Effect of Talas-induced sea-surface cooling on the generation of a subsequent typhoon

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1. Introduction

This study focuses on the effect of sea surface cooling induced by Typhoon Talas in 2011 on the genesis and development of a subsequent typhoon. In fact, a tropical depression was detected around 21.3°N, 149.8°E at 0000 UTC on 2 September and thereafter Typhoon Noru was generated at 22.2°N, 150.3°E at 1200 UTC on 3 September in 2011. The genesis location was east of the track of Talas. After the genesis, Noru moved northward, away from the Talas's track. This study performed numerical simulations using a nonhydrostatic atmosphere model coupled with an ocean wave model and a multi-layer ocean model (Wada et al., 2010) to investigate the effect.

2. Experimental design

Summary of numerical simulations performed by the atmosphere-wave-ocean coupled model is listed in Table 1. The coupled model covered nearly a 4300 km x 5000 km computational domain with a horizontal grid spacing of 6 km. The coupled model had 40 vertical levels with variable intervals from 40 m for the near-surface layer to 1180 m for the uppermost layer. The coupled model had maximum height approaching nearly 23 km. The integration time was 384 hours (384 h) with a time step of 20 seconds in the atmospheric part of the coupled model. The time step of the ocean model was six times that of the coupled model. That of the ocean wave model was 10 minutes.

Table 1 Summary of abbreviation of numerical experiment, ocean coupling/noncoupling and parameters of Rayleigh damping width associated with the lateral boundary condition used in this study.

Experiment	Ocean coupling	Rayleigh damping width
A15	NO	15
C15	YES	15
A50	NO	50
C50	YES	50

This study performed the sensitivity numerical experiments of Rayleigh damping width associated with the lateral boundary condition in order to investigate the sensitivity of lateral boundary condition provided every six hours to the generation and development of a subsequent typhoon. Oceanic initial conditions were obtained from the oceanic reanalysis datasets with horizontal resolutions of 0.1º calculated by the Meteorological Research Institute multivariate ocean variational estimation (MOVE) system (Usui, et al., 2006). The surface roughness length calculated by the coupled model was derived from the formulation based on wave steepness (Taylor and Yelland, 2001).

3. Results and discussions

Results of track simulations and the best track of Talas (Fig. 1a) and Noru (Fig. 1b) indicate that the Rayleigh damping width associated with the lateral boundary condition clearly affected the track of simulated Talas irrespective of the effect of sea surface cooling (Fig. 1a). In experiments A50 and C50, simulated Talas tended to move westward when the best-track typhoon moved to northward (Wada, 2012). In contrast, the westward movement of the simulated typhoon north of 28˚N appeared to cause errors compared with the best track in experiments A15 and C15. Sea surface cooling induced by simulated Talas affected the track simulations after 138 h when the center position of the typhoon was north of 30˚N.

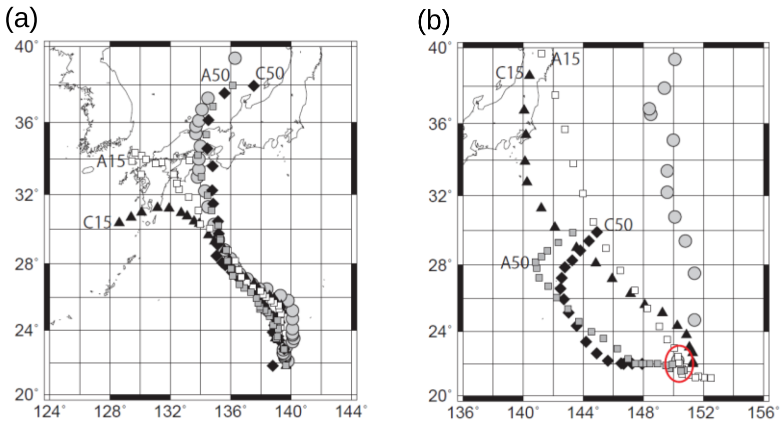

Figure 1 (a) Best track and simulated tracks of Talas in experiments A15（open squares）, C15(close triangles), A50(gray squares), and C50(close diamonds). (b) Same as Fig.1(a) except those of Noru. The end of simulated track in Naru's case is 1200 UTC on 6 September. A red circle indicates the genesis location of Naru according to the Regional

The locations of simulated Naru shown in Fig. 1b were determined from the positions that the simulated central pressure was lower than 1000 hPa with the maximum wind speed exceeding 34 knot. These criteria correspond to the phase of 'typhoon'. The results of simulations show that the locations of all simulated tropical typhoons appeared at 1800 UTC on 30 August (experiment A15), at 0600 UTC on 31 August (experiment A50), at 0000 UTC on 1 September (experiment 15) and at 0600 UTC on 2 September (experiment C50) around 22°N, 150°E. All appearance times were earlier than the time of best-track tropical cyclone genesis, at 1200 UTC on 3 September (A red circle in Fig.1b). This suggests that typhoon-induced sea surface cooling contributes to delaying of the genesis of a subsequent simulated typhoon. In addition, the parameter of lateral boundary sponge layer plays a crucial role in simulating the tracks of Talas and Nari. In fact, the simulated tracks in Fig. 1b quite differed among the four experiments. In this study, the parameter 50, corresponding to the width of 300 km, seems to be more reasonable to simulate the two typhoons than the parameter 15.

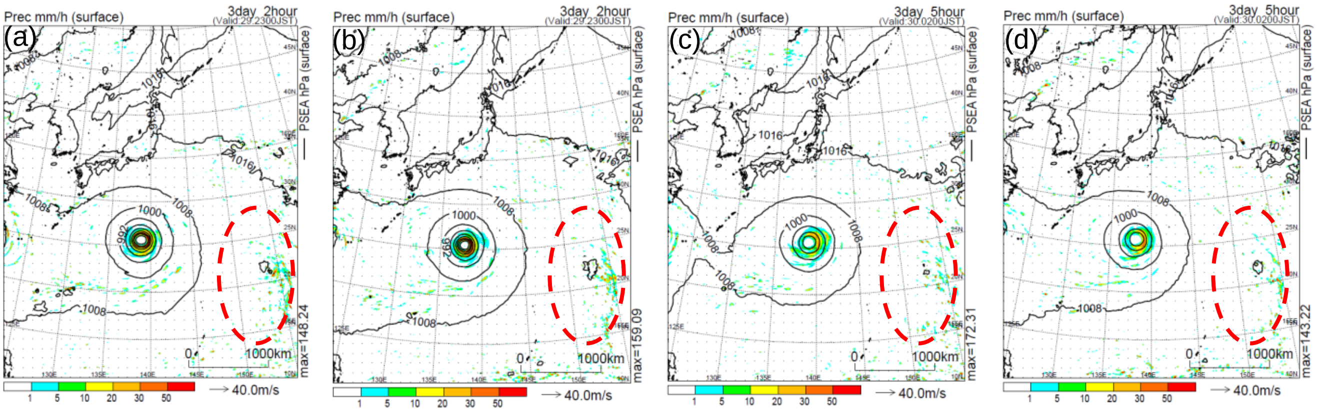

Figure 2 Horizontal distributions of hourly rainfall in (a) experiment A15 at 74 h, (b) A50 at 74 h, (c) C15 at 77h and (d) C50 at 77h.

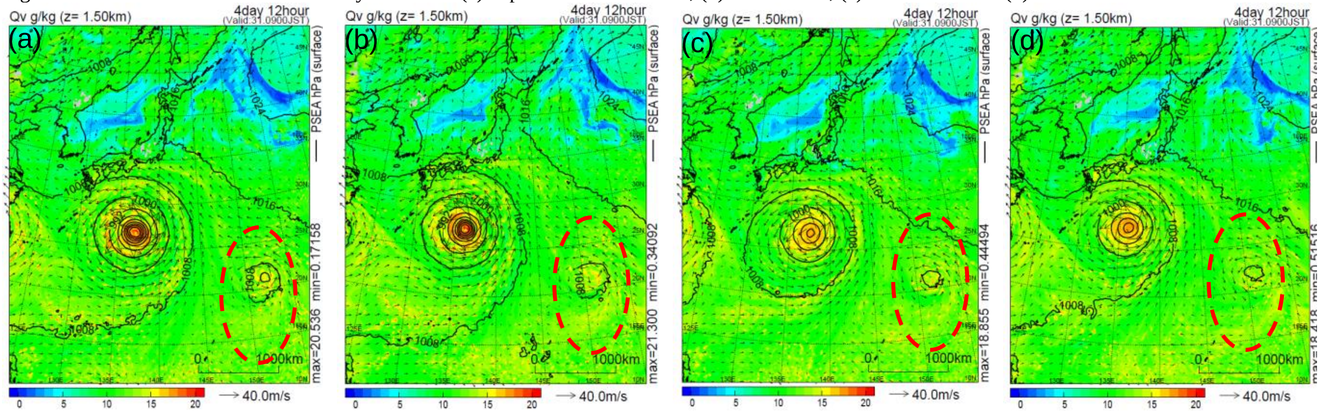

Figure 3Same as Fig.2 except for specific humidity (g/kg^{-1}) at 108 h.

Horizontal distributions of hourly rainfall indicate that a tropical depression appeared east-southeast of simulated Talas (Dashed red circle in Fig. 2a-d) for the first time of the lifecycle of the subsequent typhoon. A north-to-south sheared line of hourly rainfall appeared east of the tropical depression. The appearance time of the tropical depression in experiments C15 and C50 was three hours later than that in experiments A15 and A50. However, the location of the tropical depression little differed among the four experiments. The tropical depression was accompanied by environmental cyclonic circulation with a scale of a few hundred kilometers.

Figure 3 displays horizontal distributions of simulated specific humidity at 108 h at 1500 m height in all experiments. The amount of simulated specific humidity increased around the location of the subsequent typhoon in experiment A15 and tropical depression in the other experiments as the integration time went on. Simulated sea level pressure became low in experiment A15, while that was relatively high in the other experiments. This result suggests that the parameter of lateral boundary sponge layer affects intensification of the simulated tropical depression. In addition, simulated sea-level pressures in experiments C15 and C50 were higher than those in experiments A15 and A50 due to low simulated sea surface temperature beneath the tropical depression (not shown) and simulated specific humidity at 1500 m height around the depression, even though the environmental cyclonic circulation continuously appeared around the tropical-depression area.

This numerical study proposes the following genesis processes: environmental cyclonic circulation, an increase in specific humidity in the lower troposphere around a tropical depression within the environmental cyclonic circulation, and thereafter intensification of the circulation. Firstly, areas of high hourly rainfall (Fig. 2) and specific humidity in the lower troposphere (Fig. 3) scattered within a larger cyclonic circulation. Secondly a tropical depression intensified, shrinking the vortex. Sea surface cooling induced by preceding Talas is considered to suppress the increase in specific humidity in the lower troposphere, resulting in delaying of intensification of the subsequent tropical depression. In addition, this study shows that changes of atmospheric environments do affect the genesis process mentioned above through the results of the sensitivity experiments associated with lateral boundary conditions. Since the track simulations drastically changes, how sea surface cooling and lateral boundary condition affect the track simulation will be a subject in the future.

Acknowledgement

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