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Using The Improved Magnitude Method To Forecast Damage Level Caused By Typhoon 9918

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USING THE IMPROVED MAGNITUDE METHOD TO FORECAST DAMAGE LEVEL CAUSED BY TYPHOON 9918

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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. The improved Magnitude Method is used to estimate the number of damage cases of damaged maritime structures along the coast caused by Typhoon 9918. Based on 74 previous typhoons, the improved Magnitude 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 number of damage cases of damaged structures is estimated using the vulnerability index and the magnitude of the typhoon at a latitude of 30° N. Based on the results, the improved Magnitude Method can be used to estimate the number of damage cases of maritime structures that will occur along the coast before a typhoon strikes.

INTRODUCTION

As shown in Figure 1, Typhoon 9918 struck Kyushu Island, which is located in Western Japan. The inset in Figure 1 shows the storm area where the wind speed exceeded 25 m/s as forecasted by the JMA (Japan Meteorological Agency). 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 (Figure 2) by Typhoon 9918. The maximum anomaly was estimated to be about 3 m at the northern part of the western coast of Yatsushiro Sea (Figure 2) [1]. 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. A total of 16 people were killed, 62,772 houses damaged or destroyed and 1,883 houses were flooded. In the northern part of the western coast of Yatsushiro Sea, 12 people were killed by this storm surge. The actual total number of damage cases of damaged maritime structures facing the western coast of Yatsushiro Sea, denoted by N, is 87. This is the largest number of damage cases in at least the past 60 years or more. The damage of maritime structures means breaching of dikes, cracking of seawalls, overturning of breakwaters, shift of breakwaters, removal of rubble from groins etc. The number of damage cases is the sum of the cases of damage of structures in each region (coastal area) for each typhoon [2]. If the seawall is damaged at two points along the coastline, it is counted as two damage cases [2].

In this paper, the number of damage cases of maritime structures attributed to Typhoon 9918 was estimated using the improved Magnitude [iM] Method [3]. The improved Magnitude Method uses a vulnerability index for the given coast and typhoon passage. This index is based on the damage caused by 74 typhoons in the past 25 years.

The number of damage cases 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 number of damage cases of structures, is estimated using the vulnerability index and the magnitude of the typhoon at a latitude of 30° N. A similar estimation is done for each of the other paths.

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 (Figure 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 (Figure 2). At 3:00 on September 24th, the central pressure was 935 hPa, and the maximum wind speed was 45 m/s (Figure 1). The typhoon struck the northern part of Kumamoto Prefecture at around 06:00 on September 24th.

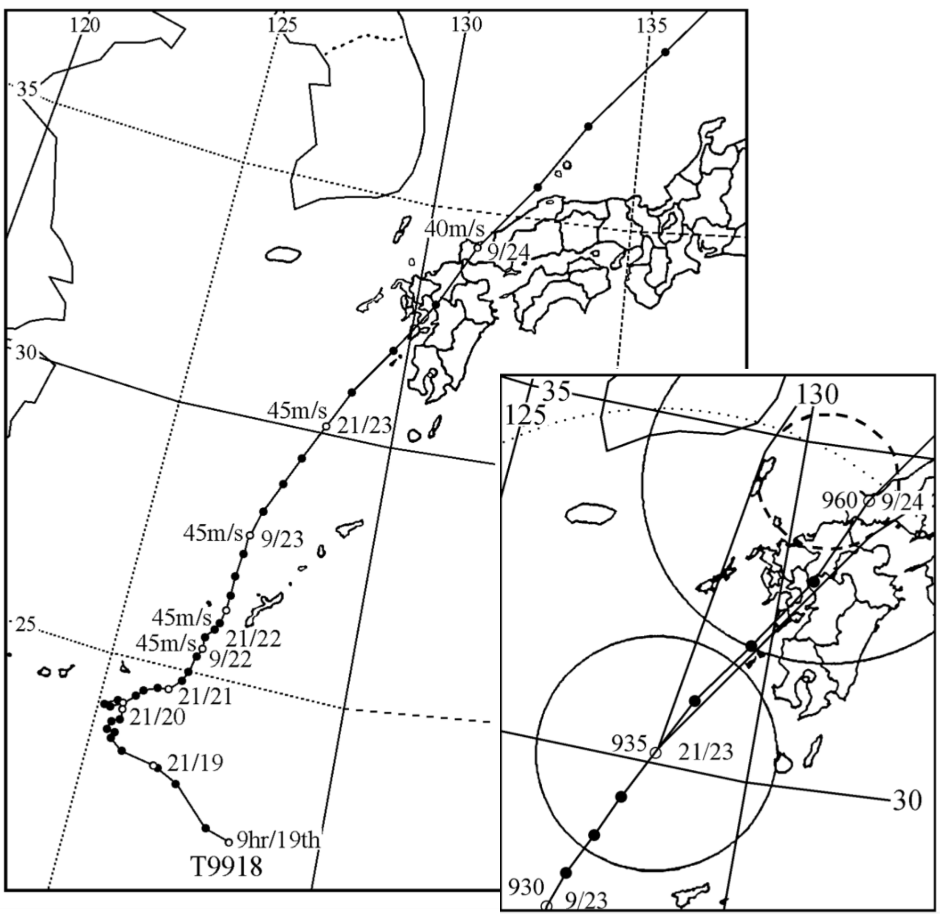

Figure 1. Track of Typhoon 9918 along with its probability circles as given by the Japan Meteorological Agency (JMA). The wind speed is in m/s, and the date is given as hours/day. In the inset, the pressure in hPa is given instead of the wind speed.

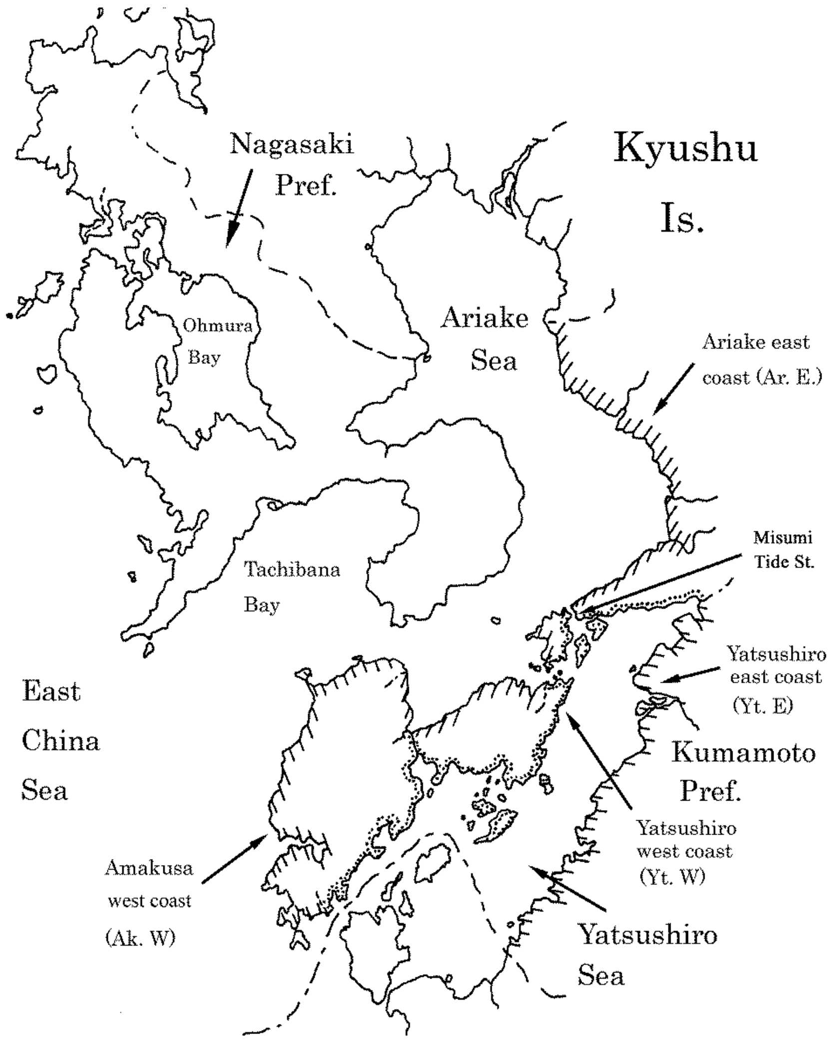

Figure 2. The 4 coastal regions located in the Kumamoto Prefecture

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 (Figure 3) [2], [3].

The path of Typhoon 9918 is shown in Figure 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 [2]. 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.

MAGNITUDE OF TYPHOONS

In this paper, it is tried to estimate the number of damage cases of maritime structures at the coasts and the harbors from the magnitude, a combination of the maximum wind speed near the center and the size of typhoon. The maximum wind speed and the size are obtained from the data observed at a latitude of 30° N periodically by JMA. In 1991, JMA defined both the

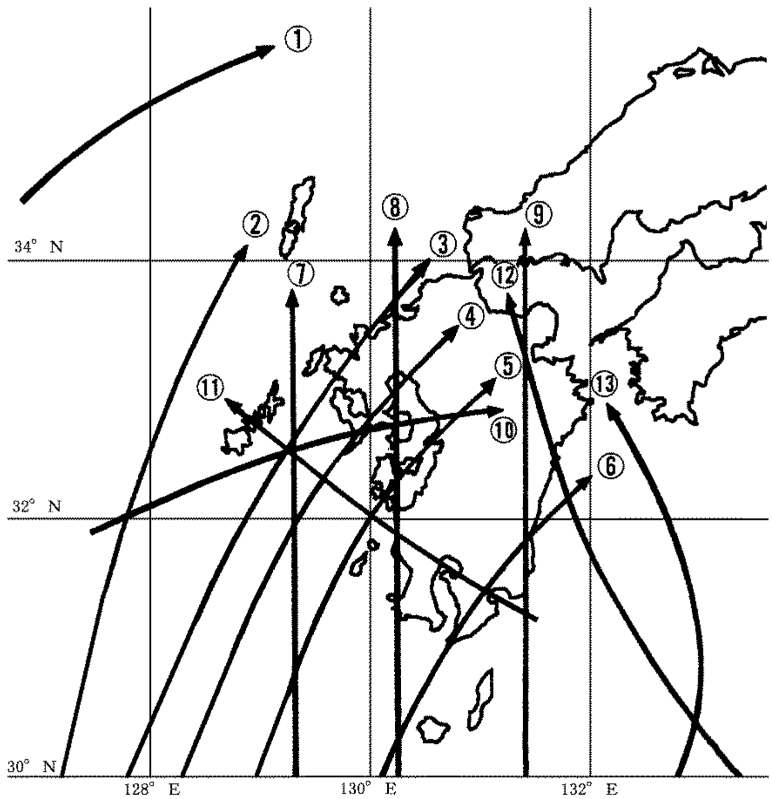

Figure 3. Historical typhoon paths

size and the intensity of typhoon as the radius of area in which the wind speed is larger than 15 m/s and the maximum wind speed respectively. In this paper, the size is classified into 8 ranks and the intensity is classified into 10 ranks as shown in Table 1.

The maximum wind speed and the size of strong winds of typhoon are closely related to the total typhoon energy. Wind waves gain its energy from the typhoon energy, and the height and period increase in the wind blowing area. Magnitude of typhoon, M, is defined by a combination of the rank of the intensity and the side shown in Table 1 [2].

Table 1. Magnitude of typhoon

				S i z e				
Intensity	1(～200km)	2(200km～)	3(300km～)	4(400km～)	5(500km～)	6(600km～)	7(700km～)	8(800km～)
D(17m/s～)	1	2	3	4	5	6	7	8
C(25m/s～)	2	3	4	5	6	7	8	9
CC(29m/s～)	3	4	5	6	7	8	9	10
B(33m/s～)	4	5	6	7	8	9	10	11
BB(37m/s～)	5	6	7	8	9	10	11	12
BBB(41m/s～)	6	7	8	9	10	11	12	13
A(44m/s～)	7	8	9	10	11	12	13	14
AA(47m/s～)	8	9	10	11	12	13	14	15
AAA(50m/s～)	9	10	11	12	13	14	15	16
AAAA(54m/s～	10	11	12	13	14	15	16	17

ESTIMATION OF THE SMOOTHED NUMBER OF DAMAGE CASES USING THE IMPROVED MAGNITUDE METHOD

The number of damage cases for each coast is defined as a summation of the damage cases of part of maritime structures of damaged by each typhoon in the coast. Smoothed number of damage cases is further defined as in Eq. (1)

$$N_s = (N_d/N_t) \times 100 \qquad (1)$$

where N_s is the smoothed number of damage cases, N_d the number of damage cases by each typhoon for each coast and N_t the total number of damage cases by all typhoons for this particular coast. The smoothed number of damage cases indicates the contribution to the total number of damage cases for the coast by each typhoon.

The smoothed number of damage cases (N_s) is expected to increase rapidly with the increase of the maximum wind speed [2], [4]. From the relationship of the maximum wind speed near the center and the Magnitude of 74 typhoons at a latitude of 30° N, the smoothed number of damage cases (Ns) can expressed by Eq. (2) [3].

$$N_s = \exp [\{(-2.74 \times 10^{-2}M^2 + 2.6015M + 18.421 - m) \ln 8\}/10] \qquad (2)$$

where M is the Magnitude of typhoon. The values of m for the lines in Figure 4 are 17, 25, 29, 33, 37, 41 and 44 m/s.

The horizontal axis in Figure 4. shows the magnitude of a typhoon at a latitude of 30° N. The vertical axis shows the smoothed number of damage cases. The symbols represent the different coasts. The lines a to g in Figure 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 magnitude of a typhoon based on the number of damage cases. The sensitivity value indicates the vulnerability of the coast to the individual typhoons.

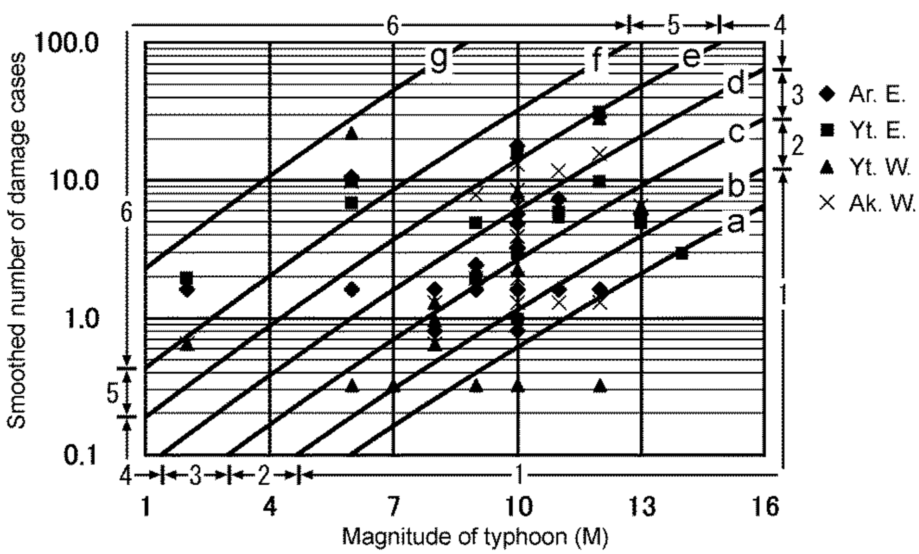

Figure 4. Magnitude and smoothed number of damage cases

Table 2. Maximum sensitivity values for the smoothed number of damage cases

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

Table 2 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.

THE APPLICATION OF THE PATHS TO TYPHOON 9918

The maximum wind speed of Typhoon 9918 at a latitude of 30° N was 46.3 m/s. The radius of the area in which the wind speed was greater than 15 m/s was 601 km. Therefore, based on Table 1, the magnitude of this typhoon was 12. Based on Table 2, the maximum sensitivity value for the western coast of Yatsushiro Sea for path No. 4 is 4. From Figure 4, it can be seen that Region 4 is located between lines d and e. Thus, the smoothed number of damage cases (N_s) is obtained from Eq. (2) for a sensitivity value of 4 and a magnitude of the Typhoon 9918, 12. The minimum smoothed number of damage cases (N_s) is 14.0, which was obtained by substituting m=33 for line d. Similarly, the maximum smoothed number of damage cases (N_s) is 32.2, which was obtained by substituting m=29 for line e. Therefore, the range for the smoothed number of damage cases along the western coast of Yatsushiro Sea for Typhoon 9918 lies between 14.0 and 32.2. The total number of damage cases along the western coast of Yatsushiro Sea during the last 25 years was N_t=307. The number of damage cases for Typhoon 9918 is estimated to be from 14.0% to 32.2% of 307, that is, from 43 to 99. The actual number of damage cases (N=87) lies between 43 and 99.

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

Based on Table 2, the maximum sensitivity value along the western coast of Yatsushiro Sea for path No. 3 is 5. Performing a calculation yields the range for the number of damage cases for Typhoon 9918 as 32.2% to 73.9% of 307, that is, from 99 to 227. These values are larger than the actual number of damage cases (N=87). Based on Table 2, 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 number of damage cases for Typhoon 9918 as 2.7% to 6.1% of 307, that is, from 8 to 19. These values are much smaller than the actual number (N=87).

Based on Table 2, the maximum sensitivity value along the western coast of Yatsushiro Sea for path No. 8 is 6. The smoothed number of damage cases (N_s) is obtained from Eq. (2) for the sensitivity value 6 and the magnitude of typhoon, 12. The minimum smoothed number of damage cases is 73.9, which was obtained by substituting m = 25 for line f. Thus, the minimum number of damage cases for Typhoon 9918 is estimated to be 73.9% of 307, that is, 227. This number is considerable large compared with the actual number of damage cases (N=87).

CONCLUSINS

In 1999, Typhoon 9918 struck Kyushu Island, which is in the western part of Japan, causing enormous damage to maritime structures. The number of damage cases of maritime structures along the western region of Yatsushiro Sea caused by Typhoon 9918 is estimated using the improved Magnitude Method and compared with the actual number of damage cases. When path No. 4 conditions, which are determined by the position and the passing direction of the typhoon at a latitude of 30° N are applied, the estimated number of damage cases is similar to the actual number of damage cases. Compared to the actual number, the estimated number of damage cases for path No. 3 conditions is larger than for path No. 4. For path No. 5 conditions, the estimated number of damage cases is much smaller; while path No. 8 conditions are very large number compared to the actual number of damage cases. 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 Magnitude Method can be used to estimate the number of damage cases 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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