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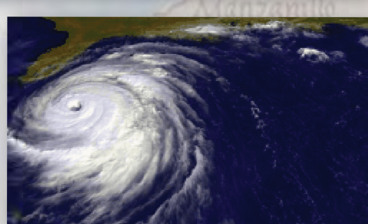
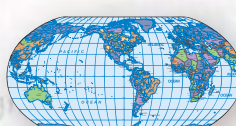
WORLDWIDE

Weather Master





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WEATHER MASTER

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Meteorology

Meteorology may be defined as the study of movements and phenomena in the earth's atmosphere, especially with regard to weather forecasting. Meteorologists obtain information from a wide range of different sources including dedicated weather satellites, weather balloons, ocean weather ships, aeroplanes, commercial shipping, weather buoys, manned and unmanned weather stations, radar installations, and so on. This information is the basis from which, using a combination of skill, experience and massive computer systems, meteorologists produce weather predictions or forecasts. Despite the sophisticated equipment and techniques the forecaster's expertise still plays a very significant part in the forecasting process.

When we use the term 'weather' we mean the atmospheric conditions existing at a specific place over a relatively short period of time. The conditions of general interest to us normally are whether it is warm or cold, raining or dry, sunny or cloudy, foggy or clear, windy or calm and so on. Yachtsmen and women are interested principally in wind strength and wind direction as these are usually the two single factors which have the most effect on anyone taking a small boat to sea, both from the point of view of safety and of enjoyment.

Nowadays we are lucky to have easy access to many different sources of high quality weather forecast information; the aim of this section is to help you to fully understand these forecasts so that you can form an intelligent picture of the changes likely to occur in the weather and the sea conditions in a particular area.

It is important to appreciate that even a basic understanding of atmospheric conditions and how they interact will help immensely when trying to decide how the actual weather and sea conditions will develop in a specific area. In some instances the following explanations have been simplified where a full understanding of a complex subject is not required.

Wind
Wind is simply the movement of air. Winds are caused by air flowing from an area of high pressure to an area of low pressure.

Air
The earth is surrounded by a layer of what we call the atmosphere or just 'air'. Air is invisible and yet it is nevertheless is composed of matter. Dry air is composed of nitrogen (78% by volume), oxygen (21%) argon, (1%) and the remainder is made up of trace gasses which include ozone (at high altitudes), hydrogen and carbon dioxide. Pollutants are present in air as well; these include carbon dioxide and various sulphur dioxides. Air also contains a quantity of water in the form of either water vapour or droplets of water; the actual percentage of water contained in the air varies from less than 1% to about 4%.

As air is composed of matter it must have weight and it follows that if air has weight it must also exert pressure on anything beneath it. The earth is completely surrounded by an envelope of air and this air, having weight, exerts pressure continuously on the earth's surface. This pressure is called atmospheric pressure, i.e. the pressure exerted by the atmosphere.

Atmospheric Pressure
The amount of pressure exerted by the atmosphere on the earth's surface at any place depends upon the depth of the air above that place and the weight of that air. The heavier the air is the greater will be the pressure it will exert on the place beneath it. Atmospheric pressure is measured by a barometer and hence the measurements are in units of barometric pressure, or 'Bar' for short. Barometric pressure measured over a period of time is called a barograph. One bar is divided into 1000 parts, each one being called a 'millibar' (mb), that is 'one thousandths of a bar'. (The modern unit of measurement is called a hectopascal (hPa) which has exactly the same value as a millibar, i.e. 1000 mb = 1000 hPa).

The variation in pressure around the world varies, very roughly, between a low of 970 millibars and a high of 1030 millibars. Although atmospheric pressure around the world is changing continuously the average pressure is taken as being 1013 millibars, at sea level, 59°F Going upwards from sea level atmospheric pressure decreases because the depth of the atmosphere above is also decreasing; for this reason the cabins of high flying aircraft must be pressurised.

Heavy air, light air

Most substances, including gasses, expand when they are heated and contract when they are cooled. Air behaves in this manner, its volume increases when it is heated and decreases when it is cooled.

This means that when air is heated it becomes lighter and when it is cooled it becomes heavier. A place which has warm air above it will be subject to low atmospheric pressure whereas an adjacent place which has cold air above it will be subject to high atmospheric pressure. Air flows from an area of high pressure to an area of low pressure so the wind will blow from the high pressure area towards the low pressure area. The greater the difference in the pressure between the two places the faster the air will move; the faster the air moves the stronger will be the wind.

A car or bicycle tire is pumped up to a high pressure; if the tire is punctured the air will flow out of the tyre (high pressure area) into the surrounding air (low pressure area) until the pressure in the tyre and the surrounding area are the same. The higher the initial pressure in the tyre the faster will be the rush of air when the puncture occurs.

Heat from the sun

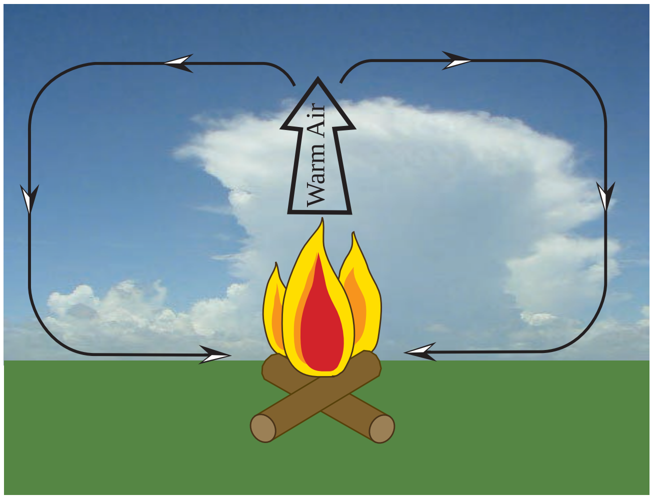
The earth has no heat source of its own, all the heat experienced on the earth comes from the sun's rays. It is this heat from the sun which supplies the energy that causes the changing weather systems throughout the world.

The sun's rays only heat solid objects so they do not heat the air directly but they do heat both the land and the sea which absorb the heat from the sun. Air which is close to the warm surface of the sea and the land is in turn warmed by this contact. Put another way the sun heats the earth and the earth transfers some of this heat back to the air which touches its surface. It follows that air which is some distance from the earth's surface does not receive the same heat and therefore air becomes colder the higher it rises in the atmosphere. This is one of the reasons why hot countries can have snow on high mountains.

Air circulation

As was explained above when air is heated it becomes lighter and being lighter than the surrounding air it will start to rise upward. A hot air balloon makes a good example, the air trapped in the balloon is heated with a gas flame so that it expands and becomes lighter than the air surrounding the outside of the balloon. The 'bubble' of light air rises lifting the balloon with it.

Air which is heated will become unstable and rise upwards but as it ascends through the atmosphere it will begin to cool until it loses its heat. When it becomes cold and heavy it will start to descend back to the earth's surface where it will once again be warmed and start to rise again, thus a continuous system of circulation is set up.



The bonfire analogy

A bonfire is often used as an example of how heat begins, and maintains, a circulation system. When the bonfire is burning you can clearly see smoke and sparks being carried upward by the rising air which has been heated by the flames. The air which rises up must be replaced and so cooler surrounding air flows into the base of the fire, causing a draught, or 'wind'. The hot air is cooled and becomes denser as it ascends until it eventually stops rising and starts to sink back down to ground level.

Finally it is drawn into the base of the fire where it is heated thus continuing the cycle until the fire, which is the heat source providing the energy keeping the circulation going, dies.

Water

Water is constantly evaporating from the oceans, seas and lakes and is absorbed by the air in the form of water vapour. The warmer the air is the more water vapour it can absorb. This absorption process can be clearly seen as 'steam' after a shower of rain on a hot day. Energy, supplied by the sun in the form of heat, is required to convert water into water vapour. If the moist air becomes cooled the water vapour condenses back into water droplets causing clouds, fog and rain; at the same time the energy contained in the water vapour is also released back into the atmosphere. This release of energy is responsible for much of the active weather we experience.

Tropical hurricanes derive their terrific energy largely from the release of latent heat which occurs when water vapour absorbed from the warm sea surface is cooled and condenses into torrential rain.

The world's air circulation.

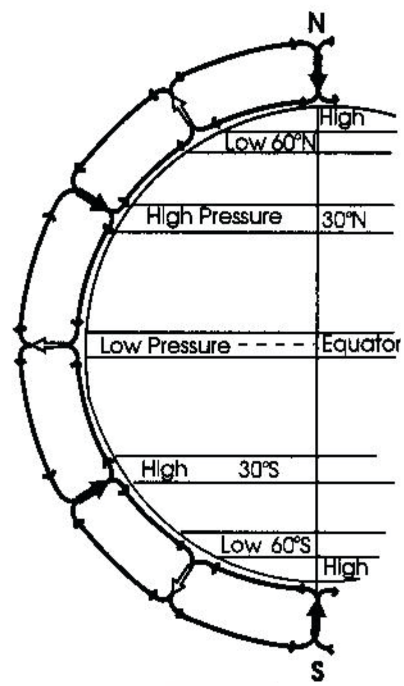
The sun does not heat the earth's surface uniformly, for example it is obviously much warmer near the equator than it is at the North or South poles. This imbalance between the heat experienced at different latitudes causes the general weather patterns of the world.

Near the equator the sun's rays fall directly on the surface of the earth and the air which is in contact with the surface is heated, expands, and rises upwards. The atmosphere is divided into two physically distinct layers, the layer nearest to the earth's surface is known as the troposphere and the next layer above is known as the stratosphere. The rising warm air cannot pass out through the troposphere but it must keep moving because it is being pushed by the warm air rising continuously behind it and so is forced into two separate streams, one moving northward and the other southward.

The air stream is now becoming colder due to its altitude, and it is therefore becoming heavier; eventually the stream of air descends to the earth's surface where it is once again warmed, completing the circulation cycle.

The air heated over the equator falls back to earth at around about latitude 30°N and 30°S. As the air rising off the equator is warm the atmospheric pressure near the equator will be low and as the air descending at 30°N and 30°S is cool the pressure at these latitudes will be high. Each hemisphere has two more similar circulation systems giving a total of three systems, or 'cells', for each hemisphere.

Figure 10.2 shows how areas of high and low pressures would appear if there were no large land masses on the surface of the earth. However there are of course large land masses and these have a great effect on the general weather patterns of the world.



The theory of the world's air circulation

Coriolis force

The earth is revolving continuously around its own axis, completing one revolution in 24 hours. This spinning causes anything which moves freely over the earth's surface to be deflected to the right of its path in the northern hemisphere and to be deflected to the left of its path in the southern hemisphere. A moving air mass is effected by this force, which is known as Coriolis force, and air flowing from an area of high pressure to an area of low pressure will not move in a straight line but will in fact be deflected to the right of its path in the northern hemisphere.

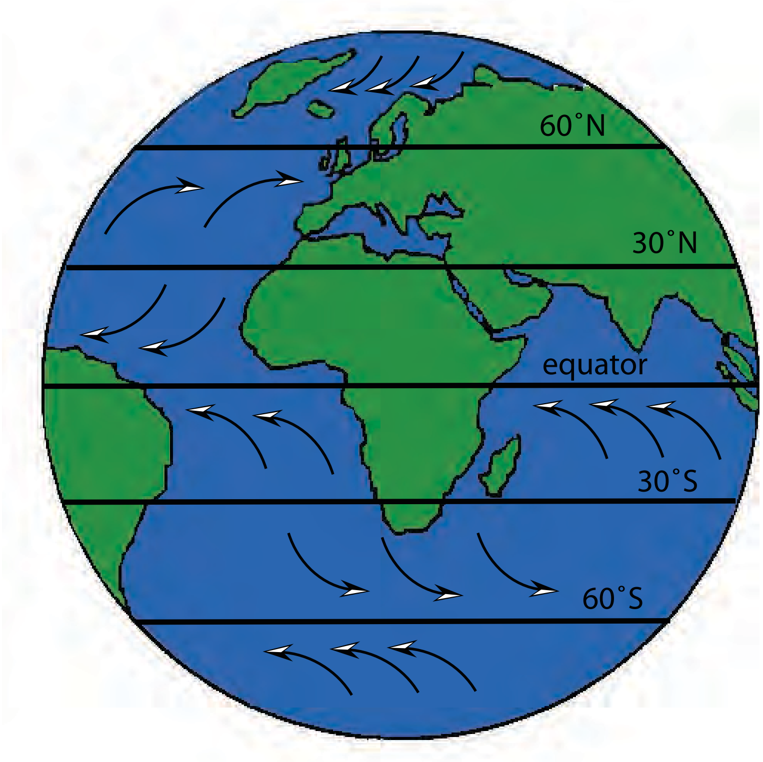
Looking at figure 10.2 it can be seen that there are belts of high and low pressure around the world. If it were not for Coriolis force the wind would blow directly from the high pressure areas to the low pressure areas. .

The wind blowing from the high pressure belt at 30N° to the low pressure area at the equator would be a north wind, that is it would blow from the north towards the south but Coriolis force deflects it to the right of its path and so the wind actually blows from the north east. Likewise the wind blowing from the high pressure belt at 30N° to the low pressure area at 60°N would be a south wind but being deflected to the right of its path it becomes a west wind.

Large, land masses generate areas of high and low pressure and large cold land masses generate areas of high pressure.

The polar front

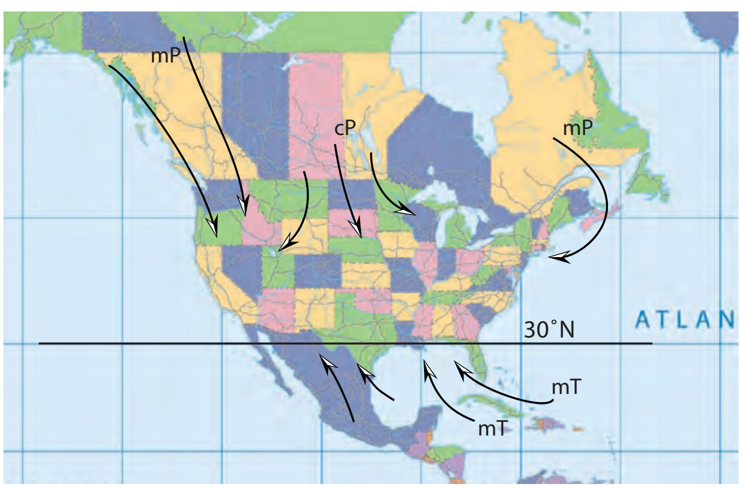
Note in particular the band of low pressure along latitude 60°N; within this low pressure belt lies what is called the polar front. The polar front is where the air from the polar regions and the air from the temperate regions meet. An important feature of the polar front is that the two air masses do not gradually mix with each other, rather the boundary between the two air masses is clearly defined. The polar front is of great importance because the depressions or 'lows' very often form initially along this front.



General direction of the Trade Winds and prevailing winds of the world

Air masses

Large masses of air are constantly on the move, these air masses exhibit definite characteristics depending upon where they originated from and what seas or lands they have passed over before they reach us. Air masses are of importance in understanding weather forecasting because disturbed weather conditions occur when two air masses having different temperatures and water content meet.



The different airmasses that effect the US in summer.

The air masses which effect us in the US come either from the cold polar regions or from the warm sub-tropical and tropical regions and can reach us from over land or from over the ocean.

Isobars

The term isobar comes from 'iso' meaning equal and 'bar' meaning barometric pressure. Isobars are lines which are drawn joining places of equal pressure. They are in effect similar to contour lines drawn on a map showing hills and valleys. The closer isobars are together the steeper will be the atmospheric pressure gradient between them and the stronger will be the wind. Isobars far apart indicate calm conditions, isobars close together indicate strong winds.

Depression
A depression is the name given to a region of closed isobars with low pressure on the inside, also called a 'low'. The wind circulates in an counter-clockwise, or cyclonic, direction around the centre of low pressure in the northern hemisphere.

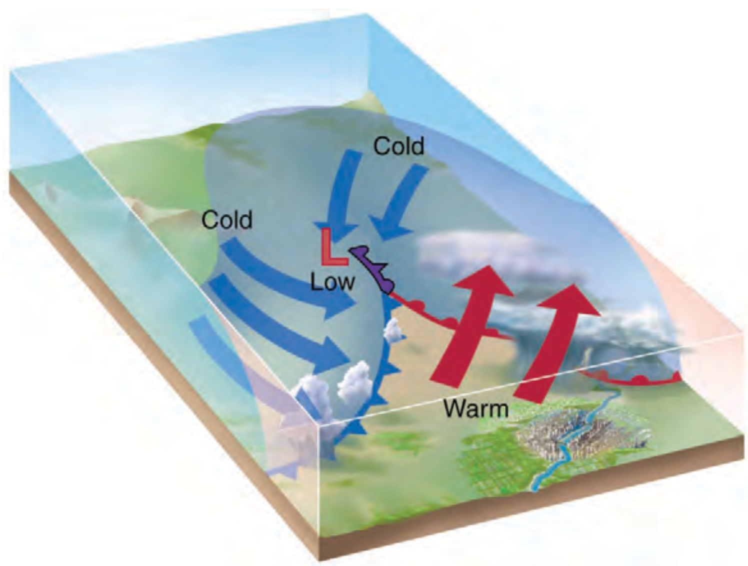
Secondary depression
If a depression is halted suddenly a wave may form on its trailing cold front. This secondary depression may not develop sufficiently to be of any consequence or it may quickly develop into a full blown deep depression giving rise to severe conditions. Secondary depressions can mature and move very rapidly.

Anti-cyclone
A region of closed isobars with high pressure on the inside; also called a 'high'. The wind circulates in a clockwise direction around the centre of high pressure in the northern hemisphere, due to the Coriolis effect.

Warm sector
The area of relatively warm air within a depression.

Cold sector
The part of a depression which is distinguished by relatively cold air.

Front
A line of separation between cold and warm air masses.



Warm front
The boundary line between the warm air of a warm sector and the cold air in front of it. In other words there is warm air behind a warm front.

Cold front
The boundary line between the warm sector and the cold air following behind as the depression moves along its path. In other words there is cold air behind a cold front.

Occluded front
In a depression the cold front moves faster than the warm front. When the cold front catches up with the warm front they combine and the result is called an occluded front.

Ridge
A ridge is an area of high pressure which lies between areas of lower pressure. As the pressure is high the weather will be good .

Trough
A trough is a valley of low pressure or the opposite of a ridge.

Squall
Sudden short lived strong storms are called squalls.

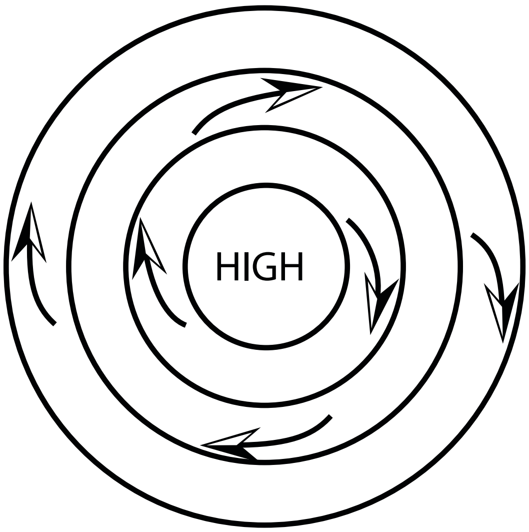
Jet streams

Jet streams are rivers of air which travel at speeds of 50 to 250 knots around temperate and sub-tropical latitudes. They occur at a height somewhere between 5,000 and 10,000 metres and they are associated with the movements of depressions.

'Bomb'

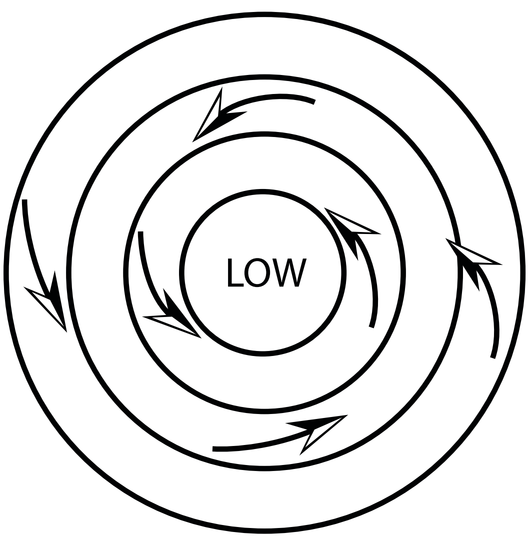
Meteorologists use the word used to describe a depression in which the pressure drops by 1 millibar per hour over a period of 24 consecutive hours. Needless to say a pressure drop of this magnitude indicates violent winds.

Wind direction in a high pressure system



As was explained earlier wind blows from a high pressure area towards a low pressure area. Coriolis force deflects the wind to the right of its path in the northern hemisphere and so wind blowing outward (diverging) from the centre of a high pressure area will spiral outwards in a clockwise direction. The wind direction is not quite parallel to the isobars but will be pointing out from the centre of high pressure. The isobars in the figure opposite are drawn as concentric circles to make the drawing as clear as possible, in reality the isobars would be much less uniform in appearance.

Wind direction in a low pressure system

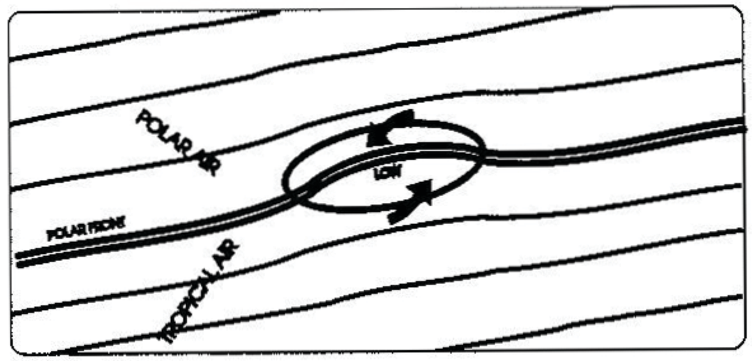


The wind in a low pressure system will be blowing inwards towards the centre of low pressure. (Converging) The wind direction will not be quite parallel to the isobars but as the air is flowing inwards the wind direction will also be a little inwards towards the centre of low pressure. As in the previous diagram the isobars are drawn as concentric circles for clarity, again in reality the isobars will be much less uniform.

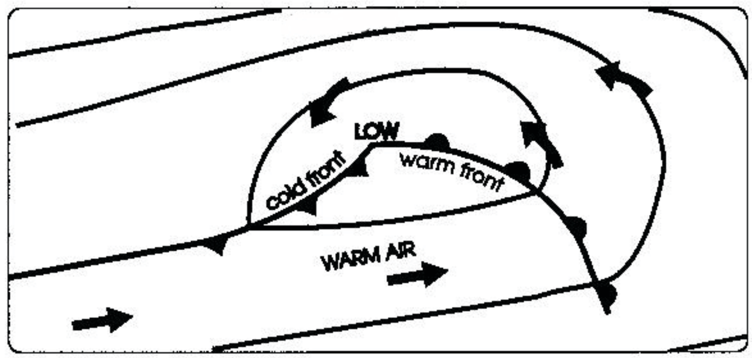
It is important to note that in the southern hemisphere a high pressure system circulates in an anti-clockwise direction and a low pressure system circulates in a clockwise direction

Frontal depressions.

A front is where two air masses with different properties meet. There is a clearly defined boundary between the two air masses. If the warm air mass pushes into the cold air mass, or vice versa, a kink or wave appears along the front.



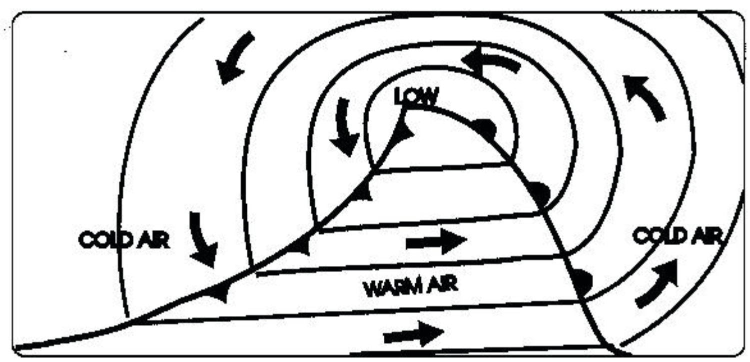
The pressure starts to drop at the bulge because warm unstable air is replacing the cold stable air. As the warm air in the wave rises up it is replaced by more warm air rushing in behind it, and Coriolis force deflects this wind to the right of its path setting up a cyclonic (counter clockwise) wind circulation around the centre of low pressure. Heavy clouds develop as the moisture which is contained in the rising warm air condenses with height. The warm front is shown by ‘bumps’, the cold front by ‘spikes’.



The deepening depression moves off in a north easterly direction (roughly in the direction of the isobars in the warm front) driven by the wind above it. It may move at any speed up to 50 knots or even more.

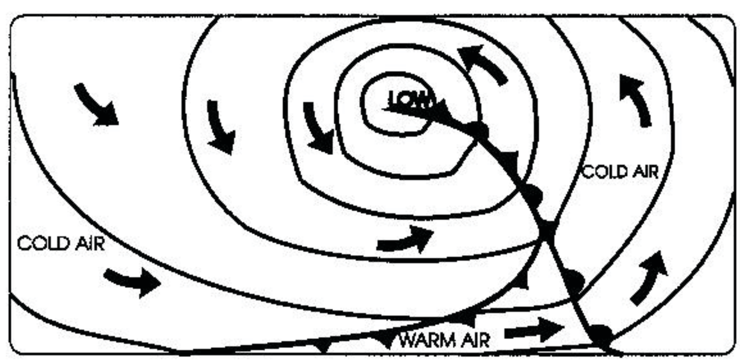
Mid life

As the pressure at the centre of the low falls so does the pressure difference, or gradient, increase causing stronger winds. Cold air moves faster than warm air and so the cold front begins to catch up on the warm front gradually reducing the size of the warm sector. The depression has expanded and may spread over thousands of miles.



Occlusion

The cold front has by now caught up with the warm front over some of its length. Because cold air is heavier than warm air the cold air pushes underneath the warm air starting from the centre of the depression.



Eventually the whole of the warm sector is raised up and as warm air can no longer feed the depression it dies. An occluded front is shown by having both bumps and points drawn on it.

Rules for depressions

No two depressions are the same but in general terms:

- Depressions usually move from SW to NE in the north Atlantic .
- A depression usually moves along a track parallel to the isobars in the warm sector.
- If a depression has been moving steadily in the same direction for 12 hours it will probably continue on the same track for the next 12 hours, as long as it does not meet land.
- If two similar sized depressions are close to each other they will often rotate around each other and combine.
- If a depression meets land, the source of its energy in the form of the warm humid air will be cut off and it will weaken.

Other sources of depressions

Depressions form in areas other than on the polar front. The most common causes of these are:

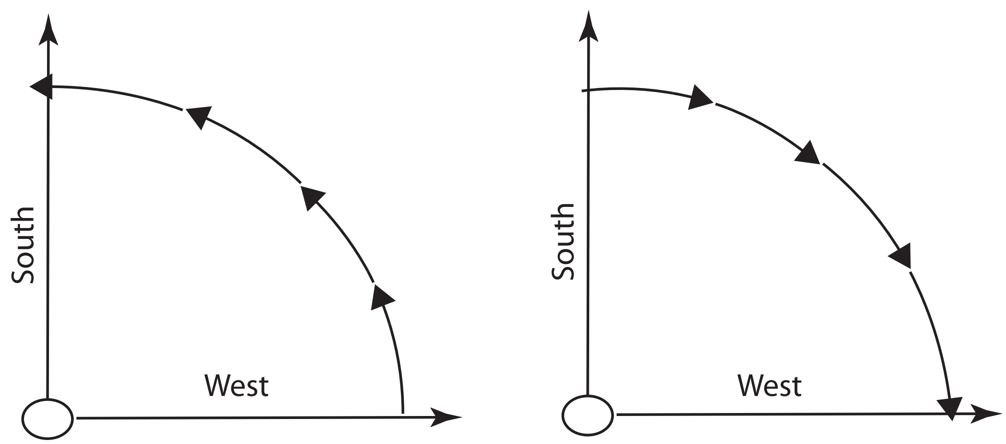
- Polar lows: cold air warmed when a cold air mass moves over warm seas.
- Heat lows: air being heated by hot land masses.
- Lee lows: a low pressure area can form in the lee of a mountain subjected to a flow of air.

Backing

A wind which is changing in a counter-clockwise direction (e.g. W-S-E-N) is said to be backing.

Veering

A wind which is changing in a clockwise direction (e.g. S-W-N-E) is said to be veering.



West wind backing southerly   South wind veering westerly

Remember that wind direction is given as the direction from which the wind is blowing. In other words a west wind comes from the west, a south wind comes from the south.

Clouds

When warm air is cooled it can no longer contain the water vapour it is has absorbed and the water vapour condenses into droplets of water which are visible in the form of clouds. Air can become cooled in a variety of ways; it will be cooled if it is forced to rise, for example, and warm air will be cooled where a cold and warm air mass meet at a front.

Cloud types

Clouds have different shapes depending on their physical properties and the conditions which caused their formation. The altitude and the shapes of clouds can give a good indication of what type of weather may be expected. Cloud shapes and altitudes are named using Latin words in a system devised in 1803 by Luke Howard, a chemist. Clouds are white when they are illuminated by the sun, if they are in shadow they appear black, the colour is of no significance.

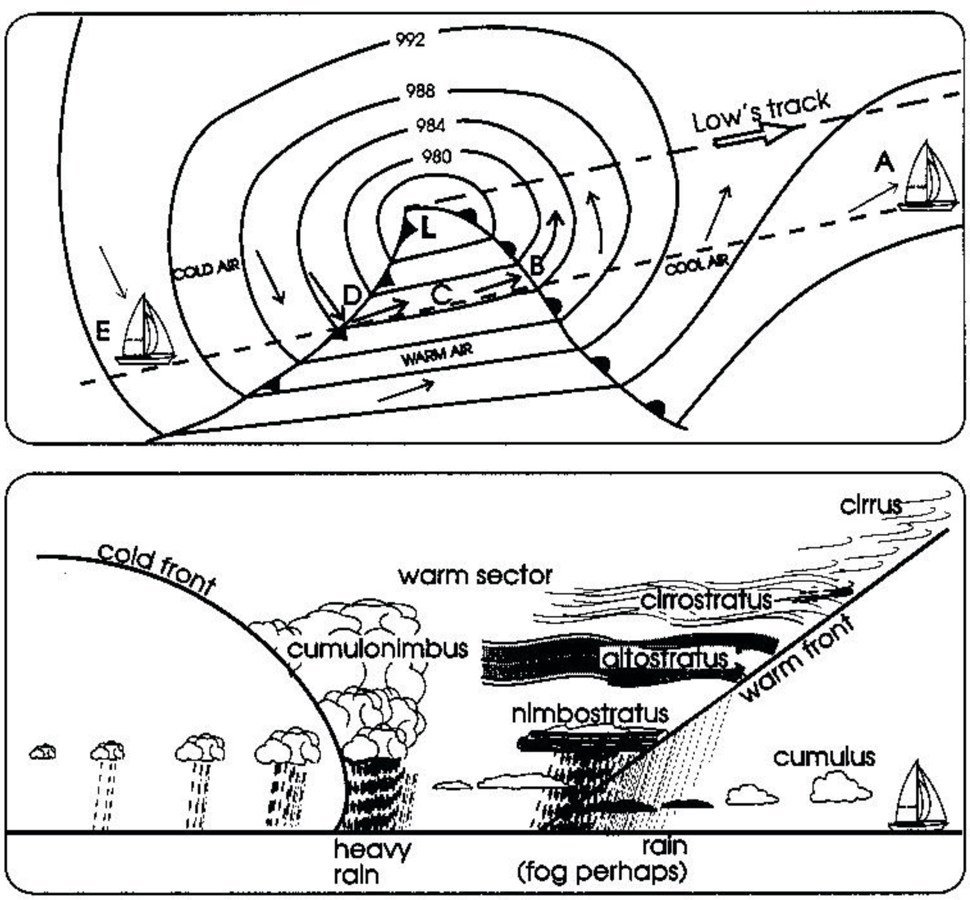
Cirrus	Cirrus means 'hair', cirrus clouds are thin wispy, or feathery clouds, at a very high altitude. The word 'cirro' is used as a prefix to denote high altitude clouds.
Cumulus	Cumulus means a 'heap', cumulus clouds are clearly outlined heaped up clouds.
Stratus	Stratus means a 'layer' and the term is used to define a uniform flat sheet of cloud cover. Cirrostratus is thus a layer of thin, uniform, high altitude cloud.
Nimbus	Nimbus means 'rain' or 'storm' and the word is used in conjunction with the terms above, thus a layer of low cloud giving rain is called 'Nimbostratus' and heaped up rain clouds are called 'Cumulonimbus' clouds.
Alto	Middle level clouds are prefixed 'alto', thus Altocumulus refers to middle level heaped up clouds.

Changes in conditions as a depression passes to the north of you.

When a depression approaches and passes to the north of your position there will be definite changes in wind direction and strength, cloud type, barometric pressure, precipitation and perhaps temperature.

The figure below shows two views of a depression; the figure is in two parts, the top figure shows the depression from above, the lower drawing shows a section through the depression. The depression is moving in a NE direction, passing over the yacht at A.

Initially the yacht at A is experiencing light winds from the SW.



As the depression approaches the yacht the wind will begin to freshen, thin whispy cirrus (mare's tails) will appear high in the sky, followed by cirrostratus. The barometer will start to fall. Small, puffy, cumulus clouds will become more frequent giving way to low dark nimbostratus clouds at the warm front, B, where the yacht will experience rain together with a decrease in visibility.

The wind will continue SW as the warm front passes and the rain will give way to drizzle, perhaps fog, the wind may increase, the barometer will steady and the temperature may increase. The atmosphere will be damp and humid with low clouds.

In the warm sector the yacht at C will have low clouds, perhaps clearing to bright spells before the approach of the cold front. The barometer will be steady, or fall only slowly, and the wind will remain from the SW.

At the cold front, D, the wind will veer to the NW and increase, becoming strong and possibly squally. There will be heavy rain with big cumulonimbus clouds perhaps accompanied by thunder and hail. The barometer will start to rise quickly and the temperature will drop. After the depression has passed the rain will turn to showers, and the wind will moderate.

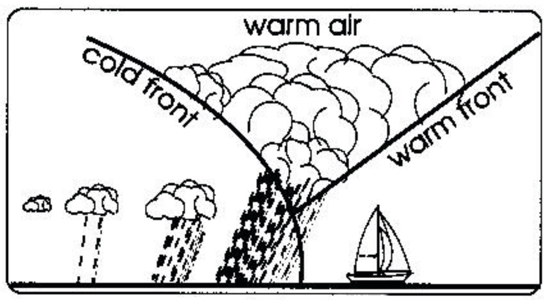
How conditions may be expected to change when a typical depression, with warm and cold fronts, passes to the north of you.

	APPROACH OF WARM FRONT	AT WARM FRONT	IN THE WARM SECTOR	AT THE COLD FRONT	WHEN COLD FRONT IS PAST
WIND DIRECTION AND STRENGTH	Veers to S.W., increases	Continues S.W. May increase, often squally	Steady S.W. May continue to increase	Sudden veer W. to N.W. with strong squalls	N.W. to N. Strong, gusty, moderating
PRESSURE	Falls quickly	Stops falling	Steady	Rises quickly	Rise slows down progressively
TEMPERATURE	Small rise	Rises	Steady	Falls quickly	Falls slowly
CLOUDS	1. Cirrus 2. Cirrostratus 3. Altostratus	Nimbostratus	Thin, low Stratus clouds	Cumulonimbus	Cumulus, clearing
RAIN	Rain starts	Heavy rain	Drizzle	Heavy rain, perhaps thunder	Showers, dying off
HUMIDITY	Slow increase	Rapid increase	Steady	Slow decrease	Quickly decreases
VISIBILITY	Slowly decreases	Poor	Poor	Poor	Improves quickly, becoming good

Changes in conditions when a depression passes to the south of your position

If a frontal depression passes to the south of you the fronts will not pass over your position. You will not therefore experience the sudden changes of wind direction associated with the passage of fronts or the temperature changes. As the low approaches the barometer will fall, cloud cover will thicken, the wind will begin to back continuously and there will be rain. After the centre of the low has passed to the south of your position the barometer will start to rise, the wind will have backed through NE to NW and the rain should become lighter. Large cumulonimbus clouds along the cold front to the south of you will be visible.

Occlusions



A cold front occlusion

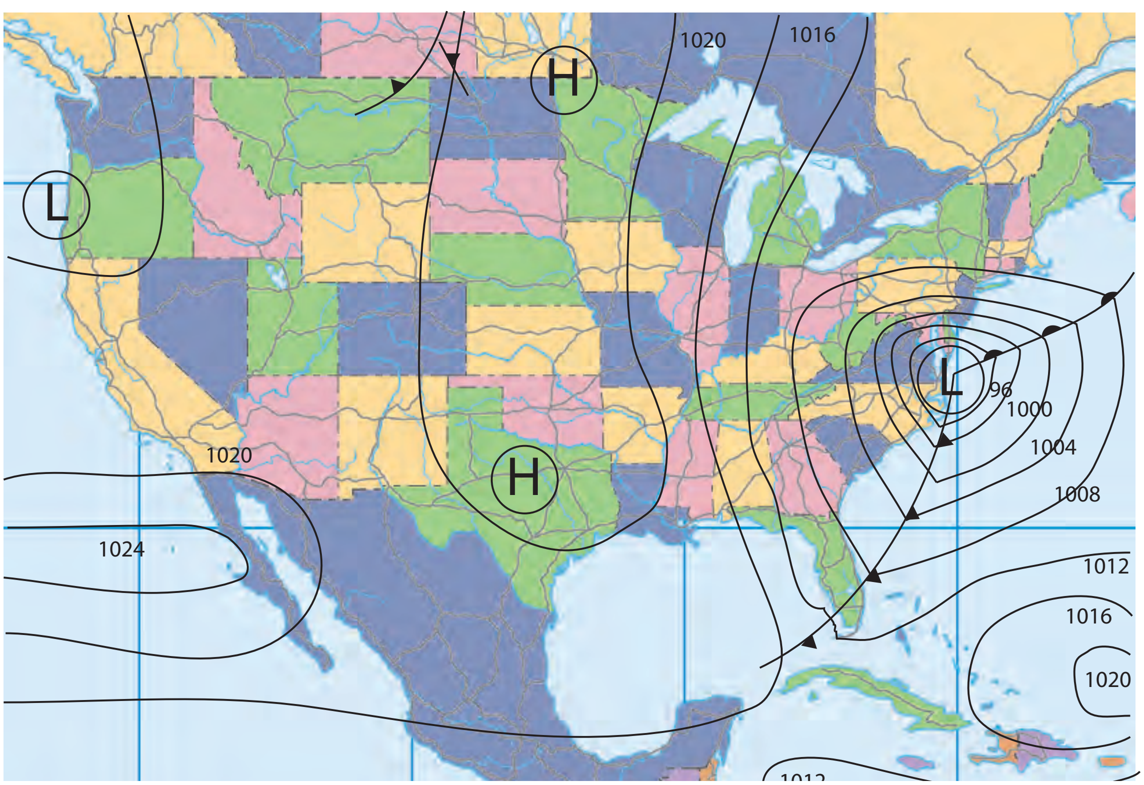
Looking at the section through the depression in figure 10.13 it will be seen that the warm front is not vertical but at an angle; the curved cold front is also at an angle. The cold front travels faster than the warm front which means that the cold front will eventually catch up with the warm front. When this occurs the heavy cold air pushes under the warm air ahead of it, like a wedge, lifting the warm air off the surface of the sea or land. This is called a cold front occlusion and it gives rain at the occlusion, followed by weather conditions similar to those normally experienced with the passage of a cold front.

Buys-Ballots law

Buys-Ballot, a Dutch professor, gave us this simple rule to locate the centre of a depression:

> *" If you stand with your back to the true wind in the northern hemisphere the centre of low pressure will be about 90° to 130° on your left hand side".*

The wind felt at ground level is not the true wind; the direction of the true wind can be seen from the direction in which the low clouds are travelling.

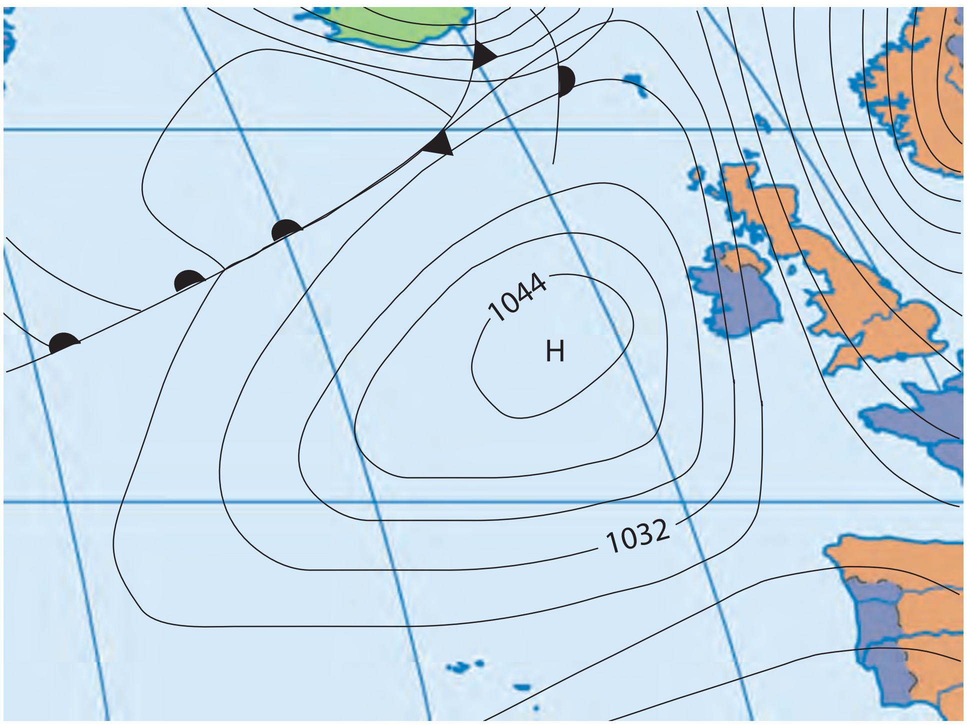


A frontal depression centred over the middle of the east coast of the US is moving in a north east direction, roughly parallel to the isobars in the warm sector. The winds associated with this depression are moving in a counter clockwise direction around the centre of the low. An anti cyclone or high pressure area covers the central U.S. The winds circulating around the anticyclone are circulating in a clockwise direction. The isobars between the high and

low pressure system are being squashed indicating high(er) winds in this area. A cold front is approaching Florida, when it passes through the wind there will veer from SW to NNW and become gusty with a fall in temperature and the possibility of showers.
The isobars on this weather map are drawn at intervals of 4 millibars.

High pressure systems

High pressure systems, or anticyclones, appear on a weather map as a system of closed isobars with high pressure at their centre. The isobars in a high pressure system are usually spaced far apart indicating light winds. Anticyclones normally move slowly or even remain stationary for some time giving settled weather. The wind flows outward from the centre of high pressure and, due to the Coriolis force, is deflected to the right of its path in the northern hemisphere, thus giving winds in a clockwise direction around the centre of the high.
Anticyclones are formed of (relatively) cold, stable, air which is slowly sinking thereby giving the outward flow of air from its centre. Cold air contains only a small amount of moisture and therefore cold air does not generate clouds. In summer anticyclones usually give clear skies, and sunny, warm weather although nights can be cool. Anticyclones can deflect depressions so that they pass to the north, however when this happens the isobars between the two systems may become noticeably compressed giving strong winds. In winter high pressure systems give cold days with frost at night and the possibility of fog over warm seas.

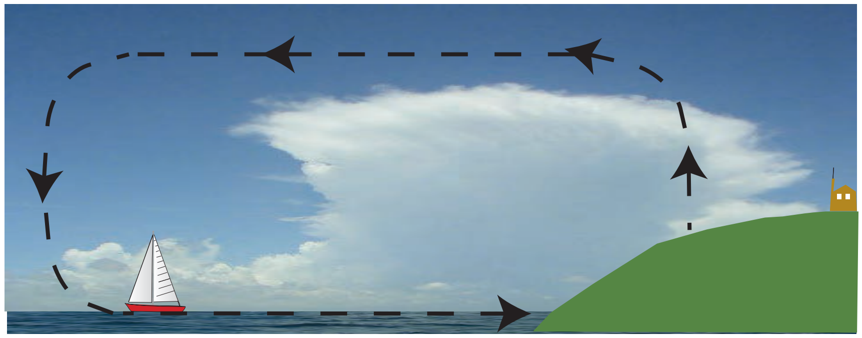


An anticyclone (high pressure system therefore the wind blows in a clockwise direction around the centre of the high pressure) covering a large part of the north Atlantic. The isobars over Ireland and the U.K. are close together, squeezed between the high in the Atlantic and the low over Scandinavia. The anticyclone is keeping a low over Iceland well to the north. Ireland is experiencing strong, cool, NW winds. If the anticyclone continues to build and drift in a north easterly direction Ireland can look forward to settled weather with light winds as the wider spaced isobars drift over Ireland. The isobars on this weather map are drawn at intervals of 4 millibars.

Sea breeze

A sea breeze is a wind which blows locally from the sea towards the land during the daytime.

If the land becomes heated by the sun during the day the air in contact with the land is heated and rises upwards. Cool air flows in from the sea to replace the air rising off the land and so a circulation system is set up.



How a sea breeze is generated during the day

Usually sea breezes begin about half a mile offshore around about 1000 to 1100, reach their strongest by 1400 and have stopped by 2000.

If there is no appreciable gradient wind the sea breeze will initially flow from the sea directly towards the land but as the day passes the wind will be deflected to the right and will end up blowing more or less parallel to the shore.

Sea breezes are common during weather associated with high pressure systems. A sea breeze will modify the wind direction and strength of the gradient wind, that is the wind associated with the isobars of the prevailing weather system. Sea breezes can be as strong as force 4 and if this combines with an onshore gradient wind the overall wind will be strong.

A sea breeze will not develop if the gradient wind is 25 knots or more. If the sea breeze and the gradient wind are in opposition one may cancel out the other, giving calm conditions. Sea breezes here seldom extend more than 10 miles offshore and are strongest near the coast.

Land Breeze

At night the land cools and the air in contact with it is cooled and flows down and out to sea. Contact with the sea, which is relatively warm, heats the air which rises up and flows back towards the land where it is cooled and a circulation is set up. A land breeze starts at the land and works its way out to sea. Land breezes are not as strong as sea breezes and they are not felt as far out to sea as a sea breeze might be.

How a land breeze is generated at night

Rain

Clouds are formed of minute droplets of condensed water vapour. When this vapour is further condensed, by cooling as the cloud rises for example, it will form into larger droplets of water. These droplets of water amalgamate and increase in both size and weight as the cloud ascends until finally they are too heavy to remain airborne and the drops of water fall down in the form of rain.

Hail

Strong air currents within a cloud may carry rain drops upwards where they freeze before falling to earth as hail stones.

Snow

If the air is cold enough to freeze condensed water vapour the vapour will form into ice crystals which fall as snow.

Thunder and lightning

If a rising air current carries water droplets up high enough so they freeze into ice crystals, they will rub and bump into each other. Those which loose an electron will become positively charged; those which gain an electron will become negatively charged. When the buildup of these opposite charges becomes great enough, a lightning flash occurs. These can occur within a cloud, from one cloud to another, or between the cloud and the ground or water. A lightning flash is incredibly powerful...up to 30 million volts at 100,000 amps! The boater must certainly take precautions to protect onboard electronics, and the personnel's safety.

Fog

Fog is defined by meteorologists as <1 kilometer of visibility. Fog is composed of droplets of water, formed when air is cooled to it's dew point,

Types of fog

- **Advection fog**, or sea fog, occurs when warm moist air flows over a cold sea surface. This condition is more likely to arise in the late spring, or early summer before the sea has warmed fully
- **Radiation fog**, a land based fog, occurs during cold clear nights when the land radiates the heat it absorbed during the day. The warm land cools the air in contact with it causing dew to develop. If there is a breeze it will spread the cooling effect through a greater depth of air and fog may form.
  Fogs which develop on land in this way can drift out to sea. Radiation fog is most likely to occur during anticyclones in the winter months; industrial areas are especially prone to radiation fog due to the higher concentration of dust particles in the air.

- **Frontal fog** may occur where two air masses of different temperatures meet. If both air masses have a high moisture content fog will form at the front between them. Frontal fog will usually be less than 50 miles in width. When rain, after descending through a layer of warm air aloft, falls into a shallow layer of colder air at the earth's surface, there will be some evaporation from the warm raindrops into the colder air. Under certain conditions this will raise the water vapor content of the cold air above the saturation point and frontal (also called rain, or precipitation) fog will result.

- **Arctic smoke** is the name given to fog caused by extremely cold air passing over warm water.

How fog is dissipated

- If the sun warms the air enough the water droplets will be reabsorbed as water vapour and the fog will disappear. During our winter months the sun may not generate sufficient heat to clear the fog and it may remain for some days.
- Wind can clear fog by mixing the layers of air.
- Fog should clear with a change of wind direction bringing air from a different source, such as occurs at the passage of a front.

The Beaufort scale
A numerical system of defining average wind strength by visual reference to the sea state was devised by Admiral Sir Francis Beaufort in 1808.

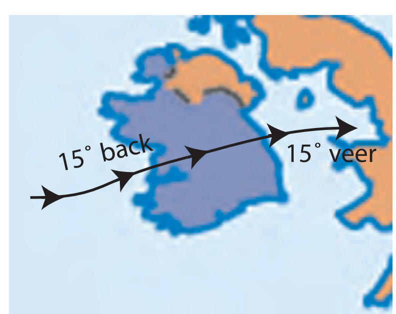
BEAUFORT FORCE	GENERAL DESCRIPTION	SEA STATE	WIND SPEED	WAVE HEIGHT
0	Calm	Sea like a mirror	0 - 1 kn	
1	Light air	Small ripples without foam crests	1 - 3 kn	
2	Light breeze	Small wavelets, short but more pronounced, crests glassy but do not break	4 - 6 kn	1/2 foot
3	Gentle breeze	Large wavelets, crests start to break, scattered white	7 - 10 kn	2 feet
4	Moderate breeze	Small waves becoming longer, fairly frequent white horses	11 - 16 kn	3 1/2 ft
5	Fresh breeze	Moderate waves, becoming longer. Many white horses some spray	17 - 21 kn	6 ft
6	Strong breeze	Large waves, extensive white foam crests and spray	22 - 27 kn	9 1/2 ft
7	Near gale	Sea heaps up, white foam streaks blown in wind direction	28 - 33 kn	13 1/2 ft
8	Gale	Moderately high waves, crests break off, visibility affected	34 - 40 kn	18 ft
9	Strong gale	High breaking waves, dense streaks of foam	41 - 47 kn	23 ft
10	Storm	Very high tumbling waves, sea looks white with large patches of foam, visibility badly affected.	48 - 55 kn	29 ft

The wave heights given are for waves in the open sea. Sea conditions will be modified by the proximity of land, in fact conditions may be more dangerous near land than in the open sea. One wave in ten may be expected to be about 30% higher than the wave heights suggested in the table.

Wind speed
The wind speeds are given in knots but the wind seldom, if ever, blows at a steady rate, particularly near land. For this reason the Beaufort scale is useful because it indicates an average wind strength.

Wind speed in metres per second
Continental forecasts often give wind speed in metres per second rather than in knots. To convert m/sec to knots multiply by 2, thus 10 m/sec = 20 knts and 5 m/sec = 10 knts.

The effect of friction
Above about 600 metres the wind moves parallel to the isobars and is called the true wind. The wind below 600 metres is subject to friction from both the land and the sea as it moves over the surface of the earth. The surface of the land is composed of mountains, valleys, forests, and so on and is much rougher than the sea. The wind is therefore subjected to more friction as it passes over the land than when it passes over the sea.



Friction effects the wind in two ways, firstly it slows the wind down and secondly it changes the direction of the wind. Due to friction, and the earth's rotation, the true wind is backed by roughly 15° over the open sea and by up to 30° over the land. This means that the wind blowing off the land will in effect be veering, through as much as 15° perhaps, for a few miles out to sea.

Local effects
Hills, mountains and valleys can cause local effects such as changes in wind direction and strength as well as back eddies and areas of calm.

The barometer
A barometer is an instrument which indicates the atmospheric pressure. Barometers originally consisted of mercury in a long glass tube but modern instruments, known as aneroid barometers, are much more compact. A single reading of barometric pressure gives no worthwhile information; it is the rate of change of the pressure that counts and this can only be seen from a series of readings, hence the importance of recording barometer readings in the ship's log book. A barograph is an instrument which records the pressure either on paper charts or electronically.

Barometer

Other indicators of approaching strong winds:
- If the wind is backing and increasing at the same time it is likely that a trough of low pressure is approaching. The barometer would also be falling.
- Swell may indicate that there is a storm somewhere.
- High cirrus clouds increasing from the direction of low pressure are the forerunner of a depression.
- Gales with a rapidly rising barometer are likely to be more squally than gales with a falling barometer.

Weather forecasts
Weather forecasts for the coastal waters of USA are available from various different sources but NOAA weather on VHF radio WX channels are of a very high quality. For cruising away from U.S. coastal waters a SSB MF/ HF radio receiver is required; sometimes it can be difficult to catch all the forecast information – a small handheld tape recorder is a great help in this case.

The National Weather Service publishes a book entitled Selected Worldwide Marine Weather Broadcasts. This publication contains weather broadcast schedules, both U.S. and foreign, from all over the planet, covering radiotelephone, radiotelegraph (Morse Code), and radiofacsimile transmissions. These schedules list broadcast times and geographic areas covered by the broadcast information, as well as station call letters, transmitting frequencies, and station locations. Those who expect to sail outside of the areas covered by VHF transmissions should consult this book to determine what radio weather information will be available to them.

Forecast format
The shipping forecasts are given in three parts, each part being of equal importance. Terminology is also standardised.

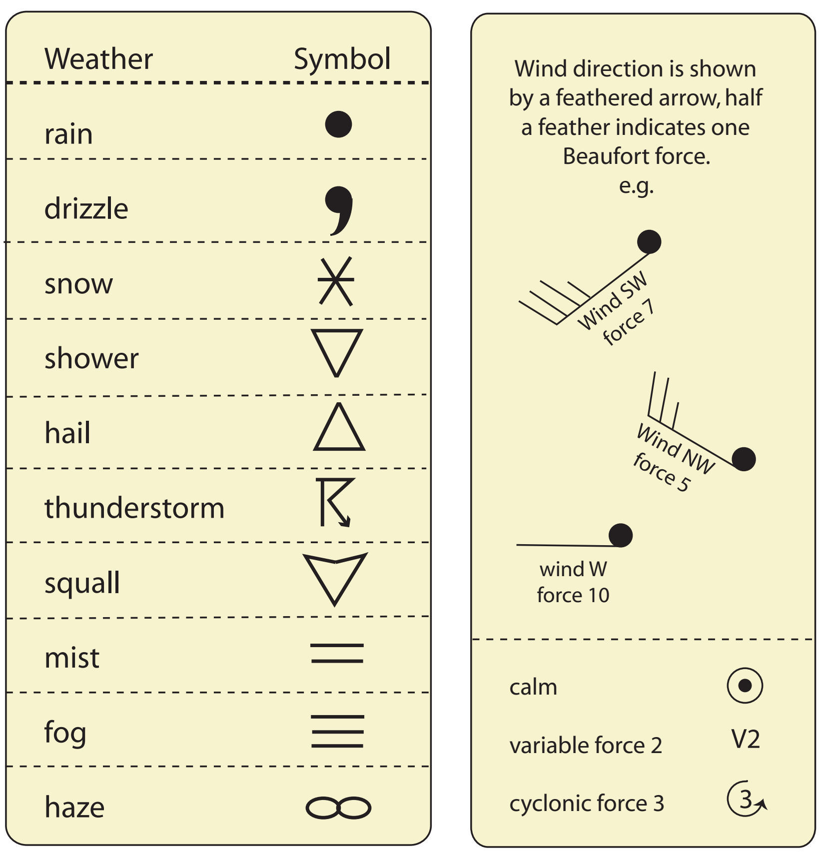
Gale warnings
Storm warnings are issued before the main forecast. Note carefully the time that the warning was issued, it may have been issued some hours before you heard it and it could therefore be quite close.

The general synopsis
The forecast starts with the general synopsis which gives the details and positions of the systems which are causing, or will effect, the weather. For example the synopsis may give the position of a depression, the direction in which it is moving and how fast it expected to move. It may also tell where it is expected to be in so many hours time.

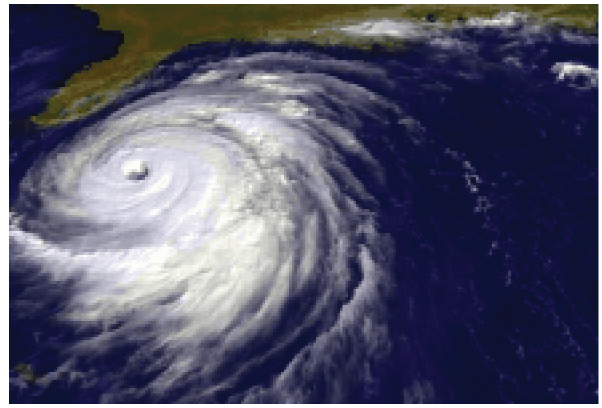
The sea area forecast
The sea area forecast follows the synopsis and a forecast is given for each area covering wind strength, wind direction, wave height, weather and visibility for the next 24 hours.

International weather map symbols
An international system of pictorial shorthand is used to show details of weather on a weather map. Many marinas and harbour offices have dedicated television monitors with a continuous display of the forecast using these symbols. Although the international convention is to draw ½ a feather for each increment of 5 knots there will be little inaccuracy if you take ½ a feather as indicating one Beaufort force.
Note that a wind strength of force ten is shown by an arrow with a triangle at the end rather than five feathers; as the strength increases single feathers are added to the triangle. A triangle with a single feather in front indicates hurricane force 12: *"Air filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected. Probable wave height 45 feet"*.

INTERNATIONAL WEATHER PLOTTING SYMBOLS



TROPICAL REVOLVING STORMS



Tropical revolving storms (TRS)
Intense depressions forming in the tropical regions are known by various names such as hurricanes (Atlantic), typhoons (Pacific), cyclones (Indian Ocean). The terms *tropical revolving storm* or *tropical cyclone* are used to describe these intense low pressure systems. These storms can give rise to violent conditions in which yachts and their crews will often be unable to survive. Tropical cyclones do not occur with anything like the frequency of the depressions experienced in temperate climates such as Ireland.

Hurricanes can seriously damage your health
Anyone venturing into areas in which Tropical Revolving Storms occur should avail of every opportunity to learn about them, possible areas of refuge ('hurricane holes') and what, if any, forecasting facilities may be available.

Many marinas in the U.S will not allow boats to enter if a hurricane is forecast, indeed some marinas may try to force boats already in the marina to leave. Insurance policies may not cover use in hurricane prone areas during the hurricane season. Some marinas will dig keel holes ashore into which the boat is craned and left until the hurricane season is over.
So-called 'hurricane holes' may well offer some degree of safety but not when they become filled with charter boats hastily anchored on hopelessly inadequate ground tackle.

Consider the following extracts:

1. "In December, 1944, vessels of the United States Pacific Fleet, operating to the east of the Philippines, were caught near the center of a typhoon of extreme violence. Three destroyers capsized and went down with practically all hands. Serious damage was sustained by a light cruiser, three small carriers, three escort carriers and three destroyers. ..About 750 officers and men were lost or killed." (Admiralty Manual of Navigation, Vol. 1).
2. "A mature hurricane is by far the most powerful event on earth; the combined nuclear arsenals of the United States and the former Soviet Union don't contain enough energy to keep a hurricane going for one day. A typical hurricane encompasses a million cubic miles of atmosphere and could provide all the electrical power needed by the United States for three or four years. During the Labor Day Hurricane of 1935, winds surpassed 200 miles an hour and people caught outside were sandblasted to death. Rescue workers found nothing but their shoes and belt buckles. So much rain can fall during a hurricane - up to 5 inches an hour - that the soil liquefies. .... In 1970, a hurricane drowned half a million people in what is now Bangladesh. In 1938, a hurricane put downtown Providence, Rhode Island, under ten feet of ocean. The waves generated by that storm were so huge that they literally shook the earth; seismographs in Alaska picked up their impact five thousand miles away." (The Perfect Storm).

Source of energy
Air is composed of nitrogen, oxygen and water in the form of vapor. The warmer the air is the more moisture it can contain. In the tropics air is heated by coming into contact with the sea which has in turn been warmed by the sun. As the air becomes warmed it is able to absorb more moisture which is supplied by evaporation from the surface of the sea. Energy, supplied by the sun, is required to evaporate the water. The warm air mass containing the water vapor rises and is cooled. The water vapor condenses back into water and the latent heat, or energy, contained by the vapor is released.

Tropical cyclones obtain their terrific energy by evaporating water from the sea surface and releasing this energy when the moisture vapor condenses into the form of torrential rain. By the time the rising air mass reaches the upper limit of the cyclone, which can be 8 miles or more above the sea surface, the air has become dry and cold. This dry cold air moves rapidly outward from the center of the hurricane and, being cold and therefore heavy, descends back to sea level Warmed by contact with the sea surface the dry air absorbs moisture once again and is drawn towards the low pressure area in the center of the cyclone and the cycle begins to repeat itself. Cyclones, once started, are therefore self generating as long as warm, moist, surface air is available. There are no fronts, either warm or cold, in a tropical cyclone and the isobars are more or less circular.

Conditions required for formation of TRS

Three conditions must be fulfilled for a tropical cyclone to develop; the first condition is that of sea surface temperature. The rate of evaporation necessary to allow a TRS to form requires a sea surface temperature greater than about 27° Centigrade (81° Fahrenheit). Sea temperatures as high as this only occur in the North Atlantic, for example, during the summer and autumn of that hemisphere and usually on the western side, i.e. in the Caribbean and Gulf of Mexico.

The second requirement for a tropical cyclone to develop is the existence of Corioli's force which will set up an counterclockwise spinning motion in the northern hemisphere or clockwise in the southern hemisphere. Corioli's force does not exist until about 7° north, or south, of the equator.

The third requirement is for weak upper level winds.

Tropical waves

An elongated area of low pressure (a trough) of low pressure is known as a Tropical wave, as it originates in the tropics. Many originate as a cluster of thunderstorms which move off the west coast of Africa. They move from east to west, carried along by the circulation around the Azores, or Bermuda High. If conditions are right, they may develop further into a Tropical Disturbance.

Tropical Disturbance

In tropical or sub-tropical areas when light winds have been circulating for 24 hours around an area of low pressure the air circulation is designated a tropical disturbance. A tropical disturbance is non frontal and may be approximately from 100 to 300 miles in diameter.

Tropical Depression

A tropical cyclone in which the sustained surface wind speed does not exceed 33 knots is called a tropical depression. At this stage the depression will be given a name such as TD2 (i.e. Tropical Depression no. 2).

Tropical Storm

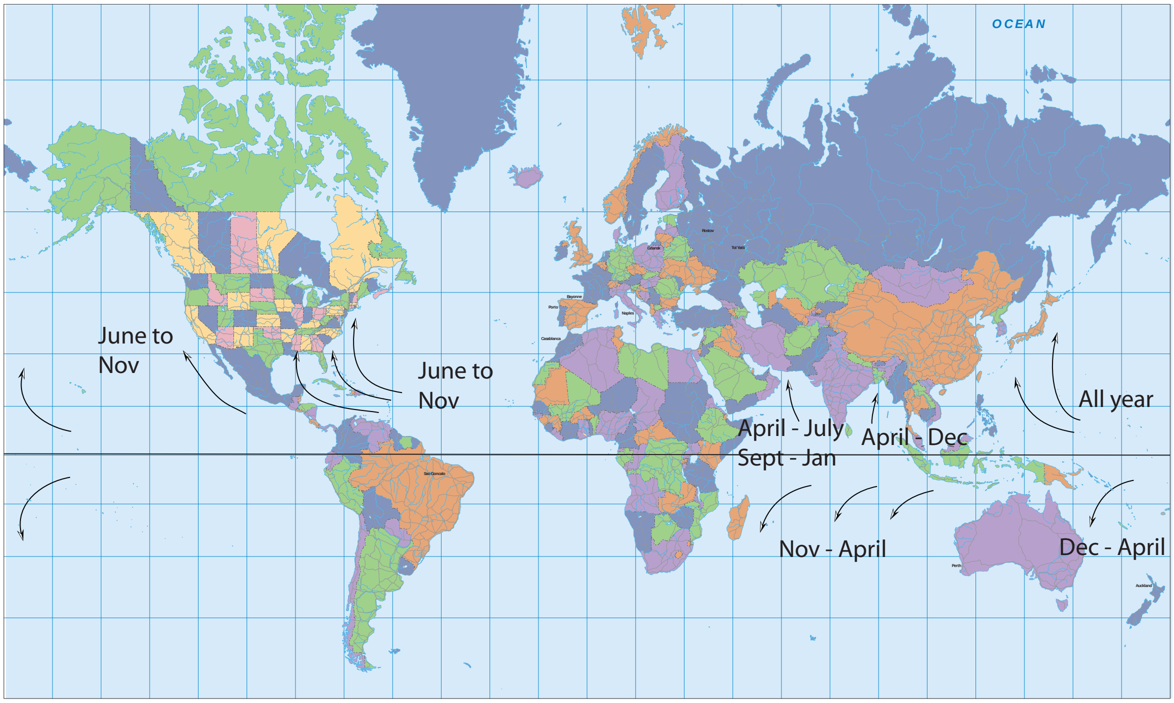
When the sustained wind speeds at surface level reach from 33 knots to a maximum of 64 knots the cyclone is designated a tropical storm. The high speed circulation of the wind in the center of the depression throws air outwards by centrifugal force and cold, dry (and therefore cloudless) air from high altitudes is drawn in to replace the outgoing air. Thus the cloudless, calm, center 'eye' of the storm is formed. At this stage the storm will be given a name, female and male names being used alternately, i.e. Hurricane Charlie, Hurricane Camille, etc., in areas such as the Caribbean covered by the US weather service.

Hurricane

When the maximum sustained surface wind speed of the TRS exceeds 64 knots the TRS is designated a hurricane. A hurricane is also given a category number from 1 to 5, based on the maximum wind speed sustained over a period of 1 minute of time. An international color tracking code is also used.

The categories are:

Category 1	wind speeds from	65 to 83 knots	(red)
Category 2		84 to 95 knots	(light red)
Category 3		96 to 113 knots	(magenta)
Category 4		114 to 134 knots	(light magenta)
Category 5		135 + knots.	(white)



Sketch of areas which experience tropical revolving storms, their average paths, and the months in which they are most likely to occur.

Areas TRS prone

Western side of the North Atlantic	(50)
Eastern side of the North Pacific	(30)
Western side of South Pacific	(30)
Western North Pacific	(250)
Southern Indian Ocean	(60)
Bay of Bengal	(20)
Arabian Sea	(10)
North West Australia.	(10)

The figures in brackets indicate the average number of severe tropical storms recorded over 10 years. These figures are from the BA Admiralty Manual of Navigation and were obtained prior to 1960. Remember that some storms may not have been recorded or the observers may not have survived to report them.

No tropical cyclones had been recorded in the South Atlantic, until 2004, when one moved onto the coast of Brazil.

North Atlantic TRS

The following numbers of tropical cyclones and hurricanes were recorded in the north Atlantic (: http://weather.unisys.com/hurricane/atlantic)

Year	Tropical Storms	Hurricanes
1995	19	11
2001	6	9
2002	8	4
2003	9	7
2004	5	9
2005	12	15

Seasons
June 1 until November 30 is the official hurricane season in the North Atlantic, although hurricanes have occurred in every month of the year. The peak of the North Atlantic hurricane season is September 14th. Generally hurricanes develop during the late summer and early autumn months of their hemisphere when the sea temperature has reached its hottest for the year. This means that they are rare from mid November until mid June in the Northern hemisphere and from mid May until November in the Southern hemisphere. The western North Pacific may have tropical cyclones during any month and they are more likely in the Arabian sea at the change of monsoon around October-November and May-June.

Path or Track
The direction along which a Tropical Cyclone is travelling.

Origins and tracks
In the northern hemisphere tropical cyclones originate north of the doldrums between about 7° and 15° north of the equator. The initial track is often between 275° and 350°. When the storm reaches about latitude 25°N the track turns (recurves) away from the equator and by the time the storm has reached 30°N it will often be travelling in NE direction.

Southern hemisphere tropical storms originate between 7° and 15° south of the equator and initially move in either a WSW or SSW direction recurving when they reach about 15° to 20° south. Having recurved the storm track usually continues in a SE direction.

Sometimes storms, both in the northern and southern hemisphere, do not recurve but continue along their original track until they reach the mainland where they usually die as they will be starved of their supply of warm surface water.

Storm tracks do not always conform to any rules, many factors such as the upper level wind direction and adjacent areas of high and low pressure effect the storms ultimate path.

The Vertex
The furthest point reached by the storm's track before the storm recurves is called the vertex.

Eye of the storm
The center of the storm, which will have light or no winds and clear skies, is called the eye. The eye will be from 10 to 30 miles in diameter and within this area winds may be expected to be light. Although the wind will be light in the eye of the storm at sea waves will be mountainous and very confused. For the crew of a yacht caught here survival may only be through resurrection!

Speed of advance
At the beginning a TRS will move along its track at a speed of 10 or perhaps 15 knots, the speed of advance increasing to between 20 and 25 knots after it has recurved. Speeds of advance up to 40 knots or more have been recorded.

Eyewall
The circle of clouds surrounding the eye of a tropical cyclone. The strongest winds will be in the eyewall.

Dimensions
Tropical cyclones cover a much smaller area than depressions in the higher latitudes. Tropical cyclones vary in size but in general terms may be about 300 miles in diameter and you may expect:

Winds of force 7 or more within 200 miles of the storm center,
Winds of force 8 or more within 100 miles of the storm center,
Winds of force 12 or more within 75 miles of the storm center,
Winds in excess of 150 knots have been recorded within 50 miles of the storm's center.

Significant wave heights

Sea conditions may be described in terms of significant wave height. Out of interest the relationship between wave heights and significant wave height is indicated by the following table, taken from the United States Coast Pilot, No.4.

Wave heights from Significant Wave Heights (SWH)	
Most frequent wave heights	0.5 x SWH
Average wave heights	0.6 x SWH
Significant wave height (average height of highest 33%)	1.0 x SWH
Height of highest 10% of the waves	1.3 x SWH
One wave in 1,175 waves	1.9 x SWH
One wave in 3,000 waves	2.5 x SWH

From the table above if significant wave heights of 6 feet were forecast the average wave height would be about 3.6 feet, the height of the highest 10% of the waves would be about 7.8 feet and one wave in 1,175 could reach 11.4 feet.

In passing it is worth defining the difference between the terms waves and swell. Swell is usually defined as a wave outside its own area of generation whereas a wave has been formed and is maintained directly by local wind.

Breaking waves

Breaking waves are by far the most dangerous waves which a yacht can encounter. A wave will break, in theory, when its height to length ratio is 1:7; but in fact this ratio is usually nearer 1:14 when breaking occurs.

The breaking crest of a wave with a 10sec period will be travelling at a forward velocity of about 30 knots.

Warnings of approach of TRS

Radio warnings of the existence of a TRS and forecasts of its track may be available in some areas. Local radio stations, television stations, newspapers, weather fax machines, etc., if available, will also give warnings and advice. Details of the radio frequencies and times of warning broadcasts are in Worldwide Marine Weather Forecasts in the U.S. (Admiralty List of Radio Signals, Vol. 111in the U.K).

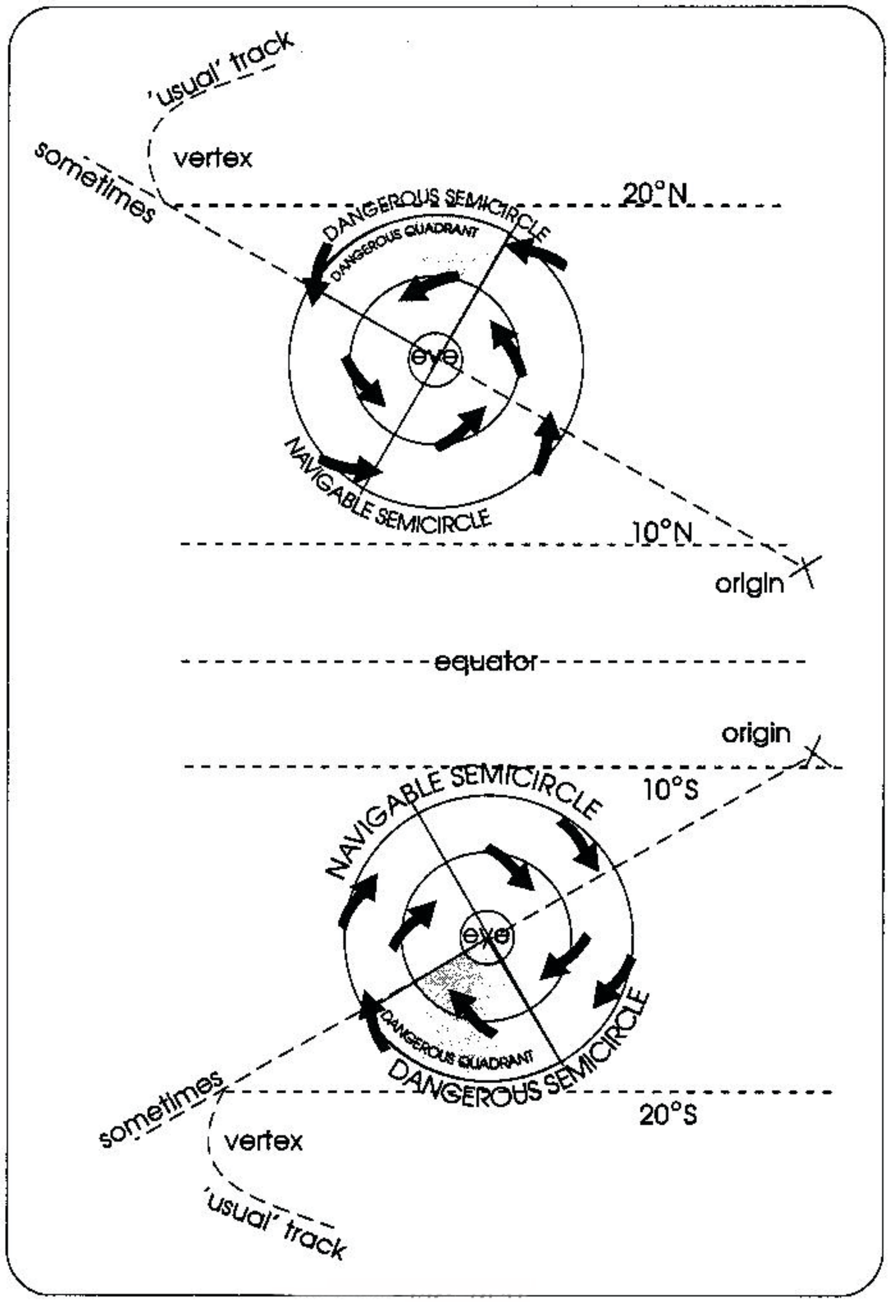
Warnings by Approach of TRS by Observation

In the tropics barometric pressure varies very little from day to day and so barometric pressure should be recorded on a regular basis in the ship's log along with the usual navigational data.

If the barometer, after correction for diurnal variation, shows a drop of 3 millibars below the average for the time of year it may be assumed that a TRS is approaching. If atmospheric pressure, after correction for diurnal variation, is 5 mb below the mean pressure it is certain that a TRS is approaching and a cours of action must be decided upon. The mean pressure and the correction for diurnal variation for the area and time of year is given in the pilot books for the area. As a rough guide diurnal variation is seldom greater than + or - 1.6 millibars. Diurnal variation is nil at 0100, 0600, 1300, and 2000 LMT.

Diurnal variation

During a 24 hour period atmospheric pressure rises and falls slowly independently of the effects caused by the passing of high and low pressure systems. Atmospheric pressure rises slowly to its maximum value at 1000 LMT and then falls until 1600 LMT. From 1600 LMT pressure rises again until 2200 LMT and then falls again until 0400 LMT. These daily variations in pressure are called *diurnal variation.* In the latitudes of Ireland and Britain the range of diurnal variation is small, about 0.5 of a millibar and so pass unnoticed by the yachtsman. In the tropics, however, the diurnal variation range is about 3 mb.



Tropical revolving storms, northern and southern hemisphere.
The arrows indicate the wind directions.

Barometric pressure
A slow fall in pressure during which time the diurnal variation is still discernible indicates that the observer is from 500 to 150 miles from the storm's centre.

A distinct fall hiding the diurnal variation indicates the observer is from 120 to 60 miles from the storm's centre.

A very rapid fall indicates the observer is from 60 to 10 miles from the storm's centre. The barometer may fall as much as 70 mb at the storm centre. (In 1975 a pressure of 870 mb was recorded at the centre of a typhoon).

Pressure will rise very rapidly as the storm passes.

When the storm center is 500 to 1,000 miles away, the barometer usually rises a little, and the skies are relatively clear. This is due to the sinking of the air due to the outflow from the cyclone. As the tropical cyclone continues to approach, the barometer usually appears restless, pumping up and down a few hundredths of an inch. It will then begin a sustained fall, the rate of decrease increasing as the cyclone gets closer.

Swell
An early indication of the approach of a tropical cyclone is the presence of a long swell. In the absence of a tropical cyclone, the crests of swells in the deep Atlantic pass at the rate of perhaps eight per minute. Swells generated by a hurricane are about twice as long, the crests passing at the rate of perhaps four per minute. Swells may be observed several days before the arrival of the storm.

Swell may extend as much as 1000 miles from a storm centre and will certainly be felt 500 to 600 miles from the centre. Higher and faster than usual swell should be taken as warning sign. As swell extends outward in concentric circle from the storm centre it may give an indication as to the direction of the TRS when away from the effect of land.

Radar
If radar is fitted it may be used to identify and track the centre of a TRS but this will depend upon the radar range and proximity of the centre of the storm.

Clouds
When the storm center is 500-1,000 miles away, Cumulus clouds, if present at all, are few in number and their vertical development appears suppressed. As the TRS comes nearer, a cloud sequence begins which resembles that associated with the approach of a warm front in the middle latitudes. Cirrus clouds appear when the storm is about 300-600 miles, which seem to converge, more or less, in the direction from which the storm is approaching. This convergence is particularly apparent at about the time of sunrise and sunset. The cirrus gradually gives way to a continuous veil of cirrostratus. Below this veil, altostratus forms, and then stratocumulus. These clouds gradually become more dense, and as they do so, the weather becomes unsettled. A fine, mist like rain begins to fall, interrupted from time to time by rain showers. The barometer has now fallen perhaps a tenth of an inch.

Wind
As the fall of the barometer becomes more rapid, the wind increases in gustiness to force 6-8. On the horizon appears a dark wall of heavy cumulonimbus, called the bar of the storm. This is the heavy bank of clouds comprising the main mass of the cyclone. Portions of this heavy cloud become detached from time to time, and drift across the sky, accompanied by rain squalls and wind of increasing speed. Between squalls, the cirrostratus can be seen through breaks in the stratocumulus.

As the bar approaches, the barometer falls more rapidly and the wind speed increases. The seas, which have been gradually mounting, become tempestuous. Squall lines, one after the other, sweep past in ever increasing number and intensity. With the arrival of the bar, the day becomes very dark, squalls become virtually continuous, and the barometer falls precipitously, with a rapid increase in wind speed. The center may still be 100 – 200 miles away. As the center of the storm approaches, the ever stronger wind shrieks through the rigging and the superstructure of the vessel. The rain falls in torrents. The wind fury increases. The seas become mountainous. The tops of huge waves are blown off to mingle with the rain and fill the air with water. Visibility is virtually zero in blinding rain and spray. Even the largest and most seaworthy vessels become virtually unmanageable and may sustain heavy damage. Less sturdy vessels may not survive. Navigation virtually stops as safety of the vessel becomes the only consideration. Words are inadequate to describe the awesome, and terrifying, fury.

The Eye
If the eye of the storm passes over the vessel, the winds suddenly drop to a breeze, or dies, as the wall of the eye passes. The rain stops, the sky clears. Visibility improves. Mountainous seas approach from all sides in complete confusion. The barometer reaches it's lowest point As the wall on the opposite side arrives, the full fury of the wind strikes as suddenly as it ceased, but from the opposite direction. The sequence of conditions that occurred during approach of the storm is reversed, and passes more quickly, as the various parts of the storm are not as wide in the rear of a storm as on it's forward side.

Rules to avoid center of TRS
Three things must be decided before avoiding action can be considered. These are:
1. the bearing from the yacht to the center of the storm
2. the expected path of the storm
3. whether the yacht is in what is known as the navigable semicircle or the dangerous semicircle.

Navigable semicircle
In the Northern Hemisphere, that part to the left of the storm track (facing in the direction toward which the storm is moving) is called the navigable semicircle. (By observation, if the wind is backing)

1) A yacht in this semicircle has a free wind to run/reach away from the center of the storm, and,
2) When (if) the storm recurves its path will move the center of the storm away from the yacht.
3) The wind speed is decreased by the forward motion of the storm.

Avoiding action, Navigable semicircle
Reach/run at the best possible speed, keeping the wind on the starboard quarter, which will take the yacht away from the storm's path.

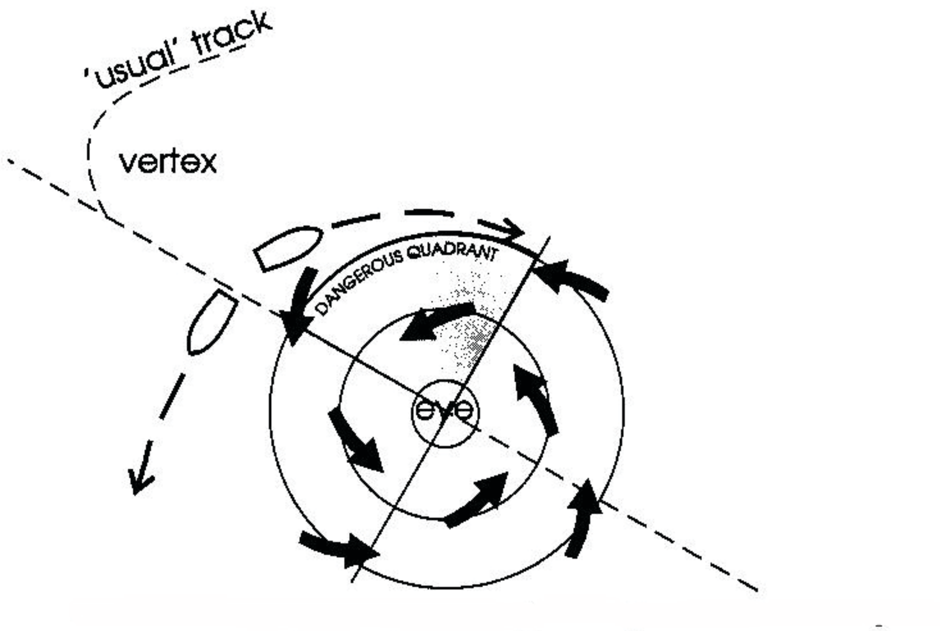
Dangerous semicircle
In the Northern Hemisphere, that part to the right of the storm track (facing the direction in which the storm is moving) is called the dangerous semicircle. (By observation, the wind is veering).

1) A yacht in this semicircle cannot escape by running or reaching before the wind. In this sector a yacht which is hove to, running or drifting is moving towards the storm's track or center. A yacht trying to move outward away from storm's track will have to beat to windward in gale conditions or worse.
2) Even if a yacht can make good to windward the storm when (if) it recurves may well pass over the yacht.
3) The apparent wind in this sector will be strongest due to the forward movement of the storm.

Dangerous quadrant
The forward, or leading, quadrant of the dangerous semicircle is called the dangerous quadrant. A yacht in this quadrant is in the most dangerous position of all. If it is considered feasible to run so that the yacht can cross the storms path and reach the navigable semicircle before being hit by the storm center then this is perhaps the best approach.

If it is felt that yacht may not cross the storm's path quickly enough the only option is to sail/motor to windward on starboard tack in the northern hemisphere, port tack in the southern hemisphere for as long as possible. If conditions become such that this is no longer feasible the yacht must heave-to and prepare for very heavy weather. In the other (rear) sector of the dangerous semicircle heave to in the hope that the storm will pass the yacht quicker than her leeway will move her near to the storm's center.

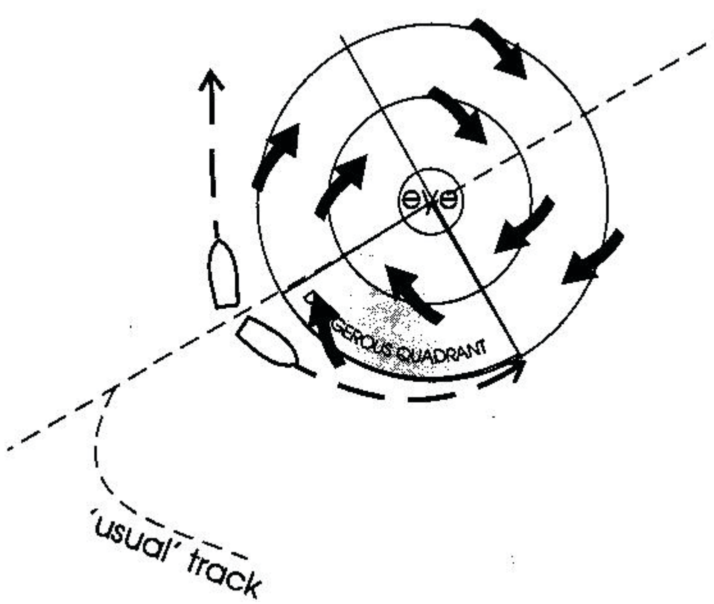
If it finally becomes necessary to run before the wind the yacht's progress must be slowed as much as possible to try to ensure that the center of the storm will have passed before the yacht reaches the storm's center line.



Avoiding action if a TRS is approaching in the northern hemisphere.

The boat ahead of the navigable semicircle has a free wind to run/ reach away from the approaching storm center with the wind on her starboard quarter. This track will also take her away from the storm center if the storm recurves.

The boat ahead of the dangerous quadrant has to decide whether she can run before the wind and reach the navigable semicircle before the center of the storm passes over her; if she does not have sufficient time to do this she must sail as close to the wind as possible for as long as the physical conditions allow in order to increase her distance from the storm center. As the wind and seas increase she may well have to heave-to or lie ahull or to a sea anchor, the aim then being to reduce the leeway to the minimum in the hope that the center of the storm will pass before the boat drifts into the storm center. Her other problem is that if she does manage to beat to windward away from the storm's center she is increasing the possibility of the storm passing over her again if it recurves.

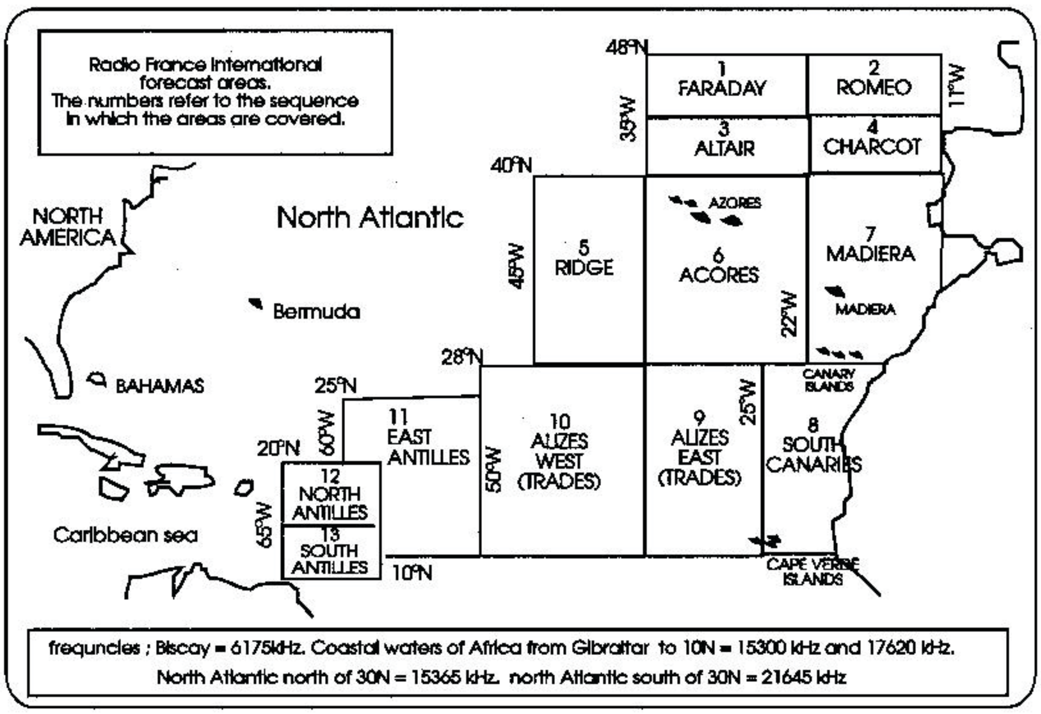


Avoiding action if a TRS is approaching in the southern hemisphere.

Radio warnings
Radio warnings of the existence of a TRS and forecasts of its track may be available in some areas. WWV Radio for example transmits TRS warnings for the north Atlantic on 2.5, 5, 10 and 20 MHz at 8 to 10 minutes past the hour. Details of the radio frequencies and times of warning broadcasts are in Worldwide Marine Weather Forecasts in the USA (Admiralty List of Radio Signals in the UK).

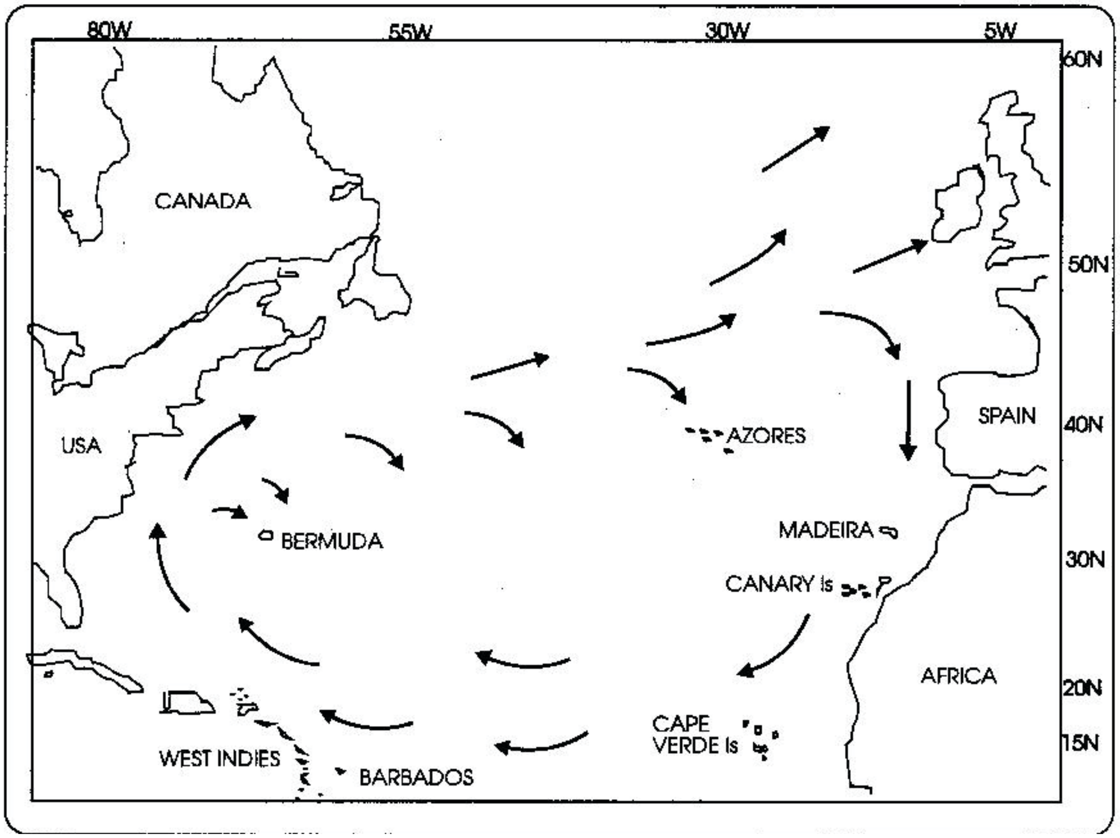
Weather forecasts
Forecasts in English are broadcast from Horta in the Azores at 0930 UT on 514.5 kHz, 3618.5 kHz and 13067kHz and at 2130 UT on 514.5 kHz, 3618.5 kHz and 6331 kHz.

Forecasts for a large area of the north Atlantic, including the tradewinds route from the Canaries to the Caribbean, are covered by forecasts in French transmitted by Radio France International (RFI) at 1138 UT. See Fig. 15.4 below. Non French speakers can use a tape recorder and dictionary to translate the basics easily enough. Trudy's maritime mobile Ham net relays an English translation at around 1300 UT on 14.300 MHz.



Hurricane warnings .
Obviously a radio receiver capable of receiving the required frequencies must also be aboard. Weather fax receivers are self explanatory and the imminent availability of world-wide e-mail reception and transmission could well prove of great use. Storm Alerts are given on local radio and TV in the Caribbean.

Another radio net, run by David Jones, transmits Caribbean weather with extra transmissions during the hurricane season. Schedules are 1215-1230 UTC on 4003 kHz USB, 1230-1300 UTC on 8104 kHz USB, and 2215-2245 UTC on 8107 kHz USB for hurricane information. The US Coastguard station MMN, amongst others, gives Caribbean coverage. Web sites: National Hurricane Prediction Center www.nhc.noaa.gov/ National Data Buoy Center www.ndbc.noaa.gov/ National weather Service Homepage www.nws.noaa.gov/ Marine weatherfax charts weather.noaa.gov/fax/gulf.shtml
Sources: The American Practical Navigator, by Nathaniel Bowditch



Sketch showing the general direction of ocean currents of the North Atlantic.

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