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# SST lowering in the Sea of Okhotsk as the result of global warming

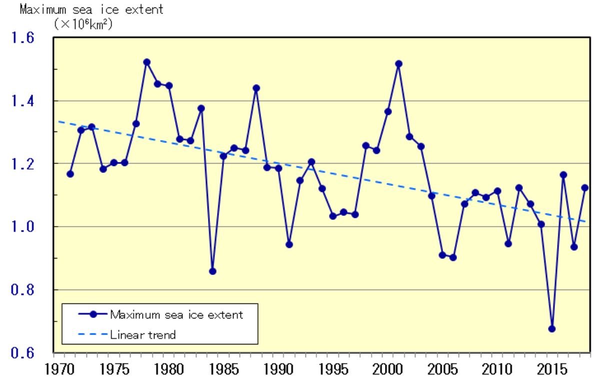
# Introduction

There is a lot of evidence of global climate change:

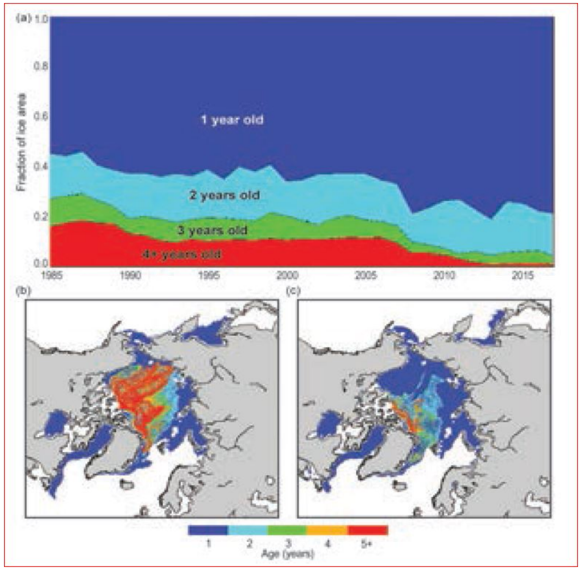
- the temperature in the Arctic latitudes (60⁰-90⁰N) is increasing;
- the average area, age and thickness of the Arctic ice is steadily declining;

A decrease in ice coverage is also observed in the Sea of Okhotsk.

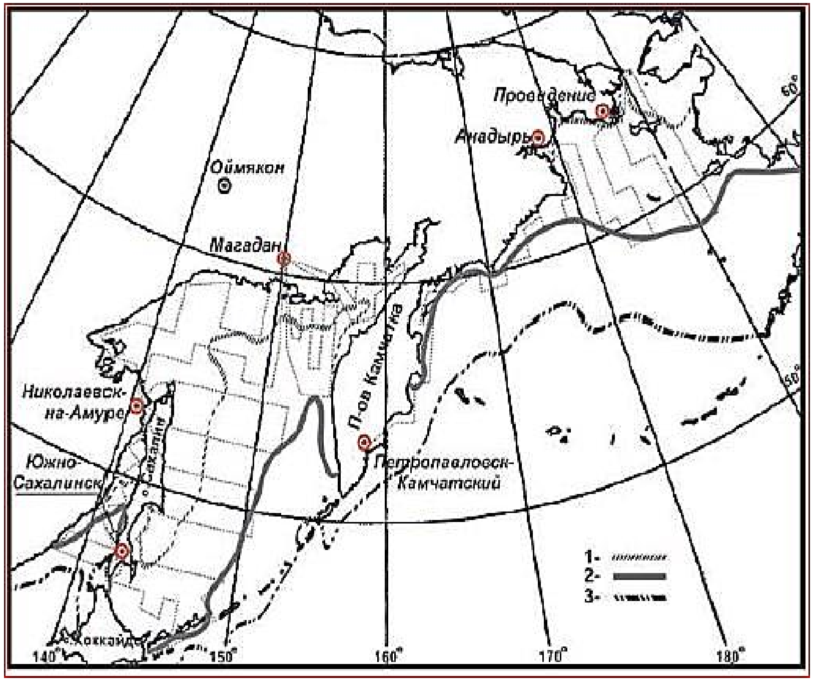
This leads to the occurrence of winter convection and more intense cooling of the surface layer of the sea in the ice-free region.



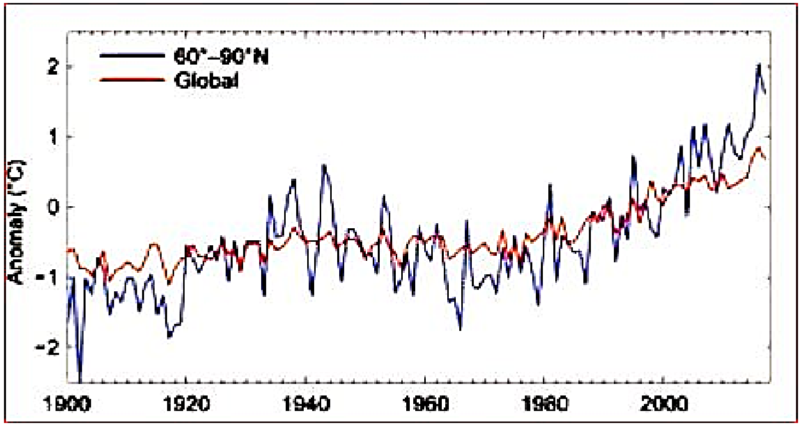

Source: JMA report




Perovich et al., 2017




Yakunin, 2012




Source: CRUTEM4 dataset

# Goals:

- **Determine the coefficients of the linear trend of the surface temperature of the Sea of Okhotsk and adjacent water areas;**
- **Analyze the relationship of these coefficients with the observed decrease in ice coverage over the past twenty years in the Sea of Okhotsk.**

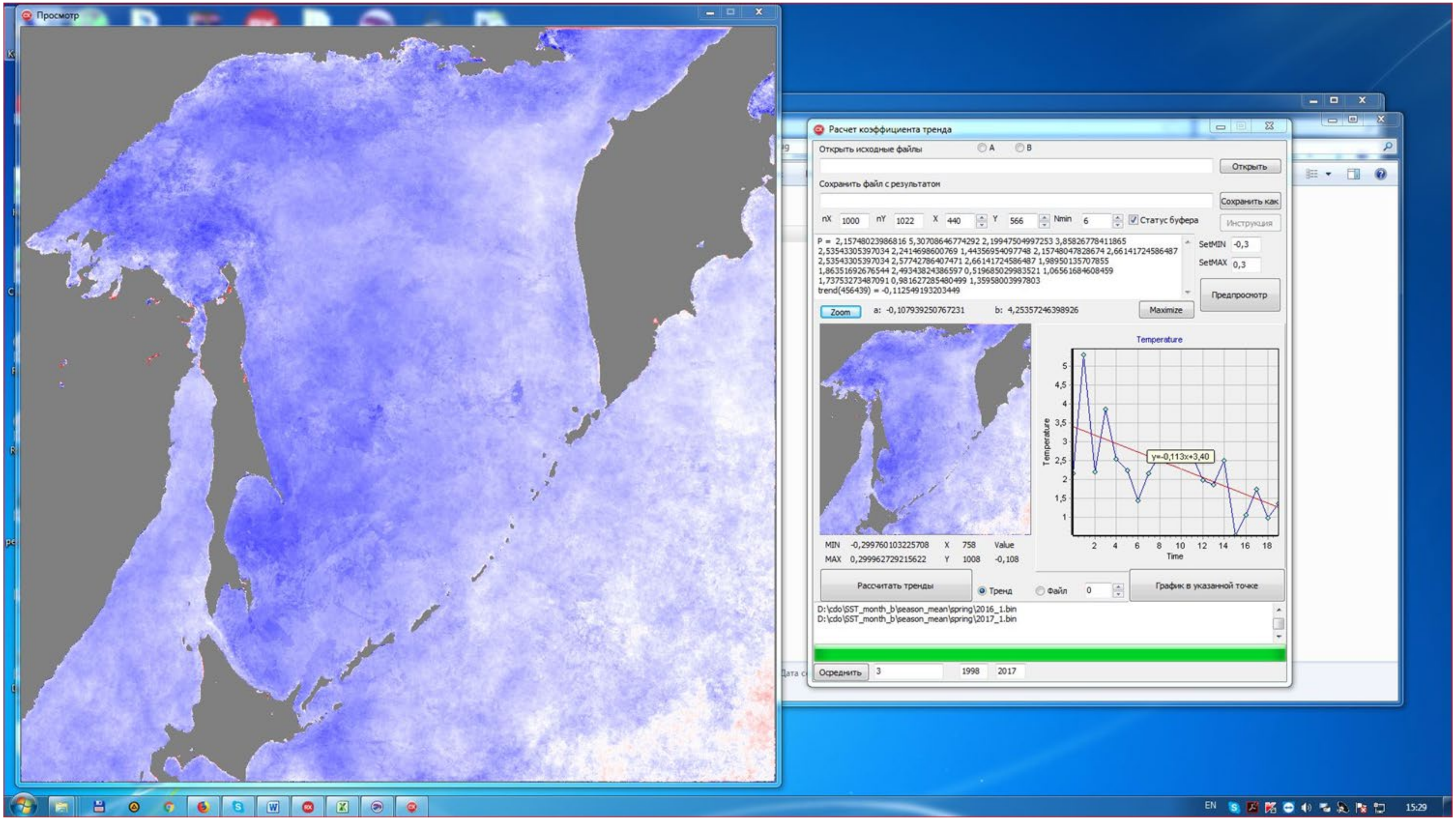
# Objectives:

- **Automate the process of calculating linear trend coefficients;**
- **Display the received data in the form of graphs and images;**
- **For each month separately, for a number of average annual values, as well as for the average temperature values for the season, build maps of the distribution of linear trend coefficients.**

# Materials and methods

- **For the entire area (from 42 ° to 60 ° north latitude and 135 to 160 ° east longitude), a series of mean monthly values of the ocean surface temperature (SST) were formed from satellite measurements with a duration of 20 years (1998-2017).**
- **The spatial resolution of the data is about 2 km.**
- **Matrix of 1000 × 1022 spatial cells processed.**
- **For each month separately, for a number of average annual values, as well as for the average temperature values for the season, for each spatial cell, the linear trend coefficients were calculated.**
- **Maps of the distribution of these coefficients were built (the files were pre-processed with the median 19 × 19 filter).**

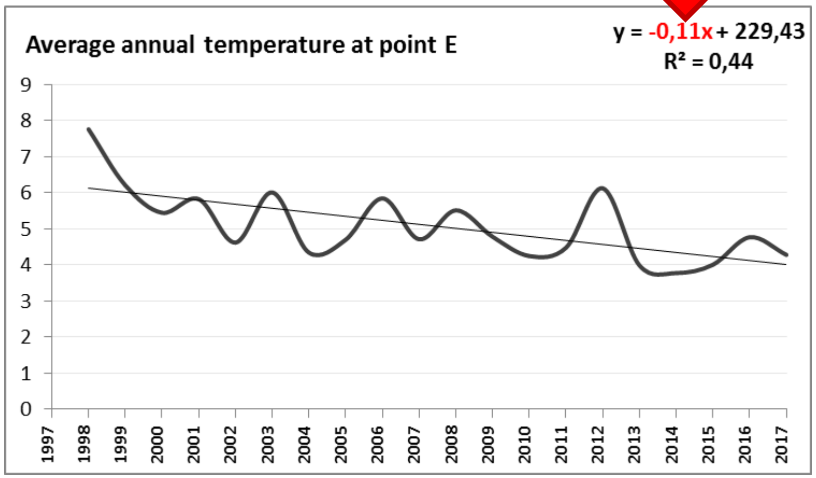
# Software



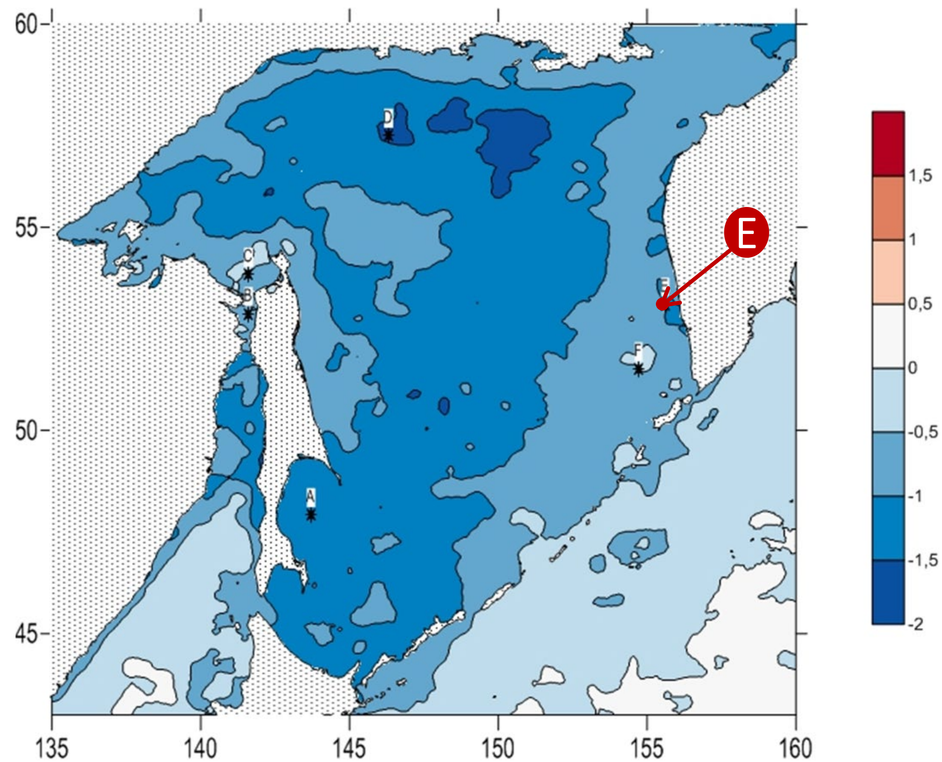
Просмотр
Расчет коэффициента тренда
Открыть исходные файлы
A
B
Открыть
Сохранить файл с результатом
Сохранить как
nX 1000 nY 1022 X 440 Y 566 Nmin 6
Статус буфера
Инструкция
P = 2,1574802398681 6 5,30708646774292 2,19947504997253 3,85826778411865
2,53543305397034 2,2414698600769 1,44356954097748 2,15748047828674 2,66141724586487
2,53543305397034 2,57742786407471 2,66141724586487 1,98950135707855
1,86351692676544 2,49343824386597 0,519685029983521 1,06561684608459
1,73753273487091 0,981627285480499 1,35958003997803
trend(456439) = -0,112549193203449
SetMIN -0,3
SetMAX 0,3
Предпросмотр
Zoom
a: -0,107939250767231
b: 4,25357246398926
Maximize
Temperature
y=-0,113x+3,40
Temperature
Time
MIN -0,299760103225708 X 758 Value
MAX 0,299962729215622 Y 1008 -0,108
Рассчитать тренды
Тренд
Файл
0
График в указанной точке
D:\cdo\SST_month_b\season_mean\spring\2016_1.bin
D:\cdo\SST_month_b\season_mean\spring\2017_1.bin
Осреднить
3
1998
2017
EN
15:29

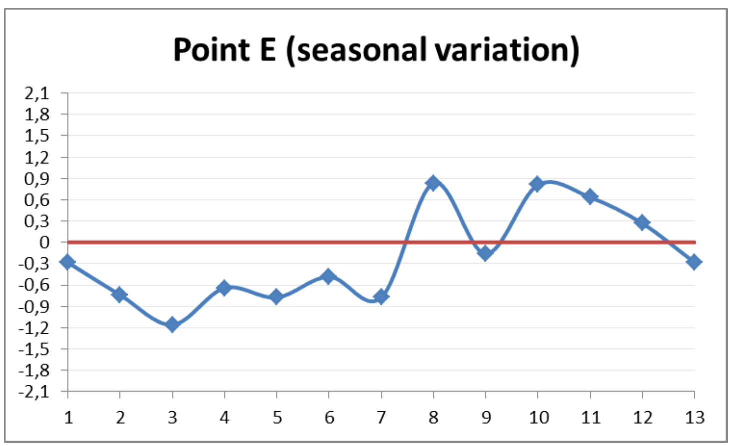
# Coefficients of linear trends in SST

**This coefficient means the rate of temperature change in one year.**



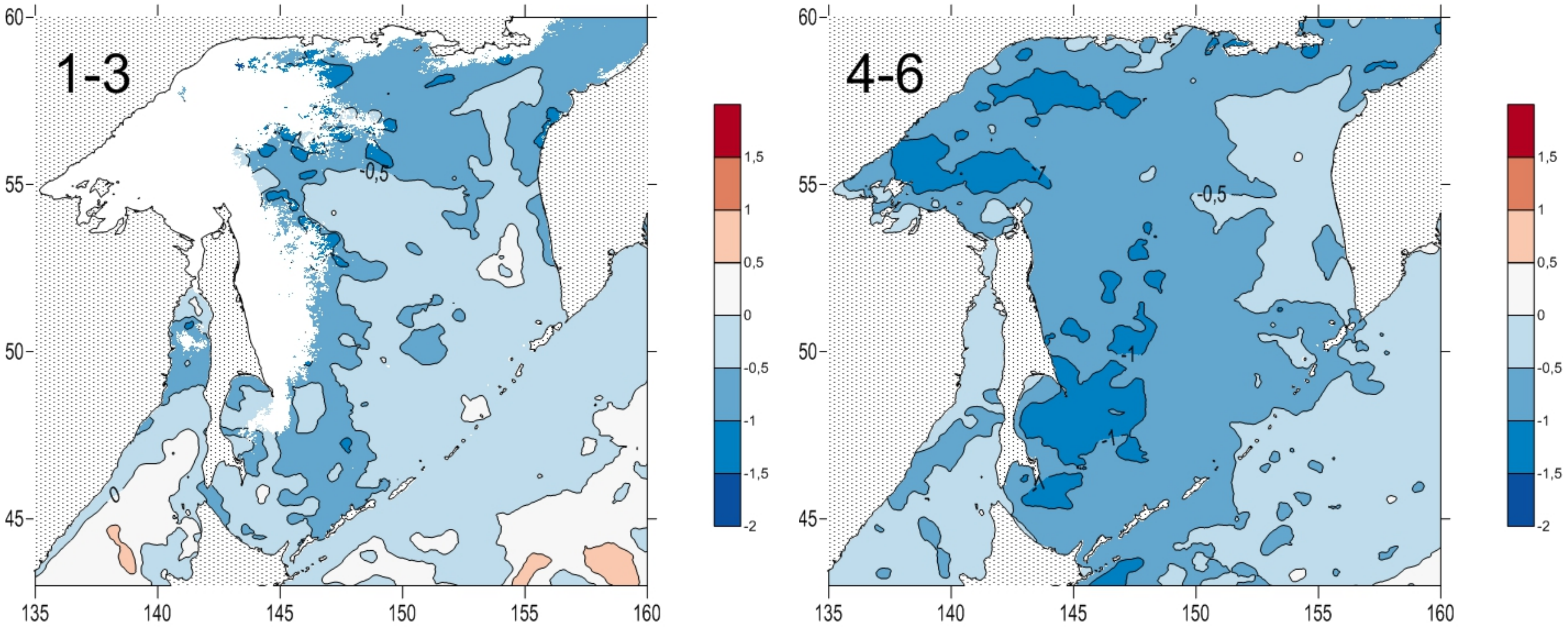

**Distribution map of coefficients of linear trend in terms of the average annual SST values (the scale corresponds to the change in temperature in $^0$C per 10 years)**




**The bottom graph shows the seasonal variations in the coefficients of the linear trend at a specified point (the scale corresponds to $^0$C per 10 years)**

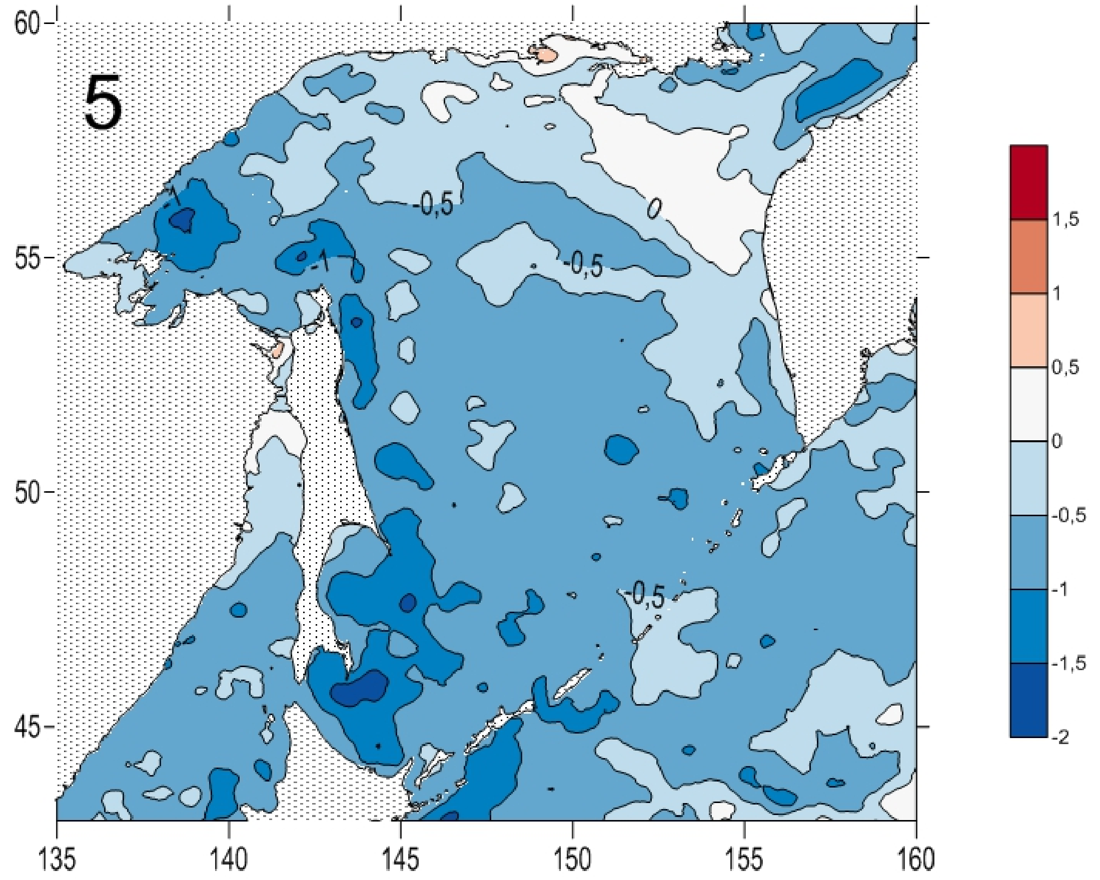
# Winter and spring




**In the northern and western parts of the Sea of Okhotsk, the rate of temperature decrease from 1 to 1.5 ° C over 10 years, in some areas even higher.**

# May

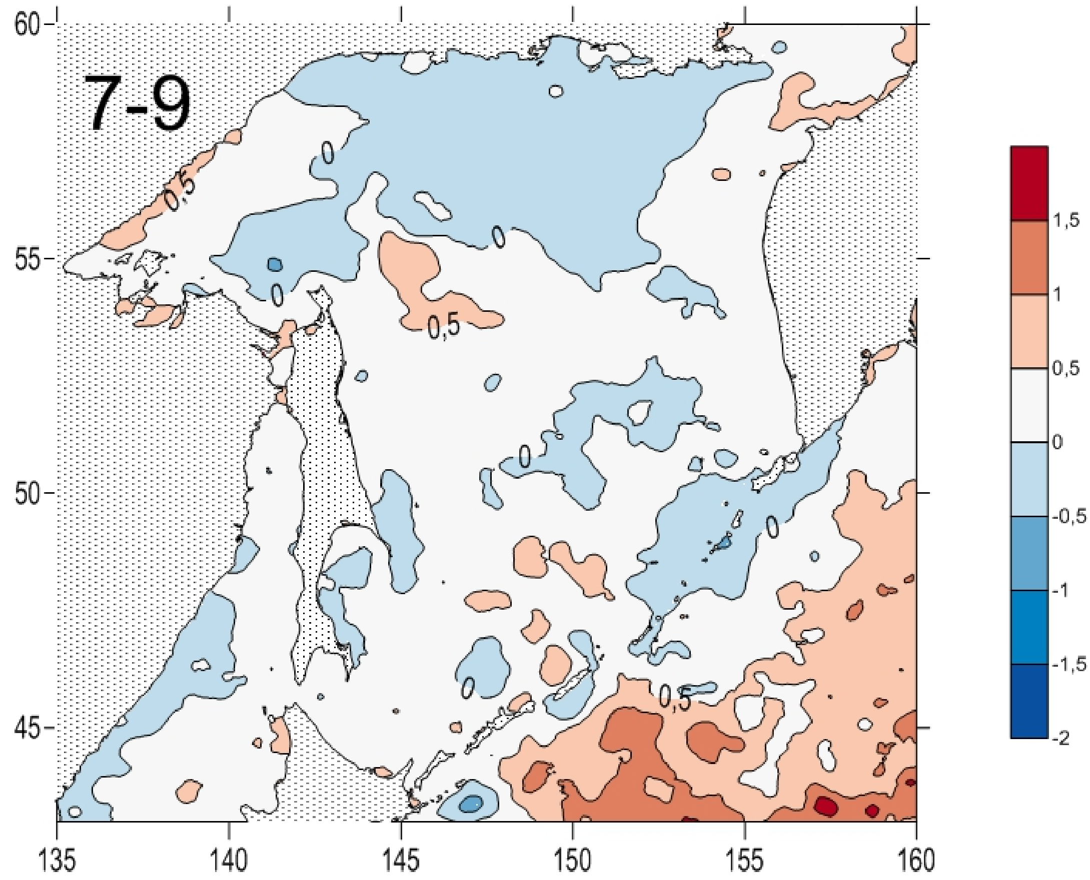
**The most intense cooling is observed in May, primarily in the northwestern part of the Sea of Okhotsk and along the entire eastern coast of about. Sakhalin from Cape Elizaveta in the north to Cape Aniva in the south. The only exceptions are the western part of the Amur estuary, which accounts for the bulk of the Amur flood waters, and the water area adjacent to the Tauiskaya Bay.**



# Summer

**The region is dominated by an upward trend in sea surface temperature, most pronounced in the northwestern Pacific. In the Sea of Okhotsk, it was recorded in its northwestern part, in the Sakhalin Bay and the Amur Estuary and in some other areas.**

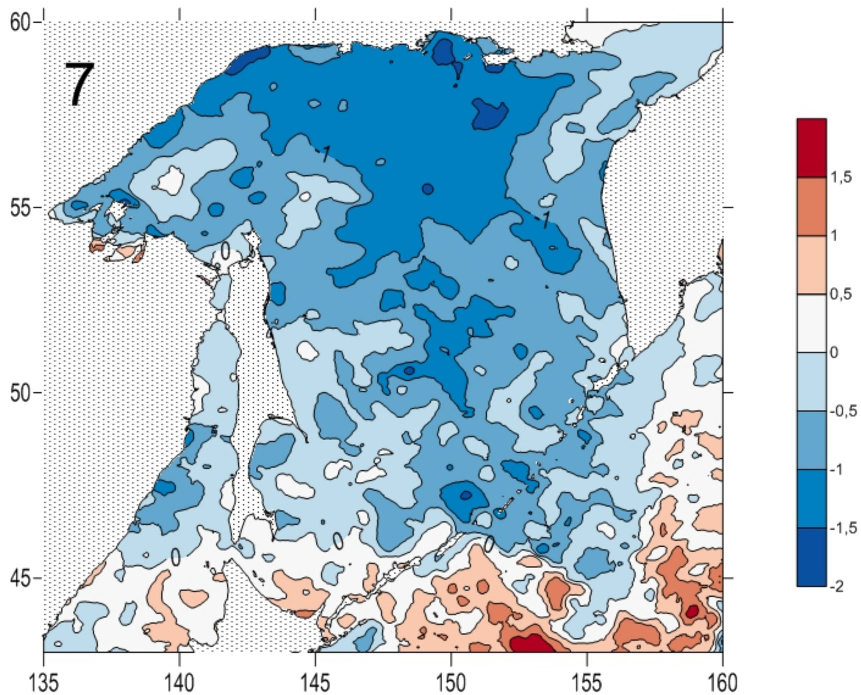
**In the northern part of the sea, near the Kuril Islands, off the southeastern coast of Sakhalin Island and along the coast of Primorye in the Sea of Japan, a tendency towards a decrease in temperature continues, although in a more moderate form than in spring.**

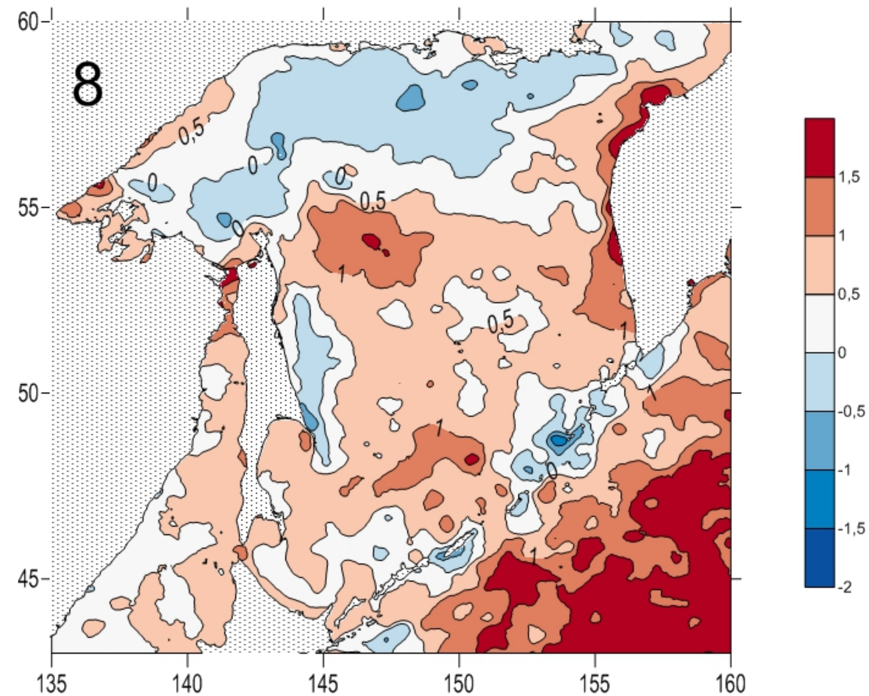


# July and August (shift)

The trend towards a decrease in sea surface temperature prevails; the trend changes only in the northwestern part of the Pacific Ocean.

The rate of warming reaches the highest values (about 1.5 °C over 10 years), an increase in temperature was noted in the central part of the Sea of Okhotsk, along the western coast of Kamchatka and off the southeastern coast of Sakhalin, in the Tatar Strait and Amur estuary.



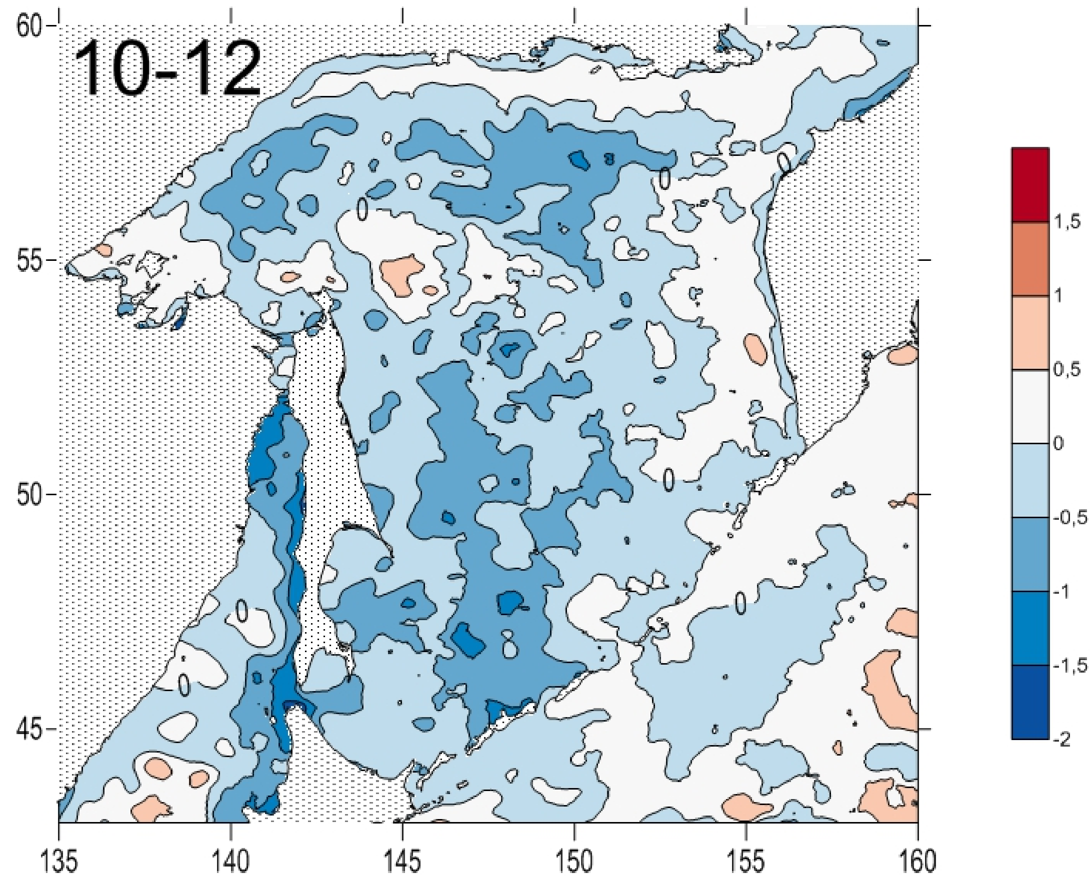




In the northern part of the sea, on the northeastern shelf of Sakhalin and in the Kuril region, a tendency towards a decrease in sea water temperature persists

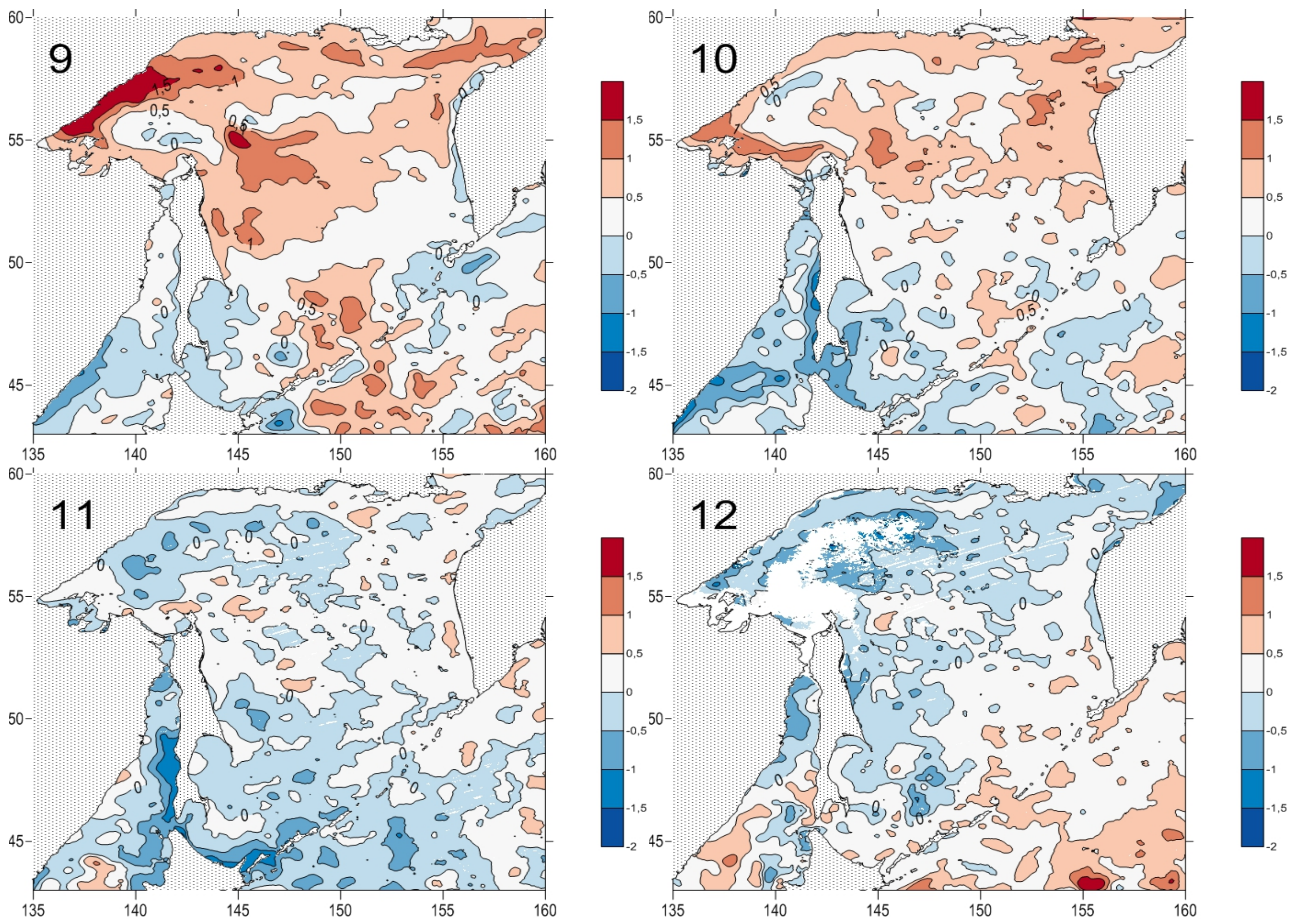
# Autumn

In most of the Sea of Okhotsk, relatively small negative trends prevail, positive (also insignificant) ones are noted in the eastern part of the sea on the western shelf of Kamchatka and in a relatively narrow strip along the northern coast. Smaller areas were also noted in the area of the Kashevarov Bank and in the southwestern part of the analyzed water area of the Sea of Japan.

The highest rates of decrease in heat content in the surface layer were noted in the Tatar Strait, in its northern part and along the western coast of Sakhalin. In the Sea of Okhotsk - in its northern part, outside the shelf, off the southeastern coast of about. Sakhalin, as well as in the strip between 145 and 150 meridians from the Urup and Iturup islands to the Kashevarov Bank.



# Switching to winter mode



# Conclusion

- The result of global warming in this basin, in addition to a decrease in ice coverage, is a decrease in the heat content of the upper water layer. The negative temperature trends in spring are especially large in the northern and western parts of the studied region, as well as in the Tatar Strait of the Sea of Japan (from 0.5 to 1.5 ° C over 10 years). It is this effect of a decrease in the area of ice cover both in time and in space that looks most logically can be explained by an increase in the depth of winter convection. The predominance of a decrease in sea surface temperature, although less pronounced, was also noted in winter and autumn, and for the whole year as a whole.
- In summer, the region is dominated by an upward trend in sea surface temperature, most pronounced in the northwestern Pacific. In the Sea of Okhotsk, it was recorded in its northwestern part, east of the northern tip of Sakhalin Island, off the northwestern coast of the Kamchatka Peninsula, and in some other areas. Moreover, in July, the processes of cooling of the surface layer also play the main role; the trend changes in August and manifests itself in September-October.
- The identified processes play a significant role in climate variations in the Sea of Okhotsk region, in particular, a decrease in sea water temperature is noticeable in the coastal waters of Sakhalin Island. In addition to weather conditions, the results obtained are important for studying the habitat conditions of commercial fish and invertebrate species in a basin of great fishery importance.