THE WATER CIRCULATION OF THE NORTH ATLANTIC

(Extract from *La Revue Maritime*, Paris, June 1934, p. 754).

The above journal contains a very interesting paper by Enseigne de Vaisseau (retd.) P. DE MORSIER, entitled *La Circulation des Eaux de l'Atlantique Nord*, on the formation of the ocean currents of the North Atlantic. He summarises and co-ordinates some general principles extracted from the oceanographical works of Professors PETTERSSON and SANDSTRÖM, of M. LE DANOIS, of Commandant BEAUGÉ and of the INTERNATIONAL ICE PATROL SERVICE, which help to explain the present conception of the general mechanism of the principal ocean currents and to make clear the hydrographical conditions found along the coasts.

If the sea is considered as a stratified fluid, external forces cannot effect any exchange of particles between the different layers, but *vertical circulation* arises when a physical change taking place in the sea water alters its density; the volume of water concerned abandons its existing level and takes up a position in a layer corresponding to its new density. (1).

The polar ice in melting acts as a hydraulic pump driving down to the bottom, by cooling, the water round it, and drawing the warmer water to the surface.

The drawing up effect of the melting ice of the southern hemisphere, much more extensive than that of the northern hemisphere, would appear to make itself felt as far as the Sargasso Sea which is the common reservoir pouring warm water towards the Arctic and Antarctic regions.

The direct cooling of the water by the air in the Arctic regions can also cause driving down of the surface water after loss of heat by radiation.

The cycle of the cold abyssal waters is completed by their return to the surface in waters where the warm currents originate. They come up notably to the southward of the Cape Verde Islands, on the African "shelf", and the isothermal chart shows an afflux of cold water on the Arguin Bank, where for this reason fish are very plentiful.

With regard to the *horizontal circulation*, P. DE MORSIER expounds succinctly the two theories on which is based the explanation of the movement of the North Atlantic waters.

In the first place he develops SANDSTRÖM's theory of a movement of turbulence causing the general S.W.-N.E. displacement of the warm surface water of this ocean, and expounds the theory of the Gulf Stream and of its various extensions as understood by Professor PETTERSSON. (2) The Gulf Stream is the result of the joining of two currents, the Antilles Current and the Florida Current, themselves derived from the E.-W. afflux composed of the North Equatorial Current and a part of the South Equatorial Current. The parts of the Gulf Stream water which attain the highest salinities and temperatures appear to come from the Sargasso Sea. Starting from Cape Hatteras, the Gulf Stream spreads to the right, loses its speed, and its water becomes mingled more and more with the normal Atlantic water.

According to Professor PETTERSSON the Gulf Stream appears (Fig. 1) to continue to the eastward at first, along the parallel of 40°, then as far as the African Continent southward of the Azores. Turned back to the northward by the presence of this continental shelf, along which it reaches a depth of 1,500 metres (820 fms.), picking up between the depths of 800 and 1,100 metres (437 and 601 fms.), the dense waters of the Mediterranean, it flows along the embankment of the European continental shelf, to dive at the parallel of 50°. Its last traces are to be found west of the coasts of Ireland, in the shape of plankton of the Sargasso Sea type.

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(1) J. W. SANDSTRÖM : Deux théorèmes fondamentaux de la dynamique de la Mer. (*Two fundamental theorems of the dynamics of the Sea*). - (*Svenska Hydrografisk-biologiska kommissionnens Skrifter - Göteborg*, 1921).

(2) Otto PETTERSSON : Aperçu d'orientation vers la conception actuelle de la circulation océanique dans l'Atlantique (1927). - (*An outline of the present-day conception of the oceanic circulation in the Atlantic*) - (*Svenska Hydrografisk-biologiska Kommissionnens Skrifter - Göteborg*).

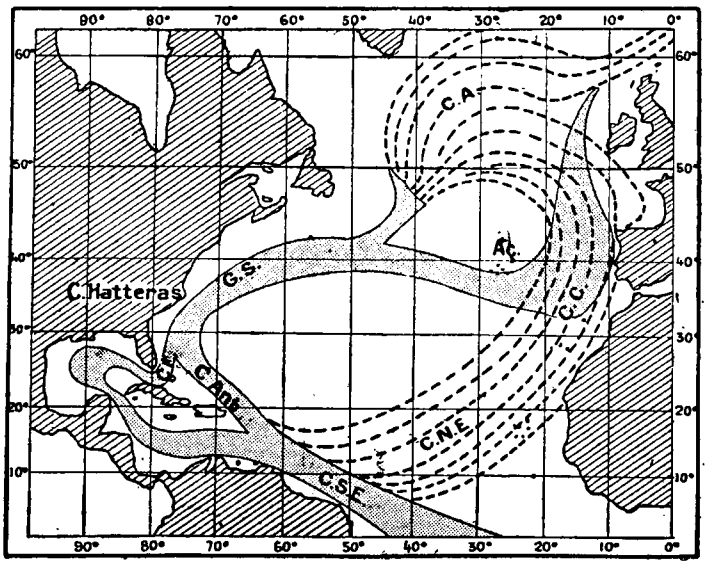

Fig. 1

On the other hand, the drawing up of warmer water (Fig. 2) due to melting ice causes a northerly movement of the Gulf Stream water at the limit of the melting zone in spite of the influence of the earth's rotation, which should tend to deviate it to the right as long as it retains any velocity. As melting of the ice only takes place in spring and in summer, this current can only be set up in summer and autumn.

The name of "Atlantic Current" has been given to the result of the mixing of the waters flowing to the northward as we have just seen and of the melted ice water. This mixture, spreading fanwise as shown in Fig. 1, advances little by little towards Europe, (1) considerably assisted by the wind. This sheet of water, of temperate sur-

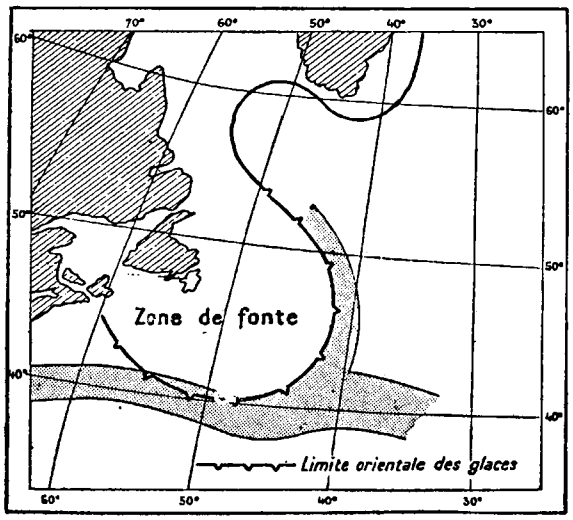

Fig. 2

(1) *The time taken by the drift across the Atlantic appears to be of the order of* 1 2/3 *year by the northern route (Atlantic current), about* 2 ½ *to* 3 *years by the southern route. It seems that one need no longer trouble to talk about a current.*

face, thus reaches the whole of the European continental shelf. It even passes on, south of the Faroes, to reach the coast of Norway and the Arctic pack-ice. Professor PETTERSSON notes that a certain velocity is recovered, starting from the Wyville-Thomson sill (joining Iceland to Scotland). He attributes this acceleration, which has a periodicity seemingly in proportion to the abundance of the polar currents, to the drawing up effect of the ice.

On the other hand, a periodic afflux of deep oceanic waters penetrating to the interior of the continental waters of the coasts of Europe is due to cosmic causes which are still not properly determined, but the influence of which on the western coasts of Sweden has been investigated. There, one finds periodical pulsations of the stratified layers of water and signs of deep internal tides.

These internal tides are also the cause of ruptures in the ice which, as soon as it is freed, is removed by the polar currents, and it has been found that the years of much drifting ice correspond to moments of strong cosmic influence.

In the second place P. DE MORSIER expounds another theory, upheld in particular by Professor LE DANOIS, which explains the North Atlantic oceanic circulation not as a vast cyclic movement but by the contrast of two masses of water, the northern water and the Atlantic water, as different as possible one from the other as to their salinity, temperature, colour and fluidity. (1)

These two masses of water have been and remain together without as a general rule mixing as far as their main content is concerned, and each retains the characteristics of its origin and a localised movement in its own sphere.

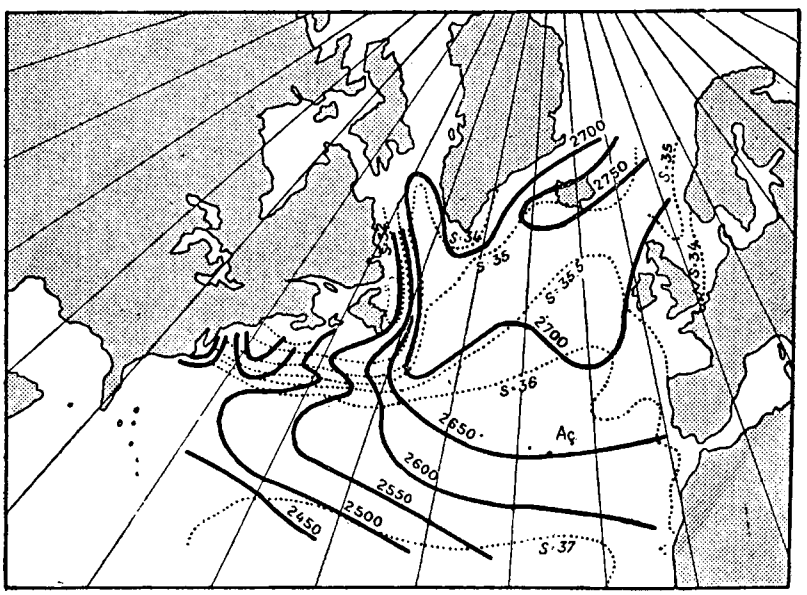

Fig. 3

The chart of surface densities (Fig. 3) summarises the situation in the North Atlantic, the general structure of which is characterised by the isohalyne, isothermal and isanomalistic lines. The densities, lying in zones roughly concentric with the coasts, increase as they run off shore and, in the western part, from S.W. to N.E. Knowing that *when two contiguous masses of water have different densities, a surface current is set up, from the water of lesser density to that of greater density,* (a compensation current is set up under-

(1) *The waters of northern origin include the Arctic waters, the abyssal waters and the continental waters of the North Atlantic, and are cold and characterised by a salinity of* 35 °/₀₀.

The Atlantic waters proper are of equatorial origin, warm and characterised by a salinity higher than 35 °/₀₀.

neath, from the greater to the lesser density), one may expect a displacement of the Atlantic waters towards the N.E. The passing of the Atlantic to the northern waters occurs through the medium of the waters known as *de la pente* (slope waters) (33.5 to 35 °/₀₀). The influence of density is in reality slight. On the other hand, that of the winds — generally westerly — is appreciable, particularly as the former acts slowly.

From December to the end of March, the line of separation of the continental and the Atlantic waters, lying off the Banks, is in stable equilibrium, waters of the same density being distributed on one side and the other in vertical slices (parallel lines of equal density).

The afflux of the Labrador waters bringing icebergs, more or less thick according to the years or the season ; the continental waters (it has been observed that the continental waters, although of very variable temperature, are characterised by a very strong degree of adherence to the shape of the coastal relief), more or less well fed by rain or snow ; the heat of the sun acting differently on the Atlantic or the northern waters ; these are the causes which, from the month of April until the winter stabilisation, set up, by hot and cold transgressions, the advance and retreat of the limit of the waters, the complex routine of which is particularly marked on the limits of the Newfoundland Banks.

We are thus, as regards the North Atlantic, in the presence of a vast gulf the edges of which are occupied by cold and stable waters, opposed by their inertia to the warm and mobile waters occupying the centre. The mobility of the latter (1) is mainly due, according to M. Le Danois, to phenomena of a cosmic order by which the former are found from their distribution and nature to be influenced.

As far as concerns currents proper, M. Le Danois reduces them to two in number, the equatorial current and the circumpolar current, both due to the rotation of the earth. The former piles up warm water in the Gulf of Mexico, from which emerges the Florida Current. The latter forces ice-laden water continuously back against Greenland, which waters finally flow towards Newfoundland.

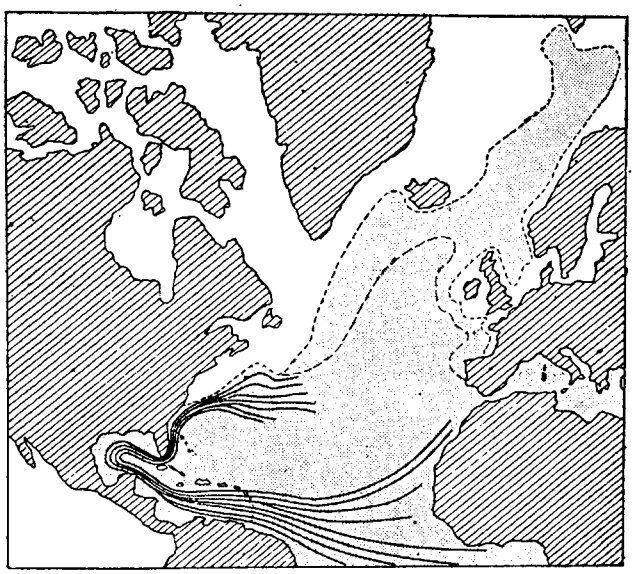

Fig. 4

Thus, according to M. Le Danois, (Fig. 4) the *Gulf Stream* hardly passes the meridian of Newfoundland, while Prof. Pettersson, as we have seen, attributes to it the presence on the coasts of Europe of the oceanic waters which afterwards only travel a short journey owing to cosmic influences.

(1) *In fact, only a thickness of* 600 *metres* (328 *fms.*) *is mobile.*

During the period of winter stabilisation the Atlantic transgression does not reach the European continental shelf, which from December to June is fully affected by seasonal influences.

Although the movement may have started from the month of February off Morocco, the tendency of the Atlantic waters to approach the coasts of Europe and Africa does not make itself felt until the month of June. During the course of the summer the transgression gains in turn the coasts of Britanny, Ireland and Scotland ; in autumn, the North Sea and the coasts of Norway, reaching its extreme limits, the distance of which varies according to the year.

The regression commences in November and is complete in May. In point of fact, the period of true stabilisation is only a few weeks.

From the thermal point of view, the transgression adds its effect to the fact that the coasts of Europe are not cooled by the Arctic waters, which have been driven to the westward.

The period of the transgressions is a result of the periods of the influence exercised by the sun and moon.

This development of the question of the *Gulf Stream* shows that there is a tendency to reduce the action of impulsion currents, and of the free currents resulting from them, to more modest proportions in favour of periodical cosmic influences.

These influences seem, further, to extend also to the atmosphere. The parallelism between the phenomena of the sea and of the atmosphere is not only due to the influence of the sea on the climate, but also to the effect of a single cosmic influence acting simultaneously on two more or less stratified media, the sea and the atmosphere.

OBERFLÄCHENSTRÖMUNGEN DES NORDATLANTISCHEN OZEANS ZWISCHEN 15° UND 50° N. B.

(SURFACE CURRENTS OF THE NORTH ATLANTIC OCEAN BETWEEN LATITUDES 15° AND 50° NORTH.)

by

OTTO HEINR. FELBER,

Hamburg, 1934, Deutsche Seewarte,

29 × 22 cm. - 18 pp. - 24 fig. - 6 tables.

Studies of the surface currents of the Atlantic Ocean are now numerous enough to make it possible to show these currents by a chart, a form of representation necessary to make the characteristic details of the phenomenon stand out clearly. The Deutsche Seewarte has done this in a publication by Dr. O. H. FELBER.

The author has set out to show us the changes undergone in the course of a year by the surface currents of the North Atlantic, and with this object he gives us a series of charts on a conformal azimuthal (stereographic) projection, on which the currents are shown month by month by continuous lines the intensity of which indicates the stability of the current. The speed of the current is given by red lines of equal velocity varying every five miles. We reproduce here the chart for the month of August.

The book compresses a considerable work, accompanied by a bibliography, into a small number of pages. It is based on more than fifty years of observations which the author has examined and discussed with the aid of isothermal and wind charts, drawing charts of pure impulsion currents and making certain that the current shown was not contrary to the laws of hydrodynamics. In regions of convergencies he has taken into account observations of salinity and temperature at various depths.

The last part of the study describes the general run of the currents of this region of the Ocean and shows the various changes undergone by the current in the course of the year, such as a displacement of the origin of the Northern Equatorial Current, to