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THE EFFECT OF THE LABRADOR CURRENT
UPON THE SURFACE TEMPERATURE OF THE NORTH ATLANTIC;
AND OF THE LATTER UPON AIR TEMPERATURE AND
PRESSURE OVER THE BRITISH ISLES.

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THE EFFECT OF THE LABRADOR CURRENT UPON THE SURFACE TEMPERATURE OF THE NORTH ATLANTIC; AND OF THE LATTER UPON AIR TEMPERATURE AND PRESSURE OVER THE BRITISH ISLES.

At the meeting of the British Association held in Dublin in 1908, a paper was read by myself relating to a comparison of the changes in the strength of the Trade Winds of the Atlantic during each of the five years, 1902-6, with average results; and of changes in the surface temperature of the North Atlantic during each of the five years, 1903-7, with normal values.*

From the examination of these comparisons there was found to be some evidence to prove that departures from the average strength of the two Trade Winds during a series of months, and at times during even so short a period as one month, were roughly reflected in deviations from the normal in the average distribution of surface temperature in the North Atlantic in the corresponding series of months, or month, as the case may be, of the succeeding year; notwithstanding the existence of many causes affecting the temperature of the surface water, which must tend towards masking the appearance of any such connexion.

To represent the North Atlantic in the comparison of the changes in the surface temperature referred to, two zones were selected; the one lying between Florida Strait and Valencia, and the other between that Strait and Cape Race.

It is now my purpose to show by diagrams that one of the causes which exercise a modifying effect upon the influence of the Gulf Stream on the temperature of the Northern waters of the North Atlantic, probably one of the most potent of them, is the encroachment of the Labrador Current. Also that during the five years, 1903-7, increased activity of this current, evinced by an increase of ice in the North-Western Atlantic, was generally followed by a diminution of temperature of the surface water in that portion of the North Atlantic represented by the Florida-Valencia zone. Moreover, from a comparison of sea-surface temperature in that part of the North Atlantic which is represented by that zone with air temperature and barometric pressure at three widely separated coast stations in the British Islands—Valencia, Sumburgh Head, and North Shields—it is found that a fall in sea temperature in that zone was often associated with a corresponding fall in air temperature at the stations named; and, in the colder months of the year, with an increase of pressure. Also that a rise in sea temperature not infrequently was accompanied by a rise in air temperature, and, except in summer, with a diminution of pressure.

I would make it plain, however, that it is not the ice in the North-Western Atlantic that lowers the temperature of the surface water in that region; it is the

* "A Comparison of the Changes in the Temperature of the Waters of the North Atlantic, and in the Strength of the Trade Winds." (Printed in M.O. Publication 203, *The Trade Winds of the Atlantic*.)

cold Labrador current—the ice-bearing current from the frigid North—which causes that effect.

In some recent and comparatively recent years, the lack of sunshine and frequency of cloudiness and rain during the spring and summer in these islands have been somewhat freely attributed in the press to the abnormally large quantities of ice in the North Atlantic at such times.

Now, during seasons when ice reports have been more than usually frequent, the ice in the North-Western Atlantic can have had no more influence upon the climatic conditions of the British Isles than would a few tons of ice, thrown into one of the lower reaches of the Thames, have upon the climatic conditions of the metropolis.

It is, as has already been mentioned, the cold Labrador Current that lowers the temperature of the ocean, not the ice which it brings south.

The temperature of the sea surface may be lowered by the Labrador Current in another way. When this Current is more than usually active, and encroaches upon the normal confines of the Stream, where the two meet the course of the Stream and its extension is diverted, and they flow north-eastward in a less northerly direction.

The northern portion of the ocean, therefore, in addition to being chilled by the cold current from the north, is thus deprived of much of the warming influence of the heated stream from the south.

Occasionally it happens that an increase in the activity of the Labrador Current is synchronous with a decline in the velocity and volume of the Gulf Stream; then, over large areas of the North Atlantic, the surface temperature is found to be considerably below the average for the period.

Air temperature over these islands is, in my opinion, modified by changes in the surface temperature of the North Atlantic in at least three ways—(1) By winds that come from seaward; (2) by the influence of sea temperature upon the paths of depressions that influence the wind and weather in these islands; (3) by a diminution of cloudiness.

The temperature of an air current is modified by the temperature of the water over which it passes.

When the surface temperature in the north-eastern arm of the North Atlantic is much below the average, atmospheric pressure over the Iceland-Faroe region has a tendency to increase, and the centres of depressions, visiting North-Western Europe, to cross directly over the British Isles, or not far north, and at times even south, of our islands, bringing much cloudiness and rain. On the other hand, during seasons in which the Gulf Stream extension follows its normal or a still more northerly course, Atlantic depressions travelling to the eastward or north-eastward pursue paths that take their centres to the westward and northward of our western and northern shores; with the result that mild, or comparatively mild, south-westerly or westerly types of weather or anticyclonic conditions prevail.

In summer the association of bright warm weather with sea temperature above the normal may perhaps be accounted for by the small difference obtaining between the temperature of the air and that of the surrounding sea; the consequent diminution of cloudiness, and corresponding increase of sunshine. Moreover, in this season a diminution even in the quantity of vapour in the atmosphere during the day and following night is attended by a rise in the mean temperature of the twenty-four

hours, because the heat the earth receives by solar radiation exceeds that which it loses by terrestrial radiation.

Before proceeding, some explanation of the diagrams is needed; but I will first point out several of the salient features in the average distribution of sea temperature in each of the months, January, April, July, and October, by a reference to Plate 1.

The areas embraced by the 80° isotherms owe their high temperature to the Equatorial Current; and the bend northward of the 70° and 80° isotherms near the coast of America is caused by that Current after it has emerged from the Strait of Florida, and become known as the Gulf Stream. The southward trend of the 40° , 50° , and 60° isotherms on the north-western side of the North Atlantic is due to the influence of the Labrador Current; the northern trend eastward of the 50° isotherm, and of the 60° in July and October, is attributable to the north-easterly extension of the Gulf Stream influence. The Greenland Current is responsible for the bend southward, on the eastern side of the North Atlantic, of the 50° and 60° isotherms in January and April, and the North-East Trade Wind drift for that of the 70° isotherm in all months.

In the set of diagrams shown on Plate 4, and in Plates 5 to 9 that follow, the curve relating to ice indicates the quantity in the North Atlantic, estimated by the number of one degree squares in which ice was observed, in each month during each of the years to which the respective diagrams refer. The values are marked on the scale at either side of the diagrams.

In the diagram relating to sea temperature in the Strait of Florida-Valencia zone, the excess or defect in the surface temperature is shown, estimated by the number of degrees of longitude by which the 70° , 60° , and 55° isotherms respectively are east or west of their average limit shown in Plate 2, which limit is referred to a zero line. The number of degrees of departure from the positions of average limits is found by means of the scales given above and below this zero line.

It should be understood that when an isotherm is west of its normal limit it is also south of that limit; and when it is east of that limit it is also north of it; because the temperature gradient lies, for the most part, in a north-east and south-west direction as shown on Plate 3.

During those months in which the normal limit of the 55° isotherm lies to the north-eastward of Valencia, this isotherm is, of course, absent from the diagrams relating to sea temperature. In the remarks which follow, however, mention is made as to whether this isotherm was east or west of the normal in those months.

The curves of air temperature at Valencia, Sumburgh Head, and North Shields, show departures from the normal in degrees Fahrenheit by reference to the scales above and below a line which represents the average temperature based on numerous observations extending over a period of thirty-five years.

The curves of barometrical pressure at the same stations show, in a similar manner to those for air temperature, the departures from the normal. In this case the excess and defect are indicated in tenths of an inch on the scales above and below the line representing average pressure; also based on observations extending over a period of thirty-five years.

1903. (PLATE 4.)

Ice.—In January and February 1903 no ice was reported on the steamer routes of the North Atlantic. **Sea temperature** in the south-western portion of that

ocean, represented by the 70° isotherm, was above the normal, and was below but increasing to the north-eastward.

Air temperature at the three stations mentioned was in excess, considerably in excess at Shields, during February.

Barometrical pressure, for the most part, was below the average.

Ice appeared in the North-Western Atlantic in March, and the quantity increased rapidly, attaining its maximum frequency in May, when it was charted in no less than 68 one-degree squares.

The steamer routes, adopted by the Transatlantic steamship companies, were specially altered, owing to the exceptional quantity of ice, from May to July inclusive. The routes normally differ according to the season. The route laid down for the period 15th January to 14th August outward, but to 25th August homeward, takes a vessel farther south than the route assigned to the remaining months of the year. In connexion with the frequency of ice reports this fact should be taken into consideration. After the middle of May ice reports became less frequent until July, when about the same number were received during each week until September; then the number steadily diminished. It should be borne in mind, however, that when the steamer routes were altered specially, and vessels were navigated in latitudes south of their usual tracks; the diminution in the quantity of ice observed followed in natural sequence. For this reason ice frequency in those months when the more southern tracks were followed cannot be considered as comparable with that of other months.

Sea Temperature, after March, quickly declined, the 55° isotherm, representing the water in the neighbourhood of our islands, retreating 8° of longitude west of its average limit in May, when the quantity of ice in the ocean had reached its maximum for the year; and the 70° isotherm, in the south-western arm of the ocean, 10° west of its average limit in June. Sea temperature exhibited fluctuations during the remainder of the year, but, although the 55° isotherm was about the average in July to October inclusive, continued for the most part below the average, except in the south-western arm of the ocean in November and December.

Air Temperature at the three representative stations, above the normal until March, fell below in April, and remained below for the most part until the close of the year, except at Shields in October, when it was well above the normal. At Sumburgh Head it is shown to have been 2° in defect in July.

Pressure was below the normal until June, except at Valencia in February and April, where it was slightly above; it was above at all three stations in June, below in July and August; above in September at Shields and Sumburgh Head, but below at Valencia; below at all three stations in October; above in November at Valencia and Shields, and slightly above at Sumburgh Head; below in December, except at Sumburgh Head.

1904. (PLATE 5.)

Ice, in large quantities, drifted south with the Labrador Current as early as February in 1904. The quantity appears to have diminished in March; increased rapidly and attained its maximum frequency in May, when it was charted in 56 one-degree squares. After May the frequency of ice reports again declined, quickly in the earlier part of June, then slowly; but there remained a considerable quantity of ice up to the end of August, and until December it was occasionally observed.

Steamer routes were altered in consequence of the ice during May and June.

Sea Temperature, found to be below the average in January and February, increased in March and April, then diminished; the eastern limit of the 60° isotherm was at least eleven degrees west of this limit at the end of June and beginning of July, and remained considerably to the west of it until October. After that month sea temperature represented by that isotherm did not differ much from the normal. The 55° isotherm was however near the average until October, when it rose and remained above until December; the 70° isotherm extending eastward in September remained to the eastward during the two following months.

Air Temperature at the three stations rose and fell, for the most part, in response to sea temperature, but lagged markedly. Associated with the rise in the temperature of the latter during March, the mean air temperature at Shields in April rose to nearly $3^{\circ}\cdot5$ above the normal, and continued above until August; but at Valencia, although fluctuations are shown, the temperature remained below the average until October; and at Sumburgh Head it fell below the average in May, and remained below until September.

Barometrical Pressure, low in January and lower still in February, increased quickly to above the average in March; but fell below the average at Shields and Sumburgh Head in April, remaining, however, above at Valencia. During the remaining months of the year pressure showed, for the most part, a steady increase until November, when it diminished.

1905. (PLATE 6.)

Ice in this year was present in the North Atlantic in small quantities in January. The quantity increased so rapidly that in March it was charted in 60 one degree squares and in April in 62. The tracks of Transatlantic steamers were specially altered on account of the large quantity of ice in the neighbourhood of these trade routes during April and May; in the latter month and in June the quantity diminished somewhat, but it again increased in July. There was less ice in August; about the same quantity in September, after which month it decreased to November, but increased slightly in December.

Sea Temperature, which had been above the average in January and February, declined in March, at which time the increased activity of the Labrador Current became evident by the rapid increase in ice frequency. In April the eastern limit of the 55° isotherm retreated as much as 6° of longitude west of its average limit; but advanced after that month, and was to the eastward of its average limit in June and July, and to the westward during the remainder of the year. The surface temperature subsequently was not, however, as a whole, far from the average until June, except near our shores. When ice frequency increased temporarily in July, although the 70° isotherm showed a decline in surface temperature in the South-Western Atlantic, the position of the 60° isotherm indicated a sharp recovery and increase to the north-eastward. The relatively warm water of the south-western arm of the North Atlantic represented by the 70° isotherm advancing eastward in August, penetrated 4° east of its average limit in September, and 6° east of that limit in December. The 60° isotherm retreated to 70° west at the beginning of August, and remained west of its average limit to the close of the year; and the 55° isotherm retreated 6° west at the end of November.

Air Temperature exhibited departures from the normal at the three stations,

resembling those of sea temperature, making due allowance for a slight lag. In January it was above the normal, it fell in February, and rose, except at Valencia, in March, at which station it remained slightly below until June. At Shields and Sumburgh Head a decided decline in air temperature occurred in April, but at Valencia the defect continued slight, and temperature commenced to recover at the three stations in May. The rise in sea temperature in the north-eastern part of the North Atlantic in July then became associated with a rise in air temperature at the three stations, and the fall in sea temperature in that region in the next month with a fall in air temperature at each of them. This decline in air temperature in the north-eastern portion of the ocean continued until October at Shields and Sumburgh Head, and until November at Valencia; after which the temperature recovered, and rose above the average in December at all the three stations.

Barometric Pressure, above the average at the three stations in January, diminished in February, when air temperature increased. It showed a departure from the average of -0.3 in. in March, when air temperature rose 3° above the normal. Then in April, as temperature declined, pressure increased, but continued to increase until June, while air temperature recovered. From that month to September pressure fluctuated, but did not depart much from the average until October. In that month, when air temperature was rapidly declining at the three stations, pressure increased, most markedly at Valencia; it decreased next month when temperature was recovering, but again increased to a height about the average in December, although the temperature was at the same time rising.

1906. (PLATE 7.)

Ice was occasionally reported in the Atlantic in this year again in January. The quantity increased slightly during February and March; diminished in April; and again increased rapidly after June, until August. Ice reported in July, when its frequency was at the maximum for the year, occupied 60 one-degree squares on the chart. In that month and in August steamer routes were altered owing to the frequency of ice on, and in the neighbourhood of, the usual Transatlantic tracks. After July the quantity of ice reported steadily diminished until November, but occasional ice reports continued to arrive in this country during the remainder of the year.

Sea Temperature appears to have been affected by the increased activity of the Labrador Current before the increasing frequency of ice reports, which followed, heralded the fact. The surface temperature, as a whole, kept near the average until May, but rose for the first three months of the year; the 55° isotherm, however, representing the temperature of the water near our western coasts, although advancing eastward, was to the west of its average limit during the three months. In April to August, inclusive, the surface had a temperature mainly below the average, notwithstanding the fact that the 60° isotherm advanced 4° of longitude to the east of its average limit in April and June; for except in May the 70° isotherm was to the west of its mean limit during these five months; and the 55° isotherm, steadily retreating until June, reached a position 10° west of its mean limit at the end of May, after which, although indicating a defect in temperature, it quickly advanced eastward until September, when it had returned to its average limit. During the four remaining months of this year the surface temperature kept chiefly above the average, and in September the 60° isotherm advanced to a position 7° east of its average limit. In this month the sea round our

south-eastern, southern, and western coasts was flooded with water having a temperature of 60° or above; and a species of pelagic mollusc, which abounds in the South-Western Atlantic, was found in the English Channel. At the end of November the 60° isotherm had receded to a position 3° west of its average limit, but the 55° and 70° isotherms were both to the east of their respective average limits.

Air Temperature, stated broadly, was above the normal in January, and after that month below until June, when it rose slightly above. It again fell below the normal, but recovered in August; and remained above until December, when it declined decidedly.

Barometrical Pressure in January and February was below the average; only slightly below, however, at Valencia. Pressure increased in March and April, and stood above the average, nearly 0.3 in., at Valencia in the latter month. It then diminished, and in May stood below the average; but increased in June, and continued, for the most part, above during that month and the next three months, as much above as 0.25 in. in September. In October pressure showed a departure from the average of from -0.17 in. to -0.06 in.; in November and December it remained slightly below at Shields and Sumburgh Head, but rose at Valencia in the latter month to 0.2 in. above the average.

1907. (PLATE 8.)

Ice reports occasionally received in January increased in number from February to May, rapidly from March to April; in May, ice was charted in 66 one-degree squares. Between May and November the quantity of ice diminished, quickly to August, slowly from that month; but ice continued to be reported occasionally to the end of the year.

Sea Temperature in the northern part of the North Atlantic was above the average until May, but in the southern part it is shown by the 70° isotherm to have been slightly below. From May to August, presumably in consequence of the increased activity and volume of the ice-bearing current, sea temperature was in defect, largely in defect in June and July, when the 60° and 70° isotherms were from 6° to 7° of longitude west of their respective average limits; the 55° isotherm slightly to the east of its normal limit in July was to the west of it in August. After August, sea temperature was above the normal over the greater part of the North Atlantic, as represented by the surface temperature in the Florida Strait-Valencia zone, for the remainder of the year, except in that portion of it represented by the 55° isotherm, which showed a defect in temperature there during September and October, and had receded from 4° to 5° west of its average limit in November, but advanced rapidly eastward in the following month.

Air Temperature in January and February is shown to have been below the normal at the three stations, very slightly below at Sumburgh Head, but nearly 3° below at Valencia and Shields. It was above the normal in March; 2.5° above at Valencia. Air temperature then declined, and remained below the normal from April to October inclusive, except at Valencia, where the extension eastward of the relatively warm water represented by the 60° and 70° isotherms was first felt. During the remaining three months air temperature stood above the normal at Sumburgh Head, and mainly above at Shields, but at Valencia below the normal.

Barometrical Pressure at the three stations stood above the average in January; the excess being greatest at Valencia, least at Sumburgh Head. It diminished in

February, but continued above the average at Valencia, and not far from the average at Shields. Pressure increased to above the average in March, but during the three months following a considerable reduction took place; the departure from the average in June ranging from nearly 0.2 in. at Valencia to 0.3 in. at Sumburgh Head. It increased to above the average in July, fell below the average, except at Valencia, in August, and was above at all three stations in September. In October a decided diminution of pressure took place, at Valencia the departure from the average being nearly 0.35 in.; but there was a brief recovery in November, followed by a rapid diminution in December.

1911. (PLATE 9.)

January to October Inclusive.

The conditions that prevailed during the spring, summer, and autumn of the year 1911 having been exceptional, the following notes and accompanying diagrams are added for the purpose of comparison with the corresponding information of previous years.

Ice.—The quantity of ice in the North Atlantic increased this year from January to May, rapidly to April, and decreased rapidly after May. There was a brief increase in the quantity of ice during August, followed by a quick decrease in September, after which the diminution was less rapid.

Sea Temperature was mainly in defect until April, particularly in the South-Western Atlantic, as shown by the absence of the 70° isotherm. Since April it has been in excess of the normal except in the south-western portion of the ocean where the 70° isotherm was to the west of its average limit in August; but this isotherm advanced nearly 9° of longitude to the east of its average limit at the end of May, and 7° east of this limit in October.

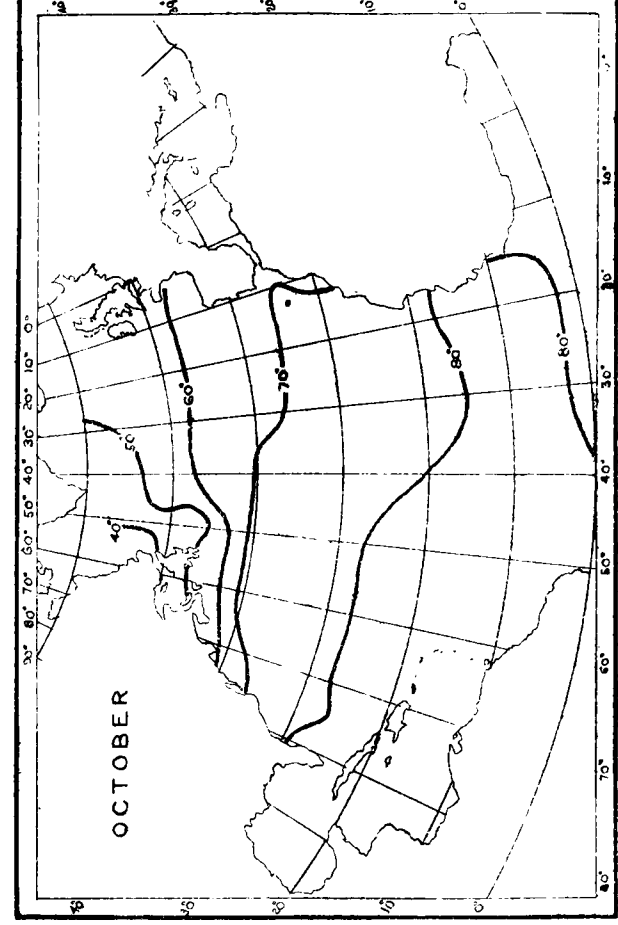
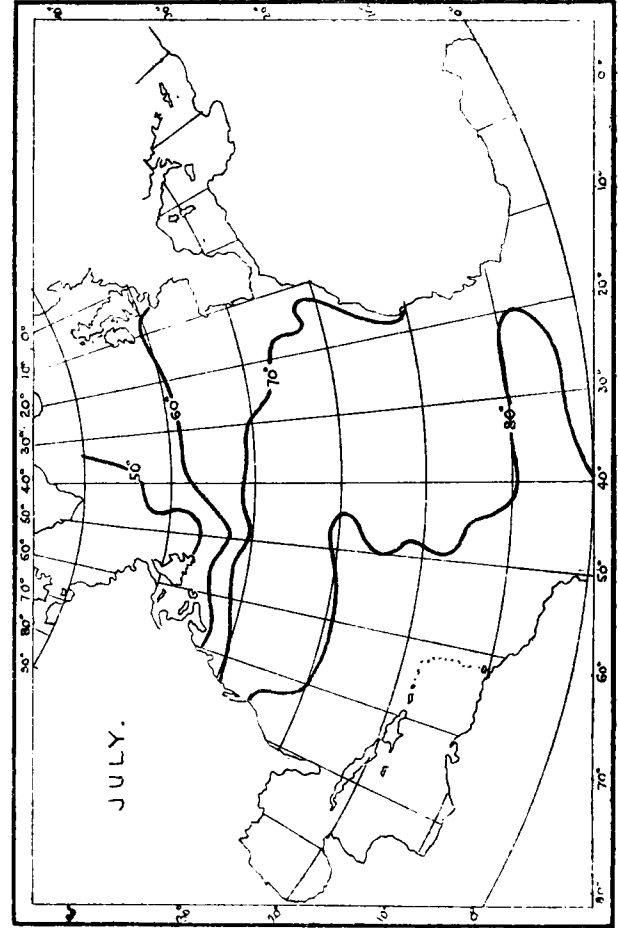
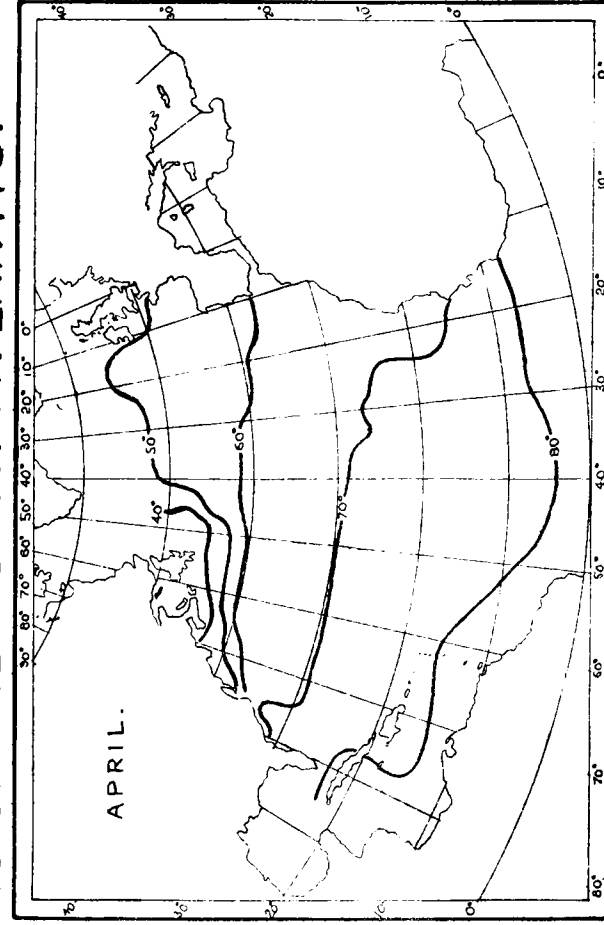
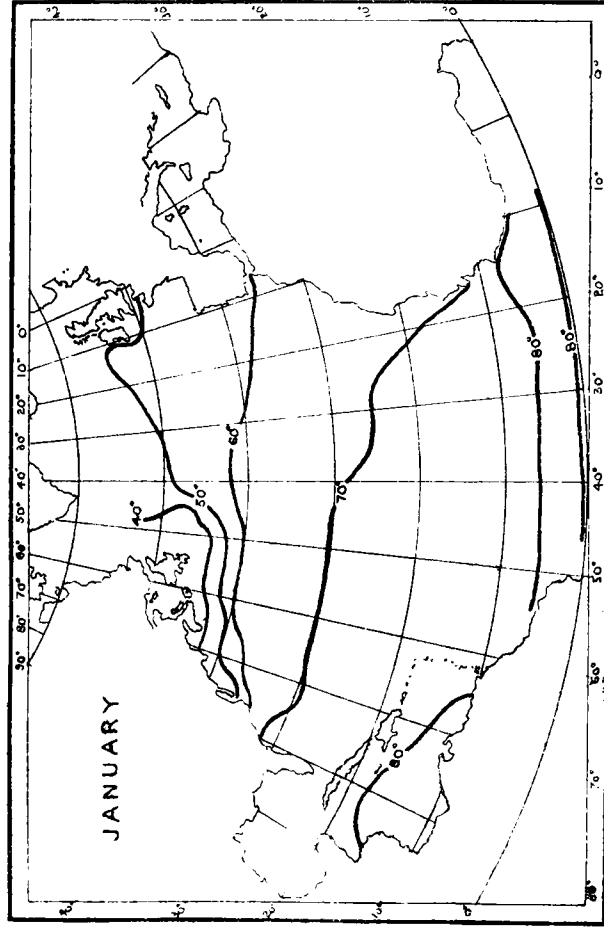
Air Temperature, somewhat above the normal at all three stations during January and February, declined in March, commenced to recover in April, and was largely in excess in May. It again declined somewhat in June, but was still above the average in that month. Rising again at the end of June it was considerably higher than the average in July and August, about the average in September, and slightly below in October.

Pressure, above the average in January, remained for the most part above until the end of July, except at Sumburgh Head in February, and again in June; in those months it fell considerably below the average at that station, although it was 0.35 in. above in May. Pressure was higher than the average in August, September, and October, except at Valencia in August, where it was 0.14 in. lower, and at Sumburgh Head, where in September it was in agreement with the average.

M. W. CAMPBELL HEPWORTH.

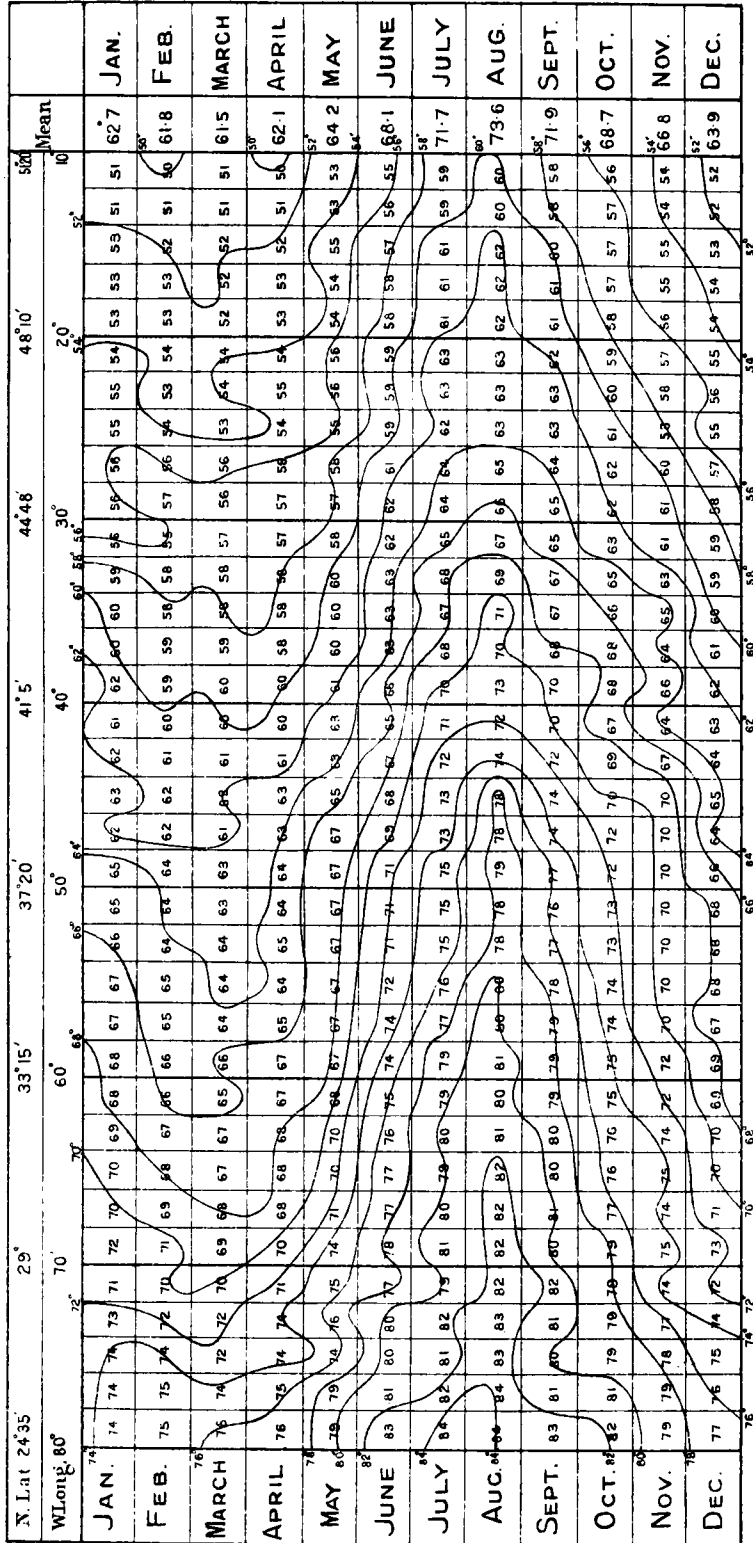
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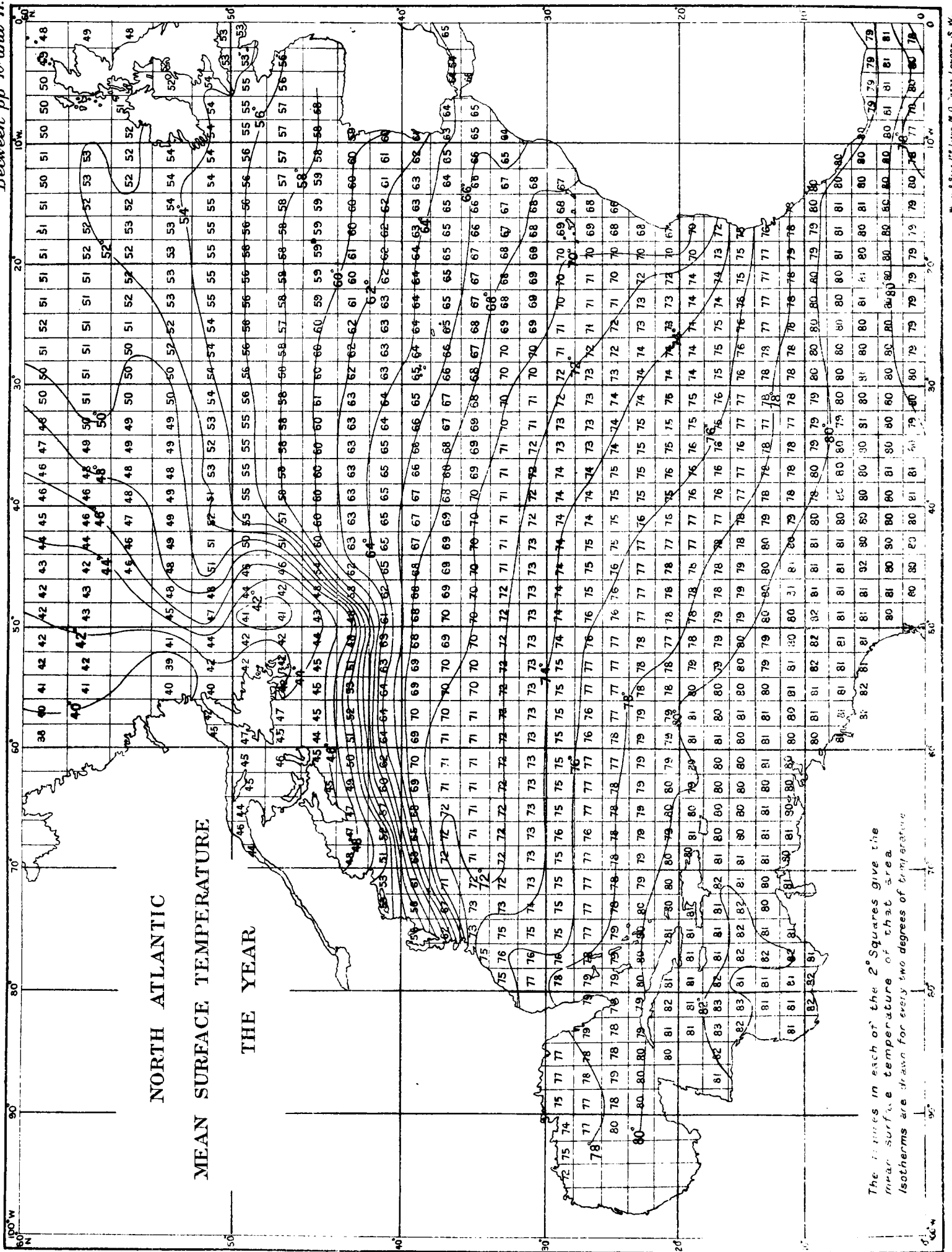
MEAN SEA SURFACE ISOTHERMS OF THE NORTH ATLANTIC.



Thermo-Isopleths for Surface Temperature
Straits of Florida to Valencia, Ireland.

Average Temperatures.





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

