M.O. 230

THE WEATHER
OF THE
BRITISH COASTS

FOR OFFICIAL USE.

M.O. 230.

METEOROLOGICAL OFFICE.

THE

WEATHER OF THE BRITISH COASTS.

Issued by the Authority of the Meteorological Committee.

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1918.

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TABLE OF ERRATA.

In Plate V. of Summary of Gales, line 6,
for Storm-Warning *read* Gale-Warning.

In Plate XXIII. some of the lines intended to represent a small percentage of "moderate or strong winds" are widened by the running of the ink; care should be taken to distinguish between them and the black areas intended to represent gales.

PREFACE.

This book has been prepared in response to a request from the Hydrographer of the Navy for information about the weather of the British Coasts in a form suitable for the general reader.

Everybody is interested in the weather and nearly everybody wishes to know more about it than he finds out for himself. Even experienced Naval Officers are sometimes surprised at anomalous behaviour on the part of the weather and we have arrived at that state of civilisation in which we feel sure that a reasoned explanation even of the most anomalous behaviour is possible if only we could see our way through it. We should want to know many facts at some of which for the present we can only guess, and perhaps we might require some reasoning, simple or difficult, to form a connected explanation. It is the business of the science of meteorology to accumulate and arrange the facts in an intelligible order and to develop the theories which demonstrate their relation one to the other.

Already there are many books on meteorology of varying degrees of excellence, which are available for those who take an interest in the subject and some apology is needed for making an addition to the number.

The truth is that the subject is so comprehensive that different classes of readers require to approach it from their own point of view. Meteorological observations are now collected day by day, week by week, or month by month, from every country of the globe where civilised people live and from many parts of the great oceans as well, and an enormous store of facts about the weather is thus accumulated in every meteorological office. When the last word on meteorology has been said, one book will give the relation of all these facts and the explanation of the weather in every part of the globe as the direct consequence of one general circulation of the atmosphere, and even now any book on meteorology can find in the records from many different parts of the world illustrations of the principles which it maintains.

Thus a book on meteorology should set forth the principles of meteorological science and illustrate them by the most telling facts from whatever part of the world they may be drawn, but a book on the weather for a particular locality or a particular section of the community has a different object. It has first to present a summary of all the known facts, whether any rational explanation of them can be given or not. Thus in the *Barometer Manual for the Use of Seamen*, M.O. 61, the Meteorological Office has made a presentation of the facts which have been compiled from observations with the barometer all over the globe and has included such theories and explanations of certain groups of facts as may be useful to the seaman whose course may lie over any part of the waste of waters. In the *Seaman's Handbook* a

(14821—12.) Wt. 9898—523. 2000. 7/18. D & S. G. 3.

more detailed view has been taken of the results of barometric observations and the point of view taken is that of the high seas, with their visitation of winds, fogs or icebergs, and now this handbook of the *Weather of the British Coasts* aims first at setting out what the experiences of the coaster have been in the past and therefore may be in the future. The steps which meteorological science has made towards the rational co-ordination of the facts are treated in the later chapters in the hope that the coaster may be able to turn the knowledge to the advantage of his ship and his country.

Endeavour has been made to deal with explanations in terms which should be understood by the general reader. But some technicalities are inevitable and the reader may be referred to the *Meteorological Glossary,* M.O. 225 (ii), for explanation of those that are inadequately dealt with in this book.

NAPIER SHAW.

March 4, 1918

THE WEATHER OF THE BRITISH COASTS.

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PART III.

MODERN METEOROLOGY.

SUMMARY OF GALES

EXPERIENCED IN THE

SEVERAL DISTRICTS

OF THE

BRITISH AND IRISH COASTS

IN THE

FORTY YEARS, 1876-1915,

COMPRISING:

1. Diagrams showing the prevalence of gales on each day of the calendar year in the most stormy district, Ireland, N.W., and in the least stormy district, England, East.
2. Maps showing the frequency of gales in each district of the coast for each month and for the year.
3. Maps showing for the 20 years, 1896–1915, the directions from which the gales of each district blew, for each month and for the year.

An explanation of the Maps and Diagrams is given on p. VI.

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Plate I.

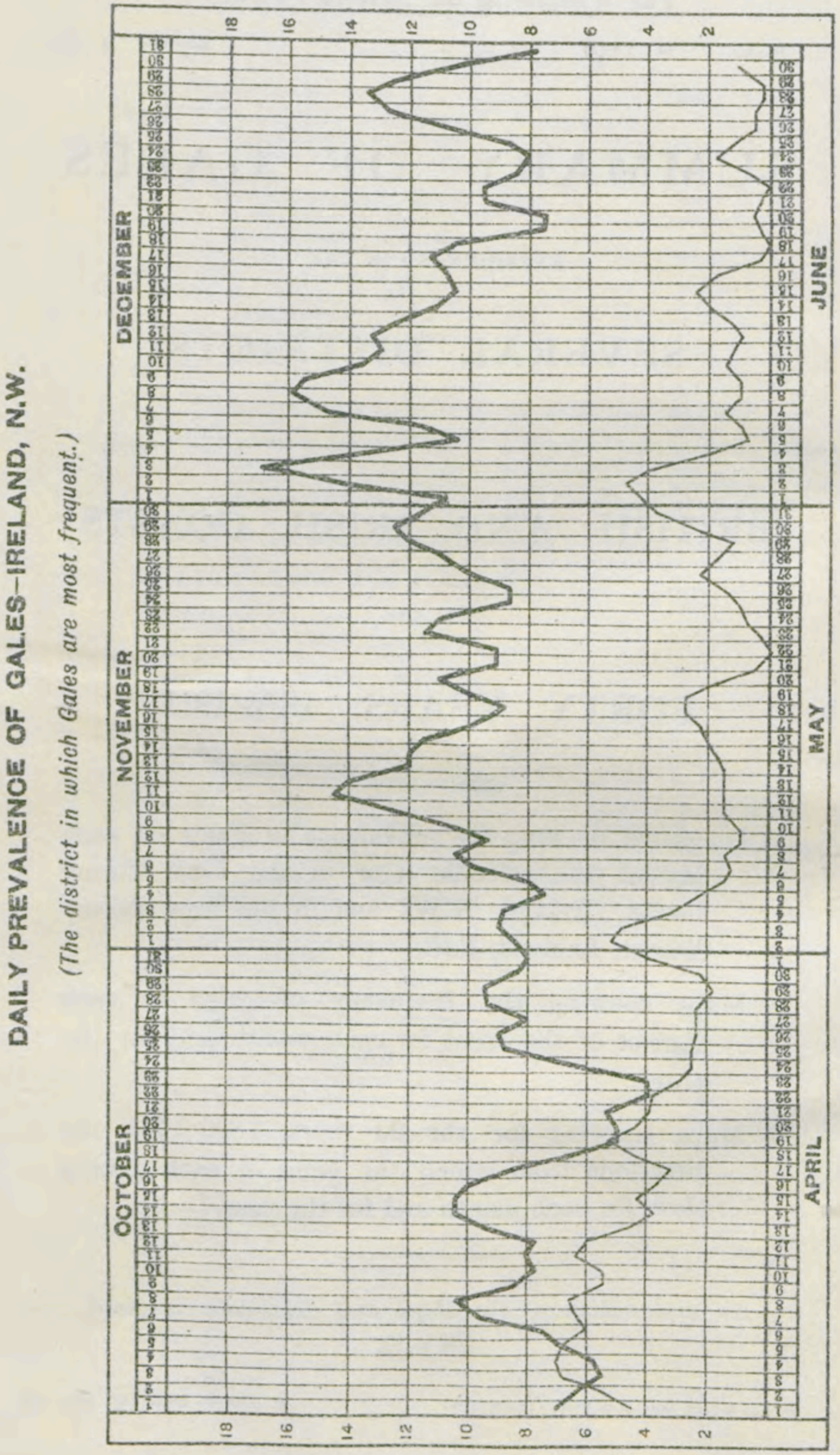
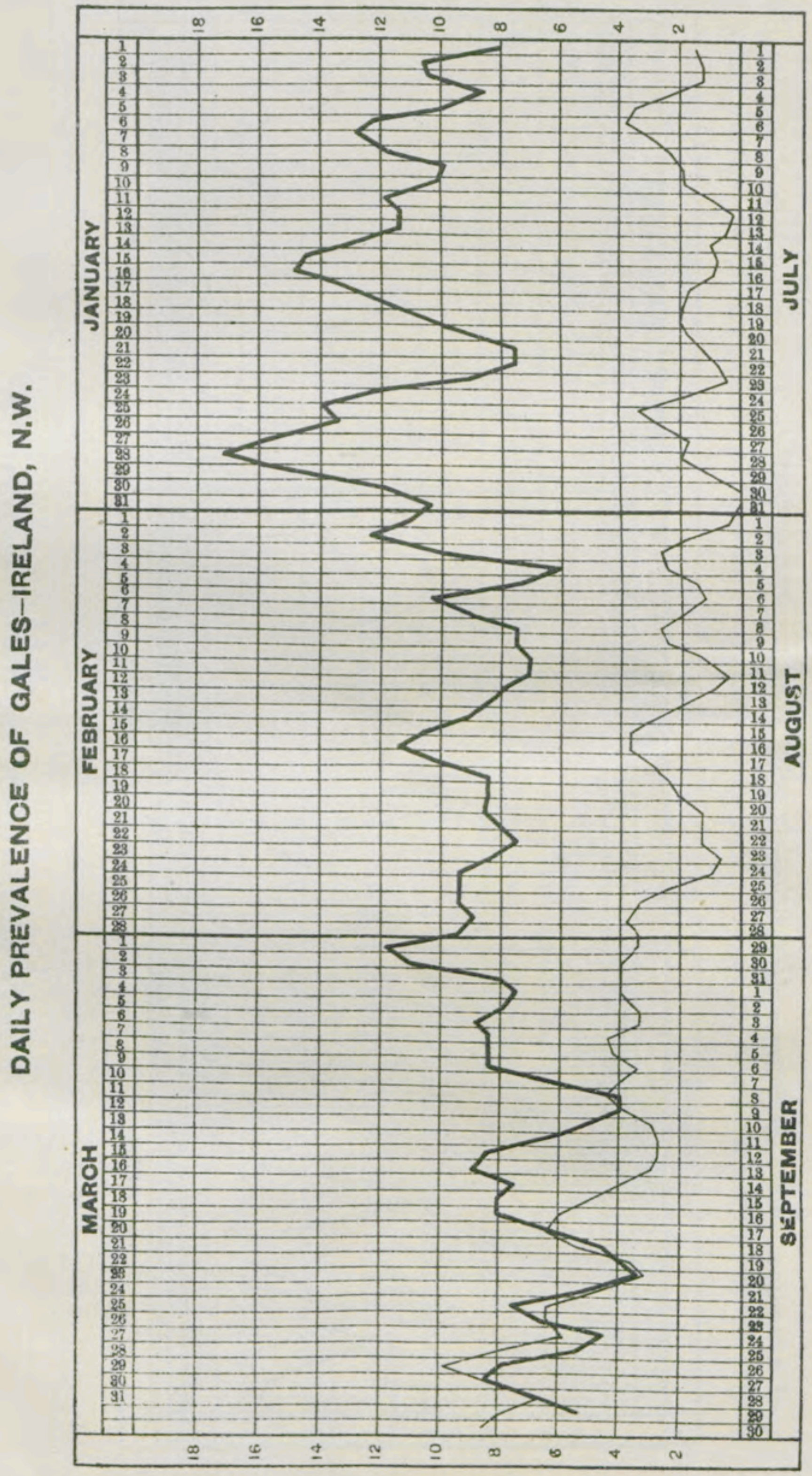
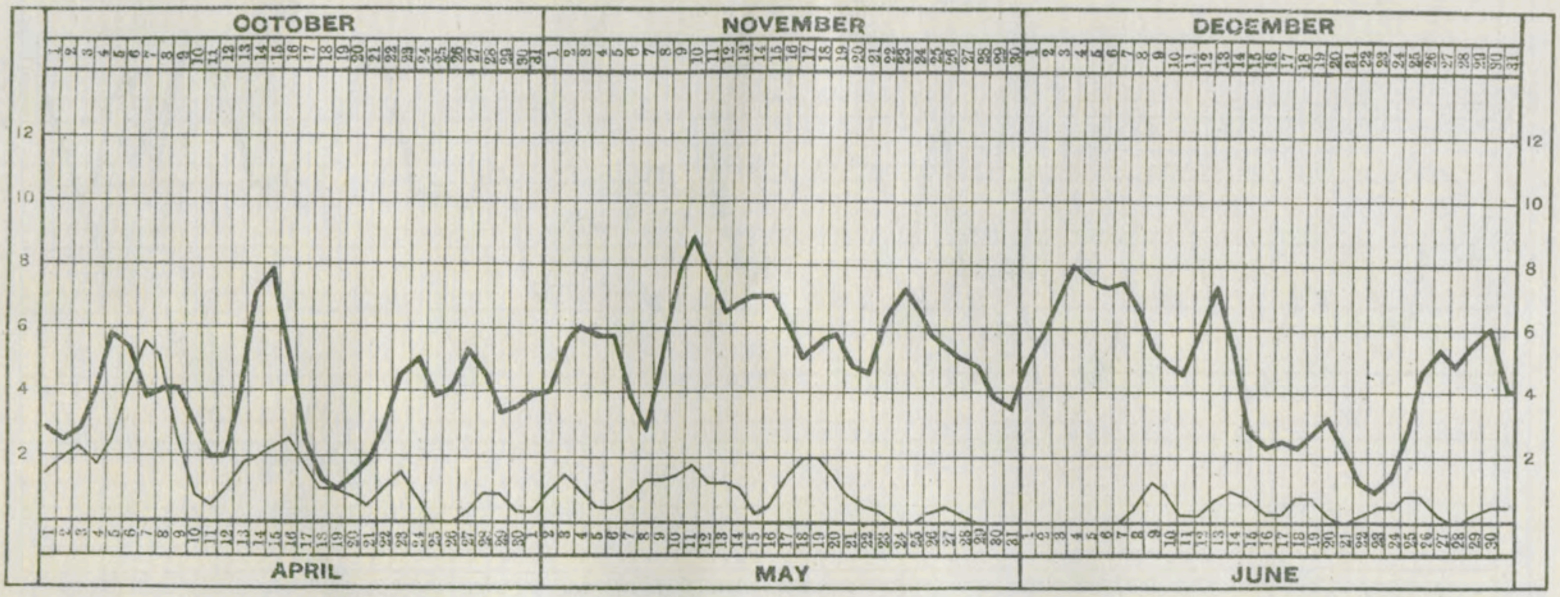


Plate II.

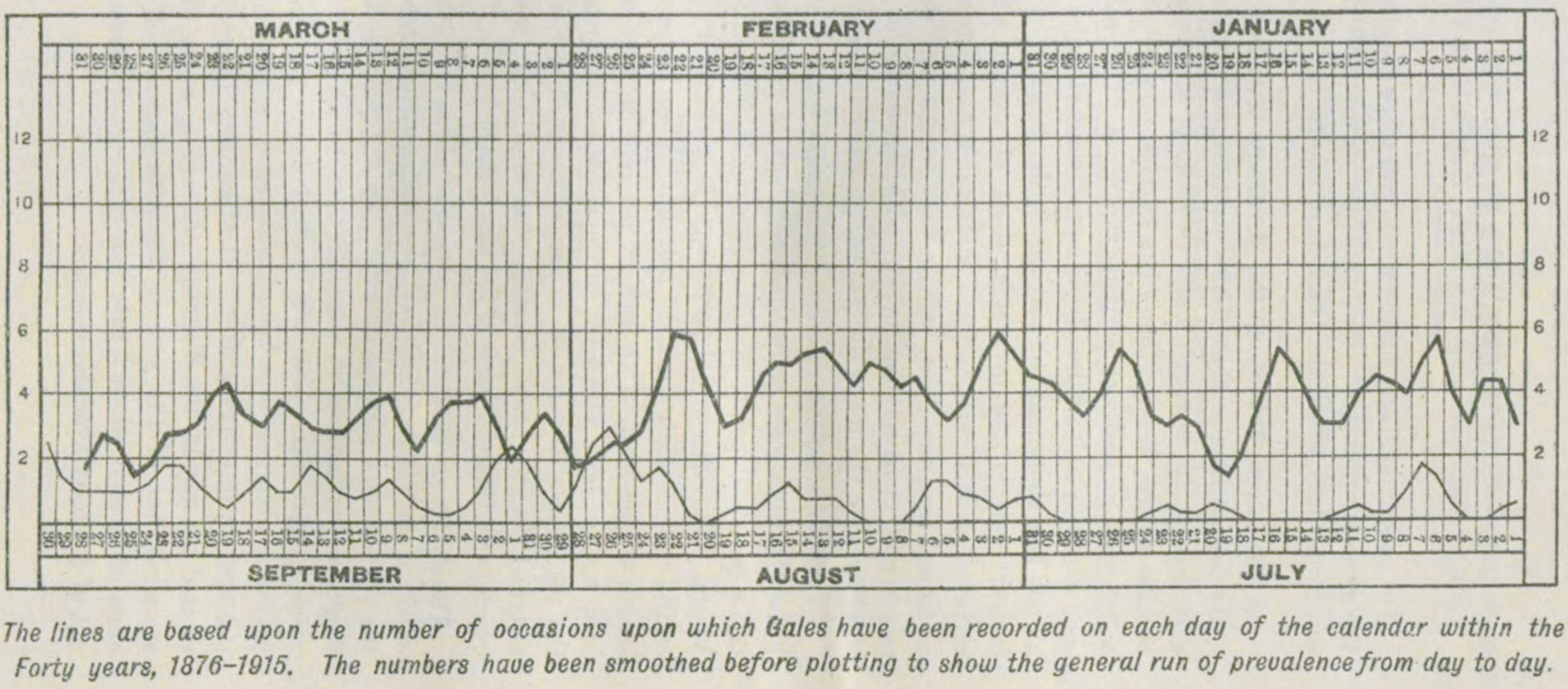


DAILY PREVALENCE OF GALES–ENGLAND, E.

(The district in which Gales are least frequent.)



DAILY PREVALENCE OF GALES–ENGLAND, E.



The lines are based upon the number of occasions upon which Gales have been recorded on each day of the calendar within the Forty years, 1876–1915. The numbers have been smoothed before plotting to show the general run of prevalence from day to day.

EXPLANATION.

For each month and for the whole year maps are given showing the average number of Gales recorded in each district and the directions from which the Gales have blown.

In the maps indicating the **Average number of Gales** *the larger figures, thus* 5·3, show for each month and for each district the average number of Gales of all strengths. *The smaller figures, thus* 1·3, show the average number of the Gales which were generally or partially severe. A "Generally Severe" gale is one in which Force 10 or more (Beaufort scale) is reported at not less than half the stations in the district. A "Partially Severe" gale is one in which winds of similar strength are reported at less than half the stations in the district. In the statistical enquiry from which the results are derived the number of Generally and of Partially Severe Gales was given separately; in the maps the two particulars have been combined.

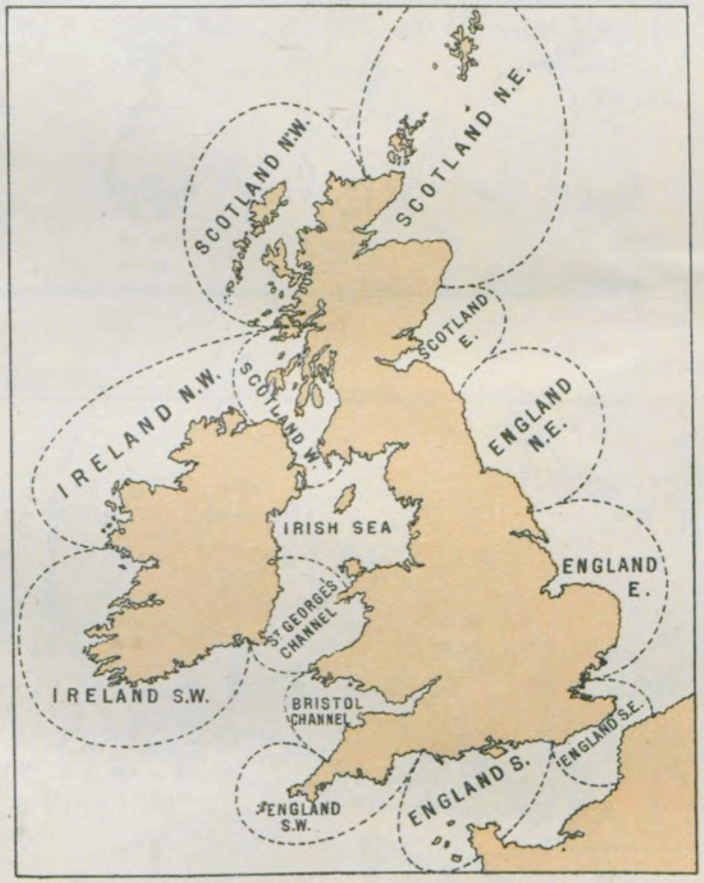
In the maps referring to the **Directions from which Gales blow** the wind-roses show the percentage of gales from each of the 8 principal points of the compass: N, NE, E, SE, S, SW, W and NW. The actual percentage is indicated by the length of the various dark lines, 10 per cent. being represented by a length of one-tenth of an inch, 20 per cent. by two-tenths of an inch, and so on. The figure in the small centre circle indicates the percentage of cases in which no single direction could be assigned for the gale because the wind blew from various quarters in different parts of the same district.

The charts are prefaced by diagrams which show the number of times on which gales have been experienced on each day of the year in two selected districts. In the preparation of these diagrams the number of occasions upon which gales have been recorded has been taken out for each day of the year, and the figures so obtained have been smoothed by taking the means of consecutive days twice over. The resulting figures have been plotted directly in the diagram. According to the diagram the stormiest day of the year is the 28th January off the N.W. coast of Ireland, where a gale has been recorded seventeen times out of the forty available occasions.

FREQUENCY OF GALES ON THE BRITISH AND IRISH COASTS DURING THE 40 YEARS, 1876–1915.

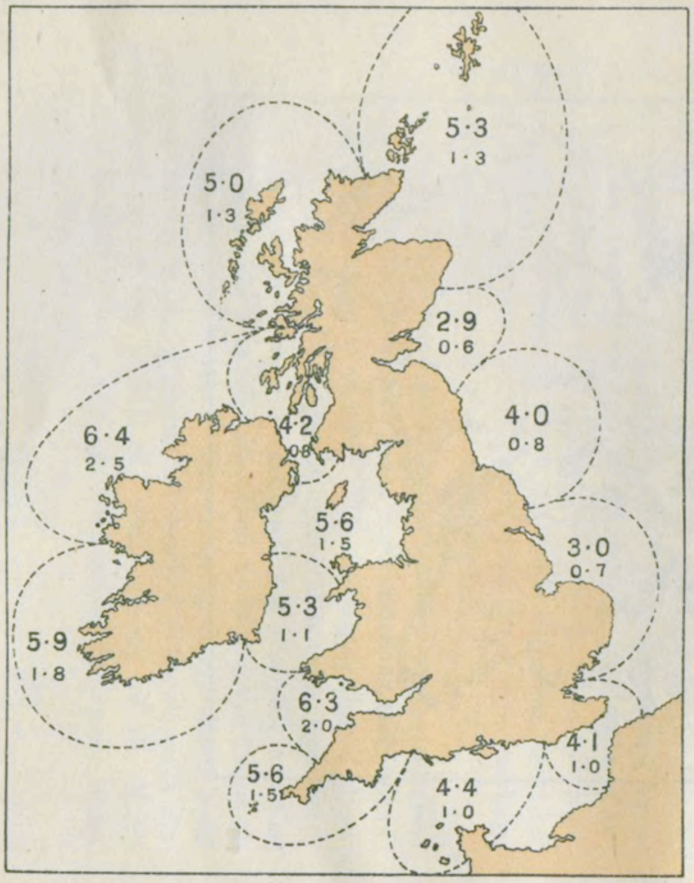
From information compiled for the purpose of testing the success of the GALE WARNINGS issued by the METEOROLOGICAL OFFICE.

MAP SHOWING DISTRICTS TO WHICH STORM WARNINGS ARE ISSUED.

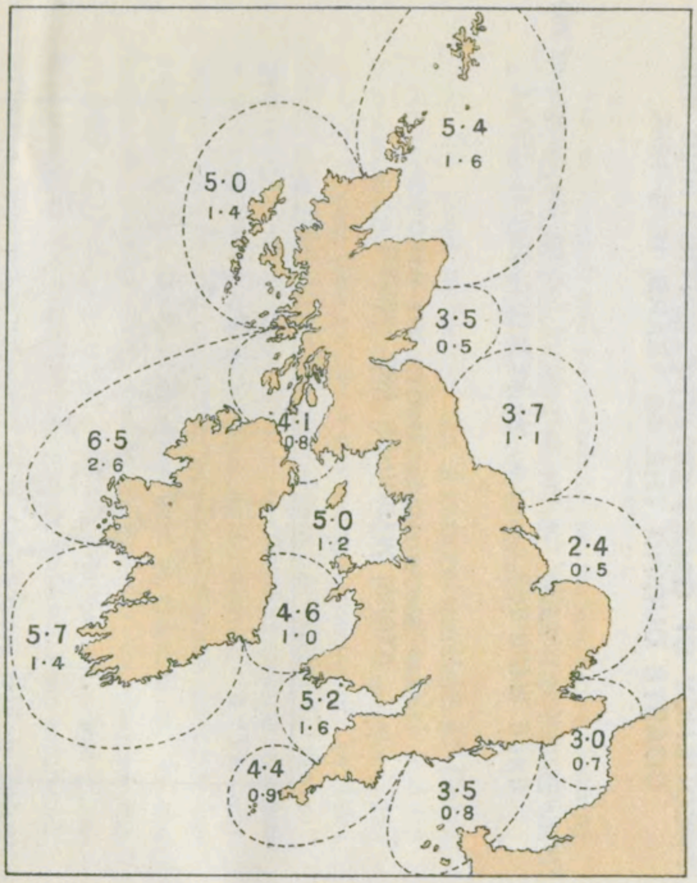


AVERAGE NUMBER OF GALES PER MONTH.

DECEMBER



JANUARY

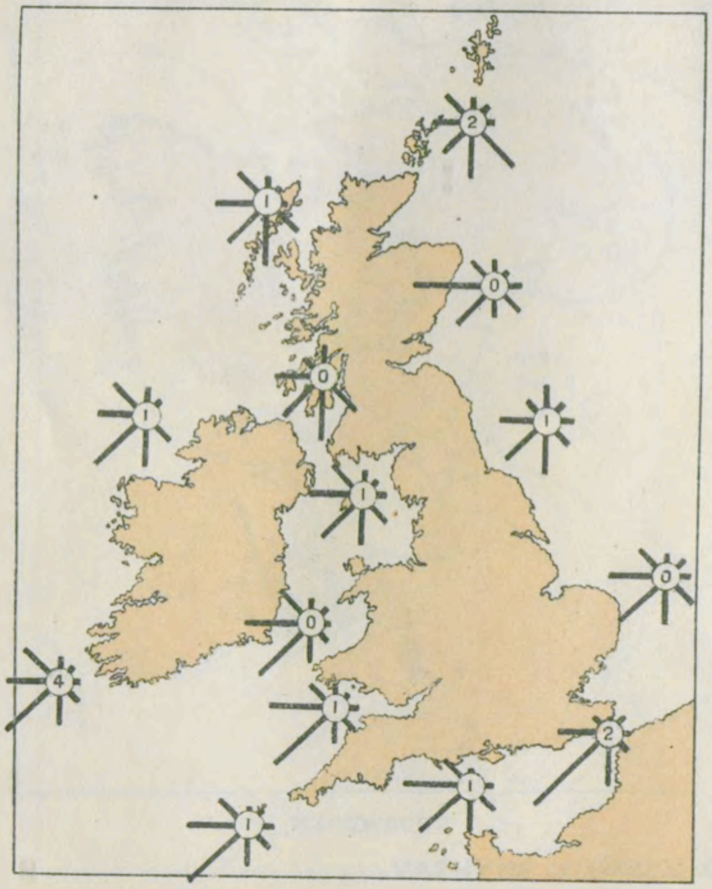


THE STORMIEST MONTHS.

For Ireland N.W. 6'4 means that the average number of gales experienced in that district in the month of December is between 6 and 7, and 2'5 means that of those gales between 2 and 3 are on the average severe.

DIRECTIONS FROM WHICH GALES BLOW.

DECEMBER



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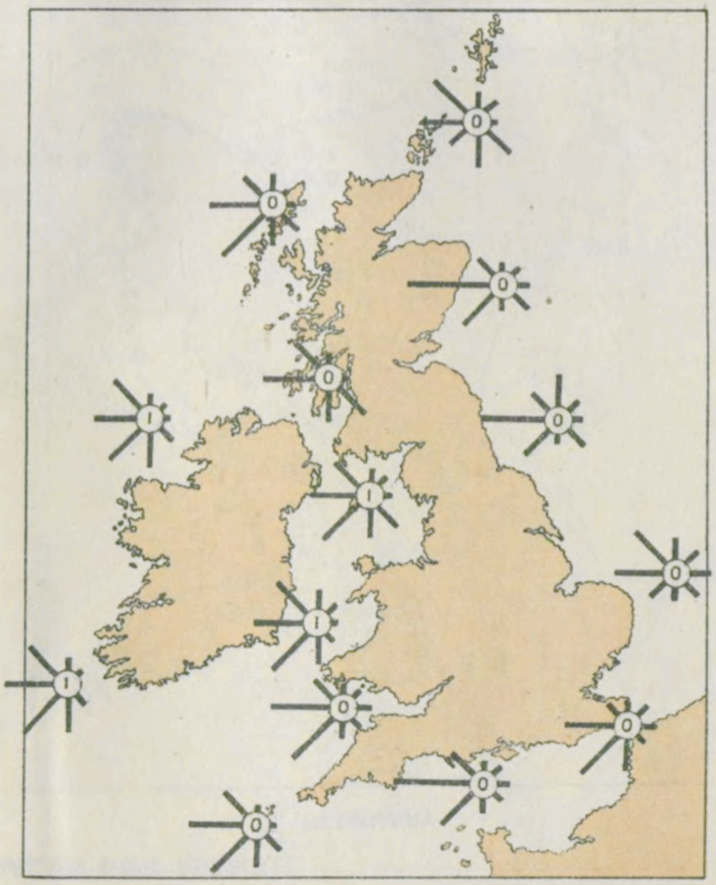
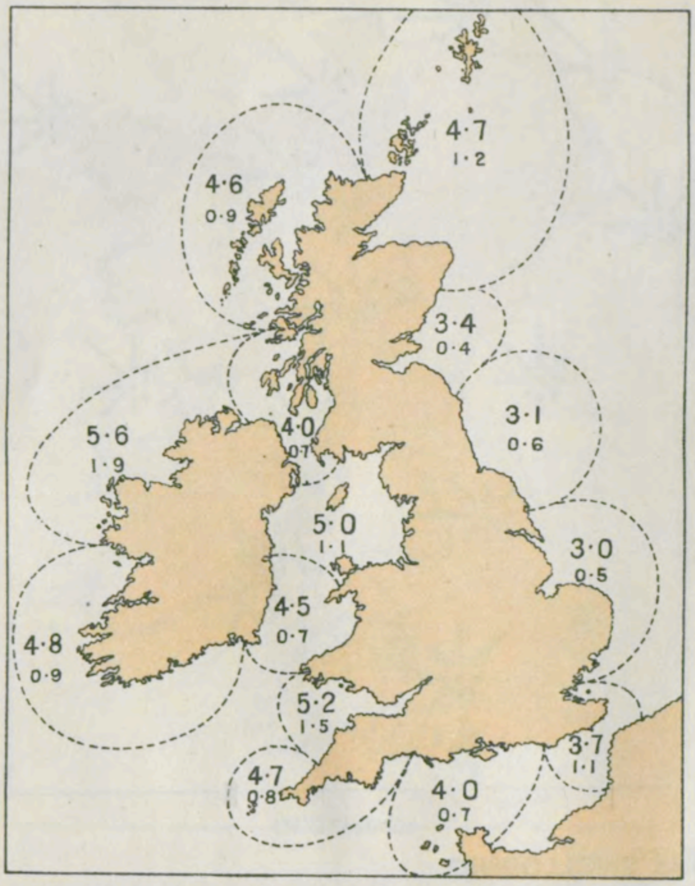


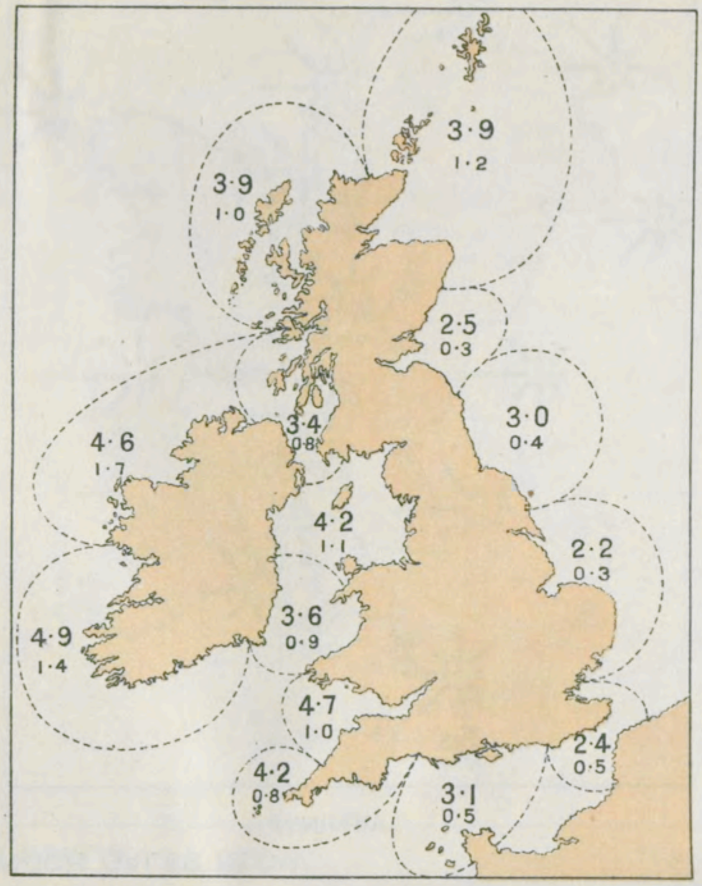
One-tenth of an inch of black line in any quarter means that 10 per cent. of the gales come from that quarter.

AVERAGE NUMBER OF GALES PER MONTH.

NOVEMBER

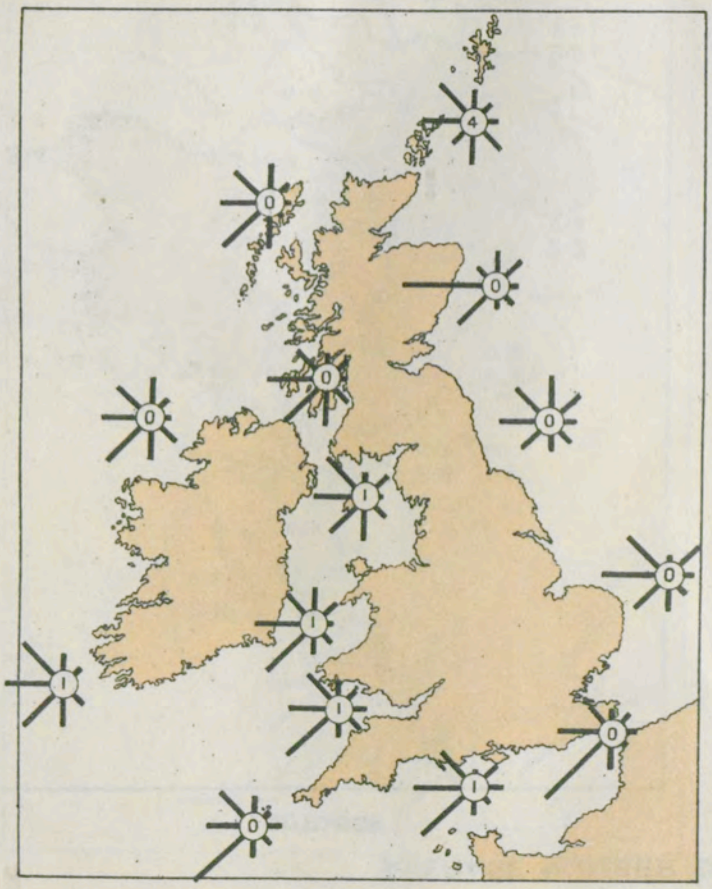


FEBRUARY

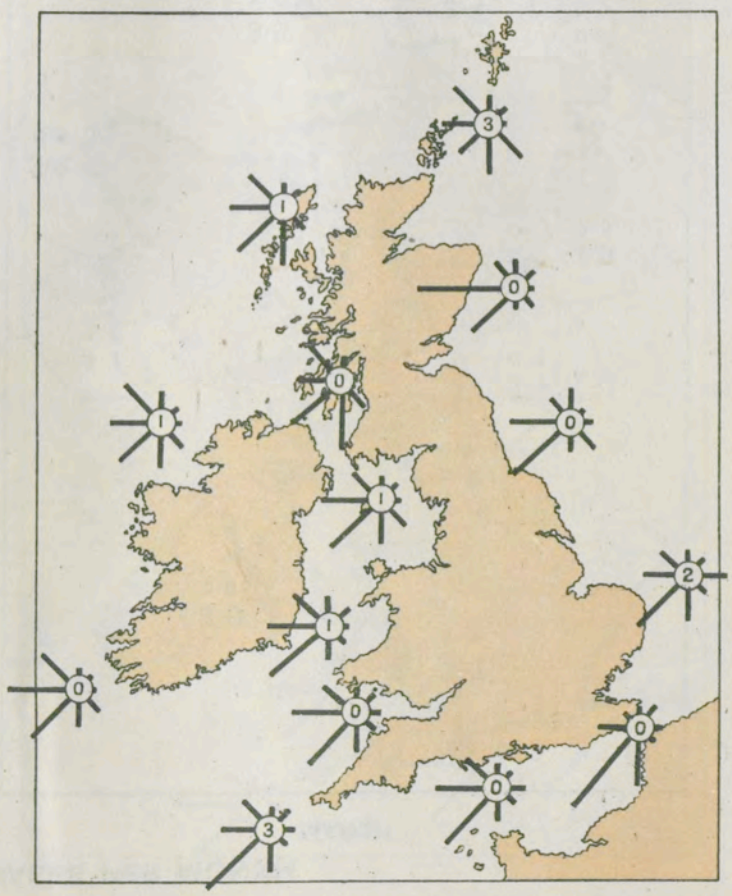


DIRECTIONS FROM WHICH GALES BLOW.

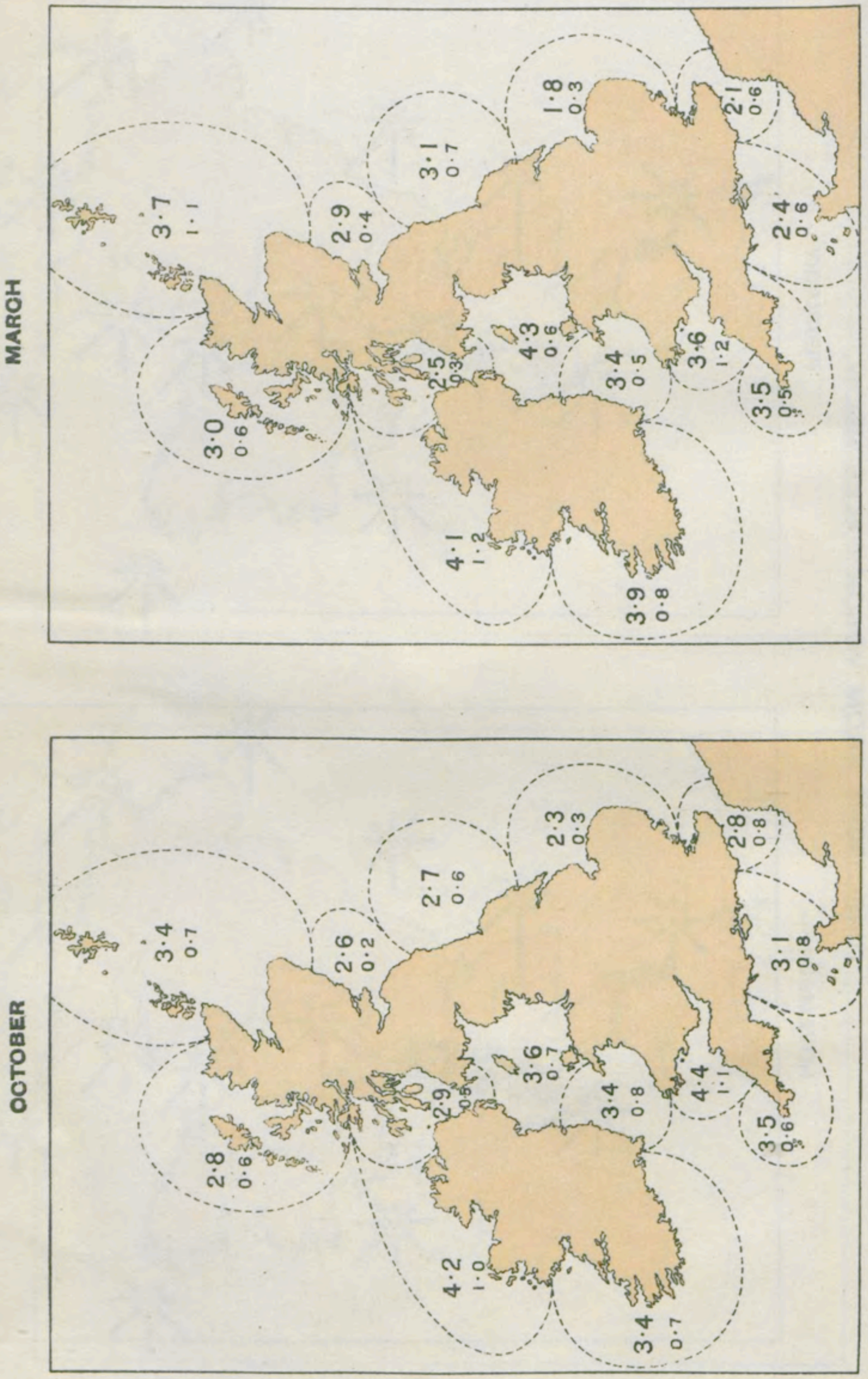
NOVEMBER



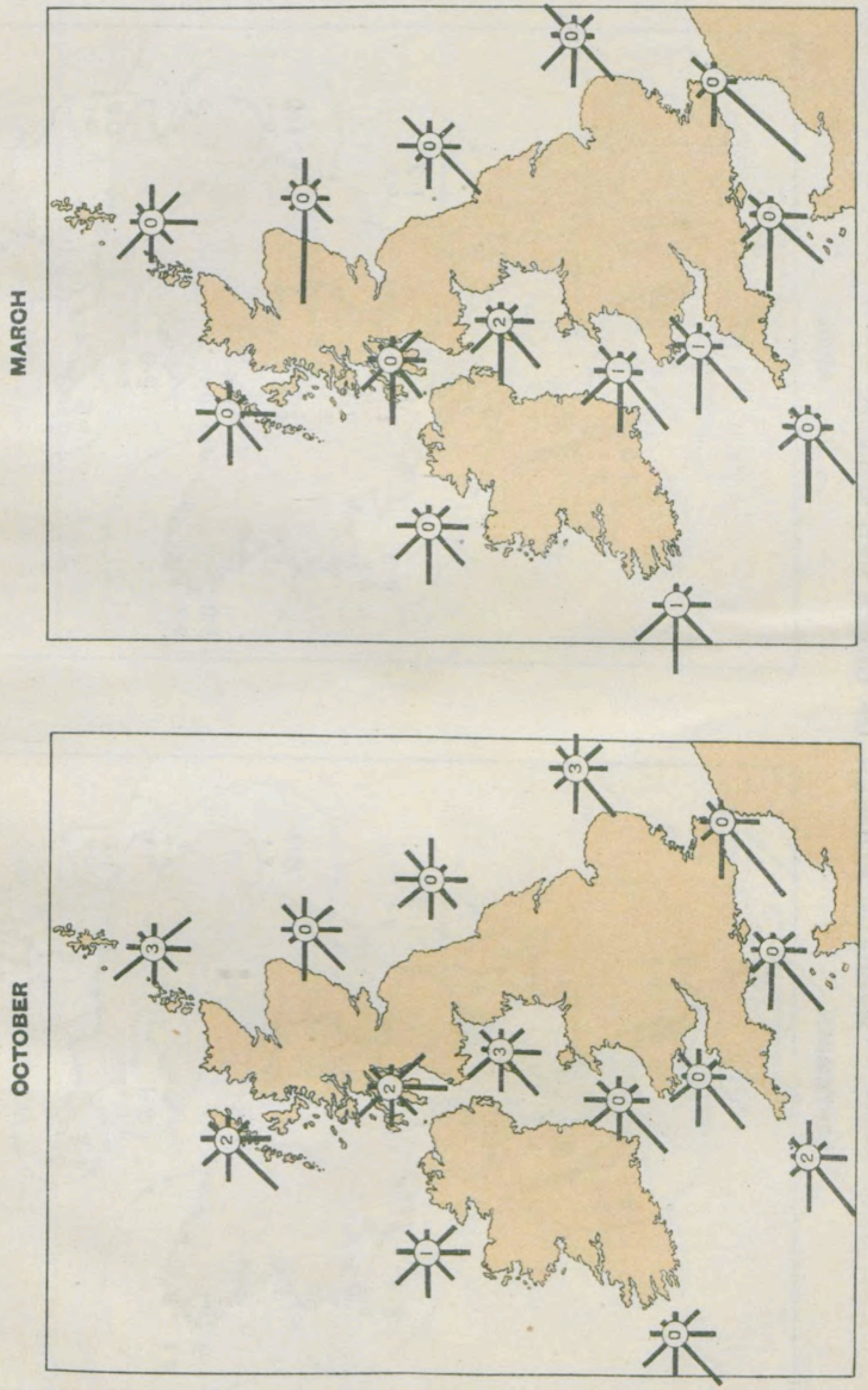
FEBRUARY



AVERAGE NUMBER OF GALES PER MONTH.

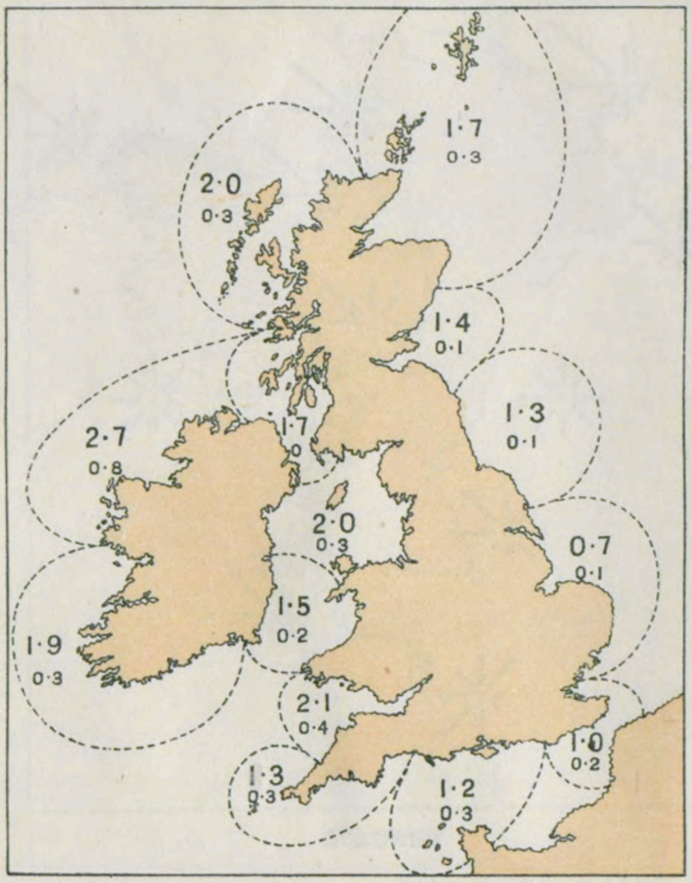


DIRECTIONS FROM WHICH GALES BLOW.

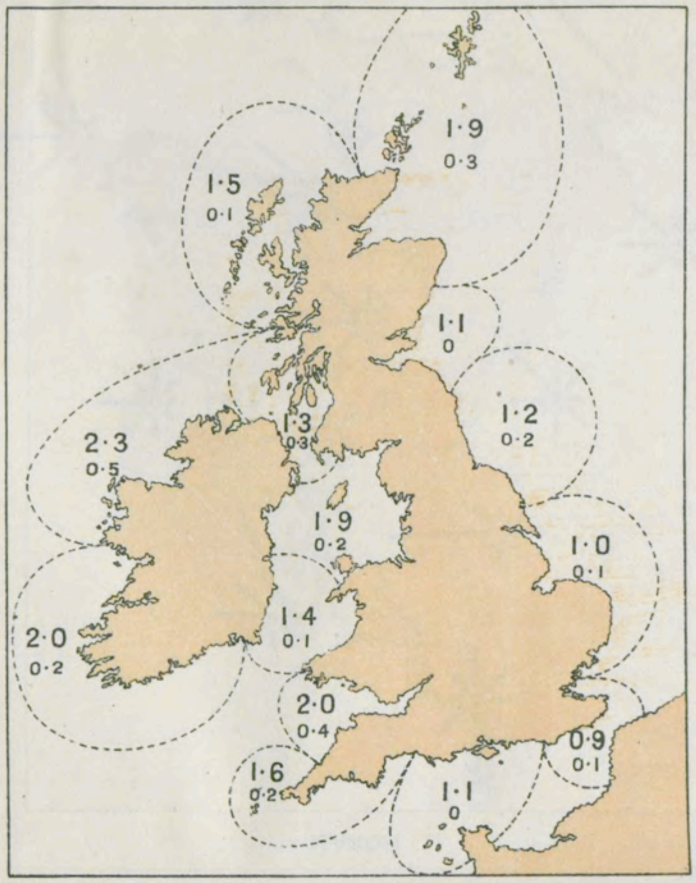


AVERAGE NUMBER OF GALES PER MONTH.

SEPTEMBER

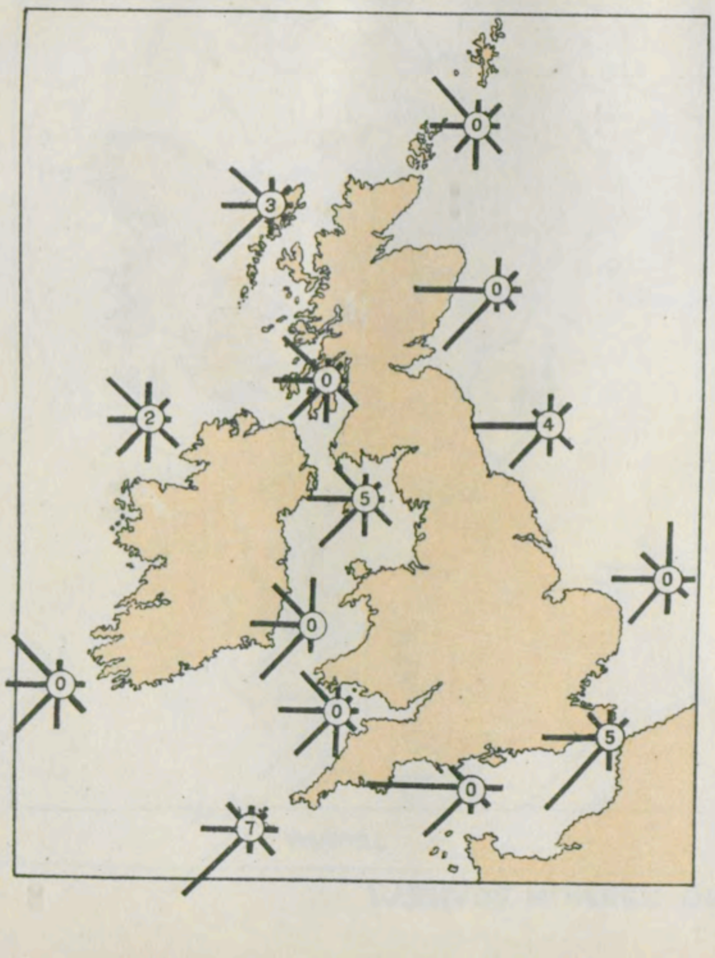


APRIL

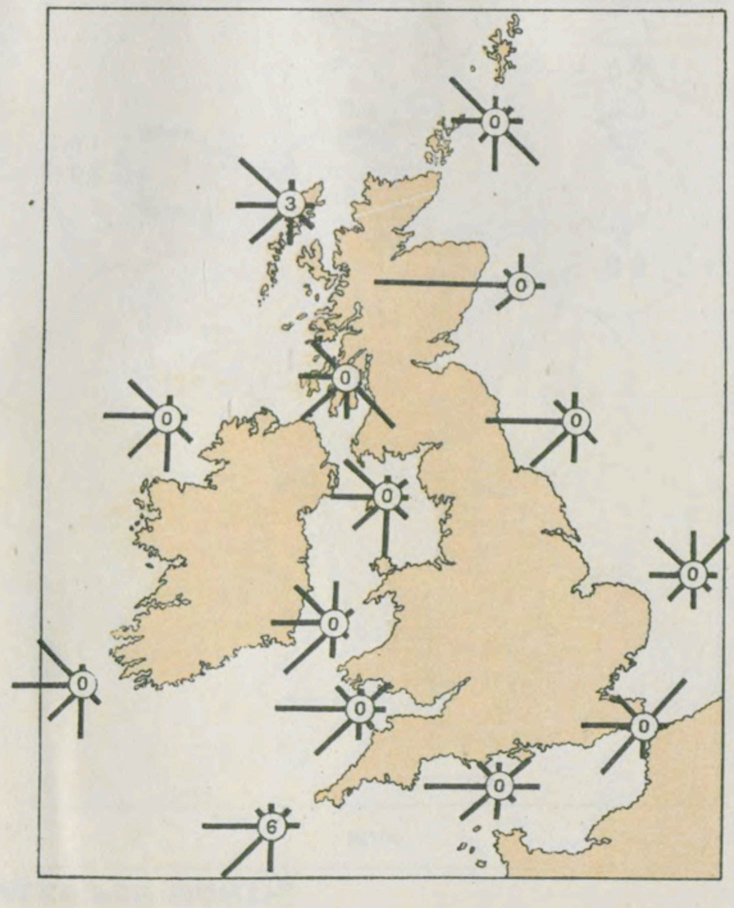


DIRECTIONS FROM WHICH GALES BLOW.

SEPTEMBER

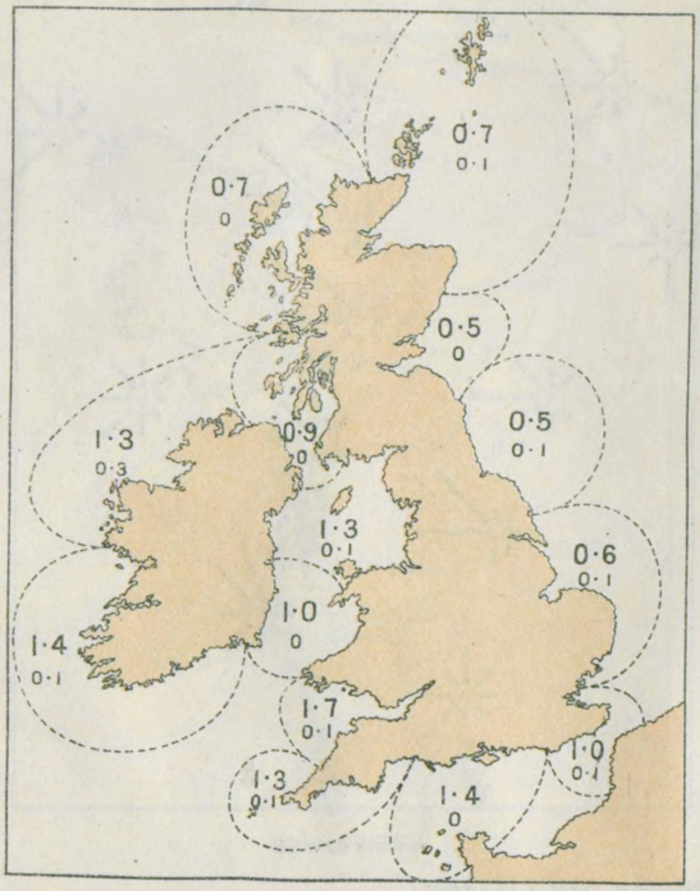


APRIL

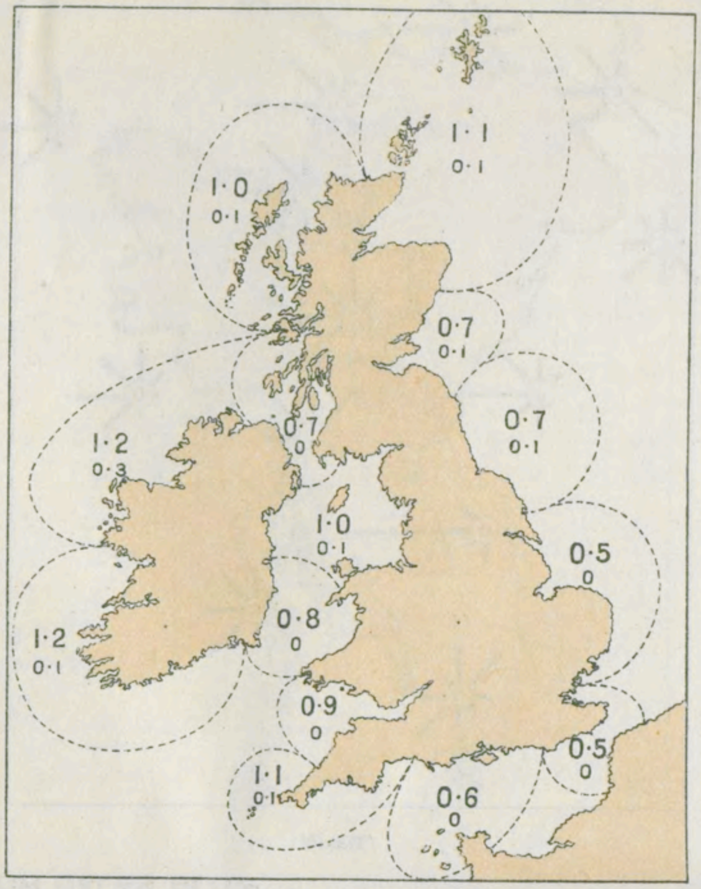


AVERAGE NUMBER OF GALES PER MONTH.

AUGUST

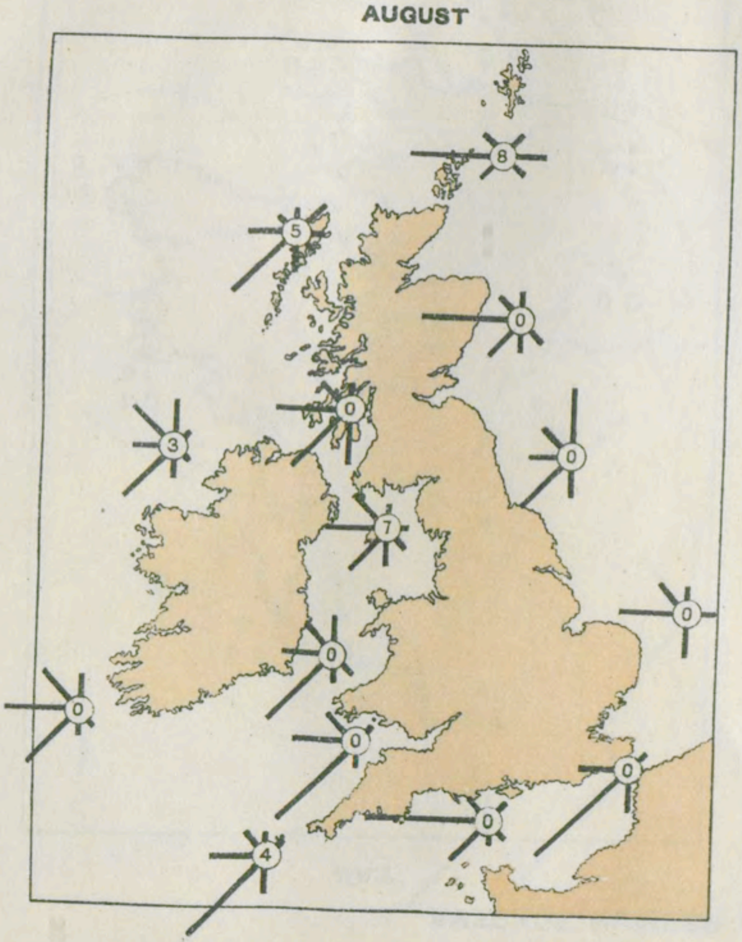


MAY

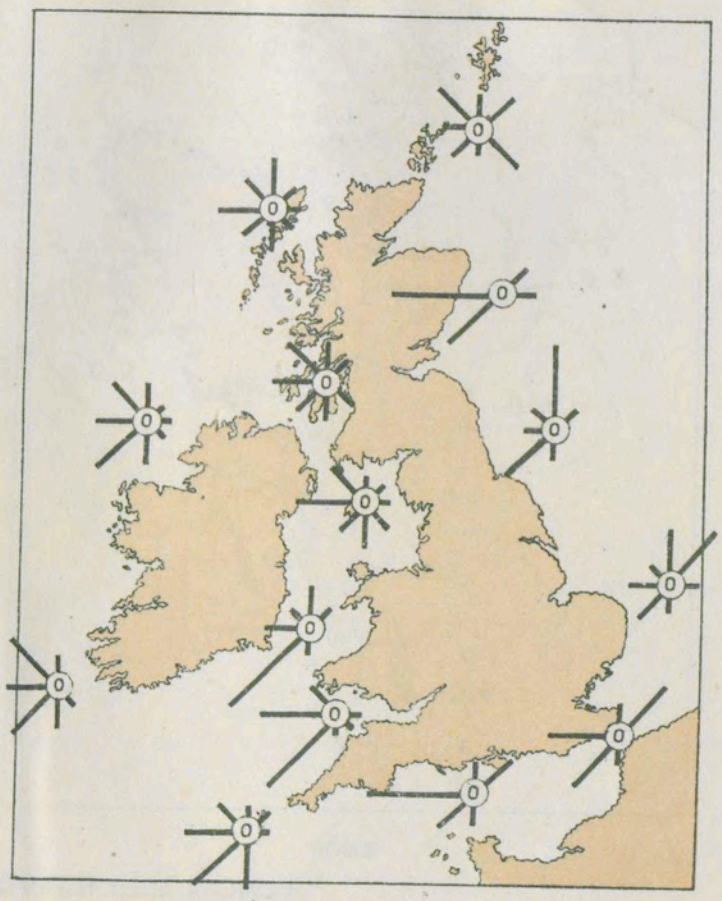


DIRECTIONS FROM WHICH GALES BLOW.

AUGUST

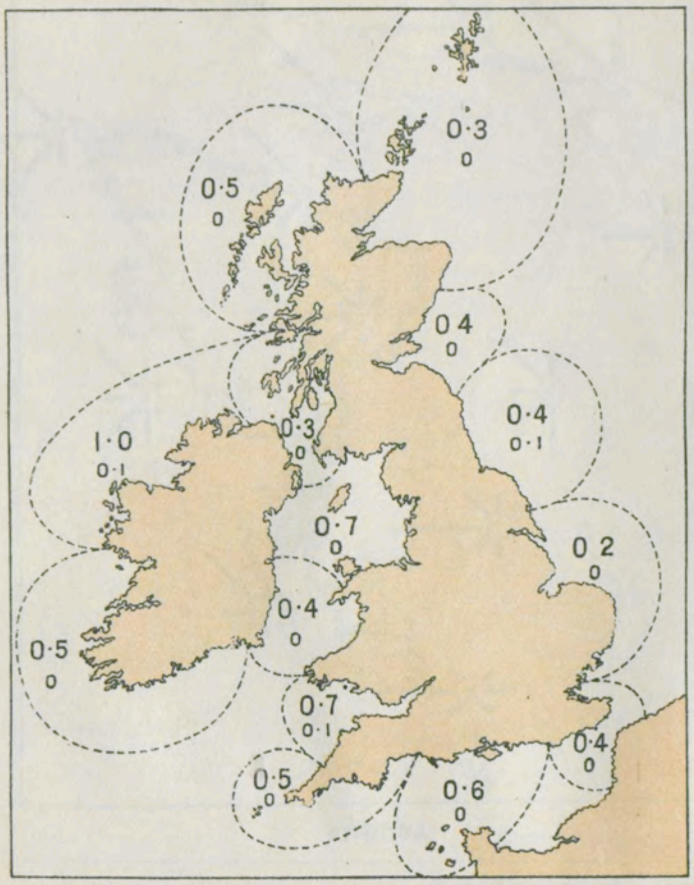


MAY

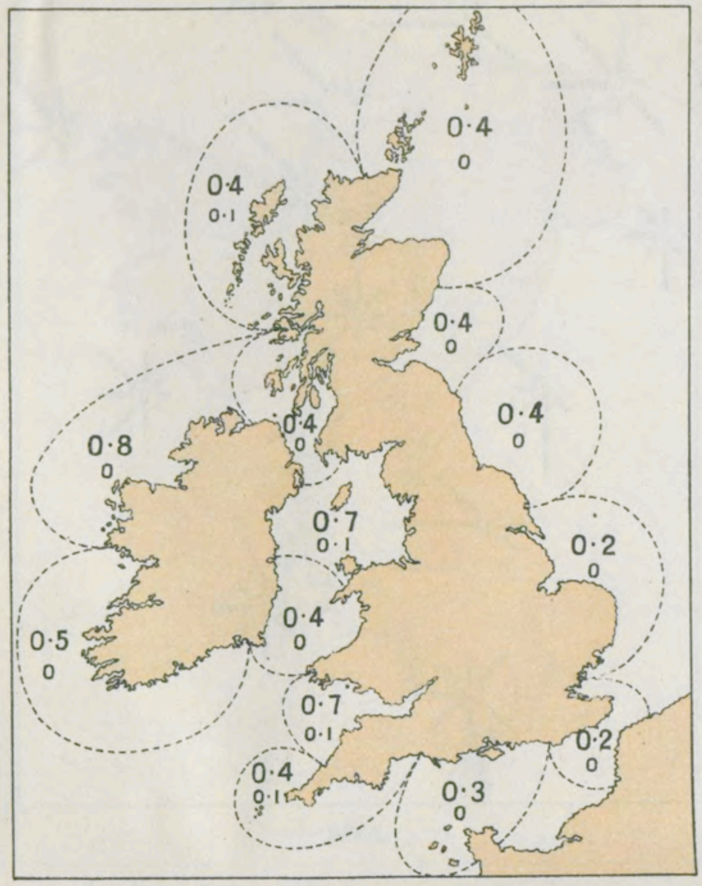


AVERAGE NUMBER OF GALES PER MONTH.

JULY



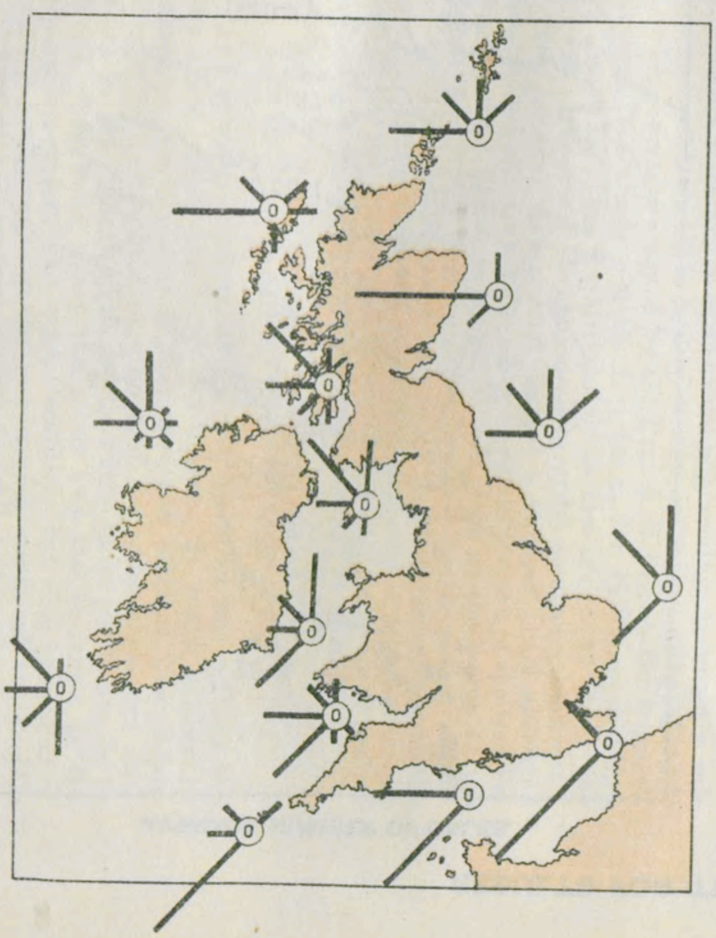
JUNE



THE QUIETEST MONTHS.

DIRECTIONS FROM WHICH GALES BLOW.

JULY



JUNE

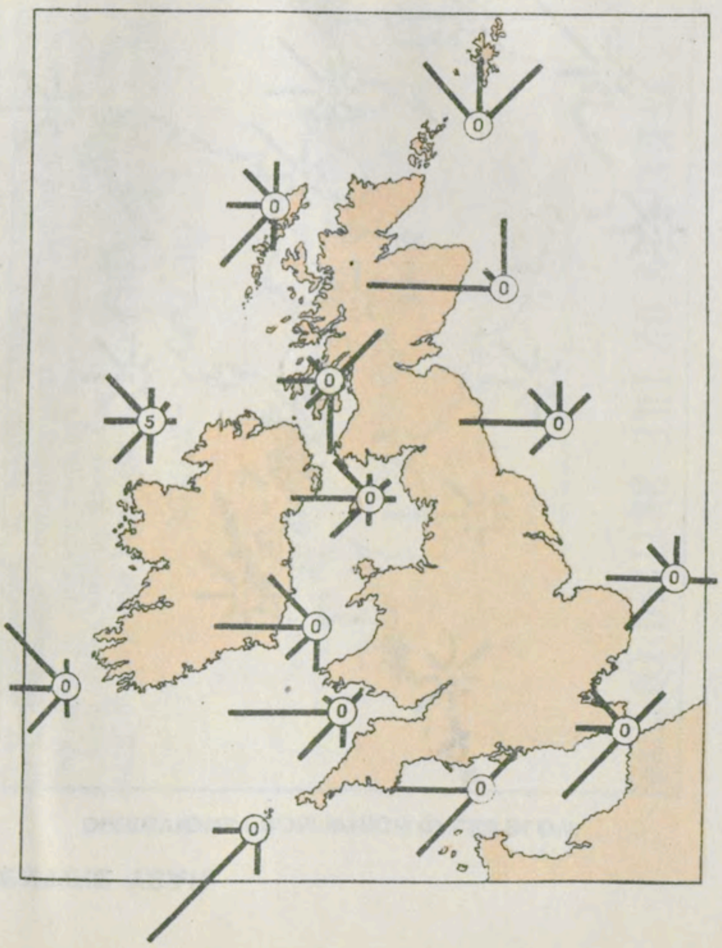
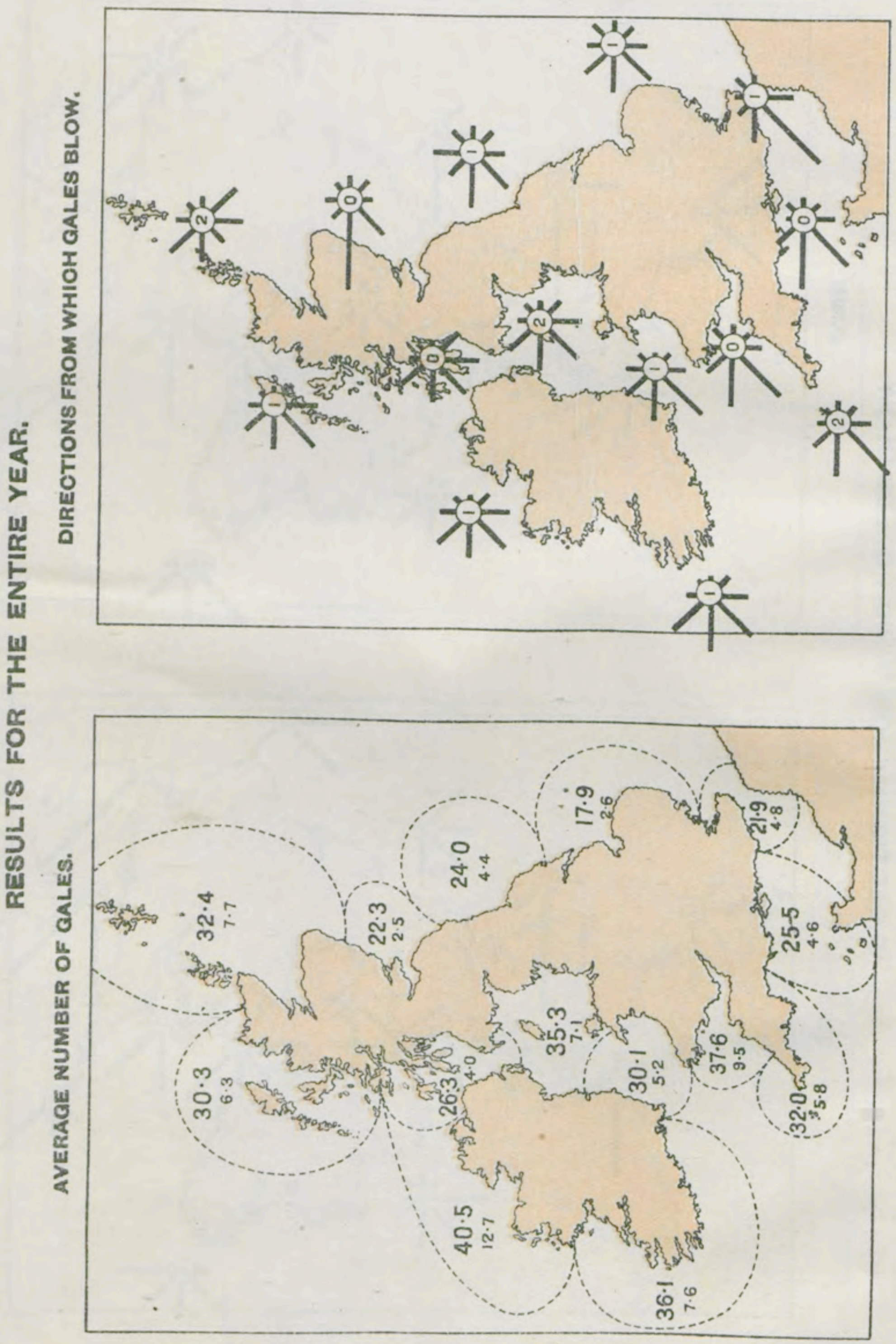


Plate XVIII.



THE WEATHER OF THE BRITISH COASTS.

PART I.

INTRODUCTION.

SEAMAN'S WEATHER: WIND, FOG, CLOUDS, WARMTH AND COLD, AND HOW THEY ARE OBSERVED AND MEASURED.

CHAPTER I.—WINDS.

Those who happened to cross the mouth of the Hudson River by the night train on the railway ferry in the early days of September, 1909, will remember the illuminations of New York harbour which formed part of the international celebration of the centenary of Robert Fulton's success in introducing steam navigation. Fulton was an American of Irish parentage; he came to England to follow the career of an artist. But he turned his attention to mechanical engineering, invented a submarine boat intended to be used in torpedo warfare and, failing to get his invention adopted by the French or British Government, devoted his abilities to steam navigation, first in France and then in America; "he is entitled to the distinction of being the first to make steam navigation an everyday commercial success."

The incident may remind us that a hundred years ago wind was beyond comparison the most important feature of the weather for seamen. Ships, being all sailers, were at the mercy of the winds upon which they depended for their motive power. Their courses from port to port had to be adjusted according to the winds. If the wind was light they made little or no progress, and if, on the other hand, it was too strong, they might become unmanageable and consequently suffer wreck or damage.

1. BEAUFORT SCALE.

And of all the features of the weather wind was perhaps the one about which the least was known. It could neither be measured like temperature, nor seen and pictured like clouds. People knew about the regularity of the trade-winds and monsoons in the regions of the earth where those winds are to be found, they knew about the calms and the doldrums of the equatorial regions and other localities, but the behaviour of tropical storms and of the ever-varying winds of the middle latitudes, or temperate zones of the earth's surface was a mystery to which no clue had been discovered. They could tell from what direction the wind came, just as the ancient Greeks and Romans had done before them; but the force of the wind, a matter of the utmost importance, was very vaguely indicated by the imperfect descriptions of airs, breezes, winds, gales, gusts, squalls, catspaws and the like. It is only a little more than a hundred years since Admiral Sir Francis Beaufort, a former Hydrographer of the Navy, devised a scale of numbers, ranging from 0 for calm to 12 for a hurricane, to indicate with some precision the force of the wind, using for the specification of the scale, which has ever since borne his name, the speed which a "well-conditioned man-of-war" could make for forces 0, 1, 2, 3, 4, and the amount of sail which she could carry for the rest of the numbers. Gales, in the nautical sense, were not the "gentle gales" that poets appeal to: they began with the number 7 which was a "moderate gale" or perhaps "half a gale," and real gales were covered by the numbers 8, 9, and 10. Force 11 counted as a storm and 12 was a hurricane "that no canvas could withstand."

That was in 1805. Since that time a good deal has happened. To begin with, ships changed their rig and the specification had to be altered, then steamships replaced sailing ships almost entirely, but still the Beaufort Scale held on and sailors of sailing ships handed on to their successors on steamers the tradition of the estimation of the wind when there were no sails, although the speed of the ship had then become a disturbing element instead of an aid to the specification. Then the measurement of wind by special instruments which are called anemometers (from two Greek words *anemos* meaning wind and *metron* a measure), was gradually perfected, so that to-day the actual velocity of the wind that passes an anemometer is known with reasonable accuracy; and by getting experienced sailors to estimate the wind on the Beaufort Scale at a place where there was an anemometer to record the velocity, we have been enabled to assign to the numbers of the Beaufort Scale the limits of the velocity of the winds which correspond therewith, and, in that way, to keep for the future the continuity which was threatened by the change from sail to steam.

2. The Force of the Wind in "Pounds per Square Foot."

Two other points must be noted with reference to the measurement or the estimation of wind. The first is concerned with the hardness of the blow, the force which the wind exerts upon an obstacle exposed to it. That is an extraordinarily complicated question about which a great deal of erroneous information may be found even in modern books; and but little can be said here. Nearly everybody knows now that the resistance which a ship has to overcome in forcing its way through the water depends upon the shape of the ship; upon the ship's "lines" to use a technical expression. And so it is with any structure that forces its way through the air or, what is the same thing, holds itself firm in a current of wind that passes it. The resistance, or force which it has to overcome, depends upon its shape. That is why they build airships with rounded nose and "lines" aft that remind one of a fast steamer; in that form they offer the least resistance for their bulk. The aim is to avoid as far as possible creating the waves and eddies to which the motion of a vessel through water or air gives rise; but to get the least resistance the ship, with proper lines, must of course go through the water or the air along the line of its length. It must go "end on"; "broadside on" it will meet with very much greater resistance, so that the resistance which a structure offers to the wind depends upon its "aspect" with regard to the wind, that is upon the way it faces the wind, as well as its shape. Even so symmetrical a body as a sphere or a globe has some peculiarities when it comes to be towed through air or water. Hence we cannot give a simple law by which the force of the wind on any complicated structure can be computed with accuracy. As a rough guide to the forces that may be expected, we may take the simple case of a circular disc or plate that is held to face the wind. For that case it has now been well established that the resistance with which it meets depends upon what is called the "square" of the velocity of the wind, and that a wind of 10 miles an hour in air of ordinary density blowing upon a circular or square plate not less than one square foot and not more than one hundred square feet in area gives a force between a quarter and a third of a pound per square foot; and a wind of 100 miles per hour gives a force, in like circumstances, of 30 lbs. per square foot. The force of a "strong breeze" upon an ordinary umbrella held to face it is between twenty and thirty pounds.

The determination of these figures is quite recent; tables may still be found in "pocket-books" which give half a pound per square foot for a ten-mile wind and 50 lbs. per square foot for a hundred-mile wind, but these figures are known now to be much too high.

3. Specification of the Beaufort Scale for Use on Land.

The other point to which reference should be made is the specification of the Beaufort Scale for use on land. That is a matter of some difficulty, because the wind produces a variety of effects on land which do not appear at sea at all, where there are only the ship and the sea; and on land the observer himself may be screened from the force of the wind by fences, trees or buildings, and he must use what he can see without any assistance from what he feels. A specification for use on land was drawn up in 1905 by Dr. G. C. Simpson, F.R.S. It has elicited some good-humoured criticisms and has been facetiously illustrated by a Naval Officer who remains anonymous, but in the course of twelve years no one has come forward with suggestions for improvement, so that it may be allowed to stand.

The same may be said for a specification of the Beaufort Scale for coast use, which we also owe to Dr. Simpson, who spent some time with a fishing fleet in the North Sea experimenting upon the upper air with kites. That likewise has been the subject of some criticism on the ground that smacks of different size and trim

SPECIFICATION OF THE BEAUFORT SCALE OF WIND FORCE WITH PROBABLE EQUIVALENTS OF THE NUMBERS OF THE SCALE.

(The equivalents refer to an anemometer at a height of 33 feet above level ground.)

Beaufort Number.	Mean wind force at standard density.		Equivalent velocity in miles per hour.‡	Limits of Velocities.§		General Description of Wind.	Specification of Beaufort Scale.	
	mb.	Lbs. per sq. ft.		Statute Miles per Hour.	Metres per Second.		For Coast Use, based on Observations made at Scilly, Yarmouth, and Holyhead.	For use on Land, based on Observations made at Land Stations.
0	0	0	0	Less than 1	Less than 0·3	Calm	Calm	Calm; smoke rises vertically.
1	·01	·01	2	1–3	0·3–1·5	Light air	Fishing smack* just has steerage way.	Direction of wind shown by smoke drift, but not by wind vanes.
2	·04	·08	5	4–7	1·6–3·3	Slight breeze ...	Wind fills the sails of smacks, which then move at about 1–2 miles per hour.	Wind felt on face; leaves rustle; ordinary vane moved by wind.
3	·13	·28	10	8–12	3·4–5·4	Gentle breeze ...	Smacks begin to careen, and travel about 3–4 miles per hour.	Leaves and small twigs in constant motion; wind extends light flag.
4	·32	·67	15	13–18	5·5–8·0	Moderate breeze ...	Good working breeze; smacks carry all canvas, with good list.	Raises dust and loose paper; small branches are moved.
5	·62	1·31	21	19–24	8·1–10·7	Fresh breeze ...	Smacks shorten sail	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	1·1	2·3	27	25–31	10·8–13·8	Strong breeze ...	Smacks have double reef in main sail. Care required when fishing.	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	1·7	3·6	35	32–38	13·9–17 1	High wind ...	Smacks remain in harbour, and those at sea lie to.	Whole trees in motion; inconvenience felt when walking against wind.
8	2·6	5·4	42	39–46	17·2–20·7	Gale	All smacks make for harbour, if near.	Breaks twigs off trees; generally impedes progress.
9	3·7	7·7	50	47–54	20·8–24·4	Strong gale ...	... ...	Slight structural damage occurs (chimney pots and slates removed).
10	5·0	10·5	59	55–63	24·5–28·4	Whole gale ...	... ...	Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	6·7	14·0	68	64–75	28·5–33·5	Storm	... ...	Very rarely experienced; accompanied by widespread damage.
12	8·1	Above 17·0	Above 75	Above 75	33·6 and above.	Hurricane	... ...	... ...

* The fishing smack in this column may be taken as representing a trawler of average type and trim. For larger or smaller boats and for special circumstances allowance must be made.

‡ For converting estimates on the Beaufort scale into miles per hour (anemometer factor, 2·2).

§ For finding the Beaufort number corresponding to a velocity expressed in miles per hour. These numbers are applicable to the readings of anemometers with a very free exposure, 30 feet to 40 feet above a level shore or open ground, and are not applicable to the readings of anemometers on the roofs of large buildings or in protected situations. For each of these a special table of equivalents is required based upon an examination of the readings in relation to the distribution of pressure.

behave differently and the scale takes no account of that; or a smack with wind abeam will careen when it would not if the wind were abaft, but allowance can easily be, and would naturally be made by the observer for these differences, and it can scarcely be denied that the behaviour of a fishing fleet off-shore gives one a better idea of the force of the wind there than one would get if the ships were not there. So until we get a form of words which is free from these objections we may still make some use of the information which the specification contains.

All these matters concerning the Beaufort Scale are set out in tabular form in the specification on pages 4 and 5.

4. The Points of the Compass and the Quadrants of the Compass Card.

We give also a well-known diagram of the points of the compass or circle which are used for specifying the direction of the wind, with the number of degrees from North to which the points correspond.

Fig. 1.

The points of orientation on this card, viz., NNE., NE., etc., are what are known as geographical or "true" and are to be distinguished from the points of the mariner's magnetic compass because the compass-needle does not point exactly North in the British Isles, but between 15° and 18° to the West of North. The exact amount of deviation from true North depends upon the locality and is known as the "variation" of the compass-needle.

It should be noticed that true North is at the point marked 360° on the card, which is also the zero point or 0° from which the counting of degrees begins. True east is marked 90°, south 180°, west 270°. By these cardinal points the circle is divided into four equal parts or quadrants of 90° each. The part of the circle between N. and E., from 0° to 90° is often spoken of as the NE. quadrant, that from E. to S. as the SE. quadrant, and so on. In like manner the quadrant between NE. and SE. is often spoken of as the Easterly quadrant, that between SE. and SW. as the southerly quadrant, and so on. The "true" points should always be used for wind, both on land and sea.

5. The Relation of Wind to the Distribution of Barometric Pressure.

While the evolution of effective methods of measuring or estimating the wind has been in continuous progress throughout the century, great advances have been made in our knowledge of the facts about the wind and its relations to other features of the weather. By the gradual accumulation of observations we know what, in the ordinary course of events, is to be expected in the way of wind in almost any part of the earth. The results are set out in charts of various kinds published by the meteorological offices of the various countries, especially by our own; and we know also a great deal about the relation of wind to pressure, so much so that meteorologists now look upon a map of the distribution of pressure as forming as good or perhaps a better guide to the general distribution of wind, whether for the moment or on the average, than the observations of wind themselves.

There is more to be said about that when we come to talk about the weather map, but in the meantime let it be understood that there are laws of relation of wind to pressure that hold good equally for the revolving storms of tropical latitudes which are still a source of grave danger to steamers, as they were to sailing ships, and for the gales, moderate winds, and even the light airs of our own coasts. The behaviour of storms is now so well known that seamen have learned what course to adopt in order to avoid at any rate the worst consequences; and laws derived therefrom, applied to the winds of our own latitudes, enable us to anticipate with a good deal of certainty the changes in the wind. When we know as much about the relation of weather to wind as we know about the relation of wind to pressure, we shall have full confidence in our power to forecast the weather with accuracy.

6. The Wind and Modern Steamers.

But in the meantime, while all this progress was being made in our knowledge of wind and weather, ships have become to some extent independent of ordinary winds. Some ten years ago the chairman of a line of steamers when asked what difference the wind made to the voyages of his ships or the consumption of his coal, replied that it made no difference, and that they did not pay any attention to it. The first part of this answer is an exaggeration excused perhaps by the last part, which may be true enough, and it represents an enormous change in the course of the century. It is true that the wind has lost much of its pre-eminence as a feature of the weather for seamen; fast steamers are more concerned about fog and ice than about wind. But still the wind is there and sometimes it reminds us with unaccustomed force of its existence, and it is well for coasters which have to navigate the narrow seas to know as much as possible about it. Moreover a knowledge of the winds is the key to nearly all the science of weather which goes by the name of meteorology. So we shall begin what we have to say about weather by some information about the winds of the British Coasts and as a preliminary will consider what an ordinary British wind is like.

7. The Ordinary Structure of Wind.—Gustiness.

The best idea of what wind is really like is to be got from the record of a well-exposed anemometer which shows clearly the rapidly recurring gusts and lulls, the gradual changes and the occasional squalls which make up the wind. Such an instrument is the one designed by Mr. W. H. Dines, F.R.S., and known as the *tube-anemometer*. Its exposure at Mr. Dines' observatory at Benson in Oxfordshire is shown in figure 2. Eighty-five feet above the ground is a vane carried by a steel-tube which is supported by a steel-tower 55 feet high; the front of the head of the vane is a short horizontal tube open to the air at one end, and having the other end connected in a special manner by means of a metal pipe, led down the tube and tower, to the recording-apparatus in the shed at its foot. The tube is kept head-to-wind by the tail of the vane, and the wind blowing into the mouth of the tube causes an increase of pressure there which is transmitted to the recording-apparatus. The central tube leading from the head is surrounded by a wider tube perforated by holes arranged in rings close to the head; the intervening space is connected with the recording-apparatus by a second metal tube; and this arrangement is necessary in order that the recording-apparatus may be affected exclusively by the wind at the head and not by the wind blowing upon the shed or the screens which surround it. The arrangement and exposure of the anemometer at Spurn Head are the same as that shown in the picture, except that the tower is 25 feet high and the vane 15 feet above its apex. Both of these instruments are provided with apparatus for recording mechanically the direction in which the vane is pointing. Many of the tube anemometers are not provided with this addition, but the lack of record of the direction of the wind is always felt to be a serious drawback.

A specimen of the record from the anemometer at Spurn Head is given in figure 3. The record of the speed of the wind is the ragged black ribbon-like trace of the upper diagram, while the record of direction is the black shading, forming a much narrower black ribbon, of the lower diagram.

The "ribbon" is made in either case by the recording-pen going up and down the paper while the paper itself is carried round on a drum turned by clockwork, once round in 24 hours. The hours are marked by vertical lines on the diagram numbered at

To face page 8.

Fig. 2.

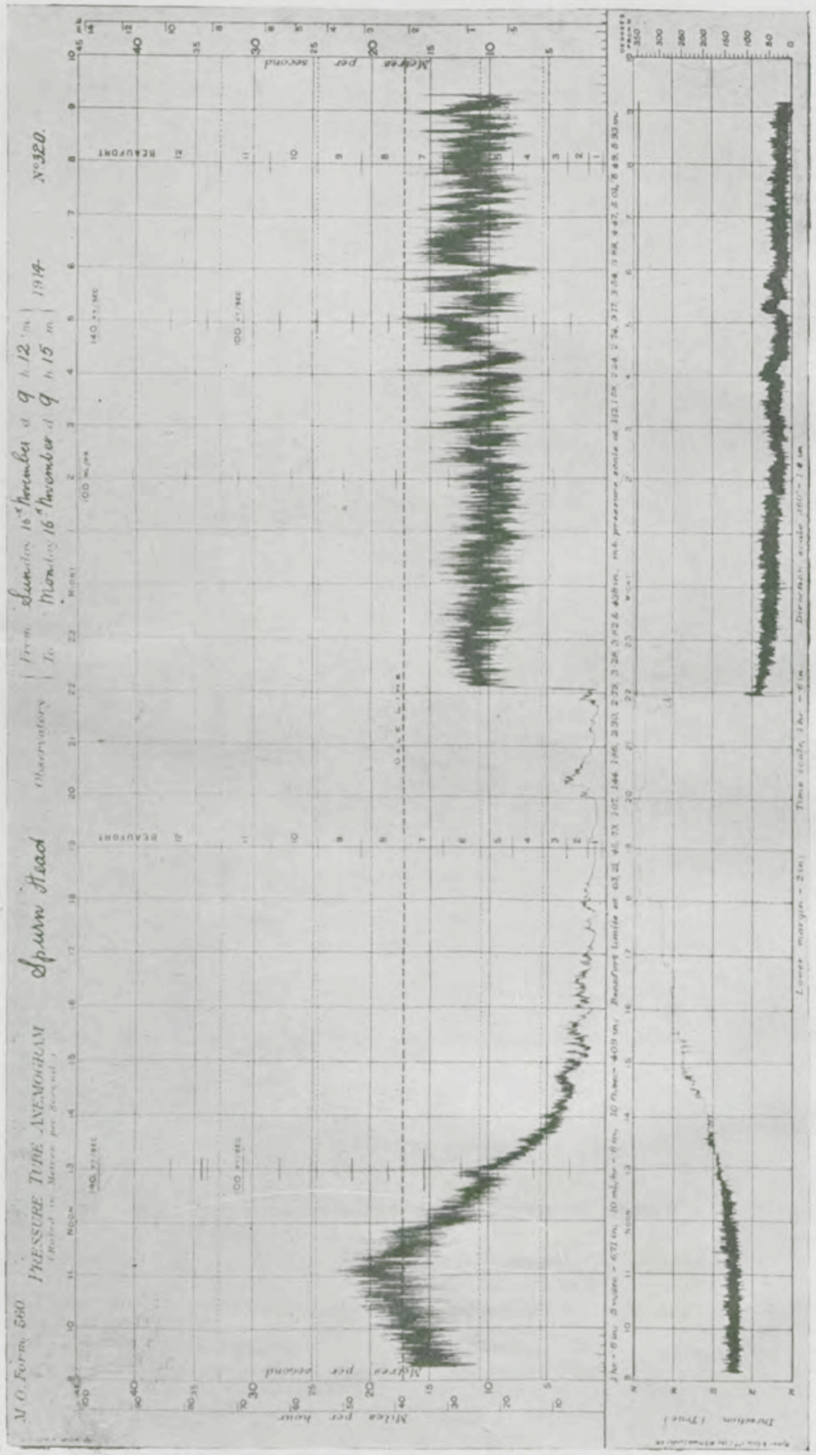
The Exposure of the pressure-tube-anemometer at the Aerological Observatory of the Meteorological Office at Benson, Oxfordshire.

There are trees in the immediate surroundings of the anemometer: the vane is, in consequence, carried at a height of 85 feet above the ground by a steel tube, supported on a steel tower 55 feet high. The tree close to the tower is about 35 feet high. In this way an excellent exposure is secured.

Experiments by Dr. Crombie, of Dyce, Aberdeenshire, with an anemometer projecting 15 feet above tree tops demonstrate a very gusty exposure.

To face page 9.

FIG. 3.



Record of the velocity and direction of the wind by the tube-anemometer at Spurn Head, 15-16 November, 1914.

the top, 9, 10, 11, Noon, 13, 14, and so on; for these purposes we number the hours consecutively from 0 (midnight) to 23 (11 p.m.). In order to read off the speed of the wind lines are drawn across the diagram and marked at either end for speeds of 5, 10, 15, 20 metres per second, and so on, with a scale of 10, 20, 30, etc., miles* per hour on the left-hand-side. The position of the pen at any moment indicates the speed of the wind on the scale and the ink of the trace is a permanent mark of where the pen was at any time. The appearance of the ribbon of the speed-trace shows that the wind is constantly varying up and down, over about 15 miles an hour to begin with, on either side of the middle line of the ribbon. That was when the mean speed was about 30 miles an hour at 9h.15m.; from that time it increased gradually until its mean velocity got over the "gale line" at 10h.15m. and remained there till 11h.30m., then it gradually fell off until it was less than 5 miles an hour at 16h. It remained light, and fluctuating slightly, until just after 22h., when the wind suddenly rose again to the line separating force 5 from force 6 of the Beaufort scale, and remained there for the rest of the record. The change of direction as indicated in the lower diagram is very noticeable. Beginning from SE., after the gale, it veered to South and West and nearly to North, then the new gale sprang up from the East, but settled down afterwards into North-east. The fluctuations of the trace show that while the speed was ranging with rapid alternations between twenty-five and forty miles an hour, the direction of the wind was altering by similarly rapid alternations over about four points of the compass, between SSE. and ESE. at the beginning of the trace, and between N. and NE. at the end of the trace reproduced in figure 3. The conclusions which can be drawn from this record are fully borne out by experience; the wind is never a perfectly steady blow, it is a perpetual succession of "gusts" and "lulls" with slight veerings and backings† this way and that. The ranging of the ordinary wind which is otherwise steady is indicated in the trace by the apparent width of the ribbon which the tracing-pen seems to be weaving. The gradually diminishing width of the ribbon shows that the range of gusts diminishes as the average speed of the wind falls off and this justifies us in thinking that the ordinary gustiness of the wind really represents the eddies set up by the travel of the wind over the surface. In this sense the gustiness of wind depends largely upon the exposure. A free exposure like that of the open sea means that the wind will be comparatively free from gusts of this kind, while an exposure over the tree-tops of a wood has proved on trial to give wind in the most gusty form within our experience. Even in the very best exposures there is a little gustiness in the wind, and observation has shown that gustiness reaches to great heights, even thousands of feet up, but

* Throughout this work "miles per hour," which is abbreviated by the symbol "m.p.h.," means statute miles per hour. The "knot" or nautical mile per hour is not used.

† The wind is said to "veer" when the vane turns in the same way as the hands of a clock move, and it is said "to back" when the vane turns in the opposite way. "Withershins" is an old word used for what is here called backing or moving against clock hands.

it gets less as the ground is left behind, so we are confirmed in our opinion that, to a large extent, the regular gustiness of wind is a matter of exposure and is due to the influence of the surface upon the free run of the wind.

8. Squalls.

But there is another form of variation of wind which has much more to do with the structure of the wind than the superficial gustiness. The period between ordinary gusts and lulls is only a few seconds, but there are changes, often much more extensive than ordinary gusts, which last with varying force for some minutes and are called squalls.* In the trace for the early hours of 16th November, 1914, shown in figure 3 a succession of squalls is shown. For example, just after 4h. the wind suddenly went up from force 5 to force 7, lasted at that, with an occasional gust up to the gale line, for about five minutes, and then slowly fell off again to force 5, the whole excursion of the pen having taken about half-an-hour.

That course of events was repeated three or four times before 9 o'clock, and on looking at the trace it will be found that, generally speaking, changes in direction and changes in speed go together; the squall is a different wind from that which it succeeds and that by which it is replaced.

What exactly the nature of these squalls is we can only surmise. They are changes which come on very suddenly; the sudden onset of the wind shown in the trace at 22h. is not to be called a squall, because when the new wind of force 6 was set up, it lasted for hours together. If it had lasted for five or ten minutes and then fallen off again we would have called it a squall, and we can find examples of squalls of that kind. They often bring in a thunderstorm.

So we must look upon the wind, not as a steady flowing river of air, but as a stream full of eddies constantly changing, and so always having some quality of gustiness, and also liable to occasional sudden and considerable changes both in the direction and force of the wind giving rise to what are well-known to sailors as squalls.

Special names are given by sailors to squalls of particular character such as Black Squall, White Squall, and meteorologists have recently paid a good deal of attention to a particular set of conditions accompanied by a notable squall called a Line Squall of which something will be said in a later chapter.

9. Hourly Run of the Wind and Gusts.

Thus when we are talking about the velocity or force of the wind we are thinking of something which is constantly varying,

* For the sake of clearness we have limited the use of the word "gust" to sudden increases of wind of very short duration, calling the more lasting increases "squalls," but in ordinary practice the word "gust" alone is sometimes used when we should speak of a "squall with accompanying gusts."

never the same from one second to the next. In order to deal at all with it in a general way it is customary to make an estimate of the average velocity or speed of the wind during an hour, so that, so far as we can judge, the gusts and lulls arrange themselves equally about the mean or average value. For that purpose we draw a line along the middle of the ribbon shown in Figure 3 as best we can, and take the average speed of the wind from hour to hour from this line. Thus in the trace which is shown the average speed of the wind between 10h. and 11h. is 40 miles an hour (force 8), during which the extreme force in a gust reached nearly to 50 miles an hour and the lowest of the lulls was well under 30 miles an hour; between 23h. and midnight the average speed was 25 miles an hour (just into force 6), during which a gust reached 34 miles an hour and in a lull the wind went down to 15 miles an hour, and so on. In this way we represent the wind of the day by estimates of the speed for each of the twenty-four hours, and with that object tabulate the records day by day. As a matter of fact we do not tabulate for the hours 10h. to 11h., 11h. to noon and so on, but for the hours 9h.30m. to 10h.30m., 10h.30m. to 11h.30m., and so on, in order that we may deal with intervals of an hour "centred" at the exact clock hours, but that is an unimportant detail of the method of tabulating; the important point is that in the tabulations we deal with the average wind for an hour, which certainly includes a succession of gusts and lulls and may include squalls, as it did between 4h. and 5h. in the trace of Figure 3.

The practice of tabulating in this way has arisen from the fact that the recording anemometers which were established by the Meteorological Office at six new observatories in 1867 were "Cup-anemometers" of the form originally devised by Dr. Robinson of Armagh, which are still known by his name. They do not show the rapid alternations of the gusts and lulls and give only slight indications of the squalls, but they make it very easy to get the "run of the wind" in an hour and so in a day. The "tube-anemometer" which gives so detailed a picture of the structure of the wind was only introduced at the end of the nineteenth century.

It is important that this point should be clearly understood by practical sailors, because the equivalents in miles per hour of the numbers of Admiral Beaufort's scale refer to the *average velocity for the hour* and may be misleading unless the seaman understands that when we say, for example, that a wind of force 7 on the Beaufort scale (less than a gale) has a velocity of 35 miles an hour, or within three miles an hour on either side of it, we mean something of which the average for the hour is within those limits but which is made up of lulls and gusts ranging between 25 miles an hour and 45 miles an hour, and therefore producing as the thrust on a square foot of board exposed to it anything between 2 lbs. and over 6 lbs. with a mean value of rather less than 4 lbs. In circumstances which are perhaps rare, but not very rare, still higher velocities and thrusts in squalls might be expected although the wind is not properly classed as a gale. In other words it must be remembered that gusts and squalls of gale-force, and even strong-gale-force or more, may occur with winds which have not on the average of an hour the velocity corresponding with gale-force.

In illustration of this point I have had table A, p. 14, made from the figures given in the annual summary of the Monthly Weather Report of the Meteorological Office of all the occasions since 1899 on which gusts of hurricane force, force 12 on the Beaufort Scale, or above 75 miles per hour, have been recorded on the anemometers of which the Meteorological Office has records. I have set against them, where possible, the average velocity for the hours in which the minimum gusts occurred. In the table an asterisk (*) marks the occasions on which force 11 has been reached *according to the average for an hour.* It will be seen that in the majority of cases the hurricane gusts came with hourly-winds of less than force 11, and in one or two instances, Roches Point, December 18, 1911, Pendennis, December 2 and Paisley, December 3, 1914, when there was no gale according to the technical definition. This table will give an idea of the frequency of occurrence of gusts of hurricane-force and of winds of storm-force at well-exposed stations like Holyhead and Southport on the Irish Sea, Quilty on the Atlantic Coast, Scilly and Pendennis Castle at the mouth of the English Channel and along the East Coast, but it must not be taken as final evidence of the frequency of occurrence of such winds over the open sea because the record is largely dependent on the exposure.

It has often been remarked that Admiral Beaufort's scale of 12 numbers is more detailed than the ordinary sailor can deal with and that a scale of fewer numbers would be more appropriate in these days. The desired result can be arrived at by grouping the numbers, as is done in the books of instruction to observers at sea issued by the Meteorological Office as shown in the following table.

Beaufort Number.	Description.	Method of Estimating aboard Sailing Vessels.
1, 2, 3 ...	Light breeze	Sufficient wind for working ship.
4, 5 ...	Moderate breeze ...	Forces most advantageous for sailing with all sail drawing.
6, 7 ...	Strong wind	Reduction of sail necessary with leading wind.
8, 9 ...	Gale forces	Considerable reduction of sail necessary even with wind quartering.
10, 11 ...	Storm forces	Close reefed sail running, or hove-to under storm sail.
12 ...	Hurricane	No sail can withstand even when running.

TABLE A.

TABLE OF GUSTS OF HURRICANE-FORCE AND WINDS OF STORM-FORCE RECORDED ON METEOROLOGICAL OFFICE ANEMOMETERS SINCE 1899.

The date after the name of each station gives the year from which the records run.

——	Date.	Velocity of hurricane gust.	Average velocity of the hour including the gust.
		m.p.h.	m.p.h.
Holyhead ... ... (1895)	1899 Jan. 2	94	84
	1905 Mar. 15	84	—
	1906 Dec. 5–6	79	55
	1913 Feb. 7	77	52
	Dec. 4	77	52
	1914 Mar. 14	76	45
	Dec. 3	77	46
	Dec. 4	86	56
	1916 Jan. 1	77	51
	Feb. 16	86	56
	Oct. 30	80	51
Kingstown ... ... (1900)	1903 Feb. 26–7	—	66*
Dwyran (Anglesey) ... (1910)	1913 Feb. 7	79	55
	Mar. 6	76	—
Scilly ... ... (1896)	1900 Dec. 28	90	61
	1903 Sept. 10–11	—	64*
	1904 Feb. 12–3	77	65*
	1906 Jan. 6	81	59
	Jan. 18	76	55
	Dec. 5–6	85	62
	1909 Jan. 16	78	55
	Oct. 23	90	70*
	1910 Jan. 24	80	57
	1912 Dec. 26	88	65*
	1914 Mar. 14	78	54
	Dec. 4	87	46
	1916 Feb. 15	76	53
Plymouth ... ... (1908)	1912 Dec. 26	82	50
	1914 Dec. 3–4	79	53
	1916 Nov. 5	79	58
Quilty (Co. Clare) ... (1911)	1911 Dec. 4–5	78	55
	1912 Dec. 24	88	62
	1913 Feb. 7	80	56
	1914 Nov. 13	80	39

* Signifies that the average for the hour reached force 11 (Beaufort).

Note.—M.p.h. is an abbreviation for statute miles per hour, the abbreviation which is used at the Meteorological Office is mi/hr and m/s is the abbreviation of metres per second.

Distinction must be drawn between statute miles per hour (m.p.h.) and knots, the accepted name for nautical miles per hour.

TABLE A.—*continued.*

TABLE OF GUSTS OF HURRICANE-FORCE AND WINDS OF STORM-FORCE—*continued.*

—	Date.			Velocity of hurricane gust.	Average velocity of the hour including the gust.
				m.p.h.	m.p.h.
Quilty—*cont.*	1914	Dec.	4	92	63
	1916	Feb.	16	78	49
		Oct.	25	79	53
Roches Point, Cork Harbour (R.) or Weaver Point (W.) (1903) R. W.	1911	Dec.	18	88	33
	1914	Nov.	11	79	60
	1916	Jan.	1	80	59
		Oct.	27	80	49
		Nov.	3	78	50
		Nov.	17	76	47
Fleetwood ... ... (1886)	1899	Jan.	12	—	75*
	1909	Dec.	3	—	66*
Southport ... ... (1899)	1899	Jan.	12	90	—
	1907	Mar.	16–17	81	60
	1909	Dec	3	76	58
	1910	Feb.	17	76	55
		Feb.	21	85	63
	1911	Nov.	5	80	57
	1913	Feb.	7–8	86	62
		Mar.	18	77	47
		Nov.	15	79	45
		Dec.	3	82	56
	1914	Sept.	14	90	65*
		Dec.	4	88	62
	1916	Jan.	1	85	59
		Feb.	16	79	57
		Oct.	30	81	56
Pendennis Castle, Falmouth (1902)	1905	Mar.	14	103	—
	1906	Jan.	6	85	65*
	1908	Aug.	31	78	58
	1910	Feb.	18–9	87	60
		Feb.	20–1	82	62
		Dec.	16	85	63
	1911	Dec.	6–7	79	64
		Dec.	10	77	53
		Dec.	13	77	61
	1912	Mar.	4	98	64*
		Mar.	5	78	...
		Mar.	21	77	...
		Nov.	26	83	66*
		Dec.	26	98	70*
	1914	Feb.	10–1	77	60
		Feb.	12	86	47
		Feb.	21–22	78	63
		Mar.	14	79	58
		Dec.	2	82	28
		Dec.	3–4	89	63
		Dec.	30	76	61

* Signifies that the average for the hour reached force 11 (Beaufort).

TABLE A.—*continued.*

TABLE OF GUSTS OF HURRICANE-FORCE AND WINDS OF STORM-FORCE—*continued.*

—	Date.			Velocity of hurricane gust.	Average velocity of the hour including the gust.
				m.p.h.	m.p.h.
Pendennis Castle—*cont.*	1916	Jan.	1	80	59
		Feb.	14	77	61
		Feb.	15	80	61
		Feb.	16	80	53
		Oct.	24	81	55
		Oct.	27	91	60
		Nov.	3	78	58
Aberdeen ... ... (1907)	1913	Feb.	8	77	51
Rosyth ... ... (1911)	1912	Nov.	26	85	54
		Dec.	24	81	48
	1914	Jan.	31	76	43
South Shields ... (1909)	1911	Nov.	5	78	50
	1912	April	8	81	53
Shoeburyness ... (1902)	1914	Dec.	28	76	49
Eskdalemuir, Dumfriesshire (1910)	1911	Nov.	5	90	62
	1912	April	8	78	52
		Dec.	24	78	52
	1913	Feb.	8	82	47
	1916	Feb.	16	76	55
Spurnhead ... ... (1913)	1914	Mar.	6	78	49
Gorleston ... ... (1908)	1916	Mar.	28	76	54
Dover ... ... (1907)	1914	Dec.	28	80	49
	1916	Mar.	28	85	50
Edinburgh ... ... (1915)	1916	Oct.	14	80	47
Paisley ... ... (1914)	1914	Dec.	3	77	35

Besides these we have a note of an average wind of 65 miles per hour on Feb. 26-27, 1903, at Liverpool Observatory (Bidston) with a gust of 88 miles an hour; and, in the same gale, a gust at Blackpool of 87 miles per hour.

10. The Lull of Wind at Night.

One of the most striking features of the records of wind at land stations is the lull of wind that generally takes place after sunset and lasts until after sunrise. It is noticeable both in summer and winter, but more especially in summer. If we look at a table of averages for the wind at Richmond (Kew Observatory), for example, we find that in July the average velocity of the wind rises from 1·8m/s at 5 o'clock in the morning to more than 4·2m/s at 2 o'clock in the afternoon, and then rapidly lapses to 2·5m/s at 7 o'clock in the evening, and slowly falls again to the 5 o'clock value. In January the effect is less marked, but it can still be observed; the rise begins at 8 o'clock in the morning from the value 3·3 maintained since midnight to 4·3 at 2 o'clock during the middle day, *i.e.*, from 12 noon to 2 o'clock, and then gradually falls away again to the midnight value.

This effect is not to be found on the open sea far away from land. Still less is it to be found on mountain tops or in such a position as the top of the Eiffel Tower in Paris. There, there is more wind in the night than in the day. It is attributed to the cooling of the surface layers in consequence of the loss of heat from the surface after the power of the sun is gone. By the operation of this cause the surface air becomes heavier and valleys and plains are filled with cold air that cannot easily be churned up by the main stream of air going over it. On the other hand, in the daytime, especially in summer, the surface layer of air gets warmed as it passes over or lies upon the ground, because the ground itself gets heated by the sun, so the surface air is easily carried upward either by the buoyancy which it gets from its own warmth or by its lack of resistance to the churning effect of the main current of air above. If there is much wind in the main current the resistance which the surface air offers to being churned up is overcome and a windy night is the result.

So accustomed are people who live inland to the dropping of the wind at night that the noise of wind is uncanny and disturbing if it goes on to the night or morning hours. Tennyson was not unmindful of this when he wrote in Gareth and Lynette:—

"When wakened by the wind which with full force
"Swept bellowing thro' the darkness on to dawn."

The habit of lulling at night is shown by the wind not only on land and in harbours, but for some distance out to sea. How far out it extends is not exactly known. There might be no difficulty in getting the information for the North Sea, the Irish Sea, the English Channel, and the seas to the west of Scotland, because mail steamers cross these seas every night, and there is opportunity for observations of wind and weather which would be of great interest. But no scheme of observations has yet been organised for cross-Channel steamers. We have stations on land and observing ships over the oceans, and there is really no reason why the weather at night in the four seas should not be as fully explored as the weather on land.

CHAPTER II.

THE WINDS EXPERIENCED ON THE BRITISH COASTS.

1. Observations of Wind.

There is a passage in "the words of the Preacher" which seems very discouraging to the study of weather as applied to farming and fruit-growing. "He that observeth the wind shall not sow and he that regardeth the clouds shall not reap. In the morning sow thy seed and in the evening withhold not thy hand for thou knowest not whether shall prosper this or that." Whatever lesson King Solomon may have intended to convey by this warning to the landsman, no one would ever think of extending it to the sailor. At sea no one has any doubt about the wisdom of observing the winds or the profit of regarding the clouds. The first step in the meteorology of the sea is to obtain a record of the direction and force of the wind; and a knowledge of the forms and grouping of clouds and their meaning is one of the surest ways for a seaman to guard himself against unpleasant surprises by the weather.

The direction of the wind is specified by the point of the compass from whence it comes. Thus a West wind comes *from* the West, a North wind *from* the North. It must be remembered in this, as in many other connexions, that the compass, in its original meaning, is the divided circle which by the aid of a magnetic needle can be placed in the proper position for naming the point from which the wind comes. The use of the compass-needle is to set the compass card and it must not be forgotten that the compass-needle does not point true North, but 15° West of North at all parts of the East and South-east Coast of England, 21° West of North in the Hebrides and the North-West of Ireland, 18° along a line from the Shetlands along the East Aberdeen coast of Scotland, the Cumberland coast, Anglesey and the Pembroke coast. Elsewhere the variation of the compass, as it is called, is intermediate between the values named.

It is better always to give the winds according to *true* compass bearings, not according to *magnetic* bearings. The force of the wind is given according to estimates on the Beaufort Scale, an account of which is given on p. 3. The proper estimation of the force of the wind on a ship at sea requires long practice and experience, because the observation is complicated with the motion of the vessel. In the days of sailing ships, when the wind was the power that moved the ship, there was no great difficulty in forming a good estimate of the force of the wind—everything on the ship depended upon it, the speed she made, the amount of sail she could carry, the heel of the ship; anyone on board need hardly go on deck to know where the wind was coming from, and how much there was of it; but in these days of fast steamers, the estimation of wind is quite a different matter. By long practice sailors learn instinctively to make allowance for the way of the ship and give accurate estimations of wind without being able to say precisely how they do it.

Estimates of the direction and force of the wind are recorded in the log books of all ocean-going vessels and at many coast stations as well. These records form the public memory of many men's experiences of wind on the coasts of the British Isles, over the surrounding seas and elsewhere.

2. The Compilation of Observations: Exposure.

Our next task is to find out how the records, or a selection of them, can be grouped and arranged so that useful information can be obtained from them as to the kind of experience that may be expected in any particular locality. Here we meet with a great difficulty; the wind on shore or close thereto is a different thing from what would be experienced in similar conditions far out to sea. It is affected both directly and indirectly by the shape of the ground in the neighbourhood, by the screening which is due to the shore or even to distant hills. People sometimes think that a difficulty of this kind could be easily overcome by having an instrument to measure the wind, which we call an anemometer, instead of letting a man estimate it by the Beaufort Scale. That is far from being the case, because the reading of an anemometer depends very much upon where you put it. In a street it is obviously of no use at all, on the top of a building its reading depends upon how high above the roof you put it—the higher up the more wind for some considerable distance beyond the height that any scaffolding or structure to carry an anemometer could reach. Anemometers are useful indicators of the velocity or force of the wind if they can be exposed at a reasonable height, forty or fifty feet above an open flat shore. There is an admirable exposure for an anemometer on the shore near Southport, another on Salt Island, Holyhead, another at Fleetwood, another at Deerness, in the Orkney Isles, another at Spurn Head, a sixth, of a different character, on the tower of Pendennis Castle, Falmouth, which itself crowns a conical hill, another at St. Mary's, Scilly, but the exposure of other anemometers leaves much to be desired. The records that come from Valencia Observatory, for example, would give the impression that the South West corner of Ireland belonged to the calmer regions of the British Isles, where gales were rare, yet the Observatory was actually placed there in 1868 for the purpose of providing means for the study of the weather of the boisterous Atlantic. It is the comparatively sheltered exposure of the anemometer, not the lack of windy weather, that accounts for the relatively calm record of the Observatory, and that must be allowed for when the records are being considered.

Then, further, the particular situation of a sea-front may affect the direction of the winds that are experienced in its immediate locality. The winds of Leith, for example, are generally from East or West and, relatively, not very strong; and the winds at Dover and Dungeness group themselves about South-West, with a subsidiary group about North in one case and North-East in the other, those being the open directions. These things ought

to be remembered when a ship is starting from a sheltered port. Leith is mentioned particularly because the fact that the wind was only force 4 there on a certain occasion was put forward to excuse the loss of a ship that found, to its cost, a North-easter of force 9 off the North-east coast of England.

So we must take the records of the winds for each separate station as we find them, and look out for the differences between different ports so that the prudent seaman may be on his guard to prevent his being surprised by the wind in the open when he puts to sea.

3. Gales On or Near the Coasts.

Table B.—Mean Number of Gales recorded in each month on various Sections of the British and Irish coasts during the 40 years 1876-1915.

Coasts.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	The year.
Scotland— NorthEast	0·3	0·7	1·7	3·4	4·7	5·3	5·4	3·9	3·7	1·9	1·1	0·4	32·4
East ...	0·4	0·5	1·4	2·6	3·4	2·9	3·5	2·5	2·9	1·1	0·7	0·4	22·3
North West	0·5	0·7	2·0	2·8	4·6	5·0	5·0	3·9	3·0	1·5	1·0	0·4	30·3
West ...	0·3	0·9	1·7	2·9	4·0	4·2	4·1	3·4	2·5	1·3	0·7	0·4	26·3
Ireland— North West	1·0	1·3	2·7	4·2	5·6	6·4	6·5	4·6	4·1	2·3	1·2	0·8	40·5
South West	0·5	1·4	1·9	3·4	4·8	5·9	5·7	4·9	3·9	2·0	1·2	0·5	36·1
Irish Sea ...	0·7	1·3	2.0	3·6	5·0	5·6	5·0	4·2	4·3	1·9	1·0	0·7	35·3
St. George's Channel	0·4	1·0	1·5	3·4	4·5	5·3	4·6	3·6	3·4	1·4	0·8	0·4	30·1
Bristol Channel	0·7	1·7	2·1	4·4	5·2	6·3	5·2	4·7	3·6	2·0	0·9	0·7	37·6
England— South West	0·5	1·3	1·3	3·5	4·7	5·6	4·4	4·2	3·5	1·6	1·1	0·4	32·0
South ...	0·6	1·4	1·2	3·1	4·0	4·4	3·5	3·1	2·4	1 1	0·6	0·3	25·5
South East	0·4	1·0	1·0	2·8	3·7	4·1	3·0	2·4	2·1	0·9	0·5	0·2	21·9
East ...	0·2	0·6	0·7	2·3	3·0	3·0	2·4	2·2	1·8	1·0	0·5	0·2	17·9
North East	0·4	0·5	1·3	2·7	3·1	4·0	3·7	3·0	3·1	1·2	0·7	0·4	24·0
Mean for British Islands generally.	0·5	1·0	1·6	3·2	4·3	4·9	4·4	3·6	3·2	1·5	0·9	0·4	29·4

TABLE C.—ODDS AGAINST THE OCCURRENCE OF A GALE ON ANY SECTION OF THE BRITISH AND IRISH COASTS on any day in the various months of the year.

Based upon records extending over the 40 years 1876–1915.

(The figures represent in each case the "odds against one.")

COASTS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Scotland—													
North East	5	6	7	15	27	74	102	43	17	8	5	5	10
East	8	10	10	26	43	74	77	61	20	11	8	10	15
North West	5	6	9	19	30	74	61	43	14	10	6	5	11
West	7	7	11	22	43	74	102	33	17	10	7	6	13
Ireland—													
North West	4	5	6	12	25	37	30	23	10	6	4	4	8
South West	4	5	7	14	25	59	61	21	15	8	5	4	9
Irish Sea ...	5	6	6	15	39	42	43	23	14	8	5	5	9
St. George's Channel	6	7	8	20	38	74	77	30	19	8	6	5	11
Bristol Channel	5	5	8	14	33	42	43	17	13	6	5	4	9
England—													
South West	6	6	8	18	27	74	61	23	22	8	5	5	10
South ...	8	8	12	26	51	99	51	21	24	9	7	6	13
South East	9	11	14	32	61	149	77	30	29	10	7	7	16
East ...	12	12	16	29	61	149	154	51	42	12	9	9	19
North East	7	8	9	24	43	74	77	61	22	10	9	7	14

The "favourite" day is 28th January in Ireland, N.W., the odds about which are just 21 to 19 against, or nearly even.

If we want to know about the frequency of gales on the coasts we must inquire of those who are stationed in very exposed situations like lighthouses and lightships. It has been the practice of the Meteorological Office to extract information about

winds from the official logs of lightships and lighthouses for the purpose of confronting the actual records of gales experienced with the warnings of gales anticipated, which have been issued to mariners by means of signal cones hoisted at the gale-warning* stations on the Coasts. This comparison has been carried on with unfailing regularity for more than forty years, and we can therefore summarise the experience of many competent observers of the frequency with which gales have been found to occur in the various districts into which the coastlines of our Islands are divided for the purpose of gale-warnings.

The average monthly frequency of gales, that is the mean number of gales per month recorded on various sections of the coast during the 40 years 1876 to 1915, is given in Table B, which gives the mean *number of gales* in tenths or "decimals of a gale." Some readers may find this mode of expression difficult to understand and the same information has accordingly been set out in Table C in the form of the *Odds against a Gale* on any day in the successive months of the year. It will be seen that the odds are as high as 154 to 1 against a gale on the East Coast in July, but only 4 to 1 against a gale on the North-West Coast of Ireland in November, December and January, and on the South-West Coast of Ireland in December and January, and in St. George's Channel in December.

4. SUMMARY OF GALES.

(See inset between pp. viii and 1.)

Further particulars about the incidence of gales are given in a special summary of gales experienced in the several districts of the British and Irish Coasts in the 40 years 1876-1915. The division of the coast into fourteen districts is shown on a map on Plate V. of the summary; and diagrams have been prepared to show the frequency of occurrence of gales on each day of the year in each of the fourteen districts. The inquiry has shown that of these districts the North-West Coast of Ireland is the "stormiest" and the East Coast of England the least stormy. The diagrams for those two districts are reproduced in the summary as specimens of the information which is available at the office for all the districts. Information as to gales in each of the districts is given in one set of maps which show the average frequency of gales in the several districts in each month of the year and in the whole year, and another set which show by means of "roses" the sorting of the gales according to the directions from which they blew. An explanation of the diagrams and maps is given in p. vi. of the summary.

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* Warnings of anticipated gales, signalled by cones at selected "storm-warning stations" on the coasts, have been called "storm-warnings" for many years, but the title is inappropriate because a storm is a gale of quite exceptional severity and since 1870 the issue of a warning has meant that a *gale* was anticipated, not necessarily a *storm*. The official title in use at the Meteorological Office is now "gale-warning" because that gives a correct indication of what is meant by the hoisting of the cone. But the habit of using the term "storm-warning" has been so familiar that it will take some time for the more accurate designation to become common.

5. Winds at Coast Stations.

In the consideration of the winds of our coasts, gales are naturally the most important feature and therefore special attention has been paid to them. We shall now endeavour to represent the experience of observers at a considerable number of points on the coasts with reference not only to gales but also to moderate winds, light winds and calms.

In dealing with gales we have purposely included the information which has been obtained from lightships because we did not wish the question of the occurrence of gales to be complicated by the shelter of harbours or anchorages, but in considering the winds, such as those which a seaman will notice for himself in an anchorage, it is important to bear in mind that the surrounding land has a considerable effect, which is very easily seen when we compare the records of observations from a number of points on the shore. Moreover in dealing with gales we have taken advantage of the fact that gales are noted at the observing stations of the Meteorological Office and at the lightships and lighthouses whenever they occur, but winds of less strength are only noted at fixed hours.

If we consider the wind from a general point of view and think of it as a great current of air sweeping over the country, we shall not expect the winds at different points on the coasts of so small an area as that of the British Isles to show any really noteworthy differences; and in a later chapter, by referring the general wind to the run of the isobars on maps of the general distribution of pressure, we shall show that this general point of view is a proper one. As the net result of the work of an average month the winds of the British Isles carry a vast quantity of air across the country, generally from WSW. with some slight variation in the course of the year. People sometimes think that one place may have Easterly winds as its own speciality, whereas another, not a hundred miles away, may be free from that kind of visitation. In one sense it is true. One place may be specially exposed to Easterly winds and feel the full force of them when they occur, whereas another, not far away, may be sheltered from the effects of wind from that quarter. And the shape of the land in the neighbourhood may be such that the general drift of the wind in a particular locality is diverted like a stream of water by its banks, or like the backwater of an eddy at a turn in the bank. But what we understand by an East wind does not really change its character by being turned round in an eddy at a street-corner, and in like manner we must regard the special characteristics of the wind at a point of the coast more as a matter of the "exposure" of the observing station than of the wind in the more general sense in which a seaman has to think of it.

Local eddies, which in exaggerated cases are represented by water-spouts, are formed sometimes even in the free air over the sea, and they may cause very violent winds which are quite local, but we know of no particular parts of the British seas

which are specially liable to such visitations. Anchorages which are at the foot of steep mountain slopes are liable to local squalls which come down the slopes and gulleys. About these we have no special information; none of the places selected for the observations which are reported daily to the Office are in localities of that kind, partly because care is taken to get stations with as free an exposure as possible, and they are therefore not suited for recording such local peculiarities.

6. The Observing Stations.

The stations of the Meteorological Office report daily by telegraph observations made simultaneously at all the stations at 7 o'clock in the morning and 6 o'clock in the evening, and when received the observations are all plotted on a map and in that way compared and examined. The stations are mostly on exposed shores, so that the observations form an exceptionally good body of material upon which to base a table of particulars about winds on the British coasts. The particulars received during the five years 1911 to 1915 have recently been arranged at the Meteorological Office with the assistance of two voluntary workers, Mr. Cecil Broadbent and Mr. R. Nahon, and the results afford a very good idea of the general habit of the wind and its local variations on the coasts. The observations from twenty-four stations have been tabulated. The stations are as follows, beginning with the shores of the Irish Sea:—For Liverpool, the Observatory of the Mersey Docks and Harbour Board at Bidston, near Birkenhead; Holyhead, at the Sailors' Home or on Salt Island; Donaghadee, at the Coastguard Station; further South, for Pembroke, the Lighthouse on St. Ann's Head. Then, taking the outer circle beginning with the Coastguard Station at St. Mary's, Scilly, we have the Railway Station at St. Aubin's, Jersey; the Lighthouse at Portland Bill; the Lighthouse at Dungeness; the Meteorological Station of the Corporation of Dover; the Municipal Meteorological Station of Clacton; the Naval Air Station at Yarmouth; the Lighthouse at Spurn Head; the Coastguard Station at Tynemouth (but for the larger part of the time the Post Office at North Shields); a station on the links of Leith; the Observatory at King's College, Aberdeen; the Coastguard Station at Wick; the Anemometer Station at Deerness, Orkney; the Coastguard Station at Lerwick, Shetland; a private garden at Stornoway, in the Western Hebrides; the Schoolhoue at Castlebay, near the southern point of those islands; the Coastguard Station at Malin Head; the Coastguard Station at Blacksod Point; the Valencia Observatory, which is at Cahirciveen, County Kerry, and the Post Office at Roche's Point, Cork Harbour.

Most of these have a very free exposure, especially Pembroke, (St. Ann's Head), Scilly, Portland, Dungeness, Spurn Head, Wick, Deerness and Malin Head. The exceptions are Dover, which is on the Strait; Leith, which is on the land-locked Firth of Forth; Aberdeen, which is in the old town; and Valencia, which is at the mouth of a glen, with Valencia Island in front of it. We shall notice that these peculiarities of exposure are represented in an interesting way in the results. Although to anyone visiting the stations the specially exposed character of some of the sites is quite striking, it may be noted that the numbers of calms shown at exposed stations are not conspicuously small. In fact, they are larger in the aggregate than those at the stations not so mentioned (with the exception of the four specially referred to as protected). The proportion of the totals of calms is roughly five to four.

7. The Observations Summarised.

For each station there are 3652 observations to be accounted for and represented. The observers are instructed to note the wind-direction according to the 16 points N., NNE., NE., and so on, round to NNW., and the force according to the 12 numbers of the Beaufort Scale. Also winds are different at different times of the year, and the month is the most convenient division of the year for exhibiting the difference. So the first stage of the process of making a summary of the experiences of the winds of the British coasts is to sort the observations at each station for each month, varying in number from 282 to 310 according as the month is February or one of the others, into 192 compartments, or 193 when we include calms, one for each force and each point of direction. The 16 compartments corresponding with force 12 are all blank because hurricane forces were not noted among the observations at the hours specified at any one of the stations in the five years. Many of the other compartments are also blank because very few 9's and 10's, and only four 11's occur. Most of the gales are 8's. There are quite a considerable number of 7's, but the large majority of the forces recorded are 3's, 4's and 5's.

For each station there are twelve of these tables which, if reproduced, would require a large part of a book to themselves. So the next step is to consolidate the multiplicity of figures by collecting all the months into a single table for the five years for each station. Of these we shall give examples by quoting the figures for Liverpool, a sort of central point of the British Seas; Scilly at the mouth of the English Channel; Jersey on the south side of it; Portland on the mainland near the middle of it; Dungeness at the entrance to the Straits of Dover, and Dover itself at the narrowest portion; Spurn Head, the best exposed station on the East Coast; Lerwick in the extreme north; Malin Head on the north-west of Ireland, fully exposed to the winds of the Atlantic; and Valencia in a comparatively sheltered situation in the south-west of Ireland.

Number of observations of winds of various strengths from the following directions in the five years 1911–15.

LIVERPOOL.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	44	44
1	68	55	46	40	42	60	105	75	52	49	55	70	73	117	77	53	—	1037
2	17	27	37	34	63	92	144	62	42	47	77	68	65	81	29	19	—	904
3	17	12	27	43	56	75	105	26	20	32	70	62	71	74	22	15	—	727
4	3	1	11	32	33	38	32	14	11	21	55	49	82	32	14	10	—	438
5	2	2	2	9	12	17	6	1	3	12	28	48	60	23	13	—	—	238
6	2	—	2	6	6	7	1	—	—	4	23	62	41	12	4	1	—	171
7	—	—	—	1	1	—	—	—	—	1	7	37	25	4	—	—	—	76
8	—	—	—	—	—	—	—	—	—	—	3	6	3	—	—	—	—	12
9	—	—	—	—	—	—	—	—	—	—	1	2	2	—	—	—	—	5
10																		
11																		
12																		
Total ... (16 points)	109	97	125	165	213	289	393	178	128	166	319	404	422	343	159	98	44	3652

SCILLY.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	129	129
1	13	19	21	17	19	17	24	10	18	6	12	9	22	27	22	20	—	276
2	30	55	52	39	37	31	35	16	23	18	30	25	46	38	43	25	—	543
3	45	36	45	32	44	30	27	37	36	33	43	37	49	59	44	26	—	623
4	40	35	23	25	79	51	28	42	56	52	70	68	94	75	65	27	—	830
5	26	22	14	12	36	37	23	33	48	40	41	62	78	60	63	19	—	614
6	12	3	15	8	18	21	14	15	23	25	24	38	57	65	46	17	—	401
7	4	2	—	—	7	4	5	3	4	4	5	16	32	38	24	6	—	154
8	1	2	1	—	1	2	1	1	5	2	1	—	20	16	12	3	—	68
9	—	—	—	—	—	—	—	—	—	—	1	4	2	2	2	1	—	12
10	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	2
11																		
12																		
Total ... (16 points)	172	174	171	133	241	193	157	157	213	180	227	259	400	381	321	144	129	3652

Number of observations of winds of various strengths from the following directions in the five years 1911–15.

JERSEY.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	11
1	15	3	23	6	23	6	6	2	6	1	7	4	8	1	9	4	—	124
2	44	18	57	32	86	36	33	23	29	16	41	24	60	45	61	30	—	635
3	77	27	105	74	87	37	52	54	72	78	162	90	214	164	127	38	—	1458
4	6	16	82	73	56	24	32	43	61	48	113	85	137	49	24	8	—	857
5	3	4	38	36	25	12	10	13	14	21	57	60	65	23	6	3	—	390
6	1	1	16	9	7	2	5	3	5	1	16	27	34	9	5	1	—	142
7	2	—	2	1	1	—	1	—	2	1	3	7	6	2	1	—	—	29
8	—	—	—	—	—	—	—	1	—	—	1	4	—	—		—	—	6
9																		
10																		
11																		
12																		
Totals ... (16 points)	148	69	323	231	285	117	139	139	189	166	400	301	524	293	233	84	11	3652

PORTLAND.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	96	96
1	27	15	36	25	30	13	6	10	8	10	18	18	37	29	26	22	—	330
2	28	36	47	39	29	16	26	13	16	16	19	40	35	35	44	20	—	459
3	29	34	62	47	47	17	16	26	25	23	69	78	62	50	65	39	—	689
4	25	34	81	56	37	18	26	21	36	37	65	114	81	51	57	23	—	762
5	14	26	79	45	29	12	14	32	25	39	100	140	75	66	39	16	—	751
6	1	10	17	20	21	11	10	6	13	31	53	67	36	31	15	1	—	343
7	—	4	4	7	3	1	1	4	10	12	33	26	14	7	5	1	—	132
8	—	3	—	1	4	—	1	3	8	13	12	10	17	4	1	1	—	78
9	—	—	—	—	—	—	1	—	—	2	3	3	3	—	—	—	—	12
10																		
11																		
12																		
Totals ... (16 points)	124	162	326	240	200	88	101	115	141	183	372	496	360	273	252	123	96	3652

Number of observations of winds of various strengths from the following directions in the five years 1911–15.

DUNGENESS.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	59	59
1	26	17	16	8	19	11	15	8	19	9	21	5	23	11	29	11	—	248
2	56	35	46	25	35	10	16	7	39	30	92	33	57	33	94	55	—	663
3	67	47	98	50	64	30	23	30	55	47	161	74	73	39	67	35	—	950
4	24	39	102	48	40	10	25	23	37	49	179	88	51	22	18	20	—	775
5	7	34	75	28	13	11	10	13	29	52	151	69	29	14	15	10	—	560
6	4	6	19	8	3	—	2	4	12	21	75	28	9	7	5	—	—	203
7	4	6	18	3	2	—	7	3	9	17	45	8	2	1	2	—	—	127
8	1	1	3	1	—	—	—	1	3	9	21	6	—	—	1	—	—	47
9	1	—	—	—	1	—	—	—	2	5	4	2	—	—	—	—	—	15
10	—	—	—	—	—	—	—	—	—	2	3	—	—	—	—	—	—	5
11																		
12																		
Totals (16 points)	180	185	377	171	177	72	98	89	205	241	752	313	244	127	231	131	59	3652
Adjusted Totals (8 points)	297		618		278		153		317		1177		386		367			

DOVER.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	181	181
1	30	20	43	6	16	8	36	19	27	26	98	24	43	17	77	13	—	503
2	26	23	42	7	20	15	31	17	37	34	112	20	59	9	78	9	—	539
3	43	28	65	15	26	10	22	14	30	41	192	34	45	22	97	20	—	704
4	63	59	90	8	24	8	19	15	32	53	220	50	41	19	117	20	—	838
5	48	39	42	4	12	3	6	6	24	43	154	25	12	5	35	20	—	478
6	36	27	23	2	7	—	3	4	25	45	86	9	5	3	22	8	—	305
7	5	6	4	1	—	—	1	2	3	17	14	4	—	1	3	2	—	63
8	—	—	2	1	—	—	—	—	5	8	11	2	1	—	—	1	—	31
9	2	—	1	—	—	—	—	—	—	1	1	—	—	1	1	1	—	8
10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
11	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
12																		
Totals (16 points)	253	203	312	44	105	44	118	77	183	268	888	168	206	77	431	94	181	3652
Adjusted Totals (8 points)	379		457		137		171		276		1246		257		548			

Number of observations of winds of various strengths from the following directions in the five years 1911–15.

SPURN HEAD.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	52	52
1	11	7	3	7	4	13	3	4	13	5	9	13	13	9	10	3	—	127
2	19	17	9	18	29	38	29	27	37	30	26	30	30	21	23	7	—	380
3	28	21	26	40	44	37	45	44	64	41	46	71	53	43	28	11	—	642
4	49	63	50	41	36	53	47	74	73	82	85	87	79	70	47	32	—	968
5	58	33	33	32	35	34	31	55	50	43	54	62	66	67	36	30	—	719
6	36	27	20	22	15	27	24	28	37	40	28	47	49	41	19	22	—	482
7	19	7	8	8	7	10	8	9	12	8	10	14	25	18	11	17	—	191
8	9	1	1	1	6	6	1	3	6	6	3	6	6	5	4	5	—	69
9	2	—	—	1	—	1	—	3	1	1	—	—	2	2	1	—	—	14
10	1	1	—	—	1	1	—	—	—	—	—	1	2	—	—	1	—	8
11																		
12																		
Totals (16 points)	232	177	150	170	177	210	188	247	293	256	261	331	325	276	179	128	52	3652

DEERNESS.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	113	113
1	38	7	25	19	22	25	31	26	36	25	19	18	38	25	30	30	—	414
2	56	31	22	26	39	31	38	46	54	38	45	31	54	45	48	28	—	632
3	44	29	20	13	35	34	50	52	71	69	44	31	41	33	50	41	—	657
4	30	21	25	11	17	28	56	65	71	42	55	34	53	31	55	40	—	634
5	27	13	8	10	9	24	42	68	66	35	29	41	57	18	32	28	—	507
6	28	8	7	5	7	21	46	34	41	25	14	24	38	17	23	23	—	361
7	18	5	4	2	14	16	27	30	17	4	3	11	18	13	15	9	—	206
8	7	—	—	—	2	11	20	10	4	2	3	10	11	5	5	—	—	90
9	—	—	—	—	1	1	14	3	1	—	1	4	5	—	3	1	—	34
10	2	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	3
11	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
12																		
Totals (16 points)	250	114	111	86	146	191	324	334	361	240	213	205	315	187	262	200	113	3652

Number of observations of winds of various strengths from the following directions in the five years 1911–15.

LERWICK.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	140	140
1	28	13	7	10	9	11	16	29	28	24	23	16	19	14	16	19	—	282
2	44	39	30	26	16	26	29	93	58	64	40	47	51	43	34	35	—	675
3	48	50	35	25	18	36	46	115	59	76	42	71	39	56	64	54	—	834
4	46	49	23	15	21	23	40	75	56	61	54	36	42	37	29	55	—	662
5	49	23	17	4	15	28	34	71	35	45	25	34	21	33	28	34	—	496
6	15	19	8	3	7	21	33	26	25	30	18	22	8	9	12	20	—	276
7	6	2	2	1	5	8	12	11	7	7	12	3	8	5	2	1	—	92
8	5	2	3	2	8	13	17	21	14	5	3	6	2	2	3	6	—	112
9	4	—	—	5	4	20	9	8	1	3	2	2	—	1	1	3	—	63
10	2	—	—	—	1	7	3	4	—	1	1	1	—	—	—	—	—	20
11																		
12																		
Totals (16 points)	247	197	125	91	104	193	239	453	283	316	220	238	190	200	189	227	140	3652

MALIN HEAD.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35	35
1	40	16	42	5	43	13	22	7	43	9	44	3	28	5	19	12	—	351
2	38	27	34	15	53	14	35	24	78	28	69	25	58	16	39	21	—	574
3	50	37	33	12	43	31	54	26	94	46	100	28	53	20	55	20	—	702
4	58	24	19	6	31	26	60	19	89	43	109	34	59	27	52	20	—	676
5	28	15	9	4	17	7	27	10	72	29	79	43	50	26	50	13	—	479
6	30	12	12	4	18	4	17	11	58	22	74	29	57	28	42	12	—	430
7	5	2	1	—	3	2	10	—	15	11	21	11	20	8	13	4	—	126
8	13	3	1	2	4	3	11	7	22	6	31	17	22	20	23	6	—	191
9	3	2	—	—	3	2	3	2	7	2	14	2	7	8	10	8	—	73
10	1	—	—	—	—	—	1	3	—	—	3	—	—	2	2	1	—	13
11	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	2
12																		
Totals (16 points)	266	138	151	48	215	102	240	109	478	196	546	192	354	160	305	117	35	3652
Adjusted Totals (8 points)	409		221		291		330		642		767		516		441			

Number of observations of winds of various strengths from the following directions in the five years 1911–15.

BLACKSOD POINT.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	83	83
1	30	24	18	12	11	11	23	14	17	16	25	27	24	25	35	27	—	339
2	37	59	43	23	12	25	38	23	26	39	44	51	49	55	43	35	—	602
3	42	66	35	23	11	22	44	39	30	70	95	83	69	77	45	34	—	785
4	33	48	42	19	11	11	39	29	45	97	77	60	45	43	18	16	—	633
5	16	33	17	21	7	21	29	23	43	105	70	39	36	48	19	15	—	542
6	9	11	2	—	5	15	10	14	39	66	60	38	33	43	8	11	—	364
7	7	3	1	3	—	1	7	10	22	36	32	17	16	7	5	4	—	171
8	4	4	—	2	2	2	4	7	11	24	10	9	8	5	1	5	—	98
9	—	1	—	—	1	—	—	2	7	3	4	3	3	1	3	2	—	30
10	—	—	1	—	—	—	—	1	—	1	2	—	—	—	—	—	—	5
11																		
12																		
Totals (16 points)	178	249	159	103	60	108	194	162	240	457	419	327	283	304	177	149	83	3652

VALENCIA.

Force, Beaufort Scale.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total.
0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	307	307
1	30	37	60	84	50	19	24	31	46	34	36	38	37	41	25	15	—	607
2	24	30	41	39	44	32	24	58	107	35	37	45	44	37	49	18	—	664
3	40	26	26	22	37	26	26	70	84	30	74	63	40	46	59	40	—	709
4	28	22	26	21	26	23	25	84	96	29	77	58	41	52	40	39	—	687
5	23	3	3	8	15	14	14	51	45	19	58	43	40	27	19	19	—	401
6	12	3	3	2	4	2	20	19	29	8	33	21	19	15	10	9	—	209
7	2	—	—	—	1	—	1	3	5	—	12	7	6	4	3	3	—	47
8	—	—	—	—	2	—	2	—	1	1	2	5	4	2	—	1	—	20
9	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
10																		
11																		
12																		
Totals (16 points)	160	121	159	176	179	116	136	316	413	156	329	280	231	224	205	144	307	3652

8. Diagrams of Results for Five Years, 1911 to 1915.

But it is difficult for any reader to keep such a multitude of figures in mind; for that purpose a diagram is much more serviceable. Even a diagram is too complicated if we try to represent all the separate forces of the Beaufort Scale. So let us group together, in accordance with the usual practice of the Marine Division of the Meteorological Office, forces 1 to 3 as representing light winds, forces 4 to 7 as representing moderate and strong winds, and forces 8 and over as representing gales. A convenient form of diagram is that in which the whole number of winds for each of the 16 points of the compass is represented by the length of a column which is divided into three portions.

The portion representing the number of light winds is at the top and is left unshaded, the portion representing moderate and strong winds is shaded by cross-lines, and the remainder, which represents the number of gales, is blackened. A separate column is added to show the number of calms.

In this way the results for the whole five years for the 24 stations can be brought within a moderate compass and they are set out here between pp. 32 and 33.

It will be noticed that all the diagrams are not in the same form; most of them show columns for the 16 points, the rest only show 8 points, N., NE., E., and so on. The reason for this is rather peculiar. The observer generally has to make his estimate of the direction of the wind with the assistance of some means of orientation. The orientation marks of a weather-cock are the best, provided they are set "true," but a weather-cock is not always available. Without some such assistance the observer not infrequently fails to notice the difference between NNE. and N. or NE., or between NNW. and NW. or N., and so on. And when the observations come to be arranged there is a striking absence of winds of the intermediate points, NNE., ENE., and so on. The diagram presents therefore a very jagged appearance, the reason for which is much more likely to be the habit of the observer than any peculiarity in the winds of the place. In those cases in which the diagram showed this jagged appearance, the relatively small numbers of winds assigned to intermediate points have been divided between the two more favourable points on either side of it in proportion to the original numbers assigned to those points, and so the diagram has been reduced to eight points. The reduction has made it necessary to alter the scale of the diagram because when there are only eight points the average number of winds for the eight must be double the average number for sixteen points: if the same scale were used the average length of the columns would be doubled and the diagram become unwieldy. The scale of the 8-point diagram has therefore been halved but a scale of percentages is set in each case against the diagram to which it refers.

In calling attention to these diagrams we may begin with that for Portland as perhaps the most strikingly regular of the series. We see at once that the winds at that station naturally divide themselves into two groups, the one about a greater maximum for WSW., the other about a smaller maximum for NE. There are comparatively few winds from N. and NNW. or from SE. The numbers of moderate and strong winds are arranged in similar groups. The gales group themselves more irregularly, but there are obviously many more from between south and west than from elsewhere, with a preponderance from west.

Blacksod Point is very similar to Portland, with a greater frequency of gales at the former place. On the other hand, Spurn Head shows more uniformity. There is a slight preponderance of winds about west, but the favourite points for gales are around north.

Lerwick, in Shetland, above latitude 60° North, and the contiguous station Deerness, in the Orkneys, show a notable prevalence of gales, and these mostly from south-easterly points.

In respect of gales the most noteworthy of the diagrams is that for Malin Head, which shows a big record of gales from nearly all directions, with a considerable preponderance of those from between S. and NW.

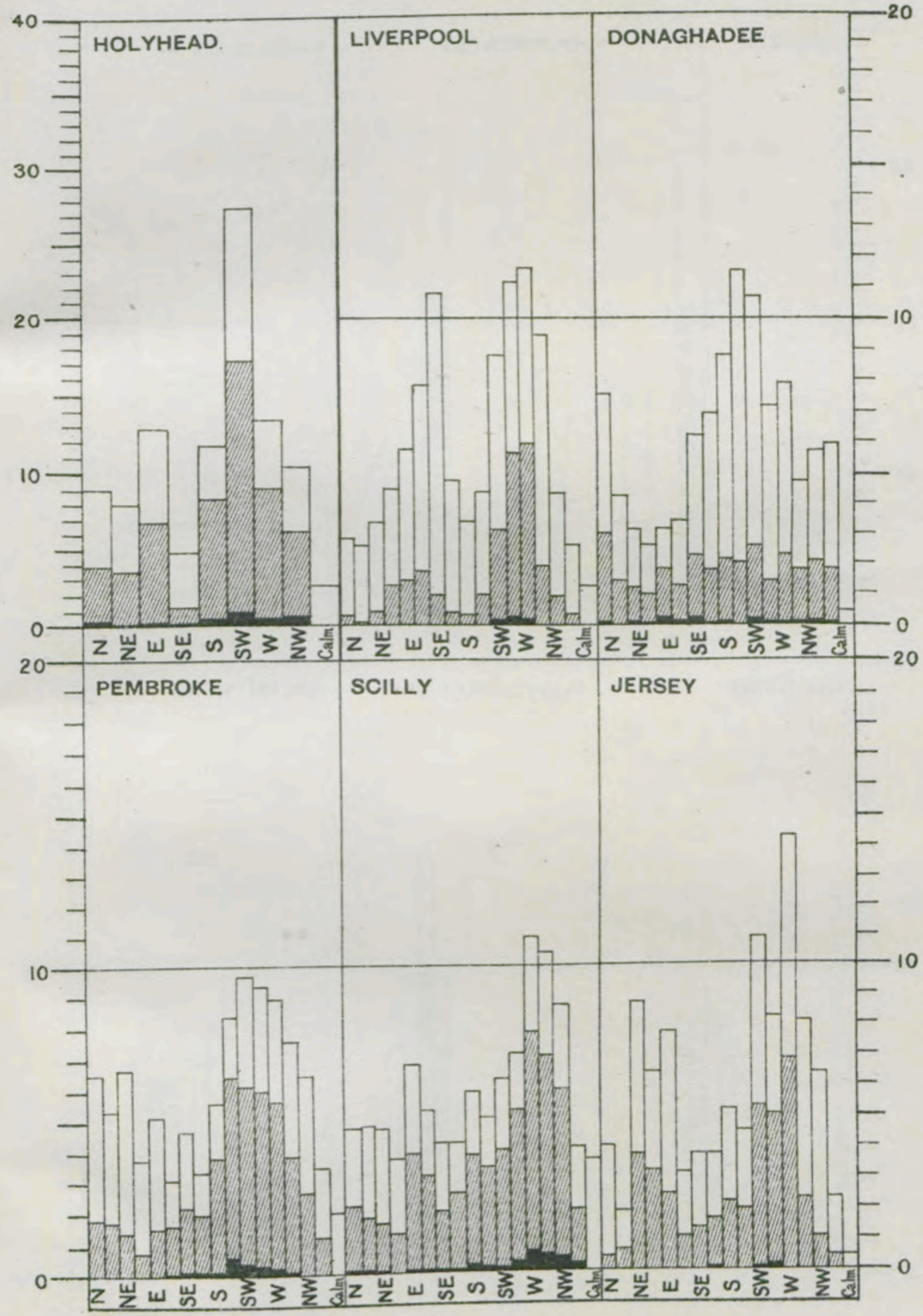
Jersey, as will be seen, with its preponderance of winds from westerly points, is conspicuous for the almost complete absence of gales—the few recorded being mostly from WSW. At Clacton and Leith also there are hardly any gales recorded.

At Dungeness and Dover there is a very striking preponderance of winds from SW. Dungeness also shows a grouping of winds about a secondary maximum of frequency in the North-east, but the Dover winds from the northerly points are grouped about North, North-west being rather more prominent than North-east. The gales are mostly from South-westerly points. These special characteristics are undoubtedly due to the geographical position of these two stations on the shores of a strait by which the winds are, to some extent, guided.

A similar remark applies to Leith, but in this case the preponderant winds are WSW. and ENE.

Plate XIX.

DIAGRAMS OF PERCENTAGE FREQUENCY OF GALES, MODERATE OR STRONG WINDS AND LIGHT WINDS AT STATIONS ON THE BRITISH COASTS.



The length of the black portion of each column represents the percentage of gales (force 8 or over), that of the shaded part the percentage of moderate and strong winds (forces 4 to 7), and the unshaded part the number of light winds (forces 1 to 3).

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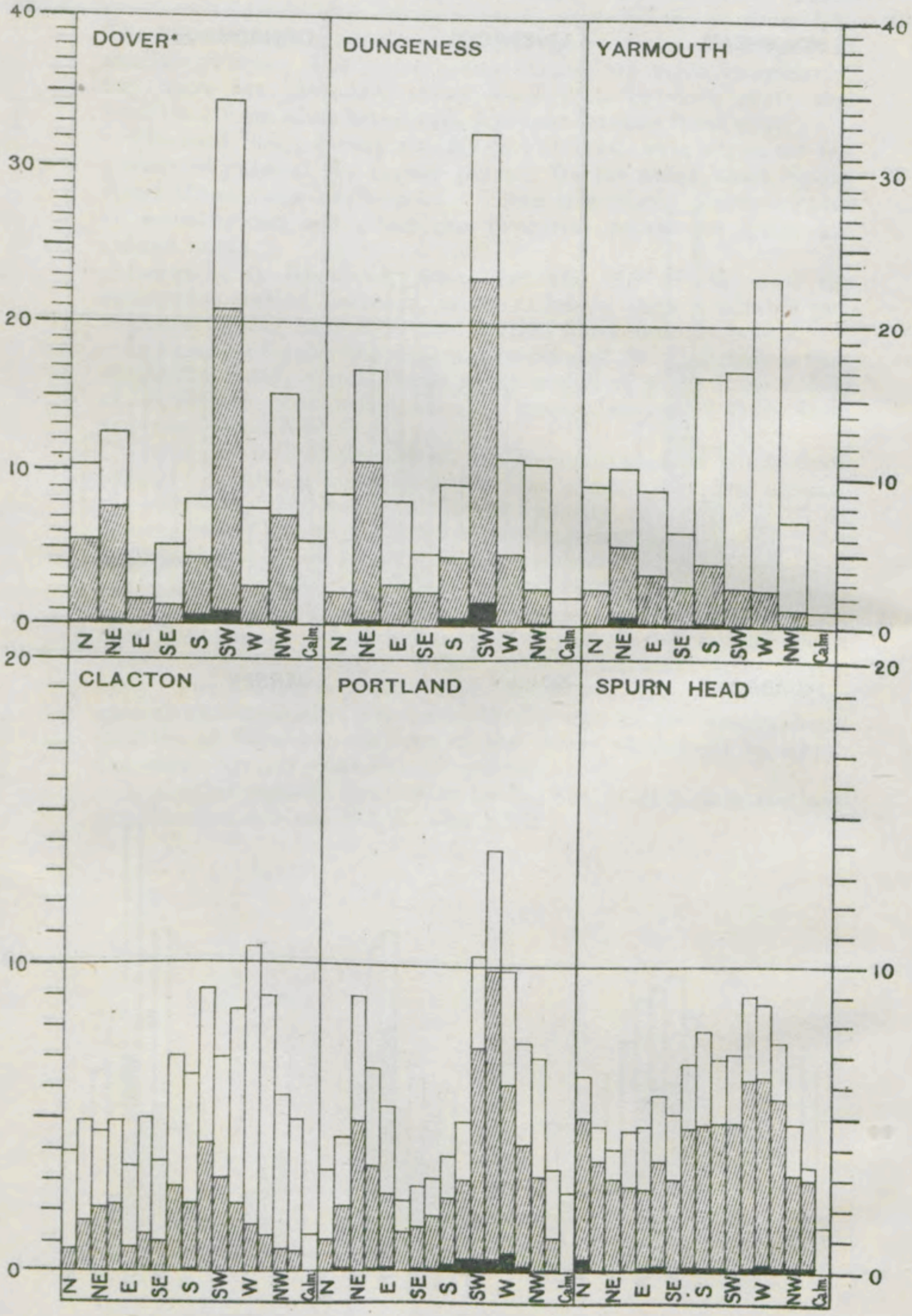
DIAGRAMS OF PERCENTAGE FREQUENCY OF GALES, MODERATE OR STRONG WINDS AND LIGHT WINDS AT STATIONS ON THE BRITISH COASTS.



* The large number of calms at this station may be attributed to the influence upon the exposure of surrounding land.

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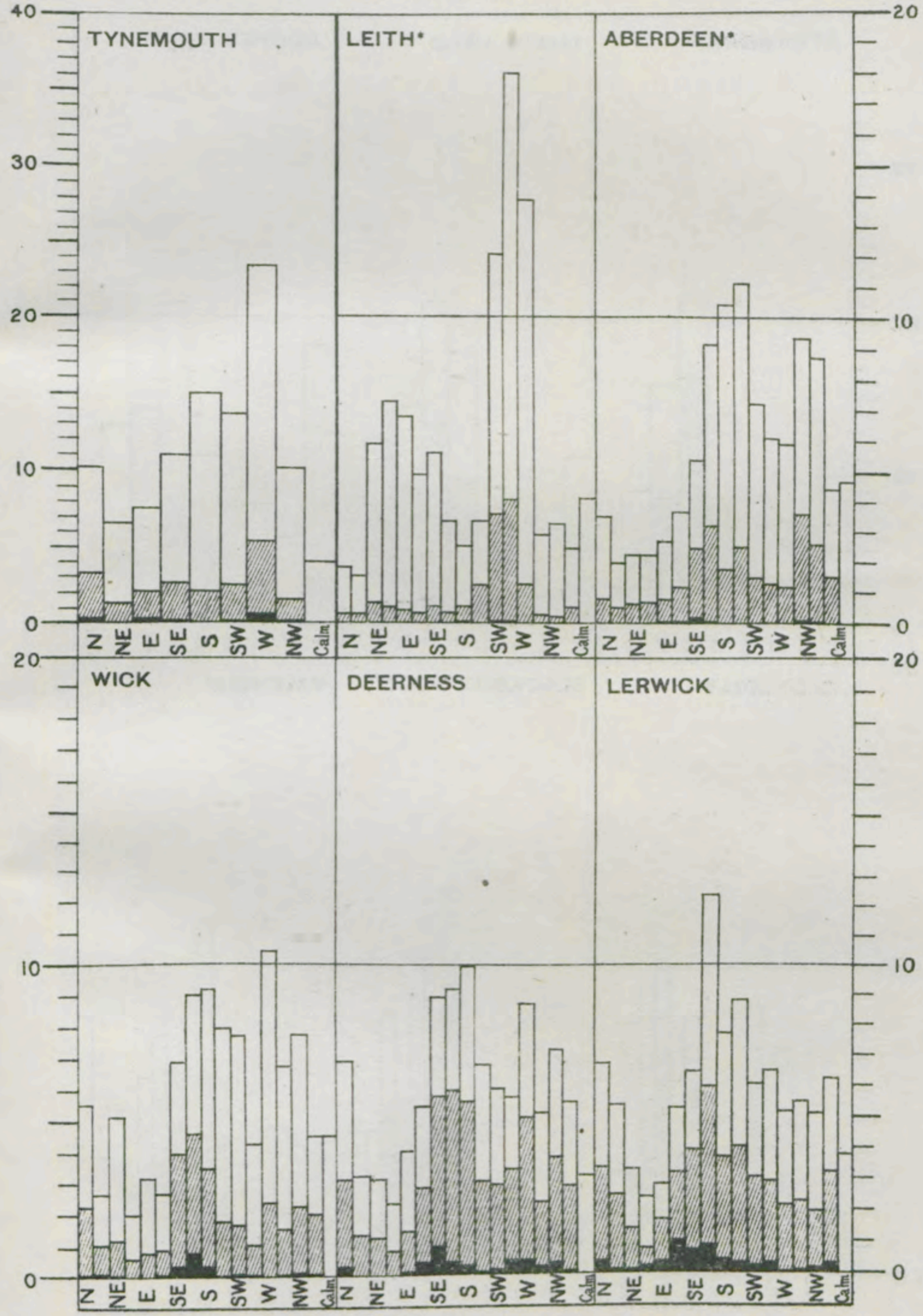
DIAGRAMS OF PERCENTAGE FREQUENCY OF GALES, MODERATE OR STRONG WINDS AND LIGHT WINDS AT STATIONS ON THE BRITISH COASTS.



* The large number of calms recorded at this station may be attributed to the protected position of the station or of the anemometer.

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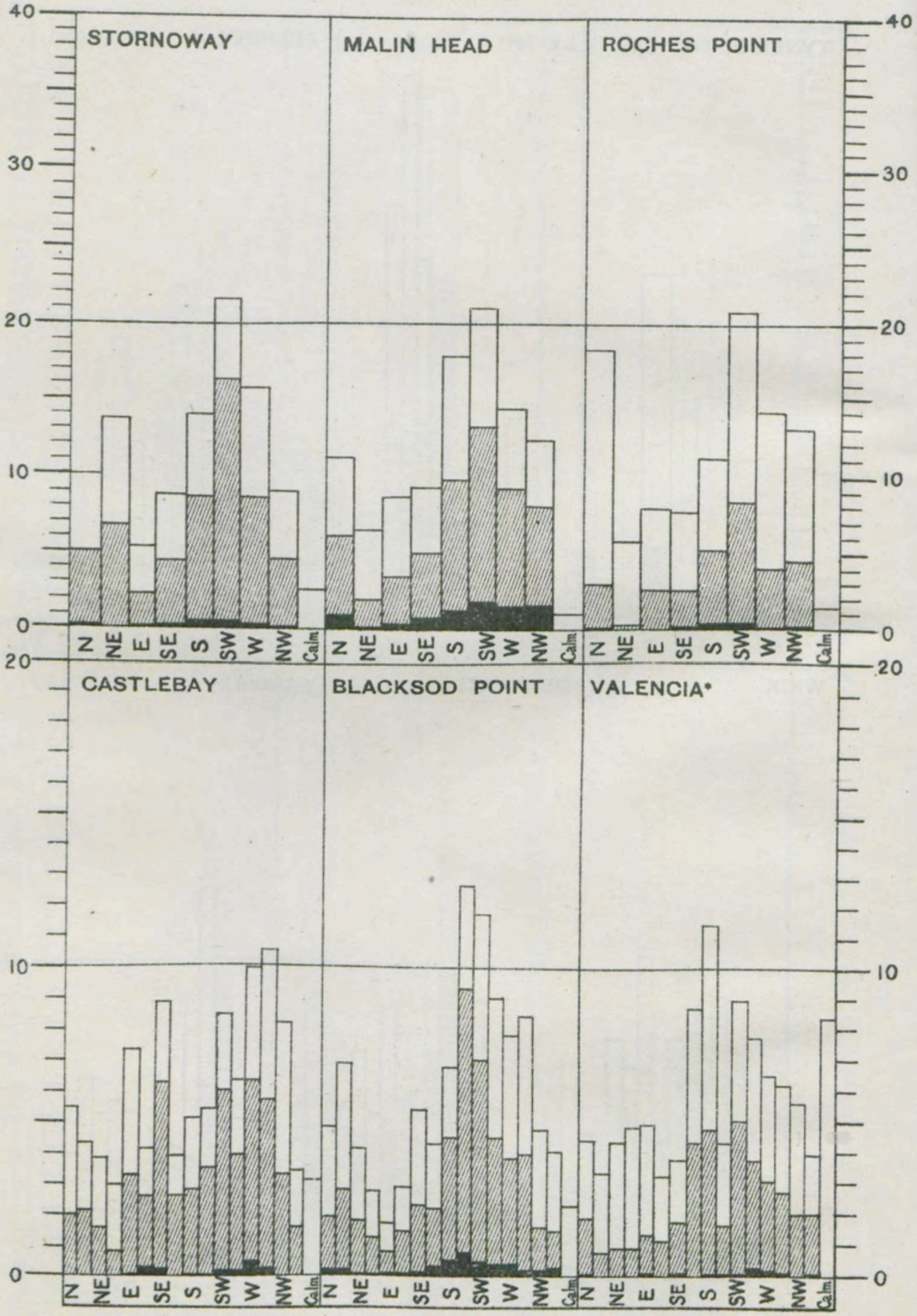
Ps. 764. 9898. 528. 2000. 12/17.

DIAGRAMS OF PERCENTAGE FREQUENCY OF GALES, MODERATE OR STRONG WINDS AND LIGHT WINDS AT STATIONS ON THE BRITISH COASTS.



* The large number of calms at this station may be attributed to the protected position of the anemometer.

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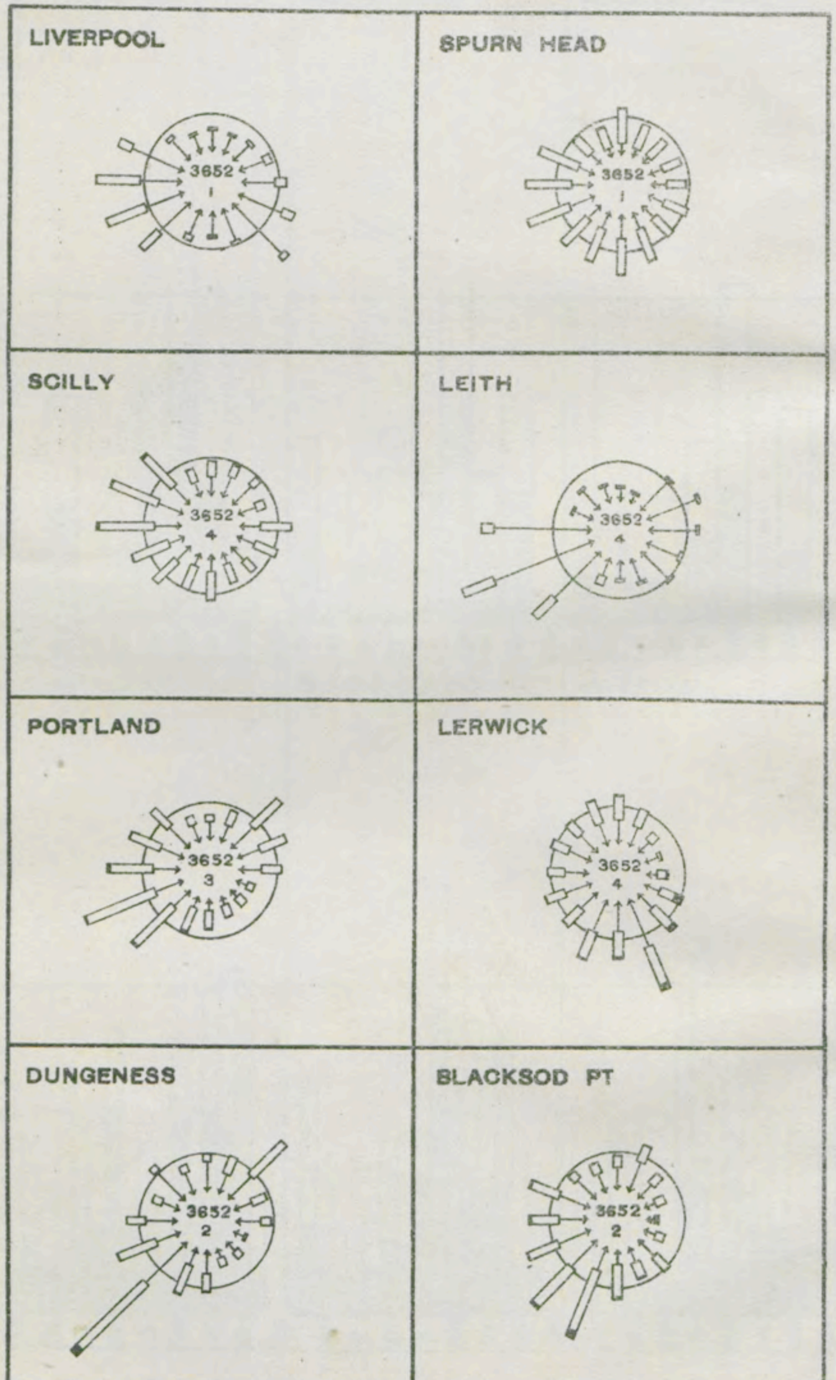
The Weather of the British Coasts.

WIND-ROSES FOR THE YEARS 1911-15.



100 per cent. = 4 inches.

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9. Wind Roses.

This form of diagram is still rather large, and on that account unsuitable for representation of the difference between the habits of the wind at the various stations in the different months. A still further reduction of the size of the diagrams can be obtained by using what is called a wind-rose. Instead of using columns placed side by side we use arrows pointing to a centre. We still make use of the sorting of the winds into light winds, forces 1-3, moderate and strong winds, forces 4-7, and gales, forces 8 and upwards. And now the length of a single line represents the number of light winds, that of a double line the number of moderate and strong winds, that of the blackened portion of the arrow the gales.

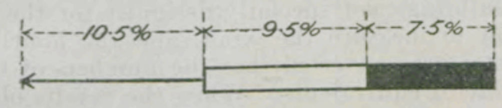


Fig. 1.

The lengths of the different sections must be properly adjusted; thus if we agree that a length of 9 inches shall represent one hundred per cent. of the whole number of winds, the composite arrow from the point to the other end as drawn in fig. 1 would represent 27·5 per cent. of the winds, of which 10·5 per cent. are light, 9·5 per cent. moderate or strong, and 7·5 per cent. are gales.

Example of Wind Rose.

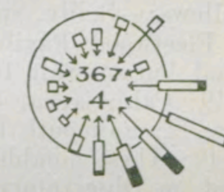


Fig. 2.

These composite arrows representing the percentage of winds of the selected groups of forces can be arranged, points inwards, to represent the distribution of winds among the several directions, arranged in groups of 16 points or 8 points as the case may be. The points are arranged round a small circle within which the number of observations and the percentage of calms is written. The length from the point of the arrow to the circle represents 5 per cent. of the whole number of winds.

Complete wind-roses on this principle for the year for Liverpool, Scilly, Portland, Dungeness, Spurn Head, Leith, Lerwick and Blacksod are given here as Plate XXIII., and wind-roses for the several stations for each of the twelve months have been prepared but are not reproduced here.

Statistics of wind-forces for a further period of five years are in course of preparation. It remains to be seen to what extent the results for the several stations retain the same characteristics as those which are portrayed here.

10. Anemometers and Exposure.

In considering the bearing of the information which is contained in these tables and diagrams, it is necessary to revert once more to the question of anemometers and exposure. If we refer to the Summary of Gales we find that the districts representing the Irish Sea and the South-west Coast of Ireland, next to the North-west of Ireland and the Bristol Channel, are the most stormy districts of our coasts, but the indications of this windy character are not to be found in the tables or diagrams for Liverpool or Valencia. Aberdeen is similarly conspicuous for the relative lightness of its winds. The explanation is probably to be found in the use of anemometers for determining the force of the wind at those stations. In each case the anemometers are on substantial buildings not specially designed for the exposure of an instrument to measure the wind, and the hourly records of the anemometer are converted into the numbers of the Beaufort scale by a table of equivalents. When the results obtained from the anemometers in this way are brought into comparison with the estimates made at other stations (as has now been done for the first time) it becomes apparent that there is something lacking in the scheme of comparison.

The same conclusion is most obviously to be drawn from a comparison of the frequency of the winds of gale force as recorded by a series of anemometers and set out in a table in the Meteorological Glossary, M.O. 225 ii p. 126, from which it appears that the average yearly number of "hours of wind of gale force" recorded on anemometers of the same type for the years 1908 to 1914 inclusive was as follows:—Scilly, special hut, 183; Deerness, special hut, 101; Fleetwood Pavilion, 100; Kingstown Pier 65; Holyhead, special hut on Salt Island, 56; Yarmouth, roof of Sailors' Home, 19; Cahirciveen, Valencia Observatory, 16; Aberdeen Observatory, 2; Falmouth Observatory, 1; Richmond, Kew Observatory, 0. These notable differences, in which the anemometers mounted on Observatory buildings are found to be all together at the bottom of the list, make it clear that one single table of equivalents for the numbers of the Beaufort Scale is not capable of being used the other way round to give the Beaufort number of the wind as recorded at any anemometer irrespective of its exposure. The anemometer at each Observatory requires a special scale of equivalents of its own, unless the exposure is made to conform to a uniform standard, and hitherto that has not been the case.

To face p. 34.

TABLE D.—The Months of Greatest Frequency of each Wind Direction at each Station, together with the percentage of the whole number of observations which that frequency represents. From observations at 7h. and 18h. G.M.T., 1911–15.

—	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.
Clacton	Oct. 0·8	Apr. 1·0	May 0·9	June 0·7	Sep. 0·6	Sep. 0·7	Feb., May 0·5	Oct. 0·8	Dec. 1·2	Feb. 1·1	Nov. 1·1	Mar. 1·2	Jan. 1·2	Sep. 1·1	Nov. 0·9	Jan. 0·7	Oct. 0·2
Dover	May 1·2	May 1·3	Aug. 1·1	Jan. 0·3	Oct. 0·5	Oct. 0·3	Sep. 0·5	Jan. 0·4	Feb. 0·8	Dec. 1·1	Mar. 2·5	Dec. 0·8	Dec. 1·0	Jan. 0·4	Sep. 1·5	Jan., Mar., Apr., June, Oct. 0·3	Sep. 0·8
Dungeness ...	May 0·7	May 0·8	Apr. 1·5	Sep. 0·6	Oct. 0·9	Oct. 0·4	Jan. 0·5	Feb. 0·6	Feb. 0·8	Dec. 1·0	Dec. 2·3	Mar. 1·0	Dec. 0·8	Nov. 0·7	Nov. 1·0	Sep. 0·5	May, Aug., 0·2
Portland... ...	Nov. 0·7	Apr., Oct. 0·7	Apr. 1·2	Sep. 0·8	Sep. 1·0	Sep. 0·4	Oct. 0·6	Feb. 0·7	Feb., Dec. 0·7	Dec. 0·9	Dec. 1·2	Mar. 1·7	Dec. 1·2	July 0·8	Nov. 0·8	Sep. 0·5	Aug. 0·5
Jersey	June 0·5	Apr. 0·5	May 1·2	Apr., Oct. 0·8	Sep. 1·2	Oct. 0·5	Feb. 0·9	Oct. 0·7	Dec. 1·0	Dec. 0·8	Dec. 1·6	Dec. 1·2	Aug. 1·9	July 1·2	Aug. 0·7	Apr. 0·3	Jan. 0·2
Scilly	July 0·6	May 1·0	Apr. 0·7	Apr. 0·5	Jan., Oct. 0·7	Sep. 1·5	Oct. 0·8	Jan. 0·7	Feb. 1·1	Dec. 0·7	Dec. 0·9	Dec. 1·0	Dec. 1·5	Aug. 1·1	July 1·3	Sep. 0·6	Aug. 0·6
Holyhead ...	May, July 1·1	Aug. 0·4	May 0·8	Oct. 0·8	Oct. 1·4	June 0·3	Jan. 0·7	Oct. 0·3	Feb. 1·4	Feb. 0·8	Aug. 2·1	Dec. 0·9	Mar. 1·2	Sep. 0·7	July 1·0	July 0·6	Sep. 0·3
Donaghadee ...	May 1·2	Apr., May 0·7	June 0·4	Nov. 0·5	Oct. 0·5	Oct. 0·6	Jan. 0·8	Feb., July 0·9	Feb., Dec. 1·0	Jan. 1·5	Nov. 1·5	Mar. 0·9	Dec. 1·1	Apr., Nov. 0·6	July 1·0	July 1·5	May, Oct. 0·1
Liverpool ...	Sep. 0·4	Nov. 0·5	Oct. 0·5	May 0·7	Sep. 0·8	Jan. 1·4	Oct. 1·6	Dec. 0·7	Dec. 0·4	Feb., Dec. 0·6	Dec. 1·1	Dec. 1·6	July 1·8	Aug. 1·5	May, July 0·7	June 0·4	July 0·3
Pembroke ...	Sep. 0·8	Apr. July 0·7	Apr. 0·8	Oct. 0·7	Sep. 0·8	Sep. 0·6	Feb., May 0·6	Feb. 0·5	Feb. 0·9	Dec. 1·3	Aug. 1·1	Dec. 1·1	Dec. 1·2	July 0·9	Aug. 0·7	July 0·6	May, Aug. 0·4
Roche's Point ...	July 1·7	Apr. 0·5	Oct. 0·7	Feb., May 0·3	Jan. 0·8	Sep. 0·4	Sep. 0·8	Sep. 0·4	July 1·0	Feb. 0·8	Dec. 1·6	Dec. 1·0	Dec. 1·6	Dec. 0·5	Dec. 1·0	May, July, Aug. 0·7	July 0·3
Valencia... ...	July 0·5	Nov. 0·5	Oct. 0·8	Nov. 0·7	Jan. 0·8	Jan. 0·6	Oct. 0·6	Dec. 1·1	Feb. 1·7	Jan. 0·6	Dec. 1·6	June 1·0	July 0·8	Mar. 0·8	July 0·9	July 0·6	Aug. 1·2
Blacksod Point...	July 1·1	June 1·1	Apr. 0·7	Mar. 0·5	Oct. 0·4	Dec. 0·5	Jan., Oct. 0·9	Jan. 0·8	Oct. 1·0	Feb., Mar., Dec. 1·4	Jan. 1·4	Apr. 1·1	June 1·1	July 1·0	Aug. 0·8	May 0·5	Apr. 0·4
Malin Head ...	July 1·0	May 0·7	Aug. 0·5	Mar. 0·4	June 0·9	May 0·4	Oct. 1·1	Oct. 0·5	Jan. 2·1	Feb. 0·7	Feb. 1·9	Apr. 0·8	June 1·1	Apr., Nov. 0·6	July 1·3	July 0·5	July 0·3
Castlebay ...	Nov. 0·7	Mar. Sep. 0·5	Apr., Oct., Nov. 0·4	Aug. 0·5	Oct. 1·0	Jan. 0·7	Oct. 1·3	Feb. 0·7	Feb. 0·8	Jan., Feb., Dec. 0·6	Dec. 1·1	Apr. 0·9	Nov. 1·4	July 1·4	July 1·3	July 0·5	Oct. 0·4
Stornoway ...	Nov. 1.4	Mar. 0·6	June, July 1·8	June 0·6	Mar. 0·4	Oct. 0·4	Oct. 1·2	Jan. 0·4	Jan. 1·3	Feb. 1·0	Dec. 1·6	Apr. 1·0	Mar., July 1·1	Apr. 0·4	Mar., Nov. 0·7	Nov. 0·4	Sep. 0·4
Lerwick	Mar. 0·9	June, July 0·7	June 0·5	May, June, Aug. 0·4	Oct. 0·5	Jan. 0·9	Jan. 1·1	Feb. 1·5	Feb. 0·9	Feb., Nov. 1·0	Nov. 0·8	May 0·8	Aug. 0·7	Aug. 0·7	Apr. 0·8	Nov. 0·8	Dec. 0·5
Deerness... ...	June 0·8	May, Dec. 0·5	June 0·6	June 0·5	Aug., Dec. 0·5	Oct. 0·8	Oct. 1·2	Oct. 1·2	Feb. 1·5	Feb. 1·1	Dec. 1·0	Apr. 0·8	Mar. 1·1	June, July 0·6	July 0·9	Nov. 0·7	July, Aug. 0·4
Wick	Apr. May 0·6	June 0·6	June 1·0	June, Aug. 0·5	May 0·5	June 0·5	Oct. 1·3	Oct. 1·3	Jan. 1·4	Dec. 1·2	Jan. 1·0	Dec. 0·7	Nov. 1·2	Mar. 1·0	June 1·1	July 0·7	July 0·8
Aberdeen ...	*Apr. 0·6*	*June 0·5*	*June 0·5*	*May 0·5*	*Aug. 0·5*	*June 0·5*	*Oct. 1·0*	*Jan. 1·3*	*July 1·3*	*Dec. 1·5*	*Dec. 1·0*	*Dec. 1·0*	*Nov., Dec. 0·8*	*Nov. 1·3*	*Sep. 1·1*	*July 0·9*	*Oct. 0·7*
Leith	Mar., Oct. 0·3	June 0·2	July 1·0	Mar. 1·5	Mar. 0·8	Oct. 0·7	Oct. 1·0	Dec. 0·5	Feb. 0·4	Feb. 0·7	Dec. 1·8	Nov. 2·0	July 1·6	May 0·5	Nov. 0·4	Oct. 0·3	June Aug. 0·6
Tynemouth ...	July 1·3	May 0·5	Oct. 0·8	May 0·5	May 0·8	May 0·5	Sep. 0·9	Jan. 0·8	Dec. 1·6	Aug. 0·7	Dec. 1·1	M y 0·7	Mar. 1·9	Aug. 0·8	Nov. 0·8	Sep., Nov. 0·5	Oct. 0·7
Spurn Head ...	July 1·0	May 0·8	May 0·7	May 0·7	Oct. 0·6	May 0·9	Sep. 0·8	Dec. 0·9	Feb. 1·3	Dec. 1·1	Dec. 1·0	Mar. 1·2	Mar. 1·2	July 0·9	Nov. 0·7	July 0·6	July 0·2
Yarmouth ...	Apr., July 1·0	May 0·9	May 1·0	Sep. 0·4	Oct. 1·0	Jan. 0·4	Sep. 0·8	May 0·5	Feb. 1·8	Dec. 0·8	Dec. 1·9	Dec. 1·0	Nov. 1·7	Feb. 0·5	Sep. 0·7	Aug. 0·5	May 0·3
Mean	0·9	0·7	0·8	0·6	0·7	0·6	0·9	0·7	1·1½	0·9	1·4	1·1	1·3	0·8	0·9	0·6	0·5

TABLE E.—Number of Stations at which the Greatest Frequency for each Wind Direction is shown in the several Months.

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
January	—	—	—	1	2½	5	4½	6	3	2⅓	2	—	1	1	—	1⅕	1
February	—	—	—	½	—	—	2	5½	13	8⅔	1	—	—	1	—	—	—
March	1½	1½	—	3	2	—	—	—	—	⅓	1	5	4½	2	½	⅕	—
April	2	4½	5⅓	1½	—	—	—	—	—	—	—	5	—	2	1	1⅓	1
May	4	8	5	4⅚	2	3	1	1	—	—	—	2	—	1	½	1⅓	2½
June	2	5	5½	3⅚	1	3	—	—	—	—	—	1	2	½	1	1⅓	½
July	8	½	1½	—	—	—	—	½	2	—	—	—	3½	6½	7½	9⅓	5½
August	—	1	2	1⅚	1½	—	—	—	—	1	2	—	2	4	3	1⅓	5
September	2	½	—	3	5	5	5	1	—	—	—	—	—	2	3	3½	3
October	1½	½	4⅓	2½	9½	7	11½	6	1	—	—	—	—	—	—	1⅕	4½
November	3	2	⅓	2	—	—	—	—	—	½	3	1	3½	3	6½	3½	—
December	—	½	—	—	½	1	—	4	5	11⅙	15	10	7½	1	1	—	1
	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

TABLE F.—The Months of Greatest Frequency of Each Wind Force,

At each station, with the percentage of the whole number of observations which that frequency represents.

From observations at 7h. and 18h. G.M.T., 1911–15.

Force	0	1	2	3	4	5	6	7	8	9	10	11 & 12
Clacton	Oct. 0·2	Oct. 1·6	July 3·5	Dec. 2·4	June 1·9	Apr. 0·8	Mar. 0·6	Dec. 0·1	Mar. 1/40			
Dover	Sep. 0·8	Oct. 1·9	July 1·7	Aug. 2·0	Nov. 2·3	Dec. 1·6	Dec. 1·5	Feb. 0·3	Dec. 0·2	Mar., Nov., Dec. 1/20	Sep. 1/40	Jan. 1/40
Dungeness	May, Aug. 0·2	Oct. 0·9	May, Oct. 1·9	July 2·7	Apr. 2·3	Jan. 1.7	Dec. 1·0	Jan., Nov., Dec. 0·5	Dec. 0·3	Dec. 0·2	Mar. 1/20	
Portland	Aug. 0·5	July 1·5	May 1·5	May 2·2	July 2·3	Dec. 2·1	Dec. 1·3	Mar., Dec. 0·6	Dec. 0·5	Dec. 0·2		
Jersey	Jan. 0·2	Sep. 0·5	Oct. 2·5	Aug. 4·1	Jan. 2·4	Apr. 1·3	Mar., Dec. 0·7	Dec. 0·3	Feb. 1/20			
Scilly	Aug. 0·6	Aug. 1·3	Aug. 1·9	May 2·2	July 2·5	Dec. 2·0	Mar. 1·7	Dec. 0·8	Dec. 0·5	Dec. 0·1	Jan., Mar. 1/40	
Holyhead	Sep. 0·3	May 1·2	Aug. 1·6	Aug. 2·5	Mar. 2·2	Mar. 1·7	Feb. 1·3	Dec. 0·7	Dec. 0·8	Nov. 0·1	Nov. 1/40	
Donaghadee ...	May, Oct. 0·1	Aug. 1·5	June 2·9	Mar. 2·9	Mar. 2·2	Nov. 0·9	Dec. 0·4	Nov. 0·2	Nov. 0·2	Dec. 0·1	Nov., Dec., 1/20	
Liverpool	July 0·3	May 3·8	Oct. 2·7	Aug. 2·5	July 1·5	Jan. 1·0	Mar. 0·9	Dec. 0·4	Feb. 0·1	Dec. 1/20		
Pembroke	May, Aug. 0·4	June 1·9	Aug. 2·0	July 2·2	July 2·1	Dec. 1·7	Nov. 1·6	Dec. 0·8	Dec. 0·3	Dec. 0·2	Dec. 1/40	
Roche's Point ...	July 0·3	Aug. 2·0	July 2·2	May 3·0	Mar. 2·3	Dec. 1·0	Feb. 0·7	Dec. 0·3	Feb. 0·2	Jan., Feb., Dec. 1/20		
Valencia	Aug. 1·2	Sep. 1·8	May 1·9	Aug. 2·1	Mar. 1·9	Dec. 1·5	Dec. 1·0	Dec. 0·3	Dec. 0·2	Nov. 1/40		
Blacksod Point ...	Apr. 0·4	Aug. 1·5	May 1·9	July 2·3	July 1·8	Mar. 1·7	Nov. 1·5	Jan. 0·9	Dec. 0·7	Feb. 0·2	Nov. 0·1	
Malin Head ...	July 0·3	June 1·6	July 1·9	Aug. 2·2	Oct. 2·1	Jan. 1·5	Mar. 1·4	Dec. 0·6	Dec. 1·0	Dec. 0·5	Nov. 0·2	Nov. 1/20
Castlebay	Oct. 0·4	Aug. 0·5	June 1·7	July 3·3	May 3·1	Jan. 2·1	Dec. 0·9	Nov. 0·5	Dec. 0·3	Jan. 0·1		
Stornoway	Sep. 0·4	Oct. 1·5	Aug. 2·0	July 2·3	Apr. 2·1	June, Sep. 1·5	Jan. 1·7	Dec. 1·0	Dec. 0·4	Dec. 1/40		
Lerwick	Dec. 0·5	July 1·1	July 2·7	May 2·5	June 1·8	Oct. 1·7	Jan. 1·3	Nov. 0·5	Jan. 0·6	Jan. 0·6	Jan. 0·2	
Deerness	July, Aug. 0·4	Aug. 1·9	Aug. 2·3	July 2·0	May 2·0	Apr., Dec. 1·5	Oct. 1·4	Jan. 1·0	Mar. 0·5	Dec. 0·2	Mar., Apr., Nov. 1/40	Oct. 1/40
Wick	July 0·8	Aug. 1·7	Aug. 2·5	July, Aug. 2·7	Nov. 2·0	Mar. 1·0	Jan. 0·7	Jan. 0·3	Jan., Dec. 0·3	Jan. 0·2	Jan. 1/20	
Aberdeen	Oct. 0·7	July 1·9	Aug. 3·1	Nov. 2·5	Mar. 1·7	Mar. 1·1	Dec. 0·7	Jan. 0·3	Jan. 0·2			
Leith	June, Aug. 0·6	Oct. 3·2	July 3·3	May 2·5	Mar. 1·2	Mar. 0·5	Dec. 0·2	Nov., Dec. 0·1	Nov. 1/20			
Tynemouth ...	Oct. 0·7	June 2·2	Aug. 3·7	Mar. 2·8	Dec. 1·2	Nov. 0·8	Feb., Nov. 0·3	Nov. 0·2	Jan. 0·2	Jan. 0·1	Nov. 1/20	
Spurn Head ...	July 0·2	Oct. 0·5	Aug. 1·6	Aug. 2·2	May 2·5	Apr. 1·9	Feb. 1·6	Dec. 0·8	Jan. 0·4	Jan., Nov. Dec. 0·1	Jan. 0·1	
*Yarmouth ...	May 0·3	May 1·6	Aug. 3·9	Dec. 2·5	Dec. 1·3	Nov. 0·7	Dec. 0·4	Nov. 0·1	Mar., Oct., Nov. 0·1	Nov. 0·1		
Mean	0·5	1·6	2·4	2·5	2·02	1·4	1·0	0·5	0·3	0·1	0·4	·004

* In July, 1915, observations were intermitted at this station for 9 days.

TABLE G.—The Number of Stations which exhibit the Maximum Frequency of the Several Forces in the Several Months.

Force by Beaufort Number.	0	1	2	3	4	5	6	7	8	9	10	11	12
Month.	Number of Stations.												
January	1	–	–	–	1	4	3	4⅓	4½	4⅔	3½	1	–
February	–	–	–	–	–	–	3½	1	3	1⅓	–	–	–
March	–	–	–	2	6	5	4½	½	2⅓	⅓	1⅚	–	–
April	1	–	–	–	2	3½	–	–	–	–	⅓	–	–
May	2½	3	3½	5	3	–	–	–	–	–	–	–	–
June	½	3	2	–	2	½	–	–	–	–	–	–	–
July	5½	3	6	6½	5	–	–	–	–	–	–	–	–
August	5	7	10	7½	–	–	–	–	–	–	–	–	–
September	3	2	–	–	–	½	–	–	–	–	1	–	–
October	4½	6	2½	–	1	1	1	–	⅓	–	–	1	–
November	–	–	–	1	2	3	2½	5⅚	2⅓	3⅔	4⅚	1	–
December	1	–	–	2	2	6½	9½	12⅓	11½	10	1½	–	–
	24	24	24	24	24	24	24	24	24	20	13	3	–

When a station shows the same maximum frequency in two months the figure ½ is assigned to each.

11. The Characteristics of the Months at the Several Stations.

Finally we may use our collection of figures to give an indication of the characteristics of the winds experienced in the several months of the year. As regards direction, it is customary to regard the spring of the year as the time for the prevalence of Easterly winds and the winter for Westerly winds. The accompanying tables D and E give us the means of examining these customary ideas. For the five years under review Table D gives the name of the month of greatest frequency of wind from each of the 16 points at each one of the 24 stations and the percentage of the whole number of observations which that frequency represents. It will be seen that the differences between the different months are not at all strongly marked. The greatest frequency shown for any one of the 16 points is two and a half per cent. for South-west winds at Dover in March out of a possible percentage of eight and a half per cent. for all the winds of one month. Upon close examination for each separate locality the table will give useful information, but general statements cannot easily be made about it.

Characteristics of the months derived from it are given in Table E, which give the number of stations at which the greatest frequency for each wind-direction is shown in the several months. From this table it becomes apparent that April, May and June are the favourite months for North-easterly winds, October is conspicuous for Easterly winds and for South-easterly winds, July is conspicuous for winds in the North-west quadrant, and December for winds in the South-west quadrant.

Corresponding information for the prevalence of the several wind-forces is given in tables F and G.

CHAPTER III.

THE WINDS OF THE OPEN SEA.

So far we have concerned ourselves only with winds estimated by observers or recorded by anemometers ashore or in light-vessels not far from the coasts. We have been careful to point out that the results obtained from these observations are records influenced, in some cases to a considerable extent, by the exposure of the station at which the observer is located, and still more by the exposure of the anemometer when an instrument is used for measuring or recording the wind. In order to complete the survey of our knowledge of the winds in the neighbourhood of the British Isles we have to take into account the winds of the four seas. For this part of our subject we are entirely dependent upon the observations made by seamen who navigate the various seas. All the ships of H.M. Navy are required to enter in the ship's log observations of wind at the six hours 4h., 8h., 12h. a.m. and p.m. according to ship's time. The officers of a considerable number of merchant vessels have also undertaken to make meteorological observations on board their ships at the same hours, and to report them in the form of a special meteorological log sent to the Meteorological Office on the completion of the voyage. This compilation of observations has been carried out on an organised plan since the year 1854, and therefore a considerable amount of material is available for trustworthy information about the winds of the British seas. The amount of information is not so large as would appear at first, because the procedure which is here indicated was initiated in order to obtain information about the winds of the oceans all over the world, and when vessels were near home they often considered themselves in a region about which everything necessary was already well known, and turned their attention to the more absorbing duties of a ship nearing or leaving port. But there are enough observations to make a satisfactory representation. For this purpose it is the regular practice of the Meteorological Office to divide the whole area of the surface of the seas into squares of one degree of latitude and longitude and to group together according to the months of the year all the observations made in each one of the squares irrespective of the year in which the observations were obtained.

The observations are then summarised in the same way as the observations inland, but as information for every square of one degree each way gives a more detailed picture of the results than is necessary, it is usual to put together the observations in groups of twenty-five squares and obtain results for five-degree squares instead of one-degree squares.

From the compilation thus obtained wind-roses have been constructed for the five-degree squares which are included, in whole or in part, within the seas which surround the British Isles, and these have been included in an atlas of the British Seas published by the Hydrographic Department of the Admiralty. To reproduce the results in this work would require maps of larger size than can be conveniently accommodated; and for the necessary information reference should accordingly be made to the publication of the Hydrographic Department already mentioned.

Outside the immediate region of the British Isles we have to deal with the Atlantic Ocean, one of the most interesting regions of the earth so far as meteorology is concerned. The winds that circulate over that ocean form an important part of the general circulation of the atmosphere. The treatment of that interesting subject is too large a matter for this book. The main features of the circulation over the surface are given in the *Barometer Manual for the use of Seamen*, M.O. 61, which contains specimen charts illustrating the winds and weather of the Atlantic Ocean, and also isobaric charts of the whole world for each month and for the year; from which a very good idea of the general circulation of the winds near the surface may be obtained.

Some meteorologists have ventured to speculate upon the circulation of the air between the equatorial and polar regions, but at present the available facts are so few that such speculations can be neither confirmed nor confuted. Such real information as we have mostly comes from observations of clouds, and these, which were put together by H.H. Hildebrandsson, a celebrated Swedish Meteorologist, show a great general circulation of the clouds round the pole, and thus confirm a conclusion previously arrived at by the study of isobars calculated from the upper air, by Leon Teisserenc de Bort, a great French Meteorologist.

CHAPTER IV.

FOG AND MIST.

1. Scale of Intensity for Observations of Fog and Mist.

Fog comes next in importance, and for the meteorologist it is much more capricious than the winds, in spite of the fact that they are proverbially fickle. But recently we have learned a great deal about fog, not as much as we want to know, but still a notable amount that is worth the seaman's attention. For the coaster it is a particularly interesting subject, because land-fog and the fog of the high seas are in many respects different things, and the coaster meets with both, sea-fog in summer and land-fog in winter. There is no part of the year when he can reckon upon there being no fog on the British coasts. The skippers of the mail-steamers in Northern waters have the reputation of being able to thread their way in a fog by instinct between the islands, but not everybody has that faculty, and those that have it wisely refrain from presuming upon it.

All that can be done in the way of measuring fog is to form an estimate of its thickness, judging from the allowance which prudent navigators make on account of the inability to see distant objects. For that purpose the scale of intensity from 0, quite clear, to 5, impenetrable fog, has been drawn up for the use of observers and is given here.

	—	On Land.	On Sea.	On River.
No Fog or Mist.	0 *f.*	Horizon clear ...	Horizon clear ...	Horizon clear.
Slight Fog or Mist.	1 *f.*	Objects indistinct, but traffic by rail or road unimpeded.	Horizon invisible, but lights and land-marks visible at working distances.	Objects indistinct, but navigation unimpeded.
Moderate Fog	2 *f.*	Traffic by rail requires additional caution.	Lights, passing vessels and land-marks generally indistinct under a mile. Fog signals are sounded.	Navigation impeded, additional caution required.
	3 *f.*	Traffic by rail or road impeded.		
Thick Fog	4 *f.*	Traffic by rail or road impeded.	Ships lights and vessels invisible at ¼ mile or less.	Navigation suspended.
	5 *f.*	Traffic by rail or road totally disorganized.		

2. Fog on the British Seas and Coasts.

This scale of fog intensity has only been in use for a few years, and we have not yet enough observations to form a sufficient body of statistics about fogs of different intensity. At sea observers

have always been accustomed to draw a distinction between fog and mist, though the distinction, which has been left to the discretion of the observers, has always been rather vague. Charts showing the distribution of fog and mist in the several months of the year over the seas surrounding Britain are given in the Meteorological Atlas to which reference has already been made. For the coasts useful information about fog is contained in the reports sent daily to the Meteorological Office from the twenty-nine coast and inland stations, which report the state of the weather at 7 a.m., 1 p.m., and 6 p.m., and note fog when it occurs at one or other of those fixed hours. The observations received during the 20 years 1896 to 1915 have been summarised for summer and winter separately. The results are represented here in an inset, p. 40; first by a table, which appears on page 4 of the inset, giving the average number of fogs at the hours of observation in a summer, in a winter, and in the year; and, secondly, by three maps, which give the average numbers of days of fog noted at the several stations irrespective of the time of day at which the visitation occurred; and also a series of roses giving the directions of the winds corresponding with the observations of fog at the fixed hours, in order that the seaman may form an idea of the conditions of wind under which fog is likely to occur. The percentage numbers of occasions of fog when the wind was noted as calm are given in a small circle at the centre of the roses. It will be noticed that at inland stations the calm air is the favourite condition for fog, but at the stations on the more exposed coasts there are comparatively few occasions when there is fog on which the wind is so light that no definite direction can be assigned to it. Also at inland stations and on the East Coast of England, as well as at Leith and Liverpool, fogs are more frequent in winter than in summer, but elsewhere the summer is the season of greater frequency. This may be associated with the distinction drawn between land fogs, which belong chiefly to autumn and winter, and sea fogs, which belong to spring and summer.

Note should be taken of the comparative rarity of days of fog at Stornoway, only 6 in the year; at Cahirciveen (Valencia) only 7; and at Blacksod Point only 13, as compared with 47 at Holyhead, 43 at Spurn Head and Yarmouth, 40 at Roche's Point, Pembroke and London, and 39 at Oxford. The geographical positions of these places are indicated on a key-map on Plate I. of the inset.

3. Mist.

One of the persistent meteorological questions for which a solution has been sought for a long time, is the difference between fog and mist. There is frequently a peculiar indistinctness in the atmosphere which makes the horizon invisible or indistinct, but does not otherwise interfere with navigation. It may be due, on the one hand, to smoke or dust, or it may be due to minute drops of water in the air that would form a fog if there were enough of them. Seamen, as a rule, do not distinguish between these two causes, but indicate the lack of good seeing by logging mist or sometimes haze. Perhaps they might draw a distinction by finding out whether the air is very moist or dry at the time, and always noting haze when the seeing is not good and the air is dry; but to find that out, careful measurements with thermometers specially arranged for the purpose are wanted, and unless all observers are suitably provided with the necessary apparatus and are careful about it on every occasion, the records are apt to become confusing, so at present we class together as mist those cases in which the horizon is obscured, but navigation is unimpeded.

4. Visibility.

It is the presence of a multitude of minute particles in the atmosphere which causes a seaman's mist, which spoils the distinctness of very distant objects at sea and makes the difference between good visibility and poor visibility on occasions when there is nothing that would be called actual fog. Whether they be water droplets too few to be recognised as a cloud or consist of smoke or dust which is carried along by a light wind in the surface layers of air and cannot get away because there is an invisible canopy of warmer air overhead impenetrable by the smoky air, the effect is the same and the difference of visibility on different occasions is very noticeable.

Dr. John Aitken, F.R.S., has given a rule for calculating the distance which limits the visibility when the number of dust particles in a specified volume of air is measured by a "dust-counter" which he has devised. But it is a process with which seamen are not familiar. Nor are there many observations of the distances at which objects can be seen in different states of the weather and the lighting. To help in deciding questions in this subject a scale of visibility has been drawn up in consultation with the Hydrographic Department which is specified as follows:—

Visibility Scale. (M.O. 2678, 25th Feb., 1918.)

1. Very low, object indistinctly seen at 0 to ½ mile.
2. Below ordinary, object indistinctly seen at ½ to 2 miles.
3. Ordinary, object indistinctly seen at 2 to 8 miles.
4. Above ordinary, object indistinctly seen at 8 to 16 miles.
5. Unusual, object indistinctly seen at 16 to 32 miles.
6. Exceptional, object indistinctly seen at above 32 miles.

From an examination of a set of observations from one of the British Seas we find that visibility goes to a certain extent with the meteorological situations, which will be described in Chapter XI. A secondary depression is bad for seeing, and roughly speaking we may pass from bad seeing to good seeing in the following order: secondary depression with an average distance of 6·6 miles, straight isobars 6·9 miles, cyclonic weather 7·3, V-shaped depression 7·7, col 8·5, anticyclone 11·3, and wedge 12·2 miles, with which we may get the "unusual visibility" denoted by *v* of the Beaufort Scale. We cannot say yet that this holds true for all seas, or indeed always. The investigation has only just begun; the reader may perhaps be interested to examine the question for himself.

FOG

Maps Showing the Average Number of

DAYS WITH FOG

At the Telegraphic Reporting Stations of the

METEOROLOGICAL OFFICE

In the Twenty Years, 1896-1915.

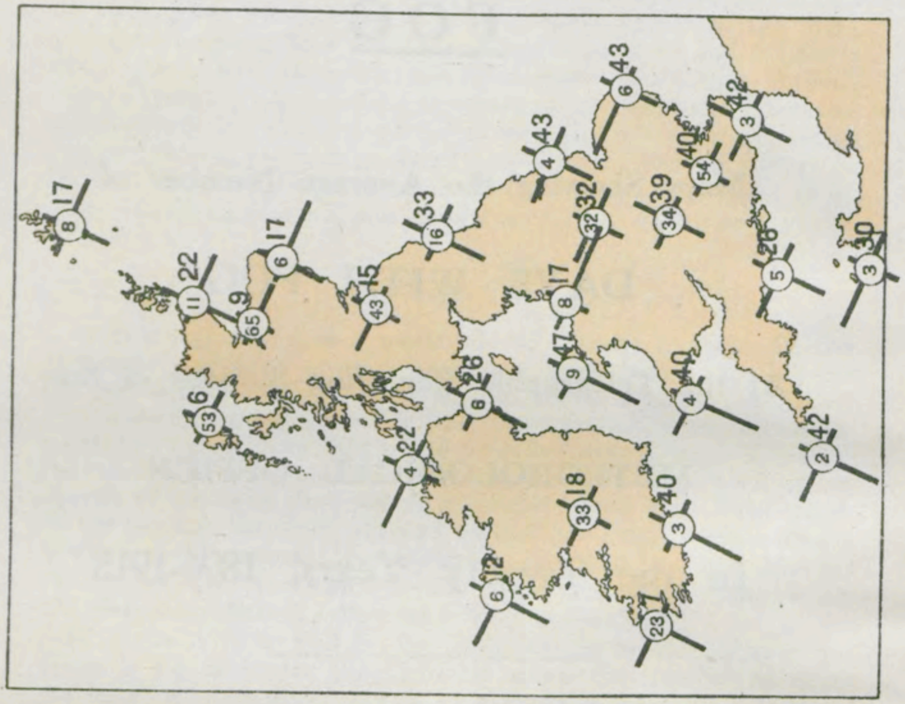
Indicating also the Relation of Fog to the Direction of the Wind from Observations made at 7 a.m., 1 p.m., 6 p.m., and 9 p.m. (7h., 13h., 18h., and 21h. G.M.T.).

Note.—*Before* 1*st July*, 1908, *the observations were made at* 8*h. and* 14*h. instead of* 7*h. and* 13*h.*

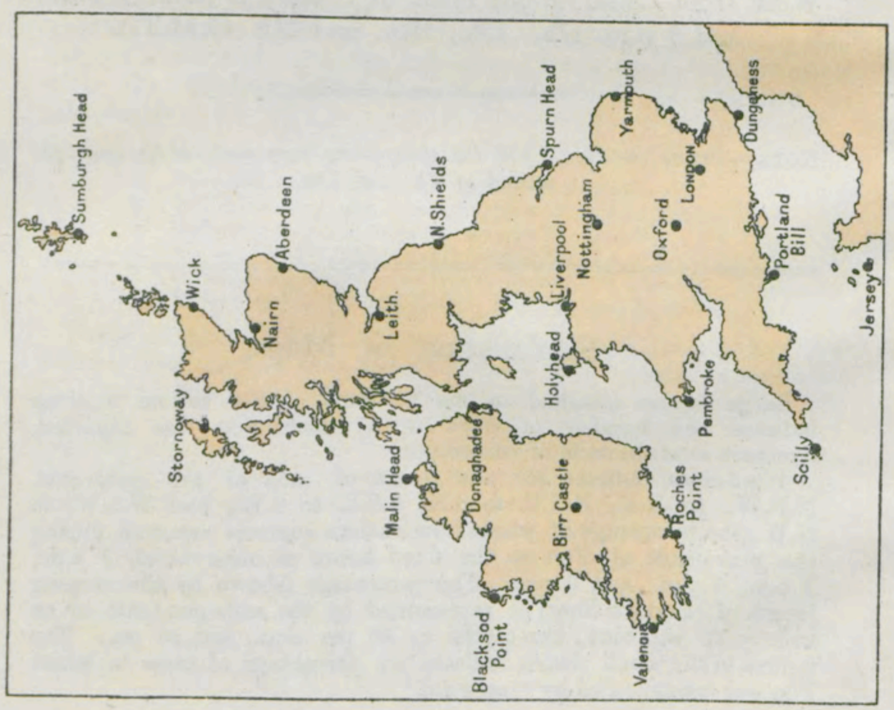
Explanation of Maps.

Large figures attached to the positions of the various stations indicate the number of days upon which Fog was reported, irrespective of the time of occurrence.

Wind-roses indicate for the centre of each of the quadrants, N.N.W., to N.E., E.N.E. to S.E., S.S.E. to S.W., and W.S.W. to N.W., the percentage of winds from various quarters reported during the prevalence of Fog at the fixed hours of observation, 7 a.m., 1 p.m., 6 p.m., and 9 p.m. The percentage (shown by the varying length of the dark lines) is represented by the scale one tenth of an inch = 20 per cent., two-tenths = 40 per cent., and so on. The figures in the small circles indicate the percentage of cases in which Fog was accompanied by "no wind."



RESULTS FOR THE ENTIRE YEAR.



MAP SHOWING POSITIONS OF STATIONS FROM WHICH INFORMATION WAS SUPPLIED.

RESULTS FOR THE WINTER HALF-YEAR
OCTOBER–MARCH.

RESULTS FOR THE SUMMER HALF-YEAR
APRIL–SEPTEMBER.

AVERAGE NUMBER OF OBSERVATIONS OF FOG PREVAILING AT FIXED HOURS AT VARIOUS STATIONS IN THE UNITED KINGDOM.

Number of Years of Observations at				—	STATION.	THE SUMMER.				THE WINTER.				THE YEAR.			
8h. or 7h.	13h. or 14h.	18h.	21h.			7h.	13h.	18h.	21h.	7h.	13h.	18h.	21h.	7h.	13h.	18h.	21h.
20	20	20	7	North Coast.	Sumburgh Head	10	4	6	9	2	1	1	1	12	5	7	10
20	20	20	7	North Coast.	Stornoway	2	0	1	0	1	0	0	0	3	0	1	0
8	8	8	7	North Coast.	Castlebay	9	3	7	3	2	1	2	0	11	4	9	3
20	5	20	5	North Coast.	Wick	11	3	7	6	1	1	1	2	12	9	8	8
20	20	20	—	North Coast.	Nairn	3	2	2	—	2	2	2	—	5	4	4	—
20	20	20	—	North Coast.	Aberdeen	4	1	3	—	1	0	0	—	5	1	3	—
20	—	20	—	North Coast.	Leith	2	—	0	—	7	—	2	—	9	—	2	—
20	20	20	2	East Coast	North Shields	8	2	3	4	8	4	4	6	16	6	7	10
20	20	20	7	East Coast	Spurn Head	7	3	3	4	12	5	7	6	19	8	10	10
20	20	20	7	East Coast	Great Yarmouth	5	1	1	1	25	10	9	8	30	11	10	9
12	7	12	7	East Coast	Clacton-on Sea	1	0	0	0	6	2	2	1	7	2	2	1
20	20	20	7	West Coast.	Malin Head	8	4	6	1	3	1	3	1	11	5	9	2
20	20	20	7	West Coast.	Belmullet / Blacksod Point	3	1	2	4	2	1	2	2	5	2	4	6
20	20	20	2	West Coast.	Valencia	2	0	1	0	2	0	0	0	4	0	1	0
20	20	20	—	West Coast.	Roche's Point	8	3	4	—	5	2	3	—	13	5	7	—
20	13	20	7	West Coast.	Donaghadee	7	2	2	3	3	2	2	4	10	4	4	7
20	—	20	—	West Coast.	Liverpool (Bidston Observatory)	1	—	0	—	6	—	1	—	7	—	1	—
20	20	20	7	West Coast.	Holyhead	16	9	9	8	9	4	7	4	25	13	16	12
20	17	20	7	West Coast.	Pembroke (St. Ann's Head)	11	6	6	7	7	3	5	5	13	9	11	12
20	20	20	8	South Coast.	Scilly (St. Mary's)	14	7	9	10	6	4	6	5	20	11	15	15
20	20	20	7	South Coast.	Jersey (St. Aubin's)	5	1	3	2	5	2	4	1	10	3	7	3
20	20	20	7	South Coast.	Hurst Castle / Portland Bill	5	4	4	3	5	2	2	2	10	6	6	5
20	20	20	—	South Coast.	Dungeness	7	2	2	—	10	3	3	—	17	5	5	—
8	—	8	—	South Coast.	Dover	3	—	0	—	7	—	2	—	10	—	2	—
20	20	20	5	Inland.	London	3	0	0	1	19	7	6	8	22	7	6	9
17	—	17	—	Inland.	Oxford	4	—	0	—	24	—	4	—	28	—	4	—
20	13	20	7	Inland.	Loughborough / Nottingham	5	0	0	0	20	6	6	5	25	6	6	5
12	—	12	—	Inland.	Bath	1	—	0	—	5	—	2	—	6	—	2	—
20	4	20	—	Inland.	Birr Castle	4	0	0	—	6	2	1	—	10	2	1	—

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CLOUDS.

SOLAR HALO OBSERVED AT ABERDEEN.

Reproduced from a sketch by G. A. Clarke, Aberdeen Observatory.

FIG. 1.

Solar Halo of 22° radius, May 27, 1912. Complete circular halo, with arc of contact. Semi-major axis of the ellipse of which the arc of contact forms a part was about 29°.

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CHAPTER V.

CLOUDS.

1. Clouds of Water Drops and Ice Particles.

Next we come to clouds. Anyone who has been in a fog at sea knows what clouds are like in the inside because fog is a cloud which lies on or moves along the surface. Some are thicker than others, but there is not much water in any of those that drift past us. A cloud may be recognised as such even when the water-drops in a cubic yard taken altogether do not amount to more than a grain, or a thick cloud may contain fifty times that amount. In the commotion of a thunder-shower more water than this may be carried upward as rain or hail in an uprush of air and help to darken the sky, but it is scarcely to be called cloud in the special sense in which we shall use the word in this chapter, any more than the débris that is carried upward from a pit-shaft in the rush of an explosion can be classed as cloud. The visible particles that form a cloud are generally globules of water, but sometimes they are minute crystals of ice, called ice needles. All the clouds that look like tufts of hair or mares' tails and for that reason are called "*cirrus*," the Latin word for a tuft of hair, are, with good reason, regarded as being formed of ice-crystals, but the difference between a cloud of water drops and a cloud of ice-crystals is hardly noticeable to anybody inside the cloud. It is more noticeable to one who looks at them from a distance. It is the clouds of ice-particles that form *halos*, which are bright rings with the sun or moon in the centre. A sketch of a halo-ring is reproduced in figure 1. Halo-rings have not, as a rule, much colour, but if they are coloured the red is inside and the blue outside. The rings are of large diameter, at least 44° of arc, and between them and the sun or moon in the centre the sky is uniformly light grey. Clouds of water-drops form brilliantly coloured rings close up to the sun or moon, which are called *coronæ*, the latin word for crowns; the outer ring is red with blue inside, and sometimes the sequence of colours is repeated. Halos are often accompanied by "mock suns" or "mock moons," which are bright patches of light at certain parts of the halo-rings, and also by "sun-pillars" or columns of bright light above the sun when it is near sunset, and all of these effects are attributed to ice-crystals.

But it is mostly with the clouds looked at from outside and not with their inner structure that the seaman is concerned. With proper care and attention he can tell the direction from which they are coming and form an estimate of the rate at which they are moving, not strictly speaking of their actual speed because to find that out he must know their height, but the rate at which they appear to cross the sky. In this way they give a good indication of the way in which the wind is blowing in the upper air.

2. Cirrus, Cumulus, Stratus and Nimbus.

Cloud forms are of almost infinite variety, and they range themselves at various heights from the ground where we find fog, up to about 30,000 feet, where we find the wisps and tufts of *cirrus*, or the beautiful groups of cloudlets that form a mackerel sky, or the pearly haze that forms the halo-sheet. In the intermediate region we find a great variety of clouds, some of which are obviously, or at least apparently, in level sheets, and are called *stratus*, the Latin word which means "spread out flat"; and others are equally obviously in heaps, large or small, sometimes detached and sometimes forming connected groups. These heap-clouds are called *cumulus*, the Latin word for a heap.

These three characteristic forms of clouds, *cirrus*, the thread cloud, Figures 2 and 3; *cumulus*, the heap cloud, Figure 4; and *stratus*, the level stretch, are quite easily distinguished. The names were introduced in 1802 by Luke Howard, a celebrated meteorologist; so that the beginning of the modern study of clouds dates back almost to the same time as the beginning of the modern study of winds. Howard introduced also into modern meterology the word *nimbus*, the Latin word for a rainstorm or rain-cloud, to define that form of cloud from which rain is falling or usually falls. It is familiar enough to all of us, a dark cloud with ragged edges, Figure 5, but it is too close to the observer for him to form any idea of the shape or structure. What takes place above the dark layer, cloud above and falling drops of rain below, is a matter of speculation. Where the raindrops are actually formed, whether within or above the clouds which we see, we cannot tell until the investigation of the upper sky by airmen or by the older means of meteorological exploration gives us the necessary information.

These fundamental forms of cloud are universal; they are to be found in every part of the world; cirrus is to be seen on occasions in any country. In some parts of the world, principally in lower latitudes, cumulus is more frequent than stratus; and in others, as in our own regions and more generally over the Northern Atlantic, stratus is more frequently in evidence. With very few exceptions, such as rain from strato-cumulus or rain from a clear sky, which the French call "serein," whenever there is rain in any part of the world there is nimbus cloud.

Clouds. Figures 2 to 5. Cirrus, Cumulus, and Nimbus.

FIG. 3.—Cirrus Clouds, Thread or Feather clouds at a height of from five to six miles, and generally of a white colour. They are composed of ice-crystals. The picture gives an idea of rather more massive structure than is usual with cirrus clouds, but the sweeps and wisps are very characteristic.

FIG. 5.—Lower part of Nimbus. 1907—May 18, 11h. 33m. (W.J.S.L.)

FIG. 2.—Cirrus.

FIG. 4.—Cumulus. 1907—June 22, 11h.

Fig. 7.—Rippled Cirro-cumulus. 1909, Feb. 4, 11h. 50m.

Fig. 9.—Alto-cumulus. 1907, Feb. 27, 14h. 10m.

Fig. 6.—Cirrus and rippled Cirro-cumulus. 1909, Feb. 4, 10h. 40m.

Fig. 8.—Cirro-cumulus becoming Alto-cumulus. 1909, Feb. 4, 12h. 15m.

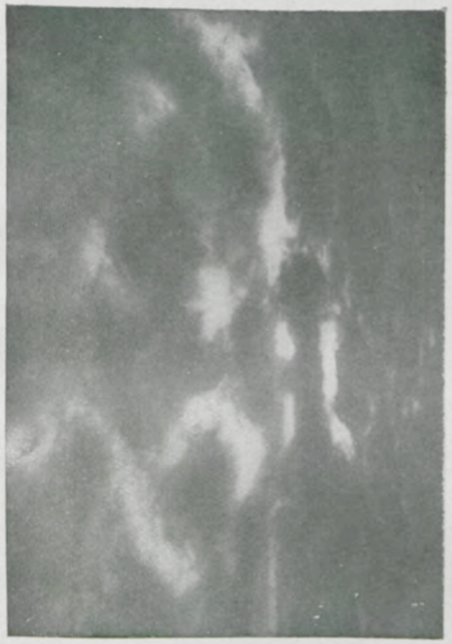


Fig. 11.—Alto Stratus. Heavy Strato-Cumulus. 15h. 20m.

Fig. 13.—Strato-Cumulus from an aeroplane (4,000 feet).

Fig. 10.—Strato-Cumulus. 14h. 20m.

Fig. 12.—Roll Cumulus.

Clouds. Figures 14 to 17. False Cirrus and Cumulo-Nimbus.

Fig. 15.—Top of Cumulo-Nimbus. 1907—June 28, 13h. (G.A.C.)

Fig. 17.—Cumulo-Nimbus (Thunder-cloud) with "Anvil" extension of false cirrus, 30th October, 1915.

Fig. 14.—A Tuft of "False" Cirrus. 1910—July 6, 16h. 55m.

Fig. 16.—"Anvil" shaped Cumulo-Nimbus

3. Other Forms of Cloud.

But all the clouds that we see cannot immediately be classified by assigning them to one or other of these four classes. Quite frequently an observer, looking at the sky, may find it full of clouds with a variety of forms, and yet he cannot find the tufted cirrus, nor the level stratus, nor the heaped cumulus, nor the rainy nimbus. We can go a step further; there is first of all the mackerel sky, Figures 6-8, a beautiful collection of little flocks of fleecy cloud arranged in patterns—stripes or waves, or even criss-cross, purely white, too thin to show any shading in their whiteness unless they happen to be quite low down against the sun These collections of cloudlets are very easily recognised. The French call them "moutons," meaning a flock of fleecy sheep. They are very high and belong to the region of cirrus; but as they are separate cloudlets and suggest very small cumulus more than wisps of hair, they are called *cirro-cumulus*, Figure 7. They seem to merge gradually into clouds of very similar type, but of coarser structure with larger cloudlets, Figure 8, that are in parts so close together as to form a layer of dappled grey. The whiteness of the separate cloudlets is tinged with the grey of shadow. They are still more suggestive of cumulus than cirro-cumulus, and they are lower and rather heavier; they belong to a region where there is more water to form clouds, but they are still high, generally between 10,000 ft. and 25,000 ft. They have got a separate name on that account, namely, *alto-cumulus*, Figure 9, or high cumulus; but sometimes it is difficult to decide whether a particular group shall be classed as *cirro-cumulus*, without shadows, or *alto-cumulus*, a similar pattern with slight shadows. On the other hand, if they are watched, they may often be seen to deepen and darken and join up into an extensive layer, when they lose any suggestion of separate cloudlets except at the edges, and are called *alto-stratus*. Still lower down, near enough for the observer to see a good deal of detail of the structure, we get clouds of great variety that are classed as *strato-cumulus* Figures 10, 11, 13, by far the most frequent and varied cloud in our islands. Its lower surface is generally worked to a sort of level. The upper surface, which has been photographed from aeroplanes, is also more or less level, with occasional bulges. The cloud may cover a large area, sometimes the whole of the observer's sky; it may be made up of regular rolls, when it is called *roll-cumulus*, Figure 12, or of irregular patches, giving the sort of appearance that alto-cumulus might give if one were much nearer to it. It is sometimes thin, showing only little shading, sometimes thick, showing patches of heavy shadow. It may deepen and darken until it passes into nimbus.

The peculiarity about this type of cloud is its persistence. It may cover the sky the whole day without letting the sun through on the one hand, or developing into rain on the other. Somewhat like it is the layer of clouds in the trade winds which form day after day in a sort of level layer. They are evidently dependent upon some element in the structure of the atmosphere which is quite general in its application, and which is more allied to the formation of fog with its level top-surface than to the formation of nimbus, with its heavy superstructure.

Besides all these, we have the peculiar high haze overspreading everything which is sufficient to hide the blue of the sky, but not thick enough to hide the sun, though it may reduce, sometimes considerably, the intensity of its light. It is the highest of all clouds, called in its thicker forms which show like a tangled web of threads, *cirro-stratus*, and in its thinner forms, *cirro-nebula* or cirrus haze. It is this layer which produces the halos.

4. Developments of Cumulus.

Cumulus cloud in its ordinary form, seen in Figure 4 as a comparatively small, detached cloud, ranks as a fine-weather-cloud, but the more exaggerated developments of the same type of structure are characteristic of showers and thunderstorms. Some towering clouds have on the margin wisps of thread-like cloud, which is called "false cirrus," Figure 14, because, though it is like a tuft of hair, it is not formed separately in the clear blue sky where cirrus is generally found, but as a tuft of thread-like structure springing out of the grosser towering mass. The towering clouds are all covered by the name *cumulo-nimbus*, a heap cloud that means rain and often thunder, Figure 15. They include the anvil-cloud, Figure 16, a turreted cloud with an anvil-shaped extension of false-cirrus; the thunder-cloud, a castellated cumulus, 17, the shower-cloud, and the arched cloud of very characteristic form, which is the forerunner of a line-squall, *see* p. 129.

Some other terms used with reference to clouds may be explained here: *Scud* is the sailor's name for detached cloud that drifts underneath nimbus; why it should form there is an interesting question.

A *hard sky* occurs when the clouds have well marked sharp or hard outlines; and, on the other hand, the sky is *soft* when there are no well-marked outlines to the features of the clouds.

5. The Extent or Amount of Cloud.

Next to forms of cloud, the extent to which the cloud-sheet spreads over the sky deserves the attention of the observer with his note-book. We have a simple way of noting this by estimating the number of tenths of the sky which are covered by cloud, and thus forming a scale of the amount of cloud in the sky. On this scale 0 means that there is no cloud at all, or that what there is covers less than one tenth of the whole sky; 10 means that the sky is completely overcast; 5 that five-tenths or one-half of the sky is covered, and so on. Some practice is required in order that a good estimate may be formed, and therefore, to begin with, an observer had better first divide his sky into quarters and estimate what fraction of each of the four quarters is covered before he settles his figure for the whole.

CHAPTER VI.

WEATHER.

1. The Beaufort Notation.

It is hardly necessary to go into any explanation of what is to be understood by *weather*, but it is desirable to have some understanding as to the way in which it may be described briefly, so that a definite impression may be preserved and conveyed. Weather includes not only wind and the state of the sky, clear, cloudy or overcast; the state of the air, clear, misty or foggy, warm or cold; but also such conditions as rain, hail or snow; and when these occur, whether it is steady rain, showers or drizzle that should be noted, and whether there is thunder or lightning, dew or hoar frost. The method of dealing with wind, fog and cloud has already been explained, and in the next chapter we shall have something to say about warmth and cold; but for a concise indication of the sequence of weather in the most general terms and in a uniform manner, we use a code of letters which was originally introduced by Admiral Sir Francis Beaufort for use at sea, but which is equally convenient for use on land. Some additions have been made to the original schedule and it now stands as follows:—

Beaufort Notation.

b	blue sky (not more than a quarter of the sky covered).	p	passing showers.
bc	sky partly cloudy (one half covered).	q	squalls.
c	generally cloudy (three quarters covered).	r	rain.
d	drizzle, or fine rain.	rs	sleet, *i.e.*, rain and snow together.
e	wet air without rain falling, a copious deposit of water on trees, buildings or rigging.	s	snow.
f	fog.	t	thunder.
g	gloom.	u	ugly, threatening sky.
h	hail.	v	unusual visibility. The horizon or distant hills unusually clear.
l	lightning.	w	dew.
m	mist.	x	hoar frost.
o	overcast sky.	y	dry air (less than 60 per cent. humidity).
		z	dust haze; the turbid atmosphere of dry weather.

2. International Weather Symbols.

It will be noticed that in this code or notation nothing is provided for noting gales or strong winds other than squalls, for warmth or cold, or for such phenomena as rainbows, halos, coronæ or glories, and many others which are of great interest for those who watch the weather. These need not, however, go unnoted on that account. Winds, clouds, and warmth and cold are otherwise specially provided for, and by international agreement a code of symbols has been arranged by which the occurrence of the various optical phenomena can be noted with brevity and accuracy. The international code of symbols includes also some of the conditions which are covered by the Beaufort notation so that there is some overlapping, but the complete code is given here for the purposes of reference.

Beaufort Letter.	International Symbol.	—
b	...	Blue sky, cloudless, or not more than one quarter covered.
bc	...	A combination of blue sky with detached clouds.
c	...	Sky mainly cloudy, but with openings between the clouds.
o	...	Completely overcast.
g	...	Gloom.
u	...	Ugly, threatening sky.
e	...	Wet air, without rain falling.
r	or ●	Continuous rain.
d	●◦	Drizzle.
s	✱	Snow.
p	●	Passing showers.
h	▲	Hail.
...	△	Soft hail.
...	↞	Ice crystals.
...	⊠	Snow on ground.
...	✢	Snowdrift.
...	⫽	Gale.
q	▽	Squalls.
l	<	Lightning.
t	T	Thunder.
...	⊤	Thunderstorm.
f	≡	Fog.
fe	≡:	Wet fog.
m	≡°	Mist.
...	☰	Ground fog.
z	∞	Dust haze.
w	△	Dew.
x	⊔	Hoar frost.

Beaufort Letter.	International Symbol.	—
...	V	Rime.
...	∼	Glazed frost.
v	...	Unusual visibility of distant objects.
...	⊕	Solar halo.
...	⦶	Solar corona.
...	⋓	Lunar halo.
...	⋓	Lunar corona.
...	⌒	Rainbow.
...	⩊	Aurora.
...	◥	Zodiacal light.

3. Other Terms Used in the Description of Weather.

There are still a number of words which are used occasionally in ordinary writing to describe special conditions of weather, and for which no definition has yet been provided. Of these let us mention in alphabetical order anticyclonic, blizzard, climate, cloudburst, cyclonic, equatorial, fair, fine, freezing, improving, mirage, normal, polar, pressure, temperature, thaw, tornado, tropical, whirlwind. Most of these words are explained in the Meteorological Glossary, M.O. 225 ii., and we may be content here with a word or two of explanation. **Anticyclonic** and **cyclonic** belong to the description of the distribution of pressure, and will be explained in the chapters on the Barometer and the Weather Map. Here we need only say that anticyclonic is used for the conditions that are to be found round a centre where the barometric pressure is higher than in the surrounding region, and, on the other hand, cyclonic is used for the conditions to be found round a centre where the barometric pressure is lower than in the surrounding region.

Blizzard is an American word used for a strong gale of intensely cold wind, far below the freezing-point, which carries fine snow. There is a tendency in this country to use it for any snowstorm accompanying strong wind.

The **climate** of any locality is the summary of the general experience of weather there, and its expression is obtained by a summary of all the observations of weather in the locality extending over a long period of time.

Cloudburst is often used to describe very heavy local rainfall common in thunderstorms.

Equatorial and **polar** are related terms applied often to winds to mean that the air which forms the wind has come from the region of the equator or from near the pole, as the case may be.

Equinoctial is often used with regard to gales if they happen to occur near the autumn equinox, September 22nd, or the vernal equinox, March 21st, the two periods of the year when the astronomical day and night are equal and each of 12 hours.

In spite of the common use of the expression equinoctial gales, it will be seen in what has been given in the chapters on wind that the equinoxes are not the most stormy times of the year in the British Seas; they are the times at which the gales of winter begin to occur towards autumn, and begin to leave off towards spring.

Fair and **fine** are words which are often used as meaning the same thing, but we find it convenient to draw a distinction by limiting the word **fine** to occasions when the sky is clear or only clouded in a small part, so that the sun, moon or stars are visible; while **fair** is reserved for occasions when we mean that no rain is falling or imminent, but we do not wish to say that the sky is clear. Fair weather becomes fine when it is bright or brilliant.

Freezing, frost and **thaw.**—These words belong to the description of the physical state of water in relation to **temperature**, which is a technical term used to define how warm or how cold the air is. The air is freezing when it is colder than water at its freezing point and water becomes ice; and a thaw occurs when the air is warmer than at the freezing point of water and ice becomes water. **Frost** is sometimes used for a period of freezing weather which the Americans call a freeze, and sometimes for a night-frost—the short period of freezing at or near the ground on a calm night or early morning when the surface is chilled by the loss of its heat by radiation into a clear sky. It is also used, as in **hoar-frost**, to indicate the deposit of feathery ice on grass, leaves, &c., which occurs during a night-frost.

Improving is a word which is very popular with writers on the weather for transition from foul, rainy and windy weather to fair or fine conditions and more moderate wind. Underlying the use of the term is the idea that perfection in weather is clear sky and no wind. It is natural for us to think so, but there are many countries where a clear sky is regarded as pitiless, so we want a better word for the transition from rainy to fair weather.

Mirage.—This is a term which is used to describe the appearance of a landscape, buildings, trees or water in positions where they do not actually exist. Mirage is caused by reflection or refraction of rays of light by the layers of air near the earth's surface. Refraction almost always has some effect in altering the apparent position of what we see at a great distance. Even the sun, moon and stars are not as a rule exactly in the line at which we see them; but in exceptional cases, looking along the surface, the apparent position of objects is very much displaced. Sometimes they appear inverted by reflexion, and the distortion of shape is often so great that the observer is quite misled as to what he sees and where he sees it. The phenomenon is a very interesting one and purely meteorological; it is curious that there is no international symbol for it.

Normal is a word which occurs very frequently in the study of weather, and indicates the condition round which actual experiences are grouped, some above normal, others below. Thus we may have a normal pressure, a normal temperature, a normal wind, a normal number of fogs or rainy days in a month or a year with which we can compare the actual pressure, temperature, wind, number of fogs or of rainy days in any month or year. There are a great variety of normals to be noted for any place, and the differences of the various normals for different localities indicate the differences of local climate.

Tornado and **whirlwind** mean much the same thing, namely, a whirling column of air that is carried along over the country causing very violent winds. In the tornado of the American plains we have the most violent winds experienced on the earth, and a whirlwind is of the same nature but generally less violent.

Tropical is generally used with regard to heat or storms. The tropics are two circles round the earth, 23½ degrees north and south of the equator, which mark the extreme limits of the region over which the sun at noon is directly overhead some time in the year. Further north or further south there is always some sloping of the sun's rays. The region between the tropics is the region where the sun's heat is most fierce, and for that reason exceptionally great heat is often called tropical. Within the tropics, and also in some other localities, violent storms of revolving winds are formed which are called tropical hurricanes. They are much more violent than our gales and storms; much larger in extent than tornadoes but rather less violent, and are the worst kind of storm experienced at sea. They generally begin over the ocean, but sometimes travel from the sea overland, particularly in the Philippines, the West Indies, India and Mauritius.

CHAPTER VII.

WARMTH AND COLD.

1. Thermometer.

The range of warmth and cold which is to be met with in the British Isles is not very large. It is very fairly represented by the graduations 0° and 100° on the scale of the Fahrenheit thermometer. On the same scale, the normal temperature of the human body, which is called "blood heat," is a little above 98°, and the temperature at which water freezes, as we go downward in the scale, or at which ice melts as we go upward in the scale is 32°. Under normal conditions water boils at 212°. Anything above 80° indicates a hot day; 90° in the shade a very hot one. The technical term for the measure of the warmth or the coldness of the air is *temperature* and the instrument for measuring it is called a *thermometer*. It is a bulb of glass about half an inch in diameter at the end of a glass tube which is called the stem of the thermometer and which has so fine a bore that it is called a capillary tube, from the latin word "capillus" meaning a hair. At the top of the stem is a little cavity. The bulb and stem and cavity are all filled with mercury or, in the case of some thermometers with alcohol or some other liquid, and when the bulb is much hotter than it is ever likely to be when it is in use, the end of the stem is sealed off in a blow-pipe. The working of the instrument depends on the fact that the mercury or the alcohol or whatever the liquid may be, expands when it is warmed and contracts when it is cooled. The glass bulb and the bore expand too, but so much less than the liquid that when the thermometer gets warmed it shows the fact by the liquid getting further up the stem. On the other hand, when it gets colder the liquid retreats towards the bulb. The accompanying figure 2 (p. 53) gives on its extreme right the picture of the graduation of a mercury thermometer such as is generally used for observations of temperature at sea.

The graduations are put on by the instrument-maker and are carefully tested by comparison with standard instruments at the National Physical Laboratory; a certificate of the comparison accompanies every instrument that is employed for observations which are to be used as records. Without the certificate one cannot be sure that the graduations of the thermometer have not serious errors. Thermometers of ordinary glass get to read too high in the course of time, sometimes by as much as a whole degree.

The mercury thermometer can be used for all the temperatures likely to be met with in the neighbourhood of our coasts. In the arctic and antarctic regions and in parts of Siberia and North America temperatures are sometimes so low that mercury may freeze. Alcohol thermometers are available below the temperature at which mercury freezes.

The measurement of temperature has been extended, both above and below, far beyond the range which is met with in the open air. Some of the temperatures which have been reached are set out in a diagram, Fig. 2. It will be seen that there are three different scales set out in the diagram. The Fahrenheit, marked Fahr.; the Centigrade, marked Cent., on which the normal freezing point of water is marked 0 and the normal boiling point 100; and the absolute (centigrade) scale which has the same divisions as the centigrade, but the zero of the scale is 273° below the freezing point of water. This is a very useful scale when calculations about air have to be made, as in the case of the buoyancy of a balloon. The weight of any sample of air is directly proportional to its volume and to its pressure divided by the temperature measured on that scale. For that and other reasons the absolute scale is now used by the Meteorological Office for the "attached thermometer" of mercury barometers.

3. Exposure of Thermometers for the Temperature of the Air.

It is not altogether an easy matter to determine the temperature of the air at sea. The thermometer must be protected from the sun and from spray and yet be freely exposed to the rush of air. A protected corner is not a good place for it. To shield it against the sun and spray a louvred box, such as is shown in figure 1, is generally used.

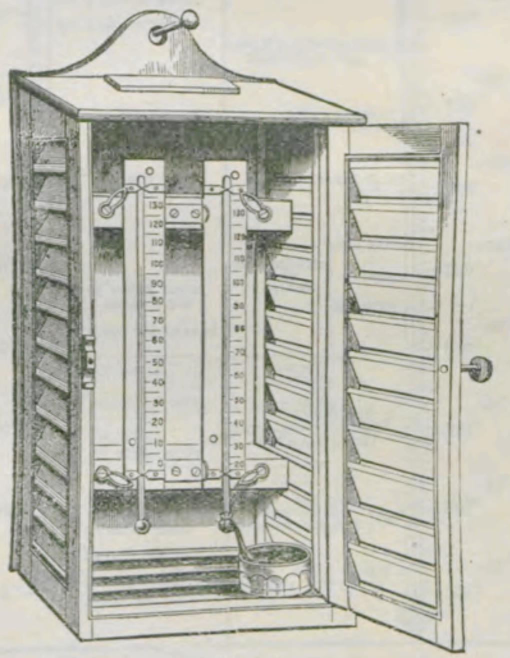


Fig. 1.

The box should be set up where it is freely exposed to the wind, and away from the hot air that surrounds funnels or finds its way from engine rooms, cook's galleys or cabins. Anyone who is curious about the difficulty of finding the temperature of the air at sea should watch what happens to the thermometer on a sunny day when the ship stops to anchor. Everybody knows that the "climate" of a moving ship is quite different from one at anchor, and the thermometer will show it.

4. Maximum and Minimum Thermometers.

Thermometers are made in many forms of which the most common is that of the simple mercury or alcohol thermometer which has been described. The most important modifications are the maximum thermometer (very much used in weather-observations to give the highest temperature of the day) which contains an index in the stem to register the highest point which the mercury has reached since the instrument was last "set"; and the minimum thermometer, generally an alcohol thermometer, which also contains an index in the stem to register the lowest point which the alcohol has reached since the instrument was last "set." This is used to register the lowest temperature of the night. A very useful instrument is the *thermograph,* which gives a continuous record of the temperature on a ruled paper driven round by clockwork like the drum of a barograph, which is described in the next chapter.

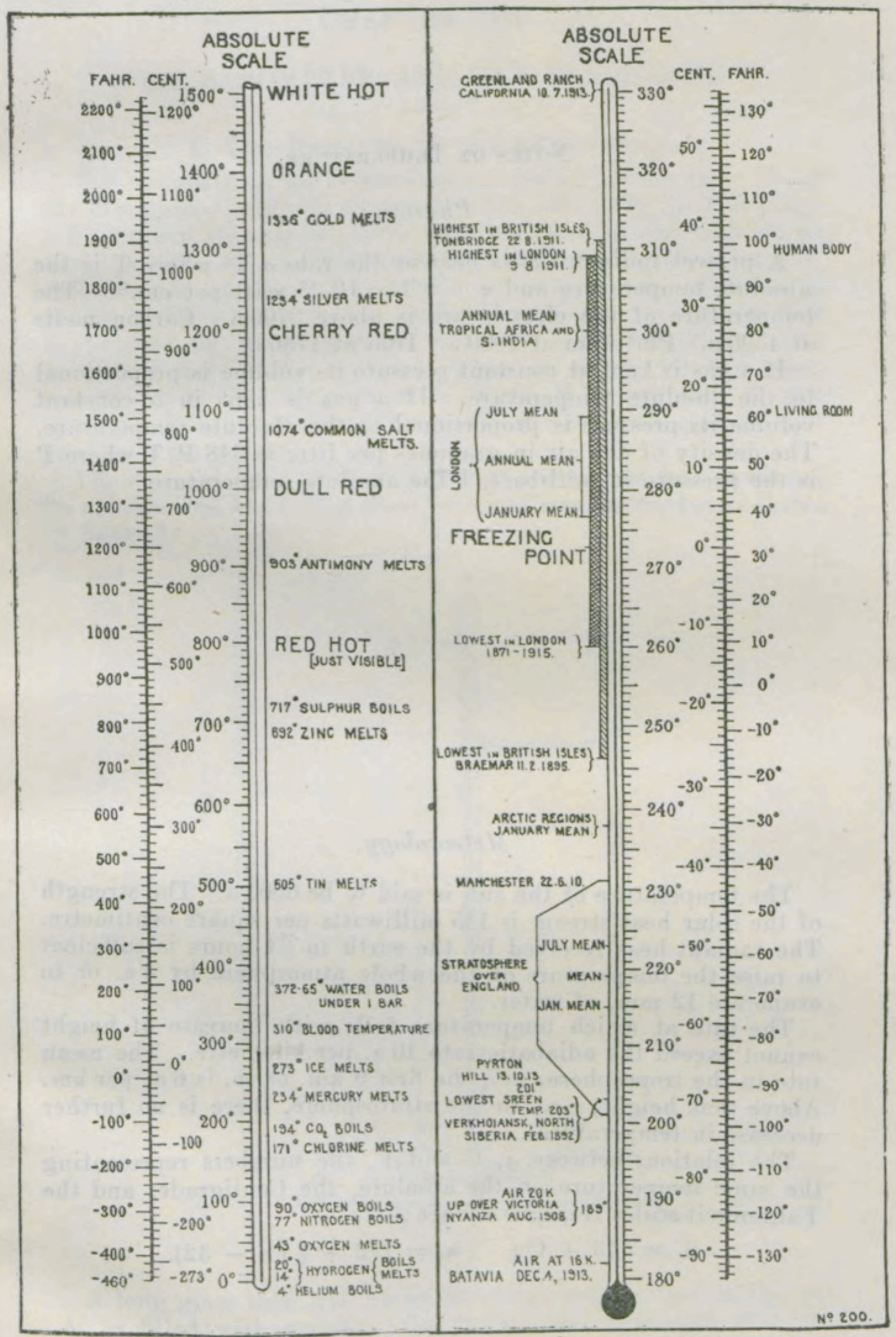


Fig. 2.—Temperature Scales.

Comparison of the Absolute Scale of temperature with the Fahrenheit and Centigrade Scales. Extreme and mean air temperatures, and a selection of physical thermometrical constants.

Notes on Temperature.

Physics.

A perfect radiator emits heat at the rate σT^4 where T is the absolute temperature and $\sigma = 5{\cdot}3 \times 10^{-12}$ watt per cm.^{2} The temperature of the electric arc is above 3700 a. Carbon melts at 4300 a. Platinum at 2000 a., Iron at 1780 a.

If a gas is kept at constant pressure its volume is proportional to the absolute temperature. If a gas is kept in a constant volume its pressure is proportional to the absolute temperature. The density of dry air in grammes per litre is 348 P/T where P is the pressure in millibars, T the absolute temperature.

Meteorology.

The temperature of the sun is said to be 6000 a. The strength of the solar heat stream is 135 milliwatts per square centimetre. The radiant heat received by the earth in 24 hours is sufficient to raise the temperature of the whole atmosphere by 3 a. or to evaporate 12 mm. of water.

The rate at which temperature falls with increase of height cannot exceed the adiabatic rate 10 a. per kilometre. The mean rate in the troposphere, *i.e.*, the first 9 km. or so, is 6 a. per km. Above that height, *i.e.*, in the stratosphere, there is no further decrease in temperature.

The relations between a, C and F, the numbers representing the same temperature on the absolute, the Centigrade, and the Fahrenheit scales respectively are:—

$$a. = 273 + C\,; \qquad a. = 273 + \tfrac{5}{9}\,(F - 32).$$

CHAPTER VIII.

THE BAROMETER AND THE BAROGRAPH.

1. The Pressure of the Atmosphere.

The barometer is an instrument for measuring the *pressure of the atmosphere*. It was invented in the year 1643 by Torricelli, a Florentine philosopher. Its name was used in this country as early as 1665; it is made up from two Greek words, *baros*, weight, and *metron*, measure, because the instrument was supposed to measure the weight of the atmosphere. But without further explanation the meaning of the statement is not very clear. The barometer does enable us to compute the weight of the atmosphere—when the calculation is made it works out at five thousand billion tons—but that is not the immediate purpose of reading a barometer.

The original form of the instrument (which can be reproduced by anyone who has a long glass tube and some mercury) is shown in figure 1.

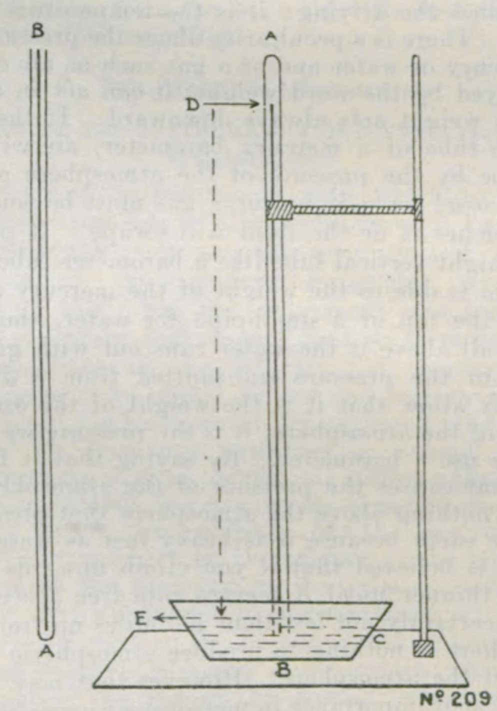


Fig. 1.

A long glass tube AB, about 33 inches long, closed at the end A, is filled with mercury; by closing the open end with the finger and dipping it under the mercury in a trough C and then removing the finger and fixing the tube in a stand, we find that the column of mercury leaves a little space at the top of the tube, but the remainder stands in the tube, supported, in fact, by the pressure of the atmosphere on the surface of the mercury in the cistern. It is the vertical distance DE between the level of the mercury in the cistern and in the tube that is the fundamental measure in a mercury barometer; all the rest in the most elaborate form of instrument is simply refinement to secure greater accuracy of measurement.

The barometer enables us to calculate the weight of the atmosphere, but the reading of the barometer depends immediately upon the pressure of the atmosphere, and the meaning of the word pressure as distinguished from weight is so important that it is worth while here to recall it to mind. Everyone who has used a bicycle pump knows that by its aid the air inside a tyre can be made to exert a very great pressure, perhaps fifty pounds per square inch, but the weight of the air in it is almost nothing, perhaps half an ounce. The manner in which the air or any other gas exerts pressure on the walls of an enclosed space is something of a mystery, but it certainly does it. It is pressure, not weight, which drives a shot along a gun, or bursts a shell. It is the pressure of steam, not its weight, that drives the piston of an engine. No great weight of water is required to make the steam that does the driving: it is the temperature of the water that counts. There is a peculiarity about the pressure of a liquid, such as mercury or water and of a gas such as air or steam, that is not conveyed by the word weight; it can act in all directions at once, but weight acts always downward. If there is a little crack in the tube of a mercury barometer, air will be pushed into the tube by the pressure of the atmosphere outside. The containing vessel for a liquid or a gas must be sound wherever the fluid touches it or the fluid will escape. It is true to say that in a straight vertical tube like a barometer tube the pressure at the bottom is due to the weight of the mercury above it; but if you turn the tap of a stand-pipe for water, though there is no water at all above it the water runs out with great force, in consequence of the pressure transmitted from a distance. So while we may allow that it is the weight of the air that causes the pressure of the atmosphere, it is the pressure we want to find out when we use a barometer. By saying that it is the weight of the air that causes the pressure of the atmosphere we imply that there is nothing above the atmosphere that presses it down: it lies on the earth because it is heavy just as water lies in the hollows. It is believed that if you climb upwards the air gets thinner and thinner until it merges into free space outside the atmosphere, certainly not less than 100 miles up from the earth's surface; so there is nothing to produce atmospheric pressure but the weight of the atmosphere. However that may be, it is the pressure that is of importance in meteorology; weight is measured in grains or pounds or tons, or grammes; pressure by pounds per square inch, or sometimes, as in the case of pressure of wind on a structure, in pounds per square foot; high pressure in tons per square inch or sometimes in "atmospheres," and we have recently found it convenient to measure all pressures, great and small, in the same way. The pressure of the atmosphere at sea level in ordinary circumstances

is about 15 lbs. per square inch, and that is roughly what an "atmosphere" means when pressures are quoted in so many atmospheres. If we want to be precise, as we have to be in the use of the barometer for the study of weather, we must allow for many things before we arrive at a correct reading of the pressure of the atmosphere, such as the temperature of the mercury and of the scale with which the column is measured and the latitude of the place of observation. When all the precautions have been taken and the length of the mercury column is exactly known, we find it best to express pressure in thousandth-parts of the pressure of the atmosphere which corresponds very nearly with 29½ inches of mercury under standard conditions. Calling that one "bar," one-thousandth part of it is called a "millibar," according to the practice of the metric system. So we may regard a millibar as one-thousandth part of an atmosphere. More exactly the relation of millibars to inches and millimetres is 1,000 millibars equal 29·531 inches or 750·1 millimetres of mercury under standand conditions, that is to say, at the temperature of the freezing point of water and at latitude 45°.

The following instructions for the accurate use of the mercury barometer are taken from the *Barometer Manual for the use of Seamen*, Eighth Edition, 1916.

2. The Mercury Barometer.

Description of the Instrument and Instructions for its Management.

The barometer is an instrument with which to measure the variations in the 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 utilised 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. 2, 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 either for mercury inches and decimals of an inch, or for centibars and millibars: the average pressure at the sea level being rather less than 30 inches, or 1015 millibars, though the mercury sometimes rises to slightly above 31 inches, 1050 millibars, or falls below 27·5 inches, 930 millibars.

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.

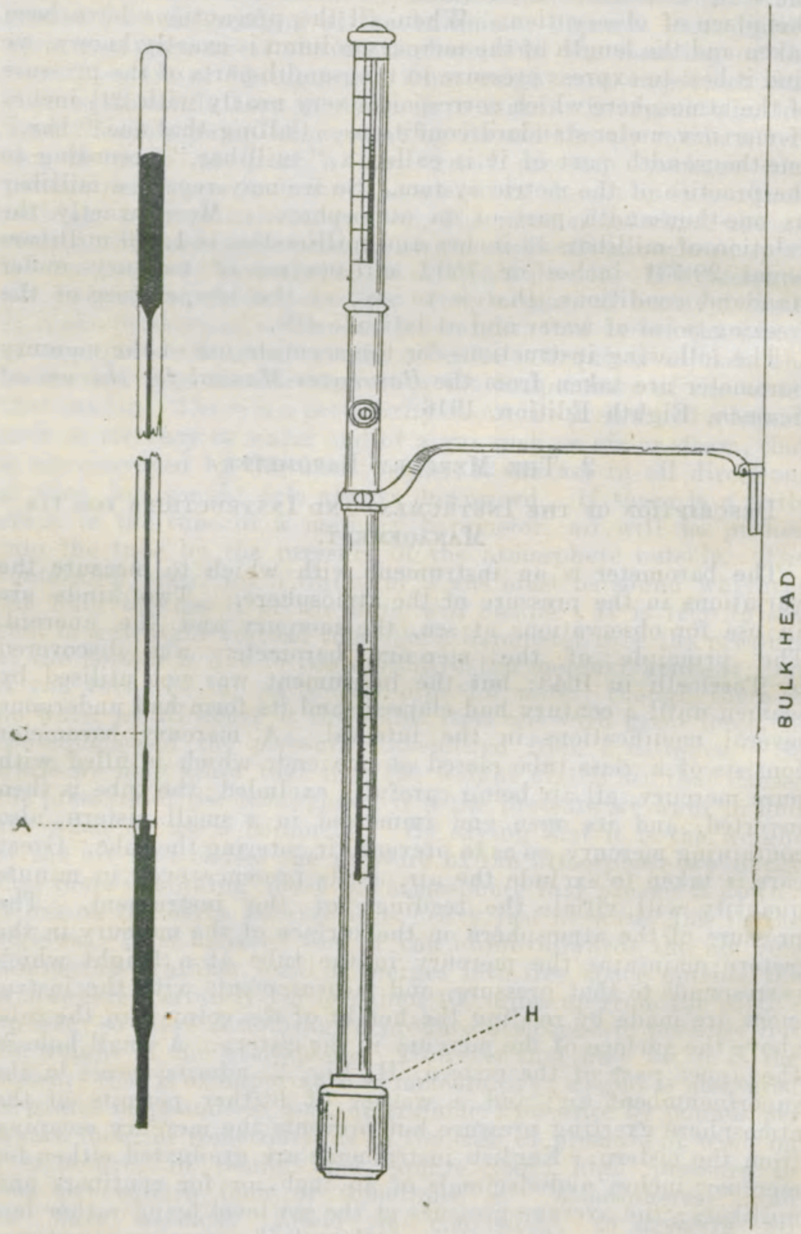


Fig. 2.

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. 2). 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. 2, 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.

On no account should a barometer or other instrument belonging to the Meteorological Office be sent to an optician for repair or an attempt be made to repair the instrument on board the ship. All damaged instruments should be returned either direct to the Meteorological Office or to an Agent for the Office at ports where there are such agencies.

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 lying flat *or with the cistern end upwards;* 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 has shown the advisability of giving directions for 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 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.

When the tube of a barometer is broken the mercury should be emptied into a bottle before the instrument is packed, otherwise the mercury will attack the brass work.

It is still usual to graduate barometers in inches, tenths and twentieths of an inch of mercury and to extend the accuracy of the reading to hundredths and thousandths of an inch by means of a vernier.

In view, however, of the close association of meteorological science with other branches of physics which are taught in schools, and which use the metric system, it has been found desirable for reasons set out in the *Marine Observer's Handbook* (M.O. 218), the *Weather Map* (M.O. 225, i.) and *Meteorological Glossary* (M.O. 225, ii.) and elsewhere, to give the results in units of the C.G.S. (centimetre—gramme—second) system, in which the *bar, centibar,* and *millibar* are actual units of *pressure.*

The inch is a unit of length, requiring a tiresome numerical calculation in order to convert barometric readings into a real estimate of pressure, and it is pressure that has to be expressed.

For the purpose of estimating the probable changes that have taken or may take place in the distribution of atmospheric pressure, a measure is wanted of the force requisite to move a given mass of air, just as a measure is needed for estimating the power which is required to drive a vessel of a given tonnage a given length or distance in a given time.

In the C.G.S. system the *gramme* of the International Bureau of Weights and Measures is the metric unit of mass.

The *centimetre* is the unit of length; it is one-hundredth part of a metre, which may be taken as being one ten-millionth of the earth's quadrant.

The *second* is the universal unit of time.

The unit of *velocity* in the C.G.S. system is the velocity of one centimetre per second.

The unit of *acceleration* in the C.G.S. system is an acceleration of one unit of velocity per second.

The unit of *force* in the C.G.S. system is the force which produces an acceleration of one centimetre per second in a mass of one gramme. In physics this unit is called a *dyne.*

The unit of *pressure* in the C.G.S. system is the dyne per square centimetre, which is so small that a practical unit of atmospheric pressure, the megadyne per square centimetre, has been substituted, which is one million times as great, and may be called the C.G.S. "atmosphere."

The megadyne is equivalent to a pressure of 29·53 inches or 750·1 millimetres of mercury at the freezing point in latitude 45°.

In expressing this unit the name *bar* has been adopted by meteorologists, from the Greek *baros,* weight. The hundredth and thousandth parts of a bar, the *centibar* and *millibar* respectively, are adopted as working pressure units in the C.G.S. system: the latter being approximately a thousandth part of the ordinary pressure of the air at sea level.

More strictly the mean pressure at sea level is 14¾ lbs. per square inch; corresponding with 760 mm., 29·92 inches of mercury at the freezing point, in latitude 45°. 1,000 millibars are very nearly 750 mm., 29·5 inches, 14½ lbs. per square inch; 1 millibar is one thousandth part of this.

The relation between the millibar and the commoner units, the inch and the millimetre, is shown in Fig. 3 and in the following table:—

EQUIVALENTS IN MILLIBARS OF INCHES AND MILLIMETRES OF MERCURY AT 32° F. AND LATITUDE 45°.

Mercury Inches.	Mercury Millimetres.	Millibars.	Mercury Inches	Mercury Millimetres	Millibars.
28·0	711·2	948	29·5	749·3	999
28·1	713·7	952	29·6	751·8	1002
28·2	716·3	955	29·7	754·4	1006
28·3	718·8	958	29·8	756·9	1009
28·4	721·4	962	29·9	759·5	1013
28·5	723·9	965	30·0	762·0	1016
28·6	726·4	969	30·1	764·5	1019
28·7	729·0	972	30·2	767·1	1023
28·8	731·5	975	30·3	769·6	1026
28·9	734·1	979	30·4	772·2	1029
29·0	736·6	982	30·5	774·7	1033
29·1	739·1	985	30·6	777·2	1036
29·2	741·7	989	30·7	779·8	1040
29·3	744·2	992	30·8	782·3	1043
29·4	746·8	996	30·9	784·9	1046

Graduation of Kew Pattern Barometer and its Attached Thermometer: The latter with graduation in degrees of Fahrenheit added for comparison.

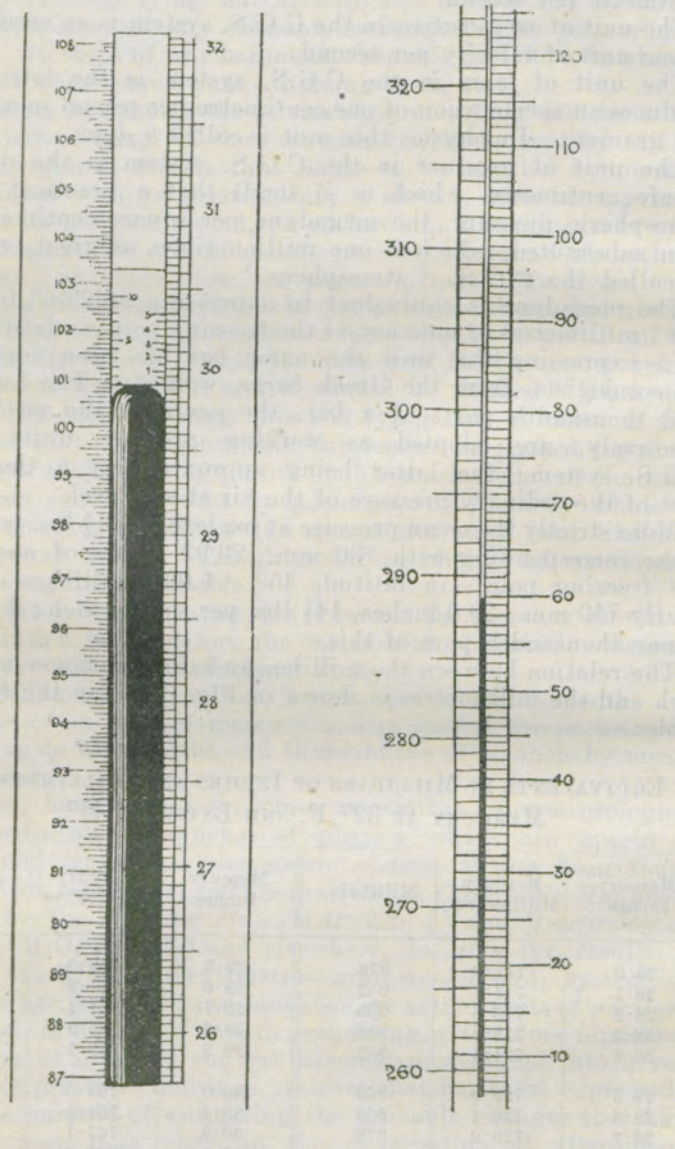


Fig. 3.

The graduation of Thermometers attached to Barometers, which are graduated in C.G.S. units, is usually in centigrade degrees from the absolute zero of temperature, which is 273° centigrade below the freezing point of water or − 459° on the Fahrenheit scale. The zero represents, so far as our knowledge goes, the temperature at which the whole of the heat of any substance whatever would be converted into some other form of energy.

The principal advantages of the absolute scale for meteorological work is that all negative values are avoided, and all calculations of the pressure and density of air are reduced to simple proportion.

3. 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 4.

Fig. 4.

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 which are graduated in inches, the fixed scale is divided into inches, tenths, and half-tenths, each of the latter being therefore ·050 of an inch. Twenty-five divisions of the vernier are made to cover 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. In standard barometers which are graduated in millibars, the fixed scale is divided into centibars and millibars. The vernier for this scale covers thirty-nine divisions of the fixed scale and therefore is less by one millibar-division than the length of forty millibars on the fixed scale.

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 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. 5 is a graphical representation of the incorrect results arising from errors of parallax.

A piece of white paper placed behind the tube to reflect the light assists in setting the vernier accurately, and at night a lamp, preferably an electric torch or a candle lamp, may for this purpose be held so as to throw a strong light on the paper.

5. To Take an Observation.

(1) *Attached thermometer.*—Observe and note the temperature of the thermometer attached to the barometer. The temperature should be read on the scale graduated from about 265° to 305°. Sufficient accuracy will be attained if the temperature be noted to the *nearest whole* degree.

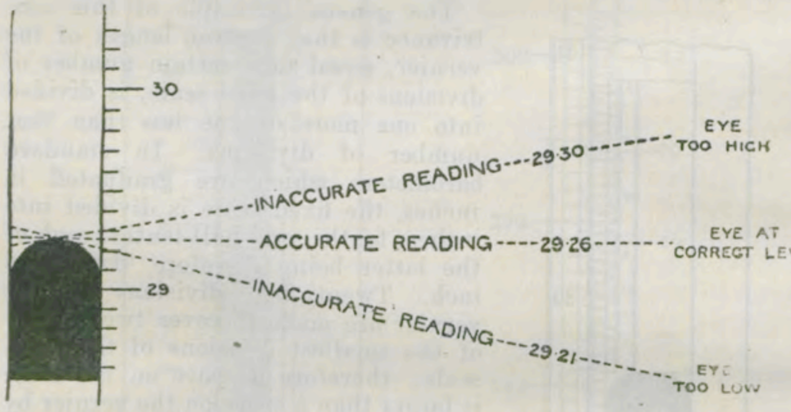


Fig. 5.

The reading of the attached thermometer should be noted before setting and reading the barometer as changes in temperature due to the presence of the observer are likely to affect the thermometer more quickly than the mercury in the tube.

(2) *Setting the vernier scale.*—(See previous page.)

(3) *Reading the scale.*—The operation of reading consists of two parts:

First. Note the number of the scale division *next below* the zero division on the vernier marked D in Figs. 6 and 7. The scale is graduated in *millibars*, and numerical values in *centibars* are figured along it (10 millibars = 1 centibar). In order to assist the eye when determining the value of a division, the marks of the millibar graduations are of unequal length. In Fig. 6, D is supposed to be in the same straight line with the fifth (the long) mark above the scale division numbered 98., in other words with

the graduation 985 millibars. In Fig. 7 the graduation next below D is the second above the graduation numbered 101·0, its value is therefore 1,012 millibars.

Second.—Look along the vernier for a division which is in one and the same straight line with a scale division. The value of this division on the vernier gives the decimal place. In Fig. 6 the vernier division 0 is exactly coincident with a scale division; the reading of the barometer is therefore 985·0. In Fig. 7 the vernier division 7 is exactly opposite a scale division; the barometer reading is therefore 1012·7.

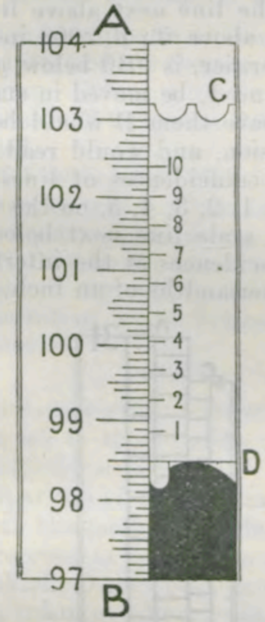


Fig. 6.

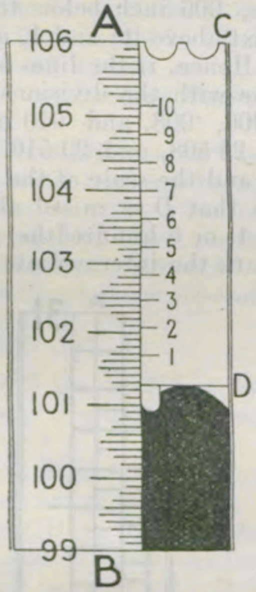


Fig. 7.

If the vernier has not been shifted between two observations, it is advisable to check the previous reading before proceeding to a fresh setting.

(4) Method of Reading the Inch-Barometer.

The mode of reading off the height, when the vernier and scale are graduated in inches, may be learned from a study of the diagrams, Figs. 8 and 9 (p. 66), 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. 8 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. 8 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.

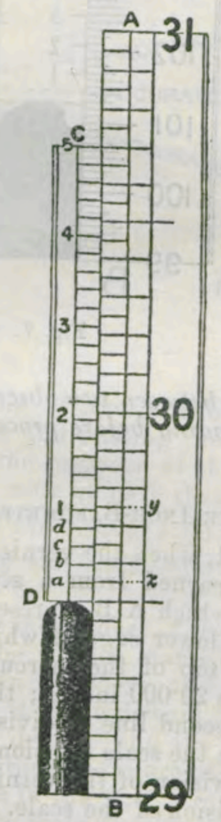


Fig. 8.

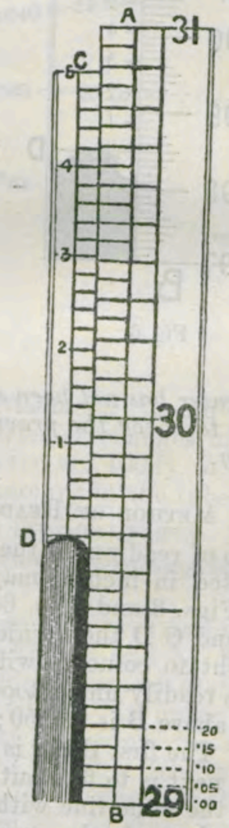


Fig. 9.

The application of this will be seen from Fig. 9 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 ·330, 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 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.

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, ·045 inch. Hence the difference of length between a division of the scale and one of the vernier is

$$·050 - ·045 = ·005 \text{ inch.}$$

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. 10 and 11, with Figs. 8 and 9 is sufficient to explain the method of effecting the change. In Figs. 10 and 11, 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 in one and the same line with a division of the scale. In Fig. 9 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 10, 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

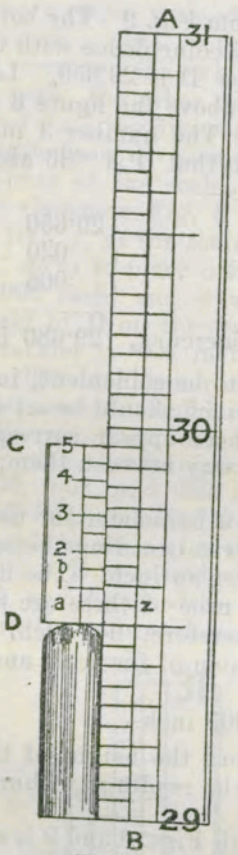


Fig. 10.

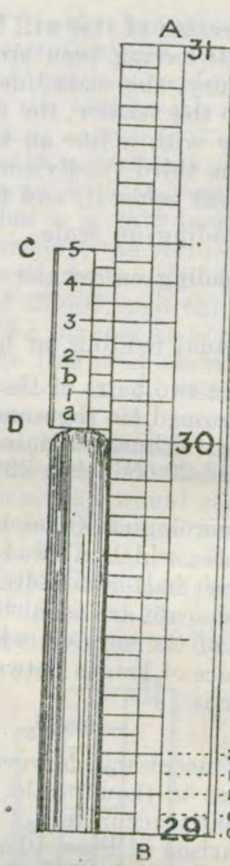


Fig. 11.

·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 11. 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 on the reading. For the ordinary purposes of marine meteorology, however, either 30·03 or 30·04 will generally be sufficiently near.

6. Pumping.

When a mercury barometer is examined on board ship in a sea way, it will be seen that the level is constantly fluctuating. This phenomenon is known as "pumping." Three separate causes may be operative in various degrees to produce this effect. The mobility of the heavy mercury comes in in two ways: first on account of the heave of the ship and secondly on account of the rocking of the instrument. Besides these, there is the effect of the wind on the air pressure in the room where the barometer is hung. An ordinary barometer with a tube of wide bore is so much affected by pumping that no useful reading is possible in a sea way. With the constricted tube of the marine barometer the effect is sufficiently reduced to make a reading possible, but there is still a residual pumping the cause of which has not yet been fully examined, and which makes the reading difficult and uncertain. The present rule of the office is that 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.

7. Corrections of Readings of the Barometer according to the Graduations in Inches.

Correction for Temperature.—As hot mercury is specifically lighter than cold, the column of mercury lengthens when heated and shortens when cooled; it is therefore 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., or other 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.

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.

Correction for Height.—As the pressure of the air becomes less 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 say 70 feet above sea level, as in the largest liners, this correction will be as much as + ·08, and may not be neglected, as the table on page 96 shows. It is, however, advisable, when 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.

Correction for Latitude.—When barometer readings from different parts of the world have to be compared by plotting on a chart, and an accuracy of a hundredth of an inch is required, a correction for gravity also is now applied because, the earth being a spheroid, the force of gravity varies with the latitude, and places at the equator are at a greater distance from the earth's centre than places at the poles. Barometer readings, therefore, are reduced to standard latitude, for which the parallels of 45° N. and 45° S. have been adopted. The corrections required in this connexion are given in the Marine Observer's Handbook, M.O. 218.

8. Correction and Reduction to Sea-Level of Millibar Barometers.

Note.—Barometers graduated to read in millibars are provided with an attached thermometer graduated according to the absolute scale of centigrade degrees, and the references to temperature in the following instructions are to the readings on that scale. In quoting the temperature the degree mark is omitted, and instead of it a small "a" follows the number. Thus 273a on this scale corresponds with the freezing point of water, that is 0° C., or 32° F., and 283a corresponds with 10° C. or 50° F. A step of 10a in temperature is the same as a step of 18° F.

Standard temperature as shown on the certificate.—The barometer will have been certified as *correct* in *latitude* 45° at a certain *temperature* which we call the *standard temperature.* The certificate means that when the temperature has the specified value the barometer reading will give the true value of the pressure in *millibars* at the *level of the barometer cistern* in the specified latitude.

Example.—Barometer M.O.A. 2074. The standard temperature is 286·5a, that is in latitude 45° the barometer reads correctly at 286·5a, which is the same as 56·3° F.

With this information it is easy to make allowance for difference of latitude and difference of temperature; it is also easy to allow for height above sea-level in a similar manner, and so put the observer in the position to compare his readings with a synoptic weather-chart or with the normal for the locality, provided that the height above sea-level is not greater than those at which ships' barometers are commonly fixed.

Fiducial temperature.—If the latitude is not 45° the reading will not be correct at the standard temperature, but there will be a temperature at which the reading would be correct if it were so chosen that the latitude correction would just balance the temperature correction. We call this temperature, at which the readings of the barometer need no correction, the *fiducial temperature* for the barometer in the particular latitude. For a station-barometer with fixed latitude the fiducial temperature remains the same, but at the sea the fiducial temperature is different for the different positions of the ship in latitude.

To allow for the height of the barometer above sea-level the fiducial temperature can be adjusted, because in the ordinary circumstances in which the barometer is used at sea the allowance to be made for 100 ft. of height lies between 3·3 mb. and 3·9 mb., and a correction of 3·6 mb., for 100 ft. would be sufficiently accurate in most cases.

Correction and Reduction.—The process of correction and reduction to sea-level is, therefore, as follows:—

(1) *To determine the fiducial temperature for the latitude at which the barometer is read use the following table:—*

Latitude	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°
Subtract from the Standard Temperature ... a	15	15	14	13	11·5	9·5	7·5	5	2·5	0
Latitude	90°	85°	80°	75°	70°	65°	60°	55°	50°	45°
Add to the Standard Temperature ... ... a	15	15	14	13	11·5	9·5	7·5	5	2·5	0

Example.—Barometer M.O.A. 2074. Standard temperature, the fiducial temperature in latitude 45°, is 286·5a. To find the fiducial temperature in latitude 52°, add 3·5a (2·5a for latitude 50°, and 1a for the additional 2°): fiducial temperature required is 286·5a + 3·5a, that is 290a.

(2) *To adjust the fiducial temperature in order to make allowance for the height above sea-level.*

Increase the fiducial temperature by 1a for every 5 feet or 1·5 metres of height.

Example.—Barometer M.O.A. 2074 is set at 52·5 feet (16 metres) above sea-level.

Its fiducial temperature is therefore increased by 10·5a from 290a to 300·5a for 52° latitude.

(3) *Having obtained the adjusted fiducial temperature, to correct the barometer reading for the difference between the actual temperature as read on the attached thermometer (absolute scale) and the adjusted fiducial temperature.*

(*a*) When the attached thermometer reads *higher* than the adjusted fiducial temperature, *subtract* from the reading 1 millibar for every 6a in the difference "actual minus adjusted fiducial."

The proportional parts are as follows:—

Difference: Actual—Adjusted fiducial a	1	2	3	4	5	6	7	8	9	10
Millibars	·2	·3	·5	·7	·9	1·0	1·2	1·4	1·5	1·7

(*b*) When the attached thermometer reads *lower* than the adjusted fiducial temperature—

Add to the reading 1 millibar for every 6a in the difference. The proportional parts are the same as before.

Example.—Barometer M.O.A.2074, 16 metres (52½ ft.) above sea-level in latitude 52° N. reads 1017·6; attached thermometer 292·4a.

To find the true pressure in millibars:—

The adjusted fiducial temperature (2) is 300·5a.

Uncorrected reading	1017·6
Correction for defect of actual − adjusted fiducial (292·4 − 300·5) = −8·1a therefore add ...	1·4
Corrected reading	1019·0

The reading is now ready for plotting on a synoptic chart, but when a high degree of accuracy is required the calculation should be carried out to the tenth of a degree to avoid the accumulation of error, and the following points must be attended to:—

SUPPLEMENTARY CORRECTIONS FOR SPECIAL ACCURACY.

(4) *Proportional Adjustment of Correction.*—The correction as set out in (3) is in reality a *fractional part* of the pressure, and ought therefore to be adjusted proportionally for different points in the range of atmospheric pressure. The adjustment is very simple: add 1 per cent. to the correction for each 10 millibars above 1000, and subtract 1 per cent. for each 10 millibars below.

One per cent. only begins to be appreciable when the whole correction is about 10 mb., and the additional correction for proportional adjustment is only necessary on quite exceptional occasions.

Example.—Barometer M.O. 2000 with fiducial temperature 306a in latitude 20° gave a reading of 920 mb. at 290a (the lowest observed reading of a cyclonic depression).

Temperature correction	add	2·7	mb.
Proportional adjustment (for 80 mb.) − 8%	subtract	·216	
Adjusted correction add		2·5	mb.
	True pressure	922·5	mb.

(5) *Correction for scale error.*—This can be provided for by the table of Kew corrections which gives the standard temperatures at different points of the scale. A properly graduated scale ought to have the same standard temperature throughout its range. If correction for standard temperature in different parts of the scale is necessary, it can be worked by the table of (3).

Example.—Barometer M.O. 2015 has standard temperature 286·5a at 1000 mb. but 280a at 900 mb.

Find the correction for scale to the reading in Example 4.

Take the standard temperature at 920 mb. to be 281·5a or 5a less than for standard conditions.

That is equivalent to reducing the fiducial temperature by 5a, which involves a correction of ·8 mb. to be subtracted from the reading.

Summary.—(6) The process may be recapitulated and summarised as follows:—

Barometer M.O. A.2074, 16 metres (52·5 feet) above sea level in latitude 52° N. reads 1017·6 with attached thermometer 292·4a.

Standard temperature (fiducial temperature in latitude 45°), by the certificate the same at all points of the scale	286·5a
Fiducial temperature in latitude 52° add ...	3·5a
For adjusted fiducial temperature at 16 metres add	10·5a
	300·5a

For adjusted fiducial − actual (300·5 − 292·4), 8·1a add 1·4 mb. to 1017·6 mb.

Corrected reading ... ... 1019·0 mb.

Proportional adjustment 2 per cent. of 1·4 mb. (negligible).

Scale error—nil.

(7) The marine observer is advised to have fixed up in the immediate neighbourhood of his barometer a card showing the adjusted fiducial temperature of his barometer for each degree of latitude. He can compile it for himself by the instructions given under (1) and (2). To correct a reading he has then only to consider the difference between the fiducial temperature and the actual temperature at the time of reading, simply *adding* $\frac{1}{10}$ mb. to the reading for every $\frac{6}{10}$ of a degree by which the adjusted "fiducial" exceeds the "actual."

9. THE ANEROID BAROMETER.

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 or latitude, 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.

* It must be noted that in making the comparison the reading of the mercury barometer must be corrected for temperature and latitude and for the height-difference between the mercury cistern and the aneroid. The aneroid needs no correction for temperature or latitude.

10. The Sea Barometer.

At the Meteorological Office a new dial has been introduced for aneroid barometers intended for use at sea, of which a representation is given in Fig. 12. The graduations are shown in "millibars" and the numbering either in millibars or in centibars. On the barometer dial, graduations in inches and in millimetres are also shown, and it will be seen that the pressure of 100 centibars or 1,000 millibars corresponds very nearly with that of 29½ ins. or 750 millimetres. The dial shows a range from below 93 centibars (27½ ins.) to 105 centibars (31 ins.), and so covers the whole range of pressure that is likely to be experienced at sea level in any part of the world. For the convenience of sailors, on the special form of instrument which is called a *sea barometer*, and which is figured here, a curve is given on the face of the dial to indicate the *mean annual pressure* in certain degrees of latitude along the meridian of 30° West. This meridian goes over sea from the Arctic to the Antarctic, and crosses the "Icelandic low," the "highs" of the tropics of Cancer and Capricorn, and the deep low of the higher southern latitudes. Similar variations are to be found in other oceans, so that the variations which are indicated by the curve are a guide to the average values which the mariner may expect. These values should enable him to judge firstly whether the instrument is in reasonable adjustment, or, secondly, whether the season of his voyage is a normal one so far as pressure is concerned.

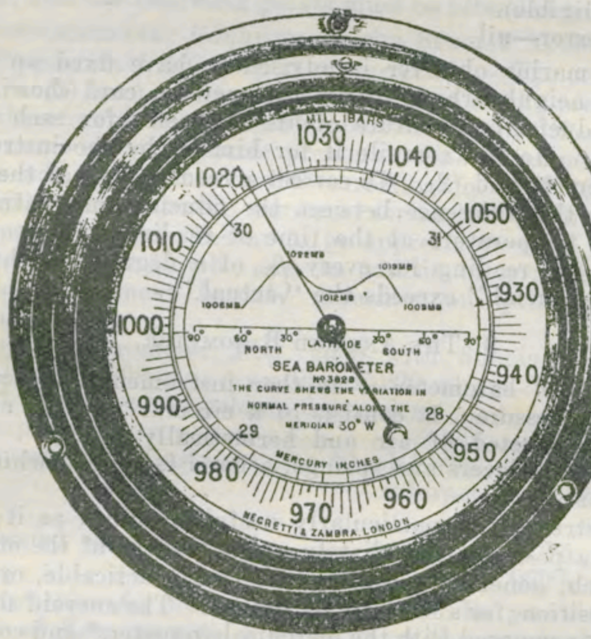


Fig. 12.

11. The Barograph.

A portable "Barograph" (Fig. 13), 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. Barograms, moreover, register minor fluctuations of atmospheric pressure which are seldom noticeable in the action of the mercury barometer, and without the uninterrupted evidence furnished by a sensitive self-recording instrument, are rarely detected.

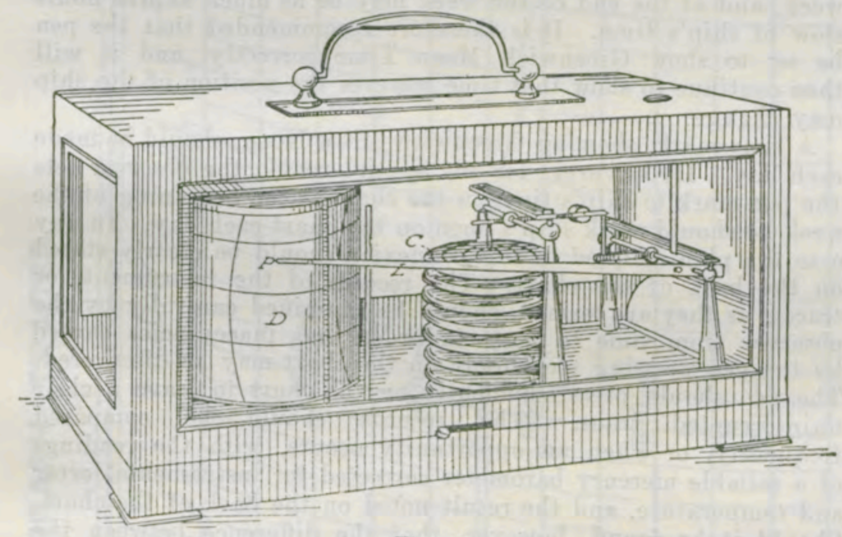


Fig. 13.

The Barograph on board ship may either be carried in a cradle slung on gimbals, the cradle being secured, or suspended by a special contrivance 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.

The action of the Barograph, briefly, is as follows:—The circular metallic chamber C, consisting of a series of vacuum metal boxes with elastic lids, is connected with the revolving drum D by means of a lever L carrying a pen P 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 ink should not be allowed to get on to the lever, as it corrodes the metal.

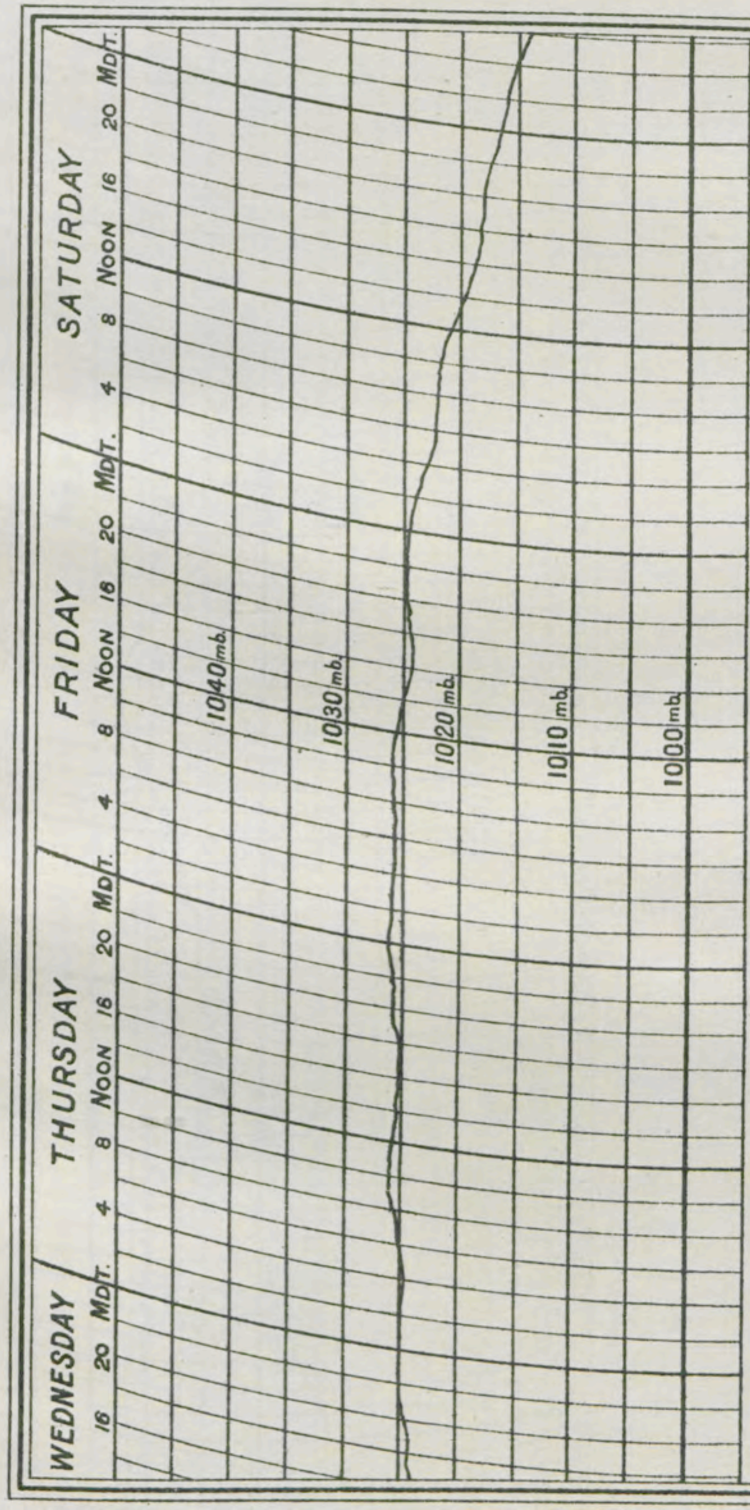
12. Barograph Traces.

Four examples of traces obtained from barographs are given here in illustration of various points to be noted in the use of this instrument.* The first is a record obtained at Leith 7th to 10th February, 1917, when the weather was quiet. It shows the pressure in millibars and, assuming that the instrument was in good order and properly set, the pressure at any time can be read off at once to one millibar from the trace or graph by estimating the fraction of the distance between two marked lines at which the pen was marking at the time when the reading of the pressure is desired. Thus at midnight on Thursday night the

Plate 1.

The Barometer and the Barograph.

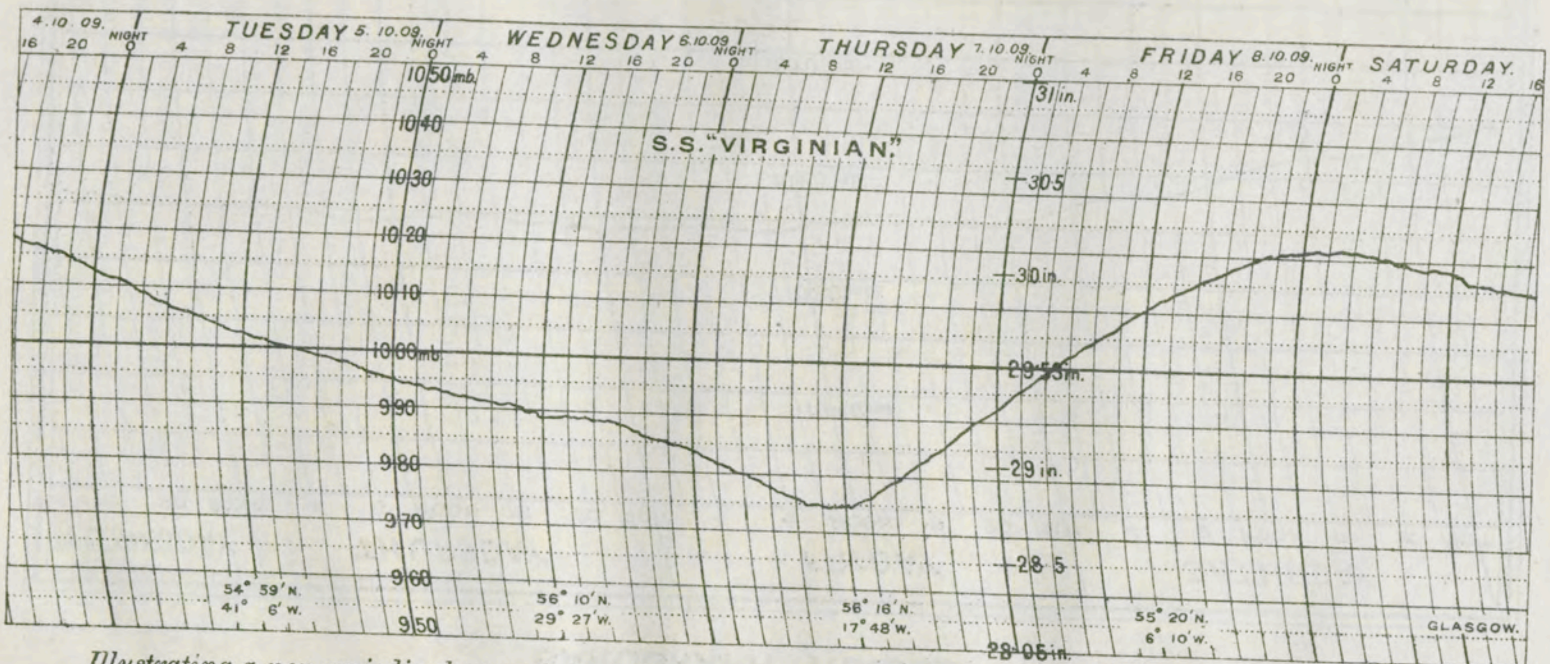
BAROGRAPH TRACES.



LEITH, 7th to 10th FEBRUARY, 1917. Barogram showing double oscillations in the 24 hours.

Wy. & S., M.O. Press, S.W. 7.
Ps. 764. 9898. 528. 2000. 12/17.

BAROGRAPH TRACES.

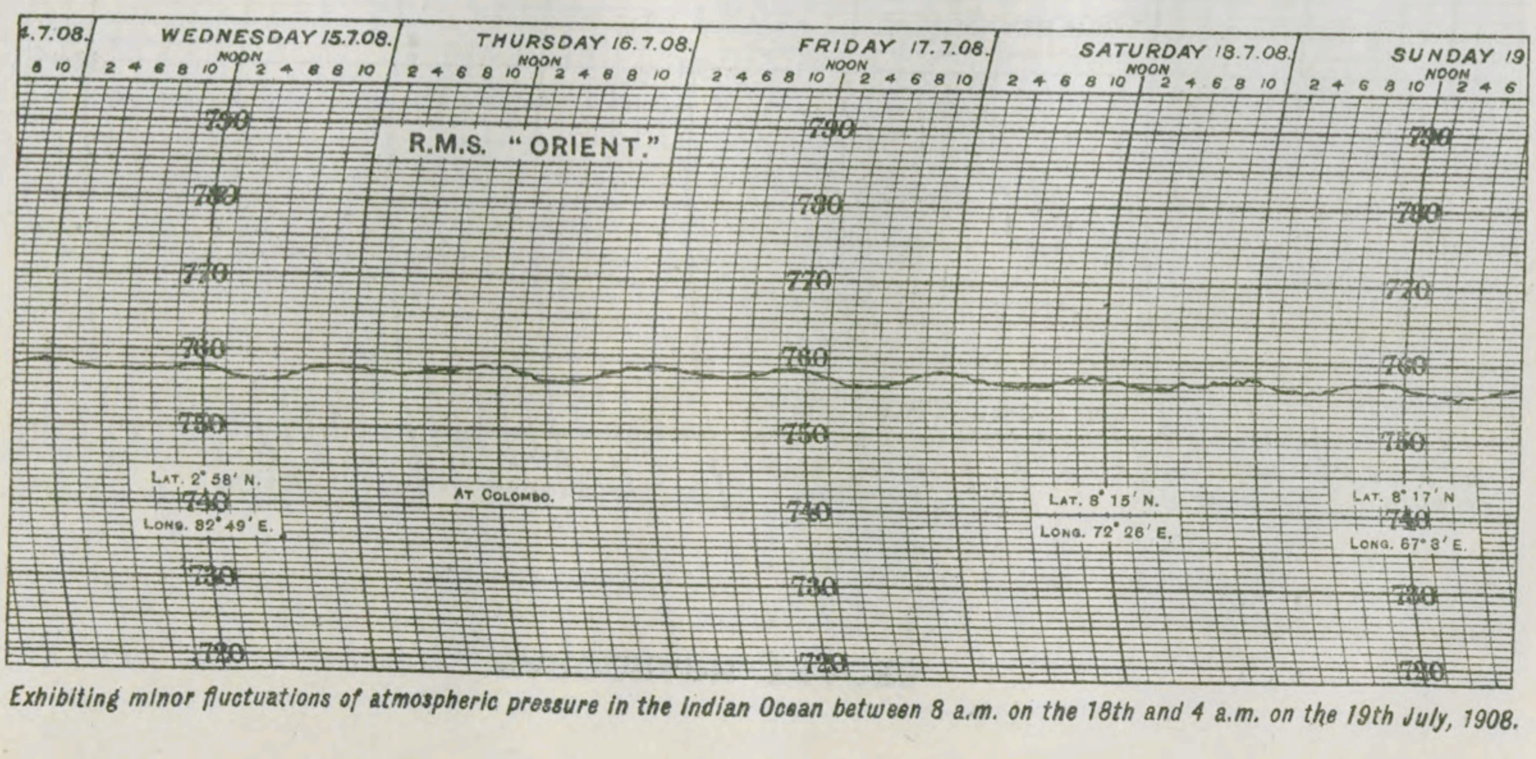


Illustrating a non-periodic change of atmospheric pressure associated with the passage of a cyclonic depression over the North Atlantic.

Wy. & S., M.O. Press, S.W. 7.

Ps. 764. 9898. 528. 2000. 12/17.

BAROGRAPH TRACES.



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.

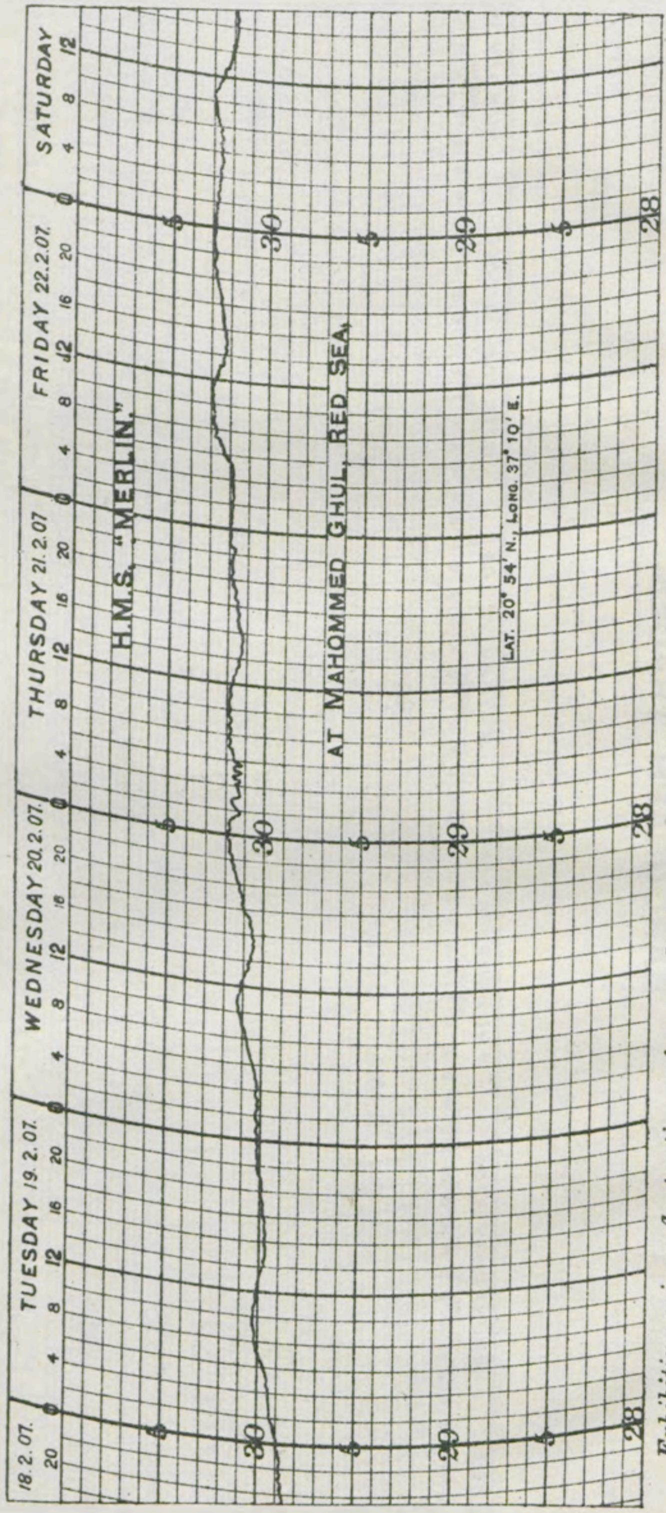
Wy. & S., M.O. Press, S.W. 7.

Ps. 764. 9898. 528. 2000. 12/17.

Plate IV.

The Barometer and the Barograph.

BAROGRAPH TRACES.



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

Wy. & S., M.O. Press, S.W. 7.

Ps. 764. 9898. 528. 2000. 12/17.

pressure was 1026 mb., on Friday night between 1024 and 1025 mb., on Saturday night 1017 mb.

This graph is reproduced to show the double oscillation within 24 hours indicated by the wavy line. This double oscillation can be detected nearly always on the barogram when the weather is quiet. When the barometer is fluctuating considerably it may not appear at all. The second graph, taken on board the s.s. "Virginian" in the Atlantic, illustrates this point. The oscillation becomes more pronounced as we approach the region of the Equator. On referring to the third graph, taken from the R.M.S. "Orient" in the Indian Ocean, there is very little variation of pressure except the double oscillation. The third graph is drawn on a sheet graduated in millimetres of mercury, while the fourth, from H.M.S. "'Merlin" in the Red Sea, shows a somewhat similar record in inches of mercury.

The fourth graph is reproduced because it exhibits a number of rapid fluctuations of the pressure on a small scale which we call the "embroidery" of the barogram, and these slight variations are of importance in relation to weather. The main features of weather in our latitudes are associated with surges in the pressure which are represented by the second trace, taken from s.s. "Virginian." That also contains some "embroidery" on the Wednesday included in the graph. These small variations in our own latitudes as well as in the region nearest the Equator, where there are no great surges, are often associated with passing showers of rain, snow or hail, sometimes with thunderstorms; they are therefore of considerable importance as regards the details of weather. Further reference will be made to this subject in Section 10 of Chapter XI.

PART II.

CHAPTER IX.

AN HISTORICAL ACCOUNT OF METEOROLOGY TO THE TIME OF ADMIRAL FITZROY.

1. Weather Lore and Maxims.

From the most ancient times up to the invention of the barometer the results of the study of weather by sailors and landsmen found expression in a number of rules and maxims for foretelling the weather from the appearance of the sky and other indications, such as the behaviour of animals which were supposed to have an instinctive knowledge of the weather to come. A survey of the study of weather on these lines was given by Aristotle in his Meteorologica and by Theophrastus in a treatise on the winds. There is also a well-known version of weather lore for farmers in the Georgics of Virgil. For many centuries the study remained in the position which is represented in these classical books, and many of the conclusions are to be found in the literature of common life as weather lore and weather maxims, of which Mr. R. Inwards, a former president of the Royal Meteorological Society, made a very extensive compilation in his book on *Weather Lore*, published in 1893.

2. The Era of the Single Barometer.

A new epoch in the history of the study of weather began with the invention of the Barometer in 1643, and extended to the introduction of the electric telegraph which was made generally available by the use of submarine cables after the middle of the 19th century. Admiral R. FitzRoy was at that time in charge of the first separate establishment provided by Government for the study of weather in this country. It was a department of the Board of Trade which was established in 1854 to collect information from ships of the Royal Navy and the Mercantile Marine in

order that the facts of the meteorology of the sea might be better known and its laws and principles laid down. The immediate cause of the establishment of the department was a conference in Brussels on the Meteorology of the Sea advocated by Lieut. Maury of the United States Navy, himself an enthusiast for the study of the meteorology of the sea and the author of many charts of the meteorology of the oceans and of a well-known book on the subject.

Another great incentive to the active prosecution of the subject was the progress that had been made in reducing to order the notable phenomena of the tropical revolving storms, the acknowledged causes of hurricanes in various parts of the world, by Espy, Redfield and Piddington. The results of these attempts were put together by Dove in a book with the title of *The Law of Storms*, which was translated into English by FitzRoy. Much of what is written there about revolving storms is still to be found incorporated in the *Barometer Manual for the use of Seamen*, which was originally prepared by FitzRoy and has been extended and revised in successive editions issued by the Meteorological Office.

The main point of difference between Meteorology as it existed from the invention of the barometer to the time of FitzRoy and after his death, was that in the earlier period meteorologists were dependent for the laws and principles of weather entirely upon the results which could be obtained by the collection of observations a long time after they had been made, and for guidance as to the coming weather upon the laws and principles which had been formed in the manner described and upon the readings of their own barometer and other instruments, with the supplementary observations of wind and weather in their own particular locality; whereas by the time of FitzRoy's death in 1865 the practice of reporting observations of weather by telegraph to a central institution had become established in France and England, and the method of studying the weather by plotting simultaneous observations on maps had begun.

The second important period, therefore, in the history of the study of weather was that which covers the two hundred years between the invention of the barometer and the introduction of the weather map, during which the weather signs and maxims which had been handed down from antiquity were reinforced by personal observations of barometric pressure. The endeavour to interpret the readings of the barometer in terms of coming weather was very persistent. The barometer came to be known as the "*weather glass*," and every well-to-do household had a barometer for foretelling the weather. Everyone is familiar with the legends on the dial of the wheel barometer, which is marked "Very Dry, Set Fair, Fair, Change, Rain, Much Rain and Stormy," which we owe to one of the earliest officers of the Royal Society. They are obviously not very satisfactory because the legends are written against particular readings of the barometer irrespective of locality or the height of the instrument above sea-level. Luke Howard and other writers devoted much attention to the interpretation of the readings of the barometer and its fluctuations, and the popular idea that the weather was in some way or other governed by the position of the moon, as the tides are, received much more attention than it really deserved.

The use of the barometer at sea was attended with a good deal of difficulty on account of the motion of the ship which caused the mercury to surge up and down in the tube and made readings impossible in a sea way. FitzRoy's first task was to provide a barometer which permitted accurate readings at sea, and the form which he adopted after consulting the authorities of the Observatory at Richmond, then and still called the Kew Observatory, is still used for ships under the name of the Kew barometer. In that way it became possible to extend the knowledge of the relations of the weather to the fluctuations of the barometer at sea, and FitzRoy collected a large amount of information in that way to supplement his own practical experience, which was very extensive.

He was therefore in a very favourable position for reviewing the whole subject as it is presented to a student who has no opportunity of making personal use of a map of simultaneous observations reported by telegraph. He did not begin the collection of observations in that way until towards the end of 1860, and in the mean time he drew up a set of instructions for the use of the barometer on what may now be called the old lines.

3. The Era of the Weather Map.

Sailors at a remote port or at sea are still, generally speaking, in the position in which FitzRoy was when he drew up his instructions unless they are able to avail themselves of radio-telegraphy, as they certainly might, in order to obtain observations from a series of stations and compile a map for themselves.

A scheme for distributing information for this purpose by radio-telegraphy from the Eiffel Tower was begun a short time before the war, but in present circumstances many masters of ships are, for various reasons, not in a position to obtain the necessary information in that way or to chart and interpret the observations if they had them. But they have their own instruments and can make their own observations. They are therefore very much in the position of the persons for whom FitzRoy wrote. Since his time much has been done in the way of interpreting some of the best weather rules and weather maxims in the light of the new method of studying the subject with the aid of maps, but no one has attempted or is likely to attempt any further development of the subject on the lines of the only method available between 1643 and 1860. We have therefore thought it well to reprint the instructions which FitzRoy gave in his Barometer Manual. They are summarised in the explanatory sheet which is reproduced here. In quoting FitzRoy's words I do not wish to be held responsible for the accuracy of the statement in all its details. Some of them would certainly be modified in the light of facts which have become patent during the sixty years that have elapsed since FitzRoy wrote. The notes and figures in brackets [ ] have been added to the original text.

Later on we shall give some indication of the greater light which is thrown upon this as well as other parts of the subject by the study of weather maps.

EXPLANATORY OF WEATHER GLASSES IN NORTH LATITUDE.

In other Latitudes substitute the word South, or Southerly or Southward, for North, &c.

THE BAROMETER RISES	THE BAROMETER FALLS
for Northerly wind, (including from North-west by the *North*, to the Eastward,) for dry, or less wet weather,—for less wind,—or for more than one of these changes :—	for Southerly wind, (including from South-east, by the *South*, to the Westward,) for wet weather,—for stronger winds, —or for more than one of these changes :—
Except on a few occasions when *rain* (or snow) comes from the Northward with *strong* wind.	Except on a few occasions when *moderate* wind with *rain* (or snow) comes from the Northward.

For change of wind towards *any* of the above directions :—	For change of wind towards the *upper* of the above directions :—
A THERMOMETER FALLS.	A THERMOMETER RISES.

Moisture, or dampness, in the air (shown by a hygrometer) increases before or with rain, fog, or dew.

On barometer scales the following contractions may be useful in *North* latitude :—		And the following Summary may be useful *generally* in *any* latitude :—	
RISE for N.Ely. N.W.—N.—E. DRY or LESS WIND.	FALL for S.Wly. S.E.—S.—W. WET or MORE WIND.	RISE for COLD DRY or LESS WIND.	FALL for WARM WET or MORE WIND.
Except wet from N. Ed.	Except wet from N. Ed.	Except wet from cooler side.	Except wet from cooler side.

4. FitzRoy's Instructions for the Use of the Barometer.

TO FORETELL WEATHER.

1. Familiar as the practical use of weather-glasses is, at sea as well as on land, only those who have long watched their indications and compared them carefully are really able to conclude more than that the rising glass* usually foretells less wind or rain, a falling barometer more rain or wind, or both, a high one fine weather, and a low the contrary. But useful as these general conclusions are *in most cases*, they are *sometimes* erroneous, and then remarks may be rather hastily made, tending to discourage the inexperienced.

2. By attention to the following observations (the results of many years' practice and many persons' experience) any one not accustomed to use a barometer may do so without much difficulty.

* Glass, barometer, column, mercury, quicksilver, or hand.

3. The barometer shows whether the air is getting lighter or heavier, or is remaining in the same state. The quicksilver falls as the air becomes lighter, rises as it becomes heavier, and remains at rest in the glass tube while the air is unchanged in weight.** Air presses on everything within about ten miles of the air's surface, like a *much* lighter ocean, at the bottom of which we live—not feeling its weight because our bodies are full of air,† but feeling its currents, the winds. Towards any place from which the air has been drawn by suction,‡ air presses with a force or weight of nearly fifteen pounds on a square inch of surface. Such a pressure holds the limpet to the rock, when, by contracting itself, the fish has made a place without air§ under its shell. Another familiar instance is that of the fly which walks on the ceiling with feet that stick.

The barometer tube, emptied of air and filled with pure mercury, is turned down into a cup or cistern containing the same fluid, which, feeling the weight of air, is so pressed by it as to balance a column of about thirty inches (more or less) in the tube, where no air presses on the top of the column.

4. If a long pipe, closed at one end only, were emptied of air, filled with water, the open end kept in water and the pipe held upright, the water would rise in it twenty-eight or toward thirty feet. In this way water barometers have been made. A proof of this effect is shown by any well with a sucking pump—up which, as is commonly known, the water will rise nearly thirty feet by what is called suction, which is, in fact, the pressure of air towards an empty space.

5. The *words* on the earlier scales of barometers should not be so much regarded for weather indications as the rising or falling of the mercury, for if it stand at *Changeable* 29·5 in. [1000 mb.] and then rise towards *Fair* 30 in. [1016 mb.], it presages a change of wind or weather, though not so great as if the mercury had risen higher; and, on the contrary, if the mercury stand above *Fair*, and then fall, it *presages a change*, though not to so great a degree as if it had stood lower, besides which, neither the direction nor force of wind, nor *elevation above the sea level*, are in any way noticed on such scales. It is not from the point at which the mercury may stand that we are alone to form a judgment of the state of the weather, but from its *rising* or *falling*, and from the movements of immediately preceding *days as well as hours*, keeping in mind effects of change of *direction* and dryness or moisture, as well as alteration of force or strength of wind.

6. The barometer is said to be *falling* when the mercury in the tube is sinking, at which time its upper surface, if large, is *sometimes* concave or hollow; or when the hand moves to the left. The barometer is rising when the mercurial column is lengthening, its upper surface being convex or rounded; or when the hand moves to the right.

** [For a more modern explanation of the meaning of a reading of the barometer, see Chapter VIII.]

† Or atmosphere, the atmospheric fluid which we breathe.

‡ Or exhaustion. § A vacuum.

7. In temperate climates, towards the higher latitudes, the quicksilver ranges, or rises or falls, nearly three inches—namely, between about 30 inches and nine-tenths [1046 mb.] and less than *twenty-eight* inches [948 mb.] on *extraordinary* occasions; but the usual range is from about thirty inches and a half [1033 mb.] to about twenty-nine inches [982 mb.]. Near the Line, or in equatorial places, the range is but a few tenths, except in storms, when it *sometimes* falls to twenty-seven inches [914 mb.].

A fall of half a tenth [1½ mb.] or, still more, of a whole tenth [3⅓ mb.] in an hour is a sure warning of storm.

8. The sliding-scale (vernier) divides the tenths into ten parts each, or hundredths of an inch. The number of divisions on the vernier exceeds *or* is less than that in an *equal space* of the *fixed* scale, by one.

9. By a thermometer the *weight* of air is *not* shown. No air is within the tube. None can get in. But the bulb of the tube is full of mercury, which contracts by cold and swells with heat—according to which effect the thread of metal in the small tube is drawn down or pushed up so many degrees—and thus shows the temperature.*

10. If a thermometer have a piece of linen or muslin tied loosely round the bulb, wetted enough to keep it *damp* by a strip or thread dipping into a cup of water, it will show less heat than a dry one, in proportion to the moisture of the air, and quickness of drying.† In very damp weather, with or *before* rain, fog or dew, two such thermometers will be nearly alike.‡

11. For ascertaining the dryness or moisture of air the readiest and surest method is the comparison of two verified thermometers, one dry, the other *just* moistened and *kept so*. Cooled by evaporation as much as the state of the air admits, the moist (or wet) bulb thermometer shows a temperature nearly equal to that of the other one when the atmosphere is extremely damp or moist; but lower at other times—in proportion to the dryness of air, and consequent evaporation—as far as twelve or fifteen degrees in this climate; twenty or even more elsewhere. From three to eight degrees of difference is usual in England; and about seven is considered healthy for inhabited rooms. The thermometers should be near each other, but not *within* three inches.§

12. The thermometer fixed or attached to a barometer, intended to be used only as a weather glass, shows the temperature of air *about* it nearly—but does not show the temperature of the mercury *within* exactly. It does so, however, near enough for ordinary practical purposes—provided that no sun, nor fire, nor lamp-heat is allowed to act in the instrument partially.

* Thirty-two degrees is the point at which fresh water begins to freeze, or ice to thaw. Salt water at 28°; when not in motion.

† Evaporation.

‡ Their difference, subtracted from the lower, gives the dew point (nearly).

§ The two thus combined, making a (Mason) hygrometer [*see* Fig. 2, p. 51], for which, however, some kinds of hair, grass or seaweed may be a substitute, though very inferior.

13. The mercury in the cistern and tube being affected by cold or heat makes it advisable to consider this when endeavouring to foretell coming weather by the varying length of the column, and indispensable when making comparisons with other instruments.

14. Briefly, the barometer shows weight, tension, or pressure of the air; the thermometer heat and cold, or temperature; and the wetted thermometer, compared with a dry one, the degree of moisture or dampness.

15. It should always be remembered that the state of the air *foretells coming* weather rather than shows the weather that is *present* (an invaluable fact too often overlooked), that the longer the time between the signs and the change foretold by them, the longer such altered weather will last; and on the contrary, the less the time between a warning and a change, the shorter will be the continuance of such foretold weather.

16. To know the state of the air, not only barometer and thermometers should be watched, but the appearance of the sky should be vigilantly noticed.

17. If the barometer has been about its ordinary height, say near thirty inches, at the sea level* [1016 mb.], and is steady or rising, while the thermometer falls, and dampness becomes less, North-westerly, Northerly or North-easterly wind, or less wind, less rain or snow, may be expected.

18. On the contrary—if a fall takes place, with a rising thermometer and increased dampness, wind and rain may be expected from the South-eastward, Southward, or South-westward.

19. In winter, a fall, with low thermometer, foretells snow.

20. Exceptions to these rules occur when a Northerly wind, with wet (rain, hail or snow), is impending, before which the barometer often *rises* (on account of the *direction* of the coming wind alone) and deceives persons who from that sign only (the rising) expect fair weather.

21. When the barometer is rather below its ordinary height down to near twenty-nine inches and a half, say (at the sea level) [1000 mb.], a rise foretells less wind, or a change in its *direction* towards the Northward, or less wet; but when it has been very low, about twenty-nine inches [982·0 mb.], the first *rising* usually precedes, or indicates, *strong* wind—at times heavy squalls—from the North-westward, Northward or North-eastward, *after* which violence a gradually rising glass foretells improving weather—if the thermometer falls. But if the warmth continue, probably the wind will back (shift against the sun's course), and more Southerly or South-westerly wind will follow, especially if the barometer rise has been sudden.

* It differs or stands lower about the tenth of an inch [4 mb.] for each hundred of feet of height directly upwards, or vertically above the sea; its *average* height being 29·95 inches [1014·2 mb.] at the mean sea level in England; which height may be called "par" for that level. Allowances must, therefore, be made for barometers on high land or in buildings; each different elevation having its own (normal) line of pressure, or par height.

22. The most dangerous shifts of wind, or the *heaviest* Northerly gales, happen *soon* after the barometer *first* rises from a very low point, or if the wind veers *gradually*, at some time afterwards, though with a *rising* glass.

23. Indications of approaching change of weather and the direction and force of winds are shown less by the *height* of the barometer than by its falling or rising. Nevertheless a height of more than 30·0 inches ([1016 mb.] at the level of the sea) is indicative of fine weather and *moderate* winds, *except* from East to North *occasionally* whence it *may* blow strongly.

24. A rapid rise of the barometer indicates unsettled weather, a slow movement to the contrary; as does likewise a *steady* barometer, which, when continued, and with dryness, foretells very fine weather, lasting for some time.

25. A rapid and considerable fall is a sign of stormy weather, with rain (or snow). Alternate rising and sinking, or oscillation, indicates unsettled and threatening weather.

26. The greatest depressions of the barometer are with gales from S.E., S., or S.W.; the greatest elevations with wind from N.W., N., or N.E., or with calm.

27. Though the barometer generally falls with a Southerly, and rises with a Northerly wind, the contrary *sometimes* occurs; in which cases the Southerly wind is usually dry with fine weather, or the Northerly wind is violent and accompanied by rain, snow or hail, perhaps with lightning.

28. When the barometer sinks considerably, much wind, rain (perhaps with hail), or snow, will follow, with or without lightning. The wind will be from the Northward, if the thermometer is low (for the season), from the Southward if the thermometer is high. Occasionally a low glass is followed or attended by lightning only; while a storm is beyond the horizon.

29. A sudden fall of the barometer, with a Westerly wind, is sometimes followed by a violent storm from N.W. or North or N.E.

30. If a gale sets in from the E. or S.E. and the wind veers by the South, the barometer will continue falling until the wind is near a marked change, when a lull *may* occur; after which the gale will soon be renewed, perhaps suddenly and violently, and the veering of the wind towards the N.W., North or N.E. will be indicated by a rising of the barometer with a fall of the thermometer.

39. Another general observation requires attention, which is that the wind usually *appears* to veer, shift, or go round *with the sun* (right-handed or from left to right)* and that when it does not do so, or backs, *more* wind or bad weather may be expected instead of improvement, *after a short interval.*

* *With* watch-hands in the Northern Hemisphere, but the *contrary in South Latitude*. This, however, may be only *apparent;* the wind actually circulating in the *contrary* direction, as a circle, or circular figure, turned horizontally, while moved across a map, or chart, will explain better than words. The *usual* alternation, from left to right, or back, is caused by the varying predominance of either wind, tropical or polar (Southerly or Northerly). [Veering is now defined by international agreement as movement *with* watch-hands in either hemisphere.]

40. It is not by any means intended to discourage attention to what is usually called "weather wisdom." On the contrary, every prudent person will combine observation of the elements with such indications as he may obtain from instruments; and will find that the more accurately the two sources of foreknowledge are compared and combined, the more satisfactory their results will prove.

41. A barometer begins to rise considerably before the conclusion of a gale, sometimes even at its commencement. Although it falls lowest before high winds, it frequently sinks very much before heavy rain. The barometer falls, but not always on the approach of thunder and lightning. Before and during the *earlier* part of settled weather it usually stands high and is stationary, the air being dry.

42. Instances of fine weather with a *low glass* occur, however, rarely, but they are always preludes to a *duration* of wind or rain, *if not both.*

43. After very warm and calm weather a squall, or storm with rain, may follow; likewise at any time when the atmosphere is *heated* much above the usual temperature of the season, and when there is, or recently has been, much electric (or magnetic) disturbance in the atmosphere.*

44. Allowance should *invariably* be made for the previous state of the glass during *some days, as well as some hours,* because their indications *may* be affected by distant causes, or by changes close at hand. Some of these changes may occur at a greater or less distance, influencing neighbouring regions, but not visible to each observer whose barometer feels their effect.

45. There may be heavy rains, or violent winds, beyond the horizon and the view of an observer, by which his instruments may be affected considerably, though no particular change of weather occurs in his immediate locality.

46. It may be repeated that the longer a change of wind or weather be foretold before it takes place, the longer the presaged weather will last; and, conversely, the shorter the warning, the less time whatever causes the warning, whether wind or a fall of rain or snow, will continue.

47. Sometimes severe weather from the Southward, *not lasting long,* may cause no great fall, because followed by a *duration* of wind from the Northward; and at times the barometer may fall with Northerly winds and fine weather, apparently against these rules, because a *continuance* of Southerly wind is about to follow. By such changes as these one may be misled, and calamity may be the consequence if not duly forewarned.

48. A few of the more marked signs of weather, useful alike to seaman, farmer and gardener, are the following:—

49. Whether clear or cloudy a rosy sky at sunset presages fine weather; an *Indian* red tint, *rain;* a red sky in the morning bad weather, or much wind (perhaps rain); a grey sky in the

* Indicated not only by electrometers, but by *telegraph wires,* and by magnetometers; also at times by the Aurora.

morning fine weather; a high dawn, wind; a low dawn, fair weather.*

50. Soft-looking or delicate clouds foretell fine weather, with moderate or light breezes; *hard-edged,* oily-looking clouds, wind. A dark, gloomy blue sky is windy, but a bright, light blue sky indicates fine weather. Generally, the *softer* clouds look, the less wind (but perhaps more rain) may be expected; and the *harder,* more greasy, rolled, tufted, or ragged, the stronger the coming wind will prove. Also a bright yellow sky at sunset presages wind; a pale yellow, wet; and a greenish, sickly-looking colour, wind and rain. Thus by the prevalence of red, yellow or other tints, the coming weather may be foretold very nearly; indeed, if aided by instruments, almost exactly.

51. Small, inky-looking clouds foretell rain; light scud clouds driving across heavy masses show wind and rain; but, if alone, may indicate wind only.

52. High upper clouds crossing the sun, moon or stars in a direction different from that of the lower clouds, or the wind then felt below, foretell a change of wind toward their direction.**

53. After fine, clear weather the first signs in the sky of a coming change are usually light streaks, curls, wisps, or mottled patches of white distant clouds, which increase and are followed by an overcasting of murky vapour which grows into cloudiness. This appearance, more or less oily, or watery, as wind or rain will prevail, is an infallible sign.

54. Usually the higher and more distant such clouds seem to be, the more gradual, but *general,* the coming change of weather will prove.

55. Light, delicate, quiet tints or colours, with soft undefined forms of clouds, indicate and accompany fine weather; but gaudy or unusual hues, with hard, definitely-outlined clouds, foretell rain, and probably strong wind.

56. Misty clouds forming or hanging on heights show wind and rain coming if they increase, remain or *descend.* If they rise or disperse the weather will improve or become fine.

57. When sea-birds fly out early and far to seaward, moderate wind and fair weather may be expected. When they hang about the land, or over it, sometimes flying inland, expect a strong wind with stormy weather. As many creatures besides birds are affected by the approach of rain or wind, such indications should not be slighted by any observer who wishes to foresee weather or compare its variations.

* A "high dawn" is when the first indications of daylight are seen above a bank of clouds. A "low dawn" is when the day breaks on or near the horizon, the first streaks of light being very low down.

** In the tropics or regions of trade winds there is generally an upper and counter current of air, with very light clouds, which is not an indication of any approaching change. In middle latitudes such upper currents are not evident, except before a change of weather, because their vapour is *uncondensed,* and therefore invisible.

58. There are other signs of a coming change in the weather known less generally than may be desirable, and therefore worth notice; such as when birds of long flight, rooks, swallows or others, hang about home and fly up and down or low, rain or wind may be expected. Also when animals seek sheltered places, instead of spreading over their usual range; when pigs carry straw to their styes; when smoke from chimneys does not ascend readily (or straight upwards *during calm*), an unfavourable change is probable.

59. Dew is an indication of fine weather; so is fog. Neither of these two formations occurs under an overcast sky, or when there is much wind. Occasionally one sees fog rolled away, as it were, by wind, but seldom or never *formed* while it is blowing.

60. Remarkable clearness of atmosphere near the horizon, distant objects, such as hills, *unusually visible*, or raised (by refraction)* and what is called a "good *hearing* day" may be mentioned among signs of wet, if not wind, to be expected.

61. More than usual twinkling of the stars; indistinctness or apparent multiplication of the moon's horns; haloes; "wind dogs,"† and the rainbow are more or less significant of increasing wind, if not approaching rain, with or without wind.***

62. Near land, in sheltered harbours, in valleys, or over low ground, there is usually a marked diminution of wind during part of the night and dispersion of clouds. At such times an eye on an overlooking height may see an extended body of vapour below (rendered visible by the cooling of night) which *seems* to check the wind.

63. The dryness or dampness of the air and its temperature (for the season) should *always* be considered, with other indications of change or continuance of wind and weather.

64. On land generally there is more difficulty in ascertaining the real direction of the wind, in practice, than there is at sea, where sails, or a vane and compass are always at hand, uninfluenced by heights or eddy winds.

65. Some observers notice smoke, others clouds (seldom going with the *local* wind below, though generally correct as respects the *prevailing* wind), some mark the vane or weathercock, while only a few observers know how their points of reference bear by the world (or map) or even by a magnetic needle, of which the *variation* is still less often known within a point of the compass (if, indeed, understood).

66. Such persons should be advised to *mark* a true east and west line, *about the time of the equinox*, by the sun at rising or setting, and by it take their bearings or directions of wind.

* Much refraction is a sign of easterly wind, veering southward.

† Fragments or pieces (as it were) of rainbows (sometimes called "Wind-galls") seen on detached cloud.

*** *Remarkable* clearness is a bad sign. The "young moon with the old moon in her arms" (Burns, Herschel, and others) is a sign of bad weather in the temperate zones or middle latitudes; probably because the air is then exceedingly clear and transparent.

And they should note its direction by that of the *lower* clouds (when they are not very distant) *compared* with that of vanes or smoke in preference to any other indication.

67. Much more care is required in noticing the veering, shift, turn or gyration of the wind, than has usually been thought necessary. Very rarely has the way the wind *went round* been noticed in ordinary registers, although of much consequence.

68. These shiftings or veerings of wind, being caused generally by the progression of circuits, or cyclonic movements of the atmosphere, which succeed or *counteract* each other, variously impinging against air at rest or moving differently, require much attention, especially in forecasts of weather. (Weather casts?)

69. With respect to the "normal levels" or lines, or barometric heights (namely, the *means* above and below which the instruments range at places of various elevations) generally used on the continent of Europe, it may be repeated here that our word "par" may be synonym for use; thus (say) twenty-four hundredths (or whatever it may be) above or below par.

70. Wherever practicable the vertical difference between any such level, and that of the ocean, should be ascertained—as each ten feet of rise lowers the barometer about eleven thousandths of an inch [·4 mb.]. This sea-level should be that of the ocean itself —at mean half tide—a level which should be the universal standard of reference throughout the globe.

71. "Weather glasses" were used before the 18th century. Among others, De Foe watched and registered them in 1703 (see his account of "The Great Storm"); but it is an instance of the necessity for repeating information, that, generally speaking, even now so little complete use is made of these instruments, however familiar, common and inexpensive they have become.

72. Like seamanship, ability to foretell weather is acquired, by degrees, practically, and has not been hitherto attained by books; though it may now be in consequence of numerous recorded observations and opinions, brought together in late years, very carefully considered and published at the lowest price by Government, without claiming copyright.

73. Instructions being thus available, based on scientific as well as practical conclusions—by such help, properly studied, any one may become "weather-wise" who will notice, even once a day, the indications of the heavens, of thermometers and of a barometric instrument.

74. As all these instruments often, if not usually, show what may be expected—a day or even days in advance, rather than the weather of the present or next few hours—and as wind, or its direction, affects them much more than rain or snow, due allowance should always be made for days as well as for hours to come.

75. Annexed is a table of average temperature, between eight and nine o'clock a.m. near London, which may be used (with allowance for ordinary differences between Greenwich temperatures and others) to assist in foretelling the direction and nature of coming wind and weather.

76. The thermometer (shaded and in open air) when much higher between eight and nine a.m. than the average, indicates southerly or westerly wind (tropical); but when considerably lower, the reverse or northerly (polar) currents of air.

77. These indications are not yet so generally familiar as they ought to become, being easily marked and very useful.

78. The average temperatures at Greenwich in the shade and open air between 8 and 9 a.m. are nearly the mean temperatures of each twenty-four hours, taking the year through, around London; and with allowances for the differences between the *means* of Greenwich temperatures and those of other places may be taken (from Glaisher's tables) for the British Isles generally as follows:—

For about the middle of—

January	37°	July	62°
February	39°	August	61°
March	41°	September	57°
April	46°	October	50°
May	53°	November	43°
June	59°	December	39°

and proportionally between each middle period.

[Some of Admiral FitzRoy's suggestions recall the rhymes which are familiar to sailors.

Thus for numbers 15 and 46:—

"Long foretold, long last;
"Short notice, soon past."

And for numbers 21 and 39:—

"When the wind backs against the sun
"Trust it not for back it will run."

And for number 22:—

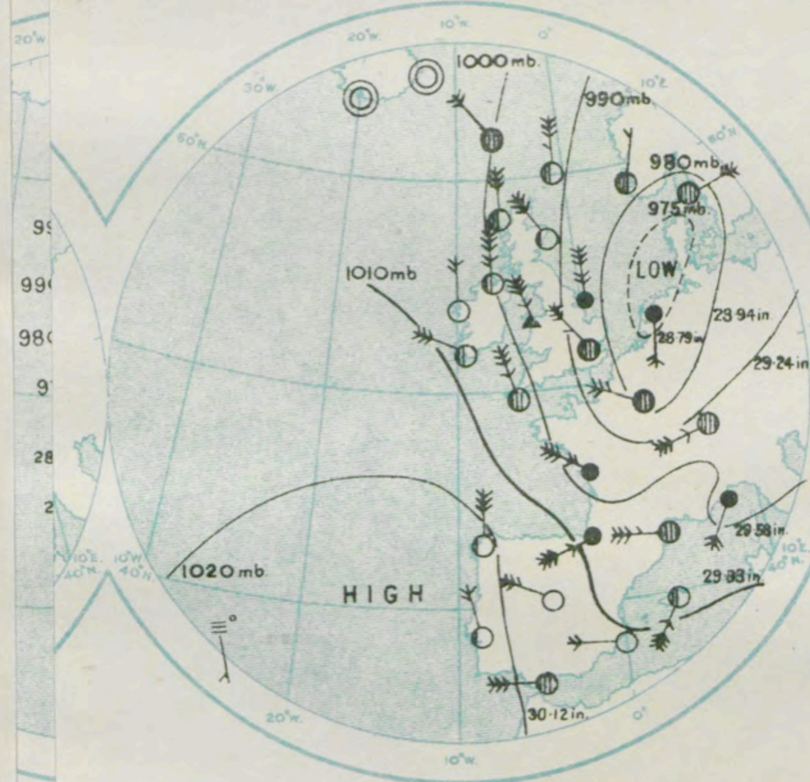
"First rise after low
"Foretells a stronger blow."

To these we may add a quatrain which is not apparently referred to, viz.:—

"When the rain comes before the wind
"Your topsail halyards you must mind;
"But when the wind's before the rain
"Hoist your topsails up again."

This maxim finds expression also in many forms and may be associated with the common saying that "it will not rain till the wind drops."]

1915. MAP 5. 7 A.M. 13th NOVEMBER, 1915.



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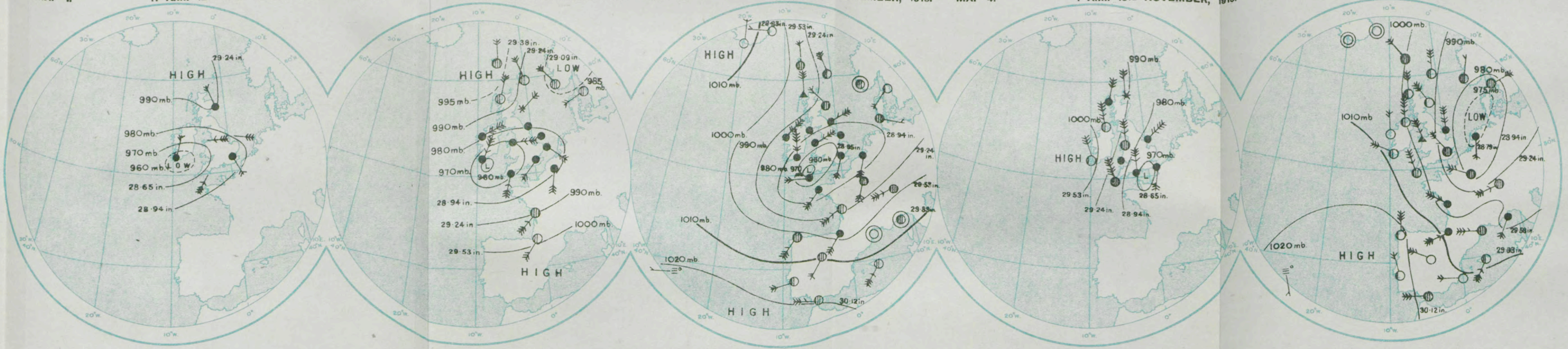
TRAVELLING DEPRESSION OF NOVEMBER 12-13, 1915.

DISTRIBUTION OF PRESSURE, WIND, AND WEATHER.

MAP 1. 11 A.M. 12th NOVEMBER, 1915. MAP 2. 1 P.M. 12th NOVEMBER, 1915. MAP 3. 6 P.M. 12th NOVEMBER, 1915. MAP 4. 1 A.M. 13th NOVEMBER, 1915. MAP 5. 7 A.M. 13th NOVEMBER, 1915.



EXPLANATION:—BAROMETER.—Isobars are drawn for intervals of ten millibars. **WIND.**—Direction is shown by arrows flying with the wind. Force, on the scale 0-12, is indicated by the number of feathers. Calm ◯ **WEATHER.**—Shown by the following symbols:—◯ clear sky. ◔ sky quarter clouded. ◑ sky half clouded. ◕ sky three-quarters clouded. ● overcast sky. ● rain falling. ✳ snow. ▲ hail. ≡ fog. ≡° mist. T thunder. ꓘ thunderstorm.

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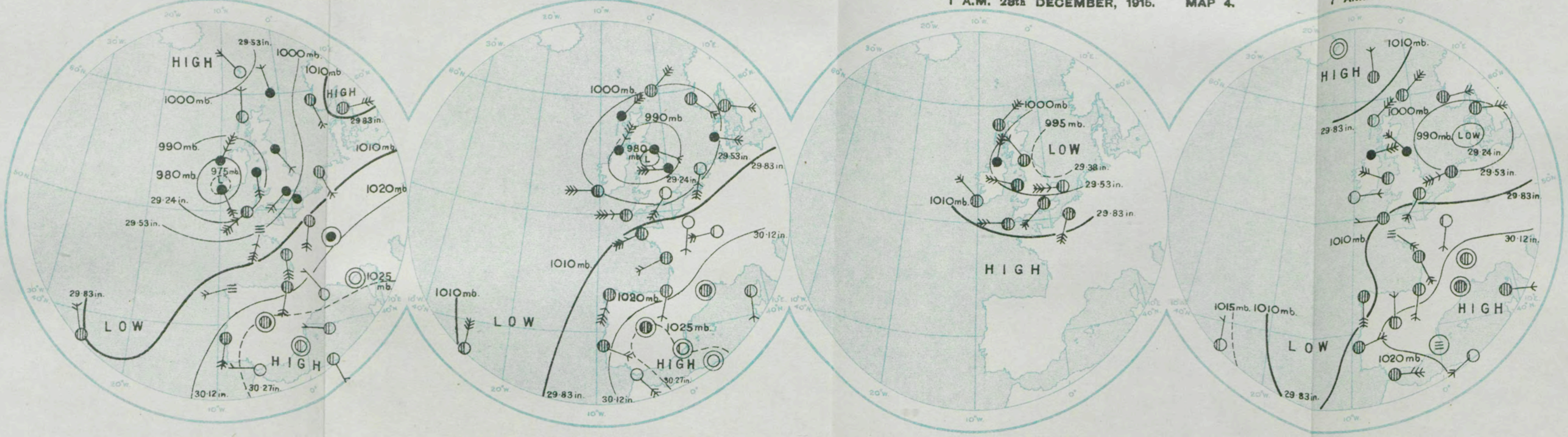
TRAVELLING DEPRESSION OF CHRISTMAS, 1915.

DISTRIBUTION OF PRESSURE, WIND, AND WEATHER.

MAP 1. 7 A.M. 27th DECEMBER, 1915. MAP 2. 6 P.M. 27th DECEMBER, 1915. MAP 3. 1 A.M. 28th DECEMBER, 1915. MAP 4. 7 A.M. 28th DECEMBER, 1915.



EXPLANATION :—BAROMETER.—Isobars are drawn for intervals of ten millibars. **WIND.**—Direction is shown by arrows flying with the wind. Force, on the scale 0–12, is indicated by the number of feathers. Calm ◯ **WEATHER.**—Shown by the following symbols :— ◯ clear sky. ◯ sky quarter clouded. ◯ sky half clouded. ◯ sky three-quarters clouded. ◯ overcast sky. ● rain falling. ✳ snow. ▲ hail. ≡ fog. ≡ mist. T thunder. Ʈ thunderstorm.

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PART III.

MODERN METEOROLOGY.

CHAPTER X.

The Weather Map and the Travel of Depressions.

1. Modern Meteorology the Work of an Organisation, not of an Individual.

Modern meteorology means a meteorological organisation, not merely the work of an individual observer. The making of a single forecast in any one of the meteorological offices of Europe, America, Australia or the Far East requires the organised co-operation of some hundreds of persons; about a hundred observers who note the necessary observations simultaneously at as many separate places and hand in their reports to the telegraphists who transmit them to one centre where the meteorological expert charts them on a map and draws therefrom the conclusions on which the forecasts are based.

The preparation of the map is an essential part of the process. No meteorologist in the modern sense attempts to forecast the weather without reference to a map prepared either by himself or by some one with whom he is in direct communication, from observations transmitted by telegraph for the purpose. No amount of weather-wisdom or weather-lore or experience is a substitute for the map. The more expert and accomplished the meteorologist the more certain he is that all he can do with a barometer and other instruments and without the materials for constructing a map, is to make a guess at what the map is like and think out from that what the weather changes are likely to be.

With sufficient intelligence and sufficient experience he may be able in that way to make useful suggestions, when forecasts in the modern sense are not available.

It is a common experience of professional meteorologists away from their base to find themselves appealed to for an opinion about the weather, judging from the signs of the sky alone, because they are learned in such things. That is exactly what they are not. Accustomed to refer everything to a map, without one they feel themselves to be rather worse off than those who are unaccustomed to its use.

In these days a meteorologist thinks in maps; his language and modes of expression are formed thereby. An explanation of the method of forecasting by means of maps is therefore offered here and thereafter we will consider how with a barometer and observation of the weather an idea of the map can be formed by an observer out of reach of maps.

2. A Map of the Weather.

Modern meteorology is essentially dependent upon the modern means of communication, the electric telegraph, the telephone or wireless telegraphy. The electric telegraph was practically a creation of the second quarter of the nineteenth century and as an organised means of communication reached its full development with the laying of the Atlantic Cable in 1866. Thereafter its history deals simply with extensions and improvements. The weather map had been brought within the range of possibility. On September 3rd, 1860, Admiral FitzRoy began the regular daily collection of reports of weather by telegraph for the Meteorological Department of the Board of Trade which, as we have seen, was under his charge.

The reports which he received included readings of the barometer and thermometer and notes of wind and weather. The reports of to-day are very little different from what they were fifty years ago. Of the barometer, thermometer and wind there is more to be said presently. For the moment I wish to confine the reader's attention to the weather.

We have already explained in Chapter VI. what is included in the term weather and the Beaufort notation which is used to make the reports uniform in style and concise in practice.

Let us now suppose that we have a corps of OBSERVERS at selected points which we call STATIONS distributed all over the country, who note the weather at an agreed hour and immediately telegraph their notes to headquarters. The information is plotted at once on a map. The result is that the staff at headquarters knows what the weather is, not only on the spot but at selected points over a large area, the British Isles, for example. The map is always instructive and sometimes astonishing. The weather may be quite fine over the greater part of the area, though it is very seldom that there is a map of the British Isles without rain shown somewhere on it. On the other hand there is hardly ever a map showing rain everywhere. Sometimes it is brilliantly fine in one region and yet it is raining, perhaps a thunderstorm, not far away. Here (*Plate I.*, Fig. 1) is an example of a map showing the distribution of weather at 6 p.m. on 2nd August, 1915.

The letters are entered in the immediate neighbourhood of the stations at which the weather is recorded. There is a thunderstorm at Paris and Flushing, rain along a line from Paris to Aberdeen through Liverpool and Glasgow; there is cloud generally except in middle France, Holland and at Stornoway.

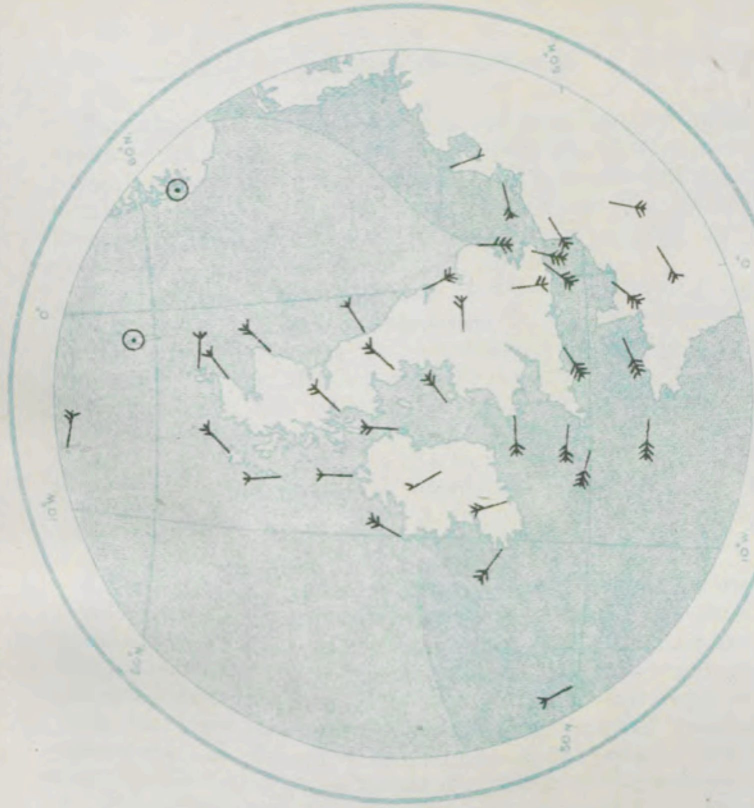
Plate I.

Fig. 1.

DISTRIBUTION OF WEATHER, 6 P.M. 2nd AUGUST, 1915.

Fig. 2.

DISTRIBUTION OF WIND, 6 P.M. 2nd AUGUST, 1915.



For the explanation of the letters *see* chapter VI.

⊙ Calm. force 3 force 1. force 4.

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For the purpose of mapping, it is more convenient to use symbols which indentify more clearly the localities referred to instead of letters for the state of the sky, so we will give later the symbols used to represent the weather in the Daily Weather Report of the Meteorological Office and a copy of the map expressed in symbols (see Fig. 5, *Plate III.*).

The first impression that one gets from looking at such a map is that everybody who is interested in the weather, for business or pleasure, would like to be informed about it; and the next impression is that there must be some reason to account for the peculiarities of the distribution, some reason why it is fine in one place and raining in another, a hundred or five hundred miles away. It is the pursuit of the impulse, which naturally follows the second impression, that constitutes modern meteorology.

3. A Map of the Winds.

First of all let us bring the wind into account, because it is a matter of common knowledge that the weather often changes when the wind changes. That is easily done because the observer who notes the weather can also observe the wind and include the observations in his telegram. As we have explained in the first three chapters he need not have any special instrument for measuring the direction and force of the wind. He can estimate the direction if he knows the points of the COMPASS and can see which way smoke is blowing, or some other common indication of the wind-motion. He can also estimate the force of the wind in accordance with a scale of numbers which we also owe to Admiral Beaufort and to which the indications have been assigned, as shown on p. 4.

We can, therefore, now put on the map the indication of the wind at each one of our stations and then it becomes quite clear that the winds at neighbouring stations stand in some relation to each other (Fig. 2). The south-westerly winds group themselves in one region about the English Channel, north-easterly ones in another over Scotland, with intermediate winds between, southerly on the east, northerly on the west. It is quite unlikely that you will find a north-easterly wind in the middle of a region of south-westerly winds. It might possibly be so if the winds generally were merely light airs but not if they were winds of moderate strength. If such a case were found it would at once arouse curiosity as to how it could possibly occur. Wind maps, to a certain extent, confirm the ordinary impression that wind and weather go together, but with many exceptions. It often rains with a south-westerly wind but it is sometimes extraordinarily fine with the same wind. An easterly or north-easterly wind often brings us fine weather and yet our most persistent rains come with easterly or north-easterly winds. Why is this?

It is clear that we must be able to answer these questions, explaining what does happen before we can say what is going to happen in the future. In order to do this we must understand something of the nature and properties of the atmosphere the gaseous envelope of our planet in which all these changes take place.

4. The Atmosphere.

The air which surrounds us and is carried along with the earth on which we live and which, regarded in its entirety, is called the atmosphere, is a mixture of gases. In the regions which are within our reach, up to 10 kilometres, 6 miles or 33,000 feet, the greater part of it is nitrogen, one of the chemical constituents of ammonia and also of nitric acid and the nitrates which are so important in gunpowder and nearly all other explosives. In the atmosphere, however, nitrogen is a peculiarly inert gas. It merely dilutes the more active gas oxygen, which forms about one-fifth of the atmosphere. Oxygen is one of the active substances in all forms of combustion. The burning of fires, and the slower processes which go on within the human body, are forms of combustion in which oxygen combines with substances like wood or coal or with the blood in the lungs. In the combination a proportionate quantity of heat is produced, and a corresponding amount of carbonic acid gas which mixes with the other gases of the atmosphere. Without oxygen no fire can be maintained and the chemical processes in the body necessary for life cannot go on. Thus the oxygen of the atmosphere is a very important element but in meteorology its special characteristics do not concern us. Combustion is constantly going on and oxygen is being used up, but there is a reverse process going on in growing plants. They act upon the carbonic acid gas in the air which surrounds them, take it into their structure and liberate oxygen. The result of these manifold chemical actions, with the mixing that is made by the winds, is to maintain the mixture of nitrogen and oxygen in the atmosphere practically unchanged.

Besides these two constituents there are small amounts of other gases, one the inert gas argon and the other carbonic acid gas, one of the products of the combustion of wood, coal, etc. These are also practically invariable in the open air, but there is also always in the open air some water-vapour which is very variable in its amount. The water-vapour passes into the atmosphere as an invisible gas by evaporation from all surfaces of water, even when it is frozen, as well as, to a less extent, from nearly all forms of combustion.

5. Water-Vapour: Evaporation and Condensation.

Unlike the other constituents of the atmosphere water-vapour is of the greatest importance in meteorology. It is the form in which the enormous quantities of water represented primarily by rain or snow, and secondarily by rivers, lakes, icebergs and glaciers, are transported from one part of the earth to another. All the water which falls as rain or snow in a year has been evaporated from the sea or other surfaces of water or ice, or from plants or wet soil and transported in the form of invisible water-vapour mixed with the other gaseous constituents of the atmosphere. By natural processes which can be imitated quite easily and effectively in a physical laboratory,

part of the invisible water-vapour in the air can be reconverted to visible water in drops as in clouds and rain, or as snow-crystals in certain kinds of cloud in the atmosphere itself, or on plants and buildings as dew or hoar-frost. The conversion of invisible vapour into visible drops or crystals is called condensation which is the counterpart of evaporation.

Evaporation and condensation are related to changes of temperature in the air and the study of these changes belongs, therefore, to the science of heat which in modern times finds its most effective illustrations in the working of the steam-engine. The atmosphere may, therefore, be looked upon as a steam-engine of huge dimensions drawing its heat from the sun and ultimately sending it out again into space. At the end of a year so much heat has been taken by the earth from the sun, so much has been used up in the operations of running water and flowing air, so much sent out again into space. As after the lapse of centuries, so far as we can tell, the whole earth becomes neither warmer nor colder we must suppose that in the end the heat which has been taken in has been got rid of by radiation into space, but in the meantime the whole course of the wind and weather all over the world has been controlled and ordered by the process of warming and cooling, evaporation and condensation.

The weather which we experience in any particular locality is a small part of the great process going on in the whole atmosphere of which evaporation and condensation are the most striking incidents. Evaporation is included because if there were no evaporation condensation would soon come to an end; but evaporation is a silent invisible process, whereas condensation furnishes in the form of cloud, rain, snow, thunderstorms, the most impressive manifestations of the energy of nature.

From recent researches by means of balloons it appears that only the lowest layer of the atmosphere, the troposphere, about 10 kilometres or 33,000 feet thick, is concerned in the process of condensation and evaporation. That does not define the limit of the atmosphere itself. Observations of meteors, auroræ and other phenomena indicate that the atmosphere is still recognisable at a height of some 80 or 100 miles. At the greatest heights the composition is probably quite different from what it is near the surface. From 57 kilometres upwards it is thought to be mainly hydrogen. But it is with the lowest 10 kilometres, the region of nitrogen, oxygen and water-vapour that meteorology is concerned.

6. Temperature and Humidity.

Our interest in the temperature and pressure of the atmosphere is however not so limited.

Temperature is indicated by the thermometer and tells us how hot or how cold the weather is. It is a very important consideration because the human organism is so adjusted that without special precautions it can only bear a very limited range of temperature with comfort. 62½° Fahrenheit, 290 absolute, is the best temperature for an ordinary living room. A thinly clad person feels very cold, unless he is actively employed, if the thermometer falls below 54° F., 285a.; and if it gets above 72° F., 295a., it feels very hot for hard work for those who are not used to it. The feeling of oppression is not simply a matter of temperature; it depends also on the dryness or moistness of the atmosphere. A moist atmosphere is peculiarly disagreeable if the temperature is below 50° F., 283a. or above 70° F., 294a. These conditions can be determined by the wet bulb thermometer. When the wet bulb is above 90° F. life is hardly supportable, and when the temperature is only a few degrees above the freezing point, very damp air is very objectionable. Consequently considerations of health lead us to pay careful attention to the wet bulb as well as the dry bulb. Humidity is the term which meteorologists use to describe the state of the atmosphere as regards dryness or moistness. When the air is dry the humidity is said to be low, and when it is damp the humidity is said to be high. The temperature, and still more the humidity, generally vary very considerably between day and night (diurnal variation) and the temperature varies still more between summer and winter (seasonal variation) but the seasonal variation of humidity is relatively small.

Conversion Table for Temperature.

a.	C	F.
320	47°	116·6°
310	37°	98·6°
300	27°	80·6°
290	17°	69·6°
280	7°	44·6°
273	0°	32°
255·2	— 17·8	0°
0	— 273	— 459·4°

The great advantage of the British climate is that during the working hours of the day the temperature and humidity generally come within a workable range at any time of the year; when it is very hot in summer it is generally very dry, so that there are very few days in the year in which outdoor work has to be suspended on account of the heat or the cold. But anyone who is accustomed to the relative dryness of the eastern side soon feels the oppression of moist heat if he goes to the extreme western side of Ireland.

Fig. 3 (*Plate II.*), opposite p. 99, shows the distribution of temperature over the British Isles at 6 p.m. on the 2nd August, 1915.

Lines are drawn separating the figures above 65 from those below, those above 60 from those below, and the figures above 55 from those below. Some figures remain isolated.

For reasons which are now clearly understood, the temperature of the air generally gets lower as one ascends. The average fall of temperature near the surface is about 1° F. for each 300 feet, 10° F. for a kilometre. With a surface temperature of 50° F. we might anticipate* that the freezing point would be reached at 5,500 feet (1¾ kilometres above the surface), or 1,000 feet above the top of Ben Nevis, 2,000 feet above the Welsh

* For further information see *Glossary s.v.*, INVERSION.

mountains. On mountain slopes temperature falls rather more than it does in the free air, but the difference is not important. The freezing point of water is the average temperature of July at 7,500 feet, 2·5 kilometres. At a height of 27,000 feet MERCURY freezes, and the seasonal variation there is much less. The fall of temperature goes on until the height of the highest mountains of the world is reached, about 30,000 feet, 10 kilometres, and then the temperature ceases to vary with further increase of height.* So the variation of temperature with height stops where the water vapour in the air ceases to be an appreciable amount, as will be gathered from the limits of cloud and temperature change in figure 8, p. 111.

The coincidence of the effective height of the water-atmosphere and the tops of the highest mountains with the cessation of the fall of temperature is curious. There is, perhaps, some connexion between them.

7. PRESSURE AND ITS MEASUREMENT.

We now come to the consideration of the pressure of the atmosphere, the most important of the meteorological elements, because all the rest of the features of weather, viz., wind, temperature, humidity, cloud, rain, seem to depend upon it, or rather, not so much upon itself as upon its changes. The winds are certainly closely related to differences of pressure, and in some way or other the adjustment of the flow of air to the requirements of pressure brings all the rest of the phenomena of weather into operation.

The ideas which form the basis of measurement of the pressure of the atmosphere are of the greatest importance in understanding the conditions of weather, but they are not to be formed without some experience of the behaviour of fluids, both liquid and gaseous. The air is held to the earth, just as water is, by its weight. The water only fails to cover the whole earth as the air does, because there is not enough of it. Both in air and water the weight of the upper layers influences the whole of the lower layers in a special way which is characteristic of fluid pressure. Everything immersed in it is pressed with a pressure that increases with the depth of immersion until the effect is absolutely crushing in actual fact. Everything that has hollow spaces must be crushed by pressure if it sinks deep enough in water. A similar statement is true of the atmosphere, only, with that, it is upwards where the pressure gets less and less that we have in mind, not so much downwards where it gets more and more.

The peculiarity of fluid pressure which we must carry with us is that of transmission. In ordinary domestic experience it is difference of level which decides which way water shall flow. "Water always finds its own level" is the proverbial way of putting it. It does not matter how little is the crevice through which the water has to creep. Give it time and it will settle itself just the same in the end as if the crevice were an open

* In equatorial regions the fall of temperature continues up to the height of 17 kilometres but in polar regions not so high as in our latitudes.

door. With air the same is true only less time is required to get the levels right, so that we come to the general principle that the pressure of still water or of the still atmosphere is always the same at the same level, inside a room or outside. In the most obscure recesses of an enclosed building there are always crevices enough to allow the pressure to be the same at the same level inside and out, except during such rapid changes of pressure as are produced by sudden gusts of wind and still more noticeably by the waves of explosions.

So we regard atmospheric pressure as ubiquitous, the same everywhere at the same level, unless the air is moving. When it is moving we regard the motion as an incident in the equalising of the level. So it is, but in the free atmosphere the process of equalising is not the simple process of flowing through a door, it has laws of its own which we shall have to consider in due time.

With the ubiquity of pressure comes the idea of its measurement and for this purpose we regard the pressure as uniform over a square inch or square centimetre. One only loses the thousandth part of the pressure of the atmosphere by climbing up ten metres (33 feet) so that the variation over a few feet is not appreciable except with a delicate instrument. We may take the pressure of the atmosphere at the surface as 14¾ lb. per square inch, or a kilogramme per square centimetre and about 7 lb. per square inch at 15,000 feet, about 5 lb. per square inch at 30,000 feet. Hence, we may form some impression of the forces with which we have to deal where atmospheric pressure is concerned. A kilogramme per square centimetre gives a ton over 1,000 square centimetres, about a square foot, and therefore nine tons to the square yard.

Thus the forces of atmospheric pressure are always very great when the areas considered are large.

8. The Barometer.

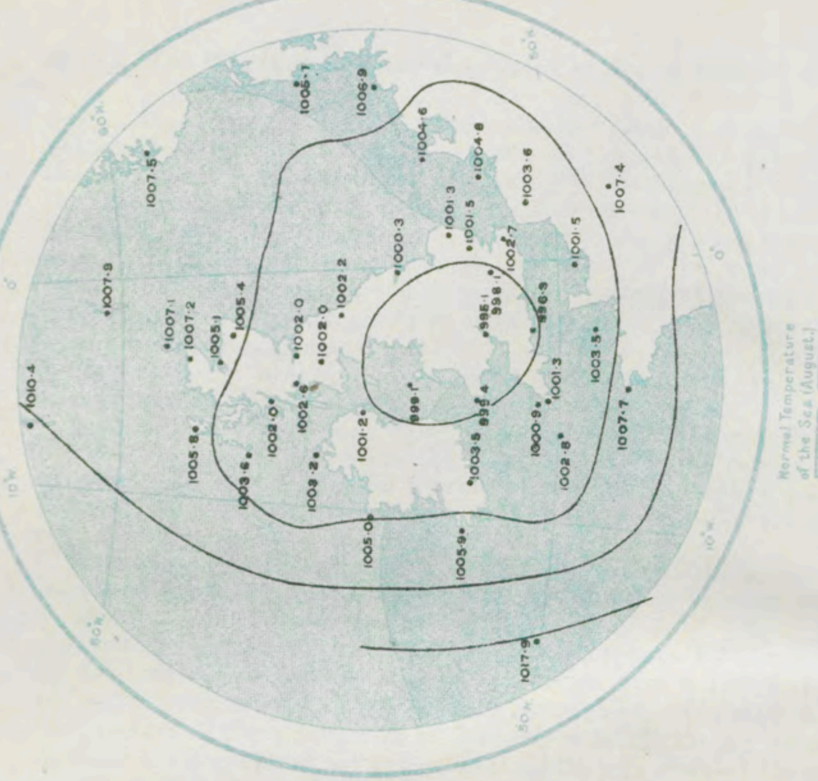
For measuring the pressure of the atmosphere we use a barometer. We have seen in Chapter VIII. that there are two common forms, the mercury barometer and the aneroid barometer. Either can be made to record its own variations by the movement of a pen over a paper carried on a drum moved by clockwork. The apparatus is then called a barograph or aneroidograph and the record is called a barogram.

The aneroid barometer gives the best idea of what is meant by the pressure of the atmosphere, because it is the crushing, or more strictly, the compression of a box which is nearly exhausted of air and has a flexible lid, and its recovery, which move the index. In the mercury barometer it is not the pressure of the atmosphere which is measured but the length of a column of mercury which will give the same pressure as that of the atmosphere at the level where the two fluids, air and mercury, meet. Mercury is a very good fluid to use because it is so heavy. It only requires a column of mercury about 30 inches or 760 millimetres (abbreviated as 760 mm.) high, without anything on the

Plate II.

DISTRIBUTION OF PRESSURE, 6 P.M. 2nd AUGUST, 1915.

Fig. 4.



The figures give the sea-level pressures in millibars.
The black lines are isobars.

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DISTRIBUTION OF TEMPERATURE, 6 P.M. 2nd AUGUST, 1915.

Fig. 3.

The figures give the observed temperatures on the Fahrenheit scale.
The black lines are isotherms.

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top of it, to balance the accumulated pressure of the atmosphere in its whole range from the sea-level to a hundred miles up. Any other liquid could be used, but a water-barometer would have to be 34 feet in height, a glycerine-barometer about 27 feet in height. So in spite of the ubiquity of atmospheric pressure and the great variety of possible liquids, when it comes to measuring, only the mercury barometer and the aneroid barometer are left and there are difficulties about the use of the aneroid barometer which make it unacceptable when weather maps have to be drawn. So the mercury barometer is always used for that purpose.

It is really only small variations of atmospheric pressure that come into consideration. If we take the average pressure as a "bar" or 1000 millibars (abbreviated as 1000 mb), the whole range of variation within a year will only be between 940 mb. and 1060 mb., except on the rarest occasions when it may include 925 mb. The variation of the hundredth of an inch in the length of the mercury column or one-third of a millibar in pressure is of importance in modern weather-study, so the manufacture, graduation and reading of barometers for the purposes of a weather map are matters for careful consideration, especially as the readings are the most important of all those which are charted. Barometer readings have to be properly examined as to temperature and index error, and, if necessary, corrected; and they have then to be reduced to sea-level, so that when they are plotted on the map we may recognise the variations from point to point at the same level, or along a horizontal surface. Sea-level is a conventional term to indicate the horizontal surface of the calm sea when the tide is at a particular level at Liverpool. We have already explained that if the air is at rest the pressure is the same at the same level. Now when we come to deal with large areas as with maps, we plot the readings of the barometer and find that this pressure is not the same everywhere at the same level. But when there are differences of pressure at sea-level, the air is, practically speaking, never at rest but is moving. The motion we call wind.

Conversion Table for Pressure.

inch.	mm.	mb.
1	25·4	33·9
·0394	1	1·33
·0295	·75	1

9. Isobars.

We can draw lines on the map which we call isobars, or lines of equal pressure which show at what points the corrected and reduced barometer readings are the same, and thus get a pictorial representation of the distribution of pressure at sea-level. These differences of pressure could not exist if the whole atmosphere were quiescent, and it is the existence of these differences which accounts, generally speaking, for the winds which we experience.

To the distribution of pressure the distribution of winds can be related and to them also, in part at least, the distribution of temperature and weather.

Figure 4 (*Plate II.*) represents the distribution of pressure shown by isobars and figures; when we have made a single figure 5 (*Plate III.*) combining all the information which has been given separately in Plates I. and II., except temperature which the reader is requested to transfer for himself from Figure 3, we have completed the weather map and the remainder of the task of modern meteorology is to understand the lessons that it teaches.

10. Lessons from Weather Maps.

The basis of forecasting is the study of a succession of maps as will be seen later on, but let us first consider what we can learn about meteorology from the study of a single map. For this purpose some examples may be better than others, but there are some things which can be illustrated by any map.

Buys Ballot's Law.

The relation of wind to pressure, or strictly speaking to the isobars which represent the distribution of pressure, is one of them. It will be noticed that the arrows which denote the wind, with some exceptions to which reference will be made later, take account of the run of the isobars in a peculiar manner. They mostly just fail to point along the isobars, not irregularly but with a sort of regularity. As one looks along an arrow from feathers to point it deviates from the line of the isobar in such a way that the feathers are on the side of the high pressure and the point on the side of the low; the deviation may be anything between nothing and half a right angle; in one case it is more. It is this regularity of direction, in spite of diversity in the deviation, which has attracted the attention of meteorologists and which has found expression in a law which was stated in 1857 by Professor Buys Ballot, of Utrecht, in the form that in the Northern Hemisphere **if you stand with your back to the wind, pressure is lower on your left hand than on your right.** This is known as Buys Ballot's law and is the fundamental law of modern meteorology. It is necessary to specify the Northern Hemisphere because in the Southern Hemisphere the reverse is true, standing with your back to the wind the pressure on your right hand is lower than it is on the left.

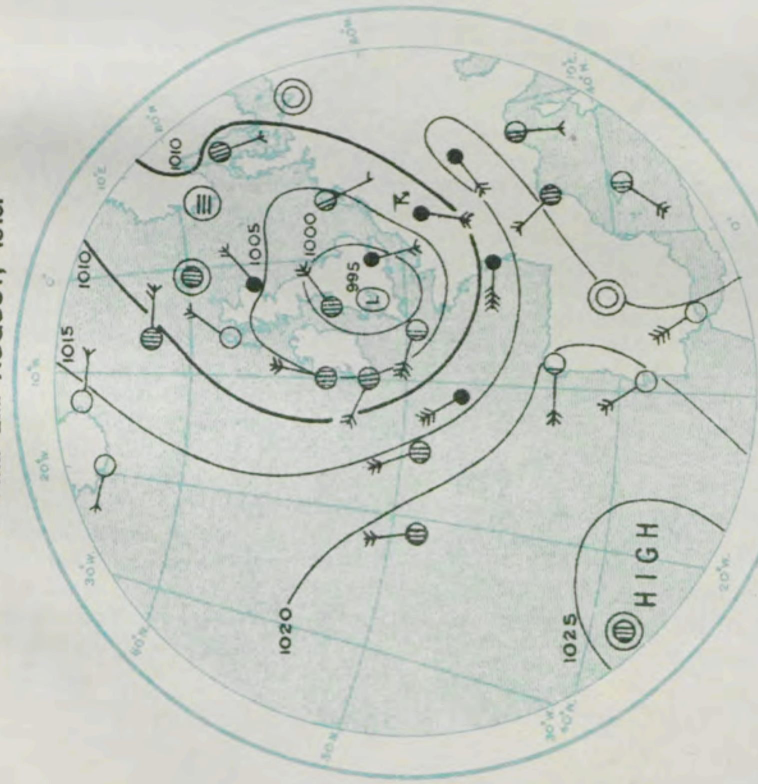
Sailors are accustomed to speak of facing the wind and, in consequence, the statement of Buys Ballot's law in books on meteorology for seamen takes the form that in the Northern Hemisphere if you face the wind, pressure is lower on the right hand than on the left, and in the Southern Hemisphere if you face the wind, pressure is lower on the left hand than on the right. Figure 6 (*Plate III.*) is a reproduction of a map drawn by the Weather Office at Melbourne and is given here to show that with the modification mentioned, the lesson to be drawn from our maps has its counterpart in a weather-map of the Southern Hemisphere.

This remarkable change on crossing the equator naturally leads

Plate III.

Fig. 5.

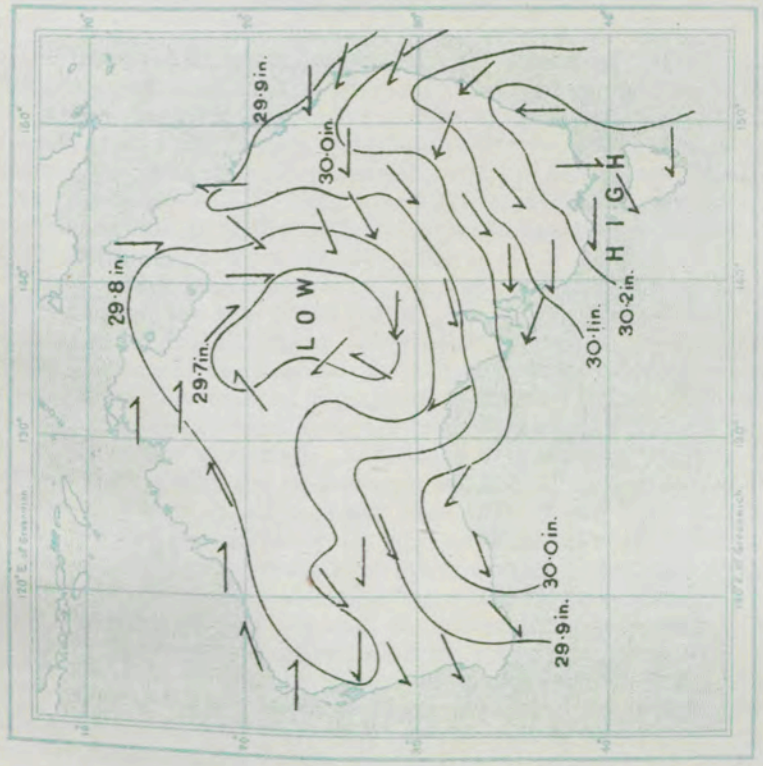
DISTRIBUTION OF WEATHER, WIND, AND PRESSURE, 6 P.M. 2nd AUGUST, 1915.



No wind. Clear sky. Half clouded. Overcast. Rain. One quarter clouded. Three quarters clouded. Thunderstorm. Mist. Fog.

Fig. 6.

CHART OF BAROMETRIC PRESSURE AND WIND, AUSTRALIA, 12th FEBRUARY, 1915.



light to moderate breeze. fresh breeze.

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to the question of what happens in the equatorial region itself which we may deal with at once. As a matter of fact the attention which the wind pays to the isobars is most pronounced in the polar regions, and is still quite noticeable to within 20° of the equator, but nearer the line it weakens and at the equator itself it is not operative at all. The effect diminishes as the equator is approached and is resumed in the opposite sense when a latitude of 20° on the opposite side is reached.

This gradual transition from the law of the Northern Hemisphere though the equatorial region without any law of this kind to the law of the Southern Hemisphere is not so noticeable in practice as might be expected, for a special meteorological reason arising from the series of regions of high pressure which form a belt of permanent high pressure round each hemisphere from about 25° to 35° of latitude, and which is penetrated only by the gaps through which the trade-winds are fed. The pressure of the equatorial region itself is lower than that of the high pressure belts, and further north or further south it falls off rapidly to certain lines of low pressure near the Arctic and Antarctic circles. Between the high pressure belts there is a large region of little or no difference of pressure and, therefore, little or no wind. So in actual experience, a traveller on his way from North to South across the line leaves the region of the Northern Hemisphere where Buys Ballot's law is effective in one way, and passes through a region of calms and variable winds, emerging again into the region of the Southern Hemisphere where Buys Ballot's law is operative in the opposite sense, without having had any opportunity of relating the wind to the pressure distribution in the intervening region.

We can look at Buys Ballot's law in a somewhat different way by considering wind as the flow of air along the surface, and we may learn from the map that air flows along the isobars round the high pressure on the right or the low pressure on the left, but with a drift across the isobars from high pressure to low pressure that gives the direction of the wind a deviation from the isobars. This way of looking at the matter is important because in recent years we have learned a good deal about the upper winds, the air currents in the free atmosphere above the surface, and one of the first conclusions from the observations of the upper air was that the flow of air was more and more strictly along the isobars in the higher levels and that the flow across the isobars is characteristic mainly of the surface winds; in other words the deviation of the wind from the isobars at the surface is perhaps attributable entirely to the indirect effect of the surface upon the flowing air.

The next important lesson to be drawn from any map refers to the strength of the wind. Hardly any map can fail to exemplify the rule that where the isobars run close together the winds are strong, and where they are wide apart the winds are weak. Any rule that could be formulated for a numerical relation between the distance apart of the isobars and the surface winds would have a good many exceptions which may be real or apparent, but, on the whole, nobody can fail to agree with the proposition that close isobars mean strong winds, and widely separated isobars light winds or calms.

An explanation of these two most important propositions, viz., Buys Ballot's law and the law of relation of wind-velocity to the distance of isobars, can be given. It connects the velocity of the wind with the distribution of pressure and the rotation of the earth, and thus accounts for the change from the Northern to the Southern Hemisphere, but the explanation obviously depends upon the theory of motion upon a rotating earth.

The calculation cannot be expected to apply fully to the surface winds because the flow of air is affected by the obstacles which it has to pass. We can attribute this interference in a general way to friction but we have no adequate numerical expression for it.

Another lesson which can be learned from a single weather map is that very little difference of pressure is accountable for a great deal of wind. If there is a fall of pressure of half an inch (16 millibars), from London to Liverpool there is almost certainly a south-westerly gale blowing over the country between them. The smallest difference of pressure that can be recognised on a barometer is the tenth of a millibar, and to show that difference, supposing the fall all along the line from London to Liverpool to be uniform, the two barometers would have to be more than a mile apart. That means that you would have to go more than a mile to detect any difference of pressure at all at the same level, even when there is enough to cause a gale. Hence we cannot be at all sure of small local details of pressure distribution which may be operative in causing or maintaining local winds. We must not be surprised, therefore, to find that Buys Ballot's law is a somewhat general statement that may appear to lack precision and to have exceptions. It is quite possible that the exceptions would really prove the rule if we could map the distribution of pressure with the accuracy necessary to apply the law to the immediate locality in which we observe the wind.

11. Weather and Temperature.

The lessons that can be drawn from a single map about the other elements, state of the sky, weather and temperature, are not generally of a very positive order.

It will be remembered that the old barometers were engraved with certain legends against certain heights, viz.: 28·0in. stormy, 28·5in. much rain, 29·0in. rain, 29·5in. change, 30·0in. fair, 30·5in. set fair, 31·0in. very dry. Consider what the result of transferring these legends to a weather map would be. Along the 28·0-isobar we should write stormy and very likely it would be true; generally it is stormy when the barometer is so low, but it can be quite stormy without the mercury falling anything like so low as that; along the 28·5-line much rain: that might or might not be true in parts; along the 29·0-line rain: that also would be true locally, but the converse proposition that it will not rain unless the barometer gets down to 29·0in. is quite untrue. 29·5 is change, a description to which no objection need be raised; 30·0 fair: often, but not by any means always; it may rain all day with the barometer at 30·0; 30·5 set fair: it is generally fair, but there is no "set" about it; 31·0 very dry: generally true, but not necessarily 31·0 when the weather is very dry.

The worst of these legends is that, though the prescribed weather does occur frequently with the barometer as described, it can and does occur with the barometer higher or lower in the scale: there is no reversibility about the propositions. If there were, how easy the study of the weather map would be. The isobars would mark out the weather, but clearly they do not. Generally speaking, weather of various kinds is to be found in different parts of the same isobar, so we cannot deal with weather on the map by assigning particular kinds of weather to particular pressures.

So, also, with temperature: to some extent it is determined by the direction of the wind, but it is modified by the action of the sea and land over which the air is passing, and the effect of the land is largely influenced by sunshine and cloud. We can only take the temperature on the map as we find it and try to connect it with the pressure and wind, making some allowance for the influence of clear sky or clouds.

12. The Sequence of Weather.

When we extend our study from separate maps to a succession of weather maps for consecutive days we obtain a further insight into the relation of weather and temperature to the distribution of pressure. This furnishes a key to the sequence of weather upon which successful forecasts can be based.

First of all, it must be noted that the variety of distribution shown by the maps is endless:

> "Age cannot wither her, nor custom stale
> Her infinite variety."

It is computed that the Daily Weather Report of the Meteorological Office for 31st December, 1916, if numbered consecutively from the beginning, should be No. 20,128. For many years maps have been prepared for three epochs for each day, and are now prepared for four, so that the number of maps of the weather over the British Isles and their neighbourhood which are preserved for reference and study now exceeds 50,000. Yet the sequence, so far as we know, has never actually lost itself in repetition, and we have no expectation that it ever will. We lay great stress on the behaviour of the weather being similar in its general features when similar maps recur, but none whatever upon the possibility of the recurrence of actual identity. No two maps are the same, and are not expected to be, any more than two men are the same, though many men have similar features.

The first step in the study of the sequence of weather is, therefore, to classify the maps; and that is done, not by dealing with the whole picture but by considering and classifying the distribution of isobars and giving names to shapes or groups which are easily recognised and which may occur in any part of the area of the map.

The most easily recognised group of isobars is the roughly circular group round a centre of low pressure, of which an example is shown over the British Isles in the map for 2nd August, 1915, round the centre marked L in Figure 5. This is called a CYCLONIC DEPRESSION or sometimes a CYCLONE or a DEPRESSION or simply a LOW. The isobar of lowest pressure in this case is marked 995mb. and the surrounding isobars are shown as closed curves on the map until that for 1010mb., which is cut in two places by the frame of the map. It may be noticed in passing that in the end, however tortuous their paths may be, all isobars are necessarily closed curves, and it only requires a map of sufficient dimensions (with observations to fill it) in order to show the isobar as closed. No isobar can have a loose end. It is always an interesting question as to how the uncompleted isobars shown on a map are ultimately closed, and it leads to the extension of the map to cover ultimately the whole hemisphere. It is an article of faith with us that an isobar may, and often does, go round the pole, but cannot cross the line. The reason for this view is not at all recondite; it is connected with Buys Ballot's law. The influence of one hemisphere upon the other we have not yet explored.

On the other hand, there is on the same map a region of high pressure, reaching a maximum at the Azores marked HIGH, within the isobar of 1025mb., with which, perhaps, the isobar of 1020mb. should be grouped to form an example of "an ANTI-CYCLONE" or "a HIGH." That particular map is sufficiently described as follows:—There is a well-marked "low" with its centre over the British Isles showing 995mb. at the mouth of the Severn, and a secondary pushing out northward along the Norwegian coast: A high of 1025mb. or more round about the Azores, with a tongue of high, 1015mb., stretching from Southern France over Eastern France between the low over Britain and a shallow low over the Mediterranean. And we can associate the weather with the distribution of pressure without much hesitation; it is cloudy over the whole area except at the root of the projecting tongue of high, and in the North-West margin of the principal low; there is rain along a strip across the low from South to North, forming a wide sector on the South, and a narrow strip to the North of the centre, extending as far as Aberdeen; there are thunderstorms on the South-Eastern front.

As regards temperature the line of 60° F., separating warm air from cold, runs through the centre of the low, following an irregular course from WSW. to ENE. The warm air is in the South and East, and the cold in the North and West. In the rear of the low, near the centre, the cold air has reached Scilly, with a North-Westerly wind; and just in front of the centre the warm air has pushed northward. The line of separation between warm air and cold is roughly the line of separation between winds with a Southerly and those with a Northerly component.

This allocation of weather and temperature to certain parts of the map indicated by the distribution of pressure is quite normal, another map covered by a similar description might vary in various details, as well as in the actual figures for the temperatures, but in general outline it would fit; but then the map for

6 p.m. of 2nd August, 1915, was carefully chosen with the object of presenting a normal, or typical, example. Other maps show various degrees of divergence from the type, or are radically different as regards the positions, areas and intensities of the "lows" and "highs," the cyclones and anticyclones. Every map has its own peculiarity. Every one is different in some way or other from the rest. But they nearly all have a common property which is the foundation of the modern method of forecasting weather, and that is that the main features of the distribution of pressure, the highs and lows, *travel* or perhaps *wander* across the map sometimes fast, sometimes slowly, sometimes on a straight path, sometimes on a devious one—nearly always from West to East or from South-West to North-East, or from South to North, or from North-West to South-East—rarely in the opposite directions; and yet examples do occur. We will take a normal example of the travelling of a depression, that which gave the great gales of November 12 and 13, 1915, which is shown on Plate IV. at the beginning of this chapter. The succession of maps for these two days which are reproduced there shows that the depression appeared first on the western margin of the map, its centre pursued a South-Easterly course until it was over Falmouth, then it made off up the Channel, crossed the land, and finally disappeared across the North Sea. Another example is also given, the gale of Christmas, 1915 which is represented in the four maps of Plate V. included with Plate IV. between pp. 90 and 91.

13. The Travel of the Centres of Cyclonic Depressions.

Cyclones and anti-cyclones are not the only forms or groups of isobars with which a meteorologist has to deal; other examples of names given to special distributions of isobars and the weather associated with them, such as straight or parallel isobars, secondary depression, sometimes called "satellite," V-shaped depression, wedge and "col" or "saddle" are given in the chapter which follows. But, from the time of its identification on the first maps of isobaric lines, the association of isobars with a centre, particularly a centre of low pressure, has had an irresistible fascination for those who are interested in the study of weather. It is to the behaviour of the cyclonic depression with its associated winds and rains that they have looked for the means of formulating new laws of weather. The less obtrusive anticyclone with its generally quiet and fair, or even fine weather has been regarded in a sort of way as a separate type of creature, resisting the approach of its mobile enemy, the cyclone, diverting him from his path while itself remaining stationary or moving only slowly and with serene dignity. So much has the cyclonic depression been regarded as the key to the secret of the weather, that, for the last forty years or more, every cyclonic depression to which a centre could be assigned on the maps of the Meterological Office has been tracked across the map, and the path of its centre laid down and published with unfailing regularity in the Monthly Weather Report. In the earlier years we had no daily telegrams from Iceland, and we formed the idea that most of the well-behaved depressions kept to a fair track between Scotland and Iceland, where we could not map them. From the beginning of 1907 we have had the great advantage of including Iceland in our daily charts, and by the end of 1916 ten years of these full charts were available for study. Mr. E. L. Hawke has recently made for me a summary of the results shown by the tracks of the depressions charted in the Monthly Weather Report for these ten years. Three conclusions drawn from this examination may be briefly mentioned here. First, 1,211 depressions have had their centres tracked in the whole period, giving, on the average, a new centre for every three days throughout the ten years. They are distributed among the calendar months as follows:—

January ...	91	July	88
February ...	94	August ...	89
March ...	133	September ...	76
April ...	98	October ...	101
May	101	November ...	103
June	102	December ...	135

Secondly, grouping the location of the centres according to five-degree-squares of latitude and longitude, the visitations of the several squares are as set out in Figure 7 (*Plate VI.*) and in the following table:—

Numbers of Centres of Depressions which have been located within certain Squares of Five Degrees of Latitude and Longitude in the Ten Years 1907 to 1916.

LATITUDE.	LONGITUDE.				
	W. 10° to 15°.	5° to 10°.	0° to 5°.	0° to 5°.	E. 5° to 10°.
60° to 65°	199	244	245	221	197
55° to 60°	241	303	274	248	249
50° to 55°	288	316	292	272	203
45° to 50°	(105)	173	193	123	56

The geographical situation of the squares may be indicated by saying that the North-Western Square includes a corner of Iceland, the North-Eastern the extreme west of Norway, the South-Western a part of the Atlantic a long way outside the Bay of Biscay for which the number (enclosed in brackets) is probably incomplete because our supply of observations for that region is inadequate; and the South-Eastern square includes, in its Southern part, the Swiss Alps. The middle column covers Shetland, Eastern Scotland, England and Wales, and France west of the mouth of the Seine, respectively. Looking along the rows and columns the reader will have no difficulty in discovering that Ireland is pre-eminently a place of depressions. The square where the highest number of centres, 316, have been located is

that which stretches from Scilly to Londonderry and from Valencia to St. Ann's Head; the square next in order of favour includes the North Coast of Ireland, the West Coast of Scotland and the Hebrides. The row between 50° and 55° is clearly the most frequented of all the rows until we come to the column 5° to 10° E., when the squares covering the Danish coasts come into greatest prominence. The belt from 45° to 50° has very few centres at the eastern end, but the western end gets the centres for the mouth of the English Channel and the Bay of Biscay, which are rather numerous.

Another curious point about the geographical distribution of depressions is that the centres favour different squares in different months of the year. For the ten years which have been summarised it may be noted that in January the distribution tends to uniformity. The Cattegat is the most frequented region with only 22 visitations in the ten Januarys, while England comes very near to the same number with 21. The British Isles generally get an average of 18. In February the region of the Faröe has the largest number of 30, and forms a definite centre of centres, while the average for the British squares is 21. In March the centre of centres appears in the southern part of the North Sea with the still larger number of 40, in the ten months of that name. In April the region of greatest frequency belongs to the two squares which cover Scotland, each with 25; in May the distribution is peculiar: there is a notable centre with 30 in the Irish square, but there are peculiar projections of frequency eastward to the Baltic and southward to the west of Biscay.

The month of June brings us back again to Eastern Scotland with a well-defined concentration of 32 centres. In the next month, July, the same square is again prominent associated with its western neighbour as it was in April, but credited this time with 29 each, and in August the same figure is set against the same two squares, and against the adjoining Irish square as well, while the English square comes pretty near with 27. September is the month when depressions are fewest; in the ten years most centres have been located in the South Norway-Denmark square, but the number only reaches 20. In October there is a recrudescence of activity in which Ireland with St. George's Channel becomes the most frequented district with 36 depressions in the ten years. The same locality is relatively even more locally prominent in November, although the number of centres which crossed the square is only 32. There is a secondary centre of frequency with 27 in the Shetland region. Still more marked again is the predominance of the same region (Ireland with St. George's Channel) in December, for in the months of that name in the ten years, that region has been credited with no fewer than 43 centres.

The third conclusion which has been drawn is that in their tracks across the region under consideration the centres of depressions seem to choose either the water-ways of the English Channel, the North Channel or St. George's Channel into the Irish Sea or pass beyond the northern coasts. When they cross the land they choose the flat parts of it. They cross Ireland, for example, by the level middle, and thence go by mid-Wales or the Solway Firth over England; or they come from the North-West to the Irish Sea. Another route is from the Bristol Channel to the mouth of the Thames, another from Cardigan Bay to the Wash or to the mouth of the Thames, another from the Mersey to the mouth of the Thames, in continuation of the route from North-west by the North Channel. There are also favourite crossings from sea to sea by the Solway Firth, as already mentioned, for depressions which have reached the Irish Sea and by the Clyde and Firth of Forth, or by the short cut from the Minch to the Moray Firth for centres which approach the Scottish coasts from the westward. The selection of these routes is not a matter of law, but rather of facility. Exceptions could probably be found to all of them.

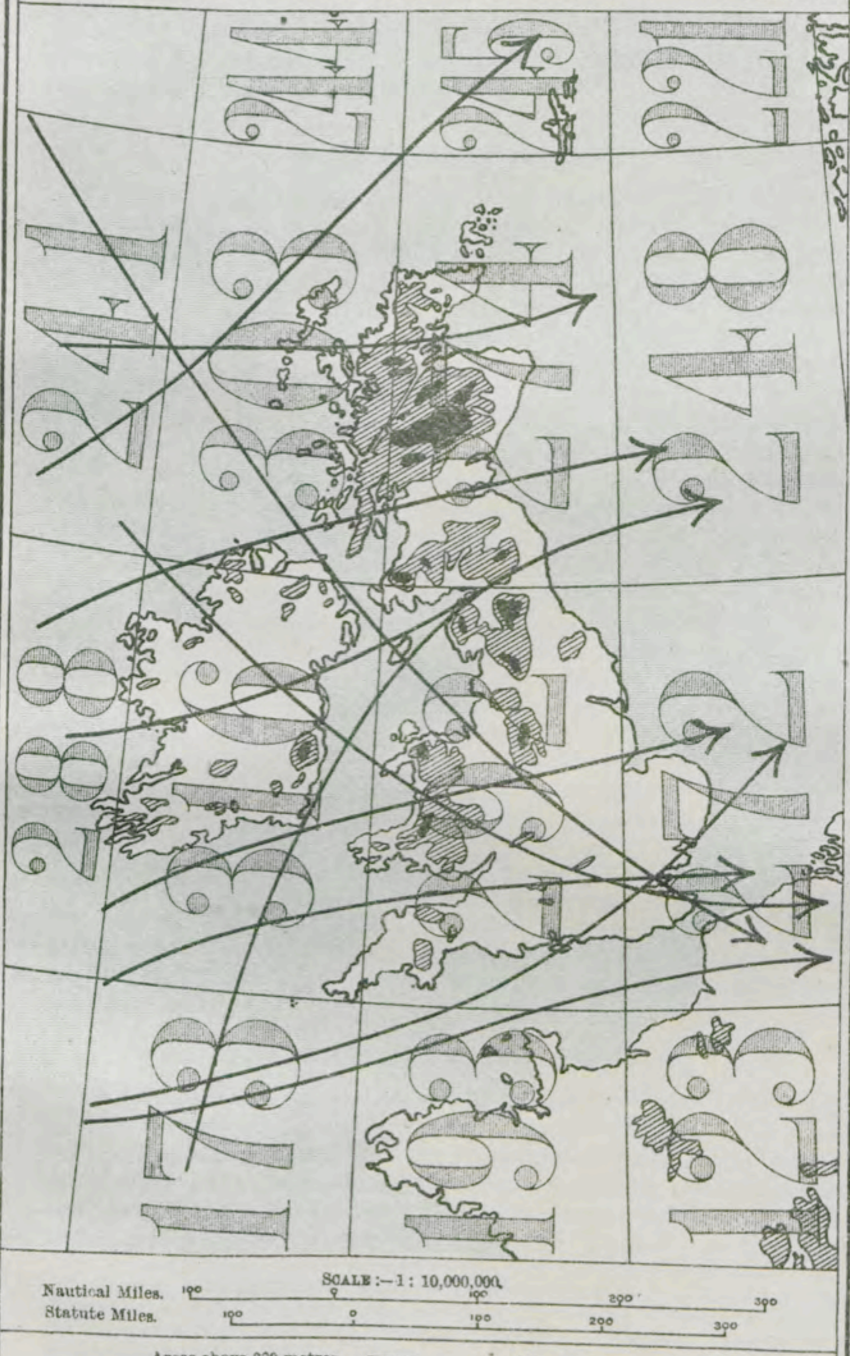
A peculiarity of the routes is that they seem to be available either way. A depression may pass from the Bay of Biscay northward over the Irish Sea and so on to the North-West, or it may travel in the reverse direction, and may even retrace its own path. It may travel from the Hebrides to London via Liverpool, or from London to the Hebrides by the same route.

Not too much stress must be laid upon the precise lines representing the tracks, as the centre of a depression is an elusive point, and all the accumulated evidence goes to show that the travel of a cyclonic depression is not a very simple matter. It used to be thought that a cyclonic depression was a great whirling mass of air that passed over the country with other smaller whirls appearing as secondaries. The use of the word "satellite," which was at one time quite popular, was intended, somewhat unfortunately, to give the idea of a revolving moon travelling in the train of a larger revolving earth. We are now able to say quite definitely that the general motion of air in a cyclone outside the tropics is different from that of a whirlwind: the ascertained motion of the centre on a map is the direct consequence of the motion of the air in the cyclone itself and part of it; it is not the general motion of the current in which the whirl is contained. A whirling mass of fluid carried along by the general current does sometimes appear on the map, but not at the central area of one of our travelling depressions, where there is cyclonic motion which we do not yet fully understand. We may find a whirling mass where American meteorologists find their tornadoes: "as the attendants of the parent cyclones of which they are the offspring. They are born in the great majority of cases in the area of warm, damp southerly winds . . . . in front of a general cyclonic storm."*

The motion of a cyclonic depression is not a dervish whirl; it is a peculiar kind of dance which it would be quite worth while for children to try to perform, in which the dancers or the samples of air are always changing their partners: the ring which appears on the map is always being freshly formed of new elements from neighbouring rings. Only the sample which travels with the speed and direction of the centre keeps its place and that not by moving in a circle but by going *straight on;* all the rest march

* Robert de C. Ward, Q.J.R.Met.Soc.

FAVOURITE TRACKS OF CENTRES OF DEPRESSIONS WITH THE NUMBERS WITHIN DIFFERENT AREAS IN TEN YEARS.



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round the centre and away again, never get in each other's way and always fill the stage. Each one takes a step in a circle and the next step in another circle, and a third in a third circle. Every step is in a circle, but no two consecutive steps are in the same circle. The dance is much too regular to be at the mercy of such accidents as warm air and cold air. It takes those in as incidental circumstances without much inconvenience, as the study of the maps of depressions will show.*

14. Barometric Tendency.

It is the business of the forecaster to find out, if he can, in what direction the cyclonic depressions or anticyclones within his region are going to move, and to issue notices of the changes of wind and weather that are incidental to the motion. For that purpose he relies mainly on what is called the BAROMETRIC TENDENCY, and the recent changes in the direction and force of the wind at all the reporting stations, which are denoted by the terms Backing and Veering.

The barometric tendency at any station is the change in the pressure at the station within the three hours immediately preceding the fixed hour of observation. It is taken from the record of a barograph, and, by an international agreement of 1913, it is included in the regular reports from all stations that are provided with barographs. For our own stations the change of pressure indicating the tendency is given in half-millibars, because that represents the highest degree of accuracy with which the change can be read from the trace of the pen of an ordinary barograph.

When the barometric tendencies are entered on the map it is easy to identify the regions where the barometer is in process of falling, and those where it is in process of rising; and this information gives a general idea of the changes of pressure that are in progress on the map. The barometric tendency is the more useful because a cyclone or anticyclone seldom travels unchanged in shape and intensity. The travel of *pressure-changes* is apparently more regular than the travel of *pressure-values*.

Some addition is made to the definiteness of the indications by transmitting also what is called the *characteristic of the tendency* according to an agreed code which tells whether the rise or fall is increasing or slackening, or is in process of reversal, and so on.

15. Veering and Backing of Wind.

The other chief indication of impending changes in the map is the change in the wind at the several stations. We know from Buys Ballot's law that the direction of the wind tells us in what direction to look for higher pressure and for lower pressure; and, when the wind changes, we must recognise that the distribution of pressure is changing also. If the *force* of the wind

* Further investigation of the relation between the motion of air in a cyclonic depression and that of a travelling revolving column of air in special cases forms the subject of No. 12 of the Geophysical Memoirs of the Meteorological Office which is now in the press.

alone changes while its direction holds, we know that closer or more widely spread isobars are passing over us; when the *direction* of the wind is changing the highs and lows must be changing their ORIENTATION.

The best examples of the usefulness of this indication are afforded when cyclonic depressions follow one another in succession, at intervals of two days or thereabouts, along their favourite track from WSW. to ENE., with the centre somewhere northward of Britain. When the centre has passed, the wind is north-westerly; the low is to the left of the wind, to the North-East—gone by—higher pressure is to the right, South-West—to come. If the wind presently BACKS, as it is called, from North-West (against clock-hands) through West to South-West again, the higher pressure has gone by, and another low is approaching. As the low passes, the wind VEERS (with clock-hands) through West to North-West.

The amount of veering or backing is usually settled by the forecaster for himself by a comparison of the record on the map with that on the preceding map. In the absence of wireless reports the backing of the wind at Valencia or Blacksod Point on the West Coast of Ireland is the first indication on the map of the approach of a new depression from the Atlantic.

16. Types of Pressure Distribution.

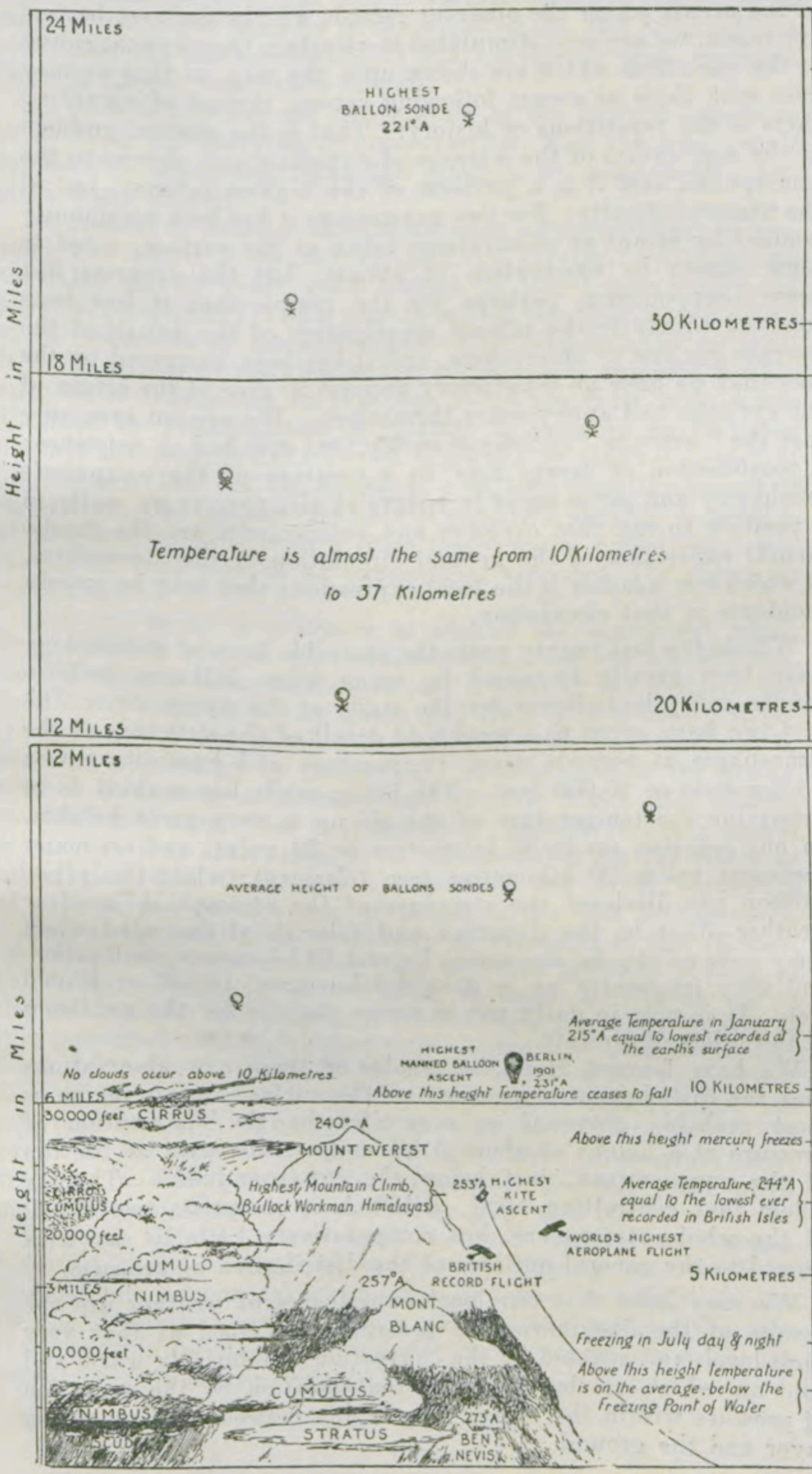
The process of classification which has been described in the preceding paragraphs is limited to the consideration of the shapes and groups of isobars; the positions of the characteristic groups have to be specified in order to define the meteorological conditions. A good deal of labour has been devoted to the method of classification by reference to the whole picture disclosed by the map. With patience and perseverance typical maps may be selected, and other maps classified according to the selected types. Rules have even been formulated about the duration of particular types and the sequence of types—but they are not very satisfying.

17. The Upper Air.

The Dynamics and Physics of the Atmosphere.

The study of the details of pressure-distribution and its changes which enable the forecaster to give precision to his forecasts is a matter of prolonged experience with weather maps, the results of which have never been formulated and cannot be set out fully without the maps themselves. It is not dependent upon any elaborate training in mathematics or physics. Anyone with an ordinary school-education can acquire the necessary experience. But when experience has done its best the most accomplished forecaster from weather maps finds himself confronted again with the fact that he cannot hope to come upon a complete and perfect repetition of a sequence which has occurred before. There is always the margin of the unexpected.

Fig. 8.



The atmosphere up to twenty-four miles: the lowest layer of six miles is called the Troposphere, and the region above that the Stratosphere.

We do not, on that account, consider that the comprehension of the events which the observer records will be for ever beyond our reach; we are only stimulated to ascertain the physical causes of the variations which are shown upon the map, so that we may deal with them as events following causes, instead of regarding them as the repetitions of history. That is the general problem of the application of the sciences of dynamics and physics to the atmosphere, and it is a problem of the highest interest, but of the utmost difficulty. For two generations it has been assiduously studied by means of observations taken at the surface, aided to some extent by observation of clouds; but the progress has been disappointing, perhaps for the reason that it has been confined chiefly to the minute specification of the details of the average cyclone or anticyclone, and it has been hampered by the fact that we have no satisfactory account to give of the origin of the cyclones and anticyclones themselves. We are not even sure that the "average" cyclone or anticyclone ever had an existence; a combination of means may be a creature of the computer's machinery and never occur in nature at all; nor are we really in a position to say that cyclones and anticyclones are the fundamental expression of the general circulation of the atmosphere, of which our weather is the local expression; they may be merely incidents in that circulation.

Within the last twenty years the available facts of meteorology have been greatly increased by using kites, balloons, ballons-sondes and pilot-balloons for the study of the upper air. The first two have given us a wealth of detail of the structure of the atmosphere as regards wind, temperature and humidity up to 3 kilometres or 10,000 feet. The ballon-sonde has enabled us to determine the temperature of the air up to very great heights, on one occasion up to 36 kilometres or 22 miles, and on many occasions up to 20 kilometres (see *Glossary*); while the pilot-balloon has disclosed the structure of the atmosphere in clear weather—that is, the direction and velocity of the wind when there were no clouds, sometimes beyond 10 kilometres, or 6 miles, and very frequently up to 3 or 4 kilometres, 10,000 or 13,000 feet. It is now in daily use at many stations for the guidance of the pilots of aircraft.

We have learned from the results of these new observations that the distribution of pressure at the surface in our region is most probably governed or controlled by the distribution of pressure at a height of about 9 kilometres, the layer at the top of the TROPOSPHERE, just below the STRATOSPHERE. The air below that controlling level, although it comprises two thirds of the whole atmosphere, has comparatively little to say with regard to the general outlines of the distribution of pressure.

We may infer that our local experiences of weather are the results of the distribution of pressure prescribed at that very high level, and affected by the convection of relatively warm and cold air which are brought into juxtaposition by the operation of pressure within the region intervening between the governing layer and the ground.

It remains for us to find out, if we can, what are the causes of the distribution of pressure in the stratosphere, and what are the conditions for the occurrence of the convection that expresses itself in clouds, rain, snow or hail.

To do this requires the co-operation of the highest ingenuity in devising and carrying out observations, with the most ample intellectual equipment that the sciences of mathematics and physics can supply.

No student of weather-maps based upon meteorological observations can afford to be shy of decimals, means, averages and normals; and he must know something about astronomy and physical geography; if he wishes to pursue the daily investigation of the structure of the atmosphere with pilot-balloons he must face the terrors of the elementary trigonometry required for the solution of triangles. In thinking about the facts as to winds disclosed by pilot-balloons in relation to pressure he will find himself involved in dynamics of a peculiarly difficult type. If he wishes to find out the height of a balloon from the record of its pressure and temperature he will require a working knowledge of practical physics, with a little mathematics added, that will inevitably land him in an exponential territory, the region of logarithms.

It is not given to everyone to acquire the equipment which these difficult sciences provide—not that they are too difficult, for difficulty in these matters is only a want of familiarity—but familiarity requires a long time, and time is notoriously short. It is therefore not possible to complete this introduction to modern meteorology by preliminary dissertations on the mathematics, dynamics, astronomy and physics which the modern meteorologist uses. Nor is it necessary, because this is a matter of co-operation; observation is as indispensable for the result as calculation, and, if there is a reasonable and candid exchange of experiences, the division of labour is the best arrangement.

But, at the same time, everybody is interested in the weather, and most men have at some time or other acquired a store of knowledge which will enable them to make intelligent use of the information which modern meteorology provides. Much of it is concerned with unfamiliar words, some of it with unfamiliar ideas. It seemed, therefore, desirable to follow the plan of the dictionary or the encyclopædia. The Meteorological Office has put together such information as may be of interest to the practical students of weather in the form of separate short articles, in alphabetical order of subject, in the form of a meteorological *Glossary* published as M.O. 225 ii.

To this Glossary have been assigned articles on various topics of interest concerning weather and climate, brief explanations of many technical meteorological terms, and short articles on the dynamical, astronomical, or physical subjects that are indispensable for those who desire to follow in greater detail the recent progress of the study of weather.

CHAPTER XI.

THE OBSERVER'S EXPERIENCE REFERRED TO THE GENERAL FEATURES OF THE WEATHER MAP.

1. Cyclones and Anticyclones.

In the preceding chapter it has been explained that what a sailor or anybody else experiences in the way of weather can best be represented by associating it with the distribution of pressure over a map. On the map the distribution of pressure is represented by isobars, or lines at every point of each of which the pressure is the same at the time for which the map is drawn. By way of recapitulation, let us remember that the pressure is not exactly the same thing as the direct reading of the mercury on the scale of the barometer. One observer's barometer may be in a warm cabin, another in a cold deck house. The reading has to be properly "corrected" and "reduced"; that is to say, allowance has to be made for the temperature of the barometer, the height of its cistern above sea-level and the latitude of the place where the observation is made, before the pressure is ready for plotting on a map in order to draw the lines of equal pressure. When all that has been done and the isobars drawn, the most noteworthy of all the possible forms of isobars are those which are like rough circles or ovals round a centre where the pressure is low, and mark what we call a "low" or cyclonic depression.

Another noteworthy form is that in which the isobars are roughly circular or oval and surround a centre where the pressure is high and thus mark a "high" or anticyclone. In our hemisphere, according to Buys Ballot's law, the winds may go round the centre of the depression keeping the "low" centre always on their left; or they may, on the other hand, go round the centre of the anticyclone, keeping the "high" centre always on their right; or they may steer a nearly straight course that is intermediate between curving round the high to the right and curving round the low to the left. There may be a drift from high to low, but always the high pressure will be on the right-hand side of the wind's path, the lower pressure on the left, whether the path curves to the right round the high or to the left round the low or keeps straight on.

It is the low pressure or cyclonic depression which brings strong winds and gales, generally accompanied with rain or dirty weather; while the high pressure or anticyclone brings light winds, often fine weather in summer, but sometimes cloud and even drizzle, in winter generally gloomy, dull skies with fogs inland and on the Southern and Eastern Coasts. Neither in summer nor winter is the rain that comes with an anticyclone anything more than a light drizzle.

If a low is passing with its centre moderately near, everything is brisk except, perhaps, the weather in the early stages which

may be close and muggy. If the centre is somewhere to the Northward and is passing from west to east or thereabouts, the low is ushered in by the barometer showing the pressure to be falling briskly and its speedy departure is marked by a brisk recovery; the wind is brisk, probably from the south or even south-east to begin with before the rain; it changes briskly by veering from south to south-west possibly on to west or north-west. There is a very brisk squall, very likely a gale, when the barometer is about at its lowest and what is called the *trough* of the depression passes; there is a brisk rain with the south-easterly or south-westerly winds, and a still brisker shower when the squall comes with the sudden change of wind to the west or north-west, and finally brisk weather in the north-westerly wind.

If the line which the centre of the low takes from west to east is to the south of the observer, there is much more persistence and less briskness about the procedure. It may begin with an easterly or north-easterly wind with rain in summer or snow in winter. The barometer falls sometimes briskly enough, but not always, and recovers equally briskly after the centre has passed. Depressions which favour our islands with a well-marked northerly side are generally slow travellers, and there is not such briskness about the changes as those which are brought in with a southerly wind. Rain sometimes occurs with the easterly and north-easterly wind, and if it does, it often lasts for a whole day and sometimes for two or three days together. In the end the wind backs to the northward. Heavy snow-storms are generally associated with the depressions of winter or spring that have the line of motion of their centre to the south of the observer.

But there is nothing brisk about an anticyclone except sometimes the weather; the barometer is generally well above the average height and has slow movements, disclosing the regular daily variation, rising very gently from three o'clock to ten o'clock and falling equally gently from ten o'clock to three o'clock morning and evening, little wind, sometimes quite pleasant sunshine; but if there is cloud it is dull, persistent, lifeless cloud, often haze and sometimes fog.

The transition from anticyclonic to cyclonic weather and the reverse sometimes takes place without very marked change in the barometric pressure. If, for example, a vessel in the English Channel is enjoying a light westerly wind belonging to an anticyclone with its centre over France, it may change to a strong cyclonic wind or a gale in consequence of a "low" travelling from the west across Scotland to the North Sea, without much sign on the ship's barometer; and on the other hand a north-easterly gale in the Channel may change to the light air of an anticyclone by the "low" passing away from France.

From these characteristics it comes about that anyone who is interested in the weather is always on the look-out for "lows" or depressions and is very keen to know whether he is going to be on the south of the centre or the north of it. He is, of course, interested in the anticyclones too, because as long as an anticyclone is there, there cannot be a depression; but is is the depression which has the life and movement about it, giving it a claim to the attention of everybody who wants to know what the weather and its changes are going to be.

This has been recognised from the very earliest days of weather maps with isobars. The depressions which pass over our shores mostly come from the west. Some of them come all the way from America; one or two have been traced from the west coast of Africa and so have crossed the Atlantic twice, first to the Westward and then to the Eastward. Some have come all the way from a sort of parent "low" in the North Pacific Ocean. So general is the tendency for "lows" to go eastward that it was thought at one time, particularly by the "New York Herald," that their departure from the American Coast and subsequent arrival on our own shores could be notified by cable, and we might thus be forewarned of their approach, some three or four days in advance. The attempt was made by the "New York Herald" acting in co-operation with the Meteorological Offices of the United Kingdom and France. But a depression keeps to no beaten track, it has as many paths for its centre as there are lines in a bundle of hay. Though groups can be picked out there are many strays, and, moreover, the depression changes its shape and intensity while it travels, so that if you lose sight of it for a day you cannot be at all sure of its identity.

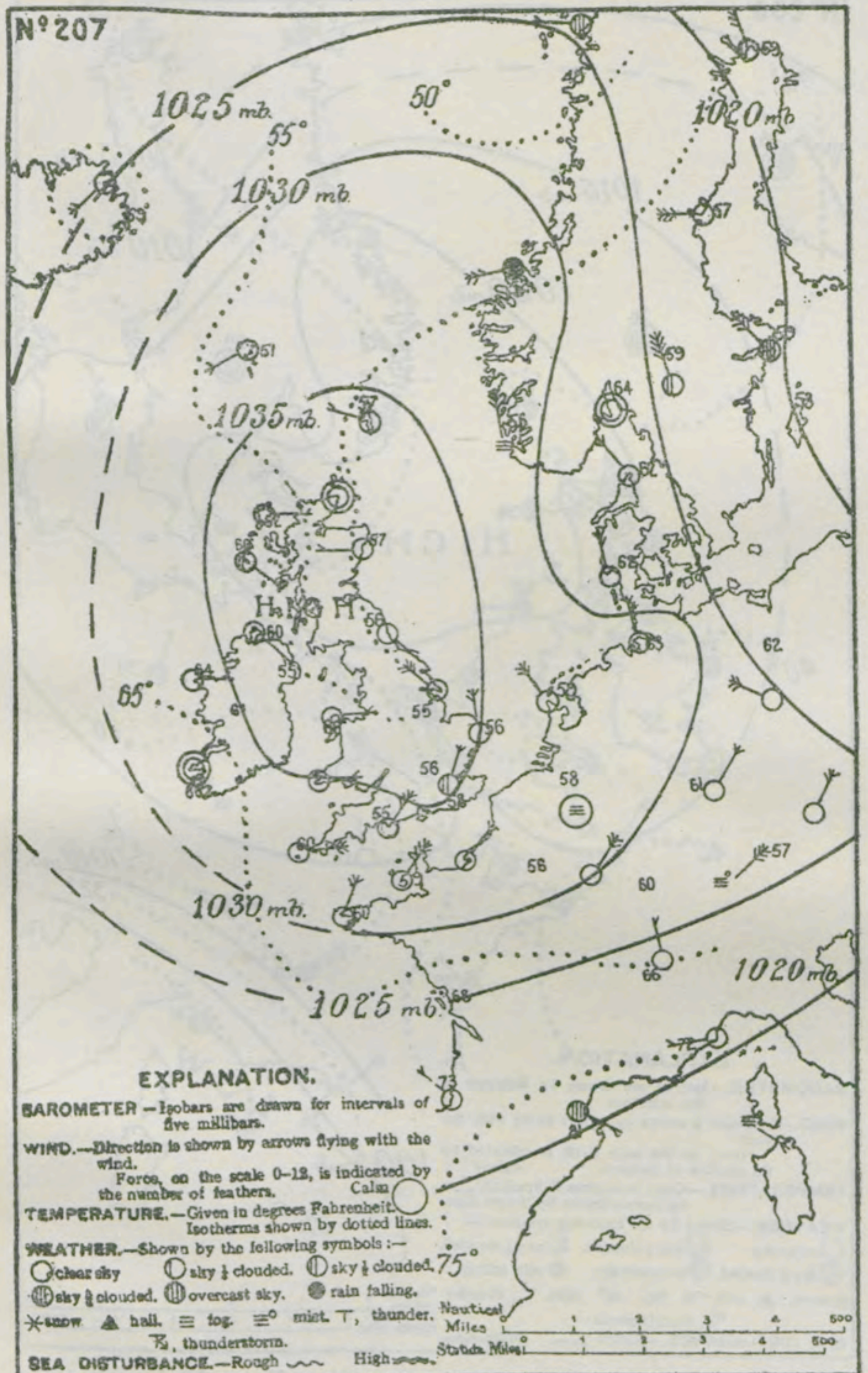
2. Anticyclonic Weather. (Figures 1 and 2, pp. 117, 118.)

The characteristic weather of an anticyclone or region of high pressure may be represented by the two maps of 10th July, 1911, 7 a.m., and 18th January, 1914, 7 a.m., which by the usual symbols give the distribution of wind and weather. Of the two examples one is chosen to represent the winter conditions and the other summer conditions. The reason for drawing a distinction between the two is that in summer an anticyclone generally brings clear as well as calm weather and consequently a good deal of sunshine and pleasant exhilarating warm days with cool nights. The heat is apt to become oppressive when the anticyclone is passing away to the eastward or north-eastward and the winds in consequence come from a southern quarter. Our highest summer temperatures come with light south-easterly winds. In winter, on the other hand, anticyclonic weather may be either clear or cloudy and we may have fine days with very cold and perhaps foggy nights, or sometimes there may be persistent low cloud causing a dullness which is sometimes called "*anticyclonic gloom.*"

3. Wintry Weather.

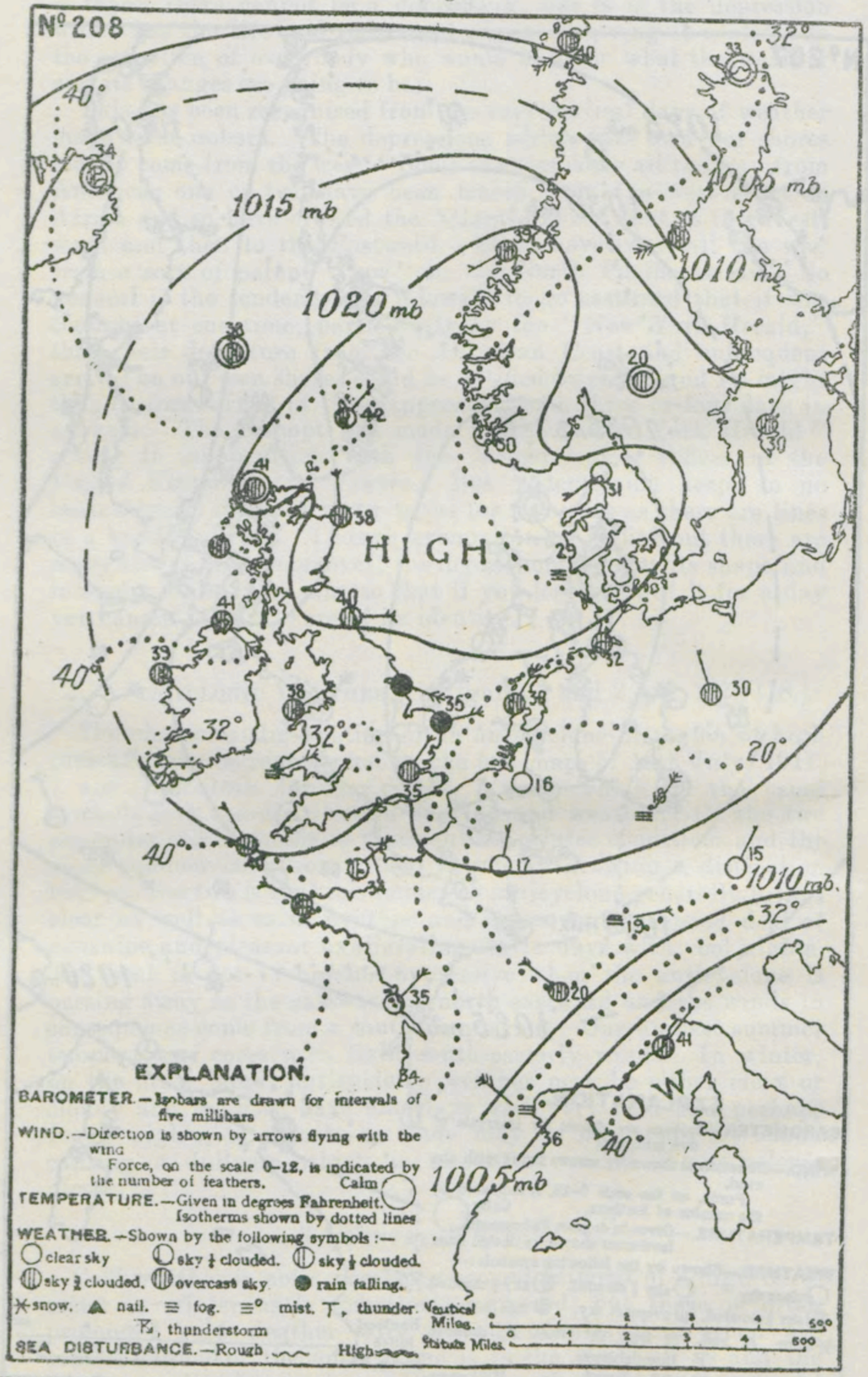
Cold weather is not a necessary accompaniment of a high barometer in winter as is sometimes supposed, but there is often prolonged cold weather with a winter anticyclone when the central region of the anticyclone is to the North of us and the winds are North-easterly or Easterly and therefore bring cold air from the great land areas which lie to the east of us.

Fig. 1.



Distribution of pressure, wind, temperature and weather at 7h. on 10th July, 1911

Fig. 2.



Distribution of pressure, wind, temperature and weather at 7h. on 18th January, 1914.

The Observer's Experience referred to the General Features of the Weather Map.

CHART OF THE DISTRIBUTION OF CLOUD AND RAINFALL WITH REFERENCE TO THE CENTRE OF THE DEPRESSION OF 11—13 NOVEMBER, 1901.

Wy. & S., M.O. Press, S.W. 7.

Ps.764. 9898. 528. 2000. 12/17.

To the North and West of the region of highest pressure there may be genial weather in an anticyclone. The most bitterly cold weather of the southern parts of our islands is cyclonic and comes when the centre of a cyclone travels up the English Channel, and the southern counties are in consequence to the north of the centre. In like manner when the path of the centre lies across the islands there may be bitterly cold weather with snowstorms in those parts of the country north of the path, because they come under the influence of easterly or northerly winds, while the more southern parts where the winds are from the southward enjoy comparatively mild weather.

The rear winds of a winter cyclone are also sometimes bitterly cold winds from the north or north-west, which occasionally produce extremely cold nights. The westerly wind of a winter cyclone is almost always colder than the winds from a southern quarter to which it succeeds and as the change often takes place quite suddenly when the barometer is near its lowest point, the change of temperature is often very marked. The same kind of change on the passage of a cyclonic depression is found in other countries and is specially marked in the United States and Canada, where the change from a falling to a rising barometer may bring with it a drop of 50° F. in the temperature or even more.

4. Cyclonic Weather.

The weather which a cyclonic depression brings is easily distinguished from that which belongs to an anticyclone. In illustration of this statement we may first refer to Figure 3 opposite which gives a generalised map of the depression which passed slowly over these islands on the 11th to 13th November, 1901. The isobars are drawn for 18 h. (6 p.m.) on 12th November. The winds are not indicated, but it may be understood that they lie more or less along the isobars and that there are gales where the isobars are as close together as they are over Southern Scotland, Ireland and St. George's Channel. The chart is specially compiled to represent the distribution of cloud and rain with reference to the centre of the depression while it travelled across the map. The boundary of the cloud area is represented by a line of fine dots and the region within the boundary is covered by dotted shading. It will be seen that the cloud area has an irregular outline but is very extensive, covering nearly the whole of the region of closed isobars and extending beyond that region to the east and south. But well within the general cloud area is a little patch, which appears in the map at the mouth of the Bristol Channel, which is not cloudy although it is not far away from the centre. Attention is drawn to this so that the reader may understand that the cloud sheet of a cyclonic depression is not an unbroken mass; there may be clear sky in places not far away from the centre.

The rain-areas are marked by chain-lines which enclose a collection of black dots representing the positions with regard to the centre where the rain was noted to be falling at the time the particular observation was made. It appears that there were two separate regions of rainfall, one a very broad belt from Clacton-on-Sea to Aberdeen in the cross direction and extending from Ireland to the Baltic along the path of the depression west to east; the other rain area a long thin belt extending nearly north and south from the middle of England to the north of Spain.

It will be noticed that no rain is marked within the most central isobar, nor to the south or south-west of that region. While that is noted it is also to be remarked that outside the region here marked as rainy there are one or two isolated points in the rear of the depression which were marked "p" in the observations.

These peculiarities of the distribution of rainfall do not belong to all depressions, each depression has its own. Four examples, of which that reproduced here is one, are given in the *Weather Map*, M.O. 225 i, pp. 51 to 54, of which one, for September 9-10, 1903, appears to show a cyclonic depression as a region of rainfall, quite irregular in shape, surrounded by a similarly irregular region of cloud, and that again surrounded by blue sky, apparently on all sides. The clouded sky covered an area which, taken as roughly circular, has a diameter of 15° of latitude or 1,000 miles and the rainfall area one of about 500 miles; but in the other cases the depression as indicated by isobars is only part of an extensive region of cloud and rain. On November 11-13, 1901, and on March 24-25, 1902, the area of cloud and rain extended southward to the confines of the map, and on November 12 to 13, 1915, the distribution of cloud and rain showed very imperfect relationship to the shape of the depression.

5. The Form of Cloud in a Cyclonic Depression.

The observations at the reporting stations from which this map was compiled do not give the forms of cloud, and, therefore, in suggesting the names of forms appropriate to different parts of the depression we are dependent upon the general knowledge of common experience. The main part of a cloudy area of a cyclone is covered with *strato-cumulus* or with *nimbus* over the rain area. The front of the advancing depression is a region of *cirrus* clouds, sometimes *feathery cirrus* becoming *cirro-cumulus*, *alto-cumulus* or *alto-stratus*, and sometimes *cirro-stratus* or *cirrus-nebula* showing halos if the sun or moon is behind it. It is on that account that a halo is taken to be a prognostic of a coming storm, but there seems no reason to suppose that a halo-sheet (cirrus-nebula) is not to be found elsewhere than in the front of a depression, though the occasions on which the air is sufficiently clear of lower clouds to enable the highest clouds to be seen give few opportunities of seeing halos except in fine weather, which sooner or later must, of course, give way. Hence of necessity, if we wait long enough, what we call bad weather follows the time when a halo is visible.

Just as cirrus clouds are characteristic of the front of an advancing depression, so cumulus clouds are characteristic of the rear. Beginning with shower clouds in the north-westerly wind, which give the clearing showers of the end of a rainy day, the

later specimens are smaller and less important examples of cumulus with clear blue sky between. The other varieties of cloud cannot be so easily assigned. Towering cumulus are often the signs and the vehicle of snow-squalls in a northerly wind in the spring. Alto-cumulus-castellatus and the varieties of cumulo-nimbus are the corresponding vehicle of thunderstorms in south-westerly winds. In the higher levels, through the gaps of the strato-cumulus of a depression, cirro-cumulus and alto-cumulus can often be seen. They have no special significance as to coming weather. Small cumulus clouds are often formed in fine weather on summer days and are of no special significance as a prognostic of rain.

Stratus belongs to anticyclones rather than cyclones. It may cover very large areas with a uniform grey sheet without changing to rain. Strato-cumulus seems to be the corresponding cloud of the cyclonic area.

A diagram illustrating the distribution of cloud in a cyclonic depression, Figure 4, is taken from the "Seaman's Handbook."

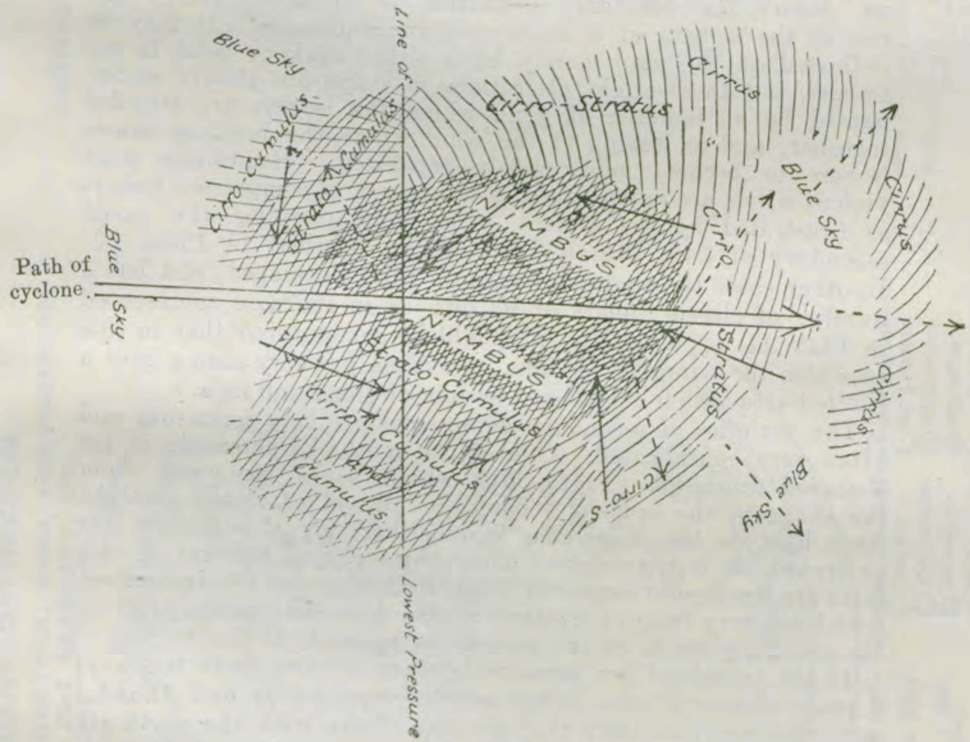


Fig. 4.

——→ Wind direction at the earth's surface.
- - - -→ Wind direction in the region of the cirrus cloud.

6. Some other Recognised Groupings of Isobaric Lines.

We have given an account of the distributions of pressure recognised as anticyclonic and cyclonic and of the weather associated therewith. If the map is sufficiently extensive the whole region will be covered by cyclonic depressions and the anticyclones which surround them. Indeed on the whole the atmosphere of the northern hemisphere north of 30° may be regarded as a collection of cyclones with intervening anticyclones all held in by the permanent belt of anticyclones of the tropics, though in summer the great land areas of the eastern and western hemispheres interfere with the simplicity of the picture. Cyclones and anticyclones are often on so large a scale that the main features of the situation are not represented on a small map; we may have before us only a limited portion representing a distribution of pressure which is easily recognised, but shows no complete cyclone or anticyclone. The subsidiary types of distribution most important for our purpose are the Secondary depression and the V-shaped depression (Plate II.), the Col and the Wedge (Plate V.). We will also notice the straight isobars which are also well represented on the map of the Wedge.

We will take these special distributions of pressure in order as set down; the **Secondary depression** is included within the run of the isobars of a large cyclonic depression. It may be indicated on the map merely by a slight kink or bend in the isobars, but these slight alterations in shape are always accompanied by an increase of wind where the isobars are crowded together, and an easing of the wind where the bending causes isobars to become more widely separated. Sometimes most violent winds are experienced in the region of compressed isobars as illustrated by the violent gales accompanying the small secondary of 24th March 1895, shown overleaf in Plate IV. In other cases the secondary is more fully developed, and has a number of closed isobars of its own as in the case represented in Plate II. opposite, and it should be remembered that in this case also the winds of the smaller system are very strong over a limited area which has its own system of cloud and rain.

The varieties of secondary depressions are very numerous and often very complicated. One of the most characteristic is the **V-shaped depression** (Plate II.), which takes its name from the shape of the isobars. They are formed of almost straight lines like the two sides of a V on either side of a middle line or trough of low pressure. The characteristic features of this form are a region of southerly winds in the front of the depression, which are very rapidly replaced as, the depression passes over, by the northerly winds of the western or rear-side of the V.

In the trough of low pressure between the two there is always a smart shower of rain, sometimes accompanied by hail, thunder or lightning, and after this the sky clears with the northerly wind very rapidly and the air becomes cold and dry.

The winds of a V-shaped depression are sometimes strong to a gale, but not generally very violent or destructive. The phenomena suggest the line-squall rather than the tornado. The most striking changes of temperature from warmth to cold sometimes occur with the passage of a V-shaped depression.

The **Col** is the region of nearly uniform pressure between two "highs" and two "lows." It is a region of very peculiar

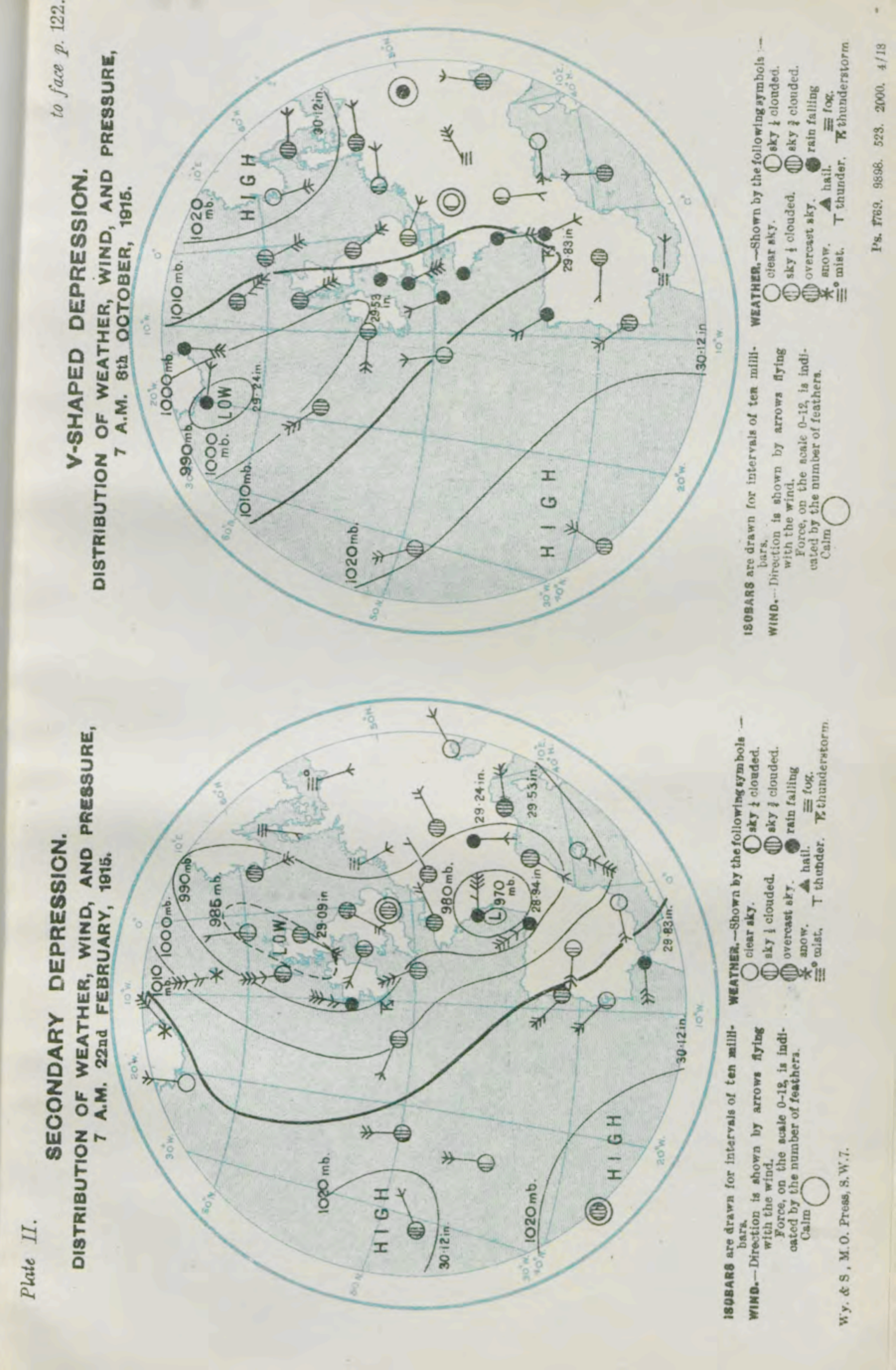


CHART OF GALE IN WHICH THE S.S. "BERLIN" WAS WRECKED OFF THE HOOK OF HOLLAND, WEDNESDAY, 20TH FEBRUARY, 1907, 8h.

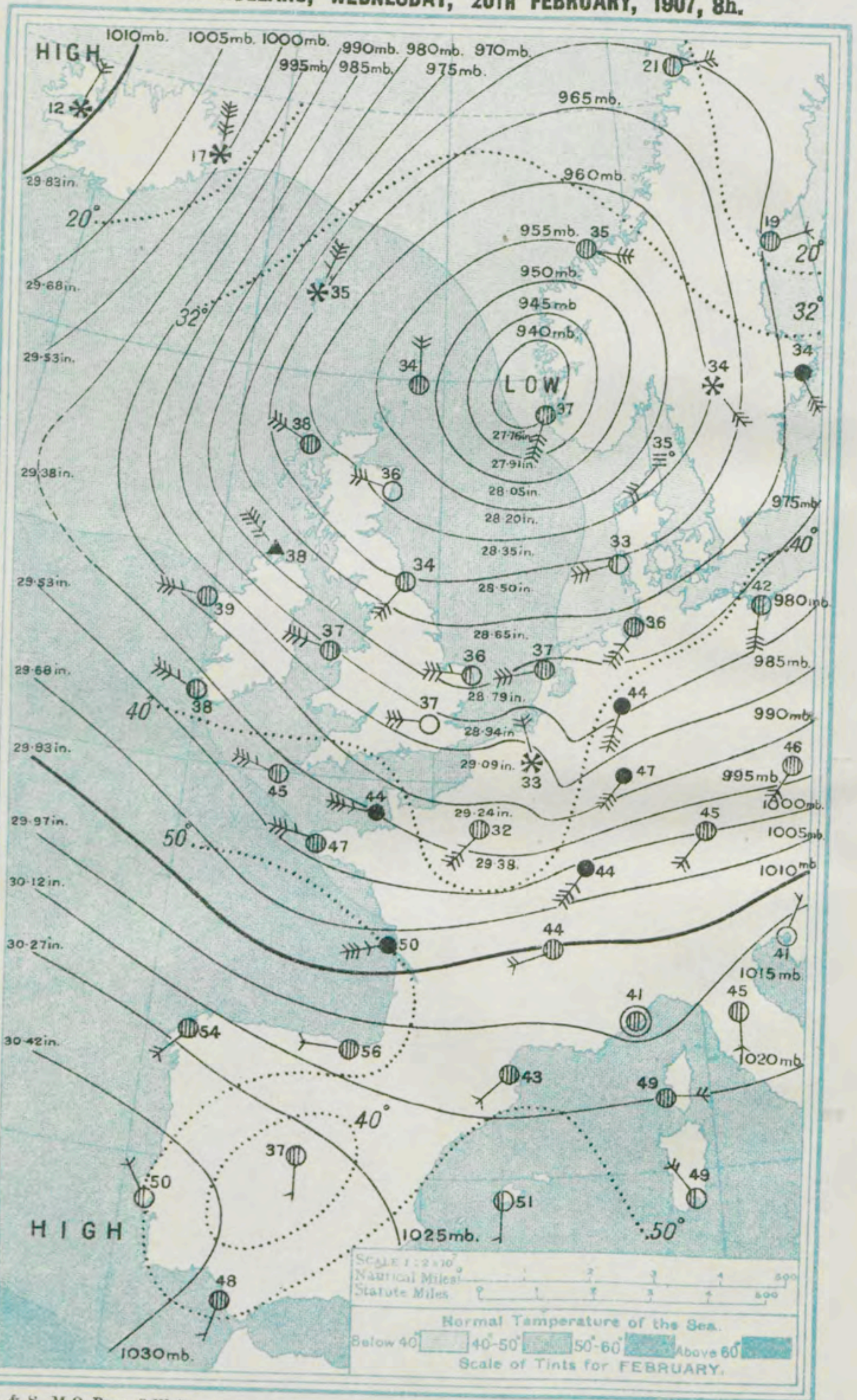


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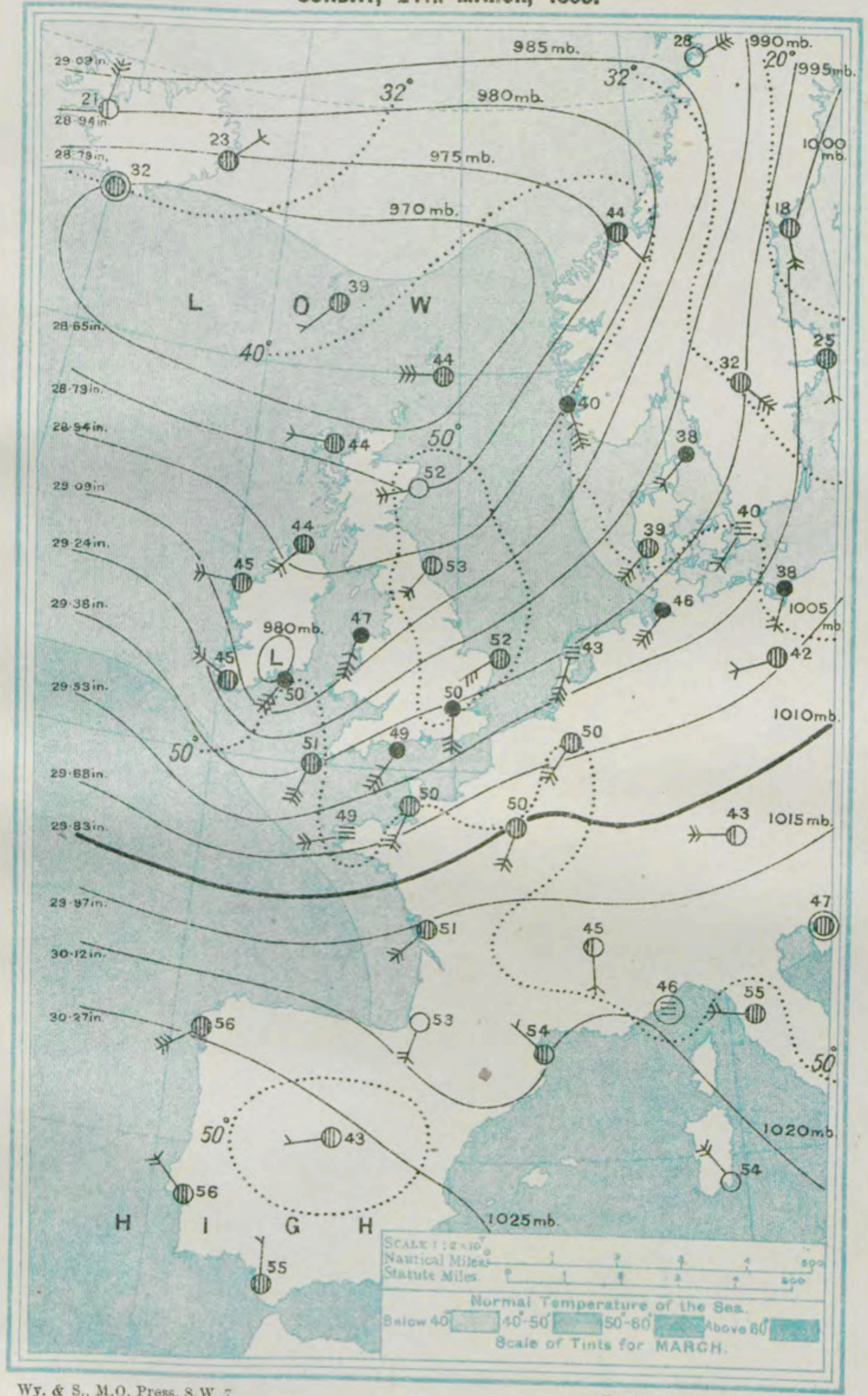
CHART OF SECONDARY DEPRESSION IN THE SOUTH OF IRELAND, MARKED L, WHICH CAUSED VIOLENT GALES DURING ITS PASSAGE EASTWARD ON SUNDAY, 24TH MARCH, 1895.



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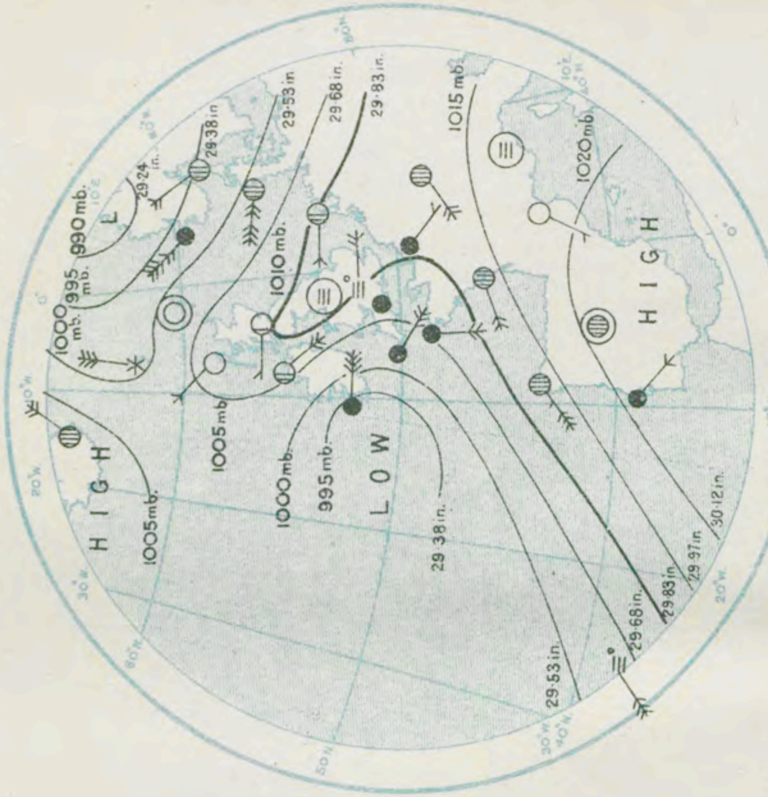
to face p. 123.

Plate V.

WEDGE.

DISTRIBUTION OF WEATHER, WIND, AND PRESSURE, 7 A.M. 9th DECEMBER, 1915.



ISOBARS are drawn for intervals of five millibars.
WIND.—Direction is shown by arrows flying with the wind. Force, on the scale 0-12, is indicated by the number of feathers. Calm ○
WEATHER.—Shown by the following symbols:— clear sky, sky ¼ clouded, sky ½ clouded, sky ¾ clouded, overcast sky, rain falling, snow, hail, fog, mist, T thunder, thunderstorm.

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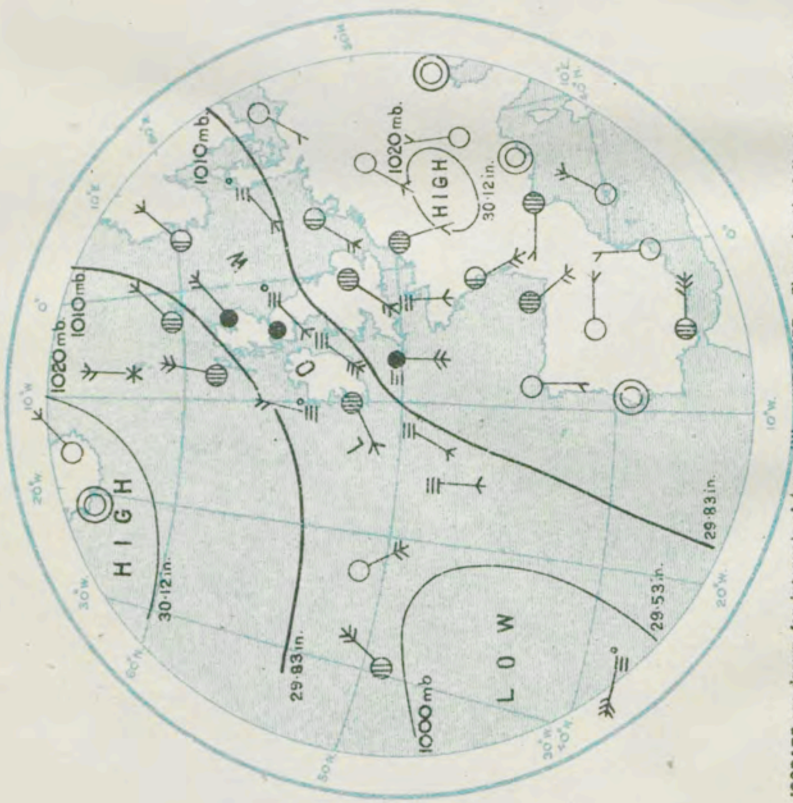
COL.

DISTRIBUTION OF WEATHER, WIND, AND PRESSURE, 7 A.M. 1st MAY, 1915.



ISOBARS are drawn for intervals of ten millibars.
WIND.—Direction is shown by arrows flying with the wind. Force, on the scale 0-12, is indicated by the number of feathers. Calm ○
WEATHER.—Shown by the following symbols:— clear sky, sky ¼ clouded, sky ½ clouded, sky ¾ clouded, overcast sky, rain falling, snow, hail, fog, mist, T thunder, thunderstorm.

Wy. & S., M.O. Press, S.W.7.

weather probably because the air of which it is composed belongs on different sides to different systems of circulation and coming from different regions may be very different in temperature and moisture. Whatever may be the explanation, however, the region of the Col sometimes displays almost ideal calm sunny weather, but on the other hand the calm bright weather is sometimes broken up by thunderstorms.

The **Wedge** is really one side of the Col, that is to say it is the extension of the high on the southern side, forming a tongue of high between two lows. It is generally a region of brilliant weather of a transient character following the rainy weather of the low that has gone by, and preceding the rainy weather of the low that is coming on. Between them is the period of clear sky during which the light wind backs from north-west to south-west. The wedge is generally the occasion of the "pet day" which is often experienced between two gales in a spell of foul weather.

Straight isobars belong to the margin of a cyclonic depression of very large area. On the left-hand side the wind or the run of the isobars the system becomes cyclonic—on the right-hand side anticyclonic. On the side of the low pressure the weather tends towards the rainy cyclonic type, and on the side of the high pressure it tends towards the fine anticyclonic type, the wind over the whole area being generally from the same quarter along the line of the isobars. But this brief account is a very inadequate description of the possibilities of weather with straight isobars. Almost every variety of weather may be found in every part on occasions, showers, fine intervals, heavy cloud, high filmy cloud, squalls, rapid alternations of warmth and cold, and all the while a persistence of wind from one general direction with temporary fluctuations. Not even the most experienced forecaster would like to compile a detailed map of the weather of the wide current with straight isobars from the information upon which the charts are constructed.

7. Maps of Two Notable Cyclonic Depressions.

The general features of the cyclonic depression have been explained by reference to a number of examples, and we now adduce two more, one of which, Plate III., represents one of the most striking examples of a depression which has been mapped in the Daily Weather Report. It is the depression by which the s.s. "Berlin" was wrecked off the Hook of Holland in the early morning of the 20th February, 1907. At the time for which the map is drawn, 8 h., the cyclone had its centre with pressure below 940 mb. off the south-west coast of Norway, and the isobars surrounding the centre extend to the south-west of Ireland and Northern France with an extension of isobars for westerly winds as far as Northern Spain and the North of the Mediterranean Sea. Beyond that are isobars over Portugal which show pressure exceeding 1030 mb., so that the whole range of pressure indicated in the map extends over 90 mb., or nearly to one-tenth of the normal pressure of the atmosphere. Corresponding with the closeness of the isobars there are gales nearly everywhere within the pressure line of 1010 mb. except to the north-east of the centre, and in places the wind is very violent, particularly so on the Eastern Frontier of Holland where there is a notable bend in the isobars with black dots indicating rain in front and wind from nearly south, and one star, indicating snow, at Brussels, with a wind from nearly north just behind the kink in the isobars. The kink in the isobars indicates a secondary and may be cited as an instance of the importance of the small variations in pressure shown by them; in front of the secondary, the temperatures are 10° or more higher than behind it.

There is very little rain shown on the map, only six rain-dots in all, three of them already referred to; one other at Jersey, one at Rochefort in the Bay of Biscay and one in the East of Sweden. There are, besides, five marks of snow and one in the North of Ireland of hail. From this we may conclude that the violence of the winds of a depression at any time is not related to the extent of the rain, snow or hail which is falling.

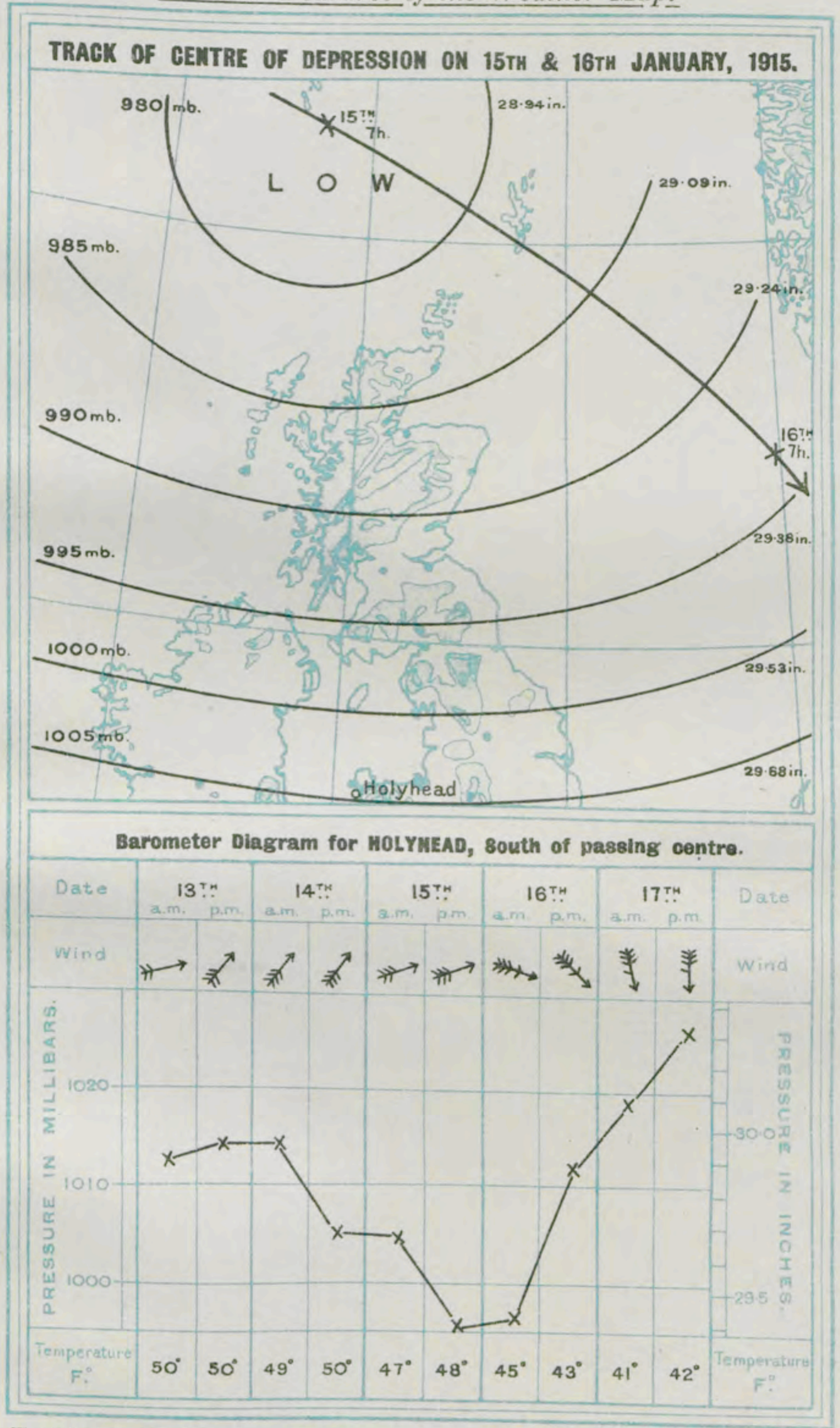
The second example is for 24th March, 1895, for which in the map for 8 a.m. we see a large cyclonic depression with a flat centre of low pressure between Scotland and Iceland. The range of pressure in this case is between 970 mb. and 1025 mb., not much more than one-half of that of the "Berlin" storm; but the feature which is most worthy of attention in this map is the small "secondary" indicated by a bend in the isobars over Ireland with a small oval-shaped isobar marked L showing a secondary centre. The winds are shown to be strong all over the west of England, Wales and the south of Ireland. The small secondary thus indicated caused a great local increase of winds on its southern side, which produced furious and destructive gales across the south of Ireland, South Wales and the central belt of England from South Wales to Norfolk, along which the secondary travelled. They were some of the most destructive gales of the past century, and the example is cited here in order again to call attention to the importance in certain cases of variations of the barometer in the course of the passage of a large depression which at other times would only excite the notice of an observer by producing a squall of wind and a shower.

8. The Relation of Local Observations to Passing Depressions.

Without a map a seaman cannot always tell for certain whether he is in a cyclonic depression or an anticyclone. On the outskirts of a deep "low" the barometer may actually read higher than it does near the centre of a local "high," but he may make a very good estimate of his position in that respect if he takes the wind and weather into account, as well as the reading of his barometer.

In illustration of the association of local changes in the barometer, wind and temperature with the passing of a depression with its centre somewhere in the neighbourhood, we may refer to Plates VI and VII. In both cases Holyhead is the station at which the observations of barometer and wind are supposed to be

The Observer's Experience referred to the General Features of the Weather Map.



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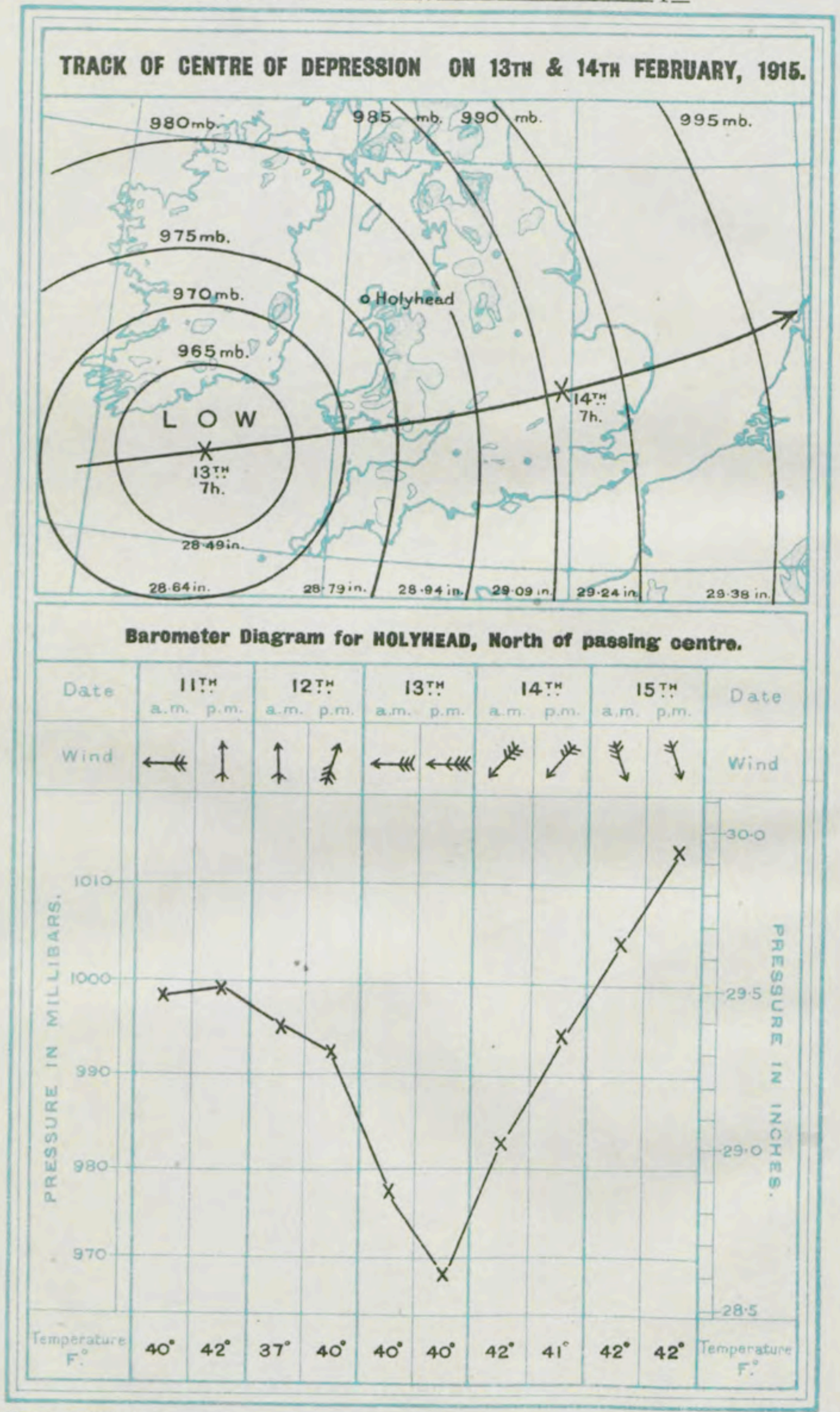
The Observer's Experience referred to the General Features of the Weather Map.



Wy. & S., M.O. Press, S.W. 7. Ps.764. 9898. 528. 2000. 12/17.

made, and the readings are put together to form a barometer-diagram such as is commonly kept by the custodian of a fishery-barometer lent to fishing ports and other small seaports originally by the Meteorological Department of the Board of Trade and since 1867 by the Meteorological Office. At the top of the barometer-diagram are the observations of wind, and at the bottom are the readings of temperature by a screened thermometer in the open air. In the particular case of these diagrams the observations of pressure, wind and temperature refer to 7h. for the morning and 18h. (6 p.m.) for the evening. On each plate the map for one point of time, in the course of the events recorded in the lower half of the plate, is reproduced in the upper half.

The first case represents the passing of a depression of which the centre travelled on the 15th-16th January, 1915, in a south-easterly direction from near the Faröe Islands, where it was shown by the map to be at 7h. on the 15th, to the North Sea. It will be seen that at that time the pressure was 1,005 mb., the temperature 47°, the wind WSW.5 having veered from SW.6, and showing by Buys Ballot's law that the centre was to the north and was moving eastward. In the course of the day the barometer fell and the pressure was reduced to 997 mb., the wind increased to Force 6 but kept its direction, and temperature rose to 48°. By the next morning the wind had begun to rise, had veered to WNW. and had reached gale force; and in the course of the day it veered further to NW., still blowing a gale. The change in direction showed that the centre was making further progress to the eastward and, as the wind remained strong, the depression was not moving away altogether. With continued rise in pressure the wind got round to the North and still blew a gale, showing that the centre was a little to the South of East. Meanwhile the temperature continued to fall with the veering wind until it reached 41° on the 17th.

The second example shows the passage of a depression of which the centre passed along the Bristol Channel, about 100 miles south of the station, taking a path from W.byS. to E.byN. on 13th and 14th of February, 1915. The first sign of the coming depression was a fall of the barometer to be noted on the morning of the 12th while the wind was light from the south; and the depression must have been out to the West on the Atlantic, perhaps a little north of the parallel of Holyhead. By the evening of the 12th the pressure had fallen and the wind veered to SSW. force 5, and then, by the morning of the 13th for which the map is drawn, had backed to E. force 6, showing that the depression had changed its course and was coming in on the south. By the evening there was a gale from the East showing that the centre must be moving nearly due east. After the passage of the trough-line the wind backed to North-East force 6 and then force 5, and then backed still further to NW. showing that a new distribution was being arranged.

It should be noted that during the whole time there was very little change of temperature. All the readings are within 5° F.

The changes of weather are not given in these diagrams. In either case the later period of the falling barometer would probably be associated with cloud and rain, and the earlier period of rising barometer with showers in the first case and rain in the second.

9. Changes of Wind and Weather without much Change in the Barometer.

In the two examples cited above the changes of wind have been regarded as the natural accompaniments of a marked change in the barometric pressure indicated by a considerable fall and subsequent equal or greater rise of the barometer.

We now give two examples in which the pressure remained nearly the same for five days, but the wind and weather went through a series of changes owing to changes in the map due to alterations of pressure north or south of the station.

In the lower compartment of the first two plates is reproduced the barogram for a position off the Isle of Wight from 13 h. (1 p.m.) on October 9th, 1916, to nearly midnight on October 14th. Very little variation is shown: for the greater part the barometer is high, the pressure considerably above 1020 mb. It falls to below 1020 mb. during the last day, the 14th, but the wind, while keeping a pretty steady direction somewhere between SW. and W., changes very considerably in force. Beginning with force 3 it goes down to 2 and then rises to a gale, 7-8, in the early hours of the 11th October, then it falls to 2 again, rises by the middle of the 12th to 7, falls again to 1 by noon of the 13th, and finishes with SW. 7 at midnight on the 14th.

These changes are explained by the maps which (on very small scale) comprise the upper compartment of the plate in six panels each representing a map for 7h. on the successive days. In the first case it appears that the centre of a "low" came in on the 10th and passed rapidly across the extreme North of Scotland to Norway by 7h. on the 11th. At midnight its centre must have been about due north of X and its influence caused the increase of wind to gale force at that hour. Then another low appeared on the 12th about Faröe, which on the morning of the 13th had passed to the North of Norway and in its passage, which would be about noon on the 12th, the strong winds occurred, less strong than on the previous occasion, however, because the centre was much further away. Finally a third depression appeared on the evening of the 14th off the west of Scotland and this keeping in lower latitudes reduced the pressure and increased the wind on the afternoon of the 14th.

Plate IX. represents the corresponding state of things for Holyhead, where very little change of pressure occurs at the station itself, as shown by the barogram, but the winds, all easterly or north-easterly, change from force 7 on 25th January to force 5 on the 26th, forces 8 and 7 on the 27th and 28th to force 3 on the 29th, up to force 7 and down to force 2 on the 30th. The period began with a "low" off the west of Ireland and a "high" over the North Sea which remained practically unchanged till the 29th. It will be seen that the isobar 1015 mb. (half way between those for 1010 and 1020 which are drawn on the map) passes quite close to Holyhead during the whole period. But considerable changes take place in the details of a belt of low pressure which

The Observer's Experience referred to the General Features of the Weather Map.

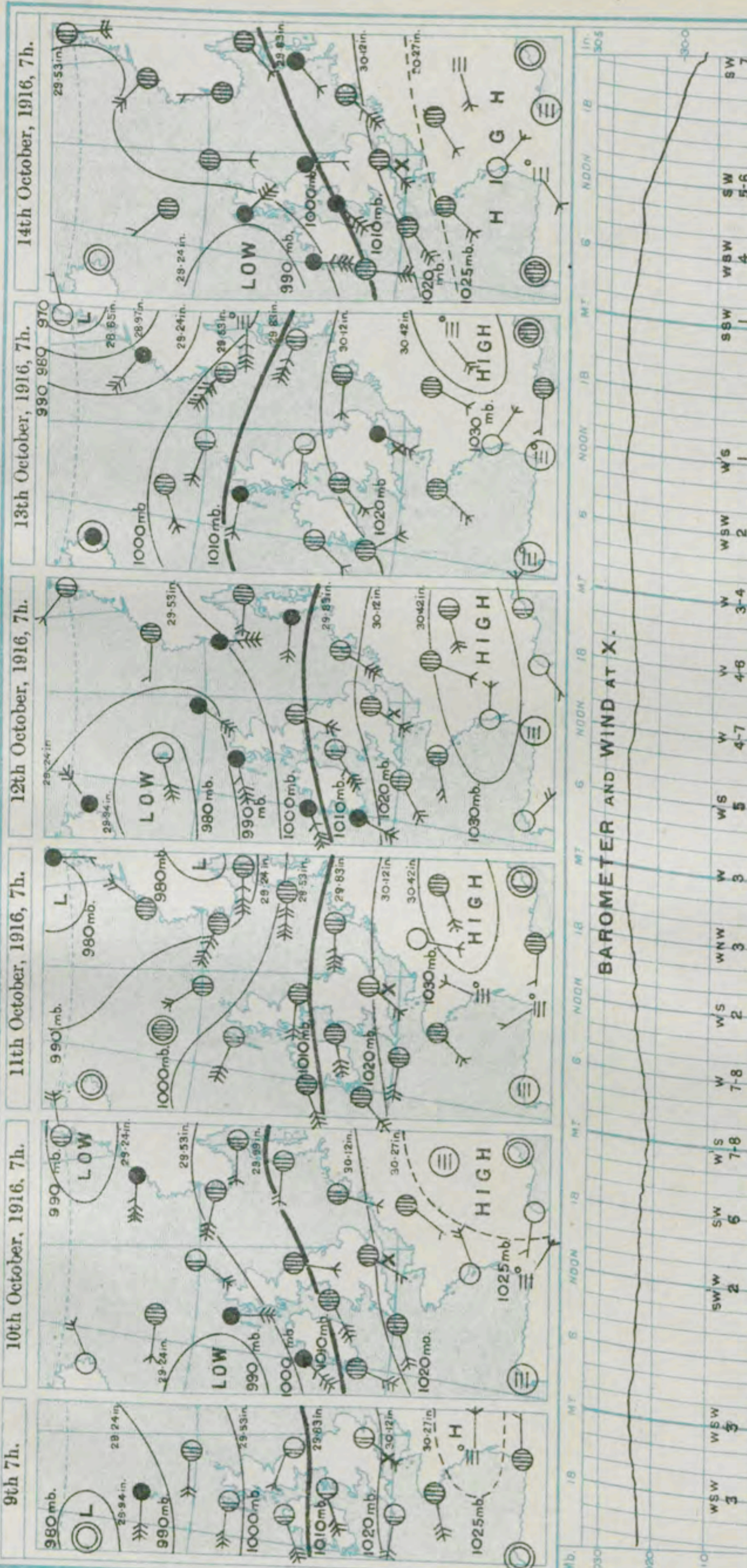


Chart showing changes from light winds to gales during a period of high pressure at a station marked X in the South of England in consequence of the passage of the centres of depressions beyond the North of Scotland.

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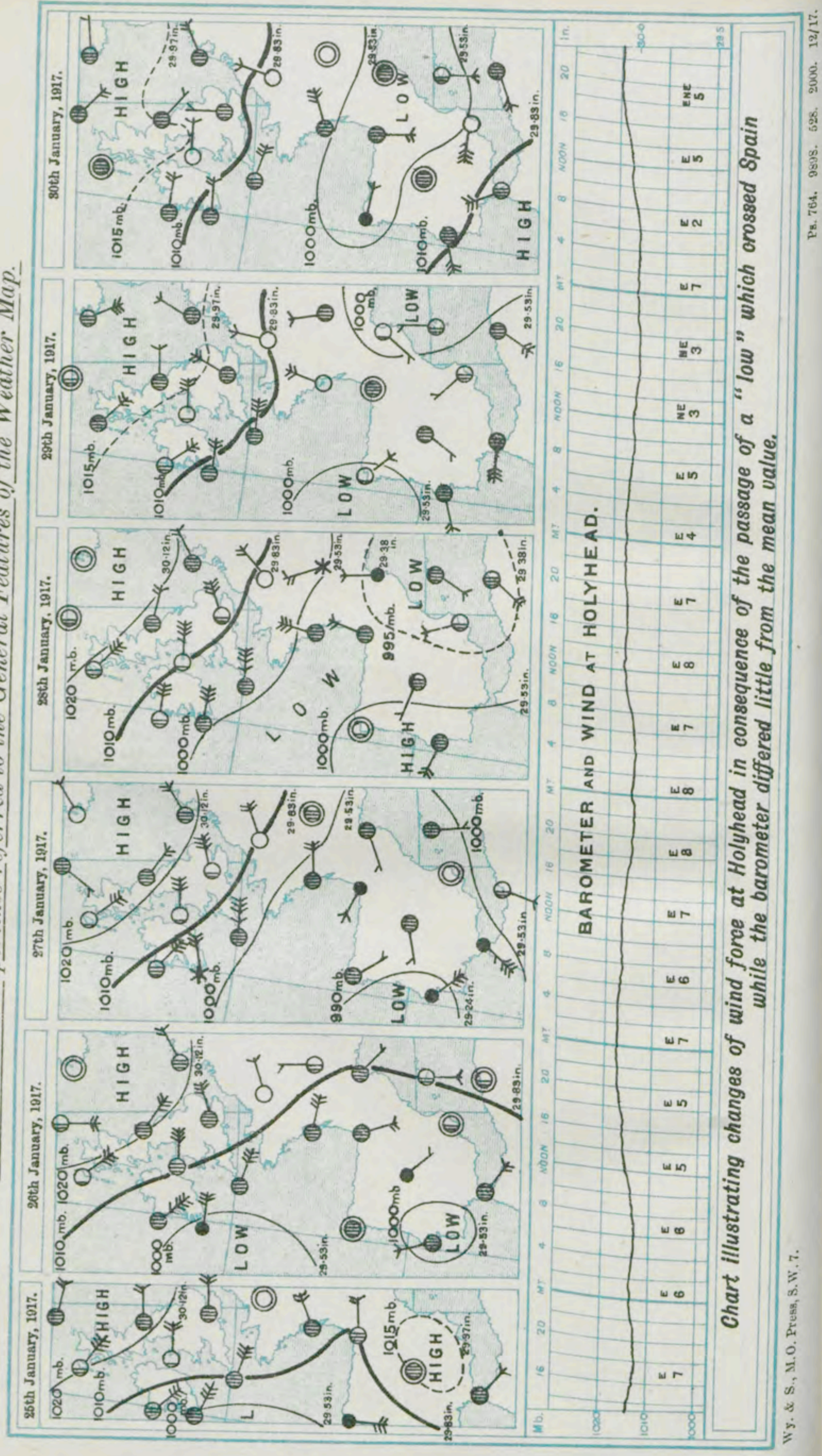


began to show off the south-west of Ireland and extended itself by the movement of a "low" over Spain to the Mediterranean.

Such changes it is hardly possible for the observer who has not access to a weather map to follow by means of his own local observations of barometer and wind. We are almost forced to the conclusion that while noteworthy changes in the barometric pressure are certainly accompanied by marked and regular changes of wind and weather, the steadiness of the barometer affords no guarantee that the wind and weather will not change, because these are dependent upon the form of the distribution of pressure over the map and not merely upon the changes of pressure in the immediate locality of the observer.

10. The Minor Fluctuations of Atmospheric Pressure.

Hitherto we have regarded the main features of the weather as being associated with the most obvious features of the weather map, which are the changes in the distribution of atmospheric pressure. In the most general way we have associated foul weather with the cyclonic depression or its secondaries, and fair weather with the anticyclone; and we have assigned various characteristics to the periods of transition between one low-pressure and its successor, or to the region which separates an anticyclone from the central region of a depression. Any observer with a barometer to help him will be able to verify these associations for himself, but if he has a barograph he can do much more than that by studying more closely the relation between the weather which he experiences and the minor fluctuations of pressure which the barograph records. In Chapter VIII. in dealing with the use of the barograph we have already called attention to the fact that in tropical regions where no great fluctuations occur in the pressure of the atmosphere, the notable changes in the weather, as from clear skies to heavy showers or thunderstorms, are associated with slight changes in pressure shown by the barograph as what we call the embroidery of the barogram. The same is true of our own latitudes, but it is less easily noticed with us because the embroidery appears as trifling irregularities in the course of great surges of pressure which affect the weather, whereas in tropical countries in the absence of embroidery there is only the regular double wave of pressure which has no influence upon the weather so far as we know.

But the careful observer will often find slight variations in the upward or downward course or the steady run of the trace of the barograph which are true embroidery and are easily distinguished from the semi-diurnal variation which is represented in Plate I. of Chapter VIII., and he will do well to pay attention to them. The shapes of these peculiarities are very various, sometimes they are merely slight depressions and recoveries that occur while the barometer is steady or slowly varying, and, generally speaking, the weather responds by slight variations in the direction and force of the wind and the cloudiness or clearness of the sky. The best occasions for watching these changes are during a long anticyclone or during the prevalence of a spell of straight isobars.

We have already said that there is a sort of museum of different kinds of weather with one prevailing direction of the wind in a field of straight isobars, and anyone who is interested in the study of weather will do well to watch its changes on such occasions and compare them with the record of the barograph. This part of meteorological study has been very little explored and some of the embroidery of the barogram, particularly regularly recurring oscillations in a period of from ten to twenty minutes, too small to show clearly on a barograph but very noteworthy when magnified, is an altogether unsolved problem. And sometimes in thundery weather when there is a large field of uniform pressure on the map, the barogram shows a V-shaped dip and recovery, very suggestive of a passing whirl taking about an hour to go by, which has little influence upon the local weather but seems to be related to a thunderstorm a hundred miles or so off. The reader who is interested will find a number of peculiarities of barograms reproduced in the annual volume of the British Association for 1908, p. 608.

These minor changes are not only difficult to interpret but they find no place in the weather map, because the scale of the map is small and the stations which contribute the observations are so wide-spread that the embroidery is not expressed in it. It can, however, be represented in maps specially drawn from a collection of barograms.

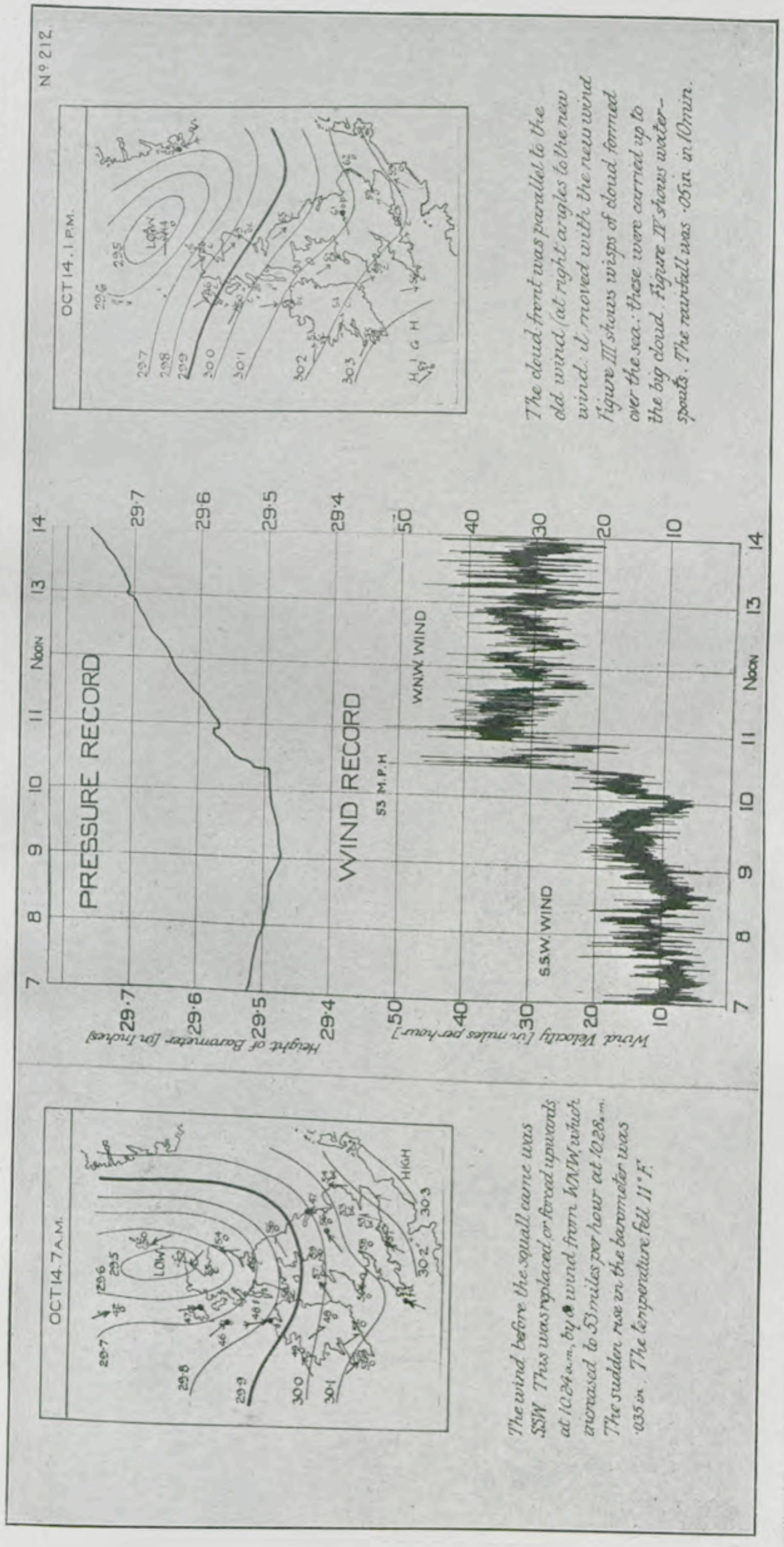
But there is one item in the embroidery of the barogram which has been carefully investigated at the Meteorological Office, and that is a sudden, almost instantaneous rise of pressure, sometimes amounting to as much as 3 mb. (0·1in.) but often smaller, which is accompanied by a sudden drop of temperature and an equally sudden veer of wind through eight points, sometimes with a notable squall at the moment of transition and a permanent change in the force of the wind. As these changes are approaching the observer a long, arched cloud appears in the sky and advances with a long front. It develops into a smart shower, perhaps with hail and thunder. This group of associated phenomena is known as a line squall, of which a full account is given in papers by Mr. R. G. K. Lempfert and Mr. R. Corless before the Royal Meteorological Society, and a summary will be found in *Forecasting Weather*, published by Messrs. Constable & Co.

A local observer can always watch this interesting sequence of weather if he is on the look-out for it when the arched cloud appears in the sky. Pictures and diagrams showing the whole sequence of events during the passage of a line squall at Aberdeen are represented in the accompanying figures, and are a sufficient indication of what the observer may look for.

The phenomena such as those which are represented generally extend along a line over a great stretch occasionally right across the British Isles and they sweep onward with a moderate speed of twenty or thirty miles an hour from West to East or from North-west to South-east. None has ever been known to go westward. They appear to be due to the advance of a sort of wave or tide of colder air which displaces the warmer air all along its front

To face p. 128.

CHAPTER XI.—THE OBSERVER'S EXPERIENCE. Fig. 5.



Maps and records of pressure and wind at Aberdeen, October 14, 1912. The squall illustrated by the drawings over leaf passed Aberdeen in the forenoon, between 10 h. 24 m. and 10 h. 30 m.

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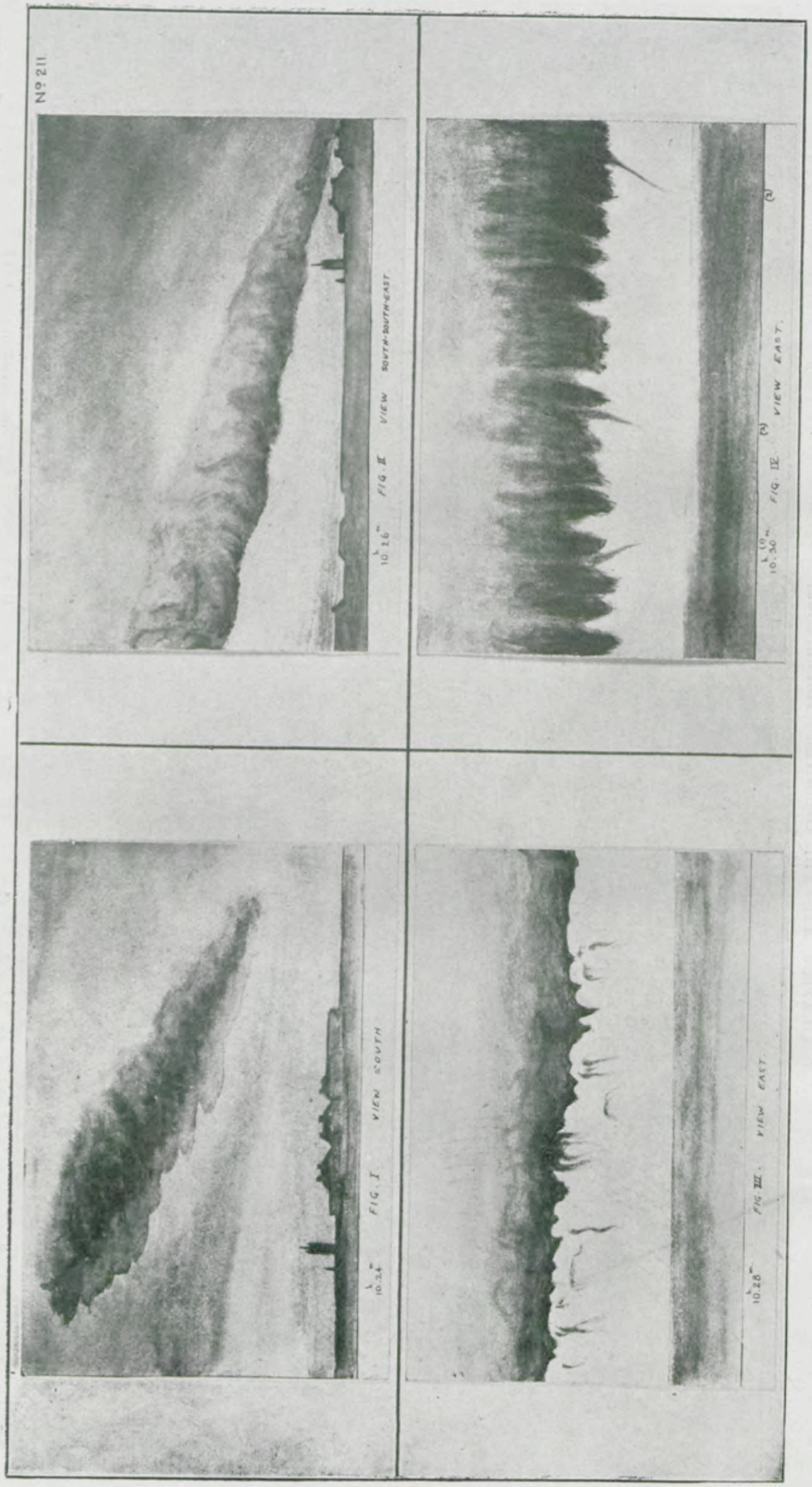
To face p. 129.



Six minutes in the life-history of a line squall. Sketches of cloud at Aberdeen at intervals of two minutes. In the first two the cloud is approaching from West-North-West; in the second two it is passing away to East-South-East.

and produces all the observed phenomena at the time of transition. The colder air comes from a point veered from the line of the air current which it displaces by about 8 points or 90°. But sometimes the wave or tide is only transient, the new air holds the field for an hour or so, then disappears, and the former conditions are restored, to be swept away again by another visitation of the same kind or perhaps a succession of them always milder than the first. And on the other hand sometimes the change is permanent and the old régime of warm wind from some southerly quarter is replaced once for all by the tide of colder air from the West or North-west. Line-squalls are most frequent near the trough on the southern side of a cyclonic depression and are marked by a sudden arrest of the fall of the barometer with a little rise instead. Sometimes the sudden rise marks the permanent termination of the cyclonic fall showing that a new supply of air has arrived, but on other occasions the rise is transient, the cyclonic fall is re-established after a brief interval.

Squalls and cold waves with a sudden rise of pressure of the kind indicated by a line-squall often occur when a summer thunderstorm breaks. Often in such cases the squall is of destructive violence, though it lasts only for a few minutes. The phenomena may perhaps be ascribed to similar causes, but in the case of a thunderstorm they are far less regular. They are subject to great local variation and it is difficult as a rule to trace the sweep of the line over any great width of country.

These special phenomena are commended to the notice of the individual observer who is interested in the weather, because he is in a position for studying these quite as favourable as the established observer at a fixed station. Nobody realises them unless he is on the look-out and even the best examples pass unnoticed until the observer begins to put together the day's observations and finds a little jolt in the barograph trace that he did not think of noticing at the time.

CHAPTER XII.

THE USE OF MONTHLY CHARTS.

1. Charts of Mean Pressure. The Winds and the Weather Map.

On any and every occasion the winds in any locality are related to the distribution of pressure as represented by isobars upon a map. The air moves along the isobars; the closer the isobars, the stronger the wind. So also, if we wish to get an idea of what the average motion of the wind is, the best way, in many respects, is to look at a map of the average distribution of pressure. With a certain reservation which need not be explained here, the average wind is fairly represented by a wind which moves along the average isobars with the speed computed from the distance by which the isobars are separated. The principle that the nearer the isobars are together the greater the velocity of the wind holds with sufficient approximation for the average as well as for the individual occasion.

An inspection of the maps for each of the twelve months and for the year, which are given between pp. 130 and 131, shows that, on the average for the year, the wind in any part of the British Isles is from the Westward, and its speed, as determined by the separation of the isobars between 8 and 9 miles an hour (about 4·2 m/s.). According to the monthly charts it varies between 15 miles per hour (7·5 m/s.) in December and January, and 2 miles per hour (1 m/s.) in May and locally, also in September; but we ought to understand what is meant by the average in this case. It certainly does not mean that the wind is always from the point which is defined by the average direction and with the average speed. The wind is perhaps most frequently from the South-west or West, and yet it is not infrequently from the North-east or East, and sometimes from points on either side intermediate between those two extremes. All these variations have to be taken into account in obtaining the average wind which is represented by the isobars. The process of taking it into account with the measurements of wind is rather intricate. The easterly wind has to be regarded as the opposite of, and therefore as cancelling a part of the westerly wind, and so on for the other opposites. Then a south-wester has to be regarded as partly from south and partly from west, and the parts or components separately accounted for and combined. This process, which is laborious with measured winds, is quite easy with the distribution of pressure. We have only to take the average values of the pressure at enough points to give a satisfactory map, and the map of average values gives the result of the combination.

MAPS

OF THE

AVERAGE DISTRIBUTION OF PRESSURE

TO SHOW THE

RESULTANT DRIFT OF AIR

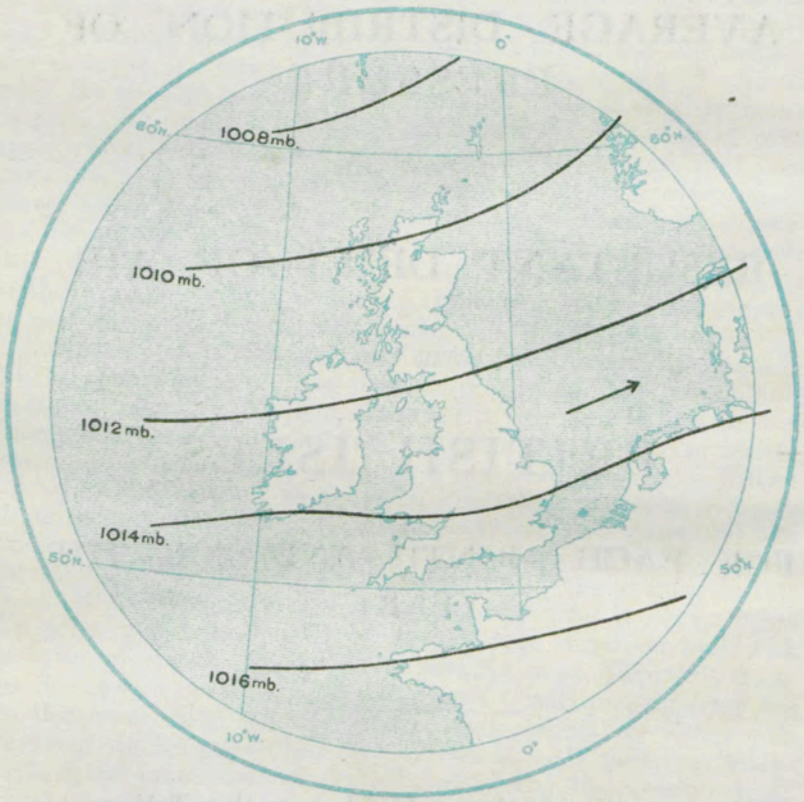
OVER THE

BRITISH ISLES

FOR EACH MONTH AND FOR THE YEAR:

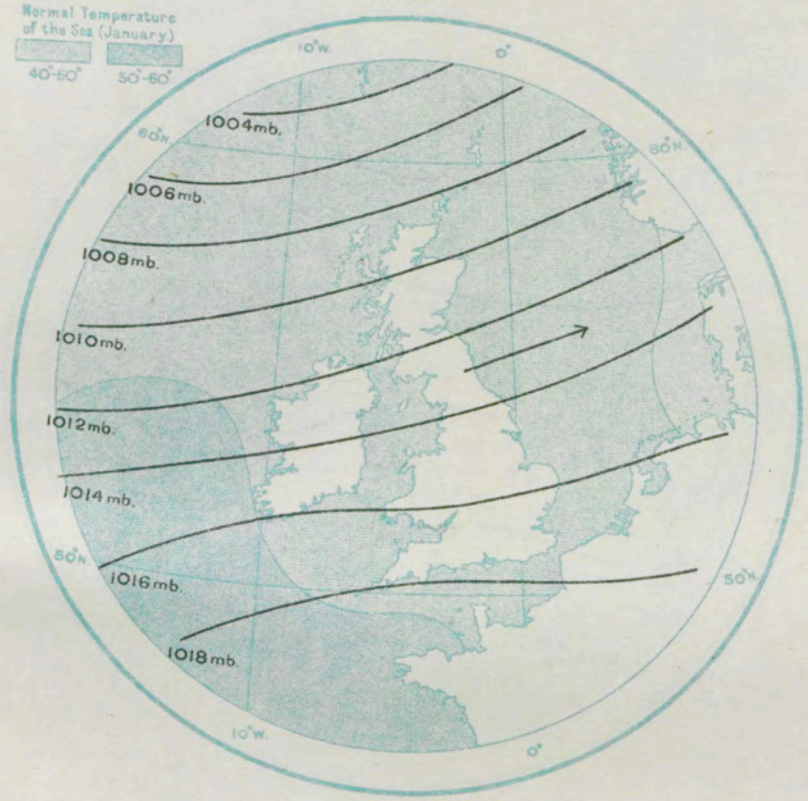
Based upon Observations at 7h. at the Telegraphic Reporting Stations of the Meteorological Office in the Ten Years, 1906 to 1915.

THE YEAR.

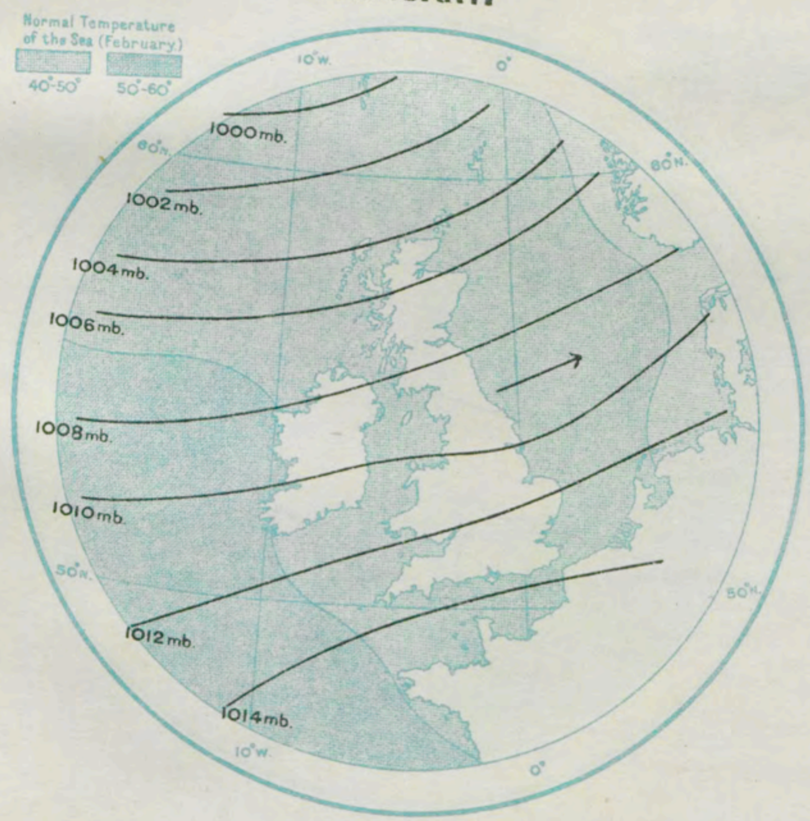


The arrows show the direction of the resultant wind and their length gives a rough indication of the resultant speed.

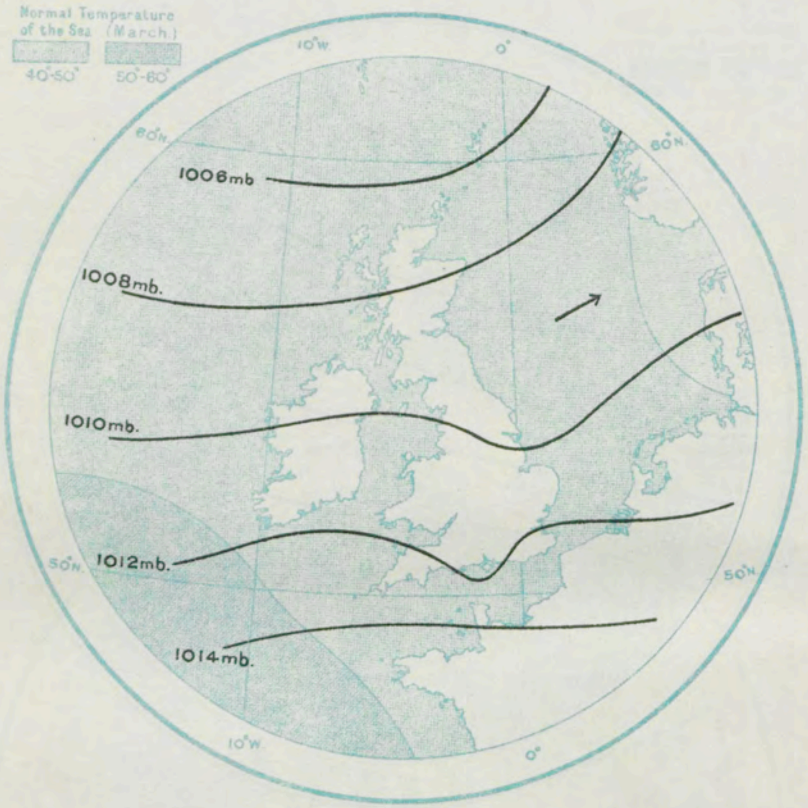
JANUARY.



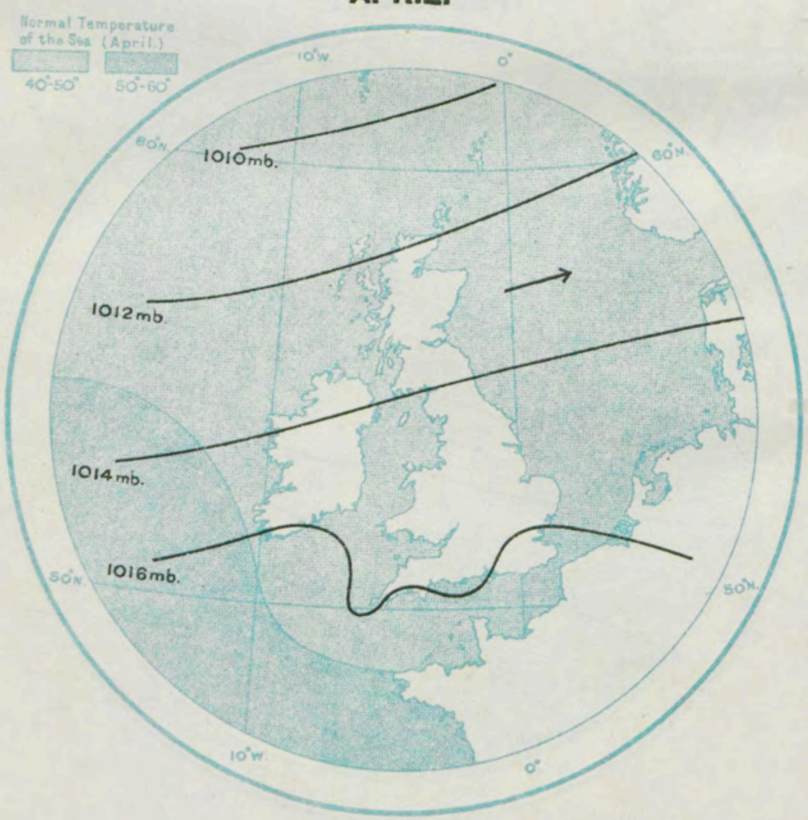
FEBRUARY.



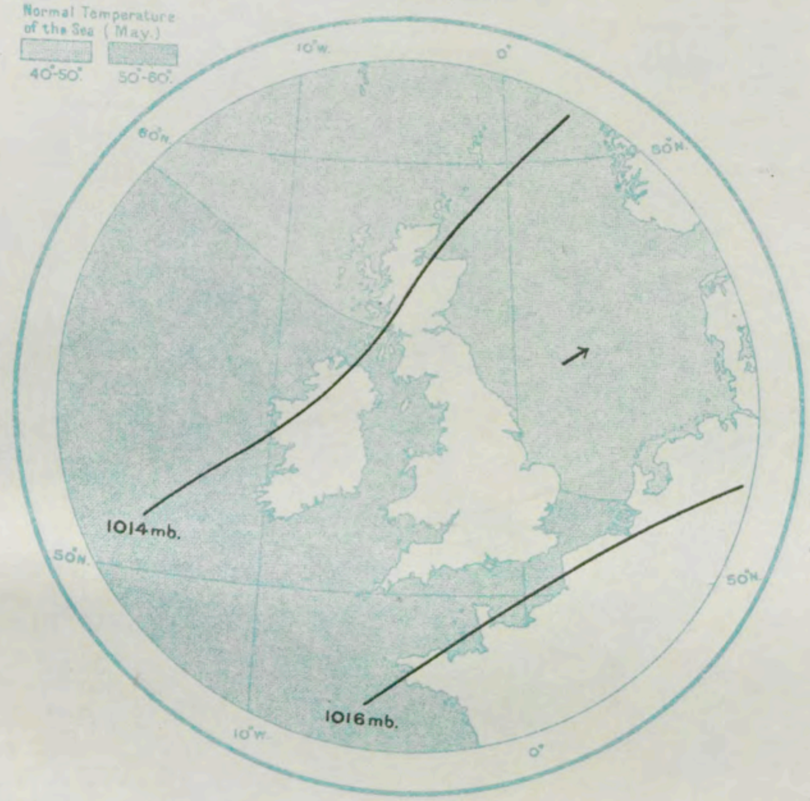
MARCH.



APRIL.



MAY.



JUNE.

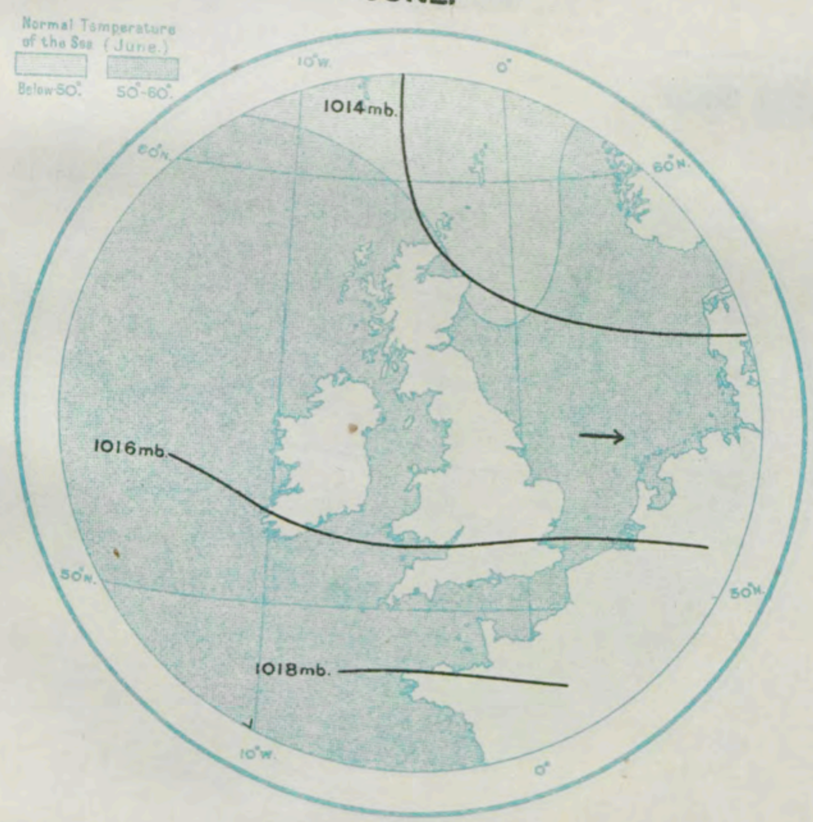
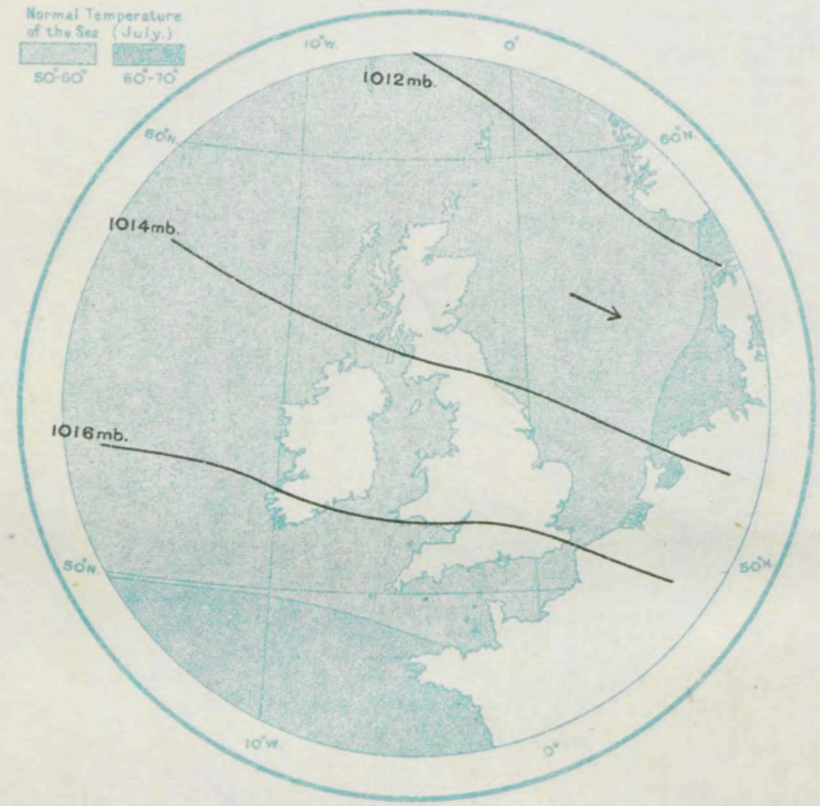
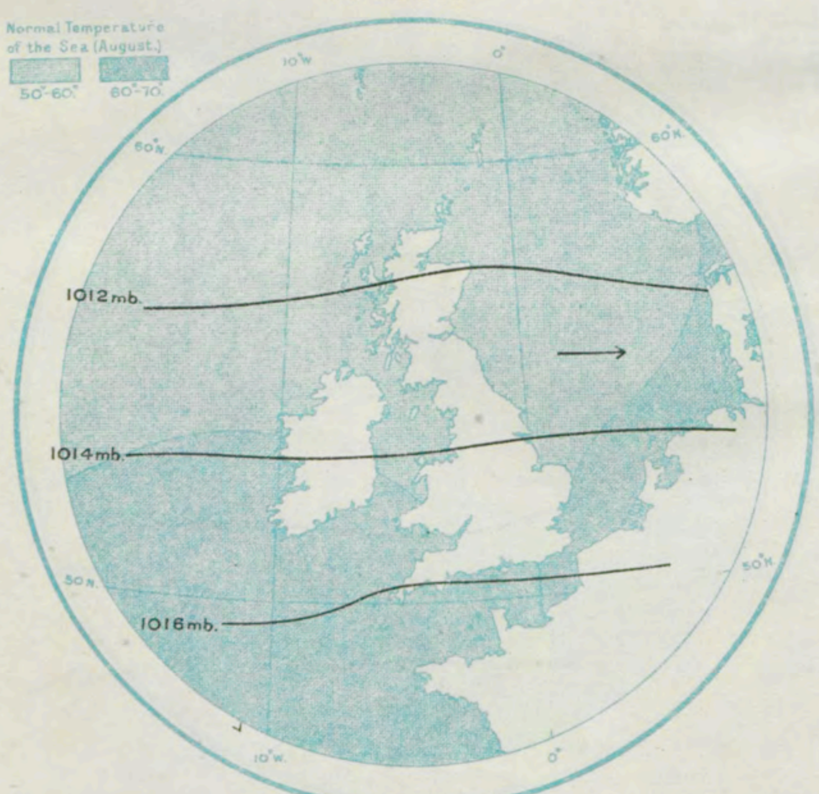


Plate V.

JULY.



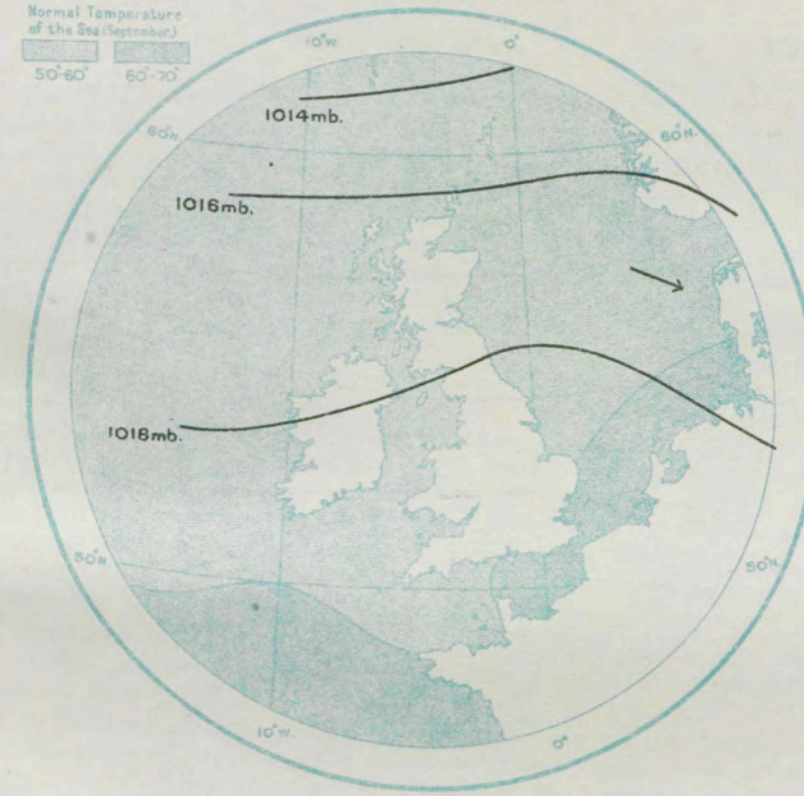
AUGUST.



The Use of Monthly Charts.

Plate VI.

SEPTEMBER.



OCTOBER.

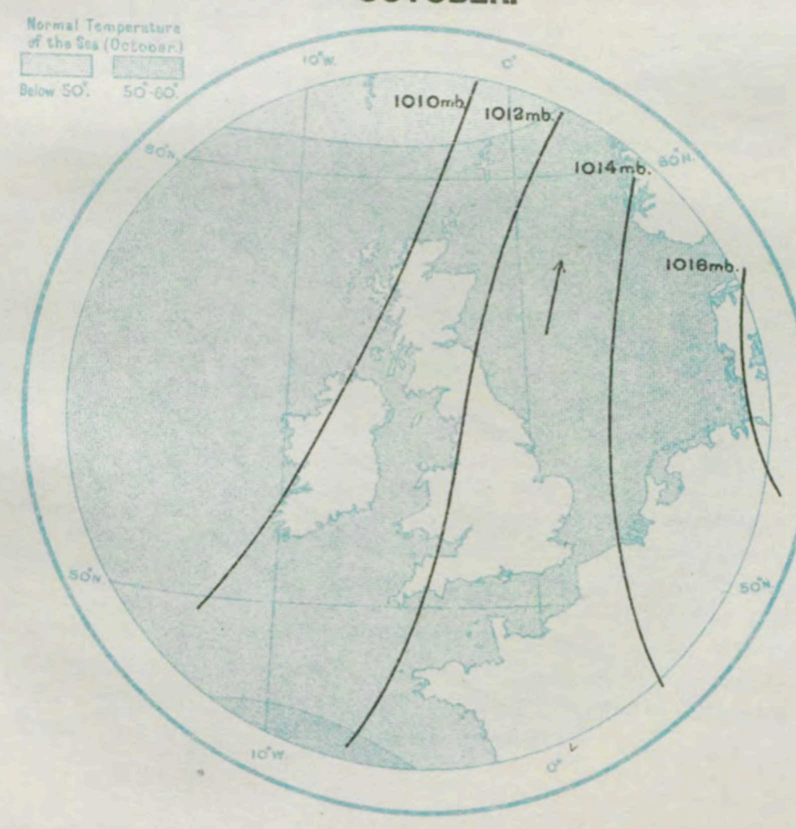
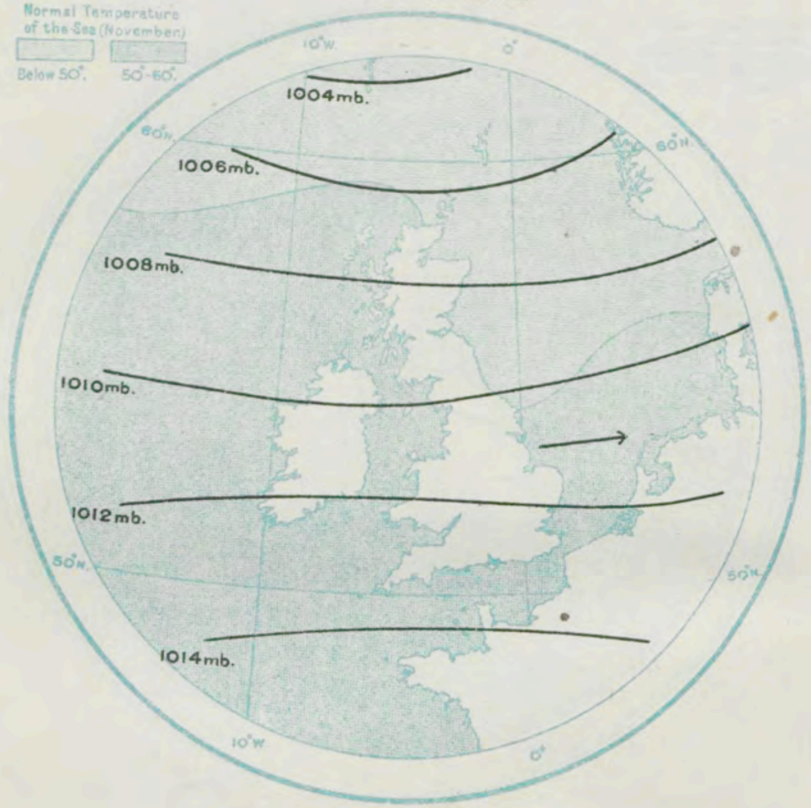


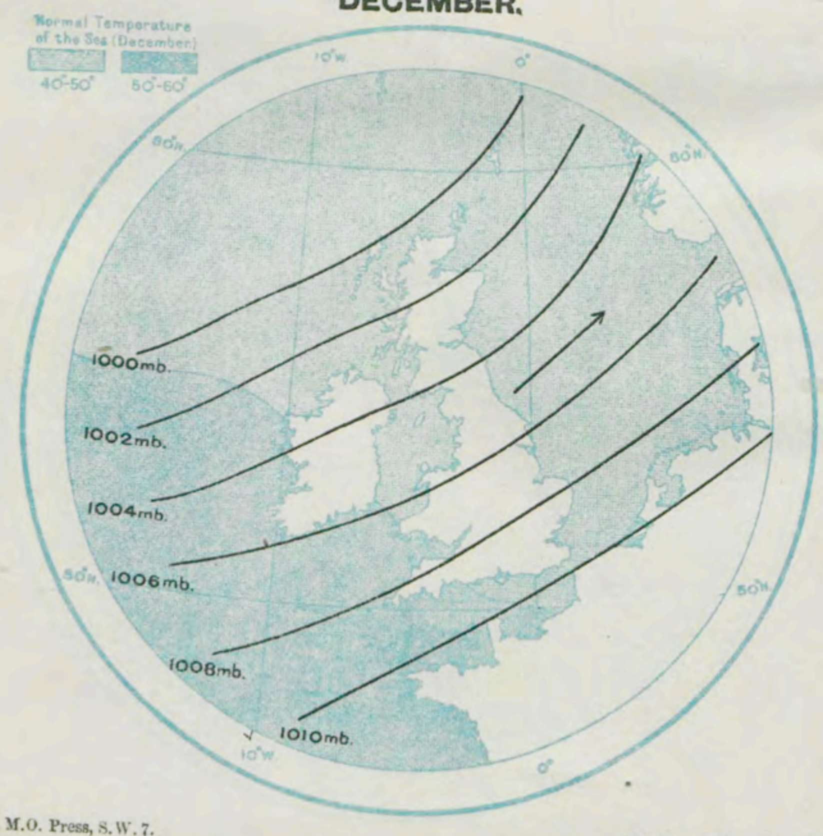
Plate VII.

The Use of Monthly Charts.

NOVEMBER.



DECEMBER.



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For those who simply want to know what the average or resultant drift of the wind is, this method of estimating the average flow will give satisfactory results. But the wind, as represented therein, is not quite the same thing as the wind observed by a sailor at sea, and still less in harbour. The wind obtained from the run and separation of the isobars is the wind free of any interference by the eddies which are formed by passing over the surface of the sea or land. The effect of those eddies is to hold up the surface layer to some extent, and to deviate its flow about two points towards the lower pressure—that is, to make the point from which the surface wind comes about two points more from the southward than the run of the isobars. It is the motion of the lower clouds that we are thinking of when we look at a pressure map as a guide to the winds. It is better so to think of it, because even on the open sea the water holds the wind back a little at the surface. Probably just at the surface the water takes as much as one-third out of the speed of the wind, and there is every stage of gradation between that and the almost complete protection of a land-locked harbour.

Indicated in this way the maps for the several months give us valuable information about the average flow of air over the British Seas at different times of the year.

In January and February the resultant winds are the strongest of the year; six isobars cross the area of the British Isles from WSW. to ENE., although in February the average pressure over the whole area is lower by about 4 millibars than in January. In March the average pressure in the South is the same as in February, but in the North it is higher, and in consequence the resultant wind is less strong. For April, pressure has risen everywhere, but most in the North, so that the resultant wind is again lighter, and there are irregularities in the South which are probably due to irregularities in the occurrence and movement of depressions there in the showery month.

For May the pressure has risen again in the North, and the general average of wind is the lightest of the year, and the isobars run from SW. to NE.; but we ought not to omit to notice that May is a favourite month for east winds, and the inference drawn as to the lightness of the winds from the uniformity of pressure may be partly accounted for by the nearer approach in May to equality between winds from the eastern side and winds from the western side.

In June the isobars show a notable change in general direction: the region of lowest pressure is now to the north-east of the map instead of the north-west as in May, or the north as in other months and on the average for the year. But in the region of the Channel the general drift of air from the westward is still well-marked.

In July the lowest pressure is still to the north-east, and the run of the isobars is from north of west all over the map.

In August the drift is westerly again, but light. In September it is still westerly, but the pressure is very uniform over England

and Ireland, indicating a general absence of strong winds in those regions. As we have already noted, September is a month of comparative freedom from cyclonic depressions.

October shows a very remarkable map in this series. The lower pressure is on the western side, and the isobars which keep the low pressure on the left hand run nearly from South to North. If this characteristic were borne out generally by maps of isobars over the British Isles in October we should have to count October as more especially a month of southerly winds as distinguished from westerly winds. The set of maps reproduced here was specially prepared for the study of the average distribution of isobars at 7 h., the morning hour of observation at the telegraphic reporting stations of the Meteorological Office during the period when the receipt of observations from Iceland made it possible to get satisfactory maps of the very important region of the North Atlantic to the north-west of our islands. Previous to 1907 Stornoway, in the Western Hebrides, and Sumburgh Head, in Shetland, marked the extreme limit of observations in the North and West. If that consideration had been disregarded we might have used average pressures for forty years* instead of nine years, which are represented as the data for reference in the maps of mean pressure in the Monthly Weather Report. These show well enough the isobars over our land areas and the central, southern and eastern seas, and in them the month of October is not specially marked out as a month of southerly winds. Hence it appears that the nine years from 1907 to 1915 were in some ways exceptions from the general run. The exceptional character is of considerable meteorological interest, because, when a long average of rainfall is taken, southerly winds and rain are associated one with the other, and October always comes out as the rainiest month of the year for England, though for the North of Scotland there is more rain in the winter months. When subsequent years are available we may find out some clue to the peculiarity of the nine years which, for the special reason given, have been chosen for these maps.

In November we get back to a general westerly current of considerable intensity marked by five isobars within our region, and December is very like January, with six isobars between Jersey and Shetland, which run from the south-west instead of west.

2. Meteorological Summaries. The Methods of Frequencies and Extremes.

We have explained that maps of the distribution of pressure are the best guide to the general drift of air over our Islands, and they illustrate the manner in which monthly summaries of pressure may be used in maps. But we had to give expression to the caution that with this method of making a summary of the

* Isobars based on averages for 35 years are given in the Atlas of Monthly Meteorological Charts, British Islands and adjacent waters. Hydrographic Office Publication. The data are given in the quarterly appendix to the Daily Weather Report.

winds it was possible if any particular month had a nearly even balance of easterly and westerly winds, northerly and southerly winds, and so on, that the apparent absence of winds shown by the results might really be explained by the alternation of winds, even strong winds, from opposite quarters. Every method of summarising results is liable to make more of regularity than actual experience would feel. September, for example, is classed as a relatively calm month, when depressions are not numerous and storms are rare. But when they come they are sometimes very severe, and one severe gale in September makes more impression on the memory than many days of the calm weather of early autumn. We must take care, therefore, in our endeavours to summarise the many thousands of observations that are recorded about the weather to give each record its due prominence, and for that purpose various methods of summarising must be used. We shall evidently avoid the difficulty of a strong easterly wind being simply used to obliterate the record of an equally strong westerly wind on another occasion in the same month if we use the method of "frequencies" instead of the method of averages derived from the distribution of pressure. The method of "frequencies" consists in counting and recording the number of occasions on which certain specified events have happened, such as winds of a particular force from a particular quarter, occasions of fog, days of rain, snow, hail, thunderstorm, clear sky, overcast sky, ground frosts, temperatures of the day or the night between certain limits, and the like. With the method of frequencies may be associated what may be called the method of "extremes," or what the newspapers call "the records," the longest duration of a spell of wind or any other special kind of weather, the warmest day, the coldest night, the heaviest fall of snow, the longest duration of fog, and so on. This method is more often used for temperature than for the other meteorological elements, but it is available for all. It is used for winds in Chapter II. for fog in Chapter IV. and for thunderstorms and snow tables at the end of this Chapter.

3. Wind Roses.

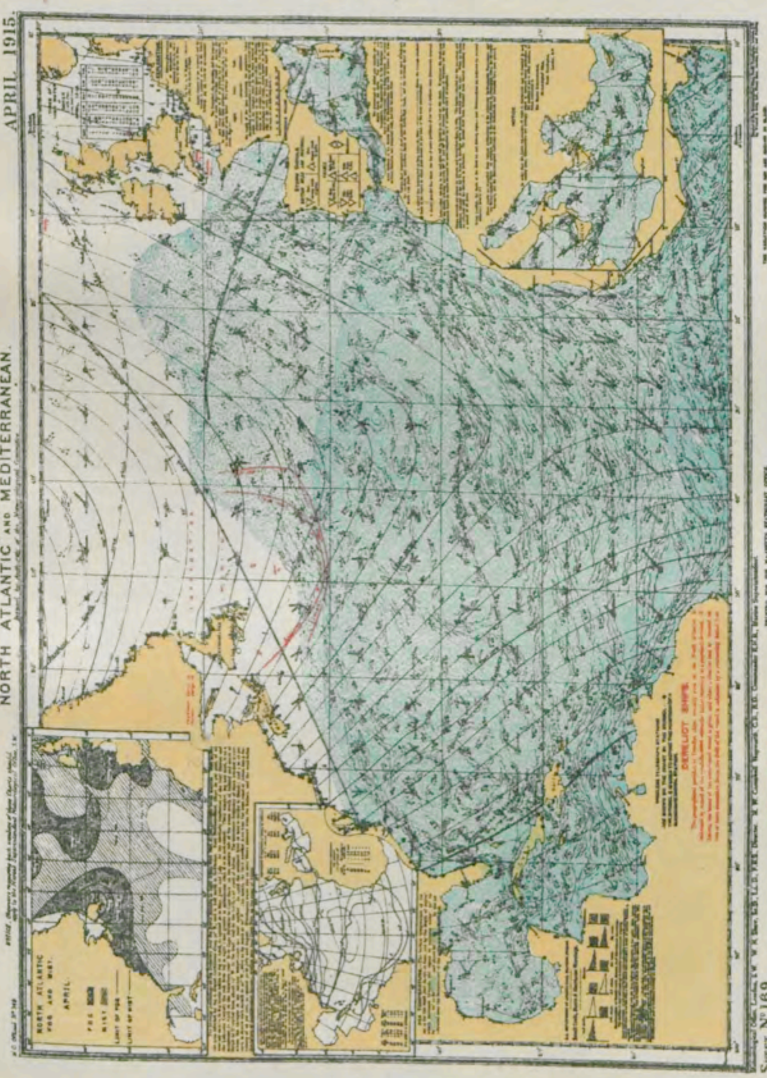
As regards the wind we have given an example of the method of extremes in the list of gusts of hurricane force contained in Chapter I, and the method of frequencies is exemplified by the use of wind roses which have already been employed to summarise the experience of winds at the telegraphic reporting stations on the Coast. Wind roses for the several months are included in the atlas of Meteorological Charts of the British Seas published by the Hydrographic Department and an examination of the information therein contained may be used to confirm and supplement that derived from the study of monthly maps of the distribution of pressure.

4. Sea Temperature.

The method of means or averages can be used with satisfactory results to represent the distribution of the temperature of the sea-water which is a potent influence in determining the occurrence of fog at sea, and which has a remarkable influence upon the climate of the shores by its effect in equalising the temperature of the air in the course of the twenty-four hours and as between summer and winter. The temperature of the water changes slowly and, except quite close to the shore, varies very little in the course of the day and night, very little as a rule from day to day; for example, off the West Coast of Ireland little more than 10° F. from a mean of 49° F. in March to 61° F. in August. On monthly charts the distribution of temperature of the water is well represented by colouring the sea in different depths of tint, the boundary line between two tints representing the average position of an *isotherm of the sea* or line of equal mean temperature. The seas of the Monthly Maps of pressure are coloured in blue tints in this way. The isotherms are marked with the number of degrees of temperature and the reader will do well to notice the gradual change in the position of the isotherms of 50° and 60°. In January the 50°-line crosses the mouth of the Channel in a curve which sweeps from Jersey to Valencia off the south-west of Ireland. In February, in spite of the season, presumably under the influence of prevailing westerly winds which bring up the warmer water of the Atlantic, the line of 50° advances slightly and reaches to the Irish coasts, though the mouth of the English Channel is a little colder, probably on account of cold water running into the shallow seas from the rivers of our Islands and the Continent. By March, the coldest month for sea water, the isotherm of 50° has receded both from Ireland and Brittany, but in April it is back again and the summer warmth begins. In May the 50° line covers the south-western half of our coasts leaving the East Coast of England and the coast of Scotland with water below 50°. By June the line separates off Orkney, Shetland and Faröe as having water below 50°; all the rest is above. In July the 60° isotherm appears on the south-west of the map, though it reaches no British land. In August, however, the water south of a line drawn roughly east and west from the middle west of Ireland to the Wash separates the water above 60° to the southward from that below 60° to the northward. In September the line is back again where it was in July, and in October the 60° line has almost disappeared from the south, while the 50° line begins to show again in the North. By November it has reached our coasts and touches them near Cape Wrath and Flamborough Head, while December shows a condition intermediate between those of April and May, only the south-west coast having water above 50°.

Minor variations of temperature of the water may be traced effectively, some of them due to local peculiarities of the regular movements of the water and others due to the effect of long-continued winds bringing colder or warmer water or causing cold water to reach the surface from below. But these minor variations require great detail of observations and are beyond the scope of the present work. Information bearing upon the subject is given in the Monthly Meteorological Charts of the Atlantic Ocean issued by the Meteorological Office.

REDUCED COPY OF THE FRONT OF THE MONTHLY METEOROLOGICAL CHART OF THE NORTH ATLANTIC AND MEDITERRANEAN FOR APRIL, 1915.



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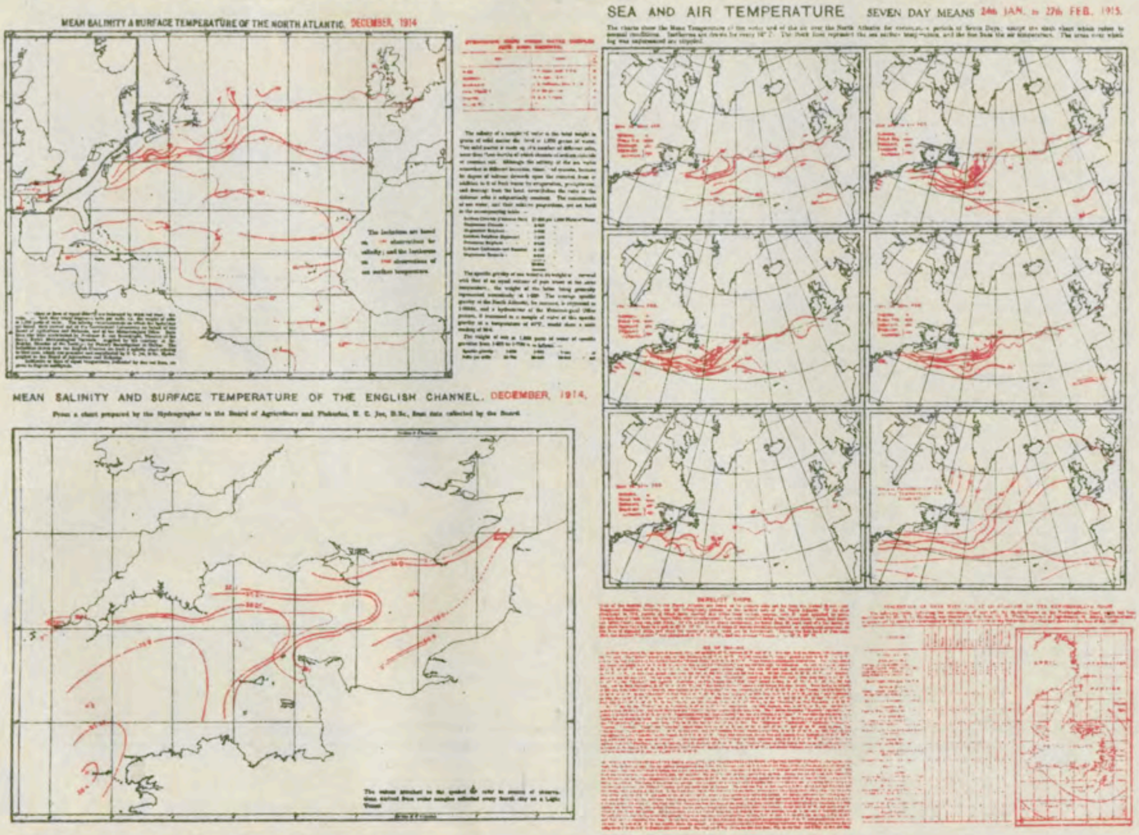
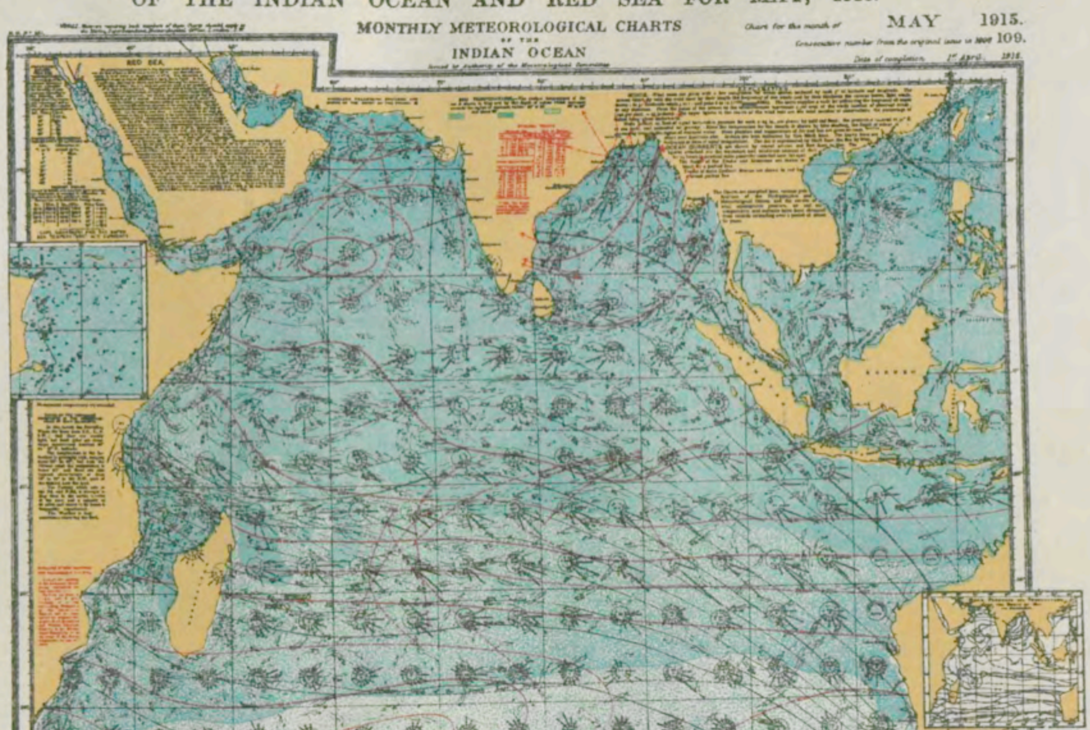


REDUCED COPY OF THE FRONT OF THE MONTHLY METEOROLOGICAL CHART OF THE INDIAN OCEAN AND RED SEA FOR MAY, 1915.



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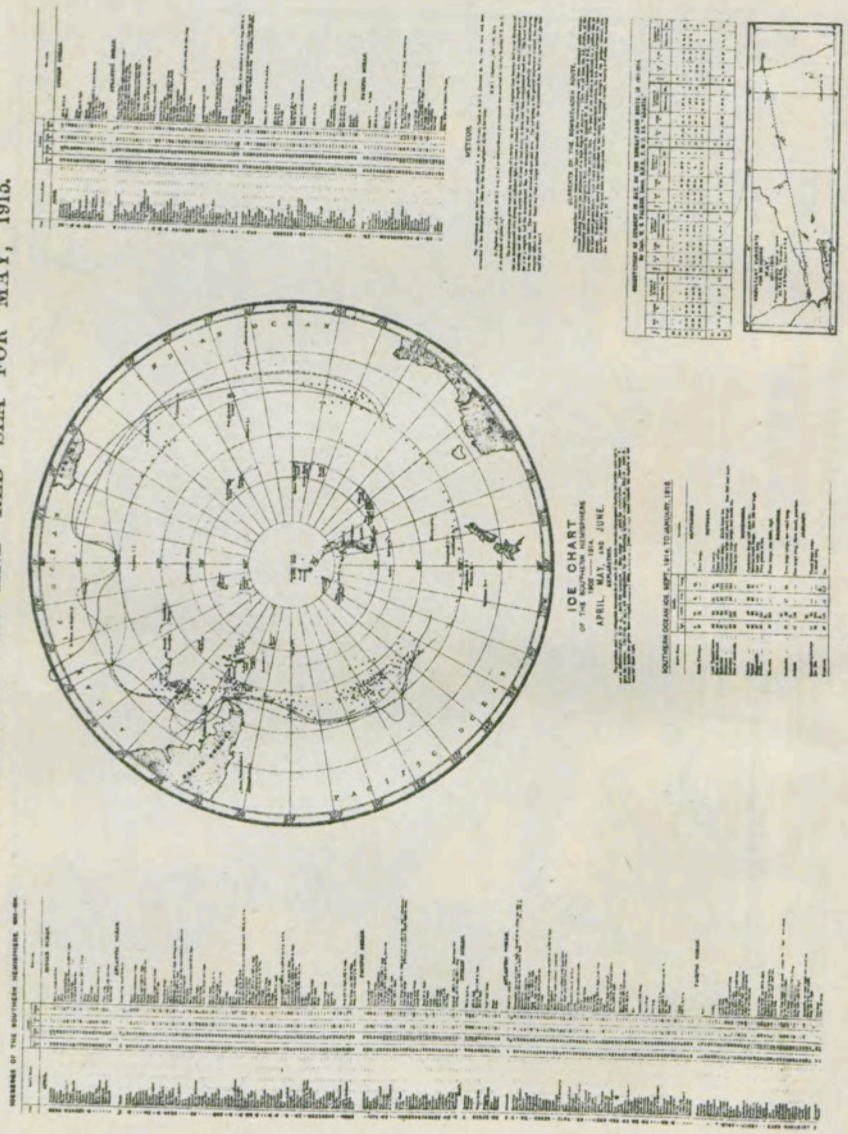


REDUCED COPY OF THE BACK OF THE MONTHLY METEOROLOGICAL CHART OF THE INDIAN OCEAN AND RED SEA FOR MAY, 1915.

5. Air Temperature.

Another subject which can be treated satisfactorily, in large part, by charts of monthly mean values, is the temperature of air over sea. For this purpose observations of temperature have been collected from ships for more than half a century, and the mean temperature of air in the various months of the year for different parts of the sea surface has in that way been ascertained. For the open ocean far from land the method is very appropriate and useful because the change of temperature between day and night, which we recognise as being a very characteristic feature on land, almost entirely disappears. It does not amount to more than one or two degrees and part of that small ascertained difference may be due to the difficulty of getting at the real temperature of the air on a large ship. Consequently the difference of an observed temperature at sea from the charted mean temperature is valuable information showing that the air which surrounds the ship is really warm or cold for the time of year. We may look for the reason for the departure from normal conditions in the direction of the winds or some more subtle cause. But near the coasts the case is quite different, the influence of the land comes in as an additional disturbing cause and the comparative simplicity of the condition of the ocean is masked. Consequently we still confine what we have to say about the temperature of the air to the results of observations inland, which are dealt with in the next chapter.

6. Currents.

Monthly Meteorological Charts of the oceans such as those of the Atlantic Ocean or East Indian Seas published by the Meteorological Office, of which a specimen on a reduced scale is shown in this place, generally include a map of the ascertained information about the currents in the open ocean. The information is not very complete; it is determined by the method of mean values obtained from a large collection of observations from a particular locality belonging to the several months.

We cannot deal in that way with the currents of the narrow seas because the flow of the surface water is so much dependent upon the tides, which belong to a different subject upon which the Hydrographic Department gives the necessary information.

CHAPTER XIII.

SEASONS IN THE BRITISH ISLES.

1. The Annual Variation in the Sun's Altitude at Noon.

The changes in the seasons which are associated with the familiar names Winter, Spring, Summer and Autumn depend upon the variation from day to day of the altitude of the sun in the sky when it crosses the meridian at noon. At the equinoxes, March 21 and September 22, the sun at noon is directly overhead at the Equator; at the summer solstice, June 21, which is midsummer for the Northern Hemisphere, midwinter for the Southern, it passes directly overhead of the places which are on the tropic of Cancer, a parallel of latitude 23½° N. of the Equator, which runs from a point on the West Coast of Africa between the Canary Isles and Cape Verd Islands, through the West Indies, Mexico, Formosa, north of Calcutta, crosses the Indian Ocean near its Northern shores and back to the West Coast of Africa over the Red Sea and the Sahara. At the winter solstice, December 21, midwinter for the Northern Hemisphere, midsummer for the Southern, the sun passes directly overhead of the places which are on the tropic of Capricorn, the parallel of latitude 23½° S. of the Equator which runs from a point on the West Coast of Africa about the centre of what was German South West Africa (now the S.W. African Protectorate), across the Atlantic and Brazil at Rio de Janeiro to a point about 4° S. of the Boundary between Peru and Chile and across the South Pacific to Australia, through the middle of Queensland and on through the southern part of Madagascar and across Africa near the northern part of the Transvaal.

Between the two tropics is the intertropical region of the globe where the sun passes overhead at noon twice in the year and where there are no seasons in the sense in which we understand the term. There may be a regular recurrence of "rainy season" and a "dry season" at definite periods of the year for meteorological reasons, but hardly any trace of summer and winter, spring or autumn as we understand them.

North of the tropic of Cancer in the Northern Hemisphere, or south of the tropic of Capricorn in the Southern, the sun never passes directly overhead because at any place the inclination of the vertical to the plane of the Equator is always greater than the sun's declination (the angle between the planeof the Equator and the sun's rays), which is never greater than 23½°. The greatest possible altitude of the sun at any place depends on the latitude. The British Isles lie almost entirely between latitude 50° and latitude 60°. In the former, latitude 50°, the greatest altitude of the sun at noon is 63½° at midsummer, and its least 16½° at midwinter; while for the latter, latitude 60°, the greatest altitude is 53½° at midsummer and the least only 6½° at midwinter.

2. The Effects of the Variation of the Sun's Altitude.

The most conspicuous effect of the variation of the sun's declination, which governs its altitude at noon, is the change in the length of the day and the night. Speaking generally for the British Isles, at midsummer there is a day for two-thirds of the twenty-four hours and night for one-third, but at midwinter the distribution is just the reverse, two-thirds of the twenty-four hours are night and only one-third day. Between those limits there is a gradual variation with the season. At the equinoxes, making no allowance for twilight or refraction, the day and night are of equal length everywhere. Allowing eight hours for sleep, if we wish to make the most of daylight in the British Isles we must get up in the dark and go to bed in the dark for three-quarters of the year, and get up in the twilight and go to bed in the twilight for the greater part of the rest of it.

The difference in the variation of the length of the day in the northern parts of our Islands as compared with the southern parts is quite appreciable. In Jersey the shortest day has a length of 8 hours and the longest 16 hours, while in Shetland the shortest day has only 5 hours, but in compensation the longest day has 19 hours, with a long twilight at either end.

The length of the day changes very little from day to day when the sun is at the solstices of midwinter and midsummer, but the change is very rapid—about 3 minutes a day—at the time of the equinoxes.

Thus the most conspicuous features of our seasons are the long days of summer, the long nights of winter and the rapid variation of the length of the day and night in spring and autumn.

These changes, which are the most obvious results of the change of the sun's altitude at noon, have indirect effects upon all the elements of weather. When there is no sun the places which are exposed to the clear sky get colder by losing heat by the process of radiation by which heat is transmitted, in the form of waves it is supposed, through the transparent atmosphere into space. Clouds may intervene and temporarily shield the clouded area from loss, but the clouds themselves will be losing heat. Long nights are therefore periods of long cooling without any compensation, but when the sun gets up, by the same process of radiation by which the heat of the earth is lost, a new supply is obtained from the sun's rays. The loss goes on, but that received from the sun helps to make good, and as the sun's rays get more powerful with his increasing altitude, the gain outweighs the loss and the solarised earth gets warmer. Ultimately when the sun's rays are nearly vertical the loss by radiation is only about one-fifth of that received from the sun, so the balance in favour of the earth in the sun is four times what it would lose if there were no sun. (Glossary, p. 330.) So short days mean a short supply of heat, not enough to keep the balance from day to day, and consequently a gradual cooling; but long days mean a large supply of heat, more than enough to keep the balance from day to day, and consequently a gradual warming.

Hence the second notable effect of the seasonal change in the sun's altitude is the general warmth of summer and the general cold of winter. We have noted that in the longer days the supply of heat is greater than the loss and in the shorter days the loss is greater than the supply. It would be fair to conclude from this that if the air above a particular locality could in some way be fenced off and isolated, the general temperature of the locality would go on getting higher from the vernal or spring equinox to the autumnal equinox, and inversely would go on getting colder from the autumnal equinox to the vernal equinox; but such isolation is not at all possible, the warmth of the sun causes motion of the air which carries the heat away and it also causes evaporation of water; in the evaporated water large quantities of heat are stored and carried away by the winds to other parts of the earth. In this way there is a distribution of the sun's heat over the whole earth by which the polar regions profit, so that the northern parts are not so cold as they would be if they were dependent entirely upon the sun's rays which reach them. Hence come two important conclusions:—the first is that the regulation of temperature depends upon the general circulation of the winds over the globe which owe their origin to the local heating caused by the sun and are therefore also liable to seasonal variations, and the second is that the accumulation of warmth at any spot does not go on all through the interval between the vernal and the autumnal equinox, but reaches a limit in our islands about a month after the summer solstice or midsummer; and in like manner the maximum of winter cold is reached about a month after the winter solstice or midwinter. In this respect the condition of things is very similar to what takes place with regard to the heat of the day. In our islands that gradually accumulates from just before dawn to about two o'clock in the afternoon and then declines, although one might suppose it to go on so long as the gain of heat from the sun is larger than the loss to the open sky.

Judging by the results sea-water in the region of our maps goes on accumulating warmth as the summer proceeds and losing it in the winter longer than the air over the land. It reaches its maximum temperature in August and its minimum in March. That is not a matter which surprises us, because water has a great capacity for heat, that is to say, a great deal can be absorbed by it, as compared with other substances, without much increase of temperature; and besides, changes of temperature produce little alteration in the density of water and the movements due to the effect of warming and cooling are much slower than in the case of air.

3. Seasonal Variations.

With the winds as we have already seen in Chapter X, the distribution of pressure must be closely associated, and so it comes about that every one of the meteorological elements, pressure, wind, temperature, humidity, weather including fog, clouds, rainfall, snow, hail and thunderstorms, show a "seasonal variation," that is to say, they are subject to variations depending on the length of the day, the most obvious expression of the sun's declination, and in consequence upon the time of the year.

Some of the variations it would be quite easy to anticipate; we may easily account for its being generally warmer in summer than in winter and we naturally associate snow with that time of the year when the temperature is low, but the seasonal variations of some of the others are surprising. If, as we suppose, the ultimate cause of the winds is the heat of the sun's rays, it might appear reasonable to suppose that the winds would be strongest in summer when the sun's heat is greatest, but it is not so; and so we might suppose summer to be also a rainy time because the greatest amount of evaporation takes place then, and the amount of water vapour in the air is greatest; but in these matters we are liable to be deceived by the indirect influence of the sun's heat in maintaining the general circulation of the atmosphere over the globe, and we must begin the study of the subject with an open mind and the collection of the actual facts for the various regions of the globe.

About rainfall, for example, in South-East England we may note a curious thing: if we take the rainfall for the whole day, October is the month of most rain and March that of least rain, but if we divide the day up into four equal parts from midnight to 6 o'clock, from 6 o'clock to noon, from noon to 6 o'clock, and from 6 o'clock to midnight, we find that for the afternoon summer is distinctly the rainiest quarter with a maximum in July, but between midnight and noon October is distinctly the most rainy, and for the quarter between 6 o'clock and midnight the rainfall of June is the greatest and is double that of May, which is the least for all months. So that in that part of England there are summer rains in the afternoon and winter rains in the forenoon, which together make up a maximum rainfall in autumn and a minimum in March.

In the north of Scotland, on the other hand, and in the west of Ireland, it is the winter even more than the autumn that brings the most rain, the summer is comparatively dry, the spring a little drier still.

4. Climatic Charts.

The facts about the seasonal variation of pressure and wind, as well as that of sea-water, have already been given in Chapter II and Chapter XII, and something has already been said about the comparative incidence of fog in winter and summer in Chapter IV. Further information about the seasonal variation of fog is given in the charts in the Seaman's Handbook, M.O. 215, Plates III-VI. The frequency of occurrence of snow and thunderstorms will be given in tables later on. Temperature of the day and of the night, rainfall and sunshine, are best dealt with by climatological charts of the normals of those elements such as those published in the "Book of Normals" of the Meteorological Office, an appendix to M.O. 214a, of which we have reproduced those for January and July in this chapter. Here we must content ourselves with a very few remarks upon the information which is contained in the maps.

5. The Seasons.

The seasons according to the "farmer's year" are autumn: September, October and November, the season of clearing and preparing; winter: December, January and February, the time for tilling; spring: March, April, May, the time for sowing and the season of early growth; and summer: June, July, August, the season for maturing and harvesting. These seasons do not quite tally with the season of longest night and longest day, because the equinoxes and solstices are on the twenty-first day of the month on which autumn, winter, spring and summer begin. So, for example, the farmer's summer is really three weeks' old when the longest day arrives. Temperature lags behind even more and goes by what is known for some unaccountable reason as the "astronomical season" which begins summer at the longest day, winter at the shortest day. But if the division of the year is to be guided by the temperature we find in counting by months not three months but about five months of possible winter weather, about four months of possible summer weather and about two months of spring, while winter is changing to summer, and one month of autumn, while summer is changing to winter. No one need be surprised at getting winter weather after November begins or summer weather so long as September lasts; and not infrequently winter lasts on until April is well begun, and the summer days of May are sometimes the brightest and warmest of the year.

The arrangement of the temperature-lines on the maps referred to is worth a passing reference. In the winter, if we look at the map of day temperatures, we see the lines run nearly north and south, that is to say the days are warmer to the westward, colder to the eastward, and the nights are very cold inland, warmer on the coasts. And looking at the summer maps, we find the day temperatures just the reverse of the night temperatures in winter, that is to say, high temperatures inland, more moderate temperatures on the coasts. And, on the other hand, the night temperatures in summer are arranged in more or less parallel lines running east and west, so that the nights are warmer in the south, colder in the north.

The best survey of the course of the seasons in the British Isles is given by the table of weekly normals of temperature, rainfall and sunshine which are used regularly in the Meteorological Office for the purposes of comparison with the observations coming in week by week for the Weekly Weather Report, the latter are therefore given here.

CHARTS

SHOWING THE

Normal Distribution over the British Isles

IN

JANUARY AND JULY

OF

Day and Night Temperature

(Reduced to Sea-Level),

Daily Duration of Bright Sunshine

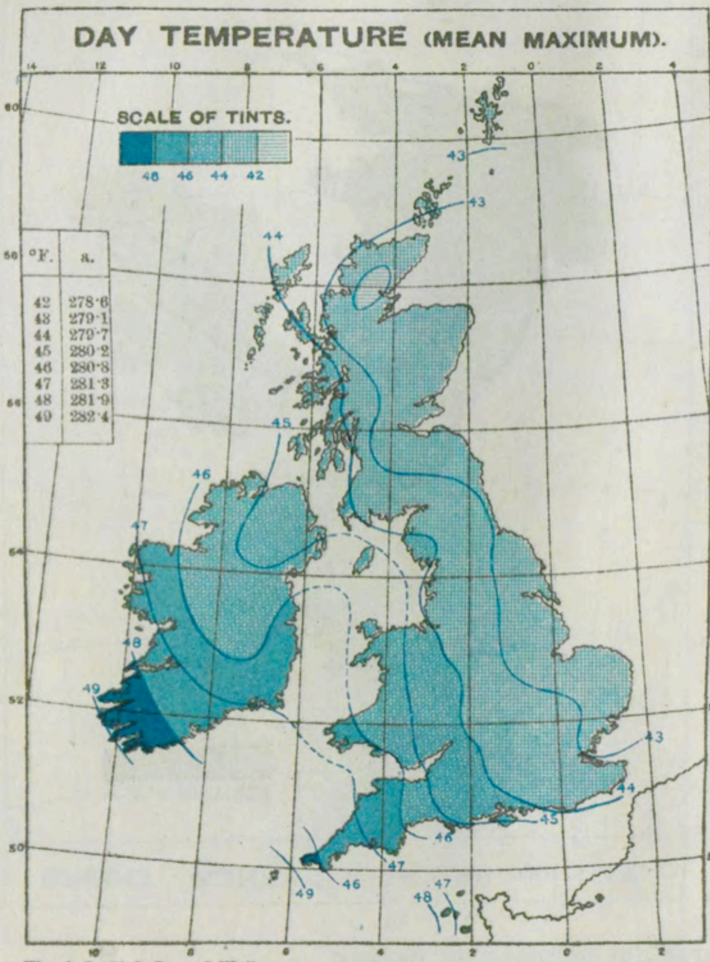
AND

Amount of Rainfall.

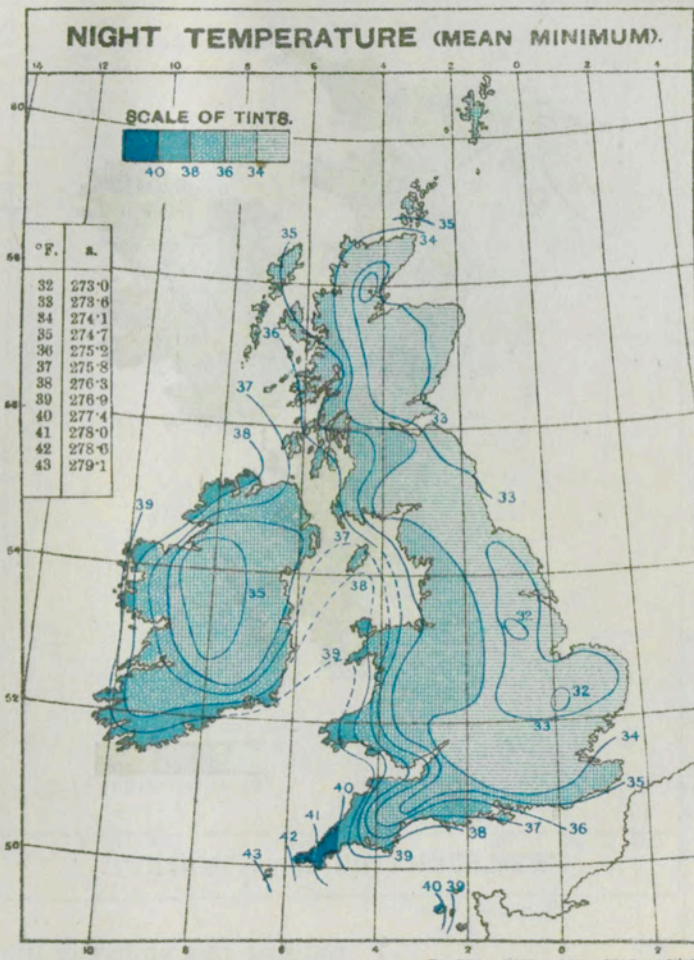
The data upon which the Charts are based are published in M.O. Publication 214a, App. IV. For final maps of the normal distribution of rainfall and sunshine, records from a much larger number of stations are desirable.

Normal Distribution for JANUARY of Air Temperature, reduced to Sea Level.

The isotherms are shown for intervals of 1°F. The corresponding values on the Absolute Scale are given in the inset tables



°F.	a.
42	278·6
43	279·1
44	279·7
45	280·2
46	280·8
47	281·3
48	281·9
49	282·4



°F.	a.
32	273·0
33	273·6
34	274·1
35	274·7
36	275·2
37	275·8
38	276·3
39	276·9
40	277·4
41	278·0
42	278·6
43	279·1

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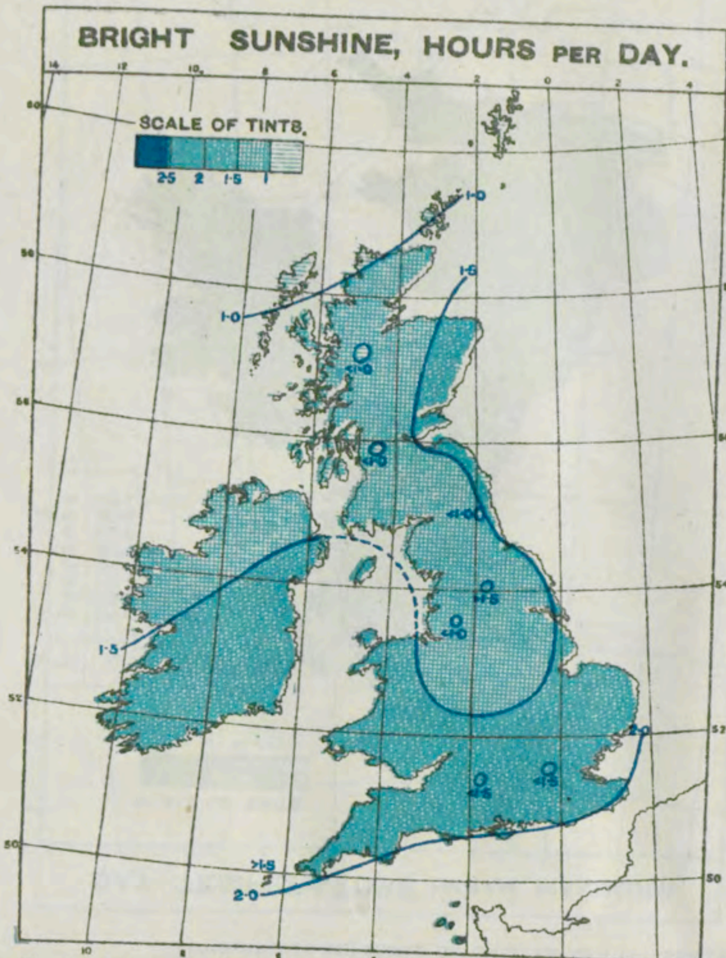
Normal Distribution for JANUARY of Bright Sunshine and Rainfall.



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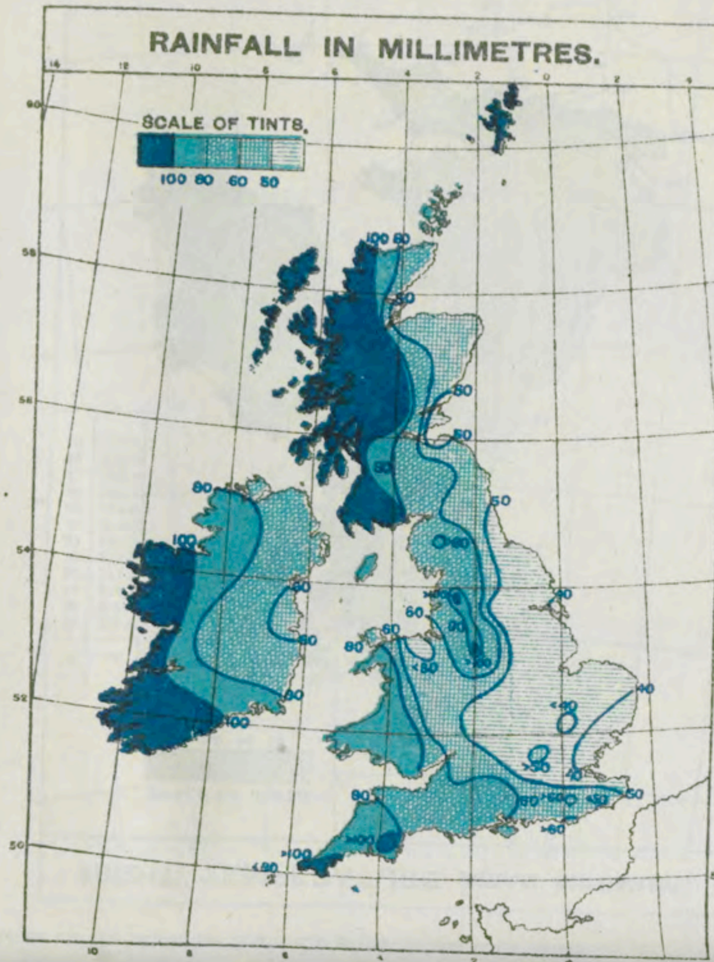

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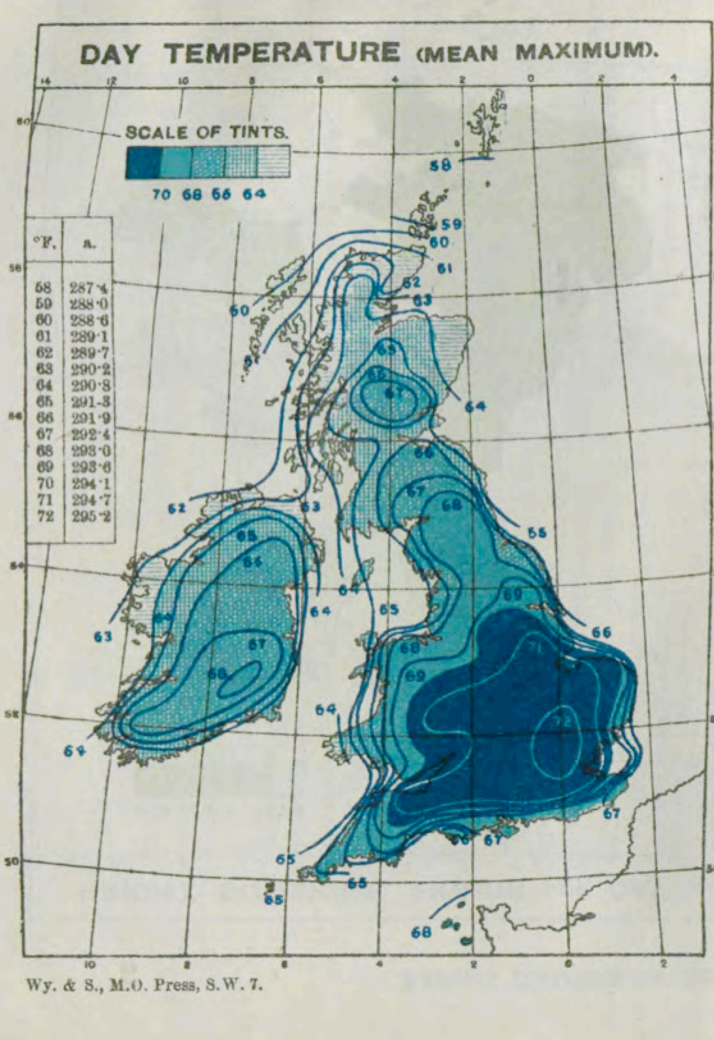
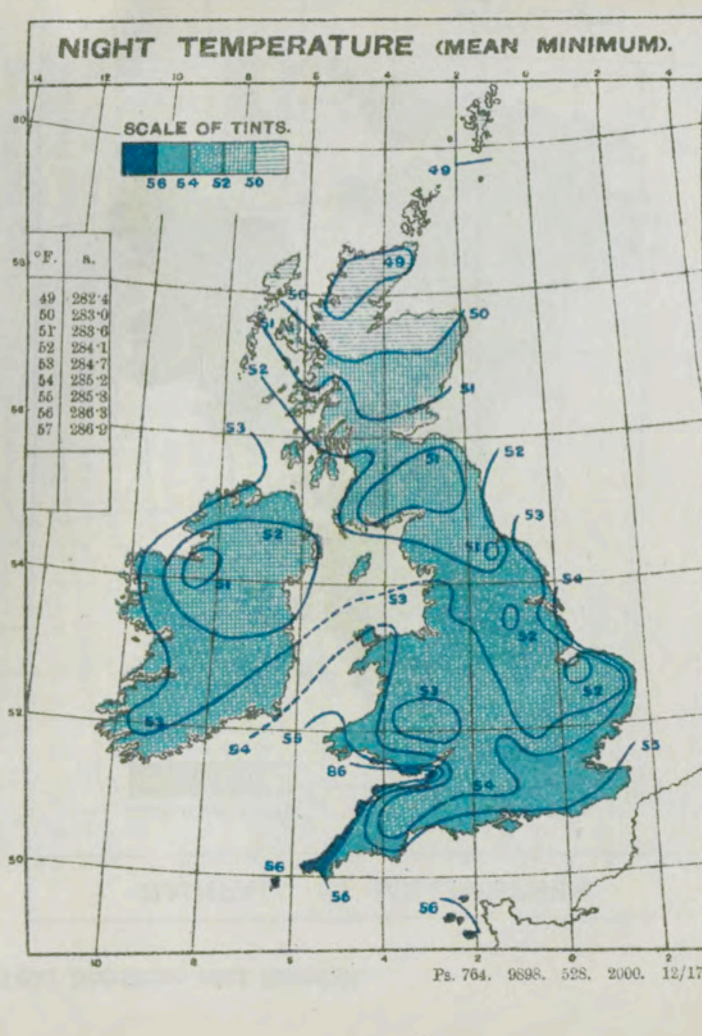
Normal Distribution for JULY of Air Temperature, reduced to Sea Level.

The isotherms are shown for intervals of 1°F. The corresponding values on the Absolute Scale are given in the inset tables.



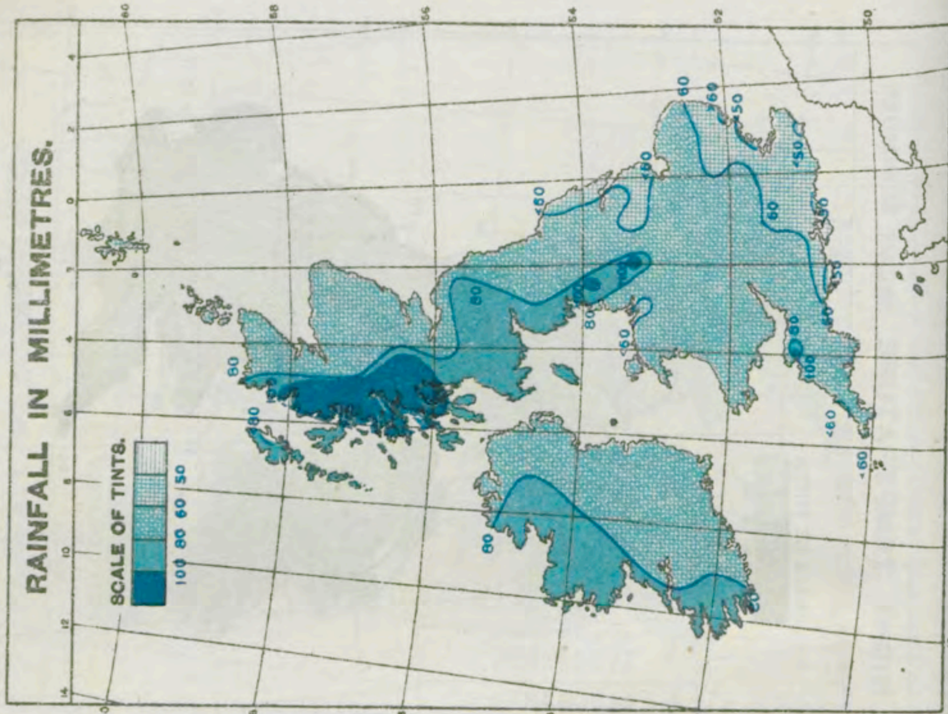
°F.	a.
58	287·4
59	288·0
60	288·6
61	289·1
62	289·7
63	290·2
64	290·8
65	291·3
66	291·9
67	292·4
68	293·0
69	293·6
70	294·1
71	294·7
72	295·2

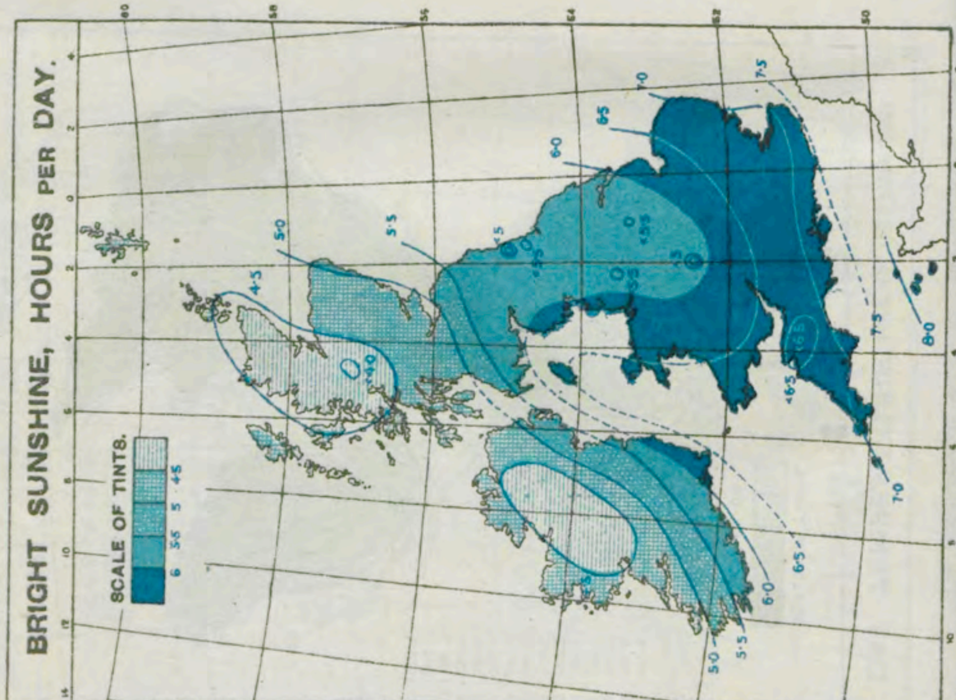
Wy. & S., M.O. Press, S.W. 7.



°F.	a.
49	282·4
50	283·0
51	283·6
52	284·1
53	284·7
54	285·2
55	285·8
56	286·3
57	286·9

Ps. 764. 9898. 528. 2000. 12/17.





Normal Distribution for JULY of Bright Sunshine and Rainfall.

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TABLES ILLUSTRATING THE COURSE OF THE SEASONS IN THE BRITISH ISLES.

For the purpose of following the course of the seasons in the several districts of the British Isles the *Weekly Weather Report* was initiated in the Meteorological Office in 1878 and is still continued on the same lines. An account of the way in which the Report deals with the representation of the climates of the several parts of the Country is given in a paper on the "Seasons in the British Isles from 1878" in Part II. of Vol. 68 of the Journal of the Royal Statistical Society.

In the present work our concern is with the conditions of weather on the Coasts, but the districts into which the Countries are divided for the purpose of the Weekly Weather Report may be so well described for the most part as strips of land bordering on the Coasts that we may usefully take the records embodied in the Report to illustrate the course of the seasons.

The whole of the land is divided into 12 districts as follows:—Scotland, with the islands to the North and West, and the Isle of Man form three districts, numbered 0, 1 and 6. No. 0 is Scotland North, the counties from Inverness northward, No. 1 is Scotland East of Inverness, Argyle and a line to the middle of the English border. No. 6 consists of Argyle and the Western counties of Scotland with the Isle of Man. England has six districts. Going round the Coast from the North-east, No. 2 includes the North-east Counties from the Tweed to the Wash, No. 3 the Eastern Counties from the Wash to the Thames, No. 5 the South-eastern Counties from the Thames to the Wiltshire Avon, No. 8 (England, S.W., and S. Wales) includes all the Coast from Dorset to Cardigan; No. 7 (England, N.W., and N. Wales) the remainder of the Welsh Counties with Cheshire, Lancashire and Cumberland. Within these coastal districts is the one inland district No. 4 called the Midland Counties, which may be retained for the purpose of comparison with the Coastal Districts. Ireland has two districts, North and South, numbered 9 and 10; and No. 11 includes the Scilly Isles and the Channel Islands.

From the results obtained in the Weekly Weather Report we give four Tables of normal values for each week of the year, namely, Mean Temperature, Rainfall, Number of Rain-days, and Daily Average of Sunshine in hours. The weeks are counted from 1 to 52, beginning on the average from January 1 but varying in consequence of the day over 52 weeks in each year between December 29 and January 3. In these tables the weeks are grouped into seasons arranged, as nearly as weeks permit, according to the months December, January and February for winter and so on. To these four tables are added two others representing the frequency of Thunderstorm and Snow promised on p. 139. They are in the form of the chances of occurrence of a day of thunder or a day of snow in the same way as the chances of occurrence of a gale were treated in Chapter II. In these tables particulars are given for individual stations with long records.

TABLE H.—NORMAL TEMPERATURE for each week in the twelve Districts of the British Isles. (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

District. Number from the beginning of the year and normal period of THE WEEK.		0 North and Islands. (Scotland.)	1 Eastern Counties. (Scotland.)	6 West and I. of Man. (Scotland.)	2 North-East Counties. (England and Wales.)	3 Eastern Counties. (England and Wales.)	4 Midland Counties. (England and Wales.)	5 South-East Counties. (England and Wales.)	7 North-West and N. Wales. (England and Wales.)	8 South-West and S. Wales. (England and Wales.)	9 North. (Ireland.)	10 South. (Ireland.)	11 English Channel.
WINTER— No.	Period.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
49	Dec. 3—Dec. 9	39	38	41	40	41	40	42	42	44	41	43	47
50	10 16	39	38	41	40	40	40	42	41	43	42	43	47
51	17 23	39	38	40	39	39	39	40	40	42	41	43	46
52	24 30	39	37	40	39	38	38	40	40	42	41	43	45
	New Year.												
1	Jan. 1—Jan. 7	38	37	39	38	38	38	40	39	41	40	42	45
2	8 14	38	36	39	38	37	37	39	39	40	40	41	44
3	15 21	39	38	40	38	38	38	39	39	41	41	43	44
4	22 28	38	38	40	38	38	38	39	40	41	41	42	44
5	29—Feb. 4	38	37	39	39	39	39	40	40	41	41	42	44
6	Feb. 5 11	38	37	39	38	39	39	40	40	41	41	42	44
7	12 18	38	37	39	39	39	39	40	40	41	40	42	44
8	19 25	38	38	40	39	39	39	40	40	41	41	42	44
9	26—Mar. 4	38	38	39	39	39	39	40	40	41	42	43	44
SPRING—													
10	Mar. 5 11	38	38	40	40	40	40	41	40	41	41	42	44
11	12 18	39	39	41	41	41	41	42	42	43	42	44	45
12	19 25	40	40	41	41	42	41	42	42	43	42	43	45
13	26—Apl. 1	41	40	42	42	43	43	44	43	44	43	45	47
14	Apl. 2 8	42	42	44	43	44	44	46	44	45	44	46	48
15	9 15	42	42	44	44	45	45	46	44	46	45	46	48
16	16 22	43	44	45	45	46	46	47	46	47	46	48	49
17	23 29	44	45	46	46	48	47	49	47	48	47	48	50
18	30—May 6	45	45	47	47	48	48	49	48	49	48	49	51
19	May 7 13	47	47	49	48	50	50	51	49	51	49	51	52
20	14 20	47	48	50	49	51	51	52	51	52	50	52	53
21	21 27	49	50	51	51	53	53	54	52	53	51	53	54
22	28—June 3	51	52	53	53	55	55	56	54	55	53	54	56

TABLE H. (*cont.*)—NORMAL TEMPERATURE for each week in the twelve Districts of the British Isles. (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

District. Number from the beginning of the year and normal period of THE WEEK.		0 North and Islands. (Scotland.)	1 Eastern Counties. (Scotland.)	6 West and I. of Man. (Scotland.)	2 North-East Counties. (England and Wales.)	3 Eastern Counties. (England and Wales.)	4 Midland Counties. (England and Wales.)	5 South-East Counties. (England and Wales.)	7 North-West and N. Wales. (England and Wales.)	8 South-West and S. Wales. (England and Wales.)	9 North. (Ireland.)	10 South. (Ireland.)	11 English Channel.
SUMMER— No.	Period.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
23	June 4—June 10	51	52	54	54	56	56	57	55	56	54	56	57
24	11 17	52	53	55	54	56	56	57	56	56	55	56	57
25	18 24	53	54	56	56	58	57	58	57	57	56	57	58
26	25—July 1	54	56	57	58	60	59	60	58	58	57	58	60
27	July 2 8	55	56	57	58	60	59	60	58	59	57	59	60
28	9 15	54	57	57	59	61	60	61	59	60	57	59	61
29	16 22	55	57	57	59	61	60	62	59	60	57	59	61
30	23 29	55	56	57	58	60	60	61	59	60	57	59	61
31	30—Aug. 5	55	57	58	59	61	60	62	59	60	58	59	62
32	Aug. 6 12	55	57	57	59	61	60	61	59	60	57	59	62
33	13 19	55	56	57	58	60	59	61	59	59	57	59	62
34	20 26	54	56	56	58	60	59	61	58	59	57	58	62
35	27—Sept. 2	53	54	55	57	59	57	60	57	58	55	57	61
AUTUMN—													
36	Sept. 3 9	53	54	55	56	58	57	59	56	58	55	57	61
37	10 16	53	53	54	55	57	56	58	56	57	55	56	60
38	17 23	51	52	53	54	56	54	56	54	56	54	55	59
39	24 30	50	51	52	53	54	53	55	53	54	53	54	58
40	Oct. 1—Oct. 7	49	49	50	51	52	51	53	52	53	51	52	56
41	8 14	47	47	49	49	51	49	52	50	51	49	51	55
42	15 21	46	46	48	48	49	48	51	49	51	49	50	54
43	22 28	44	44	46	46	47	46	49	47	48	46	47	52
44	29—Nov. 4	44	44	46	46	47	46	48	47	48	46	48	52
45	Nov. 5 11	43	43	45	45	45	45	46	46	47	45	47	51
46	12 18	41	40	42	43	43	42	44	43	45	43	45	49
47	19 25	40	40	42	42	42	44	43	43	44	43	44	48
48	26—Dec. 2	40	40	42	41	41	41	43	42	44	43	44	47

TABLE I.—The NORMAL NUMBER OF RAIN-DAYS for each week of the year in the twelve Districts of the British Isles. (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

NOTE.—The numbers show the average number of days out of the seven in the week on which rain has been recorded in the 35 years. To avoid decimal fractions, more than 3 days and less than 3½ are denoted by 3+, more than 3½ and less than 4 by 4—, and so on.

District. / Number from the beginning of the year and normal period of THE WEEK.	0 North and Islands.	1 Eastern Counties.	6 West and I. of Man.	2 North-East Counties.	3 Eastern Counties.	4 Midland Counties.	5 South-East Counties	7 North-West and N. Wales.	8 South-West and S. Wales.	9 North.	10 South.	11 English Channel.
	Scotland.			England and Wales.						Ireland.		
WINTER—												
No. Period.	days	days	days	days	days	days	days	days	days	days	days	days
49 Dec. 3—Dec. 9	6—	5	5+	4+	5—	5—	5+	5	5+	5+	5+	6
50 10 16	6—	4+	5	4	4	4+	5	5	5	5+	5	5+
51 17 23	5	4	4+	4—	4—	3—	4+	4	4	5	4+	5—
52 24 30	5+	4	5	4—	4	4—	5	4	4+	5	5	5
New Year.												
1 Jan. 1—Jan. 7	5	4	5—	4	4+	4	4	4+	4+	5	5	5
2 8 14	5	4	4+	4	4	4	4—	4	4	5—	4+	5—
3 15 21	5—	4	5—	3+	4—	3+	3+	4	4	5—	4+	4+
4 22 28	5+	4	5—	3+	4—	3+	4—	4	4+	5	4+	5—
5 29—Feb. 4	5+	4+	5—	4	4	4	4	5—	4+	5+	5	5—
6 Feb. 5 11	5+	4	5	3+	4—	4—	4—	4	4	5	5—	4+
7 12 18	5	4—	4+	4—	4	3+	4—	4	4	4+	4+	5—
8 19 25	5—	4—	4	3+	3+	3	3	3+	4—	4+	4	4
9 26—Mar. 4	5	4	4	4+	4	4—	4—	4	4	5	4+	4+
SPRING—												
10 Mar. 5 11	5+	4+	4+	4	4	4—	4—	4	4+	5	4+	5—
11 12 18	5	4	4+	3+	3+	3	3	4	4—	5—	4	4—
12 19 25	5	4	4	4	4	3+	3	4—	4—	4+	4	4+
13 26—Apl. 1	5—	4	4	3+	3	3+	3	4—	4—	4+	4	4
14 Apl. 2 8	4	3+	4—	3	3	3	3	3+	3	4	4	3+
15 9 15	5—	4	4—	3+	3+	3+	3	3+	3+	4	4—	3+
16 16 22	4	4—	3+	3	3	3	3	3	3	4	4—	3+
17 23 29	4+	4	4	4	4—	4—	4—	4	4	4+	4+	4
18 30—May 6	5—	4	4	3+	3+	3+	3	4	4	4+	4	4
19 May 7 13	4+	4—	4—	3	3	3	3—	3+	3	4	4—	3
20 14 20	4—	3+	3+	3	3	3	3	3	3	4—	3+	3
21 21 27	4	4—	3+	3	3	3	3	3	3	3+	3+	3
22 28 June 3	4	3	3+	3	3	3	2+	3	3	4—	3+	3

TABLE I (*continued*).—The NORMAL NUMBER OF RAIN-DAYS for each week of the year in the twelve Districts of the British Isles. (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

NOTE.—The numbers show the average number of days out of the seven in the week on which rain has been recorded in the 35 years. To avoid decimal fractions, more than 3 days and less than 3½ are denoted by 3+, more than 3½ and less than 4 by 4—, and so on.

District. / Number from the beginning of the year and normal period of THE WEEK.	0 North and Islands.	1 Eastern Counties.	6 West and I. of Man.	2 North-East Counties.	3 Eastern Counties.	4 Midland Counties.	5 South-East Counties.	7 North-West and N. Wales.	8 South-West and S. Wales.	9 North.	10 South.	11 English Channel.
	Scotland.			England and Wales.						Ireland.		
SUMMER—												
No. Period.	days	days	days	days	days	days	days	days	days	days	days	days
23 June 4—June 10	3	3—	3	3—	3	3	3	3—	3	3	3	3
24 11 17	4	3+	3+	3	3	3	3—	3	3	4—	3	3
25 18 24	4+	4	4	3+	3	3+	3	4—	3+	4+	4	3+
26 25—July 1	4	3+	4	3	2+	3	2+	3+	3	4	3+	3
27 July 2 8	4	4—	3+	3	3	3	3+	3	3	4	3+	3
28 9 15	4	4—	4	3	3	3	4	3+	3+	4+	4	3
29 16 22	5—	4	4	3+	3+	3	4	4—	4—	5	4	3+
30 23 29	4+	4	4	4—	3+	3+	4	4	4—	5—	4	4—
31 30—Aug. 5	5	4—	4	3	3—	3	4	4—	3+	5—	4	3
32 Aug. 6 12	5—	4	4	3+	3	3+	4	4	4—	4+	4	3+
33 13 19	5—	4	4+	4—	3	3+	4+	4	4—	5	4	4—
34 20 26	5—	4	4+	4	4—	3+	4+	4	4	5	4+	4
35 27—Sept. 2	5	4+	4+	4	4—	4—	4+	4	4	5	4	4
AUTUMN—												
36 Sept. 3 9	5—	4—	4—	3+	3+	3	4—	4—	3+	4	4	3+
37 10 16	4+	3+	3+	2+	2+	2+	3+	3	3—	4—	3	3
38 17 23	4	3	3+	3	3	3	3+	3	3	4—	3+	3+
39 24 30	5	4	4	4—	3	3+	4	4	4	5—	4+	4+
40 Oct. 1—Oct. 7	5	4	4	4	4—	4—	4	4	4	4+	4	4+
41 8 14	5	4	4+	4	4	4—	4+	4	4+	[illegible]	4+	4+
42 15 21	5	4	4	4	4	4	4	4	4	4—	4+	5—
43 22 28	5	4+	4	4	4	4	4	4	4+	4+	4+	5
44 29—Nov. 4	5+	5—	5—	4+	4+	4+	5—	5—	5	5	5	5
45 Nov. 5—Nov. 11	5	4+	4+	4	4	4	4+	4+	5—	5	5	5
46 12 18	5	4	4+	4	4+	4	4+	4	4	4+	4+	5
47 19 25	5	4+	4+	4	4	3+	4+	4+	4+	5	4+	5—
48 26—Dec. 2	5+	4	5—	4	4	4	5—	5—	5—	5	5	5

TABLE J.—The NORMAL RAINFALL for each week of the year in the twelve Districts of the British Isles. (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

NOTE.—The rainfall is given in millimetres (mm.). The average general rainfall of the British Isles is 1000 mm. a year. One millimetre is one twenty-fifth of an inch (1 mm. = ·04 in. ; 1 in. = 25 mm.).

District.		0	1	6	2	3	4	5	7	8	9	10	11
Number from the beginning of the year and normal period of THE WEEK.		North and Islands.	Eastern Counties.	West and I. of Man.	North-East Counties.	Eastern Counties.	Midland Counties.	South-East Counties.	North-West and N. Wales.	South-West and S. Wales.	North.	South.	English Channel.
		Scotland.			England and Wales.						Ireland.		
WINTER—		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
No.	Period.												
59	Dec. 3—Dec. 9	42	24	40	17	16	18	24	26	36	27	29	33
40	10 16	38	17	32	13	15	18	19	23	31	23	26	26
51	17 23	28	14	27	11	9	11	13	17	22	21	25	17
52	24 30	32	16	30	11	12	15	16	19	27	22	28	23
	New Year.												
1	Jan. 1—Jan. 7	29	16	28	13	13	15	14	19	23	21	25	20
2	8 14	29	14	23	10	10	11	12	16	19	20	23	18
3	15 21	34	15	26	8	9	10	12	16	18	18	20	14
4	22 28	40	14	26	9	9	12	12	18	21	20	20	16
5	29—Feb. 4	35	15	26	11	11	13	14	18	21	20	20	17
6	Feb. 5 11	39	15	26	9	9	12	14	17	20	20	23	16
7	12 18	31	14	27	9	11	12	14	15	20	16	21	19
8	19 25	24	13	22	8	7	9	10	14	16	17	20	14
9	26—Mar. 4	24	14	21	12	10	12	13	16	20	19	20	16
SPRING—													
10	Mar. 5 11	30	15	24	12	11	12	14	17	21	18	20	19
11	12 18	26	14	18	9	8	9	10	13	14	15	15	11
12	19 25	24	14	20	10	12	11	12	14	17	16	17	15
13	26—Apr. 1	21	13	20	10	8	10	9	15	15	18	19	12
14	Apr. 2 8	20	10	16	7	7	9	8	11	13	14	14	10
15	9 15	22	13	16	10	10	10	9	12	13	13	14	10
16	16 22	17	10	15	8	7	8	8	10	11	14	14	10
17	23 29	17	12	18	11	12	13	15	14	19	15	19	15
18	30—May 6	18	13	20	11	10	12	10	16	16	18	17	13
19	May 7 13	17	13	16	11	10	10	9	12	12	13	14	8
20	14 20	16	14	16	11	11	13	11	13	12	14	14	10
21	21 27	13	12	15	12	11	13	11	11	13	12	13	11
22	28—June 3	15	13	17	11	10	12	10	14	11	15	15	12

TABLE J (*continued*).—The NORMAL RAINFALL for each week of the year in the twelve Districts of the British Isles, (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

NOTE.—The rainfall is given in millimetres (mm.). The average general rainfall of the British Isles is 1000 mm. a year. One millimetre is one twenty-fifth of an inch (1 mm. = ·04 in. ; 1 in. = 25 mm.).

District.		0	1	6	2	3	4	5	7	8	9	10	11
Number from the beginning of the year and normal period of THE WEEK.		North and Islands.	Eastern Counties.	West and I. of Man.	North-East Counties.	Eastern Counties.	Midland Counties.	South-East Counties.	North-West and N. Wales.	South-West and S. Wales.	North.	South.	English Channel.
		Scotland.			England and Wales.						Ireland.		
SUMMER—		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
No.	Period.												
23	June 4—June 10	12	9	12	11	13	14	14	10	14	13	14	13
24	11 17	16	13	17	10	12	10	10	12	14	15	12	8
25	18 24	19	16	22	15	11	14	11	18	15	20	21	12
26	25—July 1	17	12	17	12	11	14	10	16	15	17	15	9
27	July 2 8	19	16	17	13	11	11	11	14	13	14	14	12
28	9 15	17	17	22	13	13	14	11	17	16	18	18	12
29	16 22	23	18	20	15	15	12	14	17	18	20	16	13
30	23 29	17	16	20	18	15	19	15	22	21	20	23	15
31	30—Aug. 5	22	15	21	13	10	13	10	20	17	20	20	12
32	Aug. 6 12	22	18	23	14	12	13	10	18	16	23	22	14
33	13 19	23	19	25	15	12	14	13	19	18	21	21	14
34	20 26	23	17	26	17	15	17	15	24	22	23	25	16
35	27—Sept. 2	32	21	31	15	15	17	17	23	24	23	20	16
AUTUMN—													
36	Sept. 3 9	23	11	21	11	12	12	16	16	16	17	17	14
37	10 16	21	12	17	7	9	8	8	14	12	14	13	11
38	17 23	17	13	20	9	9	10	10	14	14	15	16	12
39	24 30	26	15	26	12	14	13	15	20	21	22	19	19
40	Oct. 1—Oct. 7	32	17	26	15	13	14	18	21	24	20	19	21
41	8 14	29	20	27	18	16	19	19	22	27	22	23	23
42	15 21	25	18	25	18	15	16	19	22	25	20	23	23
43	22 28	28	18	26	18	16	17	22	23	27	22	24	28
44	29—Nov. 4	33	22	32	15	16	18	23	24	29	24	24	24
45	Nov. 5 11	33	20	34	14	13	17	21	23	28	25	27	28
46	12 18	30	18	27	14	15	14	17	20	22	22	23	22
47	19 25	33	16	30	11	11	11	14	20	21	22	21	19
48	26—Dec. 2	39	17	30	16	15	17	17	24	26	22	24	25

TABLE K.—NORMAL DAILY DURATION of SUNSHINE in hours for each week of the year in the Twelve Districts of the British Isles. (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

District. Number from the beginning of the year and normal period of THE WEEK.			0 North and Islands.	1 Eastern Counties.	6 West and I. of Man.	2 North-East Counties.	3 Eastern Counties.	4 Midland Counties.	5 South-East Counties.	7 North-West and N. Wales.	8 South-West and S. Wales.	9 North.	10 South.	11 English Channel.
			Scotland.			England and Wales.						Ireland		
WINTER—			hours.			hours.						hours.		
No.	Period.													
49	Dec. 3—Dec.	9	0·8	1·3	1·1	1·3	1·4	1·3	1·5	1·1	1·6	1·4	1·6	1·9
50	10	16	0·5	1·0	0·9	1·2	1·3	1·2	1·5	1·0	1·4	1·2	1·5	1·8
51	17	23	0·6	0·9	0·9	1·1	1·4	1·1	1·6	1·1	1·4	1·1	1·5	1·7
52	24	30	0·5	0·9	0·8	1·1	1·1	1·0	1·2	0·9	1·2	1·0	1·3	1·7
	New Year.													
1	Jan. 1—Jan.	7	0·7	1·0	1·0	1·0	1·4	1·2	1·5	1·0	1·5	1·3	1·5	1·9
2	8	14	0·8	1·1	1·1	1·2	1·6	1·3	1·6	1·2	1·6	1·2	1·6	1·9
3	15	21	0·8	1·5	1·2	1·4	1·5	1·4	1·5	1·3	1·6	1·4	1·6	2·0
4	22	28	0·9	1·7	1·3	1·6	2·1	1·6	1·9	1·6	1·8	1·6	1·8	2·3
5	29—Feb.	4	1·3	1·9	1·6	2·0	2·4	2·0	2·3	1·7	2·2	1·7	2·0	2·7
6	Feb. 5	11	1·4	2·3	2·0	2·4	2·4	2·1	2·1	2·0	2·2	2·0	2·2	2·6
7	12	18	2·1	2·7	2·2	2·6	2·6	2·4	2·7	2·5	2·7	2·4	2·6	3·4
8	19	25	2·3	2·7	2·2	2·7	3·0	2·6	3·0	2·7	3·1	2·5	2·9	3·5
9	26—Mar	4	2·4	2·8	2·6	2·9	2·9	2·6	3·1	2·8	3·0	2·5	2·9	3·8
SPRING—														
10	Mar. 5	11	2·7	3·1	3·1	3·4	3·3	3·0	3·3	3·0	3·4	3·0	3·7	3·9
11	12	18	2·9	3·5	3·4	4·0	3·8	3·5	3·8	3·4	3·8	3·1	3·4	4·9
12	19	25	3·2	3·9	3·9	4·4	4·3	3·8	4·4	4·0	4·4	3·8	4·2	4·9
13	26—Apr.	1	4·0	4·0	4·3	4·4	4·7	4·2	4·9	4·4	4·8	4·1	4·7	5·8
14	Apr. 2	8	4·1	5·0	5·2	5·5	5·6	5·0	5·6	5·2	5·2	4·8	5·2	6·0
15	9	15	4·3	4·6	4·9	4·9	5·2	4·7	5·3	5·0	5·5	5·0	5·5	6·3
16	16	22	4·9	5·0	5·2	5·2	5·6	5·0	5·7	5·5	5·6	4·8	5·2	6·6
17	23	29	4·6	5·2	5·3	5·3	5·8	5·4	6·0	5·3	5·9	5·0	5·5	6·7
18	30—May	6	5·0	5·1	5·5	5·9	6·4	5·6	6·6	5·7	6·0	5·1	6·6	7·2
19	May 7	13	5·2	5·7	5·8	6·0	6·4	5·8	6·7	6·1	6·6	5·9	6·0	8·1
20	14	20	5·7	5·9	6·5	6·2	6·6	6·0	7·0	6·6	6·9	6·2	6·8	7·7
21	21	27	5·4	5·9	6·5	6·2	6·8	5·8	7·0	6·4	6·6	6 1	6·5	7·8
22	28—June	3	5·5	6·9	6·6	6·3	7·2	6·3	7·4	6·7	6·9	6·1	6·5	8·1

TABLE K (*continued*).—NORMAL DAILY DURATION of SUNSHINE in hours for each week of the year in the Twelve Districts of the British Isles. (Compiled from the tables of the Weekly Weather Report, 1881–1915.)

District. Number from the beginning of the year and normal period of THE WEEK.			0 North and Islands.	1 Eastern Counties.	6 West and I. of Man.	2 North-East Counties.	3 Eastern Counties.	4 Midland Counties.	5 South-East Counties.	7 North-West and N. Wales.	8 South-West and S. Wales.	9 North.	10 South.	11 English Channel.
			Scotland.			England and Wales.						Ireland.		
SUMMER—			hours.			hours.						hours.		
No.	Period.													
23	June 4—June	10	5·6	6·1	6·7	6·1	6·7	6·1	6·9	6·8	6·7	5·9	6·4	7·3
24	11	17	5·7	6·3	6·8	6·4	6·7	6·4	7·1	7·1	7·2	5·9	6·3	8·2
25	18	24	4·7	5·4	6·7	5·9	6·6	5·8	6·9	5·7	6·2	5·3	5·6	7·5
26	25—July	1	4·4	6·1	6·0	6·3	6·3	6·5	7·8	6·3	7·0	4·7	5·5	8·6
27	July 2	8	4·3	5·3	6·2	6·5	7·1	6·5	7·4	6·5	7·1	5·1	5·6	8·3
28	9	15	4·6	5·5	6·2	6·1	6·8	6·0	7·2	6·3	6·5	5·0	5·5	7·9
29	16	22	4·0	5·0	5·5	5·6	6·5	5·6	6·7	5·6	6·1	4·3	4·9	7·5
30	23	29	4·1	4·5	5·1	5·2	5·9	5·2	6·4	5·2	5·7	4·4	4·9	6·9
31	30—Aug.	5	3·6	5·0	5·4	5·9	6·7	5·9	7·0	5·8	6·5	4·3	5·0	8·3
32	Aug. 6	12	3·6	4·8	5·2	5·5	6·1	5·6	6·6	5·4	6·2	4·3	5·2	8·0
33	13	19	4·0	4·7	5·1	5·2	6·3	5·6	6·7	5·3	6·2	4·7	5·2	7·7
34	20	26	3·8	4·6	4·8	4·9	5·6	5·2	6·2	5·0	5·9	4·2	4·8	7·2
35	27—Sept.	2	3·4	4·3	4·4	4·9	5·7	4·9	5·9	4·5	5·4	3·8	4·3	6·4
AUTUMN—														
36	Sept. 3	9	4·0	4·7	5·0	5·0	5·2	4·8	5·7	5·0	5·3	4·3	4·9	6·2
37	10	16	3·9	4·2	4·6	4·9	5·5	4·8	5·8	4·7	5·3	4·0	4·7	6·6
38	17	23	3·1	3·8	3·9	4·3	5·0	4·3	5·3	4·3	4·9	3·8	4·4	6·4
39	24	30	3·1	3·4	3·4	4·1	4·8	4·1	4·9	3·8	4·1	3·3	3·9	5·0
40	Oct. 1—Oct.	7	2·8	3·3	3·1	3·7	3·8	3·3	3·9	3·4	3·8	2·9	3·6	4·4
41	8	14	2·6	2·3	2·8	3·3	3·7	3·1	3·7	3·0	3·4	2·8	3·4	4·4
42	15	21	2·4	2·6	2·5	2·3	3·2	2·9	3·4	2·7	3·3	3·0	3·2	4·1
43	22	28	2·5	2·6	2·5	2·6	2·8	2·5	3·1	2·6	2·9	2·9	3·1	3·4
44	29—Nov.	4	1·7	2·0	2·1	2·2	2·6	2·2	2·8	2·2	2·5	2·4	2·7	3·1
45	Nov. 5	11	1·4	2·0	1·6	2·0	2·5	1·9	2·4	1·7	2·2	2·0	2·2	2·6
46	12	18	1·2	1·7	1·7	1·9	2·2	1·9	2·3	1·9	2·4	2·2	2·5	2·7
47	19	25	1·0	1·6	1·5	1·8	1·8	1·5	1·8	1·6	1·9	1·7	2·0	2·0
48	26—Dec.	2	0·9	1·2	1·1	1·4	1·5	1·4	1·6	1·3	1·7	1·4	1·6	1·8

IMMUNITY FROM THUNDERSTORMS.

TABLE L.—Table of "odds against one" expressing the chance of Thunder being heard on any day in the several months of the year at Coast Stations and Inland Stations.

(Compiled from a table prepared by Mr. F. J. Brodie summarising observations extending as a rule over 35 years.)

——	No. of Years' Obs.	Winter.			Spring.		
		Dec.	Jan.	Feb.	March.	April.	May.
COAST STATIONS :—							
Douglas	35	120	400	160	180	100	24
Donaghadee ...	35	200	500	500	†	120	46
Dublin	35	300	500	120	180	80	34
Southport ...	25	130	300	200	190	49	16
Liverpool	35	100	500	200	110	47	25
Llandudno ...	35	120	300	140	200	90	31
Holyhead	35	180	*	110	110	120	34
St. Ann's Head ...	35	200	300	†	†	170	60
Scilly	35	80	70	60	70	200	80
Falmouth	32	80	100	90	100	190	80
Plymouth	23	140	400	300	90	100	44
Jersey	35	44	46	80	70	43	21
Guernsey	14	42	44	50	70	80	23
Portland Bill ...	35	200	150	300	150	70	38
Ventnor	13	130	80	90	130	100	33
St. Leonards ...	35	140	140	200	200	70	18
Dover	35	150	400	500	110	50	23
Margate	31	*	300	900	190	80	22
Yarmouth... ...	35	200	500	200	90	60	25
Spurn Head ...	35	†	300	300	80	37	15
Shields	35	300	400	500	400	90	41
Leith	35	†	180	500	300	170	70
Dundee	35	†	*	500	300	70	35
Aberdeen	35	400	†	†	†	150	44
Nairn	35	500	*	*	†	500	80
Dunrobin Castle ...	35	*	500	*	*	†	180
Wick	35	200	300	200	†	170	60
Deerness	35	70	44	60	400	200	80
Lerwick	35	400	400	300	†	500	†
Stornoway ...	35	60	80	160	200	300	140
Poltalloch ...	30	43	46	50	100	90	39
Rothesay	35	80	80	80	110	70	22
Malin Head ...	31	300	100	120	160	150	60
Blacksod Point ...	35	100	80	80	140	170	110
Cahirciveen ...	35	60	44	42	70	70	60
Roche's Point ...	35	400	180	120	300	70	46
INLAND STATIONS :—							
Stonyhurst ...	35	80	110	80	50	22	12
Cambridge ...	35	500	†	160	70	31	11
London	35	400	200	160	50	27	15
Southampton ...	35	140	200	120	70	39	23
Glasgow	35	90	120	140	110	100	31
Fort Augustus ...	30	150	130	800	500	200	50
Armagh	32	200	*	300	†	100	44
Birr Castle ...	35	†	200	300	300	70	60

* No case recorded. † Off-chance, about 1,000 to 1 against.

IMMUNITY FROM THUNDERSTORMS.

TABLE L (*continued*).—Table of "odds against one" expressing the chance of Thunder being heard on any day in the several months of the year at Coast Stations and Inland Stations.

(Compiled from a table prepared by Mr. F. J. Brodie summarising observations extending as a rule over 35 years.)

Summer.			Autumn.			Year.	——
June.	July.	Aug.	Sept.	Oct.	Nov.		
							COAST STATIONS :—
17	22	23	38	36	70	42	Douglas.
38	36	41	100	200	300	90	Donaghadee.
18	14	18	70	70	150	44	Dublin.
13	16	13	30	27	100	31	Southport.
15	20	23	39	70	200	42	Liverpool.
25	33	31	50	50	90	60	Llandudno.
25	30	25	50	36	150	50	Holyhead.
70	90	70	70	90	170	110	St. Ann's Head.
70	39	38	90	41	120	60	Scilly.
50	37	42	60	39	160	70	Falmouth.
50	37	70	70	90	300	80	Plymouth.
17	15	21	20	25	50	28	Jersey.
24	18	38	17	32	46	33	Guernsey.
35	27	34	45	80	200	60	Portland Bill.
29	39	36	100	44	130	60	Ventnor.
15	11	16	25	35	130	32	St. Leonards.
16	13	17	32	46	200	36	Dover.
18	12	29	46	300	200	45	Margate.
15	11	12	39	80	300	34	Yarmouth.
10	9	10	33	70	†	26	Spurn Head.
23	14	25	70	90	500	50	Shields.
30	19	24	130	140	†	70	Leith.
21	12	17	50	150	500	46	Dundee.
22	16	19	70	500	500	60	Aberdeen.
31	28	32	300	†	300	100	Nairn.
80	60	90	†	500	300	170	Dunrobin Castle.
41	35	35	70	150	300	90	Wick.
45	50	21	60	70	60	60	Deerness.
300	300	110	500	400	200	300	Lerwick.
100	80	70	200	300	70	110	Stornoway.
31	39	60	80	130	46	50	Poltalloch.
35	31	31	70	70	80	49	Rothesay.
26	43	37	130	200	80	70	Malin Head.
47	60	110	†	180	90	100	Blacksod Point.
43	70	48	90	60	70	60	Cahirciveen.
47	42	28	130	80	150	70	Roche's Point.
							INLAND STATIONS :—
8	8	8	18	26	47	18	Stonyhurst.
10	9	9	27	60	300	23	Cambridge.
12	10	10	27	80	300	26	London.
18	16	17	39	44	150	36	Southampton.
23	20	24	90	180	300	50	Glasgow.
31	70	48	300	900	180	100	Fort Augustus.
25	21	28	160	†	*	71	Armagh.
27	46	36	170	200	300	80	Birr Castle.

* No case recorded. † Off-chance, about 1,000 to 1 against.

SNOW.

TABLE M.—The GREATEST NUMBER OF "SNOW-DAYS" recorded in a single month (generally from 1876-1915), with the year of their occurrence.

	Year.	Autumn. Sept.	Oct.	Nov.	Winter. Dec.	Jan	Feb	Spring. Mar.	Apr.	May.	Summer. June.	July.	Aug.
Douglas 1879-1915	40 '10	0	3 '95, '96	4 '04	8 '09	10 '81, '94	11 '88	14 '83	6 '10	2 '79, '85	0	0	No snow recorded.
Pembroke 1876-1915	16 '86	0	1 '80, '95	3 '04	4 '78, '06, '08.	7 '81, '95	7 '88	7 '03	3 '92	0	0	0	
Scilly 1876-1915	9 '88	0	1 '03	2 '90, '04	3 '78	5 '81	7 '88	6 00	2 '11	1 '06	0	0	
Plymouth 1893-1915	11 '95	0	1 '96	3 '04	4 'C6	8 '95	4 '06, '15	5 '00, '09	3 '11	2 '94	0	0	
Dungeness 1885-1915	26 '88, '95	0	2 '95	3 '90	6 '86	14 '£5	10 '88	9 '91, '09	6 '11	1 '97, '09, '14.	0	0	
Yarmouth 1876-1915	40 '79	1 '93	2 '87	6 '79	10 '78	13 '95	13 '79 '89	12 '78, '88	6 '83, '03	4 '02	0	0	
N. Shields 1876-1915	62 '79	1 '93	5 '80	9 '79	17 '78	15 '97.	15 '79	13 '83. '92	7 '03	3 '77, '79	1 '79	0	
Leith 1876-1915	38 '86	1 '93	3 '80	4 '80 '98	10 '78. '01	12 '86	12 '88	11 '88, '09	6 '03	5 '02	0	0	
Aberdeen 1876-1915	61 '95	1 '87, '88, '93.	8 '95	8 '80, '93, '10, '15.	19 '78	20 '95	15 '76, '86	20 '83	11 '03	5 '02	0	0	
Wick 1876-1915	43 '86	1 ,'88, '93.	5 '05	8 '03, '12	12 '86	12 '86	9 '89, '98, 'C5.	13 '83	9 '06	3 '15	1 '06	1 '06	
Shetland 1876-1905	45 '86	1 '93	3 '95, '05	6 '93	10 '86, '87	12 '86	12 '89	16 '83	10 '03	5 '77	0	1 '81	
Malin Head 1886-1915	25 '10	0	1 '95, 96	4 '04	6 '09	8 '81, '94	12 '88	9 '83	6 '10	1 '79, '85	0	0	
Valencia 1869-1900 1906-1915	13 '92, '95	0	1 '70, '71, '95.	3 '70	7 '78	7 '81, '95	5 '95, '00	6 '09	2 '87, '92, '08.	1 '83, '87	0	0	
Roche's Pt. 1876-1915	17 '92	0	2 '96	1 '78, '80, '86, '98, '04, '12.	4 '06	6 '94	8 '95	5 '92	3 '76, '92	2 '08	0	0	

TABLE N.—The NORMAL CHANCES OF SNOW. The odds against one about snow on any day of the several months of the year.

	Normal No. of "Snow-days" in the Year.	Autumn. Sept.	Oct.	Nov.	Winter. Dec.	Jan.	Feb.	Spring. Mar.	Apr.	May.	Summer. June	July.	Aug.
Douglas	1	—	76	20	13	7	7	6	22	154	—	—	No snow recorded
Pembroke	6	—	*	150	33	25	24	17	99	—	—	—	
Scilly	5	—	*	150	100	51	39	33	150	*	—	—	
Plymouth	4	—	—	100	43	30	27	30	100	309	—	—	
Dungeness	12	—	154	74	17	9	11	9	32	*	—	—	
Yarmouth	17	*	309	37	12	6½	6½	6	17	76	—	—	
N. Shields	2	*	51	15	7	5	4½	5	16	76	*	—	
Leith	14	°	154	29	10	7	7	6	22	61	—	—	
Aberdeen	34	300	21	11	5	4	3	3	11	33	—	—	
Wick	25	*	25	13	7	6	6	5	9	33	*	*	
Shetland	22	—	38	17	8	9	6	5	10	38	—	*	
Malin Head	11	—	309	42	13	13	11	10	49	309	—	—	
Valencia	4	—	309	150	38	33	27	30	97	°	—	—	
Roches Pt.	6	—	*	150	43	25	19	25	59	*	—	—	

* An off-chance; not more than once in 20 years; about 1,000 to 1 against.

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