NOAA Atlas NESDIS 67

CLIMATIC ATLAS OF THE NORTH PACIFIC SEAS 2009: Bering Sea, Sea of Okhotsk, and Sea of Japan

Silver Spring, MD
2009

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

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This publication should be cited as:
Luchin, V., A. Kruts, O. Sokolov, V. Rostov, N. Rudykh, T. Perunova, E. Zolotukhin, V. Pischalnik, L. Romeiko, V. Hramushin, V. Shustin, Y. Udens, O. Baranova, I. Smolyar, E. Yarosh. 2009. Climatic Atlas of the North Pacific Seas 2009: Bering Sea, Sea of Okhotsk, and Sea of Japan. V. Akulichev, Yu. Volkov, V. Sapozhnikov, S. Levitus, Eds., NOAA Atlas NESDIS 67, U.S. Gov. Printing Office, Wash., D.C., 329 pp., DVD Disc.

World Data Center for Oceanography, Silver Spring
International Ocean Atlas and Information Series, Volume 12
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CONTENTS

ACKNOWLEDGEMENTS

The present work has been carried out within the framework of the NOAA Climate and Global Change Program and RFBR Grant No. 06-05-96065.

A vast volume of new data has been found thanks to support of the UNESCO Intergovernmental Oceanographic Commission (IOC), GODAR Project (Global Oceanographic Data Archeology and Rescue), and the IOC World Ocean Database Project.

We are grateful to the employees of the Far East Regional Research Hydro-meteorological Institute V. Grechishchev and A. Sheshegov, employees of the V.I. Ilyichyev Pacific Oceanological Institute of the Far East Department RAS I. Rostov, E. Tikhomirov, and A. Abrosimov, as well as employees of Ocean Climate Laboratory of the NOAA National Data Center John Antonov, Tim Boyer, Carla Coleman, Hernan Garcia, Alexandra Grodsky, Daphne Johnson, Ricardo Locarnini, Alexey Mishonov, Charlotte Sazama, Dan Seidov, and Melissa Zweng for their assistance with database development and generation, procession of observation materials, and presentation of this atlas.

Special thanks go to the Chief of the Hydrometeorological Service of the Pacific Fleet of Russia 1st Captain L. V. Kobylinskii for providing publications on history of oceano-graphic research in the North Pacific by Russian Navy.

We express our special gratitude to I.N. Klimenko, a senior research associate of the Primorsky State United Museum named after V.K. Arseniev, and to V.N. Sokolov, the director of the Museum, for providing us with copies of archive photo-materials which were used in the present Atlas.

Our special thanks are to all employees of the NOAA Central Library for their thorough assistance in searching and copying historical oceanographic data and selecting photo-materials for the present paper.

We express our special gratitude to an employee of the NOAA Central Library, Dr. John Cloud, for providing us with geographical historical maps of the Northern Pacific Ocean drawn in Russia in the first half of the 19th century. These maps are an important source of information about instrumental oceanographic measurements and presented on a DVD disc enclosed with the present Atlas.

Christopher Soule has contributed significantly to the preparation of historical oceanological data for this work.

We also thank NODC colleagues Andy Allegra, John Carroll, and John Relph for the help with the preparation of the Internet version of the Atlas.

We express our gratitude to Roman Mikhalyuk for the Russian – English translation of this paper.

ABSTRACT

The present Atlas is a result of international cooperation of specialists from several institutions involved in the studies of the climatic system of the Northern Pacific seas.

This Atlas contains monthly climatic charts of temperature, salinity, and oxygen at the sea surface and at standard depth levels for the Bering Sea, Sea of Okhotsk, and Sea of Japan. Annual climatic cycles of temperature, salinity, and oxygen at various depths, as well as seasonal graphics of vertical variability of these parameters, are given for different areas of these seas. Temporal series of annual anomalies of temperature, salinity, and oxygen for 54 years (1950-2003) were developed for every sea. Primary data used in the present paper are available and accessible via Internet in ASCII and Excel formats without restriction. The present Atlas also includes rare books and papers on the history of the studies of the Northern Pacific seas in electronic format, as well as photographs giving an idea of the nature and history of the Region.

1. INTRODUCTION

The goal of this Atlas is to describe the climatic system of the Bering Sea, Sea of Okhotsk, and the Sea of Japan in quantitative terms and including trends for a 54-year observation period.

The Bering Sea, Sea of Okhotsk, and the Sea of Japan have been intensive sea shipping areas for several centuries. Hundreds of fishing vessels of many countries have been targeting fish and sea products (squids, prawns, crabs, marine mammals, jellyfishes, and algae) which are part of the diet of millions of people. Oil and gas deposits in these seas have been prospected for and developed since the second half of the 20th century. The combination of these factors, against the background of global changes of the Earth's climate determines practical and scientific interest in the studies of the climatic system of the North Pacific seas.

A significant number of papers, monographs, and atlases has been devoted to the studies of various aspects of the Bering Sea, Sea of Okhotsk, and the Sea of Japan regimes. In the overwhelming majority of these papers, historical data are presented as averaged climatic parameters characterizing the state of marine environment for a long period of time. However, these papers, as a rule, do not contain the results of expeditionary measurements. This fact does not allow one to compare present data with historical data and draw a conclusion on possible climate changes. A specific feature of this paper is that a large amount of archival oceanographic data were rescued and transferred into electronic format; unrestricted access is provided to these primary data via the Internet.

The first chapter of the Atlas gives the history of instrumental observations in the North Pacific seas. Most of the papers referred to and published before 1950 contain initial data of oceanographic observations.

The second chapter addressed issues of format selection to present oceanographic data in the way of electronic tables, as well as quality control issues of expeditionary observations.

The third and the fourth chapters contain description of climatic characteristics of the Bering Sea, Sea of Okhotsk, and the Sea of Japan and the trend of their variability for 1950-2003. Access to all graphic materials, papers on the history of oceanographic studies of the North Pacific seas, published in the 19th and early 20th centuries, earlier unavailable to the broad scientific community, as well as selective papers of the recent years is provided via WEB interface on a DVD disc and the Internet.

2. HISTORY OF INSTRUMENTAL OBSERVATIONS

This section contains a brief review of sea expeditions during which instrumental meteorological and hydrological observations in the Bering Sea, Sea of Okhotsk, and the Sea of Japan were carried out.

2.1. The Bering Sea

Expedition research and studies in the Bering Sea at the turn of the 18th and 19th centuries were mainly focused on the description of coastlines and drawing of detailed navigation maps. As a rule, those activities were carried out by the Russian Navy. The **Electronic Library** section of the disc and Internet version of the Atlas contains "*The Map of Sea Discoveries by the Russian Seafarers in the Pacific and Arctic Seas Undertaken in Various Year"* published in 1802 (Chart 1), which gives an idea of degree of geographic knowledge of the Bering Sea in the early 19th century (Akhmatov, 1926; Berg, 1924; Makarov, 1894).

The first, known to us, instrumental measurements of water temperature on the sea surface and at various depths were made by Lieutenant of the Russian Navy O.E. Kotsebu on board the brig *Ryurik* in the Bering Strait in 1816-1817. In addition to water temperature, water transparency and currents were measured (Kotsebu, 1821).

The Russian expedition headed by Kotsebu, Lents, and Hoffman on board the vessel *Predpriyatie* made hydro-meteorological measurements in the Bering Sea area during the voyage around the world in 1823-1826 (Kotsebu, 1828).

In 1826-1828, the British expedition carried out the Bering Sea studies on board the vessel *Blossom* (Captain F.W. Beechey of the British Royal Navy). Several deepwater hydrological measurements were made on board of that vessel using a **Siks system** thermometer which was unprotected from external pressure (Beechy, 1831).

In 1826-1829, the participants of the Russian expedition on board the vessel *Senyavin* led by Captain Litke made a considerable, for that time, volume of oceanographic, meteorological, and biological measurements in the area of the Aleutian Islands and along the western coast of the Bering Sea (Litke, 1834-1836).

In 1836, the French expedition on board the vessel *Venus* carried out hydro-meteorological observations including several deepwater measurements (Leonov, 1960).

Academicians of the Russian Academy of Sciences E.Kh. Lens and L.I. Shrenk on board the vessels *Abo* (1841), *Atka* (1842), and *Aurora* (1854) carried out systematic hydro-meteorological observations in the Bering Sea and made several deepwater stations (Shrenk, 1874; Plakhotnik, 1996). Besides those activities, inventory of the Alaska coast to the north of the Aleutian Islands was carried out. Materials of those and other expeditions were used by the Manager of the Russian – American Company Captain of the 1st Rank M.D.

Tabenjkov to prepare "*The Atlas of the Northwestern Coasts of America, Aleutian Islands, and Some Areas of the Northern Pacific Ocean*". The Atlas, published in 1852, contains 38 maps. The **Electronic Library** section on DVD disc and the Internet version of the present Atlas contain facsimile copies of the title page of Atlas by M.D. Tabenjkov, a list of maps and a map of the Northwestern Bering Sea (Charts 2 – 4).

In 1853-1856, the American expedition "U.S. North Pacific Exploring Expedition" on board the vessels *Vincennes* and *Fenimor Cooper* carried out research in the Bering Sea and set up an astronomic station on the coast of the Arctic Ocean.

Britain fitted out an expedition led by Sir John Franklin to search for a northwestern sea route from Europe to Asia in 1845. There was no news from the expedition for three years. Vessels were set out for the Bering Sea to search for the J. Franklin expedition. On their way they carried out hydro-meteorological observations. At the same time, whaling started to be intensively developed in the area. Up to 100 whalers entered the Bering Sea during one navigation period. Ice conditions and water surface temperature data were recorded in the whaler's log books. At the same time, the vessels of Norway went in for marine animals hunting and whaling in the north of the Barents and Norwegian Seas, and, like their colleagues in the Bering Sea, registered weather conditions and made measurements of the water surface temperature. In total, more than 50 thousand stations were made. Those data were used in Climatic Atlas of the Arctic Seas 2004 (Matishov et al., 2004) and are available and accessible via the Internet and DVD disc. This experience gives hope that hydro-meteorological data collected in the Bering Sea in the middle of the 19th century will also be rescued and, in some time, will made available for the international scientific community.

In 1865-1867, the American telegraph company with consent from the Government of Russia studied the Bering Sea and the coast of Siberia and Alaska to lay a telegraph line between Europe and America. Expeditions were carried out on board the vessels *Wright, Golden Gate,* and *Nightingale*. Water temperature both in the surface and near-bottom layers was measured during those activities as well (Tanfiljev, 1931).

In the second half of the 19th century, the Naval Ministry of Russia sent many expeditions to map the Bering Sea coastline in detail and protect marine animal hunting grounds. A considerable volume of hydro-meteorological measurements was made by naval seafarers during that period and those activities. The results of those expeditions were used by Admiral S.O. Makarov when preparing a classical paper "*The Vityaz and the Pacific Ocean*" (Makarov, 1894).

In 1871-1889, the Geodetic Survey of the U.S.A. led by G. Davidson and W.H. Dall on board the vessels *Humboldt*, *Yukon*, *Corvin,* and *Thetis* carried out expeditions in the Bering Sea with geological collections being formed, meteorological observations carried out and measurements of water temperature at the surface and different depth levels were made. On the 5th of September a hydrological transect across the Bering Strait was made on board a hydrographic vessel *Yukon* to study the water exchange between the Arctic and Pacific

Oceans. The **Electronic Library** section on the DVD disc and Internet version of the Atlas contain an electronic version of the cruise report written by Dall in 1882.

In 1874, on the U.S.A. vessel *Tuscarora* under the command of Captain G. Belknap, activities were carried out in the North Pacific searching for the route to lay a cable from Japan to the U.S.A.. During those activities, the measurements of water temperature both at the surface and at various depths in the Bering Sea were made. Section **Electronic Library** on DVD disc and Internet version of the Atlas contains an electronic version of the expedition report (Belknap, 1874).

An expedition organized by Sweden in 1878-1879 on board the vessel *Vega* conducted by A.E. Nordenskioeld made a voyage from Europe to the Pacific Ocean through the Eastern Arctic seas for the first time in world history. The expedition made several deepwater stations in the Northern Bering Sea observing temperature and density of seawater.

At the end of the 19th century, the government of the U.S.A. organized a special fisheries commission (U.S. Commission of Fisheries) to study fisheries issues in the Northern Pacific, including the Bering Sea. Commission activities resulted in many expeditions being carried out on board the vessel *Albatros* from 1888 to 1906 when a large volume of biological and hydro-meteorological data was collected. Detailed reports of those expeditions are in the NOAA Central Library.

Systematic deepwater observations in the Bering Sea began in the 1920-1930s. The employees of the State Hydrological Institute (Leningrad, U.S.S.R.) N.I. Evgenov, G.E. Ratmanov, and P.V. Ushakov made a series of deepwater hydrological stations during the voyage of icebreaker *Litke* from Petropavlovsk-Kamchatskyi to Wrangel Island. Simultaneously, in the 1920-1930s, an expedition led by L.A. Dyemin on board the vessel *Krasnyi Vympel* also conducted a series of deepwater hydrological measurements. During the Second International Polar Year (1932-1933) there were expeditions in the Bering Sea on board the vessels *Dalnevostochnik* and *Krasnoarmeets* (Ratmanov, 1932, 1933, 1937).

In the period of 1932 to 1938 the U.S.A. vessels *Gannet*, *Catalyst*, *Oglala*, *Northland,* and *Chelan,* which belonged to the U.S.A. Coast Guard and Oceanographic Laboratory of the University of Washington, made deepwater stations over a vast water area of the Eastern Bering Sea (Oceanographic observations in the Pacific, 1961).

After the World War II, the number of oceanographic expeditions to the Bering Sea increased sharply. The fact is linked with an intensive development of fisheries, in which mostly the vessels of Russia, Japan, and the U.S.A. are involved.

2.2. The Sea of Okhotsk

The first, known to us, instrumental measurements of water temperature in the Sea of Okhotsk were made during the first Russian round-the-world voyage on board the vessel *Nadezhda* led by I.F. Kruzenshtern. In May and August of 1805, measurements were made at three stations at depths of to 210 metres (Kruzenshtern, 1809-1812).

In the 19th and the early 20th centuries several dozens of expeditions were carried out in the Sea of Okhotsk, when, mainly, water temperature was measured at surface and at various depth levels. The largest amount of expeditions was carried out by Russian Navy hydrographers on board of the Russian Navy vessels (Zhdanko, 1904, 1904(a), 1905, 1907, 1907(a), 1908, 1909, 1913, 1916, 1916(a); Makarov, 1892; Davydov, 1915, 1917, 1923; Deryugin, 1928; Meder, 1916).

In the southern part of the Sea of Okhotsk, adjacent to Japan, expeditions were carried out on board the vessels of Japanese fisheries stations, located on the Island of Hokkaido. Many studies of the Sea of Okhotsk, crossed by numerous oceanographic transects, were carried out on board four vessels under the leadership of Professor H. Marukawa in the period of 1915-1918 (Deryugin, 1928). An area, adjoining the western coast of Kamchatka, was studied thoroughly. Table 1 lists expeditions of Russia and the U.S.A., carrying out instrumental measurements in the Sea of Okhotsk in the 19th century and until 1914.

Beginning in the 1930s the Pacific Research Institute for Fisheries and Oceanography (TINRO) annually conducts researches in the Sea of Okhotsk. A conclusion on a high quality of data, collected more than 70 years ago, may be drawn from the description of a cruise on board a fishing trawler *Gagara* in 1932 (Deryugin, 1933). That expedition was headed by one of the leading hydro-biologists of Russia of the first half of the 20th century K.M. Deryugin. Hydrological measurements were made by V.V. Timonov and A.K. Leonov, and each of them published a large number of papers on hydrology and measurement technology of the seas of the Far East and Eastern Arctic in the period of 1930-60 (Timonov, 1939; Leonov, 1935; Deryugin, 1929, 1930, 1932, 1933, 1933 (a), 1933 (b), 1934, 1935). The following extracts from a report of the cruise on board the expeditionary vessel *Gagara* characterize the technology of deepwater measurements: "...Water samples were taken by Nansen bathometers. Readings took place twice by different people with precision of 0.01 ^{o}C: a) right after bathometers lifting on deck, b) 10-15 minutes after lifting. ... Location of all deepwater stations was checked by reverse laying. During the cruise numerous determinations of vessel's location were made, which made the locations of many deepwater stations more precise".

A number of research expeditions in the Sea of Okhotsk increased sharply after the end of World War II. First of all, the fact was conditioned by the necessity to develop fisheries. The largest number of expeditions were carried out on board the vessels of TINRO and TURNIF (The Pacific Administration of Fisheries Surveys and Research Fleet) with participation of employees of TINRO, VNIRO (The All-Union Research Institute for Fisheries and Oceanography) and other research organizations of the U.S.S.R. (TINRO, 2005).

The P.P. Shirshov Institute of Oceanology carried out several expeditions in the Sea of Okhotsk since 1947 on board the vessel *Vityaz*. The results of these expeditions are characterized by a high quality of data and detailed description of measuring methods (Kuznetsov and Neiman, 2005).

Table 1. Information on hydrological observations made in the Sea of Okhotsk in the period from 1805 to 1914

Name of Vessel	Country	Year	Head of Expedition
Nadezhda	Russia	1805	Kruzenshtern I.F.
Varyag	Russia	1866	Staritskyi K.S.
Vostok	Russia	1868	Kologeras L.K., Staritskyi K.S.
Amerika	Russia	1869	Staritskyi K.S.
Nakhodka	Russia	1869	Staritskyi K.S.
Dzhigit	Russia	1880	
Vityaz	Russia	1887	Makarov S.O.
Vityaz	Russia	1888	Makarov S.O.
Naezdnik	Russia	1888	
Kreiser	Russia	1890	
Admiral Kornilov	Russia	1895	Makarov S.O.
Albatross	U.S.A.	1896	
Albatross	U.S.A.	1906	
Storozh	Russia	1899	Brazhnikov V.K.
Storozh	Russia	1900	Domashnev N.Ya.
Storozh	Russia	1901	Brazhnikov V.K.
Storozh	Russia	1902	Brazhnikov V.K.
Kasatka	Russia	1902	Brazhnikov V.K.
Komandor Bering	Russia	1907	Smirnov N.N.
Komandor Bering	Russia	1908	Smirnov N.N.
Leitenant Dydymov	Russia	1908	Soldatov V.K.
Leitenant Dydymov	Russia	1911	Soldatov V.K.
Leitenant Dydymov	Russia	1912	Soldatov V.K.
Neptun	Russia	1908	Zhdanko M.E.
Okhotsk	Russia	1909	Zhdanko M.E.
Okhotsk	Russia	1910	Zhdanko M.E.
Okhotsk	Russia	1911	Zhdanko M.E.
Okhotsk	Russia	1912	Zhdanko M.E.
Okhotsk	Russia	1913	Davydov B.V.
Okhotsk	Russia	1914	Davydov B.V.

The number of research expeditions in the Sea of Okhotsk has considerably decreased for the last two decades. The expeditions, mainly, are carried out on board the vessels of TINRO and focus on assessment of bio-productivity and ecological conditions of various areas of the sea.

2.3. The Sea of Japan

The Sea of Japan is one of the most data-dense areas of the World Ocean. The Republic of Korea, Russia, and Japan have access to the Sea of Japan and it is mainly these countries carry out research expeditions in this region. There is a vast amount of literature in English about the expeditions on board the vessels of the Republic of Korea and Japan. Besides, oceanographic centers of these countries ensure a free access to their databases via the Internet. Information about expeditions on board the vessels of Russia was published, in the majority of cases, only in Russian, thus making the researches carried out by the Russian specialists practically inaccessible for the world scientific community. That is why the present section will address expeditions carried out on the vessels of Russia.

It is considered that the history of studying the Sea of Japan dates back to the round-the-world expedition of 1803-1806 on board the vessel *Nadezhda* led by I.F. Kruzenshtern, when a survey of the western and northwestern coasts of the Sea of Japan of Russia was carried out (Plakhotnik, 1996).

Oceanographic studies and activities in the Sea of Japan in the 19th century were carried out by naval seafarers on board the vessels of the Navy of Russia. The first measurements of water temperature were made in 1865 on board the vessel *Varyag*. In 1873, to assess the quality of measuring instruments, water temperature measurements on surface and at the depths of 90 and 100 meters were made simultaneously (at the same time) and approximately at the same coordinates on board the vessels *Vityaz* and *Bogatyr*. The results of measurements from both the vessels correspond with each other rather well (Shrenk, 1874).

In the 1880s, to transport the settlers from the central regions of Russia to the Far East by sea, a so called “Voluntary Fleet” was established. Regular voyages from Odessa to Vladivostok and other ports on the coasts of the Sea of Okhotsk and the Kamchatka Peninsula started to run at that time as well. Navigation safety requirements for the vessels of the «Voluntary Fleet» resulted in a necessity to organize systematic activities to study the Sea of Japan. For that purpose, the Naval Ministry organized a surveying party entitled “A Separate Survey of the Eastern Ocean” led by Captain P.N. Stenin. It was renamed “Eastern Ocean Hydrographic Expedition” in 1897. The expedition had a vessel, *Okhotsk*, on board of which a large number of deepwater measurements of temperature, salinity, and other parameters of seawater in the Sea of Japan and the Sea of Okhotsk were made in 1908-1914 (Davydov, 1915, 1917, 1923).

A Navy hydrographer D.V. Davydov led “Eastern Ocean Hydrographic Expedition” in the period from 1913 to 1918. Following the results of that expedition, D.V. Davydov published a fundamental manuscript “The Sailing Directions of the Coasts of RSFSR, the Sea of Okhotsk, and Eastern Coast of the Kamchatka Peninsula with the Island of Karaginskyi Including” in 1923. This manuscript played a great role in the studies and resources exploitation of the Sea of Japan and the Sea of Okhotsk.

In 1925, the first biological station in the Far East was established in Vladivostok, and it was led by a prominent hydro-biologist K.M. Deryugin. In the early 1930s it served as a ground for establishing TINRO. Arrival of K.M. Deryugin in Vladivostok, establishment of a biological station and then TINRO induced the beginning of systematic research expeditions aimed at integrated studies of the Sea of Japan. The need to organize fisheries to provide a fast growing population of the Far East of Russia with fish determined the direction of development of the research. In the first turn, hydrological regime and bio-resources of the coastal areas, where commercial fishing was supposed to take place, were studied. Expeditions were on board the vessels *Rosinante, Gagara, Askold, Sosunov, Krasnyi Vympel, Vorovskyi, and Krasnyi Yakut*. As a rule, oceanological measurements were made down to the bottom, at standard depths. Starting with the 1930s and to the beginning of the World War II, from 3 to 6 expeditions were carried out annually, and measurements at 200-400 hydrological stations were made in total during those expeditions.

From the beginning of the World War II, neither Russia nor Japan stopped hydrological studies, including expeditionary researches, of the Sea of Japan, not even for a year. In total during the period of 1941-1945, more than five thousand hydrological stations were made in the Sea of Japan, both in the coastal areas and the open sea.

The 1950s started a period of rapid development of fish industry and maritime transportation in the Far East areas of the U.S.S.R. As a result, the number of expeditions to the Sea of Japan increased dramatically. The largest amount of expeditionary activities in the Sea of Japan took place in the 1970-80's. During that period, the research fleet belonging to three leading maritime institutions of the Far East of the U.S.S.R. (TINRO, DVNIGMI, TOI) included dozens of vessels with non-restricted navigation areas.

At present, the oceanographic database of the Northern Pacific Ocean seas consist of more than 600,000 stations:

Bering Sea: 130,000+ stations;
Sea of Okhotsk: 120,000+ stations;
Sea of Japan: 350,000+ stations.

These data can be used for a wide range of tasks in various fields of natural science.

3. DATABASE

3.1. Data sources

The sources of information for the present paper were World Data Centers as well as libraries.

The data collected during the period of expeditions carried out after the 1930s mainly was obtained from the following World Data Centers.

- World Data Center for Oceanography, Obninsk, Russia
- World Data Center for Oceanography, Silver Spring, U.S.A.

The results of measurements of seawater parameters, made prior that time, are presented in numerous publications in Russian, English, and other languages. A considerable part of these publications were found in the following libraries:

<u>Russian libraries:</u>

- Library of the Academy of Sciences, Saint-Petersburg;
- Library of Geographic Society, Yuzhno-Sakhalinsk;
- Sakhalin Regional Universal Scientific Library, Yuzhno-Sakhalinsk;
- Library of Sakhalin Integrated Research Institute, The Far East Scientific Center, Russian Academy of Sciences, Yuzhno-Sakhalinsk;
- The S.P. Krashenninikov Regional Scientific and Technical Library, Petropavlovsk-Kamchatskyi;
- Primorski Krai Scientific and Technical Library, Vladivostok.

<u>U.S.A. libraries:</u>

- NOAA Central Library (Silver Spring) and its departments (Seattle, Fairbanks);
- System of inter-librarian exchange of the NOAA Central Library (Silver Spring);
- Slavic Department of the Public Library of New York;
- Library of Dartmouth College, Hanover.

The publications were scanned using a digital camera. Some of these publications are presented in Section **Electronic Library** on a DVD disc and in the Internet version of this Atlas.

The subsequent sections of this chapter consider a data preparation in an electronic format and data quality control procedures.

3.2. Data Format

To present data in an electronic version, EXCEL tables were used.

On the basis of the proposed approach towards the formalization of data, there is a format, which has three main blocks: **STATION, HEADERS,** and **DETAILS.** A **STATION** Block contains information about the place and time of data collection. A **HEADERS** Block contains meteorological data and information about instruments and methods of measurements. A **DETAILS** Block contains results of temperature, salinity, and other parameters measurements at various profiles.

Each block contains the key words, which determine the location of different parameters in a 2-dimension field of an electronic table (Table 2).

Table 2. Data format. Example 1

STATION										
LAT DEG	LAT MIN	LAT SEC	LAT HEM	LONG DEG	LONG MIN	LONG SEC	LONG HEM	MONTH	DAY	YEAR
46	36	6	N	35	23	5	E	6	13	2004
HEADERS										
TIME	9	30		GMT						
BOTTOM DEPTH	9.9	m								
TS PROBE	CTD									
WIND DIRECTION	se	compass								
WIND SPEED	9	m/sec								
CLOUD AMOUNT	4	code10								
CLOUD TYPE	st	wmo0500								
WAVE TYPE	1	code								
WAVE DIRECTION	se	compass								
WAVE HEIGHT	1	m								
TRANSPARENCY	0.6	m								
DETAILS	DEPTH	TEMP	SAL							
UNITS	m	C								
DECIMAL PLACES	1	2	3							
	0.5	18.43	10.078							
	1.0	18.43	10.078							
	…	…	…							
	9.0	18.24	10.104							
	9.5	18.24	10.104							

When formalizing historical data, it is, sometimes, necessary to restore the stations' coordinates, because they are presented in the cruise reports in terms of local geographic sites (for example, "to the southeast of the Island of Bering"). This is a typical situation for the seas of the Northern Pacific Ocean, as the majority of measurements in the 19th and the early

20th centuries were made comparatively close to the coast, and it was easy for a navigator to determine the location of a vessel in terms of coastline outlines or a location of a settlement.

A vessel's location uncertainty is a constituent part of data quality assessment on the whole. The presence of the key words, such as **COORD DETERM DESCRIPTION** in a block of **HEADERS**, indicates a fact of restoration of the coordinates (Table 3). If these key words are absent, the vessel's location coordinates are determined by instrumental methods.

Table 3. Data format. Example 2

STATION	46									
LAT DEG	LAT MIN	LAT SEC	LAT HEM	LONG DEG	LONG MIN	LONG SEC	LONG HEM	MONTH	DAY	YEAR
47	5	22	N	37	34	17	E	11	13	1922
HEADERS										
TIME	0	40		GMT						
BOTTOM DEPTH	2.2	m								
COORD DETERM	DESCRIPTION									
DETAILS	DEPTH	TEMP	SAL							
UNITS	m	C								
DECIMAL PLACES	1	2	2							
	0	5.8	3.71							
	2	6.2	3.78							

The advantage of the format used is that it requires very little explanation. It is easy to organize the data quality control by the key words by means of BASIC language, which are a constituent part of EXCEL electronic tables.

3.3. Data Quality Control

Data quality control was according to the scheme accepted and used by the Ocean Climate Laboratory NOAA (Johnson *et. al*., 2009). Originally, gross errors in the initial data were pointed out and corrected. For example, coordinates of stations are on land, or the time interval between two consecutively made stations does not correspond with the permissible speed of a vessel's motion, etc.

Specific features of variability of the annual climatic cycle of temperature and salinity in the seas of the North Pacific Ocean were considered at the second stage of data quality control so as to determine the limits of admissible values of these parameters at various profiles.

Appendix B lists monthly, seasonal, and annual statistics of temperature, salinity, and oxygen distribution for various profiles of the Bering Sea, Sea of Okhotsk, and the Sea of Japan. The quality of every measurement was checked applying and using these statistical data. If a measurement was outside the admissible limits, it was given a special code (flag). Measurements marked with a flag, were not used when constructing climatic fields and 54-year temporal series of temperature, salinity, and oxygen in the seas of the Northern Pacific Ocean. This gives confidence that the description of ocean climate fluctuations given in this paper reflects the actual characteristics of marine environment and is not a result of errors and uncertainties of initial data.

3.4. Data Access

Data used in the present research are available without restrictions via the Internet: http://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html.

Data access procedure consists of the following steps:

1. Building a query (e.g., Figure 1).

   For example, it is necessary to request data, which were obtained in the Sea of Okhotsk during the period of 1945-1952 on board the vessel *Vityaz*. In this case, query parameters will be: a) GEOGRAPHIC COORDINATES, b) OBSERVATION DATES, c) SHIP/PLATFORM.

2. Filling in the query form to get a data inventory (e.g., Figure 2).

   In the example, the query parameters have the following values:
   a) Coordinates: 135-163 E, 45-65 N (The Sea of Okhotsk);

   b) Dates: from 01 January 1945 to 31 December 1952;

   c) Ship code: *Vityaz* - 6584. There is an internal search, which allows a user to find a ship code by country and ship name.

3. Analyzing the query results. The query results are:

   a) Data distribution plot (e.g., Figure 3).

   b) List of cruises, indicating coordinates of every station for every cruise and listing parameters measured at this station (e.g., Figure 4).

   c) Data download menu. It has choices of the data formats and depth types (observed or standard) and allows extract the data after entering e-mail address. Information (link) about data location on a server comes to the e-mail address indicated in a query. The data are available in two formats: native World Ocean Database format and 'CSV' format, which is a standard format for many types of electronic tables (e.g., Figure 5).

Figure 1. Building a query to select and search the data via the Internet

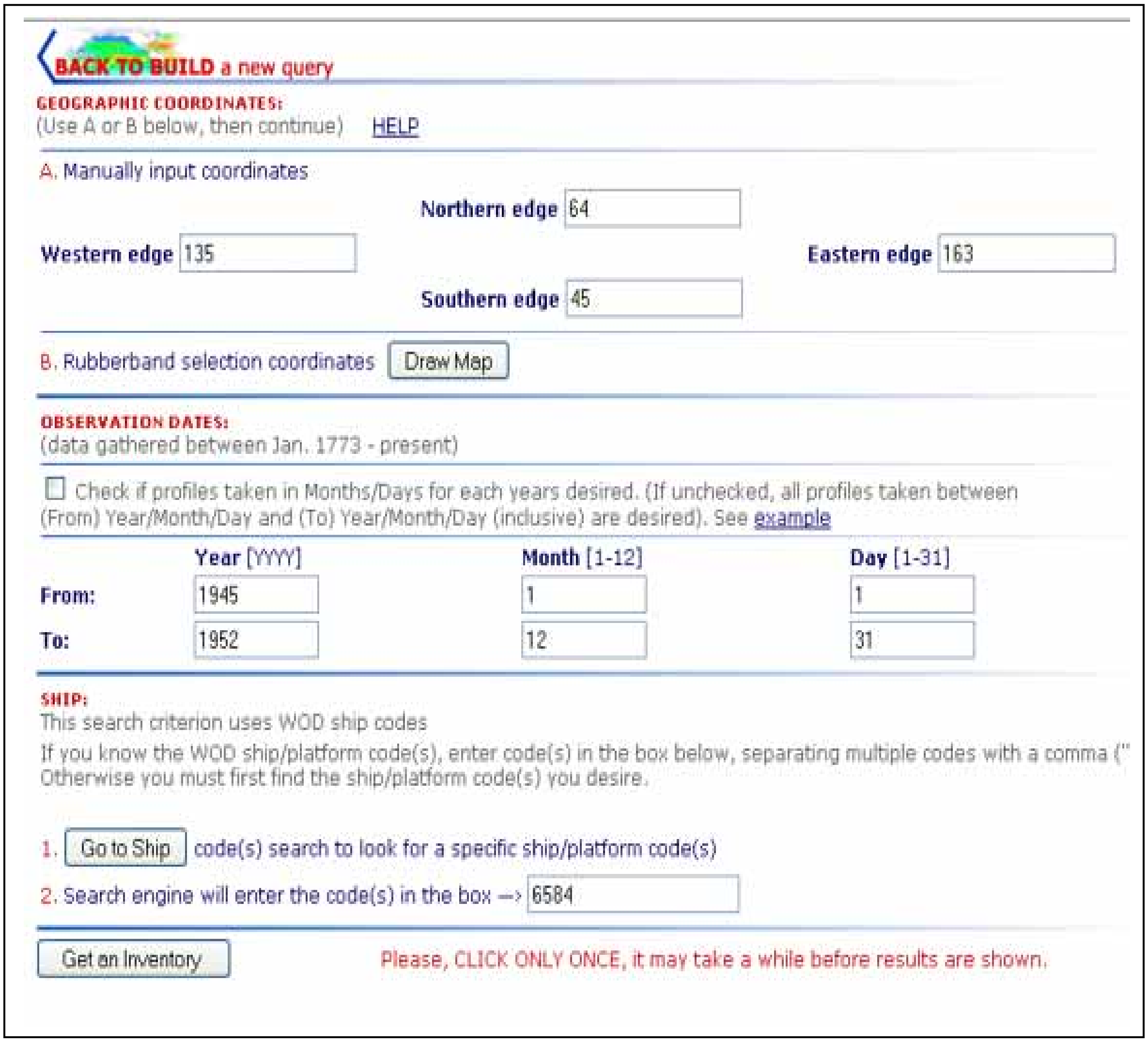
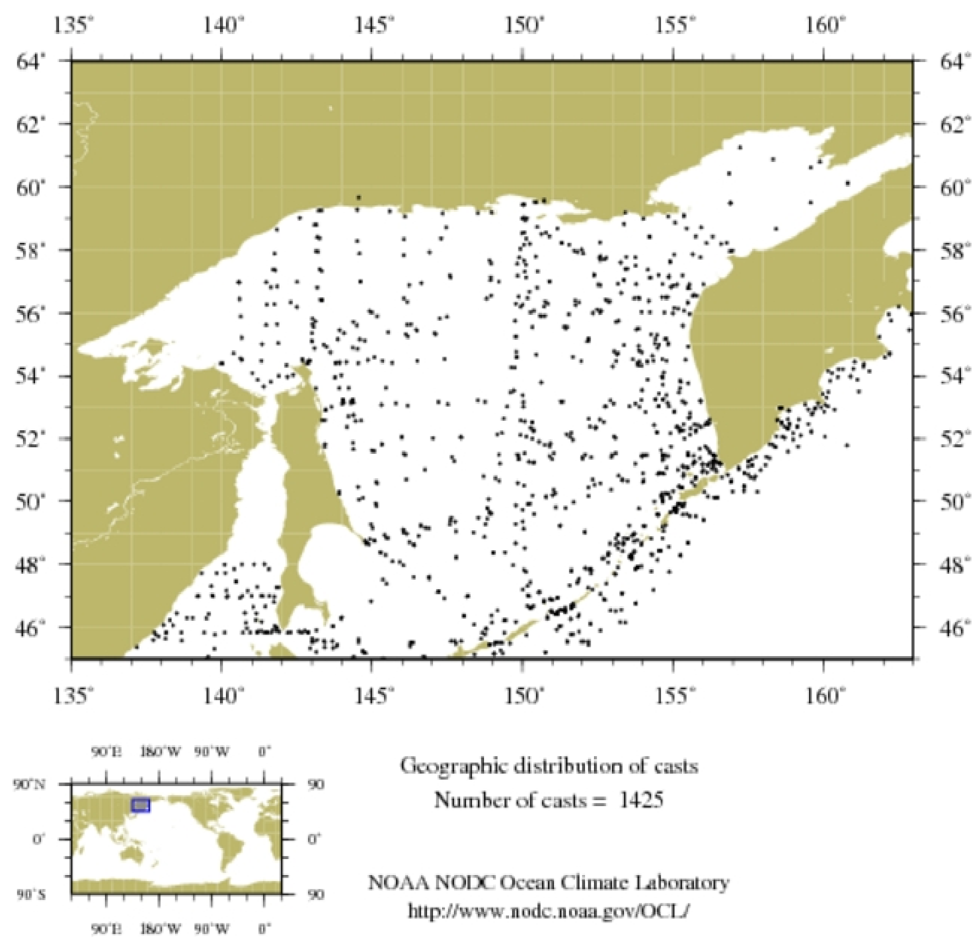


Figure 2. Filling in the query form to get a data inventory

DOWNLOAD DATA

DATA DISTRIBUTION PLOT:



COPY OF YOUR SEARCH CRITERIA:

OBSERVATION DATES:	**Year** from 1945 to 1952; **Month** from 1 to 12; **Day** from 1 to 31
GEOGRAPHIC COORDINATES:	**Longitude** from 135.0000 to 163.0000; **Latitude** from 64.0000 to 45.0(
DATASET:	OSD
MEASURED VARIABLES (extract):	all variables
SHIP/PLATFORM:	6584

Figure 3. Data distribution plot

BACK TO BUILD a new query

COPY OF YOUR SEARCH CRITERIA

To return to the EXTRACT DATA option, use browser "Back" button

OBSERVATION DATES:	**Year** from 1945 to 1952; **Month** from 1 to 12; **Day** from 1 to 31
GEOGRAPHIC COORDINATES:	**Longitude** from 135.0000 to 163.0000; **Latitude** from 64.0000 to 45.0000
DATASET:	OSD
MEASURED VARIABLES (extract):	all variables
SHIP/PLATFORM:	6584

CRUISE LIST

The individual cruise/accession links provide cruise or accession information record and a data distribution plot, e for cruise number "0". For more information, please see the "COLUMN DEFINITIONS" below. Platform and Institut codes are defined below the cruise list.

To get data for specific cruise(s) or accession(s):
1. Place check mark in front of any number of cruises and/or accessions,
2. Press [SUBMIT CRUISE/ACCESSION] button and return to the main database search page.

COLUMN DEFINITIONS

#	Cruise Reference	Institute	Platform	#Casts	Accession#	Start Date	End Date	Orig. Crui
1	☐ SU007709		6584	195	☐ 9700144	8/ 9/1949	12/ 8/1949	2
2	☐ SU007710		6584	183	☐ 9400166	1/ 7/1950	2/26/1950	3
3	☐ SU007711		6584	164	☐ 9700144	5/21/1950	7/ 1/1950	4
4	☐ SU007712		6584	117	☐ 9400166	8/10/1950	9/28/1950	13
5	☐ SU007713	859	6584	84	☐ 0036657	4/10/1951	5/17/1951	
6	☐ SU007714		6584	359	☐ 9700144	6/ 3/1951	7/26/1951	7
7	☐ SU007715		6584	124	☐ 9400166	9/14/1951	10/22/1951	8
8	☐ SU009426		6584	245	☐ 9700144	11/10/1951	12/29/1951	9
9	☐ SU007716	859	6584	169	☐ 0036657	5/10/1952	7/ 2/1952	
10	☐ SU017522			14	☐ 0039988	8/ 3/1952	8/26/1952	
11	☐ SU007717		6584	270	☐ 9700144	9/19/1952	10/31/1952	12
12	☐ SU017647	834	6584	4	☐ 0038350	12/15/1952	12/17/1952	

PLATFORM CODE LIST	
6584	VITYAZ (Built 1938;active as Vityaz 1948-81)

INSTITUTE CODE LIST	
859	FAR EASTERN REGIONAL HYDROMETEOROLOGICAL RESEARCH INSTITUTE; FERHRI
834	P.P.SHIRSHOV INSTITUTE OF OCEANOLOGY OF THE RUSSIAN ACADEMY OF SCIENCES; IO RAS

Figure 4. Cruise list and access to additional information associated with each cruise

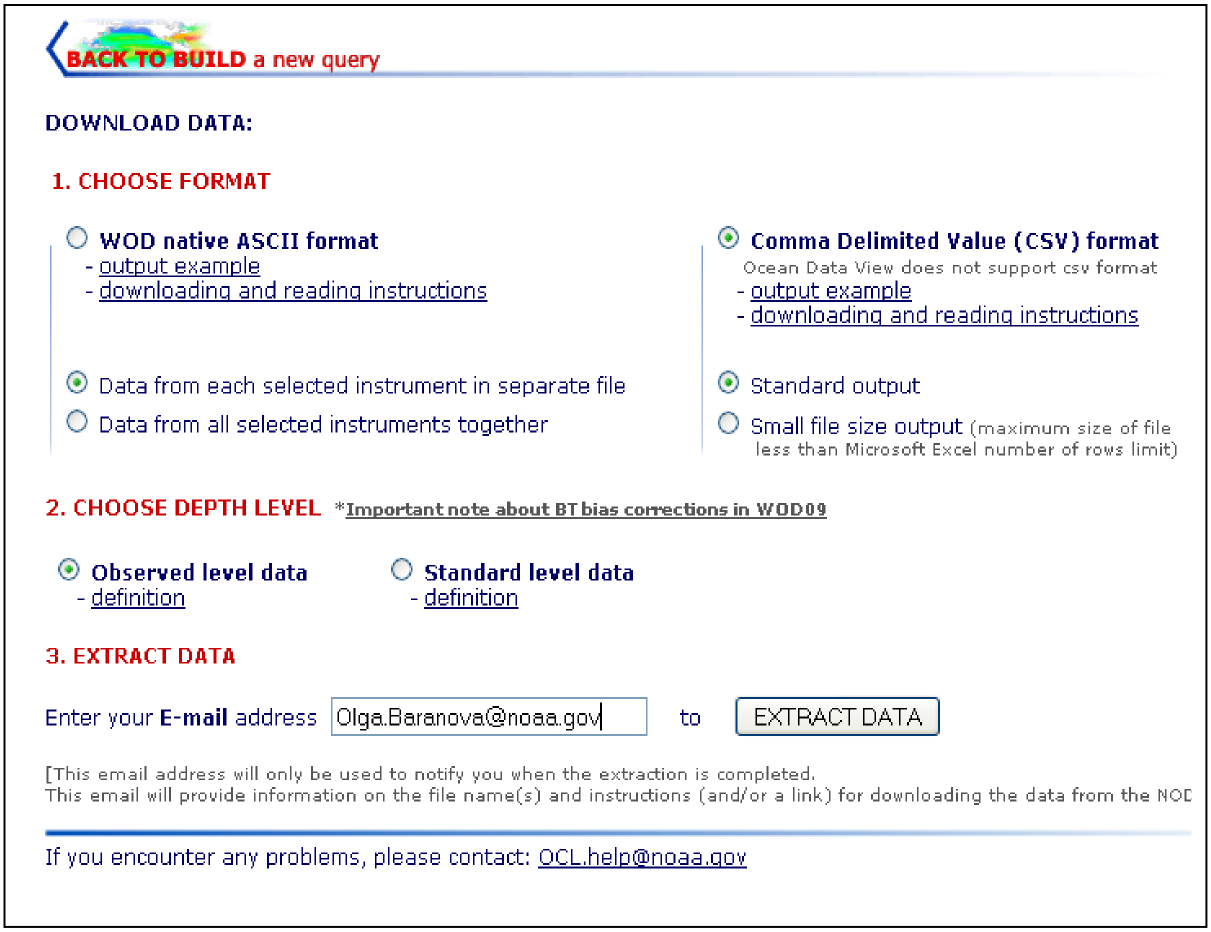


Figure 5. Data download menu, format choice and submitting request to extract the data

4. CLIMATIC CHARACTERISTICS OF TEMPERATURE, SALINITY, AND DISSOLVED OXYGEN

Each of the considered seas has a complex temperature – salinity – oxygen (T-S-O_2) structure of water, which varies considerably in space and time. To describe climatic characteristics of this structure in quantitative terms, the following charts were calculated and made for every sea in the present work:

- Climatic charts of distribution of T, S, O_2 at various horizons;
- Climatic charts of seasonal changes of T, S, O_2 at some horizons, related to the centers of squares, within which calculations were made;
- Climatic charts of vertical profiles of T, S, O_2, related to the centers of squares, within which calculations were made.

Calculation procedures and way of presenting of enumerated climatic characteristics of the Bering Sea, Sea of Okhotsk, and Sea of Japan are described below.

4.1. The Bering Sea

Procedure of construction of climatic fields (objective analysis of data), used in the present work, is analogous to the pattern proposed by Barnes (1973) and (Levitus and Boyer, 1994).

Oceanographic data observations in the Bering Sea are distributed unevenly in space and time. A considerable part of water area in winter months is covered with ice and inaccessible for observations.

The following computing scheme was applied when calculating statistical characteristics of marine environment to avoid distortions, resulting from heterogeneous distribution of initial data. Originally, mean daily values of T, S, and O_2 in the regular grid points were calculated for each month of every individual year. On the basis of daily values, mean monthly values for every individual year were calculated and then use for calculating mean long-term values of T, S, and O_2. Black and white climatic charts of temperature, salinity, and dissolved oxygen are in Appendix A. Colored climatic charts, as well as charts of seasonal variability and vertical distributions of T, S, and O_2, are given on the DVD disc and Internet versions of the Atlas.

A regular grid sized 1-degree latitude by 2-degree longitude was chosen to make climatic charts. Inventory of these charts is given in Table 4.

To construct climatic charts of seasonal variability of T, S, and O_2 and climatic charts of vertical profiles, the Bering Sea water area was divided into grid squares 2.5^o x 5^o (Figure 6). Charts of seasonal variability of T, S, and O_2 at various horizons, as well as climatic charts of vertical profiles for four months: February, May, August, and November, are given for each of these squares. Figures 7 – 12 give examples of climatic charts of seasonal variability and climatic charts of vertical profiles of T, S, and O_2 in the Bering Sea.

Complete colored climatic charts of seasonal variability of T, S, and O_2, and climatic charts of vertical distributions of T, S, and O_2 are given on a DVD disc and in the Internet version of the present Atlas.

Table 4. Inventory of climatic charts by temperature, salinity, dissolved oxygen for the Bering Sea

Depth (m)	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0	+	+	+	+	+	+	+	+	+	+	+	+
25	+	+	+	+	+	+	+	+	+	+	+	+
50	+	+	+	+	+	+	+	+	+	+	+	+
100	+	+	+	+	+	+	+	+	+	+	+	+
200		+			+			+			+	
300		+			+			+			+	
500							+					
1000							+					
2000							+					
3000							+					

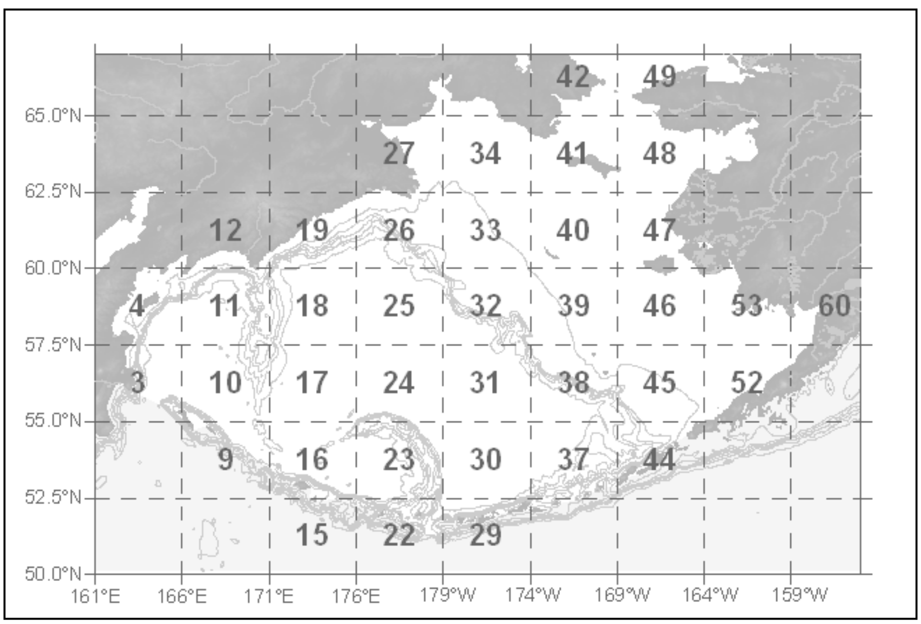


Figure 6. Pattern of squares in the Bering Sea where calculations were made and charts of climatic seasonal variability and vertical profiles of T, S, and O_2 are given

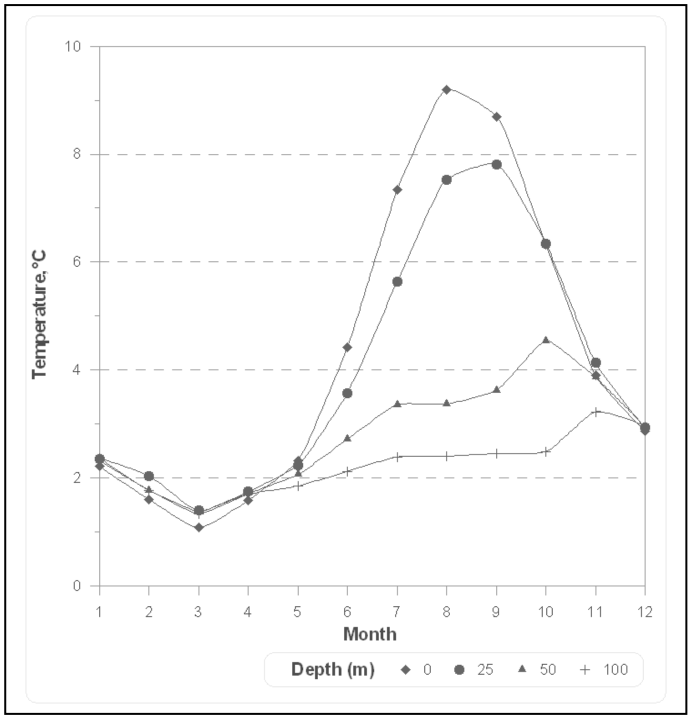


Figure 7. Climatic charts of seasonal variability of water temperature in square #25 of the Bering Sea at horizons of 0, 25, 50, and 100 m.

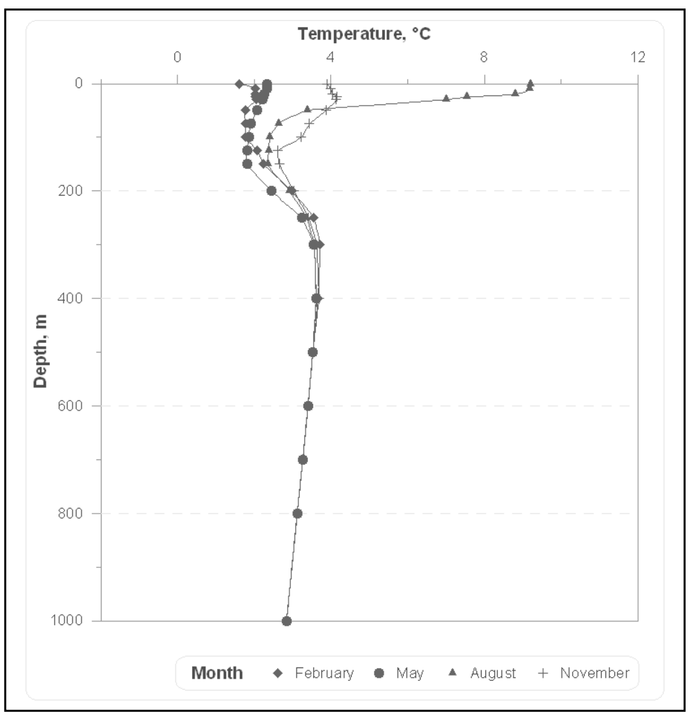


Figure 8. Climatic charts of vertical distribution of water temperature in square #25 of the Bering Sea for February, May, August, and November

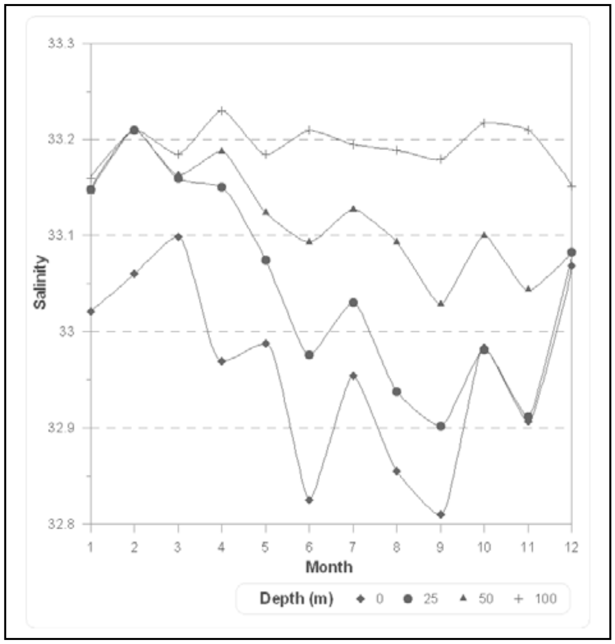


Figure 9. Climatic charts of seasonal variability of water salinity in square #25 of the Bering Sea at horizons of 0, 25, 50, and 100 m.

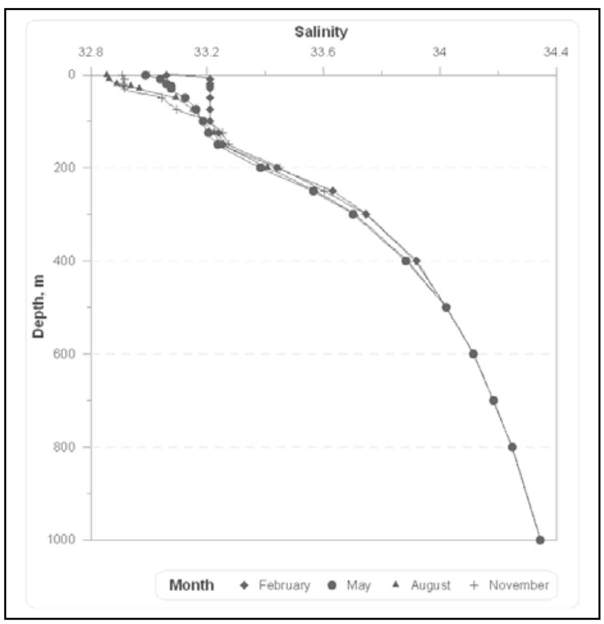


Figure 10. Climatic charts of vertical distribution of water salinity in square #25 of the Bering Sea for February, May, August, and November.

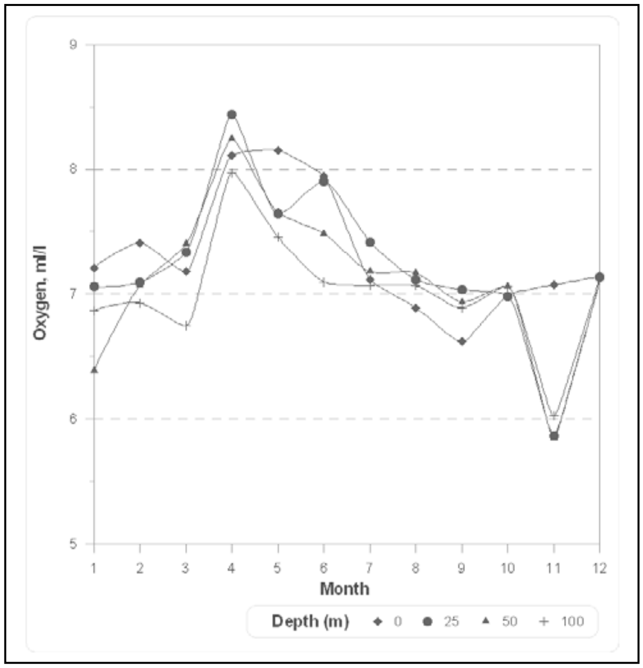


Figure 11. Climatic charts of seasonal variability of dissolved oxygen in square #25 of the Bering Sea at horizons of 0, 25, 50, and 100 m.

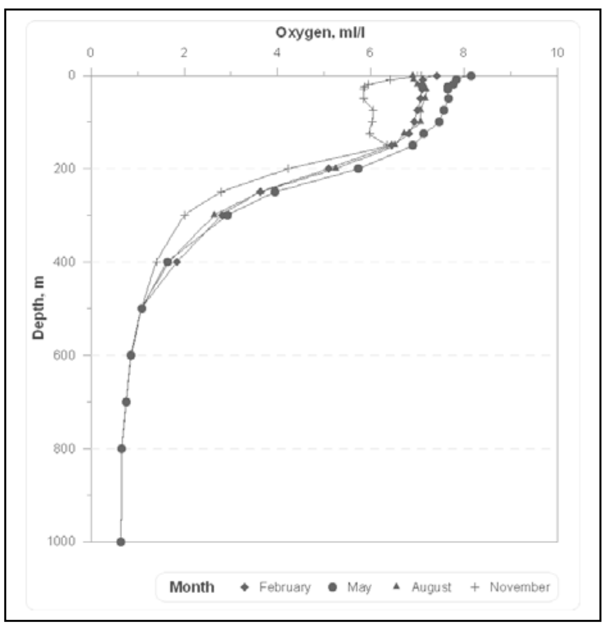


Figure 12. Climatic charts of vertical distributions of dissolved oxygen in square #25 of the Bering Sea for February, May, August, and November

4.2. The Sea of Okhotsk

The procedure for the construction of climatic charts of T, S, and O_2 for the Sea of Okhotsk is identical to the procedure of their construction for the Bering Sea. The difference is in the selection of the grid size. For the Sea of Okhotsk, a regular grid size of 1^o x 1^o is chosen. Appendix B contains climatic charts of T, S, and O_2 for various horizons. Inventory of these charts is in Table 5.

Table 5. Inventory of climatic charts by temperature, salinity, dissolved oxygen for the Sea of Okhotsk

Depth (m)	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0	+	+	+	+	+	+	+	+	+	+	+	+
25	+	+	+	+	+	+	+	+	+	+	+	+
50	+	+	+	+	+	+	+	+	+	+	+	+
100	+	+	+	+	+	+	+	+	+	+	+	+
200		+			+			+			+	
500	+											
1000	+											
2000	+											
3000	+											

To construct climatic charts of seasonal variability and climatic charts of vertical distributions of T, S, and O_2, the Sea of Okhotsk water area is divided into squares sized 3^o x 3^o (Figure 13).

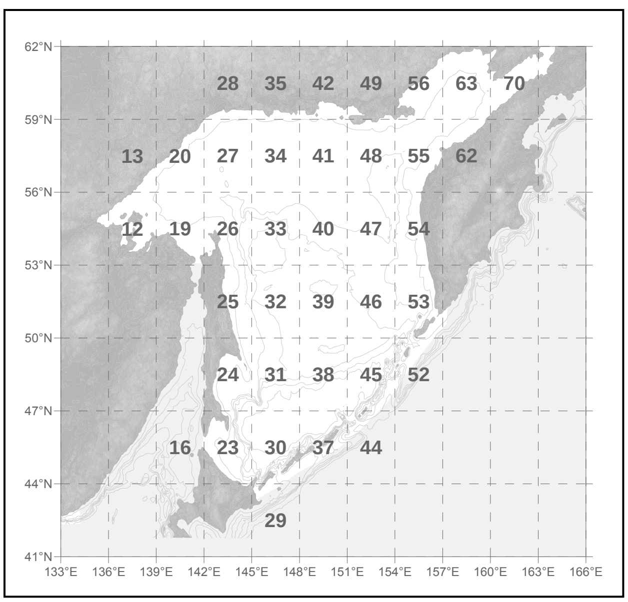


Figure 13. Pattern of squares in the Sea of Okhotsk, where calculations were made and charts of climatic seasonal variability and vertical profiles of T, S, and O_2 are given

Charts of seasonal variability of T, S, and O_2 and were constructed at various horizons for every square and climatic charts of vertical profiles of these characteristics for four months: February, May, August, November, were made. Colored climatic charts, as well as charts of seasonal variability and vertical distribution of T, S, and O_2, are given for each square on a DVD disc and in the Internet version of the Atlas.

4.3. The Sea of Japan

The procedure for the construction of climatic charts of T, S, and O_2 for the Sea of Japan is identical to the procedure of their construction for the Bering Sea and the Sea of Okhotsk. A grid size of 1^o x 1^o is chosen for the Sea of Japan. Appendix C contains climatic charts of T, S, and O_2 for various horizons. Inventory of these charts is in Table 6.

Table 6. Inventory of climatic charts by temperature, salinity, dissolved oxygen for the Sea of Japan

Depth (m)	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0	+	+	+	+	+	+	+	+	+	+	+	+
25	+	+	+	+	+	+	+	+	+	+	+	+
50	+	+	+	+	+	+	+	+	+	+	+	+
100	+	+	+	+	+	+	+	+	+	+	+	+
200	+			+			+			+		
500	+			+			+			+		
1000	+											
2000	+											
3000	+											

To construct climatic charts of seasonal variability and climatic charts of vertical distributions of T, S, and O_2, the Sea of Japan water area is divided into squares sized 3^o x 3^o (Figure 14).

Charts of seasonal variability of T, S, and O_2 and were constructed at various horizons for every square and climatic charts of vertical profiles of these characteristics for four months: February, May, August, November, were made. Colored climatic charts, as well as charts of seasonal variability and vertical distribution of T, S, and O_2, are given for each square on a DVD disc and in the Internet version of the Atlas.

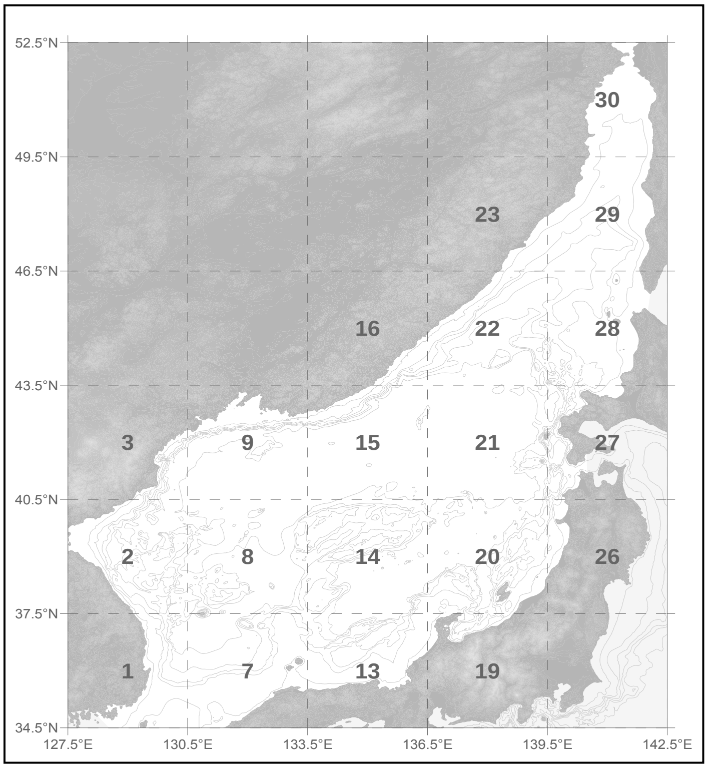


Figure 14. Pattern of squares in the Sea of Japan, where calculations were made and charts of climatic seasonal variability and vertical profiles of T, S, and O_2. are given

4.4. Climatic statistics of squares

Climatic characteristics of T, S, and O_2 squares, described in Sections 4.1 – 4.3, are presumed to be used in the future to improve oceanographic data quality control procedures. Information is presented in a format of EXCEL electronic tables on a DVD disc and in the Internet version of the present Atlas. Tables are subdivided into A Category and B Category.

Tables of Category "A" for the Bering Sea (Figure 6), the Sea of Okhotsk (Figure 13), and the Sea of Japan (Figure 14) contain the following characteristics per every square:

- Climatic variability of yearly cycle of T, S, and O_2 and
- Climatic seasonal vertical profiles of T, S, and O_2.

Tables of Category "B" contain the following information per every parameter presented in a square (temperature, salinity, and dissolved oxygen; T, S, and O_2)

- Time
- No. of a square
- Coordinates of the middle of a square
- Horizon (м)
- Layer (m)
- A number of measurements in a square
- Standard deviation
- Minimum value of parameter
- Maximum value of parameter
- Averaged value
- Median

Names of files, containing Tables of Category "A", have the following structure: '**S_XX_P_T**.xls'. Elements of a name of a file indicate the following:

S - sea:	**B**ering, **O**khotsk, **J**apan
XX - square #:	01, 02, 03…
P - parameter:	**S**alinity**, T**emperature**, O**xygen
T - type:	**S**easonal, **V**ertical

5. 54-YEAR TIME SERIES OF TEMPERATURE, SALINITY, AND OXYGEN

The present section considers one of the possible approaches of quantitative assessment of inter-annual variability of hydrological parameters in the seas of the North Pacific Ocean. The proposed algorithm was used to calculate inter-annual variability of T, S, and O_2 in different areas of the Bering Sea, Sea of Okhotsk, and Sea of Japan for the period of 1950-2003. The results obtained are considered as the first step by the authors towards the quantitative description of spatial-time variability of parameters of waters of these seas being related to the tasks of studying the climate of the World Ocean.

5.1. The Bering Sea

The Bering Sea is divided into 3 areas: B-1, B-2, and B-3 (Figure 15). The values of mean annual anomalies of T, S, and O_2 at standard horizons of 0, 10, 20, 30, 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, 100, 1200, and 1500 m were calculated for the above-mentioned areas.

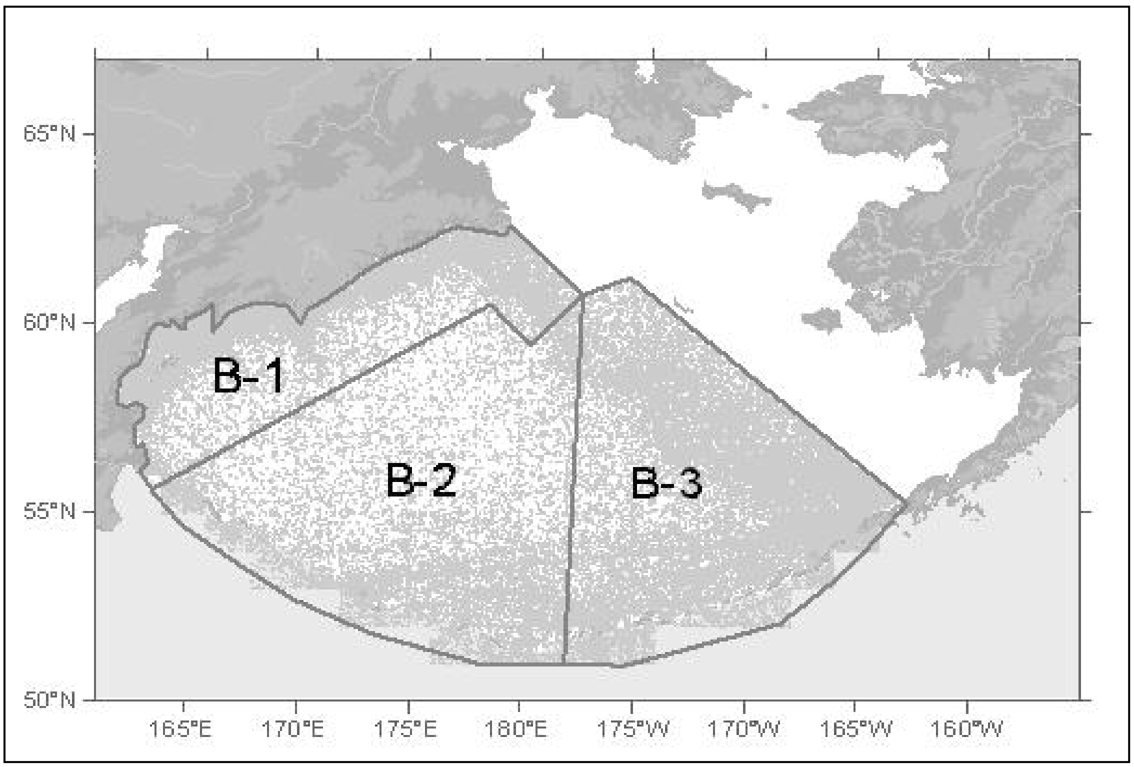


Figure 15. The Bering Sea. Areas for time series calculations

The selection of areas to construct time series of T, S, and O_2 is conditioned by the following regional factors. Area B-1 reflects inter-annual variability of intensity of autumn-winter convection near the coasts of Kamchatka. Area B-2 reflects inter-annual variability in the Pacific waters entering the sea through the Blizhnyi Strait. Area B-3 reflects inter-annual variability in the Pacific waters entering the sea through the straits of the eastern Aleutian ridge, as well as inter-annual variability of dynamic processes near the continental slope of the eastern part of deepwater sea depression.

The following algorithm was applied to calculate the values of mean annual anomalies:

- Mean long-term values of T, S, and O_2 were calculated for every area and every month. For example, $T_{climatic}$ (B-1, January, 50m) is a temperature norm or mean long-term value of temperature in the area of B-1 for January at a horizon of 50 m.
- Mean values of T, S, and O_2 were calculated for every area, every year, and month. For example, T (B-1, January 1965, 150m) is the mean temperature in the area of B-1 in January 1965 at a horizon of 150 m.
- Anomalies of T, S, and O_2 were calculated for every area, for every month of each year. For example, $T_{anomaly}$ (B-1, Feb 1965, 0m) = T (B-1, Feb 1965, 0m) – $T_{climatic}$ (B-1, Feb, 0m).
- The means for the area annual values of anomalies of T, S, and O_2 were calculated. For example, $T_{anomaly}$ 1965(B-1, 10m) =[$T_{anomaly}$ (B1, Jan 1965, 10m) + $T_{anomaly}$ (B-1, Feb 1965, 10m) + … + $T_{anomaly}$ (B-1, Dec 1965, 10m)]/12

Appendix A of this Atlas, as well as a DVD disc, and the Internet version, contains charts of anomalies of temperature, salinity, and oxygen at standard horizons within the range of 0 to 1500 m.

5.2. The Sea of Okhotsk

Figure 16 presents two areas of the Sea of Okhotsk (O-1 and O-2), for which time series of T, S, and O_2 were calculated. An algorithm of these calculations is identical to the algorithm used when calculating time series for the following areas in the Bering Sea: B-1, B-2, and B-3.

The selection of areas O-1 and O-2 for the construction of time series of T, S, and O_2 is conditioned by the following regional factors. Area O-1 reflects inter-annual variability of autumn-winter processes in an active layer of the Sea of Okhotsk waters and their interaction with the transformed Pacific waters near the continental slope of Eastern Sakhalin. Area O-2 reflects inter-annual variability in the Pacific waters entering the sea through the central and northern straits of the Kuril ridge.

Charts of anomalies of temperature, salinity, and oxygen for standard horizons within a range of 0 to 1500 m are given in Appendix B of this Atlas, as well as on a DVD disc and in the Internet version.

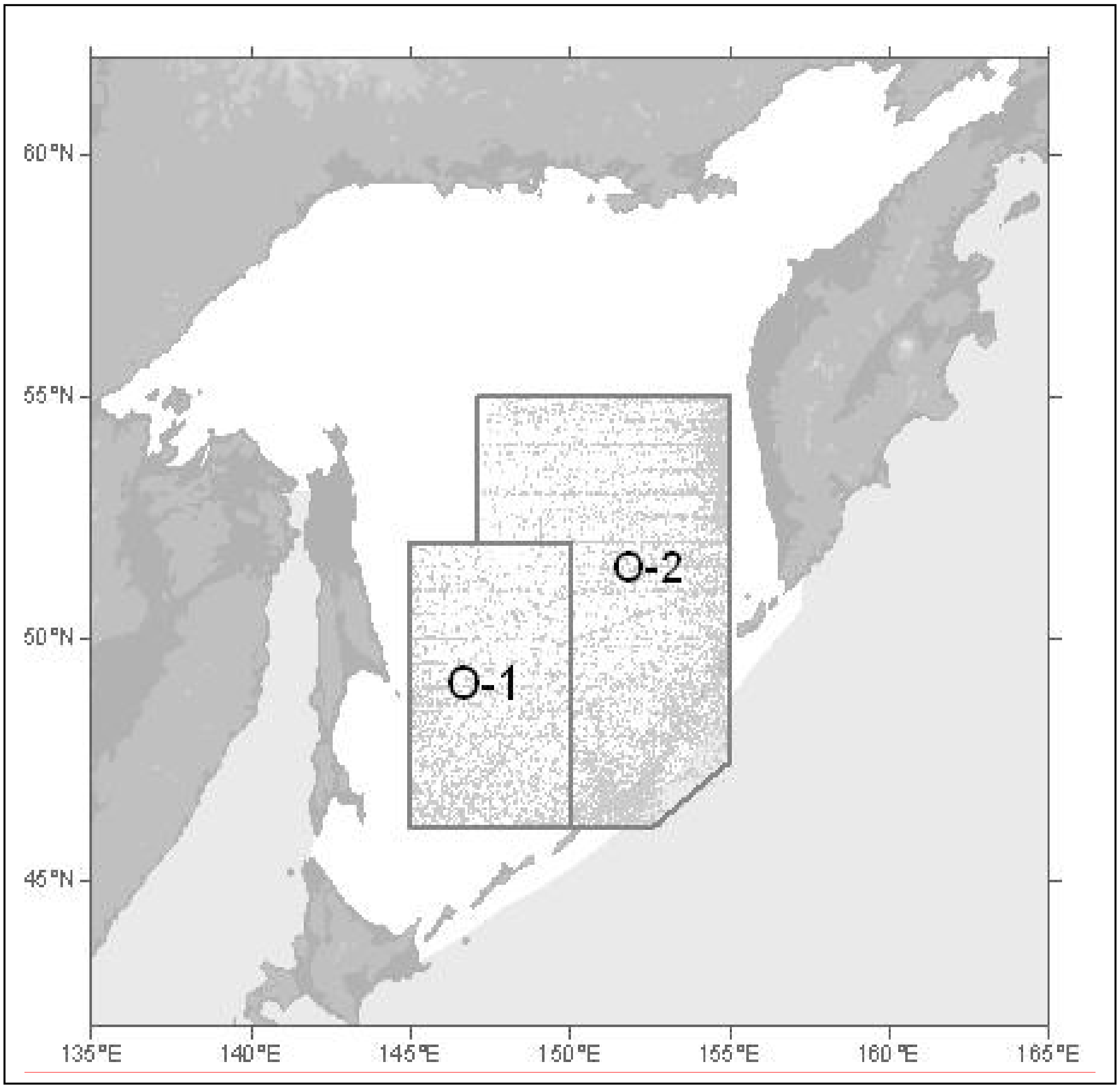


Figure 16. The Sea of Okhotsk. Areas for time series calculations

5.3. The Sea of Japan

Figure 17 introduces two areas of the Sea of Japan (J-1 and J-2), for which time series of T, S, and O_2 were calculated. An algorithm of these calculations is identical to the algorithm used when calculating time series of the areas B-1, B-2, and B-3 in the Bering Sea.

The selection of areas J-1 and J-2 for the construction of time series of T, S, and O_2 is conditioned by the following regional factors. These areas are located to the north and to the south of the Polar front, which separates the Sea of Japan waters proper from subtropical Pacific waters.

Area J-1 reflects inter-annual variability in the Pacific waters entering the sea through the Korea Strait, as well as inter-annual variability of dynamic processes within anti-cyclonical meander of the East-Korean current.

Area J-2 reflects inter-annual variability of autumn-winter processes in an active layer of the Sea of Japan waters proper of and their interaction with the transformed Pacific waters near the continental slope to the south and east of the Peter the Great Bay.

Charts of anomalies of temperature, salinity, and oxygen for standard horizons within a range of 0 to 1500 m are given in Appendix C of the present Atlas, as well as on a DVD disc and in the Internet version.

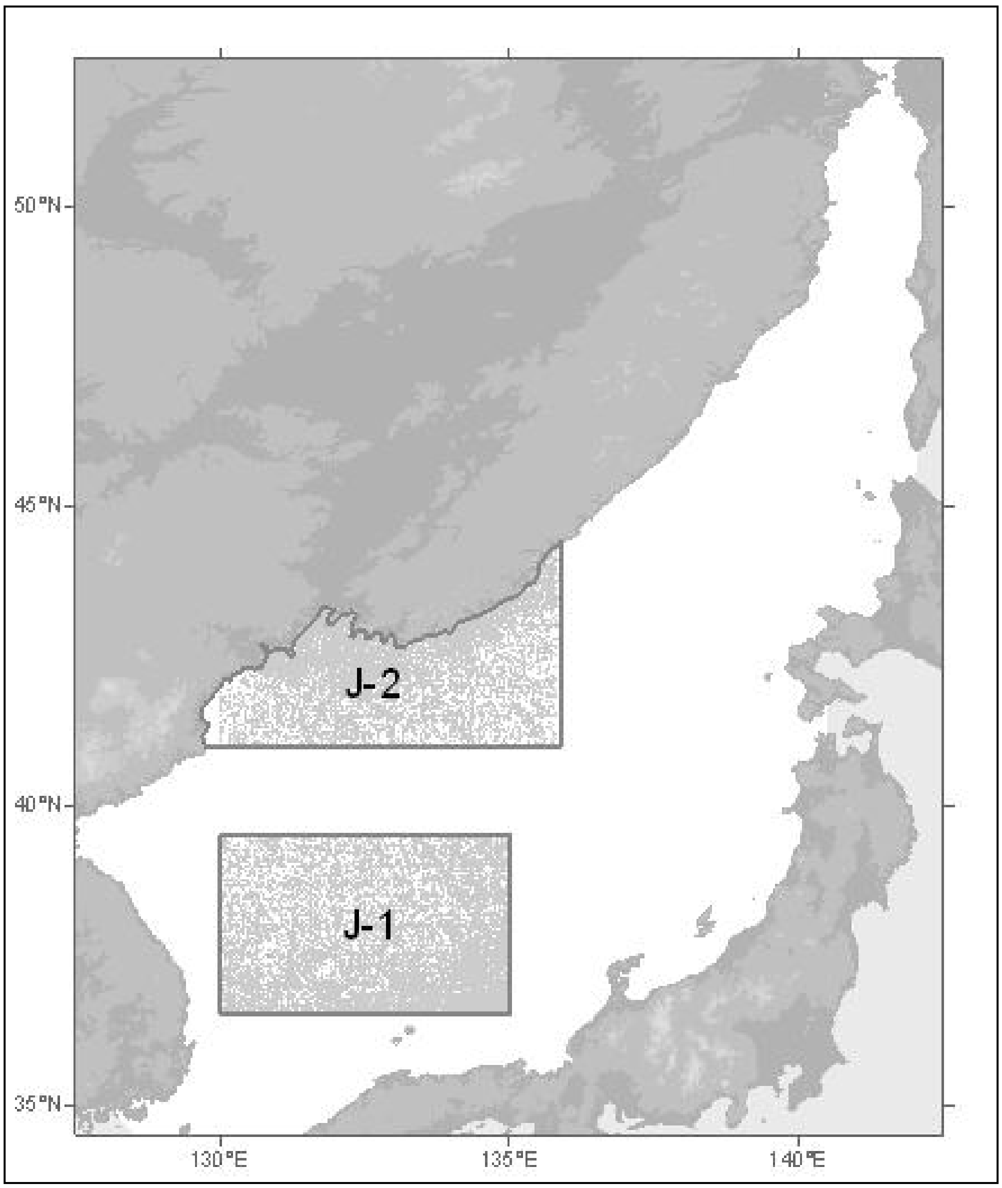


Figure 17. Sea of Japan. Areas for time series calculations

6. ELECTRONIC BOOKS AND CHARTS

The Section of **Electronic Library** on DVD disc and in the Internet version of the Atlas includes electronic versions of books on the history of pioneering the Bering Sea, the Sea of Okhotsk, and the Sea of Japan, containing initial data and description of the measuring methods. The majority of these publications belong to the category of rare books and books difficult to access for a wide circle of readers. Though the quality of a text in 'pdf' format does not always correspond to the generally accepted standards due to imperfectness of the applied technology of books' scanning, the authors, nevertheless, have considered it is expedient to include these books into the composition of the present section because of their scientific significance. Below is a list of publications, set in a chronological order:

1874: Deep-Sea sounding in the North Pacific Ocean obtained in the United States steamer Tuscarora, Commander George E. Belknap, U.S. Hydrographic Office, Washington. U.S. Government Printing Office, N 54, 23 pp.

1880: Maidel, Meteorological and hydrological observations in the Eastern Ocean, Maritime Collection, N 9, p. 37-50 (in Russian).

1880: Dall, Wm. H., Report on the currents and temperature of Bering Sea and adjacent waters, Coast and Geodetic Survey for 1880, Appendix N 16, 45 pp.

1881: Hooper C. L., Report of the cruise of the U.S. revenue-steamer Corwin in the Arctic Ocean, Washington Government Printing Office, 71 p.

1887: Materials on hydrography of the Sea of Okhotsk, Notes on hydrography, Issue 1, p. 1-11 (in Russian).

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7. PHOTO GALLERY

Photo gallery on a DVD disc and in the Internet version of the Atlas contains the photographs of the nature of the coastal zone of the North Part of the Pacific Ocean. The photo viewing is organized by regions:

- Alaska
- Kamchatka
- Kuril Islands. Onekotan
- Kuril Islands. Shikotan
- Vladivostok

The photographs acquired from the Photo Library of NOAA are accessible without restrictions via the Internet: http://www.photolib.noaa.gov/.

8. DISC CONTENTS

The major sections of the disc are follows:

DATABASE - This section contains data files of the climatic fields of temperature, salinity, and oxygen used for preparation of climatic charts of the Atlas.

DOC - This section contains the Russian and English versions of the text of the Atlas with Appendixes in 'pdf' format.

E-BOOKS – This section contains electronic copies of the books in 'pdf' format.

E-MAPS – This section contains electronic copies of the historical maps in 'png' format constructed in 19th century.

HTML - This section contains 'xhtml' files, images of the data distribution plots and climatic charts. Access to all information is done via web menu. It has the following sub-sections:

Credits - This sub-section lists organizations and authors and provides citation of the present Atlas.

Text of the Atlas - This sub-section provides access to the Russian and English version of the text of the Atlas with Appendixes in 'pdf' format.

Access to Data - This sub-section contains the database inventory tables and provides access to the originator's data and climatic field files.

Climatology - This sub-section provides access to the climatic maps and vertical charts of the temperature, salinity, and oxygen constructed for the Bering Sea, the Sea of Okhotsk, and Japan Sea.

54-years Time Series - This sub-section provides access to the time series anomaly charts of the temperature, salinity, and oxygen constructed for the Bering Sea, the Sea of Okhotsk, and Japan Sea.

Electronic Library - This sub-section provides access to the copies of the historical maps of the North part of the Pacific Ocean prepared in 19th century and books and articles devoted to exploration of the Bering Sea, the Sea of Okhotsk, and Japan Sea.

Photo Gallery - This sub-section provides access to the photographs of the nature of the coastal zone of the North Part of the Pacific Ocean.

9. FUTURE ACTIVITIES

The present Atlas considers climatic characteristics of the Bering Sea, the Sea of Okhotsk, and the Sea of Japan. Distributions of temperature, salinity, and dissolved oxygen (T, S, and O_2) at standard horizons for every individual month are given. Climatic vertical profiles of T, S, and O_2 have also been calculated for these seas. Time series of anomalies of T, S, and O_2 for different horizons for the period of 1950-2003 have been constructed for various areas of the Bering Sea, Sea of Okhotsk, and the Sea of Japan.

Originator's data, used to develop the present Atlas, are available and accessible via the Internet without restriction.

In the future, it is planned to enrich and enlarge the database and conduct analysis of time series in order to understand the mechanisms of spatial-time variability of hydrological characteristics of the seas of the North Pacific Ocean. The understanding of these mechanisms is necessary to solve a wide range of tasks in various fields of natural sciences.

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