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TYPHOON INTENSITY CHANGE BY THE OCEAN HEAT CONTENT IN THE NORTHWESTERN PACIFIC OCEAN

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1. INTRODUCTION

The prediction of typhoon intensity (central pressure) in the Northwestern Pacific Ocean is one of the important issues in the current typhoon research, since it is showed that differences between the forecasted and observed values exist in the operational field. As an index of hurricane intensity change in the Atlantic Ocean, the upper ocean thermal structure has been suggested by several researchers (Leipper and Volgenau (1972); Hong et al. (2000); Goni and Trinianes (2003)). Leipper and Volgenau (1972) proposed the hurricane heat potential, which is the oceanic heat content from the surface to the depth of the 26°C isotherm. Hong et al. (2000) studied in more detail about the intensification of hurricane by warm core ring whose has relatively higher thermal energy than around. According to their results, Hurricane Opal (1995) was additionally intensified by a warm core ring in the Gulf of Mexico about 17 hPa between the times when the hurricane entered and exited the outer edge of the warm core ring area.

Shay et al. (2000) insisted that the surface wind rapidly increased from 35 to over 60 m/s and radius of maximum wind decreased from 40 to 25 km after the Hurricane Opal (1995) passing over the warm core ring area. Even though the surface water-cooling associated with vertical mixing along the track was occurred about 2^{o}-3^{o}C in the Hurricane Opal case, the warm core ring gave the positive effect in the hurricane intensity increase. In recent, Ali et al. (2007) carried a study about the relationship between sea surface height anomaly (SSHA) and the cyclone intensity in the Indian Ocean, and concluded that eddies and dynamic topographic are better index compared with SST in the cyclone intensity change study

In this study, we mainly focused on the direct calculation of oceanic thermal amount in terms of energy source of typhoon intensity change using ocean buoy data in the Northwest Pacific Ocean. We also tried to compare to the typhoon intensity change, SST distribution, and the typhoon-related thermal energy of the ocean. The main questions to be answered here are: How does the typhoon respond with the ocean heat content in the Northwestern Pacific Ocean? And what is the time lag of the typhoon intensity change by ocean heat content? The definition of the thermal energy related typhoon intensity and data used in this study will be described in section 2 and 3. Preliminary results about application of comparison between intensity change and thermal energy distribution for typhoons in 2006-2007 are introduced in section 4. A simple summary of this study is given in section 5.

2. TYPHOON-RELATED OCEAN HEAT CONTENT

Typhoon is generated when atmospheric and oceanic environments become some state. One of known ocean conditions for typhoon formation above ocean is that the sea surface temperature is above 26^{o}C indicating that the ocean has enough thermal energy to provide it into the atmosphere (Pielke, 1991). This means that if SST is below than 26°C the typhoon is hard to be formed. Assuming that temporal and spatial distribution of water temperature

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in the ocean are known, the temperature changes before and after typhoon development could be compared and the oceanic energy loss by typhoon be estimated. Typhoon movement increases the oceanic mixed layer depth following the track and the magnitude of energy loss depends on the intensity and scale of typhoon. So, thermal structure of the ocean could be an important factor to determine the typhoon intensity change.

In general, the ocean heat content is defined by seawater density, specific heat, and temperature difference. Since seawater density is a function of salinity, temperature and pressure, the density calculation is needed three variables at the same time. In order to get the horizontal and vertical density distribution, the number of observation point should also be a appropriate level – at least several points of data exist in the typhoon-affecting area – and observation should also be carried out before and after typhoon passing to see a variation of status of ocean in terms of temporal scale, too. With given an appropriate ocean data set, we could simply calculate the typhoon-related oceanic heat content (TOHC) using the formulation below:

$$TOHC = c_p \int_{surf}^{h(T=26)} \rho(s,t,p)(T-26)dz$$

where c_p is the specific heat of water (=4.186 kJ/kg^{o}C), ρ is seawater density (kg/m^3), and *s, t, p* are salinity, temperature and pressure, respectively. Figure 1 shows an example of temperature, salinity, and density profiles obtained at the tropical area on July 4, 2006.

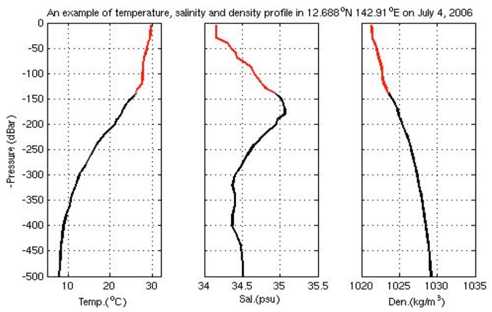


Figure 1: An example of temperature, salinity and density profile obtained at 12.68^{o}N, 142.91^{o}E on July 4, 2006. Red line shows the layer that the temperature is greater than 26^{o}C.

3. DATA

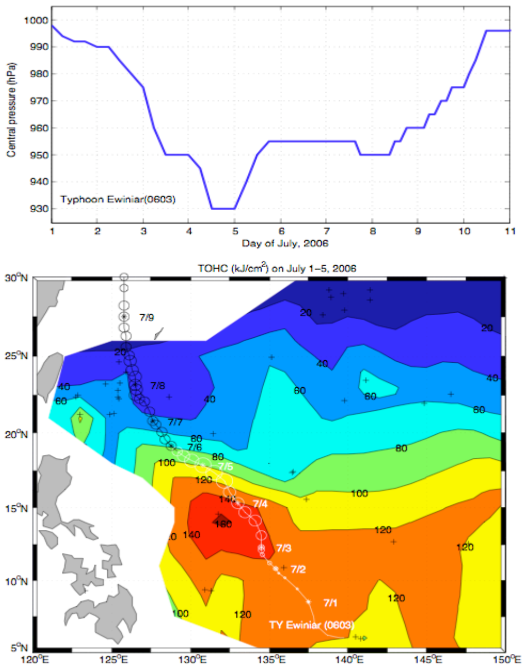
The ocean data used in this study were collected and made freely available by the International Argo (Array for Real-time Geostrophic Oceanography) Project and the national programs that contribute to it (http://www.argo.ucsd.edu). Argo is a pilot program of the Global Ocean Observing System. The Argo buoy, in general, stays at the parking depth for 10 days flowing the deep water current, and then rises up to the surface layer with the conductivity, temperature and pressure cast to send out the observed data to satellites. Because of this time schedule, the number of observation of buoys a day is not same to the number of buoy deployed so far. For example, the total number of buoy deployed and alive until June 26, 2007 was 2856 in the world oceans. The ocean profile data obtained in 2006-2007 was used in this study, and accumulates for 5 days in order to setup daily data because the number of observation point in a day was not enough. For example, we used buoy data from July 1 to July 5 to plot the heat content distribution of July 5.

The typhoon best track for 2006-2007 produced by the Regional Specialized Meteorological Center (RSMC) /Tokyo was used to see the central pressure change with each position. In 2006 the total number of typhoon generated at this area was 23, which was the lower frequency than 30-year average number (~26.7) and three typhoons directly affected the Korean peninsula area. Maximum sustained wind speed was close to 60 m/s and category 3 (945-964 hPa in central pressure) lasted for 20 days in the total typhoon activity days. The average lifetime was about 7.2 days. In 2007, the total number of typhoon was 24 generated in the area and one typhoon (typhoon Nari(0711)) was landed and two (Man-Yi (0704), Usagi(0705)) directly affected to Korean peninsula. The longest lifetime was 16 days and average lifetime of typhoons in 2007 was similar to 2006's.

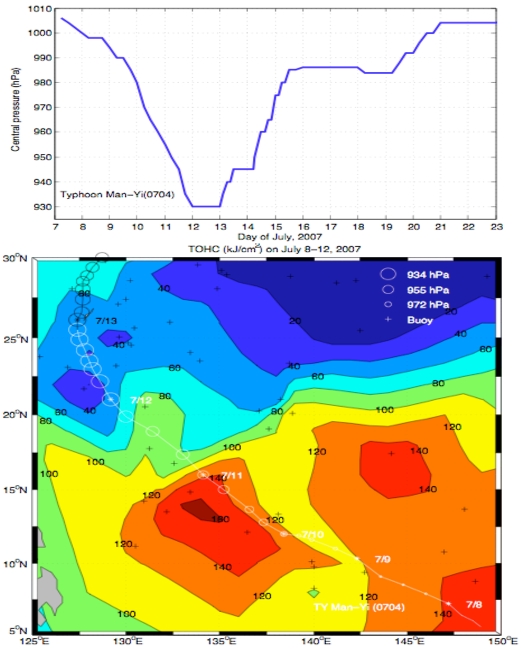
4. PRELIMINARY RESULTS

Figure 2 shows examples of comparison of the typhoon intensity (central pressure) change pattern and horizontal distribution of TOHC on July 5 for typhoon Ewiniar(0603) and on July 12, 2007, for typhoon Man-Yi(0704). On July 1-5, 2006, the sea surface temperature (not shown here) was almost homogeneous in horizontal showing above 29°C, the Ewiniar(0603)'s intensity was continuously increased. After July 5, the typhoon started to become weakened and made the ocean surface rapidly cooling. The typhoon was already under the decaying processes after July 5 even SST was over 29°C. According to TOHC distribution of July 5, 2006, the typhoon was passed over the thermal energy about 140 kJcm^{-2} for one day (on July 3) and then the intensity was dramatically increased showing a peak value on late July 4 or early July 5. Typhoon Man-Yi(0704) become intensified in maximum on July 12 (right panel in Figure 2). According to the TOHC distribution, the typhoon started to get in the area of 120 kJcm^{-2} on July 10 and then passed this area for one day and then became maximum intensity after one and half day. The time-lag between the maximum intensity and the passing time of high heat content area was a little bit longer than typhoon Ewiniar(0603) case.

In order to see how the typhoon intensity during the intensifying period changes in maximum after passing the warm ocean, the time-difference of the central pressure (after 6, 12, 24 and 48 hours) was shown in Figure 3. According to this diagram, typhoon can be more intensified with the higher thermal energy level as time goes and goes. For example of the level 60-80 kJcm^{-2}, the decrease rate in maximum was less than 20 hPa after 6 hours, and showed about 30 hPa after 12hours, and became almost 40 hPa after 24 hours. When the level is around 80-100 kJcm^{-2}, the decrease rate of the central pressure was bigger. After 24 hours in this level, the maximum decrease rate was showed around 40-60 hPa, which means the typhoon's central pressure could be decreased by 10-15 hPa per 6 hours. It is also noticed that when the level is below 40 kJcm^{-2}, the rate was not much changed. It looks like constant value.



(a)



(b)

Figure 2: Typhoon intensity change and typhoon-related ocean heat content distribution for (a) typhoon Ewiniar(0603) on July 5, 2006 and for typhoon Man-Yi(0704) on July 12, 2007.

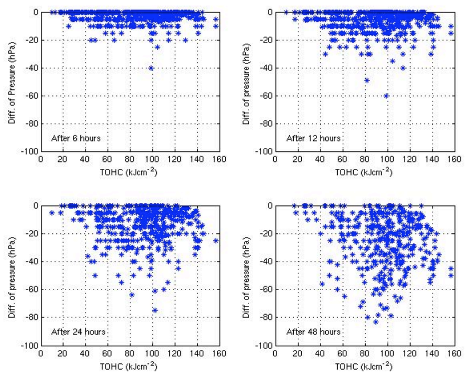


Figure 3: Time difference of the central pressure of typhoon after passing the typhoon-related ocean heat content for the cases of 2006-2007 in the Northwestern Pacific Ocean.

5. SUMMARY

The ocean heat energy could be a main factor for the typhoon to be intensified in the Northwestern Pacific Ocean. Typhoon intensity could be increased especially after passing the high ocean heat energy area, and the ocean heat effect to the typhoon showed with some different time-lag for each energy level. Even though the number of typhoon cases used in this study was just for two years to estimate the relationship between the typhoon intensity and the ocean heat content, it is still indicating, based on this study results, that this kind of concept could be an excellent potential indicator to predict the typhoon intensity change when typhoon is over the ocean.

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