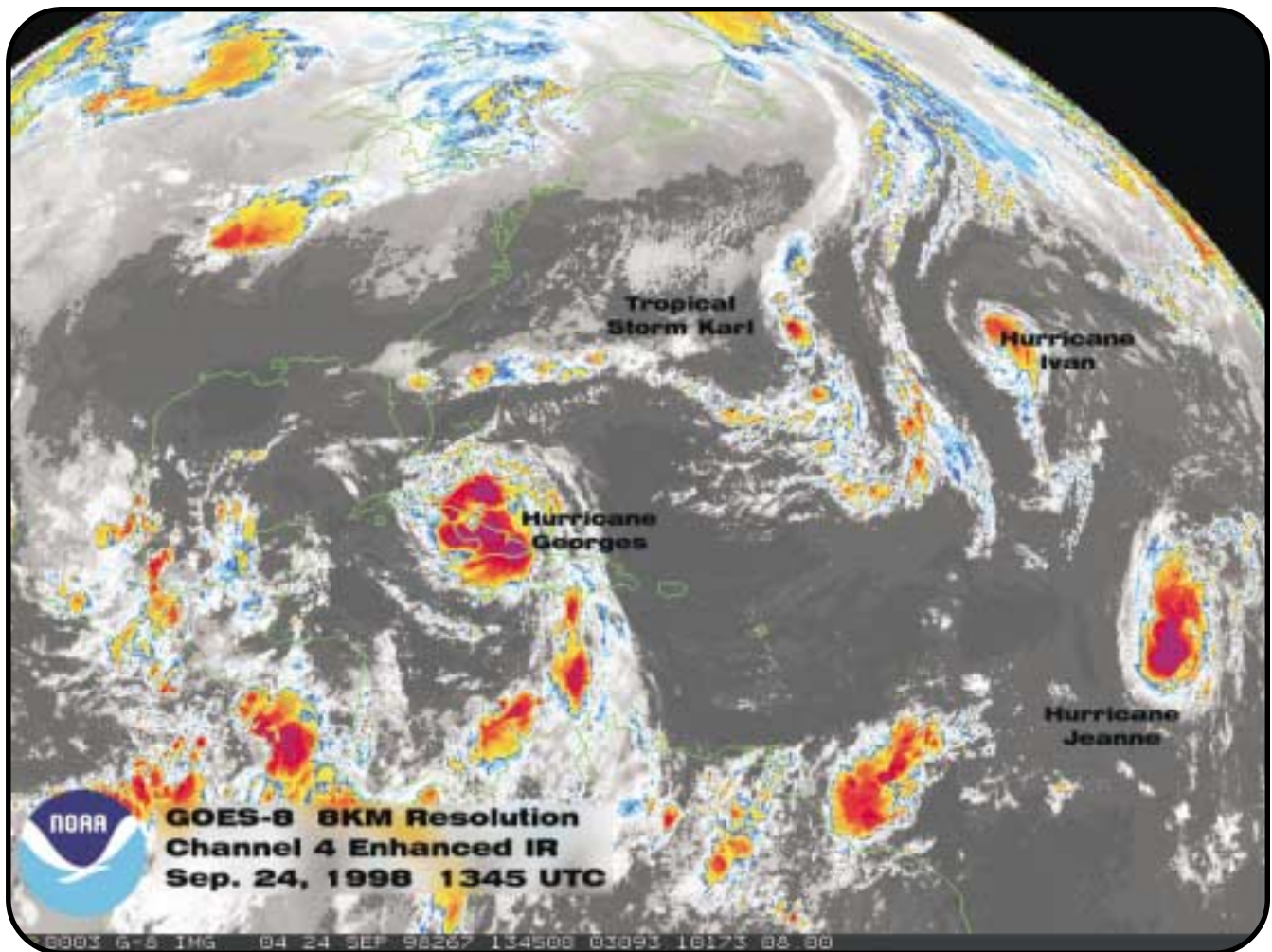


# Mariner's Guide For Hurricane Awareness In The North Atlantic Basin



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***Internet Sites with Weather and Communications Information  
Of Interest To The Mariner***

NOAA home page:	<a href="http://www.noaa.gov">http://www.noaa.gov</a>
NWS home page:	<a href="http://www.nws.noaa.gov">http://www.nws.noaa.gov</a>
NWS marine dissemination page:	<a href="http://www.nws.noaa.gov/om/marine/home.htm">http://www.nws.noaa.gov/om/marine/home.htm</a>
NWS marine text products:	<a href="http://www.nws.noaa.gov/om/marine/forecast.htm">http://www.nws.noaa.gov/om/marine/forecast.htm</a>
NWS radio facsimile/marine charts:	<a href="http://weather.noaa.gov/fax/marine.shtml">http://weather.noaa.gov/fax/marine.shtml</a>
NWS publications:	<a href="http://www.nws.noaa.gov/om/nwspub.htm">http://www.nws.noaa.gov/om/nwspub.htm</a>
NOAA Data Buoy Center:	<a href="http://www.ndbc.noaa.gov">http://www.ndbc.noaa.gov</a>
NOAA Weather Radio:	<a href="http://www.nws.noaa.gov/nwr">http://www.nws.noaa.gov/nwr</a>
National Ocean Service (NOS):	<a href="http://co-ops.nos.noaa.gov/">http://co-ops.nos.noaa.gov/</a>
NOS Tide data:	<a href="http://tidesonline.nos.noaa.gov/">http://tidesonline.nos.noaa.gov/</a>
USCG Navigation Center:	<a href="http://www.navcen.uscg.mil">http://www.navcen.uscg.mil</a>
Tropical Prediction Center:	<a href="http://www.nhc.noaa.gov/">http://www.nhc.noaa.gov/</a>
High Seas Forecasts and Charts:	<a href="http://www.nhc.noaa.gov/forecast.html">http://www.nhc.noaa.gov/forecast.html</a>
Marine Prediction Center:	<a href="http://www.mpc.ncep.noaa.gov">http://www.mpc.ncep.noaa.gov</a>
SST & Gulfstream:	<a href="http://www4.nlmoc.navy.mil/data/oceans/gulfstream.html">http://www4.nlmoc.navy.mil/data/oceans/gulfstream.html</a>
Hurricane Preparedness & Tracks:	<a href="http://www.fema.gov/fema/trop.htm">http://www.fema.gov/fema/trop.htm</a>
Time Zone Conversions:	<a href="http://tycho.usno.navy.mil/zones.html">http://tycho.usno.navy.mil/zones.html</a>

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Analysis & forecasts of all tropical cyclone activity rely heavily on ship observations in order to obtain the best estimate of the synoptic patterns guiding tropical cyclone motion and intensity. Three hourly ship observations in the vicinity of any active tropical system are an extremely valuable data point for input into tropical cyclone forecasts and guidance. All ship observations recorded near tropical cyclones are greatly appreciated and provide a most valuable data source used in determining current and forecast wave heights & wind fields associated with these systems.

## **Introduction & Purpose**

In the Atlantic Basin, they are called Hurricanes; a name derived from the Caribbean God of Evil... Hurican. With a sudden fury and unpredictable behavior, these “evil spirits” of violent, spiraling masses of thunderstorms, high seas, and devastating winds have been a nemesis to sailors since men first began to take to the oceans centuries ago. Today, as more merchant, fishing, and recreational sailors take to the sea by the thousands, the potential impacts and effects that hurricanes could have on mariners is as important as ever.

History is littered with the tales of lives lost and damage done to vessels caught at sea or in port, unaware of the threat associated with tropical cyclones. From the loss of colonial settlers traveling to the New World, through the loss and damage of 12 U.S. Navy ships during one Pacific tropical cyclone during World War II, to the recent loss of a commercial vessel during Hurricane Mitch in the Caribbean, history teaches us that accurate forecasting and a fundamental awareness of tropical cyclones are critical to the safety of Mariners.

Understanding of the development, structure, life cycle, and motion of tropical cyclones is paramount to avoiding vessel damage and loss of life and property at sea during these violent weather events. And although we know that we cannot control the path or violent fury of these systems, knowledge of them and the ability to remain clear of them are the two crucial factors to saving lives and property at sea.

This guide will hopefully aid the Mariner in understanding the complex structure and behavior of tropical cyclones in the North Atlantic Ocean. Once armed with this knowledge, and the information on where to acquire forecasts and guidance for current tropical cyclones, the mariner can be prepared to “weather the storm” or better yet, avoid these catastrophic events altogether.

Finally, this guide will discuss some ship routing and hurricane avoidance options with the intention of highlighting critical thought processes, risk analyses and required actions that should be considered in order to remain safe and secure during the threat of a tropical cyclone at sea or in port.

## **Disclaimer**

This manual was developed to enhance the mariner’s awareness of tropical cyclones in the Atlantic Basin. The advice and guidance provided herein are a courtesy of the Tropical Prediction Center & the National Weather Service (TPC/NWS). The Tropical Prediction Center/National Weather Service does not warrant that following the advice or the methodologies outlined will eliminate the risks of harm from tropical cyclones. Anyone undertaking the methodologies does so solely at his/her own risk.

## **Chapter 1 - Tropical Cyclone Basics**

Tropical cyclones are warm core, non-frontal low pressure systems of synoptic scale that develop over tropical or subtropical waters and have a definite organized surface circulation. Tropical depressions, tropical storms, and hurricanes are all forms of tropical cyclones, differentiated only by the intensity of the winds associated with them.

## Definitions and Terminology

### Tropical Wave (African or Easterly Wave)

A tropical wave is a trough or cyclonic curvature maximum in the trade wind easterlies. These waves tend to reach maximum amplitude in the lower to middle troposphere and may or may not be accompanied by thunderstorm clusters. Although there is still some debate on the issue, these easterly waves are thought to originate or become amplified as a result of meteorological conditions over the continent of Africa. Each hurricane season approximately 60 of these waves cross the tropical North Atlantic. Although the majority of these waves pass through the basin without any significant tropical cyclone development, passage of these waves is often accompanied by squally weather with brief periods of higher sustained winds. Examples of the clouds and weather types associated with tropical waves are shown in FIGURE 1.



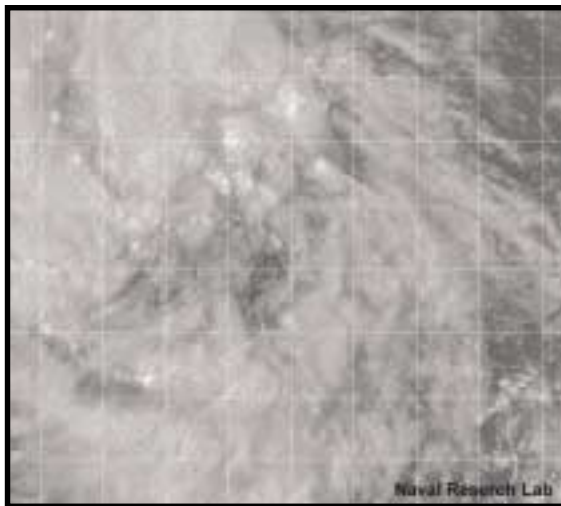
*FIGURE 1: GOES-8 image taken at 1415 UTC on 11 June 2000. The axes of two North Atlantic tropical waves are shown in the image. Notice that most of the active weather in the form of showers & thunderstorms, lies east of the wave axis. Wind reports of 20 to 25 KT were recorded in the vicinity of the wave entering the Caribbean Sea near the time of this image.*

### Tropical Disturbances

A tropical disturbance is a discrete tropical weather system with apparently organized convection (generally 100 to 300 miles in diameter) originating in the tropics or subtropics, having a non-frontal migratory character, and maintaining its identity for 24 hours or more.

### Tropical Depressions

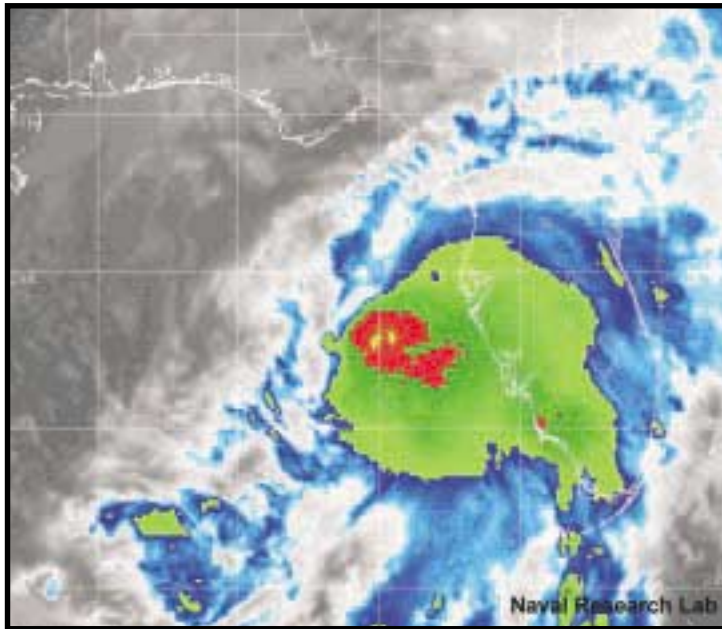
Tropical cyclones in which the maximum sustained surface wind speed (1-minute mean) is 33 KT or less. Tropical depressions must have a closed surface circulation in order to be classified in this category. An image of a tropical depression is shown in FIGURE 2.



*FIGURE 2: Visible image of Tropical Depression Number 9 taken at 1445 UTC 11 Sept 1999. 18 hours later, the depression intensified into Tropical Storm Gert over the Eastern Atlantic. During the next 12 days Gert moved NW across the Central Atlantic passing east of Bermuda. The cyclone's minimum central pressure of 930 MB with estimated winds of 130 KT and gusts to 150 KT was reached only 5 days after it was identified as a depression. Canadian news reported waves of 27 feet along the distant coast of Newfoundland as Gert weakened to tropical storm force during the system's recurve and extra-tropical transition.*

### Tropical Storms

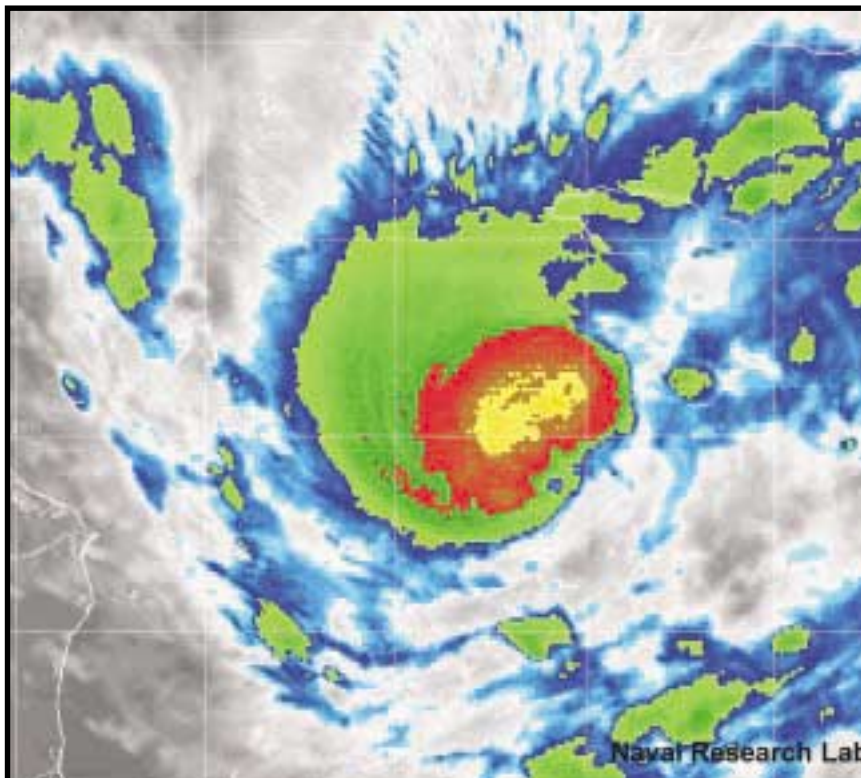
Tropical cyclones in which the maximum sustained surface wind speed (1-minute mean) ranges from 34 KT to 63 KT. A satellite image of a tropical storm is shown in FIGURE 3.



*FIGURE 3: GOES-8 Infrared image of Tropical Storm Harvey taken at 2045 UTC on 20 Sept 99. Maximum intensity at this time was 50 KT with gusts to 60 KT. Within 18 hours of this system becoming a tropical depression, 12-foot seas had developed in the vicinity of the system center. Within 36 hours after becoming a depression, ship observations within 150 NM SE of Harvey indicated tropical storm force winds and seas to 12 feet.*

### Hurricane

Tropical cyclones in which the maximum sustained surface wind speed (1-minute mean) is greater than or equal to 64 knots. These systems are also known as Typhoons in the Western Pacific and Tropical Cyclones in the Indian Ocean and Southwestern Pacific. Satellite imagery of a 70 knot hurricane is shown in FIGURE 4.



*FIGURE 4: GOES-8 infrared image of Hurricane Lenny taken 0015 UTC on 15 Nov 1999. Lenny had intensified to 70 KT with gusts to 85 KT at the time of this image. It was the first tropical cyclone with an extended west to east track across the Caribbean Sea in 113 years of tropical cyclone records. The approach of this system from the West produced unprecedented storm surge and wave heights on the normally protected westward facing ports and harbors of islands in the eastern Caribbean Sea. Estimates of wave heights to 16 ft were noted in some port locations within this region.*



### Hurricane Categories (Saffir-Simpson Hurricane Scale)

Hurricanes are further categorized according to the strength of their winds using the Saffir-Simpson Hurricane Scale (SSHs). A Category 1 storm has the lowest wind speeds, while a Category 5 has the highest. These are relative terms because lower category storms can sometimes inflict greater damage than higher category storms, depending on angle of approach, location, and many other aspects particular to each system. Even tropical storms can produce significant damage & loss of life, mainly due to floods.

CATEGORY	DEFINITION	EFFECTS	EXAMPLE
1	Winds: 64-82 KT	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal flooding and minor pier damage.	Hurricane Earl (1998)
2	Winds: 83-95 KT	Some roofing material, door, and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected moorings may break their moorings.	Hurricane Georges (1998)
3	Winds: 96-113 KT	Some structural damage to small residences and utility buildings, with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain may be flooded well inland.	Hurricane Fran (1996)
4	Winds: 114-135 KT	More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland.	Hurricane Andrew (1992)
5	Winds: >135 KT	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required.	Hurricane Camille (1969)

### Subtropical Cyclone

A low pressure system that develops over subtropical waters initially having a non-tropical circulation (i.e. cold core) but in which some elements of tropical cyclone cloud structure are present. Under certain conditions, subtropical cyclones can evolve into tropical cyclones.

### **Formation and Life Cycle of Tropical Cyclones**

The ingredients for development of a tropical cyclone in the North Atlantic Basin include a pre-existing weather disturbance, warm ocean water, atmospheric moisture, relatively light winds aloft, and formation north of approximately 5° North latitude\*. If the right conditions persist long enough, they can combine to produce the violent winds, incredible waves, torrential rains, and massive floods that we associate with hurricanes.

Tropical cyclones form over warm waters from pre-existing weather systems. Over 75 % of the tropical cyclones that form in the Atlantic basin originate from tropical easterly waves that typically emerge every three to four days from the coast of Africa. The other 25 % of tropical cyclones typi-

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\* This is required in order for the earth-atmosphere system to produce a minimum Coriolis Force on the developing tropical cyclone. Without Coriolis Force, low pressure and particularly the cyclonic circulation initially generated in a tropical disturbance could not be maintained for very long.

cally form along the trailing ends of cold fronts or can occasionally even develop from upper-level lows in the atmosphere.

Each year, an average of ten tropical storms develop over the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Of these ten storms, six typically develop into hurricanes. In an average 3-year period, roughly five hurricanes strike the United States coastline, killing approximately 50 to 100 people anywhere from Texas to Maine. Of these five hurricanes that strike the U.S., two are typically “major” hurricanes with winds greater than 96 KT. Regardless of where these systems form or to which level of intensity they develop, all tropical cyclones pose a very serious hazard to mariners throughout the Atlantic basin.

### Conditions for Development & Intensification

The process by which a tropical cyclone develops and subsequently intensifies into a hurricane depends on at least six conditions explained below:

1. A pre-existing surface disturbance with thunderstorms. As warm core systems, tropical cyclones rely on a build up of heat energy within the atmospheric column above them in order to grow and develop. A thunderstorm complex acts as a vertical transport mechanism for heat, moisture, and the cyclonic turning of winds into the upper levels of the atmosphere. This vertical transport into higher levels of the atmosphere aids the incipient tropical cyclone to grow and develop.
2. Relatively moist atmospheric layers in the middle troposphere, approximately 10,000-20,000 ft above the earth’s surface. Dry air at this level of the atmosphere is not favorable for continued development of the required thunderstorm activity in a disturbance.
3. Warm (at least 79°F or 26°C) ocean temperatures with a mixed layer depth of about 200 feet. This mixed ocean layer allows warm water to remain available to a developing system even after the wind has begun to increase in speed and the sea surface begins to get churned up by the developing cyclone.
4. Light winds aloft that do not change much in direction and speed throughout the depth of the atmosphere (low vertical wind shear). Tropical cyclones rely on a vertically stacked structure in order to grow or maintain in intensity. In other words, the ideal tropical cyclone will have its cyclonic circulation in the middle & upper levels of the atmosphere located directly above the cyclonic circulation of the surface & low levels of the atmosphere. Increases in wind speed with height will tilt the vertical structure of a tropical cyclone not allowing the system to remain stacked throughout the troposphere. If this vertical tilting of the system persists, growth will become inhibited and the tropical system will decay.
5. Must be poleward of about 5 degrees north latitude in order to meet minimum threshold values for the Coriolis Force. See footnote on previous page.
6. Upper-level outflow over a system serves to remove mass from the top of the vertical column in a tropical cyclone. As a system develops, low-level cyclonic flow pulls more mass towards the center of the system; the flow then turns upward in intense vertical motions associated with thunderstorms in the area. Without a method to dispose of this mass from above the tropical

cyclone, low-level converging flow toward the center of the system will be halted and the system will “suffocate”.

In a complex relationship, these six factors are interdependent. The absence or change in one of the ingredients often results in a change or loss in one or more of the other factors. If nature allows these conditions to remain favorable over a period of time, it can produce a spectacular atmospheric event of catastrophic proportions.

During an idealized case of tropical cyclogenesis, the following events would occur on the order of days with different factors occurring simultaneously or near-simultaneously throughout the developing phase of a tropical cyclone.

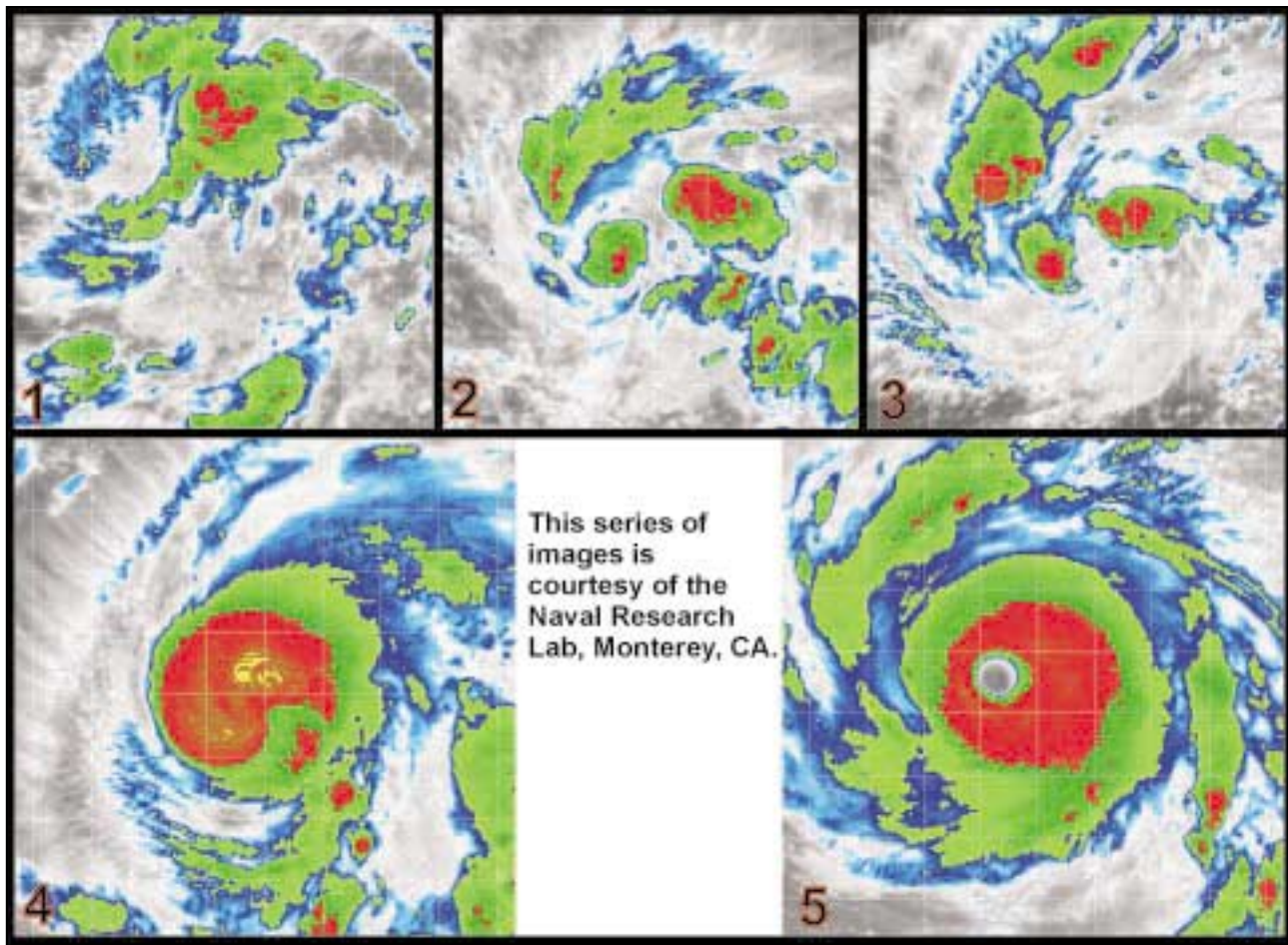
Initially, heat and therefore energy for the storm are gathered by the disturbance through contact with warm ocean waters. Thunderstorm activity begins to develop and define the vertical structure above the tropical disturbance. Soon the Coriolis Force begins to act on the system, aiding in the development of a cyclonic circulation with winds near the ocean surface now spiraling into the disturbance’s developing low pressure area. The warm ocean waters and their sufficient mixed layer depth will continue to add moisture and heat to the air that rises in the updrafts of convection near the disturbance. As the moisture condenses into drops, more heat is released into the atmosphere, adding energy to power the storm. Thunderstorms begin to take on a curved banding structure as they organize around the low-level center of the system. As these thunderstorms grow higher into the troposphere, relatively light winds at those high levels will allow the vertically stacked warm core of the storm to remain intact and continue to strengthen.

### *Tropical Cyclone Life Cycle*

Hurricanes can last for two weeks or more over the open ocean, generating incredible sea heights in excess of 50 ft with rather substantial swell trains that can extend outward from these systems for thousands of miles. All the while, these cyclones can continue to move across the entire tropical North Atlantic, Caribbean Sea, & Gulf of Mexico placing vessels both at sea and in-port into harm’s way.

In the early stages of development, the system appears in satellite imagery as relatively unorganized thunderstorm clusters generated in the low-level cyclonically curved wind flow of a tropical wave or other incipient disturbance (see FIGURE 5). If weather and ocean conditions remain favorable, the system can strengthen to become a tropical depression with winds less than 33 KT. At this point the storm begins to take on the familiar spiral appearance with increasing cyclonic wind flow around the low-level circulation center. If the storm continues to strengthen to tropical storm status (winds 34-63 KT), the developing bands of thunderstorms contribute additional heat & moisture to the storm further aiding in intensification. The storm becomes a hurricane when surface winds reach a minimum of 64 KT. About this time, the cloud-free eye typically forms in the inner region of the tropical cyclone.

The tropical cyclone will continue to grow and sustain itself until one or more of the necessary ingredients is either lost or undergoes a significant change. Wind shear can tear a system apart separating the vertically stacked warm core aloft from its low-level circulation. Movement of these systems into regions of drier mid-level air can inhibit convection and cause a weakening of the tropical cyclone. Additionally, movement into cooler water or landfall events typically shut down a



*FIGURE 5: GOES-8 infrared images of Floyd (1999) taken over a period of 6 days during the developing stages of the hurricane. Panel 1 is a very strong tropical disturbance that became a Tropical Depression, 12 hours later. Panel 2 is Tropical Depression #8, which continued to intensify into Floyd. By panel 3, Floyd has intensified into a Tropical Storm with a spiral pattern noted in the convective bands. This is indicative of the increasing low-level cyclonic flow into the system. Panels 4 & 5 are of Floyd as a category 1 hurricane and finally a category 4 system, respectively.*

tropical cyclone's warm energy source, and therefore it's fuel to survive. Landfall also increases low-level friction within a system thereby reducing the intensity of the circulation while increasing rainfall amounts.

Generally speaking, a weakening tropical cyclone can re-intensify if it moves into a more favorable region with respect to the six ingredients. Similarly, a tropical cyclone interacting with a mid-latitude cold front can intensify into an extra-tropical gale or storm force low as the result of many factors involved in the tropical to extra-tropical transition of these systems. This transition from tropical to extra-tropical can cause sudden structure changes in the cyclone, which result in dramatic variations of storm speed, direction, & position. Similarly, rather rapid fluctuations of the wind field intensity and an outward expansion of gale & storm force winds often occur, as these systems become extra-tropical. This tropical to extra-tropical transition normally occurs at higher latitudes over the cooler ocean water located in the vicinity of major transatlantic shipping lanes. Combining all of these factors, the decay of a tropical cyclone & the tropical to extra-tropical transition are extremely dangerous & often times unpredictable periods in the tropical cyclone life cycle.

## General Tropical Cyclone Characteristics

### Hurricane Size

Contrary to their appearance on weather maps, hurricanes are much larger than the point source often depicted on those maps. Similarly, their path is more than a line and should be looked at as a swath across which the system and its associated impacts are felt. This tropical cyclone swath requires the mariner to take precautions far from where the center is currently located & forecast to move.



*FIGURE 6: Images of Hurricanes Floyd (left) and Andrew (right). Both systems reached maximum intensity with sustained winds of 135 KT. During the peak intensity of Floyd, radius of tropical storm force winds extended outward to 250 NM in the NE quadrant while seas of 12 feet or greater were observed out to 300 NM in the same quadrant of the system. In contrast, Andrew's radius of tropical storm force winds only extended out to 90 NM with seas of 12 feet or higher also noted within 90 NM of the tropical cyclone center during its period of peak intensity.*

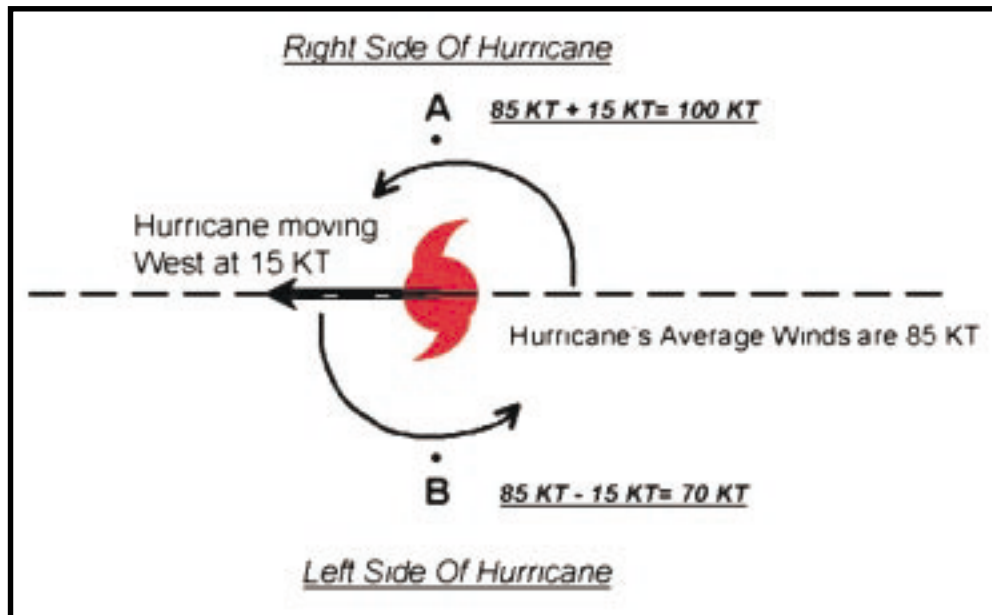
Although they can vary considerably, typical hurricanes possess tropical storm force wind fields of about 300 nautical miles in diameter. As shown in FIGURE 6, both Floyd (1999) and Andrew (1992) were category 4 systems on the SSHS with lowest recorded central pressure of 921 MB and 922 MB, respectively. Both systems reached peak intensity with maximum sustained winds estimated at 135 KT. However, the radius of tropical storm force winds with Floyd was much greater than the radius of similar winds in Andrew. Supporting the fact that size is not necessarily an indication of hurricane intensity, Andrew was the most devastating landfalling hurricane of the 20<sup>th</sup> century in terms of property damage done, yet was a relatively small hurricane.

Therefore, do not focus on the location and track of the center, because the hurricane's destructive winds and seas cover a broad path. Hurricane force winds can extend outward about 25 nautical miles from the storm center of a small hurricane to more than 150 nautical miles for a large one. The range over which tropical storm force winds occur is even greater, possibly extending as far as 300 nautical miles from the eye of a large hurricane.

## Wind Field

Although each tropical cyclone takes on characteristics determined by the environment in which it develops, there are some generalizations about the wind fields of these systems that can be addressed for most tropical cyclones in the North Atlantic basin.

The core of strongest winds associated with a tropical cyclone is concentrated around and near the center of the surface circulation. Aside from this fact and as a general rule of thumb, the hurricane's right side (relative to the direction it is traveling) is the more dangerous side of the storm. This is due to the additive effect of the hurricane's wind speed, and the speed at which the entire system is moving within the larger atmospheric steering flow. These increased winds on the right side of a tropical cyclone are accompanied by higher sea heights within that same area. Additionally, in landfall situations, storm surge is normally higher over the right semicircle of the system along with an increased likelihood of tornadoes as well. There have been some notable exceptions to these generalizations and specific structure and composition of the wind field can differ greatly from system to system.



*FIGURE 7: Illustration of the additive effects of storm motion and tropical cyclone winds over the left and right semicircles of a westward moving tropical cyclone in the North Atlantic.*

The example in FIGURE 7 shows the additive effects of tropical cyclone motion and tropical cyclone wind speed. The tropical cyclone in FIGURE 7 is moving west at 15 KT. The winds associated with the hurricane are flowing cyclonically, or counter-clockwise around the surface center. The average intensity of these hurricane-related winds is 85 KT. In this example, winds at point A, in the northern semicircle (or right side with respect to the direction of movement) are stronger due to the additive effects of the hurricane wind speed and the speed of movement for the tropical cyclone. The result is winds to 100 KT in this area. Conversely, winds at point B, on the southern side (or left side with respect to the direction of movement) are somewhat lessened because the forward speed of the system actually opposes the direction of the winds in this region thereby decreasing the overall surface winds in this area. The result is winds of 70 KT in the left side (southern semicircle) of the example hurricane.

Unfortunately, the exact structure of the wind field in any particular tropical cyclone cannot be solely defined by the concept discussed above. Location of the strongest thunderstorm activity and location of the tropical cyclone with respect to other synoptic scale features both play a large part in

the true wind field structure of any tropical cyclone. Similarly, the proximity to land and high terrain can also greatly alter the structure of a tropical cyclone's wind field. Forecasts of intensity issued by the National Hurricane Center attempt to take all of these factors into account in their official wind estimates.

### State of the Sea

Winds in a tropical cyclone produce wind waves that move outward from the center of the system. Wave height and propagation speed are dependent on the intensity of the storm, size of the system, movement of the tropical cyclone, and length of the over-water trajectory for the winds (fetch). As these wind waves move further from the center, height decreases and wavelength increases, creating swell. The more intense the system, the larger the swell, the longer the period, and the further that swell will propagate. Near the center and in the right-rear quadrant (with respect to the direction of motion) of a tropical cyclone, seas are confused in a crippling combination of wind waves and swells that are extremely difficult to navigate.

The swells from a tropical cyclone can travel on the order of 1000 NM per day and may extend in excess of 2000 NM from the storm center. In the days before weather satellites and radio communication, these swells were often the first warning to the mariner of an impending tropical cyclone.

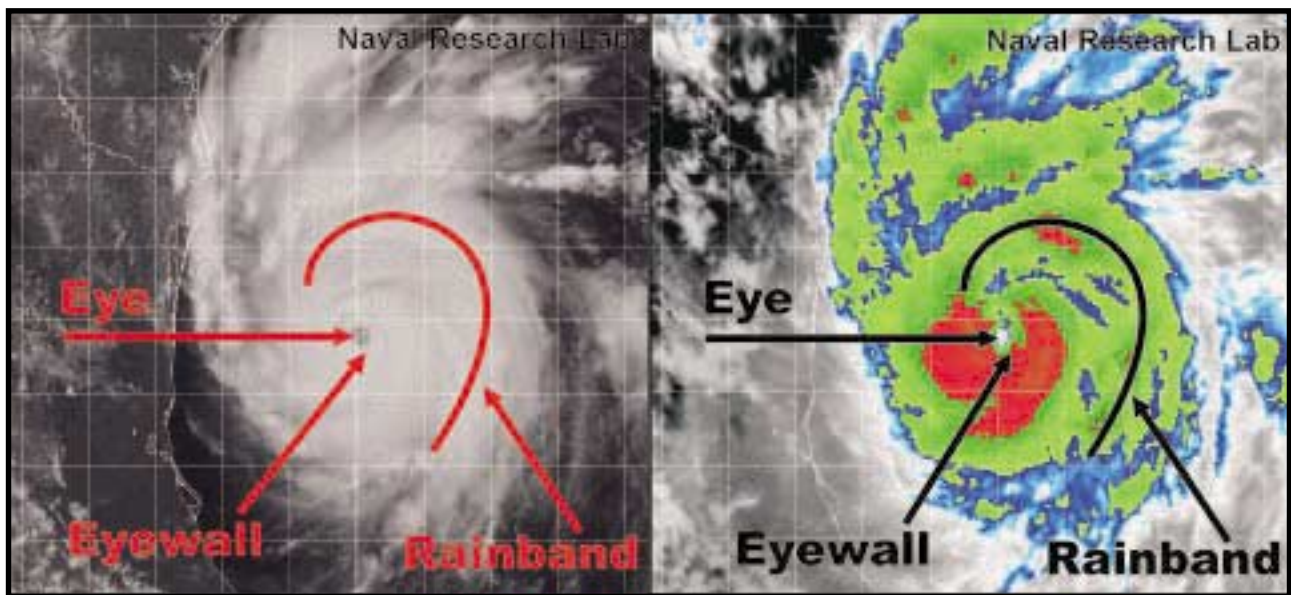


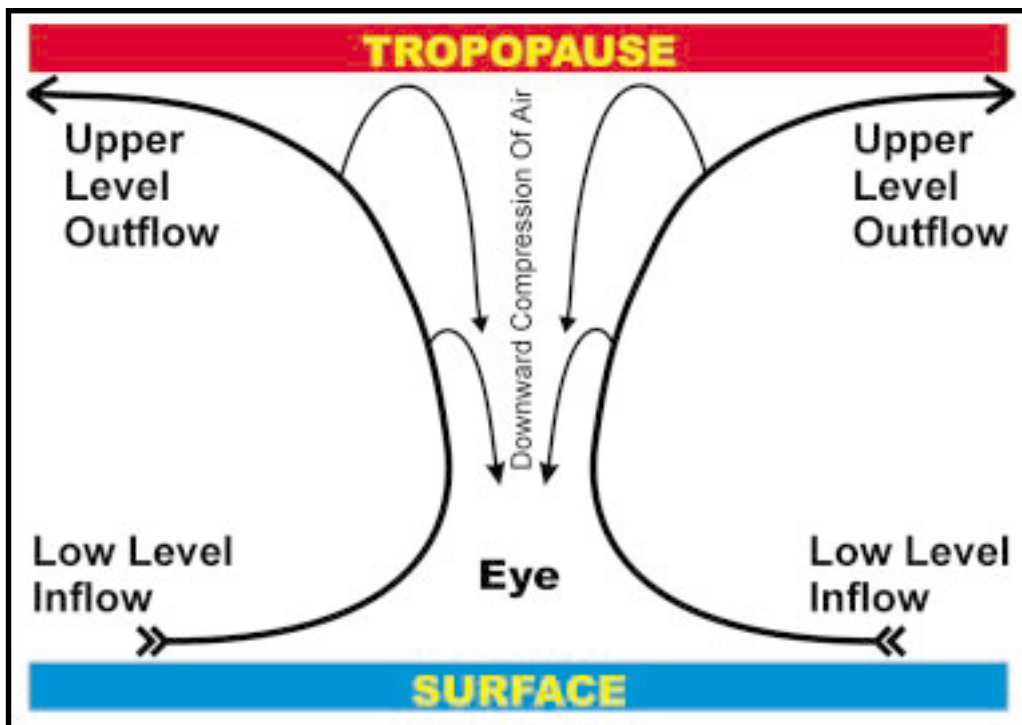
FIGURE 8: Visible (left) and Infrared (right) images of Hurricane Bret in the Gulf of Mexico taken at 1715 UTC 21 August 1999. Both images show the basic structures of eye, eyewall, and rainbands in a mature tropical cyclone.

### Hurricane Structure

The main parts of a hurricane shown in FIGURE 8 are the rainbands, the eye, and the eyewall. Air at the surface spirals in toward the center in a cyclonic (counter-clockwise) pattern, then turns upward near the center to flow out the top in an anticyclonic manner (clockwise). At the very center of the storm, air sinks, forming the warm core and relatively cloud-free eye.

### The Eye

The hurricane's center is a relatively calm, clear area usually 10-40 nautical miles wide containing the lowest surface pressure in the tropical cyclone. The eye forms as the result of intense convection within the eyewall (see FIGURE 9) that forces air to rise rapidly upward. Reaching the top of the



*FIGURE 9: Side view of a simplified model hurricane. Air in the lowest levels of the system flows cyclonically inward toward the eyewall where it rapidly turns upward toward the tropopause. Greater atmospheric stability above the tropopause forces the air to flow outward. However some of this air is pushed in toward the cyclone center and downward helping to form and maintain the eye.*

troposphere, this air spreads out horizontally in an anticyclonic manner away from the center of the system. However, some of the upward accelerating air is turned inward toward the center of the circulation where it is then forced downward into the eye. This downward motion results in a warming and drying of the air as it is compressed on its descent, helping to develop and maintain the eye of a hurricane.

### *The Eyewall*

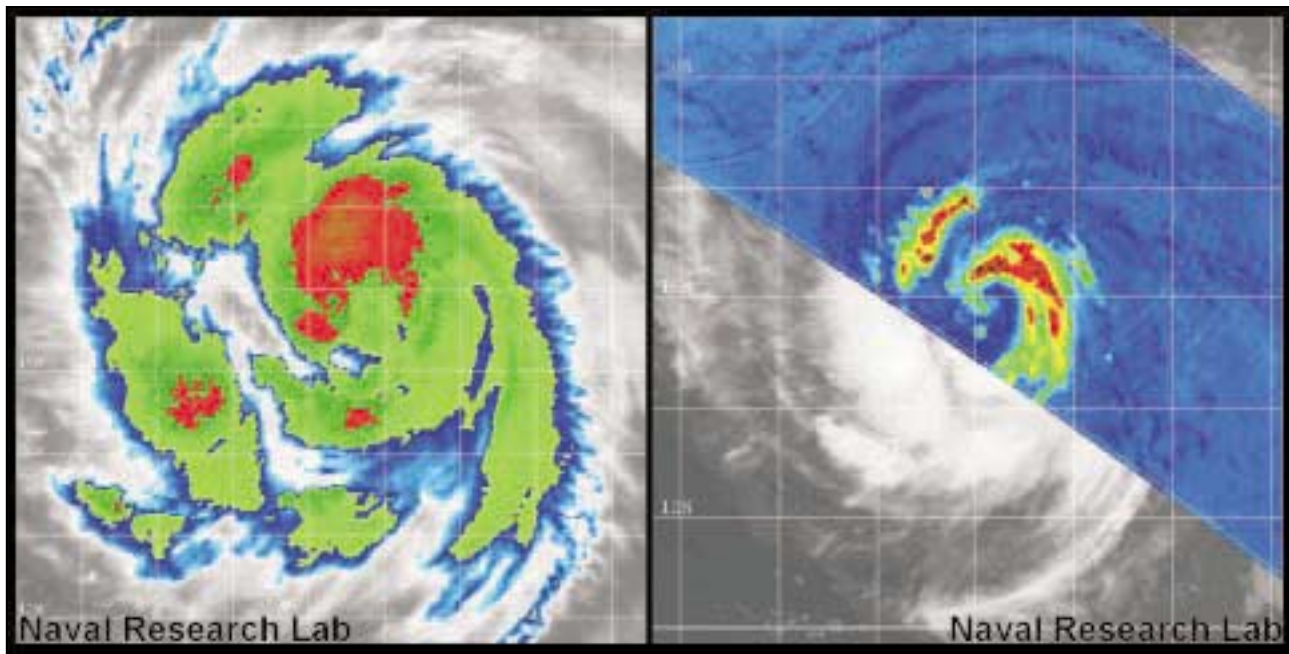
The innermost convective ring of thunderstorms that surrounds the eye of a hurricane is known as the eyewall. This region is home to the most intense winds and fiercest rains within a tropical cyclone and has a typical width of approximately 10-15 NM. Additionally, it is the most significant contributor in the vertical transport of warm moist air from the lower levels of the storm into the middle and upper levels of the troposphere over a tropical cyclone. This is a fact that agrees with observations throughout the North Atlantic basin where eyes and eyewalls are generally observed only in systems with winds of strong tropical storm force or greater.

Changes in the structure of the eye and eyewall can cause changes in surface pressure and wind speed in a tropical cyclone. The eye can grow or shrink in size, and double (concentric) eyewalls can form, dissipate, and redevelop. All of these factors play a significant role in short-term influences of hurricane intensity.

### *Rainbands*

The storm's outer rainbands (often with hurricane or tropical storm-force winds) can extend a few hundred miles from the center. However, the extent of these features differs from storm to storm. For example, Hurricane Andrew's (1992) rainbands reached only 100 NM out from the eye, while those in Hurricane Gilbert (1988) stretched out over 500 NM. These dense bands of thunderstorms, which spiral slowly counterclockwise, range in width from a few miles to tens of miles and can be up to 300 NM long. Increased gustiness of the winds associated with the convective cells in these rainbands can sometimes exceed the current intensity of the tropical cyclone by more than 40%.





*FIGURE 10: Left is an infrared GOES-8 image of Gert taken 0815 UTC Sept 13 1999 which shows the surface center obscured by high-level clouds thereby making a satellite position estimate difficult. Right is a TRMM (Tropical Rainfall Measuring Mission) microwave image taken of Gert at 0802 UTC Sept 13 1999. This TRMM image clearly indicates the circulation center along with rainbands E and NW of the center. This type of data has helped forecasters more accurately determine the location of tropical cyclones.*

These rainbands also serve as another major source of upward vertical motion and therefore play a significant part in the transport process that removes warm moist ocean air and deposits it in the middle and upper troposphere. In relation to their surroundings, this increased upward motion near these rainbands can result in slightly lower surface pressures in the area when compared to other regions in the vicinity of the rainbands.

With all of the intense thunderstorm activity in a tropical cyclone, large amounts of high-level cirrus clouds are generated in the upper regions of a tropical system. Sometimes these high-level clouds actually obscure the surface center on satellite imagery making it difficult for forecasters to monitor a storm's position and development. However, recent advances in satellite technology and remote sensing shown in FIGURE 10 are having positive impacts in the ability to see through these clouds to find the low-level center of a tropical cyclone.

### **Observations At Sea**

As mentioned earlier, tropical cyclones generally produce long period swells that propagate very far from the system center. Additionally, small changes in surface pressure are observed near the rainbands of a tropical cyclone, indicative of the great upward vertical motions in these areas. Also, the overall presence of deep persistent thunderstorm activity in tropical cyclones causes large amounts of high-level cirrus clouds to flow anticyclonically away from the system. Using this information, we can briefly discuss four observations that may alert the mariner to an approaching tropical cyclone.

### Wind

In the absence of any other information, surface winds are normally the best guide to quickly determining the direction to the center of a tropical cyclone. The wind around a North Atlantic tropical cyclone flows cyclonically or counter-clockwise around the actual low center. If an observer faces into the direction of the true wind at the surface, the center of lowest pressure, and therefore the center of the cyclone will be to the right hand side, bearing approximately 090 to 120 degrees. This method is a good initial indication of the direction to the cyclone. However, be wary of using this method in the vicinity of thunderstorms and squalls, as these features can temporarily change the wind flow around a tropical system.

### Wave

The direction of the swell encountered over open oceans is indicative of the direction to a tropical cyclone's center *when that swell was originally generated*. For example, assuming an active tropical cyclone in the region, northeast swell observed by a vessel indicates the strong wind that generated the swell and therefore the tropical system was located NE of the ship when the swell initially developed. However, in shoaling water, this is a less reliable indication of tropical cyclone position as the direction of swell in these areas is often altered by refraction.

Typical periods of swell in the Atlantic are generally 6-8 seconds. Swell periods of 9-12 seconds occurring over the tropical and subtropical Atlantic Ocean during the hurricane season can be a reasonable indicator of a tropical cyclone's existence. Similarly, longer period swells of 12-15 seconds are even better indicators of a tropical cyclone's presence in the basin. When this uncharacteristic long period swell occurs over open waters not normally accustomed to this type of swell, such as the Gulf of Mexico and Caribbean Sea, the swell becomes a very good indicator that a tropical system is in the vicinity.

### Clouds

With a system 500-1000 NM away from a vessel, skies may appear relatively clear and any low cumulus clouds will have a very shallow vertical extent. As the system and the vessel close to about 300-600 NM in distance, high level cirrus cloudiness will appear as a thin, wispy veil spreading away from the direction of the tropical system. If the separation between the tropical cyclone and the vessel continues to decrease, the cirrus will thicken and lower somewhat taking on the layered appearance of a cirrostratus deck of clouds. Even closer to the storm, layered altostratus clouds will begin to appear at the middle levels of the atmosphere. Finally, rainshowers and thick, heavy walls of cumulonimbus clouds begin to indicate the proximity of outer rainbands in the tropical cyclone. At this point the center of the system may still be as much as 200-400 NM from the location of the ship.

### Surface Pressure

Central pressures associated with tropical cyclones in the Atlantic can reach extreme values. For example, a minimum central pressure of 888 MB was measured in Hurricane Gilbert in September 1988. However, average central pressures for weak tropical storms in the Atlantic Basin are around 1000-1005 MB. These values are well below the average surface pressures measured throughout the subtropical and tropical Atlantic during the summer and fall (~1012 MB to 1020 MB). Therefore, shipboard surface pressure readings below 1010 MB during hurricane season should be viewed with at least some degree of caution.

Additionally, small rises and falls in the surface pressure can sometimes be noticed in shipboard barometers as a “pumping action” in the pressure reading. This restlessness of the barometer is related to the intense upward motions and extremely strong wind gusts associated with a tropical cyclone along with the measurably lower surface pressures near the spiral rainbands surrounding them. These small, yet measurable pressure rises and falls will often be superimposed on the overall pressure fall as the tropical system approaches and can serve as a valuable indication that a tropical system may be nearby.

## **Chapter 2 - Hurricane Motion, Climatological Tracks & Genesis Regions**

Having already discussed some of the important factors responsible for tropical cyclone development and intensification, attention can now be turned to the mechanisms that influence movement of these systems across the North Atlantic basin. Understanding tropical cyclone motion and the track tendencies of these systems in the Atlantic is a precursor to planning and evaluating hurricane avoidance options.

### **Hurricane Motion**

A hurricane’s speed and path are dependent upon two factors. First is the environmental steering that it encounters while the second is the tropical cyclones own internal influences and secondary steering influences. Typically, a hurricane’s forward speed averages around 13-17 KT. However, some hurricanes stall, while others, normally during or after recurvature, can accelerate to more than 50 KT. Hurricane Hazel (1954) hit North Carolina on the morning of 15 October. Fourteen hours later, Hazel reached Toronto, Canada where it resulted in 80 deaths. Some hurricanes follow a fairly straight course, while others loop and wobble along their path. The key to understanding where a tropical cyclone will move lies in completely understanding the steering environment in which that tropical cyclone is found.

#### *Environmental steering*

Environmental steering is the most important influence on tropical cyclone motion. To begin, one can consider as a first approximation the atmosphere in which the hurricane is embedded as a constantly moving and changing “river” of air. The tropical cyclone is like a “leaf in the river” as it flows along a path guided by the environment around it. Different features in this flow, such as high and low pressure systems, fronts, and middle or upper-level circulations and jet streams can greatly alter the speed and direction a hurricane may take.

Generally speaking, a tropical cyclone is guided along its path by the average direction and speed of the environmental steering winds throughout the depth of the atmosphere in the vicinity of the system. However, the more intense a tropical cyclone, the higher into the atmosphere one must look to determine which environmental steering influences will have the greatest impact on storm motion. Weaker and poorly organized tropical systems will generally be guided by the environmental steering in the lower to middle levels of the atmosphere (from the surface to 700 MB or approximately 10,000 ft). Alternatively, the strongest tropical cyclones will more often be guided by the winds of the middle and upper troposphere near the system.

When discussing the concept of average steering winds throughout the depth of the atmosphere, it is

important to note that synoptic features at different levels of the atmosphere have different strengths and positions that are constantly evolving and changing over time. This causes different levels of the atmosphere to become more or less important to tropical cyclone steering at certain times along the path of a system. For instance, strong high pressure at the surface with relatively light winds aloft generally means that the low-level steering influences will dominate the track of a system. However, if the surface flow weakens and the winds in the middle- or upper-levels of the atmosphere increase then the middle- and upper-levels of the atmosphere will begin to dominate the tropical cyclone's steering. There are many different variations to this concept of steering winds and although environmental steering is a fairly simple idea, nature is often much more complex in the manner which she moves tropical cyclones.

Included in this section are a few examples of steering winds and their impact on tropical cyclone motion. First, when a typical system develops south of the subtropical ridge in the North Atlantic, winds of the middle and upper troposphere are usually weak. Therefore, the dominant environmental steering factor is the low- to middle-level easterly winds south of the subtropical ridge. The result is a general westward movement of the tropical cyclone across the Atlantic, as shown in FIGURE 11.

In another scenario depicted in FIGURE 12, a system being steered westward by the subtropical ridge can begin to be influenced by a surface front or trough in the middle or upper troposphere. In these cases, the upper level southwesterly winds associated with the trough at those levels of the atmosphere will begin to impart a northward component of movement to the tropical cyclone. Additionally, the approach of a surface cold front will also erode the low-level steering for a system. In this situation, if the system moves poleward enough to become captured in the prevailing westerly winds aloft, the tropical cyclone may continue moving north then northeast accelerating as it recurves into the North Atlantic.

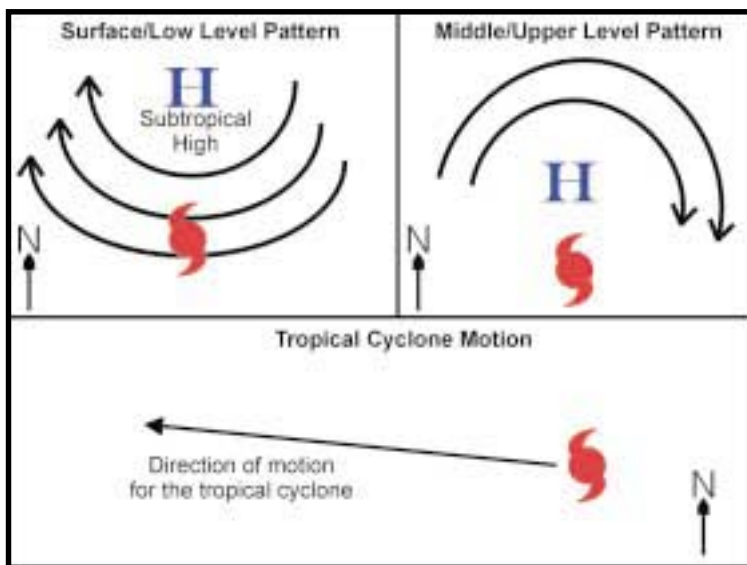


FIGURE 11 displays the general track of a tropical cyclone located south of the subtropical ridge in the Atlantic. Steering for these systems is predominantly the result of the low-level Easterly flow south of the subtropical ridge. Lines and arrows in the top two pictures denote wind flow at respective levels of the atmosphere. This is the same convention used in figures 12-15.

FIGURE 14 depicts yet another example of the complex interactions between steering levels and a tropical cyclone. In this example, wind flow in the middle and upper troposphere over a tropical cyclone is strong westerly. At the same time, the low-level steering winds are strong easterly. This situation creates a highly sheared wind environment that will likely cause the cyclone to weaken. However, as the system decays in intensity, a situation may develop where the deepest columns of thunderstorms become removed from and located east of the low-level circulation. Simultaneously, the surface circulation of the tropical cyclone continues to track westward in the low-level steering flow.

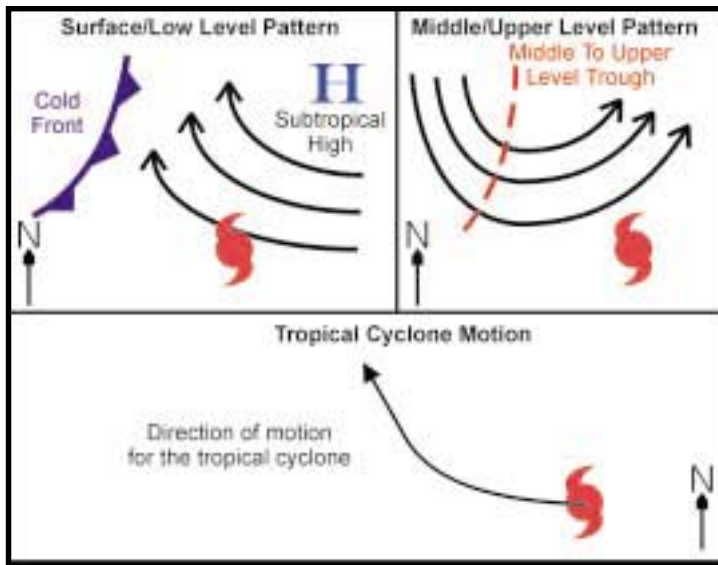


FIGURE 12 shows a likely track for tropical cyclones approaching the western periphery of the subtropical ridge with the influences of a middle to upper level trough and a surface front in the region. Steering for systems in this setting are usually a complex combination of both low-level and middle to upper level winds in the area.

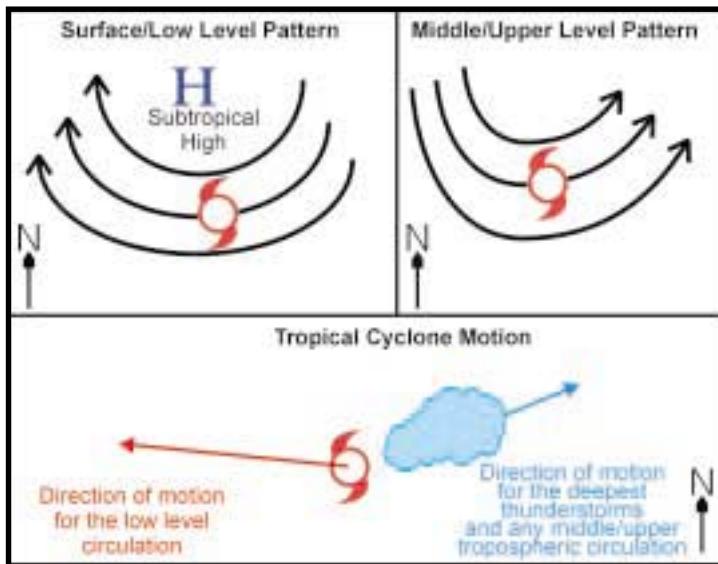


FIGURE 14: An extreme case of vertical wind shear. The opposed steering winds at the surface & middle/upper levels of a storm can result in deep convection & any middle to upper level circulation becoming strongly tilted or detached from & located east of the surface center as a result of strong westerly winds aloft. At the same time, the low-level circulation of the tropical cyclone continues to track westward in the easterly winds of the low-level steering flow.

In FIGURE 15 on the following page, the steering flow at all levels of the atmosphere is fairly weak. Without any dominant steering winds to guide the storm along, a tropical cyclone may meander aimlessly, loop, or even become stationary for periods of time. In these instances, the tropical cyclone's internal steering effects will begin to impact storm motion.

Lastly, larger and more developed tropical cyclones will also begin to effect the environmental steering flow in which they are embedded causing changes to the synoptic scale features that surround and influence their track. Well-developed systems can modify nearby synoptic features and change the expected steering pattern from those features. Sometimes, even subtle changes to the intensity or structure of a tropical cyclone can cause significant changes to its' motion.

### Internal Effects and Secondary Influences

A second, much less noticeable factor regarding tropical cyclone motion is the storms internal effects and secondary steering influences. The eyes of systems often wobble by approximately 10-20 NM from the overall average direction of motion. Additionally, other internal influences can cause deviations to motions that would not likely occur due to environmental steering effects alone. To further complicate the steering concept, one secondary factor regarding tropical cyclone motion tends to steer tropical cyclones slightly right of the primary steering influences. These internal effects and secondary influences are most often negligible when compared to environmental steering but can sometimes become noticeably more important as a system grows in size and intensity.

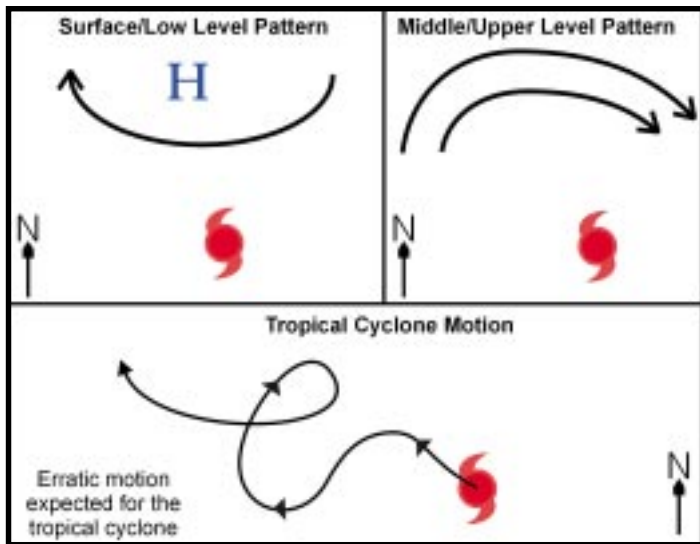


FIGURE 15 shows the effects of little to no environmental steering on a tropical cyclone. In this example the easterly winds south of the low-level high center are fairly weak. At the same time, middle- & upper-level winds over the hurricane are almost non-existent. This combination causes weak environmental steering and allows the hurricane's internal steering effects to begin impacting motion. Systems in this regime can often behave in a poorly predicted cycle of slow loops, wobbles, and other erratic motions.

Hopefully, the examples in this section illustrate that environmental steering, internal effects and secondary influences are quite complex, requiring the forecaster to look at more than just one single level of the atmosphere to determine the direction of motion that a system may take. In some situations the low-level steering will dominate. In other instances, a combination of the low and middle-levels will combine to steer a tropical system. Yet in other cases, strong environmental steering winds throughout the entire atmosphere or the lack of any steering winds altogether, will determine the track of a tropical cyclone.

In any event, track forecasting of tropical cyclones remains difficult at best and requires substantial amounts of information and data on the storm and the environment in which it is found. Track forecasts of tropical cyclones, issued by the National Hurricane Center, account for all of the influences discussed above to the greatest extent possible. Through the use of complex computer simulations or "hurricane models", weather satellites, environmental sampling of the storms by NOAA and Air Force weather reconnaissance aircraft, and all available surface or ship observations, National Hurricane Center forecasts attempt to accurately predict the environmental steering and forecast movement of these severe weather events.

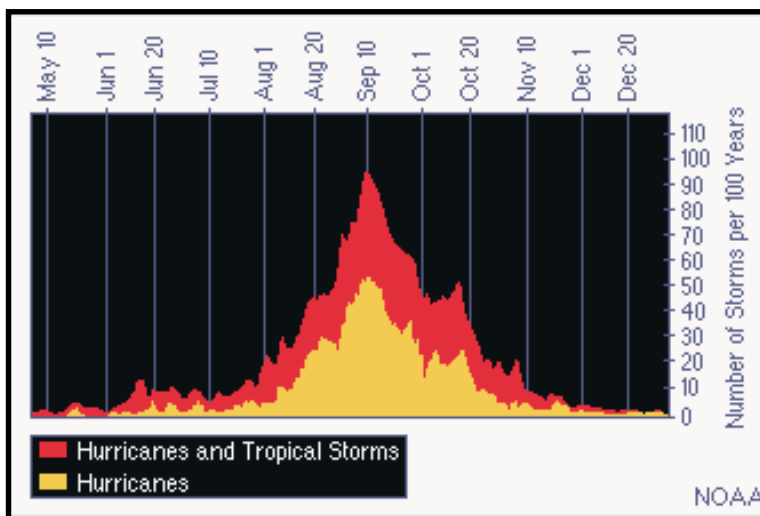


FIGURE 16: Frequency of tropical cyclone activity in the Atlantic Basin.

### Climatological Tracks & Genesis Regions

As shown in FIGURE 16, middle August through late October is usually the most active period for tropical cyclones in the North Atlantic basin with September 10<sup>th</sup> being the peak of the season. FIGURES 17a-f show the general pattern of preferred locations for tropical cyclone development and the climatological average tracks these systems often take through the North Atlantic.

These figures are included as an aid to the mariner in visualizing some general characteristics of Atlantic basin tropical cyclone tracks and genesis regions. From these graphics, it can be seen that early season storms tend to develop in the Western Caribbean Sea and the Gulf of Mexico. By the middle of the season, the focus for development shifts eastward to include most of the tropical Atlantic and Caribbean Sea. This is the portion of the season that normally results in the strongest tropical cyclones. Tropical cyclones developing during this portion of the season often take an extended westward track across warm Atlantic waters, south of the Atlantic subtropical ridge in an environment of little wind shear thereby placing them in a favored region for significant development. By the latter part of the season, tropical cyclone development once again shifts westward in the Caribbean Sea, Gulf of Mexico and the western Atlantic.

These figures must be looked upon as long-term averages and comparisons to current tropical cyclone tracks in order to aid the mariner in voyage planning and long-range hurricane avoidance considerations. The graphics only depict average conditions, tracks, and locations of tropical cyclones. Tropical cyclones can originate in many different locations, traveling much different paths than these climatological averages might indicate. Nonetheless, these figures should give the mariner a better sense of potentially active areas during the Atlantic hurricane season.

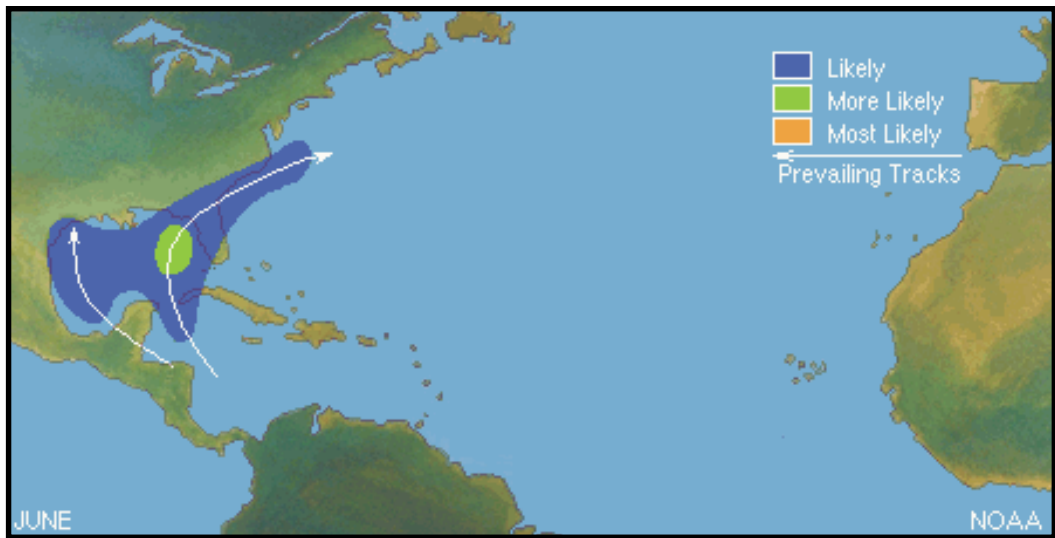


FIGURE 17a:  
Tropical cyclone  
climatological  
tracks and  
development  
regions for June.

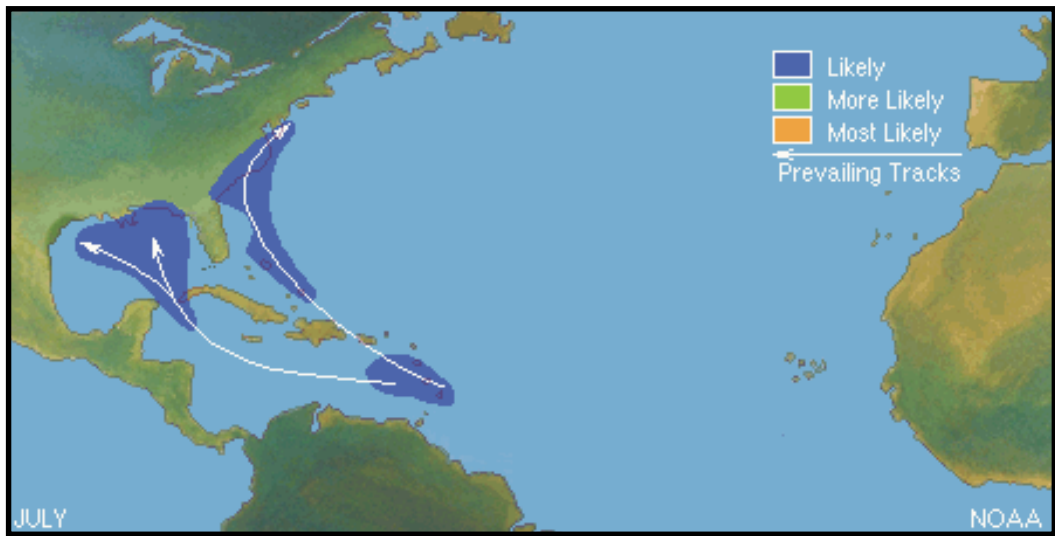


FIGURE 17b:  
Tropical cyclone  
climatological  
tracks and  
development  
regions for July.

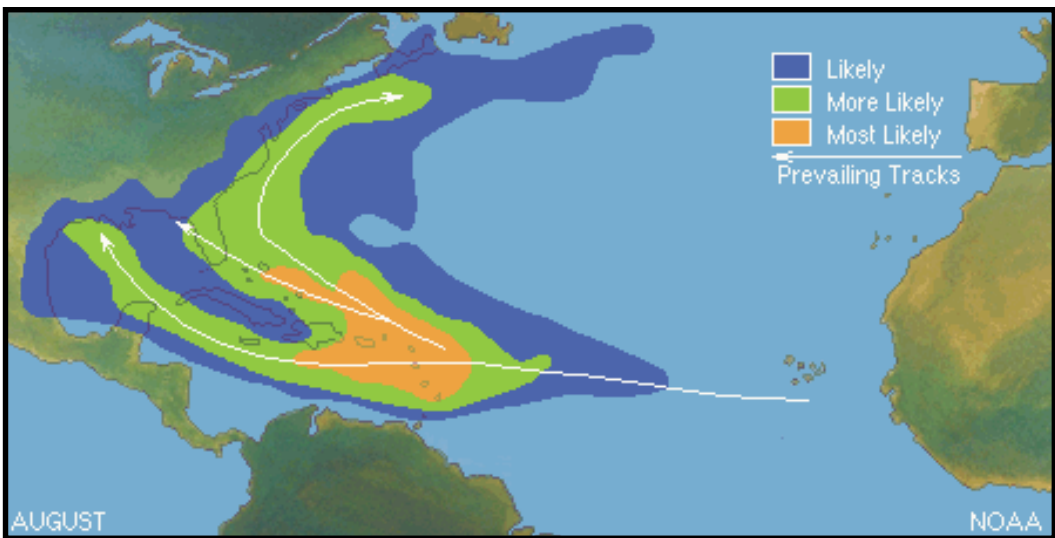


FIGURE 17c:  
Tropical cyclone  
climatological  
tracks and  
development  
regions for August.



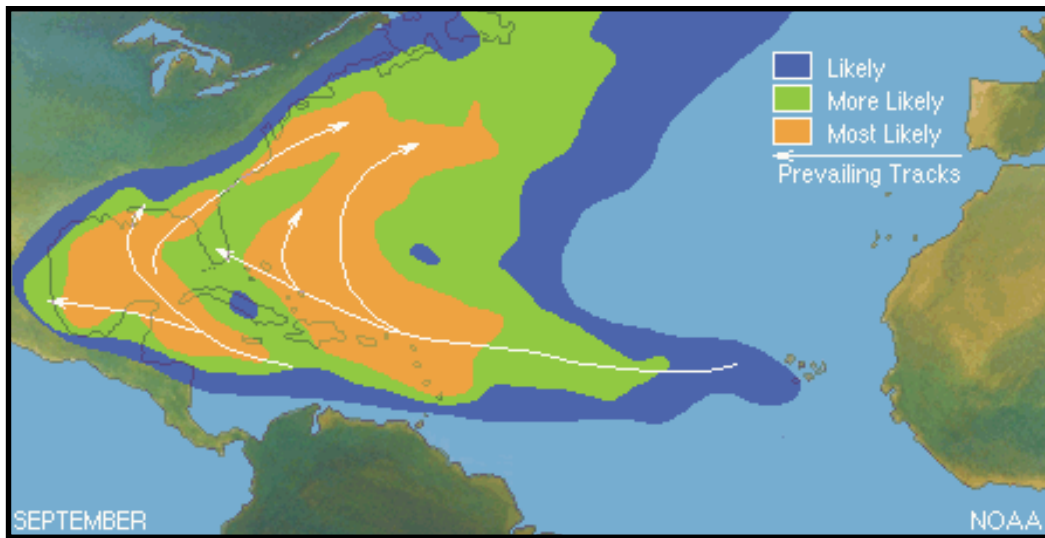


FIGURE 17d:  
Tropical cyclone climatological tracks & development regions for September.

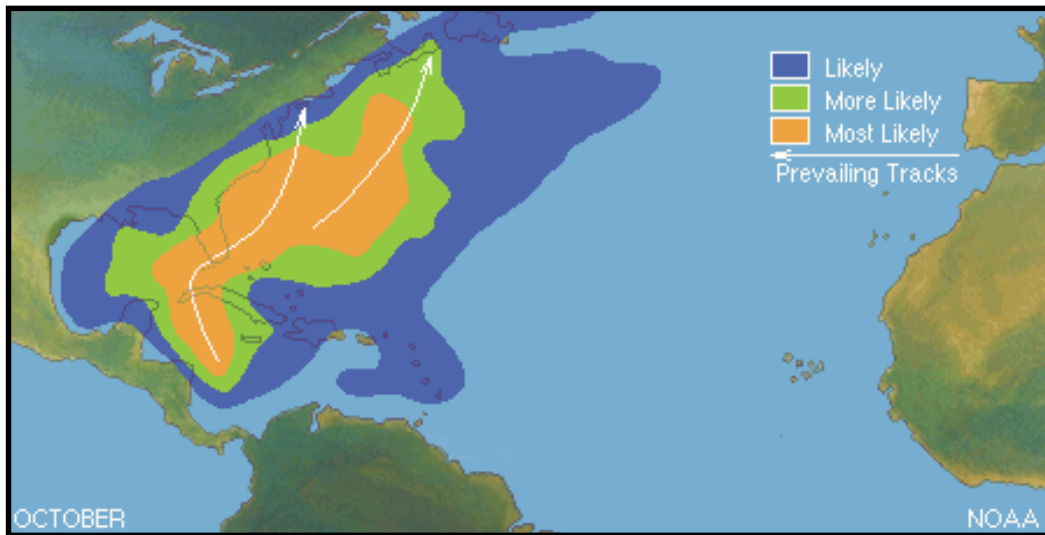


FIGURE 17e:  
Tropical cyclone climatological tracks and development regions for October.

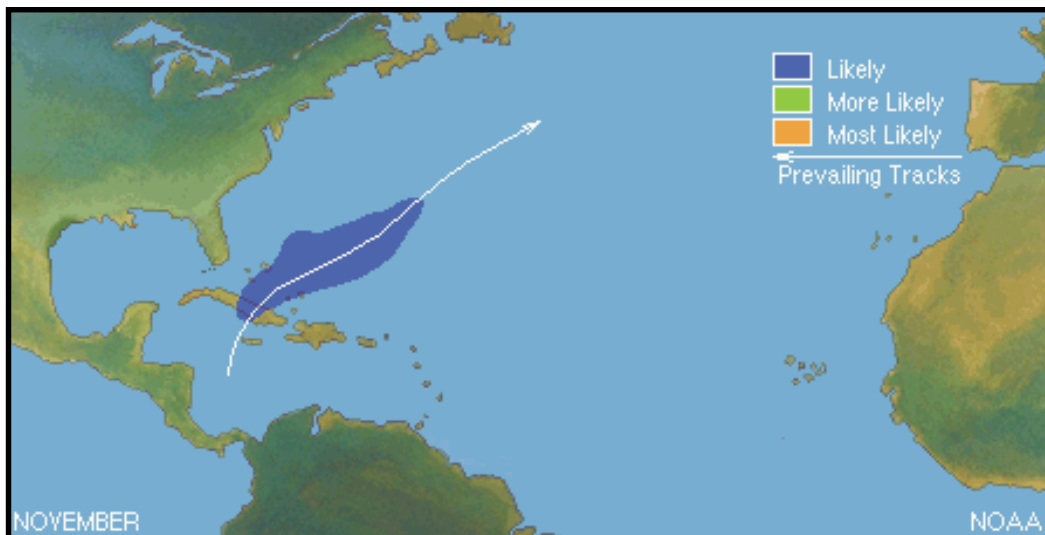


FIGURE 17f:  
Tropical cyclone climatological tracks & development regions for November.

## **Chapter 3 - Monitoring North Atlantic Tropical Cyclones**

Knowing the basic structure, development, and movement of tropical cyclones is important to the mariner in order to make knowledgeable navigation decisions to remain clear of these tempests. However, a constant, vigilant watch on current and forecasted tropical weather conditions is paramount to avoiding loss of life and property at sea or getting caught unaware of a tropical cyclone threat.

In order to accomplish this, numerous tropical weather products are created and distributed by the Tropical Prediction Center/National Hurricane Center (TPC/NHC) that can help to keep the mariner alert to existing or impending tropical cyclone activity. Various forecasts and warnings, along with other significant information regarding tropical and subtropical cyclones in the Atlantic Basin (north of the Equator including the Caribbean Sea and Gulf of Mexico) are the responsibility of TPC/NHC in Miami, FL. The U.S. Coast Guard, as part of its maritime safety responsibilities, is tasked with providing the majority of communications circuits and coastal broadcast facilities used to transmit these weather products to the seafarer. Finally, the National Weather Service issues all of these products in a variety of formats via a wide range of communications methods in order to support as broad a scope of maritime users as possible.

In this chapter, we will discuss the many tropical cyclone and marine products available from NHC and elsewhere within the National Weather Service. Additionally, we will discuss the methods currently available to obtain each product. In doing this, we will closely review the Tropical Cyclone Forecast/ Advisory, discussing the format and content of this most critical message produced for the Mariner. Finally, TABLE 10 was compiled at the end of this chapter listing various tropical cyclone products and where they may be obtained in near-real-time.

### **Tropical Cyclone Text Products for the Mariner**

#### **Tropical Weather Discussion (TWD)**

The TWD provides a detailed discussion of convective activity and the current location of synoptic features including tropical waves found throughout the Atlantic basin south of 32N latitude to the Equator from the coast of Africa to Central & South America. This product describes important tropical weather features noted in satellite imagery, radar, rawinsonde data and surface observations. The TWD is issued four times daily throughout the year highlighting any areas of persistent convective activity, some of which may be a precursor to tropical cyclone development. The TWD serves as a guide to mariners on potentially active tropical weather areas in the tropical North Atlantic. The transmission times of this product are 0005, 0605, 1205, and 1805 Universal Time Coordinated (UTC).

#### **Tropical Weather Outlook (TWO)**

The TWO briefly describes significant areas of disturbed weather & tropical disturbances in the Atlantic Basin. Additionally, this product discusses the potential for further development of these features out to 48 hours in the future. The TWO also lists any currently active tropical cyclones in the basin. It is issued four times per day during the Atlantic hurricane season and serves as a valuable aid to the mariner in maintaining tropical weather awareness and potential tropical cyclone activity in the North Atlantic. The transmission times for this product are 0530, 1130, 1730, & 2230 Eastern Local Time. FIGURE 18 is a typical TWO written near the peak of the Hurricane Season.

```

MIATWOAT
ABNT20 KNHC 110930

TROPICAL WEATHER OUTLOOK
NATIONAL WEATHER SERVICE MIAMI FL
530 AM EDT TUE SEP 11 1992

FOR THE ATLANTIC... CARIBBEAN AND THE GULF OF MEXICO

THE NATIONAL HURRICANE CENTER IS ISSUING ADVISORIES ON TROPICAL STORM LINDA LOCATED ABOUT
300 MILES SOUTHEAST OF COZUMEL MEXICO.

AN AREA OF DISTURBED WEATHER IS LOCATED IN THE EASTERN ATLANTIC SEVERAL HUNDRED MILES WEST
OF THE CAPE VERDE ISLANDS. UPPER LEVEL WINDS HAVE BECOME MORE FAVORABLE FOR THIS SYSTEM TO
BECOME BETTER ORGANIZED DURING THE NEXT SEVERAL DAYS.

A WELL ORGANIZED CLOUD SYSTEM EAST OF THE BAHAMAS IS ASSOCIATED WITH AN UPPER LEVEL LOW
PRESSURE AREA. TROPICAL DEVELOPMENT... IF ANY... WILL BE SLOW TO OCCUR.

PUBLIC ADVISORIES ON TROPICAL STORM LINDA CAN BE FOUND UNDER WMO HEADER WTNT32 KNHC
AND UNDER AFOS HEADER MIATCPAT2. FORECAST/ADVISORIES ARE FOUND UNDER WMO HEADER WTNT22 KNHC
AND AFOS HEADER MIATCMAT2.

ELSEWHERE... TROPICAL STORM DEVELOPMENT IS NOT EXPECTED THROUGH WEDNESDAY.

PASCH

```

FIGURE 18: Typical Tropical Weather Outlook during the peak of the Hurricane Season.

### Tropical Cyclone Forecast/Advisory (TCM)

This is the cornerstone of all NHC tropical cyclone products for the mariner. A TCM is issued when meteorological data indicates that a tropical (or subtropical) cyclone has formed. Subsequent advisories are issued at 0300, 0900, 1500, 2100 UTC for the life of the tropical cyclone. Special advisories or forecasts are issued whenever unanticipated significant changes occur. Additionally, a special forecast/advisory may also be sent in instances which require coastal hurricane or tropical storm watches or warnings be issued immediately.

FIGURE 19 shows a typical TCM containing forecasted position & intensity of a tropical cyclone at 12, 24, 36, 48, and 72 hours into the future. Additionally, this product possesses valuable information on the wind field of the tropical cyclone. Once a system develops to the tropical depression stage, this product is issued every 6 hours until the cyclone either becomes extra-tropical or weakens to below tropical depression status.

**Line 1:** Contains the National Weather Service header for the particular system (MIATCMAT5). There are actually five different headers for this product. They are MIATCMAT1 through MIATCMAT5 with each numbered system retaining it's own particular header for the duration of it's life.

**Line 2:** Contains the World Meteorological Organization header (WTNT 25) followed by the four-letter identifier for the National Hurricane Center (KNHC). Similar to line 1, there are actually five WMO headers (WTNT 21 through WTNT 25). The last character string in this line is the Day Hour Minute (DDHHMM) the product was actually sent from NHC.

```

1  SCSL MIATCMATS ALL.
2  WNTWTS KNHC DORHFM
3  HURRICANE DENNIS FORECAST/ADVISORY NUMBER 15
4  NATIONAL WEATHER SERVICE MIAMI FL 330599
5  1500Z FRI AUG 27 1999

6  AT 11 AM EDT...1500Z...A HURRICANE WATCH IS IN EFFECT FOR THE EAST COAST OF FLORIDA FROM
7  SEBASTIAN INLET NORTHWARD TO FERNANDINA BEACH. A HURRICANE WATCH MAY BE ADJUSTED NORTHWARD AS THE
8  HURRICANE MOVES PARALLEL TO THE EAST FLORIDA COAST.

9  AT 11 AM EDT...1500Z...THE GOVERNMENT OF THE BAHAMAS HAS DISCONTINUED A HURRICANE WARNING FOR THE
10 CENTRAL BAHAMAS AND FOR ANDROS ISLAND AND FOR NEW PROVIDENCE. HURRICANE WARNINGS ARE STILL IN
11 EFFECT FOR THE REMAINDER OF THE NORTHWESTERN BAHAMAS...ELEUTHERA ...THE ABACOS AND GRAND BAHAMA
12 ISLANDS.

13 RESIDENTS ALONG THE SOUTHEAST COAST OF THE UNITED STATES FROM CENTRAL FLORIDA THROUGH NORTH
14 CAROLINA SHOULD CLOSELY MONITOR THE PROGRESS OF DENNIS.

15 HURRICANE CENTER LOCATED NEAR 25.7N 75.9W AT 27/1500Z POSITION ACCURATE WITHIN 30 NM
16 PRESENT MOVEMENT TOWARD THE WEST NORTHWEST ON 300 DEGREES AT 6 KT

17 ESTIMATED MINIMUM CENTRAL PRESSURE 998 MB
18 MAX SUSTAINED WINDS 70 KT WITH GUSTS TO 85 KT.
19 64 KT..... 25NE 05E 05W 05W.
20 50 KT..... 65NE 25SE 05W 20NW.
21 34 KT.....125NE 100SE 05W 125NW.
22 12 FT SEAS...150NE 125SE 60SW 150NW.
23 WINDS AND SEAS VARY GREATLY IN EACH QUADRANT. RADII IN NAUTICAL MILES ARE THE
24 LARGEST RADII EXPECTED ANYWHERE IN THAT QUADRANT.

24 REPEAT...CENTER LOCATED NEAR 25.7N 75.9W AT 27/1500Z
25 AT 27/1200Z CENTER WAS LOCATED NEAR 25.6N 75.6W

26 FORECAST VALID 28/0000Z 26.2N 76.7W
27 MAX WIND 80 KT...GUSTS 95 KT.
28 64 KT... 25NE 05E 05W 05W.
29 50 KT... 65NE 25SE 05W 20NW.
30 34 KT...125NE 100SE 05W 125NW.

31 FORECAST VALID 28/1200Z 27.0N 79.0W
32 MAX WIND 90 KT...GUSTS 110 KT.
33 64 KT... 30NE 20SE 20SW 30NW.
34 50 KT... 65NE 50SE 25SW 60NW.
35 34 KT...125NE 100SE 50SW 125NW.

36 FORECAST VALID 29/0000Z 28.0N 79.0W
37 MAX WIND 95 KT...GUSTS 115 KT.
38 64 KT... 40NE 40SE 30SW 40NW.
39 50 KT... 75NE 75SE 50SW 75NW.
40 34 KT...125NE 125SE 75SW 125NW.

41 REQUEST FOR 3 HOURLY SHIP REPORTS WITHIN 300 MILES OF 25.7N 75.9W

42 EXTENDED OUTLOOK...USE FOR GUIDANCE ONLY...ERRORS MAY BE LARGE

43 OUTLOOK VALID 29/1200Z 29.5N 79.5W
44 MAX WIND 100 KT...GUSTS 120 KT.
45 50 KT... 75NE 75SE 50SW 75NW.

46 OUTLOOK VALID 30/1200Z 33.0N 79.5W
47 MAX WIND 100 KT...GUSTS 120 KT.
48 50 KT... 75NE 75SE 50SW 75NW.

49 NEXT ADVISORY AT 27/2100Z

50 FORECASTER AVILA

51 STRIKE PROBABILITIES ASSOCIATED WITH THIS ADVISORY NUMBER CAN BE FOUND UNDER AFOU HEADER.
52 MIASPPATS AND WMO HEADER WNTWTS KNHC.

```

FIGURE 19: Typical Atlantic Tropical Cyclone Forecast/Advisory.

**Line 3:** Numbering system for the Tropical Cyclone Forecast/Advisory (HURRICANE DENNIS FORECAST/ADVISORY NUMBER 15).

All tropical cyclone forecast/advisories are numbered sequentially each year; e.g.,

- Tropical Depression ONE Forecast/Advisory Number 1
  - The first tropical depression of the calendar year
- Tropical Depression ONE Forecast/Advisory Number 2
  - The second advisory on TD #1
- Tropical Storm Anita Forecast/Advisory Number 3
  - System intensifies to tropical storm force
- Hurricane Anita Forecast/Advisory Number 4
  - System intensifies to hurricane force
- Tropical Depression Anita Forecast/Advisory Number 5
  - System weakens to a tropical depression

**Line 4:** Location of center issuing the forecast/advisory (NATIONAL WEATHER SERVICE MIAMI FL) along with an internal agency tracking code specific to each numbered tropical/subtropical system in the basin during a calendar year. In the example of FIGURE 19, AL0599 indicates that Dennis is the 5<sup>th</sup> tropical cyclone in the Atlantic Basin during calendar year 1999.

**Line 5:** The nominal product time (1500Z FRI AUG 27 1999). Please note that NHC attempts to issue products shortly before this time. Hence, this time will usually not be identical to the time indicated in line 2 of the message.

**Lines 6-14:** This section of the message is used to disseminate current watch/warning status and changes to status for the particular system. Information in this section of the message may be omitted in instances where there are no active or expected watches/warnings or other administrative notes to issue.

**Line 15:** This line gives the tropical cyclone center position including the accuracy of that position at the time the product was issued. (0300/0900/1500/2100 UTC)

**Line 16:** Gives the present motion of the tropical cyclone.

**Line 17:** Reports the estimated minimum central pressure of the system at the time the message was issued.

**Line 18:** Reports the maximum sustained winds and expected gusts associated with the tropical cyclone at the time the message was issued.

**Lines 19-23:** Defines the 64 KT, 50 KT, and 34 KT wind radii of the system at the time the message is issued from NHC. Additionally, Line 22 defines the radii of the 12-foot significant wave heights associated with the tropical cyclone.

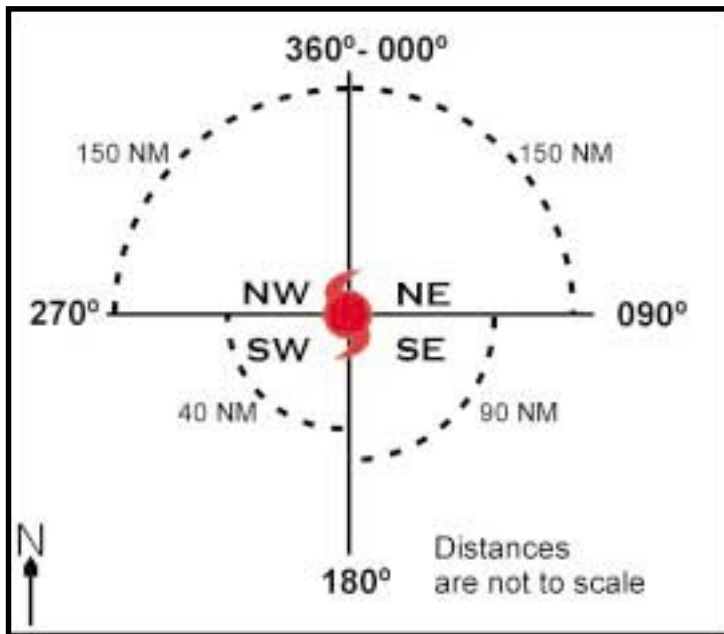
**Line 24:** Repeats the position of the center at the time the message was issued from NHC.

**Line 25:** Reports the position of the tropical cyclone center at the latest synoptic time. Synoptic times are 0000, 0600, 1200, and 1800 UTC and always precede the issue time of a standard TCM by 3 hours.

**Lines 26-30:** Forecasts the position, intensity, and wind radii for the tropical cyclone 12 hours after the latest synoptic time given in line 25.

For example, the advisory in FIGURE 19 was issued on the 27<sup>th</sup> at 1500 UTC. The latest synoptic time was the 27<sup>th</sup> at 1200 UTC as shown in line 25 of the TCM. Therefore, the 12 hour forecast position is valid 12 hours after the latest synoptic time, or the 28<sup>th</sup> at 0000 UTC.

**DEFINITION OF WIND RADII BY QUADRANT:** Uses the largest radius of that wind speed found in the quadrant. For example, NHC quadrants are defined as NE (0°-90°), SE (90°-180°), SW (180°-270°), and NW (270°-360°). Given a maximum 34 KT radius of 150 NM at 0°, 90 NM at 120°, and 40 NM at 260°, the following would be carried in the forecast/advisory: 150NE 90SE 40SW 150NW. FIGURE 20 is a graphical representation of the wind radii by quadrant.



*FIGURE 20: Graphical depiction of the wind radii quadrant system used in NHC Tropical Cyclone Forecasts/Advisories. This system allows for reasonably certain depiction of current and forecasted wind field structure in a tropical cyclone. In the example, the wind field would be given as 150 NE, 90 SE, 40 SW, and 150 NW around the center of the tropical cyclone. Note that cardinal directions are relative to true north.*

**Lines 31-35:** Forecasts the position, intensity, and wind radii for the tropical cyclone 24 hours after the latest synoptic time given in line 25.

**Lines 36-40:** Forecasts the position, intensity, and wind radii for the tropical cyclone 36 hours after the latest synoptic time given in line 25.

**NOTE:** TCM format is not completely fixed. When applicable, storm surge forecasts can be inserted before line 41.

**Line 41:** REQUESTS 3 HOURLY OBSERVATIONS FROM SHIPS WITHIN A CERTAIN DISTANCE FROM THE TROPICAL CYCLONE.

All analysis and forecasts of tropical cyclone activity rely heavily on local ship observations in order to obtain the best estimate of the synoptic patterns guiding storm motion and intensity. Any observations recorded near a tropical cyclone are used to determine current wave heights & wind fields associated with the tropical cyclone.

**Line 42:** Introduces the extended outlook section that provides forecast position, intensity, and 50 KT wind radii at the 48 and 72 hour periods.

**Lines 43-45:** Forecast of position, intensity, and 50 KT wind radii for the tropical cyclone 48 hours after the latest synoptic given in line 25.

**Lines 46-48:** Forecast of position, intensity, and 50 KT wind radii for the tropical cyclone 72 hours after the latest synoptic given in line 25.

**Line 49:** States the next issue time for the TCM.

**Line 50:** Name of NHC Forecaster who wrote the forecast/advisory.

**Lines 51-52:** Lists NWS and WMO headers for strike probability information on the tropical cyclone when applicable.

### Tropical Cyclone Discussion (TCD)

This product is issued by NHC to explain the Hurricane Forecaster's reasoning behind the latest analysis and forecast of a tropical cyclone. Similarly, the message may also provide indications of track or intensity tendencies that may be occurring in the tropical cyclone while possibly providing some discussion/insight on the current computer model guidance for the tropical cyclone. The product also contains 12 hour through 72 hour forecast positions and maximum wind speed forecasts for each time period, while providing other significant meteorological and/or emergency management information. The issue times of the discussion are 0300, 0900, 1500, 2100 UTC to coincide with the release of the TCM. This product can often times help the mariner to gauge the confidence level that NHC meteorologists have regarding a tropical cyclone's current or future track and intensity. FIGURE 21 on the next page is an example of a TCD.

### Tropical Cyclone Strike Probabilities

This product gives the percentage chance of a tropical or subtropical cyclone passing within 75 NM to the right or within 50 NM to the left of a specified point, looking in the direction of cyclone motion. The probabilities are given for the time periods 0-24, 24-36, 36-48, 48-72, and 0-72 hours. They are issued every 6 hours with the TCM for tropical storms, hurricanes, and tropical depressions forecast to become tropical storms. Information in this product may be useful to the mariner needing to make decisions on ports of possible weather haven. FIGURE 22 on the following page is an example of the information provided in this product.

ZCZC MATCOAT3 ALL  
TTAAGG KNHC DDHHMM  
HURRICANE FLOYD DISCUSSION NUMBER 14  
NATIONAL WEATHER SERVICE MIAMI FL  
11 PM EDT FRI SEP 10 1999

LAST RECON A FEW HOURS AGO, REPORTED A MINIMUM PRESSURE OF 971 MB AND DROPSONDE MEASURED WINDS OF 90 KNOTS AT 925 MB. THE CREW ALSO REPORTED A GOOD RADAR PRESENTATION AND A CENTER REFORMING INSIDE THE ORIGINAL CENTER. BASED ON RECON AND THE AVERAGE WIND ESTIMATES FROM TAFB SAB AND KGWAC...THE INITIAL INTENSITY IS ADJUSTED TO 90 KNOTS AT THIS TIME. FLOYD IS WELL ORGANIZED WITH AN EXCELLENT OUTFLOW AND VERY DEEP CONVECTION NEAR THE CENTER. HOWEVER, THE HURRICANE HAS TO MOVE THROUGH THE MID-UPPER OCEANIC TROUGH...CLEARLY OBSERVED ON WATER VAPOR IMAGERY. DURING THE NEXT 24 TO 36 HOURS, THIS FEATURE IS ALSO DEPICTED BY RAOBS FROM THE CARIBBEAN WHICH REPORTED SOUTHWESTERLY WINDS...AT 300 MB BLOWING INTO THE HURRICANE. IN ADDITION, THE AVM DEVELOPS A 200 MB NORTHWESTERLY FLOW OVER THE TROPICAL CYCLONE FOR THE NEXT 24 HOURS... RESULTING IN A SHEARING ENVIRONMENT. THEREFORE, SOME FLUCTUATIONS IN INTENSITY ARE LIKELY DURING THE NEXT 24 TO 36 HOURS. THEREAFTER, ONCE FLOYD MOVES AWAY FROM THE UPPER-TROUGH... STRENGTHENING SHOULD START AGAIN.

INITIAL MOTION IS 31015. UNANIMOUSLY, DYNAMICAL MODELS TURN THE HURRICANE ON A TRACK MORE TO THE WEST-NORTHWEST AND EVEN WESTWARD. THIS DEVIATION TO THE LEFT IS BASED ON THE DEVELOPMENT A STRONG WARM RIDGE...WHICH IS VERY STRONG AT MID TO UPPER-LEVELS OVER THE WESTERN ATLANTIC AND THE LACK OF TROUGH IN THE FORECAST ALONG EAST COAST OF THE UNITED STATES. THE RELIABLE UK MODEL IS THE MOST AGGRESSIVE IN TURNING THE HURRICANE WESTWARD AND LOCATES FLOYD NEAR THE CENTRAL BAHAMAS IN THREE DAYS AND VERY NEAR CENTRAL FLORIDA IN FIVE DAYS. NEVERTHELESS, THE CURRENT TREND OF ALL THE LONG RANGE MODELS IS A TRACK TOWARD THE U.S. EAST COAST INSTEAD OF A NORTHWARD TURN OVER OPEN WATERS. THIS IS REFLECTED IN THE OFFICIAL FORECAST.

GIVEN THESE TRENDS, RESIDENTS ALONG THE U.S. EAST COAST SHOULD MONITOR THE PROGRESS OF FLOYD DURING THE NEXT FEW DAYS.

AVLA

FORECAST POSITIONS AND MAX WINDS

INITIAL	15/0300Z	21.1N	80.8W	80 KTS
12HR VT	11/1200Z	21.9N	81.9W	80 KTS
24HR VT	12/0000Z	22.7N	83.6W	80 KTS
36HR VT	12/1200Z	23.5N	85.5W	85 KTS
48HR VT	13/0000Z	24.0N	88.0W	95 KTS
72HR VT	14/0000Z	25.0N	73.0W	105 KTS

FIGURE 21: Typical Tropical Cyclone Discussion.

ZCZC MATCOAT3 ALL  
TTAAGG KNHC DDHHMM  
HURRICANE DEBBY PROBABILITIES NUMBER 14  
NATIONAL WEATHER SERVICE MIAMI FL  
11 PM AST TUE AUG 22 2000

PROBABILITIES FOR GUIDANCE IN HURRICANE PROTECTION  
PLANNING BY GOVERNMENT AND DISASTER OFFICIALS

AT 11 PM AST...0300Z...THE CENTER OF DEBBY WAS LOCATED NEAR LATITUDE 19.4 NORTH... LONGITUDE 67.2 WEST.

CHANCES OF CENTER OF THE HURRICANE (ASSUM) WITHIN 40 NAUTICAL MILES OF LISTED LOCATIONS THROUGH 09M AST FRI AUG 25 2000.

LOCATION	A	B	C	D	E	LOCATION	A	B	C	D	E
21.0N 72.2W	5	3	X	X	5	MOBE 251N 770W	X	1	18	5	22
22.0N 74.5N	5	24	X	X	20	MOBE 260N 757W	X	20	4	14	18
23.0N 76.5N	2	14	14	1	20	SEA JUNG FR 03	X	2	8	30	
MOBE 185W 697W	25	X	X	X	25	HARATHON FL	X	2	1	12	14
MOBE 174W 734W	2	X	X	X	2	MIAMI FL	X	X	2	14	18
MTFP 160W 724W	10	4	X	1	10	N PALM BEACH FL	X	X	1	14	17
MTCG 148W 739W	1	4	1	1	7	ST PETERS FL	X	X	2	15	18
MLJE 178W 762W	X	X	1	1	2	DECOA BEACH FL	X	X	2	13	13
MLSE 165W 770W	X	X	2	2	4	DAYTONA BEACH FL	X	X	2	10	10
MWCD 150W 814W	X	X	X	2	2	JACKSONVILLE FL	X	X	X	6	8
MWDM 200W 751W	1	18	1	1	22	SAVANNAH GA	X	X	X	2	2
MWDM 214W 770W	X	2	15	3	20	KEY WEST FL	X	X	1	13	14
MWDF 223W 805W	X	X	5	10	13	BRACO ISLAND FL	X	X	X	15	15
MWDM 216W 826W	X	X	X	6	4	FT MYERS FL	X	X	X	14	14
MWDM 230W 824W	X	X	X	10	10	VENICE FL	X	X	X	13	13
MWDM 218W 850W	X	X	X	2	2	TAMPA FL	X	X	X	12	12
TJ82 184W 661W	89	X	X	X	59	CEPAA KEY FL	X	X	X	9	8
MWDF 190W 707W	62	X	X	X	62	ST MARKS FL	X	X	X	5	5
MWDF 215W 711W	62	X	X	X	62	SPALACHICOLA FL	X	X	X	4	4
MWDM 224W 730W	25	12	X	X	44	JANNAHA CITY FL	X	X	X	3	3
MWDM 241W 745W	X	24	X	X	27	GULF 29W 85W	X	X	X	5	5
MWDM 235W 758W	X	20	X	1	30	GULF 29W 87W	X	X	X	2	2
MWDM 241W 778W	X	2	13	4	20						

CHURN DEFINITIONS PROBABILITIES IN PERCENT  
A IS PROBABILITY FROM NOW TO 09M WED  
FOLLOWING ARE ADDITIONAL PROBABILITIES:  
B FROM 09M WED TO 09M THU  
C FROM 09M THU TO 09M FRI  
D FROM 09M FRI TO 09M SAT  
E IS TOTAL PROBABILITY FROM NOW TO 09M FRI  
X MEANS LESS THAN ONE PERCENT

FORECASTER AVILA

FIGURE 22: Typical Tropical Cyclone Strike Probability Message.



Coastal, Offshore, and High Seas Forecast Text Products

These products are issued four times daily throughout the year. The emphasis in these forecasts is predicting marine conditions for the next 36 to 48 hours within their respective areas of responsibility that together cover the North Atlantic Ocean from 7N to 65N Latitude, west of 35W Longitude including the Caribbean Sea & Gulf of Mexico. TABLE 1 below contains more information on issue times and specific regions for these products. During periods of tropical cyclone activity in or near particular forecast zones, these products will include the latest information on winds, seas, and other weather hazards related to the tropical cyclone. Additionally the High Seas product will contain tropical cyclone positions/intensities at the initial and forecast times for 36, 48, and 72 hours. 12 or 24 hour forecast positions/intensities would only be given in cases where the system is forecast to be upgraded/downgraded between different classes of tropical cyclones (Tropical Depression to Tropical Storm, Hurricane to Tropical Storm, etc.) during that time frame.

FORECAST PRODUCT NAME	ISSUE TIME (See notes in each section)	MARINE AREAS OF RESPONSIBILITY	
COASTAL WATERS	430AM, 1030AM, 430PM, 1030PM Given in local standard time. Issuance times are 1 hour later for those states using Daylight Savings Time	From Maine to Georgia - within approximately 20-25 NM of the coast including rivers, inlets, and bays.  From Florida through Texas – within approximately 60 NM of the coast including rivers, inlets, and bays.  Puerto Rico – from the coast to the 100 fathom curve.	
OFFSHORE WATERS	Times are similar to Coastal Marine Forecasts	New England	Continental Shelf & slope waters from 25 NM offshore to the Hague Line... except to one thousand fathoms S of New England
		W Central North Atlantic	Continental Shelf & slope waters beyond 20 NM offshore... S and E of one thousand fathoms to 65W
		SW North Atlantic & Caribbean Sea	Caribbean Sea and SW N Atlantic
		Gulf Of Mexico	Gulf of Mexico
HIGH SEAS	0430, 1030, 1630, 2230 (Listed in UTC)	7N-67N west of 35W in the North Atlantic Ocean	

TABLE 1: Issue times and areas of responsibility for coastal, offshore and high seas forecasts.

**Tropical Cyclone Graphic Products for the Mariner**

Tropical Surface Analysis

This product is generated by the Tropical Analysis & Forecast Branch of TPC and is issued four times per day based on the synoptic times of 0000, 0600, 1200, and 1800 UTC. This graphic depicts latest position and intensity of all synoptic scale surface features including highs, lows, fronts,

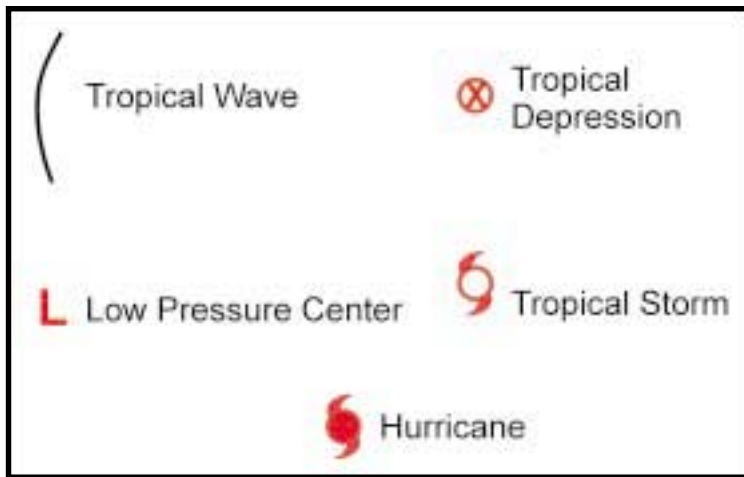


FIGURE 23: Examples of symbology used in the tropical surface analysis

troughs, and tropical waves. This product also denotes the 24 hour forecast position and intensity of all high and low centers over open waters. Additionally, the large-scale surface flow pattern is depicted through isobaric (lines of constant pressure) analysis at 4 MB intervals throughout the entire region with intermediate 2 MB spacing in the Tropics. When a tropical cyclone is in the analysis, the latest position, intensity, and current motion can be found on this chart. FIGURE 23 shows typical tropical symbology used to depict surface features on these charts. FIGURE 24 is an example of the tropical surface analysis. For further information on receiving this chart at sea, see TABLE 10 at the end of the chapter for details.

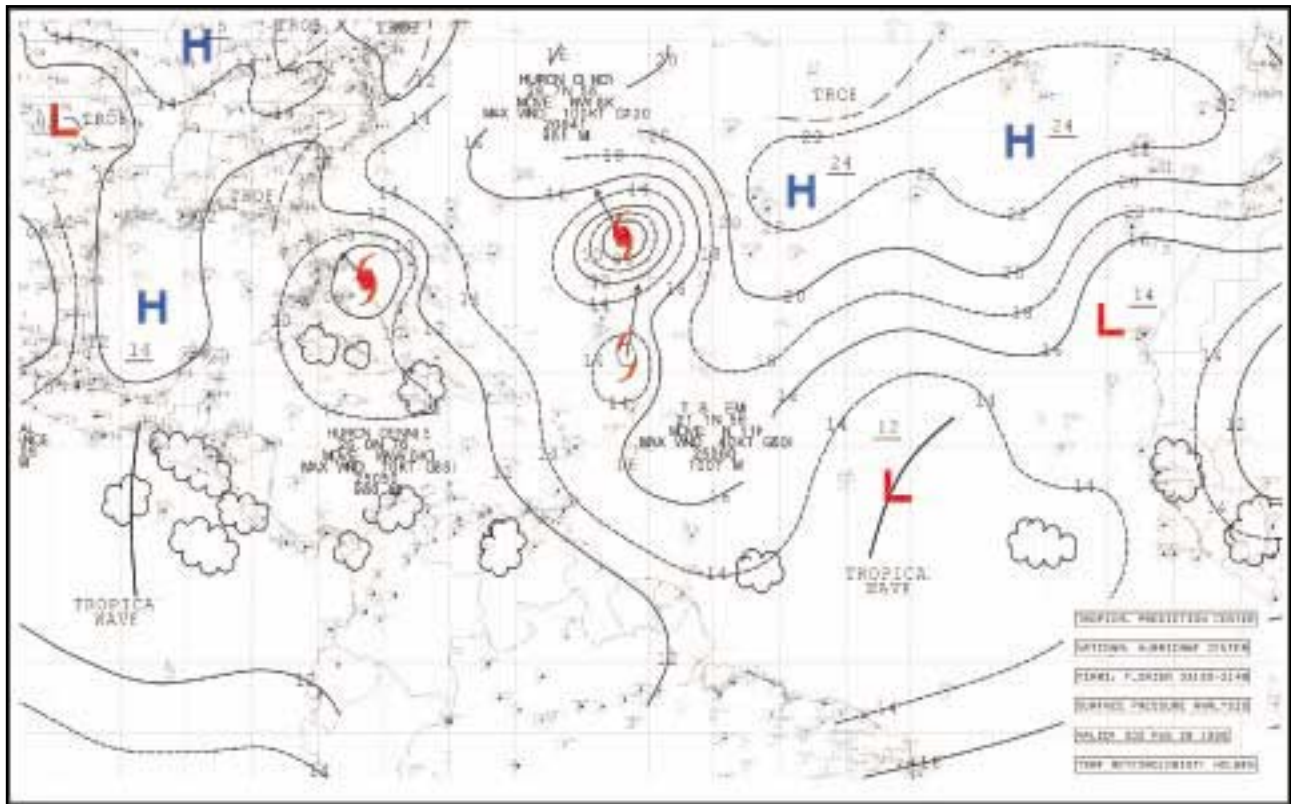


FIGURE 24: Example of a Tropical Surface Analysis. Current tropical cyclone locations, intensities, movements, & pressures are listed in the analysis near the symbol for each system. Additionally, location of latest 24 hour forecast position of the tropical cyclone is also included in this chart. The tip of the arrow originating from the center of each tropical cyclone symbol indicates the 24 hour forecast position. If the arrow is absent, then system 24 hour forecast position is nearly stationary.

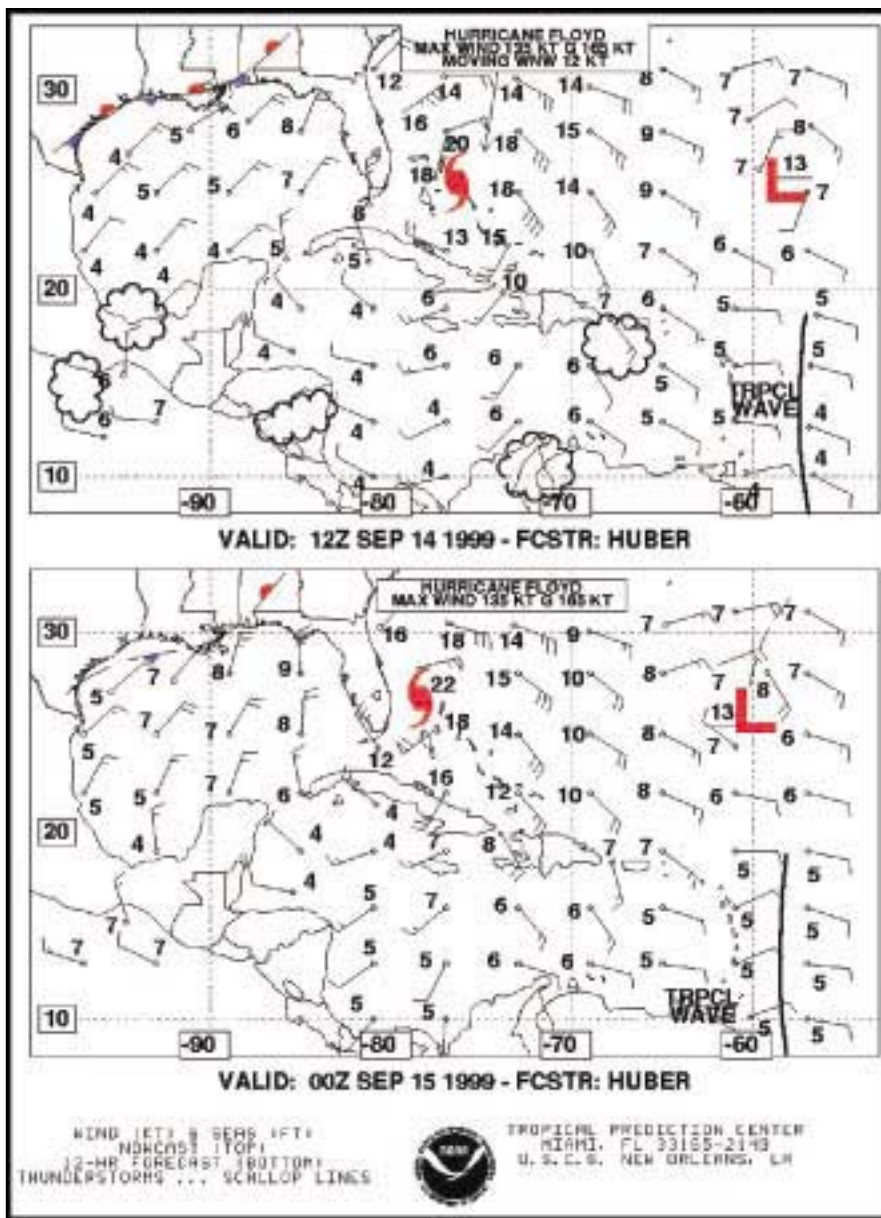


FIGURE 25: Example of NOWCAST and 12 Hour Forecast Chart. Latest forecast position of the tropical cyclone is depicted in this chart by the center of each tropical cyclone symbol. Seas are depicted in combined wind wave & swell, given in feet, next to each wind barb (speed & direction). Any current or forecasted convection of moderate or stronger intensity & scattered or greater coverage will be show in scalloped lines on these charts, as noted in the upper panel of this figure in the Mona Passage between Puerto Rico and Hispaniola.

### Tropical Cyclone Graphic Products

There are five graphical products created by NHC whenever a tropical cyclone is active in the Atlantic basin. They are; coastal watches & warnings, strike probabilities, cumulative wind distribution, wind speed forecast & probability, and wind speed probability table. These graphics are available in the graphics section of each active tropical cyclone on the NHC web site (address given in TABLE 2). All are easy to interpret and, if available, may help the mariner in the hurricane avoidance decision making process. Of particular interest are the strike probabilities graphic which show

### Wind/Wave Forecast Chart

There are two forms of this product. The first is a NOWCAST and 12 hour forecast graphic of wind & sea conditions in the Atlantic from 9N to 32N west of 50W including the Caribbean Sea & Gulf of Mexico. This is issued 4 times per day within 1 hour of the synoptic times (0000/0600/1200/1800 UTC). The second version of this product is a 24 hour and 36 hour forecast graphic covering the same area of the Atlantic. It is issued 2 times per day at the synoptic times of 0000 and 1200 UTC.

During periods of tropical cyclone activity, these products depict the latest forecast position & intensity of the tropical cyclone as based on the most recent TCM. FIGURE 25 shows an example of this graphical forecast product. Methods of receiving this information at sea are listed in TABLE 10.

the distribution of risk based on the latest 72-hour TCM forecast track. Also note the cumulative wind distribution that graphically illustrates how the size of the storm has changed, and the areas affected so far by tropical storm & hurricane force winds. A brief explanation of the information shown in each of the other graphics is included with the products on the NHC web site.

### **NWS Marine Prediction Center (MPC) Products**

All of the text offshore & high seas forecast products, in addition to the graphical products described throughout this manual, have a companion product available from MPC. Products issued by both MPC & TPC are standardized in format. This allows for a near seamless transition for sailors in need of information regarding tropical cyclones & maritime weather throughout the Atlantic west of 35°W from 7°N to 67°N with the MPC area of responsibility found north of 31°N in this region.

Some of the graphical products available from MPC are listed in TABLE 10 at the end of this chapter. More detailed information on MPC products and availability can be found in the BOSTON HF Fax schedule or by visiting the Marine Prediction Center web site (address listed in TABLE 10). Methods to acquire products from either of these NWS production centers are the same and will be discussed in much greater detail in the following section.

### **Receiving Tropical Cyclone Products At Sea**

Regardless of how accurate NHC forecasts of tropical cyclone activity are, they are useless unless reliable and timely methods are available to get this information to the mariner. In this subsection, we will discuss the many ways that tropical cyclone information is made available to the mariner. The current methods used to distribute tropical cyclone forecasts, advisories, and outlooks are many. However, knowing which products are available via which source is often the difficult part in obtaining tropical cyclone information. After reviewing the methods used to get tropical weather information to the mariner at sea, TABLE 10 at the end of this chapter attempts to summarize each product into a ready reference of what, when, and how to obtain crucial tropical cyclone information at sea. Further information on all NWS marine products can be found at the internet address:

<http://www.nws.noaa.gov/om/marine.htm>

#### **Internet**

Although internet access at sea can often be an expensive and technically challenging alternative to obtaining tropical cyclone information, use of this method while in port is becoming more popular as access costs decrease and personal computer use among mariners increases.

A majority of NWS forecasts and warnings are now available on-line from NWS web servers. Specifically, all tropical cyclone products are available in this format directly from TPC/NHC. Additionally, these products can also be found via other National Weather Service and government web servers. Although the Internet is not part of the National Weather Service's operational data stream and should never be relied upon as the primary method of obtaining the latest forecast and warning data, web servers maintained by the National Weather Service are usually reliable and can serve as a valuable source of information for the Mariner. TABLE 2 indicates current web sites

PRODUCT	INTERNET SITE	INTERNET ALTERNATE
Tropical Weather Outlook	<a href="http://www.nhc.noaa.gov/products.html">http://www.nhc.noaa.gov/products.html</a>	<a href="http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical">http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical</a>
Tropical Weather Discussion	<a href="http://www.nhc.noaa.gov/forecast.html">http://www.nhc.noaa.gov/forecast.html</a>	<a href="http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical">http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical</a>
Tropical Cyclone Forecast/ Advisory	<a href="http://www.nhc.noaa.gov/products.html">http://www.nhc.noaa.gov/products.html</a>	<a href="http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical">http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical</a>
Tropical Cyclone Discussion	<a href="http://www.nhc.noaa.gov/products.html">http://www.nhc.noaa.gov/products.html</a>	<a href="http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical">http://www.nlmoc.navy.mil/cgi-bin/main.pl?tropical</a>
High Seas Text Forecasts	<a href="http://www.nhc.noaa.gov/forecast.html">http://www.nhc.noaa.gov/forecast.html</a>	<a href="http://www.mpc.ncep.noaa.gov/graphictextF.html">http://www.mpc.ncep.noaa.gov/graphictextF.html</a>
Tropical Surface Analysis	<a href="http://www.nhc.noaa.gov/forecast.html">http://www.nhc.noaa.gov/forecast.html</a>	<a href="http://weather.noaa.gov/fax/marsh.shtml#SFC">http://weather.noaa.gov/fax/marsh.shtml#SFC</a>
Wind/Seas Graphics Forecast	<a href="http://www.nhc.noaa.gov/forecast.html">http://www.nhc.noaa.gov/forecast.html</a>	<a href="http://weather.noaa.gov/fax/marsh.shtml#SFC">http://weather.noaa.gov/fax/marsh.shtml#SFC</a>
Tropical Cyclone Graphic Products	<a href="http://www.nhc.noaa.gov/index.html">http://www.nhc.noaa.gov/index.html</a>	<a href="http://www.nhc.noaa.gov/index_text.html">http://www.nhc.noaa.gov/index_text.html</a>

TABLE 2: List of internet web sites containing latest Atlantic basin tropical cyclone information.

available for Atlantic tropical cyclone information. Finally, any active marine warning, including tropical cyclone related warnings can also be found on the Interactive Weather Information Network (IWIN) of the Emergency Managers Weather Information Network (EMWIN) at the following internet address.

<http://iwin.nws.noaa.gov/iwin/textversion/nationalwarnings.html>

### E-mail

TPC/NHC text files & graphic charts are available via email through a NWS FTPMAIL server. This server allows Mariner's who do not have direct access to the World Wide Web but who are equipped with an email system to receive NWS products at sea or in port. Using this service, users can request files from the NWS and have them automatically e-mailed back to the user. Turnaround is generally less than three hours, however, performance may vary widely and receipt cannot be guaranteed. However, this service can be a valuable tool to the Mariner in obtaining tropical cyclone information as well as other weather information over open water areas.

To start using this service, obtain the FTPMAIL help file by:

1. Sending an email to: [ftpmail@weather.noaa.gov](mailto:ftpmail@weather.noaa.gov)

2. Subject Line: Anything that you like
3. Body: help

The help file that you receive via email will discuss procedures and methods of obtaining tropical cyclone information along with a listing of available products using this method. In order to get further information on tropical cyclone specific data available via this service:

1. Send an email to: `ftpmail@weather.noaa.gov`
2. Subject Line: Anything that you like
3. Body of message (case and line sensitive):
  - `open`
  - `cd fax`
  - `get marine2.txt`
  - `quit`

This will generate an email response with a description of tropical cyclone products and file names along with further instructions on obtaining this particular information via the FTPMAIL server.

### HF Fax

The HF Fax, also known as the radiofax or WEFAX, for years has been the mainstay of weather information for the mariner. During the tropical cyclone season in the Atlantic, information on current tropical systems in text or graphical formats can be acquired via this method. Additionally, satellite imagery is made available throughout the year via this circuit. Transmitters located in Boston and New Orleans continuously transmit weather information for the Atlantic Basin available to anyone at sea with the proper receiving equipment.

TABLE 3 lists the frequencies assigned to the Boston and New Orleans sites in addition to broadcast times for each site's current HF Fax schedule. Users should occasionally review the fax schedules at each site for changes in available products and transmission times.

Transmitter	Frequencies (in kHz)	Broadcast Times	Broadcast Schedule Transmitted (in UTC)
New Orleans	4317.9	Continuous	0630 & 1830
	8503.9	Continuous	0630 & 1830
	12789.9	Continuous	0630 & 1830
Boston	4235	0230-1015 UTC	0243
	6340.5	Continuous	0243 & 1905
	9110	Continuous	0243 & 1905
	12750	1430-2215 UTC	1905

TABLE 3: HF Fax transmitter sites and assigned frequencies for the Atlantic Basin.

Typical dedicated radiofax receivers use assigned frequencies, while receivers or transceivers, connected to external recorders or personal computers, are operated in the upper sideband (USB) mode using the carrier frequencies. From the HF Fax assigned frequencies in TABLE 3 subtract 1.9 kHz for carrier frequency. All radiofax broadcasts of NWS products use a radiofax signal of 120 lines-per-minute (LPM) and an Index-of-Cooperation (IOC) of 576. Although radio reception in the high-frequency band varies greatly with a multitude of factors, generally, frequencies above 10 MHz work best during the day, while lower frequencies work best at night.

WWV HF Voice (Time Tick)

The National Institute of Standards and Technology (NIST) broadcasts a time and frequency service from station WWV in Fort Collins, Colorado. The “Time Tick” is normally used as an aid to celestial navigation but hourly voice broadcasts of Atlantic High Seas Warnings are transmitted at 8 & 9 minutes past the hour on the frequency signals: 2.5, 5, 10, 15, and 20 MHz.

U.S. Coast Guard HF SITOR (Simplex Teletype Over Radio)

Broadcasts of high seas forecasts and storm warnings are transmitted from the United States Coast Guard’s Boston high seas communications station in the SITOR mode. These text broadcasts are performed in mode B, FEC, with broadcast times & frequencies listed in TABLE 4. Information included in these broadcasts range from weather to navigational safety text information. Transmission range of these broadcasts, as with all HF signals, is dependent on operating frequency, time of day, and multiple environmental factors.

Transmitter	Frequencies (in kHz)	Broadcast Times
BOSTON	6314	0000-0200 UTC
	8416.5	Continuous
	12579	Continuous
	16806.5	1200-1700 UTC

TABLE 4: SITOR assigned frequencies for the Atlantic Basin.

U.S. Coast Guard HF Voice

High seas forecasts, offshore forecasts, and tropical cyclone marine forecasts/advisories are broadcast in voice format via two United States Coast Guard transmitters operating in the Atlantic Basin. The products are broadcast via HF in the upper sideband (USB) mode using a synthesized voice known as “Perfect Paul”. This voice is very distinctive and serves as an aid in identifying and copying these weather broadcasts. TABLE 5 lists transmitter sites, frequencies, and times to copy the HF voice broadcast in the Atlantic basin.

Transmitter	Upper Sideband Frequencies (in kHz)	Broadcast Times For Offshore Forecasts & Hurricane Information (in UTC)	Broadcast Times for High Seas Forecasts & Hurricane Information (in UTC)
New Orleans (NMG) * See Note in Label Below	4316	0330, 0930, 1600, 2200	0500, 1130, 1730, 2330
	8502	0330, 0930, 1600, 2200	0500, 1130, 1730, 2330
	12788	0330, 0930, 1600, 2200	0500, 1130, 1730, 2330
Chesapeake (NMN)	4426	0330, 0930	0500
	6501	0330, 0930, 1600, 2200	0500, 1130, 2330
	8764	0330, 0930, 1600, 2200	0500, 1130, 1730, 2330
	13089	1600, 2200	1130, 1730, 2330
	17314	NONE	1730

TABLE 5: HF Voice broadcast transmitter sites, assigned frequencies, & transmission times for offshore, high seas, & tropical cyclone information in the Atlantic Basin. NOTE: HF voice broadcasts of weather information from the New Orleans transmitter may be preempted, as this transmitter is shared with the New Orleans radiifax broadcast.

U.S. Coast Guard MF Voice

Medium frequency broadcasts of NWS offshore waters forecasts and storm warnings are conducted on 2670 kHz after an initial announcement on 2182 kHz (will become 2187.5 kHz sometime in the future although exact date is unavailable at time of publication). These broadcasts originate from

Coast Guard Group	Broadcast Time (UTC)	Coast Guard Group	Broadcast Time (UTC)	Coast Guard Group	Broadcast Time (UTC)
Southwest Harbor	1135, 2335	Hampton Roads	0203, 1333	St. Petersburg	0320, 1420
Portland	1105, 2305	Cape Hatteras	0133, 1303	Mobile	1020, 1220, 1620, 2220
Boston	1035, 2235	Fort Macon	0103, 1233	New Orleans	0550, 1035, 1235, 1635
Woods Hole	0440, 1640	Charleston	0420, 1620	New Orleans	2235
Moriches	0010, 1210	Mayport	0620, 1820	Galveston	1050, 1250, 1650, 2250
Atlantic City	1103, 2203	Miami	0350, 1550	Corpus Christi	1040, 1240, 1640, 2240
Eastern Shore	0233, 1403	Greater Antilles	0305, 1505		

TABLE 6: MF Voice broadcast transmitter sites and transmission times for offshore forecasts and tropical cyclone information during the hurricane season in the Atlantic Basin. Frequency for all USCG MF transmitters is 2670 kHz after an initial announcement on 2182 kHz (to become 2187.5 kHz some time in the future).

various Coast Guard Groups located along the Atlantic & Gulf coasts of the United States with a typical range of 50-150 NM during the day to about 150-300 NM at night. TABLE 6 lists the location and transmission times of products sent via MF voice broadcast in the Atlantic Basin.

NWS offshore waters forecast products valid for the regions where the broadcasts originate are disseminated throughout the year. The tropical weather outlook and any active tropical cyclone forecast/advisories are broadcast from some of these transmitters during the Atlantic Hurricane season of 1 June through 30 November. Additionally, Group New Orleans and Group Corpus Christi broadcast various other coastal forecasts and marine or severe weather statements when applicable throughout the year.

### U.S. Coast Guard VHF Voice

Coastal water forecasts and storm warnings of interest to mariners are broadcast by the Coast Guard on VHF channel 22A (156.8 MHz VHF FM) after an initial announcement on VHF channel 16 (157.1 MHz VHF FM). The Coast Guard VHF network provides nearly continuous coverage of all coastal areas of the United States East and Gulf coasts to a range of approximately 20 NM from shore. In regions where NOAA weather radio broadcasts provide complete coverage of the USCG VHF network, the Coast Guard may elect to only broadcast storm warnings and not any NWS marine weather information. TABLE 7 on the next page lists Coast Guard stations that transmit over VHF voice along with transmission times.

### NOAA Weather Radio

Local and coastal marine forecasts & warnings are broadcast across the NOAA weather radio network on a constant basis. This network provides near continuous coverage of the coastal waters in the Atlantic and Gulf of Mexico. Additionally, NOAA weather radio transmitters are located in the Caribbean region transmitting over the coastal waters of Puerto Rico & the U.S. Virgin Islands.



Coastal Area	Broadcast Time (UTC)	Coastal Area	Broadcast Time (UTC)	Coastal Area	Broadcast Time (UTC)
Southwest Harbor	1135, 2335	Eastern Shore	0200, 1145	St. Petersburg	1300, 2300
Portland	1105, 2305	Hampton Roads	0230, 1120	Mobile	Broadcast Warnings Only
Boston	1035, 2235	Cape Hatteras	0100, 1055	New Orleans	1035, 1235, 1635, 2235
Woods Hole	1005, 2205	Fort Macon	0103, 1233	Galveston	1050, 1250, 1650, 2250
Moriches	0010, 1210	Charleston	1200, 2200	Corpus Christi	1040, 1240, 1640, 2240
Long Island Sound	1120, 2320	Mayport	1215, 2215		
New York	1050, 2250	Miami Beach	1230, 2230		
Atlantic City	1103, 2303	Key West	1200, 2200		
Baltimore	0130, 1205	Greater Antilles	1210, 2210		

TABLE 7: USCG VHF Voice broadcast transmitter sites and transmission times for coastal forecast and marine warning information. Frequency for all USCG VHF transmitters is 156.8 MHz VHF FM (VHF Channel 22A) after an initial announcement on 157.1 MHz VHF FM (VHF Channel 16).

Reception ranges of 25 NM from the coast are typical, however coverage may be more or less depending on location of vessel and transmitter.

Most VHF radios have the ability to receive NOAA weather radio over the frequencies listed in TABLE 8. However, it is recommended that a separate NOAA Weather Radio receiver be used to copy this broadcast so that the marine VHF channels can remain clear in order to copy other important information at sea.

During severe weather situations, an automated 1050 Hz tone is transmitted to automatically turn on compatible NOAA weather radio receivers. Most, but not all, NOAA weather radios possess this feature. However, an active NOAA Weather Radio channel must be selected in order for the mariner to be alerted. Additionally, newer NOAA weather radios utilize SAME (Specific Area Message Encoding) technology. This feature allows weather radios to alert only for specific weather conditions or certain geographic areas. It is recommended that SAME technology weather radios operated by mariners making coastal transits be set to the ‘All County Code Option’ in order to avoid the need for continual reprogramming of the radio during transit. This also reduces the likelihood of missing any important weather warning information while underway.

Broadcast Channel	Broadcast Frequency in MHz
WX 1	162.550
WX 2	162.400
WX 3	162.475
WX 4	162.425
WX 5	162.450
WX 6	162.500
WX 7	162.525

TABLE 8: NOAA Weather Radio frequencies and broadcast channels.

### NAVTEX Element of the Global Maritime Distress & Safety System

NAVTEX is a low-cost, simple, and automated means of receiving important marine information aboard ships. It is an internationally accepted medium frequency (518 kHz) direct-printing service for delivery of navigational information and meteorological warnings/forecasts to ships. NAVTEX is similar to SITOR in many aspects, however SITOR does not offer the same degree of functionality that NAVTEX does, such as avoiding repeated messages. The NAVTEX system possesses typical operating ranges of approximately 200 NM from the coast.

All NAVTEX stations in the United States are operated by the Coast Guard and provide offshore forecasts of weather conditions for the region in which the transmitter is located. TABLE 9 is a listing of NAVTEX transmitter sites and scheduled broadcast times for locations along the Atlantic & Gulf coasts along with some offshore waters in the vicinity of Puerto Rico in the Caribbean region. TABLE 9 also lists the required station identifiers needed by the NAVTEX receivers in order to obtain broadcasts.

It is recommended that all mariners in U. S. waters program their NAVTEX receivers to include subject indicator “E” in order to receive both warnings & routine weather forecasts via NAVTEX. This will decrease the possibility of missing important tropical weather information at sea.

NAVTEX STATION	STATION IDENTIFIER	WEATHER BROADCAST SCHEDULE (In UTC)
BOSTON	F	0045, 0445, 0845, 1245, 1645, 2045
PORTSMOUTH	N	0130, 0530, 0930, 1330, 1730, 2130
SAVANNAH	E	0040, 0440, 0840, 1240, 1640, 2040
MIAMI	A	0000, 0400, 0800, 1200, 1600, 2000
SAN JUAN	R	0200, 0600, 1000, 1400, 1800, 2200
NEW ORLEANS	G	0300, 0700, 1100, 1500, 1900, 2300

TABLE 9:  
NAVTEX  
stations,  
identifiers, and  
weather  
broadcast  
schedule for  
transmitter  
sites operating  
in the Atlantic  
Basin.

### INMARSAT-C SafetyNET

Inmarsat-C SafetyNET is an internationally adopted, automated satellite system for promulgating weather forecasts/warnings, marine navigational warnings, and other safety related information to all types of vessels and is part of the Global Maritime Distress and Safety System (GMDSS).

National Weather Service high seas forecasts, warnings, and tropical cyclone information (when applicable) for SafetyNET Area IV, the Atlantic Basin west of 35W Longitude and north of 7N latitude, are broadcast four times per day at 0430, 1030, 1630, and 2230 UTC.

This information is sent over the INMARSAT system of geostationary satellites with each satellite in the system transmitting on a designated channel at 1.5 GHz. Any ship sailing within the coverage area of an Inmarsat satellite is able to receive all SafetyNET messages broadcast over the appropriate channel of that satellite, so long as Inmarsat-C GMDSS equipment is programmed to the proper Metarea/Navarea (Area IV for the Western Atlantic). Additionally, Inmarsat-C equipment must also be interconnected with a GPS receiver or updated with a manually entered position at least every 12 hours or SafetyNET broadcasts for several Metareas/Navareas will be received unintentionally. Finally, the broadcast transfer technology of this system is extremely reliable ensuring a high probability of receiving messages correctly during first transmission, irrespective of the atmospheric conditions or the ship’s position within the satellite coverage.

PRODUCT	TITLE/FILE or CHART NAME	DESCRIPTION	TYPE	ISSUE TIME (UTC unless noted)	DISTRIBUTION	NOTES
Atlantic Tropical Weather Discussion	AXNT20 KNHC or MIATWDAT	Covers tropical & subtropical Atlantic discussing & describing significant synoptic weather features while tracking easterly tropical waves through the Atlantic Basin.	Text	0005, 0605, 1205, 1805	INTERNET FTP MAIL	
Atlantic Tropical Weather Outlook	ABNT20 KNHC or MIATWOAT	Covers tropical & subtropical Atlantic discussing areas of disturbed weather and their potential for development out to 48 hours.	Text	0530, 1130, 1730, 2230 Eastern Local Time	INTERNET FTP MAIL MF VOICE	Only issued from June 1 to Nov 30.
Atlantic Tropical Cyclone Forecast/ Advisory	WTNT2X KNHC or MIATCMATX where X is active storm number 1 through 5	Issued for every tropical cyclone in the Atlantic Basin. Contains forecast through 72 hours for as long as the system remains a tropical cyclone.	Text	0300, 0900, 1500, 2100	INTERNET FTP MAIL HF VOICE MF VOICE	Forecast/Advisories on subtropical cyclones will use the same WMO/AFOS headers with the actual advisory labelled SUBTROPICAL. Special Forecast/Advisories can be issued at intermediate times as conditions warrant. These will use the same header as the scheduled forecast/advisory.
Atlantic Tropical Cyclone Discussion	WTNT4X KNHC or MIATCDATX where X is the active storm number 1 through 5	Issued in conjunction with the Tropical Cyclone Forecast/Advisory to explain the forecasters reasoning behind analysis and forecast of the Tropical Cyclone.	Text	0300, 0900, 1500, 2100	INTERNET FTP MAIL	
Special Tropical Disturbance Statement	WONT41 KNHC or MIADSAAT	Issued to provide information on strong, formative, non-depression systems focusing on the major threats associated with the disturbance.	Text	As Required	INTERNET FTP MAIL	
Atlantic High Seas Forecast (North Atlantic from 7N to 67N W of 35W)	FZNT01 KWBC or NFDHSFAT1	Provides analysis & forecast information on wind & sea conditions in the region out to 48 hours. During periods with active tropical cyclones in the basin, this product will include latest initial position/intensity along with the 36, 48, & 72 hour forecast positions/intensities taken from the TCM. Tropical Cyclone position/intensity at the 12 & 24 hour forecast periods will only be included if expected to be upgraded/downgraded.	Text	0430, 1030, 1630, 2230	INTERNET FTP MAIL HF FAX WWV HF VOICE HF SITOR HF VOICE INMARSAT-C	Forecast commences at latest previous synoptic time from the time product is issued. Therefore forecasts commence at 0000, 0600, 1200, 1800 UTC. This product is the combined Atlantic, Gulf of Mexico, & Caribbean Sea forecasts. This product is directed toward the largest ocean going vessels.

TABLE 10: Summary Of Tropical Weather Products

PRODUCT	TITLE/FILE or CHART NAME	DESCRIPTION	TYPE	ISSUE TIME (UTC unless noted)	DISTRIBUTION	NOTES
Atlantic High Seas Forecast (Atlantic S of 31N W of 35W including the Gulf of Mexico & Caribbean Sea)	FZNT02 KNHC or MIAHSFAT2	Provides analysis & forecast information on wind & sea conditions in the region out to 48 hours. During periods with active tropical cyclones in the basin, this product will include latest initial position/intensity along with the 36, 48, & 72 hour forecast positions/intensities taken from the TCM. Tropical Cyclone position/intensity at the 12 & 24 hour forecast periods will only be included if expected to be upgraded/downgraded.	Text	0430, 1030, 1630, 2230	INTERNET FTP MAIL HF FAX WWV HF VOICE HF SITOR HF VOICE INMARSAT-C	Forecast commences at latest previous synoptic time from the time product is issued. Therefore forecasts commence at 0000, 0600, 1200, 1800 UTC. This product is directed toward the largest ocean going vessels.
Offshore Forecasts	FZNT21 KWBC or NFDOFFNT1 FZNT22 KWBC or NFDOFFNT2 FZNT23 KNHC or MIAOFFNT3 FZNT24 KNHC or MIAOFFNT4	Provides analysis & forecast information on wind and sea conditions to mariners operating mainly a day or more from safe harbor. 3-5 day outlook for the region is included at the end of this product.	Text	430 AM, 1030AM, 430 PM, 1030 PM Local standard time. *Remember to add 1 hour during Daylight Savings Time	INTERNET FTP MAIL HF VOICE MF VOICE NAVTEX NOAA WEATHER RADIO (In Select Locations)	There are four headers for this product depending on geographic location of forecast. New England waters are FZNT21. West Central North Atlantic are FZNT22. SW North Atlantic and Caribbean Sea is FZNT 23. Gulf of Mexico is FZNT24. Availability of this product on NOAA Weather Radio is based on transmitter availability. Contact nearest NWS Forecast Office to see if this product is transmitted via NOAA weather radio in your area.
Coastal Forecasts	VARIOUS **See Notes for further information	Provides analysis & forecast information on wind and sea conditions to Mariners operating in the near shore environment. 3-5 day outlook for the region is included at the end of this product.	Text	430 AM, 1030AM, 430 PM, 1030 PM Local standard time. *Remember to add 1 hour during Daylight Savings Time	INTERNET MF VOICE USCG VHF VOICE NOAA WEATHER RADIO	File names and product headers are determined by the National Weather Service Forecast Office issuing the product. For particular file name and header information for a particular coastal forecast contact the nearest NWS Forecast Office.

TABLE 10: Summary Of Tropical Weather Products

PRODUCT	TITLE/FILE or CHART NAME	DESCRIPTION	TYPE	ISSUE TIME (UTC unless noted)	DISTRIBUTION	NOTES
Tropical Surface Analysis	Fax Chart Name: PYEA8X where X is 6 for the 0000 UTC analysis, 7 for the 0600 UTC chart, 5 for the 1200 UTC, and 8 for the 1800 UTC	Analysis of the Atlantic Basin from 5N to 35N including the Gulf of Mexico and Caribbean Sea. These charts include current position, intensity, and motion of any active tropical cyclone in the basin when applicable. Additionally, this chart shows the trough axis of any easterly tropical wave being tracked by the Tropical Prediction Center.	Graphic	As soon as completed after the synoptic times of 0000, 0600, 1200, 1800 UTC	INTERNET FTP MAIL HF FAX	
Wind/Wave Chart	Fax Chart Name: For NOWCAST/12 HR chart file name is PYEA9X where X is: 6 for the chart valid 0000/1200 UTC, 7 for chart valid 0600/1800 UTC, 8 for chart valid 1200/0000 UTC, and 9 for chart valid 1800/0600 UTC. For 24 HR/36 HR chart file name is PWED9X where X is 8 for the chart valid 0000/1200 UTC, and 9 for chart valid 1200/0000 UTC.	Issued in 2 forms. The first is a NOWCAST/12 HR forecast issued four times daily. The second is a 24 HR/36 HR forecast issued 2 times daily. These charts include latest forecast position and intensity of any active tropical cyclone in the basin. Analyzed and forecasted combined sea heights are also found on this chart.	Graphic	For the NOW/12 HR product is issued by 0055, 0655, 1255, 1855. For the 24/36 HR product is issued by 0000, 1200.	INTERNET FTP MAIL HF FAX	
Marine Prediction Center Graphical Products	Various Chart Headers. See the BOSTON HF Fax schedule or visit the MPC web site for details on product availability.	Graphical surface analysis charts Forecast surface charts out to 96 hours Forecast 500 MB charts out to 96 hours Sea height analysis Satellite Imagery	Graphic	Various	INTERNET FTP MAIL HF FAX	Products focused on area of the Atlantic from 31N-67N including Portions of the Gulf of Mexico. Format and content of products is similar to those issued from the Tropical Prediction Center. Web Site Address for MPC: <a href="http://www.mpc.ncep.noaa.gov/">http://www.mpc.ncep.noaa.gov/</a>
Strike Probabilities	WTNT71-75 or MIASPFAT1-5	Gives the percentage chance of a tropical/subtropical cyclone passing within 75 nm to the right or within 50 nm to the left of a specified point, looking in the direction of cyclone motion.	Text	0300, 0900, 1500, 2100	INTERNET	Probabilities are given for 0-24, 24-36, 36-48, & 48-72 hours, with 0-72 hour given by adding the individual probabilities together.

TABLE 10: Summary Of Tropical Weather Products

### NWS Telephone Support

Many National Weather Service forecast offices offer recorded marine & local weather forecasts similar to those found on NOAA Weather Radio. Numbers to these recorded forecasts can usually be found by contacting the nearest coastal National Weather Service Forecast Office (NWSFO). Some recorded tropical cyclone forecast/advisories can be obtained by contacting the Tropical Prediction Center/National Hurricane Center (TPC/NHC) directly at (305) 229-4483. Further information regarding tropical cyclone forecasts/advisories can be obtained from the marine forecasters at TPC by calling (305) 229-4425/4424. However, these phone lines often become unavailable due to the high volume of calls during a tropical cyclone event and may be busy for long periods of time.

## **Chapter 4 - Guidance For Hurricane Evasion In The North Atlantic**

There is no single rule of thumb that can be used by vessel masters to ensure at least minimum safe separation from a tropical cyclone. Constant monitoring of tropical cyclone potential and a continual risk analysis when used with some fundamental guidelines are the basic recommended tools to help minimize a tropical cyclone's impact to a vessel at sea or in port. Even today, as our understanding and the predictability of tropical cyclones increases, there is still much error inherent in forecasting the movement and intensity of such complex systems. Similarly, each year, ships continue to be caught in port or at sea struggling for survival in tropical cyclones. However, the topic of this chapter is focused on minimizing the impact tropical cyclones will have on the mariner through objective analysis and recurring assessment of the tropical cyclone threat to the mariner.

With an understanding of basic tropical cyclone motion and intensity characteristics along with the ability to acquire current forecasts, advisories, and discussions, we can begin to objectively analyze the tropical cyclone threat and consider possible courses of action that could be taken to avoid these tempests.

This chapter includes discussion on risk analysis, both at sea and in port, along with some issues that must be considered by the mariner in order to make the best possible decisions regarding navigation to evade tropical cyclones. A risk analysis checklist of things to consider along with a North Atlantic Hurricane Tracking Chart are included as Appendices 1 & 2 at the end of this document in order to help the mariner monitor, evaluate, and react to the tropical cyclone threat. Finally, the decisions to sortie from port, seek shelter in port, or navigating to evade at sea remain the sole responsibility of the ship captain or vessel master. Hopefully, this guide will help those with that obligation make the right decisions and avoid damage or loss of life due to tropical cyclones.

### **Risk Analysis**

The purpose of conducting a recurring risk analysis both in port and at sea is to ensure that all possible scenarios regarding a tropical cyclone's impact to the mariner are considered in a cautious and objective manner. The number of times a mariner should do this analysis is dependent upon the tropical cyclone threat. During the tropical season, the risk analysis should be made a minimum of twice daily during inactive tropical cyclone periods. However, this risk analysis needs to be made four times daily when an active tropical cyclone is approaching or near the region where the vessel is operating or expected to operate. The four per day risk analysis coincides with the number of TCM's issued daily by NHC when a tropical cyclone is active in the basin. Therefore, the risk

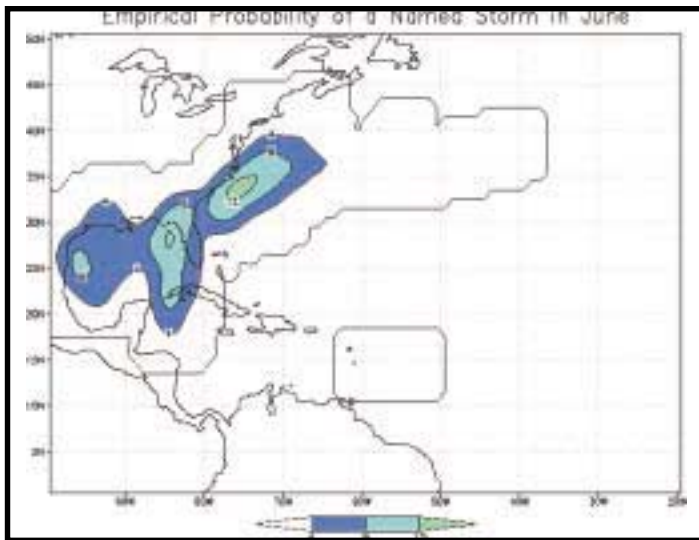


FIGURE 26a: June Probability of Named Storm within 100 NM of any point. Courtesy Kimberlain & Landsea.

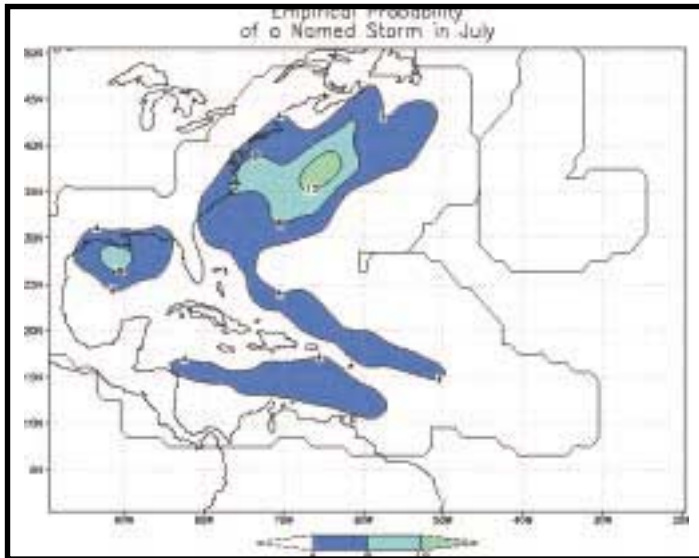


FIGURE 26b: July Probability of Named Storm within 100 NM of any point. Courtesy Kimberlain & Landsea.

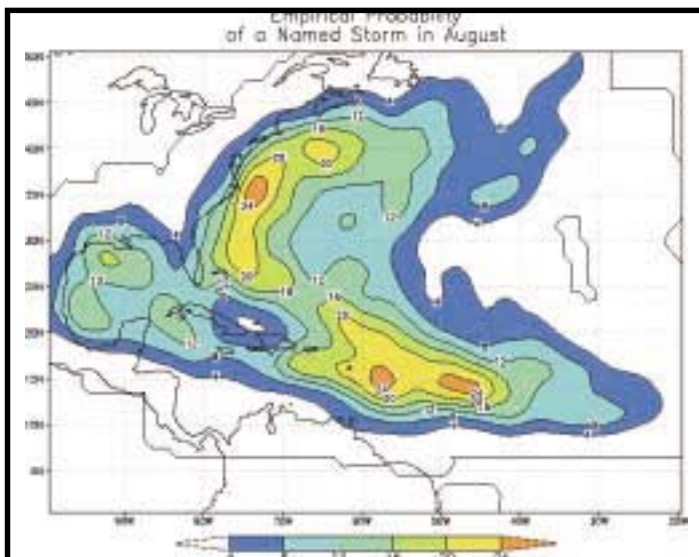


FIGURE 26c: August Probability of Named Storm within 100 NM of any point. Courtesy Kimberlain & Landsea.

analysis should be done in conjunction with these messages to help ensure that the sailor is reviewing the latest information while evaluating the tropical cyclone problem. Although the analysis can be somewhat tedious, time consuming, and slow if never before performed, the time spent conducting the risk analysis will reap a substantial return during those undesirable instances when a tropical cyclone directly threatens a vessel and it's crew. Finally, as the mariner becomes more familiar with the risk analysis, the time required to accomplish it will decrease dramatically, requiring only a few minutes and returning increased safety to vessel and sailor alike.

### History of Regional Hurricane Tracks and Intensification Factors

As was shown in chapter 2 of this guide, there are historically favored areas for tropical cyclone development in the North Atlantic Basin. Similarly, there are also climatologically favored tracks that these tropical cyclones tend to take within the Basin. Both are significant to either the vessel at sea or the ship pier side in order to begin assessing risks involved with remaining in port or getting underway during the hurricane season. Hurricane development & track history (climatology) are the first significant aids in helping the mariner to avoid tropical cyclones in the North Atlantic.

Using FIGURES 17a-f in chapter 2, the mariner can determine what months tend to be more active and where the average tracks of tropical cyclones tend to occur during each month of the season. This should alert the mariner on potential 'hot spots' in the basin throughout the tropical cyclone season.

Similarly, FIGURES 26a-f were produced by Todd Kimberlain (Colorado State

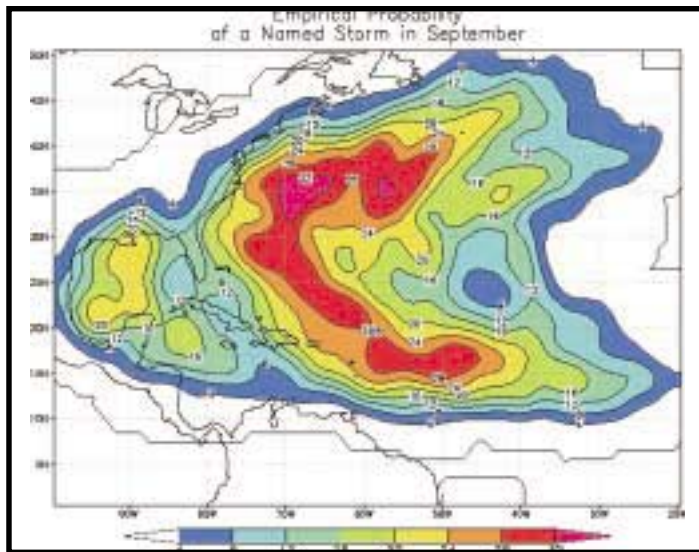


FIGURE 26d: September Probability of Named Storm within 100 NM of any point. Courtesy Kimberlain & Landsea.

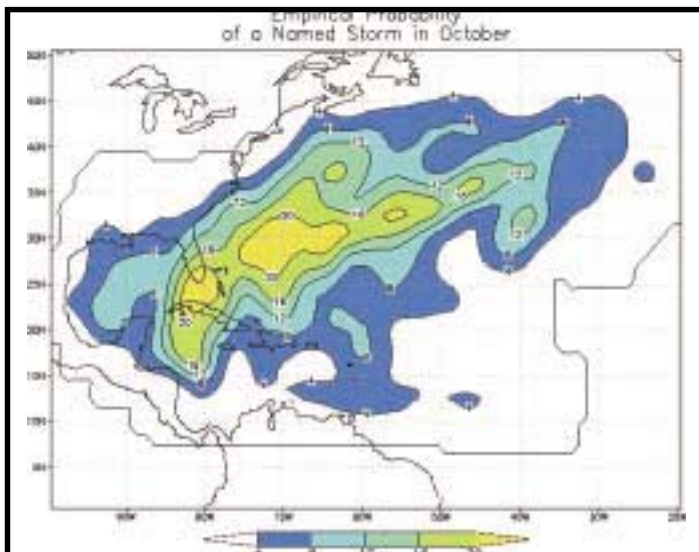


FIGURE 26e: October Probability of Named Storm within 100 NM of any point. Courtesy Kimberlain & Landsea.

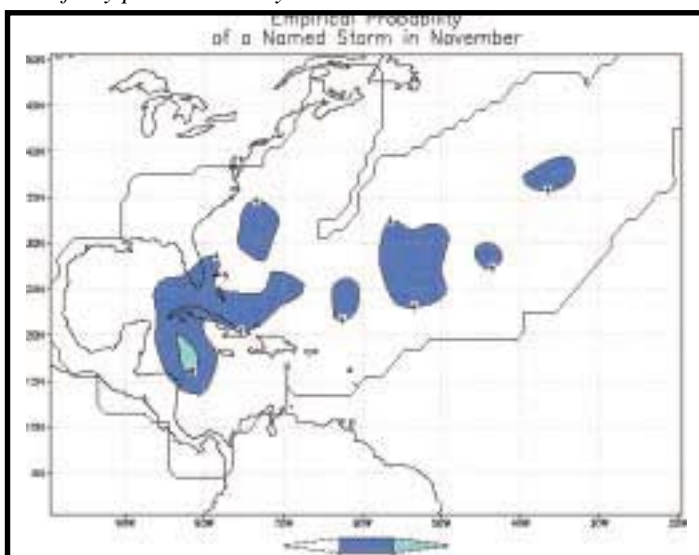


FIGURE 26f: November Probability of Named Storm within 100 NM of any point. Courtesy Kimberlain & Landsea.

University) & Dr. Christopher Landsea (NOAA/Atlantic Oceanographic and Meteorological Laboratory/Hurricane Research Division) to show for any particular location, what the chance that a tropical storm or hurricane will affect the area sometime during each individual month of the Atlantic hurricane season. For the information provided in FIGURES 26a-f, the years 1944 to 1997 were used in the analysis and counted as hits when a tropical storm or hurricane was within about 100 NM of each point in the basin.

For example, in FIGURE 26d, vessels in port New Orleans, LA would roughly have about a 20% chance (the gold yellow color) per year of experiencing a strike by a tropical storm or hurricane in the month of September. Aside from highlighting active areas throughout the basin, these charts are useful to the Mariner in determining which ports and port areas have a greater potential for tropical cyclone activity during the Atlantic hurricane season. For instance, Tampa Bay, FL has a relatively low probability (less than 12 %) that a named tropical cyclone will approach within 100 NM of that port during the month of September. Information such as this is critical for the mariner to understand and evaluate. Voyage planning and long term berthing considerations should take these factors into account if only to heighten the awareness of mariners to the potential for tropical cyclone activity in their operating areas.

#### *Impact of Ocean Currents, Eddies, and Warm Water*

Similar to the historical development areas and climatological tracks, there are also certain areas in the Basin that often support rapid intensification of tropical cyclones. Understanding the significant contribution that warm water plays in the growth of a tropical cyclone, it is easy to



appreciate that ocean regions with high sea-surface temperatures (greater than 79° F or 26° C) are often dangerous locations for the mariner to be caught in or near as a tropical cyclone threatens. Knowledge of North Atlantic sea-surface temperatures and ocean current/eddy structures are important factors to consider in the risk analysis. Areas with high sea-surface temperatures (SST) often coincide with historical instances of rapid tropical cyclone intensification.

In the North Atlantic Basin, the two most prominent areas to possess this potential danger are the Gulf of Mexico and the Gulf Stream. Both of these areas contain an abundant depth of warm water, capable of fueling sudden and sustained rapid intensification in tropical cyclones. In instances of otherwise neutral conditions for hurricane growth, the extremely warm ocean waters in these areas can often accentuate intensification and even rapid intensification of tropical cyclones. Mariners operating in these regions need to pay particularly close attention to tropical waves, disturbances, or other synoptic scale mechanisms that can initiate the tropical cyclone intensification process and quickly place a vessel in harm's way.

Aside from the effects of sea-surface temperature, an additional negative impact that Gulf Stream and tropical cyclone interaction can place on a vessel is enhanced sea states in the vicinity of the current. Similar to the often written about 'North Wall' events that routinely hazard vessels off the coast of Cape Hatteras during the winter season, winds of tropical storm or hurricane force opposing an ocean current can quickly create very steep, short period waves making navigation through these areas a difficult proposition at best. It is important that the mariner is aware of the location of the current so that it can be factored into any prospective course considerations to evade a tropical cyclone in the Western Atlantic.

Sea-surface temperature and Gulf Stream analyses are available from some of the internet sites listed in this manual. Most of these charts graphically depict the most recent location of the Gulf Stream and warm ocean eddies along with actual sea-surface temperatures for portions of the Western Atlantic. As part of the risk analysis these charts should be consulted at least every 3-4 days in order to evaluate the latest Gulf Stream position and SST's throughout the basin. This knowledge can then be applied to the risk analysis for tropical cyclone avoidance.

### *Predictability of Tropical Cyclone Motion and Intensity*

This is the second major factor involved in the mariner's recurring tropical cyclone risk analysis. As discussed earlier in this manual, tropical cyclone motion and intensity can often be very unpredictable. Even today with the arrival of super high-speed computers and complex numerical hurricane forecast models, fairly significant errors can still be found in track and intensity forecasts of tropical cyclones.

Generally speaking, the smallest errors associated with hurricane track forecasts occur while a system is moving in a general west to west-northwest track, south of the Atlantic subtropical ridge. Conversely, the largest errors involved with hurricane forecast tracks tend to occur during recurvature and beyond as systems first slow as they begin to recurve, then typically accelerate northeast into the central North Atlantic. Similarly, increased uncertainty in track forecasting often occurs when a system is in an area of little to no environmental steering. This latter uncertainty tends to occur most often in the Western Caribbean Sea and the Gulf of Mexico, however, it has even been seen with tropical cyclones as far as 35-40 degrees North latitude in the Atlantic. Errors associated with intensity forecasting can be quite large through the 72-hour forecast period in the TCM. FIGURE 27 is a graph displaying the recent average intensity errors associated with

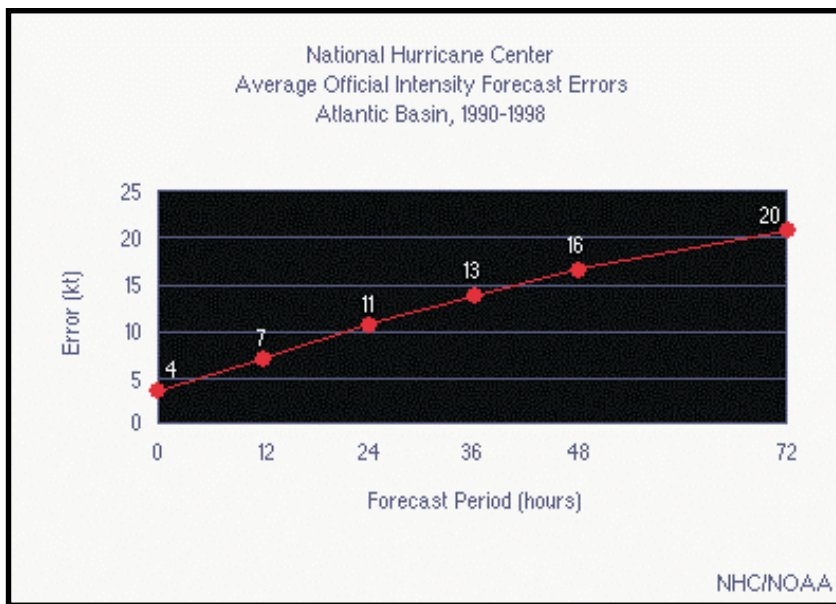


FIGURE 27: Chart displaying the average official intensity forecast errors for tropical cyclones in the Atlantic Basin from 1990-1998. Note that during this period, forecasts of tropical cyclone intensity 72 hours into the future on average differed from the actual intensity of the tropical cyclone by approximately 20 KT. That alone could be a significant factor in under forecasting the radius of 34 KT winds in a tropical cyclone.

Atlantic Basin tropical cyclones. These errors are often further accentuated by the fact that a poor forecast of intensity normally results in an even worse forecast of the radius of tropical storm force winds associated with the tropical cyclone. Additionally, unlike tropical cyclone track forecasting, very few operational computer models exist for the purpose for determining forecasts of tropical cyclone intensity & the radius of tropical storm force winds. Therefore, the forecaster is left with very little guidance to utilize in predicting the strength of these systems.

Understanding the inherent forecast errors in predicting tropical cyclone tracks and intensities are critical to the mariner. Factors regarding track and intensity error must be considered together every time the mariner begins to contemplate decisions on tropical cyclone avoidance. Similarly, knowledge of these errors provides further testimony for the need to monitor the latest tropical cyclone forecast information in order to refine those decisions on hurricane evasion. Safety of life and property at sea in the vicinity of these systems requires an understanding of, and a respect for, the forecast errors in order to minimize the potential impacts of a tropical cyclone on a ship.

### 34 KT Rule

For vessels at sea, avoiding the 34 KT wind field of a tropical cyclone is paramount. Any ship in the vicinity of a tropical cyclone should make every effort to remain clear of the maximum radius of analyzed or forecast 34 KT winds associated with the tropical cyclone. Knowing that the area of 34 KT around tropical cyclones is rarely symmetric but instead varies within semi-circles or quadrants is important. Understanding that each tropical storm or hurricane has its own unique 34 KT wind field are necessary factors to account for when attempting to remain clear of this dangerous area around a tropical cyclone. NHC forecasts attempt to define the structure of this wind field and use of the latest TCM in determining the maximum radius of 34 KT winds is necessary when trying to avoid this dangerous threshold.

Winds of 34 KT are chosen as the critical value because as wind speed doubles, the force it generates increases approximately by a factor of four. When 34 KT is reached, sea state development approaches critical levels that result in rapidly decreasing limits to ship maneuverability. The result of this decreased maneuverability is a greater restriction on subsequent ship course and speed options then available to clear the tropical cyclone.

It should also be noted at this point, that the state of the sea outside of the radius of 34 KT winds in a tropical cyclone can also be significant enough as to limit course & speed options near a tropical cyclone. Impacts of sea height on maneuverability of a ship outside of the 34 KT radius is dependent on a number of factors including crew experience level, ship characteristics (Displacement, Anti-Roll Devices, Length/Beam Ratio, Propulsion System, etc...), and wave characteristics in the vicinity of the vessel. Only the ship's captain and crew can determine what sea state can be safely handled so as not to degrade maneuverability in the worse case scenario where rapid course and speed changes are required to ensure minimum safe separation from a tropical cyclone.

### 1-2-3 Rule

The single most important aid in accounting for tropical cyclone forecast track error is the 1-2-3 rule. It should be understood and used by all Mariners when an active tropical system is found in the North Atlantic. The 1-2-3 rule is derived from the latest 10-year average forecast errors associated with tropical cyclones in the North Atlantic. TABLE 11 shows the National Hurricane Center's average initial position & track forecast errors over ten year periods from 1960 through 1999. It can be seen from this table that during the last 40 years, tropical cyclone track forecasts have gotten better within the basin. There are still, however, some rather large errors particularly at the 48 and 72-hour periods. Using the latest ten-year average from 1990-1999, the 1-2-3 rule attempts to account for some of the inherent track forecast uncertainty associated with tropical cyclones. Application of the 1-2-3 rule requires a few pieces of information from the latest TCM along with a few other details that are easily derived from information within the TCM. Current position forecasts through 72 hours along with the maximum radii of 34 KT winds at the 24 & 36 hour forecast positions must be known. Additionally, the maximum radius of 50 KT winds at the 36, 48 and 72 hour forecast times are also required to complete the simple calculations used in constructing the 1-2-3 rule.

At the present time, NHC forecasts for tropical cyclones do not attempt to define the extent of 34 KT winds at the 48 and 72 hour forecast times. This is due to the extremely limited skill in forecasting tropical cyclone intensity and wind radii beyond 36 hours. However, the mariners focus is on avoiding the 34 KT winds in a tropical cyclone. Therefore in order to construct a danger area, or "line in the sea" to gauge navigation options, 2 and 3 day estimates of maximum 34 KT wind radii must be computed by the sailor and subsequently applied to the 1-2-3 rule.

10 YEAR TIME PERIOD	AVERAGE 0 HR POSITION ERROR (NM)	AVERAGE 24 HR FORECAST POSITION ERROR (NM)	AVERAGE 48 HR FORECAST POSITION ERROR (NM) *	AVERAGE 72 HR FORECAST POSITION ERROR (NM) **
1960-1969	--	119	259	416
1970-1979	--	116	252	384
1980-1989	17	111	226	345
1990-1999	12	85	158	234
1-2-3 RULE	0	100	200	300

TABLE 11: National Hurricane Center 10 year average initial position & forecast errors for North Atlantic Tropical Cyclones & the relationship to the 1-2-3 Rule. \*Beginning in 1961. \*\*Beginning in 1964

In order to obtain an estimation of the maximum 34 KT wind radii at 48 and 72 hours, a simple calculation based on the percent change of the 50 KT wind radii from the 36 hour forecast to the 72-hour forecast is applied. For instance, assume that a tropical cyclone's forecast 50 KT wind radii at 36 hours is 50 NM while the 34 KT wind radii at the same time is 100 NM. At the 48-hour forecast, the 50 KT wind radii was increased to 75 NM. With this information, a rough approximation of the maximum 34 KT wind radii at the 48 hour time period can be calculated using the following simple formula:

$$34KT^{Estimate} = \frac{50KT^{Forecast}}{50KT^{36HR}} \times 34KT^{36HR}$$

Where:

$34KT^{Estimate}$  = Approximation of maximum 34 KT wind radius at either 48 or 72 hours.

$50KT^{Forecast}$  = Value given in TCM for maximum radius of 50 KT winds at either the 48 or 72 hour forecast time. Using the value given in the 48-hour forecast will yield a maximum radius of 34 KT winds at 48-hours. Similarly, using the 72-hour value for the maximum radius of 50 KT winds will result in an estimate of the maximum 34 KT radius at 72 hours.

$50KT^{36HR}$  = Value given in TCM for maximum radius of 50 KT winds given in the 36-hour forecast from the TCM.

$34KT^{36HR}$  = Value given in TCM for maximum radius of 34 KT winds given in the 36-hour forecast from the TCM.

Using the equation above, an estimate of the 34 KT wind radii at 48 hours can be made.

$$34KT^{Estimate} = \frac{75}{50} \times 100 = 150NM$$

Therefore the mariner would use the value of 150 NM as the maximum radius of 34 KT at the 48-hour forecast position. FIGURE 28 on the following page shows two more examples of this method for obtaining estimated maximum 34 KT wind radii. In cases where the calculation results in values less than 30 NM, mariners should always round up to a minimum value of 30 NM to provide a slight safety margin. Additionally, this minimum value of 30 NM helps account for the likely intensity errors that often result in long range forecasts of tropical cyclones.

The need to continually review the latest forecast guidance in the TCM should become readily apparent as estimations for the maximum 34 KT wind radii are not necessarily precise. Due to the inability of accurate tropical cyclone intensity forecasting coupled once again with the unpredictable nature of these beasts, it is imperative that the mariner continues to monitor the TCM every six hours in order to review and incorporate changes of track and intensity into the avoidance plan.

<p><b>Hurricane Cindy Advisory # 43</b> 1500 UTC August 29 1999</p> <p>36 Hour Forecast: Max Wind 70 KT Gusts 85 KT 50 KT...150NE 150SE 80SW 80NW 34 KT...250NE 250SE 150SW 150NW</p> <p>48 Hour Forecast: Max Wind 60 KT Gusts 75 KT 50 KT...140NE 140SE 75SW 75NW</p> <p>72 Hour Forecast: Max Wind 40 KT Gusts 50 KT</p>	<p><b>Tropical Storm Floyd Advisory # 3</b> 0900 UTC September 8 1999</p> <p>36 Hour Forecast: Max Wind 65 KT Gusts 80 KT 50 KT... 40NE 40SE 40SW 40NW 34 KT...100NE 75SE 75SW 100NW</p> <p>48 Hour Forecast: Max Wind 75 KT Gusts 90 KT 50 KT... 60NE 40SE 40SW 60NW</p> <p>72 Hour Forecast: Max Wind 90 KT Gusts 110 KT 50 KT... 75NE 75SE 75SW 75NW</p>
<p><b>Calculating for the approximate Maximum Radius of 34 KT winds at 48 &amp; 72 Hours:</b></p> <p>48 Hr Estimate= <math>(140/150) \times 250 = 233</math> Round Up to 235 NM</p> <p>72 Hr Estimate= <math>(0/150) \times 250 = 0</math> Use 30 NM as minimum radius in cases such as this</p>	<p><b>Calculating for the approximate Maximum Radius of 34 KT winds at 48 &amp; 72 Hours:</b></p> <p>48 Hr Estimate = <math>(60/40) \times 100 = 150</math> Use 150 NM</p> <p>72 Hr Estimate = <math>(75/40) \times 100 = 188</math> Round Up to 190 NM</p>

**FIGURE 28:**  
*Two examples of calculations for determining an estimated radius of 34 KT winds for the 48 and 72 hour forecasts of position, intensity, and maximum radius of 50 KT winds given in the TCM.*

In possession of all the necessary inputs, the mariner can begin to construct the danger area of the tropical cyclone using the 1-2-3 rule in the following process.

1. Plot the current and forecast tropical cyclone positions taken from the latest TCM.
2. Find the maximum radius of 34 KT winds at the current and each forecast time period of the TCM out to 72 hours.

For example, the radii of 34 KT winds given for the 24 hour forecast position in the latest TCM are:

34 KT...175NE 150SE 150SW 150NW

Therefore, the maximum radius of 34 KT winds associated with the tropical cyclone at its 24-hour forecast position is 175 NM.

3. Next apply the 1-2-3 rule to each of the radii at the 24, 48, and 72 hour forecast positions.

At the 24-hour forecast position (1 day): add 100 NM to the maximum radius of 34 KT winds found in the 24 hours forecast of step two.

>>> 175 NM (Forecast radius of 34 KT) + 100 NM = 275 NM

At the 48-hour forecast position (2 days): add 200 NM to the maximum radius of 34 KT winds found in the 48 hour forecast of step two.

At the 72-hour forecast position (3 days): add 300 NM to the maximum radius of 34 KT winds found in the 72 hour forecast of step two.

4. Now draw a circle around the 24, 48, and 72 hour forecast positions of the tropical cyclone using the radii found in step 3.
5. Connect a line tangent to each circle constructed in step 4. The area enclosed by these tangent lines is known as the danger area of the tropical cyclone and must be avoided as a vessel attempts to navigate in the vicinity of the tropical cyclone. FIGURE 29 is a graphical illustration of the 1-2-3 rule.

**Note of caution.** This rule establishes a minimum recommended distance to maintain from a tropical cyclone in the Atlantic Basin. Larger buffer zones can and should be established in situations of tropical cyclones with large forecast uncertainty, limited crew experience, decreased vessel handling, or other factors as determined by the vessel master. The 1-2-3 rule does not account for sudden & rapid intensification of tropical cyclones that could result in a rapid outward expansion of the 34 KT wind field. Also, the 1-2-3 rule does not account for the typical outward expansion of the wind field as a system transitions from tropical cyclone to extratropical gale or storm in the North Atlantic. Finally, mariners should not equate the radius of 34 KT winds with the area of 12-foot seas in the vicinity of a tropical cyclone. The 1-2-3 rule relies solely on avoiding the radius of 34 KT winds in a tropical cyclone and does not take sea heights into consideration. Vessels with lower sea keeping limits should also make adjustments to the 1-2-3 rule in order to minimize exposure to seas that will dangerously hamper ship stability and maneuverability. The radius of **current** 12-foot seas is issued in the TCM and can serve as a gauge for vessels with lower sea keeping limits in order to remain clear of potentially damaging higher seas. Further guidance on forecasted seas in excess of 12 feet in the vicinity of any active tropical cyclone is available in the Atlantic High Seas Forecasts issued by TPC and MPC.

## Diagram of the 1-2-3 Rule

The danger area to avoid is the area inscribed by the connecting tangent lines of the outer most radius of 34 knot winds plus a safety margin derived from the ten year average Atlantic tropical cyclone position errors at the 24, 48, and 72 hour forecast positions. Adding 100 NM at 24 hour forecast, 200 NM at 48 our forecast, and 300 NM at the 72 hour forecast positions.

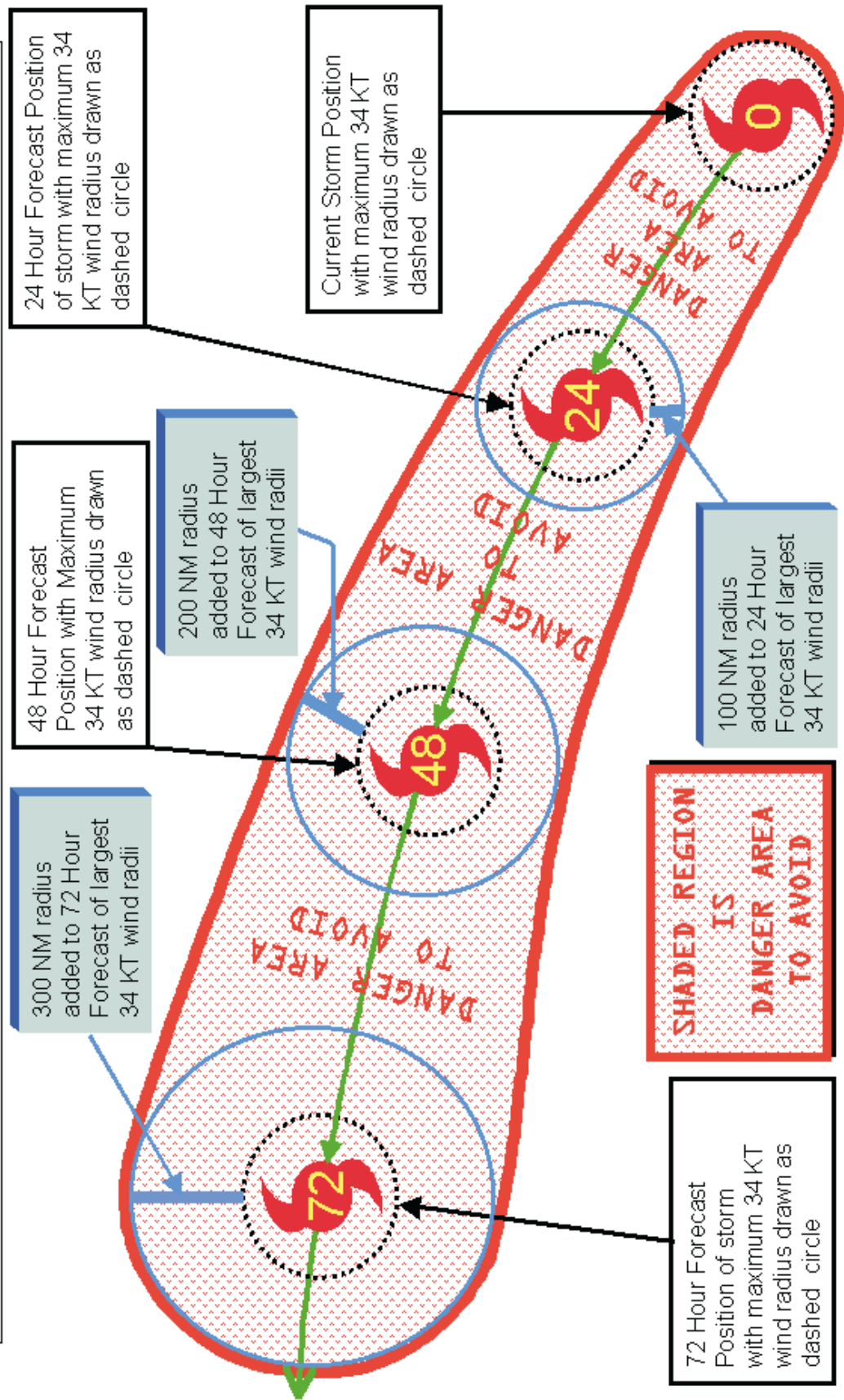


FIGURE 29: Diagram of the 1-2-3 Rule used to construct the MINIMUM DANGER AREA TO AVOID in attempting to navigate around tropical cyclones in the North Atlantic Basin.

### *Ship Versus Tropical Cyclone Track Analysis*

In the dynamic state of moving ships and tropical cyclones, recurring comparison of the tropical cyclone track versus projected ship track is mandatory. This combined with continual monitoring of the latest official NHC forecasts can greatly increase the mariner's confidence with respect to vessel safety and the future movement of the tropical cyclone.

In the process of continual comparison between vessel & tropical cyclone forecast track, it is necessary to analyze and assess the ever-changing evasion options available to the mariner. Any deliberations over evasion or escape routing must also include the options to use in worst case situations where the tropical cyclone approaches the vessels projected track. At the same time, this review of forecast ship and tropical cyclone tracks may also show some slowly evolving tendencies in the tropical cyclone that are likely to go unnoticed in a single glance.

### *Never Cross The "T"*

In track analysis, never plan to cross the track (cross the "T") of a tropical cyclone in the Atlantic. This is done out of respect for the detrimental effects that heavy weather places on vessel speed & handling. Additionally, sudden accelerations in tropical cyclone motion can ultimately place a vessel in conditions not originally expected or anticipated when setting course or speed to cross the "T". Making adjustments to course and speed in order to remain outside the danger area of the tropical cyclone are the most prudent navigation decisions a mariner can make in order to remain somewhat secure from the tropical cyclone threat.

Similarly, an understanding of climatological tropical cyclone tracks should also give the mariner a better perspective on avoidance decisions beyond the 72-hour forecast provided in the TCM. For instance, it is known that tropical cyclones will tend to accelerate as they recurve to the NE in the Atlantic basin. Knowing this fact, one may be extremely skeptical of transiting between Bermuda and Mid-Atlantic coast of the United States as a tropical cyclone approaches the southeast United States with a forecast track that is showing indications of recurvature at the 36 & 48 hour forecast position. Knowing the regions of "typical" tropical cyclone recurvature and the fact that systems tend to accelerate upon recurvature should alert the mariner to any potential course options that may cause the vessel to cross the "T" beyond the 72-hour forecast time.

### *Forecast Track Tendencies*

A comparison of the most recent NHC forecast track with NHC forecast tracks from the past 24 hours can sometimes prove useful in determining a trend in the forecasted motion of a tropical cyclone. For instance, a comparison of NHC forecast tracks issued every six hours over the last 24 hours, may show a noticeable shift to the right or left (with respect to storm motion) of the forecast over the 24 hour period. Using this information, a mariner operating in the vicinity of this system may want to consider increasing the buffer zone between vessel and tropical cyclone in that semi-circle of the track to where the forecast is tending. This technique can sometimes be extremely valuable in helping the mariner plan ship course & speed for tropical avoidance, particularly in the 2-3 day forecast range and beyond.

This technique should never be used to decrease the distance of minimum safe separation between ship and tropical cyclone as discussed in the 34 KT and 1-2-3 rules. Instead, the focus of this technique is to highlight that region which may later come into the tropical cyclone danger area as the forecast and actual track of the system shifts over time.



FIGURE 30 is an example of a forecast track analysis for Hurricane Mitch (1998) in the Caribbean Sea. Plotting the forecast tracks of Mitch over the 24 hour period from 1500 UTC 24 October to 1500 UTC 25 October shows a very slight shift left in the forecast track of Mitch over the first 12 hours with an even larger shift left during the later plotted forecasts. Similarly, the continual plotting of the tropical cyclone over the 24-hour period also shows that each initial fix location of the hurricane was southwest of the expected position from previous forecast track. This continual bias to the southwest of the forecast track remained until advisory 16 when the tropical cyclone's position was actually slightly north of the expected position based on the previous forecast track. Use of this information should alert the mariner that areas south of the forecast track and beyond the normal danger area of the 1-2-3 rule may fall into the danger area as Mitch moves West. A likely conclusion reached in this forecast track analysis would be to increase the danger area over the southern portion of the forecast track.

It is important to realize that forecast track analysis does not always provide information as clear cut and valuable as that illustrated above. However, when done consistently during the course of a tropical cyclone's life cycle in the Atlantic, it may help provide the mariner with some additional information that could help to determine subsequent course and speed options to ensure minimum safe separation from the tropical cyclone.

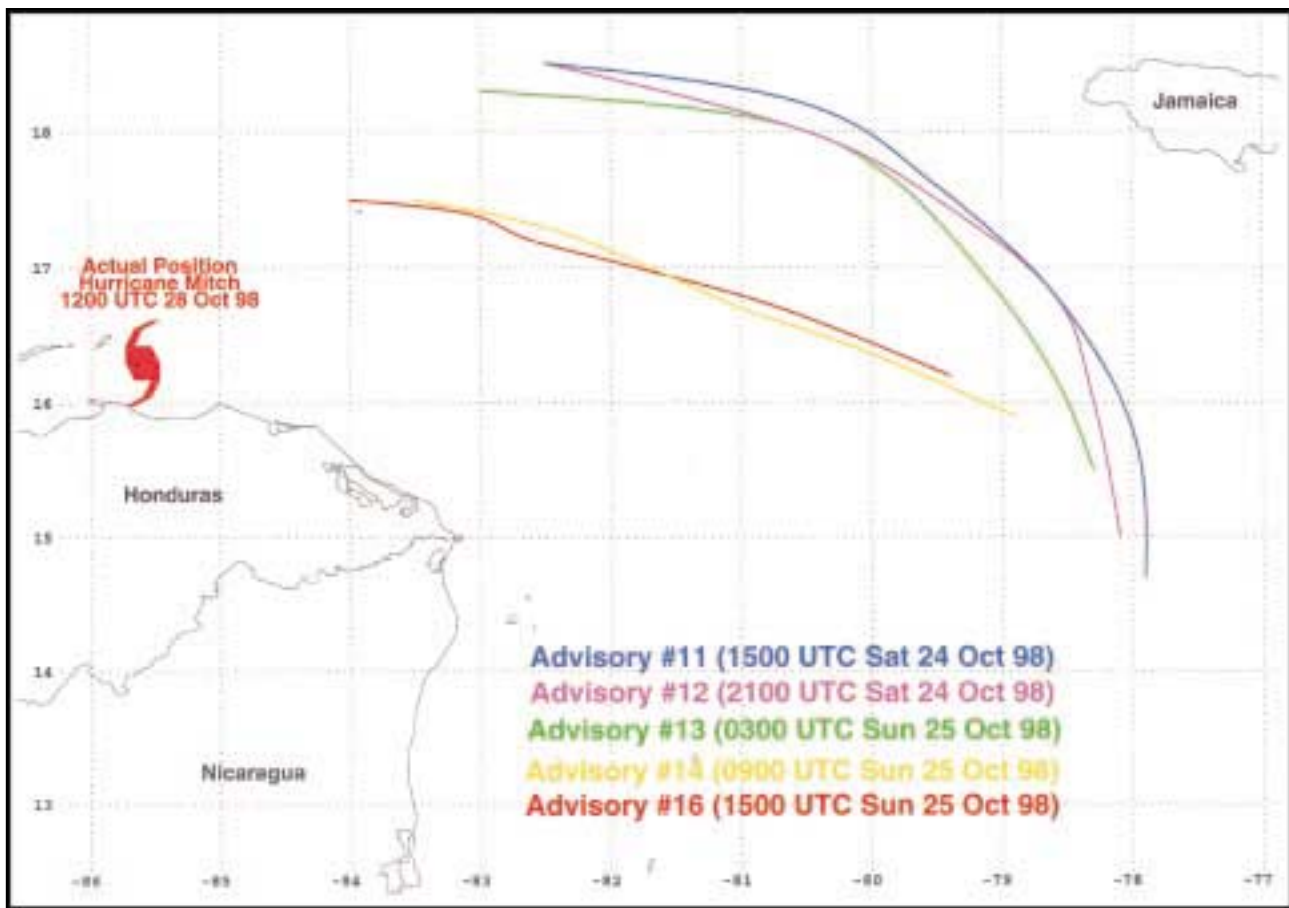


FIGURE 30: Forecast track analysis for Hurricane Mitch (98). Advisories 11, 12, 13, 14, and 16 are plotted together to show any trends in the forecast track of Mitch. The leftward shift of the forecast track over the 24 hour time period shown should have cautioned the mariner to include an additional buffer zone left of track when plotting for the 1-2-3 rule. Not plotted in the image above, Advisory 15 was an intermediate advisory issued by NHC to establish a hurricane watch for the Cayman Islands at 1200 UTC on Sun Oct 25. With a forecast track identical to Advisory 14, it was omitted from this graphic for clarity.

### *Calculating Closest Point of Approach (CPA)*

A final evaluation of ship track versus tropical cyclone track is accomplished by calculating CPA. After plotting the latest NHC tropical cyclone forecast track, calculating for the 1-2-3 rule and establishing any additional buffer from the storm that may be dictated, the last item to complete in the at-sea risk analysis is comparison of CPA between current and possible evasion options. Increases in CPA between vessel and tropical cyclone based on current navigation decisions should help to increase the mariner's confidence that those decisions remain effective in keeping clear of the tropical cyclone. However, decreases in CPA with the tropical cyclone should be dealt with using the utmost urgency. An immediate review of all evasion options combined with a further look into the latest official forecasts and discussions needs to be accomplished with the goal of establishing a new evasion course and speed option to once again increase CPA from the tropical cyclone.

### *Assessing Options*

Mariners must be cautioned never to leave themselves with only a single navigation option when attempting to avoid a tropical cyclone in the Atlantic. Sea room to maneuver is not too significant a factor in the wide open waters of the North Atlantic, but can become an extremely significant consideration when operating in the confined waters of the Western Caribbean Sea and Gulf of Mexico. More often than not, EARLY DECISIONS TO LEAVE RESTRICTED MANUEVER AREAS ARE THE MOST SENSIBLE CHOICE. Also, at the very least, evasion considerations should include safe hurricane havens and sheltered waters when operating in either of these regions.

### **Port Specific Risk Analysis Considerations**

Vessels seeking shelter in port or considering movement toward or away from port need to consider all the factors discussed above. Additionally, mariners in these situations must also acknowledge other factors to finalize their risk analysis for tropical cyclone avoidance.

### *Tropical Cyclone Approach To Port*

Aside from the inherent forecast difficulties discussed in the predictability of tropical cyclone motion and intensity above, mariners must also consider some other factors regarding tropical cyclone track forecasts and relationships to port facilities. In general, tropical cyclones forecast to make a perpendicular landfall tend to have the smallest amount of track forecast error. Conversely, systems that are forecast to parallel the coast, as is often noted in the Mid-Atlantic region of the United States, tend to have larger track errors similar to those experienced when a system recurves in the basin.

Additionally, tropical cyclones that make landfall within 50-100 NM of a particular port tend to be more destructive than those that approach the port from overland or parallel the coast in the vicinity of the port. Also, ports located in the right front quadrant (based on direction of movement) of tropical cyclones during landfall tend to have higher winds, seas, storm surge, and a greater potential of tornadic activity as these systems close the coast. FIGURE 31 on the following page graphically illustrates these points.

### *Go & No Go Decisions To Leave Port*

The decision to leave port for tropical cyclone avoidance must be made very early. Throughout the recurring risk analysis, consideration to the latest possible safe departure time and likely avoidance routes must be balanced with a number of other factors. One of the most important of these factors is time versus distance. The risk of damage to a vessel at sea increases as the speed of advance of

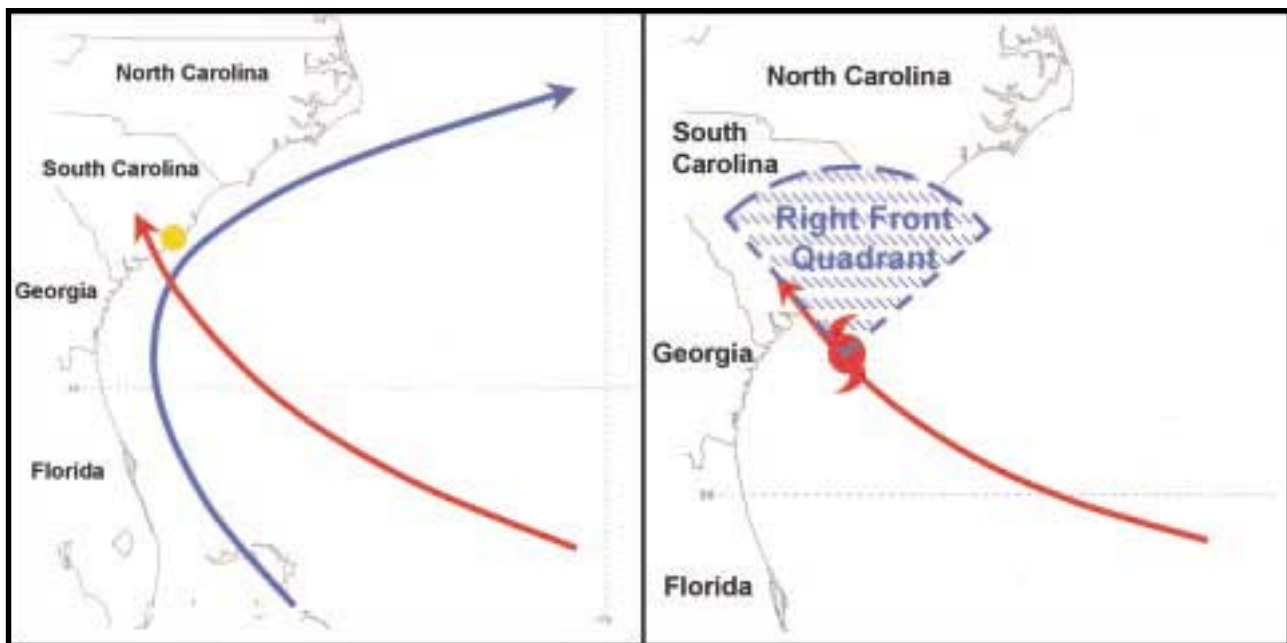


FIGURE 31: Image on left shows 2 forecast tracks for a tropical cyclone along the SE coast of the United States. In general, the *red track* (perpendicular approach to the coast) will tend to have smaller forecast track errors than will the *blue track* (parallel track along the coast). The gold circle in the image to the left denotes the port region of Charleston. A tropical cyclone approaching the Charleston area along the red track will tend to be more destructive to vessels in Charleston than would a tropical cyclone moving along the blue track. This is because a system moving along the red track would have its' right front quadrant crossing over Charleston, as shown in the image to the right.

the tropical cyclone increases towards the maximum safe speed of the vessel attempting to leave port in advance of a tropical cyclone. This is as much true with a vessel already at sea attempting to avoid a tropical cyclone as it is with a ship deciding to leave port in an attempt to ride out a tropical cyclone at sea. When reviewing these time and distance considerations, mariners must include the effects that “squally weather” associated with the outer rainbands in a tropical cyclone will have on underway preparations and movement from port to sea. Similarly, building wind and sea conditions found at sea and ahead of the tropical cyclone can also hamper speed & maneuverability of any vessels attempting to evade a tropical cyclone.

Recognizing these time/distance problems, it cannot be emphasized enough that early decisions to leave port in attempt to avoid tropical cyclones are extremely important. There have been a number of recorded instances where vessels have made the right decision to sortie from port in attempts to avoid tropical cyclones, yet were still either damaged or lost because that decision to leave came too late.

### Berthing & Shelter Requirements

Considerations to remain in port during the passage of a tropical cyclone must begin with an evaluation of the amount of protection that will be afforded in a specific location during the tropical cyclone's passage. Understanding the track, intensity, and impacts of the tropical cyclone as it moves through the region should help the mariner in making that decision. Evaluation of the direction from which the strongest winds are forecast to blow along with the potential for storm surge should be looked at by the mariner when deciding whether to seek haven pier side, at anchorage, or further inland to more protected anchorages.

For instance, depending on the direction of approach that the tropical system may take with respect

to a specific port, storm surge can pose a significant problem to a vessel tied pier side. Substantial rises in water level accompanying the storm surge may place a vessel, previously in a protected wind/wave regime, into an area exposed to significantly greater winds and waves. Similarly, many port and dock facilities, particularly in the Caribbean region are fixed. Although sufficient to support the normally small tidal range observed in the region, they can quickly become submerged when exposed to even minimal tropical cyclone related storm surge. Additionally, attention to the tying of lines is also of considerable importance. This is because the force on a moored vessel will nearly double for every 15 knots of wind from tropical storm force (34 KT) to hurricane force (64 KT) with a slightly smaller increase beyond hurricane force. Therefore, a vessel tied to the pier under normal situations can quickly break from that pier during periods of higher sustained winds and gusts causing substantial damage to it and the other vessels nearby as a tropical cyclone passes.

Evaluation of hurricane havens is extremely important in those situations where the mariner decides the best course of action is to remain in port during the passage of a tropical cyclone. The United States Navy continually evaluates some of the major deep-water ports in the Atlantic for their susceptibility and survivability during a tropical cyclone. The manual, entitled “Hurricane Havens Handbook for the North Atlantic Ocean” (NAVENVPREDRSCHFAC TECHNICAL REPORT TR 82-03) is available to the public and should be required reading for any mariner needing to make hurricane avoidance or hurricane haven decisions. This manual is also available on the World Wide Web at the following web site.

<https://www.cnmoc.navy.mil/nmosw/tr8203nc/0start.htm>

Although this manual may not include the actual port considered by a mariner when seeking weather haven, it does highlight some of the concepts needed in making decisions to seek haven or sortie from port during a tropical cyclone event.

### **Caught At Sea: Navigating To Clear The Tropical Cyclone**

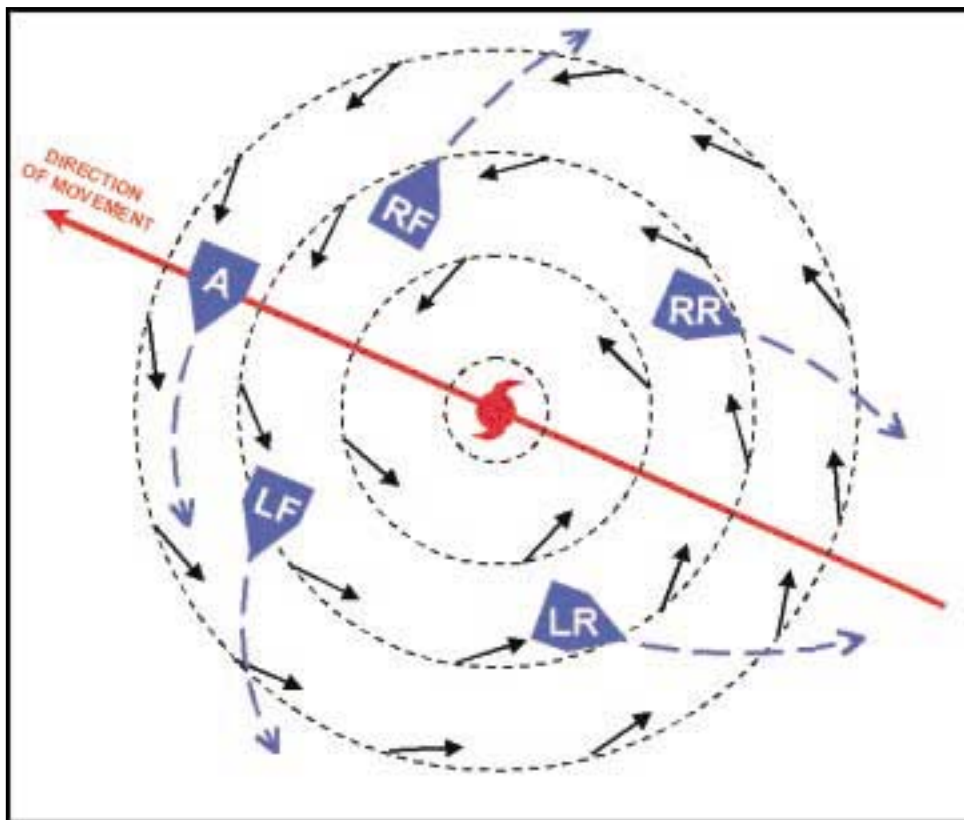
Unfortunately, any manual of this type would be incomplete without a discussion on what to do when either the risk analysis fails or the mariner is caught unaware at sea in the vicinity of a tropical cyclone. Hopefully, with the aid of this manual, the prospects of closely encountering a tropical cyclone will be lessened. However, if there is one thing to be taken away from this text, it is that knowledge and preparation are the keys to safely remaining clear of the tropical cyclone threat. Therefore, this information is included with the hope that it will never be required, but still should be known by the mariner.

The guidelines for maneuvering to clear a tropical cyclone are based on knowing the location of the system center and the speed and direction of movement for the tropical cyclone. Latest advisories from NHC should be sought out immediately, as these messages give the information required to navigate clear of the tropical cyclone. If these messages are unavailable, then local observations discussed below and in chapter 1 of the manual should help in gathering the requisite knowledge needed to plan the “escape route”.

Changes in wind direction and speed along with changes to shipboard barometric pressure are the fundamental guides to locating a vessel within the tropical cyclone’s circulation. Winds veering over time indicate that the ship is in the right semi-circle (with respect to tropical cyclone motion) of the system. Conversely, backing winds over time indicate that a vessel is in the left semi-circle of a

system. If wind direction remains steady but continues increasing in speed, a vessel is likely located ahead of the tropical cyclone. Additionally, in those instances where a vessel is caught ahead of a tropical cyclone, the barometric pressure will also continue to fall, in some cases quite rapidly as the system center moves closer. Alternatively, winds that remain steady in direction but decrease in speed are a good indication that the vessel is located to the rear of the tropical cyclone along its track. Another indication of this is a steady rise in barometric pressure. Once the location of the vessel with respect to the center of the tropical cyclone is known, the mariner can begin to make course adjustments to clear.

If the vessel is found to be located in the right semi-circle of the tropical cyclone, put the wind at  $045^\circ$  on the starboard side while attempting to make best speed to clear the tropical cyclone. Vessels caught ahead of a tropical cyclone should steer best course and speed attempting to place the wind at  $160^\circ$  on the starboard quarter of the vessel until the ship is well into the left semicircle of the system. For ships located in the left semi-circle of the system, place the wind at  $135^\circ$  on the starboard quarter, making best speed to clear the tropical cyclone. Finally, for ships found to the rear of a tropical cyclone, choose best course and speed that will increase distance from the vessel to the tropical cyclone. It is important to emphasize at this point that the wave action accompanying a tropical cyclone is often fairly complex, confused and dangerous with as many as three distinct wave patterns prevalent at any given time. This is particularly true in the right rear quadrant (with respect to direction of motion) of the tropical cyclone. A constant struggle between maintaining appropriate course requirements without losing speed and vessel stability often becomes an epic battle between mariner and Mother Nature. At this point, remaining as near to evasion course requirements while attempting to maintain ship stability and maneuverability is the only available option. FIGURE 32 below and TABLE 12 on the next page summarize required navigation to clear a tropical cyclone when caught near to its center of circulation.



*FIGURE 32: Vessel at A: put wind at  $160^\circ$  relative to the ship on the starboard side making best course and speed into the left semi-circle of the system. Vessel at RF and RR: put the wind at  $045^\circ$  relative to the ship on the starboard side attempting to make best course & speed to clear the system. NOTE: Wind and seas in the area of RF and RR may result in drastically reduced forward speeds of a ship attempting to open from the tropical cyclone. Vessel at LF & LR: put the wind at  $135^\circ$  relative to the ship on the starboard side making best course and speed to increase separation between ship and tropical cyclone.*

Vessel Location	Navigation Action
Ahead Of Tropical Cyclone	Put the wind at 160° relative to the ship on the starboard side making best course and speed into the left semi-circle of the system .
Right Semicircle Of Tropical Cyclone	Put the wind at 045° relative to the ship on the starboard side attempting to make best course and speed to clear the system . Wind & wave in this region can often drastically reduce ship forward speed.
Left Semicircle Of Tropical Cyclone	Put the wind at 135° relative to the ship on the starboard side making best course & speed to increase separation between ship & tropical cyclone.
Behind The Tropical Cyclone	Maintain best riding course and speed to increase separation between ship and tropical cyclone.

TABLE 12: Required navigation actions based on where vessel is located relative to the direction of movement of a tropical cyclone in the North Atlantic Basin.

## **Summary and Acknowledgments**

Greater understanding of the concepts and mechanisms driving tropical cyclone development, movement, and decay should help to make the mariner more aware of the threat posed from tropical cyclones. Knowing where to get the latest information regarding these systems and how to apply it in a risk analysis for hurricane avoidance should further aid the mariner in the decision making process of how to evade a tropical cyclone in the North Atlantic Basin.

Hopefully, the information presented in this manual will help mariners better understand and avoid tropical cyclones in the North Atlantic Ocean. With lives and property lost at sea each Hurricane Season as a result of these often disastrous systems, the intention of this guide was to increase the awareness of mariners regarding the Atlantic tropical cyclone threat. At the same time, providing a relatively simple and somewhat objective technique to evaluate that threat and evade these tropical tempests. It is hoped that during those instances when sailors are placed in unfortunate circumstances, forced to evade a tropical cyclone, that this manual can be of some value in helping them through the decision-making process.

In completing this manual I would like to thank a number of people who supported and contributed to this project. A sincere and special thanks to Michael Carr of the Maritime Institute of Technology and Graduate Studies whose enthusiasm, energy, and ideas for this project helped to keep me focused and provided much of the substance for this manual. Similar thanks to Lee Chesneau of the Marine Prediction Center for providing a great deal of review, feedback, and encouragement for the manual. Many thanks go to the staff of the Tropical Prediction Center, in particular Dr. Jack Beven and Dr. Ed Rappaport for their thorough reviews and recommendations for this document. Special thanks to Max Mayfield, Director of the Tropical Prediction Center and Christopher Burr, Chief of the Tropical Analysis and Forecast Branch for giving me the opportunity to work on such an important project. Additional thanks to the Technical Support Branch of the Tropical Prediction Center, in particular, Brian Maher, Chris Sisko, and Michelle Huber for their computer and graphics support. Finally, I would also like to acknowledge Steve Bingham, Patrick Dixon, & the numerous other civilian and military Fleet Forecasting & Routing personnel at the Naval Atlantic Meteorology & Oceanography Center, Norfolk Virginia. All of whom taught me so much about ship routing & hurricane avoidance during my tenure as a Ship Routing Officer.

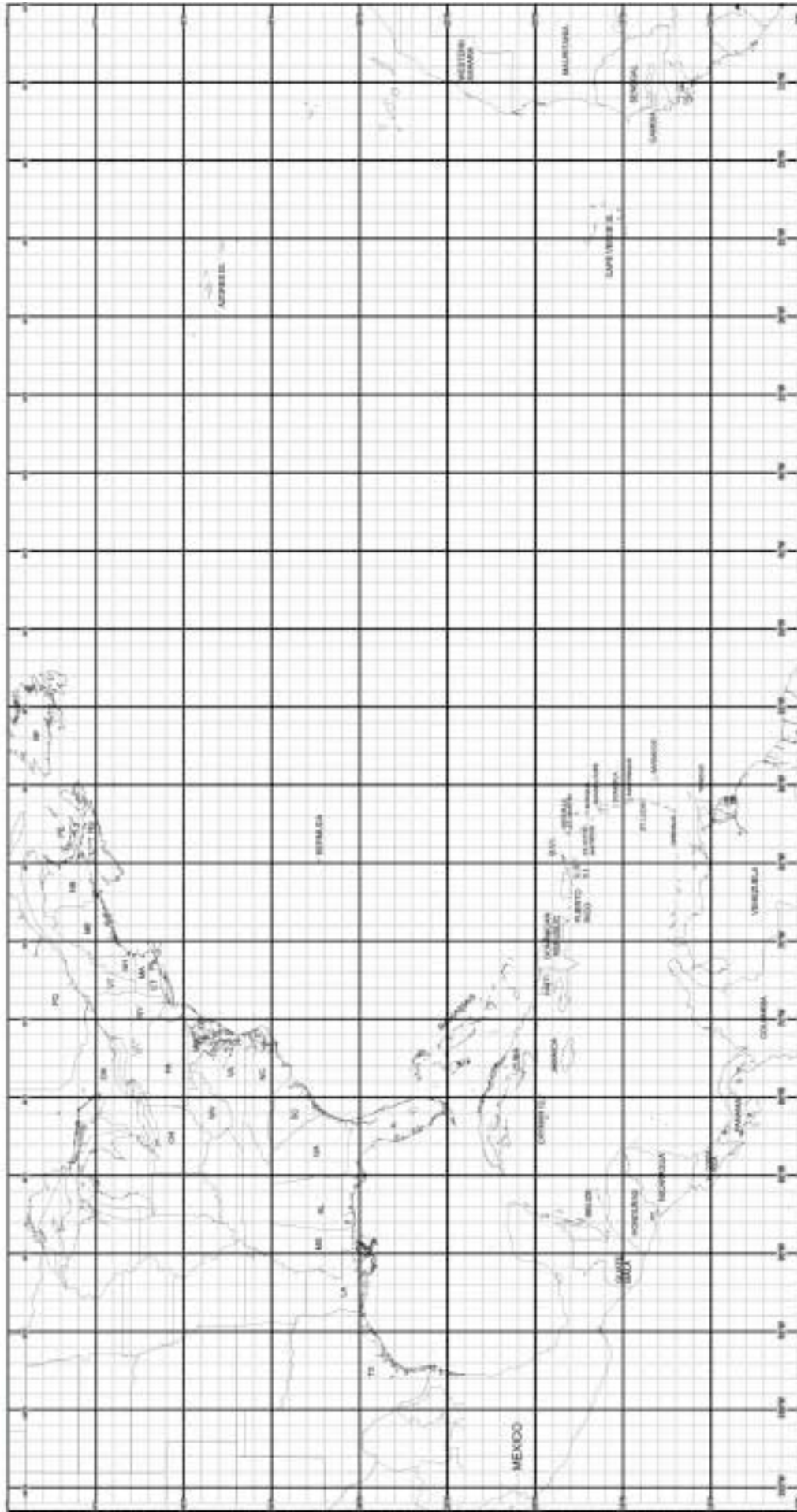
This manual would not be complete without acknowledging all sailors who continually leave the comfort of home, family, and friends taking to sea and facing all that Mother Nature can muster in order to provide for their countries and their families. May God bless you with 'Fair Winds and Following Seas'.

# Mariners Tropical Cyclone Risk Analysis Checklist

- 1. **Review regional tropical cyclone climatology for area of expected operations.**
  - Look for tropical cyclone track and development tendencies.
  - Locate areas of possible rapid intensification (Gulf Stream, Gulf of Mexico).
  - Consider likely areas for sea room in order to maneuver for avoidance.
- 2. **Obtain latest Marine Prediction Center & Tropical Prediction Center analysis/forecast charts; including surface, upper level, & Sea State (wind/wave) charts.**
  - Evaluate evolution of wind/ wave over the forecast period.
  - Look for evolution of synoptic patterns & possible relationship to any tropical cyclone track and intensity changes.
  - Obtain Sea Surface Temperature charts in order to refine location of Gulf Stream & areas with abundant warm water/warm-core ocean eddies.
- 3. **Locate & plot tropical (easterly) waves, disturbances, and tropical cyclones.**
- 4. **If available, examine current satellite imagery.**
  - View relationship and evolution of cloud features and intense convection with respect to any current or potential tropical cyclone. Note evolution & change of Central Dense Overcast (CDO) associated with any active tropical cyclone as this can sometimes provide a general indication of the extent of 34 KT winds.
- 5. **Obtain latest tropical cyclone advisory messages. Plot current/forecast positions of all active/suspected tropical cyclone activity.**
  - Ensure vessel will meet requirements of 34 KT rule**
  - Calculate and plot for the 1-2-3 rule**
    - Ensure vessel meets MINIMUM requirements of this rule.
  - Conduct forecast track comparison of latest 24-hour period (previous 5 advisories).**
    - Evaluate any increase to buffer zone around the tropical cyclone based on forecast track tendencies observed over the last 24 hour forecast period
- 6. **Plot completed tropical cyclone danger area to avoid chart.**
- 7. **Determine possible courses of action (at least 2) for vessel to take in order to remain clear of the Danger Area To Avoid in the tropical cyclone.**
  - Evaluate courses of action based on:
    1. Current Forecast Track
    2. Historically Possible Forecast Track (even beyond the 72 hour forecast period)
    3. Worse Case Forecast Track
  - Consider impact of changes in wind, wave, & weather conditions and how they may impede movement of vessel in each course of action.
  - Be aware of sea height impacts that dynamic fetch & Gulf Stream Current with opposing winds can have on vessel movement in each course of action.
- 8. **Evaluate current/nearby port & hurricane haven locations that may be considered for tropical cyclone avoidance.**
  - Consider tropical cyclone forecast track to haven
  - Evaluate berthing & shelter requirements. Consider berthing availability.
  - Compute time/distance considerations of ship versus tropical cyclone both into port or sortie from port.
  - IF ALREADY IN PORT, MAKE EARLY DETERMINATION TO REMAIN IN PORT OR EVADE AT SEA.
- 9. **Calculate Closest Point of Approach (CPA) to tropical cyclone for all courses of action based on latest forecast/advisory.**
- 10. **Make decision on course of action to follow and execute. Continue to closely monitor tropical cyclone's progress returning to step 1 of the risk analysis when new meteorological analysis & forecast information becomes available.**



# Atlantic Basin Hurricane Tracking Chart National Hurricane Center, Miami, Florida



This is a reduced version of the chart used to track hurricanes at the National Hurricane Center



## GLOSSARY OF TERMS

**Anticyclonic** – The sense of rotation about the local vertical opposite to that of the earth’s rotation; that is clockwise in the Northern Hemisphere, counter-clockwise in the Southern Hemisphere, and undefined at the equator. It is the type of flow evident around high pressure systems throughout the world. The opposite of cyclonic.

**Buffer Zone** – Any additional margin of safety radius added to the minimum values of the 1-2-3 rule. The addition of any buffer zone is solely at the discretion of the ship captain and should be based on observed or indicated forecast uncertainty and the impact that expected weather/wind/wave conditions in the vicinity of the tropical cyclone can have on ship maneuverability. Buffer Zones should only be used to add separation between the ship and tropical cyclone. It should never be used to decrease separation below the minimum values of the 1-2-3 rule.

**Cold Core System** – A cyclonic system where at any given level of the atmosphere, the center of the low is colder than the environment surrounding it. Extra-tropical cyclones and winter lows are examples of normally cold core weather systems.

**Convective Activity** – A general term used to describe the manifestations of convection in the atmosphere, alluding particularly to the development of convective clouds and resulting in weather phenomena, such as showers, thunderstorms, squalls, hail, tornadoes. The vertical extent of these features determines the type and description of convection. Deep convection is normally found to extend upward to the tropopause while shallow convection, normally observed as showers, has a much smaller vertical extent.

**Cyclogenesis** – The development or strengthening of a cyclonic circulation in the atmosphere. It is applied to the development of a cyclonic circulation where one did not previously exist.

**Cyclonic** – The sense of rotation about the local vertical the same as that of the earth’s rotation: that is, as viewed above, counterclockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere, and undefined at the equator. It is the type of flow evident around low pressure systems and tropical cyclones throughout the world. The opposite of anticyclonic.

**Danger Area** – That region surrounding the forecast track of a tropical cyclone that mariners must avoid due to a high likelihood of experiencing sustained winds greater than 34 KT associated with the tropical cyclone in the vicinity. All vessels in the vicinity of a tropical cyclone should, at a minimum, remain outside of this danger area. However, sea heights outside of this danger area can often be quite large and mariners are urged to use extreme caution when attempting to remain along the outer boundary of the danger area while navigating to evade a tropical cyclone.

**Dynamic Fetch** – This is a situation where fetch and the associated wave generating wind field move in phase with each other over an extended period of time. This situation allows for greater wave growth than would normally be expected as the developing seas can remain within the wave generation region over longer periods of time. In conditions with dynamic fetch, one can expect sea heights much greater than those experienced in cases where the fetch and/or the wave generating

wind field remain fixed at a location. Dynamic fetch can occur with both tropical and extra-tropical cyclones.

**Extratropical Transition** – The process whereby a tropical cyclone begins to lose its’ characteristics of deep convection near the center and a warm core throughout the troposphere. At this point the system begins to take on the traits of an extratropical low pressure system whereby the convection becomes less intense and concentrated. During this time, convection often becomes removed from the center of circulation. Tropical cyclones undergoing extra-tropical transition often display an outward expansion of the tropical storm force wind field that can be extremely hazardous to ships in the region.

**Frontolysis** – The process in which a front dissipates. This occurs when the temperatures and pressures equalize across a front.

**Global Maritime Distress & Safety System (GMDSS)** – System established with goals to provide more effective & efficient emergency & safety communications and disseminate Maritime Safety Information (MSI) to all ships on the world’s oceans regardless of location or atmospheric conditions. MSI includes navigational warnings, meteorological warnings/forecasts, & other urgent safety related information. GMDSS goals are defined in the International Convention for the Safety Of Life At Sea (SOLAS) 1974, as amended in 1988, & affects vessels over 300 gross tons along with passenger vessels of any size. The National Weather Service participates directly in the GMDSS by preparing meteorological forecasts/warnings for broadcast via NAVTEX & INMARSAT-C SafetyNET.

**INMARSAT-C SafetyNET** – Inmarsat provides the space segment necessary for instant and reliable distress and safety satellite communications for the maritime community. Additionally, Inmarsat offers three satellite communications systems, designed to provide most of the GMDSS medium and long-range functions: Inmarsat-A, Inmarsat-B and Inmarsat-C. All of these systems make use of 2-digit codes for easy access to various types of assistance. Finally, Inmarsat also now offers a distress alerting facility through Inmarsat-E, which is an L-band Emergency Position Indicating Radio Beacon (EPIRB).

**Minimum Safe Separation** – That distance between ship and tropical cyclone, as determined by the master or captain of a ship, which will allow the vessel to maintain sufficient speed and maneuverability in order to further evade a tropical cyclone.

**Rapid Intensification** – The sudden decrease in the minimum sea-level pressure of a tropical cyclone. Average rates of decrease in surface pressure during rapid intensification are approximately 1.25 MB per hour over a 24 hour period, 2.5 MB per hour over a 12 hour period, or 5 MB per hour for at least a 6 hour period.

**Recurvature** – The turning of a tropical cyclone from an initial path toward the west and poleward to a subsequent path toward the east and poleward. This normally occurs while the tropical cyclone moves poleward of the lower and middle tropospheric subtropical ridge axis.

**Sortie** – The act of departing from port in an attempt to minimize the impacts that a tropical cyclone will have on a vessel. Any decisions to sortie from port should be made early enough in order to clear the port and channel reaching a safe evasion point prior to the onset of winds, seas, and weather that may begin to negatively impact vessel speed and maneuverability.

**Subtropical Ridge** – A semi-permanent high pressure zone normally found centered near 30°N latitude in the North Atlantic Ocean. This feature also possesses significant vertical extent up through the lower and middle troposphere often times acting as the dominant steering influence in a tropical cyclone.

**Synoptic Scale** – The scale size of migratory high and low pressure systems occurring in the troposphere having wave lengths on the order of 550 NM to 1350 NM. Extra-tropical low pressure centers, cold/warm fronts, and high pressure centers are examples of weather features normally thought of on the synoptic scale.

**Tropopause** – The boundary at the top of the troposphere which separates it from the stratosphere above. This layer is very stable, allowing for very little transport of air from below to above and vice versa.

**Troposphere** – That portion of the atmosphere from the earth's surface to the tropopause; that is, the lowest 5 NM to 11 NM of the atmosphere. The troposphere is characterized by appreciable vertical wind, water vapor content, and weather.

**Upper Level** – Roughly the highest one-third of the troposphere. Although there is no distinct limit applied to this term, it is considered that portion of the troposphere located at and above the 300 MB level of the atmosphere still beneath the tropopause.

**Warm Core System** – A cyclonic system where at any given level of the atmosphere, the center of the low is warmer than the environment surrounding it. Tropical cyclones are warm core systems.

**WMO Header** – Globally standardized meteorological product identifiers that give each product issued by military and government weather agencies worldwide a unique identifying name.

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