ICE OBSERVATION AND PATROL IN THE WATERS OF NEWFOUNDLAND IN 1929.

by

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For some time past the menace of floating ice in the latitudes of Newfoundland, along the most frequented maritime routes of the world, which follow the arc of the great circle between the ports of Northwest Europe on the one hand and the ports of the United States and Canada on the other — a menace which is further augmented by the very thick fogs prevailing in this part of the ocean — has been a matter of great concern to navigators and the maritime nations. MAURY, in determining the steamer lane routes back and forth between the Irish Sea and the port of New York, advocated a detour to the South when to the S. E. of the Tail of the Grand Banks of Newfoundland during the season of the ice-drift (February-August) and this change in route has remained official since that time. However, this measure has not prevented the collisions and the damage occasioned by ice: from 19th March 1882 to 16th April 1890 alone, the reports showed 14 ships lost from this cause and 40 damaged, and the count is far from complete. But all of the preceding disasters fade into insignificance before the sensation aroused by the disaster of the *Titanic* (14th April, 1912). In latitude 41°46' N. and longitude 50°14' W., this vessel struck an iceberg, or possibly simply an ice-block (1) and foundered soon afterwards. There were 1,500 lives lost. Following this event a service of security was inaugurated by scouts sent out by the United States Navy in 1912 and 1913. Thereupon the Convention of London (January 20, 1914), decided on the creation of a regular observation service and patrol, the expense of which to be borne by the contracting nations and the work to be confided to the vessels of the Coast Guard of the United States. Since that time and at very regular intervals, except in 1917 and 1918, a patrol for surveillance and warning has been maintained in the critical zone in the latitudes of Newfoundland. In practice, this patrol is maintained alternately by the two vessels *Tampa* and *Modoc*, which relieve each other in the observation zone every fifteen days. Their base of supplies is Halifax. Eight times a day the vessel on patrol sends out radio warnings relative to the position of the ice under surveillance by it; and the cutter of course also receives all the information on the subject transmitted to it by other vessels. The observers endeavour not only to determine the position of all the floating ice, but to predict and describe its probable movements, particularly near the

(1) Iceblocks are small fragments of disintegrated icebergs or those in the process of disintegration. The *Bulletin* of the American Ice Patrol calls them *growlers*. The term *iceblock*, which is better, has been adopted in scientific parlance.

Tail — a task which necessitates the most precise oceanographic observations. Here there is therefore close coordination between the purely scientific work and the practical needs which gave rise to the patrol. At the end of each cruise a detailed report is published with charts and sketches showing the observations made and the results obtained which are printed in the form of a Coast Guard *Bulletin*.

The *Bulletin* of 1929, which it is proposed to analyse and discuss in this present article, offers certain material of special interest (1). The year 1929 was remarkable for the unusual quantity of floating ice at the approaches to the Grand Banks and the *Tail*. There was nothing on which this invasion could have been predicted, since the year before (1928) the cutter *Marion*, in exploring the zone between Greenland and the shores of Baffins Bay through which the icebergs pass in their descent to the southward, had remarked on the relative scarcity of ice and an almost abnormal increase in the temperature of the surface waters (2). The invasion of the year 1929 was therefore something unexpected. It was revealed as early as the month of March by the number of icebergs and the low temperature of the surface waters; in the months following it increased, as we shall see, in striking proportions, to such an extent as to necessitate an unusual prolongation of the patrol. This ice patrol commences the 1st of April, and usually terminates about the middle of July at a time when ordinarily most of the ice has disappeared from the steamer lanes; but in 1929 it was necessary to continue the patrol until the 4th of August.

I. — *THE NATURE, THE MOVEMENTS AND THE DISINTEGRATION OF THE FLOATING ICE.*

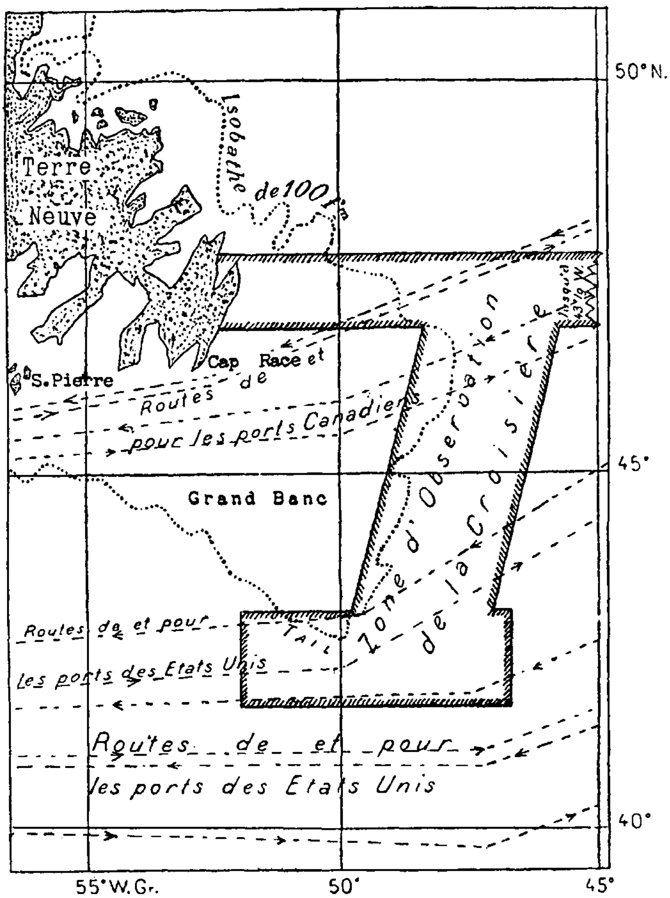
The ocean areas under surveillance by the patrol comprise essentially from the N. E. to East and to Southeast of the Grand Banks, the *melting zone* of the icebergs, which merges to a great extent with the *critical zone* traversed by the great navigational routes. It extends from latitude 41° to 48° N., and has its extreme limits between longitudes 43° and 53° W. — leaving aside, however, the edges of the Grand Banks themselves, which the floating ice never approaches except in the north. This is an expanse of some 253,000 square kilometres, which it is impossible to cover with two cutters on patrol working alternately, even though the thick fogs did not force a suspension of their activities during approximately half of the time at their disposal.

Practically all of the icebergs which drift into the zone of surveillance are masses detached from terrestrial glaciers (*icebergs*) or are fragments resulting from the breaking-up of these masses (*iceblocks*). The marine ice, formed by the freezing of the surface of the ocean (*ice-fields*; *packs* which combine a

(1) U. S. Treasury Department, U. S. Coast Guard *Bulletin* N° 18: *International Ice Observation and Ice Patrol Service in the North Atlantic Ocean*, season of 1929, Government Printing Office, Washington, 1930.

(2) Edward H. Smith: *Expedition of the U. S. Coast Guard cutter* Marion *to the region of Davis Strait in* 1928. (*Science*, Nov. 16, 1928, page 469-470).

large number of ice-fields : *icefoot*, which results from the freezing of the coastal waters) does not appear during the season of the icedrift. Even during the cold winter of 1929, the extreme southern limit of the ice-field in February was located to the East of Cape Race in about latitude 46°25' N. and longitude 47°40' W. On rare occasions one saw fragments of the ice-field in April in latitude 44°40' N. ; but as early as the beginning of May there was no further trace of ice to the southward of latitude 48° N.



Area under surveillance by the U. S. Coast Guard Patrol

The floating masses of ice which drift to the S. E. of Newfoundland are therefore icebergs or iceblocks. We should not assume, however, that the presence or absence of the icefield to the northward is a matter of indifference. The ice-field is the protector and the conserver of the icebergs. It is due solely to this that the latter are able to advance so far to the southward. Without the icefield they would never reach this point. Whenever the icefield extends further to the southward than usual, it gives the icebergs a renewed chance to survive and spread out.

The icebergs of Newfoundland proceed mostly from the large glaciers of Greenland and in particular from the imposing glacial masses which reach the ocean from the semi-circular Bay of Melville. Detached from the parent glacier when this is plunged into the waters of the ocean, by the accident of fracture or "calving" (separation) they are seized after several tentatives by the current and are dragged to the Southward along Baffins Land and Labrador. Their period of drift as far as Newfoundland lasts one or two years. Thus during the winter season they are seized and packed in the grip of the icefield and also very frequently by the coastal icefoot since the submarine slopes are very abrupt off the coast of Labrador. The icefield protects the icebergs, first by saving them from the slow melting which occurs in open waters, and further, and above all, it modifies the shock of the waves which proves to be more destructive to the icebergs than the lukewarm temperature of the water.

In February 1929, when the icefield-icefoot still packed the coasts of Labrador and of Newfoundland and the Strait of Belle-Isle, no iceberg appeared to the East and Northeast of the Grand Banks. The first turned up in March, mixed with the debris of the icefield, and soon became so numerous that it was found necessary to request the vessels from Europe to New York to change their routes 60 miles to the southward. On one single day, the 21st. of May, 76 icebergs and iceblocks were reported by the *Modoc*.

The waters in the entire melting zone remained colder by 1.11° C. to 2.22° C. than they had been during the same days of the preceding year — a fact which accentuated in a singular manner the heating effect of the waters of the Gulf Stream to the Southward of the *Tail*. Thus, on 7th June, over a very short distance there was a change in the temperature of the water from + 8.88° C. to + 17.78° C. Such great contrasts cannot exist without bringing about frequent eddies, and these eddies made the task of predetermining the probable course of the icebergs difficult and uncertain as soon as they arrived in the convergence zone of the warm and cold waters.

Up to that point the track of the icebergs from North to South could be clearly and precisely plotted. With the exception of several strays which might drift into the coastal waters or the shallow waters to the Southward of Newfoundland, opposite Cape Race and Saint Pierre, the troup of icebergs follows exactly the *eastern slope* of the Grand Banks which is marked by the bathymetric line of 100 fathoms. In the *Bulletin* of the patrol this is called the *Gateway of the Icebergs* into the Altantic, from 47° to 43° N., through a width of about 60 miles to the East of the slope of the Grand Banks. Under the influence of the terrestrial rotation, the icebergs have a tendency to deviate to the Westward, like the Labrador current which carries them. But the greater part of them are kept to the Eastward by the slope of the Grand Banks, since the immersed part strikes against the bottom. Later, interesting investigations might be carried out on the submarine glacial erosion and polishing.

The Greenland type of iceberg is characterised by a mass of ice 30 metres high, about 30 metres wide and 120 metres long: this was the average of the 1,300 icebergs seen in 1929 by the patrol, which attributes to each a volume of about 110,000 cubic metres. This is only a portion of the volume of the iceberg: one-sixth to one-eighth according to current views; and one-fifth only according to H. T. Barnes, who notes that the ice in the iceberg is much lighter than the ice formed in winter on rivers and lakes, since the ice of the icebergs contains a large number of air bubbles. BARNES attributes to them an average density of 0.830 as against 0.916 for the ice formed of pure fresh water. However that may be, a considerable portion of the icebergs remains immersed. They cannot adventure on the Grand Banks without danger of beaching, which does happen to some of them to the Southward of Newfoundland, but the greater part are swept to the Southward by the Eastern slope of the Grand Banks as though held by the banks of a canal.

Disengaged from the icefield, the icebergs would probably disappear before they reached the steamer lanes, unless they were protected in a large degree by the fog. These fogs, which are associated to some extent with the evaporation from the surface of the icebergs, calm the sea and moderate the shock of the waves, which are as destructive to the icebergs as the warmth of the waters. The fogs are one of the predominant factors of the meteorological conditions off Newfoundland during the entire year, but especially so during the drift of the ice. During the four months from April to July, the observations of the *Tampa* and the *Modoc* show a mean visibility for 1929 of less than 4 miles during 37 % of the time at sea, and in 29.7 % of this time a visibility of less than 2 miles.

The disintegration of the icebergs is brought about by dislocation into iceblocks under the shock of the waves, by surface evaporation and by melting under the influence of the waters which bathe the iceberg, even when these are relatively cold; the latter influence being shown clearly by the air bubbles which rise along the vertical flanks of the iceberg after being detached from the underwater parts. It is difficult to determine which of these actions is predominant. It is evident that the third tends to prevail when summer approaches and when the icebergs move toward the southward near the latitude of the *Tail*, where in July 1929 the most adventurous reached the latitude of 41°30' N. Under these conditions the disintegration also becomes more rapid. In July 1929 nine days sufficed completely and noiselessly to demolish an iceberg of 500,000 tons to the Southwest of the *Tail*, in waters having a temperature of + 15.56° C. In May-June, 1928, an iceberg of the same size, in the same region, persisted for fourteen days, but the mean temperature of the water was only + 3.33° C.

The static sensitivity of the icebergs when their centre of gravity nears the critical point is well known, a fact which is brought about particularly by the waterways hollowed out by the waves near the waterline. Therefore very little is required to cause them to turn about their centre of gravity and capsize — a ripple of the waves, the passage of a small steamer at a short distance, while on the other hand, when this critical point has not been reached (and nothing betrays it in advance), the most violent disturbances cannot move the iceberg or cause it to deviate from the course on which it is being carried by the current. It is seldom that they are influenced by the wind, since the larger part of their mass is withdrawn from its effect.

The patrol of 1929 definitely located 1322 icebergs between April and August to the Southward of latitude 48° N. and 134 to the Southward of latitude 43° N. The mean of the observations made up to that time gave only 377 icebergs in the first case and 51 in the second. It may be stated without error that in 1929 more than *three or four* times the amount of ice was seen drifting past Newfoundland and the Grand Banks than in normal years.

II. — *THE CURRENTS IN THE MELTING ZONE OF THE ICEBERGS.*

Frequently it is difficult to predict or even to follow the route of the icebergs; when the screen of fog falls on the water, the melting zone becomes at the same time the convergence zone of the surface currents, with all the variations in the limits and secondary gyratory movements which take place in such cases.

In a general way the layers of water which converge below and in the vicinity of the *Tail* of the Grand Banks arise from three sources — the *waters of the banks,* the *arctic waters* and the *waters of the Gulf Stream.*

Up to the month of April the *waters of the banks,* fed by the waters discharged from the Saint Lawrence, carry the ice from the icefoot and also the river ice; these waters spread out to the Southeast, beyond the Cabot Strait, which separates Newfoundland from Nova Scotia; their layers form the greater part of the shallow waters of the Banks. This shallow depth carries a rapid rise in temperature in the strata of liquid in the spring. The *Bulletin* of 1929 shows a rise in the temperature of the waters of the Banks of 12.22° C. during this season, while the waters in the Labrador Current do not show a rise of more than 8.88° C. during the same period. This thermal phenomenon doubtless contributes to the prompt disappearance of the icebergs which drift on the Banks.

The *artic waters,* which follow the eastern coast of Newfoundland and the slope of the Grand Banks, are better known under the name of *Labrador Current.* These are the waters which serve to transport the great masses of icebergs. They are covered with such great masses of drifting ice that one is tempted to attribute to the icebergs, or at least to their melting, the normally low temperature of this current and the turning effect it produces on the set of the warmer Gulf Stream to the Southeast of the *Tail.* This was particularly the view of O. PETTERSSON, who considered the melting zone of the surface ice, which is naturally found in the waters of Newfoundland, as the "place of origin of the system of oceanic currents" and one of the greatest factors in producing the vertical circulation (1).

The *Bulletin* of 1929 opposes this view by simple statistical considerations which appear convincing, particularly when they are applied, as in this case, to a year characterized by great drifts of ice (icefloes).

We have seen that 1,300 icebergs drifted to the Southeast of Newfoundland in the course of the patrol of 1929, within the 253,000 square kilometres of the melting zone. If we assign to each iceberg a volume of $110{,}000 m^3 \times 5$, which is certainly greater than the actual volume, we obtain 715 million cubic

(1) O. PETTERSSON: *Changes in the Oceanic Circulation and their Climatic Consequences* ("*Geographical Review*", January 1929, pp. 121-131).

metres of ice, or 0.715 cubic kilometre. If we now consider the affected zone of 253,000 sq. kilometres to a depth of 15 metres, the result is a volume of 3,795 cubic kilometres which must be cooled by 715/1000 cubic kilometre of ice. According to the calculations in the *Bulletin*, such a cooling could only result in lowering the temperature by the insignificant amount of 0.008° C. This is not surprising since, according to the ratios established above, the volume of floating ice does not comprise more than 1/5300, approximately, of the sheet of water in which it is drifting and this during the season when the ice is most abundant.

The ratios in the preceding paragraphs should not, of course, be taken to represent absolute values. They simply serve to give some idea of the order of magnitude of the phenomena in question. Like the authors of the *Bulletin* however, we believe that they will suffice to reduce to nil the theoretical views of Mr. O. PETTERSSON.

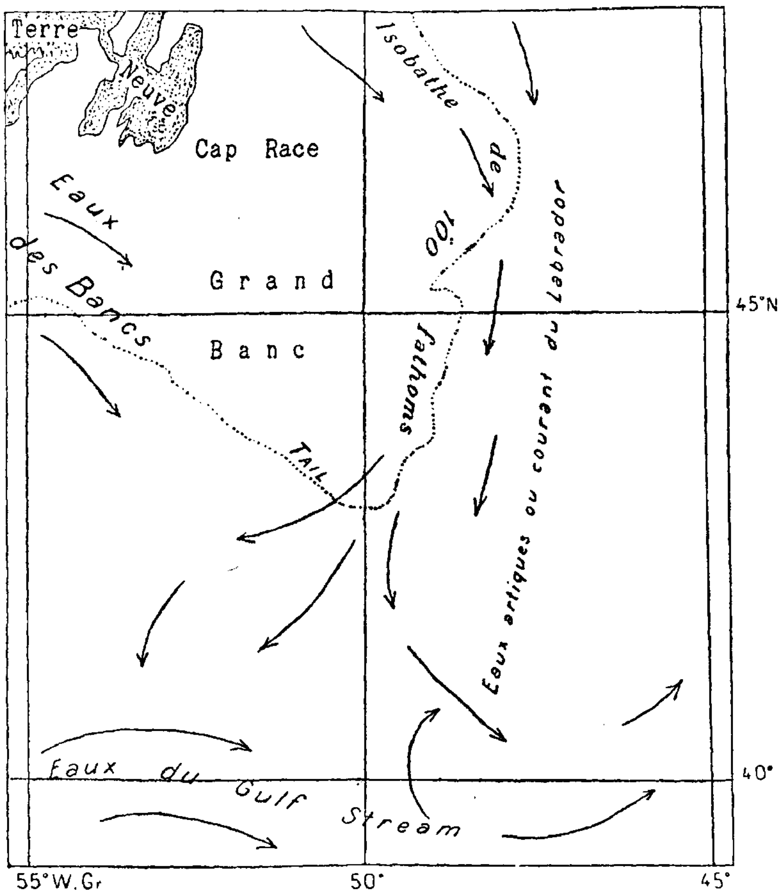
The more or less low temperature of the waters of the Labrador Current is a phenomenon concurrent with the arrival of the ice, varying in phase with it, but in no wise the cause. As a result of his explorations in the Davis Strait aboard the cutter *Marion*, Lieutenant Edward H. SMITH believes that the temperature of the current is due in part to the melting of the *icefield* and the *icefoot* in the far North, but to an even greater extent to the cooling of the surface of the ocean by the colder layers of the atmosphere in the same region. We are absolutely in accord with this opinion.

The direct observations made by the patrol on the surface temperature of the water in the vicinity of the large icebergs show how little these lower the temperature of the waters which bathe them: a fact which should destroy credence in the widespread popular belief that it is possible to determine the "approach of icebergs by thermal means." Measurements were made in the vicinity of an iceberg which was drifting in a layer of water having a temperature of + 13.89° C. On one side only of this wall of ice the temperature was found to be lowered to 11.11° C., and in a sort of pocket or hollow crevice to 10° C. Everywhere else and even close to the vertical walls of the iceberg the temperature of the water showed no indication of a drop.

These observations should also arouse some scepticism with regard to the *local convection circulation* of which the icebergs are supposed to be the cause. Experiments in the laboratory have confirmed the fact that a piece of ice immersed in water exerts some attractive force on the surface water which is compensated by a sort of repulsion beneath the surface. Professor BARNES believes that this phenomenon occurs in the vicinity of the icebergs, and that this gives rise to numerous convection currents. The patrol of 1929 was unable to confirm anything of the kind. On the contrary the measurements made of the temperature and salinity at various depths near the icebergs demonstrated the stability and regular stratification in the liquid column. For instance, below are given the measurements taken three miles to the east of the large icebergs on 18th July 1929, in latitude 42°01' N. and longitude 49°29' W.

Depth.	Temperature.	Salinity.
Surface.	+ 14° C.	32.89 °/oo
25 metres	+ 3.93°	33.31 °/oo
50 "	+ 1.72°	33.91 °/oo
120 "	+ 2.78°	34.42 °/oo

The Labrador Current was colder and more widely extended in surface in the year 1929 than in the preceding years. The icebergs were not the cause of this: they simply accompanied the movement and bore witness to it.



Currents in Newfoundland waters, June 1929

In the month of June the mass of the cold current, instead of revolving in eddies about the *Tail* as it did in the preceding years, was cut in two; one branch then set to the S.W. and carried large icebergs towards latitude 43° N. and longitude 53° W., while the other part swerved to the S.E. into a zone which is ordinarily occupied by the warm waters of the Gulf Stream, and was reported as far South as latitude 40° N., and longitude 47° W. In July the first branch had ceased to exist, but the second, while retreating to the Northward, still existed as far South as *the 42nd parallel of latitude*. These are very striking facts. The current of the warm waters in the North Atlantic was actually driven back to the Southward during the Spring and a great part of the Summer, and possibly even during the entire Summer. (Fig. 2).

III. — *METHODS OF PREDICTION AND PROTECTION.*

The public likes to believe that the existence and activities of the ice patrol safeguard the vessels from all danger of collision with drifting ice. With a frankness which does honour to its authors, the *Bulletin* of 1929 recognises the fact that this is not so. However great the vigilance of the patrol, the dangers do not disappear and cannot disappear, even if only on account of the thick fogs which often prevent *scouting* for the icebergs and their surveillance. Collisions have occurred recently, although it is true that the consequences were not grave — the *Montrose* in 1928, the *Vimeita* in 1929. But the very lack of grave consequences attending these collisions and forgetfulness of the great catastrophes of the past constitute a new danger. Very often the passenger steamers pay little attention to the change ordered in the route, which causes them to be delayed, and they pass through the danger zone at high speed. In the Spring of 1929, there were one hundred instances of liners between the United States and Europe which passed across the *Tail* at speeds of 20 knots and more, at more than 20 miles to the Northward of the prescribed routes. "Such an act", says the *Bulletin*, "is a piece of pure folly; it must result sooner or later in disaster". The vessels to and from Canada, which are not in such a hurry, are much wiser; they reduce speed to 3 knots in foggy weather when crossing the Grand Banks.

Radio communications remain the most efficacious instrument of warning, thanks to which the vessels traversing this zone receive notice of the position of the icebergs sighted by the patrol and by other vessels, eight times a day. But this information cannot be complete on account of the fogs. The warnings do not always permit the icebergs to be definitely identified and it is not possible always to follow their movements into the critical zone. The observation of the icebergs frequently gives rise to numerous optical illusions. Refraction makes them appear enormous when near the conjunction of the warm and cold waters, when very often the object is simply an iceblock. It has also happened that one of the cutters of the patrol itself, painted white, has been mistaken for an iceberg at a distance of 10 miles.

As a general rule the icebergs are little affected by the atmospheric currents. They follow the marine currents. It would appear therefore that it might suffice to know the currents in order to predict with certitude the route of an iceberg to the Northward of the danger zone and to give warning to vessels of its probable future positions. But, as we have already shown, the critical zone at the *Tail* is also a zone of convergence and eddies, with variations for which up to now we have been unable to determine any continuity or periodicity. The current chart has to be redrawn each season. For this we have two methods available: the *thermal* method and the *hydrodynamic* method. The first is based simply upon the observation of temperatures at the surface and the construction of isotherms; the work done in this manner in 1923 gives, according to information published in the *Bulletin*, some interesting information on the positions of the *tongues* of cold water projecting from the Labrador Current. But the icebergs may also be seized by the striae of warm water and drift for several days in warm currents, and we know also that they do not appreciably lower the temperature of the layers of water in which they are immersed. The hydrodynamic method, advocated by Lieutenant Edward H. SMITH according to the rules laid down by BJERKNES in Norway, is based on the observation of lines of equal pressure (*isobars*) and of lines of equal specific volume (*isosters*) through a layer of water of predetermined thickness; the inflections of these lines serve to determine in depth and on the surface the direction of the liquid strata (1). In reality this method is based on the principle that waters of different temperature and density will not mix. This principle is true in general. But if two different waters do not mix on contact, the sheets of water divide up into very numerous striae, into distinct liquid filaments which make the application of the hydrodynamic principle very difficult to apply by calculation, although the employment of the principle would be excellent for large sheets in mass (2).

IV. — *THE PROBLEM OF CLIMATIC VARIATIONS IN RELATION TO THE APPROACH OF THE ICE.*

This problem has not been touched upon by the editors of the *Bulletin*, who confine themselves strictly to their very positive and local problems. I should like, however, to add a few words on this subject for the following reasons.

The spring of 1929, which was the occasion of an absolutely unprecedented invasion of ice in the vicinity of Newfoundland, also bore witness to another unusual phenomenon, which has never been noted within the memory of man — the drift of the icebergs detached from the glaciers of Svalbard (Spitzbergen) as far as the Murman Coast in the South of the Barentz Sea.

When I reported this fact in a note in the *Annales de Géographie* (3) I thought the incident was only of local importance, as I did not then know of the great drift of icebergs which took place coincidently in the waters of Newfoundland. If other observations, the possible sources of which are unfortunately very rare, also concur to show that the *polar front* of BJERKNES has actually been subject to a marked movement towards the South in 1929, the drift of ice in the Barentz Sea and in the waters of Newfoundland take on a significance of a general order. Possibly these may be associated with the concentrations of rainfall which occur on the Northwest coast of Europe and the

(1) Edward H. SMITH: *A practical Method for determining Ocean Currents* ("*U. S. Coast Guard Bulletin*" N° 14), Washington, Government Printing Office, 1925.

(2) With regard to the efforts to destroy icebergs by means of explosives, there is little need of discussion. The *Bulletin* has recognised the absolute futility of such attempts.

(3) "*Annales de Géographie*", 15th July, 1930, page 446.

Northeast coast of North America. HILDEBRANDSSON remarked some time ago that such concentrations of this order in North America have their replica about one year later on the coasts of Europe. It might not be impossible under these conditions to connect the fresh and rainy Spring and Summer of 1930 with the great invasion of ice in the Spring of 1929 ; these invasions of ice being, as we cannot repeat too often, simply symptoms and signs, and not by any means the cause.