OFFICIAL COPY.

Official No. 177.

THE RELATION

BETWEEN

PRESSURE, TEMPERATURE, AND AIR CIRCULATION OVER THE SOUTH ATLANTIC OCEAN.

Notes with reference to the Monthly Wind Charts of the South Atlantic Ocean prepared in the Meteorological Office and published by the Hydrographic Office, January, 1904.

By

M. W. CAMPBELL HEPWORTH, C.B.,

Commander R.N.R., Marine Superintendent.

Published by the Authority of the Meteorological Committee.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
By DARLING & SON, Ltd., 34-40, Bacon Street, E.

And to be purchased, either directly or through any Bookseller, from
WYMAN AND SONS, Ltd., Fetter Lane, E.C.,
or OLIVER & BOYD, Edinburgh;
or E. PONSONBY, 116, Grafton Street, Dublin.

1905.

Price Ninepence.

Official No. 177.

THE RELATION

BETWEEN

PRESSURE, TEMPERATURE, AND AIR CIRCULATION OVER THE SOUTH ATLANTIC OCEAN.

Notes with reference to the Monthly Wind Charts of the South Atlantic Ocean prepared in the Meteorological Office and published by the Hydrographic Office, January, 1904.

By

M. W. CAMPBELL HEPWORTH, C.B.,

Commander R.N.R., Marine Superintendent.

Published by the Authority of the Meteorological Committee.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
By DARLING & SON, Ltd., 34-40, Bacon Street, E.

And to be purchased, either directly or through any Bookseller, from
WYMAN and SONS, Ltd., Fetter Lane, E.C.,
or OLIVER & BOYD, Edinburgh;
or E. PONSONBY, 116, Grafton Street, Dublin.

1905.

Price Ninepence.

PREFACE.

The discussion of the meteorological observations for the South Atlantic and the South American Coastal Regions of the Pacific occupied the attention of the Marine Department of the Meteorological Office from 1898, when the corresponding work upon the Southern Ocean was completed, until 1904. The total number of observations extracted from the Log Books of the Royal Navy, and the Meteorological Logs contributed by the Captains and Officers of the Mercantile Marine whose ships crossed the region referred to, amounted to 946,000. They have been grouped according to five degree squares of latitude and longitude, or in special cases according to one degree squares, and the mean results for Wind, Air Pressure, and Air Temperature were embodied in a series of monthly charts prepared under Captain Hepworth's superintendence in accordance with the direction of the Meteorological Council and, in particular, of the late Hydrographer of the Navy, Rear-Admiral Sir W. J. L. Wharton, F.R.S., who was ex officio a member of the Council.

Upon the completion of the Charts the Hydrographer undertook the issue of them as a publication of the Hydrographic Office. The information contained in the Charts will, it is hoped, be found to be of considerable interest and importance to mariners. At the request of the Council, Captain Hepworth undertook the preparation of some notes giving the general results which follow from an examination of the Charts. They formed the subject matter of a paper read before Section A. of the British Association at Cambridge in 1904, and are now issued by the authority of the Meteorological Committee.

Charts for the Coastal Regions of South America were issued first in 1902, and the issue of the completed work for the South Atlantic followed in 1904.

350 Wt 10061 11/05 D & S 23 22184

By way of illustration of some of the general features of the average meteorological conditions of the South Atlantic, some additional Charts on small scale have been prepared. They show the variations in the course of the year of the position and intensity of the areas of high pressure in the regions under consideration, and the position and extent of the equatorial region of doldrums in relation thereto, and the average distribution of gales and of fog. Captain Hepworth's notes call attention to the points which are illustrated by these additional Charts, and also to the effect of the air circulation upon the distribution of temperature, which is found to diverge considerably from the parallels of latitude, even over an area of such uniform geographical character as the South Atlantic.

For the facts upon which the notes depend, the Wind Charts themselves should be referred to, but it is thought that sailors and others interested in marine meteorology may wish to have the general conclusions in a separate form.

W. N. Shaw,
Director.

Meteorological Office,
63, Victoria Street, S.W.
August, 1905.

THE RELATION

BETWEEN

PRESSURE, TEMPERATURE, AND AIR CIRCULATION OVER THE SOUTH ATLANTIC OCEAN.

Wind and Barometer.

The South Atlantic offers an excellent field for the study of air circulation on a comprehensive scale and under normal conditions. An ocean covering an extensive area, connected north and south with great oceans and completely open to the south, it is at the same time free from the disturbing influences of island groups, and is bounded east and west by continents having coast-lines that are, for the most part, exempt from large irregularities of outline. The atmospheric circulation over the South Atlantic may therefore be regarded as one vast wind system, its air currents undisturbed over the northern half by the occurrence of aerial eddies for the most part; and over the southern half, although at times interrupted, yet not effaced by them.

The relation between Pressure, Temperature, and Air Circulation over this area, and also over the eastern margin of the South Pacific Ocean, is well shown by a set of monthly wind charts prepared in the Meteorological Office and published by the Admiralty, entitled "Wind Charts for the South Atlantic Ocean." These charts embody the general results of a very large number of observations of wind and simultaneous readings of the barometer and thermometer.

The anticyclone, or area of high barometric pressure is the great feature of the system. Round this central high pressure a general circulation of air is indicated.

The circulation of air is assisted on the eastern side of the ocean by the relatively low pressure over South Africa; on the northern side by the low pressure over the equatorial regions of the Atlantic; on the western side by the relatively low pressure over South America; and on the southern by the lower pressure of higher latitudes. The direction of the wind about the core of high pressure stated generally, is Southerly to South-easterly between it and the African coast, South-easterly and Easterly, towards the equator, Easterly to Northerly on its western side, and North-Westerly to South-Westerly on its southern. Over the eastern and northern segments of the system the flow of the air current is steady; over the western

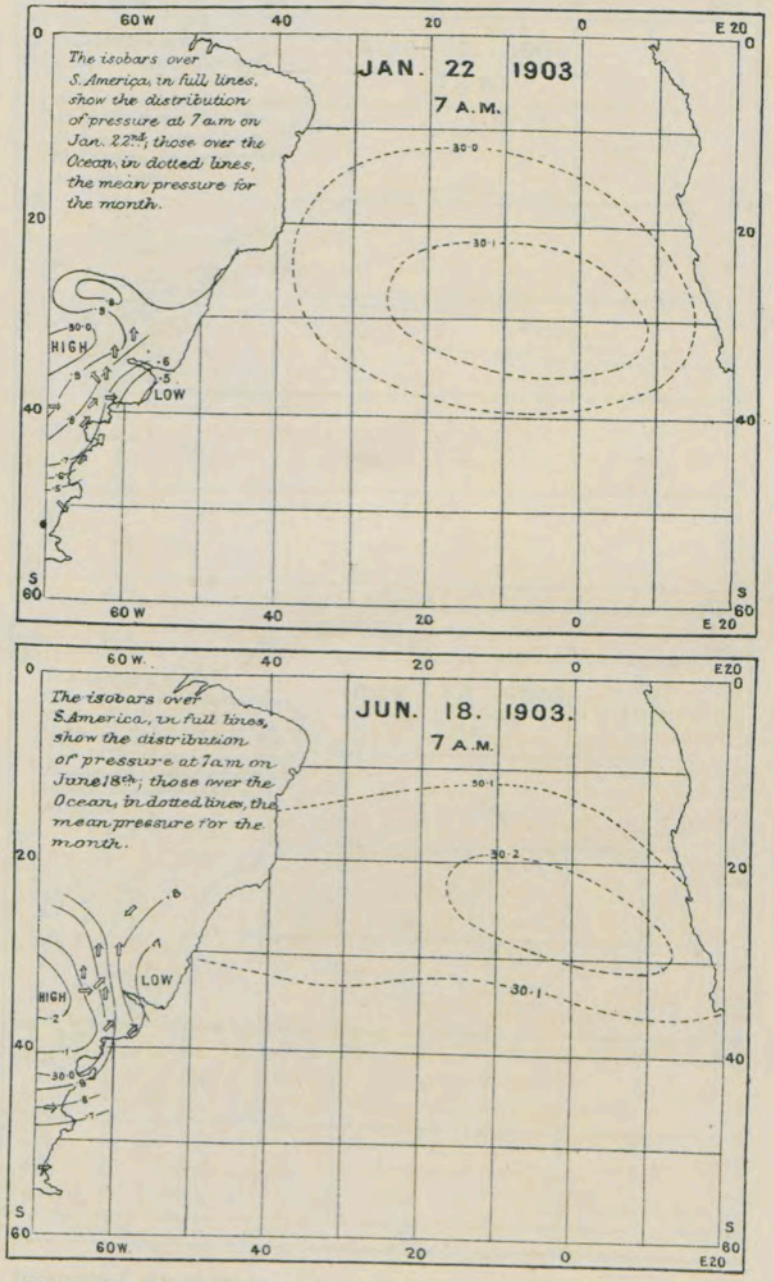
and southern, particularly over the former, the circulation is less persistent. Southward of 30° S. lat., and even farther to the northward, on the western side of the South Atlantic the apparent normal circulation of the surface wind, in harmony with the course of the average isobars, is largely masked by the effect of low pressure systems travelling eastward or south-eastward.

These low pressure systems occur more frequently from May to October inclusive than in other months, and are most frequent in July and August. South of 40° S. lat. the westerly winds, although temporarily interrupted by depressions on their approach, are intensified by them on their retreat. These depressions generally appear on the ocean between the 20th and 40th parallels, and the course of those approaching the margin of the relatively high pressure to the eastward is frequently turned south-eastward. The cool northward flowing air current, on the eastern side of the ocean, reinforces the area of high pressure which acts as a barrier to eastward moving depressions; the warm southward flowing air current, on the western side, induces conditions favourable to the formation or advance of disturbances in that region. Thus the most striking characteristic of the distribution of winds, shown on the charts referred to, is the steady south-easterly current on the eastern and northern sides of the tropical high pressure, and the varying winds on the western side. The varying character of the winds on the western side must be attributed to the passage of low pressure areas mentioned above across the region, or to the south of it. Observations in these latitudes are too few to enable us to identify the character or trace the track of these depressions over the ocean, but observations over the adjacent land area of South America occasionally show low pressure areas which pass away over the ocean not far from the localities referred to.

Four charts showing isobars over South America, *see* Plates I. and II., taken from the Daily Weather Reports issued by the Argentine Meteorological Office, may serve to illustrate the relation of the moving depressions to the general distribution of pressure over the South Atlantic. The dates given on the charts indicate the days on which the low pressure systems were observed; the dotted lines over the ocean show the distribution of mean pressure for the month. Areas of low pressure are shown, from time to time, by the Daily Weather Charts of Argentina, to reach the sea on a parallel as far north as 20° S. lat.; but observations are sparse between the 20th and 30th parallels, and no daily synoptic charts are published for Brazil.

Log books in the possession of the Meteorological Office, however, record numerous instances of strong winds associated with low pressure systems experienced in the vicinity of the Brazilian coast, between 20° S. and 30° S., 40° W. and 50° W., many of which attained gale force. In the years 1855 to 1899 no less than 184 gales were recorded in these Registers, and

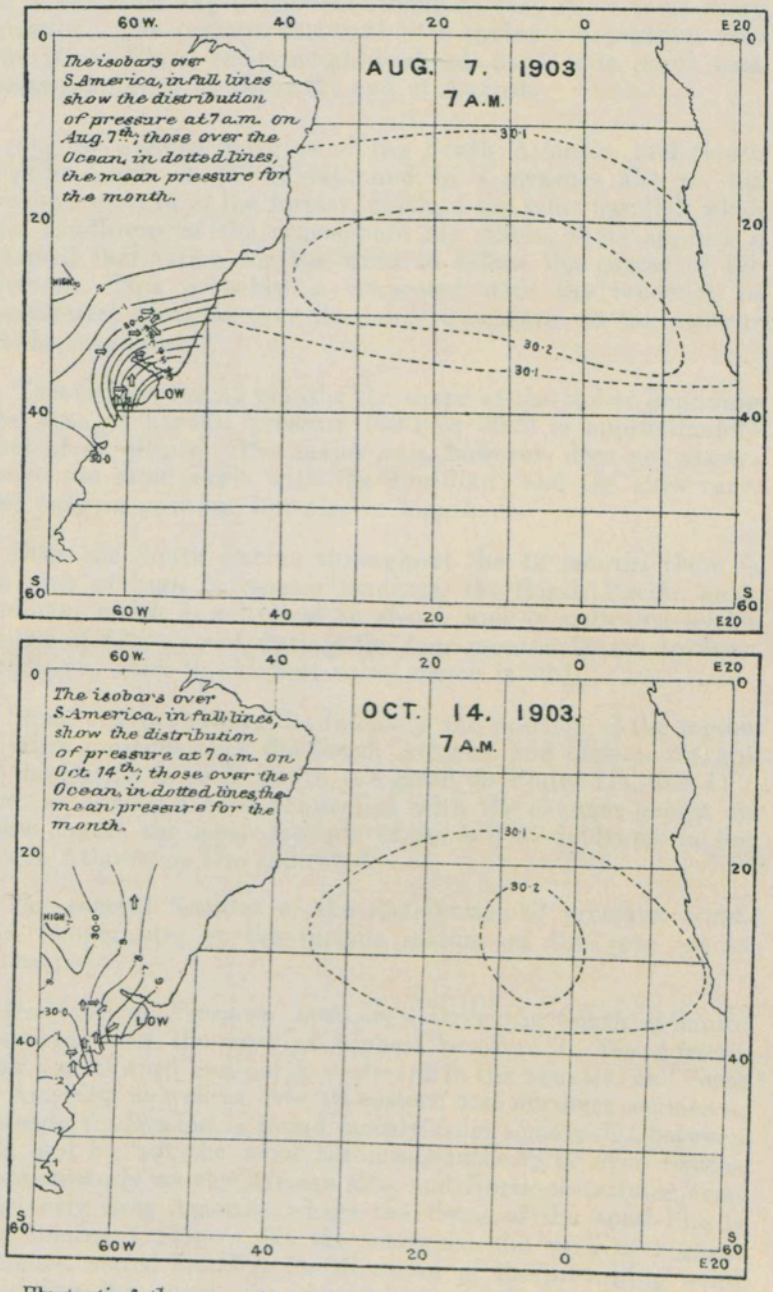
PLATE I.



Illustrating the passage of low pressure systems seaward.

5873. 11.05

Weller & Graham Ltd Litho. London



Illustrating the passage of low pressure systems seaward.

5873.11.05

Weller & Graham Ltd Litho. London.

in all of these instances the force of the wind reached, or exceeded, 8 of Beaufort Scale, and the strongest gale recorded attained force 11 of that scale. The gales cannot be assigned to winds from any particular direction; they come from every quarter. The passage eastward of a cyclonic depression over the River Plate, or its neighbourhood, appears to occur with some regularity at about the end of August.

On the eastern margins of the South Atlantic, and South Pacific north of 35° S. lat., and in a measure also on the western margin of the former, north of the same parallel, when the conditions of the atmosphere are stable, there appears a marked inclination for the wind to follow the course of the littoral. This probably is connected with the tendency of barometric pressure over the land to conform to the contour of the coast-line.

Throughout the 12 months the shape of the isobar bounding the area of highest pressure (30·1 or 30·2) is approximately that of an ellipse. The major axis, however, does not always make the same angle with the meridian; and the axes vary, not only in position, but also in length.

Over the South Pacific throughout the 12 months there is an area of high barometer readings, the South Pacific anticyclone, which is elliptical in shape, and is indicated by an isobar of 30·2 except during the four months March to June inclusive, when the highest value shown is 30·1.

Small charts showing the intensity and position of the region of high pressure over the South Atlantic and eastern margin of the Pacific in each month, are given on Plates III. and IV., and, as having a close connection with the changes shown on these charts, the mean latitude of the belt of doldrums in the North Atlantic is also indicated.

The general features of the distribution of pressure, wind, and temperature at the various seasons of the year are as follow:—

December to February inclusive.—Over the South Atlantic eastward from the area of highest pressure to the African coast; northward and north-westward to the equator, and coast of America, as well as over its eastern and northern segments, a steady trade wind is found mainly from some point between S.E. and E., but the wind becomes Southerly or even South-south-westerly on the African side, and North-easterly or even Northerly near America where the trend of the coast-line is the dominant factor. To the westward the area of highest pressure, stated broadly, the direction of the prevailing wind following the course of the isobars, is North-easterly, although depressions passing eastward and south-eastward

partly mask the circulation conforming to the average distribution of pressure, and near the American coast the influence of the land upon the direction of the wind can be clearly traced. South of the 35th parallel, which is about the latitude of Monte Video, the prevailing winds have some westing in them, and a good deal of northing, excepting where they appear to be influenced by the land west of the 40th meridian between the 35th and 40th parallels.

South of the 40th parallel Westerly winds largely predominate in all months of the year; and the relation between the shape of the gradient and the strength of the wind is well shown by the percentage of gales for the regions where the isobars close up.

Between the 40th and 55th parallels the pressure gradient is almost always towards the south, and Easterly winds are correspondingly rare.

Over the eastern margin of the Pacific from 30° S. northward, the trade winds blow steadily; they are chiefly from a South-easterly direction, but near the American Continent the prevailing winds flow parallel to the outline of the coast. Southward of 35° S., in accordance with the trend of the isobars, the air current is South-westerly, where not deflected by proximity to land; southward of 40° S. a Westerly air current predominates.

March to June inclusive.—Over the South Atlantic to the eastward of the high pressure area, as well as over its eastern and northern margins; and from 20° S. northward to the equator, the air current is mainly from some point between S. and E., excepting where deflected by land influence. Westward of the 20th meridian between 20° S. and 35° S. it has a good deal of northing and easting, but is not constant; and this area probably is visited by many small disturbances and is subject to varying influences. South of 35° S. westerly winds predominate.

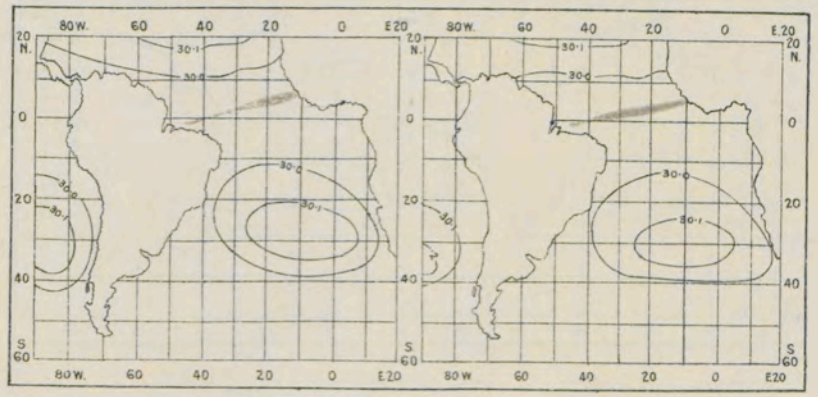
Over the south-eastern margin of the Pacific, the area over which the south-east trade winds prevail, is gradually reduced, so that in June they are not constant south of the 20th parallel. After March easterly winds become less and less frequent south of the 25th parallel; south of the 40th the westerly winds are well established.

July to September inclusive.—Over the Atlantic there is a general resemblance between the highest pressure areas of the first and this the third period; but in the one case we have a 30·1 ellipse travelling 5° to the westward, and in the other case a 30·2 ellipse moving 5° to the eastward. This contrary travel in longitude may perhaps be accounted for by the fact that the sun is well south of the equator from December to February, making the African land relatively warmer than

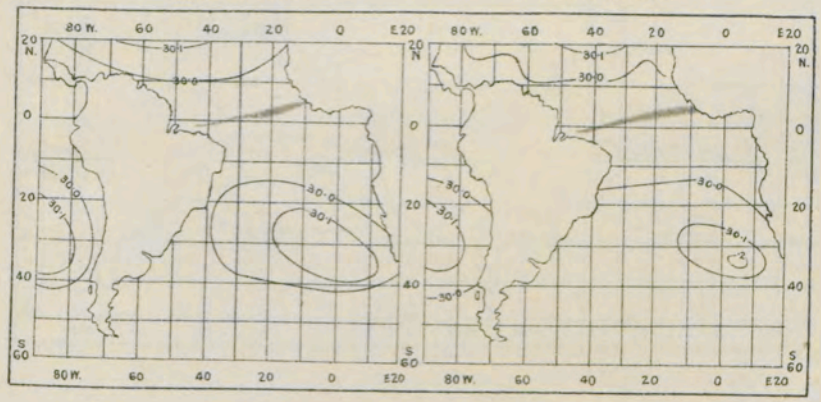
PLATE III.

MONTHLY CHARTS SHOWING THE RELATION OF THE SOUTH ATLANTIC ANTICYCLONE TO THE REGION OF DOLDRUMS.

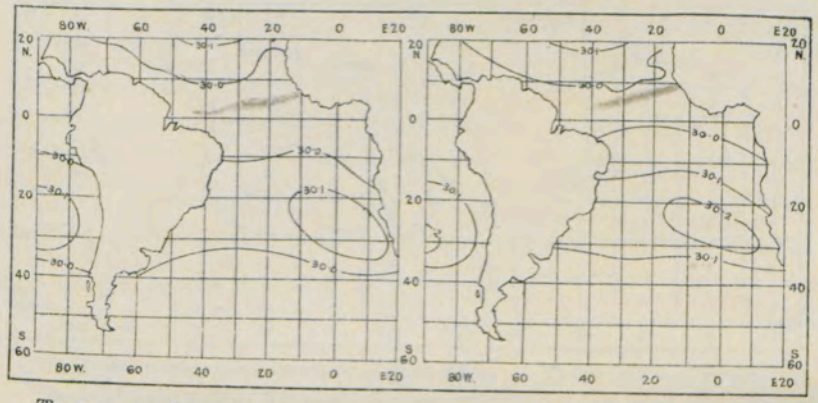
JANUARY FEBRUARY



MARCH APRIL



MAY JUNE



The pressure for each isobar is shown in figures. The extent and development of the region of Doldrums is shown by the area and depth of the shading.

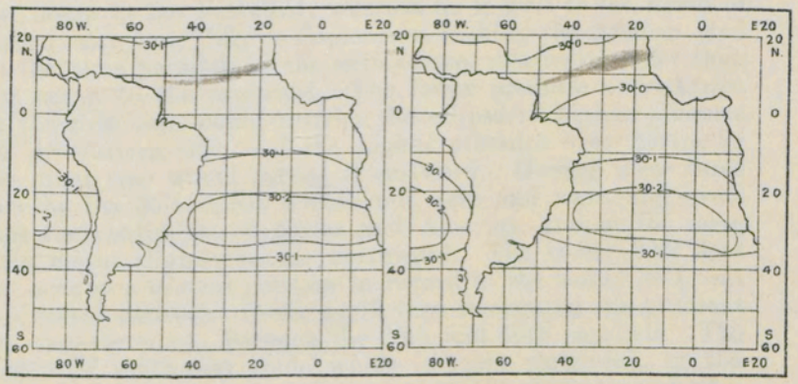
5873 11.05

Weller & Graham, Ltd Litho, London.

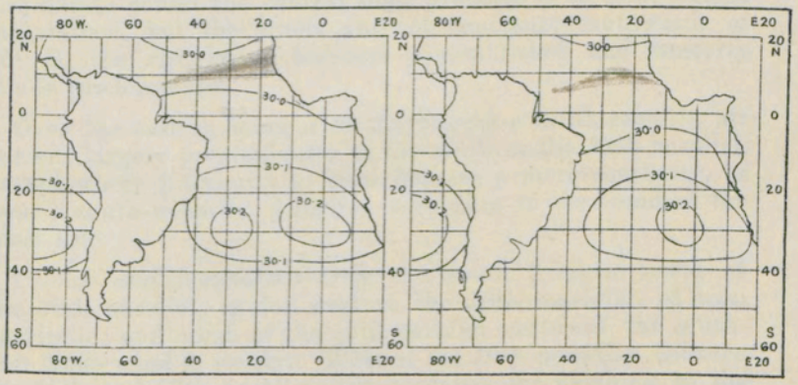
PLATE IV.

MONTHLY CHARTS SHOWING THE RELATION OF THE SOUTH ATLANTIC ANTICYCLONE TO THE REGION OF DOLDRUMS.

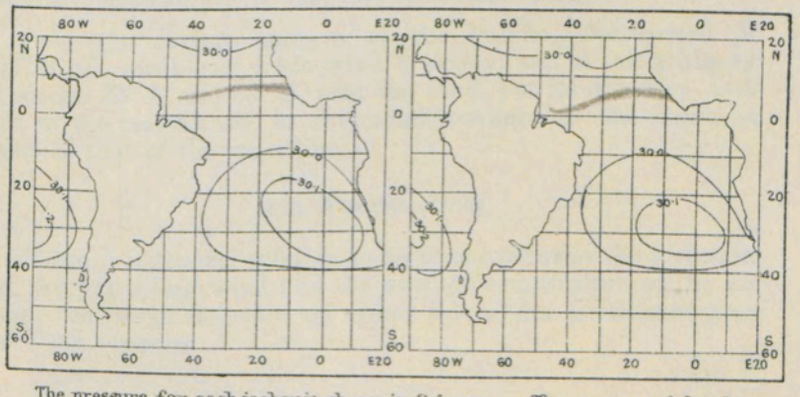
JULY AUGUST



SEPTEMBER OCTOBER



NOVEMBER DECEMBER



The pressure for each isobar is shown in figures. The extent and development of the region of Doldrums is shown by the area and depth of the shading.

5872.11.03

Weller & Graham, Lt.d Litho. London.

the ocean to the westward; whereas he is well to the north of the equator from July to September, making the African land in the same parallels as the anticyclone, relatively cooler than the ocean to the westward. The lower pressure over Africa in the first case would restrict the ellipse of higher pressure on the eastern side, and the higher pressure over Africa in the other case would extend it eastward. During these three months the 30·1 isobar widens out, east and west, and overlaps the continents of Africa and America, and at the same time moves slightly to the northward. The isobar 30·2 does not occupy a central position in regard to the isobar 30·1, but is situated somewhat to the south thus steepening the gradient for westerly winds, between the 30th and 40th parallels. The region of south-east trade winds is more restricted, in the South Atlantic, than during any other period; but north of a straight line drawn from Port Nolloth on the African coast to Bahia in Brazil, the air current is still fairly constant from a south-easterly quarter, when it is not deflected by proximity to the land. Southward of this line to 35° S. the normal circulation round the central high pressure is to some extent maintained, but the winds are not constant; southwards of 35° S. the circulation becomes re-established and westerly winds predominate.

Over the eastern margin of the Pacific a south-easterly air current largely predominates as far south as the 30th parallel, except where proximity to land induces a more southerly, or even a south-westerly, direction according to the trend of the coast-line.

October and November.—Over the South Atlantic north of the 30th parallel, as far west as the 10th meridian of west longitude; and north of the 15th parallel westward, the south-east trade wind is steady. West of the 10th meridian between the 15th and 30th parallels the tendency for northing in the prevailing winds due to the course of the isobars becomes more marked the more westerly the position; south of the 30th parallel the winds have more westing the more southerly the position. The occurrence of easterly gales from 30° W. to 40° W. between 45° S. and 50° S. is remarkable.

Over the eastern margin of the Pacific.—Northward of 30° S. the south-east trade wind is steady, and is fairly steady between 30° S. and 35° S. near the land, but its direction here as to the northward, in the neighbourhood of the coast, is largely that of the coast-line.

Air Temperature.

There is a general relation to be found between the direction of the prevailing wind and the average temperature of the air over the South Atlantic, on either side of the permanent area of high pressure.

A deviation of the isotherms from the east and west direction of the lines of latitude is found on the eastern and western sides of the high pressure area; the south-east trade wind produces a cooling effect upon the air on the eastern side, and the north-easterly wind a warming effect upon the air on the western side.

Throughout the year there is a marked tendency for air isotherms to extend along a line drawn from the Cape of Good Hope to the island of Ascension, under the influence of the relatively cool air of the south-east trades which blow on the African side of the high pressure, and in association with the cool sea surface current setting north-westward. While, at the same time, the relatively warm north-east wind, on the American side of the anticyclone, which is in association with the warm sea surface current setting south-westward, exercises a similar influence upon the air isotherms in the vicinity of South America.

From December to February, inclusive, the south-east trade wind carries the eastern ends of the air isotherms considerably to the north-west of the average latitude for that temperature. The average maximum limit of effect for the three months is in about 2° N. 18° W., although the range during the three months is from 5° N. 20° W. to 5° S. 15° W.

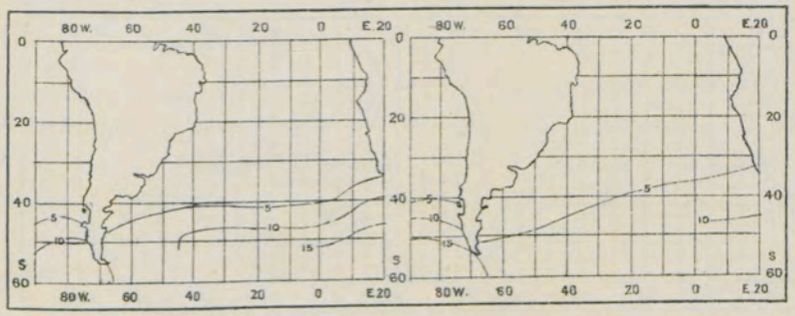
Near the American coast the effect of the north-east wind is shown in the isotherms even as far to the southward as 37° S., ranging from 40° S. to 35° S. Consequently, on an average, the air isotherm of 70° F., for example, reaches the coast of Africa in 17° S., but dips to 34° S. on the coast of South America.

On the eastern margin of the South Pacific, as a general rule, the relatively cool southerly wind, corresponding with the prevailing cool sea surface current which sets to the northward, has an appreciable effect in lowering the temperature of the air near the west coast of South America. From December to February, inclusive, the cool southerly wind affects the direction of the air isotherms, forcing their easterly ends to the north-west, from 40° S. to 5° S., thus indicating a lower air temperature than is experienced along the same parallels of latitude farther to the westward.

Over the South Atlantic during the four months March to June, inclusive, the means of extreme limits of the cooling effect of the south-east trades as indicated by the air isotherms, is 3° S. 16° W.; with a range from 8° S. 15° W. to 5° N. 20° W. The southern limit of influence of the north-east wind, on the western side of the ocean, gradually travels northward, month by month, from 30° S. to 23° S., and the average is found in about 25° S. The air isotherm of 70° F., on an average, terminates in 16° S., on the eastern side, but in 29° S. on the western side of the South Atlantic.

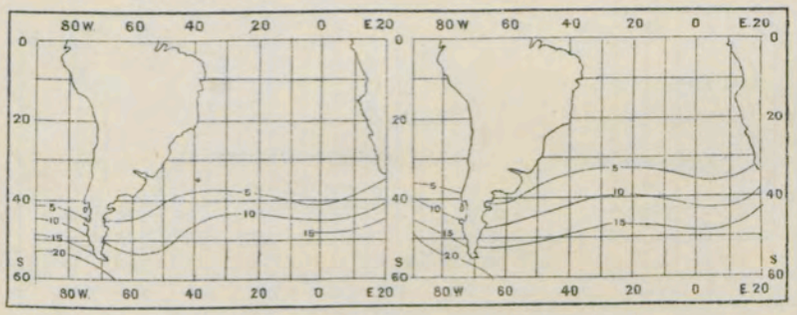
GALE FREQUENCY.

JANUARY



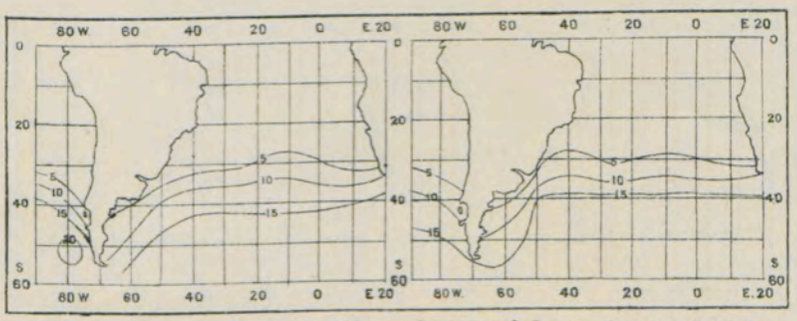
FEBRUARY

MARCH



APRIL

MAY



JUNE

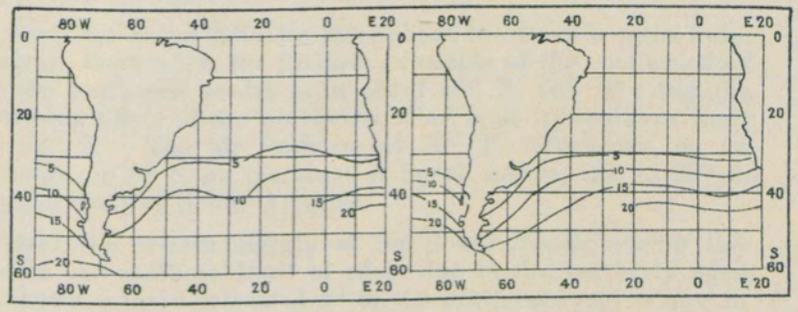
The percentage of gales to the whole number of wind observations is indicated by the figure linked to each gale frequency line.

5673.11.05

Weller & Graham, Ltd. Litho, London.

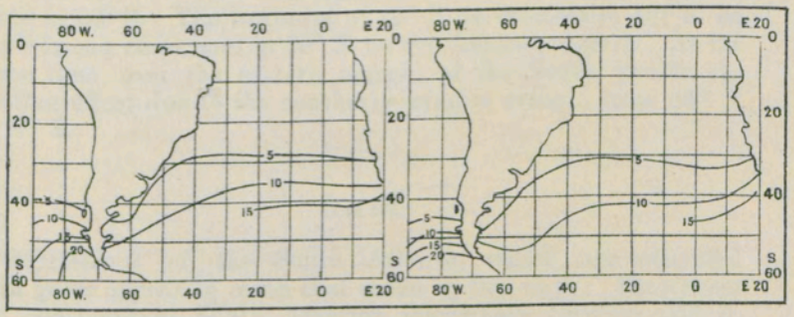
GALE FREQUENCY.

JULY



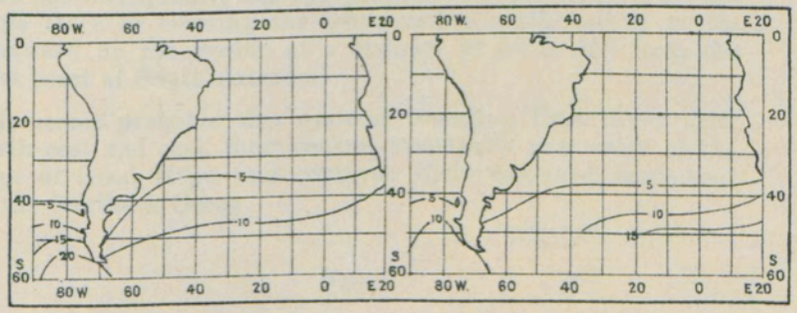
AUGUST

SEPTEMBER



OCTOBER

NOVEMBER



DECEMBER

The percentage of gales to the whole number of wind observations is indicated by the figure linked to each gale frequency line.

5873.11.65

Weller & Graham, Ltd. Litho, London.

Over the eastern margin of the South Pacific during these months, the cooling effect is noticeable from 40° S. to the equator.

Over the South Atlantic throughout the three months July, August, September, the furthest extension of the cooling effect of the south-east trades is in about 10° N. 20° W.; and the warming effect of the north-east wind is at its southern limit in 30° S. The air isotherm of 70° F. terminates, on an average, in 9° S. on the coast of South Africa, and in 25° S. on the coast of South America.

Over the eastern margin of the South Pacific during this period the southern limit of effect due to the southerly wind is shown to have retreated 5° to the northward and is now in 35° S., while the cooling of the air can be traced to the equator.

Over the South Atlantic during October and November, the extreme limit of the effect of the south-east trades is in 5° N. 20° W., and the southern limit of that due to the north-east wind in 30° S. The isotherm of 70° F. terminates in 15° S. on the African coast, and in 28° S. on the American coast. At the same time, over the eastern margin of the South Pacific the cooling effect due to the southerly wind is evident from 40° S. to 5° S.

Gales.

Depressions of the South Atlantic which are attended with gales appear to reach that ocean in two ways. They cross the continent of South America somewhere between 25° S. and Cape Horn, more frequently travelling over Patagonia; or they avoid the land altogether and round Cape Horn to the eastward, following the general drift of air and sea surface.

The percentage curves, *see* Plates V. and VI., seem to show that not infrequently the cyclonic system, instead of rounding Cape Horn or crossing the land, strikes northward or north-westward up the Pacific at a distance of 5° to 10° from the west coast of South America.

It seems probable that systems rounding Cape Horn drift north-east and east, their centres eventually pass south of the Cape of Good Hope, and continue their eastward movement in the Southern Ocean.

Fog.

Attention may here be called to the effects of a warm moist wind over cold water, and of a cold wind over warm water.

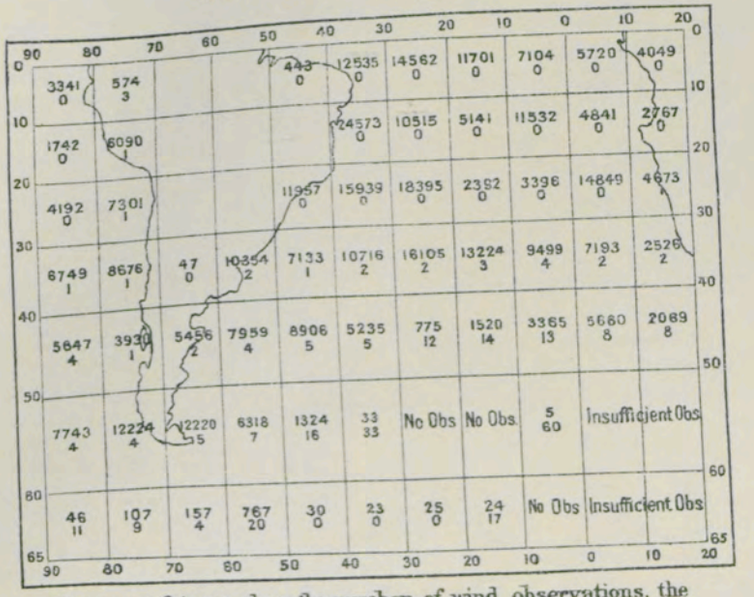
A warm humid wind passing over water of a lower temperature is cooled, and the excess of vapour, after the point of saturation has been reached may be condensed, and form mist or fog. In like manner a cold wind, blowing over water of a considerably higher temperature than its own, chills below the point of saturation the vapour as it rises, when it becomes visible. For the lower the temperature of the atmosphere the less aqueous vapour can it hold in an invisible state.

In the first case the fog, as a rule, does not extend more than a few hundred feet above the sea, and may occasionally be seen over from the masthead of a vessel; in the second case it rises to a comparatively high altitude, but does not always extend to the surface, so that objects may occasionally be seen at a distance by an observer descending to a position near sea-level. It must not be concluded that these are the only causes productive of fog at sea, but the regions of greatest fog frequency are regions in which these causes occur most conspicuously.

Over the South Atlantic, north of the 30th parallel, fog is rarely met with, except near the land on either side of the ocean. For over this area the wind circulates, for the most part, steadily round the central area of highest pressure, and the relation between air and sea surface temperature is fairly stable. Anywhere south of the 30th parallel, where a relatively warm moisture-laden wind passes over a relatively cold current, fog may be expected, and is found to become increasingly frequent the higher the latitude reached, to the southern limit of observation, *see* Plate VII. This is probably due to increase in gale frequency with latitude, the passage of cyclonic systems bringing in their train rapid fluctuations in air temperature, varying inequalities between the temperature of air and sea surface, together with the failing winds and calms which usually intervene between successive disturbances.

DISTRIBUTION AND FREQUENCY OF FOG.

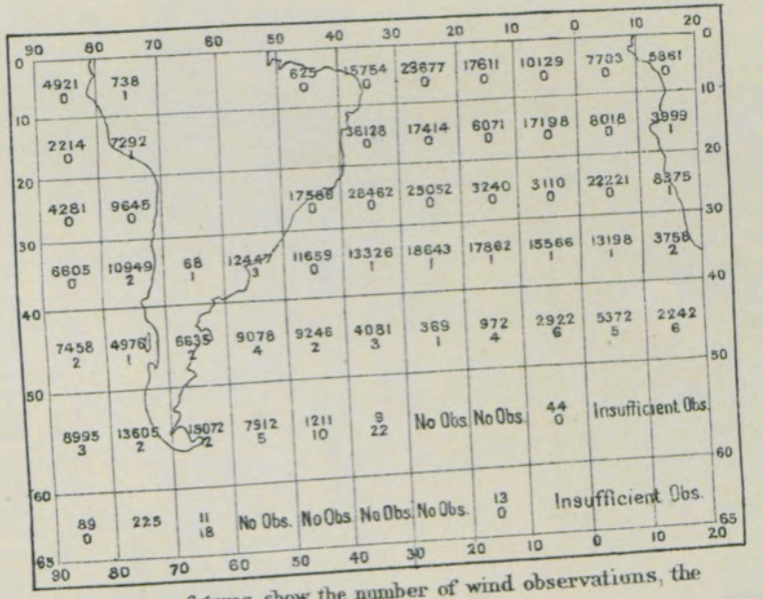
OCTOBER TO FEBRUARY



The upper figures show the number of wind observations, the lower the percentage of Fog.

DISTRIBUTION AND FREQUENCY OF FOG.

MARCH TO SEPTEMBER.



The upper figures show the number of wind observations, the lower the percentage of Fog.

Weller & Graham Ltd Litho London

5873.1105