Numerical simulation for the ocean response to Typhoons Tina and Winnie in 1997 and their relations to sudden variations of pCO_2.

Akiyoshi Wada [1*] and Takashi Midoriwaka [1]

1) Meteorological Research Institute, Tsukuba, Ibaraki, 305-0052, JAPAN

*awada@mri-jma.go.jp

1. Introduction

An automatic-measuring system for the partial pressure (pCO_2) of atmospheric and oceanic carbon dioxide mounted on the moored buoy in the East China Sea (28°10'N, 126°20'E) captured sudden variations of oceanic pCO2 during the passage of Typhoons Tina and Winnie in 1997 (Nemoto et al., 2009). In order to investigate dynamics and thermodynamic associated with the sudden variations of oceanic pCO_2, we perform numerical simulations associated with the oceanic response to Tina and Winnie using the Meteorological Research Institute Community Ocean Model (Ishikawa et al., 2005).

2. Experiment Design

First, we perform a numerical simulation using the North Pacific version of MRI.COM. The integration time is 2 months with nudging daily data of sea temperature and salinity on 3 August 1997, obtained from the oceanic reanalysis data. Second, we perform a numerical simulation by the same version of MRI.COM except that the integration time is 21 days and the run is performed without nudging daily data of sea temperature and salinity on 3 August 1997. The purpose of the second run is to make initial and lateral boundary conditions for the third run. Third, we perform a numerical simulation using the regional version of MRI.COM. The integration time is 21 days, which is the same as the second run. However, the computational domain for the regional model is 10-50°N, 120-160°E. The horizontal resolution is 0.25° and the number of vertical levels is 54. The time step is 10 minutes. The mixed-layer scheme of Noh and Kim (1999) is used now. These three procedures are the same as those of Wada et al., (2009).

NCEP R2 atmospheric reanalysis dataset with a grid spacing of 1.875° is used for making atmospheric forcings such as short-wave and long-wave radiation, sensible and latent heat fluxes, water flux and wind stress. In addition, the Rankine vortex created by using the RSMC best-track data is used for the third run (see Wada et al., 2009). Short-eave radiation is diurnally varied based on the formulas of Danabagoslu et al. (2006). In addition, the input of short-wave radiation lessens by 10% when the precipitation data is significant.

3. Results

3-1 Comparison of simulated temperature with observations

Figure 1 shows time series of observed and simulated temperature at the location of moored buoy. Even though simulated temperature at the 100 m depth was poorly reproduced in MRI.COM, the model well reproduced the evolution of observed temperature at the 0 m depth. After the passage of Tina, near-inertial oscillation was salient at the 50 m depth, which was not reproduced in MRI.COM. On the other hand, MRI.COM could reproduce the deepening of mixed-layer after the passage of Winnie.

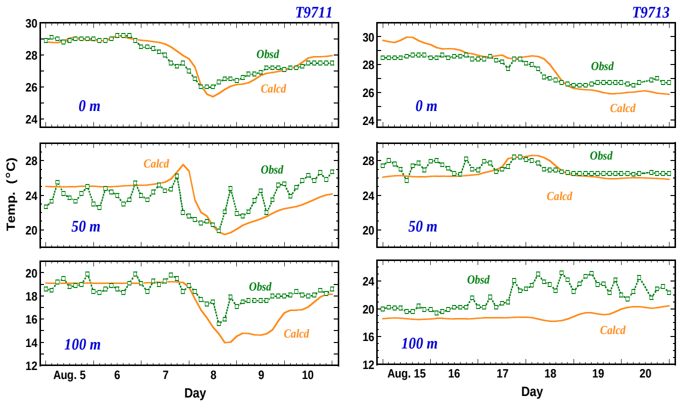

Figure 1 Time series of observed (green lines) and simulated (orange lines) temperature at 0 m (upper panels), 50 m (middle panels) and 100 m (lower panels) depths. Left panels showed the results in Typhoon Tina and right ones in Typhoon Winnie.

The results of the difference in two time series suggest that dynamics and thermodynamics related to the variations of temperature are considered to be different between Tina and Winnie.

3.2 Typhoon Tina

Figure 2 shows time series of simulated sea temperature at the location of moored buoy. First, a mixed layer deepens around 7 August. Subsequently, salient upwelling occurs from 7 to 9 August. Seasonal thermocline is raised to the surface during the passage of Tina. Figure 3 shows the latitude-depth section of simulated temperature and horizontal currents across 126.25˚E at 1500 UTC 7 August. At that time, the moored buoy is underneath the center of Tina. Cold water below the seasonal thermocline is transported to the mixed layer due to strong upwelling over the continental shelf. Behind Tina (the ocean response to Tina after its passage), near-inertial oscillation is induced at the mixed-layer base.

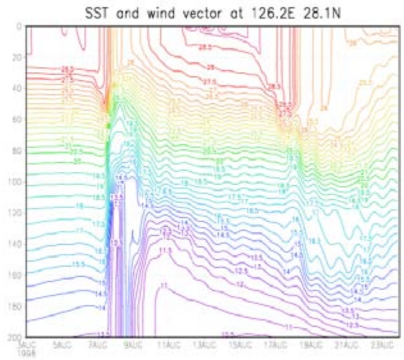

Figure 2 Time series of sea temperature at the moored buoy (28.1˚N,126.2˚E) from 3 to 19 August.

3.3 Typhoon Winnie

On the other hand, no salient upwelling occurs during the passage of Winnie. Figure 4 shows the latitude-depth section of simulated temperature and horizontal currents across 126.25 ˚E at 0600 UTC 18 August. Around the location of moored buoy, a mixed layer is relatively deep compared with that shown in Figure 3. In fact, Winnie passes 25.4 ˚N, 126.25˚E south the moored buoy during the period from 1800 UTC to 2100 UTC 17 August. Because the size of Winnie defined as the radius of 15 m s^{-1} wind speed) is relatively large, long-lasting vertical turbulent mixing induced by strong wind continuously deepens the mixed layer and lowers the mixed-layer temperature.

Although the oceanic dynamics and thermodynamic at the location of moored buoy are different between Tina and Winnie, these typhoons have a significant impact on the sudden variations of oceanic pCO_2. We need to clarify the process of acceleration in the uptake transport of oceanic CO_2 caused by typhoons and the impact of typhoon-induced increase in CO_2 fluxes on the climate.

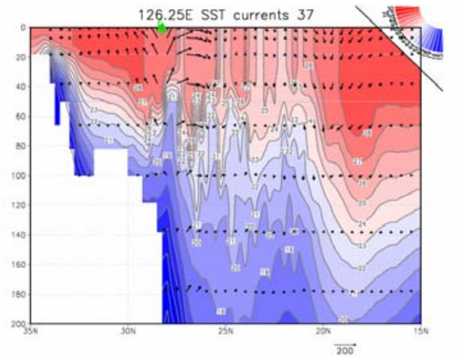

Figure 3 Latitude-depth section of simulated temperature and horizontal currents across 126.25˚E at the 37 steps every 3 hours, corresponding to 1500 UTC 7 August.

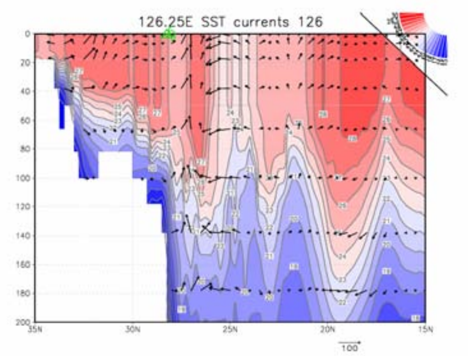

Figure 4 Same as Figure 2 except at the 126 steps every 3 hours, corresponding to 0600 UTC 18 August.

References

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