

CHAPTER 41

WEATHER ROUTING

PRINCIPLES OF WEATHER ROUTING

4100. Introduction

Ship weather routing develops an optimum track for ocean voyages based on forecasts of weather, sea conditions, and a ship's individual characteristics for a particular transit. Within specified limits of weather and sea conditions, the term optimum is used to mean maximum safety and crew comfort, minimum fuel consumption, minimum time underway, or any desired combination of these factors. The purpose of this chapter is to acquaint the mariner with the basic philosophy and procedures of ship weather routing as an aid to understanding the routing agency's recommendations.

The mariner's first resources for route planning in relation to weather are the *Pilot Chart Atlases* (Figure 4100a), the *Sailing Directions (Planning Guides)* (Figure 4100b), and other climatological sources such as historical weather data tables. These publications give climatic data, such as wind speed and direction, wave height frequencies and ice limits, for the major ocean basins of the world. They may recommend specific routes based on probabilities, but not on specific conditions.



Figure 4100a. *Pilot Chart Atlases*
https://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0003.

The ship routing agency, acting as an advisory service, attempts to avoid or reduce the effects of specific adverse weather and sea conditions by issuing initial route recommendations prior to sailing. It recommends track changes while underway (diversions), and weather advisories to alert the commanding officer or master about approaching unfavorable weather and sea conditions which cannot be effectively avoided by a diversion. Adverse weather and sea conditions are defined as those conditions which will cause damage, significant speed reduction, or time loss.



Figure 4100b. *Sailing Directions (Planning Guides)*
https://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0011.

The initial route recommendation is based on a survey of weather and sea forecasts between the point of departure and the destination. It takes into account the type of vessel, hull type, speed capability, safety considerations, cargo, and loading conditions. The vessel's progress is continually monitored, and if adverse weather and sea conditions are forecast along the vessel's current track, a recommendation for a diversion or a weather advisory is transmitted. By this process of initial route selection and continued monitoring of progress for possible changes in the forecast weather and sea conditions along a route, it is possible to maximize both speed and safety.

In providing for optimum sailing conditions, the advisory service also attempts to reduce transit time by avoiding the adverse conditions which may be encountered on a shorter route, or if the forecasts permit, diverting to a shorter track to take advantage of favorable weather and sea conditions. A significant advantage of weather routing accrues when: (1) the passage is relatively long, about 1,500 miles or more; (2) the waters are navigationally unrestricted, so that there is a choice of routes; and (3) weather is a factor in determining the route to be followed.

Use of this advisory service in no way relieves the commanding officer or master of responsibility for prudent seamanship and safe navigation. There is no intent by the routing agency to inhibit the exercise of professional judgment and prerogatives of commanding officers and masters.

The techniques of ship routing and access to the advice are increasingly less expensive, and are thus being made available to coastal vessels, smaller commercial craft, and even yachts.

4101. Historical Perspective

The advent of extended range forecasting and the development of selective climatology, along with powerful computer modeling techniques, have made ship routing systems possible. The ability to effectively advise ships to take advantage of favorable weather was hampered previously by forecast limitations and the lack of an effective communications system.

Development work in the area of data accumulation and climatology has a long history. Benjamin Franklin, as deputy postmaster general of the British Colonies in North America, produced a chart of the Gulf Stream from information supplied by masters of New England whaling ships. This first mapping of the Gulf Stream helped improve the mail packet service between the British Colonies and England. In some passages the sailing time was reduced by as much as 14 days over routes previously sailed.

In the mid-19th century, Matthew Fontaine Maury compiled large amounts of atmospheric and oceanographic data from ships' log books. For the first time, a climatology of ocean weather and currents of the world was available to the mariner. This information was used by Maury to develop seasonally recommended routes for sailing ships and early steam powered vessels in the latter half of the 19th century. In many cases, Maury's charts were proved correct by the savings in transit time. Average transit time on the New York to California via Cape Horn route was reduced from 183 days to 139 days with the use of his recommended seasonal routes.

In the 1950's the concept of ship weather routing was put into operation by several private meteorological groups and by the U.S. Navy. By applying the available surface and upper air forecasts to transoceanic shipping, it was possible to effectively avoid much heavy weather while generally sailing shorter routes than previously. The development of computers, the Internet and communications technology has made weather routing available to nearly everyone afloat.

4102. System Types

Optimum Track Ship Routing (OTSR), the ship routing service of the U.S. Navy, utilizes short to medium range forecasting techniques in route selection and surveillance procedures. The short to medium range dynamic forecasts of 3 to 10 days are derived from meteorological equations processed by high-speed super computers. These forecasts are computed at least twice daily from a data base of global surface and upper air observations, and include surface pressure, upper air constant pressure heights and spectral wave values. A significant increase in data acquisition, particularly from satellite imagery over oceans and data sparse areas have extended the time period for which these forecasts are useful.

Selective climatology has been effective in predicting average conditions months in advance during such events as the El Nino Southern Oscillation (ENSO) which encompasses both the El Nino and La Nina. Such predictions do

not represent forecasting, but can indicate the likelihood of certain atmospheric weather patterns appearing or prevailing.

For extended range forecasting, generally beyond ten days, computer models use a combination of analogs, climatology and ensemble techniques to find the logical sequence of events following the dynamic forecasts of 3 to 10 days. Beyond ten days, climatology is used to determine the optimum track.

Aviation was first in applying the principle of minimum time tracks (MTT) to a changing wind field. But the problem of finding an MTT for a specific flight is much simpler than for a transoceanic ship passage because an aircraft's transit time is much shorter than a ship's. Thus, marine minimum time tracks require significantly longer range forecasts to develop an optimum route.

Automation has enabled ship routing agencies to develop realistic minimum time tracks. Computation of minimum time tracks makes use of:

1. A navigation system to compute route distance, time enroute, estimated times of arrival (ETA's), and to provide 6 hourly DR synoptic positions for the range of the dynamic forecasts for the ship's current track.
2. A surveillance system to survey wind, seas, fog, and ocean currents obtained from the dynamic and climatological fields.
3. An environmental constraint system imposed as part of the route selection and surveillance process. Constraints are the upper limits of wind and seas desired for the transit. They are determined by the ship's loading, speed capability, and vulnerability. The constraint system is an important part of the route selection process and acts as a warning system when the weather and sea forecast along the present track exceeds predetermined limits.
4. Ship speed characteristics used to approximate ship's speed of advance (SOA) while transiting the forecast sea states.

Criteria for route selection reflect a balance between the captain's desired levels of speed, safety, comfort, and consideration of operations such as fleet maneuvers, fishing, towing, etc.

Ship weather routing services are being offered by many nations. These include Japan, United Kingdom, Russia, Netherlands, Germany, and the United States. Also, several private firms provide routing services to shipping industry clients. Several personal computer-based software applications have become available, making weather routing available to virtually everyone at sea.

There are two general types of routing services available. The first uses techniques similar to the Navy's Optimum Track Ship Routing (OTSR) system to forecast conditions and compute routing recommendations, which are then broadcast to the vessel. Because this service is per-

formed ashore, it allows for greater computer power to be applied to the routing task. The second assembles and processes weather and sea condition data and transmits this to ships at sea for on-board processing and generation of route recommendations. This system allows the ship's master to have greater flexibility in changing parameters, evaluating various scenarios, selecting routes, and displaying data.

4103. Ship and Cargo Considerations

Ship and cargo characteristics have a significant influence on the application of ship weather routing. Ship size, speed capability, and type of cargo are important considerations in the route selection process prior to sailing and the surveillance procedure while underway. A ship's characteristics identify its vulnerability to adverse conditions and its ability to avoid them.

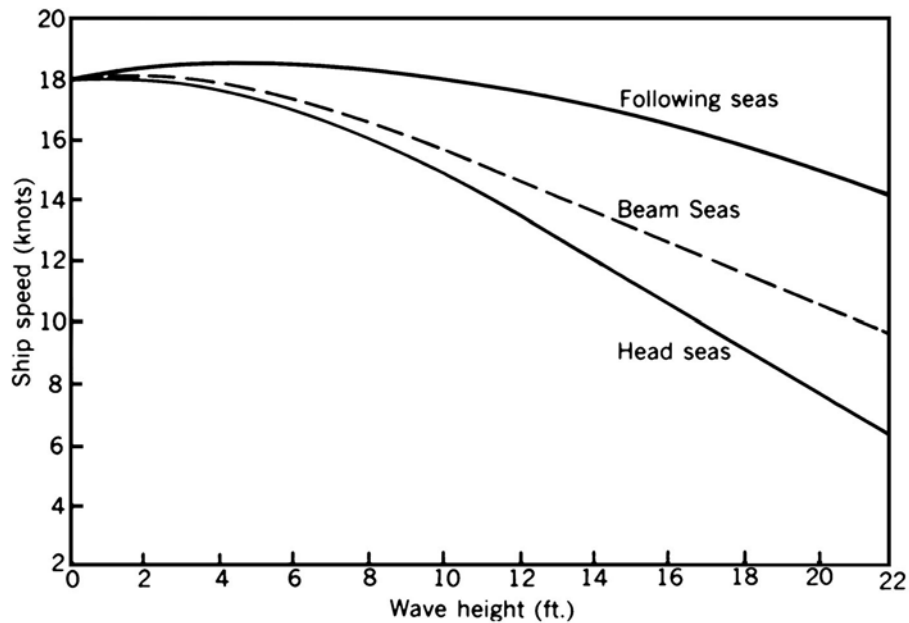


Figure 4103. Performance curves for head, beam, and following seas.

Generally, ships with higher speed capability and lighter loads will have shorter optimum routes and be better able to maintain near normal SOA's than ships with lower speed capability or heavy cargoes. Some routes are unique because of the type of ship or cargo. Avoiding one element of weather to reduce pounding or rolling may be of prime importance. For example, a 20 knot ship with a heavy deck cargo may be severely hampered in its ability to maintain a 20 knot SOA in any seas exceeding moderate head or beam seas because of the possibility of damage resulting from the deck load's characteristics. A similar ship with a stable cargo under the deck is not as vulnerable and may be able to maintain the 20 knot SOA in conditions which would drastically slow the deck-loaded vessel. In towing operations, a tug is more vulnerable to adverse weather and sea conditions, not only in consideration of the tow, but also because of its already limited speed capability. Its slow speed adds to the difficulty of avoiding adverse weather and sea conditions.

Ship performance curves (speed curves) are used to estimate the ship's SOA while transiting the forecast sea states. The curves indicate the effect of head, beam, and following seas of various significant wave heights on the ship's speed. Figure 4103 is a performance curve prepared

for a commercial 18-knot vessel. Each vessel will have its own performance curves, which vary widely according to hull type, length, beam, shape, power, and tonnage. Recommendations for sailing vessels must account for wind speed, wind angle, and vessel speed.

With the speed curves it is possible to determine just how costly a diversion will be in terms of the required distance and time. A diversion may not be necessary where the duration of the adverse conditions is limited. In this case, it may be better to ride out the weather and seas knowing that a diversion, even if able to maintain the normal SOA, will not overcome the increased distance and time required.

At other times, the diversion track is less costly because it avoids an area of adverse weather and sea conditions, while being able to maintain normal SOA even though the distance to destination is increased. Based on input data for environmental conditions and ship's behavior, route selection and surveillance techniques seek to achieve the optimum balance between time, distance, and acceptable environmental and seakeeping conditions. Although speed performance curves are an aid to the ship routing agency, the response by mariners to deteriorating weather and sea conditions is not uniform. Some reduce

speed voluntarily or change heading sooner than others when unfavorable conditions are encountered. Certain waves with characteristics such as the ship's bow and stern are in successive crests and troughs present special problems for the mariner. Being nearly equal to the ship's length, such wavelengths may induce very dangerous stresses. The degree of hogging and sagging and the associated danger may be more apparent to the mariner than to the ship routing agency. Therefore, adjustment in course and speed for a more favorable ride must be initiated by the commanding officer or master when this situation is encountered.

4104. Environmental Factors

Environmental factors of importance to ship weather routing are those elements of the atmosphere and ocean that may produce a change in the status of a ship transit. In ship routing, consideration is given to wind, seas, fog, ice, and ocean currents. While all of the environmental factors are important for route selection and surveillance, optimum routing is normally considered attained if the effects of wind and seas can be optimized.

Wind: The effect of wind speed on ship performance is difficult to determine. In light winds (less than 20-knots), ships lose speed in headwinds and gain speed slightly in following winds. For higher wind speeds, ship speed is reduced in both head and following winds. This is due to the increased wave action, which even in following seas results in increased drag from steering corrections, and indicates the importance of sea conditions in determining ship performance. In dealing with wind, it is also necessary to know the ship's sail area. High winds will have a greater adverse effect on a large, fully loaded container ship or car carrier than a fully loaded tanker of similar length. This effect is most noticeable when docking or when navigating in restricted waters, but the effect of beam winds over several days at sea can also be considerable. For sailing vessels, the wind is critical and accurate forecasts are vital to a successful voyage.

Wave Height: Wave height is the major factor affecting ship performance. Wave action is responsible for ship motions which reduce propeller thrust and cause increased drag from steering corrections. The relationship of ship speed to wave direction and height is similar to that of wind. Head seas reduce ship speed, while following seas increase ship speed slightly to a certain point, beyond which they retard it. In heavy seas, exact performance may be difficult to predict because of the adjustments to course and speed for shiphandling and comfort. Although the effect of sea and swell is much greater for large commercial vessels than is wind speed and direction, it is difficult to separate the two in ship routing.

In an effort to provide a more detailed description of the actual and forecast sea state, several countries and private companies have developed global and regional wave

forecasting computer programs. These wave forecasts are based on the analyzed and forecast planetary boundary wind fields and are produced for both the Northern and Southern Hemispheres out to 144 hours or more. Most of these forecasts produce values for significant wave height, primary wave height and secondary wave height, as well as direction and period of these waves.

Fog: Fog, while not directly affecting ship performance, should be avoided as much as feasible, in order to maintain normal speed in safe conditions. Extensive areas of fog during summertime can be avoided by selecting a lower latitude route than one based solely upon wind and seas. Although the route may be longer, transit time may be less due to not having to reduce speed in reduced visibility. In addition, crew fatigue due to increased watchkeeping vigilance can be reduced.

North Wall Effect: During the Northern Hemisphere fall and winter, the waters to the north of the Gulf Stream in the North Atlantic are at their coldest, while the Gulf Stream itself remains at a constant relatively warm temperature. After passage of a strong cold front or behind a developing coastal low pressure system, Arctic air is sometimes drawn off the Mid-Atlantic coast of the United States and out over the warm waters of the Gulf Stream by northerly winds. This cold air is warmed as it passes over the Gulf Stream, resulting in rapid and intense deepening of the low pressure system and higher than normal surface winds. Higher waves and confused seas result from these winds. When these winds oppose the northeast set of the current, the result is increased wave heights and a shortening of the wave period. If the opposing current is sufficiently strong, the waves will break. These phenomena are collectively called the "North Wall Effect," referring to the region of most dramatic temperature change between the cold water to the north and the warm Gulf Stream water to the south. The most dangerous aspect of this phenomenon is that the strong winds and extremely high, steep waves occur in a limited area and may develop without warning. Thus, a ship that is laboring in near-gale force northerly winds and rough seas, proceeding on a northerly course, can suddenly encounter storm force winds and dangerously high breaking seas. Numerous ships have foundered off the North American coast in the approximate position of the Gulf Stream's North Wall. A similar phenomenon occurs in the North Pacific near the Kuroshio Current and off the Southeast African coast near the Agulhas Current.

Ocean Currents: Ocean currents do not present a significant routing problem, but they can be a determining factor in route selection and diversion. This is especially true when the points of departure and destination are at relatively low latitudes. The important considerations to be evaluated are the difference in distance between a great-circle route and a route selected for optimum current, with the expected increase in SOA from the following current, and the decreased probability of a di-

version for weather and seas at the lower latitude. For example, it has proven beneficial to remain equatorward of approximately 22°N for westbound passages between the Canal Zone and southwest Pacific ports. For eastbound passages, if the maximum latitude on a great-circle track from the southwest Pacific to the Canal Zone is below 24°N, a route passing near the axis of the Equatorial Countercurrent is practical because the increased distance is offset by favorable current. Direction and speed of ocean currents are more predictable than wind and seas, but some variability can be expected. Major ocean currents can be disrupted for several days by very intense weather systems such as hurricanes and by global phenomena such as El Niño.



Figure 4104a. Ice accumulation on deck can cause significant problems with stability of small ships. Freezing spray conditions should be avoided when possible. Image courtesy of Lars Anderson, SMHI.

Ice: The problem of ice includes pack ice, floating ice of land origin (icebergs) and deck ice. Areas of icebergs or pack ice should be avoided because of the difficulty of detection and the potential for collision. Icebergs are a hazard in the North Atlantic from late February through July, and occasionally later. The hazard of floating ice is frequently combined with restricted visibility in fog. International Ice Patrol warnings are incorporated into the planning of routes to safely avoid dangerous iceberg areas. The International Convention for the Safety of Life At Sea (SOLAS) Chapter V, Regulation 6 requires ships transiting the region of icebergs guarded by the Ice Patrol during the ice season to make use of the services provided by the Ice Patrol. The Ice Patrol sets an Iceberg Limit to delineate this region of icebergs. Vessels are recommended to transit to the east and south of this region at all times. The Ice Patrol's iceberg warning products are updated daily in textual, graphical, and electronic format and can be accessed through the USCG NAVCEN web portal (see Figure 4104b). The U.S. Navy ship routing office at Fleet Weather Center Norfolk main-

tains a safety margin of 100 nautical miles from icebergs reported by the Ice Patrol. In a severe winter, the Denmark Strait may be closed due to the presence of icebergs.



*Figure 4104b. North American Ice Service Products
<https://www.navcen.uscg.gov/?pageName=iipProducts>.*

Deck ice may be more difficult to contend with from a ship routing point of view because it is caused by freezing weather associated with a large weather system. While mostly a nuisance factor on large ships, it causes significant problems with the stability of small ships (Figure 4104a).

Latitude: Generally, the higher the latitude of a route, even in the summer, the greater are the problems with the environment. Certain operations should benefit from seasonal planning as well as optimum routing. For example, towing operations north of about 40° latitude should be avoided in non-summer months if possible.

4105. Synoptic Weather Considerations

A ship routing agency should direct its forecasting skills to avoiding or limiting the effect of weather and seas associated with extratropical low pressure systems in the mid and higher latitudes and the tropical systems in low latitude. Seasonal or monsoon weather is also a factor in route selection and diversion in certain areas.

Despite the amount of attention and publicity given to tropical cyclones, mid-latitude low pressure systems generally present more difficult problems to a ship routing agency. This is primarily due to the fact that major ship traffic is sailing in the latitudes of the migrating low pressure systems, and the amount of potential exposure to intense weather systems, especially in winter, is much greater.

Low pressure systems weaker than gale intensity (winds less than 34 knots) are not a severe problem for most ships. However, a relatively weak system may generate prolonged periods of rough seas which may hamper normal work aboard ship. Ship weather routing can frequently limit rough conditions to short periods of time and provide more favorable conditions for most of the transit. Relatively small vessels, tugs with tows, low powered ships, yachts, and

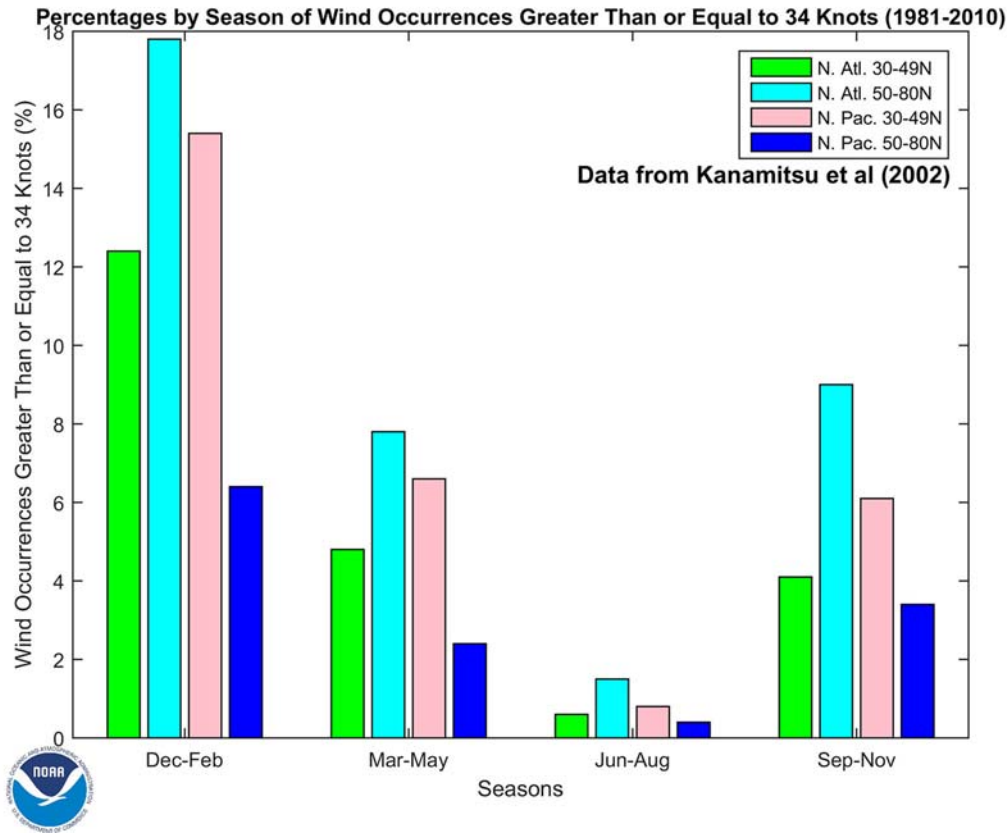


Figure 4105a. Percentages by season of wind occurrences greater than or equal to 34 knots, separated by geographic area. The percentages represent areas over the high seas only and do not include values over ice.

ships with sensitive cargoes can be significantly affected by weather systems weaker than gale intensity. Using a routing agency can enhance both safety and efficiency.

Gales (winds 34 to 47 knots) and storms (winds greater than 48 knots) in the open sea can generate very rough or high seas, particularly when an adverse current such as the Gulf Stream is involved. This can force a reduction in speed in order to gain a more comfortable and safe ride. Because of the extensive geographic area covered by a well developed low pressure system, once ship's speed is reduced the ability to improve the ship's situation is severely hampered. Thus, exposure to potential damage and danger is greatly increased. The vessel in such conditions may be forced to slow down just when it is necessary to speed up to avoid even worse conditions.

A recommendation for a diversion by a routing agency well in advance of the intense weather and associated seas will limit the duration of exposure of the vessel. If effective, ship speed will not be reduced and satisfactory progress will be maintained even though the remaining distance to destination is increased. Overall transit time is usually shorter than if no track change had been made and the ship had remained in heavy weather. In some cases diversions are

made to avoid adverse weather conditions and shorten the track at the same time. Significant savings in time and costs can result.

In very intense low pressure systems, with high winds and long duration over a long fetch, seas will be generated and propagated as swell over considerable distances. Even on a diversion, it is difficult to effectively avoid all unfavorable conditions. Generally, original routes for transoceanic passages, issued by the U.S. Navy's ship routing service, are within areas that experience gale force winds or higher often. Figure 4105a shows the frequency of gale force winds or higher by latitude in the North Atlantic and North Pacific. To avoid the area of significant gale activity in the Atlantic from October to April, the latitude of transit is generally in the lower thirties.

The areas, seasons, and the probability of development of tropical cyclones are fairly well defined in climatological publications. In long range planning, considerable benefit can be gained by limiting the exposure to the potential hazards of tropical systems.

It is advisable to avoid tropical cyclones. In the eastern North Pacific, the climatological distribution of tropical cyclones is relatively compact (See Figure 4105b). The

climatological distribution of tropical cyclones for the western North Pacific is shown in Figure 4105c. The

climatological distribution of tropical cyclones in the North Atlantic is shown in Figure 4105d.

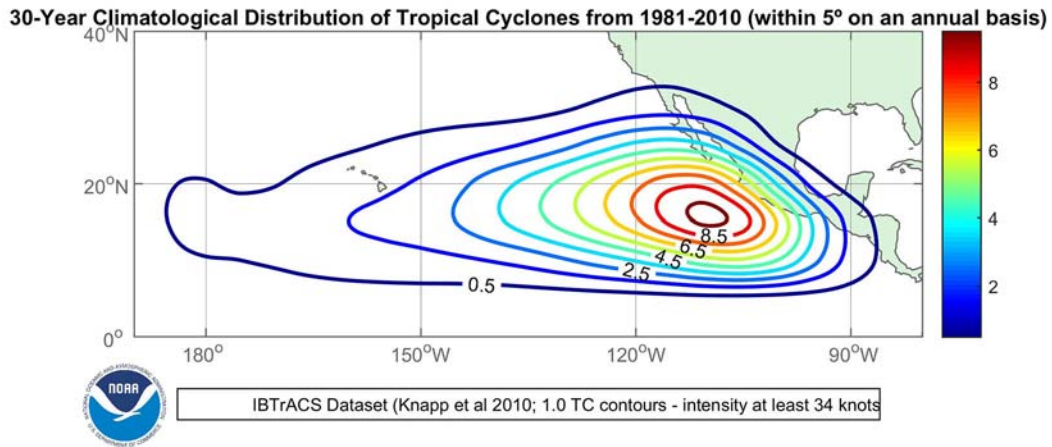


Figure 4105b. Average number of tropical cyclones that come within 5 degrees of a point in the Eastern Pacific Ocean.

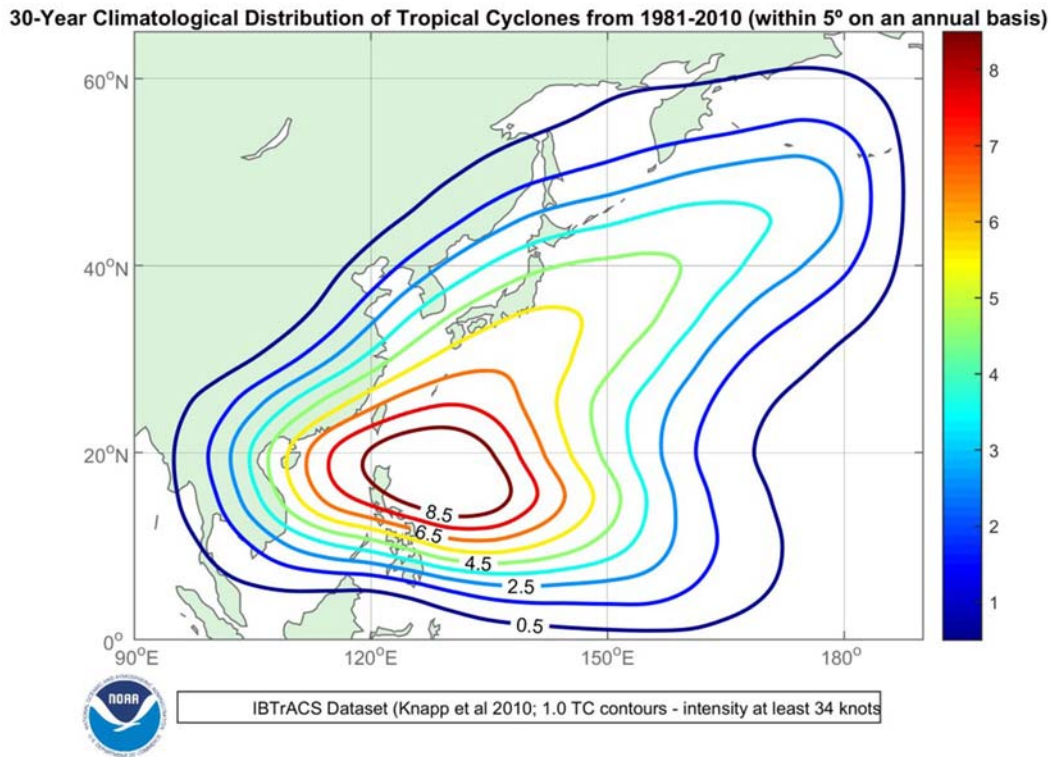


Figure 4105c. Average number of tropical cyclones that come within 5 degrees of a point in the Western Pacific Ocean.

It has proven equally beneficial to employ similar avoidance considerations for routing in the monsoon areas of the Indian Ocean and the South China Sea. This is accomplished by providing routes and diversions that generally avoid the areas of high frequency of tropical cyclones (Figure 4105e, Figure 4105f and Figure 4105g), gale force winds and asso-

ciated heavy seas, as much as feasible. Ships can then remain in satisfactory conditions with limited increases in route distance.

Depending upon the points of departure and destination, there are many combinations of routes that can be used when transiting the northern Indian Ocean (Arabian Sea, Bay of

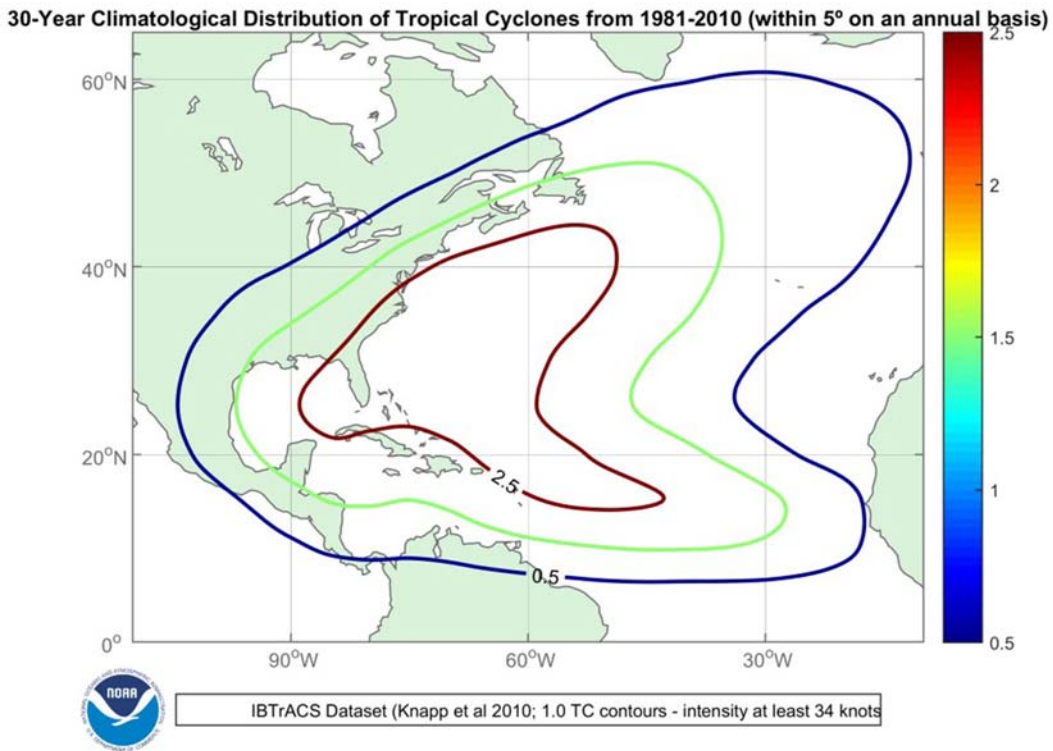


Figure 4105d. Average number of tropical cyclones that come within 5 degrees of a point in the North Atlantic Ocean.

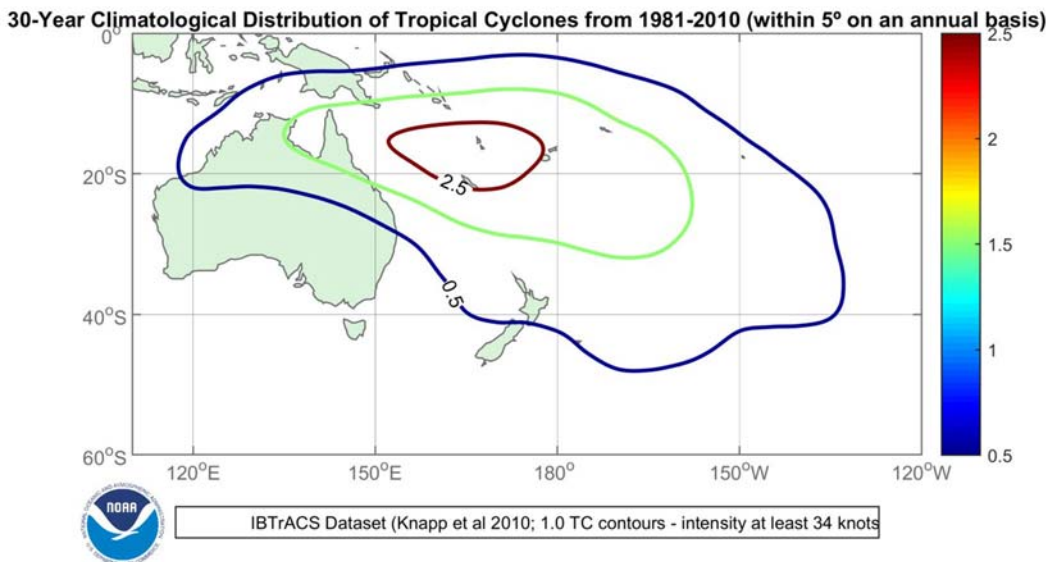


Figure 4105e. Average number of tropical cyclones that come within 5 degrees of a point in the South Pacific Ocean.

Bengal) and the South China Sea. For example, in the Arabian Sea during the summer monsoon, routes to and from the Red Sea, the western Pacific, and the eastern Indian Ocean should hold equatorward. Ships proceeding to the Persian Gulf during this period are held farther south and

west to put the heaviest seas on the quarter or stern when transiting the Arabian Sea. Eastbound ships departing the Persian Gulf may proceed generally east southeast toward the Indian sub-continent, then south, to pass north and east of the highest southwesterly seas in the Arabian Sea.

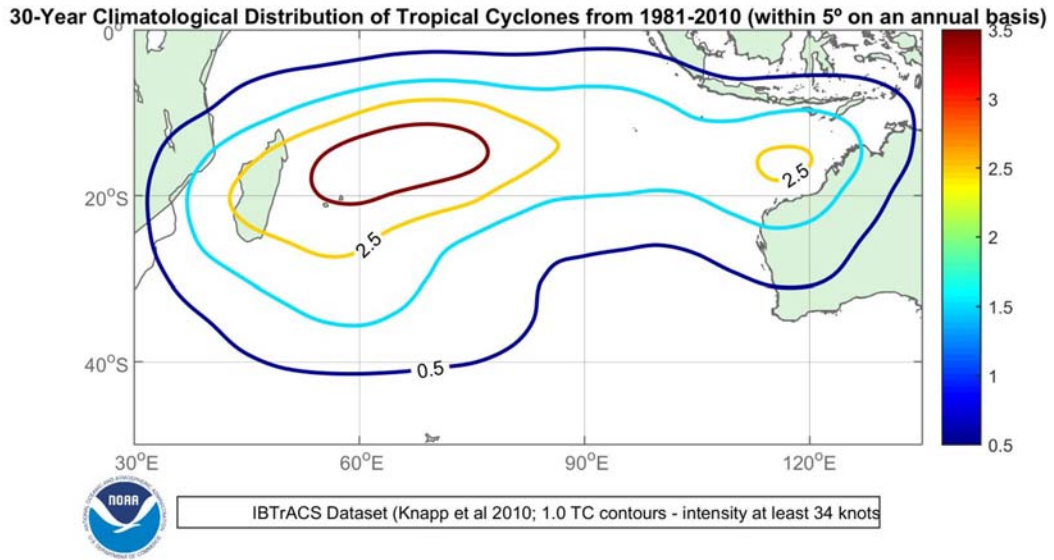


Figure 4105f. Average number of tropical cyclones that come within 5 degrees of a point in the South Indian Ocean.

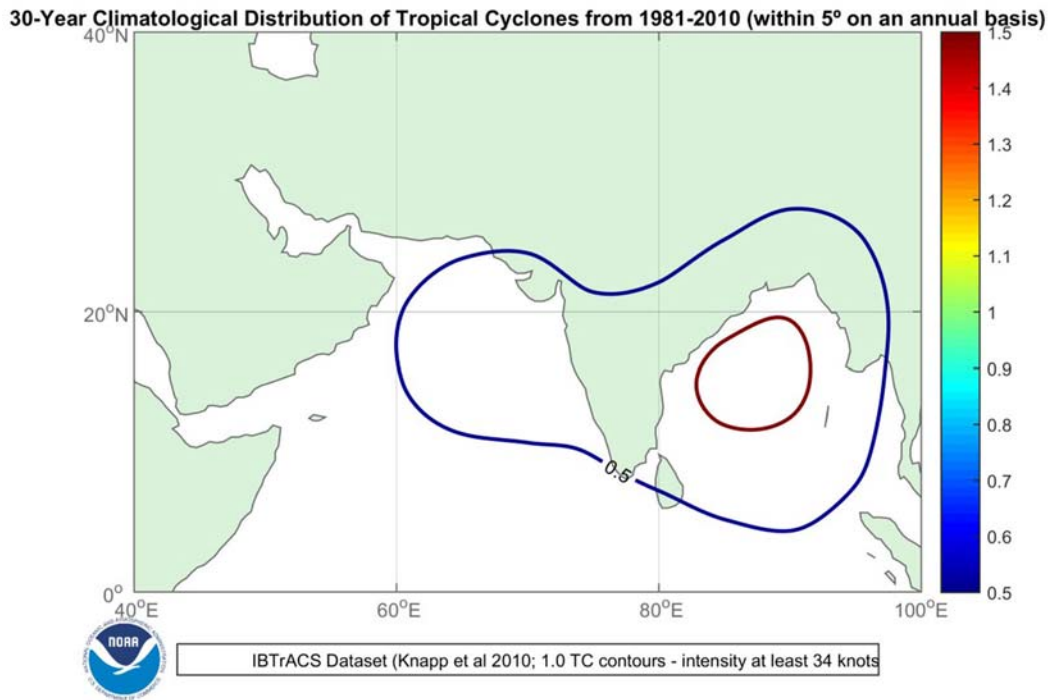


Figure 4105g. Average number of tropical cyclones (at least 34 knots) that come within 5 degrees of a point in the Bay of Bengal and Arabian Sea.

Westbound ships out of the Persian Gulf for the Cape of Good Hope appear to have little choice in routes unless considerable distance is added to the transit by passing east of the highest seas. In the winter monsoon, routes to or from the Red Sea for the western Pacific and the Indian Ocean are

held farther north in the Arabian Sea to avoid the highest seas. Ships proceeding to the Persian Gulf from the western Pacific and eastern Indian Ocean may hold more eastward when proceeding north in the Arabian Sea. Ships departing the Persian Gulf area will have considerably less difficulty

than during the summer monsoon. Similar considerations can be given when routing ships proceeding to and from the Bay of Bengal.

In the South China Sea, transits via the Palawan Passage are recommended when strong, opposing wind and seas are forecast. This is especially true during the winter monsoon. During periods when the major monsoon flow is slack, ships can use the shortest track as conditions permit.

4106. Special Weather and Environmental Considerations

In addition to the synoptic weather considerations in ship weather routing, there are special environmental problems that can be avoided by following recommendations and advisories of ship routing agencies. These problems generally cover a smaller geographic area and are seasonal in nature, but are still important to ship routing.

In the North Atlantic, because of heavy shipping traffic, frequent poor visibility in rain or fog, and restricted navigation, particularly east of Dover Strait, some mariners prefer to transit to or from the North Sea via Pentland Firth, passing north of the British Isles rather than via the English Channel.

Weather routed ships generally avoid the area of dense fog with low visibility in the vicinity of the Grand Banks off Newfoundland and the area east of Japan north of 35°N. Fishing vessels in these two areas provide an added hazard to safe navigation. This condition exists primarily from May through September. During summer, Arctic-bound shipping, transiting between the U.S. East Coast and the Davis Strait-Baffin Bay area, frequently use the Cabot Strait and the Strait of Belle Isle, where navigation aids are available and icebergs are typically present in large numbers following the melt of pack ice along the Labrador Coast in the spring.

In the northern hemisphere winter, a strong high pressure system moving southeast out of the Rocky Mountains brings cold air down across Central America and the western Gulf of Mexico producing gale force winds in the Gulf of Tehuantepec. This fall wind is similar to the pampero, mistral, and bora of other areas of the world. An adjustment to ship's track can successfully avoid the highest seas associated with the "Tehuantepecer." For transits between the Canal Zone and northwest Pacific ports, little additional distance is required to avoid this area (in winter) by remaining south of at least 12°N when crossing 97°W. While avoiding the highest seas, some unfavorable swell conditions may be encountered south of this line. Ships transiting between the Panama Canal and North American west coast ports can stay close along the coast of the Gulf of Tehuantepec to avoid heavy seas during gale conditions, but may still encounter high offshore winds.

In the summer, the semi-permanent high pressure systems over the world's oceans produce strong equatorward flow along the west coasts of continents. This feature is most pronounced off the coast of California and Portugal in the

Northern Hemisphere and along Chile, western Australia, and southwest Africa in the Southern Hemisphere. Very rough seas are generated and are considered a definite factor in route selection or diversion when transiting these areas.

4107. Types of Recommendations and Advisories

A **preliminary route recommendation** is issued to a ship more than ten days prior to sailing, then updated two days prior to sailing based on short to medium range dynamic forecasts. Preliminary route recommendations are a composite representation of experience, climatology, weather and sea state forecasts, the vessel's mission and operational concerns, and the vessel's seagoing characteristics. The U.S. Navy normally requires its units to provide a transit proposal 30 to 45 days prior to sailing, which is vetted through the OTSR program. These transit proposals are based on smart climatology, ship type, mission and environmental limits. All long range planning routes are based more on seasonal and climatological expectations than the current weather situation. Surveillance is a continuous process and these routes are subject to revision prior to sailing if weather and sea conditions dictate

Adjustment of departure time is a recommendation for delay in departure, or early departure if feasible, and is intended to avoid or significantly reduce the adverse weather and seas forecast on the first portion of the route, if sailing on the original EDD. The initial route is not revised, only the timing of the ship's transit through an area with currently unfavorable weather conditions. Adjusting the departure time is an effective method of avoiding a potentially hazardous situation where there is no optimum route for sailing at the originally scheduled time. A go/no go recommendation may be made to vessels engaged in special missions such as speed record attempts or heavy-lift voyages.

A **diversion** is an underway adjustment in track and is intended to avoid or limit the effect of adverse weather conditions forecast to be encountered along the ship's current track, or to take advantage of favorable conditions along another route. Ship's speed is expected to be reduced by the encounter with the heavy weather. In most cases the distance to destination is increased in attempting to avoid the adverse weather, but this is partially overcome by being able to maintain a nearly normal SOA.

Adjustment of SOA is a recommendation for slowing or increasing the ship's speed as much as practicable, in an attempt to avoid an adverse weather situation by adjusting the timing of the encounter. This is also an effective means of maintaining maximum ship operating efficiency, while not diverting from the present ship's track. By adjusting the SOA, a major weather system can sometimes be avoided with no increase in distance. The development of fast ships (SOA greater than 30 knots) gives the ship routing agency the potential to "make the ship's weather" by adjusting the ship's speed and track for encounter with favorable weather conditions.

Evasion is a recommendation to the vessel to take independent action to avoid, as much as possible, a potentially dangerous weather system. The ship routing meteorologist may recommend a general direction for safe evasion but does not specify an exact track. The recommendation for evasion is an indication that the weather and sea conditions have deteriorated to a point where shiphandling and safety are the primary considerations and progress toward destination has been temporarily suspended, or is at least of secondary consideration.

A **weather advisory** is a transmission sent to the ship advising the commanding officer or master of expected adverse conditions, their duration, and geographic extent. It is initiated by the ship routing agency as a service and an aid to the ship. The best example of a situation for which a forecast is helpful is when the ship is currently in good weather but adverse weather is expected within 48 hours for which a diversion has not been recommended, or a diversion where adverse weather conditions are still expected. This type of advisory may include a synoptic weather discussion and a wind, seas or fog forecast.

The ability of the routing agency to achieve optimum conditions for the ship is aided by the commanding officer or master adjusting course and speed where necessary for an efficient and safe ride. At times, the local sea conditions may dictate that the commanding officer or master take independent action.

4108. Southern Hemisphere Routing

Available data on which to base analyses and forecasts is generally very limited in the Southern Hemisphere, although this situation is improving with the increasing availability of remotely sensed data. Weather and other environmental information obtained from satellites is contributing greatly to an improvement in southern hemisphere forecast products.

Passages south of the Cape of Good Hope and Cape Horn should be timed to avoid heavy weather as much as possible, since intense and frequent low pressure systems are common in these areas. In particular, near the southeast coasts of Africa and South America, intense low pressure systems form in the lee of relatively high terrain near the coasts of both continents. Winter transits south of Cape Horn are difficult, since the time required for transit is longer than the typical interval between storms. Remaining equatorward of about 35°S as much as practicable will limit exposure to adverse conditions. If the frequency of lows passing these areas is once every three or four days, the probability of encountering heavy weather is high.

Tropical cyclones in the Southern Hemisphere present a significant problem because of the sparse surface and upper air observations from which forecasts can be made. Satellites provide the most reliable means by which to obtain accurate positions of tropical systems, and also give the first indication of tropical cyclone formation.

In the Southern Hemisphere, OTSR and other ship

weather routing services are available, but are hampered by sparse data reports from which reliable short and extended range forecasts can be produced. Strong climatological consideration is usually given to any proposed southern hemisphere transit, but satellite data is increasingly available to enhance short and extended range forecasts. OTSR procedures for the Northern Hemisphere can be instituted in the Southern Hemisphere whenever justified by basic data input and available forecast models.

4109. Communications

A vital part of a ship routing service is communication between the ship and the routing agency. Reports from the ship show the progress and ability to proceed in existing conditions. Weather reports from the ship enrich the basic data on which analyses are based and forecasts derived, assisting both the reporting ship and others in the vicinity.

Despite all efforts to achieve the best forecasts possible, the quality of forecasts does not always warrant maintaining the route selected. In the U.S. Navy's ship routing program, experience shows that one-third of the ships using OTSR receive some operational or weather-dependent change while underway.

The routing agency needs reports of the ship's position and the ability to transmit recommendations for track change or weather advisories to the ship. The ship needs both send and receive capability for the required information. Information on seakeeping changes initiated by the ship is desirable in a coordinated effort to provide optimum transit conditions. New satellite communications services are making possible the transmission of larger amounts of data than possible through traditional radio messages, a development which supports systems using on-board analysis to generate routes.

4110. Benefits

The benefits of ship weather routing services are primarily in time and cost reductions and increased safety. The savings in operating costs are derived from reductions in transit time, heavy weather encounters, fuel consumption, cargo and hull damage, and more efficient scheduling of dockside activities. The savings are further increased by fewer emergency repairs, more efficient use of personnel, improved topside working conditions, lower insurance rates because of reduced risks under weather routing, and ultimately, extended ship operating life.

An effective routing service maximizes safety by greatly reducing the probability of severe or catastrophic damage to the ship, and injury of crew members. The efficiency and health of the crew is also enhanced by avoiding heavy weather. This is especially important on modern, automated ships with reduced crews and smaller craft such as fishing vessels and yachts.

4111. Conclusion

The success of ship weather routing depends upon the validity of forecasts and the routing agency's ability to make appropriate route recommendations and diversions. Anticipated improvements in a routing agency's recommendations will come from advancements in meteorology, technology, and the application of ocean wave forecast models. Advancements in mathematical meteorology, coupled with the continued application of forecast computer models, will extend the time range and accuracy of the dynamic and statistical forecasts. Additionally, a better understanding of the problems encountered by the mariner and their implications while offshore will assist the routing agency in making appropriate recommendations.

Technological advancements in the areas of satellite and automated communications and onboard ship response systems will increase the amount and type of information to and from the ship with fewer delays. Mariners will have a better quality of meteorological information, and the meteorologists will have a better understanding of the problems, constraints, and priorities of the vessel's masters. Ship response and performance data included with the ship's weather report will provide the routing agency with real-time information with which to ascertain the actual state of the ship. Being able to predict a ship's response in most weather and sea conditions will result in improved routing procedures.

Shipboard and anchored wave measuring devices contribute to the development of ocean wave analysis and

forecast models. Shipboard seakeeping instrumentation, with input of measured wave conditions and predetermined ship response data for the particular hull, enables a master or commanding officer to adjust course and speed for actual conditions.

Modern ship designs, exotic cargoes, and sophisticated transport methods require individual attention to each ship's areas of vulnerability. Any improvement in the description of sea conditions by ocean wave models will improve the output from ship routing and seakeeping systems.

Advanced planning of a proposed transit, combined with the study of expected weather conditions, both before and during the voyage, as is done by ship routing agencies, and careful on board attention to seakeeping (with instrumentation if available) provide the greatest opportunity to achieve the goal of optimum environmental conditions for ocean transit.

4112. References

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