ON THE

TEMPERATURE OF THE SEA

AROUND THE

COASTS OF SCOTLAND,

DURING THE YEARS 1857 AND 1858;

AND THE BEARING OF THE FACTS ON THE THEORY THAT THE

MILD CLIMATE OF GREAT BRITAIN,

DURING WINTER,

IS DEPENDENT ON THE

GULF STREAM.

WITH A CHART OF THE CURRENTS IN THE NORTH ATLANTIC.

READ BEFORE THE ROYAL SOCIETY OF EDINBURGH, 3D JAN. 1859.

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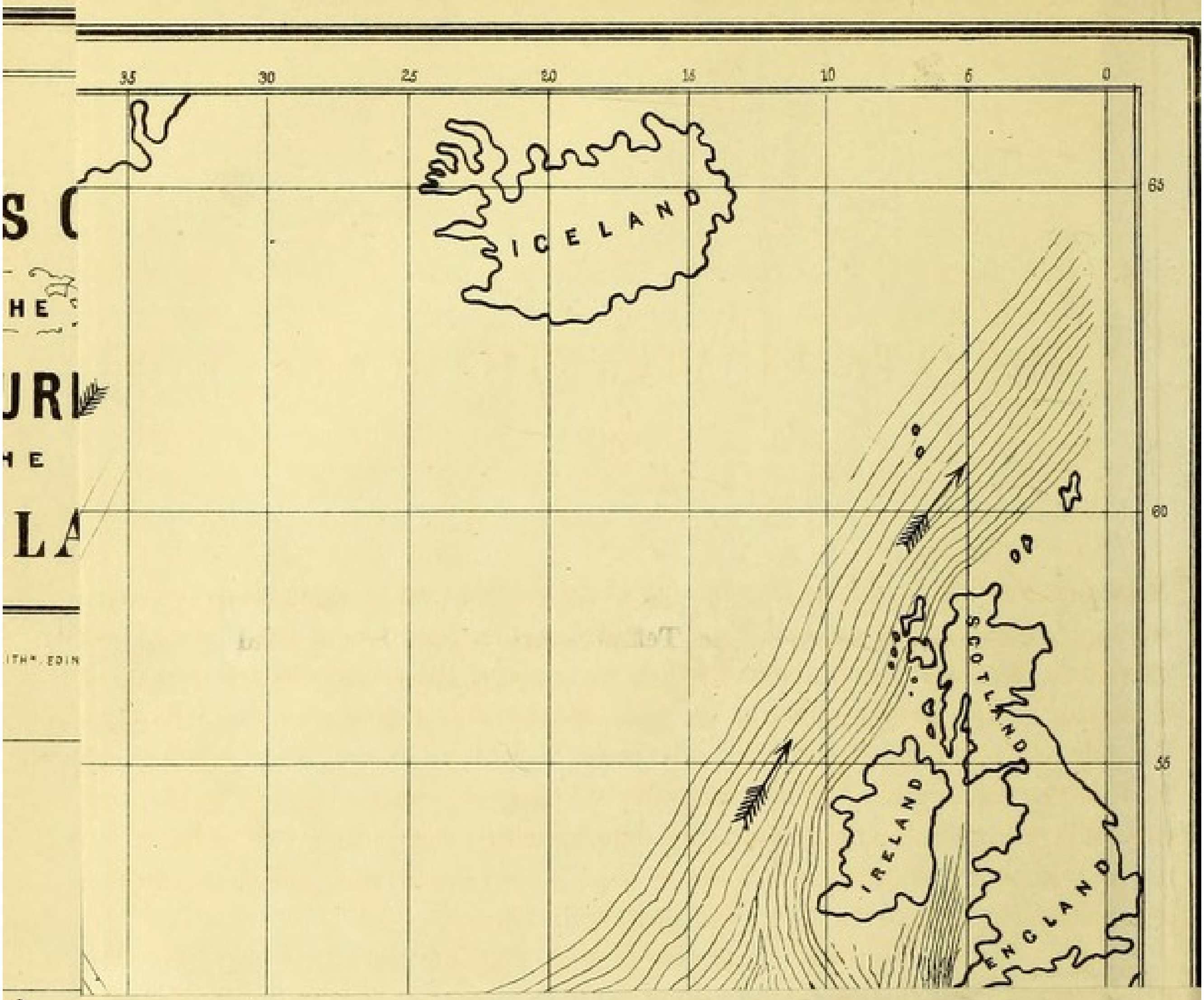
DR STARK'S CHART
OF THE
OCEANIC CURRENTS
IN THE
NORTH ATLANTIC.
GREENLAND
ICELAND
HUDSONS BAY
HUDSONS STRAIT
DAVIS STRAIT
C. Chidley
LABRADOR
CANADA
NORTH AMERICA
CALIFORNIA
UNITED STATES
GULF OF ST. LAWRENCE
NEW FOUNDLAND
C. Race
GREAT BANK
ARCTIC CURRENT
IRELAND
ENGLAND
FRANCE
C. Finisterre
SPAIN
PORTUGAL
C. St. Vincent
MEDITERRANEAN SEA
New York
Azores Is.
C. Hatteras
GULF STREAM
Bermuda Isl.
Madeira Is.
C. Cantin
NORTH AFRICAN CURRENT
Great Seaweed Bed or Sargasso Sea
Canary Is.
New Orleans
FLORIDA
GULF OF MEXICO
MEXICO
Bahama Is.
CUBA
C. Blanco
AFRICA
CENTRAL AMERICA
Cape Verde Is.
EQUATORIAL CURRENT
SOUTH AMERICA



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ICELAND
SCOTLAND
IRELAND
ENGLAND

CURRENTS IN ATLANTIC OCEAN, ETC.

Many interesting problems depend for their solution on a good and systematic series of observations on the Temperature of the Sea around our shores. Not only have the facts which are to be thus ascertained the strongest bearings on the character of the British climate, but also on the phenomena attending the Great Oceanic Currents which circulate the mass of waters in the Northern Atlantic. It would be the height of affectation to assert that two years' observations, however carefully conducted, could thoroughly determine any one point; still it is only by making known the facts which have been ascertained, and pointing out their general bearings, that the truth will eventually be arrived at.

Impressed with the belief that the Meteorology of this island was incomplete unless means were used for determining the varying conditions as to Temperature of the Sea around our shores, the Meteorological Society succeeded in getting several stations established around our coasts, and though the observations made at all these stations are not quite complete for every month, still some facts were ascertained which enable us to deduce some interesting, and, it must be confessed, quite unexpected conclusions.

It may be remarked, that, at the very outset of the inquiry, unexpected difficulties were met with in ascertaining the true temperature of the sea. In order to procure as much uniformity as possible, instructions were issued to the effect that the temperature should be taken at the time of high water, six feet below the surface, from the ends of projecting rocks or piers, and as distant as possible from a river's mouth. As several of the observers lived at some distance from the sea, all these directions could not be complied with at every observation, as they were unable to visit the sea always at the time of high water. The result has been that the mean temperature of the sea around Scotland has been slightly overrated, perhaps at least to the extent of half a degree of Fahrenheit's scale on the mean of the year. This observation applies with especial force to the summer and autumnal observations, seeing that it was found that in many of the bays the temperature of the water which came in with the tide was from 3° to 7° *colder* than the water which remained in the bay at the time of low water. This was manifestly occasioned by the water in the bay having acquired an increased temperature from the heated shore; and as the heated water clung to the shore during the recess of the tide, the heated water remained in the bay at the time of low water.

In consequence of this peculiarity it would only lead to errroneous conclusions were we to compare the mean temperature of one station with another, seeing that the difference might result from local circumstances quite unconnected with general influences. For instance, in Stornoway Bay, when the sun's rays got powerful, the sandy bottom and sheltered site had the effect of causing the mean temperature of the sea there to rise to a mean of 55° during May 1857; while at three other stations on the west coast, but in much more open situations, viz., at Tobermory, Ushenish, and the Mull of Cantyre, the mean temperature of the sea during the same month was respectively 47°.8,—47°.7, and 47°.2. As the land influence, however, seems to be entirely in favour of *heating*, not of cooling the sea, it may be safely assumed that the sea temperatures are, at all events, not underrated, and yet are not so far from the truth as to prevent their being used for the purposes of general deduction.

As it is important to compare the mean temperature of the sea with that of the air and solid land, the following table exhibits the mean temperature of the air over Scotland reduced to the sea-level, the mean temperature of the soil 22 inches below the surface, and the mean temperature of the sea around Scotland and its islands during the year 1857 :—

Months.	Air.	Land.	Sea.	Months.	Air.	Land.	Sea.
January...........	36.4	39.0	41.3	July.................	58.7	58.7	54.0
February	40.0	38.7	42.8	August	60.7	59.7	56.7
March.............	39.9	40.0	43.1	September........	56.8	57.8	56.9
April...............	43.4	43.2	44.2	October............	50.3	53.4	53.6
May................	50.5	48.2	48.4	November.........	44.4	48.8	50.7
June	58.1	55.7	52.8	December.........	45.6	44.6	47.7
				Year......	48.7	48.98	49.3

From this table it is seen that the mean temperature of the air, of the land, and of the sea, differed to such an unimportant extent, that it may be assumed that their mean temperatures were the same during the year. Even taking the results as absolute, the mean temperature of the sea was only six-tenths of a degree higher than that of the air, and not much more than three-tenths of a degree higher than that of the solid land.

But the above table allows us to deduce other conclusions. It will be seen by it that the minimum mean temperature of the air and that of the sea were attained in January, though the solid land, at the depth of 22 inches from the surface, continued to lose heat till February. After this, in proportion as the temperature of the air rose, so did that of the sea and of the land, till August, when the air and solid land attained their maximum mean temperature. As the sea, however, did not attain the same mean temperature as the land during August, it continued to increase in temperature so long as the mean temperature of the land exceeded its temperature, so that the maximum mean temperature of the sea was not attained till September. After this the mean temperature of air, land, and sea fell together till the close of the year.

These few facts, then,—viz., that the mean annual temperature of the air over Scotland, of the soil of Scotland, and of the sea around its coasts, are within a fraction of a degree of each other; that the highest and lowest mean temperatures of all are attained about the same periods, the slight difference in time being clearly due to the peculiarities of each with regard to the absorption, radiation, and conduction of heat; and that the temperatures of all these rise and fall with one another,—these few facts, I say, lead to the conclusion that their temperatures must be under the influence of the same agency, whatever that agency be.

Fortunately for science, Sir James Matheson, Bart., interested himself in these sea researches, and induced Capt. Henry Otter, of H.M.S. "Porcupine," and then Mr M'Donald at Bernera, to engage heartily in the cause. Capt. Otter accordingly instituted an elaborate series of observations in the Sound of Harris, embracing not only the temperature of the sea, but that of the air, the direction and force of the winds, the state of the tide, the density of the water, and the barometric pressure. From four to eight observations were made daily, and the following are the most important of the results which were obtained (see also Appendix):—

As the observations on the temperature of the sea were made at a place more free from land influence than any of the other stations, the result was, that in the Sound of Harris the sea attained its maximum temperature during August, at the very same time that the air attained its maximum temperature. Thus the mean temperature of the sea at the Sound of Harris was 59°.5 during August, whereas that of September was 56°.8. But the correspondence between the temperature of the sea and that of the air was more strongly marked than by a merely monthly approximation; for these observations show that the temperature of the sea continued to rise regularly with that of the air, attained its maximum almost the very same day that the air attained its maximum, and thereafter fell regularly with the fall of temperature of the air. Nay, further, so close was the connection between the rise and fall of temperature in air and sea, that, whenever a warmer day or two occurred, during which the mean temperature of the air rose above what it had been for several days, the temperature of the water was observed to rise in nearly the same proportion; so that, within certain limits, even the variations in the mean daily temperature of the air were noticeable in that of the sea. Thus the warmest days in August were from the 20th to the 24th, when the mean temperature of the air in the Sound of Harris rose to 68°.3. On the 21st the sea there attained its highest temperature; the mean of four observations, taken at nearly equal intervals day and night, giving the temperature of 62°.5. The mean temperature of the sea during the previous week only averaged 58°.2.

During the month of September, the temperature of the air slowly but pretty regularly fell from about 62° to 57°; and the temperature of the sea kept almost exact pace with it, falling from 59° to 55°.

The first week of October proved a very cold one, the mean temperature of the air falling to 47°.5 on the 6th; and the temperature of the sea, falling of course more slowly, was on the same day so low as 51°.6. Warm weather set in after this; the temperature of the air rose to a mean of 55° for several consecutive days, and the temperature of the sea rose to 54°, and remained at this temperature from the 12th to the 15th of the month. A much warmer day occurred on the 19th, the mean temperature of that day being 58°.5, and the temperature of the sea rose that day to 55°. After this the temperature of the air and sea declined together till the close of the month, when the temperature of the air was 54°, that of the sea 53°.9.

During November the temperature of the sea fell very slowly, being still 52° at the close of the month, that of the air being 45°.2; and the sea, at the depth of 24 feet from the surface, had always the same temperature as at 6 feet. A circumstance, however, deserving special notice, occurred during that month. On the 18th of November, with a south-east wind, and an air temperature of 52°.5, the temperature of the sea was 53°.4. Next day, the 19th, a very high wind blew from the south; but this wind, instead of bringing additional warmth, either by itself, or by driving before it heated water from the Gulf Stream, seemed rather to encourage evaporation, so that the temperature of the sea both at 6 and 24 feet below the surface fell to 52°.5. After this three consecutive days occurred (viz. the 24th, 25th, and 26th), during which the mean temperature of the air was so low as 39°.3, attended by a north and north-east wind, under which the temperature of the sea continued to fall until it reached 51°.5; and notwithstanding the prevalence of strong steady winds from the south and south-west after this period, and during the whole month of December (whose mean air temperature was higher than that of November), the sea was not able to recover its lost temperature, so that on the 18th of December, when Capt. Otter's series of observations was brought to a close, the temperature of the sea was only 50°.8; that of the air 46°.6.

Mr John M'Donald, however, continued this series of observations at Bernera, on the same coast; and at the close of December the temperature of the sea was 49°, that of the air 45°.

During the year 1858, daily observations were made on the temperature of the air and sea on our western shores by Mr John Whyte, manager of the Easdale Slate Quarries; by Mr John M'Donald at Bernera, Isle of Lewis; and since the 1st of June, by Lieut. Thomas, of H.M.C. "Woodlark," off the coasts of Harris and Lewis.

From Mr M'Donald's observations, which are in continuance of those of Capt. Otter, R.N., it appears that the Atlantic, which washes our shores, attained its lowest temperature for the year—viz., 40° at the surface, and 43° at the depth of 24 feet—between the 8th and 12th of March, during which period the air attained its lowest mean temperature on that coast, viz., 30° at Bernera, and 34° at Easdale. The temperature of the sea after this gradually rose; and at Bernera, where a strong tidal current washes round the Bay where the observations are taken, two maxima were attained during the summer, viz., during June, and again during August. During the very warm weather which prevailed in June, viz., from the 14th to the 25th, the air attained a mean temperature of 60°.8; while that of the sea rose to 58°. Cold weather followed, and from the 1st to the 14th of July the mean temperature of the air was only 53°.6, and the temperature of the sea fell under its cooling influence to 54°.2. After this the weather got warmer, and the air attained a second mean maximum temperature of 61°.2, between the 7th and 12th of August; and the sea temperature again attained a second maximum, its mean temperature during that period being 58°.5. From that period the temperature of air and of sea fell pretty regularly together; the mean temperature of the air during the latter half of September being 53°.8, that of the sea during the same period 56°.3. During October the mean temperature of the air fell to 45°.2, and that of the sea fell regularly with it, but of course more slowly, to 49°. From the 1st to the 13th November the mean temperature of the air was 44°.7, that of the sea 48°. From the 14th to the 20th November the mean temperature of the air fell to 34°.5; and the sea, cooling in consequence more rapidly than before, showed a mean temperature of 45° during the same period. After this warmer weather occurred, and the mean temperature of the air till the close of the month was 45°.6, that of the sea during the same period being exactly the same. Warmer weather then set in, the mean temperature of the air from the 3d to the 11th of December being 47°.2, and the temperature of the sea rose with it to 46°.2. *The air, therefore, could not have received its heat from the sea, seeing the sea was colder than the air.* Colder weather followed; from the 13th to the 24th of December the air temperature was 43°.4, and the sea again cooled down to 45°.6. The last week of December was still colder: the mean air temperature being 39°.6; and the sea temperature, falling of course more slowly, descended to 44°.6. The observations of Lieut. Thomas indicate a general accordance with those just narrated; but as they were made during a limited period, and not always at the same locality, they are not so strictly comparable with the above or with each other. Being also farther out at sea, the temperature was colder, viz. 49°.2 at the close of October, than in the land-locked station of Easdale, where the temperature of the sea at the same period was 53°. Thus, again, showing the *influence of the solid land in heating* the water of the ocean which rests on it, so long as the temperature of the solid land exceeds that of the sea.

From this series of observations we perceive that the temperature of the sea rose and fell with that of the air, and that, even in its *fluctuations* of temperature, it bore a distinct accord with the fluctuations in the temperature of the air. This ascertained fact is quite fatal to the theory of the temperature of our seas being dependent on an influx of warm waters from the Gulf Stream; for, had such taken place, any trifling variations in the temperature of the air would have failed to affect that of the sea. But when, in addition to this, we find that, notwithstanding the quite unusual circumstance of south-west winds having blown continuously for the whole month of December 1857, the sea did not increase in temperature (as it would have done had warm waters from the Gulf Stream come up along with these winds), but slowly cooled, the conclusion seems almost irresistible, that the Gulf Stream has no such effect on our seas, or on our climate, as has been supposed.

What, then, it may be asked, is the agent which drives back the winter's colds, and gives us in Scotland a milder winter than is enjoyed by any country lying in the same latitude?

That the sun is not the agent which of itself gives this milder climate *during winter* to Scotland, is manifest from the fact, that all the regions of the globe, even considerably to the south of our latitude, and which, of course, have much more of the sun's rays and heat during winter, have much more severe winters than we have. But the climate of Scotland exhibits in itself a conclusive proof of the same fact, in the circumstance that March is one of our coldest months,—that month being often in Scotland colder than February itself. This apparently results from the fact, that the piercingly cold east winds begin to blow, and are the prevalent winds during that month; and their effect on the temperature is such, that even the increased power and warmth of the sun's rays prove ineffectual in raising the mean temperature. This single fact, then, induces the belief that the mild winters in Britain are chiefly, if not entirely, due to the warm south-west and west winds, which are the prevalent aërial currents during our winter months.

Indeed, a careful consideration of all the facts has led me to the conclusion, that the mildness of the winters in Britain is chiefly due to the south-west and west winds. So long as these winds blow, we have no frosts or intense colds; but the moment the wind changes during winter to an easterly, north-easterly, or northerly direction, we have both frosts and snows, and more or less intense colds. Every one must have remarked the fact, that all our frosts and snows at once give way so soon as a west, south-west, or south wind blows: in fact, the *mildness* of our winters seems to be exactly proportioned to the prevalence of winds from the south and west, while their *severity* seems to be equally proportioned to the prevalence of winds from the north and east.

That this ought to be the case may be easily demonstrated. During our winter the sun retires far to the south of the Equator, and the region of the Trade Winds does not extend farther north than latitude 15° or 20°. The Anti-trade, or South-westerly Winds, therefore, blow during our winter season from the whole heated surface of the Atlantic north of 15° or 20°; and as these winds pass over the great mass of heated waters of the Sargasso or Grassy Sea, besides crossing the line of the Gulf Stream and waters of the Atlantic north of it, they attain a temperature much higher than these same winds could attain were they confined to the much cooler waters of the Atlantic north of 40°. In their course to us these south-west winds meet with no obstructions which could throw them into the upper regions of the air and cool them, but they blow directly to us and to Norway over the level Atlantic; and hence we enjoy a much milder climate *during winter* than any other lands not similarly situated with regard to such winds. If we take a map of Europe, we cannot fail to observe that the only countries which are at all similarly situated with regard to such winds, are Portugal, the south of Spain, Britain, and Norway; and we know that the winter climate of these countries is much milder than that of any countries situated in the same respective latitudes. Before they can reach any other country of Europe, these winds must cross high mountain ranges, which throw them into the upper regions of the air and chill them; so that all the countries of Europe, excepting those above named, have no agent which could drive back the winter's colds. But were these exceptional countries dependent on the Gulf Stream for their mild winters, France, at all events, would equally participate in the benefits which would flow from its heated waters. But the known fact that the winters in France are more severe than those of Britain, shows that it participates to but a small extent in that which is the cause of Britain's and Norway's mildness; and this of itself proves that it cannot be the Gulf Stream which produces that effect. If the cause, however, of the mildness of Britain's winters be the south-west winds, all is easily explained. These south-west winds cannot reach France till they have crossed the whole of Spain, and the high mountain range of the Pyrenees; and by the time they have got across that mountainous country, they are so much cooled down that France can derive comparatively little benefit from them, and hence her more severe winters. This theory, therefore, appears satisfactorily to account for the greater severity of the winters in France, as well as the greater mildness of the winters in Britain and Norway; but this conclusion will be brought out more strongly when we have examined the facts and theories relative to the course of the Gulf Stream.

It is, therefore, proposed, in what remains of this Paper, to investigate the facts which have been ascertained relative to the Gulf Stream, give my own view of the currents in the North Atlantic, and point out their bearings on the subject in question.

As Mr Maury, the Superintendent of the National Observatory at Washington, is not only the most recent writer on the Gulf Stream, but as his work on the "Physical Geography of the Sea" is, as it were, the embodiment of the theory that the climate of our island is dependent on that stream, I shall address myself to an examination of his theory regarding the course of that stream, and his statements regarding it, more especially as his theories appear to have met with nearly universal acceptance in this country.

Mr Maury's views may be stated to be that the Gulf Stream, leaving the Gulf of Mexico, takes the most direct route it can for the Northern Ocean, so that it brings the British Islands in the very centre of its current. That neither shoals nor counter-currents have any influence on its course, but that it follows this direction in consequence of certain fixed physical laws, which he endeavours to show (most unsatisfactorily, I think) apply to the course of the Gulf Stream. These physical laws are the rotation of the earth on its axis, and the greater lightness given to the waters of the Gulf Stream by its increased temperature. For a few of Mr Maury's statements, on which some comments will afterwards be made, it is best to quote his own words:—

"The Gulf Stream," says he, "has its fountain in the Gulf of Mexico," while "its mouth is in the Arctic Seas. From the Straits of Bemini the course of the Gulf Stream describes (as far as it can be traced, over to the British Islands, which are in the midst of its waters) the arc of a great circle as nearly as may be. Such a course as the Gulf Stream takes is very nearly the course which a cannon ball, could it be shot from these Straits to those Islands, would describe" (p. 43).

Again: "The waters of the Gulf Stream, as they escape from the Gulf, are bound for the British Islands to the North Sea and Frozen Ocean. Accordingly, they take, in obedience to this physical law, the most direct route by which nature will permit them to reach their destination. And this course, as already remarked, is nearly that of the great circle, and exactly that of the supposed cannon ball" (p. 44).

And yet again: "Many philosophers have expressed the opinion—indeed the opinion is common among mariners—that the coasts of the United States and the shoals of Nantucket turn the Gulf Stream towards the east; but if the view I have been endeavouring to make clear be correct—and I think it is—it appears that the course of the Gulf Stream is fixed and prescribed by exactly the same laws that require the planets to revolve in orbits, the planes of which shall pass through the centre of the sun; and that, were the Nantucket shoals not in existence, the course of the Gulf Stream, in the main, would be exactly as it is, and where it is. The Gulf Stream is bound to the North Sea and Bay of Biscay, partly for the reason, perhaps, *that the waters there are lighter than those of the Mexican Gulf;* and if the shoals of Nantucket were not in existence, it could not pursue a more direct route" (p. 45).

To give a distinct idea of his theory how the currents are produced, he gives the following illustration, which, it will be seen, is exactly the opposite of what the above quotation would require it to be.

"Let us now suppose that all the waters within the tropics to the depth of one hundred fathoms suddenly became oil, the aqueous equilibrium of the planet would be disturbed, and a general system of currents and counter-currents would be immediately commenced,—the oil, in an unbroken sheet on the surface, running towards the Poles, and the water, in an undercurrent, towards the Equator. The oil is supposed, as it reaches the Polar basin, to be reconverted into water, and the water to become oil, as it crosses Cancer and Capricorn, rising to the surface in the intertropical regions, and returning as before. Thus without wind we should have a perpetual and uniform system of tropical and Polar currents. In consequence of diurnal rotation of the planet on its axis, each particle of oil, were resistance small, would approach the Poles on a spiral turning to the East, with a relative velocity greater and greater, until finally it would reach the Pole, and whirl about it at the rate of nearly a thousand miles the hour. Becoming water and losing its velocity, it would approach the Tropics by a similar but inverted spiral turning towards the West. Owing to the principle here alluded to, all the currents from the Equator to the Poles have an eastward tendency, and all from the Poles towards the Equator a westward." . . . . "Now, do not the cold waters of the north and the warm waters of the Gulf, made specifically *lighter* by tropical heat, and which we see actually preserving such a system of counter-currents, hold, at least in some degree, the relation of the supposed water and oil?" (p. 33–34).

Accordingly, of the northerly or Arctic current, which meets the Gulf Stream on the Banks of Newfoundland, Mr Maury says—"We find the current from the north which meets the Gulf Stream on the Grand Banks taking a *south-westerly* direction. It runs down to the tropics by the side of the Gulf Stream, and stretches as far to the west as our shores will allow. Yet, in the face of these facts, and in spite of this force, both Major Rennell and M. Arago make the coasts of the United States and the shoals of Nantucket to turn the Gulf Stream toward the East" (p. 45).

Now, facts and theories must not be mixed up together; and in so far as I have been able to ascertain, no facts have been recorded, which prove that *a current* of Gulf Stream water, flowing to the north-east or east, has been detected higher than north latitude 42°. True it is, that over the Great Newfoundland Bank, more especially during summer and autumn, when the Gulf Stream and Arctic current are largest, a kind of whirling motion is imparted, to what might be styled the Great Still Pool of waters, which lies over the great bank; and that warm water from the Gulf Stream may often be met with at this point, so high as north latitude 45° or 46°. Ships, therefore, sailing from Britain to America, when passing over that Bank, sail through heated waters for many miles; and if they sail south of the Bank, must sail over a loop of the Gulf Stream itself. Again, no facts known to me trace the heated waters of the Gulf Stream further east than west longitude 30°; and here they are only met with as heated water, spreading out without almost any perceptible current, or if a current at all can be traced, it is towards the south-east or south, as if the waters were turning round and losing themselves in that Great Still Pool, the Sargasso Sea. True it is, that Franklin once met with surface water warmer than the surrounding Ocean, in the Bay of Biscay in 1776; and that General Sabine, in January 1822, passed through warm water when sailing between the parallels of latitude of Cape St Vincent and Cape Contin; but the very rarity with which such occurrences have been recorded, prove them to be the exceptional and not the normal case, and such occurrences will be presently explained.

After giving the most serious attention to the facts which have been ascertained, the following are my views of the course of the Arctic and Gulf Stream currents :—

Two opposing currents meet at the Newfoundland Banks—the Great Arctic Current and the Great Stream. The Great Arctic Current flows southwards, along the east coast of Greenland, and having passed its southern point, meets, and unites with, another broad current, which comes down from Davis' and Hudson's Straits. A small branch of this current flows between Newfoundland and the Labrador coast, through the Gulf of St Lawrence. Another portion of this current, deflected to the south-west by the Great Bank of Newfoundland, washes the eastern and southern shores of Newfoundland, and the south-eastern shores of Nova Scotia, and may be traced down the American coast nearly as far as Cape Hatteras. By far the greater portion of this current, however, passes to the east of the Great Bank of Newfoundland, overflowing, however, that Bank.

These various portions of the Great Arctic current encounter the Gulf Stream near the southern margin of the Great Bank; and, as the cold waters on that Bank are comparatively at rest, the icebergs ground here, and, on melting, deposit the rocks and debris they have brought down with them from the Arctic regions, and thus continue to enlarge these banks.

The Gulf Stream, after encountering the Arctic current, is no longer able to retain its eastward direction; but, in obedience to the law which regulates the meeting of currents from opposite directions, takes a mean course, proportioned to the velocities and breadths of the two currents which meet. The Gulf Stream is, therefore, deflected gradually more and more to the south-east and south; so that its upper margin describes a kind of circle round Corvo and Flores, the most western of the Azores. Here all traces of the Gulf Stream are lost in that immense pool or seaweed bed, the Sargasso or Grassy Sea, which exists in the centre of the Atlantic.

To carry out Mr Maury's theory, and that of those who, with him, trace the Gulf Stream continuously to the shores of Britain, it is necessary to prove that, when the two streams meet, the difference in the densities of the waters is such, that the waters of the Arctic Current, in consequence of their greater specific gravity, shall sink to the bottom, and allow the Gulf Stream waters to flow over them in consequence of their lesser specific gravity. The facts, however, so far as yet investigated, are entirely opposed to this view; and even Mr Maury's statement of facts on this point, is entirely opposed to his theory. Thus, he states, that the "waters of the Gulf Stream are salter than the waters of the Sea through which they flow;" and, in another passage, he states, that the waters of the North Sea "are lighter than those of the Mexican Gulf." The experiments of Thomassy confirm this statement; for he found that the waters of the Gulf Stream off Charlestown, contained one-eighth part more salt than did the waters of the Bay of Biscay. But the fact is, that the waters of the Arctic Current, instead of containing their due proportion of salt, are fresher than those of the Ocean, so long as ice is melting in the Polar regions, so that their density or specific gravity is less than that of the waters of the Gulf Stream. The waters of the Gulf Stream, on the other hand, from the great evaporations from their surface, are known to be much salter and denser than those of the general ocean; so that, when these two currents meet, notwithstanding that the density of the Arctic Current is somewhat increased by its lower temperature, its absolute density is not so great as that of the warm saline waters of the Gulf Stream. The waters of the Gulf Stream, therefore, though higher in temperature, are of greater specific gravity than those of the Arctic Current, which they encounter, and, therefore, cannot flow over that current. If the Gulf Stream, therefore, crossed the Arctic Current at all, seeing it is of greater specific gravity, it must pass it as an under-current. It is universally agreed, however, that these two currents do not commingle their waters, so long as either current can be traced; so that it is gratuitous assumption to hold that, notwithstanding these facts, and the known laws of nature with regard to the meeting of currents, the Gulf Stream crosses the Arctic Current, and flows onwards towards Britain and the Arctic Seas.

But Mr Maury endeavours to get over part of this difficulty, by assuming that the Arctic Current is split by the Gulf Stream (by what agency he does not venture to state) into two parts, one of which dips under the Gulf Stream; while the other, taking a south-west direction, flows down the side of the Gulf Stream, along the shores of Nova Scotia and the United States. This assumption appears to be made for the purpose of bearing out his theory, that currents of water from the north must assume a course to the west, in consequence of the rotation of the earth on its axis; while currents from the south must assume a course to the east. Every fact known regarding the course of the currents in the North Atlantic Ocean, disproves the truth of Mr Maury's assumption. The great mass of the Arctic Current, by virtue of the known configuration of the straits and coasts down which it runs, is thrown to the *east* of the Great Newfoundland Banks; and the icebergs, which are floated down with it, though a great many are grounded on the Banks, are often met with hundreds of miles to the east of these Banks, and still floating in the cold waters of the Arctic Current. It is quite true, as has been already stated, that one small portion of the Arctic Current takes the course assigned to it by Mr Maury. But the great mass of the current takes the opposite direction, and runs to the eastward towards the western shores of Europe and Africa. The idea, therefore, of the supposed rotation of the Earth on its axis having anything to do with the course of the Atlantic Currents, is, to say the least, still unproved.

Besides, is it not a known fact that every ship now avoids as much as possible getting into the waters of the Gulf Stream, both because storms are more frequent over its course, and also because, in consequence of its containing such a much larger quantity of salt, combined with its high temperature, it has a corrosive action on the ship's coppers, as ascertained by inquiries, made for a period of ten years, by the Secretary of the United States Navy. Yet, according to Mr Maury's theory, and that of those who hold with him that the Gulf Stream flows northwards, every ship leaving Britain for America would be sailing in these corrosive waters until she landed at Halifax or New York; whereas, we know for a fact, that unless it be when passing to the south of the Great Bank of Newfoundland, where they cross a small portion of its upper arc or bend, vessels in their passage from Great Britain to Halifax and New York never touch the heated waters of the Gulf Stream. All the ships logs which give the temperature of the sea, exhibit a gradual increase of temperature as they sail from this into lower latitudes. In the voyage to America, so long as they sail in nearly the same latitude, the temperature of the sea is pretty uniform till they approach the Banks of Newfoundland, when, if icebergs be present in any quantity, the temperature of the water is found to be considerably lower. If, however, the ship is sailing to New York, and passes south of the Great Bank, it suddenly passes from this cold water into the hot waters of the Gulf Stream, and this increased temperature is met with so long as the ship is sailing through the loop or bend of the Gulf Stream met with at this point, and shown in the accompanying chart. It is, in fact, the passing of the vessel through this loop or bend of hot water which has given rise to the notion that a branch of the Gulf Stream flows northwards.

The Arctic Current, after encountering the Gulf Stream, instead of its southern or south south-eastern direction, is, by virtue of the known laws regarding the meeting of currents, forced to assume a course more to the east; so that if a line were drawn from Cape Chudleigh, in Labrador, to the Straits of Gibraltar, it would represent, in a general way, the direction of the current. Like the Oceanic Currents, however, when not confined by other currents, or by the peculiar configuration of the land through or over which they pass, this current spreads out considerably as it approaches the western shores of Europe and Africa, so that its northern margin is met with many miles to the north of Cape Finisterre, in Spain. I suspect it is this current to which mariners have given the name of the *Western Drift* Current—that current which retards the voyage to America, but quickens that to Britain.

The northern margin then of this Arctic Current, as it crosses the Atlantic, follows very closely the line of the southern edge of that great elevated Telegraphic Plateau, which has a general direction from the Banks of Newfoundland to Ireland. It is part of this northern portion of the Arctic Current which enters the south of the Bay of Biscay on the north of Spain, and, washing round the coasts of Spain and of France, gives rise to that current so well known as Rennell's Current, which, washing round the Bay of Biscay, crosses the mouth of the English Channel, and sends a stream up both sides of Ireland, and continues its course to Norway and the Northern Arctic Seas. It is this great current flowing round the Bay of Biscay which gives to that sea its restless turbulence. Blow the wind from what quarter it may, it meets with a current opposed to it, and hence raises those waves so much dreaded by the mariner; and the continuance of the current across the mouth of the English Channel is the cause of numerous wrecks in stormy weather, by carrying vessels against the Scilly Isles.

It is a known fact that, along the Portuguese coast, there is a current, part of which flows northward, part southward. This is part of the Arctic Current, which, as it encounters the shores of Portugal, is deflected either to the north or south, by the peculiar configuration of the coast. For instance, Lord Gifford, in 1856, found this current, even so far south as the latitude of Oporto, setting northwards, but from this point the direction of the current was to the south.

It is a well-known fact that, from opposite Cape St Vincent, in Portugal, to nearly opposite Cape Contin, in Africa, and on to at least 25° west longitude, the whole Atlantic has a slow movement to the east, so that a current from the Atlantic flows through that strait at the rate of about two or three miles an hour. Admiral Smyth, in his recent work on the Mediterranean, mentions the fact, that the mean temperature of the waters of the Mediterranean "average about 3°.5 Fahrenheit more heat than those of the western part of the Atlantic Ocean;" and that around the coast of Sicily the waters of the Mediterranean are "from 10° to 12° warmer than the water is stated to be outside the Straits of Gibraltar." Lord Gifford, who visited the Mediterranean in his yacht the "Fair Rosamond," during the winter 1856–7, in the interesting Meteorological Register which he has published, confirms to the full the statements of Admiral Smyth. For instance, he found, from a three-hourly register, that the temperature of the current flowing through the Straits of Gibraltar, on the 8th November, was 61°.3, and off Gibraltar 61°.4; whereas, as soon as he got rid of the current, and sailed over the waters proper of the Mediterranean, their temperature averaged 64°, though a fortnight later in the year.

From the observations which Admiral Smyth has published, though they are by no means complete on this point, it would appear that the density of the surface water entering the Mediterranean Sea from the Atlantic is less than that of the general waters of the ocean; all which facts go to prove that the current which sets through the Straits of Gibraltar, to supply in part what is lost by evaporation from its surface, is part of the Arctic Current, which is both colder and fresher than the general waters of the ocean,—colder, because coming from the Arctic regions; fresher, because diluted with the melted water from the ice. If this current, however, had been supplied by the Gulf Stream, as the ordinary Gulf Stream theories necessitate, it ought to have been both warmer and salter than the general waters of the ocean, and than those of the Mediterranean.

From opposite Cape Contin in Africa to Cape Blanco, and out to sea at least as far west as Madeira, a cold current is met with, having a strong easterly, or, more properly speaking, a south-easterly, set towards the western shores of Africa. This is part of the Arctic Current, which, having deflected the Gulf Stream, is now rushing towards the western coasts of Africa; and its low temperature—from 6° to 10° Fahr., according to the period of the year, lower than that of the surrounding ocean—and south-easterly set, clearly point it out to be the Arctic Current, which had crossed the Atlantic from the Banks of Newfoundland. This current is well known to, and is greatly dreaded by, mariners, as it carries them to the east, out of their reckoning, and throws them on the dangerous African coast.

The further course of this current it is unnecessary to trace, farther than to say that the peculiar configuration of the African coast causes a considerable portion of this current to be deflected from the African shores, so that it sweeps through and to the south of the Cape de Verd Islands, round the southern portion of the Great Grassy Sea, and joins or accompanies the Equatorial Current in its course to the north-west. The other portion of the current continues its course down the African coast to form the Guinea Current.

Let us return, therefore, to the Gulf Stream. Mr Maury tells us that this stream originates in the Gulf of Mexico, and, as it issues from the Straits of Benimi, takes the nearest and shortest course it can for the British Islands. If, however, this stream assumed a given direction, either because that direction was given to it by the supposed effect of the rotation of the earth on its axis, or in consequence of a *vis a tergo* in the Gulf of Mexico, then the moment it issued from that gulf, it ought either to flow along the northern shores of Cuba and St Domingo, or cross the Grassy Sea in a straight line for Cape Blanco in Africa. By neither theory could it pursue the course it is known to take. Instead of this, however, the Gulf Stream, on its leaving the gulf, *turns back on itself*, bending round the peninsula of Florida, and following the hollow curved line of coast which Florida, Georgia, and the two Carolinas, present. This fact is of itself quite fatal to Mr Maury's theory of the causes of the course of the Gulf Stream. Were its course influenced or caused by the rotation of the earth on its axis, as the Stream issues from the gulf with a due easterly set, it would seek the direct route to Cape Blanco in Africa. On the other hand, had it even a north-easterly set when it issued from the gulf, the rotation of the earth, according to Mr Maury's theory, would increase its easting, so that instead of passing, as it does, far to the north of Bermuda, and entirely clear of it, it would pass it far to the south.

Were no counter agent at work, the Gulf Stream, as it issues from the Gulf of Mexico, would, from the peculiar configuration of the land, and from its leaving the gulf with a current flowing due east, or rather south-east by east, wash the northern shores of St Domingo and Cuba. There must, therefore, be some powerful agency at work to cause the Gulf Stream to *round* the point of Florida, and bending back on itself to the extent of nearly half a circle, force it round the hollowed coasts of Florida and Georgia. No one can look at the map without seeing that that agent is the Equatorial Current, which, uniting with no small portion of the North-African current, sends the much greater portion of its waters to the northward of Porto Rico, St Domingo, and Cuba. This large and powerful current, meeting the much smaller current which issues from the Gulf of Mexico, forces it back on the hollow coasts of Florida,—indeed, there can be no doubt that this, or an analogous current, has been the agent which hollowed out these shores. The Gulf Stream, therefore, follows the line of that coast, and it is unquestionably the line of that coast which imparts to the Gulf Stream its easterly direction. As to the rotation of the earth on its axis having anything to do with the direction of that current, or of any of the other currents in the North Atlantic, I am quite sceptical, and have not, as yet, met with any fact which lends countenance to such a theory.

If the views now given of the currents in the Atlantic be accepted, how, it may be asked, do they accord with the known facts regarding West India seeds, and wrecks of vessels on the American shores, being stranded on the western shores of

Ireland, Scotland, and Norway, or with the tracks of bottles thrown into the Atlantic?

Let us first take Commander Becher's Bottle Chart (not Admiral Beechey's, as Mr Maury styles it), and see whether Mr Maury's theory of the course of the Gulf Stream, or the views just propounded of the currents in the Atlantic, will best account for the track which bottles have taken when thrown into different parts of the Atlantic Ocean.

A bottle was thrown from the "Hecla" in Davis' Straits, in lat. 53° 13′, and was thrown ashore at Teneriffe. By the usual Gulf Stream theory, that bottle must not only have travelled against the current, but also against the prevalent winds, for thousands of miles. By my theory, it floated along with, and in, the Arctic Current, which naturally landed it at Teneriffe, as it happened to be in that part of the current which flowed past that island.

A bottle was thrown out in north lat. 46°, west long. 34°, that is somewhat to the east of the Newfoundland Bank, and was landed on Porto Rico, one of the West India Islands. By the Gulf Stream theory, that bottle ought to have landed in Norway or the north of Britain. By my theory it was thrown out in the Arctic Current, was with it, carried round by the coast of Africa, and joining the equatorial current off, or to the south of, the Cape de Verde Islands, was naturally landed at Porto Rico.

Several bottles thrown out in Davis' Straits were stranded at the west coast of Ireland. All such bottles, by the Gulf Stream theory, should have passed Great Britain, and been carried to Norway or the Arctic Ocean.

Many bottles were thrown out over or near the Great Newfoundland Banks. One of these was stranded at Andros Island, one of the Bahama Group. Another was stranded at Cape Finisterre, in Spain. One was carried to the west coast of Ireland, but the most of them were stranded at the Scilly Isles and west coast of England. In fact, all were carried by the Arctic Current, as I have described it, whereas by the Gulf Stream theory the one carried to the Bahamas must have been going against wind and current in its whole course; while by that theory, all the other bottles ought to have been carried past Britain, as all were on the north side of the assumed northward course of the Gulf Stream.

A bottle was thrown into the sea off Cape Sable, in Nova Scotia, and was picked up at Fuerte Ventura, one of the Canary Islands. By the usual Gulf Stream theory, that bottle must have crossed the whole breadth of the Gulf Stream, and gone against the prevalent winds for thousands of miles. By my theory, it was carried by the northern margin of the Gulf Stream, till that stream was deflected south by the Arctic Current, and being then borne onwards by that current on its southern margin, was naturally deposited at the Canaries.

Bottles thrown out between latitudes 45° and 50° north, and so far west as west longitude 25°, were almost all stranded on the north coast of Spain, on the French coast, or on the western shores of England and Ireland. A very few only reached Scotland. By the usual Gulf Stream theory, most of these ought to have been carried past Britain; but if the currents flow as I have endeavoured to show they do, then they were stranded at the very places where they might, *à priori*, have been expected to be cast ashore.

In a word, this valuable chart is the strongest possible confirmation of the truth of the theory of the currents now proposed, but records many facts quite irreconcilable with Mr Maury's on the usual theories, which hold that the Gulf Stream flows north east to the Arctic Ocean. This bottle chart also appears to me conclusively to prove that it is the conjoined current from the African coast and the Equatorial Current, flowing to the north of St Domingo and Cuba, which forces back the Gulf Stream on the curved coasts of Florida.

But this valuable chart proves much more than the direction of the currents in the ocean. It proves also that floating bodies are amenable to the prevalent winds which blow. It was stated above, that during the winter months more especially, the prevalent winds over the whole Sargasso Sea, are the south west or anti-trade winds. This valuable chart then shows that several bottles thrown out even in the middle of that mass of still water, where it is universally acknowledged there are no currents, were thrown ashore at places bearing nearly due north east from the spot where they were thrown out; thus clearly proving that they had been carried by the wind alone. Thus, one of these bottles was stranded at St Miguel, one of the Azores; another at Flores, another of the Azores, while others were blown also in the direct line of the south west wind, and stranded on the shores of Ireland or England. As all these bottles were thrown into the sea at places where all acknowledge there is no current whatever, they illustrate the effect of the prevalent wind on floating bodies, and show how a prevalent wind may even drive floating bodies against or across a current. It is this south west wind which appears to be a main agent in driving west India seeds and floating pieces of wreck to our western shores, after they have been carried so far on their way by the Gulf Stream or other currents. But the influence of the wind in impelling a floating body in its direction was never better illustrated than in the case of a bottle thrown out into the Gulf Stream in the latitude of Charlestown. This bottle, instead of being borne along with that stream, was stranded at Bermuda, which is to the west and south of that stream, and quite clear of its waters.

The circumstance of wrecks and West India seeds being carried to the shores of Britain and Norway, admits of an equally easy explanation. Every current or stream of water has a natural tendency to throw to its margin objects which are floating on its surface. We see this in rivers, and in every stream; and it is not, as Mr Maury supposes, in consequence of the surface of the current having a "roof shaped" surface, but simply by virtue of the known law that the resistance of friction being least in the centre, the current is quickest there. The water in the centre of the current thus acts the part of a wedge, and necessarily throws bodies which are floating on its surface to either side. Seeds or wrecks, therefore, floating in the Gulf Stream, or carried forward to that stream by the equatorial currents, may be deposited in the Grassy Sea if thrown off on its southern edge, but if carried to its northern margin, and especially if aided by the prevalent south west wind, they pass from the Gulf Stream to the Arctic current, and, according to the power of the wind on the floating body, they may either be landed on the French, English, Irish, or Scottish coasts, or may even be carried onward to Norway. The effect of the prevalent wind on a floating body, even when that body is wholly covered with the water, is much greater than is usually imagined. When the wind blows over the water, it ripples the surface, so that at every ripple the solid body (as a floating seed) receives on its side the full force of the wind, and therefore moves through the water in the direction of the wind faster than the current in which it is floating. This is unquestionably the explanation of the conveyance of African, West Indian, and American seeds and wrecks to our shores, aided no doubt, as these must have been, at first by the currents.

Every known fact, then, can be explained on the supposition that the course of the currents in the Atlantic is such as I have described them; but many of the facts are quite opposed to, and cannot be explained by, the theories of Mr Maury and those who hold that the Gulf Stream flows to the shores of Great Britain.

But one fact, ascertained during the two past years, appears to me to settle the question as to which is the correct theory. During the summer months it is asserted that the Gulf Stream is more voluminous than during winter; so that during summer and the beginning of autumn the Gulf Stream encroaches more on the great Newfoundland Banks; and, of course, if Mr Maury's theory were the true one, it would send to Britain, during these months, a much larger supply of hot and salt water than when its waters were lower. During summer and autumn, therefore, the seas on our western shores ought to be of greater density than they are during winter,—an effect which would be heightened by the natural evaporation which takes place from our seas during the summer months. The reverse, however, was found by Captain Otter to be the case. In the Sound of Harris, far from all rivers, he found that, during the summer and autumnal months, the density of the water was less than during the winter months. Thus, during the summer and autumnal months he found the density of the water only 9, equivalent to a specific gravity of 1025 to 1027; whereas, during the winter months, the density was 10, equivalent to a specific gravity of from 1028–1030. Mr M'Donald's observations, though not taken at such a favourable position, confirm Captain Otter's results, so that there seems to be no reason to doubt the fact. The density of the water in our bays or close to the shore would only lead to false conclusions on this point, seeing that the fresh water from our rivers renders the water lighter during winter.

The greater freshness of the waters of the Atlantic on our western shores during summer and autumn is easily explained according to my theory of the currents in the Northern Atlantic, but is quite inexplicable on the supposition of the Gulf Stream flowing to the shores of Britain. If it be the Arctic Current, coming up on Rennell's Current, which flows past Britain, then so long as ice is melting in the Arctic regions, so long will the water which reaches the shores of Britain be somewhat fresher than the waters of the surrounding ocean. But the moment the supply of ice fails, from the Polar Seas being again frozen over, from that period will the seas on our western shores recover their usual saltness.

One other argument tending to the same conclusion has yet to be adduced. Mr Maury, in his Physical Geography of the Sea, says:—"There is at the bottom of the (Atlantic) sea, between Cape Race in Newfoundland and Cape Clear in Ireland, a remarkable steppe, which is already known as the Telegraphic Plateau." On examining the sand or mud brought up from this plateau, it was at first found to consist almost entirely of minute microscopic shells, foramaniferæ, and diatomaceæ, from which Mr Maury drew the conclusion, "that there, if anywhere, the waters of the sea are at rest. There was not motion enough there to abraid these very delicate organisms, nor current enough to sweep them about and mix them up with a particle of the finest sand." In his Appendix, however, he adds some further facts relative to this mud from that plateau. When examined by the microscope with greater care, it was found to contain also fine volcanic dust, which Professor Bailey describes as "glassy obsidian and minute fragments of pumice," which "has usually sharp angles, and is such as might be dropped from icebergs as they melt." Of course the presence of such peculiar volcanic dust or ashes cannot be explained by Mr Maury according to his theory of the Gulf Stream passing over all this plateau on its way to the northern seas. But, according to the view of the currents just propounded, the deposition of volcanic dust on this plateau could have been predicted, and, moreover, that this dust would get finer and finer as it approached Ireland, which, so far examined, it certainly does. This plateau, according to my theory, marks very nearly the northern limit or edge of the Arctic Current, which in its passage past Iceland carries along with it ice containing the very peculiar volcanic ashes of that island. These volcanic fragments on the Newfoundland Banks are very distinct. Some of the finer particles are, however, carried along with the Arctic Current as it crosses the Atlantic towards Western Europe, and hence their occurrence on this plateau.

But, it may be said, the Gulf Stream water, or at least water somewhat above the temperature of the surrounding ocean, has been once met with during winter so far north as the Bay of Biscay, and on another occasion out at sea opposite the Straits of Gibraltar. Such an occurrence, however, is quite consistent with the theory of the currents as just propounded, without considering that that water was furnished by the Gulf Stream. Every one knows the power of the wind to excite a current when it blows continuously over a surface of water. But we do not require to go further than the Gulf Stream itself to prove the fact. During summer and autumn the volume of the Gulf Stream is considerably larger than it is during winter and spring. This is a well ascertained fact. Now, how is this? During summer and autumn the north-east trade winds blow over a much greater breadth of the North Atlantic Ocean than they do during winter, when, in consequence of the sun being to the south of the equator, they are confined to 15° or 20° north latitude. During summer, therefore, a much larger and broader surface of water is set in motion by these winds, and the Equatorial Current, which is the true source of the Gulf Stream, is consequently much more voluminous during summer than it is during winter. But during winter the principal wind over the North Atlantic is the south-west wind; and, as during winter it blows over a very large extent of the Atlantic, if it blows with any strength at all, or continuously, it drives before it, or carries along with it, a superficial current of warm water from the hot Grassy Sea. If this hot layer of water be once thrown over any portion of the Arctic Current, it may be carried to any part of Europe reached by that current; or if the wind be sufficiently continuous, that heated water may be carried continuously forward in the line of that wind. This is unquestionably the explanation of the fact of Franklin having encountered a surface current of hot water in the Bay of Biscay, and General Sabine having found a similar layer out at sea off the Straits of Gibraltar. Both occurred in winter when the south-west winds are strong, and are the prevalent aerial currents.

Great misconceptions exist as to the difference of temperature between the waters of the Gulf Stream and the waters of the surrounding ocean, or that of the Arctic Current when it meets that stream at the Banks of Newfoundland. The difference of temperature between the Arctic Current and the Gulf Stream when they encounter each other, varies from 6° to 10° Fahr. only, seeing that as the Arctic Current flows southwards, it is continually acquiring heat. Thus, though in the Wellington Channel its temperature is only from 32° to 33° Fahr. in September, it has increased to 46° Fahr. by the time it has reached the latitude of 60°, that is the south point of Greenland; and before it reaches the south of the Great Newfoundland Bank, its temperature has increased to from 58° to 65°, the Gulf Stream at the same point being usually about 70°. In spring however, when the temperature of the Arctic Current is lowered by the quantity of icebergs brought down with it, its temperature is often 20° below that of the Gulf Stream. As the Arctic Current, however, crosses the Atlantic, it acquires additional heat, *bringing its temperature to the normal heat of the latitude before it reaches the European shores.* All that portion, therefore, which flows northward along the shores of France and Britain, and onwards to Norway, is higher in temperature than is due to the latitude, and as the current comes from the south, it encourages a marine vegetation, approaching what we should expect farther south. It is this warmer current from the south which keeps open the western harbours of Norway during winter. That portion, however, of the Arctic Current which flows to the south along the African coast, as it is constantly flowing into a warmer region, has a temperature somewhat lower than that of the surrounding ocean; but after all, the difference is only from 5° to 10°, depending on the season of the year and the place of observation.

One other argument for the truth of the theory now propounded, relative to the currents of the Atlantic, is derived from the known habits of the leviathans of the deep. All naturalists are aware that a curved line drawn from Cape Hatteras in America to the island of Madeira, the top of whose arc shall touch the southern extremity of the great Bank, separates from each other two of our largest mammalians—the whalebone and the spermaceti whale. These animals differ entirely in their habits, and in the kind of water in which each delights. The true or whalebone whale is never met with but in the cold water, but it comes down with the Arctic Current, and may be encountered wherever that current occurs, so that it is met with as far south as off New York on the American coast, and comes down even to Madeira, on the eastern side of the same ocean. This animal, so far as known to me, has never been met with in the hot waters of the Gulf Stream. The limits of the Arctic Current are therefore its limits southwards, and the line which marks these limits is also the limit of the Gulf Stream northwards. The spermaceti whale, on the other hand, is alone found in the warm waters of the ocean, and never ventures into the colder Arctic Current; and as neither of these animals has been observed to cross the curved line above indicated, it is a tolerably strong argument in favour of the Gulf Stream waters reaching no farther north.

From what has been said, then, it will be seen, that no known fact is contradictory of the theory just stated, relative to the currents in the North Atlantic, or to the course of the Gulf Stream, and its want of influence on our island. On the other hand, many of the ascertained facts are irreconcilable with the theory, that the Gulf Stream flows to the shores of Britain, and the Northern or Arctic Seas.

Mr Maury's theory of the Gulf Stream's course being directed by the rotation of the earth on its axis, is irreconcilable with the known fact, that when it issues from the Gulf of Mexico, it does not follow such an eastern course, but doubles back upon itself, to sweep in a *north-westerly* direction round the curved coasts of Florida. That theory of the rotation of the earth on its axis, directing the course of the currents, is irreconcilable with the *south-easterly course* of the Arctic and North African Currents, and with the *north-westerly* course of the equatorial current. The theory of the Gulf Stream flowing direct for the North Seas, is irreconcilable with the fact, that a bottle, thrown out from the "Hecla," in Davis' Straits, was landed at Teneriffe; and is also opposed to many of the facts proved by Becher's bottle chart. That theory is irreconcilable with, and will not account for the difference in climate during winter between Britain and France; for, by that theory, both these countries would be equally under the influence of the Gulf Stream waters. That theory is irreconcilable with the now established fact, that even the variations in the temperature of the air, and of the sea in Scotland, both during summer and winter, have the closest accord with each other; which that of the Sea could not have, were its temperature dependent on the influx of warm water from the Gulf Stream. That theory is irreconcilable with the fact, which every ship's log proves, that in crossing the Atlantic from Britain, the warm waters of the Gulf Stream are never met with, but when the ship is sailing over, or to the south of the Newfoundland Banks, and passes through the loop which the Gulf Stream forms there, and is come suddenly upon at that point, and is as suddenly left as the ship nears the American shores. That theory fails to account for the fact, that the current which flows from the Atlantic into the Mediterranean Sea through the Straits of Gibraltar is not salter, nor of greater density, nor of higher temperature than the ordinary waters of the Ocean, which it would be, were it supplied by the Gulf Stream. That theory is irreconcilable with the fact, that the waters on our western shores are, during summer and autumn, of less density than they are during winter. That theory fails to explain how the heavier and salter waters of the Gulf Stream could float over the somewhat colder, but much fresher and lighter waters of the Arctic Currents and Northern Seas. That theory virtually ignores the existence of Rennell's current; and both ignores the existence of the North African current, and fails to give any explanation of the long ascertained fact, that the temperature of that North African Current is from 6° to 10° colder than the waters of the surrounding ocean in the same parallel of latitude. That theory will not account for the existence of the great elevated telegraphic plateau between Newfoundland and Ireland, nor for the existence of volcanic ashes on that plateau identical, in so far as yet examined, with those from Iceland. That theory will not account for the fact, that vessels in their course to and from America, if they sail over the telegraphic plateau, or within what I have described as the limits of the Arctic Current, never encounter the hot water of the Gulf Stream, except when crossing its bend south of the Banks of Newfoundland, and thus avoid that corrosion of their coppers, which the researches of the Secretary of the United States navy prove to occur, when they sail in the hot and salt waters of the Gulf Stream; for by that theory they would be sailing in the hot waters of the Gulf Stream during their whole voyage. That theory fails to explain the fact known to all naturalists, that a curved line carried from the

Island of Madeira to Cape Hatteras, touching with the upper part of its arc the southern extremity of the Great Newfoundland Bank, marks the limit southwards of the true whalebone whale, and the limits northward of the spermaceti whale. And, lastly, that theory which makes the climate of our island and the temperature of our seas to be dependent on a supply of heated water from the Gulf Stream, fails to account for the fact, that the mean temperature of air, land, and sea in Scotland, is nearly the same; and that their fluctuations in temperature, both during summer and winter, show a marked accord with each other.

This whole investigation, then, leads to the conclusion—indeed, seems to me to prove—that the climate of Britain is in no respects influenced by the heated waters of the Gulf Stream, which do not approach our island within thousands of miles. It also confirms the conclusion to which the consideration of the other facts previously stated lead, that the mildness of the winters in Britain is chiefly due to the south-west or anti-trade winds, which are the prevalent aerial currents in this latitude during winter. These winds, originating during winter about north latitude 15° or 20°, blow direct to us over the level Atlantic Ocean, bringing with them much of the heat and moisture they had acquired during their passage over the great expanse of the heated waters of the Sargasso Sea and Atlantic Ocean north of it.

It is because no other country in the globe is similarly situated with regard to such winds that no other country in a similar latitude enjoys such a mild winter climate. Labrador, from its geographical position, must be very much colder. It is in the region of the south-west winds; but in order that they may reach it, they have to traverse the whole breadth of the American continent, where they lose both their heat and moisture on the high mountain ridges they have to cross; so that these winds carry to that inhospitable country only cold. The same agencies are at work in Newfoundland and Nova Scotia; and though these countries are but a very short distance from the Gulf Stream, they so little experience any benefit from it, that their winters are very severe, and more intense than is ever likely to be experienced in this country. It is the very same agency which causes the eastern counties of the United States, even below the latitude of New York, though they have the Gulf Stream not very far from their shores, to suffer from a winter's cold much more severe than is ever experienced in these favoured lands.

But, in fact, the greater severity of the winters in France, though so much further south than Britain, is a standing proof of the correctness of the theory now proposed. If the south-west winds reached France uncooled, its temperature during winter would more than equal that of Britain. But France lies far back, having the whole peninsula of Spain interposed between it and these balmy south-west winds. These winds, therefore, before they reach France, are thrown upwards and are chilled by the mountain ridges of Spain, so that they descend on France as partially cold winds; and as that country has no other agency capable of driving back the winter's colds, she has a winter temperature considerably below that of Britain.

P.S.—Much of the fallacies regarding the Oceanic Currents are founded on the mistaken idea that the currents from the Tropical Seas must restore to the

Polar and other seas as much water as these Polar and other currents bring down to them (Maury, § 401, p. 149). This is a complete mistake. The intertropical seas are the great evaporating basins of the world; and it may be safely assumed that the greater portion of the water brought into these regions by the Polar and other currents is removed by evaporation in the form of vapour. This is especially the case with the North Atlantic. The Gulf Stream does not nearly represent the mass of water contained in the equatorial current, which is its true source, and it diminishes rapidly by evaporation as it flows onwards. Few have any idea of the amount of water raised from the sea by evaporation, From repeated experiments, conducted with much care, during summer, it was ascertained that a square foot of sea-water, of the density of 1025 (water of Firth of Forth), lost by evaporation 3379 grains of water every forty-eight hours, when exposed in a room where the air was perfectly still, and the temperature nearly steady at 62° Fahr. The water was renewed every second day, as by that time its density had sensibly increased. When a current of air was allowed to play over the basins of water, the evaporation was greater. As the air, however, is never absolutely calm over the ocean, and as the mean temperature of the intertropical seas is much above 62°, the evaporation must be much beyond what these experiments indicate. Nevertheless, these experiments show that, were the air still and the temperature 62° Fahr., every square mile on the surface of the ocean would lose *daily* by evaporation no less than 3287 tons 17 cwt. 100 lbs. and 353 grains of water. If, even with these data, any one will take the trouble to make the calculation, he will find that the loss of water by evaporation from the immense expanse of the North Atlantic, within and somewhat beyond the tropics, is such that it would require the whole supply of the Equatorial Current, and no small portion of the Arctic Current to supply that loss, without leaving one drop of the Gulf Stream to spare for any counter-current to the Polar Seas.

APPENDIX.

Captain Otter's *and* Mr John McDonald's *Observations on the Temperature of the Air and Sea in the Sound of Harris and Bay of Bernera, from August* 13, 1857, *to* 31*st December* 1858.

Date.	Temp. of Air.	Temp. of Sea.	Date.	Temp. of Air.	Temp. of Sea.
1857.			1858.		
August 13-19	63.3	58.6	March 18-23	46.7	45.0
„ 20-24	68.3	62.5	„ 24-31	43.7	46.5
Sept., gradual descent from	62°-57°	59°-55°	April 1-14	38.0	42.6
October 6	47.5	51.6	„ 15-20	48.2	46.6
„ 12-15	55.0	54.0	„ 21-30	52.0	48.7
„ 19	58.5	55.0	May 1-31	50.5	49.3
„ 30	54.0	53.9	June 1-11	55.9	52.9
November 18, S.E.	52.5	53.4	„ 14-25	60.8	58.0
„ 19, S. gale	51.2	52.4	„ (24)	..	61.0
„ 24, 25, 26	39.3	51.5	„ 26-30	57.0	56.2
December 18	46.6	50.8	July 1-14	53.6	54.2
„ 31	45.0	49.0	„ 15-31	58.8	56.9
			August 1-6	58.4	57.2
1858.			„ 7-18	61.2	58.5
January 1-3	50.0	49.0	„ 19-31	55.7	57.3
„ 4-15	43.1	46.4	September 1-18	55.5	56.9
„ 16-24	42.8	45.5	„ 19-30	53.8	56.3
„ 25-Feb. 3	41.0	46.0	October 1-30	45.2	49.0
February 4-10	43.3	45.0	November 1-13	44.7	48.0
„ 11-28	39.0	44.2	„ 14-20	34.5	45.0
March 1-5	38.0	43.9	„ 21-30	45.6	45.6
„ 6-8	30.0	43.0	December 3-11	47.2	46.6
„ 9-12	35.0	43.0	„ 13-24	43.4	45.6
On Surface	...	40.0	„ 25-31	39.6	44.6
„ 13-17	42.5	44.0			

Mr John Whyte's *Observations on the Temperature of the Air and Sea, at the Island of Easdale in* 1858.

Date.	Temp. of Air.	Temp. of Sea.	Date.	Temp. of Air.	Temp. of Sea.
January 1-3	50.0	50.0	July 6-14	56.4	51.0
„ 4-15	42.6	49.0	„ 15-16	56.6	52.0
„ 16-24	42.4	48.0	„ 17-28	58.0	53.0
January 25-February 3 ...	41.5	47.0	„ 29-August 7	58.8	54.0
February 4-10	43.2	46.0	August 8-20	60.2	55.0
„ 11-28	37.3	45.0	„ 21-Sept. 18	56.0	55.0
March 1-5	37.0	45.0	September 19-30	54.8	56.0
„ 6-7	36.5	44.0	October 1-7	47.4	55.0
„ 8-12	34.0	43.0	„ 8-28	46.4	54.0
„ 13-31	43.8	44.0	„ 29-31	46.0	53.0
April 1-14	38.5	43.0	November 1-9	43.0	53.0
„ 15-26	48.4	44.0	„ 10-15	42.0	52.0
April 27-May 17	48.9	45.0	„ 16-22	37.4	51.0
May 18-23	49.9	46.0	„ 23-24	36.0	50.0
„ 24-June 2	52.3	47.0	„ 25-30	47.5	50.0
June 3-10	56°.	48.0	December 1-4	46.0	50.0
„ 11-17	58.5	49.0	„ 5-11	45.0	49.0
„ 19-30	56.5	50.0	„ 12-31	44.2	48.0
July 1-5	54.2	50.0			