# Numerical experiments of intensification of an idealized typhoon-like vortex under various sea surface temperatures by a nonhydrostatic atmosphere-ocean coupled model


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## 1. Introduction

We investigated the impact of environmental sea surface temperature (SST) and local sea surface cooling (SSC) caused by the typhoon-like vortex on its intensity and intensification using a nonhydrostatic atmosphere-ocean coupled model. The coupled model was a nonhydrostatic atmosphere-slab mixed-layer ocean model developed by the first author. We examined the process of intensification in detail under various environmental SSTs and their local SSCs caused by the vortex. The process of interaction between local SSC and intensification has not been clarified even though the impact of local SSC on vortex's warm-core temperature and maximum wind speeds have been studied.

## 2. Methods

Table 1 shows the specification of numerical experiments. In the present report, three values of SST (28, 30, and 32℃) were used as an initial environmental SST. An initial wind field was assumed to be cyclonically axisymmetric (Nasuno and Yamasaki,1997). A radius of initial maximum wind was set to be 80 km and initial maximum wind speed was set to 20 m $s^{-1}$(Fig. 1). An atmospheric thermodynamic condition was horizontally homogeneous. The thermodynamic profile was obtained from the regional objective analysis dataset on 26 July in 2004 when Typhoon Namutheun in 2004 was located around 25°N, 150°E. The homogeneous initial field was made by extracting and averaging the domain of Typhoon Namutheun (600 km X 600 km) centered at the storm center.

Table 1 Specification of numerical experiments

| | |
|---|---|
| Numerical model | Wada and Murata (2007) (NHM + slab mixed-layer ocean coupled model) |
| Grid number | 301 x 301 x 40 (600 km x 600 km x ~23km) |
| Horizontal resolution | 2 km |
| Vertical resolution | 40 m – 1180 m |
| Coriolis parameter | $5.0 \times 10^{-5}$ |
| Cumulus parameterization | None |
| Cloud physics | 3-ice bulk |
| Integration time | 81 hours (after 27 hours, both non-coupled and coupled experiments are performed) |
| Initial sea temperature profile | 2nd level: SST – 1 ℃, 3rd level: SST – 12℃, bottom level: 5℃ |
| Number of oceanic layer | 3 |
| Initial layer thickness | 30 m in a mixed layer, 170 m in a thermocline, 800 m below a thermocline |

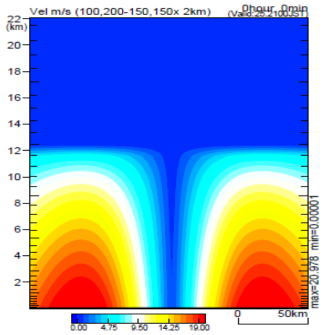


Figure 1 Initial wind field used in the present numerical experiments

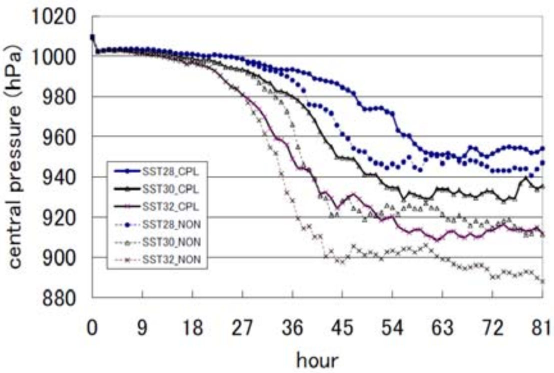


Figure 2 Time series of simulated minimum sea level pressure. CPL indicates a coupled experiment, while NON indicates a non-coupled experiment. The figures 28, 30, and 32 are values of initial sea surface temperature.

## 3. Results

### 3.1 Sea surface temperature

Time series of minimum sea level pressure (Fig. 2) indicated that the intensity and intensification of typhoon-like vortex depended on a value of initial environmental SST. From the result shown in Fig. 2, high initial environmental SST led to decrease in minimum sea level pressure. In particular, a typhoon-like vortex rapidly intensified from 27 to 45 hours integration when the initial environmental SST was 32℃, while the intensification of typhoon-like vortex comparably delayed when the initial environmental SST was 28℃. The difference in minimum sea level pressure between sea surface temperatures of 28℃ and 32℃ was nearly 50 hPa (Fig. 2).

Intensification of typhoon-like vortex is related to the development of warming area formed around the center of typhoon-like vortex. High potential vorticity (PV) on the 345K-isotherm concentrated on the vortex center when the initial environmental SST was 30 ℃ (Fig. 3a). However, high PV area was not overlapped with the warming area indicated by the low height on the 345-K isotherm. In contrast, high PV area was overlapped with the area of low height on the 345K-isotherm when the initial SST was 32℃ (Fig. 3b). The result suggests that high initial environmental SST leads to easily establish a warm-core ring formed around the center of typhoon-like vortex.

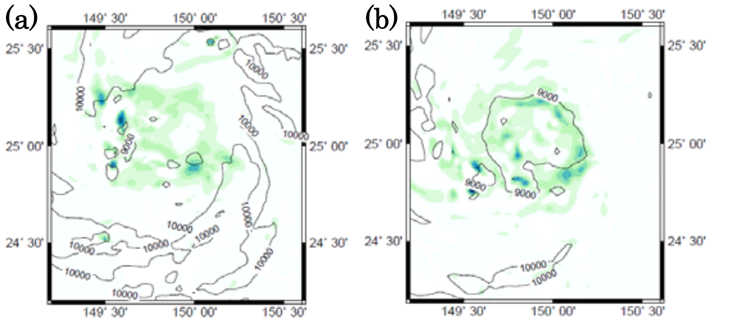


Figure 3 Contours show a height on the isotherm of 345 K at 27-hour. Shades show potential vorticity on the isotherm of 345K. Color bars in Fig. 3 are also used. (a) sea surface temperature is 30℃. (b) sea surface temperature is 32℃.

## 3.2 Sea surface cooling

The impact of local SSC on the intensity and intensification of typhoon-like vortex was salient when the initial environmental SST was 32℃ and local SSC was the largest in all initial environmental SSTs. The increase in minimum sea level pressure was nearly 25 hPa at 81-hour integration in the coupled experiment. The amount of increase in minimum sea level pressure in coupled experiments usually decreased as the initial environmental SST was lower. It is because the magnitude of SSC is small and is depended on the value of initial environmental SST and initial oceanic stratification such as mixed-layer depth and vertical gradient of temperature in the thermocline.

The impact of local SSC on the intensification of typhoon-like vortex was represented by the amount of PV production alongside spiral rainbands and around the center of typhoon-like vortex (Fig. 4a-b). In Fig. 4a, both a warming area and high PV concentration were salient, while a warming area was not salient in Fig. 4b. Therefore, local SSC also plays a role in delaying the intensification due to weak PV production and small warming region.

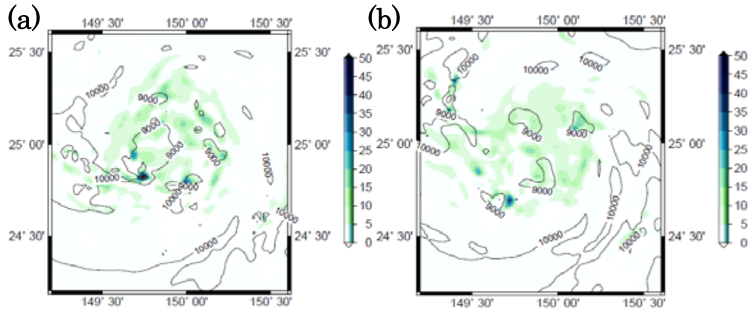


Figure 4 Contours show a height on the isotherm of 345 K. Shades show potential vorticity on the isotherm of 345K. (a) sea surface temperature is 30℃. (b) sea surface temperature is 30℃ but in a coupled experiment.

The axisymmetrical mean PV on the 305K-isotherm (Fig. 5) indicated that a typhoon-like vortex intensified through an inward isothermal transportation of PV, conserving angular momentum. The inward transportation of PV within a typhoon-like vortex simulated by a non-coupled model (Fig. 5a) was much stronger than that by a coupled model (Fig. 5b). In fact, the amplitude of PV production had a direct effect on the structure of typhoon-like vortex during the intensification. Therefore, isothermal transportation of PV in the atmospheric boundary layer (on the 305K-isotherm surface) is related to the intensification and it is sensitive to local SSC.

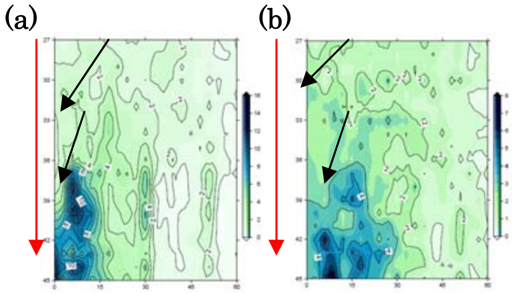


Figure 5 Time series of 2-dimensional axisymmetrical mean potential vorticity. A horizontal axis indicates a distance from the vortex center and a vertical axis indicates the integration hour. (a) the result in the non-coupled experiment. (b) the result in the coupled experiment. Black arrows show inward transportation of potential vorticity on the 305-K isotherm. Red arrows show the temporal transition.

## Reference

Nasuno, T and M. Yamasaki (1997): J. Meteor.Soc. Japan, 75, 907-924.