The effect of the cloud-water conversion rate in the cumulus parameterization on the simulation of Typhoon Lionrock (2016)

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1. Introduction

Wada et al. (2019) performed numerical simulations of Typhoon Lionrock (2016) using the 7-km mesh nonhydrostatic global spectral atmospheric Double Fourier Series Model (DFSM) (Nakano et al., 2017) coupled with the MRI Community Ocean Model Version 4.4 (MRI.COM) and showed that the simulated typhoon track greatly changed due to the effect of ocean coupling when the cumulus parameterization was used in DFSM. The purpose of this study is to understand the effect of the cumulus parameterization on the typhoon track simulation in a coupled atmosphere and ocean framework, and to improve the typhoon track simulation. We investigated the impact of the rate (hereafter referred as 'rtau') that adjusts the conversion from cloud water to precipitation during the updraft of cumulus on the simulation of Lionrock. The smaller rtau is, the smaller the conversion rate from cloud water to precipitation is. The reduction in the conversion rate is expected to contribute to increases in the number of tall cumulus due to increases in latent heat release of cloud ice without falling directly below, to increases in the cloud amount detrained from the cloud top, and to decreases in the amount of precipitation converted from cumulus.

2. Experimental design

The experimental design is almost the same as Wada et al. (2019). The list is shown in Table 1. The initial time of the simulation of Lionrock is set to 0000 UTC on August 23 in 2016. The period is from this initial time to 0000 UTC on August 31 in 2016. The integration time is 8 days. The DFSM and MRI.COM used in this study are the same as Wada et al. (2019). The Japan Meteorological Agency 6-hourly global objective analysis data are used for each experiment to create atmospheric initial conditions (Nakano et al., 2017). In addition, the global ocean reanalysis data are used for each experiment to create oceanic initial conditions (Toyoda, private communication).

Table 1 List of sensitivity numerical experiments for the prediction of Lionrock

Experiment name	OCEAN	rtau (1/m)
ASM_CNTL	SST	4.0d-3
CASM_CNTL	Couple	4.0d-3
ASM_RT_S	SST	4.0d-5
CASM_RT_S	Couple	4.0d-5

3. Results

3.1 Track and SST simulations

Figure 1a-b shows the horizontal distributions of simulated sea surface temperature in the (a) CASM_CNTL and (b) CASM_RT_S experiments together with the simulated tracks and the Regional Specialized Meteorological Center Tokyo best-track. Both experiments showed that Lionrock-induced sea surface cooling is caused beneath the typhoon around the recurvature area. However, after the recurvature, the sea surface cooling is induced along the right side of the track only in the CASM_CNTL experiment. Sea surface cooling in Fig. 1b is relatively small compared with the analyzed sea surface temperature field (Fig. 1d in Wada et al., 2019). The large differences in simulated tracks between the ASM_CNTL and CASM_CNTL experiments in Fig. 1a becomes small in Fig. 1b. It is suggested the simulated tracks affected by ocean coupling are improved by adjusting the parameter rtau when the cumulus parameterization is used.

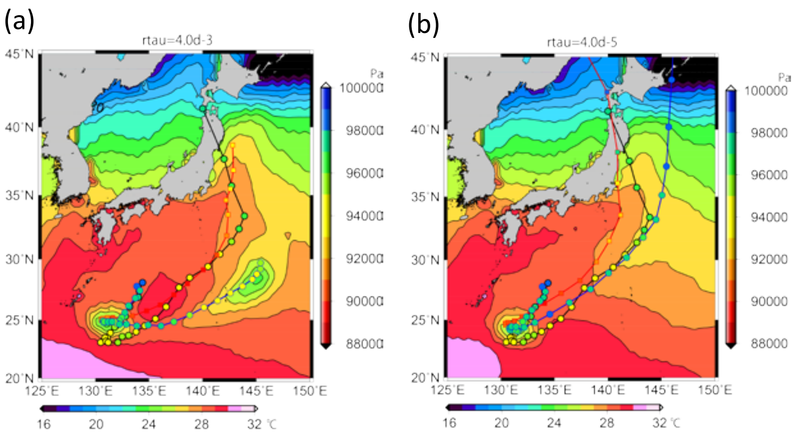

Figure 1 Horizontal distributions of simulated sea surface temperature in (a) CASM_CNTL and (b) CASM_RT_S (colors with the contours (1 ℃) at 0000 UTC on August 31 in 2016 with the best track (black line: the color within a circle indicates central pressures) and simulated tracks (red: results by DFSM alone, blue: results by the coupled model) in (a) ASM_CNTL and CASM_CNTL experiments and in (b) ASM_RT_S and CASM_RT_S experiments.

3.2 Intensity simulations

Figure 2 shows the time series of best-track and simulated central pressures in the (a) ASM_CNTL and CASM_CNTL and (b) ASM_RT_S and CASM_RT_S experiments. Minimum central pressure in the ASM_RT_S (CASM_RT_S) experiment is higher than that in the ASM_CNTL (CASM_CNTL) experiments. The relatively weak intensity in the CASM_RT_S experiment leads to relatively small sea surface cooling along the right side of the track after the recurvature of simulated Lionrock. The result suggests that improving the typhoon track simulation does not lead to the improvement of the typhoon intensity simulation.

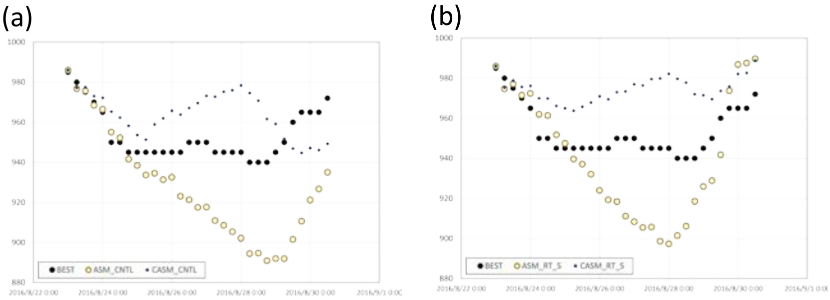

Figure 2 Time series of best-track (BEST) and simulated central pressures in (a) ASM_CNTL and CASM_CNTL and (b) ASM_RT_S and CASM_RT_S experiments.

3.3 Sea surface temperature and precipitable water

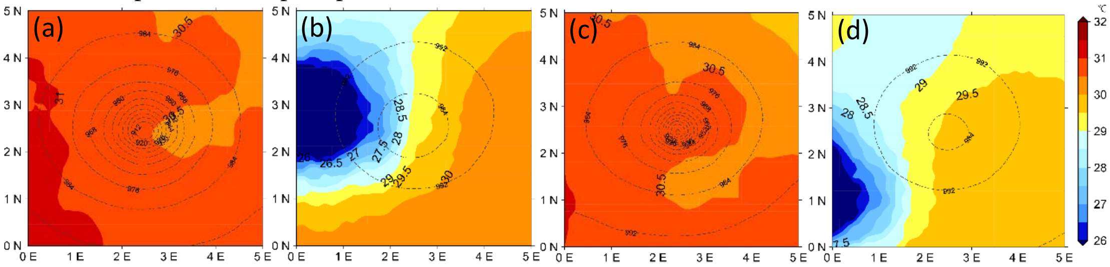

Figure 3 Horizontal distributions of sea surface temperature (shades) collocated at the simulated storm center at the 120-h integration time in the (a)ASM_CNTL, (b) CASM_CNTL, (c) ASM_RT_S and (d) CASM_RT_S experiments.

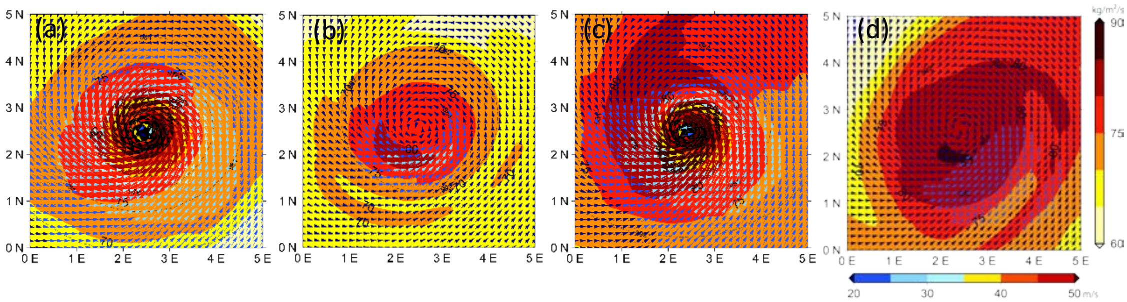

Figure 4 Horizontal distributions of precipitable water (shades: color bar is shown in the right side) together with the surface wind vector (color bar is shown on the lower side) collocated at the predicted storm center at the 120-h integration time in the (a)ASM_CNTL, (b) CASM_CNTL, (c) ASM_RT_S and (d) CASM_RT_S experiments.

Figure 3 shows the horizontal distribution of sea surface temperature around the simulated typhoon center at the 120-h integration time. In the ASM_CNTL experiment, the location of the typhoon is more southward compared with the location in the ASM_RT_S experiment although the difference of the value of simulated sea surface temperature is relatively small compared with the difference between CASM_CNTL and CASM_RT_S experiments. In the CASM_RT_S experiment, sea surface temperature underneath the simulated typhoon is relatively high compared with that in the CASM_CNTL experiments. In fact, the area of relatively strong surface wind speeds southeast of the typhoon center in the CASM_RT_S is wider than that south of the typhoon center in the CASM_CNTL experiment. The inner-core structural change caused by the change in the value of rtau in the cumulus parameterization may be related to the change in the track simulation in the coupled atmosphere-ocean framework.

4. Concluding remarks

This study confirmed that changing one parameter 'rtau' (the rate that adjusts the conversion from cloud water to precipitation) in the cumulus parameterization leads to the inner-core structural change of simulated typhoon, differences in the amount of precipitable water, and changes in the track simulation. However, the simulated typhoon intensity is not still accurate compared with the best track analysis. Nevertheless, this study implies that the improvement of cumulus parameterization certainly plays a key role to improve the typhoon prediction in the coupled atmosphere-ocean framework.

References

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