International Journal of Navigation and Port Research
Vol.29, No.2 pp. 151~157, 2005 (ISSN-1598-7701)

Occurrence Characteristics of Marine Accidents Caused by Typhoons around Korean Peninsula

Chan-Su Yang · Yeon-Gyu Kim***

*, ** *Senior Researcher, Maritime Safety and Pollution Control Research Division, KRISO/KORDI, 171 Jang-Dong, Yuseong-ku, Daejon 305-343 Korea*

Abstract : *During the period of every summer to early autumn seasons, ships have been wrecked or grounded from effect of a typhoon in the water areas around Korean Peninsula. Typhoon Rusa killed more than 100 people in September 2002. Super Typhoon Maemi passed southeast of South Korea in September 12-13, 2003, with a strong gale blowing at a record 60 m/s and caused much ship groundings, collisions and sinkings over 3000 in dockyards, harbors and places of refuge. These are things that could have been prevented had there merely been prior warning. This study outlines the occurrence characteristics of maritime accidents caused by a typhoon in South Korea for the period from 1962 to 2002. The distribution of the accident records is also compared with the trajectories , winds, central pressures of typhoons, passed during the 1990-2003. It is shown that attack frequency of typhoon and number of marine accidents is the highest in August and the marine accidents due to typhoon have a close relation to the distribution of accumulated wind and pressure fields.*

Key words : *Typhoon, Marine accidents, Trajectory of typhoon, Wind and central pressure of typhoon*

1. Introduction

The 1978-built Russian passenger ship ANTONINA NEZHDANOVA was severely damaged by a typhoon at her berth in the port of Fushiki, Japan on October 21, 2004, as shown in Fig. 1. Typhoon "Tokage" smashed the Far Eastern Shipping Company's vessel against the concrete pier, cracking the hull.

Typhoons have always been a major threat to the lives and property in shipping. During the period of every summer to early autumn seasons, ships have been wrecked or grounded from the effect of a typhoon in the water areas around Korean Peninsula. Typhoon Rusa killed more than 100 people in September 2002.

Fig. 2 shows the trajectory of Typhoon Maemi for the period of 5-12 September 2003, classified as Category 1 typhoon by the Joint Typhoon Warning Center on 7 September 2003. Maemi is the Korean name for a cicada that legend says chirps madly to warn of a coming typhoon. Maemi formed as a tropical depression near Mariana Islands and became a tropical storm (TS) around 16.5° N and 141.4° E at 06UTC 06 September. Moving almost northwestward far east of the Philippines, Maemi developed into a severe tropical storm shortly and became a typhoon at 18UTC 08 September. Soon after reaching its peak intensity at 12UTC 10 September, it passed Miyako-jima around 19UTC on that day, keeping the peak intensity. Maemi then changed its direction from northwest to north (more accurately, NNE), then to northeast gradually. It made landfall on the south coast of the Korean Peninsula with typhoon intensity blowing at a record 60 m/s

Fig. 1 Antonina Nezhdanova, at Fushiki, Japan October 21, 2004 damaged in Typhoon Tokage

* Corresponding Author : Chan-Su Yang, yangcs@kriso.re.kr, 042)868-7276
** ygkim@kriso.re.kr, 042)868-7262

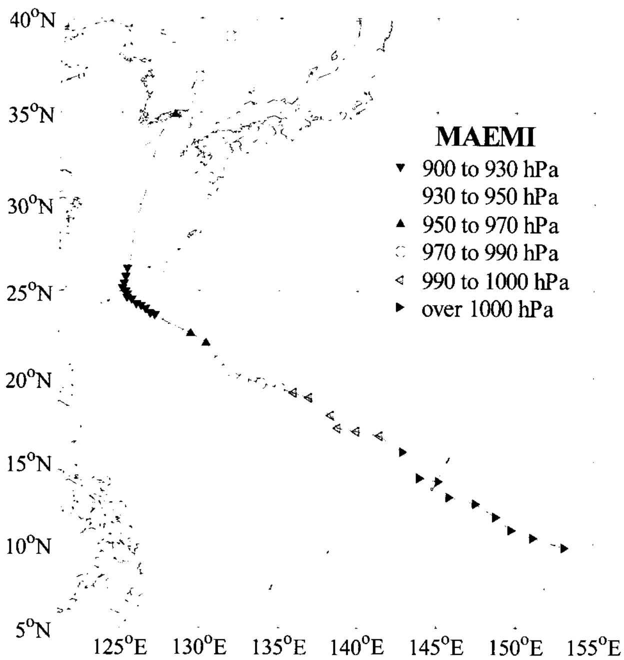

Fig. 2 Trajectory of Typhoon Maemi for the period of 5-12 September 2003, classified as Category 1 typhoon by the Joint Typhoon Warning Center on 7 September 2003.

around 10UTC 12 September and brought heavy damage to the country. The storm transformed into an extratropical cyclone east of the Korean Peninsula at 18UTC on that day and dissipated. Typhoon Maemi was one of the most intense typhoons ever approached the southern part of Korea. The typhoon's strong winds caused much ship groundings, collisions and sinkings over 3000 in dockyards, harbors and places of refuge.

Fig. 3 shows a temporal change in the number of marine accidents caused by a storm or typhoon in South Korea. The data was extracted from Korean Maritime Safety Tribunal (KMST) and the number of accident is based on a date judged by the authority. Although the annual variability in the number is comparatively high, the effect of typhoon on the accident could be not less because as it was the number is much higher than that of the inquired accident. For example, according to the National Maritime Police Agency of South Korea, the sinkings and groundings of 3,023 and 1,688 ships, individually, occurred during the passage of Typhoon Maemi, but only a portion of them was sent to the Court of District Maritime Safety Tribunal for inquiry.

This work is a fundamental research to find a method to bring a ship into a place of refuge and to suggest a suitable anchoring, mooring and navigation for ships in Typhoon. The aim of this study is to examine what effect these typhoons had on occurrence characteristics of the maritime accidents in South Korea, based on the marine accident and typhoon data. Tropical cyclone data is archived by the Regional Specialized Meteorological Centers - Tokyo Typhoon Center. Additionally, annual reports by Korea Meteorological Administration and marine accident records inquired by the KMST are used here.

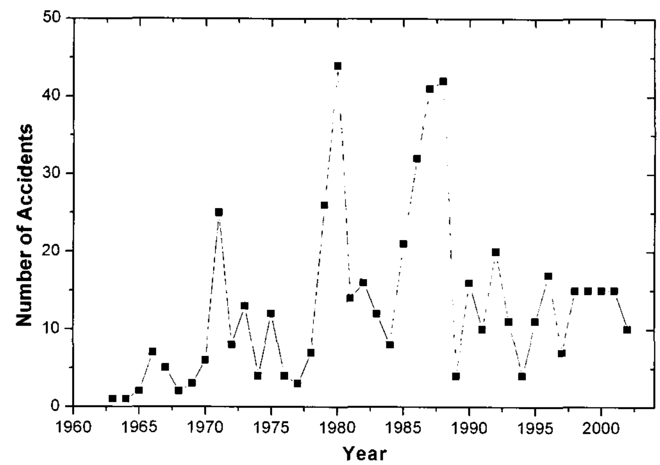

Fig. 3 Temporal changes in the number of marine accidents caused by a storm or typhoon in South Korea. The data was extracted from Korean Maritime Safety Tribunal and the number of accident is based on a date judged by the authority.

In Chapter 2, the typhoon cyclones formed for 1971 to 2003 are briefly described. In Chapters 3 and 4, the marine accidents due to the tropical cyclones for the similar period are investigated and compared with the typhoon information such as a trajectory, wind velocity and central pressure of typhoon.

2. Tropical Cyclones in 1971-2003

Typhoon is a tropical cyclone occurring in the West Pacific or Indian oceans and the intensity of the cyclone is classified as a "tropical depression" (TD, less than 17 m/s), a "tropical storm" (TS, at least 17 m/s), a "severe tropical storm" (STS, at least 25 m/s), a "typhoon" (TY, at least 33 m/s) and a "super typhoon" (ST, at least 65 m/s) according to maximum sustained 1-minute surface winds. List of names for tropical cyclones is adopted by the Typhoon Committee for the western North Pacific Ocean and the South China Sea and these names are used sequentially. On the whole, typhoons move along the west edge of high pressure system, and then progress northeastward at a

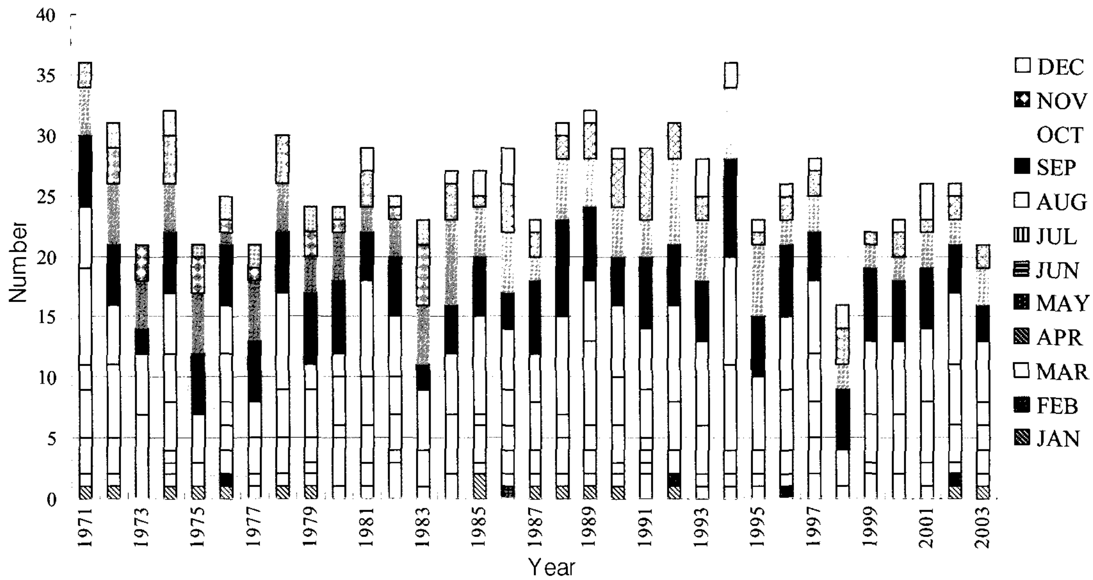

Fig. 4 Comparison of the monthly and annual numbers of tropical cyclones that developed as tropical storm (TS) intensity or higher in North Pacific from 1971 to 2003.

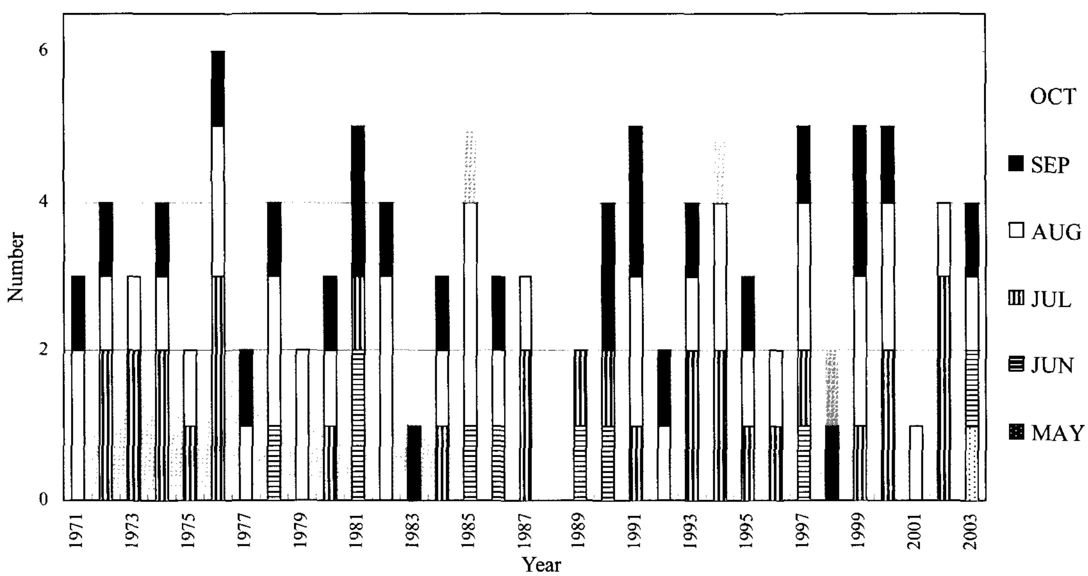

Fig. 5 Monthly and annual numbers of typhoon passed South Korea of the tropical cyclones occurred for 1971 through 2003

latitude of approximately 25 degrees north. However, it is difficult to forecast tracks for each tropical cyclone, because typhoons don't take a steady course and their turning points are ambivalent.

Annual and monthly frequency of tropical cyclones of tropical storm intensity or higher since 1971 were investigated in the western North Pacific and South China Sea, as shown in Fig. 4. The thirty-year average is 26.7 for 1971-2000 and 54 % of the total (24-year average for 1977-2000) reached typhoon intensity (Japan Meteorological Agency, 2002).

Fig. 5 represents monthly and annual numbers of typhoon passed South Korea of the tropical cyclones formed for 1971 through 2003. In the months from November to April, there was no tropical cyclones of tropical storm intensity or higher which hit or passed South Korea. In addition to that, the tropical cyclone season began in the end of May, but in August tropical cyclones were concentrated. 89 % of the total is generated in the period of July to September, and 3.3 typhoons hit or pass South Korea every year.

The ratio of typhoon passed the country out of the total tropical cyclones ranges from 0 % (1998) to 24 % (1976) with average of 13 %. Fig. 6 shows trajectories of the tropical cyclones which had a direct effect on the water areas around the Korean Peninsula for 1990 - 2003 (Korea Meteorological Administration, 19990-2003). The data was resampled using the annual report issued by the Korea Meteorological Administration. The closed circle (•) denotes the genesis point of a tropical cyclone. The mean formation latitude of 18.5° N was higher than the 30-year (1971-2000) average of 16.2 °N for the total tropical cyclones as shown in Fig. 4, while the mean formation longitude of 136.5° E was western compared to the location of the total tropical cyclones. In summer, genesis points of tropical cyclones are located at the latitudes 10-20° N and in other seasons the points are lower than 15° N. These tracks are similar to a typical pattern which proceed northwestward along the west edge of a high pressure area, and then progress northeastward at approximately 25° N.

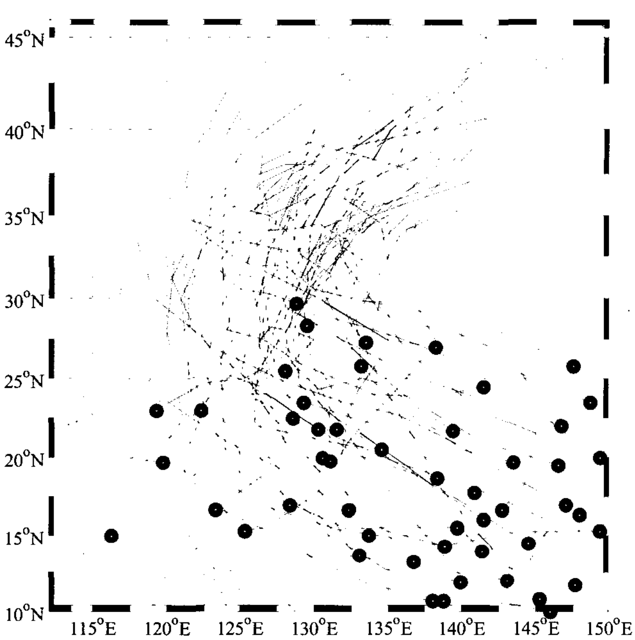

Fig. 6 Trajectories of the tropical cyclones which had a direct effect on the water areas around the Korean Peninsula for 1990-2003. The data was resampled using the annual report issued by the Korea eteorological Administration (KMA). The closed circle (•) denotes the genesis point of a tropical cyclone.

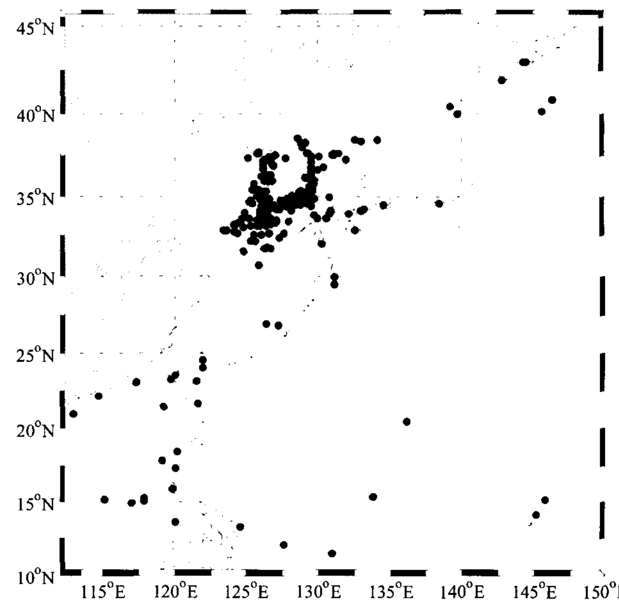

Fig. 7 Distribution map of marine accidents caused by typhoon during the period from 1963 to 2002. The accident data are obtained from Korean Maritime Safety Tribunal.

3. Marine Accidents Due to Tropical Cyclones in 1963-2002

The distribution of marine accidents caused by typhoon during the period from 1963 to 2002 is plotted in Fig. 7. The accident data are obtained from KMST and inquired by the authority. Marine accidents occurred mainly in the coastal areas that connect Pohang along the south coast of South Korea, but those locations were comparatively distributed broadly from Jeju Island to a western area of Pacific Sea.

Fig. 8 shows the distribution map detailed for the water areas around Korean Peninsula for the same marine accidents as shown in Fig. 7 and the accident map in August, respectively. It is shown that the August map does not differ greatly from a distribution pattern of the total map.

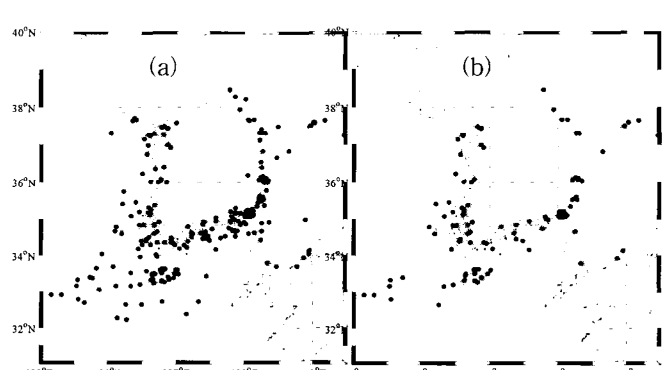

Fig. 8 Detailed distributions (a) for the same marine accidents as Fig. 7 and the accident map in August (b).

Fig. 9 represents monthly distribution in the number of marine accidents, related to, directly or indirectly, a typhoon in South Korea, based on the data from KMST in the years 1963 to 2002. During July through November, the number of marine accidents is 406 that are about 77 % of the total number of accident. The month of August is the highest in the number out of the period. This trend corresponds to a tendency in the arrival frequency of typhoon which is represented in Fig. 5.

From Fig. 8, marine accident in port or harbour area consists of about 36 % that is derived from the locations in the written decision books of KMST. That is, marine accidents due to typhoon are much more in port and entry waterway while the general marine accident is about 19.5 % in the area(Yang and Park, 2003).

To understand a density of marine accident, the number of marine accidents is accumulated per 0.2° × 0.2° grid box by using the accident records as Fig. 9. After summing for each grid, a two-dimensional averaging filter for a 3 square matrix is applied to the grid data as follows:

$$h = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \div 3^2 \qquad (1)$$

$$I = \sum_{i=1}^{9} h_i Mi$$

Here, h means 3 square averaging filter matrix, i means the ith element of 3 square matrix and M means input data represented as a accumulated number of accident for each grid.

As shown in the figure, typhoon-related accidents have happened far more in the area around Busan and Ulsan than any other areas. coastal areas around Jeju Island and Yeusu are the second-highest zone but represent comparatively low values.

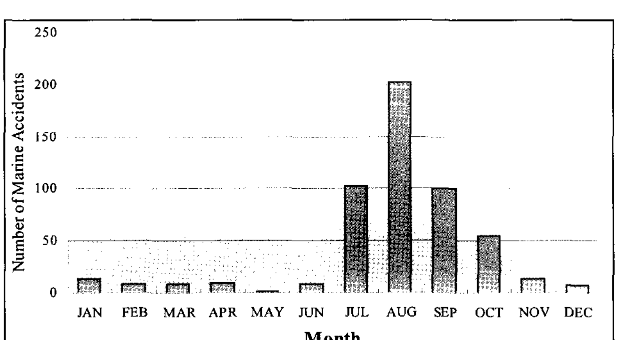

Fig. 9 Monthly distribution in the number of marine accidents, related to, directly or indirectly, a typhoon in South Korea, based on the data from Korean Maritime Safety Tribunal in the years 1963 to 2002.

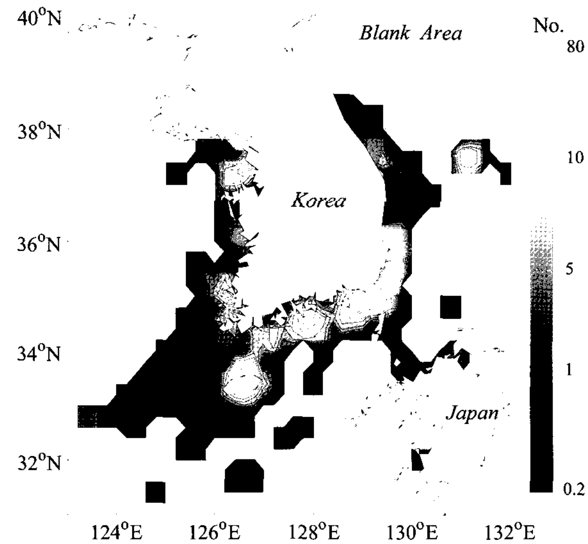

Fig. 10 Contour map for the accumulated marine accident number per 0.2° × 0.2° grid box 1963 to 2002. Refer to Fig. 8 (a). The log scale is used in mapping data.

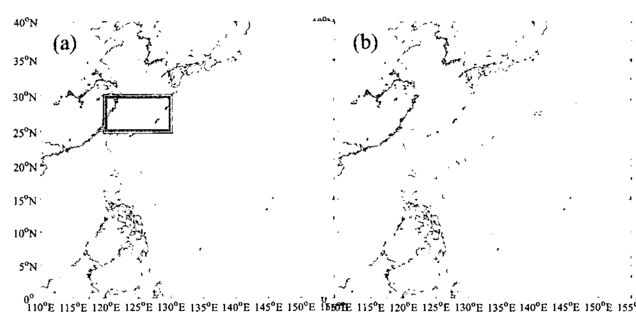

Fig. 11 Example of a tropical cyclone track (a) and its interpolated track (b) with 0.2° intervals in longitudinal or latitudinal direction. The box in (a) figure represents the area passed by the tropical cyclones that reached the Korean Peninsula.

4. Atmospheric Pressure and Wind Speed Fields of Tropical Cyclones in 1996-2003

Atmospheric pressure and wind speed fields are prepared to investigate the extent of the impact of typhoon on ship accidents in Korean water areas. Figure 11 shows an example of a tropical cyclone track and its new line interpolated with 0.2° intervals in longitudinal or latitudinal direction. A linear interpolation method is adopted to interpolate the one-dimensional data here. The tropical cyclones that reached the Korean Peninsula passed the box in the left figure in the period of 1996-2003.

Fig. 12 shows the contour map for accumulated central pressures (hPa) per 0.2° × 0.2° grid box using interpolated tropical cyclone tracks, passed through the area shown in

Fig. 11 (a) out of the total tropical cyclones of tropical storms intensity or higher 1996 to 2003. Fig. 13 represent the contour map for accumulated maximum sustained wind speeds (m/s) per 0.2° × 0.2° grid box using interpolated tropical cyclone tracks, passed through the area shown in Fig.11 (a) out of the total tropical cyclones of tropical storms intensity or higher 1996 to 2003. After summation for each grid, average filtering of 3 × 3 grid was conducted to interpolate the grid data.

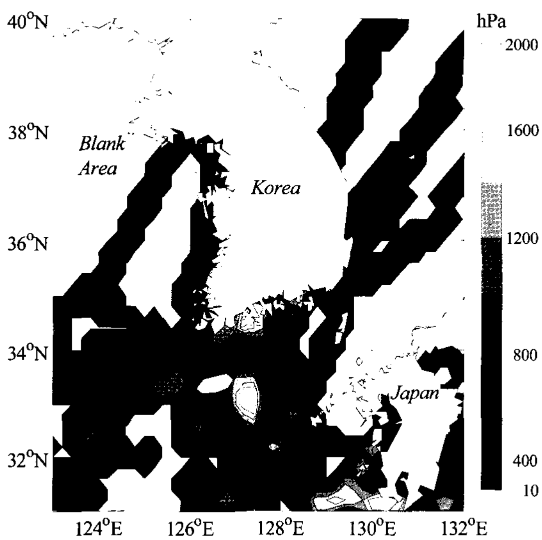

Fig. 12 Contour map for accumulated central pressures (hPa) per 0.2° × 0.2° grid box using interpolated tropical cyclone tracks, passed through the area shown in Fig.11 (a) out of the total tropical cyclones of tropical storms intensity or higher 1996 to 2003.

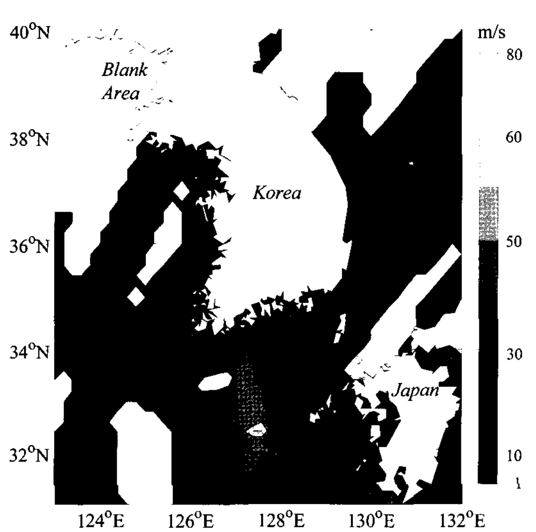

Fig. 13 Contour map for accumulated maximum sustained wind speeds (m/s) per 0.2° × 0.2°grid box using interpolated tropical cyclone tracks, passed through the area shown in Fig. 11 (a) out of the total tropical cyclones of tropical storms intensity or higher 1996 to 2003.

Typhoons have a considerable impact on the southern area of Korean water areas, but have least impact in the eastern and western waters.

To investigate a degree of association between the marine accidents and typhoon routes, the accumulated central pressure and wind speed fields are statistically compared to the 2-dimensional smoothed data of the accidents as shown in Fig. 10. The coefficient of determination (ρ^2) in the two typhoon components, central pressures and wind speeds, is 0.88 and their components and the accidents are positively related. Here, a coefficient of determination is the square of the correlation coefficient, indicating the proportion of the variation in one variable that is described by the other.

The correlations between the three variables are statistically significant with the p-values (confidence intervals to test hypotheses) less than 0.05 at the 0.05 level. The occurrence probability of the accidents is above 92.6 % under the typhoon-related wind condition and 86.6 % under the typhoon-related pressure. The wind variable above 12.9 m/s (approximately 25 kts) accounts for the accident occurrence ratios of at least 61.2 %. It follows that the marine accidents in Fig. 10 have a close relation to the distribution of accumulated wind and pressure fields on the course of typhoons and are more affected by the mean wind speed than the pressure.

5. Concluding Remarks

When a ship is overtaken by a typhoon, even if the typhoon is not on her way, a huge wave or fierce storm can cause her capsized or sank. As a result, they are the major target for us to investigate a typhoon-related accident, analyze a risk in refuge places based on a track forecast of typhoon and induce ships in navigation, mooring, anchoring and so on to a safe measure such as a safe zone, a suitable mooring or anchoring guideline and a refuge place.

In this paper, the authors have attempted to demonstrate how marine accidents caused by a typhoon are associated with the trajectories, winds, central pressures of typhoons, passed during the 1990-2003. It is shown that arrival frequency of typhoon and number of marine accidents is the highest in August. We can also say that the marine accidents due to typhoon have a close relation to the distribution of accumulated wind and pressure fields.

Future studies will focus on a detailed record of marine accident due to a tropical cyclone to understand its pattern at sea and anchor.

Acknowledgement

The content of this paper is one of the results of Inherent Research Project of KRISO, "Development of Base Technology for Integrated Maritime Risk Management System(III)", and "Development of Safety Evaluation Technologies for Marine Structures in Disastrous Ocean Waves", and the Public Benefit Project of Remote Sensing, "Risk Map of Marine Accidents Based on Satellite Data" of Korea Aerospace Research Institute. The authors wish to thank Young-Hun Yang for his help in preparing this paper.

References

[1] Japan Meteorological Agency (2002): Annual Report 2002.

[2] Korea Meteorological Administration (1990-2003): Annual Report 1990 -2003.

[3] Yang, C. S. and Y. S. Park (2003): Merging of Satellite Remote Sensing and Environmental Stress Model for Ensuring Marine Safety, International Journal of Navigation and Port Research, Vol. 27, No. 6. pp. 645-652.

Received 7 December 2004
Accepted 29 March 2005