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MASTER'S THESIS

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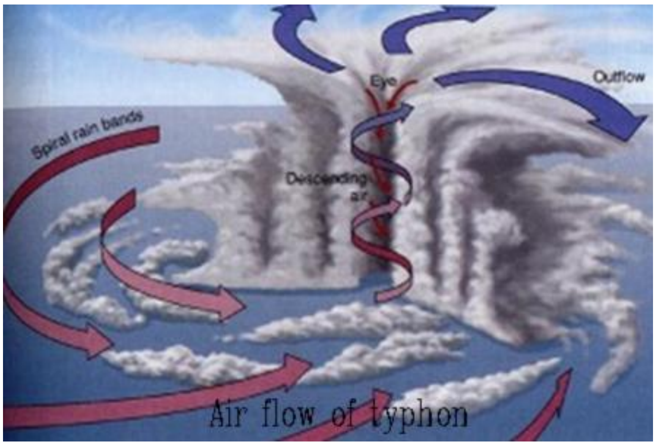
Weather sensitivity of maritime activities on Chinese Shelf


Oil tanker (BinHai 607) berthing oil production platform Jinzhou (9-3)

Grounded chemical tanker (HaiYangShiYou 881) in the storm



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Tanggu Tianjin February, 2013
Youyu Lu
路友于

Abstract:

The objective of the thesis is to discuss the weather sensitivity of maritime activities, inter alia, with respect to the aspects of passage planning, load plan-making, and ship maneuvering. As maritime activities represent a high risk industry, the risk analysis is not only a mandatory requirement of the administration but also a need during practice. A risk analysis will also be carried out in this thesis.

With the improvement of the state of technology, a myriad of state-of-art technologies and equipment have been applied in oil field service realm, for example, shuttle tankers with DP2 (Dynamic Position System) have been used extensively in the North Sea area of Norway. However, there is none of this kind of shuttle tankers in Chinese costal area yet, therefore, this thesis will also discuss the prospect that such shuttle tanker will be used in Chinese costal area.

In recent years, the global climate is getting increasingly unstable. Extreme weather, like typhoons, abnormal temperature, and storm occur frequently. According to a survey, in 2011, the US lost 50 billion dollars and in the recent 17 years, China mainland lost in average 185.9 billons RMB every year due to the damage of weather. Numerous professions， for example the oil field service and shipping industry, which we are engaged in, were affected mostly.

When it comes to the Chinese costal area, it is also one of the most famous zones of heavy storms and waves in the world. Up to this day, I still remember clearly that on 4th Nov, 2004, due to hash weather, two cargo ships went down in the Bohai Bay, and 44 members of the crew lost their life. At that time, I experienced the rescue activity in personal as the chief officer of a rescue boat. Therefore, there is a need to analyze the weather system and its influence on marine transportation on the Chinese Shelf. The final goal is to lower the risk of a marine operation by use of its advantages and avoidance of its disadvantages.

In addition, in order to integrate methodology with practice closely, in the process of the thesis writing, the ships and the business of the Marine and Transportation (M&T) department of COSL will be referenced in discussing subtopics.

Abstract in Chinese：

近些年，全球气候变得越来越不稳定，极端天气越来越多，台风频发，高温，暴雨。在 2011 年，美国因为极端天气的损失达到了，500 亿美元，中国大陆近 17 年来每年因气象灾害损失 1859 亿元。其中，我们所从事的行业—海上运输和油田服务业，是受天气影响最大的行业之一。

时至今日，我依然清晰的记得，在 2004 年 11 月 4 日那天，在渤海湾里有两条货轮因为大风浪，引起货仓进水，导致货船倾斜，最后沉没。44 名船员失去了生命。那时候我作为救助船的大副亲身经历了这场大风浪的的洗礼。

所以，我们应该仔细的分析天气系统，以及它对海上运输的影响。最终的目的是趋利避害，降低恶劣天气下海上作业的风险。

本文将探讨天气因素对船舶航线设计，货物配载，船舶操纵等方面的影响。同时，作为一个高风险的行业，作业前的风险分析已经成为主管机关的强制要求，也是我们实际工作的需要，本文将对相关的海上作业作风险分析。

近年来，随着技术的进步，许多新工艺，新设备在油田服务领域应用。比如 DP2 定位的穿梭油轮。这种船舶已经在北海区域广泛使用，但是在中国沿海地区还没有一条这样的船。本文也将讨论一下未来 DP 定位的穿梭油轮在中国沿海使用的前景。

此外，为了使理论和实践紧密结合，在论文写作过程中，作者将结合油服海运事业部的船舶和业务特点展开各分论点的讨论。

Contents:

ABBREVIATIONS:
Ac: Alto-cumulus
AIS: Automatic Identification System
ARPA: Automatic Radar Plotting Aid
Cb: Cumulo-nimbus
CCS: China Classification Society
CNOOC: China National Offshore Oil Corporation
COSL: China Oilfield Services Ltd.
Cu: Cumulus
DP: Dynamic Position
DWT： Deadweight Ton
Fn: Fracto-nimbus
GMDSS: Global Maritime Distress and safety System
GPS: Global Position System
GT: Gross Tonnage
Hpa: Hundred Pascal
IMO: International Marine Organization
ISGOTT: International Safety Guide for Oil Tankers and Terminals
IVS: Infield supply vessel
JSA: Job safety analysis
Kn: knot
MARPOL: Maritime Agreement Regarding Oil Pollution
M&T: Marine and Transportation
NAVTEX: Navigational Telex
NM: Nautical Mile
NT： Net Tonnage
OCIMF: Oil Company International Marine Forum
Sc: Stratus-cumulus
SMS: Safety Management System
SOLAS: Safety of Life at Sea
STCW: International Convention on Standards of Training, Certification and Watch-keeping for Seafarers
VDR: Voyage Data Recorder
VLCC: Very Large Crude Carrier
VTS: Vessel Traffic System
WPSH: Western Pacific Subtropical High
ZC: Register of Shipping of China

List of Tables:

List of appendix:

Appendix 1: Ridge line and contour line
Appendix 2: ISV
Appendix 3: Static tow

List of Figures:

Chapter 1: Introduction to maritime activities and the M&T of COSL

The maritime activities discussed in this thesis come from the real works in our company, and some of them were operated by me (I am educated as a captain and have been captain on vessels for 4 years). So, there is a need to take a moment to introduce my company and relevant maritime activities.

1.1: The brief introduction of history of M&T of COSL, (See Figure 1.1)

The predecessor of the M&T department of COSL was China Oil Offshore Tanker Company, which was a wholly-owned subsidiary of CNOOC (China National Offshore Oil Corporation). It was started in 1975 and was mainly engaged in the transportation of crude oil from oil production platforms to harbor. Before COSL was established, China Oil Offshore Tanker Company had 8 shuttle oil tankers with a gross tonnage from 2,000GT to 10,000GT.

In 2002, in order to rationalize the business of CNOOC, the following 7 companies, namely China Offshore Oil Southern Drilling Company, China Offshore Oil Northern Drilling Company, Petrotech Services CNOOC, China Offshore Oil Geophysical Company, China Offshore Oil Northern Shipping Company, China Offshore Oil Southern Shipping Company, China offshore Oil Logging Company (see Figure 1.1), merged into COSL, which is primarily engaged in delivering technical services for offshore oil & gas exploration and production. COSL processes a complete service chain, including geophysical survey, engineering geological survey, drilling & completion, logging as well as data interpretation, research & development, vessel support and marine transportation service.

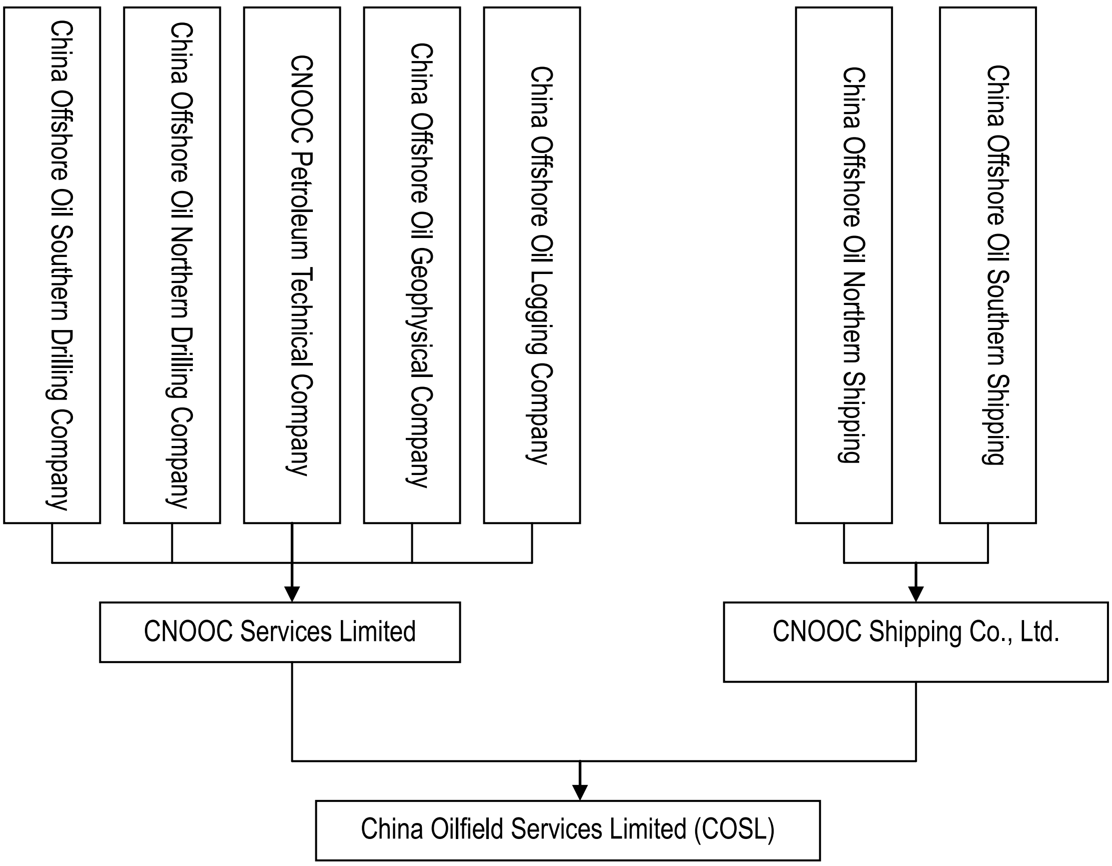


Figure 1.1: The historical evolution chart of COSL [Made by author]

In order to provide professional shipping services to our customers, COSL established the Marine & Transportation Division at the end of year 2004. Up to now, the M&T Division operates 6 oil tankers with gross tonnage from 4000GT to 10000GT and 7 chemical tankers with gross tonnage from 2，000GT to 1，200GT.

1.2: The technical specification of oil and chemical tankers of the M&T division of COSL

Quite a lot of work of our company's tankers is to transport the crude oil from oil production platforms to port. Compared to berth at wharf, it is more difficult to berth at the platform, because the sea condition in the open sea is much harsher than inside a port and the marine operation is influenced by weather significantly. In the Chinese costal area, 60% of oil has been produced in the Bohai Bay where the sea ice condition is serious in winter. Thus, in order to deal with the influence of bad weather, our company's ship is fitted with some special equipment, like bow thruster, fast decoupling device, etc. Meanwhile, account has been taken of weather forcast and ice condition forcasts to ensure the marine operation to be carried out safely and smoothly.

Tables 1.1 and 1.2 illustrate the state of technology of the company's tankers. In the discussion as to marine operations, I will make use of those ships as examples.

Table 1.1：The ship particular of chemical tanker fleet of M&T of COSL

Ship's Name	HaiYang ShiYou 881	HaiYang ShiYou 882	HaiYang ShiYou 851	HaiYang ShiYou 852	HaiYang ShiYou 801	FengFan 17	HaiChang 18
Date of Built	Jan, 2007	Jan, 2007	Apr, 2007	Jul, 2007	Jan, 2004	Aug, 2008	Mar, 2009
Class Society	CCS	CCS	CCS	CCS	ZC	CCS	CCS
Flag	China	China	China	China	China	China	China
Ship Type	Oil/ Chemical	Oil/ Chemical	Oil/ Chemical	Oil/ Chemical	Oil/ Chemical	Oil/ Chemical	Oil/ Chemical
Hull Structure	Double Hull	Double Hull	Double Hull	Double Hull	Double Hull	Double Hull	Double Hull
Breadth	22	22	14	15	13.2	18	17.8
Length	134	134	89	96	75.6	117	113.4
GT	8479	8479	2356	2834	1578	5199	4978
NT	3574	3574	1319	1117	883	2416	2270
DWT	12000	12000	2300	3610	1800	7966	7250
Speed(NM)	12.5	12.5	11	11	12	12	12.6
Light Draught(m)	4.1	4.1	3	4	2.75	4.5	4
Load Draught(m)	7.42	7.42	4	5	4	7	6.5

Table 1.2: The ship particular of oil tanker fleet of M&T of COSL

Ship's Name	HaiYang ShiYou 822	BinHai 606	BinHai 607	BinHai 608	DongMao 18	WanHeng 9
Date of Built	Mar, 2004	Jan, 1988	Jul, 1998	Jul, 1998	Jun, 2006	Jun, 2012
Class Society	CCS	CCS	CCS	CCS	CCS	CCS
Flag	China	China	China	China	China	China
Ship Type	Class I Oiltanker	Class I Oiltanker	Class I Oiltanker	Class I Oiltanker	Class I Oiltanker	Class I Oiltanker
Hull Structure	Double Hull	Double Hull	Double Hull	Double Hull	Double Hull	Double Hull
Breadth	17.5	15	16	16	13.5	16
Length	105	107	115	115	90	110
GT	3980	3456	4044	4044	2231	2996
NT	1813	1413	2264	2264	1249	1982
DWT	5800	4703	4990	4990	3650	5400
Speed(NM)	11	10	12	12	13	12.5
Light Draught(m)	3.8	3.79	2.8	2.8	2.7	3.1
Load Draught(m)	6.5	6.38	5.7	5.7	5.6	6

1.3: The work activities in a complete voyage

A complete voyage contains a myriad of activities and the people who participate in the voyage involve not only the crew but also on-shore employee. The work includes, but is not limited to, the following contents.

1.3.1 Passage plan making:

Prior to proceeding to sea, the master shall ensure that the intended voyage has been planned using appropriate charts and publications for the area concerned. (SOLAS v/34 and IMO res.A.839, ref [4])

The passage plan is completed by the navigation officer and verified and approved by the master. It is comprehensive, contains full details of the voyage and is easy to interpret.

The passage plan should be written on each applicable chart, which may be supported by a dedicated SMS (Safety Management system) form. Excessive information in the navigational areas of a chart must be avoided by recording the information away from the track and by drawing attention to this by a line or a reference letter.

The following information should be marked on the chart, where it enhances safe navigation:

- Chart changes;
- Methods and frequency of position fixing;
- Prominent navigation and radar marks;
- No-go areas;
- Landfall targets and lights;
- Clearing lines and bearings;
- Transits, heading marks and leading lines;
- Significant tides or currents;
- Safe speed and necessary speed alterations;
- Changes in machinery status;
- Minimum under keel clearance;
- Positions where the echo sounder should be activated;
- Crossings and high density traffic areas;
- Safe distance off;
- Anchor clearance;
- Contingency plans;
- Abort positions;
- VTS (Vessel Traffic System) and reporting points, etc.

Additionally, the weather factor in the passage plan-making process is extremely important, and it shall be taken into account seriously. Today, the weather forcast information can be obtained through many ways, such as, NAVTEX, inmarsat-c station, weather facsimile maps including satellite images, surface analysis map, etc. The officer in charge of the passage plan making can design the navigation line against the hydrological and weather information.

1.3.2: Cargo plan making

All cargo operations should be carefully planned and documented well in advance of their execution. The details of the plans should be discussed with all personnel, both on the ship and at the terminal. Plans may need to be modified following consultation with the terminal and following changing circumstances, either onboard or ashore. Any changes should be formally recorded and brought to the attention of all personnel involved with the operation. (ISGOTT 11.1.1, issued by OCIMF, ref [3])

All stages of the cargo operations should be taken into account and, as a minimum, contain:

- Density, temperature and other relevant properties
- A plan of the distribution, lines and pumps to be used
- Transfer rates and maximum allowable pressures
- Critical stages of the operation
- Notice of rate changes
- Venting requirements
- Stability and stress information
- Drafts and trims
- Ballast operations
- Emergency stop procedures
- Emergency spill procedures and spill containment; and
- Hazards of the particular cargos

And also, as required:

- Precautions against static electric generation
- Initial start-up rates
- Control of cargo heating systems
- Line clearing
- Crude oil washing procedures
- Under keel clearance limitations
- Bunkering; and
- Special precautions required for the particular operation

1.3.3: Ship handling

The activity of Ship handling runs through the complete voyage. It is a process of changing the state of motion of the ship, in which the marine navigator uses the maneuvering equipment of the ship, including the propeller, rudder, anchor, mooring rope, and tug to resist the influence of the environment, such as wind, current, wave, shallow water, and so on. The ship handling system can be regarded as a closed-loop system which consist of human, machine, and the environment.

Under different environment, ship handling involves inside-port maneuvering, such as berthing and unberthing, hooking up to mooring buoys, anchoring; particular water area handling, including ship handling in narrow channels, ship handling in waters reefs, ship handing in traffic separation scheme water; ship handling in hash weather, like ship handling of avoiding a typhoon, and so on.

Ship handling is an operation with extreme high weather sensitivity. The navigator must pay much attention to it.

1.3.4: Navigation

In our industrialized society, the shipping industry is an indicator of the macroeconomic which is supported by fast logistics. Meanwhile, people pay more attention on environment and need a cleaner ocean than ever before, so ships shall navigate on the sea fast and safely. In the history of the shipping industry, it is common to hear the news of oil tanker leaking, which is a disaster not only due to the loss of life and property but also due to the damage to the environment. From this point of view, navigation is a vital link in the whole shipping process. For example, on 13th Nov, 2002, the Greek oil tanker with 77,000 tons of fuel oil, the “Prestige” (Figure 1.2), sank near Spain in a storm due to improper navigation. This accident caused serious pollution and economic loss to Spain. According to a report [Ref 9], beaches were severely polluted; more than 10,000 sea birds died; around 4,000 fishermen lost their jobs; and the direct economic losses amounted to 300,000,000 Euros.

Figure 1.2: The oil tanker "Prestige" [Ref 9]

In order to keep the safety of humans, ship, and environment, a great number of international shipping legislations have been established, including but are not limited to, <SOLAS>, <MARPOL>, <STCW>, etc., which can regulate the marine activities, while lots of modern navigation and communication equipment were applied widely on board the ships, including GPS, AIS, VDR, GMDSS, ARPA, etc., which lay a solid foundation for safe navigation on the sea. In addition, the supervision of the port country and the flag country is increasingly strict.

Navigation can be divided into terrestrial and celestial navigation. The terrestrial navigation mainly includes the dead reckoning, fixing by landmarks, navigation method, and so on. The celestial navigation can simply be regarded as celestial positioning. Its primary method is to get the astronomical position line through observing the celestial altitude.

In practice, during navigation at sea, the following factors should be taken into account.

- Navigation and positioning
- The use of publications of navigation, such as tide tables, lists of lights, maps of the sailing direction, etc.
- Navigation method: the great circle sailing method, reef area navigation method, method of sailing in narrow waterway, and so on.
- Measuring the compass error by making use of landmarks.
- The dead reckoning and chart work
- Keeping a safe navigation watch
- Making use of Radar and ARPA to keep safe navigation.
- Emergency response
- The response to distress signal at sea.

Shortly, the navigators should maneuver their ship with good seamanship to complete the voyage securely and speedily.

Chapter 2: Weather system and phenomena impacting Chinese costal area

Maritime activities are inevitably limited by the weather and ocean conditions, particularly, extremely weather system such as typhoons, cold waves, cold high, fog, and other severe convective weather etc., which will cause wide-range harsh weather and sea states, and severely impact maritime activities. It often causes damage of vessel or cargo, even maritime disaster, and greatly threatens the security of maritime activities. Therefore, weather is not only a difficult-to-control factor but also a decisive factor for maritime activities. In this chapter, I would like to introduce the weather systems and phenomena impacting Chinese Costal Shelf, which can lay a solid foundation for the discussion about maritime operations in the subsequent chapter.

2.1 Subtropical high

2.1.1: The general atmospheric circulation

Prior to introduction of subtropical high, we should talk about the general atmospheric circulation in which the subtropical high exists. The general atmospheric circulation refers to a phenomenon of large-scale and global air movement. Its horizontal scale can become thousands of kilometers with the vertical scale being dozens of kilometers and the duration can be longer than 24hours. The general atmospheric circulation reflects the basic state and characteristic of the air movements. It is basis for the different weather systems. Meanwhile, it is also the background for the formation and evolution of the climate. Generally recognizing, the main factors which can influence the general atmospheric circulation are solar radiation, earth rotation, uneven distribution of sea and land, and so on.

We can make use of the following figure (Figure 2.1) to illustrate the general atmospheric circulation.

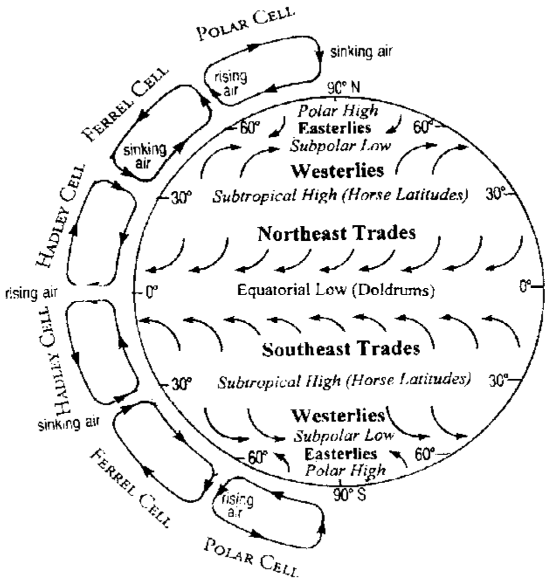


Figure 2.1: Three-cell circulation [Ref 10]

2.1.2: Subtropical high:

The subtropical high regions refer to the area of 20° N～35° N and the area of 20° S～35° S. The warm high pressure system appearing in subtropical high regions is called subtropical high. Due to uneven heating effect along the circle of latitude, the distribution of the subtropical high along the circle of latitude is not continuous but breaks up into several high-pressure monomers with closed centers, which are mainly situated on the ocean. In those subtropical high, the WPSH (western pacific subtropical high) impact on the weather of China directly and significantly, especially, in summer, thus, we put much emphasis on it.

2.1.2.1: Basic characteristics of the WPSH

a) The location and trend of the subtropical high:
The location and trend: the location and trend of the ridge line (See appendix 1) on the 500Hpa upper-level weather chart expresses the location and trend of the subtropical high. The movement of the ridge line in south and north direction expresses the movement of subtropical high (See figure 2.2)

b)The range of the subtropical high:
The range: the range surrounded by the 588 meters contour on 500Hpa map expresses the range of the subtropical high.
The location, strength, and range of the WPSH change periodically over the season. At the same time, there exist short-term non-periodic changes.

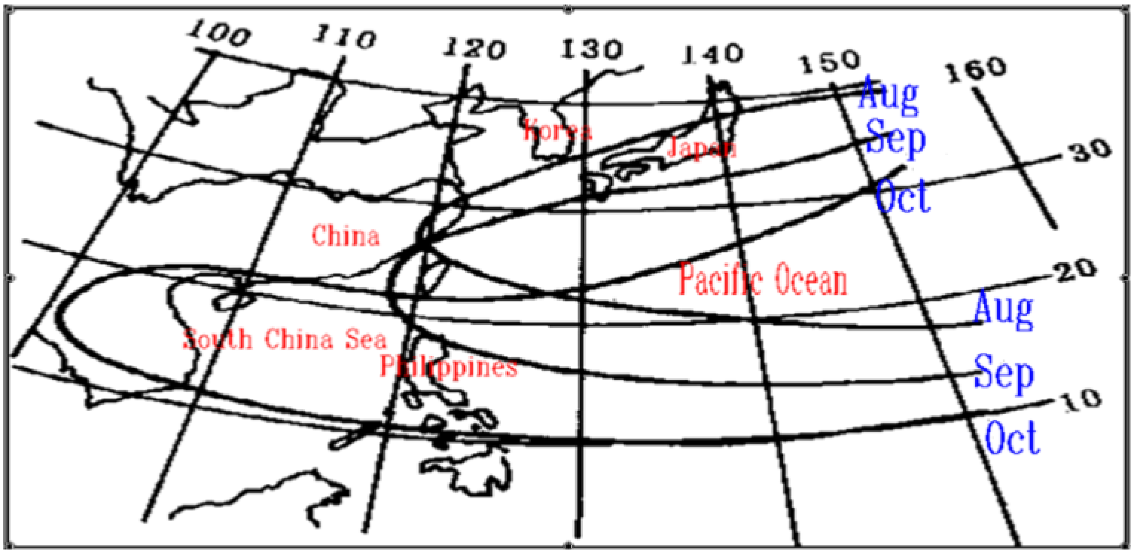


Figure 2.2: 500 Hpa monthly average position of the subtropical ridge line (Ref [11])

c): Seasonal change and shape of the WPSH

From winter to summer, the WPSH moves from south to north, changing from weak to strong. From summer to winter, the WPSH moves from north to south, changing from strong to weak. The shape of the WPSH is an oval with long axis in east-west direction and short axis in south-north direction.

2.1.2.2: The weather of the WPSH

a): The weather close to ridge line： It is sunny, cloudless, breeze and hot weather mainly.
b) The weather in the east of the WPSH: The northerly winds prevail in the east of WPSH.
c) The weather in the west of the WPSH: Due to unsteady atmospheric conditions, there are much thunder showers and thunderstorms and gales. If the ridge of the WPSH stretches westward to the Chinese costal area, advection fog easily appears.
d) The weather in the south of the WPSH: The weather here is usually sunny and cloudless. If a tropical cyclone turns up here, disaster weather, with thunderstorms or gales, will appear.

e) The weather at the edge northwest and north: because it is next to westerlies, there are a lot of frontal cyclones, and rain and storm always appear here.

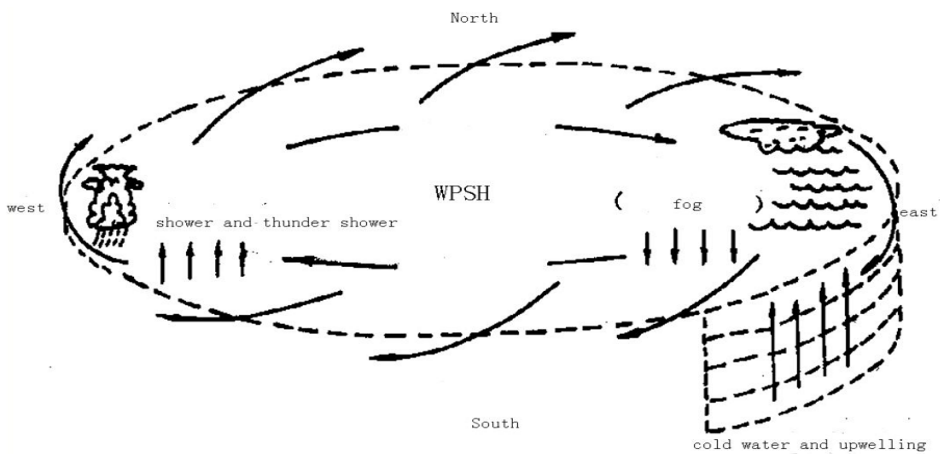


Figure 2.3: The weather of the WPSH Ref [10]

2.1.3 The influence of Subtropical high to China

2.1.3.1) The influence of short-term movements:

There is a front area and a strong west wind in the northern edge of a subtropical high, the southerly air current in the west brings plentiful of aqueous vapor from the ocean to the front area and due to significant warming effect in low altitude, the air layer is getting more and more instable. The aqueous vapor in the north of a subtropical high will condense to form a large-scale rain band with heavy rain, as low trough or low vortex exists in the west. The rain band usually is situated at 5-8 degrees latitude distances north of the ridge line of the subtropical high and the trend is roughly parallel with the ridge line. If there is an easterly disturbance in the southern edge of the subtropical high, the extreme weather will appear, such as heavy rain, thunderstorm, gale, and so on.

The short-term movement of the subtropical high in the east-west direction significant impacts its western weather. When the contour line of the subtropical high moves toward west, thunderstorms will appear at the cyclonic shear area in the west of high pressure contour; when the contour of the subtropical high moves toward east, often low troughs move toward east as well, and extensive thundershowers will appear at atmospheric unstable areas in the west of high pressure contour.

2.1.3.2) The influence of seasonal movement

a) The seasonal movement of east china rain band is closely related to the position of pacific subtropical high.

In South China (south of 27.5° N)，it is rainy season from March to June. The rainfall increases gradually from March to April, while the ridge of subtropical high moves northward slowly from around 18° N.

In early May, the rainfall increases abruptly in the South China costal area and maximize in the early June. Meanwhile, the ridge of subtropical high arrive at around 20° N. The rainfall in South China decreases quickly after June, which indicates the end of the flood season of South China and the start of the Meiyu (Plum Rain) season in the middle and lower reaches of the Yangtze River. Actually, it is the result of the northward movement of the ridge of the subtropical high.

Around the middle of July, the ridge line of the subtropical high crosses over the 25° N, and the rainfall in the middle and lower reaches of the Yangtze River reduces rapidly, which brings to an end the Meiyu. Meanwhile, the rain band moves northward to the Yellow River basin.

In the late July or early August, the ridge line of subtropical high crosses over 30° N，at this moment, the ridge of subtropical high is just situated over the Yangtze River basin and it is the North China rain season.

In September, the subtropical climate begins to retreat southward with the rain band also moving south. After the ridge line retreats back to the south of 25° N, it is the autumn rainy season in the Yangtze River basin.

After the ridge line retreats back to the south of 20° N，the second rainy season in one year is coming in South China.

b) The position of subtropical high is closely related to drought or flood in certain area

If the seasonal movement of the subtropical high in the south-north direction is abnormal, it will contribute to drought in certain areas and flood in other place. For example, in July 1998, the position of the subtropical high was steadily in the south of its normal location, which caused the most extremely severe flooding of this century in the middle and lower reaches of the Yangtze River.

c) The Subtropical high has decisive impact on the track of the tropical-cyclones of the North Pacific.

d) In spring and early summer, the contour of the subtropical high stretches westward, the southeastern air flow in its west side conveys the warm and wet air to the cold costal-current area, which will generate an extensive advection fog area. It is disaster weather for marine transportation.

e) When the subtropical high stretches strongly westward, and the low pressure or the trough of the low pressure in the continent moves eastward, which shapes a situation of high pressure in the east and low in the west, in this condition, southerly gales will appear in the west of the subtropical.

2.2: Cold High

2.2.1: The concept of Cold High

Cold high is a cold anticyclone in mid- to high-latitudes, moving in the middle and lower troposphere creating a movable weather system with unbalanced thermal and pressure field. During moving toward south, it will weaken gradually, at last, diminishing or merging into the Subtropical High. The Asian Cold High is the strongest in the world.

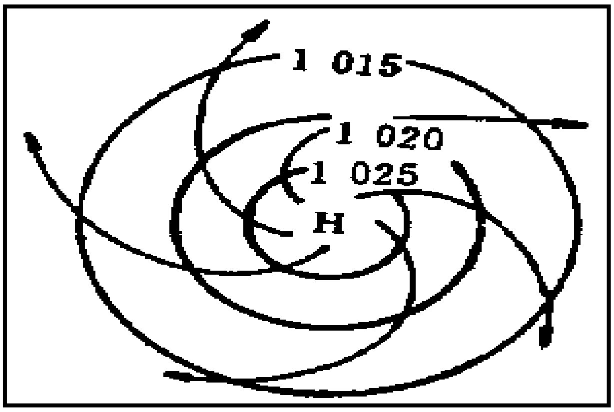


Figure 2.4: Cold High [Ref 11]

2.2.2: The formation and development of a Cold High

a) Formation: in the high latitude, the thermal field is behind the height field, meanwhile, a high-pressure ridge at ground level is behind high altitude high-pressure ridge; the cold convection in front of a ridge contributes to strengthening of the high-pressure ridge and leads finally to the formation of the Cold High. Additionally, radiate cooling of the underlying surface plays an important role in forming a Cold High in mid to high latitude area. [See figure: 2.5]

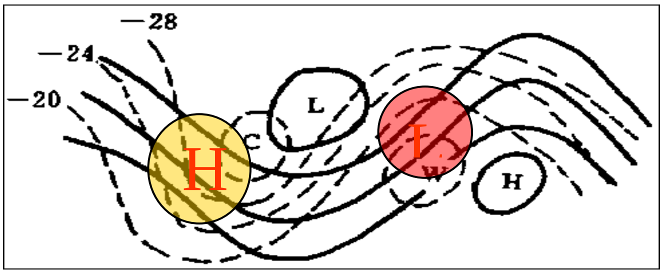


Figure: 2.5: sketch map of formation of Cold High [Ref 11]

b) Development: when the high altitude temperature ridge approaches the center of the Cold High, the cold advection is getting increasingly powerful and prosperous, and the Cold High develops to the strongest stage. When a high altitude temperature ridge overpasses the pressure ridge, the warm advection weakens the Cold High, subsequently; the Cold High has two types of changes. (1) The temperature-asymmetrical weak Cold High converts to a temperature-symmetrical quasi – stationary warm high. (2) During moving to the south, the Cold High fades away or merges into the subtropical high.

2.2.3: the weather distribution of a Cold High

1) The front of a Cold High (the eastern part):
The harsh weather caused by a Cold High mainly appears in the front edge of it and close to the cold front. Over there, the isobar is intensive and cold advection is strong. The following weather will appear, including sharp dropping of temperature, northern gale which may reach 11 level, rain, and snow. When arriving at the ocean, it will contribute to huge waves which represent a disaster for maritime activities. In winter, when navigating in the high latitude ocean, a sharp drop in of temperature may easily cause hull icing besides the heavy weather.

2) The internal of a Cold High (middle part):
Within the Cold High, the wind velocity decreases obviously when the isobars are becoming sparse. Because air mass is dry and cold with prevailing downdraft, the weather within the Cold High is sunny with cloudless and weak wind. Radiation fog, smoke, and haze are most likely in the inland, at ports, and coastal areas. In winter, it is easy that stratus clouds and cumulostratu appear; in summer, it is prone to appear cumulus humilis clouds. Typically, the weather within a Cold High can sustain two or three days. And then, with air mass warming, the temperature is slow to rebound.

3) The back of Cold High (west part):

After the center of a Cold High moves into the sea, the Chinese costal area is in the back of the Cold High, and the warm and moist sea air is conveyed to the this area by the southerly air flow. The temperature begins to rebound with the humidity increasing, and the warm front weather appears. In spring, advection fog, drizzle, and stratus clouds turn up very often in the back of a Cold High.

4) The movement of a Cold High:
The movement of a Cold High is guided by the high latitude air flow, thus, it moves, by and large, from west to east or from northwest to southeast. In winter, the duration of a strong Cold High is about 7 days.

2.2.4: the Cold Wave:
2.2.4.1 The concept of a Cold Wave:

A Cold Wave refers to those disaster weather including severe cooling, frost, precipitation, gale, etc. caused by large-scale strong cold air. A Cold Wave can appear in East Asia, Europe, North America, and Australia. In China, it is divided into four grades, nationwide Cold Wave, regional Cold Wave, strong cold air, and ordinary cold air. The cold air is very normal in China, and occurs once every four days on average.

2.2.4.2 The weather during a Cold Wave:

In front of the passage of the Cold Wave, figure 2.6, it is warm, sunny, and prevailing southerly winds. In the back of the passage of the Cold Wave, the temperature drops sharply; the pressure increases rapidly; wind force surges up to 6-8 level with maximum level up to 11 level; the gale can sustain 1-2 days; a huge wave will emerge on the sea . After invasion of a Cold Wave to China, it will cause gale in BohaiBay and Yellow Sea, and then extend to East Sea and South Sea, even to Viet Nam and Philippines.

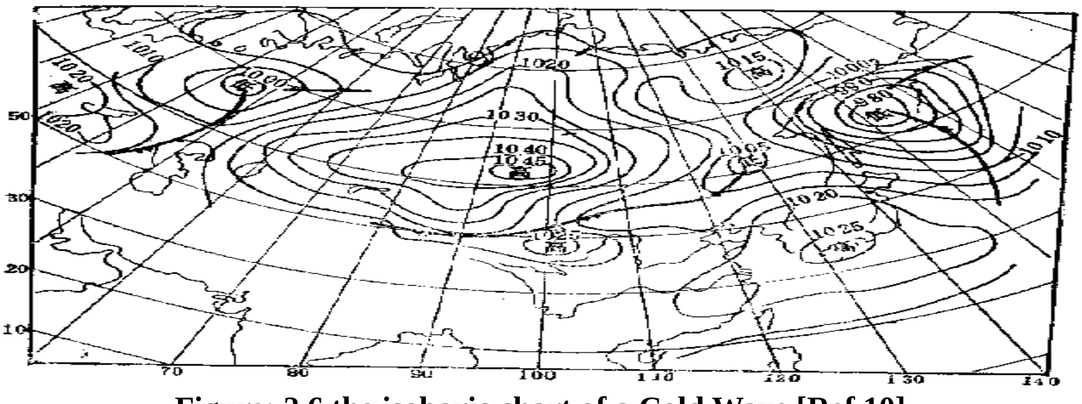


Figure: 2.6 the isobaric chart of a Cold Wave [Ref 10]

2.2.5: the sources and passage of cold air:

Cold air plays an important role in weather changes. The weather processes in most part of China are the processes of cold air southwards. During winter, China is usually located in the back of the Eastern Asia Trough; the influence of cold air activities to China is very significance. During summer, cold air activities are the main reason of causing gale, participation, hail, and extreme weather. Therefore, in order to make an actuate weather forecast, the condition of cold air activities in the upper region of China must be watched carefully.
The relationship between cold air and a Cold High is extremely close. Before the cold air goes down south, the Cold High provides the perfect circulation condition forming cold air mass.

The strength of a Cold High can reflect the strength of cold air.

2.2.5.1: the sources of cold air:

There are three sources of Cold High which can impact China, cold ocean surface in the east of Novaya Zemlya(18% cold air comes there), cold ocean surface in the west of Novaya Zemlya (49% cold air comes from there), cold ocean surface in the south of Iceland (33% cold air comes from there). In addition, during winter, the Siberian and Mongolia are favorable areas as well.

2.2.5.2: the passage of cold air:

The passage of cold air refers to the moving path of the main body of cold air. According to the statistics between 1970 and 1973 carried out by China Meteorological Agency, 95% cold air produced in foregoing sources had passed the "crux area" (70° E to 90° E; 43° N to 65° N) (See figure 2.7) . The cold air goes down south from the crux area invading China through three paths:

1) Northwest path(middle path)：Cold air non-stop arrives at the Middle-Lower Yangtze region from the crux area through the Nei Mongol Region.
2) West path: Cold air goes down south from the crux area through Xinjiang province, Qinghai province, and east of the Tibet Plateau.
3) East path: Cold air arrives at the northeast region of China from the crux area through Mongolia.

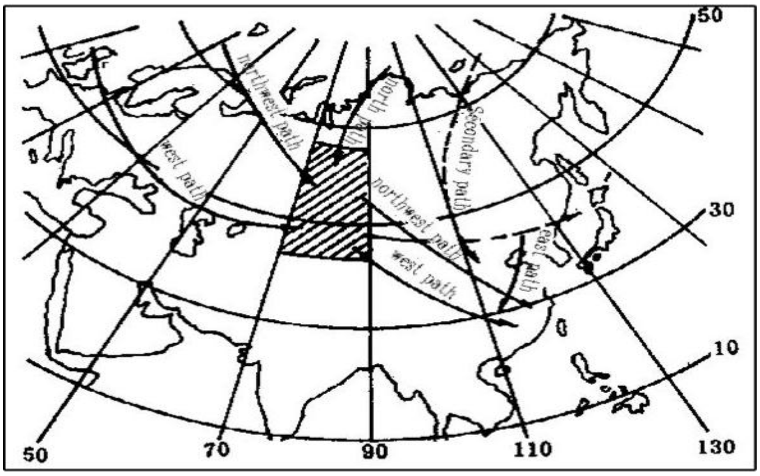


Figure 2.7 the passage of cold air impacting China [ref 10]

2.3: Monsoon

2.3.1: the concept of the monsoon:

Monsoon is traditionally defined as a seasonal reversing wind accompanied by corresponding changes in precipitation, but is now used to describe seasonal changes in atmospheric circulation and precipitation associated with the asymmetric heating of land and sea.
[reference21]

2.3.2: Formation of monsoons:

1) Sea-land monsoon:
Sea-land distribution impacts the movement of the atmosphere, which can form a wind system named Sea-land monsoon. It is mainly caused by the thermal difference between sea

and land, changing obviously from season to season.
2) Planetary monsoon:
The planetary wind belt moves in South-North direction with change of season, which leads to the seasonal variation of the wind direction. The monsoon formed by the seasonal variation of the wind direction is defined as the planetary monsoon. The typical planetary monsoon is the South Asia monsoon.
3) Effect of terrain of the Qinghai-Tibet plateau:
The average height of The Qinghai-Tibet plateau is around 4km with 1600 kilometers from north to south and 3000 kilometers from east to west. This huge plateau protruding in the atmosphere is a heat source in summer and cold source in winter, which plays an important role in maintaining and strengthening the South Asia monsoon.

2.3.3: The distribution of monsoons:

The monsoons in the world are mainly distributed in South Asia, East Asia, Southeast Asia, and Equatorial Africa area. (See figure 2.8)

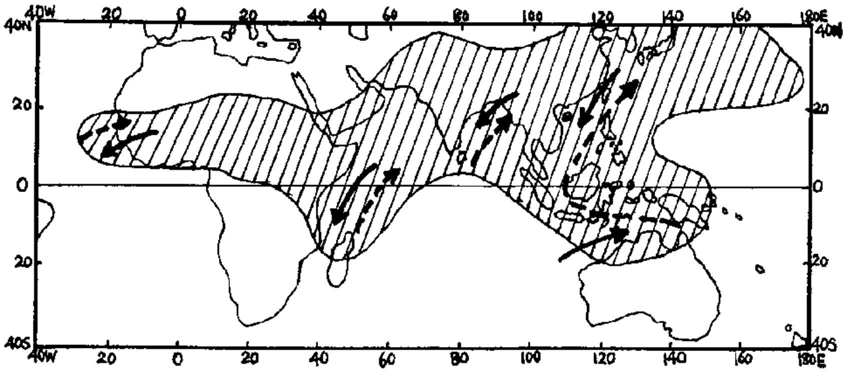


Figure 2.8 the distribution of monsoon in the world [ref 10]

The monsoon influencing the Chinese Shelf (Asia monsoon):
i) The East Asia monsoon:

The East Asia monsoon is mainly caused by the thermal difference between sea and land. It is occurring in between the largest continent in the world (Eurasia) and the largest ocean in the world (Pacific). The seasonal change of temperature and pressure gradient here is more severe than in other places in the world. Therefore, the East Asia monsoon is strongest of all monsoons caused by the thermal difference between sea and land. Its range includes East China, Korea, Japan, and adjacent oceans.
The features of the winter monsoon: In winter, the Mongolia high settles in the Asian mainland, the cold wave and cold air break out and go down south frequently. The northerly winds in the front of the high pressure become the winter East Asia monsoon. In most part of China, Korean peninsula, and the ocean close to Japan, the wind direction is northwest. In south of East China Sea, South of China Sea, Taiwan Strait, the wind direction is northeast, the wind force level is around 5-6 level with maximum 9 level.
The features of the summer monsoon: In summer, the thermal low is on land, and the subtropical high is on the sea. The southerly winds in between the thermal low and subtropical high is the summer monsoon in East Asia. In the East of China Sea, Korea, Sea of Japan, the wind direction is southeasterly. In South of China Sea, Taiwan Strait, the ocean nearby the Philippines, the wind direction is southwesterly with general wind force being 3-4 level.

ii) The South Asia monsoon:

The South Asia monsoon area is large; including North of Indian Ocean, East Africa, South of Asia, South Asia, and Indochina; and is connecting to East Asia monsoon. It is caused by seasonal movements of the planetary wind belt, while the thermal difference and terrain of the Qinghai-Tibet plateau influence it deeply as well.

The features of the winter monsoon: in winter, the planetary wind belt moves southward, the high pressure in the Asian mainland is powerful; the northeasterly wind in the south of a high pressure becomes the winter monsoon. In the North of Indian Ocean, the wind direction is north with wind force being 3-4 level. It is the best season for navigation in Indian Ocean during winter.

The features of the summer monsoon: the southwesterly wind is powerful in the monsoon area, which is an overlying result of the following factors.

- The south east trade wind in the Southern Hemisphere when passing through the equator, under the action of Coriolis force, changes into southwesterly wind.
- The southwesterly wind in the south side of Indian Low overlies with the forgoing southwesterly wind.
- The blocking effect of the high plateau
- The effect of the cape of the Indian Peninsula

In between July and August, the wind force can achieve 8-9 level. From September, the wind force begins to decrease. In the North of Indian Ocean, the southerly wind is extremely strong as a famous fierce storm region in the world.

2.4: Tropical cyclone：

The Tropical cyclone (figure 2.9) is a kind of a violent warm cyclonic vortex occurring on the tropical ocean surface. It is the strongest storm in the troposphere under the title of “king of storms”, having enormous destructive power, threatening seriously the safety of ships at sea. Thus it is extremely important to master the law of tropical cyclone occurring, developing, and moving.

2.4.1 The grade of a tropical cyclone:

2.4.1.1 Northwest Pacific region:

- Tropical depression: the maximum wind force close to the center is less than level 8 (34kn).
- Tropical storm: the maximum wind force close to center is around level 8-9 (34-47kn)

Severe tropic storm: the maximum wind force close to center is around level 10-11 (48-63kn)

- Typhoon: the maximum wind force close to center is more than level 12 (64kn)

Figure 2.9: satellite cloud image of a typhoon [ref 12]

2.4.1.2 Northeast Pacific and Atlantic (including Caribbean and Gulf of Mexico):

- Tropical depression: the maximum wind force close to the center is less than level 8 (34kn).
- Tropical storm: the maximum wind force close to the center is around level 8-9 (34-47kn)
- Severe tropic storm: the maximum wind force close to the center is around level 10-11 (48-63kn)
- Hurricane : the maximum wind force close to the center is more than level 12 (64kn)

2.4.1.3 North Indian Ocean and the Southern Hemisphere Ocean:

2.4.1.3.1: The Arabian Sea and the Bay of Bengal

- Depression: the maximum wind force close to the center is less than level 8 (34kn)
- Cyclonic storm: the maximum wind force close to the center is more than level 8 (34kn)

2.4.1.3.2: the Southern Hemisphere Ocean

- Tropical disturbance: the maximum wind force close to the center is less than level 8 (34kn)
- Tropical cyclone: the maximum wind force close to the center is more than level 8 (34kn)

2.4.2: The place of origin and frequency of occurrence:

The tropical cyclones in the world are concentrated to some specific low latitude regions. They are Northwest Pacific, Northeast Pacific, Southwest Pacific, Northwest Atlantic, the Bay of Bengal, and Northwest of Australia. There is none of occurrence of tropical cyclone in South of Atlantic and Southeast Pacific. The tropical cyclones occur mainly in between 5° N/S and 20° N/S, especially in between 10° - 20° where 65% of tropical cyclones occur.

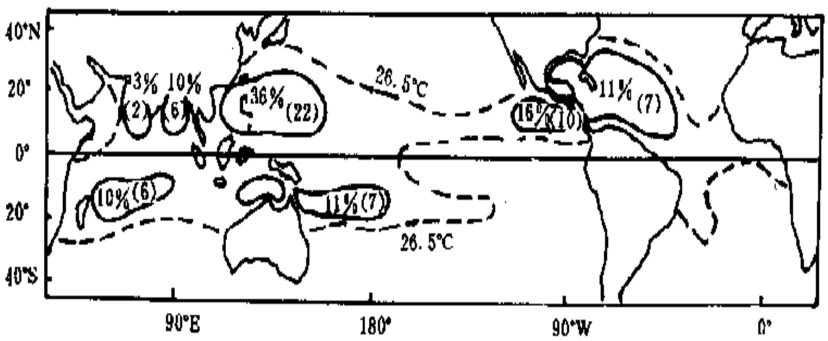


Figure 2.10 the regional distribution of tropical cyclone [ref 11]

China facing Northwest Pacific is one of the countries which are severely impacted by tropical cyclones. According a survey, an annual average of 20.1 tropical cyclones enter into Chinese Shelf area every year, 60% of which enter into South China Sea with 8 tropical cyclones on average landing each year. The original places of tropical cyclones influencing China include the ocean in the east of the Philippines, the ocean close to Guam, and the ocean in the middle of South of China Sea.

2.4.3 The duration of tropical cyclone:

The duration of a tropical cyclone is 3-8 days in general, with the longest being 20 days and shortest only 1-2 days. For typical tropical cyclones (typhoons), the duration can be divided into four stages.

- The newly born stage: From beginning of development to wind force reaching to the low limitation of level 12.
- Deepening stage: The center air pressure is reaching the minimum value and the wind speed increases to the maximum value.
- Maturity stage: The center air pressure deepens no longer, the wind speed does not increase any more, but the range of gale and storm extends.
- Decaying stage: It enters the mid-high latitude, changing into extra tropical cyclone due to invasion of cold air, or dissipating after landing.

2.4.4: The weather and structural features of a tropical cyclone:

2.4.4.1: The structure features of a tropical cyclone:

The mature tropical cyclone appears as a circular symmetrical distribution, vertically stretching to the top of the troposphere (15-20km), and the diameter of the circular vortex is around 600-1000km. Proportion of vertical dimension to horizontal dimension is about 1:50, it is thus clear that the tropical cyclone is an oval cyclonic vortex.

Its structural features are as follows (See figures 2.11 and 2.12):

- Outer zone：It extends from the outer edge of a tropical cyclone to the outer edge of maximum wind speed with a mean breadth of 200-300km.
- Vortex zone：It is from the outer edge of the maximum wind speed to the wall of the typhoon eye with a mean breadth of 10～20km.
- Eye zone：The center of tropical zone with a mean radius of 10～50km.

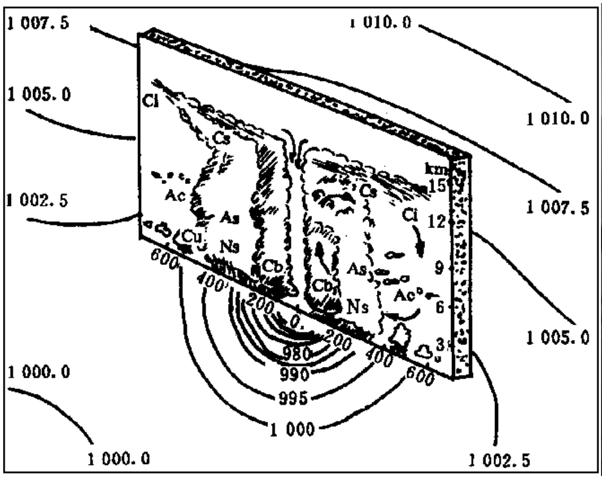


Figure 2.11 the structure of a typhoon [ref10].Figure2.12 the air flow of typhoon [ref 11]

2.4.4.2: The weather features of tropical cyclone

There are different weather features in different parts of a tropical cyclone. Table 2.1 illustrates the weather features of a tropical cyclone.

Table 2.1: The weather features of a tropical cyclone

Weather and sea condition factors	Outer zone	Vortex zone	Eye zone
Temperature	Increasing gradually as approaching to center; sultry	Increasing gradually as approaching center	Achieving to the peak, forming a warm center
Air pressure	Decreasing gradually as approaching to center	Decreasing sharply as approaching to center; funnel shape; large gradient; Isobar intensive	Dropping down to the lowest point
Wind speed	Increasing sharply as approaching to center	Arriving at the peak; the maximum value is close to the wall of eye; can reach to 60-70m/s	Suddenly dropping down under level 4
Cloud system	Spiraling cloud bands with mid-low cloud mainly(Sc,Cu,Fn)	Cb and Ns form a huge cloud wall	Sunny; little cloud, appearing Ac by chance
Precipitation	Intermittent rainfall; increasing as approaching to center	A drenching rain; thunder and lightning; the amount of precipitation to the right can achieve at 100-200mm/day	Suddenly stop
Visibility	Deteriorating as approaching to center	Extremely bad; darkness	Still very bad
Sea conditions	Increasing as approaching to center; wave coming from center	As high as more than ten meters wave; extremely harsh sea state	Pyramid wave; harsh sea state

2.4.5: The moving path and speed of tropical cyclones impacting China:

2.4.5.1 The moving path of tropical cyclones impacting China:

The tropical cyclones impacting China is the Northwest Pacific tropical cyclone, which has three moving paths, west bound, northwest bound (landing), and changing direction on the sea. (See figure 2.13):

1) West bound tropical cyclone: the tropical cyclone moves straight forward to west from east of the Philippines, landing at Hainan island China or Viet Nam through South China Sea. The westbound tropical cyclones impact severely to the South China Costal area.
2) Northwest bound tropical cyclone (landing): the tropical cyclone moves toward west-northwest from east of Philippines, landing at Taiwan, Fujian province of China, or move toward northwest, passing through the Ryukyu Islands and landing at Zhejiang province, subsequently, dissipating in China. Northwest bound tropical cyclones impact severely to the East China Costal area.
3) Direction-changing tropical cyclone: the tropical cyclone moves toward northwest from east of Philippines; after arriving at East China Sea or landing at China Costal area, it turns to northeast, and moving to Japan. Its moving path is the shape of a parabola, which is the most common path.

2.4.5.2 The moving speed of tropical cyclones impacting China:

The average speed of a tropical cyclone is 20-30km/h with the fastest being 100km/h. the speed of a tropical cyclone is relating to the moving path. To the direction-changing tropical cyclone, prior to changing direction, it moves faster than after changing direction and move slowest during changing direction. Generally speaking, during enhancing, it move slower and during weakening, it move faster. It is notable that prior to changing direction, it moves in an S-shaped path. Every change of direction will cause chaos of the forecast, so the weather forecaster has to revise the conclusion of the forecast very often. In addition, when the abnormal moving paths appear, more often than not, the tropical cyclone will slow down, even stop.

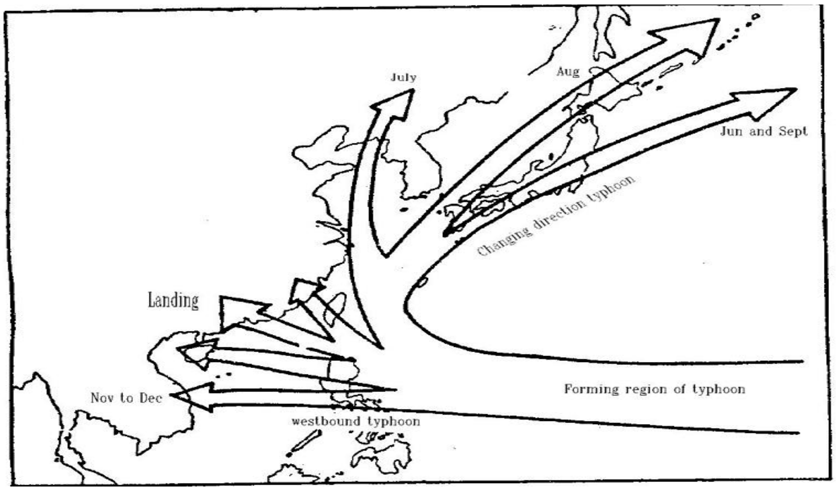


Figure 2.13 moving path of Northwest Pacific typhoon [ref13]

2.4.6: South China Sea cyclones

The South China Sea is not only an important sea passage connecting China to South Asia, Africa, and Europe but also a region in which tropical cyclones occur frequently. A cyclone impacts the maritime activities severely; therefore, there is a need to discuss it.

2.4.6.1: Overview:

1) Definition: South China Sea cyclone is a kind of cyclone born and grown in South China Sea, accounting for about one third of total number of Northwest Pacific tropical cyclone, and mainly impacting the weather of South China Sea and South China.
2) The place of origin: the middle of South China Sea.
3) Frequency: mean nine each year, four of which was born and grown in South China Sea.
4) Occurrence time: it can occur all year round, around 45% of which appear in August and September.
5) Landing time: from July to September.

2.4.6.2: The features of South China Sea cyclone:

- The horizontal scope of it is small; the vertical height is low; the duration is short; it grows and moves fast with complex moving path and huge destructive power.
- The asymmetrical distribution of cloud: in the right-front side of the cyclone, the cloud area is large, the layer of cloud is thick, the top of cloud is high, and the rain is heavy. In left-back side of the cyclone, the cloud area is small, the layer of cloud is thin, the rain is

light, the distribution of cloud system from outer to center is Ci—Ac—Sc—Cu—Cb.

- Midget typhoon: there is a small-scale tropical cyclone in South China Sea called midget typhoon, however, it develop rapidly moving fast with extremely destructive power. For example [ref 13], No.7314 typhoon, when it was on the sea, the maximum wind force even cannot reach level 6. However, when it landing at Hainan Island, the center maximum wind speed achieved at 70m/s. so, if the midget typhoon is neglected during making weather forcast, it can result in substantial losses to the lives and properties.

2.4.6.3: The moving path of the South China Sea cyclone:

The scale of the South China Sea cyclone is small with weak strength;, therefore its moving path is easily influenced by upper air. Generally speaking, its moving path can be divided into three types, parabola, reverted parabola, west-bound shape, and spinning to north.

- Parabola: most of time, it occurs in May and June.
- Reverted parabola: it often occurs in July and August.
- West-bound shape: it occurs in between June and September, northerly from June to September, southerly from October to September.
- Spinning to north: when the upper circular is weak, it often spins on the sea and there is no regular pattern of the moving path.

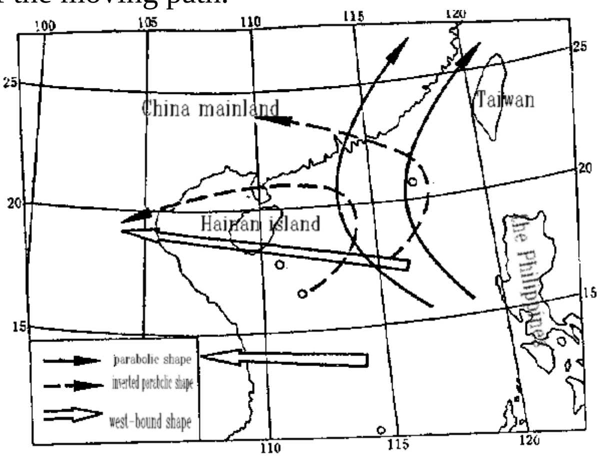


Figure 2.14 the moving path of South China Sea cyclone [13]

2.5: Sea current

The surface current affects directly the maritime activities. Sea current can drive floating ice; the formation of fog is closely related to the distribution of warm/cold Sea current; strong sea current has significantly influence on climate. So, it is very important to master the sea current condition during maritime activities.

2.5.1: the current in the Bohai Sea, the Yellow Sea, and the East China Sea

The current of the Bohai Bay, the Huanghai Sea, and the East China Sea consists of open sea current and coastal current, having features of cyclonic circulation.

1) The Open sea current system: it is constituted by the main stem of the black current originating from the north equatorial current and its branch (Taiwan warm current, Tsushima Current, and Huanghai sea current). The current speed of the black current is 1.02-1.54m/s, with average water temperature 29 centigrade in summer and 20 centigrade in winter, reducing from south to north.
2) The Coastal sea current system: it is formed due to the rivers running into the sea. The

coastal currents dilute the sea water, and the diluent sea water streams along with the shore. In order to balance with the open sea current, the tendency of its movement is from north to south, while it continuously mixed with open sea water, producing a lot of small vortexes. From north to south, there are mainly the following costal current in the Chinese Costal area, including Liaonan costal current, Liaodong costal current, Bohai costal current, north of Jiangsu province costal current, Zhejiang province costal current and Fujian province costal current.

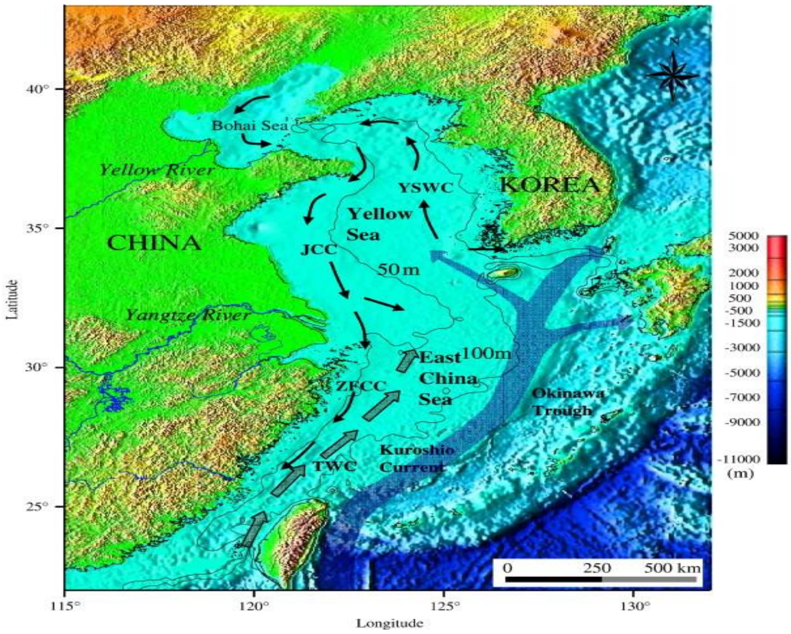


Figure 2.15 The current map of the Bohai Sea， Yellow Sea and East China Sea **[ref 14]**

2.5.2: the sea current in the South China Sea:

The South China Sea is located in the tropical monsoon zone; it has a prevailing southeast wind in summer and northeast wind in winter. The direction of monsoon is the same as the longitudinal direction of the sea area, and the sea current has the feature of monsoon drift. During the southwest monsoon season, the current direction is mainly northeastward; during the northeast monsoon season, the current direction is mainly southwestward.

During the southwest monsoon season, the sea water from Java Sea enters into the South China Sea through Karimata Strait and Caspar strait. The main current is close to Malay Peninsula with fast velocity and narrow amplitude. During moving toward northeast, the current amplitude expands gradually. After arriving at the north of South China Sea, most of sea water flow out of the South China Sea through Bashi Channel, converging with Kuroshio Current and flowing north. A small part of sea water continues to go north to East China Sea through the Taiwan Strait.

During the northeast monsoon season, the southwest drift is prevailing in South China Sea. Contrary to summer, a branch of the Kuroshio Current enters into the north of South China Sea through Bashi Channel, converging with the costal current from Taiwan Strait and flowing southwest. The main current goes south along with Indo-China Peninsula, the vast majority of the sea water enters into the Java Sea through Karimata Strait and Caspar strait with a small part of water entering into the Andaman Sea through Strait of Malacca.

The current in the northwest of South China Sea is stronger than the east both in the summer and winter. The strong current area is in the Vietnam offshore. (See figure 15)

2.5.3: the seasonal change of currents on the Chinese Costal Shelf:

The open sea currents have the following features:

- The seasonal change of Kuroshio is irregular.
- The maximum speed of Tsushima current is in September around 0.62m/s, with minimum speed in February around 0.1m/s.
- The Yellow Sea warm current varies with season change;, usually it is strong in summer and weak in winter.

- The speed of the Taiwan warm current has obvious seasonal changes as well, strong in winter and weak in summer.
- The current direction of South China Sea, as foregoing, is northeast in summer with maximum speed around 1.02m/s, southwest in winter with maximum speed around 1.54m/s.

The Chinese Costal current; the main reasons which can affect its seasonal change are the runoff variations of coastal rivers and the monsoon. The runoff of coastal rivers achieve crest in summer and trough in winter; the fluctuation of the coastal current correspond to this variation. Meanwhile, its change is also influenced by the variation of the monsoon.

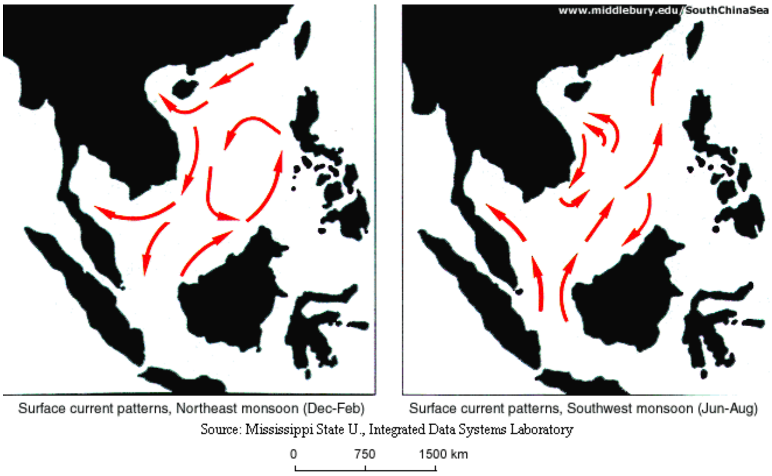


Figure 2.16 the current directions in South China Sea [ref 15]

2.6 Fog on Chinese Costal Shelf:

Fog is a kind of condensation of moisture. It is the same as a cloud in essence, just existing in different altitude. It is a primary impacting visibility, which contribute to significant difficulties for navigation. A myriad of statistics show that although vessels have been equipped with modern navigational instruments like Radar, GPS, ARPA, etc, a great number of serious accidents, like off-course, grounding, or collision still occurred frequently. Therefore, there is a need to master the regular pattern of fog forming and disappearing for a seafarer.

2.6.1 The geographical distribution of fog:

The Chinese Costal area is a foggy region of the Pacific Ocean. From Bohai Bay (the northernmost of China) to Beibuwan Bay (the southernmost of China), the fog distribution is roughly like a belt with two features.

The fog belt is narrow in the south and wide in the north.
The fog belt is around 100-200km in the South China Sea, 400km in the East China Sea and more broad in the north. During June and July, Yellow Sea is almost shrouded by fog; therefore, it has a nickname, "Fog Cave". There are three foggy areas on the Chinese Costal Shelf, the middle and south of Yellow Sea, and the area from Yangtze River estuary to Zhoushan Islands Beibuwan Bay.
The fog is less in the south and more in the north.
It is foggy in the Qiongzhou Strait and northwest of Beibuwan Bay in spring with 20-30 foggy days each year. The mean foggy days in the west of Taiwan Strait and Fujian province coastal area are 20-35 days. The mean foggy days from Zhejiang province to Yangtze River estuary increase to 50-60 days. The mean foggy days close to Chengshan Cape are more than 80 days, with longest continuous foggy days 25 days, which is a disaster to maritime activities. Bohai Bay is an enclosed sea and the warm current cannot arrive at there easily. Thus, the fog is rare. In addition, because the warm current is prevailing in the area east of Taiwan and south of Hainan Island and there is a lack of cooling conditions, fog is rarely found as well in those regions.

2.6.2 the seasonal change of fog：

On the Chinese Costal Shelf, fog appears firstly in the north of South China Sea with fog season from December to April and the densest fog from February to March. The fog season in East China Sea is from March to July with the densest fog appearing from April to June. In the Yellow Sea, the fog season is from April to August with peak during June and July. After August, except the north of Yellow Sea, the fog in the Chinese Coastal Shelf plunge abruptly.

The foregoing demonstrate that the season of the fog in Chinese Coastal Self occurring is from spring to summer, moving from south to north with features early in the south and late in the north.

2.7 The sea ice in Chinese Coastal Shelf:

Sea ice is a generic term to various kinds of ice in the sea, including the ice from frozen seawater, land-origin ice (formed by the ice in the rivers flowing into the sea). Sea ice can destroy the port facility, freezing the port, blocking the fairway.. There appears sea ice in the Bohai Bay and in the north of Yellow Sea each year. In the Chinese Costal Shelf, there is only ice in the Bohai Bay and in the north of Yellow Sea.

2.7.1 The classification of ice in Bohai Bay:

According to the phase of development of ice, it can be divided into seven classes:
- New ice: formed by sea water frozen directly with needle-like, lamellar, or spongy shape.
- Ice rind: it is a kind ice shell formed by new ice frozen.
- Nilas: the thickness is less than 10 cm with finger shape.
- Lily-pad ice: formed by rupture of ice rind.
- Grey ice: it is grey color with the thickness 10-15cm.
- Grey-white ice: it is grey-white color with thickness 15-30cm.
- White ice: it is white color with thickness more than 30cm

Figure 2.17: the classification of ice in Bohai Bay [Taken and edited by author]

2.7.2 The ice condition in the Bohai Bay:

The ice condition in Bohai Bay and Yellow Sea can be divided into 5 levels, less light ice year, light ice year, normal ice year, less heavy year, and heavy ice year.
The ice features in different ice year are as the following table:

Table 2.2: The ice level table [ref 16]

Ice level	Liaodong Bay		Liaodong Bay		Hazardous nature
	Outline(mile)	Thickness(cm)	Outline(mile)	Thickness(cm)	
less light ice year	＜20	＜10	＜5	＜10	No danger
Light ice year	20-30	10--25	5--15	10--15	Safety
Normal ice year	30-45	25--35	15--25	15--25	Sudden danger
Less heavy ice year	45-60	35--50	25--35	25--35	Heavy danger
Heavy ice year	＞70	＞60	＞35	＞35	Disaster

The ice period in Liaodong Bay is from the middle of January to the middle of March, lasting around 2 months. In the north of the Yellow Sea, the ice period is from the middle of January to the end of February, lasting around 2 months; the ice period in the Laizhou Bay is the shortest which is less than one month. (See figure 2.18)

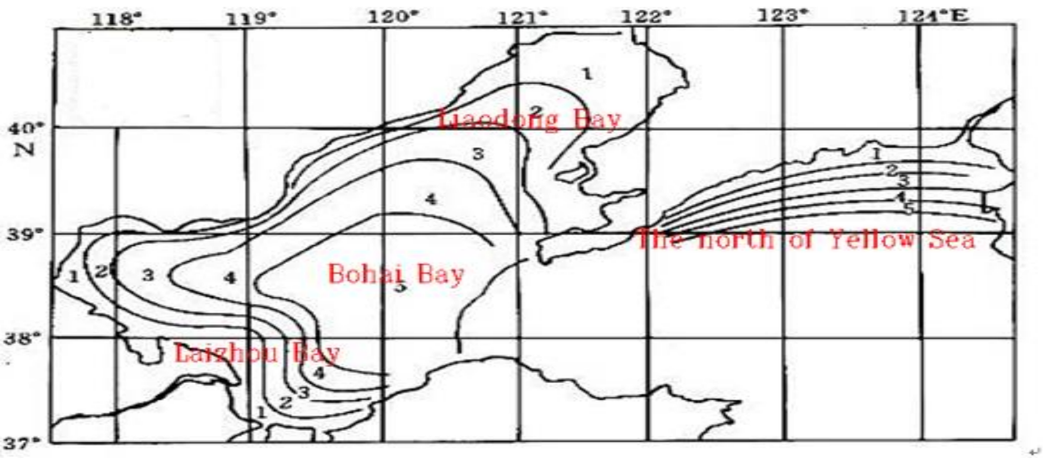


Figure 2.18 the distribution of ice in Bohai Bay and the North of Yellow Sea [ref16]

2.8 Other small and gusty weather systems, figure 2-19:

2.8.1 A Thunderstorm:

It is a kind of violent discharge phenomena occurring in cumulonimbus, usually with strong convective weather like storm, gusty gale, hail, tornado, etc. The lasting time of thunderstorms is very short, normally not more than 2 hours. In China, the number of thunderstorm in the South is more than in the north, with mountainous area more often than in plain. It appears mostly in the summer and autumn, and in the afternoon within one day. I remember that during navigation on South China Sea, I bumped into thunderstorms several times.

2.8.2 Squall line:

It is a developed thunder cloud under favorable conditions, usually not an isolated unit but a convective cloud group. Under favorable conditions, the convective cloud group can line up to be belt shape. Therefore, we call the thunderstorms distributed like a ribbon or cumulonimbus as a squall line. It is a middle dimension weather system with horizontal dimensions 150-300km, duration 4-18 hours. Some violent weather phenomena like thunderstorms, storms, gusty gales, hail, or tornados can appear in the squall line. With the squall line passing, the wind direction suddenly changes; the wind speed fiercely increases; and air pressure soars.

2.8.3 Tornado:

It is a small-scale strong vortex with a vertical axis, appearing with strong convection cloud, having extremely destructive power. Most of tornados appear during strong thunder shower; a handful of them appear during shower. A Tornado has the following features:

- Small horizontal scale: At the bottom, the diameter of a tornado is only in between several meters and several hundred meters; in the middle part, its diameter is around 1km; on the top of the tornado, its diameter is around 3-4km.
- Short duration: the duration of a tornado is only in between several minutes and dozens of minutes.
- Extremely low air pressure: the central pressure is extremely low, can get at below 200hPa.
- Extremely strong wind force: although the diameter is very small, the wind speed is extremely high with maximum wind speed of 100-200m/s.
- Extremely destructive power: the huge destructive power is produced by its extremely high wind speed and strong the air pressure gap between inside and outside.
- Moving quickly with the moving path usually being a straight line: its mean moving speed is 15m/s with maximum speed of 70m/s; most of time, the moving path is straight line with 5-10km long.

Photo 1: Thunderstorm Photo 2: Squall line Photo 3: Tornado

Photo 1 and 2 source: http://image.baidu.com/ Photo 3: Taken by author

Figure: 2.19: The small-scale weather systems

In summary, the weather systems which can cause a strong gale include tropical cyclones, the front of cold highs, squall lines, tornados, developed cumulonimbus, and so on; they are all negative factors for maritime activities, meanwhile, sea current, fog, sea ice can impact maritime activities as well. As forgoing, weather is not only a difficult-to-control but a decisive factor for maritime activities. Therefore, making weather forcasts though a variety of means or acquiring weather information prior to carrying out a maritime activity are essential work, meanwhile, the weather sensitivity of maritime activities must be taken into account as well. In the following chapter, I would like to discuss some maritime activities in combination with weather systems which can impact the Chinese Coastal Shelf.

Chapter 3 Weather sensitivity of ship handling

3.1: Ship handling in ice area

3.1.1 Ice volume:

We can make use of the percentage method to measure the proportion of coverage of ice within range of visibility, namely, ice volume which can be classed into the following 5 grades:

- Open water: the proportion of coverage is less than 10 percent.
- Scattered ice: the proportion of coverage is in between 10-50 percent.
- Broken ice: the proportion of coverage is in between 50-80 percent.
- Close pack ice: the proportion of coverage is in between 80-100 percent.
- Consolidated ice: the proportion of coverage is 100 percent.

The ice volume indicates the difficulty level of vessel navigating in ice area. As the ice volume is less than 10 percent, the vessels can navigate freely; 10-50 percent, the vessels cannot navigate according to the planned navigation line; 50-80 percent, the navigation will impede by ice; above 80 percent, the vessel cannot navigate without help of ice breaker.

3.1.2 The drifting law of sea ice and the sign of approaching ice area:

3.1.2.1 The drifting law of sea ice:

The main causes affecting the drifting of sea ice are wind and sea current. The floating sea ice and icebergs drift with the sea current in those sea areas without wind; the drifting speed and direction is the same as the sea current. In those sea areas without current, in the north sphere, the drifting direction is around 28 centigrade on the right side of leeward wind; in south sphere, the drifting direction is around 28 centigrade on the left side of leeward wind; the drifting speed is around 1/50 of the wind speed. Actually, the drifting of sea ice is a kind of movement combined from wind and current.

3.1.2.2 The sign of approaching ice area:

- A sharp decline of the temperature of the sea water indicates that there exists sea ice ahead of the vessel. The crew can measure the temperature of the surface seawater continuously, and accordingly figure out how long the vessel is from the ice area. Usually, when the temperature of sea water is +1 centigrade, the distance from vessel to ice area is around 100-150 mile; when the temperature of sea water is +0.5 centigrade, the distance from vessel to ice area is around 50 mile. In addition, when the vessel is approaching sea ice, the salinity of the sea water is also dropping obviously as approaching the ice area.
- Some small floating ice floes appear, sometimes, the sound of percussion of sea ice is audible.

- Dense fog, which is formed due to the warmer air moving to the cold sea surface nearby the ice, usually appears at the edge of the floating ice.
- If ice blinks, reflections from distant sea surface, can be seen, the sea ice can be found in this direction.
- During navigating in the zones of heavy storm, the wave weakens suddenly, or the sea surface calms down abruptly, which indicates that there is sea ice in the upwind direction. According to my personal experience, a significant 2-3m high wave will disappear within 1,000m from the sea ice, because the sea ice blocks the movement of waves.
- The crunch of ice, the sound of ice impacting with each other, the sound of iceberg collapsing, and so on is audible.
- If on the open sea, the echo of the whistle of the own vessel can be heard, it indicates that there are upright icebergs close to own vessel.
- When there is sea ice in the long distance, sometimes, mirage can appear on the sky line.
- When a vessel is navigating far from land, sea animals like sea lions, seal can be found.

In short, the vessels navigating at high latitude should, on one hand, pay attention to the radar echo, receiving the ice map, ice report and ice warning in time; on the other hand, the duty officer should be on strength watch, observing the foregoing signs.

3.1.3 Ship maneuvering in ice areas

3.1.3.1 Preparations prior to entering an ice area:

1) The navigators shall have a good understanding of the character of ice and its law by reading <sailing direction>, ice condition report, ice map, and so on.
2) Enough fuel, fresh water, and food should be prepared.
3) The hull structure, especially the bow structure, shall be inspected, if necessary, the carling and beam should be installed in the forepeak to increase the strength of bow.
4) The drainage system and the life-saving equipment should be checked to ensure that they are in good order and condition.
5) The ledge close to water line, like ring plate, the cover of drainage hole, the Pitot tube of Hydraulic pressure log should be dismantled.
6) When a ship is in ballast state or with a small amount of cargos, the crew should adjust the cargo, ballast water, fuel, fresh water to make the whole propeller merge into the sea water and keep trim by stern 1-1.5 m. To those B class ice-strengthened ships, the forward draft should be in between above 1m of the light load water line and below 0.5m of the load water line. The methods have the following reasons:

- Making a vessel having ice-breaking ability and maneuverability.
- Protecting hull, propeller, and rudder.
- Increasing stability.
- Avoiding the sea chest from blocking by trash ice.

7) In aspect of stowage, those low value cargo and moisture resistant should be loaded

in No 1 cargo hold. When there is cargo on the deck, deck icing, which can contribute to increasing of gravity center and decreasing of stability, should be taken into account. Meanwhile, the deck drainage system shall be in good order and condition.

8) Anti-freezing work:

- Navigation light, out-door compass light, and the light of repeater of gyrocompass should remain switch-on day and night.
- The fresh water cask, located in life boat, cannot be full, wrapped with canvas, or moving into the room.
- Closing cargo hold ventilation tube.
- Draining off the water residual water in the fire-fighting pipe. The outlet valve for washing anchor chain should always be in always-on state.
- Out-door pipe should be wrapped with heat insulating material.
- The upper wing water tank and fore/after peak tank cannot be filled more than 85 % of its volume.
- The double bottom water tank cannot be filled more than 95% of its capacity.
- Equipped with special material including immersion suits, safety goggles, ice axe and so on.
- Carrying out anti-slipping treatment to outdoor working site, like catwalk, foredeck, passage, etc.
- Enabling the warm water from main engine cooler to circulate at its inlet valve to avoid it from blocking by ice, which will cause the main engine shut down.

3.1.3.2 Selection of circuitous routing:

When there are icebergs or ice canopy in the navigation line, the best way is to select circuitous routing to avoid it. Although, sometimes, the range of icy water is quite wide, compared to passing through the ice area, navigating on the circuitous routing can still save a lot of time and fuel, and is of course, much safer. The crew should make no effort to figure out the ice range and navigable water according to the ice forecast and own lookout. If the edge of ice area can be seen, the vessel can navigate along the upwind boundary.

3.1.3.3 Entering into the ice area:

When the ice volume is in between 50%-60%, it is not difficult to find a navigable passage between ice blocks as long as the thickness of ice is no more than 30 cm. when the ice volume is more than 60%, it is difficult for a vessel to navigate depending on herself, therefore, there is a need to apply for the assistance of an icebreaker. After a decision of passing through ice area has been made, the navigator shall select a suitable place, timing, and method to enter the ice area. The following aspects should be taken into account:

- Entering into ice area from leeward side is safer than entering into ice area from upwind side. Because the ice block drift is intensive on the upwind side, it is easy to damage the vessel’s hull by a wave-driven ice block.

- During tide rising, the ice is easy to aggregate; during ebbing, the ice is easy to break. The ships should enter into the ice area in the time with slow flow or without flow.
- It is not suitable time for entering the ice area with larger swells or with crosswind more than level 5.
- The edge of ice area is irregular; therefore, a vessel should enter into the ice area at relatively smooth part where the swell is relatively small.
- When entering the ice area, the vessel should keep the bow perpendicular to the edge of the ice area, and reducing the speed to 2-3 n miles, which is the minimum speed that can maintain steerability. After the vessel bear against the ice block, and then it can increase speed gradually, pushing the ice, and steering into the ice area.

3.1.3.4 Navigating in the ice area:

When a vessel is navigating in the ice area, making use of the following seamanship should be taken into account carefully:

1) Selecting navigational speed according to ice volume.

- When the ice volume is in between 40%-50%, the vessel can navigate with normal speed.
- When the ice volume is in between 60%-70%, the vessel should navigate with slow speed.
- When the vessel navigating at night, the navigational speed should be lower than in the day.
- When the visibility is not good, the vessel can only navigate with a speed necessary for maintaining steerability.

2) When the wind direction is off-shore, usually, there is navigable water way close to shore; when the wind direction is on-shore, the vessel cannot navigate on the side close to shore.

3) Ship handling method for breaking big ice block into pieces:
When navigating in the ice area, the vessel has better not to change course frequently. If there is a big ice block in front of the vessel, the vessel should try to break the ice with the bow, if the big ice cannot be broken, the vessel should back off immediately. Prior to backing off, the stern trash ice should be pushed away by going ahead momentarily, meanwhile, the wheel should be kept in amidships position. When the backing ship approaches the trash ice, the engine should be stopped. By making use of the force of regressive inertia, the ship will enter into the trash ice. And then, the ship will go ahead to break the big ice block by use of the progressive inertia. If the operation cannot be successful first time, the crew can try again for several times. During breaking the big ice block, the ship’s speed should be controlled properly; the bow should head-on collide with ice block.

4) During navigating at ice area, the fore peak and bilge should be measured frequently. The sea chest is likely to be blocked by trash ice, so the crew should inspect it regularly.

5) During changing direction in ice area, the large rudder angle cannot be employed. The good seamanship is to alter direction 5° ~10° one time with small rudder angle to avoid the damage of rudder and propeller. If the vessel cannot move forward and need to leave ice area away, it is a convenient way to return from the original passage.

3.1.3.5 The method of escaping from the besiegement of ice:

During navigating at ice area, when the forepart of a vessel is stuck by ice and the vessel cannot go forward or back, the crew shall figure out a method to escape from ice. Otherwise, the vessel will drift with ice to a danger area or the hull of the vessel will be damaged by ice. The following methods can be referred to.

1) Full ahead; steering from hard-a-port to hard-a-starboard; making the bow unstuck from ice; and then, making a fast astern and midships to exit from ice.
2) Loading/discharging ballast water to loosen the ship's body.
3) Dropping an ice anchor at back of the ship; putting out a stern line and picking up the slack on the stern line while making a full astern.
4) After the foregoing methods failed, the crew can make use of explosives to break the big ice block into pieces. When the ship's bow is stuck, the crew can bore a small hole with diameter 15cm in front of the ship, firstly, putting half kilogram explosive into it to blow open a larger hole, and then putting four kilogram explosive into it, its explosive power is enough to break the ice block into pieces.

It's worth highlighting that when a vessel is besieged by ice, whether during waiting for ice breaker or waiting for the weather changing better or escaping danger by herself, the propeller and rudder should run continuously to avoid the passage at back of the vessel from being blocked by ice.

3.1.3.5 Anchoring in ice area:

If a vessel wants to anchor at an ice area, the anchorage should be selected carefully. Usually, shallow water with the thin ice or trash ice is a good place. The length of anchor chain cannot be more than double water depth, otherwise, the vessel is easy to be stuck by ice and the anchor chain is easy to be broken as well. During anchorage, the winch and main engine should be in stand-by state to ensure that the vessel can get away as necessary.

When it comes to Chinese costal area, if a vessel anchors in Liaodong Bay (the north of Bohai Bay), the crew should pay attention to the condition that there are a lot of small oil production platform, like GZ-93, Suizhong 3-2, Suizhong36-1 and so on. Also, there are a lot of subsea pipeline connecting those platforms and on-shore terminals. Dragging is a kind of inevitable phenomenon during anchoring at an ice area, so it is not a big deal. The most important thing is to prevent the vessel from colliding with a platform or hooking up to the subsea pipeline during dragging.

The current direction in Liaodong Bay is Northeastward with speed around 1.2 knots during tide rising and Southwestward with speed around 1.5 knots during ebbing. In order to prevent the vessel from colliding with the platform, the direction from the vessel to the platform cannot be the same as the current direction, and the safety range from the vessel to platform is 10 n miles at least.

3.1.3.6 Making use of ice breaker:

To those non- ice-strengthening vessels, when the ice volume is more than 60%, they had better to use ice breakers to assist. During navigation, the smaller ship should be arranged in the middle of a convoy. The interval between ships should keep 2-3 times the length of the ship. The vessel should pay close attention to the signal of the front vessel, and keep communication with the other vessel unblocked. When the front vessel slows down, the following vessel must alter course immediately to avoid collision with the front vessel.
During navigating in ice formation, the navigational speed can maintain 8 knots with the ice volume less than 40%, and reducing by 1 knot with the ice volume increasing 10%.

3.1.3.7 Escorted by ice breaker

To those vessel designed for non-ice area use, when the ice volume is more than 60%, they had better to use ice breaker for escorting. The vessel with small power and weak hull should be arranged in the middle of the convoy. The interval of two vessels should be 2-3 lengths of a ship. During navigation, the rear ship should keep careful watch on the signal of the front ship, adjusting the interval; all vessels must guarantee the expedite communication. When the front ship slows down and the rear ship cannot stop because of inertia, the rear ship can alter the course to avoid collision.

Navigational speed: when the ice volume is less than 40%, the navigational speed can be maintained at 8 knots. Subsequently, the navigational speed should be reduced by 1 knot with the ice volume increasing 10%.
When it is difficult to carry out escorting operation, the ice breaker can perform towing operation. During towing operation, the towing line from the ice breaker should pass through the fairlead, and then, taking one or two full turns around the leading post before eighting. The reason for this is to reduce the tendency to pull the two posts together. However, when turning up unjacketed high modulus lines around bitts, two turns should be taken around the leading post prior to turning the line up in a figure of eight fashion.
When the towing operation is carried out in consolidated ice area, after the ice breaker passing by, the waterway will close immediately because of pressure. Therefore, the

vessel being towed and the ice breaker should be tied together. In this case, there is a challenge in ice breaker handling.

3.1.3.8: Berthing in ice area:

When there is ice in a port, usually, a ship cannot be close up to the dock because of the ice between the ship and dock. At this time, a tug should be used to break the consolidated ice by cruising along the dock.
If there is enough space at the end of dock, the ship can draw close to the dock with the bow aiming at the end of the berth, putting out the head line on the front bollard far from berth, heaving on the head line, slow ahead, steering the rudder toward outboard side, making the bow close to the dock to sweep along the dock, then, the trash ice can be pushed aside. When the bow arrives at the front end of berth, if there is a small amount of trash ice between ship and dock, the ship can put out the fore spring line and stern line, slow ahead, pushing out the trash ice by making use of discharging current. And then, the stern can be drawn close to the dock.

3.2 Navigation in fog:

Navigation in fog refers to navigating in or near an area where visibility is restricted by fog, mist, falling snow, heavy rainstorms, sandstorms or any other similar causes.

3.2.1 Preparation for navigation in fog:
1）Receiving the weather forecast, NAVTEX, navigational warnings and fog warnings in time.
2）Before navigating in fog, the master and watch officers should be familiar with the information about fog, characteristics of the navigation area, tide, traffic density and means of position fixing.
3）Before navigating in fog, various navigational instruments, fog signals and navigational lights should be checked to ensure that all equipment is in good condition during navigation in fog.
4）Before navigating in fog, the drainage facilities and watertight equipment should be inspected to ensure that all equipment is in good order and condition.
5）Standby main engine for maneuvering at any time.
6）The watch officer should maintain proper lookout to determine whether the visibility is reducing/ deteriorating through observing lights, waterline and objects, whether the vessel is proceeding into fog.
7）Before fog set in, the watch officer should obtain exactly position of vessel and record the movements of other vessels in the vicinity in order to avoid collision.

3.2.2: Good seamanship of navigating in fog:

In order to ensure the safety of navigating in fog, if the following condition is found,

- The visibility is deteriorating,

- Fishing boats are intensive,
- It is difficult to take actions to avoid collision, and
- The safety of navigation is not granted,

The following measures can be adopted
- Anchoring
- Deviation
- Heaving to (see 3.3.4.4)

2）When the visibility is 3~5 nautical miles, it can be regarded as restricted visibility and the following measures should be adopted by the watch officer.
- Informing master,
- Informing engine room,
- Switching on two radars,
- Sound fog signals as per regulations,
- Keeping listening watch on VHF and
- Enhancing lookout.

3）When the visibility is reduced to 3 nautical miles or less, it can be regarded as poor visibility, and the following measures should be adopted by the watch officer.
- Calling the master to the bridge and deliver the conning to the master.
- Reporting the necessary information to the master, including vessel's position, the movements of other vessels in the vicinity, and preventive collision actions.
- Informing the engine room to keep the main engine in stand-by state,
- Adjusting the radar to the best working condition and proper use it.
- Navigational lights should be exhibited all times whatever it is in the day or at night.

4）In poor visibility, the master must be on the bridge conning the vessel himself and keep watch on the bridge（otherwise he is regarded as neglecting his duty）.

5）After receiving the notice of stand by engine, the engineer on duty should report to the chief engineer, and the chief engineer should go down to the engine room to check the preparations for engine maneuvering.

6）The article 6 of "International Regulations for Preventing Collision at Sea" should be adhered to, proceeding with safe speed in order to take proper and effect avoiding action, and can stop the vessel within a distance appropriate to the prevailing circumstances and conditions.

7）In poor visibility, if it is necessary that the vessel should reduce speed or stop or anchoring in selected anchorage, the relevant appropriate actions should be taken immediately.

8）Add an extra officer or crew for lookout. Keep quiet on bridge in order not to interfere the lookout by hearing. Proper lookout should be maintained by all available means, talking not relating to their works should be prohibited. The window and door of the bridge should be opened to observe any doubtful sign and sound by visual and hearing.

9）When a ship is approaching to complex waters near the coast, with high traffic density, and in narrow channels, a lookout at forecastle should be arranged. Any

findings, hearing and doubtful conditions should be reported to bridge in time.
10）Keep listening watch on VHF channel 16 and transmit the safety message of own vessel in Chinese and English on VHF channel 16. The massage should include name of vessel, time, position, course, speed and movements.
11）The auto pilot is not allowed while navigating in fog.
12）Close all watertight doors.
13）Keep continuous sounding if necessary.

3.2.3 Collision avoidance action in fog:

1）The article 19（conduct of vessel in restricted visibility）of the “International Regulations for Preventing Collision at Sea” should be adhered to.
2）The master and officers should be familiar with the characteristics of radar and ARPA radar. The weak targets and false echoes can be figured out through changing range scales, tuning gain.
3）The master and duty officer should understand the limitations of radar used in rain/snow. When operating in rain/ snowy weather conditions, 10 cm radar is better than 3 cm radar in detecting objects.
4）The master and duty officer should use radar to observe and plot continuously to determine the movements of approaching vessels, the action taken to avoid collision should be early and by a large margin.
5）When two vessels are meeting in fog and the risk of collision exists, both vessels should take action to avoid collision early, irrespective of giving way vessel or stand-on vessel.
6）The vessel which apparently hears the fog signal of another vessel coming from forward of her beam, or which cannot avoid a close-quarters situation with another vessel in forward of her beam, should reduce her speed to the minimum at which she can be kept on her course. If necessary, she should take all her way off and in any event navigate with extreme caution until danger of collision is over.
7）In order to avoid the approaching vessel in fog, if the condition permits, actions should be taken early（usually, the distance from the approaching vessel is 6 nautical miles）, wide berth （the distance at Closest Point of Approach should be larger than 2 nautical miles）and much substantial（using larger rudder angle altering course apparently） a succession of small alterations of course should be avoided. After taking an avoiding action, the effectiveness of the action should be carefully checked until the other vessel is finally past and clear.
8）When detecting the presence of another vessel by radar alone, the vessel should determine whether a close-quarter situation is developing and/or risk of collision exists. If so, she should take avoiding action in ample time, and when her action consists of an alteration of course, so far as possible the following should be avoided:

- Alteration of the course to port for a vessel forward of the beam, other than for a vessel being overtaken.
- Alteration of course towards a vessel abeam or abaft the abeam.

3.3: Ship handling in heavy weather:

3.3.1 A ship's motions in waves:

In his compendium of Marine technology and operation, Ove Tobias Gudmestad elaborates that a ship can be considered to have six degrees of freedom motion and it can move in any of six axes.

Three of these involve translations:

- Surge(forward/astern)
- Sway(starboard/port)
- Heave(up/down)

And the other three rotations:

- Roll(rotation about surge axis)
- Pitch (rotation about sway axis)
- Yaw (rotation about heave axis)

3.3.2: The hazard suffered by a vessel during navigating in heavy weather:

3.3.2.1: The hazard caused by transverse wave:

During navigating in heavy weather, roll easily appears because of crosswise waves. Violent rolling will contribute to the following hazard.

- Generating large rolling angle
- Water on deck
- Causing the movements of goods and increasing the impacting force of free surface
- Causing the crew uncomfortable, the equipment difficult to use, the damage of ship structure, increasing the hazard of ship capsizing.

3.3.2.2: The hazard caused by longitudinal wave:

1: Slamming

During violent pitching and heaving, the phenomenon, which the bow of a ship falls down after rising, and impacting with the rising wave, is called slamming. The bottom of the bow, even the 1/4 length of a ship area, impacting with the wave, will generate large stresses. The stresses will contribute to the damage of the bow structure, meanwhile, during slamming, the hull will produce violence vibrations.

The conditions when the slamming phenomenon is easy to occur:

1) When $\lambda / L \approx 1$ （λ： the length of wave; L: the length of ship）, the phenomenon of slamming will occur severely. The range of wave length is in between 80-140m; therefore if the range of the length of a ship is in between 80-140m as well, the phenomenon of slamming is easy to occur.
2) When d/L＜5%，（d: the draught of a ship; L the length of ship）, the phenomenon

of slamming is easy to occur. That is to say, when the ship is in light load state, slamming is easy to occur.

3) The speed of ship is an important factor to generate the phenomenon of slamming. According Lehman’s study, when Fr (Fr: Froude number; Fr=Vs/ sqrt (gL)) is in between 0.14-0.21, slamming is easy to occur.
4) A ship with large block coefficient and prismatic coefficient will suffer large impacting force. The ship with U-shape bow suffers more impact than the ship with V-shape bow.

According to forgoing discussion, the crew can adopt the following methods to lighten slamming.

1) Keeping the fore draft more than 1/2 full load draft.
2) Avoiding the resonance of swaying and heaving.
3) Slow down, keeping the speed in the state where Fr≈0.1

2: Ship water on deck

The water on deck can be regarded as free surface, which can reduce the stability with icing hazard in severe cold environment. Meanwhile, the wave will damage the deck equipment and superstructure directly, particularly, causing the movement of deck goods, threatening the safety of ship.

Ship water on deck is relevant to the height of freeboard, speed, and relative wave height ($h_{w/3}/L$). The lower the bow freeboard is, the higher the speed is, the higher the wave height is, the more severe the ship water on deck is.

In order to reduce the ship water on deck, reducing speed is necessary way. And then, selecting a course, which can relive swaying, is an effective method as well.

3: Pooping

During navigating in waves, the poop usually sinks into the trough of the wave with the ship water on the poop deck, which is called pooping. In this case, the relative speed between the wave and ship is small, the duration of the wave passing by the ship is long, and therefore the chance of water on deck is larger. When the ship is in the slope of the chasing wave, the heading is unstable, even the ship will be broaching, which is a very dangerous condition. If this condition appears, in order to avoid the danger, the crew shall decidedly alter the speed to make the relative speed between wave and ship increasing.

4: Racing

Violent pitching and heaving will cause a part or all parts of the propeller emerging above the water surface, which is called racing. The racing will contribute to speed down, the vibration of the propeller, shafting, and body of ship, which may be damaged at any time due to suffering huge impact. The racing is more likely to occur as the ship is in light load state.

In order to lighten the racing and prevent the propeller from damage, the blade should immerse into the water 20%-30% the diameter of the propeller. When the racing occurs, the course and speed can be adjusted to lighten the pitching and heaving.

3.3.3 The preparation work prior to navigating in heavy weather:

The following preparations should be made when a ship navigating in heavy weather:

1) All openings on deck should be checked to ensure that they are enough strengthened and in watertight state.

- The covers of measuring pipes of each oil and water tanks should be tightened up.
- Watertight doors should be closed.
- The inside and outside of the scuttle should be closed and the screws should be tightened.
- All accommodation spaces, cargo holds, ventilators should be closed and the screws should be tightened.
- The hawse pipe and the access from the fore peak tank to the chain locker should be covered, to avoid entering of seawater.

2）The drainage pipeline system, pump system, separating valves should be checked and be in good condition. The draining pipes, draining holes should be checked and be free of obstructions.

3）Inspect and fix the two anchors, spare anchor, gangway, portable ladder, lifeboat, life raft, derricks and hull fittings. Fore and aft mooring lines and movable articles should be stowed into the storeroom and secured. Deck fittings should be lashed and secured. Inform all hands to lash and secure all movable items.

4）In order to reduce the effect of free surface and strengthen the stability, water tanks, fuel oil tanks should, so far as practicable, be full or empty.

5） The emergency rudder, emergency generator （power）, antenna should be checked and be in good working condition.

6）Check the life saving, fire-fighting, flooding equipments if they are in normal condition.

7）The manrope should be rigged in the access of deck, especially when there is ice on deck in winter.

3.3.4: The handling of ship in heavy weather:

3.3.4.1: Heave to (see also 3.3.4.4)

1）When vessel sails against waves, the wave slamming on the bow is very violent, so the speed should be reduced appropriately. When the angle between the vessel's heading and the direction of the sea is about 20 degrees, the pitching and pounding of the sea may be reduced. If sailing against waves for long period of time, the waves should be kept on port bow and starboard bow in rotation, the vessel should be maintained on intended course to avoid the risk of broaching.

2）The vessel should, so far as practicable, avoid hog or sag and "racing" of the propeller caused by the difference of the length of the swell.

3.3.4.2: Scudding

1）The slamming of the wave can be reduced greatly while scudding.
2）The waves sweep the stern of the vessel easily while scudding, especially when the speed of the wave is faster than the speed of the vessel. The slamming to rudder face is also very violent.
3）Steady the course is not easy while scudding. Large rudder angle should not be used in order to avoid reducing the stability.

3.3.4.3: The operation of turning round in heavy weather:

1）The turning should be avoided so far as practicable when a vessel is navigating in severe weather and sea condition. If necessary, turning can only be done at the time when the sea surface is relatively calm. Abeam with high waves should be avoided while vessel is turning.
2）The vessel's speed should be reduced before turning. The rudder angle should be increased to full gradually.
3）Generally speaking, the turning is easy from the state of following the sea to the state of scudding. But from scudding to following the sea is difficult and dangerous, especially in ballast condition. This condition should be avoided. Before turning, the speed of the vessel shall be reduced. The turning operation shall be carried out as soon as possible when the sea is flat. If necessary, the main engine can be used to increase the effectiveness of the rudder
4）The turning should not be made when the vessel is rolling and pitching heavily, it is better to turn at light swaying occasion.
5）Turning with large rudder angle should not be used when the ship is suffering abeam waves or the speed of vessel is very fast. Otherwise violent listing can be generated.
6）It is easy turning from the state of scudding to the state of following waves for a vessel with higher aftercastle and bigger wind affecting areas. Also, it is easy turning from the state of following the waves to the state of scudding for a vessel with higher forecastle and bigger wind affecting areas.
7）It is better to turn to port for the vessel with right-handed rotation propeller.
8）The wheel should be steered by a skilled quartermaster. The engine room should be noticed to get ready to change the speed. The crew should also be noticed to fix movable items in cabins to prevent damages owing to swaying of the vessel in turning.

3.3.4.4: Heave to and drifting:

1）The " heave to" is an ship maneuvering method that keeps the vessel steady in a fixed position, neither forward nor backward, by using engine and rudder. The aim is to keep the vessel against waves in a fixed position, and the voyage can be resumed when the heavy weather is over.

2）the “drifting” is a maneuvering method that allows the vessel drifting down-winds without using engine and rudder. Other than the vessel is forced to drift owing to the main engine or rudder breakdown, sometimes, it is actively adopted by the vessel in very severe weather and sea conditions or for other reasons. Before make drifting, all conditions and factors should be analyzed and considered thoroughly.

3.3.4.5: The speed control in heavy weather:

1) The master must decide the vessel’s speed under heavy weather conditions with due regard to the observance of good seamanship to avoid damage to the vessel/cargo and unnecessary fuel oil consuming.
2) The vessel cannot go forward at full speed against swells. Sometimes, alteration of course is not enough to prevent the damage from the waves, whatever the ship is in loaded or ballast condition. If the vessel’s speed reduces 25% under the condition of normal RPM of the main engine, the RPM of the main engine should be reduced to decrease the wave damage. For laden huge tankers/ultra huge tankers, when wind and sea are coming from the bow, under normal RPM of the main engine, if the vessel’s speed reduce one knot, which indicate that the bow is suffering from huge pounding and the vessel hull may had been suffered serious damage.
3) To those ships that the distance from bow to bridge is about 200~300 meters, at night, waves on the bow may not be seen from the bridge. This case should be taken into account.
4) After encountering heavy weather at night, the bow and forecastle should be checked the next day. If the weather condition permits, it had better to alter course to make leeway for the crew inspection. The designated officer is responsible for the communication with bridge and ensures that the safety measures are taken. For example, being equipped with safe line and putting on working clothes.

3.4: The ship handling for avoiding typhoons:

3.4.1 Ship position in typhoon:

Dangerous and navigable semicircile: in the northern hemisphere, the weather in the right semicircle is harsher than the weather in the left semicircle, because the movement of anti-clockwise rotation of the typhoon overlays with its movement of going forward. Therefore, the right semicircle is called dangerous semicircile, and the left semicircle is called navigable semicircle. In the south hemisphere, the law is contrary because the typhoon is clockwise rotation.
When navigating in a typhoon, only after having a good understanding of the tendency of the typhoon and the ship’s position in the typhoon, the ship can take an effectively action to avoid the center of the typhoon. According to the changes of the weather, in the northern hemisphere, the navigators should have the following understanding of the position of the ship:

- When the wind direction is turning right, the ship is in right semicircle;

- When the wind direction is turning left, the ship is in left semicircle;
- When there is none of obvious change of wind direction, the ship is in the moving direction of the typhoon;
- When the air pressure is decreasing, the ship is in the front of the typhoon;
- When the air pressure is increasing, the ship is in the back of the typhoon;
- The air pressure is at the lowest value with pyramid-shape wave on the surface of sea and windless.

3.4.2: The ship handling method of avoiding a typhoon

3.4.2.1 The notice of avoiding typhoon:

After receiving the weather forecast about a typhoon, the following factors should be taken into account when the navigator determines whether they will proceed on, avoid typhoon, or bound for the nearby port:

1) The moving path and the power of the typhoon, the tendency of development of sea condition.
2) The distance between the ship and the center of typhoon; whether the moving path of typhoon crosses with the navigation line; the distance at Closest Point of Approach to the center of typhoon; the ship will be in the dangerous semicircular or navigable semicircular.

According to my personal experience, when a typhoon is coming and the air pressure is decreasing 1hPa per hour, the crew should pay seriously attention to this condition. When the air pressure is decreasing more than 2hPa per hour, the ship must alter course to avoid the typhoon.

3) Whether there is a sheltered port close to the ship; the distance from the ship to the port must be known.
4) The consideration to Sea Keeping Quality of the ship. The Sea Keeping Quality refer to the ship's ability which in hash weather, the ship's hull and cargo cannot be damaged, the ship can navigate in safety and relatively comfortable manner.
5) The crew should pay attention to both the general and special law of typhoons. The movement law of a typhoon varies with season. Its moving speed is from slow to fast. After alteration and entering the middle latitude area, it will speed up again. This is the general law of a typhoon. However, the movement of a typhoon is still affected by the scale of its own circulation, the distribution of high or low pressure in its moving range. A few typhoons can move to low latitude firstly. After making several turns, moving to the east rather than to the northwestward. Therefore, after mastering the general law of a typhoon, the crew should judge the situation of the typhoon according to the observation in person by making use of the instrument on board the ship. Only in this way, can the ship avoid the typhoon successfully.

3.4.2.2 The operation of avoiding typhoon:

The critical question is that the ship should keep away from the center of typhoon as far as possible. Generally speaking, the distance from the center of typhoon to the ship should be kept more than 300 nautical miles with the wind force Beaufort 6-7 level and the air pressure more than 10^5 Pa. Under an extreme situation, the distance from the center of typhoon to the ship should be more than 100 nautical miles with the wind force no more than Beaufort 8 level.

To those ships navigating in coastal areas, before typhoon arrival, it should go to the sheltered anchorage as soon as possible. To those ships navigating in ocean, it shall alter the course and speed to avoid the center of typhoon.

1) The method of avoiding typhoon when the ship is in dangerous circular:

In the northern hemisphere, the wind in the right semicircular is stronger than in the left semicircular with the wind turning right gradually (clockwise direction), and there is a risk that the ship is involved into the center of the typhoon. Therefore, the right semicircular is called the dangerous semicircle. When in the dangerous semicircle, the ship should run away from the center of the typhoon at full speed with course perpendicular to the moving path of the typhoon, namely, with starboard bow 15° -20 ° against the wind. (See figure 3.1)

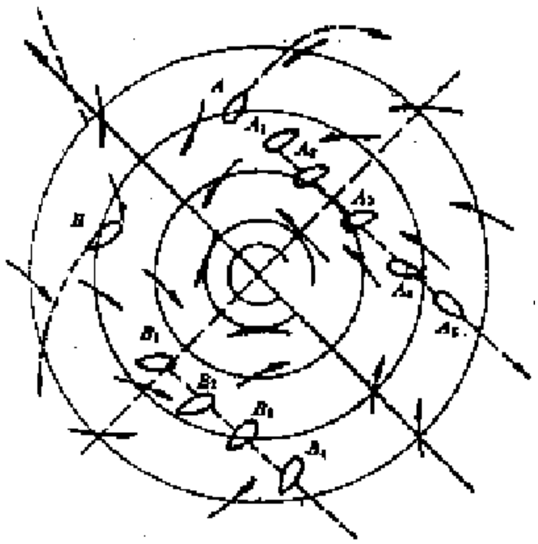


Figure 3.1: The ship handling method of avoiding typhoon [ref 17]

If the weather has been very violent and the ship cannot run away at full speed, the ship can lie to with starboard bow against wind. Its track is like the dot line A1, A2, A3, --- (illustrated in figure 3.1).

To sum up, the navigation method of avoiding typhoon in the northern hemisphere can be generalized with a word “three right” , namely, in right hemisphere of typhoon, the wind turning right, and running away with the right bow against the wind.

2) The method of avoiding typhoon when the ship is in navigable circular:

In the northern hemisphere, in the left semicircle of the typhoon, the wind direction is contrary to the moving path of the typhoon with the wind direction turning left gradually, and the wind is weaker than in the right semicircle. Therefore, the risk that the ship is involved into the center of typhoon is much smaller. In this case, the ship should run away from the center of typhoon with the starboard stern against the wind. When the wind weakens and air pressure increase, it indicates that the typhoon has passed by.

If there is not enough space for the ship to avoid the typhoon, the ship can go with the starboard bow against the typhoon. Its track is like the dot line B1, B2, B3, --- (illustrated in figure 3.1)

3) The method of avoiding typhoon when the ship is on the moving path of typhoon.

When the ship is on the moving path of typhoon, the wind direction is stable and the air pressure decrease, which indicate that the center of typhoon is coming. At this time, in the northern hemisphere, the ship should run into the left semicircle with the starboard against wind as quick as she can. After the wind weakens and the air pressure increase, it indicates that the ship has run away from the dangerous area.

3.4.3 The protection against the typhoon when the ship is alongside the dock:

1) Adding the mooring line, especially in the direction against the typhoon; every mooring line should bear stress evenly; the mooring point should be as much as possible;
2) The longer mooring line can increase the potential energy;
3) The friction parts of the mooring line should be wrapped properly or be greased with lubricating oil.
4) Bumpers between the ship and dock should be added.
5) All ballast tanks shall be full to reduce the windward area of the ship and increase the hydrodynamic resistance of the ship.
6) The bow should be toward the departure direction in order to unberth as soon as possible, if necessary.

3.5 A case study: an accident of vessel grounding during a typhoon:

Several years ago, there was a chemical tanker grounded in the Qiongzhou strait, Hainan province, China, because the crew did not adopt the correct methods to avoid the typhoon. After occurrence of this accident, I attended the investigation of this accident and have a good understanding of the process and reasons of this accident. So, I would like to introduce this accident as an example of the method and experience which I discussed in the foregoing section. For the sake of confidentiality, I use “Nanhai” as the name of this ship, rather than the real name of this ship, also I do not mention the name of the ship owner.

3.5.1 General information:

Table 3.1 ship particular of Nanhai(made by author)

Ship name	Nationality	Port of registry	Classification	Length	Width	Gross tonnage
Nanhai (anonymous)	China	Guangzhou	CCS	134.85m	22m	8479T
Net tonnage	Dead weight tonnage	Power	Light draught	Full load draught	Vessel type	Date of built
3165T	12500T	3824kw	3m	7.42m	Chemical tanker	Dec, 2006

Table 3.2 weather information (Made by author)

Date	Place	Wind direction	Wind force
24th Step, 2007	Linchang reef Qiongzhou strait Hainan province	NNW	8-9 level with gust 10 level
Visability	Current direction	Current speed	Wave height
0.5 nautical mile	SE	3	6-7m

Figure 3.2 the location of accident occurring

3.5.2 The process of this accident:

At 07:23, 23rd, Sept, 2007，Nanhai set sail from Guangzhou to Basuo, Hainan province. According to the weather facsimile chart received at 02:00, 23rd, there was a tropical low pressure in the north of South China Sea with moving direction 263° and moving speed 15km per hour. Captain was of opinion that the tropical low would not threaten the ship and decided that the ship would continue to go forward to Hainan Island.

At 24:00 23rd, Nanhai entered the Qiongzhou strait, and received the weather forcast that the tropical low pressure would be likely to develop into a typhoon. Meanwhile, the Vessel Traffic Services Center suggests the vessel to go to Houshuiwan Gulf anchorage for taking a shelter from the wind.

At 04:00 24th, the tropical low pressure had been developed into a typhoon, and Nanhai was in the moving path of the typhoon. Captain is of the opinion that the ship cannot turn around for taking a shelter because if the ship turns around, it will enter into the dangerous semicircle. Hence, the captain decides that the ship continued to be bound for original anchorage for taking a shelter from wind.

At 07:00 24th, the ship was away 12 nautical miles from Linchang reef with course 226°. Captain requested the engine room standby engine.

At 07:45 24th, Captain informed chief officer to have both anchors ready.

At 07:50 24th, Anchors are ready for dropping.

At 07:57 24th, the course is 226°. The original plan is to anchor at the scheduled anchorage location (the north of Linchang reef). However, captain is of opinion that when the typhoon is passing by, the wind direction will change from northwest to southwest, finally, to southeast; the shore configurations in the southeast can weaken the wind. Therefore, captain makes a snap decision that the ship would anchor in the south of Linchang reef (the scheduled plan is to anchor in the north of Linchang reef). The method of ship handling is to make the bow against the wind, stop the ship, and drop the anchor. (See figure 3.3 sketch map of location of accident occurring)

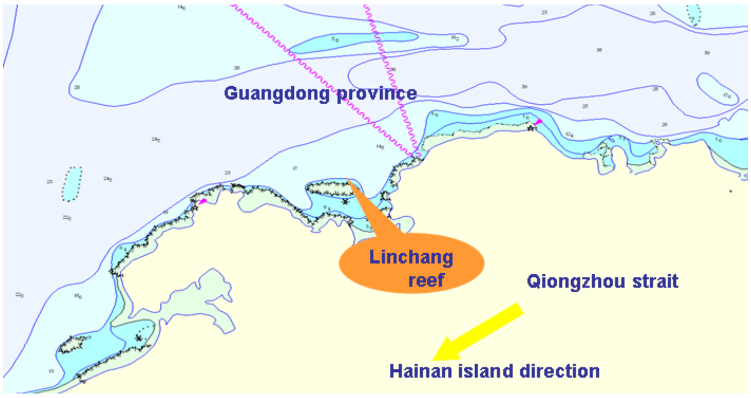


Figure 3.3 sketch of location of accident occurring (made by author)

At 08:04 24th, the weather deteriorated sharply, with heavy storm, northwest wind 10-11 level, the wave height 6-7m, visibility less than 0.5 nautical mile. At that time, the starboard side of the ship was against the wind and sea current, and the ship was drifting to portside under the action of wind and sea current. The distance between the ship and Linchang reef became more and more small.
At 08:05 24th, in order to keep away from the Linchang reef, the ship wants to turn around, and captain makes the following actions --- Slow ahead, Starboard twenty.

However, due to strong wind and wave, the ship cannot turn right.
At 08:06 24th, captain makes the following actions--- Half ahead, Hard-a-starboard. Due to strong wind, the ship still cannot turn right, and the speed of approaching Linchang reef is increasing. So, captain decides to stop the ship by making use of dropping anchor.
At 08:07, 24th, Slow ahead.
At 08:08, 24th, Stop engine.
At 08:09, 24th, Slow ahead, Hard-a-starboard.
At 08:14, 24th, the ship was 0.5 nautical miles away from Linchang reef, which was a very critical condition. Captain orders to drop starboard anchor with two shackles in water. The anchor position was 19° 55.82N/109° 27.31E, however, the bow of ship still was pushed to portside by the wind.
At 08:15,24th, Half ahead, Hard-a-starboard. However the ship cannot turn right as before.
At 08:16, 24th, Paying out the cables to three shackles in water. Although, captain took the forgoing emergency actions, it is too late.
At 08:29, 24th, The strong wind pushed the ship onto the Linchang reef, and the ship grounded. The grounding position was 19° 55.21N/109° 27.68E.
At 08:30,24th, the main engine stopped. The crew asked for rescue to Yangpu marine administration through VHF channel 08.
(See figure 3.4 and figure 3.5 Nanhai grounded on the Linchang reef, these pictures were taken by rescue worker)

Figure 3.4 Nanhai grounded on the Linchang reef (taken by rescue worker)

Figure 3.5 Nanhai grounded on the Linchang reef (taken by rescue worker)

3.5.3: Emergency rescue action:

After receiving the accident report, the MSA assigned two tugs to help Nanhai refloat. Due to hash sea conditions, the two tugs failed to tie up Nanhai. And then, the captain decided to evacuate. The company arranged two helicopters to evacuate the crew, and ordered two tugs stand-by on site. (See figure 3.5 and figure 3.6 taken by rescue worker)

Figure 3.6 crew was evacuating from Nanhai (Taken by rescue worker)

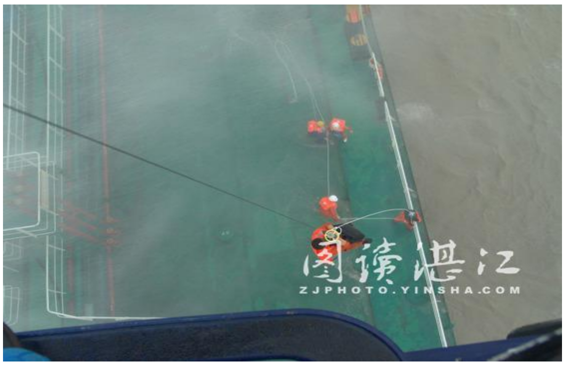


Figure 3.7 crew was evacuating from Nanhai (Taken by rescue worker)

3.5.4 The loss of accident

This accident caused bottom deformation and breakage, rudder damage, and propeller damage without casualties. (See the following picture, Figures 3.8 to 3.11, which were taken by the author)

Figure 3.8 Bottom deformation and breakage

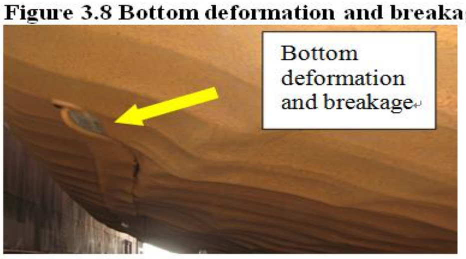


figure 3.9 Rudder damage

Figure 3.10 propeller damage

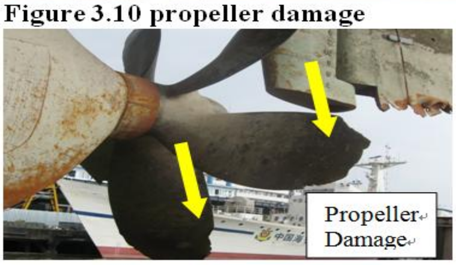
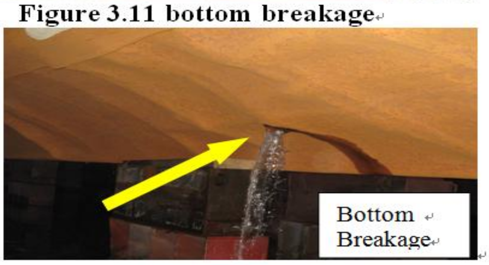


Figure 3.11 bottom breakage



3.5.5 Root cause analysis:

3.5.5.1 Direct cause:

1) Captain selected the sheltered anchorage wrongly.
According to the weather forecast, the typhoon would land in between Zhanjiang (a sea port of Guangdong province) and Haikou (a sea port of Hainan province). Captain selected Houshuiwan Bay as sheltered anchorage. At that time, the ship was in the left semicircle, and the wind direction was northwest. However, a ship cannot take a shelter from northwest wind in Houshuiwan Bay.

2) Under the urgent situation, captain's decision was not decisive; the measure of ship handling was ineffective.

Captain-selected sheltered anchorage location is in the north and 3 nautical miles away from Linchang reef. When the ship arrived at the place, the captain found that this place is not suitable for taking a shelter from northwest wind. At that moment, the captain made a snap decision to take shelter in the south of Linchang reef. However, at that time, it was difficult for the ship to change course against wind owing to the influence of crosswind and transverse current. Meanwhile, captain did not take decisive action to control the ship's position, so that the ship was pushed on the Linchang reef by strong wind and current.

3.5.5.2 Indirect cause:

1）Before arrival of the typhoon, the vessel had obtained the suggestion from VTSC (Vessel Traffic Services Center) that the vessels should go to Houshuiwan Bay for taking shelter from wind. However, the captain did not make an effective decision combining the VTSC's suggestion with the ship's characteristics, which contributed to that the captain selected sheltered anchorage wrongly.
2) The numerical value of the leeway and the drift angle, which influence the operation of ship handling severely, could not be taken into account sufficiently.
3) Under the condition that the ship could not be controlled effectively, the captain did not decidedly drop both anchors or handled the ship with "Full ahead" and Hard-a-starboard" to get control of the ship.
4) The duty officer did not provide enough data including water depth, ship position, the distance from reef, and so on, for captain, which are the basis for the captain to make a decision.
5) In hash sea condition and poor visibility, the position error caused by radar echo could not be taken into account seriously by the duty officer, and could not be revised by making use of GPS.

3.5.5.2 Management cause:

1) Before arrival of the typhoon, the management company did not do a good preparation against typhoon.
2) When the wind was strengthening and the captain was making a decision of taking a shelter from wind, the management company over relied on captain's

experience without giving clear instructions to the crew.
3）The management company did not have a good tracking and control of the ship, especially, during typhoon.
4) The management company did not give a good training and assessment to new crew.
In summary, in chapter 3, I discussed the ship handling in hash weather, including in ice area, fog, and heavy weather. Also, I analyzed an accident of ship grounding during a typhoon. Through analysis to this accident, we can get a lot of useful lessons which lay a solid foundation for us to avoid the same fault in the future work.

Chapter 4 Oil tanker operations of berthing/unberthing platforms:

Compared to the maritime operations in a conventional shipping company, there are a lot of special operations in the business of M&T of COSL, because, the main task of the company's tankers is to transport the crude oil from the sea terminals to port. Due to harsh sea conditions in open water, berthing/unberthing a sea terminal is more difficult than berthing/unberthing a dock in a port which is semi-closed water.

As a captain, I have maneuvered lots of shuttle tankers to berth at the sea terminals, therefore, I would like to share my personal experience in the following sections. Additionally, there are different weather conditions, different hydrological conditions, and different berthing facilities in different sea terminals. So, I selected three typical terminals situated in the BohaiBay, which are most difficult to berth in my experience, as examples to discuss the operation of berthing and unberthing marine terminals:

- The first one is Zhaodong platform, which located in shallow water;
- The second is the BZ3-2 platform, where the two point mooring method is used in berthing/unberthing operations.
- The third is the Penglai19-3 terminal， which is a PFSO.

4.1: The tanker operation of berthing/unberthing the Zhaodong platform:

In this section, I would like to use the Zhaodong platform as an example to discuss the method of berthing/unberthing an oil production platform.

4.1.1 The brief introduction to the platform:

1) General information: Zhaodong oil field, which is a joint venture of China National Petroleum Corporation and Apache Corporation, is situated in the west of Bohai bay. Geographic coordinates are38° 28′ 47″ N, 117° 44′ 22″ E. This oil field is within the 5m isobath and the charted depth of the water is around 2.2m. The daily output of this oilfield is 3,500 barrel.
2) Tide: The tides close to the oil field is regular semi-diurnal tides. The tide current rotate anti-clockwise mainly. During rising tide, the direction of main tide current

is in between 245° -275° with speed 0.6-1.3 nautical miles/hr. During ebb tide, the direction of the main tide current is 65° -85° with speed 0.5-1.5 nautical miles/hr.

3) Prevailing wind: the prevailing wind direction is south by southwest; the strong wind direction is north by northeast appearing in winter. The annual average wind speed is 4.6m/s with a maximum wind speed 31m/s. The annual average days with wind force more than 6 levels are up to 56 days, most of which appears in between March and May with 4-6 days every month.
4) Fog: the annual mean foggy days are around 14.7 days, which appears in between October to next February mainly, with the peak in December and January.
5) Ice condition: the ice condition is severe nearby the platform in winter. The range of land-fast sea ice is 10-15 nautical miles from the shore, and it roughly distributed along the 10-15m isobath with thickness around 15-25 cm.
6) Bottom material: the bottom material close to the platform is silt.

In order to meet the requirements of operation of the shuttle tanker, there is an artificial channel connecting the platform and deep sea dug by the oil field. The channel is 6 kilometers long, with upside 70 meters wide and downside 50 meters wide. The water depth is 3.8 meter. The direction of entering/leaving the channel is 250° and 070° respectively.(See figure 4.1Zhaodong platform—we can see that the water in this area is very turbid because of the shallow water)

Figure 4.1: Zhaodong platform (picture taken by the author)

4.1.2 Operation characteristics at this platform:

1) The channel is narrow; the room for maneuvering ship in front of the platform is limited, so, the ship maneuverability is restricted severely. During heavy weather or heavy ice conditions in winter season, the fairway buoy is easy to move. Additionally, it is much more difficult to berth/unberth the platform at night.

2) The charted water depth in the channel is 3.8m; the charted water depth close to No.1 and No.2 buoys is around 3.7m;the charted water depth nearby the platform is in between 4.5-4.7m. Therefore, the oil tanker needs to wait for high tide to berth/unberth the platform. The maximum permitted deadweight cargo capacity is

just 2100 tons, thus, Company's tankers can be partly loaded only).

3) There are a lot of fishing boats catching fish close to the channel and the platform. So, prior to 1 hour of an oil tanker entering/leaving the channel, the standby vessel of the platform should notice those fishing boats to keep far away from the channel and the platform. During entering/leaving the channel, the standby vessel should be escort for the oil tanker.

4) The requirement of the sea condition: when the visibility is less than 0.5 nautical miles, entering/leaving the channel cannot be carried out; when the wind force is more than 5 level (west to south wind more than 6 level), the berthing/unberthing should not performed. If there exists ice on the surface of the sea in the winter, the standby vessel should break the ice for the oil tanker.

4.1.3 My personal experience of operation of berthing/unberthing the Zhaodong platform:

1) **Entering/leaving the channel:**
The channel from the deep sea to the platform is an artificial channel6 kilometers long. There are 5 pairs of buoys with intervals 1.5 kilometers. The width of channel is 54 meters. When coming from open sea, the vessel should enter the channel at the middle point between No.1 and No.2 buoys, taking course 250° . During navigating in the channel, the captain should adjust the course according to the variation of azimuth of the buoys to ensure that the ship is navigating in the middle of the channel.

2) Preparation for berthing:
After passing No.9 and No.10 buoys, the oil tanker should reduce speed immediately. Generally speaking, the ship's speed in the channel should be faster for the need of keeping position. However, the navigable water range is limited around the platform, and in order to reduce the speed, the oil tanker can drop a single anchor with longer chain or both anchors with shorter chains. If the captain makes use of reversing the propeller to stop the ship, particular attention should be given to the bow turning to prevent the ship from rushing to the platform or into the shallow water area. At this time, the bow thruster must be used to keep the ship heading stable.
There are two berths on each side of the platform, with NE-SW direction. The length of each berth is 70m. The captain should select the berth according to the direction of wind and speed. The principal of berthing is that the bow of ship shall be against the wind and current to increase the steerage. The fender of the platform is much thinner, thus, during berthing the transverse speed should be as small as possible to avoid bumping against the fender.

3）The method of berthing:

After passing through the channel, the ship can berth alongside the platform directly with bow direction SW, or turn round to berth alongside another side of the platform with bow direction NE. It is convenient to berth alongside the Zhaodong platform with bow direction SW. So, a conventional method for berthing a platform/dock is enough. It is inconvenient to turn round for berthing the Zhaodong platform, because the turning area, which is located in between No.9, No.10 buoys and the platform, is limited. Therefore, it is not a good choice to turn round immediately in the turning area after passing through the channel. In practice, the oil tanker can bypass the platform from one side to another side alongside which the oil tanker will berth. During turning round, the captain must pay attention to the condition that the available sea area for turning round is only 60m wide, and the shallow water point must be prevented from being entered. The influence of wind and current to the ship should be taken seriously into account to prevent the ship from being pushed to the platform or into shallow water area because of the slow speed of the ship. During turning round, the captain should make joint use of a variety of methods including engine, rudder, anchor, bow thruster, and tug to turn round as soon as possible. After turning round, the tanker can berth in accordance with the conventional method.

3) The method of unberthing:

If the ship berths alongside the platform directly with the bow direction SW, when it comes to unberthing, the stern of the ship should leave at first. The captain can make the following operation:

- Let go head line, stern line, and after spring line.
- Single up to forward spring line.
- Take in the slack on the outboard chain (Avoiding the bow from colliding with platform. This anchor was dropped during berthing operation)
- Hard-a-starboard(in order to swing out the stern of the ship)
- Slow ahead
- Thruster slow pushing port(avoiding the bow from colliding with platform)
- Let the ship swing out stern first.

After the ship swings out stern 20m away from the platform, the captain should make the following operation.

- Stop engine
- Let go the forward spring line.
- Slow astern.
- Heave in the outboard anchor chain.

After the ship leaves 50m away from the platform and back into the turning round area which is situated in the northeast of the platform, the ship can turn round and enter the channel for departure.

During backing up, it is difficult to keep track of the ship is straight. So, the captain can make use of bow thruster or let the ship drag a short length of anchor to ensure the track of the ship in straight.

If the ship turns round to berth along another side of the platform with bow direction NE, it is more convenient to unberth. The best way to unberth is to swing out bow at first. The captain can make the following operation.

- Let go all lines
- Hard-a-starboard (making use of inboard rudder in order to prevent the rudder from colliding with the platform)
- Heave in the outboard anchor chain.(In order to swing out the bow. This anchor was dropped during berthing operation)
- Slow ahead

After leaving the platform, the vessel can make half ahead, and then enter the channel directly.

4.1.4: Contingency preparation during berthing/unberthing the Zhaodong platform:

Due to the special environment close to the Zhaodong platform (shallow water, ice operations, etc.), the captain must make a contingency plan aimed at the operation of berthing/unberthing and the special operation environment. Once a close-quarters situation occurs, the crew can operate according to instruction of contingency plan to avoid accident or to minimize the loss. During working at the tanker Binhai 607 as captain, I made the following contingency plan with the help from other crew:

4.1.4.1 Grounding in the channel:

1) During navigating in the channel, once the accident of grounding occurs, the captain must stop engine immediately, and cannot use the main engine blindly. The alarm should be sent to the crew and call the stand-by tug on site.
2) The captain should request the chief officer to measure the water depth around the vessel with sounding leadline in order to figure out the degree of grounding and the direction for refloating.
3) Changing sea chest from low level to the high level.
4) Bosun should measure the liquid level of all tanks, including cargo tanks, ballast tanks, fresh water tanks.
5) The engineers should measure the liquid level of all oil tanks, bilge tanks, side bilges.
6) Because the bottom material is silt (without rock) in this sea area and the speed of the ship is not fast (below 8 knots), normally, the hull of the ship cannot be damaged. If the captain confirms that the hull is intact, he should make a judgment whether the ship can refloat by itself according to the following factors---tide, wind, current, loading condition, degree of grounding and the water depth around the vessel.
7) When the captain judges that the ship cannot refloat by its natural abilities, and need to wait for the tide or external assistance, proper methods should be taken to

prevent the situation from worsening. Those factors which can worsen the situation of grounding include, but are not limited to, the following factors, wind, wave, surge, tide, floating ice, etc.

8) Because the channel is only 54m wide, whatever the ship refloat by herself or with help of external assistance, the situation that the bow of the vessel refloats but the stern of the vessel is grounded owing to the vessel crossing over the channel should be avoided utmostly.
9) During the vessel grounding, an abnormal inclination is likely to occur because of the influence of wind, wave, swell, current and so on. The captain should pay attention to this kind of phenomenon and preventive measures, including ballasting/deballasting water, transferring cargo oil, etc. should be taken into account.
10) During the vessel grounding and refloating, the chief engineer must personally command in the engine room to ensure that the fuel oil, water, compressed air, can be supplied as usual, and the critical equipment, including the main dynamic system, electrical power system, bow thruster, rudder and steering gear, anchor gear, boiler, and so on, can function well.
11) After the accident of the ship grounding occur, the captain should report the accident to the local MSA (marine safety administration) and company immediately, in order to get external help as soon as possible.

4.1.4.2: The ship out of control:

A sudden failure of a main dynamic system, electrical power system, rudder and steering gear will contribute to the ship coming out of control. Especially in the channel, it will threaten the safety of the ship and other ships. Compared to a ship out of control in open sea, once the ship is out of control in the channel, the situation is a worse threat to the ship, because the channel of the Zhaodong platform is very narrow. The following emergency measures should be taken into account to make the ship under control.

1) Sending the signal of "the ship out of control", arranging a special person to keep visual watch and radar watch. Keeping communication with other ships and MSA effectively and smoothly. Conforming the drifting direction and speed.
2) When the ship is out of control, effective measures should be taken immediately to stop the drifting state as soon as possible. If the residual speed is still high, the ship cannot maintain the course, and the ship may rush into shallow water, colliding with other ships or dock, the anchor must be dropped to stop the ship. This operation will cause the ship to swing the stern.
3) After making the initial measure to stop the ship coming out of control, the captain should call the stand-by tug to the scene.
4) Observing the change of water depth continuously by making use of the echo sounder. Essential measures should be taken to prevent the ship from grounding.
5) Starting emergency generator to supply power to emergency equipment.

6) All external doors, ports and similar openings must be closed; the tank hatches, tank cleaning apertures and sighting ports must be closed and kept liquid tight.
7) The captain should report the accident of the ship being out of control to MSA and company.
8) Keeping in touch with all relevant parties including MSA, company, platform, stand-by tug, and other ships passing by.

Additionally, we also prepared other emergency plans including emergency response for oil spills, serious injury, severe ice condition, fire and explosion, emergency towing, and so on. However, as these emergency plans are suitable for general use in any condition and not especially for Zhaodong platform, these emergency plans are not introduced here.

4.2: The tanker operation of two-point mooring:

BZ3-2 is the only platform, which adopts the method of two-point mooring for lifting oil into shuttle tankers in Bohai bay. (See Figure 4.2 the sketch of the two-point mooring system of the BZ3-2). Due to the specificity and complexity of the two-point mooring operation, I would like to introduce the operation for reader.

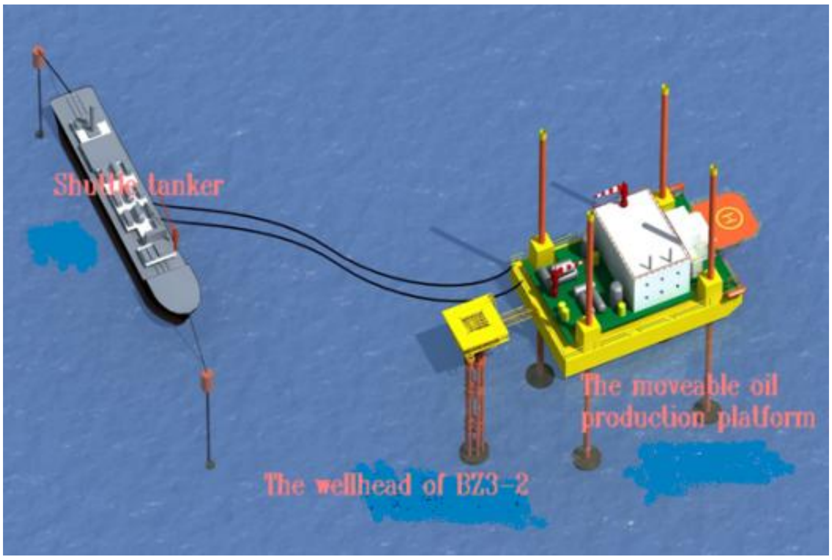


Figure 4.2: The sketch of the two-point mooring system of BZ3-2 [Made by author]

4.2.1 A brief introduction to BZ3-2 platform:

The BZ3-2 platform is situated in the middle of the Bohai bay, 145km east of Tianjin, 165km west of Dalian, Liaoning province. The geographic coordinatesare38° 55′ 00″ N, 119° 16′ 00″ E.(See figure 4.3)

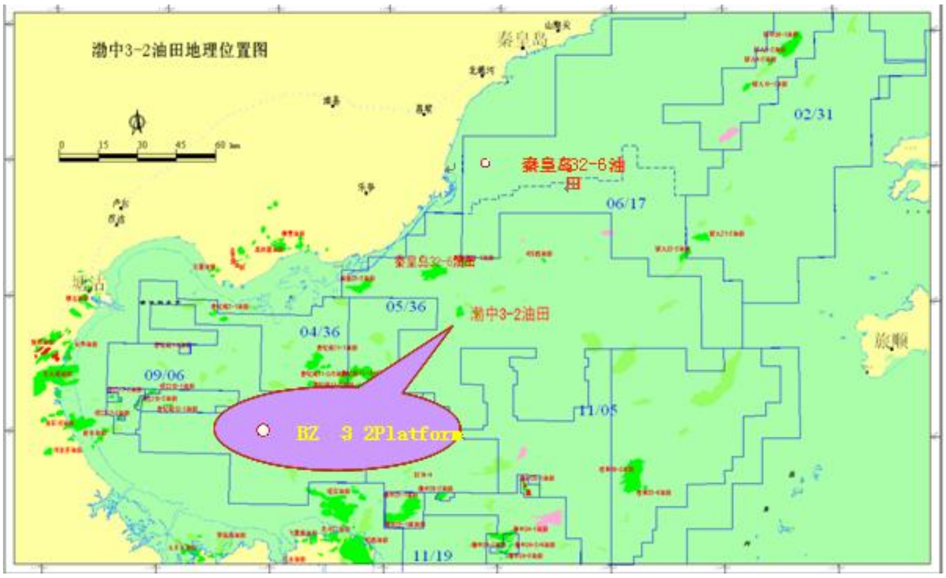


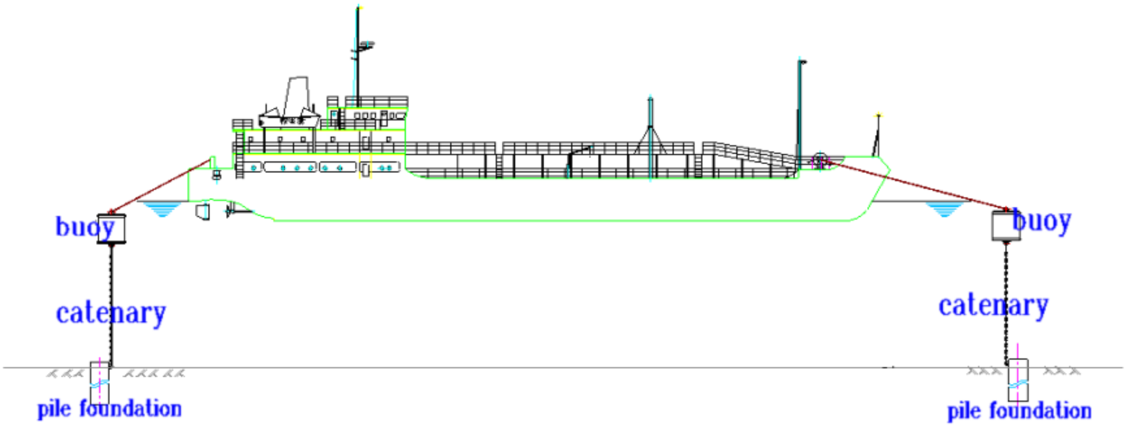
Figure 4.3: The location of the BZ3-2 platform [made by author]

The average water depth in this area is 30m; the mean annual temperature is 13.5℃; the mean wave high is 3.5m; the maximum wave high is 9m; the highest air temperature is 34℃; the lowest air temperature is -20 ℃; In winter, the thickness of level ice is 40cm; the thickness of rafted ice is 50 cm (once in 50 years); the maximum wind speed is 13m/s.

4.2.2 A brief introduction to the two-point mooring system:

1) The overview of two-point mooring system:

In this system, the oil tanker is tied in between two pontoons, of the two-point mooring system. (See figure4.4: The sketch of the two-point mooring system). In this sketch, the floating body can be an oil tanker or other floating body; the bow and stern is tied on to the two pontoons. The pile foundations are piled 35m deep into the sea bed; catenaries are connecting the piled foundations to the buoys, and the oil tanker is tied to the buoy by nylon hawsers on the top of buoys.



4.4: The sketch of two-point mooring system [made by author]

2) The main components of two-point mooring system:

- The friction chains on board the ship, which connect the ship to the nylon hawsers.
- Nylon hawsers, which connect the friction chains on board the ship to the friction chains on the underwater buoys.
- Friction chains on the underwater buoys, which connect the nylon hawsers to the underwater buoys.
- Catenaries which connect the underwater buoys to the pile foundations.
- Pile foundations, which fix the systems in the sea bed.

3) The characteristic of the two-point mooring system:

This mooring system is a set of large elastic systems. The first providers of elasticity are the underwater buoys with the second provider the nylon hawsers. After the underwater buoys connect with other components, these will generate buoyancy forces. Besides offsetting the gravity of itself, the catenaries, and friction chains, there is still remaining buoyancy force, namely, net buoyancy, which can contribute to the external force acting on the oil tanker tardily. In the two-point mooring system, when the oil tanker moves away from the original place under the action of external force, the net buoyancy can make the oil tanker go back to the original position. In the whole elastic system, the net buoyancy takes up large proportion, so, the underwater buoys are the main providers of the elasticity in the two-point mooring system.

4）The advantages/disadvantages of a two-point mooring system:

Advantages:

- Low cost, compared to conventional platform.
- Can be reutilized.
- The oil tanker does not need to be largely converted.
- It is convenient to install.

Disadvantages:

- There are two force directions (the bow and stern direction) without the effect of a vane like for a single-point mooring system.
- The ability to resist the external forces on the sides of the ship is low.
- The tonnage of the oil tanker which can be moored in this system is small.
- The suitable water depth is less than 50m.

4.2.3 My personal experience of operation of berthing/unberthing the BZ3-2 platform:

4.2.3.1 The technical characteristic of oil tanker berthing this platform:

In the company, there are only two oil tankers whose characteristic can meet the requirement to carry out this task; they are Binhai606 and Binhai607. The technical characteristic of the oil tankers are as follows:

- Control mode: centralized bridge control; variable pitch
- Bow thruster: 300kW
- Winch: the drawing force of the bow winch is more than 6t, with the stern winch more than 5t.
- The mooring hook can be decoupled immediately: the safe work load is more than 1.5 times of the breaking force of the mooring line.
- Crane: the length of the crane jib is more than half the width of the oil tanker plus 1m with the safety work load more than 4t.

4.2.3.2 The requirement of the technical characteristics of the assistance tug:

- The power of the main engine should be more than 4000 horse powers.
- Double propeller, double rudder, adjustable pitch propeller or Z-shape propeller.
- Bow thruster should be more than 300kW; it has better to have stern thruster.
- The 40 meters oil pipe can be coiled on the deck of tug.
- The rubber fender from the bow to stern should be fitted to both sides of the tug.
- A winch used to heave up the friction chain should be with the tug.
- A device on which the friction chain can be fixed should be fitted on the deck of the tug.
- The mooring line of the tug should be 6 inch diameter or more.
- The tug must be capable of maintaining the relative location to the oil tanker stable.

4.2.3.3 The requirement to weather condition during berthing/unberthing:

The weather should meet the following conditions:

- At the time of prior to and after slack water.
- .
- The wind force is below Beaufort6 level (strong breeze); the sea condition is under 3class (slight sea).
- In daytime; the visibility is 3 class or more (more than 500 meters).
- When the wind force is above 7 level, the oil tanker should unberth under assistance of tug.

Notice that the berthing/unberthing should be with assistance of the tug

4.2.3.4: The operation of the berthing

The principle of berthing is that during mooring to the ahead buoy, the tanker should maintain the stable position by herself with the bow against the sea current; during mooring to the astern buoy, the tanker should maintain the stable position under the assistance of the tug. Additionally, during operation, the oil tanker needs the assistance of two tugs. In practice, I carried out the operation of berthing in the following steps:

- The tanker should make the following preparations prior to 1 hour of slack water: stand-by engine, heave up the anchor, and crew in place.
- The No.1 tug is moored abreast the oil tanker and make fast forward and aft.
- The No.2 tug fishes up the head line and stand by prior to the oil tanker in place.
- The oil tanker sails into the berthing position, with the bow approaching to the buoy as close to as she could. The bow direction should be kept the same as the mooring direction, if possible.
- The No.2 tug gets close to the oil tanker with the main mooring line.
- The oil tanker connects the heaving line to self-mooring line, and then throws the heaving line to the tug.
- The No.2 tug pulls the oil tanker’s mooring line to the deck of the tug through the heaving line.
- The No.2 tug connects the oil tanker’s mooring line to the main mooring line connected to the buoy with a shackle.
- The oil tanker heaves in the main mooring line to the deck through tanker’s line and connect it to the main mooring hook.
- The No.2 tug leaves for fishing up the stern main mooring line.
- After the No.2 tug fishes up the stern main mooring line, the oil tanker backs slow astern to keep the bow mooring line tight and makes the stern of tanker approach to the stern buoy as close to as possible.
- The No.1 assists the oil tanker to maintain the position close to the astern mooring buoy.
- The No.2 tug gets close to the oil tanker with the mooring line.
- The oil tanker connects the heaving line to the self-mooring line, and then throws the heaving line to the No.2 tug.
- The No.2 tug pull the oil tanker’s mooring line to the deck of the tug through the heaving line.
- The No.2 tug connects the oil tanker’s mooring line to the main mooring line connected to the buoy with a shackle.
- The berthing operation is over.

4.2.3.4: The operation of unberthing:

1) The bow is toward the terminal and against the sea current (unberthing is forbidden when the bow is down with the sea current).

- Let go the stern line.
- After the stern is clear, slow ahead to slack the headline; and then, let go the headline.
- The bow thruster pushes the bow to starboard; starboard 20; half ahead; and then, leave the terminal.

2) The stern is toward the platform and against the sea current.

- Let go the stern line.

- After the stern is clear, slow ahead to slack the headline; and then, let go the headline.
- Pushing the bow to keep away from the buoy; half ahead; and then, leave the terminal.

3) The stern is toward the terminal and down with the sea current.

- Slow astern to slack the stern line, and then, let go the stern line.
- Let go the headline after the bow turn round 30° -40 ° under the influence of leeway and drift.
- Slow astern or making use of the leeway and drift to make the bow clear; half ahead, and then, leave the terminal.

In summary, as the environment on the sea always changes with time, I can only make a qualitative analysis for berthing/unberthing the site. Additionally, different captains have different understandings of operation method in detail, and every operation of berthing/unberthing is different from last time. Therefore, the foregoing operation method of berthing/unberthing platform is only the general method.

4.3: The operation of berthing FPSO of Penglai 19-3 oilfield:

4.3.1 The brief introduction to FPSO of Penglai 19-3 oilfield:

The BohaiPenglai terminal is located offshore approximately 50 nautical miles NW of Penglai, China, at the entrance to the Bohai Bay. The terminal is located in a particularly sensitive area with commercial fishing being a major activity and is also close to commercial shipping lanes with a high traffic density.

The geographic latitude of the FPSO is in position: latitude: 38° 23' 34" north, longitude: 120° 04' 52" east. (See figure: 4.5)

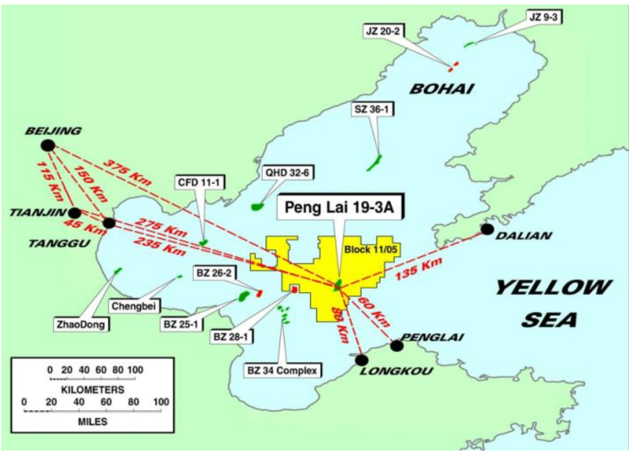


Figure 4.5The position of the Penglai 19-3oilfield [made by author]

The Penglai 19-3terminal is a FPSO with 281,000 tones deadweight. It was built in 2007. The FPSO is moored at the bow to a fixed tower by means of a soft mooring yoke that allows the FPSO to weathervane through 360 degrees and gives full freedom for pitch and roll. The terminal is located in a water depth of 25.5m (chart datum) and 26.2m (mean sea level). The tanker mooring for crude export is in tandem with the terminal, i.e., the lifting tanker's bow to the terminal's stern via a combined chain/synthesis rope mooring hawser that has the capability for quick release. The FPSO is designed to stay connected to the mooring tower through all regional weather conditions and has no self-propulsion systems. (See figure 4.6 the layout of Penglai 19-3 oilfield)

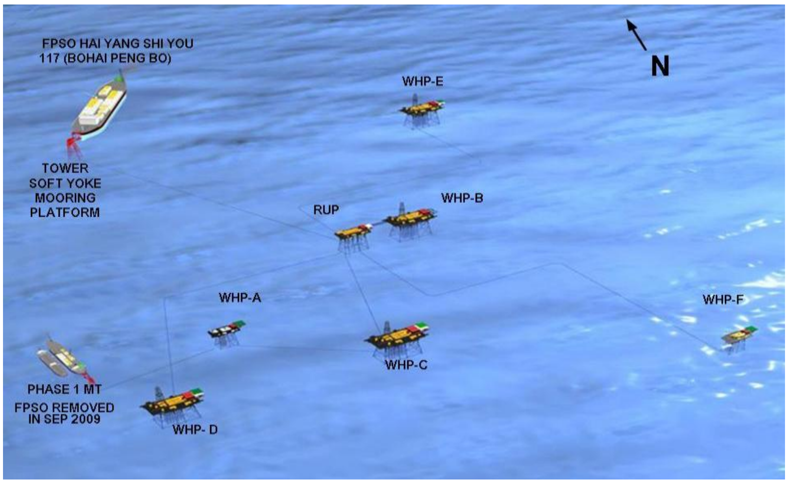


Figure 4.6The layout of the Penglai 19-3 oilfield [made by author]

Penglai crude oil is delivered through a lifting loading hose with an "ANSI 150" 16-inch or 400-mm diameter flange. The loading hose is fitted with a quick connect/disconnect coupling and a breakaway coupling. The breakaway coupling will close and part when the loads on it exceed 36 tons. In case of an emergency it disconnects to minimize crude release to the environment. The lifting export loading hose is fitted with 4 lengths of electrically discontinuous hose sections in order to eliminate electrical current in the loading hose string.

An ISV[sea appendix2] is available in a static tow arrangement made fast to the stern of the lifting tanker so as to maintain the lifting tanker at a safe distance from the terminal. On occasions, the lifting tanker may be required to have its engines running astern for some of the time it is moored to the terminal.

4.3.2: The brief introduction to local weather:

During the winter monsoon, NW winds averaging force 4 last from early September through March and occasionally into April. Gales represent 5-10% of the observations in December and January and 1-5% in the other winter months. From June to August the SE to SW winds of the summer monsoon are not as dominant or as strong as winter winds, and at times there are spells of light variable winds much as in spring and autumn. The summer winds average force 2 to 3; gale frequency is less than 1% in June and September, but is 1-5% in July and August when typhoons, though rare, usually occur. The average frequency of typhoons is less than one per year [reference 24].

Winters are exceptionally cold with a mean monthly temperature below 0 ℃. Summer is, however, very hot, and the seasonal range of temperatures is extremely large. Average air temperature in the summer is 22 ℃ in July and August, dropping to –2 ℃ in January and February and can drop to as low as –16 ℃.

Rainfall is the greatest during the summer months, with the maximum falling in June, July, and August. Thunderstorms occur, on average, 20 days annually. Precipitation falling as snow has a duration of about five months from November to March. The average ice and snow accumulation in February is about 3.3 cm, about 2.3 cm in January, and no more than 2 cm in November and December.

Humidity is greatest in the summer at 90% in July and falling to 25% in March. The yearly average is 72%.

Sea fog is rare during the months from August to January. The most frequent fog occurs from March to July, with the worst month being May. Dust and sandstorms are experienced at times, with dust haze being fairly extensive.

Sea conditions are rarely calm at the location. The combined (sea and swell) wave heights can exceed 4.0 m.

The location can be subject to the formation of sea ice. The sea's temperature ranges from 23 ℃ in the summer to 1 ℃ in the winter. The shores of Bohai Bay and Liaodong Wan are bordered by a belt of ice of varying extent from December to March. The central part of Bohai Bay is mainly ice-free, but areas of drift ice may be encountered.

The terminal's location is in an area of irregular semi-diurnal tide flow. The flooding tide sets about NW (315°) and ebbing tide sets SE (135°) at rates of about 0.5 to 1.5 knots. There is no regular set pattern to the current's flow in the comparatively shallow and murky waters of Bohai Bay. Tide height has no effect on the floating sea berth, but is included for interest only. The highest astronomical tide is 1.6 m above chart datum and the lowest astronomical tide is -.2 m. The greatest tide range is 1.8 m.

Typhoons rarely occur, and they are usually downgraded to a tropical depression when approaching. The average frequency of typhoons is less than one per year [reference 24].

4.3.3: The method of berthing the PFSO

After 1-2 hours of rising tide or ebb tide, the heading of the FPSO will become stable. At this time, the shuttle tanker sails on the course, which is the heading of the FPSO, in the back of FPSO, with very slow speed. At about one nautical mile off the FPSO, the shuttle tanker keeps steady and the ISV/tug will be made fast to the stern by the ISV/tug line. To assist in the mooring operation, the same ISV/tug will act as a static tow (See note 1) after the tanker has been secured.

A second ISV or terminal workboat will pass the mooring hawser messenger line to the lifting tanker's forecastle area. This messenger must lead through the shuttle tanker's centerline panama lead, through the chain stopper to an empty mooring winch drum. The messenger line must be run directly onto the shuttle tanker mooring winch drum and must never be placed around the mooring winch drum end. The mooring winch must be capable of lifting at least 15 tones to allow for losses due to changes in lead direction and friction and must allow the shuttle tanker bow to be warped in, if necessary.

The mooring hawser messenger/pickup line will be heaved in as the shuttle tanker approaches the terminal. The pickup line is permanently attached to the mooring hawser chafing chain, and the combined weight of the mooring hawser and the chafing chain is about six tones. Three links of the mooring hawser chafing chain must pass through the shuttle tanker chain stopper when it is brought inboard prior to the chain stopper's securing bar being locked into position. The shuttle tanker will then be moved astern until there is a moderate weight on the mooring hawser to confirm the integrity of the mooring system.

The shuttle tanker's main engines should keep running astern from the time the shuttle tanker is deemed safely moored until the lifting export loading hose is connected to the shuttle tanker's starboard manifold and the ISV has connected the static towline to the shuttle tanker's stern.

4.3.4 The method of unberthing the FPSO:

The shuttle tanker will usually be let go immediately after the lifting export loading hose is released. The ISV will not be disconnected from the shuttle tanker's static tow for the unmooring operation. However, the ISV towline may be altered appropriately.

A responsible officer with continuous radio contact with the bridge must be located on the shuttle tanker forecastle during the unmooring operation. The mooring hawser shall be released from the shuttle tanker chain stopper by either stopping the shuttle tanker's astern main engine movement or reducing the load tension of the ISV static tow.

The mooring hawser pickup/messenger line must be "paid out" in a controlled manner as the shuttle tanker moves astern of the terminal. When the mooring hawser pickup/messenger line is clear of the shuttle tanker, the captain will maneuver the shuttle tanker to a position at least three nautical miles to any terminal facilities.

Additionally, during operation, the shuttle tanker should provide a good lee on the starboard side to affect a safe transfer of the terminal's personnel and equipment to the ISV or terminal workboat.

4.4: The discussion on how to use shuttle tankers with DP system on Chinese Costal Shelf:

4.4.1 The brief introduction to DP system:

A DP system is designed to perform a wide range of activities where the vessel is to be maintained **a**t a fixed location relative to the sea bed, or moved in a desired direction. The system controls the vessel by means of active thrust and makes the vessel to move(or keep its position and heading) as specified by the operator, in the presence of wind, currents and waves, which generate force acting upon the vessel. （See figure 4.7 Dynamic Positioning simply explained）.

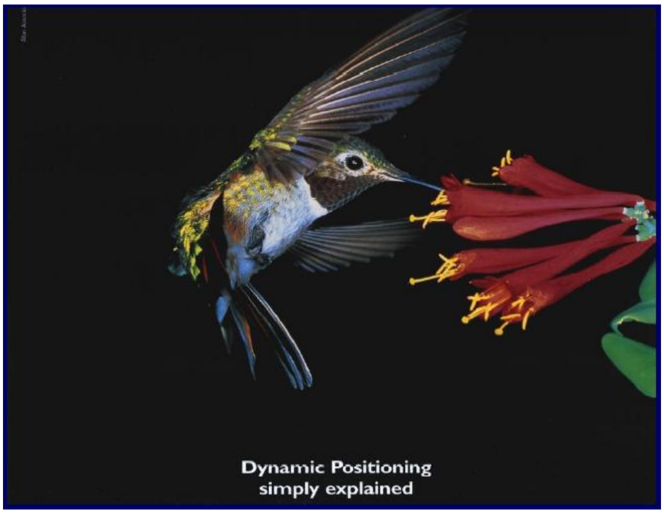


Figure 4.7 Dynamic Positioning simply explained (Ref: 20)

The DP system has a specified set of operational modes. In each mode, the operator enters data which exactly specify the maneuver to be performed. The control system uses this information as well as data from reference systems and sensors and generates the control signals (desired revolutions per minute, pitch or azimuth angle etc.) to each thruster, so that the vessel moves in the specified manner.

The DP system receives information from DGPS's, (DGPS: Differential Global Positioning System) gyrocompasses, vertical reference sensors, wind sensors, HPR (hydro positioning reference) and laser radar. It controls the vessel in three coordinates- in the surge, sway and yaw axes. The coordinates can be controlled both manually and automatically; it is also possible to control some coordinates manually while the others are under automatic control.(See figure 4.8: the components of a DP system)

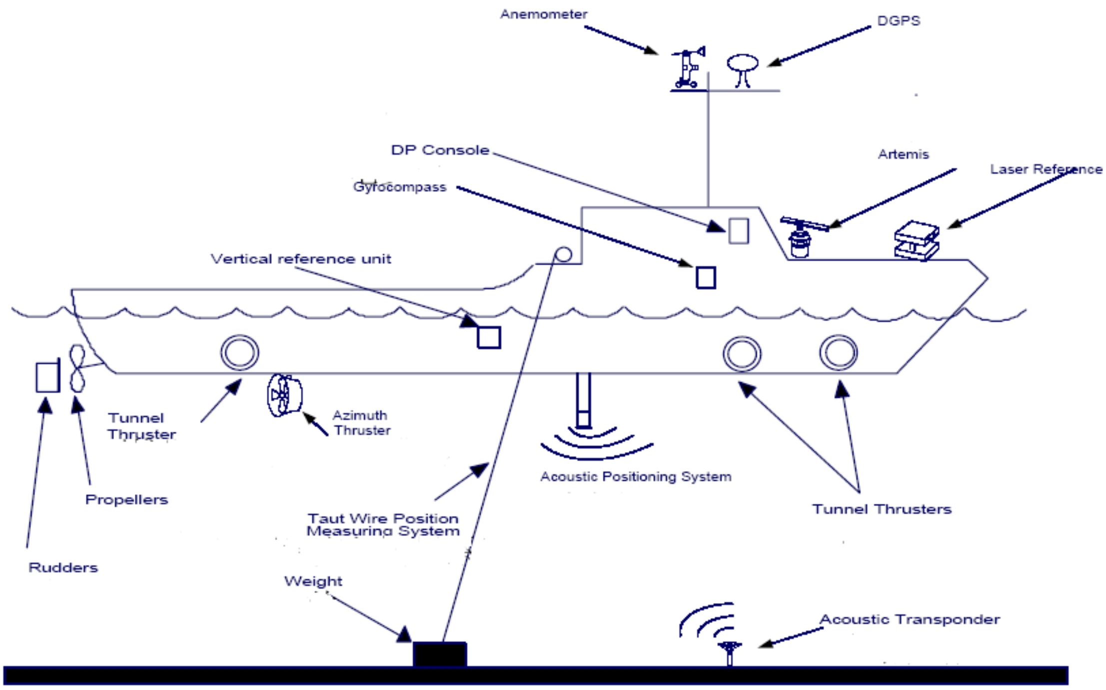


Figure4.8: the components of DP system [ref 18]

4.4.2: The application of DP systems in the marine industry:

The dynamic positioning system of vessels is developing rapidly and is getting extensive application in the military and in special vessels in the world. Firstly, the DPS system was employed on the drilling ships, the parent ships of ROVs (Remote Operated Vehicles), and fire-fighting ships, which need to operate in fixed position on the deep ocean. As of 1980s, the DP system was applied extensively on the following ships, drilling ships, marine research ships, salvage ships, deep sea mining ships, pipe laying ships, lifting ships, parent ships of ROVs, FPSOs, shuttle tankers, and so on (See figure 4.4.6 vessels with DPS).The first DP shuttle tanker entered into service in NW European waters. This was carried out by Statoil in 1981 at single point loading facility at the Statfjord Field. As early as 1997, there are around 20 DP shuttle tankers in the NW European shuttle tanker fleet. (The statistical figures come from [ref 19])

Regarding the aspect of regulations, in 1977, DNV issued the first specification for the DP system[reference 25], and in the late of 1990s, the major classification societies in the world made relevant specifications successively. Also, in 2002, China Classification Society issued guide lines for dynamic positioning systems[reference 25]. Therefore, the technology of DPS has been pretty mature now. However, when it comes to the application of shuttle tanker on Chinese Costal Shelf, there is not even one tanker with DPS, according to my survey of CNOOC, CCS, and several oil tanker companies.

Figure 4.9Vessels with DPS [reference 23]

4.4.3 Discussion of the application of shuttle tankers with DPS on Chinese costal Shelf

4.4.3.1Overview of oil platform exporting crude oil through shuttle tanker on Chinese Costal Shelf:

1) The exporting terminals in the Bohaibay :(See Figure 4.10Oilfields in the Bohai bay)

- BZ34-4 oil field: exporting terminal is FPSO(BohaiChangqing)
- QHD32-6 oil field: exporting terminal is FPSO(BohaiShiji)
- BZ25-1 oil field: exporting terminal is FPSO(Haiyangshiyou 113)
- CFD11-1/2 oil field: exporting terminal is FPSO(Haiyangshiyou 112)
- BZ34 oil field: exporting terminal is FPSO(BohaiYouyi)
- FL19-3 oil field: exporting terminal is FPSO(BohaiMingzhu)
- BZ 3-2 oil field: exporting terminal is a two-point mooring
- GZ9-3 oil field: exporting terminal is a platform
- Zhaodong oil field: exporting terminal is a platform
- Chengbei- B platform: exporting terminal is a platform

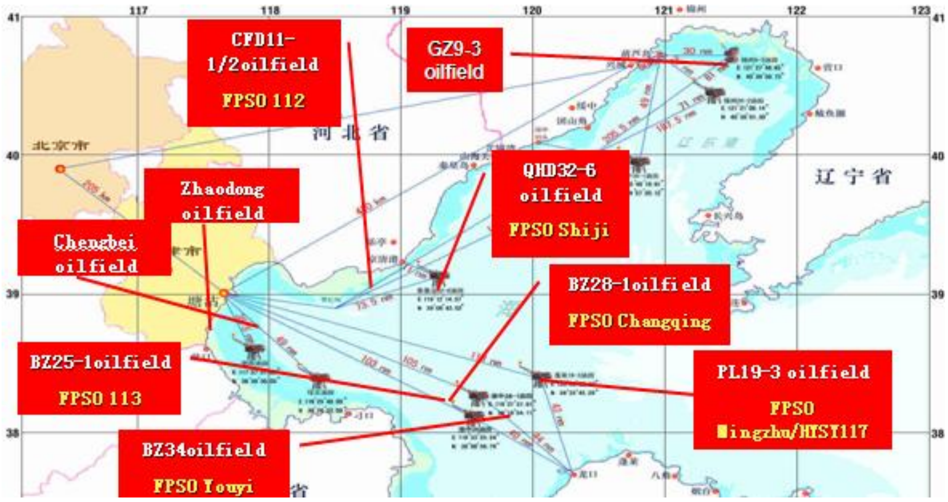


Figure 4.10oilfields on the BohaiBay (made by the author)

2) The exporting terminals in the South China Sea (See Figure 4.11):

- Huizhou oil field: exporting terminal is FPSO(Nanhai Faxian)
- Panyu oil field: exporting terminal is FPSO(Haiyangshiyou 111)
- Xijiang oil field: exporting terminal is FPSO(Haiyangshiyou 111)
- Lufeng oil field: exporting terminal is FPSO(NanhaiShengkai)
- Liuhua oil field: exporting terminal is FPSO(Nanhaishengli)
- Wenchang oilfield exporting terminal is FPSO(NanhaiFenjin)

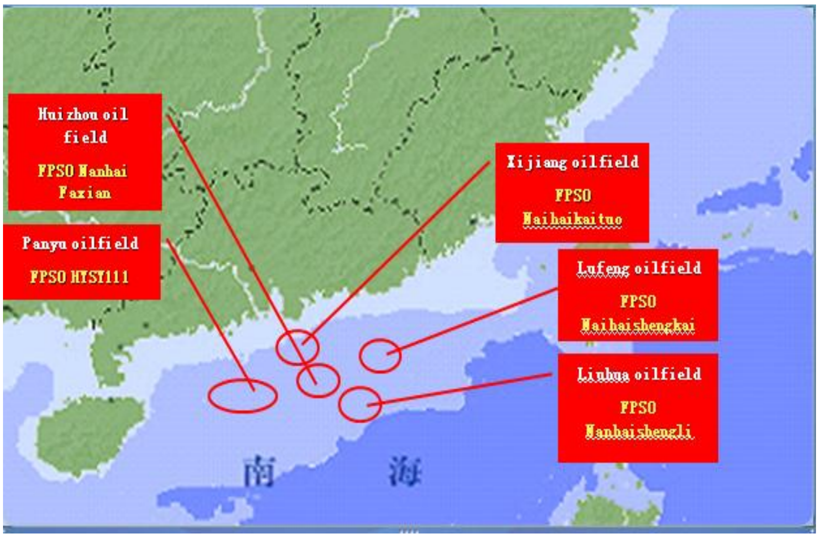


Figure 4.11Oilfields on the South China Sea (made by author)

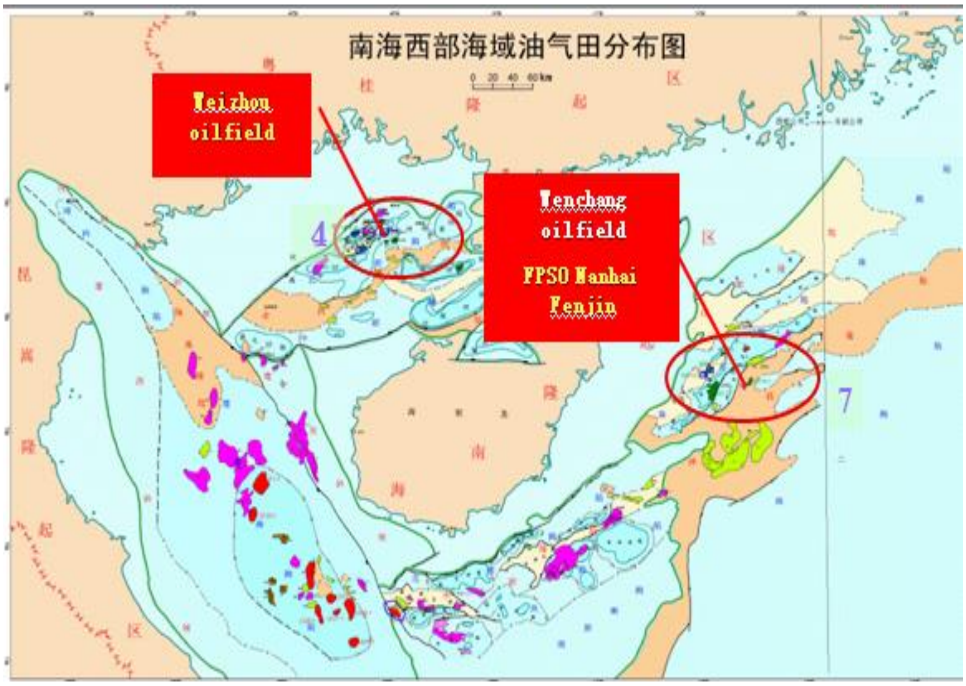


Figure 4.12Oilfields in the South China Sea (made by author)

4.4.3.2）The advantage of application of oil tankers with DPS:

- The oil tankers with DPS can operate in deep water sea area.
- The oil tankers with DPS are easy to operate and they do not need the help of support tugs, so it is convenient to berth/unberth sea terminals with low weather restrictions. Also, the risk of operation of berthing/unberthing a sea terminal can be reduced.
- The cost of DPS is not very high. According to an interview to the new ship building supervisor of our company, a set of DP-2 system is 0.5 million U.S. dollars without taking into account the propeller cost and installation cost.
- Reducing the construction cost of a sea terminal. If a platform exports crude oil through oil tankers with DPS, they do not build a complex mooring system like a two-point mooring system or berthing platform for shuttle tanker.

4.4.3.3）The cause analysis of oil tankers with DPS not being used on Chinese Costal Shelf.

- Most of sea terminals are situated in the shallow water on the Chinese Costal Shelf. In shallow water, the technology of berthing/unberthing a sea terminal by making use of two-point mooring system or other traditional ways is very mature, though there are still lots of risks existing in the operation. That is to say, there is none of an absolute need to employ the DP technology.
- The master of an oil tanker with DPS needs special training with high training cost and longer duration.

- There is none of a precedent of using oil tanker with DPS on Chinese Costal Shelf, so there is none who wants to be the first “crab-eater”.
- An oil tanker with DPS is customized for sea terminals; therefore, if a shipping company wants to develop this kind of ship, it must get a long term contract from Oil Companies.

4.4.3.4）The prospect of development of shuttle tanker with DPS in COSL:

As there are lots of sea terminals exporting crude oil with shuttle tanker on the Chinese Costal Shelf, there is a big prospect for making use of oil tankers with DPS to export crude oil from sea terminals. Now, through communicating with other shipping companies, I found that a great number of shipping companies want to develop this type of shuttle tankers. As subsidiary of CNOOC, COSL has a chance to get higher market share. So, COSL should seize the initiative to develop the shuttle tanker with DPS. However, there are still some barriers in the way of development.

Firstly, the shipping business is not the main business in COSL, so, COSL may prefer to spend more money on other main business departments, such as the drilling department, logging department and so on, rather than on the shipping department.

Secondly, compared to other business, there exist more risks in the shipping business, for example oil pollution risk, berthing/unberthing sea terminal risks etc. , therefore, COSL is very cautions in aspect of investing in the shipping business. Then, how can we solve the problems? I have the following suggestions.
The shipping business can be divided away from COSL, and an independent legal entity can be established, meanwhile, capital can be drawn into the new company. In the new company COSL is only a major shareholder. Like this, on one hand, if oil pollution or other marine perils occur, the main business of COSL will not be impacted; on the other hand, the fund, which new ship building need, can be rose through multi ways. One word, whatever the development way COSL select, as a new technology in Chinese Costal Shelf, the DPS should be adopted.

In summary, in this chapter, I have discussed several berthing/unberthing methods to berth sea terminals, including conventional platforms (Zhaodong platform), two point mooring platforms (BZ3-2), and FPSOs (Penglai19-3), and then, through my personal operation, I underline that the operation of berthing/unberthing sea terminals is very difficult and is influenced by weather very deeply. So, I suggest that shuttle tankers with DPS should be used on the Chinese Costal Shelf. However, even it is still a kind of new ship type and new operation type with lots of barriers to be implemented for widely use, this kind of technology has been employed as of the 1970s. At last, through analysis of marketing requirements, I strongly suggest that COSL should spend more funds on building shuttle tankers with DPS. In order to realize this target, COSL can fit the organization structure to shipping business.

Chapter 5: Risk analysis in maritime activities:

As discussed in chapters 3 and 4, there are a great number of risks in maritime activities. So, in order to ensure safety of life at sea and prevent pollution, there is a need to figure out the risks existing in the marine activities.

5.1: Hazard identification:

The factors, which affect the safety of maritime activities, including weather conditions, hydrological conditions, equipment conditions, human factors, and so on, always change with time; therefore, we can only use a simple qualitative risk analysis methodology to identify hazards that are associated with a maritime operation. In practice, we make use of the JSA method to identify the risks existing in the maritime activities. Additionally, because there are a myriad of risks existing in every links of maritime activities, such as passing a shoal, tank washing operation, mooring a buoy operation, navigating in narrow channel, and so on, in this chapter, I can only identify the risks existing in the operations discussed in previous chapters, namely, the risks of avoiding typhoon, and the risks of berthing/unberthing a platform.

5.1.1: The JSA (job safety analysis) of avoiding a typhoon:

Table: 5.1 JSA of avoiding typhoon

JSA of avoiding typhoon		
No	Sequence of Basic Job Step	Potential Accidents or Hazards
1	The preparedness of technologies and skills	1）The shortage of technology of avoiding typhoon causes personal injury and property loss.
2	Increasing the crew's awareness of avoiding typhoon	2）Weak awareness of avoiding typhoon causes personal injury and property loss.
3	Learning and exercising the emergency procedures.	3）Poor understanding of emergency procedures, roles, and responsibility cause personal injury and property loss.
4	Collecting information of typhoon forecast.	4）Collecting the information of typhoon forecast untimely and inaccurately causes personal injury and property loss.
5	Inspection prior to typhoon arriving.	5）Failure of engine, rudder or other equipment cause personal injury and property loss.
		6）Failure of watertight fittings causes water entering into the ship and damage of equipment.

		7）Failure of communication equipment causes internal or external communication stop, and the emergency action cannot get necessary supports.
		8）Failure or lack of plugging device and drainage device cause water entering into the ship and damage of equipment.
		9）Drainage on deck is not sufficient.
		10）Insufficient stability causes damage of the ship.
		11）The movement of the equipment causes damage of ship and equipment.
		12）The movement of cargo causes damage of ship and equipment.
6	Avoiding the typhoon when a vessel is alongside the dock.	13）The mooring line is breaking cause the damage of the ship.
		14）Collision between ship and dock causes damage of ship and dock.
		15）Improper temporary response causes damage of the ship.
7	Avoiding the typhoon when the vessel is in anchorage.	16）Selecting improper anchorage causes damage of the ship.
		17）Improper anchor point causes damage of the ship.
		18）Collision with other anchored ship or dangerous obstacles cause damage of the ship.
		19）Improper temporary response causes damage of the ship.
8	Avoiding typhoon during navigating on the sea.	20）Wind and wave cause the damage of crew and ship.

5.1.2: The JSA of berthing the terminals on the sea:

Table 5.2: JSA of berthing a docks or terminals

JSA of berthing a docks or terminals		
No	Sequence of Basic Job Step	Potential Accidents or Hazards
1	Berthing plan making	1) Unclear assignments of responsibility and lack of unified command cause failure of berthing, collision, and personal injury.
2	Approaching platform	2) Collision with platform because the speed is too fast.

3	Control the speed through anchoring	3) Collision with platform because the anchor cannot be dropped off timely to control the ship’s speed.
		4) The anchor cannot be dropped off; failure of winches causes the failure of berthing or collision with platform.
		5) The anchor hooks up and damages a submarine cable or pipe.
4	Entering the berth	6) The ship is out of control or collides with the platform because of the impact of the wind and current.
		7) Disturbed communication causes the failure of berthing, collision with platform, or personal injury.
5	Sending the heaving line	8) Injury of personnel because of failure to inform them.
		9) Damage of the equipment due to inattention to the environment.
6	Sending the mooring line	10) Failure of berthing because the heaving lines fail to be sent to shore due to entangling.
		11)During the mooring line floating on the surface of sea, the mooring line gets involved in the propeller, and break because of improper use of main engine
		12) Failure of berthing and collision with platform because breakdown of winches causes the mooring line not to be heaved up or sent out.

5.1.3: The JSA of unberthing the terminals on the sea:

Table 5.3: JSA of unberthing a docks or terminals

JSA of unberthing a docks or terminals		
No	Sequence of Basic Job Step	Potential Accidents or Hazards
1	Preparation prior to departure	1)The operators working at the bow and stern do not have good understanding of the unberthing plan, which causes collision with dock, broken mooring line, injury of personnel and grounding.
		2) Poor communication about the unberthing plan between the ship and shore causes collision with dock, mooring line broken, injury of personnel, grounding.
		3) Disturbed communication cause collision with dock, mooring line broken, personal injury, and grounding.

		4) Failure of the communication equipment causes the collision with dock, mooring line broken, injury of personnel, grounding.
		5) Poor communication between bridge and engine room causes that the information of engine failure cannot be informed to bridge timely, which contributes to accidents.
2	Stand-by engine	Engine order telegraph out of order causes failure to deliver the engine order, which contributes to collision with dock, mooring line broken, injury of personnel, grounding.
		During unberthing, the engine or rudder is out of order which causes collision with dock, mooring line broken, injury of personnel, grounding.
		The mooring line is cast off before the main engine gets ready.
3	Unberthing	Inattention to the environment causes collision with dock, other ship, and facilities of the dock.
		The environmental changes cannot be informed to the captain by the commander working at the bow and stern of the ship, which causes collision with dock, other ship, and facilities of the dock.
		Improper use of engine causes collision with dock, other ship, and facilities of the dock.
		Mooring line is not withdrawn in time, which causes the mooring line to involve the propeller, and then, causes the mooring line broken and injury of personnel.
		During unberthing the terminals at sea, none of the standby tugs is available, which causes collision with terminal, the mooring broken and injury of personnel.
		Collision with dock, other ship, and facilities of dock, because of the impact of wind, wave and current.

5.2: Risk analysis and assessment:

5.2.1: Introduction to the method of risk analysis:

The bulk of risks exited in the maritime operation can just be analyzed and assessed qualitatively. In our daily work, the LEC (Likelihood, Exposure, and Consequence) method is adopted widely. In this method, the risk is defined by the product of three factors related to the operation. The three factors are as follows:

1) The likelihood of the accident occurring (L).
2) The frequency of the personal exposing in the danger environment.(E)

3) The possible consequence of the accident occurring (C).

Every factor will be assigned a seriousness grades. The final result of risk assessment (R) is the product of the grade of three factors, namely, R=L*E*C

The scoring criteria of the three factors are as follows:

Table 5.4: The likelihood of accident occurring（L）

Grade	The likelihood of accident occurring	Grade	The likelihood of accident occurring
10	Utterly predictable	0.5	impossible
6	Highly possible	0.2	Very impossible
3	Possible, but not often	0.1	Impossible in practice
1	Low possibility，completely unexpected		

Table 5.5: The frequency of the personnel exposure in the dangerous environment.(E)

Grade	E1（personal injury and occupational disease）： The frequency of personnel exposed in the dangerous environment.	E2（property loss and environment pollution）： The frequency of appearance of dangerous state.
10	Continuous exposure	Normal state
6	Exposure in work time	Exposure in work time
3	Once every week or accidental exposure	Once every week or accidental exposure
2	Once every month	Once every month
1	Several times each year	Several times each year
0.5	Rarely exposure	Rarely exposure

Table:5.6 The possible consequence of the accident occurring (C)

grade	**The possible consequence of the accident occurring**			
	Personal injury	**Occupational health**	**Property loss**	**Impact to environment**
10	More than 1 persons die		＞10 million RMB	Heavy impact to environment, Uncontrollable discharge

8	One person die or more than one person disabled	More than one occupational disease	1—10million	Medium impact to environment, Uncontrollable discharge
4	One person disabled permanently	occupational disease (one person)	100thousand—1million	Slight impact to environment, Uncontrollable discharge
2	Loss time	occupational frequently-occurring disease	10 thousand —100thousand	Slight impact to environment, controllable discharge
1	Slight，only first aid	Occupational poor health	＜10 thousand	No impact to environment

5.2.2 The identification of risk level:

After figuring out the R value, we can compare the R value with the standard value to identify the risk level of a specific operation, and grade the risk according to the result of the risk assessment. The following is a form for risk classification.

Table 5.7: Form of risk classification:

R=L*E*C	Risk level
＞180	Level 1
90-150	Level 2
50-80	Level 3
20-48	Level 4
≤18	Level 5

Note:
Level 1: Very dangerous, stop work.
Level 2: High risk, rectify immediately.
Level 3: Significant risk, need rectification.
Level 4: Normal risk, attention
Level 5: Slight risk, attention

5.2.3: Assessment of the identified risk:

In this section, I will carry out the assessment of the identified risk according to the LEC method.

5.2.3.1: Risk assessment of avoiding typhoons:

Table 5.8 Risk assessment of avoiding typhoons:

No	Operation/program/ activities	Risk resources	Possible consequence	Likelihood （L）	Frequency of exposure （E）	Consequence(C)	Risk grade （R）	Risk level
1	The preparation of technologies and skills	1）The technology shortage of avoiding typhoon	personal injury and property loss	3	3	10	90	Level 2
2	Increasing the crew's awareness of avoiding typhoon	2）Weak awareness of avoiding typhoon	personal injury and property loss	5	3	10	150	Level 2
3	Learning and exercising the emergency procedures.	3）Poor understanding of emergency procedures, roles, and responsibility	personal injury and property loss	3	3	10	90	Level 2
4	Collecting the information of typhoon forecast.	4）Collecting the information of typhoon forecast untimely and inaccurately	personal injury and property loss	3	3	10	90	Level 2
5	Inspection before typhoon arriving.	5）Failure of engine, rudder or other equipment	personal injury and property loss	3	3	10	90	Level 2
		6）Failure of watertight fittings	Damage of equipment	3	3	2	18	Level 5
		7）Failure of communication equipment	Emergency response cannot get the support from shore	3	3	10	90	Level 2
		8）Failure or lack of plugging device、drainage device	Damage of equipment	3	1	8	24	Level 4

		9）Drainage on deck are not fluent.	Damage of cargo	3	3	2	18	Level5
		10）Unreasonable stability cause the damage of ship.	Damage of ship	3	3	10	90	Level 2
		11）The movement of equipment	Damage of equipment	3	3	4	36	Level 4
		12）The movement of cargo	Damage of cargo	3	3	4	36	Level 4
6	Avoiding typhoon when alongside the dock.	13）The mooring line breaking	Damage of ship	3	3	4	36	Level 4
		14）Collision between ship and dock	Damage of dock and ship	3	3	4	36	Level 4
		15）Improper temporary response	Damage of ship	3	3	8	72	Level 3
7	Avoiding typhoon when in anchorage.	16）Selecting improper anchorage	Damage of ship	3	3	10	90	Level 2
		17）Improper anchor point	Damage of ship	3	3	4	36	Level 4
		18）Collision with other anchored ship or dangerous obstacles	Damage of ship	3	3	4	36	Level 4
		19）Improper temporary response	Damage of ship	3	3	8	72	Level 3
8	Avoiding typhoon when navigating on the sea.	20）Wind, wave cause the damage of crew and ship.	Personal injury and damage of ship	1	6	10	60	Level 3

5.2.3.2: Risk assessment of berthing a platform:

Table 5.9: Risk assessment of berthing a platform

No	Operation/program/activities	Risk resources	Possible consequence	Likelihood （L）	Frequency of exposure（E）	consequence(C)	Risk grade （R）	Risk level
1	Berthing plan making	1)Unclear assignments of responsibility, lack of unified command	Failure of berthing, collision, and personal injury.	3	2	4	24	Level 4
2	Approaching platform	2) The speed is too fast.	Collision with platform	3	3	4	36	Level 4
3	Anchoring for controlling the speed of the ship	3) The anchor cannot be dropped off timely to control the ship's speed.	Collision with platform	3	3	2	18	Level 5
		4)The anchor cannot be dropped off, the Failure of windless	The failure of berthing or collision with platform.	3	1	4	12	Level 5
		5) The anchor hooks up and damages the submarine cable or pipe.	The anchor hooks up and damages the submarine cable or pipe.	3	1	4	12	Level 5
4	Entering the berth	6) The impact of the wind and current.	Collision with platform	3	2	4	24	Level 4

		7)Disturbed communication	Collision with platform, or personal injury	3	2	4	24	Level 4
5	Sending the heaving line	8) Bad communication	Injury of the personal	3	2	2	12	Level 5
		9) Inattention to the environment.	Damage of the equipment	3	2	4	24	Level 4
6	Sending the mooring line	10) Failure of berthing because the heaving line fails to be sent to shore due to entangling.	Collision with platform, failure to berthing	3	2	4	24	Level 4
		11)During the mooring line floating on the surface of sea, improper use of main engine	The mooring line involve in the propeller, and break	3	1	4	12	Level 5
		12) Failure of berthing, collision with platform because breakdown of windlass cause the mooring line cannot be heaved up or sent out.	Collision with platform, failure of berthing	3	2	4	24	Level 4

‘

5.2.3.3Risk assessment of unberthing a platform:

Table 5.10: Risk assessment of unberthing a platform

No	operation/program/ activities	Risk resources	Possible consequence	Likelihood（L）	Frequency of exposure（E）	Consequence(C)	Risk grade （R）	Risk level
1	Preparation prior to departure	1）The operators working at the bow and stern do not have good understanding of unberthing plan	Collision with dock, mooring line broken, injury of personal, grounding	3	3	10	90	level 2
		2)Poor communication about the unberthing plan between the ship and terminals	Collision with dock, mooring line broken, injury of personal, grounding.	5	3	10	150	level 2
		3)Disturbed communication	Collision with dock, mooring line broken, injury of personal, grounding.	3	3	8	72	level 3
		4)Failure of the communication equipment	Collision with dock, mooring line broken, injury of personal, grounding.	3	3	4	36	level 4
		5)Poor communication between bridge and engine room	The information of engine failure cannot be informed to bridge timely, which	3	3	4	36	level 4

			contribute to accidents.					
2	Stand-by engine	6)Engine order telegraph out of order cause failure to deliver the engine order	Collision with dock, mooring line broken, injury of personal, grounding.	5	3	10	150	level 2
		7)During unberthing, the engine or rudder out of order	Collision with dock, mooring line broken, injury of personal, grounding.	3	3	10	90	level 2
		8) The mooring line is cast off before the main engine get ready.	The ship is out of control.	3	3	4	36	level 4
		9)Inattention to the environment	Collision with dock, other ship, and facilities of dock.	3	3	10	90	level 2
	Unberthing	10)The environmental changes cannot be informed to caption by the commander working at the bow and stern of ship	Collision with dock, other ship, and facilities of dock.	3	3	4	36	level 4
		11）Improper use of engine	Collision with dock, other ship, and facilities of dock.	3	3	10	90	level 2
		12)Mooring line is not withdrawn	The mooring line to involve the propeller, and then, cause the	3	3	8	72	level 3

			mooring broken and injury of personal.					
		13)During unberthing the terminals at sea, none of standby tug is available,	Collision with terminal, the mooring broken and injury of personal.	3	3	10	90	level 2
		14) The impact of wind, wave, and current.	Collision with dock, other ship, and facilities of dock	3	1	8	24	level 4

5.3. Risk reduction measures：

5.3.1 Risk reduction measures of avoiding typhoon:

Table 5.11: Risk reduction measures of avoiding typhoon:

No	**operation/program/ activities**	**Risk resources**	**Possible consequence**	**Risk grade （R）**	**Risk level**	**Risk reduction measures**
1	The preparedness of technologies and skills	1）The technology shortage of avoiding typhoon	Personal injury and property loss	90	Level 2	1. Learning the instruction of SMS, <the rule of avoiding the typhoon and storm surge>, < the emergency plan of avoiding typhoon> 2. Learning the historical successful experience of avoiding typhoon.

2	Increasing the crew's awareness of guarding against/avoiding typhoon	2）Weak awareness of avoiding typhoon	Personal injury and property loss	150	Level 2	Learning the document issued by company associated with the avoidance of typhoon and assurance of safety protection.
3	Learning and exercising the emergency procedures.	3）Poor understanding of emergency procedures, roles, and responsibility	Personal injury and property loss	90	Level 2	Learning the emergency procedure and emergency responsibilities, and then, carrying out the emergency exercising.
4	Collecting the information of typhoon forcast.	4）Collecting the information of typhoon forcast untimely and inaccurately	Personal injury and property loss	90	Level 2	1. Receiving the weather forecast and typhoon warning on time; making a comparison and assessment to the information coming from different ways, and plotting those information on the chart. 2. Observation of the meteorological elements on site and making a record continuously.
5	Inspection before typhoon arriving.	5）Failure of engine, rudder or other equipment	Personal injury and property loss	90	Level 2	1. Check whether the power equipment, such as engine, rudder is in good order, the cooling equipment and the pressure of hydraulic oil is in good condition as well. 2. The test of conversion between conventional and emergency steering equipment.

		6）Failure of watertight fittings	Damage of equipment	18	Level 5	1: Carrying out the open/close operation; testing the effectiveness of water tight. 2: The cover of hatch opening, ventilating trunk, air pipe, sounding pipe should be tighten. 3: The porthole should be tighten and covered with an iron cover.
		7）Failure of communication equipment	Emergency response cannot get the support from shore	90	Level 2	1: Testing the communication equipment to make sure it is in good condition. 2: Check the power supply, whether the emergency battery is full; whether the conversion from normal to emergency is in good order.
		8）Failure or lack of plugging device、drainage device	Damage of equipment	24	Level 4	1: Checking whether the plugging device, drainage device is enough and in good order. 2: Mastering the function and usage of plugging device and drainage device.
		9）Drainage on deck is not fluent.	Damage of cargo	18	Level 5	Checking the outlet of deck to make sure that drainage on deck is fluent.
		10）Unreasonable stability cause the damage of ship.	Damage of ship	90	Level 2	1: Increasing the value of GM through adjusting the ballasting; if the vessel is empty, the ballast water should be full.

		11）The movement of equipment	Damage of equipment	36	Level 4	Fixing the moveable equipments and fitting appropriately.
		12）The movement of cargo	Damage of cargo	36	Level 4	The deck cargo must be fixed.
6	Avoiding typhoon alongside the dock.	13）The mooring line breaking	Damage of ship	36	Level 4	Adjusting all mooring line balanced; adding pad at the friction point
		14）Collision between ship and dock	Damage of dock and ship	36	Level 4	Inserting the fender between the dock and ship.
		15）Improper temporary response	Damage of ship	72	Level 3	1: The crew cannot leave the ship, stick to the post : the watch keeper should pay attention to the change of wind force, air pressure, other ship's status. Other crew is on standby. 3: when the wind is more than force 7, making the engine is on standby state.
7	Avoiding typhoon in anchorage.	16）Selecting improper anchorage	Damage of ship	90	Level 2	1: Selecting the shelter anchorage in accordance with the typhoon's position, moving path, the variation of wind direction. 2: Under keel clearance in shelter anchorage must be enough; the safe distance between the ship and dangerous obstacles must be enough.

		17）Improper anchor point	Damage of ship	36	Level 4	1: The safe distance between the ship and other ship and dangerous obstacles must be enough. 2: the possibility of dragging must be taken into account.
		18）Collision with other anchored ship or dangerous obstacles	Damage of ship	36	Level 4	1: Cross- checking the ship's position through different position-fixing methods. 2: Pay attention to the nearby ship movement and the variation of the distance between own ship and other dangerous obstacles. 3: any doubt, if any, should be reported to captain, and get in touch with other ship.
		19）Improper temporary response	Damage of ship	72	Level 3	1: The watch keeper should pay attention to the variation of wind and air pressure; other crew should be in standby state. 2: When the wind is on force 7 or above, the engine, rudder, and thruster should be on standby state. 3: Let go both anchor

8	Avoiding typhoon during navigating on the sea.	20）Wind, wave cause the damage of crew and ship.	Personal injury and damage of ship	60	Level 3	1: Keep in touch with other ship and coast station, pay attention the variation of wind direction and air pressure. 2: Making use good seaman ship to run out of gale area. 3: When navigating in dangerous semicircle, go ahead with full speed and starboard-bow against the wind. 4: When navigating in the navigable semicircle, go ahead with full speed and starboard-stern against the wind.

5.3.2：Risk reduction measures of berthing a platform:

Table 5.12: Risk reduction measures of berthing a platform

No	Operation/program/activities	Risk resources	Possible consequence	Risk grade （R）	Risk level	Risk reduction measures
1	Berthing plan making	1)Unclear assignments of responsibility, lack of unified command	Failure of berthing, collision, and personal injury.	24	level 4	1: Making the berthing plan including clear assignment of responsibility. 2: Making emergency berthing plan, once, the original plan fail.
2	Approaching platform	2) The speed is too fast.	Collision with platform	36	level 4	Defining the maximum approaching speed according to the loading condition and environment condition.

3	Anchoring for controlling the speed of the ship	3)The anchor cannot be dropped off timely to control the ship’s speed.	Collision with platform	18	level 5	Reducing the speed through dropping anchor.
		4)The anchor cannot be dropped off, the Failure of windless	The failure of berthing or collision with platform.	12	level 5	Prior to berthing, test the winch, getting ready to the anchor in advance.
		5) The anchor hooks up and damages the submarine cable or pipe.	The anchor hooks up and damages the submarine cable or pipe.	12	level 5	Checking the chart to ensure that there is none of submarine cable or pipe in anchoring area.
4	Entering the berth	6) The impact of the wind and current.	Collision with platform	24	level 4	1: Prior to berthing, analyzing the influence of wind and current, 2: Selecting proper berthing method, 3: Asking for tug assistance, if necessary.
		7)Disturbed communication	Collision with platform, or personal injury	24	level 4	Testing the communication tool, defining the emergency contact ways once the communication is disturbed
5	Sending the heaving line	8) Bad communication	Injury of the mooring worker	12	level 5	Informing the mooring worker before sending the heaving line.
		9) Inattention to the environment.	Damage of the equipment	24	level 4	Observing the surrounding before sending the heaving line.
6	Sending the mooring line	10) Failure of berthing because the heaving lines fail to be sent to shore due to entangling.	Collision with platform, failure to berthing	24	level 4	Disentangling the heaving line by sailor before sending it.
		11)During the mooring line floating on the surface of sea, improper use of main engine	The mooring lines involve in the propeller, and cause it breaking up.	12	level 5	The speed of sending mooring line should not be too fast to avoid the mooring line to pile up on the surface of water.

		12) Failure of berthing, collision with platform because breakdown of windlass cause the mooring line cannot be heaved up or sent out.	Collision with platform, failure of berthing	24	level 4	Testing the windlass to make sure that it is in good order before berthing.

5.3.3：Risk reduction measures of unberthing a platform:

Table 5.12: Risk reduction measures of berthing a platform:

No	operation/program/activities	Risk resources	Possible consequence	Risk grade （R）	Risk level	Risk reduction measures
1	Preparation prior to departure	1）The operators working at the bow and stern do not have good understanding of unberthing plan	Collision with dock, mooring line broken, injury of personal, grounding	90	level 2	Prior to departure, captain must inform the unberthing plan to the operator working at the bow and stern.
		2)Poor communication about the unberthing plan between the ship and terminals	Collision with dock, mooring line broken, injury of personal, grounding.	150	level 2	Prior to unberthing, the operator working at the bow and stern must told the worker of terminal the order of casting off the lines timely.
		3)Disturbed communication	Collision with dock, mooring line broken, injury of personal, grounding.	72	level 3	Prior to berthing, making a emergency contact way, once the normal communication is disturbed
		4)Failure of the communication equipment	Collision with dock, mooring line broken, injury of personal, grounding.	36	level 4	Prior to unberthing, testing the communication equipment to make sure that it is in good order.

		5)Poor communication between bridge and engine room	The information of engine failure cannot be informed to bridge timely, which contribute to accidents.	36	level 4	Prior to unberthing, testing the communication equipment between bridge and engine room to make sure that it is in good order.
2	Stand-by engine	6)Engine order telegraph out of order cause failure to deliver the engine order	Collision with dock, mooring line broken, injury of personal, grounding.	150	level 2	Prior to unberthing, testing the telegraph to make sure that it is in good order.
		7)During unberthing, the engine or rudder out of order	Collision with dock, mooring line broken, injury of personal, grounding.	90	level 2	Prior to unberthing, testing the engine, rudder gear to ensure that it is in good order.
		8) The mooring line is cast off before the main engine get ready.	The ship is out of control.	36	level 4	After conforming that the engine is in good order, let go mooring lines.
		9)Inattention to the environment	Collision with dock, other ship, and facilities of dock.	90	level 2	During unberthing, assign a specific watch-keeper to keep watching in order to find out the nearby ship's movement state.
3	Unberthing	10)The environmental changes cannot be informed to caption by the commander working at the bow and stern of ship	Collision with dock, other ship, and facilities of dock.	36	level 4	During unberthing, the commander working at the bow and stern of the ship must pay attention to the surroundings, and the traffic condition shall be reported to captain timely.
		11)Improper use of engine	Collision with dock, other ship, and facilities of dock.	90	level 2	Making use of engine appropriately according to the wind and current condition; if necessary, ask for the tug assistance.

		12)Mooring line is not withdrawn	The mooring line to involve the propeller, and then, cause the mooring broken and injury of personal.	72	level 3	after the mooring lines was cast off, heaving it up timely; the commander working at the bow and stern of the ship must inform captain the floating state of mooring lines to instruct caption using the engine properly.
		13)During unberthing the terminals at sea, none of standby tug is available,	Collision with terminal, the mooring broken and injury of personal.	90	level 2	During unberthing, ask for the standby tug on guard.
		14) The impact of wind, wave, and current.	Collision with dock, other ship, and facilities of dock	24	level 4	Analyzing the impact of the wind and current to the ship; making the emergency plan; if necessary, ask the tug to assist.

Chapter 6 Conclusions and recommendations

6.1: Summary:

The main objective of this thesis is to discuss the weather sensitivity of maritime activities on Chinese Costal Shelf. All maritime activities analyzed are based on the business of M&T of COSL and the author's operation experience.

As we know, weather always changes with time. Although, the level of science and technology are very high in our modern society, the weather forecast is still not very accurate, especially for long term weather forecasts. According to the introduction of my teacher of Marine Meteorology &Oceanography (Xia, Yonghua), the accuracy of weather forecast in winter is around 70% while the accuracy in summer is just around 50%.Because the shipping industry is impacted by weather severely, mariners should have good understanding of the weather system. And then, in accordance with the weather system maps coming from weather fax and the data collected on site, the mariner should be capable of making more accurate weather forecast locally, which can be used for selecting the action of the vessel at sea.

In chapter 2, those critical weather systems and weather phenomena, which can impact the maritime operation on the Chinese Costal Shelf, have been introduced according to the personnel understandings and some introductions from other literature. The critical weather systems and phenomena include, but are not limited to:

- Subtropical high
- Cold high
- Monsoon
- Tropical cyclone
- Sea current
- Fog on the Chinese Costal Shelf
- The sea ice on the Chinese Coastal Shelf
- Thunderstorm
- Squall line
- Tornado

Subsequently, according to the author's personal navigational experience, the vessel-handling methods, in combination with a detailed working scenario, in hash weather have been discussed in chapters 3 and 4. Also, a vessel grounding accident during efforts avoiding typhoons was discussed in order to figure out the lessons and demonstrate the importance of a mariner mastering the weather knowledge and having good seamanship.

As we know, there are a great number of risks in the maritime activities. Therefore, we must figure out the possible risks existing in the maritime activities as much as we can, prior to a maritime activity being carried out. We have discussed three maritime activities in the previous chapters; they are operations of avoiding the typhoon, berthing a platform, and unberthing a platform. So, there is a need to discuss the risks associated with the maritime operations. In chapter 5, the risks existing in three maritime activities were figure out, assessed and risk reduction methods were developed. During risk analysis, the method of JSA, LEC, which is relatively suitable for maritime operations, were adopted.

Unfortunately, the factors, which can impact the maritime operations, are many and always change over time. So, we can just perform a qualitative analysis. However, after all, it is my personal working experiences, and I hope that it can provide my counterparts a little bit of reference.

6.2: Recommendations

Firstly, I would like to share my maritime operational experiences, discussed in this thesis, to other counterparts and my coworkers for reference, including the methods of avoiding typhoon, berthing/unberthing a platform.

Secondly, I would like to recommend to the leaders of COSL to pay attention to the market of shuttle tankers with DPS. Meanwhile, in order to fit the organization structure to the business development, COSL can build up the organization structure of one-ship Company to avoid unlimited oil pollution risk and invest more founds on the project of shuttle tanker with DPS.

Thirdly, I would like to recommend the leader of M&T department to set up a file of risks for all maritime activities. And, the crew, who will carry out those operations, shall be trained about relevant risks. I am sure that if this work can be done continuously and reviewed on a periodic basis, the incidents, accidents, and near misses existed in our daily work will sharply decline.

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Appendix:

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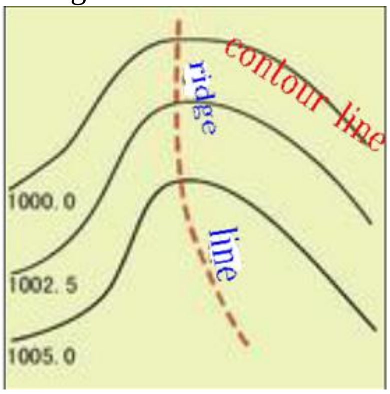

2: ISV: (infield supply vessel) the terminal maintains boats that are directed by the pilot and the terminal loading master to assist in mooring and unmooring vessels.

3:Static tow: condition when the lifting tanker is moored in tandem to the terminal and the ISV is made fast astern of the lifting tanker to stop the lifting tanker from fishtailing tanker to stop the lifting tanker from fishtailing and jackknifing.