Comparison of J-OFURO remote-sensing based ocean flux data with numerical simulations by a coupled atmosphere-wave-ocean model in Typhoon Dujuan (2015) case

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1. Introduction

A third-generation data set developed by the Japanese Ocean Flux Data Sets with Use of Remote-Sensing Observations (J-OFURO) research project provides surface heat, momentum, freshwater fluxes, and related parameters over the global oceans (Tomita et al., 2019). The data set currently covers the years from 1988 to 2013 with a daily temporal resolution and a horizontal resolution of 0.25 ˚. In addition, a preliminary data set is available from 2014 to 2015. It is expected that it will be possible to use this data set for typhoon and extreme weather research by realizing high resolution in space and time. On the other hand, 'typhoon' is a phenomenon in which time fluctuations shorter than one day are predominant, including its ocean response. It is thought to be difficult to represent four-dimensional overall phenomena by using a data set with one-day time resolution and 0.25 degree spatial resolution. Therefore, in order to evaluate the applicability of the J-OFURO version 3 (J-OFURO3) data set to typhoon research, data comparison was performed with numerical simulation results by a 2 km-mesh nonhydrostatic atmosphere model coupled with ocean-surface wave and multilayer-ocean models (Wada et al., 2010, 2018) in the case of Typhoon Dujuan (2015).

Dujuan is one of the typhoons that made landfall in Taiwan. According to the Regional Specialized Meteorological Center (RSMC) Tokyo best track analysis, Dujuan was generated at 21 UTC on 22 September in 2015 and moved west-northwestward. The central pressure reached 925 hPa at 00 UTC on 27 September around 22.3˚N and 127.5 ˚E. Around 20.0 ˚N and 130.0 ˚E, Dujuan underwent steady intensification and the storm-induced sea surface cooling occurred by passage of the storm (Figure 1). In this study, the initial time and integration period for the numerical simulation of Dujuan are 00 UTC on 23 September in 2015 and 120 hours with the time interval of 3 seconds. The Japan Meteorological Agency (JMA) global objective analysis with horizontal resolution of 20 km and the JMA North Pacific Ocean analysis with horizontal resolution of 0.5° were used for creating atmospheric and oceanic initial conditions and atmospheric lateral boundary conditions. For comparison, a numerical simulation was performed by a nonhydrostatic atmosphere model with the same initial and boundary conditions.

2. Method

Sea surface temperature (˚C), surface wind speed (m s^{-1}) and air-sea latent heat flux (W m^{-2}) were used for comparing the J-OFURO3 data with the results of numerical simulations. The domain for the comparison covers the area from 16 to 32 ˚N and 122 to 138 ˚E. Around 20.0 ˚N and 130.0 ˚E, the location of the simulated storm was close to that of the best track although the northward bias was found west of 130.0 ˚E. The comparison was made around 20.0 ˚N and 130.0 ˚E from 24 and 25 September in 2015 when the storm did not arrive at the location.

Sea surface temperature, surface wind speed and air-sea latent heat flux simulated by the coupled model were averaged over a 0.25˚ x 0.25˚ grid, corresponding to the horizontal resolution of the J- OFURO3 data set every 6 hours. The correlation between the simulation results and J-OFURO3 data was investigated for each element from 12 UTC 24 September to 06 UTC 25 September 2015, after correcting the difference of the location between the simulation and the best-track analysis although the difference was smaller than 1˚.

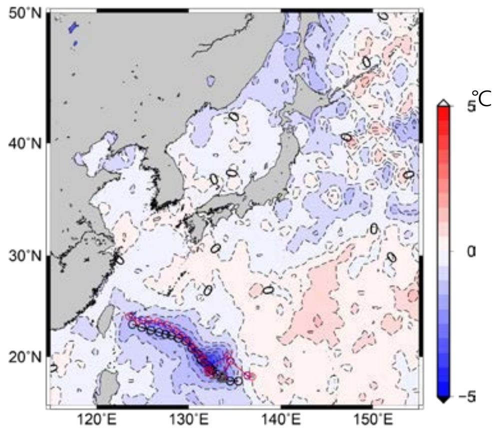

Figure 1. The best track (black circles) and simulated tracks (red circles by the uncoupled model and blue circles by the coupled model) and the difference in SST between before (-3 days) and after (+ 3 days) the passage of Dujuan derived from J-OFURO3 daily SST data.

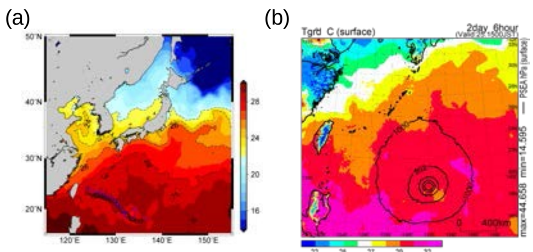

Figure 2. Horizontal distributions of (a) J-OFURO3 daily sea surface temperature on 25 September with the tracks shown in Fig. 1 and (b) simulated sea surface temperature (colors) at 06UTC (15JST) on 25 September with sea-level pressure at the contour interval of 8 hPa.

3. Results

Figure 2a shows the horizontal distribution of J-OFURO3 sea surface temperature on 25 September. Sea surface cooling induced by Dujuan was found along the track. Figure 2b shows the horizontal distribution of sea surface temperature simulated by the coupled model. The sea surface cooling induced by Dujuan was also found after the passage of the typhoon. This result indicates that J-OFURO3 sea surface temperature can capture storm-induced sea surface cooling.

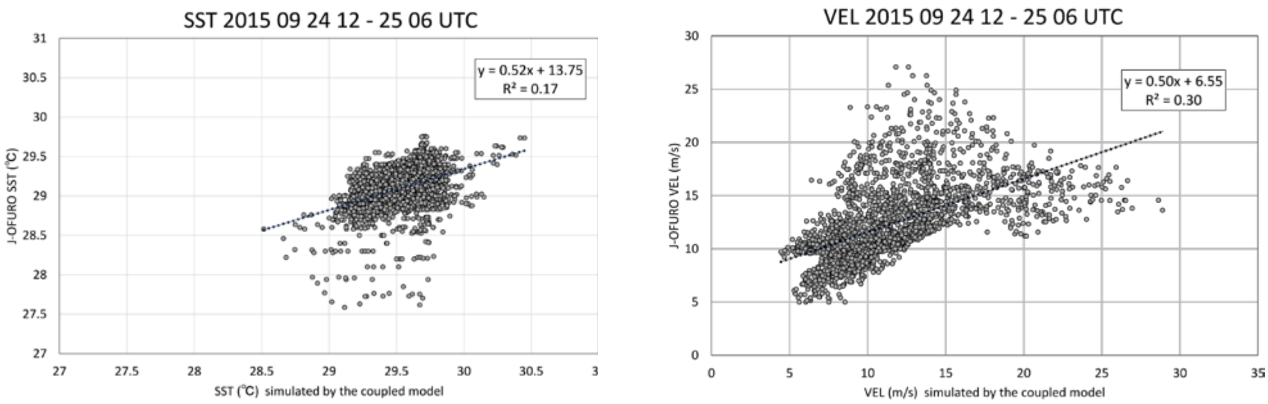

Figure 3. Correlation, simple linear regression model and coefficient of determination between J-OFURO3 data and simulation results for (a) sea surface temperature and (b) surface wind speed from 12 UTC on 24 September to 06 UTC on 25 September in 2015.

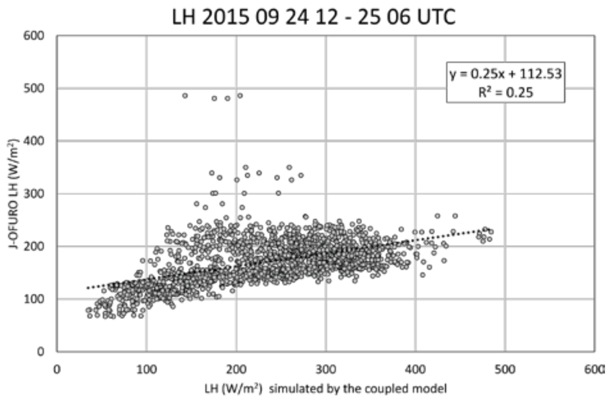

Figure 4. Same as Fig. 3 except for air-sea latent heat flux.

Figure 3 shows a scatter diagram, simple linear regression model and square of correlation coefficient between J-OFURO3 data and simulation results for sea surface temperature (Fig. 3a) and surface wind speed (defined by simulated wind speed at 10-m height) (Fig. 3b) from 12 UTC on 24 September to 06 UTC on 25 September in 2015. Although the coefficient of determination was relatively small, both correlation coefficients were significant at a significant level higher than 99.999% based on a *p*-value. However, the result also shows that there were positive biases in both simulated sea surface temperature and surface wind speed. The positive bias for sea surface temperature was possibly caused by the occurrence of TC-induced sea surface cooling after 06 UTC on 25 September.

The positive bias for surface wind speed was possibly caused by the following factors: Satellite wind observations could not capture high surface winds in the vicinity of a storm. Otherwise, the inner-core radial wind profile differed between the J-OFURO3 surface wind data and simulated surface wind speeds. In addition, the simulated Dujuan moved westward, while the J-OFURO3 surface wind data cannot include the variation on a time scale shorter than a day.

Figure 4 shows a scatter diagram, simple linear regression model and coefficient of determination between J-OFURO3 data and simulation results for air-sea latent heat flux. The correlation coefficient was also significant at a significant level higher than 99.999% based on a *p*-value. The positive bias of simulated air-sea latent heat flux was caused by the positive biases of both sea surface temperature and surface wind speed. In fact, the slope of the linear regression model for air-sea latent heat flux (0.25) was almost the same as that for sea surface temperature (0.52) times that for surface wind speed (0.5). It should be noted that there were some grids where the J-OFURO3 air-sea latent heat flux was higher than the simulated one. This means that the J-OFURO3 could capture high air-sea latent heat flux in the vicinity of the storm although the location and inner-core structure of the typhoon differed between J-OFURO3 data and simulation results due to the difference of special and temporal resolution.

4. Future subjects

J-OFURO3 air-sea sensible and latent heat fluxes are determined by not only sea surface temperature and surface wind speed, but also surface air temperature, surface specific humidity and exchange coefficients. Comparison of these elements simulated by the coupled model should be made with the J-OFURO3 data, separately. The results of the comparison will lead to the development of the coupled model in the future.

References

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Acknowledgements

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