Preliminary numerical experiments on the prediction of Typhoon Lionrock (2016) using the global atmosphere-ocean coupled model

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1. Introduction

Previous studies have reported that typhoons tended to be overdeveloped compared with the best-track analysis when the intensity was predicted using the 7-km mesh nonhydrostatic global spectral atmospheric Double Fourier Series Model (DFSM) (Nakano et al., 2017). In addition, the typhoon intensity predicted by DFSM was sensitive to surface boundary (Wada et al., 2018a) and cloud-physics scheme (Wada et al., 2018b) incorporated into the DFSM. Aside from this fact, it is known that sea surface cooling caused by typhoons helps suppress the overdevelopment of typhoons. However, it is necessary to use a global atmosphere-ocean coupled model to introduce the negative-feedback effect. In this report, preliminary numerical simulations were performed on Typhoon Lionrock (2016) by using the DFSM-based 7-km mesh global atmosphere model coupled with the MRI Community Ocean Model Version 4.4 (MRI.COM). The MRI.COM has been developed for contributing the projects of the Coupled Model Intercomparison Project (CMIP) phases (https://cera-www.dkrz.de/WDCC/ui/cerasearch/cmip6?input=CMIP6.CMIP.MRI.MRI-ESM2-0). The purpose of this study is to understand the impact of cloud physics and cumulus parameterization on the typhoon simulations in a coupled atmosphere and ocean framework.

2. Experimental design

The initial time of the prediction of Lionrock is set to 0000 UTC 23 August 2016. The prediction period is from this initial time to 0000 UTC 31 August 2016. The integration time is 8 days. Table 1 shows a list of sensitivity numerical experiments for the prediction of Lionrock. The DFSM-based 7-km mesh global atmosphere model is almost the same as that used in Wada et al (2018a). The MRI.COM is a free-surface, depth-coordinate ocean-ice model that solves primitive equations using Boussinesq and hydrostatic approximation in a tripolar grid system. The horizontal grid arrangement is primarily 0.5-degree latitude/1-degree longitude with meridional refinement down to 0.3 degree within 10 degrees north and south of the equator. The number of the vertical level is 61 with a top grid cell of 0-2 m. The Japan Meteorological Agency 6-hourly global objective analysis data are used for each experiment to derive atmospheric initial conditions (Nakano et al., 2017). In addition, the global ocean reanalysis data are used for each experiment to derive oceanic initial conditions (Toyoda, private communication).

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

Experiment name	Cloud physics	Cumulus parameterization
NSMITH	Smith (1990)	×
NTDK	Tiedtke(1993)	×
ASSMITH	Smith (1990)	Randall and Pan (1993)

3. Results

3.1 Track and SST simulations

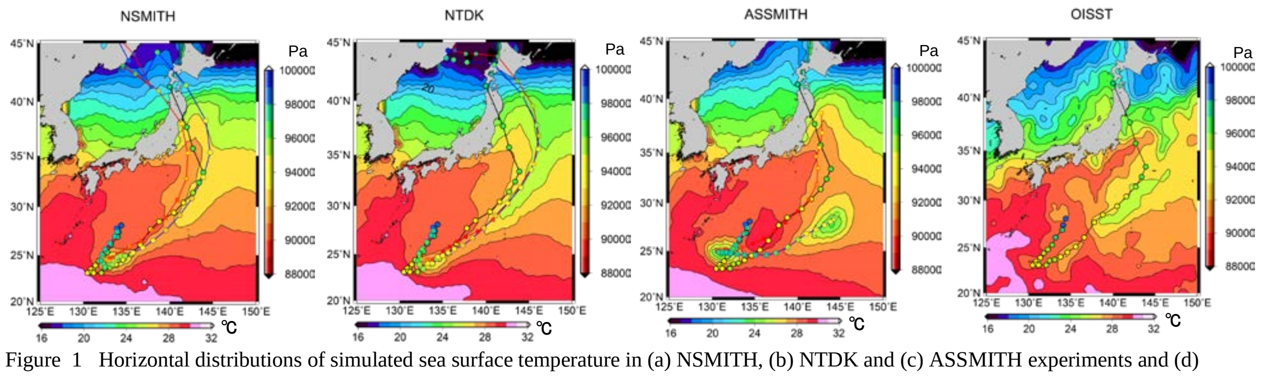

Figure 1 Horizontal distributions of simulated sea surface temperature in (a) NSMITH, (b) NTDK and (c) ASSMITH experiments and (d) analyzed sea surface temperature (colors with the contours (1 ℃) on 0000 UTC 31 August with the best track (the color within a circle indicates central pressures) and simulated tracks (red: results by DFSM alone, blue: results by the coupled model) in (a) NSMITH, (b) NTDK and (c) ASSMITH experiments.

Figures 1a-c show the horizontal distributions of simulated sea surface temperature in (a) NSMITH, (b) NTDK and (c) ASSMITH experiments together with the simulated tracks and the analyzed best track. The Regional Specialized Meteorological Center Tokyo best-track analysis is used as the analyzed best track in this study. Sea surface cooling areas induced by simulated Lionrock are found just after the recurvature and along the right side of the track afterward in the NSMITH and NTDK experiments, while the areas are clear before the recurvature and around 27.5°N, 145°E in the ASSMITH experiment. The locations of the simulated sea surface cooling areas are consistent with the analyzed sea surface temperature field (Fig. 1d). It is interesting to note that ASSMITH experiments alone have large differences in simulated tracks between the atmosphere-ocean coupled model experiment and the DFSM-alone experiment. It is suggested that the typhoon tracks simulated with the cumulus parameterization are highly influenced by ocean coupling.

3.2 Intensity simulations

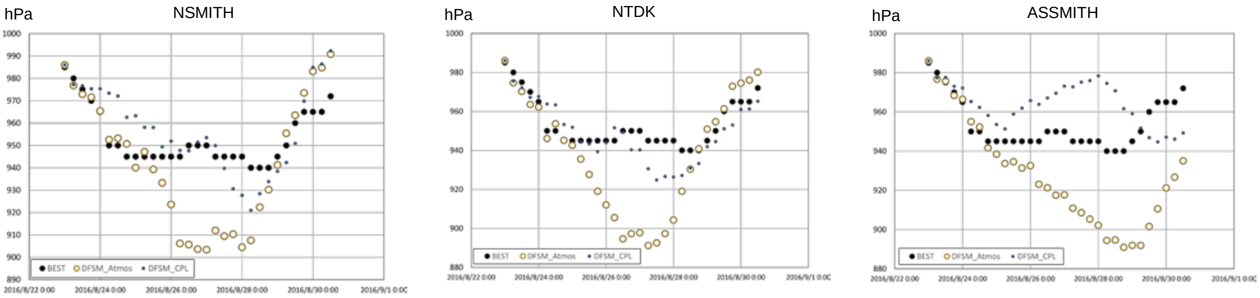

Figure 2 Time series of best-track (BEST) and simulated central pressures in (a) NSMITH, (b) NTDK and (c) ASSMITH experiments. 'DFSM_Atmos' indicates the central pressures simulated by the DFSM-alone model, while 'DFSM_CPL' indicates the central pressures simulated by the atmosphere-ocean coupled model.

Figure 2 shows the time series of best-track and simulated central pressures in (a) NSMITH, (b) NTDK and (c) ASSMITH experiments. During the early intensification phase, the Smith cloud physics scheme is highly sensitive of simulated central pressure to ocean coupling. The simulated typhoon in the NSMITH and NTDK experiments continued to intensify even around 0000 UTC on 28 August, while the simulated typhoon became weakened after 0000 TUTC on 25 August to 0000 UTC on 28 August and then intensified again in the ASSMITH experiment. It should be noted that the tracks quite differ between the atmosphere-ocean coupled model experiment and the DFSM-alone experiment. However, the effect of ocean coupling on simulated central pressures becomes much clearer during the late intensification and mature phases, which is different from the effect reported in the previous studies (e.g., Wada et al., 2018c).

4. Future subject

The cumulus parameterization used in the Meteorological Research Institute Earth System Model version 2.0 (MRI-ESM2.0) is not based on the Arakawa-Schubert cumulus parameterization (Randall and Pan, 1993) but based on Yoshimura et al. (2015). However, the 7-km mesh DFSM with the cumulus parameterization of Yoshimura et al. (2015) also tends to overdevelop the intensity of typhoons (not shown). It is a future subject to clarify whether the influence of sea surface cooling simulated by the atmosphere-ocean coupled model on typhoon prediction depends on the formulation in each scheme or the concept of cumulus parameterization itself.

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