Numerical Experiments of Typhoons in 2004 typhoon season using a non-hydrostatic atmospheric model coupled with a mixed-layer ocean model

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1. Introduction

Wada (2005a) has developed the non-hydrostatic atmospheric model coupled with a mixed layer ocean model. The coupled model successfully reproduced sea surface cooling (SSC) on the rightward of the moving direction by typhoons. The suppression of typhoon intensity caused by the SSC was successfully simulated in the case of Typhoon Bilis (T0010). The suppression by ocean coupling was more salient using the coupled model with finer horizontal resolution. In the present report, numerical experiments are performed in the cases of six typhoons making landfall on Japan in 2004. A role of ocean coupling on the intensification or maintenance of typhoons is addressed here.

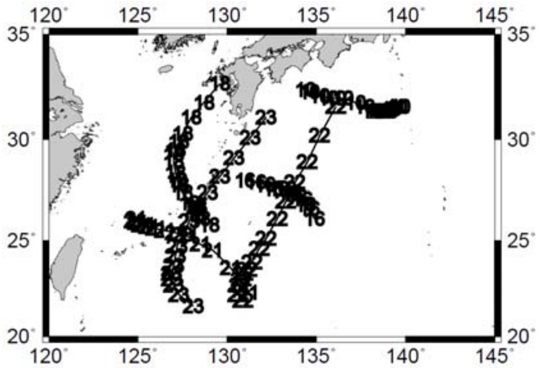

Figure 1 Positions analyzed in Japan Meteorological Agency of six typhoons in 2004 typhoon season.

2. Typhoons in 2004 typhoon season

In 2004 typhoon season, ten typhoons made landfall on Japan, which brought dreadful disasters by destructive wind and torrential rain. Here, six typhoons (T0410, T0416, T0418, T0421, T0422, and T0423) are numerically investigated. Figure 1 shows typhoon tracks during the period of integration (every typhoon is calculated during 48 hours). All the typhoons passed by in the western north Pacific where SSC appeared notably (Wada, 2005b). As for the development stage of T0423, Wada (2005c) suggested that the suppression of minimum central pressure (MCP) was notable in the case of SST lower than 28℃, while the MCP did not appear in the case of SST higher than 28℃ even in the coupled experiment in spite that SSC of about 1℃ could be reproduced. In contrast, all the stages of six typhoons are in maintaining or decaying stage. According to the result of singular value decomposition analysis in Wada (2005b), six typhoons can be divided into two categories; summer typhoons (T0410, T0416, T0418) and autumn typhoons (T0421, T0422, T0423). In the summer season, solar radiation dominates the SST variation, while the effect of solar radiation on the SST variation is smaller in the autumn season.

3. Numerical experiments

The specification of numerical experiments is almost the same as Wada (2005a) except for the oceanic initial condition, sea spray parameterization and cumulus parameterization. The initialization of oceanic condition is the same as Wada (2006). The sea spray parameterization and cumulus parameterization are not incorporated into the present specification. Horizontal resolution of the model is 6km with 391x391 grids and 40 vertical layers. The integration time is 48 hours. The reanalysis SST by the MRI Ocean Variational Estimation (MOVE) system (Usui et al., submitted) is used in the numerical experiment

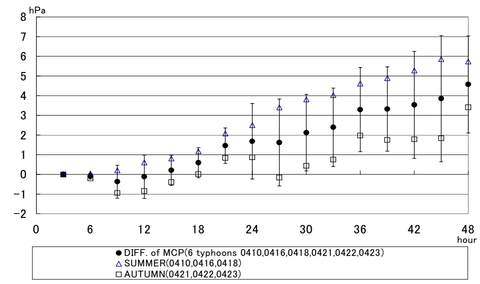

Figure 2 Difference of minimum central pressure between in coupled and non-coupled experiments.

4. Results

4-1 Intensity predictions

Figure 2 shows differences of MCP between in coupled and non-coupled experiments. Except for T0410 case, there is a tendency of underestimation of MCP in comparison with analyzed MCP in Japan Meteorological Agency (JMA). The maximum averaged difference of 6 typhoons is about 4.6hPa at T+48h. The difference of MCP in the summer season is more evident than that in the autumn season. This suggests that ocean coupling effect is a minor role to determine the intensity of

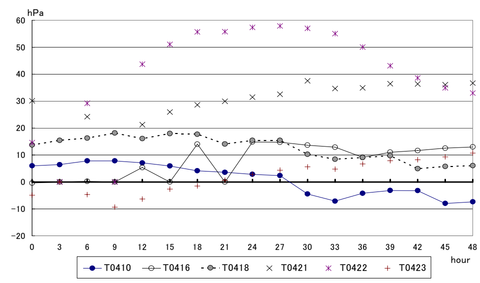

Figure 3 Difference of minimum central pressure between in coupled experiment and best track one.

autumn typhoons.

4.2 Track Predictions

The effect of ocean coupling on the track is shown in Figs.3. The errors from the JMA best track position (Fig. 3(a)) are larger than deviations between the coupled and non-coupled experiments. The improvement of ocean coupling for track prediction is negligibly small (Fig. 3(b)). However, systematic differences of typhoon positions appear in the latter integration in the case of T0410 experiment (not shown).

4.3 Heat flux and precipitation

The ocean coupling effect is evidently found in latent heat flux and accumulated precipitation within a radius of 100km from the typhoon center (not shown). The impact of ocean coupling on latent heat flux and precipitation appears nearest the typhoon center particularly in the early integration. However, this is not always found in the later integration because asymmetrical distribution of latent heat flux and precipitation appears obviously in the typhoons during mature and decaying stages.

4.4 Tropical cyclone heat content

Tropical cyclone heat content (TCHP) is often used to predict the tendency of change of MCP although there was only a few investigation concerning with the relationship between TCHP and intensity of typhoons. Here, we focus on accumulated TCHP, which is defined as summation of TCHP within a radius of 100km from the center every hour. As the mixed layer deepens by entrainment, the SSC around the typhoon center is enhanced (Fig. 5). At that time, TCHP and accumulated TCHP decrease and the difference of MCP in coupled and non-coupled experiments increases (Fig. 5). The tendency of changes of TCHP or accumulated TCHP is notably correlated with that of MCP. Figure 6 indicates the relationship between the tendency of MCP and that of accumulated TCHP, which shows good correlation between them.

However, MCP in T0416 does not fall exceptionally in spite of positive tendency of accumulated TCHP. This suggests that TCHP could not be a dominant factor to determine the intensity of the typhoon. The other physical processes particularly in the atmospheric model, initial and boundary conditions in the atmosphere and oceanic initial condition may be more important for typhoon predictions. The relationship between multi-scale interaction of typhoons and their TCHP conditions will be a future subject of typhoon intensity prediction.

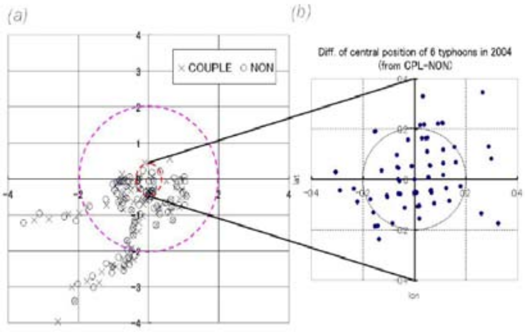

Figure 4 Difference of central position. (a) between in coupled and non-coupled experiment. (b) between in coupled experiment and best track one.

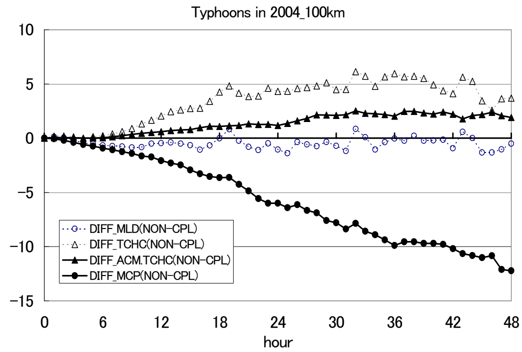

Figure 5 Differences of minimum central pressure, mixed layer depth, TCHP averaged within a radius of 100km from the center, and accumulated TCHP.

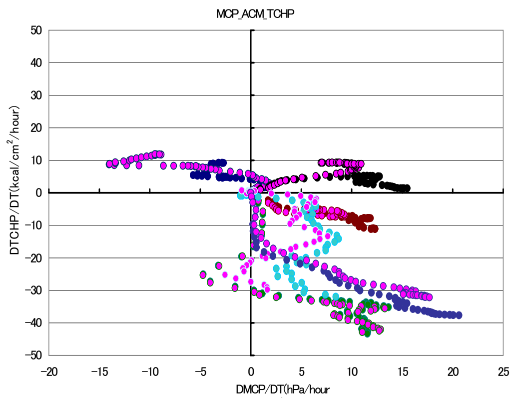

Figure 6 Differences of minimum central pressure, mixed layer depth, TCHP averaged within a radius of 100km from the center, and accumulated TCHP.

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