NOAA Atlas NESDIS 59

CLIMATIC ATLAS OF THE SEA OF AZOV 2006

Silver Spring, MD
July 2006

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Настоящая работа выполнена в рамках:

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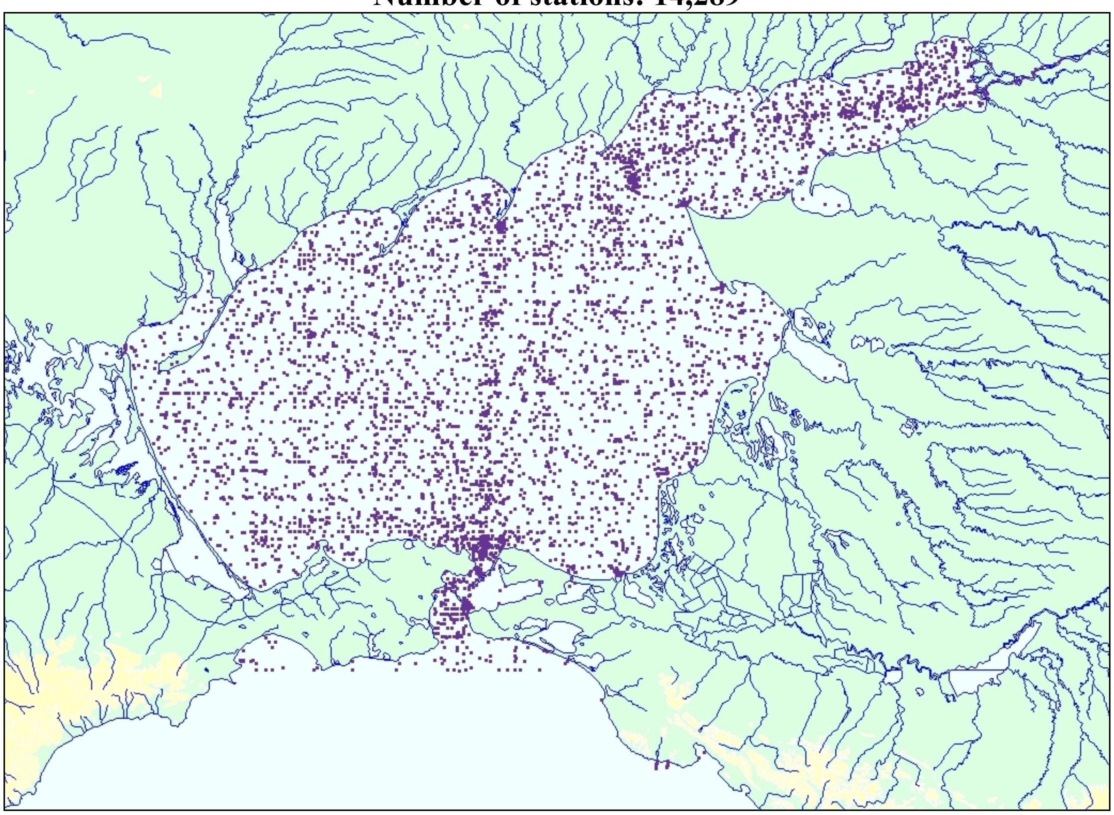
- Меморандума о взаимопонимании между Российской академией наук и Национальной администрацией по океану и атмосфере Министерства Коммерции Соединенных Штатов Америки о сотрудничестве в области Мирового океана и полярных регионов

The present work is prepared within the framework of:

- “Global Oceanographic Data Archaeology and Rescue” (GODAR) and “World Ocean Database” projects endorsed by the Intergovernmental Oceanographic Commission (IOC) UNESCO

- Memorandum of Understanding between the National Oceanic and Atmospheric Administration of the Department of Commerce of the United States of America and the Russian Academy of Sciences of the Russian Federation on Cooperation in the Area of the World Oceans and Polar Regions

Time: 1913-2004
Number of stations: 14,289



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CLIMATIC ATLAS OF THE SEA OF AZOV 2006

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ABSTRACT

This Atlas and accompanying CD-ROM contains oceanographic data collected by the scientific specialists of the Academy of Sciences, Ministry of Fisheries, and the Hydrometeorological Service of Russia in the Sea of Azov and the adjacent part of the Black Sea during 1913 - 2004. Monthly data distribution plots are provided for each year. Monthly climatic maps of temperature and salinity at the sea surface and depth levels of 5 and 10 meters are computed using objective analysis. Intra-annual variability of temperature and salinity of the Sea of Azov is discussed with respect to the quality control of the primary data. The Atlas also includes, in electronic format, selected copies of rare books and articles about the history of the Sea of Azov exploration and climate studies as well as photos, which provide information about the people and environment of this region.

1. INTRODUCTION

The climate of the Sea of Azov and state of its biological resources throughout the centuries have determined the living conditions and economic activities of the surrounding region, with a population exceeding 20 million people. This circumstance has motivated the urgency and topicality of studying the Sea of Azov on regional and global temporal-spatial scales.

Many monographs and papers have been dedicated to climate studies of the Sea of Azov. A set of background papers describing the climate of the Sea of Azov was published as atlases and aimed at various scientific and applied problems. However, the utilization of the obtained results is hampered for the present Climatic Atlas of the Sea of Azov for several reasons:

- The procedures for primary data quality control and construction of climatic maps were not formalized;
- The primary data utilized for the climatic maps were not open to public and thus, were inaccessible for many users.

As a result, the comparative analysis of the climatic fields presented in these papers is hindered, and the absence of primary data does not allow for using climatic features of the marine environment with the updated information. Thus, these papers are losing their significance;: the climate has been changing faster than the scientific community realizes and a new updated climatic atlas is necessary.

At the end of the 20th century some fundamental changes occurred in the basin of the Sea of Azov. They resulted from both increased anthropogenic effects in the region and natural climatic changes. To understand the nature of climatic changes of the Sea of Azov and to be able to predict them, a complex investigation program based on both collection of the environmental data and development of the methods of their analysis is needed. Recently developed information techniques for data collection and processing created the necessary prerequisites for the successful solution of this problem.

This atlas considers the problems of generation of a database for the Sea of Azov and the development of formal procedures for its analysis. The primary data are presented in an accompanying CD-ROM which is a part of this Atlas. We believe that the present publication could become a prototype for a hydrobiological atlas of the Sea of Azov.

2. THE HISTORY OF OCEANOGRAPHIC STUDY OF THE SEA OF AZOV

The instrumental investigation of oceanographic and biological features of the Sea of Azov was launched in the mid of the 19th century (Danilevsky, 1871).

The regular study of the hydrometeorological regime of the Sea of Azov succeeded simultaneously with the development of a network of coastal stations. The information on hydrological conditions of the central Sea of Azov was incoming from different vessels but mostly in the form of a supplement. In the late of 19th century and early 20th century, I. Shpindler (1890), F. Wrangel (1873), and later L. Antonov (1913) organized field expeditionary studies of the outer sea.

In 1922-28, under the guidance of N. Knipovich and within the framework of the Sea of Azov and the Black Sea Scientific and Fishery Expedition, a set of studies of both seas were conducted. The expedition reports disclosed all primary data and described the methods of measurements (Knipovich, 1926, 1932, 1938). The complete texts of the reports "The Essay on Study Performed by the Sea of Azov and the Black Sea Scientific and Fishery Expedition in 1925" and "The Hydrobiological Study in the Sea of Azov" are presented on CD-ROM in the Section "Electronic Books".

In 1928-32, the expeditionary studies were conducted by the fishery station of the Sea of Azov and the Black Sea, later reorganized into the Azov Fisheries Research Institute (AzCherNIRO).

In 1946, AzCherNIRO restarted the expeditionary studies and, besides biological and hydrological investigations, conducted hydrochemical investigations including measurements of chlorinity, phosphates, nitrogen, oxygen, *etc*.. The expedition materials were published in the Marine Hydrometeorological Year-books. Since 1961, the Hydrometeorological Observatory Center for the Black Sea and the Sea of Azov basins, which coordinated all expeditionary studies in the Sea of Azov, had been issuing monthly publications. The primary data from the Marine Year-books, 1946-58 are incorporated into the database of the present Atlas.

In 1936, the State Hydrometeorological Service of the USSR set up a network of hydrometeorological stations and standard hydrometeorological sections in the Sea of Azov. This network was used by the State Oceanographic Institute (SOI) for the study of the Sea of Azov climatic system. In the late-1980s, more than 20 coastal stations were providing hydrometeorological information on a daily basis (Figure 1a). A system of six hydrological sections was utilized for the Sea of Azov data collection which was usually performed per season. Moreover, some expeditionary studies targeted specific problems.

Since 1958, the Azov Fisheries Research Institute has been conducting regular expeditions for the study of oceanographic and biological features of the Sea of Azov through a set of stations presented on Fig. 1b. Besides observations of the state of the fish resources, the seasonal studies of physical and biological parameters are conducted in the region annually.

The collected data on the state of the environment and bioresources of the Sea of Azov were used as a basis for numerous publications presenting climatic studies of the Sea of Azov (Hydrometeorological Reference Book of the Sea of Azov, 1962; Hydrometeorological conditions of the Shelf Zone of the Seas of the USSR, 1986; Hydrometeorology and Hydrochemistry of the Seas of the USSR, 1991). However, all these publications contained general conclusions based on the primary data such as the computation of monthly mean values.

The Murmansk Marine Biological Institute (MMBI) has conducted its studies in the Sea of Azov since 1997. The Azov Branch of MMBI was founded in 1999. The results of the investigations were presented in a set of publications (Complex ecological studies of the Sea of Azov, 1998; Modern development of Estuaries Ecosystems based on the sample of the Sea of Azov, 1999; Environment, Biota, and Modeling of the Ecological Processes in the Sea of Azov, 2001; Ecosystem Studies of the Sea of Azov and the Coastal zone, 2002; Matishov *et al*., 2003; Complex Monitoring of the Environment and Biota of the Azov basin,. 2004; Marishov, *et al.*, 2004).

Based on the Azov Branch of MMBI, the Southern Scientific Center of the Russian Academy of Sciences was founded in Rostov-on-Don in 2002. The Center foundation made it possible to carry out observations on a regular basis. During this period more than 40 scientific expeditions have been organized, and their materials serve as the basis for understanding the climate of the Sea of Azov region. Background papers in the educational process for students of the Rostov-on-Don and Kuban State Universities are being utilized by the Universities of Moscow, St. Petersburg, and Helsinki. Moreover, the Southern Scientific Center of the Russian Academy of Sciences made a decision to rescue historical oceanographic data and make them available to the international scientific community in order to stimulate studies of the climatic system of the Sea of Azov region.

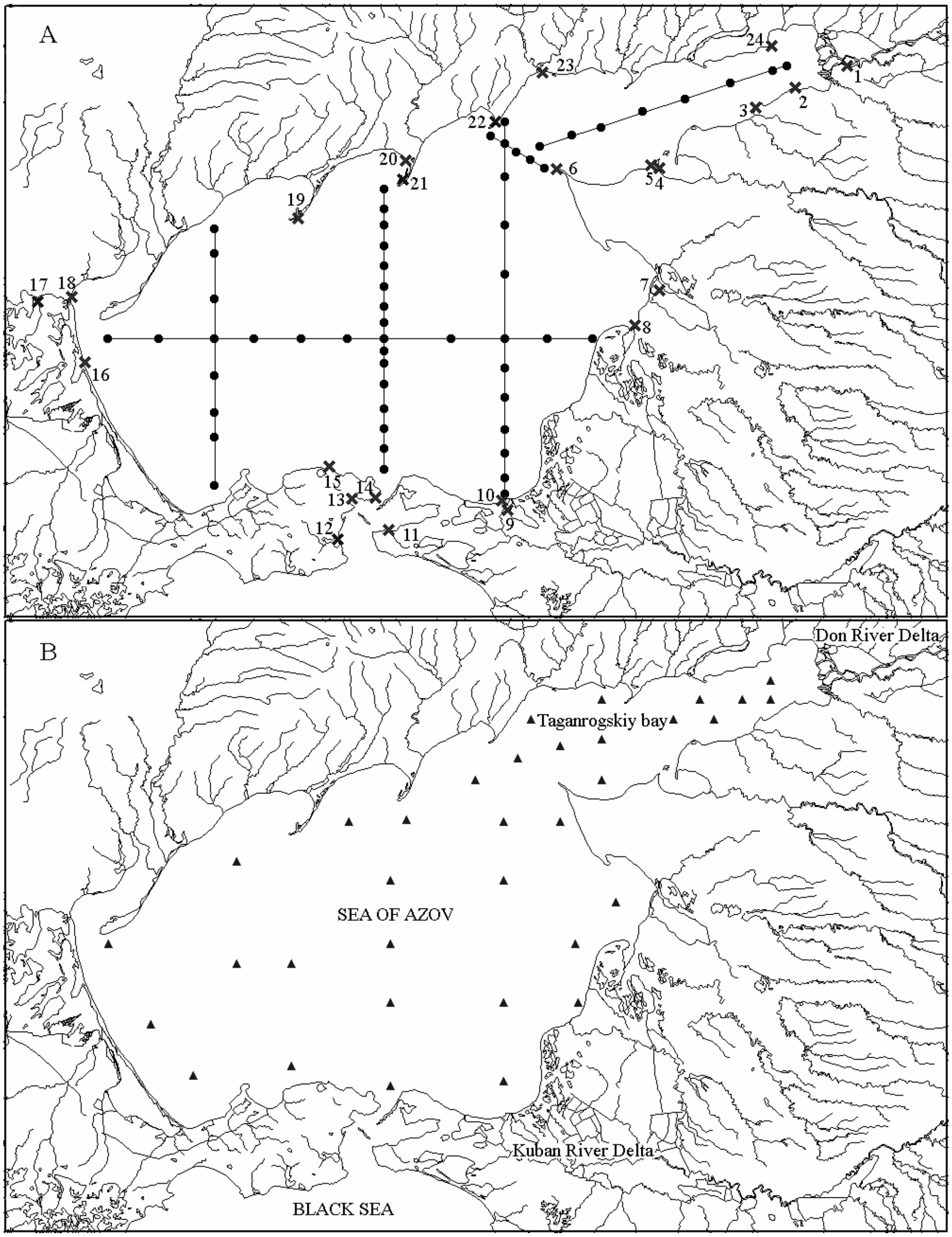

Figure 1. Chart of sections and the position of stations for coastal observations (A), the location of AzCherNIRO stations (B).
1 - Azov, 2- Ochakov spit; 3 - Margaritovo; 4 - Eiskiy port; 5 - Eisk, 6 - Dolzanskaia; 7 - Jaiasenskaia ferry; 8 - Primorsko-Akhtarsk; 9 - Temryuk; 10 - Temryuk; 11 - Taman; 12 - Zavetnoe; 13 - Kerch; 14 - Opasnoe; 15 - Mysovoe; 16 - Strelkovoe; 17 - Chongarsky bridge; 18-Genichesk; 19 - Obitochnaya spit; 20 - Berdyansk; 21 - Berdyanskaya spit; 22 - Beslosaraiskaya spit; 23 - Mariupol; 24 - Taganrog.

3. THE NEW DATA ON GEOMORPHOLOGY OF THE SEA OF AZOV BOTTOM

The Sea of Azov is a shallow water shelf basin of estuarine type. Steep coasts (up to 10-25 m) separate the shelf from the chernozem (organic rich) steppe plains with semi-arid climate. The coastal Azov shelf is limited by a 10-meter isobaths (Figure 2). This hydrodynamically active zone is characterized by widely spread sand spits, barrier spits, bars, deltas, limans[1], and bays (Mamykina and Khrustalev, 1980). Among big spits composed of quartz sand and shell detritus the most distinguished ones in the northern coastal zone are the ones of the so-called Azov type: Biryuchiya, Obitochnaya, Berdyanskaya, Belosaraiskaya, Krivaya and Beglitskaya. Their lengths are: 40, 30, 18, 13, 6, and 4 km, respectively. The Yasensky, Temryuksky, Kazantinsky, Arabatsky, Obitochny, Berdyansky, Belosaraisky Bays with depths of 6-10 m occur between the spits and coastal headlands.

The spits of the eastern coast, such as Ochakovskaya, Chumburskaya, Dolgaya and Kamyshevatskaya are less extended into the sea (for 3, 4, 14, and 7 km, respectively). They all consist of beach ridges consecutively joining the bedrock coast and have low elevation (usually 1-1.5 m); only some parts of the Eiskskaya and Ochakovskaya spits reach 2-2.5 m. The spits mostly consist of the shell origin material.

Along the eastern and northern coasts, a narrow barrier spit separates the system of estuaries from the open sea. The lengths of limans vary between 20 and 40 km. The bottom depths of the limans along the deepened axis line do not exceed 1.5-3.5 m. The limans are connected to the sea by narrow, relatively deep (4-9 m) swash[2] channels.

A vast depression of the Taganrog Bay stretches to the west of the Don delta. The numerous flooded riverbeds are typical of the underwater area of the river Don delta. All of them are connected to the delta river valleys and their relative depth is about 1-2 m.

The most pronounced geomorphologic feature of the Taganrog Bay along its axis line is a gently sloping hollow that covers 150 km from the Don out-delta to the underwater Panov plain in the open area of the Sea of Azov. Probably during the Late Quarternary regression there was the paleo-Don riverbed. It is typical of the Taganrog Bay that the Dolgaya, Sazalnitskaya, Chumburskaya, Ochakovskaya, Petrushina, Beglitskaya spits have their underwater extensions. They tend from 8-11 km to 20 km as loop-like steps and shoals in the direction of the offshore currents.

The biggest shoal of the Dolgaya spit is outlined with a 1-2-meter isobaths. It narrows northwestwards from 6 km to 2 km. Several small sand isles come over the gently sloping shoal. The total length of the spit – underwater rise system exceeds 60 km.

The coastal shelf in the 100-km zone to the west of Primorsko-Akhtarsk and Dolgaya spit has a number of characteristic geomorphologic features. It abounds with many large-scale underwater ranges (ridges) of a length of about 35-40 km. The lengths of Elenenin, Zhelezinskaya, Akhtarskaya and Achuevskaya banks reach 35-50 km. It is natural that the banks are typically shelf

[1] A long narrow lagoon near the mouth of a river
[2] A narrow channel through which tides flow

relief formations which do not relate to the prominence of spits into the shore. The minimum depths over the tops of the banks are 3-7 m, over the Elenenin bank the depth reaches 1-2 m. The height of ranges with respect to the bottom of adjacent hollows varies between 2 and 5 meters. Shells with sandy aleurite filling are bedded on tops and slopes of all bottom rises.

The Zhelezinskaya and Akhtarskaya banks are separated by a narrow, gently sloping Achuevskaya hollow with bottom depths of 8-10 m. From the west, the Achuevskaya and Zhelezinskaya ranges are framed by the closed Zhelezinskaya hollow with depths of 13.0-13.5 m. The Zhelezinskaya hollow with a width of 4-12 km stretches for 80 km. It should be noted that this hollow (lowland) represents the lowest bathymetric level on the Azov shelf.

For the northern coastal shelf at a distance of about 20-30 km off the shore, the geomorphologic bottom contour is determined by the systems of narrow, gently sloping beach ridges and ranges with a width of 0.2-0.8 km, length of 2-9 km and relative height of 1.5-3.5 m. The origination of such elongated sand formations is stipulated by a complex interaction between the wind, wind driven, and alongshore currents. These sand formations are of the similar origin.

Beach ridges are mostly developed to the south of the Obitochnaya spit. The narrow sand ridges (up to 0.7 km) are developed to the south of the Belosaraiskaya spit, at the depths of 5-8 m. Their length is about 4 km and height is 2-3 m.

Besides gently sloping waved relief, the coastal zone (up to 6-11 m) of the Sea of Azov demonstrates numerous flat underwater terraces. These are abrasion and abrasion accumulative steps which probably were generated during the Holocene transgression. Westward of the Dolgaya spit a terrace lies between the isobaths of 6 and 8 m. A similar 10-km wide terrace occurs at the depths of 4-5 m to the west of the Chumburskaya spit and Port-Katon. In the Taranjya Bay a 4-kilometer terrace lies between isobaths of 4 and 5 m. A wider (6-7 km) terrace is distinguished to the south of the Belosaraisk and Obitochny Bays at the depths of 8-9 m. From the Kuban delta in the Temruk Bay a flat (gradients $\leq$ 0.005-0.001) terrace stretches northwards between isobaths of 10-12 m. A slightly noticeable underwater gradient of terraces is a result of a 10-cm difference in the depths along a 1-2 km zone. In the coastal zone, in particular to the south of Port-Katon, the narrow abrasion terraces or benches are widely spread.

The role of biogenic processes related to the benthos population activity is important for the formation of geomorphologic feature of the coastal Azov shelf (up to 8-10 cm). Thus, it is typical that the majority of drifts (shell, detritus, shell sand) come from the sea bottom. The banks are formed at the location of steady colonial mollusk settlements. Almost everywhere one can distinguish various bottom relief nannoforms as gangs, furrows, holes, and cones that resulted from the activity of digging organisms.

In the Sea of Azov coastal zone the geomorphologic relief is formed under the effect of both natural and anthropogenic factors. Among the artificial formations the most noticeable are numerous embankments along the underwater ground dumps, as well as seaway ship canals. The longest (up to 20-30 km) and deepest (5-9 m) underwater canals are dug towards the ports of Azov, Taganrog, Mariupol and Berdyansk. The gently sloping steps of ground dumps lie on both sides of the canals. The bottom level of the canals is 4-5 m deeper than that of the adjacent shelf.

The bathymetric disclosure makes it possible for the Black Sea species and bottom fauna of the central shelf to enter freely into the coastal zone. Such geo-ecological situation definitely determine specific character of biogeocenoses.

In the central part of the shelf at the depths of 10-13 m there is a vast (with the area of 5,000 km^2), gently sloping and waved accumulative clay and silt plain. We suggest calling it the Panov underwater plain. The length of this low-lying plain is 120-140 km. The barely visible underwater surface bottom gradient faces the Zhelezinskaya and other hollows at the depth of 13.0-13.5 m. The gently sloping bottom rises are outlined in the northern knoll-like part of the plain by the 10-meter depth isobath. Up to 15 gently sloping knolls depths being less than 12 m are distinguished in the inner part of the lowland. Their length is 5-20 km and height is 40-60 cm.

Thus, the dominating types of the Sea of Azov shelf relief are: (i) sandy ridges and shell ridges and other forms that resulted from the drift (wind) currents; (ii) abrasion and abrasion and accumulative terraces at the depth of 4-9 m; (iii) accumulative (clay and silt) plains; (iv) erosive, gentle bottom hollows.

As it is well known, during the new Euxinic regressive phase of development (about 18 thousand years ago) the draining of the Sea of Azov water area took place (Panov and Khrustalev, 1966). The main area of the dried bottom of the Sea of Azov was covered by the lacustrine alluvial plain crossed by the palaeo-valleys of the steppe rivers in the Azov region. All these small rivers fell into the palaeo-Don. The modern geomorphologic outline was formed during the Holocene under the influence of both hydrodynamical and sedimentary processes and as a result of neotectonic background.

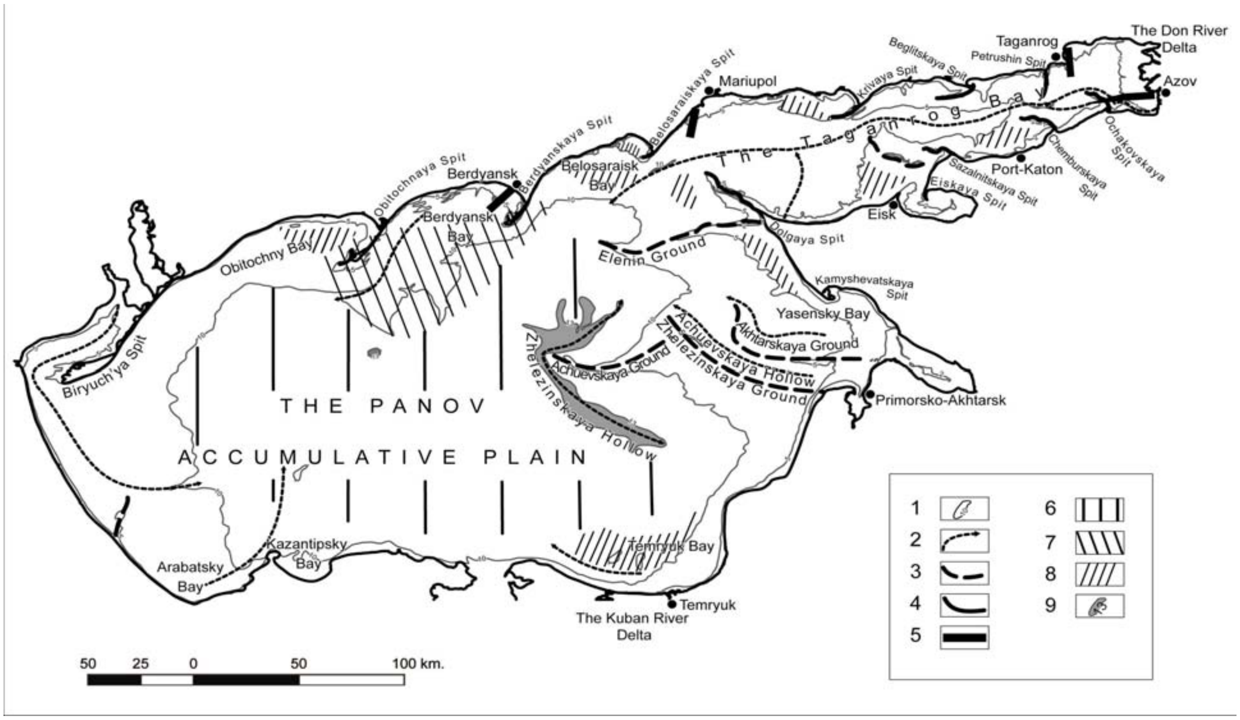

Figure 2. The major geomorphologic elements of the Azov shelf.
1 - Isobaths 2, 5, 10, 13 m;
2 - large-scale hollows and depressions;
3 - large-scale ranges and uplands;
4 - sand waves or knolls (underwater spit continuation);
5 - navigation canals;
6 - accumulative (clay and silt) plain;
7 - the zone of generation of sand waves and ranges;
8 - abrasion (abrasion and accumulative) terraces;
9 - the range of deep (13-13.5 m) shelf areas.

4. INTERANNUAL VARIABILITY OF TEMPERATURE AND SALINITY

The interannual variability of temperature and salinity of the Sea of Azov is depicted in Figure 3 (Hydrometeorology and Hydrochemistry of the Seas of the USSR, 1991; Matishov *et al.*, 2003; Matishov, *et al*., 2006). The multi-year (between the second half of 1920 and the late 20th century) surface layer temperature oscillations did not exceed 2-3 ^{o}C in the coastal waters of the Sea of Azov (Figure 3a).

The interannual dynamic of salinity (Figure 3b) depends significantly on the variability of inflow of salt water from the Black Sea, rivers discharge, and atmospheric processes affecting the balance of precipitation and moisture evaporation from the sea surface. Thus, the Sea of Azov is characterized by the periods of both relative desalination and salination. An example is the time period between 1970 and 1980 when substantial anthropogenic intake of the river discharge concurred simultaneously with decreased water balance of the Don and the Kuban rivers.

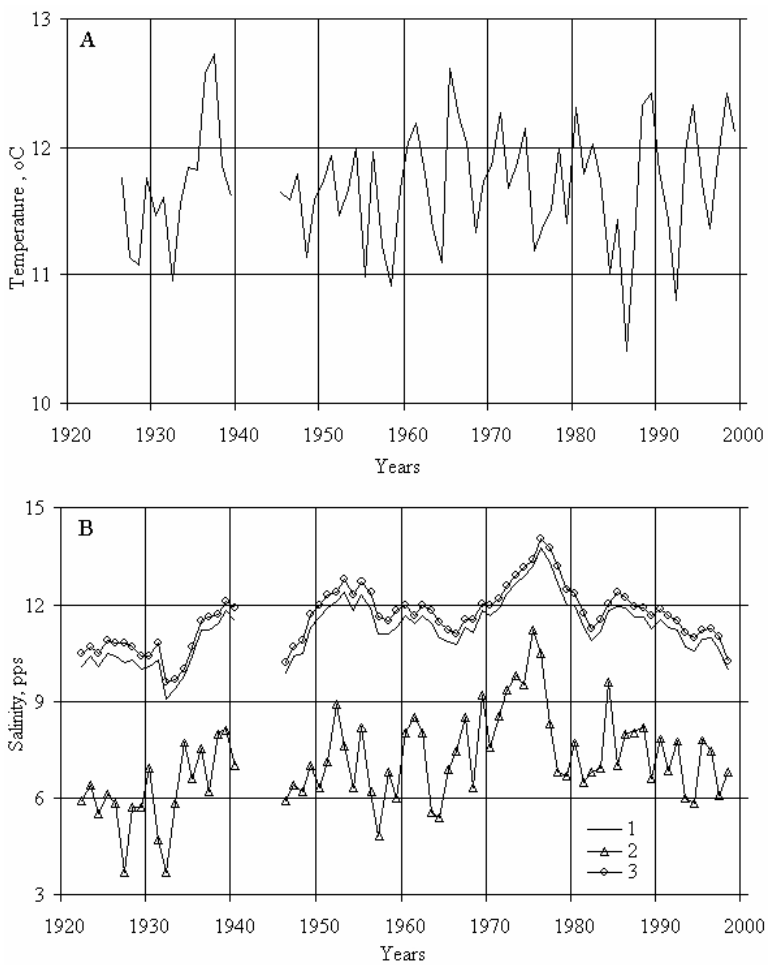

Figure 3. The multi-year oscillations of the annual mean values of the water surface temperature (A) and salinity (B) of the Sea of Azov. 1- Sea of Azov, 2 - Taganrog Bay, 3 - Sea of Azov (excluding the Taganrog Bay).

5. THE DATABASE FOR ECOLOGICAL STUDIES

5.1. Data Sources

Data for the present Atlas came from the following sources:

- Publications of Hydrometeorological Service of Russia, Ministry of Fisheries, Academy of Sciences of Russia,
- Cruise reports of the Southern Scientific Center and Murmansk Marine Biological Institute of the Kola Branch of the Academy of Sciences of Russia,
- Taganrog State University of Radioengineering, (professor A. I. Suhinov),
- Southern Branch of the Shirshov Institute of Oceanology of the Russian Academy of Sciences (Dr. E. V. Jakushev).

5.2. Data Formalization

The suggested approach to the data formalization is based on the format of the data description (Table 1) developed by the NOAA/NODC Ocean Climate Laboratory in collaboration with the colleagues from MMBI. The format is of a block structure, which, even with some minor changes, is preserved during the data description presented in the given paper. It consists of three blocks STATION, HEADERS, and DETAILS: (i) the STATION block incorporates the information on location and time of the data collection; (ii) the HEADERS block presents the meteorologycal data and the information on the methods applied during the measurements; (iii) the DETAILS block provides the data on temperature, salinity and some other parameters.

During historical data formalization station coordinates should be restored as the cruise reports present them in terms of local geographical locations (for example, Akhtari dock in nowadays is a city called Primorsko-Akhtarsk). This situation is typical for the Sea of Azov as the majority of the expeditions of the late 19th-early 20th centuries were conducted not far from the coast, and thus for a navigator it was easier to determine their location according to the coastal outline or to a nearby settlement.

The error in determination of the vessel location is an important ingredient for the data quality in general. The information on the method of determining the coordinates is accessible for users in the HEADERS block. The presence of COORD DETERM DESCRIPTION in HEADERS block indicates that the coordinates had been restored (Table 2). If these key words are not available, then the location was determined through instrumental method.

5.3 Data Access

The data are divided into 296 files as electronic tables in spreadsheet format with extension “csv” and archived in the same zip-file. The data are presented on CD-ROM in the DATABASE section.

Table 1. Data format. Sample 1.

STATION										
LAT DEG	LAT MIN	LAT SEC	LAT HEM	LON DEG	LON MIN	LON SEC	LON HEM	MONTH	DAY	YEAR
46	36	6	N	35	23	5	E	6	13	2004
HEADERS										
TIME	9	30	0	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	psu							
DECIMAL PLACES	1	2	3							
	0.5	18.43	10.078							
	1.0	18.43	10.078							
	…	…	…							
	9.0	18.24	10.104							

Table 2. Data format. Sample 2 (Knipovich, 1923, p. 431).

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

5.4. Data inventory

The Atlas database includes 14,145 stations covering the period between 1913 and 2004 (Fig. 4). Appendix A presents the table of monthly station distribution for each separate year and Appendix B gives the charts of the station location throughout the Sea of Azov and some part of the adjacent Black Sea water areas.

The relatively high number of stations in 1958 can be explained by the fact that the time series performed at the inshore and offshore stations were also included into the database.

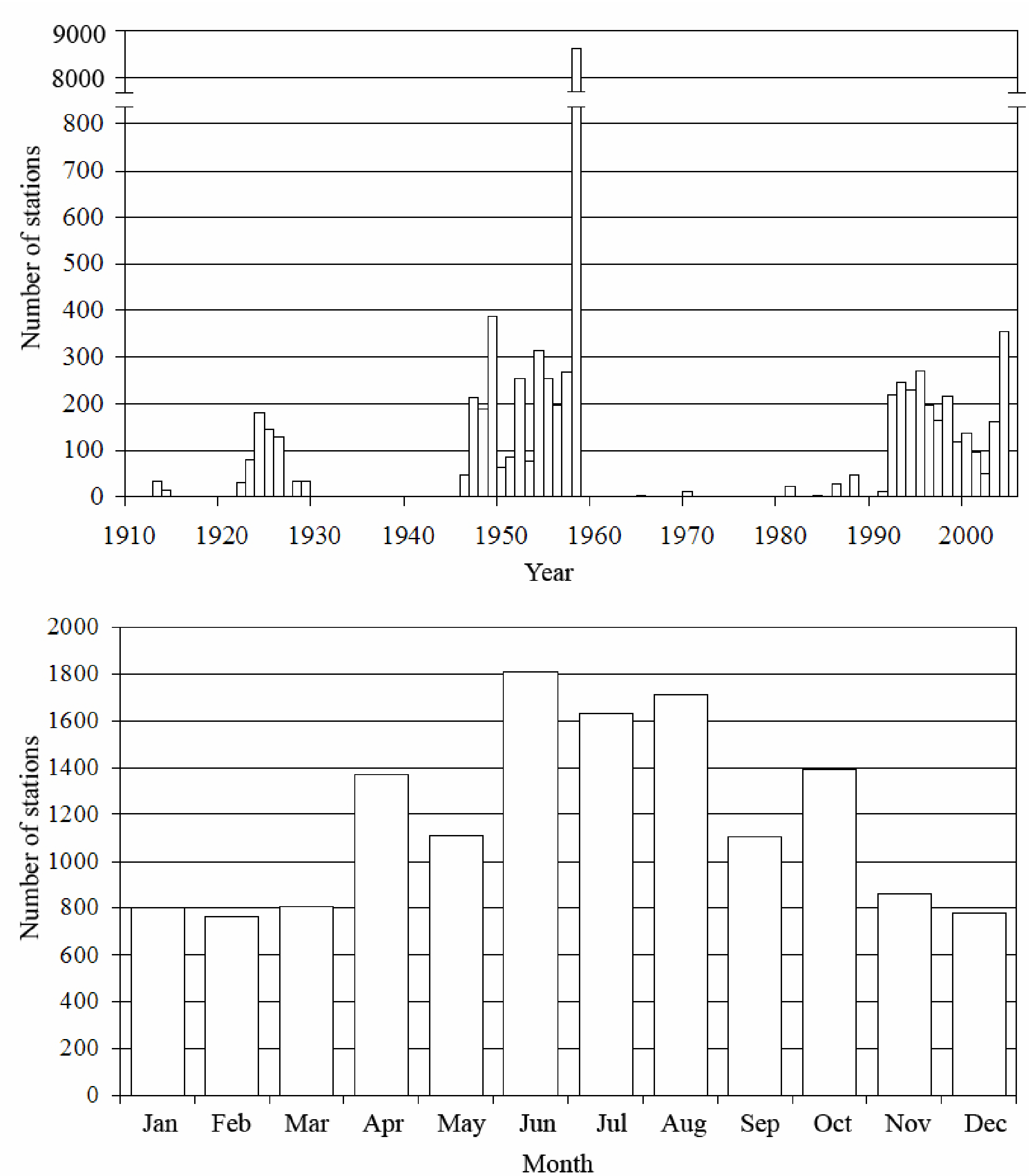

Figure 4. Data distribution by years (A) and by months (B).

5.4. Data Quality Control

The data quality control was carried out according to the scheme approved by the NOAA/NODC Ocean Climate Laboratory. First, gross errors in the primary data were determined and fixed. For example, the station coordinates were on shore and the time of station performance did not correspond to possible speed of the vessel travel, *etc*.

Temperature and salinity variation for the Sea of Azov were considered at the second stage of the data quality control to determine the limits of admissible values for these parameters.

For each individual month, the minimum T_{min} and maximum T_{max} limits of temperature variation for the entire water area of the Sea of Azov were calculated. Then, for each individual month, the frequency of temperature distribution within T_{min} and T_{max} was calculated (Figure 6). Table 4 lists the values of T_{min} and T_{max} for each individual month.

Three regions are distinguished to describe patterns of the salinity variation in the Sea of Azov (Figure 5).

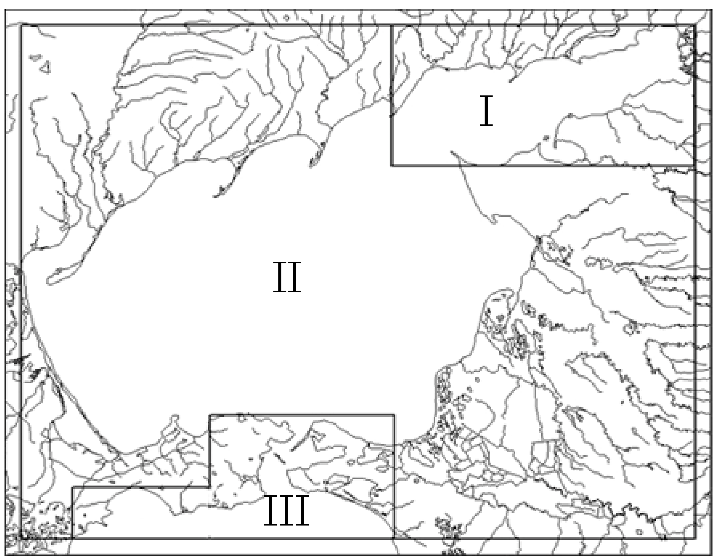

Figure 5. Three regions of the Sea of Azov for the quality control of salinity data.
I – the Taganrog Bay,
II – Central part of the Sea of Azov,
III- the Kerchensky strait and the adjacent part of the Black Sea.

Table 3 lists maximum and minimum levels of salinity values S_{min} and S_{max} and frequency of salinity distribution in these regions within S_{min} and S_{max}.

Table 3. Salinity ranges for three regions of the Sea of Azov.

Region		**Salinity, psu**	
#	Coordinates	S_{min}	S_{max}
I+II+III	34°47′ E - 39°20′ E 44°53′ N - 47°17′ N	0.0	19.56
I	37°18′ E - 39°20′ E 46°37′ N - 47°17′ N	0.0	12.87
III	35°09′ N - 37°19′ N 44°53′ N - 45°27′ N	6.06	19.56

Table 4.The permissible range of temperature variation for the Sea of Azov.

Month	$\mathbf{T_{min}}$	$\mathbf{T_{max}}$
January	-0.80	7.10
February	-0.80	9.00
March	-0.50	9.00
April	1.00	19.18
May	1.16	24.00
June	8.07	30.20
July	8.00	29.23
August	14.27	29.47
September	6.40	26.80
October	4.40	20.05
November	-0.50	16.40
December	-0.80	13.70

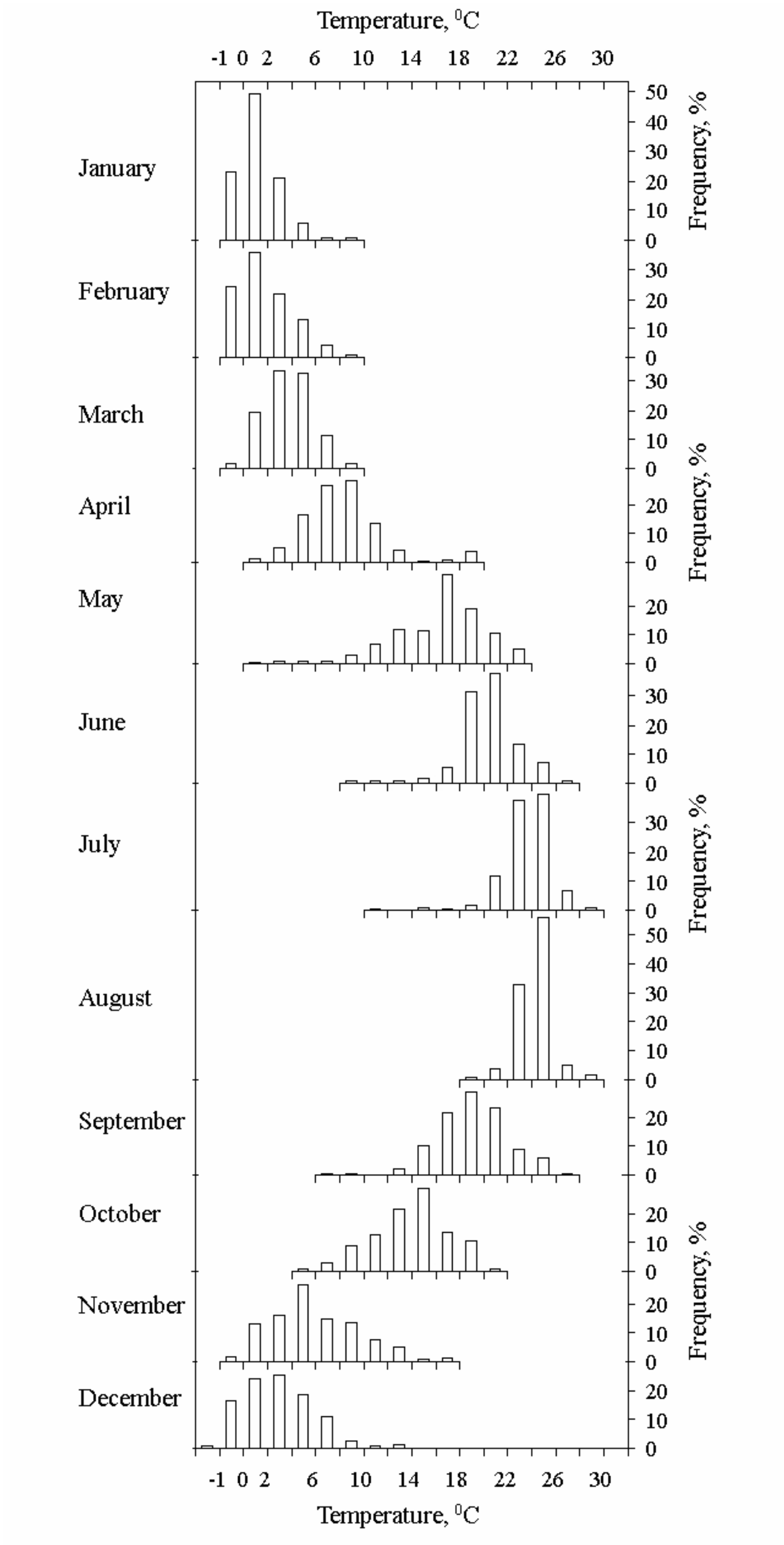

Figure 6. Monthly frequency distributions of the water temperature for the Sea of Azov.

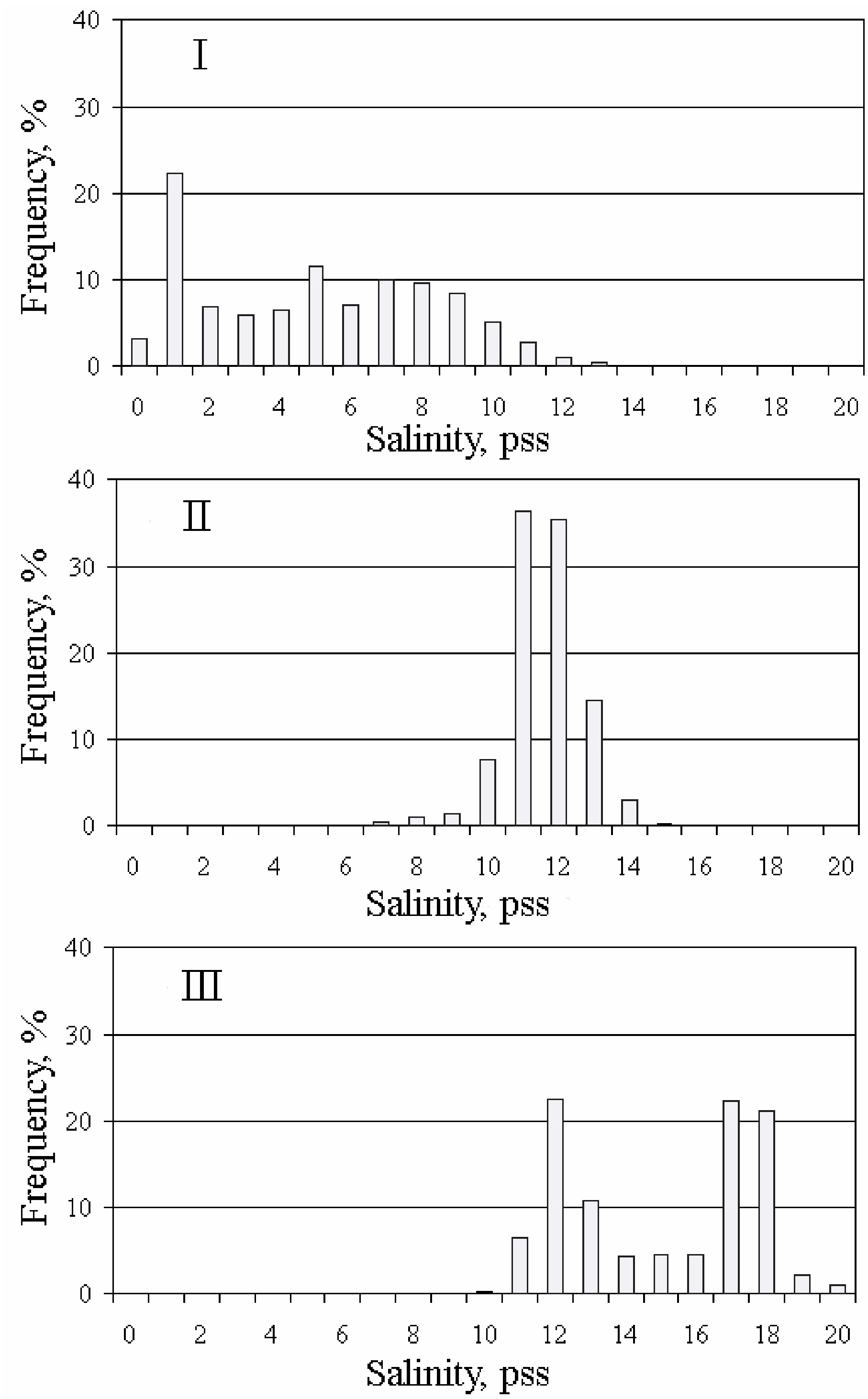

Figure 7. Annual frequency of salinity distribution in three regions of the Sea of Azov.

6. ALGORITHM OF CLIMATIC FIELDS CONSTRUCTION

The procedure for the climatic fields construction (the objective data analysis) utilized in this paper corresponds to the pattern suggested by Barnes, 1973 and the methods of calculation of the data spatial distribution and chart construction (Levitus and Boyer, 1994). It incorporates two stages.

At the first stage, the Sea of Azov was divided into squares of 10 x10 km. For each month and each individual year, the temperature and salinity values were calculated in regular grid points. Data absence was flagged by special code. In the second stage, monthly average temperature and salinity values were calculated in regular grid points for each individual year. As a result, each year was represented by a single temperature and salinity value in regular grid points.

The Appendix C provides climatic charts of temperature and salinity plotted for each individual month for the surface, and standard 5- and 10-meter horizons. They compare well with the climatic charts constructed by experts, based on their experience and intuition (Hydrometeorology and Hydrochemistry, 1991; Matishov *et al*., 2003; Matishov *et al*., 2006). This confirms the choice of methods, used for the objective analysis, and the standardization of the procedure used to construct the climatic charts of the Sea of Azov. It also creates a basis for application of formal procedures for the analysis of the climatic system of the Sea of Azov.

7. ELECTRONIC BOOKS

The Section "Electronic Library" presented on CD-ROM suggests the electronic versions of books on the history of exploration of the Sea of Azov. These references contain the primary data, and describe the sampling. The majority of these publications belong to the category of rare books, almost inaccessible for a wide audience. Although the quality of text in "pdf" format does not always correspond to acceptable standards as a result of an imperfect scanning technique (as a result of digital camera utilization), the authors believe it would be reasonable and expedient to incorporate these books into this section because of their scientific worthiness. The alphabetical list of publications is as follows:

- Antonov, L. 1926. The Notes on Hydrophraphy, vol. 51, L. p. 195-223. (in Russian)
- Endros A. 1932. Die Seiches des Schwarzen und Saowschen Meers, Annalen der Hydrographie und Maritimen Meteorologie, November 1932, s. 442-455 (in German).
- Klossovsky, A. 1890. The Level and Temperature Variations in the Coastal Line of the Black Sea and the Sea of Azov. 70 p. (in Russian)
- Knipovich, N. 1926. The Essay on Works Conducted by the Scientific and Fishery Expedition in the Black Sea and the Sea of Azov in 1925, Moscow. pp. 75-106. (in Russian)
- Knipovich, N. 1932. The Hydrological Studies in the Sea of Azov. Papers of the Scientific and Fishery Expedition of the Black Sea and the Sea of Azov, Issue 5, Moscow. 497 p. (in Russian)
- Shpindler, I. and F. Wrangel. 1899. The Materials on Hydrology of the Black Sea and the Sea of Azov for the Expeditions Performed in 1890-91. 70p. (in Russian)

8. PHOTO GALLERY

As a source of material for this section (Section Photo Gallery on the CD-ROM) we used the photos taken by the staff of the Southern Scientific Center of the Russia Academy of Sciences and MMBI during the expeditionary observations in the Sea of Azov.

In the Subsection "People and Environment" photographs with the images of the Sea of Azov give an idea on the activity of marine ecologists. The Subsection "Phenomenal Winter" presents the photographs taken in winter of 2005-06 during the expedition on board of the ice-breaker "Kapitan Demidov" and depicts some extreme meteorological conditions which may occur in this southern sea during the winter time.

9. CD-ROM CONTENT

The key part of the present paper comprises primary data on the Sea of Azov, the Kerchensky Strait and the adjacent part of the Black Sea. All primary data (14,145 stations sampled between 1913 and 2004) are presented on attached CD-ROM in electronic tables in Excel with extension "csv" archived in a single zipped file. The CD-ROM incorporates the following sections:

DATABASE (data files).
DOC (text files of the Section Documentation).
HTML (HTML files).

An access to all information is performed through HTML menu presenting the following main sections:

- **Documentation –** The section contains the text of the Atlas with Appendices in Russian and English in .pdf format.
- **Bathymetry –** The section presents historical (1932) and bathymetric charts of the Sea of Azov constructed in 2006.
- **Database –** The section contains 296 data files in "csv" format. All files are compressed in one "zip" file.
- **Climatology –** The section provides monthly climatic fields of temperature and salinity presented as charts for surface and standard 5- and 10-meter horizons.
- **Electronic Library –** The section contains complete copies of books and papers on studies of the Sea of Azov.
- **Photo Gallery –** The section presents photographs taken during field investigations in the Sea of Azov performed by the staff of the Southern Scientific Center of the Russian Academy of Sciences.
- **Authors –** The section lists the authors and bibliographic references.

10. DISCUSSION AND FUTURE STUDY

The present Atlas incorporates the data from more than 14 thousand stations sampled between 1913 and 2004. The data are distributed unevenly over time. The major data mass is given for the 30-s, 50-s, the late-20th and the early 21st century.

The climatic fields of temperature and salinity were constructed based on these data and using the method of the objective analysis. These fields comply well with the existing views on thermohaline variability of the Sea of Azov.

In the future we are planning to add to the database with hydrological and hydrochemical data for time periods not included in this Atlas. In addition to offshore stations, the inshore stations will be added, at which temperature and salinity measurements were taken daily on different horizons during a long time period.

Moreover, the methods of the objective analysis and the data quality control will be improved through taking into account the bottom contour and including the information on thermohaline conditions in various regions of the Sea of Azov.

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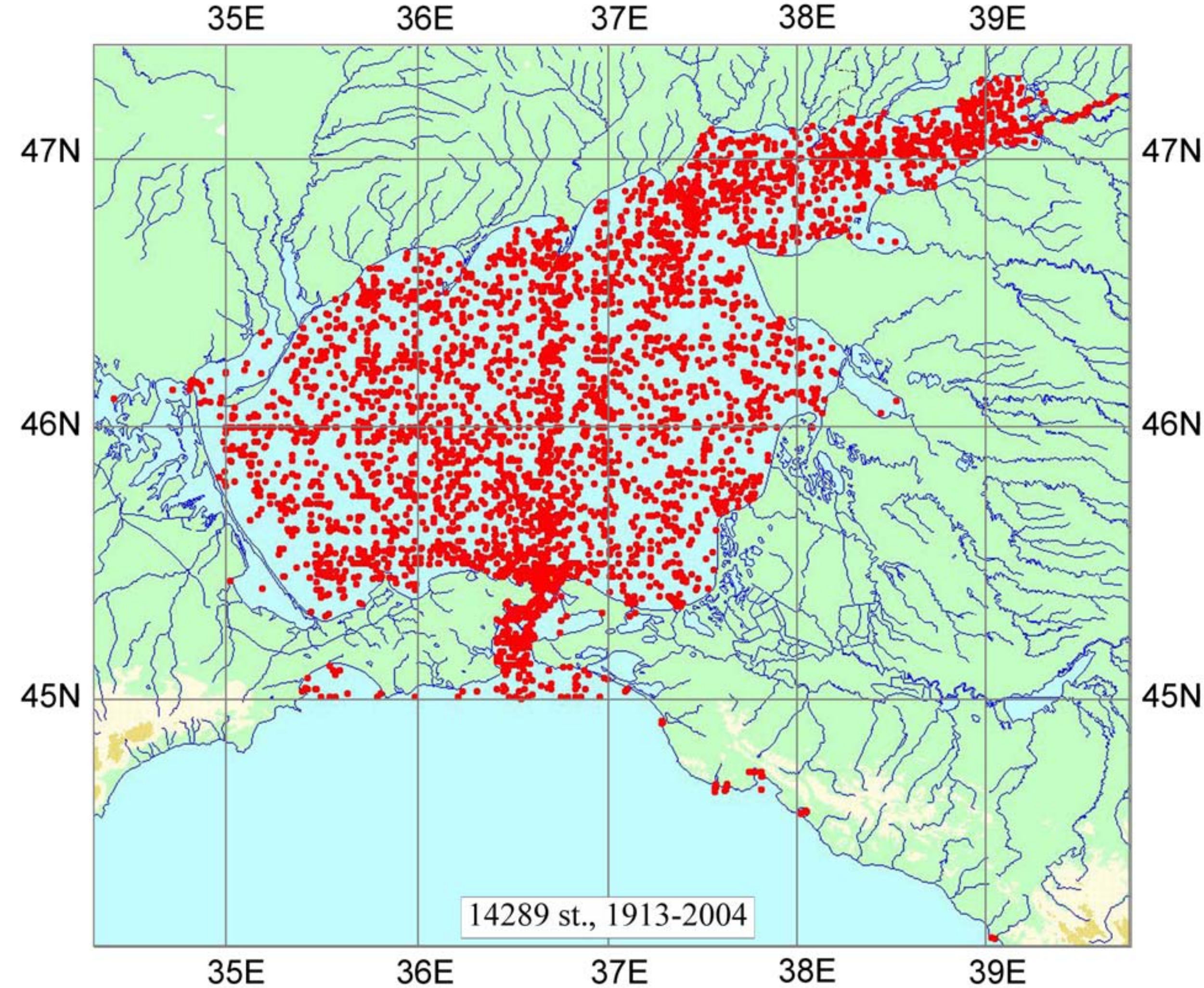
APPENDIX A. Inventory

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1913	-	-	-	-	-	4	5	5	5	4	5	5	33
1914	10	-	5	-	-	-	-	-	-	-	-	-	15
1922	-	-	-	-	-	-	-	-	14	7	10	-	31
1923	-	-	-	-	-	-	20	11	23	-	10	16	80
1924	-	-	11	4	34	21	21	21	27	33	-	10	182
1925	-	-	3	-	2	60	17	47	4	10	-	-	143
1926	-	7	-	25	14	29	5	26	7	13	1	-	127
1928	-	-	-	-	-	-	-	-	-	32	-	-	32
1929	-	-	-	-	-	-	-	-	-	33	-	-	33
1931	-	-	-	-	-	-	1	-	-	-	-	-	1
1946	-	-	-	-	-	-	-	-	46	-	-	-	46
1947	-	-	-	52	-	-	60	-	50	42	10	-	214
1948	-	-	-	36	91	46	-	-	-	7	8	-	188
1949	-	-	-	93	23	51	42	133	15	6	7	18	388
1950	-	-	-	-	6	13	34	9	-	-	-	-	62
1951	-	-	-	-	-	-	-	23	-	62	-	-	85
1952	-	-	-	80	-	64	54	14	16	25	-	-	253
1953	-	-	7	26	-	-	24	-	-	5	14	-	76
1954	-	-	-	12	87	72	75	-	-	64	5	-	315
1955	13	42	-	69	-	-	64	-	-	61	6	-	255
1956	-	-	-	51	-	-	54	40	-	53	-	-	198
1957	-	-	-	31	43	31	68	5	36	54	-	-	268
1958	735	645	722	757	720	709	769	742	666	671	727	673	8536
1962	-	-	-	-	1	-	-	-	-	-	-	-	1
1965	-	-	-	-	1	-	-	-	-	3	-	-	4
1970	-	-	-	-	11	-	-	-	-	-	-	-	11
1981	-	-	-	-	-	-	10	11	-	-	-	-	21
1983	-	1	-	-	-	-	-	-	-	-	-	-	1
1984	-	-	-	-	3	-	-	-	-	-	-	-	3
1986	-	-	-	-	-	7	-	18	2	-	1	-	28
1988	-	-	2	-	10	13	2	3	9	3	2	2	46
1991	-	-	-	-	-	-	1	2	3	1	4	-	11
1992	-	-	4	-	3	2	14	100	7	70	10	7	217
1993	1	2	-	35	3	54	37	38	34	42	-	1	247
1994	7	8	8	46	4	50	30	57	9	-	-	9	228
1995	16	12	12	36	-	31	36	99	-	23	5	-	270
1996	-	-	-	-	-	-	48	52	47	28	9	14	198
1997	-	-	13	8	-	-	38	67	36	-	2	-	164
1998	-	-	-	-	-	109	16	50	10	16	5	10	216
1999	12	15	8	-	1	57	-	25	-	-	-	-	118
2000	-	-	-	-	-	96	-	46	-	-	-	-	142
2001	-	-	-	-	-	25	44	28	-	-	-	-	97
2002	-	-	-	-	-	50	-	-	-	-	-	-	50
2003	-	21	1	8	11	59	22	48	16	6	-	2	194
2004	7	8	11	1	43	272	29	10	26	18	21	15	461
Total	801	761	807	1370	1111	1925	1640	1730	1108	1392	862	782	**14,289**

APPENDIX B. Annual data distribution plots 1913-2004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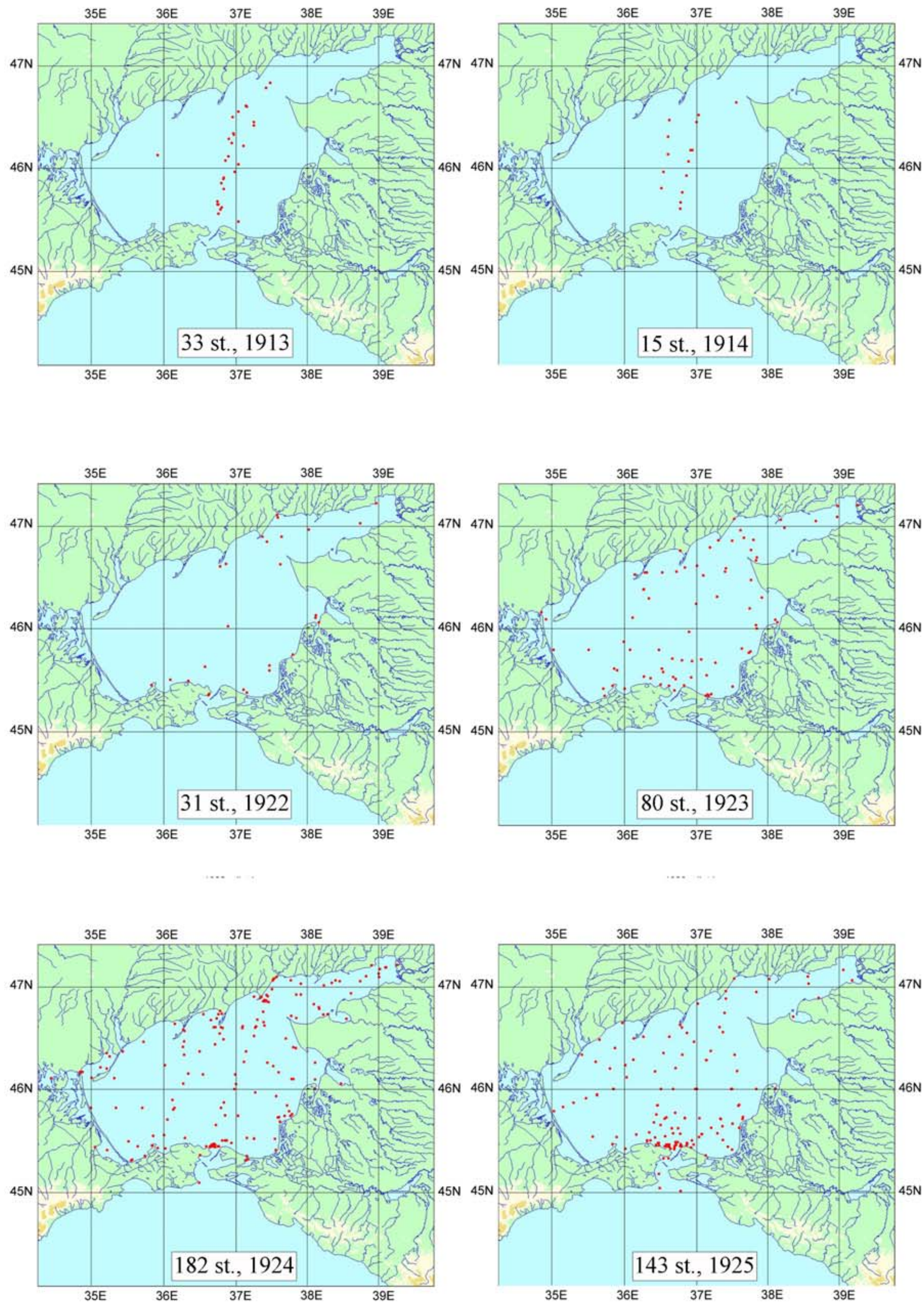
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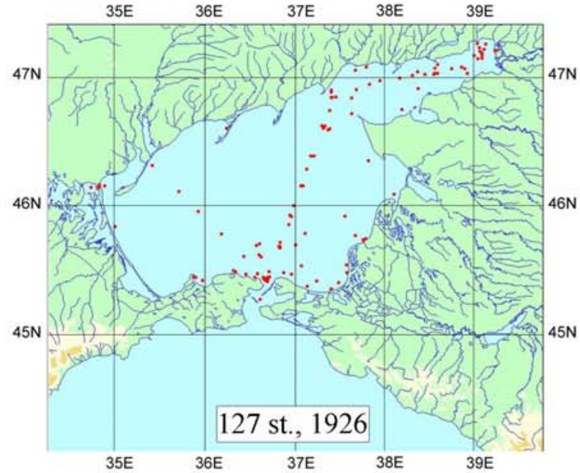
15 st., 1914
31 st., 1922
80 st., 1923
182 st., 1924
143 st., 1925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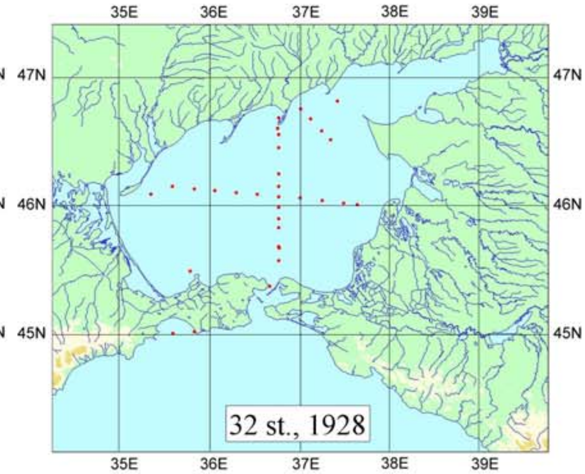
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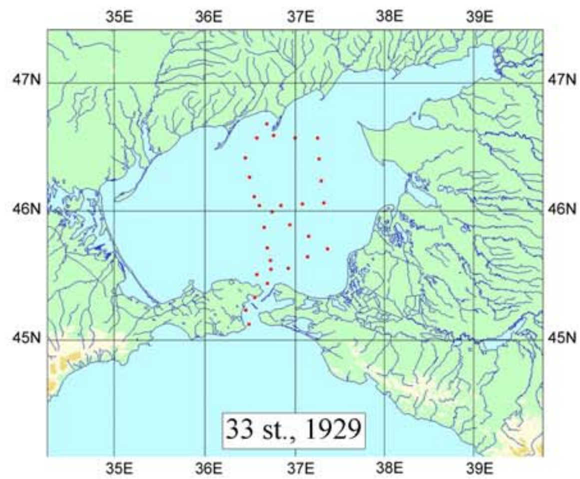
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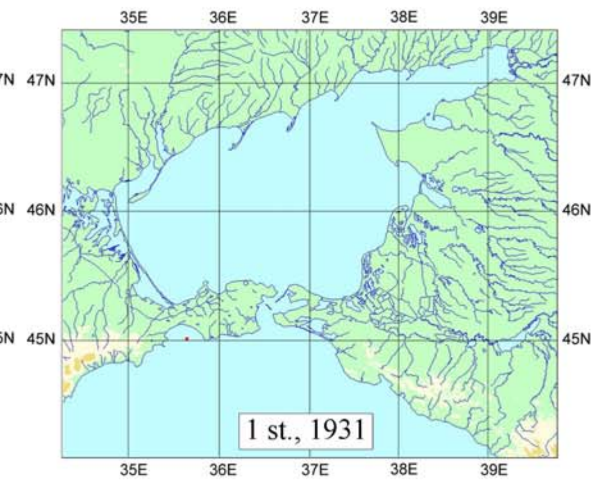
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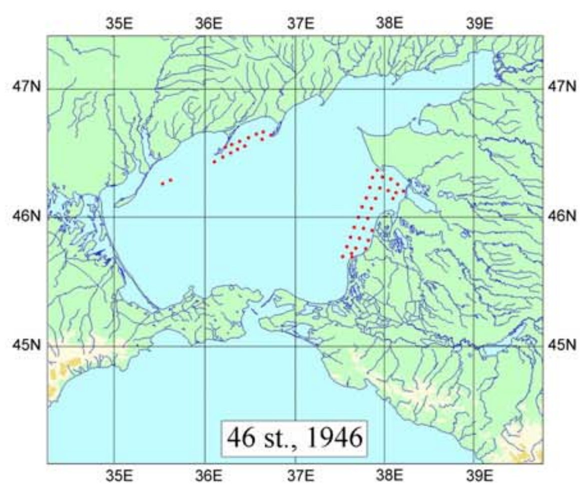
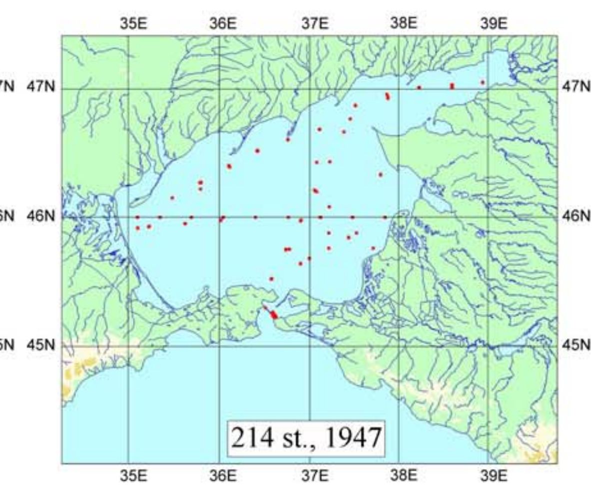

46 st., 1946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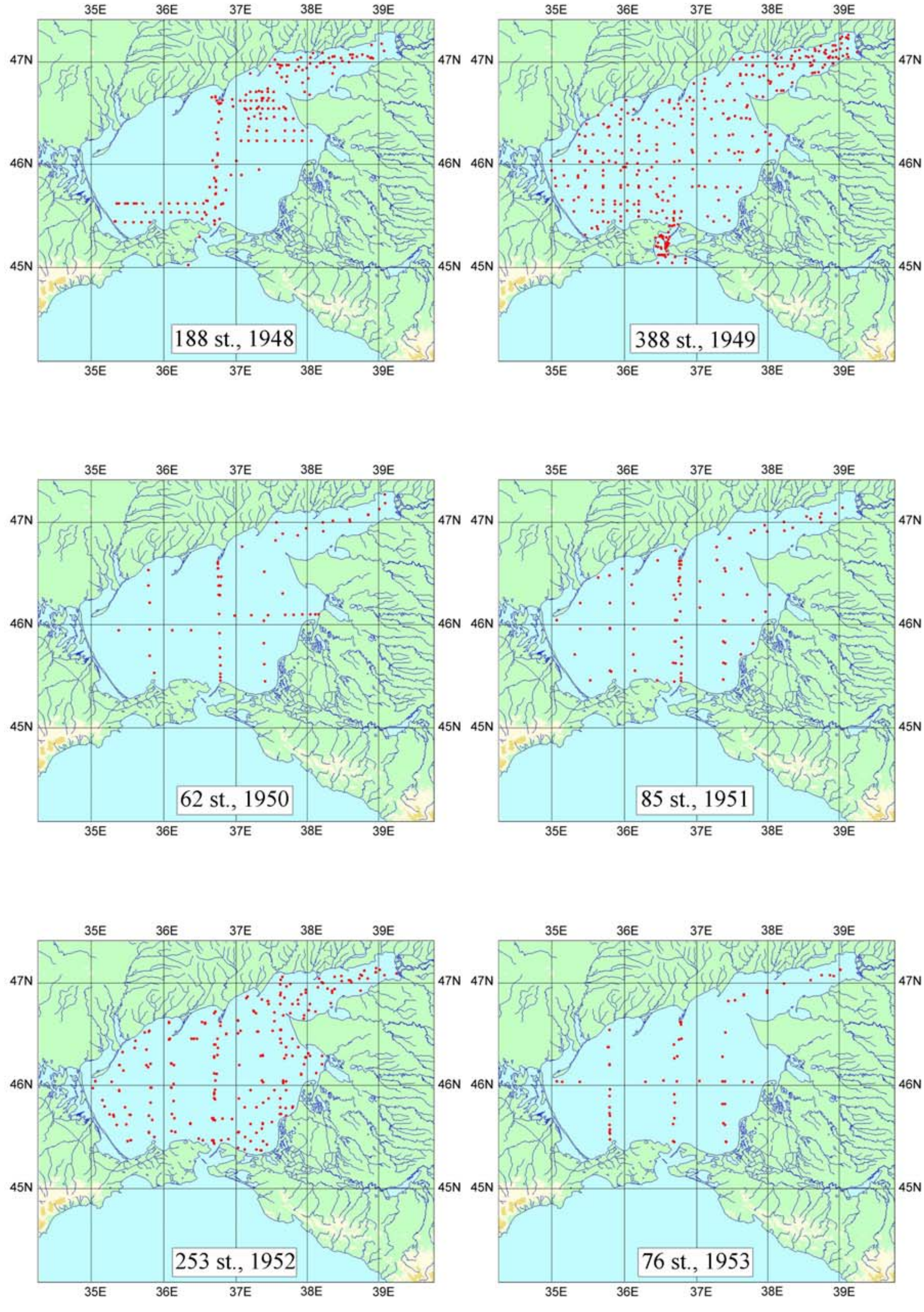
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47N 46N 45N
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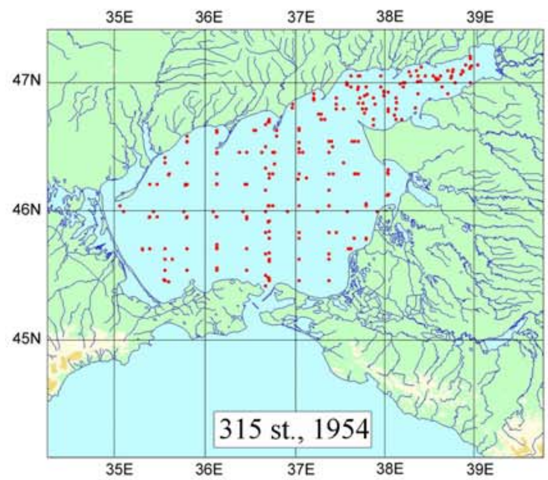
62 st., 1950
85 st., 1951
253 st., 1952
76 st., 1953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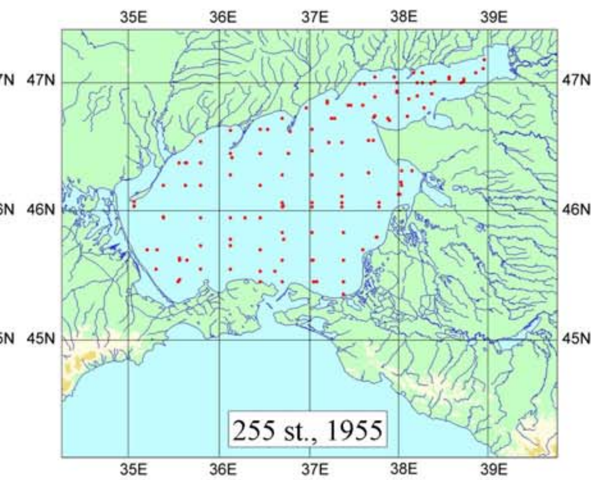
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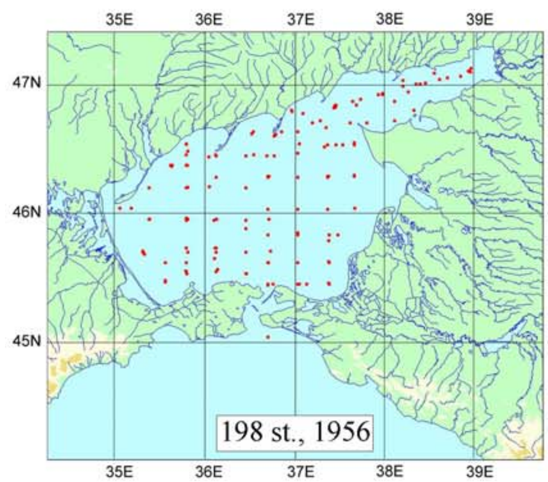
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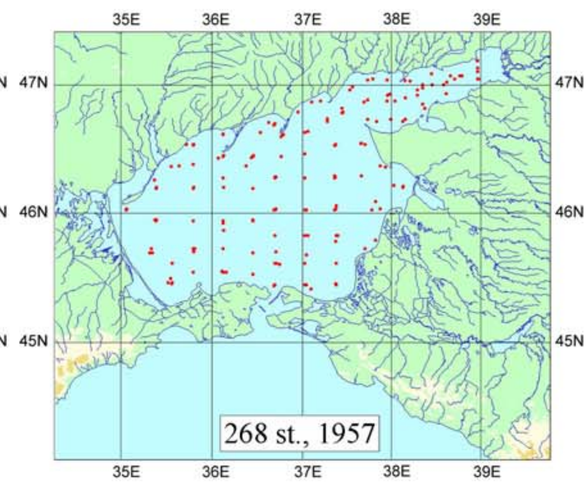
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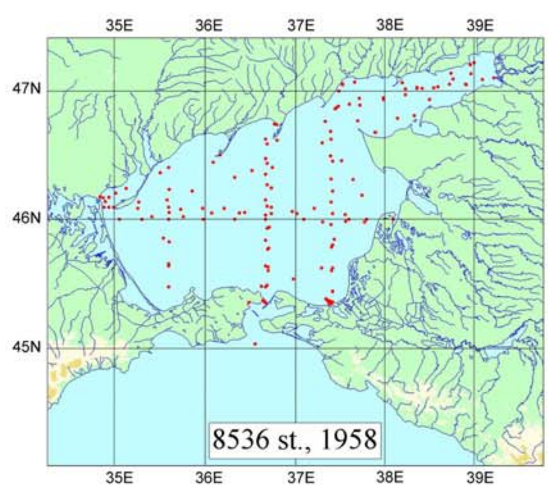
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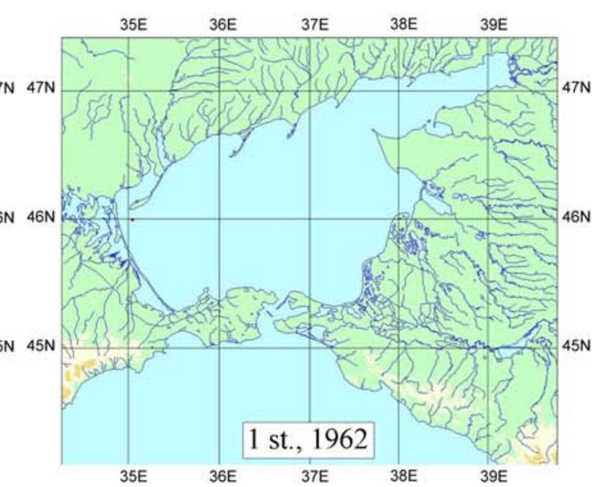
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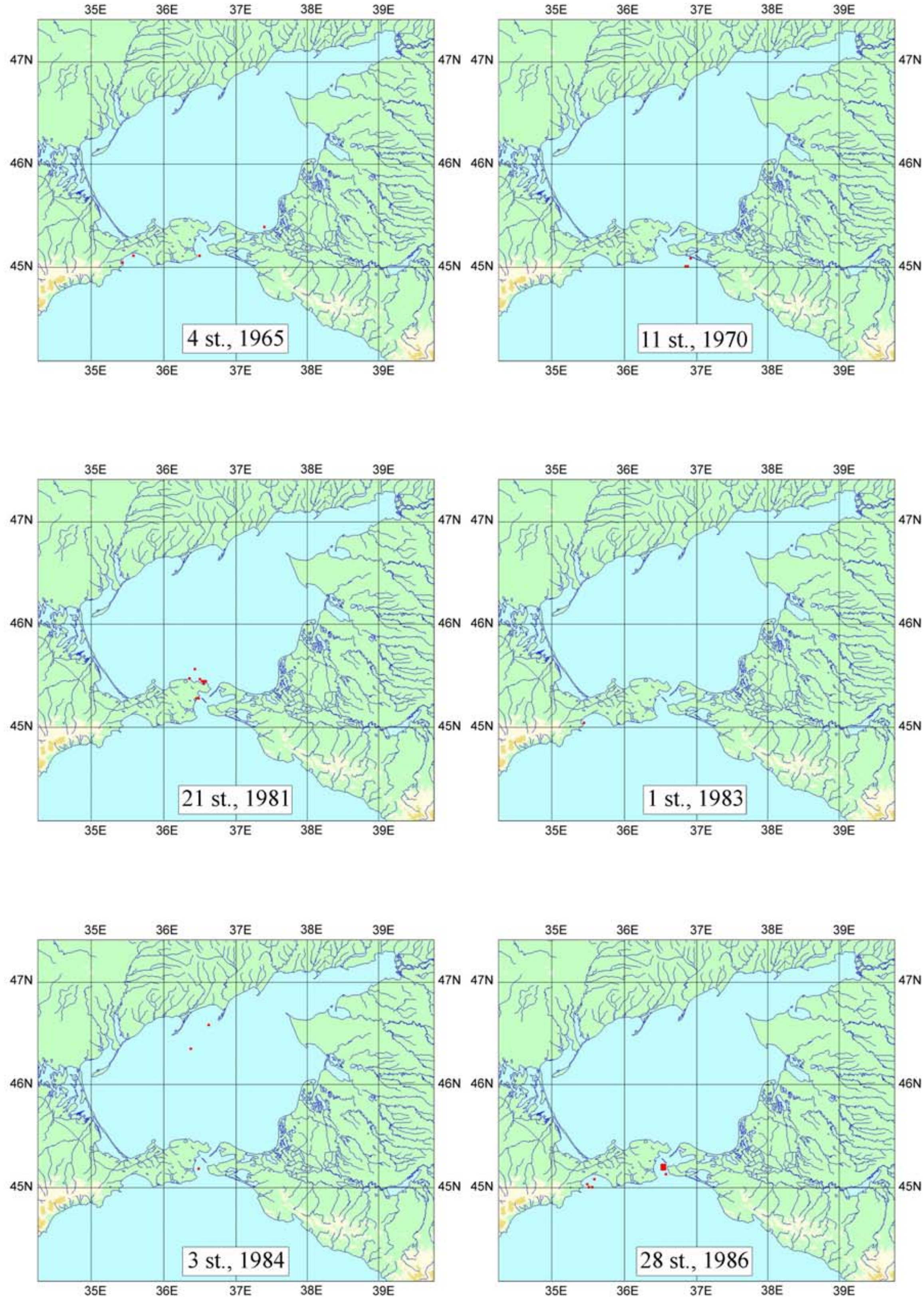
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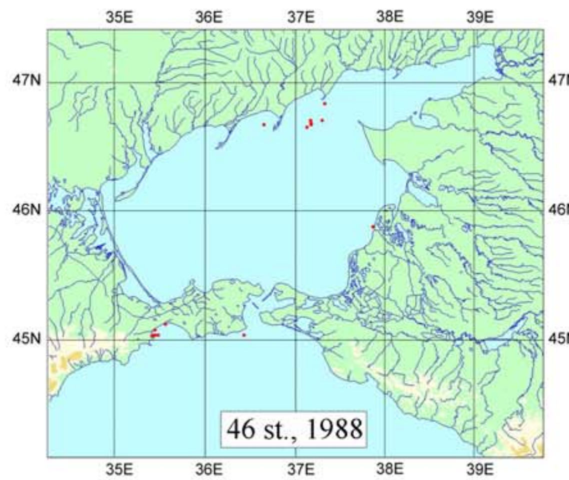
28 st., 1986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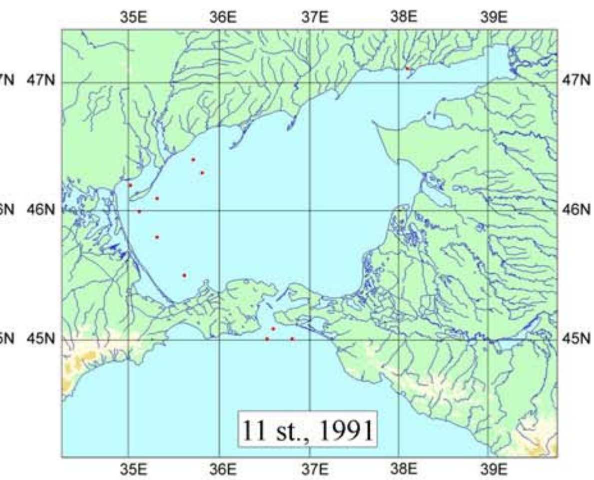
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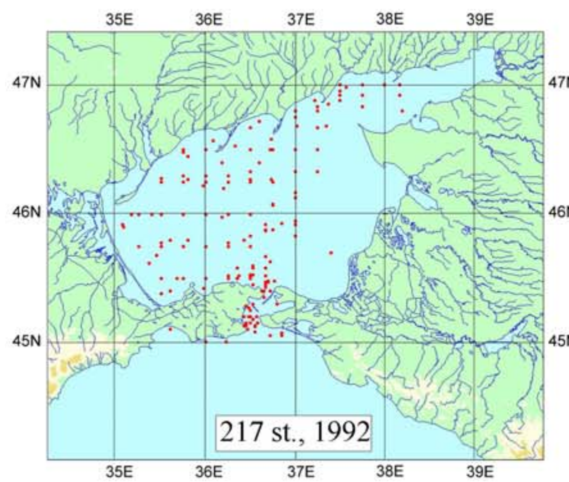
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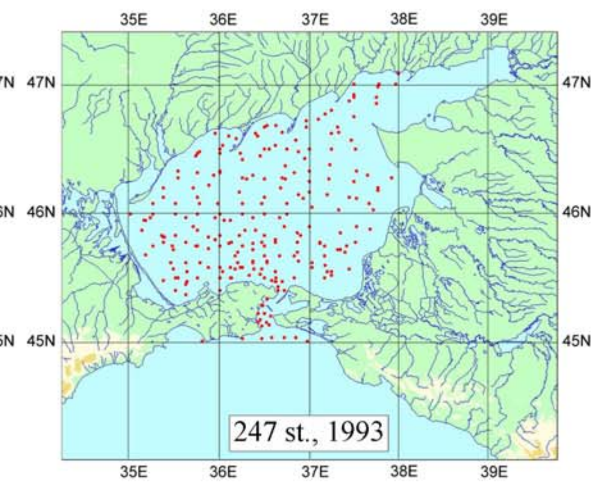
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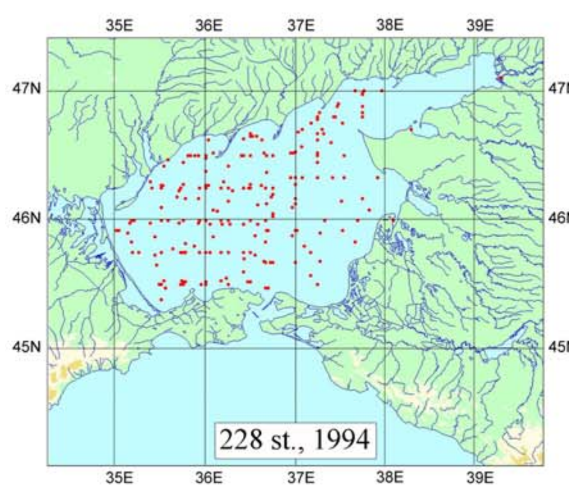
47N 46N 45N
247 st., 1993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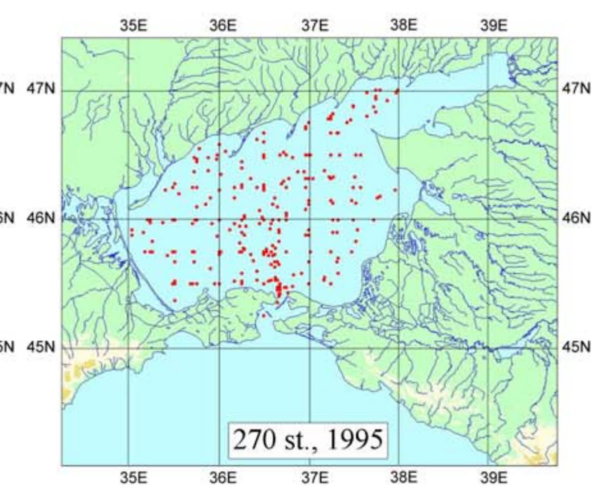
228 st., 1994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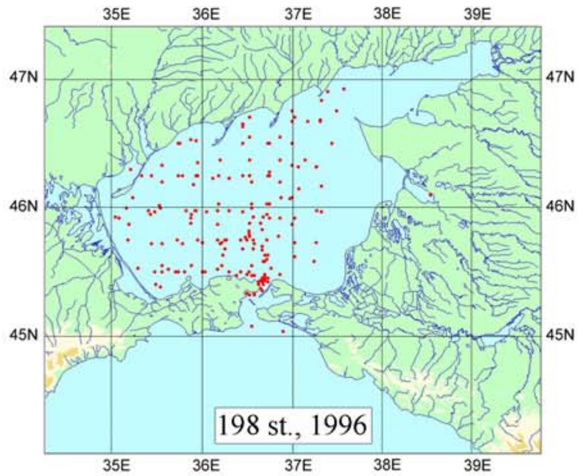
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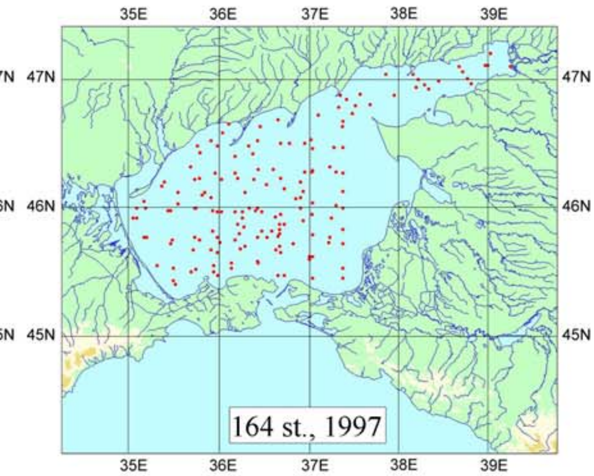
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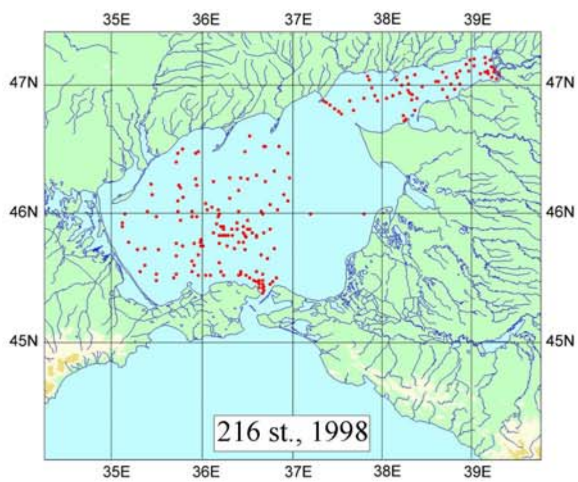
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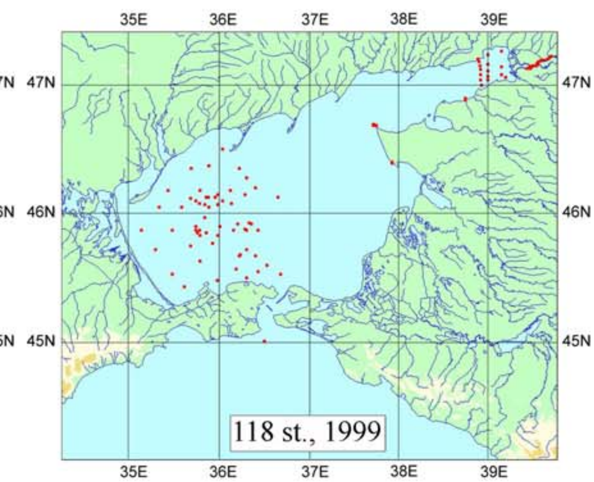
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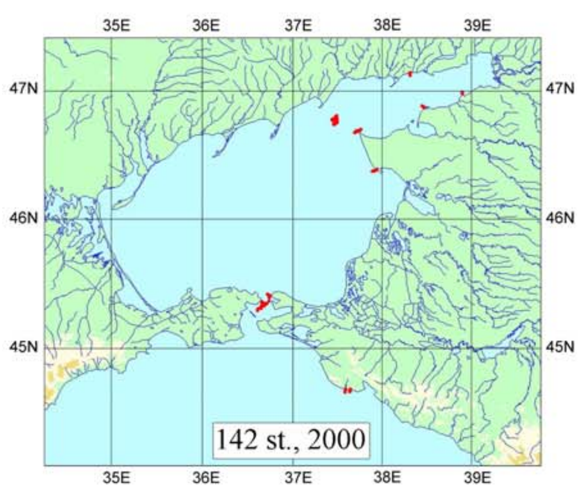
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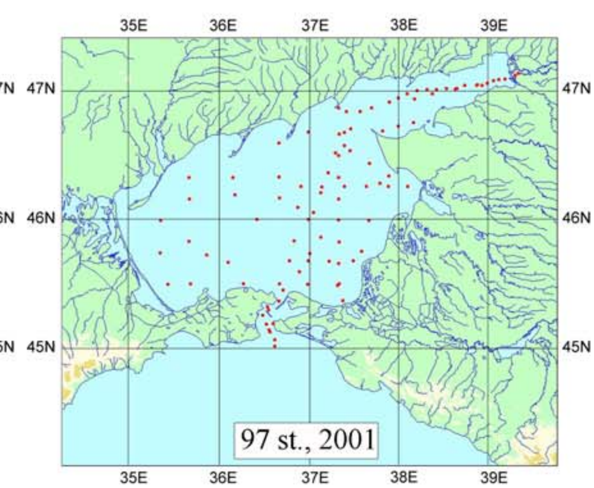
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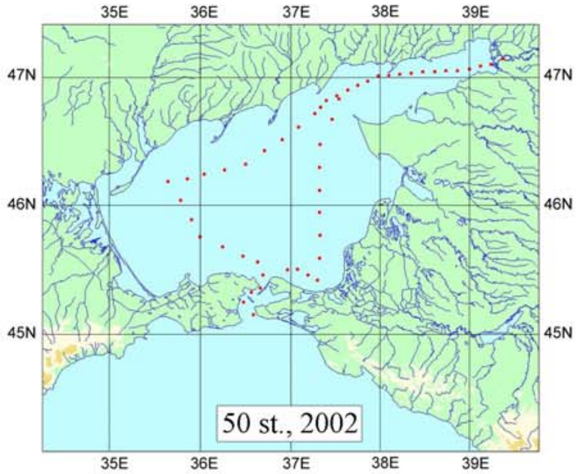
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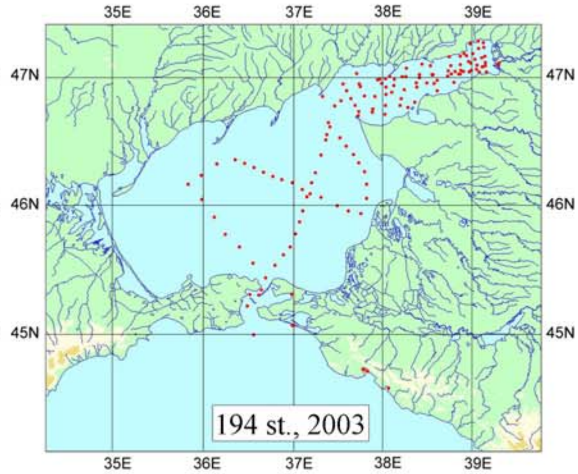
50 st., 2002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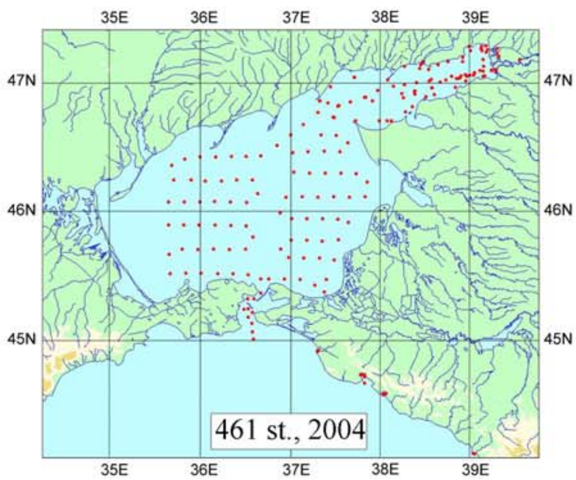
194 st., 2003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39E
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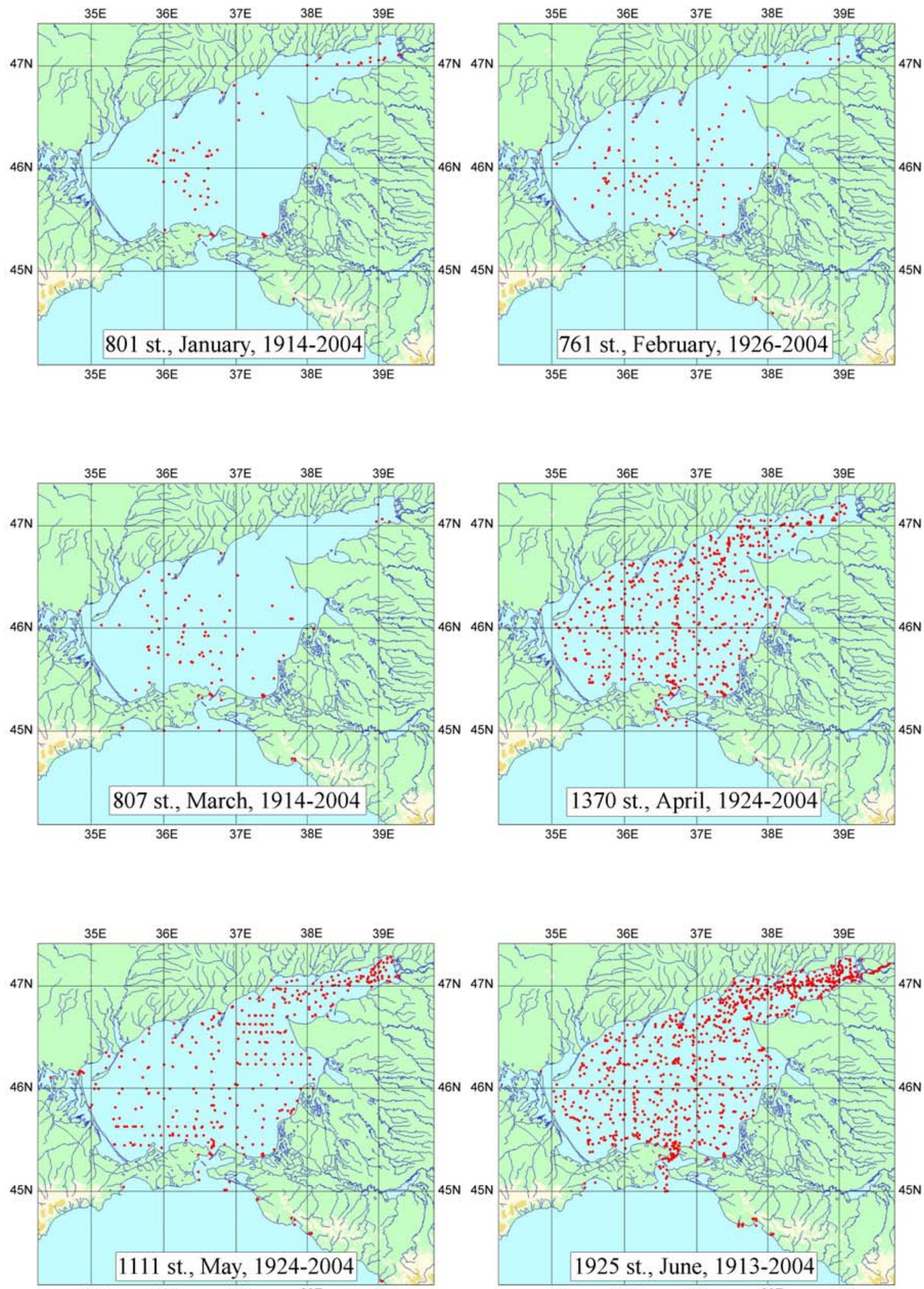
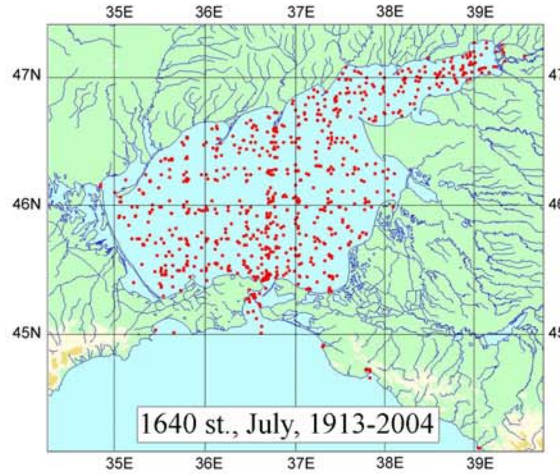
46N
45N
461 st., 2004


801 st., January, 1914-2004
761 st., February, 1926-2004
807 st., March, 1914-2004
1370 st., April, 1924-2004
1111 st., May, 1924-2004
1925 st., June, 1913-2004
35E
36E
37E
38E
39E
47N
46N
45N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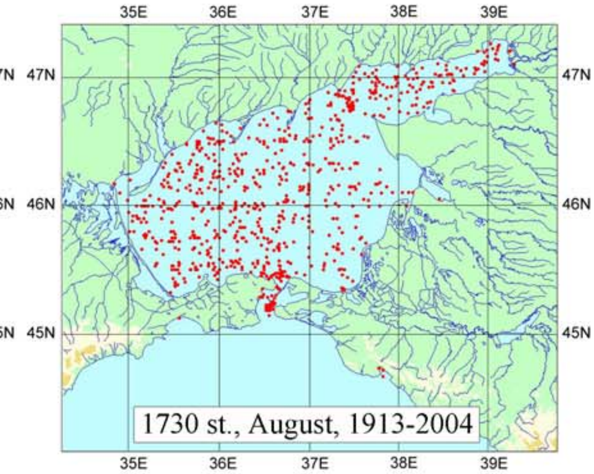
38E
39E
47N
46N
45N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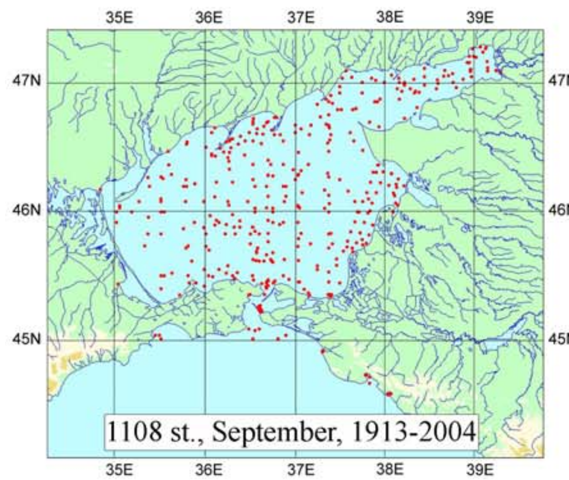
45N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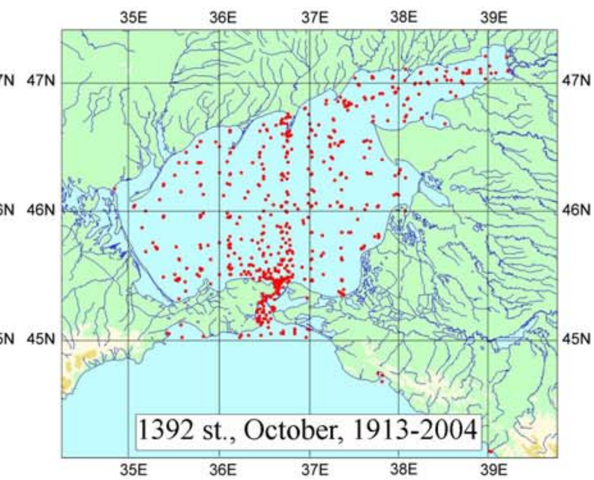
46N
45N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39E
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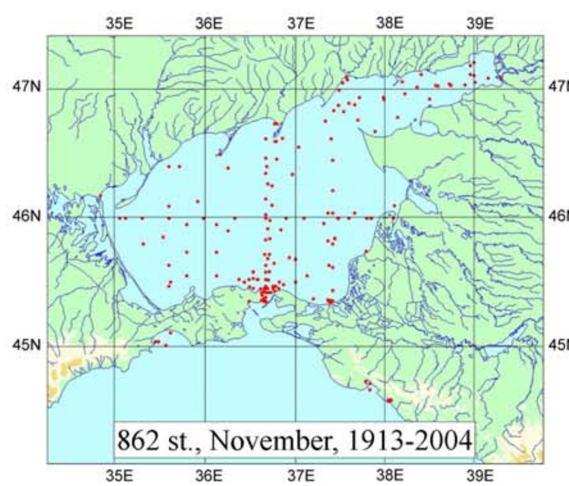
46N
45N


862 st., November, 1913-2004
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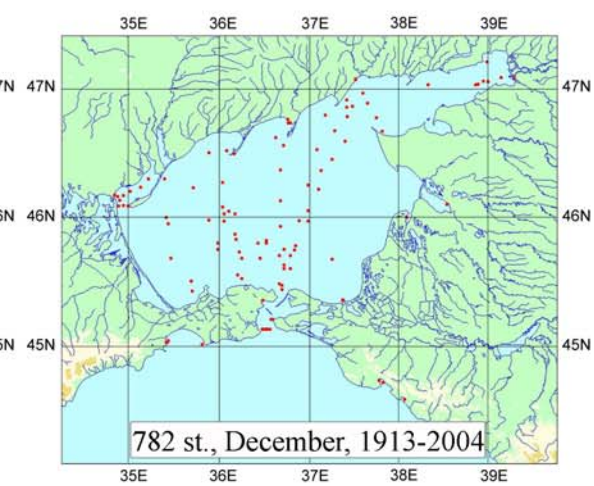
36E
37E
38E
39E
47N
46N
45N


782 st., December, 1913-2004
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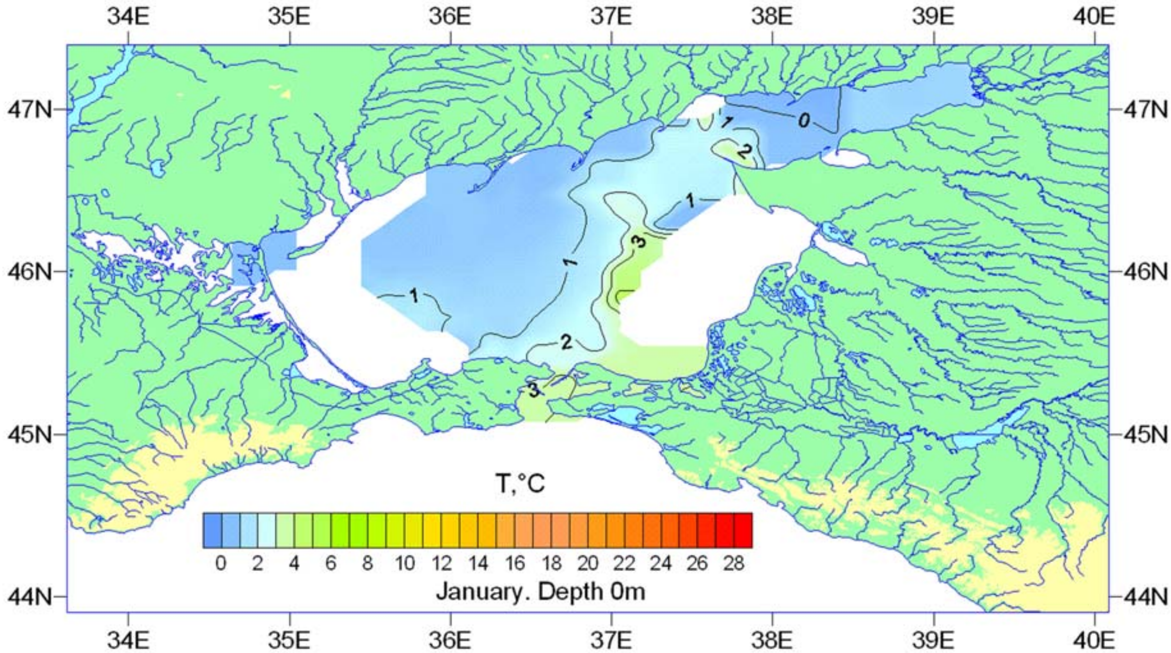
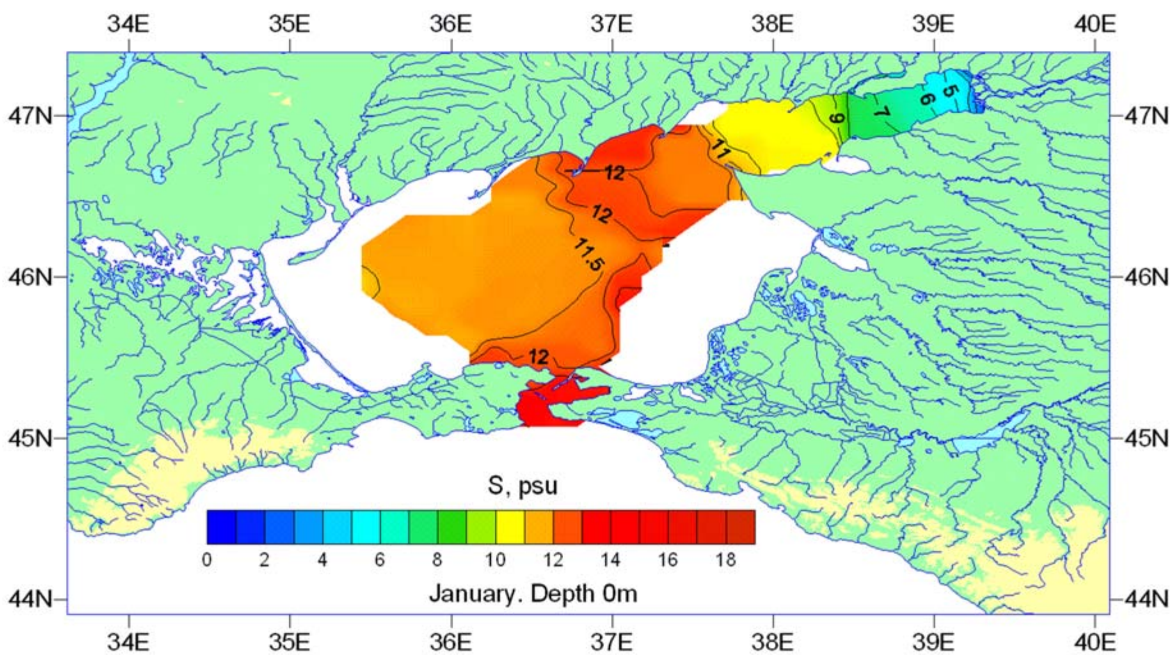
36E
37E
38E
39E
47N
46N
45N

APPENDIX C. Monthly climatic charts of temperature and salinity


T,°C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
January. Depth 0m
34E 35E 36E 37E 38E 39E 40E
47N 46N 45N 44N


S, psu
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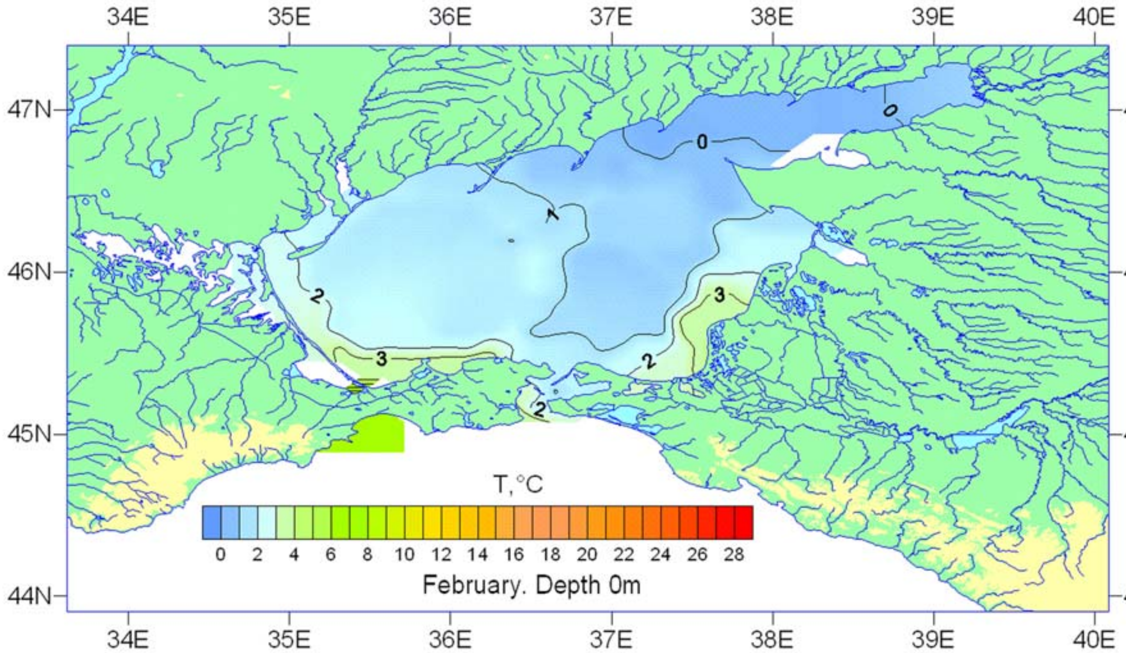
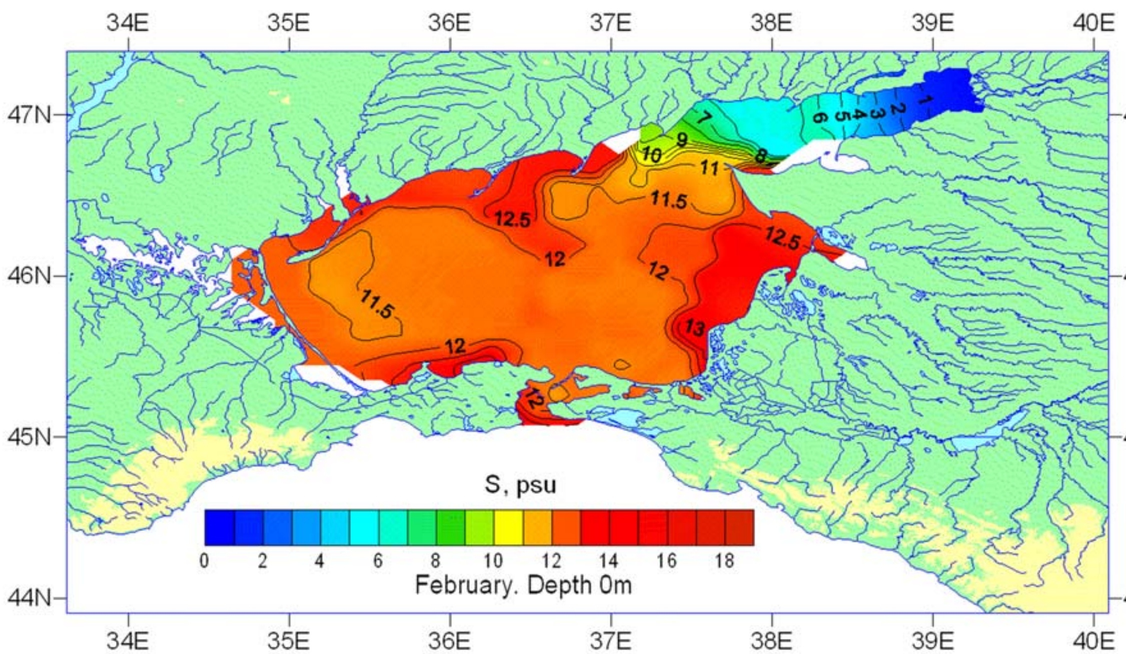
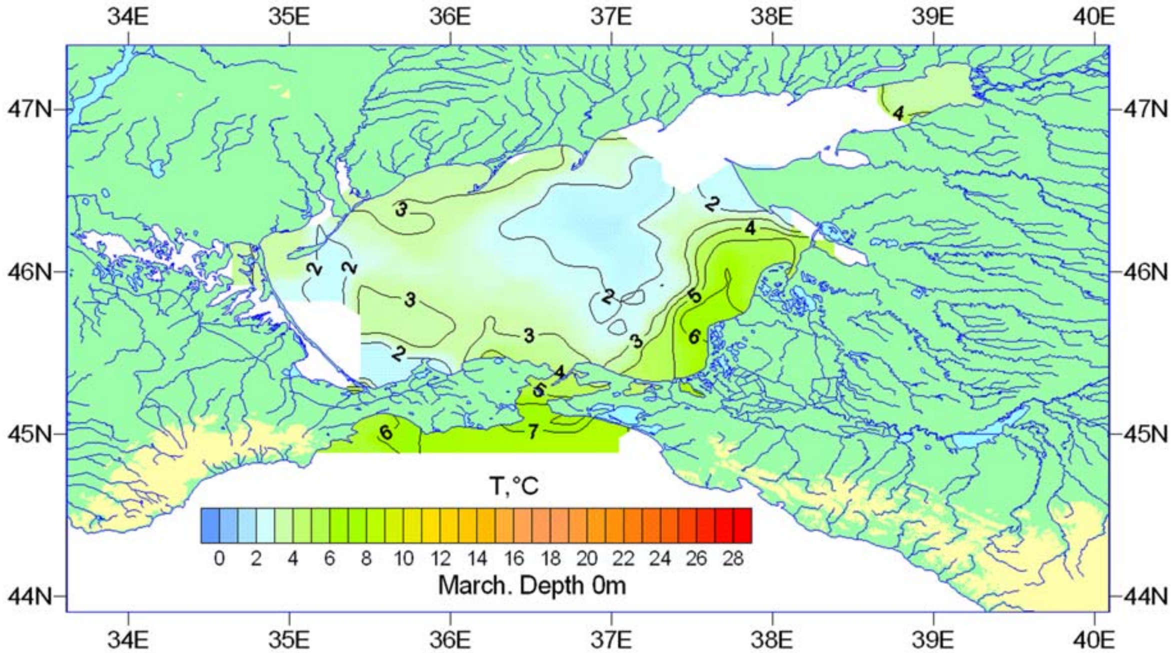
January. Depth 0m
34E 35E 36E 37E 38E 39E 40E
47N 46N 45N 44N


34E
35E
36E
37E
38E
39E
40E
47N
46N
45N
44N
T,°C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
February. Depth 0m


34E
35E
36E
37E
38E
39E
40E
47N
46N
45N
44N
S, psu
0 2 4 6 8 10 12 14 16 18
February. Depth 0m


34E
35E
36E
37E
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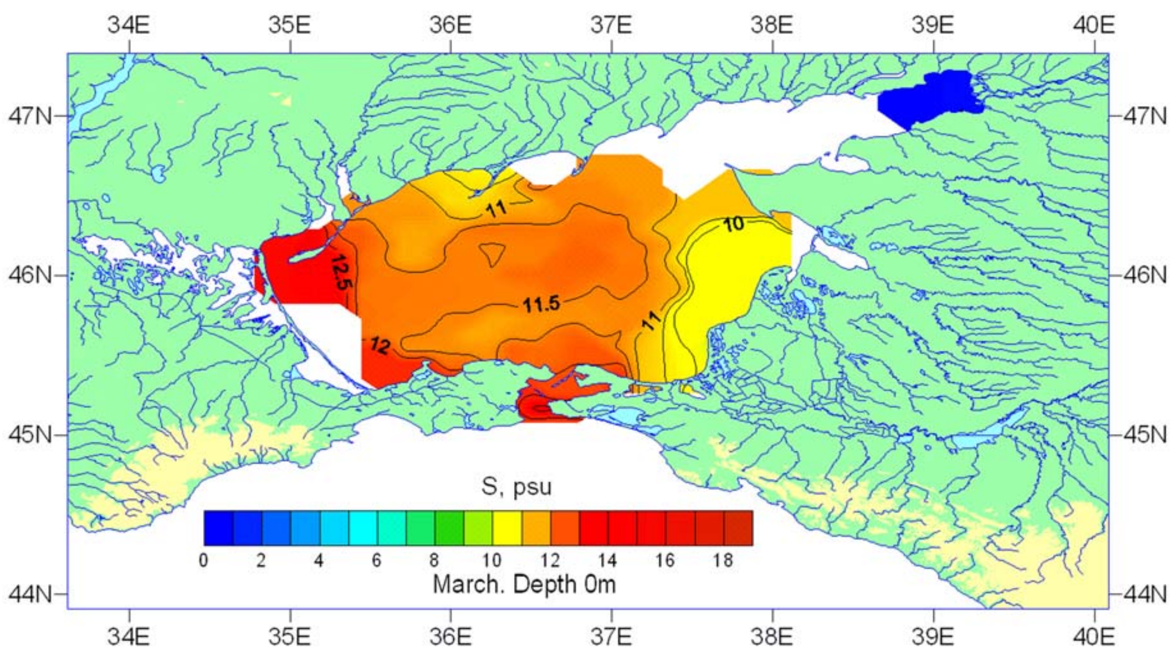
39E
40E
47N
46N
45N
44N
T,°C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
March. Depth 0m


34E
35E
36E
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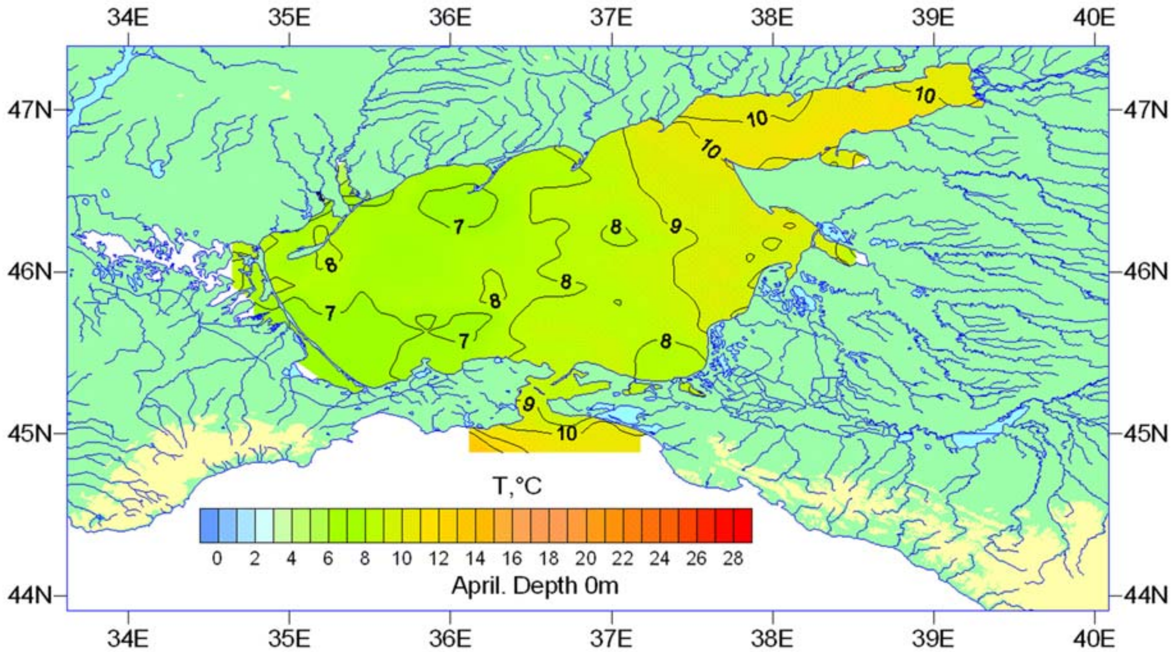
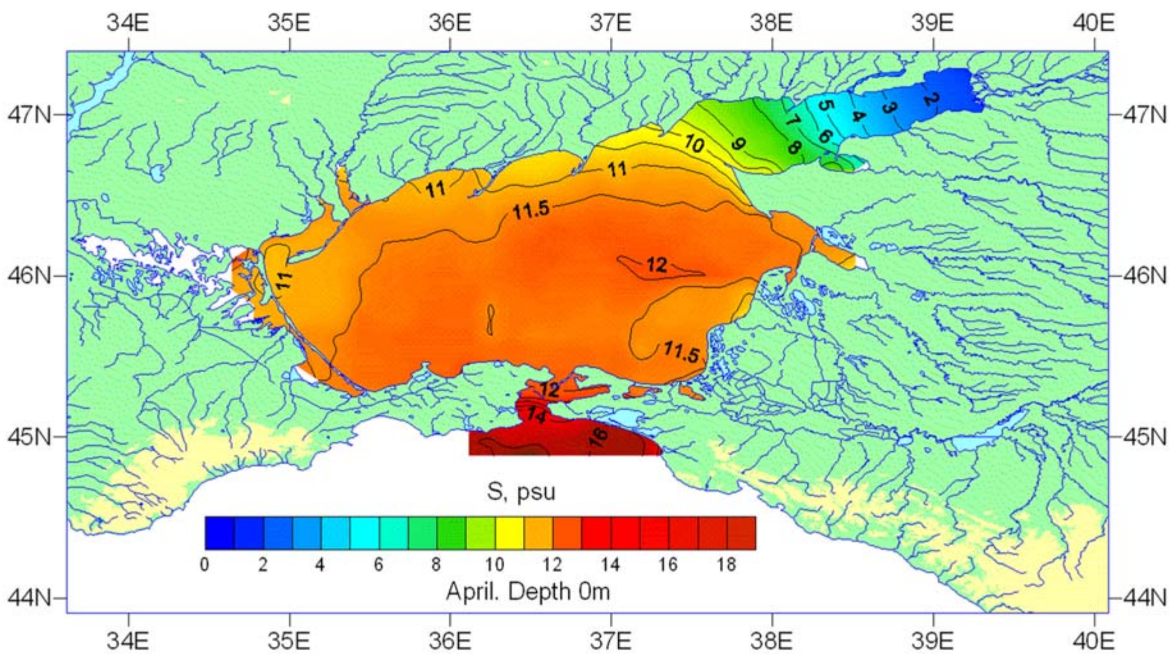
38E
39E
40E
47N
46N
45N
44N
S, psu
0 2 4 6 8 10 12 14 16 18
March. Depth 0m


34E
35E
36E
37E
38E
39E
40E
47N
46N
45N
44N
T,°C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
April. Depth 0m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35E
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39E
40E
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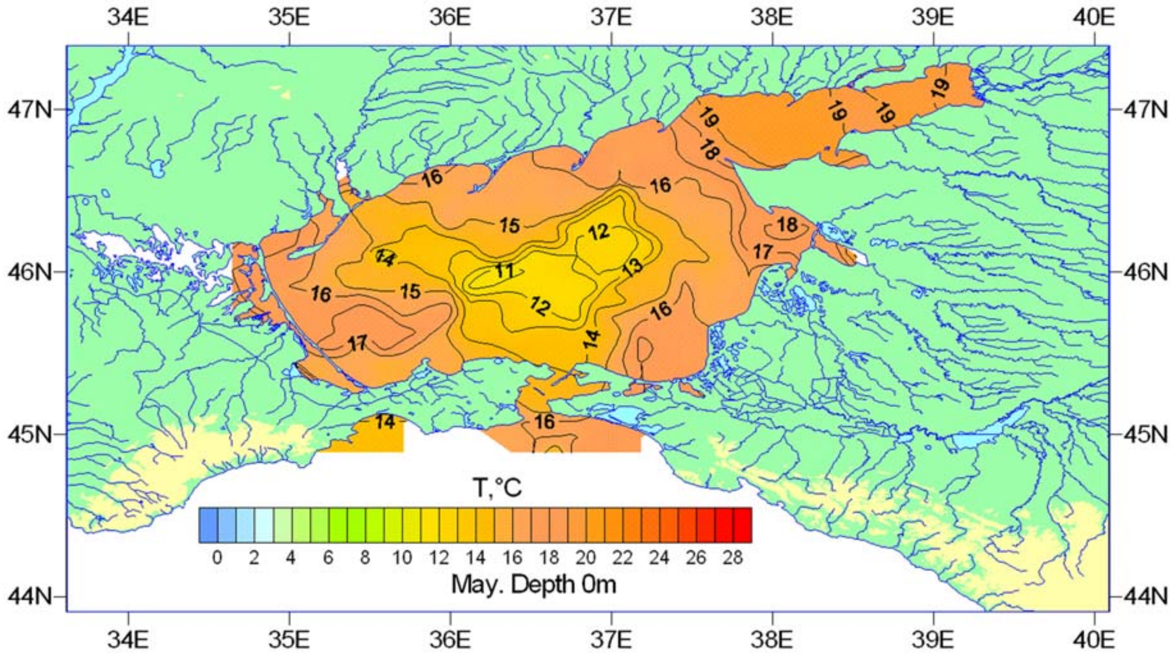
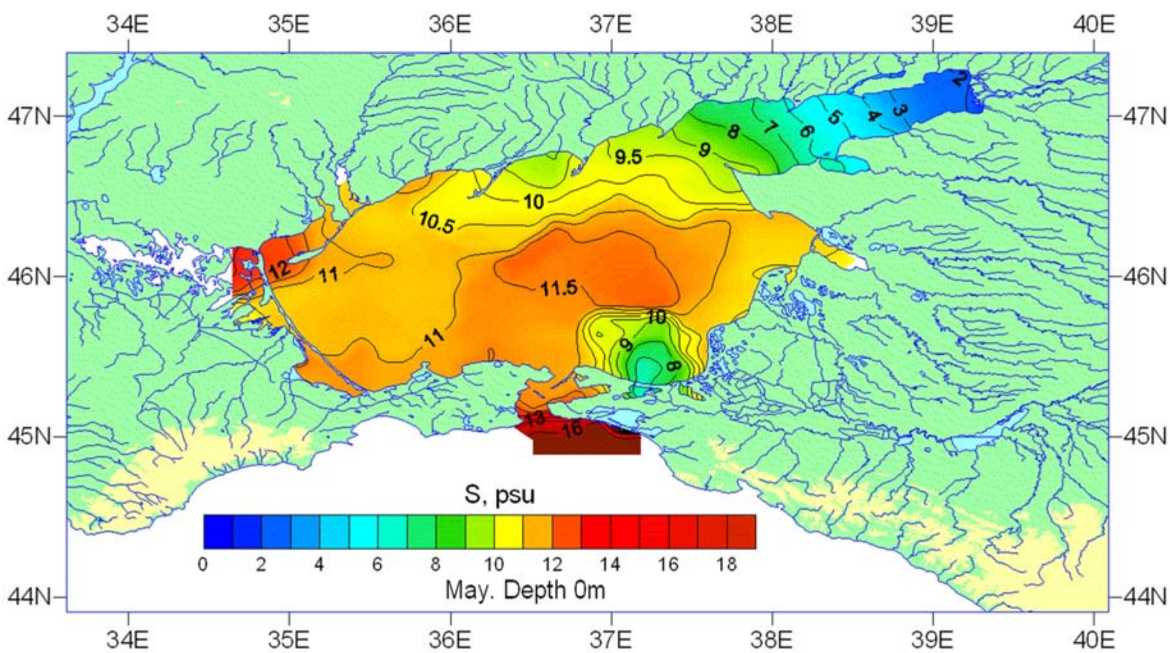
46N
45N
44N
S, psu
0 2 4 6 8 10 12 14 16 18
April. Depth 0m


T,°C
May. Depth 0m


S, psu
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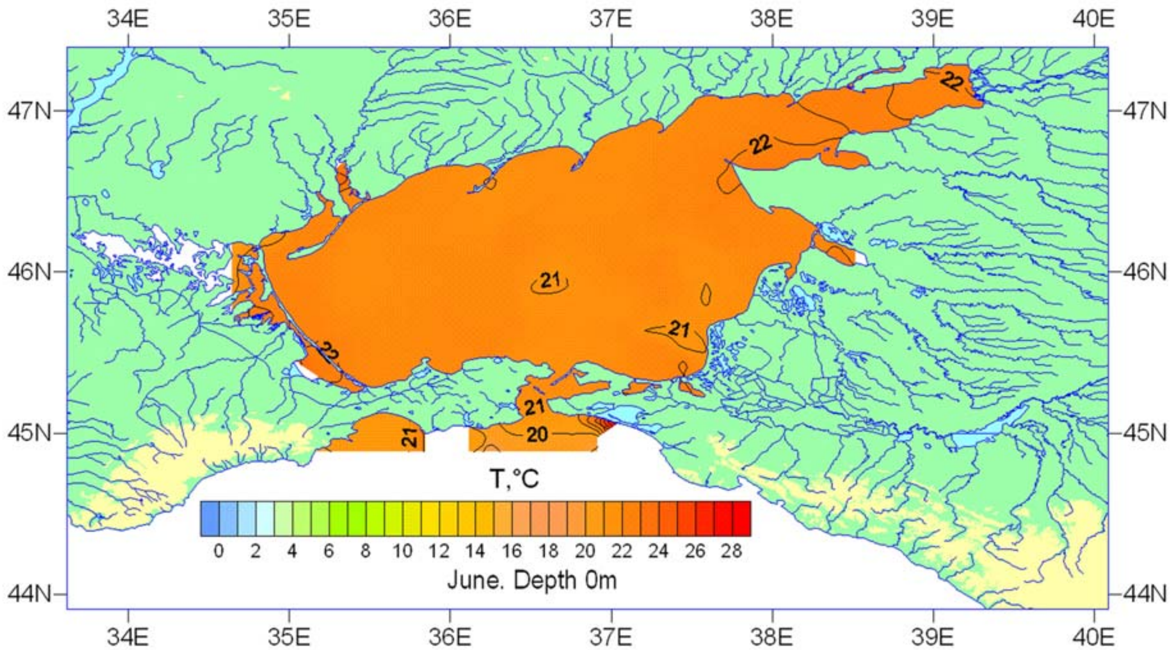

T,°C
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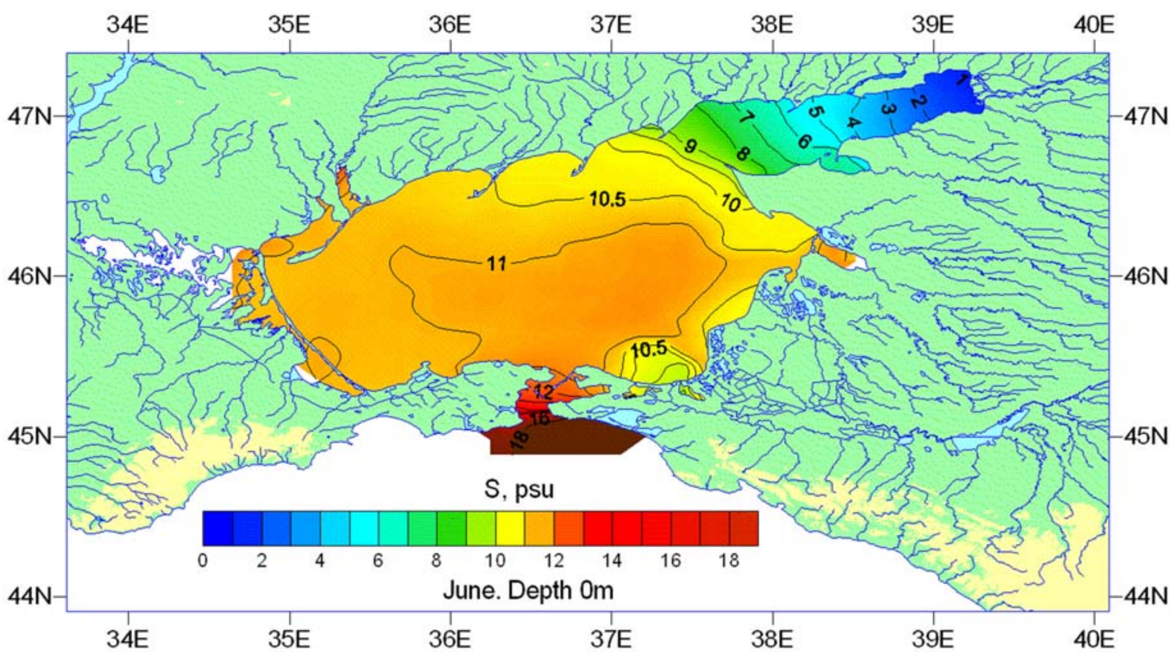
June. Depth 0m
34E 35E 36E 37E 38E 39E 40E
47N 46N 45N 44N
22
21
20



S, psu
0 2 4 6 8 10 12 14 16 18
June. Depth 0m
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47N 46N 45N 44N
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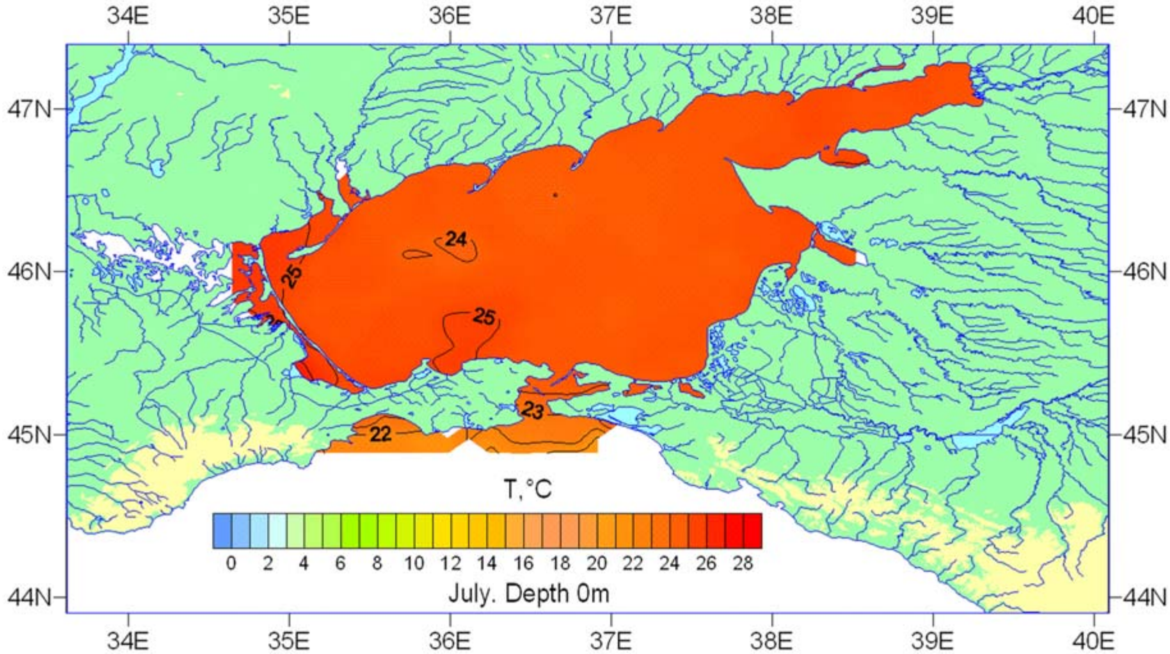
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35E
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39E
40E
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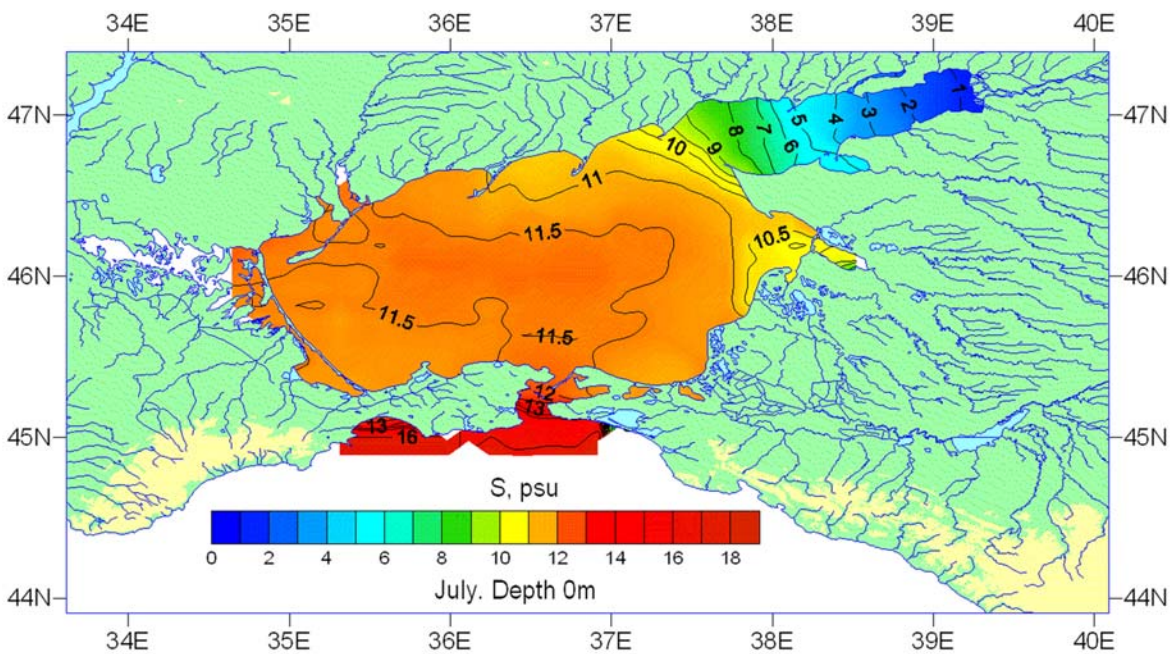
45N
44N
24
25
25
22
23
T,°C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
July. Depth 0m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44N
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8
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11.5
10.5
12
13
13
16
S, psu
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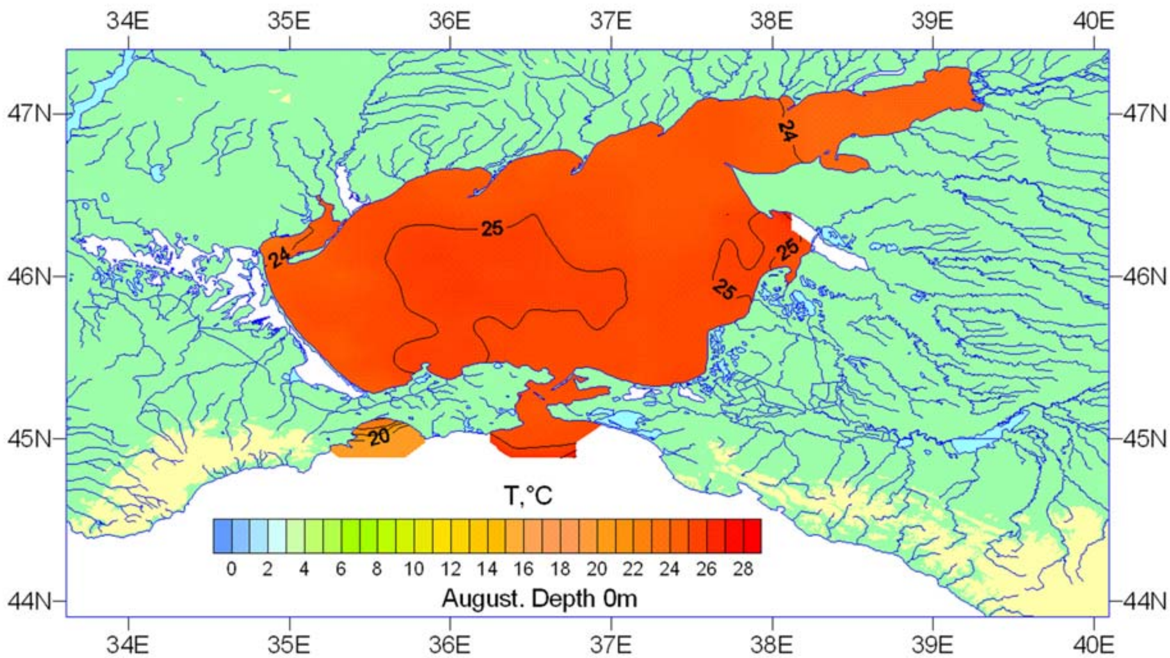
July. Depth 0m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August. Depth 0m
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47N 46N 45N 44N
24
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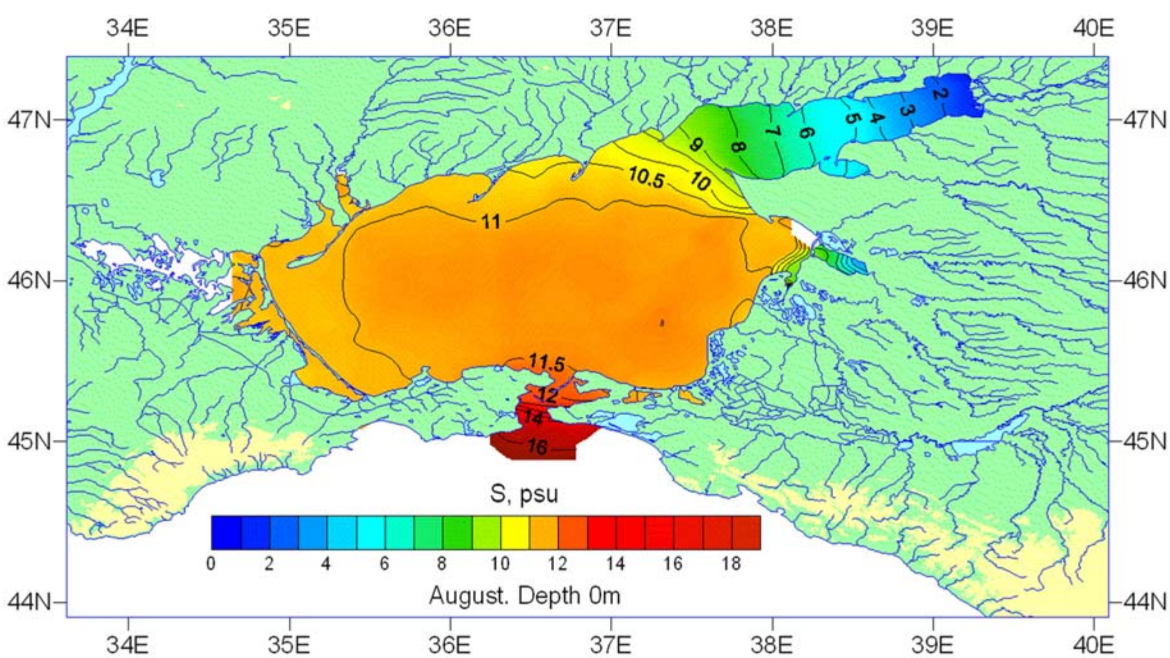
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August. Depth 0m
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47N 46N 45N 44N
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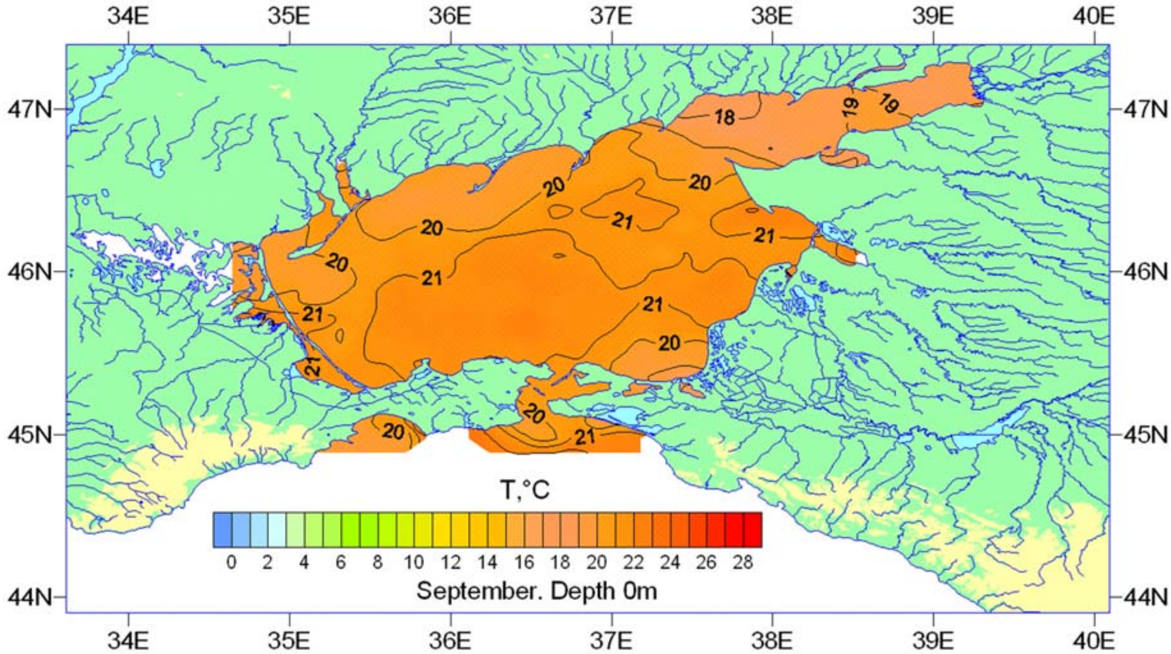
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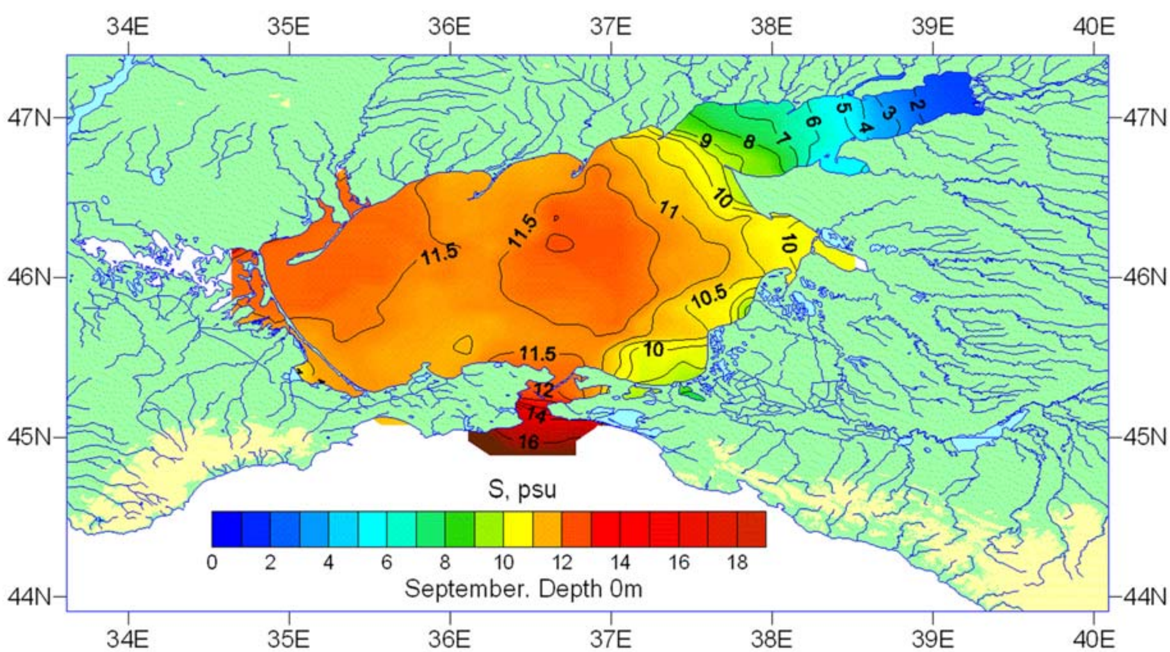
September. Depth 0m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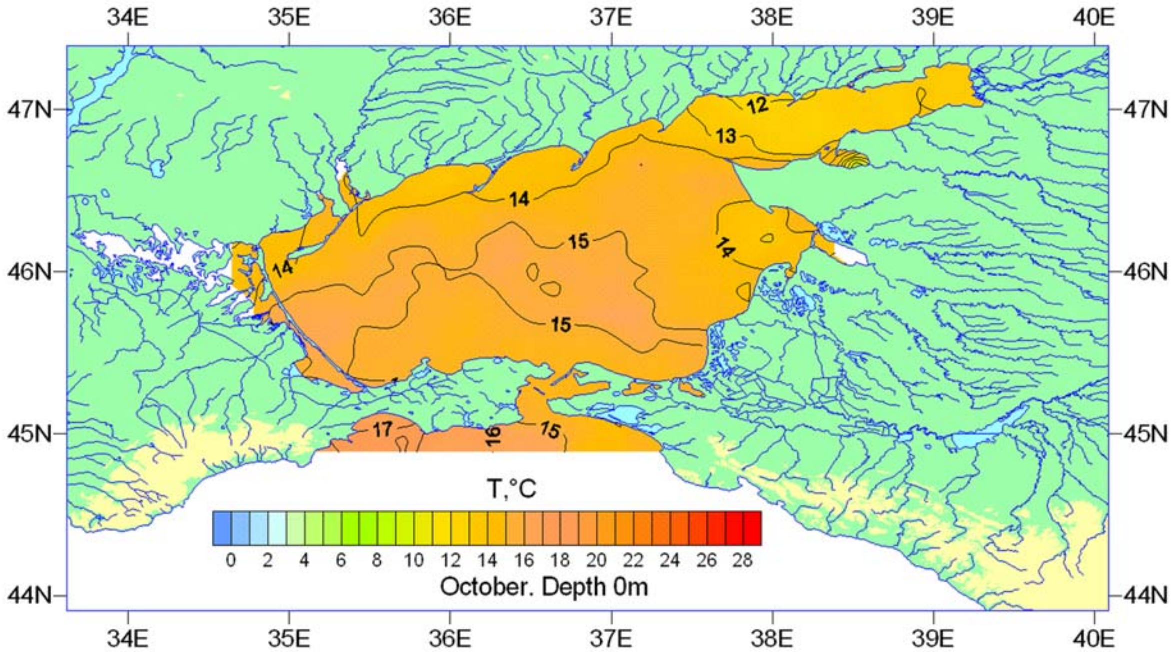
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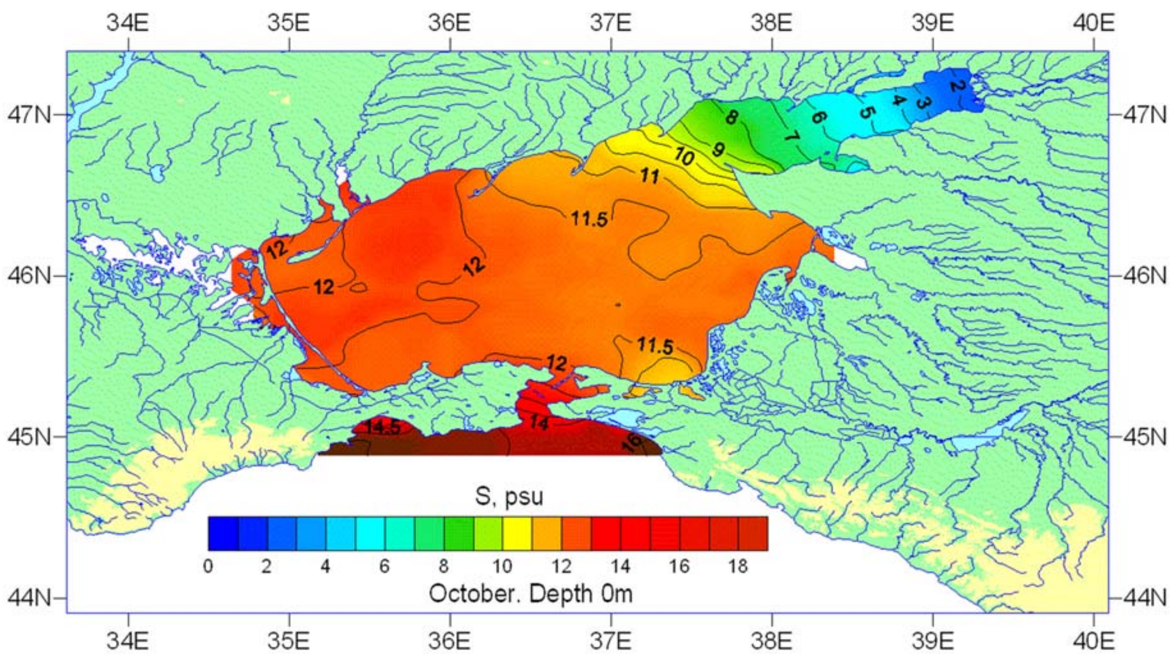
October. Depth 0m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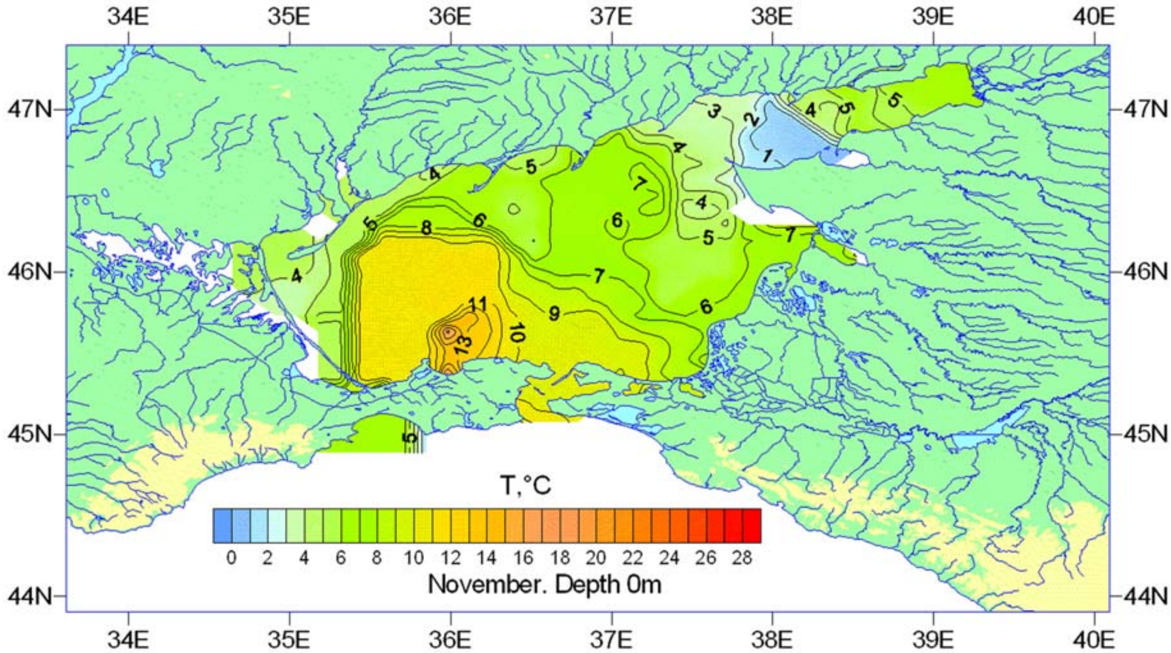
October. Depth 0m



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T,°C
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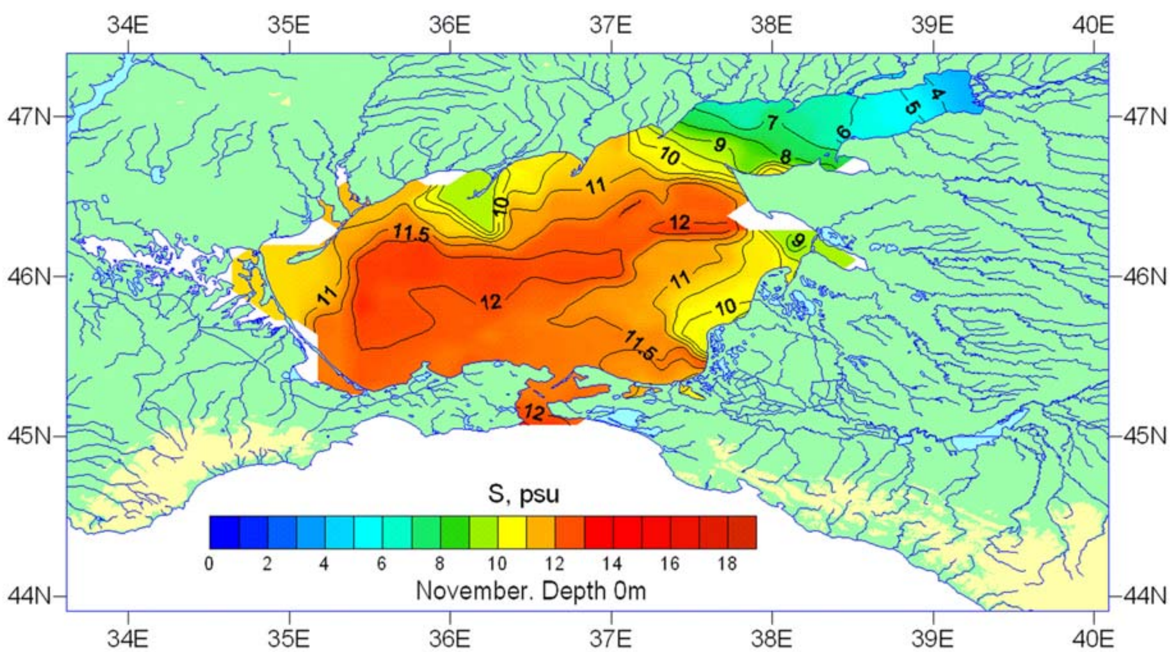
November. Depth 0m



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S, psu
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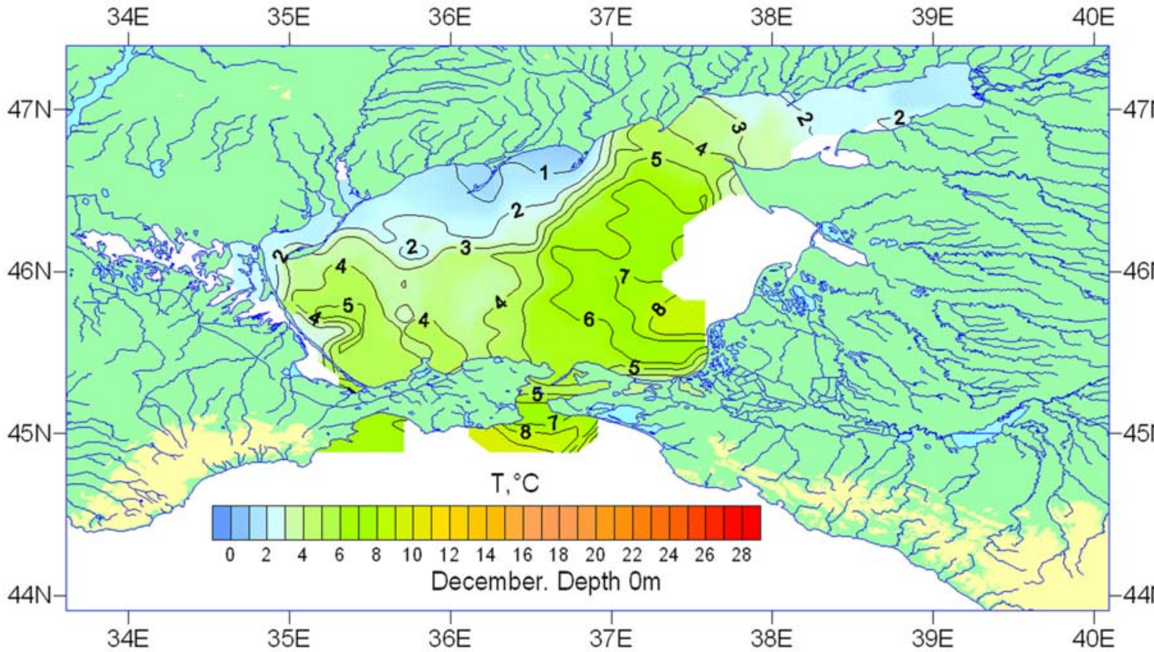
November. Depth 0m



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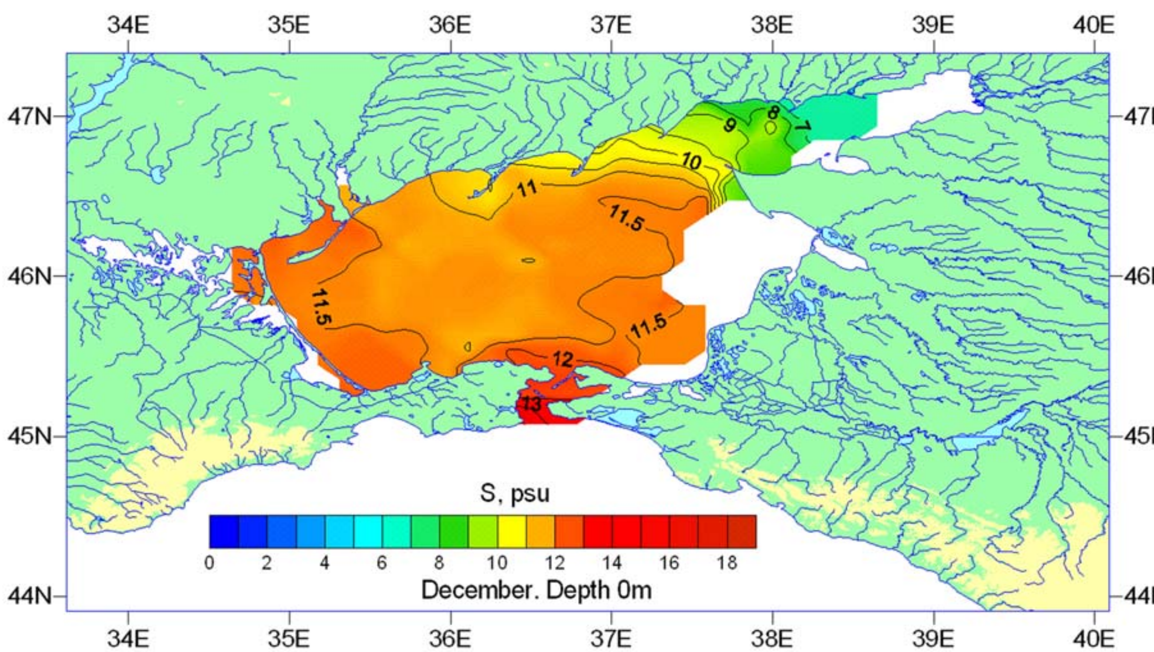
December. Depth 0m



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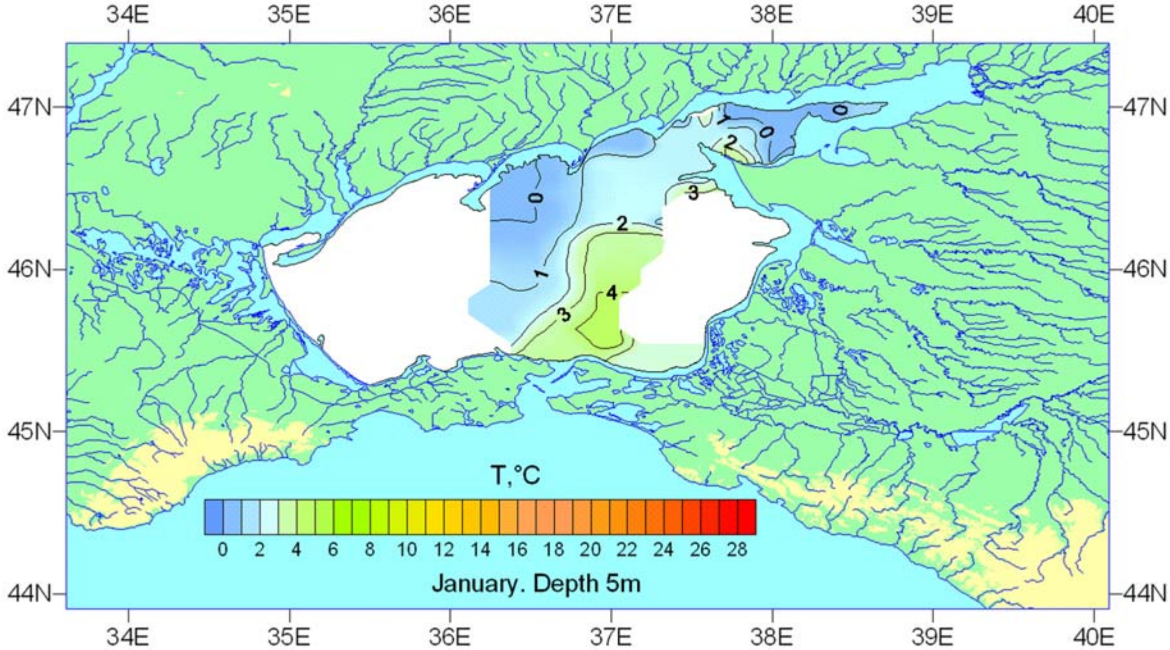
December. Depth 0m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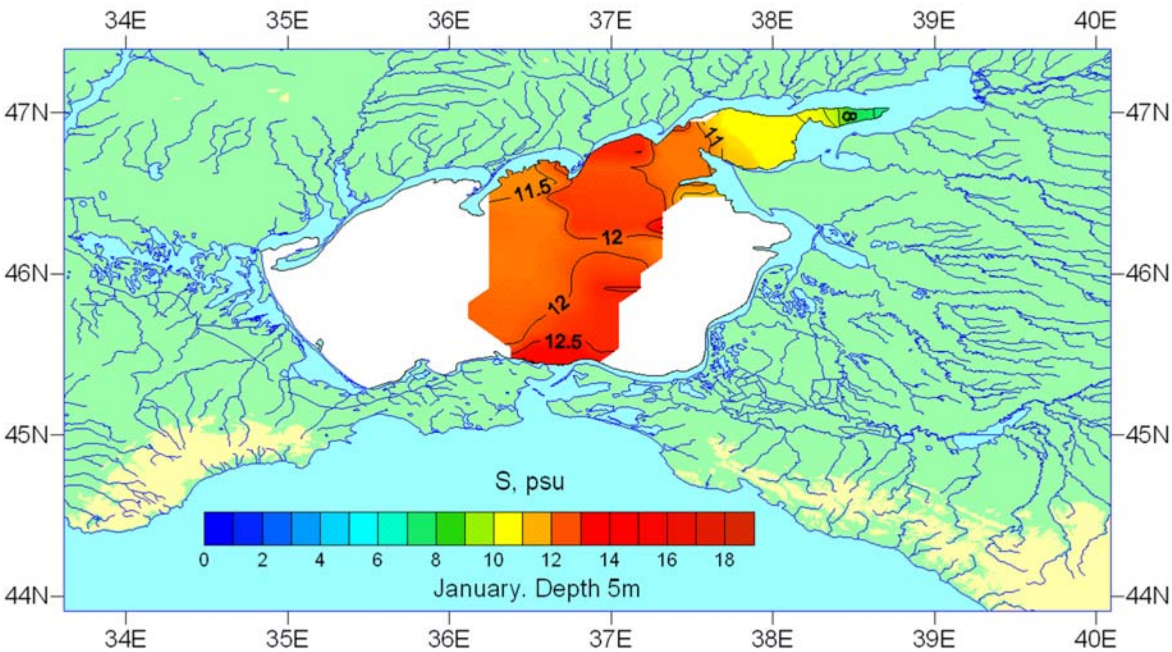
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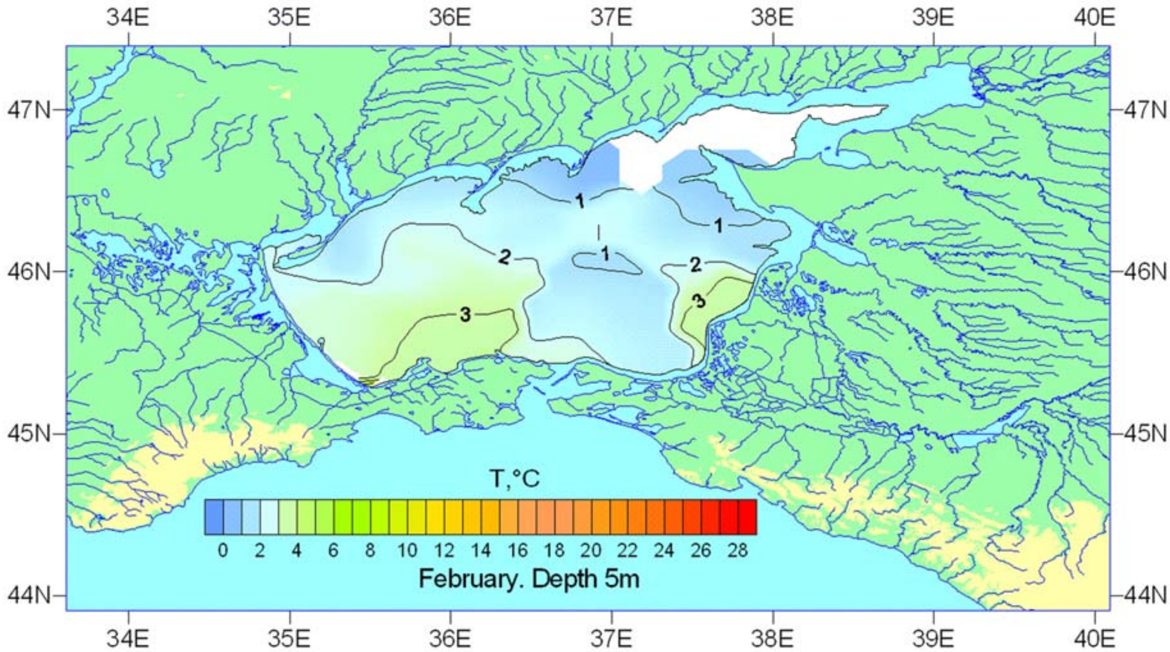
January. Depth 5m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3
T,°C
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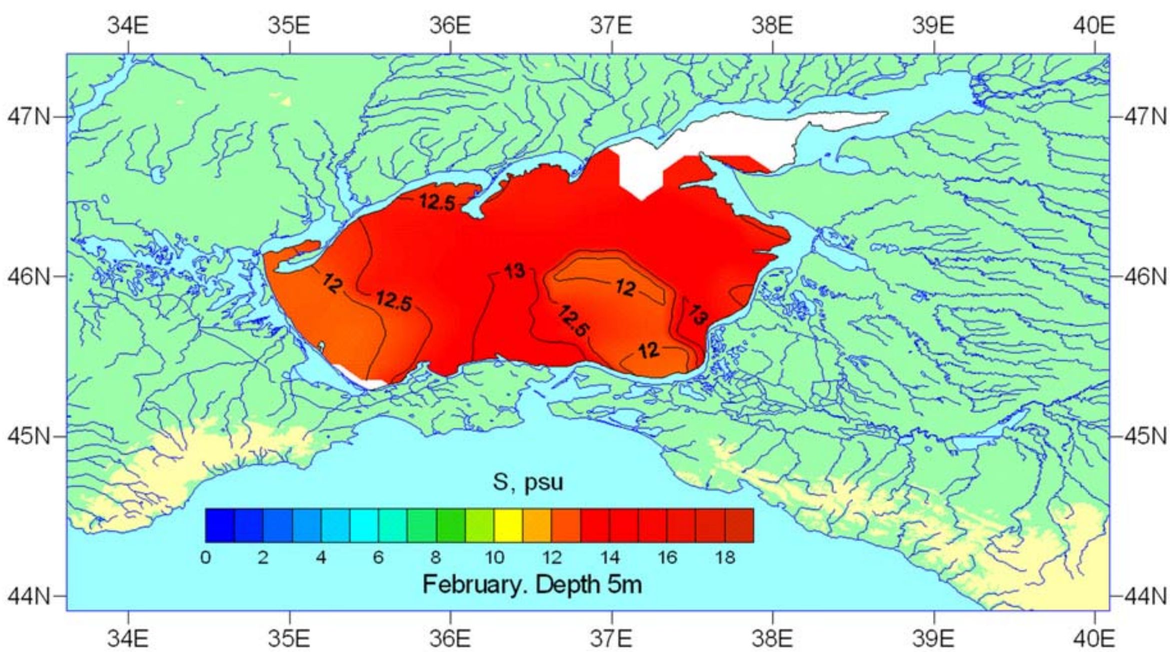
February. Depth 5m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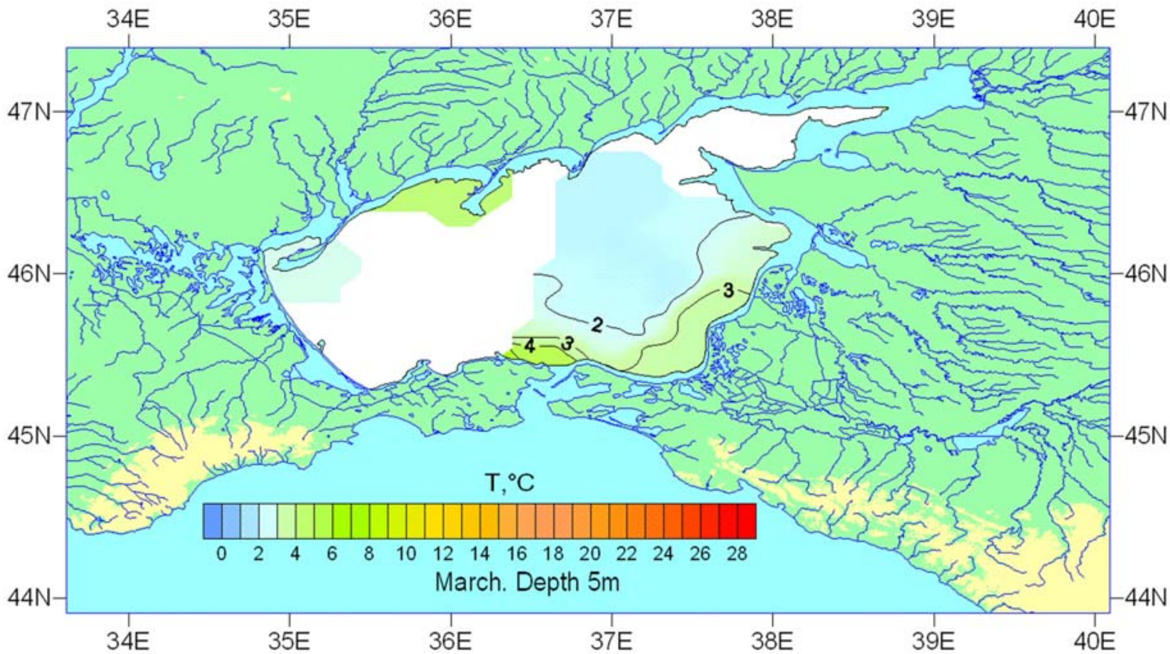
February. Depth 5m



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T,°C
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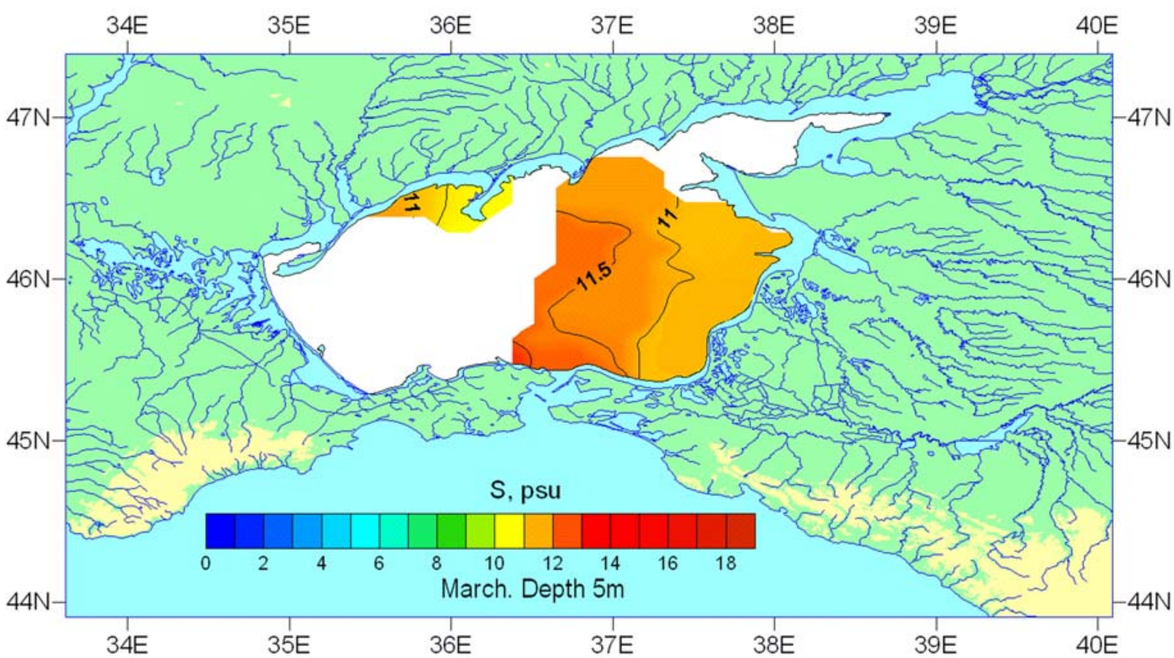
March. Depth 5m



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11
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S, psu
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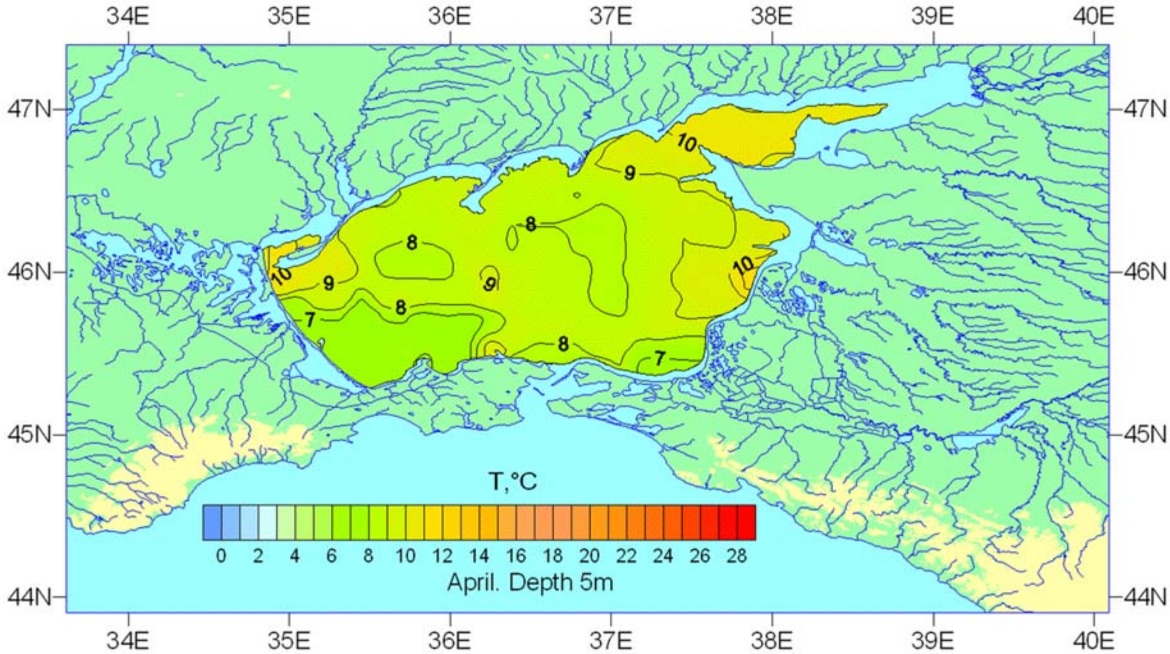
March. Depth 5m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47N 46N 45N 44N
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T,°C
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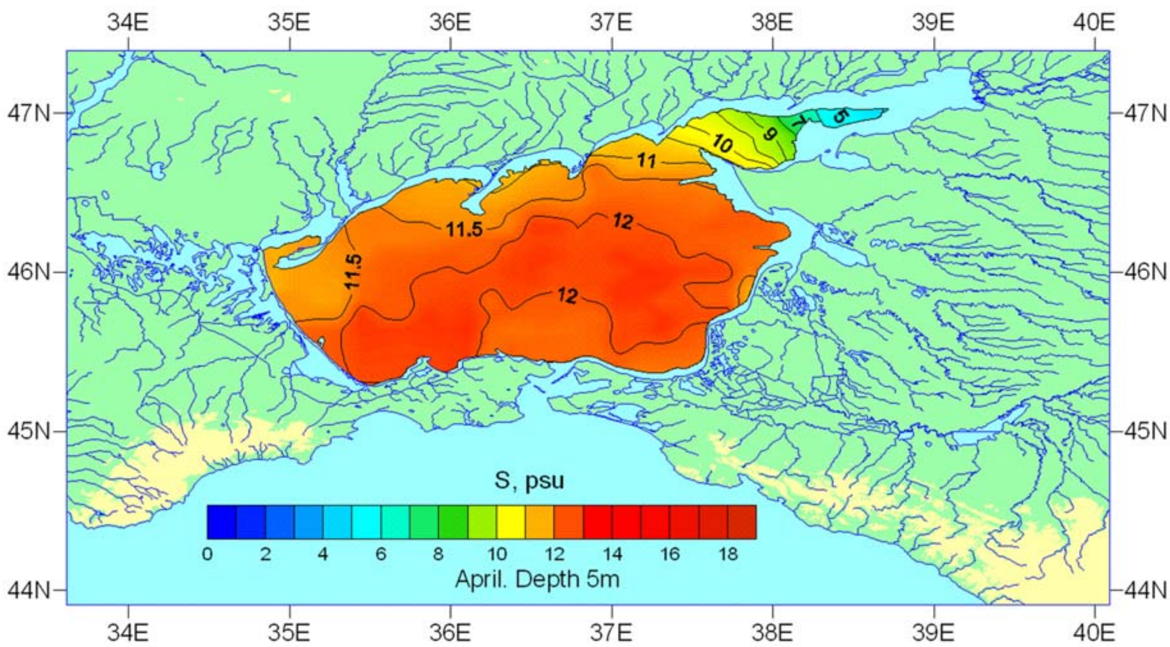
April. Depth 5m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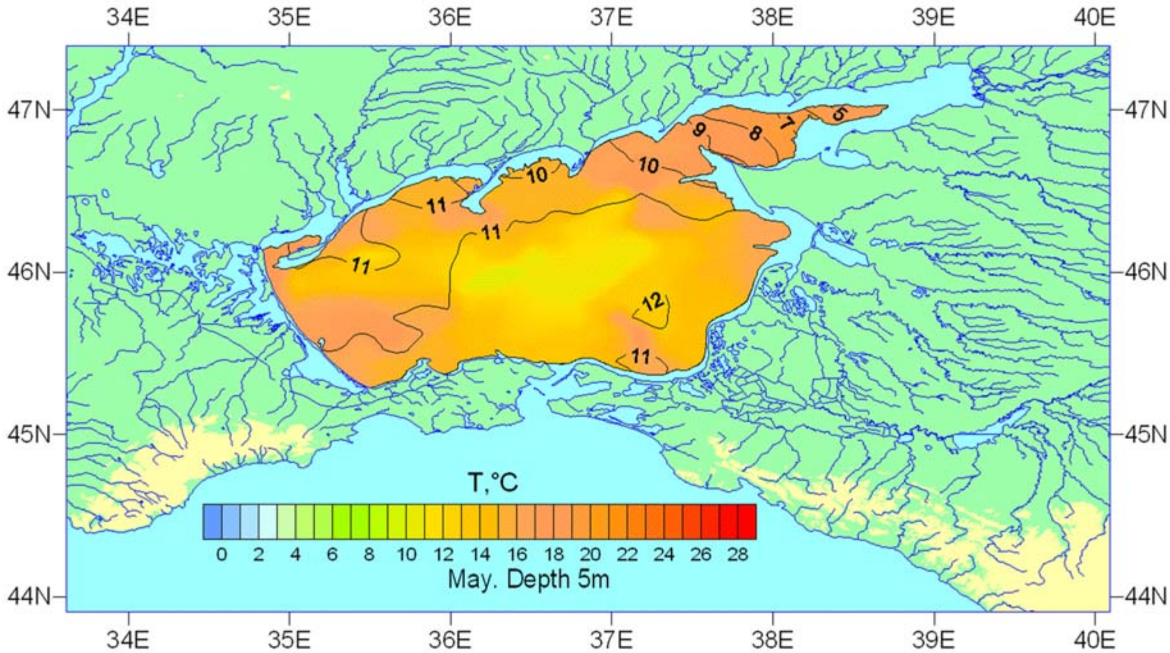
April. Depth 5m



T,°C
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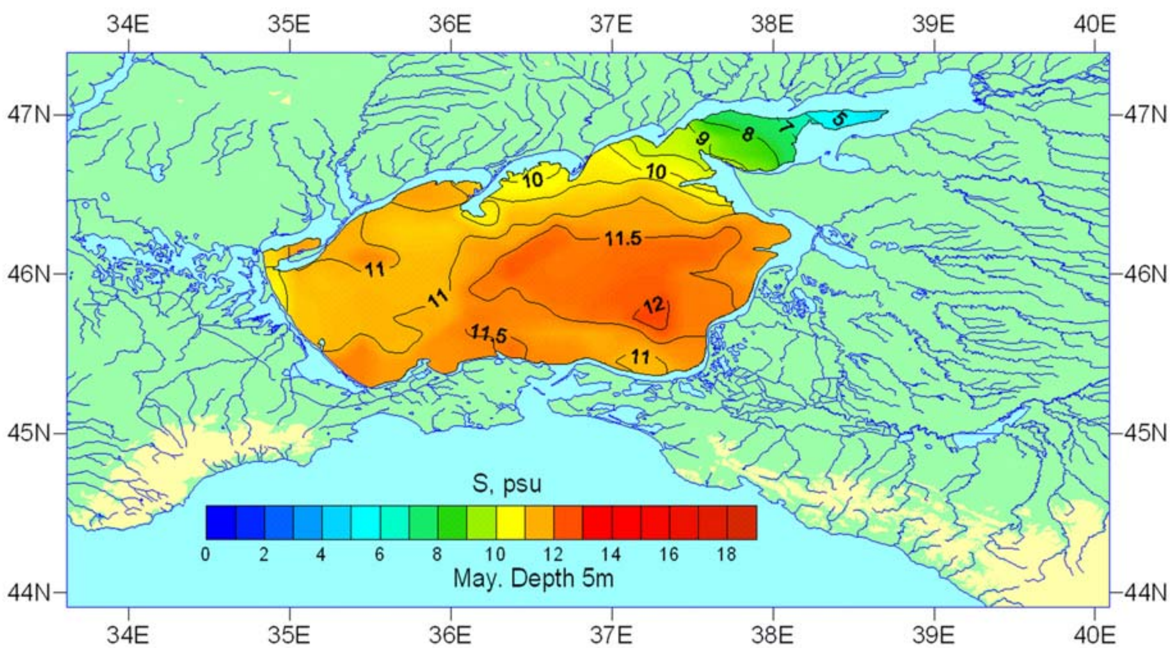
May. Depth 5m



S, psu
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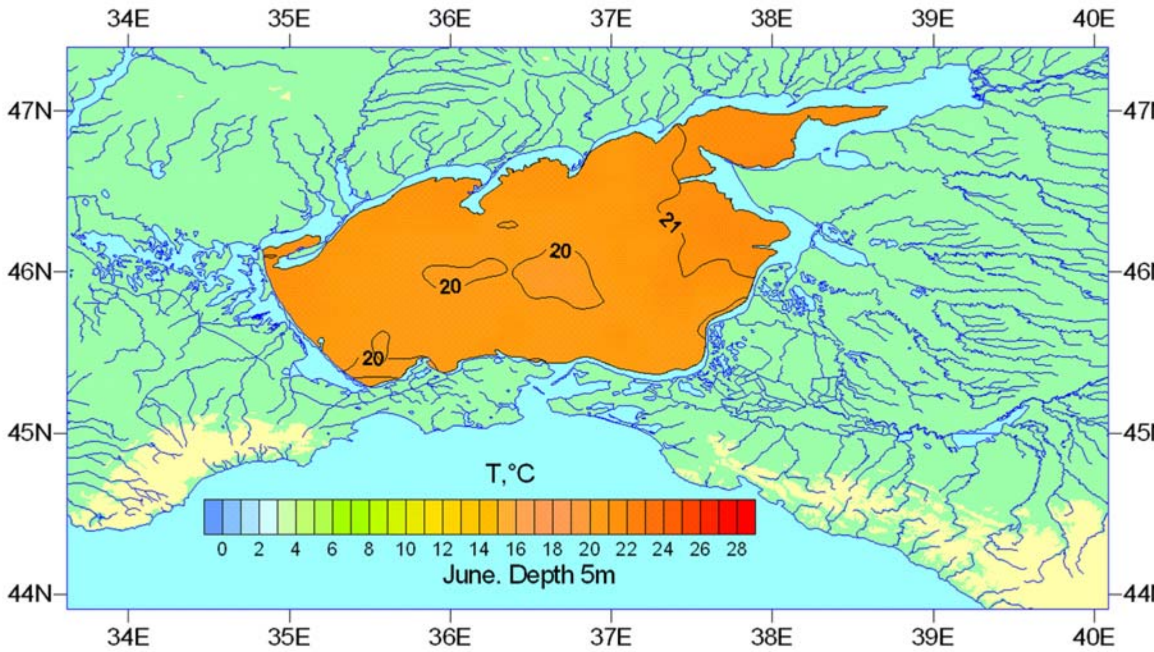
May. Depth 5m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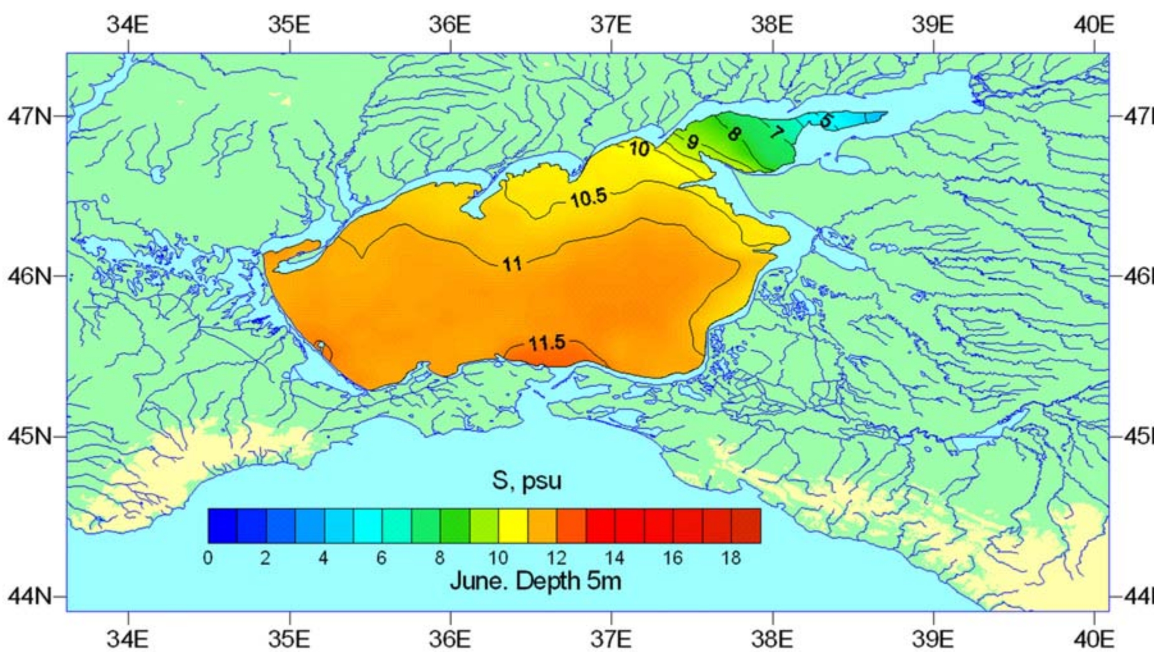
June. Depth 5m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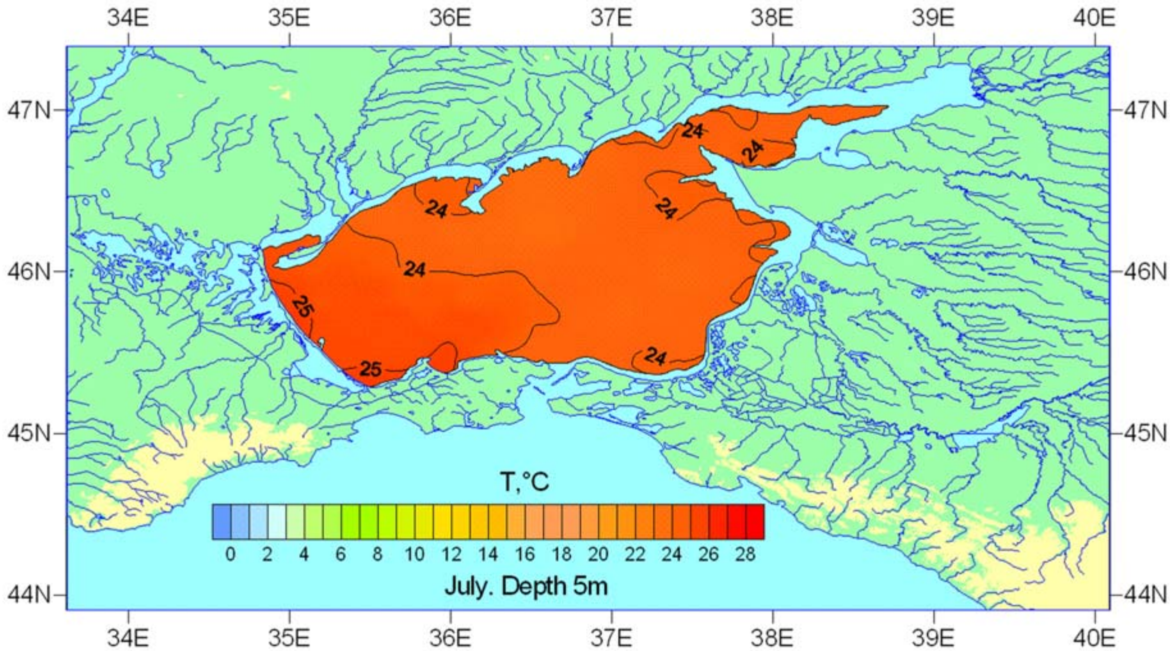
June. Depth 5m



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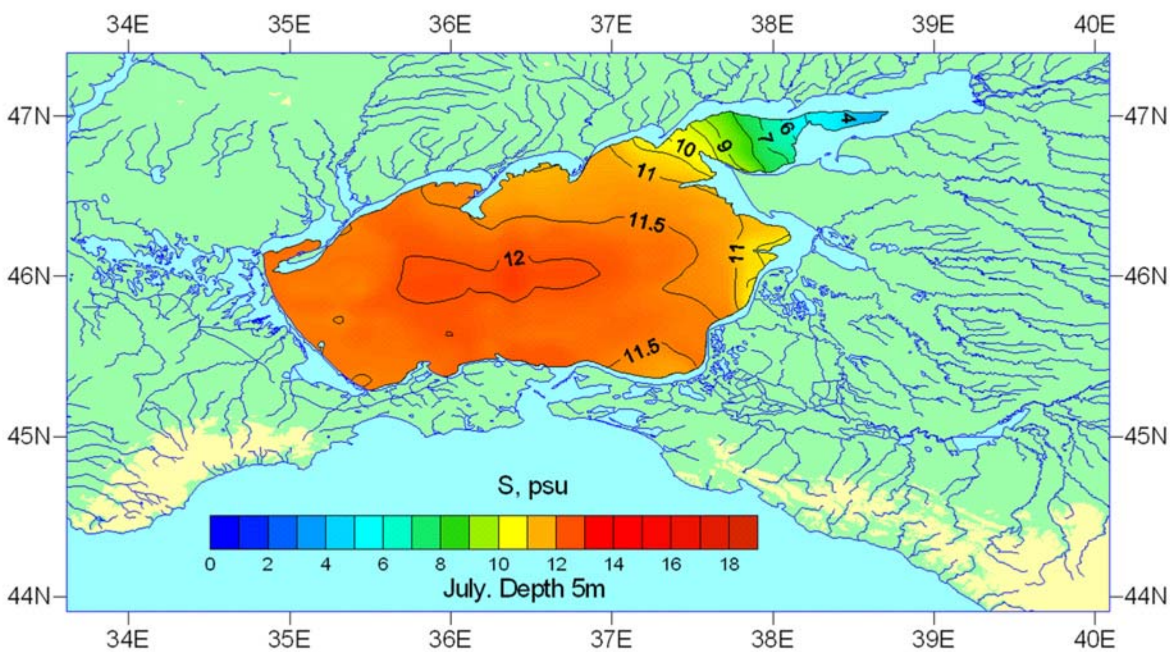

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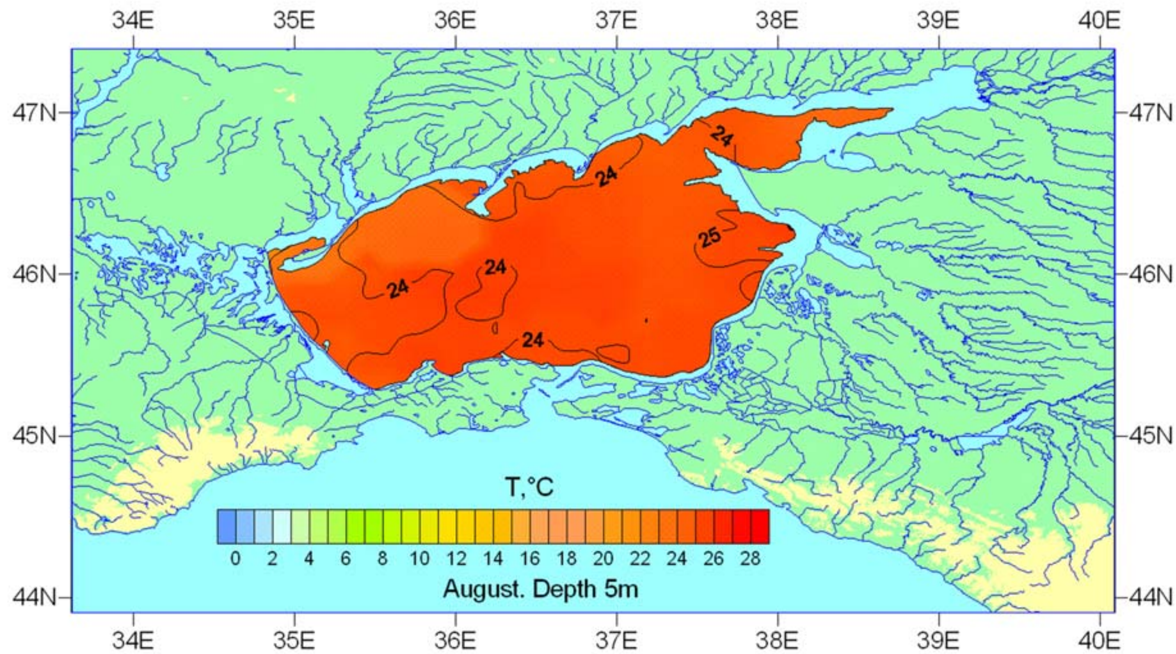
July. Depth 5m



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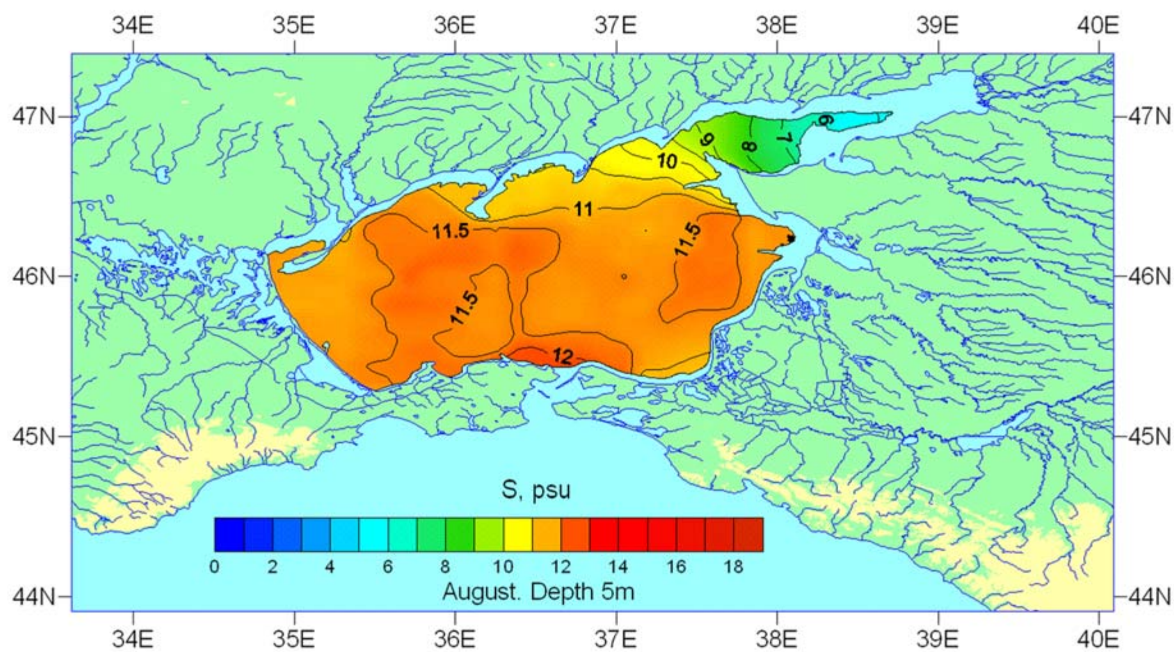
August. Depth 5m



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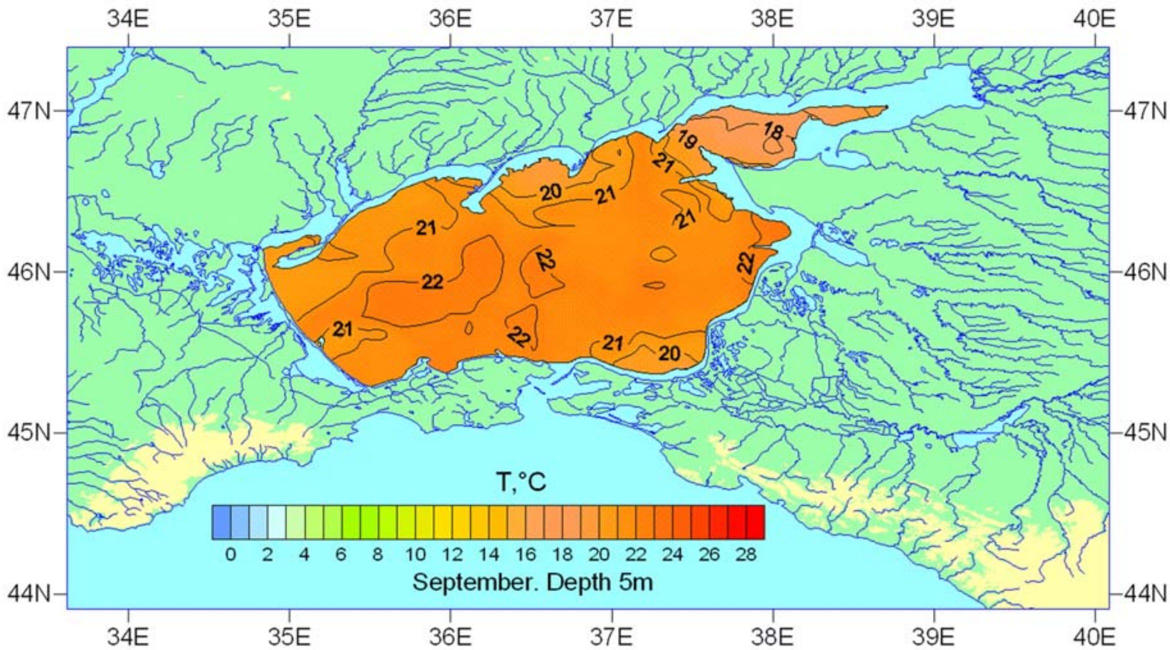
August. Depth 5m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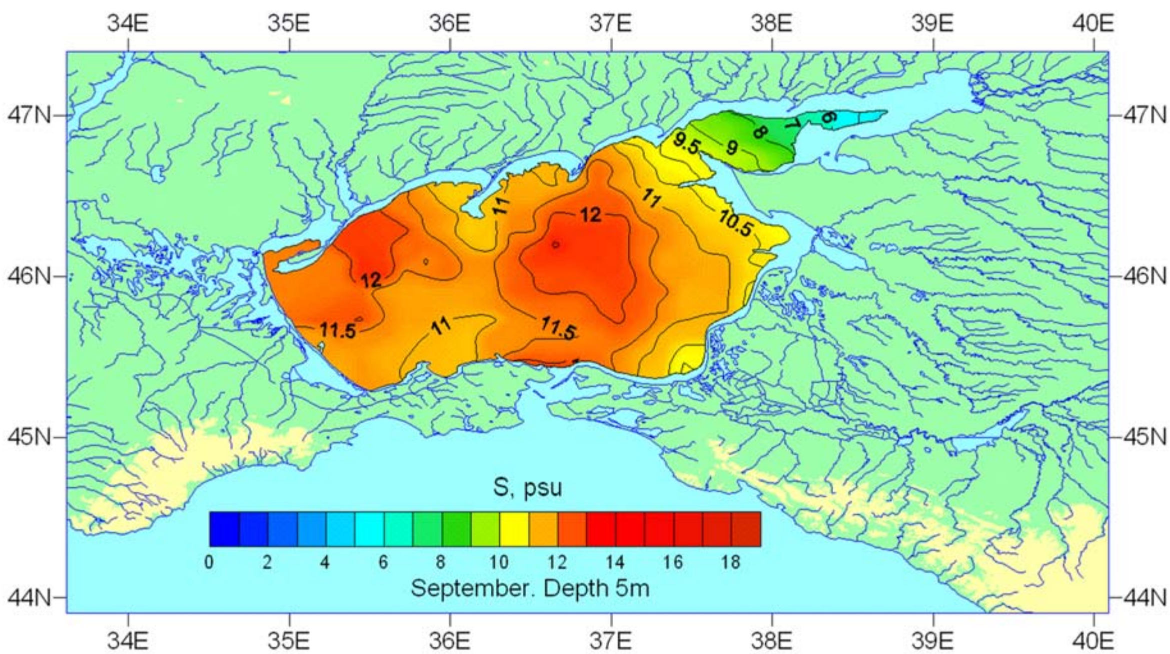
September. Depth 5m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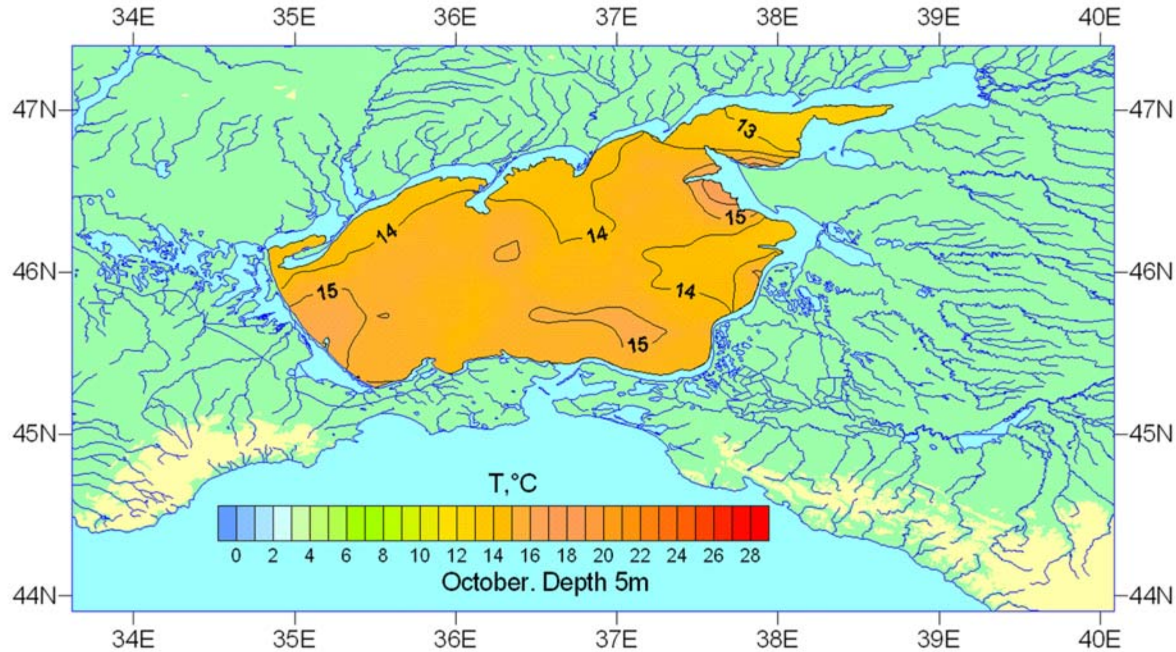
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October. Depth 5m
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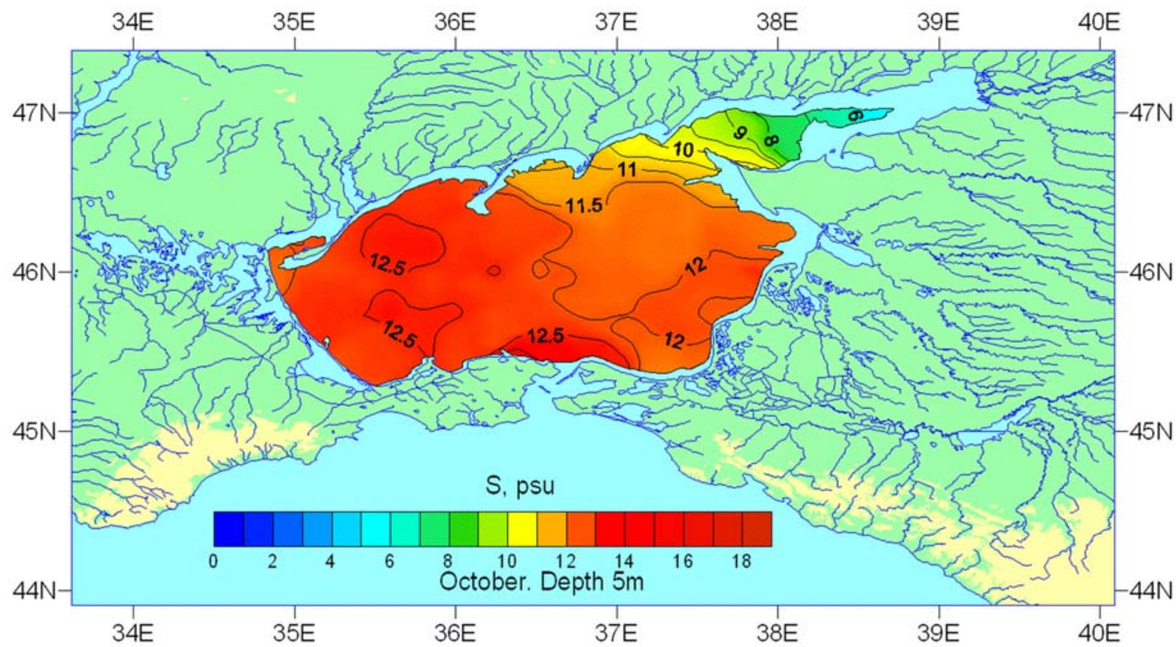
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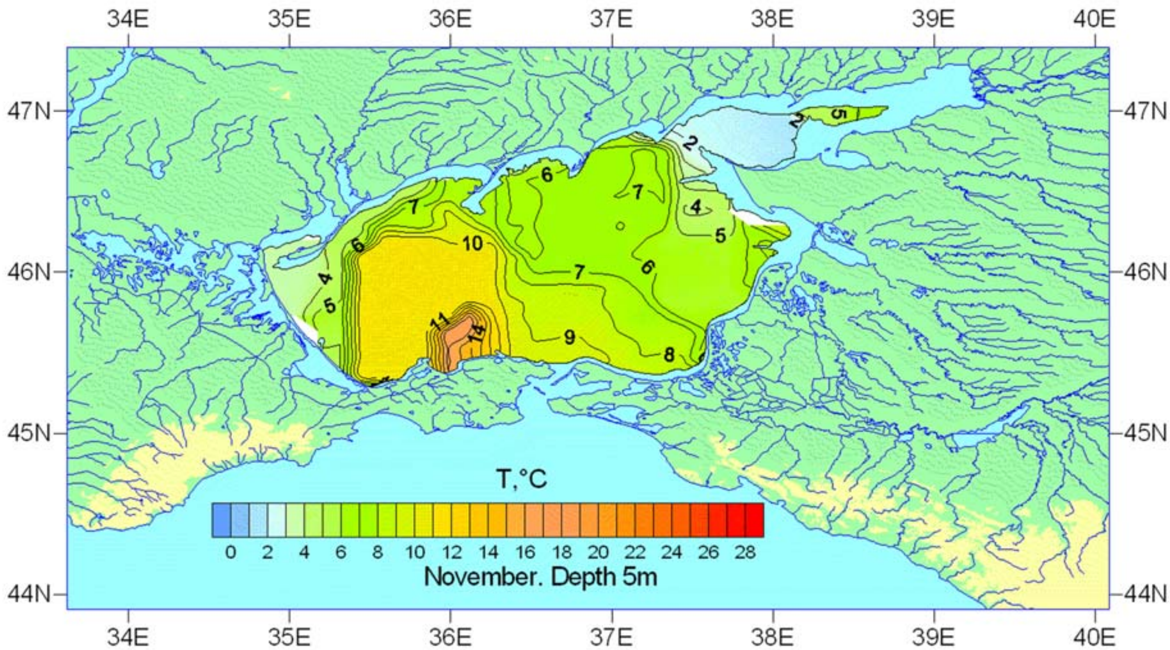
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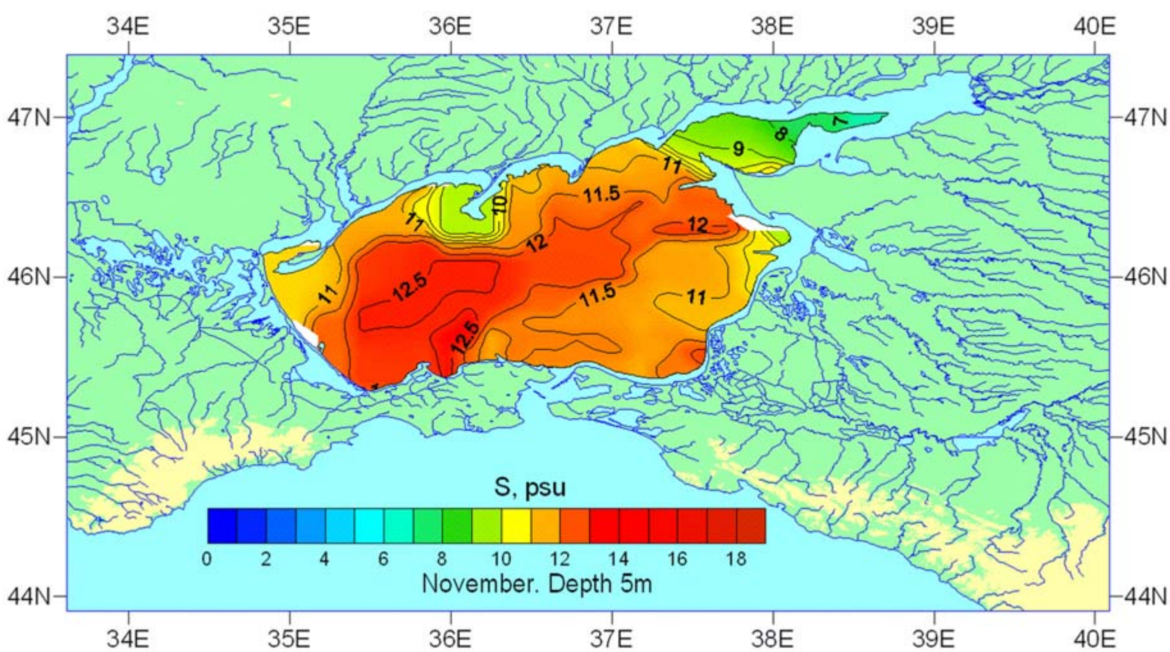
November. Depth 5m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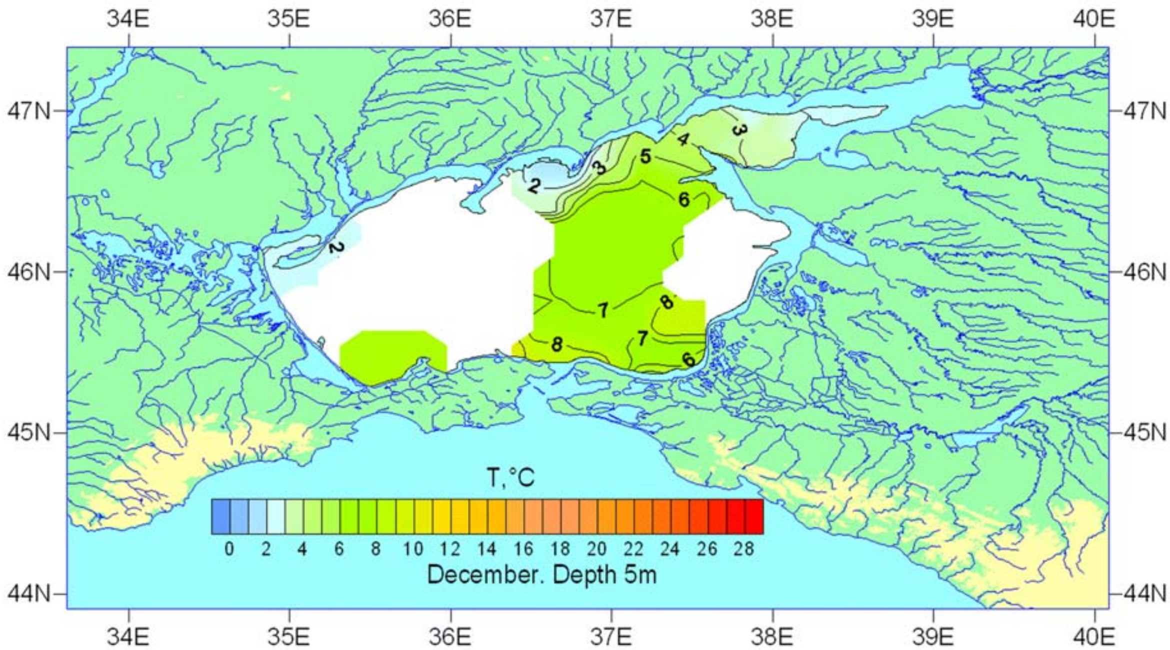
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December. Depth 5m
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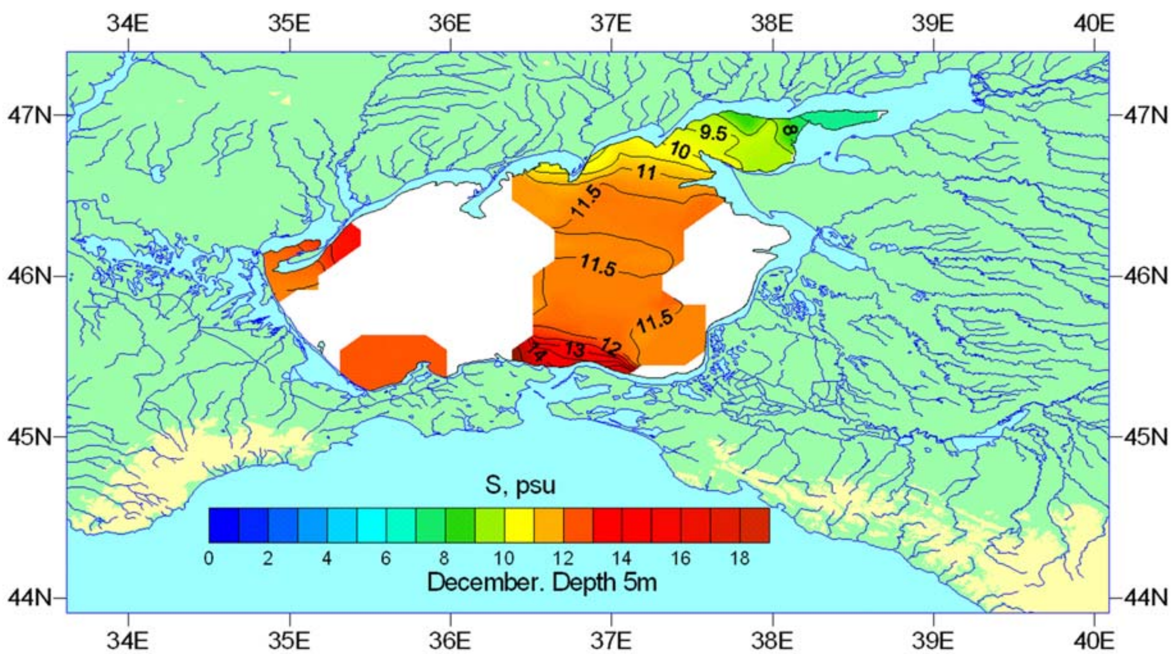
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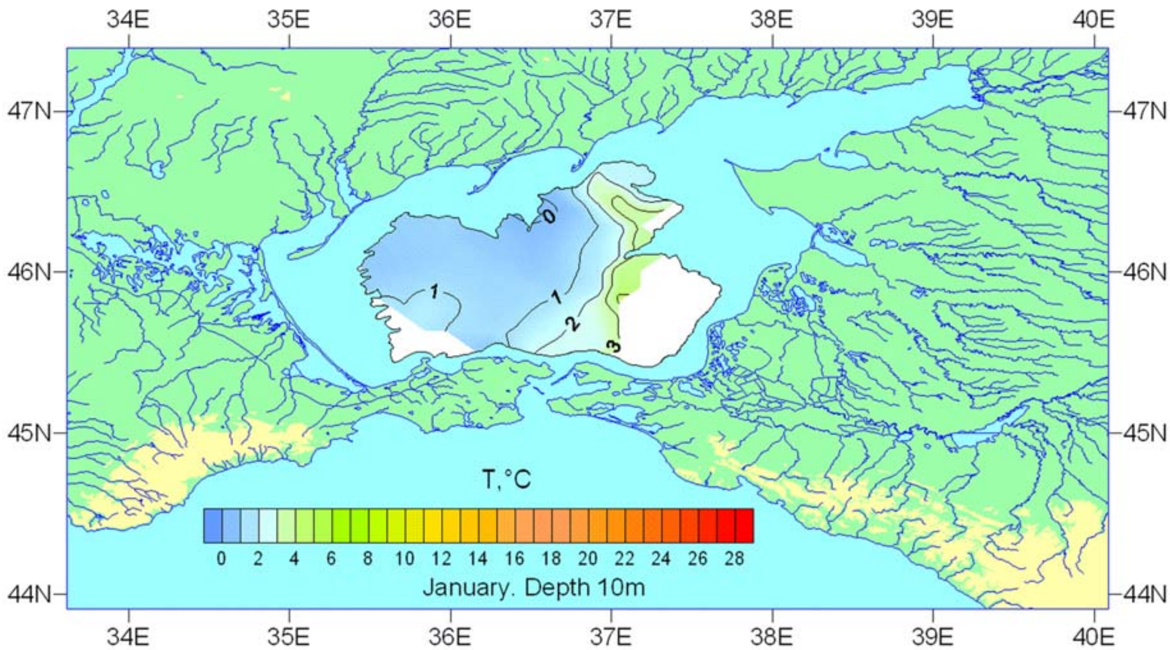
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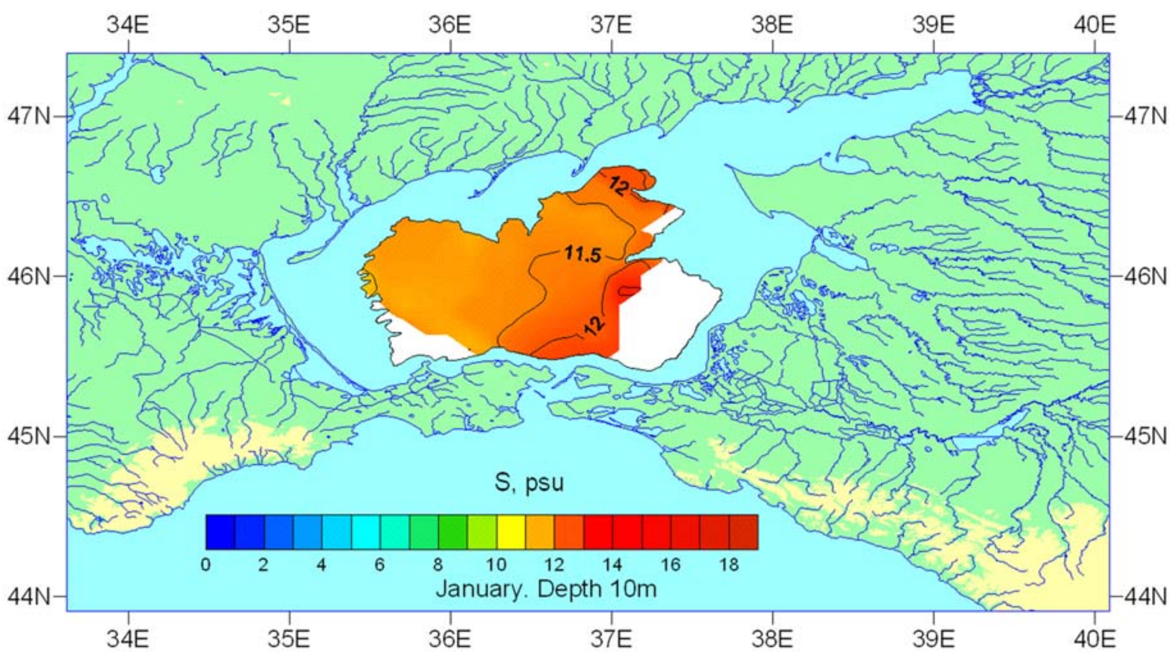
January. Depth 10m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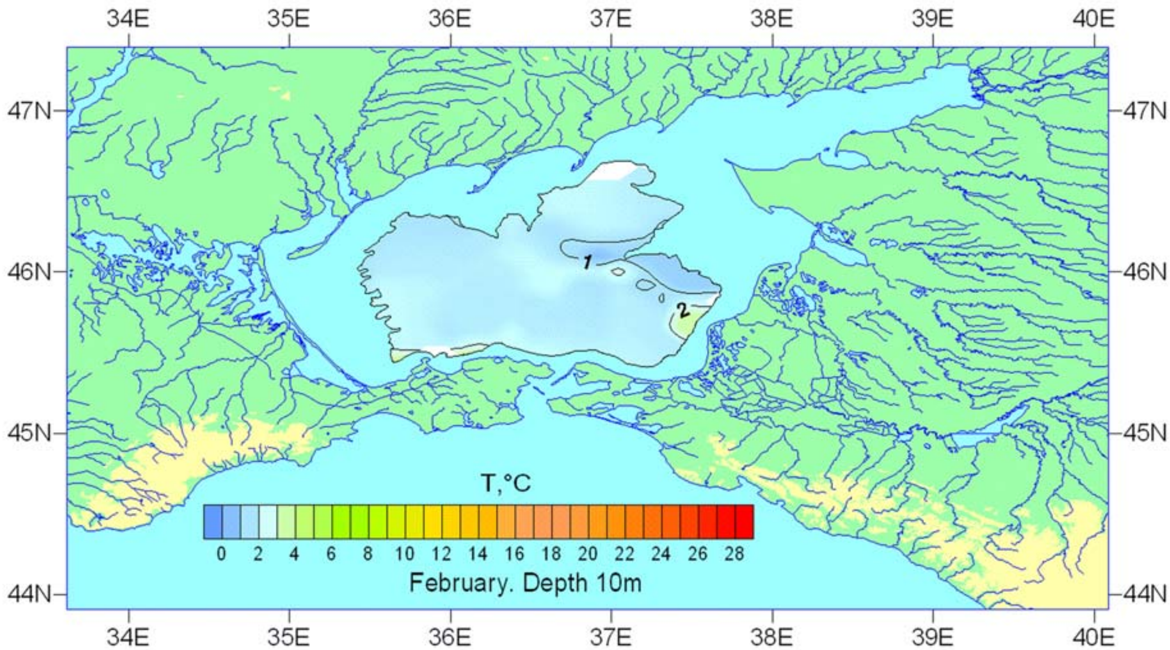
January. Depth 10m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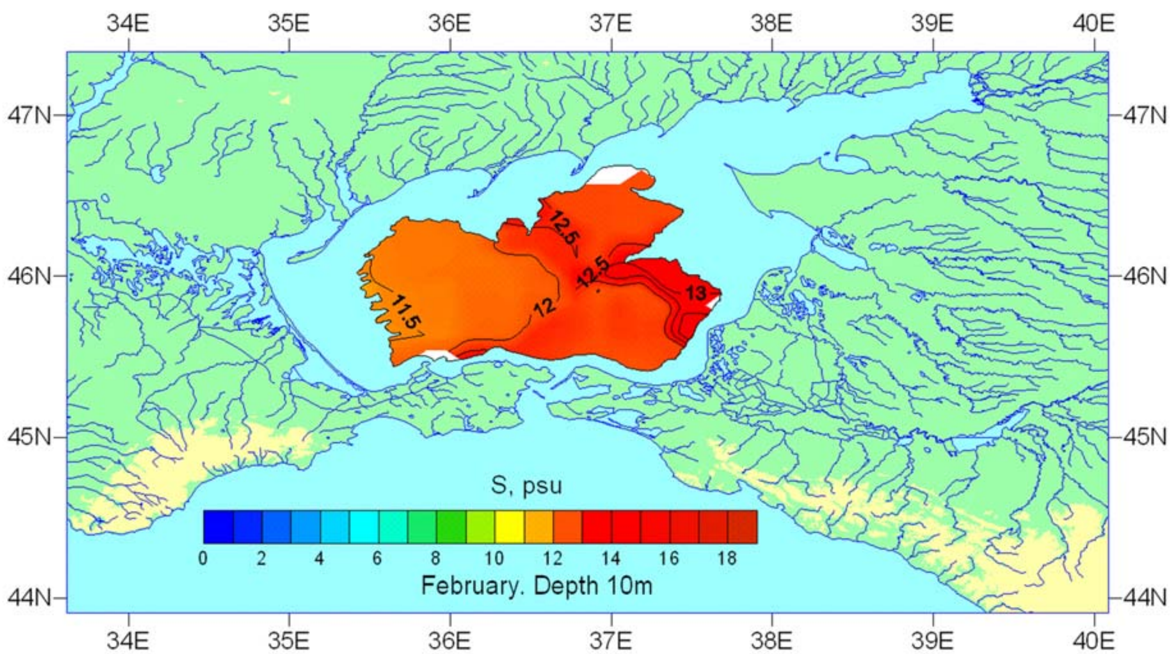
February. Depth 10m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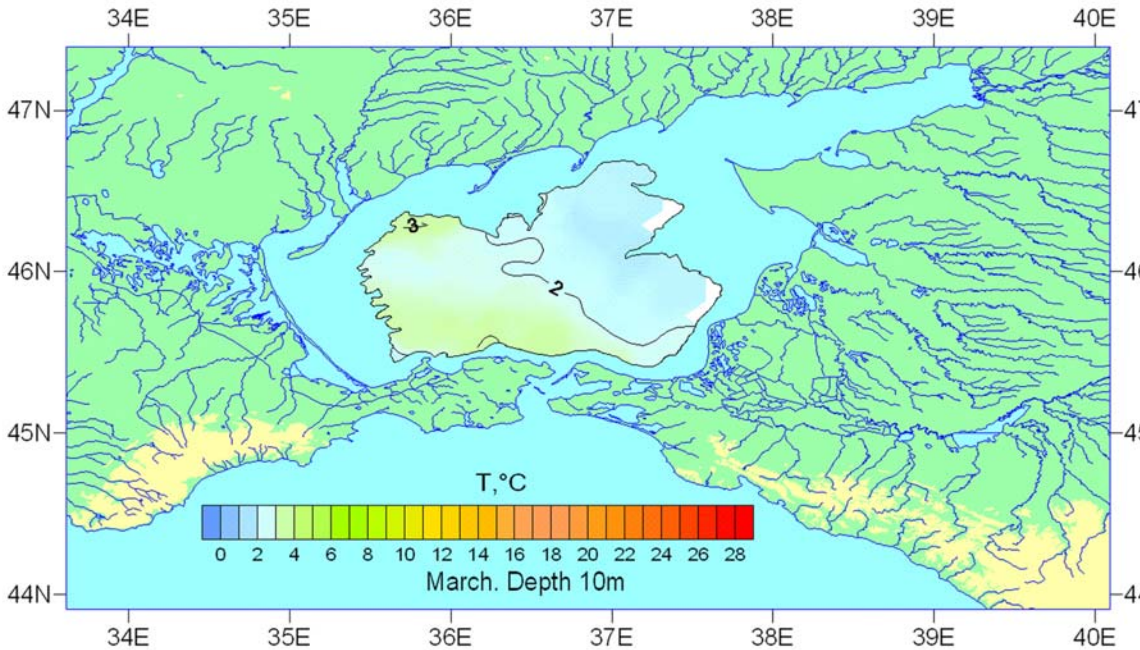
February. Depth 10m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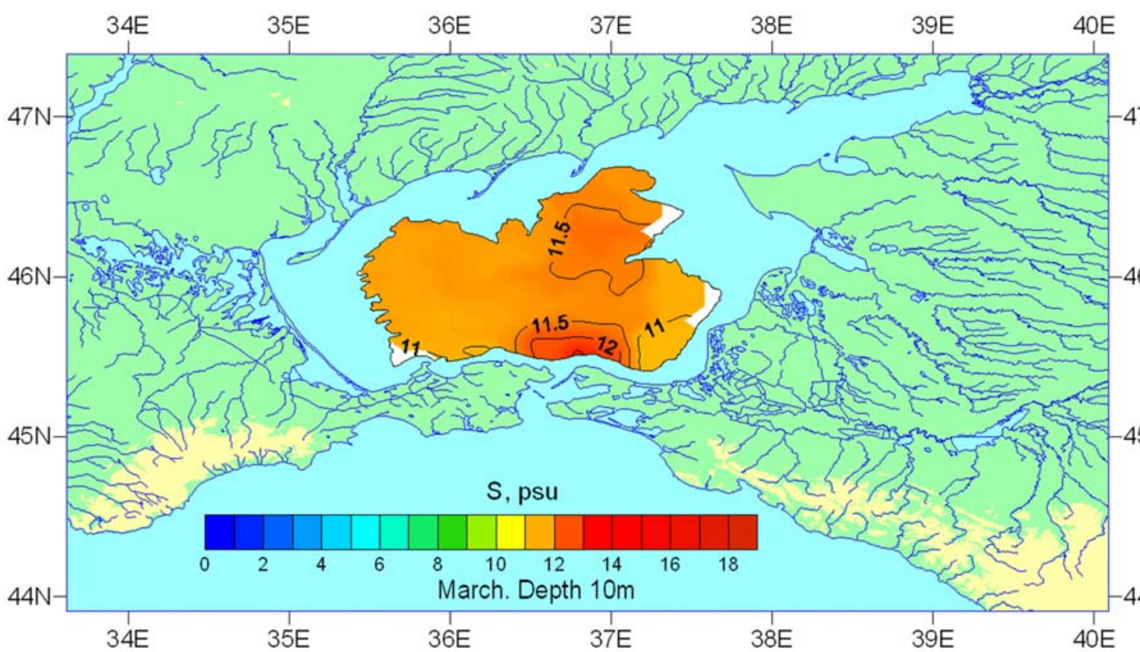
March. Depth 10m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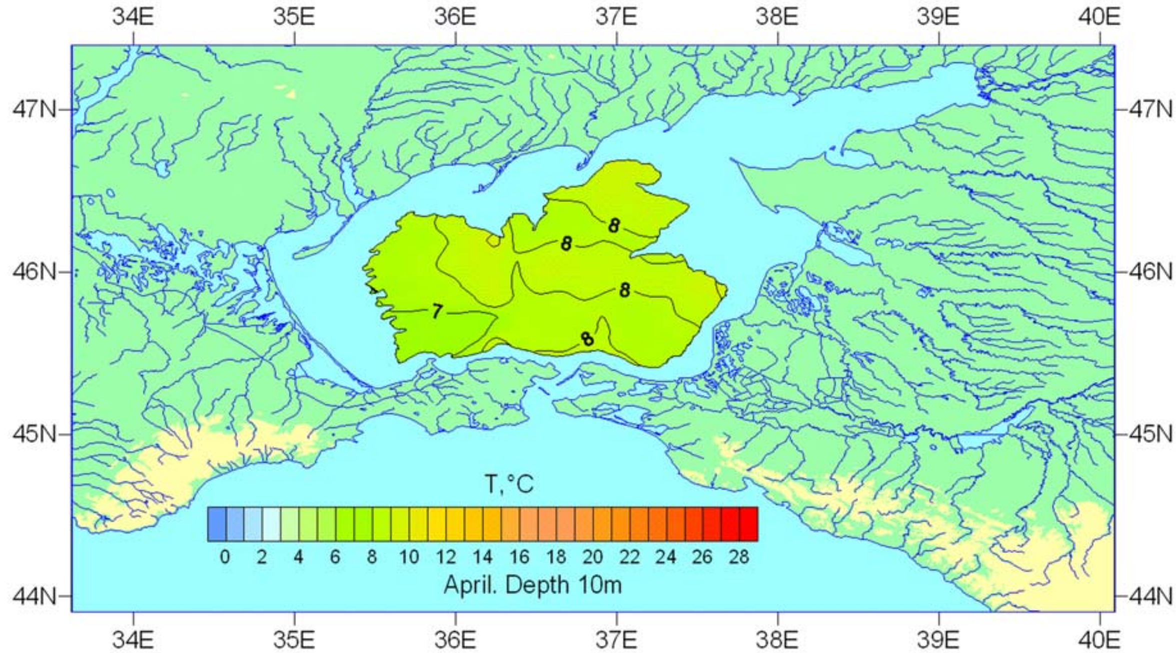
March. Depth 10m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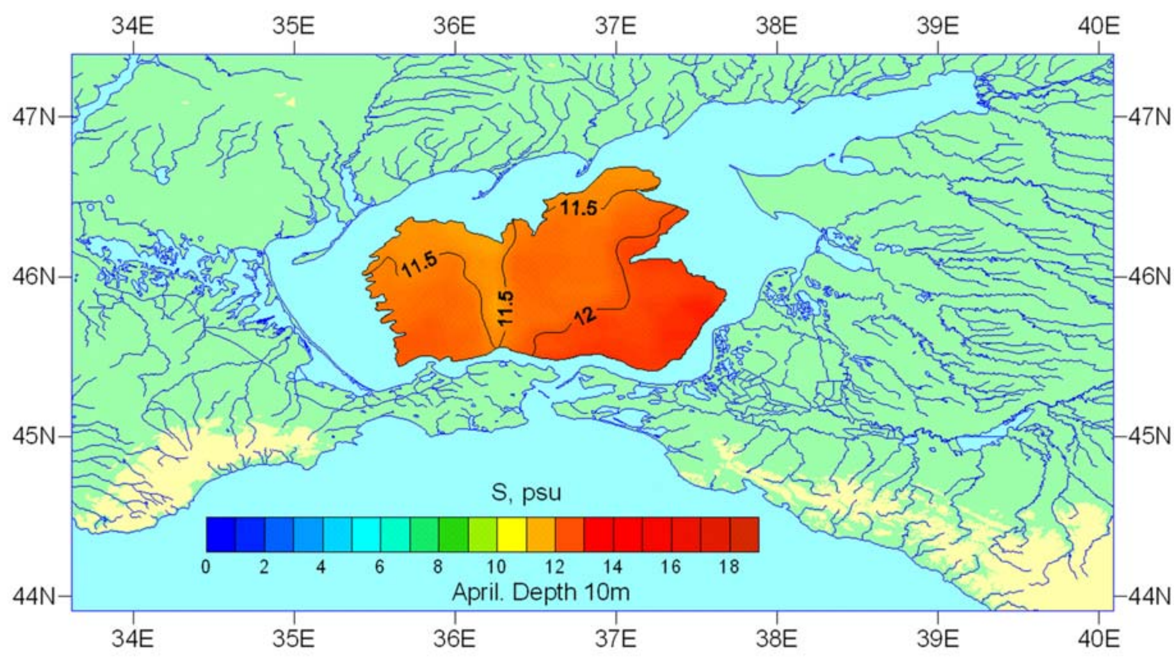
April. Depth 10m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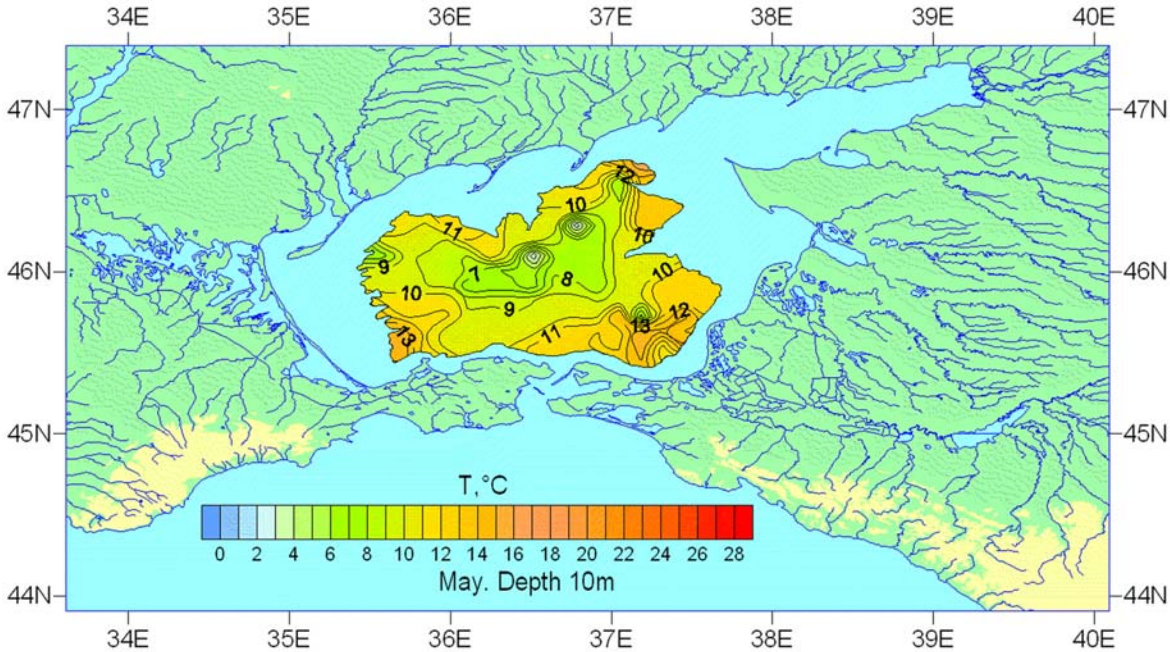
April. Depth 10m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May. Depth 10m
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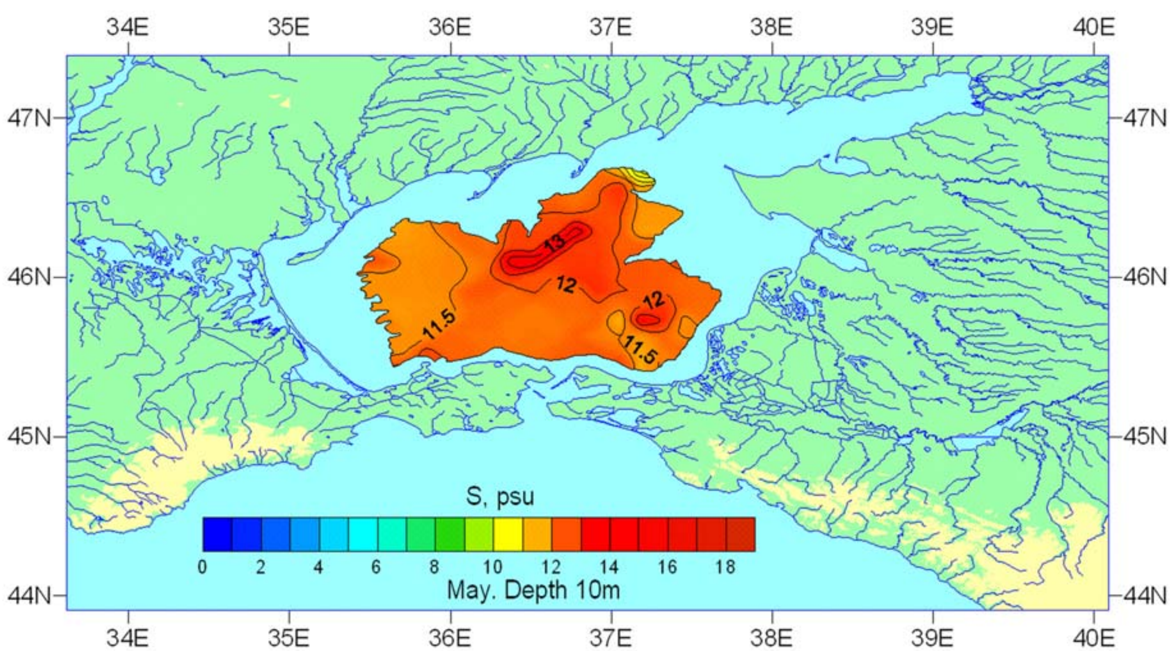
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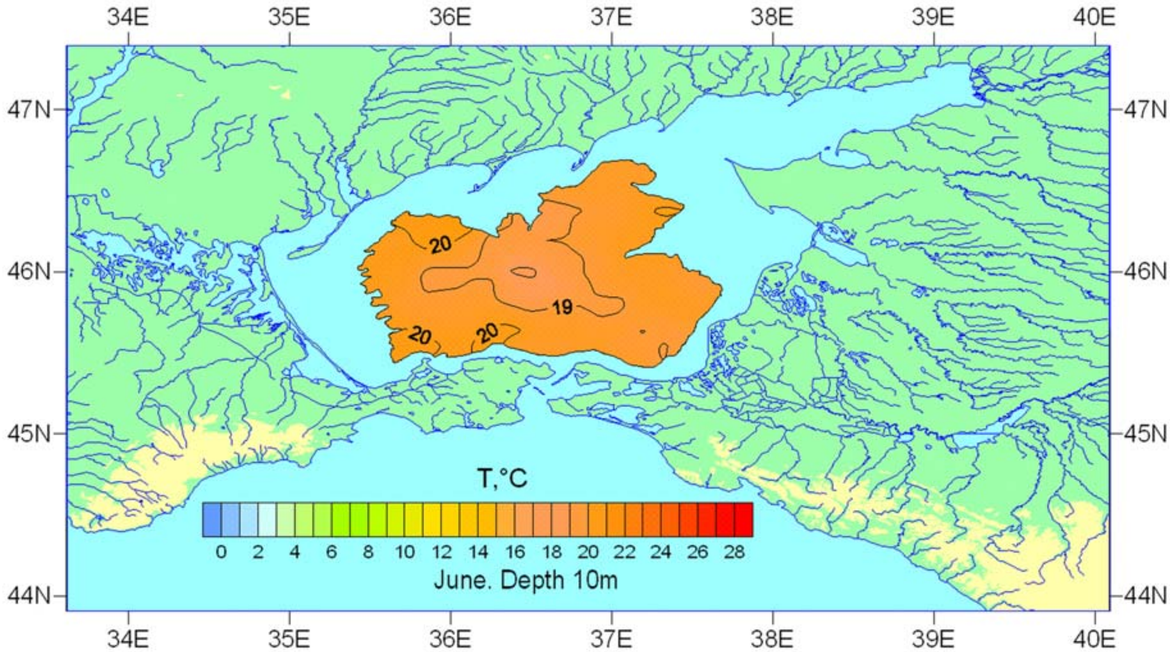
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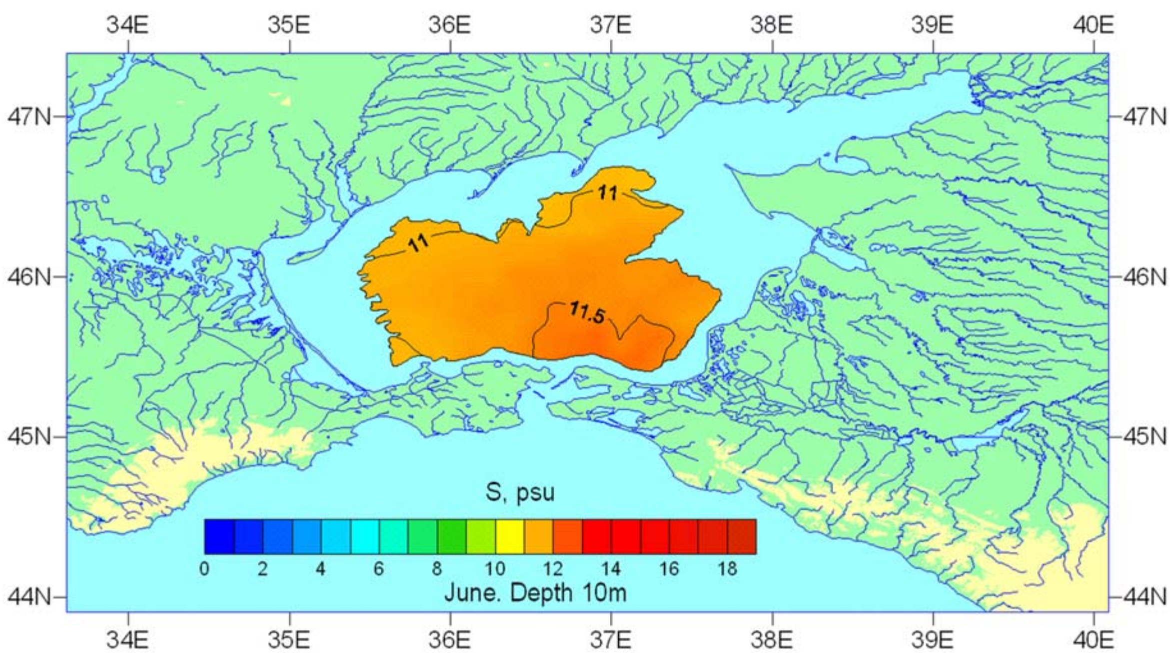
June. Depth 10m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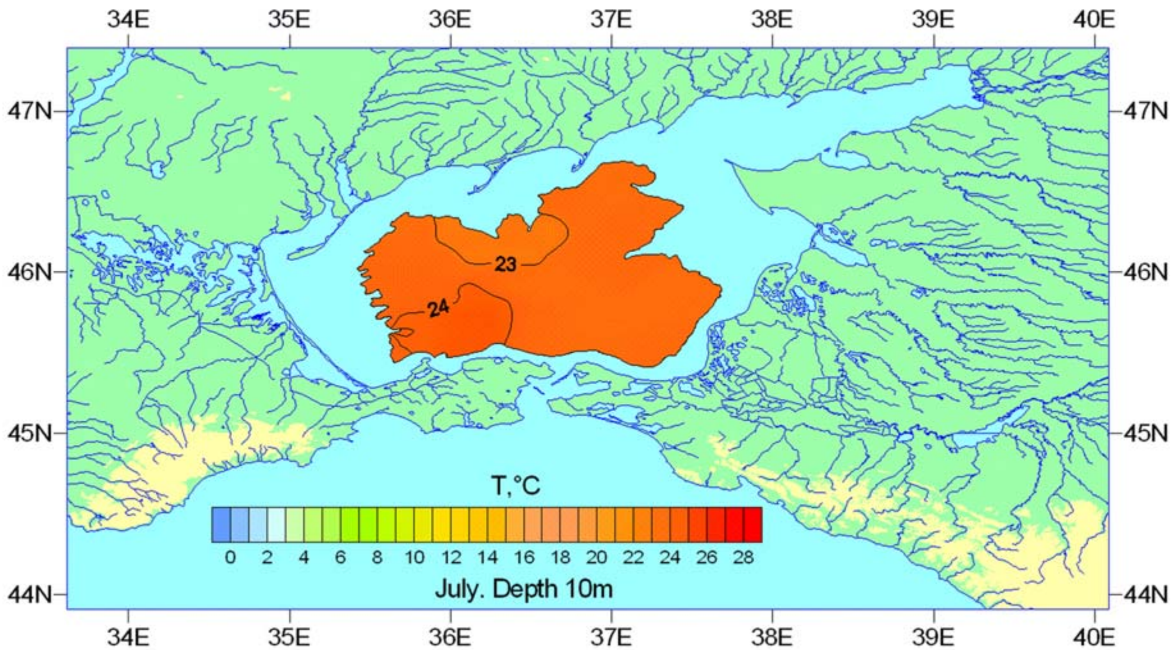
June. Depth 10m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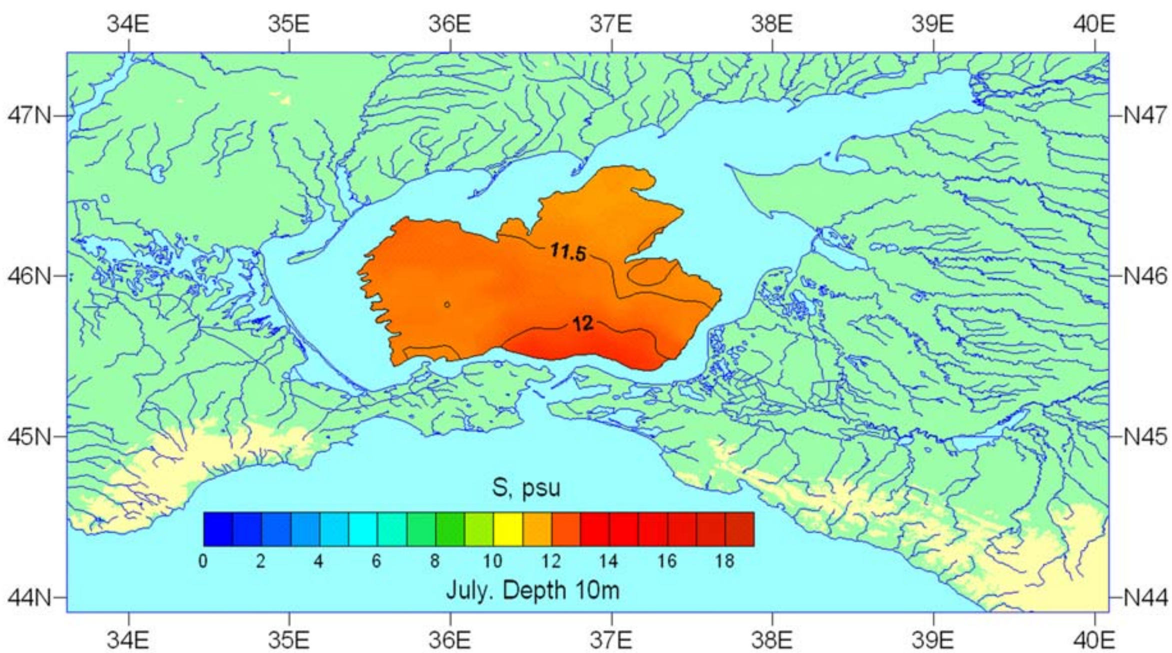
July. Depth 10m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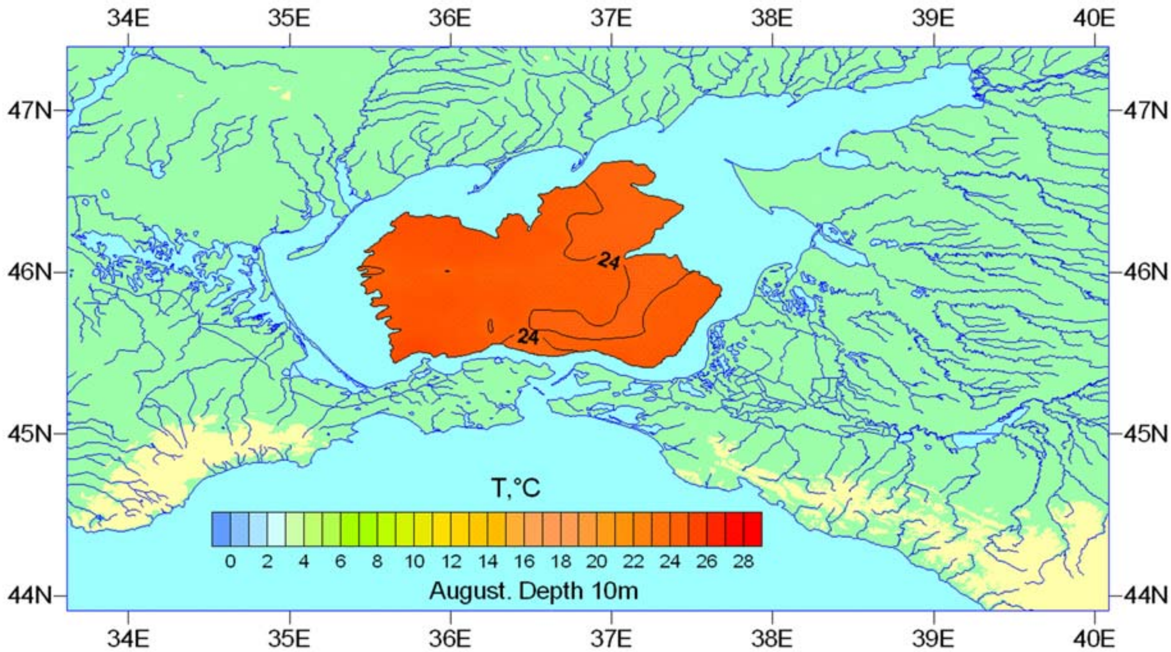
July. Depth 10m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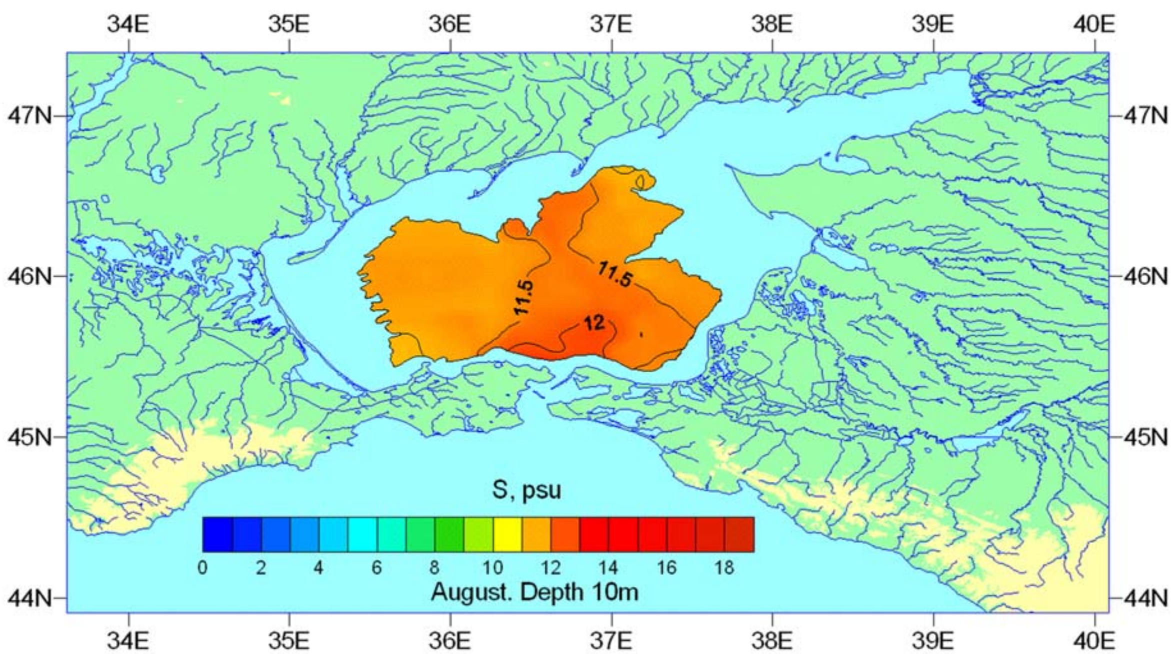
August. Depth 10m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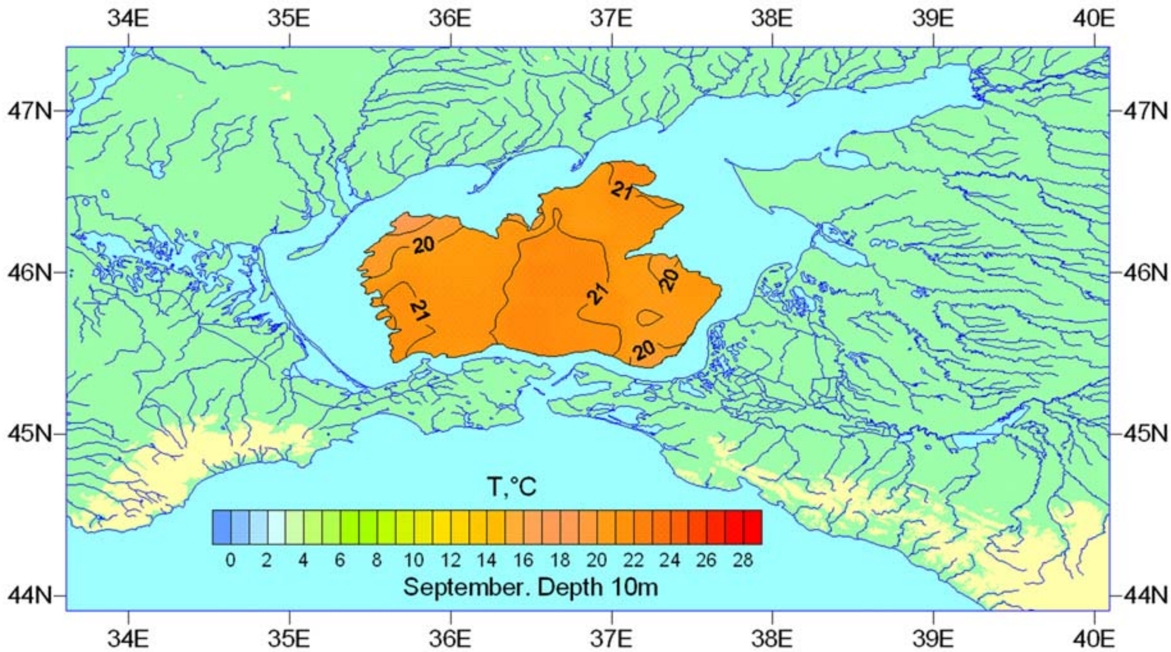
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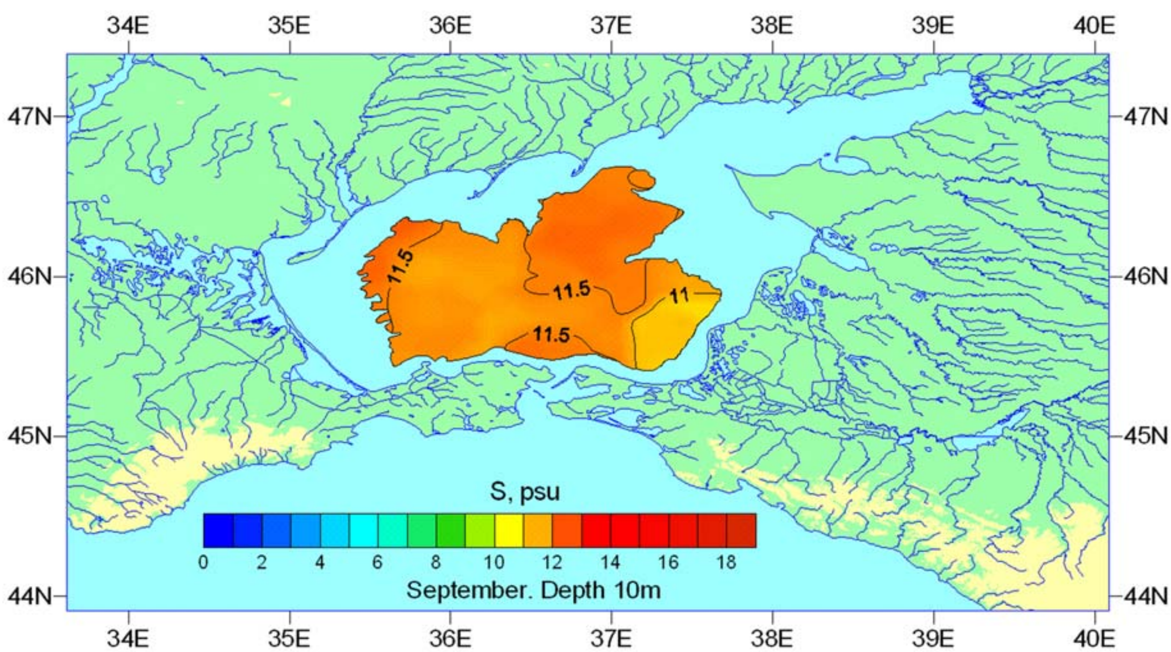
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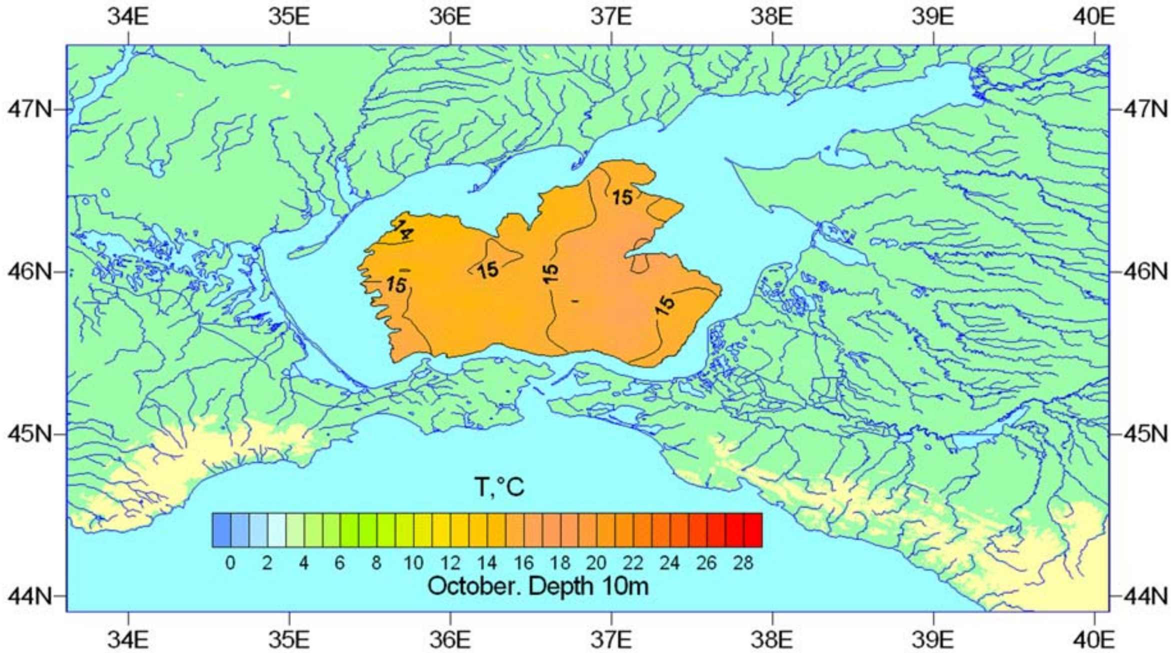
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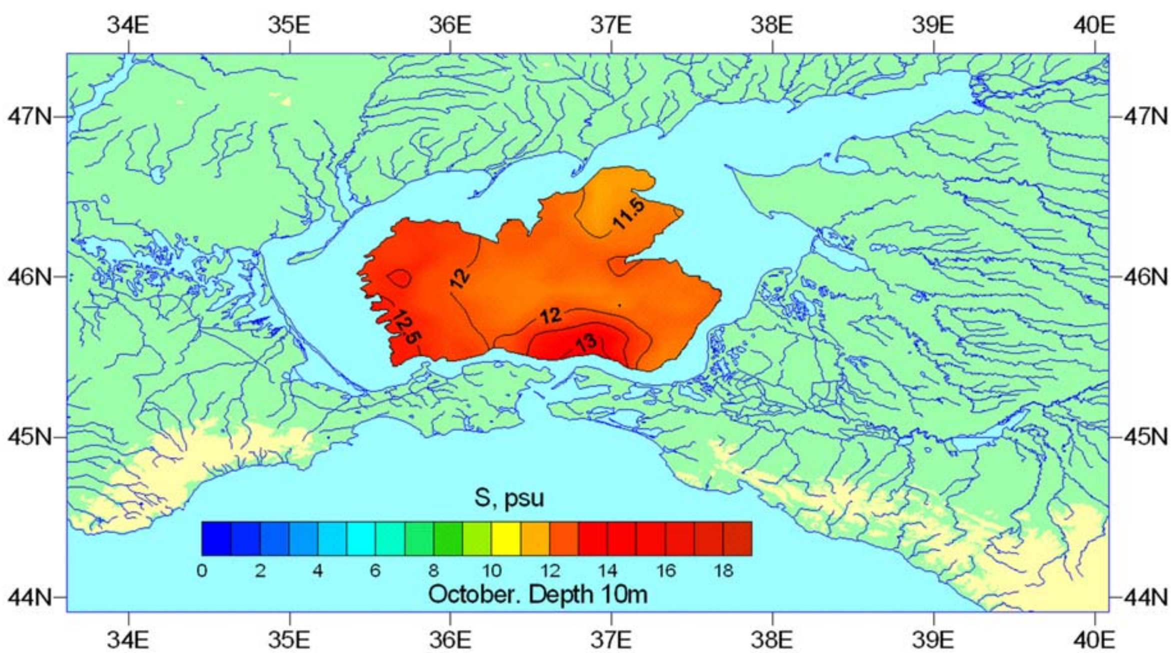
October. Depth 10m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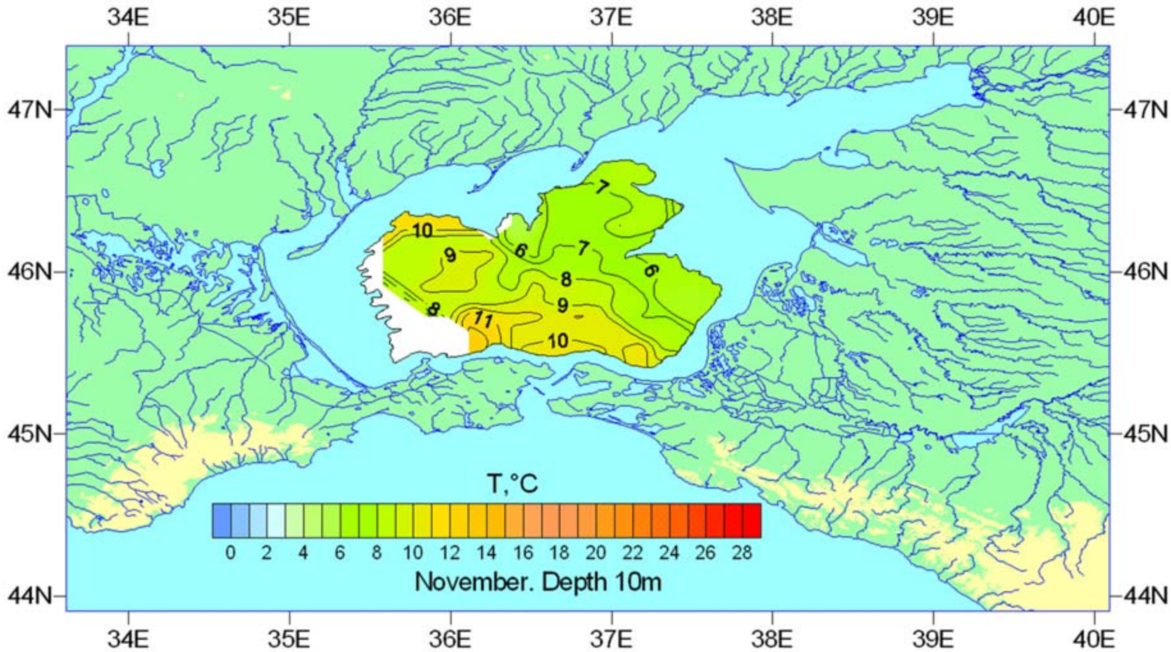
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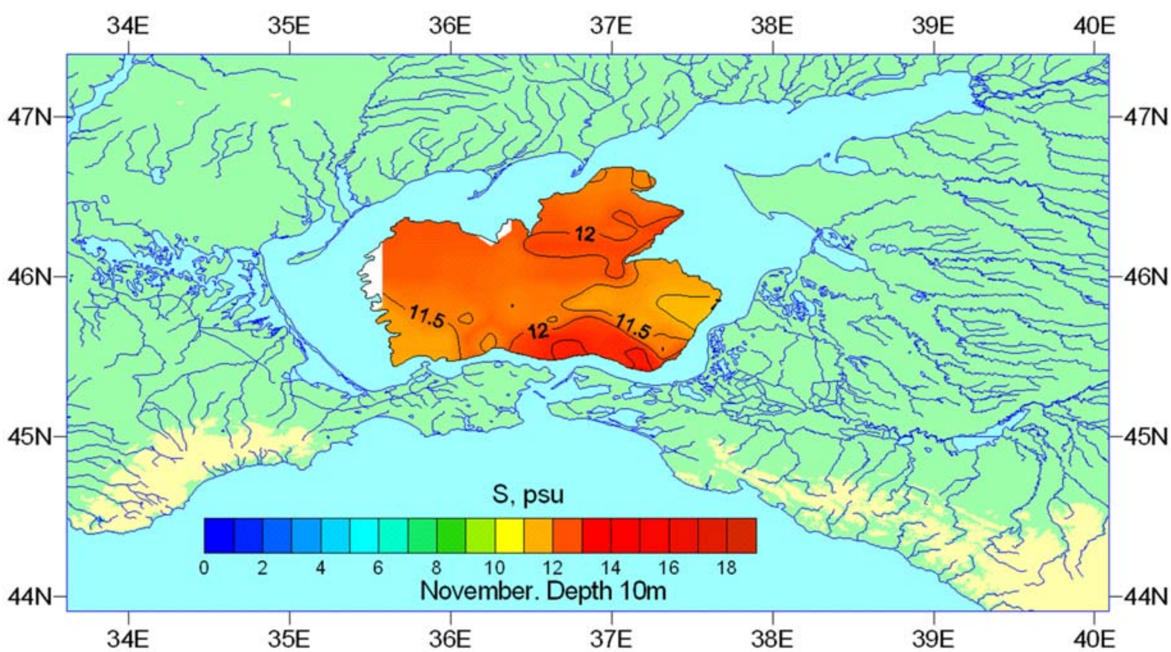
November. Depth 10m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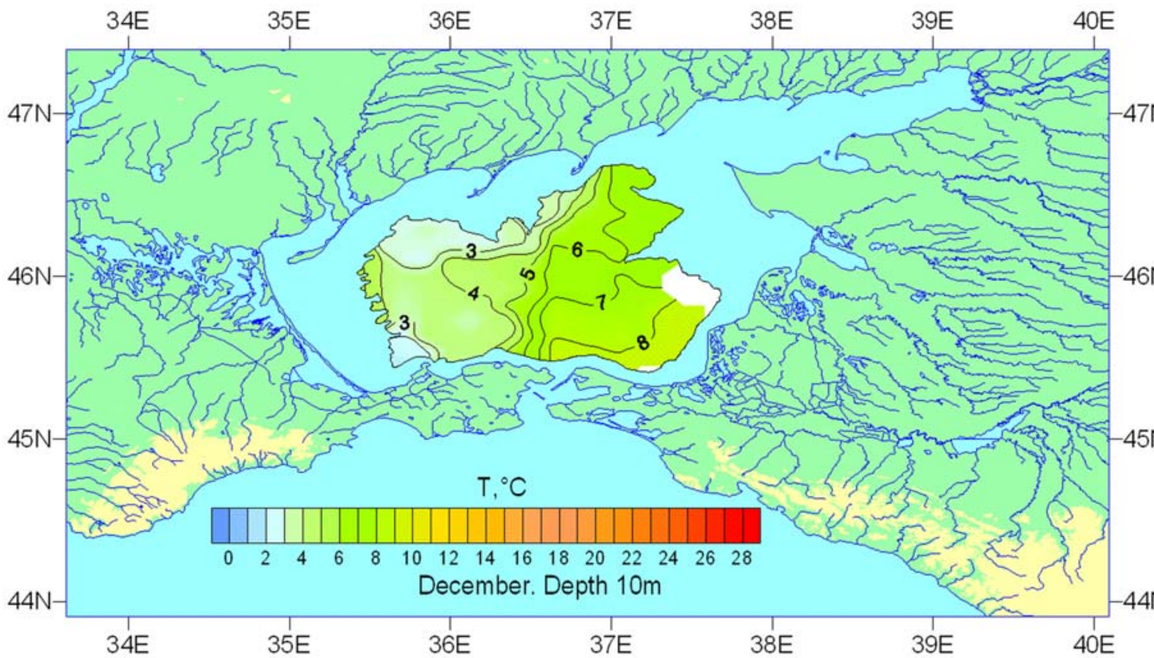
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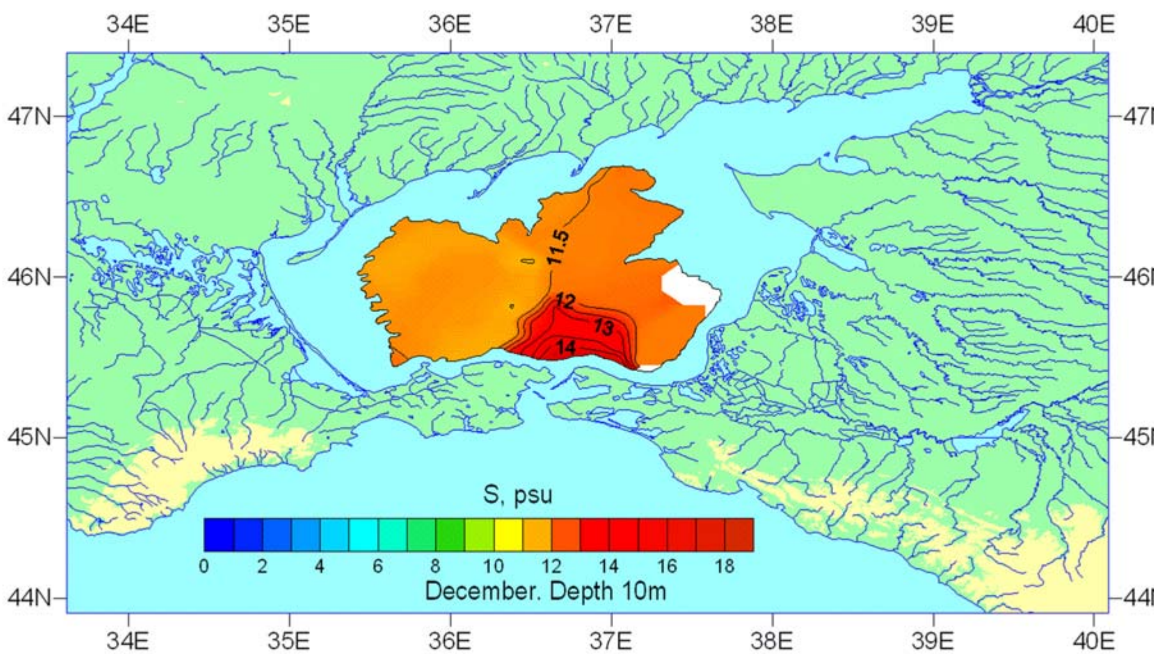
December. Depth 10m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December. Depth 10m