ISSN 0001-4370, Oceanology, 2015, Vol. 55, No. 4, pp. 472–484. © Pleiades Publishing, Inc., 2015.
Original Russian Text © A.G. Zatsepin, S.G. Poyarkov, V.V. Kremenetskiy, A.A. Nedospasov, S.A. Shchuka, V.I. Baranov, A.A. Kondrashov, A.O. Korzh, 2015, published in Okeanologiya, 2015, Vol. 55, No. 4, pp. 526–539.

Hydrophysical Features of Deep Water Troughs in the Western Kara Sea

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Received September 30, 2014; in final form February 25, 2015

Abstract—In the 59th cruise of the RV *Akademik Mstislav Keldysh* (September–October, 2011) a large amount of hydrophysical data was obtained with the help of various measuring systems. The data allowed us to study the dynamics and hydrological structure of deep-sea troughs of the western part of the Kara Sea at a high spatial resolution. In particular, the analysis of this material showed that a cyclonic jet exists in the central spur of the St. Anna Trough at depths of 150–300 m and penetrates down to the bottom. The jet is able to play a role of a dynamic barrier that prevents the penetration of water from the southwestern part of the Kara Sea to higher latitudes. In the eastern spur of the St. Anna Trough, the jet weakens, becomes less barotropic, and can no longer inhibit the northward spreading of the shelf waters of the Kara Sea. The weakest and least coherent currents were recorded in the Novaya Zemlya trough, in the southern part of which we traced waters of a Barents Sea origin.

DOI: 10.1134/S0001437015040165

INTRODUCTION

The present study continues the research initiated in the 54th cruise of the RV *Akademik Mstislav Keldysh* in the Kara Sea (September–October, 2007). During this cruise, use was made of a wide range of hardware and software for the continuous recording of the hydrophysical features of the surface layer, the scanning of the 150–200-m layer to measure the vertical profiles of current velocity, vertical profiling of hydrophysical and bio-optical characteristics at stations, receiving satellite imagery (SST, concentration of chlorophyll-a, radiance). As a result, a large volume of data, unique in its spatial–temporal resolution and informativeness, has been acquired, which allows us to obtain valuable experimental evidence concerning the dynamics and hydrological structure of the southwestern Kara Sea. It was shown that the main elements of the general circulation of water in the aquatic area examined involve the Yamal Current, the east Novaya Zemlya current, and a current in the central spur of the St. Anna Trough as well a current related to a lens of waters desalinated due to river runoff [5]. The first three of the above currents are topography referenced, i.e., they follow the isobaths and propagate lengthwise along the bottom slope. The Yamal current arises near the Karskie Vorota strait and follows in a cyclonic direction a 100 m isobath along the Yamal shores. It was found that the east Novaya Zemlya current, which is located near the western slope of the Novaya Zemlya basin, moves to the northeast rather than to the southwest, contrary to current ideas [16]. This current intersects the loop current in the spur of the trough, comes off from the shore, and propagates further eastward, near the northern tip of the Novaya Zemlya, close to the isthmus that separates the central spur of the St. Anna Trough and the Novaya Zemlya basin. The interaction of these currents leads to the formation of a sharp front that divides the relatively warm and salty waters of the loop current from the cooler and desalinated waters of the western Kara Sea. These observations provided a basis to the inference that the isthmus, being only 100–150 m deep, is a barrier preventing the penetration of the transformed Atlantic waters of the Arctic basin through the St. Anna Trough into the western Kara Sea [5].

The present work refines and supplements concepts resulting from the analytical treatment of data collected during the 59th cruise of the RV *Akademik Mstislav Keldysh* in September–October 2011. Specifically, we compare the dynamics and structure of the waters in the central and eastern spurs of the St. Anna Trough. We refine the question concerning the effect of topography-bound dynamic fronts in spurs of the trough upon the propagation of waters of the surface desalinated layer (SDL [3]) near the shores of Novaya Zemlya. Profiles of current velocity, temperature, salinity, and water density, recorded with the profiling probe "Aqualog" [8, 9, 13] are given. The latter was anchored at the isthmus between the central spur of the St. Anna Trough and the Novaya Zemlya basin. In

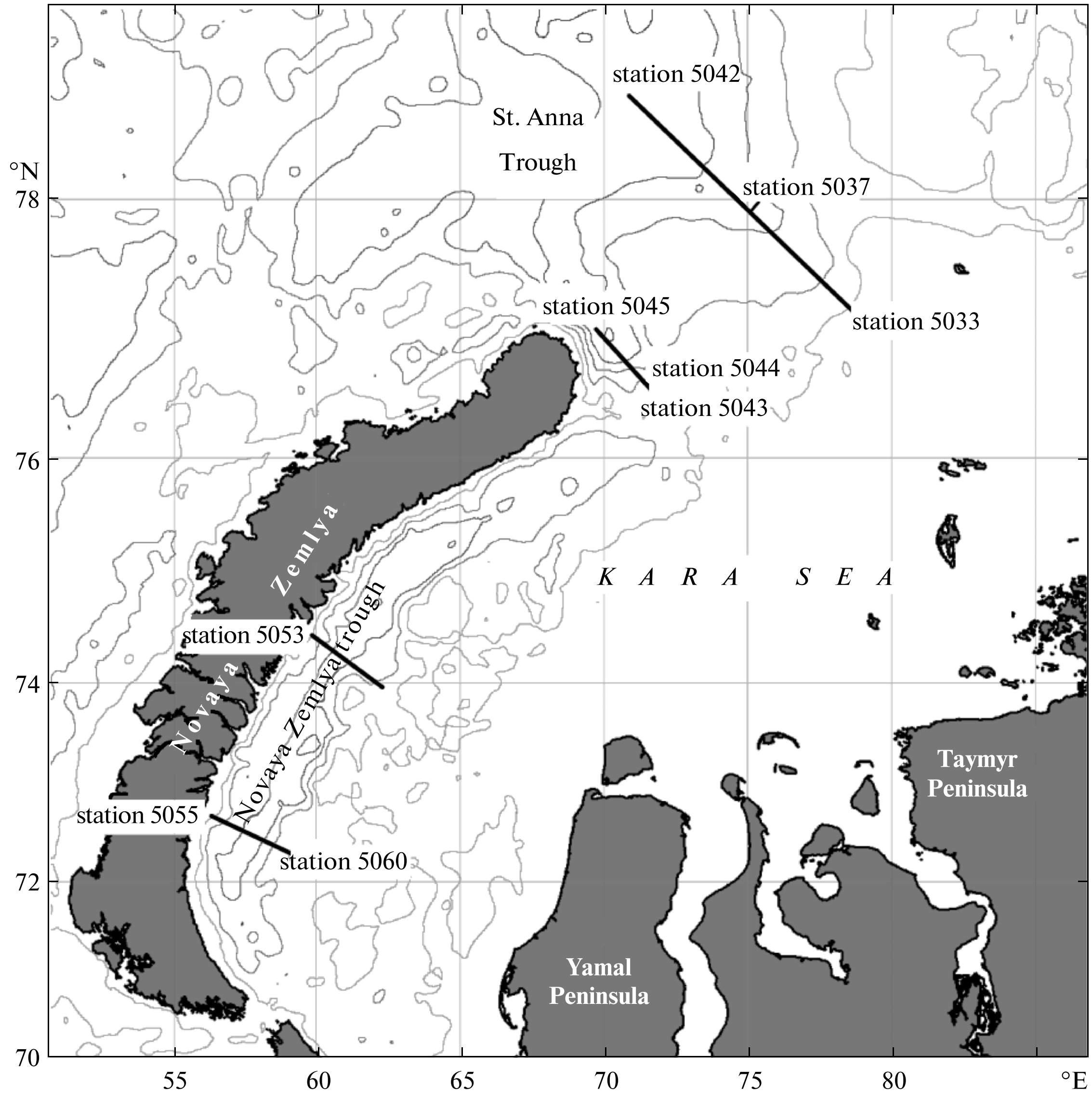


Fig. 1. Study areas in the Kara Sea in September–October, 2011.

addition, we checked the occurrence of the east Novaya Zemlya current over the western slope of the basin and refined its direction.

STUDY AREA, TECHNIQUES, AND MEANS OF OBSERVATION

The locations of transects of the towed scanning hydrophysical probe (TSP) "Rybka," the stations of CTD-profiling, and towed ADCP measurements are given in Fig. 1.

The 2011 study involved almost the same hardware complex as was used in 2007 during the 54th cruise of the RV *Akademik Mstislav Keldysh* (see [3, 5]). The present study is based on the following data: a) the vertical distributions of hydrophysical and bio-optical characteristics obtained at stations with the CTD-probe SBE-19plus supplemented with transparency and fluorescence sensors; b) vertical scans of water thickness obtained underway with the towed hydrophysical CTD-probe Idronaut (TSP "Rybka"); c) current velocity measured underway with a towed ADCP RDI (300 kHz) in a streamlined body under "bottom tracking" conditions; d) current velocity, temperature, salinity, and density measured with the self-contained profiling probe "Aqualog" at anchor station [8, 9, 13].

The transect along the central spur of the St. Anna Trough. The TSP "Rybka" and the ADCP were towed when passing into the spur of the trough from south to north up to the 200 m isobath. On the way back, complex CTD-stations were occupied. The distributions of temperature and salinity, based on the data of TSP "Rybka", are given in Figs. 2a and 2b.

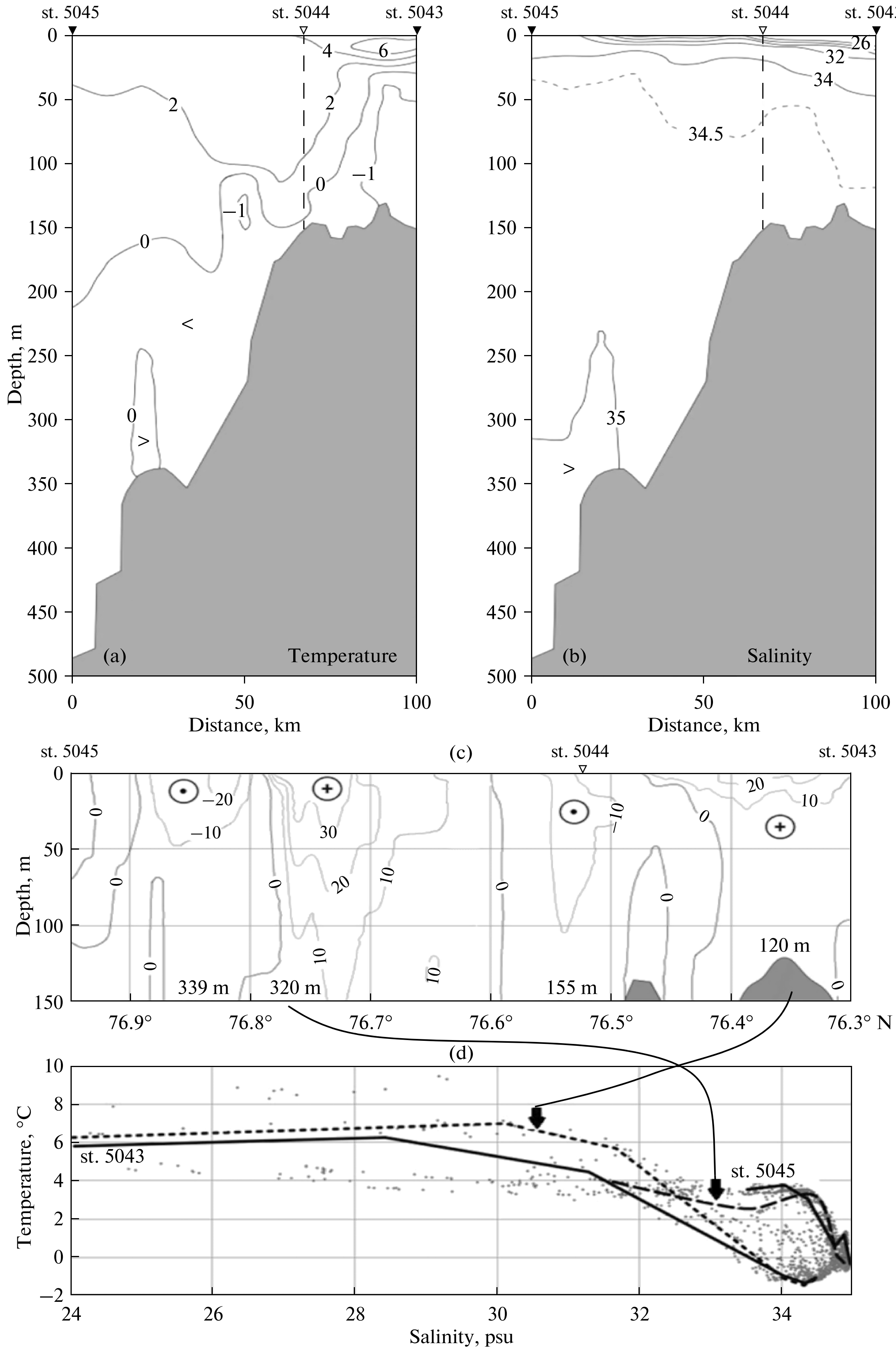
A well-defined "overthrust" of desalinated (22–26 psu) and warm (more than 6°C) surface waters in the thin 10–15-m layer merits notice. The frontal interface, outcropping at station 5044 (see below), marks the "overthrust."

Figures 2c and 2d demonstrate the geostrophic currents calculated from the data of TSP "Rybka" in the transect along the central spur of the St. Anna Trough as well as the *TS*-relationships in transects along both spurs of the trough. Here and in the following, local depth is considered as a reference depth level of zero velocity. This choice is justified by direct ADCP measurements of current velocities at reference sites of the study area. These measurements were performed in several tidal cycles and provided evidence that bottom currents faster than 5 m s^{-1} were actually conditioned during the study period by the barotropic component of tides.

The most powerful jet of the northeastern transport at 76.7°–76.8° N (Fig. 2b) belongs to the loop current of the central spur of the St. Anna Trough. It is easy to recognize the transect of the temperature field (Fig. 2a) where the more than 100 m thick layer of warmer water (2.0–4.0°C) occurs over the slope while the background temperature at the same depth is at least one degree lower. The current, whose geostrophic velocity in the core is as high as 35 cm s^{-1}, is located above the steep slope from 170 to 320 m deep and, apparently, penetrates down to the very bottom. Another domain of the northwest-bound current at 76.3°–76.4° N above the 120–130-m depth is confined (excluding the upper 20–30-m layer) by an almost vertical wall of cold waters (Fig. 2a). They are distinguished by negative temperature and belong to the proper waters of the Kara Sea. According to information from the 54th cruise of RV *Akademik Mstislav Keldysh*, a well-defined frontal interface has been discovered in this region. It is related to the convergence zone between the loop current in the central spur of the St. Anna Trough and the east Novaya Zemlya current, which bears desalinated waters [5]. Under conditions of observations in 2011, this current occurs independently rather than due to the frontal zone of the SDL. The reason is that the layer, entrained in well-defined northeastern transport, is much more than 20 m thick (this is an approximate thickness for the SDL) and is characterized by a velocity as high as 25 cm s^{-1} (Fig. 2c). At the same time, this current prevents the propagation of the desalinated water further northwards. Therefore, it is possible that this current is a continuation of the east Novaya Zemlya current, which comes off from the northeastern shores of Novaya Zemlya. If so, contrary to 2007, this current did not contact the loop current of the central spur of the St. Anna Trough in 2011 since the temperature is at least 1°C lower at these depths. The current, whose geostrophic core velocity at the surface reaches 35 cm s^{-1}, occurs above the steep slope at depths from 170 to 320 m and, apparently, extends down to the very bottom. Another area of the northeast bound current at 76.3°–76.4° N above the 120–130-m depth is limited by a virtually vertical wall of cold waters, excluding the upper 20–30-m layer (Fig. 2a). This water has a negative temperature and belongs to the proper waters of the Kara Sea. According to the data of the 54th cruise of RV *Akademik Mstislav Keldysh*, a well-defined frontal interface has been discovered just in this area, the interface being related to the convergence zone between the loop current in the central spur of the St. Anna Trough and the east Novaya Zemlya current transporting the desalinated waters [5]. Under conditions of observations in 2011, this current occurs independently rather than due to the frontal zone of the SDL. The reason is that the layer, entrained in the well-defined northeastern transport, is much more than 20 m thick (this is an approximate thickness of the SDL) and is characterized by velocity as high as 25 cm s^{-1} (Fig. 2c). At the same time, this current prevents the propagation of the desalinated water further northwards. Therefore it is possible that this current is a continuation of the east Novaya Zemlya current, which comes off from the northeastern shores of Novaya Zemlya. If so, in contrast to 2007, this current does not contact the loop current of the central spur of the St. Anna Trough in 2011 but detaches from the latter by the southwestern countercurrent (Fig. 2c). It penetrates to a depth of 150 m and has a surface velocity of up to 20 cm s^{-1}.

The nature of this countercurrent is not quite clear. Possibly it is not stationary but is related to variations of the loop current in the trough. Let us imagine that the current in the trough enhances, ascends along the slope, and even crops out at the sill that separates the central spur of the St. Anna Trough from the Novaya Zemlya trough. Then, as follows from the law of conservation of potential vorticity, an anticyclonic circulation, namely the southwest-directed current, must arise around the elevation. Exactly this is demonstrated in Fig. 2c. It is not inconceivable that the occurrence of the southwestern transport between jets of southwest-directed currents is due to mesoscale eddy structures similarly to the pattern at 76.8°–76.9° N.

Fig. 2. Sections along the central spur of the St. Anna Trough, according to data of the TSP "Rybka." (a) temperature, °C. (b) salinity, psu, (white triangle marks the site of deployment of the "Aqualog" profiler), (c) distribution of geostrophic velocity, cm s^{-1}, in the layer from 0 to 150 m; fletching (figure symbol) means northeastward water transport, while arrow (figure symbol) designates opposite southwest water transport; below are highlighted the bottom depths underlying jets of currents revealed. (d) TS diagram for both sections along the central and eastern spurs of the St. Anna Trough. Solid T,S curves designate the beginning (station 5043) and the end (station 5045) of section in the central spur. Dashed T,S curves mark two recognized jets of northeast transport.


st. 5045
st. 5044
st. 5043
Depth, m
Temperature
Salinity
(a)
(b)
(c)
(d)
Distance, km
339 m
320 m
155 m
120 m
76.9°
76.8°
76.7°
76.6°
76.5°
76.4°
76.3° N
Temperature, °C
Salinity, psu

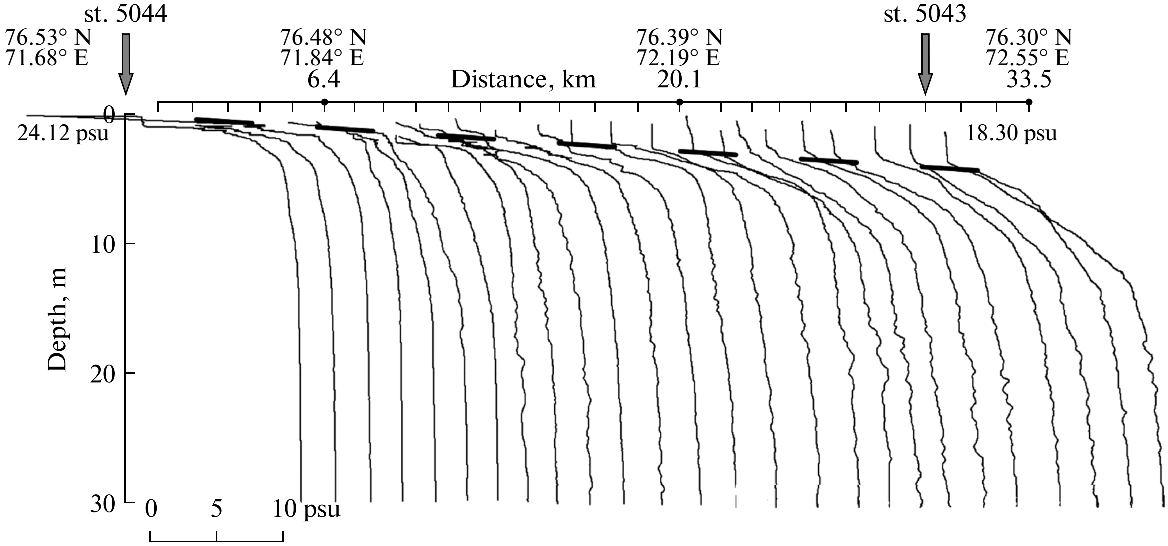


Fig. 3. Sequential distribution of vertical profiles of salinity in the 0 to 30-m layer from data of the TSP "Rybka" recorded between stations 5043 and 5044 in the central spur of the St. Anna Trough. The dashed line designates the frontal interface of the surface desalinated layer (SDL) of the Kara Sea. The scale of vertical changes in salinity (psu) is given at the foot of the figure.

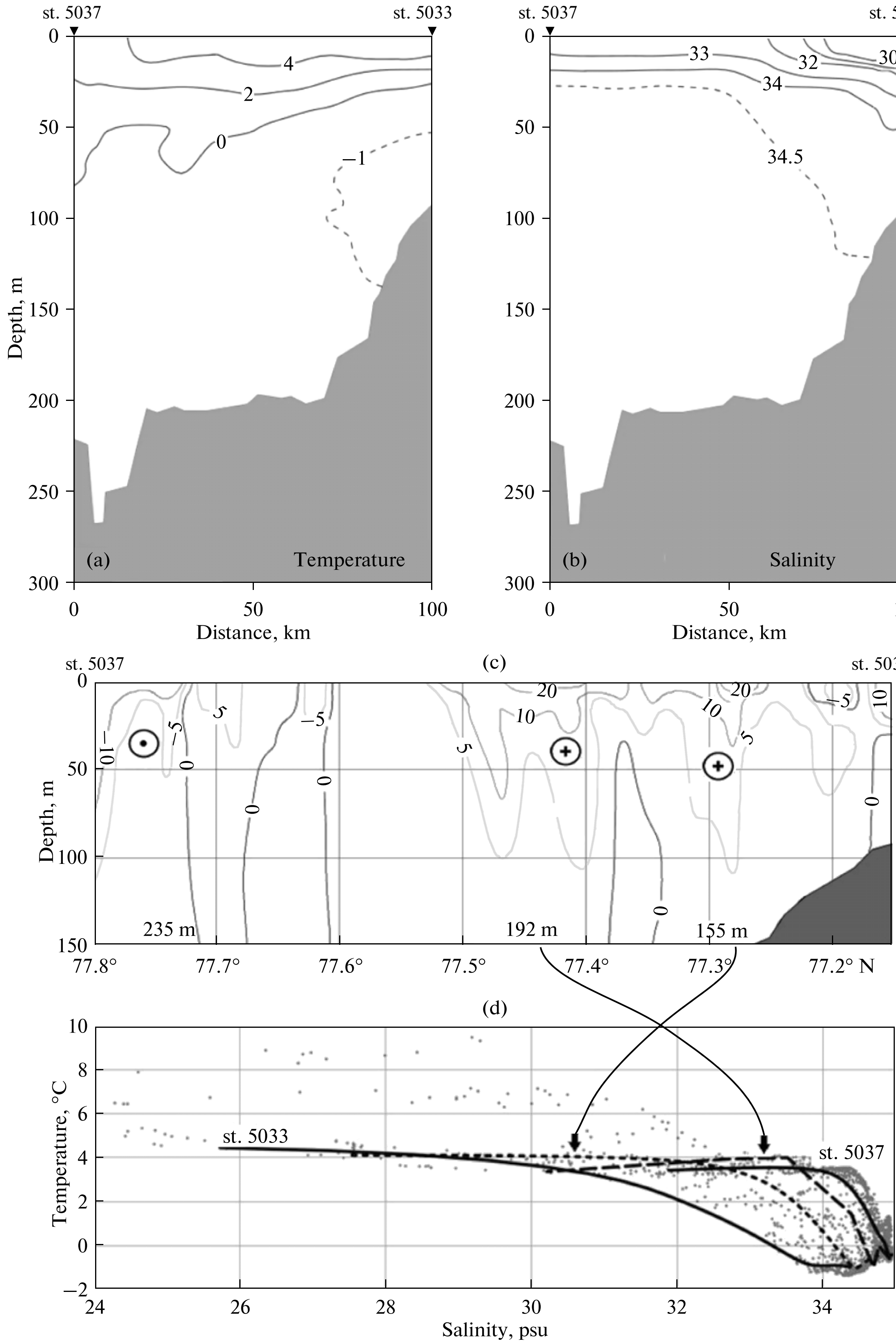
As already noted, the dynamic frontal zone that forms from the northeastern current, detached from the northern tip of Novaya Zemlya, and the adjacent countercurrent, limits the northward propagation of the SDL. Fig. 3 shows the incremental distribution ("paling") of vertical profiles of salinity from the data of the TSP "Rybka" in the upper 30-m layer in the transect from station 5043 to station 5044. It is evident that the frontal interface, cropping out at station 5044, occurred exactly between these stations. Records of surface salinity, obtained with the help of a an underway flow-through system, show that the salinity jump associated with the SDL front made up about 10 psu (from 22 to 32 psu) with a frontal zone that was only 200 m wide. It should be noted that a front of such sharpness occurred under gentle breeze conditions lasting at least a week before observations. When returning two days later, with a stronger wind, up to 12–14 m s^{-1}, crossing the same part of the aquatic area, no sharp frontal interfaces were revealed. This circumstance indirectly supports the hypothesis on radical transformation of frontal zones of SDL in the Kara Sea due to the impact of strong wind [4].

Transect along the eastern spur of the St. Anna Trough. This transect is about 100 km long. The CTD stations were occupied when passing from south to north into the spur of the trough. In the return itinerary from north to south, the TSP "Rybka" and the ADCP were towed from the 200-m deep isobath to shallower depths. The sections in the fields of temperature and salinity, based on data of the TSP "Rybka", are shown in Figs. 4a and 4b.

In this transect and in the central spur of the trough alike, more desalinated (less than 30 psu) and warmer (about 4°C) waters from the south of aquatic area, were traceable in the upper 10–20-m layer as far as 30 km from station 5033. In total, the water structure over the upper part of the trough slope down to 100–130 m corresponded to the water structure of the southwestern Kara Sea as far as 77.35° N. However, Arctic waters occupied the center of the area about 200 m deep from 77.4° to 77.6° N.

A detailed view of the geostrophic currents from the data of TSP "Rybka" and calculations of the *T,S*-relationships for both transects along the central and eastern spurs of the trough is given in Figs. 4c and 4d. From this figure, we notice that the northeast-bound current in transect from 77.2° to 77.6° N is not coherent but involves two adjacent jets whose velocity measures 20–25 cm s^{-1} in the surface 10-m layer. It should be noted that the pattern of geostrophic currents, calculated from the CTD data, revealed only one current jet across the trough. This is attributable to the large separation of CTD observations (the between-station distance was about 10 miles). Thus, the data of the TSP "Rybka"

Fig. 4. A part of section along the eastern spur of the St. Anna Trough based on the TSP "Rybka" data: (a) the temperature, °C; (b) salinity, psu; (c) distribution of geostrophic current's velocity (cm s^{-1}) in the 0-150 m layer (the fletching means northeastward water transport while the arrow head designates the opposite southwest water flow; below are highlighted the bottom depths underlying jets of currents revealed); (d) *T,S*-diagram for both sections along the central and eastern spurs of the St. Anna Trough. Solid TS curves characterize stations 5033 and 5037 of the eastern section and the dashed *T,S* curves mark two recognized jets of northeast transport.


st. 5037
st. 5033
Depth, m
Distance, km
(a)
Temperature
(b)
Salinity
(c)
(d)
235 m
192 m
155 m
77.8°
77.7°
77.6°
77.5°
77.4°
77.3°
77.2° N
Temperature, °C
Salinity, psu

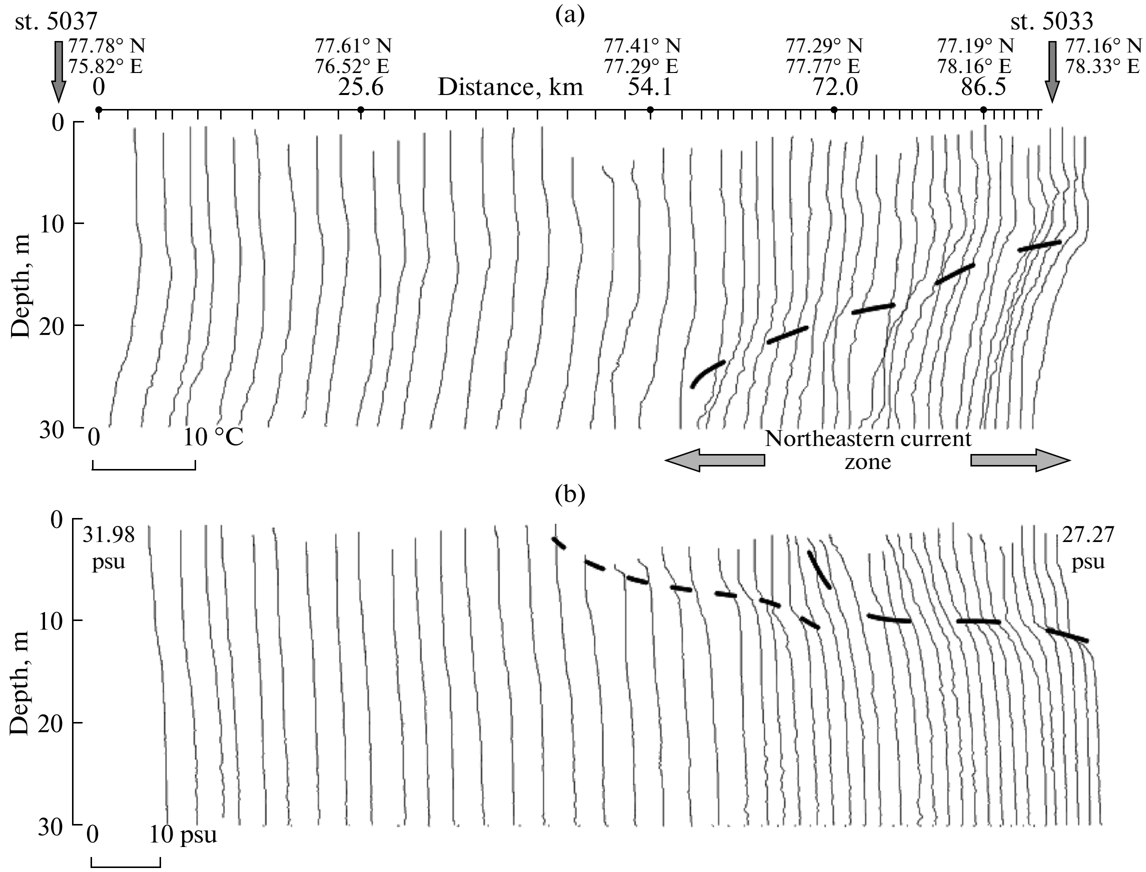


Fig. 5. Sequential distribution of vertical profiles of the temperature (a) and salinity (b) in the 0–30 m layer based on the TSP "Rybka" data from sta 5033 to sta 5037 in the eastern spur of St. Anna Trough. Dashed line marks the frontal interfaces, related to the jets of the northwest transport of waters. The scales of vertical changes in temperature (°C) and salinity (psu) are given at the foot of the figure.

played a key role in discovering the true structure of currents above the eastern spur of the trough.

The jet at 77.3° N (Fig. 4c) is located above the upper part of the slope of the eastern spur of the trough and penetrates virtually down to the bottom. Judging from the T,S-relationships (Fig. 4d), this jet of a northeastern direction bears mostly waters characteristic of the southwestern Kara Sea. The layer of the jet between the 50 and 130 m depth levels featured a cold intermediate layer (CIL) having a temperature of –1.1 to –1.3°C and a salinity of 34.0–34.5 psu (Figs. 4a and 4b), which is quite typical of this part of the sea [7]. It is felt that this jet is a continuation of the Yamal or east Novaya Zemlya current and has no relation to the loop current in the St. Anna Trough.

However, another jet at 77.4°–77.5° N, whose core occurs above the deeper part of the slope (190–200 m) and whose baroclinic component does not penetrate deeper than 100m, belongs apparently to the loop current in the trough because it bears warmer and more salty water (Figs. 4a and 4b). The CIL, being inherent to the waters of the SW part of the Kara Sea, degenerates within this component, but at the same time waters appear distinguished by a cold intermediate layer at 160–240-m levels (Arctic CIL). The temperature and salinity of the Arctic intermediated waters are slightly higher (–0.4 to –0.6°C and 34.7–35.0 psu, respectively), than those typical of the intermediate waters in the SW Kara Sea [7].

Note that, according to observations in the transect across the eastern spur of the St. Anna Trough, SDL waters occur in the surface 10–20-m layer above the upper slope and extend to the domain of the core of loop current (NE transport) only near 77.4° N (Figs. 4b and 4c). Seemingly, this jet limits the further penetration of the desalinated waters northwards, due to which the frontal zone of the SDL is located exactly here (Fig. 5).

The fact that no deep penetrating loop current has been found in the eastern spur of the St. Anna Trough means that the local bottom layer is free of a dynamical barrier that may prevent water exchange between the spur and the shelf zone of the sea. This may be the cause of widespread occurrence of benthic species of the Kara Sea biota in the eastern spur but their negli-

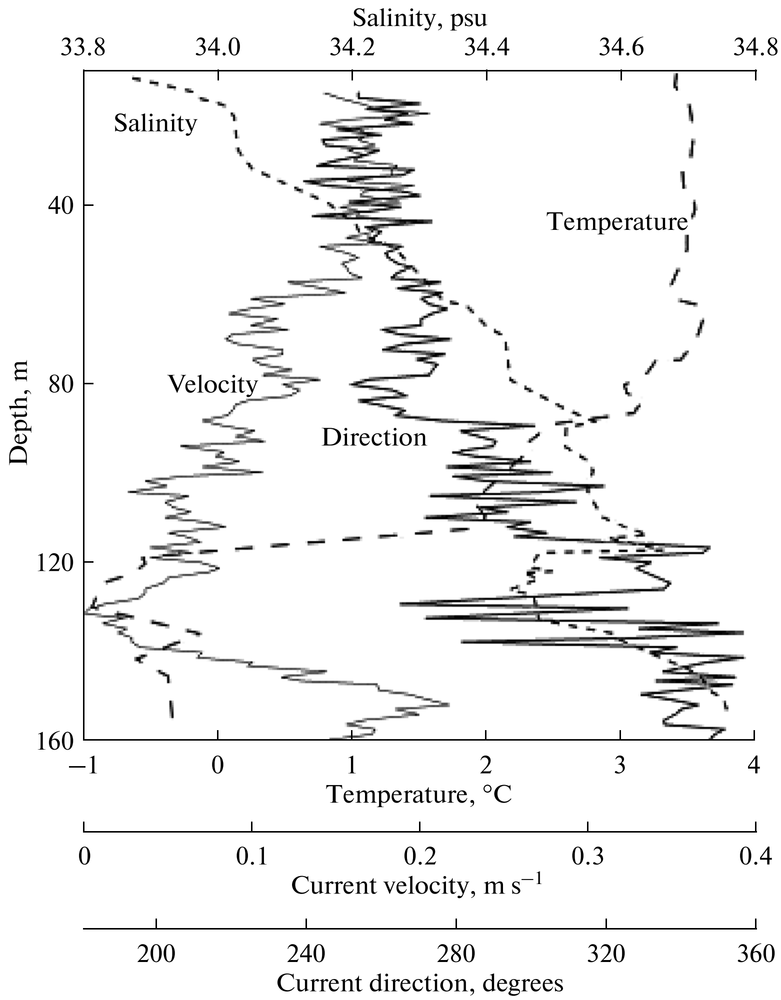


Fig. 6. The distributions of temperature (°C), salinity (psu), current direction (deg) and current velocity (m s^{-1}) in the 10–155 m layer over the isthmus between the central spur of the St. Anna Trough and Novaya Zemlya trough based on the measurement data of the "Aqualog" profiler.

gible presence in the central one [1, 11] where such a barrier exists (see the foregoing).

RESULTS OF DEPLOYMENT OF THE "AQUALOG" PROFILER

The site of the deployment of the anchor station with the "Aqualog" profiler at the isthmus between the central spur of the St. Anna Trough and the Novaya Zemlya trough is shown in Fig. 2. The profiler operated in the frontal zone (Figs. 2a and 2b), which separates the relatively warm and salty waters of the loop current in the trough and the fairly cold and desalinated waters of the southeastern Kara Sea. The deployment took place at 76°32.5′ N, 71°39.9′ E with 157 m of water for profiling from depth levels of 10 to 155 m. The instrument operated from 16:00 on September 28 to 06:00 on September 30; i.e., it functioned for more than one and a half days. The profiler had to perform one up-and-down cycle every hour at a rate of 20 cm s^{-1}, with equal rests between ascending and descending motions. However, due to a failure of the pressure gauge controlling the profiler's functioning, only two full cycles of measurements were accomplished at the beginning of deployment on September 28 from 16:30 to 18:30, another four cycles being successful at the end of the deployment on September 29–30 from 19:00 to 04:30). The rest of the time the instrument operated at a depth of 155 m and was switched on and off every 20 minutes to perform representative measurements of current velocity for 3 minutes.

Figure 6 displays profiles of the temperature, salinity, modulus, and direction of current velocity from the data of "Aqualog" profiler at the initial stage of its operation. It is evident that the probe moved in warmer water above a 110-m depth, but below 120 m it occurred in substantially colder water. Most likely, the latter originated from the Kara Sea. It should be noted that measurement-based data point to a mostly westward transport of waters in the upper 100-m layer, which corresponds to the calculations of geostrophic velocity in Fig. 2c, while northward transport pre-

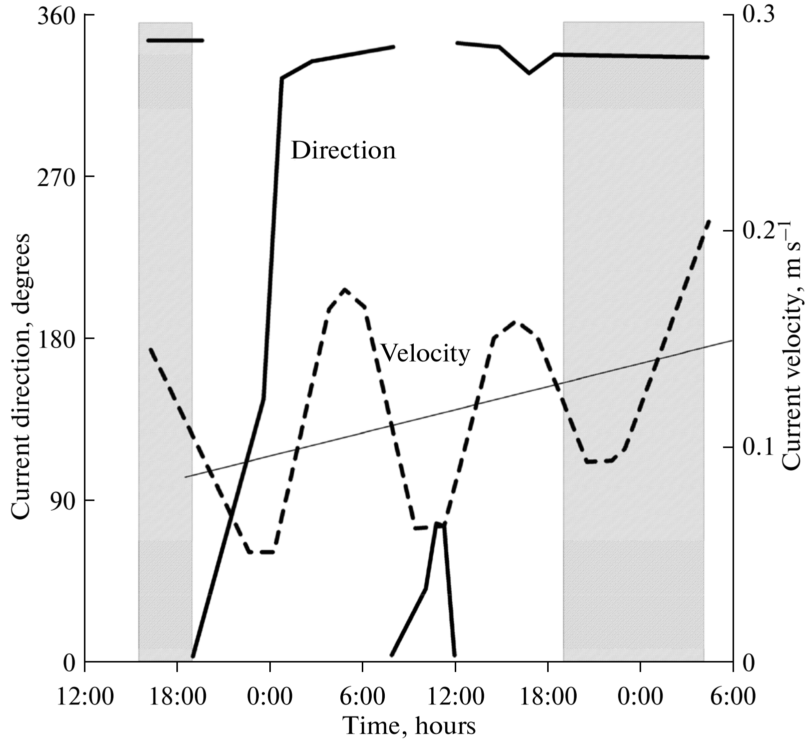


Fig. 7. Time dependence of direction (deg) and modulus (m s^{-1}) of current velocity in the bottom layer of the isthmus between the central spur of the St. Anna Trough and Novaya Zemlya trough based on the measurement data of the "Aqualog" profiler. The hatching marks periods of CTD profiling from 10 to 155 m depth, and the thin line symbolizes the trend in current velocity behavior.

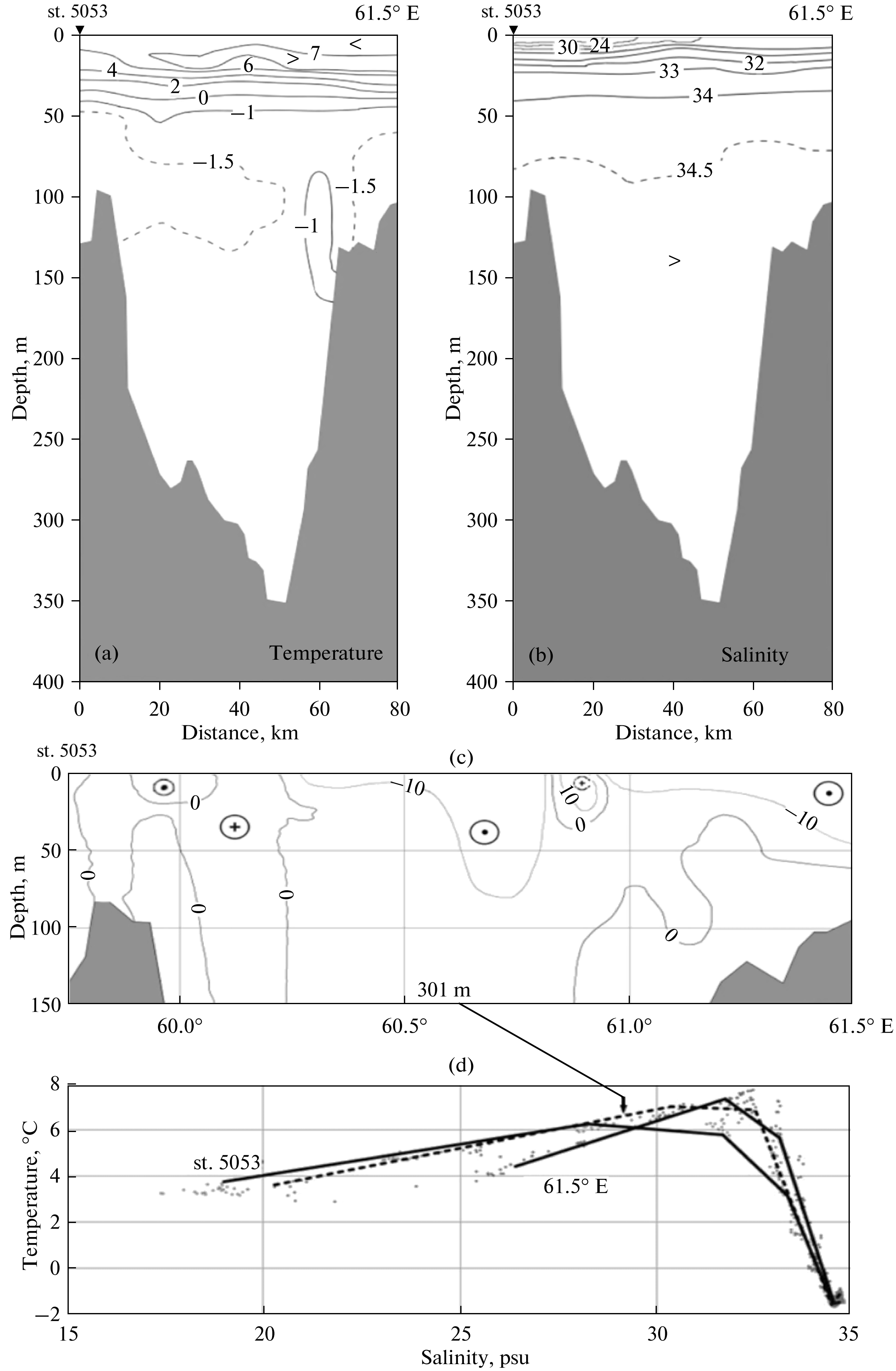
vailed in the lower layer from the 120–155-m depth. In other word, the bottom current crossed the isthmus between the Novaya Zemlya basin and the central spur of the St. Anna Trough and was able to support water exchange between these areas. However, the current must be quasi-stationary in order to support substantial water exchange. A measurement series more than 36-h long corroborates the sufficiency of bottom-current duration as compared with the tidal cycle (Fig. 7). The rate of the northward transport made up 0.1–0.2 m s^{-1} and increased from the beginning to the end of measurements (Fig. 7). It is evident that the current's direction persisted despite the occurrence of tidal oscillations of the order of 0.1 m s^{-1}. Similar estimates of barotropic component of tidal currents at actual coordinates and time of current measurements by means of the ADCP, mounted in the "Aqualog" profiler, were calculated from the Arctic tidal model [14].

North transect across the Novaya Zemlya trough. This transect was occupied by the TSP "Rybka" from the Novaya Zemlya coast orthogonally to the shore from 74°29′ N to 73°56′ N (Fig. 1). It was found that the salinity in the upper 6–7-m layer over the western slope of the Novaya Zemlya trough measured only 23–24 psu lower than the eastern one (about 29 psu) (Fig. 8b).

Taking into account that the transect started at a depth of 70 m about 9 km from the shore (station 5053), this may be attributed both to the desalinated waters near Novaya Zemlya from the melting of coastal ice and snow-field basins and to the southwestward propagation of waters, desalinated by Ob and Yenisey discharge, along the archipelago shores. According to satellite images, SDL waters reached the Novaya Zemlya by September, 2011, and a coastal southwestward current arose due to the geostrophic adjustment (see, for example, [12, 15]) as was actually observed [4].

When studying the specific features of the hydrochemical structure of the coastal zone of the Novaya Zemlya archipelago in September 2007, it was shown that the impact of land runoff is traceable in the upper 10-m layer as far as about 20 km offshore [6]. In our case, i.e., in early October, 2011, the propagation of the desalinated waters in the surface layer is traceable as far as 40 km (Fig. 8b). It is remarkable that more desalinated waters at the west side of the Novaya Zemlya trough occurred also in another transect, located

Fig. 8. The north section across the Novaya Zemlya trough based on TSP "Rybka" data. (a) temperature, °C. (b) salinity, psu; (c) distribution of geostrophic current velocity (m s^{-1}) in the 0–1500 m layer. The fletching and arrowhead designate northeast and southwest water transport, respectively. The depth of the bottom underlying the southwest transport, is given at the foot of the figure. (d) T,S-diagram for both the north and south sections across the trough where solid T,S curves correspond to the starting (station 5053) and end (61.5° E) points of the section, while dashed curves characterize the areas of the southwestward transport.


st. 5053
61.5° E
Depth, m
Distance, km
(a)
Temperature
(b)
Salinity
(c)
301 m
60.0°
60.5°
61.0°
61.5° E
(d)
Temperature, °C
Salinity, psu
st. 5053
61.5° E

much further south (Fig. 1). Apparently this circumstance is related to the transport of desalinated surface waters from the Ob and Yenisey rivers and shores of the archipelago along the Novaya Zemlya. This southward-directed transport (the Novaya Zemlya current, according to [2]) made itself evident in satellite images dating to August–early September. The traces of desalination are likely to disappear over the western slope of the trough after the change in prevailing wind from north to south rhumbs in the second decade of September. However, they were observable even in early October, which may indicate the adjustment of the frontal interfaces of the SDL to the changes in wind forcing.

Figures 8c and 8d demonstrate geostrophic currents in the north transect across the Novaya Zemlya trough, calculated from the data of TSP "Rybka," and the *T*,*S*-relationships for both transects across the trough, respectively.

The characteristic feature of this transect is a fairly mixed picture of multidirectional geostrophic currents whose velocity does not exceed 15 cm s^{-1}. The southwestward transport, having 5–7 m s^{-1} velocity, prevailed in the whole 200-m layer over the central and eastern part of the trough. The transport was not coherent but involved at least two domains interfaced by a counter current (Fig. 8c). The southwest current, having an axis at 60.6° E, is traceable to 100–120-m depth levels and featured velocity at the surface as high as 12–15 cm s^{-1}. Another domain of the southwest transport located between 61° and 61.5°, extended down to the 70–80-m level, and have a near-surface velocity of 10–12 cm s^{-1}. The northeastern jet of the counter current located in the upper 15 m thick layer only where its velocity made up the same 10–12 cm s^{-1}.

The southwesterly current (the Novaya Zemlya current according to [2]), which transported desalinated waters along the shores of the Novaya Zemlya at a rate of 2–3 cm s^{-1}, was observed in the surface layer of 15–20 m, which excellently corresponds to patterns in satellite imagery. The occurrence of a slow southwest transport along the shore, entraining the upper 30 m thick layer, was reported earlier in [15].

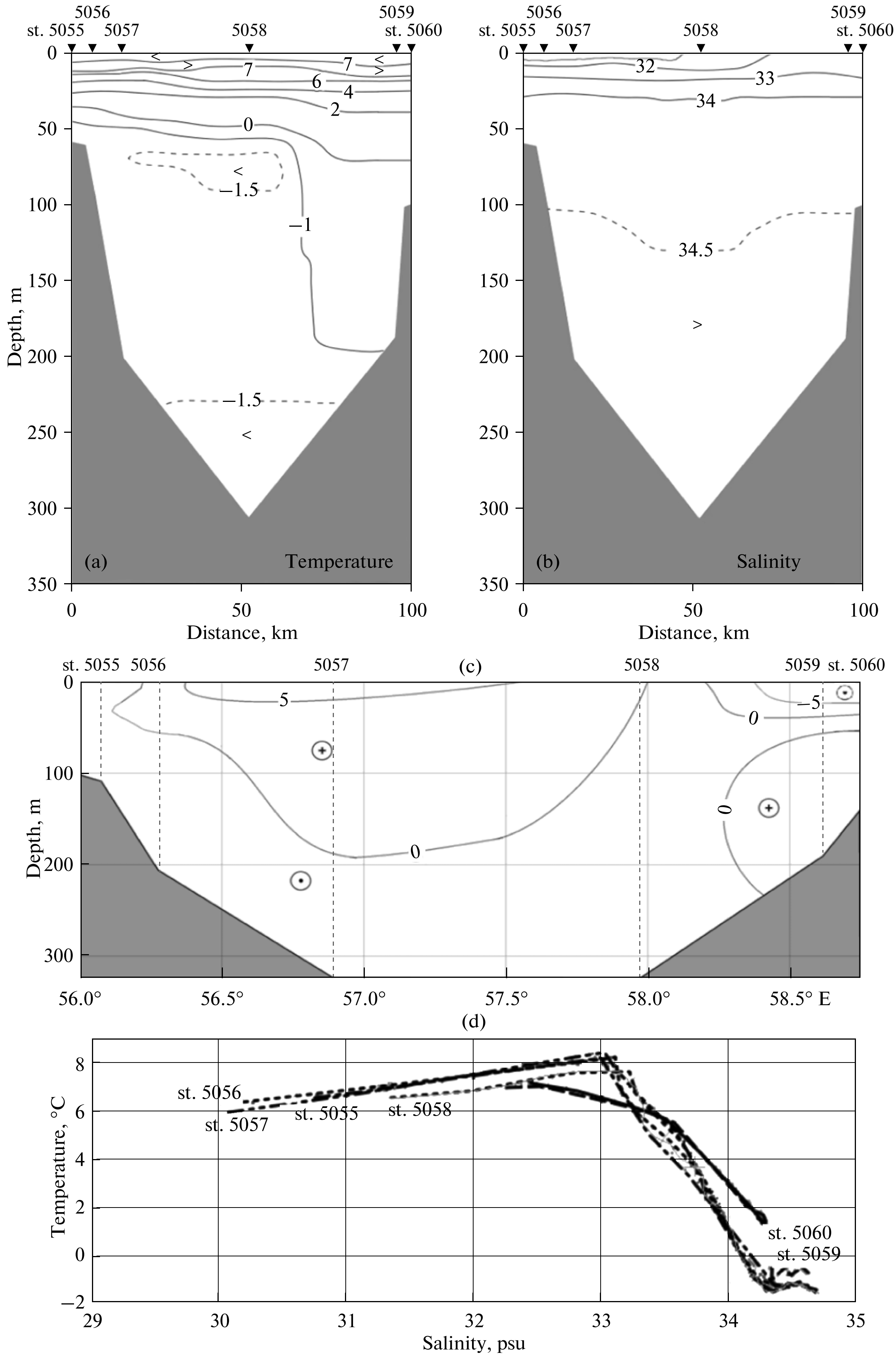
South transect across the Novaya Zemlya trough. As already noted, the surface layer of water in this transect at the western side of the trough was less salty and colder than at its eastern side (Figs. 9a and 9b). It is evident that the freshening and cooling of the surface layer of coastal waters (the transect begins in about 3 km from the shore of the Novaya Zemlya) took place thanks to the runoff of melted waters that originate during this season due to the melting of glaciers and snow fields. Hypotheses of this kind on the decisive impact of desalinated runoff from archipelago shores are justified by observations of local hydrochemical characteristics [10]. Water of a salinity of 30 psu and of a temperature of 6.5°C has been found above the western slope of the trough in the 10-m surface layer (stations 5055–5057). At the same time, the quasi-homogenous layer in the east of trough (station 5060) featured 12–15 m thickness, 32.5 psu salinity and 7°C temperature of water. The underlying pycno-halocline extended down to 25–30 m and the difference of thermohaline parameters at its interfaces were 4–5°C in temperature and about 2 psu in salinity. Further downward, the salinity smoothly increased up to 34.5 psu at the 100–120-m level, reaching 34.7–34.8 psu near the bottom of the trough.

The temperature distribution below the gradient layer exhibited a monotonous decrease to –1.7 °C at a 60–80-m depth. This cold slightly desalinated water may have formed as a result of winter convection in the near-slope shelf domain. In contrast, the warmer and saltier water originating in the Barents Sea was traceable at the eastern slope of the trough below the pycno-halocline down to 200 m (Figs. 9a and 9b).

A geostrophic current of a SW direction, having a velocity as low as 2–3 cm s^{-1}, was observed at the western side of the trough at a distance of 10–15 km from the transect's starting point (station 5055). This current occupied the entire thickness above the level from 100 to 125 m (Fig. 9c, see also [15]). Southwestward water transport at a rate of 7–9 cm s^{-1} was discovered in the upper 50-m layer above the eastern slope of the trough. A slow (2–3 cm s^{-1}) northeastward current was observed deeper down to the bottom, which was responsible for the water transport of the warmer and more saline water from the Barents Sea (Figs. 9a and 9b). This is confirmed by *T*,*S*-diagrams in Fig. 9d. For instance, the temperature and salinity within a depth range of 50 to 100 m at stations 5059 and 5060 above the eastern slope of trough have magnitudes much higher than those of stations 5055–5057, above its western slope. It should be noted that the formation of such a subsurface northeastward current along the eastern slope of the Novaya Zemlya trough, which merged with the main branch of flow of the Barents Sea waters, coming into the sea through the Karskie Vorota strait, has been obtained earlier from calculations of summer circulation [15] and was observed in laboratory modeling [12].

It may be concluded that water circulation in the Novaya Zemlya trough is weak and exhibits a variegated structure of currents as compared to that in the St. Anna Trough. As rule, northwestward transport dominates the eastern slope while the southwestward transport prevails over the western slope. However, the data obtained give no reason to infer with confidence

Fig. 9. The south section across the Novaya Zemlya trough according to data of CTD profiling at stations. (a) temperature, °C. (b) salinity, psu. (c) geostrophic current velocity cm s^{-1}) where fletching and arrow head designate northeastward and southwestward water transport respectively. (d) *T,S* curves at stations in the transect.


5056
st. 5055
5057
5058
5059
st. 5060
Depth, m
(a)
Temperature
Distance, km
(b)
Salinity
(c)
st. 5055
5056
5057
5058
5059
st. 5060
56.0°
56.5°
57.0°
57.5°
58.0°
58.5° E
(d)
st. 5056
st. 5057
st. 5055
st. 5058
st. 5060
st. 5059
Temperature, °C
Salinity, psu

the occurrence and direction of the coherent jet of the East Novaya Zemlya current in autumn 2011.

CONCLUSIONS

1. Similarly to the findings of 2007, a fairly strong geostrophic current, having a velocity of 0.35 m s^{-1}, has been detected in the central spur of the St. Anna Trough at sites with 150–300-m depths. This current represents, possibly, a topographically attached loop flow and plays a role of dynamical barrier preventing the travel of waters from the southwestern Kara Sea into high-latitude areas.

2. A much weaker and less barotropic current was observed in the eastern spur of the St. Anna Trough. This flow cannot be an obstacle to the northward spread of the shelf waters of the Kara Sea shelf. Exactly this may be the cause of the widespread occurrence of pelagic and benthic species of the Kara Sea biota in the eastern spur of the trough and their uniqueness in the central spur where such a barrier is present.

3. According to the data of the self-contained "Aqualog" profiler, a steady northward current took place for 1.5 days in the bottom layer of 20–30 m at the isthmus between the Novaya Zemlya trough and the central spur of the St. Anna Trough. This flow transports water whose temperature and salinity measured about −1°C and 34.6–34.7 psu, respectively. This fact may be regarded as evidence of a limited water exchange between the Novaya Zemlya trough and the central spur of the St. Anna Trough. In addition, direct recording of current velocity confirmed the presence of southwestward water transport in the upper 120-m layer above the isthmus. This phenomenon was discovered earlier from geostrophic calculations.

4. Water of lower salinity and temperature has been found in the 10-m surface layer over the western slope of the Novaya Zemlya trough lengthwise the shores of Novaya Zemlya from 72.5° and 74.5° N. The origination of this water relates both to runoff of melted water from small glaciers and snow fields and to waters of the SDL that reach the shores of Novaya Zemlya by early September.

5. The desalinated waters from the Ob and Yenisey rivers and archipelagos are transported from north to south over the western slope of the Novaya Zemlya trough by a surface current that was well defined from mid-August to the first decade of September, according to satellite imagery.

6. Relatively warm and salty water from the Barents Sea is traceable in the south of the Novaya Zemlya trough over its eastern slope between the pycno-halocline and the 200-m depth. Such water has not been found in the north of the trough.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, projects no. 14-17-00681, (field research), and no. 14-50-00095, (data processing).

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Translated by G. Karabashev