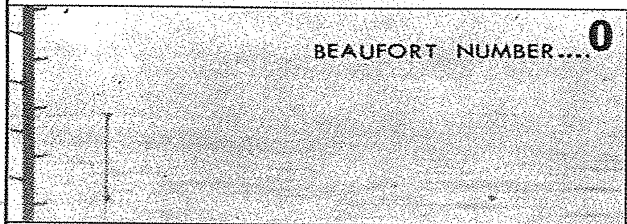
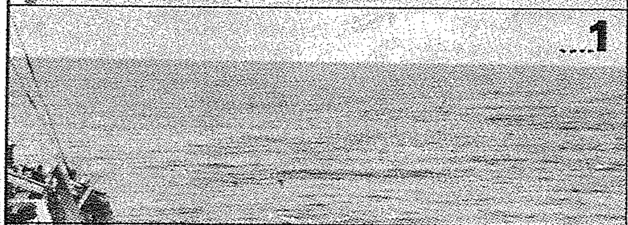
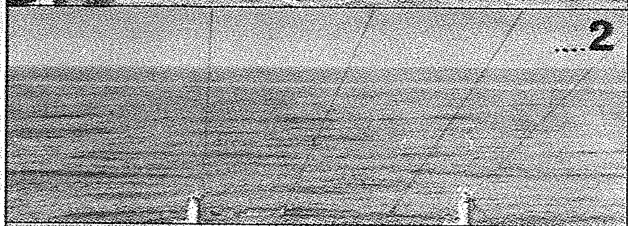
Chapter 20

METEOROLOGY
(Weather)

BEAUFORT WIND SCALE

	Mean wave height in metres
	CALM 0-1 KTS Sea like a mirror.
	LIGHT AIR 1-3 KTS. O.1 WAVES Ripples with appearance of scales; no foam crests
	LIGHT BREEZE 4-6 KTS. 0.2 WAVES Small wavelets; crests of glassy appearance, not breaking.
	GENTLE BREEZE 7-10 KTS. 0.6 WAVES Large wavelets; crests begin to break; scattered whitecaps.
	MODERATE BREEZE11-16 KTS. 1.0 WAVES Small waves, becoming longer; numerous whitecaps
	FRESH BREEZE 17-21 KTS. 2.0 WAVES Moderate waves, taking longer form, many whitecaps; some spray.

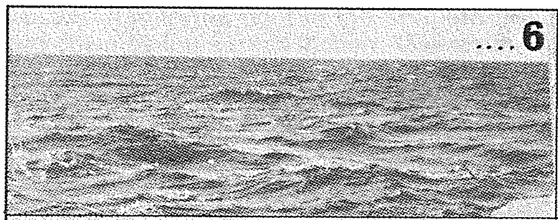
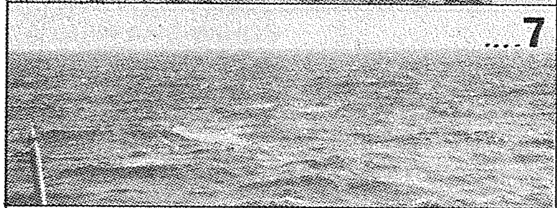
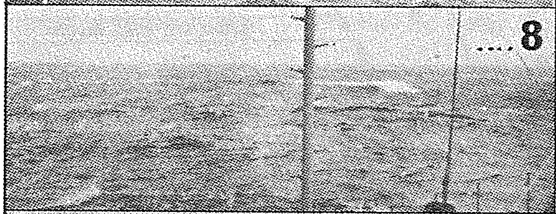
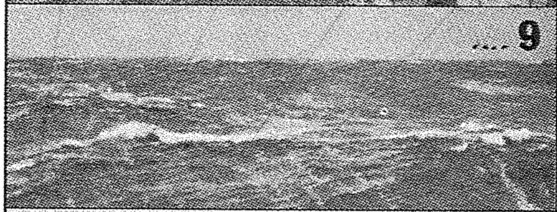
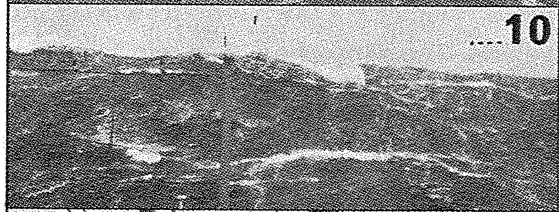
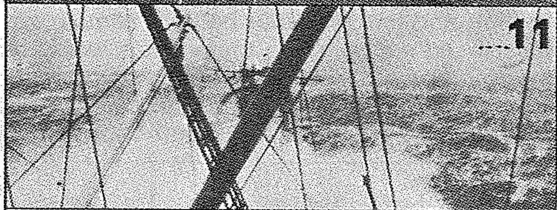
	STRONG BREEZE 22-27 KTS. 3.0 WAVES Larger waves forming, whitecaps everywhere, more spray.
	NEAR GALE 28-33 KTS. 4.0 WAVES Sea heaps up, white foam from breaking waves begins to be blown in streaks.
	GALE 34-40 KTS 5.5 WAVES Moderately high waves of greater length, edges of crests begin to break into spindrift, foam is blown into well-marked streaks.
	STRONG GALE 41-47 KTS. 7.0 WAVES High waves, sea begins to roll, dense streaks of foam, spray may reduce visibility..
	STORM 48-55 KTS. 9.0 WAVES Very high waves with overhanging crests, sea takes white appearance as foam is blown in very dense streaks, rolling is heavy and visibility reduced.
	VIOLENT STORM 53-64 KTS. 11.5 WAVES Exceptionally high waves, sea covered with white foam patches, visibility still more reduced.
	HURRICANE 64-71 KTS. 14.0 WAVES Air filled with foam, sea completely white with driving spray, visibility greatly reduced.

Fig 20.1: BEAUFORT WIND SCALE (It expresses wind strength & wave height with a single numeral)

You don't have to memorise each Beaufort wind scale. Get a general idea. Looking at the scale, you will notice that:

- Zero is for calm
- Scale 2-6 is for breezes
- 7-9 is for gales
- 10-12 is storms and hurricane.

Furthermore, the Beaufort scale can be converted into average wind speed in knots as follows:

- Up to Force 8, multiply the scale by 4
- Above force 8 multiply it by 5

For example, Beaufort Scale 6 = a wind speed of 6 x 4 = 24 knots. Also, don't confuse wind speed in knots (nautical miles per hour) with kilometres per hour. 1 knot = approx. 1.8 km/h. (It is roughly double) Therefore, Force 8 = gale force winds = wind speed 40 knots or 80 km/h.

AIR MASSES, ATMOSPHERE, CLIMATE ZONES, PRESSURE BELTS & TRADE WINDS

The earth's atmosphere is an ocean of air. Technically the atmosphere is said to extend out to 100 kilometres from the earth's surface. However, on average, the ocean of air is only about 8 kilometres deep over the poles and 16 kilometres deep over the equator. It is known as the troposphere, and its upper boundary is called the tropopause. Above it is the stratosphere. We live at the bottom of the atmosphere. The polar air is cold and dense. Its sinking character exerts high atmospheric pressure. The tropical air is warm, light and rising. The atmospheric pressure in the tropics is therefore low. The atmospheric pressure also falls with height, from about 1000 hPa at the surface of the earth to about 200 hPa at the tropopause.

Warm tropical air rises all the way to the top of the troposphere and then moves off towards the poles. Some of it sinks along the way to create different pressure zones. Cold air at the poles sinks and moves down towards the equator. These cycles of rising and falling air and, due to earth's rotation, the swirling movement of air masses of various densities, temperatures and humidity give shape to a variety of climates on earth.

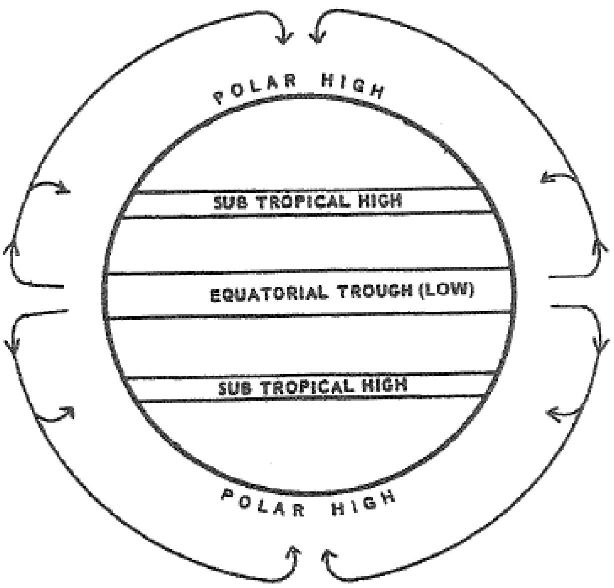


Fig 20.2: ATMOSPHERIC WIND CIRCULATION

The sun does not warm the earth uniformly. The wind too is obstructed from blowing uniformly by the mountains. The atmosphere thus remains in constant turbulent motion. Air masses (bodies of air) measuring thousands of kilometres across are heated or cooled as they pass over land or oceans. The air masses that form over the oceans are called "maritime", and those that form over the land are called "continental". Thus an air mass can be polar maritime, tropical maritime, polar continental or tropical continental.

The prevailing wind directions, called Trade Winds since the days of the old sailing ships, can best be understood by looking at the globe in bands of alternating high and low pressure belts or climate zones. The winds blow from high-pressure belts to low-pressure belts. If the earth did not spin, the trade winds would blow in the north or south direction. However, the spin of the earth makes the wind appear deflected by up to 45 degrees from the north south axis. Imagine firing a canon from the South Pole towards Sydney. By the time the canon ball reaches where Sydney was supposed to have been, the earth has spun around by a few degrees and Sydney has moved to the right. The canon ball lands somewhere in Western New South Wales, appearing to have deflected to the left. Had we fired it somewhere in the Northern hemisphere it would have appeared to deflect to the right. This is because if a globe were seen to be spinning anti-clockwise when viewed from the top, it would appear to spin in the opposite direction (clockwise)

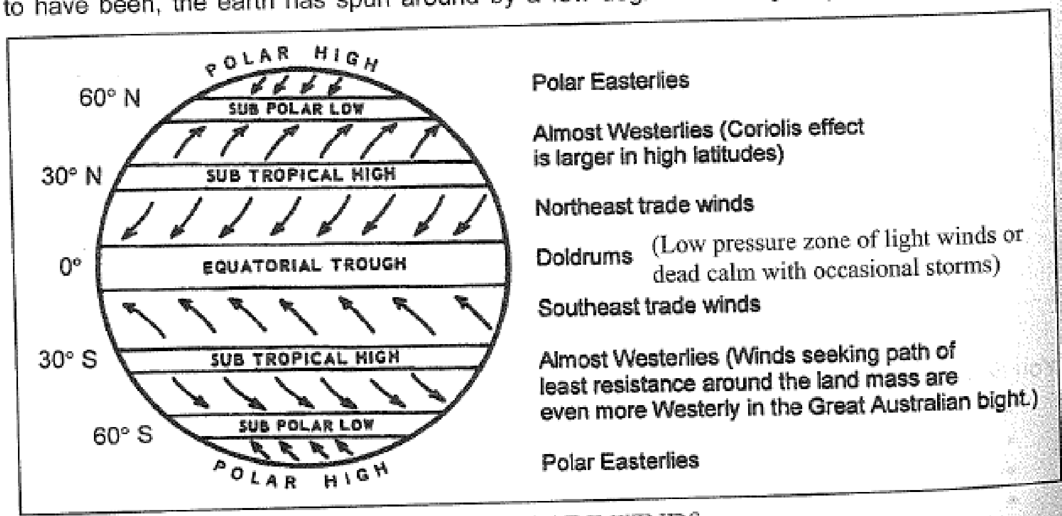


Fig 20.3: TRADE WINDS

when viewed from the bottom. This deflection is known as the **CORIOLIS EFFECT**, which is zero at the equator and maximum at the poles. It is to the right in the northern hemisphere and to the left in the southern hemisphere. The wind is also slowed down by the earth's friction. The resultant spiralling movement of wind in the southern hemisphere is clockwise into low-pressure centres and anti-clockwise out of high-pressure centres. It is in reverse in the northern hemisphere.

In the short flight of a football or a cricket ball, the Coriolis effect is insignificant. However, if aircraft pilots did not make navigational corrections for the Coriolis effect, they would land at wrong airports; and uncorrected artillery shells would destroy wrong targets.

GEOSTROPHIC & SURFACE WINDS

Geostrophic winds are largely driven by temperature differences, i.e., pressure differences. Using weather balloons and such implements, these winds are measured at an altitude of about 1 kilometer above the ground, i.e., outside the effects of friction due to the earth's surface.

Surface winds are measured within 100 metres above the ground (10 metres above the sea surface). Their direction and speed are influenced by the Coriolis force as well as friction due to the earth's surface. Mariners are mostly concerned with surface winds, which may be estimated from the following table when used with a weather map.

SURFACE WIND SPEED IN KNOTS FROM 4-HPa ISOBAR SPACING
(David Burch, STARPATH, USA)

	Isobar spacing in degrees of latitude													
Latitude	0.5°	1°	1.5°	2°	2.5°	3°	3.5°	4°	4.5°	5°	6°	8°	10°	12°
10°	288	144	96	72	58	48	41	36	32	29	24	18	14	12
15°	193	97	64	48	39	32	28	24	21	19	16	12	10	8
20°	146	73	49	37	29	24	21	18	16	15	12	9	7	6
25°	118	59	39	30	24	20	17	15	13	12	10	7	6	5
30°	100	50	33	25	20	17	14	12	11	10	8	6	5	4
35°	87	44	29	22	17	15	12	11	10	9	7	5	4	4
40°	78	39	26	19	16	13	11	10	9	8	6	5	4	3
45°	71	35	24	18	14	12	10	9	8	7	6	4	4	3
50°	65	33	22	16	13	11	9	8	7	7	5	4	3	3
55°	61	31	20	15	12	10	9	8	7	6	5	4	3	3
60°	58	29	19	14	12	10	8	7	6	6	5	4	3	2
65°	55	28	18	14	11	9	8	7	6	6	5	3	3	2
70°	53	27	18	13	11	9	8	7	6	5	4	3	3	2
75°	52	26	17	13	10	9	7	6	6	5	4	3	3	2

Fig 20.4

NOTES:

1. The table assumes the isobars are straight. For curved isobars, the wind speed will be up to 30% less around a Low and up to 30% greater around a High - depending on the radius of the isobar curvature.
2. The table assumes the surface wind is 65% of the geostrophic wind. With units conversions and numerical approximations, the equation used for the table results reduces to:
   Winds = 25/[sin (Lat) x spacing].
3. Set dividers across 4-HPa separation and transfer to Lat scale to measure spacing from a weather map, showing both isobars and latitude scale.
4. **Example**: If at latitude 45° the 4-HPa isobars are 120 nautical miles apart (2°), then the expected surface wind is 18 knots, directed anticlockwise around the high pressure, pointed 10° to 30° out of the High, or clockwise around a Low, pointed 10° to 30° into the Low - the angle being smaller over water than over land.
5. Wind gusts can be up to 40% more than the average wind speed.

The southeasterly trade winds over Australia are the result of air moving from the "calm sinking air" sub-tropical high-pressure belt to the "thundery rising air" equatorial low-pressure belt.

Countries in the calm sinking-air high-pressure belt (such as Australia) generally enjoy better climate than those in the changeable rising-air low-pressure belt (such as northern Europe). The sinking air generally creates dry and settled weather in the high-pressure belts. It tends to compress and evaporate any clouds. In the low-pressure belts, on the other hand, the rising air cools in the upper atmosphere and condenses into clouds, resulting in disturbed weather conditions. The bad weather is further fuelled by air masses of varying characteristics moving in from the adjacent high-pressure belts to replace the rising air.

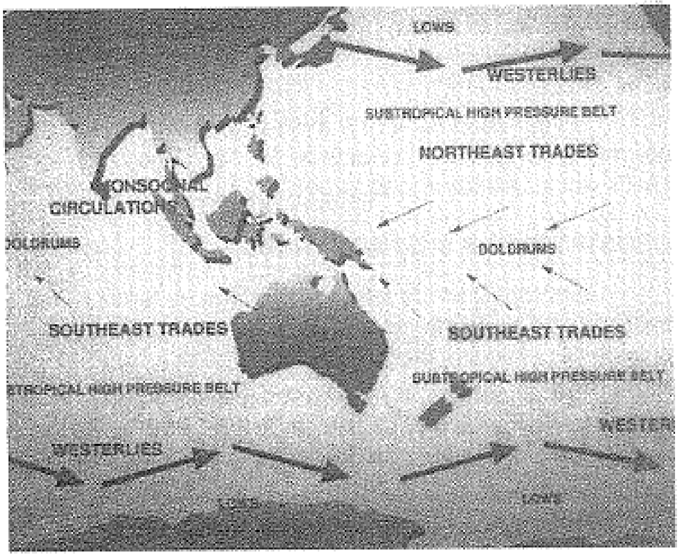


Fig 20.5

The equatorial trough or the Inter-tropical Confluence (ITC), also known as the Inter-tropical Convergence Zone (ITCZ) - which is like the weather equator - moves northwards or southwards with the sun during the year. Thus the summer months in Australia (particularly the tropical part) experience a lower atmospheric pressure than the winter months.

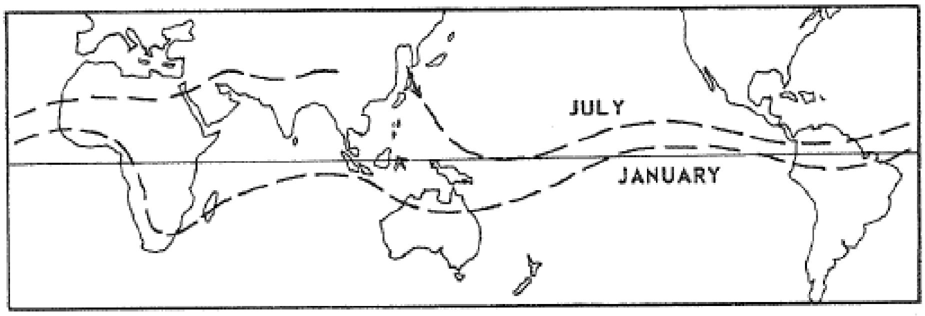


Fig 20.6: THE LOCATION OF ITC IN WINTER AND SUMMER

The movement of ITC causes the global pressure belts to move with it, which results in the difference in the winter and summer winds. In our summer the equatorial low pressure belt moves southwards over Australia, which moves the sub-tropical high pressure belt from overland Australia to the south of the continent. The Southeast Trade winds too move about 10° southwards and can be experienced as low as in 30°S latitude. The northern part of Australia experiences a cyclone and a monsoon season

In our winter the opposite happens. The sub-tropical high-pressure belt moves back over the continent, where it is reinforced by the cooler land mass. The changeable "rising air" low-pressure belt also moves up to the south of the continent, where it gives rise to a series of lows and strong westerlies.

The above seasonal changes must not be confused with the local day-to-day weather patterns such as sea and land breezes and thunderstorms.

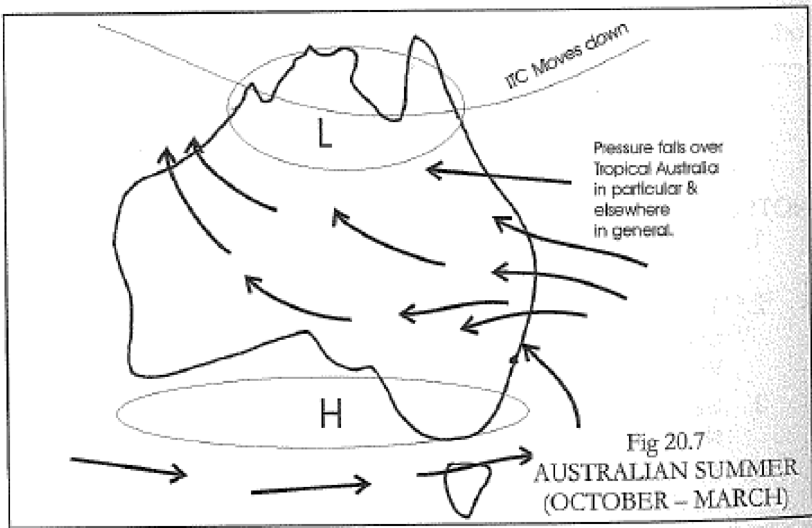


Fig 20.7
AUSTRALIAN SUMMER
(OCTOBER – MARCH)

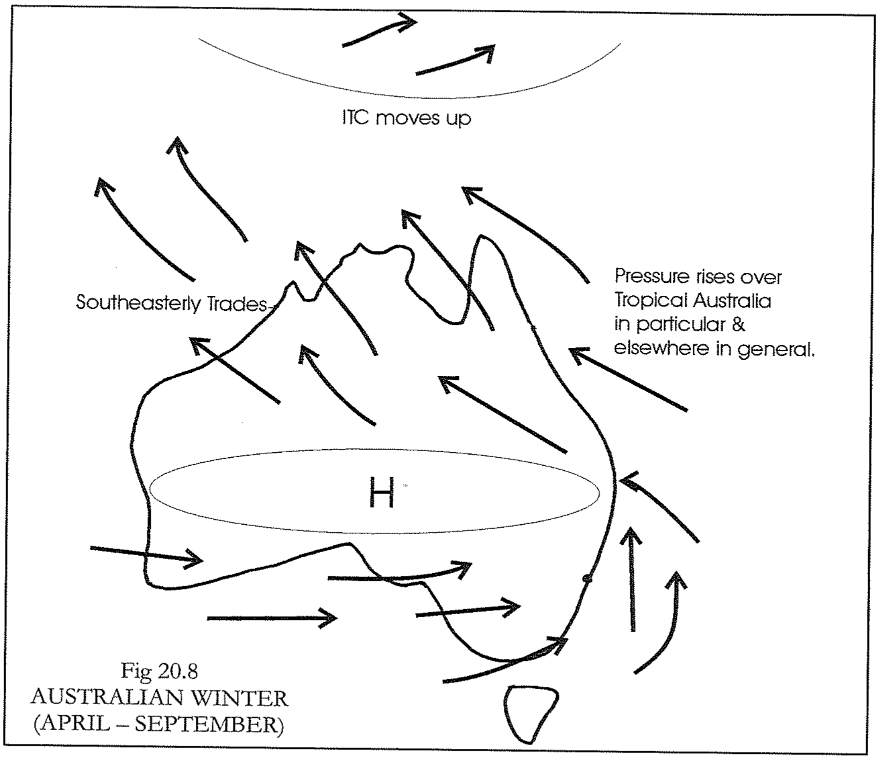


Fig 20.8
AUSTRALIAN WINTER
(APRIL – SEPTEMBER)

BAROMETER

Barometer measures atmospheric pressure, which is the force exerted by the earth's atmosphere. It can be thought of as the weight of air.

By indicating the atmospheric pressure, the rise or fall in it and the amount and speed (rate) of such a change, a barometer helps us to forecast weather.

There are two types of mechanical barometers: mercury-filled and aneroid. The former is found only in the meteorological offices and laboratories. It is not as convenient an instrument as the aneroid barometer. In addition, there are electronic barometers, either in the form of wristwatches or 'stand alone' instruments. A pressure sensing electronic component inside these instruments measures the pressure. They are relatively cheap and usually more accurate than the aneroid barometers.

Inside an aneroid barometer is a closed sealed capsule with flexible sides (marked "A"). Any change in pressure alters the thickness of the capsule. A set of levers is fitted to magnify these changes, causing a pointer to move on a dial or numbers to change on a digital readout device.

The capsule must be kept exposed to the air pressure that it is designed to measure. To prevent the air passages on the back of the barometer becoming sealed with paint, you must remove the instrument before painting the bulkhead.

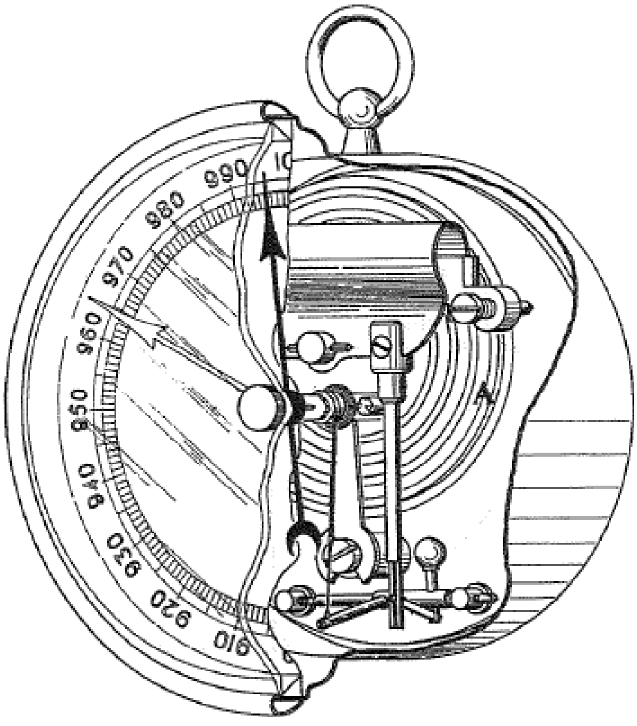
The barometric pressure is measured in hectoPascals (hPa). The term "millibar" is the old name for hectoPascal.

A barometer should be installed in a well-ventilated dry position away from the weather and direct sunlight. It should be securely fastened to a vertical bulkhead where it is safe from physical damage and easily readable.

An aneroid barometric reading is subject to two errors: index error (instrument error) and the height above the sea. The barometer correction for the index error, if any, can be checked by calling a Coast Radio Station (Maritime Coast Station). It doesn't matter if you are 20 or 30 miles away from the station.

A barometer can be corrected for the index error by turning a screw that is usually fitted at the back of the instrument. Small vessels usually don't need to worry about the correction for the height above the sea, unless the instrument is fitted on a high flying bridge. **Pressure falls 1 hPa for every 10 metres of height**. The mercury barometers also need to be corrected for latitude and temperature.

A barometer, which is uncorrected, is good enough to indicate a change in weather. The direction of change in pressure (its fall or rise) and the rate of change (amount of fall or rise in a period) are all indications of the expected weather.



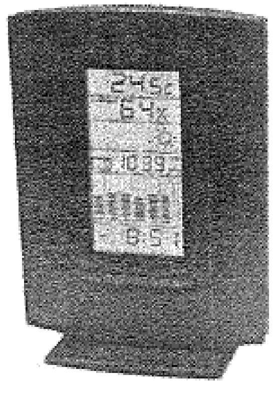


Fig 20.9: (Left): THE ANEROID BAROMETER
("A" is the closed sealed capsule)
(Handbook of Meteorological Instruments, Meteorological Office, London)

Fig 20.10 (Above): ELECTRONIC BAROMETER–CUM-HYGROMETER *(Dick Smith)*
(Battery-operated display of temperature, humidity, barometric pressure, barographic record & time)

A ROUGH GUIDE TO FALL IN PRESSURE & WIND STRENGTH
(Corrected for diurnal variation, mentioned below)

3 hPa fall in 3 hours	Strong to gale-force winds within 6 to 12 hours
6 hPa fall in 3 hours	Gale force winds within next 6 hours
9 hPa fall in 3 hours	Gale to storm-force or stronger winds within 3 hours

Before reading a barometer, tap the glass lightly but firmly to make sure that linkages are not sticky. After reading it, turn the set hand by the knob at the centre of the glass so that it covers the reading hand. This will help you to see at your next reading whether the pressure has risen or fallen and by how much.

A good mariner enters the barometer readings in the logbook every 3 hours in normal weather and more frequently on indication of poorer weather. Some vessels carry a BAROGRAPH. In a mechanical barograph, a pen attached to a barometer traces changes in atmospheric pressure on a 7-day graph paper wrapped around a clockwork driven drum.

Many of the electronic barometers are also barographs. The atmospheric pressure history can be accessed at any time.

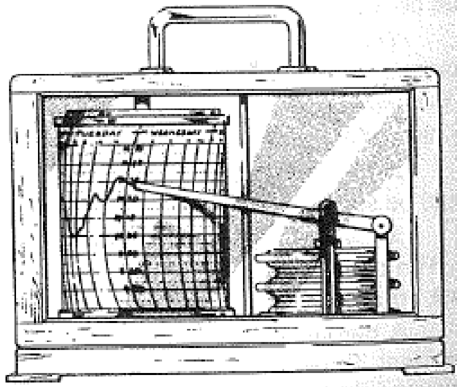


Fig 20.11: BAROGRAPH

DIURNAL CHANGES IN BAROMETRIC PRESSURE

The word "diurnal" means daily cycle or occurring everyday. Unaffected by any change in weather, the barometer rises from 0400 to 1000 then falls until 1600. It then rises till 2200 when it once more falls until 0400. These times are approximate and are in Local Mean Time of the place.

These changes result from atmospheric pressure waves that sweep regularly around the earth from east to west. The effect is maximum at the equator where the variation is about 3 hPa. At latitude 51° the range is about 0.8 hPa. In higher latitudes it is inappreciable. To avoid mistaking the diurnal change for a change in weather, observations should be made over 24 hour periods.

Atmospheric pressures vary throughout the world and between seasons. It is therefore incorrect to print "fair", "rain" and "change" on a barometer's face based on one set of pressures.

WEATHER TERMINOLOGY & DEFINITIONS

WEATHER FORECASTS: Most national weather services and their cooperative observing networks of selected ships, aircraft, airports, weather balloons, drifting buoys and farmers make weather observations at least every 3 hours. The weather forecasts are complied from the 6-hourly observations, together with the information received from weather satellites and the historical data stored in the computer. The internationally agreed hours of observations are 0000, 0600, 1200 & 1800 UTC (GMT).

The reports are then produced to describe the *SIGNIFICANT WEATHER* expected to occur in the forecast period, which is not description of the worst weather condition but the average of the one-third of the worst conditions. The high seas weather reports are given in UTC. The worldwide radio weather broadcast system is detailed in the Admiralty List of Radio Signals, Volume 3.

SYNOPTIC CHART: Weather map. (Figures 20.33 & 20.34)

WIND DIRECTION & SPEED: Wind direction is given in 16 compass points and is the direction the wind is coming from. The direction of waves (not swell) is the true wind direction. The direction of a telltale on a shroud or of a flag or funnel smoke or the direction indicated by a wind-measuring instrument such as shown in Fig. 17.17 indicates the relative or apparent wind direction. It is relative to the direction of ship's motion and of the true wind.

Wind speed (in knots) refers to the average speed over a 10-minute period at a height of 10 metres above the surface. One knot = 1.85 km/h (roughly 1 knot = 2 km/h).

It is important to note that weather observations and forecasts provide only the average wind direction and speed. The wind can gust up to 40% more than the average wind speed.

GUST: Gust is a sudden increase in wind strength of very short duration, usually a few seconds. It can be up to 40% stronger than the average speed.

SQUALL: A squall is a sudden and often violent increase in wind speed that lasts for at least one minute. It may include many gusts and a change in wind direction, usually blowing at twice the speed of the wind that will follow. It can come with rain or snow. A heavy rainsquall can flatten the sea, at times.

WAVES, FETCH & SWELL: Waves are created by wind passing over the water surface. Wave height is the vertical distance between the top of the crest and bottom of trough. The significant wave (or swell) height stated in a weather report or forecast is the average of the highest one-third of the waves (See below). Some waves will be higher and some lower than the significant height. Typically one in 2000 waves will be twice this height *(See NSCV definition below).*

Sometimes, wind waves and/or swell waves join to produce a very high wave. This is known as the KING, FREAK or ROGUE WAVE. Such a wave is much higher than the significant wave height.

The length of water over which the wind blows is known as the FETCH. The stronger the wind and longer the Fetch, the bigger the waves become. Wind blowing over water first develops 'sea' waves. If the wind blows for a long time, these sea waves join together to form 'swell' waves, which often have enough energy to travel thousands of miles over a number of days until they break on the shore. Sea and Swell waves can occur at the same time, often coming from different directions.

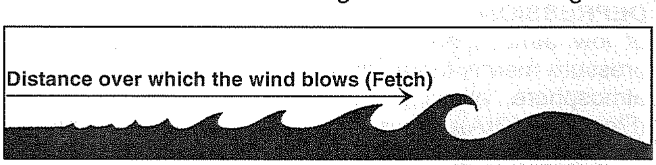


Figure 20.12: FETCH

SIGNIFICANT WAVE HEIGHT *(defined in NSCV Part B):* It is the mean value of the highest one third of the heights measured from trough to crest recorded in a wave time history.
(Note: It is probable that one in every 1000 waves will have a height at least 1.86 times the significant wave height.)

LINE SQUALL (SQUALL LINE): Thunderstorms in a cold front are forced into forming a long narrow band. The forward edge of this formation is known as the Line Squall or squall line. It can be 10-15 miles wide and up to a hundred miles long. See Thunderstorms.

VISIBILITY: The only correct way to measure visibility at sea is by measuring the radar distance of an echo that has just become visible. Fog and Mist are defined below.

CLOUDS: Cloud cover is expressed in the eighths of the sky, such as 1/8th, 2/8th, etc. If the clouds cover 50% of the sky, it is a 4/8th cover. An overcast sky is an 8/8 cover.

According to the Howard system of 1803 still in use, clouds are divided into three categories based on the height of the bottom (base) of the cloud, even though these heights vary considerably between latitudes. Forecasting weather from clouds is far from accurate.

Low Clouds: their bases are less than 2 km above the horizon. The typical puffy looking Cumulus clouds (Cumulus meaning heap or puffy in Latin) can be quite tall, but their bases remain low. A tall cumulus cloud can, at times, become a cumulonimbus (Nimbus is Latin for rain) or thunderstorm cloud at times. A cumulonimbus is tall with a cauliflower shape and distinctive anvil top.

Medium Clouds: their bases are between 2 and 6 km above the horizon, such as Alto Cumulus and Alto Stratus clouds (Stratus is Latin for layer). They are associated with unstable weather ahead of a cold front.

High Clouds: their bases are over 6 km above the horizon. Cirrus (meaning curls of hair in Latin) are the most common high clouds. They are white thin fibrous ice clouds, thin enough to allow the sun or moon to shine through. No rain falls from them.

(NOTE: For more detailed cloud types, a cloud chart should be consulted.)

SHOWERS: Meteorologically speaking, only the rain from cumulus clouds is referred to as showers, whether it is periods of light intermittent rain or torrential downpours of heaviest rains on record.

PRESSURE: As discussed above, atmospheric pressure is the force exerted by the earth's atmosphere. It can be thought of as the weight of air. A high pressure is usually associated with good weather and a low pressure with poor weather.

In southern hemisphere, wind blows CLOCKWISE spirally around a LOW, making its way inwards towards the lowest pressure at the centre; and it spirals ANTI-CLOCKWISE outwards around a HIGH, away from the highest pressure at the centre.

Reverse for the northern hemisphere. In the Southern Hemisphere, wind rotates clockwise around a cyclone (low) and anti-clockwise around an anticyclone (high). It is the reverse in the Northern Hemisphere.

ISOBARS & PRESSURE GRADIENT: An isobar is a line on a weather map that joins places having the same atmospheric pressure. By examining the spacing between isobars (known as pressure gradient) we can get an idea of the direction and strength of wind. Isobars closer together means steeper pressure gradient, which means stronger wind in the direction parallel or nearly parallel to the isobars. (Figures 20.13)

GRADIENT WIND: Wind resulting from the pressure gradient (assuming no friction). It blows parallel to isobars, clockwise around the Lows and anticlockwise around the Highs.

DEPRESSION: Another name for a low-pressure area, which is an area of low atmospheric pressure within a closed system of isobars. Low pressure means the air is light so it will rise from its centre into the upper atmosphere, allowing more surface air to flow in towards its centre. (Figure 20.13(A)). Lows quite readily disperse moisture and pollution from the earth's surface, giving rise to clouds and strong winds.

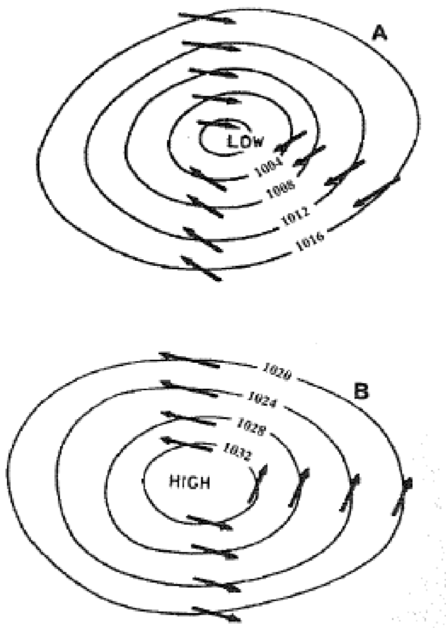


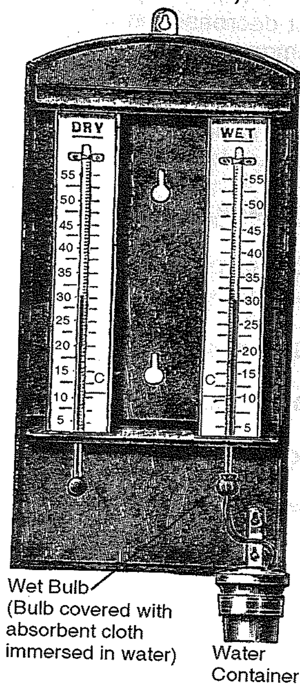
Fig 20.13
(A) A LOW, DEPRESSION OR CYCLONE
(B) A HIGH OR ANTICYCLONE
(Both in the southern hemisphere)

TROPICAL DEPRESSION / CYCLONE / TROPICAL CYCLONE: It is a Low originating in tropics. These are the Lows that sometimes deepen and become cyclones as they travel away from the equator. The signs of an advancing depression or a cyclone are the same - only the severity may differ. Cyclones are discussed in more details below.

ANTICYCLONE: Another name for a high-pressure area, which is an area of high atmospheric pressure within a closed system of isobars. High pressure means the air is heavy so it will be sinking down from the upper atmosphere to its centre, and then flowing outward on the earth's surface. (Figure 20.13(B)). Descending air does not form clouds, and the weak pressure gradient does not generate strong winds. Anticyclones do not allow water vapour and pollution from earth's surface to disperse. Fog and smog are therefore a common phenomenon in the outer regions of anticyclones.

RELATIVE HUMIDITY: Humidity is the amount of moisture in the air. Relative humidity is the comparison of how much moisture there is to how much the air could hold. A 95% humidity means the air is loaded with moisture to almost its capacity. Relative humidity is measured by a pair of "wet and dry bulb thermometers", known as the **HYGROMETER** or an electronic hygrometer (see "electronic barometer-cum-hygrometer" above), and an associated table.

HYGROMETER
(WET & DRY BULB THERMOMETERS)



HOW WET & DRY BULB THERMOMETERS & THE TABLE WORK

Water evaporating from the surface of the wet bulb cools the bulb, just as water evaporating from the surface of a human body cools the body. When the air is dry, there is greater evaporation, causing the wet bulb thermometer to record a lower temperature. The difference between the wet and dry bulb thermometers is then greater. When the air is moist, there is less evaporation, and the difference between the wet and dry bulb thermometers is smaller. Reading the table - an example: For a dry bulb reading of 30°C and the difference between the wet and dry bulb thermometers of 2°C, the Relative Humidity is 85%.

FRONT: Two air masses of different characteristics (i.e., of different temperature & moisture, etc.) do not want to mix when brought together. They thus form a front between them where they clash, generally causing bad weather. Fronts are discussed below. (Figure 20.20)

COLD FRONT: When a mass of cold air meets a mass of warm air, the cold air being heavier, pushes its way under the warm air and forces it to rise almost vertically. This can often result in violent weather for a short period of time, as discussed below. (Figures 20.20 to 20. 22)

WARM FRONT: When a mass of warm air meets a mass of cold air, the warm air being lighter, rises over it in a slope extending 300-400 miles horizontally. Its moisture content causes overcast sky and possibly rain, drizzle, fog, etc. (Figures 20.20 & 20.23)

TABLE FOR FINDING THE RELATIVE HUMIDITY (%)
(For use with Wet & Dry Bulb Thermometers)

Dry Bulb — Depression of Wet Bulb (°C)

°C	0·2°	0·4°	0·6°	0·8°	1·0°	1·2°	1·4°	1·6°	1·8°	2·0°	2·5°	3·0°	3·5°	4·0°	4·5°	5·0°	5·5°	6·0°	6·5°	7·0°	7·5°	8·0°	8·5°	9·0°
40	99	97	96	95	94	92	91	90	89	88	85	82	79	76	73	71	68	66	63	61	58	56	53	51
39	99	97	96	95	94	92	91	90	89	87	84	82	79	76	73	70	68	65	63	60	58	55	53	50
38	99	97	96	95	94	92	91	90	89	87	84	81	78	75	73	70	67	65	62	59	57	54	52	50
37	99	97	96	95	93	92	91	90	88	87	84	81	78	75	72	69	67	64	61	59	56	54	51	49
36	99	97	96	95	93	92	91	90	88	87	84	81	78	75	72	69	66	63	61	58	55	53	50	48
35	99	97	96	95	93	92	91	89	88	87	83	80	77	74	71	68	65	63	60	57	55	52	49	47
34	99	97	96	95	93	92	91	89	88	86	83	80	77	74	71	68	65	62	59	56	54	51	49	46
33	99	97	96	94	93	91	90	89	87	86	83	80	76	73	70	67	64	61	58	56	53	50	48	45
32	99	97	96	94	93	91	90	89	87	86	83	79	76	73	70	67	64	61	58	55	52	49	47	44
31	99	97	96	94	93	91	90	88	87	86	82	79	75	72	69	66	63	60	57	54	51	48	46	43
30	98	97	95	94	93	91	90	88	87	85	82	78	75	72	68	65	62	59	56	53	50	47	44	42
29	98	97	95	94	92	91	89	88	86	85	81	78	74	71	68	65	61	58	55	52	49	46	43	40
28	98	97	95	94	92	91	89	88	86	85	81	77	74	70	67	64	60	57	54	51	48	45	42	39
27	98	97	95	94	92	90	89	87	86	84	81	77	73	70	66	63	60	56	53	50	47	44	41	38
26	98	97	95	93	92	90	89	87	86	84	80	76	73	69	66	62	59	55	52	49	46	42	39	36
25	98	97	95	93	92	90	88	87	85	84	80	76	72	68	65	61	58	54	51	47	44	41	38	35
24	98	97	95	93	91	90	88	86	85	83	79	75	71	68	64	60	57	53	50	46	43	39	36	33
23	98	96	95	93	91	90	88	86	84	83	79	75	71	67	63	59	56	52	48	45	41	38	35	31
22	98	96	95	93	91	89	88	86	84	82	78	74	70	66	62	58	54	51	47	43	40	36	33	29
21	98	96	94	93	91	89	87	85	84	82	78	73	69	65	61	57	53	49	45	42	38	34	31	27
20	98	96	94	92	91	89	87	85	83	81	77	73	68	64	60	56	52	48	44	40	36	33	29	25
19	98	96	94	92	90	88	86	85	83	81	76	72	67	63	59	55	50	46	42	38	34	31	27	23
18	98	96	94	92	90	88	86	84	82	80	76	71	66	62	58	53	49	45	41	36	32	28	25	21
17	98	96	94	92	90	88	86	84	82	80	75	70	65	61	56	52	47	43	39	34	30	26	22	18
16	98	96	94	91	89	87	85	83	81	79	74	69	64	60	55	50	46	41	37	32	28	24	20	16
15	98	96	93	91	89	87	85	83	81	78	73	68	63	58	53	49	44	39	35	30	26	21	17	13
14	98	95	93	91	89	86	84	82	80	78	72	67	62	57	52	47	42	37	32	28	23	18	14	10
13	98	95	93	91	88	86	84	81	79	77	71	66	61	55	50	45	40	35	30	25	20	16	11	6
12	98	95	93	90	88	86	83	81	78	76	70	65	59	54	48	43	38	32	27	22	17	12	8	3
11	97	95	92	90	87	85	83	80	78	75	69	63	58	52	46	41	35	30	25	19	14	9	4	
10	97	95	92	90	87	84	82	79	77	74	68	62	56	50	44	38	33	27	22	16	11	5		

Fig 20.14 (A & B): HYGROMETER & RELATIVE HUMIDITY TABLE

OCCLUDED FRONT: An occluded front is a combination of a warm and a cold front. Occlusion occurs when a faster moving cold front catches up with a warm front. It pushes the warm air mass off the ground, which becomes wedged between the two cold air masses. (Figure 20.23A)

The rising warm air is likely to produce cloud and rain. But, as the depression becomes surrounded by cold air, it decreases in intensity. The resultant weather is often similar to that of a warm front. Occluded fronts are not common in Australia.

COL: A region between diagonally opposed two Highs and two Lows. It is a no-person's land. The wind may blow from any direction and any type of weather can be expected. The centre of a Col is associated with very light and variable winds, and fog in colder months.

STORM SURGE: Read the effect of weather on tides in Chapter 17.3.

FOG: Suspension of very small water droplets in the air, reducing visibility - a form of low clouds. In a cloud, when the horizontal visibility is less than 1000 metres then technically we are in fog conditions.

MIST: Less dense fog -Horizontal visibility greater than 1000 metres.

RIDGE: Elongated area of high pressure extending out from a High.

TROUGH: Elongated area of low pressure, extending south from a Low.

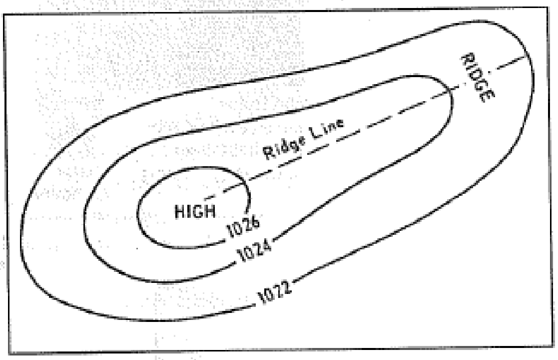


Fig 20.15: A RIDGE OF HIGH PRESSURE

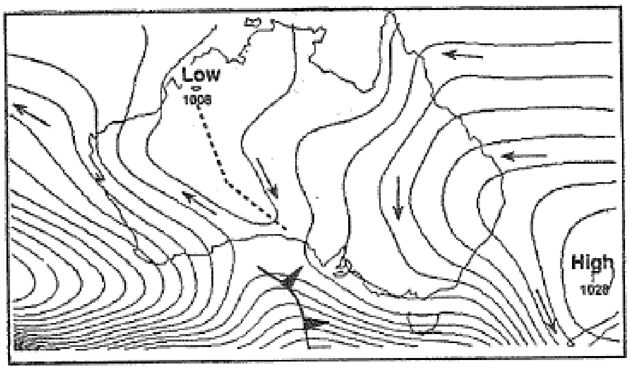


Fig 20.16: A TROUGH OF LOW PRESSURE
(The dotted line)

WEATHER FORECASTS & WARNINGS

(See last two pages of this book for the Bureau of Meteorology's weather service by phone, fax, radio and Website address)

- Boating weather information on the Bureau of Meteorology's State-wise phone numbers – see back page of the book.
- Routine coastal waters forecasts and observation reports for areas within 60 nautical miles of the coast are issued twice daily via marine radio and Inmarsat. However, these are liable to be amended anytime.
- Coastal warnings are issued via marine radio and Inmarsat whenever strong winds, gales, storm-force or greater winds are expected, and are renewed every 6 hours.
- Routine high seas forecasts are issued twice daily via marine radio and Inmarsat for the areas beyond the coastal waters surrounding Australia.
- High seas warnings are issued via marine radio and Inmarsat whenever gale, storm-force or greater winds are expected, and are renewed every 6 hours. (See NAVAREA X warnings in Chapter 12 & AUSCOAST warnings in Chapter 18).

RADIO WIND WARNINGS PREFIXED BY SECURITÉ (SAFETY MESSAGE)

- Strong Wind Warning (for coastal waters only): Winds 25 – 33 knots (Beaufort Force 6 - 7)
- Gale Warning: Winds 34 - 47 knots (Beaufort Force 8 - 9)
- Storm Warning: Winds exceeding 47 knots (Beaufort Force 10 - 11)
- Hurricane Warning (for tropical high seas only): Winds exceeding 63 knots (Beaufort Force 12)

Note: the speed ranges quoted above are average. Wind gusts can be up to 40% stronger.

WHEN TO LISTEN TO WEATHER FORECASTS

You should listen to weather forecasts on radio:

- While in port and before departure
- At sea: to the regular schedule weather reports & forecasts
- When there are signs of approaching bad weather as well as during bad weather

THUNDERSTORMS

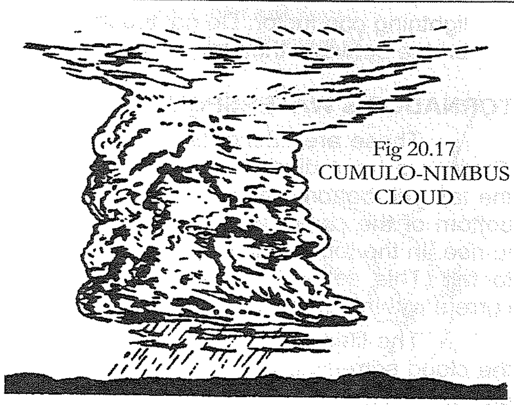


Fig 20.17
CUMULO-NIMBUS CLOUD

Thunderstorms can be a serious hazard for small vessels. They usually produce strong gusty winds that blow out from the front of the storm. In general, they are local storms produced by Cumulo-nimbus clouds. (Cumulus means 'heaps', i.e., clouds piled up on each other. Nimbus means rain bearing.) These are the grey towering clouds that you sometimes see on the horizon. The clouds often move in different directions to the wind at the surface. If you observe that clouds will pass over or within a few miles of your position, you should head for shore.

The lightning is a discharge of electricity between cloud and ground (or sea) or between clouds. The thunder is due to the rapid expansion of atmospheric gases in the path of a lightning strike. The lightning and thunder occur at the same time, but we see the flash before hearing the thunder. It is because the light travels faster than sound. A 5 second interval between the flash and sound indicates that the lightning struck at a distance of approximate 1 mile. This relationship is constant and can be used for general calculations, as long as the flash and the thunder are from the same source.

A cumulus (cotton wool appearance) cloud growing larger and larger is the main danger signal of a developing thunderstorm. Static crashes on the AM radio receiver are also a good early indication. The cloud will eventually develop four distinct features. (Some of these may not be visible, being blocked by other clouds):

- The top of the cloud is shaped like an anvil. *[The "anvil" is made up of ice crystals due to the cloud rising above freezing level (becoming cirrus clouds)].*
- The main body is very tall with cauliflower sides.
- Roll clouds develop along the leading edge of the base. *[Caused by violent air currents]*
- A dark area extends from the base of the cloud to the ground. [It is mostly rain in the middle and hail and rain on the edges].

The direction of movement of a thunderstorm can sometimes be estimated from the direction of the 'anvil' on top of the thunderstorm cloud. The storm usually moves in the direction in which the 'anvil' is pointing.

The thunderstorm weather is usually showers, possibly with hail, thunder and lightning; and occasionally strong squally winds and rough seas. It consists of abrupt fluctuations of pressure, temperature and wind.

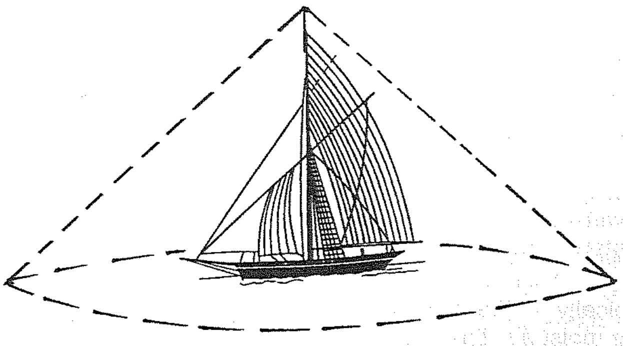


Fig 20.18: LIGHTNING CONDUCTOR
(The higher the conductor, the greater the area of protection)

PROTECTION AGAINST ELECTRICAL STORMS

An electrical storm can upset the vessel's compass; burn out equipment such as radio and radar. These should be switched off. It can also cause fire on board due to lightning. You don't often hear of boats being struck by lightning, but it can happen. It is advisable to rig a lightning conductor on the vessel. A properly rigged conductor will provide 99.9% protection. The greater the height of the conductor (or the lightning protective mast), the greater the area of protection around it. It protects a conical area of a radius equal to its own height above the water.

The following information is based on the Safety Standard E-4 of the American Boat & Yacht Council:

- The conducting wire or the copper strip should be of a suitable gauge (#8 gauge for wire and #20 gauge for copper strip). The path followed by the grounding conductor should be as straight as possible with no sharp bends. All metal objects close to the lightning conductor and large metal objects in other parts of the vessel should be connected to it. This is to safeguard against sparks and side flashes jumping from one metal to another or dangerous levels of voltage rising in them.

- Sailing vessels with metal standing rigging are adequately protected if all rigging is bonded together and grounded. A metal chain, shackled to a stay, can be hung into the water as a temporary measure. The modern fibreglass whip aerial with an internal wire conductor will not provide lightning protection. However, the older metal rod aerials, when connected to earth, can do the job.
- Whether or not a lightning conductor is fitted in a vessel, metal objects, such as spotlights, projecting through cabin tops should be solidly grounded. The submerged ground connection in non-metal hulls can be achieved via the dyna plate used for grounding the radio, the metal propeller or the metal rudder.
- For personal protection from lightning, stay inside a closed vessel. Avoid touching any item connected to the lightning conductor. Do not touch two separately grounded objects at the same time. If you do, you may become a bridge between their grounding systems. Do not immerse any part of your body in the water.

TORNADOS & WATERSPOUTS

These are offshoots of tall cumulus clouds. There is a large difference of temperature between the top and bottom ends of the cloud. The air in the bottom of the cloud, being humid and warm, starts to rise. In the top end it is cold and heavy and starts to fall. This sets off a strong vertical upward air current within the cloud.

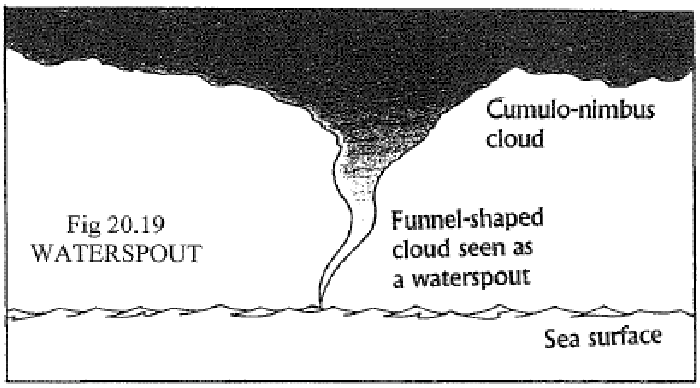


Fig 20.19
WATERSPOUT

The lifting effect thus caused at the base of the cloud sometimes sucks air from underneath the cloud. This can result in a funnel-shaped protuberance appearing at the base of the cloud growing downward toward the ground or the sea. Over the ground this whirlpool of air is called a tornado; and over the sea, in the form of sea spray, it is a waterspout. The average diameter of a tornado is about 250 metres and of a waterspout about 30 metres. At the core of the waterspout there may appear a mound of water, about 30 cm high. This is because the pressure inside the funnel can be up to 40 HPa less than its surroundings.

The waterspouts, being heavy with water, break and fall apart within about half an hour. But the tornados, once formed, may travel for long distances causing wind speeds of up to 150 knots. Their destructive effect can extend up to half a mile from the centre. They do occur in Australia as "Willie - Willies", but those in the southern states of the USA are known to cause greater destruction.

FRONTS

Two air masses of different characteristics (i.e., of different temperature & moisture, etc.) do not want to mix when brought together. They thus form a front between them where they clash, causing bad weather.

As shown in the figures 20.13 & 20.20, wind rotates clockwise in a low-pressure system (in the southern hemisphere). It brings in air from adjacent different regions. For example, on its eastern side, the wind is coming from a warm sea. It is thus warm and humid. On the southern side, it is coming from the cold Antarctic region. On the western side it is again warm and humid. On the northern side it is blowing over the desert. It is thus hot and dry.

This pushing and shoving by different air masses into one system causes one or more fronts to build up. Typically, in the right hand section, the warm and highly moist tropical air is trying to push its way into the colder and less moist air. The front formed between them is known as the warm front. [It's easy to remember: in a warm front, the warm air pushes its way in]. In the left hand section, on the other hand, the cold polar air is pushing its way into warm air. The front formed between them is known as the cold front. [Remember: In a cold front, cold air pushes its way in].

A COLD FRONT

As discussed above, when a mass of cold air meets a mass of warm air, the cold air being heavier, pushes its way under the warm air and forces it to rise almost vertically. A steadily falling barometer heralds the approach of a cold front. Immediately on or after the passage of the front the barometric reading increases rapidly, and then flattens out as the high winds accompanying it, ease down.

The early signs of a Cold Front are a significant drop in barometer and large cumulous clouds aligned along the leading edge of the Front. As a result of the warm moist air rising so steeply, you may also see the towering cumulonimbus clouds with the distinctive anvils on top. However, occasionally, and particularly in summer months, a southerly change (Cold Front) can be cloud-free and treacherous. This is especially true for the more serious cold fronts, known as Southerly Busters in NSW.

The NSW coast experiences about 60 cold fronts a year, mainly in the warmer months. About 10 of these are strong enough to be called Busters, which are almost exclusively confined to the period of September to March, with the greater number in November and December. They are less frequent on the north NSW coast. They most often arrive in the afternoon and evening.

Be warned if the wind speed drops. If this happens, look to the south for signs of an approaching low. Don't rely on its position being indicated by a roll cloud or long line of cloud. The most common indicator is a line of haze or low clouds approaching from the south, along with a change in the colour of the sea surface. In Sydney area, you may also see a line of small cumulus clouds over land and along the leading edge of the front in the southwest to northeast line. Of course, get into a port if there is a significant drop in barometer.

The important thing to note about the Cold Fronts is that because of their steep slope, the change is usually violent but short lived. An average Cold Front stretches only about 30 miles over the ground, but the wind speed can at times reach 40 knots or more, accompanied by thunderstorm and heavy rain showers. As shown in figure 20.20, the air behind the Cold Front is colder and blows from southwest to south. This is the change in temperature and wind direction experienced after a Cold Front.

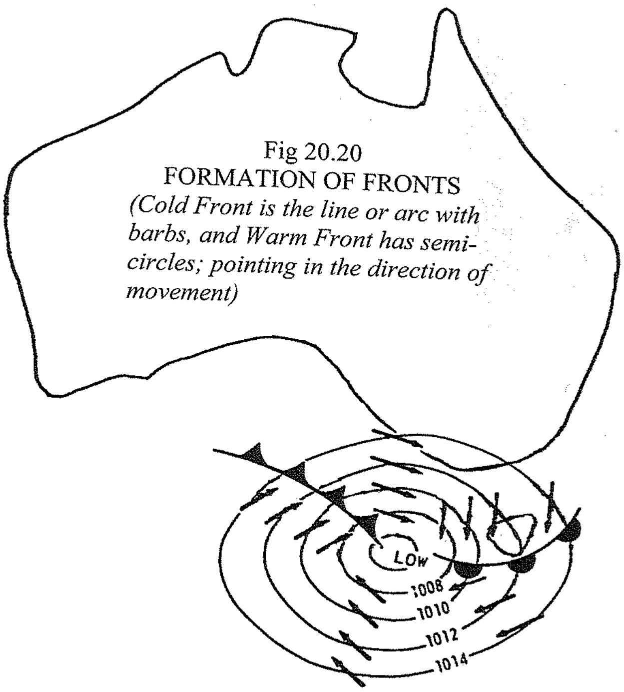


Fig 20.20
FORMATION OF FRONTS
(Cold Front is the line or arc with barbs, and Warm Front has semi-circles; pointing in the direction of movement)

EAST COAST LOWS AND BOMBS

An East coast low is a tightly closed coastal cold front (within 5° of latitude or longitude from the coast). On average, we experience about two of them in a year, one of which is strong enough to be referred to as a Bomb or Explosive Cyclogenesis The Bomb is more likely to occur in the winter or either side of winter when there is a large difference in the sea and land temperatures and the conditions in the upper atmosphere are generally unstable.

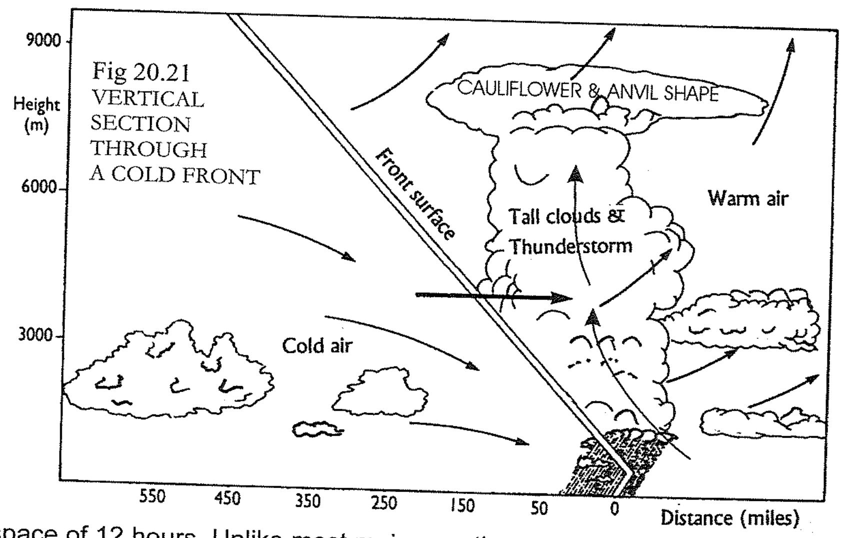


Fig 20.21
VERTICAL SECTION THROUGH A COLD FRONT

The weather before an east coast low can be deceptively good – so good that you don't bother listening to weather reports. But, severe weather is usually around the corner. The low can develop in a space of 12 hours. Unlike most major weather systems, it does not show up in weather maps until about 12 hours before the event. Then, suddenly the barometer drops sharply and winds can rapidly build up to a squally 50 knots with gusts to 70 knots. Seas can build up to 6 or more metres high, and the rain so heavy that you can barely see. It is like being in a tropical cyclone. Indeed, many of these lows tend to form a distinct eye and look like a tropical cyclone in the satellite picture, including spiral bands, though they may be very small. Forecasting the movement of east coast lows is also difficult because they can speed up or stall.

Be warned if the wind speed drops. If this happens, look to the south for signs of an approaching low. Don't rely on its position being indicated by a roll cloud or long line of cloud. The most common indicator is a line of haze or low clouds approaching from the south, along with a change in the colour of the sea surface. In Sydney area, you may also see a line of small cumulous clouds over land and along the leading edge of the front in the southwest to northeast line. Of course, get into a port if there is a significant drop in barometer.

Fig 20.22: COLD FRONT – A PHOTOGRAPH

A WARM FRONT

When a mass of warm air meets a mass of cold air, the warm air being lighter, rises over it in a slope extending 300-400 miles horizontally. Its moisture content causes overcast sky and possibly rain, drizzle, fog, etc.

The temperature, barometer, wind direction and wind speed change gradually as the Front takes a few days to pass. Because of their gentle slope, Warm Fronts are usually not violent, but they stay much longer. Wind speeds usually do not reach beyond Force 5 (17 - 21 knots).

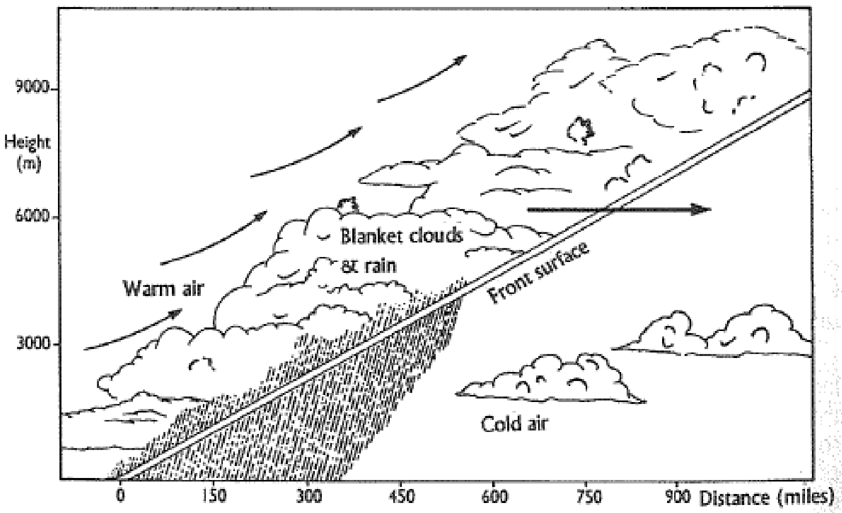


Fig 20.23 VERTICAL SECTION THROUGH A WARM FRONT

THE WEATHER EXPECTED IN A COLD FRONT

- It is usually a sudden and violent change
- Steady drop in barometer before the change
- Towering high grey (Cumulo-nimbus) clouds
- Shift in wind direction. The synoptic or gradient wind of a Front backs to southward during the Front's passage. Due to the Coriolis effect, the gradient wind always backs in the southern hemisphere. (See Cyclone terminology for the meaning of Wind Veering or Backing).
- Increase in wind speed up to force 8 (34 - 40 knots). Choppy or worse than choppy seas. Southern waters are known for strong to gale force N/NW winds before the change, accompanied by worse than choppy seas.
- Possible thunderstorms
- Poor visibility
- Drop in temperature

SAFETY PRECAUTIONS WHEN A COLD FRONT APPROACHES

- Good seamanship and safe practice.
- If in port: wait for it to pass.
- If close to shore: return immediately.
- If far from shore: keep in contact with a Maritime Coast Station (Coast Radio Station), batten down, heave-to if necessary and turn your vessel into a watertight cocoon, switch off all fires and shut off gas.

OCCLUDED FRONT

As mentioned earlier, an occluded front is a combination of a warm and a cold front. Therefore, on weather maps it is shown as a line of alternative barbs and semi-circles on the same side of the line. (Alternative symbols on the opposite sides of the line indicates a stationary front). Occlusion occurs when a faster moving cold front catches up with a warm front. It pushes the warm air mass off the ground, which becomes wedged between the two cold air masses.

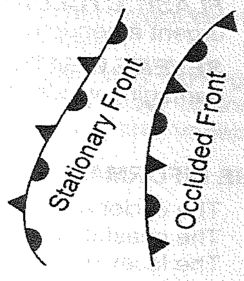


Fig 20.23 (A)

The rising warm air is likely to produce cloud and rain. But, as the depression becomes surrounded by cold air, it decreases in intensity. The resultant weather is often similar to that of a warm front. Occluded fronts are not common in Australia.

CONCLUSION ABOUT THE FRONTS

Both the Cold and Warm Fronts bring a change. From a mariner's point of view, <u>there is no such thing as a nice Front</u>. The difference is that the Cold Fronts are quick and violent, whereas Warm Fronts are not so violent and tend to set in for a few days. A good example of the Warm Front weather is the weather in Britain and Tasmania. [Both places also experience Cold Fronts].

<u>Warm Fronts are not common on mainland Australia</u>. It is because the deep Lows that develop south of the mainland and rotate clockwise, as shown in figure 20.20, tend to swing the Cold Fronts northwards (towards the southern mainland) and the Warm Fronts southwards (towards Tasmania and beyond).

EL NINO, LA NINA & SOUTHERN OSCILLATION INDEX

The El Nino Southern Oscillation (**ENSO**) causes the southeast trade winds to weaken. Therefore, the warm surface water of the Southern Pacific stays much farther to the east than usual. This causes drought in Eastern Australia and floods in Peru. Cyclones, needing warm water, also develop much further to the east, in places as far as French Polynesia and less on the east coast of Australia.

La Nina, on the other hand, has the opposite effect. Strong trade winds bring the warm water to the western part of the Ocean. This results in higher frequency of cyclones on the east coast of Australia.

The Southern Oscillation Index measures the difference from "normal" of the mean atmospheric pressure recorded in Darwin and Tahiti. A positive **SOI** indicates La Nina. It means strong SE trade winds, strong westerly flowing south equatorial drift and more cyclones in Eastern Australia.

A negative SOI, on the other hand, indicates El Nino. It is associated with weak SE trade winds, a drought over Eastern Australia, minimum or even reversed south equatorial drift, and a greater likelihood of cyclones in central Pacific.

The Indian Ocean weather seems to influence the severity of an El Nino. **NORTH-WEST CLOUD BANDS** coming in from the Indian Ocean at a height of about 5 km, north of Perth, between April and October, spread across the continent and interact with frontal systems. They encourage the high pressure systems over Tasman to strengthen, thus increasing the chance of rain in Queensland and NSW and drier winters in Victoria and SA.

TROPICAL CYCLONES

CYCLONE WARNING SYSTEM

Tropical Cyclone Threat Maps and Warning Messages are available from the Bureau of Meteorology's weather service by radio, phone, fax and website. Details are listed on the last two pages of this book. Further information on cyclone preparedness can be obtained from the State/Territory Emergency Services phone numbers, also listed on the last two pages of the book.

HIGH SEAS WARNING

Warnings for cyclones and other dangers existing or likely to move into the region are broadcast every hour via AMSA Radio Network commencing at 0000 hours EST & WST. The broadcast radio frequencies and phone and fax numbers are listed on the last two pages of this book. (See also NAVAREA X warning system in Chapter 12)

CYCLONE WARNINGS ISSUED BY THE METEOROLOGICAL OFFICE

- ***CYCLONE WATCH OR CYCLONE ALERT:*** Winds above gale force from a cyclone will affect coastal or island communities within 24 to 48 hours. These messages are renewed every 6 hours.
- ***CYCLONE WARNING:*** Gales or stronger winds are expected to affect coastal or island communities within 24 hours. These warnings are issued every 3 hours, and every hour when the threat becomes severe.
- ***FLASH CYCLONE WARNING:*** An area not previously affected has now come under threat. Or, there is an urgent amendment to an earlier warning, e.g., the cyclone has changed its course.
- ***SEVERE WEATHER WARNING:*** It may be issued if the system is no longer a cyclone but there is still a threat of damaging winds, flooding rain or pounding seas.

THE INFORMATION BROADCAST WITH A CYCLONE WARNING:

- The cyclone's name.
- The coastal area under threat.
- The location of the cyclone's centre, its central pressure and the CYCLONE CATEGORY on a scale of 1 to 5 with 5 being the most severe. The strongest gust in Category 1 is of less than 70 knots. In category 5, it is of more than 150 knots. Cyclone Winifred was of category 3, Tracy of category 4 and Orson of category 5.
- The direction of movement and speed at which the storm is travelling and intensity (including maximum wind gusts).
- A forecast of heavy rain, flooding, abnormal tides and storm surges.

WHAT ARE CYCLONES:

The word Cyclone is derived from the Greek word 'kukloma', meaning 'coiled snake'. Tropical cyclones are extremely violent. Even a small one has enough power to theoretically provide for Australia's electrical needs for several years. Cyclones generate extreme winds and flood rains. The sea conditions become dangerous both for vessels out at sea and those moored in harbours. Storm surges cause havoc on low-lying coastal areas. Storm surges are a raised dome of water up to 80 metres across and up to 5 metres higher than the normal tide level. The damage is worst when a storm surge coincides with a high tide. The cyclone centre or "eye" would produce a temporary lull in the wind but this would soon be replaced by extreme winds from another direction.

From November to April the coastline of the northern half of Australia is vulnerable to up to 10 tropical cyclones a year. A quarter of these are classified as severe. Australia experiences the world's highest percentage of slow-moving, stationary and erratic cyclones.

Tropical cyclones are also known as:

- Tropical Revolving Storms (TRS)
- Cyclones
- Tropical Storms
- Hurricanes
- Typhoon

DEVELOPMENT OF A CYCLONE

The tropical region, being hot, is a low-pressure belt around the globe. It constantly gives rise to lows, resulting in rain showers and sunshine almost every day many times a day. At times one of these tropical lows deepens and becomes a cyclone as it travels away from the equator. This happens in summer months when the sea temperature and humidity are at their highest and the atmospheric pressure is at its lowest, resulting in maximum converge of warm and moist air over the sea – an essential ingredient for cyclones.

A cyclone often begins its life as a tropical wave, which is a non-circulatory trough of low pressure. The Coriolis force causes a part of the wave to start revolving, making it a circulatory tropical disturbance.

Cyclones do not form within 5° of the equator where there is not enough Coriolis effect. The wind cannot deflect to form a circular motion without the Coriolis effect. Even outside the 5° limits, very few lows develop into cyclones. A whole range of conditions has to be met for a cyclone to form, but the following four events must take place for a cyclone to form:

- Sea surface temperature must reach at least 27°C.
- There must exist a surface low-pressure area over the ocean.
- Surface winds must converge around an eye (not in the eye, as in an ordinary low). This would require the existence of a divergent mechanism (jet stream) in the upper atmosphere. [**JET STREAMS** are meandering air currents in the upper atmosphere. They blow in narrow shallow streams, usually from W to E and close to the operating levels of commercial passenger aircraft. Thus, flying time from UK to Australia is usually shorter than the other way].
- The Coriolis wind shift must be assisted by an activity such as the tropical airwave disturbance.

Cyclone develop in three stages, taking anywhere from hours to several days:

- **Tropical depression** – swirling clouds and rain with wind speeds of less than 33 knots.
- **Tropical storm** – wind speeds of 34 to 63 knots.
- **Tropical cyclone** – wind speeds greater than 64 knots.

They are formally designated Tropical Cyclones and named when winds of at least gale force have developed. The name given to a cyclone at this time is used throughout its life. The Bureau of Meteorology's public warning system is activated if a cyclone threatens coastal and island communities within 48 hours. Other cyclones and developing depressions are mentioned in the Bureau's weather notes and advice to shipping and aviation.

The normal path of a cyclone is parabolic (Fig. 20.25). In the southern hemisphere they usually start moving to west-southwest due to the Coriolis effect and then curve towards southeast. On average their speed is under 10 knots before recurving and about 15 knots after recurving. However the behaviour of cyclones is erratic and variable. Almost everything about them is unpredictable.

CYCLONE SEASON (in the southern hemisphere): About November to April

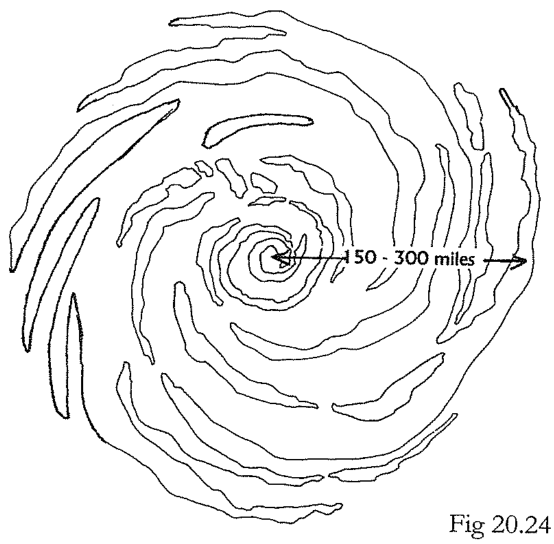
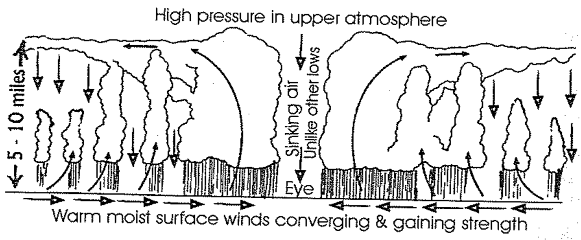


Fig 20.24

A TROPICAL CYCLONE IN THE SOUTHERN HEMISPHERE
(Left: Satellite View
Below: Section View)



CYCLONE MOVEMENT

For some reason, paths taken by tropical cyclones in the Australian region are more erratic than in any other part of the world. Cyclones can last for up to two or three weeks. They may take sharp turns and even form loops. However, as shown in Figures 20.25 & 20.27, cyclones in the southern hemisphere usually curve eastward in their travel. Therefore, a vessel on the eastern side of the cyclone (i.e., on the left side of its path) is likely to remain in it for a longer period and has a greater possibility to get trapped in its centre than a vessel on the western side. The winds are also typically stronger on the eastern side, because they are moving in the same direction as the eye. On the western side the winds are going to the opposite side of the movement of the cyclone. Some of their speed is thus taken off. For this reason, the eastern semicircle of the cyclone is known as the NON-NAVIGABLE (OR MORE DANGEROUS) SEMICIRCLE and the western semicircle as the NAVIGABLE SEMICIRCLE.

The front half of the Non-navigable semi-circle is known as the MOST DANGEROUS QUADRANT. It is so for three reasons: First, the wind and waves are running almost head-on into the path of the storm. They are thus strongest and biggest. Second, the wind will try to blow a vessel in this quadrant into the path of the storm. Third, any recurving of the cyclone is most likely to be towards this quadrant. A vessel in this quadrant is therefore more likely to run into the path of the storm.

Some books use the term "Dangerous" for the "Non-navigable" semi-circle. Do not interpret it to mean that the Navigable semi-circle is safe. It is dangerous to be anywhere in a cyclone, but one half of it is more risky than the other.

CYCLONE TERMINOLOGY
(Figures 20.25 & 20.26)

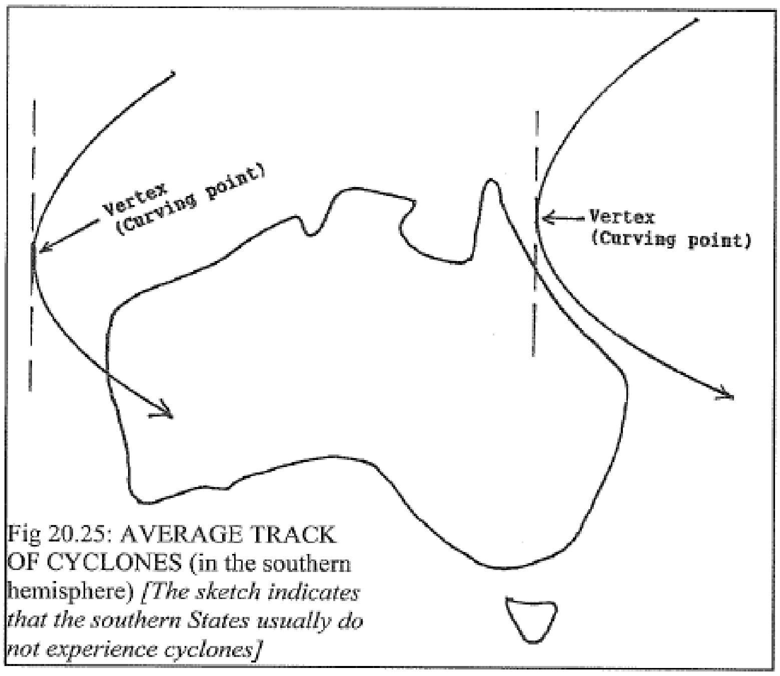


Fig 20.25: AVERAGE TRACK OF CYCLONES (in the southern hemisphere) *[The sketch indicates that the southern States usually do not experience cyclones]*

TROUGH LINE: It is the line of least barometric pressure, drawn at right angle to the path. The barometer starts to rise when the vessel crosses the trough line.

PATH: The predicted course of a cyclone.

TRACK: The trail left by the passage of a cyclone.

VORTEX: The cyclone's eye

VERTEX: The most westerly point of a cyclone's track.

ANGLE OF INDRAFT: It is the angle at which the wind cuts isobars. On the outskirts of a cyclone the wind may cut the isobars at 45° (i.e., 135° to the path), whereas near the centre it would be almost parallel to the isobars (an angle of 0° to the isobars or 90° to the path). Wind tends to eddy round the centre. See Buys Ballot Law below.

BUYS BALLOT'S LAW: The Buys Ballot's Law is a way of determining the approximate direction of the centre of a Low of a High pressure system - in the absence of a reliable weather forecast.

In the Southern hemisphere, if you face the wind, the centre of the low pressure lies between 90 and 135 degrees (8-12 points) on your left hand side, depending on your distance from the centre of the storm. When the pressure begins to fall, the centre is at about 12 points (135°). When it has fallen 10 hPa the centre is at about 10 points (112.5°). And when it has fallen 20 hPa the centre is at about 8 points (90°). See "Angle of Indraft" above.

Reverse this rule for the high pressure [and for the northern hemisphere].

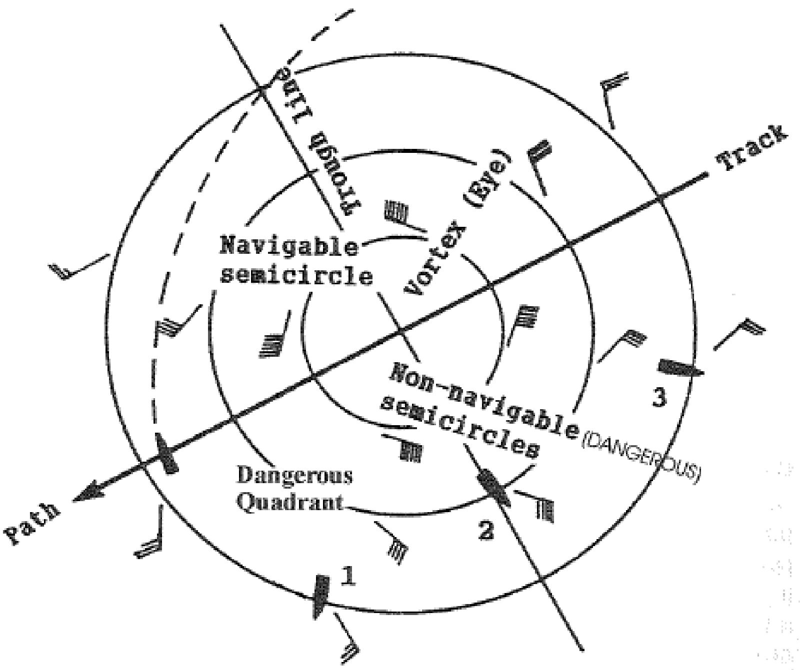


Fig 20.26: PARTS OF A CYCLONE & ESCAPE ROUTES
(See "How To Get Out Of A Cyclone")

WIND BACKING & VEERING: In the absence of a reliable weather forecast, a vessel in a cyclone (i.e., a low pressure) can also assess whether she is in the navigable or the non-navigable semicircle. In a cyclone the wind direction changes constantly, except on its path. A vessel can assess the direction of the shift of wind by recording it over a period of time. In the southern hemisphere, if the shift is clockwise (i.e., the wind VEERS), the vessel is in the navigable semi-circle. If the shift is anti-clockwise (i.e., it BACKS), then she is in the non-navigable semicircle. If the wind direction remains steady, then the vessel is on the cyclone's path. It is best to make this observation from a heaved-to vessel. Observations of wind shift made from a vessel making way through a storm may be inaccurate.

STORM SURGES & TIDE SURGES: Storm Surge is the name given to flooding in low-lying coastal areas caused by onshore winds and the low atmospheric pressure in a storm. They are raised domes of water of some 80 kilometres across and up to 5 metres higher than the normal tide level. The damage is worst when a storm surge coincides with a high tide. Slow moving storms of large diameter create higher storm surges.

Some authorities split the above description into two: Storm Surges and Storm Tides. In which case, the Storm Surge is the rise in the sea level of about a metre or so. The Tide Surge is the combined effect of a storm surge, high tide, wave set-up (the addition to the water column by broken waves), and wave run-up (the rushing of broken waves up the beach and sand dunes). This is what generates the 5 metres high and 80 kilometres across mound of seawater. Also note that a negative storm surge can drop the sea level to below that of predicted tide.

WIND ARROWS: Each feather on wind arrows represents 10 knots (5k for half feathers). Wind is stronger closer to the centre of a low. There are thus more feathers on the arrows nearer the centre.

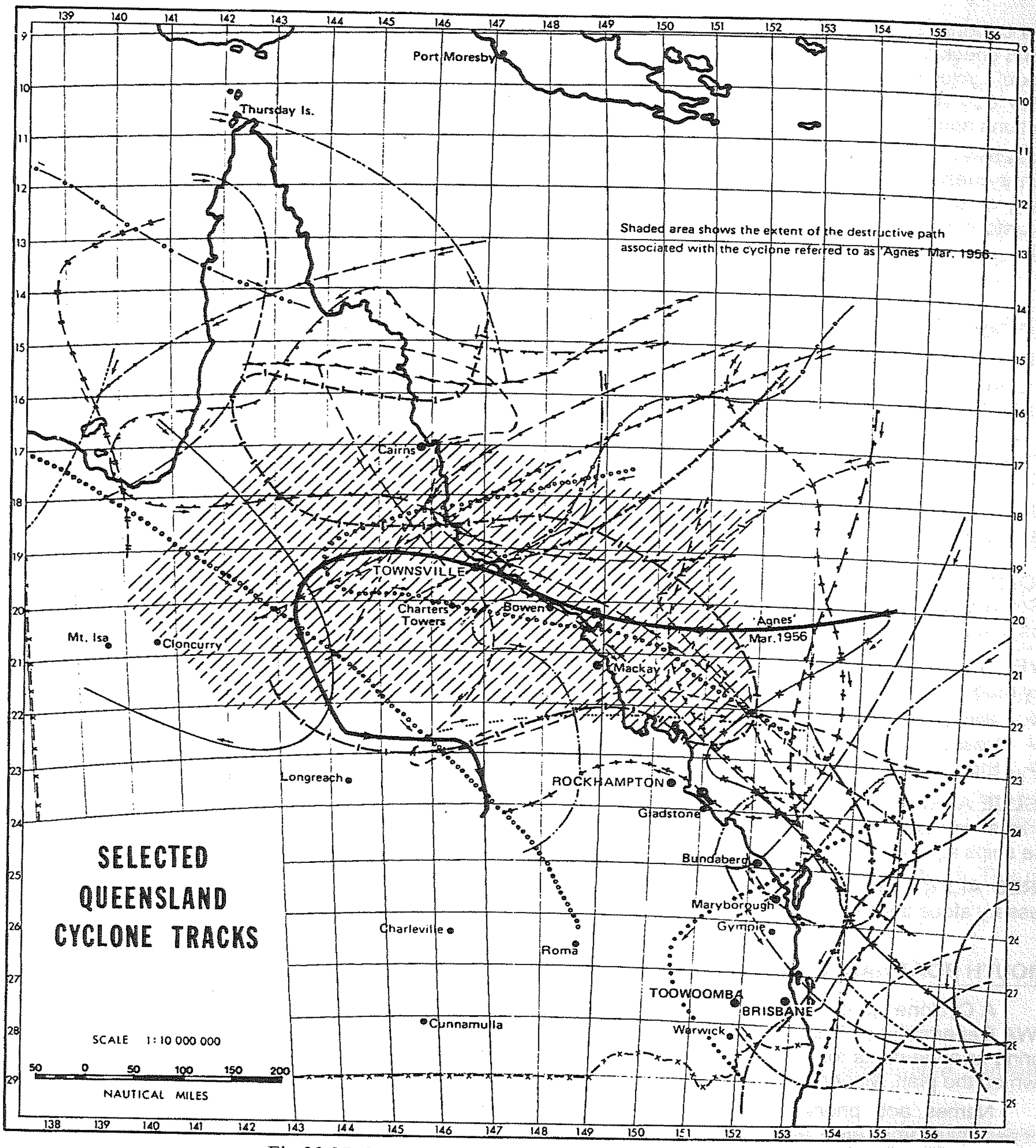


Fig 20.27: SELECTED QUEENSLAND CYCLONE TRACKS

CLONE CONTINGENCY PLANS & SAFE HAVENS

- In cyclonic regions, contingency plans need to be made during calm weather.
- Visit and check out suitable safe havens, obtain extra large-scale charts and notes from pilot books for these places.
- Note down relevant names and telephone numbers.
- Listen to weather forecasts at schedule times.
- Start plotting cyclone's position as soon as broadcast.
- Brief the crew, batten down the vessel and prepare a supply of sandwiches.
- Change course as necessary and radio in your deviation report.
- Allow at least 24 hours barrier to be in safe haven.

If a cyclone is expected, travel up an inlet and check the depths and clearances. You should know your boat's draft and check that you have plenty of lines to secure it. A trailer boat could be left with a friend further inland where the risk of cyclonic winds is lower than on the coast. If going out of town during the cyclone season, get a responsible friend to look after your boat. The local Coast Guard or Coastal Patrol may look after your boat if you leave written instructions and the access keys with them.

Australian cyclone-affected ports have cyclone contingency plans in place. Mariners operating in a cyclone season in these areas should find out the plan from the local maritime centre. The contingency plans are aimed at advising vessels to move from the risky areas of ports into designated shelters in creeks and waterways at least 6 hours before the destructive winds commence. Vessels with shallower drafts are moved to the upper reaches of the creeks.

CAIRNS (QLD) EXAMPLE

The port of CAIRNS has been divided into alphabetically marked sections. The maps are available at any time from Cairns Maritime Office (Ph. 07 4052-7400). At the possibility of a cyclone being in the vicinity the Harbour Master's Office becomes the Maritime Control Centre and the Pier Master's Office becomes the initial Communication Centre. Both the centres operate under the radio Callsign of "Port Emergency Control". All vessels must contact the Communication Centre before moving to their area of shelter.

Vessels can telephone on 4051-2558 or call on VHF Channel 16 or on 27 MHz Channel 88. The Control Centre telephone numbers are 4035-1025 and 4052-7412. See also Bureau of Meteorology's broadcast schedule and contact details on the last two pages of this book.

COLOUR CODED CYCLONE ALERT SYSTEM

Some States use a colour coding system to describe the closeness of a cyclone. The code may vary between States and is not used by the Bureau of Meteorology. The following colour code is used in Cairns.

YELLOW ALERT means destructive winds are expected within 20 hours. Vessels are to proceed to allocated safety moorings and anchorages.

- Vessels in port area A move to … … Creek
- Vessels in port area B move to … … Creek
- Etc.

BLUE ALERT means destructive winds are expected within 16 hours. Vessels should be in their allocated safety moorings and anchorages. They should prepare to batten down. This is the last opportunity to evacuate to shore. Large ships are ordered to sea and wharves cleared.

RED ALERT means destructive winds are expected within 6 hours. Vessels should be well battened down. All necessary steps should be taken to secure people and vessels. Port closed. No vessel movement.

EXMOUTH BOAT HARBOUR (WA) EXAMPLE:

A Cyclone Contingency Plan is made available to the boating public. The Plan can also be downloaded from the WA Department of Planning & Infrastructure website listed on the last page of this book. It recommends minimum mooring arrangements for various sizes of vessels. Boat pens for trawlers, charter boats and for general purpose are shown on the plan. Mooring priority is given to vessels covered by an existing mooring agreement.

Names and phone numbers of Harbour Coordinators for different interest groups (Transport, Marina, Fisheries, Customs, etc.) are written on the Plan. In cases of any difficulty, contact can be established through Exmouth Police (08 9949 2444), Exmouth SES (08 9949 1488) or Exmouth Sea Rescue (on VHF, HF or 27 MHz radio).

CYCLONE ALERT SYSTEM AT EXMOUTH

CYCLONE WATCH ISSUED (Threat of gale force winds within 48 hours): Vessels to maintain contact with the harbour Coordinator, and plan to be in the harbour at least 24 hours before the gale force winds.

CYCLONE WARNING ISSUED (Gale force winds forecast within 24 hours): Vessels have to ensure that their vessel and the area of responsibility have been secured.

SES STAGE RED (High winds imminent): Seek appropriate shelter until the State Emergency Service declares the "All Clear".

WARNING SIGNS OF AN APPROACHING CYCLONE

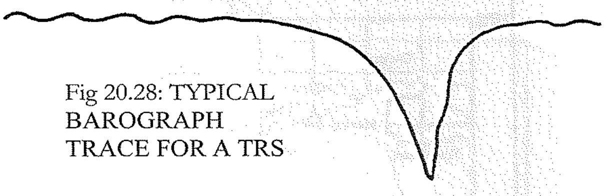


Fig 20.28: TYPICAL BAROGRAPH TRACE FOR A TRS

- Radio broadcasts.
- Long heavy swell from the direction of the storm centre is experienced up to a distance of 1000 miles from the centre. This is a good long-range indicator.
- Tides become higher due to drop in the atmospheric pressure.
- Unusually good visibility.
- Initially falling or unsteady barometric pressure. This is followed by a definite steep fall (If 3 hPa fall = beware; 5 hPa fall = cyclone probably within 200 miles. If the wind is above force 8, the centre is probably within 100 miles)
- Lurid (odd coloured) sky caused by ice crystals in the upper atmosphere giving the effect of a horizontal rainbow. [The high fibrous (cirrus) clouds make the sunny sky appear to glow through a haze, as flames enveloped by smoke. Fiery copper-coloured sunrises and sunsets are common, especially in tropics. The direction of the streaky cirrus clouds can sometimes indicate the direction of the storm centre.] As you get closer to the cyclone, there is a significant increase in cloud formation.
- Changes in the strength and direction of wind, as it shifts due to the Coriolis effect and becomes stronger closer to the cyclone.
- Sultry weather - very humid. Heavy rain within 150 miles of the centre.
- Unusual behaviour of sea birds. They will either roost ashore all day or disappear all together.

SAFETY PRECAUTIONS NEAR CYCLONES

As discussed above, when a cyclone is forecasted to hit a port, small vessels are better out of water or in a sheltered creek or anchorage. Large vessels usually handle storms better at sea. So, they secure for sea and sail out.

Large vessels can usually handle cyclonic bad weather as long as they are not within four or five hundred miles of the centre. However, it is advisable for all vessels to avoid this area due to the damage it can cause. Stay as far away from the storm centre or the eye as possible, which is about 20 miles across. The eye wall has the strongest winds and heaviest rainfall. The wind blows around the eye in the form of an inescapable eddy. Inside the eye there is little wind and the sky may be blue, but the sea is confused and swell heaves like a sleeping giant. The barometer will read very low. The eye can be a deceptively calm trap, from which escape can be difficult. A vessel trapped in the eye goes where the storm takes it.

If a cyclone warning is issued, monitor the storm and avoid it at all cost. Small vessels should head inshore away from violent winds to a safe anchorage or shallow mangrove creeks. In a creek, allow the vessel settle in the mud with anchors leading well ahead secured ashore without letting the vessel get too close to the shoreline.

Stow all gear as low in the vessel as possible and secure her watertight and wind tight. Secure deadlights and tape down glass portholes. Make sure the bilge pump is in working order. Take the motor off the tender and submerge the tender so it can't be tossed around. If it has positive buoyancy it will not sink. Filling any small light boat is a good way to secure it ashore.

If shelter is out of reach and you are near a reef, head for deeper water to ride out the storm. The major factors that would influence a vessel's decision in the proximity of a cyclone are:

- Size of vessel
- Sea-keeping capabilities of vessel
- Proximity of a suitable shelter
- Radio contact
- Position of the storm
- Path of the storm
- Position of vessel relative to storm - whether in navigable or non-navigable (more dangerous) semicircle.

Wind speeds must average at least 65 km/h (35 knots) for a low-pressure system to be labelled a tropical cyclone. It is therefore possible to inadvertently overtake a developing cyclone and be misled by the rising barometer while on its path. So, be careful.

Cyclone plotting maps are available from maritime centres in relevant ports as well as in the local telephone directories. The successive positions of the cyclone centre are continuously broadcast. The positions are broadcast in degrees and decimals of degrees (not degrees and minutes) of latitude and longitude, and in bearing and distance from a town or coastal landmark. The cyclone advice also defines the zones of dangerous winds that may be expected. These dangerous zones can be experienced on the coast several hours ahead of the arrival of the cyclone. The forecast speed and path of the cyclone are also broadcast.

CYCLONE PLOTTING MAP (& KEEPING CLEAR OF DANGER)

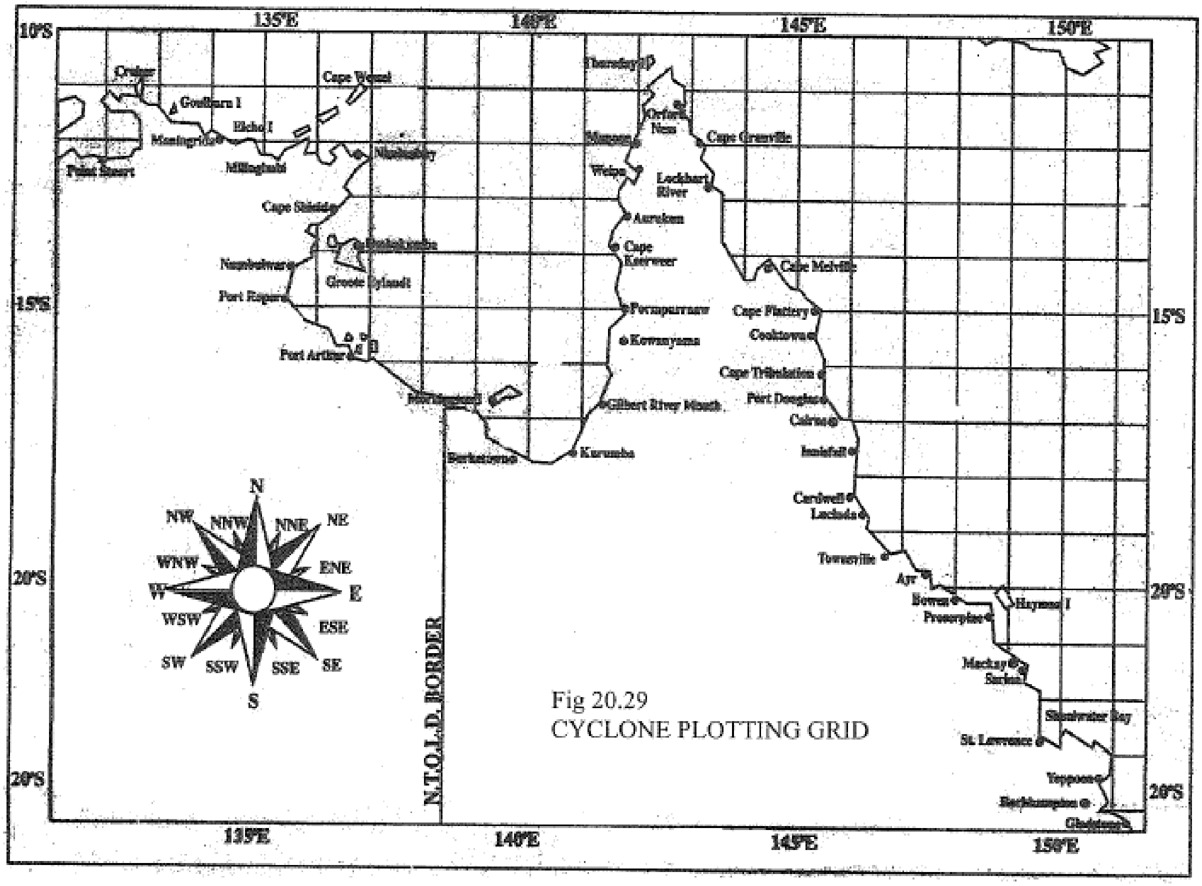


Fig 20.29
CYCLONE PLOTTING GRID

If you are unable to seek shelter from a cyclone, you must give it as wide a berth as possible as follows: Maintain a continuous plot of the cyclone's track by plotting the positions of its centre. From each successive position of its centre draw an angle of 40° on each side of its forecast path. This is to allow for the possibility of the storm deviating from this path. Then draw a curve between the above lines equal to 48 hours of its speed. For example, if the cyclone is travelling at 10 knots, draw the curve at 48 x 10 = 480 miles. Plan your courses outside of this area, updating it as and when new information comes to hand.

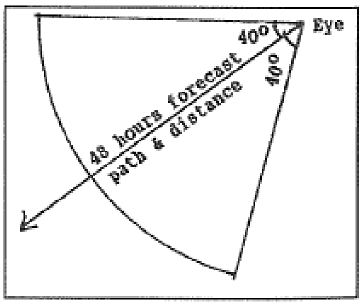


Fig 20.30: AVOIDING (RUNNING CLEAR) OF A CYCLONE (When unable to seek shelter)

HOW TO GET OUT OF A CYCLONE *(Figure 20.26)*

If you are already in a cyclone, you should take the following course in order to avoid its eye.

- If you are in the non-navigable semi-circle: steam to windward with wind on port bow. You will thus be steering a course away from and at right angles to the path of the storm.
- If you are in the path of the storm or in the navigable semi-circle: run with wind on the port quarter. Similarly, you will be steering a course away from and at right angles to the path of the storm.

(For the Northern Hemisphere, see the back of figures 20.24 and 20.26 in front of a light.)

YOUR LOCAL WEATHER

It is essential for all boat skippers to become familiar with their local weather patterns. Nationally speaking, the Northern half of Australia is prone to tropical cyclones, and the southern half to cold fronts. Warm fronts are restricted mainly to Tasmania.

More specifically, on the New South Wales Coast, winds are predominantly NE'ly in summer and SE'ly in winter. Sometimes hot westerlies blow during the summer months. The temperature on the coast is also influenced by sea breezes during the day and land breezes at night. Cold fronts and thunderstorms are common. Weather can suddenly become violent with gale force winds, rain, hale, thunder and lightening.

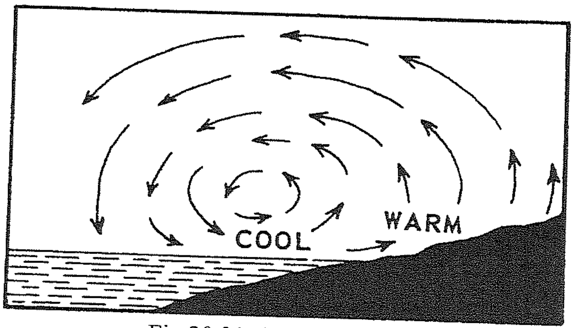


Fig 20.31: SEA BREEZE

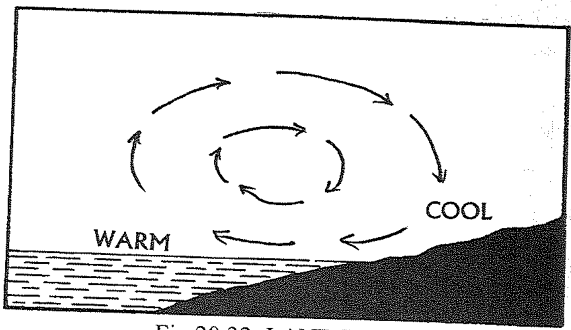


Fig 20.32: LAND BREEZE

SEA BREEZES & LAND BREEZES

Breezes that blow in coastal areas due to uneven heating and cooling of land and sea are known as Sea Breezes and Land Breezes.

SEA BREEZES blow during the day when land heats faster than the sea, and the atmospheric pressure on land becomes lower than on the sea. The surface wind thus blows from an area of high pressure (the sea) to an area of low pressure (the land). Cause = Effect. Being temperature driven, sea breezes attain maximum strength about mid-afternoon. Unless affected by trade winds or a pressure gradient, the speed of sea breezes is around 15 knots. They extend up to 20 miles each way from the coast.

In Perth and some other places around the world, a sea breeze may cool a scorching hot day by as much as 10 degrees Celsius. People thus refer to it as a 'doctor'. The **FREMANTLE DOCTOR** is well known for its strength.

LAND BREEZES blow during the night because land cools faster than the sea, making its atmospheric pressure higher. The surface wind direction is thus reversed. The land breeze flowing off the land is not as strong as the sea breeze, nor does it extend as far inland or to sea. Their speed is around 5 knots and they extend up to 2 to 5 miles from the coast. Land breezes become most evident after midnight.

On an east coast in the southern hemisphere, a sea breeze starts from the easterly direction in the morning. Then, on picking up speed as the day warms up, it swings to the north-easterly direction due to the Coriolis effect. Similarly, on a west coast it swings from west to southwest. As discussed earlier, the *Coriolis effect is the apparent shift in wind direction due to the earth's rotation: to the left in the southern hemisphere and to the right in the northern hemisphere.*

On the approach of a Front, the sea breeze, which is a local wind, weakens and swings back to the easterly (westerly on the west coast) direction. The synoptic or gradient wind of a Front backs to southward during the Front's passage. The gradient wind always backs in the southern hemisphere.

ANALYSING A WEATHER MAP: SOME POSSIBLE FORECASTS

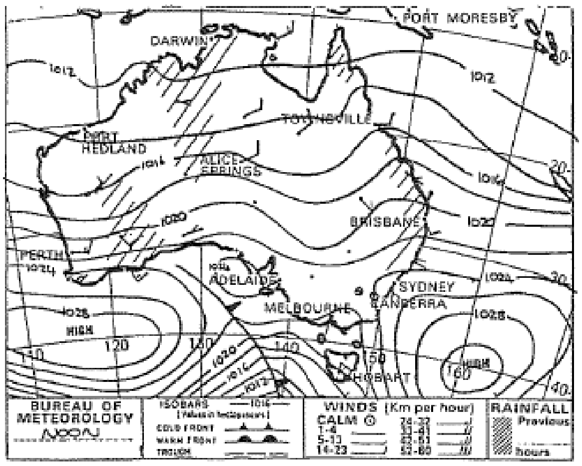
- Northerly winds over Australia will carry hot, dry air from inland towards coastal areas.
- Easterly winds blowing from the sea over eastern Australia will create humid and sultry weather - often leading to "unstable" weather such as showers and thunderstorms. Westerly winds will do the same on the west coast.
- A cold front on the south Coast will replace hot dry north-westerlies with southerlies carrying cooler, often relatively humid air.
- Southerly wind blowing over northern Australia will carry cool to mild, relatively more moist air, as it travels from southern to northern parts.
- A high pressure normally results in stable weather.
- A low pressure normally causes unstable weather.
- Closer the isobars the stronger the wind.

WEATHER INFORMATION SOURCES FOR VESSELS

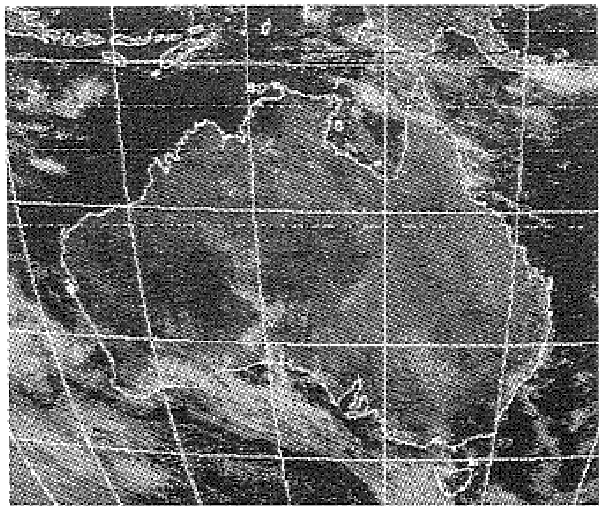
- Coastal: Newspapers, radio, TV, Telstra recorded weather service, Coast Radio Networks.
- Marine: Maritime Communication Stations (Coast Stations). See Chapter 18 and the last two pages of the book.
- Boating weather information on the Bureau of Meteorology's State-wise phone numbers listed on the last page of the book.
- Bureau's National Weather internet & fax services, listed on the last two pages of the book.

Fig 20.33: SYNOPTIC CHART (WEATHER MAP) No. 1

Situation at noon yesterday



Satellite picture — noon yesterday.



Cloud approaching WA is associated with an upper level trough. Cloud over the Bight is associated with a cold front. Cloud about the E coast is associated with a moist SE airstream.

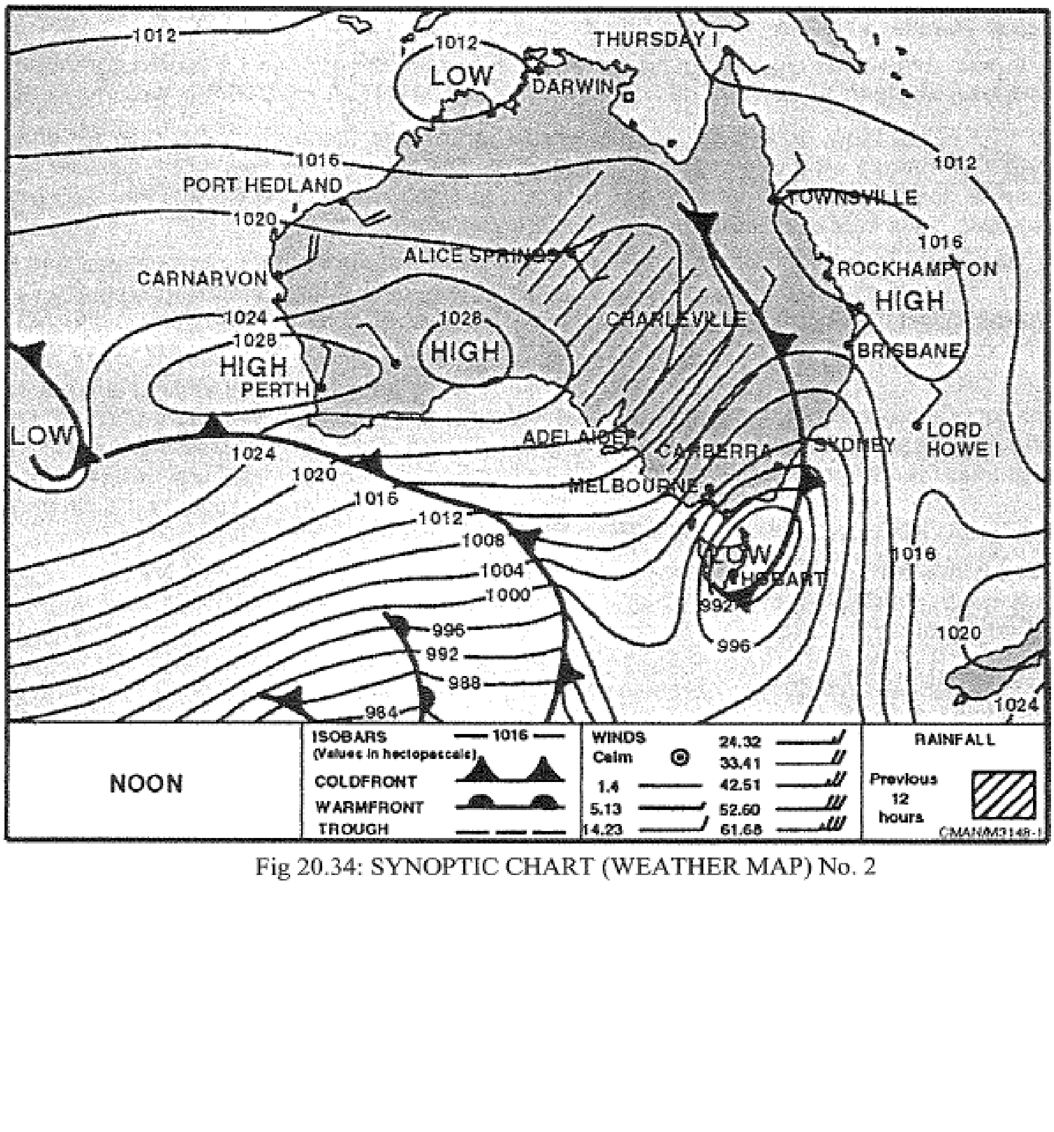


Fig 20.34: SYNOPTIC CHART (WEATHER MAP) No. 2