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Frontispiece.

WIND CHARTS OF THE INTERTROPICAL BELT OF THE ATLANTIC OCEAN.

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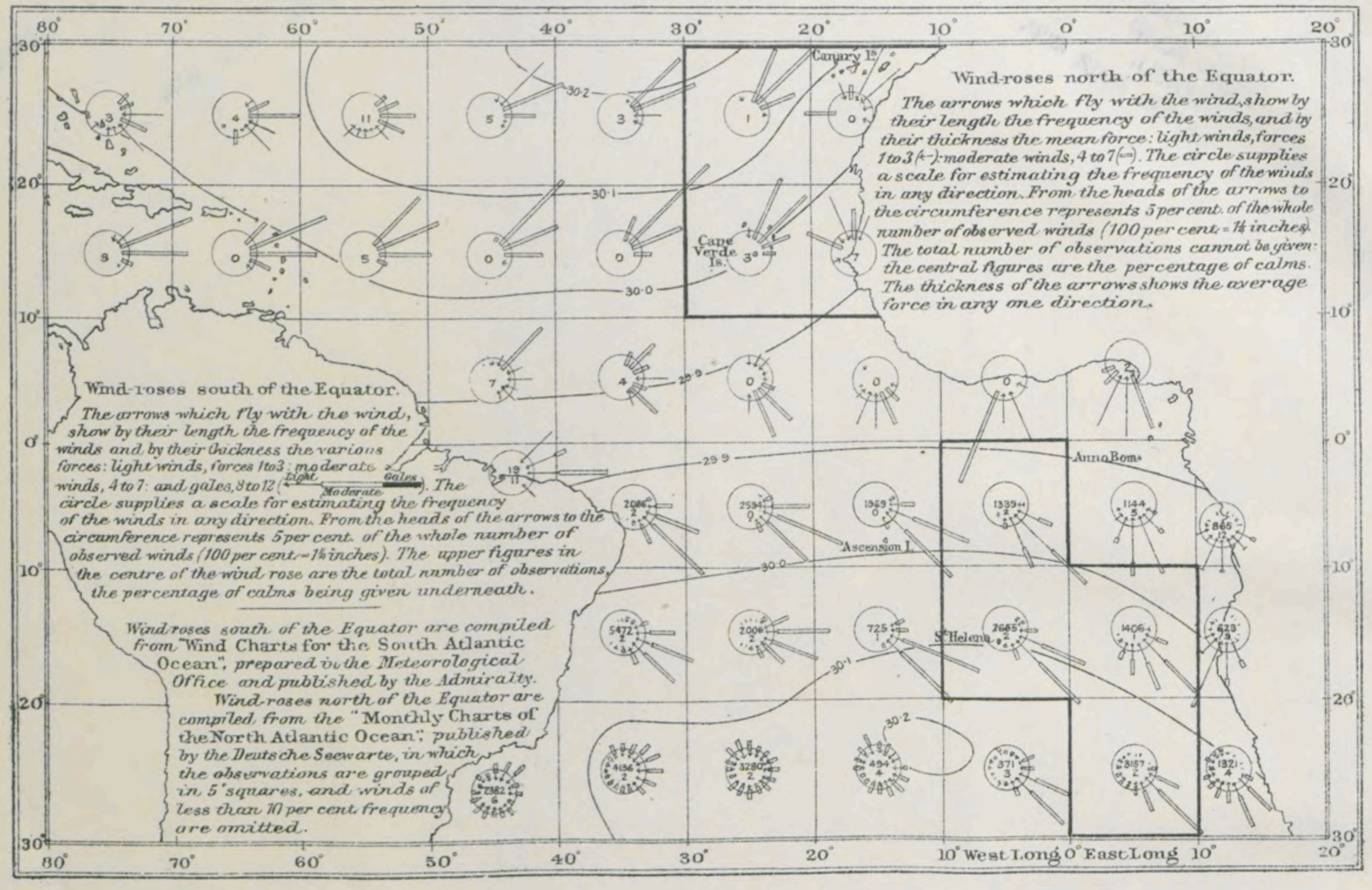

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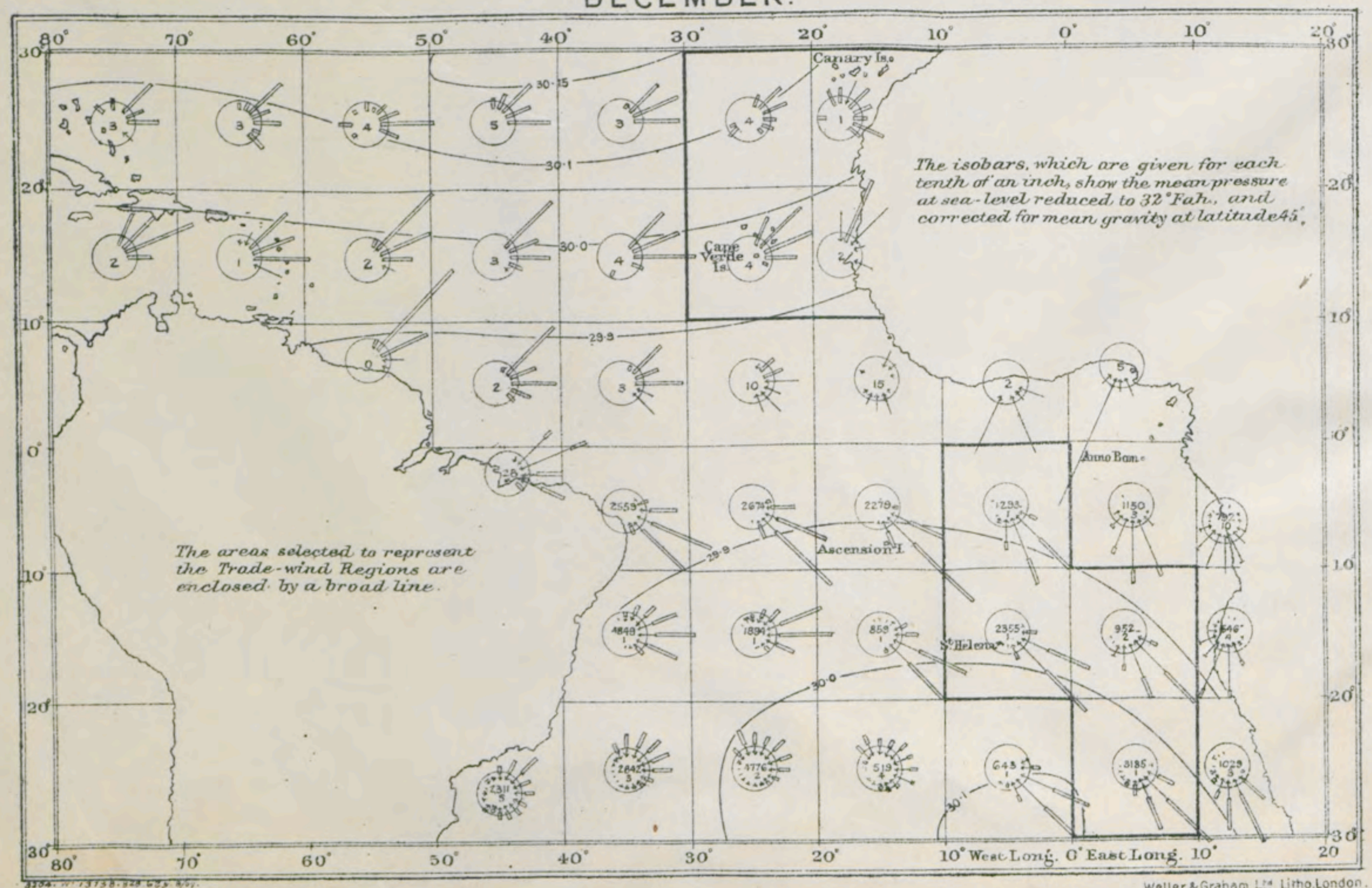

M.O. 203.

METEOROLOGICAL OFFICE.

THE TRADE WINDS OF THE ATLANTIC OCEAN.

CONTRIBUTIONS TO THE STUDY OF THE NORTH-EAST AND SOUTH-EAST TRADE WINDS,

COMPRISING

A COMPARISON OF THE CHANGES IN THE TEMPERATURE OF THE WATER OF THE NORTH ATLANTIC AND IN THE STRENGTH OF THE TRADE WINDS,

BY

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

Commander, R.N.R., Marine Superintendent.

CLIMATOLOGICAL TABLES FOR ST. HELENA, WITH A REPORT UPON THE RECORDS OF THE ROBINSON ANEMOGRAPH, FROM 1892 TO 1907,

BY

JOHN SOMERS DINES, B.A.,

AND

NOTE ON THE CONNEXION BETWEEN THE PERIODIC VARIATIONS OF WIND-VELOCITY AND OF ATMOSPHERIC PRESSURE,

BY

ERNEST GOLD, M.A.,

Schuster Reader in Meteorology.

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THE TRADE WINDS OF THE ATLANTIC OCEAN.

PREFACE,

BY

W. N. SHAW, Sc.D., F.R.S.,

Director of the Meteorological Office.

METEROLOGICAL OBSERVATIONS AT ST. HELENA.

The primary purpose of the publication of the papers included in this volume is to present the results obtained by the installation of an anemograph and other meteorological instruments near St. Matthew's Vicarage in St. Helena by the Meteorological Council in the year 1892. In 1889 an American eclipse expedition visited the island and, on leaving, represented to the Governor, Mr. R. L. Antrobus, now of the Colonial Office, the importance of re-establishing a meteorological observatory. The representation was forwarded to the Colonial Office and in that way reached the Meteorological Office.

The Meteorological Council provided the equipment of a station of the second order to be lent to the Colony, and placed in charge of Mr. H. S. Hands, and subsequently of Mr. A. L. C. Hands, at St. Matthew's Vicarage. They also provided for the installation in the same neighbourhood, and in Mr. Hands' charge, of a Robinson anemograph of the same type as those now in operation at Scilly and at Phœnix Park, Dublin. The instrument had been originally erected on Heligoland and has 5-inch cups, 12-inch arms, and the factor employed for the expression of its records in miles per hour is 2·8 (*see* Plate A, p. 26).

It is needless here to recapitulate the reasons urged for the maintenance of a meteorological station at St. Helena. The desirability of close investigation of the meteorological conditions prevailing in the South East trade wind is evident enough and was indeed recognised many years ago. A magnetical and meteorological observatory, practically of the first order, was maintained there in charge of a detachment of the Royal Artillery from 1840 to 1847, as part of a general scheme of observations promoted by the late Sir E. Sabine with the support of the British Association for the Advancement of Science.

The Royal Engineers maintained a station of the second order from 1853 to 1862.

The results of these observations are given in the two volumes of "Observations made at the Magnetical and Meteorological Observatory at St. Helena, computed under the superintendence of Lieutenant-Colonel Edward Sabine," and in the volume of "Meteorological Observations at the Foreign and Colonial Stations of the Royal Engineers and Army Medical Department, 1852–1886," Meteorological Office publication No. 83. Reference may also be made to the volume on St. Helena, by J. C. Melliss, 1875.

PAPERS INCLUDED IN THE PRESENT VOLUME.

In the present volume summaries of the results of the earlier observations are given in order to make the conspectus of meteorological conditions as complete as circumstances permit, and the results of a number of short series of rainfall observations at various stations in the island have been added. A map taken from the Admiralty Chart faces page 9, and will be found useful for identifying the positions of the various stations.

No systematic publication of the results obtained by means of the instruments provided by the Meteorological Council had been undertaken, and when the matter first came to my notice there was a large accumulation of data awaiting discussion. In compiling the results of the tabulations of the anemograms I was struck with the remarkable seasonal variation in the velocity of the wind and in a short article on "The Pulse of the Atmospheric Circulation," contributed to "Nature" of December 21, 1905, I called attention to the analogy between the seasonal variation of the trade wind and that of the rainfall of the South of England. I added a number of other considerations that seemed to point to a connexion between what may be called the main arterial circulation of the atmosphere as represented by the Trade wind and the meteorological consequences of that circulation in other parts of the world remote, in many senses, from the region where the arterial circulation is measured. However complex may be the mechanism which connects the general Westerly flow of air over these Islands with the persistent South Easterly current of the Trade wind of the South Atlantic it is evident that the existence of a real connexion is not an unreasonable working hypothesis, and the considerations which I put forward suggested that it might be possible to identify the connexion and even to trace the links in the chain of cause and effect. Actuated by this suggestion Commander Hepworth made an endeavour to trace what may be regarded as the first link in the chain, namely the effect of variations of the trade winds upon the temperature of the water in the North Atlantic presumably through the action of the Equatorial current. For that purpose he thought it best to deal with the North East as well as the South East Trade wind, and in order to have the representation of both Trade winds on a similar footing he made use of the estimates of wind force, according to the Beaufort scale, contributed to the Office, for the years 1902 to 1906 inclusive, by ships crossing certain areas of the North and South Atlantic respectively which are indicated in the frontispiece. With the results thus obtained he has compared those derived from the observations of sea temperature of the North Atlantic contributed to the Office by ships crossing that ocean during the years 1902 to 1907 inclusive. These observations have already been summarised upon the inset charts of sea temperature included in the "Monthly Meteorological Charts of the North Atlantic and Mediterranean," and, in the present contribution, the differences from the normal values are examined and compared for each of the years mentioned, with the variations of the Trade wind of the preceding year.

The paper representing these results was read before the Meeting of the British Association at Dublin in September, 1908.

It is followed, in this volume, by a resumé of all the meteorological data for St. Helena which we have in the Meteorological Office and a discussion of the tabulations of the anemographic records drawn up by Mr. J. S. Dines, who during the year 1908 was a student-assistant in the office. The most striking results of that discussion are represented by the diagrams of the direction and velocity of the mean yearly wind and of mean monthly wind contained in Plate 11, and also the vector diagrams of mean diurnal variation of the wind given in Plates 12 and 13. The discussion of these diagrams by the aid of harmonic analysis gives some very interesting results for the regular sequence of diurnal changes in the South East Trade wind represented in Plates 14, 15 and 16, and a striking diagram of the relation of the second harmonic component of the diurnal variation of the wind to the isobars representing the distribution of superposed pressure due to the second harmonic component of the diurnal variation of pressure in Plate 17. For the purposes of comparison the diurnal variations in the horizontal component of the earth's magnetic force at St. Helena are given in Plate 18.

The relation of the corresponding variations of wind velocity and barometric distribution represented in Plate 17 is one of the meteorological questions which are amenable to mathematical treatment, and having that diagram in view Mr. Gold has contributed a calculation of the relation between the periodic variations of wind velocity and of atmospheric pressure, and has also given a solution by Margules of a similar problem. The application of the general theorem to the particular case of St. Helena has been added.

These three papers form the contributions to the study of the Trade winds which I now present. It will be noticed that while they all originate from the same motive they represent fundamentally different points of view, and it is desirable that I should add some remarks upon some of the results which are disclosed.

Seasonal Variation of the Trade Wind.

The first point that will challenge attention is with reference to the seasonal variations of the Trade winds. The marine results for the South East Trade, whether taken for the five years 1902–1906 or for the long period of 45 years, 1855–1899 (Tables I. and II. and Plate 1), show hardly any seasonal variation. The long period means range between 13·7 miles per hour in May and 15·5 miles per hour in February or, in Beaufort numbers, between 3·3 and 3·7; the means for the shorter period between 13·0 miles per hour in July and 15·0 miles per hour in April, June and August (3·2 and 3·6 Beaufort). The mean value for the long period of years is 14·7 miles per hour.

On the other hand the anemometer record at St. Helena shows a very marked and regular seasonal variation between 12·88 miles per hour in May and 20·00 miles per hour in September (Plate 11), or if the means be taken irrespective of direction, the variation is between 14·2 miles per hour in May and 21·2 miles per hour in September (Table XIV.). The vector mean is 16·2 miles per hour. The older results obtained at Longwood with an Osler's anemometer (Table X.) show substantially the same thing as the mean values vary between 15·5 miles per hour for April and May, and 22·7 miles per hour in November.

It is perhaps desirable that some explanation should be given of the mode in which the resultants were arrived at in dealing with the marine observations.

For the computation of the direction and force of the resultant winds, the original observations were grouped according to direction under 32 points. The component velocity for each point was obtained by converting into velocities the mean of the several groups of Beaufort numbers for the several points, and thus obtaining the mean velocity for each point. The components were resolved along the cardinal lines, and the resultant velocity and direction obtained therefrom. The resultants have been re-converted into Beaufort numbers.

For the purpose of conversion a continuous scale has been assumed giving the following equivalents in miles per hour of the Beaufort numbers :—

Beaufort number	1·0	2·0	3·0	4·0	5·0	6·0
Equivalent velocity in miles per hour	2	7	12	17	22	27

These values, as well as the intermediate ones, in decimals on the Beaufort scale, are thus given by the formula $V + 3 = 5B$, where V is the velocity in miles per hour, and B the corresponding value on a continuous scale, agreeing with the Beaufort at the whole numbers.

This mode of conversion is in agreement at the extreme points, numbered 1 and 6, with the scale of equivalents based upon the formula $V = 1{\cdot}87 \sqrt{B^3}$ now adopted in the Observer's Handbook* and other official publications, but not at the intermediate points. For the points 2, 3, and 4, it gives results two miles too high (including the throw up or down of the fraction of a mile), and for the point 5 it gives one mile of excess. A special investigation of the consequences of these differences has shown that the equivalents in miles per hour of the Trade Winds as set out in Captain Hepworth's discussion, pp. 1–8, are about one mile per hour too high, but the reconverted equivalents in Beaufort scale are only slightly affected. In dealing with the marine results I shall use Captain Hepworth's numbers as they stand in the tables.

It should further be noted with regard to the substitution of a continuous scale for the series of Beaufort numbers that in estimating wind force a single Beaufort number would be used to denote all winds within certain limits on the scale. Thus all winds between 3·5 and 4·5 would be logged as of force 4, and so on. In the columns indicating the results in Tables I. and II., 3·5, which is the borderline point, should be regarded as belonging to the 4's. This mode of interpreting the continuous Beaufort scale must be borne in mind with reference to the diagrams, Plates 1–9.

In contrast with the slight variations for the South East Trade the marine results for the North East Trade for the five years 1902–1906 (Table II. and Plate 2) show a very marked seasonal variation, very nearly complementary to the seasonal variation at St. Helena. The values range with fair regularity between 7·4 miles per hour, 2·1 Beaufort, in October, and 13·5 miles per hour, 3·3 Beaufort, in April. We have, moreover, the following facts to take into account. The marine observations are made close to sea level, whereas the anemometer readings are from 1,960 feet above sea level at St. Matthew's Vicarage, and from about 1,760 feet above the sea at Longwood. The differences between stations near sea level and at heights of 1,700 feet to 2,000 feet are very conspicuous in the rainfall, temperature, and other meteorological elements. Thus the yearly rainfall at the station of the Royal Engineers (40 feet) is 5·47 inches, and at Jamestown (150 feet) 6·07 inches falling in 82 days, whereas at St. Matthew's Vicarage (1,890 feet) it is 39·47 inches falling in 250 days, and at Oak Bank (1,700 feet) 43 inches falling in 223 days. Similar differences may be noticed in the temperatures.

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* The values now employed for official use are :—

Beaufort number	1	2	3	4	5	6
Equivalent velocity	2	5	10	15	21	27 miles per hour.

The decimal amount of cloud at 9 a.m. at St. Matthew's Vicarage shows little variation during the year, for which the average is 8·5, so that the higher levels of the island are cloudy, much more rainy and much more uniform in temperature than the sea-shore. We might, therefore, suppose that the wind conditions at the high levels are different from the sea level. But it is only in the matter of the seasonal variation of the wind that there is any serious discrepancy between the land and sea observations. The average values for the year are 14·7 miles per hour for the sea, 16·2 miles per hour for St. Matthew's Vicarage, and 18·8 miles per hour as estimated, probably with some exaggeration, by the Osler anemometer at Longwood. The agreement is not unsatisfactory; and the values are quite of the same order as the averages for the year of the gradient velocity at sea level referred to later, namely, 14·8 to 16·7 miles per hour. Considering that the Beaufort estimates, which give a rather coarse wind scale, have been converted into miles per hour by a table of equivalents (as indicated above), and that the friction of the sea implies some diminution of velocity near the surface of the sea, no nearer approach to equality could be expected; but the seasonal variation shown by the anemometer is of the order of seven miles per hour on an average vector velocity of about 16.

It is unfortunate that the comparison of the marine observations with the land observations cannot be dealt with adequately by a comparison of the variations from year to year. It happens that three of the years selected by Captain Hepworth corresponded with the time when the anemometer was being overhauled, and the two series of observations have only 1902 and 1906 in common; for these years the figures are:—

	Marine.	Land.
1902	11·8 ...	19·3 miles per hour.
1906	14·6 ...	16·5 do.

Here the discrepancy is very marked; the low number for the marine observations for the year 1902 depends to some extent upon an extraordinarily low figure for February (Table IV.), and for that month there are an exceptionally small number of observations so that the evidence for an exceptionally low value in 1902 is not quite decisive.

In order to get independent evidence upon the question of the existence of a seasonal variation in the South East Trade, I have endeavoured to make use of the computation of the wind velocity from the average monthly pressure gradient, which might be expected to give a measure of the vector resultant wind for each month.* The result has been disappointing, apparently because the gradient cannot be determined with sufficient precision. I first of all took the gradients for each month in the neighbourhood of St. Helena as indicated by the isobaric lines on the *Monthly Wind Charts of the South Atlantic Ocean* (M. O. Publication, No. 168). The results showed a variation between 12 miles per hour in January and February, and 19·5 miles per hour in October, but a strong secondary maximum of 18 to 19 miles per hour was shown in May and June. An independent repetition of the determination by Mr. R. Corless gave a variation of from 13 miles per hour in April to 19 miles in October and 20 in November, but again with a maximum in June, this time as great as that in October. The means for the whole year, as determined in this way, were 16·7 and 16·5 miles per hour respectively, which compare satisfactorily with 16·2 miles per hour, the vector mean for the year obtained from the anemometer at St. Helena. To get a more definite monthly measurement I took the distance between consecutive isobaric lines on the eastern side of the region indicated in the frontispiece as selected to represent the South East Trade. The mean of the 12 monthly values was higher in this case, 17·6 miles per hour, as might be expected from the geographical situation. The monthly values ranged from 14 miles per hour in April to 23 miles per hour in October, with again a secondary maximum of 18 to 20 in May–June.

The figures thus obtained are suggestive of a seasonal variation with an autumnal maximum, but the appearance of a second maximum in May–June clearly contradicts the anemometrical results. It seemed not unlikely that this contradiction might arise from the drawing of the isobaric lines, and that a computation depending upon direct numerical results would be better. For the preparation of the South Atlantic charts average pressure values were taken out for each five-degree square, and the lower three ten-degree squares of the region selected to represent the South East Trade wind include twelve of these squares. Assigning the numerical mean values of the pressure to the middle points of the five-degree squares we get twelve points which can be connected diagonally by five lines which are very nearly transverse to the Trade wind. The pressure differences between the points on these

* For the formula of computation, see *Barometric Gradient and Wind Force* (M. O. Publication, No. 199).

five diagonal lines are therefore fairly indicative of the gradient for the corresponding areas of the South East Trade. Monthly values have been obtained by taking the mean of the results derived from the five gradients. These are shown in the following table:—

SOUTH EAST TRADE WIND IN MILES PER HOUR.

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Gradient Velocity ...	16	15	16	15	11*	13	14	15	15	15	17	16	14·8
Anemometer, St. Helena	16	15	15	14	13*	14	14	18	20	18	19	17	16·2

The figures show perhaps as much correspondence with the anemometric values as could fairly be expected. The May minimum is shown; the maximum is in November instead of September; the mean for the year is 14·8 miles per hour, and some allowance may be made for inclination of the diagonals to the lines of the resultant wind. But an examination of the detailed figures would disclose the fact that the mean values are made up of very discordant numbers for the different squares. One can hardly regard the coincidence of the results as anything more than a fortunate accident. Such evidence cannot, of course, be regarded as decisive, but it adds something in favour of the anemometer as compared with the marine results.

I am therefore disposed to regard the seasonal variation indicated by the anemometer as really characteristic of the South East Trade, and to seek for an explanation of its absence from the marine observations. The explanation is perhaps to be found in the peculiarities of the Beaufort scale.

Making numerical allowance for all the circumstances which have been referred to, I have made a table giving the most probable values of the average monthly velocity of the wind at sea level in the North East and South East Trades respectively, deducing the former from Captain Hepworth's results for 1902–1906 (Table II.), and the latter from the St. Helena results for 1892–1906 (Plates 12 and 13), with a *deduction of* 15 *per cent.* to bring the values to *sea level.* This final table is as follows:—

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
North East Trade. Miles per hour.	10	11	11	12	11	10	9	7	8	6*	8	10	9·4
South East Trade. Miles per hour.	14	13	13	12	11*	12	12	15	17	15	16	15	13·8
Mean. Miles per hour	12	12	12	12	11	11	10·5*	11	12·5	10·5	12	12·5	11·6

Accepting this table as the best representation which can be given of the monthly values, it will be noticed that in the North East Trade the values range from 6 miles to 12 miles per hour, and in the South East Trade from 11 miles to 17 miles per hour. These are corrected values to which the scale of equivalents given in the footnote of p. vii. is applicable, and therefore, the range on the Beaufort scale may be taken as being from 2 to half-way between 3 and 4 for the North East, and from 3 to half-way between 4 and 5 for the South East.

The original estimates of the North East would therefore, be mainly 2, 3 and 4 on the Beaufort scale, while the South East would be concerned mainly with estimates of 3, 4 and 5.

It is true that the difference of range here indicated is small, but the numbers 2, 3 and 4 of the Beaufort are precisely those which were determinable by the speed of the ship in sailing days and for which therefore instrumental precision was almost attainable, whereas the number 5 of the Beaufort scale marks the first step in the estimation by the amount of sail a ship can carry and is therefore a cruder estimate.

I am consequently led to the opinion that the absence of the seasonal variation from the marine observations is really due to the unfortunate circumstance that for winds of the velocity of the South East Trade at sea the variations which, on the average, are just included within the range of one point of the scale are not likely to be exhibited. On the other hand, there is every likelihood that

* The asterisk marks the lowest of the monthly values.

the seasonal variation in the marine observations of the North East Trade are real and in that case the results of the investigation bring out the interesting point that the variations in the North East Trade are practically complementary to those of the South East. In the table on p. ix. I have given the means of the two Trades for each month to show how nearly complementary the variations are.

A comparison of the difference of character of the diagrams for each year of the respective winds, Plates 5 to 9, will bear out the conclusion. The irregular fluctuations of the South East Trade are in marked contrast with the orderly march of the North East. A diagram (not reproduced in this volume) representing the consecutive monthly results for St. Helena (Table X.) and the corresponding serial monthly results for the North East Trade (Table III.) is very suggestive in the contrast of the run of the two curves.

The same considerations point to a similar difficulty in dealing with the variations in the strength of the South East Trade from year to year for the purpose of comparison with the temperature of the North Atlantic. It is much to be regretted that the records of the anemometer for the years 1903–05 are not available to give a measure of the variations from year to year of the same kind as that of the seasonal variation. According to the Table III. of p. 7 the North East Trade is remarkably uniform in the mean of the year, the variation does not exceed half a mile per hour, but the anemometer at St. Helena shows variations of as much as 3·7 miles per hour. We must wait for further data to decide the points which turn on these variations.

It is, however, interesting to note other meteorological changes with which the seasonal changes in the wind velocity may be associated. Let me first call attention to the seasonal variation in the position of the equatorial region of doldrums, the meeting-place of the two Trade Winds. In the year 1904, when the publication of the *Wind Charts of the South Atlantic* was completed, Commander Hepworth prepared some notes to accompany the charts. They formed the subject of a paper before the British Association at Cambridge in 1904, and were published as an official publication (M.O. 177) in 1905. Among the illustrations are a series of twelve "Monthly Charts showing the relation of the South Atlantic Anticyclone to the region of Doldrums." From these charts it appears that in March or April the belt of doldrums is at the furthest south; its western extension crosses the equator at from 35° to 40° W. Long.; stretching further north its eastward portion still remains within the 5th parallel of N. Latitude. In May the belt begins to recede to the northward. The recession continues until September, when the central line of the belt crosses the 10th parallel of N. Latitude at the 40th meridian and extends eastward to the coast of Africa in the 15th parallel. The belt of doldrums is then at its furthest north, and, from September onward, it wanders southward until it reaches its southern position in March. Thus the period of strongest Trade Wind at St. Helena corresponds with that of the most northerly position of the belt of doldrums. The central line is then nearly twice as far north of the parallel of St. Helena as it is in March and April when the strength of the Trade is nearing its annual minimum. The seasonal variation of wind velocity thus appears to be primarily associated with the seasonal variation of the position of the belt of doldrums. In view of the complementary character of the variation in the two opposing Trades the pushing forward of the belt of doldrums with increasing southerly wind is very suggestive.

There are also marked seasonal variations in the other meteorological elements. In order to facilitate an examination of this point I have had the highest and lowest monthly values specially marked in the various numerical summaries which are printed here.

In the tables on p. ix. the highest of the monthly values has been indicated by "clarendon" type and the lowest by an asterisk *, in accordance with the practice of Professor Hann and of the Meteorologische Zeitschrift. In the tables i. to xv. the asterisk has already been employed for other purposes, and in consequence two different "clarendon" types are used for the highest and lowest values. Looking through the maxima and minima thus indicated we notice that the period August to November includes the months of lowest temperature, lowest vapour pressure and lowest rainfall, and, as we have seen, it is the period of greatest wind velocity. On the other hand, the period March to May includes the months of highest temperature, greatest vapour pressure and greatest rainfall; it is nearly coincident with the period of least wind velocity—April, May, June. The difference between the maxima and minima of the several elements will be seen to be considerable. We may thus draw the conclusion that as the South-East Trade wind becomes stronger, and pushes the belt of doldrums to the northward against the weakening North-East Trade, it also becomes colder at St. Helena, carries less water vapour and produces less rainfall. This sequence of events takes place while the sun is north of the equator. When the sun crosses the line again on its southward journey

the changes are reversed; the North-East Trade strengthens, the South-East weakens, and the belt of doldrums moves back again to the equator.

It is curious that, according to table xi., p. 22, the seasonal change is echoed in the amount of cloud at 9 a.m. which varies from 8 to 9 between March—May and September at St. Matthew's vicarage; thus there is least cloud at 9 a.m. in the time of the year when the rainfall is greatest, and *vice-versâ*.

In two of the meteorological elements at the same station the seasonal variation does not correspond with the changes in the Trade wind: they are the barometric pressure and the mean relative humidity at 9 a.m. The range of monthly values of humidity is only three per cent. Pressure is at its maximum in July and its minimum in March. The seasonal variation of pressure is probably less closely related to local conditions than those of the other elements.

Thus seasonal variation in the strength of the South-East Trade fits in very appropriately with other recognised changes which are incidental to the movement of the sun in declination, and the general sequence of events is in reasonable accord with what we should expect.

Changes in the Direction of the South East Trade.

Another point of difference between the Marine observations for the South East Trade and the anemograph records occurs with reference to the change of direction shown in Plate 11, Figure 1. Reading off from that diagram it will be seen that there is a change of more than 22° towards the South between the dismounting of the anemograph in 1902, when the direction was 133° (S. 47° E.), and the re-erection in 1905, when it was shown as 155° (S. 25° E.). There is no such change of direction indicated in Table IV., p. 8, which shows a difference in the same sense between 1902 and 1905, but only of 2°. Careful inquiry has failed to elicit any good reason for attributing the difference to defects in the instrument, moreover, the direction in 1905 differs little from the original direction, 152°, in 1892. Upon consideration I think the difference may be connected with actual meteorological facts. An examination of the *Wind Charts of the South Atlantic* (M. O. Publication, No. 168), shows that St. Helena is in what may be called an unstable position with reference to the run of the isobars and, in consequence, with reference to the winds related thereto. An oval shaped closed isobar is nearly to the South of its position and the displacement of the oval to the Eastward may put a good deal of easting into the direction of the wind at St. Helena, while a displacement to the Westward would exaggerate the southing. One cannot speak in the same way with reference to the whole of the area indicated in the frontispiece as that used for the marine observations representing the South East Trade. At the present time I have no means of testing the suggestion, but I am not disposed to leave out of sight the possibility of a meteorological explanation of the phenomenon. It furnishes an additional reason for a closer examination of the fluctuations in position and intensity of the high pressure areas of the southern oceans.

Diurnal Variations of the South East Trade.

Whatever be the explanation of these perplexing differences they do not in any way invalidate the results which Mr. Dines has obtained for the average vector changes in the South East Trade, as represented for the several months in Plates 12 and 13, and for the year in Plate 14. The constancy of the phase of the second harmonic component, as represented in the lower figures of Plate 16, is very remarkable, and it is still further to be noted that the phases of the East-West component agree very nearly with those of the second harmonic curve in pressure, which are the same the world over, starting with a maximum of Eastern velocity when the pressure is at its maximum.

It may be of interest for those readers who are unfamiliar with sine curves and their composition to consider how the actual process of the diurnal variation in the record should be pictured. The trade wind passing the anemometer traverses on the average about 400 miles in a day, and supposing that the diurnal changes at St. Helena are equally characteristic of the 400 mile stretch, 200 miles on either side of the station, the diurnal changes will be regularly experienced by the wind during that stretch. We may, therefore, picture to ourselves air starting for the anemometer from 200 miles off at 7 a.m. with a velocity, along its mean direction (*see* Fig. 4, Plate 14), of 17 miles per hour. For some cause or other it will forthwith begin to yaw to the left and by 4 p.m. when it will have traversed about 150 miles it will be about 9 miles out of its course but will be moving parallel to its original direction. At 4 p.m. it will begin to yaw back again, but it will actually leave the anemometer some miles on its right at 7 p.m., and by 7 a.m. the next morning it will have got on its original track again with the anemometer directly behind it, but between 9 o'clock at night and 5 o'clock in the morning it will have made another and slighter lurch to the left and have recovered itself again. If we imagine a track 400 miles long and 9 miles wide and suppose a car travelling along it, starting at top speed along the right hand side at 7 a.m., beginning to slow and lurching over to the other side of the track between 7 a.m. and 4 p.m., then getting back again but setting up at the 325th milestone a fresh lurch backwards and forwards and finally recovering its proper position on the right hand side at 7 a.m., within the 75 miles, we shall have a fair impression of the regular unsteadiness of the gait of the Trade wind as it travels over the South-Atlantic.

The concluding sections of the paper and Mr. Gold's contribution are devoted to an endeavour to trace the origin of this regular unsteadiness. Mr. Dines's diagram, Plate 17, shows that so far as the semi-diurnal change is concerned it is just the opposite of what it would be if it followed the semi-diurnal change in the pressure gradient. Mr. Gold's solution of the question on dynamical principles gives results which are hopeful but not final. The agreement between the theoretical and actual values of the amplitudes and phases of the East-West component as shown on p. 44 is very striking.

The remarkable contrast between the persistence of the type of diurnal wind changes in all months, Plates 12, 13, and the seasonal variation of type of the corresponding sequence of changes in magnetic force, Plate 18, is a very suggestive result.

The collection of papers here presented will no doubt strike the reader as fragmentary in character, and in many ways incomplete. That result is due to a combination of circumstances which need not be detailed here.

The time for the completed story has not yet been reached, and the opportunities for work at it are few. We are dealing in these papers for the first time with certain aspects of a difficult subject, and until now we have not realised what the difficulties are. What has been done is sufficient to show that there is an interesting story under the apparently monotonous surface of the Trade winds. Had I kept back what is now done until all was completed, I should have lost one of the strongest inducements for the completion of the work, and by their publication the data will be available for other meteorologists who are interested in the subject. The discussion of the St. Helena records is limited to the anemometric results. It was brought to a close when Mr. Dines left the Office for Kew Observatory at the end of the year 1908.

While the discussion has been in progress much information about the upper wind of the Trade region has been obtained by Messrs. L. Teisserenc de Bort and A. L. Rotch, by Professor Hergesell, with the co-operation of the Prince of Monaco or by Professor H. H. Hildebrandsson, for which reference may be made to the following papers :—

L. Teisserenc de Bort and A. L. Rotch.—Sur les preuves directes de l'existence du contre alizé. Comptes Rendus, 141, 605, 1905.

A. L. Rotch and L. Teisserenc de Bort.—Meteorological conditions above the Tropical North Atlantic. Met. Zeit. Hann Band, p. 270, 1906.

L. Teisserenc de Bort and A. L. Rotch.—General results of the meteorological cruises of the *Otaria* on the Atlantic in 1905, 1906, and 1907. Nature, 80, 219, 1909.

H. Hergesell.—Drachenaufstiege auf dem Mittelmeer und dem Atlantischen Ozean an Bord der Yacht Seiner Hoheit des Fürsten v. Monaco, im Jahre 1904, Proc. verb. Comm. internat. aérostat. Sci., St. Petersburg, p. 86, 1904. *See also* Comptes Rendus, **140**, 331, 1905

H. Hergesell.—Ascensions de ballons en pleine mer, pour étudier les conditions de température et d'humidité, ainsi que les courants atmosphériques jusqu' à des altitudes très élevées de l'atmosphère. Bull. Musée Océanogr. Monaco, 1905.

H. Hergesell.—Sur une exploration de l'atmosphère libre au dessus de l'Ocean Atlantique, au nord des régions tropicales, en 1905. Bull. Musée Océanogr. Monaco, 1905.

H. H. Hildebrandsson.—Sur la circulation des couches supérieures de l'air au dessus du maximum de l'Atlantique Nord. Met. Zeit., Hann Band, p. 117, 1906.

Meteorological Office, London, S.W., 26th July, 1910.

A COMPARISON OF THE CHANGES IN THE TEMPERATURE OF THE WATER OF THE NORTH ATLANTIC, AND IN THE STRENGTH OF THE TRADE WINDS.

BY

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The information upon which this inquiry is based is derived from various sources, but chiefly from logs and similar documents, contributed by marine observers to the Meteorological Office ; and, as regards the South-East Trade wind averages, and all the data relating to the five years' period 1902–1906, entirely from that source. The principal objects of the investigation are as follow :—To ascertain what changes occur normally in the strength of the Atlantic Trade winds, month by month ; and what departures from the average have taken place during the five years 1902–1906. To determine the changes in the distribution of surface temperature in the North Atlantic that occur normally in succeeding months, and to compare these average results with similar data recorded in each month during the five years' period 1903–1907. To find whether or not any relation can be traced between variations in the strength of the Trade winds and the distribution of surface temperature in the North Atlantic, during the periods referred to.

In order to confine that portion of the inquiry which relates to the Trade winds within manageable limits, two representative areas have been selected for examination. One of these areas lies well within the region of the North-East Trade, and the other is in the heart of the South-East Trade. For both these areas a vast number of observations is available monthly. The area selected to represent the conditions obtaining in the North-East Trade wind region is situated between the 10th and 30th parallels of North latitude, and between the 30th meridian of West longitude and the African coast. It covers 1,000,000 square miles. The South-East Trade wind region is represented by an area covering 1,380,000 square miles. This area is contained between the meridian of Greenwich and the 10th meridian of East longitude, from the 10th to the 30th parallels of South latitude ; and by the meridian of Greenwich and the 10th meridian of West longitude, between the Equator and the 20th parallel of South latitude (*see* Frontispiece).

For the comparison of the data relating to the North-East Trade, month by month, during the five years 1902–6, with normal conditions, homogeneous averages for a long period are not available ; that is to say, the averages which are obtainable for the area selected are not all from the same source, and are not referable to the same series of years, and are not therefore suitable.

For the area chosen to represent the normal conditions of the South-East Trade wind region, reliable resultants have been computed from data utilized in the Meteorological Office in the preparation of a set of wind charts for the South Atlantic Ocean, published in 1904. The four hourly observations used in the compilation of these monthly charts were recorded during the 45 years 1855–1899. The number of observations used in the several months range between 87,000 for January and 73,000 for June. In connexion with the foregoing, four Tables have been prepared. Table I. shows resultants of wind direction and force in the South-East Trade wind region, compiled from the above mentioned data ; Table II., resultants of wind direction and force derived from observations recorded during the five years 1902–1906, for the North-East and South-East Trade wind regions respectively ; and Tables III. and IV., similar results for each of the five years referred to.

Each of these tables is supplemented by illustrations, exhibiting graphically the information set forth in the tables. (Plates 1 to 2 and 5 to 9.) In these diagrams the direction of the wind is shown by the angle the arrow representing it makes with the perpendicular. The force of the wind is indicated by the position of the arrow-head on the diagram in relation to a scale erected perpendicularly on either side of the diagram ; it can also be estimated by the length of the arrow, which is drawn in proportion to a scale supplied representing the Beaufort numbers. The arrow-heads are connected by lines, these forming a curve of wind velocities ; and at the shaft end of each arrow the number of observations is given from which each wind resultant has been computed.

Commencing on January, 1902, charts showing the distribution of temperature at the surface of the North Atlantic have been drafted in the Meteorological Office for each succeeding month, to the present time. Since April, 1902, these charts have been reproduced as insets, each month, on the Monthly Meteorological Charts of the North Atlantic and Mediterranean, which are issued within six weeks of the close of the month to which the surface temperature results refer. At first the results reproduced on the Monthly Charts related only to that portion of the Ocean which lies to the North of the 30th parallel, but subsequent to March, 1906, the whole of the results charted have been reproduced on the Monthly Charts. In the compilation of each of these monthly sea surface temperature charts upwards of 4,000 observations are plotted. The values for each month are shown for spaces of 2° of latitude by 2° of longitude, and the departures from the averages, which are obtained from observations extending over a long series of years, are given underneath the mean temperature for the month in each 2° square. The areas of excess and of defect of temperature are separated by a fine line.

The grouping of the areas of excess and defect, month by month, demonstrated that, in addition to the periodical changes in the distribution of surface temperature of the North Atlantic, in the different months, marked changes take place in the degree of excess or defect, and in the actual distribution of temperature also.

The data upon which the averages of sea surface temperature for each 2° square are based have been obtained principally from the following sources :—

(1.) "Charts showing the Surface Temperature of the Atlantic, Indian, and Pacific Oceans" (for the months of February, May, August and November). Compiled from observations recorded during the twenty-nine years 1855–1883 ; and published by the authority of the Meteorological Council.

(2.) "Resultate Meteorologischer Beobachtungen von Deutschen und Holländischen Schiffen für Eingradfelder des Nordatlantischen Ozeans" published by the Deutsche Seewarte, 1893. The number of years' observations, from which the mean results obtained from the latter source are derived, varies, but the average number is about seven.

(3.) "Onderzoekingen met den Zeethermometer" by the Royal Meteorological Institute of the Netherlands in 1861. In addition to the above, some unpublished data, collated in the Meteorological Office within the last decade have been used, and all of the sea surface temperature observations relevant to the North Atlantic contributed to the Office in recent years have been employed.

(Plate 3.) A glance at the accompanying Chart of Mean Surface Temperature for the year reveals the general effect of the equatorial current, and its branches, upon the surface temperature of the Southern and South-Western Atlantic. The equatorial current, the counter and the Guinea currents, roughly stated, are found between the 80° isotherms. West of the 30th Meridian of West longitude the equatorial current divides, part of the stream continuing its course to the Westward, part turning Southward and merging into the Brazil current. The area enclosed by the 82° isotherm, in the Caribbean Sea, probably owes its slightly higher temperature to the shoals in the locality.* For the Southern and Western portions of the Gulf of Mexico observations are wanting, but the values charted over the remaining portion of the Gulf suffice to show that the temperature of the equatorial current is still high in this locality. From Florida Strait, Northward and Eastward, the effect of the current, known during the remainder of its course as the Gulf Stream, is indicated by the deviation of the isotherms from the East and West direction, and their bend North-Eastward as far as the 38th parallel of North latitude on a line drawn between the Strait and Cape Race. The influence of the Labrador Current upon the surface temperature can be traced from the far North, on the Western side of the Atlantic, Southward and Westward to its place of meeting with the Gulf Stream, which is made apparent by the steepening of the surface temperature gradient as the two currents run side by side in opposite directions. The existence of a 41° patch of surface water, situated to the East of Newfoundland, may be accounted for by the prevalence of ice in that locality from March to September.

For the present inquiry the surface temperature observations relating to the Northern portion of the North Atlantic, from the 30th parallel Northwards only are dealt with. It is desirable to exhibit, in as comprehensive a manner as possible, characteristics in the distribution of surface temperature, during each month of the five years 1903–1907, and to show, by comparison with average results, the departures from the normal that have taken place in those years.

The difficulty of introducing for comparison, compactly, and yet on a sufficiently large scale, sixty of these charts, and the laboriousness of comparing the results with a chart showing normal

* Presuming the temperature of the stream in the Caribbean Sea to be fairly uniform to a considerable depth, then the water flowing over the shoals, although coming from a greater depth, would nevertheless have about the same temperature normally as the surface of the deeper water, and would be more readily heated by the sun's rays than the latter.

conditions is obvious. It happens, however, that some of the most important changes in temperature which take place on the surface of the North Atlantic, are found to occur in two belts, or zones : the one lying between Florida Strait and the South-West coast of Ireland, and the other between Florida Strait and Cape Race. The changes which take place in the former zone may be attributed largely to the influence of the Gulf Stream, and in a lesser degree to that of the Labrador and Greenland Currents ; but the changes which occur in the latter zone are probably due almost as much to the activity of the Labrador Current as to that of the Gulf Stream.

A graphic method of showing the distribution of sea temperature in successive months, on selected routes, has recently been made use of with success by Professor D'Arcy W. Thompson, C.B., to show the results of observations of surface temperature of the North Sea. (See Second Report, Northern Area of the North Sea Investigation Committee.) In this method, which, as he mentions, was introduced into meteorology by M. Lalanne, in 1843, time is represented in the diagram (Plate 4) in one direction ; and space, or distance in a direction perpendicular to it. For instance, on the horizontal line representing the route between Florida Strait and Valencia, each degree of longitude is indicated ; and the successive months of the year (1905) are noted on the left-hand side of the diagram, in a vertical direction. Mean results of observations of equal surface temperature, plotted in the position relevant to the locality, and to the month in which they were taken, are then connected by lines, and the value of each line, which is termed a Thermo-isopleth, is given on either side of the diagram, or in other suitable position. By this method a year's observations, on any particular route can be shown in a small compass ; it has, therefore, been adopted here for the purpose of showing the surface temperatures on the two zones referred to, under normal conditions and during each of the five years mentioned.

Trade Winds.

The average results obtained for the 45 years' period, 1855–1899 (Table I., Plate 1), show that normally the South-East Trade is strongest (15·5 miles per hour) in February. It is relatively strong (15·0 miles per hour) in April and November ; also in March and December (14·9 miles per hour). This Trade is at about its average strength, which is 14·7 miles per hour, in January, August and October. It is lightest in May (13·7 miles per hour), and from that month gradually increases and is at its average strength in August. In September, the strength of the Trade decreases to 14·5 miles per hour. Average results of South-East Trade wind velocity for the five years 1902–1906, are somewhat in agreement with those for the long period. (Table II., Plate 2.) During these five years the Trade was strongest (15·0 miles per hour) in April, June, and August ; and was relatively strong (14·9 miles per hour) in November. It was lightest (13·0 miles per hour) in July ; and very light (13·1 and 13·3 miles per hour, respectively) in January and March ; and lighter than the average for the year in October (13·7 miles per hour). Averages for the same five years show that the North-East Trade wind during this period was strongest in April (13·5 miles per hour) ; that it was relatively strong in February (13·0 miles per hour) ; in March (12·6 miles), and in May (12·4 miles). From May it rapidly decreased in strength until August, when it had a mean velocity of only 8·2 miles per hour. The Trade was lightest (7·4 miles per hour) in October, after having increased somewhat in strength to 9·7 miles in September. From October the mean velocity of the Trade wind increased until February.

Sea Surface Temperature.

Average results of observations of surface temperature extending over a long series of years (Plate 4) show that, in the Florida Strait to Cape Race zone, as well as in the Florida Strait to Valencia zone, the temperature of the surface water normally is lower in February, March and April than during any other period of the year, and is lowest in March. It is relatively low, as compared with any other months than the above, in January, May, and December ; and in these months January has the lowest mean surface temperature, and May the highest.

The surface temperature in these two zones is relatively high in June, October and November ; highest as regards those months in October, lowest in November ; it is higher in July, August and September than during any other period of the year ; highest in August, not quite so high in July as in September in the Florida Strait to Valencia zone, but in the Florida Strait to Cape Race zone the mean is found to be the same in the two months July and September.

Wind Force and Surface Temperature.

A close comparison between results of Atlantic Trade wind velocity and North Atlantic sea surface temperature, in the two zones referred to, leads to the belief that a relation may be traced between departures from the average in the velocities of the North-East and South-East Trades, in any one year, and deviations from the normal in the distribution of surface temperature in the North Atlantic in the succeeding year. There appears to be considerable evidence, indeed, to prove that variations in the average strength of the Trades, North-East and South-East, during a series of months, and at times during even so short a period as a month, are roughly reflected in the distribution of surface temperature in the North Atlantic in the corresponding series of months, or month, as the case may be, of the year following. The connexion is not always apparent, as many other causes affecting the temperature of the water of the ocean tend to mask it, notably the activity of the Labrador and Greenland Currents, and the strength and persistency of the Westerly winds; moreover, the effects of variation in the velocity of the Trades, upon the temperature of the water through the agency of Equatorial Current, obviously is not always produced in the same time.

In order to trace this relation a comparison of the temperature results for all of the 2° squares for each month in the zones referred to with similar average results does not suffice because, frequently, an area of relatively warm Gulf Stream water, extending East-North-Eastward of its normal limit is cut in two by a cold current from the North. Another series of diagrams has therefore been introduced to supplement the method of comparison referred to. On these diagrams a vertical line is drawn to represent the average Easternmost limits of certain selected isopleths, for each succeeding month of the year. Time is represented vertically in columns right and left on the diagram; space, to right and left on either side of the vertical line, which represents normal limits, is divided into degrees of longitude, from 0° to 10° East and West of normal.

By these means the effect produced by the flooding, with Gulf Stream water, of the North Atlantic, as represented by the Florida Strait to Valencia, and the Florida Strait to Cape Race zones, is usually indicated.

1902–3.

(Plate 5.) The average velocity of the South-East Trade wind in the year 1902 was nearly 3 miles per hour below the average of the 45 years' period (1855–1899). The average velocity of the North-East Trade wind in this year is found to have been slightly above that of the five years' period (1902–1906). The mean temperature of the surface water of the North Atlantic, between Florida Strait and Valencia, and Florida Strait and Cape Race, is shown to have been considerably below the average in the following year. The curve of average velocity relevant to each Trade wind in 1902 is erratic; and, while the curve of averages for the South-East Trade shows a considerably lower velocity than the curve of the 45 years' averages from January to May, that of the North-East Trade exhibits, for the most part, a higher velocity during that period. The results combined are roughly reflected in the surface temperature results, relating to the two zones in the North Atlantic, from January to May, 1903. From June to October, 1902, inclusive, the South-East Trade was, for the most part, deficient in strength, and the North-East Trade, although its velocity is found to have been higher than the average of the five years' period, was rapidly declining in strength. From June to October, 1903, inclusive, the mean surface temperature in both zones of the Atlantic is shown to have been in defect of the normal. From October to December, 1902, inclusive, the velocity of the South-East Trade was normal; and that of the North-East Trade in defect. In the corresponding months of the following year the surface temperature in the Florida–Valencia zone was in defect, but the 70° isopleth in November and December is found to have been considerably to the Eastward of normal limits. In the Florida–Cape Race zone the surface temperature in the three months October to December was in defect.

1903–4.

(Plate 6.) In the year 1903 the strength of the South-East Trade was slightly below the average, and the strength of the North-East Trade was the same as the average of the five years' period. The mean surface temperature in both the Florida–Valencia and the Florida-Cape Race zones in the following year was not far from normal, but slightly in defect. In the months of January and February, 1903, both Trades were below their average strength, and in January and February, 1904, the surface temperature in both zones was in defect. In March and April, 1903, the strength of both Trades was above the average, and in the corresponding months of 1904 the surface temperature in the Florida–Valencia zone was about normal, and in the Florida–Cape Race zone it was becoming higher but still slightly below normal. During the four months May to August the strength of the South-East Trade was slightly below the average; and that of the North-East Trade considerably below. In the same months of the following year the surface temperature in the two zones was below the mean for the period. In the three months October to December, 1903, both Trades had a strength above the average; and in the corresponding months of the year following, the surface temperature in the Florida–Valencia zone was above normal, the 80° isopleth reaching far to the Eastward of its normal position for the month in September, and the 70° isopleth being well to the Eastward of its normal position at the end of October, and in the beginning of November. In the Florida–Cape Race zone the surface temperature during these three months was in defect, but the 70° isopleth is found to have been to the Eastward of its normal limit, and at the end of December as much as 3° of longitude to the Eastward.

1904–5.

(Plate 7.) The strength of both Trades was below the average during 1904. The velocity of the South-East Trades was ¾ mile per hour below the average of the 45 years' period; and the velocity of the North-East Trades ¼ mile per hour below that of the five years' average. The surface temperature in the following year (1905), in the Florida–Valencia zone, as a whole, was slightly below normal, and in the Florida–Cape Race zone it was almost persistently below normal.

In January, February and March, 1904, the strength of the South-East Trade is found to have been considerably below the average for those months, but the North-East Trade in January and February blew with a strength above that of the average for those months in the five years' period, and differed but little from the average in March. The surface temperature in the Florida–Valencia zone is found to have been rather below normal in the same months of the following year; and in the Florida–Cape Race zone decidedly below. The South-East Trade had a higher velocity than the average in April, May and June, 1904, and the North-East Trade also had a higher velocity in April and May; but a lower in June. In the corresponding months of the following year the surface temperature was about normal in the Florida–Valencia zone, but slightly below in the Florida-Cape Race zone. In July, August and September, 1904, the average strength of the South-East and North-East Trades was slightly below normal; and in the corresponding months of 1905 the surface temperature in the Florida–Valencia zone is found to have been rather below normal. In the Florida–Cape Race zone the temperature was below normal. In September, however, the 80° isopleth extended Eastward of normal as much as 5° of longitude. During the three last months of 1904 the strength of both Trades was slightly below the average for the period; and in the months October and November, 1905, the surface temperature in both zones was slightly below normal, but in December it was normal. The 70° isopleth, however, was to the Eastward of its normal limits in November and December.

1905–6.

(Plate 8.) During the year 1905 the combined strength of the Trades was somewhat below the average. The South-East Trade had a velocity of half a mile per hour below the average; and the North-East Trade a velocity of nearly a quarter of a mile above; the curve of velocities representing the latter followed closely the average curve for the five years' period. The mean sea surface temperature in the Florida–Valencia zone in the following year was, as a whole, above normal. In the Florida–Cape Race zone also the surface temperature was above normal except in the months of June, July, August and December, when it was slightly below. In January, 1905, both South-East and North-East Trades were below their average strength. The surface temperature, between the Florida Strait and Valencia, and the Florida Strait and Cape Race in January, 1906, was slightly above normal. From February to June, inclusive, the velocity of the South-East Trade was nearly half a mile per hour above the average of the 45 years' period; and that of the North-East Trade nearly a quarter of a mile per hour above the average of the five years' period. In February, March, April and May, of the following year, the surface temperature in both zones was about normal. The 60° isopleth is found, however, to have been to the Eastward of its normal limit for the period, and the 70° isopleth to the Eastward, for the most part, also. In June the surface temperature was below normal. In July, 1905, the South-East Trade was 1·7 mile per hour below its average velocity; and the North-East Trade 0·8 mile below. In July of the next year the surface temperature in the Florida–Valencia zone was normal, but in the Florida–Cape Race it was considerably below. In August, 1905, the velocity of the South-East Trade exceeded the average by 1·6 mile per hour; after that it declined, and remained considerably below until December, when it increased and almost attained its average velocity. The North-East Trade, however, had a velocity well above that of the average of the five years' period until December, when it declined, and was a good deal below. In August, 1906, the surface temperature in the Florida–Valencia zone was above normal; in September and October it was very much above; and in November and December it was slightly above normal. In the Florida–Cape Race zone the surface temperature was slightly below normal in August and September, and about normal to the close of the year.

1906–7.

(Plate 9.) During 1906 the combined strength of both Trades was about normal. The South-East Trade had a mean velocity of 0·1 mile per hour below the average of the 45 years' period; and the North-East Trade a mean velocity of 0·2 mile per hour above the average of the five years' period. During the year following the mean surface temperature in the Florida–Valencia zone was about normal, but in the Florida–Cape Race zone it was below. In the four months January to April, 1906, the mean velocity of the South-East Trade was nearly one mile per hour below the average for the period, and that of the North-East Trade rather more than ½ mile below. The surface temperature in the Florida–Valencia zone in the corresponding months of the following year, was normal, and in the Florida–Cape Race zone was below normal. In the four months May to August, 1906, the combined velocity of both Trades was below the average, for, whereas the velocity of the South-East Trade was 0·15 mile per hour above the average for the period, that of the North-East Trade was 1 mile per hour below. In the corresponding months of the following year the surface temperature was well below normal in both zones. For the last four months of the year 1906, the velocities of both Trades were largely above the averages for the period; the velocity of the South-East Trade being 1·1 mile per hour above, and that of the North-East Trade 2 miles per hour above. The surface temperature in the Florida–Valencia zone during the corresponding months of the following year was in excess of normal, but in the Florida–Cape Race zone it was in defect.

TABLE I.—S.E. TRADE WIND.

FORTY-FIVE YEARS' RESULTANT FOR EACH MONTH, AND FOR THE TWELVE MONTHS.

Month.	Direction.	Statute miles per hour.	Equivalent Beaufort numbers.
January	S. 41° E.	14·7	3·5
February	S. 42° E.	15·5	3·7
March	S. 43° E.	14·9	3·6
April	S. 42° E.	15·0	3·6
May	S. 43° E.	13.7	3·3
June	S. 44° E.	14·2	3·4
July	S. 41° E.	14·4	3·5
August	S. 41° E.	14·7	3·5
September	S. 37° E.	14·5	3·5
October	S. 39° E.	14·7	3·5
November	S. 41° E.	15·0	3·6
December...	S. 41° E.	14·9	3·6
Year	S. 41° E.	14·7	3·5

TABLE II.—1902–1906.

FIVE YEARS' RESULTANT FOR EACH MONTH, AND FOR THE TWELVE MONTHS.

Month.	N.E. Trade.				Month.	S.E. Trade.			
	Wind.			No. of Observations.		Wind.			No. of Observations.
	Direction.	Miles.	Beaufort.			Direction.	Miles.	Beaufort.	
January ...	N. 48° E.	11·9	3·0	1,644	January ...	S. 36° E.	13·1	3·2	1,516
February ...	N. 41° E.	13·0	3·2	1,680	February ...	S. 35° E.	14·1	3·4	946
March	N. 20° E.	12·6	3·1	1,820	March	S. 37° E.	13·3	3·2	993
April	N. 20° E.	13·5	3·3	1,874	April	S. 40° E.	15·0	3·6	1,437
May	N. 18° E.	12·4	3·1	2,013	May	S. 37° E.	14·3	3·4	1,274
June	N. 23° E.	11·3	2·9	1,667	June	S. 39° E.	15·0	3·6	1,191
July	N. 23° E.	10·2	2·6	1,823	July	S. 40° E.	13·0	3·2	1,140
August	N. 24° E.	8·2	2·2	2,032	August ...	S. 41° E.	15·0	3·6	1,359
September ...	N. 31° E.	9·7	2·5	2,595	September ...	S. 38° E.	14·3	3·4	1,136
October ...	N. 29° E.	7·4	2·1	1,936	October ...	S. 35° E.	13·7	3·4	1,559
November ...	N. 44° E.	9·8	2·6	1,652	November ...	S. 41° E.	14·9	3·6	1,118
December ...	N. 44° E.	11·7	3·0	2,232	December ...	S. 38° E.	14·4	3·4	1,259
Year ...	N. 30° E.	10·6	2·7	22,968	Year ...	S. 38° E.	14·2	3·4	14,928

TABLE III.—N.E. TRADE WIND.

RESULTANTS FOR EACH OF THE FIVE YEARS 1902–6.

DIRECTION.

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1902	N. 43° E.	N. 35° E.	N. 25° E.	N. 1° E.	N. 15° E.	N. 28° E.	N. 28° E.	N. 27° E.	N. 24° E.	N. 43° E.	N. 21° E.	N. 54° E.	N. 29° E.
1903	N. 46 E.	N. 28 E.	N. 20 E.	N. 21 E.	N. 11 E.	N. 2 W.	N. 11 E.	N. 24 E.	N. 31 E.	N. 21 E.	N. 61 E.	N. 35 E.	N. 27 E.
1904	N. 49 E.	N. 32 E.	N. 5 E.	N. 16 E.	N. 21 E.	N. 16 E.	N. 22 E.	N. 16 E.	N. 29 E.	N. 32 E.	N. 42 E.	N. 50 E.	N. 27 E.
1905	N. 52 E.	N. 48 E.	N. 27 E.	N. 24 E.	N. 22 E,	N. 27 E.	N. 23 E.	N. 24 E.	N. 33 E.	N. 21 E.	N. 37 E.	N. 43 E.	N. 33 E.
1906	N. 47 E.	N. 46 E.	N. 19 E.	N. 26 E.	N. 17 E.	N. 26 E.	N. 27 E.	N. 32 E.	N. 36 E.	N. 30 E.	N. 54 E.	N. 44 E.	N. 34 E.

VELOCITY IN MILES PER HOUR.

Force by Beaufort Scale given in *italic* figures underneath.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1902	11·1 *2·8*	11·7 *2·9*	13·9 *3·4*	10·8 *2·8*	15·0 *3·6*	12·1 *3·0*	14·7 *3·5*	9·2 *2·4*	9·9 *2·6*	6·5 *1·9*	9·0 *2·4*	11·1 *2·8*	10·8 *2·8*
1903	11·8 *3·0*	9·9 *2·6*	13·4 *3·3*	15·4 *3·7*	11·2 *2·8*	8·0 *2·2*	8·6 *2·3*	6·1 *1·8*	9·5 *2·5*	9·6 *2·5*	10·5 *2·7*	14·2 *3·4*	10·6 *2·7*
1904	13·4 *3·3*	14·5 *3·5*	12·3 *3·1*	13·9 *3·4*	13·4 *3·3*	10·0 *2·6*	10·7 *2·7*	7·8 *2·2*	9·7 *2·5*	7·2 *2·0*	7·5 *2·1*	11·5 *2·9*	10·3 *2·7*
1905	10·8 *2·8*	14·4 *3·5*	12·3 *3·1*	12·9 *3·2*	12·1 *3·0*	12·0 *3·0*	9·4 *2·5*	9·5 *2·5*	10·3 *2·7*	7·0 *2·0*	10·6 *2·7*	9·1 *2·4*	10·8 *2·8*
1906	12·4 *3·1*	14·0 *3·4*	9·4 *2·5*	14·0 *3·4*	10·7 *2·7*	12·3 *3·1*	7·1 *2·0*	8·0 *2·2*	8·9 *2·4*	9·3 *2·5*	14·0 *3·4*	14·1 *3·4*	10·8 *2·8*

NUMBER OF OBSERVATIONS.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1902	205	182	296	163	254	291	343	479	351	375	259	342	3,540
1903	205	325	215	295	270	164	309	230	360	306	232	436	3,347
1904	254	205	212	556	538	310	451	649	651	460	524	621	5,431
1905	524	603	402	538	403	437	451	360	615	500	308	473	5,614
1906	456	365	695	322	548	465	269	314	618	295	329	360	5,036

TABLE IV.—S.E. TRADE WIND.

Resultants for each of the five years 1902–6.

Direction.

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1902	S. 41° E.	S. 36° E.	S. 23° E.	S. 42° E.	S. 33° E.	S. 40° E.	S. 42° E.	S. 40° E.	S. 38° E.	S. 36° E.	S. 41° E.	S. 44° E.	S. 39° E.
1903	S. 36 E.	S. 32 E.	S. 45 E.	S. 40 E.	S. 36 E.	S. 42 E.	S. 43 E.	S. 47 E.	S. 35 E.	S. 41 E.	S. 49 E.	S. 27 E.	S. 40 E.
1904	S. 30 E.	S. 40 E.	S. 41 E.	S. 41 E.	S. 33 E.	S. 32 E.	S. 42 E.	S. 41 E	S. 39 E.	S. 32 E.	S. 41 E.	S. 42 E.	S. 38 E.
1905	S. 37 E.	S. 34 E.	S. 38 E.	S. 35 E.	S. 41 E.	S. 42 E.	S. 38 E.	S. 40 E.	S. 33 E.	S. 32 E.	S. 34 E.	S. 37 E.	S. 37 E.
1906	S. 35 E.	S. 34 E.	S. 35 E.	S. 39 E.	S. 38 E.	S. 42 E.	S. 36 E.	S. 35 E.	S. 42 E.	S. 39 E.	S. 40 E.	S. 33 E.	S. 38 E.

Velocity in Miles per Hour.

Force by Beaufort Scale given in *italic* figures underneath.

1902	16·0 *3·8*	**9·8** *2·6*	10·6 *2·7*	13·1 *3·2*	12·8 *3·2*	**16·7** *3·9*	11·4 *2·9*	14·0 *3·4*	11·6 *2·9*	14·1 *3·4*	15·5 *3·7*	14·4 *3·5*	11·8 *3·0*
1903	13·1 *3·2*	14·4 *3·5*	13·2 *3·2*	16·0 *3·8*	**9·4** *2·5*	15·1 *3·6*	**17·2** *4·0*	15·2 *3·6*	12·8 *3·2*	15·8 *3·8*	15·4 *3·7*	14·0 *3·4*	14·5 *3·5*
1904	13·8 *3·4*	13·7 *3·3*	11·0 *2·8*	**15·5** *3·7*	14·3 *3·5*	14·7 *3·5*	**10·8** *2·8*	14·8 *3·6*	15·4 *3·7*	12·8 *3·2*	15·1 *3·6*	14·7 *3·5*	13·9 *3·4*
1905	13·0 *3·2*	15·0 *3·6*	14·7 *3·5*	16·0 *3·8*	14·9 *3·6*	16·0 *3·8*	12·7 *3·1*	**16·3** *3·9*	13·7 *3·3*	**12·3** *3·1*	12·6 *3·1*	14·7 *3·5*	14·2 *3·4*
1906	**12·3** *3·1*	14·7 *3·5*	14·4 *3·5*	15·2 *3·6*	15·7 *3·7*	12·5 *3·1*	14·8 *3·6*	14·6 *3·5*	**17·2** *4·0*	14·9 *3·6*	16·3 *3·9*	15·3 *3·7*	14·6 *3·5*

Number of Observations.

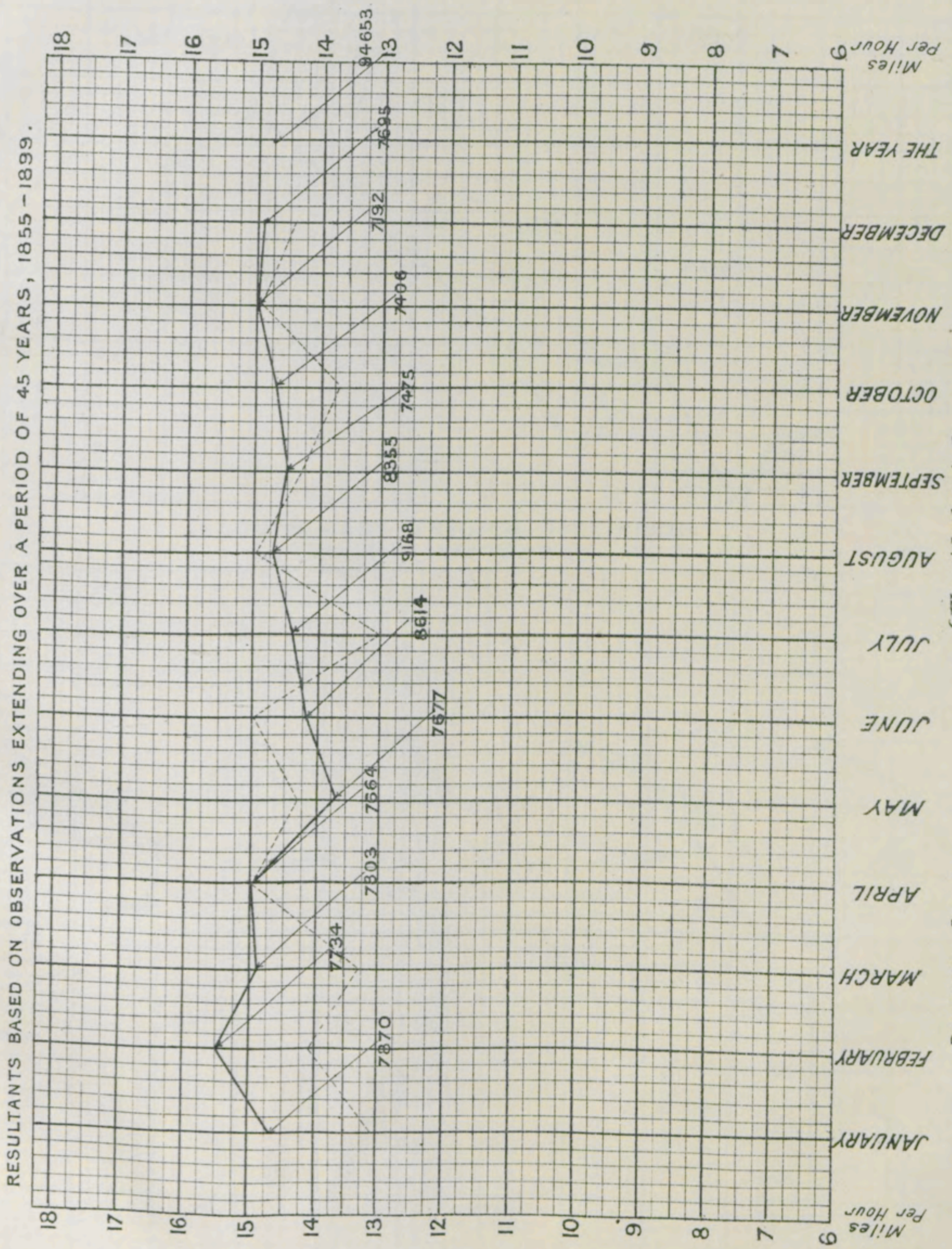
1902	155	75	126	383	136	284	95	224	256	230	261	274	2,499
1903	159	282	134	202	91	227	166	197	151	192	168	169	2,138
1904	185	191	148	370	368	210	370	383	222	413	295	346	3,501
1905	549	304	203	255	309	222	302	367	215	414	227	257	3,624
1906	468	94	382	227	370	248	207	188	292	310	167	213	3,166

Plate 1.

TRADE WIND RESULTANTS.

SOUTH EAST TRADES.

RESULTANTS BASED ON OBSERVATIONS EXTENDING OVER A PERIOD OF 45 YEARS, 1855–1899.



Arrows {Fly with the wind / Length proportional to Beaufort Scale / Number of observations for each month at tail of arrow.

Beaufort Scale 0 1 2 3 4 5

Dotted line is the resultant mean velocity for the 5 Years 1902-06.

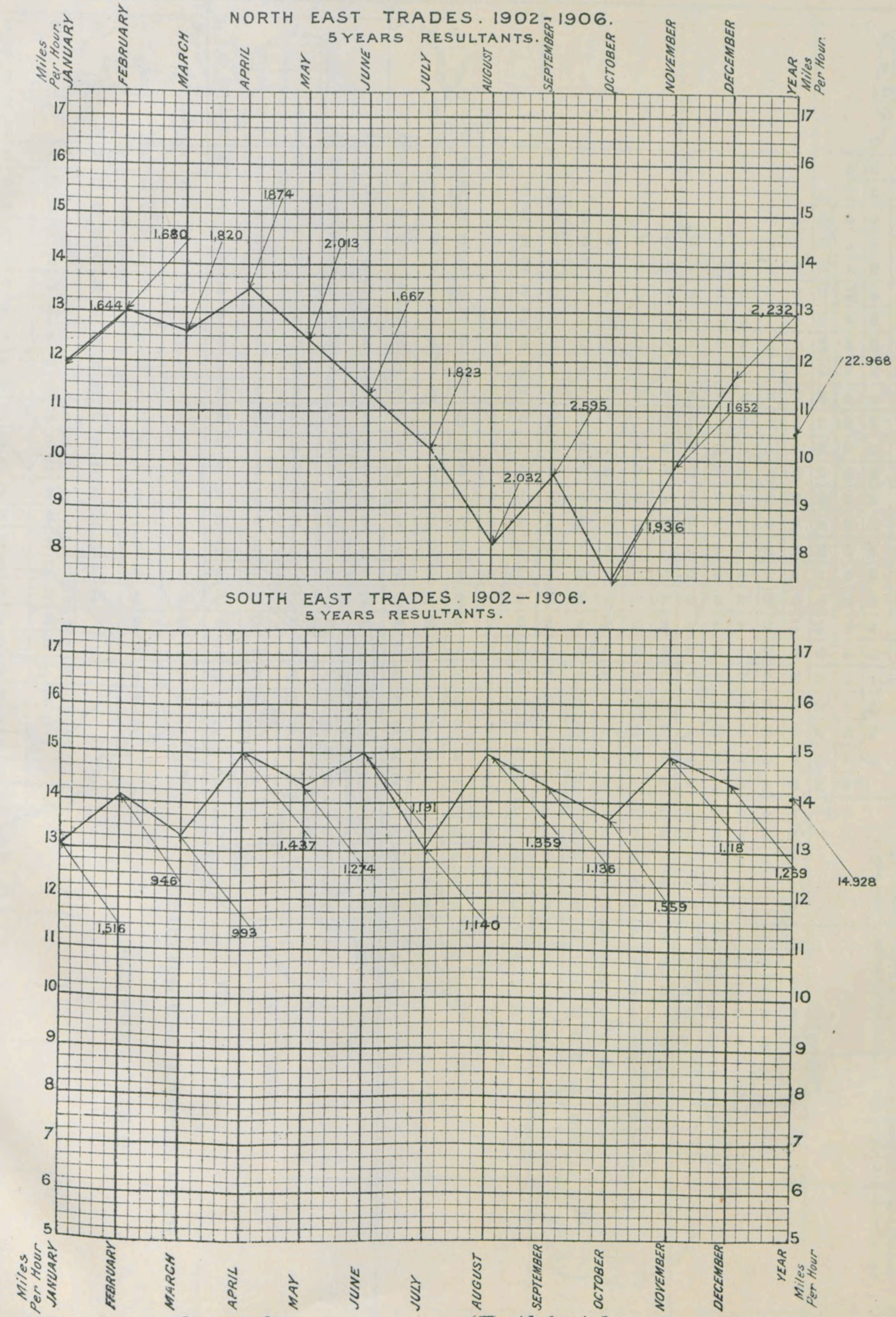
Between pp. 8 and 9.

Weller & Graham. Ltd Litho London.

3024.

Plate 2. *Between pp 8 and 9.*

TRADE WIND RESULTANTS.



BEAUFORT SCALE. 0 1 2 3 4 5

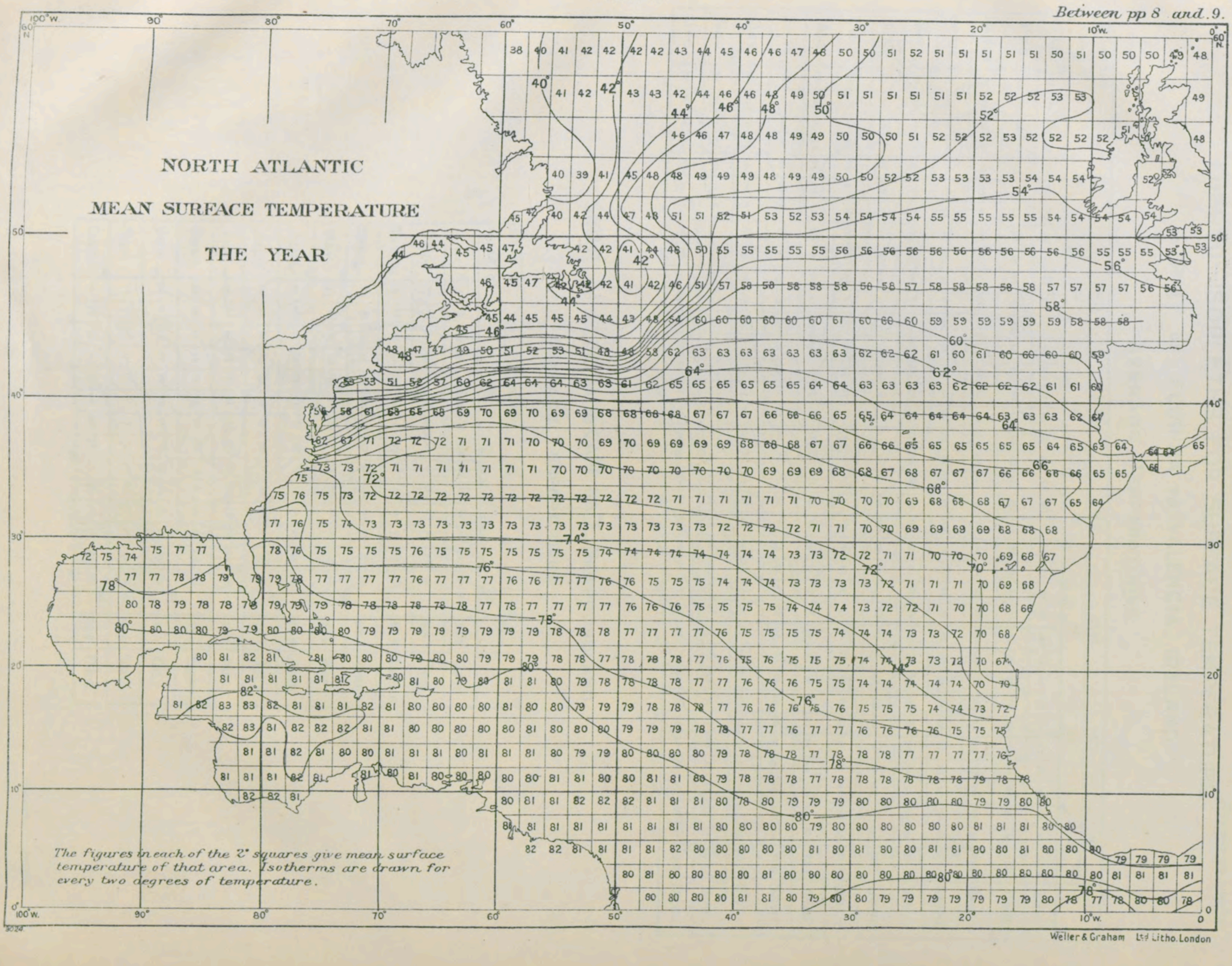
ARROWS { *Fly with the wind.* *Length proportional to Beaufort Scale.* *Number of observations for each month at tail of arrow.*

3024.

Weller & Graham, Ltd Litho. London.

Plate 3.

Between pp 8 and 9.



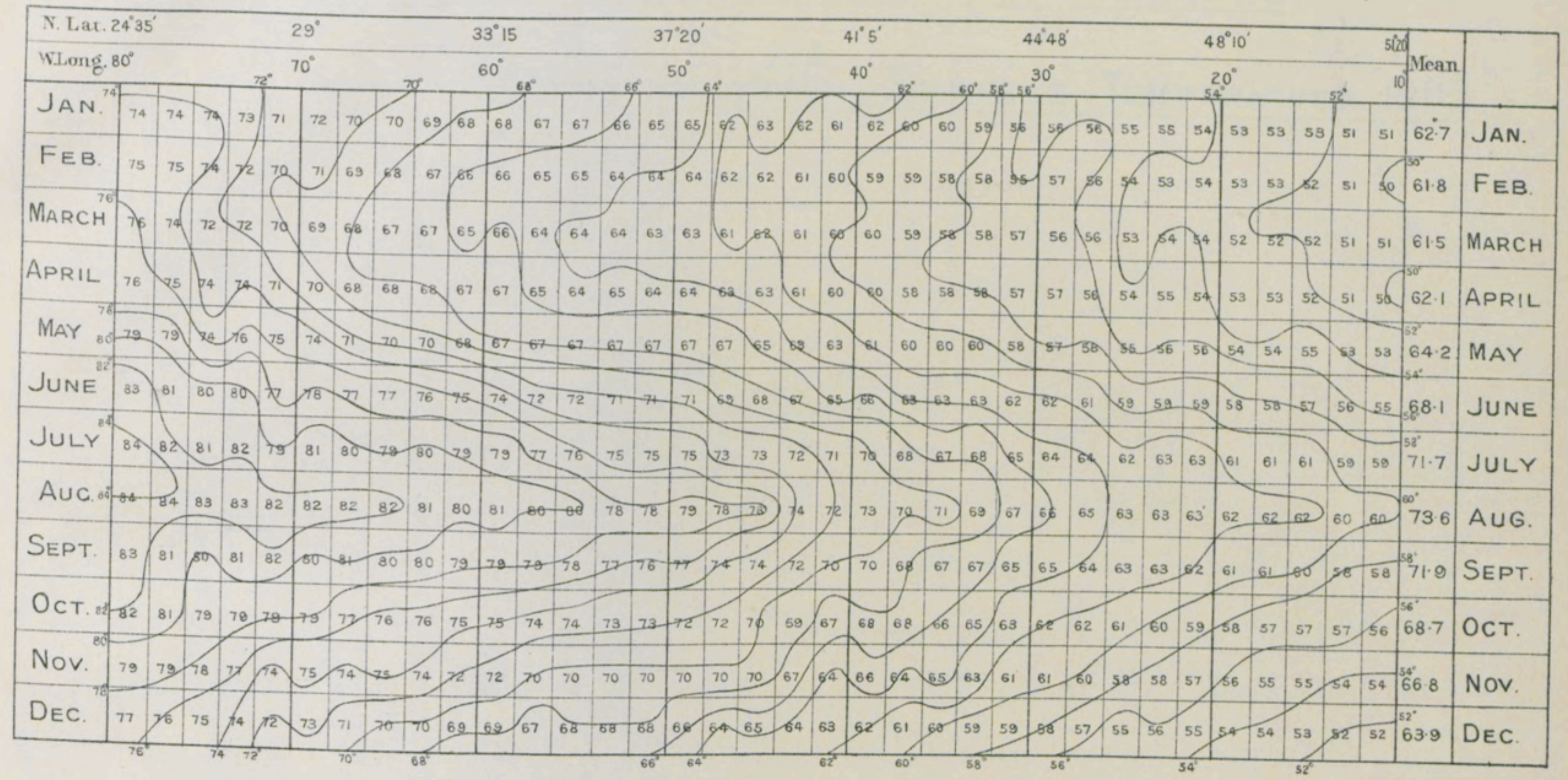
The figures in each of the 2° squares give mean surface temperature of that area. Isotherms are drawn for every two degrees of temperature.

Between pp. 8 and 9.

THERMO-ISOPLETHS FOR SURFACE TEMPERATURE

STRAIT OF FLORIDA TO VALENCIA, IRELAND.

AVERAGE TEMPERATURES.



STRAIT OF FLORIDA TO CAPE RACE, NEWFOUNDLAND.

AVERAGE TEMPERATURES.

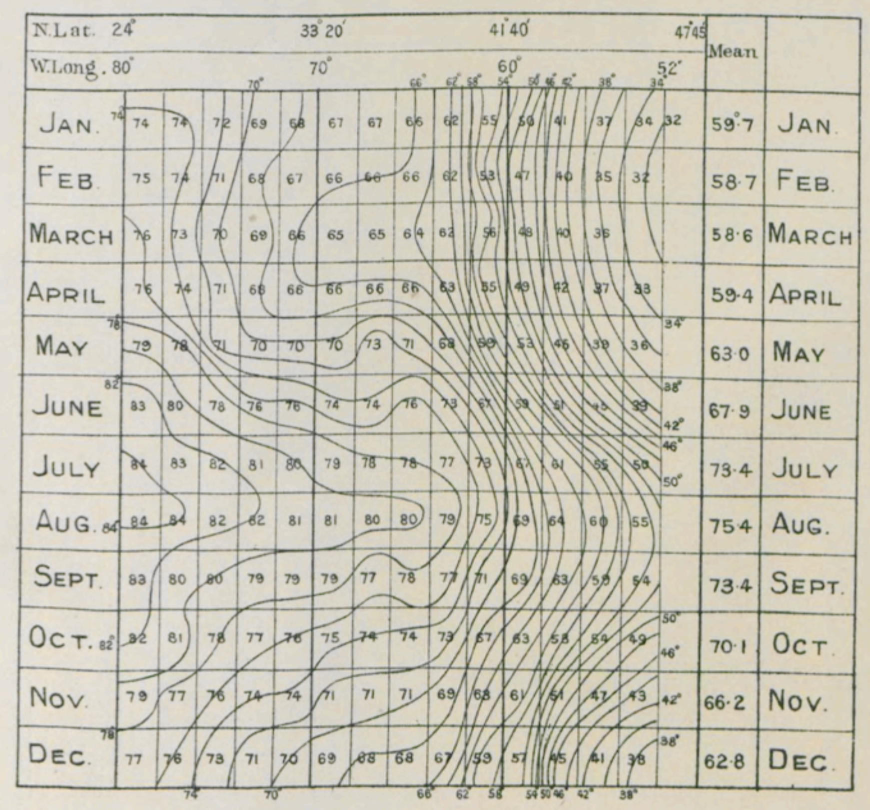


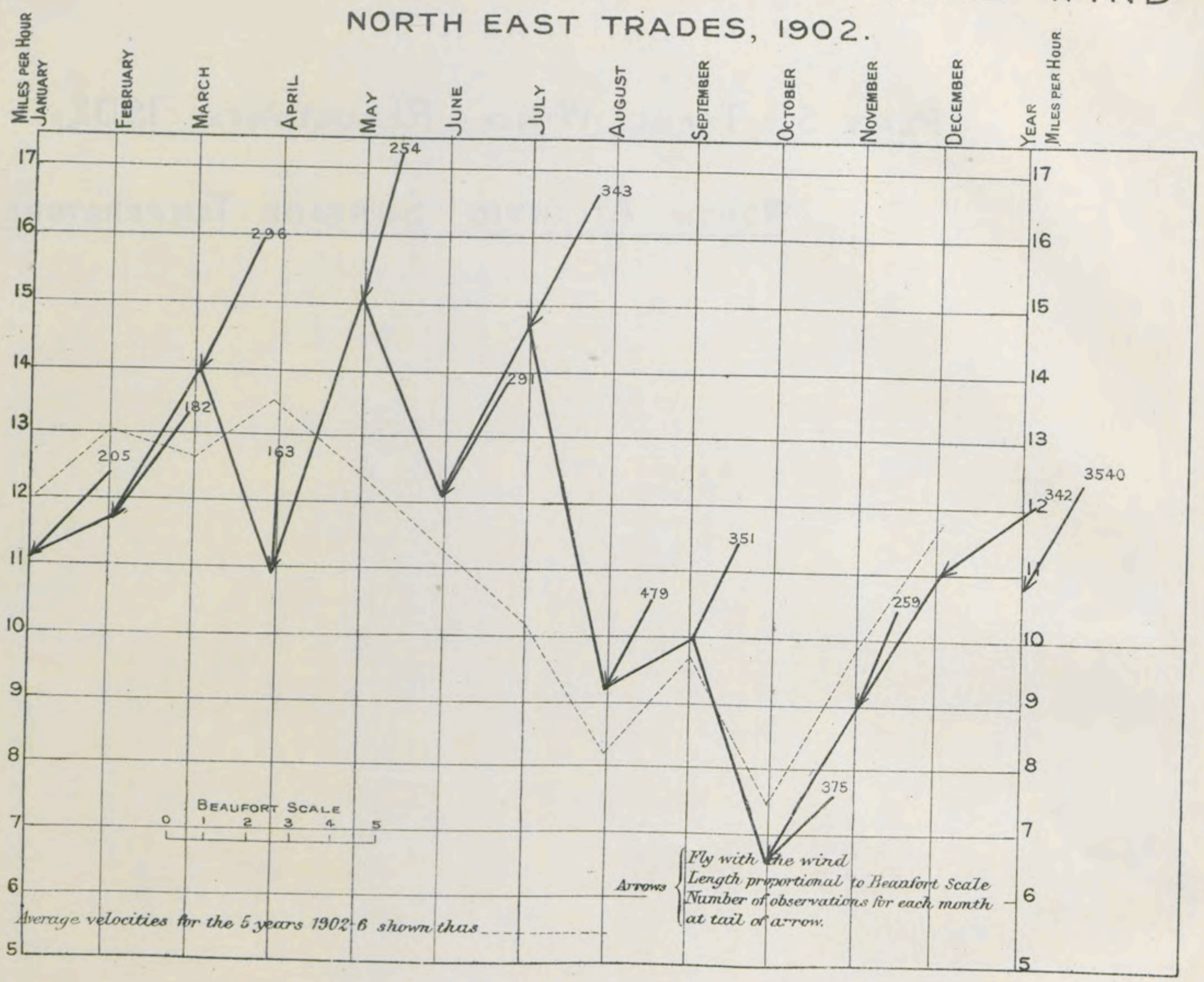
Plate 5 - Trade Wind Resultants, 1902.

North Atlantic Surface Temperature, 1903.

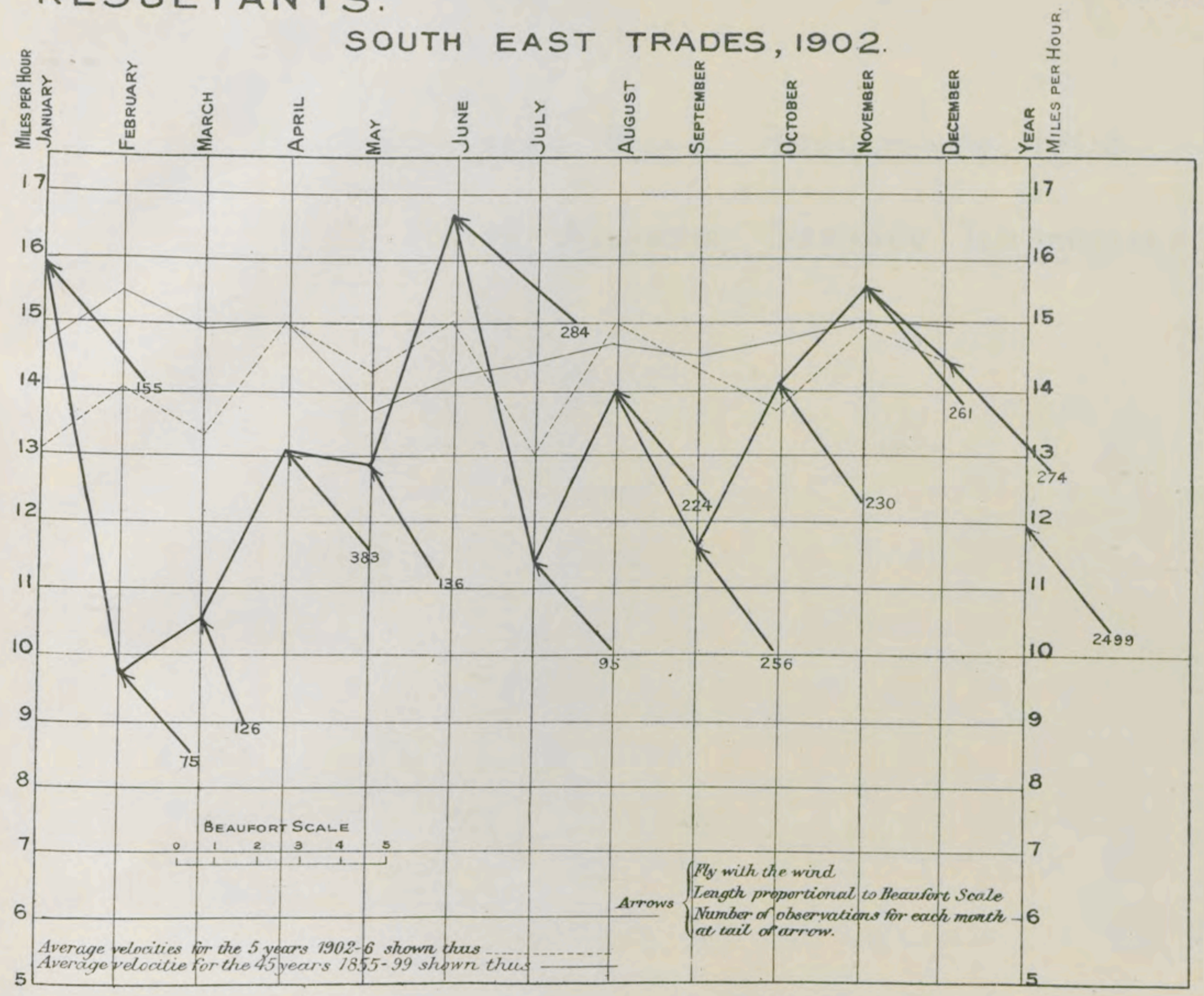
Between pp. 8 and 9.

TRADE WIND RESULTANTS.

NORTH EAST TRADES, 1902.

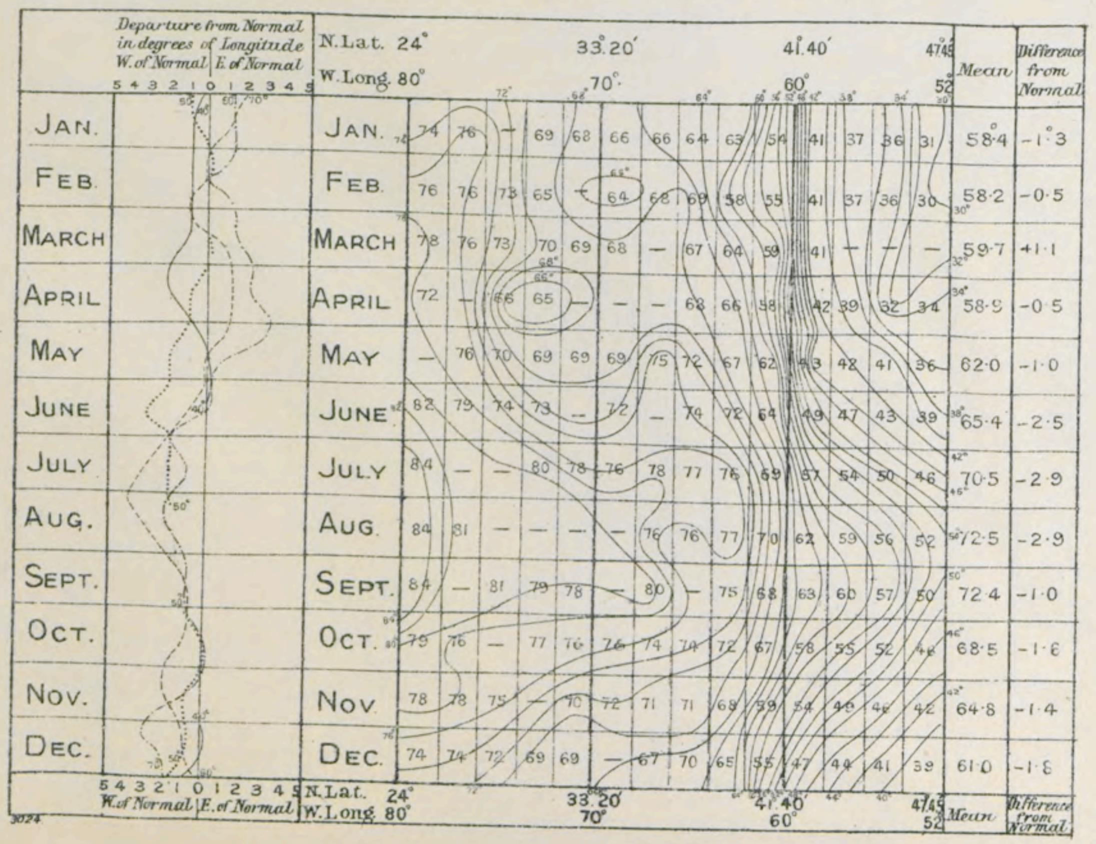


SOUTH EAST TRADES, 1902.

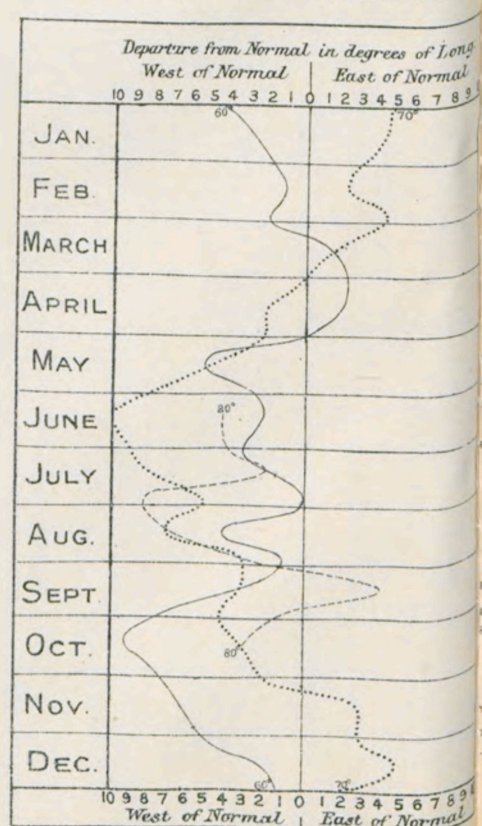


SURFACE TEMPERATURE

FLORIDA TO CAPE RACE, 1903.



FLORIDA to VALENCIA



FLORIDA TO VALENCIA, 1903.

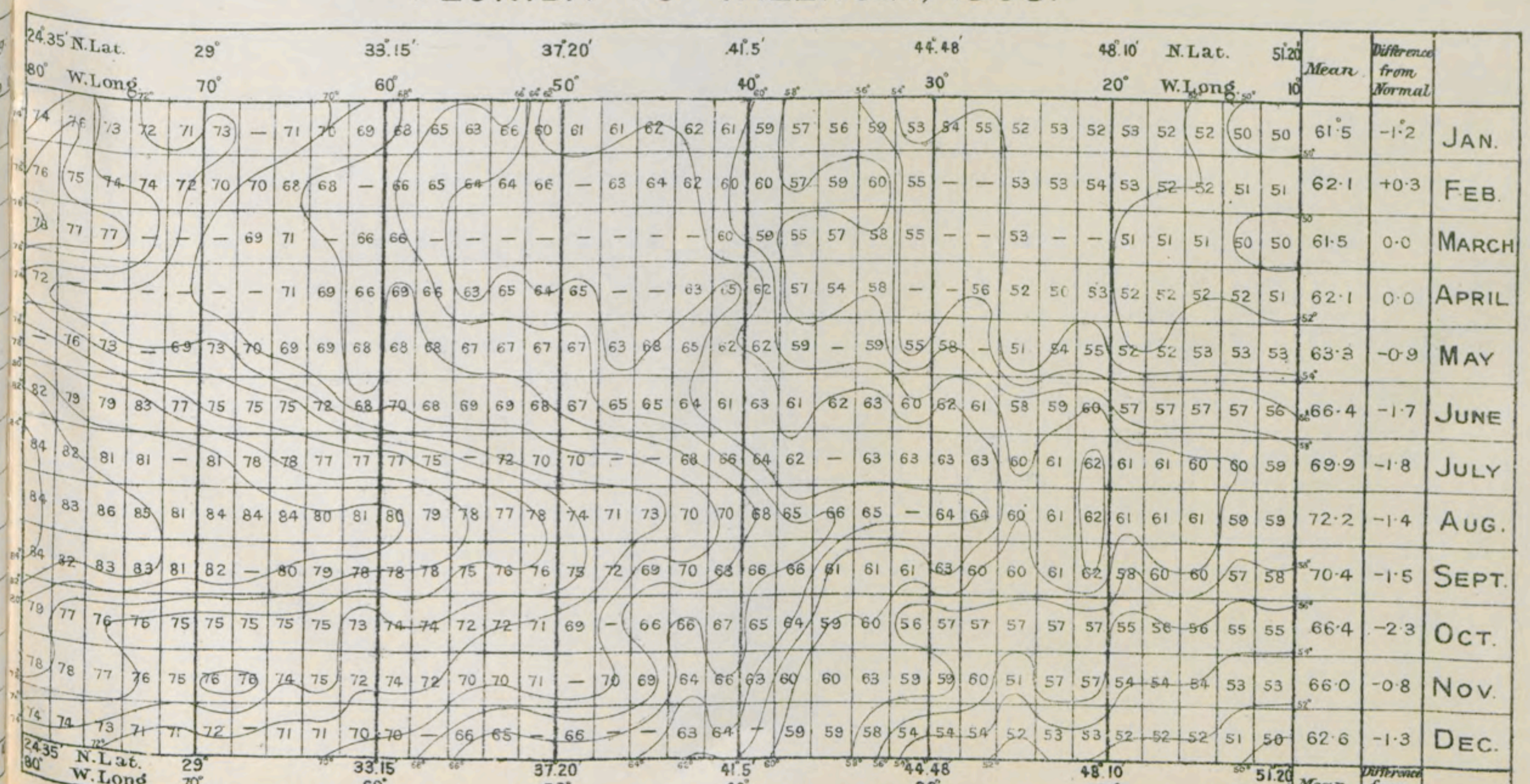
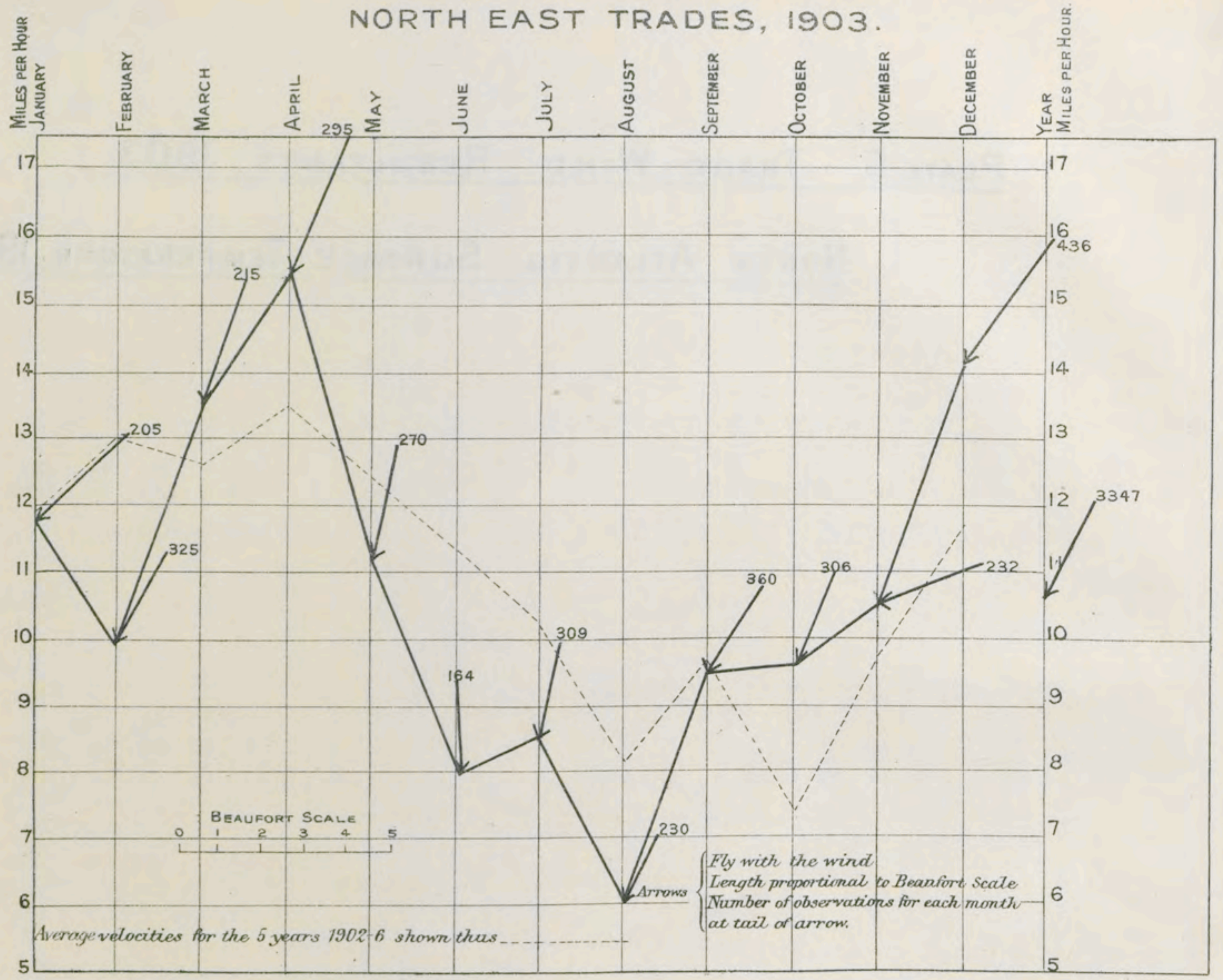


PLATE 6 - TRADE WIND RESULTANTS, 1903.

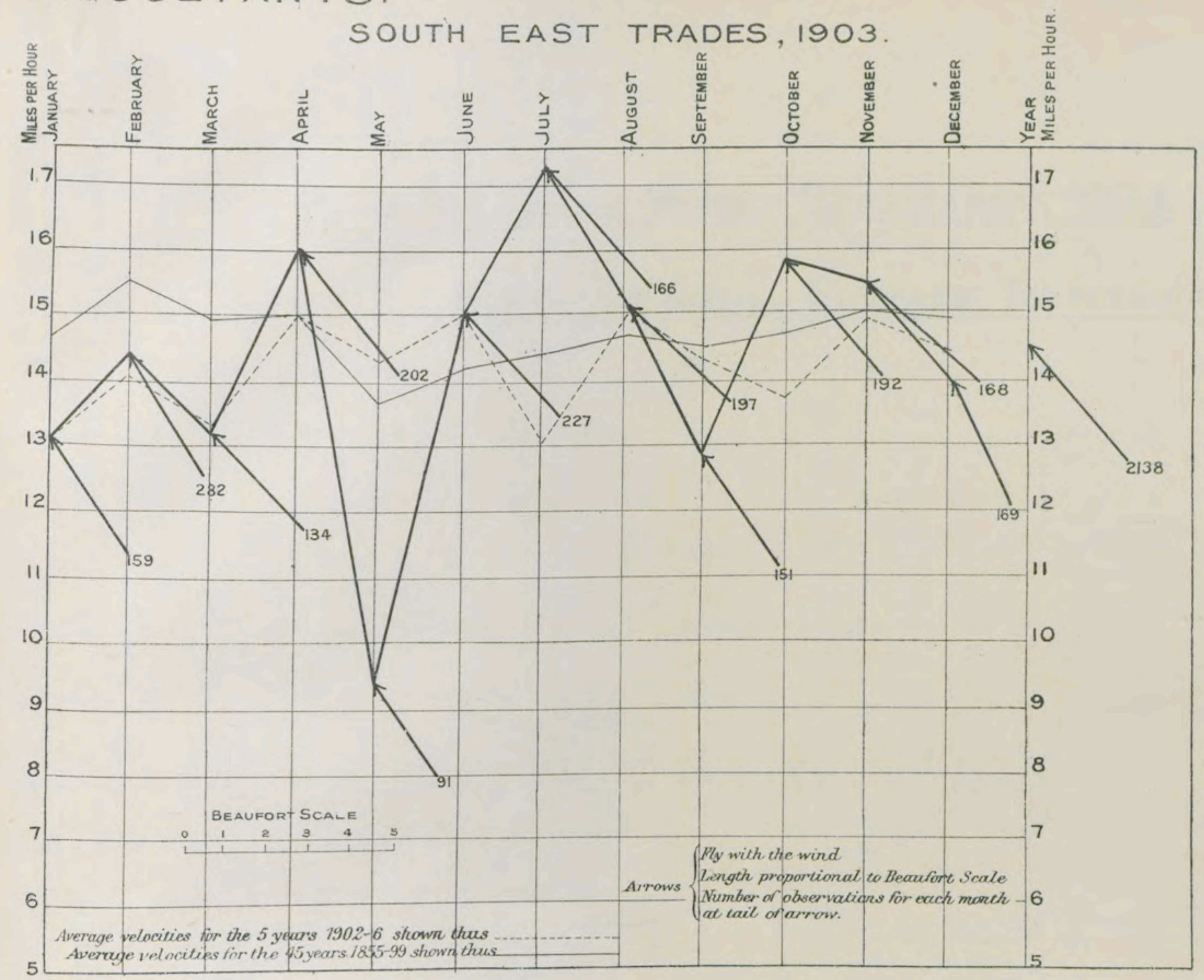
NORTH ATLANTIC SURFACE TEMPERATURE, 1904.

TRADE WIND RESULTANTS.

NORTH EAST TRADES, 1903.

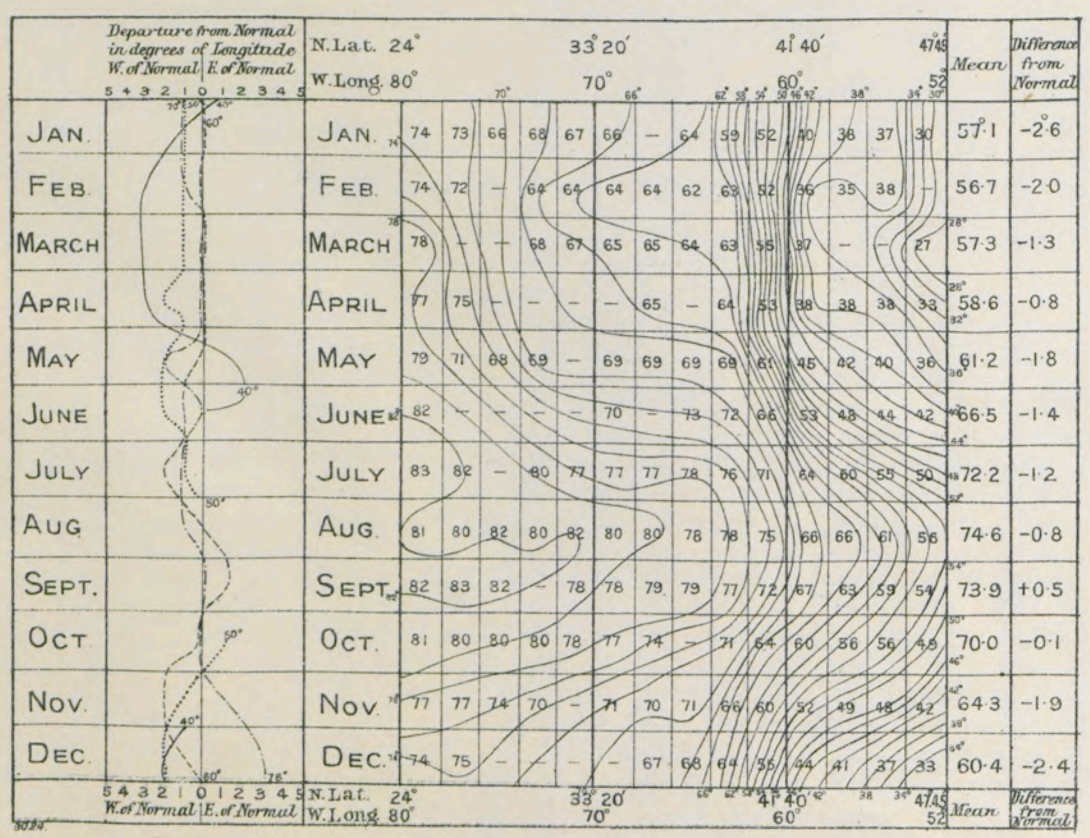


SOUTH EAST TRADES, 1903.



SURFACE TEMPERATURE.

FLORIDA TO CAPE RACE, 1904.



FLORIDA TO VALENCIA, 1904.

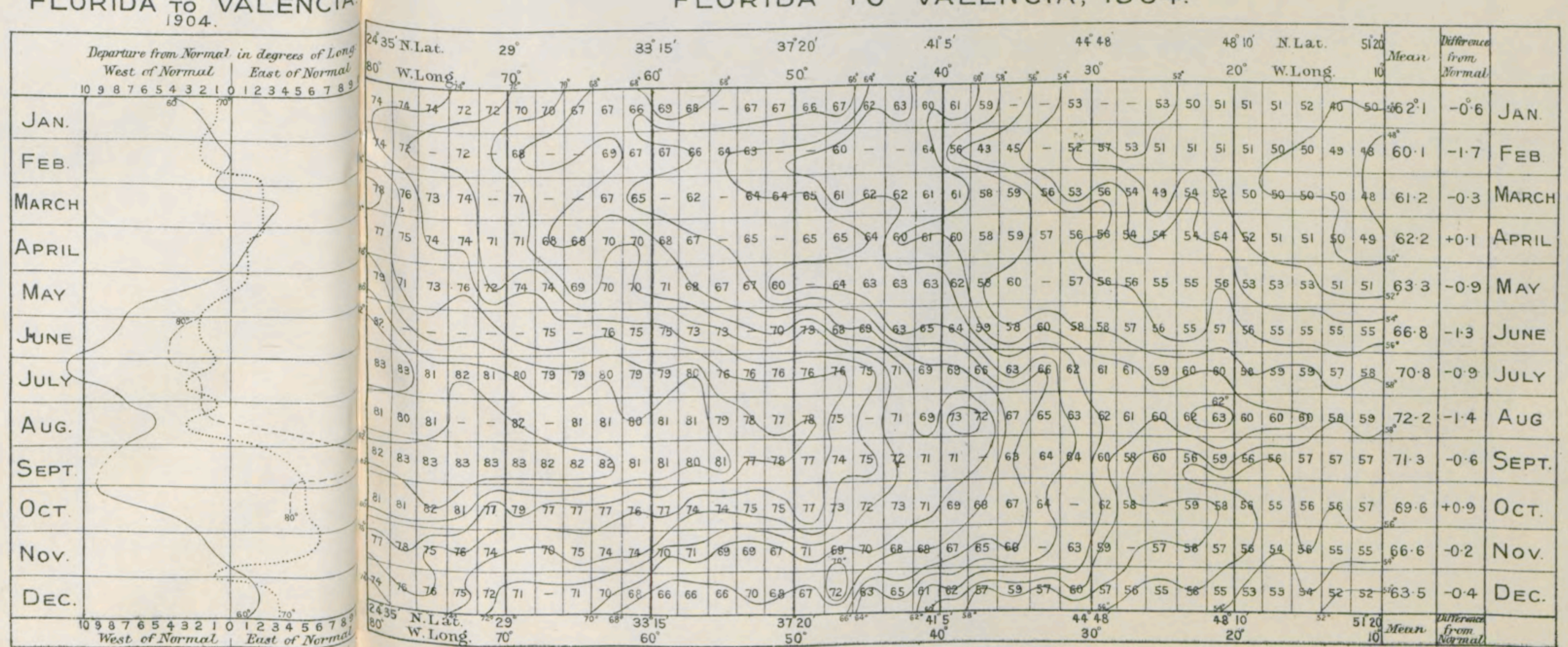
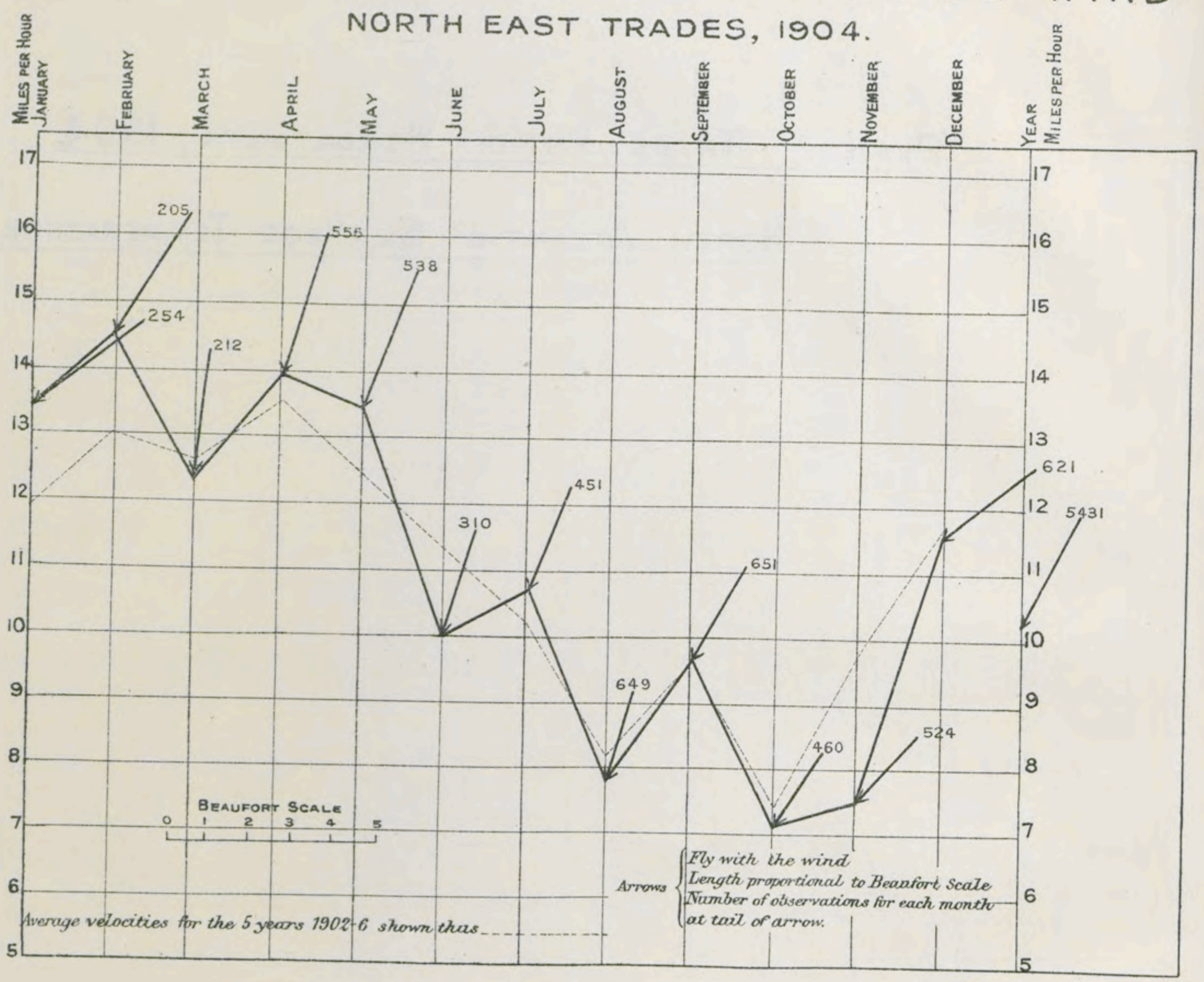


Plate 7 - Trade Wind Resultants, 1904.

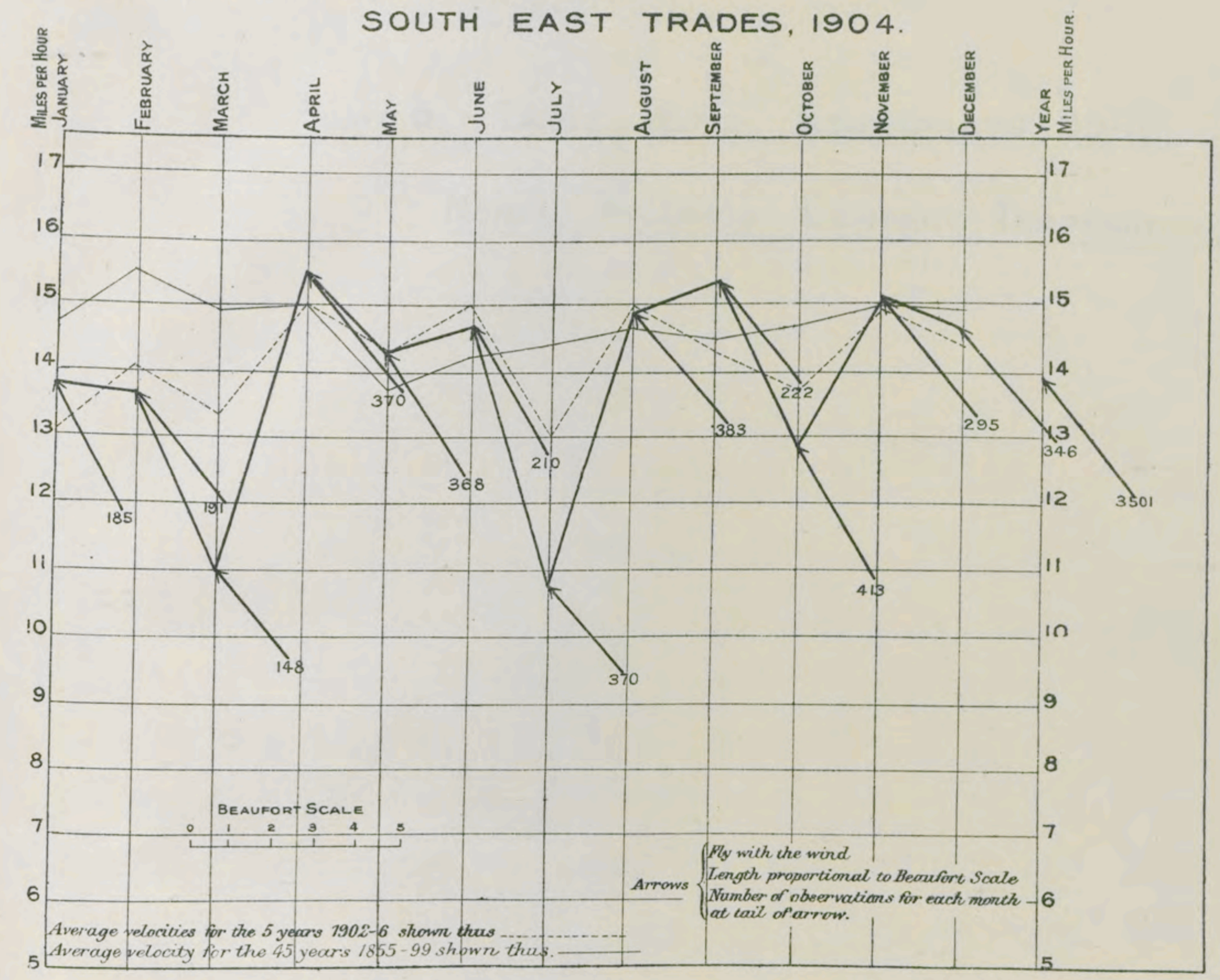
North Atlantic Surface Temperature, 1905.

TRADE WIND RESULTANTS.

NORTH EAST TRADES, 1904.

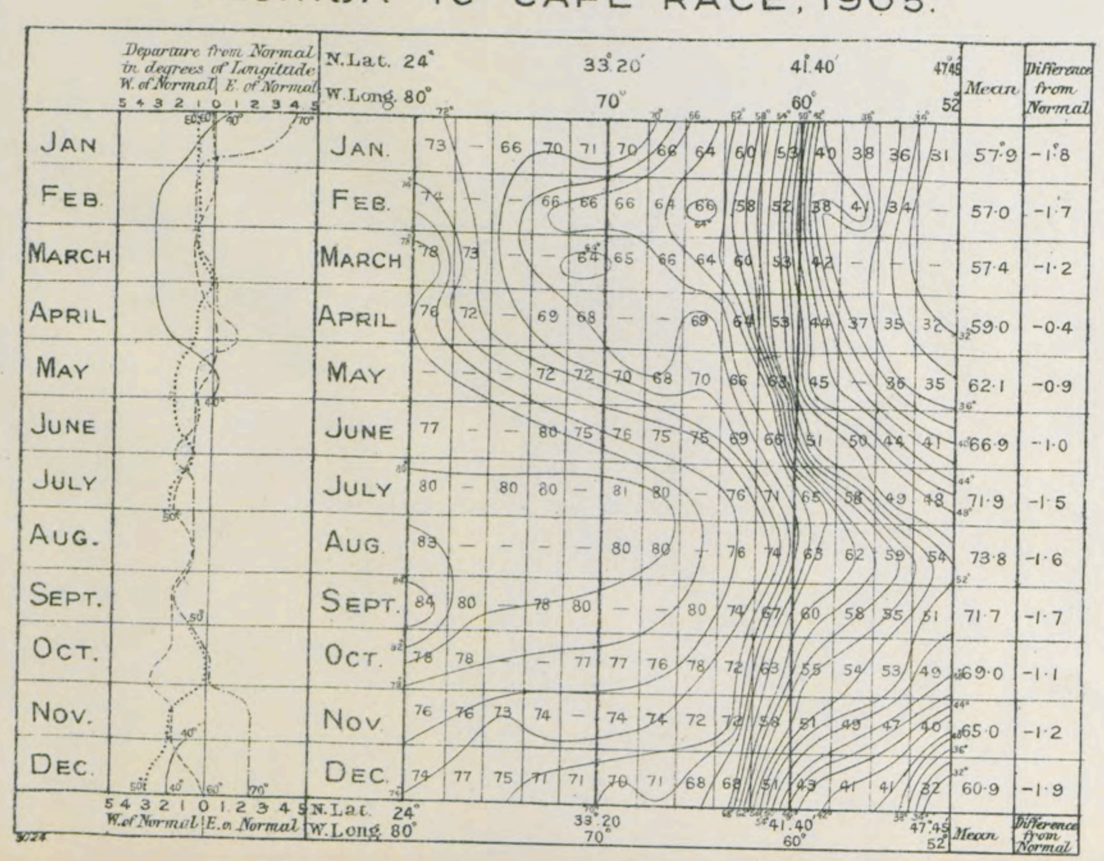


SOUTH EAST TRADES, 1904.

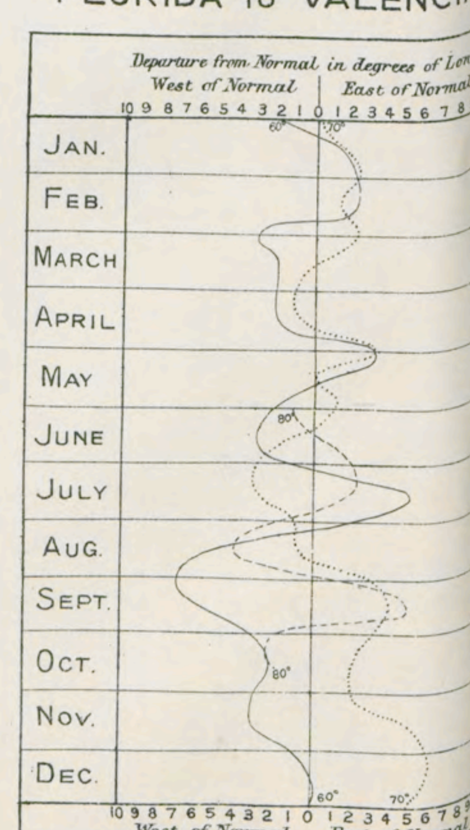


SURFACE TEMPERATURE

FLORIDA TO CAPE RACE, 1905.



FLORIDA TO VALENCIA



FLORIDA TO VALENCIA, 1905.

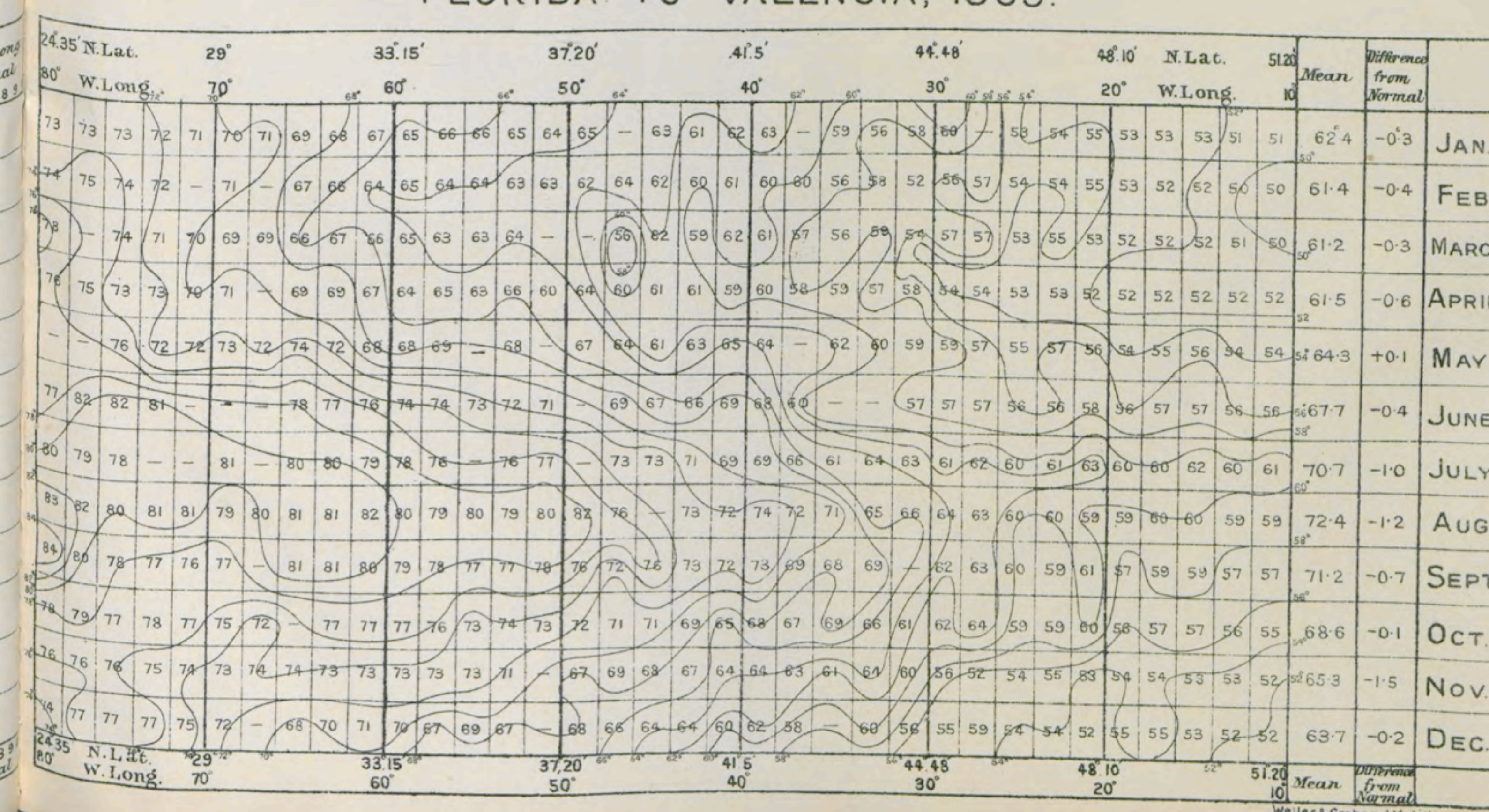
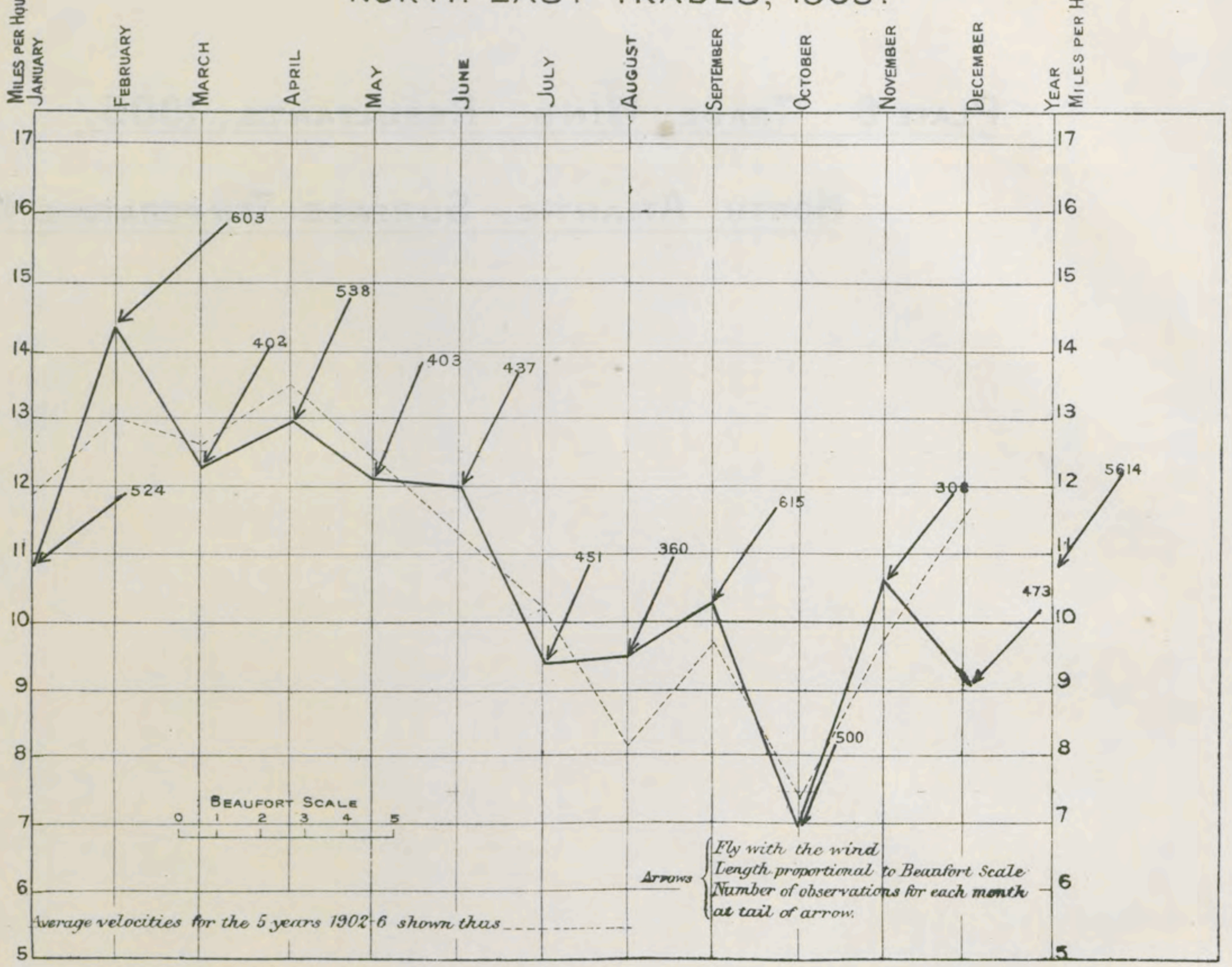


PLATE 8 - TRADE WIND RESULTANTS, 1905.

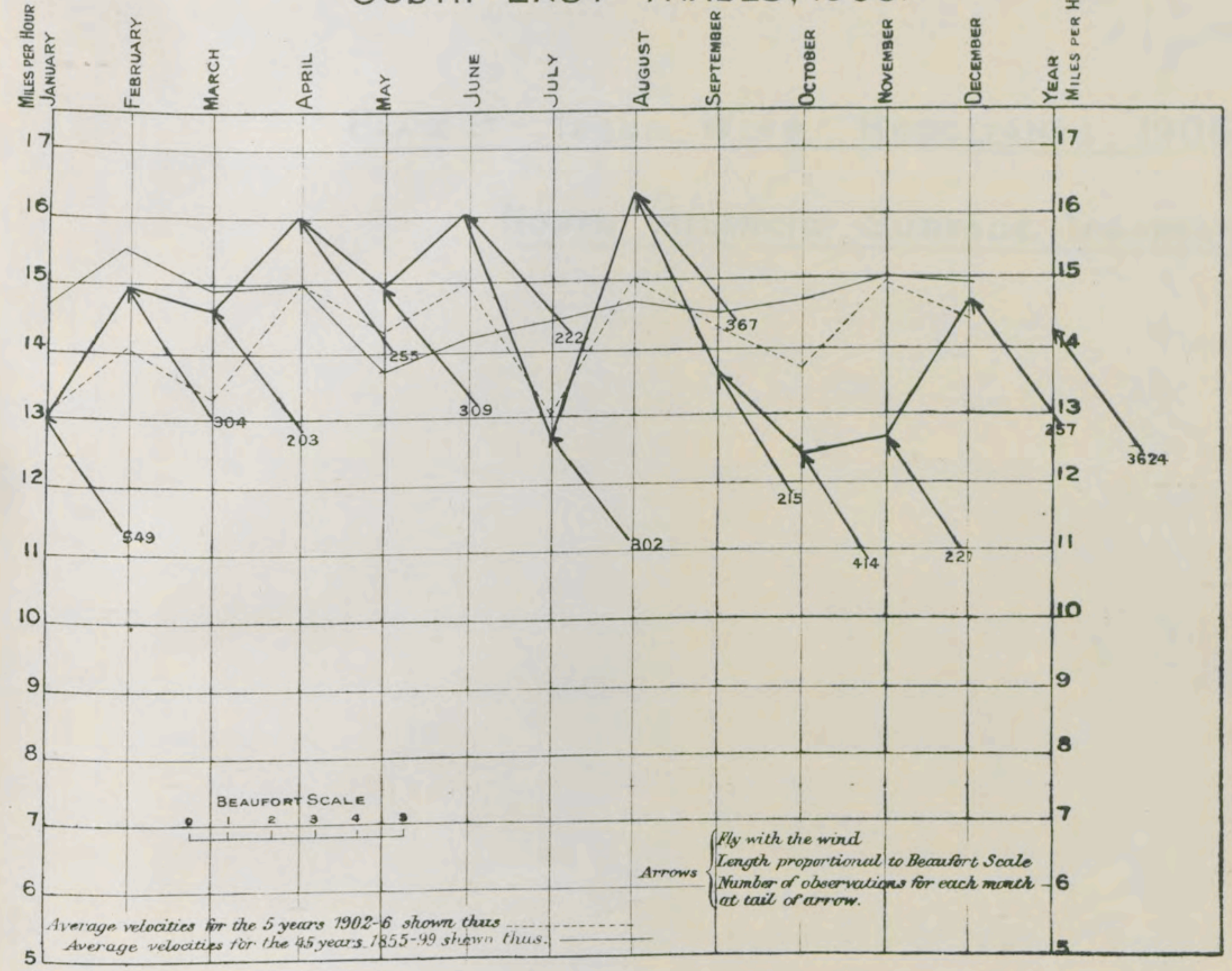
NORTH ATLANTIC SURFACE TEMPERATURE, 1906.

TRADE WIND RESULTANTS.

NORTH EAST TRADES, 1905.

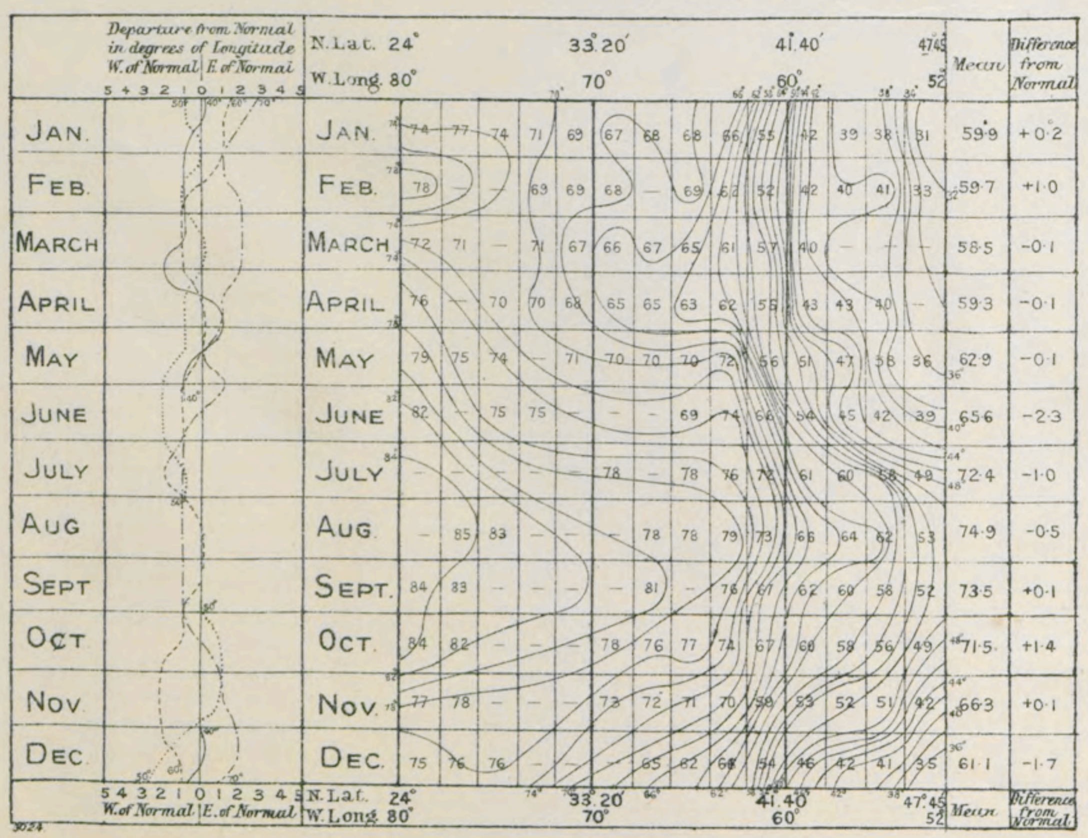


SOUTH EAST TRADES, 1905.

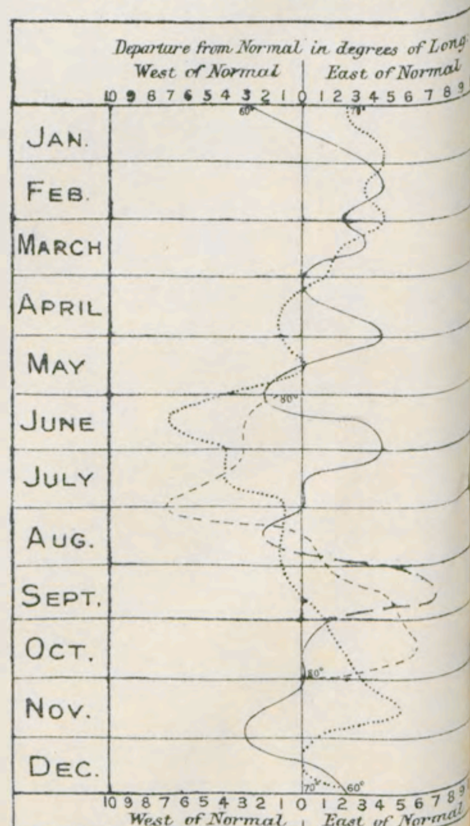


SURFACE TEMPERATURE

FLORIDA TO CAPE RACE, 1906.



FLORIDA TO VALENCIA.



FLORIDA TO VALENCIA, 1906.

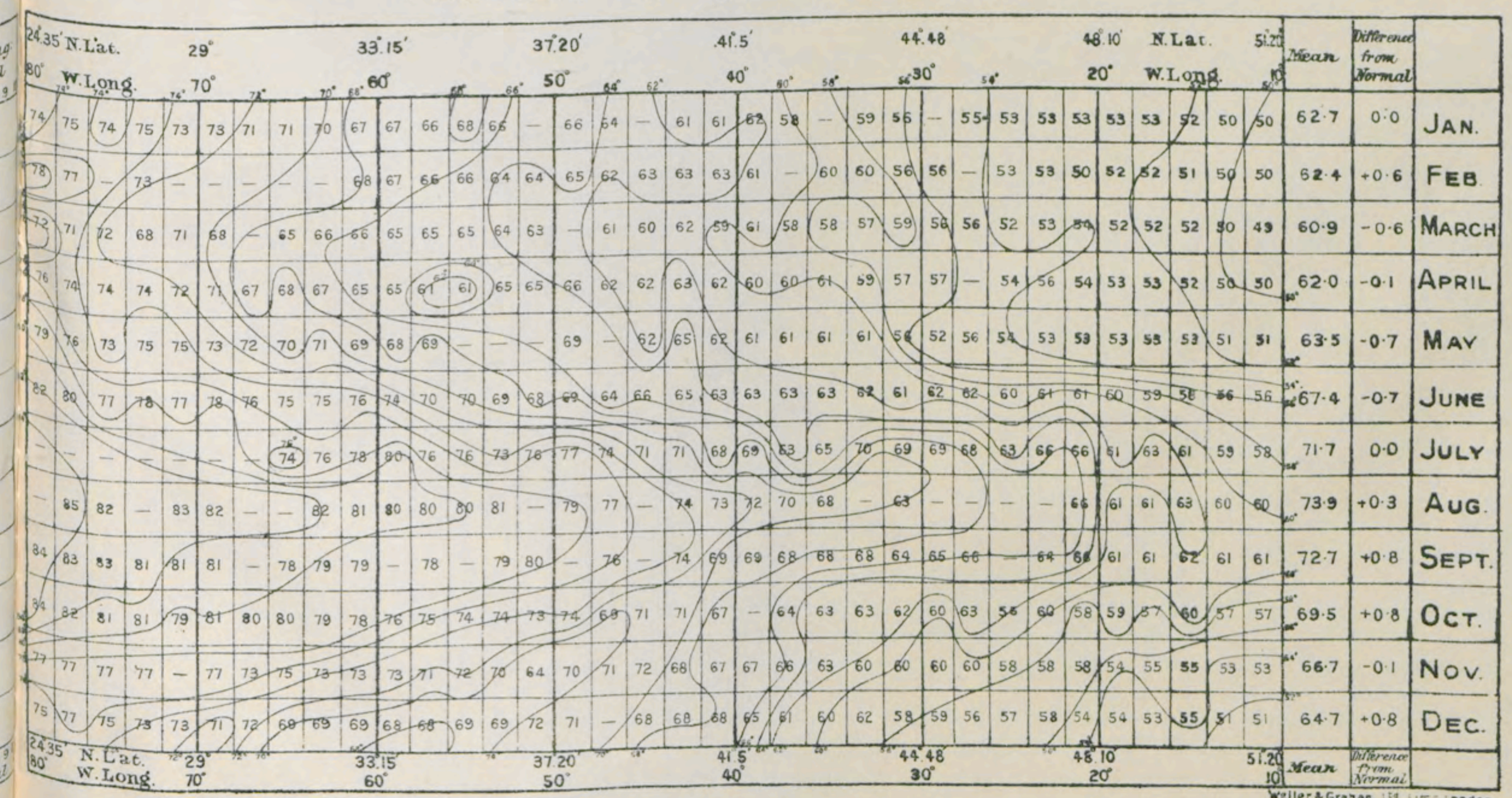
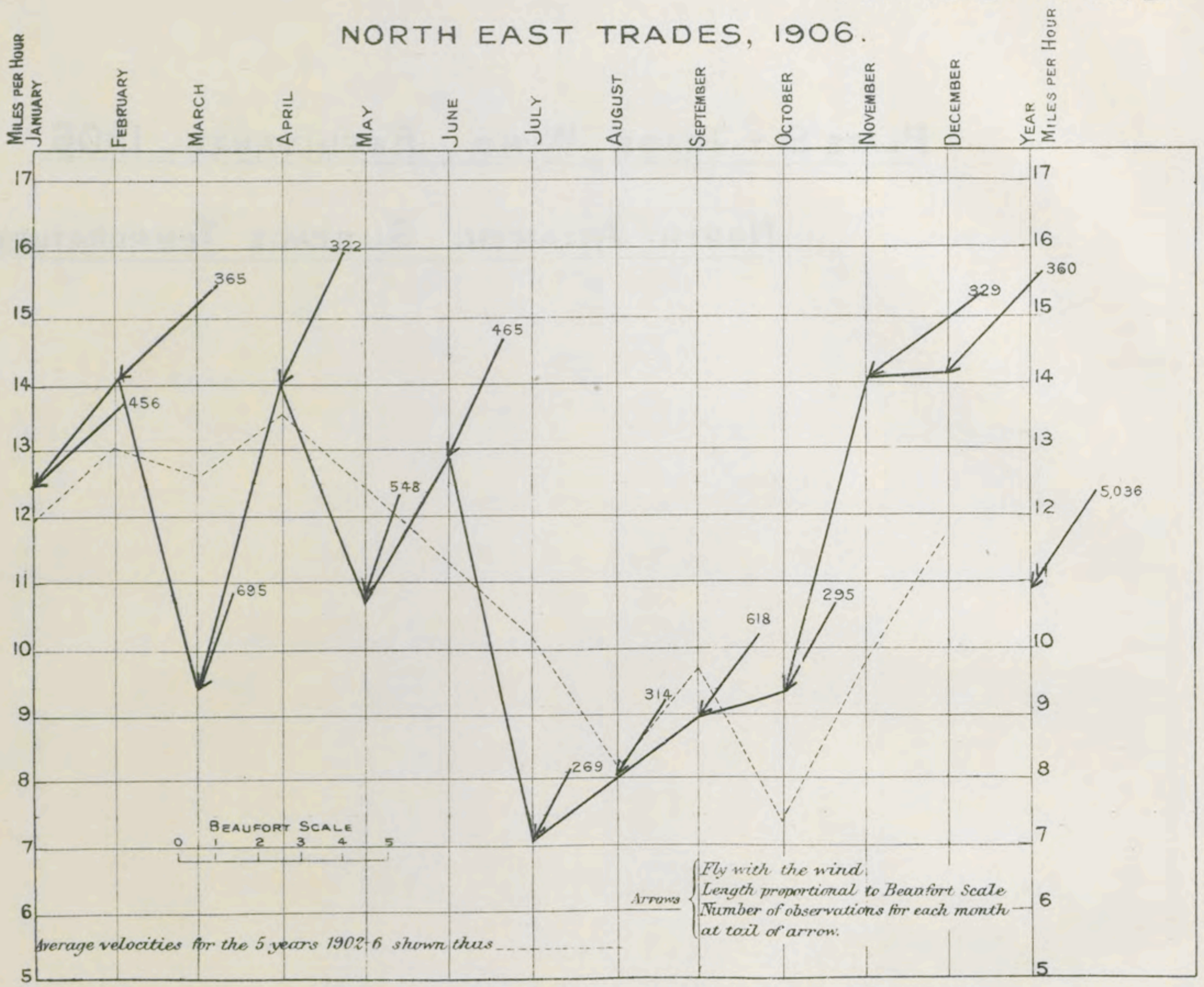


Plate 9 - Trade Wind Resultants, 1906.

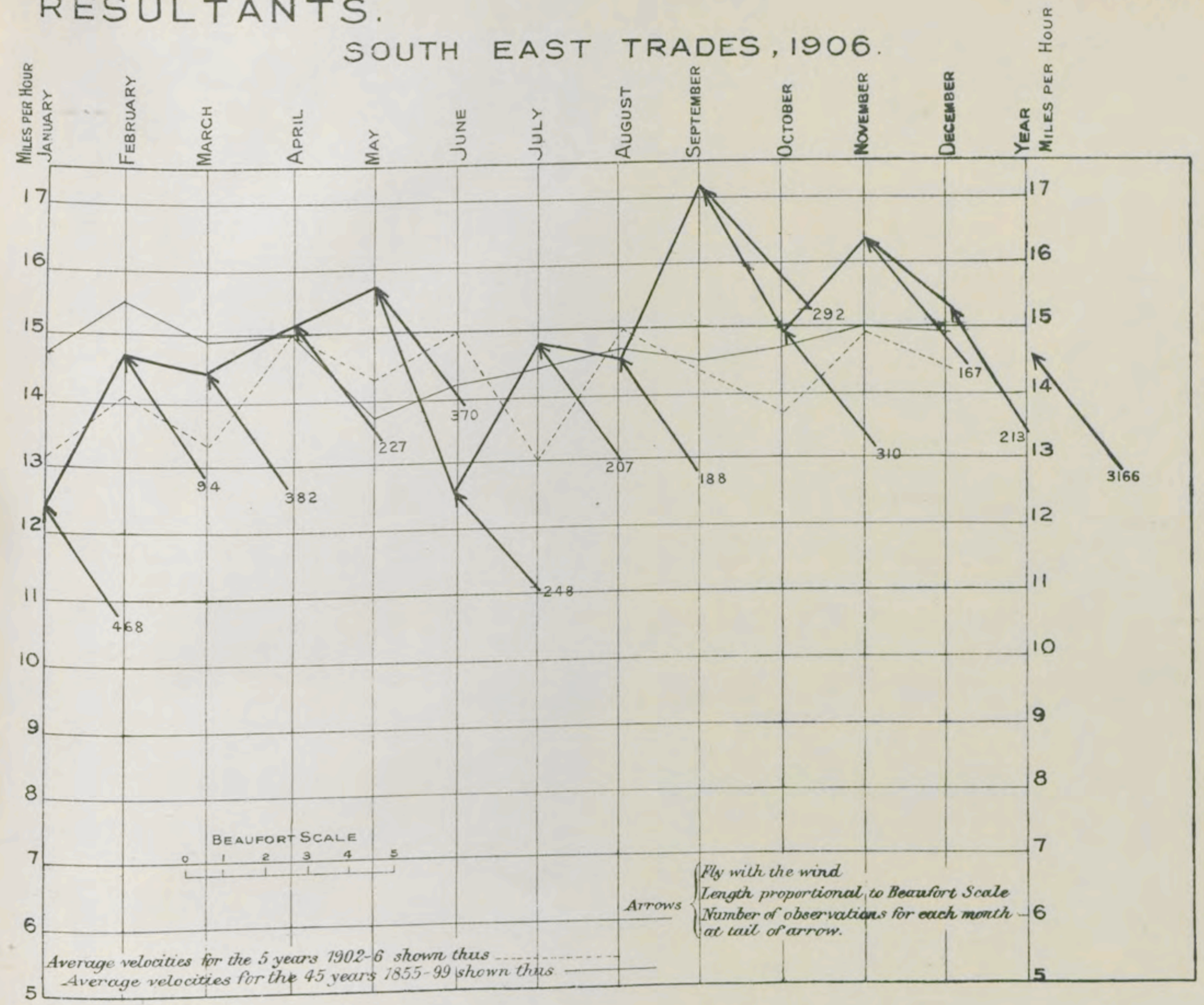
North Atlantic Surface Temperature, 1907.

TRADE WIND RESULTANTS.

NORTH EAST TRADES, 1906.

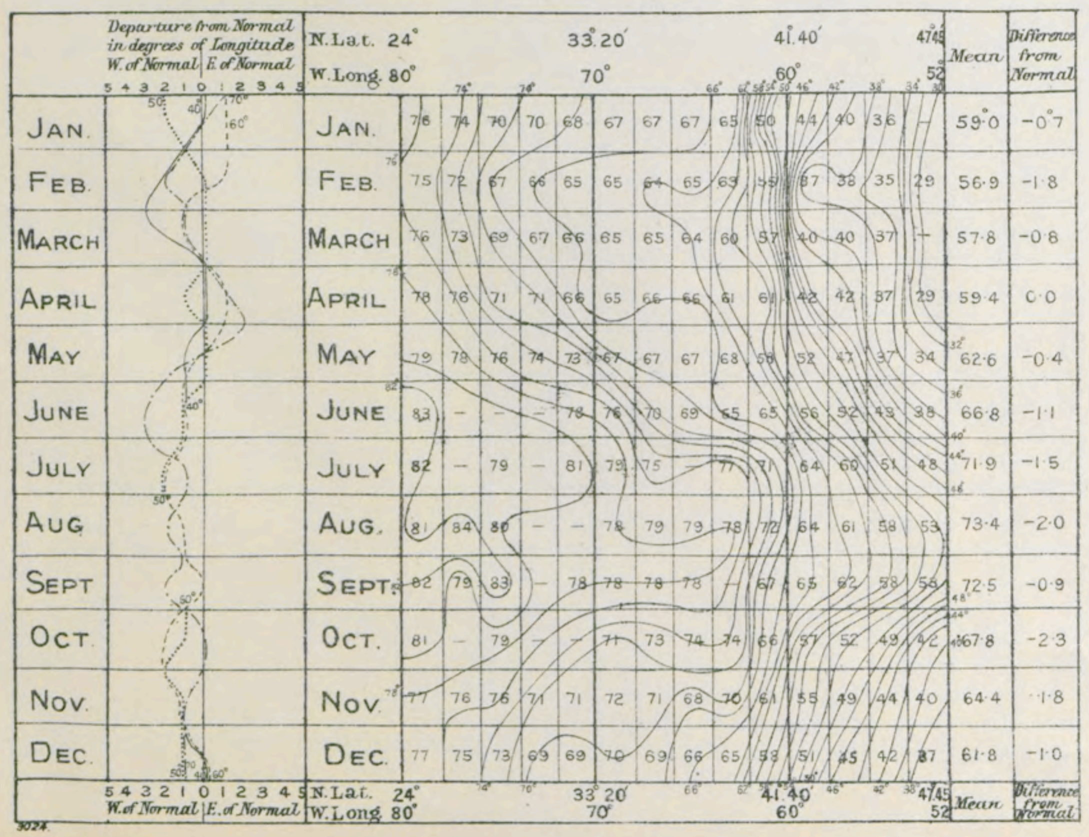


SOUTH EAST TRADES, 1906.

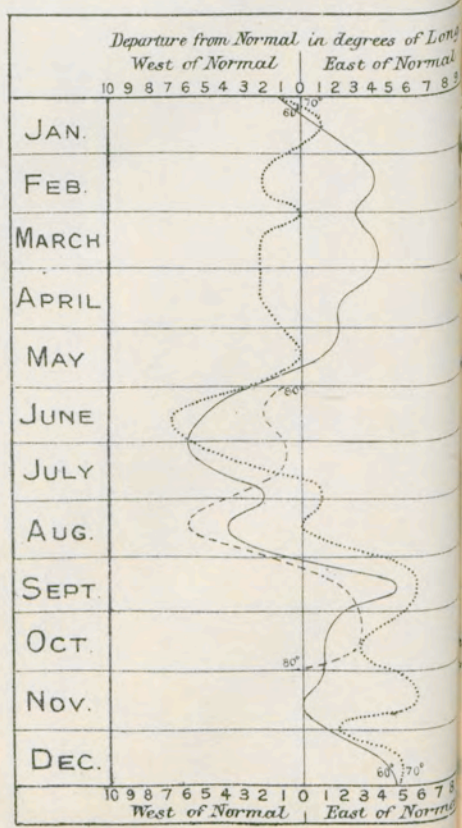


SURFACE TEMPERATURE

FLORIDA TO CAPE RACE, 1907.



FLORIDA to VALENCIA



FLORIDA TO VALENCIA, 1907.

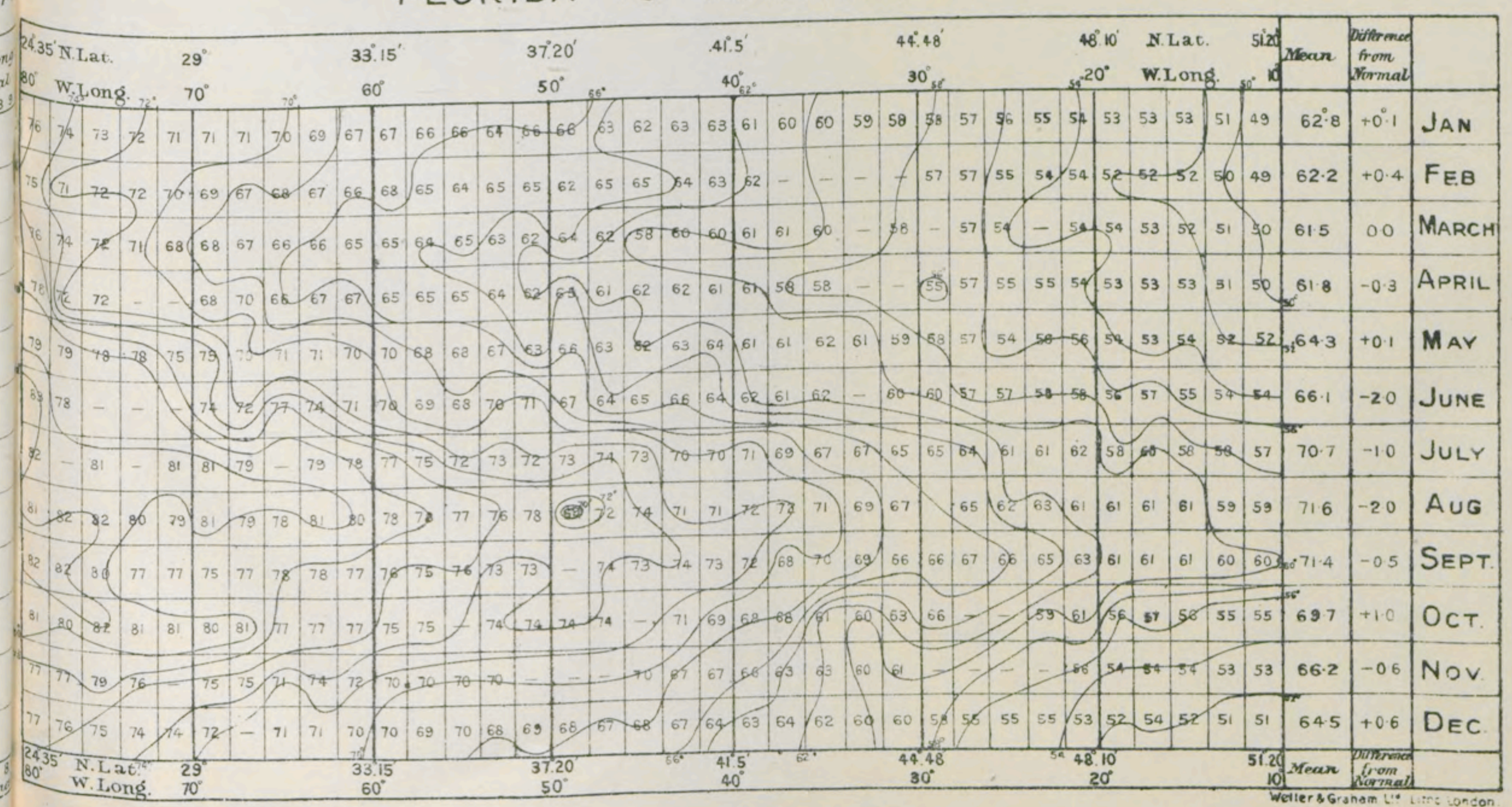


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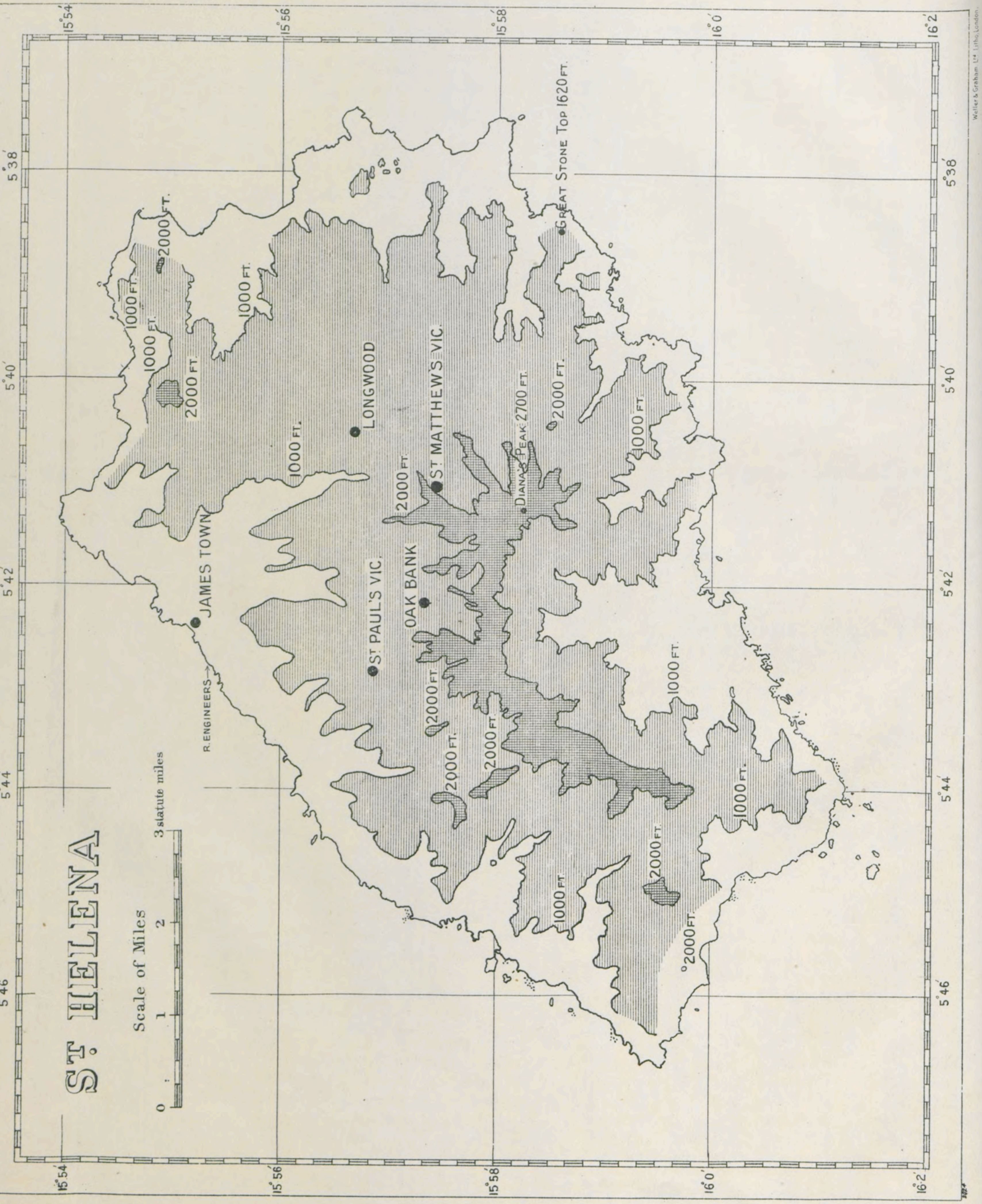
Plate 10.

To face p. 9



G.R.

ST. HELENA. 1908-1910.

Mean Wind Velocity (Irrespective of Direction).m.p.h.

	1908	1909	1910
January	19.3	16.2	17.1
February	14.7	15.3	15.9
March	16.5	14.5	13.3
April	18.1	17.6	11.7
May	15.5	14.5	14.0
June	14.3	12.2	16.4
July	17.9	15.2	14.9
August	20.3	21.1	21.2
September	15.9	22.3	20.0
October	22.7	22.7	21.0
November	24.8	16.6	20.3
December	17.8	16.4	18.0

CLIMATOLOGICAL TABLES FOR ST. HELENA,

WITH A REPORT UPON THE

RECORDS OF THE ANEMOGRAPH FROM 1892 TO 1907.

BY

JOHN SOMERS DINES, B.A.

PART I.—CLIMATOLOGICAL TABLES FOR ST. HELENA.

The climatological information given in the Tables on pages 10 to 25 is obtained from records from the following stations :—

(1.) *Longwood* (1,765 *ft.*).—Longwood is situated on an elevated plain towards the N.E. end of the island, and about three miles distant from the sea; the intervening ground to windward (S.E.) is a naked and barren plain, in which the highest peak (Great Stone Top) is about 150 feet lower than Longwood. The meteorological observations were made by a detachment of the Royal Artillery and extend over the period 1840–7. Two hourly readings of the barometer and dry and wet bulb thermometers were taken from September, 1840–August, 1842, and hourly readings from September, 1842–December, 1845. The thermometers were fixed to horizontal wooden battens, the bulbs being quite free. They were placed in front of a window (through which they were read) under a deep verandah on the south side of the Observatory, and were screened by the form of the building from all but a south-eastern aspect. The force of the wind was also taken hourly from an Osler pressure plate for two years (1844–5). In addition to these the maximum and minimum thermometers were read daily and also a very complete record kept of the state of the weather.

No observations were made on Sundays. All the figures given for this station were obtained from the two volumes of "Observations made at the Magnetical and Meteorological Observatory at St. Helena," compiled under the superintendence of Lieutenant-Colonel Edward Sabine. Astronomical Solar mean time was used, but in the tables here given it has been altered to civil time, to fall into line with the other stations.

(2.) *The Station of the Royal Engineers, situated near Jamestown* (40 *ft.*).—The records cover the period 1853–62 and comprise readings of the barometer and dry and wet bulb thermometers taken at 9.30 a.m. and 3.30 p.m. local time. Also daily readings of the maximum and minimum thermometers and raingauge.

These observations do not all extend over the whole period.

Estimates were also made of the direction of the wind and amount of cloud.

No observations were made on Sundays until September, 1860. The values given here were obtained from the volume "Meteorological Observations at the Foreign and Colonial Stations of the Royal Engineers and Army Medical Department, 1852–1886," published by the Meteorological Office, and access was also had to some of the original manuscripts.*

(3.) *St. Matthew's Vicarage*, situated near the centre of the island at a height of about 1,900 feet above sea level. Observations were commenced at the station in February, 1892, and have been carried on to the present date. They consist of 9 a.m. (local time) readings of pressure,

* The vapour pressures were re-calculated by Glaisher's Hygrometric Tables from the dry and wet bulb values.

maximum and minimum, dry and wet bulb thermometers, and a raingauge. Estimates are also made of the amount and type of cloud. There is a recording anemometer, the records from which are discussed in the second part of this paper. (*See* Plate A, p. 26.)

(4.) The records from the following rainfall stations are also given :--

		Height of gauge in feet above M.S.L.	above ground.	Diameter of gauge.
				ins.
Mount Pleasant	1896–1904	2,000	3	8
Hussey Charity School, Jamestown...	1896–1902	150	5	8
Oak Bank	1901–1907	1,700	4	8
St. Paul's Vicarage	1905–1907	1,700	6	10
The corresponding values for the St. Matthew's Vicarage gauge are...	1892–1907	1,890	3	8

The means given with the tables do not always include the whole period. Where the records are defective for a certain year the entire year is, in some cases, omitted from the means.

Note.—In the following tables of pressure the readings are corrected for index error and reduced to 32° F., but not reduced to sea-level nor corrected for latitude. All the times given are local times.

TABLE V.—MONTHLY MEANS FOR LUSTRA.

Pressure at Station Level.

Height in feet above sea level.	Station.	Period.	Local Time of Observations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
				ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1,765	Longwood	1841–45	9 a.m.	28·280	28·269	28·269	28·287	28·322	28·371	28·398	28·388	28·349	28·320	28·292	28·291
40	Royal Engineers ...	1856–60	9.30 a.m.	30·039	30·007	30·010	30 028	30·069	30·116	30·141	30·130	30·109	30·090	30·072	30·071
1,900	St. Matthew's Vicarage ...	*1892–95*	*9 a.m.*	*27·985*	*27·990*	*27·992*	*28·019*	*28·053*	*28·115*	*28·117*	*28·103*	*28·077*	*28·044*	*28·028*	*28·014*
"	" " ...	1896–1900	9 a.m.	28·002	28·012	27·995	28·019	28·052	28·106	28·108	28·100	28·077	28·061	28·035	28·033
"	" " ...	1901–05	"	28·042	28·024	28·031	28·043	28·055	28·075	28 075	28·091	28·079	28·065	28·063	28·048

Temperature.

Height in feet above sea level.	Station.	Period.	Local Time of Observations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1,765	Longwood	1841–45	9 a.m.	64°1	65°7	66°4	65°7	63°2	60°2	58°1	57°2	57°2	58°4	60°0	61°8
40	Royal Engineers ...	*1858–61*	*9.30 a.m.*	—	*77·8*	*78·4*	*78·3*	*73·8*	*71·9*	*70·0*	*70·0*	*69·9*	*71·2*	*72·5*	*74·3*
1,900	St. Matthew's Vicarage...	*1892–95*	*9 a.m.*	*63·9*	*65·4*	*65·7*	*64·6*	*62·8*	*59·6*	*58·5*	*57·1*	*57·0*	*58·5*	*59·1*	*61·7*
"	" " ...	1896–1900	9 a.m.	63·2	64·9	65·6	64·9	62·5	60·4	58·2	56·8	57·2	57·8	59·6	60·2
"	" " ...	1901–05	"	63·8	66·1	66·2	65·0	63·7	60·9	58·4	56·8	56·8	58·2	59·0	60·6

Vapour Pressure.

Height in feet above sea level.	Station.	Period.	Local Time of Observations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
				ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1,765	Longwood	1841–45	9 a.m.	·497	·543	·567	·550	·500	·443	·414	·412	·419	·434	·445	·468
40	Royal Engineers ...	*1858–61*	*9.30 a.m.*	—	*·573*	*·575*	*·580*	*·567*	*·531*	*·509*	*·517*	*·526*	*·496*	*·510*	*·506*
1,900	St. Matthew's Vicarage ...	*1892–95*	*9 a.m.*	*·510*	*·559*	*·568*	*·530*	*·496*	*·449*	*·427*	*·414*	*·424*	*·424*	*·443*	*·468*
"	" " ...	1896–1900	9 a.m.	·502	·542	·567	·547	·492	·459	·430	·436	·426	·438	·442	·458
"	" " ...	1901–05	"	·525	·562	·582	·556	·522	·486	·432	·418	·416	·430	·453	·476

The V.P. for Longwood was calculated from Kupffer's Tables (St. Petersburg, 1841), which are based on the formula $e'' = e' - 0{\cdot}257\ (t - t') - 0{\cdot}000857\ (t - t')\ (b - 30)$, in which e'' and e' are the vapour pressure in millimetres at the dew point and at the temperature of the wet bulb respectively, t and t' the temperatures of the dry and wet bulb thermometers in Reaumur degrees, b the height of the barometer in Russian or English "lines."

For the observations from the station of the Royal Engineers and from St. Matthew's Vicarage Glaisher's Hygrometrical Tables have been used.

TABLE VI.—BI-HOURLY VALUES OF WIND DIRECTION AT LONGWOOD FOR THE YEAR.

Degrees from N., by E., to S.

Civil Time. Hrs.	1.	3.	5.	7.	9.	11.	13.	15.	17.	19.	21.	23.
	°	°	°	°	°	°	°	°	°	°	°	°
1841	138·1	139·2	140·1	139·5	138·0	136·6	137·6	137·5	139·0	139·1	138·9	138·5
1844	137·8	138·5	138·7	138·6	137·8	135·9	133·9	136·1	137·6	137·5	137·9	137·2
1845	144·2	145·0	144·7	143·0	141·7	140·1	140·1	142·3	144·2	146·3	145·5	145·4
Mean	140·0	140·9	141·2	140·4	139·2	137·5	137·2	138·6	140·3	141·0	140·8	140·4

TABLE VII.—SERIAL MONTHLY VALUES FOR LONGWOOD.

Wind Direction.

Degrees from N., by E., to S.

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1841	136·1	142·7	140·7	135·1	130·4	129·1	134·2	139·7	143·5	143·3	146·9	141·0	138·6
1844	138·5	141·0	145·9	130·3	136·2	140·5	136·7	136·4	134·8	139·7	134·7	133·2	137·3
1845	130·7	144·9	143·6	139·1	139·3	138·6	136·1	143·9	147·2	152·1	154·1	152·9	143·5
Mean	135·1	142·9	143·4	134·5	135·3	133·4	135·7	140·0	144·8	145·7	145·2	142·4	139·9

Monthly Means of Pressure at 9 a.m. (Local Time), 1840–47.

Height of Barometer cistern, 1,765 feet above low water mark.

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	28 ins. +												
1840	—	—	—	—	—	—	—	—	·345	·282	·305	·287	—
1841	·267	·281	·267	·267	·314	·359	·379	·372	·350	·307	·267	·275	·309
1842	·276	·254	·271	·281	·321	·359	·426	·396	·340	·318	·298	·309	·321
1843	·279	·258	·258	·295	·335	·374	·381	·396	·361	·315	·289	·294	·320
1844	·282	·263	·240	·276	·304	·360	·401	·388	·328	·326	·293	·287	·312
1845	·296	·289	·311	·315	·334	·403	·403	·389	·365	·334	·315	·291	·337
1846	·289	·288	·280	·286	·329	·356	·389	·385	·331	·318	·307	·289	·321
1847	·264	·291	·259	·307	·316	·349	·356	—	—	—	—	—	—

The readings have been reduced to 32° F., and the correction for index error + 0·007 has been applied.

TABLE VII.—SERIAL MONTHLY VALUES FOR LONGWOOD—*continued.*

MONTHLY MEANS OF TEMPERATURE AND VAPOUR PRESSURE AT 9 A.M. LOCAL TIME, 1840–47.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Year.	
	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.
	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.
1840	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	57·1	·410	59·5	·436	61·4	·446	62·8	·467	—	—
1841	63·9	·488	65·8	·545	66·7	·583	65·9	·594	63·4	·515	61·1	·464	59·1	·425	58·5	·422	57·6	·419	58·2	·431	61·3	·469	63·2	·474	62·1	·486
1842	63·8	·514	65·3	·560	66·8	·581	65·4	·537	64·2	·509	59·8	·452	57·7	·408	57·2	·399	58·0	·412	59·0	·425	60·6	·441	61·5	·464	61·6	·475
1843	64·6	·510	66·0	·525	65·4	·563	65·0	·507	61·6	·470	58·8	·414	57·4	·408	56·6	·390	56·7	·403	57·4	·417	59·6	·435	62·4	·489	61·0	·461
1844	65·5	·511	67·3	·569	**68·1**	·590	67·1	·574	64·0	·501	61·2	·441	58·4	·410	57·1	·426	57·4	·442	58·3	·443	59·0	·438	61·1	·457	62·0	·484
1845	62·6	·464	64·3	·515	65·0	·516	65·2	·539	62·9	·505	59·9	·443	57·9	·419	56·6	·422	56·2	·417	59·3	·454	59·3	·441	60·9	·455	60·8	·466
1846	64·6	·507	66·9	**·604**	68·0	·592	66·6	·579	63·5	·515	61·1	·453	58·6	·431	58·1	·427	58·5	·431	59·0	·424	60·0	·468	61·6	·456	62·2	·491
1847	63·2	·503	65·8	·547	66·3	·579	65·4	·535	64·0	·488	59·8	·476	58·5	·432	—	—	—	—	—	—	—	—	—	—	—	—

The Vapour Pressures have been computed from the dry and wet bulb readings by Kupffer's Tables.

ABSOLUTE EXTREME TEMPERATURES, 1841–45.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1841	70·6	59·2	73·2	60·0	71·8	61·9	71·6	61·0	69·5	57·5	69·2	55·2	65·0	54·9	63·8	53·9	64·7	54·2	66·3	54·0	71·4	55·3	70·6	59·2
1842	72·5	59·1	72·8	61·6	**77·6**	62·6	71·6	61·1	71·1	57·8	68·6	55·4	62·7	52·1	62·0	52·4	66·9	54·0	66·2	53·8	69·0	56·2	72·5	55·6
1843	73·1	60·3	73·2	61·4	71·3	61·9	69·9	61·5	68·2	56·7	65·1	54·3	62·2	52·7	63·5	52·3	63·7	53·0	63·7	53·5	67·8	54·7	72·4	58·0
1844	—	—	74·3	62·5	74·8	**63·4**	74·8	63·1	70·2	59·3	66·4	57·2	64·0	53·6	63·7	53·3	66·6	53·0	65·3	53·8	65·5	56·0	69·0	56·5
1845	70·2	58·8	71·8	60·2	71·3	60·5	71·7	61·6	71·0	59·0	65·9	55·2	63·9	53·5	61·1	53·4	61·7	52·0	67·8	54·9	66·4	55·6	67·7	55·7

TABLE VIII.—AVERAGE HOURLY VALUES FOR LONGWOOD, 1841–45.*

PRESSURE. Height of Cistern, 1,765 feet above Low Water Mark.

Local Time.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Midt.	Daily Means.
	28 inches +																								ins.
January	·235	·223	·216	·219	·227	·246	·263	·274	·280	·280	·273	·263	·251	·235	·220	·211	·214	·223	·235	·250	·263	·271	·267	·252	28·245
February ...	·229	·215	·206	·209	·213	·227	·245	·259	·269	·270	·264	·254	·237	·222	·208	·200	·200	·208	·219	·235	·247	·256	·256	·244	28·233
March	·232	·218	·208	·206	·213	·224	·241	·258	·269	·271	·264	·251	·230	·214	·201	**·196**	·199	·207	·220	·235	·250	·259	·255	·245	**28·232**
April	·254	·239	·227	·225	·229	·244	·260	·276	·287	·293	·282	·263	·245	·229	·216	·215	·219	·225	·237	·253	·265	·270	·269	·265	28·249
May	·283	·274	·264	·263	·267	·277	·293	·309	·322	·325	·316	·299	·280	·263	·254	·253	·259	·266	·276	·290	·300	·303	·301	·293	28·284
June	·337	·326	·315	·314	·316	·325	·339	·356	·371	·374	·366	·351	·333	·330	·312	·312	·316	·325	·334	·344	·352	·356	·352	·343	28·338
July	·369	·357	·346	·342	·344	·352	·365	·382	·398	**·401**	·395	·379	·363	·347	·341	·343	·351	·358	·366	·376	·383	·387	·384	·379	**28·367**
August	·357	·344	·335	·331	·332	·345	·357	·373	·388	·394	·385	·370	·353	·339	·330	·331	·337	·343	·355	·367	·375	·380	·378	·370	28·357
September ...	·318	·304	·294	·290	·296	·308	·323	·337	·348	·352	·347	·331	·316	·301	·291	·291	·298	·306	·320	·334	·345	·347	·345	·335	28·320
October... ...	·274	·260	·249	·251	·258	·272	·290	·305	·314	·313	·310	·297	·280	·266	·256	·253	·258	·269	·281	·295	·306	·312	·305	·291	28·282
November ...	·246	·233	·228	·231	·238	·256	·273	·287	·295	·295	·288	·275	·261	·246	·234	·228	·229	·238	·251	·267	·278	·286	·279	·265	28·259
December ...	·245	·233	·226	·227	·238	·258	·275	·285	·291	·290	·285	·275	·261	·247	·232	·223	·225	·235	·248	·263	·274	·283	·278	·264	28·257
Year ...	·282	·269	·259	·259	·264	·278	·294	·308	·319	**·322**	·315	·301	·284	·270	·258	**·255**	·259	·267	·278	·292	·303	·309	·306	·295	28·285

* The values for the even hours, 2, 4, &c., are from September, 1842, to December, 1845, only.

TABLE VIII.—AVERAGE HOURLY VALUES FOR LONGWOOD—*continued.*

TEMPERATURE, 1841–45.*

Local Time.	1.	2.	3.	4.	5.	6.	7	8.	9.	10.	11.	Noon.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Midt.	Daily Means.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
January ...	61·9	61·7	61·6	61·5	61·4	61·4	61·8	62·8	64·1	65·4	66·6	67·7	68·1	67·9	67·8	67·3	66·0	64·6	63·4	62·9	62·6	62·4	62·3	62·1	64·0
February ...	64·0	63·8	63·6	63·5	63·4	63·4	63·6	64·4	65·7	67·1	68·2	69·1	69·6	69·9	69·6	69·0	67·9	66·6	65·4	64·9	64·7	64·5	64·3	64·1	65·9
March	64·5	64·3	64·2	64·2	64·0	64·1	64·3	65·1	66·4	67·4	68·4	69·1	69·6	69·9	69·7	69·1	68·1	66·9	65·8	65·5	65·2	65·0	64·8	64·7	66·2
April	64·0	63·9	63·8	63·7	63·5	63·5	63·7	64·5	65·7	66·7	67·9	68·5	68·9	69·0	68·6	68·0	67·0	65·8	65·2	64·8	64·6	64·5	64·3	64·1	65·6
May	61·6	61·4	61·2	61·2	61·2	61·0	61·1	62·0	63·2	64·1	65·2	65·8	66·0	66·1	65·8	65·2	64·1	63·6	63·3	62·7	62·1	62·0	61·9	61·7	63·1
June	58·9	58·7	58·6	58·6	58·5	58·5	58·5	59·1	60·2	61·0	61·8	62·4	62·8	62·7	62·4	61·8	61·0	60·1	59·7	59·5	59·3	59·2	59·1	59·0	60·1
July	56·7	56·6	56·5	56·4	56·4	56·3	56·4	57·1	58·1	58·9	59·7	60·4	60·8	60·8	60·5	59·9	59·0	58·1	57·7	57·5	57·3	57·1	56·9	56·8	58·0
August	56·0	55·8	55·7	55·5	55·5	55·4	55·6	56·2	57·2	58·1	59·0	59·7	60·0	60·1	59·7	59·1	58·1	57·2	56·8	56·6	56·5	56·3	56·2	56·1	57·2
September ...	55·7	55·5	55·4	55·3	55·2	55·2	55·4	56·1	57·2	58·3	59·1	59·9	60·3	60·2	59·8	59·1	58·0	57·1	56·6	56·4	56·2	56·0	55·9	55·8	57·1
October... ...	56·5	56·3	56·2	56·1	56·0	56·1	56·5	57·4	58·6	59·7	60·7	61·5	62·0	61·9	61·3	60·5	59·3	58·2	57·6	57·6	57·1	57·0	56·8	56·6	58·2
November ...	57·9	57·7	57·6	57·6	57·4	57·5	58·0	58·9	60·2	61·4	62·4	63·4	63·9	64·0	63·5	62·6	61·3	59·9	59·1	58·8	58·6	58·4	58·2	58·1	59·9
December ...	59·8	59·6	59·5	59·3	59·3	59·4	59·8	60·7	62·0	63·0	64·2	65·2	65·8	65·9	65·7	64·9	63·6	62·2	61·1	60·7	60·5	60·3	60·1	60·0	61·8
Year ...	59·8	59·6	59·5	59·4	59·3	59·3	59·6	60·4	61·6	62·6	63·6	64·4	64·8	64·9	64·5	63·9	62·8	61·7	61·0	60·7	60·4	60·2	60·1	59·9	61·4

* The values for the even hours, 2, 4, &c., are from September, 1842, to December, 1845, only.

VAPOUR PRESSURE, 1841–1845.*

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Midt.	Daily Means.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
January ...	·493	·489	·489	·488	·484	·484	·486	·496	·497	·498	·502	·501	·503	·503	·503	·501	·502	·499	·499	·502	·502	·502	·499	·497	·497
February ...	·534	·532	·527	·528	·527	·527	·528	·540	·543	·543	·542	·541	·548	·544	·544	·545	·538	·535	·538	·536	·538	·537	·538	·536	·537
March	·552	·550	·547	·548	·543	·545	·551	·559	·567	·570	·576	·573	·573	·572	·570	·564	·561	·557	·556	·555	·556	·557	·555	·554	·559
April	·535	·533	·533	·531	·527	·531	·532	·542	·550	·552	·558	·565	·564	·562	·561	·557	·550	·544	·543	·542	·544	·541	·539	·535	·545
May	·483	·480	·477	·477	·479	·476	·477	·491	·500	·506	·511	·516	·513	·512	·506	·497	·492	·486	·488	·489	·485	·485	·485	·481	·491
June	·433	·433	·426	·429	·431	·428	·434	·440	·443	·457	·459	·460	·461	·463	·456	·452	·448	·445	·442	·442	·439	·438	·438	·438	·443
July	·403	·404	·403	·401	·398	·399	·400	·411	·414	·418	·422	·426	·427	·425	·422	·421	·418	·413	·411	·411	·411	·409	·406	·404	·412
August	·405	·401	·398	·396	·397	·398	·402	·406	·412	·421	·425	·426	·429	·425	·421	·420	·414	·411	·412	·412	·409	·409	·404	·407	·411
September ...	·403	·401	·398	·398	·398	·398	·402	·408	·417	·423	·427	·431	·429	·430	·426	·420	·415	·412	·410	·410	·409	·408	·406	·403	·412
October... ...	·416	·416	·413	·414	·412	·414	·418	·425	·434	·439	·445	·447	·448	·444	·442	·437	·431	·426	·423	·421	·423	·423	·421	·418	·427
November ...	·432	·425	·424	·426	·421	·424	·429	·433	·445	·449	·452	·455	·455	·457	·451	·449	·445	·440	·438	·436	·437	·435	·434	·432	·438
December ...	·458	·456	·456	·451	·449	·453	·456	·464	·468	·472	·474	·476	·478	·474	·472	·473	·471	·465	·465	·464	·465	·462	·463	·461	·464
Year ...	·462	·460	·458	·457	·455	·456	·460	·468	·474	·479	·483	·485	·486	·484	·481	·478	·474	·469	·469	·468	·468	·467	·466	·464	·470

* The values for the even hours, 2, 4, &c., are from September, 1842, to December, 1845, only.

The Vapour Pressures have been computed from the dry and wet bulb readings by Kupffer's Tables.

WIND VELOCITY IN MILES PER HOUR, 1844–5.

Converted from pressures recorded by Osler's anemometer by the formula P = ·003 V² (Units :—lbs. per sq. ft. and miles per hour).

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Midt.	Daily Means.
January ...	20·4	20·6	20·8	21·7	22·3	22·5	22·3	22·3	22·5	22·5	22·5	20·4	19·7	19·3	19·2	18·8	19·3	19·0	19·4	19·4	19·0	19·7	20·8	20·8	20·6
February ...	17·0	17·3	17·2	17·7	18·1	18·3	19·0	19·0	19·3	19·7	20·1	19·5	18·8	18·4	17·9	17·5	17·7	17·5	17·5	17·4	17·4	17·3	17·3	17·3	18·1
March	16·6	17·0	17·3	17·7	17·9	18·1	18·1	18·1	17·9	17·9	18·3	16·6	16·4	16·6	16·1	15·7	15·9	16·1	16·2	16·2	16·4	16·8	16·8	16·4	17·0
April	15·0	15·4	15·5	16·1	16·1	16·3	16·8	16·6	16·8	16·8	17·0	14·8	14·8	14·4	14·4	14·2	14·4	14·4	15·0	15·5	15·5	15·1	15·2	15·0	15·5
May	15·0	15·0	14·8	15·2	15·7	15·9	15·9	16·1	16·5	16·4	17·0	14·8	14·6	15·2	15·0	15·1	15·3	15·5	15·7	15·9	15·7	15·5	15·3	15·3	15·5
June	16·3	16·3	16·6	17·0	17·4	17·5	17·7	17·9	18·1	18·3	17·7	16·1	15·9	15·5	15·7	15·5	15·5	15·9	15·9	16·1	15·9	15·9	16·3	16·1	16·5
July	16·6	16·6	16·4	16·6	15·5	17·5	17·9	18·4	19·0	19·2	20·1	18·1	17·5	17·0	17·0	16·6	16·8	16·4	16·8	16·6	17·2	17·2	17·0	16·8	17·3
August	20·8	20·6	20·1	20·3	20·5	21·0	21·6	21·5	21·6	22·5	22·5	20·8	20·3	19·7	19·5	19·7	19·7	19·9	19·7	20·2	20·6	20·8	20·8	20·8	20·6
September ...	18·4	18·1	17·9	18·1	19·0	19·4	19·7	20·1	20·5	21·0	21·0	19·2	19·2	19·0	19·0	19·2	19·5	19·5	19·4	19·2	19·0	18·8	18·8	18·4	19·2
October... ...	20·6	20·6	21·6	21·7	22·1	22·5	22·8	23·0	23·4	23·8	23·2	21·4	20·8	20·3	19·9	20·3	20·4	20·6	20·6	20·4	20·2	20·4	20·4	20·6	21·3
November ...	21·4	21·6	21·6	21·9	22·3	22·8	23·6	*23·8*†	23·8	23·9	23·9	22·8	22·8	22·8	23·0	23·0	23·4	23·0	23·0	22·3	21·9	21·9	22·1	21·8	22·7
December ...	20·1	20·3	21·0	21·9	22·3	22·5	22·8	23·2	23·2	23·2	22·8	20·6	20·8	20·8	20·4	20·1	20·3	20·4	20·1	20·1	19·7	19·4	19·7	19·7	21·1
Year ...	18·2	18·3	18·4	18·8	19·1	19·5	19·9	20·0	20·2	20·4	20·5	18·8	18·5	18·3	18·1	18·0	18·2	18·2	18·3	18·3	18·2	18·2	18·4	18·3	18·8

† Missing value assumed to be 23·8 for inclusion in the means.

Further reference to this Table is made on page 28.

TABLE IX.—SERIAL MONTHLY VALUES FOR THE STATION OF THE ROYAL ENGINEERS. READINGS TAKEN AT 9.30 A.M. LOCAL TIME.

* PRESSURE, 1853–62. (Height of Cistern 40 ft. above M.S.L.)

—	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1853	—	—	—	—	—	—	—	—	0·105	0·087	0·036	0·046	—
1854	9·990	0·019	0·014	0·038	0·065	0·143	0·185	0·158	0·151	0·118	0·084	0·026	0·083
1855	0·009	0·060	0·021	0·004	0·050	0·098	0·144	0·167	0·146	0·073	0·039	0·041	0·071
1856	0·039	0·021	0·025	0·048	0·081	0·107	0·131	0·109	0·073	0·061	0·000	—	—
1857	—	—	—	0·015	0·063	0·118	0·109	0·139	0·110	0·098	0·028	0·051	—
1858	—	0·015	0·009	0·025	0·059	0·077	0·155	0·110	0·109	0·087	0·155	0·131	—
1859	0·031	0·007	9·997	0·015	0·042	0·146	0·169	0·158	0·127	0·109	0·096	0·051	0·079
1860	0·048	9·985	0·008	0·037	0·098	0·130	0·140	0·134	0·124	0·094	0·081	0·052	0·078
1861	0·027	0·112	0·104	0·035	0·061	0·120	0·132	0·161	0·109	0·018	0·045	0·010	0·078
1862	0·002	9·978	9·974	9·964	—	—	—	—	—	—	—	—	—
Averages, 1854, 1855, 1859–1861.	0·021	0·037	0·029	0·026	0·063	0·127	0·154	0·156	0·131	0·082	0·069	0·036	0·078

† TEMPERATURE AND VAPOUR PRESSURE, 1857–62.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Year.	
	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.	T.	V.P.
	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.	° F.	ins.
1857	—	—	—	—	—	—	—	—	—	—	—	—	—	—	69·5	·564	71·4	·528	72·1	·577	73·2	·654	74·1	·521	—	—
1858	—	—	76·7	·651	76·6	·611	78·4	·615	74·3	·614	72·9	·628	68·5	·642	68·9	·651	70·1	·645	72·3	·520	74·4	·511	76·6	·525	—	—
1859	—	—	77·9	·601	78·4	·648	77·2	·659	73·6	·574	71·3	·578	70·7	·551	70·9	·534	70·4	·539	70·7	·467	72·4	·498	74·6	·484	—	—
1860	79·0	·495	80·5	·521	82·6	·504	83·2	·501	73·6	·571	72·2	·461	70·6	·400	70·6	·416	71·0	·420	71·4	·457	71·6	·509	72·1	·482	74·9	·478
1861	74·4	·514	76·2	·517	76·0	·535	74·3	·544	73·5	·510	71·3	·455	70·0	·443	69·6	·467	68·2	·501	70·2	·538	71·5	·523	74·0	·532	72·4	·507
1862	74·4	·565	76·5	·587	78·8	·578	77·9	·560	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Averages, 1858-1861.	—	—	77·8	·573	78·4	·575	78·3	·580	73·8	·567	71·9	·531	70·0	·509	70·0	·517	69·9	·526	71·2	·496	72·5	·510	74·3	·506	—	—

ABSOLUTE EXTREME TEMPERATURES, 1853–62.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1853	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	75·2	—	76·0	—	78·2	—	81·0	—
1854	85·6	—	88·0	—	86·2	—	84·1	—	82·2	—	75·0	—	71·0	—	70·5	—	70·0	—	71·2	—	76·0	—	80·0	—
1855	85·0	—	86·0	—	84·5	—	82·0	—	78·2	—	75·0	—	70·2	—	70·0	—	69·2	—	76·0	—	75·5	—	80·0	—
1856	80·0	—	86·0	66·0	85·0	66·0	84·0	68·0	83·0	64·0	75·0	62·0	—	—	—	—	—	—	—	—	—	—	—	—
1857	—	—	—	—	—	—	84·0	65·0	81·5	63·5	81·0	61·0	79·0	58·0	76·0	60·0	76·0	58·0	75·8	61·0	78·2	64·0	78·0	60·0
1858	—	—	83·0	67·0	83·0	67·0	82·5	66·0	79·5	64·0	77·5	63·0	71·5	61·0	74·0	58·5	75·0	61·5	77·0	63·0	78·0	62·0	81·0	65·0
1859	84·0	68·0	—	67·0	84·5	69·0	84·0	69·0	79·0	64·0	79·0	61·0	78·0	62·0	78·0	60·0	77·0	62·0	77·0	61·0	80·0	62·0	82·0	64·0
1860	89·0	63·0	90·0	69·0	92·0	68·0	93·0	68·0	78·0	61·0	80·0	62·0	78·0	59·0	78·0	60·0	78·0	61·0	78·0	60·0	77·0	62·0	78·0	63·0
1861	80·0	64·0	82·0	67·0	81·0	68·0	79·0	63·0	78·0	64·0	78·0	61·0	79·0	60·0	78·0	59·0	—	62·0	—	61·0	79·0	64·0	80·0	65·0
1862	83·2	67·0	83·0	68·0	87·0	67·0	87·0	67·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* In the results for Pressure the first figure (2 or 3) is omitted.

† The means for Vapour Pressure are deduced from the readings of the dry and wet bulb thermometers by means of Glaisher's Hygrometrical Tables.

RAINFALL, 1853–62.

—	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Totals.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1853	—	—	—	—	—	—	—	—	·68	·01	·04	·04	—
1854	·16	·25	1·55	·00	1·28	1·09	2·86	·00	·69	·20	·00	·20	8·28
1855	·62	·98	1·43	·15	·49	1·14	·91	1·18	·12	·20	·00	·00	7·22
1856	·53	·61	·58	·39	·00	·40	2·76	·25	·00	·00	·00	—	—
1857	—	—	—	·83	·00	·43	·55	·22	·00	·00	·00	·00	—
1858	·04	·10	·86	·23	·88	·15	·90	·67	·00	·00	·00	·12	3·95
1859	·14	.52	·57	·38	·60	1·52	·66	·14	·00	·00	·05	·00	4·58
1860	·17	·23	·16	·60	1·04	·07	·56	·16	·18	·02	·00	·12	3·31
1861	·05	·03	·81	—	·98	1·13	1·03	·64	·04	·00	·00	·10	—
1862	1·09	·34	·45	·55	—	—	—	—	—	—	—	—	—
Averages, 1854, 1855, 1858–1860.	·23	·42	·91	·27	·86	·79	1·18	·43	·20	·08	·01	·09	5·47

TABLE X.—SERIAL MONTHLY RESULTS FOR ST. MATTHEW'S VICARAGE.

* Pressure at 9 a.m. Local Time and Wind Velocity in Miles per Hour.

(Height of barometer cistern, 1,900 feet.)

The Wind Velocities are the means for 24 hours, taken independently of direction. The vector resultants for the months are given in the diagrams of Plates 12 and 13.

—	January.		February.		March.		April.		May.		June.	
	ins.	m. p. h.	ins.	m. p. h.	ins.	m. p. h.	ins.	m. p. h.	ins.	m. p. h.	ins.	m. p. h.
1892	—	—	7·980	14·5	7·979	11·7	8·025	13·3	8·080	—	8·122	16·9
1893	7·973	15·0	7·989	—	8·007	—	8·014	13·5	8·032	13·3	8·091	—
1894	7·991	15·7	7·998	—	8·002	13·9	8·018	—	8·030	—	8·105	—
1895	7·992	17·0	7·992	14·2	7·980	17·7	8·018	13·2	8·071	12·6	8·141	14·3
1896	8·003	15·9	8·021	15·8	7·987	14·6	7·992	16·0	8·066	10·3	8·140	15·1
1897	7·998	14·9	8·036	15·1	7·994	11·1	8·044	16·0	8·033	12·2	8·107	14·0
1898	8·010	17·3	7·988	18·1	7·968	20·3	8·019	18·3	8·045	18·1	8·092	15·2
1899	7·984	18·5	7·972	16·5	7·998	15·6	8·006	14·8	8·062	14·0	8·098	15·8
1900	8·013	15·6	8·041	18·5	8·026	14·4	8·032	15·9	8·056	14·1	8·092	13·7
1901	8·052	17·6	8·026	16·0	8·043	14·8	8·052	17·0	8·053	17·2	8·049	—
1902	8·056	18·1	8·045	—	8·035	15·0	8·048	14·5	8·058	14·3	8·061	20·0
1903	8·023	—	8·017	19·8	8·037	—	8·047	—	8·060	—	8·101	—
1904	8·049	—	8·031	—	8·013	—	8·035	—	8·056	—	8·106	—
1905	8·030	—	8·000	—	8·026	—	8·035	—	8·046	—	8·057	17·3
1906	8·052	16·7	8·043	14·3	8·053	15·1	8·055	10·7	8·071	13·7	8·107	14·1
1907	8·067	18·7	8·033	13·3	8·038	16·8	8·012	14·7	8·042	15·5	8·087	15·2
1908†	*8·107*	*19·3*	*8·105*	*14·7*	*8·086*	*16·5*	*8·077*	*18·1*	*8·064*	*15·5*	*8·051*	*14·3*
Averages	8·020	17·0	8·013	15·8	8·012	15·5	8·028	15·1	8·054	14·2	8·097	15·3

—	July.		August.		September.		October.		November.		December.		Year.	
	ins.	m.p.h.	ins.	m.p.h.	ins.	m.p.h.	ins.	m.p.h.	ins.	m.p.h.	ins.	m.p.h.	ins.	m. p. h.
1892	8·149	—	8·099	—	8·086	—	8·042	16·9	8·002	21·3	8·009	16·8	—	—
1893	8·094	18·4	8·115	22·2	8·071	23·0	8·040	—	8·042	—	7·991	—	8·038	—
1894	8·105	12·7	8·109	—	8·085	—	8·051	16·5	8·033	20·6	8·040	15·8	8·048	—
1895	8·120	12·6	8·087	15·9	8·063	18·6	8·043	—	8·035	18·9	8·015	17·1	8·046	15·6
1896	8·139	13·4	8·138	20·1	8·053	15·1	8·041	18·1	8·026	20·8	8·027	18·9	8·053	16·2
1897	8·116	15·9	8·106	18·2	8·105	22·4	8·080	19·5	8·032	20·6	8·041	20·2	8·058	16·7
1898	8·115	14·6	8·092	13·6	8·068	20·5	8·060	22·5	8·021	18·9	8·013	19·0	8·041	18·0
1899	8·073	13·9	8·075	18·2	8·091	26·7	8·054	19·2	8·036	18·1	8·020	19·2	8·039	17·5
1900	8·095	15·5	8·090	18·6	8·069	20·5	8·070	19·0	8·059	19·3	8·062	18·4	8·059	17·0
1901	8·064	18·9	8·099	17·6	8·089	24·0	8·066	21·3	8·069	18·5	8·056	19·3	8·060	18·4
1902	8·075	20·0	8·083	25·8	8·072	21·5	8·068	22·2	8·070	21·2	8·042	—	8·059	19·3
1903	8·059	—	8·082	—	8·076	—	8·072	—	8·059	—	8·038	—	8·056	—
1904	8·126	—	8·128	—	8·091	—	8·046	—	8·060	—	8·046	—	8·066	—
1905	8·052	14·4	8·064	20·2	8·065	16·6	8·071	19·3	8·055	18·6	8·058	17·6	8·047	—
1906	8·106	19·2	8·084	21·1	8·082	19·0	8·070	15·2	8·066	20·2	8·036	18·2	8·069	16·5
1907	8·100	12·7	8·094	12·7	8·084	23·3	8·077	20·0	8·090	20·3	8·095	18·5	8·068	16·8
1908†	*8·049*	*17·9*	*8·051*	*20·3*	*8·060*	*15·9*	*8·048*	*22·5*	*8·042*	*24·8*	*8·013*	*17·8*	*8·063*	*18·2*
Averages	8·099	15·7	8·097	18·2	8·078	21·2	8·059	19·1	8·047	19·7	8·037	18·8	8·054	17·2

* Pressure is given in inches with the first figure omitted.

Monthly Means of Temperature and Vapour Pressure at 9 a.m.

—	January.		February.		March.		April.		May.		June.	
	°F.	ins.	°F.	ins.	°F.	ins.	°F.	ins.	°F.	ins.	°F.	ins.
1892	—	—	66·4	·625	66·3	·581	64·2	·547	61·5	·493	58·6	·464
1893	61·9	·524	63·5	·539	64·6	·550	64·6	·523	63·2	·510	60·5	·452
1894	64·8	·488	65·4	·521	65·6	·574	64·0	·529	62·3	·483	59·4	·425
1895	64·9	·518	66·2	·551	66·4	·565	65·6	·522	64·0	·499	59·8	·454
1896	64·4	·512	64·8	·538	66·5	·582	66·4	·573	62·9	·482	61·5	·463
1897	63·1	·505	65·9	·566	66·9	·580	66·4	·544	63·3	·516	62·0	·472
1898	63·4	·500	64·2	·506	64·4	·558	63·4	·507	60·2	·453	58·0	·424
1899	63·4	·510	65·5	·565	65·5	·568	64·2	·568	62·2	·484	60·0	·463
1900	61·8	·482	64·0	·536	64·8	·547	64·3	·545	63·7	·523	60·7	·474
1901	65·8	·523	68·4	·566	66·4	·584	63·7	·551	63·6	·529	65·7	·565
1902	65·0	·562	67·6	·624	67·3	·625	65·8	·571	65·2	·534	61·0	·487
1903	64·7	·546	65·3	·561	65·6	·585	64·6	·550	62·9	·539	57·6	·448
1904	61·0	·483	63·8	·495	66·1	·549	64·7	·549	62·1	·499	59·7	·470
1905	62·5	·510	65·2	·566	65·4	·567	66·2	·558	64·5	·511	60·5	·462
1906	63·2	·559	64·7	·593	64·9	·595	64·2	·575	62·0	·513	60·0	·492
1907	60·8	·476	64·6	·520	65·8	·578	63·7	·536	61·0	·464	59·1	·454
1908†	*60·3*	*·503*	*62·7*	*·542*	*63·7*	*·558*	*62·3*	*·527*	*60·7*	*·500*	*58·1*	*·465*
Averages, 1892–1907.	63·4	·513	65·3	·555	65·8	·574	64·8	·547	62·8	·502	60·3	·467

—	July.		August.		September.		October.		November.		December.		Year.	
	°F.	ins.	°F.	ins.	°F.	ins.	°F.	ins.	°F.	ins.	°F.	ins.	°F.	ins.
1892	57·0	·425	56·8	·429	55·5	·424	57·6	·424	57·8	·440	60·4	·466	60·2	·483
1893	58·7	·420	56·3	·407	56·2	·422	58·0	·418	57·8	·440	60·9	·450	60·5	·471
1894	58·6	·410	56·4	·407	57·5	·419	59·4	·417	60·4	·447	63·5	·486	61·4	·467
1895	59·8	·454	58·9	·414	58·7	·429	59·0	·436	60·2	·444	61·8	·469	62·1	·480
1896	58·8	·413	56·0	·416	58·2	·430	59·1	·451	59·2	·461	60·0	·472	61·5	·483
1897	59·3	·441	57·6	·424	56·8	·417	57·2	·412	59·3	·423	61·1	·444	61·6	·479
1898	56·3	·404	56·5	·395	56·5	·415	56·4	·425	60·4	·445	61·4	·477	60·1	·459
1899	58·0	·436	57·4	·409	56·8	·429	57·4	·441	58·6	·434	59·5	·457	60·7	·480
1900	58·5	·455	56·7	·536	57·8	·440	58·8	·461	60·5	·446	59·2	·439	60·9	·490
1901	59·8	·438	57·7	·423	56·7	·415	59·1	·441	59·9	·454	60·8	·490	62·3	·498
1902	58·1	·452	56·4	·422	57·0	·414	59·0	·445	59·1	·447	61·1	·495	61·9	·507
1903	56·7	·433	56·2	·410	55·7	·407	55·6	·405	56·2	·416	59·4	·450	60·0	·479
1904	57·9	·420	56·3	·407	56·4	·422	57·8	·427	59·1	·469	60·2	·460	60·4	·471
1905	59·6	·417	57·5	·430	58·1	·423	59·4	·434	60·9	·478	61·6	·485	61·8	·487
1906	56·8	·435	56·3	·421	56·2	·405	57·3	·424	57·9	·438	59·9	·449	60·3	·492
1907	57·6	·432	58·1	·412	56·2	·402	57·2	·418	57·8	·452	58·7	·471	60·1	·468
1908†	*56·6*	*·444*	*55·6*	*·425*	*56·3*	*·433*	*56·6*	*·429*	*56·0*	*·434*	*58·6*	*·477*	*59·0*	*·478*
Averages, 1892–1907.	58·2	·430	56·9	·423	56·9	·420	58·0	·430	59·1	·446	60·6	·466	61·0	·481

The means for Vapour Pressure are deduced from the readings of the dry and wet bulb thermometers by means of Glaisher's Hygrometrical Tables.

† The values for 1908 were inserted in proof and have not been included in the averages.

TABLE X.—SERIAL MONTHLY RESULTS FOR ST. MATTHEW'S VICARAGE—*continued.*

Mean Maximum and Minimum Temperatures, 1892–1908.

—	January.		February.		March.		April.		May.		June.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1892	—	—	73·1	61·7	72·1	61·4	68·9	60·8	66·2	57·2	63·0	56·0
1893	67·6	58·4	68·9	59·9	68·5	61·6	69·1	60·7	69·1	58·9	65·4	57·7
1894	70·2	59·5	71·6	60·8	69·8	61·9	68·1	60·3	67·3	58·0	63·2	55·9
1895	70·8	60·4	73·0	61·6	71·3	62·4	71·3	60·8	69·2	59·0	64·1	56·3
1896	69·9	59·7	70·1	60·5	71·4	**62·5**	70·3	61·7	67·3	57·7	65·9	57·2
1897	66·9	58·5	70·3	60·8	71·3	61·3	70·5	61·8	68·6	58·5	65·8	57·4
1898	69·5	58·4	69·7	59·4	69·1	60·4	68·3	58·5	64·5	56·5	63·2	54·3
1899	69·8	59·3	71·3	62·1	70·9	62·3	69·8	61·1	67·9	58·2	65·9	56·7
1900	69·6	57·3	70·5	59·7	71·4	60·2	70·3	60·3	69·7	59·3	67·2	56·2
1901	70·1	59·7	74·4	61·7	70·9	60·3	69·2	59·4	69·3	59·2	71·0	59·6
1902	70·3	57·8	**73·7**	60·7	73·6	61·3	71·3	60·0	71·0	59·3	66·2	55·5
1903	70·6	60·5	72·8	61·6	71·4	60·8	69·1	60·1	67·2	59·5	63·1	53·3
1904	65·6	56·7	69·4	58·5	72·1	59·9	68·9	60·0	66·6	57·2	64·5	54·9
1905	67·6	57·6	70·0	60·0	70·5	59·9	71·7	60·3	70·2	59·1	65·2	56·1
1906	68·7	59·0	70·5	60·3	71·0	60·5	70·1	59·4	68·1	57·0	65·4	54·7
1907	67·3	57·1	71·5	59·6	71·4	61·9	68·6	59·8	66·9	57·0	64·8	55·2
*1908**	*65·7*	*57·0*	*69·1*	*58·7*	*70·3*	*59·8*	*68·5*	*58·8*	*67·2*	*56·9*	*63·9*	*55·3*
Avers. 1893–1907.	69·0	58·7	**71·3**	60·6	71·0	**61·2**	69·7	60·3	68·1	58·2	65·2	56·1

—	July.		August.		September.		October.		November.		December.		Year.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1892	61·5	54·0	61·0	53·1	**59·6**	52·5	61·5	53·6	61·9	55·0	65·9	56·6	—	—
1893	63·2	55·2	60·9	53·5	59·7	53·6	62·9	54·1	62·1	54·9	66·4	56·9	65·3	57·1
1894	63·3	54·7	59·9	53·3	61·5	53·7	63·7	54·4	65·5	56·6	69·6	58·3	66·1	57·3
1895	64·0	55·4	63·3	55·0	62·8	54·6	63·2	55·1	64·9	55·7	67·1	57·3	67·1	57·8
1896	63·0	54·5	59·8	52·7	62·0	53·9	62·5	54·8	62·6	55·1	64·0	56·1	65·7	57·2
1897	63·3	55·5	61·9	54·0	60·3	53·4	61·2	53·0	63·6	54·5	65·8	56·0	65·8	57·1
1898	61·0	51·7	61·5	51·9	61·2	52·8	61·0	52·8	65·6	54·6	67·1	57·2	65·1	55·7
1899	63·9	53·6	62·9	53·3	61·5	53·4	62·1	53·3	65·0	54·4	65·0	55·6	66·3	56·9
1900	64·4	54·6	63·1	53·5	64·4	54·5	65·4	54·9	66·6	55·9	66·3	55·4	67·4	56·8
1901	66·5	55·0	63·7	53·1	61·8	52·3	64·5	53·0	65·9	54·4	66·9	55·8	67·9	57·0
1902	64·4	52·9	63·4	52·4	63·0	52·0	65·0	52·7	64·8	55·4	65·8	58·1	67·7	56·5
1903	61·7	52·1	61·4	51·7	60·6	**51·1**	59·9	51·8	61·3	52·1	63·8	54·7	65·2	55·8
1904	63·3	53·0	61·0	52·3	60·6	52·3	62·8	53·2	64·1	54·8	65·2	55·7	65·3	55·7
1905	66·0	55·0	62·0	53·9	63·7	53·0	65·3	54·6	66·5	55·9	67·0	56·8	67·1	56·9
1906	62·8	52·3	60·4	52·8	61·4	51·8	62·6	52·7	62·5	53·9	65·6	55·2	65·8	55·8
1907	63·3	54·0	64·0	53·8	61·4	52·9	62·7	53·5	62·3	54·2	64·0	55·1	65·7	56·2
*1908**	*62·5*	*53·7*	*60·4*	*52·8*	*63·5*	*52·9*	*62·5*	*53·5*	*60·9*	*52·9*	*64·1*	*55·0*	*64·8*	*55·6*
Avers. 1893–1907.	63·5	54·0	61·9	53·1	**61·6**	**53·0**	62·9	53·6	64·1	54·8	66·0	56·3	66·2	56·7

* The values for 1908 have not been included in the averages.

Absolute Extreme Temperatures.

—	January.		February.		March.		April.		May.		June.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1892	—	—	78·1	59·5	78·0	59·0	73·2	57·5	70·0	51·5	66·3	53·0
1893	73·1	56·3	72·3	58·0	74·1	59·1	72·6	58·0	75·6	55·1	72·0	54·9
1894	74·0	57·6	75·7	59·1	74·5	59·1	77·9	58·1	71·0	55·0	68·5	53·2
1895	74·7	56·3	77·5	59·7	77·1	60·0	75·0	58·2	75·1	55·5	67·8	54·6
1896	73·4	51·2	76·5	58·5	77·6	59·0	75·0	58·6	73·0	54·8	71·0	54·7
1897	70·2	56·3	74·0	55·0	75 3	58·5	74·2	**60·4**	76·1	56·0	69·6	54·1
1898	73·0	57·1	73·2	57·2	72·8	54·3	76·6	52·2	70·1	52·2	67·0	49·0
1899	76·1	57·1	75·0	60·0	76·6	59·6	75·0	57·0	73·0	54·0	70·0	53·0
1900	74·6	55·0	74·0	58·0	75·6	57·1	75·0	58·0	75·0	53·6	72·0	53·1
1901	76·1	56·0	78·0	59·0	78·0	55·0	74·0	56·6	78·0	56·0	78·0	50·0
1902	74·6	54·6	78·0	59·0	76·6	60·0	76·0	56·0	76·6	55·0	70·0	53·0
1903	74·7	56·3	76·1	59·0	77·0	58·6	73·0	58·0	73·0	50·0	67·5	50·0
1904	71·0	55·0	74·0	57·0	77·6	56·0	72·5	58·0	70·6	51·0	69·0	52·0
1905	74·0	55·1	74·0	58·0	76·0	58·0	**80·0**	57·6	77·0	56·1	72·3	53·1
1906	72·0	56·1	76·0	59·0	75·0	58·1	75·0	57·0	73·0	54·0	70·0	52·0
1907	70·1	55·9	74·5	58·0	76·0	59·0	72·1	57·5	71·9	55·0	68·0	52·9
1908	74·	55·	73·	57·	75·	58·	72·	53·	75·	53·	67·	54·

—	July.		August.		September.		October.		November.		December.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1892	67·3	51·7	64·3	50·0	62·6	51·3	67·3	51·3	65·9	54·0	72·6	54·5
1893	66·7	53·3	64·8	51·3	62·4	52·0	69·7	52·8	66·0	53·9	72·3	56·0
1894	68·7	52·3	62·1	52·0	66·2	51·0	71·0	51·6	71·1	55·5	76·2	57·0
1895	69·2	52·5	67·0	53·0	64·0	53·2	67·3	54·0	67·6	54·1	71·7	55·5
1896	67·2	51·5	63·7	50·6	66·7	50·2	66·2	53·3	65·7	53·5	67·7	53·9
1897	68·2	53·8	66·1	51·2	63·3	52·0	64·8	51·0	67·8	53·0	71·1	54·8
1898	65·0	46·0	66·0	49·0	65·1	51·0	63·6	51·6	72·0	53·1	71·0	55·6
1899	67·0	49·0	68·0	51·0	64·1	52·0	65·6	51·0	72·0	53·0	68·0	54·0
1900	68·1	50·6	66·0	51·0	66·6	52·0	67·6	53·0	70·0	54·0	72·0	53·0
1901	69·0	53·0	72·6	50·6	67·6	51·0	72·0	50·0	70·1	52·6	71·1	53·0
1902	67·0	51·0	66·6	50·0	65·0	49·0	69·0	51·0	69·0	52·0	70·0	55·0
1903	64·0	50·0	65·0	50·0	64·1	49·6	63·0	50·0	64·6	51·0	69·0	52·0
1904	66·1	51·1	66·5	49·6	68·5	51·0	65·0	52·0	70·0	53·0	70·0	54·0
1905	72·6	51·1	67·0	52·5	68·0	51·0	71·1	52·1	74·0	54·0	71·9	55·0
1906	64·6	51·0	67·8	51·0	68·1	48·5	71·1	50·5	67·0	53·0	69·9	54·0
1907	70·0	51·5	71·0	49·9	68·1	50·5	71·0	51·9	66·0	52·9	68·0	53·0
1908	73·	51·	68·	51·	68·	51·	73·	52·	65·	51·	68·	52·

TABLE X.—SERIAL MONTHLY RESULTS FOR ST. MATTHEW'S VICARAGE—*continued.*

RAINFALL AND RAIN-DAYS. READ AT 9 A.M.

Height above M.S.L. 1,900 ft.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Yearly Totals.	
	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.
1892	—	—	2·59	18	3·45	21	6·28	25	4·73	24	3·60	17	2·83	16	1·49	16	5·79	27	1·54	16	0·70	15	0·67	13	—	—
1893	5·66	25	6·28	19	8·03	24	3·14	18	1·56	16	1·19	15	3·12	17	4·60	26	2·90	19	1·53	17	1·99	21	**0·35**	10	40·35	227
1894	2·05	13	2·22	16	**11·05**	31	5·23	21	3·92	22	3·06	19	1·71	15	3·70	23	2·95	26	1·13	15	0·61	9	1·47	21	39·10	231
1895	0·97	17	1·76	19	5·09	24	1·35	22	3·93	19	7·94	25	3·27	19	2·01	18	2·41	19	1·03	13	1·34	13	1·21	16	32·31	224
1896	2·44	21	4·11	25	6·71	26	1·55	16	3·30	22	2·77	18	2·34	12	7·70	26	1·53	17	1·67	18	2·70	26	3·71	30	40·53	257
1897	4·77	24	3·86	24	4·59	23	1·57	20	6·15	27	1·52	21	3·41	22	4·13	22	2·58	23	1·63	22	0·47	13	0·53	8	35·21	249
1898	2·36	24	2·96	21	4·04	25	4·28	20	5·30	21	2·03	20	4·67	24	1·98	19	1·77	12	2·29	22	0·97	15	1·32	17	33·97	240
1899	2·02	22	4·48	19	6·01	25	7·19	27	6·32	20	2·27	16	4·54	25	3·61	20	4·42	23	3·88	23	0·37	10	2·23	22	47·34	252
1900	1·45	17	2·07	16	3·49	24	3·32	25	1·81	17	3·37	21	5·21	22	3·42	26	1·35	18	2·05	23	0·39	9	3·05	26	30·98	244
1901	1·66	18	2·46	20	5·88	31	7·94	26	2·24	19	1·35	17	1·35	14	3·93	14	5·41	22	1·74	12	2·09	16	2·86	23	38·91	232
1902	1·37	19	1·39	10	2·42	25	1·98	22	2·74	16	4·01	23	6·20	27	6·76	28	2·76	19	0·77	21	1·90	18	2·74	23	35·04	251
1903	3·33	21	6·08	27	3·00	19	2·21	20	4·38	26	5·97	26	3·98	24	2·92	26	1·61	24	2·98	26	2·76	26	4·18	23	43·40	288
1904	4·24	26	2·09	21	4·89	21	10·11	23	4·34	22	2·92	16	2·64	21	3·89	23	3·08	22	3·10	20	1·89	24	2·52	16	45·71	255
1905	2·56	24	3·82	22	4·35	22	0·55	13	3·38	20	4·59	23	0·56	12	5·64	30	2·26	24	1·26	18	2·41	22	4·22	26	35·60	256
1906	3·66	23	5·35	26	5·54	28	4·15	19	3·19	23	7·08	21	6·34	28	4·91	23	3·13	25	1·87	19	1·36	21	3·20	20	49·78	276
1907	3·15	24	1·78	19	5·57	21	8·20	30	4·06	29	4·28	27	3·51	24	1·85	17	2·28	18	3·59	18	3·67	26	1·87	24	43·81	277
*1908**	*3·90*	*26*	*3·37*	*25*	*1·41*	*17*	*2·97*	*22*	*3·01*	*14*	*4·72*	*26*	*3·11*	*22*	*6·18*	*27*	*2·75*	*20*	*1·96*	*22*	*3·93*	*30*	*2·05*	*23*	*39·36*	*274*
Average, 1892–1907.	2·78	21·2	3·33	20·1	**5·26**	24·4	4·32	21·7	3·83	21·4	3·62	20·3	3·48	20·1	3·91	22·3	2·89	21·1	2·00	18·9	1·60	17·8	2·26	19·9	39·47	250·6

* The values for 1908 were inserted in proof and have not been included in the average.

TABLE XI.—CLIMATOLOGICAL SUMMARY FOR ST. MATTHEW'S VICARAGE.

AVERAGE VALUES, BASED ON OBSERVATIONS EXTENDING OVER 16 YEARS, 1892–1907.

Longitude, 5° 40′ W.; Latitude, 16° 0′ S. Height of Barometer, 1,900 feet. Gravity Correction, − 0·061 inch.

—	Mean Pressure at 32° Fahrenheit at Level and Latitude of Station.	Air Temperature. 9 a.m.	Means of Max.	Means of Min.	Max. and Min. Combined.	Absolute Max. and Min. Max.	Year.	Min.	Year.	Humidity. Depression of Wet Bulb. 9 a.m.	Vapour Pressure. 9 a.m.	Percentage. 9 a.m.	Amount of Cloud (0–10). 9 a.m.	Rainfall. Total.	Max.	Day.	No. of Days.
	ins.	°	°	°	°	°		°		°	in.	%		ins.	ins.		
Jan.	28·020	63·4	69·0	58·7	63·9	76·1	'99,'01	51·2	1896	2·0	0·513	88	8·4	2·78	1·20	24th, 1903	21·2
Feb.	·013	65·3	71·3	60·6	66·0	78·1	1892	55·0	1897	1·9	·555	89	8·3	3·33	3·17	8th, 1903	20·1
Mar.	·012	65·8	71·0	61·2	66·1	78·0	'92,'01	54·3	1898	1·6	·574	91	8·1	5·26	1·59	12th, 1894	24·4
April	·028	64·8	69·7	60·3	65·0	80·0	1905	52·2	1898	1·8	·547	90	8·2	4·32	2·18	3rd, 1904	21·7
May	·054	62·8	68·1	58·2	63·2	78·0	1901	50·0	1903	2·0	·502	88	8·1	3·83	1·90	21st, 1899	21·4
June	·097	60·3	65·2	56·1	60·7	78·0	1901	49·0	1898	1·7	·467	90	8·3	3·62	1·91	15th, 1906	20·3
July	·099	58·2	63·5	54·0	58·8	72·6	1905*	46·0	1898	1·8	·430	89	8·3	3·48	1·11	25th, 1900	20·1
Aug.	·097	56·9	61·9	53·1	57·5	72·6	1901	49·0	1898	1·6	·423	90	8·9	3·91	2·17	6th, 1901	22·3
Sept.	·078	56·9	61·6	53·0	57·3	68·5	1904	48·5	1906	1·5	·420	90	9·1	2·89	1·12	2nd, 1901	21·1
Oct.	·059	58·0	62·9	53·6	58·3	72·0	1901*	50·0	'01,'03	1·7	·430	89	8·9	2·00	0·77	7th, 1904	18·9
Nov.	·047	59·1	64·1	54·8	59·5	74·0	1905	51·0	1903	1·8	·446	89	8·7	1·60	0·56	14th, 1902	17·8
Dec.	28·037	60·6	66·0	56·3	61·2	76·2	1894	52·0	1903	1·9	0·466	89	8·7	2·26	1·87	8th, 1905	19·9
Year	28·054	61·0	66·2	56·7	61·5	80·0	1905	46·0	1898	1·8	0·481	89	8·5	39·47	3·17	Feb. 8th, 1903.	250·6

* 73° in 1908.

Wind. Mean Velocity m.p.h.	N. Percentage frequency.	N. Mean Velocity m.p.h.	N.E. Percentage frequency.	N.E. Mean Velocity m.p.h.	E. Percentage frequency.	E. Mean Velocity m.p.h.	S.E. Percentage frequency.	S.E. Mean Velocity m.p.h.	S. Percentage frequency.	S. Mean Velocity m.p.h.	S.W. Percentage frequency.	S.W. Mean Velocity m.p.h.	Calms. Percentage frequency.	—
	Wind—Averages, 1892–1898.													
17·0	—	—	—	—	5·0	13·5	75·5	17·5	19·5	17·5	—	—	—	Jan.
15·8	—	—	1·0	6·5	6·0	13·5	70·0	17·0	22·0	16·5	—	—	1·0	Feb.
15·5	—	—	—	—	5·0	13·0	67·0	17·0	26·0	16·5	0·5	11·0	1·5	Mar.
15·1	0·5	7·5	1·5	8·0	7·0	13·0	68·0	17·0	21·0	16·5	—	—	2·0	Apr.
14·2	2·0	9·5	2·0	7·5	10·0	11·5	63·0	15·5	18·0	15·5	1·0	10·0	4·0	May.
15·3	—	—	1·5	6·0	12·0	15·0	66·0	17·5	17·5	16·0	0·5	10·5	2·5	June.
15·7	1·0	8·0	2·0	6·0	9·0	13·5	62·0	17·5	20·5	17·5	0·5	7·0	5·0	July.
18·2	—	—	0·5	7·0	6·0	15·5	73·0	20·5	19·5	19·0	—	—	1·0	Aug.
21·2	—	—	0·5	7·0	2·5	13·5	73·0	21·5	23·0	20·5	—	—	1·0	Sept.
19·7	—	—	—	—	2·0	13·5	70·0	21·0	27·0	19·0	—	—	1·0	Oct.
19·7	—	—	—	—	2·0	15·5	74·0	21·5	24·0	22·5	—	—	—	Nov.
18·8	—	—	—	—	4·5	15·0	77·5	19·5	17·0	18·5	—	—	1·0	Dec.
17·2	—	—	—	—	—	—	—	—	—	—	—	—	—	Year.

TABLE XII.—RAINFALL AND RAIN-DAYS AT MOUNT PLEASANT. READ AT 9 A.M.

Height, 2,000 feet above M.S.L.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Yearly Totals.	
	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.
1896	—	—	4·45	27	7·83	28	2·17	17	4·07	19	3·28	17	2·78	13	8·01	26	1·40	16	1·44	19	2·43	26	3·12	29	—	—
1897	6·13	26	4·26	25	6·37	21	2·16	18	7·29	27	1·83	16	4·60	21	2·95	21	2·34	19	1·57	20	0·46	12	0·38	9	40·34	235
1898	3·14	21	4·26	19	4·09	23	5·05	19	5·07	22	1·89	19	5·02	21	2·27	18	1·68	10	2·06	19	0·76	13	0·93	12	36·22	216
1899	1·61	18	4·72	18	6·55	26	8·92	27	6·64	18	2·86	20	5·37	24	2·76	19	4·03	22	3·50	23	0·32	8	1·85	17	49·13	240
1900	1·42	14	1·70	14	3·47	24	2·95	18	—	—	—	—	—	—	3·97	24	1·79	17	2·05	17	0·33	8	3·38	22	—	—
1901	1·74	14	1·64	16	8·03	29	9·51	26	2·88	17	2·51	18	2·81	20	3·92	19	5·38	22	1·02	11	1·73	12	—	—	—	—
1902	0·74	12	1·21	5	3·42	20	2·54	12	3·06	17	4·25	22	5·96	24	4·68	24	3·41	21	0·52	13	1·69	12	1·44	17	32·92	199
1903	3·75	21	4·78	27	2·41	17	2·35	15	4·82	27	5·14	23	—	—	1·16	19	0·80	14	2·00	23	1·91	24	3·69	22	—	—
1904	3·72	24	3·30	10	3·54	15	13·57	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Averages, 1896–1903.	2·65	18·0	3·38	18·9	5·27	23·5	4·46	19·0	4·83	21·0	3·11	19·3	4·42	20·5	3·72	21·3	2·60	17·6	1·77	18·1	1·20	14·4	2·11	18·3	—	—

TABLE XIII.—RAINFALL AND RAIN-DAYS AT HUSSEY CHARITY SCHOOL, JAMESTOWN. READ AT 9 A.M.

Height, 150 feet above M.S.L.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Yearly Totals.	
	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.
1896	—	—	1·03	14	0·82	16	0·25	7	1·34	19	0·58	10	0·54	11	1·32	20	0·05	3	0·04	3	0·21	8	0·20	7	—	—
1897	0·57	10	0·79	11	1·15	9	0·05	3	1·92	19	0·49	6	0·46	8	0·64	8	0·07	3	0·08	4	0·00	0	0·00	0	6·22	81
1898	0·55	11	0·39	7	0·82	16	0·68	10	0·95	9	0·46	6	0·87	11	0·22	4	0·11	4	0·08	4	0·04	1	0·06	5	5·23	88
1899	0·15	4	1·03	8	0·80	14	1·36	12	0·85	7	0·53	4	0·85	8	0·85	6	0·48	10	0·24	7	0·03	2	0·09	3	7·26	85
1900	0·28	4	0·09	5	0·76	14	0·54	4	0·61	6	1·15	9	1·74	15	0·10	3	0·09	4	0·04	3	0·03	2	0·12	5	5·55	74
1901	0·22	7	0·40	10	1·41	18	1·35	14	0·94	11	0·28	3	—	—	0·57	9	0·26	4	0·14	3	0·13	2	0·03	2	—	—
1902	0·37	6	0·21	4	—	—	0·48	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Averages, 1896–1901.	0·35	7·2	0·62	9·2	0·96	14·5	0·71	8·3	1·10	11·8	0·58	6·3	0·89	10·6	0·62	8·3	0·18	4·7	0·10	4·0	0·07	2·5	0·08	3·7	6·07	82·0

TABLE XIV.—RAINFALL AND RAIN-DAYS AT OAK BANK. READ AT 8 A.M.

Height, 1,700 feet above M.S.L.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Yearly Totals.	
	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.
1901	1·30	15	1·95	15	6·71	26	8·29	26	3·47	16	1·35	12	3·09	17	4·15	17	5·29	21	1·56	15	1·54	11	2·45	20	41·15	211
1902	1·26	14	1·52	8	3·44	21	2·08	14	2·71	11	4·16	23	7·04	24	6·30	24	3·13	21	0·65	11	1·65	13	1·39	18	35·33	202
1903	2·60	17	4·35	20	2·47	15	2·22	16	3·75	24	6·96	24	4·49	22	2·37	20	1·14	17	2·75	25	2·24	26	3·78	21	39·12	247
1904	4·74	24	2·26	17	4·40	17	11·39	21	4·69	19	3·87	14	2·80	21	4·18	22	3·01	18	2·39	17	1·58	19	2·71	18	48·02	227
1905	2·57	19	3·45	20	4·00	19	0·60	10	4·33	15	6·17	19	0·78	8	5·27	29	2·59	18	0·95	13	2·75	14	4·90	27	38·36	211
1906	3·41	19	5·39	23	5·81	24	4·31	17	2·93	18	7·17	20	5·84	20	4·80	19	2·91	23	1·52	16	0·98	14	3·44	15	48·51	228
1907	3·13	22	2·23	15	6·54	18	13·41	29	4·72	25	4·90	22	3·68	14	1·14	11	2·37	14	3·05	18	3·05	26	1·84	23	50·06	237
*1908**	*4·39*	*21*	*3·36*	*24*	*1·55*	*16*	*3·67*	*22*	*3·71*	*14*	*4·39*	*20*	*3·39*	*18*	*6·26*	*25*	*2·84*	*17*	*1·72*	*16*	*3·05*	*26*	*1·72*	*19*	*48·85*	*238*
Averages, 1901–1907	2·72	18·6	3·02	16·9	4·77	20·0	6·04	19·0	3·80	18·3	4·94	19·1	3·96	18·0	4·03	20·3	2·92	18·9	1·84	16·4	1·97	17·6	2·93	20·3	42·94	223·3

TABLE XV.—RAINFALL AND RAIN-DAYS AT ST. PAUL'S VICARAGE. READ AT 9 A.M.

Height, 1,700 feet above M.S.L.

—	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Yearly Totals.	
	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.	ins.	days.
1905	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·70	20	0·47	9	1·72	14	3·04	27	—	—
1906	2·02	19	3·32	21	4·40	27	3·23	17	2·45	17	4·68	18	4·30	18	3·47	17	2·11	21	0·97	13	0·50	10	2·44	11	33·89	209
1907	2·23	24	2·10	13	5·36	17	10·51	29	4·03	22	3·97	16	3·16	13	0·93	6	1·84	10	2·08	10	2·29	14	1·21	7	39·71	181
1908	3·06	11	2·10	12	1·25	7	2·91	14	2·51	11	3·22	12	—	—	4·63	15	2·00	9	1·31	8	2·62	13	0·88	5	—	—

* The values for 1908 were inserted in proof and have not been included in the averages.

Part II.—Observations on the South-East Trade Wind at St. Helena.

The observations on which the following discussion is based are from the records of a Robinson anemograph situated close to the St. Matthew's Vicarage Station (Lat. 15° 57′ S., Long. 5° 41′ W.), at a height of 1,960 feet above sea level and near the centre of the Island (Plate 10). The instrument is mounted on a site open to the S.E. The ground slopes away at first, and then rises to a little over 2,000 feet at a distance of half a mile. Beyond this it slopes away to the sea. To the Southward and South-Westward the highest range in the island is encountered at a distance of somewhat under a mile, Diana's Peak, the highest of the range, rising to 2,700 feet. The exposure to the prevailing wind may be taken as good (Plate A).

The anemograph was erected in 1892, and records were first received for February of that year. In 1903 the traces began to be very unsatisfactory; the continual motion on the S.E. part of the metallic pencil wore its surface quite flat, the result being that the direction curve was almost undecipherable. The instrument was therefore dismantled in August, 1904, and sent to England for repairs. These were effected, and the instrument re-erected by June in the following year, and since this time special arrangements have been made to prevent undue wear coming on any one part of the pencil.

The method of dealing with the records has been as follows:—The curves when received by the Meteorological Office are regularly tabulated, the distance run in the interval from thirty minutes before to thirty minutes after the full hour is entered as the velocity for the hour. All the velocities given in this paper are derived from the use of the factor 2·8 for the slip of the wind past the cups, this being the value now adopted for instruments of this pattern and size.

The directions are tabulated under 32 points. For the special purpose of this discussion they were grouped under 16 points. The method employed for most of the observations was to divide the readings falling in the uneven directions (9, 11, 13, &c.) in any month equally between the two adjacent even directions, each of the hours 1—24 being treated separately. For the last few years, however, they were divided proportionally instead of equally, the proportion being fixed by the respective number of observations in the two adjoining directions. Thus if the two directions (12 = S.E.) and 14 (= S.S.E.) had respectively 8 and 4 hours of wind falling to them, while the direction 13 had 6 hours, these 6 hours would be divided into groups of 4 and 2, the 4 being put with the direction 12 and the 2 with 14. The method adopted for the earlier years would have given 3 to each.

The readings were collected for each hour of the day under these 16 points, the different months being treated separately. The velocities thus collected were resolved into their S. and E. components and all these components added together, the resultant velocities in the S. and E. directions divided by the number of hourly values which were combined in them giving the mean component velocities for the particular hour. The monthly mean values are the means of the 24 hourly ones.

The method employed in the diagrams to denote the resultant wind for any period has been to imagine a vector, drawn from the origin, of length proportional to the velocity of the wind and in direction representing its direction; the end of this vector is marked by a point. These points only are marked to avoid complicating the figures. The S.-N. line has been taken as running up the page so that a vector representing a Southerly wind would run from the bottom to the top and similarly a South-Easterly wind would be shown by one running from the bottom right-hand corner at 45° to either side.

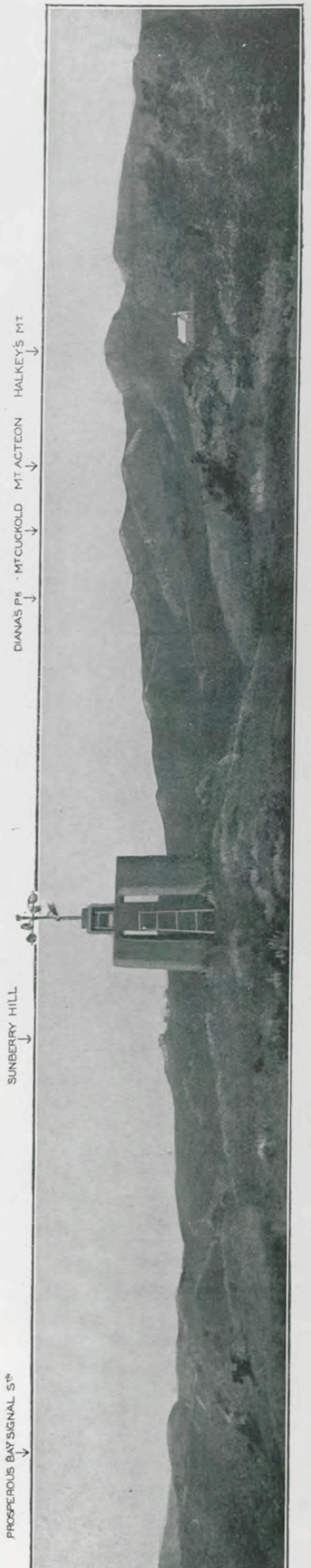
Fig. 1, Plate 11, shows the resultant wind for each year, the years 1892–4 and 1905 being connected with broken lines because the resultants were not obtained from observations extending over the complete year. Since the mean direction of the wind taken over a series of years does not vary much from month to month (*see* Fig. 2, Plate 11) these points should represent the direction of the wind for the year moderately well, although for the velocity, which has more variation, they may not be trustworthy.

The diagram brings to light a very curious result as regards the wind direction, though whether it should be attributed to instrumental error or not has not been ascertained. According to the records it would appear that the wind became considerably more easterly in the periods 1892–3 and 1898–1900 while remaining practically constant in direction during 1893–8 and 1900–2. Then when the anemometer was re-erected in 1905 the wind was found to be back again in its original direction of 1892, and in the two latest years a creeping to the Eastward is again noticeable. In order to throw further light upon this phenomenon the directions for individual months in certain years have been calculated and are shown in Table XVI. (p. 31). The first column under each year gives the number

To face page 26.

PLATE A.

Meteorological Station at St. Matthew's Vicarage—St. Helena.



Panoramic View of the Exposure of the Anemograph; the middle of the view is nearly due South.

Anemometer, 1,960 ft. above M.S.L.

Thermometer Screen, 1,900 ft. above M.S.L.

Rain Gauge, 1,890 ft. above M.S.L.

View of the Climatological Station looking East of North from a point due South of the Anemometer.

of days' records which are included in the means and the second the direction of the resultant wind measured in degrees from North to South by East. In 1892 the wind was to the Southward of S. 30° E. (150°) in all months for which figures were available except June and December, while in 1893 and 1894 it was to the Eastward of S. 35° E. (145°) in all months except October, 1894, when it was S. 34° E. (146°) and September, 1894, when there were only 8 days' records available. Thus there appears to have been a marked change in direction which took place at the end of 1892. Looking at the values for the individual months in the second period of change, 1898–1900, with the exception of March, 1898, which appears to have been exceptional, the direction in 1898 and the first three months of 1899 was not far from S. 40° E. (140°). From April, 1899, a well defined oscillation is apparent, for March, May and July the directions being 142°, 147° and 144°, while the angles for the alternate months April, June and August were 132°, 132°, 134°. In the first half of 1900 the wind had got round to S. 50° E. (130°), while during the latter part of the year it returned somewhat to the Southward. It must be pointed out that at this time the direction trace from the instrument was getting somewhat faulty, and considerable care was needed in working up the curves.

The explanation of the great change in direction between 1902 and 1905 which naturally suggests itself is that the orientation of the instrument was different by about two points after its re-erection from what it was before it was dismantled. To ascertain the possibility of this, the observer was requested to state what means were taken to test the correctness of the orientation when the instrument was re-erected. His reply was to the effect that when the instrument was first set up a mark corresponding to S. was made on the stone erection on which the apparatus is mounted, and that since then the orientation has always been adjusted to the same mark. Since 1905, the orientation has been checked once a month. The vane is clamped in a S. direction while the clock drum is revolved under the pencil and thus a line is marked on the record which corresponds with a South wind. These sheets are sent in to the Meteorological Office and afford information as to the wind direction which is to be associated with any given position of the pencil on the paper. These precautions were not taken prior to the dismantling of the instrument and there is thus room for a certain amount of doubt as to the actual direction of the vane corresponding to a given position of the pencil on the paper. If an alteration of this relation actually took place one would have expected it to have done so suddenly. The change in direction at the end of 1892 has this characteristic, but the changes during 1899 which have been analysed above are of the same order of magnitude but do not appear to be attributable to such a cause. It is worthy of notice that the change from 1902 to 1905 was scarcely greater than the change (of opposite sign) during the period 1892–1900, the rate of change being approximately the same in each case if we exclude from the latter the years 1893–1898 when the direction remained almost stationary.

Looking next at the monthly variation of the wind shown in Figure 2 (Plate 11) it appears that the direction varies but slightly throughout the year as previously mentioned, the extreme range being from S. 42½° E. (137½°) in April to S. 35° E. (145°) in October. The velocity rises steadily from 13 m.p.h. in May to a maximum of 20 m.p.h. in September, the greatest difference between two adjacent months being 3½ m.p.h. (July–August) or half the total annual variation. With the exception of October a similar steady fall occurs between September and May. The rate of change is however considerably smaller during this part of the year. The wind for January very closely represents the mean for the year both in direction and velocity. (*See* Table XVII., p. 32.)

Table XVII., p. 32, gives the mean hourly values of the South and East components of the wind for each month of the year expressed in miles per hour. The hours 1–24 refer to local time. These component values are combined in the diagrams on Plates 12 and 13 to form for each month a vector diagram showing, in the manner already explained, the diurnal variation in direction and velocity. The values were carried to one more figure than those given in the Table, for plotting the curves and obtaining the means and harmonic components. The curve for the whole year in Fig. 1 of Plate 14, shows the general nature of the diurnal variation. Throughout the night, from 19 hrs. to 5 hrs., the end of the wind vector travels round an almost closed curve, the change in direction being slight, while in velocity it amounts to a little over one mile per hour. From 5 hrs. to 19 hrs., that is approximately throughout the daylight hours, a much larger curve is traversed, the extreme change in velocity between 7 hrs. and 14 hrs. being 2½ m.p.h. and in direction between 11 hrs. and 19 hrs., 8°.

If we draw vectors from the point representing the mean diurnal wind, shown by a small circle, to each of the points marked 1, 2, 3, etc., we may take these vectors as representing the wind which must be superposed upon the mean wind to obtain the actual values at the times 1, 2, 3, etc. Looked at in this light the diagram shows that the superposed wind travels completely round the compass from 5 hrs. to 19 hrs. and makes an oscillation through 75° during the night (19 hrs. to 5 hrs.). The maximum velocity of this wind is 1·8 m.p.h. at 13 hrs.

In the curves for the separate months (Plates 12 and 13) considerable differences from the mean variation over the year are apparent. The small closed curve seen in the night hours for the annual variation is quite obliterated in several individual months, of which January and June are the most marked. The type seems to be somewhat varied in October, the small change in direction which is associated in general with the night hours becoming earlier and the direction itself during this period being more nearly the same as the mean for the 24 hours. The diurnal change in direction is greatest in January, amounting to 15°, and least in September, when it is only 5°. The maximum component of the superposed wind perpendicular to the resultant wind direction is also greatest (2·7 m.p.h.) in January and least (1 m.p.h.) in September, this latter value together with the high average velocity of September combining to make the angular variation throughout the day exceptionally small. April shows the most pronounced double diurnal curve, the smaller or night variation being considerable both in direction and velocity. In the adjoining months, March and May, although the velocity change is quite as pronounced, the directions are irregular and the polygon ceases to suggest a regular curve. The same cause is partly responsible for the different form taken by the curves for August and September, although these directions exhibit a more systematic difference. Some features are extremely constant in the different months. Thus one of the hours 20 or 21 is in every case, except January, either the principal or secondary maximum ; the other maximum is not quite so regular but in 7 months occurs at 7 hrs. and in 3 at 9 hrs. This draws attention to the fact that the maximum never occurs at 8 hrs., there being in most months an inward bend of the curve between 7 hrs. and 9 hrs. Other small but marked breaks in the smoothness of the curves occur in all months at 2 hrs. and 4 hrs. These irregularities in the wind in the early hours of the morning will be further noticed when the South and East components are dealt with separately. The principal minimum occurs in all cases at one of the hours 13, 14, 15, while the secondary one is fairly regular at 2 hrs.

In connexion with these diagrams it must be pointed out that at St. Helena (Lat. 16° S.) the sun at noon has a minimum altitude in the North of 50½° in June and a minimum in the South of 82½° in December, passing overhead on November 7th and February 6th.

It will be seen that the direction of rotation of the superposed wind is the same (counter-clock-wise) for each of the twelve months, irrespective of whether the sun passes to the North or the South of the zenith at noon. It is interesting to note in this connexion that Goutereau, in a paper* on the Diurnal Variation of the horizontal air currents, has published curves similar to the above for Batavia in the East Indies, among other places. The latitude of Batavia is 6°22′ S. so that here the sun passes to the South of the zenith for a longer period of the year than at St. Helena. The curves for January and July only are shown. The one is roughly an image of the other in the N.-S. line, the January showing a clock-wise rotation and the July a counter-clock-wise. This would lead us to suppose that the direction of the diurnal rotation depended on whether the sun passed to the North or South of the zenith. If this be so in general, St. Helena is an exception.

On Plate 14, a curve (Fig. 2) has also been plotted from the wind records at Longwood from an Osler anemometer given in Table VIII. of Part I. of this paper. These figures were obtained from the mean hourly wind pressures by the formula $p = \cdot 003\ v^2$ where p is measured in lbs. per square foot and v in miles per hour. More accurate results for the velocity would have been obtained if each reading had been converted by this formula instead of the monthly means. In the "Magnetical and Meteorological Observations at St. Helena," from which the table is obtained, it is mentioned that the anemometer which gave the record was not very suitable for the conditions, as it was not sufficiently sensitive for the winds experienced. It is thus probable that the errors arising from the simpler method of converting pressure into velocity are not more serious than those originally introduced instrumentally. Before comparing the Longwood curve with the modern ones, it must also be pointed out that the method of treating the observations in the two cases was essentially different, the Longwood velocities and directions being averaged independently of one another. Since the changes in the velocity and direction are slight this would not introduce any serious cause of difference. Although the force is given for every hour, the direction is only tabulated

* Annales du Bureau Central Météorologique, 1898, I., p. B. 105.

for the odd hours (Table VI., p. 11). With the aid of the velocities the curve has been filled in between the two-hourly points which are plotted definitely.

On comparing the two diurnal curves it is apparent that the velocities are not in good agreement, the maximum at Longwood occurring at 11 hrs., and the hours 17 to 3 being near the minimum, while in the St. Matthew's Vicarage curve the value at 11 hrs. is below the mean for the day and the average for the night hours 17 to 3 somewhat above it. The values at 20 hrs. and 21 hrs. at St. Matthew's Vicarage are only slightly below the absolute maximum. The directions are in much better agreement. The most Easterly current occurs at about 12 hrs. in both curves and the smallness of the change during the night hours is equally marked in both. The harmonic components of the South and East variation have been obtained for both curves and in the discussion of these the matter will be again referred to.

The South and East components shown in Table XVII. are plotted separately, as differences from their mean diurnal values, in Plate 15, the velocity scale being one half that employed in Plates 12 and 13.

The South components for all the months show a pronounced minimum occurring between 12 hrs. and 14 hrs. In December and January the lowest value is 2·3 m.p.h. below the mean. In June and again in December and January, the velocity only undergoes slight changes during the night hours, while in the other months there are as a rule two fairly pronounced maxima at about 20 hrs. and 7 hrs., with a secondary minimum between them, this latter showing particularly in September. Of the two maxima, that occurring in the evening is slightly the more prominent in the Autumn months, March, April, May, and also in July and August, while the morning one is more pronounced in September, October and November, being especially so in October. The small irregularities of the early morning which have been mentioned in dealing with the vector diagrams are here apparent as a two hourly variation of the South component. This occurs with such regularity in most of the months that it can hardly be put down as accidental, and as each hour has been dealt with separately it does not seem possible that it can have crept in during the working up of the observations. It will be noticed that the minima occur at the even hours 24, 2, 4, 6, those at 2 hrs. and 4 hrs. being more regular than those at 24 hrs. and 6 hrs.

The range of the variation of the East component is not so large as that of the South and tends somewhat more to the type having two equally pronounced maxima and minima during the 24 hrs. The January curve departs most from this type in having a single maximum at 11 hrs. and only small variations from 17 hrs. to 4 hrs. ; the June and July curves are somewhat similar. In the other months the two maxima occur at about 10 hrs. and 20 hrs., the former being the more prominent, while the two minima are almost equally pronounced and occur at 3 hrs. and 16 hrs. Some traces are visible of local minima at 2 hrs. and 4 hrs., but these are not so pronounced as in the South component. The mean curves for the year are given on Plate 14, Fig. 3, on the same scale as the individual monthly ones.

The diurnal variations of the South and East components for each month and the year have been harmonically analysed and the results are given in Table XVIII. The constants c_1, a_1 ; c_2, a_2 ; etc. belong to the Fourier series

$$c_1 \sin (t + a_1) + c_2 \sin (2t + a_2) + \text{etc.}$$

the amplitudes being expressed in miles per hour and the phase angles measured from the hour 24, 15° corresponding to one hour. The time of a maximum is also given in the table. The 1st and 2nd harmonic terms have been calculated for all the months, while the 3rd and 4th were got out for the four months January, April, July, October, these months being taken to ascertain whether the amplitude of these terms was appreciable. In none of the months tested were the values of either c_3 or c_4 as great as 0·1 m.p.h. for the South component, and in the East component 0·11 m.p.h. was the maximum found. As noticed below, it appears that certain months would have given larger values for the amplitude than these.

On Plate 14, Fig. 3, in company with the South and East mean curves for the year, the sums of the 1st and 2nd harmonic terms of the variations have been plotted. These show that the representation of the diurnal variations in the South and East components by the sum of their first two harmonic terms is an approximately correct one. The differences between the actual values and those so obtained are plotted in Fig. 5 of Plate 14 the velocity scale being the same as in the other South and East component diagrams, (Plate 15) which it must be remembered is one half that employed in the vector diagrams. The outstanding feature in the differences for both South and East is the two-hourly variation already noticed, which is seen in the South component to extend over a longer period than that previously mentioned, it being quite pronounced from 24 hrs. to 10 hrs. The East component shows also a distinct eight-hourly variation. An inspection of similar curves (not shown in the diagrams) which were prepared for the individual months showed that this eight-hourly variation appears in most months, being especially pronounced in June and November. Thus there appears good reason to believe that it is a real phenomenon and not one introduced by an insufficiency of observations. The curve shown in Fig. 4 of Plate 14 is constructed from the sums of the 1st and 2nd harmonic terms only of the South and East components. If we neglect the two-hourly disturbance in the South and East components and the small eight-hourly one in the East component we may consider this curve to represent the ideal diurnal variation of the wind for the whole year at St. Matthew's Vicarage station.

Turning to Table XVIII, (*see* also Plate 16) it appears that the amplitude of the 1st or 24 hour term in both the South and East components has an absolute maximum in January, a secondary maximum occurring in the winter. In the South component the two minima are well marked, the principal one occurring in September and the secondary in March. The extreme range for the year is very great, amounting to 1·29 m.p.h. while the mean value is 1·05 m.p.h. In the East component the double oscillation in the year is not so marked, there being minima in April and September, but not of a pronounced nature. The range is 0·87 m.p.h. and the mean 0·51 m.p.h. The times of maximum show no regular change throughout the year. In the South component the two months September and October stand alone, the maximum occurring very much later than in the surrounding ones. Leaving out these months the range is only 1 hour 40 minutes. In the East component the maximum in August occurs nearly 3 hours earlier than in either July or September but the time is almost identical with that in November. There is remarkably little variation from December to April. The total range is 3 hours 20 minutes. The phases of the two 1st harmonic terms are very different, the maximum in the South component occurring soon after midnight and in the East component at about 10 in the morning.

The 2nd or 12 hour terms present a much more uniform appearance, though it must be borne in mind that the times of maximum have a possible range of 12 hours only, compared with 24 hours for the 1st term. In the South component c_2 has a principal maximum in September and minimum in July and secondaries in May and February respectively. The total range is 0·36 m.p.h. The East component has its principal maximum in January and minimum in March, the range being 0·23 m.p.h. The variations in the time of a maximum in the South component are small, the time varying from 6 hours 43 minutes in May to 7 hours 45 minutes in August, and again to 6 hours 48 minutes in November. The secondary maximum is in January. The East component has a larger range from 10 hours 24 minutes in June to 8 hours 54 minutes in October and again to 10 hours 22 minutes in February. For comparison the following table gives the respective ranges, those for the amplitudes being expressed as ratios to the mean of the twelve monthly values.

		South Component.	East Component.
24-hour term	Range of c_1 / Mean Value.	1·20	1·70
	Range of time of maximum.	4h. 12m.	3h. 20m.
12-hour term	Range of c_2 / Mean Value.	0·45	0·44
	Range of time of maximum.	1h. 2m.	1h. 30m.

This shows that the ranges of variation of the constants in the 2nd harmonic terms are uniformly less than the corresponding ranges in the 1st.

The diurnal variations of the component winds from the Longwood observations were also analysed to ascertain wherein lay the difference between the Longwood and St. Matthew's Vicarage curves. The constants were found to be

South ... $c_1 = \cdot 60$ ... $a_1 = 350° 20'$
$c_2 = \cdot 51$ ... $a_2 = 213° 10'$

Time of maximum ... 1st or 24 hour term, 6h. 39m.
2nd or 12 hour term, 7h. 54m.

East ... $c_1 = \cdot 83$ ... $a_1 = 302° 20'$
$c_2 = \cdot 42$ ... $a_2 = 141° 35'$

Time of maximum ... 1st or 24 hour term, 9h. 51m.
2nd or 12 hour term, 10h. 17m.

Comparing these times of maximum with those for St. Matthew's Vicarage for the year we see that there is a difference in the 24-hour terms of the South components of about 6 hours, while the 24-hour terms of the East components are in very close agreement. In the 12-hour terms there are differences of 48 minutes and 34 minutes for the South and East components respectively. Thus the difference occurs mainly in the 1st or 24-hour terms in the South component.

The mean diurnal variation of pressure for the year has also been analysed. The observations used are those from Longwood (*see* page 12, Table VIII.). The values of the harmonic constants are :—

$c_1 = \cdot 00696$ in. ... $a_1 = 324° 45'$
$c_2 = \cdot 02906$ in. ... $a_2 = 153° 0'$

and the corresponding times of maximum,

1st harmonic term, 8h. 21m.
2nd „ „ 9h. 54m.

The hourly temperature means from Longwood were also analysed and gave the following values :—

$c_1 = 2\cdot 6°$ ... $a_1 = 239° 0'$
$c_2 = 1\cdot 0°$ ... $a_2 = 55° 35'$

and times of maximum,

1st harmonic term, 14h. 4m.
2nd „ „ 1h. 9m.

As the times of a maximum for the South and East component winds are not the same for either the 1st or 2nd harmonic terms, in looking for a common cause the idea suggests itself of combining the two to form a vector diagram. This has been done for the year in Figs. 6 and 7 of Plate 14.

TABLE XVI.—NUMBER OF DAYS OF AVAILABLE RECORD OF THE ANEMOGRAPH, 1892–1907, WITH THE MEAN DIRECTION OF THE WIND FOR CERTAIN MONTHS.

—	1892.		1893.		1894.		1895.	1896.	1897.	1898.		1899.		1900.		1901.	1902.	1903.	1904.	1905.	1906.	1907.
Jan. ...	—		28	141°	27	142°	31	24	22	25	140°	30	140°	21	129°	30	23	8	—	—	31	28
Feb. ...	16	153°	13	143°	—		27	29	28	25	140°	28	138°	25	132°	27	13	—	—	—	26	28
March ...	17	158°	—		17	141°	30	30	30	30	151°	26	142°	28	129°	30	22	—	—	—	29	31
April ...	28	151°	22	138°	—		30	29	30	27	141°	25	132°	27	130°	30	26	—	—	—	30	30
May ...	14	163°	27	138°	—		31	26	31	29	137°	31	147°	31	130°	17	23	—	—	—	26	30
June ...	29	145°	—		9	125°	27	24	26	30	140°	29	132°	30	122°	14	21	—	—	29	30	27
July ...	8	153°	23	145°	31	138°	28	22	31	31	140°	28	144°	21	132°	22	27	—	—	29	22	29
Aug. ...	—		31	143°	13	145°	27	22	31	31	145°	26	134°	29	130°	22	27	—	—	30	30	31
Sept. ...	—		16	139°	8	155°	28	26	26	30	142°	22	134°	24	140°	28	26	—	—	28	28	29
Oct. ...	30	158°	—		31	146°	15	25	30	29	140°	25	137°	31	135°	29	26	—	—	30	30	24
Nov. ...	29	163°	—		30	138°	29	24	25	28	135°	19	134°	26	134°	21	15	—	—	29	29	27
Dec. ...	30	146°	—		31	140°	30	30	19	30	143°	25	131°	31	135°	21	—	—	—	30	26	31

1st column—No. of days' observations available. 2nd column—Direction of resultant wind. (Degrees from N. to S. through E.) These angles have only been calculated for certain years which were suggested by Fig. 1, Plate 11.

TABLE XVII.—MEAN HOURLY COMPONENT VALUES OF WIND VELOCITY IN MILES PER HOUR.

South Component.

—		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Midt.	Monthly Means.
January	...	13·8	13·5	13·6	13·4	13·7	13·3	13·2	12·7	12·2	11·1	10·8	10·5	10·4	10·4	11·1	11·9	12·6	13·1	13·8	14·1	14·3	13·9	14·2	13·8	12·7
February	...	12·6	12·3	12·4	12·1	12·6	12·2	12·2	11·7	11·8	10·6	10·2	9·9	9·6	9·9	10·3	10·9	11·8	12·3	12·5	12·6	12·9	12·5	12·5	12·4	11·7
March ...	...	11·4	11·2	11·9	11·7	12·1	12·1	12·1	11·3	11·3	10·5	10·3	10·2	9·9	10·1	10·4	10·9	11·4	12·0	12·5	12·6	12·1	11·9	11·8	11·4	11·4
April ...	...	10·6	10·4	10·8	10·6	10·9	10·8	11·2	10·3	9·8	9·4	9·1	8·6	8·6	8·8	9·3	10·3	10·9	11·2	11·4	11·6	11·5	11·0	10·6	10·6	10·3
May ...	...	10·1	10·0	10·4	10·2	10·6	10·4	10·5	9·8	9·1	8·4	7·8	7·8	7·8	8·2	8·4	9·1	10·1	10·5	11·1	11·0	11·0	10·4	10·5	10·3	9·7
June ...	...	11·4	11·1	11·4	11·3	11·6	11·4	11·5	11·1	11·2	9·8	9·4	9·1	8·9	8·7	9·3	9·8	10·5	11·1	11·5	11·7	11·7	11·4	11·5	11·2	10·7
July ...	...	11·8	11·3	11·8	11·7	11·7	11·9	12·2	11·8	11·5	10·6	10·5	10·4	9·9	9·8	10·4	10·5	11·2	11·7	12·0	12·4	12·3	12·0	11·7	11·8	11·4
August	...	14·2	13·8	14·3	14·1	14·3	14·4	14·5	14·2	14·2	13·4	13·3	12·9	12·9	12·4	13·0	13·2	14·0	14·4	14·8	15·4	15·2	14·8	14·6	14·3	14·0
September	...	15·4	15·2	15·8	16·0	16·4	16·8	17·4	16·9	17·4	15·9	15·5	15·0	14·7	14·6	15·0	15·4	15·9	16·2	16·4	16·8	16·8	16·3	16·0	15·2	15·9
October...	...	15·1	15·3	15·9	15·9	16·6	16·7	16·9	16·3	16·0	14·8	14·3	13·7	13·4	13·3	13·8	14·3	14·6	15·1	15·3	15·4	15·5	15·1	14·9	14·9	15·1
November	...	15·9	15·8	16·3	16·1	16·5	16·7	16·9	16·1	15·3	14·0	13·9	13·2	13·2	13·2	14·1	14·7	15·4	15·8	16·0	16·5	16·3	16·2	16·1	15·7	15·4
December	...	14·5	14·2	15·0	14·5	15·0	14·7	14·9	14·2	13·6	12·8	12·2	11·9	11·6	12·0	12·5	13·3	14·0	14·5	14·8	14·8	15·2	14·9	14·8	14·7	13·9
Year	...	13·1	12·9	13·3	13·1	13·5	13·4	13·6	13·0	12·8	11·8	11·4	11·1	10·9	10·9	11·5	12·0	12·7	13·2	13·5	13·7	13·7	13·4	13·3	13·0	12·7

East Component.

—		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	Midt.	Monthly Means.
January	...	9·4	9·2	9·4	9·3	9·7	10·1	11·0	11·0	11·5	11·6	11·8	11·7	10·9	10·4	9·7	9·2	8·9	9·2	9·2	9·5	9·4	9·4	9·6	9·3	10·0
February	...	9·2	8·6	8·8	8·9	9·4	9·5	9·8	10·0	10·1	10·6	10·5	10·5	10·0	9·6	9·2	8·9	8·5	8·6	8·9	9·2	9·4	9·3	9·4	9·1	9·4
March ...	...	8·3	8·3	8·7	8·6	8·9	9·3	9·6	9·6	9·8	10·1	9·9	9·8	9·4	9·2	8·8	8·6	8·2	8·7	8·5	8·9	9·0	8·7	9·0	8·6	9·0
April ...	...	9·2	9·1	9·0	8·9	9·0	9·3	9·9	10·1	10·3	10·1	10·2	9·7	9·6	9·1	8·9	8·8	8·9	9·2	9·6	9·8	9·9	9·7	9·5	9·5	9·5
May ...	...	8·2	7·8	7·9	7·8	8·0	8·4	8·7	8·9	9·1	9·0	9·4	8·9	8·6	8·4	8·2	7·9	8·1	8·4	8·4	8·9	8·8	8·7	8·5	8·2	8·5
June ...	...	8·9	8·9	9·0	8·8	9·2	9·0	9·4	9·7	10·2	10·5	10·7	10·5	9·9	9·3	9·2	9·0	9·1	9·0	9·2	9·3	9·1	9·2	9·1	9·1	9·4
July ...	...	8·9	8·3	8·3	8·4	8·4	8·8	9·0	9·3	9·9	9·9	10·0	9·7	9·4	8·9	8·8	8·8	8·7	8·7	8·8	8·8	9·0	8·9	8·8	9·0	9·0
August ...	...	11·2	10·8	10·9	11·1	11·2	11·3	11·7	11·8	12·2	12·1	12·1	11·7	11·3	10·9	10·8	10·6	10·5	11·0	11·1	11·3	11·2	11·2	11·3	11·0	11·3
September	...	12·0	11·5	11·4	11·3	12·1	12·3	12·5	12·4	12·9	12·8	12·9	12·4	12·4	11·8	11·8	11·7	11·9	12·2	12·3	12·2	12·4	12·1	12·1	12·0	12·1
October...	...	10·0	9·5	10·2	10·0	10·6	10·7	11·3	11·1	11·5	11·6	11·4	11·2	10·6	10·4	10·1	10·2	10·2	10·5	10·5	10·8	10·6	10·6	10·1	10·2	10·6
November	...	10·9	10·8	11·0	11·0	11·5	11·8	11·9	12·2	12·1	12·2	12·2	11·8	11·3	10·9	10·5	10·4	10·6	11·2	11·3	11·6	11·6	11·5	11·2	11·0	11·4
December	...	10·0	9·7	9·7	10·0	10·4	10·8	11·3	11·5	11·5	11·7	11·7	11·5	10·9	10·6	10·3	9·9	9·8	9·7	10·1	10·4	10·3	10·2	10·3	10·2	10·5
Year	...	9·7	9·4	9·5	9·5	9·9	10·1	10·5	10·6	10·9	11·0	11·1	10·8	10·4	10·0	9·7	9·5	9·4	9·7	9·8	10·0	10·1	9·9	9·9	9·8	10·1

TABLE XVIII.—DIURNAL HARMONIC CONSTANTS OF SOUTHERLY AND EASTERLY COMPONENTS OF WIND VELOCITY.

Southerly Component.

—	c_1.	a_1.	Time of Max.	c_2.	a_2.	Time of Max.	c_3.	a_3.	Time of Max.	c_4.	a_1.	Time of Max.
	m.p.h.		h. m.	m.p.h.		h. m.	m.p.h.		h. m.	m.p.h.		h. m.
January ...	1·67	86° 5′	0 16	0·71	236° 40′	7 7	0·08	74° 40′	0 20	0·03	23° 30′	1 7
February ...	1·25	83° 10′	0 27	0·69	236° 50′	7 6	—	—	—	—	—	—
March ...	0·77	88° 10′	0 7	0·73	240° 40′	6 59	—	—	—	—	—	—
April ...	0·95	96° 50′	23 33	0·83	247° 30′	6 45	0·08	21° 15′	1 32	0·03	84° 30′	0 5
May ...	1·24	91° 40′	23 53	0·86	248° 20′	6 43	—	—	—	—	—	—
June ...	1·14	74° 30′	1 2	0·75	230° 50′	7 18	—	—	—	—	—	—
July ...	0·82	79° 20′	0 43	0·65	224° 35′	7 31	0·03	7° 0′	1 51	0·08	12° 30′	1 17
August ...	0·76	90° 5′	0 0	0·71	217° 45′	7 45	—	—	—	—	—	—
September ...	0·38	33° 40′	3 45	1·01	222° 30′	7 35	—	—	—	—	—	—
October ...	1·03	34° 50′	3 41	0·93	241° 55′	6 56	0·05	90° 0′	0 0	0·05	313° 5′	2 17
November ...	1·28	71° 50′	1 13	0·97	246° 15′	6 48	—	—	—	—	—	—
December ...	1·34	81° 0′	0 36	0·82	242° 50′	6 54	—	—	—	—	—	—
Year ...	1·01	78° 45′	0 45	0·79	236° 45′	7 6	—	—	—	—	—	—

TABLE XVIII.—*continued.*

Easterly Component.

—	c_1.	a_1.	Time of Max.	c_2.	a_2.	Time of Max.	c_3.	a_3.	Time of Max.	c_4.	a_4.	Time of Max.
	m.p.h.		h. m.	m.p.h.		h. m.	m.p.h.		h. m.	m.p.h.		h. m.
January ...	1·09	301° 5′	9 56	0·65	140° 5′	10 20	0·11	274° 45′	3 54	0·09	43° 35′	0 46
February ...	0·62	300° 30′	9 58	0·54	138° 55′	10 22	—	—	—	—	—	—
March ...	0·61	300° 45′	9 57	0·42	158° 20′	9 43	—	—	—	—	—	—
April ...	0·22	303° 30′	9 46	0·58	164° 45′	9 31	0·06	325° 0′	2 47	0·11	350° 30′	1 39
May ...	0·28	271° 35′	11 54	0·54	162° 20′	9 35	—	—	—	—	—	—
June ...	0·58	285° 5′	11 0	0·46	138° 10′	10 24	—	—	—	—	—	—
July ...	0·45	278° 55′	11 24	0·47	143° 45′	10 13	0·09	18° 0′	1 36	0·07	130° 0′	23 20
August ...	0·42	321° 25′	8 34	0·46	161° 30′	9 37	—	—	—	—	—	—
September ...	0·29	280° 0′	11 20	0·47	173° 50′	9 12	—	—	—	—	—	—
October ...	0·50	294° 0′	10 24	0·50	182° 50′	8 54	0·09	281° 20′	3 45	0·06	117° 0′	23 33
November ...	0·36	320° 40′	8 37	0·61	179° 30′	9 1	—	—	—	—	—	—
December ...	0·72	302° 45′	9 49	0·54	158° 10′	9 44	—	—	—	—	—	—
Year ...	0·50	298° 20′	10 7	0·50	158° 30′	9 43	—	—	—	—	—	—

Part III.—The Relation between the Semidiurnal Variations of Wind and Pressure.

It seemed an interesting point to compare for St. Helena the 12-hour terms of the variations of wind and pressure. The pressure terms have been obtained from a paper by Angot on the diurnal variation of the barometer.* Angot separates the actual diurnal variations of pressure into two parts which he calls respectively the Principal and the Thermal Waves. The Principal Wave is a semidiurnal oscillation, and may be represented for all stations by the expression

$$\varpi = 0{\cdot}0364 . \frac{h}{29{\cdot}92} . \frac{\cos^2\delta}{r^2} . \cos^4\lambda \cos(2t + 64°) \text{ ins.}$$

where h is the mean pressure at the station in inches of mercury

δ the declination of the Sun,

r the radius vector from the Sun to the Earth expressed as a ratio of its mean value

and λ the latitude of the station.

The variation is here represented by a formula involving a cosine and not a sine, as in the previous part of this paper. The expression is independent of the particular geographical features of the stations.

The Thermal Wave (*Onde Thermique*) is represented by the expression†

$$a_1 \cos(t + \psi_1) + a_2 \cos(2t + \psi_2) + \text{etc.}$$

The values of the amplitudes are given by the equation

$$a_n = m_n + r_n \cos(l + \xi_n)$$

where l = longitude of the Sun

$m_n = k_n \cos^2\lambda$; r_n is a constant depending on the position of the station.

* Annales du Bureau Central Météorologique de France, Part I., 1887, p. B. 237. *See* also footnote p. 38.

† In the original paper the 2nd term constants a_2 and ψ_2 are written a_2'' and ψ_2'' as the unaccented letters have another meaning; it is, however, unnecessary to retain the accents here.

The particular oscillation we are considering is the semidiurnal one, for which $n = 2$; and from the paper we find that $k_2 = 0{\cdot}0109$ ins. for continental stations and 0·0056 ins. for maritime stations. If we deal only with mean values for the whole year, $a_2 = m_2$ and the mean value of the amplitude of the semidiurnal part of the temperature wave becomes $0{\cdot}0056 \cos^2\lambda$. The amplitude of the Principal Wave is

$$0{\cdot}0364 \cos^4\lambda \;\frac{h}{29{\cdot}92}\;\frac{\cos^2\delta}{r^2}$$

which for simplicity may be taken as $0{\cdot}0364 \cos^4\lambda$.* Putting in the value of $\cos\lambda$ for St. Helena ($\lambda = 16°$) we find that the two amplitudes are

Principal Wave 0·031 ins.
Thermal Wave (12-hour term) 0·0052 ins.

Thus the Principal Wave is about six times the magnitude of the semidiurnal component of the Thermal Wave.

Plate 17 shows the system of isobars due to the Principal Wave only, plotted on a polar projection of the Earth. The three factors

$$\frac{h}{29{\cdot}92},\quad \cos^2\delta,\quad \frac{1}{r^2}$$

are taken as equal to unity. The diagram refers particularly to the Southern Hemisphere, the latitude circle of St. Helena being put in as a broken line.

Since the local time of maximum pressure is the same at all places (9 hrs. 52 mins. and 21 hrs. 52 mins.), it is convenient to imagine the Earth rotating under the system of isobars, which remain relatively fixed with regard to the Mean Sun. The times marked on the line of the Equator indicate the local times at which the respective points of the isobaric system pass over any point on the Earth.

For purposes of comparison arrows are drawn representing the velocity and direction of the semidiurnal component of the wind at each hour throughout the day (the length of the arrow is proportional to the strength of the wind). These arrows correspond with the radii vectores in the curve of semidiurnal variation of wind in Fig. 7, Plate 14.

A very close agreement is noticeable between these arrows and the isobars as regards both magnitude and direction, the magnitude being proportional to the pressure gradient. The direction is, however, opposite to that given by Buys Ballot's law, that is the high pressure is found on the right-hand side, although the station is in the Southern Hemisphere.

It must be remembered that this map represents the mean conditions for the year, and only takes account of Angot's "Principal Wave" of pressure.

A Table (XIX) is appended giving the four harmonic constants c_1, a_1 c_2, a_2 for the South and East Component winds for a number of stations**. All these figures were obtained from a paper by Goutereau† with the exception of those for St. Helena, East London, and Kimberley. The values for the last two have been computed from figures given in two papers‡ by J. R. Sutton dealing with the winds of these places. Vector diagrams for various Indian stations will be found in the Memoirs of the Indian Meteorological Department§, but the harmonic components of these wind variations have not been computed.

* The factor $\cos^2\delta$ is the most important of those of which the variations are neglected. This would reduce the amplitude at the Solstices to ·84 of its value at the Equinoxes.
** These constants belong to the sine formula, as on p. 29.
† Annales du Bureau Central Météorologique, Part I., 1898, p. B. 105.
‡ Quarterly Journal, R. Met. Soc., April, 1905; and Transactions of the South African Philosophical Society. Vol. II. p. 75.
§ Vol. XVIII., Parts I., II., III., IV. Vol. XIX., Part I. Vol. XX., Part V.

TABLE XIX.—DIURNAL HARMONIC CONSTANTS OF THE SOUTHERLY AND EASTERLY COMPONENTS OF WIND VELOCITY.

The formula is $c_1 \sin(t + a_1) + c_2 \sin(2t + a_2)$.

SOUTHERLY COMPONENT.

Station.	Period.	c_1	a_1	c_2	a_2
		m.p.h.	°	m.p.h.	°
Paris	Summer	1·08	300	·45	51
Hamburg	January	·18	340	·49	140
	April	1·72	335	·83	90
	July	2·26	334	·67	84
	October	·49	303	·63	108
Wustrow	Summer	1·03	352	·51	218
Orkneys	January	·74	100	·25	230
	April	·43	75	·65	120
	July	·45	34	·22	54
	October	·31	109	·25	75
Zürich	July	·72	43	·13	180
Säntis	July	·69	333	·76	66
Eiffel Tower	January	·58	67	·38	150
	July	3·12	307	·38	30
Bombay	Year	1·88	10	1·03	124
Batavia	January	1·88	55	1·03	225
	April	1·48	55	1·14	199
	July	1·72	41	1·41	180
	October	2·08	55	1·77	195
St. Helena	Year	1·01	79	·79	237
Cordoba	Summer	1·90	45	·34	206
	Autumn	1·48	40	·60	193
	Winter	1·21	33	·69	196
	Spring	1·61	37	·49	211
East London (Cape Colony) ...	Year	4·95	248	1·37	43
Kimberley	Year	2·45	113	·85	292

EASTERLY COMPONENT.

Station.	Period.	c_1	a_1	c_2	a_2
Paris	Summer	·63	66	·31	193
Hamburg	January	·27	24	·27	245
	April	1·19	90	·45	198
	July	2·62	75	·60	217
	October...	·70	120	·78	240
Wustrow	Summer	1·12	110	·45	260
Orkneys	January	·58	90	·16	270
	April	·60	155	·40	180
	July	·78	45	·40	226
	October...	·60	138	·29	206
Zürich	July	1·84	65	·78	180
Säntis	July	1·52	270	·96	247
Eiffel Tower	January	·27	135	·04	194
	July	·78	48	·63	172
Bombay	Year	5·18	27	2·13	201
Batavia	January	1·12	80	·49	264
	April	·85	258	·40	43
	July	1·59	247	·65	45
	October...	1·12	250	·45	45
St. Helena	Year	·50	298	·50	158
Cordoba	Summer	2·04	217	·36	340
	Autumn	1·72	221	·58	0
	Winter	1·66	219	·67	0
	Spring	2·24	223	·49	349
East London (Cape Colony) ...	Year	5·14	211	·89	15
Kimberley	Year	3·02	55	·98	212

Part IV.—Diurnal Magnetic Variation.

Appended are vector diagrams (Plate 18) showing the diurnal variation of the Horizontal Force and Declination at St. Helena for the four months January, April, July and October. The inclusion of these was suggested by the form of similar diagrams which have been obtained from the observations at Kew Observatory.* These showed a certain resemblance to the St. Helena Wind diagrams, the most pronounced similarity being in the comparatively small motion during the night hours followed by a considerable movement during the day. The St. Helena diagrams are based on hourly observations made during the five years September 1st, 1842–August 31st, 1847, and are drawn from summaries published in the "Magnetical and Meteorological Observations at St. Helena," Vol. II., referred to in Part I. of this paper. The station was situated at Longwood. No observations were taken on Sundays. The scale of the diagrams is such that two inches in the N.–S. (Magnetic) direction represent a change in the Horizontal Force equal to 0·001 of its absolute value. In the E.–W. direction this gives 0·58 inches to 1 minute change of Declination.

The slight change during the time, 18 hrs. to 6 hrs., is very noticeable, but the direction of the diurnal rotation is not as constant as was the case in the Wind diagrams, being clockwise in October and January, partly clockwise and partly counter-clockwise in April, and almost wholly counter-clockwise in July. This appears to indicate a tendency to follow the direction of the Sun. The figures have not been harmonically analysed. The hourly values of departures from the mean for the month are given in Table XX. In the case of Horizontal Force the unit adopted is 0·01 of the mean force for the month. In the case of Declination it is 1 minute; a positive sign signifying that the N. end of the magnet is to the E. of the normal position.

TABLE XX.—DEVIATION FROM THE MEAN FOR THE MONTH OF THE EARTH'S HORIZONTAL MAGNETIC FORCE AND DECLINATION.

The unit for the Horizontal Force is 0·01 of the mean force for the month in absolute measure.
The Declination is expressed in minutes of arc.

St. Helena Civil Time.	January.		April.		July.		October.	
	Horizontal Force.	Declination.	Horizontal Force.	Declination.	Horizontal Force.	Declination.	Horizontal Force.	Declination.
1	− ·049	+ 0·32	− ·051	+ 0·26	− ·038	+ 0·08	− ·049	− 0·16
2	− ·047	+ 0·12	− ·045	+ 0·23	− ·042	+ 0·13	− ·041	− 0·23
3	− ·046	− 0·07	− ·043	+ 0·30	− ·031	+ 0·09	− ·040	− 0·31
4	− ·041	− 0·31	− ·036	+ 0·39	− ·028	+ 0·31	− ·040	− 0·42
5	− ·040	− 0·40	− ·039	+ 0·50	− ·025	+ 0·57	− ·039	− 0·40
6	− ·038	− 0·60	− ·033	+ 0·84	− ·024	+ 1·15	− ·042	− 0·14
7	− ·017	− 1·68	− ·023	+ 0·43	− ·015	+ 2·34	− ·019	− 1·62
8	+ ·017	− 2·35	+ ·013	− 1·08	+ ·004	+ 1·73	+ ·012	− 2·08
9	+ ·045	− 1·51	+ ·064	− 1·78	+ ·036	+ 0·45	+ ·051	− 1·39
10	+ ·074	− 0·56	+ ·110	− 1·09	+ ·076	− 0·39	+ ·077	− 0·15
11	+ ·098	+ 0·84	+ ·142	+ 0·69	+ ·098	− 0·53	+ ·095	+ 1·49
Noon	+ ·110	+ 1·37	+ ·135	+ 1·52	+ ·106	− 0·50	+ ·100	+ 2·30
13	+ ·099	+ 1·02	+ ·099	+ 0·77	+ ·090	− 0·44	+ ·088	+ 2·35
14	+ ·071	+ 0·42	+ ·065	− 0·11	+ ·060	− 0·26	+ ·063	+ 1·52
15	+ ·048	+ 0·13	+ ·038	− 0·46	+ ·027	− 0·13	+ ·035	+ 0·14
16	+ ·026	− 0·15	+ ·006	− 0·66	+ ·008	− 0·58	+ ·005	− 0·77
17	+ ·004	− 0·31	− ·019	− 0·66	− ·006	− 1·08	− ·012	− 0·73
18	− ·015	− 0·21	− ·036	− 0·36	− ·027	− 1·01	− ·026	− 0·22
19	− ·031	+ 0·33	− ·054	− 0·10	− ·038	− 0·76	− ·037	− 0·04
20	− ·044	+ 0·70	− ·057	− 0·11	− ·043	− 0·58	− ·045	+ 0·08
21	− ·054	+ 0·84	− ·063	− 0·03	− ·045	− 0·40	− ·055	+ 0·18
22	− ·055	+ 0·80	− ·059	+ 0·11	− ·048	− 0·23	− ·052	+ 0·28
23	− ·058	+ 0·68	− ·058	+ 0·20	− ·050	− 0·06	− ·050	+ 0·23
Midt.	− ·055	+ 0·54	− ·057	+ 0·28	− ·045	+ 0·04	− ·049	+ 0·02

* Chree. "An Analysis of the Results from the Falmouth Magnetographs on 'Quiet' Days during the years 1891–1902. Phil. Trans., Vol. 204 A. In the above table, the larger magnetic disturbances have been omitted from the results for horizontal force (corresponding with "quiet" days). In the case of the declination all observations are included, since the effect of disturbances at St. Helena on this element is "so small as to be almost insignificant."

Plate II.

Between pp 36 and 37

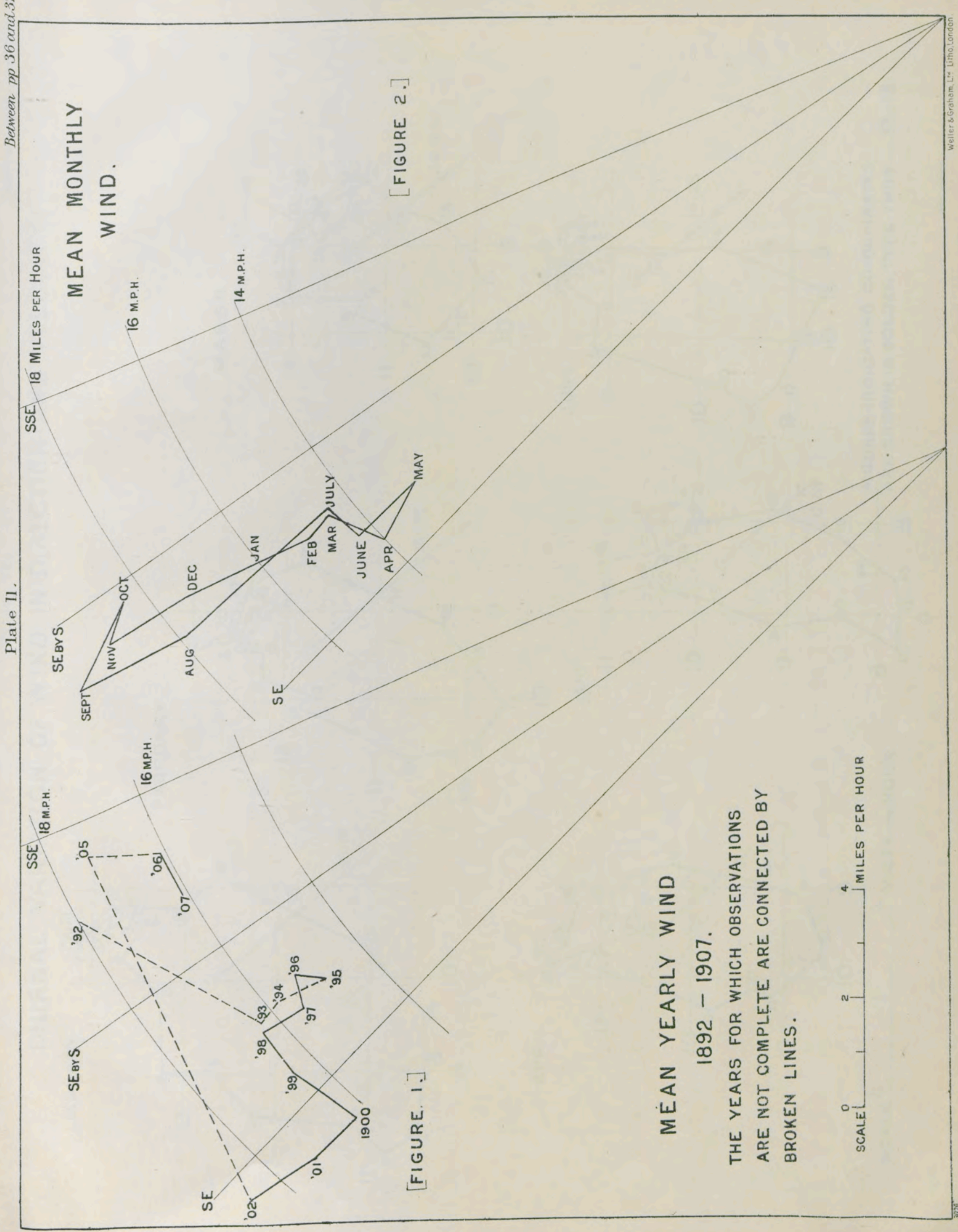
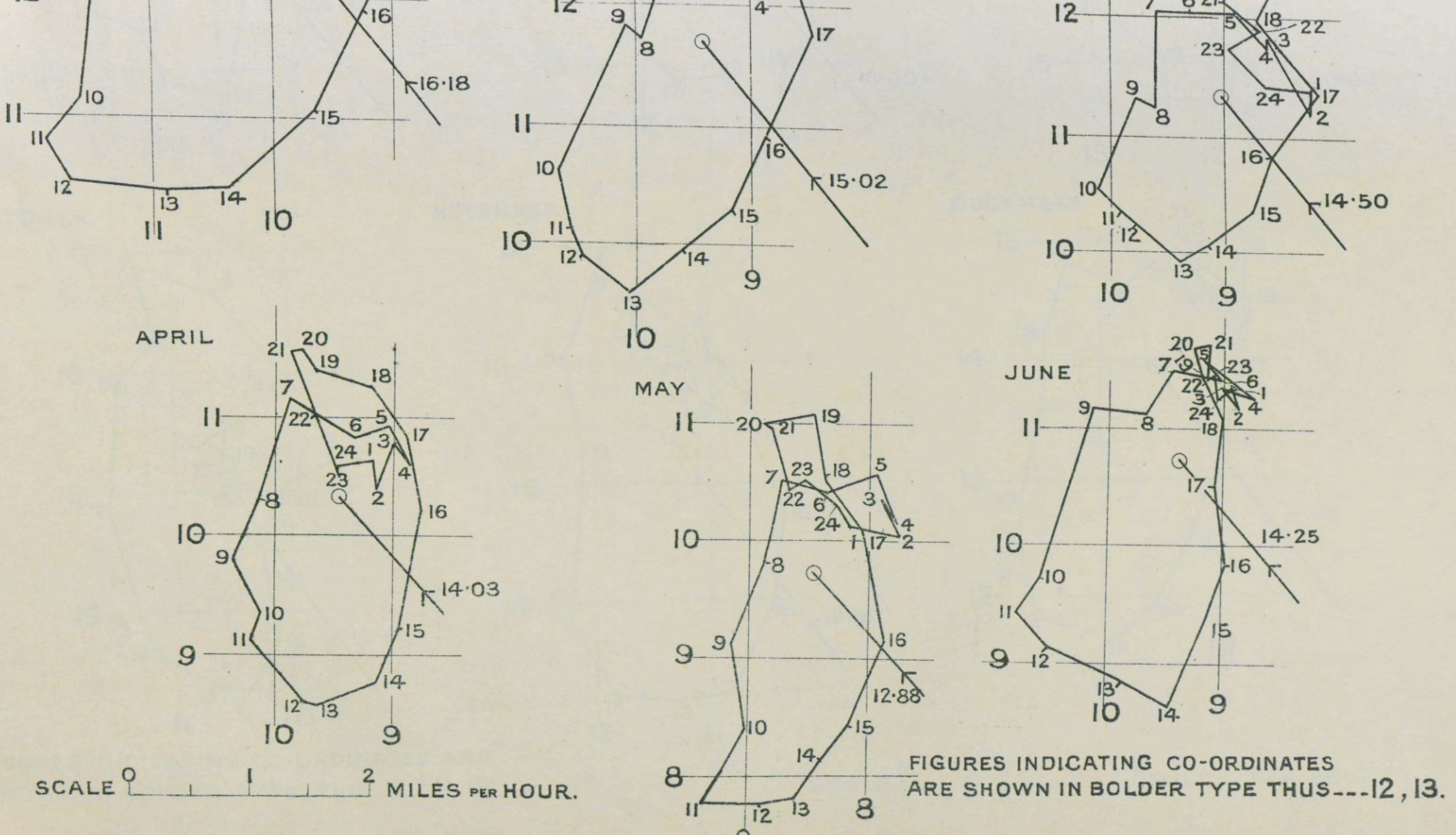


Plate. 12. *Between pp 36 and 37.*

DIURNAL VARIATION OF WIND IN DIRECTION AND VELOCITY.



FIGURES INDICATING CO-ORDINATES ARE SHOWN IN BOLDER TYPE THUS---12, 13.

3024.

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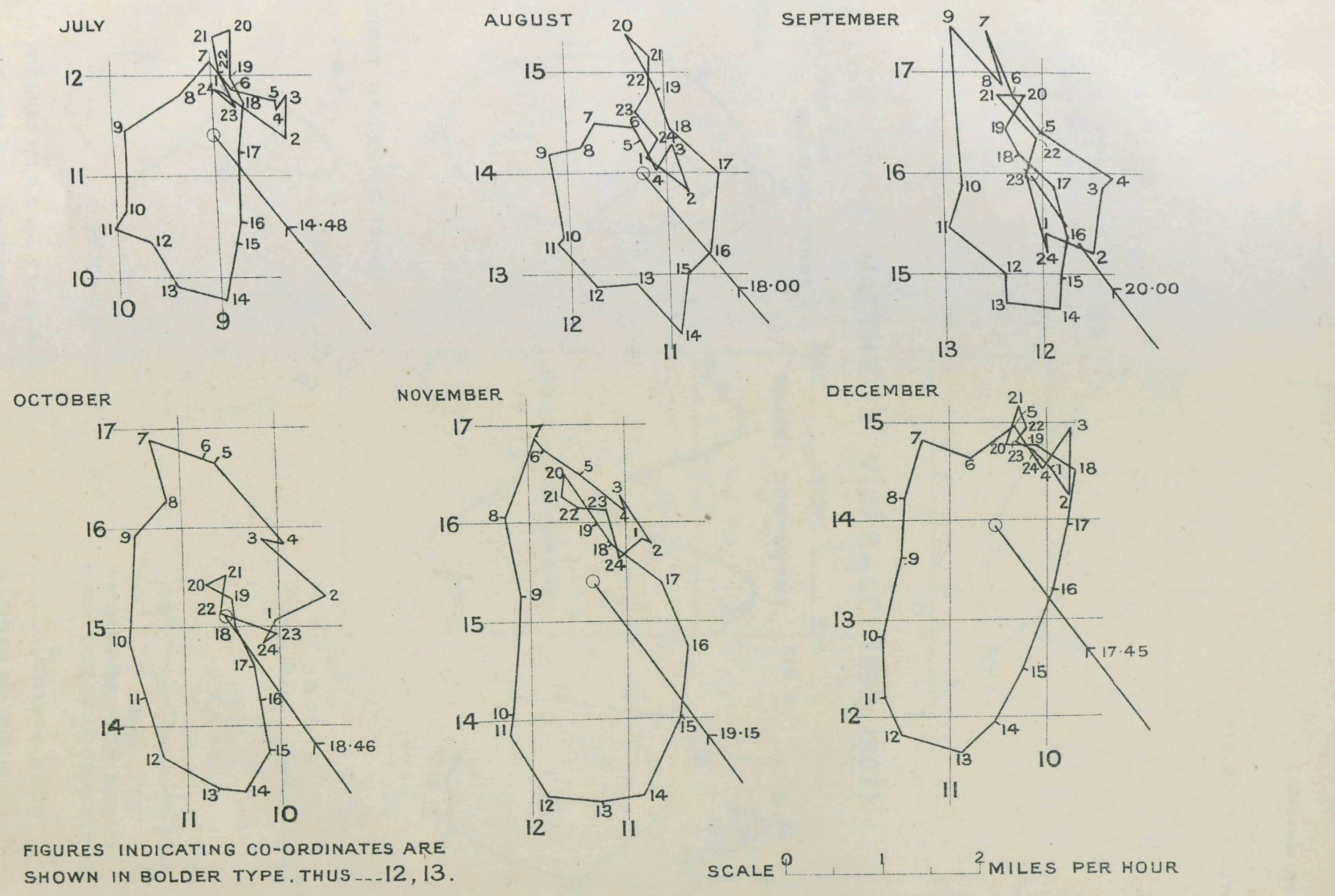
Plate 13. *Between pp36 and 37.*

DIURNAL VARIATION OF WIND IN DIRECTION AND VELOCITY.



FIGURES INDICATING CO-ORDINATES ARE SHOWN IN BOLDER TYPE. THUS ---12, 13.

SCALE 0 1 2 MILES PER HOUR

3024.

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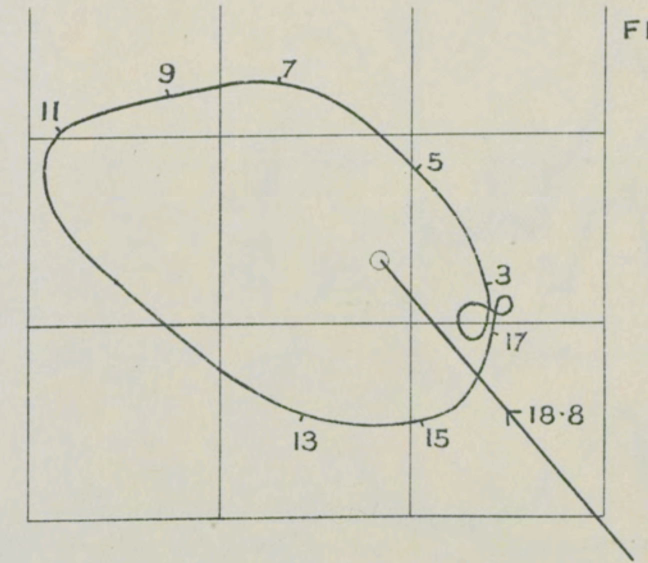
LONGWOOD

FROM OBSERVATIONS TAKEN DURING 1844-6.

FIG. 2.



S^T MATTHEW'S VICARAGE. (1892-1907.)

SUM OF FIRST TWO HARMONIC TERMS.

FIG. 4.

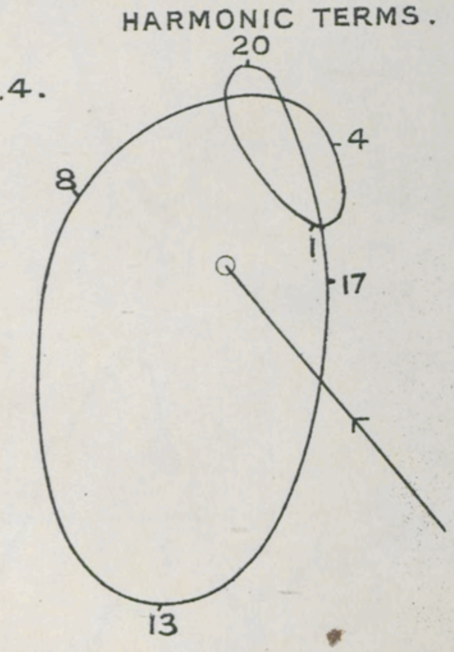


FIG. 3.

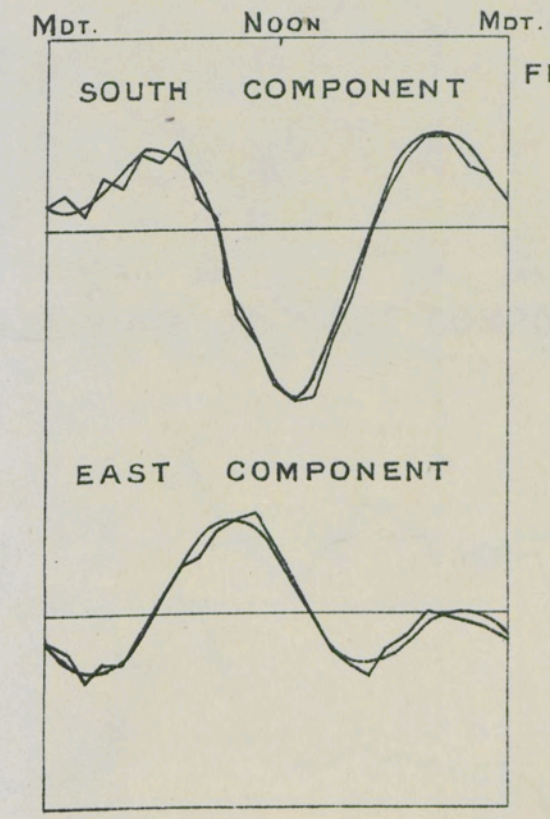
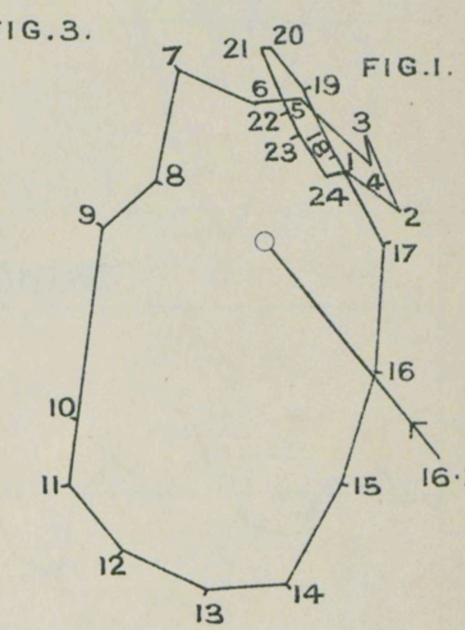


FIG. 1.



FIRST HARMONIC TERM.

FIG. 6.

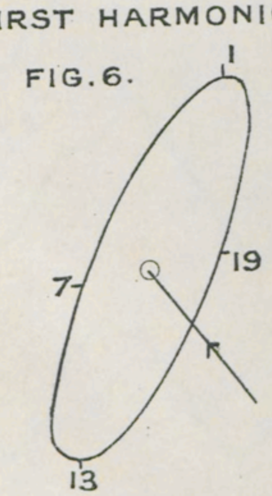
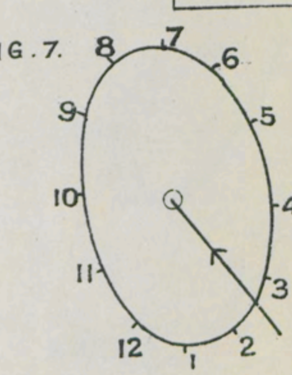
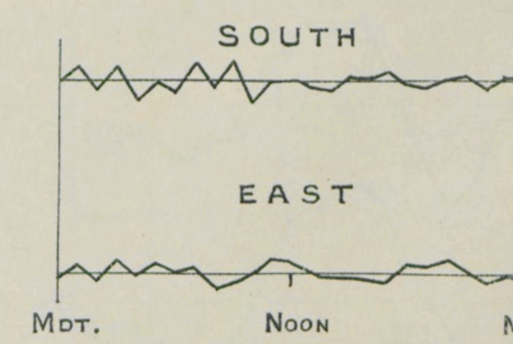


FIG. 7.



SECOND HARMONIC TERM.

FIG. 5.



DIFFERENCES FROM SUM OF FIRST TWO HARMONIC TERMS.

FIGURES 1, 2, 4, 6 AND 7 — SCALE 0 1 2 MILES PER HOUR.

FIGURES 3 AND 5 — SCALE 0 2 4 MILES PER HOUR.

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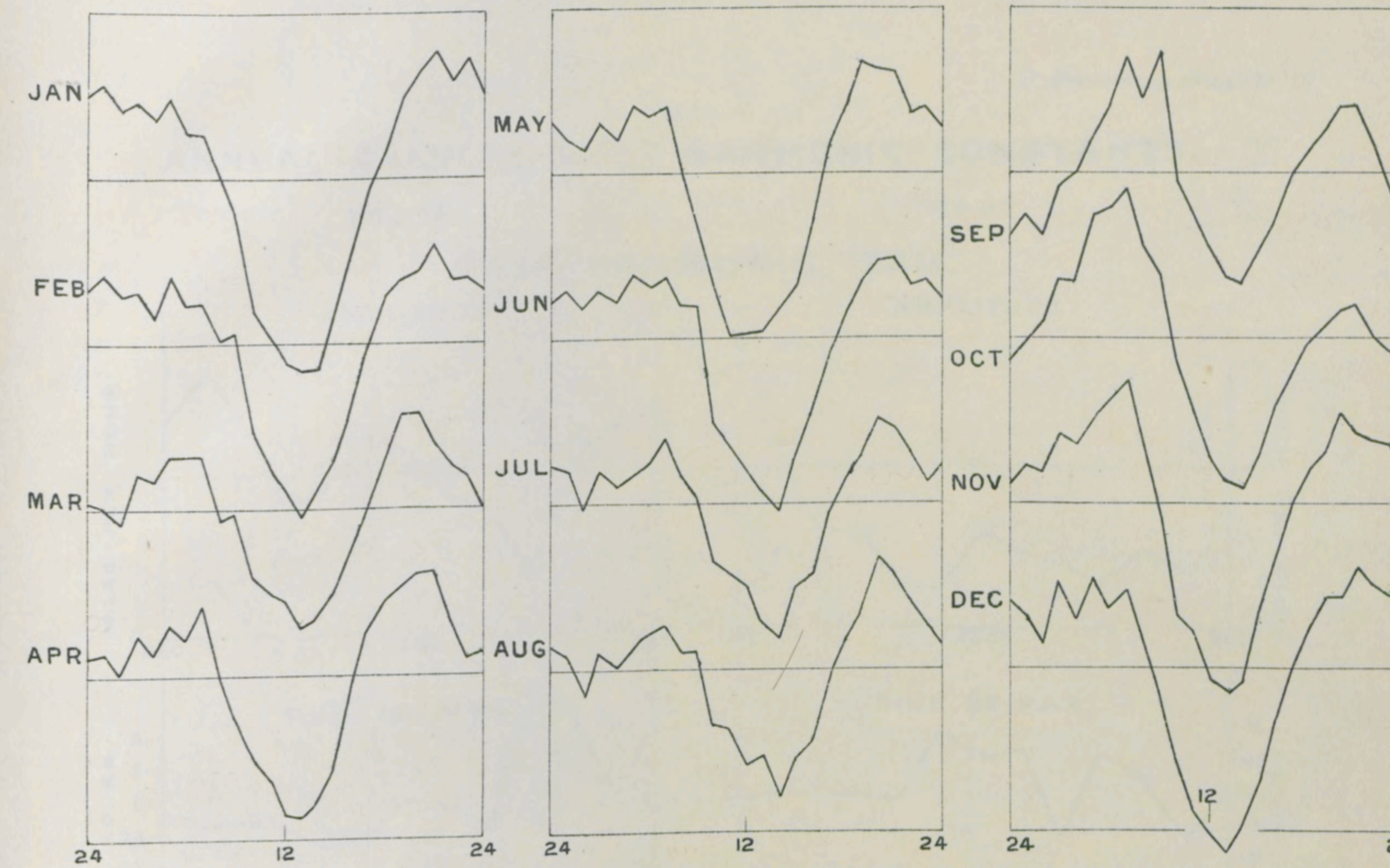
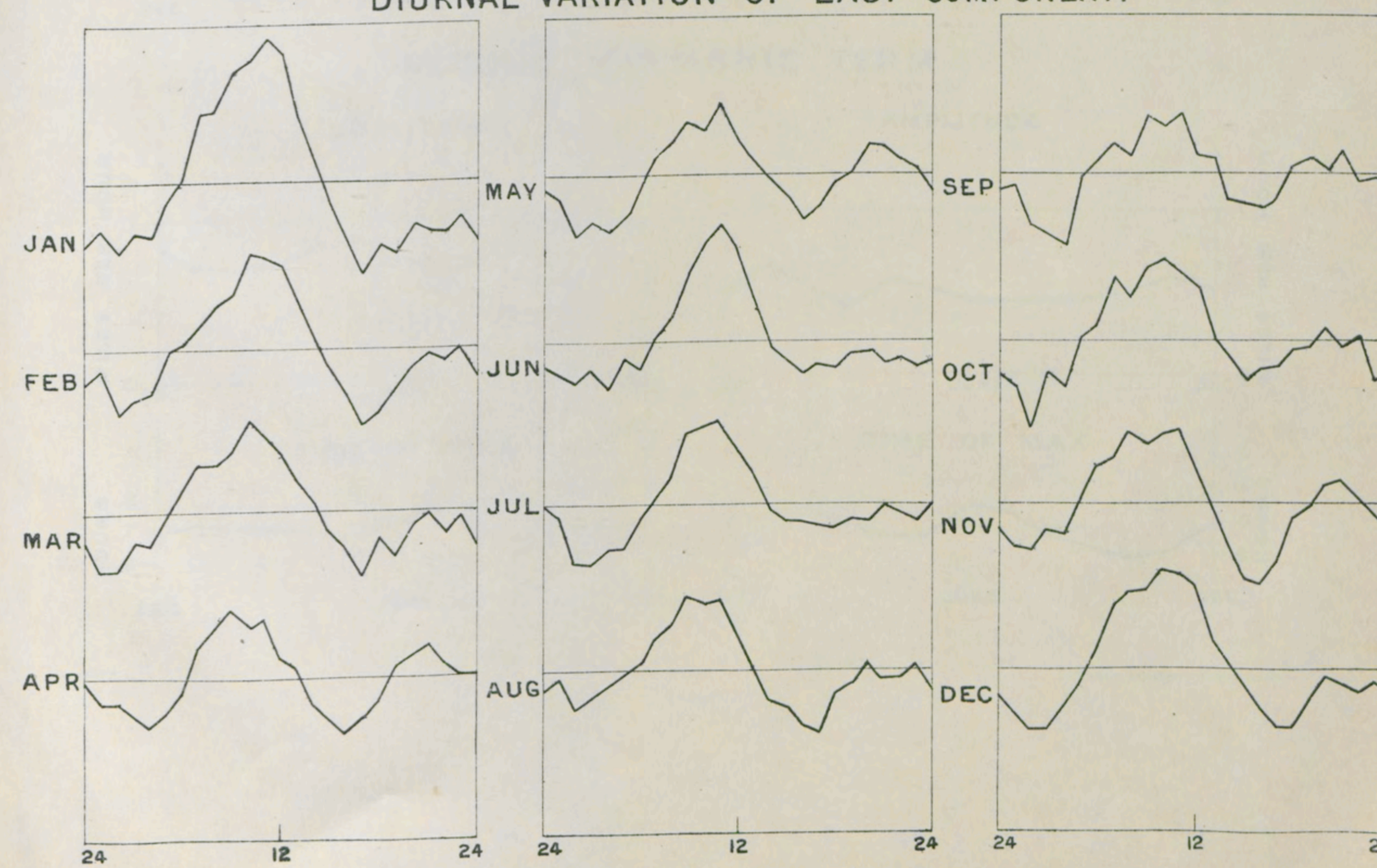
DIURNAL VARIATION OF SOUTH COMPONENT.



DIURNAL VARIATION OF EAST COMPONENT.



SCALE OF ORDINATES 0 2 4 MILES PER HOUR.

Between pp 36 and 37.

Plate 16.

ANNUAL CHANGES IN THE HARMONIC CONSTANTS.

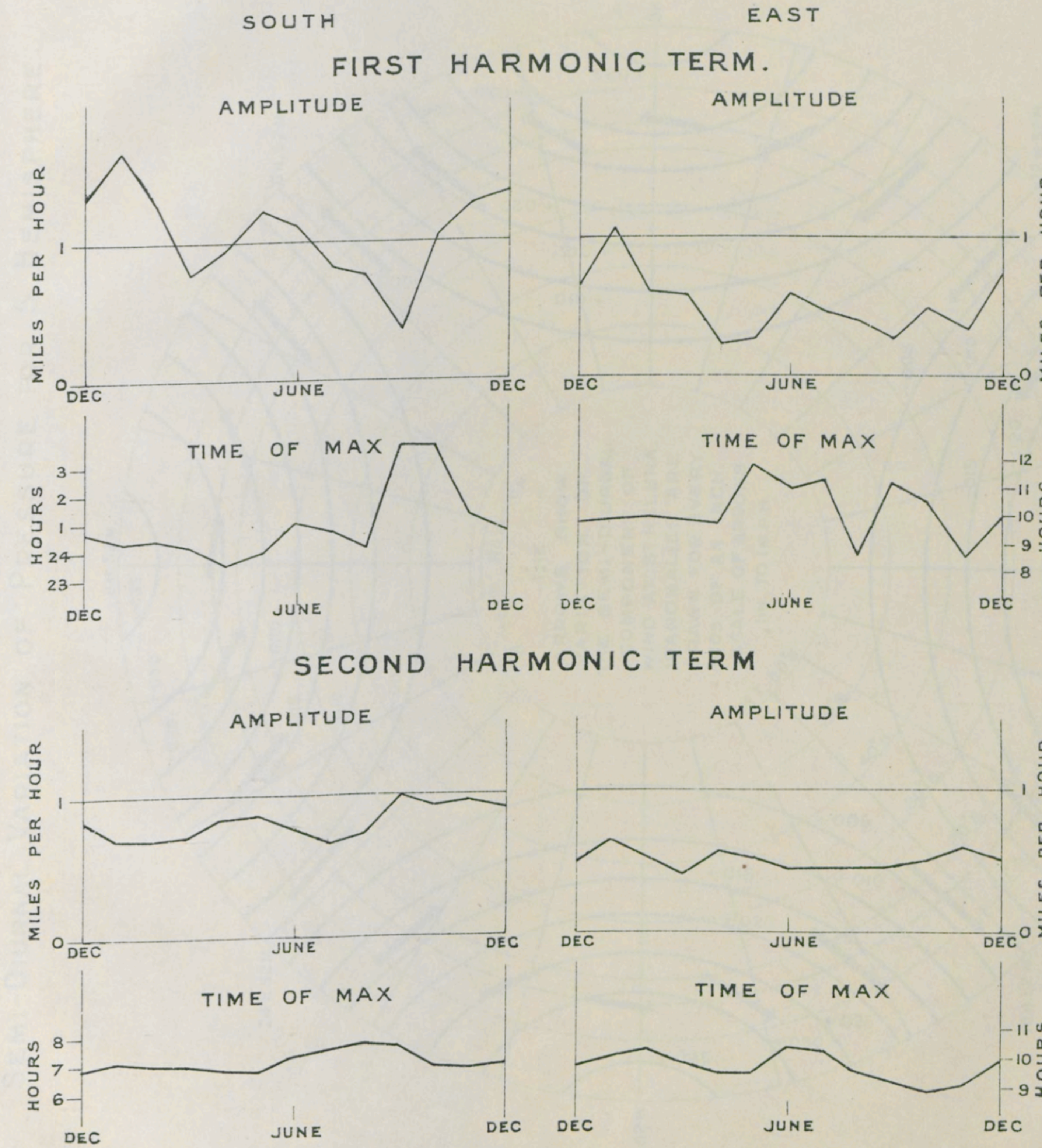


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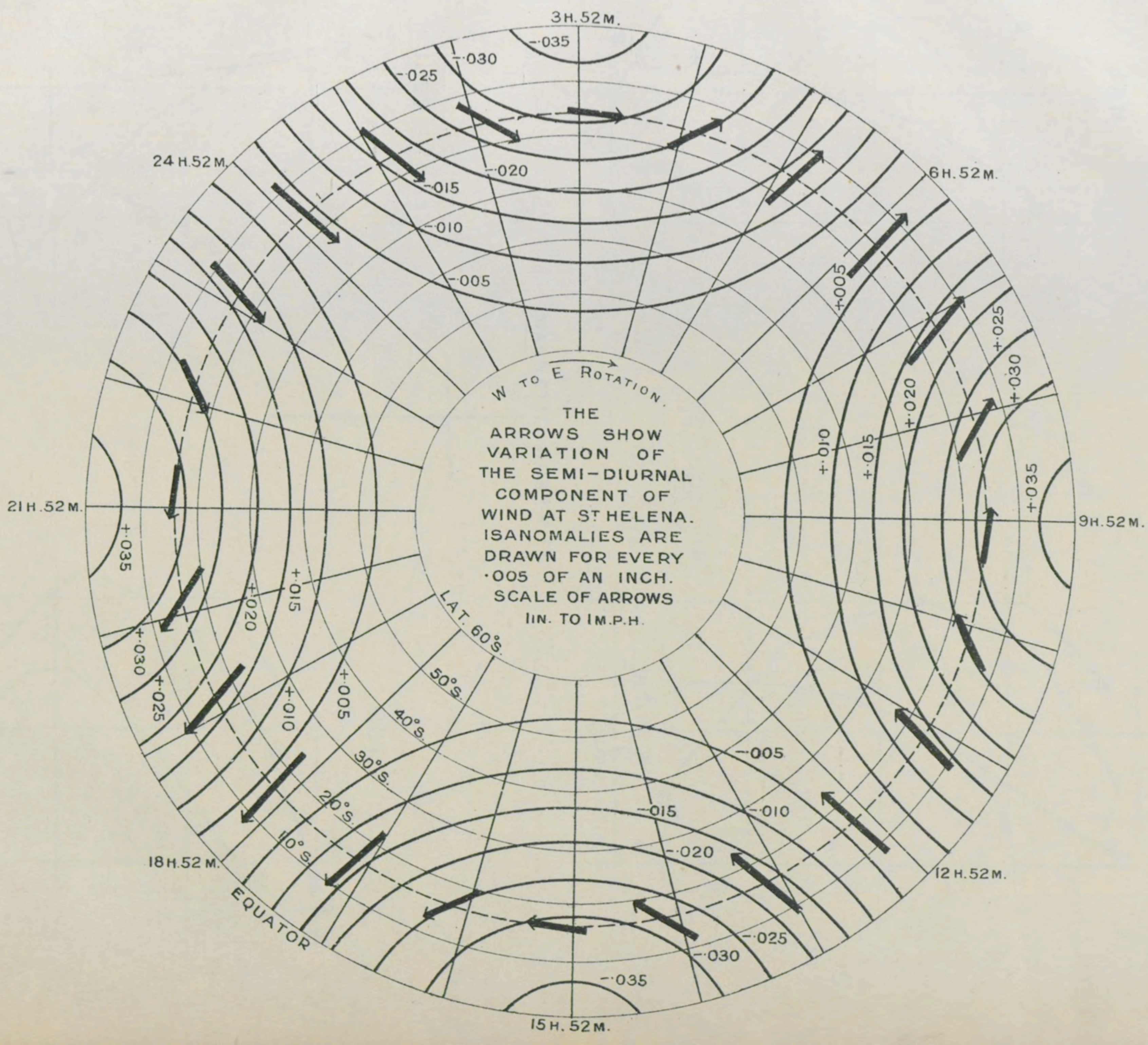
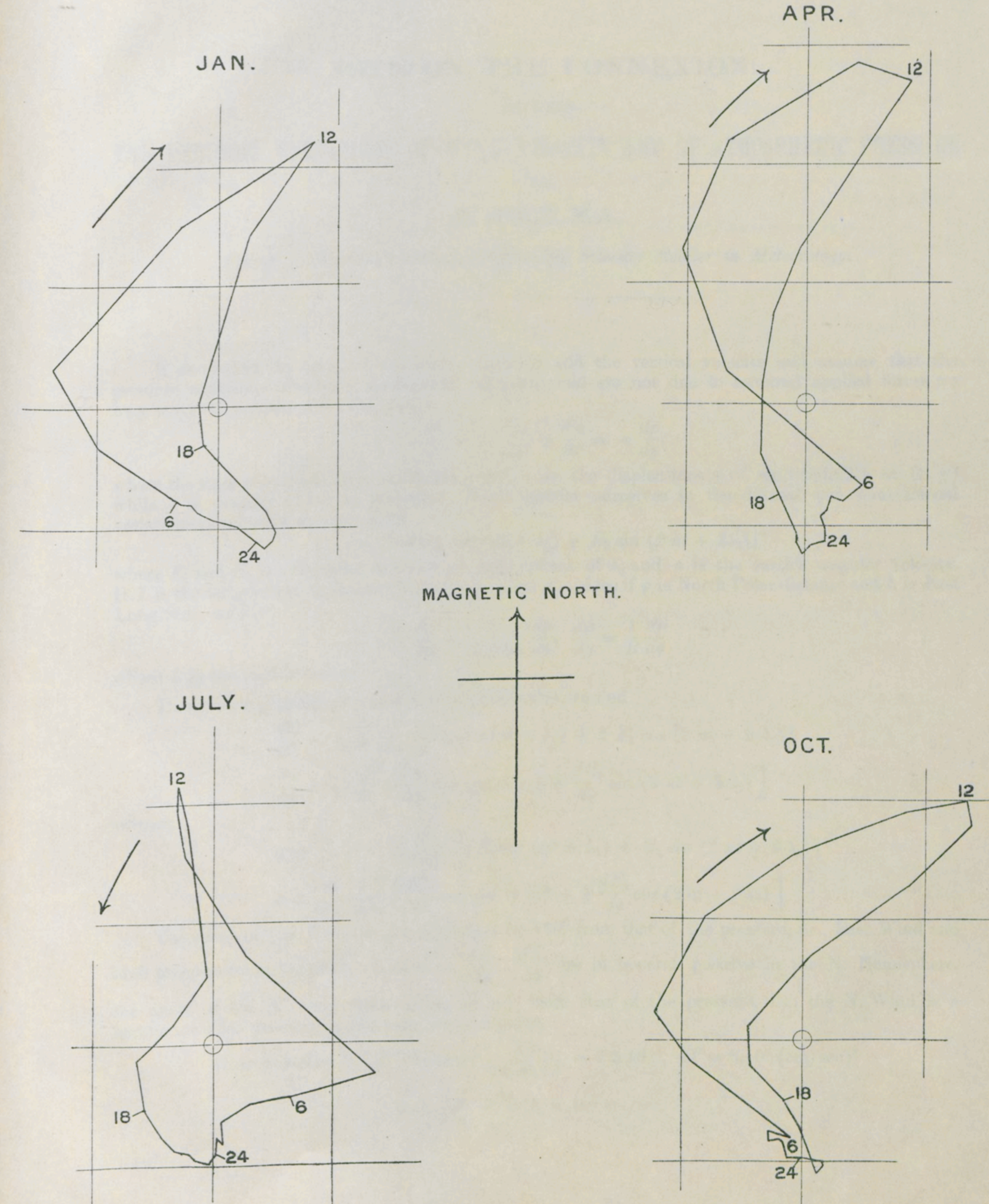
Plate 17.

Semi-Diurnal Variation of Pressure for S. Hemisphere.



VECTOR DIAGRAMS OF THE DIURNAL VARIATION OF THE MAGNETIC ELEMENTS IN A HORIZONTAL PLANE.



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NOTE ON THE CONNEXION

BETWEEN

THE PERIODIC VARIATIONS OF WIND VELOCITY AND OF ATMOSPHERIC PRESSURE

BY

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Fellow of St. John's College, Cambridge, Schuster Reader in Meteorology.

I.

If we neglect the effect of the earth's rotation and the vertical velocity and assume that the pressure variations arise from temperature variations and are not due to external applied forces we may write the equations for the motion

$$\rho \frac{d^2\xi}{dt^2} = -\frac{dp}{dx}, \quad \rho \frac{d^2\eta}{dt^2} = -\frac{dp}{dy}$$

where the axes of x, y are East and South and ξ, η are the displacements of air originally at (x, y) while ρ is density and p is pressure. If we restrict ourselves to the diurnal and semi-diurnal variations of pressure we may write

$$p = p_0 \{1 + E_1 \sin (nt + \lambda_1) + E_2 \sin (2\,nt + 2\lambda_2)\}$$

where E_1 and E_2 are functions of ϕ and are independent of λ, and n is the earth's angular velocity. If T is the temperature from absolute zero, $p = k\,\rho\,T$. Also if ϕ is North Polar distance and λ is East Longitude, we have

$$\frac{dp}{dx} = \frac{1}{R \sin \phi}\frac{dp}{d\lambda}, \quad \frac{dp}{dy} = \frac{1}{R}\frac{dp}{d\phi}$$

where R is the earth's radius.

Therefore neglecting products of small quantities we find

$$\frac{d^2\xi}{dt^2} = -\frac{kT}{R \sin \phi}\left[E_1 \cos (nt + \lambda_1) + 2\,E_2 \cos (2\,nt + 2\,\lambda_2)\right]$$

$$\frac{d^2\eta}{dt^2} = -\frac{kT}{R}\left[\frac{dE_1}{d\phi} \sin (nt + \lambda_1) + \frac{dE_2}{d\phi} \sin (2\,nt + 2\,\lambda_2)\right]$$

whence

$$u = \frac{d\xi}{dt} = -\frac{kT}{nR \sin \phi}\left[E_1 \sin (nt + \lambda_1) + E_2 \sin (2\,nt + 2\,\lambda_2)\right]$$

$$v = \frac{d\eta}{dt} = \frac{kT}{nR}\left[\frac{dE_1}{d\phi} \cos (nt + \lambda_1) + \tfrac{1}{2}\,\frac{dE_2}{d\phi} \cos (2\,nt + 2\,\lambda_2)\right]$$

The phase of the West component differs by 180° from that of the pressure, *i.e.*, East Wind and high pressure occur together. Also since $\frac{dE_1}{d\phi}$, $\frac{dE_2}{d\phi}$ are in general positive in the N. Hemisphere, the phase of the N. component differs by 90° from that of the pressure, *i.e.*, the N. Wind is a maximum when pressure is increasing most rapidly.

If we put $R = 6{\cdot}3.10^8$ cm, $n = \frac{2\,\pi}{24.60.60} = 7{\cdot}3.10^{-5}$, $kT = 8.10^8$ (cm/sec)^2

then $\frac{kT}{nR} = 1{\cdot}74 \times 10^4$ cm/sec.

If further we put E_1 proportional to $\sin^2\phi$, and E_2 to $\sin^3\phi$* agreeing approximately with observation, and take the amplitudes of the pressure waves at the equator to be 0·5 mm. and 1·0 mm. respectively we get

$$u = -11{\cdot}5\sin\phi\left[\sin(nt+\lambda_1) + 2\sin\phi\sin(2nt+2\lambda_2)\right]\ \text{cm/sec}$$
$$v = 11{\cdot}5\sin\phi\cos\phi\left[2\cos(nt+\lambda_1) + 3\sin\phi\cos(2nt+2\lambda_2)\right]\ \text{cm/sec.}$$

These equations would give a fair approximation to the variations in wind velocity for places near the equator, but they fail altogether for latitudes where the free period of oscillation of moving air due to the earth's rotation coincides with the period of the wind variation, *i.e.*, near latitude 30° and the poles.

If we take account of the earth's rotation and further assume that the motion is resisted by a force equal to $k_1 \times$ velocity, the equations of motion become

$$\frac{du}{dt} + 2nv\cos\phi + k_1 u = -\frac{kT}{R\sin\phi}\left[E_1\cos(nt+\lambda_1) + 2E_2\cos(2nt+2\lambda_2)\right]$$
$$\frac{dv}{dt} - 2nu\cos\phi + k_1 v = -\frac{kT}{R}\left[\frac{dE_1}{d\phi}\sin(nt+\lambda_1) + \frac{dE_2}{d\phi}\sin(2nt+2\lambda_2)\right]$$

If we put

$$\frac{kTE_1}{R\sin\phi} = \alpha_1,\ \frac{kT}{R}\frac{dE_1}{d\phi} = \beta_1$$
$$2n\cos\phi = a,\ a^2+n^2+k_1^2 = X_1,\ 2an = Y_1$$

we get for the whole-day variation in u, v

$$u_1 = \left\{\frac{(a\beta_1+n\alpha_1)^2+k_1^2\alpha_1^2}{X_1^2-Y_1^2}\right\}^{\frac{1}{2}}\sin(nt+\lambda_1+\theta_1)$$
$$v_1 = \left\{\frac{(n\beta_1+a\alpha_1)^2+k_1^2\beta_1^2}{X_1^2-Y_1^2}\right\}^{\frac{1}{2}}\cos(nt+\lambda_1+\psi_1)$$

where

$$\tan\theta_1 = \frac{-k_1(\alpha_1X_1+\beta_1Y_1)}{\alpha_1(aY_1-nX_1)+\beta_1(aX_1-nY_1)}$$
$$\tan\psi_1 = \frac{k_1(\beta_1X_1+\alpha_1Y_1)}{\alpha_1(nY_1-aX_1)+\beta_1(nX_1-aY_1)}$$

and those values of θ_1, ψ_1 are to be taken which give to $\sin\theta_1$, $\cos\theta_1$, $\sin\psi_1$, $\cos\psi_1$, the same signs as the numerators and denominators of these expressions. The square roots are then to be taken with the + sign.

Similarly for the semi-diurnal terms if

$$\frac{2kTE_2}{R\sin\phi} = \alpha_2,\ \frac{kT}{R}\frac{dE_2}{d\phi} = \beta_2$$
$$a^2+4n^2+k_1^2 = X_2,\ 4an = Y_2$$

we get

$$u_2 = \left\{\frac{(a\beta_2+2n\alpha_2)^2+k_1^2\alpha_2^2}{X_2^2-Y_2^2}\right\}^{\frac{1}{2}}\sin(2nt+2\lambda_2+\theta_2)$$
$$v_2 = \left\{\frac{(2n\beta_2+a\alpha_2)^2+k_1^2\beta_2^2}{X_2^2-Y_2^2}\right\}^{\frac{1}{2}}\cos(2nt+2\lambda_2+\psi_2)$$

and

$$\tan\theta_2 = \frac{-k_1(\alpha_2X_2+\beta_2Y_2)}{\alpha_2(aY_2-2nX_2)+\beta_2(aX_2-2nY_2)}$$
$$\tan\psi_2 = \frac{k_1(\alpha_2Y_2+\beta_2X_2)}{\alpha_2(2nY_2-aX_2)+\beta_2(2nX_2-aY_2)}$$

* Jaerisch "Zur Theorie der Luftdruckschwankung . . . ." Meteorolog. Zeitschr. 24, 1907, p. 481. On p. 33 of this Report, Mr. Dines, following M. Angot, has assumed E_2 to be proportional to $\sin^4\phi$.

The effect of friction is to change both the amplitude and the phase of the motion. The amplitude is always diminished if α_1, β_1, α_2, β_2 are positive, *i.e.*, if the amplitude of the pressure variation increases from the pole to the equator.

If $k_1 = 0$ the expressions for u_1, v_1, u_2, v_2 become

$$u_1 = -\frac{\alpha_1+2\beta_1\cos\phi}{n(1-4\cos^2\phi)}\sin(nt+\lambda_1)$$
$$v_1 = \frac{2\alpha_1\cos\phi+\beta_1}{n(1-4\cos^2\phi)}\cos(nt+\lambda_1)$$
$$u_2 = -\frac{\alpha_2+\beta_2\cos\phi}{2n\sin^2\phi}\sin(2nt+2\lambda_2)$$
$$v_2 = \frac{\alpha_2\cos\phi+\beta_2}{2n\sin^2\phi}\cos(2nt+2\lambda_2)$$

These pairs of expressions become infinite at latitude 30° and the pole respectively; but so long as k_1 is different from zero the terms in the denominator never vanish and the infinities do not enter.

If we take, as above, E_1 proportional to $\sin^2\phi$, and E_2 to $\sin^3\phi$, then we find

(i.) θ_1 increases from $180° + \tan^{-1}\frac{k_1}{n}$ to 270° in passing from the equator to latitude 30°.

From latitude 30° to the pole it increases from 270° to $360° - \tan^{-1}\frac{k_1}{n}$ nearly.

(ii.) ψ_1 increases from $\tan^{-1}\frac{3k_1}{2n}\left(1+\frac{k_1^2}{3n^2}\right)$ to 90° in passing from the equator to latitude 30°. From latitude 30° to the pole it increases from 90° to $180° - \tan^{-1}\frac{k_1}{n}$ nearly.

(iii.) θ_2 increases from $180+\tan^{-1}\frac{k_1}{2n}$ to 270° in passing from the equator to the latitude near the pole for which $\tan\theta_2$ is infinite. Afterwards it varies very slightly and is equal to $360° - \tan^{-1}\left(\frac{k_1}{n}+\frac{20n}{k_1}\right)$ at the pole.

(iv.) ψ_2 increases from $\tan^{-1}\frac{k_1}{2n}\left(\frac{3k_1^2+28n^2}{k_1^2+20n^2}\right)$ to $\tan^{-1}\left(\frac{3k_1}{2n}+\frac{20n}{k_1}\right)$ in passing from the equator to the pole.

If we put $k_1 = \frac{1}{2}n$ as a value suggested by the inclination of the wind direction to the isobars we get the following table of values, the velocities being expressed in cm/sec. The values for $k_1 = 0$ are given in *italics*.

Latitude.	0°		30° N.		45° N.		60° N.	
u_1 (amplitude of) ...	10	*11·5*	20	∞	15	*24*	9·5	*11·5*
v_1 (amplitude of) ...	0	*0*	20	∞	15	*23*	8·5	*10*
θ_1	207°	*180°*	270°	—	312°	*360°*	329°	*360°*
ψ_1	39°	*0°*	90°	—	127°	*180°*	142°	*180°*
u_2 (amplitude of) ...	22	*23*	28	*32*	31	*40*	23	*49*
v^2 (amplitude of) ...	0	*0*	26	*29*	31	*41*	25	*50*
θ_2	194°	*180°*	206°	*180°*	221°	*180°*	243°	*180°*
ψ_2	20°	*0°*	28°	*0°*	40°	*0°*	61°	*0°*

The nature of the motion for Lat. 45° N. for the diurnal and semi-diurnal waves of pressure is shown in the diagrams (Fig. 1.):—I. and III. for $k_1 = 0$, II. and IV. for $k_1 = \frac{1}{2}n$. The arrows are drawn in the positions for which the winds denoted are at their maximum value.

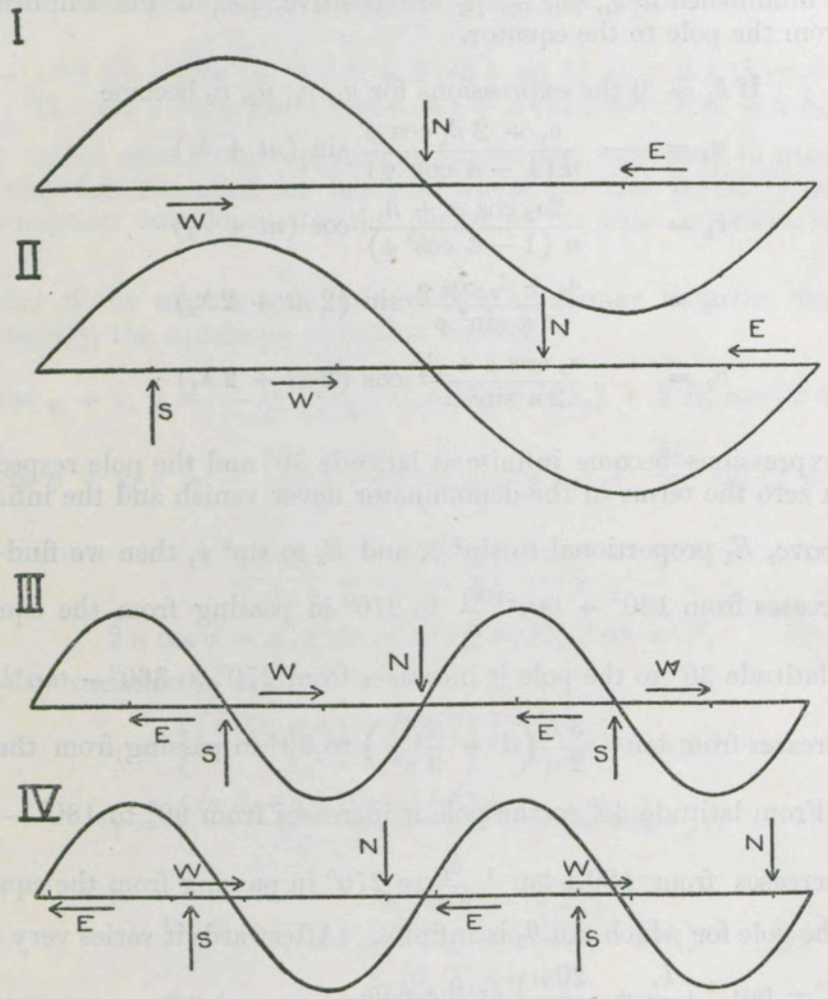

FIG. 1.

II.

Margules* has treated very fully the oscillations of an atmosphere on a rotating sphere; he regards the atmosphere as a thin layer in which the vertical motion can be neglected.

He takes the dynamical equations

$$\frac{du}{dt} + lu + 2\,nv\cos\phi = -\frac{k\,T}{R\sin\phi}\cdot\frac{d\epsilon}{d\lambda}$$

$$\frac{dv}{dt} + lv - 2\,nu\cos\phi = -\frac{k\,T}{R}\frac{d\epsilon}{d\phi}$$

in which u, v, are as above, l is introduced to represent the frictional effect and the pressure variation is $p_0\epsilon$.

With these he joins the equation of continuity

$$\frac{d\epsilon}{dt} - \frac{d\tau}{dt} + \frac{1}{R\sin\phi}\left\{\frac{d\,(v\sin\phi)}{d\,\phi} + \frac{du}{d\lambda}\right\} = 0$$

and assumes a form $T\tau$ for variation in the temperature T.

* Sitzungsberichten der K. Akad. der Wissenschaften in Wien, March, 1890, April, 1892, January, 1893, December, 1893. A translation of the first paper is given in Smithsonian Miscellaneous Collections, Vol. XXXIV.

Taking $T = 273$, $\tau = \frac{1}{273}\sin\phi\sin(nt + \lambda)$ for the whole day wave he solves the equations and finds for the case $l = 0$

$$\epsilon = E\,(\phi)\sin(nt + \lambda)$$
$$u = f\,(\phi)\sin(nt + \lambda)$$
$$v = g\,(\phi)\cos(nt + \lambda)$$

where $10^3\,E\,(\phi) = 4{\cdot}20\sin\phi - 1{\cdot}55\sin^3\phi - 1{\cdot}28\sin^5\phi - 0{\cdot}39\sin^7\phi - 0{\cdot}06\sin^9\phi$

$$f\,(\phi) = 71 - 14\sin^2\phi - 46\sin^4\phi - 21\sin^6\phi - 5\sin^8\phi$$
$$g\,(\phi) = \cos\phi\{-71 - 51\sin^2\phi - 17\sin^4\phi - 3\sin^6\phi\}.$$

The form of $E\,(\phi)$ is such that the velocities do not take infinite values at lat. 30°, but remain finite in all latitudes. The resulting amplitude of the pressure variation is, however, more than twice as great at lat. 45° as it is at the Equator. The following table given by Margules, shows the values of $T\tau$, E, f, g for different latitudes:—

Lat.	273 τ.	10^3 E.	f.	g.
0	1·00 sin (nt + λ)	0·91	−15	0
15°	0·97 „	1·22	− 3	−35
30°	0·87 „	1·84	24	−60
45°	0·71 „	2·15	50	−72
60°	0·50 „	1·86	64	−74
75°	0·26 „	1·06	70	−72
90°	0·00 „	0	71	−71

If l is not zero, a solution may be found by putting

$$\epsilon = E_1\sin(nt + \lambda) + E_2\cos(nt + \lambda) = E\sin(nt + \lambda + \delta_1)$$
$$u = f_1\sin(nt + \lambda) + f_2\cos(nt + \lambda) = f\sin(nt + \lambda + \delta_2)$$
$$v = g_1\cos(nt + \lambda) - g_2\sin(nt + \lambda) = g\cos(nt + \lambda + \delta_3).$$

The method of determining the constants in the series for E, f, g is explained in Margules' paper or in the chapter on Tides in Lamb's Hydrodynamics.

With the same expression for $T\tau$ as before, the following Table gives the values of E, f, g, δ_1, δ_2, δ_3 for different latitudes for the case $l = n$.

Lat. N.	10^3 E.	δ_1.	f.	δ_2.	g.	δ_3.
°0	2·69	33°	40	− 48°	0	− 25°
15	2·72	31°	42	− 45°	− 20	− 26°
30	2·72	24°	45	− 37°	− 35	− 28°
45	2·48	18°	48	− 33°	− 44	− 31°
60	1·92	12°	49	− 33°	− 47	− 35°
75	1·04	9°	49	− 35°	− 49	− 36°
90	0	8°	49	− 37°	− 49	− 37°

Thus the effect of the friction is to make the pressure maximum precede the temperature maximum, while the maximum west wind occurs after the temperature maximum and the maximum north wind after the time of greatest increase of temperature.

The diagrams (Fig. 2) show for Lat. 45° the nature of the motion in the pressure wave, I. for the case $l = 0$, II. for the case $l = n$, the arrows being drawn in the positions for which the winds denoted are at their maximum.

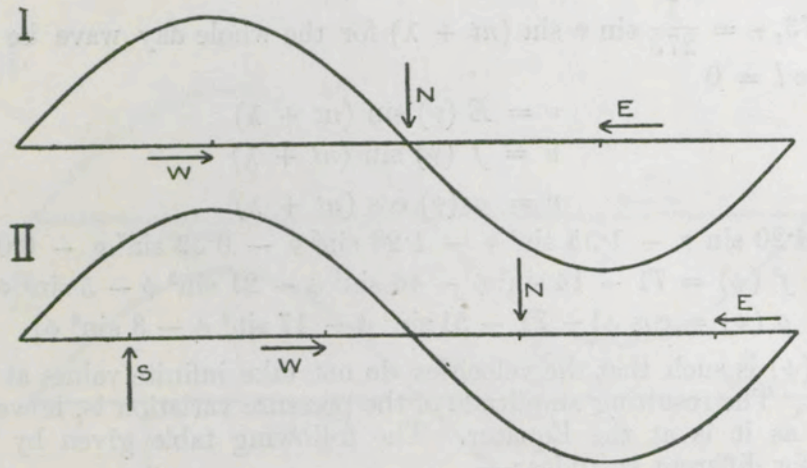

FIG. 2.

For the semi-diurnal wave, Margules takes

$$\tau = \frac{1}{273} \sin^2 \phi \sin (2\,nt + 2\,\lambda)$$

and for $l = 0$

$$\epsilon = E \sin (2\,nt + 2\,\lambda),$$
$$u = f \sin (2\,nt + 2\,\lambda),$$
$$v = g \cos (2\,nt + 2\,\lambda)$$

and finds

$$10^3\, E = -\,138{\cdot}7 \sin^4 \phi - 84{\cdot}2 \sin^6 \phi - 21 \sin^8 \phi - 2{\cdot}9 \sin^{10} \phi - 0{\cdot}3 \sin^{12} \phi$$

$$f = 7040 \sin \phi + 1000 \sin^3 \phi - 2510 \sin^5 \phi - 1120 \sin^7 \phi - 220 \sin^9 \phi - 30 \sin^{11} \phi$$

$$g = \cos \phi \,\{ -\,7040 \sin \phi - 5700 \sin^3 \phi - 1780 \sin^5 \phi - 300 \sin^7 \phi - 30 \sin^9 \phi \}$$

the velocities being in cm/sec.

This leads to the following table of values for different latitudes.

Lat. N.	$273\,\tau$.	$10^3\,E$.	f.	g.
0°	1·00 sin $(2nt + 2\lambda)$	−247	4170	0
15°	0·93 ,,	−207	4540	− 3540
30°	0·75 ,,	−121	5050	− 5390
45°	0·50 ,,	− 46·6	4780	− 5190
60°	0·25 ,,	− 10·1	3560	− 3720
75°	0·07 ,,	− 0·6	1840	− 1860
90°	0·00 ,,	0	0	0

The values of E, f, g are of course much greater than actually occur. They are given to show how much greater for the same temperature variation are the amplitudes of pressure and wind variation in the semi-diurnal wave, owing to the fact that their period nearly coincides with a free period of oscillation of the atmosphere.

In the case when l is not zero a solution of the equation is given by

$$\epsilon = E \sin (2\,nt + 2\,\lambda + \delta_1)$$
$$u = f \sin (2\,nt + 2\,\lambda + \delta_2)$$
$$v = g \cos (2\,nt + 2\,\lambda + \delta_3)$$

For $l = n$ and the same value of τ as above, the following table gives the values of E, etc., for different latitudes.

Lat.	$10^3\,E$.	δ_1.	f.	δ_2.	g.	δ_3.
0°	5·66	49°	87	−104°	0	99°
15	5·06	46°	89	−101°	56	98°
30	3·66	38°	93	− 93°	86	98°
45	2·15	28°	83	− 87°	85	98°
60	0·98	18°	62	− 83°	63	99°
75	0·25	12°	32	− 81°	32	99°
90	0·0	10°	0	− 80°	0	100°

Thus the effect of the friction is greatly to reduce the pressure and velocity amplitudes, and to introduce considerable differences of phase. The pressure maximum precedes the temperature maximum but the maximum West wind occurs much later while the maximum North wind occurs at the time of minimum pressure nearly. The nature of the motion for latitude 45° in the pressure wave in the two cases is shown in the diagram (Fig. 3) I. for $l = 0$, II. for $l = n$. The motion is quite similar to that obtained by assuming a value for the pressure variation suggested by the observational results.

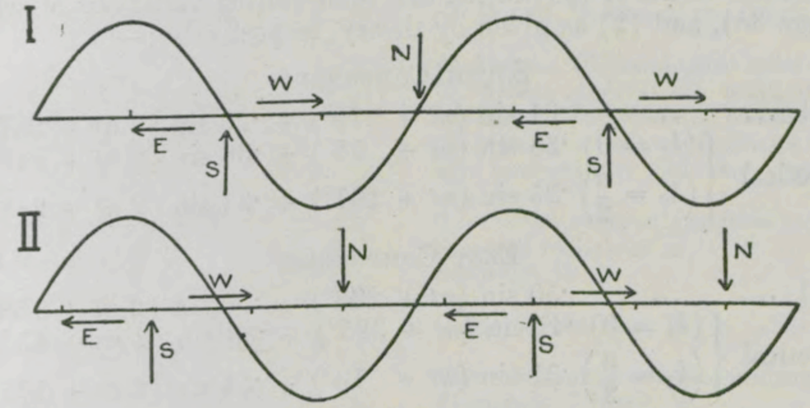

FIG. 3.

It is not to be expected that these results will agree fully with the variations in wind velocity deduced from observation. The effect of vertical convection near the earth's surface will be to change both the phase and the amplitude, especially of the diurnal wind variation. This effect was first noted by Espy as long ago as 1840, in a paper read before the British Association. His words are sufficiently interesting to be reproduced. "The commencement of up-moving columns in the morning will be attended with an increase of wind and its force will increase with the increasing columns, both keeping pace with the increasing temperature. This increase of wind is produced, partly by the rush of air on all sides at the surface of the earth, towards the centre of the ascending columns, producing fitful breezes; and partly by the depression of air all round the ascending columns, bringing down with it the motion which it has above, which is known to be greater than that which the air has in contact with the asperities of the earth's surface."

For a place which has a similar exposure on all sides and at which winds from two opposite directions are equally frequent for similar conditions of temperature and sunshine, this effect of convection can be eliminated.

If the periodic variations for the two directions are V_1, V_2 we may write

$$V_1 = v_1 + v_c$$
$$V_2 = -\,v_1 + v_c$$

where v_1 is the variation associated with the pressure variation and v_c that due to the vertical convection.

Thus $2\,v_1 = V_1 - V_2$ gives the required variation v_1, which alone can be fairly compared with the theoretical results.

Note.—In order to compare Mr. Gold's results (Section I.) with the actual values for St. Helena given on page 35, it is necessary to compute the values of u_1, v_1, u_2, v_2 for latitude 16° S. from the formulæ on page 38.

$$\text{We have } \phi = 90° + 16° = 106°$$

$$\left.\begin{array}{r} \lambda_1 = 325° \\ 2\,\lambda_2 = 153° \end{array}\right\} (\textit{see} \text{ page 31}).$$

The computation gives

$$\left.\begin{array}{ll} u_1 = \cdot 31 \sin(nt + \lambda_1 + 225°) & \text{m.p.h.} \\ v_1 = \cdot 25 \cos(nt + \lambda_1 + 232°) & \text{,,} \\ u_2 = \cdot 54 \sin(2\,nt + 2\,\lambda_2 + 198°) & \text{,,} \\ v_2 = \cdot 34 \cos(2\,nt + 2\,\lambda_2 + 202°) & \text{,,} \end{array}\right\} \text{for } k_1 = n/2$$

and

$$\left.\begin{array}{ll} u_1 = \cdot 47 \sin(nt + \lambda_1 + 180°) & \text{m.p.h.} \\ v_1 = \cdot 38 \cos(nt + \lambda_1 + 180°) & \text{,,} \\ u_2 = \cdot 58 \sin(2\,nt + 2\,\lambda_2 + 180°) & \text{,,} \\ v_2 = \cdot 36 \cos(2\,nt + 2\,\lambda_2 + 180°) & \text{,,} \end{array}\right\} \text{for } k_1 = 0.$$

In the above the u's are positive for a West wind, and the v's are positive for a North wind.

On transforming the cosines into sines and substituting for λ_1 and λ_2, the expressions become exactly comparable with those on page 35.

The following are the values of the diurnal and semi-diurnal variations of wind (1) as computed from the records (page 35), and (2) as given by theory, respectively :—

South Component.

(1) Actual ... ... $1{\cdot}01 \sin(nt + 79°) + \cdot 79 \sin(2\,nt + 237°)$ m.p.h.

(2) Theoretical $\left\{\begin{array}{l} (k_1 = 0)\ \cdot 38 \sin(nt + 55°) + \cdot 36 \sin(2\,nt + 243°) \quad \text{,,} \\ \left(k_1 = \frac{n}{2}\right) \cdot 25 \sin(nt + 107°) + \cdot 34 \sin(2\,nt + 265°) \quad \text{,,} \end{array}\right.$

East Component.

(1) Actual ... ... $\cdot 50 \sin(nt + 298°) + \cdot 50 \sin(2\,nt + 158°)$ m.p.h.

(2) Theoretical $\left\{\begin{array}{l} (k_1 = 0)\ \cdot 47 \sin(nt + 325°) + \cdot 58 \sin(2\,nt + 153°) \quad \text{,,} \\ \left(k_1 = \frac{n}{2}\right) \cdot 31 \sin(nt + 10°) + \cdot 54 \sin(2\,nt + 171°) \quad \text{,,} \end{array}\right.$

Diagrams showing the nature of the theoretical wind changes in the diurnal pressure waves for the latitude of St. Helena, corresponding with those given on page 40 (Fig. 1), are reproduced below (Fig. 4).

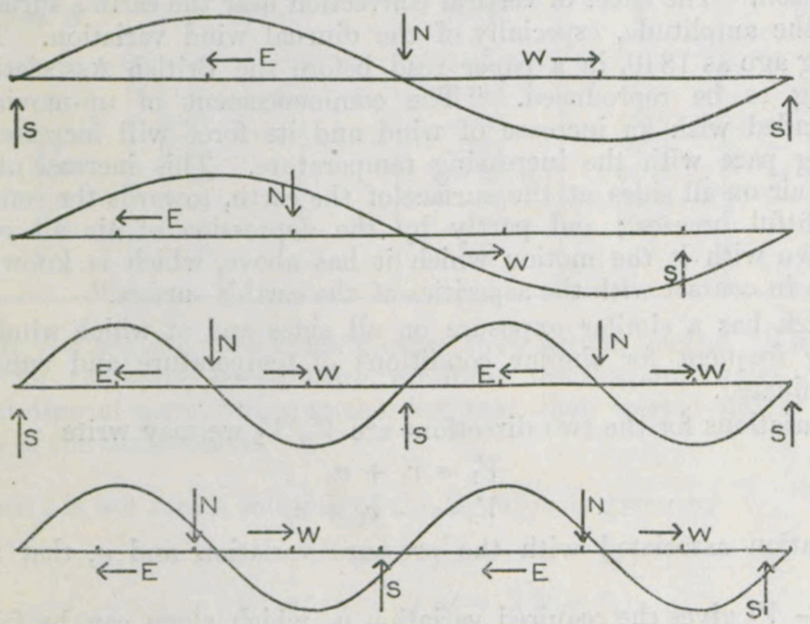

Fig. 4.

The last two diagrams should be compared with Plate 17.

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Thorshavn.		0	3	6	9	12	15.
	+	136	247	361	283	139	259
	−	275	140	208	166	223	70
		−139	+107	+153	+117	−84	+189
1891-1922 Thors Σ^2		421	441	1508	1891-21 658	412	402

Bergen.							
	+	196	706	631	923	181	706
	−	631	309	508	391	750	279
		−435	+397	+113	+532	−569	+427
1891-23	Σ^2	3484	3615	5985	1891-22 6933	3241	3357

Ponta Delgada.							
	+	403	457	1617	287	321	491
	−	535	864	1328	1538	437	617
		−132	−407	+289	−1251	−116	−126
1894-20	Σ^2	3066	5709	41383	1894-19 13087	3002	5588
		3.4866	3.7566	4.6168			
		1.7433	1.8783	2.3084			

Valencia							
	+	131	282	592	277	155	210
	−	211	198	285	393	210	247
		−80	+84	+307	−116	−55	−37
1891-24	Σ^2	556	921	2902	1891-23 1717	449	921

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1716	1664	1769	1716	1823	1796	1850	1690	1638	1392	1210	1232	1188	1188	1323	1440	1613
941	884	903	903	920	1020	1103	1124	1188	1210	1232	1166	1082	1000	941	903	884
2657	2548	2672	2619	2743	2816	2953	2814	2826	2602	2442	2398	2270	2188	2264	2343	2497
16.3	16.0	16.3	16.2	16.6	16.8	17.2	16.8	16.8	16.1	15.6	15.5	15.1	14.8	15.0	15.3	15.8

18	19	20	21	22	23	24	mean.
1742	1823	1877	1877	1796	1769	1690	1613
941	960	1000	1020	980	980	960	1020
2683	2783	2877	2897	2776	2749	2650	2633
16.4	16.7	17.0	17.0	16.7	16.6	16.3	16.2

mean hourly velocity 1892-1907

P. Keep in this volume.