The impact of a sea-spray parameterization on the assimilation of Typhoon Sinlaku (2008)

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1. Introduction

The effect of the ocean on tropical cyclone (TC) intensity and intensification is important for predicting TC intensity accurately. Wada and Kunii (2014) previously reported the construction of data assimilation system based on the local ensemble transform Kalman filter (LETKF) and the nonhydrostatic atmosphere model (NHM) coupled with the multilayer ocean model and the third generation ocean surface-wave model (Wada et al. 2010). The coupled system was able to analyze a TC affected by sea surface cooling caused by upwelling and vertical turbulent mixing. However, the NHM-LETKF system was not able to analyze realistic TC intensification (particularly rapid intensification) due to relatively coarse horizontal resolution (15 km in Wada and Kunii 2014). The TC-induced sea surface cooling excessively suppressed TC intensification in the assimilation system so that TC intensification was poorly assimilated when the coupled atmosphere-ocean prediction system was used.

In order to improve the analysis of TC intensification in the coupled atmosphere-ocean prediction system, a sea-spray parameterization is introduced into the atmosphere-wave-ocean coupled model. The impact of the sea-spray parameterization (Bao et al. 2000) on TC intensification has been already investigated by using the atmosphere-wave-ocean coupled model (e.g., Wada 2013, 2014). The studies suggested that the sea-spray parameterization helped TC intensification by increasing turbulent heat fluxes near the atmospheric surface-boundary layer. The purpose of this study is to understand the impact of the sea-spray parameterization on the assimilation of TCs by using the coupled atmosphere-ocean prediction system. Numerical experiments were conducted by the coupled NHM-ocean assimilation system for Typhoon Sinlaku in 2008.

2. Experimental design

The experimental design was almost the same as Wada and Kunii (2014) except that this study used the coupled model incorporating the sea-spray parameterization of Bao et al. (2000).

The coupled atmosphere-wave ocean model consists of the NHM, the third generation ocean-wave model, and a multilayer ocean model (Wada et al., 2010). Sea surface temperature calculated by the coupled model in the prediction part was not used in the subsequent sea surface temperature analysis, which is the same as Wada and Kunii (2014). The analysis component of the LETKF system was not changed from Kunii (2014). The ocean state (wave conditions) was assumed to be motionless at the initial time every analyses.

The analysis and prediction for the storm covered a ~3600 km x ~1900 km computational domain with a horizontal grid spacing of 15 km. The system had 40 vertical levels with variable intervals from 40 m for the near-surface layer to 1180 m for the uppermost layer. The system had maximum height approaching ~23 km. The analysis period was from 1200 UTC 1 to 1800 UTC 19 September in 2008. The number of ensemble member was 20.

3. Results and concluding remarks

The original NHM-LETKF system used merged satellite and in situ data global daily sea surface temperature (hereafter CNTL experiment). To conduct the numerical prediction by the coupled model, daily oceanic reanalysis data calculated by the Meteorological Research Institute multivariate ocean variational estimation (MOVE) system (Usui et al. 2006) was used, too. When the atmosphere model and MOVE dataset were used, the experiment calls “MOVE”, whereas it calls “MOVECP” when the atmosphere-wave-ocean coupled model was used. Moreover, when the atmosphere-wave-ocean coupled model incorporating the sea-spray parameterization was used, the experiment calls “MOVECSP”. The analyzed center positions of Typhoon Sinlaku in the MOVECSP experiment is more close to those of the Regional Specialized Meteorological Center (RSMC)-Tokyo best track and the CNTL experiment than those of MOVE and MOVECP.

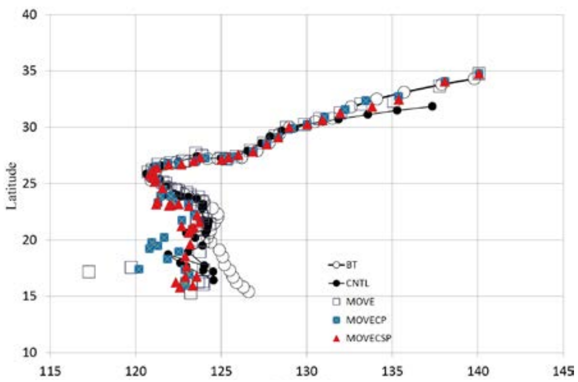

Figure 1 Results of analyzed center positions of Typhoon Sinlaku in CNTL, MOVE, MOVECP and MOVECSP along with the RSMC-Tokyo best track.

Figure 2 depicts the evolutions of analyzed central pressures along with the RSMC-Tokyo best-track central pressure. In the MOVECSP experiment, the falling rate of the analyzed central pressure was more rapid than that in the MOVECP experiment even though sea surface cooling induced by the storm was calculated in the forecast part for each cycle. The falling rate was similar to that in the CNTL experiment. TC intensification in the MOVECSP experiment occurred earlier than that in the MOVE experiment. The results suggest that the improvement of atmospheric surface boundary scheme is effective for the analysis of TC intensification in the NHM-LETKF system.

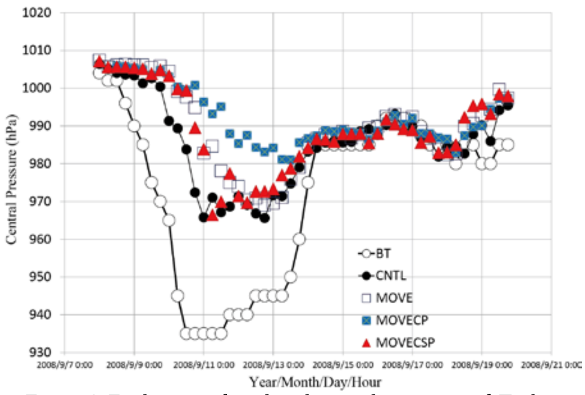

Figure 2 Evolutions of analyzed central pressures of Typhoon Sinlaku in CNTL, MOVE, MOVECP and MOVECSP along with the RSMC-Tokyo best track central pressure.

Figure 3 shows radial-height profiles of axisymmetrical mean radial and tangential flows in the MOVECSP and MOVECP experiments. Mean radial inflow and tangential flow in the MOVECSP experiment were stronger than those in the MOVESP experiment. This result suggests that the enhancement of turbulent heat fluxes near the atmospheric surface-boundary layer directly affect the inner-core structure of the TC and TC intensity analysis.

In Figure 3, a few peaks of radial inflow and tangential flow are analyzed. The distance of each peak from the storm center was longer than the analysis in Wu et al. (2012) and Huang et al. (2012). This is due to relatively coarse horizontal resolution (15 km) in the present experiments compared with 5 km in Wu et al. (2012) and Huang et al. (2012). However, the amplitude of radial inflow and the outer maximum tangential flow became greater due to the sea-spray parameterization in the NHM-LETKF system.

This study reveals that the impact of the sea-spray parameterization is effective to resolve the inner-core structure of the TC and thus improve the TC intensity analysis. However, high horizontal resolution (at least 5 km) is required to analyze the inner-core structure of the TC more accurately. In addition, the analysis in the ocean part needs to be developed.

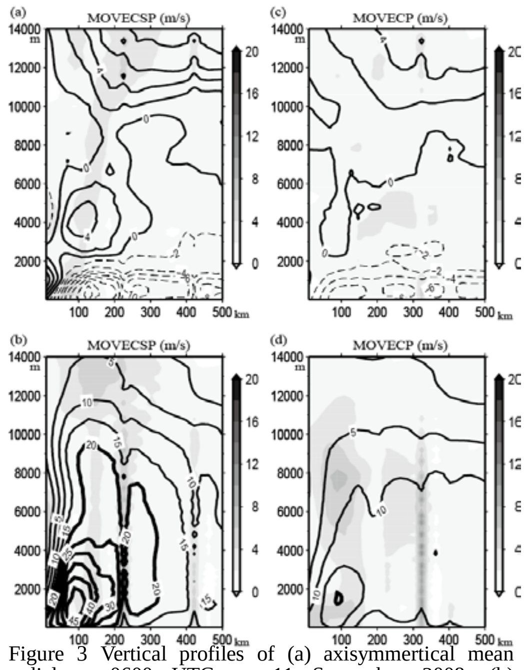

Figure 3 Vertical profiles of (a) axisymmertical mean radial at 0600 UTC on 11 September 2008, (b) axisymmertically mean tangential flow (contours) and the standard deviations (shades) in the MOVECSP experiment and (c) same as (a) except in the MOVECP experiment and (d) same as (c) except for axisymmertically mean tangential flow.

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