Official, No. 61.

A BAROMETER MANUAL
FOR THE USE OF SEAMEN;
A TEXT BOOK OF MARINE METEOROLOGY

WITH AN APPENDIX
ON
THE THERMOMETER, HYGROMETER, AND HYDROMETER.

Issued by the Authority of the Meteorological Committee.

SEVENTH EDITION.

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.
To be purchased, either directly or through any Bookseller, from
WYMAN AND SONS, LIMITED, FETTER LANE, E.C.; or
H.M. STATIONERY OFFICE (SCOTTISH BRANCH),
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T. FISHER UNWIN, LONDON, W.C.

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PREFACE.

The Barometer Manual for the use of Seamen was originally issued by the Meteorological Council in 1884 as a revised edition of the Barometer Manual prepared by Admiral Fitzroy, which had then long been out of print.

The editions which have been issued from the Meteorological Office are as follows :—

First edition	... ...	1884
Second „	... ...	1894
Third „	... ...	1896
Fourth „	... ...	1900
Fifth „	... ...	1905
Sixth „	... ...	1909

Altogether, about 25,000 copies of the work have been issued.

The charts of barometric pressure for the globe (Plates III. to VIII.) have been compiled from the material in possession of the Office, and on those for January and July wind arrows have been inserted showing the actual results of the wind observations, based for the most part on data arranged according to two-degree squares, for those parts of the ocean of which the observations have been discussed in this Office.

The present edition has been prepared in the Marine Division of the Office under the superintendence of Commander M. W. Campbell Hepworth, C.B., R.D., R.N.R. It differs from the Sixth edition mainly by the addition of certain paragraphs in the text and of tables for the mutual conversion of temperature observations on the Fahrenheit, Centigrade and Absolute scales. An additional Appendix has been inserted giving the velocity equivalents of the several numbers of the Beaufort scale of wind force and the wave heights corresponding with the scale, 0—10, of sea disturbance, both of which have been drawn up in the Office ; together with empirical formulæ by which the two pairs of quantities may be respectively connected.

W. N. Shaw,
Director.

Meteorological Office,
London, S.W.,
11th April, 1912.

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A

BAROMETER MANUAL

FOR THE USE OF SEAMEN.

Chapter I.

THE BAROMETER.

Description of the Instrument and Instructions for its Management.

The barometer is an instrument with which to measure the variations in the weight or pressure of the atmosphere. Two kinds are in use for observations at sea, the mercury and the aneroid. The principle of the mercury barometer was discovered by Torricelli in 1643; but the instrument was not utilized by seamen until a century had elapsed, and its form had undergone several modifications in the interval. A mercury barometer consists of a glass tube closed at one end, which is filled with pure mercury, all air being carefully excluded; the tube is then inverted, and its open end immersed in a small cistern, also containing mercury, so as to prevent air entering the tube. Great care is taken to exclude the air, as its presence even in minute quantity will vitiate the readings of the instrument. The pressure of the atmosphere on the surface of the mercury in the cistern maintains the mercury in the tube at a height which corresponds to that pressure, and measurements with the instrument are made by reading the height of the column in the tube above the surface of the mercury in the cistern. A small hole in the upper part of the cistern, H, Fig. 1, admits access to the superincumbent air; and a washer of leather permits of the atmosphere exerting pressure but prevents the mercury escaping from the cistern. English instruments are graduated in inches and decimals of an inch, the average height at the sea level being rather less than 30 inches, though the mercury sometimes rises to slightly above 31 inches and falls below 27·5 inches.

In all mercury barometers of the Kew pattern issued by the Meteorological Office the glass tube is considerably contracted for the greater part of its length in order to prevent unsteadiness of the mercury column or "pumping," as this is called; also to strengthen the tube, and to lessen the weight of mercury.

The tubes are furnished with an "air trap" to prevent air from working into the space at the top of the mercury column. The air trap consists of a small funnel or "pipette" which is introduced between the cistern and the wider portion of the tube (*see* Fig. 1).

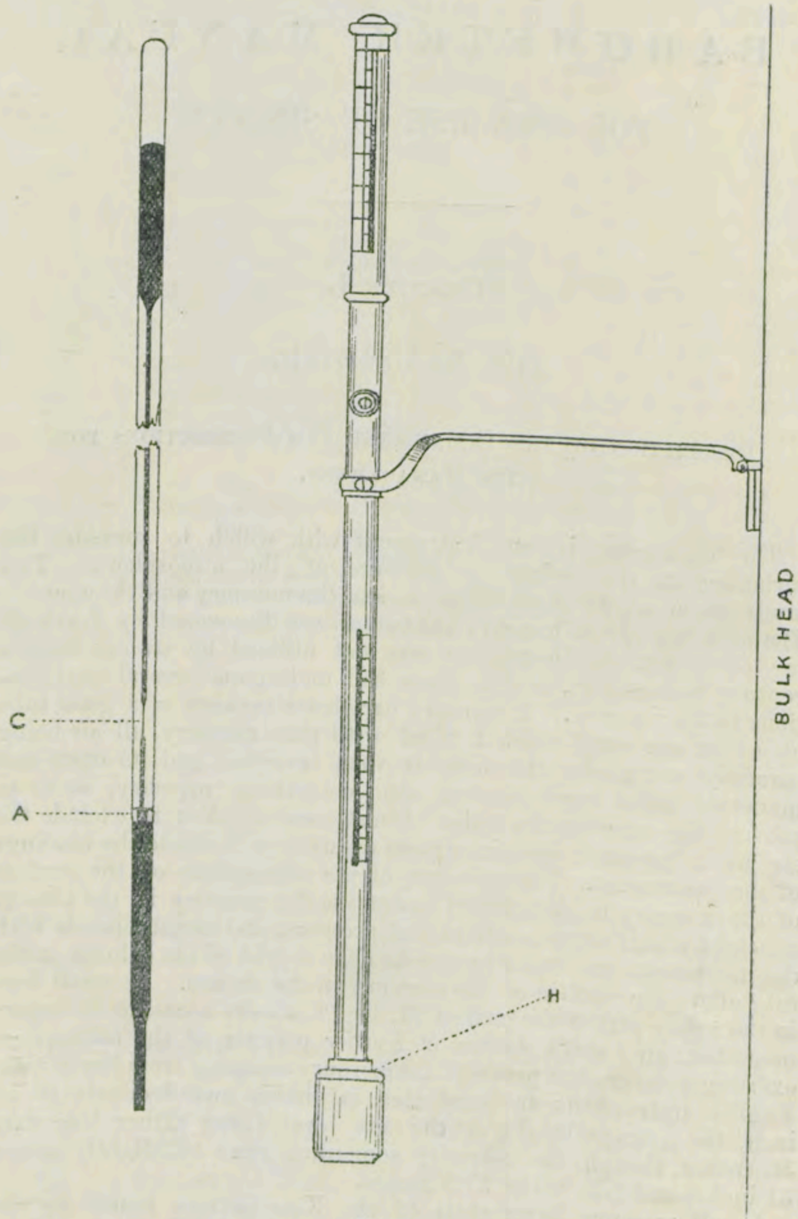


Fig. 1.

By means of this arrangement any air entering the tube becomes imprisoned at the shoulder A, and therefore cannot interfere with the efficiency of the instrument. In marine barometers of this

pattern a part of the contracted portion of the tube is further constricted with the object of reducing the pumping caused by the labouring of a vessel in a seaway. In Fig. 1, a Meteorological Office barometer is shown suspended from a bulkhead ; a principal section of the tube, in which A indicates the air trap ; and C, a specially contracted portion of the capillary tube, is also shown.

In handling barometers it should be remembered that they are delicate and expensive instruments. The result of rough treatment is breakage ; and for scientific purposes, observations with an instrument that has been repaired, and not verified by comparison with an instrument the error of which is known, may prove useless.

The barometer should hang where it can swing freely, so as always to take up an exactly vertical position ; it should be carefully protected from injury ; out of the reach of persons passing near it ; and fixed in a convenient place for observing, if possible with the light coming from behind the observer, and where it is not liable to considerable changes of temperature, and therefore away from the influence of sunshine or the direct heat of fires or lamps.

A bracket and screws for suspending the barometer are supplied with it. The bracket having been screwed to the bulkhead, the instrument should be carefully lifted out of its box, the hinged part of the suspension arm bent back, and the barometer shipped into the bracket. The mercury will then fall gradually, and the instrument will usually be ready for observation in about an hour ; but, as local temperature affects the instrument slowly, it may be well not to record observations from it for some hours after first fixing. Sometimes in a new tube the mercury does not readily quit the top of the tube. If, after an hour or so, the mercury has not descended, tap the cistern end rather sharply, or make the instrument swing a little in its gimbals, which should cause the mercury to fall in the tube. If this method does not succeed, the force of the tap must be slightly increased, but violence must not be used.

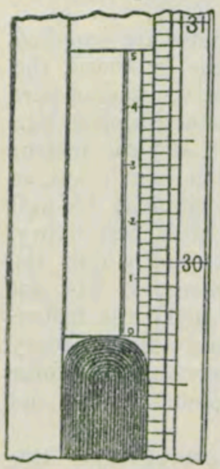
Whenever a barometer has to be unshipped and placed in its box, first lift the instrument out of the bracket, and bring it gradually into an inclined position, to allow the mercury to flow very gently up to the top of the glass tube, avoiding any sudden movement which would cause the mercury to strike the top of the tube with violence, as the absence of air there makes the force of the blow little different from that of a solid rod of metal, so that it might break the tube. The barometer should then be taken lengthwise and laid in its box. To be carried with safety it should be held with the cistern end upwards, or lying flat ; and it must not, on any account, be subjected to jars or concussions. In ships of war barometers should, therefore, be always unshipped when heavy guns are being fired, etc.

Experience shows that it is advisable to give some directions as to packing barometers. If the instrument is to be sent by rail or other conveyance, and is thus liable to be handled by persons unacquainted with its construction, it should, after having been placed in its box as directed, be enclosed in a packing case with two or three inches of soft elastic packing all round it, such as hay, straw, shavings, tow, or paper-cuttings. To avoid concussion, the lid of the case should not be nailed down, but always fastened with screws. The address label should be pasted, or nailed, on the end of the case which is next the cistern of the barometer before the lid is screwed down, and it should be marked "Glass and fragile instruments. Keep this box lying flat, or carry it this end upwards." If two or more barometers be packed together, the cisterns should all be placed at this marked end of the case. Barometers should be sent by passenger train, or by whatever route or conveyance affords the means of transit least likely to lead to rough usage. Transhipment or change of conveyance should be avoided if possible.

Method of Reading the Barometer.

To facilitate taking accurate readings of the barometer, a small moveable scale, called a "vernier," so named after its inventor Pierre Vernier (A.D. 1630), is attached to the instrument as shown in Fig. 2.

Fig. 2.



The general principle of this contrivance is that a given length of the vernier, equal to a certain number of divisions of the fixed scale, is divided into one more or one less than that number of divisions. In standard barometers the fixed scale is divided into inches, tenths, and half-tenths, each of which last is therefore ·050 of an inch. Twenty-five divisions of the vernier are made to coincide with twenty-four of the smallest divisions of the fixed scale; therefore a space on the scale is larger than a space on the vernier by the twenty-fifth part of ·050, that is to say by ·002 of an inch.*

The vernier is moved by a rack and pinion which ends in a milled head. To set the vernier for reading, turn the milled head of the pinion so as to bring the lower edge of the vernier exactly on a level with the top of the mercury column. When set properly, the front edge of the vernier, the top of the mercury, and the back edge of the sliding piece, must

* *Note on the graduation of barometers.*—It is still usual to graduate barometers for use in English speaking countries in inches, tenths and twentieths of an inch of mercury and to extend the accuracy of reading to the hundredth or thousandth of an inch by means of a vernier. In view of the close association of meteorological science with other branches of physics which are taught in English schools and which use the metric system it has been found desirable in some of the publications of the Meteorological Office, particularly in those which deal with the investigation of the upper air, to give the results in units belonging to the metric system. The unit of pressure employed in such cases is independent of the particular liquid used or of the position on the earth's surface and is called the *millibar* and is about three-quarters of a *millimetre* of mercury at latitude 45° or one thirtieth of an *inch* of mercury at the same latitude. This unit is within narrow limits one thousandth part of the average pressure at sea level and for many practical purposes can be taken as such. The unit is not used in this work but the explanation may be required in connexion with the other publications referred to.

be in the line of sight, which line will thus just touch the middle and uppermost point of the convex or curved surface of the mercury in the tube. Great care should be taken to acquire the habit of setting the vernier with the eye exactly on a level with the top of the mercury, that is, with the line of sight at right angles to the tube, which, while the observation is being made, should hang freely in a truly vertical position. The instrument should not be disturbed by being held or even touched; because any inclination will cause the column to rise in the tube. Fig. 3 is a graphical representation of the incorrect results arising from errors of parallax.

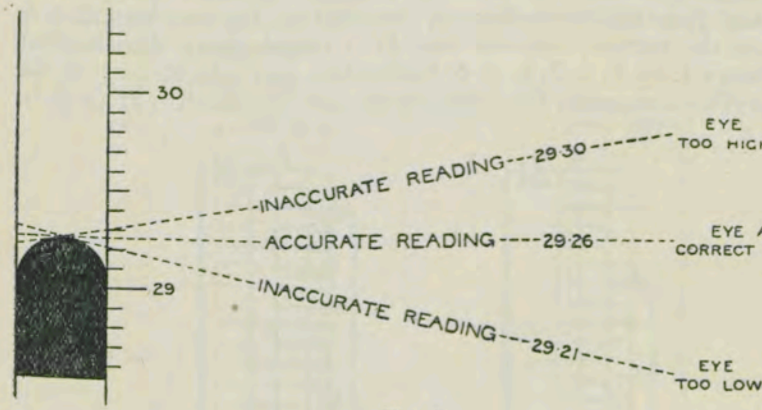


Fig. 3.

If the vernier has not been moved between two successive observations, it is advisable to check the previous reading before proceeding to reset the vernier.

A piece of white paper placed behind the tube to reflect the light assists in setting the vernier accurately, and at night a small bull's-eye lamp may for this purpose be held so as to throw a strong light on the paper.

The mode of reading off the height, when the vernier has been set, may be learned from a study of the diagrams, Figs. 4 and 5 (p. 10), in which A B represents part of the scale, and C D the vernier, the lower edge of which, D, has been brought to coincide with the top of the mercury column. The scale is readily understood; B is 29·000 inches; the first line or division above B is 29·050; the second line or division 29·100, and so on. The first thing is to note the scale division just below D, and the next is to find out the division of the vernier which is in one and the same line with a division of the scale. In Fig. 4 the lower edge of the vernier, D, is represented in exact coincidence with scale division 29·5; the barometer therefore reads 29·500 inches. Studying it attentively in this position it will be perceived that while the top C again coincides with a line on the scale, the other divisions of the vernier are more or less separated from the divisions of the scale nearest to them. As was before stated one division of the vernier is ·002 inch smaller than one division of the scale, consequently with the vernier in the position shown in Fig. 4 the division *a* is ·002 inch below the nearest line, *z*, of the scale. If, therefore, the vernier be moved upward, so as to place *a* in a line with *z*, the edge D would be raised ·002 inch, and it would read 29·502, and this would be the height of D on the scale. In like manner it is seen that *b* on the vernier is ·004 inch below the line next above it on the scale; *c*, ·006 inch below that next above it; *d*, ·008 inch from that next above it; and 1, on the vernier, is ·010 below *y* on the scale. Hence, if the lines *b*, *c*, *d*, and 1, be moved in succession into line with the divisions next above them D would be raised ·004, ·006, ·008, and ·010 in succession, and would read 29·504, 29·506, 29·508, and 29·510. Thus, coincidences of lines on the vernier and the scale at the numbers 1, 2, 3, 4, 5, on the vernier, indicate that D is raised above the scale line next below it by 1, 2, 3, 4, or 5 hundredths, and coincidences at the intermediate lines mark the intermediate even thousandths of an inch.

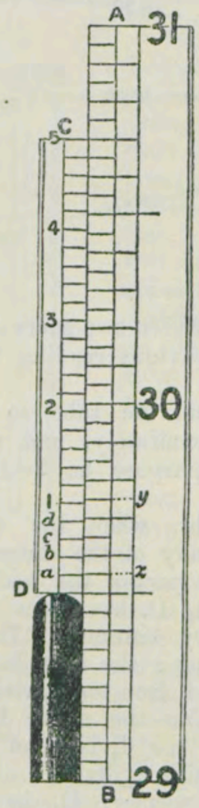


Fig. 4.

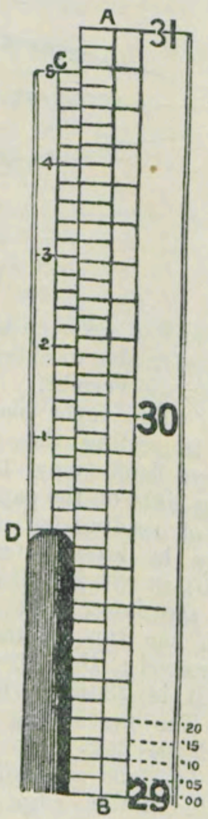


Fig. 5.

The application of this will be seen from Fig. 5. The bottom of the vernier D having been brought into coincidence with the top of the mercury, the scale line just below D is 29·650. Looking carefully up the vernier, the third line above the figure 3 is seen to lie evenly with a line on the scale. The number 3 indicates ·030,

and the third subdivision ·006; so that D is ·036 above the scale line next below it, and thus we get—

Reading on scale	29·650
Reading on vernier	{ ·030 ·006
Actual reading, or height of mercury,	29·686 inches.

Sometimes two pairs of lines will appear to be coincident, in which case the intermediate thousandth of an inch should be set down as the reading. Thus, suppose coincidences appear corresponding to 29·684 and 29·686, then 29·685, half way between them, should be adopted.

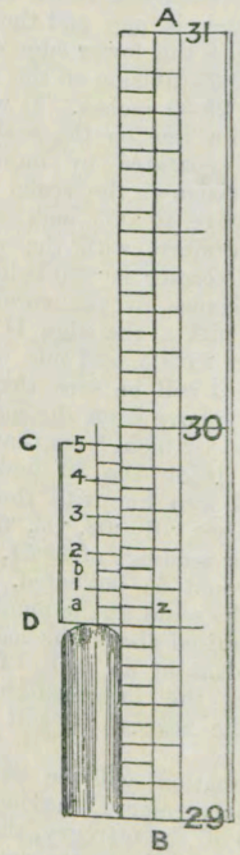


Fig. 6.

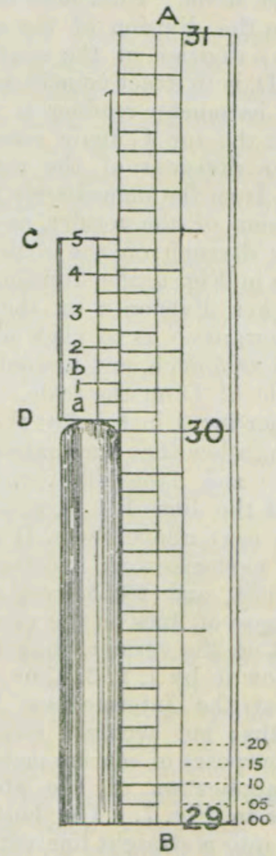


Fig. 7.

The Meteorological Office has issued a barometer for use at sea with a vernier which allows of barometrical readings being taken to the nearest half-hundredth, or ·005 of an inch. The divisions of the fixed scale are each ·050 inch; nine of these are taken as the length of the vernier, which is, therefore, ·45 inch. This length is divided into ten equal parts, consequently each division of the vernier is ·045 inch. Hence the difference of length between a division of the scale and one of the vernier is

·050 − ·045 = ·005 inch.

It is not necessary, however, to record the height of the barometer at sea to thousandths of an inch, readings to hundredths are sufficiently accurate.

A comparison of Figs. 6 and 7 with Figs. 4 and 5 is sufficient to explain the method of effecting the change. In Figs. 6 and 7, AB represents part of the scale, and CD the vernier, the lower end of which, D, has been brought to coincide with the top of the mercury column. The scale is readily understood. B is 29·00 inches, the first line or division above B is 29·05, the second line or division is 29·10, and so on. First note the scale division just below D, next determine the division of the vernier which is one and the same line with a division of the scale. In Fig. 6 the lower edge of the vernier, D, is in exact coincidence with 29·50 division on the scale; and the barometer reading is therefore 29·50 inches. It will be seen that the top C again coincides with a line on the scale, but the other divisions of the vernier are separated by increasing amounts from the immediately higher division on the scale. Now one division of the vernier, as stated above, is ·005 inch smaller than one division on the scale, and, therefore, with the vernier shown as in Fig. 6, the division *a* on the vernier is ·005 below the next higher division *z* on the scale. Hence, if the vernier be moved upward so as to place *a* in a line with *z*, the edge D would be raised ·005 inch, and it would indicate 29·505, and this will be the height of D on the scale. Similarly it will be seen that 1 on the vernier is ·01 inch below the line next above it on the scale; *b*, ·015 inch below that next above it; 2 is ·02 inch from that next above it; and 5 on the vernier is ·05 below the 30 inch line. Hence if the lines 1, 2, 3, 4, 5 be raised into line with the scale divisions next above them, D will be raised ·01, ·02, ·03, ·04, and ·05 inch, in succession; and the barometer readings of 29·51, 29·52, 29·53, 29·54, and 29·55, respectively, would be indicated. Thus coincidences of lines on the vernier and the scale at the numbers 1, 2, 3, 4, 5 on the vernier, show that D is raised above the scale line next below it by 1, 2, 3, 4, or 5 hundredths of an inch. Coincidences at the intermediate lines mark the intermediate half hundredths; but accurate readings to the nearest ·01 will suffice for the purposes of marine meteorology.

The application of the above explanation will be seen by reference to Fig. 7. The bottom of the vernier D having been brought into a straight line with the top of the mercury, the scale line just below D is 30 inches. Looking carefully up the vernier it will be seen that the line against the figure 3 lies evenly with a line on the scale. The number 3 indicates ·03; hence D is ·03 above the scale line next below it, and thus we get—

Reading on scale	30·00
Reading on vernier	·03
Actual reading, or height of mercury,	30·03 inches.

Sometimes two pairs of lines will appear to be coincident as with the 3 line and the shorter line in figure; then, if extreme accuracy is required, half way between them is 30·035, and that should be adopted as the reading. For the ordinary purposes of marine meteorology, however, either 30·03 or 30·04 will be sufficiently near.

If the barometer is pumping at the time of observation the vernier should be set for reading when the mercury, rising and falling in the tube with the heave of the ship, has completed its downward movement. It should be borne in mind that it is not the mercury in the cistern of a barometer which rises and falls with the motion of the ship, but the mercury in the tube.

Corrections of Readings of the Barometer.

As the column of mercury lengthens when heated and shortens when cooled, because hot mercury is specifically lighter than cold, it is necessary to apply to the readings of the instrument a correction for temperature, to show what the reading would have been at the temperature of 32° F., the standard temperature to which all barometrical readings are reduced. A correction is also required to compensate for the variations of temperature of the brass scale. It is therefore essential to take, and register, a careful reading of the thermometer fixed to the instrument, usually called the "attached thermometer," whenever an observation of the barometer is made. When the thermometer attached to the barometer is above 28°, the correction, for which a table will be found in Appendix II. (p. 62), must be subtracted, and when at, or below, 28°, must be added.

The readings taken on board ship, where the temperature is usually above the freezing point, will therefore commonly be higher than the values given on charts which show the mean height of the barometer, corrected for temperature; the difference depending on the temperature at which the barometer on board happens to be at the time the reading is taken and the height of the instrument above sea level. For a temperature of 80° and a barometrical reading of 30 inches, the correction, to be subtracted from the observed height, would be ·139 of an inch with the barometer cistern at sea level.

The marine barometer which is issued to observers by the Meteorological Office is so constructed as to obviate the necessity for applying corrections, either for capillarity, which tends to depress the mercury in the tube, or for the varying quantity of mercury in the cistern, which are required for some barometers. A label giving the results of a comparison with a standard is pasted in the case.

As the pressure of the air is reduced as we rise above the sea level, a correction of the barometer readings is also required to obtain the pressure at sea level. This amounts to about ·001 inch for each foot above the sea, and is always to be added.

The correction for height above sea level in the days of small sailing ships was comparatively unimportant; but with the barometer cistern 60 or 70 feet above sea level as in the largest liners,

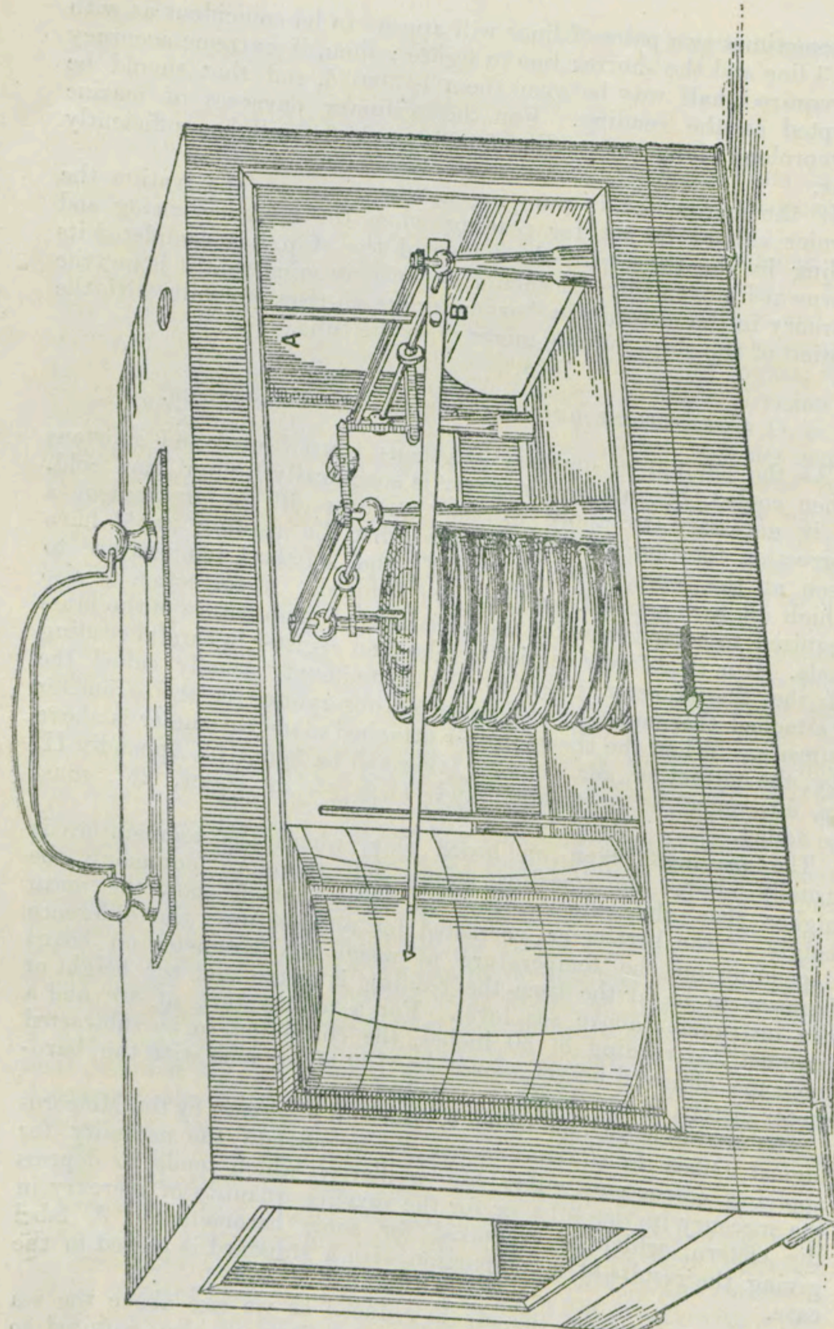


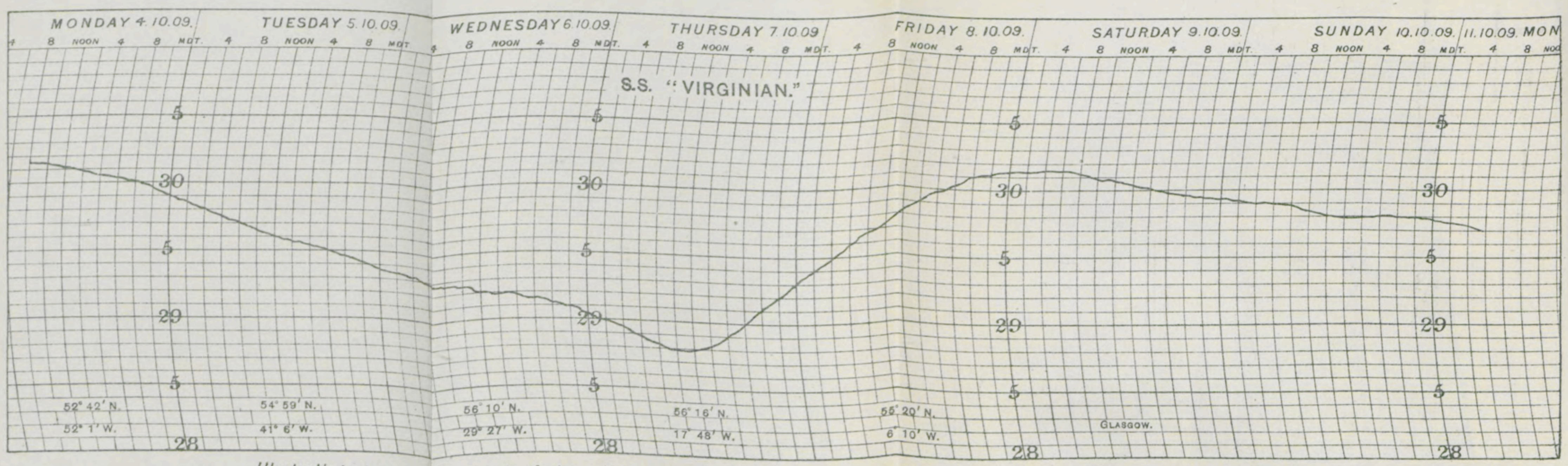
Fig. 8.

this correction will be as much as + ·08, and may not be neglected as the table on p. 20 shows. It is, however, advisable, when

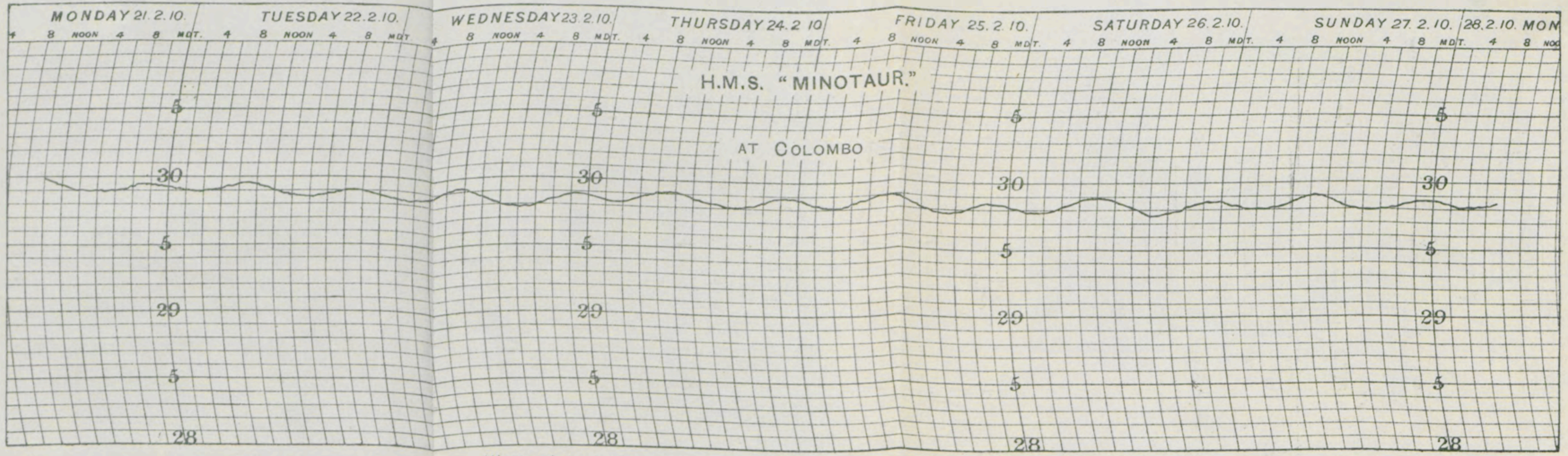
To face p. 15.

BAROGRAPH TRACES.

PLATE II.



Illustrating a non-periodic change of atmospheric pressure associated with the passage of a cyclonic depression over the North Atlantic.



Illustrating diurnal range of atmospheric pressure in the Indian Ocean.

Wyman & Sons, Ltd Litho. M.O. Press London S.W.

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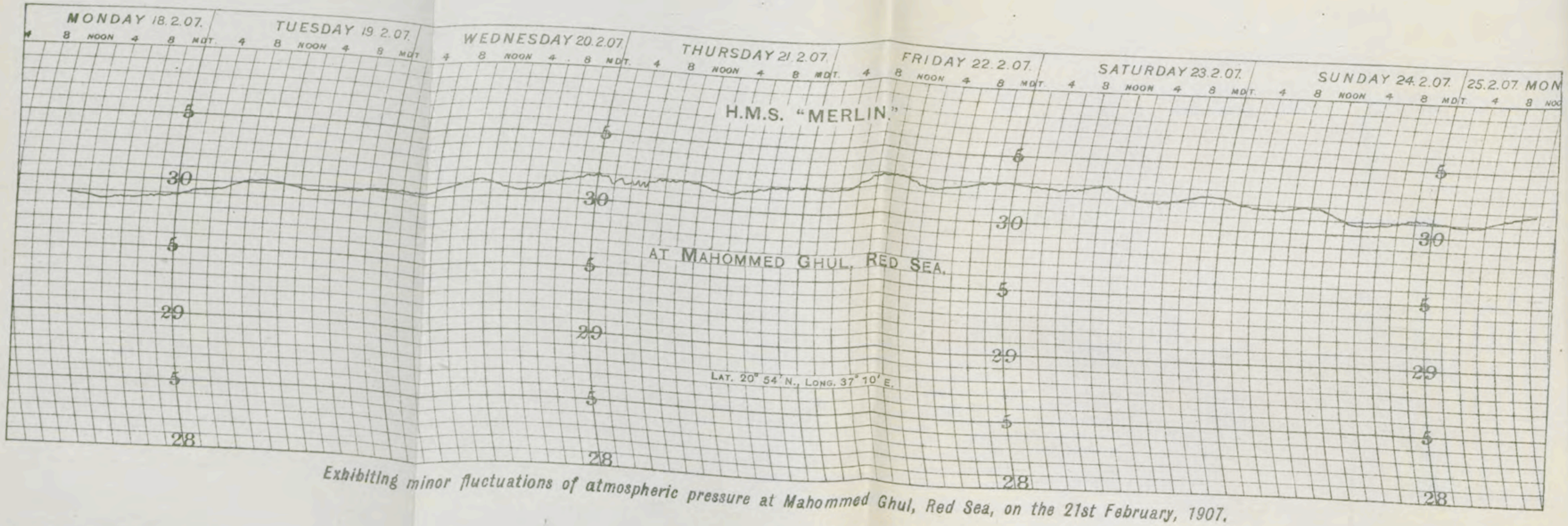
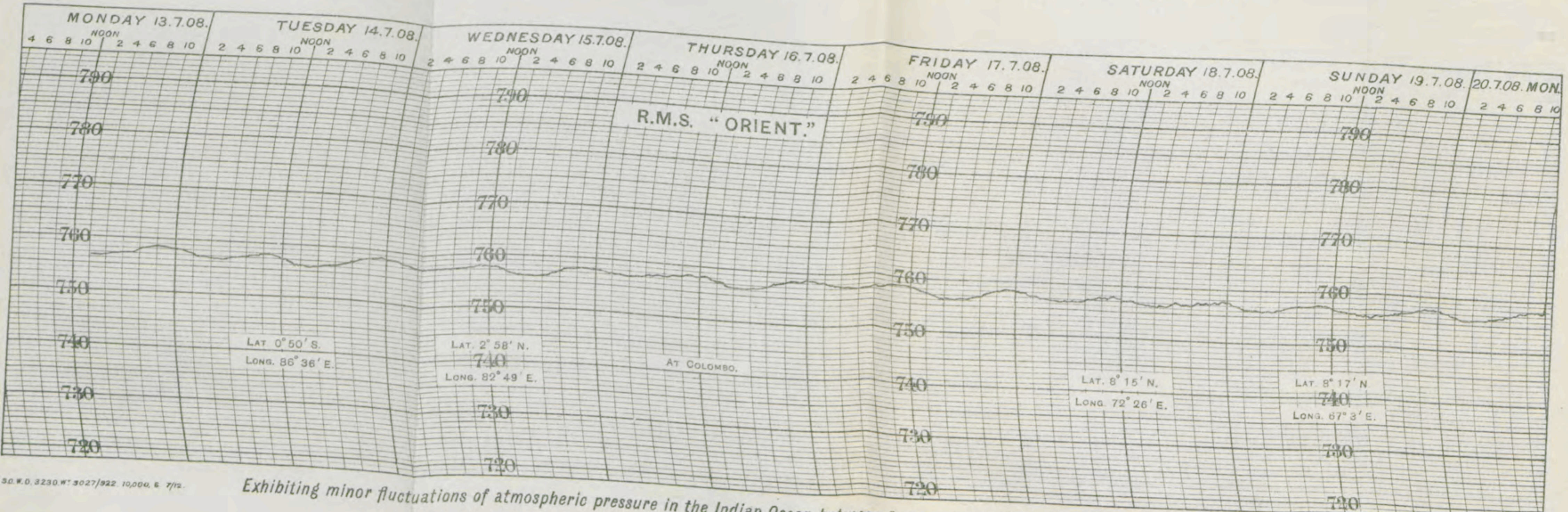
BAROGRAPH TRACES.

PLATE I.



Exhibiting minor fluctuations of atmospheric pressure at Mahommed Ghul, Red Sea, on the 21st February, 1907.



Exhibiting minor fluctuations of atmospheric pressure in the Indian Ocean between 8 a.m. on the 18th and 4 a.m. on the 19th July, 1908.

SO.W.D. 3230.WT 3027/922. 10,000. 8. 7/12.
WYMAN & SONS Ltd LITHO. M.O. PRESS, LONDON, S.W.

practicable, to hang the barometer in a position near the centre of gravity of the ship, as then the mercury will oscillate least as the ship pitches or rolls.

The Aneroid barometer is another instrument for measuring changes in pressure. It consists of a circular metallic chamber partially exhausted of air and hermetically sealed. By an arrangement of levers and springs, a hand is worked which indicates the pressure.

This instrument is particularly useful in ships, as it can be placed in a position immediately under the eye of the officer on deck, which, generally speaking, is not a practicable, or advantageous position, for a mercury barometer. The aneroid should be frequently compared with the mercury barometer, and corrected, when necessary, by means of the adjusting screw at the back. Whenever such an alteration of the index error is made, the fact should be clearly stated in the logbook, or on any records of observations, as a guide to persons consulting the data for use in the future.

Readings of aneroids do not require correction for temperature, but only for height above sea level and index error. The figure given for the correction of the aneroid barometer of ships in communication with the Meteorological Office is frequently a combined result, and makes allowance for both height and index error.

A portable "Barograph," which is an aneroid barometer provided with a lever recording variations of pressure on a revolving drum, is in some respects a more valuable supplement to the mercury barometer on board ship than the aneroid of the ordinary form. It is not only useful in enabling an observer to detect casual errors in the readings of the mercury barometer but also gives a continuous record of barometric pressure for reference (*see* Plates I. and II.). Barograms, moreover, register minor fluctuations of atmospheric pressure which are seldom noticeable in the action of the mercury barometer, and that without the uninterrupted evidence furnished by a sensitive self-recording instrument are rarely detected. The instrument should be secured or suspended in a position where it will be least affected by concussion, vibration, or the movements of the ship.

Attention has been directed on several occasions by the Meteorological Office to the association of these minor fluctuations of pressure disclosed by the barogram, which are aptly described as the "embroidery" of the trace, with occurrences of rain, hail or snow showers, usually accompanying a squall. This joggle in the trace concurrent with showers, and not infrequently with a transient increase of wind, is an interesting feature in barographic records, showing as it does the close connexion that exists between variations in barometrical pressure, however slight, and weather changes.

A barogram, reproduced on Plate I., recorded on board H.M.S. "Merlin" at Mahommed Ghul on the Red Sea exhibits small fluctuations of pressure from noon to noon on the 20th and 21st of February 1907. In the meteorological log kept on board the "Merlin" passing showers are recorded during that period, accompanied at times by squalls; but during the rest of the period to which the barogram relates fair weather conditions obtained. On the same Plate is also given a copy of a barogram registered on board the R.M.S. "Orient," during a passage in the Indian Ocean between Ceylon and the Red Sea. Slight variations in pressure are discernible in this trace between noon and noon on the 18th and 19 which relates to July 1908; and these minute joggles are found, by referring to the meteorological log kept on board the "Orient," to be associated with the occurrence of a number of squalls accompanied by rain. Prior and subsequent to this period, during the week on which the trace was made, the weather was overcast or cloudy, but not disturbed.

The action of the Barograph, briefly, is as follows:—The circular metallic chamber, consisting of a series of vacuum metal boxes with elastic lids, is connected with the revolving drum by means of a lever carrying a pen filled with specially prepared ink. The rotation of the drum is effected by means of clockwork contained in the drum which is designed to complete a revolution in seven days.

The variation in the volume of these vacuum boxes, caused by changes in atmospheric pressure, is transmitted through the lever to the pen, which registers the changes in a continuous line on a printed chart fitted round the drum.

The timepiece may be regulated by moving the pointer on the balance of the clockwork. Should the timepiece be fast the pointer should be moved in the direction R.S. (retard, slow); if slow, in the direction A. F. (avance, fast); but frequent movement of the pointer should be avoided.

The setting of the Barograph to time presents some difficulties, because ship's time changes from day to day during a passage, while the timepiece of the instrument, if in proper order, will keep the time at which it is originally set. Thus, if the pen is set correctly for ship's time in longitude 75° W., the instrument will continue to show the time for that longitude for the whole week, and at the end of the week may be as much as five hours slow of ship's time. It is therefore recommended that the pen be set to show Greenwich Mean Time correctly, and it will then continue to show that time however the position of the ship may change.

A time mark, showing Greenwich Mean Noon, should be made each day. If, however, for any special reason the observer sets the pen mark to ship's time on the chart at the beginning of the week he should mark ship's noon on the chart each day. In any case the plan adopted in this connexion should be clearly stated on the back of the chart. The records of the instrument, or *traces* as they are termed, should be examined carefully by the observer from time to time, in order that inaccuracies caused by the pen pressing too closely on the chart may be discovered. The pen should press sufficiently on the chart to leave a clear uninterrupted trace. The records should be compared frequently, or when an opportunity occurs, with the readings of a reliable mercury barometer corrected for instrumental error and temperature, and the result noted on the back of the chart. Should it be found, however, that the difference between the Barograph and the Barometer readings is large the pen of the former should be reset.

A fine clear line should be traced by the pen of the barograph; if a thick line is produced it may be due to rough or badly sized paper, to bad ink, or to a foul pen. If the pen requires cleaning it should be carefully cleansed with a brush and as carefully dried. An implement such as a knife should on no account be used for this purpose.

The Barograph, when used on board ship, may either be carried in a cradle slung on gimbals, the cradle being secured, or suspended from the deck above. It should be located in a position where it will be least affected by concussion, vibration, or movement of the ship. During gun firing the pen's point should be moved from the paper.

Chapter II.

BAROMETRICAL PRESSURE.

Connexion of Changes of Barometrical Pressure with Changes of Weather.

All wind is air in sensible motion. The force of the wind, and changes of weather generally, are closely related to the disturbances of pressure which accompany or cause them, and to the rapidity with which those disturbances take place. The barometer furnishes the seaman with the means of ascertaining with considerable certainty both the magnitude of these disturbances and the manner in which they are occurring, and it is the object of this manual to explain how this knowledge may be best obtained and applied.

If readings of the barometer be taken carefully and regularly at equal intervals of time, it will be found that consecutive readings will rarely coincide with one another. By such observations the changes which take place from hour to hour and from day to day in the pressure of the atmosphere may be observed, and useful indications obtained of the approach of disturbances likely to be accompanied by strong winds or storms.

The barometer should therefore be set and read at regular hours, if possible at 4-hour intervals, or in doubtful weather more frequently, and the readings entered in the log. This is of primary importance, for if such a record is not kept, the person who consults the barometer will have no means of knowing when the instrument was last set, or at what rate any change he may notice is taking place.

The changes of pressure shown by the barometer may conveniently be classed as regular, or irregular, in their occurrence; or, in other words, periodical or non-periodical. The periodical changes of pressure, which depend on the time of the day or year, are hardly connected with changes of weather; it is the non-periodical changes which specially call for attention, as being indicative of probable strong winds or dangerous storms.

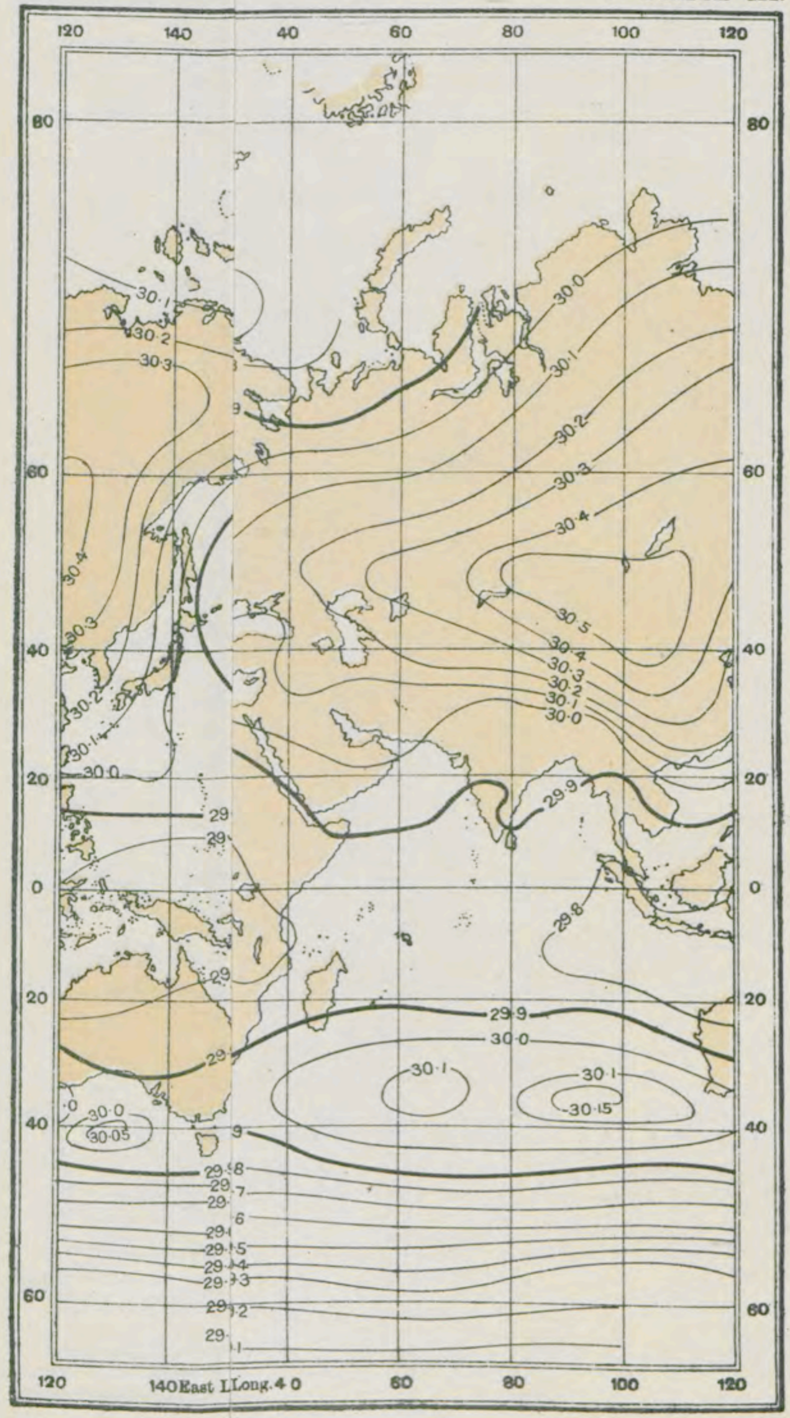
Influence of Temperature on Barometrical Pressure.

All changes in the pressure of the air, whether periodical or non-periodical, depend greatly on the changes of temperature, which take place at different hours of the day, or at the various seasons of the year, or arise at different places on the earth from various causes, among which may be mentioned, position with respect to latitude, distribution of land and sea, greater or less abundance of cloud or rain or quantity of vapour in the air. Speaking generally, since air expands with heat and contracts with cold, the result of any place being more heated than its neighbourhood is that the air above it expands, and the upper strata flow away from it over the surrounding less heated area. Conversely, above a relatively cold area the air will contract, and the upper strata will flow in towards it from the neighbouring areas. When a difference of pressure is established air tends to flow from high pressure to low pressure. But it must be remembered that the pressure measured by the barometer is determined by the whole height of the atmosphere and not by the lower layers alone. The distribution of pressure in the upper air may mask the effects of the lower strata. Consequently it must not be expected that the distribution of surface pressure can always be accounted for by the distribution of temperature as recorded at the surface. The motion of the air is not direct from high pressure to low pressure. The flow is indeed generally round the areas of high or low pressure, though there is as a rule an inclination towards the low pressure side from the high pressure side.

The accompanying charts (Plates III., IV., V., and VI.), to which reference will be made hereafter, show the average distribution of air pressure over the globe as given by the barometer for the months of February, May, August, and November, respectively. On these charts lines are drawn, showing where the average barometrical pressures indicated by the figures upon them are observed. These lines are termed isobaric lines, or isobars, because they pass through places having equal average barometrical pressure. They are drawn for each tenth of an inch of the barometer. Seamen are familiar with lines of soundings, and variation curves, laid down on navigating charts; and isobars are similarly used with respect to barometer readings on meteorological charts.

From these charts it will be seen that, speaking generally, in both hemispheres, in the winter, the barometer is higher over the land, which is then colder than the sea; and lower over the sea, which is then warmer than the land. In the summer the barometer is lower over the great continents, which are then relatively hot;

To face p. 18. PLATE III.



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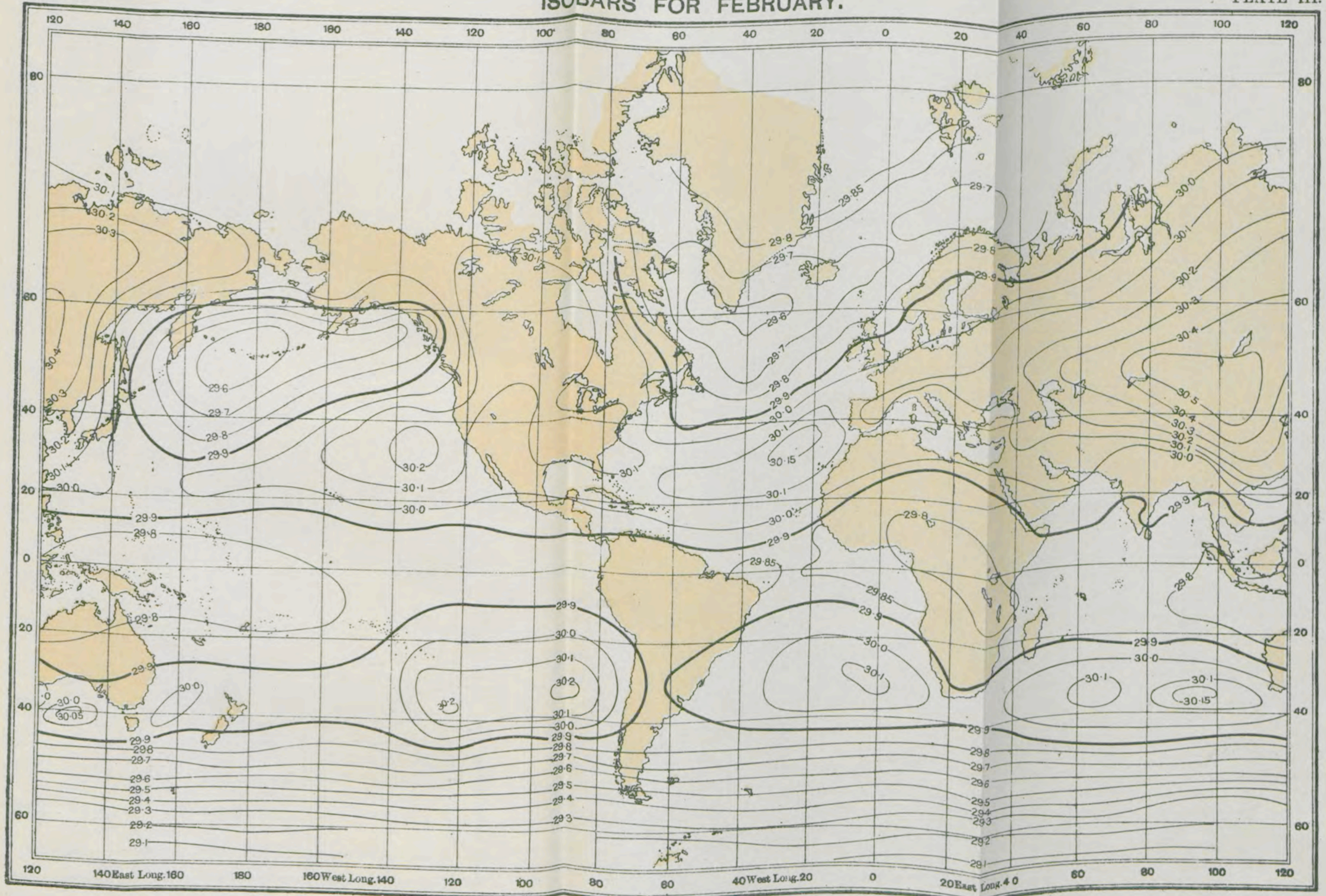
To face p. 18.

ISOBARS FOR FEBRUARY.

PLATE III.



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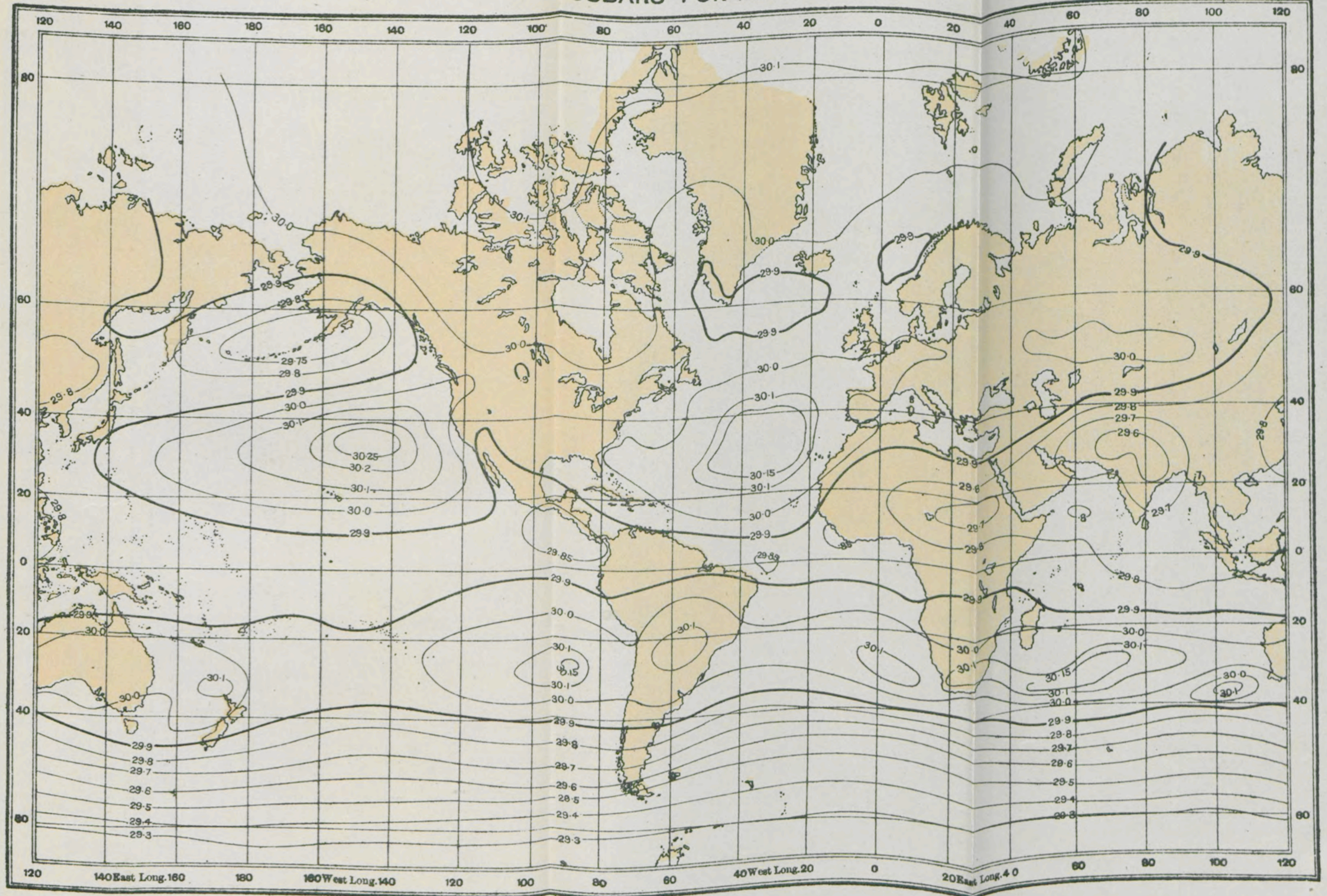
To face p. 18.

ISOBARS FOR MAY.

PLATE IV.



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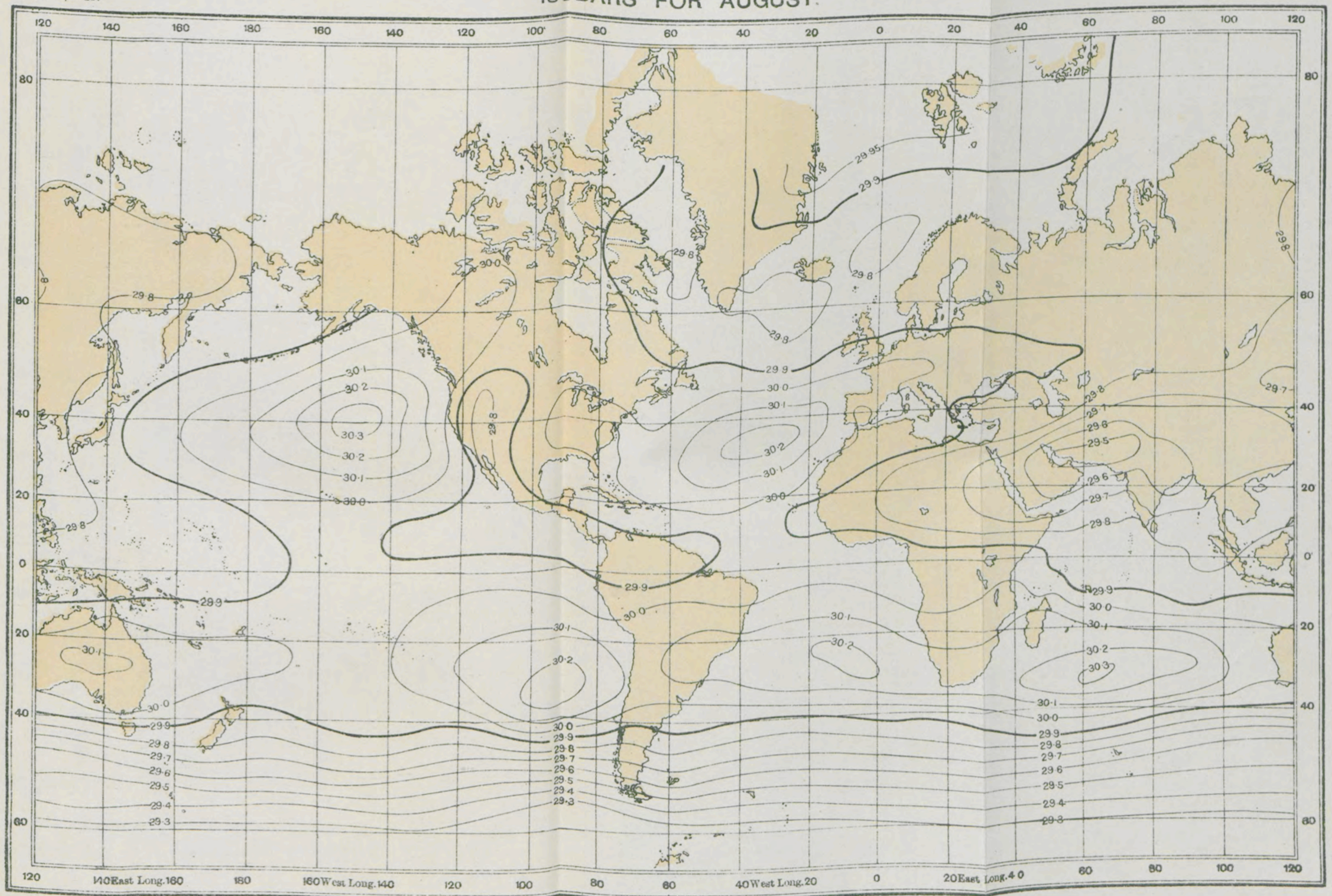
To face p. 18.

ISOBARS FOR AUGUST.

PLATE V.



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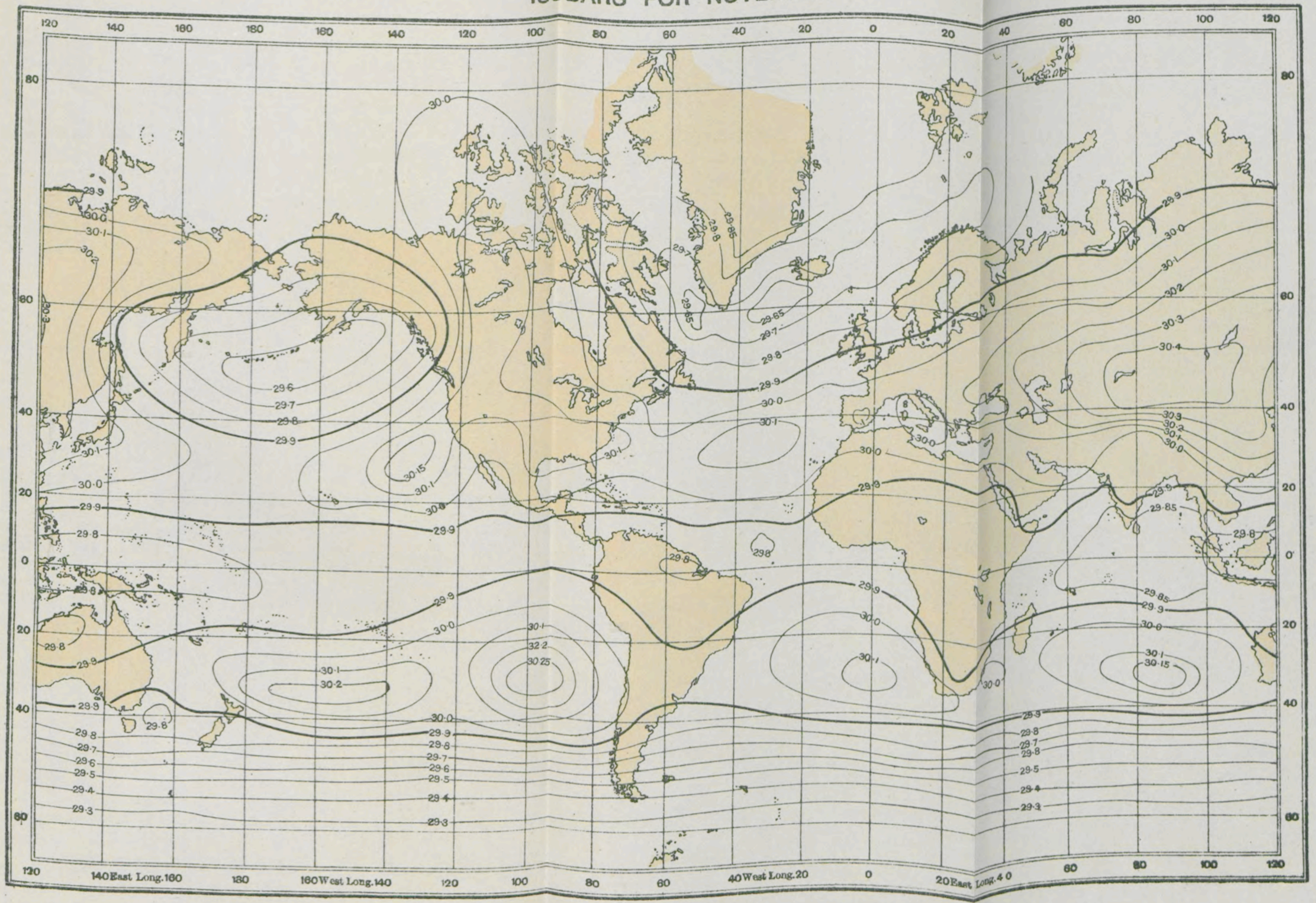
To face p. 18.

ISOBARS FOR NOVEMBER.

PLATE VI.



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and higher over the sea, which is then relatively cool. In the Southern Hemisphere these changes are not nearly so marked as in the Northern. The summer and winter occurring at opposite times of the year in the North and South Hemisphere, the greatest development of both high and low pressure in the Northern Hemisphere is seen in January, and in the Southern Hemisphere in July (see Plates VII., VIII.).

Over the Equator, between the tropics, the barometer is low relatively to the neighbouring zones. Over the sea, just north of Cancer and south of Capricorn, the barometer is always high.

The variations of pressure which thus arise over certain tracts of sea and land are related to permanent winds, such as the Trades, and also to periodical winds, such as the Monsoons, these last-named following a corresponding periodical change of pressure over the tracts where they are established.

Distribution of Mean Barometrical Pressure.

Before proceeding to consider more at length the relations which exist between winds and barometrical pressure, it is desirable to convey to the seaman a general conception of the usual distribution of pressure over the globe, and of the readings he may expect to obtain, as well as of the inferences which he may deduce from his actual observations.

With this object it is necessary again to refer to Plates III., IV., V., and VI., on which are shown the average or mean barometrical pressure over the several oceans and seas. The values used for the construction of the isobars have been corrected for index error of instrument, and reduced to the sea level at a standard temperature of 32° F. at the latitude of 45° N. or S. It will not be difficult from these Plates, together with those of January and July, to estimate with fair accuracy the probable mean pressure for the intervening months.

Inasmuch as the earth is a spheroid flattened at the poles, the weight of a given body, a column of mercury for example, is greatest at the Poles. As the weight of the same column of mercury increases from the Equator to either Pole, it is necessary for the sake of precision in comparison that some latitude shall be agreed upon as the standard for the measurement of weight. The latitude chosen is 45°. In latitudes lower than 45° N. or S., the mercurial column is longer than that at 45° for the same atmospheric pressure ; and shorter in latitudes higher than 45° N. or S. Hence the necessity for the reduction of barometer readings to standard gravity at 45°.

For purposes of comparison between an actual reading by a mercury barometer on board ship with the average value given on the isobar chart in this manual, at the same geographical position and for the same month, the seaman must first apply the correction for index error, if any, and then allow for the corrections for the temperature shown by the thermometer attached to the barometer, the height of the barometer cistern above sea level, and the reduction to standard gravity, by the aid of the following table :—

Corrections for Reducing Readings by Mercury Barometer.

To Temperature of 32° F.		To Sea Level.		To Standard Gravity at Latitude 45° N. or S.					
Temp. by Att. Ther.	Correction.	Height in feet.	Correction.	Lat. N. or S.	Correction. At 27 ins.	Correction. At 30 ins.	Lat. N. or S.	Correction. At 27 ins.	Correction. At 30 ins.
°	in. —	ft.	in. +	°	in. —	in. —	°	in. +	in. +
30	·00	10	·01	0	·07	·08	90	·07	·08
35	·02	20	·02	10	·07	·07	80	·07	·07
40	·03	30	·03	20	·05	·06	70	·05	·06
50	·06	40	·04	25	·05	·05	65	·05	·05
60	·09	50	·05	30	·04	·04	60	·04	·04
70	·11	60	·07	35	·02	·03	55	·02	·03
80	·14	70	·08	40	·01	·01	50	·01	·01
90	·16	80	·09	45	·00	·00	45	·00	·00

The correction is to be added when the sign +, and subtracted when the sign −, is at the head of the column.

Turning to Plate VII., it will be seen that in January, in about 10° N. 25° W., the average barometer is 29·95 inches ; suppose that the seaman desires to find the approximate error of his barometer from a mean of six consecutive four-hourly observations which is 30·06, the attached thermometer 78°, and the height of the barometer cistern 50 feet above sea level. The above table shows that entering it with the given values, the corrections for temperature, height and gravity, are −·14, +·05, and −·07, respectively. Combining these, the correction necessary to apply is −·16, and the reading for comparison with the chart is 30·06−·16 = 29·90 inches. Hence his barometer is ·05 inch too low ; or requires a correction of +·05, in addition to corrections for temperature, height, and gravity in order to make the readings comparable with those of the chart. Should the comparison be made with observations which are not corrected to standard gravity at latitude 45°, only the tables for temperature and height must be used according to the precept at the head of the column.

See also p. 62, relative to corrections of barometer readings. If an aneroid is used, the correction for temperature is not required when making a comparison.

The main features brought out by an examination of these charts are that over the sea the pressure is more uniform throughout the year than over the continents, and that, roughly speaking, the ocean, the part of the earth's surface which more immediately concerns the seaman, may be divided in respect of barometrical pressure into five great areas.

First, there is a belt of moderately low pressure over the equatorial regions. Then North and South of the equatorial region

are belts of high pressure. Proceeding to the higher latitudes, we find two areas of lower pressure ; a marked feature of the great Southern Ocean being a zone of low pressure forming a complete circuit of the globe, which, during the entire year, on the parallel of Cape Horn, is indicated by an average depression of the column of mercury to 29·50 ins., or fully half an inch below the pressure prevailing generally over the navigable oceans.

In the equatorial parts of these great oceanic areas the barometer stands at, or close to, 29·90 inches ; in the Atlantic Ocean for 10° of latitude on either side of the Equator the yearly mean is about 29·85 ins. From the tropics to about the 40th parallels of North and South latitude, the barometrical readings are above 30·00 inches, and in the central parts of these areas readings as high as 30·30 inches are found.

Proceeding into the higher latitudes North and South of the parallels of 40°, the pressure diminishes, and, as before stated, markedly so in the Southern Hemisphere, for on the parallel of the southern part of New Zealand, lat. 45° S., the mean pressure during the year is not more than 29·80 ins., and on the parallel of Cape Horn, lat. 55° S., is about 29·50 ins. In the northern part of the Atlantic Ocean, South of Greenland and Iceland, an area of low pressure is shown on all maps of monthly averages, but on the average in mid-summer, the barometer is three-tenths of an inch higher there than in mid-winter.

In the British Islands and adjacent waters, proceeding from South to North, the mean barometrical pressure ranges from 30·00 inches to 29·80 inches in mid-winter, and from 30·00 inches to 29·85 inches in mid-summer.

From these charts it will also be seen that during a voyage, made at any period of the year, from England to Australia or New Zealand by way of the Cape of Good Hope and thence back to England by way of Cape Horn, the readings of the barometer will, under average conditions of weather, have varied as much as seven-tenths of an inch, that is, between 30·2 inches, found in the high pressure areas of the North and South Atlantic Oceans, and 29·5 inches, found in the low pressure zone on the parallel of Cape Horn.

On the other hand, in a voyage from London by way of the Suez Canal to Bombay or Calcutta, or to ports in China, the barometer, under similar average conditions of weather, will not in mid-winter (January) stand below 29·8 inches, whereas in mid-summer (July) the readings will range from 30·0 inches in the Atlantic Ocean to 29·6 inches at the Indian ports, and 29·7 inches in the Chinese ports ; the low pressures last named mainly depending on the high summer temperature of the adjoining great continental masses of land.

Chapter III.

VARIATIONS OF PRESSURE.

Variations of Pressure from Mean Values.

The mean barometrical pressure over the several oceans having been studied, it is important to learn the extent of the variations from the mean values which are likely to be observed, and what is to be inferred from these variations.

In all parts of the earth, the pressure of the air, and therefore the height of the mercury in the barometrical column, is constantly varying. In the higher latitudes these variations have a range of nearly four inches, and the familiar terms "high" and "low" barometer are applied when there is some marked difference in the readings above or below the average value at any place. Moreover, as wind is directly connected with alterations in the pressure of the atmosphere, it becomes desirable to discriminate carefully between the varying degrees of importance to be attached, in different seasons of the year and in different latitudes, to any observed high or low barometer, in relation to the winds which accompany, or result from, the alterations of pressure so indicated.

As before stated, changes of pressure may be classed under two heads, periodical and non-periodical. The periodical changes recur at nearly regular intervals during the course of the day or the year; on the other hand the non-periodical or irregular changes are indicative of disturbances of the atmosphere which cause departures from the regular or average condition.

Periodical Variations of Pressure.

Of the periodical changes the Diurnal Variation, though small in its amount, chiefly demands the consideration of seamen when navigating in tropical or in sub-tropical seas, where it is one of the most regular of recurring phenomena.

This diurnal variation of pressure consists of a double oscillation, there being two periods of increase and two of decrease within 24 hours; the barometer rising from about 4 a.m. to about 10 a.m., then falling to about 4 p.m., and again rising till about 10 p.m., when it once more falls to about 4 a.m. The forenoon maximum is commonly, but not invariably, higher than the afternoon maximum; and the former usually occurs rather before than after 10 a.m., while the latter tends to be later rather than earlier than 10 p.m. The afternoon minimum is, with rare exceptions, lower than the morning minimum, and occurs after rather than before 4 p.m.

At sea the diurnal variation attains its greatest magnitude within the tropics, and gradually diminishes in higher latitudes, being hardly perceptible within the Arctic or Antarctic circles. The extent of the oscillation of the mercury due to this cause, at any place at different times of the year, depends much on the range of daily temperature, and the times of maxima and minima are

influenced by the times of sunrise and sunset. At sea within the tropics, therefore, the range of temperature and the length of the day, not being subject to any considerable change in the course of a year, the diurnal variation does not change in any important feature from one month to another.

In tropical seas the daily range of the barometer between the highest and lowest may be taken at about 0·07 of an inch or 0·08 of an inch, the greatest rise above the mean of the 24 hours being somewhat less than the greatest fall below it. The mean pressure in these seas will be found to occur between midnight and 1 a.m., 6 a.m. and 7 a.m., noon and 1 p.m., and about 7 p.m.

At Calcutta the daily range varies from about 0·14 inch in April and May, when the range of temperature is greatest, to about 0·09 inch in July, when it is least.*

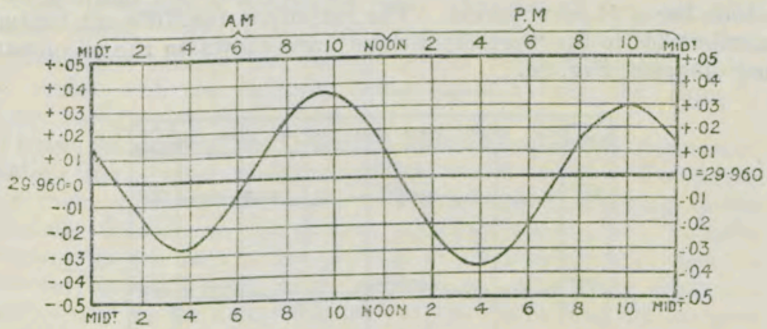


Fig. 9.

In the British Isles the changes of pressure due to this cause are hardly more than one fourth of those observed in the tropics amounting on the average to about 0·02 inch, so that, except in very calm settled weather, the daily oscillations can seldom be recognised in the hourly readings of a barometer during any given day, though they become quite apparent in the means of such a period as a month.

The diagram (Fig. 9), the scale of which is much enlarged, represents the mean curve of daily range of the barometer for

* The following examples are instructive; the values (in decimals of an inch) indicated by + and − signs, show approximately the mean rise or fall above and below the average reading of the barometer :—

Calcutta [22½° N. lat.].			Ascension [8° S. lat.].		Mauritius [20° S. at.].	
Hour.	Jan.	July.	Mean Year.		Mean Year.	
	In.	In.	Hour.	In.	Hour.	In.
3½ a.m.	−·019	−·017	3 a.m.	−·020	3½ a.m.	−·018
9½ a.m.	+·076	+·039	9 a.m.	+·035	9½ a.m.	+·030
4½ p.m.	−·051	−·054	3½ p.m.	−·040	3½ p.m.	−·040
10½ p.m.	+·080	+·026	10 p.m.	+·027	9½ p.m.	+·029

the central portion of the Atlantic between lat. 5° N. and the Equator, and it may be taken as typical of the daily variation in tropical seas. *If, then, in the tropics, the seaman observes in the readings of his barometer any marked deviation from such a curve he may anticipate that some considerable atmospheric disturbance has arisen, and that a change of weather, possibly a hurricane, is impending. Such deviations have not been observed with reliable barometers except in those regions where hurricanes are experienced.*

In a paper by M. Alfred Angot, entitled *Etude sur la Marche Diurne du Baromètre*, which appears in the *Annales du Bureau Central Météorologique de France*, of 1887, the author furnishes formulæ for calculating the diurnal range of barometrical pressure for any parallel of latitude. M. Angot divides the actual diurnal variation of pressure into two parts: (1) the principal or semi-diurnal wave, having a 12-hour period; (2) the thermal wave, which has a 24-hour period. The variations for different latitudes attributable to the "principal wave" are shown in the accompanying diagram, Fig. 9*a*.

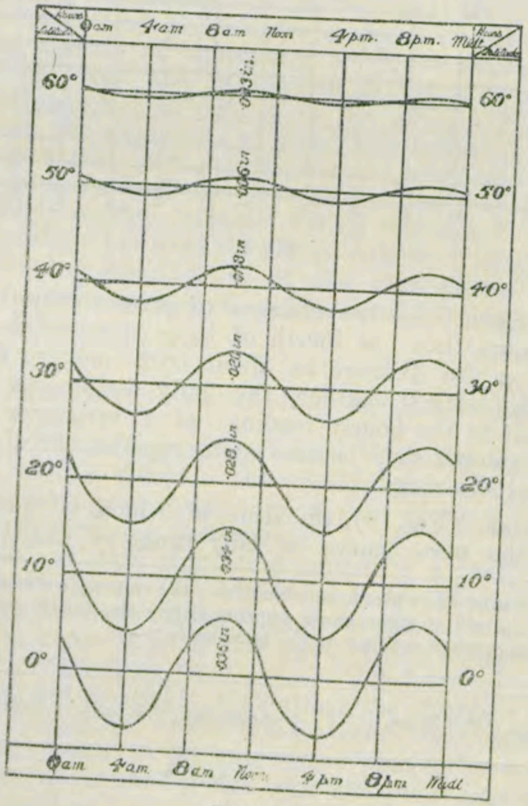


Fig. 9*a*.

The Annual Variation of pressure is also a well-marked phenomenon within the tropics both on land and sea, following the apparent motion of the sun North and South of the Equator, and giving rise to modifications of the Trade winds, and producing

periodical winds such as the Monsoons of the Indian Seas. The extent of the variation thus caused is indicated on the charts. In the tropical seas it amounts to about 0·10 inch between the highest and lowest monthly mean; on approaching the land it becomes much greater, being about 0·30 inch at Bombay, while at Calcutta it reaches 0·45 inch, and in the interior of Asia the yearly variation is as much as 0·80 inch.

As, however, the annual variation takes place very gradually, it has no characteristics which make it of special importance to seamen in relation to possible sudden changes of weather, it therefore calls for no further comment here.

Non-Periodical Variations of Pressure.

The non-periodical changes of pressure, which, as before said, are those immediately associated with changes of weather, next demand notice. The extent of these changes, under ordinary conditions, and taking the average of the various seasons of the year, varies with the latitude, being smallest near the Equator and increasing as we recede from it.

Within the tropics, the ordinary fluctuations of the barometer, including the diurnal variation, seldom exceed three or four-tenths of an inch, except in the event of one of those revolving storms commonly known as hurricanes, cyclonic storms, or typhoons (according to the part of the globe in which they occur), when the barometer may fall much more, as will be more fully explained hereafter, and in the dangerous part of the storm field the mercury may fall to the extent of two inches or more.

At Ascension, in lat. 8° S., the greatest range observed in two years scarcely reached four-tenths of an inch. The highest reading, 30·178, was recorded in June, the lowest, 29·800, in April. Similarly, in the tropical zone of the Atlantic Ocean, between the Equator and 10° N. lat., and between 20° and 30° W. long., based upon a large number of observations extending over many years, the highest reading, 30·138, was observed in July, the lowest, 29·725, in December, a range of only 0·413 inch.

The average range of the barometer gradually increases with the latitude, and appears to reach its maximum—at least in the Northern Hemisphere—between the 60th and 65th parallels; thence towards the pole decreasing. The magnitude of this range in the higher latitudes, as compared with the tropics, is exemplified in the British Islands, where the average range in the course of a month is about 1·7 inch for January, 0·9 inch for July.

In nearly 60 years, since the beginning of the year 1841, the highest corrected reading of the barometer at the Royal Observatory, Greenwich, was 30·972 inches, on January 18, 1882; the lowest, 28·272 inches, on January 13, 1843—the absolute range, therefore, being 2·700 inches. These extreme values, however, must be considered quite exceptional, instances above 30·8 inches and below 28·5 inches being very rare.*

* In the storm of Jan. 26, 1884, a reading of 27·33 ins. was recorded at Ochtertyre, Perthshire, and on Feb. 5, 1870, a reading of 27·33 ins. had also been recorded on board R.M.S. "Tarifa" in 51° 3′ N. 23° 39′ W. The absolutely highest reading on record in these islands is 31·108 inches at Ochtertyre, on January 9th, 1896.

The following tabulated values, arranged according to latitude, have been compiled from all available authorities, and may, under ordinary conditions, and excluding exceptional storms of great severity, such as tropical cyclones, be accepted as the approximate mean range of the barometer, in the months of January and July respectively, over the several oceans :—

Latitude.	January.	July.
	Ins.	Ins.
Between 65° and 60° N.	1·70 to 1·80	1·00
60° „ 50° „	1·80 „ 1·50	1·00 to 0·80
50° „ 40° „	1·50 „ 1·25	0·80 „ 0·60
40° „ 30° „	1·25 „ 0·65	0·60 „ 0·40
30° „ Nn. Tropic ...	0·65 „ 0·40	0·40 „ 0·30
Tropic „ Equator ...	0·40 „ 0·20	0·30 „ 0·20
Equator „ Sn. Tropic ...	0·20 „ 0·35	0·20 „ 0·35
Tropic „ 30° S.	0·35 „ 0·55	0·35 „ 0·60
30° „ 40° „	0·55 „ 0·80	0·60 „ 1·00
40° „ 50° „	0·80 „ 1·20	1·00 „ 1·60
50° „ 55° „	1·20 „ 1·30	1·75

For the smaller ranges the assumption that the variations of the height of the barometer are of nearly equal amount on each side of the mean reading is sufficiently exact for practical purposes ; in the greater ranges it requires modification. An examination of the behaviour of the barometer at Greenwich, between 1841 and 1858 (excluding extraordinary disturbances), goes to show that in January—as typical of the winter months, when the fluctuations are greatest—the mercury falls below the mean reading in the proportion of about five-eighths of the whole range to a rise above the mean reading of three-eighths of the whole range ; while in July—as typical of the summer months, when the fluctuations are least—the rise and the fall in the range appear nearly equally divided.

Thus with an average barometer reading in the English Channel of 29·95 inches we should have in the winter, with a range of 1·5 inch, a fall of 0·95 and a rise of 0·55 as representing the lowest and highest barometer (29·00 and 30·50) that might be expected. Under similar conditions in the Southern Hemisphere, when off Cape Horn, with an average barometer of 29·50 inches and a winter range of 1·75 inch, 28·40 and 30·15 would represent the probable lowest and highest readings.

By the aid of these considerations, an estimate can be formed, with a fair approach to precision, from the figures in the above table, and those entered on the isobaric charts, of the probable ordinary range of a high or a low barometer at any place where a vessel may be, from which, when compared with the barometrical readings taken on the vessel, a judgment may be come to whether there is any serious departure in these readings from the mean value of the pressure either in the way of excess or deficiency, and this knowledge, combined with observations of the actual direction and force of the wind, and of the changes that take place in these, will furnish the seaman with the means of guiding his action with confidence, as will be further explained.

Cyclonic Depressions and Anticyclones.

The most marked changes of weather associated with non-periodical variations of pressure in any locality are usually due to the approach of cyclonic depressions, or of their opposites, anticyclones, and their passage over the locality.

Over any area where atmospheric pressure is below that of the surrounding region a cyclonic circulation is developed. Air currents, under the action of gravity, set towards an area of relatively low pressure from the relatively high pressure by which it is surrounded ; but, by the earth's rotation they are deflected to the right in the Northern Hemisphere, and to the left in the Southern ; so that, instead of flowing direct towards the centre of depression, they acquire a motion round it, but inclined inwards towards the centre. Therefore the wind circulating about an area of low pressure in the Northern Hemisphere will have a movement against that of watch hands, while in the Southern Hemisphere the movement will be in the same direction as watch hands. Such a distribution of pressure and wind was called by Piddington *a cyclone* ; and is now known as *a cyclonic depression*.

In recent years the term *cyclone* has largely become associated with atmospheric disturbances in which the wind blows with violence round a central area of low pressure, and is often used to express the force of the wind rather than a characteristic distribution of pressure and wind.

The term *cyclone* was, however, originally adopted by Piddington in a publication entitled *Sailor's Horn Book* (1848), in connexion with the classification of winds. He says : *I suggest that we might for this last class of circular, or highly curved winds, adopt the term "cyclone" from the Greek* Κύκλος *(which signifies, amongst other things, the coil of a snake), as neither affirming the circle to be a true one, though the circuit may be complete, yet expressing sufficiently the tendency to circular motion in these meteors.*

Thus, in a cyclonic depression the wind has a *tendency* to circulate round an area of relatively low pressure ; it may be of moderate force, and in some parts of the system even light, or it can be strong to a gale, and, especially in the tropics, may attain to the force of a hurricane.

Over any area where pressure is high, and decreases in all directions from the maximum, an anticyclonic circulation of wind is developed ; for air setting outward from the centre of a high pressure area towards the relatively low pressure surrounding it is deflected to the right, or to the left, according to the hemisphere in which the system is situated, and thus acquires a motion round the high pressure, but inclined outward from it. The circulation of the wind about the high pressure will, therefore, in the Northern Hemisphere, be in the same direction as watch hands ; but in the Southern Hemisphere it will be in a contrary direction to watch hands. Such a distribution of pressure and wind is called an *anticyclone*.

Cyclonic depressions when formed travel, generally speaking, in temperate latitudes towards some easterly point in either hemisphere. The passage of a succession of depressions, with intervening high pressures, which may appear as separate anticyclones, or simply relatively high pressure areas between lows, is indicated on a barometrical chart by the alternations of low and high barometer such as are illustrated in Fig. 15, p. 44.

These constitute the non-periodical changes of pressure.

For further information as to nature and behaviour of cyclonic depressions, and anticyclones, see *Forecasting Weather* by the Director of the Meteorological Office, W. N. Shaw, F.R.S., Sc.D., 1911.

Chapter IV.

WINDS, THEIR CAUSES AND DISTRIBUTION.

Causes which Determine the Force and Direction of the Wind.

The force of a wind accompanying a difference in barometric pressure at two places at the same instant is greater as that difference is greater; and it therefore depends, not on the mere height of the barometer on board a ship, but on the difference between that height and the height which subsists over a neighbouring ship, or place. Civil engineers speak of a gradient in connection with the slope of a road; and a gradient of one in sixty, for example, signifies that the road rises one unit vertically for each sixty such units measured horizontally. When the rise or fall of a railway level is stated thus, the amount is termed the gradient; and a comparison of two gradients then becomes simply that of two numbers. Meteorologists have conveniently adopted the term gradient to express a difference of atmospheric pressure between two places. A slight gradient, or a steep gradient, is a description which is equally applicable to a railway slope or to difference in barometric pressure between two places. The civil engineer applies the same unit of measurement to both his horizontal and vertical scales; but the meteorologist employs miles of distance in the former, and inches of barometric pressure in the latter. These differences of pressure are spoken of as barometrical gradients; and the standard for their comparison that has been adopted is the difference of pressure, expressed in hundredths of an inch, in 15 miles of distance. The greater the difference, the steeper will be the gradient, the closer will be the isobaric lines on a chart representing the pressure, and the stronger will be the winds.

But the direction of the wind is governed by another very distinct influence, which it is important to understand clearly, as it fundamentally affects all classes of wind, and calls for special attention in the case of the most dangerous winds, namely, hurricanes or cyclonic storms.

The air, when it is apparently wholly at rest, and a complete calm prevails, is in truth moving with great rapidity together with the earth. The velocity of the earth's rotation at the Equator is about 1,000 miles per hour from West to East, and it gradually diminishes towards the poles, where it is zero. So long as the air remains

at rest (relative to the earth's surface), this movement is not sensible, but it at once becomes effective if the air is impelled to a latitude having either a higher or lower velocity of revolution. In the former case, air possessed of a less velocity from West to East reaches a part of the earth's surface having a higher velocity, and therefore appears to be impressed with a movement from East to West, or contrary to the earth's direction of revolution, equal to the difference between the two velocities, though the friction against the earth's surface of air passing from one latitude to another soon reduces the initial excess velocity of movement, or makes good the deficiency.* If a body move in any direction on the earth's surface, there is a deflecting force arising from the earth's rotation which deflects to the right in the Northern Hemisphere but to the left in the Southern Hemisphere.

In the Northern Hemisphere, for the reason thus stated, a current of air setting from a lower latitude to a higher gives rise to a South-westerly wind, and a current in the opposite direction to a North-easterly wind. When, therefore, an area of low pressure arises North of the Equator, surrounded by comparatively high pressure, the primary tendency of the air to flow from the outside towards the centre of the area of low pressure will be modified so as to impart a more Easterly direction to the wind in the northern half of that area, and a more Westerly direction to the wind in its southern half, the joint influence of which will be to set up a circulation round the centre of lowest pressure from West through South, to East and North, round again to the West, *i.e.*, against the motion of the hands of a watch. In the Southern Hemisphere a similar circulation would be established, but in the opposite direction, or with the motion of the hands of a watch. Winds thus circulating round an area of low pressure are spoken of as cyclonic, and they are related in a manner similar to that of the winds of the great storms known as tropical revolving storms.

It will readily be seen that, in like manner, air flowing from an area of high pressure to areas of relatively low pressure, will in the Northern Hemisphere develop a circulation in the opposite direction to that caused round an area of low pressure, that is, passing from East through South to West and North back to East. Winds thus circulating round an area of high pressure are termed anti-cyclonic, because they revolve in a direction opposite to that of the cyclonic winds.

The general statement of the facts, thus explained, is known as Buys Ballot's law, because it was first publicly announced in Europe by Professor Buys Ballot, of Utrecht. It may be enunciated thus:—†

In the Northern Hemisphere.	In the Southern Hemisphere.
Stand with your face to the wind, and the barometer will be lower on your right hand than on your left.	**Stand with your face to the wind, and the barometer will be lower on your left hand than on your right.**

* This explanation is sufficient for the purposes of this Manual, though not a complete statement of the laws that govern the movement of the air on the earth's surface, which could not be given in a treatise such as the present.

† Buys Ballot reversed the expressions, and supposed the observer to stand with his back to the wind, but as a seaman invariably faces the wind when he wishes to ascertain its direction, it is put here as above.

In the Northern Hemisphere, within or on the borders of an area of low barometrical readings, the wind blows round it in a direction contrary to the movement of the hands of a watch, and within, or on the border of, an area of high readings, the wind blows round it in the same direction as the hands of a watch. In the Southern Hemisphere the converse is true in both cases.

Fig. 10 and Figs. 10*a* and 10*b* illustrate the application of the foregoing observations to the Northern Hemisphere. They show the conditions of barometrical pressure, and the direction and force of the wind consequent on the formation of areas of low and high pressure over, and in the neighbourhood of, the British Isles.

The lines drawn on the map are isobars, which, as before stated, are lines indicating equal barometrical readings. The arrows indicate the direction and force of the wind; arrows with one barb signifying light winds, two barbs stronger winds, those representing gales being feathered.

It will be seen that, in accordance with Buys Ballot's law, the wind blows so that at each point the observer with his face to the wind would have a lower barometer on his right hand than on his left. Further, though circulating generally round the isobaric lines, the arrows mostly cut these lines at an acute angle, and generally so as to show an indraft towards the area of lowest pressure.

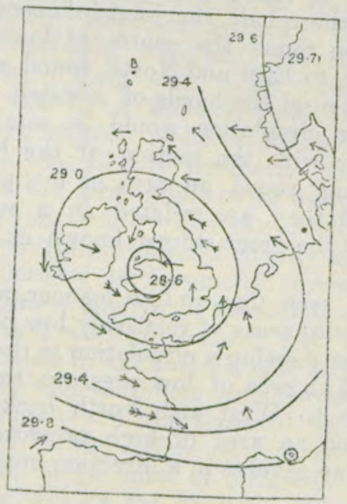


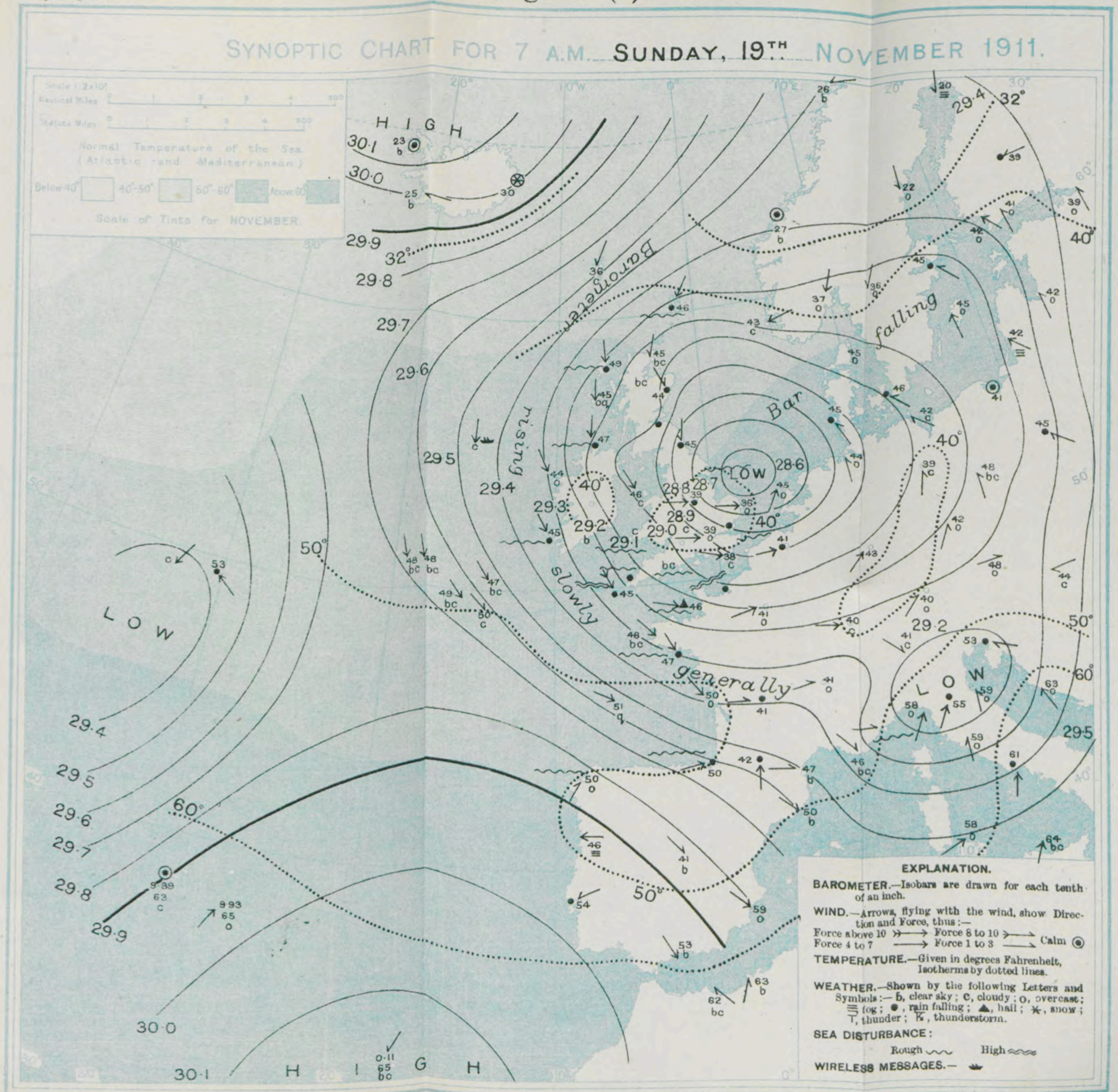
Fig. 10.

CIRCULATION OF THE WIND IN A CYCLONIC SYSTEM. NORTHERN HEMISPHERE. See also the reproduction of the Charts from the Daily Weather Report, Fig. 10*a*.

No general law has yet been established determining the angle of indraft of the wind, that is to say, the angle which the wind makes with the direction of the isobar at the place, but it is generally agreed by meteorologists that 20° may be taken as a fair average value of this angle, though it certainly varies greatly with the velocity of the wind, as well as with the position as regards the centre of the area of low pressure, and the movement of progression thereof.

To face p. 30.

Fig. 10 (a).



CIRCULATION OF THE WIND IN A CYCLONIC SYSTEM NORTHERN HEMISPHERE.

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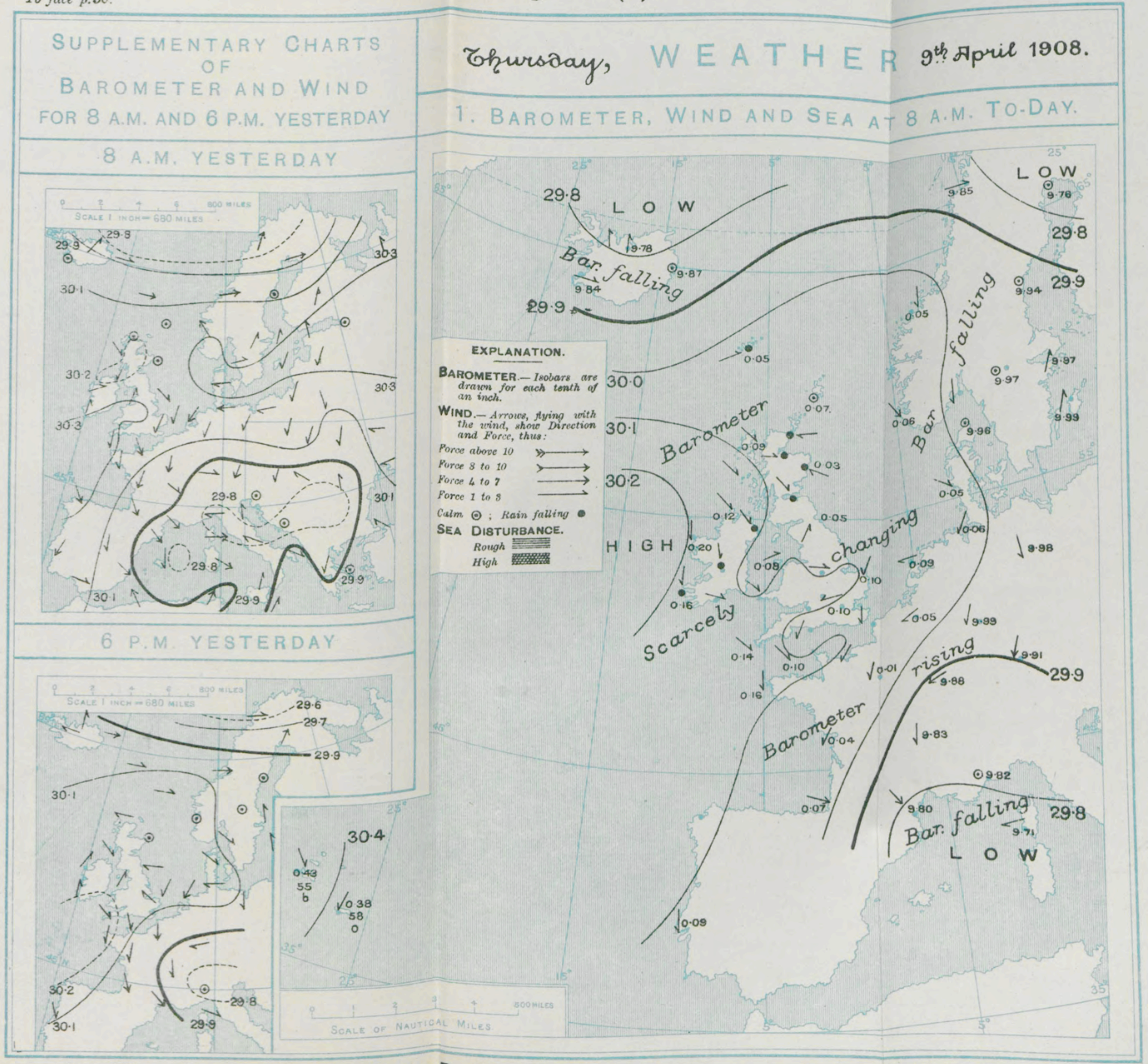
Fig. 10 (b).



DAILY WEATHER CHART FROM THE DAILY WEATHER REPORT FOR 9TH APRIL, 1908, ILLUSTRATING THE RELATION OF WINDS TO ISOBARIC LINES.

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Fig. 11 indicates the wind circulation of the Southern Hemisphere. It also shows the height of the barometer, and the direction and force of the wind, during a cyclone central over the east coast of Australia.

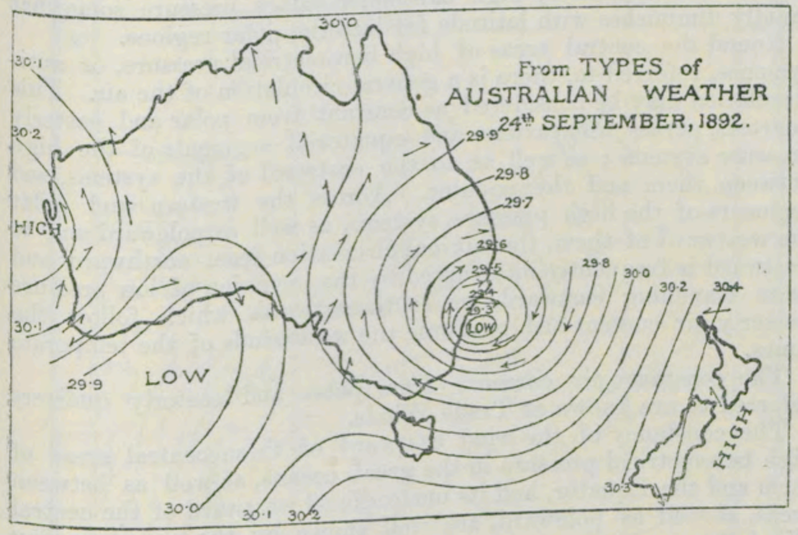


Fig. 11.

Circulation of Wind in a Cyclonic System. Southern Hemisphere.

Inasmuch as the distribution of barometrical pressure is subject to almost infinite variety and change, the occurrence of regularly formed areas of high or low pressure over any place is comparatively rare, but the more violent the wind the more regular does the distribution of the isobars round the centre of a cyclone tend to become, and whatever be the arrangement of the isobars, the winds will be found to blow along or round them in accordance with the general principles that have been explained, as is shown in Fig. 11.

Prevailing Winds at various Seasons over different Parts of the Globe.

From these considerations it will be seen that a knowledge of the relative distribution of mean atmospheric pressure on the earth's surface at different times of the year, gives a general idea of the prevailing winds at those times; and, conversely, that a knowledge of the prevailing direction and force of the winds enables us to indicate the relative distribution of mean atmospheric pressure.

The leading features of the relation between mean barometrical pressure and wind distribution over the oceans are shown on the maps dealing with Pressure and Prevailing Winds (*see* Plates VII and VIII).

It has been pointed out (p. 20) that, broadly stated, barometrical pressure over the oceans may be divided into five great areas. North and South of a belt of moderately low pressure, lying over the equatorial regions, are belts of relatively high pressure, in each of which are situated areas of maximum barometer reading, or anti-cyclones, elliptical in shape, which have a seasonal oscillation North and South, in accordance with the sun's declination, and also a movement East and West; but are, so far as is at present known, in other respects permanent. At the polar extremities of these belts of relatively high barometer values, pressure somewhat rapidly diminishes with latitude far into the polar regions.

Round the central areas of high barometrical pressure, or anti-cyclones, referred to, there is a general circulation of the air. This circulation may be considered as constant from polar and easterly quarters, across the eastern and equatorial segments of the high pressure systems; as well as to the eastward of the systems, and between them and the equator. Across the western and polar segments of the high pressure systems, as well as poleward and to the westward of them, the normal circulation from northward and westward is frequently interrupted by the incursion of low pressure areas travelling eastward, or south-eastward, which follow the westerly air current and reinforce the west winds of the temperate zones.

The constant air currents from polar and easterly quarters referred to are known as Trade Winds.

The constancy of the wind eastward of these central areas of high barometrical pressure in the great oceans, as well as between them and the Equator, and its unsteadiness westward of the central areas, as well as poleward, are well shown by the accompanying Wind-Roses.

A Wind-Rose is a diagram designed to illustrate the proportion of wind frequency for each point of the compass, or for characteristic winds, over a given area. It is used, as a rule, for indicating the force of the wind also.

The Wind-Roses here given relate to the South Atlantic in the month of October, and are reproduced from the Wind Charts for the South Atlantic Ocean, prepared in the Meteorological Office, and published by the Admiralty. In these diagrams the arrows, which fly with the wind, show by their length the frequency of the wind, and by their thickness the various forces. Forces 1 to 3 are light winds, forces 4 to 7 are moderate winds, and forces 8 to 12 are gales. (See Fig. 12.)

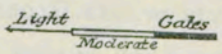


Fig. 12.

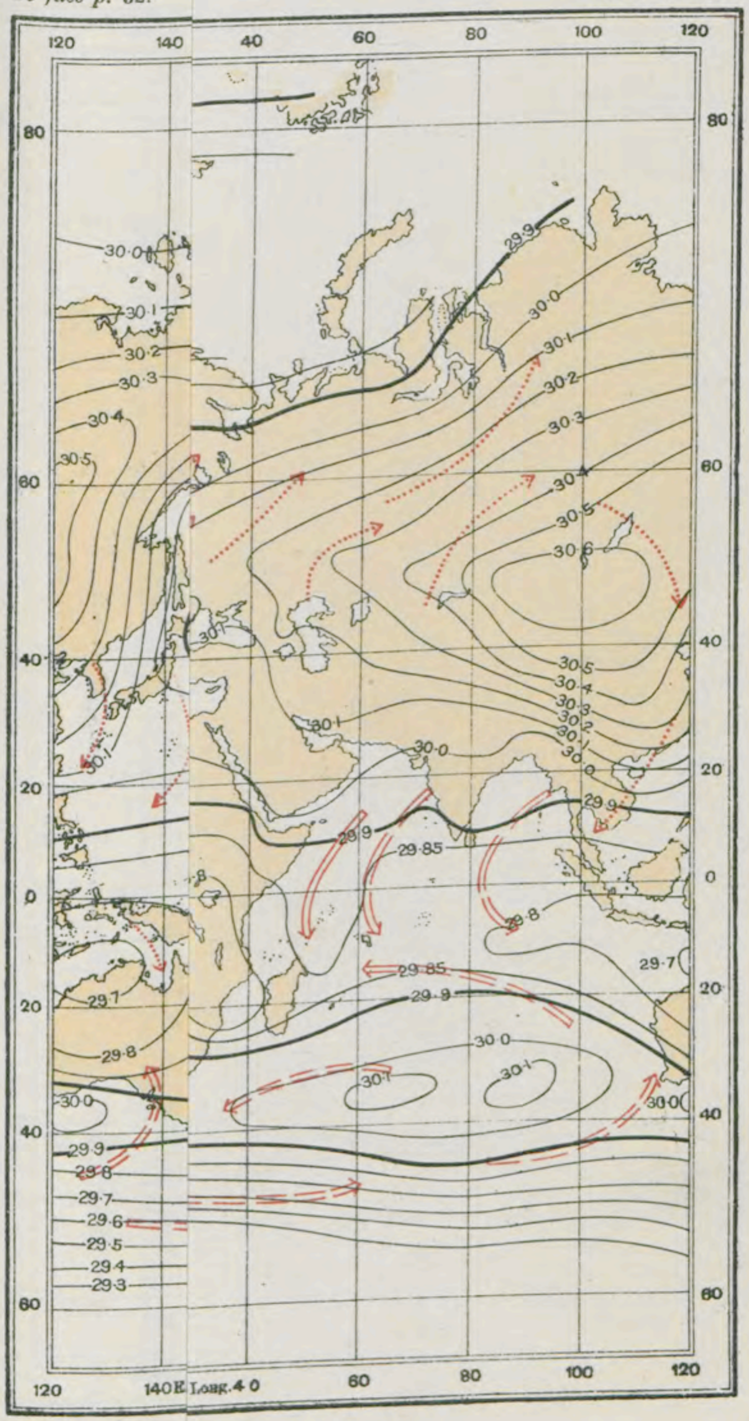
The circle supplies a scale for estimating the frequency of winds in any direction. From the heads of the arrows to the circumference represents 5 per cent. of the whole number of observed winds (100 per cent. = 2½ inches). The upper figures in the centre of the wind-rose are the total number of observations, the percentage of calms being given underneath. (See Fig. 12*a*.)

This form of Wind-Rose is the one which has been adopted by the Meteorological Office. There are, however, many forms of Wind-Roses.

It will be shown later, that in the Indian Ocean, north of about 10° S. latitude, and in the China Seas, owing to the land influence, the conditions which obtain in the great oceans, as outlined above, are not reproduced.

To face p. 32.

PLATE VII.



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anti-cyclones, elliptical in shape, which have a seasonal oscillation North and South, in accordance with the sun's declination, and also a movement East and West; but are, so far as is at present known, in other respects permanent. At the polar extremities of these belts of relatively high barometer values, pressure somewhat rapidly diminishes with latitude far into the polar regions.

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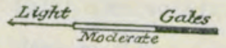

Fig. 12.

The circle supplies a scale for estimating the frequency of winds in any direction. From the heads of the arrows to the circumference represents 5 per cent. of the whole number of observed winds (100 per cent. = $2\frac{1}{2}$ inches). The upper figures in the centre of the wind-rose are the total number of observations, the percentage of calms being given underneath. (See Fig. 12*a*.)

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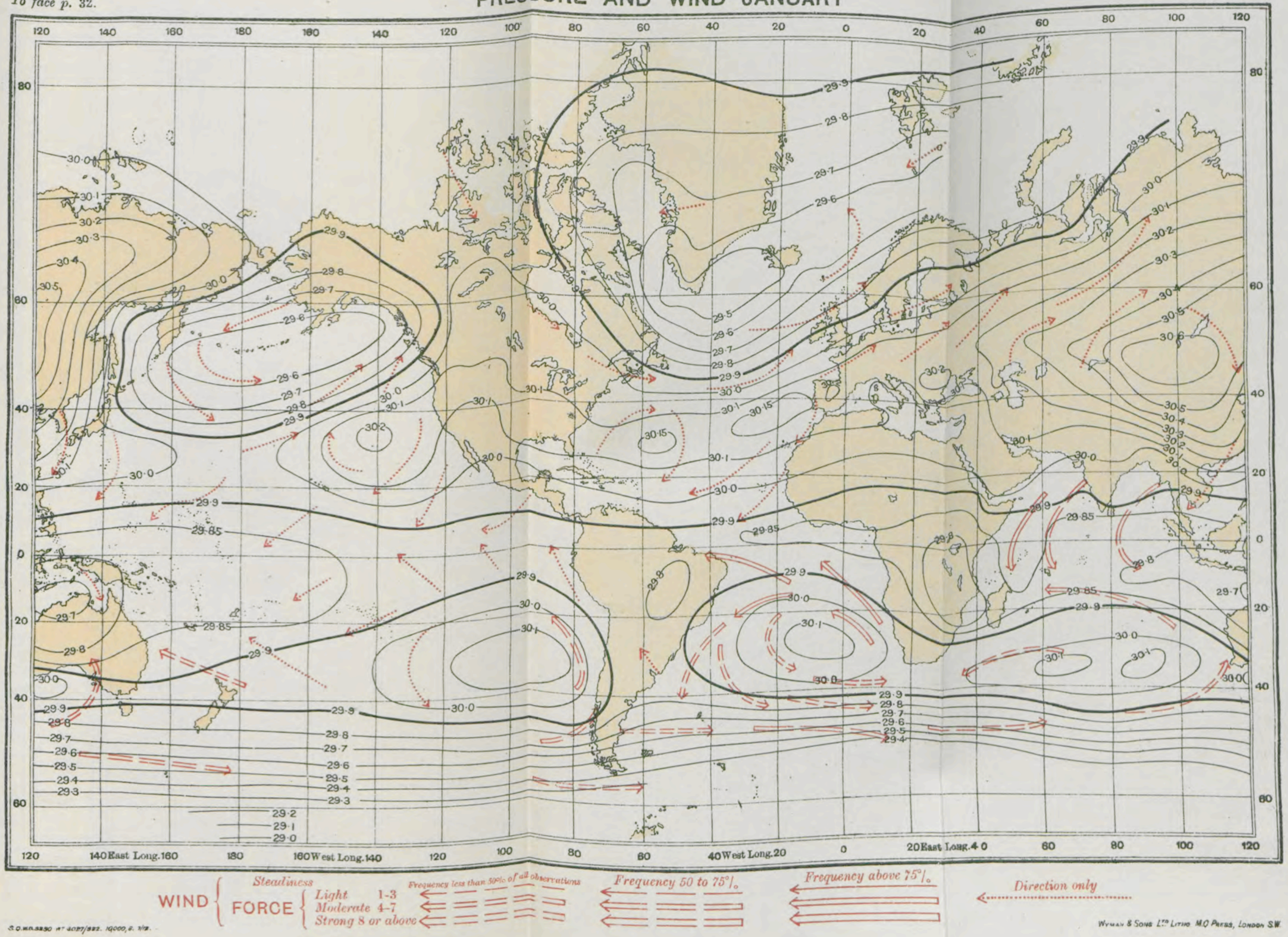
To face p. 32.

PRESSURE AND WIND–JANUARY

PLATE VII.



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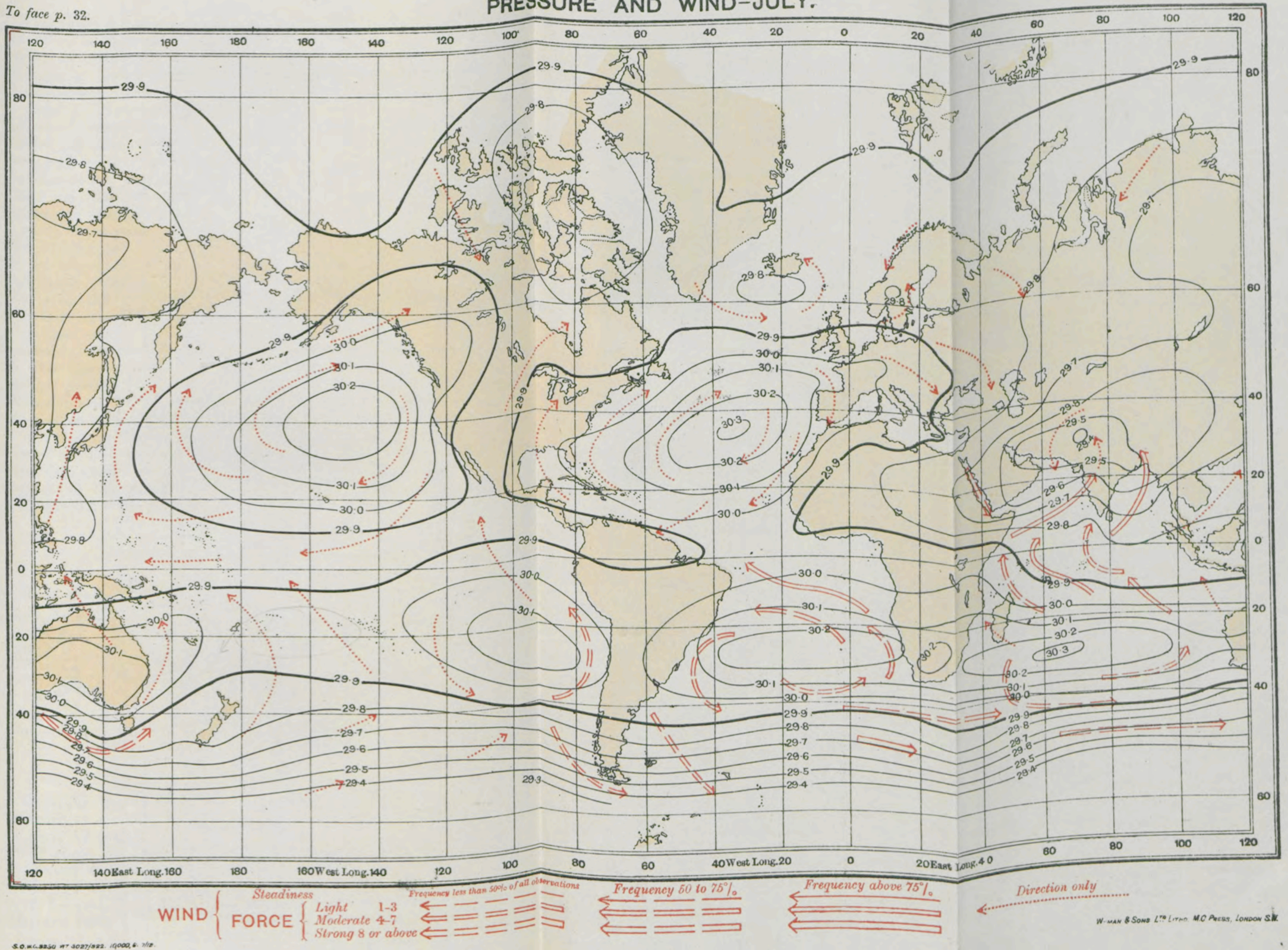
PRESSURE AND WIND—JULY.



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The chart for January (Plate VII) shows that under average conditions an area of low barometrical pressure lies over the greater portion of the North Atlantic, north of the 40th parallel, and that pressure is lowest between Iceland and the southern extremity of Greenland. Between the 40th and 20th parallels, barometrical pressure is relatively high; and in this belt there are two areas of maximum barometer readings of 30·15 ins., one situated on the eastern side of the ocean, and the other on the western side. Round these high-pressure areas we have a definite anticyclonic circulation. Further south, near the equator, we reach a region of variable winds and calms, called the Doldrums, which is always to be found somewhere near the equator. In January the region of Doldrums is south of its mean annual position. It extends westward from the African coast in about 7° N. to about the 45th meridian in 2° S. where the breadth of the belt is narrow. Pressure is high over Southern Europe and the extreme North of Africa, and over the greater portion of North America. Following the law enunciated by Buys Ballot, the prevailing wind over the eastern half of the North American continent, and immediately to the eastward of the coast, from the Arctic Circle to the 35th parallel of latitude is north-westerly; over the greater portion of the Atlantic, north of the 35th parallel, it is westerly, i.e., from between north-west and south-west, but over the eastern arm of the Atlantic, and near the western seaboard of North-western Europe far into the Arctic Ocean, it is south-westerly. Between the 35th and 30th parallels, the wind is for the most part variable, while across and to the eastward of the eastern segment of the anticyclone it is north-easterly, and south of the 30th parallel from between north-east and east.

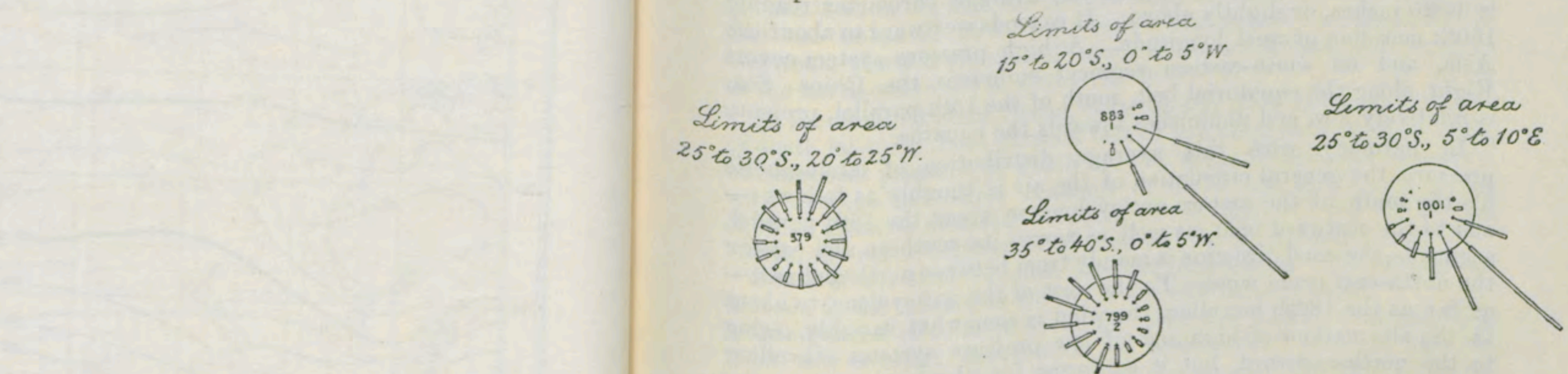

Fig. 12a.

Over the South Atlantic the atmospheric circulation may be regarded as one vast wind system, controlled by a permanent area of high barometrical pressure. The direction of the wind circulating about the centre of this anticyclone, broadly stated, is from southward and south-eastward between it and the African coast where pressure is relatively low; from south-eastward and eastward between the latitude in which its centre is situated and the equator; from north-eastward and northward to the westward of the anticyclone; and from north-westward and westward to the south of it.

Across the eastern and northern segments of the anticyclone, as well as to the eastward of the system and between it and the equator, the wind is steady from between south and east and is called the South-East Trade Wind; to the west, south-west, and south of the anticyclone, especially to the west of it, the northerly wind which belongs to the normal circulation of the air, although fairly constant in this month, is at times interrupted by the passage of alternations of high and low pressure areas travelling eastward and south-eastward. South of 35° S. latitude the prevailing winds are westerly; i.e. from between north-west and south-west. They have a considerable northerly component, in harmony with decreasing pressure poleward. These westerly winds extend to high latitudes, and have been experienced in regions well within the Antarctic circle. Their southern limits in Antarctica vary with the locality but probably reach to some parallel where sea meets land and the slope of the pressure gradient is slightly reversed inducing an easterly air current.

The salient features in the average distribution of barometrical pressure over the North Pacific, as shown on the chart for January, are as follow:—An extensive area of relatively low barometrical pressure covers the ocean north of the 40th parallel, its centre probably situated over, or immediately south of the Aleutian Islands, between the 140th meridian of west longitude and the 160th meridian of east longitude. A large anticyclone lies to the south-east of this low pressure area, within a belt of relatively high pressure between the 40th and 15th parallels, extending right across the Ocean. This anticyclone has its centre in about 35° N. latitude, 140° W. longitude, where the average barometer reading is 30·20 inches, or slightly above. It extends westward to about the 160th meridian of west longitude. A high pressure system covers Asia, and its south-eastern segment embraces the China Sea. Right along the equatorial belt, south of the 15th parallel, pressure is relatively low, and diminishes towards the equator.

In harmony with this average distribution of atmospheric pressure, the general circulation of the air is roughly as follows:—To the south of the eastern anticyclone to about the 15th parallel, and to the eastward of it, as well as across its southern and eastern segments, the wind direction is mainly from between north and east—the north-east trade wind. To the west of the anticyclone, to about as far as the 180th meridian, the wind is somewhat variable, owing to the alternations of high and of low pressure systems travelling to the north-eastward, but it conforms for the most part to the normal circulation about a high pressure system near the Northern Tropic, and is mainly from between south-east and south-west, through south. West of the 180th meridian the wind is drawn from northward, or north-eastward, through the influence of the high pressure over Asia, and is known as the North-east Monsoon. Along the equatorial belt, south of about the 15th parallel, the air current is from eastward, and across the southern portion of the temperate zone, north of the 40th parallel, it is chiefly from westward, i.e., from between south-west and north-west.

Over the South Pacific Ocean barometrical pressure is for the most part relatively low between the 20th parallel and the equator. It is low also from the 45th parallel southward, diminishing with latitude as far south, at least, as the Antarctic Circle. Over the south-eastern part of the ocean, between the 20th and 40th parallels, pressure is high and increasing to a central maximum situated between 30° S. and 40° S. latitude, 90° W. and 120° W. longitude. Over South America pressure is relatively low.

Associated with this average distribution of barometrical pressure over the South Pacific the circulation of the air is from between south and east to the eastward and northward of the high pressure or anticyclone, as well as across its eastern and northern segments. West of the anticyclone to about as far as 160° W. longitude, as well as across its western segment, the circulation is mainly from north-eastward, northward, and north-westward. West of 160° W. longitude, between the equator and 20° S. latitude, the wind is chiefly from northward, but gradually draws to the south-eastward through east with increase of latitude to about 35° S., and to the southward and south-westward to about 38° S., south of which latitude the westerly winds prevail. These westerly winds are strongest and have most westing in them between the 40th and 50th parallels.

In the month under notice, when mean atmospheric pressure is relatively high over Asia, and high over Southern Siberia and Northern China, it is relatively high also over the Arabian Sea and Bay of Bengal, but diminishes with latitude to about 15° S. over the Indian Ocean. Pressure is relatively low over Africa south of about the 15th parallel of N. latitude.

It will be seen by referring to the chart for January that over the sea in these regions the isobars slope to the south-westward, and that the isobar of 29·85 ins. crosses the equator in about 62° E. longitude, where it trends still more to the southward, but recurves to the north-westward in about 12° S. 53° E.

In the South Indian Ocean, between the 20th and 42nd parallels of south latitude, there exists a belt of comparatively high, or high, barometrical pressure, in which are two areas of maximum intensity, with average barometer readings of 30·10 ins. and above. One of these areas is situated between 34° S. and 37° S., 60° E. and 75° E., the other between 31° S. and 38° S., 85° E. and 95° E.

South of the 42nd parallel, pressure diminishes with increase of latitude to the Antarctic Circle, if not still farther south.

The general circulation of the air over the Indian Seas resulting from this average distribution of atmospheric pressure may be briefly summarised thus:—North of the equator the wind is north-easterly—the North-East Monsoon; between the equator and about 10° S. latitude, it is mainly from north-westward—the North-West or Equatorial Monsoon. The latter appears as an extension southward of the North-East Monsoon, and the westerly component in this northerly wind south of the equator is due to the rotation of the earth on its axis, as is the easterly component of the northerly wind north of the equator.

Between 10° S. and 36° S. latitude the air current is chiefly from south-eastward—the South-East Trade—except in the locality

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of the highest pressure, where the wind is variable. Between 36° S. and 45° S. latitude, the wind is usually from some point between north and west, and south of 45° S. it is mainly from between north-west and south-west, the northerly component predominating in the lower latitudes, and the southerly component in the higher.

The distribution of atmospheric pressure and wind over the oceans in the month of January, as outlined in the foregoing, may be regarded as largely characteristic of pressure and wind distribution during the five months of November to March.

In April the equatorial belt of low pressure surrounding the globe is travelling rather rapidly northward with the sun, and the belts of relatively high, or high, pressure north and south of the equatorial belt are moving with it.

The cooled land in temperate latitudes of the northern hemisphere is gaining heat; the warmed land in corresponding latitudes of the southern hemisphere is losing it; and the adjacent seas and oceans are undergoing similar changes more slowly and in a modified degree. The month of April, therefore, is one of transitional conditions.

The Chart for July (*see* Plate VIII) shows that over the Atlantic in that month, under average conditions, barometrical pressure in high northern latitudes is considerably higher than it is in January, but that north of the 50th parallel it is still relatively low. A relatively high, or high, pressure system covers that portion of the ocean which lies between the 15th and 50th parallels of north latitude, increasing in intensity towards a central area of maximum pressure, situated between 35° N. and 38° N., 30° W. and 38° W., where the average barometer is as high as 30·3 ins., and above.

Between latitudes 15° N. and 10° S., barometrical pressure is relatively low, and the region of Doldrums is found from about 8° N. to 12° N. Between latitudes 10° S. and 40° S. pressure is relatively high right across the ocean; and this belt of high barometer extends eastward and westward over those regions of South Africa and South America which are within these parallels.

Within this high pressure area the barometer is highest, 30·2 ins. and above, between 20° S. and 35° S. South of about 37° S. pressure steadily diminishes with increase of latitude to some parallel within the Antarctic Circle.

Responsive to this average pressure distribution the prevailing wind is south-westerly to the north of the North Atlantic high pressure system, as well as over its northern segment, as far as the 60th parallel of north latitude, or still farther north; it is north-easterly to the eastward of the system, and over its eastern segment; north-easterly to easterly to the southward of the system to about 10° N. latitude; and variable to south-westerly to westward of it. From 10° N. latitude to 20° S. the wind is easterly to south-easterly, except in the region of Doldrums, where it is light and variable, and off the West Coast of Africa, between Bathurst and the Cameroon River, where it draws to the south and south-west under the influence of the heated land. This South-West Monsoon is experienced during the height of the northern summer,

occasionally as far seaward as twelve hundred miles from the coast, between the 6th and 10th parallels of north latitude.

Within the anticyclonic belt between 20° S. and 35° S. the wind is mainly south-easterly over the eastern half of the ocean area, but northerly and variable over the western half, owing to the passage eastward of depressions. South of 35° S. westerly winds prevail and extend to latitudes bordering on, or within, the Antarctic Circle.

Over the Pacific Ocean in July barometrical pressure has undergone the following changes with regard to average distribution :—

The North Pacific anticyclone is located farther north than it is in January, and has expanded considerably. It now occupies a large portion of the North Pacific between the Aleutian Islands and the 15th parallel of north latitude, from the American coast to the 165th meridian of east longitude.

It increases in intensity towards a central area of maximum pressure situated between 30° N. and 45° N., 135° W. and 165° W., where the mean barometer reading is 30·20 ins. or above.

Barometrical pressure is low over Asia, and over the China Seas, but it increases eastward towards the high pressure system referred to.

The South Pacific anticyclone occupies an area extending over the greater portion of the ocean, between the 5th parallel of south latitude and the 40th parallel of south latitude, east of the 130th meridian of west longitude. The equatorial belt of relatively low pressure is, therefore, farther north in this month than it is in the month of January, and its area is more restricted. The highest barometer readings in the South Pacific anticyclone, 30·1 ins. and above, are found in the south-eastern segment of the ellipse. From 45° S. latitude poleward, pressure diminishes rather rapidly; therefore the barometrical gradient immediately south of this central area of high pressure is steep, and the winds, which are principally from westward, are correspondingly strong.

A neck of relatively high pressure joins the South Pacific anticyclone to a high pressure system which lies over Australia and extends eastward over the South Pacific to about the 170th meridian of east longitude.

The effect of these changes in average pressure distribution upon the general circulation of the air is :—(1) To contract the area of westerly winds in the North Pacific Ocean, and to augment that of the North East Trade Wind; (2) to induce a southerly wind—the South-West Monsoon—in the China Seas in place of the North-East Monsoon of the northern winter; (3) to contract the South-East Trade Wind area on the eastern side of the South Pacific; to augment it on the western side; and greatly to reduce the width of the equatorial belt of variable winds and calms.

In July, and also in August and September, it is difficult to define in the Pacific the southern limits of the North-East Trade, and the northern limit of the South-East Trade, as they appear to merge one into the other without interruption.

Barometrical pressure is low, or relatively low, in July, over the whole of Asia; and, broadly stated, is lowest over Northern India and Baluchistan. It is low, or relatively low, over the Arabian

Sea, the Bay of Bengal, and the Indian Ocean to about the 10th parallel of south latitude, pressure being lowest in the north and increasing southward towards the high pressure belt in the South Indian Ocean. Over the Arabian Sea and Bay of Bengal, the isobars follow more nearly an east and west direction in this month than obtained in January; but they still slope slightly to the south-westward. South of the equator the direction in which the isobars trend from the African coast is mainly south-eastward.

Barometrical pressure is relatively high, or high, between the 10th and 40th parallels of south latitude, and the 35th and 100th meridians of east longitude. It is highest, 30·3 ins. and above, between the 32nd and 35th parallels, and the 55th and 70th meridians. East of 100°E. longitude, the isobars of 30·1 ins. to 29·7 ins., and in a lesser degree those of a lower value also, turn somewhat sharply to the north-eastward to about 120° E., where they take on the shape of the southern coastline of Australia.

Dominated by this average distribution of atmospheric pressure in July, the prevailing winds are from southward and south-eastward—the South-East Trade—north of 30° S. latitude to the equator, and from south-westward—the South-West Monsoon—north of the equator. South of 30° S. latitude the prevailing winds are westerly and north-westerly to the Antarctic circle, where, there is reason to believe, the slope of the pressure gradient is reversed so that in still higher latitudes the prevailing winds are easterly.

The conditions obtaining in July may be considered as typical of the conditions existing in the months of May, June, August, and September. In October, the equatorial belt of low pressure is travelling somewhat rapidly southward, and the belts of relatively high pressure with it. The land in temperate latitudes of the Northern Hemisphere is losing the warmth acquired during the northern summer, and the cooled land in corresponding parallels of the Southern Hemisphere is gaining heat. The adjacent seas and oceans are undergoing similar changes more slowly, and in a lesser degree. In the month of October then, as in the month of April, the distributions of atmospheric pressure and wind are in a state of transition.

Chapter V.

WINDS AND GALES OF THE TEMPERATE ZONES.

Winds of the Atlantic Ocean, which are typical of those of other Seas.

The North Atlantic supplies types of the winds usually met with in all oceans. From Plates III. to VIII. it will be seen that an area of high pressure occurs in the North Atlantic

between the parallels of 20° N. and 40° N.; according to Buys Ballot's law, the wind draws round it, being Northerly on its eastern, Easterly on its southern, Southerly on its western, and Westerly on its northern side. The wind-arrows on Plates VII., VIII., indicate such a circulation of the air.

Vessels, therefore, outward bound from England to the Cape of Good Hope, pass from the north-east to the east and south-east side of an area of high pressure lying to the Westward, and as the coast of Portugal is approached the wind very generally comes from the North-west, gradually shifting to North and North-east as more Southing is made.

On the other hand, homeward-bound vessels approaching the southern verge of the N.E. Trade, with a rising barometer, find the wind draws to the Eastward. As the area of highest pressure is reached the barometer ceases to rise, and the wind dies away. These are the "Calms," and light baffling winds known as the "Doldrums of Cancer." There being no difference of pressure, there is no wind, and these calms coincide with a large area of high and even pressure, and a ship will experience little or no wind until a part of the sea is reached where the pressure commences to decrease.

If, as occasionally happens, it is found that the N.E. Trade gradually turns into a S.E., S., and S.W., wind, it will be understood from what has already been said, that a vessel experiencing these changes has passed round the S.W., W., and N.W. sides of this area of high pressure, thereby avoiding the region of calms altogether.

There are, as has been already shown, similar areas of high pressure in the South Atlantic, North and South Pacific, and South Indian Oceans, with a corresponding circulation of the wind round them germane to the Hemisphere.

Homeward-bound vessels, after rounding the Cape of Good Hope, are at the polar edge of the S.E. Trade on the Eastern side of the South Atlantic, just as the outward-bound ship is at the polar edge of the N.E. Trade when off the coast of Portugal (see Plates VII., VIII.), and the first wind experienced is from S.W., backing to S. and S.E. as Northing is made, which (according to Buys Ballot's law, when applied to the Southern Hemisphere) shows that the vessel has passed along the S.E., E., and N.E. sides of an area of high pressure.

Again, outward-bound vessels drawing towards the northern verge of the S.E. Trades on the western side of the South Atlantic, very generally experience changes of wind to N.E., N., and N.W., which are the winds met with in the Southern Hemisphere on the N.W., W., and S.W. sides of an area of high pressure corresponding to the winds already noticed as being experienced on the western side of the North Atlantic.

The study of Plates III. to VIII. will show how areas of high barometrical pressure occur in many other parts of the ocean, similar to those of the Atlantic, and that corresponding winds circulate round them.

In reference to the terms "veering" and "backing," there appears to have been some uncertainty in former years as to the meaning of the words as applied to the changes in the direction of the wind in the Southern Hemisphere. At the International Conference of Directors of Meteorological Institutes and Observatories, held at Innsbruck in 1905, a question was raised in this connexion. The Conference having ascertained the rule in use at the British Meteorological Office agreed that the same should be recommended for general adoption by passing the following resolution :—"That Meteorologists in the Southern Hemisphere, as in the Northern Hemisphere, are requested—without regard to other weather phenomena—to employ the term 'backing,' whether at an observing station or on board ship, exclusively to denote a change in direction against the hands of a watch, *i.e.*, W-S-E-N.; and the term 'veering' for changes in the opposite direction, with the hands of a watch, *i.e.*, W-N-E-S."

Gales of the Temperate Zones.

The great currents of the atmosphere, which give rise to the prevailing winds, are thus seen to be regulated by the positions of the permanent areas of high and low pressure, and in these currents, secondary areas of low pressure make their appearance, and are carried along with them. As represented on a synoptic pressure chart, that is to say, a chart showing the distribution of pressure, these low pressure areas are represented by a series of isobars curving sharply round a low pressure centre. The completed isobars may be either approximately circular or V-shaped. These travelling areas of low pressure frequently give rise to gales, to the characteristics of which attention will be next given.

Along the tracks of steamships engaged in the trans-Atlantic trade these gales very frequently travel eastward in the region of the westerly wind which forms a part of the oceanic high pressure system. Their centres are often far north of the vessels using the adopted routes; and therefore these disturbances generally commence with a wind from the south-westward and cease with the wind from the north-westward. Should, however, the storm centre be south of the observer, as sometimes happens, then the first wind of the system is from the south-eastward and the last is from the north-eastward. The force of the easterly winds is comparatively light, very often owing to the fact that the cyclones of the temperate zones of the North Atlantic do not have the barometric gradient so steep on the northern side as on the side nearer to the equator. In other words the isobars, or lines of equal barometric pressure, are much more widely separated on the polar side of the system than elsewhere.

The gales of the Temperate Zone of the Southern Hemisphere are similar in character to those of the Northern Hemisphere. In either Hemisphere, in the Temperate Zone, the areas of low barometric pressure travel eastward; and the strength of the wind is determined by the amount of the difference between the barometer readings at places not far distant from each other. In the Southern Hemisphere the wind circulation of a cyclone is from the opposite direction to that of the Northern Hemisphere. Hence these atmospheric disturbances in the South Temperate Zone, when passing over a ship that is north of the centre, commence with the wind from north-west and terminate with a shift to south-west; but from north-

east, and south-east, respectively, when the centre is north of the observer.

Whenever areas of both high and low pressure are liable to pass over any region it is obvious that the direction of the wind, taken alone, will not be a sufficient guide as to what weather is to be expected. If, for instance, in the Northern Hemisphere an area of high pressure be passing off to the East North-Eastward, the wind in the rear of it will veer through E.S.E. to Sd. Although this direction of the wind shows that the barometrical readings are lower to the Westward than to the Eastward, it is not by any means an indication that a serious diminution of pressure, which may possibly bring a storm with it, is approaching, although the wind in front of such a depression would be Southerly also. It is, therefore, necessary in such circumstances to look for other signs, besides the mere direction of the wind, when striving to foresee what is coming.

If the shape of an area of low pressure could be foretold, its gradients, the rate at which it is increasing or decreasing in intensity, the direction in which it is moving, and its speed, it would be possible to calculate very correctly what sort of weather would be experienced at a land station or on board vessels at sea, and it is upon observations of this description, made simultaneously at many places, that forecasts of weather are based; but the seaman can have no certain knowledge of these data, and has to make the best estimate he can from the indications afforded by the wind and the barometer as observed on board his own vessel alone.*

Moreover, it must always be remembered that, although it is most commonly in connexion with considerable falls of the barometer that storms are experienced, yet the sudden large increase of pressure, which is not infrequent with such depressions, is usually accompanied by very violent winds. Caution, therefore, will always be requisite on the occasion of any sudden change of pressure, whether it be in the direction of increase or decrease.

The cyclones of the Temperate Zones do not often present the phenomenon of a central calm, with the winds blowing from nearly opposite directions on each side of it. There is, therefore, not so much risk of being taken aback as in tropical cyclones (*see* p. 53); but it is advisable for a captain to know on which tack it will be safer to lie-to if obliged to do so, and this will be the same as that for the tropical cyclones of the respective hemispheres.

The most sudden shift of wind which is to be expected in these cyclones in latitudes generally frequented by shipping is that from South-west to North-west in the Northern Hemisphere, or from North-west to South-west in the Southern. This is generally accompanied by heavy rain or hail, with thunder and lightning, while the temperature falls several degrees with the first blast of North-west or South-west wind, as the case may be, according to the hemisphere.

There are two matters to which the seaman's attention should be directed, as they seriously affect the conclusions he should draw from his barometer readings.

* The general introduction of wireless telegraphy now enables ships at great distances to exchange barometer readings, and thus it is possible for a synoptic chart to be prepared at sea.

The first is that on the one tack his barometer has a tendency to rise, on the other it has a tendency to fall. The tack of rising barometer is the starboard in the Northern, the port in the Southern Hemisphere. This may be explained as follows :—

According to Buys Ballot's law, in the Northern Hemisphere (see Fig. 13) the lower barometer is on your right when your face is turned to the wind, and as, when you are thus placed, a vessel on the starboard tack is advancing towards your left, she goes towards the higher barometer and recedes from the lower. In the Southern Hemisphere this is reversed, and the vessel on the port tack advances towards the higher and leaves the lower barometer.

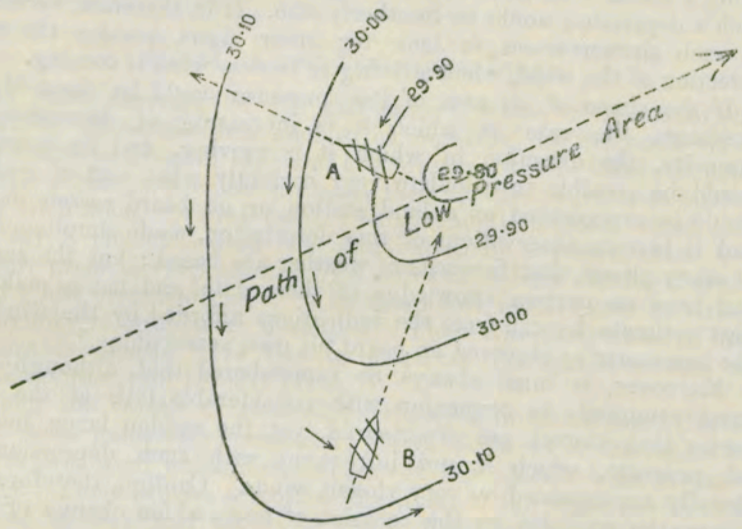


Fig. 13.

Northern Hemisphere.

A. Vessel on Starboard Tack.

B. Vessel on Port Tack.

But this rule will only be strictly applicable so long as no change takes place in the position of the area of barometrical pressure, and it may so happen that a high pressure, towards which the vessel is going, may be receding from her faster than she sails, and a lower pressure may be coming up astern and overtaking her; or it may be that a lower pressure towards which the vessel is sailing may be moving away faster than she sails. Still the influence of the tack must always be felt, and, on the whole, it may be said that in the Northern Hemisphere a rising barometer on the starboard tack is not a sufficient indication of improving weather, and other signs should be looked for before trusting it. In all cases for the Northern Hemisphere a rising barometer on the port tack is a valuable indication of improving weather, while a falling barometer on the starboard tack is a valuable warning in the other direction. This order is reversed in the Southern Hemisphere. (See Fig. 14, p. 43.)

The second point to consider is the relation which the course and speed of the vessel bear to the tracks and progress of the areas of low barometrical pressure and their corresponding wind-systems, in parts of the sea where the general tracks of storms are known. This will be easily done by taking, as an illustration, the case of a steamer traversing the North Atlantic between England and America, where storms generally move in an easterly direction.

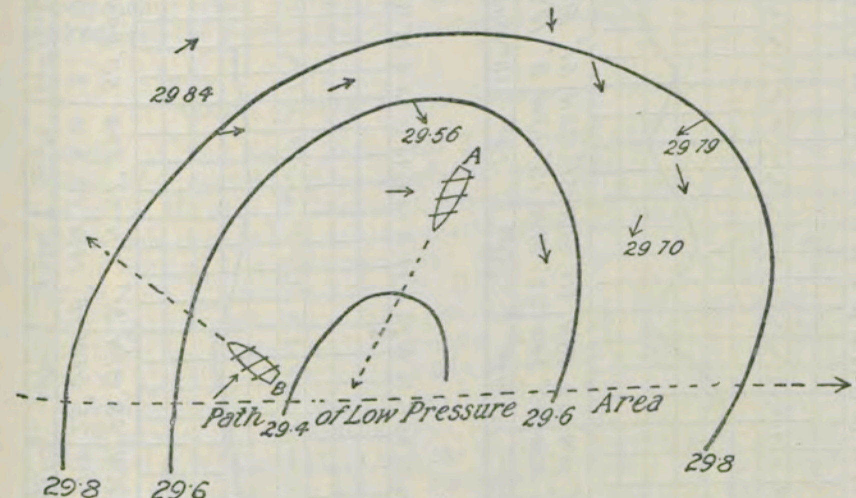


Fig. 14.

Southern Hemisphere.

A. Vessel on Starboard Tack.

B. Vessel on Port Tack.

If a low pressure system is advancing Eastwards at the rate of, say, 20 miles an hour, and the vessel is steaming at the average rate of, say, 10 miles an hour, the result will be that when going westward the vessel will have a relative rate of motion towards the low pressure of 30 miles an hour, but when going eastward, of only 10 miles an hour.

In other words, vessels when outward bound across the Atlantic meet the advancing low pressure systems, which commonly travel from West to East, and when homeward bound run with them, consequently the rapidity with which the barometer falls or rises and the wind shifts is proportionately greater in the former cases than in the latter.

Figs. 15 and 16 illustrate these cases. The arrows fly with the wind, and the curves give the height of the barometer at every sixth hour. They represent observations taken by Capt. W. Watson, of the Cunard steamer "Algeria," Fig. 15, during a passage *to* New York, and Fig. 16 during a passage *from* New York. They are types of the differences experienced, which are so great that it is often possible to tell whether the vessel was steering to the eastward or westward by a comparison of her barometer curves alone.

In Fig. 15, where the passage was to the Westward, the dates run from right to left. It shows that the barometer fell and rose quickly, and that the steamer met with six alternations of high and low pressure, with their accompanying wind-systems. Also that the fall of the barometer was generally accompanied by a

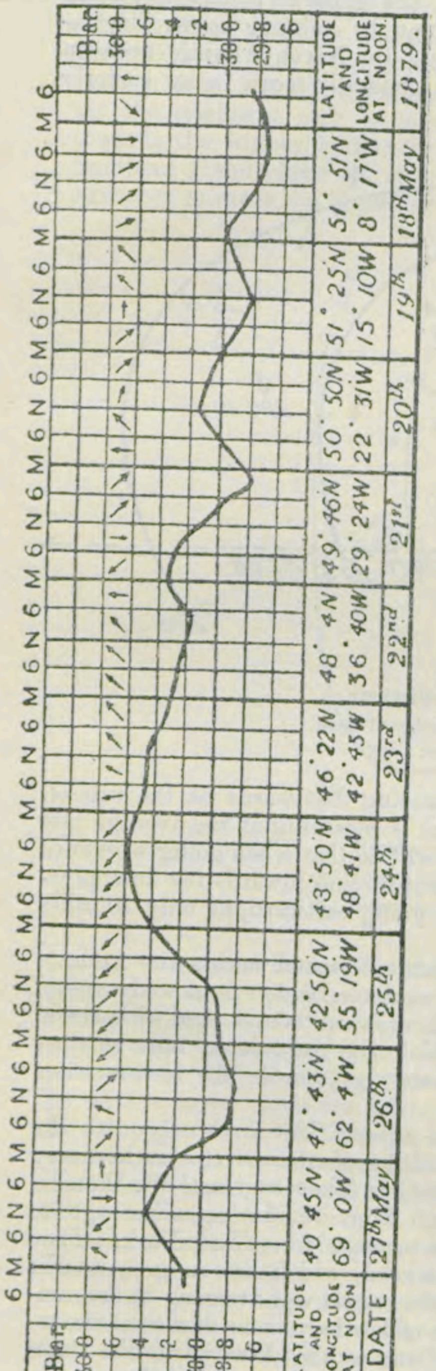


Fig. 15.

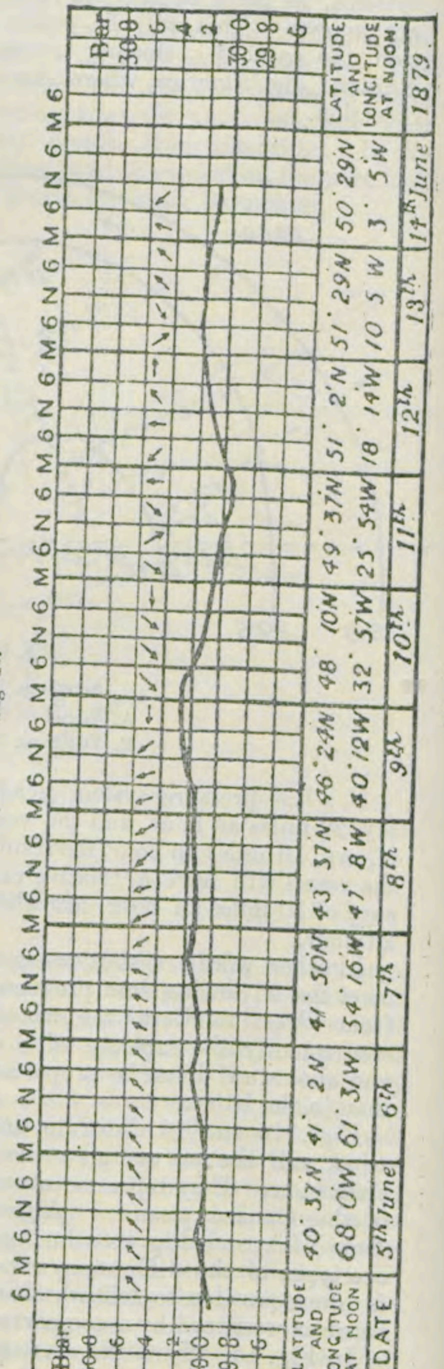


Fig. 16.

South-easterly or Southerly wind, and that with a rise the wind drew more Westerly and Northerly.

In Fig. 16, where the passage was to the Eastward, the dates run from left to right. It shows that the barometer rose and fell slowly, and that the steamer experienced only two wind-systems; also that the barometer rose with a Southerly and South-easterly wind, and fell with a Northerly wind, indicating that the steamer moved to the Eastward faster than the wind-system which she was experiencing when starting; in fact, showing that she caught up and entered the western side of another wind-system.

Gales of the North Temperate Zone.

Gales of the North Temperate Zone which are experienced in latitudes frequented by shipping usually commence at S.E., S., or S.W. and end at W. or N.W. because the central area of the wind system with which these winds are associated generally travels on a path that is situated in higher parallels. If a vessel in the North Temperate Zone experiences a fresh S., S.E., or S.W., wind, with a relatively high temperature and falling barometer, Buys Ballot's law shows that there is an area of low pressure to the W. or S.W. of her; and, as already said, it is probably travelling to the E. or N.E. Experience shows that whether the vessel be hove to or stands to the Westward, the barometer will fall until the wind shifts to the Westward (which generally happens during a heavy shower of rain, together with a sudden fall of temperature), when the barometer will probably rise as fast as it previously fell, and a strong N.W. wind will set in. (*See* Plate IX.)

The general belief that the rate at which the barometer falls is an indication of the strength of a Southerly wind of gale force in these latitudes requires some qualification. The fact that the force of the wind depends on the amount of the barometrical gradient supports this idea; but we must also take into consideration the speed at which the area of low pressure is travelling. Suppose, for instance, that having a very steep gradient, it stood still, as sometimes happens, the wind would blow furiously, although the barometer would cease falling, unless the depression were becoming deeper. Then, again, suppose that a depression with a comparatively slight gradient were passing very quickly, the barometer would fall quickly, though the wind would not be strong.

It is also important to consider the vessel's course and speed in connexion with the course and speed of the area of low pressure, as already remarked on p. 43, and illustrated by Figs. 15 and 16.

The following instance may be cited as an illustration of what frequently occurs to a sailing vessel. A homeward-bound vessel in about 45° N. 30° W., falls in with a fresh Southerly wind, and from what has been said the captain knows that there is a lower pressure to the West of him, and he may safely consider that it is travelling to the Eastward or North-east; but his vessel is also going in the same direction, and his barometer may remain steady, or even rise, if he is outstripping the low pressure in its advance.

If, in such a case, on taking into consideration the state of sea and other weather indications, the conclusion is come to that a gale is coming up from the Westward, and the vessel is likely to have to reduce her speed, on closing with the land, or otherwise, it may be well to prepare for worse weather. In the event of heaving-to, the amount of fall in the barometer per hour is a good, though not certain guide in this connexion, as before said; a fall of ·04 to ·10 of an inch per hour is usually considered to be a serious indication of the approach of a Southerly wind of gale force, which may be followed by an equally fast rise, accompanied by a W. or N.W. wind of gale force.

From what has been said it will be clear to the navigator that in northern latitudes, at the setting in of a Southerly wind, a sailing ship, as well as a steamer, bound to the Westward will, by her course and speed, cause the barometer to fall quicker than if she hove-to or stood to the Eastward, so that in this case also the state of the sea and other appearances ought to be considered, or her captain may be led to anticipate worse weather than is really coming.

With a Southerly wind and falling barometer, a sailing vessel bound to the Westward might gain by running to the Northward, with the object of reaching the northern side of the approaching system and a wind backing to the Eastward. Again, it might be possible for a sailing vessel, with the first of the southerly wind which exists on the east side of the area of low pressure, to get less wind by running North, but as the extent in latitude of the disturbed area is not known, and, consequently, there is no certainty of running into more moderate weather, the manœuvre might be contrary to her interests, especially as the path of the storm would be crossed. (*See* Plate X.)

It seems, then, probable that a sailing vessel bound to the Southward or Westward must face one of these gales if she meets it. A weak vessel, with which it is desired to stem the sea and get safely through, without considering progress, should lie-to on the starboard tack, as the wind generally shifts from S. to S.W., W., and N.W. This would, of course, be the best plan for any vessel which found the gale too heavy for her. But a well-conditioned vessel, bound to the Westward, might keep on the port tack until the wind shifts to West with a rising barometer, and then tack to the South-westward. This plan, would, of course, tend to bring her into the trough of the sea, and she would be more likely to be caught aback as the wind changed, but it is assumed the captain is aware of and prepared to meet these risks.

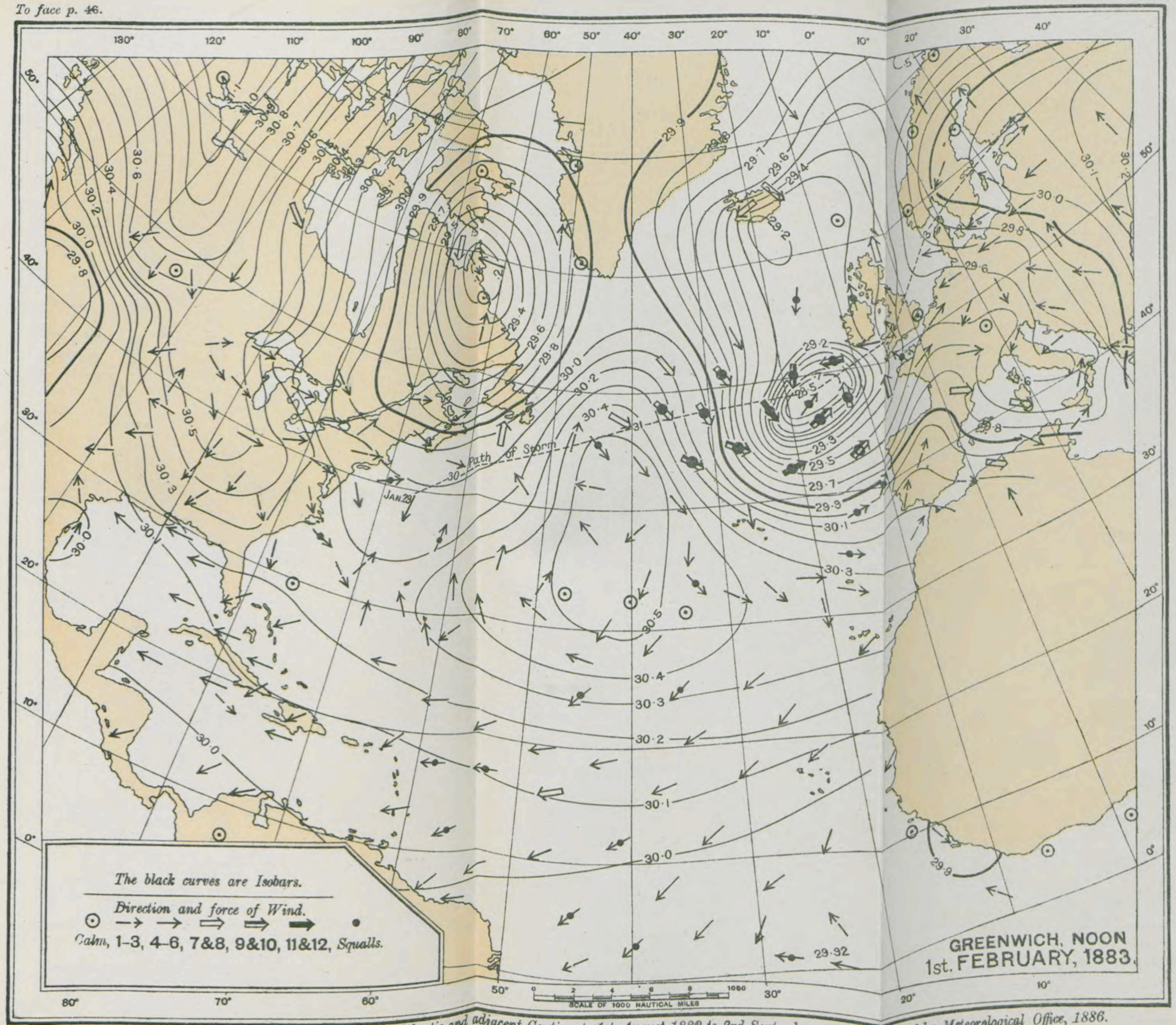
When the wind has shifted to N.W. the starboard tack takes a vessel away from the centre of such a disturbance, though she may soon sail into the Southerly wind of the Eastern side of another low-pressure area coming towards her. This would be a very common occurrence in winter.

Gales of the South Temperate Zone.

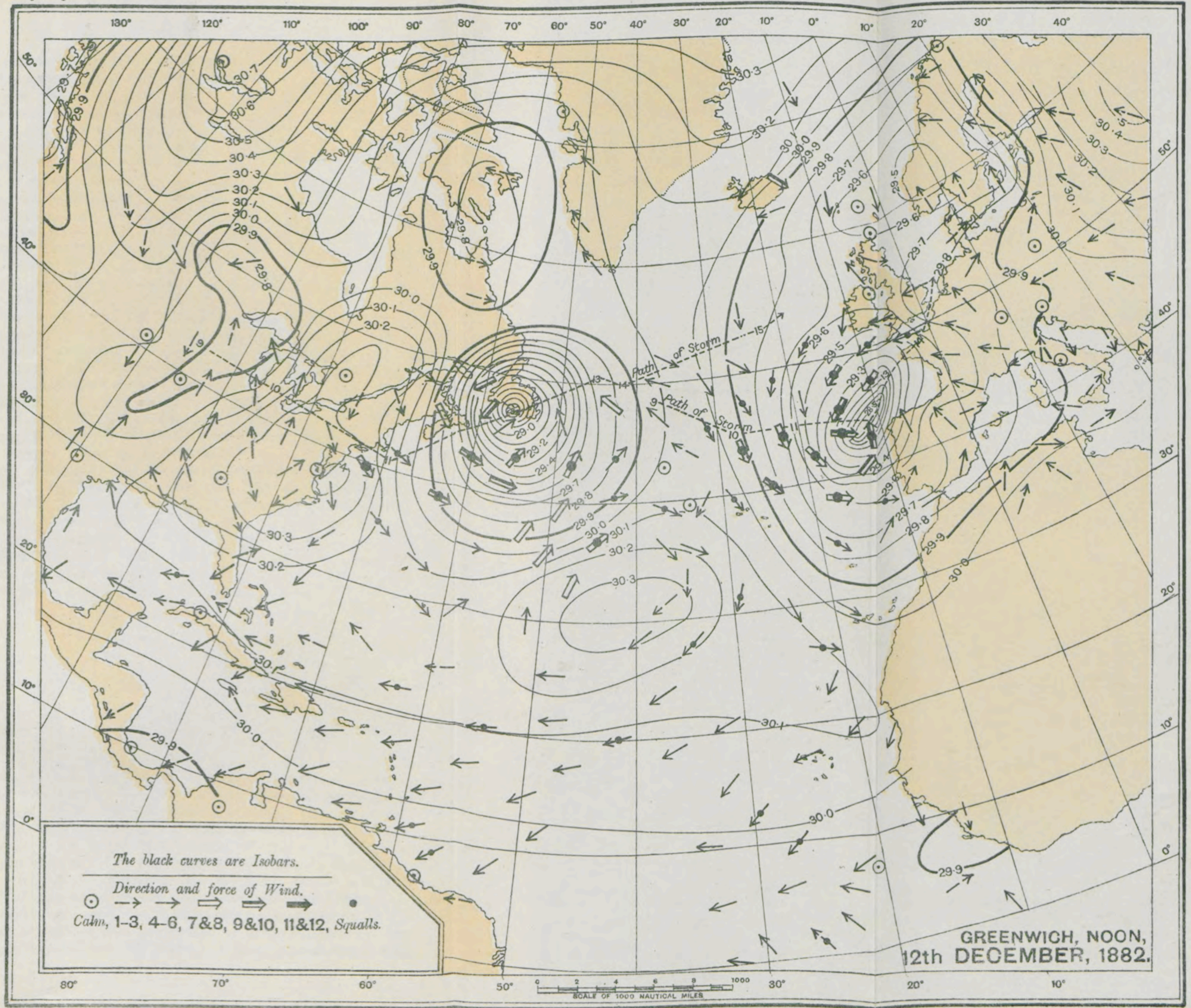
The prevailing gales of the South Temperate Zone resemble those of the Northern, and in describing them it is only requisite to remember that there North and South change places. For instance, as a ship bound to Australia gets into 40° S., "the Roaring Forties," a series of gales will probably be experienced, which, commencing at

To face p. 46.

PLATE IX.



From "Synchronous Weather Charts of the North Atlantic and adjacent Continents 1st August 1882 to 3rd September 1883," Published by Meteorological Office, 1886.



From "Synchronous Weather Charts of the North Atlantic and adjacent Continents 1st August 1882 to 3rd September 1883," Published by Meteorological Office, 1886.

N. or N.E., end at W. or S.W. Now with a Northerly wind in the Southern Hemisphere there is a low pressure to the Westward, and the way in which the wind usually changes proves that those areas of low pressure are also travelling to the Eastward. Vessels which keep a steady Westerly wind for days as they run to the Eastward in comparatively high Southern latitudes, are probably keeping company with one of these areas of low pressure, and if they had hove-to or commenced beating to the Westward they also would have experienced many changes just in the same manner as is the case with steamers in the North Atlantic bound to ports in America, whilst those from America frequently keep a steady barometer and Westerly wind for days. This receives abundant confirmation from the frequency of the barometrical oscillations and changes of wind experienced by vessels bound to the Westward, in rounding either the Cape of Good Hope or Cape Horn.

The best method of manœuvring in a heavy gale, or with a weak vessel in an ordinary gale, is reversed for southern latitudes: there the port is the "coming up" tack, which enables her to stem the sea, as the wind usually shifts from N. through N.W. to S.W., the centre being south of the ship, and the port tack with a S.W. wind takes her away from the low pressure to which the wind is related, though of course it may, and in the winter months most probably will, soon take her into the Northerly wind on the Eastern side of another low pressure area coming towards her.

For a ship beating to the Westward, of course the best progress is made by keeping on the starboard tack with the wind N. and N.W. until it shifts to W. and S.W., when she ought to tack to the North-westward; but it will be seen that, as in the best method for making progress to the Westward in high northern latitudes, the ship will be headed off, and get into the trough of the sea; she will also be more liable to be taken aback as the wind changes than if she were on the port tack.

Chapter VI.

TROPICAL REVOLVING STORMS.

The wind in a cyclone blows round a central area of relatively low barometric pressure; the direction of revolution being opposite to that of the hands of a watch in the northern hemisphere, but with watch hands in the southern hemisphere. The statement of this rule more familiar to seamen is—in either hemisphere the wind travels round the central area of a cyclonic system in a direction contrary to that of the apparent diurnal course of the sun in the heavens. The westerly wind of a cyclone in either hemisphere is, therefore, always found on that portion of the whirl which is nearest to the equator. It has already been shown that when facing the wind of a cyclone in the northern hemisphere the barometer is always lower on the observer's right hand than it is on his left hand; and, similarly, in the southern hemisphere, facing the wind of a cyclone the barometer is always lower on the observer's left than it is on his right. A close acquaintance with this law is most important. By its aid the seaman who comes under the influence of a tropical revolving storm, and who has to rely solely upon the indications of his own barometer, supplemented by observations of wind, clouds and weather, is able to determine the approximate geographical position of the centre of a cyclone; and with this knowledge may manœuvre his ship so as to avoid this region of maximum danger in the vicinity of which the force of the wind is greatest, the changes in its direction are most sudden, and the sea most dangerous.

The wind force in a cyclonic system does not necessarily attain to that of a gale, as estimated by Beaufort's scale;* the air circulation may be complete, but, if the barometric gradient is slight, the wind may be moderate or even light. The direction and strength of the wind depend upon the direction and steepness of the barometric gradient which, as already stated, may be defined as the difference in atmospheric pressure in hundredths of an inch for each 15 miles. In alluding to a cyclone then we are referring to a characteristic circulation of air round a central area of low atmospheric pressure without regard to the force of the wind associated with it. The term "cyclone" therefore includes not only the revolving storms of the tropics, in which the wind blows with great violence, but also all wind systems, of high and low latitudes, in which the air circulation is cyclonic. In these storms absolutely the same air particles do not keep with the whirl throughout its career; as there is a continual degradation and reformation as it moves along the earth's surface. For the purposes of the practical navigator, however, it may be assumed that the tropical revolving storm is invariable in its composition over small distances of the track followed.

The cyclone of tropical origin, or tropical revolving storm, with which we have now to deal, is known in different localities by distinctive names. In the West Indies and in the islands of the South Pacific these storms are called Hurricanes, in the North-West Pacific and China Sea they are known as Typhoons, and in the Indian Seas simply as Cyclones. Of all the atmospheric disturbances the approach of which the barometer indicates, and consequently enables the seaman to avoid, these storms are the most serious. They are seldom experienced within 5° or 6° of the equator; but their track occasionally extends from the tropics to high latitudes.†

* The Specification of the Beaufort Scale is given in Appendix III.

† TABLE of recorded HURRICANES, CYCLONES, and TYPHOONS, in various parts of the World.

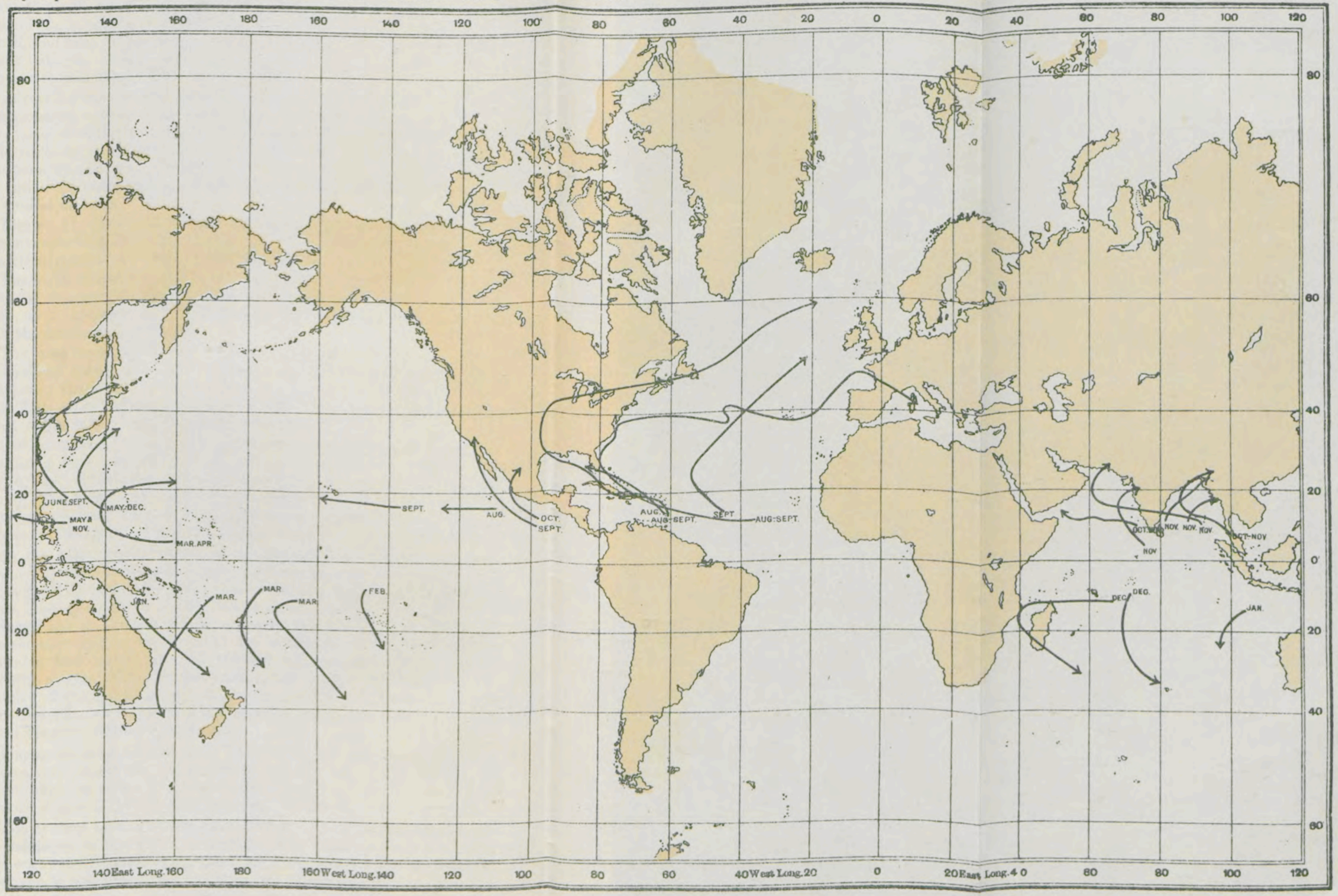
Region and Period.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL.
West Indies, 300 years	5	7	11	6	5	10	42	96	80	69	17	7	355
South Indian Ocean (38 years, 1848 to 1885)‡	71	61	59	50	19	3	2	—	—	5	25	33	328
Bombay, 25 years	1	1	1	5	9	2	4	5	8	12	9	5	62
Bay of Bengal, 139 years	2	—	2	9	21	10	3	4	6	31	18	9	115
China Sea, 85 years	5	1	5	5	11	10	22	40	58	35	16	6	214
Arabian Sea, 1877–1903	—	—	—	1	5	6	—	—	—	2	7	—	21
Bay of Bengal, 1877–1903	—	—	—	1	8	4	4	2	6	8	17	6	56
South Pacific, 1789–1891	36	22	35	8	1	—	—	—	2	1	4	16	125

‡ No information for the years 1849, 1850, and 1853.

To face p. 48.

SELECTED EXAMPLES OF TRACKS OF TROPICAL REVOLVING STORMS.

PLATE XI.



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The geographical conditions which are most favourable to their formation and development are found where the coastlines of large continents, in which are many bays and indentations, run north and south, and face to the eastward a wide expanse of sea, in which are many islands. Such conditions are more or less fulfilled in the regions to which reference has been made.

Revolving storms have, in addition to a motion round a centre of low pressure, a progressive movement. The wind blows in a more or less spiral direction towards the centre, and at the same time the storm field advances on a straight or curved track. Cases exist in which the velocity of advance of the system has amounted to as much as 45 miles an hour, and in others the translation was not more than two miles an hour.

Figure 17 (page 50) illustrates the average paths followed by storms travelling from the Tropics into the Temperate Zones ; also the circulation of the wind in the storm-field.

The track which the centre of the storm follows is known as the path of the storm, and that part of the storm on the right of the path, as it advances, is named the right hand semicircle, and on the left, the left hand semicircle.

The area over which these storms have been known to extend themselves varies from 20 or 30 miles to some hundreds of miles in diameter, the wind blowing with varying force, sometimes lulling into little more than a strong breeze, and as the centre is approached often rising into a blast of almost irresistible fury.

One semicircle of a storm is known as the dangerous semicircle because a vessel might be driven when in it across the path of the storm, and would certainly cross the path if she ran before the wind. The right hand is the dangerous semicircle in the Northern Hemisphere, and the left hand semicircle in the Southern Hemisphere. The other semicircle, in each case, is termed navigable.

In the Atlantic and South Indian Oceans these storms commence to the Eastward and travel along a path not exactly West, but inclining a point or two towards the pole of the hemisphere in which they have been generated ; as they advance, they curve away still more towards the pole, and finally move to the N.E. in the Northern Hemisphere and to the S.E. in the Southern Hemisphere. They move in fact round the sub-tropical high pressure areas. The Atlantic storms almost always wheel round to the Northward in the vicinity of the Bahamas, and follow the sea-board of North America ; but some recurve in the Gulf of Mexico, and a few appear to pass on to Mexico without recurvation.

Tracks of some of the most remarkable hurricanes, or cyclonic storms, are shown by thick arrows on Plate XI ; the months in which they occurred being given at the ends of the arrows. For a more complete list of their seasons, see the footnote to page 48.

The cyclone season of the South Indian Ocean may be considered to commence in November and end in May ; but cyclones occasionally occur in October, June, and July. In August and September, however, it would appear that they are altogether absent from the South Indian Ocean, as there are no records of their occurrence in those months. The maximum frequency is found between January

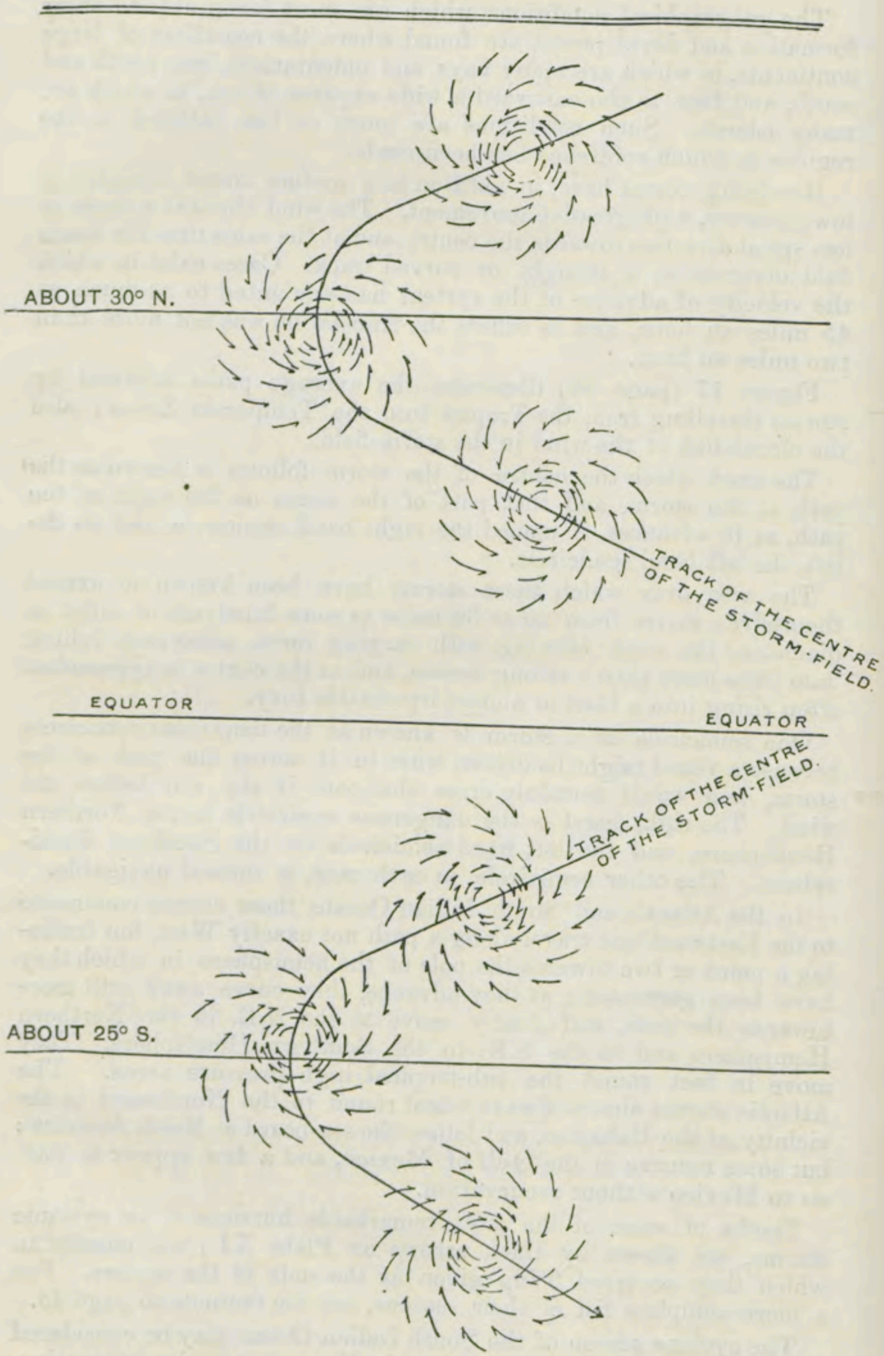

Fig. 17.

DIAGRAM SHEWING THE AVERAGE SHAPE AND TRACKS OF CYCLONIC STORMS, NORTH AND SOUTH OF THE EQUATOR.

and March, and the minimum from May to October. The probability of encountering a South Indian Ocean cyclone is therefore greatest when the sun's declination is south, and least when it is north. These cyclones frequently originate on the tenth parallel of south latitude, travel south-west along a parabolic track to a vertex in about 21° S., then recurve, and eventually move to the south-eastward. At rare intervals, however, the point of curvature is as far north as 8° S., or as far south as 32° S. As regards the longitude of the vertex, it may be on any meridian between Keeling Island and the Mozambique Channel. The cyclone tracks of this ocean are similar to those of the North Atlantic, but are apparently more nearly in agreement with a smooth curve. South Indian Ocean cyclones travel but slowly, the average rate being about six miles per hour.

The late Dr. C. Meldrum, C.M.G., F.R.S., when stationed at Mauritius, was favourably situated for receiving reports from sailing ships which had suffered from cyclones in the South Indian Ocean and put into Mauritius for repairs. He dealt with the cyclones of that ocean in great detail, and his tracks, with additions, will be found on the monthly Meteorological Charts of the Indian Ocean and Red Sea, which were issued by the Meteorological Office during the years 1906–9.

In the South Pacific, the season for tropical revolving storms commences with December and ends with March, although an occasional hurricane may be experienced in April. They generally originate to the north-east of the Fiji islands, and the rate of travel is said to vary from about two miles an hour in the lower latitudes to twenty miles an hour in 30° S. While passing over the island groups these storms appear to be almost stationary for a time.

Typhoons of the China Sea originate to the eastward of the Philippines, Carolines, and Ladrones. In the lower latitudes the centres travel westward. Some pass over the mainland, some recurve to the eastward, and eventually reach the west coast of North America by way of Japan. Tracks of tropical storms of the North Pacific are very similar to those of the North Atlantic. The Rev. José Algué, S.J., Director of the Manila Weather Bureau, in his valuable report on "The Cyclones of the Far East," divides the tracks into two broad classes—those of the Pacific, which do not cross the meridian of 124° E., and those of the China Sea, which either cross that meridian or are formed in the China Sea.

Between December and March, the centres of the former class of cyclones travel N.N.W., the latitude of the vertex lies between 15° N. and 19° N., and they travel thence to the N.N.E. In April and May, as also in October and November, the corresponding movement of the centres is N.W. to about 16° N. to 21° N., thence N.E. Between June and September the tracks are N.W. by N. to about 21° N. to 25° N., thence N.E. by N. Adopting three groups of the same months for the tropical storms of the China Sea, it is found that the tracks of the first period do not recurve over the sea. Of those of the second period only a portion have parabolic tracks; and the vertices of these latter are found in the China Sea to the southward of Formosa Channel. During the months called by Algué typhoon months, cyclones belonging to the third of these groups recurve much more frequently than during either of the preceding periods. The parabolic tracks of China Sea typhoons, as shown on Plate XI, are similar to those of the Pacific Cyclones belonging to the corresponding groups. The zone of origin for typhoons of the first group is bounded by the parallels of 5° N. and 12° N., and they reach the mainland between 8° N. and 15° N.; that for typhoons of the second group is from 6° N. to 17° N., and they reach the coast of Asia between 12° N. and 23° N.; and finally, the zone of the third group is between 8° N. and 20° N., and they reach the mainland on parallels from 18° N. to 30° N.

A typhoon is considered to travel rapidly, in the vicinity of the Philippines, if its velocity of translation exceeds 12 miles an hour; and slowly if it moves at a rate of less than 12 miles an hour. The same storm may be rapid, moderate, or slow, during varying phases of its existence; it may be moderate in the lower latitudes, almost stationary at point of recurvature, and rapid in the higher latitudes. Of typhoons that crossed the Archipelago, or the adjacent regions of the ocean, which have been traced; 40 travelled rapidly, 180 with moderate speed, 30 moved slowly, and a few remained stationary for several days.

The Bay of Bengal has not in recent years been visited by storms in January, February, and March, and they seldom occur in April. During the remaining months of the year they are not infrequent, the maxima occurring in May and October. They are most violent in October and November. Storms of the Arabian Sea may be divided into two classes: those which have their origin over the sea, and those which reach the Sea from the Bay of Bengal. Several have been traced from the Andamans across the southern portion of the Peninsula and over the Arabian Sea for a considerable distance.

In April, the storms of the Bay of Bengal originate in mid-ocean, between the Nicobars and Ceylon, and travel N.E.; in May some appear first near the Andamans, and proceed either N.E. or N.W., and some originate near Madras and travel W.N.W. During June, July, August, and September, storms commence in the head of the Bay and move N.W. In October they have their origin to the north of 8° N., and travel either N.E. or W.N.W. They either take a similar path in November, or cross the Peninsula and continue their course in the Arabian Sea. In December the majority have their birth between 8° N. and 16° N., to the N.E. of Ceylon, move between N.W. and W., and sometimes reach the Arabian Sea; a few, which originate a little to the westward of the Andamans, proceed N.E. towards the head of the Bay.

The rate of movement of these storms, though variable, may be averaged at 300 miles a day in the West Indies; in the Arabian Sea, in the Bay of Bengal, and in the China Sea, 200 miles a day; whilst in the Southern Indian Ocean their rates vary from 50 to 200 miles a day. Records seem to show that at the beginning or end of the hurricane season a considerable proportion of the storms in the Indian Ocean are either stationary or slow in movement.

The indications of the approach of a revolving storm are (*a*) an unsteady barometer or even a cessation in its usual diurnal range; (*b*) the usual ugly and threatening appearance of the weather which forebodes most storms, and the increasing number and severity of the gusts with the rising of the wind; (*c*) a long heavy swell which generally comes from the direction in which the storm is approaching, or a confused sea.

In every case there is great barometrical disturbance, the barometer at the centres of some of these storms standing fully two inches lower than outside the storm-field.

Practical Rules for Seamen in Tropical Cyclones.

When in the region, and in the season of revolving storms, be constantly on the watch for the premonitory signs, *and carefully observe and record the barometer.*

When there is reason to believe that a storm is approaching, the two points necessary for the seaman to know are (*a*) the direction in which the centre of the storm is situated, and (*b*) in which semicircle of the storm the vessel is situated.

In order to ascertain these two points it is necessary that the observer should be stationary; the first thing, therefore, to be done is to stop head to wind, or heave-to, and as it is always wise to assume the vessel may be in the dangerous semicircle, she should be hove-to, on the starboard tack in the Northern Hemisphere, and on the port tack in the Southern Hemisphere. There should be no hesitation in heaving-to, as the sooner a clear knowledge of the position of the ship in the stormfield is ascertained the sooner can the necessary action be taken to avert the danger.

When hove-to, the bearing of the centre, if the observer faces the wind, will be from 12 to 8 points on the right hand in the Northern Hemisphere, and on the left hand in the Southern Hemisphere. At the beginning of a storm allow 12 points, when the barometer has fallen $\frac{3}{10}$ of an inch about 10 points, and when it has fallen $\frac{6}{10}$ or upwards 8 points.

Having ascertained the bearing of the centre, the semicircle in which the vessel is situated may be found by observing in which direction the wind shifts. If it shifts to the right, the ship is in the right-hand semicircle; if to the left, in the left-hand semicircle; and if the wind is steady in direction, but increasing in force, with a falling barometer, the vessel is in the direct path of the storm. This law holds good in both hemispheres.

If a seaman has reason to think he is in the direct path of the storm's centre, the most prudent course to pursue is to run his ship, in the Northern Hemisphere, with the wind on the starboard quarter; in the Southern Hemisphere, with the wind on the port quarter, until the barometer has ceased to fall.

This course of action should be adopted in the case of a steamship as well as in that of a sailing vessel.

In the Northern Hemisphere, if your ship is in the right-hand semicircle, and she is a sailing vessel, remain hove-to on the starboard tack, so as to come up to wind and sea as the former continues to draw aft; if a steamship, heave-to with the wind ahead, if possible, f not with the wind on the starboard bow.

In the Southern Hemisphere, if your ship is in the right-hand semicircle, whether she be a sailing vessel or a steamship, run with the wind on her port quarter, until the barometer commences to rise.

In the Northern Hemisphere, if your ship is in the left-hand semicircle, whether she be a sailing vessel, or a steamship, run with the wind on her starboard quarter, until the barometer commences to rise.

In the Southern Hemisphere, if your ship is in the left-hand semicircle, and she is a sailing vessel, remain hove-to on the port tack; if a steamship, heave-to with the wind ahead if possible, if not with the wind on the port bow.

The researches of Dr. Meldrum, formerly Director of the Government Observatory at Mauritius, have shown that, in the South Indian Ocean, a vessel approaching a cyclone on its southern side almost always encounters a strong Trade wind, which freshens to a gale. It is difficult to tell when the Trade forms part of the storm area; consequently the bearing of the centre can seldom, in this position, be inferred from the direction of the wind.

It is therefore recommended under such circumstances to heave-to and watch the wind and barometer; when the wind has shifted decidedly to the East or South the passage of the centre with respect to the vessel's position may be approximately inferred.

If the wind shift from S.E. decidedly towards the South, run to the N.W. Or, if the wind remain steady at S.E., and increase in force, the barometer still falling, it is probable the storm is advancing directly towards the vessel; in such case, the most dangerous of all, run to the N.W.

It is also stated that in the cyclones of the South Indian Ocean, North-easterly and Easterly winds often, if not always, blow towards the centre. Such being the case, it is better to make as much easting as possible.

It might easily be shown, Dr. Meldrum remarks, that all the homeward-bound vessels that put into Mauritius for repairs do so in consequence of damage sustained in a cyclone which they entered on its northern side. There is a strong temptation to such vessels to run on with a favourable breeze; but a freshening Northerly or North-easterly wind, with a falling barometer and threatening appearance of the weather, should warn them to heave-to in time.*

* For recorded tracks of cyclones in the Southern Indian Ocean see the Monthly Meteorological Charts of the Indian Ocean and Red Sea, published by the Meteorological Office during the years 1906-9. For further information concerning tropical revolving storms the reader may consult Eliot's "Handbook of cyclonic storms in the Bay of Bengal" and Algué on "The typhoons of the Far East."

APPENDIX I.

THE THERMOMETER, HYGROMETER, AND HYDROMETER.

Thermometer.—This instrument shows increase or decrease of temperature but is not sensibly affected by changes of the pressure of the air. It consists of a glass tube of very small bore, closed at one end, and united at the other to a bulb, which is commonly filled with mercury. Thermometers intended for use in very cold climates are filled with spirit instead of mercury, which would freeze and solidify at the low temperatures of the Arctic regions, whereas spirit would not freeze. Mercury freezes at a temperature of about − 38·2° Fahr. = 39° Cent.; spirit (pure alcohol) becomes a thick liquid at − 130° Fahr., and solidifies into a white mass at − 202° Fahr. Almost all substances expand when they are heated, and contract when they are cooled, but they do not all expand equally. Mercury expands more than glass, and so when the thermometer is heated the mercury in the bulb expands, and that portion of it which can no longer be contained in the bulb rises in the tube, in the form of a thin thread. The tube being very minute, a small expansion of the mercury in the bulb, which it would be difficult to measure directly, becomes readily perceived as a thread of considerable length in the tube. When the instrument is cooled the mercury shrinks, and the thin thread becomes shorter, as the mercury subsides towards the bulb. By observing the length of the thread of mercury in the tube, as measured by the graduation on the scale at its side, or marked on the tube, the thermometer shows the temperature of the bulb at the time, which thus indicates the temperature of the surrounding air, or of any liquid in which the bulb is immersed.

The indications of a thermometer are recorded in degrees, the scale for which is obtained as follows. There are two fixed points on the scale according to which thermometers are graduated, viz., that at which ice melts, and that at which water boils. In the thermometers in ordinary use in England, the distance between these two points is divided into 180 parts, or degrees. When surrounded by melting ice an accurate thermometer on this scale indicates thirty-two degrees (32°) and if placed in boiling water, when the barometer reading is 30 inches, the reading is two hundred and twelve degrees (212°). This graduation was adopted by Fahrenheit, a native of Dantzig, in the year 1721. Other graduations were devised about twenty years later; one by Celsius, a professor at Upsala, in 1742; and another by Réaumur, a French physicist, at about the same period. Celsius suggested that the boiling-point be called zero, and the freezing-point 100°. In the modern Centigrade scale, which is an adaptation of the Celsius, and in general use at the present time in most Continental countries, the freezing-point is taken at zero, and the boiling-point at 100°. Réaumur framed a scale somewhat similar to the Centigrade but divided the interval between the freezing and boiling-points into eighty divisions. This scale, which at one time was commonly employed on the Continent, is now almost obsolete.

The Absolute scale is yet another measure of temperature, that has been introduced, based on the researches of the late Lord Kelvin, Dr. J. P. Joule and others, who found the absolute zero of temperature to be 273° Centigrade below the freezing-point of water, or 459° on the Fahrenheit scale. This zero of temperature is based on the doctrine of the dissipation of energy, heat having for a long time previously been recognized as a form of energy. It represents, so far as our present knowledge goes, the temperature at which the whole of the heat of any substance whatever would have been converted into some other form of energy. The principal advantage of the Absolute scale for meteorological work is that all negative values are avoided.

In order to convert readings of the Centigrade scale to that of the Fahrenheit: double the Centigrade number, diminish this by one-tenth of itself and add 32. To convert from Fahrenheit to Centigrade: subtract 32 from the former, increase the remainder by one-ninth of itself and take the half.

In Table II. the conversion of Centigrade degrees into degrees Fahrenheit is given; and in Table III. the conversion of Fahrenheit degrees into Centigrade. For the conversion of temperature readings of the Fahrenheit and Centigrade scales to the Absolute scale Table IV. is furnished.

The usual range of a thermometer in the shade in the open air, in England, is about seventy degrees, viz., from 10° to 80°. In very hard frosts the temperature of the air sometimes falls below 10°, and on very hot summer days it rises above 80°. If the instrument is exposed directly to the rays of the sun, th mercury will rise much higher, and at night, if exposed to radiation to a clear sky, may fall many degrees below what would be due to the temperature of the surrounding air. It is therefore necessary to take precautions for protecting the instrument from the direct rays of the sun, or from exposure to the clear sky at night, in order to obtain a correct indication of the temperature of the air. The range of the thermometer, or more correctly of the temperature of the air, is greater in many other countries, especially in the interior of the great continents, where the winters are much colder and the summers much hotter than here. In islands of small extent in the warmer regions of the earth the range is much less than in the British Isles.

The Thermograph.—A self-recording thermometer, or thermograph may be employed with advantage on board ship for obtaining a continuous record of temperature, which, if studied in connexion with the record of a barograph for the same period, will demonstrate the close relation existing between the fluctuations in temperature and pressure respectively.

The instrument will be found, after the observer has had a little experience with it, a valuable aid in foretelling changes in weather conditions. For instance: a marked rise in temperature, detected by a glance at the thermogram, if associated with a shift of wind to an equatorial quarter, will frequently give warning of the approach of an atmospheric disturbance before the barometer has commenced to fall.

In most thermographs the thermometer consists of a slightly curved metal tube filled with spirit (Bourdon tube). One end of this is fixed rigidly to the instrument while the other is attached to the system of levers which actuates the recording pen.

From the nature of the case thermographs for meteorological use must be exposed out of doors, preferably in a Stevenson screen, and hence it is necessary to clean and oil their bearings much more frequently than is the case with barographs.

The instrument may be set by comparing its indications with the reading of a standard mercury thermometer placed beside it in the screen. The setting should only be attempted at times when the temperature is constant or changing slowly, and only when the pen is near the middle of its range. As the thermometer is in thermal contact with the body of the instrument (which takes an appreciable time to alter in temperature) it is apt to be somewhat sluggish when the changes of temperature are rapid.

The readings of the thermograph require frequent checking by comparison with standard instruments. A convenient plan is to place a standard maximum and a standard minimum thermometer in the screen with the instrument and to read and set these at regular hours, time marks being made at the hours of reading. It should be borne in mind that in cases when the trace shows that the extreme was of very short duration the sluggishness referred to above may cause a considerable difference between the reading of the standard and that of the recorder.

Hygrometer.—This instrument measures the humidity of the air. There are several kinds of hygrometers, but the easiest to make and to manage consists of a pair of thermometers placed near each other. If one of these be fitted with a single thickness of fine muslin or cambric fastened tightly round the bulb, and this coating be kept damp by means of a few strands of cotton wick, which are passed round the glass stem close to the bulb so as to touch the muslin, and have their lower ends dipping into a cup of water placed close to the thermometer, it will usually show a temperature lower than that shown by the other thermometer which is near it, the amount of the difference, commonly called the depression of the wet bulb, being dependent on the degree of dryness of the air.

A thermometer fitted in the manner described above is called a wet-bulb thermometer, to distinguish it from the ordinary thermometer, which has its bulb uncovered and is known as a dry-bulb.

The depression of the wet-bulb thermometer is caused by the evaporation from the moistened covering of the bulb. When the humidity of the atmosphere is very great, during, or just before rain, or when fog is prevalent or dew is forming, there is little or no evaporation, and the two thermometers read very nearly alike, but at other times the wet-bulb thermometer reads lower than the dry, because the water dries off or evaporates from the muslin coating, in which process it passes into the state of invisible vapour, and absorbs heat from the mercury in the bulb of the thermometer, which consequently indicates a lower temperature. As the air becomes less humid the evaporation is greater, and the fall of temperature of the wetted bulb is also greater, and accordingly the difference in readings between the dry- and the wet-bulb is then also greater. The difference sometimes amounts to 15 or 20 degrees in England, and to more in some other parts of the world, but at sea the difference seldom exceeds 10 degrees.

To ensure correct records of the temperature and humidity of the air, the dry- and wet-bulb thermometers should be placed in a screen, the sides of which are protected from the sun and rain by "jalousies," that is, narrow sloping boards overlapping each other, but with spaces between, so as to let in the air freely.

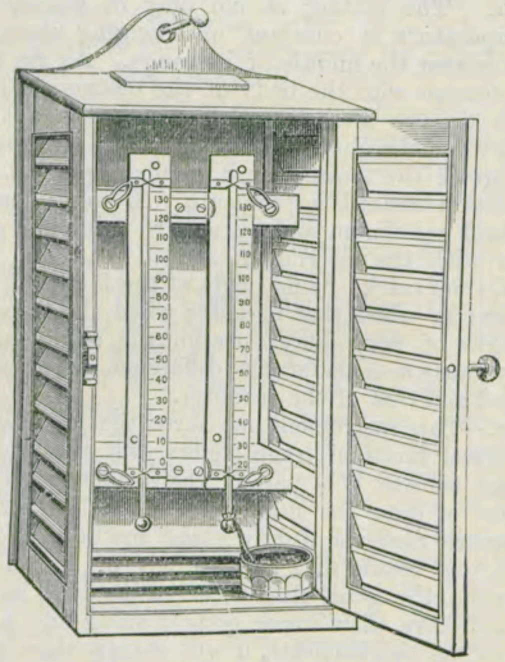

Fig. 18.

The annexed engraving shows the form of screen used for mounting the dry- and wet-bulb thermometers on board ship; it should be fixed in a suitable position about four feet above the upper deck, freely exposed to the external air, but protected from sun, rain, or spray, and as free as possible from radiation, or warm currents of air from cabins and engine-rooms.

The glass, or other small vessel to hold the water required for the wet-bulb should be as far as possible from the dry thermometer (see Fig. 18). The water should be either distilled or rain water, or, if this be not procurable, the softest fresh water which can be had, to avoid the deposit of lime or other impurity on the bulb. When fresh water is poured into the vessel it should be done after, or some little time before observing; because observations are incorrect if made before the temperature of the wet-bulb has fallen to that it would acquire, after being some time exposed to the air.

The muslin and wick should be well washed before being applied, and occasionally while in use. They should be changed once a

month or oftener, according to the quality of the muslin, &c., and the exposure to dust or blacks. Accuracy depends much on the care taken to ensure cleanliness, and also a proper supply of fresh water. It should be borne in mind that observations of the wet-bulb thermometer are impaired by the presence of salt water on the cambric, and, therefore, that in the event of such impregnation taking place through spray, or by any other means, the cambric, or muslin, and the wick, should be cleansed or renewed. Care also should be taken when reading the dry-bulb thermometer that moisture be not adhering to the bulb.

During frost, when the water on the muslin is frozen and thinly coated with ice, the readings are quite good, as evaporation takes place from a surface of ice as freely as from one of water, but if the muslin be dry, and no ice on it, it must first be wetted, and then allowed time to freeze and to take up its normal temperature before the observation is recorded.

Hydrometer.—This instrument is employed for determining the specific gravity of liquids. The hydrometer used at sea is constructed of glass. If made of brass, the corrosive action of salt water soon renders the instrument erroneous in its indications. The form of the instrument in common use is shown in the engraving. It consists of a glass tube ending in a globular bulb partly filled with mercury or small shot, to act as ballast and to make the instrument float steadily in a vertical position. From the neck of the bulb the glass is expanded into an oval or cylindrical shape, to give the instrument sufficient volume for flotation; above this it is tapered off to a narrow upright stem closed at the top, attached to which is an ivory scale. The divisions on the scale read downwards, so as to measure the length of the stem which stands above the surface of any fluid in which the hydrometer is floated. The denser the fluid, or the greater its specific gravity, the higher will the instrument rise; the rarer the fluid, or the smaller its specific gravity, the lower it will sink.

The indications depend upon the well-known principle, that any floating body displaces a quantity of the fluid which sustains it, equal in weight to the weight of the floating body itself. According therefore, as the specific gravities of fluids differ from each other, so will the quantities of the fluids displaced by any floating body, or the depth of its immersion, vary, when it is floated successively in each.

The specific gravity of distilled water, or its relative weight, compared at the temperature of 62° F., to an equal volume of other substances, being taken as unity, the depth at which the instrument remains at rest when floating in distilled water is the zero of the scale on which its indications are recorded. If the specific gravity, or the density of the water be increased, as it is by the presence of salt in solution, the hydrometer will rise, and the scale is so prepared as to indicate successive increases of density up to 4 per cent., or 40 in the thousand parts. The graduations thus extend from 0 to 40; the latter corresponding to the mark on the scale which will be level with the surface when the instrument is placed in water, the specific gravity of which is 1·040. In recording observations, the last two figures only—being the figures on the scale—are written down. As indicated in the following illustration, Fig. 20, there has recently been introduced an hydrometer of more open scale, which has a range of from 15 to 35, instead of from 0 to 40, as in Fig. 19. This change will facilitate reading, and serve nearly every purpose for observations on board ship.

Fig. 19.

Fig. 20.

The instrument is used on board ship to show the relative density of different parts of the ocean. It may float at 40 or even higher in some parts of the Suez Canal, where the water is exceedingly salt. On the western side of the North Atlantic; in the Tropics, Bay of Bengal, and Black Sea; and in the vicinity of the mouth of a large river, the hydrometer will sink much deeper owing to the comparative freshness of the water. The water employed for taking the specific gravity of the sea should be drawn in a bucket from over the ship's side, forward of all ejection pipes, and its temperature immediately observed and recorded, so that by its aid the specific gravity may be reduced to what it would have been at the temperature of 62° F. as explained below. The hydrometer should be slightly spun in the centre of the bucket; it soon loses any up-and-down motion; and the scale can be read before the turning motion has entirely ceased.

Whenever the temperature of the water tested differs from 62°, a correction to the reading is necessary, for the expansion or contraction of the glass, as well as for the temperature of the water itself, in order to reduce all observations to one generally adopted standard. Tables have been constructed for this purpose.

When using the hydrometer, it should be scrupulously clean, all dust, smears, or greasiness, being got rid of by wiping the instrument with a clean soft cloth, before and after use.

APPENDIX II.

TABLE I.

TABLE of CORRECTION 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	·053	·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	·027	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	· 49	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 "attache1 thermometer" should be used when applying these corrections.

TABLE I.—*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	·103	·105	·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 II.

Conversion of Centigrade Degrees into Degrees of Fahrenheit.

Centigrade Degrees.	Tenths of Degrees. 0	1	2	3	4	5	6	7	8	9
−39°	−38·2	−38·4	−38·6	−38·7	−38·9	−39·1	−39·3	−39·5	−39·6	−39·8
38	36·4	36·6	36·8	36·9	37·1	37·3	37·5	37·7	37·8	38·0
37	34·6	34·8	35·0	35·1	35·3	35·5	35·7	35·9	36·0	36·2
36	32·8	33·0	33·2	33·3	33·5	33·7	33·9	34·1	34·2	34·4
35	31·0	31·2	31·4	31·5	31·7	31·9	32·1	32·3	32·4	32·6
34	29·2	29·4	29·6	29·7	29·9	30·1	30·3	30·5	30·6	30·8
33	27·4	27·6	27·8	27·9	28·1	28·3	28·5	28·7	28·8	29·0
32	25·6	25·8	26·0	26·1	26·3	26·5	26·7	26·9	27·0	27·2
31	23·8	24·0	24·2	24·3	24·5	24·7	24·9	25·1	25·2	25·4
30	22·0	22·2	22·4	22·5	22·7	22·9	23·1	23·3	23·4	23·6
29	20·2	20·4	20·6	20·7	20·9	21·1	21·3	21·5	21·6	21·8
28	18·4	18·6	18·8	18·9	19·1	19·3	19·5	19·7	19·8	20·0
27	16·6	16·8	17·0	17·1	17·3	17·5	17·7	17·9	18·0	18·2
26	14·8	15·0	15·2	15·3	15·5	15·7	15·9	16·1	16·2	16·4
25	13·0	13·2	13·4	13·5	13·7	13·9	14·1	14·3	14·4	14·6
24	11·2	11·4	11·6	11·7	11·9	12·1	12·3	12·5	12·6	12·8
23	9·4	9·6	9·8	9·9	10·1	10·3	10·5	10·7	10·8	11·0
22	7·6	7·8	8·0	8·1	8·3	8·5	8·7	8·9	9·0	9·2
21	5·8	6·0	6·2	6·3	6·5	6·7	6·9	7·1	7·2	7·4
20	4·0	4·2	4·4	4·5	4·7	4·9	5·1	5·3	5·4	5·6
19	2·2	2·4	2·6	2·7	2·9	3·1	3·3	3·5	3·6	3·8
18	−0·4	−0·6	−0·8	−0·9	−1·1	−1·3	−1·5	−1·7	−1·8	2·0
17	+1·4	+1·2	+1·0	+0·9	+0·7	+0·5	+0·3	+0·1	0·0	− 0·2
16	3·2	3·0	2·8	2·7	2·5	2·3	2·1	1·9	+1·8	+ 1·6
15	5·0	4·8	4·6	4·5	4·3	4·1	3·9	3·7	3·6	3·4
14	6·8	6·6	6·4	6·3	6·1	5·9	5·7	5·5	5·4	5·2
13	8·6	8·4	8·2	8·1	7·9	7·7	7·5	7·3	7·2	7·0
12	10·4	10·2	10·0	9·9	9·7	9·5	9·3	9·1	9·0	8·8
11	12·2	12·0	11·8	11·7	11·5	11·3	11·1	10·9	10·8	10·6
10	14·0	13·8	13·6	13·5	13·3	13·1	12·9	12·7	12·6	12·4
9	15·8	15·6	15·4	15·3	15·1	14·9	14·7	14·5	14·4	14·2
8	17·6	17·4	17·2	17·1	16·9	16·7	16·5	16·3	16·2	16·0
7	19·4	19·2	19·0	18·9	18·7	18·5	18·3	18·1	18·0	17·8
6	21·2	21·0	20·8	20·7	20·5	20·3	20·1	19·9	19·8	19·6
5	23·0	22·8	22·6	22·5	22·3	22·1	21·9	21·7	21·6	21·4
4	24·8	24·6	24·4	24·3	24·1	23·9	23·7	23·5	23·4	23·2
3	26·6	26·4	26·2	26·1	25·9	25·7	25·5	25·3	25·2	25·0
2	28·4	28·2	28·0	27·9	27·7	27·5	27·3	27·1	27·0	26·8
1	30·2	30·0	29·8	29·7	29·5	29·3	29·1	28·9	28·8	28·6
−0	+32·0	+31·8	+31·6	+31·5	+31·3	+31·1	+30·9	+30·7	+30·6	+30·4

TABLE II.—*continued.*

Conversion of Centigrade Degrees into Degrees of Fahrenheit.

Centigrade Degrees.	Tenths of Degrees. 0	1	2	3	4	5	6	7	8	9
+ 0°	+32·0	+32·2	+32·4	+32·5	+32·7	+32·9	+33·1	+33·3	+33·4	+33·6
1	33·8	34·0	34·2	34·3	34·5	34·7	34·9	35·1	35·2	35·4
2	35·6	35·8	36·0	36·1	36·3	36·5	36·7	36·9	37·0	37·2
3	37·4	37·6	37·8	37·9	38·1	38·3	38·5	38·7	38·8	39·0
4	39·2	39·4	39·6	39·7	39·9	40·1	40·3	40·5	40·6	40·8
5	41·0	41·2	41·4	41·5	41·7	41·9	42·1	42·3	42·4	42·6
6	42·8	43·0	43·2	43·3	43·5	43·7	43·9	44·1	44·2	44·4
7	44·6	44·8	45·0	45·1	45·3	45·5	45·7	45·9	46·0	46·2
8	46·4	46·6	46·8	46·9	47·1	47·3	47·5	47·7	47·8	48·0
9	48·2	48·4	48·6	48·7	48·9	49·1	49·3	49·5	49·6	49·8
10	50·0	50·2	50·4	50·5	50·7	50·9	51·1	51·3	51·4	51·6
11	51·8	52·0	52·2	52·3	52·5	52·7	52·9	53·1	53·2	53·4
12	53·6	53·8	54·0	54·1	54·3	54·5	54·7	54·9	55·0	55·2
13	55·4	55·6	55·8	55·9	56·1	56·3	56·5	56·7	56·8	57·0
14	57·2	57·4	57·6	57·7	57·9	58·1	58·3	58·5	58·6	58·8
15	59·0	59·2	59·4	59·5	59·7	59·9	60·1	60·3	60·4	60·6
16	60·8	61·0	61·2	61·3	61·5	61·7	61·9	62·1	62·2	62·4
17	62·6	62·8	63·0	63·1	63·3	63·5	63·7	63·9	64·0	64·2
18	64·4	64·6	64·8	64·9	65·1	65·3	65·5	65·7	65·8	66·0
19	66·2	66·4	66·6	66·7	66·9	67·1	67·3	67·5	67·6	67·8
20	68·0	68·2	68·4	68·5	68·7	68·9	69·1	69·3	69·4	69·6
21	69·8	70·0	70·2	70·3	70·5	70·7	70·9	71·1	71·2	71·4
22	71·6	71·8	72·0	72·1	72·3	72·5	72·7	72·9	73·0	73·2
23	73·4	73·6	73·8	73·9	74·1	74·3	74·5	74·7	74·8	75·0
24	75·2	75·4	75·6	75·7	75·9	76·1	76·3	76·5	76·6	76·8
25	77·0	77·2	77·4	77·5	77·7	77·9	78·1	78·3	78·4	78·6
26	78·8	79·0	79·2	79·3	79·5	79·7	79·9	80·1	80·2	80·4
27	80·6	80·8	81·0	81·1	81·3	81·5	81·7	81·9	82·0	82·2
28	82·4	82·6	82·8	82·9	83·1	83·3	83·5	83·7	83·8	84·0
29	84·2	84·4	84·6	84·7	84·9	85·1	85·3	85·5	85·6	85·8
30	86·0	86·2	86·4	86·5	86·7	86·9	87·1	87·3	87·4	87·6
31	87·8	88·0	88·2	88·3	88·5	88·7	88·9	89·1	89·2	89·4
32	89·6	89·8	90·0	90·1	90·3	90·5	90·7	90·9	91·0	91·2
33	91·4	91·6	91·8	91·9	92·1	92·3	92·5	92·7	92·8	93·0
34	93·2	93·4	93·6	93·7	93·9	94·1	94·3	94·5	94·6	94·8
35	95·0	95·2	95·4	95·5	95·7	95·9	96·1	96·3	96·4	96·6
36	96·8	97·0	97·2	97·3	97·5	97·7	97·9	98·1	98·2	98·4
37	98·6	98·8	99·0	99·1	99·3	99·5	99·7	99·9	100·0	100·2
38	100·4	100·6	100·8	100·9	101·1	101·3	101·5	101·7	101·8	102·0
+39	+102·2	+102·4	+102·6	+102·7	+102·9	+103·1	+103·3	+103·5	+103·6	+103·8

TABLE II.—*continued.*

CONVERSION of CENTIGRADE DEGREES into DEGREES of FAHRENHEIT.

Centigrade Degrees.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
° + 40	+104·0	+104·2	+104·4	+104·5	+104·7	+104·9	+105·1	+105·3	+105·4	+105·6
41	105·8	106·0	106·2	106·3	106·5	106·7	106·9	107·1	107·2	107·4
42	107·6	107·8	108·0	108·1	108·3	108·5	108·7	108·9	109·0	109·2
43	109·4	109·6	109·8	109·9	110·1	110·3	110·5	110·7	110·8	111·0
44	111·2	111·4	111·6	111·7	111·9	112·1	112·3	112·5	112·6	112·8
45	113·0	113·2	113·4	113·5	113·7	113·9	114·1	114·3	114·4	114·6
46	114·8	115·0	115·2	115·3	115·5	115·7	115·9	116·1	116·2	116·4
47	116·6	116·8	117·0	117·1	117·3	117·5	117·7	117·9	118·0	118·2
48	118·4	118·6	118·8	118·9	119·1	119·3	119·5	119·7	119·8	120·0
49	120·2	120·4	120·6	120·7	120·9	121·1	121·3	121·5	121·6	121·8
50	122·0	122·2	122·4	122·5	122·7	122·9	123·1	123·3	123·4	123·6
51	123·8	124·0	124·2	124·3	124·5	124·7	124·9	125·1	125·2	125·4
52	125·6	125·8	126·0	126·1	126·3	126·5	126·7	126·9	127·0	127·2
53	127·4	127·6	127·8	127·9	128·1	128·3	128·5	128·7	128·8	129·0
54	129·2	129·4	129·6	129·7	129·9	130·1	130·3	130·5	130·6	130·8
55	131·0	131·2	131·4	131·5	131·7	131·9	132·1	132·3	132·4	132·6
56	132·8	133·0	133·2	133·3	133·5	133·7	133·9	134·1	134·2	134·4
57	134·6	134·8	135·0	135·1	135·3	135·5	135·7	135·9	136·0	136·2
58	136·4	136·6	136·8	136·9	137·1	137·3	137·5	137·7	137·8	138·0
59	138·2	138·4	138·6	138·7	138·9	139·1	139·3	139·5	139·6	139·8
60	140·0	140·2	140·4	140·5	140·7	140·9	141·1	141·3	141·4	141·6
61	141·8	142·0	142·2	142·3	142·5	142·7	142·9	143·1	143·2	143·4
62	143·6	143·8	144·0	144·1	144·3	144·5	144·7	144·9	145·0	145·2
63	145·4	145·6	145·8	145·9	146·1	146·3	146·5	146·7	146·8	147·0
64	147·2	147·4	147·6	147·7	147·9	148·1	148·3	148·5	148·6	148·8
65	149·0	149·2	149·4	149·5	149·7	149·9	150·1	150·3	150·4	150·6
66	150·8	151·0	151·2	151·3	151·5	151·7	151·9	152·1	152·2	152·4
67	152·6	152·8	153·0	153·1	153·3	153·5	153·7	153·9	154·0	154·2
68	154·4	154·6	154·8	154·9	155·1	155·3	155·5	155·7	155·8	156·0
69	156·2	156·4	156·6	156·7	156·9	157·1	157·3	157·5	157·6	157·8
70	158·0	158·2	158·4	158·5	158·7	158·9	159·1	159·3	159·4	159·6
71	159·8	160·0	160·2	160·3	160·5	160·7	160·9	161·1	161·2	161·4
72	161·6	161·8	162·0	162·1	162·3	162·5	162·7	162·9	163·0	163·2
73	163·4	163·6	163·8	163·9	164·1	164·3	164·5	164·7	164·8	165·0
74	165·2	165·4	165·6	165·7	165·9	166·1	166·3	166·5	166·6	166·8
75	167·0	167·2	167·4	167·5	167·7	167·9	168·1	168·3	168·4	168·6
76	168·8	169·0	169·2	169·3	169·5	169·7	169·9	170·1	170·2	170·4
77	170·6	170·8	171·0	171·1	171·3	171·5	171·7	171·9	172·0	172·2
78	172·4	172·6	172·8	172·9	173·1	173·3	173·5	173·7	173·8	174·0
79	174·2	174·4	174·6	174·7	174·9	175·1	175·3	175·5	175·6	175·8

TABLE III.

CONVERSION of DEGREES of FAHRENHEIT into CENTIGRADE DEGREES.

Degrees of Fah.	Tenths of Degrees. With this argument the Centigrade values are *plus.*											
	0	1	2	3	4	5	6	7	8	9		
° 32	0·0	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·6	31
33	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·1	1·1	30
34	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·6	1·6	1·7	29
35	1·7	1·7	1·8	1·8	1·9	1·9	2·0	2·1	2·1	2·2	2·2	28
36	2·2	2·3	2·3	2·4	2·4	2·5	2·6	2·6	2·7	2·7	2·8	27
37	2·8	2·8	2·9	2·9	3·0	3·1	3·1	3·2	3·2	3·3	3·3	26
38	3·3	3·4	3·4	3·5	3·6	3·6	3·7	3·7	3·8	3·8	3·9	25
39	3·9	3·9	4·0	4·1	4·1	4·2	4·2	4·3	4·3	4·4	4·4	24
40	4·4	4·5	4·6	4·6	4·7	4·7	4·8	4·8	4·9	4·9	5·0	23
41	5·0	5·1	5·1	5·2	5·2	5·3	5·3	5·4	5·4	5·5	5·6	22
42	5·6	5·6	5·7	5·7	5·8	5·8	5·9	5·9	6·0	6·1	6·1	21
43	6·1	6·2	6·2	6·3	6·3	6·4	6·4	6·5	6·6	6·6	6·7	20
44	6·7	6·7	6·8	6·8	6·9	6·9	7·0	7·1	7·1	7·2	7·2	19
45	7·2	7·3	7·3	7·4	7·4	7·5	7·6	7·6	7·7	7·7	7·8	18
46	7·8	7·8	7·9	7·9	8·0	8·1	8·1	8·2	8·2	8·3	8·3	17
47	8·3	8·4	8·4	8·5	8·6	8·6	8·7	8·7	8·8	8·8	8·9	16
48	8·9	8·9	9·0	9·1	9·1	9·2	9·2	9·3	9·3	9·4	9·4	15
49	9·4	9·5	9·6	9·6	9·7	9·7	9·8	9·8	9·9	9·9	10·0	14
50	10·0	10·1	10·1	10·2	10·2	10·3	10·3	10·4	10·4	10·5	10·6	13
51	10·6	10·6	10·7	10·7	10·8	10·8	10·9	10·9	11·0	11·1	11·1	12
52	11·1	11·2	11·2	11·3	11·3	11·4	11·4	11·5	11·6	11·6	11·7	11
53	11·7	11·7	11·8	11·8	11·9	11·9	12·0	12·1	12·1	12·2	12·2	10
54	12·2	12·3	12·3	12·4	12·4	12·5	12·6	12·6	12·7	12·7	12·8	9
55	12·8	12·8	12·9	12·9	13·0	13·1	13·1	13·2	13·2	13·3	13·3	8
56	13·3	13·4	13·4	13·5	13·6	13·6	13·7	13·7	13·8	13·8	13·9	7
57	13·9	13·9	14·0	14·1	14·1	14·2	14·2	14·3	14·3	14·4	14·4	6
58	14·4	14·5	14·6	14·6	14·7	14·7	14·8	14·8	14·9	14·9	15·0	5
59	15·0	15·1	15·1	15·2	15·2	15·3	15·3	15·4	15·4	15·5	15·6	4
60	15·6	15·6	15·7	15·7	15·8	15·8	15·9	15·9	16·0	16·1	16·1	3
61	16·1	16·2	16·2	16·3	16·3	16·4	16·4	16·5	16·6	16·6	16·7	2
62	16·7	16·7	16·8	16·8	16·9	16·9	17·0	17·1	17·1	17·2	17·2	1
63	17·2	17·3	17·3	17·4	17·4	17·5	17·6	17·6	17·7	17·7	17·8	0
		9	8	7	6	5	4	3	2	1	0	Degrees of Fah.
	With this argument the Centigrade values are *minus.* Tenths of Degrees.											

TABLE III.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.		Tenths of Degrees.									
Plus.	Minus.	0	1	2	3	4	5	6	7	8	9
° 64	0	17·8	17·8	17·9	17·9	18·0	18·1	18·1	18·2	18·2	18·3
65	1	18·3	18·4	18·4	18·5	18·6	18·6	18·7	18·7	18·8	18·8
66	2	18·9	18·9	19·0	19·1	19·1	19·2	19·2	19·3	19·3	19·4
67	3	19·4	19·5	19·6	19·6	19·7	19·7	19·8	19·8	19·9	19·9
68	4	20·0	20·1	20·1	20·2	20·2	20·3	20·3	20·4	20·4	20·5
69	5	20·6	20·6	20·7	20·7	20·8	20·8	20·9	20·9	21·0	21·1
70	6	21·1	21·2	21·2	21·3	21·3	21·4	21·4	21·5	21·6	21·6
71	7	21·7	21·7	21·8	21·8	21·9	21·9	22·0	22·1	22·1	22·2
72	8	22·2	22·3	22·3	22·4	22·4	22·5	22·6	22·6	22·7	22·7
73	9	22·8	22·8	22·9	22·9	23·0	23·1	23·1	23·2	23·2	23·3
74	10	23·3	23·4	23·4	23·5	23·6	23·6	23·7	23·7	23·8	23·8
75	11	23·9	23·9	24·0	24·1	24·1	24·2	24·2	24·3	24·3	24·4
76	12	24·4	24·5	24·6	24·6	24·7	24·7	24·8	24·8	24·9	24·9
77	13	25·0	25·1	25·1	25·2	25·2	25·3	25·3	25·4	25·4	25·5
78	14	25·6	25·6	25·7	25·7	25·8	25·8	25·9	25·9	26·0	26·1
79	15	26·1	26·2	26·2	26·3	26·3	26·4	26·4	26·5	26·6	26·6
80	16	26·7	26·7	26·8	26·8	26·9	26·9	27·0	27·1	27·1	27·2
81	17	27·2	27·3	27·3	27·4	27·4	27·5	27·6	27·6	27·7	27·7
82	18	27·8	27·8	27·9	27·9	28·0	28·1	28·1	28·2	28·2	28·3
83	19	28·3	28·4	28·4	28·5	28·6	28·6	28·7	28·7	28·8	28·8
84	20	28·9	28·9	29·0	29·1	29·1	29·2	29·2	29·3	29·3	29·4
85	21	29·4	29·5	29·6	29·6	29·7	29·7	29·8	29·8	29·9	29·9
86	22	30·0	30·1	30·1	30·2	30·2	30·3	30·3	30·4	30·4	30·5
87	23	30·6	30·6	30·7	30·7	30·8	30·8	30·9	30·9	31·0	31·1
88	24	31·1	31·2	31·2	31·3	31·3	31·4	31·4	31·5	31·6	31·6
89	25	31·7	31·7	31·8	31·8	31·9	31·9	32·0	32·1	32·1	32·2
90	26	32·2	32·3	32·3	32·4	32·4	32·5	32·6	32·6	32·7	32·7
91	27	32·8	32·8	32·9	32·9	33·0	33·1	33·1	33·2	33·2	33·3
92	28	33·3	33·4	33·4	33·5	33·6	33·6	33·7	33·7	33·8	33·8
93	29	33·9	33·9	34·0	34·1	34·1	34·2	34·2	34·3	34·3	34·4
94	30	34·4	34·5	34·6	34·6	34·7	34·7	34·8	34·8	34·9	34·9
95	31	35·0	35·1	35·1	35·2	35·2	35·3	35·3	35·4	35·4	35·5
96	32	35·6	35·6	35·7	35·7	35·8	35·8	35·9	35·9	36·0	36·1
97	33	36·1	36·2	36·2	36·3	36·3	36·4	36·4	36·5	36·6	36·6
98	34	36·7	36·7	36·8	36·8	36·9	36·9	37·0	37·1	37·1	37·2
99	35	37·2	37·3	37·3	37·4	37·4	37·5	37·6	37·6	37·7	37·7
100	36	37·8	37·8	37·9	37·9	38·0	38·1	38·1	38·2	38·2	38·3
101	37	38·3	38·4	38·4	38·5	38·6	38·6	38·7	38·7	38·8	38·8
102	38	38·9	38·9	39·0	39·1	39·1	39·2	39·2	39·3	39·3	39·4
103	39	39·4	39·5	39·6	39·6	39·7	39·7	39·8	39·8	39·9	39·9
104	40	40·0	40·1	40·1	40·2	40·2	40·3	40·3	40·4	40·4	40·5

On this page Centigrade has the same sign as Fahrenheit.

TABLE III.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.		Tenths of Degrees.									
Plus.	Minus.	0	1	2	3	4	5	6	7	8	9
° 105	41	40·6	40·6	40·7	40·7	40·8	40·8	40·9	40·9	41·0	41·1
106	42	41·1	41·2	41·2	41·3	41·3	41·4	41·4	41·5	41·6	41·6
107	43	41·7	41·7	41·8	41·8	41·9	41·9	42·0	42·1	42·1	42·2
108	44	42·2	42·3	42·3	42·4	42·4	42·5	42·6	42·6	42·7	42·7
109	45	42·8	42·8	42·9	42·9	43·0	43·1	43·1	43·2	43·2	43·3
110	46	43·3	43·4	43·4	43·5	43·6	43·6	43·7	43·7	43·8	43·8
111	47	43·9	43·9	44·0	44·1	44·1	44·2	44·2	44·3	44·3	44·4
112	48	44·4	44·5	44·6	44·6	44·7	44·7	44·8	44·8	44·9	44·9
113	49	45·0	45·1	45·1	45·2	45·2	45·3	45·3	45·4	45·4	45·5
114	50	45·6	45·6	45·7	45·7	45·8	45·8	45·9	45·9	46·0	46·1
115	51	46·1	46·2	46·2	46·3	46·3	46·4	46·4	46·5	46·6	46·6
116	52	46·7	46·7	46·8	46·8	46·9	46·9	47·0	47·1	47·1	47·2
117	53	47·2	47·3	47·3	47·4	47·4	47·5	47·6	47·6	47·7	47·7
118	54	47·8	47·8	47·9	47·9	48·0	48·1	48·1	48·2	48·2	48·3
119	55	48·3	48·4	48·4	48·5	48·6	48·6	48·7	48·7	48·8	48·8
120	56	48·9	48·9	49·0	49·1	49·1	49·2	49·2	49·3	49·3	49·4
121	57	49·4	49·5	49·6	49·6	49·7	49·7	49·8	49·8	49·9	49·9
122	58	50·0	50·1	50·1	50·2	50·2	50·3	50·3	50·4	50·4	50·5
123	59	50·6	50·6	50·7	50·7	50·8	50·8	50·9	50·9	51·0	51·1
124	60	51·1	51·2	51·2	51·3	51·3	51·4	51·4	51·5	51·6	51·6
125	61	51·7	51·7	51·8	51·8	51·9	51·9	52·0	52·1	52·1	52·2
126	62	52·2	52·3	52·3	52·4	52·4	52·5	52·6	52·6	52·7	52·7
127	63	52·8	52·8	52·9	52·9	53·0	53·1	53·1	53·2	53·2	53·3
128	64	53·3	53·4	53·4	53·5	53·6	53·6	53·7	53·7	53·8	53·8
129	65	53·9	53·9	54·0	54·1	54·1	54·2	54·2	54·3	54·3	54·4
130	66	54·4	54·5	54·6	54·6	54·7	54·7	54·8	54·8	54·9	54·9
131	67	55·0	55·1	55·1	55·2	55·2	55·3	55·3	55·4	55·4	55·5
132	68	55·6	55·6	55·7	55·7	55·8	55·8	55·9	55·9	56·0	56·1
133	69	56·1	56·2	56·2	56·3	56·3	56·4	56·4	56·5	56·6	56·6
134	70	56·7	56·7	56·8	56·8	56·9	56·9	57·0	57·1	57·1	57·2
135	71	57·2	57·3	57·3	57·4	57·4	57·5	57·6	57·6	57·7	57·7
136	72	57·8	57·8	57·9	57·9	58·0	58·1	58·1	58·2	58·2	58·3
137	73	58·3	58·4	58·4	58·5	58·6	58·6	58·7	58·7	58·8	58·8
138	74	58·9	58·9	59·0	59·1	59·1	59·2	59·2	59·3	59·3	59·4
139	75	59·4	59·5	59·6	59·6	59·7	59·7	59·8	59·8	59·9	59·9
140	76	60·0	60·1	60·1	60·2	60·2	60·3	60·3	60·4	60·4	60·5
141	77	60·6	60·6	60·7	60·7	60·8	60·8	60·9	60·9	61·0	61·1
142	78	61·1	61·2	61·2	61·3	61·3	61·4	61·4	61·5	61·6	61·6
143	79	61·7	61·7	61·8	61·8	61·9	61·9	62·0	62·1	62·1	62·2
144	80	62·2	62·3	62·3	62·4	62·4	62·5	62·6	62·6	62·7	62·7

On this page Centigrade has the same sign as Fahrenheit.

TABLE III.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.		Tenths of Degrees.									
Plus.	Minus.	0	1	2	3	4	5	6	7	8	9
°											
145	81	62·8	62·8	62·9	62·9	63·0	63·1	63·1	63·2	63·2	63·3
146	82	63·3	63·4	63·4	63·5	63·6	63·6	63·7	63·7	63·8	63·8
147	83	63·9	63·9	64·0	64·1	64·1	64·2	64·2	64·3	64·3	64·4
148	84	64·4	64·5	64·6	64·6	64·7	64·7	64·8	64·8	64·9	64·9
149	85	65·0	65·1	65·1	65·2	65·2	65·3	65·3	65·4	65·4	65·5
150	86	65·6	65·6	65·7	65·7	65·8	65·8	65·9	65·9	66·0	66·1
151	87	66·1	66·2	66·2	66·3	66·3	66·4	66·4	66·5	66·6	66·6
152	88	66·7	66·7	66·8	66·8	66·9	66·9	67·0	67·1	67·1	67·2*
153	89	67·2	67·3	67·3	67·4	67·4	67·5	67·6	67·6	67·7	67·7
154	90	67·8	67·8	67·9	67·9	68·0	68·1	68·1	68·2	68·2	68·3
155	91	68·3	68·4	68·4	68·5	68·6	68·6	68·7	68·7	68·8	68·8
156	92	68·9	68·9	69·0	69·1	69·1	69·2	69·2	69·3	69·3	69·4
157	93	69·4	69·5	69·6	69·6	69·7	69·7	69·8	69·8	69·9	69·9
158	94	70·0	70·1	70·1	70·2	70·2	70·3	70·3	70·4	70·4	70·5
159	95	70·6	70·6	70·7	70·7	70·8	70·8	70·9	70·9	71·0	71·1
160	96	71·1	71·2	71·2	71·3	71·3	71·4	71·4	71·5	71·6	71·6
161	97	71·7	71·7	71·8	71·8	71·9	71·9	72·0	72·1	72·1	72·2
162	98	72·2	72·3	72·3	72·4	72·4	72·5	72·6	72·6	72·7	72·7
163	99	72·8	72·8	72·9	72·9	73·0	73·1	73·1	73·2	73·2	73·3
164	100	73·3	73·4	73·4	73·5	73·6	73·6	73·7	73·7	73·8	73·8

On this page Centigrade has the same sign as Fahrenheit.

TABLE IV.

TABLE for the CONVERSION of TEMPERATURE READINGS on the FAHRENHEIT and CENTIGRADE SCALE to ABSOLUTE SCALE.

Fahr.	Cent.	Abs.	Fahr.	Cent.	Abs.	Fahr.	Cent.	Abs.
—99	—72·8	200·2	—66	—54·4	218·6	—33	—36·1	236·9
98	72·2	00·8	65	53·9	19·1	32	35·6	37·4
97	71·7	01·3	64	53·3	19·7	31	35·0	38·0
96	71·1	01·9	63	52·8	20·2	30	34·4	38·6
95	70·6	02·4	62	52·2	20·8	29	33·9	39·1
94	70·0	03·0	61	51·7	21·3	28	33·3	39·7
93	69·4	03·6	60	51·1	21·9	27	32·8	40·2
92	68·9	04·1	59	50·6	22·4	26	32·2	40·8
91	68·3	04·7	58	50·0	23·0	25	31·7	41·3
90	67·8	205·2	57	49·4	223·6	24	31·1	241·9
89	67·2	205·8	56	48·9	224·1	23	30·6	242·4
88	66·7	06·3	55	48·3	24·7	22	30·0	43·0
87	66·1	06·9	54	47·8	25·2	21	29·4	43·6
86	65·6	07·4	53	47·2	25·8	20	28·9	44·1
85	65·0	08·0	52	46·7	26·3	19	28·3	44·7
84	64·4	08·6	51	46·1	26·9	18	27·8	45·2
83	63·9	09·1	50	45·6	27·4	17	27·2	45·8
82	63·3	09·7	49	45·0	28·0	16	26·7	46·3
81	62·8	10·2	48	44·4	28·6	15	26·1	46·9
80	62·2	210·8	47	43·9	229·1	14	25·6	247·4
79	61·7	211·3	46	43·3	229·7	13	25·0	248·0
78	61·1	11·9	45	42·8	30·2	12	24·4	48·6
77	60·6	12·4	44	42·2	30·8	11	23·9	49·1
76	60·0	13·0	43	41·7	31·3	10	23·3	49·7
75	59·4	13·6	42	41·1	31·9	9	22·8	50·2
74	58·9	14·1	41	40·6	32·4	8	22·2	50·8
73	58·3	14·7	40	40·0	33·0	7	21·7	51·3
72	57·8	15·2	39	39·4	33·6	6	21·1	51·9
71	57·2	15·8	38	38·9	34·1	5	20·6	52·4
70	56·7	216·3	37	38·3	234·7	4	20·0	253·0
69	56·1	216·9	36	37·8	235·2	3	19·4	253·6
68	55·6	17·4	35	37·2	35·8	2	18·9	54·1
—67	—55·0	218·0	34	—36·7	236·3	—1	—18·3	254·7

TABLE IV.—*continued.*

TABLE for the CONVERSION of TEMPERATURE READINGS on the FAHRENHEIT and CENTIGRADE SCALES to the ABSOLUTE SCALE—*continued.*

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

APPENDIX III.

SPECIFICATION OF THE BEAUFORT SCALE,

With a Table of equivalent velocities in miles per hour for the several numbers based upon the formulæ—

$$P = \cdot 003\ V^2$$
$$P = \cdot 0105\ B^3$$
$$V = 1{\cdot}87\ \sqrt{B^3}$$

Where B is the Beaufort number; V is the corresponding velocity, in miles per hour; and P is the corresponding pressure in pounds per square foot.

In connexion with the above a Naval Officer has pointed out that there appears to be a cube root relation for the Sea Disturbance Scale adopted by the Meteorological Office; and suggests the following formula: $H = \cdot 05\ C^3$; where H is the height and C the corresponding scale number. The formula is shown below to be approximately in agreement as regards the several numbers of the scale with the arbitrary scale recommended for use at sea by the Meteorological Office.

Scale No.	Height in Feet. Recommended.	Height in Feet. Calculated.	Scale No.	Height in Feet. Recommended.	Height in Feet. Calculated.
0	0	0	5, 6	5–10	6·25, 10·5
1	—	·05	7	11–15	17·1
2, 3, 4	Under 5	·40, 1·35, 3·20	8	16–25	25·6
			9, 10	36 +	36·4 +

Specification of the Beaufort Scale with Probable Equivalents of the Numbers of the Scale.

Beaufort Number.	Admiral Beaufort's General Description of Wind.	Admiral Beaufort's Specification 1805.		Description of Wind.
0	Calm	Calm		—
1	Light air ...	Just sufficient to give steerage way ...		
2	Light breeze		1 to 2 knots.	Light breeze
3	Gentle breeze	That in which a well-conditioned man-of-war, with all sail set and "clean full" would go in smooth water from	3 to 4 knots.	
4	Moderate breeze.		5 to 6 knots.	Moderate breeze.
5	Fresh breeze		Royals, &c. ...	
6	Strong breeze		Single-reefed topsails and top-gallant sails.	
7	Moderate gale (*High wind*)*	That to which she could just carry in chase "full and by."	Double-reefed topsails, jib, &c.	Strong wind
8	Fresh gale ... (*Gale*)*		Triple-reefed topsails, &c.	
9	Strong gale ...		Close-reefed topsails and courses.	Gale forces
10	Whole gale ...	That which she could scarcely bear with close-reefed main topsail and reefed foresail.		
11	Storm ...	That which would reduce her to storm stay-sails.		Storm forces
12	Hurricane ...	That which no canvas could withstand		Hurricane ...

Beaufort Number.	Mode of Estimating aboard Sailing Vessels.	Mean wind force in lbs. per square ft. at standard density. ($P = \cdot0105B^3$.)	Equivalent velocity in miles per hour.†	Limits of Velocity.§
0	—	0	0	Less than 1
1		·01	2	1–3
2	Sufficient wind for working ship.	·08	5	4–7
3		·28	10	8–12
4		·67	15	13–18
5	Forces most advantageous for sailing with leading wind and all sail drawing.	1·31	21	19–24
6		2·3	27	25–31
7	Reduction of sail necessary with leading wind.	3·6	35	32–38
8		5·4	42	39–46
9	Considerable reduction of sail necessary even with wind quartering.	7·7	50	47–54
10		10·5	59	55–63
11	Close reefed sail running, or hove to under storm sail.	14·0	68	64–75
12	No sail can stand even when running.	Above 17·0	Above 75	Above 75

* It has recently been decided that for statistical purposes winds of force less than 8 shall not be counted as gales, and to avoid the ambiguity implied by the use of the term "moderate gale" for force 7 the Beaufort description has been modified for use in connexion with the daily weather service by the substitution of the descriptions in italics for forces 7 and 8.

† For converting estimates on the Beaufort scale into miles per hour.

§ For finding the Beaufort number corresponding to a velocity expressed in miles per hour.

Velocity Equivalents of the Beaufort Numbers.

The question of the velocity equivalents of the Beaufort numbers is one which has claimed much attention. From the nature of the case the estmates of different observers and even the estimates of one and the same observer under different circumstances must vary considerably.

A careful comparison of the Beaufort estimates with the wind velocities recorded simultaneously by anemometers belonging to the Office made in the course of the inquiry referred to above showed that the most probable equivalent hourly velocity for expressing individual estimates in miles per hour or *vice versa* agree very closely with the results calculated by the formula

$$V = 1{\cdot}87\sqrt{B^3}$$

where V is the wind velocity expressed in miles per hour and B the Beaufort number.

The relation between the wind pressure and the Beaufort numbers is given by the corresponding formula

$$P = {\cdot}0105\ B^3$$

where P is the pressure in pounds per square foot.

The velocity and pressure equivalents calculated from these two formulæ have been included in the table on pp. 74, 75.

The following table is used in the Meteorological Office for converting estimates on the Beaufort scale into velocities in statute miles per hour or *vice versa* :—

Beaufort Number.	Corresponding Mean Hourly Velocity in Statute Miles per hour.
0	0
1	1–3
2	4–7
3	8–12
4	13–18
5	19–24
6	25–31
7	32–38
8	39–46
9	47–54
10	55–63
11	64–75
12	Above 75.

APPENDIX IV.

Notice to Captains of Ships.

The Director of the Meteorological Office is authorised to lend instruments which are of first-rate character, and have been properly verified, to Captains who are willing to keep a Meteorological Log for the Office.

The instruments supplied are :—

One barometer ; six thermometers, with a screen ; four hydrometers.

A Meteorological Log and a Rough Book for recording the observations are also supplied. The Rough Book becomes the property of the observer.

The Office Log Book and Rough Book will be sent to Captains who undertake to make such observations. Application may be made to the Director, or to the Marine Superintendent.

Various publications by the Office are presented to observers.

Those who are willing to help in a work which is calculated to be of very great advantage to navigators and to science generally, should apply, in person if possible, between the hours of 10 a.m. and 4 p.m., to the Marine Superintendent, Meteorological Office, Exhibition Road, South Kensington, S.W., who will supply all ships in London, and, in special cases, those in outports where the Office has no Agents. Application may also be made by letter to the Director.

He will also be glad to receive observations of wind, weather, barometer, and temperature of air and sea, or as many of these as possible, from Captains who cannot undertake to keep the full log of four-hourly observations, for which verified instruments are lent by the Office. In such cases it is important that the instruments employed should be described as fully as possible, and, when practicable, that their readings should be compared with instruments on board ships which have been supplied by the Office, or with the standards which are available in certain ports.

Readings of a barometer, recorded in the log at 7 a.m. in European or at 8 a.m. in American ports, afford a fair means for finding the error of that barometer, as a reference to the Daily Weather Charts of the country enables the Office to find what those readings ought to have been.

It is hoped that Captains who are interested in Meteorology will assist in the work by observing for the Office.

The expenses incurred by co-operating captains, with respect to postage of log books and the transit of instruments, are borne by the Meteorological Office.

An abbreviated Meteorological Log for the entry of observations made with the ship's instruments at Noon and Midnight is issued for the use of observers who cannot give the usual four-hourly observations.

A special Form (No. 121) ruled for the entry of observations at 8 a.m. and 8 p.m. is issued for use in connexion with the Monthly Meteorological Chart of the North Atlantic and Mediterraneau; and a similar Form (No. 122) in connexion with the Monthly Meteorological Chart of the Indian Ocean.

The Director is desirous of obtaining recent particulars as to the position of ice, or other information that can be utilized in keeping the Meteorological Charts up to date.

The following gentlemen are the agents at their respective ports, and to them application should be made by captains at those ports:—

Cardiff	Capt. J. Weir, Examiner of Masters and Mates, Local Marine Board.
Dundee	Capt. J. A. S. Chalmers, Examiner of Masters and Mates, Local Marine Board.
Glasgow	Messrs. D. McGregor & Co., 57, Bothwell Street.
Greenock	Messrs. D. McGregor & Co., 33, Cathcart Street.
Hull	Capt. W. Ellery, Examiner of Masters and Mates, Mercantile Marine Office.
Liverpool	Commander F. M. Sergeant, R.D., R.N.R., Chief Examiner and Secretary, Local Marine Board, Canning Place (E.).
Southampton ...	Capt. D. Forbes, 1, Albion Place.
Sunderland ...	Messrs. J. J. Wilson & Son, 18 and 19, Hudson Road.

A set of instruments is kept in working order at the Office in London, and at each Agency, for inspection by Captains and Officers; and intending observers can get from the Marine Superintendent at the Meteorological Office, or from an Agent, any further information they may require on the subject.

Monthly Meteorological Charts.

The information collected in the manner indicated is now immediately used in the preparation of the monthly meteorological charts of the North Atlantic and Mediterranean, and of the Indian Ocean.

These series of charts give the average values for the months of pressure, temperature of the air and sea, winds and currents; together with routes recommended for steamers and sailing vessels, and other information useful to mariners.

The former are issued in weekly instalments, and include on the back of the chart eleven daily maps showing the distribution of pressure, and other elements over Europe, the North Atlantic, and the East of North America during a period ended on the same day as that on which the chart is issued. Also five maps, for successive periods of seven days, which include the most recent information regarding the temperature of the sea surface, and of the air over the North Atlantic; the geographical positions in which ice and derelicts were observed and in which fog was reported.

The back of the Indian Ocean chart contains the latest reports of ice in the Southern Hemisphere and of cyclonic storms, with other intelligence of importance to seamen and others.

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LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY DARLING & SON, LTD., 34–40, BACON STREET, E.

1912.

List of some of the Publications issued—*cont.*

No.

177. The relation between Pressure, Temperature, and Air Circulation over the South Atlantic Ocean, 1905. 9*d*.

181. Monthly Meteorological Charts of the Indian Ocean, commencing May, 1906. 6*d*. each. Subscription for one year 5*s*., (exclusive of postage).

191. The Observer's Handbook. A new Edition of Instructions in the use of Meteorological Instruments. 3*s*.

NON-OFFICIAL.

2. Report to the Committee of the Meteorological Office on the Meteorology of the North Atlantic. By Capt. H. Toynbee, F.R.A.S. 1*s*.

4. Routes for Steamers from Aden to the Straits of Sunda and back. Translated from a Paper issued by the Royal Meteorological Institute of the Netherlands. 6*d*. (Out of Print.)

5. On the Winds, &c., of the North Atlantic along the Tracks of Steamers from the Channel to New York. Translated from a Paper issued by the Deutsche Seewarte, Hamburg. 6*d*.

N.B.—*Daily, Weekly, and Annual Reports are also published. The Daily Reports can be obtained direct from the Office; subscription £1 per annum. The Annual Reports may be obtained at the appointed Sale Offices for Parliamentary Papers, or directly through any Bookseller; the Monthly Current Charts (Official* 124, 132, *and* 134) *published by the Admiralty, and the Monthly Meteorological Charts (Official* 149 *and* 181), *of J. D. Potter,* 145, *Minories, E., and* 11, *King Street, Tower Hill. The Weekly Reports and all other publications are sold by the Publishers of this Manual.*
