NOUVELLES RECHERCHES AMÉRICAINES SUR LA CIRCULATION DE L'ATLANTIQUE NORD

(NEW AMERICAN RESEARCH ON THE CIRCULATION OF THE NORTH ATLANTIC).

by

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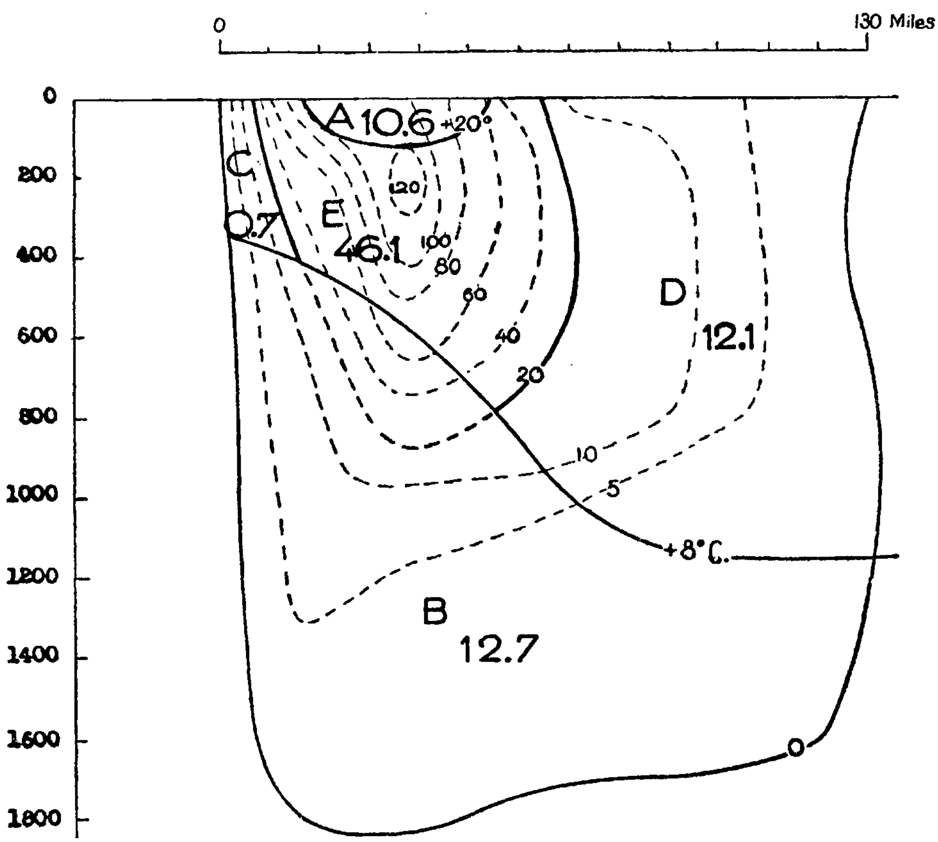
Bulletin N° 723 of the *Institut Océanographique,* Monaco, 25th April 1937, contains an article by M. Camille VALLAUX on the new American studies concerning the circulation of the North Atlantic carried out under the direction of the Woods Hole Oceanographic Institute and its research ship *Atlantis.*

The method of study, explained in the work of C. O'D. ISELIN entitled : "A Study in the Circulation of the Western North Atlantic", Cambridge, 1936, indicates that the true oceanic circulation cannot be studied solely on the surface but that account must be taken of the subsurface and medium depths, without neglecting the influence of the great depths. The method is essentially based on the two principal factors acting on the density : the thermal index and the salinity index, the first of these being, according to Iselin, the principal generator of the density coefficient. The difficulties of interpretation of the oxygen index have caused the observers on the *Atlantis* to neglect this element up to the present.

THE ORIGIN OF THE GULF STREAM AND THE SEA OF SARGASSO:

As a result of the *Atlantis* observations on the Haiti-Bermuda and Bermuda-Elbo Cay sections, it has been recognized that the Antilles current which flows on the surface to



the northward of the Bahamas, is not the principal source of the Gulf Stream, since this supplies only about 12 million M^3 per second and the Florida Current 25 million M^3 while the maximum intensity of the Gulf Stream at a point opposite Chesapeake Bay amounts to 82 million M^3.

The Sargasso Sea, whose internal dynamics have been the object of particular study by the *Atlantis* observers, is supposed to be the site, not of a sinking of the heavier waters by vertical convection, but of a turbulent movement, which at depths of about 800 metres and more gives rise to lateral movements and causes the waters of the Sargasso Sea to flow into the Gulf Stream system. At depths of 1000 to 1800 metres these waters constitute a sixth part of the volume of the Gulf Stream.

COASTAL WATERS, SLOPE WATERS AND THE GULF STREAM SYSTEM:

The very detailed observations of the *Atlantis* cover the oceanic area which extends from 300 to 500 miles off the North American coast, from Florida to Nova Scotia. The coastal waters comprised between the coast and the isobath of 200 metres constitute active mixing zones for the waters, and show considerable seasonal variations.

The slope water comprised between the isobaths of 200 and 900 metres also shows large seasonal variations of temperature and salinity (12° to 26° and 34.5 to 33.6‰) of the same nature as those of the central Atlantic waters and the Sargasso Sea.

Between the central waters and the slope waters there appears a mixture which is clearly characterized by the fixity of its thermal and saline characteristics and by the general movement of the waters, to which Iselin gives the conventional name : "Gulf Stream System" and which is composed of three parts :—

1. — The Florida Current from the Straits of Yucatan to the north of Cape Hatteras;
2. — The Gulf Stream proper, from this point to the longitude of the Grand Banks;
3. — The Atlantic Current forked into branches to the eastward of this meridian.

The observations of the *Atlantis* show that the usual assumption that the Gulf Stream expands greatly after leaving Cape Hatteras is without foundation. If its depth increases greatly, up to 1800 metres, well beyond the maximum depth which earlier observations assigned to the Gulf Stream, its width, which does not exceed 130 miles opposite Chesapeake Bay, is still only 130 miles at the meridian of Nova Scotia. The volume of water transported at the latitude of Chesepeake Bay, however, exceeds more than three times the volume of the waters in the Florida Current.

There, according to the annexed sections established by Iselin, the waters of source coming from Florida Straits have already been diluted 50% in their stretch of 600 miles (fraction E: 46 million M^3/sec.). The superficial fraction A (10.6 million M^3/sec.) reproduces better the characteristics of source of the warm current, being heated more than 20° C., but it does not constitute more than 1/8th of the volume of the Gulf Stream.

The fraction C is composed of the coastal waters. The fraction D which corresponds to it in the east and which comprises 12 millions M^3, comes from the return flow which has its origin in the region of the tail of the Grand Banks and rejoins the Gulf Stream to the S. W. of Bermuda, and above all in the Sargasso Sea. This is even truer for Section B (12.7 million M^3/sec.) the waters of which, with a temperature lower than 8°C., cannot come from the Florida Straits except in a very slight proportion.

THE NORTH ATLANTIC DRIFT AND THE THEORY OF TRANSGRESSIONS:

Starting from the meridian of the Grand Banks, the current forks into several branches known on the surface as the delta of the Gulf Stream which, according to recent American studies, are even more definitely marked and continuous in the depths than on the surface.

The northern branch, considered by Iselin as the principal one, had a width of 140 miles in July 1931, i. e. greater than the entire Gulf Stream off Chesapeake Bay. The seasonal variations of this branch have caused the *Atlantis* observers to make particular reference to the theory known in France under the name of the "Theory of Transgressions".

This theory of transgressions, presented for the first time, in 1922, by Ed. Le Danois, is based on three postulates :— the Florida Current or the Gulf Stream ceases to exist between the 40th and 50th meridians; the periodical movements of the Central Atlantic and the eastern part, are due to the transgression of the equatorial waters, giving an extension to the northward due to thermal dilatation of volume in summer, retraction to the southward in winter; the liquid masses of different signs, from the thermal and saline point of view do not mix, the waters having a salt content of 35‰, on the one hand, being definitely separated and not mixing at all with the waters having a content of 35.5‰.

The point of view arrived at by the observers aboard the *Atlantis* and by Iselin is directly opposed to the above theory.

Neglecting the surface phenomena, the *Atlantis* has demonstrated the continuity of the Gulf Stream in depth; she has also shown the effects of internal mixing of the waters, which effect is positively denied in the theory of transgressions; finally the *Atlantis* has given to the thermal index, hitherto much neglected, the preponderant role which belongs to it in the determination of the movement of the deep waters.

THE EASTERN PART OF THE NORTH ATLANTIC AND THE MEDITERRANEAN WATERS.

Although the research work of the *Atlantis* has been confined to the western and central part of the North Atlantic Ocean, the American report states that in spite of some discrepancies yet to be cleared up by further investigation, the deep currents determined at 1200 to 1400 metres in the North-eastern Atlantic according to B. HELLAND-HANSEN as a result of the cruise of the *Armauer Hansen,* agree well on the whole, in spite of their gyrations, with the general view of the afflux of the Gulf Stream towards the coasts of Europe and Africa. As for the west and centre of the ocean, the topographical influences of the submarine relief make themselves distinctly felt in the direction taken by the currents studied.

A study of the true influence of the Mediterranean waters on the deep waters of the North Atlantic tends to reduce the importance of that afflux on the excess of salinity in the depths, which has been found to the eastward of the central portion and as far as the western portion of the North Atlantic.

The transport of saline waters of more than 38‰ which flow annually from the Mediterranean to the Atlantic through the Straits of Gibraltar at depths of from 200 to 300 metres, has been evaluated at 56,200 Km^3. In the eastern portion of the North Atlantic the Mediterranean waters are at the isobath of 1200 metres. They have therefore slid down an inclined plane. It is impossible that under the circumstances they should not be subjected to considerable mixing with the Atlantic waters and this is proven by the fact that in the depths of the Atlantic they do not reach a salinity greater than 36‰, without taking into account the thermal drop. We see therefore that the so-called *Mediterranean waters* do not exist in the Atlantic except in a very diluted state.

CIRCULATION IN THE DEPTHS AND ON THE SURFACE: TROPOSPHERE AND STRATOSPHERE.

It is known that by an inverted analogy of the terms which are used in meteorology, the German school applies the designation *troposphere* to the surface and subsurface circulation of the ocean the movements of which are very rapid and vigorous; while the designation *stratosphere* is applied to the slow circulation in the depths which is scarcely discernible.

However, while the atmosphere is composed of two masses of air which are superposed and clearly distinguishable chemically by the presence of water vapour in the lower strata and its absence in the upper strata, the ocean presents a practically continuous homogeneous mass from the surface down to the greatest depths.

The American oceanographer states that the comparison between the Ocean and the atmosphere should not be pushed too far, for in the Ocean, the horizontal circulation is vigorous at the surface and decreases with depth, while in the atmosphere no marked lessening of the movement is found until the stratosphere is reached. Again, in contrast with the troposphere in the air, in the surface layers of the ocean the convectional forces are probably less important than in the atmosphere while the frictional forces increase rather than diminish the currents set up by the wind.

In the atmosphere the boundary between the two zones is rather sharp; above this boundary there is a relatively great stability. In the Ocean, except near the Equator, the thermocline occupies a layer of several hundreds of metres thick, while below this layer the stability is rather uncertain.

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