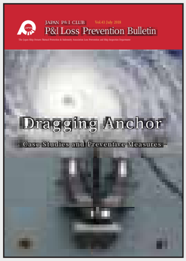
4−2−4 Courses of Extra-tropical Cyclones

We introduced typhoon courses in sea waters around Japan in our Loss Prevention Bulletin " Dragging Anchor - Case Studies and Preventive Measures - (Vol.43) " issued in July, 2018. Please refer to this for more details.



At its early stage, the typhoon migrates westward slowly at a speed of 10 to 20 kms per hour pushed by the easterly trade wind (Fig. 38).

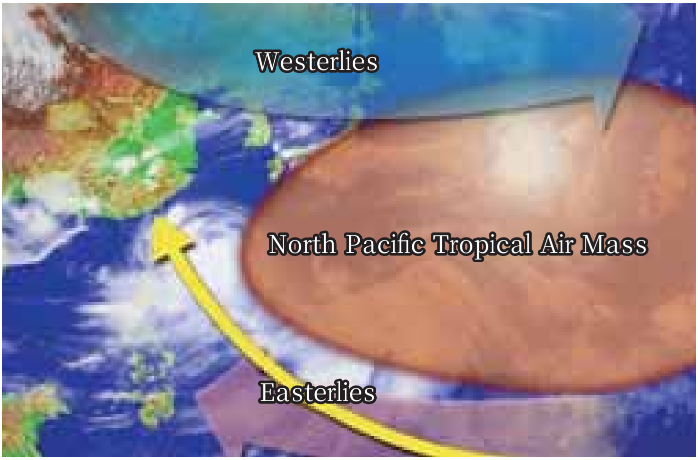


Fig. 38 Japan Captains' Association, DVD

Then, it turns northward under the influence of the general circulation of the North Pacific High. As it migrates northward, the typhoon changes its course eastward, influenced by westerlies in the upper air. This point of course change is known as the "point of recurvature." After changing course to the northeast, the typhoon's speed increases to 30 to 40 kilometres per hour at about 30° north latitude, and to approximately 50 kilometres per hour at about 40° north latitude.

In general, a typhoon's intensity weakens due to the cold waters and low atmospheric temperature as it moves northward. Finally, by the time it reaches the Okhotsk Sea or the North Pacific waters off Hokkaido, it has become an extra-tropical cyclone (Fig. 39).

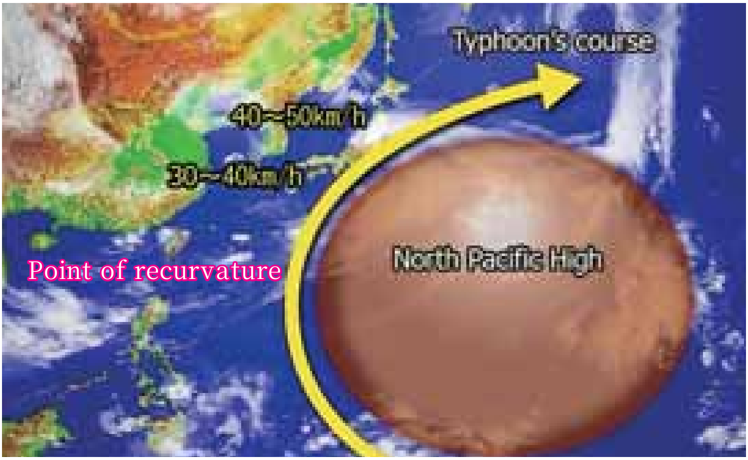


Fig. 39 Japan Captains' Association, DVD

Regarding this latitude point of recurvature, the author was taught during a university lecture on meteorology that it was located in the vicinity of 25° north latitude in the east of Taiwan. However, on observing recent typhoon routes, it seems that the number of typhoons, that significantly migrate northward and turn at the south of Kagoshima Amami-Oshima (in the vicinity of 25° north latitude), have been increasing. That is to say, although this may be caused by global warming, it seems that more and more of the strongest typhoons are landing on Japan's mainland.

On a 500 hpa upper-air chart, if the Northern Pacific High expands westward widely to the Chinese Continent, it is unlikely that the typhoon will turn and migrate westward. On the other hand, as the North Pacific High retreats to the east and the continent becomes a pressure trough, it is highly likely that the typhoon, drifting on a westerly path, will turn eastward at the western edge of the North Pacific High and be steered to the northeast.

That is, on a 500 hPa upper-air chart, the typhoon frequently takes a course around the North Pacific High, with the North Pacific High remaining on its right. This motion is called "steering." Statistically speaking, if a typhoon passes the eastern area of the point at 20° north latitude and 130° east longitude, it will turn eastward and head for the southern coast of Japan. If it passes the western or southern area of that location, we know that it will keep westward and head for Taiwan (Fig. 40) .

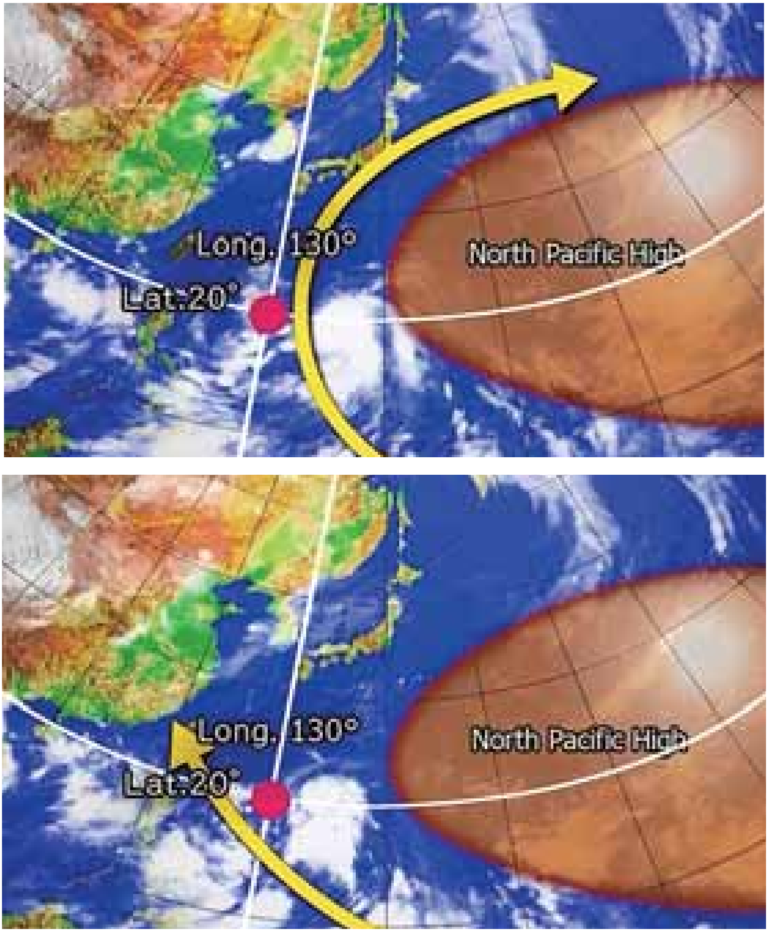


Fig. 40 Japan Captains' Association, DVD

4−2−5　How to read a route map of Extra-tropical Cyclones

We often see nowcasts of typhoon and extra-tropical cyclone tracks in weather forecasts on TV, in newspapers and on the internet (Fig. 41). It is necessary that these nowcasts be properly understood.

Fig. 41 From the Japan Meteorological Agency website

❶ Centre position current typhoon

This shows the typhoon's centre position at the time the forecast was broadcasted.

❷ Storm zone

The red line refers to a range where strong winds of average speed in excess of 25 meters per second are presumed to be blowing. No. 2 is the storm zone of No. 1.

❸ Strong wind area

The yellow line refers to a range where strong winds of average speed in excess of 14 meters per second, at the time the forecast was broadcasted, are presumed to be blowing.

❹ Forecast circle

This indicates a 70% probability that the typhoon ' s centre position at the time of forecast will move into the forecast circle.

❺ Storm alert zone

The red line around the typhoon forecast circle identifies the area that will enter the storm zone if the typhoon's centre advances into the forecast circle.

When working on an evacuation (sheltering) plan, it is necessary to check the estimated positions of each heading the ship will take towards her destination following the originally plotted (charted) course while checking the progress of the typhoon’s track at each interval using nowcasts. Also, if the ship enters the storm alert zone, it is a necessary requirement to revise the evacuation plan while checking the weather charts every time there is an announcement - in order to escape.

4—2—6 Dangerous Semicircle and Navigable Semicircle

A typhoon’s winds blow counterclockwise into its centre. Wind speed in the right semicircle is strengthened as the typhoon’s migration speed increases. Therefore, because wind speed and waves are always higher in the right semicircle than in the left semicircle, the right semicircle of the typhoon is known as the “dangerous semicircle”. On the other hand, because a typhoon’s wind speed and blowing wind are reversed, wind is always weaker than in the right semicircle. Thus, the left semicircle of the typhoon is known as the “navigable semicircle” (Fig. 42).

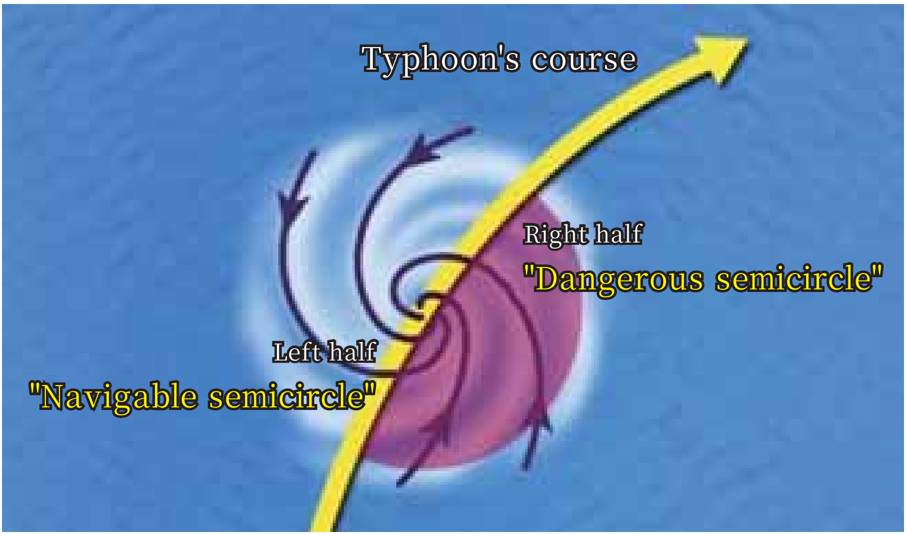


Fig. 42 Japan Captains’ Association, DVD

Suppose a typhoon approaches your ship, and your ship enters the "dangerous semicircle" which is the storm zone, navigating along the migrating direction (Fig. 43) of the typhoon. When she navigates having winds and waves from a quarter stern on the starboard side, she cannot escape from the stronger storm zone (Fig. 44).

So, if a ship is about to enter the edge of the typhoon's right-side semicircle, it is a requirement that she avoid the rough sea area and leave it by turning clockwise having winds and waves from a quarter head on the starboard side (Fig. 45).

If a ship enters a storm zone of the left semicircle of the typhoon, she can escape and leave from the storm area by turning her counterclockwise having winds and waves from a quarter stern on the starboard side. She navigates outward of the typhoon and can escape and leave from the storm zone.

Fig. 43 Japan Captains' Association, DVD

Fig. 44 Japan Captains' Association, DVD

Fig. 45 Japan Captains' Association, DVD

Fig. 46 Japan Captains' Association, DVD

Therefore, if a ship is about to enter the left-side semicircle, she can escape and leave the rough sea area by turning counterclockwise with winds and waves from a quarter stern on the starboard side (Fig. 46).

It is important to remember that the semicircle is a rough sea area even if it is the navigable semicircle. So always bear in mind that your vessel should stay away from a typhoon. It is best to think of the navigable semicircle as **"the semicircle where she can escape from rough seas"** rather than the semicircle "where she can navigate safely" .

If your ship is likely to encounter a typhoon during her voyage, do your best to avoid the storm zone taking her course and size into account, as well as her position relative to the typhoon – in other words relative to the "right-side or left-side semicircles" – and the performance capability of your ship.

Also, when the typhoon is likely to approach while anchoring or loading or unloading in port, take every possible evacuation action well in advance by collecting and analysing weather information as well as following the harbour master's instructions.

§ 5 How to Obtain Weather Information

During voyages, obtaining and then analysing the latest information is essential for any ships seeking to avoid rough weather due to typhoons, extra-tropical cyclones which rapidly develop ("bomb cyclone") and so on. The final examination of meteorology at my university was to draw surface weather charts on a blank map while listening to the weather information on the radio. However, these days, meteorological information can be obtained from the following sources: weather charts distributed by the Japan Meteorological Agency; typhoon course forecasts available for free on the Internet; and weather information supplied for a fee by weather information companies. Among them, weather information from the Internet and companies is useful when working an evacuation plan because both provide estimated typhoon courses at least a week in advance. Because of this, it is a must that masters and each navigation officer are able to interpret weather information obtained in this way. As there are many weather reference books available, it is necessary that they be distributed throughout the entire crew and that they be reviewed on a daily basis. Here we will introduce the various weather charts issued by the Japan Meteorological Agency and show you how to use them.

5－1　Surface Weather Charts

Usually, “weather charts” refer to “surface weather charts” that show weather conditions on the Earth’s surface. On a surface weather chart, isobars for each 4 hPa are drawn with 1,000 hPa as the standard. The chart is published every six hours. Besides barometric pressure distribution, temperature, wind and weather are also drawn. Weather phenomena such as isobars and fronts are analysed using these charts (Fig. 47).

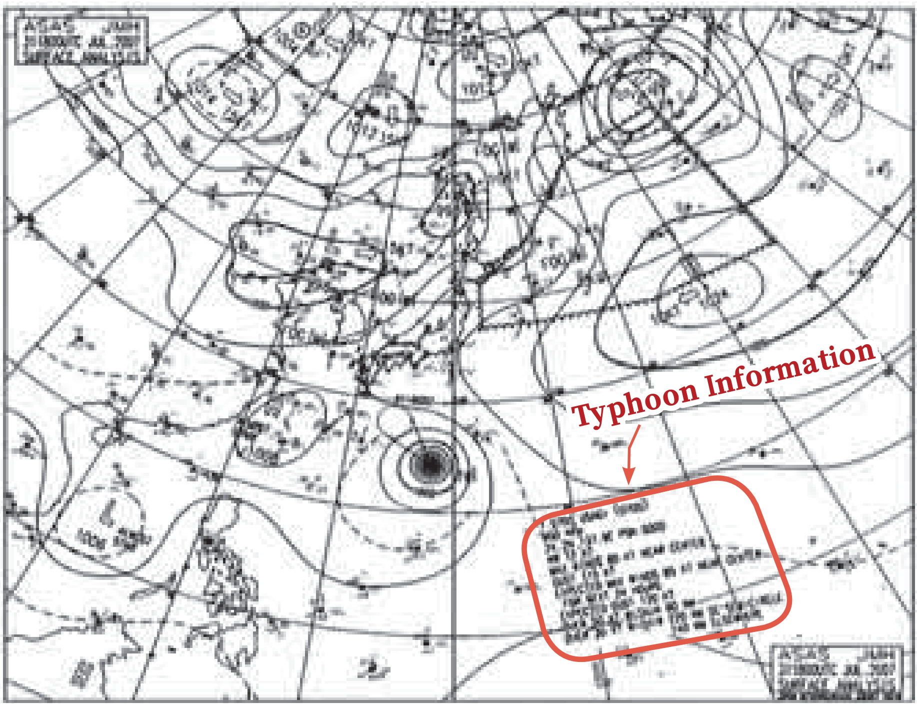


Fig. 47 From the Japan Meteorological Agency website　Surface weather chart

Typhoon information can also be found on the surface weather chart. For instance, information related to the precision of the typhoon's center position are shown as follows. It is also important that this be understood. "Good" means that the margin of error for the position of the typhoon's centre is less than 30 miles. "Poor" means the margin of error is more than 60 miles, and "Fair" means the margin of error is more than 30 miles but less than 60 miles. It is a must that each piece of written information be understood, this includes other information which is not discussed here.

5－2　Wave Charts

Wave charts issued by the Japan Meteorological Agency are as follows:

1	Ocean Wave Analysis Chart
2	Ocean Wave Prognosis Chart (24hour)
3	Coastal Wave Analysis Chart
4	Coastal Wave Prognosis Chart (24hour)

The nowcast and forecast wave charts display "equal wave height lines" composed of meter-by-meter heights of significant waves [Note No.3] and swells, along with "prevailing wave directions," "anticyclonic and cyclonic central positions" and "fronts" (Fig. 48). Just as with surface weather charts and upper-air Weather Charts (upper-air Charts) that will be mentioned below, it is important read the descriptions.

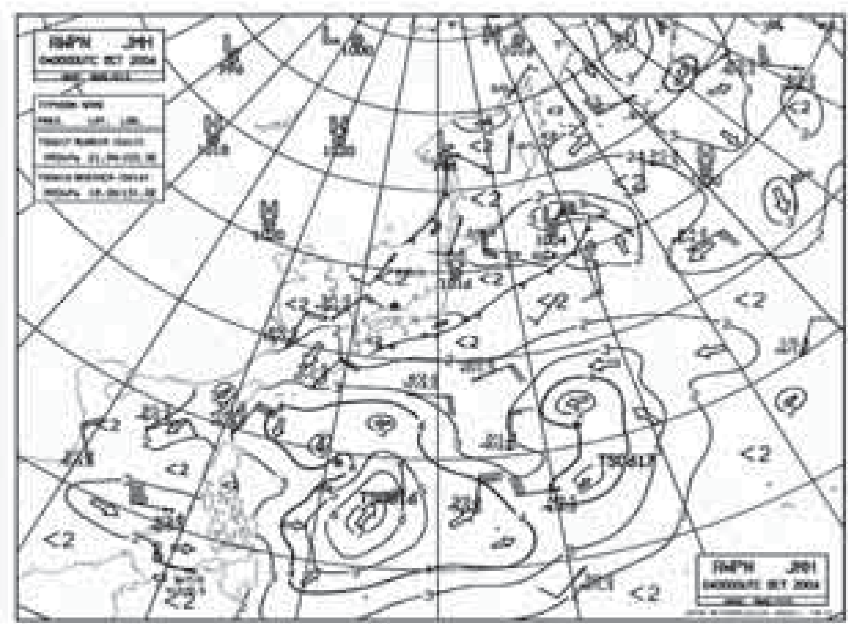


Fig. 48 Ocean wave chart From the Japan Meteorological Agency website

Especially when operating in rough seas, it is important to understand the actual wave cycles, wave heights, wave lengths and so on. By referring to the wave charts, it is a requirement that actual conditions be compared with those on the wave charts.

For example, the outlined arrow shown in Figure 49 represents the propagation direction of the waves that appear to be most prominent in that area. The outlined arrow on the wave chart indicates the prevailing direction of wave propagation in the sea area concerned. Waves propagate in the direction of the arrow. From this example, you can see that the prevailing waves are propagating from northwest to southeast.

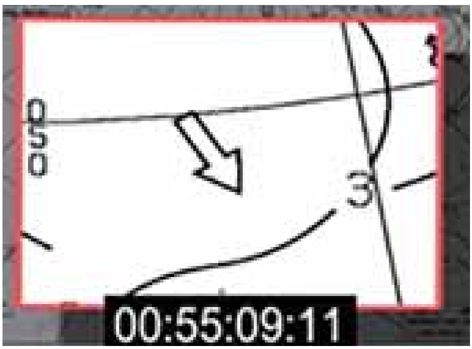


Fig. 49 Japan Captains' Association, DVD

Note 3: Significant wave height

Significant wave can be defined as follows: Choose 1/3 of the wave observations (within a timeframe of 20 mins.) in descending order from the top. Of those, the average wave height and period becomes the significant wave. According to this definition, this is also referred to as the “ 1/3 maximum wave ” . According to this definition, this is also referred to as the “ 1/3 maximum wave ” . (From the Japan Meteorological Agency website)

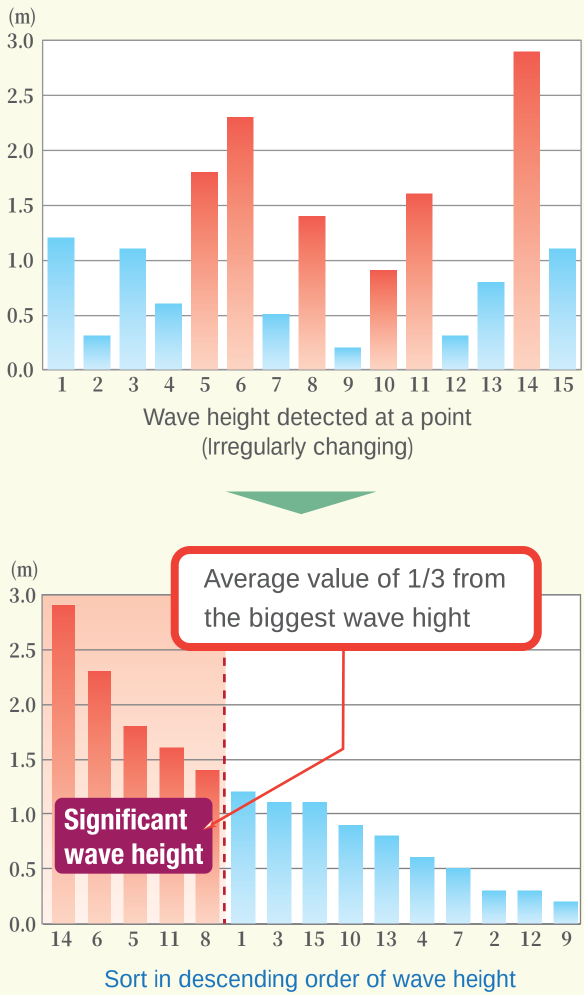


Fig. 51

Also, as can be seen in Fig. 50, if an "outlined arrow in a white circle" is indicated on the wave forecast chart, it means anticipated direction of wave propagation. The number assigned to it represents a forecast value for wave cycles in one-second units; the first decimal place represents a forecast value of the significant wave heights (Note 3) in one-meter units. As such, this example forecasts Northerly waves at a cycle of 11 seconds and wave heights of 2.3 meters.

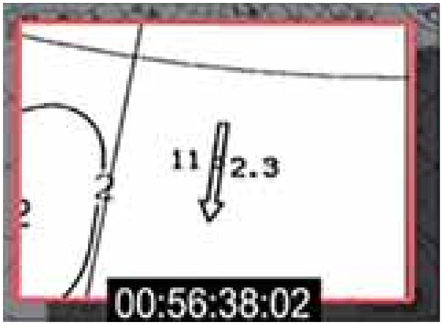


Fig. 50 Japan Captains' Association, DVD

5－3　Upper-air Weather Charts (Upper-air Charts)

Regarding the upper atmosphere, air pressure, wind, temperature and humidity are commonly observed using a balloon. Upper-air Weather Charts are also known as Upper-air Charts, which show the values of upper meteorological parameters that are measured in each area of the world on the atmospheric pressure surface. The surface where atmospheric pressure is constant is known as constant pressure surface. The curve shown on the upper weather chart is the height of the constant pressure surface, the same that is shown on a terrestrial map. All four different upper weather charts (or upper-air chart) shown in Table 52 are issued by the Japan Meteorological Agency.

Constant pressure surface (hPa)	850	700	500	300
Altitude (m)	1,500	3,000	5,500	9,500

Fig. 52

Because the meteorological phenomenon is an atmospheric motional phenomenon in the Troposphere from the ground to the Thermopause, it is necessary to observe it three-dimensionally. In this respect, a surface weather chart is insufficient, because it only illustrates the surface weather condition. Therefore, it is only representing one aspect of the weather. On surface weather charts that can be largely influenced by the form of the land, solar insolation and eradiation, both potential temperature analysis (analysis of air mass) and equivalent potential temperature (analysis of the front) cannot be carried out. Therefore, it is difficult to understand and forecast accurately the generation and migration of large-scaled high or low pressure, typhoons and so on. On the other hand, as the upper layer is even without air turbulence, it is possible to trace the atmospheric-pressure migration over a long period of time and forecast it. Further, it is known that there is a close relationship between the upper and lower layers. Therefore, it would be important to analyse the weather using upper-air weather charts also.

Along with surface weather charts, upper-air weather charts, which are often used on ships, are 850 hPa （AUAS85） and 500 hPa (AUAS50) upper weather charts (upper-air weather charts).

5−3−1　500 hPa (AUAS50) Upper-air Weather Chart (Upper-air Chart)

An Example of a 500 hPa upper-air chart (Upper-air Weather Chart) is shown in Figure 53.

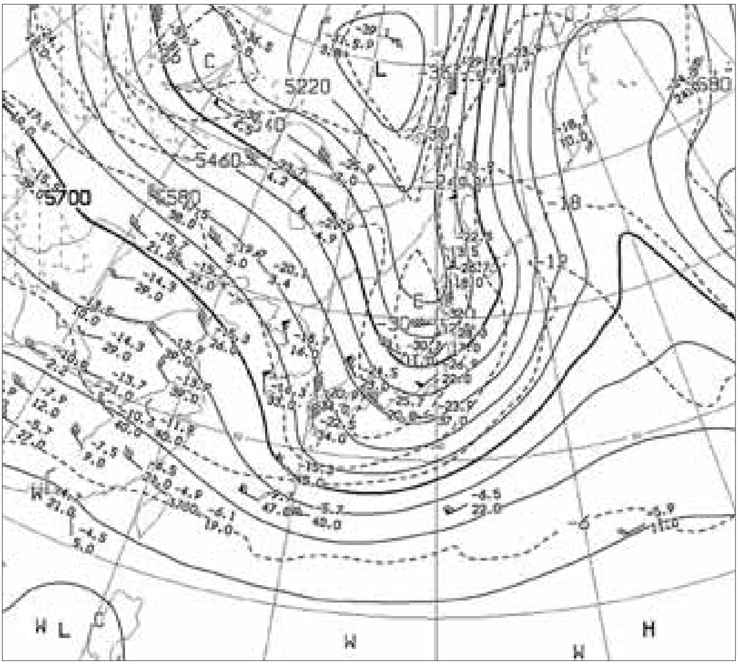


Fig.53 500 hPa Upper-air chart from the Japan Meteorological Agency website

In this figure, solid lines on a 500 hPa upper-air chart are contour lines, and broken lines are isothermal lines. The contour lines show 60-meter increments and the isothermal lines represent increments of 6 degrees (or 3 degrees, if necessary). W denotes a warm region, and C denotes a cold region. The temperature is shown on the upper left of the “point circle” and the dew-point (spread) is indicated on the lower left of the point circle. Both are indicated at one decimal place. For your reference, regarding the dew-point (spread), the numerical number whose temperature minus dew point temperature is indicated with a unit °C applies to temperature. Therefore, when relative humidity is 100%, its dew-point (spread) becomes 0°C.

From the distribution of the contour lines on a 500 hPa upper-air chart, it is possible to estimate the locations and strengths of westerly sea waves and cores of jet streams. In addition, barometric pressure distribution helps us to locate the regions of cold or warm air. Also, depending on the degree of cold air, it is possible to determine the strength of precipitation and discriminate between rain or snow.

If sea waves of westerlies on the upper layer are closely related to the anticyclones and cyclones on the ground, then, according to the contour lines on a 500 hPa upper-air chart, we are able to interpret the fundamental circulation of the atmosphere among various meteorological phenomena shown in the surface barometric pressure distribution. With this, by inserting a pressure trough and the movement of/variation of peaks (and troughs) on a 500 hPa upper-air chart, we are able to make a more accurate forecast of the circulation, more so than inserting movements of the anticyclones and cyclones, using a surface weather chart.

5−3−2 850 hPa (AUAS85) Upper-air Weather Chart (Upper-air Chart) (Fig. 54)

Observed wind direction is not always in accordance with the that of barometric gradients on the surface weather chart, because surface friction is influential. On a 850 hPa upper-air chart, the height is so that there is no influence caused by surface friction. Thus, convergence or divergence of the lower layer can be more frequently seen on this weather chart. In addi-

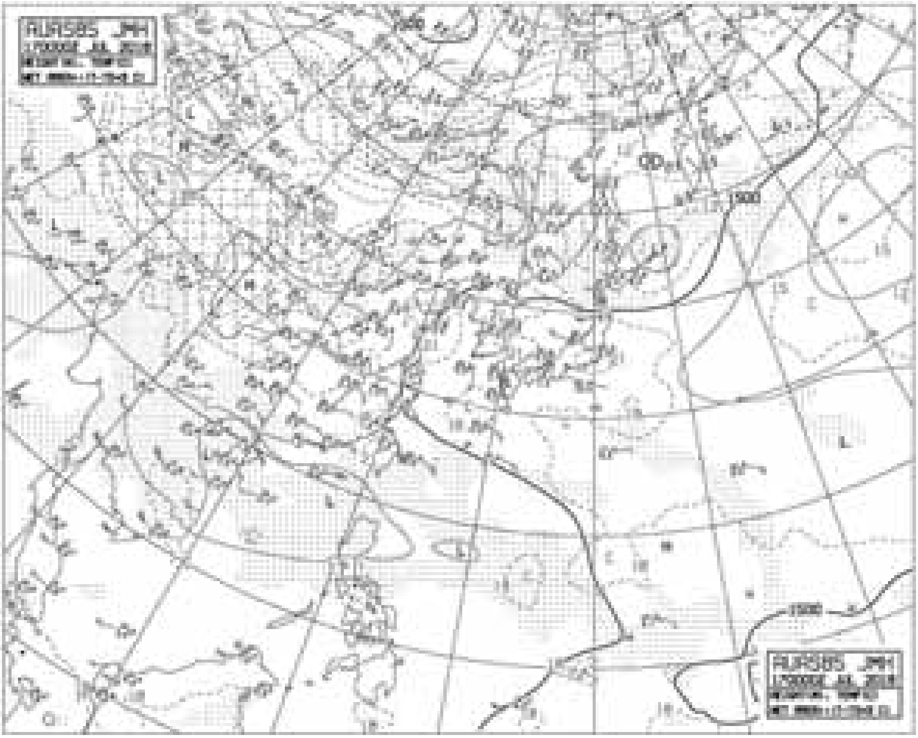


Fig. 54　850 hPa Upper-air Weather Chart　From the Japan Meteorological Agency website

tion, front and air masses can be located easily using temperature distribution information. In other words, the isothermal lines are crowded at the point where 850 hPa and the front intersect. This area shows a significant change of wind direction and wind speed. It is also possible to ascertain temperature advection from temperature distribution and wind patterns. On both of the 850 hPa and 700 hPa weather charts, the regions, where dew-point (spread) is less than 3°C, are shaded. At 850 hPa, this area is almost equal to that of the spread of lower clouds.

§ 6 Wind and Waves and Undulations (swells)

When operating in rough seas, waves will be caused by winds and swell from several different directions, which will cause the vessels to undergo a number of complicated oscillations. In this situation, it is important to have a precise grasp of the lengths of waves and their undulations, their cycle and wave heights in order to operate safely. Wind and waves and undulations (swells) will be described below.

6－1 Basic Form of a Wave

As can be seen in Figure 55, a single wave has a sine curve movement and the relationship between the wave length, wave speed and cycle can be shown in the following formula.

$$\text{Wave speed } [v] \ \mathbf{m/sec} = \frac{\text{Wave length } \ \boldsymbol{\lambda} \ [\mathbf{m}]}{\text{Wave cycle period } \ \mathbf{T} \ [\mathbf{sec}]}$$

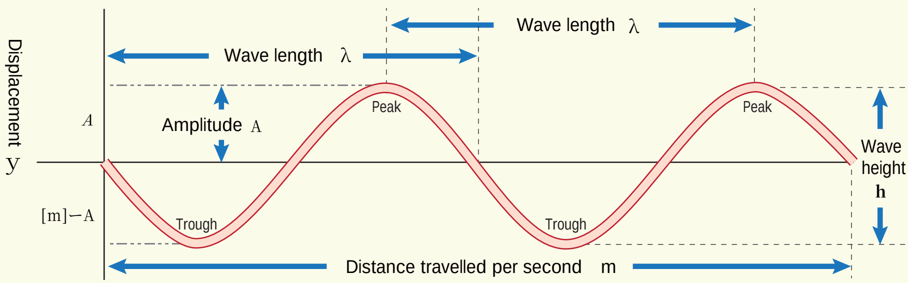


Fig. 55

In reality, there is rarely one wave or swell, but rather, the ship is tossed in several different waves, winds and swells, all of which differ in wavelength, speed, number of cycles and come from different directions. An example of synthetic waves is shown in Figure 56.

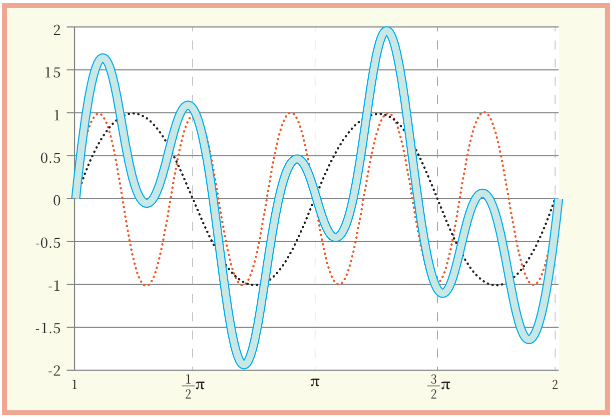


Fig. 56

Wave height [Hc], when some waves mix, can be determined when using the following; by taking the root mean square surface of each wave height.

$$Hc = \sqrt{H_w^2 + H_a^2 + H_b^2 + \cdots\cdots\cdots\cdots}$$

For instance, if the wave height is 1m and the height of the swell is 2m, the wave height of the synthetic wave shall be 2.236m.

$$\sqrt{1^2+2^2} = \sqrt{5} = 2.236\text{m}$$

6－2 Differences between Wind and Waves and Undulations (swells)

As can be seen in Figure 57 below, when wind blows on the sea, the sea surface starts to move and riffled waves propagate in the direction of the blowing wind. If the wave speed is greater than the wind speed, the wave will continue to develop as it is pushed by the wind. Waves that are produced by the wind blowing on the sea are referred to as “wind and waves”. Moreover, when wind and waves continue on to an area of sea where no wind is blowing, when the sea wind weakens, or when the direction of the wind suddenly changes, the type of wave that is no longer driven by the wind is referred to as an undulation (swell). An undulation (swell) is a propagating wave that attenuates. Compared with other wind and waves of the same height, its shape is regular and rounded, and the peak of the wave is also horizontally wide.

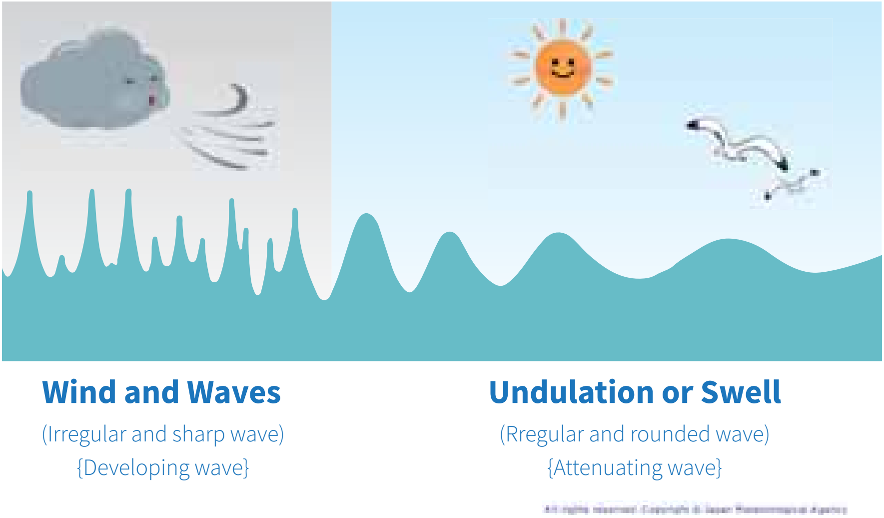


Fig. 57 From the Japan Meteorological Agency website

§ 7 Ship Handling in Rough Sea: Head and Countering / Following Seas

In this chapter, Ship Handling in Rough Sea, I would like to explain how dangerous it is when a ship is pitching and rolling in the event of it being exposed to head and countering or following seas.

7 — 1 Ship Handling in Head and Countering Seas

When a ship navigates in head seas, its hull is subjected to severe shocks which induce violent ship motions. Well trained and experienced navigators are able to respond to this by altering the ship's course and speed as required. However, to accomplish safe navigation in head seas, it is advisable to have more reliable ship-handling techniques backed by theoretical knowledge as to why these phenomena are created and how to avoid the generation of these critical effects, in addition to possessing sea-going experience.

When there are wind and waves and huge undulations (swells) coming from several different directions, a ship at the mercy of wave forces, heaves, pitches and rolls repeatedly. Also, depending on the ship's relative position in waves and, whether it is being lifted up to the top of a crest or falling into a trough, hogging, sagging and twisting forces generate great deflections in the entire hull structure (Fig. 58). In addition, the ship's speed is usually decreased by wind and wave resistance. This phenomenon is particularly augmented in head seas.

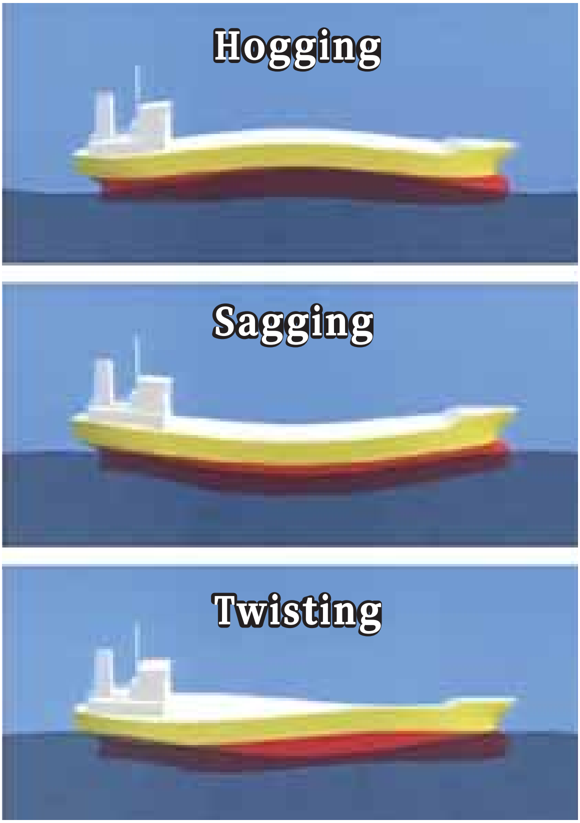


Fig. 58 Japan Captains' Association, DVD

Pitching intensified motion in head and countering seas of rough weather has the greatest influence on the safety of a ship. In particular attention is to be paid to the following relationship between the length of a wave and the length of a ship (Lpp):

① When wave length is shorter than ship length(Lpp)

Because the ship motions are insignificant as the influence of waves is weak, the bottom of the bow neither rises enough to be exposed dangerously nor dips enough for the fore deck to take on water (Fig. 59).

Fig. 59 Japan Captains' Association, DVD

② When wave length is longer than ship length (Lpp)

A ship pitches and heaves slowly at the front and rear surface of waves that will affect its form. However, this does not cause significant movement (Fig. 60).

Fig. 60 Japan Captains' Association, DVD

③ When wave length is almost equal to ship length (Lpp)

When wave length is almost equal to ship length, ship motion will be most intense. The heaving of the bow on a crest and the plunging of it into the succeeding wave will be accelerated (Fig. 61).

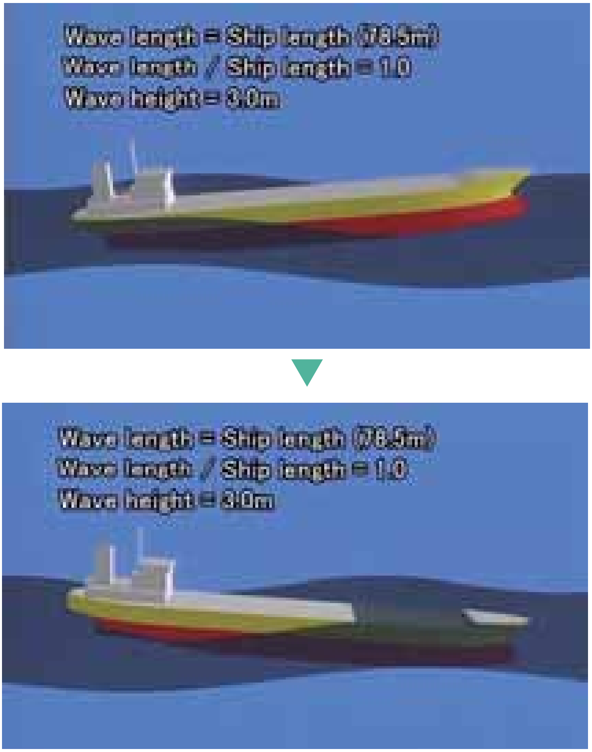


Fig. 61 Japan Captains' Association, DVD

In such cases, changes in water level both forward and aft become particularly great in regular wave conditions (See Fig. 62) and relative water level at the bow is greatest when wave length is equal to ship length, and seas are likely to be shipped when the relative water level exceeds the freeboard at the bow (highlighted in orange colour), while in contrast, slamming may occur when the relative water level drops far enough below the forward draft to the extent that the bottom plates at the bow are exposed (highlighted in red).

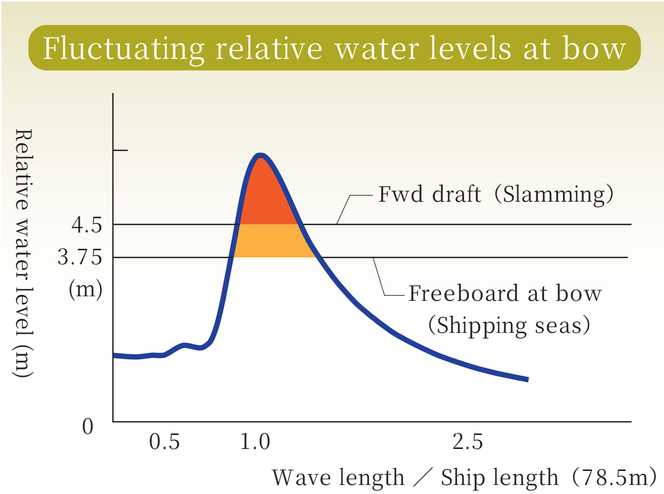


Fig. 62 Japan Captains' Association, DVD

These head and countering seas cause the following phenomena:

1	Propeller Racing
2	Speed reduction and a torque rich effect on the engine
3	Shipping Seas
4	Slamming Phenomenon

7−1−1 Propeller Racing

Whenever a ship pitches and heaves heavily at the bow, an equivalent heaving motion is generated at the stern. Due to these motions, the stern lifts out of the sea at intervals exposing part of the propeller and causing instant increases of propeller revolutions accompanied by intense vibrations due to the abrupt reduction of propeller load. This phenomenon is called propeller racing and can have adverse effects not only on the propeller itself, but also on the propeller shaft and engine (Photographs 63 and 64).


Photograph 63 Japan Captains' Association, DVD


Photograph 64 Japan Captains' Association, DVD

Therefore, it is recommended to make the stern draft as deep as possible so that propeller immersion is kept at more than 20 percent of the diameter of the propeller when navigating in rough seas. However, when trimming excessively for a ballast passage, forward draft will be reduced. As the possibility of slamming phenomenon increases (mentioned below), it is essential that the hull's condition be properly maintained in light of this (Fig. 65).

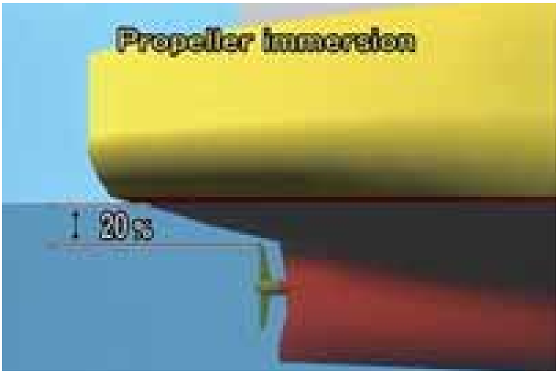


Fig. 65 Japan Captains' Association, DVD

7−1−2 Speed Reduction and the Torque Rich Effect on the Engine

When the vessel receives waves and undulation (swells) from the front, the resistance of these combined with additional wind pressure, the ship's speed will decrease, and the engine will undergo a torque rich effect. Figure 66 illustrates speed reduction characteristics in irregular waves. For instance, in the case of a container ship with a length of 250m, the ratio of speed reduction becomes markedly larger at approximately 30%, when wave height is greater than 6m.

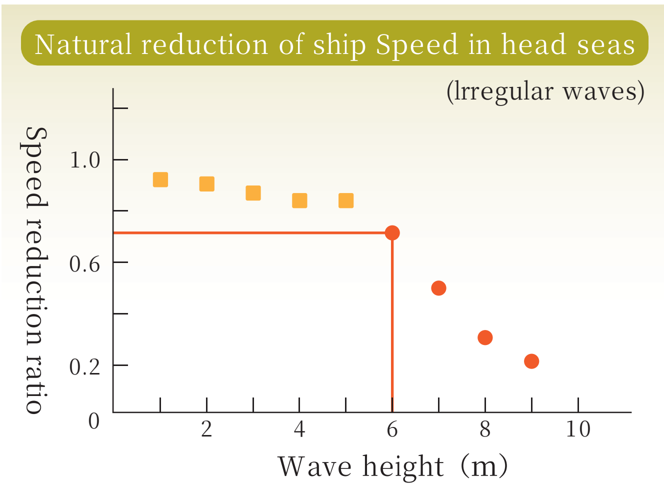


Fig. 66 Japan Captains' Association, DVD

As resistance to the hull increases, the engine requires more fuel in order to maintain the same number of revolutions as set under normal conditions, forcing the ship to plough through the water under excess engine load. This causes what is known as a torque rich effect and may often result in engine trouble due to overheating, or in a great waste of fuel. In such conditions, it is essential to reduce ship speed, because the engine might be damaged as a result of over-heating or it may consume a huge amount of fuel unnecessarily.

Photograph 67 Japan Captains' Association, DVD

If I compare the torque rich effect to driving a car, I am sure that many of our Club members may be able to relate to the following scenario. When a car being driven on a level road comes across a very steep upward slope, its speed falls. In an effort to maintain the same speed, the driver often reacts, by pressing the accelerator down hard. However, the engine output is limited and the speed does not increase. If the effort is continued, the engine will overheat. This is referred to as the torque rich effect.

Fig. 68 Japan Captains' Association, DVD

As with the car, it is essential for a ship to reduce engine revolutions, while the Master and Chief Engineer have in-depth meetings regarding the load status of the engine, whenever there are signs that the engine is becoming torque rich.

7−1−3 Shipping Seas

A ship may sometimes sustain severe damage from the impacting green seas. Deck machinery, deck cargo and hatch covers are often damaged as a result of shipping seas which may cause water to enter into the holds. Damage sustained from shipping seas is two-fold: damage caused to the bow from green sea pounding, and damage inflicted on deck machinery and appliances from the subsequent incursion of sea water.

Photograph 69 Japan Captains' Association, DVD

Photograph 70 Japan Captains' Association, DVD

Photograph 71 Japan Captains' Association, DVD

Photograph 72 Japan Captains' Association, DVD

The dynamic pressure of green sea pounding on the deck vertically from above may reach around twice that of seas being shipped. For example, if a 100 ton mass of sea water fell from 4m above deck, the stress would be equivalent to what 20 fully grown elephants each weighing 5 tons would generate by jumping one after another at intervals of no more than three seconds onto a deck area of 40 m^2 from a height of 4m above the deck. It is easy to imagine the scale of such huge dynamic pressure. Furthermore, the dynamic stress of a sweeping mass of launched and shipped seas over decks, proportional to the square of the ship's speed, becomes almost as great as that from vertical pounding. Deck machinery such as sounding pipes and so on can be damaged as a result.

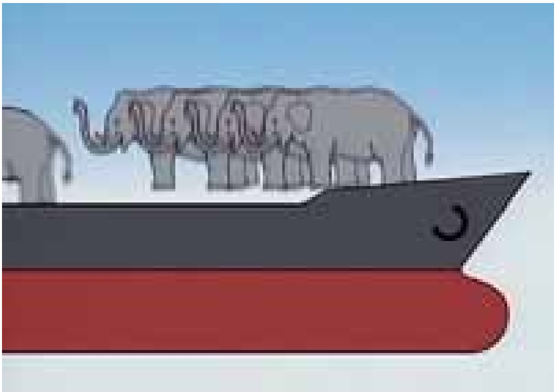


Fig. 73 Japan Captains' Association, DVD

The following are the results obtained from ship model trials of shipping seas: the simulation was carried out under the following conditions:

Gross tonnage	Length	Breadth	Depth	Design draft	Beaufort scale	Wave hight	Mean wave period	Ship speed
699 G/T	78.5m (Lpp)	12.8 m	7.8m	4.52m Even Keel	6	3 m	7.13 secs	9 knots

① When changing the wave length and encounter angle of ship to wave

Results of trials which were conducted using varying wave length to ship length (Lpp) ratios of 0.5 (wave length: 39m), 2.5 (196m) and 1.0 (79m), and by changing the encounter angle of ship to wave from zero to 90 degrees by 15 degrees per each wave length, are indicated in the Figure 74 (three dimensional).

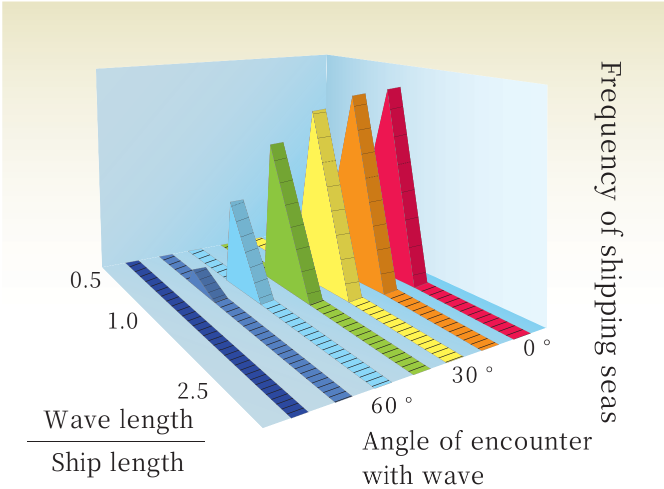


Fig. 74 Japan Captains' Association, DVD

Because the effect of the wave was minimal when applying a wave length to ship length (Lpp) ratio of 0.5 (wave length: 39m), ship motion was insignificant, and no seas were shipped. Also, when wave length was increased to 196m, equivalent to 2.5 times the ship length (Lpp), the ship only pitched and heaved slowly along the surfaces of the waves and, again, no seas were shipped.

When a wave length of 79 m, which is equal to the ship's length, was applied, the pitching motion was intensified, and the phenomena associated with shipping seas constantly occurred.

Meanwhile, when the encounter angle of ship to wave was anywhere between zero to 90 degrees, and wave length was equal to the ship's length, there was almost no change in frequency of shipping seas compared with the encounter angle of ship to wave set between zero to 45 degrees.

When the angle of encounter of ship to the waves was increased to more than 45 degrees, the frequency of seas being shipped started to decrease. Moreover, when the same angle was