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A HANDBOOK OF WEATHER, CURRENTS AND ICE, FOR SEAMEN

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1935

A HANDBOOK
of Weather, Currents and Ice
FOR SEAMEN

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PREFACE

The aim of this book is to assist seamen. It is intended mainly for the great majority of the navigating officers of the merchant navy who do not receive information regularly through the medium of THE MARINE OBSERVER.

The officers of the merchant navy of the present day are expected to have a working knowledge of a great many subjects. It is desirable that technical literature for them should be clear and concise.

The endeavour has been to make this book fit the title on its cover, to compress into one small volume and in language simple to seamen, as much of the information as is most desirable for seamen, as can now be given with confidence.

Universal power propulsion, general use of wireless telegraphy, modern navigational instruments and aids, the greater knowledge of the atmosphere and the sea, and the increasing skill of observation by seamen all call for revision of the old literature on weather, currents and ice at sea.

With this end in view THE MARINE OBSERVER was established in January, 1924, and the work which has been done in this connection has been largely responsible for the production of this book.

Its production marks a natural step in the development of knowledge gathered by seamen of the weather and its ways, currents and their vagaries, and ice, that obstacle harder than salt water, which has been responsible for the end of many a fine ship.

This book is mainly compiled from information provided by seamen, and particularly by the British corps of voluntary marine observers, who have returned observations from the sea since 1855. In compiling it I have had the benefit of the work done under Admiral FITZROY, C.B., the first Superintendent under the Board of Trade; Captain HENRY TOYNBEE the first Master Mariner in charge of the work at the Meteorological Office; Lieutenant C. W. BAILLIE, R.N., and Captain CAMPBELL HEPWORTH, C.B., R.N.R., all of whom were responsible for advancing the knowledge of seamen upon this subject during their time.

I have also had the benefit derived from the work of many highly specialized scientific meteorologists ashore.

My assistants in the Marine Division have done the greater part in working out the details, and particularly those which have led to a newer conception of the behaviour of weather at sea and the variations of current.

I have consulted and used the information from too many books, charts, and atlases of different nations to name them; and every effort has been made to select the most suitable and reliable sources for the statements made, while preserving words best suited for the purpose.

No footnotes are given, this being complete and grateful acknowledgement to all authorities.

I am indebted to a master mariner of great experience, and independent of the service, for reading the manuscript and verifying this conception of the needs of the merchant navy.

L. A. BROOKE SMITH,
MARINE SUPERINTENDENT.

Meteorological Office,
London.
15*th March*, 1934.

CHAPTER I

ABOUT THE AIR AND THE SEA

We live at the bottom of a great ocean of air, known as the atmosphere; and we navigate our ships upon the surface of the sea over the oceans.

We are therefore concerned with the conditions which happen at the meeting of these two great oceans of air and sea water. Those conditions are forced upon us; we have to cope with them continually; they are not only a matter of interest or scientific study to the seaman.

Let us endeavour to set out, in the language of seamen, an account of these conditions as we know them from observation; and give some guidance in the method of applying knowledge of these conditions to navigation, omitting as far as possible mathematical and physical explanations or descriptions. For such, we refer our readers to books of meteorology and oceanography; and for methods of observation, including scales and notations, types of clouds, descriptions and handling of instruments, to THE MARINE OBSERVER'S HANDBOOK.

The air covers the whole surface of the globe, and reaches to a height of at least 130 statute miles. In consequence of its compressibility, about three-quarters of the whole mass of air lies between sea level and the level of the summit of the highest mountain peak, Mount Everest.

The sea covers about three-quarters of the surface of the globe, only one-quarter being covered by land; and the greatest sounding has been made in the Pacific in the Emden Deep, east of the Philippine Islands, of 5,703 fathoms. That is, the height of the atmosphere is at least twenty times that of the greatest depth of the oceans.

The weight of the air presses upon the sea surface with mean force of about 15 lb. to the square inch, and this mean pressure is the same on the land at sea level. Atmospheric pressure.

Atmospheric pressure is not at all times and at all places the same. Differences of pressure are primarily due to temperature differences; if there were no temperature differences there would be no winds, and pressure at sea level would be everywhere the same.

The natural tendency of air is to flow from an area of high pressure towards an area of low pressure at the same level, and to continue thus to flow until pressures are equal at that level. Wind.

This flow of air, which is wind, is deflected by the rotation of the earth, so the movement is never straight from high to low pressure.

The rotation of the earth is from west to east. Places near the Equator rotate at a greater velocity than those near the Poles. The result is that air moving from high to low is deflected from the straight path to the *right* in North latitude, and to the *left* in South latitude. If there were no friction, the deflection of the wind from its straight path would result in its following round the low, along the lines of equal pressure which surround that low. At a height of about 1,500 ft. the wind actually does follow the lines of equal pressure round the low. Later we shall see how lines of equal atmospheric pressure as measured by the barometer at sea level, are drawn on charts. These are called " isobars."

At the sea surface the wind blows at an angle to the isobars always inclining *inwards* to the low.

Buys Ballot's Law.

From knowledge, built up from observation, Buys Ballot first summarized a law, which has been proved by experience at sea to be fundamental. The barometer cannot be used properly without this law.

Buys Ballot's Law.—In North Latitude, face the wind and the barometer will be lowest to your right.

In South Latitude, face the wind and the barometer will be lowest to your left.

When the wind blows spirally inwards from high pressure towards low pressure, the system is termed a cyclone. When the wind blows spirally outwards from a centre of high pressure towards a centre of low pressure, the system is termed an anticyclone.

In a cyclone in the Northern Hemisphere, the wind blows round and towards the centre anticlockwise, and clockwise in the Southern Hemisphere. The reverse is the case with anticyclones.

Moisture

Water vapour passes into the lower layers of the atmosphere as an invisible gas by evaporation (due to the sun's heating) from the sea and all water surfaces, even when frozen.

Moisture is thus transported by the wind over the surface of the globe, and by condensation, becomes visible as cloud or fog, and is precipitated to the surface as rain, snow or hail and dew.

The circulation of the air over the surface of the oceans will be apparent when, in later chapters, the wind systems of the oceans are described.

Sea and swell.

Wind not only carries and distributes moisture and heat, but by its action upon the surface of the sea, sets up waves, which we term " seas." These seas travel and become " swell ", reaching great distances from where they were set up by the wind.

Though waves travel at considerable speed, this motion is not the bodily advance of the mass of water in the wave, except in broken crests. The particles of water revolve in a circular orbit perpendicular to the wave ridge, and this revolution occupies the same time as the wave takes to advance its own length.

Solar energy is the original power that keeps the waters of the ocean moving.

Ocean currents.

Wind is the main force which induces current; and the direction of the wind, the rotation of the earth, and the coast lines, direct the flow of the water.

There are a number of forces at work which produce currents in the ocean, some internal, some external.

The internal forces are differences of specific gravity due to variations in the temperature and salinity of the water. Differences in salinity arise from the movement of water from different parts of the ocean or from different depths of the ocean, or from loss of water due to evaporation or excess of fresh water due to rain, rivers and melting ice.

Of external forces the rotation of the earth influences and controls currents from whatsoever cause they occur. Difference of atmospheric pressure has a two-fold effect, one direct upon the surface waters transmitted to the depths, but probably small in its contribution, the other indirect through wind which by friction induces motion in the surface layers of the water.

Wind is probably the most powerful of all the forces producing surface current, that is to the depth of the keel of ships.

The effect of wind friction upon the sea surface is to produce current running with the wind, but the rotation of the earth deflects it to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The angle of deflection has been found in Latitude 50° N. to be four points near the surface, that is at a depth of about half the draught of ships. This angle of deflection increases with depth, and the current due to wind decreases with depth, the effect of wind of force 5 ceasing at a depth of about 45 fathoms in Latitude 50°. The nearer the Equator and the stronger the wind the deeper the effect goes.

As all the forces before mentioned interplay, the wind or any other of the forces mentioned cannot be alone responsible for current. Current may run athwart the wind or against it. It is not possible to say definitely at any time how the current will run, and the navigator must ever be watchful for current which may set his ship from her course.

Currents are very variable, even in the well-defined main streams of the oceans.

In later chapters, when the wind systems of the oceans have been described and the currents of the oceans are described, the circulation of the surface waters will be apparent, and it will also be seen that surface currents mainly conform to the wind circulation, but are deflected by the coasts.

Ocean currents are themselves transporters of heat and so greatly influence climates.

The ocean allows the normal system of atmospheric circulation to be more perfectly established than on the land, and so gives rise to the steady winds of the oceans which dominate the climates of the globe.

Heating of Sea and Land.

The sun heats the land more quickly than it does the ocean, but penetrates to the depth of only a few feet, and the land loses its heat more quickly than the ocean. The sun's rays penetrate the ocean to a great depth, but the temperature of the surface is only slightly raised; and the ocean does not lose its heat quickly like the land. The changes of air temperature over the land are consequently much greater than those over the sea. The climates of the oceans are more equable than those of the continents.

CHAPTER II

THE WIND SYSTEMS OF THE OCEANS

Doldrums.

The Doldrums, a belt of calms and variable winds, in which there is much rain and thunderstorms, lie east and west almost across the oceans near the Equator. This is a region of comparatively low atmospheric pressure, which moves bodily north and south following the sun, as do the wind systems of the oceans.

Trade winds.

North and south of the Doldrums lie great anticyclones, except during the summer months in the North Indian Ocean, when the south west monsoon occurs. Between the region of high barometer at the centre of these anticyclones and the low barometer of the Doldrums, are the trade winds, the steadiest of all oceanic winds; their strength depending on the barometric gradient between the centre of the anticyclone and the low of the Doldrums. Their direction depends upon the relative positions of these Highs and Lows, and where the observer is situated relative to these Highs and Lows.

Generally—but not always—when a ship has entered the trade winds on the eastern side of the anticyclone from a higher latitude steering towards the Equator, she will experience a more easterly wind as she reduces her latitude. The wind takes a spiral course outwards from the centre of the High towards the centre of the Low and so is more easterly near the Doldrums, and to the westward of the High.

The trade winds may be interrupted by the formation of tropical revolving storms originating near the Equator, and passing to higher latitudes.

Variables.

At the centres of the anticyclones beyond the trade winds, calms and light variable winds occur, but with less frequency than in the Doldrums; the notable example of these calms and variables being the " Horse Latitudes " of the North Atlantic, in the region known as the " Sargasso Sea."

Westerlies.

Beyond these regions of calms and variables, on the polar side of the anticyclones, in about 40° to 50° Latitude, lie the regions of the Brave Westerly winds, known as the " Roaring Forties " in the southern hemisphere.

Upon the average, the barometer, which oscillates continually and irregularly in middle and high latitudes, is lowest near the Arctic and Antarctic Circles. Cyclonic systems travel continuously at varying intervals in an easterly direction in these latitudes, so that though the wind comes from all points of the compass, its prevailing direction is westerly, because the low barometer at the centres of these cyclonic depressions, being mainly situated nearer the Poles, their semicircles of westerly winds cover these regions.

These westerly winds have a more regular sweep over the oceans in the southern hemisphere, where cyclonic systems may encircle the globe, without the interruption of great continents, which extend to higher latitudes in the northern hemisphere.

In the northern hemisphere not only do the continents interrupt the clean sweep of the westerly winds over the oceans round the globe, but the heating of great continents during the summer and especially that of Asia, causes a reduction of atmospheric pressure during that season, so that the barometer is *low* over Asia in a latitude where, in the southern hemisphere, it is *high* in the corresponding season of that hemisphere.

Monsoons.

Due to this *low* barometer over Asia in the summer, the South West Monsoon prevails in the northern part of the Indian Ocean and China Sea for about half the year. The South West Monsoon of the Arabian Sea is in fact the South East Trade of the Southern Indian Ocean continued across the Equator towards the *low* and turned in direction by the rotation of the earth.

A similar, but less intense, monsoon exists in the South West Monsoon of the Equatorial North Atlantic, due to the heating of the air over the Sahara desert.

General pressure distribution.

The charts of the world indicate the general atmospheric pressure distribution and the wind systems of the oceans for February and August. (FIGURES 1 AND 2.)

Here follows a brief description of the wind systems of the different oceans, taking February and August as months at the height of the summer and winter seasons, according to hemisphere. Monthly or quarterly descriptions would be too lengthy, and beyond the scope of this book.

Atlantic Ocean

The wind systems of the Atlantic are as generally described for all oceans at the beginning of this Chapter.

Doldrums.

The Doldrums are narrowest in February and March, averaging about 200 miles in breadth. They are broadest in August and September, when their breadth averages about 400 miles, and they are sometimes as much as 600 miles across. The narrowest part of the Doldrums lies between Longitude 25° and 35° W. Occasionally, in February and March the Doldrum belt may be so narrow in the region of Longitude 30° W. that a vessel may pass from one Trade to the other during a squall.

GENERAL ATMOSPHERIC PRESSURE DISTRIBUTION AND WIND SYSTEMS OF THE OCEANS IN FEBRUARY

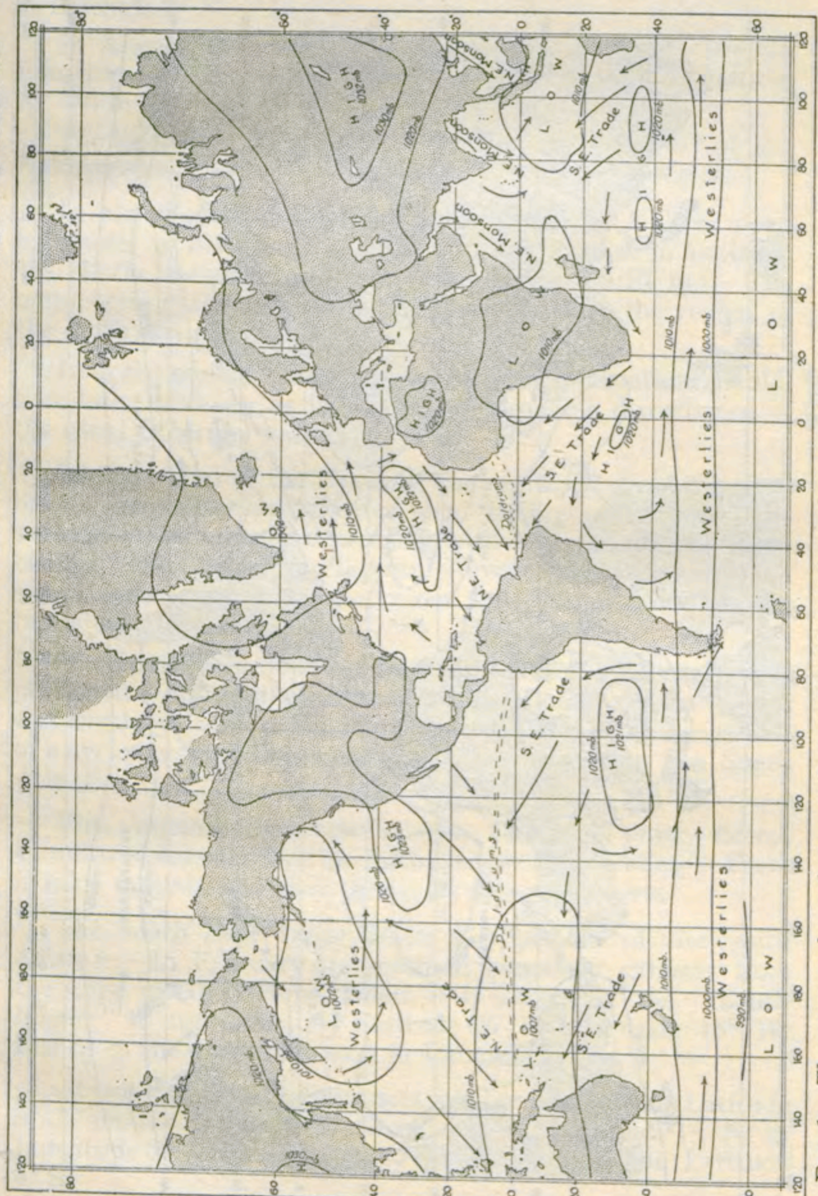


FIG. 1.—The arrows show the general direction of the wind. The isobars are drawn for each 10mb. only.

GENERAL ATMOSPHERIC PRESSURE DISTRIBUTION AND WIND SYSTEMS OF THE OCEANS IN AUGUST

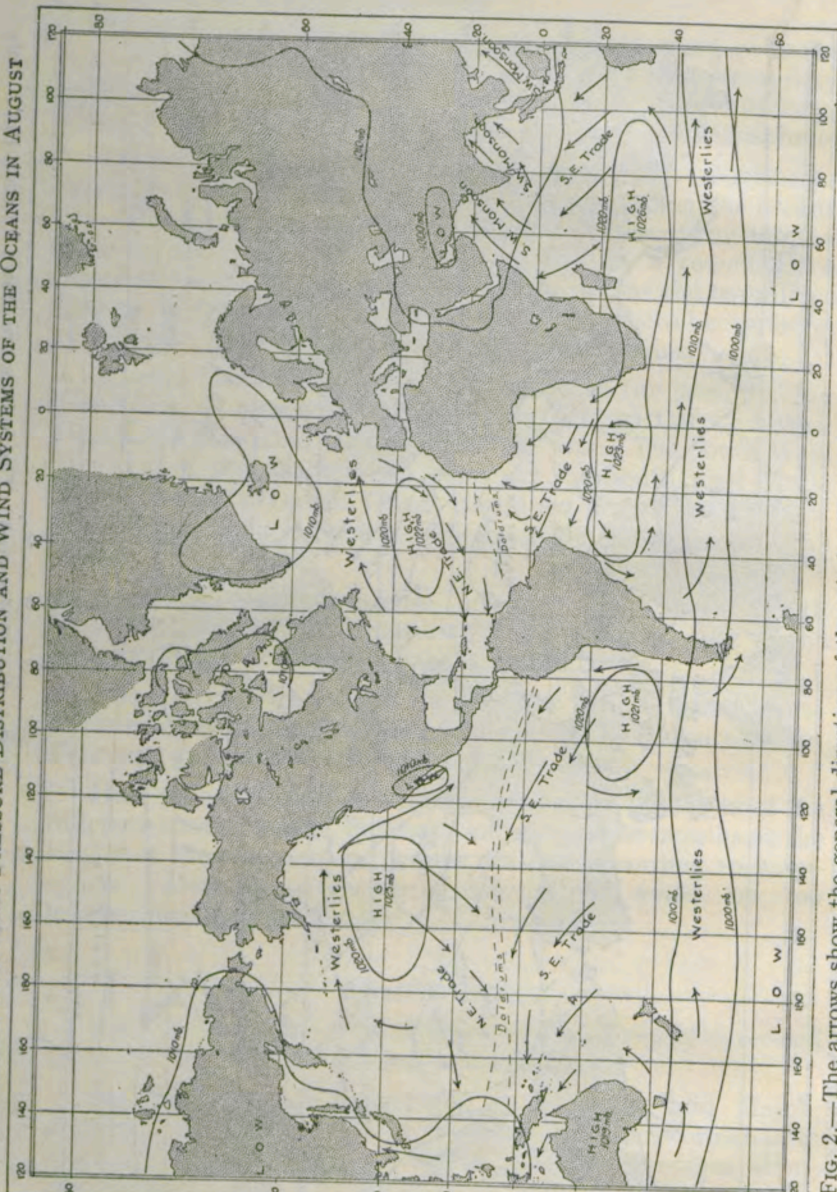


FIG. 2.—The arrows show the general direction of the wind. The isobars are drawn for each 10mb. only.

In February the approximate mean centre line of the Doldrums lies in an E. by N. and W. by S. direction, passing a little north of St. Paul's Rocks, through Longitude 20° W. in Latitude 2° N.

In August, this centre line passes approximately through Longitude 30° W., in Latitude 12° N. and through Longitude 20° W. in Latitude 14° N.

The position and extent, as well as the weather, of the Doldrums are variable ; much rain occurs in this region.

In the month of February in Latitude 5° N. the mean barometer is 1010·8 mb. (29·85 in.). In August in Latitude 15° N. the mean barometer is 1013·0 mb. (29·91 in.). The barometric gradient is very shallow indeed in the region of the Doldrums.

Diurnal Range of Barometer.

Irregular oscillations of the barometer are unusual and should, therefore, be taken as indications of probable disturbance of the usual Doldrum weather.

In the region of the Equator, the regular daily oscillations of the barometer are greater than in higher latitudes, the amount of daily range decreasing with latitude, and when we come to the Chapter on Tropical Revolving Storms we shall see how necessary it is to consider this diurnal range of the barometer.

South East Trade.

The South East Trade of the South Atlantic Ocean is very persistent ; and unlike the trade winds of other oceans, is not disturbed by tropical revolving storms, there being no record of a cyclonic storm of intensity near the Equator in the South Atlantic.

Fine weather, blue skies, with beautiful white, fleecy, cumulus clouds are the rule in the South East Trades. There is little rainfall, and that mostly in passing showers.

The South East Trade covers a large area of the South Atlantic. In February its southern boundary extends from the Cape of Good Hope, where it is known as the " South Easter " to approximately Latitude 25° S. Longitude 15° W. thence to the Brazilian coast in Latitude 17° S.

At this time of the year its northern boundary lies in Latitude 8° S. on the meridian of Greenwich, in Latitude 1° N. in Longitude 30° W., and thence to the Brazilian coast in Latitude 4° S.

In August the southern boundary extends from the neighbourhood of Port Nolloth to the tropic of Capricorn in Longitude 15° W., and thence to the South American coast in Latitude 16° S.

South West Monsoon.

During the northern summer, and especially in August the South East Trade on its eastern side, as it crosses the Equator gradually changes its direction to South West, and blows on to the African coast as far north as Latitude 12° N. During August, this South West monsoon wind reaches as far to the westward as Longitude 34° W.

South East Trade.

The northern boundary of the South East trade in August lies in Latitude 3° S. on the meridian of Greenwich, passes through Latitude 5° N. in Longitude 30° W. and thence to Latitude 4° N. in Longitude 50° W.

The South Easter at the Cape at times reaches gale force, but the South East Trade seldom blows with that force. It varies from a light to a strong breeze. The mean force of the wind in the heart of the South East Trade throughout the year is 3·5 of the Beaufort Scale, or a velocity of 11½ knots, and its average direction is S. 41° E. Its lowest mean force occurs in May, when it is 3·3 of the Beaufort Scale, with a mean direction of S. 43° E. Its highest mean force is in February, 3·7, when its mean direction is S. 42° E. It varies a few points in direction in all parts of the Trade, but is generally more southerly near its eastern edge, and more easterly in the north western part of the region.

Southern Variables.

In February the centre of the South Atlantic anticyclone lies in the region of Latitude 30° S. and Longitude 5° W. where the mean barometric pressure is 1020 mb. (30·12 in.). At this time of the year, it is calm on the average six times out of a hundred occasions in this region.

In August the centre of the South Atlantic anticyclone lies in the region of Latitude 25° S. Longitude 10° W. where the mean barometric pressure is 1023 mb. (30·21 in.). At this time of the year, it is calm on the average four times out of a hundred occasions in this region.

At all times of the year, the wind may come from any point of the compass in this region, and gales occasionally occur, the weather being influenced considerably by the eastward passage of cyclonic systems to the southward.

North East Trade.

The North East Trade of the North Atlantic is a steady wind which is interrupted at times in the summer and autumn by the passage of hurricanes which may form in the Doldrums particularly near their northern boundary, in the region of the South West Monsoon, or in the western region of the trade, passing on over the West Indies or to higher latitudes.

The usual weather of the North East Trades is fine, with little rain, blue sky, and trade wind clouds—small masses of cumulus—continually passing.

In February its northern boundary extends from Latitude 31° N. on the African coast, to Latitude 24° N. Longitude 40° W. and thence along the 24th parallel to the Bahamas.

At this time of the year its southern boundary lies in Latitude 8° N. off Sierra Leone, passes through Latitude 3° N. Longitude 30° W. and thence to the Equator off the mouth of the Amazon.

In the summer months the trade wind may extend northward to the coast of Portugal, where it is known as the " Portuguese Trade "; and sometimes when the anticyclone is displaced to the northward, northerly and north-easterly winds may extend from the English Channel, off the Coast of Portugal and Africa, to the southern boundary of the North East Trade. This is the exception rather than the rule.

The average northern boundary in August lies from off Lisbon, passing through Latitude 30° N. in Longitude 40° W, thence to the northern coasts of the Bahama Islands.

The southern boundary in August extends from Cape Verde through Latitude 11° N. Longitude 40° W. and thence to a little south of Trinidad.

In the heart of the North East Trade, and on the eastern side of the trade wind region throughout the year, the mean force of the wind is 2·7 of the Beaufort Scale, or a velocity of 7¾ knots, that is 0·7 of the Beaufort Scale, less than the mean force of the South East Trade.

In this region the mean direction of the wind throughout the year is N. 30° E. It is usually more easterly in the winter months than in the summer.

Over the whole region of the North East Trade the wind direction varies a few points; it is generally more easterly in the middle of the region and in the neighbourhood of the West Indies than it is off the African Coast.

The wind force is generally from a light to a strong breeze, though occasionally it reaches gale force, and during the existence of a hurricane, even in places remote from the hurricane the force and direction of the wind may be affected by it.

Horse Latitudes.

In February the centre of the North Atlantic anticyclone lies in the region of Latitude 32° N. Longitude 30° W. where the mean barometric pressure is 1022 mb. (30·18 in.). At this time of the year, it is calm on the average eight times out of a hundred occasions in this region.

In August the centre of the North Atlantic anticyclone lies in the region of Latitude 35° N. Longitude 35° W. where the mean barometric pressure is 1022 mb. (30·18 in.). At this time of the year it is calm on the average twelve times out of a hundred occasions in this region.

At all times of the year the wind may come from any point of the compass in this region, and gales occasionally occur, the weather being influenced considerably by the eastward passage of cyclonic systems to the northward.

Roaring Forties.

In the region south of the South Atlantic High, cyclonic systems, separated by Highs, continually travel in a more or less easterly direction. The centres of these cyclonic systems mainly traverse an easterly course south of Latitude 50° S., so that the prevailing winds are westerly between the parallels of 40° and 50° S. Latitude. The mean latitude of the passage of the centres of Lows is more southerly in the southern summer than in the winter, so that the "Roaring Forties" move bodily north or south, with the sun, to some extent, just as do the Trade Winds.

The average pressure gradient of the region of the "Roaring Forties" right round the globe is the steepest known average gradient throughout the year over the oceans.

The average force of westerly winds in this region is 6 of the Beaufort Scale throughout the year. Calms are infrequent, but occur as often as five times in a hundred occasions in some longitudes. With the approach of a cyclonic system passing to the southward, a ship will experience a freshening wind from N.W., often increasing to a gale, and backing to S.W. and moderating.

In winter time easterly winds are encountered more frequently, for then Lows travel in lower latitudes.

Generally the winds and weather in latitudes higher than those of the great anticyclones in all oceans are so changeable that they require a special method of description, which will be given when we come to consider what is termed weather forecasting.

Westerlies.

In the region north of the Horse Latitudes cyclonic systems separated by Highs travel mainly across the ocean in an east-north-easterly direction.

In the winter these cyclonic systems are more frequent, their track more north-easterly in direction and they traverse generally lower latitudes than they do in the summer. Their tracks are erratic and may be in any direction between North and South by way of East, and very rarely, they may travel north-west or south-west for short periods.

In the summer months cyclonic systems are usually less intense and less frequent than in the winter; and their tracks lie in higher latitudes than in the winter; though sometimes they travel east or south-east in a lower latitude. Some of these summer cyclonic systems traversing the North Atlantic to the northward of the anticyclone, originate in or near the

Doldrums, as tropical revolving storms, and often travelling westward, recurve usually on the western side of the anticyclone, and travel eastward, sometimes as far as the British Isles or Bay of Biscay.

Highest and lowest Barometer.

The average pressure gradient of the region of the Westerlies is not so steep as it is in the "Roaring Forties". The barometer falls lower in mid-North Atlantic in the region of the Westerlies than anywhere else at sea in northern middle latitudes. S.S. *Tarifa* on February 5th, 1870 logged true atmospheric pressure 925·5 mb. (27·33 in.) in Latitude 51° N. Longitude 24° W. The barometer rises higher in the "Horse Latitudes" of the North Atlantic than in any other part of the oceans. The Barque *Victory* on January 23rd, 1859, logged true atmospheric pressure, 1050·1 mb. (31·01 in.) in Latitude 40° N. Longitude 29° W.

The weather is very changeable in the region of the Westerlies, where the wind may come from any direction, and have frequent changes of force from calm to gale and sometimes hurricane force.

The average force of the westerly winds in the winter only is the same in this region, force 6, as it is throughout the year in the "Roaring Forties."

The centres of the majority of cyclonic systems traversing this ocean pass well to the Northward, so that the wind is more frequently from a westerly direction than any other, between the anticyclone and a line between Nova Scotia and the Faroes in February, and between Newfoundland and Iceland in August.

Highest Seas.

So far as measured observations made in all parts of the world since 1855 indicate, the highest seas due to the wind occur in mid-North Atlantic in the middle of the region of the Westerlies, where they have been measured to a height of 80 ft.

Pacific Ocean

The wind systems of the Pacific have a strong resemblance to those of the Atlantic, though weakened by islands, and the anticyclones are less central, the Highs being on the eastern side of the Ocean.

The Doldrums.

The Doldrums have an average width of about 180 miles, though sometimes in September, they may be as much as 350 miles across.

In February the middle line of the Doldrums lies on the Equator in Longitude 170° W. and in Latitude 6° N. in Longitude 120° W.

In August the middle line of the Doldrums is in Latitude 8° N. on the 170th meridian West Longitude, and in 13° N. on the 120th meridian of West Longitude.

In the month of February in Latitude 6° N. Longitude 120° W. the mean barometer is 1011 mb. (29·86 in.). At this time of the year there is an extensive area of low pressure over the Western Equatorial Pacific centred in the region of Latitude 3° S. Longitude 170° E. where the mean barometer is 1007 mb. (29·74 in.).

In August in Latitude 13° N. Longitude 120° W. between the anticyclones, the mean barometer is 1010 mb. (29·83 in.).

During this month the low pressure centred over Asia extends south-eastward in the North Pacific, in the shape of a tongue, and is extended by the Low of the Doldrums, across the Equatorial Pacific.

South East Trade. The South East Trade of the Pacific, unlike the South East Trade of the Atlantic, is not so strong as the North East Trade.

It is a steady wind throughout the year on the eastern side of the region. From the 130th Meridian westward, the trade wind is less steady, both in direction and force and during the southern summer is erratic and frequently there are calms.

During the summer and autumn, hurricanes originate near the Equator to the westward of Longitude 140° W., and travel south-west and south, recurving to the south-east, and passing into middle latitudes.

In February the northern boundary of the South East Trade lies in Latitude 2° S. in Longitude 170° W., passes through Latitude 4° N. in Longitude 130° W., and thence to a little north of the Galapagos Islands.

At this time of the year, its southern boundary lies in Latitude 24° S. Longitude 170° W., passes through Longitude 130° W. on the same parallel, and thence to Latitude 29° S. in Longitude 90° W.

During the southern summer, southerly winds off the west coast of South America extend the Trade Wind, in the same way as the " South Easter " of the Cape, to Latitude 37° S.

In August the northern boundary of the South East Trade lies in Latitude 6° N. in Longitude 170° W., passes through Longitude 130° W. in Latitude 9° N., thence to a little north of the Galapagos Islands.

South-westerly and variable winds occur in the region north of the Galapagos Islands.

At this time of the year its southern boundary lies in Latitude 21° S. in Longitude 170° W., passes through Longitude 130° W. in Latitude 19° S., and thence to Latitude 25° S. Longitude 90° W.

Southern Variables. In February the centre of the South Pacific anticyclone lies in the region of Latitude 30° S. Longitude 100° W., where the mean barometric pressure is 1021 mb. (30·16 in.).

In August the centre of the South Pacific anticyclone lies in the region of Latitude 34° S. Longitude 90° W. where the mean barometric pressure is 1021 mb. (30·16 in.).

At this time of the year the mean atmospheric pressure system is anticyclonic over Australia, and this anticyclone extends from the coast of Queensland and New South Wales into the Pacific.

The winds are variable along the parallels of latitude in which these Highs are situated.

North East Trades. The North East Trades prevail across the greater width of the Pacific during the northern winter. Westward of Longitude 150° E. is a region of Monsoons. The South West Monsoon which prevails in the China Sea from June to August extends to the Western North Pacific.

The North East Trade is steadiest and strongest in the winter.

During the summer and autumn, tropical revolving storms, which occasionally reach hurricane force, originate in the region of south-westerly and variable winds north of the Galapagos Islands and near the southern limit of the North East Trade, travelling north-westward into the Trade wind region, and sometimes recurving towards the North American coast.

These storms also occasionally occur near the centre of the ocean.

Typhoons frequently during the summer and autumn months and occasionally during the rest of the year, originate between the China Coast and the Marianne and Caroline Islands and usually travel in a north-westerly direction, frequently recurving to the north-eastward before reaching the China Coast, and passing on to middle latitudes. Their tracks are erratic.

In February the southern boundary of the North East Trade lies in Latitude 8° N. in Longitude 120° W., passes through the 150th meridian in Latitude 5° N., thence to Latitude 1° N. in Longitude 180°.

At this time of the year its northern boundary lies in Latitude 27° N. Longitude 120° W., passing through Latitude 27° N. Longitude 150° W., thence to the 180th meridian in Latitude 21° N.

In August the southern boundary of the North East Trade lies in Latitude 15° N. in Longitude 120° W., passes through Longitude 150° W. in Latitude 10° N., and crosses the 180th meridian in Latitude 7° N.

At this time of the year, its northern boundary lies in Latitude 26° N. Longitude 120° W., passing through the 150th meridian in Latitude 35° N., thence to the 180th meridian in Latitude 31° N.

Northern Variables.

In February the centre of the North Pacific anticyclone lies in the region of Latitude 35° N. Longitude 135° W., where the mean barometer is 1023 mb. (30·21 in.).

In August the centre of the North Pacific anticyclone lies in the region of Latitude 40° N. Longitude 150° W., where the mean barometer is 1025 mb. (30·27 in.).

The winds are very variable in the region of these Highs, calms being frequent.

Roaring Forties.

The winds and weather in the region south of the South Pacific High are similar to the "Roaring Forties" of the other oceans (*see* page 12).

The lowest reading of the barometer recorded in Southern Middle Latitudes occurred in the South Pacific Ocean on April 24th, 1933, when S.S. *Somerset's* tested Mercurial Barometer indicated 27·32 in. (925 mb.) reduced to sea level.

Westerlies.

In the region north of the North Pacific anticyclone, cyclonic systems travel frequently, generally in a north-easterly direction, in the winter. In the summer they take a more northerly track, and some originate in the tropics on the western side of the Ocean or in the China Sea as typhoons.

In the North Pacific there is considerably more bad weather in the western portion than in the eastern part, and during the winter, north-westerly winds predominate to the westward of the 180th meridian.

Generally, the conditions experienced in the region of the westerlies in the North Pacific are similar to those of the Atlantic.

Indian Ocean

Land and Sea Breezes.

Close into the coast, and particularly in the tropics, land and sea breezes are common in all oceans.

During the day the temperature of the land rises more quickly than that of the sea. The air warmed over the hot land rises, and flows out to sea ; over the sea atmospheric pressure is thereby increased. This increase of atmospheric pressure over the sea produces a flow of air towards the land, near the surface, which is the sea breeze.

At night time conditions are reversed. The land cools more quickly than the sea. Pressure is higher over the land than at sea. The result is the land breeze.

This daily change of wind from the sea during part of the day, and off the land during part of the night is confined to an area extending only about 15 miles each way from the coast line, and up to a height of about 1,000 ft.

Monsoons.

The Atlantic and Pacific Oceans extend into high northern latitudes, but the Indian Ocean only extends over a small part of the northern hemisphere. North of the Indian Ocean is the great continent of Asia.

In the description of the wind systems of the Atlantic and Pacific Oceans, it has been shown that their main wind systems are more or less constant throughout the year. This is not so in the North Indian Ocean.

The summer heating and winter cooling of the great land mass of the continent of Asia produces a seasonal effect upon the winds of the Indian Ocean similar to the daily land and sea breezes, but on a great scale. These seasonal winds are the monsoons.

Doldrums.

The position of the Doldrums is more southerly and less constant than in the oceans where the wind systems are purely oceanic, and cannot be so clearly defined.

South East Trade.

The South East Trade of the Indian Ocean is persistent throughout the year.

Cyclones originate to the southward of the Equator and traverse the region of the South East Trade in the summer months, October to May.

On the southern side of a cyclone in the region of the South East Trade, there is a strong SE. wind. It is therefore difficult to tell when the South East Trade forms part of a cyclone. We shall deal with this in greater detail in a later chapter.

Fine weather, blue skies, and beautiful, white, fleecy, cumulus clouds are the rule in the South East Trades. There is some rainfall, but it is mostly in passing showers.

The South East Trade extends across the Indian Ocean from the coasts of Madagascar and Africa to the West Coast of Australia. From May to September it spreads to the northward of Australia and continues into the South East Trade wind of the Pacific.

In February its southern boundary extends from the neighbourhood of the Leeuwin to Latitude 31° S. Longitude 90° E., thence along the 31st parallel of South Latitude to Longitude 40° E., and thence to Cape Vidal on the Zululand coast.

At this time of the year its northern boundary is well to the southward and extends from Latitude 22° S. off the west coast of Australia, thence to Latitude 11° S. Longitude 90° E., thence to Latitude 12° S. Longitude 70° E.

North West or Middle Monsoon.

The northern boundary of the South East Trade during the southern summer is also the southern boundary of the North West or Middle Monsoon, which prevails in the equatorial region of the Indian Ocean from October to March.

South East Trade. In August the southern boundary of the South East Trade extends from Latitude 25° S. off the west coast of Australia through Latitude 28° S. in Longitude 80° E., thence to Cape Inyack on the African Coast.

At this time of the year the northern boundary lies in Latitude 4° S. off the coast of Sumatra, but towards the western side of the ocean during the northern summer the Equator may be taken as the northern boundary, as here the South East Trade crosses the Equator, changing in direction to south-west with the rotation of the earth, and becomes the South West Monsoon.

The South East Trade of the Indian Ocean is the strongest of all the Trade winds. It occasionally reaches gale force, but generally varies from a light to a strong breeze. The mean force of the wind in the heart of the Trade throughout the year is 4·1 of the Beaufort Scale, or a velocity of 14½ knots. Its average direction is south-east. Its lowest mean force occurs in March, when it is 2·9 of the Beaufort scale with a mean direction of S. 52° E. Its highest mean force is in July, 4·8, and its mean direction is S. 37° E.

During August and September it is nearly as strong as in July.

The South East Trade of the Indian Ocean is stronger when the South West Monsoon continues from it to the northward of the Equator, than during the prevalence of the North East Monsoon.

Southern Variables. The anticyclone of the southern Indian Ocean is similar to those of the South Pacific and South Atlantic.

In February it is very extensive, having two centres where the mean barometer is 1020 mb. (30·12 in.), one in the region of Latitude 37° S. Longitude 100° E., and the other in the region of Latitude 36° S. Longitude 63° E. In these regions at this time of the year calms are experienced on the average five times out of a hundred occasions.

In August the anticyclone is intense, the mean barometer being 1026 mb. (30·30 in.) in Latitude 31° S. Longitude 67° E. At this time of the year in this region there are calms on the average four times out of a hundred occasions.

Throughout the year the winds are variable in direction, from light airs to an occasional gale.

Roaring Forties. The winds and weather in the region south of the anticyclone of the South Indian Ocean are similar to the " Roaring Forties " of the other oceans (*see* page 12).

South of Latitude 48° S. from April to July westerly gales occur with great frequency. Over the whole region gales are more frequent in the winter than in the summer.

Generally bad weather increases with latitude.

North West or Middle Monsoon, Variables and calms. During the northern winter, October to March, when the barometer is high over Asia, pressure is comparatively low in the equatorial Indian Ocean, and between the Equator and the northern boundary of the South East Trade north-westerly winds prevail, particularly in December, January and February, interspersed with calms.

During April, calms are frequent all over the Indian Ocean northward of the South East Trade. During October calms and light variable winds also occur, before the setting in of the North East Monsoon, all over the Indian Ocean to the northward of the South East Trade

North East Monsoon. During the northern winter, October to March, the distribution of pressure over the northern Indian Ocean is not materially different from that over corresponding latitudes of the North Atlantic Ocean; that is to say, pressure is low near the Equator, and higher at the head of the Arabian Sea and Bay of Bengal; the High corresponding to that of the Atlantic Horse Latitudes being in a higher latitude.

In February the Asiatic High is situated over central Asia where the mean barometer is 1032 mb. (30·48 in.) when the mean barometer in the Southern Equatorial Indian Ocean in Latitude 10° S. is 1010 mb. (29·83 in.) in a belt of low atmospheric pressure connecting Lows centred over Central Africa and Northern Australia. This distribution remains much the same from November to March, when consequently the wind is north-east over the Arabian Sea, Bay of Bengal and the Indian Ocean, north of the Equator.

The North East Monsoon usually varies from a light to a fresh breeze accompanied by very pleasant weather. In the heart of the North East Monsoon in the Arabian Sea the mean force from November to March is 2·6 of the Beaufort Scale or a velocity of 7½ knots, and mean direction N. 61° E. It is strongest in December when the mean force is 3·2, with direction N. 54° E.

The North East Monsoon is occasionally interrupted by cyclones, except in February and March.

South West Monsoon. During the northern summer from May to September, the barometer is low over Asia. In August, when the mean barometer in the Southern Anticyclone is 1026 mb. (30·30 in.) in Latitude 31° S., the mean barometer at the Mekran Coast at the head of the Arabian Sea in Latitude 25° N. is 1000 mb. (29·53 in.), a difference in the mean atmospheric pressure for the month between these Latitudes of 26 mb. (0·77 in.).

The result is that the South East Trade wind is drawn across the Equator, and veering with the rotation of the earth continues to blow over the whole of the north Indian Ocean as the South West Monsoon.

Following the calms and variables of April, which are often attended by heavy rain, usually about the middle of May the South West Monsoon is first felt off the East Coast of Africa, south of Sokotra, from whence it spreads, bursting on the coasts of India, usually early in June.

The strongest part of the South West Monsoon covers a strip of the ocean trending to the north-east from Latitude 7° N., where it is about 100 miles wide, and passing close to the eastward of Ras Hafan and Sokotra, and extending to a width of about 350 miles at its widest part.

During July and August, when the South West Monsoon is at its height, the mean force of the wind in this region is 6·3 of the Beaufort Scale, that is, it has a velocity of 26 knots, and mean direction SW. This is the highest mean force of any known trade or monsoon wind at sea.

In the Arabian Sea the wind is generally more from the westward and lighter with easting. In the Bay of Bengal the mean direction is generally south-west, and the force of the wind is generally more uniform over the Bay.

The South West Monsoon all over the region may vary several points in direction and from a light breeze to a gale. It may be interrupted in the Arabian Sea, except during August, by cyclones, and frequently in the Bay of Bengal during the season.

Sea and Swell

Generally the state of the sea in the different parts of the ocean varies or persists according to the wind in that part of the ocean, sea being set up by wind; so that generally the foregoing description of the average state of the winds of the oceans gives some indication of the sea which may be expected in the different wind belts.

Length of waves.

The length of waves is increased when the length of the sheet of water to windward, that is the "fetch," is great, with the same wind force.

In the region of the Roaring Forties, the sea is more continuously heavy, for here the winds and the waves almost completely have a free girdling of the earth from the westward.

Long waves travel faster than short waves.

Height of waves.

The height of a wave increases quickly with an increase of wind, and soon attains its maximum height for a given wind force. The height also decreases more rapidly than the other dimensions of a wave when the wind drops.

Waves set up by the wind as sea, pass on to great distances, the length and velocity remaining the same, the height diminishing as they proceed.

Their course is straight, and not affected by the rotation of the earth, as is the wind; the water itself does not travel bodily.

Rollers.

Upon reaching shallow water or a coast line, they regain height and lose length, becoming rollers and breaking as surf. The "Rollers" of Ascension are a striking case of this. These rollers originate as sea in the north-westerly gales of the North Atlantic, thousands of miles from the Island, continuing as swell they may be imperceptible to a ship in mid ocean in their path, until they approach the island, where they mount up and break with such violence as to render landing by boat impossible.

The highest waves due to wind are encountered near the middle of the North Atlantic (*see* page 13).

Sea and Swell are often present at the same time, and from different directions.

Cross Seas and Swell.

Cross seas and swell may be encountered in all parts of the oceans, but in some regions they are frequent and in some regions the sea may be steep and very dangerous. To cite two examples only :—

During westerly to south-west gales off the South African coast, the long waves from the deep water of the Southern Ocean are suddenly shortened at the edge of the Agulhas Bank, and the wind being against the Agulhas Current, a very steep dangerous sea results.

Generally in the region of the Trade Winds and Monsoons where the wind is very steady, when there is not swell coming from a region of distant storms, the sea runs true, if there are not other disturbing agencies. Some 100 to 250 miles south of the island of Sokotra, during the South West Monsoon season, a very strong current sets in an ESE. direction, right athwart the wind; and there is very often a dangerous cross sea. In July and August, when the monsoon and the current are usually strongest, on as many as 44 in 100 occasions, cross seas are encountered in this region.

The Winds of the Lesser Seas and the Influence of the Land

Over the oceans a true system of atmospheric circulation, governed by pressure, has full sway. Near the coasts and in the lesser seas the land causes deviations.

Mediterranean.

In the Mediterranean cyclonic wind systems during the winter pass from the Atlantic, or form locally, and frequently traverse the sea from west to east, causing the wind to come from all points of the compass but mainly from NW.

During the summer these travelling depressions occur less often, and are confined to the western and northern portions of

North West Monsoon of Levant.

the Mediterranean. In the Eastern Mediterranean and Levant, during the summer, the winds are mainly from the NW., and are in the nature of a monsoon ; for due to heating of the atmosphere over the Syrian Desert, the barometer is comparatively lower in that region than it is in the Levant.

Character of Wind.

Generally in all parts of the world both ashore and at sea, the pressure distribution produces the wind, but the character of the wind—that is its temperature, moisture, and purity—is governed by the nature of the land or the sea from whence it comes.

Scirocco.

For instance the Scirocco, a hot, dusty, South East wind—as its Italian name implies—which occurs in the Mediterranean most frequently during the spring, always occurs on the eastern side of depressions, thus conforming to Buys' Ballots Law.

It comes from the North African deserts, where it is heated and charged with fine sand.

In the English Channel and coastal waters of the British Isles, the South West wind is usually a comparatively warm, moist wind, coming as it does over great stretches of the North Atlantic, where the air is heated and charged with moisture ; while usually in the winter Easterly or North Easterly winds are cold and dry, coming as they do from off the chilled land of Northern Europe.

Exceptions to rule of Wind and Barometer.

There are exceptions to the rule that the wind is due to the difference of atmospheric pressure at different places as measured by the barometer, that is barometric gradient.

Mistral and Bora.

In coastal waters adjacent to high mountains strong winds, largely caused by gravitation, occur ; a well known case of which are the Mistral and Bora of the Gulf of Lyons and the Adriatic.

With a clear sky, the air over the mountain tops of the Pyrenees and Cevennes, cooled by terrestrial radiation at night, and set upon its course towards the Southern steep slope of the mountains by the wind associated with the rear of a depression, being cold, dry and heavy, rushes down to the sea by gravitation as the " Mistral," its force being out of all proportion to the existing gradient.

The " Mistral " sets up a very high steep sea in the Gulf of Lyons, owing to its descent upon the surface of the sea, as well as its force.

CHAPTER III

TROPICAL REVOLVING STORMS

The strongest winds at sea are encountered in tropical revolving storms. The maximum velocity of the wind in these storms has never been measured at sea, but velocities up to 130 knots have been measured in tropical revolving storms on the coasts.

Winds of hurricane force, 12 on the Beaufort Scale (above 65 knots) are frequent in tropical revolving storms.

General Description.

The tropical revolving storm is more nearly a perfect vortex than any other cyclone, being of a more compact form than cyclones of middle and high latitudes. The laws of storms were formulated from experience in these storms.

A tropical revolving storm is an intense whirl in the atmosphere, which if the horizontal movement of the air near the sea surface could be seen from above, would appear as illustrated in the sketch on page 24.

When ships at sea encounter heavy storms it is often impossible to fix their positions exactly. Observations do not exactly synchronize, and therefore there have been few if any cases where even a partially exact representation of the actual paths of the whole of the winds in a tropical revolving storm has been ascertained.

Nevertheless, by records of countless experiences in these storms for many years, the general path of the winds in them is fairly well known.

In the sketch of a tropical cyclone of the South Indian Ocean the arrows represent the actual winds reported at the positions indicated in one particular cyclone. The flow lines represent the general flow of the wind as learned from observations in many tropical cyclones.

Visualizing weather systems.

In considering storms and weather systems with the aid of diagrams and weather charts, we should visualize the whole of the winds in the system, though our diagrams and weather charts only actually indicate the winds and conditions at a comparatively small number of positions covered by the system for the time being.

The centre of a full tropical revolving storm is usually a comparative calm. Around this region of calm there is a belt of winds of hurricane force in which the wind is circular or nearly circular. Further from the centre the wind has less force, and its direction is generally inclined more towards the centre. On the outskirts of the storm the wind may be light, but conforming to the circulation of the system.

WIND FLOW LINES IN A TROPICAL REVOLVING STORM OF THE SOUTHERN HEMISPHERE

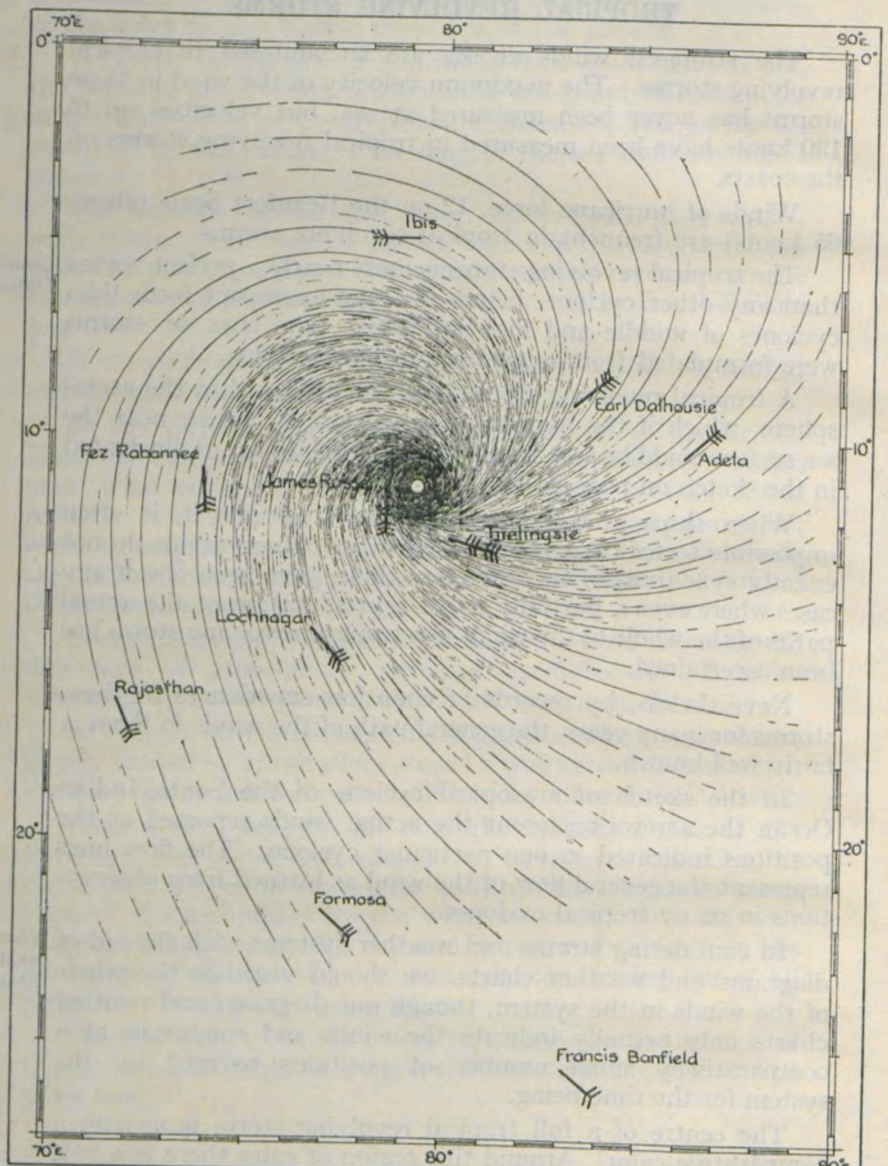


FIG. 3.—The superimposed wind arrows are actual observations recorded by the ships named at noon on May 16th, 1863, as plotted by Meldrum of Mauritius.

In the same part of the storm the wind may vary considerably, at times being of hurricane force, and at others lulling to little more than a strong breeze.

Tropical revolving storms as well as the circular motion of the wind have a bodily forward or progressive movement.

In north latitudes the wind blows in the opposite direction to the hands of a watch. In the south latitudes the wind blows in the same direction as the hands of a watch.

These storms often originate near the Equator, but seldom within six degrees of the Equator. From the place of origin they first travel westward and away from the Equator with gradually increasing speed. Usual tracks.

In the vicinity of the tropic or a little beyond it, they sometimes recurve. During recurvature their progressive movement slackens. After recurvature they travel to the eastward and pass into middle latitudes, expanding and travelling at a great rate. Some tropical revolving storms make erratic tracks.

The storm field may have a diameter of several hundred miles, increasing as the storm progresses into higher latitudes, where the diameter of the same storm may be over 1,000 miles.

The calm centre, in which the wind is variable, light or calm, but where there is a cross confused sea, often tremendous, has been found to be from 4 to 28 miles across.

The belt of hurricane winds has been found to be from 4 miles to 64 miles across. The width of this belt is sometimes greater in rear of the centre than in advance of it. It is probable that these dimensions are exceeded in some tropical revolving storms.

Terms

Vortex, or Eye of the Storm.—The central calm area within the ring of hurricane winds, where the barometer is lowest.

Centre.—That part of any cyclonic wind system where the barometer is lowest.

Angle of Indraft.—The angle which the direction of the wind makes with an isobar. In tropical revolving storms, when the wind is circular near the centre, the isobars are circular, and the centre will bear 8 points from the direction of the wind. Then there is no indraft. There is an indraft when the wind inclines towards the isobars. If the wind has an indraft of 2 points, i.e., inclines towards an isobar at an angle of 2 points, the centre will bear 10 points from the direction of the wind if the isobar is circular.

Path.—The path along which the centre *will* probably travel.

Track.—The track along which the centre *has* travelled.

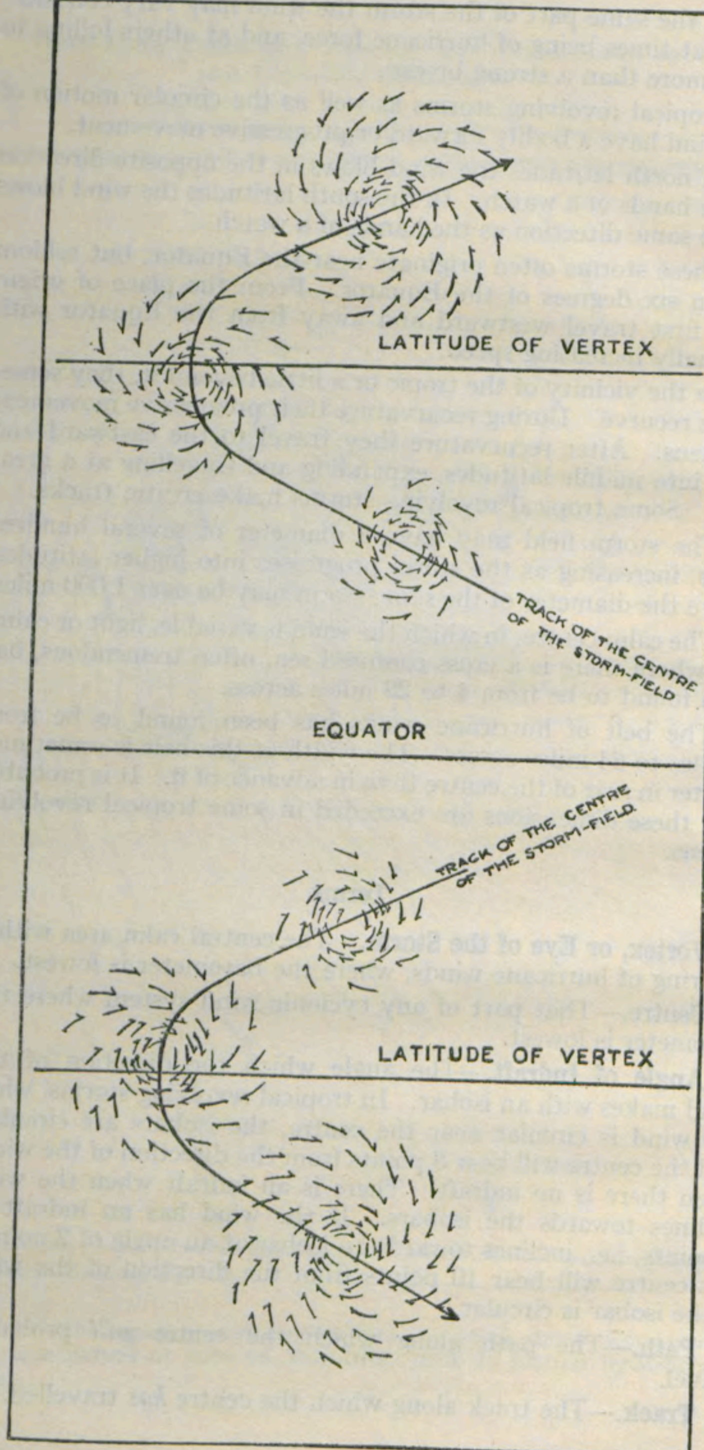


FIG. 4.

Vertex.—The most westerly point reached by the centre *when* recurvature takes place. Also known as the " cod " of the track.

Right Semicircle.—Looking along the path, that half of the storm which lies to the right.

Left Semicircle.—Looking along the path, that half of the storm which lies to the left.

Trough.—The line of lowest barometer athwart the line of the path, extending right across the storm field.

Storm Field.—The region covered for the time being by the winds forming the storm system.

Dangerous Quadrant.—The advance quadrant of the semicircle which lies on the side of the path towards the usual direction of recurvature. That is *right* advance quadrant in *north* latitude, and *left* advance quadrant in *south* latitude. The dangerous quadrant is so named because a ship caught in it may be blown towards the path over which the vortex will pass, or the storm may recurve and the vortex pass over her. The strongest winds usually occur after the trough has passed.

Navigable Semicircle.—That semicircle which lies on the side of the path away from the usual direction of recurvature. That is, *left* semicircle in north latitude, *right* semicircle in south latitude.

Regions and Seasons

Tropical revolving storms are known as Hurricanes, Cyclones, or Typhoons, according to region.

The word " Hurricane " is of Spanish or Portuguese origin. " Cyclone," Greek—Kuklos, a circle, and " Typhoon," Chinese meaning " Great wind."

North Atlantic.

The hurricanes of the North Atlantic—West India Hurricanes—occur mainly after the summer's heat, September being the month when they are most frequent. The season extends from June to November.

Arabian Sea.

Cyclones mostly occur in the Arabian Sea at or just after the change of the monsoons, being most frequent in May and June, and October and November. They have occurred in all months of the year except February, March, and August.

Bay of Bengal.

Cyclones have occurred in the Bay of Bengal in all months of the year except January, February, and March when no cyclone with winds of hurricane force has been reported. The worst months are May, October and November.

China Seas and Western N. Pacific.

Typhoons occur in all months of the year, and are frequent in the late summer and autumn, July to November ; September being the worst month.

Eastern North Pacific.

Hurricanes are encountered in the Eastern North Pacific and have been reported as far west as the 155th meridian of West longitude. They occur in the summer and autumn, June to November, the worst month being September.

South Atlantic.

A tropical revolving storm, having winds of hurricane force, has never been reported in the South Atlantic Ocean.

South Indian Ocean.

Cyclones are frequent in the summer, November to April, in the South Indian Ocean, where the worst month is February. They occasionally occur as early as October and as late as May.

South Pacific.

Hurricanes occur in the Western South Pacific—none have been reported east of Longitude 140° W.—frequently during the summer, and on rare occasions in all months of the year. The worst months are January, February and March.

The following table gives the actual numbers of tropical revolving storms which have been reported in the various regions, with period in each case.

Number of Tropical Revolving Storms Reported for each Region, with Period

Region and Period.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.
West Indies, 1887–1923 (37 years).	—	—	—	—	—	11	13	35	61	49	8	2	179
Arabian Sea, 1842–1925 (84 years).	2	—	—	4	10	12	3	—	1	12	13	4	61
Bay of Bengal, 1891–1923 (35 years).	—	—	—	4	8	2	3	1	5	9	10	4	46
China Sea and Western N. Pacific, 1893–1918 (26 years).	31	17	18	14	33	34	90	92	110	95	52	34	620
Eastern N. Pacific, 1910–1928 (19 years).	—	—	—	—	1	11	14	15	34	17	2	1	95
South Indian Ocean, 1886–1917 (32 years).	42	54	39	18	6	—	—	—	—	2	8	25	194
South Pacific, 1789–1924 (136 years).	66	48	62	17	3	2	1	1	3	4	7	33	247

Tracks

Paths.

The tracks of tropical revolving storms are found to generally curve round the great anticyclones; and the paths of these storms are greatly influenced by the general atmospheric pressure distribution over the ocean *at the time of their occurrence.*

Now a tropical revolving storm is an eddy or whirl in the general air current, and is carried along in the same way as an eddy is carried along in a stream of water.

The general air circulation conforms to the general pressure distribution. Where the general air current moves slowly the tropical revolving storm within it moves slowly; and where the general air current moves swiftly, the storm moves swiftly.

Speed.

In the tropics the drift of the air—the Trade Wind—is mainly to the westward, from the surface to a great height; while in middle and high latitudes it is to the eastward. Hence tropical revolving storms usually travel at moderate speeds to the westward from their point of origin in equatorial regions, recurving round the western edge of the anticyclone. Their progressive movement is slow and is sometimes checked for short periods in the region of the western end of the anticyclone. When this occurs it has been found that the general distribution of atmospheric pressure has been such that comparatively high pressure has existed in the direction towards which the storm had been travelling.

After recurvature upon passing the northern side of the anticyclone where the general atmospheric drift is to the westward, these storms travel sometimes at great speeds.

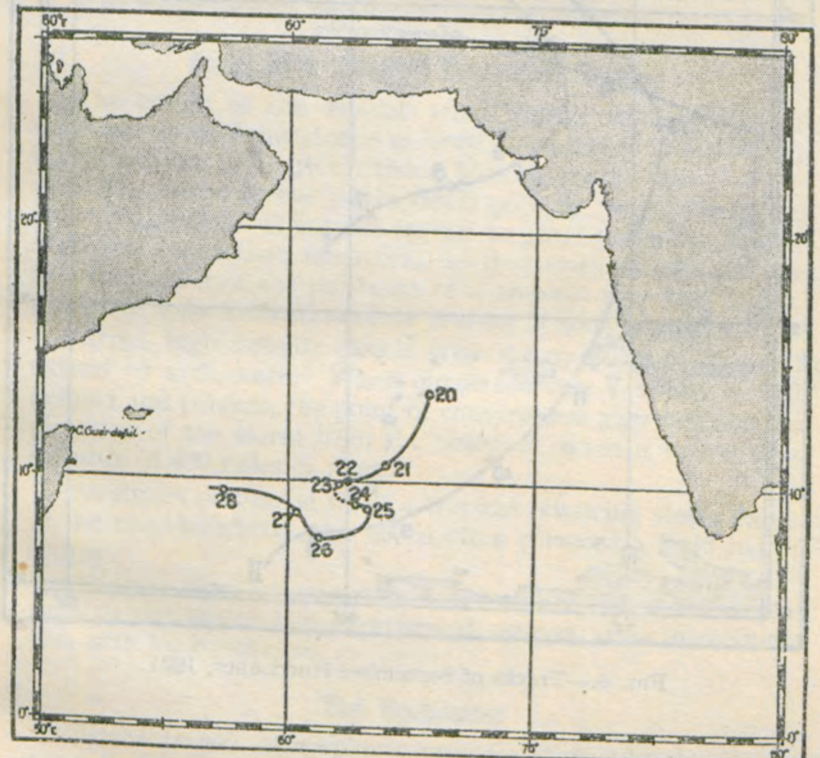


FIG. 5.—Track of Cyclone with noon positions, November 20–28, 1920.

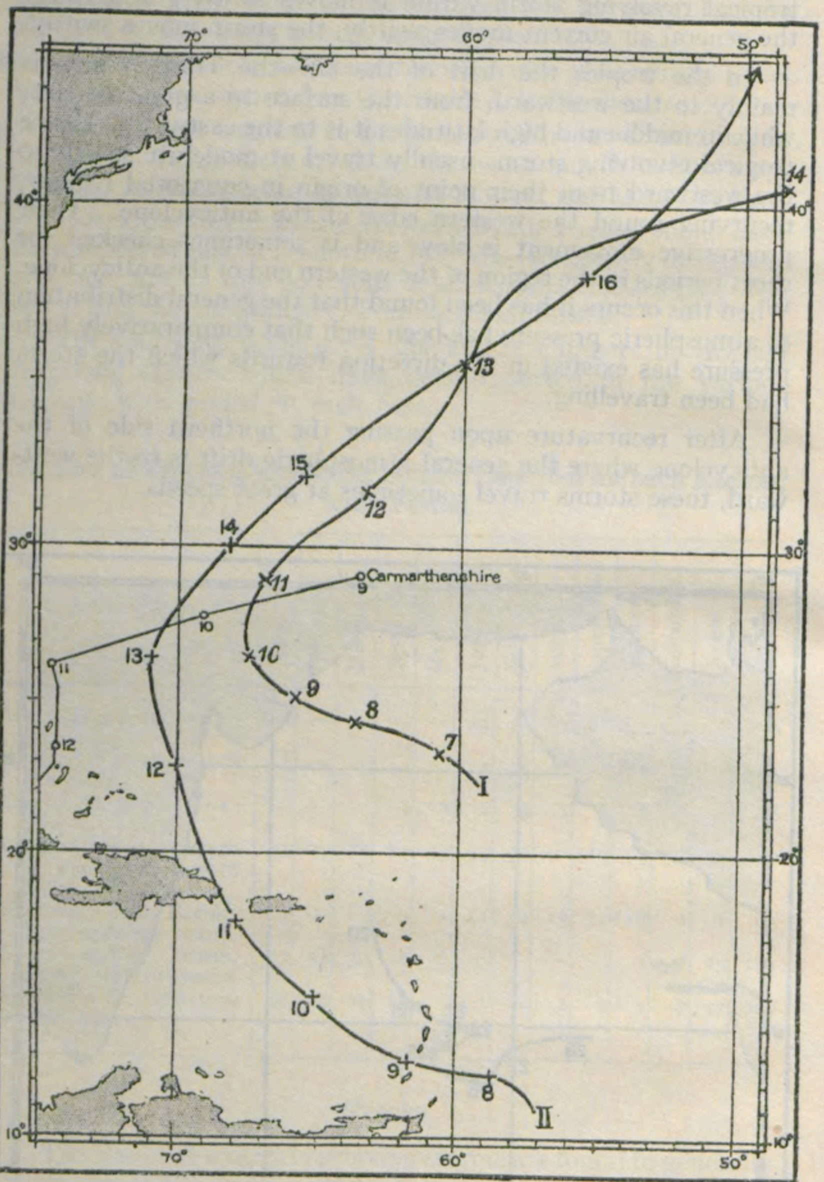


FIG. 6.—Tracks of September Hurricanes, 1921.

Generally, the rate of progression of cyclonic storms within the tropics and before recurvature does not exceed 12 knots. A typhoon has been known to travel at 20 knots, but this is exceptional.

After recurvature, in middle and high latitudes, the speed of progression varies, and has reached 50 knots.

Tracks.

The tracks of tropical revolving storms are erratic, particularly in the monsoon regions, that is, the Arabian Sea, Bay of Bengal and China Sea.

Occasionally two revolving storms have occurred in close proximity to each other ; sometimes one following the other, at other times the pair advancing nearly abreast, their centres being as close to each other as 600 miles.

FIGURE 5 is the erratic track of a cyclone which occurred in the Arabian Sea.

FIGURE 6 indicates the tracks taken by two Hurricanes which existed at the same time in the North Atlantic.

FIGURE 4 gives an approximation of the average trend of the tracks of tropical revolving storms which recurved. Some of these storms make tracks which do not recurve.

Signs of a Tropical Revolving Storm

Swell.

The action of the violent winds in the right hand rear quadrant of revolving storms in North latitudes, or the left-hand rear quadrant in South latitudes, blowing mainly in the direction of advance of the storm develops large seas, which pass onward as swell. This swell travels to great distances, and at a greater speed than the storm, so that swell often gives the first indication of the existence of a tropical revolving storm, and gives some indication of its bearing at some previous time.

Cirrus Clouds.

Cirrus, high delicate clouds originate over the vortex and extend to a distance. When cirrus forms a **V** which is well defined and persists, the point of convergence may indicate the direction of the storm from the observer, when it is still at a distance of 400 miles or more.

Sky colouring.

At sunset or sunrise when a tropical revolving storm exists in the neighbourhood, the sky is often çoloured a lurid red or copper.

All these signs are uncertain, but they may be useful indications to the skilled and experienced seaman, used in conjunction with his barometer.

The Barometer

The Barometer.

In the tropics atmospheric pressure is usually steady but for a double daily regular oscillation, only changing gradually with the season.

This steadiness of the barometer is so marked that should at any time the atmospheric pressure be found to differ from the mean for the time of day, season, and place, disturbed conditions are indicated.

Diurnal Range.

A double wave of atmospheric pressure sweeps regularly round the earth from east to west, being at a maximum near the Equator, where it is clearly indicated by the rise and fall of the barometer.

Due to this diurnal range of pressure, the barometer is highest at 10 a.m. and 10 p.m. and lowest at 4 a.m. and 4 p.m. each day. To compare the true atmospheric pressure as found by the barometer with the average for the season and place within the tropics, an adjustment should be made for this daily range. For this purpose the following tables have been calculated from a great number of observations.

Tables to Correct Barometric Pressure for Diurnal Variation

Latitude 10° to 20° N. in all Longitudes at Sea

Ship's Time.	Northern Spring.		Northern Summer.		Northern Autumn.		Northern Winter.	
	Mbs.	In.	Mbs.	In.	Mbs.	In.	Mbs.	In.
4 a.m.	+0·8	+·02	+0·7	+·02	+0·8	+·02	+0·3	+·01
8 a.m.	−1·1	−·03	−0·9	−·03	−0·9	−·03	−0·9	−·03
Noon	−0·9	−·03	−0·6	−·02	−0·7	−·02	−0·6	−·02
4 p.m.	+1·3	+·04	+1·2	+·04	+1·3	+·04	+1·4	+·04
8 p.m.	+0·1	·00	+0·1	·00	−0·1	·00	0·0	·00
Midnight	−0·4	−·01	−0·3	−·01	−0·3	−·01	−0·2	−·01

Latitude 10° to 20° S. in all Longitudes at Sea

Ship's Time.	Southern Spring.		Southern Summer.		Southern Autumn.		Southern Winter.	
	Mbs.	In.	Mbs.	In.	Mbs.	In.	Mbs.	In.
4 a.m.	+0·6	+·02	+0·7	+·02	+0·7	+·02	+0·5	+·02
8 a.m.	−1·0	−·03	−1·0	−·03	−0·8	−·02	−0·9	−·03
Noon	−0·5	−·02	−0·4	−·01	−0·4	−·01	−0·4	−·01
4 p.m.	+1·4	+·04	+1·3	+·04	+1·1	+·03	+1·2	+·04
8 p.m.	−0·0	·00	−0·1	·00	−0·2	−·01	−0·2	−·01
Midnight	−0·5	−·02	−0·4	−·01	−0·4	−·01	−0·5	−·02

If the atmospheric pressure (that is the barometer reading reduced to the standard datum of sea level, latitude 45°, temperature 32° F) adjusted for diurnal range, is one-tenth of an inch (3 mb.) below the average, it is probable that a tropical revolving storm is forming or has formed in the vicinity.

It should be remembered that the barometer frequently stands above the average on the outskirts of a storm.

In the tropics if the barometer indicates a departure of one-tenth of an inch or more from normal the mariner should be on the alert.

Indication of Existing Storm.

If the barometer is two-tenths of an inch below the average, a tropical revolving storm is most probably in the vicinity.

Places of Origin.

Tropical revolving storms only originate over the sea. They do not form over the land.

Some hurricanes of the North Atlantic have formed in the region of the Doldrums, between the South West Monsoon wind and the North East Trade.

Some cyclones of the South Indian Ocean have formed in the region of the Doldrums between the North West Monsoon and the South East Trade, and in the early part of their existence the North West Monsoon and the South East Trade have both actually formed part of the cyclonic circulation.

In the Arabian Sea cyclones form at the change of the monsoons between the verges of the North East and South West Monsoon.

In all these regions temperatures are high and moisture excessive, with barometer lower than in the bordering regions of the trade or monsoon winds. Before a tropical revolving storm forms there is a further reduction of atmospheric pressure, and when a tropical revolving storm forms, this reduction increases rapidly, particularly at the centre.

There are no Doldrums in the South Atlantic, and tropical revolving storms do not occur in that ocean.

Consequence of remaining in path of storm.

A ship in the path of a tropical revolving storm having observed any or all of the signs before mentioned, will experience a freshening wind and a falling barometer as the storm field approaches her.

If she remains in the path of the storm, the barometer will continue to fall ; the wind and sea will become increasingly worse ; the wind remaining nearly from the same direction though becoming more unsteady and squally, reaching hurricane force near the centre.

When the centre arrives the wind drops ; the barometer, which has fallen more and more rapidly until now, ceases to fall, being at its lowest ; the sea which is high, becomes cross, confused, and tremendous.

As the centre passes, the wind comes with fury from nearly the opposite point of the compass to that from which it came before it dropped, and soon reaches a maximum force, the barometer in the meantime rising.

After this, the squalls become less frequent ; the wind moderates ; the barometer continues to rise, and the storm passes onward.

Few, if any, vessels have been through the ordeal of passing through the vortex of a full tropical revolving storm, in which there were winds of hurricane force, without sustaining damage. Many sailing ships have been dismasted in these storms. Numbers have been lost through being taken aback or caught by the lee when the wind shifted upon passing through the vortex.

Some have foundered through being forced into sternway against an overpowering sea. The destructive consequences of the vortex passing over a ship are common knowledge amongst seamen. They need not be further enlarged upon here.

These storms are accompanied by heavy rain. The clouds are usually broken at the centre; and sometimes over the centre the sky is almost cloudless; hence the term the eye of the storm.

Laws of Storms

The words "Laws of Storms" convey the meaning of those now well established natural laws governing the behaviour of the wind and barometer in tropical revolving storms; and by long usage amongst seamen they also convey rules for handling ships which have gradually been built up from experience in ships in these storms.

Sailor's Horn Card.

The Horn Card, a transparent disc, with a diagram representing the approximate average winds and fall of the barometer in tropical revolving storms in North or South latitudes —in pocket at end of book—makes clear why the wind remains nearly from the same direction, increases, veers, or backs in a ship in the storm field.

For example—let a small mark on a piece of white paper, spread on the chart house table, represent your ship hove to, in northern latitude, in the path of a storm, travelling WNW.—place the arrow head of the line of progression over the ship, pointing WNW., and move the Horn Card in that direction over the ship. The arrows of the Horn Card indicate the directions and forces of the wind, and the concentric lines the fall and rise of the barometer as the storm field passes.

Every conceivable example showing the changes of wind and barometer which may be experienced, according to the ship's position, course, and speed relative to the position of the centre, course, and speed of the storm, can be illustrated by manipulating the mark representing the ship and the Horn Card.

It must not be forgotten that the forces and directions of the wind on the Horn Card are *average* or approximate.

There may be greater or less indraft. It must also not be forgotten that storms are not exactly circular, and that the

barometric gradient varies in different storms. The barometric gradient may be changing throughout the whole of the storm field.

The falls of the barometer indicated by the values at the concentric circles on the Horn Card are *average* or approximate. Isobars represented by the concentric circles on the Horn Card may not be actually true circles in a storm, and are often oval or irregular towards the outskirts of the storm field.

Rules for handling ships.

1. In the season and region of tropical revolving storms, watch the barometer with special care, log it regularly, and compare the readings reduced to the standard datum with the average for locality, time, and season. Look out for other signs.

2. When there is reason to believe that a storm is approaching, or that the ship is within the system of a tropical revolving storm, it is necessary to know two things. First, the bearing of the centre, and second, which semicircle the ship is in.

An isolated observer can only ascertain the latter if he is stationary; therefore, heave to, assuming that you are in the dangerous quadrant.

That is, heave to on the starboard tack in North latitude or on the port tack in South latitude.

3. Face the wind and the centre will bear about 12 points to the right in North latitude at the commencement of the storm; when the barometer has fallen three-tenths of an inch (10 mb.) the centre will bear about 10 points to the right; and when the barometer has fallen six-tenths of an inch (20 mb.) or more, the centre will bear eight points to the right.

In South latitude the centre bears about 12 points *or more* to the left at the commencement of the storm; when the barometer has fallen three-tenths of an inch (10 mb.), 10 points or more to the left; and when the barometer has fallen six-tenths of an inch (20 mb.) or more, 8 points to the left.

4. In North latitude, having hove to on the starboard tack, if the wind veers the ship is in the right semicircle. Remain hove to. A sailing ship thus hove to will come up and head the sea as the wind veers. In a steamer keep the wind on the starboard bow.

If the wind remains steady in direction and increases in force, with falling barometer, the ship is near the path of the storm. Run with the wind on the starboard quarter. This will take the ship into the navigable (left) semicircle.

If the wind backs, the ship is in the left semicircle; run with the wind on the starboard quarter (keep it abaft the beam) until the barometer rises.

In South latitude, having hove to on the port tack, if the wind backs, the ship is in the left semicircle. Remain hove to. A sailing ship thus hove to will come up and head the sea as the wind backs. In a steamer keep the wind on the port bow.

If the wind remains steady in direction and increases in force, with falling barometer, the ship is near the path of the storm. Run with the wind on the port quarter. This will take the ship into the navigable (right) semicircle.

If the wind veers, the ship is in the right semicircle; run with the wind on the port quarter (keep it abaft the beam) until the barometer rises.

In the South Indian Ocean on the south side of a cyclone there is a strong South East Trade wind. It is therefore difficult to know *when* the South East Trade forms part of a cyclone.

In the South Indian Ocean it has been found that the South East and North East winds in a cyclone blow almost directly towards the centre; that is there is a great indraft towards the vortex close to which the hurricane winds are more or less circular.

If the South East Trade increases to a gale, heave to and watch the barometer. If the wind shifts to the South or East the passage of the centre with respect to the ship may be inferred. If the wind remains steady, and increases in force, and the barometer falls, the ship is in the path of the storm, a most dangerous position.

In such case, only when the barometer has fallen six-tenths of an inch (20 mb.), can the bearing of the centre be indicated by the above rules.

By running to the north-west with a south-easterly wind, before the barometer has fallen six-tenths of an inch (20 mb.) you may be heading direct for the centre. *When* you do run keep the wind well out on the port quarter only a couple of points or so abaft the port beam.

These rules for sailing ships were learned from long and many experiences in sailing ships. Many bitter experiences proved the error of the old rules, based upon the assumption that the wind in tropical revolving storms was circular, so that the bearing of the centre would always be at right angles to the direction of the wind.

Old false rules.

There was also an old theory that by scudding before the wind a ship would run out of a hurricane. The most remarkable case on record of a vessel scudding is that of the brig *Charles Heddle.* Her track between the 23rd and 27th February 1845, during which she ran round the centre five times, as plotted by PIDDINGTON, is given on page 37, FIGURE 7.

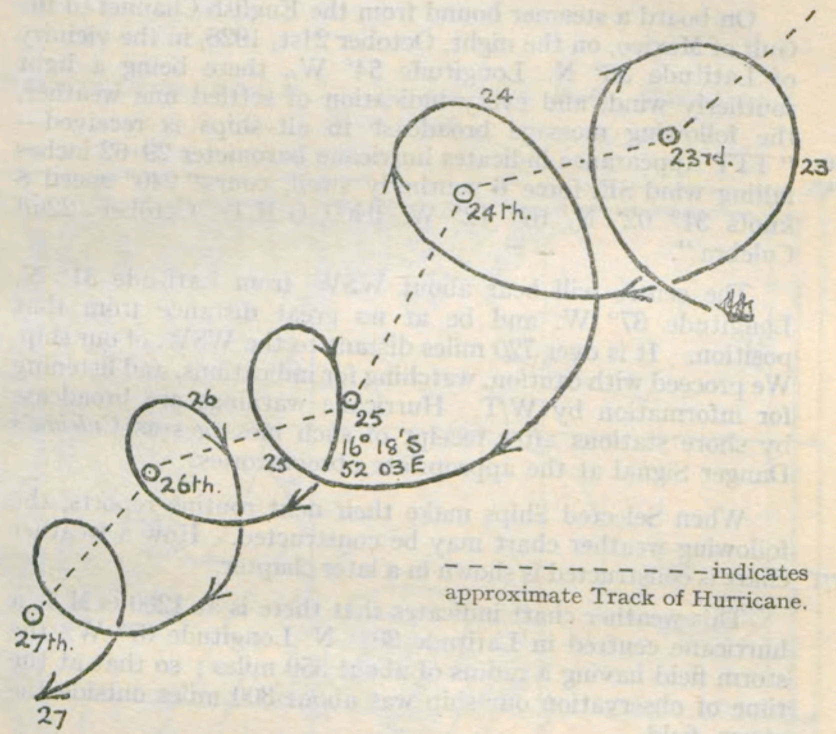


FIG. 7.—Track of brig "Charles Heddle," 23rd to 27th February, 1845, as deduced by Henry Piddington.

These rules hold good for power propelled vessels, and once a ship is in the storm field she should be handled accordingly. Sea room is of course necessary.

Rules hold good.

Wireless Telegraphy Communication

Information of a tropical revolving storm received by wireless telegraphy at a distance, may be the means of avoiding the storm altogether, or by early manoeuvring reducing the risk of encountering the vortex. Particularly in the tropics, before and during recurvature, when generally a storm travels with less speed than in middle and high latitudes after recurvature, early and distant information of the existence of a storm may be used to great advantage, and in high latitudes it will at least give earlier warning than is possible to obtain by isolated observation.

Wireless communication.

With the following example and a knowledge of the law of storms, the application of information received by wireless telegraphy will be apparent, whatever the varying circumstances which are bound to confront seamen navigating regions where tropical revolving storms are met with.

On board a steamer bound from the English Channel to the Gulf of Mexico, on the night, October 21st, 1926, in the vicinity of Latitude 36° N. Longitude 54° W., there being a light southerly wind, and every indication of settled fine weather, the following message broadcast to all ships is received—

Storm Danger Message.

" TTT Appearance indicates hurricane barometer 29·62 inches falling wind SE. force 6 southerly swell, course 240° speed 8 knots 31° 02′ N. 67° 12′ W. 0400 G.M.T. October 22nd Culebra ".

The centre will bear about WSW. from Latitude 31° N. Longitude 67° W. and be at no great distance from that position. It is over 720 miles distant to the WSW. of our ship. We proceed with caution, watching for indications, and listening for information by W/T. Hurricane warnings are broadcast by shore stations after receipt of such messages as *Culebra's* Danger Signal at the appropriate observatories.

Use of Selected Ship's routine W/T Weather Reports.

When Selected Ships make their next routine reports, the following weather chart may be constructed. How a weather chart is constructed is shown in a later chapter.

This weather chart indicates that there is at 1200 G.M.T. a hurricane centred in Latitude 30½° N. Longitude 67° W., the storm field having a radius of about 350 miles ; so that at the time of observation our ship was about 300 miles outside the storm field.

The general pressure distribution indicates an anticyclone to the south-east of our ship (the North Atlantic anticyclone), an anticyclone in the region of the eastern United States coast, and a depression off the east coast of Nova Scotia.

As has been indicated earlier in this chapter, the path curves round the western edge of the anticyclone, taking a course which will not be impeded by comparatively high pressure.

From the chart it may be estimated that the path lies in a north-easterly direction, and as there is no indication of high pressure developing in this direction, but rather that the depression off Nova Scotia will move eastward, and so still further reduce pressure to the north-east of the hurricane, the progressive movement may be fast.

The changes of the barometer indicated at Bermuda, and at the positions of *Canadian Forester* and *Culebra* are consistent with a north-easterly movement of the hurricane.

The Barometer.

In such circumstances it would be folly to proceed at speed on the course S. 63° W. Course should be altered to pass to the eastward and in rear of the hurricane. Should the barometer fall materially and the wind increase we must be guided in our actions by the Laws of Storms.

Weather Chart 1200 G.M.T. October 22nd, 1926. West Indian Hurricane

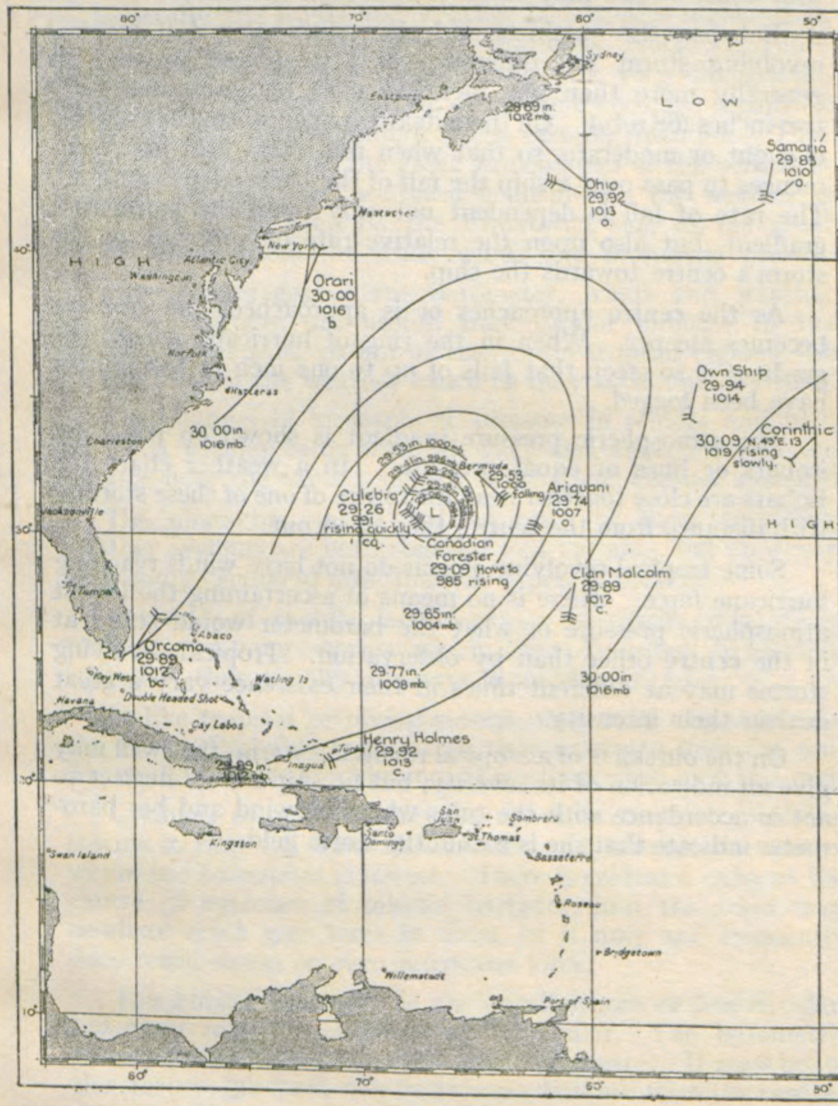


Fig. 8.

The barometer is very low indeed in the centre of a full tropical revolving storm. Owing to the centrifugal force within the whirl, it may fall lower than in the cyclones of middle and high latitudes. Atmospheric pressure of 27 in. (914 mb.) has been known at sea in the centre of these storms. When they come ashore they begin to lose their intensity.

Between the outskirts and the centre of a full tropical revolving storm the difference of atmospheric pressure is generally more than one inch (34 mb.) and sometimes over two inches (68 mb.). On the outskirts of the storm the gradient is slight or moderate, so that when the storm field first commences to pass over a ship the fall of the barometer is gradual. The rate of fall is dependent not only upon the barometric gradient, but also upon the relative rate of approach of the storm's centre towards the ship.

As the centre approaches or is approached, the gradient becomes steeper. When in the ring of hurricane winds, the gradient is so steep that falls of up to one inch in 15 minutes have been logged.

The atmospheric pressure gradient is shown on paper by isobars or lines of equal pressure. In a weather chart the isobars are close together near the centre of one of these storms; with distance from the centre, they open out.

Some tropical revolving storms do not have winds reaching hurricane force. There is no means of ascertaining the lowest hurricane pressure or what the barometer would stand at atmospheric pressure other than by observation. Tropical revolving in the centre other than by observation. Tropical revolving storms may at different times in their existence vary a great deal in their intensity.

On the outskirts of a tropical revolving storm, the swell may give an indication of its severity, but no ship should neglect to act in accordance with the rules when the wind and her barometer indicate that she is within the storm field.

CHAPTER IV

WEATHER IN MIDDLE AND HIGH LATITUDES

Generally the winds and weather in latitudes higher than the regions of the Trade Winds, Monsoons, Horse Latitudes and Southern Variables, in all oceans, are very changeable, owing to the continual passage of cyclonic systems, separated by Highs, travelling in a more or less easterly direction. That is, on the polar side of the great anticyclones of the oceans in both the northern and southern hemispheres, the weather is much less stable than on the Equatorial side of the great anticyclones, where the trade winds and monsoons prevail.

Though averages of the barometer, winds and weather in these latitudes are useful, they cannot indicate to the mariner to the same extent as they do in tropical regions, the probabilities of the weather which he may expect at any time.

The changes of atmospheric pressure in middle and high latitudes, besides being seasonal, vary and alternate with the passage over the earth's surface of different weather systems.

The character, shape and intensity of these travelling weather systems are both complex and variable, but they may be broadly classifield into different types, as follows :—

Cyclones of middle latitudes may originally have been tropical revolving storms which have travelled to middle latitudes; they usually originate in middle latitudes. Cyclones.

Unlike tropical revolving storms, they may originate over the land. Probably more often they originate over the sea. Generally they are more intense at sea than when over the land.

Cyclones of middle latitudes resemble tropical revolving storms in that the wind blows round and towards the centre, where the barometer is lowest. There is seldom a calm at the centre of cyclones of middle latitudes, and the wind may nowhere reach gale force in them, or it may and frequently does reach storm or even hurricane force.

The isobars in a cyclone are usually more or less circular, but they may be elliptical and irregular. The barometric gradient is not always steepest near the centre. It may be, or the steepest gradient may be at some distance from the centre; consequently the strongest winds, though usually near the centre, may be experienced at some distance from the centre, the force of the wind being strongest where the barometric gradient is steepest, and light where the barometric gradient is slight.

Cyclones vary one from another in intensity. When they are deep, that is to say when the difference between the barometer at the centre and on their outskirts is great, with consequent steep gradients, there are heavy gales. When they are shallow they only cause moderate winds. They may be accompanied by rain, hail or snow, or by fine weather. Cyclones of middle latitudes are also known as "depressions."

Just as a tropical revolving storm has a circular motion of the wind within it, and a bodily forward or progressive movement, so too have cyclones of middle latitudes; but the latter cover generally much greater areas, having a diameter of up to 2,000 miles in extreme cases. They have less intense wind motion within them, and the centre is seldom a calm; and they have greater variations of progressive movement.

The Horn Card may be used in the same way as was indicated in CHAPTER III—if allowance is made for the differences between a cyclone of middle latitudes and a tropical revolving storm—to illustrate the changes of wind which a ship would experience during her passage through a cyclone.

Tracks of Cyclones.

The tracks and rate of progression of cyclones in middle latitudes vary considerably. Sometimes they remain nearly stationary for days, or they may travel at great speed in an easterly direction, up to rates of 1,200 miles a day.

Tracks of all Weather Systems in Middle Latitudes.

The tracks of all weather systems in middle latitudes vary in different oceans, and in accordance with the general pressure distribution at the time, but their general movement is mainly from West to East inclining towards the Pole.

Secondary Cyclones.

Secondary cyclones, small depressions, sometimes form on the outer parts of cyclones in middle latitudes, at first causing a break in the wind circulation of the cyclone, and then at times developing into a separate system.

Very heavy gales sometimes are caused by secondaries forming on the Equatorial side of depressions; while sometimes secondaries, though accompanied with much rain, do not develop steep barometric gradients and strong winds.

The conditions of secondaries differ from one another, as do the winds and weather they beget.

V-shaped Depressions.

A **V**-shaped extension of a cyclonic wind system on its Equatorial side is known as a **V**-shaped Depression. In advance of the trough the wind is from an equatorial quarter, and in the rear of the trough from a polar quarter, so that with the passing of the trough there is a sudden shift of wind. The isobars in these systems form a **V**, which is inverted thus **Λ** in southern latitudes.

Forward of the trough there is often much cloud and rain. As the trough passes with the sudden shift of wind, usually accompanied by a heavy squall, the weather clears, and in the rear of the trough of a **V**-shaped depression, the visibility is usually very good.

Anti-cyclones.

An anticyclone is the opposite to a cyclone; that is, high pressure is at the centre, so that the wind blows round and out from the centre, clockwise in the northern hemisphere, and anti-clockwise in the southern hemisphere.

Near the centre the barometric gradient may be very shallow; consequently it may be a region of calms and light airs. At the outskirts of an anticyclone the gradient may be steeper, according to the pressure distribution in the surrounding neighbourhood, with consequent strong winds.

Anticyclones often cover great areas, in which there is generally fine weather, but there may be rain, and fog is often experienced in anticyclones, when there are conditions mainly governed by temperature.

The changes of weather in a region covered by an anticyclone, due to its movement, are usually much less than are changes of weather during the passage of other weather systems; but diurnal variations of weather are usually more marked.

Wedge of High Pressure.

Sometimes between two cyclonic systems there is a wedge of high pressure extending from an anticyclone, the opposite to a **V**-shaped depression.

In the front of a wedge the wind is from a polar direction, and in the rear from an equatorial direction, along its centre line there generally being calm. In a wedge there is usually fine weather.

As a wedge of high pressure generally moves between and in the same direction as two cyclonic systems, it causes the barometer to rise and then fall quickly. Hence the saying, "The barometer rose too rapidly to last."

Col.

A col covers the area between two anticyclones, where there is little wind, slight barometric gradient, and comparatively low pressure.

Here there is often cloudy weather, fog, or thunderstorms.

Such are broadly the types of weather systems which are continually forming, developing, passing, and dying out in every varying complexity over the oceans in middle and high latitudes, and to which are attributable the changeableness and uncertainty of the wind and weather in these latitudes.

Where the weather is most changeable generally the navigator has the greater need to be able to forecast it; how to do this can best be shown by examples derived from actual experience.

Weather Forecasting

Even with the knowledge of many years' experience in any particular region or trade, and with perfect instruments, in a ship at sea if there is not communication with distant vessels the navigator's weather observation is restricted to his range of vision, and he can but conjecture the type and nature of the travelling weather systems he may encounter; and in his conjectures he may very easily be wrong.

If he has information from a few other vessels at different distances and on different bearings from his ship, and from the neighbouring coast, he may be able to visualize the weather systems predominating at the time. While if he is prepared to spend a little time and trouble, he can make a weather chart which will show him more definite information of the weather systems predominating by actually indicating the distribution of atmospheric pressure.

Example in the Southern Ocean.

For example, on the 17th April, 1932, s.s. *Piako*, in the South Pacific, bound from New Zealand to England round Cape Horn, had a fresh NNW. breeze, with overcast sky, and very slowly rising barometer. The wind had been northerly for some days, the swell was from the northward.

According to Buys Ballot's law (in South latitude face the wind and the barometer will be lowest to your left) the barometer must be low to the westward, that is, astern of the ship on her course to Cape Horn. The northerly swell may be an indication that there have been strong northerly winds at some distance north of the ship, or may be that the ship is in advance of a cyclone which is travelling to the eastward, not quite as fast as the ship, so that the barometer rises as she draws slowly ahead of the cyclone, but we do not *know*.

Selected Ship's Wireless Weather Reports.

Selected ships make weather reports by wireless telegraphy to "all ships" and certain coast stations at specified times daily in all oceans. By intercepting these reports—the system of communication and code used is described in the pamphlet numbered M.O.329, price 6*d*., which may be obtained through any bookseller from H.M. Stationery Office—information of atmospheric pressure, wind, weather, set and drift of current, and floating ice, may be had.

To illustrate the manner of using these reports, let us see how much more *Piako* can know by constructing a weather chart.

To draw a weather chart.

Using a handy outline chart for the part of the world, which are published for the purpose, the position of each reporting ship is plotted, *see* FIGURE 9. To this position an arrow is drawn representing the direction of the wind, the head of the arrow being at the position of the ship and the number

SOUTH WEST PACIFIC

SYNCHRONOUS WEATHER OBSERVATIONS PLOTTED. GREENWICH MEAN TIME 0000—APRIL 17TH, 1932

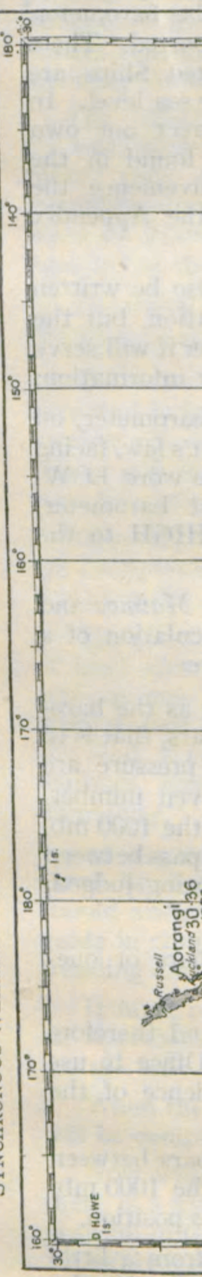


FIG. 9.

of feathers indicating the force of the wind, the arrow pointing with the wind. Abreast the ship's position write her name. Under the ship's name write the reading of the barometer, course and speed and behaviour of barometer reported. These barometer readings reported by British Selected Ships are corrected and reduced to the standard datum for sea level. In using this method we must take care to correct our own barometer; instructions for doing this will be found in the MARINE OBSERVER'S HANDBOOK, and for convenience the necessary tables and an example are given in the Appendix at the end of this book.

The weather reported by each ship should also be written under her name by means of the Beaufort notation, but the clearer the chart can be made and kept, the better it will serve its purpose, so long as it contains all the relevant information.

Now pick out the ship reporting the lowest barometer, on this occasion *Cambridge* and following Buys Ballot's law, facing the wind and to the left of her position write the word LOW. Next pick out the ship reporting the highest barometer, *Monowai* and facing the wind write the word HIGH to the right of her position.

It will now be seen that the winds reported by *Maimoa* and *Port Alma* are in conformity with the wind circulation of a large cyclonic system with *Cambridge* in the centre.

Drawing Isobars.

The winds as indicated by the arrows as well as the barometer readings reported, assist us to place the isobars, that is to indicate where the lines of equal atmospheric pressure are situated. To draw the isobars start with an even number. As the lowest barometer is 29·50 (999 mb.) draw the 1000 mb. line first. This will completely encircle the low and pass between *Port Alma* and *Cambridge*, the size of the circle being judged, always remembering Buys Ballot's law.

For work at sea, steppings of either four millibars or one-tenth of an inch are generally most suitable.

The majority of ships use inch barometers, and therefore although it is the practice of the Meteorological Office to use millibars, we give both readings for the convenience of the great majority of seamen.

Next mark off roughly the spacings of the isobars between *Port Alma's* and *Piako's* positions, also between the 1000 mb. isobar on the western side of the Low and *Maimoa's* position.

Now draw in the 1004 mb. isobar. It passes from a little to the eastward of *Port Alma* right round the Low, following the same trend as the 1000 mb. isobar. The 1008 mb. isobar is similarly drawn in; and portions of the 1012 mb. and 1016 mb.

isobars are drawn in between *Port Alma* and *Piako*, while portions of the 1012 mb., 1016 mb., 1020 mb. and 1024 mb. isobars are drawn in between the 1008 mb. isobar and *Maimoa*, always remembering that the wind blows along the isobars, inclining towards the Low.

The 1028 mb. isobar passes through *Aorangi's* position—the wind blows out of an anticyclone, and the barometer is *high* to the right of an observer facing to the wind in southern latitudes—and curves round passing at a distance to the westward of *Maimoa* consistent with the gradient for the wind reported at that ship.

The isobars should be spaced so that they are nearest where the wind is strongest, and widest where the wind is light.

The correct drawing of isobars is a matter of practice, experience and judgment; and if there be available to the reader a brother officer who is skilled in the drawing of isobars, the reader will learn better by watching him than he can alone from this brief description of the process.

Wind true to pressure.

Generally at sea the wind blows true to pressure, but there are exceptions to the rule, as has been shown at the end of CHAPTER II.

Exceptions to the rule.

The coast line may deflect the wind or under the conditions of land and sea breezes the direction of the wind at coast stations may be affected, and here the rule may not entirely hold, so that the trend of the isobars in the vicinity of, or over the land, may sometimes be drawn better from the barometer readings reported, than by the combination of wind and barometer.

At sea, where error of barometric observation may sometimes be unavoidable, the force and direction of the wind should always be taken into consideration as an indispensable guide in conjunction with the barometer readings reported, in trending and spacing the isobars.

It must be remembered that the placing of these isobars is an approximation, and that the weather chart gives a true picture only for the time of synchronised observation.

When the isobars have all been faired up, our weather chart will be complete as in FIGURE 10.

What a Weather Chart tells us.

Now what does it tell us? We can see at a glance that there is a cyclonic system centred a little to the north of the position of *Cambridge* and that our ship is on its eastern verge. Probably it extends to the westward as far as *Maimoa's* position with the wind conforming to the isobars drawn. There is no observation to tell us for certain that the wind circulation is continuous so far in rear of the centre.

SOUTH WEST PACIFIC

SYNCHRONOUS WEATHER CHART. GREENWICH MEAN TIME 0000—APRIL 17TH, 1932

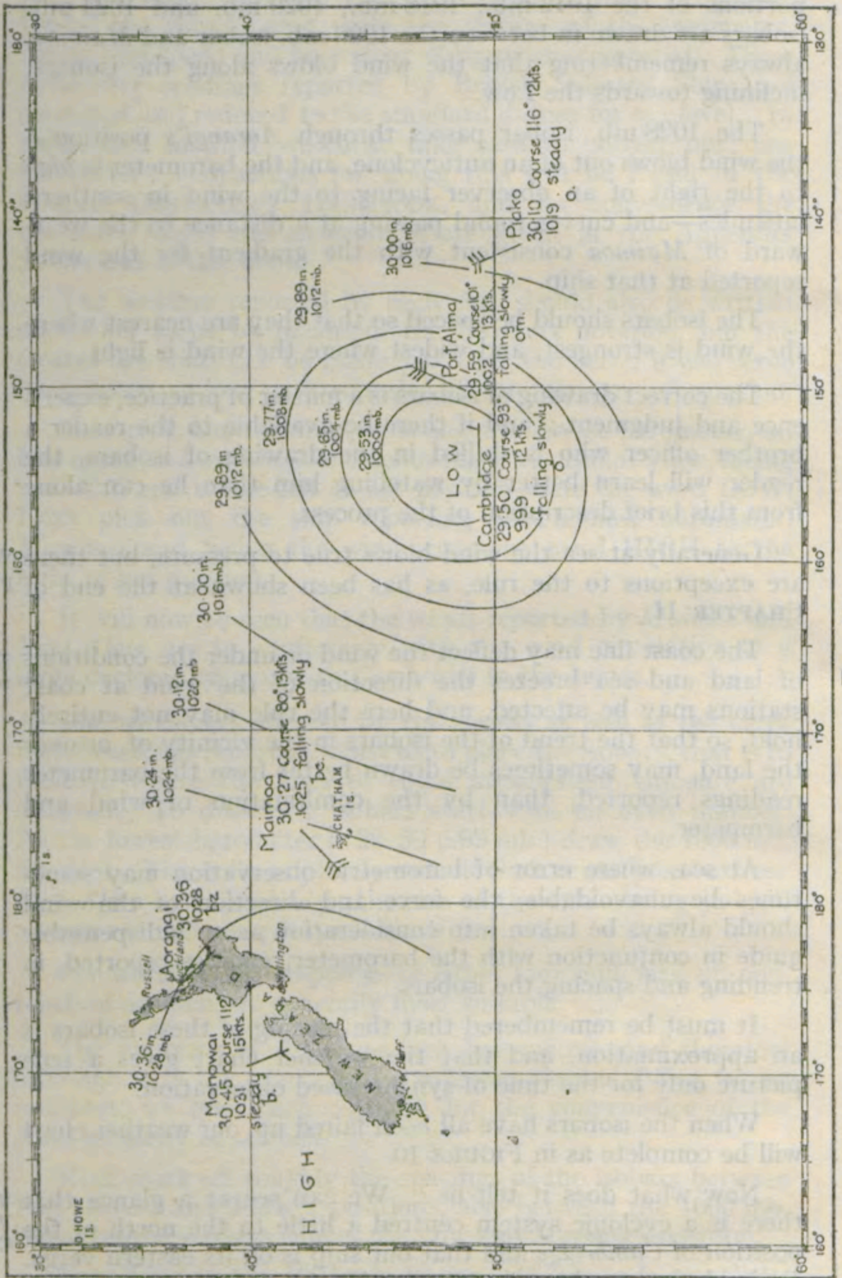


FIG. 10.

It was emphasised at the end of CHAPTER III that there was no means of ascertaining the lowest atmospheric pressure in a revolving storm, other than by observation. There is an advantage in knowing the lowest barometer in a cyclonic system :—

With the wind circulation as shown on this chart, and the light wind which *Cambridge* is experiencing, there is little doubt that her barometer indicates very nearly the lowest pressure in this system, that is 29·50 in. (999 mb.).

Between our own position in *Piako* and that of *Cambridge*, a distance of about 550 miles cutting across the isobar nearly at right angles, there is only a difference of 0·60 in. (20 mb.) of pressure ; while between the position of *Maimoa* and *Cambridge*, a distance of about 900 miles at right angles to the isobars, there is a difference of 0·77 in. (26 mb.) giving no steep gradient. Therefore, apart from the winds actually reported, we know that the system is not intense and, in this cyclone in its present state, winds are not likely to reach gale force. Gradient will be more fully dealt with later.

The fact that the barometer has fallen slowly within the last few hours on board *Port Alma* in advance of the centre, and *Cambridge* now in the centre, is an indication that the Low has been overhauling those ships on their course to the eastward ; and it may also be an indication that this cyclonic system is very gradually deepening. On board *Piako*, on our course 116° at 12 knots, we should expect no material change in the weather on this day.

Method applicable to all parts of the oceans.

This method of constructing and using weather charts is applicable to all parts of the oceans, but it is most useful in the regions we are now dealing with, and in the seasons and regions where tropical revolving storms are experienced.

By this example of weather forecasting in the Southern Ocean, where the winds of the oceans have less land to interrupt them right round the globe than anywhere else, the method of drawing of weather charts for all parts of the world may be learned, remembering that in north latitudes the barometer is low on *right* when facing the wind.

In drawing the isobars at sea, Buys Ballot's law tells us how each should pass the positions at which the force and direction of the wind and the height of the barometer are indicated. These lines indicate equal atmospheric pressure in the same way as the five, ten and hundred fathom lines indicate the contour of the sea bottom.

Generally the types of weather systems which have been broadly classified earlier in this chapter are common to middle and high latitudes in both the northern and southern hemispheres. We will therefore continue our examples in northern latitudes where more shipping is concerned.

Apparent absence of weather system types.

At times the wind blows from one quarter over great stretches of the ocean, extending beyond the wireless range of a ship. That is, the isobars are nearly straight and the wind steady from one direction over a considerable region, so that with observations from ships in wireless range it may appear that none of the six types of weather systems are present; but two or more are always in existence somewhere over an ocean in middle and high latitudes.

These straight winds are in fact parts of neighbouring systems, and generally they do not last long.

At times there are great regions where atmospheric pressure is comparatively low, where the barometric gradient is shallow, and the winds are light and variable, though conforming to cyclonic circulation. When such large shallow depressions occur, the weather is unsettled and changes follow.

Coast station Wireless Weather reports.

Reports of observations made at coast stations included in wireless weather shipping bulletins enable the navigator to extend his weather chart to the coasts, often with great advantage. These reports are made in the ship's International wireless weather telegraphy code, the decode for which is given in the pamphlet M.O.329, before mentioned in this chapter.

Straight isobars.

On 10th February, 1931, there were westerly winds over a great stretch of the Eastern North Atlantic. FIGURE 11 shows the pressure distribution at 18 hours G.M.T., by which it will be seen that the centre of the permanent North Atlantic anticyclone was north of its usual position, that the isobars were nearly straight from west to east between the parallels of 47° N. and 63° N., and that the lowest barometer was north of Thorshavn in the Faroes.

Now somewhere to the northward of Thorshavn, a cyclonic system was centred.

Significance of change of barometer.

When isobars can be drawn correctly—and this means that the barometer readings reported must be accurate—not only does a weather chart give us the distribution of pressure, and therefore a good means of estimating the force and direction of the wind at places between positions from which we have information, but knowing the distribution, the change of the barometer can tell us more.

It will be noted that *Scythia*, steering 261°, nearly in line with the isobars, has a quickly falling barometer. Remember the isobars are only correct for the time of observation, if atmospheric pressure is changing at any place covered by the weather chart.

Montrose, on a nearly parallel course and at very little more speed, also has a falling barometer. These two ships are steaming in or towards a place of reducing atmospheric pressure.

SYNCHRONOUS WEATHER CHART. GREENWICH MEAN TIME 1800—
FEBRUARY 10TH, 1931

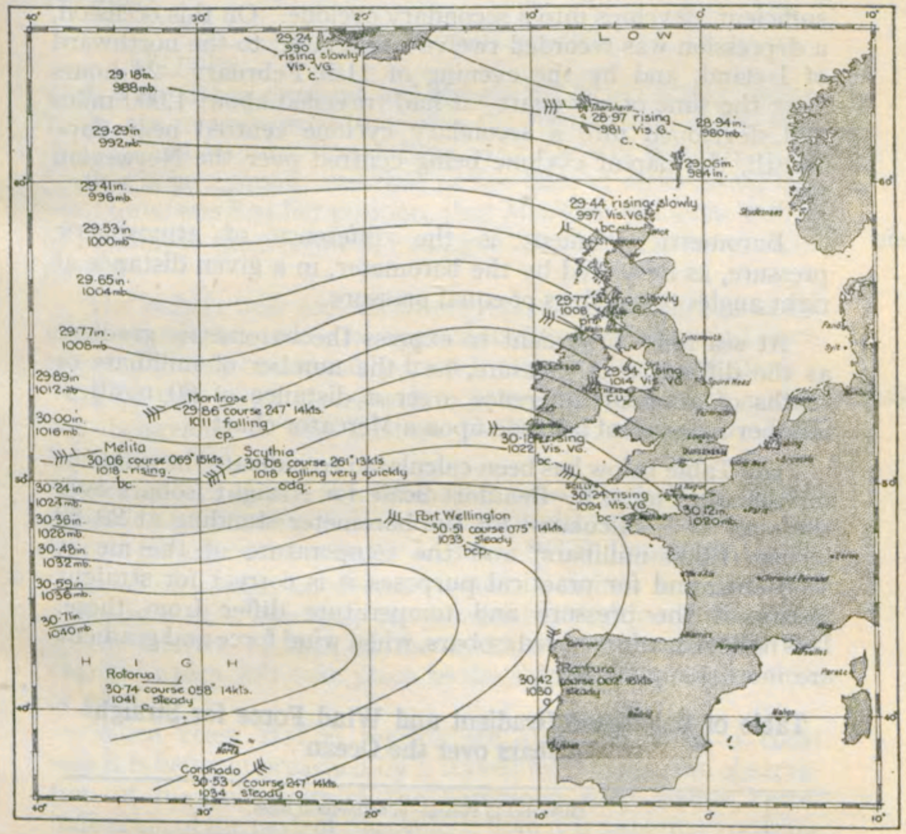


FIG. 11.

Melita, steering 69°, on a nearly opposite course to the two other ships named, has a rising barometer. From this, it may be judged that the place of reducing atmospheric pressure was between the three ships, and was travelling to the eastward at a greater speed than *Melita*.

When the general distribution of pressure, the lay of the isobars, and the gradient at the time of observation, are known, the changes of pressure taking place may be estimated—from collective observations of the change of barometer reported by different ships on different courses—by that natural judgment which is so highly developed by those expert in the handling of ships, where the eye so often solves what may be a complicated problem in the parallelogram of velocity or force, with accuracy, and far quicker than by mathematics.

Formation of secondary cyclone. Now when reduction of atmospheric pressure is localized, that is there is a greater fall of the barometer in one place than in the surrounding region, there is a depression which, if sufficient, develops into a secondary cyclone. On this occasion, a depression was recorded twelve hours later, to the northward of Ireland, and by the evening of 11th February—24 hours after the time of our chart—it had travelled about 1,000 miles and developed into a secondary cyclone centred near Cape Wrath, the parent cyclone being centred over the Norwegian Sea.

Gradient. Barometric gradient is the difference of atmospheric pressure, as measured by the barometer, in a given distance at right angles to the lines of equal pressure.

At sea it is convenient to express the barometric gradient as the difference of pressure, i.e., the number of millibars or tenths of an inch difference, over a distance of 60 nautical miles or a degree of latitude upon a Mercator chart.

The Table below has been calculated to indicate the gradient for the wind force by Beaufort Scale for straight isobars over the sea. It is calculated for the barometer standing at 29·53 inches (1,000 millibars) and the temperature of the air at 45° Fahr., and for practical purposes it is correct for straight isobars if the pressure and temperature differ from these. It is not correct for curved isobars, when wind force and gradient are more complicated.

Table of Calculated Gradient and Wind Force for Straight Isobars over the Ocean

Beaufort wind force.	Difference in Pressure in 60 Nautical Miles.															
	Lat. 60°.		Lat. 55°.		Lat. 50°.		Lat. 45°.		Lat. 40°.		Lat. 30°.		Lat. 20°.		Lat. 15°.	
	in.	mb.	in.	mb.	in.	mb.	in.	mb.	in.	mb.	in.	mb.	in.	mb.	in.	mb.
2	·021	0·7	·018	0·6	·018	0·6	·015	0·5	·012	0·4	·012	0·4	·009	0·3	·009	0·3
3	·035	1·2	·032	1·1	·029	1·0	·027	0·9	·024	0·8	·021	0·7	·015	0·5	·012	0·4
4	·053	1·8	·050	1·7	·044	1·5	·041	1·4	·038	1·3	·029	1·0	·021	0·7	·015	0·5
5	·074	2·5	·068	2·3	·062	2·1	·059	2·0	·053	1·8	·041	1·4	·029	1·0	·021	0·7
6	·094	3·2	·089	3·0	·083	2·8	·077	2·6	·071	2·4	·056	1·9	·038	1·3	·027	0·9
7	·118	4·0	·112	3·8	·106	3·6	·097	3·3	·089	3·0	·071	2·4	·047	1·6	·032	1·1
8	·142	4·8	·139	4·7	·130	4·4	·118	4·0	·109	3·7	·086	2·9	·056	1·9	·041	1·4
9	·171	5·8	·165	5·6	·153	5·2	·142	4·8	·130	4·4	·100	3·4	·068	2·3	·050	1·7
10	·204	6·9	·195	6·6	·180	6·1	·168	5·7	·153	5·2	·118	4·0	·080	2·7	·059	2·0
11 12	·239 over ·260	8·1 over 8·8	·227 over ·245	7·7 over 8·3	·212 over ·230	7·2 over 7·8	·195 over ·212	6·6 over 7·2	·177 over ·189	6·0 over 6·4	·139 over ·147	4·7 over 5·0	·094 over ·103	3·2 over 3·5	·071 over ·077	2·4 over 2·6

The difference of pressure between the positions of *Scythia* and *Montrose* (FIGURE 11) is 7 mb. The distance between the ships is 165 miles, but it is not this distance which should be

used for finding the gradient. The distance—at right angles—between the isobars running through these ships' positions is 140 miles.

$$\frac{7 \text{ mb.}}{140 \text{ miles}} \times 60 \text{ miles} = 3 \text{ mb. gradient.}$$

With a 3 millibar gradient in Latitude 52° N. according to the Table, the average wind force over the region between the two ships should be force 6 or a little over. It will be noted that *Scythia* is in a squall, and that at the time of observation the wind force was 8 at her position, that *Melita* on the same isobar as *Scythia*, to the westward, had force 7, and that *Montrose* had force 6.

The isobars over regions where reported observations are a long way apart can only be approximations, and the wind force may differ very considerably from that found by calculation.

A cyclone which serves well to indicate their general nature and behaviour in the Eastern North Atlantic occurred in November, 1931. **A cyclone.**

FIGURE 12 shows the conditions over the Eastern North Atlantic and the British Isles on the evening of November 9th, when a cyclone was centred in Latitude 54° N. Longitude 18° W.

Now in order to forecast what weather a vessel will experience, it is necessary to consider her position, course, and speed, relative to that of the cyclone, and to estimate the changes which will take place as the ship and the centre close or open.

When coast station reports are available, from a coast which is being approached by a travelling cyclone, the observation of the behaviour of the barometer may give a better indication of the path of the cyclone than it is sometimes possible to estimate from the behaviour of the barometer in ships proceeding at speed.

From the change of the barometer reported at 1800 hours G.M.T. on November 9th, as indicated in FIGURE 12, it may be judged that the cyclone has travelled in an east-north-east direction during the last three hours, the period of observation for reporting the change of the barometer at coast stations. The change of the barometer reported by the ships is consistent with this.

The change in the wind direction and force at any position covered by the isobars in FIGURE 12 can be estimated when we know how to read charts, and can judge correctly the path of the cyclone, in much the same way that we use the Horn Card. For instance, it is easy to see that provided this cyclone retained its form and intensity as it travelled ENE. the wind, then a fresh gale, at the mouth of the Bay of Biscay, would increase for some time and later veer and moderate.

Synchronous Weather Chart. Greenwich Mean Time 1800—
November 9th, 1931

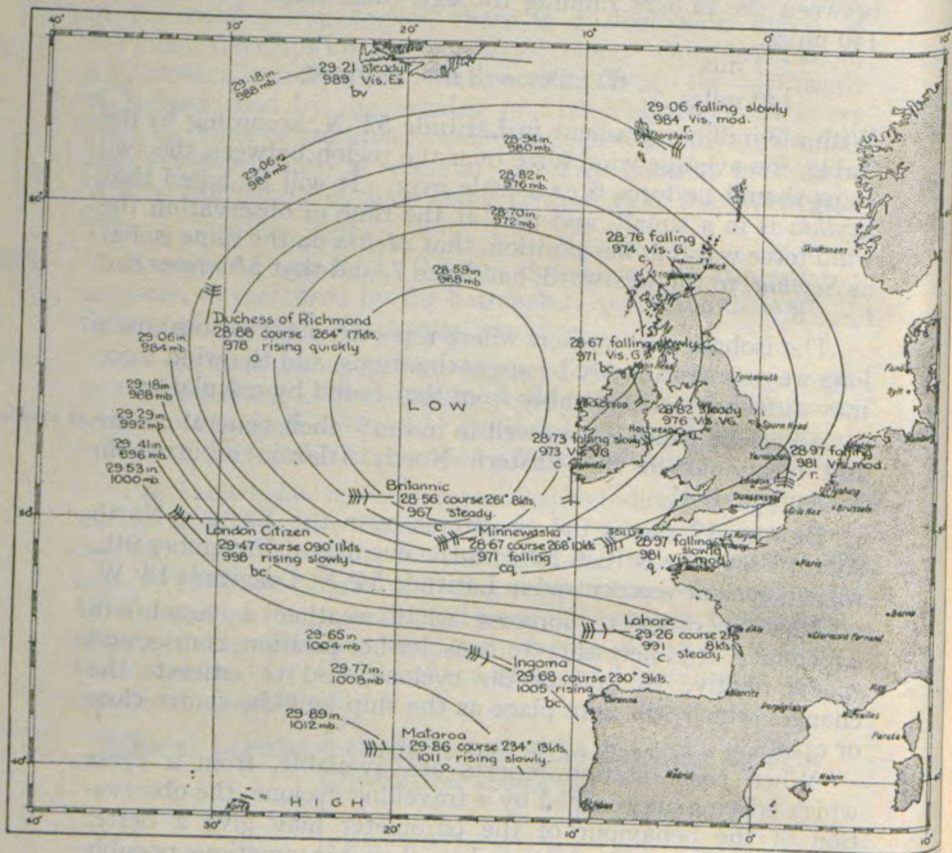


Fig. 12.

Twenty-four hours later, as indicated by Figure 13, this cyclone was centred in Latitude 56° N. Longitude 10° W., having travelled ENE. 300 miles and the wind at the mouth of the Bay of Biscay was then a whole gale.

If a weather chart can be made daily during a passage, the navigator may see the sequence of changes in the weather systems as they aproach, converge with, or pass away from his ship; and this knowledge will materially assist him in forecasting the weather as he proceeds.

Anti-cyclones, a "V" depression and a Col.

On 10th December, 1931, the ever-changing distribution of atmospheric pressure and winds over the North Atlantic showed, as is indicated in Figure 14, two anticyclones in middle latitudes, one covering the Eastern North Atlantic as far as Longitude 30° W., the other to the westward of Longitude 40° W., with a Col between them; north of the Col a "V"-shaped depression with its trough lying nearly north and south in Longitude 33° W.

Synchronous Weather Chart. Greenwich Mean Time 1800—
November 10th, 1931

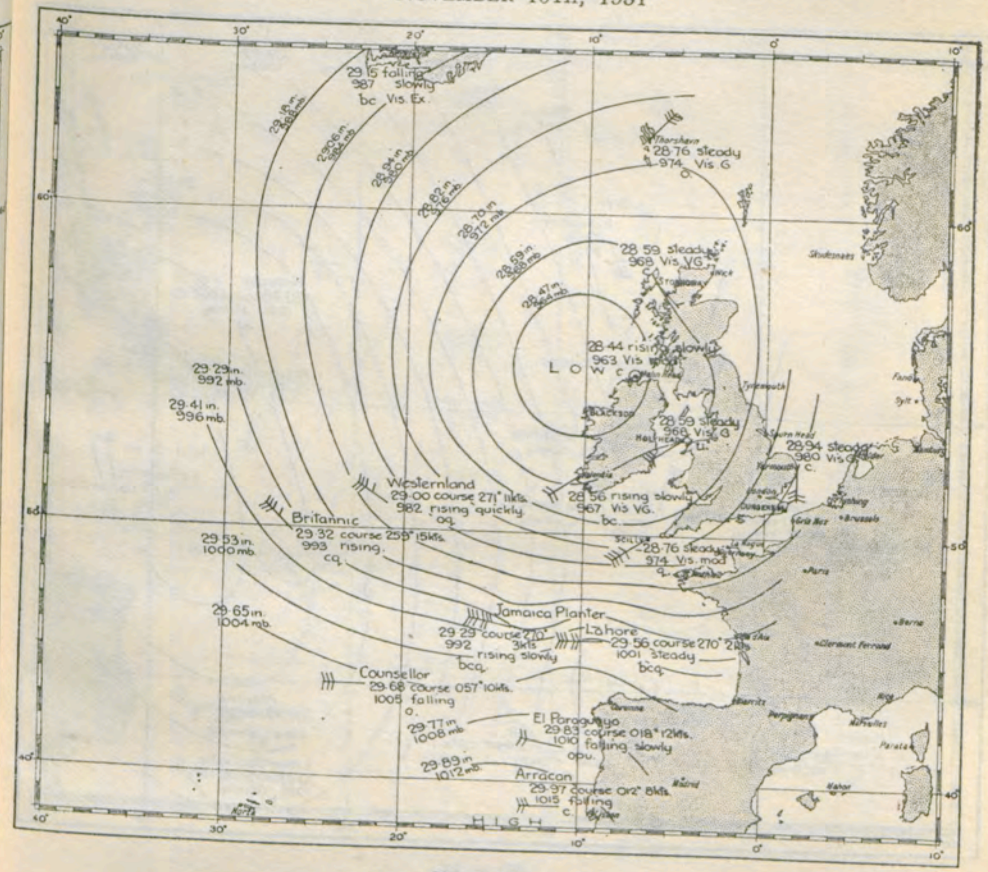


Fig. 13.

A ship in the vicinity of Latitude 48° N. Longitude 20° W., proceeding towards the English Channel in such case would be able to forecast a continuance of southerly wind, with fine weather, since three other ships bound the same way report the barometer steady, indicating that the anticyclone is travelling with them.

A ship in the vicinity of Latitude 53° N. Longitude 30° W., bound to the westward—it will be seen by the chart—would experience an increasing S. by W. wind as she approached the trough. Upon reaching the trough, the wind would fly round to NW., probably with a squall.

Synchronous Weather Chart. Greenwich Mean Time 0600—
December 10th, 1931

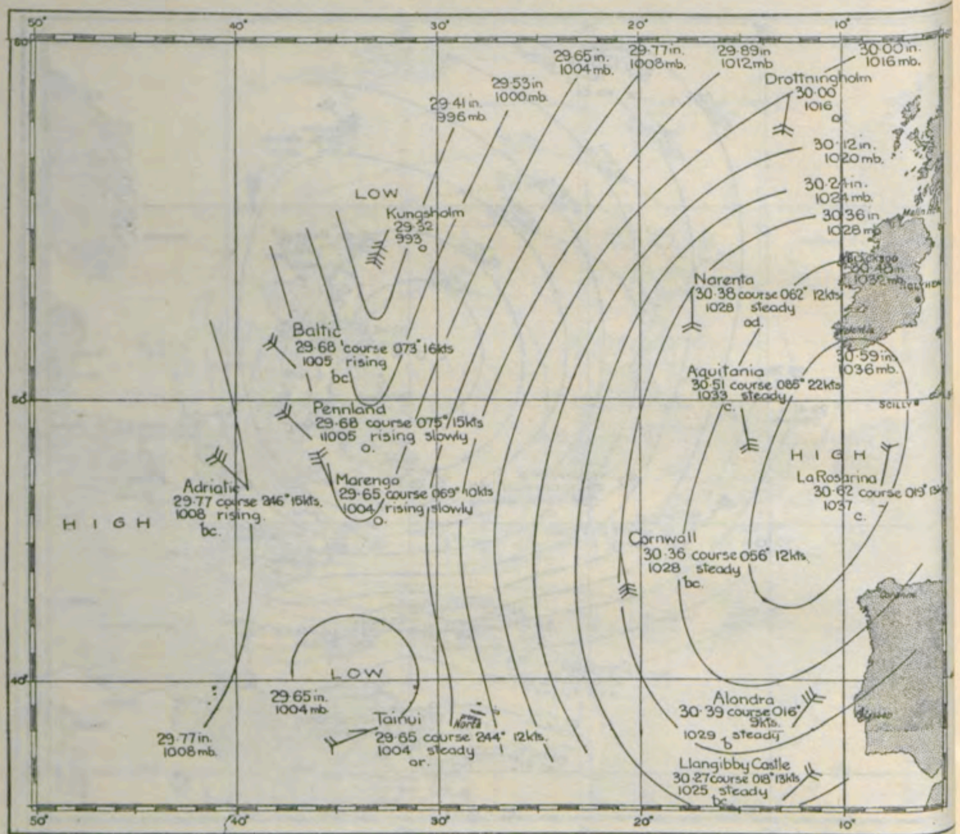


Fig. 14.

Wedge. On the morning of January 11th, 1932, a wedge of high pressure extended northward along the 30th meridian of west longitude, between two cyclonic systems, one centred north of Ireland, and the other in the vicinity of Latitude 49° N. Longitude 49° W. The westernmost cyclone was evidently travelling in an east-north-easterly direction at a greater speed than *Mauretania*, while the eastern cyclone is also travelling east.

It is easy to see (from Figure 15) that on this occasion, with such a chart, *Montcalm* would expect the rapid changes consistent with the description of a wedge of high pressure given earlier in this chapter.

The wind continued from WNW. with squalls, rain, and snow until the afternoon of January 11th, when it fell light and shifted to SW. by W. with fine weather during the passage

Synchronous Weather Chart. Greenwich Mean Time 0600—
January 11th, 1932

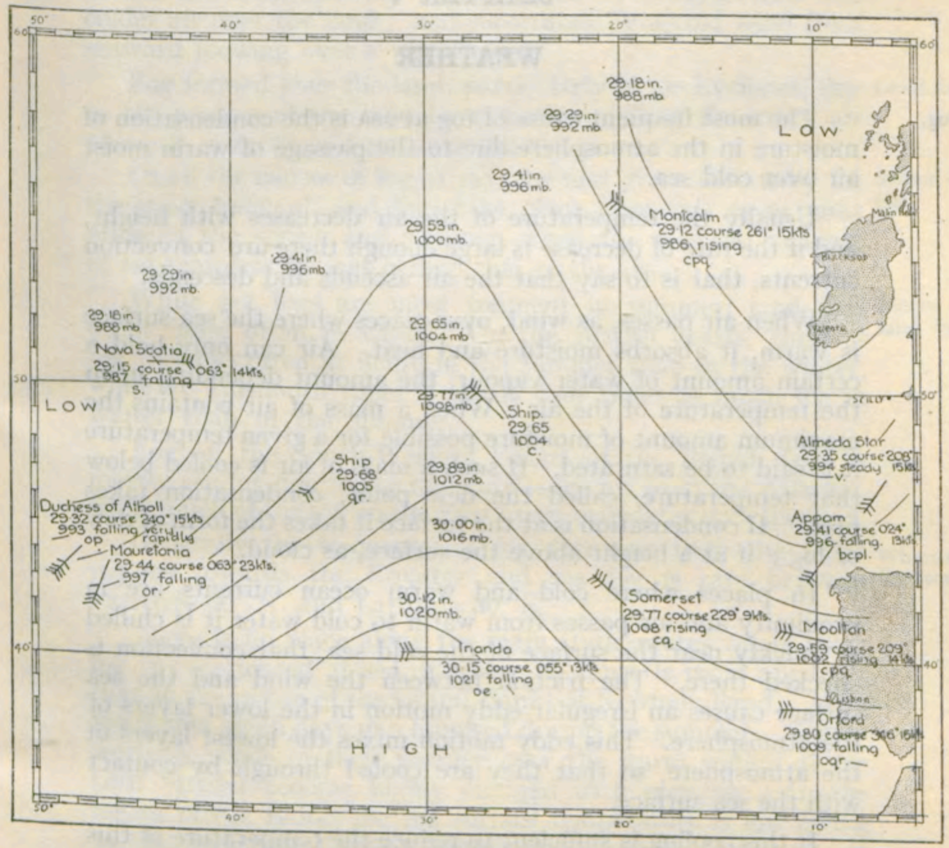


Fig. 15.

through the wedge; after which the ship ran into the northern side of the advancing cyclone, and experienced a fresh gale from ESE.

These examples with the general descriptions of the weather systems in middle and high latitudes, no two of which are ever exactly alike, indicate the method of construction and use of weather charts and show how wind may be forecast.

To forecast the different kinds of weather, that is whether to expect fog or clear weather, wet or fine weather, it is necessary to know something of the temperature of the air and of the sea.

CHAPTER V

WEATHER

Sea fog.

The most frequent cause of fog at sea is the condensation of moisture in the atmosphere due to the passage of warm moist air over cold sea.

Usually the temperature of the air decreases with height, and if the rate of decrease is large enough there are convection currents, that is to say that the air ascends and descends.

When air passes, as wind, over places where the sea surface is warm, it absorbs moisture and heat. Air can only hold a certain amount of water vapour, the amount depending upon the temperature of the air. When a mass of air contains the maximum amount of moisture possible for a given temperature it is said to be saturated. If such a mass of air is cooled below that temperature, called the dew point, condensation takes place. If condensation is at the surface it takes the form of dew or fog ; if at a height above the surface, as cloud.

In places where cold and warm ocean currents are in proximity and air passes from warm to cold water it is chilled so quickly near the surface of the cold sea, that convection is checked there. The friction between the wind and the sea surface causes an irregular eddy motion in the lower layers of the atmosphere. This eddy motion mixes the lowest layers of the atmosphere, so that they are cooled through by contact with the sea surface.

If this cooling is sufficient to reduce the temperature of this mixing air near the surface below the dew point, condensation takes place as fog. If there were no eddy motion, and, therefore, no mixing in the lower layers of the atmosphere, condensation would take the form of dew. Convection being checked, the air cooler near the surface than that above it, the fog remains at the surface.

In low-lying fogs, the reversal of the normal fall of temperature with height, though considerable, only extends up to a few hundred feet above the sea.

The well-known sign of the likelihood of fog, the smoke from the funnel lying in layers close to the sea, indicates the absence of convection currents.

Fog is sometimes formed at sea when two winds of different temperatures mix.

Fog may be formed when cold air flows over warm water, but how it then forms is more difficult to explain.

Coast fog.

Fog is frequently caused in coastal waters by the warm humid air from seaward being cooled in contact with the colder air over the land ; and sometimes by a cold wind from seaward blowing over a warm coast.

Land fog.

Fog formed over the land, particularly in anticyclones, due to the cooling of the land by radiation chilling the moist air above it, sometimes spreads seaward.

Season of sea fog.

Of all the causes of fog at sea, the first given here is by far the most frequent, and fogs take place from this cause most often in the spring and summer, when the seasonal increase of sea temperature lags behind that of the air.

Season of land fog.

While sea fogs are most frequent in summer, land fogs occur more often in winter. On the British coasts, there is fog twice as often at Scilly in the summer than in the winter, while at Yarmouth there is nearly four times as much fog in winter than in the summer.

Fog off the South-Western Coasts of the British Isles is mostly sea fog due to the moisture laden air from the Atlantic, while much of the fog on the East Coast originates over the land.

Where sea fog occurs.

Generally the frequency of fog decreases from the Polar regions towards the Equator and sea fog is rare between Latitude 30° N. and Latitude 30° S.

There is no place along the main trade routes where more fog is experienced at sea or where its cause is more apparent than in the region of the Grand Banks of Newfoundland. Here fog occurs on 50 days in a hundred during the summer. South-westerly winds in their passage over the warm waters of the Gulf Stream become highly charged with moisture. In the region of the Banks the sea surface temperature is low owing to the Labrador Current bringing cold water and pack ice from the Polar regions and icebergs from the glaciers of Greenland.

The line of demarcation or Cold Wall of the south-east edge of the Labrador Current is clearly defined, there being differences in the temperature of the surface waters of the Labrador Current and Gulf Stream of as much as 24° F. less than a mile apart.

The moisture in the warm air from over the Gulf Stream upon reaching these cold waters becomes fog. In the same way there is much fog in the North Pacific over the cold waters south-west of Kamchatka.

Here the water is cold owing to the Oyo Siwo, while the Kuro Siwo, warm like the Gulf Stream, is to the southward, and the same process of fog formation takes place.

In the region North-eastward of Cape Horn, where icebergs drift, fog is frequent. In certain regions of the Southern Ocean and where ever much fog is experienced at sea there are marked differences in the sea surface temperature of adjacent waters. Usually these differences of sea temperature are due to two currents, the cold current coming from the Polar and the warm current from the Equatorial regions. Fog occurs mostly over the cold water and when it does the process by which it forms is the same in all parts of the Oceans.

Fog occurs but less frequently where the differences of sea surface temperature with locality are small. Fog may drift from the place at which it formed to other places where there are not conditions in which fog forms and it may not form when conditions appear in which it would be expected. Though the causes and processes of formation of sea fog are believed to be as here briefly described, the balance is so delicate that observation often fails to detect the presence or absence of all the conditions which contribute to its making.

Prediction of fog.

As an illustration of how to read the indications which Nature displays to the observant seaman, aided by wireless communication, of the probability of fog, the conditions which prevailed in the vicinity of the Newfoundland Banks on the 20th and 21st July, 1931, FIGURES 16 and 17 will assist us, provided that we know something of the differences of the average or mean sea surface temperature, and how they are distributed over the region.

Mean sea surface temperature.

All who are experienced in navigating this region will know, and those who are not may see by charts of mean sea temperature that the sea isotherms—lines of equal mean sea surface temperature—are crowded close together in the Western North Atlantic. They run in an east or east-north-east direction from the United States coast to abreast the southern edge of the Grand Banks, whence they spread fanwise to the east and north-east. The change of sea temperature is rapid from the south to the north, in the vicinity traversed by shipping bound from Europe to the United States, to the southward and westward of the Newfoundland Banks. The water is cold over the Banks and vicinity, and it is comparatively cold along the east coast of the United States as far south as Cape Hatteras.

Conditions with no fog.

On 20th July, 1931, *see* FIGURE 16, owing to the distribution of atmospheric pressure over the Western North Atlantic and North America, the wind was light from northwest over the Grand Banks and vicinity.

The temperature of the air was observed to be generally lower than that of the sea surface in the vicinity, and there was no fog in this region.

Conditions with fog in coastal waters.

On part of the United States coast and at Nantucket, where the wind was light from the southward in front of a depression, there was fog, as would be expected, this light southerly air having brought moisture from the hot waters to the southward, to the cold coastal waters.

WEATHER CHART

SHIPS OBSERVATIONS, GREENWICH MEAN TIME, NOON, 20TH JULY, 1931

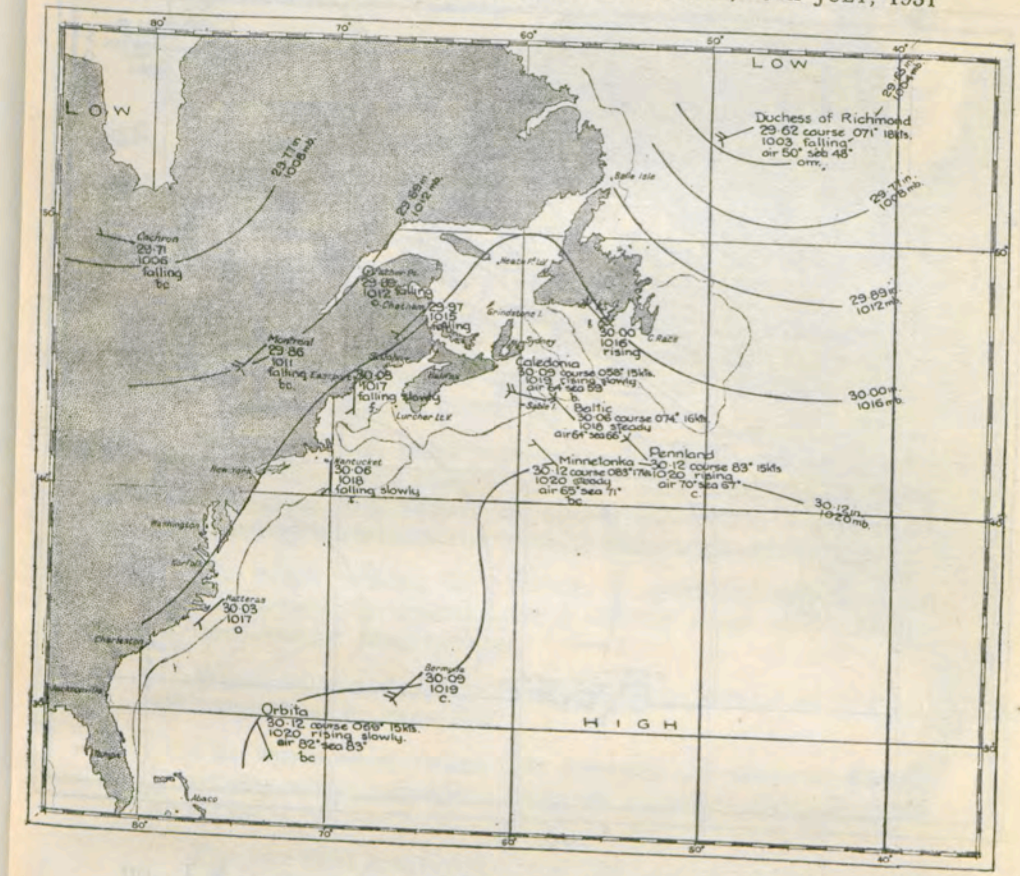


FIG. 16.

Conditions preceding fog.

The changes of the barometer reported at shore stations indicate that the depression centred in the vicinity of Hudson's Bay is moving to the eastward and therefore the wind which is north-west over the Newfoundland Banks may be expected to back to south-west. The gradients are shallow, so that the wind may remain light. After the wind backs to the southward, fog is highly probable.

It will be seen that *Caledonia*, about 60 miles to the eastward of Sable Island at noon G.M.T. on 20th July, had a gentle WNW. wind, air temperature 64°, and sea temperature 59°, and there was a blue sky and no fog. She was steering 58° at 15 knots, on which course and speed she will remain in cold water for more than 24 hours.

WEATHER CHART
SHIP OBSERVATIONS, GREENWICH MEAN TIME, NOON, 21ST JULY, 1931

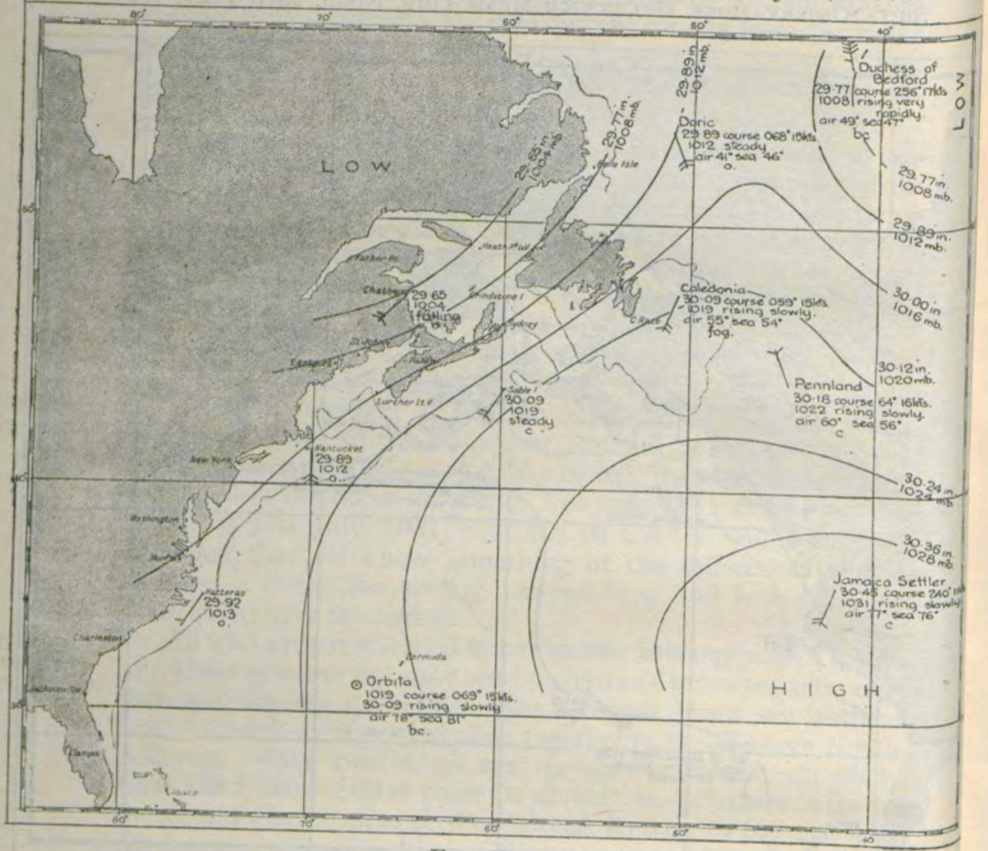


FIG. 17.

Fog experienced.

FIGURE 17 indicates the conditions at noon G.M.T. on 21st July, 1931. The depressions have travelled eastward since yesterday. The wind is light from the southward and south-westward between the coast of North America and Longitude 50° W., from the latitude of Bermuda to the northward of Belle Isle; and *Caledonia* to the north-eastward of Cape Race has fog with a gentle SSW. breeze, air temperature 55°, sea temperature 54°.

Use of Humidity observation.

If a wet bulb thermometer is employed, the humidity of the air and the dew point may be found by comparing the air temperature as measured by a dry thermometer with the wet bulb thermometer, by the Tables given in the Appendix. For example, at midnight, ship's time, on 21st July, 1931 (22nd 0418 G.M.T., approximately) when off the coast of Nova Scotia, s.s. *Newfoundland* had a moderate SSW. breeze, air temperature 65°, wet bulb 64°, and misty weather.

Now the tables indicate that the relative humidity is 95 per cent., and that the dew point is 63°. If the air temperature decreases more than two degrees, condensation will take place.

Two and three-quarter hours later the ship ran into dense fog, and at 4 a.m. the temperature of the air was logged as 60° F.

These examples of fog and the conditions before and during its presence, though the indications may be less marked, serve to show how fog or clear weather may be forecast in middle and high latitudes at sea, by careful observation of sea and air temperature, as well as barometer and wind.

The Character of Polar and Equatorial winds.

The air moves as wind in great masses over the oceans. When air from equatorial regions reaches higher latitudes, it is usually warmer than the sea surface, is comparatively humid, and is apt to produce haze, mist or drizzle.

When air from polar regions reaches lower latitudes, it is usually colder than the sea surface. This wind is apt to be squally, clear, and subject to strong convection currents as indicated by the presence of cumulus and cumulo-nimbus clouds.

The winds forming these masses of equatorial and polar air may sometimes be traced upon a weather chart, with the aid of temperature observations.

The effects of meeting winds.

Where masses of equatorial and polar air meet, bad weather with rain may be expected.

The winds blow round and towards the place of lowest barometer where ascending moisture is cooled, there is cloud and rain.

Reason for old markings on barometers.

The fact that much rain often falls in and near the central region of a cyclonic system was responsible for the old method of using the barometer, and aneroids are still sold with old markings, such as 30·0 in., Fair; 29·5 in., Change; 29·0 in., Rain; 28·5 in., Much Rain. It frequently happens that these markings are right, because with rain near the centre of a cyclonic system, the barometer is falling at a place which this rain is approaching.

There is sometimes little rain in a cyclone and sometimes rain may occur at considerable distance from the centre of a cyclone, and in anticyclones, so that these markings are often far from the truth.

Rain, snow, hail, thunder, and squalls.

Rain, snow or hail are generally due to cooling of ascending air, often produced by converging or crossing winds of different temperatures. Warm moist wind, which is light, riding up over a cool wind of heavy air causes cloud, rain, and gusts.

When a warm wind of light moist air blows under a layer of cold heavier air, instability is produced, causing a violent upward air current until stability is restored. Heavy showers of rain or hail, thunderstorms, and squalls are the result of such instability.

Shifts of wind.

In the description of cyclones of middle latitudes given in the last Chapter, it was stated that the wind blows round and towards the centre. From this, it might be supposed that the wind veered in one semi-circle and backed in the other, more or less regularly. This is not so in all parts of many cyclones. In the description of **V**-shaped depressions, it was shown that with the passing of the trough—the meeting place of the equatorial and polar winds—the wind shifts suddenly.

Now as every experienced seaman knows, in cyclones there are also shifts of wind—a shift may only be a point or two, or it may be eight points or more—and these shifts are most marked at the boundaries of the winds of different origins, having different temperatures.

Angles in isobars.

As the wind blows along and towards lines of equal atmospheric pressure, it follows that where there is a sudden shift of wind, the isobar on a weather chart must have a sharp bend.

Having grasped the principles of wind and pressure described in the previous chapter, and with the brief foregoing account of the influences of temperature upon wind and weather, cyclonic systems may be better understood, and the different kinds of weather forecast.

Warm and cold parts of cyclones.

A cyclone which is developing may be divided into two parts at the surface, viz. warm and cold, as well as in the way previously described. Figure 18 shows this dividing in a cyclone travelling East in northern middle latitude.

Cold front.

The warm sector is wind from the equatorial regions passing from warm to cooler sea surface. The cold sector is composed of cold air brought from higher latitudes. Where it cuts the equatorial wind in the rear of the warm sector, the line of demarcation is called the "Cold front" which is in fact the trough of the cyclone. At the cold front, the warm air of the equatorial wind rises, and the cold air of the polar wind cuts underneath the warm air. Cumulo-nimbus and nimbo-stratus clouds predominate from which heavy showers fall. With the passage of the cold front, the wind shifts and there are heavy squalls. In rear of the cold front, the wind persists for a time, decreasing in force, as the cyclone passes away; visibility is generally very good, any fog being swept away when the cold front passes.

Warm sector.

In the warm sector, the equatorial wind is comparatively steady; there may be cloud, haze, fog, drizzle or some rain.

HORIZONTAL PLAN OF WIND AND TEMPERATURE IN A DEVELOPING CYLCONE OF MIDDLE NORTHERN LATITUDES, AFTER BJERKNES

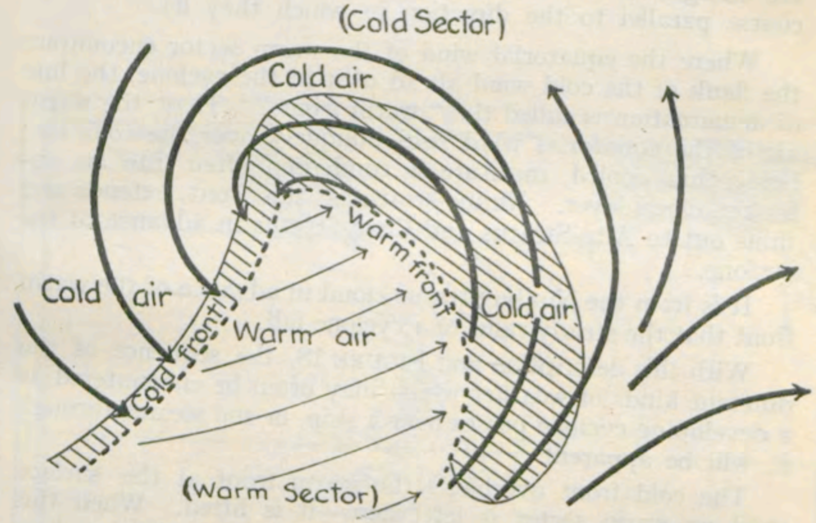


FIG. 18.

SOUTHERN LATITUDES

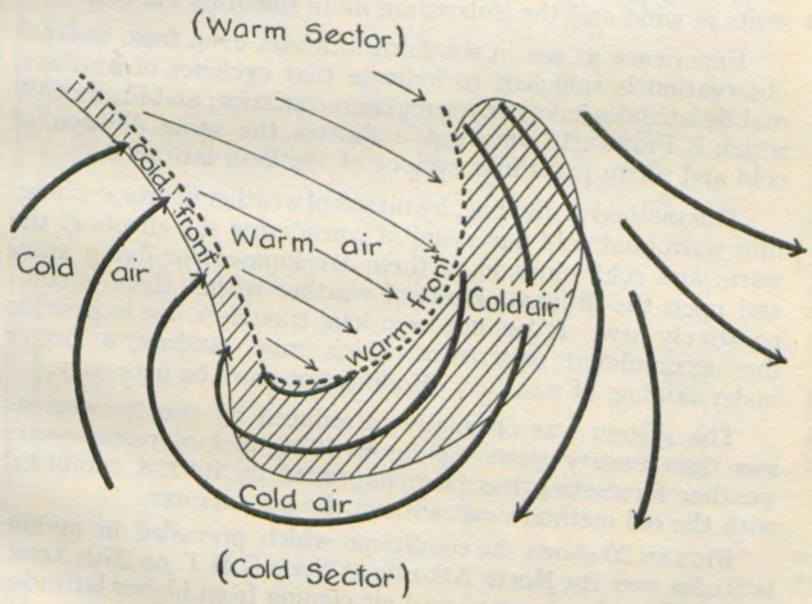


FIG. 19.

The isobars which bend sharply at the cold front or trough, are straight in the warm sector, and the storm travels on a course parallel to the direction in which they lie.

Warm front.

Where the equatorial wind of the warm sector encounters the flank of the cold wind ahead of it in the cyclone, the line of demarcation is called the "warm front." Here, the warm air of the equatorial wind rises obliquely over the cold air; being thus cooled, moisture is condensed often into an unbroken cloud layer. Nimbo-stratus at this front, extends and thins out to Alto-Stratus and Cirro-Stratus in advance of the cyclone.

Steady rains.

It is from the Nimbo-Stratus cloud in advance of the warm front that the steady rains of a cyclone fall.

With this description and FIGURE 18, the sequence of the different kinds of weather which may often be encountered as a developing cyclone passes over a ship, or she steams through it, will be apparent.

Occlusion.

The cold front overhauls the warm front at the surface until no warm sector is left there—it is lifted. When this happens cold air is blowing more or less right round the cyclone at the surface, and the warm equatorial wind feeding the cyclone at the surface is cut off. Then a cyclone is said to be occluded, that is closed. Occluded cyclones cease developing and die out.

Usually in occluded cyclones there are not such sudden shifts of wind and the isobars are more smoothly curved.

Southern latitudes.

Experience at sea in southern latitudes even from isolated observation is sufficient to indicate that cyclones of southern middle latitudes have these same characteristics; and FIGURE 19, which is FIGURE 18 reversed, indicates the same division of cold and warm parts in a cyclone of southern latitudes.

Qualification of new method and its use.

This method of dividing, by means of weather charts, cyclones into warm and cold parts and of considering the effects of the warm and cold winds upon their development or dying away and upon the different kinds of weather within them is comparatively new. It has not been long enough in use to provide the accumulated experience which may produce a better understanding of weather. Modification may be necessary.

The system was originally introduced by the Norwegians less than twenty years ago (now 1934) and of recent years weather forecasting has been improved by its use combined with the old method dealt with in the last chapter.

Example of weather and cold front.

FIGURE 20 shows the conditions which prevailed in middle latitudes over the North Atlantic at Noon G.M.T. on 25th April, 1933. There is a mass of cold air coming from higher latitudes over a region generally of increasing sea temperature with

WEATHER CHART

SHIP OBSERVATIONS, GREENWICH MEAN TIME 0000, 25TH APRIL, 1933

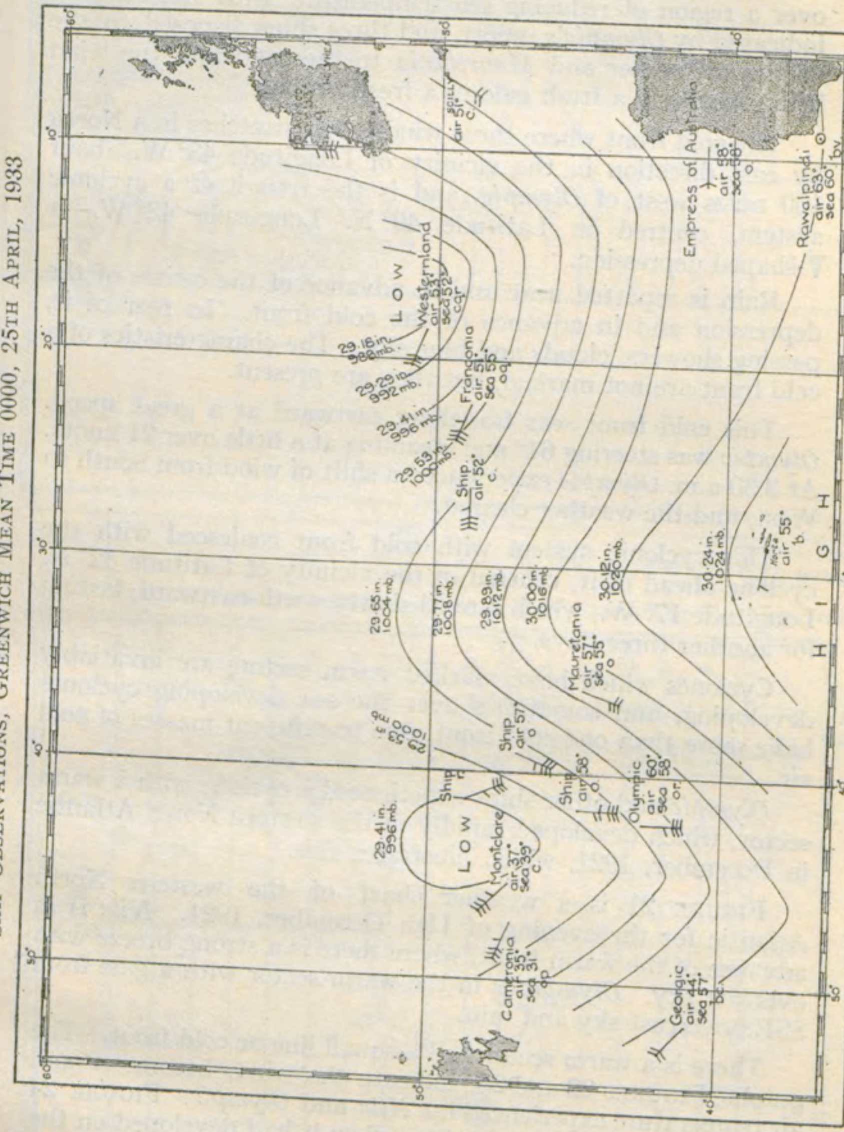


FIG. 20.

southing as indicated by the observations reported by *Montclare, Cameronia* and *Georgic*. The wind being North-westerly from a moderate gale to a moderate breeze.

A great mass of warm air is blowing from lower latitudes over a region of reducing sea temperature with northing, as indicated by *Olympic's* report, and three ships disposed to the northward of her and *Mauretania* to the eastward, the wind being southerly a fresh gale to a fresh breeze.

The cold front where these winds meet stretches in a North by east direction in the vicinity of Longitude 43° W. about 100 miles west of *Olympic*, and is the trough of a cyclonic system, centred in Latitude 49° N. Longitude 43° W.—a **V**-shaped depression.

Rain is reported near and in advance of the centre of the depression and in advance of the cold front. In rear of it, passing showers, clouds and blue sky. The characteristics of a cold front are not marked, but they are present.

This cold front was travelling eastward at a great speed. *Olympic* was steering 61° and steaming at a little over 21 knots. At 3.30 a.m. *Olympic* experienced a shift of wind from South to West, and the weather cleared.

This cyclonic system with cold front coalesced with the cyclone ahead of it, centred in the vicinity of Latitude 52° N. Longitude 17° W., which moved slowly north-eastward, lasting for another three days.

Developing Cyclone with warm sector and squall line.

Cyclones which have marked warm sectors are invariably developing, and sometimes over the sea developing cyclones have more than one cold front, due to different masses of cold air.

Olympic and other ships experienced a cyclone with a warm sector, which developed rapidly in the western North Atlantic in December, 1921, which illustrates this.

FIGURE 21 is a weather chart of the western North Atlantic for the evening of 11th December, 1921. *Nile* is in advance of the warm front, where there is a strong breeze with overcast sky. *Olympic* is in the warm sector with a gale from SSE., overcast sky and rain.

There is a warm sector and a squall line or cold front. The graphs, FIGURES 22 and 23, indicate the wind, barometer and air temperature experienced by *Nile* and *Olympic*. FIGURE 24 shows the sectors of this cyclone when it had developed on the morning of 12th December, 1921.

Nile is in the warm sector where the wind is storm force, this air having come from warm southern regions. The cold front or squall line passed over *Olympic* in the morning watch.

WEATHER CHART, EVENING OF DECEMBER 11TH, 1921

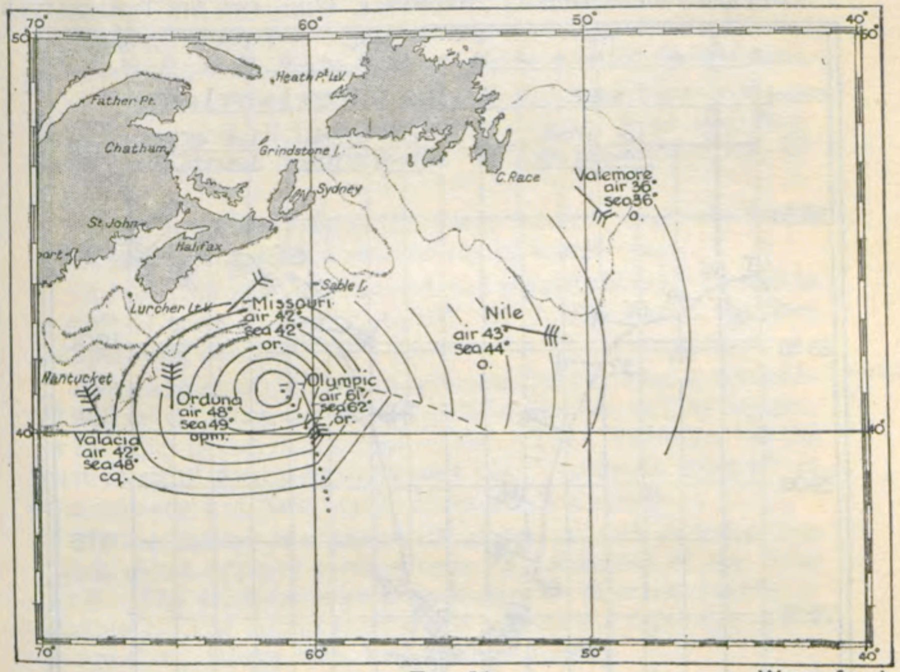


FIG. 21. - - - - - Warm front ○ ○ ○ ○ ○ ○ Cold front

S.S. "NILE"—WESTBOUND, BAROMETER, WIND AND AIR TEMPERATURE

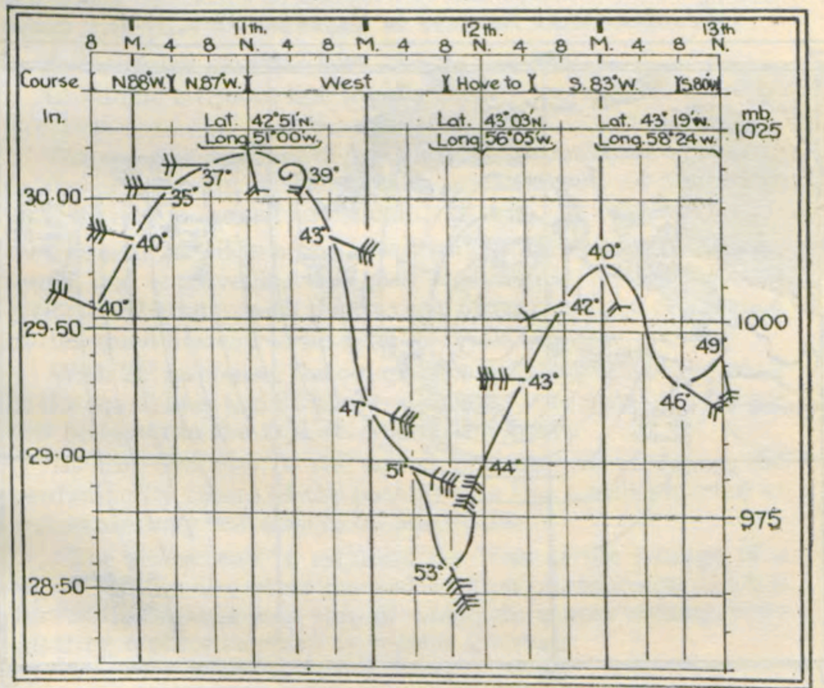


FIG. 22.

S.S. "OLYMPIC"—EASTBOUND. BAROMETER, WIND AND AIR TEMPERATURE

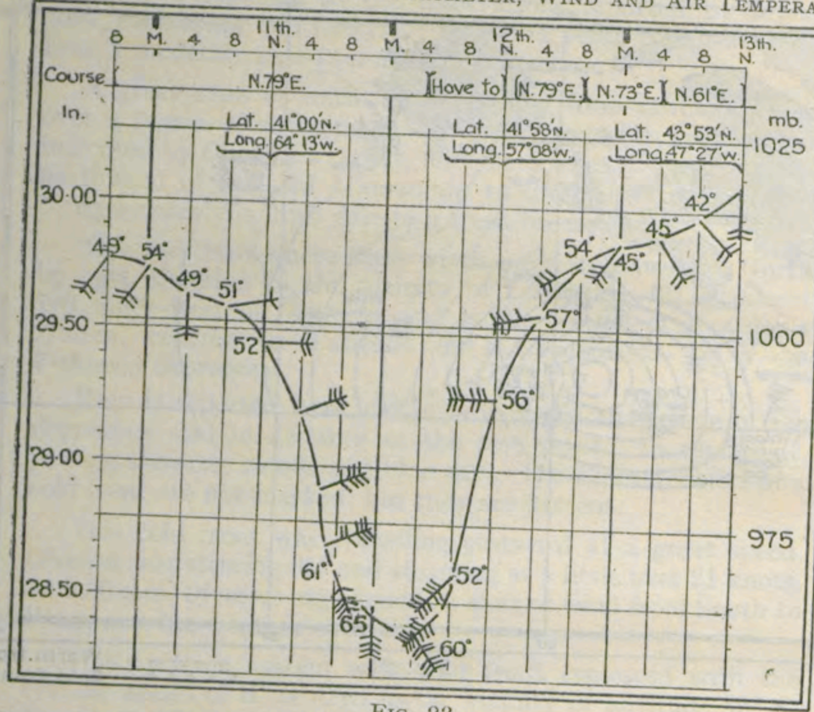


FIG. 23.

WEATHER CHART MORNING OF DECEMBER 12TH, 1921

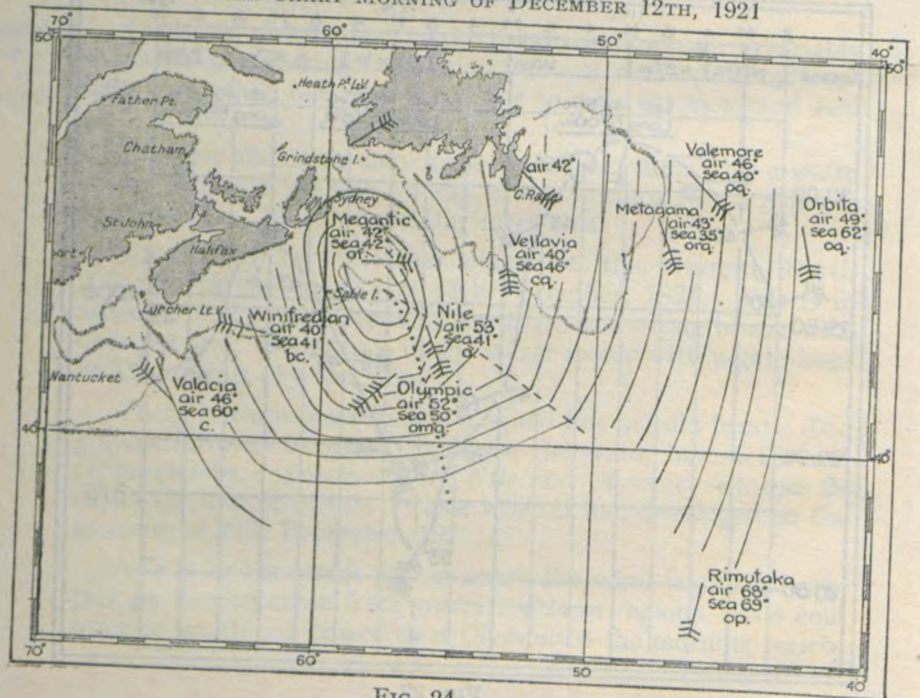


FIG. 24.

- - - - - - Warm front
o o o o o o Cold front

In rear of this cold front the air has come from the Polar regions but has travelled over a part of the American continent, and has been somewhat warmed in its passage over the Gulf Stream.

Further to the westward, *Winifredian* and *Valacia* are in the cold air which has come more directly from the Polar regions, and over eastern North America and the Labrador Current.

There was some rain in the warm sector. When the warm front passed there was a marked rise of temperature.

As the cold front overhauled and passed *Olympic* there was a shift of wind from SSE. to SW. by S., five points, and the temperature dropped.

Squall lines or cold fronts are sometimes as long as upwards of 400 miles. Such extended squalls are known as Line Squalls, or by other names in different regions. The "Pampero" of the east coast of South America and the "Southerly Buster" of the east coast of New South Wales are line squalls. Line Squalls.

In the passage of a line squall at sea, an arch or line of low black cloud appears coming from the direction of the polar wind. The wind increases and changes its direction rapidly or suddenly. The temperature drops; there is a rapid rise of the barometer. Heavy rain, hail or snow follow.

If the equatorial wind in advance of the squall line is moist, there is much cloud and rain during the passage of the squall; but where the wind in advance of the squall line is dry, the squall may pass without rain, or even without cloud.

A line squall may exist for 24 hours or more.

In middle latitudes line squalls usually travel in an easterly direction.

The speed of advance of a line squall is approximately equal to the component, perpendicular to the front, of the wind immediately in rear of the squall; that is, the cold wind.

For example, if in a line squall which extends due north and south, and is travelling due east, the wind is WNW. force 10 (velocity 52 knots), with the traverse table, the speed of advance of the squall line can be ascertained as follows :—

With 22° as course, the complement of the angle of the wind to the squall line, and 52 knots as distance, the speed of advance will be found in the D. Lat. column, 48 knots.

As the direction of the squall line may be changing, the prediction by means of the passage of a line squall reported at a distance may not always be practicable.

The surest way to estimate the time of the passage of a squall line, or any other marked weather phenomenon which is travelling towards your ship or which she is approaching, is by plotting reports received at regular intervals.

The term "Weather Forecast."

The term "Weather forecast" was introduced by Admiral FITZROY as meaning a statement of weather which may be expected in the near future. This term has sometimes been taken to convey the meaning that a prophecy of weather is intended. That is not so. Every experienced seaman knows, only too well, that the elements at sea often act in ways which are beyond the comprehension of man.

Experience has abundantly proved that careful observation and wireless communication, used with seamanlike judgment along the lines outlined in the three previous Chapters will generally give good forewarning.

Weather observation at sea has been developed through centuries of experience by seamen. Ability to read the signs of sky, cloud, and wind by eye, to appreciate the significance of changes of the barometer and to anticipate the meanings of these are gifts which come naturally to seamen.

Wireless communication and the modern methods described in this book are accessories and are not intended to replace the method of old experience which has recently been termed "Isolated Observer Forecasting".

CHAPTER VI

CURRENTS OF THE OCEANS

Set of current, how named.

The set of the current is the direction towards which it flows, not the direction from which it comes, as in the case of the wind. The drift of the current is the rate at which it flows.

Drift.

The drift may be expressed in knots (miles per hour) or in miles per day.

Generally, but not always, the surface currents, with which the navigator is most concerned, flow before the prevailing wind, and in the Doldrums there are counter currents.

Forces producing current.

In CHAPTER I are briefly given the forces which produce, influence, control, and deflect the surface currents.

Wind as well as producing current by friction upon the sea surface has a great effect on the temperature distribution of the sea, which in turn affects the currents, as do evaporation and rainfall.

Surface current circulation of Oceans.

The current systems of the oceans should, therefore, be considered with the wind systems of the oceans which have been described in CHAPTER II.

The surface water of the oceans for the most part circulates round the areas of high atmospheric pressure in an anticyclonic direction and round the areas of low atmospheric pressure in a cyclonic direction.

The contour of the ocean bed, its deeps and shoals, influences the set and drift of current in the depths and at the surface, as the valleys and mountains of the land affect the wind.

Tidal currents.

Tidal currents are beyond the scope of this book. It seems probable that ocean currents may in places be influenced by the tides, and there is no clear demarcation where ocean currents cease and tidal streams commence.

Even in the open ocean where there is sudden shoaling, tidal currents have been measured, notably over the Dacia and Gettysburg Banks in the Eastern North Atlantic.

Cold Water from Polar regions.

Melting ice of the polar regions—and particularly in the Antarctic Seas which are open and connected with the Indian Ocean, as well as the Atlantic and Pacific Oceans—not only produces cold ice-bearing surface currents running from the polar seas, but this cold water also sinks and spreads slowly over the bed of the ocean.

Upwelling cold water affects the distribution of the temperature of the sea, which also affects the surface currents. Upwelling is most marked where the prevailing wind is off the land, and where the wind blows towards the land and the water is banked up on a lee shore, it descends.

Variability of currents.

Currents are very variable, and even in the main stream currents which are usually steady in direction, at times the set may be towards any point of the compass. It is necessary to stress this fact of the variableness of currents, which should not be forgotten in the description of the currents of the oceans which follows, and which mainly deals with the mean or resultant set and drift.

Fog and change of current.

It may often happen and particularly off a coast where there is upwelling cold water, that the changes of atmospheric conditions which bring about fog or thick weather may coincide with or bring about changes of surface currents.

Drift current.

A drift current is a surface current mainly set up by the wind.

Stream current.

A stream current may either be the continuation of a drift current, which has by the obstruction of a coast or impinging upon another current, taken the form of an ocean river; or a stream current may be a counter current replacing the water displaced by other currents. Stream currents generally extend to much greater depths than drift currents.

Counter current.

The survey and charting of the surface currents of the Indian Ocean have reached a more advanced stage than that of any other ocean; and, owing to the fact that the Indian Ocean is enclosed by land to the northward, the current system is more self-contained than those of the Atlantic and Pacific.

For these reasons the Indian Ocean, which we dealt with last regarding its wind systems, is dealt with first for currents in this Chapter.

Southern Ocean Drift.

The Southern Ocean drift sets generally to the eastward right round the globe. At all times and in all longitudes it is subject to considerable variations. Its branches and offshoots setting to the northward penetrate the Indian, Atlantic and Pacific Oceans.

Indian Ocean

Seasonal strength of Southern Ocean Drift.

Over that region of the Southern Ocean between Latitude 38° and 50° S. extending from the Indian Ocean between the meridians of 20° and 80° of East longitude, the Southern Ocean drift sets ENE., 6 miles per day on an average throughout the year, being strongest in the southern summer and weakest in the southern winter.

Between the meridians of 80° E. and 140° E. in the same latitudes, the current sets ESE., 2 miles per day on an average throughout the year, being rather stronger in the southern winter than in the southern summer, the reverse to the currents of the western half of the Indian Ocean sector of the Southern Ocean.

On the western side of the Indian Ocean sector, the drift to the eastward is strongest between the parallels of 40° and 42° S., being at an average 7½ miles per day throughout the year. In the eastern sector the strongest easterly set is between the parallels of 44° and 46° S., being on the average 6 miles per day throughout the year.

The current often sets to the northward in the vicinity of the Crozet Islands, particularly during the months of November to January, when the mean current for the region, Latitude 38° to 50° S. Longitude 40° to 60° E., is NE. by E., 8 miles a day, calculated from 246 observations made during the years 1910 to 1932 in those months only.

In the region of Latitude 30° to 38° S. and Longitude 100° to 112° E. there is a weak connecting current, generally setting to the north-east at an average rate of 3 miles per day; but in this region, as in the same latitudes in the central portion of the ocean, the current is very variable, and generally weak.

Connecting current.

Nearer Cape Leeuwin the prevailing set is to the south-east, at an average rate of 3 miles per day, being strongest in the months of February to April, when it is 5 miles per day.

Leeuwin current.

On the eastern side of the ocean, between the parallels of 18° S. and 30° south latitude, the South East trade drift is a weak and variable current, with a mean set NW. by N., 3 miles per day from November to April. During May to October, when the South East Trade does not blow so far south, the current in this region is still more variable, so that the resultant set to the northward and westward is negligible.

South East Trade Drift.

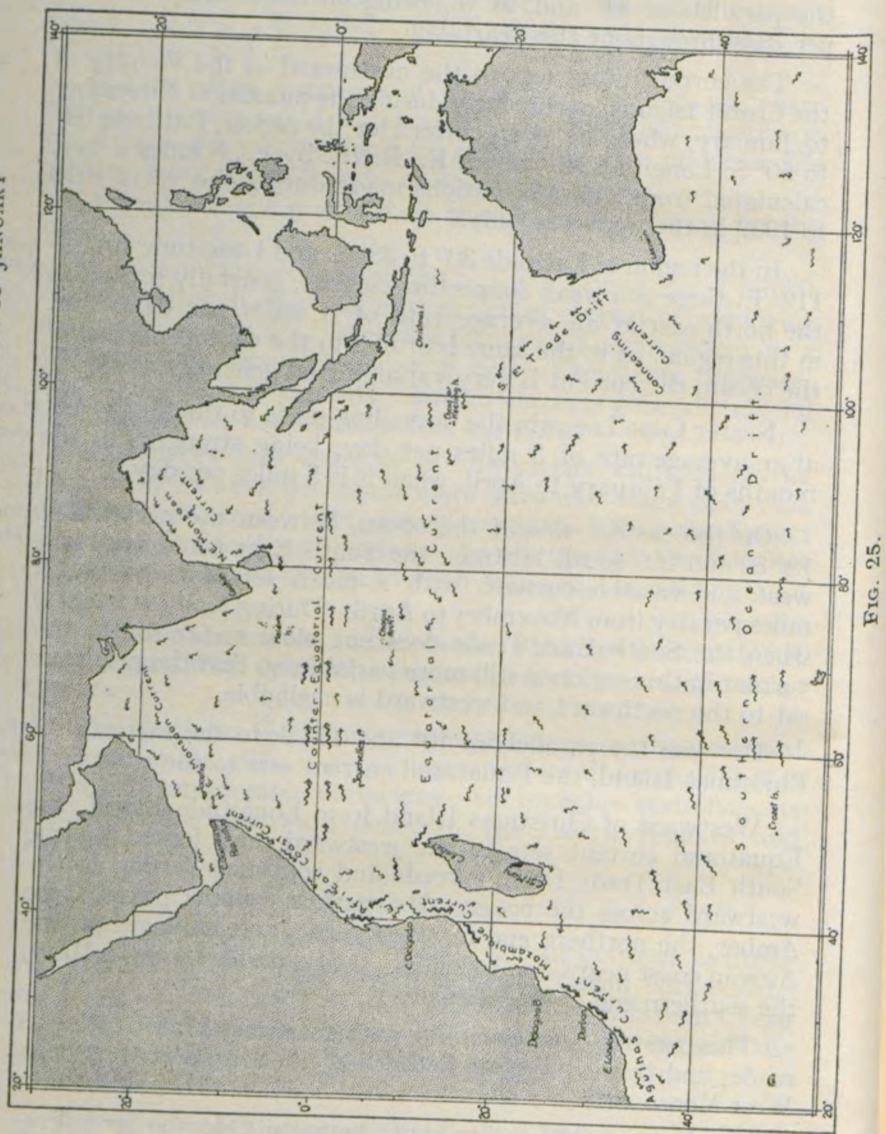
Between the parallels of 10° and 12° S. to the eastward of Christmas Island, the Equatorial current sets to the westward.

Equatorial current.

Westward of Christmas Island from Longitude 105° E. the Equatorial current sets to the westward, and joined by the South East Trade Drift, spreads and continues setting to the westward across the ocean. Its greatest volume passes Cape Amber, the northern end of Madagascar, and impinges on the African coast near Cape Delgado. It also passes Cape St. Mary, the southern end of Madagascar.

This westerly set generally gathers strength as westing is made, and this is most marked during the season of the South West Monsoon.

On the main steamship route between Colombo and Fremantle, between Latitude 6° S. and 18° S., the mean set and drift, during the season of the North East Monsoon of the Arabian Sea and Bay of Bengal, is WSW., 4 miles per day; while in the region about Cape Amber it is W. by N., 9 miles per day.



Currents in the Indian Ocean
First Half of N.E. Monsoon Season, November to January

Fig. 25.

In the same regions, during the season of the South West Monsoon, when the South East trade is stronger than during the prevalence of the North East Monsoon, the mean set and drift on the Fremantle–Colombo route is WSW., 6 miles per day, and in the region about Cape Amber is W. by N., 22 miles per day.

Off the south end of Madagascar the mean rate of the current is more uniform, being about 8 miles per day to the WSW., but the set is more southerly in November to January.

The great volume of water carried in the Equatorial current past Cape Amber to the coast of Africa divides near Cape Delgado, and great stream currents are formed running along the East Coast of Africa.

The stream going south from Cape Delgado is known as the Mozambique Current to as far south as Delagoa Bay, and from there southward as the Agulhas Current. Mozambique and Agulhas currents.

The stream going north from Cape Delgado is known as the East African Coast Current.

During the South West Monsoon season of the Arabian Sea, May to October, when the Equatorial Current is at its strongest in the region about Cape Amber, the African Coast Current setting northward from Cape Delgado is stronger than during the remainder of the year.

The Mozambique and Agulhas Currents are stronger during November to April, the southern summer, than during the southern winter when the South West Monsoon prevails in the Arabian Sea; so that in the season when the greater volume of surface water flows northward from Cape Delgado the Mozambique and Agulhas Currents are weakened; and in the season when the lesser volume of water flows northward from Cape Delgado, the Mozambique and Agulhas Currents are strengthened.

The following Table, calculated from observations made in the years 1910 to 1930, indicates the mean set and drift of the Mozambique Current and the Agulhas Current in two parts during four quarters of the year.

	Mozambique Current. Lat, 10° to 26° S.			Agulhas Current. Lat. 26° S. to Long. 24° E.			Agulhas Current. Between Long. 24° E. and Long. 20° E.		
	Mean Set and Drift.		No. of Obsns.	Mean Set and Drift.		No. of Obsns.	Mean Set and Drift.		No. of Obsns.
		mls.			mls.			mls.	
Southern Summer									
November to January	S. 20° W.	19	246	S. 43° W.	32	244	S. 74° W.	9	152
February to April ..	S. 30° W.	12	283	S. 41° W.	33	193	S. 72° W.	9	114
Southern Winter									
May to July	S. 32° W.	9	207	S. 40° W.	25	168	S. 36° W.	4	100
August to October ..	S. 25° W.	15	213	S. 41° W.	31	173	S. 75° W.	4	100

The Agulhas Current is generally strongest between Durban and East London, where during the months of its greatest strength, February to April, the mean set and drift of the stream is as much as SW. by S., 58 miles per day. The strongest part of the stream is near the 100 fathom line, where the drift of the current is occasionally as much as 5 knots.

The width of the Mozambique and Agulhas Currents probably varies considerably both in different parts of the stream, and in the same part of the stream at different times. Off the mouth of the St. Johns River, where the Agulhas Current is strongest, and in February to April the months of its greatest strength, a south-westerly set has been experienced to a distance of as much as 150 miles from the coast.

In addition to the influence already referred to of the lesser volume of water running northward from Cape Delgado during the northern winter, and consequent strengthening of the Mozambique and Agulhas Currents between November and April at this time of the year, there is also the more direct influence of the South Easter which prevails off the Cape and the South East Trade which extends farther south.

In the vicinity of Longitude 24° E., where the 100 fathom line trends further from the coast, the Agulhas Current spreads out and weakens, part of it continuing over the Agulhas Bank past Cape Agulhas and entering the South Atlantic, its warm waters being felt in False Bay.

The mean set and drift of the Agulhas Current for the different seasons of the year between Longitude 24° and 20° E. are given in the Table on page 77 calculated from observations made during the years 1910 to 1930.

Part of the Agulhas Current is diverted southward by the Agulhas Bank and running outside the 100 fathom line, recurves and joins the eastgoing Southern Ocean Drift, completing the circulation of the surface current of the Indian Ocean south of the Equator.

The current in the region of this recurvature is subject to great variations, and on occasion sets at the rate of three knots to the eastward in the vicinity of Latitude 39° S. Longitude 30° E.

East African Coast current during South West Monsoon.

During the northern summer, when the South East Trade is strongest over the Indian Ocean, and the South West Monsoon prevails in the Arabian Sea, the East African Coast Current runs very strong to the northward from Cape Delgado along the coast, which gives it its name.

Northward of Cape Delgado to Latitude 4° N. the stream does not generally extend more than 130 miles from the coast, and the current is at its strongest up to 40 miles from the coast. Outside 40 miles from the land the current decreases.

The East African Coast Current is generally strongest between Latitude 3° S. and Latitude 3° N. in May to July, when the mean set and drift over this stretch of 500 miles of the current is NE. by E., 55 miles per day.

During August to October the coast current is strongest between Latitude 3° N. and Latitude 8° N., when the set and drift over this 400 miles stretch of the current is NE., 46 miles per day.

Between Latitude 3° S. and 8° N. the East African coast current frequently reaches 4 knots.

From the Equator northward the outer edge of the current trends away from the land, and from about Latitude 7° N. it divides, part of the current continuing to set along the coast past Cape Guardafui, but the main strength of the current recurves away from the land to the East and SE.

In the vicinity of 170 miles due south of Sokotra this East-south-easterly set occasionally reaches 7 knots during the height of the South West Monsoon. The mean set and drift during the four quarters of the year, between Cape Delgado and Latitude 2° S., from thence to Latitude 6° N., and from Latitude 6° N. to Cape Guardafui, are given in the table which follows, which is calculated from observations made in the years 1910 to 1930. This does not include the strong Easterly and SE. current south of Sokotra.

East African Coast Current

	From Cape Delgado, to Lat. 2° S.			From Lat. 2° S. to Lat. 6° N.			From Lat. 6° N. to Cape Guardafui.		
	Mean Set and Drift.		No. of Obsns.	Mean Set and Drift.		No. of Obsns.	Mean Set and Drift.		No. of Obsns.
		mls.			mls.			mls.	
North East Monsoon Season.									
November to January	N. 14° E.	13	86	S. 48° W.	18	105	S. 85° W.	11	43
February to April ..	N. 7° E.	10	79	N. 53° W.	7	125	N. 11° E.	10	63
South West Monsoon Season.									
May to July	N. 11° E.	27	52	N. 53° E.	44	76	N. 44° E.	18	35
August to October ..	N. 4° W.	23	78	N. 47° E.	27	104	N. 43° E.	28	29

East African Coast current during North East Monsoon season.

The East African coast current is a continuous stream setting along the coast to the northward and north-eastward only as far north as Latitude 3° S. during November to April, the North East Monsoon season.

Northward of Latitude 3° S. the set of the current along the African coast during these months is reversed to the south-westward from November to January as far north as Ras Hafun, and in February to April between the Equator and Latitude 6° N. it is deflected to the westward, as is indicated in the Tables above.

The seasonal variations of the current system of the South Indian Ocean are indirectly influenced by the monsoons prevailing in the northern part of the ocean.

Seasonal Reversal of current in Northern Indian Ocean.

In the northern part of the Indian Ocean, the region of the great monsoons, the current systems are more complicated. The surface currents have more than seasonal variations for they reverse with the seasons.

The trend of the coasts of Southern Asia, the rotation of the earth, the change of the wind from NE. to SW. and from SW. to NE., with the monsoonal changes of temperature and all the directing and propelling forces, are so balanced and brought into play that the current circulation which is clockwise during the South West Monsoon season, is reversed during the greater part of the season of the North East monsoon.

Currents in the Northern Indian Ocean during the first half of the North East Monsoon season.

During November to January when the East African coast current sets to the south-west from Ras Hafun, near the Equator, much of its water recurves and a strong Counter Current flows eastward along the Equator across the ocean. It has a breadth of about 400 miles. On the steamship route between Cape Leeuwin and Cape Guardafui the mean set is N. 88° E., 17 miles per day, calculated from 143 observations made between 1910 and 1930, and the current occasionally sets to the eastward as much as three knots. On the Fremantle to Colombo route the set and drift is N. 82° E., 8 miles per day, calculated from 233 observations for the same period.

The current sets to the westward from the Malacca Straits across the mouth of the Bay of Bengal. There is a set to the westward, northward of Latitude 12° N. in the Bay of Bengal, and to the south-west and southward off the east coasts of India and Ceylon.

South of Ceylon the current sets to the westward. This current off the east and south coasts of Ceylon has a mean drift of 23 miles per day.

Along the west coast of India the current sets to the NNW., and is mainly to the westward over the Arabian Sea.

The currents off the coasts of India, the SE. coast of Arabia and the East coast of Africa to the Equator being mainly with the prevailing NE. monsoon wind and counter clockwise. The Counter Equatorial Current completing the surface current circulation of the Indian Ocean north of the parallel of 3° S. Latitude.

Currents in the Northern Indian Ocean during the latter half of the North East Monsoon season.

During February to April when between the Equator and Latitude 6° N. the current sets to the westward towards the African Coast part of the west setting Equatorial current running past Cape Amber recurves before reaching the vicinity of Cape Delgado and passing northward of the Seychelles Islands sets Eastward. This joins the Counter Equatorial

Currents in the Indian Ocean. Second Half of N.E. Monsoon Season, February to April

Fig. 26.

current, which is further south than during the first half of the NE. monsoon season, being south of the Equator on the Western side of the ocean and usually having its northern edge not further North than Latitude 2° N., at this time of the year on the Fremantle-Colombo track, where it is about 600 miles broad.

During February to April the Counter Equatorial Current has a mean set and drift of N. 72° E., 10 miles per day, calculated from 75 observations made in 1910 to 1930 on the Cape Leeuwin-Cape Guardafui track, and N. 88° E., 9 miles a day, calculated from 240 observations taken in the same period on the Fremantle-Colombo track. From Malacca Straits the current sets to the westward past the south coast of Ceylon and right across the ocean to the African coast.

It is strongest between the Equator and Latitude 3° N. in Longitude 57° E. to 67° E., where the mean drift during February to April is 18 miles per day to West, and occasionally the drift is as much as 2½ knots.

In the central part of the Arabian Sea the current is weak and variable setting mainly to the Northward or Westward.

In the Northern part of the Arabian Sea the current sets to the Eastward and SSE. along the West Coast of India.

In the Bay of Bengal the current runs N. by W., North, and NE. along the East Coast of India, and is SW. and West over the rest of the Bay.

Thus the current which is mainly with the wind in the first half of the NE. monsoon season and of counter-clockwise circulation, is reversed before the NE. monsoon season is over, and while it is still blowing over the greater part of the Indian Ocean North of the Equator, but with less force.

Times of Reversal of Current during North East Monsoon season off the shores.

On the average this reversal of the current is not simultaneous. In the region of Ras Hafun, along the African coast, the general current change takes place at the latter end of January or the beginning of February, from south-westerly to northerly, though north-easterly winds prevail until March, and the South West monsoon does not make until May.

Off the SE. coast of Arabia the current changes from westerly to north-easterly from March to April, when the wind is variable, and the South West monsoon makes in May.

In the northern part of the Arabian Sea the weak westerly current lasts until February, and in March the easterly current commences to assert itself, the winds being variable, but northerly predominating, the South West Monsoon commencing in May or June.

Currents in the Indian Ocean. S.W. Monsoon Season, May to October

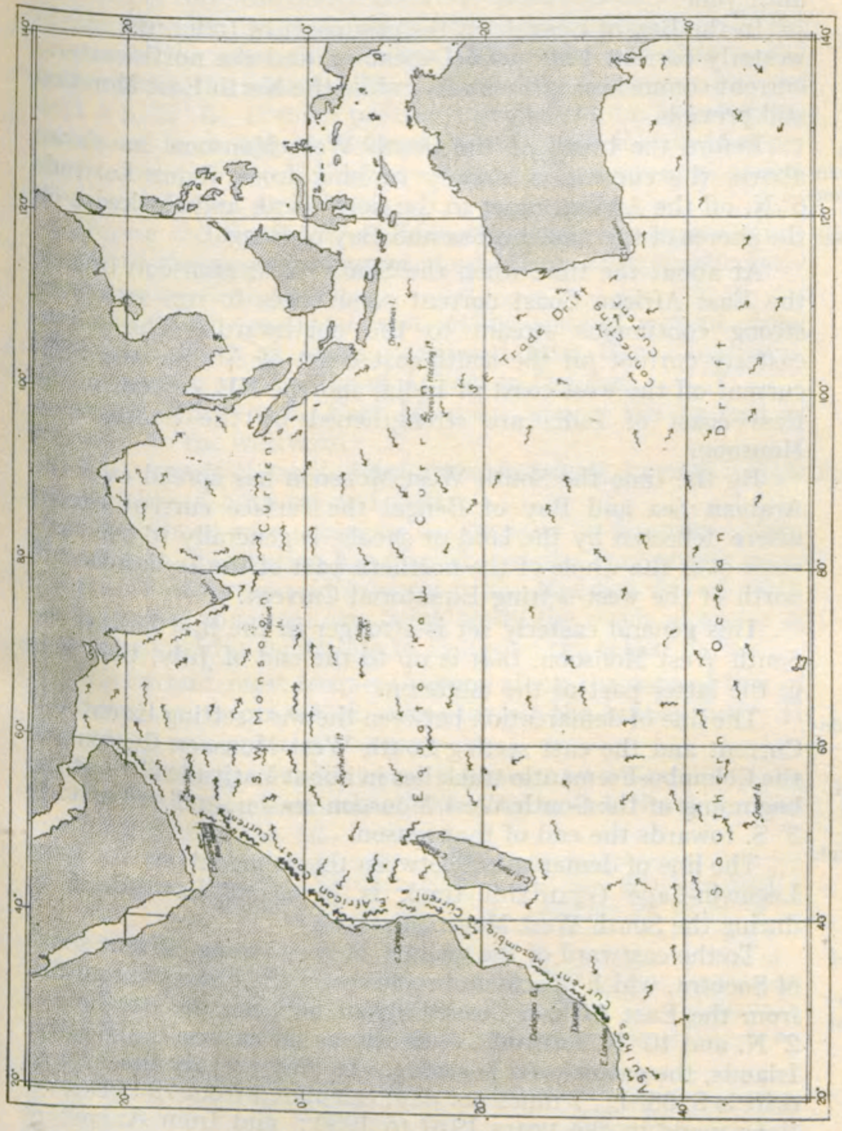


Fig. 27.

Off the W. coast of India, between Bombay and Cochin, the NNW. current persists until January, and by March the SSE. current has commenced, northerly winds predominating at this time of the year, the South West Monsoon not prevailing until June.

In the Bay of Bengal, off the east coast of India, the south-westerly current lasts until December, and the north-easterly current commences in February, while the North East Monsoon still prevails.

Currents in the Northern Indian Ocean during the South West Monsoon season.

Before the break of the South West Monsoon, as shown above, the current is already running from about Latitude 6° N. off the African coast to the northward, and clockwise off the shores of the Arabian Sea and Bay of Bengal.

At about the time when the South West Monsoon breaks, the East African Coast current commences to run as a very strong continuous stream to the northward. The north-easterly current off the south-east coast of Arabia, the SSE. current off the west coast of India, and the NE. current of the East coast of India are strengthened by the South West Monsoon.

By the time the South West Monsoon has spread over the Arabian Sea and Bay of Bengal the surface current except where deflected by the land or shoals, is generally to the eastward over the whole of the northern part of the Indian Ocean, north of the west setting Equatorial Current.

This general easterly set is stronger in the first half of the South West Monsoon, that is up to the end of July, than it is in the latter part of the monsoon.

Line of demarcation between Equatorial and South West Monsoon current.

The line of demarcation between the west setting Equatorial Current and the east setting South West Monsoon Current on the Colombo-Fremantle track lies in about Latitude 6° S. at the beginning of the South West Monsoon season, and in Latitude 3° S. towards the end of that season.

The line of demarcation between these currents on the Cape Leeuwin-Cape Guardafui track is in about Latitude 5° S. during the South West Monsoon season.

Strength of currents during the South West Monsoon season.

To the eastward of the vicinity of very strong current south of Socotra, which offsets and recurves to the eastward and SE. from the East African Coast Current between the parallels of 2° N. and 10° N. Latitude, to nearly as far east as the Maldive Islands, the easterly set is strong. In May to July the set and drift is S. 68° E., 7 miles per day, calculated from 793 observations made in the years 1910 to 1930; and from August to October it is S. 57° E., 5 miles per day, calculated from 676 observations for the same period.

In the region south of Latitude 2° N. between the longitudes of the Seychelles and the Chagos Islands, the South West Monsoon easterly current is very strong during May to July,

when the current occasionally runs at as much as 4 knots, the mean set and drift being N. 84° E., 14 miles per day, calculated from 97 observations; but it weakens somewhat in the latter half of the season, August to October, when it is N. 84° E., 9 miles per day, calculated from 151 observations.

Between the South Coast of Ceylon and Latitude 2° N. the reverse is the case, the current being slightly weaker in the first half of the season. In May to July the mean set and drift is S. 87° E., 12 miles per day, calculated from 114 observations, and from August to October it is N. 87° E., 14 miles per day, calculated from 117 observations. This current occasionally runs as much as 2½ knots.

Gulf of Aden.

During the South West Monsoon season the current runs strong to the eastward out of the Gulf of Aden, particularly along the coast of Arabia.

There is an occasional west setting counter current along the North coast of Africa, westward from Cape Guardafui, particularly in the months of August to October.

During the North East Monsoon season the current is generally to the westward.

Red Sea.

The currents of the Red Sea are mainly drift currents. They are variable in both set and drift.

The drift on rare occasions has been up to 50 miles a day, but modern observation has proved that the very strong cross currents which were said to occur in the Red Sea do not exist, the supposed abnormal sets being really the result of errors in position found by sights due to excessive refraction.

The current most frequently runs along the central line of the sea; less frequently it runs athwart the central line. It may set to any point of the compass.

The following table indicates the mean set and drift of the current during each month of the year in the Northern and Southern half of the sea.

Month.	Red Sea, Northern Half. Latitude 28° to 20° N.		Red Sea, Southern Half. Latitude 20° to 12° N.	
	Mean Set and Drift.	No. of Observations.	Mean Set and Drift.	No. of Observations.
November ..	N. 4° W. 1	326	N. 2° W. 4	281
December ..	N. 41° W. 1	347	N. 3° W. 3	294
January ..	N. 19° W. 2	277	N. 9° E. 3	243
February ..	N. 11° W. 1	247	N. 1° E. 3	221
March ..	N. 71° W. 1	253	N. 22° W. 3	269
April ..	S. 33° W. 1	248	N. 52° W. 1	199
May ..	N. 39° W. 1	244	N. 27° W. 1	182
June ..	S. 9° W. 3	285	S. 18° E. 3	212
July ..	S. 16° E. 3	242	S. 19° E. 7	156
August ..	S. 11° E. 1·5	260	S. 23° E. 6	209
September ..	S. 15° E. 4·5	292	S. 13° E. 3	247
October ..	S. 32° E. 1	301	N. 19° E. 1	265

Atlantic Ocean

The narrowest part of the Southern Ocean is Drake Passage, which is about 500 miles across from Cape Horn to Graham Land, the most northerly part of Antarctica.

Cape Horn current.

The Cape Horn current sets to the north-east, as has long been well known; and of recent years *Discovery* has found that this set and drift of the current to the north-east through Drake Passage is not confined to the surface layers of the sea, but that it is continuous to great depths.

Thus this current is formed by a great volume of water running from the Pacific sector into the Atlantic Sector of the Southern Ocean.

The Cape Horn current at the surface runs past the cape which gives it its name. Near Cape Horn the average set and drift is NE. 22 miles per day. Part of it turns northward,

Falkland current.

passing on either side of the Falkland Islands, from whence it is known as the Falkland Current, and has a mean set and drift of N. by E., 10 miles per day, throughout the year, being strongest in February to April, and weakest in November to January.

It runs as far north as the mouth of the River Plate, and during part of the winter, May to July, as far north as the mouth of the Rio Grande do Sul, or even to Latitude 30° S.

The greater part of the Cape Horn Current passes to southward of the Falkland Islands, setting to the eastward and north-eastward.

Southern Ocean Drift current.

The drift in the Southern Ocean is generally to the eastward and north-eastward.

Benguela current.

Off the Cape of Good Hope the part of the Agulhas Current which has entered the South Atlantic is joined by an offshoot of the Southern Ocean drift, and the Benguela current sets to the northward along the west coast of Africa to the Bight of Biafra.

The Benguela Current and the South East Trade drift feed the South Equatorial Current.

Along the west coast of South Africa the sea surface is colder than it is further to seaward, and there is much upwelling of cold bottom water. The South Easter blowing at an angle across the coast line and to seaward, has the effect of drawing the water away from the coast, which is partly compensated by upwelling, and produces differences of pressure in the water, which, combined with the effect of the rotation of the earth, accelerate the northerly current.

Off the coast of the Cape Province the Benguela Current sets on an average throughout the year N. 38° W., 7 miles per day, calculated from 128 observations made in the years 1910 to 1922. This north-westerly set is strongest in November to January, when the South Easter prevails.

Currents in the Atlantic

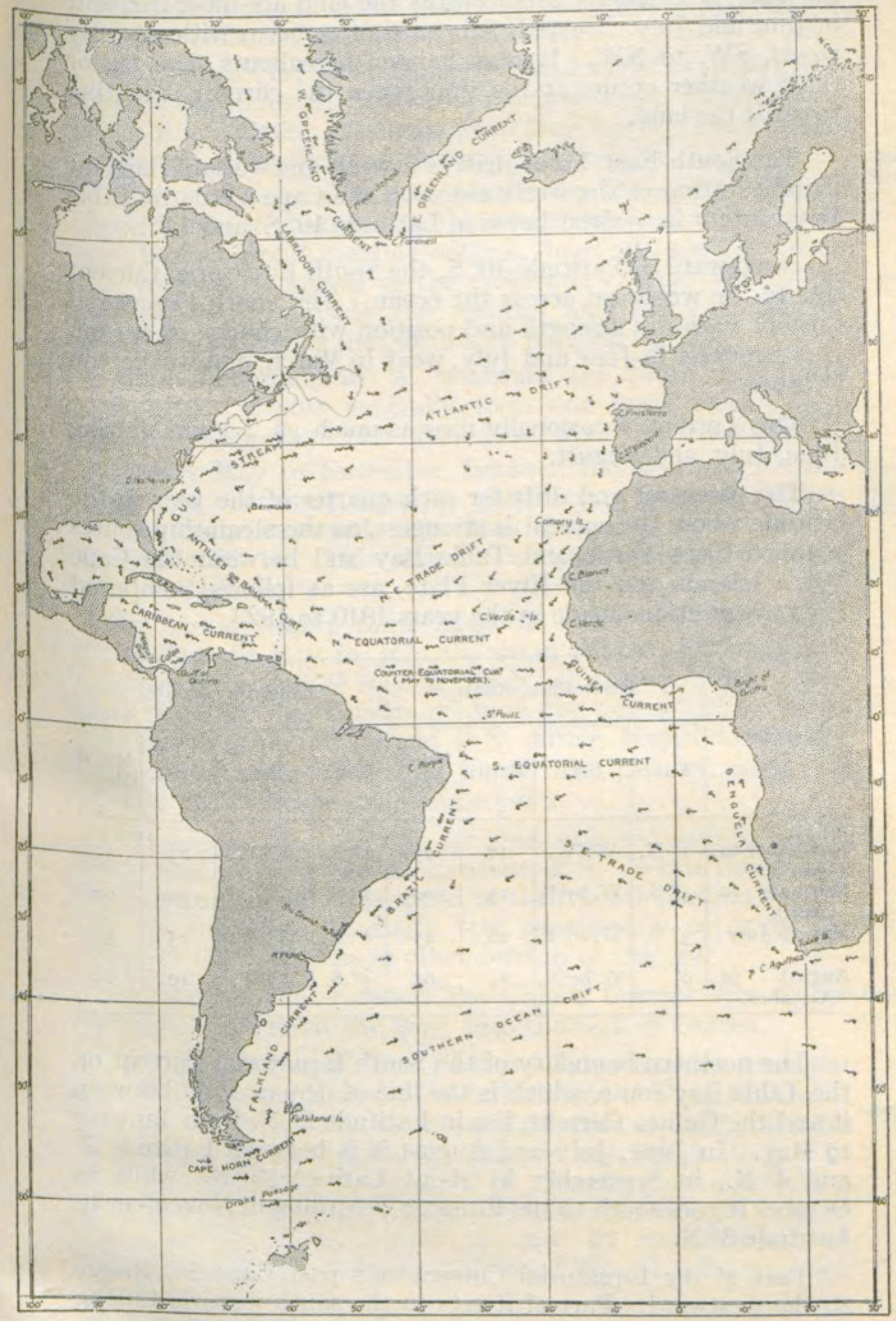


Fig. 28.

Sets towards the land.

The current in this region may be variable at all times of the year, but easterly sets towards the land are most frequent in June and July. Easterly sets most often occur with westerly winds, SW. to NW. It may happen hereabouts that fog or thick weather occurs at the time when the current is setting towards the land.

South East Trade Drift.

The South East Trade drift is a weak and variable current mainly setting to the westward. On the Cape Verde to Table Bay route it is weakest between Latitude 10° S. and 14° S.

South Equatorial current.

Northward of Latitude 10° S. the South Equatorial Current sets to the westward across the ocean. The South Equatorial Current varies in strength and position with change of season. It is strongest in June and July, weak in March, and weakest in October.

This current occasionally runs as much as 2 knots during June, July, and August.

The mean set and drift for each quarter of the year in the latitude where the current is strongest, on the steamship routes between Cape Verde and Table Bay and between the Cape Verde Islands and the River Plate, are as follows, computed from observations made in the years 1910 to 1923.

Quarter.	River Plate Route.				Table Bay Route.			
	Lat.	Set.	Drift.	No. of Obsns.	Lat.	Set.	Drift.	No. of Obsns.
November to January.	1° N.	WNW.	18	23	1° S.	WNW.	15	57
February to April.	4° S.	W. by S.	13	100	1° S.	W.	10	62
May to July	3° S.	W. by S.	16	45	1° N.	WNW.	23	35
August to October.	0°	W. by N.	14	65	3° S.	WSW.	10	65

Boundary between South Equatorial and Guinea currents.

The northern boundary of the South Equatorial Current on the Table Bay route, which is the line of demarcation between it and the Guinea Current, lies in Latitude 2° N. from January to May. In June, July and August it is between Latitude 3° and 4° N., in September in about Latitude 3° N., while in October it goes south to the Equator, returning in November to Latitude 3° N.

Brazil current.

Part of the Equatorial Current sets past Cape St. Roque to the westward. Part of it sets to the south-westward along the coast of Brazil, where it is known as the Brazil Current. Upon reaching Latitude 30° S. or the latitude of the River Plate, according to season, it recurves to the south-east and east joining the Southern Ocean Drift, and so completing the surface current circulation of the South Atlantic.

The Brazil Current is strongest from November to January, when it continues furthest south along the coast to the mouth of the River Plate. It is weakest in May to July, when it runs south-west along the coast as far as Latitude 30° S.

The part of the South Equatorial Current which sets past Cape St. Roque continues to the west-north-west. The North Equatorial Current merging with it, flows into the Caribbean Sea, where it is known as the Caribbean Current and to the north-westward outside the Antilles and Bahama Islands, where it is known as the Antilles or Bahama Current.

From Longitude 26° W. westward the South and North Equatorial Currents generally form one great west setting current, during about half of the year, from December to May.

Counter Equatorial current.

During May to November, between the South and North Equatorial Currents, there is generally a counter current setting to the eastward, sometimes extending as far west as Longitude 50° W. This easterly current at times runs at as much as 1½ knots.

On the steamship route from the Cape Verde Islands to River Plate in May to July the mean set and drift between Latitude 8° N. and 4° N. is E. by N., 6 miles per day, calculated from 85 observations made in the years 1910 to 1923. Between Latitude 10° N. and 4° N. during August to October the mean set and drift is E. by N., 12 miles per day, calculated from 80 observations in the same years.

Occasionally this easterly set is experienced near St. Paul's Rocks and as far south as Latitude 2° S. When this occurs the Doldrums have been south of their usual position for the time of the year. Easterly sets occasionally occur in the region of the Doldrums in other months of the year.

Guinea current.

Further to the eastward the Guinea Current sets to the eastward throughout the year, into the Gulf of Guinea.

On the route from Cape Verde to Table Bay the strongest part of the Guinea Current lies in Latitude 4° N. in November to January, when the mean set and drift is ESE., 9 miles per day, calculated from 26 observations (1910–1922). In February to April in Latitude 4° N., the mean set and drift is ESE., 11 miles per day, 22 observations ; in May to July, in Latitude 6° N., East, 8 miles per day, 21 observations ; in August to October, in Latitude 5° N., ESE., 11 miles per day, 35 observations.

The North East Trade Drift and the Equatorial Currents carry a great volume of warm water into the Caribbean Sea, the Gulf of Mexico, and to the region of the West India Islands. The mean sea level of the Gulf of Mexico is raised about 3 ft. above that of mean sea level in the neighbourhood of Sandy Hook.

Caribbean current.

The Caribbean Current sets to the westward and north-west for the whole length of the Caribbean Sea, occasionally during the summer running as much as 3 knots. On the steamship routes between the Panama Canal and the Windward and Mona Passages it is strongest between Latitude 12° and 14° N., where the mean set and drift found from observations made from 1910 to 1925 are as follows :—

Season.	Set.	Drift Miles per day.	No. of Observations.
Winter.			
November to January ..	W.	17½	55
February to April ..	W.	17	53
Summer.			
May to July	WNW.	21	43
August to October ..	WNW.	18	60

Central American counter current.

A counter current runs to the eastward following the trend of the shores of the Mosquito Gulf and across the mouth of the Gulf of Darien, occasionally reaching as much as 2½ knots in summer.

In the vicinity of 100 miles north-east of Colon the mean set and drift found by observations made during the years 1910 to 1925 are as follows :—

Season.	Set.	Drift Miles per day.	No. of Observations.
Winter.			
November to January ..	NW. by W.	6	24
February to April ..	ESE.	5½	22
Summer.			
May to July	E.N.E.	11	21
August to October ..	E. by N.	12	38

Cuban counter current.

A counter current also runs to the eastward off the south coast of Cuba during the summer.

Currents of the Gulf of Mexico.

From the Yucatan Channel the currents in the Gulf of Mexico vary with the season and are much affected by the prevailing winds.

Generally from the Yucatan Channel the current spreads, part of it flowing to the westward and following the trend of the coast round the Gulf, the other part setting to the northward towards the mouth of the Mississippi River. Off the mouth of the Mississippi these two parts of the current rejoin, and set out of the Gulf through the Florida Strait. Along the coasts there are counter-currents.

The Gulf Stream.

In the Straits of Florida, which is a bottle neck, the velocity of the current is affected by the tide and by winds in the Gulf of Mexico.

After passing through Florida Strait the Gulf Stream is increased in volume by the Bahama Current, which is a continuation of the North Equatorial and Antilles Currents previously referred to.

From Florida Strait the Gulf Stream follows the trend of the 100 fathom line to Cape Hatteras, running at great strength, and reaching up to 5 knots.

The mean drift of the Gulf Stream between Havana and Cape Hatteras in the different seasons, calculated from observations made between 1910 and 1925, is as follows :—

Season.	Drift Miles per day.	No. of Observations.
Winter.		
November to January	23	87
February to April	30	125
Summer.		
May to July	29	139
August to October	19	116

From Cape Hatteras the Gulf Stream turns more to the eastward and commences to spread, and in the region to the southward of Sable Island and the Grand Banks of Newfoundland its mean set is nearly due East, the mean drift for the seasons being as follows :—

Season.	Drift Miles per day.	No. of Observations.
Winter.		
November to January	9	460
February to April	9	1,565
Summer.		
May to July	10	2,211
August to October	9	989

In this region where the Gulf Stream generally sets East and sometimes with velocity of 3½ knots, it is occasionally reversed in direction. Sets to SSW. up to 3 knots have been experienced, and to every point of the compass with lower velocities well within the usual limits of the normally East setting Gulf Stream.

Gulf Stream counter current.

As well as the Labrador Current, which runs in a counter direction to the Gulf Stream on its northern and western side, where the Cold Wall is the line of demarcation, there is at times on its southern and eastern side a counter current also. This counter current is most marked in Latitude 37° N. between Longitude 46° W. and 60° W. during August to October, when the mean set and drift is West, 4 miles per day, calculated from 77 observations. This westerly and south-westerly set continues to the westward of the longitude of Bermuda along the south-east edge of the Gulf Stream to as far south as Latitude 28° N. in the spring and early summer.

Atlantic Drift.

Eastward of the Grand Banks of Newfoundland the Gulf Stream further spreads and becomes the Atlantic Drift, which is comparatively weak and variable. From mid-Atlantic to the approaches to the Fastnet and the Scilly Islands the North Atlantic Drift, along the trans-North Atlantic steamship routes, has a mean set of E. by N., the mean drift to E. by N. being as follows, calculated from observations made in the years 1910 to 1925 :—

Season.	Drift Miles per day.	No. of Observations.
Winter.		
November to January	3	1,325
February to April	3	2,619
Summer.		
May to July	3	2,876
August to October	2	1,579

Much relatively warm water is widely spread over the eastern North Atlantic in the North Atlantic Drift, which, as we have seen is a continuation of the Gulf Stream, which is fed by the surface waters of the Equatorial currents on either side of the Equator in the Atlantic.

Part of the North Atlantic Drift continues north-eastward past the coast of Scotland, off the coast of Norway, past the North Cape, and continues as the Murman Current, south-eastward off the coast of Lapland, where its influence is shown by keeping these waters open to navigation in the winter, when those in lower latitudes in other longitudes are closed by ice.

Murman current.

Arctic Waters.

The currents of the Arctic Ocean are imperfectly known, and it is beyond the scope of this book to attempt to describe them.

Wherever Gulf Stream waters, as off the Murman coast, penetrate the Arctic Ocean, it may be known by the bright blue colour of the sea and its great transparency.

The natural waters of the Arctic Ocean are green.

When Gulf Stream waters become mixed with adjacent Arctic waters the sea is leaden blue or bluish green.

It should be borne in mind by seamen that in high latitudes, particularly in the spring and early summer, probably due to melting ice, the surface current may be that of a very thin film of water only. The set and drift of the water at the surface may be entirely different from or even opposite to that at quite a small depth. This fact should always be remembered in working boats from a ship in regions of ice.

With a ship drawing not more than 18 ft., and her boat with a draught of 3 ft., currents off the coast of Lapland have been known to set them in opposite directions at a combined speed of not less than 3 knots.

Atlantic Drift.

Eastward of Longitude 30° W. part of the North Atlantic Drift sets to the south-east.

Whereas the currents of the North Atlantic are mainly strong stream currents on the western side of the ocean, on the eastern side the circulation mainly consists of drift currents, which vary considerably in set as well as drift.

Along the steamship route from the English Channel to the southward, across the mouth of the Bay of Biscay during the winter and spring, the general set of the current is easterly at the rate of 2 miles per day. During summer and autumn the general set is southerly at the rate of 2 miles per day.

Between Cape Finisterre and Latitude 44° N. westerly sets predominate during May to January, the drift occasionally being as much as 2 knots, and the mean set is to the westward at the rate of 3 miles per day. In February to April it is SSW., 2 miles per day.

Rennell's current.

This current is said to be an occasional current. A continuance of a circulation round the shores of the Bay of Biscay, setting to the northward across the mouth of the English Channel.

Investigation by means of observations made between the years 1910 and 1925 indicates the predominance of westerly sets out of the Bay of Biscay in the region of Finisterre during the greater part of the year ; and has failed to establish the fact that there is a north-westerly set at the northern end of the mouth of the Bay of Biscay.

Evidence seems to indicate that there is a set occasionally to the northward between the latitude of Ushant and that of the Lizard, which cannot be accounted for by normal tidal streams only.

The possibility of a set to the northward, across the mouth of the English Channel and the approaches to the St. George's and Bristol Channels, should always be considered.

Portugal current.

The Portugal Current is the southerly flow on the eastern side of the North Atlantic off the coast of Portugal, which further south is known as the Canary Current.

Between the latitudes of Cape Finisterre and Cape St. Vincent, southerly sets predominate throughout the year, at an average of two miles per day during the winter, and three miles per day during the summer.

Canary current.

From the latitude of Cape St. Vincent to the latitude of Cape Blanco, the southerly current is known as the Canary Current, after the group of islands through which it runs.

The set of the Canary Current is mainly S. by W. to the latitude of Cape Juby (Latitude 28° N.) whence it sets south-westerly, occasionally reaching as much as two knots.

It is stronger south of the Canary Islands than to the northward of them. The mean drift of this current to the south-westward is as follows during the different seasons, calculated from observations made between 1910 and 1924.

Season.	Drift Miles per day.	No. of Observations.
Winter.		
November to January	3	662
February to April	5	793
Summer.		
May to July	4	774
August to October	5	682

Africa Coast current.

A part of this current flows along the African Coast, past Cape Verde, joining the Guinea Current.

North East Trade Drift.

Between Latitude 20° N. and 10° N. along the steamship route to the Brazils, which passes through the Cape Verde Islands, the North East Trade Drift is variable, setting mainly SW. by W.

Its mean drift, calculated from observations made between 1910 and 1924, is as follows :—

Season.	Drift Miles per day.	No. of Observations.
Winter.		
November to January	5	179
February to April	5	217
Summer.		
May to July	4	215
August to October	3	142

The North East Trade Drift continues to the westward as the North Equatorial Current, and joining the South Equatorial Current, as already described enters the Caribbean Sea and the region of the West Indies, completing the general surface circulation of the North Atlantic Ocean.

Sargasso Sea.

Over a great central area and within the region of the high atmospheric pressure of the North Atlantic anticyclone, the currents are mainly weak and variable. This region of indefinite boundary is known as the Sargasso Sea, owing to sargasso or gulf weed, which is abundant there, being torn from the coasts of the West Indies and Florida, and carried by the currents into these waters.

Ice bearing currents.

The best known currents of the Arctic Ocean are those which flow from the Arctic into the North Atlantic Ocean, bringing loose ice down to the latitudes of the trade routes, and much has been learned of them through the drift of this ice.

East Greenland current.

The East Greenland Current sets south-west along the coast which gives it its name.

West Greenland current.

Rounding Cape Farewell, the southern point of Greenland, the current sets north-west along the west coast of Greenland.

Abreast of Frederikshaab part of the current sets west across Davis Strait.

From the Polar Sea the current sets south through Smith Sound, and in Baffin Bay is joined by the West Greenland Current, which recurves in the region of Latitude 75° N.

The current also sets out of Lancaster Sound and these three branches uniting flow SSW. down the western shore of Baffin Bay and Davis Strait, and in about Latitude 62° N. this south-going stream is joined by the part of the Greenland Current which sets to the westward from the vicinity of Frederikshaab.

Labrador current. The stream continues south and SSE. down the coast of Labrador and the east coast of Newfoundland. Its cold waters spread over the Grand Banks and run down their eastern edge. Part of the stream recurves and flows northward towards the south-west coast of Greenland, but most of this water, meeting the Gulf Stream, turns to the north-east and mingles with the Atlantic Drift.

Cabot current. Part of the Labrador Current finds its way through Belle Isle Strait and sets southward off the west coast of Newfoundland. Passing through Cabot Strait it sets SW. and south inside the Gulf Stream along the west coasts of Nova Scotia and the United States as far as Cape Hatteras.

From Cape Hatteras southward there is also a counter-current inside the Gulf Stream.

Cold Wall. The line of demarcation, or "Cold Wall," between the cold waters of the Labrador and Cabot Currents (which cold water may also be due in some measure to upwelling) and the warm water of the Gulf Stream is marked, both in colour contrast, as already described, and in temperature as already stated in the chapter upon Weather.

Pacific Ocean

The currents of the Pacific Ocean have not been charted to the same extent as those of the Indian and Atlantic Oceans, and are not so well known.

Bering Strait which connects the Pacific with the Arctic Ocean, is only 50 miles wide, and 32 fathoms deep, so that the currents of the North Pacific are much less affected than those of the Atlantic by the flow of water from the northern polar regions, and the spread of cold water from polar regions over the bed of the ocean cannot take place to any great extent from the Arctic Ocean.

The surface current, as in the other oceans, for the most part circulates round the areas of high atmospheric pressure.

Humboldt's current. An offshoot of the Southern Ocean drift setting to the northward on arriving off the west coast of South America joins Humboldt's current, which sets northward from the region of the Chiloe Islands along the coasts of Chile and Peru, nearly as far as the equator, part of it branching off to the north-west and westward.

South Equatorial current. The South Equatorial current sets to the westward right across the ocean.

CURRENTS IN THE PACIFIC

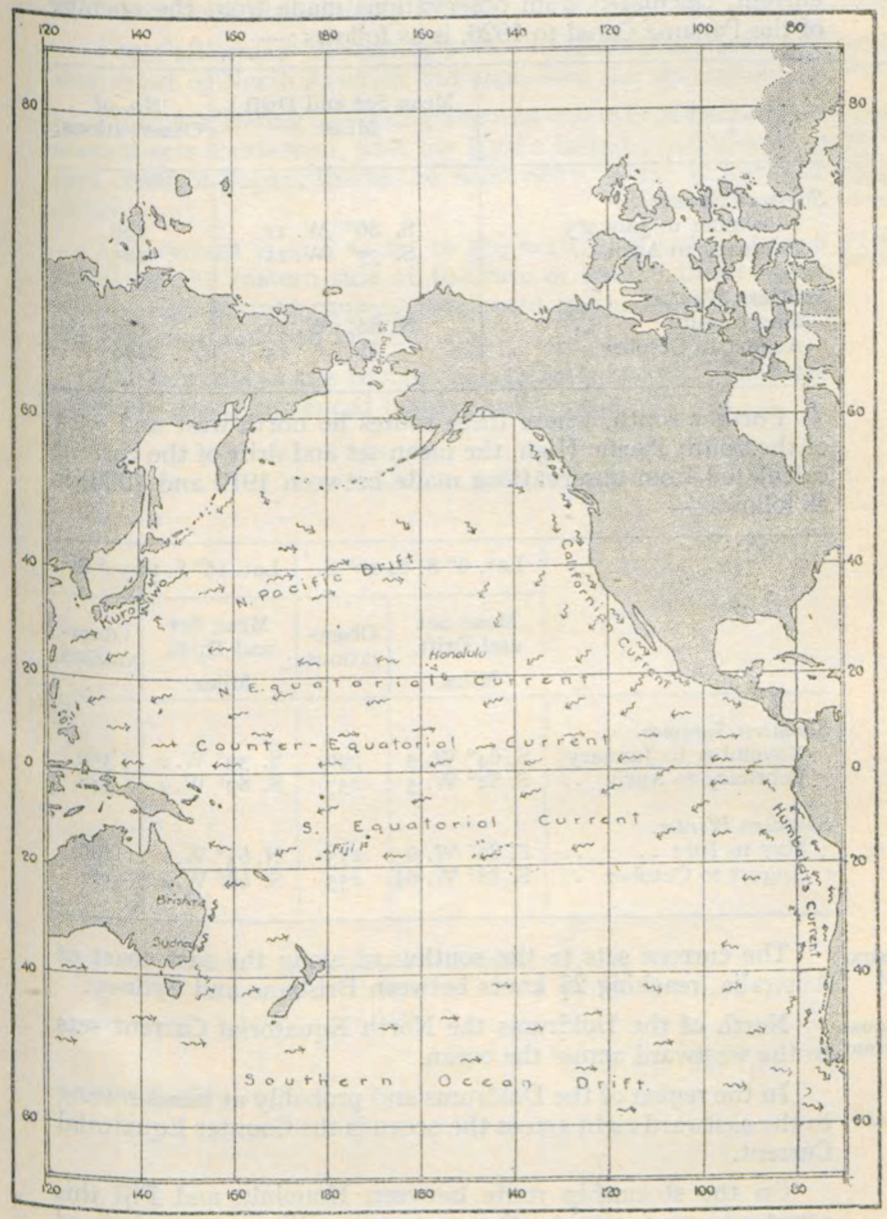


FIG. 29.

Currents on the route Panama to Australasia.

On the steamship routes between Panama and the ports on the east coast of Australia and New Zealand, between Latitude 2° N. and 6° S. the mean set and drift of the South Equatorial current, calculated from observations made from the opening of the Panama Canal to 1926, is as follows :—

	Mean Set and Drift, Miles.	No. of Observations.
Southern Summer.		
November to January	S. 86° W. 11	198
February to April	S. 77° W. 11	185
Southern Winter.		
May to July	N. 88° W. 11	186
August to October ..	W. 15	179

Further south, where these routes lie north-west and west of the South Pacific High, the mean set and drift of the current calculated from observations made between 1910 and 1926, is as follows :—

	Lat. 6° S. to 16° S.		Lat. 16° S. to 30° S.	
	Mean Set and Drift. Miles.	Observations.	Mean Set and Drift. Miles.	Observations.
Southern Summer.				
November to January	S, 64° W. 5	296	S. 39° W. 2	356
February to April ..	S. 82° W. 5	257	S. 87° W. 2	348
Southern Winter.				
May to July	S. 82° W. 6	275	N. 63° W. 1	306
August to October ..	S. 88° W. 6½	255	S. 68° W. 4	321

East Australian Coast current.

The current sets to the southward along the east coast of Australia, reaching 2½ knots between Brisbane and Sydney.

North Equatorial current

North of the Doldrums the North Equatorial Current sets to the westward across the ocean.

Counter Equatorial current.

In the region of the Doldrums and probably at times setting to the eastward right across the ocean is the Counter Equatorial Current.

On the steamship route between Honolulu and Fiji this counter-current sets to the eastward with a mean drift of 6 miles per day in November to January in Latitude 7° N., and in August to October between Latitude 4° N. and 6° N., its mean set and drift is ENE. 13 miles per day.

Kuro Siwo.

The Japan Current or Kuro Siwo is a warm current which carries the water of the North Equatorial Current past the south-east coast of Japan and becomes the North Pacific Drift in the region of the westerly winds.

North Pacific Drift.

Californian current.

The Californian current sets to the southward down the west coast of North America and completes the circulation.

Kurile current or Oya Siwo, and Kamchatka currents.

From the Bering Sea along the east coast of Kamchatka a current sets south-west, past the Kurile Islands, and along the east coast of Japan, inside the Kuro Siwo, as far as Latitude 35° N.

Bering Strait.

The current is said to set to the northward out of Bering Strait on the eastern side at the rate of two to three knots, while a cold current running southward on the western side of the Strait attains two knots.

The currents of the Bering Sea are little known. They are probably much influenced by tide and wind.

CHAPTER VII

ICE

Ice a danger to navigation.

Ice drifted to the routes used by shipping is a great danger to navigation.

The loss of ships, and the damage done to ships, known to be due to collision with ice, has been great ; besides which many a ship posted missing has probably met her fate by collision with ice in the Southern Ocean or the Western North Atlantic.

The terms used to distinguish the different kinds and conditions of ice are given in the MARINE OBSERVER'S HANDBOOK.

The ice which drifts to the trade routes, and which is a danger to navigation, is of two main types :—Land ice, that is glacier ice, bergs ; and sea ice, pack.

In southern latitudes pack does not usually drift as far north as the trade routes.

In northern latitudes pack drifts to as far south as Latitude 43° N. in the Western North Atlantic.

Icebergs are especially dangerous. A berg of pure ice would float with approximately one-ninth of its mass above water, a cubic foot of sea water weighing 64 lb., while a cubic foot of pure ice weighs 57 lb. Some bergs carry appreciable loads of rock or earth, while in others snow may not be completely transformed into ice or they may contain a large proportion of air. Bergs may float with as much as one-third of their mass out of water, or they may have only one-tenth of their mass above water.

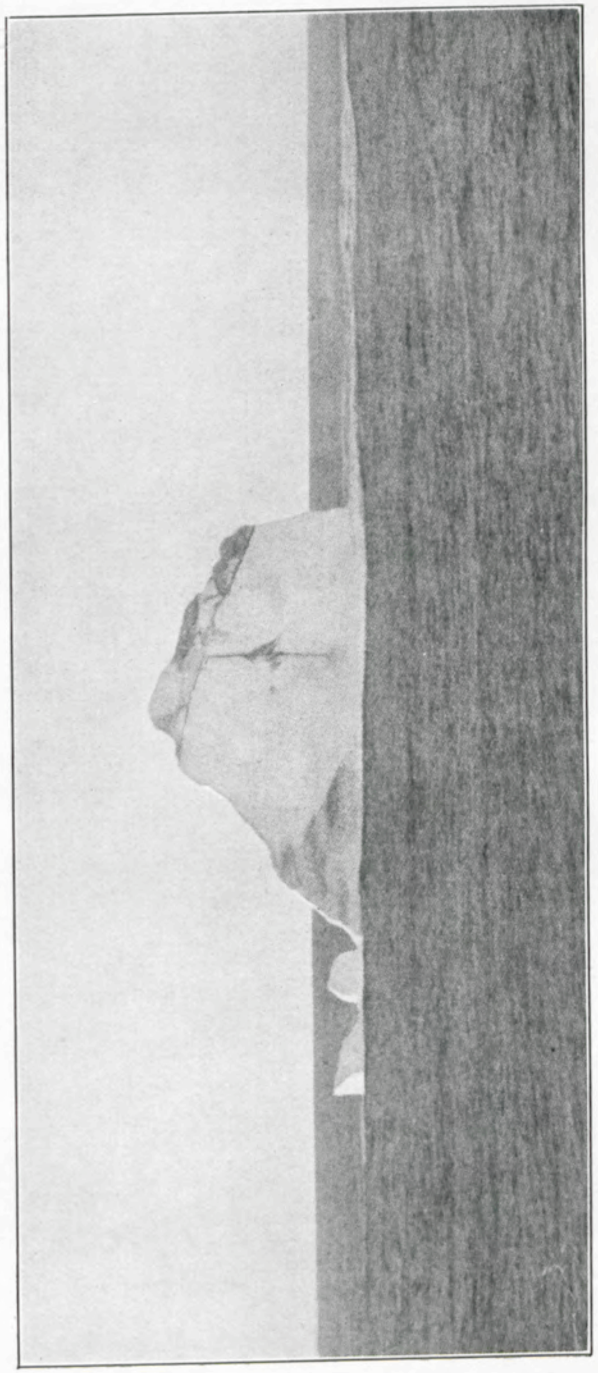
The size of icebergs is often deceptive to the eye. Glacier bergs measured do not exceed 450 ft. above the sea surface after calving ; and in the region of the trade routes in the Western North Atlantic those measured do not exceed 270 ft. above the sea, or 1,700 ft. from end to end above the water.

Bergs from the Barrier in the south are mostly tabular in shape and sometimes resemble floating islands. Ice islands up to 70 miles in length have been seen in as low a latitude as 55° S. in the region near South Georgia.

Barrier bergs measured have not exceeded 180 ft. above the water.

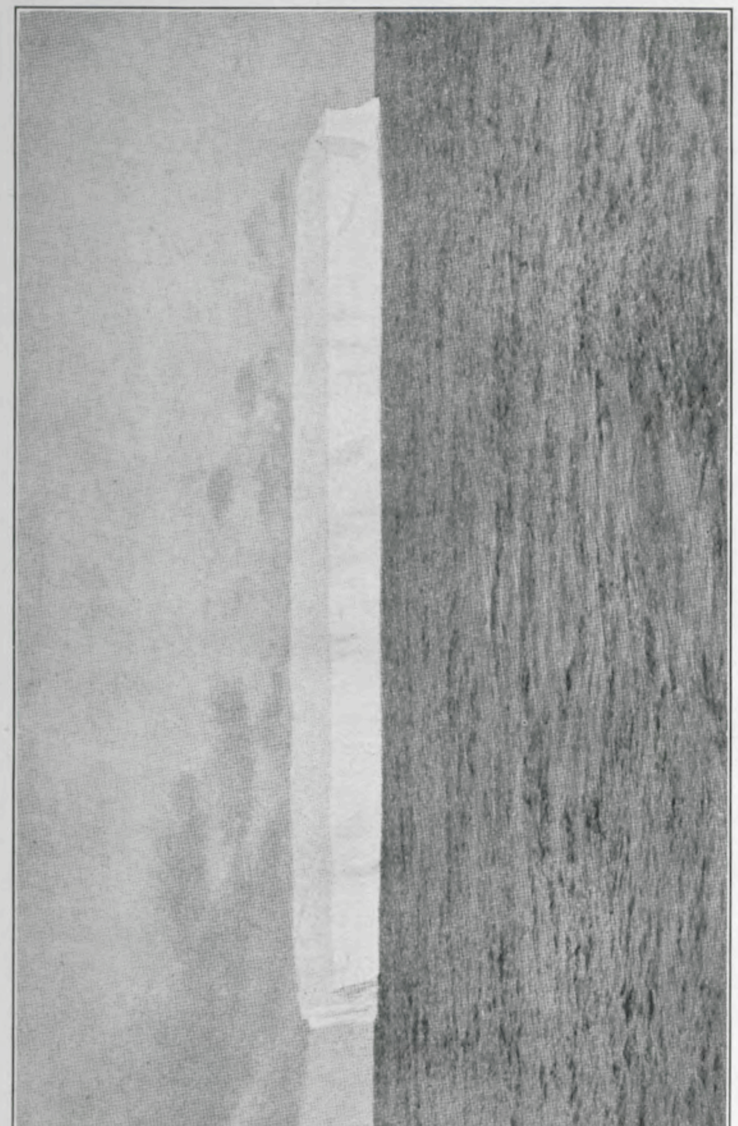
Ice blink indicates pack ice, but icebergs are rarely attended by blink.

[To face page 100



ICEBERG IN WESTERN NORTH ATLANTIC

FIG. 30.



Tabular Berg.

Fig. 31.

Reproduced by kind permission of the Director, Polar Research Institute, Cambridge.

On clear dark nights bergs may not be seen with the naked eye more than a quarter of a mile, but if the bearing of a berg is known it can be sighted with glasses at a distance of a mile. On a clear moonlight night, according to relative position of moon, berg, and ship, an iceberg may be seen at a considerable distance and under favourable conditions up to eight miles.

In clear weather bergs sometimes become surrounded with a faint mist at night which makes it very difficult to see them.

Fog occurs frequently in the regions where drifting ice is met.

In dense fog, when the sun is shining, a berg 100 yards distant appears a luminous white mass. If the sun is not shining it first appears close aboard as a dark shape.

When ice is reported or known to be in or near the course of a ship it is necessary to proceed at a moderate speed or to alter course well clear of the danger zone.

The presence of an iceberg has no appreciable effect on the temperature of the air or the sea in its vicinity, and therefore the thermometer cannot be relied upon to give warning of ice, though as the ice bearing currents from the polar regions are cold there is more likelihood of seeing ice when the sea temperature and set and drift of the current indicate that a ship is in one of these ice-bearing currents.

Echoes of sound reflected from icebergs are uncertain, so that warning by echo of the steam whistle or siren is quite unreliable. A good look out is the most dependable method of detection of the presence of ice.

A wide berth should always be given to icebergs. Beneath the water, ledges sometimes stand out. If an iceberg is not seen until too late to avoid a collision it may be fatal to take a glancing blow by which such a ledge may rip the ship's side or bilge. In such circumstances it may be better to take the blow with the stem and end on.

Over both polar regions there lie great caps of heavy ice. Polar ice caps.

During winter these ice caps grow, expanding to their greatest volume.

During spring and summer melting takes place with a reduction of the ice caps, but a permanent central core remains.

Throughout the year cold ocean currents bear ice broken from the ice caps to lower latitudes.

Ice in the Northern Hemisphere

The Arctic Basin extends from the North Pole to the northern coasts of Spitsbergen, Franz Josef Land, Siberia, Alaska, the Canadian Archipelago and Greenland. Arctic Ocean.

This basin is probably a fairly deep ocean, but the water shoals towards the northern coasts of Europe, Asia and America.

The greater part of the Arctic Basin is covered with the Arctic pack throughout the year. The Arctic pack consists of old ice, which due to rafting and hummocking forms massive fields, with little open water in winter. The thickness of the pack is from 8 ft. to 14 ft., but in places winds and currents may telescope the fields and floes layer upon layer to much greater thickness.

During the autumn and winter the Arctic Pack extends, and at the same time fast ice forms along the coasts and spreads, except where this is prevented by warm currents.

Between the Arctic Pack and the fast ice is a moving belt consisting partly of new ice and partly of broken ice from the pack and from the fast ice.

The Arctic Pack is always working and pieces breaking away, the main escape being towards the Atlantic through the opening between Spitsbergen and Greenland. Smaller ice-bearing currents also emerge from the Arctic Ocean round the south coast of Spitsbergen, through Robeson Channel and Smith Sound, also through the sounds of the Canadian Archipelago.

The drift in the Arctic Ocean seems to be away from the Bering Strait.

Leads open up in the pack during the summer and lanes appear along the coasts in spring. The amount of open water varies each summer.

The ice-bearing currents are strongest and extend furthest south during spring and early summer, carrying great volumes of water and huge quantities of ice with them to the southward.

Barents sea.

Owing to warm water from the Atlantic Drift passing the North Cape into Barents Sea there is open water off the Murman coast through the year.

During the summer the ice recedes to the north and east, and by August there is open water as far as Hope Island and the northernmost point of Nova Zembla.

Kara sea.

The Kara Sea is frozen over during the greater part of the year ; only from July to September are parts of it open. In August the Kara Sea is nearly free of ice. In these months, when northerly winds persist, the sea is filled with polar ice.

White sea.

Polar ice does not enter the White Sea.

Ice commences to form at the beginning of November and lasts until the middle of May.

Bering sea.

Throughout the winter months the Bering Sea is frozen with heavy ice to as far south as Latitude 60° N., and it extends in floes and broken ice all over the sea in some seasons.

During April the ice commences to recede northward, and by the beginning of July the ice edge usually lies north of Bering Strait.

Only in August, September and part of October is navigation possible north of Bering Strait. As a rule during those months the ice edge lies from Point Barrow towards Wrangel Island, which is always surrounded by ice.

North Pacific.

With the exception of pieces of glacial ice sufficient to be a danger to navigation, which may be encountered in the vicinity of Cross Sound in the north-east Pacific, drifting ice seldom if ever constitutes a danger to navigation south of the Aleutian Islands.

Origin of Northern icebergs.

The interior of Greenland is covered by a massive ice cap, formed by layer upon layer of snow changed into ice by pressure. Under pressure the ice from this ice cap flows outward in all directions but mainly where there is least obstruction, so that the chief flow is down the sloping valleys towards the sea. These ice rivers are the glaciers.

On reaching the coast the glaciers protrude as ice tongues ; continuing to move seaward the outer part of the ice tongue becomes waterborne and huge pieces break off under the increasing strain of buoyancy and the action of the tide, sea, swell and wind, and float away as icebergs.

It is estimated that between 10,000 and 15,000 icebergs calve from the Greenland glaciers every year, the greater number coming from the glaciers on the west coast.

There are glaciers in Spitsbergen, but the bergs calved from them are much smaller than those of Greenland.

Bergs are calved from the glaciers of Ellesmere Land and Baffin Land.

As soon as an iceberg has calved from the glacier and is waterborne wastage commences, which proceeds by melting, washing by sea and rain and calving.

Drift of ice.

Many icebergs do not drift far from where they calved from the glacier, being carried into bays by wind-driven pack. Some bergs may be several years upon their voyage to lower latitudes, where they disappear by melting. Many icebergs take about one year in reaching the neighbourhood of the Newfoundland Banks, and some only take four or five months to make the passage.

Wind as well as current has a great influence on the drift of pack, but current is mainly responsible for the drift of icebergs, clear of the pack.

We have seen how the pack emerges from the Arctic Ocean mainly between Spitsbergen and Greenland and also south of Spitsbergen.

On reaching the East coast of Greenland this pack is joined by icebergs from the East Greenland glaciers and drifts to the south-west with the East Greenland current, *see* FIGURE 28.

Off Cape Farewell the ice tends to congregate, and the edge of the fields sometimes in June and July is 100 to 200 miles off the land. The current sweeps the ice round Cape Farewell, and it is carried northward by the West Greenland Current. It seems that the ice from the eastward of Greenland does not drift from the vicinity of Cape Farewell southward direct to the vicinity of the eastern edge of the Newfoundland Banks, which is the region where the drift of ice from higher latitudes carries many bergs.

The greater number of Greenland icebergs calved from the glaciers on the west coast, previously mentioned, are carried by the West Greenland Current to the head of Baffin Bay.

Some bergs drift to the westward from the vicinity of Frederickshaab in the branch of the current mentioned in CHAPTER VI and indicated on FIGURE 28. In the centre of Davis Strait the water is comparatively warm and very few of these bergs survive to reach the Labrador Current on the western side of Davis Strait.

Many of the bergs carried by the West Greenland Current to the head of Baffin Bay are caught in the southerly drift setting out of Smith Sound, with the pack from the Arctic Ocean, bergs from Ellesmere Land and Baffin Land, and pack emerging through the sounds of the Canadian Archipelago, so that the Labrador Current is the great carrier of ice to the ice danger zone for shipping in the North Atlantic.

North Water.

Near the head of Baffin Bay there is a region of open sea called the North Water, more or less ice free throughout the year. This is probably due to fast ice in the comparatively narrow and deep Smith Sound in the vicinity of Etah—the northernmost settlement of the Eskimos—being so strong as to resist the current. From just south of this ice bridge the current sweeps the ice away, leaving open water. The break up of the fast ice in Smith Sound during June and July temporarily chokes the North Water, but it clears and is greatest in extent at the end of the summer.

Drift of ice.

The greatest release of ice is in the spring and summer. Then the great movement southward commences for, as we have seen, the ice-bearing currents are strongest and extend furthest south at that time.

The bulk of the pack drifting south in the Labrador Current is abreast of Cape Chidley, south-east of Hudson Strait, usually in early November, and hugging the land arrives off the Newfoundland coast in January. At the same time fast ice forms in the bays and harbours.

Part of the ice stream, which arrives off Southern Newfoundland about the beginning of February, rounds Cape Race, moving through the Gully or comparatively deep water near the land. The greater part of the ice stream sets down the eastern edge of the Grand Banks, and arrives at the Tail of the Bank at about the end of March.

Icebergs sometimes ground on the Grand Banks and remain stranded for a week or more.

The pack becomes more open and lighter as it moves south, but the fields on the Grand Banks are often sufficiently large and heavy to impede navigation. With the approach of warmer weather, and usually by the end of April or early May, the pack ice has melted before reaching the Grand Banks.

Towards the end of June the east coast of Newfoundland is usually clear of pack, and during July Labrador waters are generally navigable.

Icebergs in the North Atlantic.

The number of bergs which drift as far south as the vicinity of the Tail of the Grand Banks of Newfoundland varies from year to year, and this number depends upon the conditions in higher latitudes, and to a large extent according to the prevalence of North and North-easterly winds in Baffin Bay and Davis Strait.

North-easterly winds accelerate the Labrador Current and are most frequent in spring at the time of the break up of the ice.

We have seen in CHAPTER VI that the Labrador Current spreads over the Grand Banks, and runs down their eastern edge; that part of this stream recurves and flows northward, but that most of this water meets the Gulf Stream, turns to the north-east and mingles with the Atlantic Drift.

Bergs carried south in the cold Labrador Current melt more quickly upon reaching the mingled waters south of the Tail of the Bank, and if they enter the Gulf Stream melt rapidly.

Westward of Longitude 43° W. the average number of bergs each year, between 1900 and 1926, which were sighted south the 48th parallel and the 43rd parallel of North Latitude in each month was as follows :—

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
South of 48° N. ..	3	10	36	83	130	68	25	13	9	4	3	2
South of 43° N. ..	0	1	4	9	18	13	3	2	1	0	0	0

Bergs, growlers, or pieces of ice have been sighted at one time or another over the greater part of the North Atlantic, north of Latitude 30° N. It is improbable that ice sighted in the North Atlantic south of the latitude of Cape Farewell has arrived in that position by any other way than that of the Labrador Current and its branches.

International Ice Patrol.

In the spring and early summer the ice season of the Newfoundland Banks, the International Ice Patrol worked by the United States Coastguard, locates the ice and informs shipping by wireless telegraphy as far as possible of its position.

River and Gulf of St. Lawrence.

Usually about the end of November the River St. Lawrence freezes over and the Gulf of St. Lawrence becomes ice bound with new ice and masses of pack entering through Belle Isle Strait.

At times through the winter the ice is broken by wind, leaving leads of open water.

Owing to ice drifting in through Belle Isle Strait from the eastward this entrance is usually not navigable until the end of June.

The ice drifting out of the Gulf of St. Lawrence sometimes causes a block in Cabot Strait, but the Gulf of St. Lawrence is usually navigable by way of Cabot Strait from the latter half of April to early December.

The Canadian Ice Patrol Service, from the opening of navigation and so long as necessary, informs ships by wireless telegraphy of the ice conditions from Cape Ray to Quebec.

The Baltic.

In the Gulfs of Bothnia and Finland and the Baltic Sea sufficient ice forms to impede or close navigation, but ice conditions vary considerably from year to year according to the severity of the winter.

In the Gulfs of Bothnia and Finland the harbours usually commence to freeze during November, but if the season is mild some ports may remain navigable until late December or early January.

With periods of calms, light winds and clear skies, which may be prolonged at about the New Year, the Gulfs freeze over, but storms break up the ice, which forms large fields and obstructs navigation in some years until as late as May.

In the Baltic Sea, ice usually commences to form in the bays and harbours during the latter half of December or January and persists until April. This fast ice seldom extends far from the coast, but loose fields drift into the open sea and obstruct navigation.

In severe winters during February and March the southern approaches to the entrance to the Sound may be blocked by ice.

Ice breakers are able to keep many of the Baltic Sea ports open to navigation.

The Kattegat and the Belts.

Ice seldom forms in the Kattegat and Belts to such an extent as to stop navigation, but in most winters there is sufficient ice to make navigation difficult.

Ice in the Southern Hemisphere

The Antarctic Continent.

The Antarctic continent is probably some 5,000,000 square miles in extent. The greater part of it is a high plateau, rising to 9,000 ft., covered with ice and snow of enormous thickness. The cold of the Antarctic is more severe than that of the Arctic. The coast line of the Antarctic continent has only been fixed in places, largely owing to the difficulty of finding the line of demarcation between the ice-covered land and the ice-covered sea.

Where soundings have been taken along the coast it is steep to.

Southern ice cap.

The great southern ice cap flows outward in all directions, but mainly where there is the least obstruction down the sloping valleys as glaciers and over the flatter sloping land.

Upon reaching the coast the ice continues to move seaward, its weight being taken by the sea bottom until there is sufficient depth of water to float it and ice tongues are formed. These ice tongues of the south extend floating for many miles to seaward.

Ice shelves and barriers.

In some places a number of ice tongues extend seaward close to one another and become cemented together, forming a great shelf of ice. The best known ice shelf is the Ross Barrier, which fills the southern end of the Ross Sea.

The Ross Barrier is an almost level snow-laden floating sheet of ice 500 miles by 400 miles and 1,400 ft. thick, with about 170 ft. above the water line.

There are probably other great ice shelves, but they have not yet been surveyed. It is probable that at the head of the Weddell Sea between Coats Land and Graham Land there is an ice shelf which may be even greater than the Ross Barrier, and from which many tabular bergs and ice islands calve, some of them being as much as 180 ft. high above the water line.

With the great stretches of coast line in high southern latitudes which are unexplored, much less surveyed, the extent of ice barriers and glacier tongues from which bergs are calved is not known.

Calving of icebergs.

Bergs are calved from the barriers or glacier tongues by the action of the tides, swell and wind, the largest being from the barriers.

The Antarctic pack.

The pack is composed partly of sea ice formed in the open sea and of fast ice formed along the coast during the winter and also partly of land ice which has drifted away from the coast.

Floes, by being hummocked, may reach a height of 30 ft.

In the spring the Antarctic pack breaks away and drifts generally north-westward to about Latitude 60° S. when the general drift changes to the eastward and north-eastward.

North of the 60th parallel of South Latitude field ice quickly melts.

Drift of icebergs.

Compared with the drift of ice in northern latitudes little is known of the drift of ice in the south.

The ice conditions around the Antarctic continent may vary from season to season as do the number of bergs which drift to lower latitudes.

Generally icebergs seem to drift to the northward to about the 60th parallel, and thence to the eastward and northward until they are melted.

Icebergs have been seen drifting with the deep current through the pack, and churning up the sea ice.

From reports made of icebergs sighted in southern latitudes during the last thirty-two years 1902–1933—during the first part of which period many sailing ships were using routes in higher latitudes than are now used by steamers making the same passages—we can see where ice congregates most in waters used by ships of commerce, but we cannot say where it may *not* be, south of Latitude 50° S.

North of Latitude 60° S. icebergs are most frequently sighted in the south-west region of the Atlantic to the eastward of the longitude of Cape Horn.

It seems that there is a large drift of bergs from the Weddell Sea, there being an ice-bearing current to the northward off the east coast of Graham Land, which carries the bergs past the South Orkneys and the South Shetlands.

The Cape Horn and Falkland Currents carry a large number of bergs northward of the Falkland Islands, where ice may be seen at all times of the year, but it is most frequent in October, November and December, the spring and early summer of the south.

During the summer months bergs are occasionally seen within 150 miles of the River Plate, and they have been seen as far north as Latitude 33° S. in the vicinity of Longitude 50° W.

From the meridian of Greenwich by way of the longitude of the Cape, across the southern Indian Ocean, right round to Longitude 160° W., reports of bergs north of Latitude 60° S. have been fewer in comparison with the rest of the Southern Ocean, north of Latitude 60° S.

From time to time since 1902 many bergs have been sighted north of Latitude 60° S., between Longitude 160° W. and Cape Horn.

Very occasionally bergs or growlers have been seen in as low a latitude as 35° S. in the vicinity of the Cape of Good Hope and in the Great Australian Bight.

Generally reports of ice sighted north of Latitude 40° S., with the exception of the region off the River Plate, are unusual, but it must be remembered that an iceberg cannot be seen a great many miles even in clear weather, and that there are comparatively few ships constantly making passages in southern waters.

CHAPTER VIII

OCEAN PILOTAGE

The quickest or best route from departure to landfall may not be the great circle or rhumb line. It may pay to diverge somewhat from a direct route, and so reduce the effect of head winds, gain by favourable currents, or avoid regions of fog and ice on the passage.

The growth of ocean pilotage.

By comparing winds and currents experienced during the passage between certain ports by different ships, and by the same ships at different times of the year, suitable routes for sailing ships were found by old navigators long ago.

From about the middle of the nineteenth century the comparison of winds and currents were further developed by State institutions with the aid of statistical weather science. By the time the sailing ship had reached her greatest perfection in the latter half of the nineteenth century, the best routes for sailing ships, under average conditions for different times of the year, had been found and were recommended in the sailing directions.

Modern need for good ocean pilotage.

The wind is no longer the propelling power, but it causes resistance to steam and motor-propelled ships, both directly and by the sea it raises, with consequent slip of the propeller. This is a thing to be avoided as far as possible. The higher speeds of to-day render good visibility still more desirable to the navigator than in the past. Information of the set and drift with variations of current is also a greater factor in safe and economical navigation on account of the improvement in compasses, logs and revolution counters.

In the selection of the best route the modern navigator has to consider not only the prime factors of safety, economy in time and in the fuel used, but also the comfort of passengers and the maintenance of cargo in good condition. The care of the comfort of passengers and the efficient carriage of cargo have been developed into such fine arts that it may be desirable to consider the temperature of sea and air and the humidity, as well as wind, sea and current, in choosing the best route.

Sea temperature should be considered because it not only affects the free air over the sea and its humidity, but the temperature of the ship herself. It is therefore a factor not to be neglected in the carriage of refrigerated or chilled cargoes, nor in good ventilation, and the reduction of sweat in holds.

The clipper ship called for skilled seamanship in making, trimming and taking in sail, and in handling her; and in combination with these a knowledge of wind, the natural power which drove her.

To get the best out of the well-designed mechanical power ships of to-day, with the new and improved aids to navigation, including the direction finder and the echo-sounder, requires a combination of knowledge and skill of high degree. That combination calls for more exact information of the different elements which make up the climates of the different parts of the oceans.

Pilot charts.

The old pilot charts have served their purpose; from the data in them the sailing directions were largely compiled and the seasonal zones for load lines were largely determined. The term "pilot charts" is here used in the broad sense, meaning the wind and current charts, and the meteorological charts of the oceans.

Ocean Passages for the World.

The Admiralty Pilots or Sailing Directions are continually being overhauled, brought up to date, and improved, and in the Admiralty book "Ocean Passages for the World" routes are systematically given.

The urge of progress and competition in sea-borne trade continually calls for improved information.

Data collected.

Since the year 1855 the masters and mates of a number of British ships have regularly returned to the Meteorological Office observations carefully recorded every four hours at sea in all parts of the world. The introduction of electric tabulating machines has made possible the conversion of this vast store of data into averages by which the climate and the currents of the different parts of the ocean may be more accurately compared and the recommendations for routes improved.

Climate and current averages.

In presenting the large number of elements of which averages are desirable for the purpose of modern ocean pilotage, clarity is essential.

FIGURES 32 and 33 illustrate how this may be done; and it will be realised what an enormous amount of information can be displayed upon monthly charts of the different oceans bound in atlases in this way, so that routes best suited to different ships may be ascertained. Statistics, and particularly statistics of such variable elements as those of the weather, may be misleading. Their importance must not be exaggerated, and they should be used with experienced judgment. Pilot charts may be very useful to the experienced and intelligent navigator; they are indispensable to those responsible for the compilation of sailing directions.

Proper use of Pilot charts.

Pilot charts can only tell us how often there have been different kinds of weather, winds from certain directions, the mean, highest, and lowest temperatures, etc.; and, therefore, the laws of Nature remaining the same, the chances there are of the same weather or wind, etc., occurring again at the particular time of the year in a particular region.

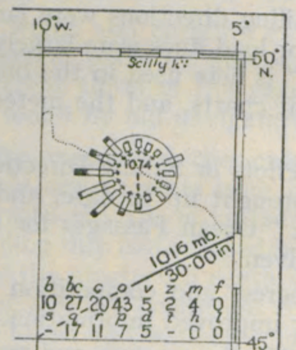
[*Continued on page* 116

CLIMATE AVERAGES

Region South of Scilly Islands

February, for the Years 1921–1933

Wind Rose, Weather and Barometer



Wind Rose for region 5° Latitude, 5° Longitude.

Directions of the Wind are shown by arrows which fly with the wind, the percentage frequency of winds from each direction being indicated by the length of the arrow according to the scale— 0 10 20 30 40 50% (10 per cent. being the same length as 1° of longitude).

Force of the Wind is indicated by the thickness of the arrow, the Beaufort figures being grouped as follows—Light winds 1–3, Moderate winds 4–7, Gales, 8–12, thus 1-3 4-7 8-12

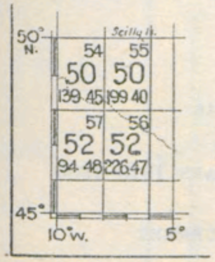
In the centre of the rose the upper figure is the number of observations, the middle figure the percentage frequency of calms, the lower figure the percentage frequency of variable winds.

Weather.—The percentage frequency of the different elements of weather is shown by the number under the letters of the Beaufort Weather Notation (see Appendix, p. 142). — under a letter indicates no observation of that element of the weather reported. O under a letter indicates that less than 1 observation in 200 of that element of weather has been reported.

Barometer.—Mean pressure of the atmosphere at sea level is shown by isobars.

[*Continued on page* 113

Sea Surface Temperatures



Mean Sea Surface Temperatures are given for each area of 2° of latitude and longitude.

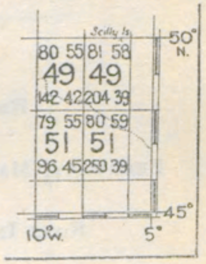
The mean sea surface temperature is indicated by the figure in the centre of the square.

The highest observed sea surface temperature is shown in the top right corner.

The lowest observed sea surface temperature is shown in the lower right corner.

The number of observations on which the mean is based is shown in the lower left corner.

Air Temperatures and Humidity



Mean Air Temperatures are given for each area of 2° of latitude and longitude.

The mean air temperature is indicated by the figure in the centre of the square.

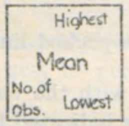
The highest observed air temperature is shown in the top right corner.

The lowest observed air temperature is shown in the lower right corner.

The Humidity is shown in the top left corner.

The number of observations on which the mean is based is shown in the lower left corner.

KEY



The number of observations gives an indication of the degree of reliance which may be placed upon the information.

KEY

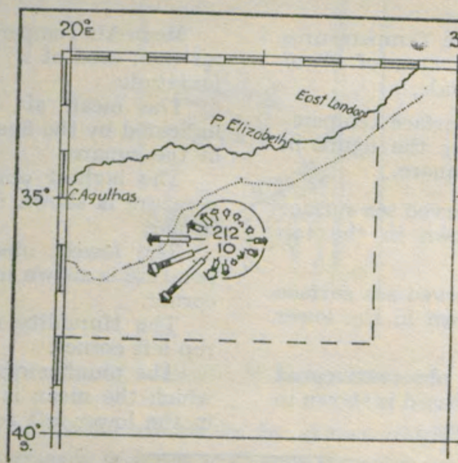
Fig. 32.

CURRENTS

Region East of Cape Agulhas

February, March and April, for the Years 1910–1930

Rose Indicating Variations of Current



The current rose is drawn from observations within the pecked lines.

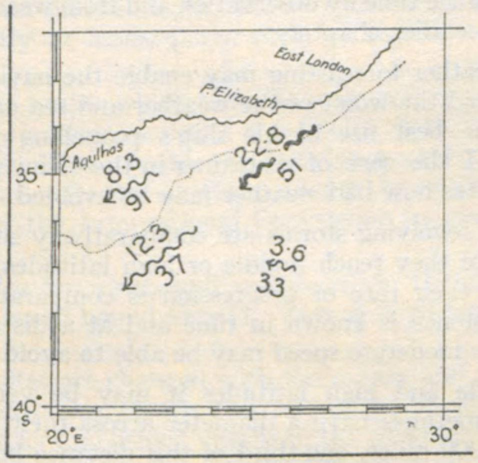
Directions of Currents are shown by arrows which flow with the current. The percentage frequency of current for each direction being indicated by the length of the arrow according to the scale— 0 10 20 30 40 60% (10 per cent. being the same length as 1° of Longitude).

Strength of Current in miles per day is indicated by the thickness of the arrow thus— 6-12, 13-24, 25-48, 49-72, 73 and above.

In the centre of the rose the upper figure gives the number of observations, the lower gives the percentage frequency of currents less than 6 miles per day.

[*Continued on page* 115

Arrows Indicating Mean Current



The arrow flows with the current and represents the resultant of different currents observed in an area of 2° of latitude by 4° of longitude. The centre of each arrow lies in the mean position of observation. The figure above each arrow gives the velocity in miles per day; the figure below, the number of observations.

The lengths of the arrows are proportionate to the velocity of the current but where the current is strong a thick split arrow thus is used.

The number of observations gives an indication of the degree of reliance which may be placed upon the information.

Fig. 33.

The use of Weather reports.

They cannot tell us what weather is coming; that we can only learn at the time by observation and from weather reports, as shown in earlier chapters.

Weather forecasting in aid of safe and economical navigation.

Good weather forecasting may enable the navigator sometimes to avoid the worst of the weather and sea and generally to make the best use of his ship's propelling power. In CHAPTER III the case of a steamer in the vicinity of a hurricane illustrates how bad weather may be avoided.

Tropical revolving storms are comparatively small in their extent before they reach middle or high latitudes, and before recurvature their rate of progression is comparatively small. If their existence is known in time and at a distance, power ships of only moderate speed may be able to avoid them.

In middle and high latitudes it may be very different. Cyclones sometimes have a diameter across their path of not less than 1,000 miles, one-third of this distance being covered by winds of storm and hurricane force, and the whole system advancing eastward at the rate of as much as 1,200 miles per day.

In middle and high latitudes where spells of bad and fine weather alternate, it is more a matter of judgment in using power than of altering course. For instance, steamers engaged in comparatively short voyages have raised steam in fewer boilers for the same passage when fine weather has been forecast than when there was bad weather, with consequent saving.

Or another example is that of a coal-burning steamer with reciprocating engines steaming to arrive at her port of destination at a definite time, and having a good reserve of speed. If weather conditions are good and she proceeds at a higher speed than the mean speed required to arrive on time, in order to allow a margin in case of heavy or thick weather, and the weather remaining fine she later reduces speed to maintain her proper arrival time, coal consumption is unnecessarily high. The coal consumption varies as the cube of the speed. If fine weather until time of arrival at her port of destination can be forecast, and a nearly uniform speed maintained throughout the passage, the time of passage will be the same, and the coal consumption less. The same principles, with the appropriate ratios for consumption, can be worked with oil-burning or motor ships. There are many ways in which foreknowledge of weather may be of assistance in safe and economical navigation.

The methods of forecasting weather given in the preceding chapters and the weather forecasts broadcast in weather shipping bulletins for coastal waters have enabled ships to make good use of their horse-power to save fuel or time.

Ocean routes.

As the result of experience of all the routes which have been used by power-driven vessels, numbers of routes have become defined nearly as lanes, particularly to regular traders upon them.

Trans North Atlantic routes.

Of all the routes which have become so defined the Trans North Atlantic routes are the ones which should be followed most closely. These routes are laid down on the Admiralty North Atlantic Route Charts, and are in accordance with Article 39 of the International Convention for Safety of Life at Sea.

The routes for westbound vessels are to the northward of those of eastward bound vessels. This is to reduce the risk of collision.

These routes are changed with the season and according to the condition of ice reported at any time, to reduce risk of collision with ice and fishing vessels on the Newfoundland Banks during the fishing season.

The changes of these routes and the dates from which they take effect are arranged by the North Atlantic Track Convention, an international shipowners' organization.

North Atlantic ice danger.

As mentioned in the previous chapter, during the ice season of the Newfoundland Banks the International Ice Patrol locates ice and informs shipping by wireless telegraphy.

By Article 34 of the Convention for Safety of Life at Sea, ships sighting ice which is dangerous to navigation are bound to communicate this information to ships in the vicinity.

Article 38 of the same Convention requires the master of every ship at night to proceed at moderate speed or alter course when ice is reported, to clear the danger zone.

It is well to remember that notwithstanding all these safeguards, if there is fog when in the ice region, and fog *is* frequent there, it is prudent to stop the engines, and to remain stopped. Some vessels having stopped in fog, and who had not previously sighted ice, have found themselves nearly surrounded by bergs, growlers or pack upon the weather clearing. This applies more particularly to the northern routes to the St. Lawrence, which, unlike the routes to New York, cannot be diverted sufficiently far to the southward to clear the ice region.

Advantages of seasonal routes.

In some regions the seasonal changes of winds, weather, currents, and temperature are much greater than they are in others, and where this is so, it may be desirable to take different routes in different seasons.

The passage from Colombo or the East to the Straits of Bab-el-Mandeb provides an example of the desirability of using different routes in making the same passage, at different times of the year, in regions where there are great seasonal differences of wind, sea, and currents. There is no passage, within our experience, where this can be shown more clearly and where gain is more likely if suitable seasonal routes are used.

Passage from Colombo or the East to Bab-el-Mandeb.

As has been shown in the Chapters on the winds and currents of the oceans, the North East Monsoon prevails in the region traversed in making this passage during the northern winter. Thus, generally there is a fair wind, little sea, fine weather and a favourable current along the shortest track, which is by rhumb lines from Colombo to the Eight Degree Channel, thence to the northward of Cape Guardafui, and thence to Bab-el-Mandeb, there being no appreciable difference in the Mercator and great circle distances.

This route is the shortest navigable route, 2,182 miles, and is also the best route for power-driven vessels except during the South West Monsoon, when it is uneconomical and unsafe.

It is unsafe because, as we have seen, in the Chapters above referred to, there is a very strong persistent strip of south-westerly wind, setting up a sea, which makes the south coasts of Sokotra and the Abd-el-Kuri Islands a dangerous lee shore with the land often hidden by haze and mist.

Of every 100 observations of weather recorded along the south and east coasts of Sokotra during the height of the South West Monsoon season on fifty occasions there was mist or haze, and the bank of soundings does not extend to give sufficient warning. It is dangerous to attempt to make Ras Radressa.

In the vicinity of Cape Guardafui and Sokotra, dust from Somaliland in addition to moisture, accounts for much of the haze and mist. This region, where visibility is sometimes reduced, and where haze or mist which may often be very slight, but which is found upon the average on 50 in every 100 occasions, extends northward along the African coast from Latitude 8° N. to the vicinity of Cape Guardafui, and to about 50 miles to the eastward of Ras Radressa.

There are also areas where haze and mist are equally as frequent at some distance to the northward and north-eastward of Sokotra.

If during the South West Monsoon a route is not taken at a safe distance to the north-eastward of Ras Radressa it is safest to make the landfall in the vicinity of Ras Hafun or Ras Jard Hafun. Ras Hafun is the eastern extremity of a promontory which rises in steep cliffs from the sea to a height of nearly 600 ft., and is a conspicuous landmark. Ras Jard Hafun is a high bluff, some 10 miles south of Cape Guardafui, which is easily distinguishable in clear weather, and off which is a bank of soundings extending about 30 miles to seaward, which is a natural guide to ships making a landfall from the south-eastward

in hazy weather. The use of the lead or echo-sounder is most necessary. In the past ships have been stranded and lost in this vicinity. Navigational aids are continually improving.

There is now (1934) a 4,000 candle-power light at Cape Guardafui and a small light at Ras Hafun. There are wireless stations at Cape Guardafui and Ras Hafun. There is a D/F station at Cape Guardafui; but experience has shown that direction finding with these stations has been inaccurate at times. Caution with the direction finder in obtaining bearings of these stations is necessary, as it is in obtaining bearings from Cape Guardafui direction finder.

The 100 fathom line passes eastward at a distance of about three miles to the northward of Cape Guardafui, so that a vessel having soundings on the bank off Ras Jard Hafun and steaming to the northward may know by the depth when it is safe to alter course to the westward.

The channel between Cape Guardafui and Abd-el-Kuri is just over 50 miles wide.

The region some 100 to 250 miles south of Sokotra, which has been mentioned in CHAPTER II, where there is so often a dangerous cross sea, can be fairly well located, though of course dangerous cross seas may at times be encountered over a larger area. This region is indicated by cross hatching on FIGURE 34.

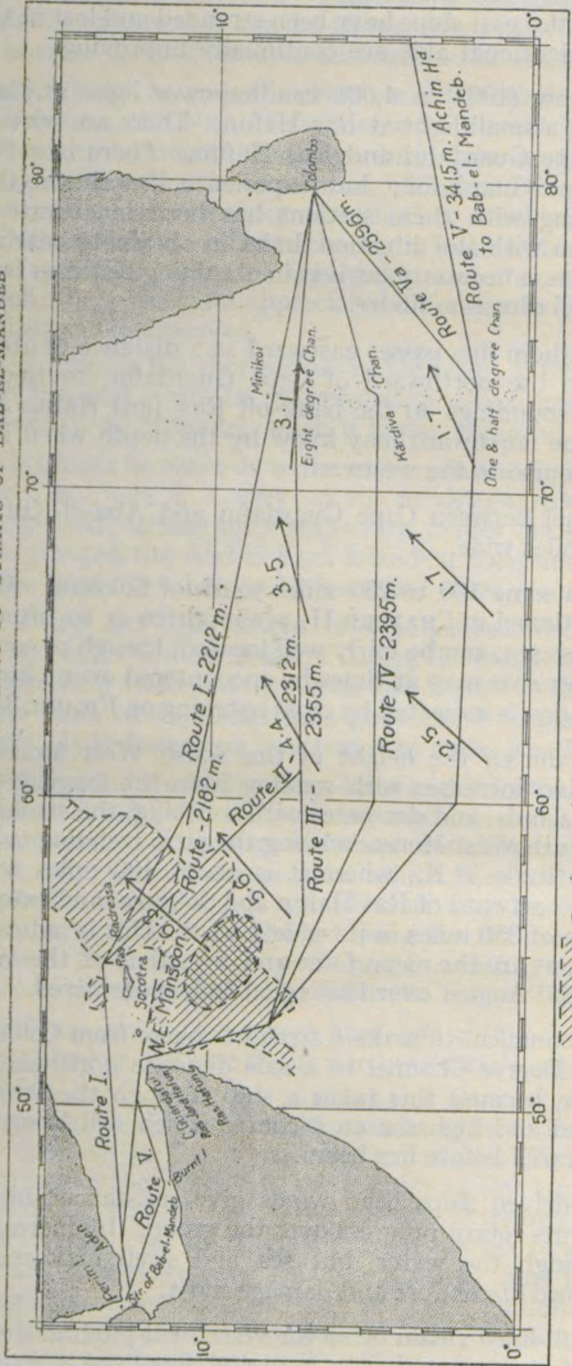
Generally during the height of the South West Monsoon season the wind increases with westing from the longitude of the Maldive Islands, and decreases with southing, the strongest part of the South West Monsoon being the strip trending to the NE. from Latitude 7° N., where it is about 100 miles wide, passing to the eastward of Ras Hafun and Sokotra, and extending to a width of 350 miles in its widest part. This is indicated in FIGURE 34, as are the mean force and direction of the wind during July and August over the region to be considered.

It is uneconomical to make a straight course from Colombo or the Eight Degree Channel to a safe distance northward of Ras Radressa, because this takes a ship through the strip of strongest wind and high sea on a course which will bring the wind and sea well before her beam.

In power-driven ships head winds give resistance; unfavourable currents retard progress over the ground by increasing distance through the water, but sea and swell may reduce speed and cause discomfort and damage most.

A short full-lined steam or motor vessel will pitch and have her way deadened more than a powerful fine-lined ship in a seaway.

ROUTES FROM COLOMBO AND THE EAST TO STRAITS OF BAB-EL-MANDEB



Region of strongest S.W. Monsoon.
Area of strong E.S.E. current and dangerous cross swell.

Mean Wind for July and August is shown by the arrows which fly with the wind and give the mean direction, the figures above the arrows give the mean force by the Beaufort Scale to decimal points.

FIG. 34.

To find the best route—always maintaining safe navigation—it is desirable to balance the minimum increase of distance over the ground necessary to reduce the adverse effect of head wind and sea upon each type of ship. It is also necessary to balance the distance to be steamed through the water in the time to be occupied on passage, on the different routes, allowing for current.

To do this, seamanlike judgment combined with calculation are necessary.

For this purpose ships may be broadly divided into four types :—

Large Powerful Liners.—Fine-lined steam and motor vessels of 12,000 tons gross and upwards with a speed of 16 knots and over in smooth water.

Medium Ships.—Medium-lined steam and motor vessels of 8,000 tons gross and upwards with a speed of not less than 13 knots in smooth water.

Slow Ships.—Full-lined steam and motor vessels with a speed of less than 13 knots in smooth water.

Small Ships.—Steam and motor vessels of less than 2,000 tons gross.

Even for large powerful liners, if it is not desired to take a southerly route, it will pay to make some diversion to the southward of a straight course to the position at a safe distance north of Ras Radressa, as far as Longitude 60° E., so as to bring the strength of the monsoon and its attendant sea less on the bow. This will tend to the comfort of all on board as well as to some reduction of resistance, through less pitching ; and possibly some improvement of ventilation in the living quarters and holds may be gained, as shipping of water and sprays may be less. This route is indicated as Route I on FIGURE 34. Route I.

ROUTE I is as follows :—

Passing to the southward of Minikoi, follow the usual North East monsoon route to Latitude 10° 25′ N., Longitude 60° E., thence alter course to pass at a distance of 40 miles north of Ras Radressa. The distance from Colombo to Bab-el-Mandeb by Route I is 2,212 miles.

ROUTE V may be adopted with advantage by all vessels bound from Malacca Strait to the Strait of Bab-el-Mandeb, if not calling at Colombo, with the exception of large powerful liners. Route V.

ROUTE V is as follows :—

After passing Achin Head steer for the One and Half Degree Channel, thus avoiding the strongest part of the easterly current south of Ceylon.

After passing the Maldive Islands steer to cross the 60th meridian in Latitude 2° N. The monsoon is generally light here. In Longitude 60° E. the monsoon will usually freshen. Course should now be shaped for a position in Latitude 8° N., Longitude 52° 30′ E. The increasing monsoon will be on the port beam, and this course gives a wide berth to the area of strong ESE. current and confused swell indicated in FIGURE 34.

Over and over again ships taking the southern routes during the South West Monsoon have not shaped their course enough to the southward to avoid this area, and having altered course to the northward too soon, have encountered the full strength of the current setting ESE. and a heavy confused swell or cross sea.

Some ships have been damaged, some have run and passed to the eastward and northward of Sokotra.

Once bitten, twice shy !

Their masters have not returned to the southern routes, and these experiences led many to doubt the wisdom of going to the southward of Sokotra during the South West Monsoon.

Of recent years the southern routes have become more generally recognised as the best, and the different routes now advocated are the most suitable for the different types of ships.

This Route V has the great advantage of comfort to all on board and better ventilation of the holds is possible, while it may often be the most economical in fuel.

From the last position given, course may be shaped to pass Cape Guardafui, passing within sight of Ras Hafun in daylight and clear weather, and over the bank of soundings off Ras Jard Hafun. On this course the current, wind and sea will be mainly on the port quarter.

After rounding Cape Guardafui and passing Ras Filuk, keep the African coast aboard as far as Burnt Island, thus avoiding the adverse currents to the northward, keeping in smooth water and possibly carrying a favourable current which is sometimes experienced hereabouts.

From Burnt Island steer as requisite for the Strait.

The distance by Route V from Achin Head to the Strait of Bab-el-Mandeb is 3,415 miles.

Route III. From Colombo medium ships will be well advised to adopt ROUTE III.

By this route, pass through the Eight Degree Channel, giving Turakuna Island, the northern extreme of Ihavandiffulu Atoll, a good berth, particularly at night, for the current may be variable, but generally sets to the SE. in the South West monsoon.

Thence steer to a position Latitude 7° N., Longitude 56° E., nothing to the Northward. From this position steer to pass through Latitude 8° N., Longitude 52° 30′ E. Thence as Route V.

The distance from Colombo to the Strait of Bab-el-Mandeb by Route III is 2,355 miles.

For slow ships, provided the time of departure from Colombo and speed can be regulated to make Olivelifuri Island between sunrise and noon, ROUTE IV is the most consistent with the principles we have referred to. Route IV.

If it is decided to use this route, time of sailing should be suitable, having regard to the conditions of weather reported, for frequently the South West Monsoon is fresh, with corresponding sea, between Colombo and the Kardiva Channel.

From Colombo, shape a course to pass close to the southward of Olivelifuri Island, Fadiffolu Atoll, and passing through the Kardiva Channel and to the southward of Horsburgh Atoll, steer to cross the 60th meridian in Latitude 4° 44′ N. Thence alter course to pass through the position Latitude 8° N., Longitude 52° 30′ E. and follow Route V.

The distance from Colombo to Bab-el-Mandeb by Route IV is 2,395 miles.

When it is not considered advisable for slow ships to use Route IV, they will find it advantageous to proceed from Colombo through the One and Half Degree Channel, thence following Route V. Though this lengthens the distance considerably, they will have more favourable weather, and will save time and fuel by doing so. This route is recommended for small ships. Route Va.

The distance from Colombo to Bab-el-Mandeb by ROUTE VA is 2,596 miles.

Masters of medium and slow ships who do not wish to use the southern routes which are advocated will find ROUTE II an alternative. Route II.

From Colombo, follow Route III to Longitude 61° E., thence alter course to pass 40 miles to the northward of Ras Radressa, thus bringing wind and sea on the beam when they are at their worst.

After passing Ras Radressa follow Route I.

The distance from Colombo to the Strait of Bab-el-Mandeb by this route is 2,312 miles.

Route II is not suitable for deeply laden ships with a large G.M., because as well as a greater resistance than on the southern routes, with the wind and sea abeam passing through the strongest part of the South West Monsoon, they are likely to roll heavily and ship water.

Considerations in selecting which route.

These routes are for average conditions, and for average ships of the types given. In deciding upon which route is to be taken, the weather conditions reported up to the time of sailing should always be taken into consideration.

Cyclones in the Arabian Sea occasionally affect the conditions on Route I and the western part of Route II considerably.

Some navigators may prefer to make several alterations of course instead of one, at the bends in the routes ; and wireless weather reports from day to day from ships on the different routes are useful and may indicate desirable deviations.

It should be remembered that observation for many years has indicated the area of strong ESE. current and frequent cross swell is a region to be avoided.

By getting into this small region of disturbance what has been gained by taking a southern route may be lost, and more.

The routes from Colombo and the East to Bab-el-Mandeb have been worked out from the great store of data used in the construction of the Pilot Charts, and recent investigations of currents, sea, swell, and weather combined with the personal experience of many navigators.

They were revised in 1921 and in 1931, these revisions being concurred in by the Hydrographer of the Navy and are given in " Ocean Passages for the World " and its Supplement.

Accurate information of climates desirable for routing.

When climate and current averages such as those given in FIGURES 32 and 33 have been worked out, it may be possible to recommend seasonal routes in certain parts of the Pacific and in other parts of the world.

Meanwhile the route for the NE. monsoon and change of monsoon seasons, and the routes for the SW. monsoon across the Southern part of the Arabian Sea—though they may be more easily defined—point to the way we should work to solve similar problems for other passages.

These are but comparatively short routes. There are wider aspects of the problem of selecting the most suitable seasonable routes for long voyages. For instance, the shipowner may require the advice of his Marine Superintendent or nautical adviser as to which is the most suitable route, at a particular time of the year, to send a ship laden with chilled or refrigerated cargo from a port on the east coast of Australia to the English Channel.

Across the Pacific via Panama ; through Torres Straits and via the Suez Canal ; via Bass Strait and the Suez Canal ; South-about round the Cape of Good Hope ; or via Cape Horn ?

Winds, currents, temperature, and humidity are all factors to be considered, as well as distance and cost of canal dues, for the fuel bill and the time and condition of delivery of the cargo.

Work of British Corps of Voluntary Marine Observers.

For determining accurately the climates of the different parts of the oceans observations are being made, according to time at place, and returned to the Meteorological Office, by the commanders and officers of suitable ships traversing regions where data are still needed.

A number of British ships termed " Selected Ships," appropriate to the British proportion of the world's tonnage, are making observations according to fixed Greenwich times, so that they will synchronize, and reporting them by wireless telegraphy for the information of all ships and the weather offices ashore.

The commanders and officers of these regular observing ships are known as the British Voluntary Corps of Marine Observers, and this corps, at any time, numbers not less than 1,200.

This work is part of an international organization.

Weather notations and scales.

In order that the observations of the ships of different nations might be readily compared, it was necessary to adopt a certain degree of uniformity in scales and notations for observing the weather. These date from 1853, and Admiral BEAUFORT's scales made in about 1805 are their foundation.

Code and regulation of wireless weather reports.

When wireless communication became general at sea not only was one code for weather desirable, but it was necessary, if communication of weather reports was to be effective, that there should be some regulation.

Guide for observation.

The MARINE OBSERVER'S HANDBOOK, M.O.218, is the guide for observation of the corps of voluntary marine observers. Much of the guidance in it is suitable for observation in the general service of the merchant navy, and it is commended to all sea officers.

Decode and information of when and how ships' weather reports are made.

The pamphlet M.O.329, " DECODE FOR USE WITH THE INTERNATIONAL CODE FOR WIRELESS WEATHER MESSAGES FROM SHIPS," not only provides the tables for decoding weather reports made by Selected Ships, but it also gives particulars of how and when these reports are made.

The Marine Observer.

THE MARINE OBSERVER is the review of the Marine Division of the Meteorological Office in co-operation with the voluntary corps of marine observers.

It gives the names of all observing ships, indicates which are Selected Ships, and gives the names of the personnel of the corps of voluntary marine observers ; and in it are published remarks of useful and interesting observations received from ships at sea.

It is the medium for communicating to the corps of marine observers and those interested, the results of the investigations carried out in the Marine Division of the Meteorological Office with the data returned from the sea.

Organized observation.

Thus it will be seen that observation is organized with a limited number of ships and for a limited number of officers of the merchant navy. Observation has been so organized to make it more effective and to keep the data returned from the sea to the Meteorological Office within bounds which can be effectively dealt with.

Recognition in Merchant Shipping Act.

This voluntary service carried out by the corps of marine observers, with the guidance of the Meteorological Office, has received recognition in the Merchant Shipping Act, and Article 35 of the Convention for Safety of Life at Sea defines it.

If this book assists, however slightly, the officers of the merchant navy, for whom it is written, to put to better use the services which the corps of marine observers is rendering to them, and to see more clearly through the fog which surrounds the study of the winds, weather, and currents of the sea, it will have achieved its purpose.

APPENDIX

APPENDIX

Extracts from Marine Observer's Handbook
Fifth Edition
Correction Tables
MILLIBAR BAROMETERS

TABLE I

The Adjustment of Fiducial Temperature

Latitude N. or S.	Height in Feet of Barometer: 0	5	10	15	20	25	30	35	40
°	a	a	a	a	a	a	a	a	a
0	−15·2	−14·2	−13·1	−12·1	−11·0	−10·0	− 8·9	− 7·8	− 6·8
2	15·1	14·1	13·0	12·0	10·9	9·9	8·8	7·7	6·7
4	15·0	14·0	12·9	11·8	10·8	9·8	8·7	7·6	6·5
6	14·8	13·8	12·7	11·7	10·6	9·6	8·5	7·4	6·4
8	14·6	13·6	12·5	11·5	10·4	9·4	8·3	7·2	6·2
10	14·2	13·2	12·1	11·1	10·0	9·0	7·9	6·8	5·8
12	13·8	12·8	11·7	10·7	9·6	8·6	7·5	6·4	5·4
14	13·4	12·4	11·3	10·3	9·2	8·2	7·1	6·0	5·0
16	12·8	11·8	10·7	9·7	8·6	7·6	6·5	5·4	4·4
18	12·3	11·3	10·2	9·2	8·1	7·1	6·0	4·9	3·9
20	11·6	10·6	9·5	8·5	7·4	6·4	5·3	4·2	3·2
22	10·9	9·9	8·8	7·8	6·7	5·7	4·6	3·5	2·5
24	10·1	9·1	8·0	7·0	5·9	4·9	3·8	2·7	1·7
26	9·3	8·3	7·2	6·2	5·1	4·1	3·0	1·9	0·9
28	8·5	7·5	6·4	5·4	4·3	3·3	2·2	1·1	− 0·1
30	7·6	6·6	5·5	4·5	3·4	2·4	1·3	− 0·2	+ 0·8
32	6·6	5·6	4·5	3·5	2·4	1·4	− 0·3	+ 0·8	1·8
34	5·7	4·7	3·6	2·6	1·5	− 0·5	+ 0·6	1·7	2·7
36	4·7	3·7	2·6	1·6	− 0·5	+ 0·5	1·6	2·7	3·7
38	3·7	2·7	1·6	− 0·6	+ 0·5	1·5	2·6	3·7	4·7
40	2·6	1·6	− 0·5	+ 0·5	1·6	2·6	3·7	4·8	5·8
42	1·6	− 0·6	+ 0·5	1·5	2·6	3·6	4·7	5·8	6·8
44	− 0·5	+0·5	1·6	2·6	3·7	4·7	5·8	6·9	7·9
46	+ 0·5	1·5	2·6	3·6	4·7	5·7	6·8	7·9	8·9
48	1·6	2·6	3·7	4·7	5·8	6·8	7·9	9·0	10·0
50	2·6	3·6	4·7	5·7	6·8	7·8	8·9	10·0	11·0
52	3·7	4·7	5·8	6·8	7·9	8·9	10·0	11·1	12·1
54	4·7	5·7	6·8	7·8	8·9	9·9	11·0	12·1	13·1
56	5·7	6·7	7·8	8·8	9·9	10·9	12·0	13·1	14·1
58	6·6	7·6	8·7	9·7	10·8	11·8	12·9	14·0	15·0
60	+ 7·6	+ 8·6	+ 9·7	+10·7	+11·8	+12·8	+13·9	+15·0	+16·0

Based on a Temperature of 290a.

TABLE I

for Latitude and Height Above Sea Level.

Cistern above Sea Level: 45	50	55	60	65	70	75	80	Latitude N. or S.
a	a	a	a	a	a	a	a	°
− 5·7	− 4·7	− 3·6	− 2·6	− 1·5	− 0·5	+ 0·6	+ 1·6	0
5·6	4·6	3·5	2·5	1·4	0·4	0·7	1·7	2
5·5	4·5	3·4	2·4	1·3	0·3	0·8	1·8	4
5·3	4·3	3·2	2·2	1·1	− 0·1	1·0	2·0	6
5·1	4·1	3·0	2·0	0·9	+ 0·1	1·2	2·2	8
4·7	3·7	2·6	1·6	0·5	0·5	1·6	2·6	10
4·3	3·3	2·2	1·2	− 0·1	0·9	2·0	3·0	12
3·9	2·9	1·8	0·8	+ 0·3	1·3	2·4	3·4	14
3·3	2·3	1·2	− 0·2	0·9	1·9	3·0	4·0	16
2·8	1·8	− 0·7	+ 0·3	1·4	2·4	3·5	4·5	18
2·1	1·1	0·0	1·0	2·1	3·1	4·2	5·2	20
1·4	− 0·4	+ 0·7	1·7	2·8	3·6	4·9	5·9	22
− 0·6	+ 0·4	1·5	2·5	3·6	4·6	5·7	6·7	24
+ 0·2	1·2	2·3	3·3	4·4	5·4	6·5	7·5	26
1·0	2·0	3·1	4·1	5·2	6·2	7·3	8·3	28
1·9	2·9	4·0	5·0	6·1	7·1	8·2	9·2	30
2·9	3·9	5·0	6·0	7·1	8·1	9·2	10·2	32
3·8	4·8	5·9	6·9	8·0	9·0	10·1	11·1	34
4·8	5·8	6·9	7·9	9·0	10·0	11·1	12·1	36
5·8	6·8	7·9	8·9	10·0	11·0	12·1	13·1	38
6·9	7·9	9·0	10·0	11·1	12·1	13·2	14·2	40
7·9	8·9	10·0	11·0	12·1	13·1	14·2	15·2	42
9·0	10·0	11·1	12·1	13·2	14·2	15·3	16·3	44
10·0	11·0	12·1	13·1	14·2	15·2	16·3	17·3	46
11·1	12·1	13·2	14·2	15·3	16·3	17·4	18·4	48
12·1	13·1	14·2	15·2	16·3	17·3	18·4	19·4	50
13·2	14·2	15·3	16·3	17·4	18·4	19·5	20·5	52
14·2	15·2	16·3	17·3	18·4	19·4	20·5	21·5	54
15·2	16·2	17·3	18·3	19·4	20·4	21·5	22·5	56
16·1	17·1	18·2	19·2	20·3	21·3	22·4	23·4	58
+17·1	+18·1	+19·2	+20·2	+21·3	+22·3	+23·4	+24·4	60

and Barometer height of 1000 mb.

TABLE II

Correction of Barometer for Difference Adjusted Fiducial

Attached Thermometer.	271	272	273	274	275	276	277	278	279	280	Attached Thermometer.
	Adjusted Fiducial Temperature.										
a.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	a.
271	0·0	+0·2	+0·3	+0·5	+0·7	+0·9	+1·0	+1·2	+1·4	+1·5	271
272	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	272
273	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	273
274	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	274
275	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	275
276	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	276
277	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	277
278	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	278
279	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	279
280	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	280
281	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	281
282	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	282
283	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	283
284	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	284
285	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	285
286	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	286
287	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	287
288	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	288
289	3·1	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·6	289
290	3·2	3·1	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	290
291	3·4	3·2	3·1	2·9	2·7	2·6	2·4	2·2	2·0	1·9	291
292	3·6	3·4	3·2	3·1	2·9	2·7	2·6	2·4	2·2	2·0	292
293	3·8	3·6	3·4	3·2	3·1	2·9	2·7	2·6	2·4	2·2	293
294	3·9	3·8	3·6	3·4	3·2	3·1	2·9	2·7	2·6	2·4	294
295	4·1	3·9	3·8	3·6	3·4	3·2	3·1	2·9	2·7	2·6	295
296	4·3	4·1	3·9	3·8	3·6	3·4	3·2	3·1	2·9	2·7	296
297	4·4	4·3	4·1	3·9	3·8	3·6	3·4	3·2	3·1	2·9	297
298	4·6	4·4	4·3	4·1	3·9	3·8	3·6	3·4	3·2	3·1	298
299	4·8	4·6	4·4	4·3	4·1	3·9	3·8	3·6	3·4	3·2	299
300	5·0	4·8	4·6	4·4	4·3	4·1	3·9	3·8	3·6	3·4	300
301	5·1	5·0	4·8	4·6	4·4	4·3	4·1	3·9	3·8	3·6	301
302	5·3	5·1	5·0	4·8	4·6	4·4	4·3	4·1	3·9	3·8	302
303	5·5	5·3	5·1	5·0	4·8	4·6	4·4	4·3	4·1	3·9	303
304	5·6	5·5	5·3	5·1	5·0	4·8	4·6	4·4	4·3	4·1	304
305	5·8	5·6	5·5	5·3	5·1	5·0	4·8	4·6	4·4	4·3	305
306	6·0	5·8	5·6	5·5	5·3	5·1	5·0	4·8	4·6	4·4	306
307	6·2	6·0	5·8	5·6	5·5	5·3	5·1	5·0	4·8	4·6	307
308	6·3	6·2	6·0	5·8	5·6	5·5	5·3	5·1	5·0	4·8	308
309	6·5	6·3	6·2	6·0	5·8	5·6	5·5	5·3	5·1	5·0	309
310	−6·7	−6·5	−6·3	−6·2	−6·0	−5·8	−5·6	−5·5	−5·3	−5·1	310

NOTE.—This table is based on a Standard Pressure of 1,000 mb. For other cent. of the correction for each 10 millibars above 1,000, and subtract one per

TABLE II.—*cont.*

Between "Attached Thermometer" and Temperature.

Attached Thermometer.	281	282	283	284	285	286	287	288	289	290	Attached Thermometer.
	Adjusted Fiducial Temperature.										
a.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	a.
271	+1·7	+1·9	+2·0	+2·2	+2·4	+2·6	+2·7	+2·9	+3·1	+3·2	271
272	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	3·1	272
273	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	273
274	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	274
275	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	275
276	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	276
277	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	277
278	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	278
279	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	279
280	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	280
281	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	281
282	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	282
283	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	283
284	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	284
285	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	285
286	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	286
287	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	287
288	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	288
289	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	289
290	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	290
291	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	291
292	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	292
293	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	293
294	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	294
295	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	295
296	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	296
297	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	297
298	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	298
299	3·1	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	299
300	3·2	3·1	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	300
301	3·4	3·2	3·1	2·9	2·7	2·6	2·4	2·2	2·0	1·9	301
302	3·6	3·4	3·2	3·1	2·9	2·7	2·6	2·4	2·2	2·0	302
303	3·8	3·6	3·4	3·2	3·1	2·9	2·7	2·6	2·4	2·2	303
304	3·9	3·8	3·6	3·4	3·2	3·1	2·9	2·7	2·6	2·4	304
305	4·1	3·9	3·8	3·6	3·4	3·2	3·1	2·9	2·7	2·6	305
306	4·3	4·1	3·9	3·8	3·6	3·4	3·2	3·1	2·9	2·7	306
307	4·4	4·3	4·1	3·9	3·8	3·6	3·4	3·2	3·1	2·9	307
308	4·6	4·4	4·3	4·1	3·9	3·8	3·6	3·4	3·2	3·1	308
309	4·8	4·6	4·4	4·3	4·1	3·9	3·8	3·6	3·4	3·2	309
310	−5·0	−4·8	−4·6	−4·4	−4·3	−4·1	−3·9	−3·8	−3·6	−3·4	310

pressures an additional correction is necessary, the rule being, "Add one per cent. for each 10 millibars below."

TABLE II.—*cont.*

CORRECTION OF BAROMETER FOR DIFFERENCE
ADJUSTED FIDUCIAL

Attached Thermometer.	Adjusted Fiducial Temperature.										Attached Thermometer.
	291	292	293	294	295	296	297	298	299	300	
a.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	a.
271	+3·4	+3·6	+3·8	+3·9	+4·1	+4·3	+4·4	+4·6	+4·8	+5·0	271
272	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·4	4·6	4·8	272
273	3·1	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·4	4·6	273
274	2·9	3·1	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·4	274
275	2·7	2·9	3·1	3·2	3·4	3·6	3·8	3·9	4·1	4·3	275
276	2·6	2·7	2·9	3·1	3·2	3·4	3·6	3·8	3·9	4·1	276
277	2·4	2·6	2·7	2·9	3·1	3·2	3·4	3·6	3·8	3·9	277
278	2·2	2·4	2·6	2·7	2·9	3·1	3·2	3·4	3·6	3·8	278
279	2·0	2·2	2·4	2·6	2·7	2·9	3·1	3·2	3·4	3·6	279
280	1·9	2·0	2·2	2·4	2·6	2·7	2·9	3·1	3·2	3·4	280
281	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	3·1	3·2	281
282	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	3·1	282
283	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	283
284	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	284
285	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	285
286	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	286
287	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	287
288	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	288
289	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	289
290	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	290
291	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	291
292	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	292
293	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	293
294	0·5	0·3	−0·2	0·0	+0·2	0·3	0·6	0·7	0·9	1·0	294
295	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	295
296	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	296
297	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	297
298	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	298
299	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	299
300	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	300
301	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	301
302	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	0·3	302
303	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	0·5	303
304	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	0·7	304
305	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	0·9	305
306	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	1·0	306
307	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	1·2	307
308	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	1·4	308
309	3·1	2·9	2·7	2·6	2·4	2·2	2·0	1·9	1·7	1·5	309
310	−3·2	−3·1	−2·9	−2·7	−2·6	−2·4	−2·2	−2·0	−1·9	−1·7	310

NOTE.—This table is based on a Standard Pressure of 1,000 mb. For other pressures an additional correction is necessary, the rule being, " Add one per cent. of the correction for each 10 millibars above 1,000, and subtract one per cent. for each 10 millibars below."

TABLE II.—*cont.*

BETWEEN " ATTACHED THERMOMETER " AND
TEMPERATURE.

Attached Thermometer.	Adjusted Fiducial Temperature.										Attached Thermometer.
	301	302	303	304	305	306	307	308	309	310	
a.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	a.
271	+5·1	+5·3	+5·5	+5·6	+5·8	+6·0	+6·2	+6·3	+6·5	+6·7	271
272	5·0	5·1	5·3	5·5	5·6	5·8	6·0	6·2	6·3	6·5	272
273	4·8	5·0	5·1	5·3	5·5	5·6	5·8	6·0	6·2	6·3	273
274	4·6	4·8	5·0	5·1	5·3	5·5	5·6	5·8	6·0	6·2	274
275	4·4	4·6	4·8	5·0	5·1	5·3	5·5	5·6	5·8	6·0	275
276	4·3	4·4	4·6	4·8	5·0	5·1	5·3	5·5	5·6	5·8	276
277	4·1	4·3	4·4	4·6	4·8	5·0	5·1	5·3	5·5	5·6	277
278	3·9	4·1	4·3	4·4	4·6	4·8	5·0	5·1	5·3	5·5	278
279	3·8	3·9	4·1	4·3	4·4	4·6	4·8	5·0	5·1	5·3	279
280	3·6	3·8	3·9	4·1	4·3	4·4	4·6	4·8	5·0	5·1	280
281	3·4	3·6	3·8	3·9	4·1	4·3	4·4	4·6	4·8	5·0	281
282	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·4	4·6	4·8	282
283	3·1	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·4	4·6	283
284	2·9	3·1	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·4	284
285	2·7	2·9	3·1	3·2	3·4	3·6	3·8	3·9	4·1	4·3	285
286	2·6	2·7	2·9	3·1	3·2	3·4	3·6	3·8	3·9	4·1	286
287	2·4	2·6	2·7	2·9	3·1	3·2	3·4	3·6	3·8	3·9	287
288	2·2	2·4	2·6	2·7	2·9	3·1	3·2	3·4	3·6	3·8	288
289	2·0	2·2	2·4	2·6	2·7	2·9	3·1	3·2	3·4	3·6	289
290	1·9	2·0	2·2	2·4	2·6	2·7	2·9	3·1	3·2	3·4	290
291	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	3·1	3·2	291
292	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	3·1	292
293	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	2·9	293
294	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	2·7	294
295	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·6	295
296	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	296
297	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	297
298	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	2·0	298
299	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	1·9	299
300	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	1·7	300
301	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	1·5	301
302	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	1·4	302
303	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	1·2	303
304	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	1·0	304
305	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	0·9	305
306	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	0·7	306
307	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	0·5	307
308	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	0·3	308
309	1·4	1·2	1·0	0·9	0·7	0·5	0·3	−0·2	0·0	+0·2	309
310	−1·5	−1·4	−1·2	−1·0	−0·9	−0·7	−0·5	−0·3	−0·2	−0·0	310

Example for correcting Millibar Barometer

M.O. Barometer No. 922 has a standard temperature of 285·0a at 1,000 millibars. In latitude 32° 39′ N., the reading of the barometer was 1016·9 mb., and of the attached thermometer 293a. The height of the barometer cistern was 42 ft. above sea level.

Standard temperature of barometer	..		285·0a
Ship's latitude, 32° 39′ } Height of barometer above sea level, 42 ft.	Correction from Table I ..	+	2·4a
Adjusted fiducial temperature	.. ..		287·4a
Attached thermometer reading	.. ..		293·0a
From Table II—*Correction* ..	.. ..	—	1·0 mb.
Observed barometric reading	.. ..		1016·9 mb.
Correction as above	.. ..	—	1·0 mb.
Corrected barometric reading	.. ..		1015·9 mb.

INCH BAROMETERS

TABLE III

TABLE OF CORRECTIONS TO BE APPLIED TO BAROMETERS WITH *Brass Scales* EXTENDING FROM THE CISTERN TO THE TOP OF THE MERCURIAL COLUMN, TO REDUCE THE OBSERVATION TO 32° FAHRENHEIT.

Temp.	INCHES.											Temp.
	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
°	+	+	+	+	+	+	+	+	+	+	+	°
0	·068	·069	·070	·072	·073	·074	·076	·077	·078	·080	·081	0
1	·065	·067	·068	·069	·070	·072	·073	·074	·076	·077	·078	1
2	·063	·064	·065	·067	·068	·069	·070	·072	·073	·074	·075	2
3	·061	·062	·063	·064	·065	·066	·068	·069	·070	·071	·072	3
4	·058	·060	·061	·062	·063	·064	·065	·066	·067	·069	·070	4
5	·056	·057	·058	·059	·060	·061	·062	·064	·065	·066	·067	5
6	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·064	6
7	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	7
8	·049	·050	·051	·052	·053	·054	·054	·055	·056	·057	·058	8
9	·046	·047	·048	·049	·050	·051	·052	·053	·054	·054	·055	9
10	·044	·045	·046	·046	·047	·048	·049	·050	·051	·052	·053	10
11	·042	·043	·043	·044	·045	·046	·047	·047	·048	·049	·050	11
12	·039	·040	·041	·042	·042	·043	·044	·044	·045	·046	·047	12
13	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	·044	13
14	·035	·035	·036	·036	·037	·038	·039	·039	·040	·041	·041	14
15	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	·038	15
16	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	·036	16
17	·027	·028	·029	·029	·030	·030	·031	·031	·032	·032	·033	17
18	·025	·026	·026	·027	·027	·028	·028	·029	·029	·030	·030	18
19	·023	·023	·024	·024	·025	·025	·025	·026	·026	·027	·028	19
20	·020	·021	·021	·022	·022	·022	·023	·023	·024	·024	·024	20
21	·018	·018	·019	·019	·019	·020	·020	·021	·021	·021	·022	21
22	·016	·016	·016	·017	·017	·017	·017	·018	·018	·018	·019	22
23	·013	·014	·014	·014	·014	·015	·015	·015	·015	·016	·016	23
24	·011	·011	·011	·012	·012	·012	·012	·012	·013	·013	·013	24
25	·009	·009	·009	·009	·009	·009	·010	·010	·010	·010	·010	25
26	·006	·006	·006	·007	·007	·007	·007	·007	·007	·007	·007	26
27	·004	·004	·004	·004	·004	·004	·004	·004	·004	·005	·005	27
28	·001	·002	·002	·002	·002	·002	·002	·002	·002	·002	·002	28
	—	—	—	—	—	—	—	—	—	—	—	
29	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	29
30	·003	·003	·003	·003	·003	·004	·004	·004	·004	·004	·004	30
31	·006	·006	·006	·006	·006	·006	·006	·006	·006	·007	·007	31
32	·008	·008	·008	·008	·009	·009	·009	·009	·009	·009	·009	32
33	·010	·011	·011	·011	·011	·011	·012	·012	·012	·012	·012	33
34	·013	·013	·013	·013	·014	·014	·014	·014	·015	·015	·015	34
35	·015	·015	·016	·016	·016	·017	·017	·017	·017	·018	·018	35
36	·017	·018	·018	·018	·019	·019	·019	·020	·020	·020	·021	36
37	·020	·020	·021	·021	·021	·022	·022	·022	·023	·023	·024	37
38	·022	·023	·023	·023	·024	·024	·025	·025	·026	·026	·026	38
39	·024	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	39
40	·027	·027	·028	·028	·029	·030	·030	·031	·031	·032	·032	40
41	·029	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	41
42	·032	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	42
43	·034	·035	·035	·036	·036	·037	·038	·038	·039	·040	·040	43
44	·036	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	44
45	·039	·039	·040	·041	·042	·042	·043	·044	·045	·045	·046	45
46	·041	·042	·043	·043	·044	·045	·046	·047	·047	·048	·049	46
47	·043	·044	·045	·046	·047	·048	·048	·049	·050	·051	·052	47
48	·046	·047	·047	·048	·049	·050	·051	·052	·053	·054	·054	48
49	·048	·049	·050	·051	·052	·053	·054	·055	·055	·056	·057	49
50	·050	·052	·052	·053	·054	·055	·056	·057	·058	·059	·060	50

NOTE.—The temperature of the "ATTACHED THERMOMETER" should be used when applying these corrections.

TABLE III—*continued*

Temp.	INCHES.											Temp.
	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
°	—	—	—	—	—	—	—	—	—	—	—	°
51	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	51
52	·055	·056	·057	·058	059	·060	·061	·062	·064	·065	·066	52
53	·057	·059	·060	·061	·062	·063	·064	·065	·066	·067	·068	53
54	·060	·061	·062	·063	·064	·065	·067	·068	·069	·070	·071	54
55	·062	·063	·064	·065	·067	·068	·069	·071	·072	·073	·074	55
56	·064	·066	·067	·068	·069	·070	·072	·073	·074	·076	·077	56
57	·067	·068	·069	·071	·072	·073	·075	·076	·077	·078	·080	57
58	·069	·071	·072	·073	·074	·076	·077	·078	·080	·081	·082	58
59	·072	·073	·074	·076	·077	·078	·080	·081	·083	·084	·085	59
60	·074	·075	·077	·078	·080	·081	·082	·084	·085	·087	·088	60
61	·076	·078	·079	·080	·082	·084	·085	·087	·088	·090	·091	61
62	·079	·080	·082	·083	·085	·086	·088	·089	·091	·092	·094	62
63	·081	·083	·084	·086	·087	·089	·090	·092	·093	·095	·096	63
64	·083	·085	·086	·088	·090	·092	·093	·095	·096	·097	·099	64
65	·086	·088	·089	·091	·092	·094	·095	·097	·099	·101	·102	65
66	·088	·090	·091	·093	·095	·097	·098	·100	·101	·103	·105	66
67	·090	·092	·094	·096	·097	·099	·101	·102	·104	·106	·108	67
68	·093	·095	·096	·098	·100	·102	·105	·107	·107	·109	·110	68
69	·095	·097	·099	·101	·102	·104	·106	·108	·110	·112	·113	69
70	·097	·099	·101	·103	·105	·107	·109	·111	·112	·114	·116	70
71	·100	·102	·103	·105	·107	·109	·111	·113	·115	·117	·119	71
72	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	72
73	·104	·106	·108	·110	·112	·114	·116	·118	·120	·123	·124	73
74	·107	·109	·111	·113	·115	·117	·119	·121	·123	·125	·127	74
75	·109	·111	·113	·115	·117	·120	·122	·124	·126	·128	·130	75
76	·111	·113	·116	·118	·120	·122	·124	·126	·128	·131	·133	76
77	·114	·116	·118	·120	·122	·125	·127	·129	·131	·134	·136	77
78	·116	·118	·120	·123	·125	·127	·129	·132	·134	·136	·138	78
79	·118	·121	·123	·125	·127	·130	·132	·135	·137	·139	·141	79
80	·121	·123	·125	·128	·130	·133	·135	·137	·139	·142	·144	80
81	·123	·126	·128	·130	·132	·135	·137	·140	·142	·145	·147	81
82	·125	·128	·130	·133	·135	·138	·140	·143	·145	·148	·149	82
83	·128	·131	·133	·136	·138	·140	·142	·145	·147	·150	·152	83
84	·130	·133	·135	·138	·140	·143	·145	·148	·150	·153	·155	84
85	·132	·135	·137	·140	·143	·146	·148	·151	·153	·156	·158	85
86	·135	·138	·140	·143	·145	·148	·150	·153	·155	·159	·161	86
87	·137	·140	·142	·145	·148	·151	·153	·156	·158	·161	·163	87
88	·139	·143	·145	·148	·150	·153	·155	·159	·161	·164	·166	88
89	·142	·145	·147	·150	·153	·156	·158	·161	·164	·167	·169	89
90	·144	·147	·150	·153	155	·158	·161	·164	·166	·169	·172	90
91	·146	·150	·152	·155	·158	·161	·163	·167	·169	·172	·175	91
92	·149	·152	·154	·158	·160	·163	·166	·169	·172	·175	·177	92
93	·151	·154	·157	·160	·163	·166	·168	·172	·174	·178	·180	93
94	·153	·157	·159	·163	·165	·169	·171	·174	·177	·180	·183	94
95	·156	·159	·162	·165	·168	·171	·174	·177	·180	·183	·186	95
96	·158	·161	·164	·168	·170	·174	·176	·180	·182	·186	·188	96
97	·160	·164	·167	·170	·173	·176	·179	·182	·185	·188	·191	97
98	·163	·166	·169	·172	·175	·179	·181	·185	·188	·191	·194	98
99	·165	·169	·171	·175	·178	·181	·184	·188	·190	·194	·197	99
100	·167	·171	·174	·177	·180	·184	·187	·190	·193	·197	·200	100

TABLE IV

REDUCTION OF BAROMETRIC READINGS TO MEAN SEA LEVEL. READING, 30 INCHES.

Height in feet.	Temperature of Air. (Dry Bulb in Screen.)										Height in feet.
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	
5	·006	·006	·006	·006	·006	·006	·006	·005	·005	·005	5
10	·012	·012	·012	·011	·011	·011	·011	·010	·010	·010	10
15	·019	·018	·018	·017	·017	·017	·017	·016	·016	·015	15
20	·025	·024	·023	·023	·023	·022	·022	·021	·021	·020	20
25	·031	·030	·029	·029	·029	·028	·027	·027	·026	·026	25
30	·037	·036	·035	·035	·034	·033	·032	·032	·031	·031	30
35	·043	·042	·041	·041	·040	·039	·038	·037	·037	·036	35
40	·049	·048	·047	·046	·045	·044	·043	·042	·042	·041	40
45	·056	·054	·053	·052	·051	·050	·049	·048	·047	·046	45
50	·062	·060	·059	·058	·056	·055	·054	·053	·052	·051	50
55	·068	·066	·065	·064	·062	·061	·060	·059	·057	·056	55
60	·074	·072	·071	·069	·068	·066	·065	·064	·062	·061	60
65	·080	·078	·077	·075	·074	·072	·071	·069	·068	·066	65
70	·086	·084	·083	·081	·079	·077	·076	·074	·073	·071	70
75	·092	·090	·089	·087	·085	·083	·082	·080	·078	·076	75
80	·098	·096	·094	·092	·091	·089	·087	·085	·083	·081	80
85	·105	·102	·100	·098	·097	·095	·093	·090	·089	·087	85
90	·111	·108	·106	·104	·102	·101	·098	·095	·094	·092	90
95	·117	·114	·112	·110	·108	·106	·103	·101	·099	·097	95
100	·123	·120	·118	·115	·113	·111	·108	·106	·104	·101	100

The correction is always ADDITIVE.

TABLE V

CORRECTIONS FOR REDUCING BAROMETRIC READINGS TO STANDARD GRAVITY IN LATITUDE 45°.

Lat. N. or S.	Correction. At 27.	Correction. At 30.	Lat. N. or S.	Correction. At 27.	Correction. At 30.	Lat. N. or S.	Correction. At 27.	Correction. At 30.	Lat. N. or S.	Correction. At 27	Correction. At 30.
°	ins.	ins.	°	ins.	ins.	°	ins.	ins.	°	ins.	ins.
0	−·070	−·078	23	−·049	−·054	46	+·002	+·003	69	+·052	+·058
1	·070	·078	24	·047	·052	47	·005	·005	70	·054	·060
2	·070	·078	25	·045	·050	48	·007	·008	71	·055	·061
3	·070	·077	26	·043	·048	49	·010	·011	72	·057	·063
4	·069	·077	27	·041	·046	50	·012	·013	73	·058	·064
5	·069	·077	28	·039	·043	51	·015	·016	74	·059	·066
6	·068	·076	29	·037	·041	52	·017	·019	75	·061	·067
7	·068	·075	30	·035	·039	53	·019	·021	76	·062	·069
8	·067	·075	31	·033	·036	54	·022	·024	77	·063	·070
9	·067	·074	32	·031	·034	55	·024	·027	78	·064	·071
10	·066	·073	33	·028	·032	56	·026	·029	79	·065	·072
11	·065	·072	34	·026	·029	57	·028	·032	80	·066	·073
12	·064	·071	35	·024	·027	58	·031	·034	81	·067	·074
13	·063	·070	36	·022	·024	59	·033	·036	82	·067	·075
14	·062	·069	37	·019	·021	60	·035	·039	83	·068	·075
15	·061	·067	38	·017	·019	61	·037	·041	84	·068	·076
16	·059	·066	39	·015	·016	62	·039	·043	85	·069	·077
17	·058	·064	40	·012	·013	63	·041	·046	86	·069	·077
18	·057	·063	41	·010	·011	64	·043	·048	87	·070	·077
19	·055	·061	42	·007	·008	65	·045	·050	88	·070	·078
20	·054	·060	43	·005	·005	66	·047	·052	89	·070	·078
21	·052	·058	44	−·002	−·003	67	·049	·054	90	+·070	+·078
22	−·050	−·056	45	± 0	± 0	68	+·050	+·056			

Example for correcting Inch Barometer

In latitude 51° N., barometer reads 30·240 at a height of 36 ft. above sea level. The attached thermometer reads 58° F., and the index error is +·005.

		Inches.
Uncorrected reading		30·240
Index error correction	+	·005
		30·245
Temperature correction for 58° F. (Table III)	−	·080
		30·165
Height correction for 36 ft. at air temperature of 58° F. (Table IV)	+	·039
		30·204
Gravity correction in latitude 51° N. (Table V)	+	·016
		30·220

Example for correcting an Aneroid

The Aneroid is not very reliable for measuring absolute pressure, but if constant precautions are taken by frequent comparison with mercurial barometers, its readings will usually be sufficiently accurate, in the absence of a mercurial barometer, to use in conjunction with reports received from Selected Ships.

Usually aneroid barometer readings should not be included in routine weather reports, though of course they should be used, when no mercurial barometer is available, for making Storm Danger messages, such as the one given at the end of Chapter III.

Aneroids are compensated for temperature and they are not affected by gravity. They should therefore only be correct for index error and height above sea level, as follows :—

		Inches.
Aneroid reading		30·14
Index error	+	·06
		30·20
Height above sea level, 40 ft., correction being +·01 in. for each 9 ft. .. .. .. Table IV gives the exact correction.	+	·04
		30·24

TABLE VI

PRESSURE VALUES.

EQUIVALENTS IN MILLIBARS AND MILLIMETRES OF MERCURY OF INCHES OF MERCURY AT 32° F. IN LATITUDE 45°.

Mercury. Inches.	Milli-bars.	Mercury. Milli-metres.	Mercury. Inches.	Milli-bars.	Mercury. Milli-metres.	Mercury. Inches.	Milli-bars.	Mercury. Milli-metres.
27·02	915	686·3	28·35	960	720·1	29·68	1,005	753·8
27·05	916	687·1	28·38	961	720·8	29·71	1,006	754·6
27·08	917	687·8	28·41	962	721·6	29·74	1,007	755·3
27·11	918	688·6	28·44	963	722·3	29·77	1,008	756·1
27·14	919	689·3	28·47	964	723·1	29·80	1,009	756·8
27·17	920	690·1	28·50	965	723·8	29·83	1,010	757·6
27·20	921	690·8	28·53	966	724·6	29·86	1,011	758·3
27·23	922	691·6	28·56	967	725·3	29·89	1,012	759·1
27·26	923	692·3	28·59	968	726·1	29·92	1,013	759·8
27·29	924	693·1	28·62	969	726·8	29·94	1,014	760·6
27·32	925	693·8	28·65	970	727·6	29·97	1,015	761·3
27·35	926	694·6	28·67	971	728·3	30·00	1,016	762·1
27·38	927	695·3	28·70	972	729·1	30·03	1,017	762·8
27·41	928	696·1	28·73	973	729·8	30·06	1,018	763·6
27·44	929	696·8	28·76	974	730·6	30·09	1,019	764·3
27·46	930	697·6	28·79	975	731·3	30·12	1,020	765·1
27·49	931	698·3	28·82	976	732·1	30·15	1,021	765·8
27·52	932	699·1	28·85	977	732·8	30·18	1,022	766·6
27·55	933	699·8	28·88	978	733·6	30·21	1,023	767·3
27·58	934	700·6	28·91	979	734·3	30·24	1,024	768·1
27·61	935	701·3	28·94	980	735·1	30·27	1,025	768·8
27·64	936	702·1	28·97	981	735·8	30·30	1,026	769·6
27·67	937	702·8	29·00	982	736·6	30·33	1,027	770·3
27·70	938	703·6	29·03	983	737·3	30·36	1,028	771·1
27·73	939	704·3	29·06	984	738·1	30·39	1,029	771·8
27·76	940	705·1	29·09	985	738·8	30·42	1,030	772·6
27·79	941	705·8	29·12	986	739·6	30·45	1,031	773·3
27·82	942	706·6	29·15	987	740·3	30·48	1,032	774·1
27·85	943	707·3	29·18	988	741·1	30·51	1,033	774·8
27·88	944	708·1	29·21	989	741·8	30·53	1,034	775·6
27·91	945	708·8	29·24	990	742·6	30·56	1,035	776·3
27·94	946	709·6	29·26	991	743·3	30·59	1,036	777·1
27·97	947	710·3	29·29	992	744·1	30·62	1,037	777·8
28·00	948	711·1	29·32	993	744·8	30·65	1,038	778·6
28·03	949	711·8	29·35	994	745·6	30·68	1,039	779·3
28·05	950	712·6	29·38	995	746·3	30·71	1,040	780·1
28·08	951	713·3	29·41	996	747·1	30·74	1,041	780·8
28·11	952	714·1	29·44	997	747·8	30·77	1,042	781·6
28·14	953	714·8	29·47	998	748·6	30·80	1,043	782·3
28·17	954	715·6	29·50	999	749·3	30·83	1,044	783·1
28·20	955	716·3	29·53	1,000	750·1	30·86	1,045	783·8
28·23	956	717·1	29·56	1,001	750·8	30·89	1,046	784·6
28·26	957	717·8	29·59	1,002	751·6	30·92	1,047	785·3
28·29	958	718·6	29·62	1,003	752·3	30·95	1,048	786·1
28·32	959	719·3	29·65	1,004	753·1	30·98	1,049	786·8

This Table must only be used for converting barometer readings after they have been *fully corrected* by Tables I to II, or III to V.

Beaufort Scale of Wind Force

Beaufort Number. International.	Meteorological Wind Scale. Determined at coast stations for a height of 33 ft. above sea level. Limits of Velocity nautical miles per hour. *knots.*	Average Velocity nautical miles per hour. *knots.*	Equivalent pressure in pounds upon a circular disc of one square foot.	Beaufort's description of Wind. International.	The Seamen's Wind Scale. Deep Sea Criterion, 1874. International.		Coastal Criterion.	Beaufort Number. International.
1	2	3	4	5	6		7	8
0	Less than 1	0	0	**Calm**	—		—	**0**
1	1 to 3	2	·01	**Light air** ..	**Just sufficient to give steerage way*** ..		Sufficient to give good steerage way to fishing smacks with the "wind free."†	**1**
2	4 to 6	5	·08	**Light breeze** ..	**That in which a well-conditioned man-of-war, with all sail set, and clean full, would go in smooth water from—**	**1 to 2 knots**	Fishing smacks with top-sails and light canvas "full and by" make up to 2 knots.	**2**
3	7 to 10	9	·28	**Gentle breeze** ..		**3 to 4 knots**	Smacks begin to heel over slightly under topsails and light canvas make up to 3 knots "full and by."	**3**
4	11 to 16	14	·67	**Moderate breeze**		**5 to 6 knots**	Good working breeze. Smacks heel over considerably on a wind under all sail.	**4**
5	17 to 21	19	1·31	**Fresh breeze** ..	**That to which she could just carry in chase, full and by—**	**Royals, &c.**	Smacks shorten sail ..	**5**
6	22 to 27	24	2·3	**Strong breeze** ..		**Topgallant sails.**	Smacks double-reef gaff mainsails.	**6**
7	28 to 33	30	3·6	**Moderate gale** ..	**That to which she could just carry in chase, full and by—**	**Topsails, jib, &c.**	Smacks remain in harbour and those at sea lie to.	**7**
8	34 to 40	37	5·4	**Fresh gale** ..		**Reefed upper topsails and courses.**	Smacks take shelter if possible.	**8**
9	41 to 47	44	7·7	**Strong gale** ..		**Lower top-sails and courses.**	—	**9**
10	48 to 55	52	10·5	**Whole gale** ..	**That with which she could scarcely bear lower maintopsail and reefed foresail.**		—	**10**
11	56 to 65	60	14·0	**Storm**	**That which would reduce her to storm stay-sails.**		—	**11**
12	Above 65	—	Above 17·0	**Hurricane** ..	**That which no canvas could withstand**		—	**12**

For the purpose of showing the forces of winds by wind roses on Meteorological Charts, winds are grouped as follows :—

Scale Numbers	
0	Calm.
1 to 3	Light winds.
4 to 7	Moderate winds.
8 and above	Gales.

The scale numbers are attributed to the wind force at the time of observation by judgment of the observer.

The Gale Warning Signal in the British Isles is hoisted for winds which may reach force 8 or above. For this purpose force 7 is not considered a gale.

In a steamer the force of the wind may be judged by an experienced observer by the appearance of the sea, remembering that polar winds create more sea than equatorial winds, rain has a smoothing effect, and tides or currents influence the sea surface differently when there is a weather or lee tide or current.

*A full-rigged ship of 1874.

† Cutter or Yawl rigged average sized sailing trawler, loaded, with clean bottom.

BEAUFORT WEATHER NOTATION

Letters to indicate the State of the Weather

b = blue sky whether with clear or hazy atmosphere.
c = cloudy (i.e., detached opening clouds).
d = drizzle or fine rain.
e = wet air without rain falling.
f = fog.
fe = wet fog.
g = gloomy.
h = hail.
kq = line squall.
l = lightning.
m = mist.
o = overcast sky.
p = passing showers.
q = squalls.
r = rain.
rs = sleet (i.e., rain and snow together).
s = snow.
t = thunder.
tl = thunderstorm.
u = ugly, threatening sky.
v = unusual visibility.
w = dew.
z = dust haze; the turbid atmosphere of dry weather.

Fog and Visibility Scale

0	Dense fog..	Objects not visible at 50 yards.
1	Thick fog..	„ „ „ 1 cable.
2	Fog	„ „ „ 2 cables.
3	Moderate fog	„ „ „ ½ mile.
4	Mist or haze, or very poor visibility	„ „ „ 1 mile.
5	Poor visibility	„ „ „ 2 miles.
6	Moderate visibility ..	„ „ „ 5 „
7	Good visibility	„ „ „ 10 „
8	Very good visibility ..	„ „ „ 30 „
9	Excellent visibility ..	Objects visible more than 30 miles.

Douglas Sea and Swell Scale

SEA.	SWELL.									
		Low.		Moderate.			Heavy.			
	No swell.	Short or Average.	Long.	Short.	Average.	Long.	Short.	Average.	Long.	Confused.
	0	1	2	3	4	5	6	7	8	9
0 Calm	00	01	02	03	04	05	06	07	08	09
1 Smooth ..	10	11	12	13	14	15	16	17	18	19
2 Slight	20	21	22	23	24	25	26	27	28	29
3 Moderate ..	30	31	32	33	34	35	36	37	38	39
4 Rough ..	40	41	42	43	44	45	46	47	48	49
5 Very Rough ..	50	51	52	53	54	55	56	57	58	59
6 High	60	61	62	63	64	65	66	67	68	69
7 Very High ..	70	71	72	73	74	75	76	77	78	79
8 Precipitous ..	80	81	82	83	84	85	86	87	88	89
9 Confused ..	90	91	92	93	94	95	96	97	98	99

TABLE

For Finding the Relative Humidity (per cent.).

Dry Bulb.	Depression of Wet Bulb.												
°F.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
90	100	96	92	88	84	81	77	74	70	67	63	60	57
88	100	96	92	88	84	80	77	73	69	66	63	59	56
86	100	96	92	88	84	80	76	72	69	65	62	58	55
84	100	96	92	87	83	79	76	72	68	64	61	57	54
82	100	96	91	87	83	79	75	71	67	64	60	57	53
80	100	96	91	87	83	79	74	70	66	63	59	55	52
78	100	95	91	86	82	78	74	70	66	62	58	54	50
76	100	95	91	86	82	78	73	69	65	61	57	53	49
74	100	95	90	86	81	77	72	68	64	60	56	52	48
72	100	95	90	85	80	76	71	67	63	58	54	50	46
70	100	95	90	85	80	75	71	66	62	57	53	49	44
68	100	95	90	84	79	75	70	65	60	56	51	47	43
66	100	95	89	84	79	74	69	64	59	54	50	45	41
64	100	94	89	83	78	73	68	63	58	53	48	43	39
62	100	94	88	83	77	72	67	61	56	51	46	41	37
60	100	94	88	82	77	71	65	60	55	50	44	39	34
58	100	94	88	82	76	70	64	59	53	48	42	37	31
56	100	94	87	81	75	69	63	57	51	46	40	35	29
54	100	93	87	80	74	68	61	55	49	43	38	32	26
52	100	93	86	79	73	66	60	54	47	41	35	29	23
50	100	93	86	79	72	65	59	52	45	38	32	26	20
48	100	92	85	77	70	63	56	49	42	36	29	22	16
46	100	92	84	77	69	62	54	47	40	33	26	19	—
44	100	92	84	75	68	60	52	45	37	29	22	—	—
42	100	91	83	74	66	58	50	42	34	26	18	16	—
40	100	91	82	73	65	56	47	39	30	27	—	—	—
38	100	91	81	72	63	54	44	39	31	22	—	—	—
36	100	90	80	70	60	54	44	35	26	18	—	—	—
34	100	90	79	70	60	50	41	31	21	—	—	—	—
32	100	89	79	68	57	47	36	27	17	—	—	—	—
30	100	88	76	65	53	43	33	22	—	—	—	—	—

TABLE

For Finding the Dew Point (°F.).

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

TABLE

For the Conversion of Temperature Readings on the Fahrenheit and Centigrade Scales to the Absolute Scale.

Fahr.	Cent.	Abs.	Fahr.	Cent.	Abs.	Fahr.	Cent.	Abs.
0	−17·8	255·2	40	+ 4·4	277·4	80	+26·7	299·7
1	17·2	55·8	41	5·0	78·0	81	27·2	300·2
2	16·7	56·3	42	5·6	78·6	82	27·8	0·8
3	16·1	56·9	43	6·1	79·1	83	28·3	1·3
4	15·6	57·4	44	6·7	79·7	84	28·9	1·9
5	15·0	58·0	45	7·2	80·2	85	29·4	2·4
6	14·4	58·6	46	7·8	80·8	86	30·0	3·0
7	13·9	59·1	47	8·3	81·3	87	30·6	3·6
8	13·3	59·7	48	8·9	81·9	88	31·1	4·1
9	12·8	260·2	49	9·4	282·4	89	31·7	304·7
10	12·2	260·8	50	10·0	283·0	90	32·2	305·2
11	11·7	61·3	51	10·6	83·6	91	32·8	5·8
12	11·1	61·9	52	11·1	84·1	92	33·3	6·3
13	10·6	62·4	53	11·7	84·7	93	33·9	6·9
14	10·0	63·0	54	12·2	85·2	94	34·4	7·4
15	9·4	63·6	55	12·8	85·8	95	35·0	8·0
16	8·9	64·1	56	13·3	86·3	96	35·6	8·6
17	8·3	64·7	57	13·9	86·9	97	36·1	9·1
18	7·8	65·2	58	14·4	87·4	98	36·7	9·7
19	7·2	265·8	59	15·0	288·0	99	37·2	310·2
20	6·7	266·3	60	15·6	288·6	100	37·8	310·8
21	6·1	66·9	61	16·1	89·1	101	38·3	11·3
22	5·6	67·4	62	16·7	89·7	102	38·9	11·9
23	5·0	68·0	63	17·2	90·2	103	39·4	12·4
24	4·4	68·6	64	17·8	90·8	104	40·0	13·0
25	3·9	69·1	65	18·3	91·3	105	40·6	13·6
26	3·3	69·7	66	18·9	91·9	106	41·1	14·1
27	2·8	70·2	67	19·4	92·4	107	41·7	14·7
28	2·2	70·8	68	20·0	93·0	108	42·2	15·2
29	1·7	271·3	69	20·6	293·6	109	42·8	315·8
30	1·1	271·9	70	21·1	294·1	110	43·3	316·3
31	− 0·6	72·4	71	21·7	94·7	111	43·9	16·9
32	± 0·0	73·0	72	22·2	95·2	112	44·4	17·4
33	+ 0·6	73·6	73	22·8	95·8	113	45·0	18·0
34	1·1	74·1	74	23·3	96·3	114	45·6	18·6
35	1·7	74·7	75	23·9	96·9	115	46·1	19·1
36	2·2	75·2	76	24·4	97·4	116	46·7	19·7
37	2·8	75·8	77	25·0	98·0	117	47·2	20·2
38	3·3	76·3	78	25·6	98·6	118	47·8	20·8
39	+ 3·9	276·9	79	+26·1	299·1	119	+48·3	321·3

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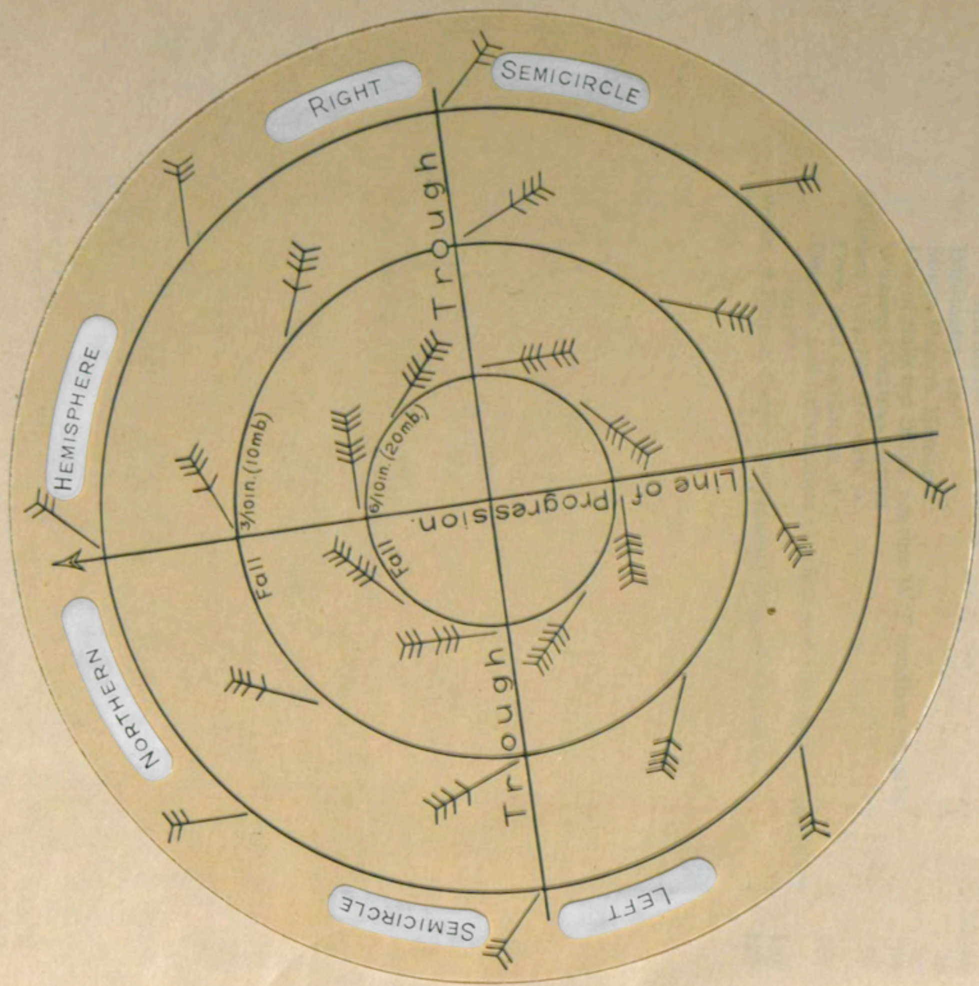

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