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CLIMATIC ATLAS OF THE BARENTS SEA 1998: Temperature, salinity, oxygen

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CONTENTS

PREFACE

Joint Research of the Murmansk Marine Biological Institute (Russia) and the Ocean Climate Laboratory (USA) within the Framework of the GODAR Project.

The Intergovernmental Oceanographic Commission (IOC) GODAR Project (Global Oceanographic Data Archaeology and Rescue) has it roots at a meeting held in September 1990. Scientists and data managers from oceanographic data centers from the USSR, Republic of Korea, Japan, Chile, Australia, the USA, and the International Council for the Exploration of the Sea (ICES) gathered to discuss the problem of oceanographic data preservation. The discussion of this problem resulted in the organiza-tion of several national projects on oceanographic data archaeology and rescue. In particular, projects were launched at the World Data Center-A (Washington, D.C. USA), the World Data Center-B (Obninsk, Russia), and the World Data Center-D (Tianjin, China). They were supported by IOC UNESCO. With the beginning of such projects, data exchange between scientists and institutions of different countries intensified, procedures of data quality control were updated, and access to data was simplified.

Since 1992 the Murmansk Marine Biological Institute has worked with the WDC-A for Oceanography and the NODC Ocean Climate Laboratory (NOAA), within the framework of the GODAR Project. Main elements of the joint work are:

- archiving of oceanographic data and their digitization;
- quantitative estimation of accuracy of the data obtained with different procedures and measurement techniques;
- development of data quality control programs.

The Climatic Atlas of the Barents Sea 1998: Temperature, salinity, oxygen sums up the first stage of this joint work. We assumed at the beginning of this project that we would be able to carry out all works on archiving and data quality control within several years. After six years of cooperation we state that more work lies ahead.

The initial data of this atlas are being distributed internationally without restrictions via the CD-ROM.

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ACKNOWLEDGMENTS

This work became possible due to the efforts of many generations of scientists, observers, and seamen, who, for more than a century, carried out the enormous amount of work on the collection and analysis of data on the state of the Barents Sea and its biological resources.

For many decades, the leading role in research belonged to the Murmansk-based Polar Scientific Institute for Fishery and Oceanography (PINRO) and the Murmansk Administration of Hydrometeorolo-gical Service (MUGMS). Our knowledge on regularities in the distribution of the Barents Sea waters is largely based on the data collected by the personnel of these institutions.

Special thanks are due to the expedition staff of the Northern Fishery Reconnaissance, led by the PINRO scientists, in oceanographic survey of the Barents Sea.

The Russian Academy of Sciences, the Kola Scientific Center, the NOAA *Climate and Global Change Program* and the NOAA Environmental Science Data and Information Management program have supported this work on the development of an oceanographic database and the computation of the Barents Sea climatic fields.

The UNESCO Intergovernmental Oceanographic Commission (IOC) sponsored the GODAR Project, which resulted in the rescue of large amount of oceanographic data. The help of Dr. Y. Oliounine has been especially critical for the success of the GODAR Project.

We wish to express our gratitude to scientists of the Murmansk Marine Biological Institute (MMBI) especially to Vladimir Denisov, Vladimir Petrov, Oleg Sochnev, Gennadiy Ilyin, Vladimir Savinov, Denis Moiseev, Andrey Kuznetsov. We also wish to thank Todd O'Brien, Daphne Johnson, Margarita Conkright, Tim Boyer, Olga Baranova, Jennifer Rochester, and Carla Forgy of the NODC Ocean Climate Laboratory for their multifacetal help in the database deve-lopment. We would like to thank Misha Trufanov for translating this work from Russian to English.

Dr. Igor Belkin and Dr. Gennady Chepurin reviewed the manuscript version of this atlas.

ABSTRACT

The time and space distribution of 74,256 ocean stations (temperature, salinity, and oxygen) occupied in the Barents Sea during 1898-1993 is presented. These data are recorded on CD-ROM in a format designed for use in electronic spreadsheets and / or databases. Monthly maps defining the station distribution over the Barents Sea are given for every year. Monthly mean fields of temperature and salinity distribution for the depths 0, 30, 50, 100, and 200 m, with a grid distance of 10'x30' are plotted using objective analysis techniques. A description of the summer and winter seasons is given in terms of the spatial-temporal variability of thermohaline characteristics of the Barents Sea.

1. INTRODUCTION

The Barents Sea, owing to its unique natural characteristics, is outstanding among the seas of the polar oceans. Penetration of warm Atlantic Ocean waters to the Barents Sea produces climatic conditions for this area which are anomalous for the Arctic Ocean. These anomalous climatic conditions have various forms of manifestation.

The Barents Sea is the only Arctic region which remains unfrozen throughout the year. During some years the ice boundary in winter passes along 75°N. The inflow of warm Atlantic waters makes the climate of the Kola Peninsula and adjacent regions more benign during winter time. Rain in January - February is a typical phenomenon for Murmansk. At the same time, the proximity to the Arctic is demonstrated by snow storms which may occur in any summer month.

The Barents Sea is renowned for its biological riches. Hundreds of vessels from different countries fish there for valuable fish species and invertebrates. Sea products harvested in the Barents Sea are a significant dietary supplement for the population of Europe and Asian Russia. The Barents Sea biological productivity is largely dependent on the variability of the inflow of the Atlantic waters.

The anomalous oceanographic characteristics of the Barents Sea make the Barents Sea a natural laboratory for studying a large number of problems on the ocean's effect on climate and the distribution of marine life.

The anomalous climatic conditions also result in diversified human activities. The Russian city of Murmansk is a large base for research, fishery and transport vessels. Nuclear-powered ice-breakers (a part of the Northern Maritime Shipping Company) based in Murmansk, have turned annual trips to the North Pole into a routine. During the past decade, interest in the

Barents Sea has drastically increased due to the discovery of oil and natural gas, and due to radioactivity waste disposal concerns.

Moscow and St. Petersburg, Russia's largest marine scientific centers, are located relatively close to the Barents Sea. As a result, many outstanding Russian marine biologists and oceanographers have devoted part of their scientific careers to research involving the Barents Sea and its bioresources. In the mid-1930s, owing to their efforts, the Murmansk Marine Biological Institute of the USSR Academy of Sciences, and the Polar Research Institute for Marine Fishery and Oceanography of the USSR Fishery Ministry were founded. These institutes explore the Barents Sea and North-Eastern Atlantic.

In 1937, the Administration for Northern Fish Reconnaissance was established to provide fleet with information on sea state, and to develop new areas for fishing. In 1938, the Murmansk Administration for Hydrometeorological Service started operations.

During 1920-1940, regular oceanographic observations in the open Barents Sea were carried out by 2-3 vessels. After World War II, the number of research vessels surveying the Barents Sea on a regular basis increased drastically. During some periods, more than 10 ships simultaneously gathered oceanographic and biological data over the entire Barents Sea. For instance, during 1950-1995, the Kola Meridian transect was made 723 times. During the period 1870-1995, we estimate that the total number of hydrological stations occupied in the Barents Sea by Russian scientists was 300,000-400,000.

This publication contains oceanographic data on the Barents Sea collected by the Murmansk Marine Biological Institute and World Data Center-A for Oceanography (Silver Spring, USA) as part of the Global Oceanographic Data Archaeology and Rescue (IOC UNESCO). Based on the objective analysis of these, the monthly mean fields of temperature (T), salinity (S), at standard levels of 0, 30, 50, 100 and 200m are plotted. The initial data (74,256 stations for the period 1898-1993) are on CD-ROM in a format convenient for electronic use.

2. OCEANOGRAPHIC EXPEDITIONS TO THE BARENTS SEA

Many countries have launched scientific expeditions to the Barents Sea. The results of Norwegian, English, Swedish, and German expeditions were published in the western literature and became accessible to the scientists from the different countries. These papers are well known in Russia and are widely used by specialists in various fields of natural sciences. The materials by Russian scientists, in most cases, are published only in Russian, and are there-fore inaccessible to many English language readers. Therefore, information about the Russian expeditions to the Barents Sea will be provided in this section.

Reference contains a list of books and papers comprising the cruise reports and the measurement data collected in the Barents Sea and adjacent regions during 1870-1927.

During the 19th and 20th centuries, the Barents Sea has been the area of the Arctic basin which has been most explored by research ships. As early as 1837, the expedition aboard the French ship La Recherche carried out measurements of sea surface temperature as far north as 79º36'. A large number of sea surface temperature measurements were made by the Dutch ship Willem Barents during seven cruises to the Barents Sea in 1878-1884. Data on these cruises were used by P. van Heert for plotting maps of summer sea surface temperature distribution for the Barents Sea. In the 19th century, Russian, Norwegian, German, Swedish, Dutch, and Austrian vessels made sea temperature and density measurements at the surface and at different depths. For instance, during 1870 - 1871 in the Barents Sea, seawater temperature was measured by the following vessels: Variag, Zhemchug, Samoed (Russia), Johanna Maria, Polarstjernen, Samson, Skjon Valborg, Ellida, Freya, (Norway), Diana, (Great Britain), and Germania (Germany).

Starting in 1880, Russian military and commercial ships were used on an annual basis for meteorological and hydrological surveys of the Barents Sea. Although hydrological measurements were not the principal objective of the cruises and were made en route, the results were thoroughly analyzed and published in key Russian scientific journals. The young university graduates N. Knipovich and M. Zhdanko, who made these measurements, later became leading oceanographers.

In 1899, the Stockholm conference raised the issue about the establishment of the International Council for the Exploration of the Sea (ICES). Research Program aimed at exploration of marine fishing areas was suggested. The council was facing a series of problems on the standardization of measurements in the ocean. In the Barents Sea, three standard transects were planned, the main one being the transect along the Kola Meridian 33°30' E. The ICES council planned to repeat the standard transects annually in February, May, August, and November, however this plan was not realized and the transects were made not more than two times a year. In the Barents Sea research on the transects ceased in 1906 and resumed after 1917.

At the end of the 19th century a new stage in research on the Barents Sea commenced. The Russian government allotted funds for two large-scale expeditions to the Barents Sea.

The first expedition was launched in the summers of 1898-1906 on the ships Pomor and Andrey Pervozvannyi. The expedition ship Andrey Pervozvannyi was built specially for oceanographic research. Initially the expedition was headed by N. Knipovich, and after 1902, by L. Breitfus. Within the period 1898-1906, more than 800 deep-sea stations were made mainly in the southern and south-eastern Barents Sea, and along three transects (international triangle): Kola Bay - Kola Meridian to 75°30' N - Novaya Zemlya - Kola Bay. In addition, plankton and benthos were collected.

The second expedition was carried out during 1899-1914 on the ship Pakhtusov. During this expedition all meteorological and hydrological measurements were taken by the officers of the Russian Navy. In total, more than 200 deep-sea stations and 9000 sea surface temperature measurements were made.

In February 1899, Admiral S.O. Makarov initiated the construction of a powerful ice-breaker Ermak which in August reached as far North as 81°21' N. In 1901, S.O. Makarov on the Ermak sailed for the Barents Sea, but was entrapped by floating ice at the latitude of 77°30' N near Novay Zemlya. After a month-long ice drift, the crew managed to make its way to Franz-Josef Land. In total, Ermak made 62 deep-sea hydrological stations.

In 1914, a small number of deep-sea temperature and salinity measurements were made in the coastal waters off the Kola Peninsula while searching for a place for the construction of a merchant seaport. In the same year the vessels Vitaliy, Vaigatch, Sergeyi Vitte, Velikaya Knyaginya Olga Konstantinovna, Keret, Vasiliy Velikiy, and Nikolay of the Arctic Ocean Hydrometeorological Service made about 700 temperature/salinity measurements in the surface layer along with the measurement of pressure, air temperature, and weather.

During World War I the number of scientific cruises to the Barents Sea decreased drastically. Our database contains not a single station made during 1914-1917. Beginning in 1917, the number of scientific cruises to the Barents Sea increased sharply. This was related to the organization of fisheries and exploration of Russia's northern regions.

In 1919, the Pechora Expedition was organized, and in 1920 the Northern scientific-fishery expedition was organized. The latter started the Arctic and Antarctic Research Institute. Beginning in May 1921 the Murmansk Biological Station launched regular observations at the Kola meridian with the help of the State Hydrological Institute. In the same year the Floating Marine Scientific Institute (Plavmornin) was founded.

In the summer of 1921, a 3,000 ton ice-breaker Solovey Budimirovitch, soon afterwards renamed Malygin, was transferred for the Plavmornin. On January 10, 1922, an unfinished 550-t and 41.5 m long whaler Persey was commissioned for the Plavmornin. Her bow compartment accommodated 5 laboratories. Hydrological and hydrochemical studies were made at the afterpart. Later Polar Research Institute for Marine Fishery and Oceanography was founded on the basis of the Plavmornin.

In the period 1923-1941 Persey made more than 100 cruises and 2,000 deep-sea stations in the Barents Sea and Kara Sea. In 1932-1933, during the Second International Polar Year, 18 cruises with 476 deep-sea stations were made in the Barents Sea and Kara Sea.

The data collected served as a basis for plotting the main isobaths and isotherms. A rather substantial oceanographic database was built. In 1932-1938, the first atlases, fishery maps, sailing directions, and other manuals were published.

In 1938, PINRO for the first time used sonars to study sea bottom morphology, which allowed a qualitatively new step of research, publication of large-scale navigation and fishery maps, and compilation of a detailed bathymetric map of the Barents Sea.

In 1934, a system of standard transects was proposed, and in 1935 approved by the PINRO Scientific Council, as well as the volume and methods of the multidisciplinal oceanographic observations, seasonal oceanographic surveys, and monthly observations along the Kola Meridian transect. From April 1938 until present, observations in the Barents Sea were made by this system. Owing to this fact, we have now a unique oceanographic database systematized in time and space.

During World War II, no oceanographic research was carried out in the Barents Sea. After World War II the structure of the scientific fleet in the Barents Sea changed both qualitatively and quantitatively. For instance, in 1958-59 more than 15 vessels made oceanographic and meteorological observations in the Barents Sea. Altogether during these two years about 10,000 deep-sea stations were occupied in the Barents Sea. Apart from the standard temperature and salinity measurements, oxygen, pH, and alkalinity were made at about one-third of all stations. At approximately 10% of the stations, phosphates and nitrates were made. During August-September 1984, 12 vessels made a seawide survey of the Barents Sea. More than 2500 deep-sea stations were occupied.

3. DATA ANALYSIS

3.1. Data Sources

Oceanographic data used for this publication were obtained from the following institutions:

a. World Data Center - A (WDC-A) for Oceanography, Silver Spring, USA. WDC-A has been recieving oceanographic data from many marine organizations including WDC-B, Obninsk, Russia and WDC-D, Tianjin, China.

b. Murmansk Marine Biological Institute, Russian Academy of Sciences. The oceanographic data base of the Murmansk Marine Biological Institute consists of data measured by MMBI scientists, data found in libraries, and data acquired during joint scientific work with marine organizations in particular PINRO, North Fishing Reconnaissance, and the Murmansk Hydrometeorological Service.

c. CD-ROM: Eastern Arctic Ice, Ocean and Atmosphere Data, Volume 1, 1991, National Snow and Ice Data Center, CIRES-1, University of Colorado, USA

Initially, the database was formed for the region 66-82° N and 5-105° E, which slightly exceeds the Barents Sea area. For this region the WDC-A files contained 104,370 stations, from them 47,863 were within the Barents Sea. The CD-ROM (CIRES-1, University of Colorado, USA) for the data sampling region (the Barents Sea and the region adjacent to the Spitsbergen) contains 2,148 stations. The Murmansk Marine Biological Institute files contained 42,654 stations, and 36,203 of them were within the limits of the Barents Sea.

After merging all data and rejection of duplicate stations, 74,280 stations within the Barents Sea were put on the CD-ROM.

3.2. Data Processing Steps

The data banks of MMBI, NODC/WDC-A, and the CD-ROM CIRES-1, have different formats. Therefore, the first step of data processing consisted of conversion into the format described in Section 4.2. At the same time, data were converted into consistent measurement units, and the preliminary deletion of erratic values, was carried out.

Twelve files were formed, each consisting of the stations occupied within one month. Along with this, data formats, depth inversion and depth duplication, were checked. Data were sorted over time and duplicate stations were deleted. Thus the resulting twelve data arrays form the first level of database (directory "DATA\STEP_1" on the CD-ROM).

The values outside the limits of 3s were deleted at the next stage of the data quality control (Golubev et al., 1992; Levitus S. and Boyer T.P., 1990). The computations were made for each month and observation depth separately. The twelve data arrays thus obtained form the second level database (directory "DATA\STEP_2" on the CD-ROM).

To solve a wide variety of problems, one needs data interpolated to several levels. Therefore the data obtained at the second stage (directory "DATA\STEP_2" on the CD-ROM) were interpo-lated to the standard levels (directory "DATA\STEP_3") and the regular 5-m levels: 0, 5 m, 10 m, ...500 m (directory "DATA\STEP_4"). Data of the directory "STEP_3" was used for the objective analysis, plotting the maps of spatial distribution of parameters at different levels, and for generalizations.

3.3. Data Quality Control

3.3.a. Duplicate Check

The data merged were checked for the coincidence of the coordinates, date, and time of station. When no station time is indicated, all the stations made during one calendar day were compared. For the stations without time indication, their depth is compared and the data available at the first level. If at two stations the coordinates and time coincide or, if time is absent, the first level data and depth coincide, the station containing more parameters at more levels is selected for further processing and analysis.

3.3.b. Data Sampling Ranges Checks

There are numerous references containing the admissible ranges of variation of the oceanographic characteristics for the Barents Sea. For our range checks we used the criteria which are given in one of the latest references on the Barents Sea (Barents Sea, 1990).

The following ranges were set: for temperature -2.00 to 15.00 C°, salinity 0.000 - 36.000 pss, and oxygen 0.00 - 19.00 mg/l.

The data sampling range according to the observation date and time was set from 00 h GMT January 1, 1898 to 2400 h GMT December 31, 1993.

For the Barents Sea the maximum possible observation depth cannot exceed 550 m.

3.3.c. Statistical Check

The check for statistical data uniformity and the elimination of sharply deviating values was performed separately for each month and observation level. Data were interpolated to standard levels.

The limits of admissible values were calculated using a 3s criterion (Levitus and Boyer, 1990). The values falling outside these limits were deleted from use. About 0.3% of all data appeared to lie outside the limits of 3s. These agrees well with the theoretical estimate for the number of observations which should be outside the limits of 3s. This indicates that this criterion is applicable for quality control of oceanographic data of the Barents Sea. When considering several months of data together, one can observe a sharp (5-7%) increase of the amount of data rejected. This indicates that the selected time intervals are the optimal.

Numerical experiments aimed at a finer consideration of statistical data inhomogeneity (e.g. the selection of the shorter data consideration intervals, front-induced horizontal inhomogeneity, or the attempts to increase the statistical data homogeneity based on the other limitations of the initial sampling), provided no essential increase of homogeneity due to the large spatial-temporal generalization scale.

3.4. Interpolation to Standard Levels

Variables were interpolated vertically to standard levels according to the procedure adopted by UNESCO (Reiniger and Ross, 1968; UNESCO, 1991). The considerable vertical variability of hydrological parameters in the Barents Sea entailed more rigorous limitations for vertical interpolation as compared with a standard procedure. A decrease of the admissible interpolation depth range for 25 - 35% designated this limitation compared to (Levitus and Boyer , 1990).

3.5. Objective Data Analysis

The objective data analysis procedure used for this work generally corresponds to the scheme suggested by Barnes (1973) and the methods for calculating the data spatial distribution and map plotting used by Levitus S., Boyer T.P. (1994). Considerable changes and additions to the algorithm have been made to account for the anisotropic structure of oceanographic fields in the Barents Sea.

When solving such problems in oceanology, frequent use is made of various forms of optimum interpolation (Gandin and Kagan, 1966; Artem'ev and Blinov, 1986; Nelepo and Timchenko, 1978) suggested by L.S.Gandin (1965) as well as of polynomial field approximation (a detailed review contains in the paper by E.D. Vyazilov, 1981).

The application of optimum interpolation is assumed to be preferable due to minimization of the field reconstruction error. However, the algorithm of this method is rather complicated, since to determine the interpolation coefficients, a system of linear equations is solved individually for every gridpoint, also the exact knowledge of the field statistical structure is necessary.

Frequent infringements of the imhomogeneous and isotropic character of the oceanographic fields (especially in the seas and coastal regions) require the additional specification of estimates of the spatial correlation functions based on observational data for which the necessary data is not readily available (Gandin and Kagan, 1966).

At the same time, providing the minimum dispersion of the reconstruction error, the optimum interpolation produces the essential smoothing effect for the field (interpolated values objectively approach the average level), and as a result, useful data can be lost.

In this work the computation of the spatial correlation functions and verification of the objective analysis procedure have been made using the data of the interdepartmental surveys in the Barents Sea (Golubev et al., 1985, Denisov et al., 1987, Golubev et al., 1989).

For sea surface temperature in the Barents Sea the correlation radii vary from 180 km in winter to 270 km in summer. Down to 100 m depth, this radius decreases by 35 - 40%, and it increases again by 35 - 40% as the bottom is approached.

For salinity the correlation radii exceed those for temperature by as much as a factor of two, the seasonal variations of this characteristic are lower, however general regulations remain the same. The data available are insufficient to reliably reveal the statistical oxygen concentration variability. From a numerical viewpoint, oxygen concentration variability characteristics are close to the analogous parameters obtained for winter seawater temperature for some depths.

It is noteworthy that in homogeneous water masses of the Barents Sea, the correlation radii for the hydrological parameters approach values typical for the ocean (Ivanov, 1981). For instance, the correlation radius can reach 350 km for the temperature of the cold surface layers, and it can be larger below 200 m. On the whole, these values are not advisable to be used for the computations for the Barents Sea, since they results in the excessive smoothing due to the generalization of dissimilar data.

The formula for the computation of parametric value in the knot of the grid area has the following form:

$$S_{ij} = \frac{\sum_{k=1}^{k=N} S_k W_k}{\sum_{k=1}^{k=N} W_k}$$

$$W_k = \begin{cases} 0 & npu \quad r_{ijk} \geq R \\ 1 & npu \quad r_{ijk} \leq d \\ \dfrac{1}{\left(1 - \dfrac{r_{ijk}}{R}\right)^x} & npu \quad d < r_{ijk} < R \end{cases}$$

where

i, j are the coordinates for the grid area cell east-westwards and north - southwards, espectively;

k is the number assigned to a data value that occurs in the region around each grid-point defined by the correlation radius R;

d is the coordinates determination accuracy;

Sij is the value of parameter reconstructed in the cell of the grid area with the coordinates i,j;

Sk is the value of the parameter observed;

N is the number of data points used for interpolation;

Wk is the weight coefficient for Sk;

r_{ijk} is the distance between the observed data value to the interpolation point;

R is the correlation radius;

c is the optimum exponent of the weight function power derived from numerical experiments

In general, the temperature and salinity maps plotted using our objective procedures reflect the structure of the principal currents in the Barents Sea (Tantsyura, 1959), and coordinate with the maps plotted subjectively (Barents sea, 1990).

4. CD-ROM STRUCTURE

The CD-ROM CLIMATIC ATLAS OF THE BARENTS SEA 1998: temperature, salinity, oxygen contains the temperature profiles ($C^{o)}$, salinity (pss), and dissolved oxygen concentration (mg/l) for the period 1898-1993. The data have been collected within the official boundaries of the Barents Sea and the northern inlet of the White Sea, limited from the south by the transect Voronov cape - Sosnovets Island.

For recording the data on the CD-ROM the following formats were used:

1. CSV - the text format of MS Excel electronic spreadsheets with separating commas is used for storing the hydrological data;

2. DOC - files in WinWord 7.0 Widows 95;

3. TXT - DOS text files;

4. XLS - files in Excel 7.0 Windows 95;

5. CDR - files in CorelDraw 8 Windows 95;

6. TIF - tagged image file format;

7. GRD - ASCII GRID format files of SURFER program by Golden Software, Inc.;

8. EXE - executable files of DOS;

9. DAN-DOS managing files;

10. LST - program execution protocols - DOS text files.

4.1. CD-ROM Contents

The Main directory:

PREFER_R.DOC- Message from the Governor

of the Murmansk Region (in Russian)

PREFER_R.DOC- Message from the Governor

of the Murmansk region (in English)

A1.CDR - Observation network of the Barents sea

READ_MRU.DOC - CD-ROM disc structure (in

Russian)

READ_MEN. DOC - CD-ROM disc structure (in

English)

ZONE.DOC - Coordinates of borders of a zone

of data.

Directory REPORT - Climatic Atlas of the Barents Sea (text)

REPORTRU.DOC - CLIMATIC ATLAS OF THE BARENTS SEA 1998: temperature, salinity, oxygen (in Russian and English)

Directory INVENT- Data distribution during 1898-1993

B1.TIF - distribution of stations only containing temperature data

B2.TIF - distribution of stations only

containing temperature and salinity data

B3.TIF - distribution of stations only containing temperature, salinity

and oxygen data during 1898-1993

C1.XLS-C24.XLS - Monthly distribution of stations

Directory MAPS - Climatic maps for the period 1898-1993

D1.TIF - D60.TIF -Temperature, salinity.

Mean monthly fields for depths 0, 30, 50, 100, and 200

D61.TIF - D62.TIF-Oxygen. Mean fields for

May-September. Depths 0, 50, 100, and 200

Directory TSO_TIME - Norms and anomalies of temperature and salinity for station 5 of the transect IV

E1.XLS - Distribution of temperature measurements over the years

E2.XLS - Distribution of salinity measurements over the years

E3.XLS - Monthly temperature norms

E4.XLS - Monthly salinity norms

E5.XLS - Temperature anomalies

E6.XLS - Salinity anomalies

Directory DATA - Data for 1898-1993

SHIPLIST.TXT - List of ships.

Directory STEP_1 - Original data

1_01.CSV-1_12.CSV - January- December

Directory STEP_2 - Original data after quality control

2_01.CSV - 2_12.CSV- January- December

Directory STEP_3 - Interpolation to standard levels

3_01.CSV - 3_12.CSV - January- December

Directory STEP_4 - Interpolation to the levels 5, 10, 15,...500 m

4_01.CSV - 4_12.CSV - January- December

Directory PROGRAMM- Programs

Directory SAM_CUT- Data sampling

SAM_CUT.EXE - Program of data sampling from CD-ROM

SAM_CUT.DAN - Example of program's managing file.

SAM_CUT.LST - Example of program execution protocol

SAM_CUTR.DOC - Program's manual in Russian

SAM_CUTE.DOC - Program's manual in English

Directory SAM_OBJ - Objective analysis

SAM_OBJ.EXE - Field computation program

SAM_OBJ.DAN - Example of program's managing file

SAM_CUT.LST - Example of program execution protocol

SAM_OBJR.DOC - Program's manual in Russian

SAM_OBJE.DOC - Program's manual in English

SAM_OBJ.GRD - Computation example

4.2. Data Formats

Every oceanographic station has been put on the CD-ROM in the form of a separate record, which is ended with the characters of transfer to a new line and the line end character (HEX-code=0D0A). A decimal point in numerical data is indicated in the explicit form. The comma character (HEX-code=2C) is a separator between the parameters. Before the first data record the file contains a line which lists the parameter's names. The sequence of the parameter fields is fixed (Table 1a). The coordinates and data of observations and the value of at least one parameter at every station's levels is compulsory. Further, the information at observation levels is entered in groups containing four digits. The groups are preset sequentially for increasing depth values. In total, not more than 101 groups of values can be preset for the levels.

Parameter name	**Number**	**Field Format**	**Parameter Description**

Station Code	1	10 Digits	Station Condition Code: • First 2 positions - NODC country code(1993), if code unknown, the line �XX or �99� is preset. • Positions 3 and 4 - NODC ship code (1993), if code unknown, the line �XX� or �99� is preset; • Positions 5 to 9 cruise number, if cruise unknown, the line �XXXXX� or �99999� is preset; • Position 10 - NODC instrument type (1993): �B�- Nansen bottle �C�,�D�,�I� et al. - different probes �X�, �M� - expendable and mechanical BT
Year	2	4 digits integer	Year (YYYY)
Month	3	2 digits integer	Month (MM)
Day	4	2 digits integer	Day (DD)
Time	5	number with point to 6 digits	Time in GMT (HH.HHH with accuracy to thousandth parts of hour)
Latitude	6	number with point to 8 digits	Degrees (GGGG.GGG with accuracy to thousandth parts of degree), northern latitude is positive, southern - negative
Longitude	7	number with point to 8 digits	Degrees (GGGG.GGG with accuracy to thousandth parts of degree); eastern - positive, western - negative
Depth	8	number with point to 7 digits	Meters (DDDDD.D with accuracy to tenth parts of meter)

L k	1	number with point to 6 digits	Level in meters (DDDDD.D with accuracy to tenth part of meter)
T k	2	number with point to 6 digits	Temperature in oC (GGG.GG with accuracy to hundredth parts of degree)
S k	3	number with point to 6 digits	Salinity in pss (GG.GGG with accuracy to thousandth parts of pss)
O k	4	number with point to 6 digits	Oxygen in mg/l (GGG.GG with accuracy to hundredth parts of mg/l)

Note: k is the number of the level

5. VARIABILITY OF TEMPERATURE AND SALINITY

5.1. Data Distribution

Appendix B1 contains maps showing the distribution of stations containing temperature data; B2 - temperature and salinity data; B3 - temperature, salinity, and oxygen data. Appendix C show monthly station distribution plots by individual years. The form of the data representation selected provides a detailed idea about how the Barents Sea is covered by measurements, and allows one to determine a region for which time series can be formed.

The primary data array on the CD-ROM has the following characteristics:

- the number of stations containing temperature profiles - 74, 256
- the number of stations containing temperature and salinity profiles - 51,719
- the number of stations containing temperature, salinity and oxygen profiles - 3,334

5.2. Seasonal Cycle of Temperature and Salinity

The objective analysis method, given in section 3.5, was used for the calculation of the temperature, salinity, and oxygen fields. The fields were computed at gridpoints with a spacing 10' x 30' over the region 66 - 82° N, 5- 10° E. The output of computation was in the format ASCII GRID of the program SURFER used for plotting the contour and three-dimensional maps. Appendix D contains the monthly average temperature and salinity maps for levels 0, 30, 50, 100, and 200 m and the seasonal maps of oxygen distribution at 0, 50, 100, and 200 m for the period 1898-1993. These maps are represented in the form obtained using SURFER without additional editing.

The seasonal cycle of temperature and salinity variability for the Barents Sea is determined by several factors, among which the following should be mentioned. In summer, the process of warming of seawater surface layer intensifies, the freshening of these layers due to thawing ice in the north and the increase of river discharge in the south is observed; in winter as compared to summer, the inflow of the Atlantic Waters increases (Loeng, 1997). The differences between the summer and fall thermohaline structure of the Barents Sea waters are most pronounced in the layer of 0 - 50 m . In quantitative form these differences can be described as follows. In winter vertical homogeneity is observed, the temperature varies within the limits 1.5-5° C, salinity varies in the range 34.5-35.3 pss. In summer the temperature changes from 10-12° C at the surface in the southern part of the sea to the seawater freezing temperature at depth in the north. At the surface, in the regions with ice melting and fresh water discharge, the salinity decreases to 15pss, and as the depth increases, the salinity tends to reach the winter time values. The winter type of thermohaline structure is most marked from January to May, the summer - from July to October.

5.3. Interannual Variability of Temperature and Salinity

To illustrate the potentialities of using the CD-ROM oceanographic database to analyze the interannual variability of the Barents Sea, we consider thermohaline characteristics in the vicinity of Station 5 transect VI (71° 30' N, 33° 30' E) during 1898-1993. Station 5 has been selected because its location represent the area of the Barents Sea most dense with observations , and is situated within the water mass of the warm Murmansk Flow. The data were interpolated to the station point and for the analysis described in Chapter 3 of the present work. The correlation radii were 180 km for temperature and 270 km for salinity.

The most oceanographic data with temperature and salinity collected in this region are from the period 1970-1990 (Appendix E, Figs. E1 and E2). Seasonal data distribution is fairly uniform. This permits the computation of monthly values of temperature and salinity at the levels 0, 50, and 100 m averaged over 1898 - 1993. Figures E3 and E4 (Appendix E) describe the annual cycle of variations of temperature and salinity norms at Station 5 of transect VI.

Variations of the temperature and salinity norms at depths of 0, 50, and 100 m (Fig. E3 and E4) conform with the existing ideas about seasonal variability of the thermohaline processes in the Barents Sea: vertical uniformity is observed in the winter period, the maximum of the summer temperature is displaced as the depth rises, whereas salinity change is practically synchronous at different levels.

The annual average temperature and salinity anomaly values for the 0-50 m layer are computed on the basis of monthly norms (Figs. E5 and E6). The diagrams in Figs. E5 and E6 indicate that the beginning of the century was the coldest period for this region. Temperature maxima, which can be traced from the limited data available, correspond to the beginning of the 1930s and 1950s. In the second half of the 1960s some cooling occurred, which in the early 1990s, was replaced by a warming tendency in the course of several cycles.

This section considers the interannual variability for the area of one station. As follows from the observation density distribution, shown in Figs.B1 and B2, the same analysis can be performed for the other stations on transects VI and XXIX. Thus, the temperature and salinity anomalies can be computed not as the averaged values for the entire year but as the average values for winter and spring (section 5.2).

6. SUMMARY

Data distribution indicates that the Barents Sea is one of the regions in the world's oceans mostly covered with observations. We have used objective analysis to construct climatic fields of temperature and salinity distribution . These fields agree well with existing qualitative notions about basic features in variability of the Barents Sea thermohaline fields. They are insufficient to allow for the effect of river discharge in the coastal zone in the southern Barents Sea and ice melting in the northern latitudes. To the largest degree, these features are manifested in summer within the layer of 0-30m .

7. FUTURE WORKS

In the future, it is planned to supplement the data available with measurements for the upper layer, as well as with the deep sea stations by digitizing manuscript data. In addition we hope to improve the data quality control and objective analysis procedures, allowing for the bottom topography and the data on the features of variability of oceanographic variables in the separate regions of the Barents Sea.

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