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The Hornsund Fiord: Water Masses

ABSTRACT: Investigations dealing with physico-chemical parameters of the Hornsund Fiord waters are analyzed.

The development of hydrological conditions and influence of great water masses: warm West Spitsbergen Current and cold Sørkapp Current are presented.

KEY WORDS: Fiords oceanography, Arctic, Swalbard waters.

1. Introduction

The South Spitsbergen lying on the border line between the Greenląnd Sea and the Barents Sea is affected distinctly by oceanographic conditions dominating in them. The border line between the above two seas runs along the line Sørkapp-Bjørnøya-Nordkapp (Demel and Rutkowicz 1958), whereas the Greenland Sea begins to be regarded recently as one system with the Norwegian Sea, while giving it a common name of the Greenland--Norwegian Sea (Metcalf 1960). It has been dictated by the character of water masses movement.

The general scheme of the oceanic circulation in this region is presented in Fig. 1. The warm Norwegian Current carries, on the average, about 8 million m^3/s of Atlantic water (Worthington 1970). While meeting on its way the underwater East Jan Mayen Ridge stretching along the parallel of latitude, it bends west-wards, entering the area of Norwegian Cyral, where forming of deep-sea waters occurs. The remaining masses of water continue to flow along the scandinavian Peninsula. In the vicinity of its nothern borders the Norwegian Current divides into several arms. Northwards warm West Spitsbergen Current flows along margins of the Barents Sea shelf. In its region two water masses can be distinguished structurally (Yv. Herman 1974):

1) Atlantic water in the upper about 800 m thick layer. Its assumed

lower border runs the isotherm of 0° C. The temperature of upper 100 m thick layer is often higher than 5 C. The salinity in this layer rapidly increases with depth, reaching $35.0-35.2^{0}/_{00}$. Below it insignificantly decreases.

2) Deep-sea water laying under Atlantic one. Its temperature varies within the limits from $-1°$ to $0°$ C. Salinity westwards Spitsbergen exceeds $34.9^{0}/_{00}$.

The western part of the current participates in forming the Greenland

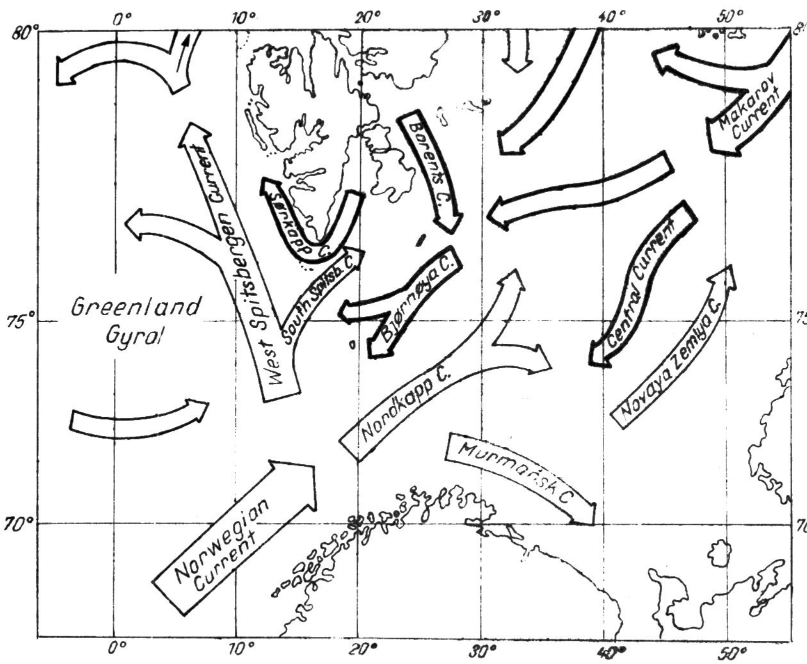

Fig. 1. Scheme of the surface circulation in the Greenland and Barents seas

Gyral, where, similarly as in the Norwegian Gyral, during the winter cooling cold deep-sea water is forming. Prevailing part of the West Spitsbergen Current flows into the Arctic Basin. Vowinkel and Orvig (1961) and Worthington (1970) estimate the amount of the water mass volume for about 3 million m^3/s.

Formation of eastern arms of the West Spitsbergen Current in the sector Nordkapp-southern border of Spitsbergen, depends distinctly on the bottom morphology. Thus the Nordkapp Current enters the Barents Sea along the Bjørnøyarenna and reaches the Central Bank situated in the middle part of the sea. There it undergoes a considerable transformation in the contact with cold waters, whereas its northern part forms a stream bending westwards and then south-westwards. It submerges to the depth

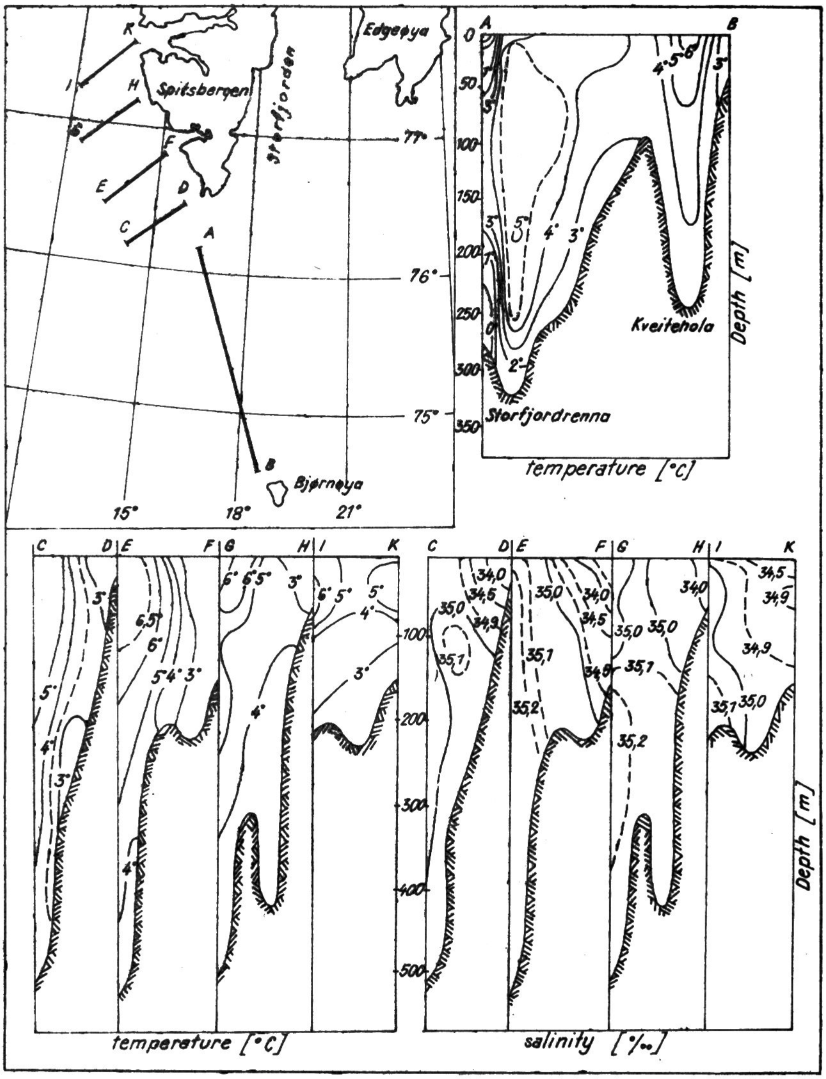

Fig. 2. Hydrological profiles of temperature and salinity in the region of South Spitsbergen (after Adrow 1959). The A-B profile — July 1952, C-D, E-F, G-H, I-K profiles — August and September 1955

of 250–300 m washing eastern Hopen Banken slopes (Androv. 1959, Tantsjura 1959).

In the Bjørnøya-Sørkapp region two ramifications of the West Spitsbergen Current are to be found: the first, small-just beyond Bjørnøya. The second, in Storfjordrenna, enters the Barents Sea under the name of South Spitsbergen Current (Fig. 2, profile A–B) and reaches the area stretching between

Edgeøya and Hopen. In summer the core of this current is shifted towards southern slope of Storfjordrenna, pushed by cold waters flowing along the northern trough slope from Storfjorden. The warm South Spitsbergen Current reaches most often northern borders of Storfjordrenna and divides Storfjorden cold water masses from the system of currents of the East Spitsbergen (Bjørnøya and Barents currents). This phenomenon can be

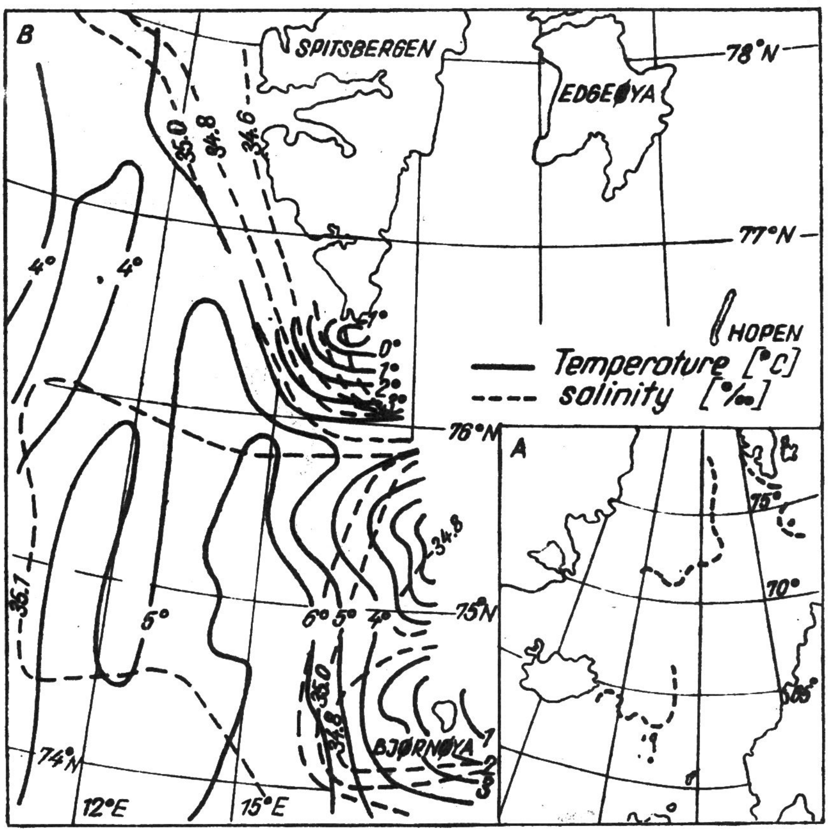

Fig. 3A. Course of polar hydrological fronts in the Greenland sea area. 3B. Layout of isotherms and isohalines over the sea surface in July 1954 (after Alekseyev 1959)

regarded as typical for this region (Androw 1959). The South Spitsbergen Current can periodically penetrate into Storfjorden. There its waters are mixed with local waters and gradually cooling occurs, particularly in the winter season. This initiates the cold Sørkapp Current surrounding the South Spitsbergen and then flowing along its western coast. It carries in its upper layer local waters from Stonfjord, of lower salinity than oceanic sea, and in deeper layer cooled waters genetically connected with the South Spitsbergen Current. It can be distinctly seen in Fig. 2, near the point A of the A, B profile and in two nwxt profiles on Sørkappbanken (C–D) as well as at the outlet of the Hornusnd Fiord (E–F). According to Adrov (1959), the division of the Sørkapp Current into surface and by-bottom layer would occur directly after the summer season. The stream of by-bottom waters submerges westwards, perpendicularly the direction of the warm West Spitsbergen Current.

It was assumed for a long time that cold water masses of the western part of the Barents Sea — the Sørkapp. Barents and Bjørnøya Currents, had their source in the Polar Basin. After the Soviet studies of 1955, their genesis proved to be different. They are local currents originating in different regions of the Barents Sea: Sørkapp Current in Storfjorden, Bjørnøya Current in the region eastwards Edgeøya. Of such genesis of the both currents mainly the higher constant of water-dissolved oxygen than in currents of the Arctic Basin covered with maritime ice can bear evidence. It is also higher than in Atlantic waters of this region.

The hydrological conditions of waters surrounding the South Spitsbergen depend to a considerable extend on the amount of cold waters forming in winter in northern regions of the Barents Sea, Storfjorden and on Spitsbergen Banken. On the area of their interaction with Atlantic waters hydrological polar front maintains permanently (Alekseyev 1959). The layout of surface isotherms and isohalines in this region is presented in Fig. 3. After Shpaikher and Moretsky (1964) it characterizes by a fairly uniform separation depth (125–750 m) by high temperature gradients (0.11–0.16° C/km), little width of mixing (25–36 km) and appropriately low separation area inclibations (17′54″–31′50″). Horizontal gradients of salinity reach $0.4^{0}/_{00}$/km.

2. Situation of the Hornsund Fiord

The Hornsund Fiord is situated most southwards in Spitsbergen. It is connected with open sea by a wide fully unlimited outlet, what facilitates its penetration by oceanic waters. On the fiord's foreground the banks: Hornsund Banken and Sørkapp Banken are situated. The fiord constitutes as if an end of a long trough, the forepart of which called Hornsund djupet outs across the continental slope southwards Hornsund. The trough runs between the banks mentioned, passes westwards the bottom elevations at the sauthern side of the outlet and enters Hornsund from its northern side. Its ending constitutes the Central Depth reaching 245 m (Fig. 4).

The Hornsund Fiord has a complicated coast line with numerous

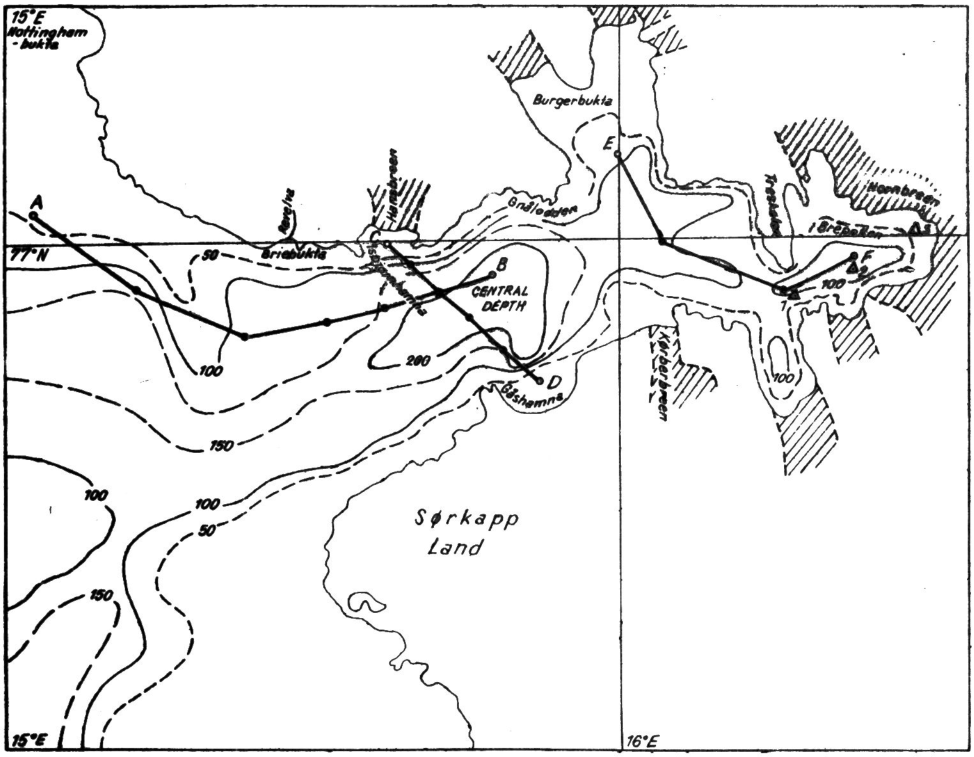

Fig. 4. Course of measuring profiles and layout of some important measuring points over the fiord's area. Some important isobates (depths in m) are plotted and some important inner water basins of the fiord and glaciers are marked

bays. The greatest of them are Brepollen and Burgerbukta situated in its interior. The bays are of over 100 m in depth. In 1979 during carrying out oceanographic works by the expedition of the University of Gdańsk, the depths of the order of 180–200 m at the ice wall of the Paierl. Glacier were encountered (Węsławski et al., unpublished materials).

Thirteen glaciers enter directly the fiord causing a complicated structure of waters in the coastal zone.

3. Research works

The research work in the fiord was carried out mainly by expeditions of the University of Gdańsk in 1974, 1975, 1977 and 1979–1981. They comprised in the first period mainly the coastal zone and were carried out in the summer season only. Since 1979 the investigations of the central part of the fiord and the Brepollen bay began. They were extended also over other seasons.

4. Outlet and central part of the fiord

The basic feature of this area is a distinct occurrence of outer waters. The warm West Spitsbergen Current penetrates into the Hornsund Fiord flowing along the line conditioned by the bottom morphology, i.e. along the through mentioned. In Fig. 5 and 6 the core of warm water at the

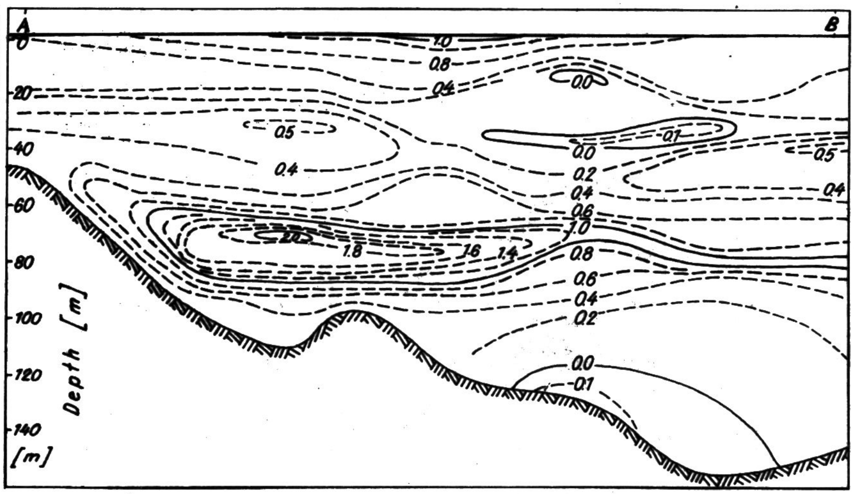

Fig. 5. Vertical distribution of water temperature in the A-B profile, 26th August 1979

depth of the order of 70–100 m of the temperature of 1.6–2.0° C is distinctly discernible. Below and above distinct thermoclines occur, separating it from adjoining layers. The vertical temperature gradients reach at this place the values of 0.1–0.2° C/km. In the profile across the fiord the core of warm water adjoins its northern slopes (Fig. 6). Under favourable hydrological conditions it can occur also inside the fiord (Fig. 7).

The second among the outer water masses — the surface stream of the cold South Spitsbergen Current can penetrate into Horsund. Its by-bottom part, which after leaving the Storfjordrenna lies below Atlantic waters (Adrov 1959, Tancjura 1959) is not able due to higher density to penetrate into Hornsund. On the other hand, the surface stream of the current, still before entering Hornsund, undergoes transformation connected with action of coastal waters along southern and western coasts of Sørkappland. Its waters can enter the fiord over Atlantic waters while undergoing further transformation. Warm Atlantic waters determine to a considerable degree the structure of waters in this part of the fiord. Below them cooler water is to be found, of the temperature of T > 1.0° C and with approximate salinity of the value of 34–35‰ (Fig. 5, 6).

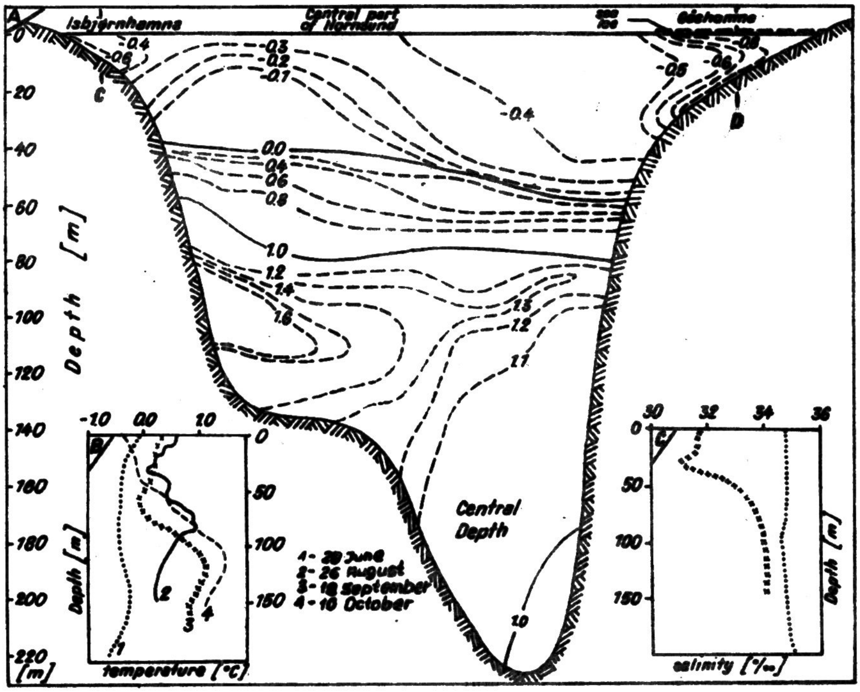

Fig. 6A. Vertical distribution of water temperature over the middle part of the fiord's area (C-O profile), 10th October 1979. 6B, C. Vertical profiles of temperature and salinity on the area of Central Depth made in summer 1979: 1st-28th June, 2nd-26th August, 3rd-18th September, 4th-10th October (profiles 1 and 3, after Urbański et al., 1980)

Mixing of waters in this layer due to existing stable thermohalic stratification is difficult. The core of Atlantic waters distinctly isolates this layer from above water layers. Hence its source can be waters of inner areas of the fiord cooled in the winter season and dropping onto bottom. The age of the by-bottom layer can be estimated on the basis of the water-dissolved oxygen content in it. Results of the measurements carried out in 1979 (Urbański et al. 1980) suggest an increase of the water saturation with oxygen below the lower limit of Atlantic waters to the value of over 80%. The main period of forming the by-bottom layer falls most probably for the last winter season.

The layer lying over the core of Atlantic waters undergoes considerable seasonal changes. The temperature and salinity values vary quite significantly in the summer season (Fig. 6B, C). Early in summer the temperature changes in the vertical are little (Fig. 6, curve 1). A gradual superficial warming up of water owing to solar radiation and turbulent heat exchange with atmosphere takes place. The water temperature at the surface amounts to about 0° C. An intensive solar radiation causes a rapid melting of snow cover on land and of various sea ice forms in the fiord. A massy inflow of fresh (unsalted) waters of the temperature of about 0° C is taking place.

In the summer season considerable changes in the surface layer occur. Of it a complicated course of the distribution or temperature in the

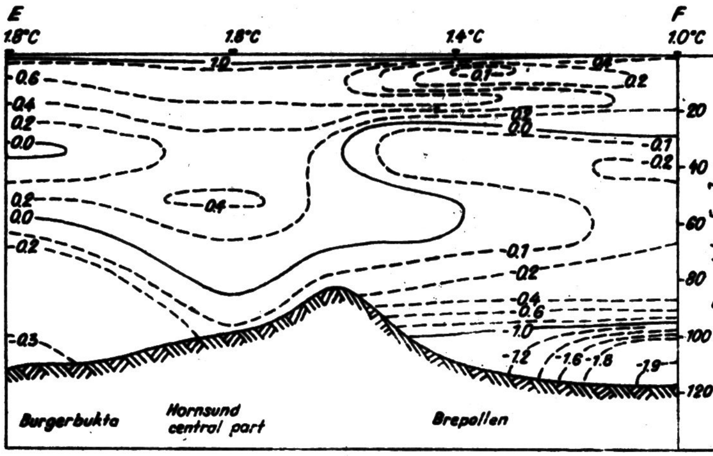

Fig. 7. Vertical distribution of water temperature in the profile inside the fiord (E-F profile); 19th August 1979

function of depth can bear evidence (Fig. 6B, curve 2). The runoff is then very intensive. They have the temperature of several degrees over zero. This layer is visible very distinctly in the vicinity of outlets of land watercourses. For instance, in Fig. 5 warm waters of the temperature of T > 1° C visible on the surface are consequence of the effect of land waters of the Revelva river.

The temperature drops just below the surface and its first minimum is often encountered at the depth of 7–15 m. This layer is connected most probably with occurrence of various forms of sea ice and with inflow of cold waters directly from glaciers. This is stressed still stronger by the rise of water temperature just at the surface (Swerpel 1977, Siwecki and Swerpel 1979, Urbański et al. 1980). The temperature inversior at the above depth is encountered in the open fiord beyond borders of its coastal water basins (Fig. 5).

Between surface waters and Atlantic waters an intermediate layer is to be found, described already by Urbański et al. (1980). In summer its development occurs mainly on the basis of processes of heat exchange with warmer surface waters and Atlantic waters as well as with inserts of cold water of the temperature below 0° C occurring often in the lower part of the surface layer.

Late in summer the formed thermohaline structure of surface and intermediate layers begins gradually to vanish. In autumn the surface layer connected with land waters does not occur any more on the fiord's area (Fig. 6). Watercourses cease gradually to carry their waters. A continuous drop of the water temperature occurs advancing from the surface towards Atlantic waters (Fig. 6B, curve 4). On the surface, at negative air temperatures the water temperature begins slowly to drop down to the freezing temperature of sea water. This process runs quicker in the vicinity of coastal water basins, when freezing of the sea surface begins. In Fig. 6 can be seen as cold-bound denser waters of the Isbjørnhamna and Gashamna bays flow into the fiord. They probably play later an important role in forming the layer of cold waters in intermediate water layers occurring often at the depth of 30–40 m (Fig. 6, 7).

5. Fiord interior, Brepollen Bay

Warm waters of the West Spitsbergen Current reach deep into Hornsund. Their distinct difference determined mainly by the thermocline occurrence, vanishes here. In Fig. 7 a weak layer of warmer waters of the temperature of about 0.4° C at the depth of about 50 m can be noticed. The maximum temperatures occur here at the fiord's surface.

In the inner part of the fiord, beyond the line connecting the Gnålodden with western side of the Køerberbreen, almost all Hornsund glaciers, except Hansbreen, are to be found. This fact is responsible for the development of different hydrological conditions: we have to do here with massy outflow of ablation waters in summer and with cooling of fiord's waters from the ice wall of glaciers slipping into sea. This can be observed most distinctly in Brepollen.

The Brepollen Bay is partly separated from the fiord by the Treskelen Peninsula. It is connected with the fiord only by a narrow isthmus of about 2 km in width. The northern and eastern bay shore constitutes the ice wall of six glaciers, of which the greatest — the Hornbreen system, slips also onto the East Spitsbergen coast, to Storfjorden. The Brepollen depth reaches 38 m, decreasing at the passage to the fiord by what the isthmus character is stressed still more.

Hydrological studies carried out in summer 1979 by the expedition of the University of Gdańsk revealed different hydrological conditions of the bay in relation to the open fiord. (Węsławski et al. 1979, unpublished materials). The water layers have been distinguished by the authors (Fig. 8): surface water layer of 0–20 m, of the temperature of about 0° C and the salinity of about 25‰, intermediate layer of 20–70 m of the temperature of −1°–0° C and the salinity of 31–33‰ as well as by-bottom layer of the temperature of about −1.9° C and the salinity of about 34‰.

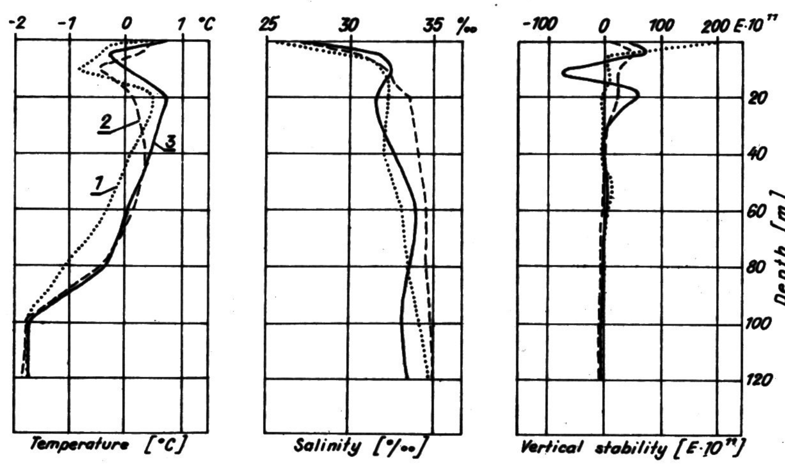

Fig. 8. Vertical distribution of temperature, salinity and stability function at the measuring points 1, 2, 3 in Brepollen on the 1st August 1979 (after Węsławski et al., unpublished materials, 1979)

The occurrence of the cold by-bottom water was not found at any other measuring points, except Brepollen in the summer season. On the other hand, similar features show by-bottom waters of Storfjorden (Adrov 1959). One of the hypotheses explaining this similarity is based on the assumption that sea waters between Hornsund and Storfjorden would flow under the system of the Hornbreen glacier (Węsławski et al. 1979, unpublished materials). Results of the Soviet radar soundings carried out with the use of helicopter in 1980, have proved that the sea bottom under the Hornbreen system lies at least 50 m below the sea level (L. Troitsky, E. Zinger, oral information).

Other hypotheses explaining the genesis of these waters are: convectional mixing of waters in Brepollen and cooling and dropping of Atlantic waters flowing into bay in the autumn-winter period (Węsławski et al. 1979, unpublished materials, Urbański et al. 1980).

In Fig. 7 a core of warmer water in Brepollen is visible at the depth of about 20 m. The occurrence of this layer has been corroborated by temperature profiles presented in Fig. 8. Above extend surface waters occur of the features typical for the coastal water basins of the fiord (very high salinity and temperature gradients, temperature inversion). Below lies cooler layer with insignificant temperature minimum occurring at the depth of about 40 m. At the same depth similar minimum occurs in the Burgerbukta

Characteristic is simmilarity of the temperature and salinity course in the vertical profile at the points 1 and 3 situated at the bay marginn (Fig. 4 and 8). Of different character are the temperature and salinity profiles in the middle of Brepollen (point 2). Here the warm water layer is not be found any more at the depth of 20 m and insignificant temperature maximum occurs at the depth of 40–60 m.

Basing on the hitherto results of the investigations, the following scheme of the development of hydrological conditions in the Brepollen bay can be proposed (Fig. 9):

In the autumn season vanishes the surface layer connected with the inflow of waters from land and glaciers and with melting of sea ice. Waters of high salinity flowing into the bay are gradually cooled from surface and go deep downwards. On the sea surface the ice cover forms making partly difficult further exchange of waters with fiord. The convectional mixing process begins to be more and more distinct. The layer of cold by-bottom water of the temperature of about $-1.8°$ C and the salinity of 34.0–35.0‰, maintains over the whole winter-spring period.

In summer snow melting and ice ablation lead to a gradual formation of the surface layer. Ice over the bay surface disappears or disintegrates and the exchange of waters with the fiord begins. Approximate courses of temperature and salinity at the points situated extremally on either side of the bay (Fig. 8, points 1, 3) and different course of the profiles in the middle part of Brepollen (point 2) suggest that the movement of waters on the bay area is circuitous. In 1979 random measurements of surface and by-bottom currents at the depth of 115 m were carried out by the expedition of the University of Gdańsk. During the measurements circuitous movements of waters — on the surface clockwise and at the bottom counter-clock-wise took place (Students, Oceanographers Scientific Group — edit. 1981). The circulation on the bay area changes depending on the tide phase and the wind situation.

Warm waters from the fiord entering the body and flowing around it are gradually cooled at the contact with ice walls and slowly go downwards. In such a way a layer of cold waters of a high salinity forms above the by-bottom winter waters at the depth of 30–60 m (Fig. 7, 9). Their temperature is about 0° C and the salinity — of the order of 32–34‰.

The influence of Atlantic waters is equalized by the surface outflow and efflux of cold by-bottom waters (Cool Brepollen Water and Winter Cooled Brepollen Water, Fig. 9). As it follows from the course of the

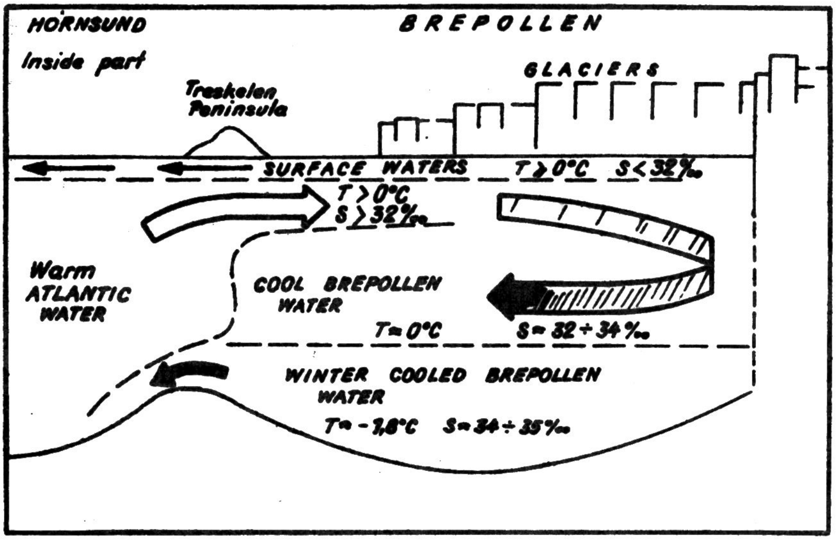

Fig. 9. Development scheme of the structure of water masses on the Brepollen area

function of estability of waters of the bay presented in Fig. 8 (Węsławski et al. 1979, unpublished materials), that are only surface waters and the layer of warm Atlantic water, which maintain a high stability.

6. Coastal waters of the fiord

In coastal waters of the fiord very distinct differences occur in the distribution of temperatures and salinity. Horizontal gradients of temperature exceed in the zone of contact of land and sea waters 0.2° C/100 m, horizontal gradients of salinity reach there the value of $10^0/_{00}$/100 m. Still more distinctly is it visible in the vertical, particularly in the surface layer to the depth of 2 m. Vertical gradients of temperature exceed sometimes 1° C/1 m, vertical gradients of salinity reach at the outlets of watercourses $15^0/_{00}$/1 m.

Such high differences of the sea water parameters are caused by a number of factors. The most important of them are:

a) land waters; if they constitute glacier waters flowing directly off the glacier, so their temperature is about 0° C; if they flow over the land area (moraines, tundras), their temperature is usually higher than 0° C. These waters carry usually great amounts of suspended matter, marking distinctly the line of their reach on the fiord area (Swerpel 1977, Majewicz and Pietrucień 1977);

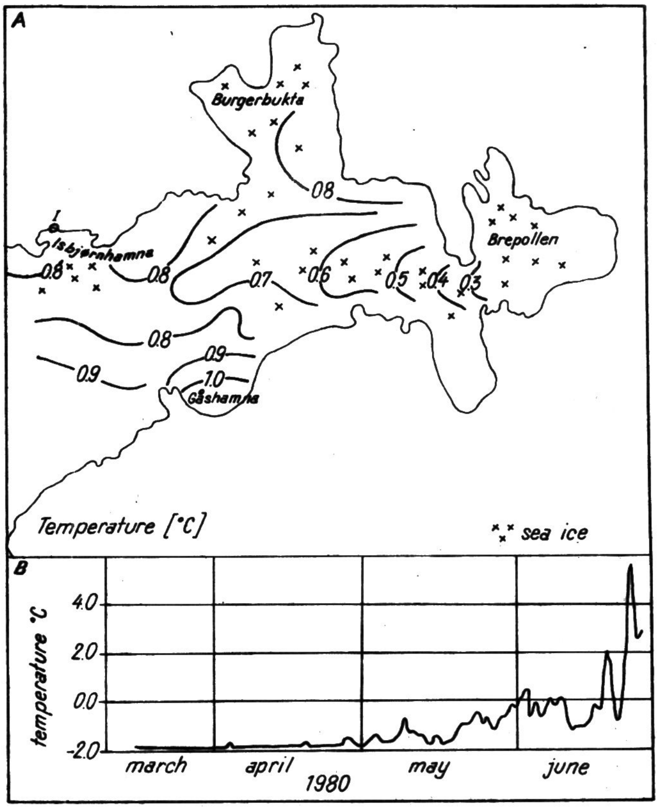

Fig. 10A. Distribution of surface water temperature over the fiord's area on 6th September 1979. 10B. Example of seasonal changes of water temperatures on the sea surface at the measuring point I at Isbjørnhamna

b) sea ice and processes connected with it: summer melting and autumn-winter formation of new ice cover;

c) solar radiation causing warming up surface waters, particularly on very shallow areas;

d) air temperature fluctuations creating conditions for the heat exchange at the contact of sea with atmosphere;

e) tides, particularly in the regions of shallow bays.

The influence of the above factors in the coastal waters of Hornsund is differentiated and quickly vanishes in direction of the fiord open from the seaside. Land waters can sometimes determine hydrological conditions in some fiords, if the access to them of oceanic waters is difficult. An example of such a situation on Spitsbergen is Van Mijenfjorden (Schei et al. 1979). In Hornsund the greatest area being under the influence

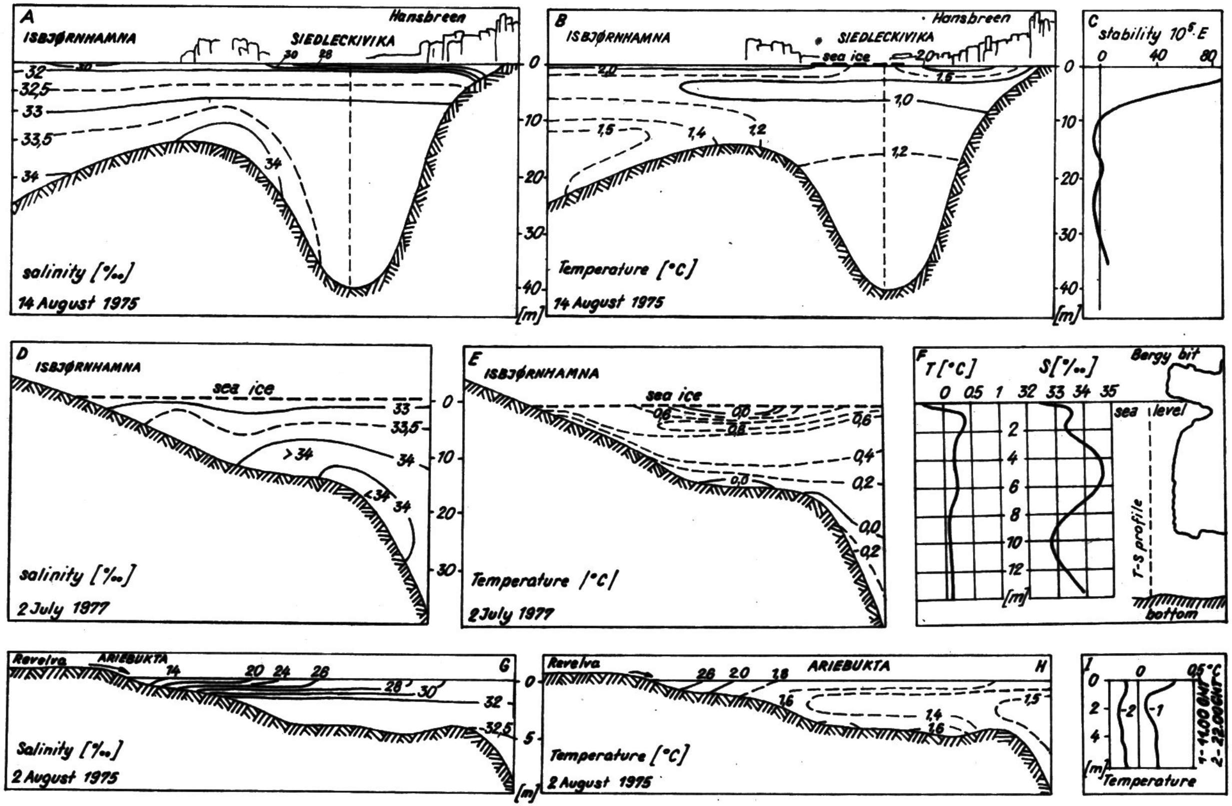

Fig. 11. Example of various hydrological situations in coastal waters of the Hornsund Fiord (explanation in the text)

of land waters occurs on the area of Brepollen. This is marked by the temperature distribution of surface waters in summer (Fig. 10A). The efflux of surface waters from Brepollen is recompensed by the influx of warm waters from the fiord. The exchange is influenced here most often by the wind and tide conditions.

A typical example of the glacier's influence on hydrological conditions of the adjacent water basin in the summer season can be the bays situated directly in the zone of the Hansbreen glacier: Isbjørnhamna, Siedleckivika, Hansvika and Kamavika (Fig. 11). On the surface of these water basins the influence of land waters is noticed: the salinity decreases below $30^0/_{00}$ the temperature is higher than 2° C. They are mainly Hansbreen Glacier waters and snowmelt waters from adjacent land areas. The surface layer of these waters displays a distinct thermohaline stratification. Just on the surface river and glacier waters as well as waters from melting sea ice are to be found. Their temperature increases due to heat exchange process and under the effect of insolation. Below the temperature rapidly decreases and the salinity grows. A thin layer of high temperature and salinity gradients is connected with cold glacier waters and waters of melting sea ice, the temperature of which did not increase mainly due to a limited solar radiation. The temperature minimum occurs at the depth of 5–7 m, where the value of salinity gradients considerably decreases. The water salinity is there of the order of $32.5^0/_{00}$, i.e. approximates oceanic one. This minimum is most probably formed in consequence of cooling the mixed oceanic and land waters caused by longer stay of the sea ice and by a decrease of the temperature near the ice wall. The high stability occurring in the water column above (Siwecki and Swerpel 1979) decreases at this depth. The graph of the stability function in the vertical profile in Siedleckivika is presented in Fig. 11C. Its value at the depth of 10 m drops down to zero. Below this depth there occurs a labile equilibrium, which considerably facilitates mixing. In the surface layers mixing processes are difficult and at a lack of the effect of some other factors, like winds, the stratification maintains. Typical sea waters occur in coastal basins below 10 m.

An example of formation of thermohaline conditions in the bay with sea ice occurring in masses on its surface is presented in Fig. 11 D, E. This is a start of the stratification process after mixing bay waters and influx of ice during the several-day storm. With a compact ice cover (pack ice of various size, bergy bits) a decrease of the salinity and temperature on the sea surface is connected. The temperature maximum is shifted downwards. Cooling of the surface leads to a disturbance of equilibrium in the water column and then to a gradual formation of the temperature minimum at the depth of about 5 m (Fig. 11B).

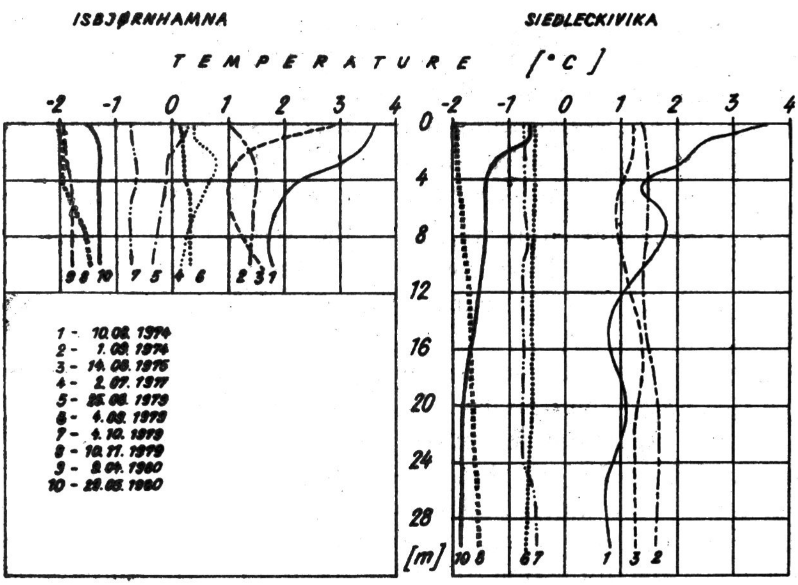

Fig. 12. Examples of vertical distribution of water temperature at measuring points at Isbjørnhamna and Siedleckivika in particular year seasons

Also big forms of sea ice (icebergs and their bits) can considerably affect at someplaces the water temperature and salinity distribution (Fig. 11F). Characteristic phenomenon of the salinity decrease at the ice block foot occurs here.

An example of the coastal water basin of Hornsund into which river waters are inflowing, is presented also in Fig. 11 G, H). Waters of the Revelva River, one of the greatest rivers in the Hornsund region, are inflowing into Ariebukta A considerable freshing of bay waters in the summer season is taking place here. At the river shore the salinity of surface waters drops below $15^{0}/_{00}$. The vertical gradients of salinity are the highest to the depth of 2 m. They reach at the shore $10^{0}/_{00}/1$ m.

The water temperature in bays, into which land waters flow, varies considerably within 24 hours. In cool part of the day the temperature decreases near outlets in the whole vertical profile (Fig. 11 I).

The process of freshing of bay waters under the land water effect occurs most clearly in Nottinghambukta (Fig. 4). The bay is closed from open sea by the archipelago of Dunoyane. On a half of this area depths are less than 0.5 m, the maximum depth amounting to 2.5 m, The bay is defined as an arctic estuary or as a tide bay. Namely, two elements are responsible here for hydrological conditions, viz.: tide phenomena and waters of the Werenskiøld Glacier inflowing into it. Isohaline $5^{0}/_{00}$ constituting the border of reach of land waters runs during ebbtide outside the bay. In summer the water temperature in bay assumes the values of 0.5–0.9° C (Students Oceanographers Scientific Group — edit. 1981).

The temperature of coastal waters undergoes considerable fluctuations in the whole vertical profile in the course of year. In Fig. 12 its changes at two measuring point at Isbjørnhamna and Siedleckivika, are presented.

In summer the teperature values in the vertical profile drop only in some cases below 0° C. Their courses are sometimes complicated in view of a number of elements determining thermal conditions. Curve 4 (Isbjørnhamna) presents the vertical course of the water temperature under sea ice brought onto the bay surface during storm. Then a gradual cooling of the surfące water layer occurs. If ice stays for a long time over the bay surface and no conditions for mixing occur, so the temperature minimum can form at the depth of about 5 m (prof. 1, Siedleckivika). A massy inflow of warm river waters and intensive solar radiation cause sometimes a considerable increase of the temperature of surface waters and lead to the thermocline formation (prof. 1, Isbjørnhamna). In the profile 2 temperature gradients are low due to a strong mixing of bay waters during storm.

In autumn the temperature decreases in the whole vertical. Its courses are of isothermal character (profiles 6, 7). Temperatures on the sea surface are lower than at the bottom. Further cooling creates favourable conditions for the ice cover formation. Surface water is often cold, having the temperature less than its freezing temperature (prof. 8). In winter (profile 9, Isbjørnhamna) temperature values in the whole vertical usually are not higher than $-1.8°$ C. Only disapperance or disintegration of the ice cover and a subsequent inflow of land waters early in summer cause changes in the vertical distribution of temperatures advancing from sea surface (prof. 10).

Variability of thermohaline conditions of surface water can be presented in a statistical diagram T-S. In Fig. 13 such elaboration for 3 seasons: summer, autumn-winter and winter-spring one, carried out on the basis of measurements at a shore part of Isbjørnhamna (point I in Fig. 10A) is presented. The linear type of the distribution with the distinct temperature maximum within the interval of $-2.0 \leqslant T < -1.5°$ C in the autumn-winter season (over 80% of all samples in a series) assumes in spring a more dissipated character, and the distribution of samples is determined by solar radiation and snow- and icemelt. With oncoming summer season the temperature maximum leaves gradually its distinct character and shifts towards higher values. On the other hand, in the salinity distribution the maximum within the interval of $32 \leqslant S < 34^0/_{00}$ begins more and more clearly predominate. Summer samples are concentrated around mean values of temperature and salinity.

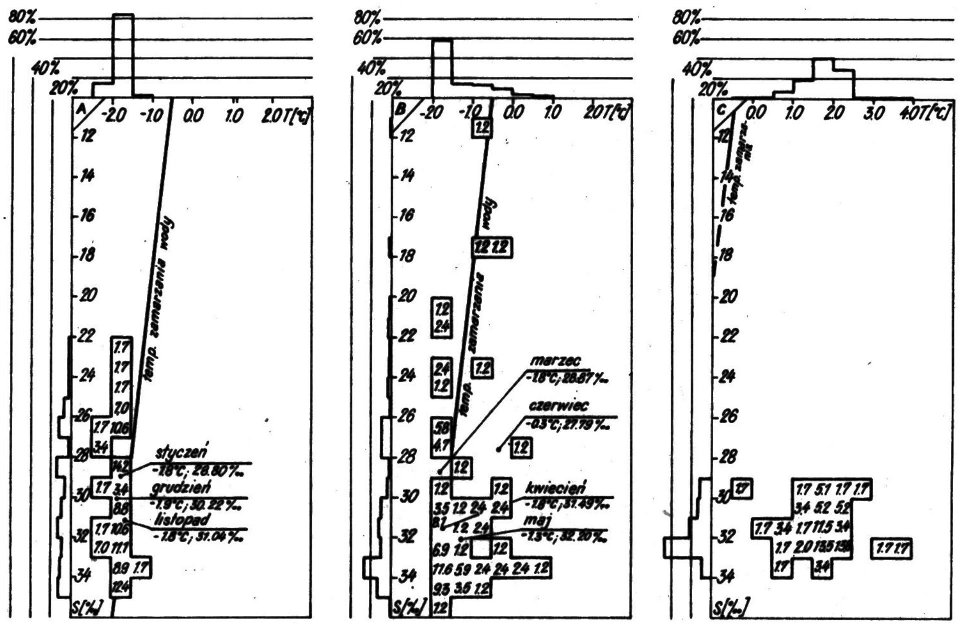

Fig. 13. Statistical diagrams T–S made on the basis of measurements of temperature and salinity of surface water at the measuring point at Isbjørnhamna. Specifications for the periods: A — 19th November 1979-27th January 1980, B — 14th March 1980–13th June 1980, C — 15th July 1975–10th September 1975 (Siwecki and Swerpel 1979). The occurrence frequency of samples is given within the intervals of $\Delta T = 0.5°$ C, $\Delta S = 1^{0}/_{00}$. The position of samples of mean values for particular months is marked

Values of mean sample for November approximate the freezing temperatures, whereas mean values for December and January distinctly indicate the occurrence of cooled surface water. The point of mean values for measurements carried out in March is at the left side of the line determining the water freezing temperatures — water is not yet cooled. In April values of mean sample approximate the freezing temperature, in May and June temperatures are higher than the former. Fluctuations of surface water temperature at this point in winter-spring season are presented in Fig. 10 B.

7. Conclusions

7.1. The Hornsund Fiord is steadily affected by the margin of warm waters of West Spitsbergen Current, cold Sørkapp Current and own inner waters, the development of which is closely connected with the year season.

7.2. Warm Atlantic waters are responsible for hydrological conditions mainly in the middle part and partly in inner and coastal areas of the fiord. They separate by-bottom waters from the layer of surface and intermediate waters chacking the processes of convectional mixing between them. Processes forming different hydrological conditions are of a very dynamical course in the layer over Atlantic waters.

7.3. The Sørkapp Current originating in Storfjorden extends also over waters of the sea area surrounding the South Spitsbergen, viz: Sørkapp Banken and Hornsund Banken. Local Hornsund waters are forming in the way very approximating the formation of waters of Sørkapp Current in Storfjorden (effect of surface waters, winter cooling of Atlantic waters). Thus it can be generally spoken about the Spitsbergen Coastal Water Current.

7.4. In the cooling processes of surface and Atlantic waters running both in winter and summer, cold local waters are forming. 'his is visible most clearly in Brepollen (Cool Brepollen Water and Winter Cooled Brepollen Water).

7.5. Activity of surface waters is connected mainly with the zone of coastal water basins and is taking place in summer only. In autumn, due to checking the inflow of fresh waters this layer disappears leaving room to the processes connected with the formation of the sea ice cover in the fiord.

7.6. Sea ice strongly affects the structure of fiord waters in the surface layer. It is connected with the temperature minimum occuring there in summer. In winter its cover forms a barrier checking the heat exchange processes between sea and air and leads to the formation of cold coastal waters, partically inside the fiord.

8. Резюме

Район моря вокруг южного Шпицбергена находится под влиянием теплого Западно-Шпицбергенского течения и холодного Течения южного мыса (рис. 1 и 2). На их границе образуется постоянный гидрологический полярный фронт (рис. 3). Благодаря морфологии дна крайняя часть теплых атлантических вод легко проникает во фиорд Горнсунд. В его центральной части стержень этих вод выступает на глубине разряда 70—100 м, а первую очерадь на северной стороне фиорда (рис. 5 и 6). Воды Западно-Шпицбергенского течения отделены четкой термоклиной от остальных водных слоев.

В расположенных более выского посредственных водах часто встречаются многочисленные переслоения более теплой и более холодной воды. Их генез связан с выступанием морского льда, влиянием поверхностного стержня Течения южного мыса и с местными водами фиорда.

Воды внутри фиорда характеризуются различной гидрологической структурой в сравнении с его центральной частью. Это можно особенноч четко наблюдать на Бреполлен (рис. 7 и 8). Это единственный район фиорда Горнсунд, в котором установлено

наличие летом холодной воды (Winter Cooled Brepollen Water) залегающей вблизи дна и образующейся главным. образом в зимний период (рис. 9.).

Связанный с летним сезоном слой поверхностных вод является наиболее заметным на Бреполлен, внутри фиорда и в прибрежных водоемах (рис. 10 A). В нем часто наблюдается термическая инверсия, а также очень высокие градиенты температуры и засоленности. Это связано с влиянием континентальных вод, морского льда, солнечной радиацией и процессами обмена тепла с атмосферой (рис. II). Термогалические условия в прибрежной зоне изменяются очень значительно как на поверхности моря так и в вертикальном профиле на протяжении года (рис. 12 и 13).

9. Streszczenie

Rejon morza dookoła południowego Spitsbergenu znajduje się pod wpływem ciepłego Prądu Zachodniospitsbergeńskiego i zimnego Prądu Południowego Przylądka (fig. 1 i 2). Na ich granicy tworzy się stały hydrologiczny front polarny (fig. 3). Dzięki ukształtowaniu dna skrajna część ciepłych wód atlantyckich łatwo wnika do fiordu Hornsund. W jego części centralnej rdzeń tych wód występuje na głębokości rzędu 70 ÷ 100 m głównie po północnej stronie fiordu (fig. 5 i 6). Wody Prądu Zachodniospitsbergeńskiego odgraniczone są wyraźną termokliną od pozostałych warstw wodnych.

W położonych powyżej wodach pośrednich występują często liczne przewarstwienia cieplejszej i zimniejszej wody. Ich geneza wiąże się z występowaniem lodu morskiego, wpływem powierzchniowego rdzenia Prądu Południowego Przylądka oraz z wodami lokalnymi fiordu.

Wody wnętrza fiordu posiadają odrębną strukturę hydrologiczną niż jego część centralna. Szczególnie widać to na Brepollen (fig. 7 i 8). Jest to jedyny rejon Hornsundu, w którym stwierdzono występowanie latem zimnej wody (Winter Cooled Brepollen Water) zalegającej przy dnie a tworzącej się głównie w porze zimowej. (fig. 9).

Związana z porą letnią warstwa wód powierzchniowych jest najbardziej widoczna na Brepollen, wewnątrz fiordu i w akwenach przybrzeżnych (fig. 10A). Występuje w niej często inwersja termiczna oraz bardzo duże gradienty temperatury i zasolenia. Wiąże się to z wpływem wód lądowych, lodu morskiego, radiacją słoneczną i procesami wymiany ciepła z atmosferą (fig. 11). Warunki termohaliczne w strefie przybrzeżnej zmieniają się zarówno na powierzchni morza jak i w profilu pionowym bardzo znacznie w ciągu roku (fig. 12 i 13).

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