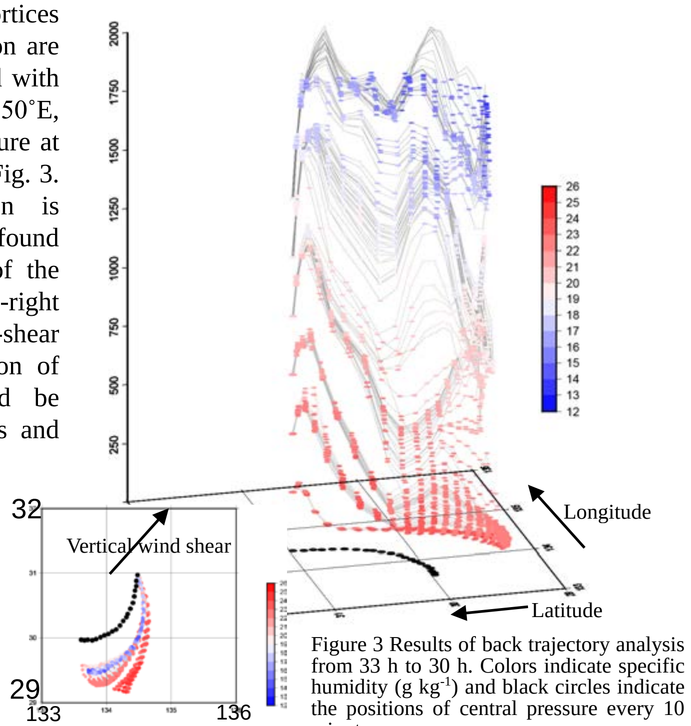

Figure 3 Results of back trajectory analysis from 33 h to 30 h. Colors indicate specific humidity (g kg^{-1}) and black circles indicate the positions of central pressure every 10 minutes.

Acknowledgement

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