



## Temporal-spatial characteristics and path analysis of maritime cyclones in Guangdong coastal areas in the South China Sea

Cheng Chen<sup>1\*</sup>, Lei Wang<sup>2</sup>, Ruozhou Chen<sup>2</sup>, Fangliang Xing<sup>2</sup>, Jun Chen<sup>2</sup>

<sup>1</sup>College of Civil Engineering, Fuzhou University, Fuzhou, 350116, China

<sup>2</sup>The Pearl River Hydraulic Research Institute, Guangzhou, 510611, China

\*Corresponding author: [chencheng\\_1117@163.com](mailto:chencheng_1117@163.com)

### ABSTRACT

This study was conducted to analyze the maritime cyclone characteristics in Guangdong coast in the years of 1949 to 2016, including inter-annual variation, the intensity of tropical cyclones, generating location and time, and path direction. Also, the temporal-spatial characteristics were also studied. Results show there were 183 tropical cyclones landed in Guangdong coast in the past 68 years, with an average of 2.7 each year, which more than 60 percent were a typhoon. Most of the tropical cyclones were generated in the northwest Pacific, spanning from April to December. The path directions were mainly north, northwest, and west. The strengths of the tropical cyclones were reduced from central Guangdong coast to the east and the west sides, and the section of Zhanjiang city to Shenzhen city was the most vulnerable to tropical cyclones. Tropical cyclones that generated in the South China Sea tend to attack the west of the Guangdong coast, while the ones that produced in the northwest Pacific tend to attack the east of the Guangdong coast. In the study area, the tropical cyclones frequently occurred from July to September and became strongest in September. There are a most common landing section and path direction for each month. Finally, based on the statistical data and research results, the tropical cyclone paths in Guangdong coast were preliminarily analyzed.

*Keywords: Guangdong coast; Maritime cyclones; Statistical characteristics; Temporal-spatial characteristics; Path analysis.*

## Características temporales y espaciales y análisis de recorrido de ciclones marítimos en las áreas costeras de Guangdong, en el Mar de la China Meridional

### RESUMEN

Este estudio se realizó para analizar las características de los ciclones marítimos en la costa de Guangdong entre los años 1949 y 2016, además de su variación interanual, la intensidad de los ciclones tropicales, el lugar y el momento de creación, y su recorrido. Las características temporales y espaciales también fueron estudiadas. Los resultados muestran que 183 ciclones tropicales tocaron tierra en la costa de Guangdong en estos 68 años, con un promedio de 2.7 por año, de los cuales el 60 por ciento se consideran tifones. Muchos de los ciclones tropicales se generaron en el noroeste del Pacífico, y van de abril a diciembre. Las direcciones de recorrido son principalmente norte, noroeste, y oeste. La fuerza de los ciclones tropicales se redujeron desde la costa central de Guangdong hacia el este y el oeste, mientras que el sector entre las ciudades de Zhanjiang y Shenzhen es el más vulnerable a los ciclones. Los ciclones tropicales generados en el mar del Sur de China tienden a tocar tierra en el oeste de la costa de Guangdong, mientras que aquellos que se producen en el noroeste del Pacífico suelen recorrer hacia la costa este. En el área de estudio, los ciclones tropicales frecuentemente ocurren de julio a septiembre y son más fuertes en septiembre. Se evidenciaron recorridos y direcciones de los ciclones propias a cada mes. Finalmente, de acuerdo con la información estadística y los resultados de investigación, el recorrido de los ciclones tropicales en la costa de Guangdong fueron analizados preliminarmente.

*Palabras clave: Guangdong coast; Maritime cyclones; Statistical characteristics; Temporal-spatial characteristics; Path analysis.*

### Record

Manuscript received: 24/07/2018

Accepted for publication: 01/12/2018

### How to cite item

Chen, C., Wang, L., Chen, R., Xing, F., & Chen, J. (2018). Temporal-spatial characteristics and path analysis of maritime cyclones in Guangdong coastal areas in the South China Sea. *Earth Sciences Research Journal*, 22(4), 319-325. DOI: <https://doi.org/10.15446/esrj.v22n4.77361>

## 1. Introduction

A tropical cyclone is an intense natural phenomenon, and the destructiveness of tropical cyclones over the past years is increasing (Emanuel, 2005). It is generated in the ocean, which may cause substantial wind waves and storm surge. Therefore, devastating damages will be induced in the coastal areas due to a tropical cyclone (Yuan et al., 2010). China is one of the most vulnerable countries that suffered from the wind waves and storm surge disasters (Jia et al., 2010), and according to the official records, there were thirteen major maritime disasters possibly caused by the tropical cyclones (Liu et al., 2017). Consequently, more and more researchers are focusing on this topic (Li et al., 2004; Yuan et al., 2011; Zhang & Cui, 2013).

Guangdong Province is located on the west bank of the Pacific Ocean, and it is on the brink of the South China Sea. It is frequently subjected to the invasion of tropical cyclones that generated in the Northwest Pacific or the South China Sea (Wen, 2002; Tang et al., 2003). The cyclone weather conditions and huge waves generated by tropical cyclones will affect the fishing vessels (Rezaee et al., 2016). Also, huge waves are a severe threat to the structural safety of coastal, offshore, and marine projects, as well as the daily life of coastal residents (Xu et al., 2008; Zhao et al., 2010). Three rings of the coastal planning record cyclones when they attack the coast (Tucker et al., 2018). Also, coastal planning such as mangrove creeks provides the service of protection (Williams et al., 2007). It is essential to study the characteristics of the tropical cyclones that generated in the ocean to mitigate the disasters in coastal areas (Zheng et al., 2014). Also, observations of the maritime cyclones help forecasts of the maritime disasters (Liou and Elsberry, 1987).

In this study, the landing tropical cyclones characteristics in Guangdong coast in the years of 1949 to 2016 were analyzed, including inter-annual variation, the intensity of tropical cyclones, generating source and time, and path direction. Based on the statistical data and research results, the tropical cyclone paths in Guangdong coast were preliminarily analyzed, which may provide some useful information for wind wave simulations and disaster prevention in coastal engineering.

## 2. Material and Methods

### 2.1. Tropical cyclone classification on the sea

In the South China Sea, most of the tropical cyclones that affect the Guangdong coastal areas are generated in the South China Sea and North-western Pacific. The intensity of the tropical cyclone is based on the maximum wind speed near the center of the tropical cyclone. Generally, the intensity of the tropical cyclone is divided as follows: 1) Super strong typhoon, the maximum average wind speed near the bottom centre is greater than 51.0 m/s (16 stages and above); 2) Strong typhoon, the maximum average wind speed near the bottom center is 41.5-50.9 m/s (14-15 stage); 3) Typhoon, the maximum average wind speed near the bottom centre is 32.7 - 41.4 m/s (12-13 stage); 4) Strong tropical storm, the maximum average wind speed near the bottom center is 24.5-32.6 m/s (10-11 stage); 5) Tropical storm, the maximum average wind speed near the bottom center is 17.2-24.4 m/s (8-9 stage); 6) Tropical depression, the maximum average wind speed near the bottom center is 10.8-17.1 m/s (6-7 stage). The typhoon, strong typhoon and super strong typhoon are classified as typhoons in this study because the cyclones stronger than typhoon will demonstrate destructive power to coastal engineering.

### 2.2. Data collection

In this study, the data of the cyclones were collected from the Fujian water conservancy information network in China. The cyclone data include all the previous tropical cyclone numbers, Chinese and English names, hourly path (in coordinates), wind stage, maximum wind speed, central pressure, shift speed and direction of the wind center, radius of 7 and 10 stages wind, etc. The cyclones that weaker than 7 stage were not analyzed

in this study because they hardly cause huge damages. The cyclones are chosen from the years of 1949 to 2016, with the period of 68 years. The statistical space area is a square area (17-29 °N, 108-120 °E), including Guangdong province and its coastal area. In data selection, 4 data points (i.e. 0:00, 6:00, 12:00, 18:00) are selected at a daily interval. As the wind power is weaker than stage 7, it was assumed the cyclone is disappeared, and the data collection is stopped. The coastal line of Guangdong is divided into six sections, to distinguish the landing area of the tropical cyclone in Guangdong province, starting from the Xuwen county in the West, to the Raoping county in the East. Figure 1 shows the classification of the sections: A - Xuwen county; B - Zhanjiang city; C - Yangjiang city; D - Shenzhen city; E - Shanwei city; F - Shantou city; G - Raoping county.

## 3. Results

### 3.1. Inter-annual variation

Figure 2 presents the number of tropical cyclones landing in Guangdong province every year (from 1949 to 2016). Results show that the frequency distribution of tropical cyclones which landed in Guangdong province every year is not uniform, and the tendency is irregular. During the 68 years, 183 tropical cyclones landed in Guangdong province, with an average of 2.7 per year. To be more specific, the largest number of landing time is in the year 1999, which exceeded seven times. The second largest amount of the landing time is the years of 1961, 1993, and 2008, which exceeded six times. The smallest number of the landing time is the years of 1950, 1956, 1959, and 2000, which is 0. That means no tropical cyclone was observed in the study area in these years. For most of the years, the landing time of the tropical cyclones is 2 - 4, which also accords with the landing time in recent eight years.

### 3.2. Tropical cyclone intensity in the coastal area

In this study, the strength of the tropical cyclone that lands in Guangdong coast is divided into four types: 1) tropical depression, 2) tropical storm, 3) strong tropical storm, and 4) typhoon. Figure 3 shows the intensity distribution of tropical cyclones. Results show that the landing times increases as increasing cyclone intensity. To be more specific, typhoon occurs for the most of the landing times, which exceeded to 114 times (accounting for more than 60% of the total), and the averaged landing time in each year is 1.7. For the strong tropical cyclone, it is the second most of the landing times, which exceeded to 40 times (accounting for about 20% in total), and the averaged landing time in each year is 0.6. However, the tropical depression that landing Guangdong coast occurred for only seven times during the 68 years (only accounting for 4% of the total), which means it lands Guangdong coast once every ten years. According to the statistical results, the strongest typhoon during these 68 years is No. 16 "Sally" in 1946. The highest stage of typhoon "Sally" was 17 stage, and the maximum wind speed near center during the moving exceeded to 87 m/s. The second strongest cyclones during these 68 years are No. 27 in 1954 and No. 14 in 1968. The intensities of both of them also exceed to the 17 stage, and their maximum wind speeds near center during the moving exceeded to 77 m/s.

### 3.3. Generation location and time

The generation sea areas of the tropical cyclones that land in Guangdong province are the South China Sea and the Northwest Pacific. One hundred eighty-three tropical cyclones fell in Guangdong province during these 68 years, in which 134 cyclones were generated in the Northwest Pacific, and only 49 cyclones were generated in the South China Sea.

The first and the last cyclones that landed in Guangdong coastal area each year were selected and analyzed in this study. For the first cyclones every year during the 68 years, the earliest time is April 19, which occurred in No. 1 cyclone in 2008, while the latest time is October 6, which is the No. 13

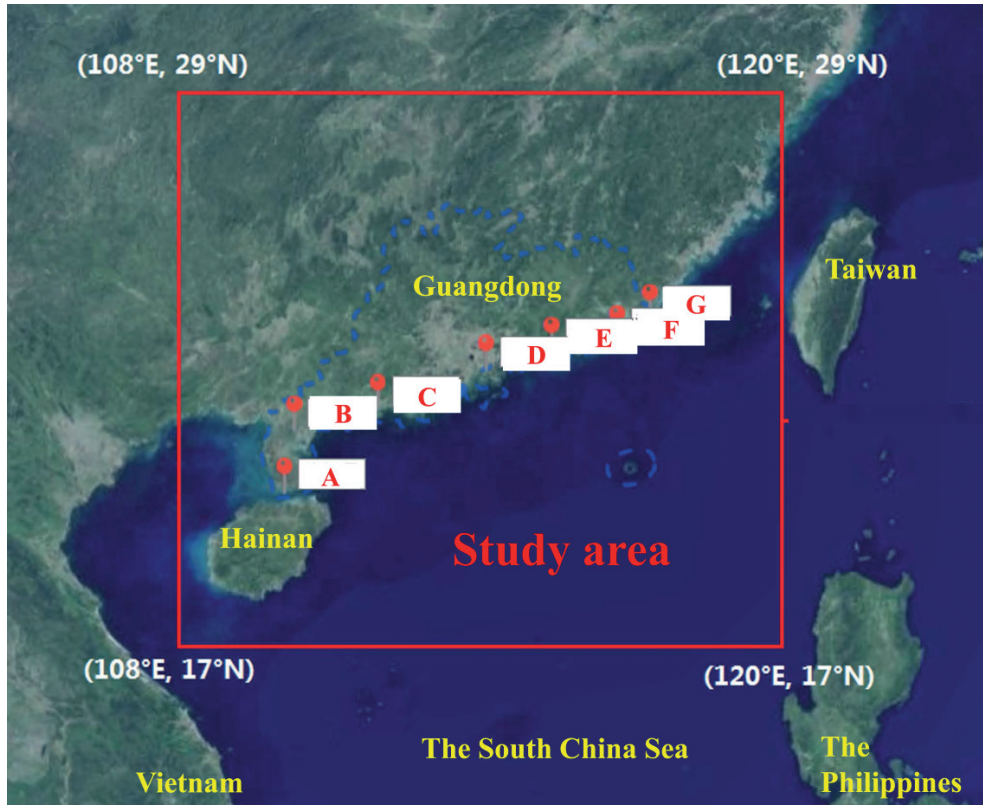


Figure 1. Study area and section classification.

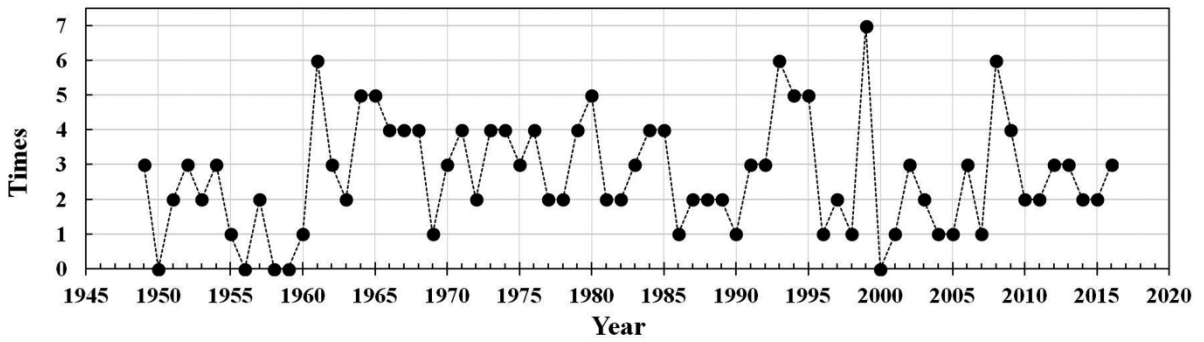


Figure 2. Times of tropical cyclones that landing Guangdong each year

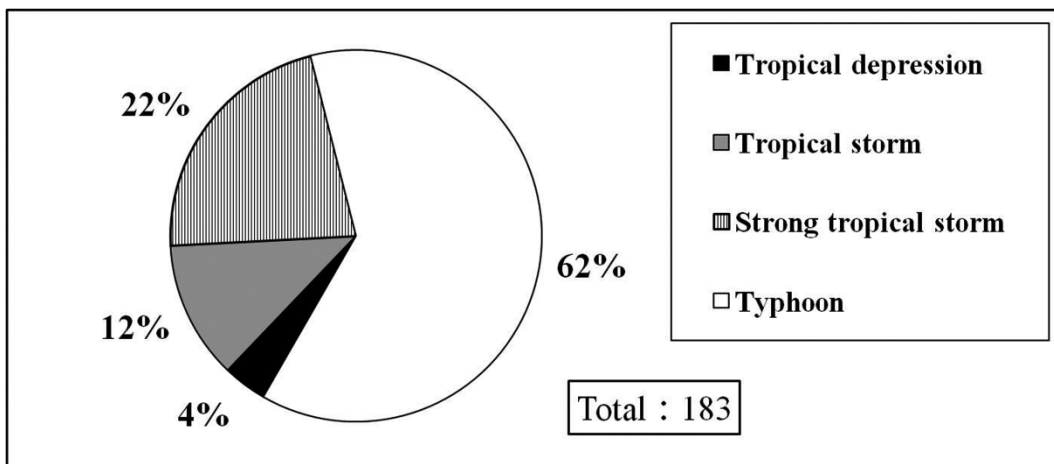


Figure 3. Intensity distributions of tropical cyclones

cyclone in 1975. In general, the first cyclones that landed in Guangdong coastal area every year occurred in June or July. For the last cyclones every year during the 68 years, the earliest time is June 6, which occurred in No. 5 cyclone in 1955, while the latest time is December 2, which is the No. 27 cyclone in 1974. In general, the last cyclones that landed in Guangdong coastal area every year occurred in September, October or November.

### 3.4. Moving directions

When the tropical cyclone is moving into the Guangdong coastal area, it presents a general moving direction. Table 1 listed the moving direction distributions of the tropical cyclones. From the table, it can be seen that in the past 68 years there were mainly three moving directions when the cyclones entered the study area, North, Northwest and West, and the Northwest direction was the most common direction, which took up half of the total. It is relatively rare for the moving directions of southwest and south because their total number was only four. The four of them are as follows: (1) No. 18 tropical cyclone in 1952, moving from Fujian province to Meizhou city via Guangzhou city, Guangdong province. After that, it was heading South and finally entered the South China Sea. (2) No. 14 tropical cyclone in 1966, moving from Fujian province to Shantou city. After that, it was heading south and finally entered the South China Sea. (3) No. 3 tropical cyclone in 1999, landing between Shantou city and Shanwei city, heading south along the coast of Guangdong province, turning to the southwest near Yangjiang city, and then entering to Guangxi province. (4) No. 7 tropical cyclone in 2009, landing near Yangjiang city, heading southwest to Zhanjiang city, and then moving towards southwest to Hainan province. The four cyclones above were unique. Also, there was only one cyclone that ran towards the south for 68 years, which only account for 0.5%. It should be noted that there were no cyclones that moved towards east or southeast during the 68 years.

**Table 1.** Moving directions of tropical cyclones in Guangdong coastal areas

Moving direction	Frequency of occurrence	Percentage (%)
North	38	20.8
Northeast	8	4.4
South	1	0.5
Southwest	3	1.6
West	49	26.8
Northwest	84	45.9

### 3.5. Spatial characteristics of landing sections

The coastal line of Guangdong province that was attacked by the tropical cyclones is divided into six sections (shown as Figure 1). Table 2 lists the spatial characteristics of landing locations. Results show that the tropical cyclones most frequently attacked the section B-C (from Zhanjiang city to Yangjiang city), followed by C-D (from Yangjiang city to Shenzhen city), and these two sections are subjected to 43% cyclones in total. Therefore, the coastal line from Zhanjiang city to Shenzhen city, which is the most developed area in Guangdong province, is most vulnerable to the tropical cyclones. To be more specific, during 68 years 30 tropical cyclones were landing from Xuwen county to Zhanjiang city, with an annual average of 0.44. Forty-three tropical cyclones fell from Zhanjiang city to Yangjiang city, with a yearly average of 0.63. Forty-one tropical cyclones landed from Yangjiang city to Shenzhen city, with an annual average of 0.60. Thirty-four tropical cyclones fell from Shenzhen city to Shanwei city, with a yearly average of 0.50. There were 27 tropical cyclones landing from Shanwei city to Shantou city, with an annual average of 0.40. And there were eight tropical cyclones landing from Shantou city to Raoping county, with a yearly average of 0.12.

For the first landing month in each year, the most common month is May; the earliest month is April, and the latest month is June. For the last landing month in each year, the most common months are October and November; the earliest month is September, and the latest month is December. The period of the first landing month to the last landing month decreases from the center of the Guangdong coastal line to the East and West sides (decreasing from 9 months to 5 months). For the moving direction, most of them are West and Northwest. Notably, the moving direction is North for the sections C-D and F-G. For the intensity of the tropical cyclones, most of them are typhoons. Specifically, the strongest intensity of the tropical cyclones occurred between the Yangjiang city and Shenzhen city (the occurrence frequency of the typhoon is 25 with the annual average of 0.37). The occurrence frequency of typhoon decreases from the coastal center line to East and West sides (dropping from 25 to 5).

The generation locations of the typhoon landing in Guangdong sea areas are also studied. The tropical cyclones affecting the Guangdong coastal area mainly generated from northwest Pacific. The cyclones that produced from the South China sea tend to land in the West of the Guangdong coastal line, i.e., Xuwen county to Shenzhen city (section A–D), while the cyclones that generated from northwest Pacific tend to land in the East of the Guangdong coastal line, i.e., Shenzhen city to Raoping county (section D–G). It can be concluded that the landing location of the cyclones is likely influenced by its generation location. Also, according to the data of the cyclones from 1949 to 2016, the first cyclones every year is likely to attack Yangjiang city to Shenzheng city (section C–D). However, the last cyclones every year is expected to attack Zhanjiang city to Yangjiang city (section B – C).

**Table 2.** Spatial distribution of landing sections for tropical cyclones

Landing section	Times	First landing month	Latest landing month	Direction	Intensity				Generation location	
					TD	TS	STS	Ty	South China Sea	Northwest Pacific
A - B	30	June	October	West / Northwest	1	4	5	20	9	21
B - C	43	June	November	West / Northwest	3	6	11	23	17	26
C - D	41	April	December	North / Northwest	2	5	9	25	10	31
D - E	34	May	November	West / Northwest	1	4	5	24	7	27
E - F	27	May	October	West / Northwest	0	2	8	17	4	23
F - G	8	May	September	North	0	2	1	5	2	6

Note: location A, B, C, D, E, F, G are shown in Figure 1; TD - Tropical depression; TS - Tropical storm; STS - Strong tropical storm; Ty - Typhoon

### 3.6. Month distribution of cyclones in the coastal area

Although the occurrence time of tropical cyclones attacking Guangdong province is not evenly distributed among each year, it demonstrates certain regularity in the distribution of the months. Table 3 lists the monthly distribution of tropical cyclone landings Guangdong coastal area. Results show that the generation time of the tropical cyclones is from April to December. Most cyclones are generated in July, and there are more than 70% of cyclones generated in three months (July, August, and September), which indicates the concentricity of the tropical cyclones in the generation time. To be more specific, during 68 years, there were 49 tropical cyclones striking Guangdong coastal area in July, with an annual average of 0.72; there were 40 tropical cyclones attacking Guangdong coastal area in August, with a yearly average of 0.59; and there were 42 tropical cyclones attacking Guangdong coastal area in August, with an annual average of 0.62.

Variations of the landing locations are also observed for each generation month. Specifically, the most frequent landing location for July is in between Shanwei city to Shantou city (in section E-F). The most frequent landing locations for June and August are in between Zhanjiang city to Yangjiang city (in part B-C). And the most frequent landing locations for the rest of the months are in between Yangjiang city to Shenzhen city (in section C-D). The results above suggest that the landing locations may be influenced by the generation month. Also, the main moving directions for each month are North, Northwest, and West.

For the intensity, the strongest tropical cyclones tend to occur in September (29 typhoons, with an annual average of 0.43), followed by July and August. For the generation location, the tropical cyclones that generated in April and May are likely produced in the South China Sea, while the tropical cyclones that generated in other months are probably caused in the northwest Pacific. It was found that in the earlier time each year, Guangdong coastal areas are vulnerable to the tropical cyclones generated in the South China Sea; while in the latter time each year, Guangdong coastal areas are vulnerable to the tropical cyclones generated in the Northwest Pacific.

## 4. Discussion

### 4.1. Analysis procedure of moving characteristics

This study collected the data of the tropical cyclones in Guangdong coastal areas during 68 years (from 1949 to 2016) and selected all on the tropical cyclone path of them in 6 hours interval (in latitude and longitude). Therefore, a total of 2040 path points were analyzed. Also, to analyze the tropical cyclones that occurred in summer (the peak period), 511 records, 467 records, and 502 records for July, August and September were also analyzed, respectively. The moving path characteristics on the sea were analyzed according to the statistical results. The analysis procedure is as follows:

- (1) The most frequent landing location was marked as the constraint condition for a certain month, and the middle point of the section in Guangdong coast was taken as the landing location of the specific path.
- (2) The trend line for a particular month was fitted from the path points of the tropical cyclone that in the study area.
- (3) The moving direction for the path was used as the check condition of the path characteristics analysis.

### 4.2. Equations for moving path

The center coordinates of the tropical cyclones are used in the trend line fitting. The latitudes are used as independent variables, and the longitudes are used as dependent variables. The least squares approximation method is used to propose the functions for the tropical cyclone paths in this study area, so the moving path characteristics are described. The tropical cyclone paths in the peak period months (July, August, and September) are shown in Figure 4(a), Figure 4(b), and Figure 4(c), respectively. The equations are described as follows:

The traditional path for July is:

$$0.3843x^2 - 87.879x + y + 5000 = 0, (115 < x < 120) \quad (1)$$

The traditional path for August is:

$$0.2561x + y - 50 = 0, (110.8 < x < 120) \quad (2)$$

The traditional path for September is:

$$1.1294x + y - 150 = 0, (110.8 < x < 120) \quad (3)$$

in which,  $x$  is the longitude (in °E),  $y$  is the latitude (in °N).

Based on the frequency analysis of the path of all tropical cyclones, a dense area of path points can be obtained, which falls between the upper boundary and the lower boundary, as shown in Figure 4 (d).

The upper boundary is:

$$0.55x + y - 85 = 0, (112 < x < 120) \quad (4)$$

The lower boundary is:

$$0.27x + y - 50 = 0, (109.2 < x < 120) \quad (5)$$

in which,  $x$  is the longitude (in °E),  $y$  is the latitude (in °N).

## 5. Conclusions

This study analyzes the tropical cyclones that affect the Guangdong coastal areas in the South China Sea. The tropical cyclone data from 1949

**Table 3.** Temporal distribution of landing month for tropical cyclones

Month	Times	Moving path		Intensity				Generation location	
		Most common landing location	Main direction	TD	TS	STS	Ty	South China Sea	Northwest Pacific
April	1	C - D	West	0	0	0	1	1	0
May	6	C - D	West	0	0	1	5	5	1
June	25	B - C	Northwest	2	6	4	13	10	15
July	49	E - F	Northwest	4	4	14	27	8	41
August	40	B - C	Northwest	0	6	12	22	14	26
September	42	C - D	West	1	6	6	29	9	33
October	15	C - D	North	0	1	1	13	2	13
November	4	C - D	Northwest	0	0	1	3	0	4
December	1	C - D	North	0	0	0	1	0	1

Note: location A, B, C, D, E, F, G are shown in Figure 1; TD - Tropical depression; TS - Tropical storm; STS - Strong tropical storm; Ty - Typhoon

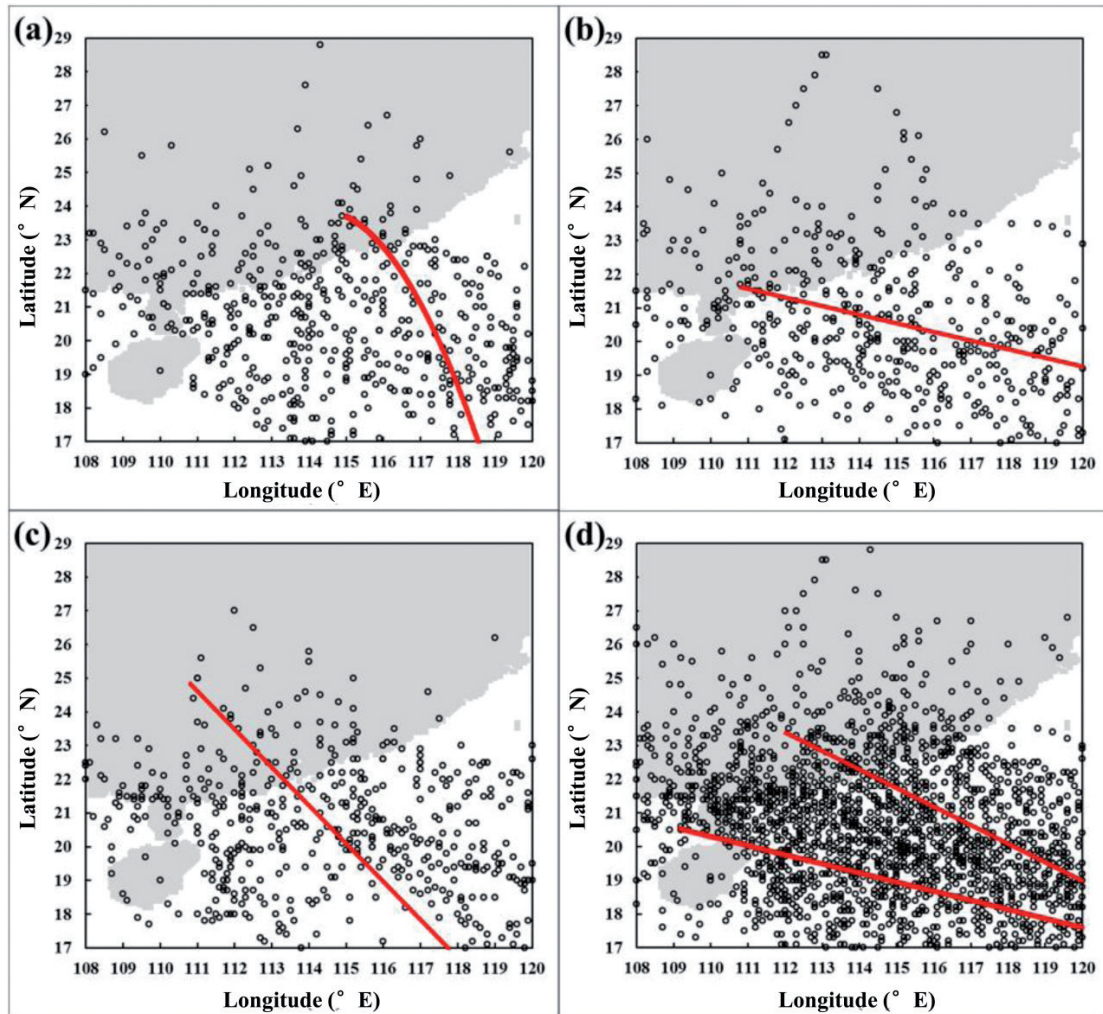


Figure 4. Typical paths for tropical cyclones in the Guangdong coastal areas: (a) for July; (b) for August; (c) for September; (d) upper and lower boundaries for overall months

to 2016 were collected. Key characteristics of the tropical cyclones on the sea were investigated, such as the inter-annual variation, the intensity of tropical cyclones, the generating source and time, and the path directions. The results are summarized as follows:

- 1) There were 183 tropical cyclones landed in Guangdong province in the past 68 years, with an average of 2.7 each year, which more than 60 percent was a typhoon.
- 2) Most of the tropical cyclones were generated in the Northwest Pacific, spanning from April to December. The path directions were mainly North, Northwest, and West.
- 3) The strengths of the tropical cyclones were reduced from central Guangdong coast to both sides, and the section of Zhanjiang to Shenzhen was the most vulnerable to tropical cyclones.
- 4) Tropical cyclones that generated in the South China Sea and the Pacific Northwest tend to land in the West and East of the Guangdong coastline, respectively.
- 5) Cyclones frequently occurred from July to September and became strongest in September.
- 6) There are a most common landing section and path direction for each month.

Finally, the temporal-spatial characteristics were investigated, and the functions for describing moving path characteristics are proposed based on the data.

#### Acknowledgments

The authors gratefully acknowledge the support of the National Natural Science Foundation of China (Grant No. 51809047) and the Youth Teacher Education Scientific Research Project in the Education Department of Fujian Province, China (Grant No. JT180049).

#### References

- Emanuel, K. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, 436(7051), 686.
- Jia, X., Lu, C. T., Lu, J., & Zhou, Z. P. (2010). Statistical characteristics of typhoons affecting China coast and numerical simulation of typhoon waves. *Journal of Waterway and Harbor*, 31(5), 433-436.
- Li, Y., Chen, L. S., & Zhang, S. J. (2004). Statistical characteristics of tropical cyclone making landfalls on China. *Journal of Tropical Meteorology*, 20(1), 14-23.
- Liou, C. S., & Elsberry, R. L. (1987). Heat budgets of analyses and forecasts of an explosively deepening maritime cyclone. *Monthly Weather Review*, 115 (9), 1809-1824.
- Liu, Y. C., Chen, H. F., Liu, X., & Chang, Y. P. (2017). Insight into tropical cyclone behaviour through examining maritime disasters over the past 1000 years based on the dynastic histories of China—A dedication to Ocean Researcher V. *Quaternary International*, 440, 72-81.

- Rezaee, S., Pelot, R., & Finnis, J. (2016). The effect of extratropical cyclone weather conditions on fishing vessel incidents' severity level in Atlantic Canada. *Safety Science*, 85, 33-40.
- Tang, X. C., Liu, H. P., Pan, A. D., Liang, B. Q., Li, Y. T., & Wang, T. M. (2003). Analysis of disastrous features of landing typhoon in coastal regions of Guangdong province in recent 50 years. *Scientia Geographica Sinica*, 23(2), 182-187.
- Tucker, C. S., Trepanier, J. C., Harley, G. L., & Delong, K. L. (2018). Recording tropical cyclone activity from 1909 to 2014 along the northern Gulf of Mexico using maritime slash pine trees (*pinus elliottii* var. *elliottii* engelm.). *Journal of Coastal Research*, 34(2), 328-340.
- Wen, Y. (2002). The characteristics of typhoon disaster and disaster countermeasures in Guangdong province. *Journal of Catastrophology*, 17(3), 54-59.
- Williams, M. J., Coles, R., & Primavera, J. H. (2007). A lesson from cyclone Larry: An untold story of the success of good coastal planning. *Estuarine, Coastal and Shelf Science*, 71(3-4), 364-367.
- Xu, F. M., Huang, Y. F., & Song, Z. Y. (2008). Numerical simulation of typhoon-driven-waves from the East China Sea to Yangtze Estuary. *Chinese Journal of Hydrodynamics*, 23(6), 604-611.
- Yuan, F. C., Chen, M. N., & Chen, D. W. (2010). Changes of tropical cyclones in China and Fujian in recent 60 years. *Marine Forecasts*, 27(5), 34-39.
- Yuan, J. J., Ding, Z. Y., & Wang, L. (2011). A statistical study and composite analysis on the characteristics of the extratropical transition of landfall typhoons during 1949-2007. *Journal of Tropical Meteorology*, 27(4), 529-541.
- Zhang, W. L., & Cui, X. P. (2013). Review of the studies on tropical cyclone genesis. *Journal of Tropical Meteorology*, 29(2), 337-346.
- Zhao, H. J., Song, Z. Y., Xu, F. M., & Cheng, C. (2010). Numerical simulation of typhoon waves in the South China Sea – a case study of Typhoon Chanchu. *The Ocean Engineering*, 28(3), 128-134.
- Zheng, C. W., Zhou, L., Song, S., & Pan, J. (2014). Simulation of the wave field caused by No. 1307 typhoon "Soulik." *Journal of Xiamen University (Natural Science)*, 53(2), 257-262.