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A Brief Analysis of the Impact of Tropical Cyclone on Ships

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Abstract

Tropical cyclone has a strong destructive effect, affecting the navigation safety of ships has been a difficult problem. Based on the principle of tropical cyclone, this paper classifies the intensity grade of tropical cyclone, deeply analyzes the whole process of ship navigation affected by tropical cyclone, and points out the problems affecting navigation safety. Put forward some ideas and solutions to these problems. In particular, some matters that should be paid attention to during the voyage of the ship have certain guiding significance to the safe navigation and how to evade in the practice of the ship.

Keywords

Tropical cyclone, Safety of navigation, How to reduce, Characteristics of tropical cyclones.

1. Introduction

Tropical cyclones are the most powerful storms in the troposphere, known as "storm Kings", and are vortices that develop strong warm cyclones. In the study of the climate change rules of tropical cyclones, meteorologists have conducted extensive research and obtained meaningful results, providing important reference for the short-term climate prediction of tropical cyclones [1]-[3].However, in a comprehensive view of these studies, the data analysis is mostly theoretical principles and the analysis perspective is often limited to a certain or a few aspects of activity characteristics of the study, the lack of a more systematic and comprehensive analysis[4]-[5]. This paper starts from the actual summary, has certain guiding function to the practice.

Tropical cyclones affect a large area and are very destructive. According to relevant statistics, the number of natural disasters recorded on earth from 1980 to 2016 was 24,668, among which tropical cyclones accounted for 38.7% and 9,537.

The tropical cyclone data were obtained from the tropical cyclone yearbook from 2006 to 2015 compiled by the China meteorological administration and the biographic ground analysis map released by Japan. According to the national standard for tropical cyclone classification (GB/T 19201-2006), tropical cyclones are classified into 6 grades ,see Table 1.

Table 1. Classification of tropical cyclones in China

Tropical cyclone class	Maximum mean wind speed near bottom center (m/s)	Maximum mean wind force near bottom center /level
Tropical Depression	10.8~17.1	6~7
Tropical Storm	17.2~24.4	8~9
Severe Tropical Storm	24.5~32.6	10~11
Typhon	32.7~41.4	12~13
Severe Typhon	41.5~50.9	14~15
Super Typhon	≥51.0	Level 16 or above

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Tropical cyclones occur mainly in the northwest Pacific Ocean, northeast Pacific Ocean, southwest Pacific Ocean, north Atlantic Ocean, bay of Bengal, Arabian sea, western southern Indian Ocean and northwest Australia, while no tropical cyclones occur in the southeast Pacific Ocean and south Atlantic ocean. The major distribution areas of tropical cyclones are between 5 ° and 10 ° latitudes in the northern and southern hemispheres.

2. Characteristics of Tropical Cyclones

2.1. Conditions for Tropical Cyclone Formation

The formation of tropical cyclones not only requires a relatively wide ocean surface, but also requires high temperature and high humidity. The flow field should be suitable for the generation of tropical cyclone, the vertical shear force of troposphere wind speed should be small, plus the appropriate geostrophic deflection force.

2.2. Development of Tropical Cyclones

After the tropical cyclone, due to the change of the external environment, and the reduction of their own energy finally disappeared. There are two trends. One is a tropical cyclone that reaches land and then gradually weakens until it disappears because there are no suitable conditions for it to develop. The other is to move to the middle and high latitudes of the cold sea or have cold air intrusion into the extratropical cyclone. However, there are special situations, such as some tropical cyclones moving to warmer water, some tropical cyclones logging back into the sea for other reasons, or tropical cyclones may move below the high divergence zone. These conditions can make tropical cyclones gain energy to strengthen.

2.3. Weather Patterns of Tropical Cyclones at Sea

The weather conditions associated with tropical cyclones are mainly heavy rain, high winds, high waves and other severe weather conditions. The weather conditions formed by tropical cyclones are generally large cylindrical and symmetrical. It is divided into three areas :(1) the peripheral area, with an average width of 200 to 300KM.(2) vortex region, where the temperature rises rapidly towards the center and the pressure gradient is particularly large.(3) in the eye area, the temperature is the highest, while the pressure is the lowest, the rainfall stops, and there is little rain in sunny days. Here, the waves are triangular waves or pyramid waves, and the meteorological conditions are relatively bad.

2.4. Cycles of Tropical Cyclones

The cycle of tropical cyclones is about 3 to 8 days, and the longest ones are rarely more than 20 days, at least 1 to 2 days. The activity cycle of tropical cyclones is from the disturbance to the closed circulation and the tropical depression until the circulation disappears or the tropical cyclone. The cycle of tropical cyclones is divided into four stages ,see figure 1 .(1) the initial stage a-b (2) the deepening stage c-d (3) the maturation stage e-f (4) the extinction stage g-h.

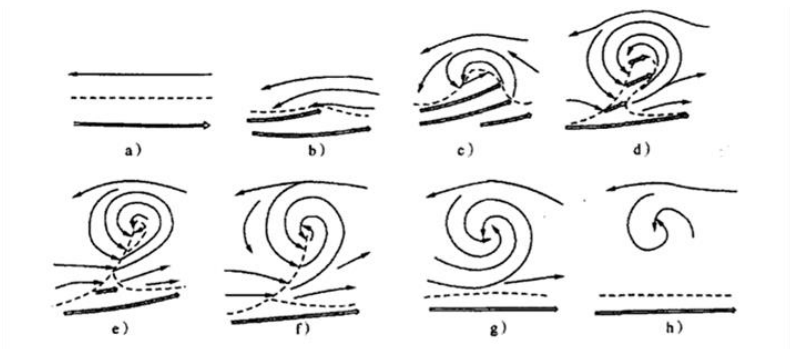

Figure 1. Life history of tropical cyclones

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2.5. Movement Patterns of Tropical Cyclones

1. Tropical cyclones move on the earth under the action of pressure gradient force, geostrophic deflection force, internal force, and other external environment.

2. The subtropical high is the system closest to the tropical cyclone. It plays a very important role in the tropical cyclone and directly affects the generation and extinction of the tropical cyclone. Other weather systems that affect the movement of tropical cyclones are the westerly trough ridge and the "double tropical cyclone" effect.

3. Different geographical location of tropical cyclones moving path is different, in the northern hemisphere in the ocean, most of the tropical cyclone is the path of moving to the west and northwest and parabolic type steering; In the southern ocean, tropical cyclone movement direction is to the west, the southwest direction and reverse parabolic type.

3. Research on Tropical Cyclone Related Detection

Studies have found that the near-center maximum average wind speed of a tropical cyclone has a very close relationship with its intensity, and the near-center maximum average wind speed gradually decreases with the increase of the central air pressure, it is found that there is a good quadratic nonlinear relationship between them, the Correlation Coefficient R is as high as 0.996. The fitting equation is

$$y=-0.037x2-2.999x+121.4 \tag{1}$$

y represents the maximum average wind speed near the center, kn; x=(Pmin-895)/5, and Pmin is the minimum pressure near the center, hpa; According to the fitting equation to calculate the maximum average wind speed near the center of the average absolute error is less than the experience formula of the export of cyclostrophic wind equation[6] and the current business use empirical formula Atkinson – Holliday[7] is achieved with the mean absolute error ,see table 2. The results could be used to ship using the tropical cyclone central pressure value to estimate the tropical cyclone maximum average wind speed near center provides an effective way.

Table 2. Comparison of mean absolute errors of maximum mean wind speed in tropical cyclone centers calculated by different methods

	A formula to calculate	Wind speed unit	Mean absolute error /kn
Quadratic fitting equation	-0.037((Pmin-895)/5)2-2.999(Pmin-895)/5+121.4	Kn	5.78
An empirical formula is derived by using the equation of the wind	5.7(1010-Pmin)1/2	m/s	6.27
Atkingson-Holliday Empirical formula	6.7(1010-Pmin)0.644	Kn	8.31

As the changes of tropical cyclones are very complex and there are many factors affecting tropical cyclones, the previous research progress has been hindered [8]-[10]. The meteorological observation of various countries is still concentrated on the land, and the data observation data on the ocean is still very limited. At present, there are mainly several kinds of atmospheric sounding technologies: aircraft airborne equipment observation, downward sounding detection, maritime meteorological observation platform and ground mobile observation.

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Most tropical cyclones are located on the ocean, and few observation stations on the ocean can obtain effective observation data. In addition, tropical cyclones are inherently destructive, which may cause the equipment concerned to not work properly, or affect its observation accuracy. In order to solve these problems, it is necessary to develop unmanned remote control aircraft detection and aerospace satellite technology, so as to improve the technical level of tropical cyclone research.

4. Effects of Tropical Cyclones on Sailing Vessels

4.1. Effects of Tropical Cyclones on Crew and Ship Equipment

Severe weather conditions, which made the ship roll more and the crew more seasick, combined with splashing waves and low light intensity, affected the crew's visual and auditory outlook. Due to the increase of sea waves, the clutter in radar use increases, which may not clearly show the echo of the target ship, increasing the risk of collision.

4.2. Effects of Tropical Cyclones on Ship Handling

Sometimes, in order to reduce the impact of wind and waves, the ship is often in a state of oblique sailing. The ratio of rudder area is relatively small, and the transshipment effect of rudder force is relatively poor. If the ship wants to avoid other ships in such a state, when the ship takes the helm, the rudder will be changed in a larger amplitude and the rudder will be changed for a longer time, which increases the risk of ship collision. In particular, when large ships encounter large waves, in order to ship safe navigation in the sea, the operation of the ship will inevitably increase the load of the main engine, easy to cause the failure of machinery and equipment on the ship, increasing the risk of the ship out of control.

4.3. Impact of Tropical Cyclone on Ship Stability

The stability of a ship has a great influence on its voyage. In the course of navigation, if the ship is affected by the tropical cyclone, it will inevitably generate waves on deck, cargo movement, free liquid level and so on, which will reduce the stability of the ship. It is possible to add the influence of seasonal weather, such as rain and snow, which increases the load and reduces the initial stability of the ship. Especially now the rapid development of container ships, the tropical cyclone on the ship container cargo is also a great impact. If the storm and huge waves caused by the tropical cyclone cause the ship to shake more, for the container on the ship, it may cause the container to fall, resulting in the imbalance of the weight of the ship's cargo, affecting the stability of the ship, and thus affecting the navigation safety of the ship.

4.4. Free Liquid Level Is Generated for Ore Carriers

The raw material ore is generally a kind of local mud, containing high moisture, in the loading process, when the bad rain weather did not close the hatches in time, further increased the moisture of the ore. In the process of ship transportation, it is easy to generate turbulence, which is originally full of water in the ore to free up, forming a layer of liquid ore, thus forming a free liquid level, the free liquid level has a serious impact on the navigation safety of the ship. Under the influence of the tropical cyclone, the ship shakes more violently, leading to the shaking of the free liquid level, which changes the center of gravity of the liquid and the total center of gravity of the ship. Finally, the stability of the ship is reduced.

4.5. Hull Deformation Caused By Tropical Cyclone

The rise and fall of the waves lead to the arch or heavy sag of the ship. In addition, the force exerted by the hull on the cargo is not uniform. When the influence is relatively small, the shape of the hull plate is deformed. From tropical cyclone waves influence there is a big threat for container shipping, container due to the large-scale direction, now its deck loading capacity is

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becoming more and more windage area increased, plus the capacity is different, the loading of ship loading container, so to ship the wind moment changed, is not conducive to safety of the ship.

5. Reduce the Impact of Tropical Cyclones on Ship Navigation Safety

5.1. Pay Close Attention to Meteorological Trends

1) Ships at sea may receive corresponding weather reports or warnings issued by nearby coastal radio stations through NAVTEX and enhanced group call (EGC). See figure 2

2) The global maritime distress and safety system can provide an effective way to issue navigational warnings, weather forecasts and other information to ensure the navigation safety of ships.

3) In the vicinity of the coast, you can also listen to the radio, through the mobile phone, through the Internet search lights.

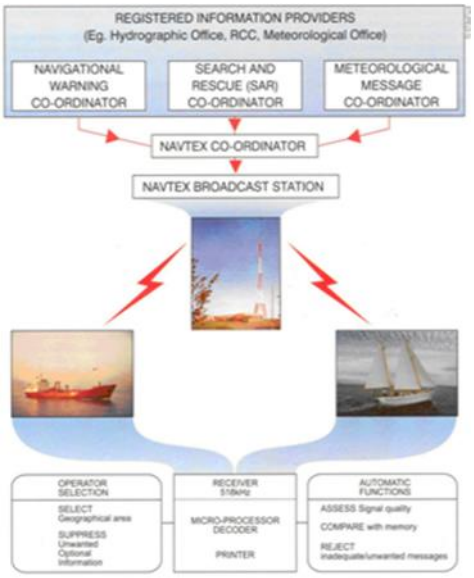

Figure 2. Ship - shore interaction mode of weather fax

5.2. Ships Should Take Preventive Measures in Advance Before Tropical Cyclone

It is of vital importance for the ship's navigation safety to prepare for typhoon in advance. The most basic and most important thing in preparing for typhoon is to eliminate the hidden danger. The captain and relevant responsible personnel should check whether the relevant equipment is normal. For example, check whether the main engine, auxiliary machinery and other power and standby equipment is normal. Check whether the windlass, anchor and chain can be normally thrown and retracted. Check the normal operation of steering equipment, navigation AIDS and communication equipment. Check the water tightness of the ship's cargo hatch to prevent the ship from taking in water and losing stability after waves on deck. Check whether the cargo is secured, etc.

The strong natural destructive force of tropical cyclone is a serious threat to the safety of shipping. "Prevention first, combination of prevention and resistance, timely and early avoidance, leaving room", when necessary in the anti-typhoon process needs to be combined with the guidance of the company, as far as possible to reduce the damage of tropical cyclone to ships. There are two options when ships are caught in a tropical cyclone, one is that if the time is not too urgent, the economic loss is not very large, you can choose to bypass the

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operation of the typhoon. The other is to prepare to fight against the typhoon in the typhoon, in different positions of the typhoon to conduct relevant avoidance operations and related preparations, and continue to sail after the typhoon has passed.

5.3. Plan Safe and Economical Routes

In order to ensure the safety of ships in the sea, we must first design a reasonable and safe route. The design of a safe and reasonable route not only requires the designer to have rich navigation experience, but also requires the designer to be able to consider as much as possible the factors affecting the ship on the route. For the merchant ships that sailed, the required routes had to be set with economic considerations in mind, provided that they were safe.

1) Factors to be considered from the perspective of safety are:1. The loading status of the ship's goods, the types of goods, the handling capacity of personnel, etc.;2. Weather conditions in the navigation area of the ship;3. Geographical characteristics of the sea area;4. Accuracy of the ship's equipment and maneuverability of the ship.

2) The factors considered from the economic perspective are:1. Voyage, such as ocean voyage, generally choose the great circle route, which is shorter than the constant direction route;2. Sailing time, sailing time is a problem that must be considered in the design of a route.

5.4. Methods When Unavoidable

1) Determine the location of tropical cyclone

For ship pilots on the voyage, they can accurately know the position of the tropical cyclone, and then analyze the relative position between the current ship and the tropical cyclone, which can well predict the path of the tropical cyclone, minimize the damage to the ship and even avoid the impact of the tropical cyclone on the ship. From the perspective of the moving direction of the tropical cyclone, a tropical cyclone can be divided into two semicircles, the left is the left semicircle, the right is the right semicircle. For ships sailing in the northern hemisphere, the right side is more dangerous for ships than the left side. On the contrary, the dangerous semicircle on the left of ships sailing in the southern hemisphere. Ships sailing in a dangerous semicircle should be steered especially carefully to avoid the possibility of capsizing.

2) Control methods of ships in tropical cyclone

Within the dangerous semicircle manipulation method: sailing ships operating in the northern hemisphere, for example, the tropical cyclone wind is around the center counterclockwise, when the ship is located in dangerous semicircle, if improper operation, it is easy to tropical cyclone blows into the path of cyclone center, this will through the center of the typhoon, the ship to the more serious damage to the ship. And if that happens, it will be harder to escape. When the ship is in a dangerous semicircle, steer the ship so that the starboard side of the ship's bow is upwind, and then steer the ship away at full speed, keeping the wind blowing from starboard 10 ° ~ 45 ° (port if in the southern hemisphere) until the ship leaves the tropical cyclone area.

Within the navigable semicircle manipulation method: if after relevant professional judgment, found that the ship is located in the navigable semicircle of a tropical cyclone. This time, the driver should use the ship to starboard side of the ship tail wind (if in the southern hemisphere, is the left side), 30 ° ~ 40 ° Angle of the wind out of danger area.

Maneuverability in the path of a typhoon: if the ship encounters a tropical cyclone and finds that the wind direction is constant and the pressure begins to decrease, these signs indicate that the typhoon center is approaching. In this case, the pilot should immediately make the ship's aft starboard side subject to the wind (port if in the southern hemisphere) and allow the ship to enter a navigable semicircle until the air pressure rises and the winds weaken out of the typhoon zone.

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6. Conclusion

The tropical cyclone affects the navigation safety of ships. Its bad weather makes the navigation of ships difficult and may even bring the danger of capsizing. In addition, the research on tropical cyclone related technical theory needs to be improved, and there is no fully mature system. With the continuous progress of science and technology, although the current ship construction technology has made a breakthrough, but for the ship can safely travel in the tropical cyclone under the influence of the sea, there is still a certain distance.

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