UPPER OCEAN RESPONSE TO INTENSE TYPHOONS IN THE SOUTH CHINA SEA

Zhe-Wen Zheng[1], Chung-Ru Ho[*2], Nan-Jung Kuo[2], and Yu-Hsin Cheng[2]
[1]Institute of Marine Environmental Science and Technology, National Taiwan Normal University,
88 Tingzhou Road, Taipei, Taiwan; Tel: +886-02-77346439;
Email: zhengzhewen1123@gmail.com

[2]Department of Marine Environmental Informatics, National Taiwan Ocean University,
2 Pei-Ning Road, Keelung ,Taiwan; Tel: +886-02-24622192#6345;
E-mail: chungru.ho@gmail.com

KEY WORDS: Typhoons, South China Sea, Sea Surface Temperature, Sea Surface Height Anomaly, Air-Sea Interaction

ABSTRACT: In this study, the upper ocean physical response to intense (Category 4) typhoons passages were investigated by mutli-satellite observed data. Sequential microwave sea surface temperature merged from Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and Advanced Microwave Scanning Radiometer (AMSR-E) sensors were used to detect the physical responses (surface cooling) to these typhoons. Sea surface height anomaly (SSHA) merged from Jason-2 and ENVISAT satellite altimeter data was used to detect the location of where the cyclone eddy/circulation took place. Aforementioned parameters of all intense super-typhoons took place/passed over South China Sea (SCS) during 2003-2009 were collected to complete a systematical analysis focused on upper ocean physical response to intense typhoons in the SCS. Comparison between these parameters suggests a scenario that cooling response took place within SCS show a similar property of typhoon cases took place at open ocean (e.g. western North Pacific). Typhoon intensity and upper ocean dynamics dominate the distribution of maximum cooling responses in the SCS. This result implies that the upper ocean dynamical conditions should be taken into account for further understanding the generation mechanism of cooling response to a typhoon passed over the SCS.

1. Introduction

The South China Sea (SCS) is the largest marginal sea in the southeastern Asia. The SCS was surrounded by Luzon, Borneo Island, eastern Vietnam and south portion of China. Because the SCS is a semi-closed system, therefore it is necessary to confirm if the process of tropical cyclone (TC) caused upper ocean response shows the same/similar properties as shown in open ocean (e.g. western North Pacific) [Zheng et al., 2008; Zheng et al., 2010a; Zheng et al., 2010b] due to its unique hydrological environment.

There are not too many intense tropical cyclones (Saffir-Simpson hurricane scale larger than 3) passe over SCS. From 2003 to 2009, there are only four TC cases passed over SCS with category more than 3. These cases include typhoons Dujuan in 2003, Xangsane and Chanchu in 2006, and Hagupit in 2008. These TC cases provide a great opportunity for us to resolve the process of TC induced upper ocean response in the SCS. The main goal of this study is to resolve following questions: What's the main mechanism dominates the process of TC inducing upper ocean response in the SCS? When and where the most marked upper ocean response would take place in the SCS? Aforementioned problems will be attempted to resolve in this study.

2. Data and Methods

In this study, sequential microwave sea surface temperature (SST) merged from Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and Advanced Microwave Scanning Radiometer (AMSR-E) sensors were used to detect the physical responses to these typhoons [Wentz et al., 2000].

Meanwhile, sea surface height anomaly (SSHA) merged from Jason-2 and ENVISAT satellite altimeter data was used to detect the location of where the cyclone eddy/circulation took place. Typhoon related information (including moving track, translation speed, and typhoon intensity) was derived from Unisys through http://weather.unisys.com/hurricane/. These data are put into together to give a systematic analysis of upper ocean response to intense tropical cyclone taking place in the SCS.

3. Results and Discussions

Form 2003 to 2009, there are four typhoon cases which took place or passed over the SCS with Saffir-Simpson category larger than 3. They are typhoons Dujuan in 2003, Xangsane and Chanchu in 2006, and Hagupit in 2008, respectively.

All of these intense typhoon cases were collected here to give a systematic comparison for elucidating the processes of intense TC caused upper ocean responses in the SCS. Upper ocean response to a certain typhoon was presented by sequential TMI/AMSR-E SST images. Figure 1 to Figure 4 shows the upper ocean response caused by typhoons Dujuan (2003), Xangsane (2006), Chanchu (2006), and Hagupit (2008). Similar usage of these data can be seen in previous studies [Walker et al., 2005; Lin et al., 2003; Zheng et al., 2008].

Moreover, SSHA were also collected to reflect the upper ocean dynamic condition existing prior to typhoon passage. Negative SSHA denoted by solid contours showed in Figure 1 to Figure 4 represents cyclonic circulations/eddies existing before typhoon passage. These cyclonic features were overlapped with those upper ocean responses to examine the relationship between upper ocean response to a typhoon and pre-existing upper ocean dynamic environment.

3.1 Upper ocean responses to Dujuan

Figure 1 shows the upper ocean response caused by Dujuan (2003) passage. Sequential SST images show a slight cooling taking place along moving of Dujuan. Relative to original SST distribution, the cooling response attends to ~3°C. It is worth to note that there is no pre-existing cyclonic eddies or circulation existing along the moving track of Dujuan. On the other hand, there is a remarkable cyclonic feature existing around 200km north off the moving track.

However, most interesting is that there is a relative marked cooling took place within the area of negative SSHA close to its track. One can see that the cooling responses to Dujuan passage are highly associated with upper ocean dynamic condition existing prior to typhoon passage. These results are consistent with previous investigations [Walker et al., 2005; Zheng et al., 2008].

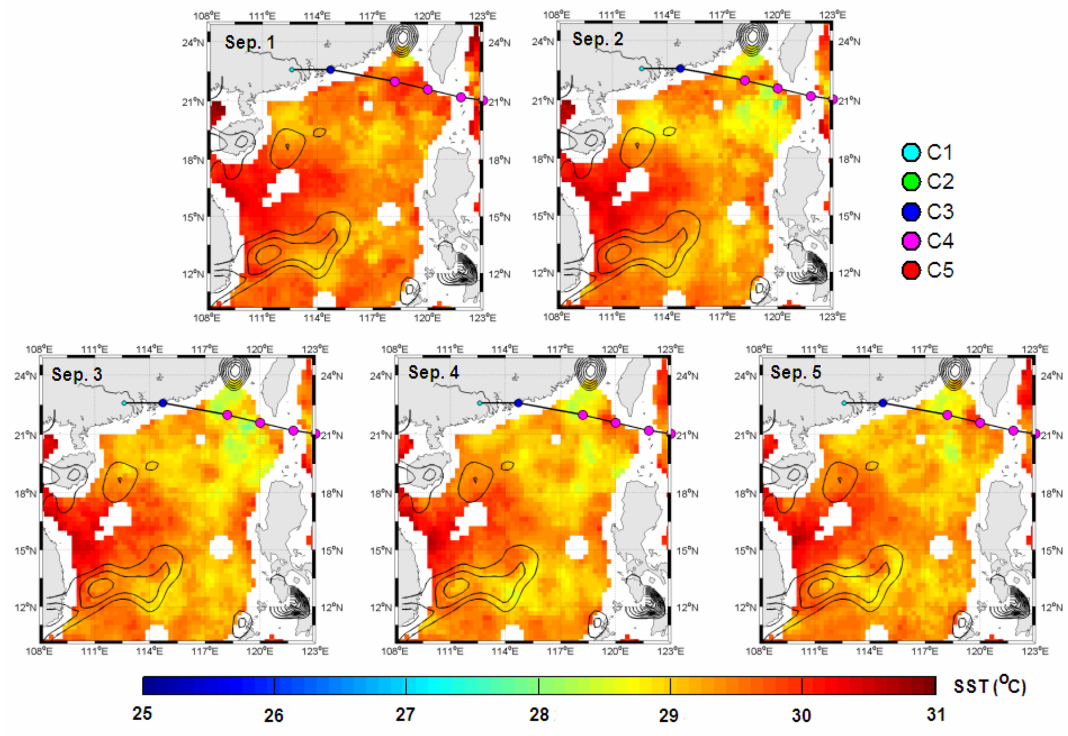

Figure 1. Upper ocean response caused by Dujuan (2003). Color patches represent the surface cooling in response to Dujuan passage. Solid contours reflected the locations where negative SSHA (cyclonic circulations or eddies) existing. Color dots denote the moving track and intensity of Dujuan.

3.2 Upper ocean responses to Chanchu

Figure 2 are sequential SST images which were collected during the typhoon passage of Chanchu (2006). From Figure 2, one can see that the passage of Chanchu caused a remarkable cooling along its passage. The SST drops attend to almost 6°C. This surface cooling in response to Chanchu's passage is believed to largely influence the upper ocean environment of middle and north SCS. More interesting is that, before the cooling response attends to maximum, the surface cooling seems can be separate into both parts (seeing SST images on 15th May).

According to the extra information provided by SSHA and typhoon itself moving, one can found that these two cooling parts are dominated by typhoon intensity, and cyclonic features distributing along the north continental shelf of SCS. Although cooling responses caused by typhoon Chanchu are much larger than those caused by Dujuan (2003), however, cooling responses to both typhoons show similar properties.

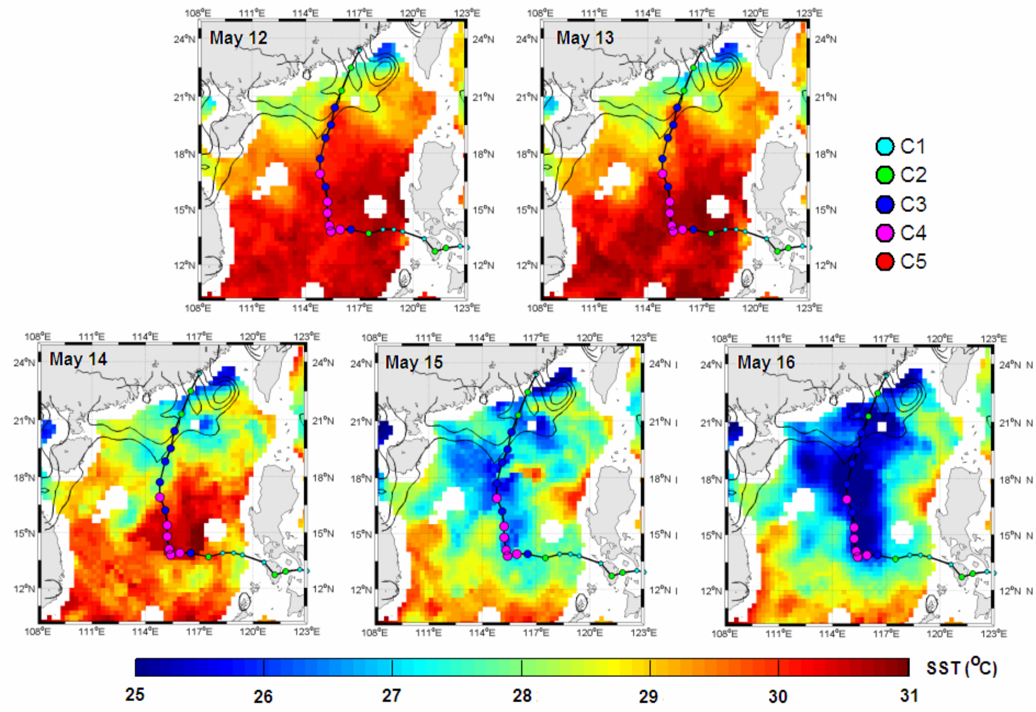

Figure 2. Sequential upper ocean cooling images during Chanchu (2006) passage. Color patches represent the surface cooling in response to Chanchu passage. Solid contours reflected the locations where negative SSHA (cyclonic circulations or eddies) existing. Color dots denote the moving track and intensity of Chanchu.

3.3 Upper ocean responses to Xangsane

Figure 3 shows the cooling response caused by typhoon Xangsane (2006). Relative to typhoons Chanchu and Dujune, typhoon Xingsane passed through the central of SCS. The passage of Xingsane cause a noticeable cooling response located at 16°N, 112°E.

Again, the distribution of maximum cooling responses shows good agreement with the intense typhoon intensity. Moreover, the distribution of those cooling response also shows good agreement with the distribution of cyclonic features. Cooperation of intense typhoon intensity and cyclonic eddies/circulation induce the maximum cooling. This implies that the rule of combination of cyclonic features and intense typhoon wind forcing usually causes maximum cooling response to a typhoon which was concluded from typhoon cases took place in the open ocean is also suitable for marginal sea such as SCS.

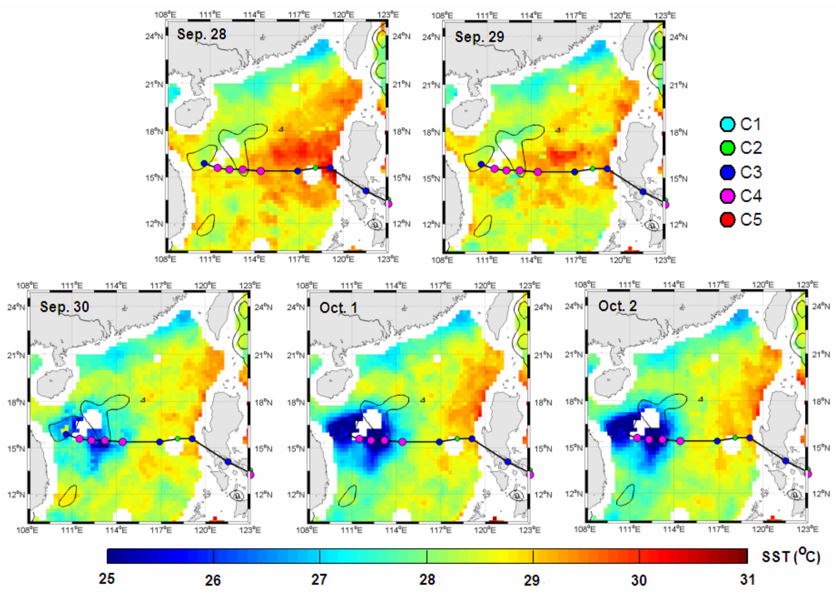

Figure 3. Sequential upper ocean response to typhoon Xangsane (2006) passage. Color patches represent the surface cooling in response to Xangsane passage. Solid contours reflected the locations where negative SSHA (cyclonic circulations or eddies) existing. Color dots denote the moving track and intensity of Xangsane.

3.4 Upper ocean response to Hagupit

Figure 4 shows the surface cooling in response to typhoon Hagupit passage. Moving track of typhoon Hagupit is quite similar with track of typhoon Dujune. Meanwhile, the cooling response caused by Haguipit documents a similar scenario as documented by Dujune. Cooling responses to Hagupit distributes almost along the moving track of Hagupit.

This is attributed to the disappearance of cyclonic features near the moving track. Without the influence of cyclonic upper ocean dynamics, these cooling responses dominated mainly by typhoon intensity only. In addition, without the influence of cyclonic features, one can see that the distribution of those cooling responses are much uniform.

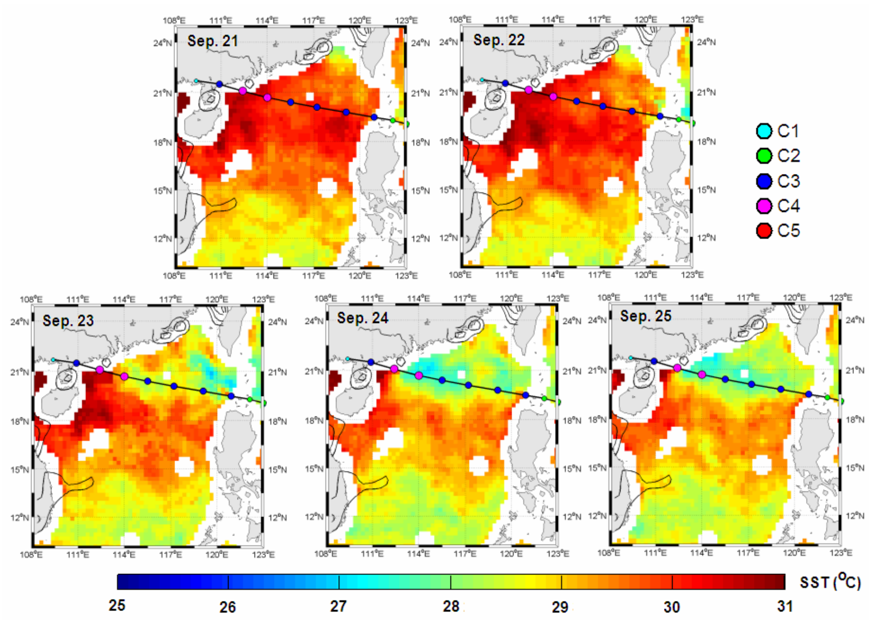

Figure 4. Upper ocean response caused by Hagupit (2008). Color patches represent the surface cooling to Hagupit passage. Solid contours reflected the locations where negative SSHA (cyclonic circulations or eddies) existing. Color dots denote the moving track and intensity of Hagupit.

4. Summary

This study investigates upper ocean response to a typhoon in the SCS. The results reveal that the process of TC caused upper ocean response shows similar properties as shown by those TC cases took place at open ocean (e.g. western North Pacific). The cooling responses caused by a certain TC case distribute mainly according to the typhoon intensity and upper ocean dynamical conditions.

Maximum cooling response caused by a certain typhoon usually takes place accompanying with intense typhoon intensity and cyclonic circulation/eddy (reflected by negative SSHA) existing prior to typhoon passage. These results can be treated as the preliminary result for subsequent in depth analysis of the processes of TC caused upper ocean physical and biological responses within the self-closed basin SCS.

References

Lin, I., W. T. Liu, C. Wu, G. T. F. Wong, C. Hu, Z. Chen, W. Liang, Y. Yang, and K. Liu (2003), New evidence for enhanced ocean primary production triggered by tropical cyclone, *Geophys. Res. Lett.*, 30(13), 1718, doi:10.1029/2003GL017141.

Walker, N. D., R. R. Leben, and S. Balasubramanian (2005), Hurricaneforced upwelling and chlorophyll a enhancement within cold-core cyclones in the Gulf of Mexico, *Geophys. Res. Lett.*, 32, L18610, doi:10.1029/2005GL023716.

Wentz, F. J., C. Gentemann, D. Smith, and D. Chelton (2000), Satellite measurements of sea surface temperature through clouds, *Science*, 288, 847– 850.

Zheng, Z.-W., C.-R. Ho, and N.-J. Kuo (2008), Importance of pre-existing oceanic conditions to upper ocean response induced by Super Typhoon Hai-Tang, *Geophys. Res. Lett.*, 35, L20603, doi:10.1029/2008GL035524.

Zheng, Z.-W., C.-R. Ho, Q. Zheng, N.-J. Kuo, and Y.-T. Lo (2010a), Satellite observation and model simulation of upper ocean biophysical response to Super Typhoon Nakri, *Cont. Shelf. Res.*, *30*, 1450-1457.

Zheng, Z.-W., C.-R. Ho, Q. Zheng, Y.-T. Lo, N.-J. Kuo, and G. Gopalakrishnan (2010b), Effects of preexisting cyclonic eddies on upper ocean responses to Category 5 typhoons in the western North Pacific, *J. Geophys. Res.*, *115*, C09013, doi:10.1029/2009JC005562.