Numerical Experiments of Typhoon Namtheun (T0410) using different atmosphere-ocean coupled models

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1. Observation in Typhoon Namtheun (T0410)

Typhoon Namtheun (T0410) is one of the typhoons making landfall on Japan in 2004 typhoon seasons. During the mature stage, the distribution of 1-hour precipitation changed from the symmetric pattern (Fig. 1(a) and (b)) to asymmetric one (Fig.1(c) and (d)). At that time, salient sea surface cooling (SSC) appears on the rightward of the track (Fig.2). The area where low temperature appears within the eyewall is located south of the center of the typhoon (Figs.1), which is opposite of SSC. The relationship between asymmetry of 1-hour precipitation and that of SSC is investigated numerically using atmosphere-ocean coupled models with different specifications.

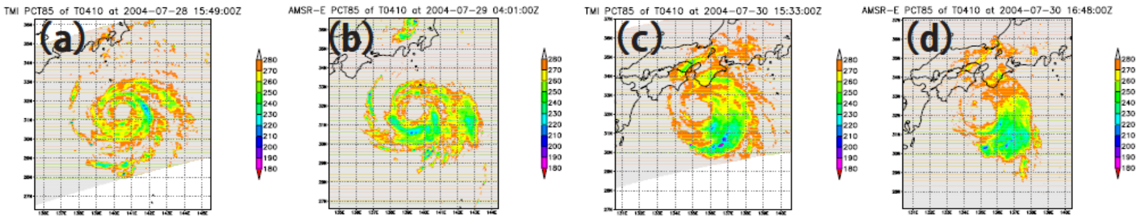

Figure 1 The polarization corrected temperature (PCT) derived from 85GHz channels by TRMM/TMI ((a) and (b)) and AMSR-E ((c) and (d)), (a) at 1549UTC on July 28, (b) at 0401UTC on July 29. (c) at 1533UTC on July 30, (d) at 1648UTC on July 30.

2. Results of hydrostatic typhoon-ocean coupled model

The atmospheric part of hydrostatic typhoon-ocean coupled model (TYM) is a spectral model with 20km horizontal resolution and 40 vertical layers. The mixed-layer ocean model coupled with the TYM is a slab model with 0.2 degrees horizontal resolution and 8 vertical layers. Detailed description of the coupled model is referred in Wada (2003) except for 25 vertical layers in Wada (2003). The initial time of numerical integration is at 12UTC on July 28 in 2004. As for the oceanic initial condition, the analyzed SST by Numerical Prediction Department in Japan Meteorological Agency (JMA) is used. Although the location of SSC by the coupled model (Fig. 3) is different from that by TRMM/TMI SST because of the error of track prediction, the SSC by the coupled model is evident on the rightward of moving direction. Horizontal distribution of sensible plus latent heat flux shows that the maximum heat flux appears ahead of moving direction of T0410, while the minimum appears behind the typhoon (Fig. 4).

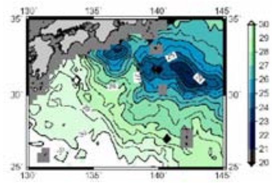

Figure 2 TRMM/TMI 3-day average SST on July 31 in 2004.

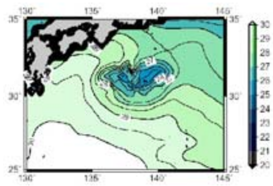

Figure 3 SST by the coupled model at T+48h.

The location of maximum heat flux is different from that in the non-coupled experiment (not shown), which the maximum is evident on the rightward of the moving direction. Asymmetric distribution of cloud water content, which the maximum appears southeastward of the typhoon center, is evident at a level of 500hPa (Fig. 5) where air temperature is under 0℃ and ice particles coexists in the air. In the non-coupled experiment, the pattern of cloud water content is rather like symmetry (not shown).

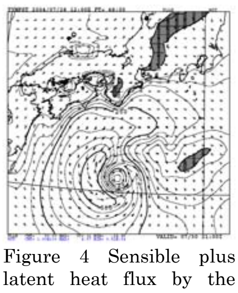

Figure 4 Sensible plus latent heat flux by the coupled model at T+48h.

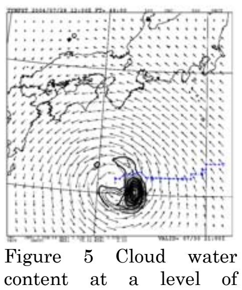

Figure 5 Cloud water content at a level of 500hPa by the coupled model at T+48h and center positions of the typhoon.

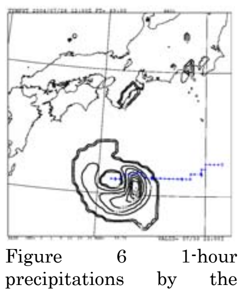

Figure 6 1-hour precipitations by the coupled model at T+49h and center positions of the typhoon.

The 1-hour precipitation pattern at T+49h is similar to the pattern of cloud water content at T+48h. In the TYM, precipitation is determined from the cloud water content using the empirical formula of Sundqvist (1978). The Coalescence and Bergeron-Findeisen effects (Sundqvist et al., 1989) may enhance the transformation from cloud water to rain or snow in the eyewall where upward flow is salient. This suggests that the cloud water content affected by SSC determines the asymmetric pattern of precipitation in the TYM-ocean coupled model.

3. Results of non-hydrostatic atmosphere-ocean coupled model

The non-hydrostatic atmosphere-ocean coupled model is referred to Wada (2005). The initial time of numerical integration is at 00UTC on July 29 in 2004, which is 12-hour later than that in the TYM-ocean coupled model. The reanalysis SST by the MRI Ocean Variational Estimation (MOVE) system (Usui et al., submitted) is used in the numerical experiment, which is different from that of TYM-ocean coupled model.

Results of track predictions indicate that northward deflection of the typhoon track is simulated, which is closer to JMA best track positions than that of TYM-ocean coupled model. In addition, the ocean coupling has the track deflect further northward. The difference of minimum central pressure in between coupled and non-coupled experiments is smaller than that of TYM-ocean coupled model (Wada, 2003). However, the intensity is overestimated even in the coupled simulation.

The SSC (Fig. 9) is comparable to TRMM/TMI SSC (Fig. 2), which the SSC appears south of Kii peninsula. The SSC can be successfully simulated in comparison with the result of TYM-ocean coupled model (Fig. 3). The maximum latent heat flux is located in westward of the typhoon center (Fig. 10). This location and asymmetry of the distribution is similar to those in Fig. 4. The decrease of heat flux behind the typhoon also appears in Fig. 10, which is similar to that in Fig. 4. Figures 11 show two kinds of mixing ratio (cloud water (Qc) and rain water (Qr)) at T+36h, total mixing ratio including cold rain elements at T+36h, and 1-hour precipitation at T+37h. The location of broad rainband (Fig. 1(c)) can be successfully simulated in Figs. 11(a)-(c) although the width of rainbands is narrower. The 1-hour precipitation is notable east of the typhoon center (Fig. 11(d)), which is comparable to observation (Fig. 1(c)), too. In the non-coupled experiment, the location of Qc is different from that of Qr. Because Qc is small in comparison with Qr around T0410, the total cloud water is possibly explained from Qr at the height of 5.91km. The Qr, total mixing ratio, and 1-hour precipitation in an hour, all in the non-coupled experiment have the maxima northward from the typhoon center, which make the distribution of precipitation more symmetrical.

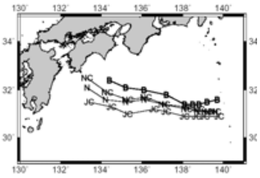

Figure.7 JMA best track positions (B), the predicted positions of hydrostatic coupled model (JC), nonhydrostatic model (N), and nonhydrostatic coupled model (NC).

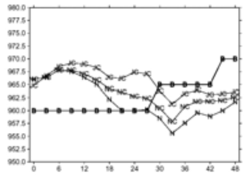

Figure.8 JMA best track minimum central pressure (B), the predicted minimum central pressure of hydrostatic coupled model (JC), nonhydrostatic model (N), and nonhydrostatic coupled model (NC).

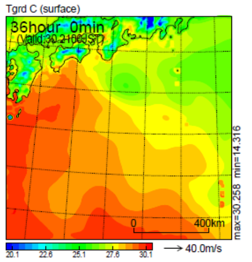

Figure 9 SST by the coupled model at T+36h.

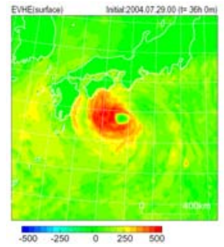

Figure 10 Latent heat flux by the coupled model at T+36h.

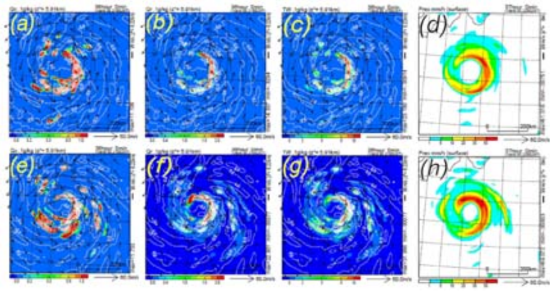

Figure 11 Results of coupled experiment ((a)-(d)) and non-coupled experiment ((e)-(h)) at the height of 5.91km. (a) mixing ratio of cloud water at T+36h, (b) mixing ratio of rain water at T+36h, (c) total mixing ratio at T+36h, (d) 1-hour precipitation at T+37h, (e) same as (a) except for non-coupled experiment, (f) same as (b) except for non-coupled experiment, (g) same as (c) except for non-coupled experiment, (h) same as (d) except for non-coupled experiment.

In conclusion, the TYM-ocean coupled model, which has coarser horizontal resolution, can simulate suppression of intensification and asymmetry of horizontal distribution of precipitation to an extent. Besides, the non-hydrostatic atmosphere-ocean coupled model, which has finer horizontal resolution, can simulate more detail and realistic distribution of precipitation. The ocean coupling effect may influence the track prediction when the non-hydrostatic atmosphere-ocean coupled model is used. For the purpose of prevention of dreadful disasters by typhoons, the non-hydrostatic atmosphere-ocean coupled model will be required but its computational resource is still expensive. Confined to intensity predictions during a several days, the TYM-ocean coupled model is capable of reflecting the effect of typhoon-ocean interaction on the typhoon prediction.

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