Effects of horizontal resolution and sea surface cooling on simulations of tropical cyclones in case of Typhoon Namtheun (2004) by a coupled MRI tropical cyclone-ocean model.

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1. Outline of numerical simulations

Numerical experiments were performed in case of Typhoon Namtheun (2004) by the coupled meteorological Research Institute (MRI) interactive multiply-nested movable mesh tropical cyclone-mixed layer slab ocean model (CTCM) to investigate the dependency of tropical cyclone (TC) intensity on the grid-spacing in the horizontal resolution in a coupled TC-ocean system.

Figure 1 illustrates the computational domain in the outer nest of CTCM with a horizontal grid-spacing of 6 km. The domain in the inner nest with a horizontal grid-spacing of 2 km is reallocated to involve the TC. The initial time of integration was at 0000 UTC 29 July 2004. The detail of experimental design was almost the same as that used in Wada and Mashiko (2006). However, cumulus parameterization of Grell (1993) and modified version of Deardorff (1983) entrainment parameterization are installed to the CTCM.

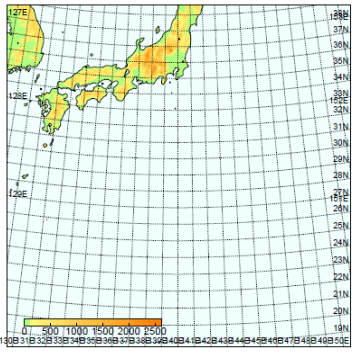

Fig.1 Computational domain in case of the numerical experiment with a horizontal grid-spacing of 6 km.

The numerical experiments by using the CTCM were conducted with a horizontal grid-spacing of 6 km alone and with horizontal grid-spaces of 2km and 6 km, respectively with/without the cumulus parameterization. Figure 2 denotes the procedures of numerical experiments. After the 30-hour integration in CTCM, numerical experiments with the two-nest version of CTCM were performed in cases with/without coupling with the ocean model. The numerical experiments with the cumulus parameterization were performed only with coupling with the ocean model.

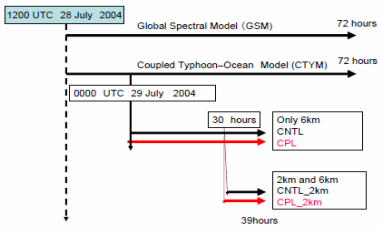

Fig.2 Procedures of numerical experiments

Here, the numerical experiment in the one-nest without coupling the ocean model is called 'CNTL', that but with coupling the ocean model is called 'CPL'. In cases of the two-nest numerical experiments, '_2km' is added to each acronym. The numerical experiment by using the CTCM with the Grell's cumulus parameterization and modified Deardorff's entrainment parameterization is expressed as the acronym '_p'.

2. Results

2.1 Tropical cyclone intensity prediction

Predicted central pressures in CTCM are depicted in Fig. 3 every numerical experiments. The impact of local sea surface cooling (SSC) of TC intensity was initiated to appear around 21-hour integration. After 30-hour integration, the difference of central pressures between CNTL and CPL was larger than 5 hPa. After 30-hour integration, the difference of the central pressures became larger, which reached its peak of about 13hPa. In CNTL, rapid TC intensification occurred from 35-hour to 38-hour integration, while rapid TC intensification suppressed in CPL.

In CNTL_2km and CPL_2km, central pressures tended to be deeper than those in CNTL and CPL. The over-development suggests that finer horizontal resolutions enable TCs to further develop and intensify in CTCM. The peak of difference of central pressures between CNTL_2km and CPL_2km was about 9hPa, which was smaller than that between CNTL and CPL. The result of numerical experiment by CTCM in CPL_2km_p indicates that the prediction of the tendency of TC intensity is improved compared to the result in CPL_2km. This suggests that local SSC plays an important role in predicting realistic TC intensity. However, the role of cumulus parameterization in TC intensity has become an issue for further investigation.

2.2 Impact of horizontal resolution on local sea surface cooling and 1-hour precipitation

Figure 4 illustrates horizontal distribution of sea surface temperature (SST) and surface pressure at

36-hour integration in CNTL_2km (Fig. 4a), CPL_2km (Fig. 4b) and CPL_2km_p (Fig. 4c). Local SSC was significant around 137°E, 32°N where it was on the rightward of the moving direction of the TC. The amplitudes of SSC were the largest in CPL_2km_p.

Figure 5 illustrates horizontal distribution of 1-hour precipitation and surface pressure at 36-hour integration in CNTL_2km (Fig. 5a), CPL_2km (Fig. 5b), and CPL_2km_p (Fig. 5c). Outer spiral rainbands were simulated in CNTL_2km and CPL_2km, while those were not found in CPL_2km_p. Magnitude of 1-hour rainfall in Kii peninsula increased in all experiments, which was consistent with the observations (Wada, 2006). In contrast, broadly salient precipitations were found east of the TC vortex where it was behind the running direction in CPL_2km_p. The asymmetry of 1-hour precipitation may be related to the magnitude of local SSC. Moreover, the role of cumulus parameterization in asymmetry of 1-hour precipitation may be significant. These factors have now become an issue for further investigation.

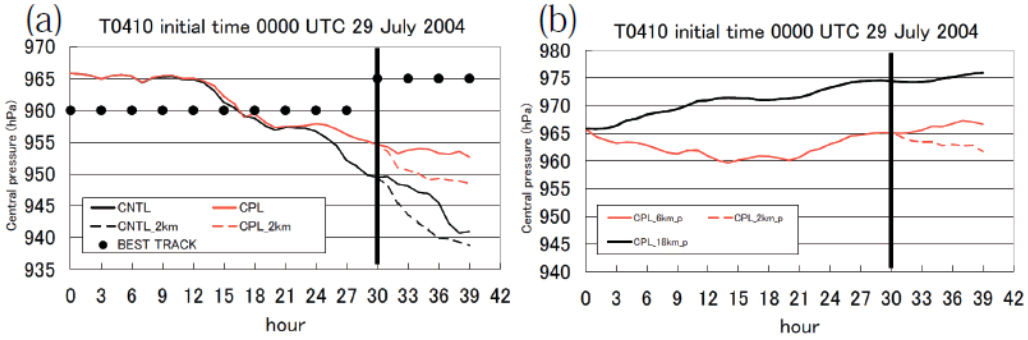

Fig. 3 Evolutions of central pressures (a) in CNTL, CPL, CNTL_2km, CPL_2km, and best track data, (b) in CPL and CPL_2km with the cumulus parameterization and modified Deardorff's entrainment parameterization.

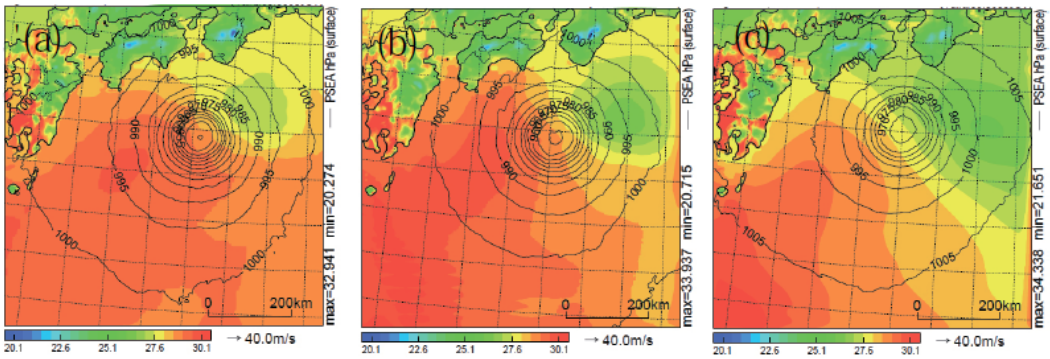

Fig. 4 Horizontal distribution of SST and surface pressure at 36-hour integration, (a) in CNTL_2km, (b) in CPL_2km, and (c) in CPL_2km with Grell's cumulus parameterization and modified Deardorff's entrainment parameterization.

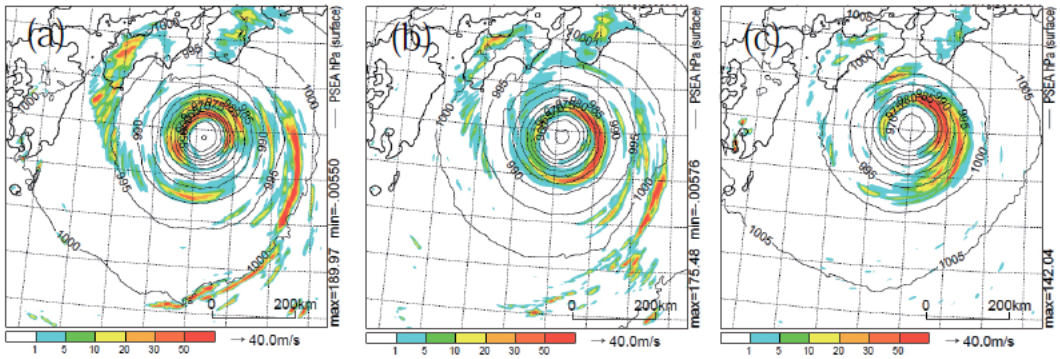

Fig. 5. Horizontal distribution of 1-hour precipitation and surface pressure at 36-hour integration, (a) in CNTL_2km, (b) in CPL_2km, and (c) in CPL_2km with Grell's cumulus parameterization and modified Deardorff's entrainment parameterization.

Acknowledgement

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References

Deardorff, J. W. (1983): A multi-limit mixed-layer entrainment formulation. *J. Phys. Oceanogr.*, **13**, 988-1002.

Grell, G. A. (1993): Prognostic evaluation of assumptions used by cumulus parameterizations. *Mon. Wea. Rev.*, **121**, 764-787.

Wada, A., and W. Mashiko (2006): Introduction of a mixed layer ocean model into the MRI interactive multiply-nested movable mesh tropical cyclone model. WMO CAS/JSC WGNE Report. 09-11.

Wada, A. (2006): Numerical experiments of Typhoon Namtheun (T0410) using different artmosphere-ocean coupled model. WMO CAS/JSC WGNE Report. 09-13.