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Is There Any Impact to the Coastal Regions Caused by Typhoon due to Global Warming

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ABSTRACT

To develop the improved Maximum Wind Speed (iMWS) Method to account for the influence of global warming, long term data based on the maximum wind speed of typhoons is required. However, the maximum wind speed of typhoons was not routinely observed prior to 1977. The lack of data concerning the maximum wind speed is compensated for using the relationship between central pressure and maximum wind speed. An analysis conducted with fragmentary wind speed data is reported based on the long term data. Furthermore, categorized numerical vulnerabilities of the coastal region are estimated using the iMWS Method.

KEY WORDS: iMWS Method; Coasts; Global Warming; Typhoon Weather; Vulnerability; Categorize; Smoothed damage length

INTRODUCTION

Typhoons strike Kyushu Island, located in western Japan (Fig. 1), many times in a year. The maritime structures along the coastal lines in Kumamoto Prefecture are routinely affected by typhoons passing through Kyushu Island. The forecasting of damage levels which occur along coastal areas is very important to the safety and economic activities of fishermen, the management and operation of port facilities, and the security of residents along the coastal region. The forecasting method introduced in this paper targets the damage length of maritime structures along the coastal areas of Kumamoto Prefecture (Fig. 2).

In this prefecture the coasts face open and closed seas. The open sea is the East China Sea and the closed seas are the Ariake and Yatsushiro Seas. In this paper, we divided these areas into 4 coasts. Each coast has different topographical characteristics (Fig. 2).

The analysis of iMWS is done on the length of damage to maritime structures in harbors and coastal areas, according to the path and scale of typhoons during a 25 year period from 1980 to 2004 (Hashimura,R., 2007). Based on the analysis, a forecasting method is proposed for the damage in each coast caused by a typhoon. All typhoons dealt with in this paper passed through an area delineated by a latitude of 30° N to 35° N and a longitude of 127° E to 132° E in the period from 1951 to 2010. The number of typhoons passing through the delineated area is 137. A statistical analysis of the long term data of typhoon is presented, and the length of damage to the maritime structures based on these data is discussed. Finally, an estimation of the vulnerability of coastal areas is presented using the strongest wind speed of typhoons from 1950 to 2013.

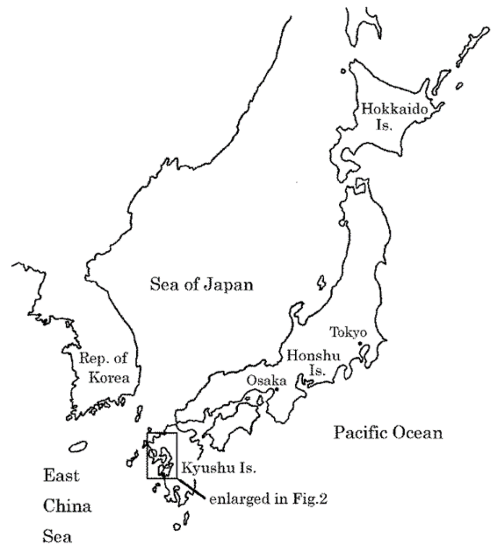

Fig. 1 Location of Kyushu Island of Japan

CLASSIFICATION OF TYPHOONS

The above mentioned area was determined judging from the possibility of damage to the maritime structures along the coasts in Kumamoto Prefecture. The typhoons are divided into 13 groups based on their paths (Fig. 3). Typhoons which did not follow the paths of any of these 13 groups are neglected.

In the northern hemisphere, the strength of the wind in the right area of a typhoon in the direction of movement is greater than that in the left area. The direction of strongest wind is between ENE and SE.

Therefore, a coast facing the sea rightwards near the center of the typhoon in the right area of typhoon is largely affected by high waves coming from SE.

In this paper, an attempt is made to estimate the damage to maritime structures at the coasts from the maximum wind speed near the center of typhoon. The maximum wind speed is obtained from data observed periodically at a latitude of 30° N by the Japan Meteorological Agency (JMA). The reason a latitude of 30° N is selected is that the direction of movement of typhoon is roughly fixed and the scale becomes stable there.

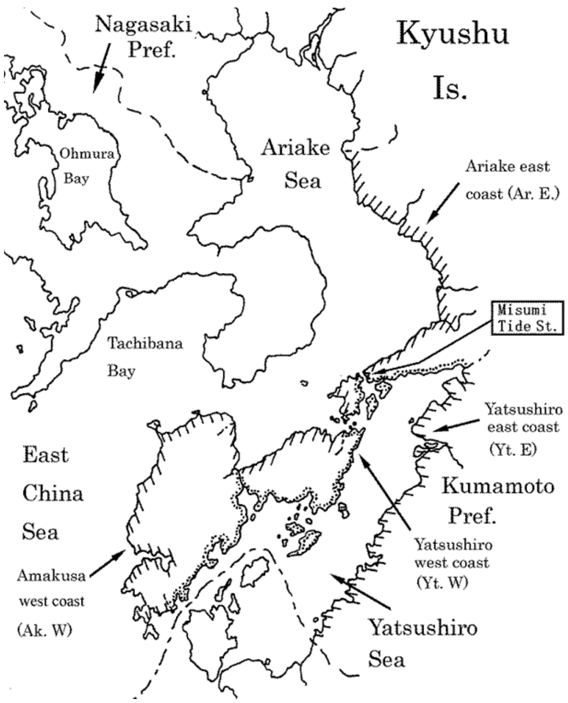

Fig. 2 The 4 coastal regions located in the Kumamoto Prefecture

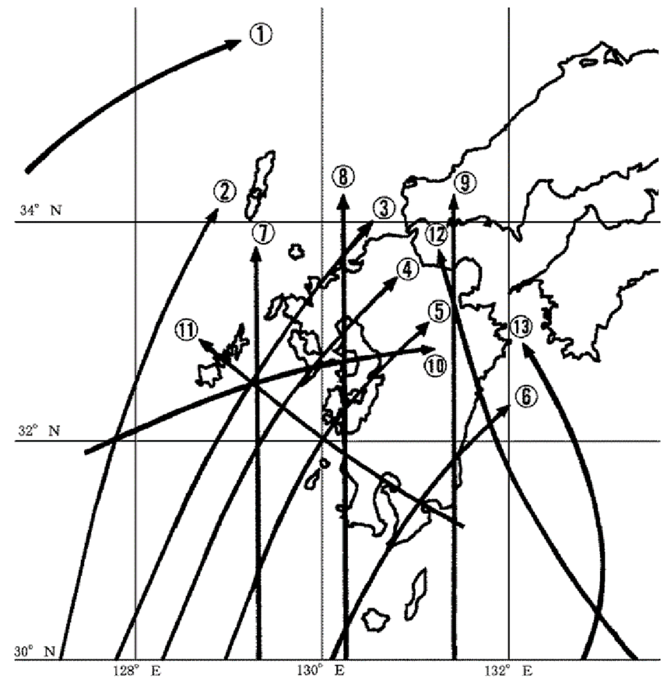

Fig. 3 Historical typhoons paths

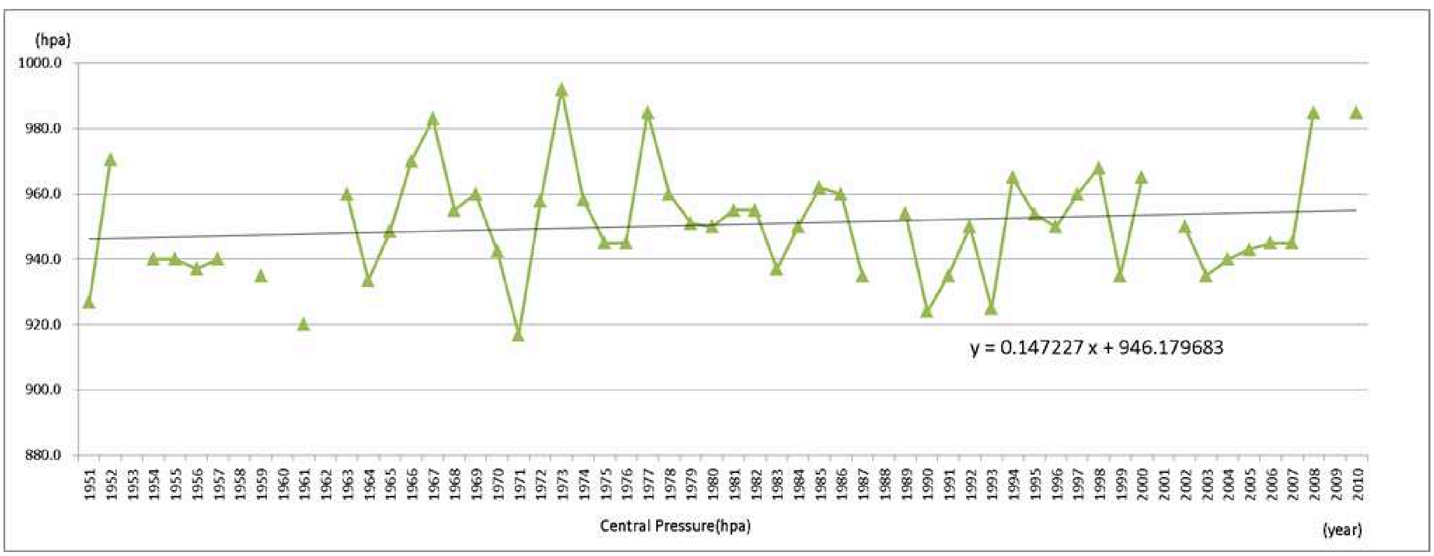

Fig. 4 The annual lowest central pressure, 1951-2010

MAXIMUM WIND SPEED NEAR TYPHOON CENTER BETWEEN 1802 AND 2012

Central Pressure of Typhoon

The maximum wind speed near the center of typhoon occurring before 1977 is not presented in the formal site of JMA (Japan Meteorological Agency). On the other hand, the relation between the maximum wind speed and the central pressure is shown by Eq. (1) which is proposed by Takahashi (Nyomura, Y., 1993),

$$V_{max} = 6(1010 - P)^{1/2} \tag{1}$$

where Vmax is the maximum wind speed (m/s) near the center of typhoon and P the central pressure (hPa).
Similarly, Eq. (2) is written in the reference (Nyomura, Y., 1993).

$$V_{max} = 6(1015 - P)^{1/2} \tag{2}$$

Applying regression analysis to a relation between the central pressure and the maximum wind speed near the center of typhoons at a latitude of 30° N, we get

$$Vmax = - 0.001844P^2 + 3.127769P - 1266.830082 \quad (3)$$

Therefore, the author proposes Eq. (3) for the relationship between maximum wind speed and central pressure. As a result, the central pressure of typhoons before 1977 is used to establish the maximum wind speed using Eq. (3).

Figure 4 shows that the value of the annual lowest central pressures is gradually increasing. In other words, the intensity of typhoons shows a gradually decreasing trend. Similarly, Fig. 5 shows that the annual strongest maximum wind speed including the maximum wind speed calculated based on the central pressure during 1951 to 1976. The annual intensity of typhoons shown in Fig. 5 means a gradually decreasing trend.

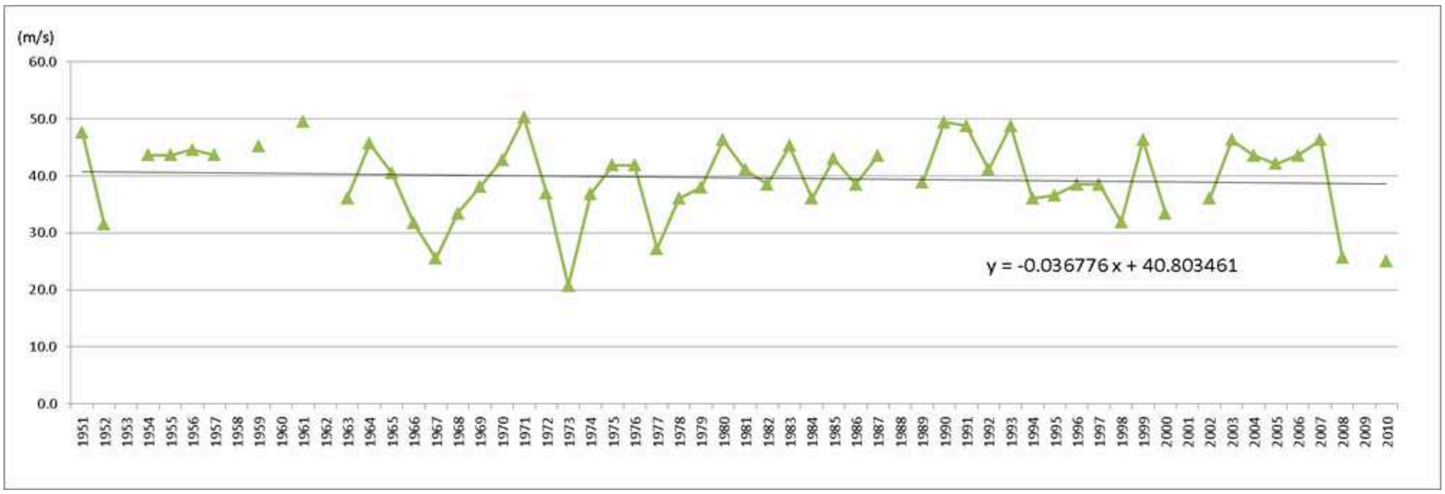

Fig. 5 The annual strongest maximum wind speed during 1951 to 2010

FORECASTING OF DAMAGE USING iMWS METHOD

The damage length for each coast is defined as the damage length of maritime structures affected by each typhoon, which can be given by Eq. (4).

$$Ls = (Ld/Lt)\times 100 \quad (4)$$

where Ls is the smoothed damage length, Ld is the damage length caused by each typhoon for each coast and Lt 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 is expected to increase rapidly with an increase in the maximum wind speed. In this paper this trend can be expressed by Eq. (5).

$$Ls = \exp[\{(Vmax - m) \ln 8\}/10] \quad (5)$$

where Vmax is the maximum wind speed near the typhoon center, Ls is the smoothed length of damage. Based on the classification of JMA, the value of m for the first 7 ranks are 17, 25, 29, 33, 37, 41 and 44 m/s respectively for lines a, b, c, d, e, f and g (Hashimura, R., 2007).

The horizontal axis in Fig. 6 shows the maximum wind speed near the typhoon center at a latitude of 30° N. The vertical axis shows the smoothed damage length for each typhoon along each coast as plotted points. The symbols represent the different coasts. The lines a to g in Fig. 6 show the theoretical values predicted using Equation (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 delineate by lines b to f.

The value given in Table 1 is termed the "sensitivity value" for typhoon MWS based on the damage length. The sensitivity value indicates the vulnerability of the coast to individual typhoons. It should be noted that a typhoon with the largest smoothed damage length at the coast does not always have the largest sensitivity value.

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

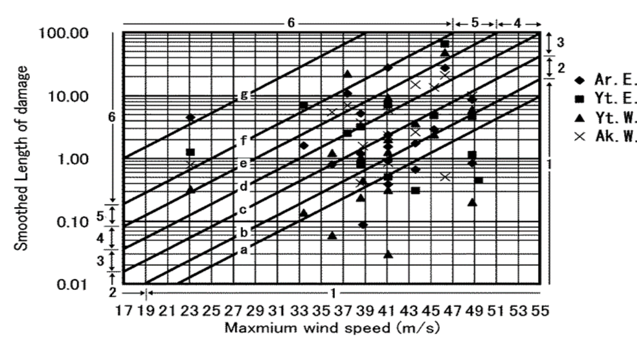

Fig. 6 Maximum wind speed and smoothed damage length

Table 1 The vulnerability values at each coast

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

The total length of damage induced by a coming typhoon for a coast can be estimated as follows: The path is determined based on the Fig. 3 from the track of typhoon, which is forecasted by the JMA, near a latitude of 30° N. The maximum wind speed at a latitude of 30° N is calculated based on data obtained from JMA. Then the maximum sensitivity value of maximum wind speed is determined from the path and the coast based on Table 1. The smoothed length of damage is determined in Fig. 6 by giving the maximum wind speed and the maximum sensitivity value. The total length of damage by this typhoon for a coast is forecast by substituting the value of smoothed length and the total length of damage by all 75 typhoons during a 25 year period from 1980 to 2004 for the same coast in Eq. (4).

THE APPLICATION OF THE PATHS TO THE MOST SEVERE TYPHOON

Typhoon 194516 moved northward and entered its strongest stage on the south at about 110 km from a latitude line of 30° N in the south sea of Kyushu Island on September 17th, 1945. The central pressure was 910 hPa. The central pressure of Typhoon 194516 at Makurazaki Station on the north of 130 km from a latitude line of 30° N was 916.6 hPa. The typhoon 194516 was named the Makurazaki typhoon by JMA. The central pressure at a latitude of 30° N as adjusted by the author is 913 hPa. Therefore, the calculated wind speed using Eq. (3) is 51.1 m/s. Enormous damage was caused by the Typhoon in the western area of Japan. A total of 2,473 people were killed, 1,283 people were missing, and reported 89,839 houses were damaged.

Comparing the track of Typhoon 194516 with the 13 tracks shown in Fig. 3, the path corresponds to that of No. 6. In considering the most dangerous case for the western coast of the Yatsushiro Sea for Typhoon 194516, track of No. 8 is applied.

Based on Table 1, the vulnerability values along the western coast of the Yatsushiro Sea for path No. 8 is 6. The smoothed damage length, Y, is obtained from Eq. (5) using Fig. 6 for the sensitivity value 6 and the maximum wind speed of 51.1 m/s. The minimum smoothed damage length is 227.5, which is obtained by substituting m=25 for the line f in Fig. 6. Thus, the minimum damage length for Typhoon 194516 is estimated to be 227.5% of 16,544 m, that is, 37,638 m. This damage length is about 4.7 times larger than the actual damage length (L=8,047 m) due to the wind speed of 51.1 m/s caused by Typhoon 199918. The estimated minimum damage length for Typhoon 199918 based on the iMWS method is 13,880 m. The damage length of 37,638 m for Typhoon 194516 is about 2.7 times longer than 13,880 m.

CONCLUSIONS

The lack of data concerning the maximum wind speed of tropical cyclones is compensated for using the relationship between central pressure and maximum wind speed. An analysis conducted with fragmentary wind speed data is reported. As a result, the MWS Method is discussed based on the long term data from 1951 to 2010.

Paper proposes Equation for the relationship between maximum wind speed and central pressure at a latitude of 30° N. The intensity of typhoons shows a gradually decreasing trend.

The damage length to maritime structures caused by Typhoon 194516 is estimated using the iMWS method, which is determined by the position and the direction of the typhoon at a latitude of 30° N and is compared with the actual damage length and the estimated damage length due to Typhoon 199918.

The maximum wind speed of Typhoon 194516 is only 5 m/s higher than the speed of Typhoon 199918. The estimation of the damage length due to 194516 is more than 4.7 times longer than the real damage length of maritime structures caused by Typhoon 199918.

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