THE WEATHER MAP

AND

GLOSSARY.

225.

~~D. R.~~

~~A24~~

R. Lane

Authors Copy

Captain C. J. P. Cave.

from C. J. P. Cave (one of the authors) to A. L. Cave.
March 1920.

~~from Tony Warre~~
~~to G. Currie~~

M.O. 225 i.

METEOROLOGICAL OFFICE.

[Confidential.]

THE WEATHER MAP.

AN INTRODUCTION TO MODERN METEOROLOGY,

to which is appended a Meteorological Glossary drawn up by the Meteorological Office for the use of the Military Services.

PART I.—INTRODUCTION.

Issued by the Authority of the Meteorological Committee.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE
BY DARLING AND SON, LIMITED, BACON STREET, E.

1916.

TABLE OF CONTENTS.

*** Words printed in capitals in the text are explained in the Glossary.

THE WEATHER MAP.

AN INTRODUCTION TO MODERN METEOROLOGY.

Meteorology and Military Operations.

The reason why those who are concerned in military operations wish to know something of modern METEOROLOGY is that the weather is one of the elements of success in the conduct of the operations whether they are on sea or land or in the air. The weather is, indeed, a consideration in nearly all human occupations, not less in military operations than in others.

When the weather is the only obstacle to success it may be possible by suitable precautions to get the better of it. A large part of the energy and enterprise of civilisation has been devoted to making the ordinary course of life independent of the weather. The dweller in a large city is enabled by the arts of the builder and engineer, by the makers of clothes, and by the organisation of the means of locomotion, to live in comfort and to carry on his business whatever the weather may be. Occasionally a snowstorm or a thunderstorm or a long drought may overpower the precautions that have been taken, but in our climate that seldom happens. And so far as locomotion is concerned, if the weather is the only enemy to be considered, it may be possible, for example, to improve the construction of aircraft so that a pilot may go out in all weathers and reach his objective without serious misadventure; and, at the worst, the journey can be postponed and the pilot can take shelter till the weather

(6623—12.) Wt. 50046—8406. 1250. 2/16. D & S. G. 3.

improves. But when other considerations enter into the question and it becomes a matter of working not only against the weather but against time, as in the case of provisioning cities or large bodies of men or in the case of a steamer of the mercantile marine, where time is money, or in that of a farmer whose crops are lost if favourable opportunities are missed, or if it be against some other enemy as in military operations, when it is often a question of now or never, or indeed whenever it is a matter of competition, rivalry or antagonism, the influence of favourable or unfavourable weather is far too great to be disregarded.

It is needless to give an historical account of the influence of weather in war, the following episode in a Syrian Campaign will suffice.

> "Now they that were in the tower sent messengers unto Tryphon to the end that he should hasten his coming unto them by the wilderness, and send them victuals.
>
> "Wherefore Tryphon made ready all his horsemen to come that night; but there fell a very great snow, by reason whereof he came not."

An expedition that is just within the range of an airman's powers with a favourable wind is outside the range if the wind and its changes turn out to be adverse. By working with a liberal factor of safety and by limiting the scope of operations according to the range for the most unfavourable conditions, we may secure safety but fail to command success; whereas to take advantage of the variation of wind at different levels, or of a spell of fine weather long enough for the enterprise in hand but not longer is worth trying for. Nor is the airman in the air the only consideration. A good deal of damage may be done to his belongings on land while he is in the air.

It is easy to say that, in spite of the progress of meteorology within the last sixty years, we are still unable to predict the weather with actual certainty, and that as you cannot be certain it is just as well not to think about it at all. But although our knowledge is imperfect it is not therefore advisable to disregard what we know. It comes to this: that, in spite of the remaining uncertainty, of two sides which are otherwise equally balanced, the one that is more skilful in making use of a knowledge of the weather has the best prospect of winning in any operations in which they are opposed.

Weather Records and Climate.

There is, as a matter of fact, a great deal of information about the weather which is not dependent on prediction and which is still emphatically useful. For example, the organised study of weather over the sea enables a seaman to know, simply from the recorded experience of others, what kind of weather may be expected in any particular locality, what is the greatest heat or the greatest cold, the nature of the **PREVAILING WINDS**, the **FREQUENCY** of fog, the frequency of rainfall and of snowfall, and so on. All these things can be obtained simply by organising the recorded experience of others. And a similar statement is true for those who are responsible for military operations of all kinds. What is the extent of the cold of winter or the heat of summer against which precautions must be taken in the interest of the men or their engines? At what times of the year will the roads be dry either from being frozen or from dry weather? What are the prevailing winds? and so on. These are the matters which are summed up in a statement of **CLIMATE**. To neglect the experience of the past in such matters is hardly permissible and is, in fact, never really contemplated by any responsible person. But even responsible persons are apt to think that the recollections of their own experience in situations which they think are similar are a sufficient guide. That is, unfortunately, not always good enough in modern conditions, when particulars of the climate of any locality can generally be had for the asking. In all such matters a written record on an organised plan is much better than the most voluminous personal recollections.

The first business, therefore, of the military meteorologist is to put together in the most telling form all the available records of TEMPERATURE, WIND and WEATHER for the neighbourhood of the operations. With a little practice one finds that a map is the best form in which to give the information and the month is a convenient division of the year for the purpose. So the first exercise in military meteorology is to read a monthly meteorological or CLIMATIC CHART.

THE NECESSITY FOR FORECASTS OF WEATHER.

But CLIMATOLOGICAL information is only preliminary; the anticipation of weather to come remains an imperative necessity. It always has been so. No one can undertake military operations on sea or land or in the air without forming the best idea possible to him of what the weather is going to be. The monthly climatic chart will tell him what it may be but not what it will be. Even if he decides to ask no opinion and chance it, he only means that in his own opinion the probability of really prohibitive weather is so small that it may be disregarded. It is quite unusual to find anyone who is willing simply to chance it. Very few persons are

content to act upon their own opinion about coming changes of weather. If the weather happens to be favourable when the decision has to be taken they may assume that it will go on being so; if not, as from time immemorial, they will appeal to all sorts of signs in the sky, or in the behaviour of birds, or to the opinion of some weatherwise person who is personified in meteorological history as the "SHEPHERD OF BANBURY."

The WEATHER MAXIMS for sailors which one finds in handbooks on navigation are very good examples of the results of experience, and in an emergency anything must be clutched at to help towards a decision one way or the other. Forecast of some sort everyone must have. It is desirable to have the best that can be got, and according to the experience of all civilised nations the best is to be obtained by FORECASTS based upon the methods developed by modern meteorology.

MODERN METEOROLOGY THE WORK OF AN ORGANISATION, NOT OF AN INDIVIDUAL.

It is necessary to point out that modern meteorology means a meteorological organisation, not merely an individual meteorological expert. 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 Meteorologist at Head Quarters.

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 without the materials for constructing a map, though he may have a barometer and other instruments at hand, 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, but they are not forecasts in the modern sense.

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 are who are unaccustomed to its use.

Consequently, in making provision for expert meteorological assistance in the conduct of military operations it is not enough to have an expert meteorologist on the spot; he must have the material for making a weather map or have access to the organisation which makes one day by day and indicates to him the conclusions to be drawn from it, which can only be transmitted in technical

language, and are therefore not necessarily understood by those who are unfamiliar with scientific terms.

A modern 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.

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 was under his charge.

The reports which he received included readings of the BAROMETER and THERMOMETER and notes of WIND and WEATHER. 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.

First, what does it include and how is it to be described? It includes the STATE OF THE SKY, whether it is clear, cloudy or overcast, the state of the air, whether it is clear, MISTY or FOGGY, whether RAIN, HAIL or SNOW is falling, and if so, whether it is steady rain, showers or drizzle; whether there is THUNDER or LIGHTNING; and, as reports are always sent in the early morning, to these we may add whether there is DEW or HOAR FROST.

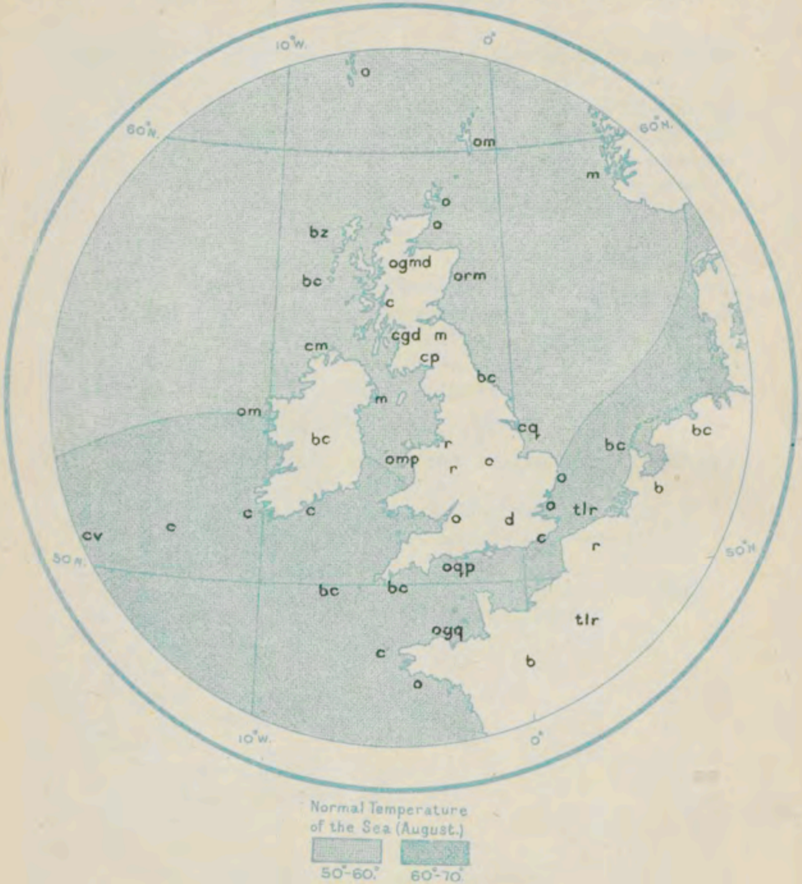
These, with the wind and the vagaries of temperature, are the matters which affect everyone and which the science of meteorology has to account for and explain. In these matters the observer is simply the reporter of the local conditions; he is not required to offer any explanation of his own.

To make the reports concise and for the sake of uniformity the observer learns to 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).
bc sky partly cloudy (one half covered).
c generally cloudy (three quarters covered).
d drizzle, or fine rain.
e wet air without rain falling, a copious deposit of water on trees, buildings or rigging.
f fog.
g gloom.
h hail.
l lightning.
m mist.
o overcast sky.
p passing showers.
q squalls.
r rain.
rs sleet, *i.e.*, rain and snow together.
s snow.

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



For the explanation of the letters *see* p. 10.

Wy. & S., M.O. Press, S.W. 55308. Wt. 50046. 8466. 1300. 2/16.

- t thunder.
- u ugly, threatening sky.
- v unusual visibility. The horizon or distant hills unusually clear.
- w dew.
- x hoar frost.
- z dust haze; the turbid atmosphere of dry weather.

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. These results are 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*) 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.

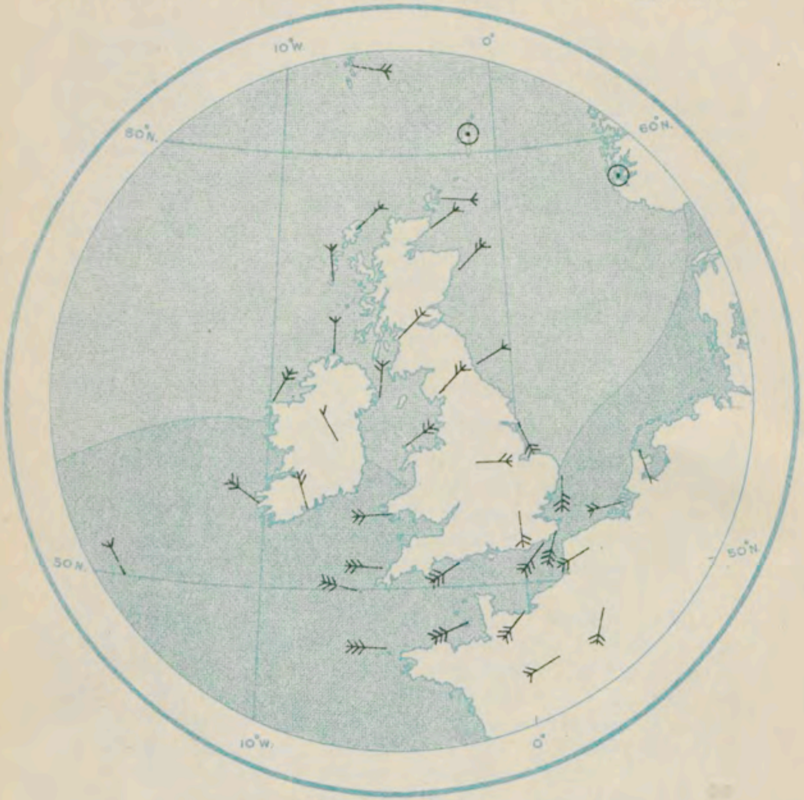
For the purpose of mapping, it is more convenient to use symbols which identify more clearly the localities referred to instead of letters for the state of the sky, so we will give later the symbols used to represent the weather in the Daily Weather Report of the Meteorological Office and a copy of the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

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.

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. He may not have any special instrument for measuring the direction and force of the wind, but 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. If necessary he must find out the points of the compass and in that case he must recollect that the mariner's compass or MAGNETIC NEEDLE does not point exactly North but about 18 degrees to the west of it in these Islands. 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 pp. 14–15.

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



Normal Temperature of the Sea (August.)

50°-60° 60°-70°

⊙ Calm. force 1.

force 3 force 4.

Wy. & S., M.O. Press, S.W 55306. Wt. 506/46. 8466. 1300. 2/16.

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 (*Plate II*). 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.

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.

THE BEAUFORT SCALE. See p. 12.

Velocities at about 30 feet above ground. Statute Miles per Hour.	Velocities at about 30 feet above ground. Metres per Second.	Beaufort Number.	Description of Wind. General.	Description of Wind. At Sea.	Description of Wind. On Land.
Less than 1	Less than 0·3	0	Calm ...	... ...	Calm ; smoke rises vertically.
1 to 3	0·3 to 1·5	1	Light air ...	Light breeze.	Direction of wind shown by smoke drift, but not by wind vanes.
4 to 7	1·6 to 3·3	2	Slight breeze		Wind felt on face ; leaves rustle ; ordinary vane moved by wind.
8 to 12	3·4 to 5·4	3	Gentle breeze		Leaves and small twigs in constant motion ; wind extends light flag.
13 to 18	5·5 to 8·0	4	Moderate breeze.	Moderate breeze.	Raises dust and loose paper ; small branches are moved.
19 to 24	8·1 to 10·7	5	Fresh breeze		Small trees in leaf begin to sway ; crested wavelets form on inland waters.
25 to 31	10·8 to 13·8	6	Strong breeze	Strong wind.	Large branches in motion ; whistling heard in telegraph wires ; umbrellas used with difficulty.
32 to 38	13·9 to 17·1	7	Moderate gale (*High Wind.*)		Whole trees in motion ; inconvenience felt when walking against wind.
39 to 46	17·2 to 20·7	8	Fresh Gale ... (*Gale.*)	Gale forces.	Breaks twigs off trees ; generally impedes progress.
47 to 54	20·8 to 24·4	9	Strong gale...		Slight structural damage occurs (chimney-pots and slates removed).
55 to 63	24·5 to 28·4	10	Whole gale...	Storm forces.	Seldom experienced inland ; trees uprooted ; considerable structural damage occurs.
64 to 75	28·5 to 33·5	11	Storm ...		Very rarely experienced ; accompanied by widespread damage.
Above 75	33·6 or above.	12	Hurricane ...	Hurricane	

In the regions which are within our reach, up to 10 kilometres, 6 miles or 30,000 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.

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 30,000 ft. 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.

TEMPERATURE AND HUMIDITY.

We have already seen that in mapping the weather we can note and chart the distribution of clear weather, cloud, rain, etc., and that these are confined to the TROPOSPHERE the lowest ten kilometres. There are some physical properties of the atmosphere, its TEMPERATURE and PRESSURE, which are 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. 62° 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., 285° A. and if it gets above 72° F., 295° A. 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. 283° A. or above 70° F. 294° A. 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. 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.

Plate 3 shows the distribution of temperature over the British Isles at 6 p.m. on the 2nd August, 1915.

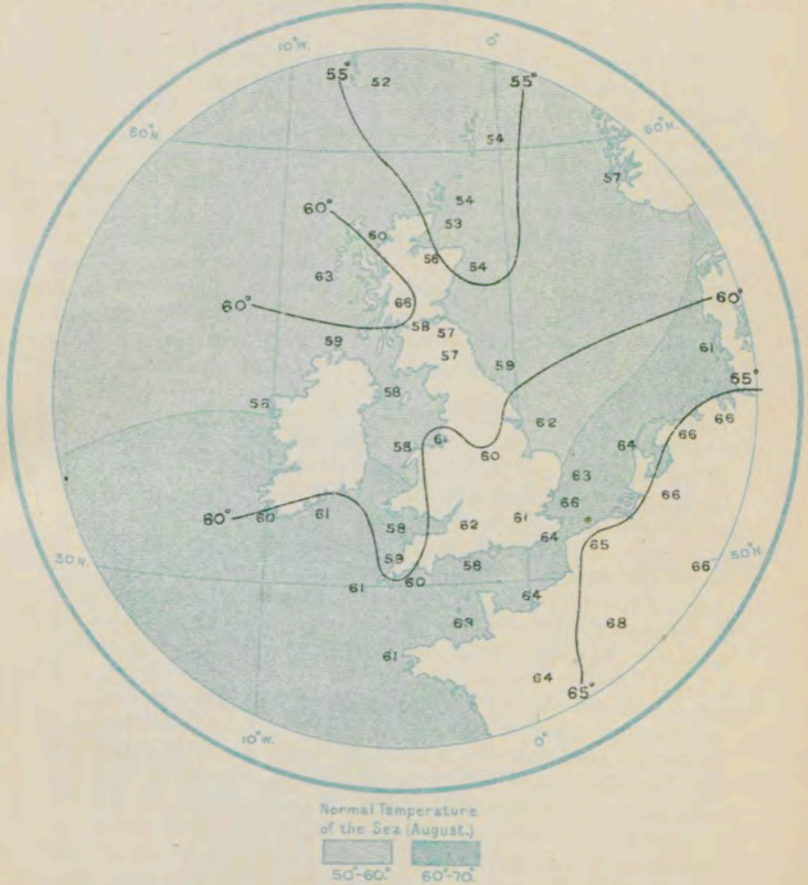
Lines are drawn separating the figures above 65 from those below, those above 60 from those below, and the figures above 55 from those below. Some figures remain isolated.

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 ($1\frac{3}{4}$ kilometres above the surface), or 1,000 feet above the top of Ben Nevis, 2,000 feet above the Welsh 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

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

Plate III *to face p. 20*

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



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

Wy. & S., M O. Press, S.W.
55306. Wt. 50046. 8468. 1300. 2 16.

July at 7,500 feet, 2·5 kilometres. At a height of 27,000 feet MERCURY freezes, and the seasonal variation then 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, see pp. 40, 41.

The coincidence of the 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.

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 bring 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 think about, 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 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 distribution and for this purpose we regard the pressure as uniform. 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. So if we take the pressure of the atmosphere as $14\frac{3}{4}$ lb. per square inch or a kilogramme per square centimetre, we soon see that the forces which we have to deal with when atmospheric pressure is concerned are enormous. A kilogramme per square centimetre gives a ton over 1000 square centimetres, about a square foot, and therefore nine tons to the square yard.

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

The Barometer.

For measuring the pressure of the atmosphere we use a BAROMETER. 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 clock-work. The apparatus is then called a BAROGRAPH or ANEROIDOGRAPH and the record is called a BAROGRAM.

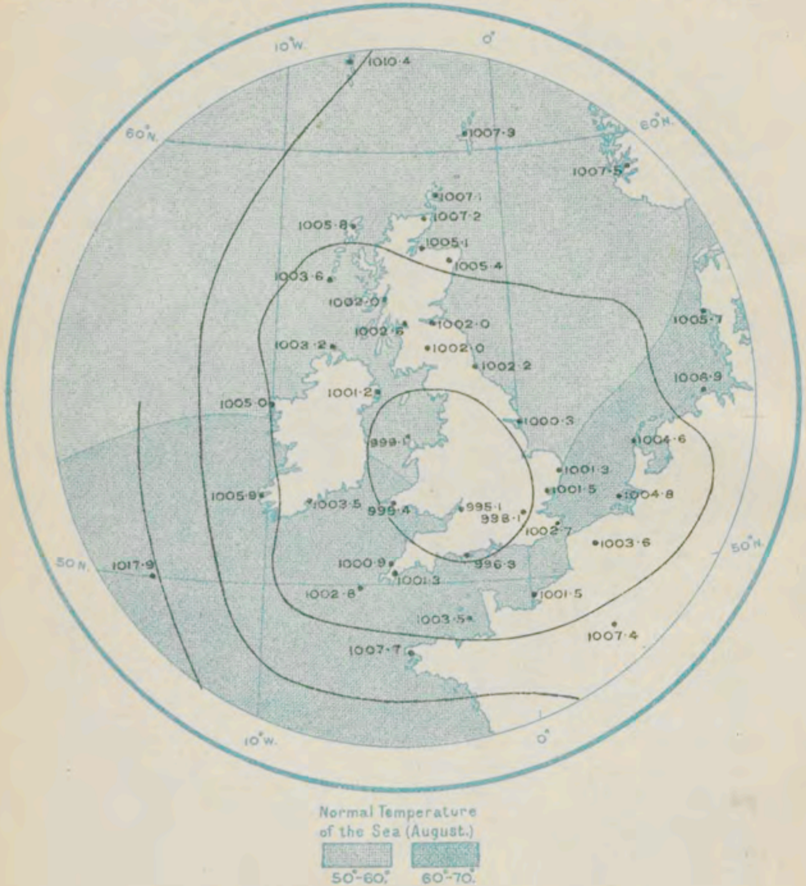
The aneroid barometer gives the best idea of what is meant by the pressure of the atmosphere, because it is the crushing, or more strictly, the compression of a box which is nearly exhausted of air and has a flexible lid, and its recovery, which move the index. In the mercury barometer it is not the 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 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 30 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 (indicated by the abbreviation 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 fall to 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

Conversion Table for Pressure.

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

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



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

Wy. & S., M.O. Press, S.W. 55306. Wt. 50046. 8466. 1300. 2/16.

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.

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.

Plate 4 represents the distribution of pressure shown by isobars and figures; when we have made a single Plate No. 5 combining all the information which has been given separately in Charts 1, 2, 3, and 4, except temperature which the reader is requested to transfer for himself from Chart 3, we have completed the weather map and the remainder of the task of modern meteorology is to understand the lessons that it teaches.

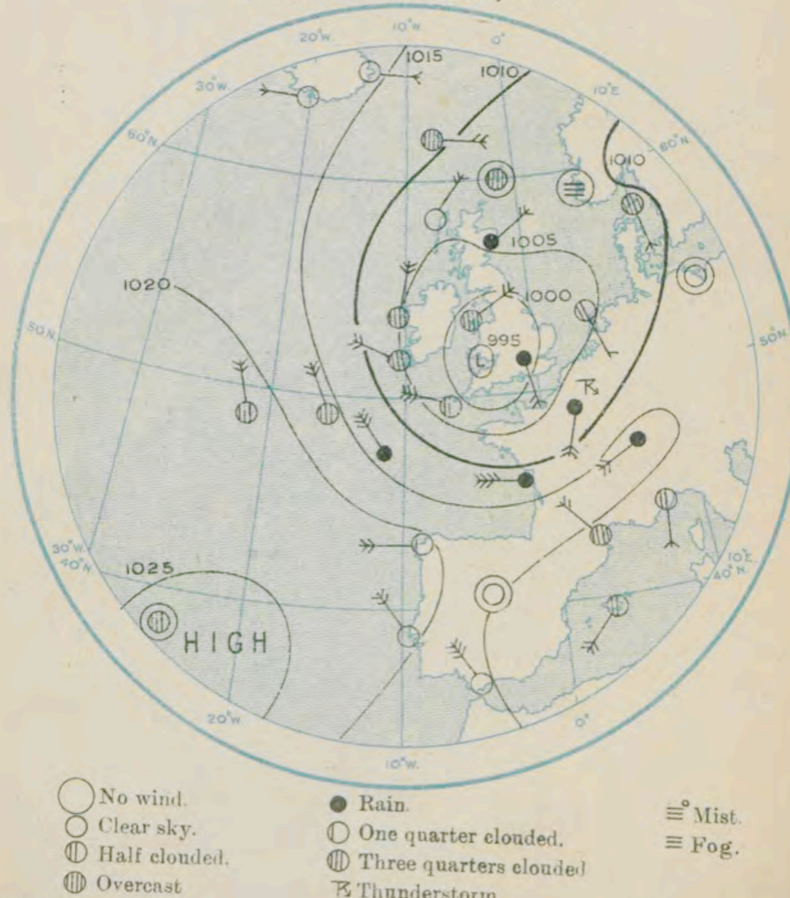
Lessons from Weather Maps.

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 particularly 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**

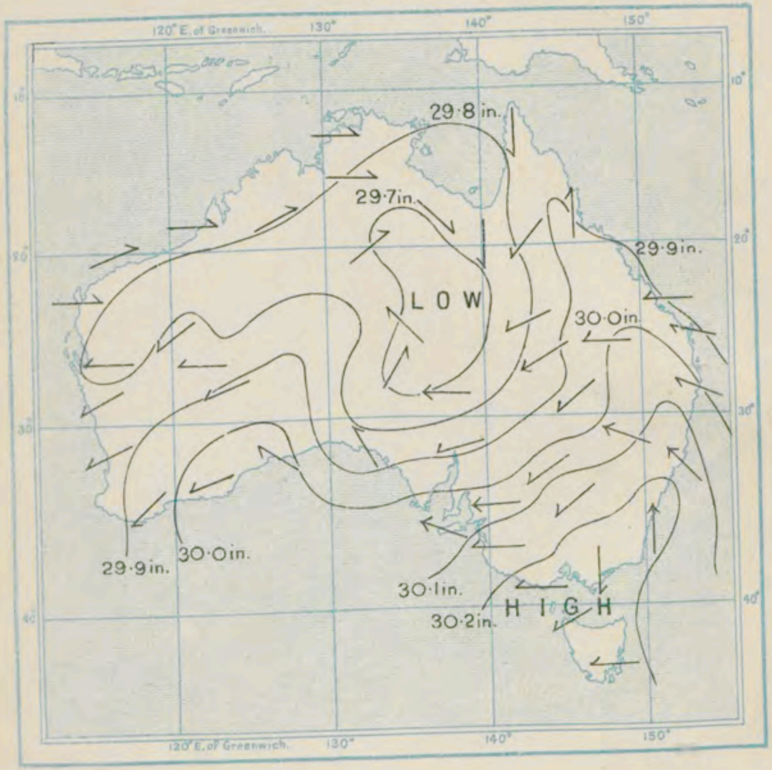
DISTRIBUTION OF WEATHER, WIND, AND PRESSURE, 6 P.M. 2nd AUGUST, 1915.



Wy. & S., M.O. Press, S.W
55306. Wt. 50046. 8/66. 1300. 2/16.

Plate VI. to face p. 27.

CHART OF BAROMETRIC PRESSURE AND WIND, AUSTRALIA, 12th FEBRUARY, 1913.



⟵ light to moderate breeze.
⟵ fresh breeze.

Wy. & S., M.O. Press, S.W. 55306. Wt. 50046. 8468. 1300. 2/16

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. Plate VI is a reproduction of one 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 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 through 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 forms 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 it is in the high pressure belt, 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.

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 mostly of a negative order.

It will be remembered that the old barometers were engraved with certain legends against certain heights, viz.: 28·0 in. stormy, 28·5 in. much rain, 29·0 in. rain, 29·5 in. change, 30·0 in. fair, 30·5 in. set fair, 31·0 in. 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; it generally 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 29·0 in. 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 it 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 as modified by the sunshine.

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, 1915, if numbered consecutively from the beginning, should be No. 19,762. 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 that 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 Plate V. 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.

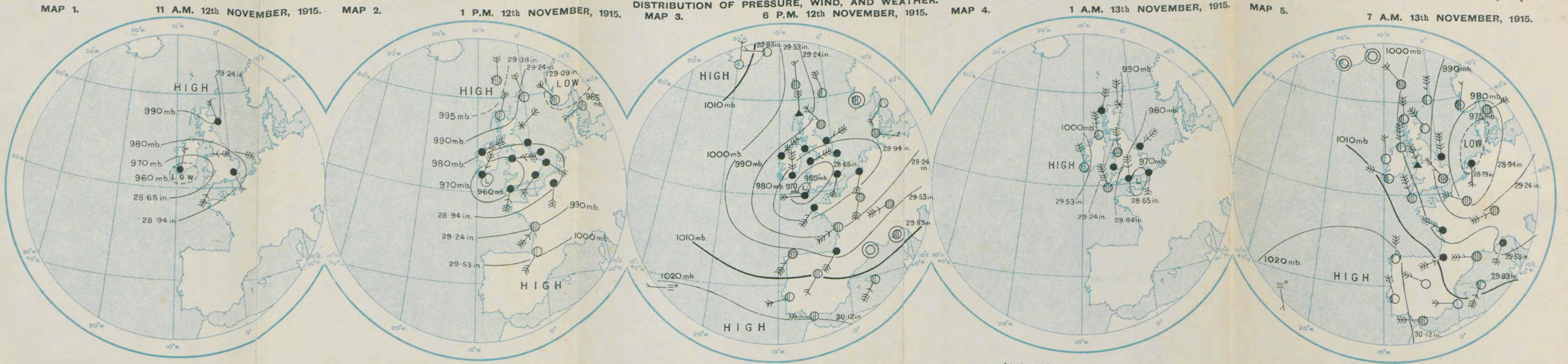
On the other hand, there is on the same map a region of high pressure reaching a maximum at the Azores marked HIGH, within the isobar of 1025mb., with which perhaps the isobar of 1020mb. should be grouped to form an example of "an ANTICYCLONE" or "a HIGH." That particular map is sufficiently described 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°, separating warm air from cold, runs through the centre of the low following an irregular course from W.S.W. to E.N.E. 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 anti-cyclones. Every map has its own peculiarity. Every

TRAVELLING DEPRESSION OF NOVEMBER 12-13, 1915.

DISTRIBUTION OF PRESSURE, WIND, AND WEATHER.



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. ⊤ thunder. ⊼ thunderstorm.

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

55306. Wt. 50046. 8466. 1300. 2/16.

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 or 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 one example of the travelling of a depression, that which gave the great gales of November 12 and 13 of 1915. The succession of maps for these two days which are reproduced here 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. (See Plate VIII. facing page 44.)

Cyclones and anticyclones 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 are given under the heading Isobars in the Glossary which follows.

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.

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 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 W.S.W. to E.N.E. 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, 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.

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.

The Upper Air.

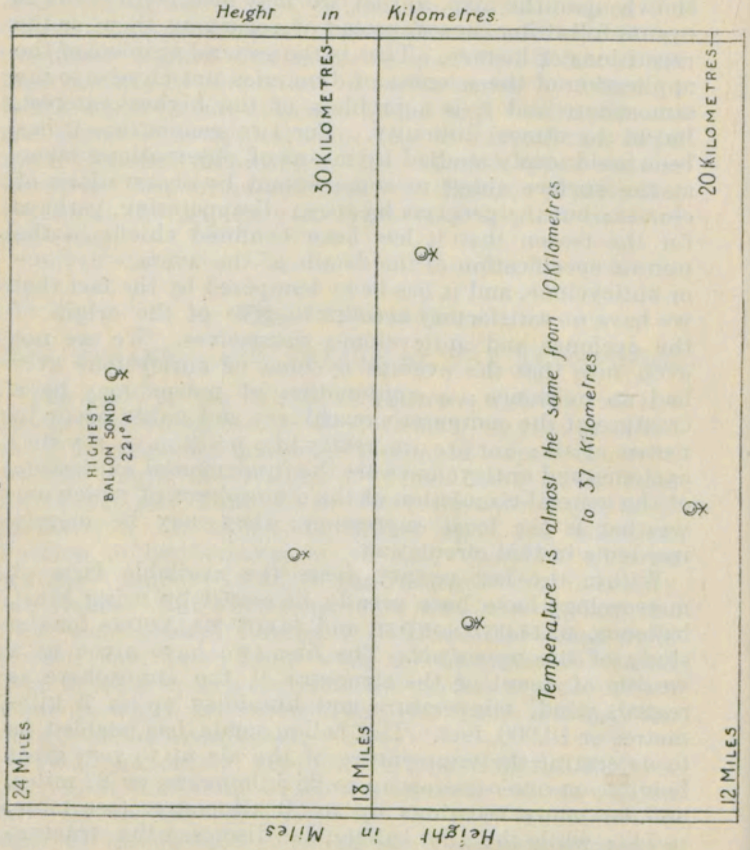
The Dynamics and Physics of the Atmosphere.

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.

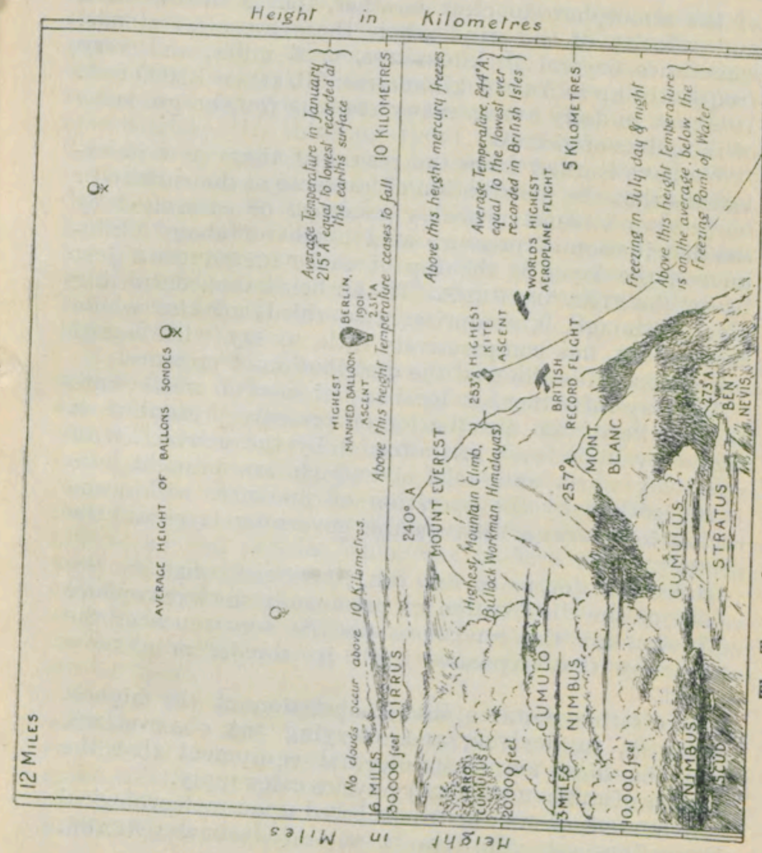
We do not, on that account, consider that the comprehension of the events which the observer records will be for ever beyond our reach; we are only stimulated to ascertain the physical causes of the variations which are

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 observations 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 table, p. 74); while the pilot balloon has disclosed the structure



The Stratosphere from 12 to 24 miles.



The Troposphere and lower region of the Stratosphere.

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 the 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.

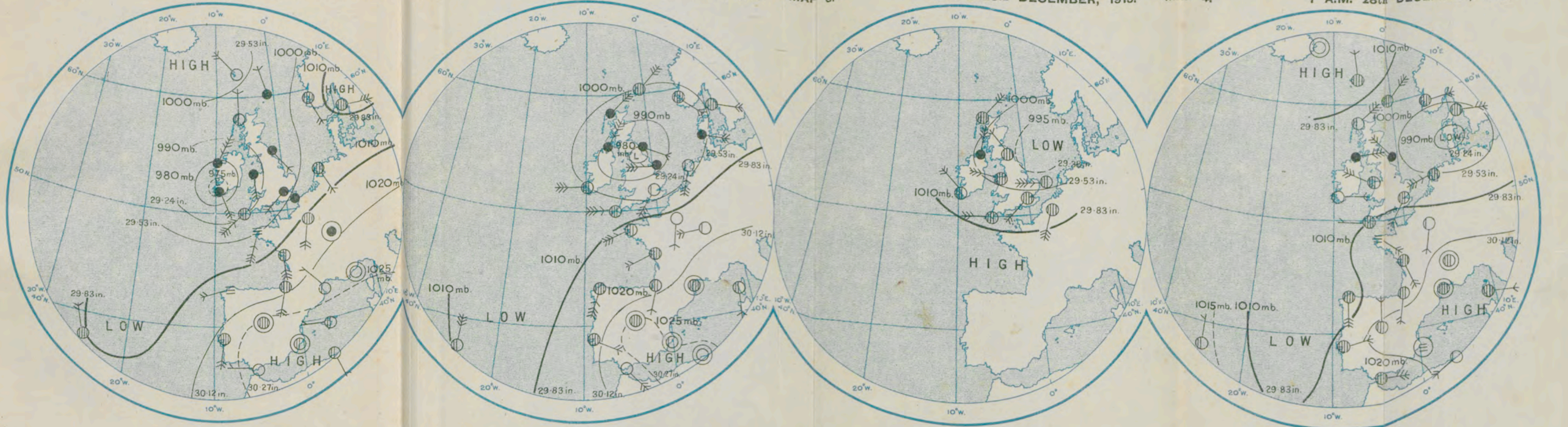
But, at the same time, everybody is interested in the weather and most men have at some time or other acquired a store of knowledge which will enable them to make intelligent use of the information which modern meteorology provides. Much of it is concerned with unfamiliar words, some of it with unfamiliar ideas. It seems therefore desirable to follow the plan of the dictionary or the encyclopædia and 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, forming a meteorological Glossary.

To this Glossary have been assigned such meteorological details as the different forms and groups of isobars, the classification of clouds, the frequency of gales and fogs, and articles on other topics of interest concerning weather and climate which might perhaps have been looked for in this introduction. There appear also 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.

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. Ꝁ thunderstorm.

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

55306. Wt. 30046. 8466. 1300. 2/16.

METEOROLOGICAL GLOSSARY.

LIST OF TITLES.

For the entries marked * short articles are given.

Those marked (I) are also referred to in the Introduction.

Absolute Extremes.
Absolute Temperature.*
Adiabatic.*
Aërology.
Air. (I)
Air-Meter.
Airship-Weather.*
Altimeter.
Alto-cumulus.
Alto-stratus.
Anemobiagraph.
Anemogram.
Anemograph.
Anemometer.
Anemoscope.
Aneroid barometer.
Aneroidograph.
Anticyclone. (I)
Aqueous-vapour.*
Atmosphere. (I)
Aurora.
Autumn.
Average.
Azimuth.

Backing.
Ballon sonde.*
Bar.
Barogram.
Barograph.*
Barometer.*
Barometric Tendency.
Beaufort Scale. (I)
Beaufort Scale. Table of Equivalents in Force and Velocity.
Beaufort Notation. (I)
Blizzard.*
Bora.
Breeze.
Brontometer.
Buys Ballot's Law. (I)

C.G.S.
Calm.
Celsius.
Centibar.
Centigrade.
Centimetre.
Cirro-cumulus.
Cirro-stratus.
Cirrus.
Climate.
Climatic Chart.
Climatology.
Cloud.*
Col.
Compass.*
Components.
Condensation. (See Aqueous Vapour.)
Conduction.*
Convection.*
Corona.
Correction.
Correlation.
Cosecant.
Cosine.
Cotangent.
Cumulo-stratus.
Cumulus.
Cyclone. (I)

Damp Air.
Density.*
Depression.*
Dew.
Dewpoint.
Diathermancy.
Diffusion.
Diurnal.*
Drought.
Dry Air.
Dry Bulb.
Dynamics.
Dynamic Cooling. (See Adiabatic.)

Eddy.
Electrometer.
Energy.*
Entropy.*
Equator.
Equatorial.*
Equilibrium.
Equinox.
Error.*
Evaporation.
Extremes.

Fahrenheit.
Fall.
Fluid.*
Fog.*
Föhn.
Forecast.*
Freezing.
Frequency.*
Friction.*
Frost.

Gale.*
Gas.
Glacier.
Glazed Frost.
Gradient.*
Gradient Wind.
Gramme.
Gust.*
Gustiness.

Hail.
Halo.
Haze.
Heat.
High. (I)
Hoar Frost.
Horizontal.
Humidity. (I)
Hurricane.*
Hydrometer.
Hydrosphere.
Hyetograph.
Hygrograph.
Hygrometer.
Hypsometer.

Iceberg.
Index.
Index Error.
Insolation.
Inversion.
Ion.
Ionisation.
Iridescence.
Isabnormals.
Isanomalies.
Iso.
Isobars.*
Isohels.
Isohyets.
Isopleths.*
Isotherm.
Isothermal.*

Khamsin.
Kilometre.

Lake.
Land Breeze.
Lenticular.
Level.*
Lightning.
Line Squall.*
Liquid.
Low. (I)
Lunar.

Mackerel Sky.
Magnetic Needle.
Mammato-Cumulus.

Mares' Tails.
Maximum.
Mean.
Meniscus.
Mercury.
Meteor.
Meteorograph.
Meteorology.
Metre.
Microbarograph.
Millibar.*
Millimetre.
Minimum.
Mirage.
Mist.
Mistral.
Mock Sun.
Monsoon.
Moon.*

Nadir.
Nephoscope.
Nimbus.
Normal.*

Observer.
Ombrometer.
Orientation
Ozone.

Paraselenae.
Parhelia.
Pentad.
Periodical.
Persistence.*
Persistent Rains.
Phases of the Moon.
Phenology.
Pilot balloon.
Pluviograph.
Pluviometer.
Pocky cloud.
Polar.*
Pole.
Potential.
Potential Temperature.
Pressure.
Prevailing winds.*
Probability.*
Prognostics.*
Psychrometer.
Pumping.
Pyrheliometer.

Radiation.
Rain.
Rainbow.
Rainday.
Rainfall.
Raingauge.
Réaumur.
Reduction.*
Registering balloon.*
Relative humidity.
Ridge.

Rime.
River.

Saturation.
Screen.
Scud.
Sea-breeze.
Sea-level.
Seasons.
Secant.
Secondary.
Seismograph.
Serein.
Shepherd of Banbury.*
Silver Thaw.
Sine.*
Sine curve.
Sleet.
Snow.
Snow crystals.
Solarisation.
Solstice.
Spring.
Squall.
Stability.
Standard Time.
State of the Sky.
Statics.
Station.*
Statoscope.
Storm.
Strato-cumulus.
Stratosphere.
Stratus.
Summer.
Sun.
Sunshine.
Sundogs.
Sun Pillar.
Synoptic chart.

Tangent.
Temperature. (I)
Temperature Gradient.*
Tension of Vapour.
Terrestrial.
Thermogram.
Thermograph.
Thermometer.
Thunder.
Thunderstorm.*
Time.
Tornado.*
Trajectory.
Tramontana.
Transparency.
Tropic.
Tropical.
Troposphere.
Trough.
Type.*
Typhoon.

V-Shaped depression.
Vapour Pressure.

M.O. 225 ii.

METEOROLOGICAL OFFICE.

[Confidential.]

METEOROLOGICAL GLOSSARY

Drawn up by the Meteorological Office,
for the use of

THE MILITARY SERVICES.

Issued by the Authority of the Meteorological Committee.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE
BY DARLING AND SON, LIMITED, BACON STREET, E.

1916.