Project no. 265863

ACCESS

Arctic Climate Change, Economy and Society

Instrument: Collaborative Project
Thematic Priority: Ocean.2010-1 "Quantification of climate change impacts on economic sectors in the Arctic"

D1.34 – Report from AARI on analysis of recent oceanographic voyages in Russian Arctic

Due date of deliverable: **30/09/2013**

Actual submission date: **05/02/2014**

Start date of project: **March 1st, 2011** Duration: **48 months**

Organisation name of lead contractor for this deliverable: **AARI**

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	X
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Introduction

Several recent years after the International Polar (IPY-207-2009) were characterized by intensive field oceanographic studies in the Arctic Ocean, and in particular in its Eurasian sector. This was caused by substantial reduction of the summer sea ice, which allowed vessels without high degree of ice-navigation endurance to operate in the polar waters. In this report we present the description of major Russian oceanographic voyages in the Russian sector of the Arctic Ocean within the recent 6 years, starting from 2007 – the IPY, and present generalized analysis of information collected in these cruises. The data from some of these cruises have already been processed and are included in the supplement to this report. The data from the more recent cruises are not processed yet and only general information on these cruises is available. The list of cruises is presented in Table 1. In the following chapters we give systematic description of oceanographic research, which was carried out during these cruises.

Table 1

List of oceanographic cruises included in this report

#	Vessel	Cruise dates	Operation region	Data included	Responsible person	Numb. of CTD casts
1.	"Akademik Fedorov"	2007: July 27 – August 15	Barents Sea, Kara Sea, Laptev Sea, East Siberian Sea Nansen Basin, Amundsen Basin, Makarov Basin	Yes	Igor Ashik: AARI, ashik@aari.ru	96
2.	"Victor Buynitskiy"	2007: September 7 – October 17	Laptev Sea, East Siberian Sea	Yes	Igor Polyakov: IARC, igor@iarc.uaf.edu	91
3.	"Akademik Fedorov"	2008: August 22 – September 20	Kara Sea, Laptev Sea, East Siberian Sea	Yes	Igor Ashik: AARI, ashik@aari.ru	72
4.	"Kapitan Dranitsyn"	2008: October 2 - 30	Nansen Basin, Laptev Sea, East-Siberian Sea	Yes	Igor Polyakov: IARC, igor@iarc.uaf.edu	54
5.	"Kapitan Dranitsyn"	2009: August 15 – September 7	Nansen Basin, Laptev Sea, East-Siberian Sea	Yes	Igor Polyakov: IARC, igor@iarc.uaf.edu	89
6.	"Akademik Fedorov"	2010: July, 28 – October, 13	Kara Sea, Amundsen Basin, Makarov Basin	No	Igor Ashik: AARI, ashik@aari.ru	30 (119 XCTD)
7.	"Akademik Fedorov"	2011: July, 8 – September, 7	Nansen Basin, Amundsen Basin, Makarov Basin	No	Igor Ashik: AARI, ashik@aari.ru	2 (58 XCTD)
8.	"Professor	2012: June,	Barents Sea, Kara Sea,	No	Michail Makhotin;	81

	Molchanov ”	1 – July, 10	Greenland Sea		AARI, m-makhotin@mail.ru	
9.	“Professor Molchanov ”	2013: June, 1 – July, 25	Barents Sea, Kara Sea	No	Michail Makhotin: AARI, m-makhotin@mail.ru	151
10.	“Akademik Fedorov”	2013: August, 21 – September, 22	Nansen Basin, Laptev Sea, East-Siberian Sea	No	Igor Polyakov: IARC, igor@iarc.uaf.edu	116 (49 XBT/ XCTD)

1. “Akademik Fedorov”: 2007 cruise

The cruise was conducted by Arctic and Antarctic research institute (AARI) under the aegis of the IPY. The overall goal of oceanographic work was to collect detailed data on the properties of Atlantic Water in the central Arctic Ocean in order to estimate their current state and transformation en route. The map of oceanographic stations is presented in Fig.1.1. In the near-pole region the ship was escorted by nuclear icebreaker, while in the waters to the south “Akademik Fedorov” operated on her own. About one-third of CTD stations during this cruise were done from ice, where operators were delivered by the deck helicopter.

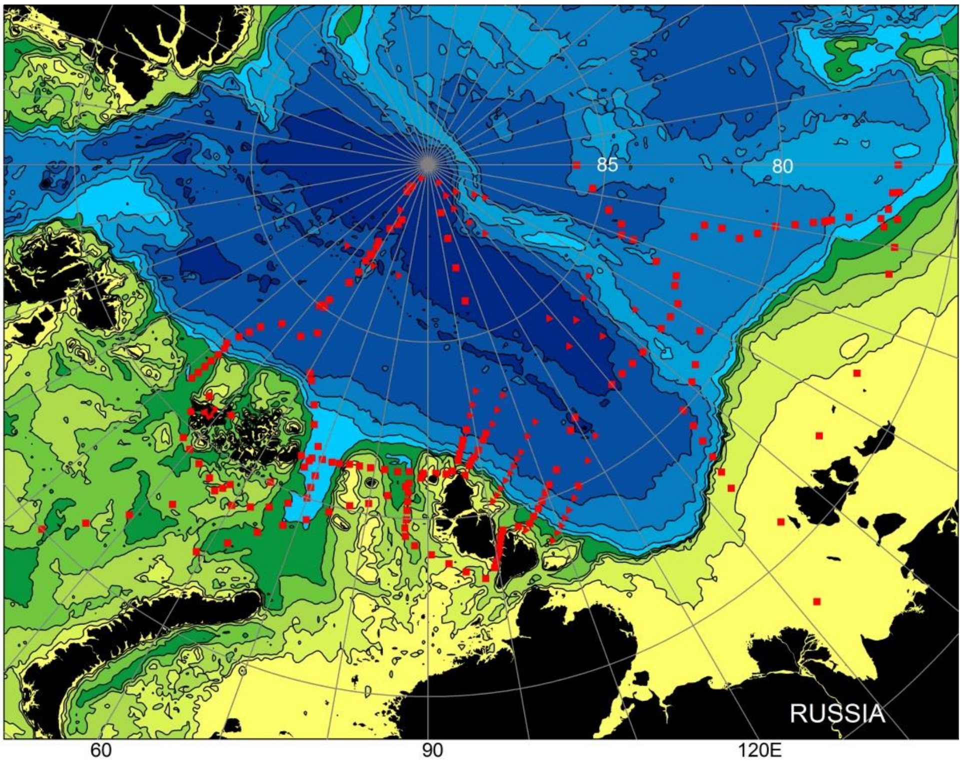


Fig. 1.1. “Akademik Fedorov” – 2007 oceanographic stations

1.1 Objectives

The major objectives of oceanographic studies were to:

- document thermohaline state of Atlantic Water (AW) in the boundary current and in the central Arctic Basin;
- quantify spatial variability of the upper mixed layer and cold halocline;
- trace spatial transformation of water masses along the Laptev Sea continental slope.

1.2 Methods and equipment

Traditional CTD surveys at oceanographic transects with s measurements from surface to bottom were used. CTD profiles were carried out with a SeaBird Profiler SBE911plus. This system continuously measures conductivity, temperature, and pressure at 0.25 m intervals in the vertical. Temperature and conductivity sensors are calibrated yearly. The technical description of sensors can be downloaded from http://www.seabird.com/products/CTDprofilers.htm.

1.3 Main Results

Shelf and slope east of Severnaya Zemlya is remarkable for variety of oceanographic processes shaping the water mass structure. CTD-polygon in summer 2007 allowed detailed 'snap-shooting' of two branches of Atlantic Water and their complex interaction through intrusions and eddy-formation. Extremely cold and relatively fresh water at shallow depth (100 m and above) is probably the remnants of winter-origin dense water formed via brine ejection over the adjacent shelf (Fig. 1.2).

(a) (b)

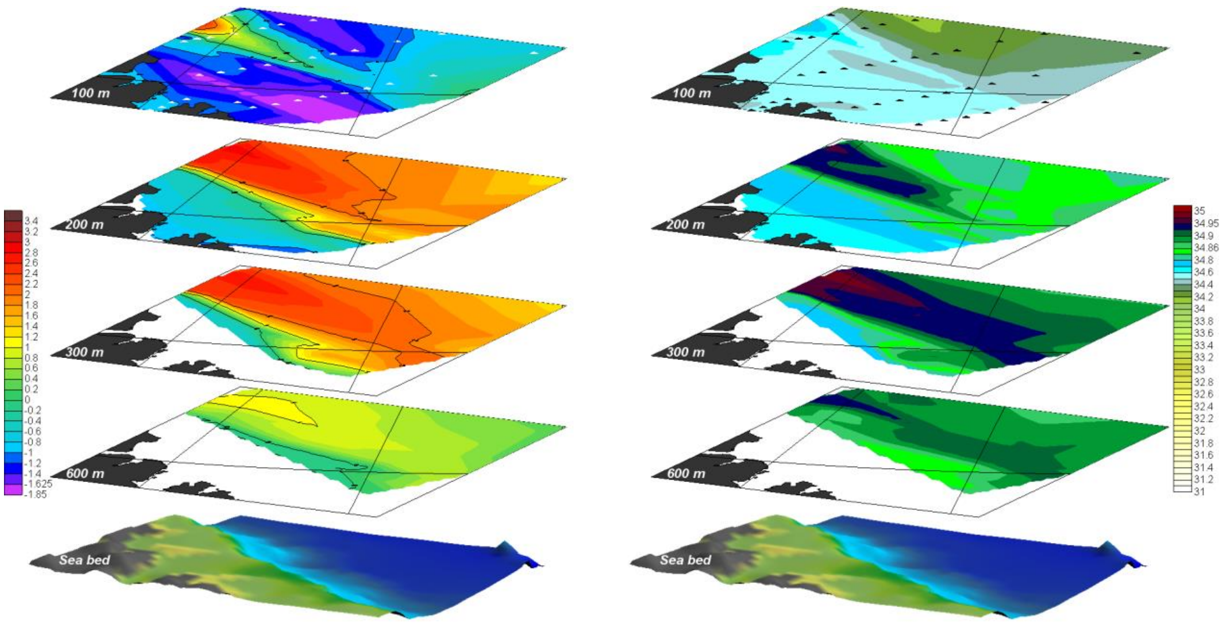


Fig. 1.2. Spatial structure of water masses east of Severnaya Zemlya Archipelago

Average water temperature in the core of Atlantic Water (AW) in the central Arctic Ocean has increased by ~0.5°C, and the AW layer thickened by ~100-150 meters over climatology. T&S in the Fram Strait branch of AW (FSAW) reached absolute maximum in 2007 (at the Eurasian continental slope east of St. Anna Trough). Significant freshening of the surface layer over climatology is observed around the entire Arctic Ocean covered by measurements. Retreat of the summer ice edge far to the north caused anomalous warming (up to 5-7°C) in the surface layer of the East-Siberian and Chukchi seas. Combination of these shifts in oceanographic conditions may have a long lasting effect on the water masses and ice cover in the Arctic Ocean and marginal seas. Main results of presented studies are published in the "Review of hydrometeorological processes in the Arctic Ocean", St.Petersburg, 2008.

2. "Victor Buynitskiy": 2007 cruise

The cruise was conducted by the International Arctic Research Center University of Alaska Fairbanks (IARC UAF) in partnership with AARI under the aegis of the NABOS (=Nansen and Amundsen Observations System) project (http://nabos.iarc.uaf.edu/). The overall goal of NABOS, launched in 2002, is to provide quantitative, observationally based assessment of circulation, water mass transformations, and their temporal variability along the principal pathways transporting water from the Nordic Seas into the central Arctic Basin. The map of oceanographic stations is presented in Fig. 2.1.

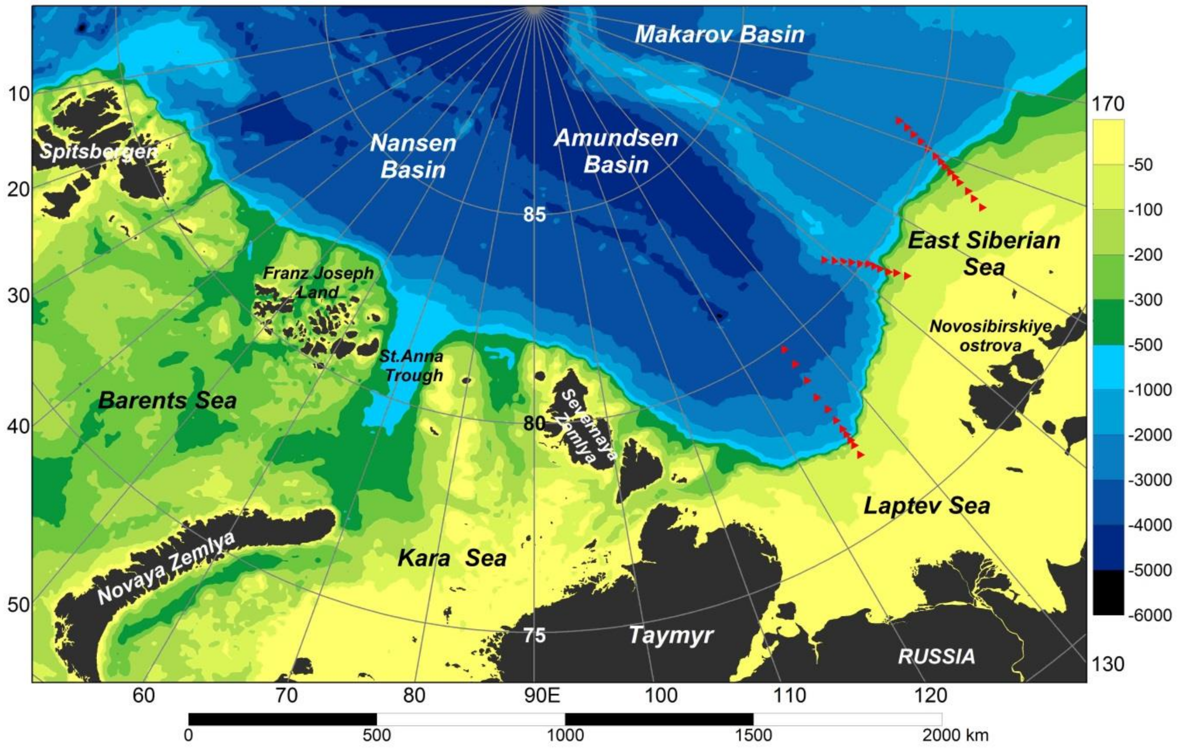


Fig. 2.1. "Victor Buynitskiy" – 2007 oceanographic stations

2.1 Objectives

The major objectives of oceanographic studies were to:

- document progression of strong warming found in the AW core during previous NABOS expeditions that was approaching Canadian Arctic;
- quantify changes in the structure and spatial variability of the main water masses over the continental shelf of the Barents, Laptev, and East Siberian seas and adjoining Eurasian Basin in 2007;
- enhance understanding of the mechanisms by which AW is transformed across and along the continental slope of the Eurasian Basin.
- recover and redeploy long term oceanographic moorings

2.2 Methods and equipment

Basic NABOS approach is to get continuous time series of water properties in key locations along the Atlantic Water pathways in the Arctic Ocean. Methods include the use of autonomous anchored moorings, operating for one year at a time, with replacement every year. Mooring records are supplemented by CTD casts along the mooring lines from the surface to the depth 1000 m. CTD profiles were carried out with a SeaBird Profiler SBE19plus. This system continuously measures conductivity, temperature, and pressure at 0.25 m intervals in the vertical. Temperature and conductivity sensors are calibrated yearly. The technical description of sensors can be downloaded from http://www.seabird.com/products/CTDprofilers.htm.

2.3 Main Results

The advantage of 2007 field operation season in the Arctic Ocean was that it coincided with the first year of the IPY. Thence, the summer of 2007 was marked by intensive multinational oceanographic studies all around the Arctic Ocean, and in particular in the Siberian sector. Putting together oceanographic data at cross-slope sections, carried out by different vessels allowed obtaining unique collection of quasi-synchronous measurements. In fact, for the first time in the history of oceanographic studies in the Arctic Ocean the "snap-shot" of the FSBW pathway in the Eurasian sector of the Arctic Ocean was done. This pathway (marked by temperature maximum in the AW core) is presented in Fig. 2.2.

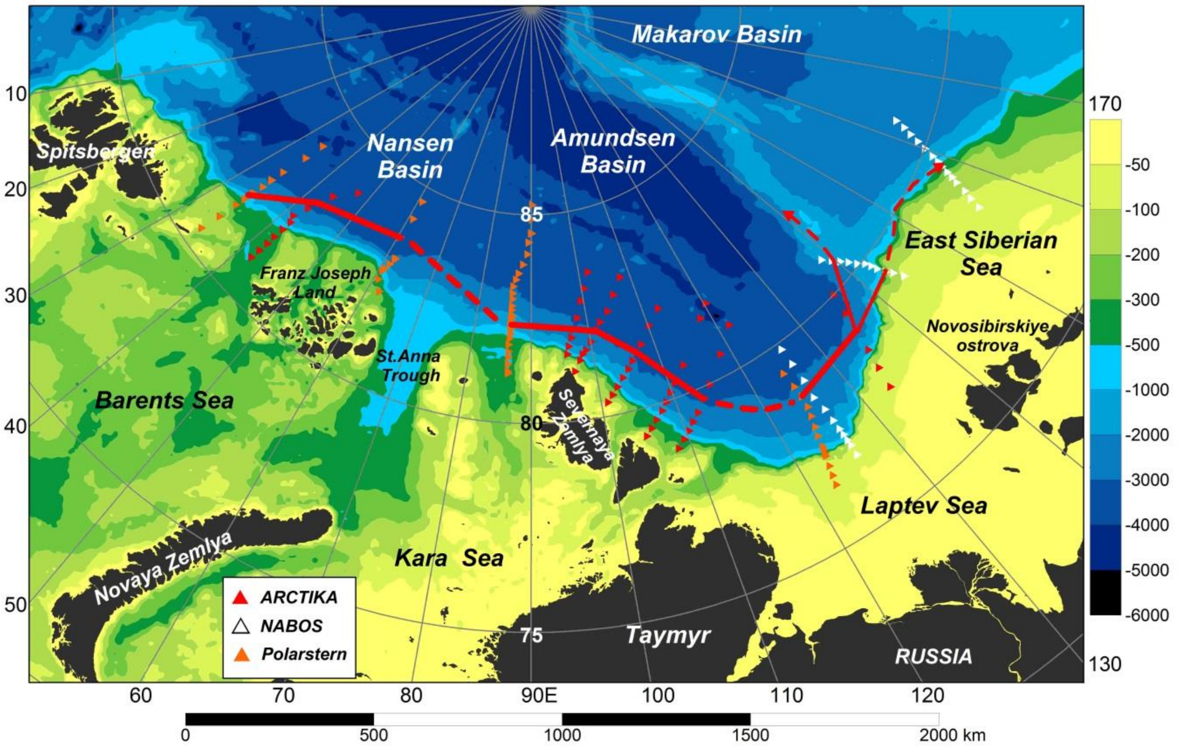


Fig. 2.2. The “snap-shot” of the pathway of the Fram Strait branch of AW, reconstructed from quasi-synchronous data, obtained in 3 cruises in August-September, 2007.

Sporadic shifts of the FSBW pathway off the continental slope is the outstanding feature of this scheme. Location of these shifts generally coincide with location of cross-slope canyons (Franz Victoria, St. Anna), which cut the continental slope and are the conduits of shelf origin water, which eventually enters the deep basin. The FSBW warm core appears to be at the largest distance off slope in the western Laptev Sea, where the Barents Sea branch of AW propagates along the slope after entering the Nanse Basin through St. Anna Trough.

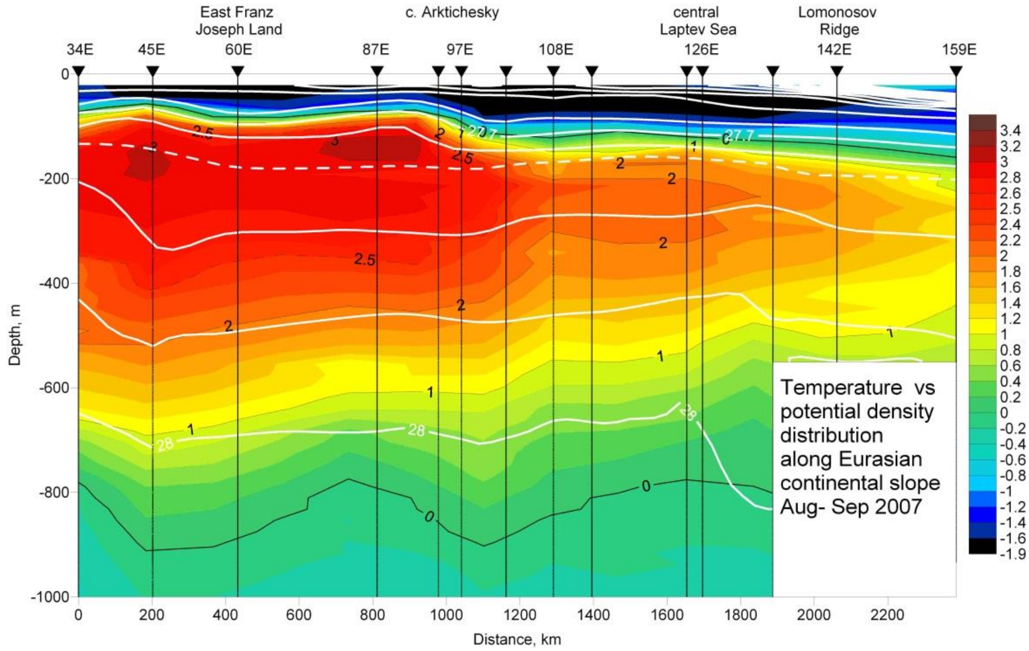


Fig. 2.3. Temperature distribution in the warm core of AW along the boundary current, based on all available data of quasi-synchronous oceanographic surveys in August-September, 2007.

Another important finding, which follows from the joint analysis of data, obtained in 2007, is the disappearance of the upper warm core of FSBW after passing the traverse of cape. Arkticheskiy (the northernmost point of Severnaya Zemlya Archipelago) – see Fig. 2.3. At short distance (about 350 km along stream), between 87ºE and 108 ºE the warm maximum in FSBW deepens from 120 m to 250 m. Possible explanation of such rapid structural change is intensive isopycnal and diapycnal mixing between two branches of AW in this area, which leads to dilution of FSBW shallow maximum (Ivanov and Aksenov, 2013).

3. “Akademik Fedorov”: 2008 cruise

The cruise was conducted by Arctic and Antarctic research institute (AARI) under the aegis of the IPY. This cruise was planned as a continuation of the previous year cruise. The overall goal of oceanographic work was to collect detailed data on the water properties along the pathway of FSBW in the Laptev Sea and across St. Anna Trough in order to assess year to year changes. The map of oceanographic stations is presented in Fig. 3.1.

3.1 Objectives

The major objectives of oceanographic studies were to:

- carry out oceanographic stations at the recurrent cross-slope lines in the Kara Sea, Laptev Sea and East-Siberian Sea;
- quantify temporal (year to year) variability of the upper mixed layer and cold halocline;
- trace propagation of maximum temperature in FSBW to the east of Lomonosov Ridge.

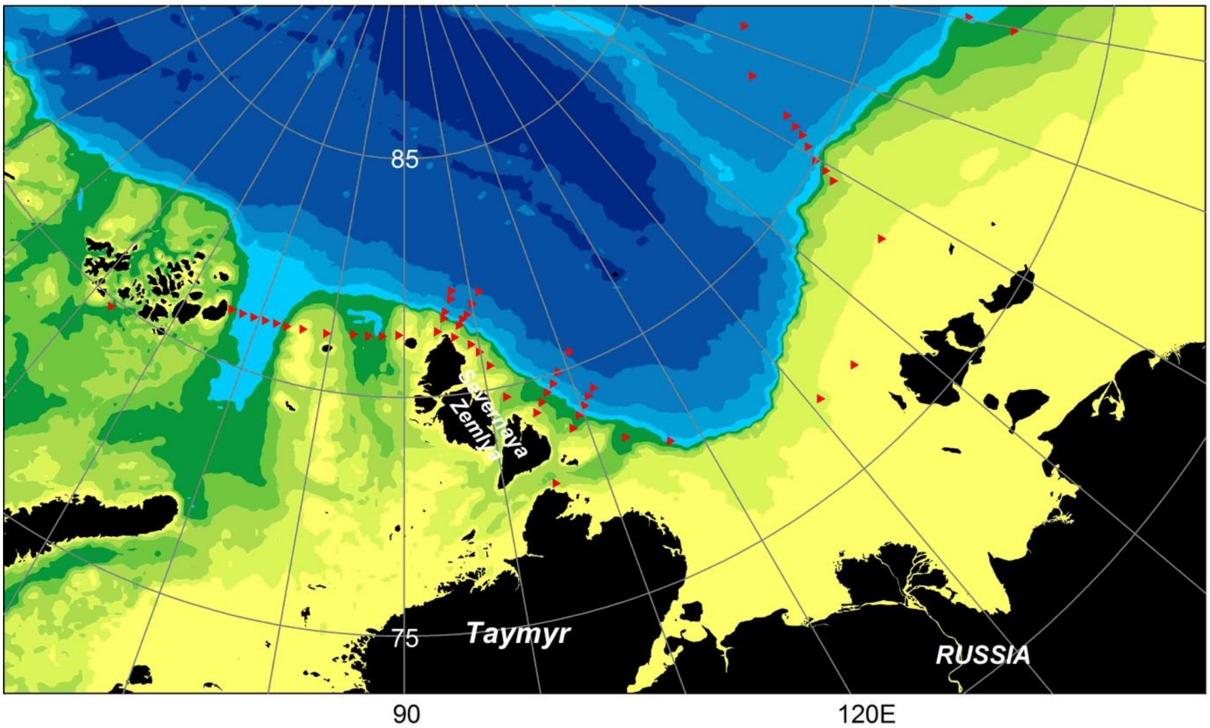


Fig. 3.1. "Akademik Fedorov" – 2008 oceanographic stations

3.2 Methods and equipment

CTD surveys at oceanographic transects with s measurements from surface to bottom were used. CTD profiles were carried out with a SeaBird Profiler SBE911plus. This system continuously measures conductivity, temperature, and pressure at 0.25 m intervals in the vertical. Temperature and conductivity sensors are calibrated yearly. The technical description of sensors can be downloaded from http://www.seabird.com/products/CTDprofilers.htm.

3.3 Main Results

Recurrent CTD sections across the Laptev Sea continental slope have shown decrease of temperature in the AW warm core by about 0.5ºC at the average (Fig. 3.2). This result confirmed prediction of AW temperature decrease in the Eurasian Arctic after maximum in 2006-2007 (Holliday et al., 2008). Another specific feature of vertical thermohaline structure in the Laptev Sea in summer 2008 is the presence of very thick (deeper than 150 m) cold surface layer with temperature close to the freezing point. Formation of deep cold layer may be explained by anomalous decay of ice cover in the previous summer (2007), which preconditioned deep penetration of thermohaline convection and intensive ice freezing with surplus ejection of brine in the water column.

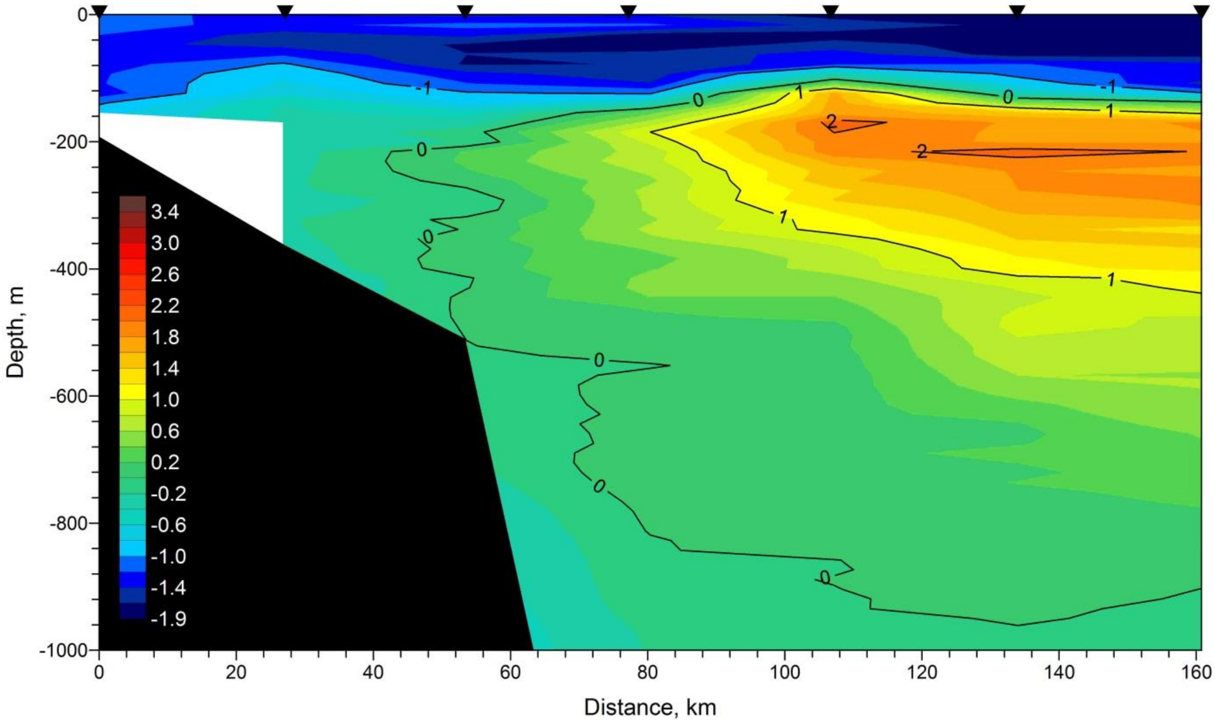


Fig. 3.2. Distribution of temperature. ºC, at cross-slope section 105-108ºE.

4. "Kapitan Dranitsyn": 2008 cruise

The cruise was conducted by the International Arctic Research Center University of Alaska Fairbanks (IARC UAF) in partnership with AARI under the aegis of the NABOS project. This cruise was the 7th annual expedition in the framework of this project with the overarching goal of the AW properties monitoring. Specific feature of the 2008 NABOS cruise was that it was carried out in the beginning of the Arctic winter, when the light day was limited by 4-6 hours, the temperature was permanently below zero and the ice was growing rapidly. The information collected under these extreme conditions appeared to be very valid for understanding of the Arctic climate (because of limited number of expeditions in the winter time in high Arctic). However, the complexity of all field activities, especially mooring deployment/recovery increased tremendously. The map of oceanographic stations is presented in Fig. 4.1.

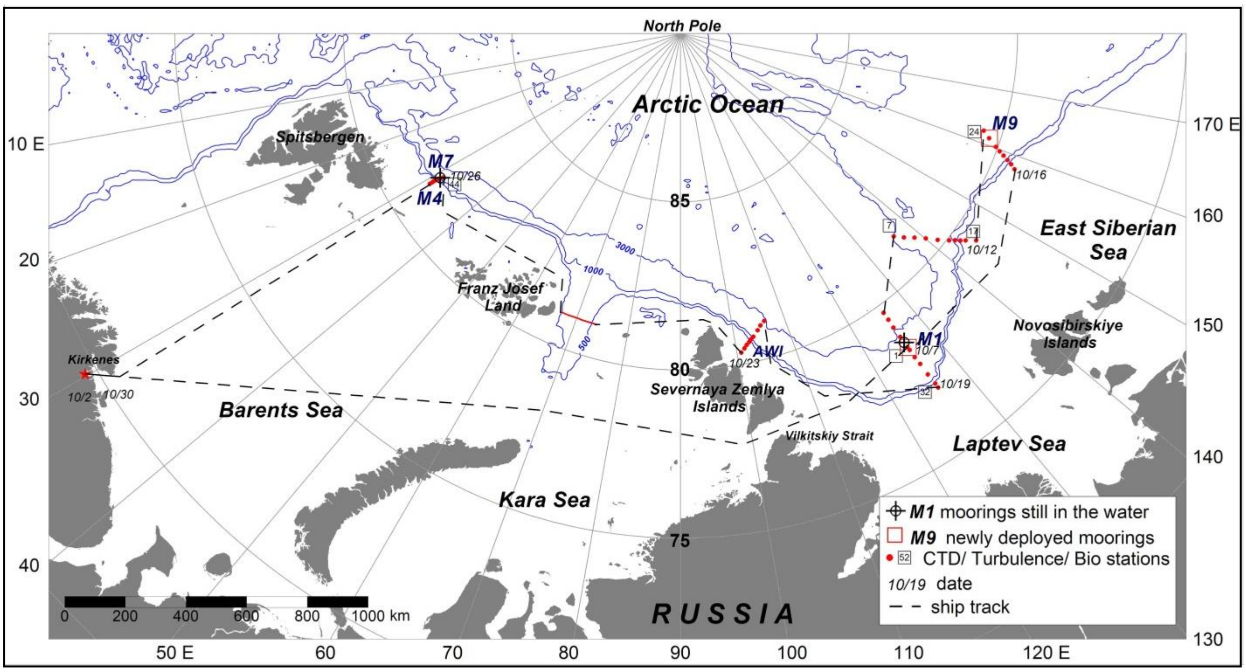


Fig. 4.1. "Kapitan Dranitsyn" – 2008 cruise track and oceanographic sections

4.1 Objectives

The major objectives of oceanographic studies were to:

- assess the thermal state of FSBW in the Nansen Basin after the culmination of warming in 2007;
- document thermohaline properties in the upper mixed layer during the onset of freezing;
- measure vertical thermohaline structure across St. Anna Trough;
- recover and redeploy long term oceanographic moorings.

4.2 Methods and equipment

Methods and technical approach were the same as in previous NABOS expeditions (see 2.2). CTD profiles were carried out with a SeaBird Profiler SBE19plus and with expendable devices (XBT/XCTD). The technical description of XBT/XCTD can be downloaded from http://www.sippican.com/stuff/contentmgr/files/bace7539fb038189533b4923ffc3e69b/sheet/xcdt92005.pdf . Mooring design and oceanographic equipment, used at moorings, are presented in Fig 4.2. The McLane Moored Profiler (MMP), designed and manufactured by McLane Research Laboratories, Inc. is the main component of NABOS moorings. Technical information and a description are available at http://www.mclanelabs.com. Moorings equipped with conventional devices (Microcats and RCMs) were placed at monitoring (recurrent) positions, thus avoiding gaps in records which may be caused (and were sometimes caused) by malfunctioning of the MMPs. MMP-equipped moorings were mostly used for process-oriented studies.

(a) (b)

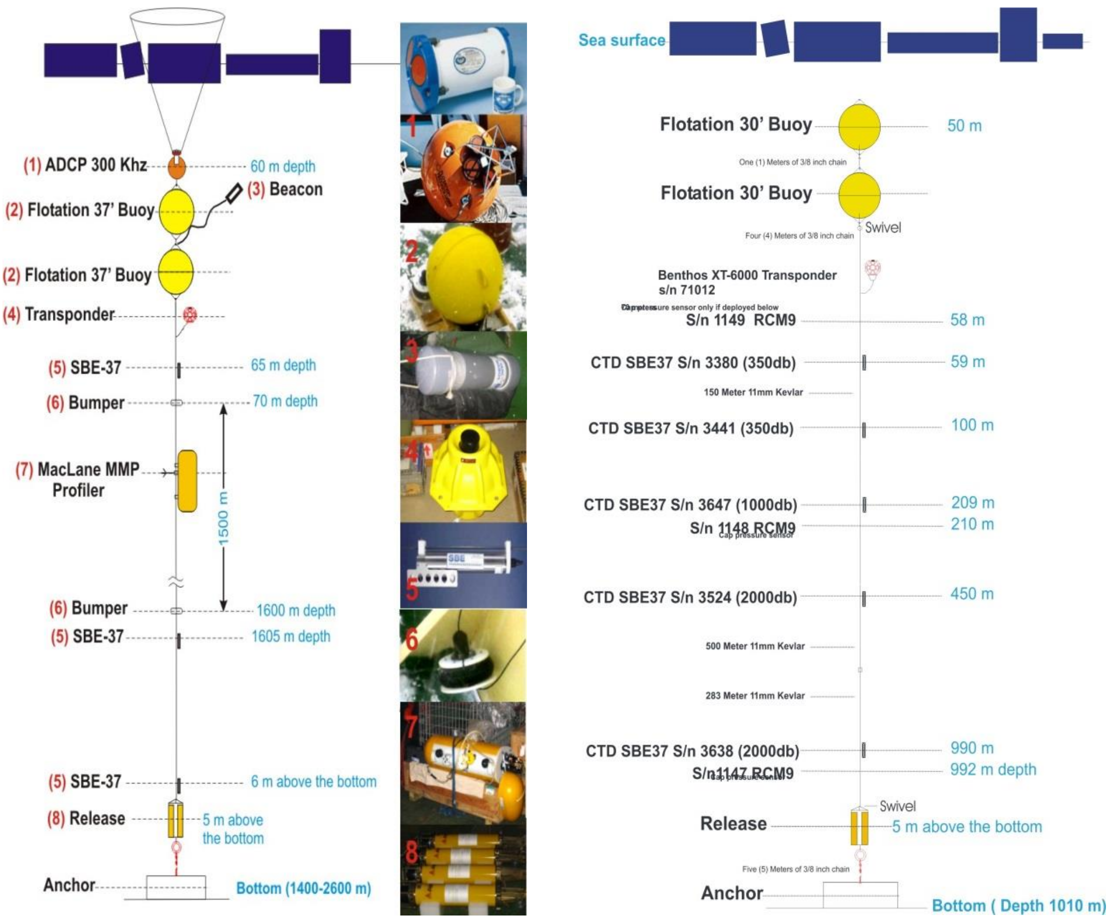


Fig. 4.2. Typical design and equipment of NABOS MMP-based (a) and conventional (b) moorings

4.3 Main Results

In 2008 the NABOS project hit its 6-year anniversary. Taking into account that the major research target of the project was obtaining long term time series of oceanographic parameters, six year period provided sufficient duration to assess whether the chosen strategy of observations was consistent with the goal? Looking back from this point in time it should be stressed that although there were several technical issues, the information, collected by moored instruments appeared to be absolutely critical in explaining known features of oceanographic regime and in revealing previously unknown phenomena. Outstanding result, which could only be discovered with the help of long term measurement devices, is strong seasonal oscillations in the FSBW, which has not been reported before. In 2008 five moorings were recovered. Temperature records in the FSBW core at two of these moorings is presented at Fig. 4.3 and Fig. 4.4. The combined four-year temperature record from the mooring M4, located at 1000 m depth at 31ºE, north-east of Svalbard confirmed persistent seasonal cycle in the AW core water temperature, which was initially discovered in 2006 (Ivanov et al., 2009). The phase of this signal is shifted from the astronomical one (temperature maximum is observed in November and minimum in April), thus pointing out that the signal is not generated locally by atmospheric forcing, but is advected by the boundary current from upstream. One-year-long MMP temperature records from the long term mooring M5 (at the eastern slope of Severnaya Zemlya) also demonstrated a well-defined seasonal cycle with maximum temperature and salinity in January and minimum in July. The range of seasonal oscillations (about 0.5°C) is consistent with the concept, that oscillations are being advected by the boundary current and slowly decay downstream due to mixing with the surrounding water.

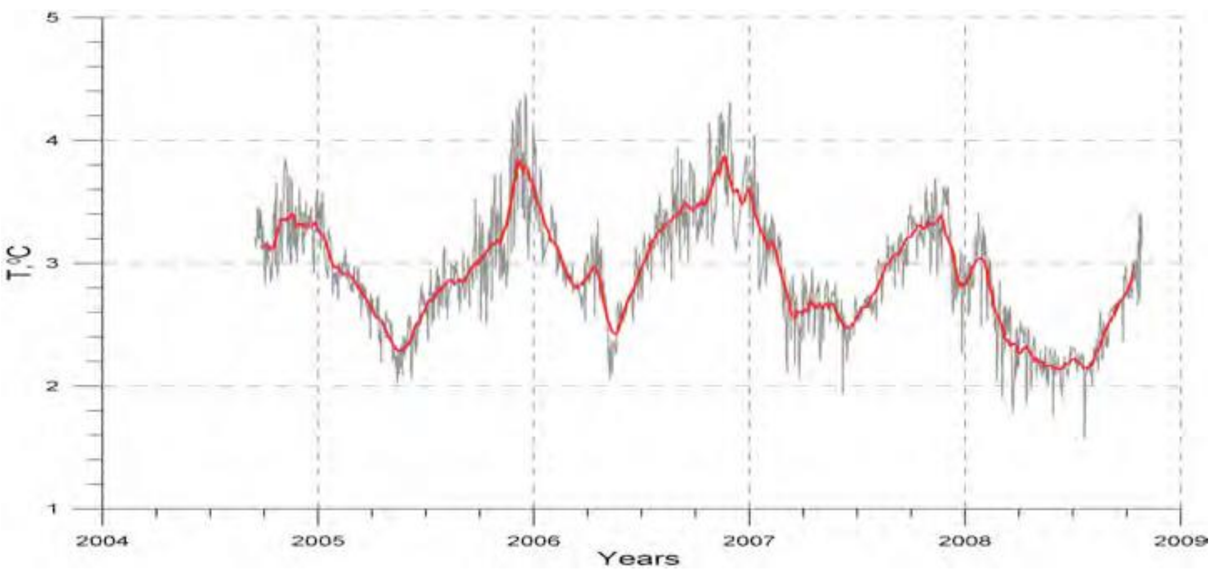


Fig. 4.3. Temperature record at 240 m at M4 mooring (81º30'N, 31ºE). Red line represent 1-month running average.

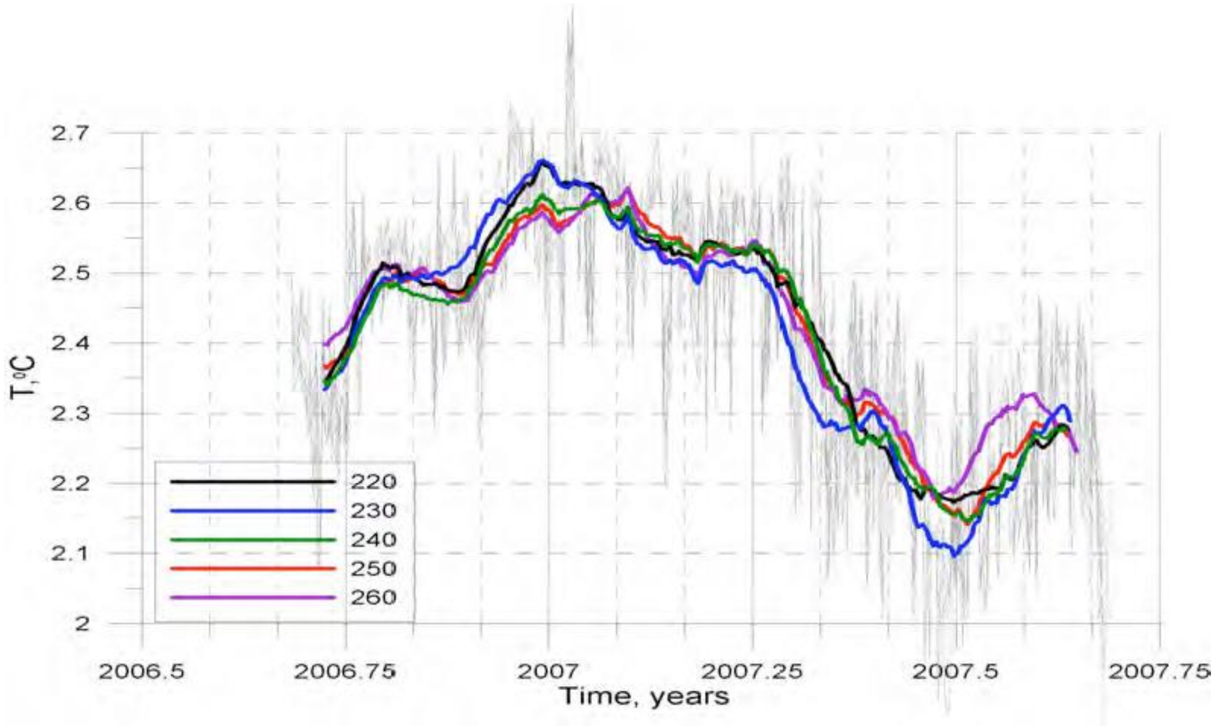


Fig. 4.4. Temperature record in the FSBW core at M5 mooring (81º'N, 105ºE). Color lines represent 1-month running average.

5. "Kapitan Dranitsyn": 2009 cruise

The cruise was conducted by the International Arctic Research Center University of Alaska Fairbanks (IARC UAF) in partnership with AARI under the aegis of the NABOS project. This cruise was the 8^{th} annual expedition in the framework of this project with the overarching goal of the AW properties monitoring. During 7 years of annual operation the NABOS provided vital information about the state of the boundary current system, thus closing a substantial observational gap. In particular it was demonstrated that a strong cooling tendency detected near Svalbard since 2006 is spreading over the Nansen Basin. New technology allowing survival of buoys deployed in seasonally ice-free areas was emerging, and several buoys were deployed in ice-free areas of the eastern Eurasian Basin during this cruise. Recurrent CTD sections were also carried out. The map of oceanographic stations is presented in Fig. 5.1.

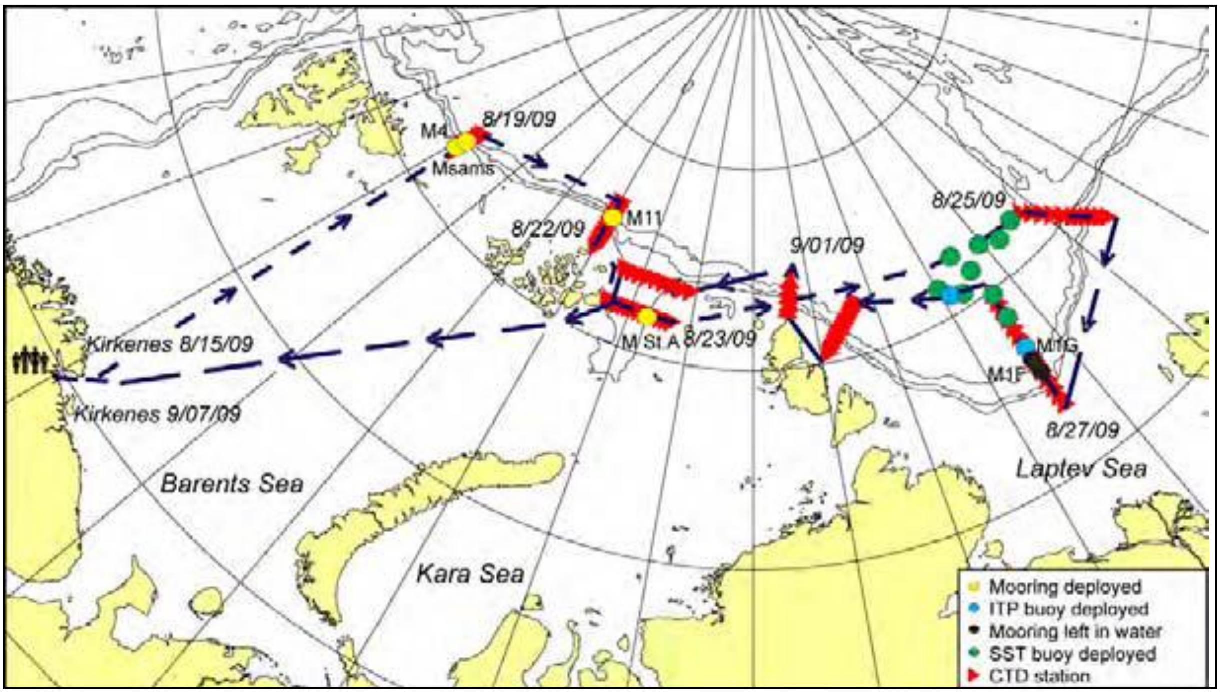


Fig. 5.1. "Kapitan Dranitsyn" – 2009 cruise track and oceanographic sections

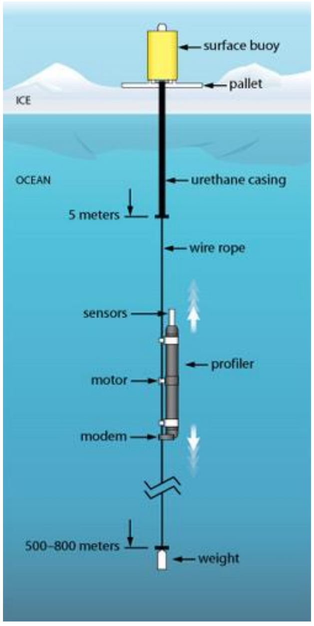
5.1 Objectives

The major objectives of oceanographic studies were to:

- study interaction of two branches of AW around the confluence zone in the mouth of St. Anna Trough;
- study split of AW flow at the intersection of Lomonosov Ridge with the Eaurasian continental slope;
- recover and redeploy long term mooring instruments
- deploy Ice Tethered buoys (ITP).

5.2 Methods and equipment

Methods and technical approach were the same as in previous NABOS expeditions (see 2.2 and 4.2). CTD profiles were carried out with a SeaBird Profiler SBE19plus and with expendable devices (XBT/XCTD). During this expedition 2 ITPs were deployed as a contribution to IABP program (http://iabp.apl.washington.edu/overview). Typical ITP design is shown in Fig. 5.2.



The Ice-Tethered Profiler was developed at the Woods Hole Oceanographic Institution. The system consists of a small surface capsule housing a controller interfaced to an Iridium data telemetry unit and inductive modem, a plastic-jacketed wire rope tether extending down 500 to 800 m into the ocean terminated by a ballast weight, and a new variation of the WHOI Moored Profiler (in shape and size much like an Argo float) that mounts on the tether and cycles vertically along it. Communication between the Profiler and surface controller is supported by an inductive modem (utilizing the wire tether and seawater return), and between the surface unit and shore via a satellite link.
(http://iabp.apl.washington.edu/overview_hardware.html)

Fig.5.2. The Ice-Tethered Profiler scheme

5.3 Main Results

Water mass thermohaline parameters (T&S) in St. Anna Trough are reliable indicators of heat input with two branches of Atlantic Water (Fig. 5.3). The heat input with the Fram Strait branch was at its minimum in 2008 and increased back in 2009. Year-to year variation in the Barents Sea branch is the opposite (the highest heat input was in 2008). Substantial changes of water properties were also observed in the upper mixed layer. In 2007 the entire water column from the depth of the upper boundary of AW at 100 m was at near to freezing point temperature. Reduction of the summer Arctic sea ice after 2007 markedly changed this situation. In 2008 the cold subsurface layer was about twice thinner, than in 2007, while in 2009 warm surface water with positive temperature occupied the most part of the transect. The thickness of this warm water pool was about 20-25 m. The origin of this warm layer is apparently linked with local atmospheric heating over the areas which remained ice free for a long time during summer 2009.

Temperature and salinity sections to the north of cape Arctichesky (Fig. 5.4) demonstrate weakening of the Fram Strait branch of Atlantic Water after 2007. 2009 data show that T&S minimum has passed in 2008 and there is a restoring trend in thermohaline properties. This year-to-year variation corresponds with observations in St. Anna (see above), Fram Strait mooring-based data (Schauer et al., 2008) and NABOS observations north of Svalbard (http://www.iarc.uaf.edu/nabos.php).

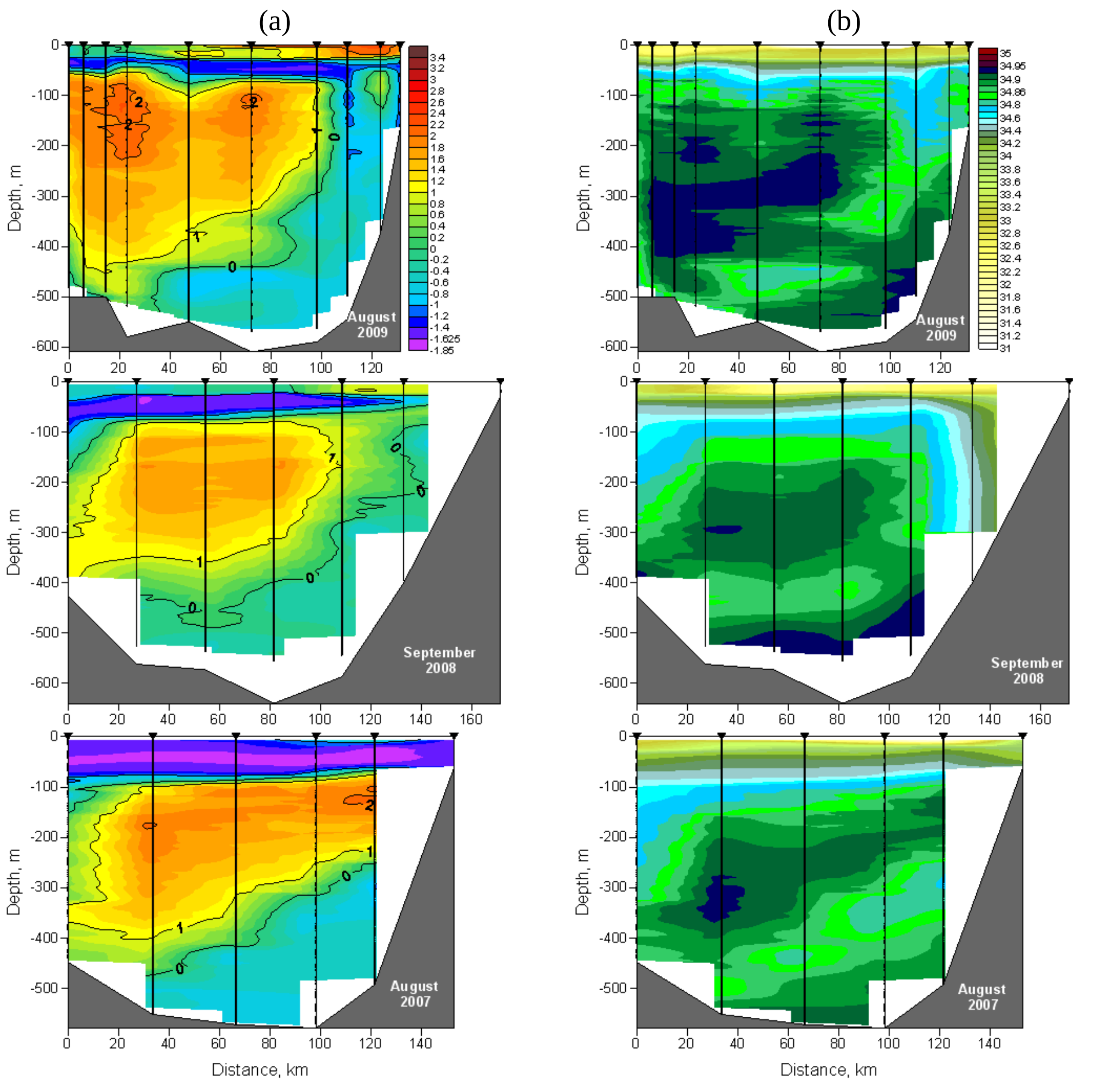


Fig. 5.3. Temperature (a) and salinity (b) distribution at vertical sections across St.Anna Trough in 2007-2009.

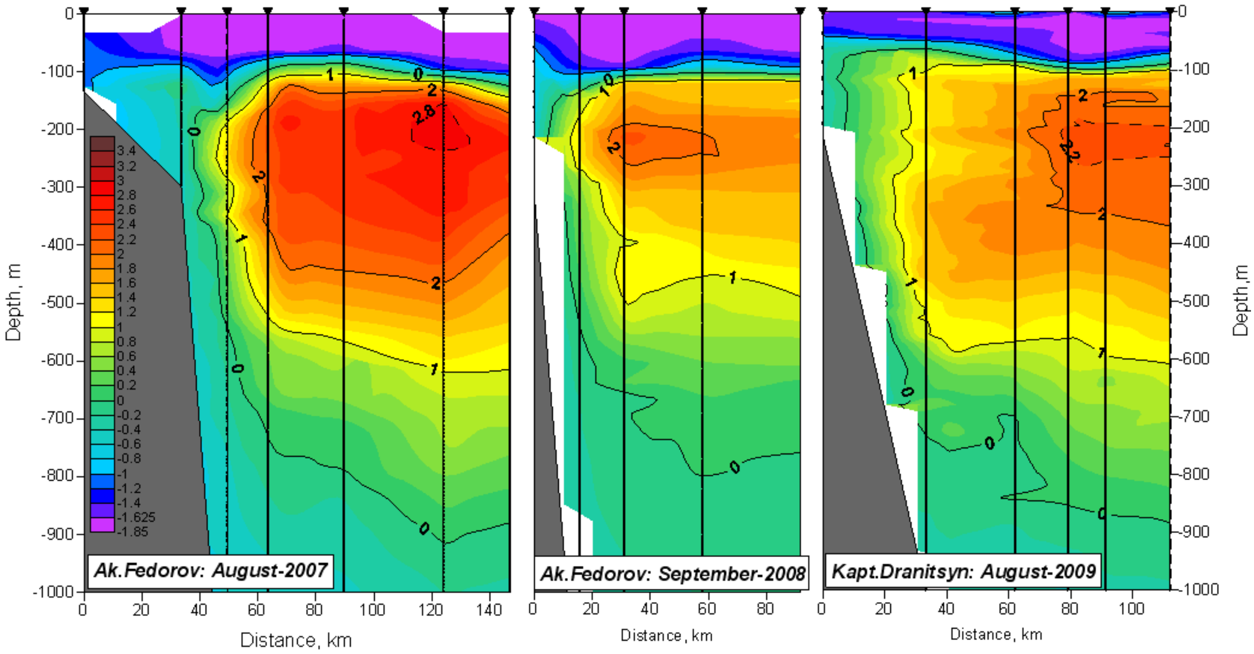


Fig. 5.4-a. Temperature distribution at vertical cross-slope sections near cape Arkticheskiy (the northernmost point of Severnaya Zemlya Archipelago) in 2007-2009.

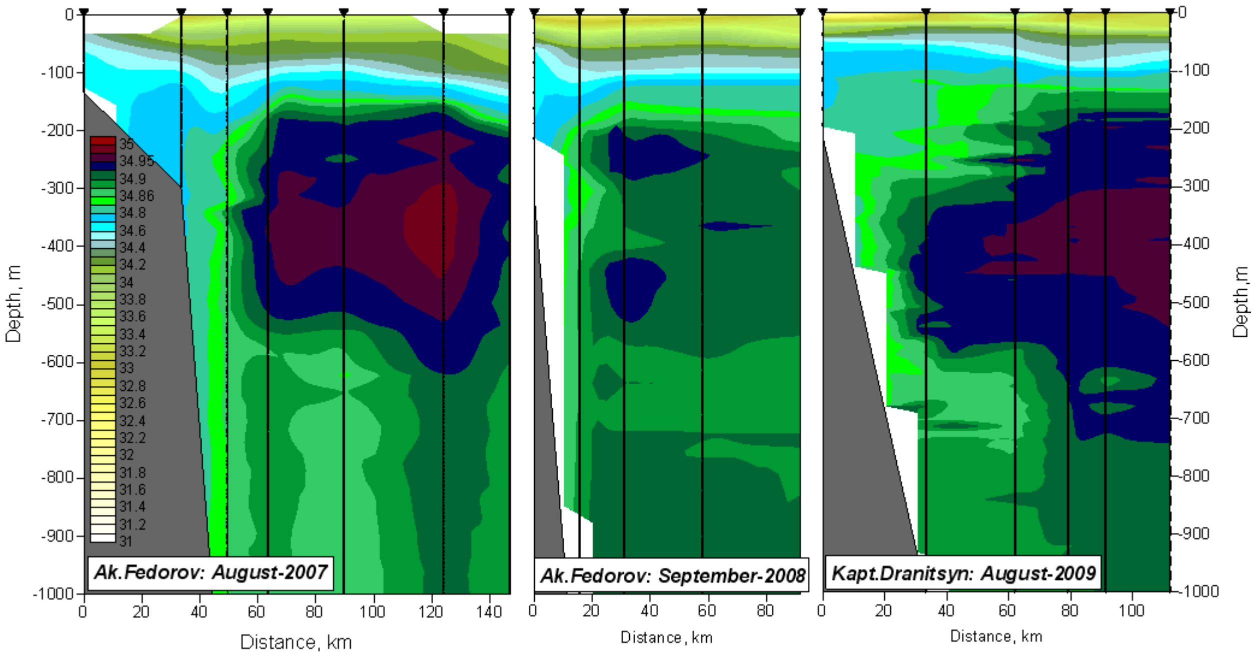


Fig. 5.4-b. Salinity distribution at vertical cross-slope sections near cape Arkticheskiy (the northernmost point of Severnaya Zemlya Archipelago) in 2007-2009.

6. "Akademik Fedorov": 2010 cruise

The cruise was conducted by Arctic and Antarctic research institute (AARI) under the aegis of the Russian national program VGKS (=External Shelf Margin Determination). This cruise was mostly dedicated to geological studies, while oceanographic works were done as a supplementary research. This dictated the number and location of hydrographic casts, most of which were done with expandable devices (XBT/XCTD) en route. The main operational area covered the central Arctic basins around the Lomonosov Ridge (Fig. 6.1).

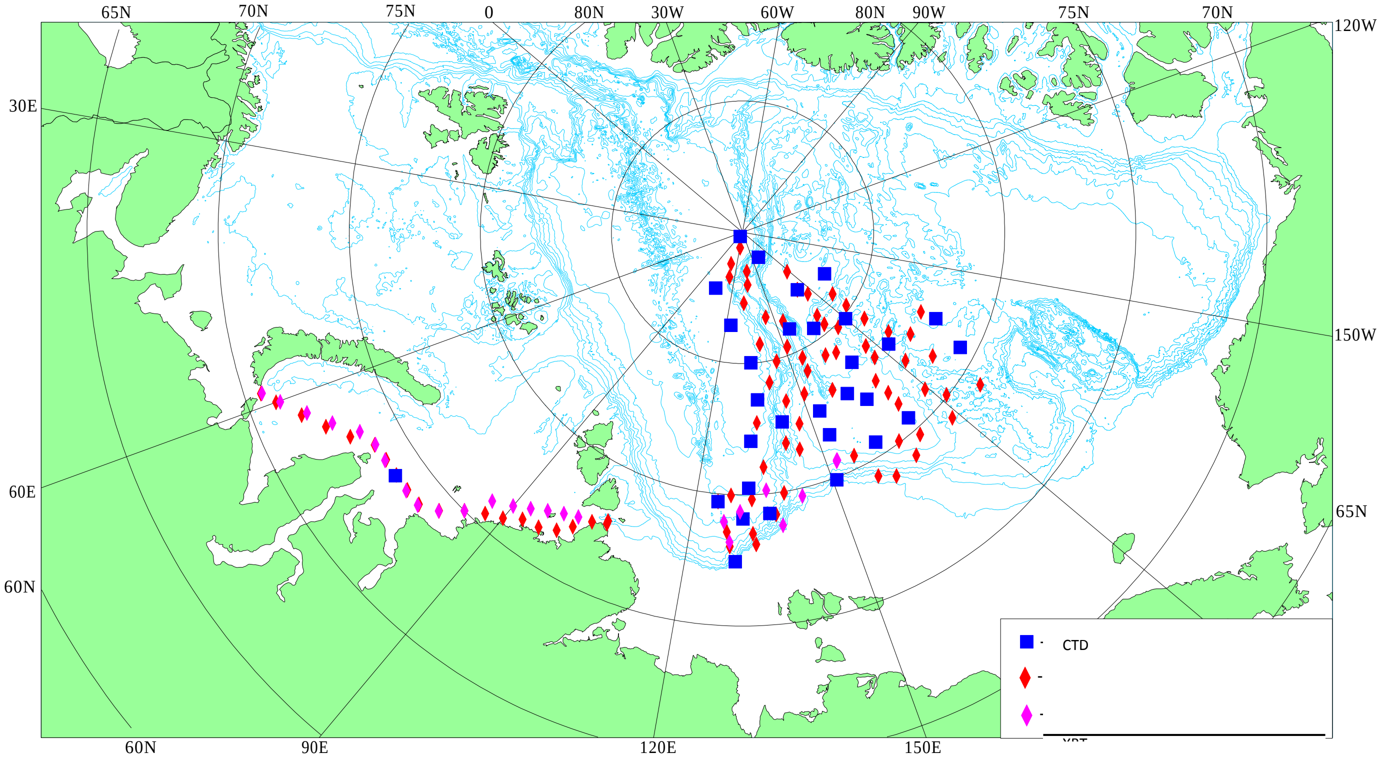


Fig. 6.1. "Akademik Fedorov" – 2010 oceanographic stations

6.1 Objectives

The major objectives of oceanographic studies were:

- Collection of new oceanographic data in the deep Arctic Basin;
- Monitoring of water masses and their dynamics;
- Study of water mass formation
- Study of AW properties transformation in the deep Arctic basins.

6.2 Methods and equipment

Main method used during this cruise was CTD/XCTD/XBT casts en route. CTD profiles were done from surface to bottom with a SeaBird Profiler SBE911plus. XBT/XCTD profiling was done from the surface to 600 m and 1000 m correspondingly.

6.3 Main results

Loop-wise circulation of Atlantic Water in the Nansen-Anundsen Basins is very well traced at the transect across Lomonosov Ridge (Fig. 6.2). Upper boundary of AW is embedded within 135-175 layer, while the lower one stays within 775-980 m. The warm kernel is very well distinguished at the western edge of the transect within the depth 270-290 m. Maximum temperature in AW layer is 1.47ºC, which is rather high compared to XX century climatology (EWG, 1997,1998). Salinity in the warm core is 34.88 PSU. To the east of Lomonosov Ridge the temperature in AW is about half degree colder. This probably indicates that direct penetration of AW across the ridge does not happen at routine basis.

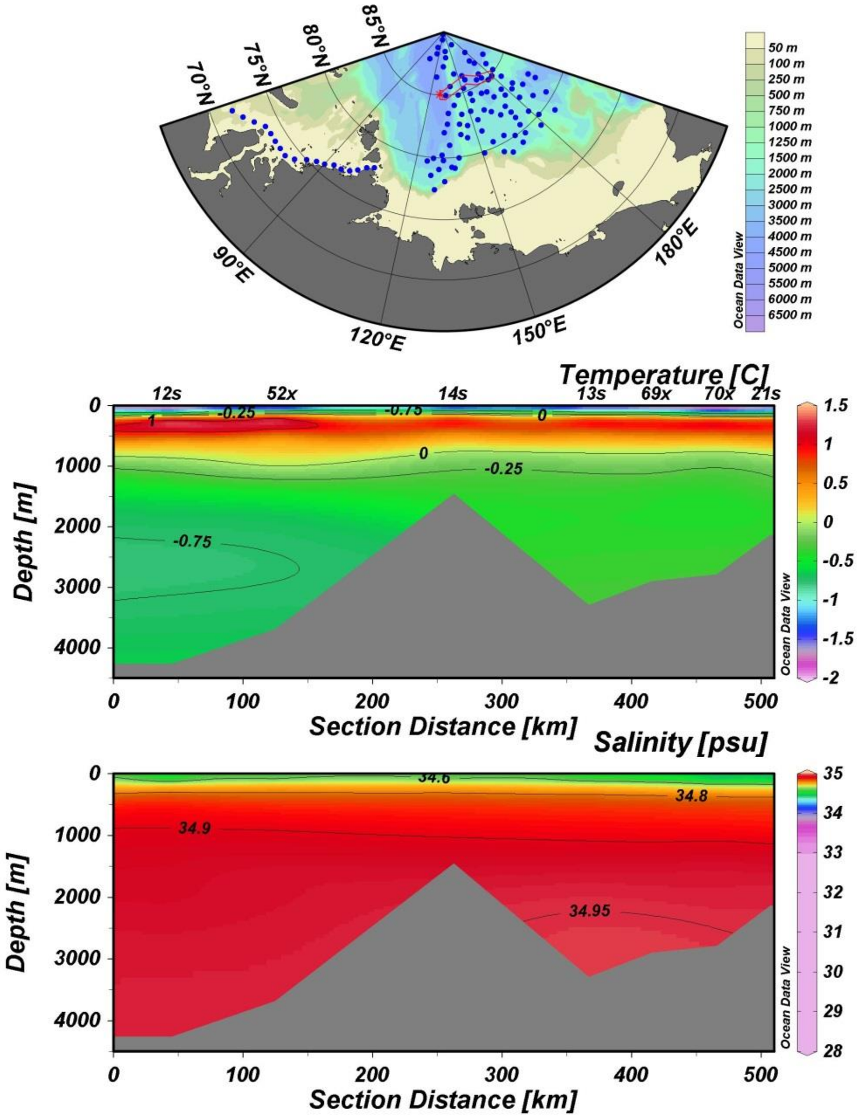


Fig. 6.2. "West-East" combined section across Lomonosov Ridge at 85ºN: position of stations (upper), temperature (middle), salinity (lower).

7. "Akademik Fedorov": 2011 cruise

The cruise was conducted by Arctic and Antarctic research institute (AARI) under the aegis of the Russian national program VGKS. This cruise was a continuation of geological studies, started in 2010 cruise. Similar as in the previous year, oceanographic works were done as a supplementary research with the same objectives. All hydrographic casts were done en route. Most casts were done with expandable devices (XBT/XCTD). The main operational area covered deep areas of Nansen and Amundsen basins in the vicinity of Lomonosov Ridge (Fig. 7.1).

7.1 Objectives

The major objectives of oceanographic studies were:

- Collection of new oceanographic data in the deep Arctic Basin;
- Monitoring of water masses and their dynamics;
- Study of water mass formation
- Study of AW properties transformation in the deep Arctic basins.

7.2 Methods and equipment

Main method used during this cruise was CTD/XCTD/XBT casts en route. CTD profiles were done from surface to bottom with a SeaBird Profiler SBE911plus. XBT/XCTD profiling was done from the surface to 600 m and 1000 m correspondingly.

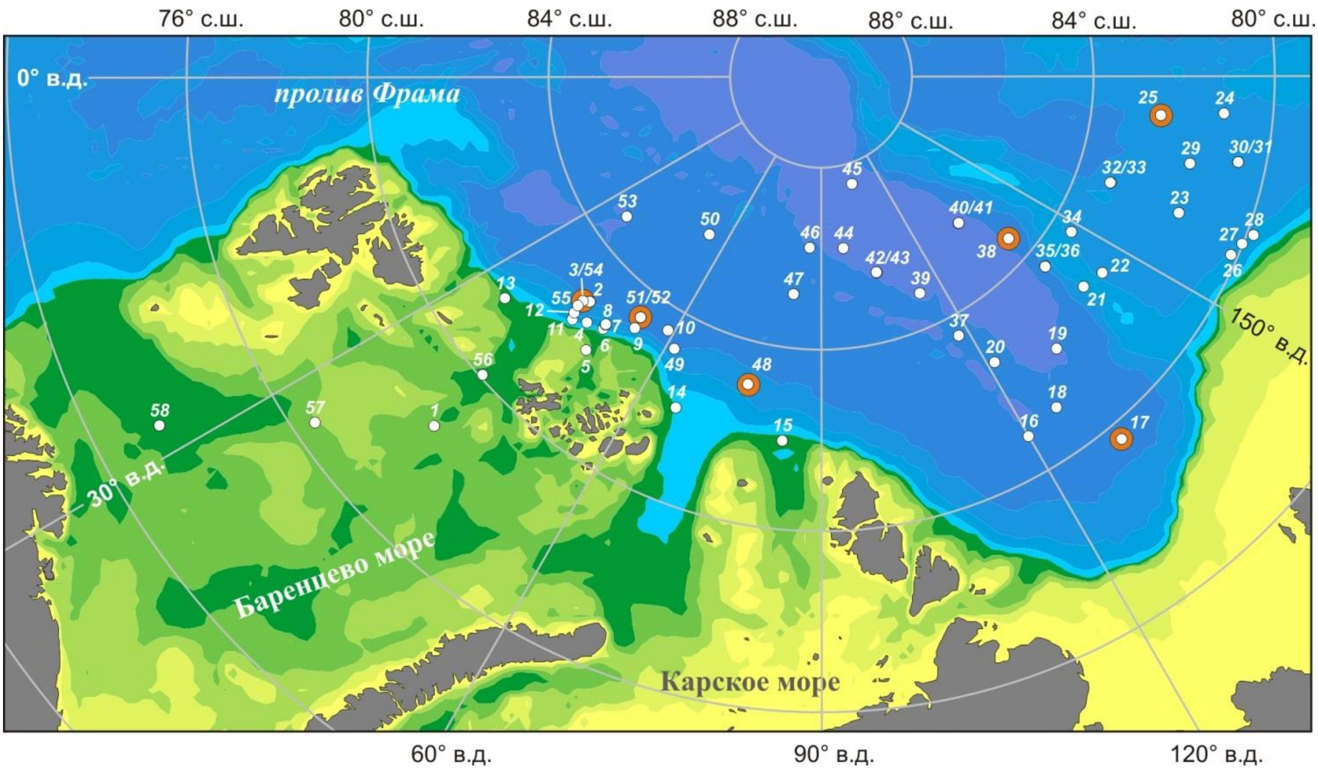


Fig. 7.1. “Akademik Fedorov” – 2011 oceanographic stations

7.3 Main results

During the 2011 cruise large number of hydrographic casts was done in the deep basins of Atlantic sector of the Arctic Ocean. Comparison of temperature and salinity at these profiles with climatological values allowed making quantitative assessment of the current "warm" state of AW (see Fig. 7.2). The main conclusion coming up from this analysis may be summarised in the following way. Despite moderate cooling of the inflowing through Fram Strait Atlantic Water after 2006-2007 (Polyakov et al., 2011), the temperature in the AW layer in the central Arctic basins stays well above the XX century climatology. The positive deviation is typically between 0.1 and 0.5ºC. Salinity anomalies are also positive in the range 0.02 - 0.06 PSU. The later indicates that the new "warm" state of AW in the Arctic Ocean is rather stable and might affect other components of the Arctic climate system: sea ice and atmosphere.

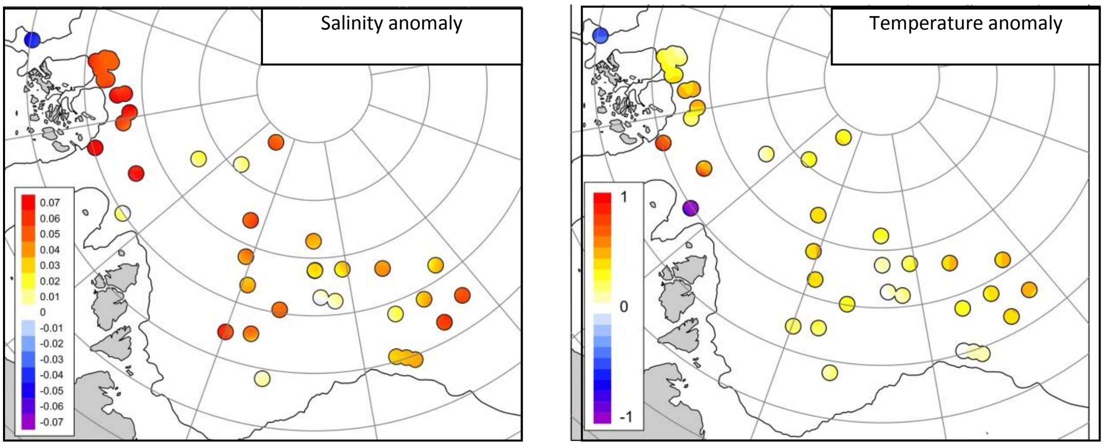


Fig. 7.2. Spatial distribution of salinity (a) and temperature (b) anomalies from the XX century climatology (EWG, 1997, 1998)

8. "Professor Molchanov": 2012 cruise

The cruise was conducted by the Northern Arctic Federal University (SAFU, Arkhangelsk) under the national program of Northern research. Oceanographic program was carried out by Arctic and Antarctic research institute (AARI). The overall goal of oceanographic studies was to collect new data at the recurrent sections in the Barents Sea. The scheme of accomplished oceanographic stations is presented in Fig. 8.1.

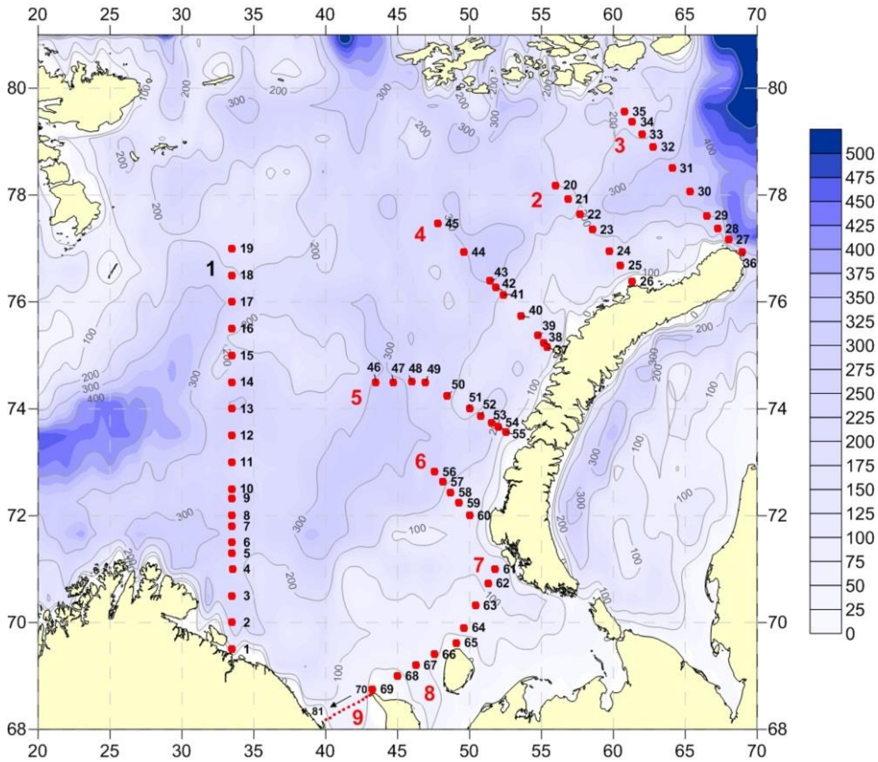


Fig. 8.1. “Professor Molchanov” – 2012 oceanographic stations

8.1 Objectives

The major objectives of oceanographic studies were to:

- Get detailed information on oceanographic regime of the Barents Sea
- Study transformation of the Barents Sea Branch of Atlantic water along its pathway in the Barents Sea
- Distinguish water masses and hydrological fronts and estimate their parameters

8.2 Methods and equipment

Traditional oceanographic method of making measurements at sequential sections across the gradient of bottom topography was used. CTD profiles were done from surface to bottom with a SeaBird Profiler SBE911plus.

8.3 Main results

During the recent years winter sea ice cover in the Barents has substantially retreated to the north (Arthun et al., 2012). This shift may have affected hydrographic regime due to change of ocean-air energy fluxes at the sea surface. A set of transects along the pathway of

AW in the Barents Sea allowed to measure spatial variation of thermohaline properties under altered conditions at the sea surface.

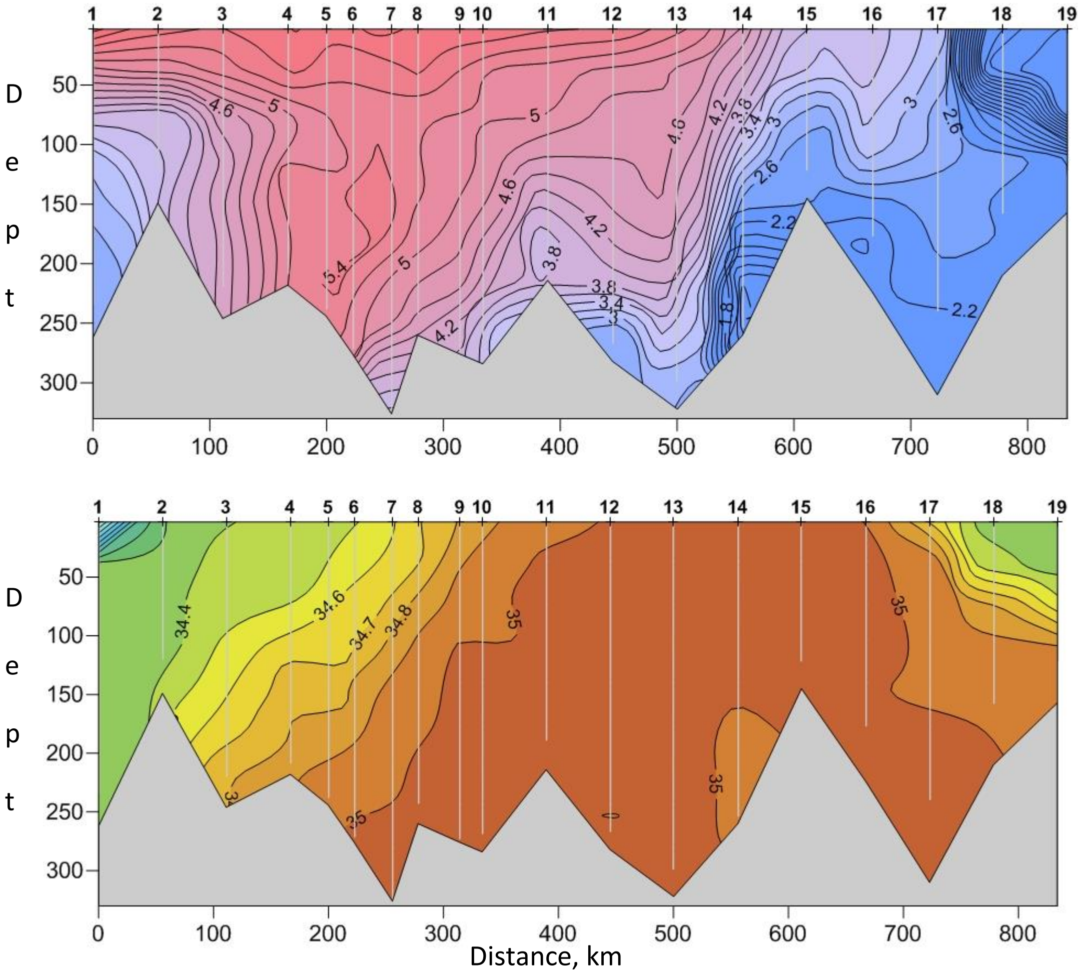


Fig. 8.2. Temperature (upper panel) and salinity (lower panel) distribution along Kola section

In June 2012 AW inflow through the Barents Sea opening (BSO) was rather strong. At the Kola section, which is the oldest recurrent section in the Barents Sea, the temperature of the inflowing water was about 0.5 - 1ºC warmer, than the average June value over the time period 1952-1994 (Tereschenko, 1997). This warmer water kept positive anomalies over the mean as far downstream as the Matochkin Shar traverse (about 74ºN).

9. "Professor Molchanov": 2013 cruise

The cruise was conducted by the Northern Arctic Federal University (SAFU, Arkhangelsk) under the national program of Northern research. Oceanographic program was carried out by Arctic and Antarctic research institute (AARI). The overall goal of oceanographic studies was to continue monitoring studies resumed in 2012. The scheme of accomplished oceanographic stations is presented in Fig. 9.1.

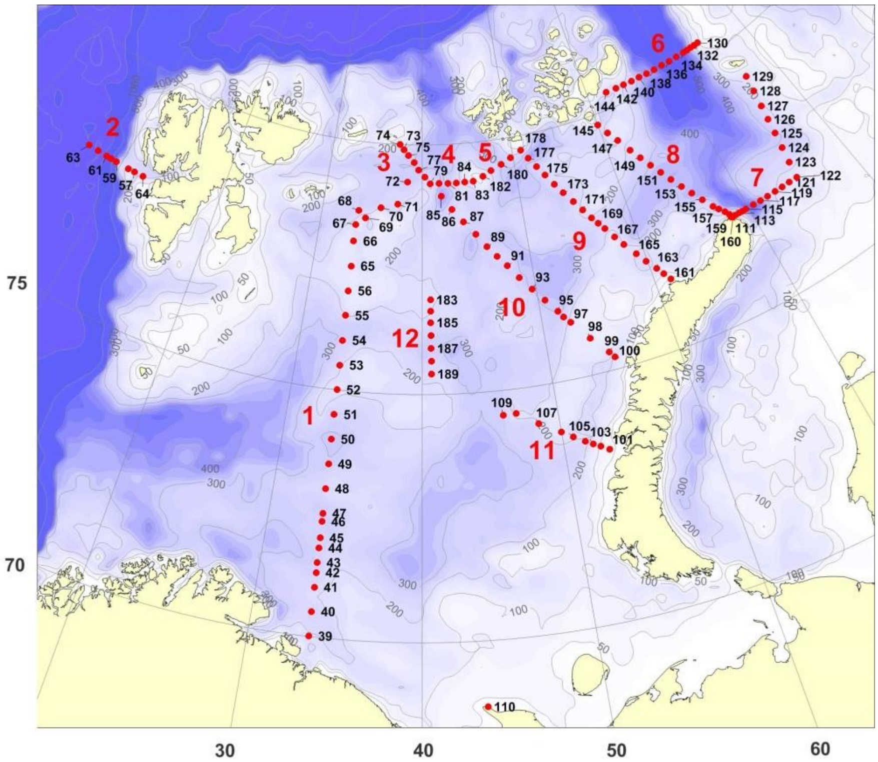


Fig. 9.1. “Professor Molchanov” – 2013 oceanographic stations

9.1 Objectives

The major objectives of oceanographic studies were to:

- Document year to year changes in the water mass properties
- Measure transformation of AW in the North Barents Sea and North Kara Sea
- Map the location of main water flows in the north-eastern Barents Sea

9.2 Methods and equipment

Detailed (polygon-wise) positioning of oceanographic sections was used in order to resolve horizontal structure of temperature and salinity fields. CTD profiles were done from surface to bottom with a SeaBird Profiler SBE911plus.

9.3 Main results

Detailed CTD surveys with high spatial resolution between sections allowed precise mapping of the AW pathways in the Barents Sea. BSBW is carried with North Cape current from the west and is distinguished by warm and salty core up to the traverse of Matochkin Shar (the strait between Novaya Zemlya isles). On its further motion northward this water is probably diluted by cold and salty shelf water originated over shallow banks of the western shelf of Novaya Zemlya (Ivanov and Shapiro, 2005). As a result the temperature of BSBW eventually entering the north Kara Sea is near zero, or below zero. The Fram Strait branch of AW enters Barents Sea from the Kara Sea, through St.Anna Trough and through Franz Victoria Channel. These two water flows of the same origin are moving in the opposite directions and probably meet and merge up to the south of Franz Joseph Land. Temperature in the core of BSBW experiences strong seasonality, with the range of up to 2ºC. In comparison with 2012 (see Figs. 9.2 and 8.2), thermal state of BFBW was colder: maximum temperature of the inflow water at Kola meridian was about 0.5ºC lower in the same season (mid-June).

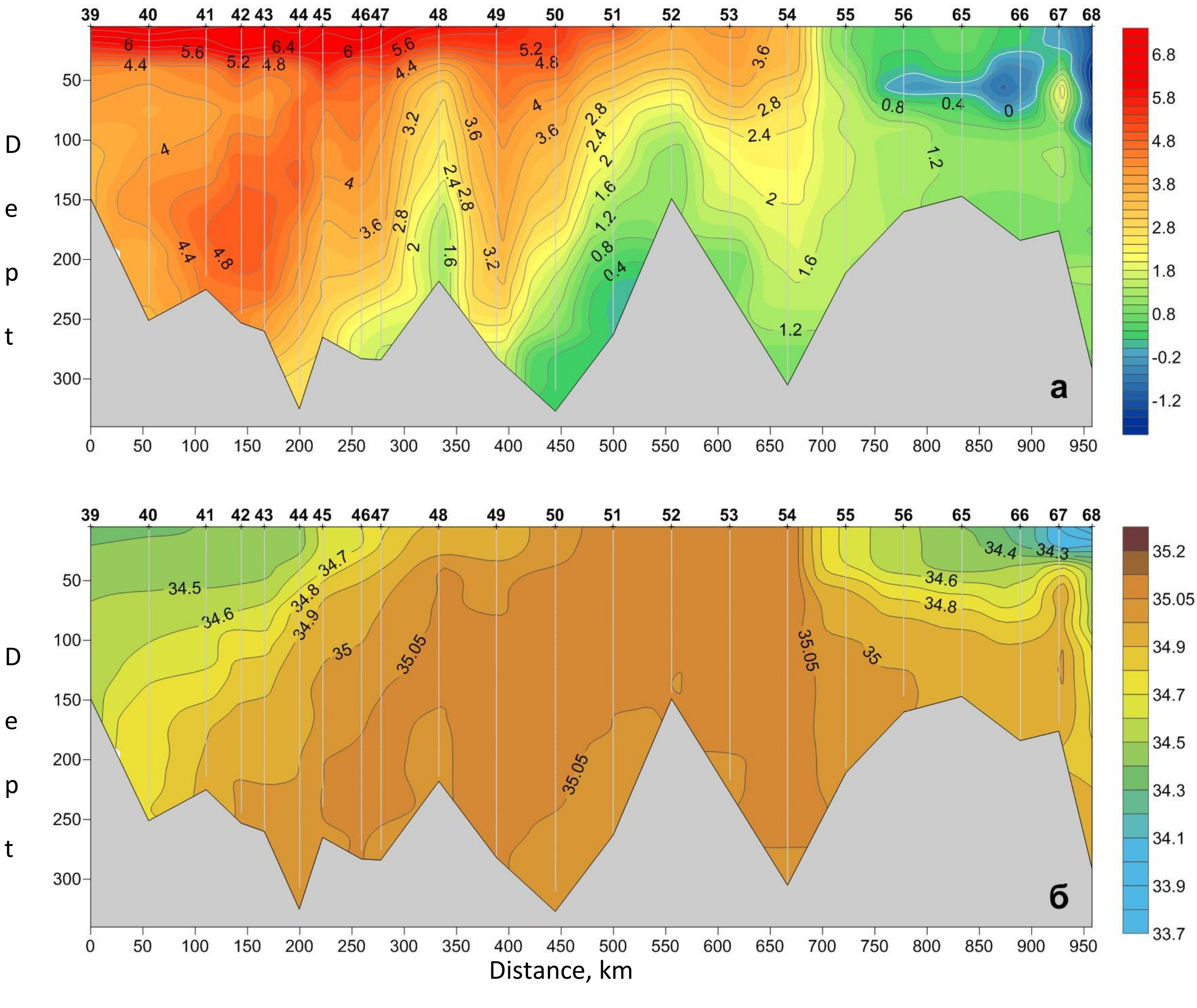


Fig. 8.2. Temperature (upper panel) and salinity (lower panel) distribution along Kola section

10. "Akademik Fedorov": 2013 cruise

The 2013 research cruise in the Arctic Ocean aboard icebreaker Akademik Fedorov was the 9th annual expedition under the aegis of NABOS (=Nansen Amundsen Basin Observations System) conducted by International Arctic Research Center (IARC) University of Alaska Fairbanks, USA in partnership with Arctic and Antarctic Research Institute (AARI) St.Petersburg Russia. This cruise resumed NABOS field research after 4-year time gap. Reduced sea ice causes changes in the water column and in the overlying atmosphere. Documenting of these changes was the main target of the NABOS 2013 cruise. Information collected during the cruise is unique and very valid for understanding of the Arctic climate change. Important outreach component of the cruise was the Summer School, which provided an excellent opportunity for graduate students, PhD students and early career scientists from US, Europe and Russia to learn about the climate change in the Arctic and to participate in field experiments onboard.

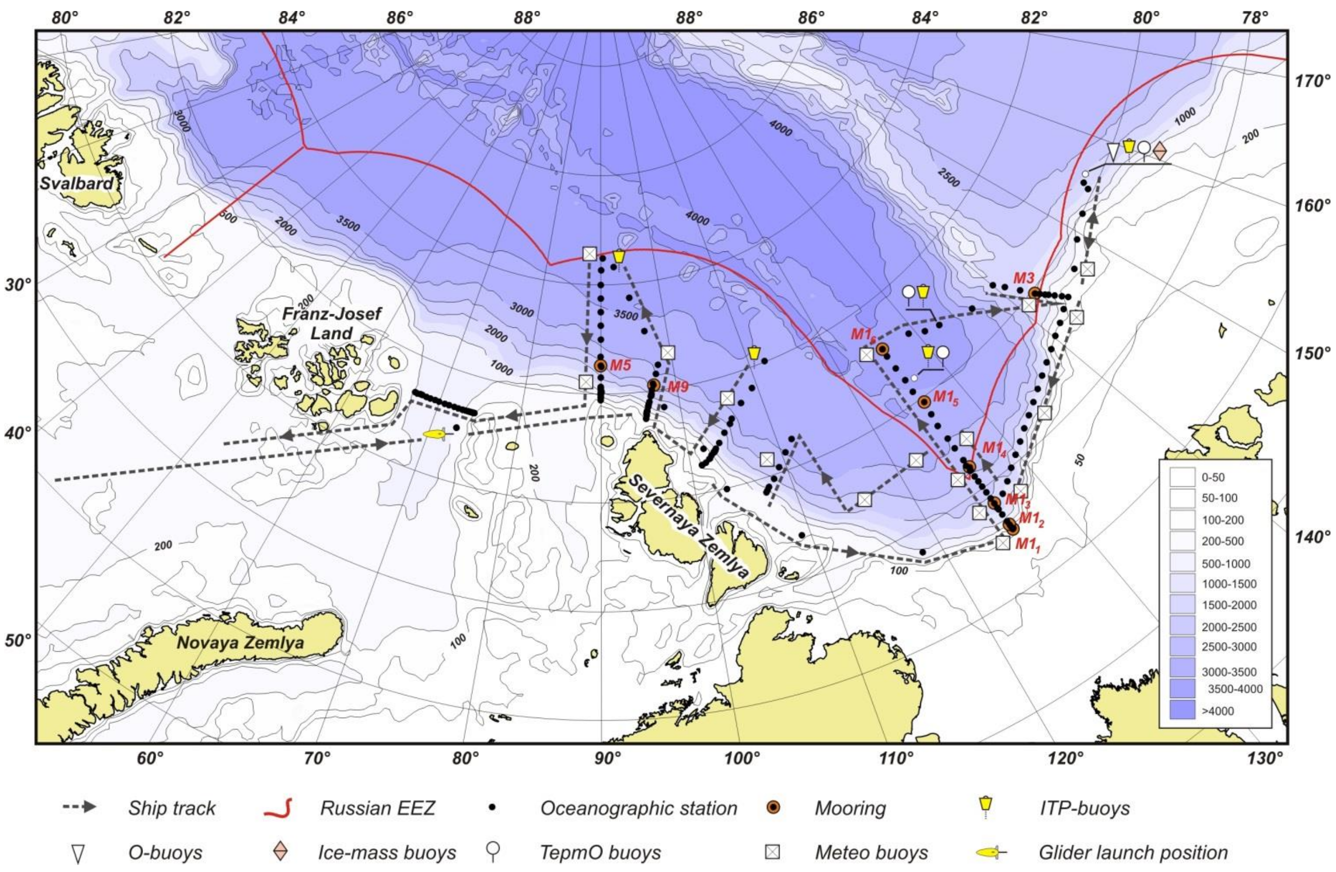


Fig.10.1. "Akademik Fedorov" 2013 cruise map

10.1 Objectives

The major objectives of oceanographic studies were to:

- study water mass structure and year to year variability at standard NABOS sections in the Laptev Sea;
- reveal mechanisms of mixing of two branches of AW to the east of St. Anna Trough;
- deploy long term mooring instruments;
- deploy Ice Tethered buoys (ITP);
- launch the glider.

10.2 Methods and equipment

Methods and technical approach, applied in previous NABOS expeditions, was improved by using SeaBird Profiler SBE19plus and taking online measurements from surface to bottom. Higher spatial resolution at transects were achieved by using expendable devices (XBT/XCTD) in between CTD casts. During this expedition 5 ITPs were deployed as a contribution to IABP program (http://iabp.apl.washington.edu/overview). Glider (undewater remote vehicle – Fig.10.2) was launched in the mouth of St.Anna Trough. This device operated for 10 days, transmitting data via satellite.

Fig. 10.2. Glider launch

10.3 Main results

The prominent feature of 2013 thermohaline structure is strong near surface temperature maximum in the Atlantic sector, where ice free conditions were observed for a long time during this summer. In several instances the thickness of the surface mixed layer exceeded 40-50 m, and its temperature was up to 4ºC above the freezing point (Fig. 10.3). At some CTD casts the upper boundary of AW (if counted by zero-degree isothermal) almost merged with the warm surface layer, which may substantially precondition the next winter ice formation in this area. Preliminary estimations show that the amount of heat accumulated in the surface mixed layer is able to delay ice formation by about 45 days. Specific feature of the area under consideration is that the upper boundary of warm Atlantic origin water (AW) is located reasonably close to the surface (about 60 m). According to the accomplished CTD observations, in several instances warm upper mixed layer almost reached AW, producing a continuous pool of warm water from the sea surface to the depth of several hundred meters. Model estimations demonstrate that under described preconditioning winter thermohaline convection is able to penetrate in the AW layer, efficiently delivering sensible heat from the deep to the surface, and thus, additionally impeding ice formation.

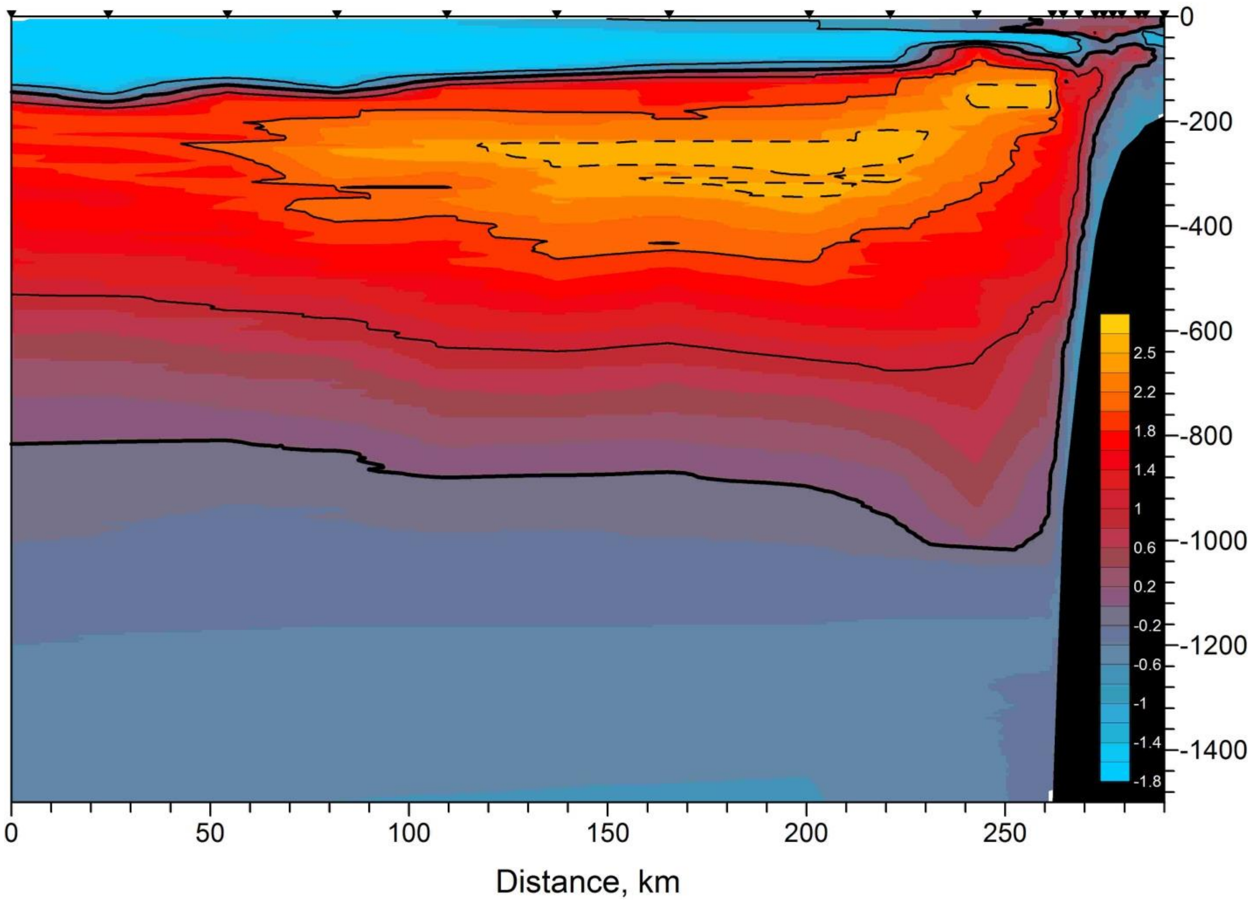


Fig. 10.2. Temperature distribution, ºC at cross-slope section along 90ºE.

Summary

International Polar Year (IPY, 2007-2009) gave a powerful impulse for expansion of the Arctic Ocean research and exploration. The obvious reason behind this is that among predicted consequences of climate change, the one of the ice-free Arctic Ocean is probably the most dramatic and impacting for society in general and for the Arctic-bounding nations in particular. The other reason is that advancing technology of oceanographic observations provided possibilities for experimental studies, which could not be imagined 20 years ago. Increasing cost of fuel and thence field research carriers (vessels, icebreakers) called for consolidating international efforts and funds in big field projects in order to get maximum benefit from the ship-time and to conduct truly multidisciplinary research studies.

Russian polar science responded to these realities by intensified endeavours in the high Arctic, which included manned drifting stations North Pole (resumed in 2003) and scientific cruises onboard research vessels and icebreakers. In this report we have given general description of main Russian expeditions in the Arctic Ocean onboard ships, which had occurred during the recent 6 years (2007-2013). The total number of research cruises included in this report is 10. The basic method of observations in these cruises was CTD profiling (with measurements of temperature and conductivity) along transects, configured across the bottom topography. In total, 782 CTD casts were done in the Barents, Kara, Laptev and East Siberian seas, and in the deep basins of the Arctic Oceans. Besides traditional research methods, new measurement techniques were also used. These new technologies included: (i) anchored moorings equipped with modern measurement devises, like MMP, ADCP and others; Lagrangian drifters - ice tethered profilers (ITP); (iii) underwater remote vehicles - gliders. Oceanographic data, collected in these cruises compose a unique database, which may serve as the basis for statistical and model studies, aimed on understanding of the current state of the Arctic climate system and prediction of its evolution in future. The data from some of these cruises are included in the Supplement to this report. Description of data format is given in the Appendix.

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Appendix: Data description

1. ***"Akademik Fedorov" 2007 and 2008 cruises***

The data are in the supplement archive ASCII file: *Fedorov_2007_2008.zip*. The data include the *header* (info on the cast) and the *rows* (temperature and salinity data with 2 m vertical step).

Description:

Header

<Identifier>

<Day> <Month> <Year>

<Hours> <Minutes>

<Latitude: ddmmss> <Longitude: dddmmss>

<Depth: m>

<Number of levels> <Number of cast>

<Row numbers>

Rows

DDD1 TT.TTT1 SS.SSS1

DDD2 TT.TTT2 SS.SSS2

………………………………

DDDn TT.TTTn SS.SSSn

Example:

AKADEMIK FEDOROV
27 7 2007

19 39
792400 580900
100
199 1
1 2

2	-1.059	31.052
4	-1.017	31.129
6	-0.777	31.598
8	-0.854	31.940
10	-1.045	32.295

2. "Victor Buynitskiy" 2007 cruise: the ASCII file with data can be access via address: http://nabos.iarc.uaf.edu/data/registered/tmp/N3Wkit7vBndgHkczQ2sEXnwUAr0d1j/p2w/nabos_cruise_ctd/2007CTD_SBE19plus4255_XCTD.txt

3. "Kapitan Dranitsyn" 2008 cruise: the ASCII file with data can be access via address: http://nabos.iarc.uaf.edu/data/registered/tmp/N3Wkit7vBndgHkczQ2sEXnwUAr0d1j/p2w/nabos_cruise_ctd/2008CTD_SBE19plus_0.5m.txt

4. "Kapitan Dranitsyn" 2008 cruise: the ASCII file with data can be access via address: http://nabos.iarc.uaf.edu/data/registered/tmp/N3Wkit7vBndgHkczQ2sEXnwUAr0d1j/p2w/nabos_cruise_ctd/2009CTD_SBE19plus_proc.txt