The effect of predicted oceanic conditions on the assimilation of Typhoon Sinlaku (2008)

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1. Introduction

This report follows the work of Wada and Kunii (2014, 2015) that described the development of a regional coupled atmosphere-ocean 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 includes the effect of sea spray. The sea-spray parameterization helped tropical cyclone (TC) intensification by increasing turbulent heat fluxes near the atmospheric surface-boundary layer as described in Wada and Kunii (2015).

In the previous works of Wada and Kunii, ocean predictions calculated in a forecasting part of the coupled system were not used in both the analysis and the following prediction. The purpose of this study is to introduce the ocean predictions into the following calculation in order to understand the effect of oceanic variations on the analysis of the TC. This study addresses Typhoon Sinlaku (2008) as a case study, which is the same as considered in Wada and Kunii (2014, 2015).

2. Experimental design

Figure 1 displays a schematic diagram of the revised NHM-LETKF assimilation system. It uses daily oceanic reanalysis data calculated by the Meteorological Research Institute multivariate ocean variational estimation (MOVE) system (Usui et al., 2006) only at the initial step. After that, restart data calculated by the ocean and wave models were used as input for the following predictions in the next cycle. The restart data were used for conducting numerical simulations as a sequential job. Therefore, the ocean is continuously predicted through the entire assimilation period without taking into account the influence of in situ observations and oceanic reanalysis data.

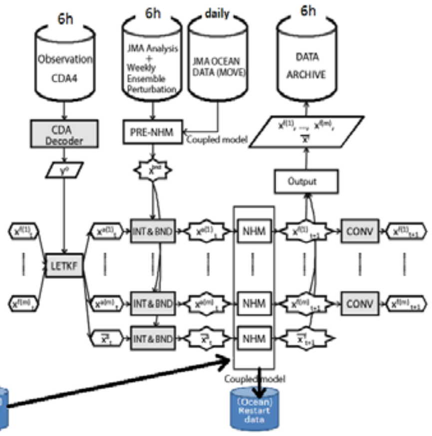

Figure 1 Schematic diagram of NHM-LETKF coupled with the atmosphere-wave-ocean model in the prediction part with oceanic reanalysis data.

The experimental design was almost the same as in Wada and Kunii (2015). 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). The analysis component of the LETKF system was the same as in Kunii (2014). The ocean (wave conditions) was assumed to be motionless only at the initial time

The analysis and prediction of the storm were performed over 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 September to 1800 UTC 19 September in 2008. The number of ensemble members was 50. Wind stresses from the atmosphere to the ocean were tuned to be twice larger in the ocean model since the horizontal resolution (15 km) was relatively coarse for tropical cyclone simulations and thus the atmosphere model predicted relatively weak wind stresses. Table 1 shows experimental design. ‘Atmos’, ‘Wave’ and ‘Ocean’ means a component of forecasting model. ‘Restart’ means that predicted ocean waves and ocean components are propagated in the next cycle. This is only used in ‘REST’. The left vertical column in Table 1 indicates the name for each experiment. ‘CNTL’ used the NHM, ‘Wave’ used the NHM-wave-coupled model, and ‘FULL’ and ‘REST’ used the NHM-wave-ocean coupled model.

3. Results and concluding remarks

Figure 2 presents the results of ensemble mean TC track positions every 6 hours with Regional Specialized Meteorological Center (RSMC) Tokyo best track (BT). The effect of ocean coupling in the ensemble mean TC track is negligible among the four experiments except for an early phase of Typhoon Sinlaku, corresponding to the genesis phase. On the mid-latitude TC, the ensemble mean TC track is almost the same among the four experiments.

Table 1 Experimental design

Exp./Model	Atmos.	Wave	Ocean	Restart
CNTL	○	×	×	×
WAVE	○	○	×	×
FULL	○	○	○	×
REST	○	○	○	○

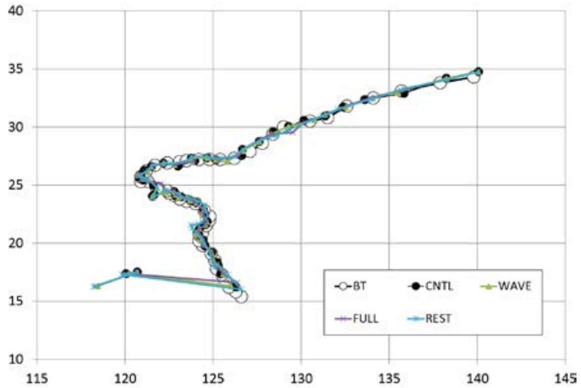

Figure 2 The results of ensemble mean TC track. BT indicates RSMC Tokyo best track positions every 6 hours.

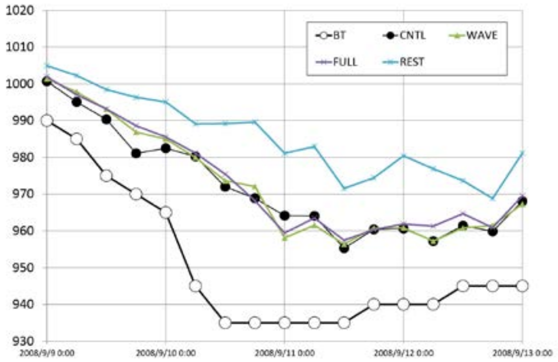

Figure 3 As in Fig. 2 except for ensemble mean TC central pressure.

Figure 3 shows the evolution of ensemble mean TC central pressures with RSMC Tokyo best-track central pressure. The effect of ocean waves (experiment WAVE) on the changes in ensemble mean central pressure is found during the intensification phase around 11 September, compared with those in CNTL. The intensification in FULL is similar to that in WAVE: The difference in the ensemble mean central pressure between CNTL and FULL is small. The result is different from the previous results reported in Wada and Kunii (2014, 2015) because the effect of turbulent heat fluxes on sea surface cooling induced by the typhoon was excessive in the previous coupled system. The current system improves the process based on the original coupled model (Wada et al., 2010).

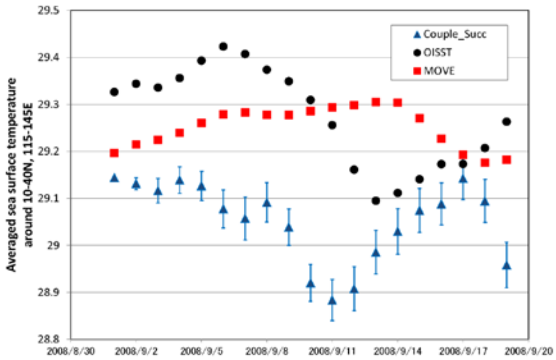

Figure 4 Evolutions of sea surface temperature averaged over the computational domain obtained from REST, MOVE and OISST.

Figure 4 shows the evolution of sea surface temperature averaged over the computational domain obtained from REST together with the average sea surface temperatures obtained from MOVE and OISST (http://www.remss.com/). The change in sea surface temperature is well reproduced in REST against that in MOVE with reference to that in OISST.

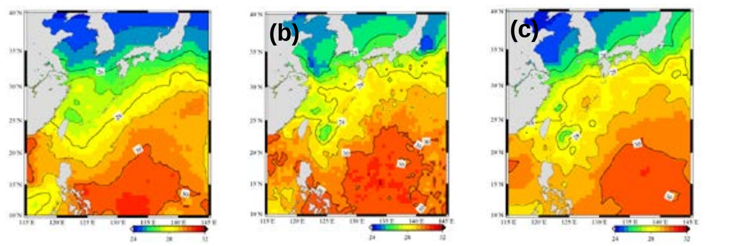

Figure 5 Horizontal distributions of sea surface temperature at 18 UTC on 19 September obtained in (a) REST,(b) OISST (http://www.remss. com

Figure 5 displays the horizontal distribution of sea surface temperature at 18UTC on 19 September and the horizontal distributions of daily sea surface temperature in OISST and MOVE. The horizontal distribution of the sea surface temperature in MOVE is similar to that in OISST and is different from that in REST particularly in the location of Sinlaku induced sea surface cooling.

Therefore, the use of predicted oceanic conditions are able to change the prediction of TC intensity. This suggests that errors of ocean predictions do affect the accuracy of TC intensity analysis if oceanic valuables such as water temperatures are not controlled by observations. In order to improve the representation of the distribution of sea surface temperature, it should be dealt with control variables in the coupled assimilation system.

Acknowledgement

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