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Analysis of applicable methods for the safety navigation of ship within tropical cyclone environment in South China Sea

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ANALYSIS OF APPLICABLE METHODS FOR THE SAFETY NAVIGATION OF SHIP WITHIN TROPICAL CYCLONE ENVIRONMENT IN SOUTH CHINA SEA

By

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DECLARATION

I certify that all the materials in this research paper that are not my own work have been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title: Analysis of Applicable Methods for the Safety Navigation of Ship within Tropical Cyclone Environment in South China Sea

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Tropical cyclone is a kind of super destructive meteorological disaster. West Pacific is one of the largest global TC regions. South China Sea (SCS) as one of the most active sea areas for TC, there are collision, grounding, shipwrecks and other maritime accidents happening every year. This paper is an analysis of the applicable methods to improve the safety of ships within TC environment in SCS.

Some typical accidents happened in SCS are chosen and analyzed to find the main causes of these accidents. Subjective and objective factors are summarized. For the lack of enough knowledge of TC in SCS，the author summed up and analyzed the features of TC in SCS with the application of literature and statistics.

For ships, navigation methods can be different according to their position. As avoiding TC can greatly reduce risk, it is always a better choice to avoid. At the same, scientifically selecting the avoiding TC program also can reduce the cost and enhance the economic benefits of shipping companies.

If avoiding is unable to carry out, mooring can be used to fight against TC. In detail, the paper has stated three mooring ways and their application and requirements. Finally, applicable methods and advice were given in the conclusion part.

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Key words: Tropical Cyclone (TC), Typical Accidents, Navigation Methods, Avoiding, Mooring

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LIST OF ABBREVIATIONS

BS	Beaufort scale
DWT	Deadweight Ton
ECA	Emission Control Areas
etc	and so on
GT	Gross Tonnage
MSA	Marine Safety Administration
LOA	Length Overall
NT	Net Tonnage
STS	Strong tropical storm
TD	Tropical depression
TS	Tropical Storm
TY	Typhoon
SCS	South China Sea

Chapter 1 Introduction

1.1 TC-A big threat to the safety of ships in SCS

TC is a kind of super destructive meteorological disaster which generates in tropical or sub-tropical oceans. West Pacific is one of the largest global TC regions. While China is located in the West Coast of Pacific, with long stretching coastline, is one of the countries vulnerable to the invasion of TC. TCs affecting China's coastal are about 20 per year, and average annual landing number makes seven. SCS as one of the most active sea areas for TC, there are collision, grounding, shipwrecks and other maritime accidents happening every year. Take jurisdiction area of Zhanjiang Maritime Safety Administration (MSA) for example, merely from 2001 to 2010, there had been seven traffic accidents caused by TC in the area, including three as major accidents and three large ones. (Zhanjiang MSA, 2012) Maritime accidents caused directly or indirectly by TC lead great losses to ship’s navigation safety and people's lives and property in SCS.

To improve the safety of ship within TC environment in SCS, this research paper puts emphasis on finding the causes of the accidents and applicable methods to solve these problems.

1.2 Objectives of research

The purpose of this research is to find causes of ship anti-TC accidents in SCS and make recommendations for improving the safety. The study offers the feature analysis of TC in SCS to give a basic TC knowledge to the readers. Different anti-TC methods used at different stages of TC are proposed. Also, a comparison of them is made for reference.

1.3 Methodology and main contents

The study carried out research by the analysis of representative cases. Through the analysis, the study analyzed the causes of anti-TC accidents. Documental method, comparative method and method cited were used in this thesis to make detailed introductions and descriptions of ships' applicable safety methods.

The main contents consist of seven chapters. Chapter two analyzes of the typical accidents happened within TC environment in SCS. Chapter three offers the feature analysis of TC in SCS. Chapter four introduces different navigation methods which can be used according to ship-TC position. Chapter five describes avoiding TC methods, while chapter six is about how to fight against TC by mooring. In the end, chapter seven provides the overall summaries and conclusions.

Chapter 2 Typical accidents happened in SCS

For anti-TC accidents of ships happened in SCS, at different stages of anti-TC process, the causes of anti-TC accidents can be various. Here are three typical accidents happened at the different stages of the process.

2.1 "Yue Gong Zhua 7"

2.1.1 Accident Brief

0530s August 29, 1990, "Yue Gong Zhua 7", owned by the No.3 Company of Ministry of Transportation's Fourth Harbor Engineering Bureau, tugged by "Yue Gong Tuo 11" on the way to Yangpu Port was attacked by the No. 9016 typhoon. Finally, it sank in 19 °23'50 "N / 108 °37'15" E, causing the vessel 1 person killed and 12 missing. (Basuo MSA，2011)

2.1.2 Ship details

Vessel name: Yue Gong Zhua 7	Type: No power engineering ship
LOA: 35 m	Breadth: 16 m
Moulded depth: 3 m	Design draft: 1.9 m
DWT: 945.44 tons	Navigation area: coastal
Built date: 1974	Ship loading: None

2.1.3 Hydrological and meteorological conditions

Through the Wenzhou typhoon path website, during the accident it was northeast wind Beaufort scale (BS) 7-8, gust BS 11, the maximum wind speed of 34m / s. Relevant information provided by the Dong Fang weather and ocean observation station showed that the tide was rising and flows northeast. The wind and tide were in the same direction.

2.1.4 Causes of this accident

According to the accident investigation report of "Yue Gong Zhua 7", the main reasons for the accident were:

2.1.4.1 Bad weather and sea conditions.

By checking the Wenzhou typhoon path website, maritime accident investigators found that during the accident it was northeast wind BS 7-8, gust BS 11, the maximum wind speed of 34m / s. Through access to relevant information provided by the Dong Fang weather and ocean observation station, it showed the tide was rising and flows northeast. What's more, the wind and tide shared the same direction. The ship's movement was greatly impacted by cross-wind and horizontal waves.

2.1.4.2 Human issues.

In the early days of TC season, "Yue Gong Zhua 7" didn't strictly check its communication equipment and watertight equipment. Worse more, there were no anti-TC plan and anti-TC staffing deployment. All above leading waves to the upper deck which eventually leads to the accident.

2.1.4.3 Unable to grasp the proper anti-TC opportunity.

At the very beginning, the ship did not depart from Basuo port to choose proper anchorage to fight against TC as soon as possible, but hastily be towed northward after the tropical storm had strengthened into a typhoon. The reinforced wind leading the towing ship too difficult to implement towing and cable between "Yue Gong Tuo 11" and "Yue Gong Zhua 7" disconnected, resulting in that "Yue Gong Zhua 7" sinking at last.

2.1.4.4 Emergency anchor position selection mistakes.

According to the sinking accident investigation report of "Yue Gong Zhua 7", "Yue Gong Tuo 11" towing "Yue Gong Zhua 7" en route to Yangpu, the wind increasing continually made it very difficult to move on. Difficult to achieve the plan of fighting TC in Yangpu, "Yue Gong Tuo 11" had no choice but drop anchor in open waters at a depth of 30 meters to fight TC. "Yue Gong Zhua 7" and "Yue Gong Tuo 11" stepped further into danger in result. According to the temporal sea conditions and technical condition of the ship, there remaining was the possibility that "Yue Gong Tuo 11" towed " Yue Gong Zhua 7" to shallow waters to avoid of the accident, but the ship kept on its way and missed the opportunity.

2.2 “Hua Peng Hai”

2.2.1 Accident Brief

August 7, 2009, "Hua Peng Hai" which belongs to Yangpu Hua Sheng Jing Peng Shipping Co., Ltd. sunk at port of Basuo 1# anchorage. The accident made 15 crew members overboard, 11 people were rescued, 1 died and 3 missing, direct economic losses of 14 million yuan. (Basuo MSA，2011)

2.2.2 Ship details

Port of registry: Phnom Penh, Cambodia   Ship Type: Bulk Carrier

Hull material: steel   GT: 3598

NT: 2014   DWT: 6376

LOA: 109.8 m   Breadth: 16.4 m

Moulded Depth: 8.1 m   Host Power: 2793KW

Built date: 1985s   Loading conditions: full

Owner: Yangpu Hua Sheng Jing Peng Shipping Co., Ltd.

2.2.3 Hydrological, meteorological conditions

When the accident happened, the forecast wind was southwest wind BS 7, gust BS 9, rotating wind BS 8 in the sea area near the TC center, gusts BS 10. However, the actual sea surface wind was BS 9-10, 5-7 meter swell, southwest current, current about 4 knots, the wind and the current were in the same direction.

2.2.4 Causes of the accident

According to the accident investigation report of “Hua Peng Hai”, the main reasons for the accident were:

2.2.4.1 Human issues.

The ship company and the captain had underestimated the harm of TC. During early time of TC in affect, there was no arrangement for each department to make the necessary preparations against TC, such as checking the conditions of each watertight compartment, reinforcing hatch canvas and inspecting seaworthiness of major equipment etc. Later, the ship was hit by the great storms, the captain ship attempted to steer to get rid of danger. However, the waves on the deck caused windlass serious electromechanical short circuit fault which made the ship hard to heave up anchor and failed further into danger.

2.2.4.2 Unreasonable anchorage position.

The water depth of the ship’s anchorage position showed on chart is -10.1 meters. On the very day, the average tide around 1800 to 2100 is 2.0 meters high in Basuo and it was at low tide. The ship's maximum draft was 7.1 meters, the underkeel clearance 5 meters, wave about 5-7 meters then. Obviously, underkeel clearance was less than the waves. For the sea conditions at that time, the ship would possibly suffer serious grounding. According to the divers’ report, there were two positions broken at the ship’s end. Due to rupture, a lot of water had flowed into the cargo hold and the ship sank at last.

2.3 "Yue Yang"

1.3.1 Accident Brief

August 22, 1995, "Yue Yang" on its voyage from Singapore to Shanghai hit a tropical depression which might develop into a typhoon (later developed into a strong tropical storm named LOIS) in the SCS. The ship took scheme to avoid the TC at first, and changed to anchor in Wanning County to fight TC after. 28 August 0800s, LOIS landed with center in Wanning County sea area, in south-east of Hainan Island. Unfortunately, "Yue Yang" was dragging just in the vicinity of the TC center with stern on reef. Heavy diesel oil tanks overflowed and caused two deaths and total loss of the ship.

2.3.2 Process of the accident

August 22, 1995, "Yue Yang" set out from Singapore to Shanghai. Heading northeast the ship was unloaded and sailing in speed of 12 kn ~ 13kn. August 23, when the ship was passing through the SCS, a tropical depression between Hainan Island and Luzon in the Philippines has formed, central pressure 1002hPa. 24 August 0200s (Beijing time) the tropical low pressure center was located 18. 0 °N, 116 .5 °E, central pressure wass 1002 hPa, near the center of the wind BS 6-7, the position was relatively stable. On 1400s and 2000s the same day, the tropical depression started slowly moving eastward. Founding that the center of the tropical depression was located near in front of the ship design course, the ship began to monitor the dynamic of the tropical depression.

August 24th, the ship was at 9.5 °N, 110 .0 °E, with course 027 °and navigated in speed of 14 kn. 25 August 0200s, the center of the tropical depression located at 18.0°N, 117.0 °E and continued to move slowly eastward. Research on board believed that: the tropical depression would likely develop into a typhoon. According to the small range and eastward movement of the tropical depression, the ship decided to adjust its route to pass through the tropical depression from its rear (west) side, so as to avoid entering into the path of the tropical depression (the tropical depression was moving east).

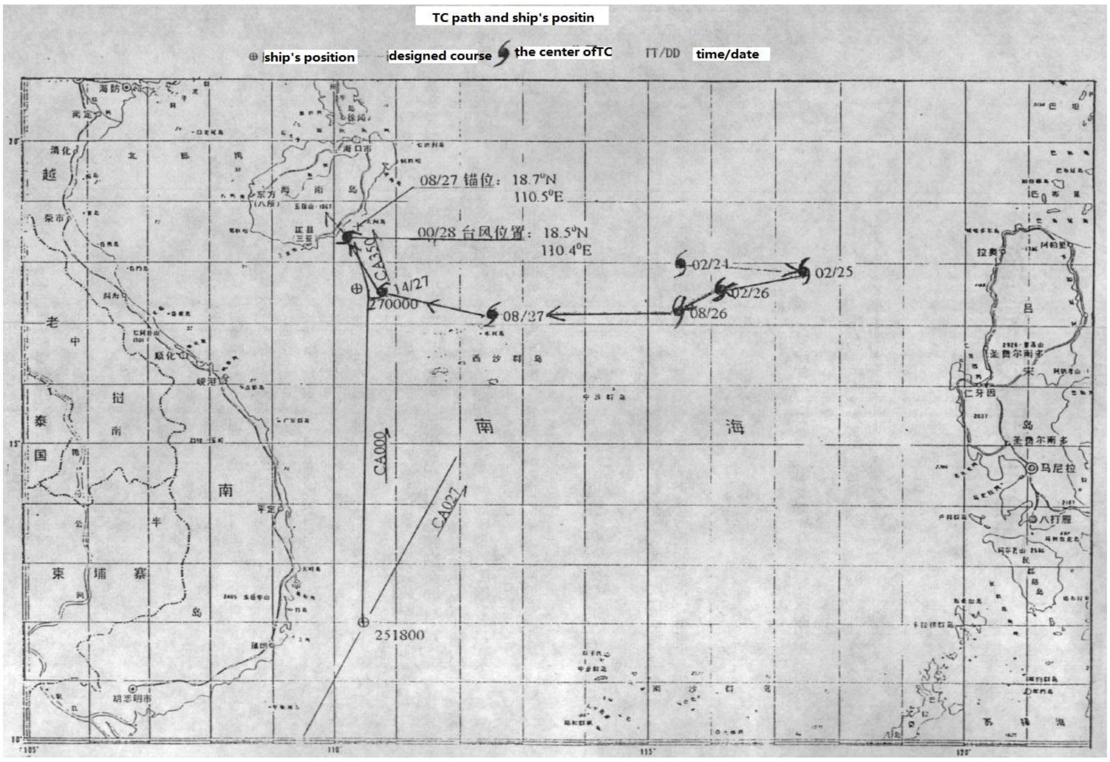
26 August 0200s, the weather fax showed that the central pressure of the tropical depression was still 1000 hPa. Its moving was almost stationary, but the scope had expanded. However 6 hours after, the tropical depression suddenly began to turn westward. At this point, the ship had been imposed in abeam tropical depression right into its path. The ship altered its course to Hainan to avoid TC. Early morning of August 27, 0200s ~ 0300s, storm surged. As the ship was empty with bow draft 1.1 m (bow ballast tank cannot ballast fully because of leakage) and the stern draft 4.7 m, the ship's bow couldn't stand the storm. Although in full speed, the ship was still

unable to keep steady which made it rather difficult to sail. Thus, the captain decided to go to Wanning County, Hainan province to take shelter.

27 August 0800s, the tropical depression developed into a tropical storm, named LOIS, wind scale near the center up to BS 10. Moving northwest side at a speed of 6 kn. The wind scale might strengthen to about BS 12 in the next 24 hours. 27 August 0719s, the ship anchored in Da Zhou Dao Bay southeast of Wanning County Hainan province, about 1.5 n miles from the shore, 200 n miles from the TC center. It was relatively good weather sea conditions. In this case, the original intention of the ship to avoid TC turned into fighting TC in anchorage.

27 May 1400s, the TC, about 200 n miles from the ship, had expanded, the wind continued to strengthen. At that night, the wind increased to about BS 10, weather and sea conditions of the sea area the ship anchored quickly became very bad. 2225s, the ship was dragging. 28, 0016s, the ship anchored its left anchor in the vicinity of the original anchorage position .The starboard side anchor failed. The result was the ship still the single anchor against TC. 28 August 0300s, the ship dragged its anchor again. The ship started its engine but had already lost orientation-preserving ability. 0335s when twisted anchor the windlass stuck failed to work, the ship floated toward shore rapidly. 0515s, the ship ran aground, water in engine room. 0518s, the whole ship was power off.

28 August 0800s, LOIS had strengthened in to strong tropical storm. It landed in waters near Wanning County, southeast of Hainan province. The largest wind near center was more than BS 12 and waves up to 10 meters. Just in the vicinity of the center of TC LOIS, "Yue Yang" dragged anchor and stern sat on reef unfortunately. Heavy diesel oil overflowed seriously and polluted sea seriously. In the end, two people on board were killed, the ship total loss. (Gao, Wang , 1999a)



Figue1.Positions of TC and M/V "Yue Yang"

Source: Gao, Wang , (1999b)

2.3.3 Causes of this accident.

The occurrence of this accident first is due to improper weather analysis, poor master of the characteristics of TC in the SCS and a lack of a comprehensive analysis of the situation of the TC circulation around.

According to the survey, the ship hadn't received weather information (such as receiving NAVTEX, plain language broadcasting and fax weather chart, etc.) continuously and timely, and received figures were insufficient (lack of TC warning diagram). In result, the fact that TC steered westward was found too late to analyze and make judgment. This also is one cause of the accident.

Because of misjudgment, the ship chose to avoid TC by anchoring in Hainan Wanning

County. At that time, as the ship was unloaded, the wind area turned bigger. Even worse, the ship had anchored in improper way which gave rise to dragging of anchor. When trying to correct, because of the wind and waves, ship maneuvering difficulties coupled with lack of skill, the ship failed to achieve the goal. Again, it was a single anchor in water against TC. When the TC center got closer, the wind strengthened, the surge got high, resulted in the dragging of anchor and ship's grounding. (Gao , Wang, 1999a)

2.4 Summary:

Seafarers' subjectively poor safety awareness or lack of adequate understanding of TC, underestimating its impact, risky sailing or ignorance of signs of accidents give rise to delay in discovering the danger of accidents. Remedial measures not taken timely often lead to major accidents.

The seafarers should improve their ability to make analysis of weather forecasting information, the development of severe weather, dynamic analysis and judgment particularly. When the movement of TC is unknown or unstable, ships should not rush to sail close to the wind. Seafarers should make full use of the meteorological information they can collect to closely monitor TC, so that they can take preventive measures to avoid dangerous situations from occurring.

In the early days, anti-TC preparations should be done fully so as to judge TC developments, reasonably avoiding or mooring. Once facing tropical storm directly, related personnel must take appropriate operating mode of navigation and reasonably positive anti- measures. Otherwise, the incident will be inevitable.

Chapter 3 Feature analysis of the TC in SCS

SCS, located in marginal sea south of China, the shipping hub between the Western Pacific and Indian Ocean, surrounded mostly by peninsulas and islands. SCS is in south of China mainland and Taiwan Island, west of the Philippine Islands, north of Kalimantan and Sumatra, and east of Indochina and the Malay Peninsula. It's this unique location, has great significance for China's shipping industry. However, due to frequent TC activity in the region and some ships' poor anti-TC measures, collision, grounding, shipwrecks and other maritime accidents often occur.

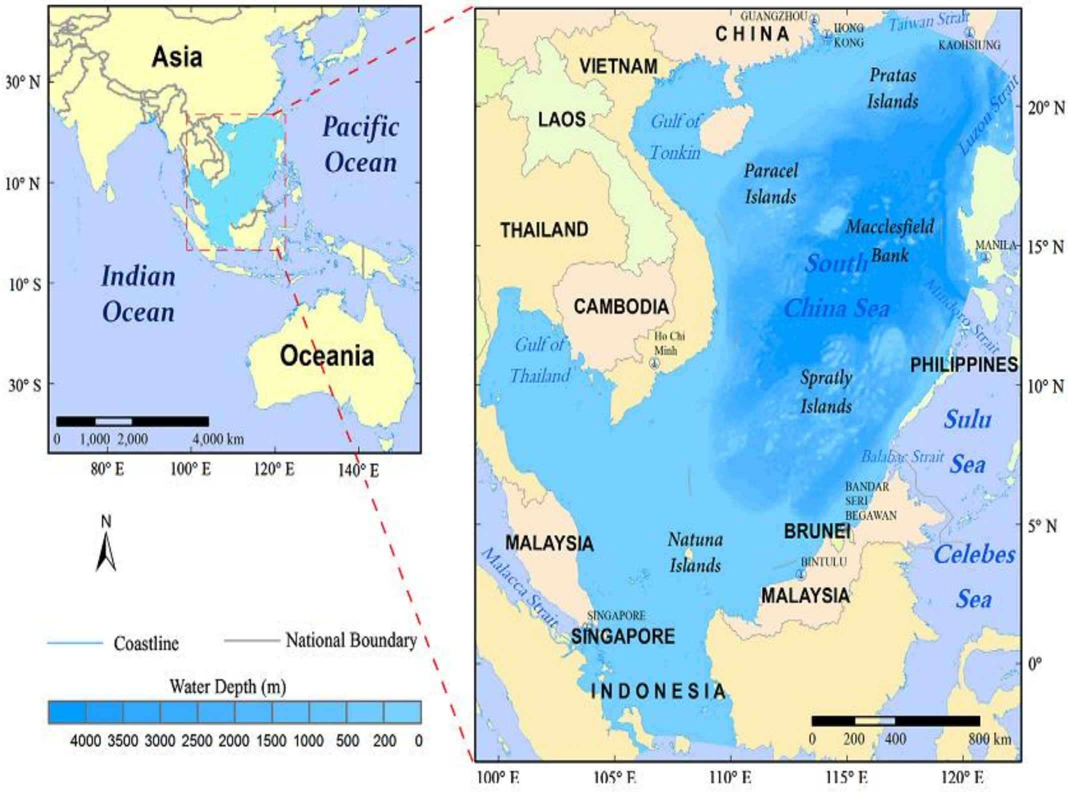


Figure 2: The location of the SCS

Source: Wang, Li, Liu, Zhang, Zou, & Cheng, (2014)

3.1 The basic information

TCs in different regions have different names. Countries and the regions in the western Pacific Ocean and the SCS coast call TC typhoon on customary, while countries and regions in the Northeast Pacific, Atlantic called TC hurricanes. The formation of TC depends on: (a) high water temperatures and humidity, surface water temperatures is not less than 26.5 ℃elsius, and a depth of no less than 60m. (b) The appropriate circulation field, proper circulation condition, can start and induce hot and humid air to produce disturbance leading airflow to converge and rise. (c) There is sufficient magnetic bias force which is conducive for cyclonic vortex's generation. (d) Little Wind Speed difference between high and low altitude so that the accumulation of heat rises in the air, the latent heat is not spread out, which makes it easy to keep warm core structure of the cyclones. The formation of TC is a complex process. Conditions above are necessary but not complete conditions for the forming of TC. (Zhou, Shi, & Fan,. 2004)

3.1.1 Classification of TC and warning signal

In China, TC, according to the maximum wind near the center, are generally divided into four grades:

(A) Tropical depression (TD): BS 6-7 (10.8-17.1 m / sec).

(B) Tropical Storm (TS): BS 8-9 (17.2-24.4 m / sec).

(C) Strong tropical storm (STS): BS 10-11 (24.5-32.6 m / sec).

(D) Typhoon (TY): ≥BS 12 level (≥32.6 m / s)

TC affecting SCS, according to the process from generation to demise of, is usually divided into four stages:

1, the primary stage: starting from the development of the wind to wind scale 12

2, strengthen stage: central pressure reached a minimum value, maximum wind reached.

3, mature stage: central pressure no longer deepen, the wind is no longer enhanced, but the scope of strong winds and rain still explodes.

4, the declining phase: for the demise, there are two cases, one after the TC, due to the reduced amount of water vapor supply, depletion of energy sources, and because the land friction effect, which quickly weakened, and finally disappeared. The other is when the TC moved to higher latitudes, generally there is cold air invasion. At this time, the TC is no longer a single heating group, the warm and cold fronts will gradually become extratropical frontal cyclone, gradually weakened and vanished. TC in SCS usually lasts 3-8 days from generation to die out. The longest may be up to 20 days, while the shortest only 1--2 days.

3.1.2 Anti-TC warning signal specified

In china, signals are showed respectively by blue, yellow, orange and red.

Figure 3: Chinese TC warning signals

Source: China Meteorological Administration, 2004

Blue TC warning signal indicates that it is likely or already affected by TCs within 24 hours, mean wind along the coast or on land more than BS 6 or gust stronger than BS 8 and may continue.

Yellow TC warning signal indicates that it is likely or already affected by TCs within 24 hours, mean wind along the coast or on land more than eight or gust stronger than ten and may continue.

Orange TC warning signal indicates that it is likely or already affected by TCs within 12 hours, mean wind along the coast or on land more than ten or gust stronger than twelve and may continue.

Red TC warning signal indicates that it is likely or already affected by TCs within 6 hours, mean wind along the coast or on land more than twelve or gust stronger than fourteen and may continue. (China Meteorological Administration, 2004)

3.2 Time and location feature of TC in SCS

3.2.1 The time characteristics of TCs impact SCS

TCs affecting the SCS can be divided into two categories, one is moving from the western Pacific, and the other is generated in the SCS.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
TY				1	6	8	8	5	11	9	2	1	51
TS		1		1	11	15	18	30	26	17	17	5	141
TD	1				7	20	12	33	34	13	10	7	137
Total	1	1		2	24	43	38	68	71	39	29	13	329
Average	0.02	0.02		0.04	0.45	0.81	0.74	1.28	1.34	0.74	0.55	0.25	6.20
Max	1	1		1	3	2	5	3	4	4	3	2	11
Min	0	0		0	0	0	0	0	0	0	0	0	1

Table1: The number of TC monthly found in SCS from 1949 to 2001(Here TS means both STS and TS)

Source: Liu, Wu，(2004)

From 1949 to 2001, according to statistics of the Typhoon Yearbook, TC had occurred in every month besides March in SCS, of which 78% appeared within June to October. From Table 1, a total of 53 years of statistics from 1949 to 2001, we can see the total number of TCs each month are diverse, the most in September 71 times, accounting for 21.6 percent, followed by August 68, June, October, July 43, 39 and 38 respectively, January and February both once only. Changes the statement to an annual change of each month, from December to May of the following year, there had been TCs every month except March. For January and February, there were only a tropical depression in 1965 and a tropical storm in 1956. In April, a tropical storm appeared in 1956 and a typhoon appeared in 1999. There were 19 years in which TC appeared in May, 11 years in December, 47 years in September and 41 years in

August. Obviously, august and September are the months when TC in SCS happen most frequently. In these 53 years, TCs originated in SCS a total of 51 strengthened into a typhoon. Eleven TCs strength up to typhoons in September serve as the most, followed by nine in October.

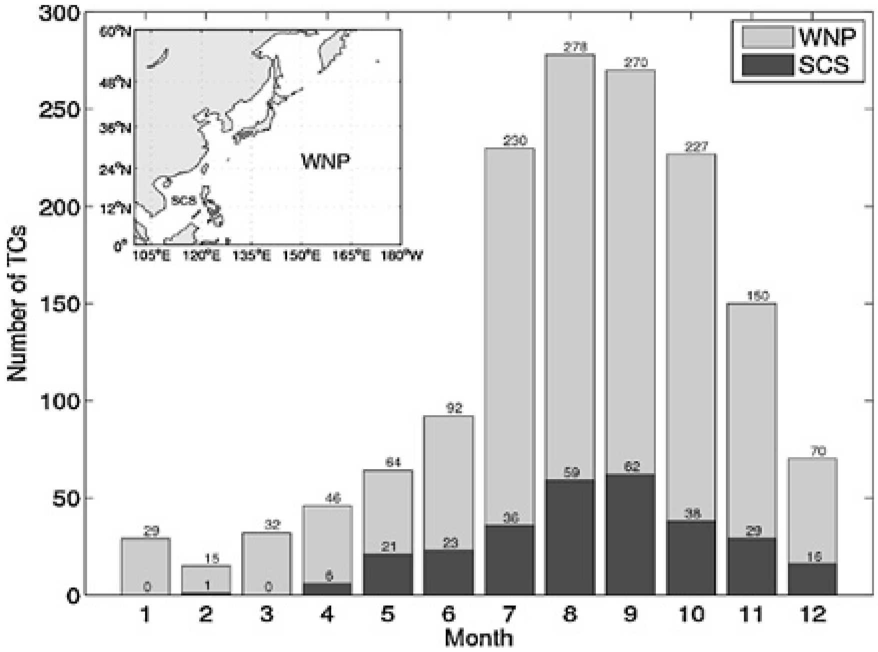


Figure 4:The monthly number of TCs formed in the WNP (shaded gray) and in the SCS (shaded dark) during the period 1945–2009.

Source: Yan, Qian, &Zhou, (2012)

3.2.2 General characteristics of TC source

Space frequency of the TC has a very uneven distribution. In the south of the 4 °N and north of 30 °N, the west of 110 °E and east of 170 °E, there had rarely been TC. High generating area of TC distributed in the following three sea areas: the ocean east of the Northern SCS (14 °N-18 °N, 114 °E-120 °E), sea surface between east of the Philippines and the Caroline Islands (10 °N-14 °N, 130 °E-134 °E) and Caroline Islands area (8 °N-12 °N, 140 °E-145 °E). The number of TC centers in the three regions reduces radiatingly in all directions. In these three above TCs birthplaces, the east of western Pacific (Caroline Islands area) is most southerly location, high frequency happening latitude around 10 ° N. West Pacific Western sources (the Caroline Islands east of the Philippines between the ocean) is located centrally, high frequency latitude around 12 °N. Northern of SCS is most northerly source position, around latitude 16 ° N. In the three sources, the eastern Western Pacific generates most of the TCs.

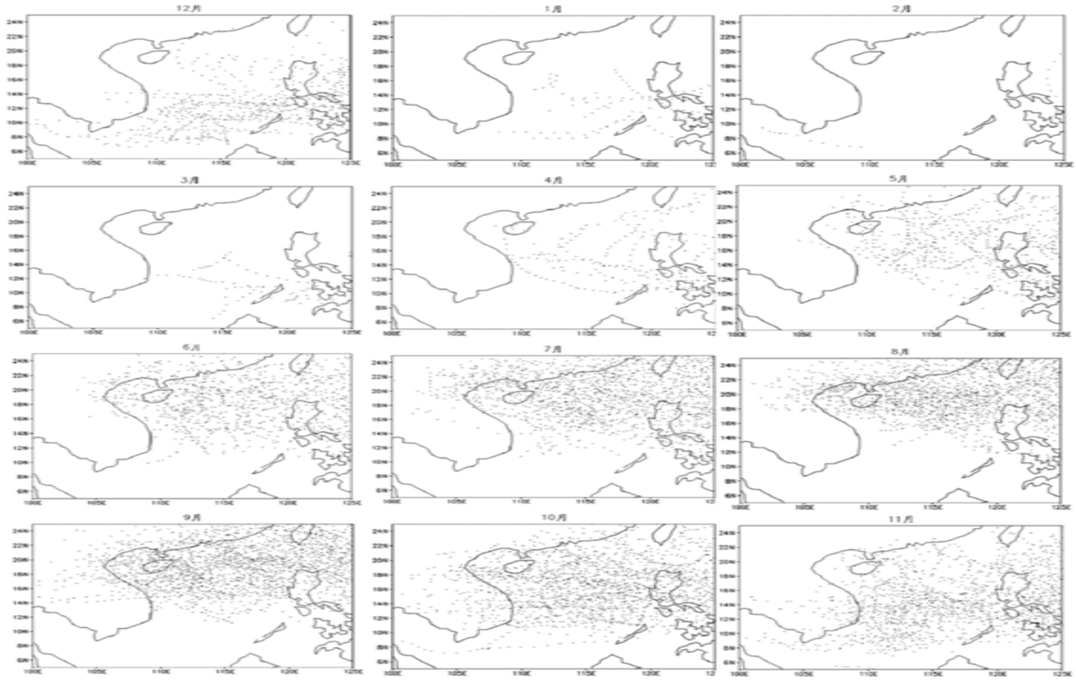


Figure 5: Distribution of TCs' generation and location points at intervals of six hours 1949—1999s SCS (105-120 °E, 5-25 °N)

Source: Wu, etal(2005)

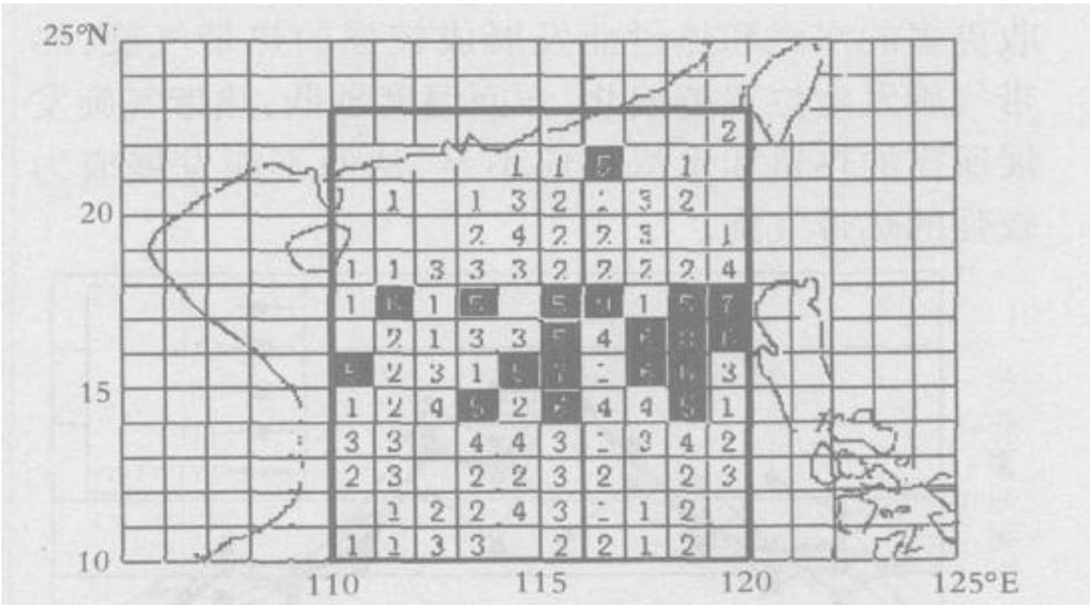


Figure 6: 1949- 2003 1 °X 1 °latitude and longitude range frequency distribution of TCs in SCS

Source: (Yang, 2005)

3. 3 Regular pattern of TC moving path and moving speed in SCS

TC of SCS, part of moving in by ocean east of the Philippines from the western north Pacific, the others generated in the local sea area. The scope of the TC in SCS is small. Its path under the influence of air flow field is relatively large. In the summer, when the force of the western Pacific subtropical high is stronger and the situation is stable, the TC in SCS is most likely westward or parabolic. When the upper air circulation is weak or there are twin typhoons, steering flow of TC is weak. The TC's looping and unpredictable motion, forming an irregular path, is common in the sea. Transition and winter season strong cold air southward, enhancement of northeast airflow in northern SCS can make the TC moving south. According to statistics, TCs in SCS if entering in areas north of 18 °N, west of 115 °E, generally move west-northwest, rarely move north or turning. In SCS, the TCs' mobile path can be roughly divided into four categories after generation: parabolic, inverted parabolic, moving westward and moving north after looping. (Li, 1999).

For May to June and October to November, TCs in SCS are mostly generated in the sea area south of latitude 15 °N. Their moving paths are of three kinds: (1) First to the northeast direction after generation, then moving northwest in 15°- 17°N and landing in western Guangdong. (2) Moving north after generation, heading northeast to affect Jiangxi and Fujian after landing in central Guangdong.(3) once generated, moving northeast all through, disappear in sea area from Taiwan strait or Bashi channel to Ryukyu.

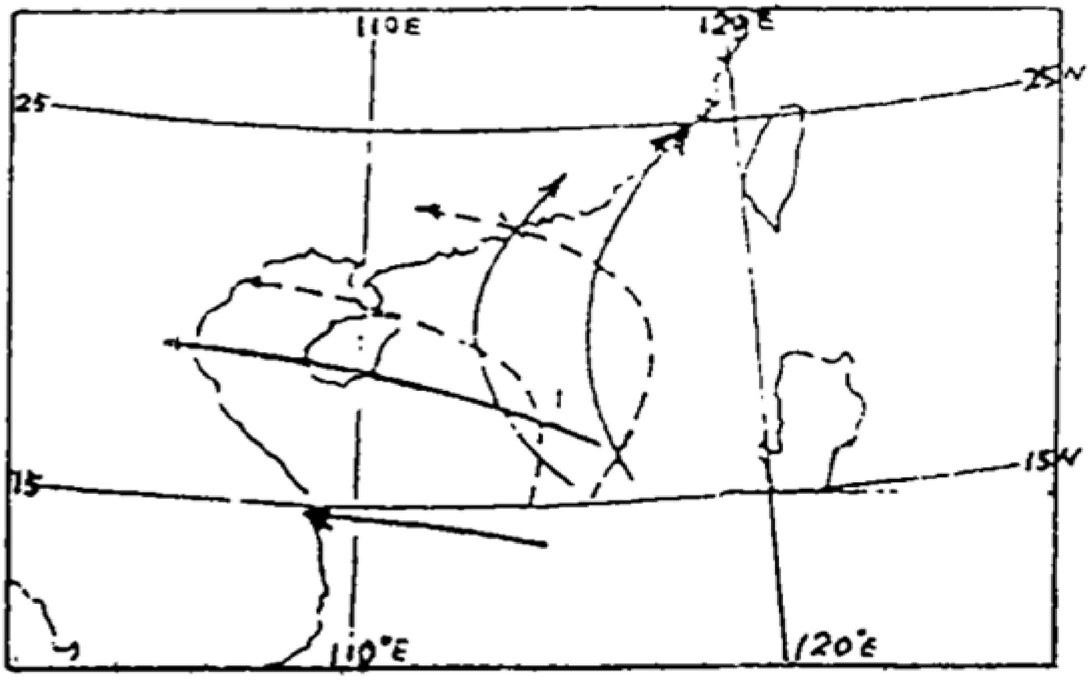


Figure 7:TC moving path for May to June and October to November

Source:Hu,(2009)

In SCS, July to September is a prevalent season of TC. The TC’s path is almost the same to the TC happen in May-June, October-November, but because TC of the western North Pacific is rather active in this period, it is often the case simultaneous emergence of TC in the western North Pacific and the SCS. This phenomenon is known as "twin typhoon". When "twin typhoon" appears, TC in SCS typhoon turn out to move very irregularly which will bring great difficulties to avoiding TC.

3.4 Other features

TC in SCS is generally of small horizontal scope, low vertical stretch and weak strength. This is considered because it lands soon after generation leaving no time to be fully developed. Horizontal radius of TC in SCS is only 300-500 km in general, a minimum less than 100 kilometers. Its vertical height is of about 6-8 km stretch, up to about 10 kilometers. The maximum wind speed 50 m/s. Central pressure value is generally 980-990 hPa, a minimum of 960 hPa. Pressure values below 950 hPa rarely observed.

Besides the usual TCs in SCS, there are two special types: one is small but strong, usually called "pin-point typhoon". These small-scale ones are usually of rapid development, high strength and destructive power. Their pressure versus time curve shapes like “funnel”, weather chart on the ground is often only one closed isobars, sometimes only some low pressure circulation of wind field can be seen, range of wind BS 6 not exceeding 50-100 km. It’s easily overlooked and cause harm. The other type is called "hollow typhoon", its periphery wind (wind scale up to 6-8) is stronger than the wind near the center (wind scale 4-5). Air pressure versus time curve is of "basin" shape. TC of this kind develops slow, but maintain until landing and disappearing. Since their damage is small, they have a little impact on coastal areas in general. (Liu, Li, 2011).

Basically, there is a certain relationship between the TC’s moving speed with its mobile path. The average moving speed is 20-30 km/ h. At low latitudes, TC turns forward at the slow speed of about 8-20 km / h. it moves even slower when steering, about 4-15 km / h. After entering middle latitudes, TC moves quickly, about 35 to 40 km/h, fast can reach 80 km/h. During stagnation or spinning, TC moves the slowest. (Chen, 2001)

3.5 Summary

The TCs in SCS mainly occur in the ocean 14 °N-18 °N, 113 °E-120°E in the middle of the SCS. The stronger the TCs are the more easterly they occur frequently. The weaker TCs are the location of high incidence more northerly.

The occurrence of TCs in SCS shows obvious characteristics of seasonal changes. Easy to see, the TC in SCS generally starts from April until the end of December, June up to October is active season. Average 73% of SCS tropical depressions appear from April to December can develop into TC, with the highest probability of May and October. However, for the monthly number of TCs in SCS, most TCs still happen in August and September, because most of the SCS low pressures develop in summer. Position SCS tropical depressions occur most is in the middle of the SCS waters (12 °N -20 °N, 112 °E-120 °E).

The average latitude of the TCs in SCS has obvious seasonal variation. From May to September, the average latitude TCs in SCS occur in the north of latitude 15 °N, the most northerly appear in August. The average location of the rest months is in the south of latitude 15 °N. Average longitude of TCs in SCS seasonal variation is not obvious.

Chapter 4 Optional Navigation Methods

4.1 Basic Work

Good preparatory work ought to be done before the arrival of the TC season because of that the ship's marine equipment in good condition is an important guarantee for the anti-TC work. Therefore, before the arrival of the TC season, the ship should make inspection and maintenance on life-saving equipment, sealing equipment, communication and navigation, main engine, auxiliary engine and anchoring equipment to ensure that they are in good usable condition all the time. The captain shall personally organize the crew inspect related equipment before the TC season. Once there is defect discovered, immediate rectification must be done in no delay. Ensure that the ship maintained in good technical condition.

Checking items:

(1) Mooring equipment - anchors, anchor chain, windlass, anchor mark, insurance cables, ropes, fenders, chain system equipment, tools and spare parts;

(2) Steering device - the rotation of the steering gear and the force means, prime mover, buffer winch, emergency steering equipment and spare parts etc.;

(3) Navigational aids - electronic compass, radar, AIS, GPS, depth sounder, log devices and meteorological instruments and so on;

(4) Communication equipment --SSB, DSC, SAT-A or C, EPIRB, emergency batteries, VHF, loudspeaker, clock and bell, telephone, contact lights and so on;

(5) Watertight device - Watertight doors, windows, skylights, watertight iron cover, wind scoop and hawsehole are closed;

(6) Batten tool - tarpaulin cover, mound layer, wedge and batten bolts;

(7) Drainage - deck drainage holes, drainage system, drainage pump, tunnel exit

(8) Plugging equipment - cement, wood, cork and litter and the like;

(9) The towing equipment and attachments - towing winch, the main streamers, asparagus cable, cable protection devices, shackles, triangle, heaving gun (applicable to the tugboat towing device);

(10) Lashing: on deck cargo or removable attachments, materials and ship’s spare parts in the treasury may move, etc. be lashed;

(11) Other items - lifeboats, life rafts, deck construction and equipment etc.

4.2 Optional navigation methods

4.2.1 Dangerous semicircle.

In the northern hemisphere, for right semicircle of TCs is generally adjacent to the subtropical high, storm of the right semicircle is higher than the left semicircle. In addition, the wind direction in the right semicircle is close to the same direction with the moving of TCs, superposition resulting in bigger waves. When the ship is in the right semicircle, it can be easily blown to the moving route of the TC center, so right semicircle (Northern Hemisphere) is called dangerous semicircle.

In dangerous semicircle, ship course should be taken in the direction perpendicular with the TC’s movement at full speed. To leave from the TC, the starboard bow should be against the wind, and try to keep the direction 10 º~ 15 ºin starboard side. Later on, gradually change ship’s course to starboard in clockwise corresponding to wind direction till leaving the strong wind area. If the storm is too violent or due to obstruction of land in front, etc., ship cannot leave at full speed, the ship can use its right bow against the wind. If because of failure of the host or steering engine or the storm is too violent the ship is out of control and unable to move forward or sail at a standstill, floating will be a choice.（Zhuang, 1998）

4.2.2 Navigation method in navigable semicircle.

Ship should take course to make itself sailing at right angles to the TC route. With stern starboard tack, get away from the TC center at full speed in order to leave strong wind area as soon as possible. In this case, the size of the stern windward angle is usually about 30 º ~ 40 º. Sailing course should be changed to left in the counterclockwise direction according to the wind. If there is shoal or coast, the ship can no longer continue to sail with the wind, the ship can make a turn to let starboard bow against wind, sail at a standstill against the wind. If the storm is too violent, or for failure of the host or steering engine, the ship is out of control and unable to move forward, the ship can use floating as a method. In addition, vessels sailing in the SCS should pay special attention to the TC of "inverted parabola" type which uses to move westward after moving north.

4.2.3 Navigation method while ship is on TC moving path.

When the ship is on the path of a TC, the wind direction can be constant but the air pressure drops. At this time, ship should take the same navigation method as in navigable semicircle of in the northern hemisphere, namely sail on the starboard tack and direct flow, quickly pull into the left semicircle, until air pressure rise and wind power becomes smaller, leave the danger zone finally. (Wang, Ai, 2013)

4.3 Summary

In the northern hemisphere, right semicircle is called dangerous semicircle. Ship's course should be perpendicular with the TC's moving direction. Try to leave the scope of TC as soon as possible. If failed, ship can use its right bow against the wind.

In navigable semicircle, keep the size of the stern windward angle about $30^{\circ} \sim 40^{\circ}$, change sailing course to left in the counterclockwise direction according to the wind. Furthermore, pay special attention to the TC of "inverted parabola" type

For ship on TC moving path, it should take the same navigation method as in navigable semicircle to leave the danger zone.

Chapter 5 Avoiding TC on the Sea

TC, as a big threat to ships at sea, is a kind of very large destructive ocean tropical weather system. Statics from 1949s to 2008s showed that the TC influence on China's coastal shipping routes cover 24. 7% of the sea area’s annual generated TC in average. (Wen, Wu, &Chen. 2010).On the implementation of anti-TC work, the shipping companies stick to the principle of "give priority to prevention, fighting and binding together, timely early to avoid, leave room as always." On a security standpoint, the risk of fighting TC directly is much higher than avoiding. In nowadays, weather forecasting and navigation technology have been improved continually. On the basis of safety, scientific avoiding TC program can also reduce the cost and enhance the economic benefits of shipping companies. When selecting the avoiding TC program, to determine the danger zone around the TC is the key. On the premise of effectively guarantee the ship’s navigation safety, to scientifically determine the danger areas around the TC can minimize the shipping date and fuel consumption, has great significance to the shipping enterprise.

5.1 Traditional methods of meteorological textbooks

5.1.1 Sector avoidance method

Seafarers used to utilize this method to avoid TC in the 1970s. Marine Navigation Center of China Meteorological Agency, after nearly three years of exploration, improved the method in 1998 for ships to design avoiding TC routes. According to the positions, moving direction and speed in TC track forecast, combined with the ship's position, course and speed, use the current position of the TC as a starting point, draw tangent to probability circle into which TC 70% chance of falling according to forecasting, as pie charts; or take the forecasting distance of TC in future 24h as radius (or wind circle of BS 8), forecast future TCs direction as the midline, at an angle from each side (as in low-latitude sea and TCs turning point may be near 40 °~ 45 °, in sea areas of high latitudes and after TCs turning shift 30 °) as a pie chart, update pie chart every 6h. When a deviation, avoid sailing towards opening direction of the sector, less into the sector-zone. (Chen , Zhang, 2001)

5.1.2 Plotting method

Some maritime meteorology textbooks have described methods of avoiding TC by drawing tangent for their scope of influence, plotting is representative. First, this approach is to develop a safety radius basing on the intensity of TCs and ships' specific situation, keep the closest distance between ship and TC center not less than the safety radius. When plotting, take TC position at the time as the center, the safety circle radius as radius, and plot a tangent from the same time the ship's position to the circle. In the end, using the relative motion principle, taking the course, speed, and TCs' moving direction and moving speed into consideration, find the course to ensure a sufficient distance. (Liu &Wu，2004)

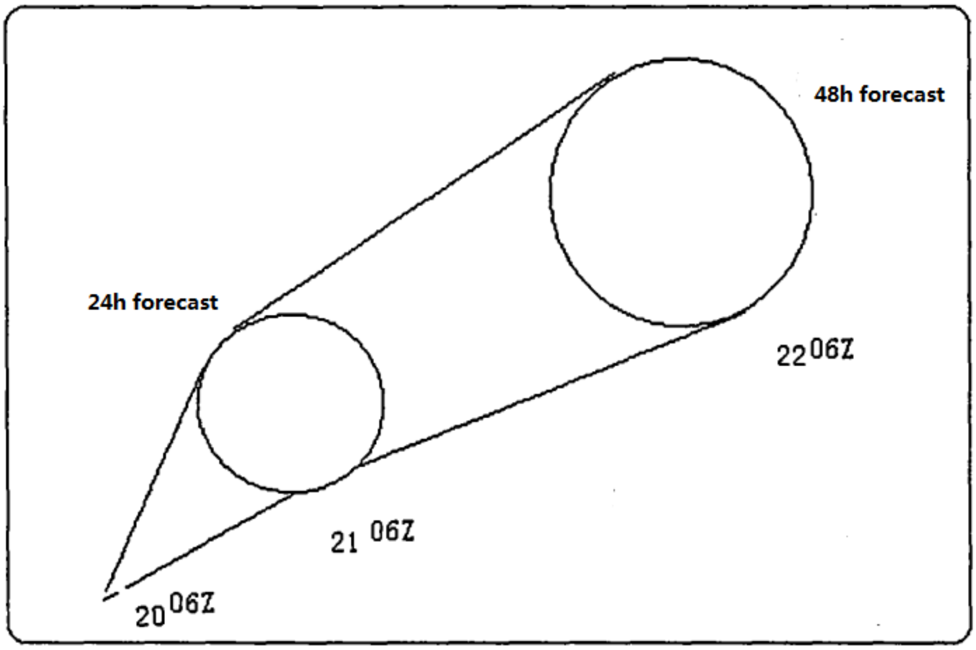


Figure 8: plotting method

Source：Liu &Wu，2004

In addition, there are the ship operating diagram and triangle calculation methods of the same principle as the above ones, the overall same.

5.2 Avoiding method basing on practical experiences in shipping

In practice, captains generally carry out a full analysis on TC information that countries issued, next assume that the meteorological department's TC track forecasts are basically accurate and put forward several avoiding TC programs. In developing a variety of avoiding TC programs, fully consider the actual situation of the ship, including the impact of large waves on ship's speed, loading of the goods, wind resistance and the working conditions of the ship's main and auxiliary equipment, probably the closest distance to the TC and largest wind power and so on. On this basis, according to the captains' knowledge of TCs: understand of the general path and weather patterns, etc., or according to the companies' related avoiding TC provisions will they determine route as not to enter BS 7 or 8 wind laps, or 200 miles, 300 sea miles, 400 sea miles or 500 nautical miles from the TC center, or the ship measuring pressure is maintained at 1,000 hPa and more. Finally, in determining the avoiding TC route during the voyage, attention should be paid to the movement of TCs. Maintaining uninterrupted receiving of weather fax maps and the latest TC warning, make adjustments to ship course at any time according to the latest status of TCs to ensure the safety of the ship.(Huang, Qing& Liao,2004)

5.3 Best sector method

First use CLIPPER method, used in statistical models of climate, forecasting future movement of TC, and make wind wave forecast and TC wind field calculation. On this basis, by plotting, using the principle of relative motion determine "basically navigable sector" and insecurity "harmonic wave sector". Then use marine science calculate "minimum shipping time sector". Finally, consider the above results, select out preferable sailing sector and effective speed. Since the determination of "best sailing sector" has returned to the plotting method for practical avoiding TC, there are many issues to be further studied and solved and few people use this method now.(Song, 2001)

5.4 Methods used by Chinese domestic and foreign meteorological department

In the implementation of weather routing, China National Meteorological Center owned Navigation Technology Co., Ltd. Beijing has developed a set of ship avoiding TC operational procedures. With the forecast accuracy of TC and distribution characteristics of its surrounding wind field and the wave field as the basis, circle of error probability as the background and the ship's ability to resist the wind and stall in the storm as restrictions, a comprehensive dynamic avoiding figure can be drawn. This figure can provide us the change of the relative orientation and distance between ship and TCs, the shortest distance between ship and TCs and its emergence time, whether or not the ship will enter into TCs' wind circle of wind scale BS 7 and BS 10 and entering time, and the emergence time and position of the most unfavorable wind direction and wind force for the ship. According to the ship's wind resistance, the sea areas surrounding TC are designated as safe areas, risk areas and danger zones according to storm intensity. So that avoiding TC navigation schemes such as deceleration, acceleration, trailing, deviation and lying to will be made according to ship's wind resistance ability and avoiding TC risk level. Since in drawing a comprehensive ship-TC dynamic figure, circle of error probability of TC track is also called the target circle, therefore the method is also known as the target circle method.

Hawaii Joint Typhoon Warning Center issues an analysis chart to show TC forecasting situation and gives TC's past and present live position, 12h, 24h, 36h, 48h and 72h forecast position, intensity, scope and the sea area ship should avoid. TC forecasting chart issued by meteorological institute in University of Wisconsin Madison (CIMSS) also has given an uncertain moving path region in consideration of many years' TC forecasting error. In the United States, NOAA gives every position and intensity past 3h and danger zone the ship should not enter on TC forecast chart. In Japan, JMA and JMH indicate the circle into which TC has 70% probability of falling the next 24h, 48h, 72h, and gives the corresponding BS 10 wind range of 70% chance. (Liu, Wu, &Li, 2011)

5.5 Developing Direction of the Avoiding TC Programs

To avoid TC intelligently, the self-guided avoiding technique proposed by scholars in related fields has considered the application of control theory, the latest achievements in information technology and intelligent decision-making and other modern scientific and technological development. The specific idea is to first build a dynamic model of the ship – TC on the ECDIS platform, using modern computer technology to complete ship – TC parameter calculation and automatic plotting of TC tracks and ship tracks. Secondly, after correcting the TC track and wind wave forecast, using artificial intelligence theory BP neural network algorithm set a model to judge TC threat level. Finally, build an avoidance decision system based on ECDIS, complete route planning, risk of TCs judging and generating avoiding TC program. (Ma, 2010).

5.6 Summary:

Information about the latest developments of TCs is the primary basis to determine avoiding measures. It must also take into account the performance and wind resistance of the ship, in order to make taken measures safe and effective.

In an avoiding process, often not just one measure makes sense. Thus, the integrated application of these measures is very important.

Chapter 6 Mooring to Fight TC

When the ships at sea can not avoid TC, if the ship is in the harbor, rivers and shallow water areas along the coast, the attack of TCs will be diminished greatly. If the conditions and time permit, ships should head to appropriate harbor, rivers, islands or coastal shallow water to get moored. Mooring to fight TC, ship can choose droping anchor, securing to a buoy and berthing accordingly.

6.1 Anchoring

6.1.1 Selection of anchorage

(1) try to avoid the TC path;

(2) should be able to avoid multi-directional waves, try to avoid the long waves in direction of TC comes;

(3) try to choose water areas wide and easy to get out to anchor avert anchoring in the place too dense and very close from breeding areas;

(4) away from the waters of underwater obstructions，to prevent them affectt the safety of ships when dragging anchor;

(5) try to choose bay with no undertow impact and low current speed to anchor;

(6) sediment clay, argillaceous is better

(7) when at anchor, the required length of chain can refer to the following empirical formula 4D + 145m (where D means water depth);

(8) for the ship at anchor against TC， the host should be ready for, keep sailing shift.

(9) anchorage water depth: According to the ship draft, charted depth and high tide, the wave (wave) height near the waters ship, to determine the required minimum water depth during low tide of the selected area. General should be met:

$$H\min > 1.5d + \frac{2}{3}H\max$$

Hmin: the required minimum water depth when low tide, d: based ship draft, Hmax: the maximum height of wave

In general, 10000-ton class vessel required anchorage depth 15-20m.

(10) size of ship’s turning basin and distance with other vessel. Based on actual experience, anchorage ship’s turning basin in large storm should be met:

$$R \geq L + Lc + 2r$$

$$r = 0.02 \times D$$

R is the radius cycle, L is the length of the ship, Lc of the chain length, r is the ship's position error, D is radar positioning error.

The distance between the ship and other vessels at anchor should be met:

$$Dss \geq L + 2(Lc + 2r)$$

$$r = 0.02 \times D$$

Dss means spacing of the anchored ship and other vessels, L is length of the ship, Lc of the chain length, r is the ship's position error, D radar positioning error. (Lv, 2014)

6.1.2 2 Anchor method.

Seafarers mainly use single anchor, back anchor, weather moor and riding one point anchors and other methods. Maritime practice shows that riding one point anchors has an advantage in fullfiling anti-TCs. By throwing two bow anchors and loosing chain simultaneously to make two anchors landing at the same time, riding one point anchors is like throwing two anchors at the same point. Advantages are bigger holding power, less yawing in the storm, not easy to cause the anchor chain scission go, flexible bow and simple operation.

During anchoring anti-TC, ships should strengthen the crew on duty, maintain regular lookout and keep in touch with the company and the relevant administrative departments. The main engine should be standby all the time. Make sure the marine power is always ready to use, so the ship will be able to maintain a proper situation to reduce rolling and yawing and resist the invasion of storms.

6.2 Buoy mooring and precautions

This anti-TC method is more suitable for ships of poor wind-resisting ability. Buoy mooring can be divided into double buoy mooring and single buoy mooring. Single buoy mooring, directly fasten a rope on a buoy from the bow, is a common mooring way. This mooring way is easy to operate, ships can change direction with the water and wind with small resistance. What's more, water area required is small compared with anchorage. Double buoy mooring, with the bow and stern respectively tied to buoys, is more applicable to ships in the waters of the narrow place, largely used in river.

When moored to buoy, it's generally ship's bower cable tied to a single buoy. In the case of double buoys, the stern line with sufficient strength shall be fastened. Under strong tropical storm, the chains and buoy must be connected. If necessary, there can be added mooring lines. In the TC, if anchor chain's loading is too large, it may be appropriate to use engine. However, the engine must be proceed with caution to prevent breakage of anchor chain.

6.3 Berthing and precautions.

This anti-TC manner is often used by small vessels, and only suitable for ports with less swell affected. Before berthing pier, it is rather important to fully understand the situation, such as the relationship between the shoreline and the wind direction, intensity and distribution of bollards, fenders equipment, tide, swell and so on. Understand the effects of wind, wind direction and velocity, the flow of the berthing to proper use engine, rudder, anchor and cable. At the same time, pay attention to strengthening mooring line, wrap mooring line's friction-prone areas with sacks to prevent break, and keep the mooring force uniform. Put the touch pad to easy collision place between the berth and the ship. If it is floating fenders matter, it shall be fixed on the quay wall to prevent it emerge between the pier and floating hull under the influence of tidal surge. Ship berthing with noload should be properly ballasted, not only to increase the draft and reduce wind pressure, but also improve stability and avoid the danger of tilting. (Ma, 2008)

Problems which should be paid attention to:

6.3.1 To choose berth

For ship anti-TC in berth, it shall own detailed knowledge such as the relationship between the shoreline and the wind direction, distribution and intensity of the shore bollards, fenders device, power and water supply, tides and trends, waters level changes under the impact of TCs and other mooring ships and so on. In addition, full consideration also should be given to berth and surrounding waters. when forced to move due to wind and waves, or perform emergency duties by scheduling requirements. Always be ready to untwist and sail.

6.3.2Effect of tides, currents and swell

Within TC environment, weather phenomenon can be very complex. There may be low air pressure, thick clouds, accompanied by wind, waves, rain, local tides, the trend may be disturbed, upstream river water increases and the port surges in serious condition. The above circumstances give a big threat to the safety of anti- TC ships.

6.3.3 Weather forecasting and meteorological observations

During the anti-TC time, listen to meteorological report and pay attention to weather observation are very important to fulfill the job. Collect weather forecast and TC warning in strict accordance with the provisions, receive the weather faxes map, path chart, satellite images and so on if possible. Combine ship's hydrological and meteorological observation, carefully analyse and take timely preventive measures.

6.3.4 Mooring line

Mooring lines is one of the most important anti-TC measures. The wear degree of mooring lines and eye splice, whether ship-shore bollards is intact, windlass warping winch is normal, stanby cable is in good condition, cushions, skimming cable and lead cable are ready, bolsters (tires, sacks, blankets, etc.) to prevent wear are ready, and whether a flashlight to check the mooring lines on night patrol inspection tour is ready should be strictly checked before mooring.

Maintain adequate mooring lines and reasonable bollards distribution. The mooring points should not be too concentrated. Mooring lines in the direction of wind should be strengthened. Do not make mooring too vertical, namely horizontal angle of cable and dock is not too large. Adjust the tension of the cable according to the ship stress condition, try to keep rope uniformly forced and always ready to adding the mooring line. (Li, Wu, &Qin, 2010)

6.4 Summary

Mooring to fight TCs, there are three modes: droping anchor, securing to a buoy and berthing accordingly.

To choose anchoring, several requirements should be met in selection of anchorage. Compared with other anchor methods, maritime practice shows that riding one point anchors fullfils anti-TCs better.

Buoy mooring is more suitable for ships of poor wind-resisting ability, while berthing is often used by small vessels, and only suitable for ports with less swell affected.

Chapter 7 Summary and Conclusions

To fully carry out anti-TC object, the work must be done comprehensively and effectively.

Before the arrival of the TC season in SCS, ships sailing in the sea area first ought to ensure a good state of their marine equipments, the officers shall obtain a comprehensive study of knowledge of the TC in SCS, which is the base of anti- TC work. TC in SCS have special own characters in generation position, time and moving path.

When running in the scope of TC, the correct navigation method will ensure the safety of the ship's departure or in TC. Using the proper navigation method, try to leave the scope as soon as possible.

In the work of anti-TC, ships should make anylasis and decisions according to the actual situation they face. If possible, reasonably taking avoiding action is always a bettter choice.

Provided that circumstances permit, mooring also is a good choice for anti-TCs. According to the actual situation of ship, reasonable anchoring, buoys mooring and berthing methods can be taken.

TC is a kind of natural disasters of enormous destructive power and serious threat to the safety of ship. For ships within TC environment in SCS, to do a good job of anti –TC work, all stackholders must attach great importance to it. To prepare fully, precautions must be taken in advance as far as possible. Take appropriate measures to prevent dangerous situations, so as to improve the safety of ships and personnel and lower down the loss.

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