HIGH WAVE CONIDITIONS DUE TO TYPHOONS MEASURED AT AN OFFSHORE OBSERVATION TOWER

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ABSTRACT

This paper shows some observation results on high wave condition due to typhoons measured at an offshore observation tower. Japan is affected by typhoons every year, and some typhoons cause serious damages in Kii peninsula and its surrounding areas sometimes. In 2018, three typhoons (No.20, 21, 24) approached around the Kii peninsula, and the severe wave conditions caused by the typhoon Jebi (No.21) and the typhoon Trami (No.24) are observed at the observation tower of SOO. During the typhoon Jebi and the typhoon Trami approaching, the maximum significant wave heights reach 9.60m by the typhoon Jebi and 11.09m by the typhoon Trami, respectively. On the other hand, wave condition caused by the typhoon Cimaron (No.20) is relatively milder than the ones by the typhoon Jebi and the typhoon Trami, even though a central atmospheric pressure and the distance between the center of the typhoon and the observation tower are similar to those of the typhoon Jebi and the typhoon Trami. In case of 2018, it is pointed out that the magnitude of high wave condition is associated with the offshore wave direction around Kii peninsula because the observation site opens to the south-west (between about 190deg and 240deg). In this paper, the factors and backgrounds related to high wave conditions by typhoons are discussed based on the observation results including other typhoon cases.

Keywords: Typhoon, High wave, Field observation

1. INTRODUCTION

Severe high wave conditions generated by typhoons and low pressures are the major disasters in many coastal areas and causes serious and widespread damages. The coastal zone of Japan is often affected by typhoons, and thousands of people were suffered from several typhoons from past to present as well as the local environment and infrastructures.

In 2018, three typhoons (No.20, 21, 24) approached around the middle of Japanese islands, maintaining those strength (Takabatake et al., 2018). Especially, the typhoon 21(Jebi) wreaked havoc in the Kansai region. Kansai international airport attacked by sever storm surge due to the typhoon 21 was suffered from inundation of sea

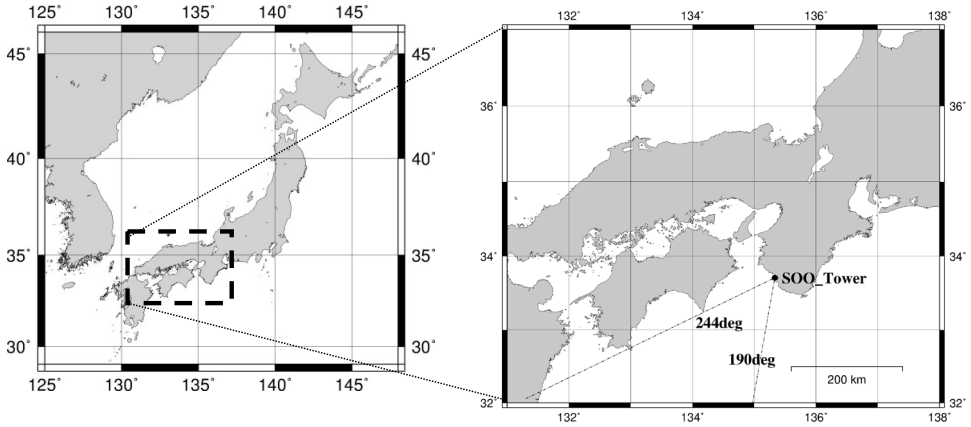


Figure 1 Observation tower, Shirahama Oceanographic Observatory (SOO)

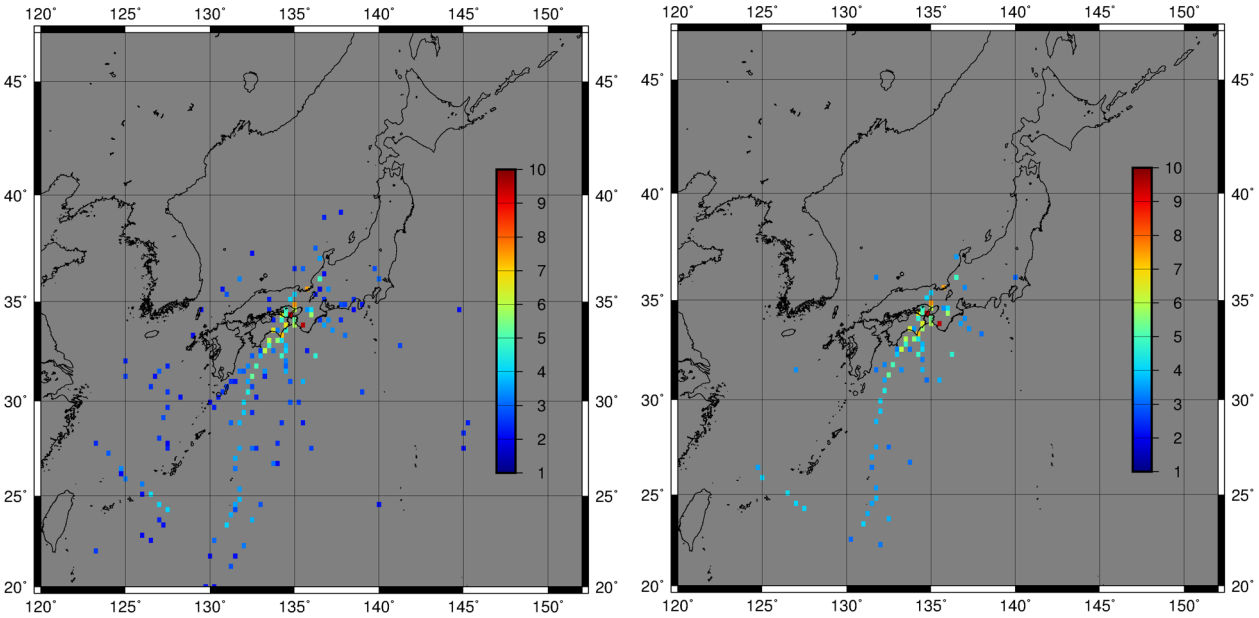


Figure 2 Distributions of the positions of typhoon center with color-coded significant wave height (left) Significant wave height more than 2m, (right) Significant wave height more than 3m

water, and it took some time before full operations resume (Mori et al., 2019). In 2019, two typhoons (No.15, 19) hit around the Kanto region. The typhoon 15 (Faxai) brought strong wind. The strong wind gave huge damage to power grid and caused a lot of fallen trees as well as great damage to a wide range of coastal areas (Takagi et al., 2020). The typhoon 19 (Hagibis) was strong and large typhoon and brought record-breaking torrential rains over large areas of both Kanto and Tohoku regions. Due to the heavy rainfall caused by the typhoon 19, overtopping and flood disasters occurred in many places. As mentioned above, massive damage due to powerful typhoons have been caused in recent years.

On the opposite side, severe high wave generated by typhoons and low pressures have specific characteristics in different places in coastal regions. In order to clarify the specific characteristics of severe high wave conditions, it is considered desirable that the relationship between local characteristics of high wave and the parameters related to typhoons and low-pressures is analyzed based on on-site observed data. The understanding of the specific characteristics of severe high wave conditions is also expected to be help for local people to make decision about their evacuation to save their life and property. In this paper, the relationship between high wave conditions observed at an offshore site and the parameters related to typhoons is investigated. The controlling factors regarding high wave conditions are extracted, and the greatly high wave conditions are also discussed.

2. OBSERVATION SITE AND OUTLINE OF MESURED DATA

The observation site is an offshore tower for the oceanographic and meteorological observation belonging to Shirahama Oceanographic Observatory (SOO), Disaster Prevention Research Institute (DPRI), Kyoto University. The observation tower of SOO is located at the bay mouth of Tanabe bay in the south-western part

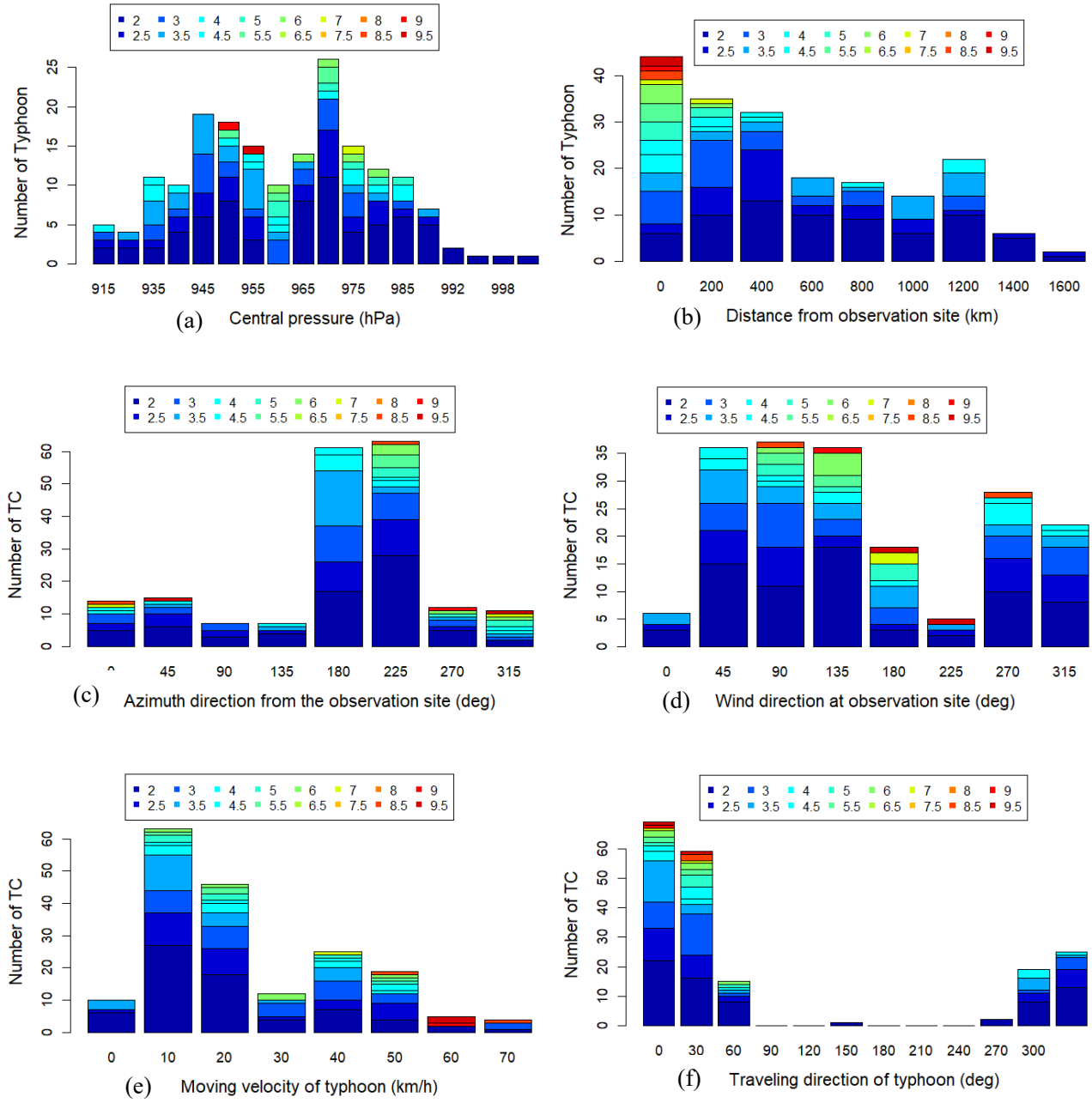


Figure 3 Crosstabulation of typhoon parameters and significant wave height

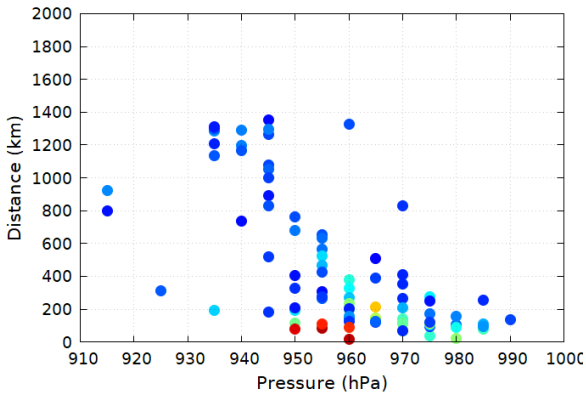
of Kii Peninsula, Japan (Figure 1). High wave conditions at the observation site often occur, especially when typhoons come close to the site.

In this paper, the followings are observed data for the data analysis and discussion;

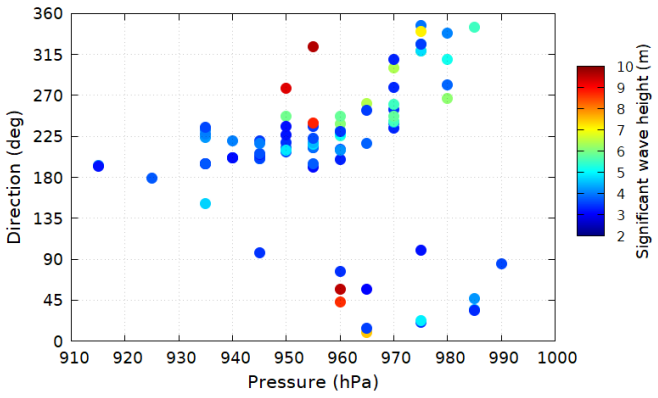
1. Significant wave height data from 2014 to 2018 measured by radiowave wave gauge
2. Best Track Data of typhoons by JMA (Japan Meteorological Agency)

Figure 2 shows the distributions of the locations of typhoon center with color-coded significant wave height measured at the observation site (The plotted data are within 2000 km from the observation site). The plotted data are scattered around the Japanese islands (Figure 2(a)), and, almost high wave data are located in the southwestward of the Japanese islands (Figure 2(b)). Generally, many typhoons approach to the Japanese islands from south or southwest, and this corresponds to the data scattering in Figure 2(b). This study focuses on "high wave conditions brought by typhoons" to support the decision-making for any action to ensure the safety of citizens.

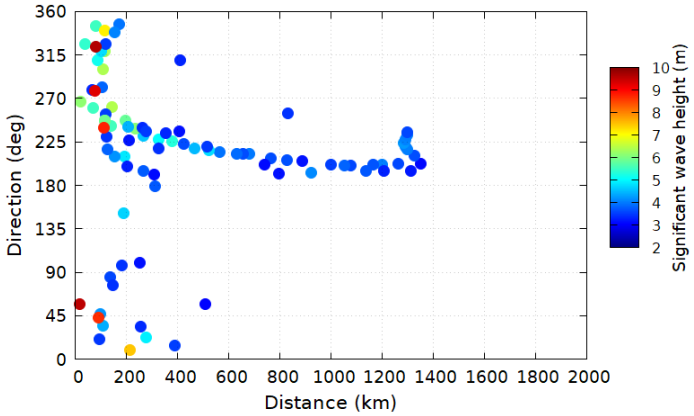
Figure 3 are the results of cross table among measured wave data (more than 2m high, number of data is 190) and typhoon parameters. The main results are as follows;



(a) central pressure and distance from observation site



(b) central pressure and direction from observation site



(c) distance and direction from observation site

Figure 4 Wave height distribution against two typhoon parameters
(Significant wave height more than 3m high)

1. High wave conditions are caused by strong typhoons with the center pressure from 930 to 960 hPa,
2. The closer the center of typhoon is to the observation site, the more frequently the high wave conditions occur
3. The directions from the observation site are fallen within a range of south to southwest, even though high wave conditions occur in wide range of the directions from the observation site
4. Wind directions at the observation site are also distributed in the wide range, however, easterly wind (wind blowing from land side) blows in many cases
5. Typhoons have very high moving velocity when severe high wave conditions happen
6. Traveling direction of typhoons are almost limited from north to northeast when high wave conditions happen.

These results mentioned above illustrates the overviews of high wave occurrence due to typhoons at the observation site, and this information would be help for the preparation against the damage by severe high wave.

3. FACTORS CONTRIBUTING TO HIGH WAVE CONDITIONS

In the previous chapter, it is found that high wave conditions at the observation site are related to some typhoon parameters. Herein, higher wave conditions data (more than 3m high, number of data is 90) is used to investigate the relationship between high wave conditions and typhoon parameters. Figure 4 shows the wave height distributions against two typhoon parameters with color-coded significant wave height. From Figure 4(a), typhoons with high intensity (lower pressure) cause high wave conditions, even the location of typhoon is very far away from the observation site. And it is also found that much higher wave conditions occur close to the observation site.

On the other hand, much higher wave conditions occur in the wide range of the direction from observation site shown in Figure 4(b). In Figure 4(c), the wave height distribution is roughly separated into two groups, one is data cluster close to the observation site and the other data cluster aligning in the almost same direction. The latter data cluster corresponds to the plotted points aligning in the southwestward of the Japanese islands in Figure 2(b). These data mean high wave conditions brought by "approaching typhoons", and the data clusters

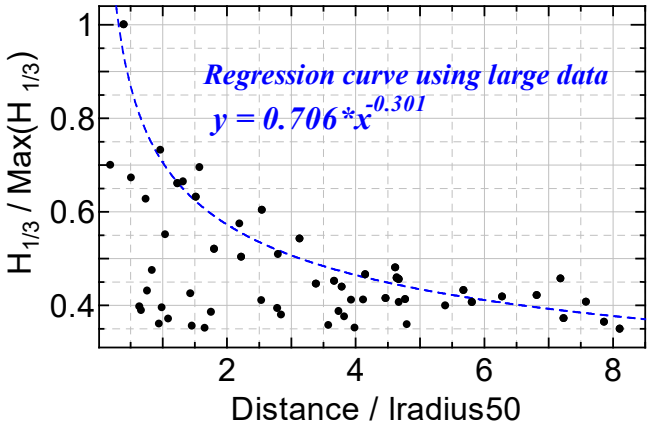


Figure 5 Relation between wave height and distance from observation site
(wave height is more than 3m, direction from observation site from 180 to 270)

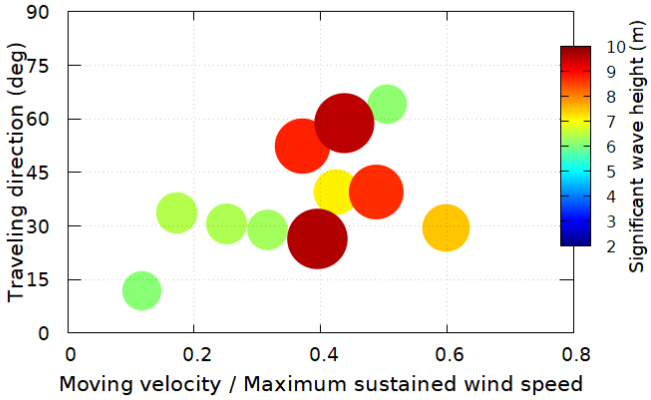


Figure 6 Wave height distribution against moving velocity and traveling direction of typhoon
(Significant wave height is more than 6m)

mentioned above might be rephrased as "data cluster in neighboring region" and "data cluster in approaching phase", respectively.

3.1 Wave data distribution in approaching phase

The data cluster in approaching phase distributes in a range of 180 to 270 degrees from the observation site shown in Figure 4(c). The observation site presented in this paper is in the western side of Kii peninsula, and the southwest direction from about 190 to 240 degrees of the site is open to the ocean (see in Figure 1 and 7). If typhoons locate in the southwest direction of the observation site, high waves generated by typhoons propagate to the observation site more directly.

Figure 5 illustrates the relationship between wave height and distance from the observation site. "lradius50" in Figure 5 means the longest radius of 50 kt winds or greater of typhoon at the measured time, and the average value of "lradius50" in approaching phase is around 100 nm (about 180 km). Therefore, rough guide of approaching phase in horizontal axis of Figure 5 is more than around 2 or 3. Plotted data in Figure 5 doesn't have clear relationship between non-dimensional wave height and distance from the observation site, however, increasing tendency of wave height is shown according to the decrease of the distance from the observation site. The dotted line in Figure 5 is an example of regression curve based on large wave height data. This dotted line would be also an envelope curve of wave data distribution in Figure 5, and this result shows that relatively high wave height in approaching phase could be estimated by using a power law.

3.2 Factors related to greatly high wave condition

High wave conditions occur frequently when typhoons with enough strength locate within less than 400km from the observation site (see in Figure 3(a) and 3(b)). On the other hand, wave height data measured not so far from the observation site (data in neighboring region) displays wide variation against central pressure and direction from the observation site in Figure 4. In order to define wave height distribution in neighboring region, some other factors would be required.

It is seen in Figure 3 that moving velocity and traveling direction of typhoons are likely associated with high wave condition, especially, greatly high wave condition (more than 6m high, number of dextreata is 12) bears

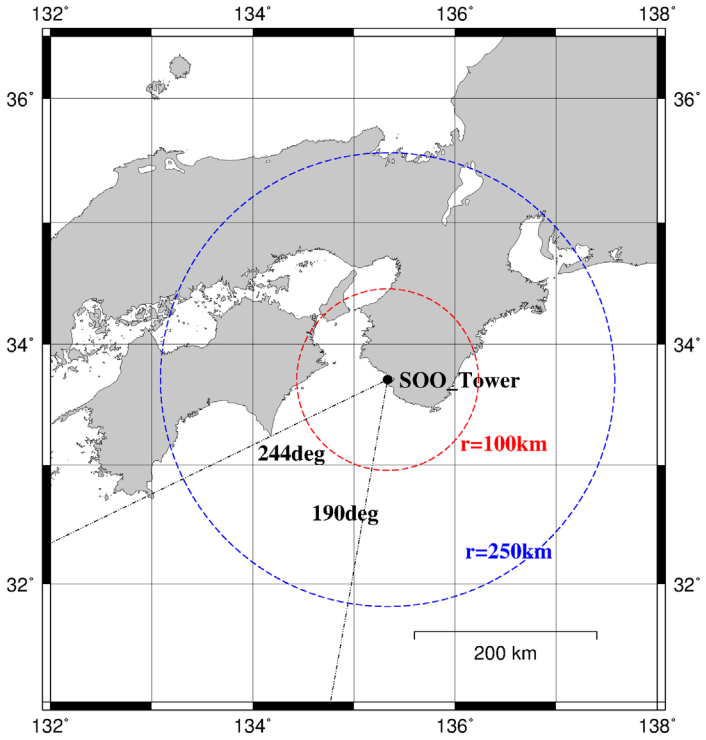


Figure 7 Expected range of the occurrence of high wave conditions
(dashed double-dotted lines show open directions to the ocean from the observation site)

considerable relations with moving velocity and traveling direction of typhoons. In case of greatly high wave condition, the locations of typhoons are limited within a radius of about 250 km from the observation site. Measured data in greatly high wave condition is plotted in Figure 6 with color-coded significant wave height. The plot size also corresponds to the significant wave height. It is found in Figure 6 that high moving velocity is required to generate severe wave condition. Under much further high wave condition such as significant wave height exceeds more than 7m high, non-dimensional moving velocity reach about 40% of maximum sustained wind speed of typhoon. In Figure 6, traveling direction of typhoons is limited approximately within a range from 30 to 60 degrees. The typhoon 21(Jebi) and the typhoon 24(Trami) in 2018 caused extremely high wave condition at the observation site (maximum significant wave height up to around 9m and 11m, respectively), and it is reported that traveling direction of typhoon 21(Jebi) is about 30 degrees and traveling direction of typhoon 24(Trami) about 60 degrees and that the distance between the center of typhoon and the distance from the observation site is less than 100 km in each case when maximum wave height recorded (Baba et al., 2019). Figure 7 shows two circles of 100 km and 250 km round the observation site, and each circle indicates the range of the possible occurrence of greatly or extremely high wave conditions, respectively.

In summary, the following factors have some roles to generate greatly high wave condition at the observation site; a) typhoons keep enough strength, b) locate in neighbor region (less than 250km in this case), c) have high moving velocity and d) move in a north-eastward direction.

4. CONCLUSIONS

This paper investigates the relationship between high wave conditions observed at a specific offshore site and the parameters related to typhoons.

High wave conditions more than 3m high are classified into two groups, "data cluster in neighboring region" and "data cluster in approaching phase". High wave data in in approaching phase distributes in southwest region of the observation site because the southwest direction of the site is open to the ocean and high waves generated by typhoons propagate more directly. And wave height in approaching phase could be estimated by using a power law of distance from the observation site.

When typhoons come close to the observation site, other factors have some influence to define high wave conditions. Based on the measured results and typhoon parameters, the following four factors are listed as important components of greatly high wave condition; a) typhoon strength, b) location of typhoon, c) moving velocity and d) traveling direction. Certain combination of four factors above might cause greatly high wave condition, and these four factors should be closely monitored in order to prepare and strengthen the countermeasures against wave related disasters.

ACKNOWLEDGMENTS

This work was supported by JSPS KAKENHI Grant Numbers JP18H03791, JP19H00782.

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