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Changes of Temperature Field in Storms Under Influence of Cold Surge

Huong Chu Thi Thu[1], Linh Tran Dinh[1], Dinh Tran Ngoc Huy[2, 3], Nguyen Binh Phong[1]

[1]Hanoi University of Natural Resources and Environment (HUNRE), Hanoi, Vietnam
[2]Banking University HCMC, Ho Chi Minh City, Vietnam
[3]International University of Japan, Japan
[*]Corresponding author

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***Abstract*— *This study goal is to explore changes of the temperature field during storms operating in the East Sea under the influence of cold air over time. Studies on wave–current interaction have focused mainly on tropical cyclones, while less attention has been paid to other weather systems (Gong et al, 2018). Strong winds in coastal areas can cause dramatic changes in water level and currents, which influence wave height and direction, thereby increasing hazardous conditions (Sun et al, 2018). Wave parameters in the outer region of the typhoon are more sensitive to the current but less sensitive to the water elevation than those in the inner region of the typhoon (Hsiao et al, 2020). The results show that the temperature field in the storm under the influence of cold air has an asymmetrical distribution around the center.*

***Keywords*— Thermal Core, Effect of Cold Air on Tropical Storm, Distribution of Temperature in Tropical Storm**

I. INTRODUCTION

Haghroosta & Ismali (2017) describe temporal and spatial variations of sea surface temperature (SST), latent heat flux (LHF), sensible heat flux (SHF), and precipitation rate with typhoon activity over the South China Sea. The correlations of the parameters and their connections with the physical phenomena are clearly presented. This is fundamental to predict a typhoon's intensity and track. The effects were investigated from 1991 to 2011 based on archived data from the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP-NCAR) and the number of typhoons were sourced from the International Best Track Archive for Climate Stewardship (IBTrACS). The results showed that most typhoons occurred in August and September, which was related to high temperature in the summer season and the southwest monsoon in the area. The maximum mean values of SST in May and June were related to the East Asian Monsoon. The average values of LHF were highest in July, and the mean values of SHF were highest in July and August. SHF varied gradually at different months compared with LHF. In addition, the average of precipitation rate was highest in November, which can be related to the northeasterly winter monsoon. The relationships of the aforementioned parameters were obtained using Pearson's correlation analysis. Moreover, the highest and lowest mean values of the parameters in different areas were considered, and their spatial relationships were analyzed.

The hurricane season usually starts from May to December (Binh T. D, 1993) or from June to November (Huong C. T. T., et al, 2022; Weatherford, C. L, et al, 1988a) and gradually shifts from North to South with frequency that is higher in August, September. From January to May, the frequency of storms is very small, even in February there is no storm (Huong C. T. T., et al, 2022).

II. DATA AND METHOD

2.1. Data

2.1.1. Storm Data

The storm data set including storm name, location, intensity (Pmin, Vmax) every 6 hours during its existence (from formation to disintegration) is provided by the Japan Meteorological Agency (JMA). Download from website: http://agora.ex.nii.ac.jp/.

2.2 Research Methods

2.2.1. Determining the Period of Operation of Cold Surge

To determine the activities of the cold surge, the study analyzes the evolution of the 24-hour sea level barometric value in the region of 20-250N; 105-1150E. This is the area that is often affected first when KKL operates in East Asia in general and Vietnam in particular. Then, cold surge is considered to affect the area when the 24-hour transformer has a value greater than 1hPa.

III. FINDINGS AND DISCUSSION

3.1. The Key Problem

The sea surface temperature (SST) is an important factor in the supply of energy to typhoons (hurricanes, or tropical cyclones) and affects not only their formation, but also their track and intensity (Mei et al, 2015). Even if other atmospheric conditions are favorable for the development of typhoons, it will be difficult for typhoons to develop if the SST is low [8] and no storm will develop at an SST < 26 ◦C. Satellite observations of SST began in the 1970s using infrared radiometers onboard the National Oceanic and Atmospheric Administration’s geostationary and polar-orbiting satellites (McClain et al, 1985).

Tropical cyclones (TCs) are large-scale destructive natural hazards that cause serious ecological and human damage. Heavy winds and rainfall from TCs could lead to severe disasters, such as storm surges and flooding. In fact, warm humid air is used as a reinforcement factor for huge “engine-like”TCs. Thus, TCs form over warm water in tropical areas (Anthes, 1986).

Mo et al (2021) showed Storm surges and disastrous waves induced by cold air outbreaks, a type of severe weather system, often impact the coastal economic development. Using the Climate Forecast System Reanalysis wind product and the Coupled Ocean–Atmosphere–Wave–Sediment Transport model, we developed a coupled numerical model and applied it to examine the interaction between surface gravity waves and ocean currents during cold air outbreaks in two case studies in the northern East China Sea. The results revealed that wave–current interactions improved the simulation accuracy, especially the water level, as verified by tidal station measurements. We conducted sensitivity experiments to explore the spatiotemporal variation of the impact of wave–current interactions on storm surges and waves in the northern East China Sea, away from the coastline. The wave-induced surge (up to 0.4 m) and the wave-induced current (up to 0.5 m/s) were found to be related to the difference between wave direction and current direction. The significant wave height difference (up to 0.5 m) was sensitive to the storm surge nearshore and sensitive to the current field offshore, while the mean wave direction change (up to 40°) was more sensitive to the current field than to the storm surge. Additionally, the wave–current interaction regulated the momentum balance and wave action balance, respectively. By comparison, the momentum residuals of pressure gradient, Coriolis force, Coriolis–Stokes force, and bottom stress, which were pronounced in different areas, were modulated more significantly by the wave effect than other terms. The dominant mechanisms of wave–current interactions on waves included the current-induced modification of energy generation caused by wind input, the current-induced modification of energy dissipation caused by whitecapping, and the current-induced wave advection.

Typhoon Durian formed in the Northwest Pacific Ocean from 13:00 on November 25, 2006. The storm moved westward and was very intense as it passed over the Philippine peninsula. Even, the wind speed near the center of the storm at 19h on November 29 was up to 53.5m/s. At 13:00 on December 1, 2006, Typhoon Durian moved into the East Sea with the strongest wind speed of about 38m/s. The storm weakened to a tropical depression then disintegrated on December 6 (Figure 1a). Also during the period from November 27, 2006, a cold surge accompanied by a front affected the northern climate regions of Vietnam, causing the temperature in the area to drop from 5 to 70C. After that, the cold ải intensified, affecting Vietnam until 7:00 am on December 4, 2006, when it weakened.

The proposed method based on satellite observations did not give consistent results and different parameters need to be used in different situations. The following issues require further study. (1) Calculation of the background SST. We used the two-day average SST before the initial time that the typhoon arrived in the grid as the background SST. We could also have used the one-day or three-day average SST (Li et al, 2020).

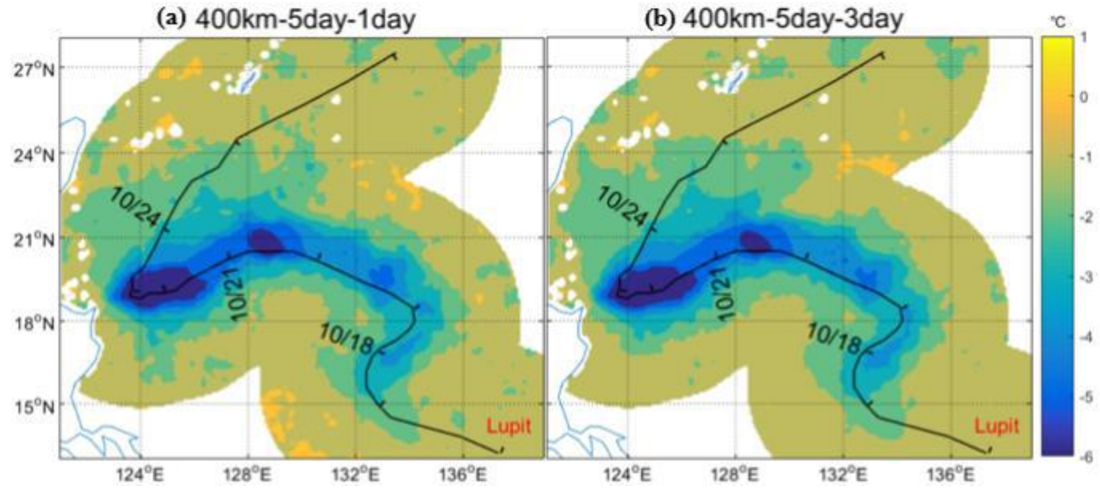

Fig.1. The storm Typhoon Durian

3.2. Characteristics of the Heat Field in the storm Before and After cold Air Infiltration

3.2.1. Before Cold Air Penetrates

During the time before the impact of the cold air, the temperature in the storm was still evident with a hot core in the center of the storm.

Storm surges and huge waves induced by cold air outbreaks (CAOs, also known as cold waves) adversely affect the economic development of coastal cities [1, 2, 3]. Researchers have simulated the marine dynamic environment during CAOs using numerical models and hindcasted the water level, currents, and waves separately

3.2.2. After the cold air penetrates

Thus, the intrusion of cold air into the storm has increased the asymmetry of the temperature distribution in the storm. After the time of cold surge infiltrating into the East sea, the cold advection brought cold air in from the northern and western areas to make the temperature in these areas.

IV. CONCLUSION

The results show that the temperature field in the storm under the influence of cold air has an asymmetrical distribution around the center at the center of the storm, after the cold air entered, the temperature was even lower in the eastern and southern parts of the storm.

AUTHOR'S CONTRIBUTION

Developing ideas and choosing research methods: Huong C. T. T.; Data analysis and processing: Huong C. T. T.; Linh T. D.; Writing the manuscript: Huong C. T. T.; Linh T. D.; Revised: Dinh, T. N. H; Editing of the article: Huong C. T. T.

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APPENDIX

a)

b)

c)

d)

Fig. A1. Trajectories of hurricanes: Durian 2006 (a), Damrey 2017 (b), Kammuri 2019 (c) and Vamco 2020 (d) (Source: NOAA).

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