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Using the Improved CP Method to Forecast Damage Length Cause by Typhoon 9918

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Abstract. In 1999, Typhoon 9918 struck Kyushu Island, which is located in Western Japan. Due to the storm surges and wind waves, the typhoon caused enormous damage to maritime structures.
In this paper, the Improved Central Pressure Method is used to estimate the damage length of maritime structures along the coast caused by Typhoon 9918. Based on 74 previous typhoons, the improved Central Pressure Method creates an index that determines the vulnerability of the coast to a typhoon with a specified path. The vulnerability index of maritime structures is calculated based on the path of the typhoon and coastline. The damage length of maritime structures is estimated using the vulnerability index and the central pressure of the typhoon at a latitude of 30 °N. Based on the results, the improved Central Pressure Method can be used to estimate the damage length of maritime structures that will occur along the coast before a typhoon strikes.

Keywords: Central Pressure, Sensitivity, Vulnerability, Tropical Cyclone.

1. Introduction

As shown in Fig. 1, Typhoon 9918 struck Kyushu Island, which is located in Western Japan. Fig. 1 shows the storm area where the wind speed exceeded 25 m/s as forecasted by the JMA. The dotted circle in the inset shows the area where the wind speed exceeded 15 m/s. The long-dash circle is the 70% probability circle for the location of the center of Typhoon 9918 at 09:00 on September 24th, 1999. An anomalous storm surge was induced in the closed sea of the western region of Kyushu Island (Fig. 2) by Typhoon 9918. The maximum anomaly was estimated to be about 3 m at the northern part of the west coast of Yatsushiro Sea [1]-[3]. The maximum sea level was equivalent to about 2.2 m above Highest High Water Level (H.H.W.L).

The significant storm surge due to Typhoon 9918 caused extensive flooding. In the northern part of the western coast of Yatsushiro Sea, 12 people were killed by this storm surge [3]. The actual total alongshore damage length of damaged maritime structures facing the west coast of Yatsushiro Sea, denoted by L, is 8,047 m. This is the longest damage length of damage in at least the past 60 years or more. The total damage length is the sum of the length of damage of structures in each region (coast) for each typhoon.

In this paper, the damage length of maritime structures attributed to Typhoon 9918 was estimated using the improved Central Pressure [iCP] Method. The improved Central Pressure Method uses a vulnerability index for the given coast and typhoon passage [4]-[8]. This index is based on the damage caused by 74 typhoons in the past 25 years.

The damage length is estimated based on the path of Typhoon 9918 as determined from the typhoon's location and direction of movement at a latitude of 30 °N. The vulnerability index of maritime structures at the coast is given from the path and the coast. The damage level, which is shown by the damage length of structures, is estimated using the vulnerability index and the central pressure of the typhoon at a latitude of 30 °N. A similar estimation is done for each of the other paths.

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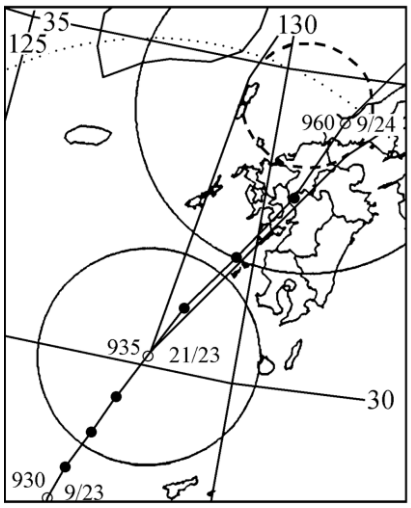

Fig. 1: Track of Typhoon 9918 along with its probability circles as given by the Japan Meteorological Agency (JMA). The date is given as hours/day. The pressure in hPa is given instead of the wind speed.

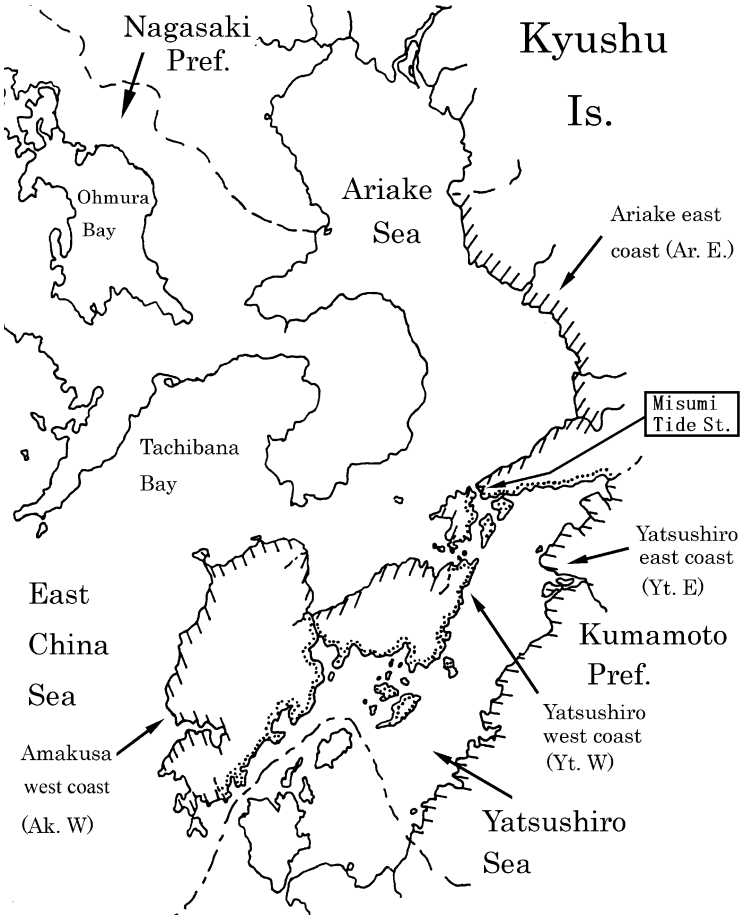

Fig. 2: The 4 coastal regions located in the Kumamoto Prefecture.

2. Outline of Typhoon 9918

Typhoon 9918 moved northward and grew to its strongest stage in the East China Sea at 21:00 on September 22nd, 1999 (Fig. 1). After that, Typhoon 9918 passed through the Ariake Sea off the southern coast of the Kumamoto Prefecture, which is located in the western part of Kyushu Island (Fig. 2). At 3:00 on September 24th, the central pressure was 935 hPa, and the maximum wind speed was 45 m/s (Fig. 1). The typhoon struck the northern part of Kumamoto Prefecture at around 06:00 on September 24th.

The 74 typhoons, which passed through an area delineated by a latitude of 30 ° N and 35 ° N and a longitude of 127 ° E and 132 ° E between 1980 and 2004, were divided into 13 groups based on their paths (Fig. 3) [2].

The path of Typhoon 9918 is shown in Fig. 1. The longitude of the typhoon's position at a latitude of 30 ° N was 128.3 °E. The direction of progress was 22.5 °clockwise from north. Therefore, Typhoon 9918 can be classified as a No. 4 typhoon based on the classification. The classification is based on a latitude of 30 °N, since at this point the typhoon's direction of movement is roughly fixed and the scale becomes stable.

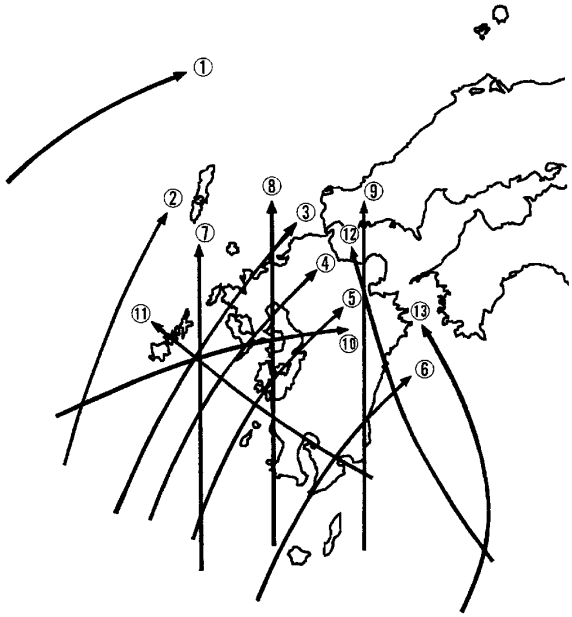

Fig. 3: Historical typhoon paths.

3. Estimation of the smoothed damage length using the improved Central Pressure Method

The damage length for each coast is defined as an alongshore length of damaged part of the maritime structures caused by each typhoon on the coast. Smoothed damage length is further defined as in Eq. (1)

$$L_s = (L_d/L_t) \times 100 \quad (1)$$

where L_s is the smoothed damage length, L_d is the damage length by each typhoon for each coast and L_t is the total damage length by all typhoons for this particular coast. The smoothed damage length indicates the contribution to the total damage length for the coast by each typhoon.

The smoothed damage length (L_s) is expected to increase rapidly with the increase of the maximum wind speed [2]. From the relationship of the maximum wind speed near the center and the central pressure of 74 typhoons at a latitude of 30° N, the smoothed damage length (L_s) can expressed by Eq. (2) [4].

$$L_s = \exp [\{(- 2.932 \times 10^{-3} P^2 + 5.209518 P - 2262.334518 - m) \ln 8\}/10] \quad (2)$$

where P is the central pressure of typhoon. The values of m for the lines in Fig. 4 are 17, 25, 29, 33, 37, 41 and 44 m/s.

The horizontal axis in Fig. 4 shows the central pressure of a typhoon at a latitude of 30 °N. The vertical axis shows the smoothed damage length. The symbols represent the different coasts. The lines a to g in Fig. 4 show the theoretical values predicted using Eq. (2), with the values of m varying from 44 to 17. The numerical values, 1 to 6, shown outside of the figure, denote the six areas delineated by the lines b to f. The numerical numbers are termed as a "sensitivity value" for central pressure of a typhoon based on the damage length. The sensitivity value indicates the vulnerability of the coast to the individual typhoons.

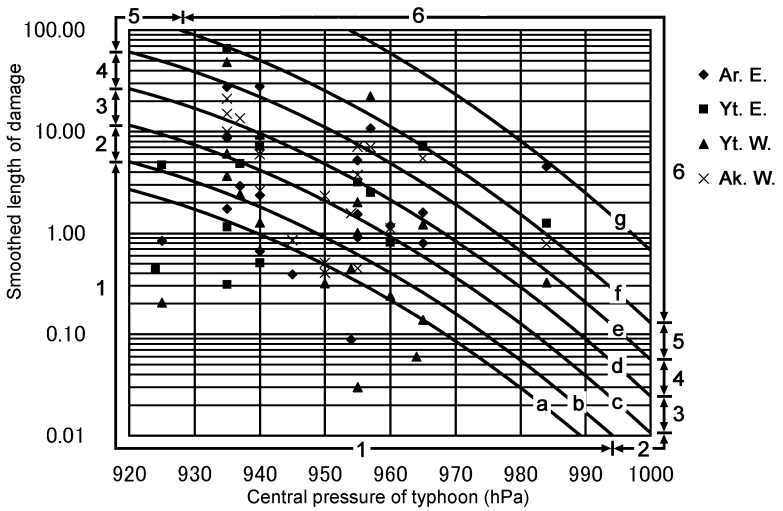

Fig. 4: Central pressure and smoothed damage length

Table 1 shows the maximum sensitivity value for each path at the individual coasts. This table indicates the vulnerability index for an individual typhoon path at each coast.

Table 1: Maximum sensitivity values for the smoothed damage length.

Path No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Ar. E. (Closed)	2	3	5	4	4	4	1	5	0	2	6	0	0
Yt. E. (closed)	0	1	3	5	3	5	0	3	0	2	6	0	0
Yt. W. (closed)	1	3	3	5	2	1	0	6	1	2	4	0	0
Ak. W. (Open)	4	5	3	4	4	3	2	5	0	4	5	0	0

4. The application of the paths to Typhoon 9918

The central pressure of typhoon 9918 was 935 hPa at a latitude of 30 ° N. Based on Table 1, the maximum sensitivity value for the western coast of Yatsushiro Sea for path No. 4 is 5. From Fig. 4, it can be seen that Region 5 is located between lines e and f. Thus, the smoothed damage length (L_s) is obtained from Eq. (2) for a sensitivity value of 5 and a central pressure of the typhoon, 935 hPa. The maximum smoothed damage length (L_s) is 68.6, which was obtained by substituting m=25 for line f. Similarly, the minimum smoothed damage length (L_s) is 29.9, which was obtained by substituting m=29 for line e. Therefore, the range for the smoothed damage length along the western coast of Yatsushiro Sea for Typhoon 9918 lies between 29.9 and 68.6. The total damage length along the western coast of Yatsushiro Sea during the last 25 years was L_t=16,544 m. The damage length for Typhoon 9918 is estimated to be from 29.9% to 68.6% of 16,544 m, that is, from 4,947 m to 11,349 m. The actual damage length (L=8,047 m) lies between 4,947 m and 11,349 m.

On the other hand, comparing the track of Typhoon 9918, shown in Fig. 1 with the 13 tracks given in Fig. 3, the path of Typhoon 9918 is considered similar to the paths Nos. 3, 4, 5, 6, 7, or 8. In this paper, the damage length for path No. 3 to 5 and No. 8 are discussed.

Based on Table 1, the maximum sensitivity value along the western coast of Yatsushiro Sea for path No. 3 is 3. Performing a calculation yields the range for the damage length for Typhoon 9918 as 5.7% to 13.0% of 16,544 m, that is, from 943 m to 2,151 m. Based on Table 1, the maximum sensitivity value along the western coast of Yatsushiro Sea for path No. 5 is 2. Performing a similar calculation yields the range for the damage length for Typhoon 9918 as 2.5% to 5.7% of 16,544 m, that is, from 414 m to 943 m. These values are much smaller than the actual length (L=8,047 m).

Based on Table 1, the maximum sensitivity value along the western coast of Yatsushiro Sea for path No. 8 is 6. The smoothed damage length (Ls) is obtained from Eq. (2) for the sensitivity value 6 and the central pressure of typhoon, 935 hPa. The minimum smoothed damage length is 68.6, which was obtained by substituting m = 25 for line f. Thus, the minimum damage length for Typhoon 9918 is estimated to be 68.6%

of 16,544 m, that is, 11,349 m. This length is considerably larger compared with the actual damage length (L=8,047 m).

5. Conclusions

In 1999, Typhoon 9918 struck Kyushu Island, which is in the western part of Japan, causing enormous damage to maritime structures. The damage length of maritime structures caused by Typhoon 9918 is estimated using the improved Central Pressure Method and compared with the actual damage length. When path No. 4 conditions, which are determined by the position and the direction of the typhoon at a latitude of 30 ° N are applied, the estimated damage length is similar to the actual damage length. Compared to the actual length, the estimated damage length for path No. 3 conditions is smaller than for path No. 4. For path No. 5 conditions, the estimated damage length is much smaller; while path No. 8 conditions are very large in size compared to the actual damage length. This can be explained by noting that, with the exception of No. 5 typhoon's path, serious storm surges were observed for path No. 3, 4, and 8 typhoons.

The improved Central Pressure Method can be used to estimate the damage length of maritime structures that will occur along the coast before a typhoon strikes. The forecasting method reported here will be used for the purpose of coastal zone management in disaster prevention works. Further, it is useful for storm warnings and evacuation orders for residents along the coastlines.

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