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Oceanological conditions on the southeastern Sakhalin shelf according to surveys on standard sections and satellite SST observations

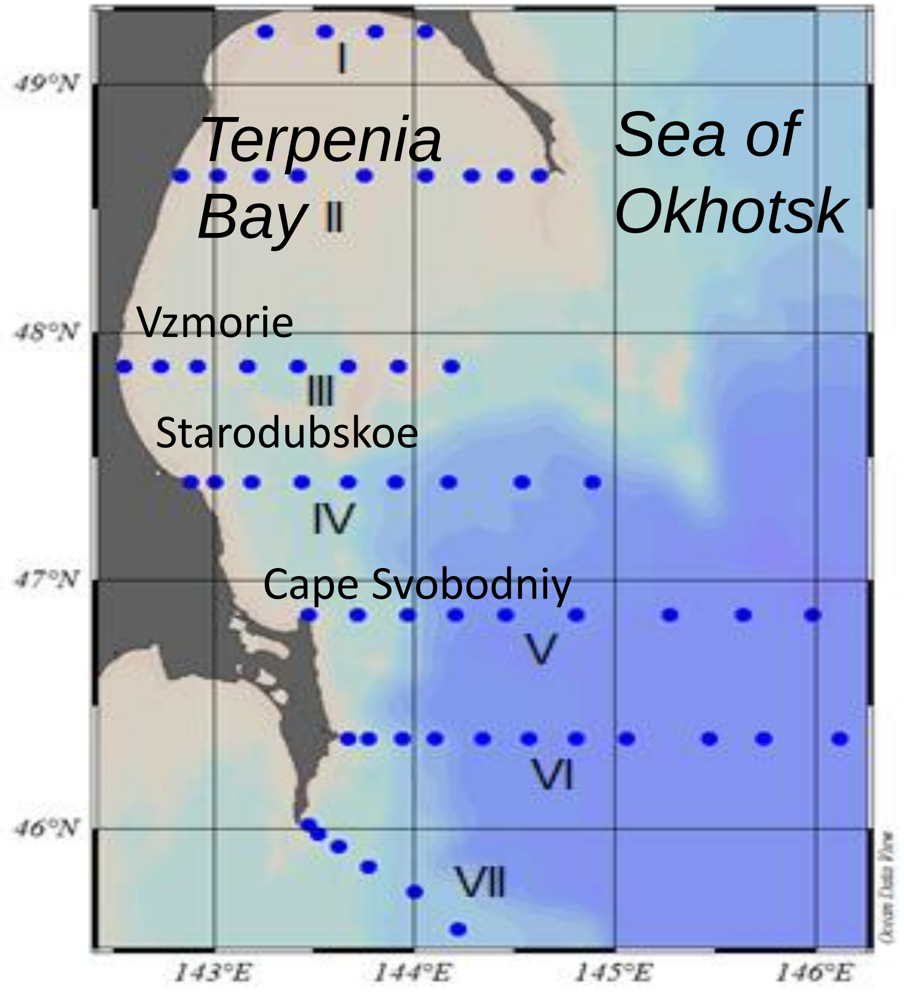
Introduction

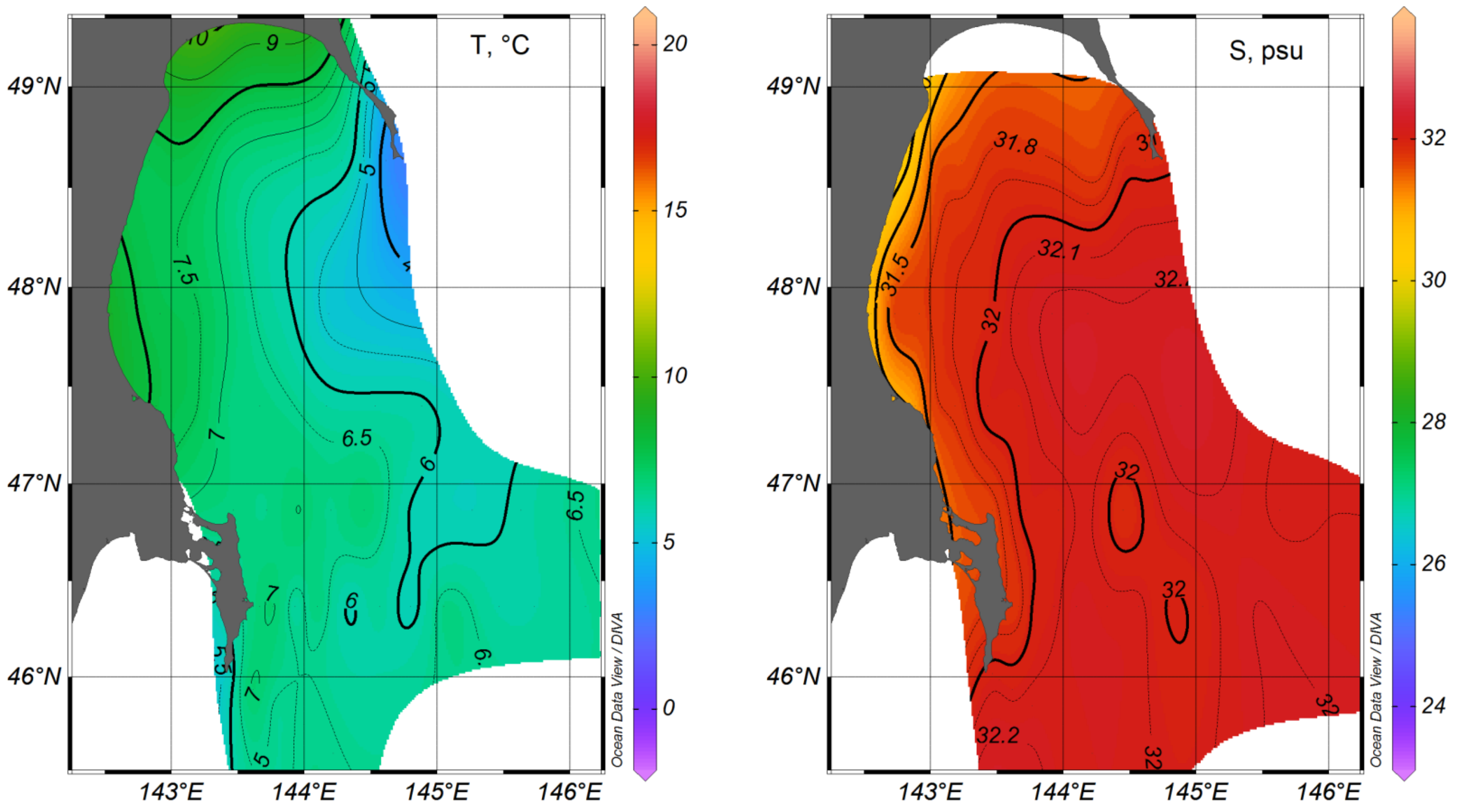
The extended shelf and continental slope adjacent to the southeastern coast of Sakhalin is an important fishing area. A large number of pink salmon and chum salmon are caught here (most of Sakhalin's salmon hatcheries are located on this coast), cod, flounder and other fish species. Therefore, the study of the features of oceanological conditions in this area, their seasonal and interannual variability is an important task. Seasonal variations are very significant here, they are caused by the transport of freshened water from the Amur River runoff by the East Sakhalin Current in autumn. The peculiarities of the spatial distributions of temperature and salinity in different seasons have not been sufficiently studied, although there is observational material for this on 7 standard oceanological sections. The interannual variations in the thermal conditions of this area have been studied even less; for this purpose, data from satellite observations of the sea surface temperature were used.

DATA

Multiyear mean water temperature and salinity values on the 7 standard oceanological sections crossed SE Sakhalin shelf calculated for the standard horizons 0, 10, 20, 30, 50, 100, 200, 300 and 500 m (Pishchalnik, Bobkov, 2000).

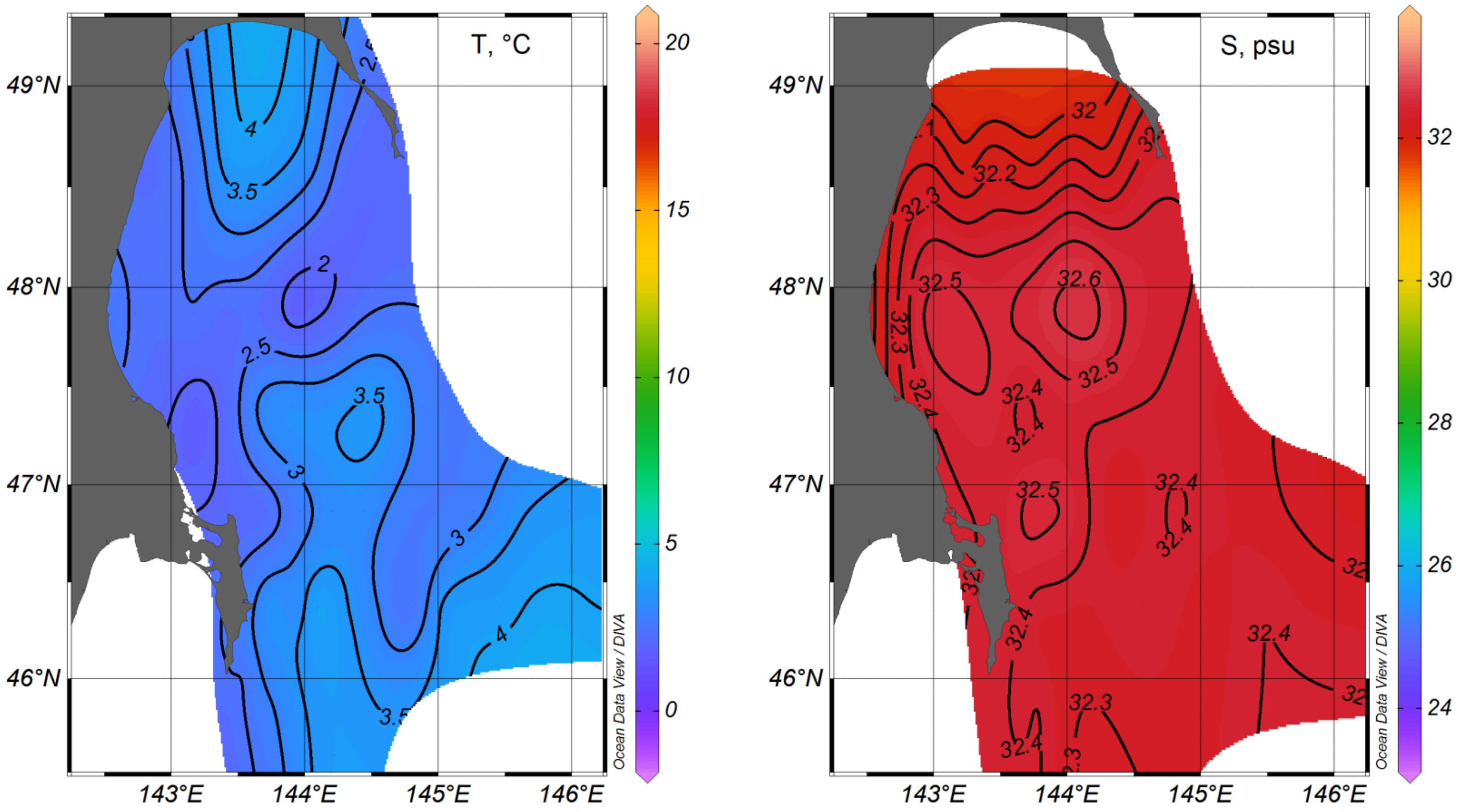
Monthly mean satellite SST values in the 0.25° x 0.25° squares for period 1998 – 2018 obtained using RFIFO (Sakhalin branch) satellite receiving station TeraScan (website www.sakhniro.ru).





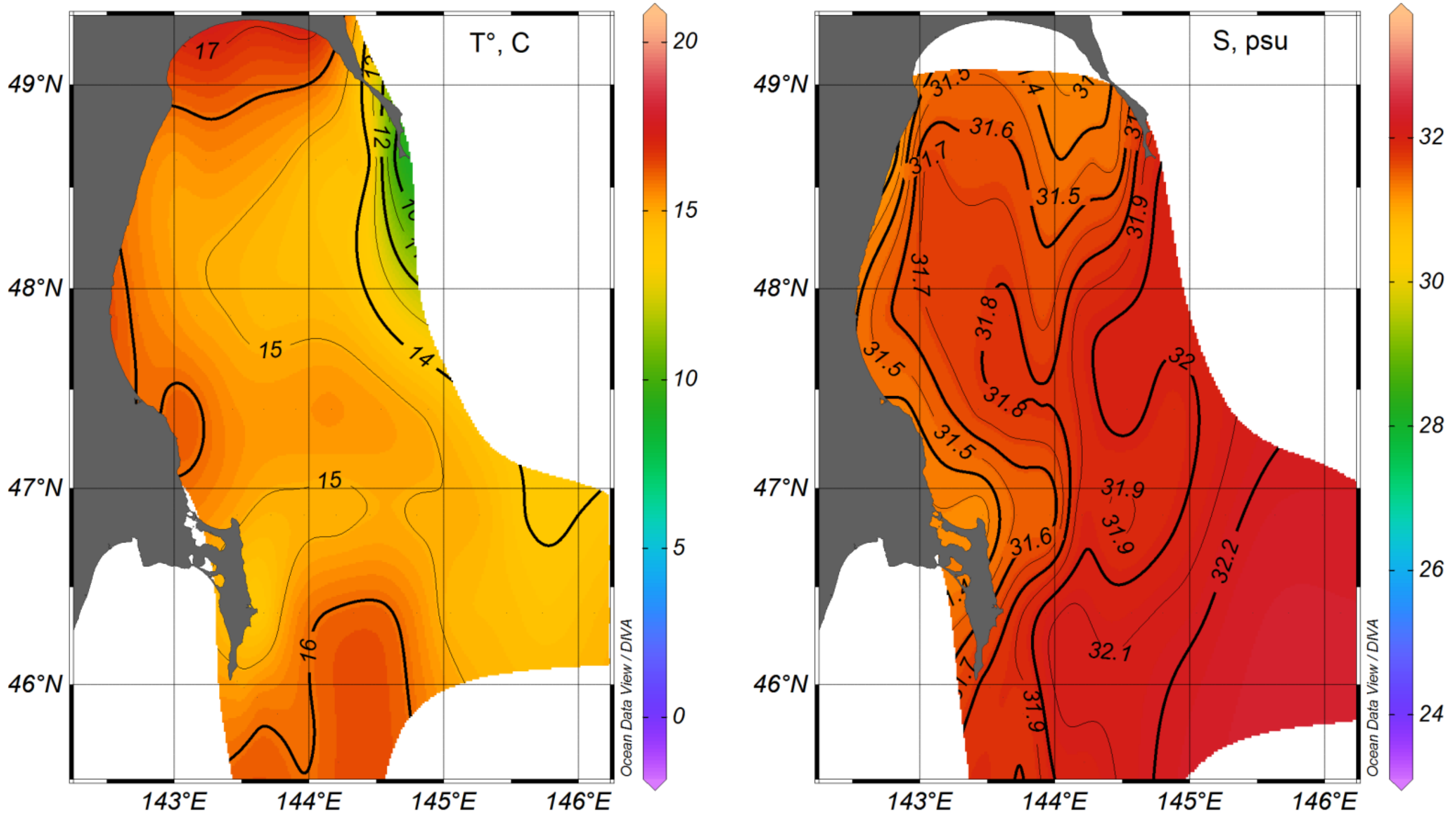
Multiyear mean water temperature and salinity distributions on the sea surface based on the data obtained on 7 standard sections. Late spring (June).

In June, the warming up of the surface water layer is just beginning, the warmest water (about 8°C) is observed in the coastal zone in the northern and western parts of the study area. This water also has low salinity values (about 31 psu), which indicates the important role of river runoff in their formation (primarily the Poronai River). Melting of remnants of the ice cover may also have some effect, although usually the area of the southeastern shelf is cleared of ice in May. In the eastern part of the region there is colder (5–6°C) and salty (32.2 psu) water.



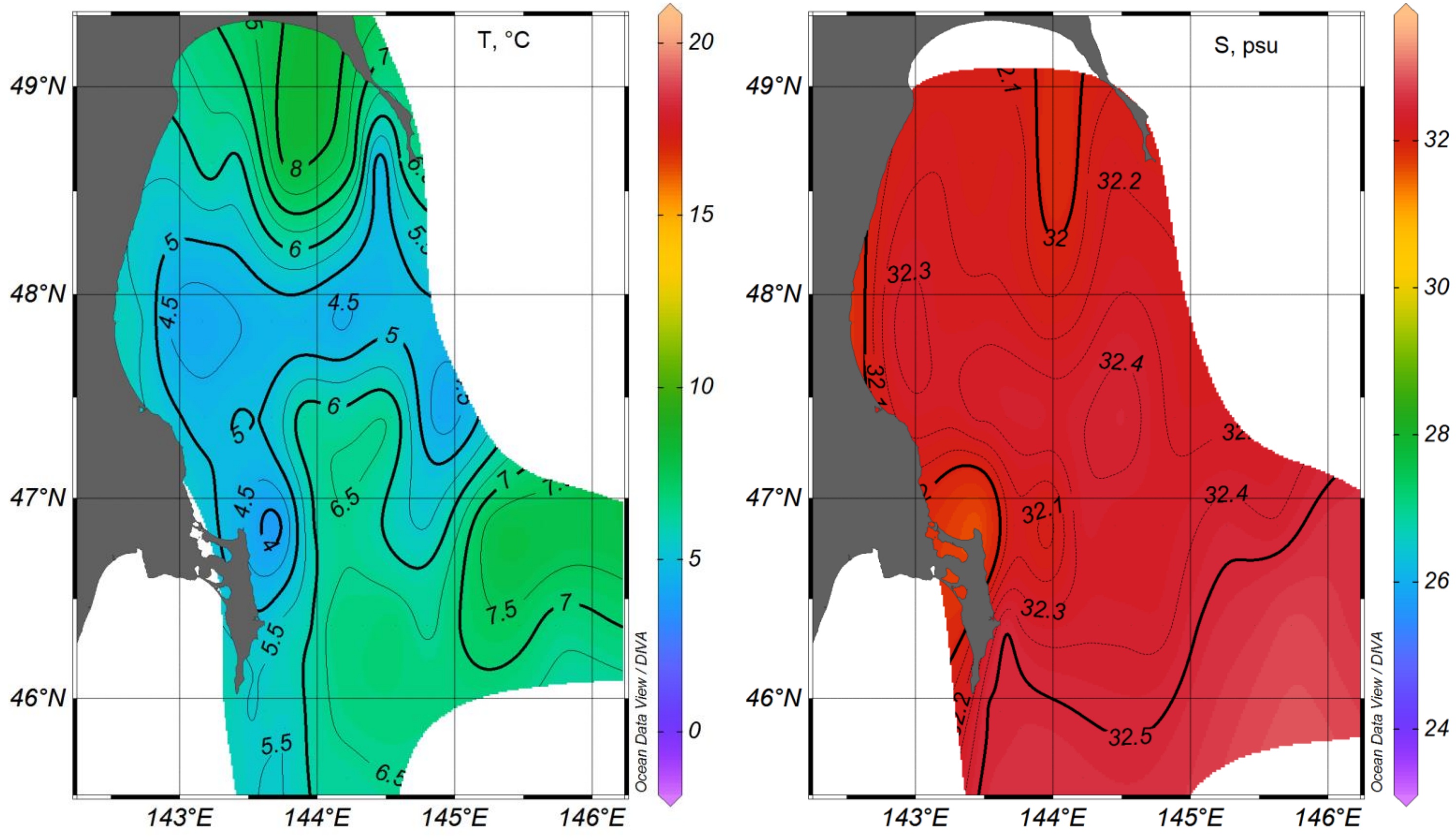
Multiyear mean water temperature and salinity distributions at the depth 20 m based on the data obtained on 7 standard sections. Spring (June).

In deeper layers, the distributions of oceanological parameters are more uniform; cold salt water is observed throughout the entire area. The lowest temperatures (2–2.5 °C) and the highest salinity (32.5–32.6 psu) were recorded along the continental slope from the Cape Terpenia to southwest. The warmest water (more than 4 °C) was found in the top of Terpeniya Bay and in the southeastern part of the study area. Salinity in the Bay is rather low (less than 32 psu) then in the seaward part about (32.3 - 32.4 psu).



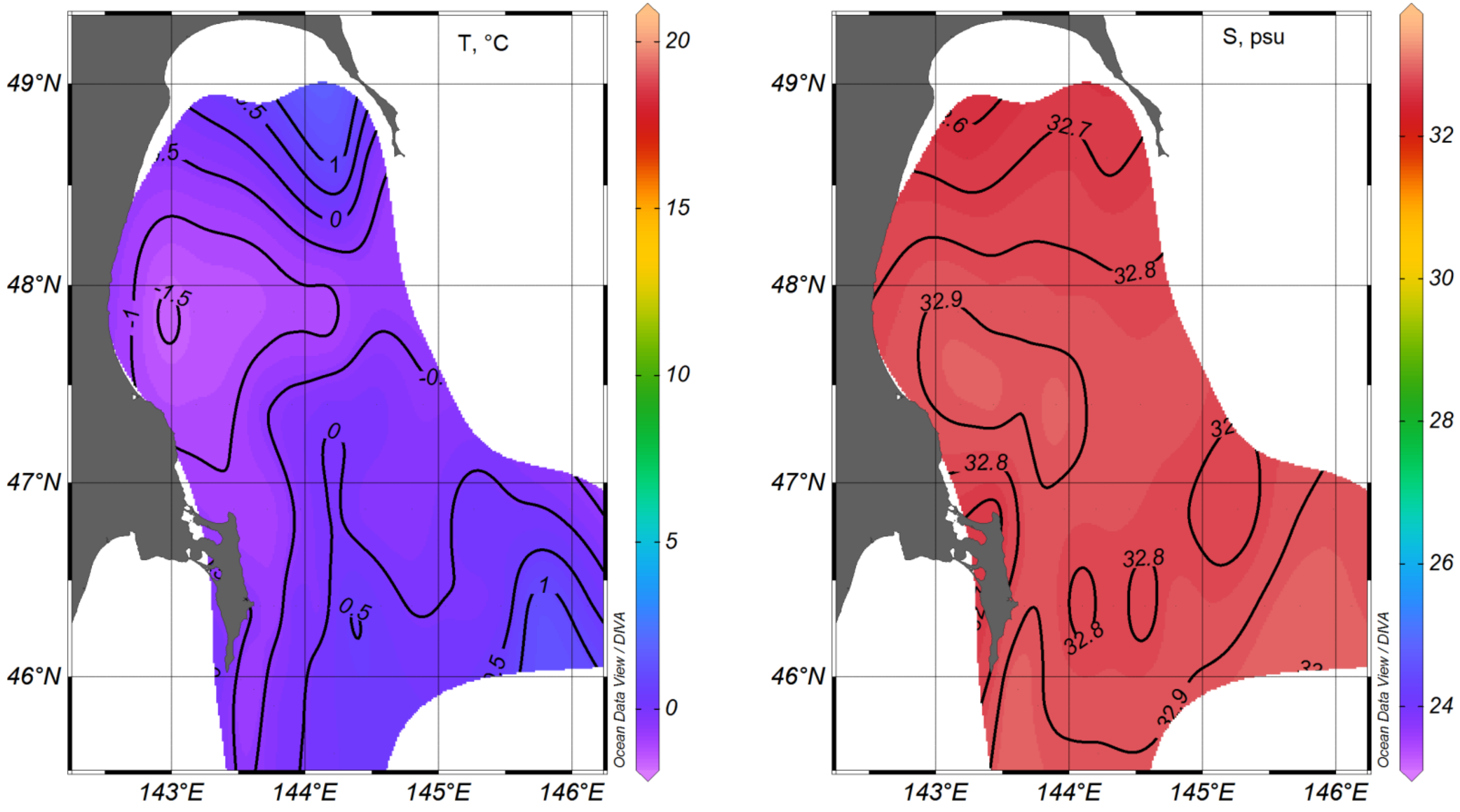
Multiyear mean water temperature and salinity distributions on the sea surface based on the data obtained on 7 standard sections. Warmest season (August).

In summer (July-September), the spatial distribution of water temperature on the sea surface has a similar structure as in spring. The warmest water (15–17°C) was observed at the top of the Terpeniya Bay. Warm water is also observed along the Sakhalin coast and in the southern part of study area. In the salinity distribution, we found two streams of freshened water from the top of the Terpeniya Bay – directed to the south along the coast, and to the southeast, to Cape Terpeniya. Near Cape Svobodny, low salinity water flowing along the coast forms a local lens and does not spread further to the south.



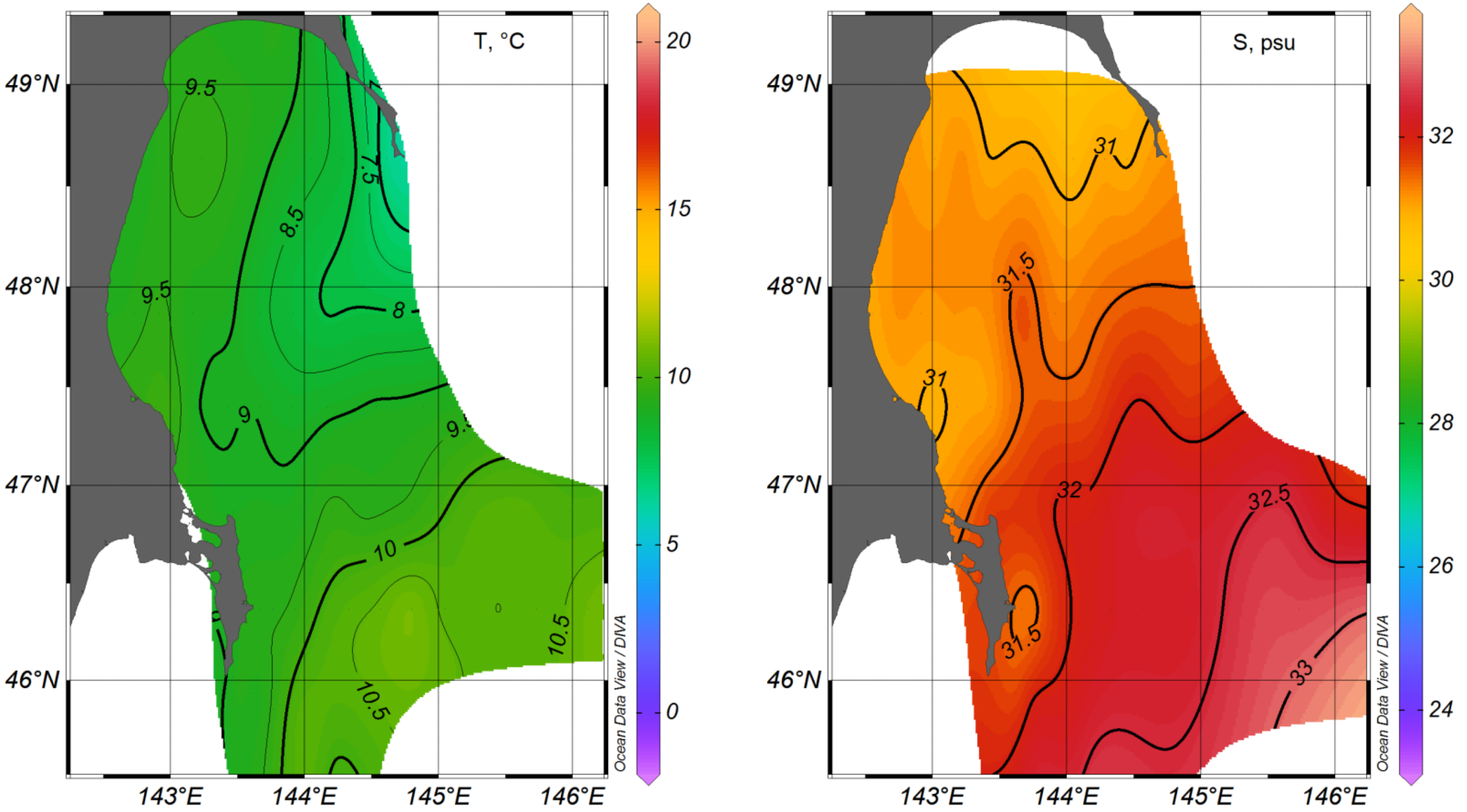
Multiyear mean water temperature and salinity distributions at the depth 20 m based on the data obtained on 7 standard sections. Warmest season (August).

At a depth of 20 m, a warmer water is found in the top of Terpeniya Bay and in the southeastern part of the study area. In the central part, along the continental slope, there is colder water (4-5°C). The deepening of warm low salinity water at the top of the bay is due to the effect of the southerly wind which are typical for the warm season. The reason for the localization and deepening of low salinity water near Cape Svobodny is unclear, most likely the features of the local topography play the main role here.



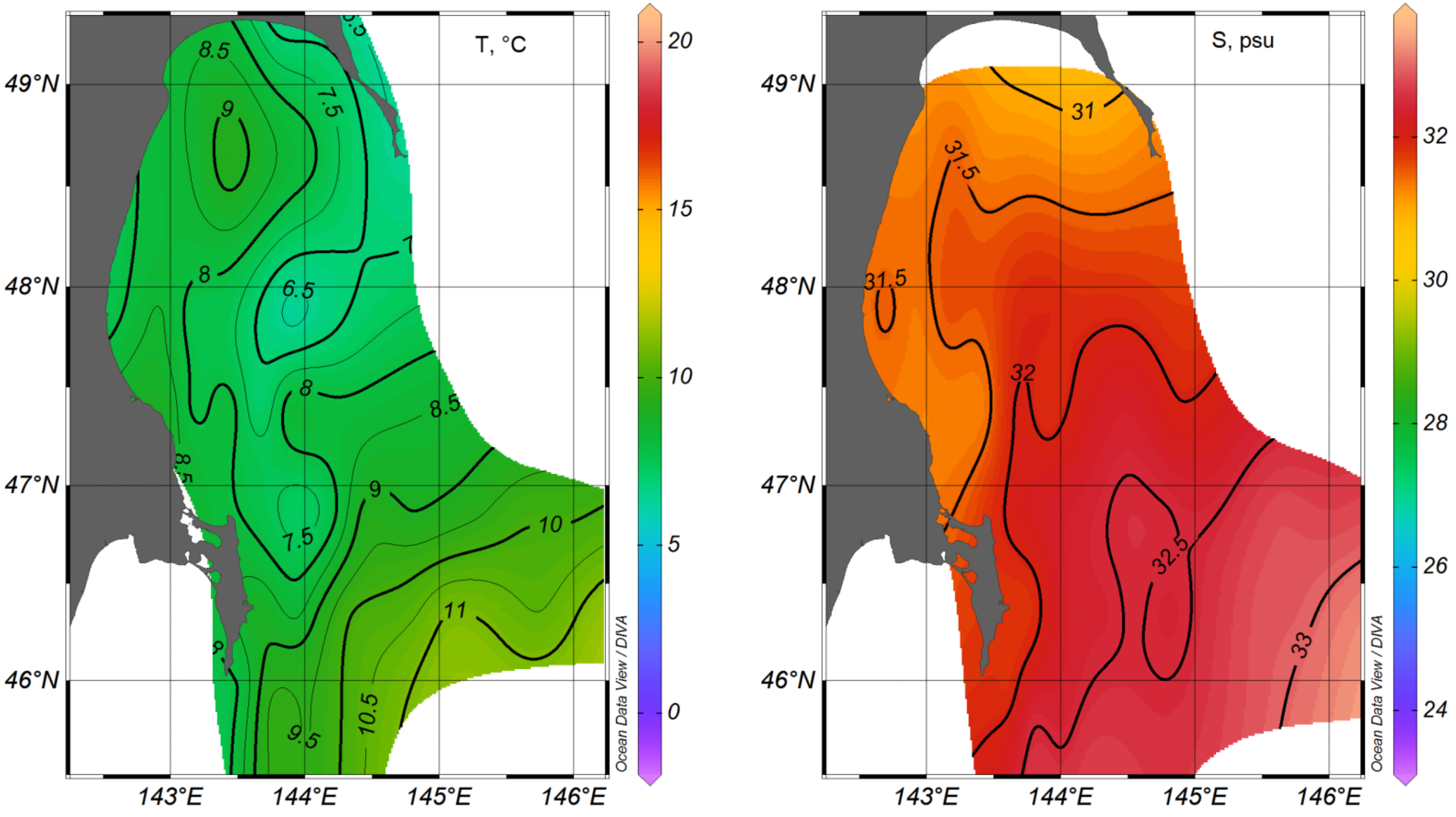
Multiyear mean water temperature and salinity distributions at the depth 50 m based on the data on 7 standard section. Warmest season (August).

Cold (up to negative values) and salt water (32.7- 33 psu) were found at a depth of more than 40 m. It is a cold intermediate layer that forms in the study area in winter during the formation of an ice cover.



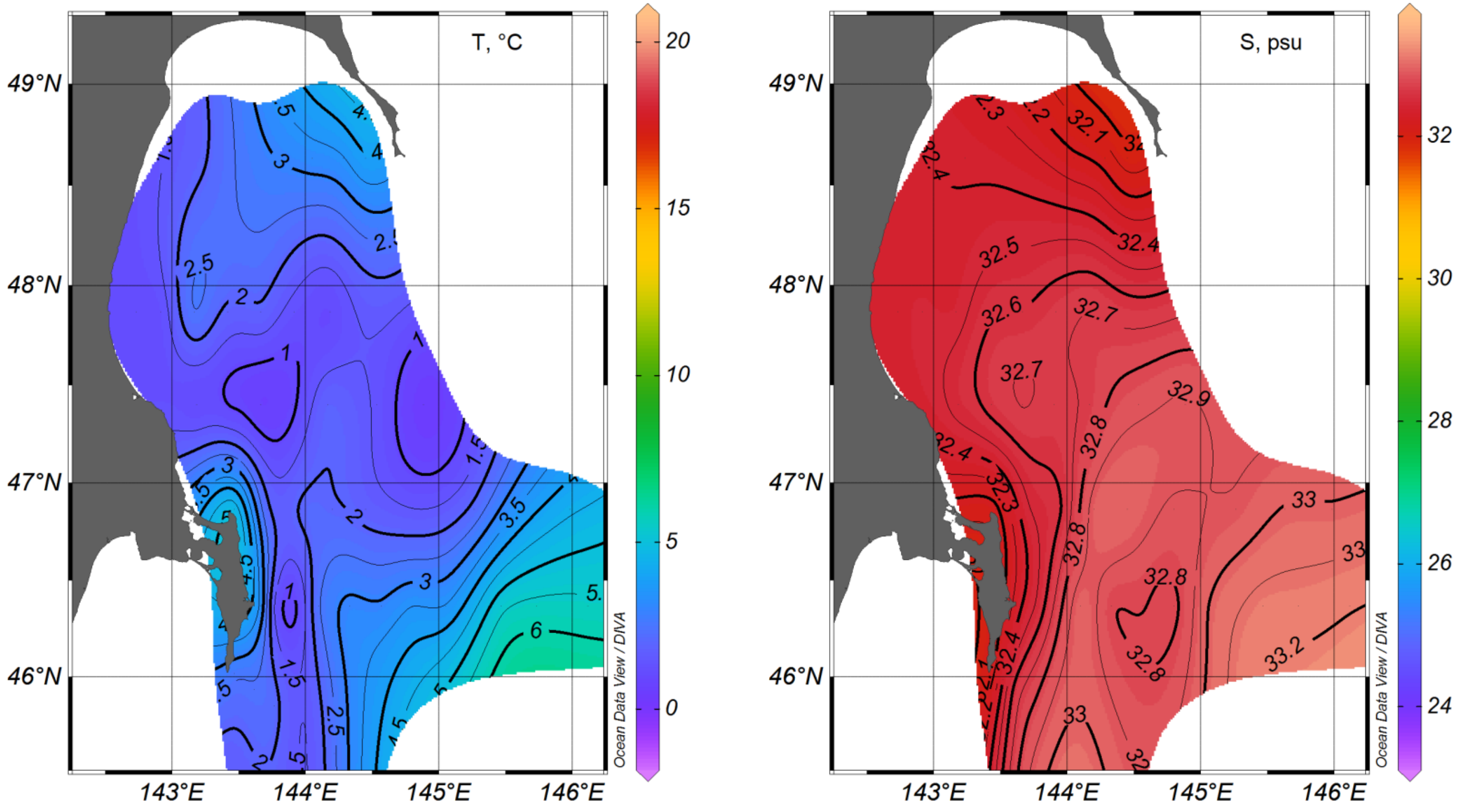
Multiyear mean water temperature and salinity distributions on the sea surface based on the data on 7 standard section. Fall season (October).

In October, the northern part of the study area is filled with modified Amur River low salinity water, isohaline 31.5 psu passes over the continental slope, separating two water masses with different salinity. The temperature distribution in the surface layer is uniform; a significant gradient in the salinity (and water density) field means a high flow rate corresponding to the autumn intensification of the East Sakhalin Current.



Multiyear mean water temperature and salinity distributions at the depth 20 m based on the data obtained on 7 standard sections. Fall season (October).

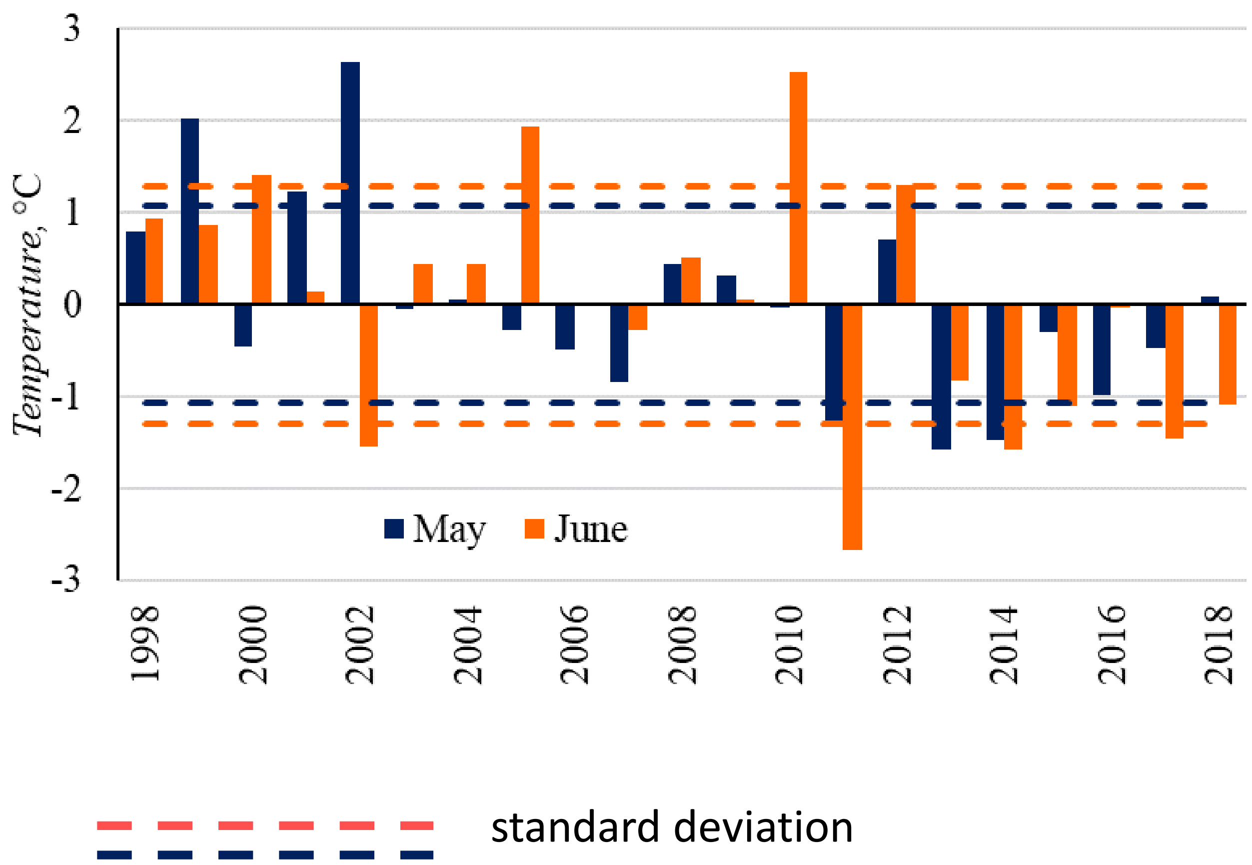
A similar structure of the spatial distributions of water temperature and salinity we found at the depth of 20 m, and only at a depth of 30 m the influence of freshened water is weaker, and it affects primarily from the western side of the Terpeniya Peninsula.



Multiyear mean water temperature and salinity distributions at the depth 50 m based on the data obtained on 7 standard sections. Fall season (October).

At a depth of 50 m, the water is significantly warmer than in the warmest season in August (minimum value + 1°C). Salinity decreased in comparison with summer in the northwestern shallow part of the study area. This is due to the deepening of the local surface water under the influence of the north wind (winter monsoon). More significant freshening is observed in November-December, when modified water of the Amur River runoff comes from the northeastern shelf.

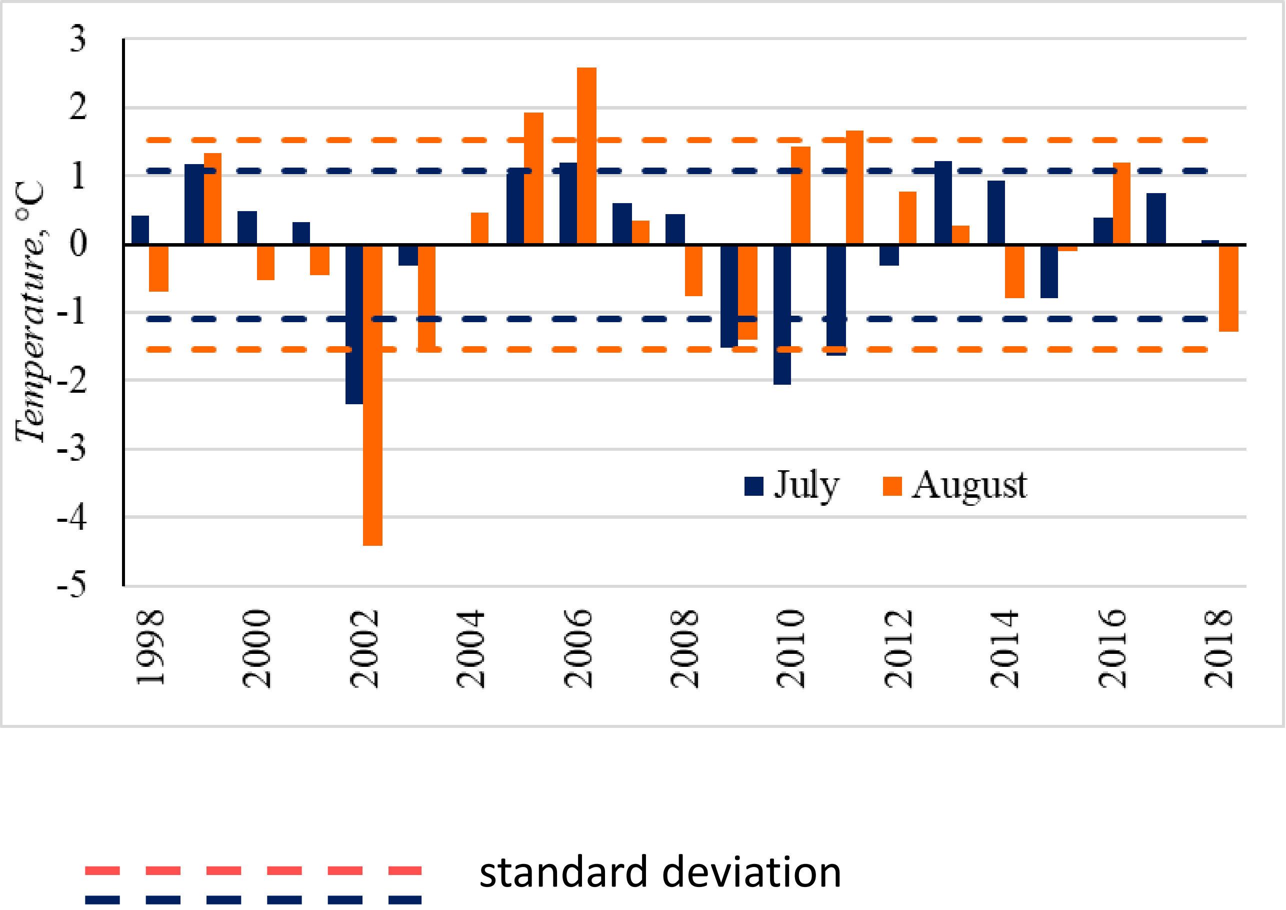
SST anomalies based on the satellite observations 1998-2018 in spring season.



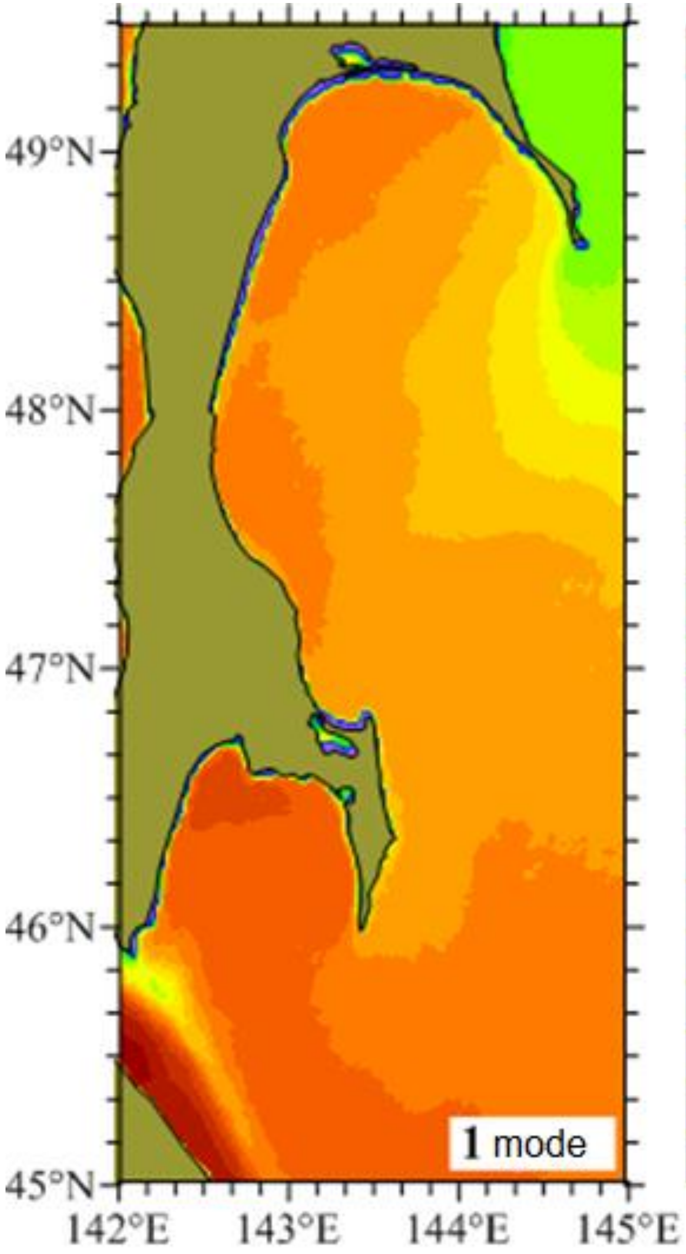
In spring, in the early 2000s, near the southeastern coast of Sakhalin, the SST was above normal, the largest positive anomalies were found in May. In the 2010s, the situation changed significantly, in the study area, predominantly negative anomalies were recorded (especially in June).
The most extreme year was 2011, when the water temperature anomaly was twice the standard deviation. 2002 was characterized by unstable thermal conditions, when, following significant positive anomalies in May, there were significant negative anomalies in June

In the period 2003-2009, thermal conditions in the study area were close to normal excluding significant positive anomaly in June 2005.

SST anomalies based on the satellite observations 1998-2018 in summer season.

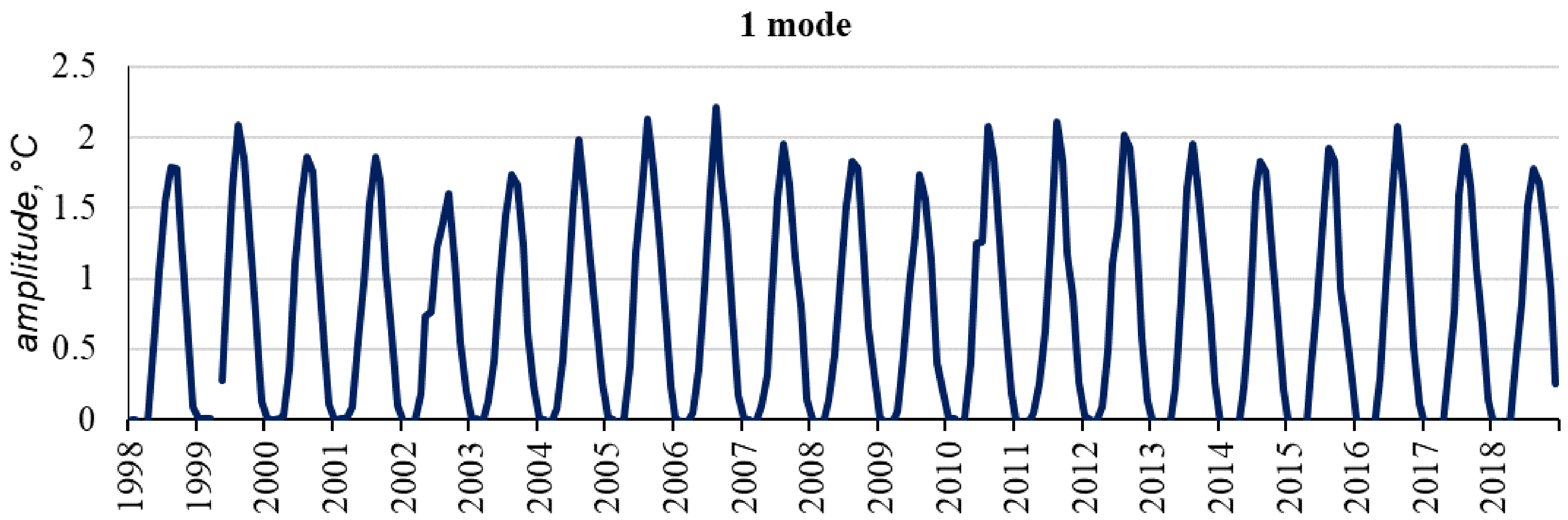


The summer months can be described as more sustainable than the spring season. The coldest summer was observed in the aforementioned 2002 (in August, the negative anomaly exceeded the value of the standard deviation by almost three times, which indicates the exceptional nature of thermal conditions), the warmest in 2006. In recent years, a stable temperature regime has been observed in the area of southeastern Sakhalin. Since 2012, the SST has been close to normal (the anomalies did not exceed the standard deviation). In this case, the changes in the anomalies in time were of a quasi-periodic with a period of about 7–8 years.



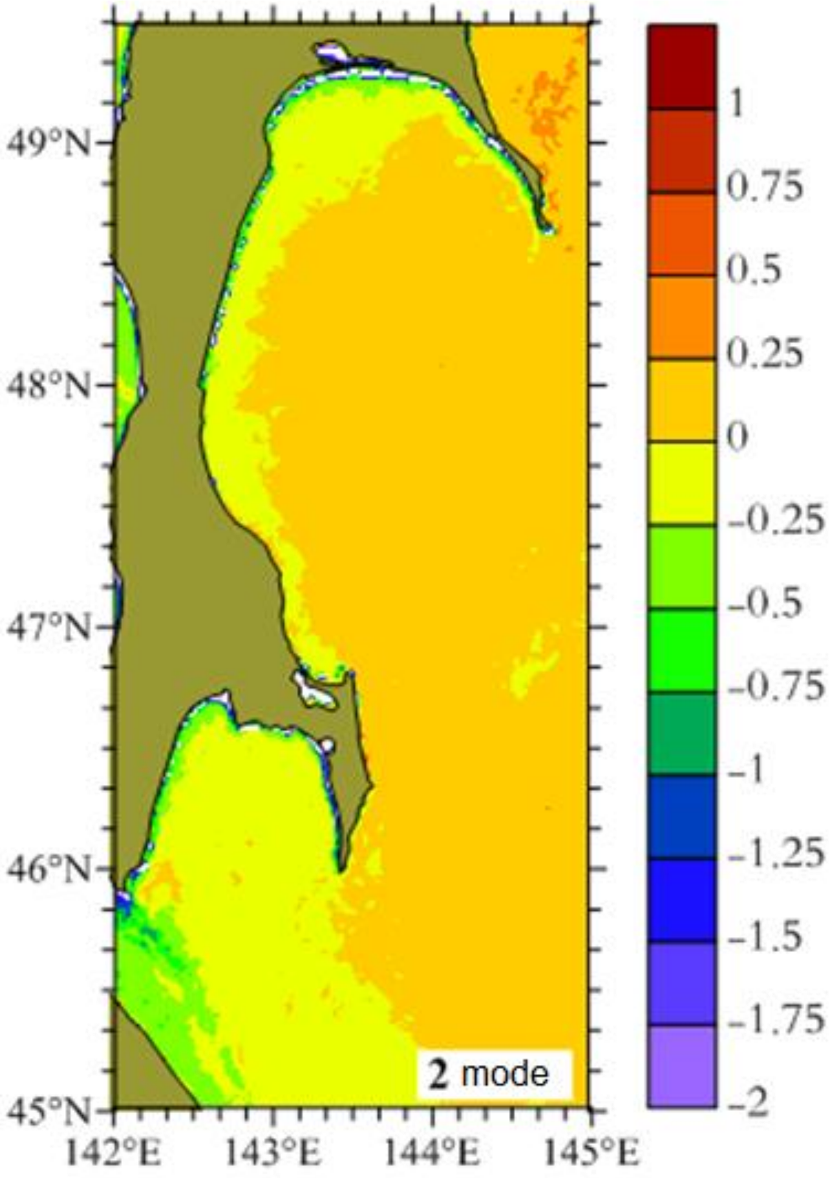
Spatial distribution of the first mode of the EOF (dimensionless, 97.6% of total variance)

The spatial distribution of the first mode (all values are positive) has a pronounced structure. The highest values are in the southern area (in addition to the Aniva Bay, which is not part of the study area), to the southeast of the Cape Aniva and in western (coastal) part of study area. The figure clearly shows the area of colder water brought from the northeastern shelf of Sakhalin by the East Sakhalin current, coming from Cape Terpeniya to the southwest. This picture has much in common with the above-considered distribution of temperature in the surface layer in summer based on the results of ship surveys.



Amplitude of first mode EOF (°C)

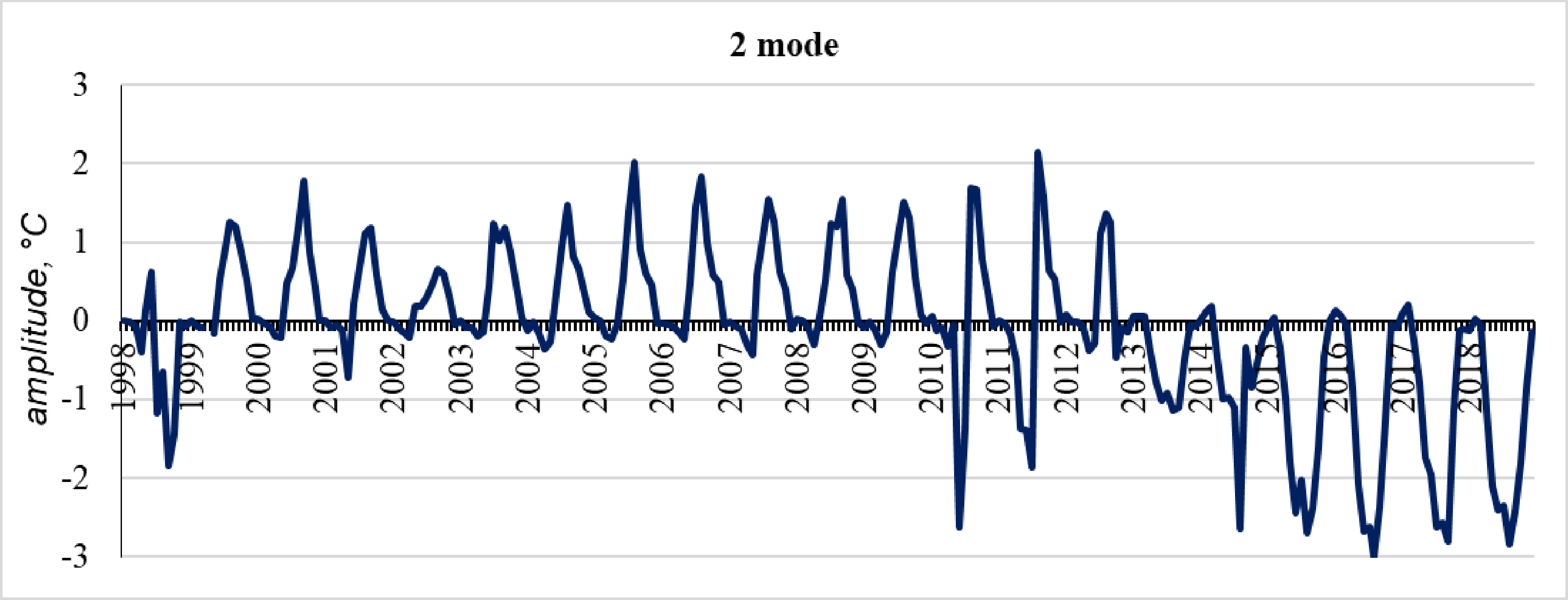
The amplitude of the first mode shows the SST seasonal and long-term dynamics. There are pronounced seasonal variations (from zero to 1.6 – 2.2°C). In the interannual variations, a 6–7 periodic cycle is distinguished. It is important that for 21 years of observations no unidirectional trend was detected, that indicates the absence of manifestations of global warming in the study area.



Spatial distribution of the second mode of the EOF (dimensionless, 0.6% of total variance)

The spatial distribution of the second mode is characterized by the presence of a nodal line that separates areas with different signs. It runs along the coast, separating the relatively narrow coastal zone from the deeper area. The width of this zone is 7-10 km along the eastern coast of Sakhalin and increases to 40 km at the top of Terpeniya Bay.

In the central and eastern parts of the study area, the mode values change little and are about 0.2, only in the northeastern part of study area they increase to 0.4.



Amplitude of second mode EOF (°C)

The amplitude of the second mode is very interesting. It, like the amplitude of the first mode, has pronounced seasonal variations. From 1999 to 2009 its annual changes are approximately the same. In the winter months, amplitude fluctuations are close to zero, in spring in April – May they take negative values, and in summer and autumn they are positive, with a maximum in August or September. Changes in the annual variations begin in 2010 with negative values in May and June, and since 2013, the amplitudes become negative from May to December, and in August or September they are maximum in absolute value. A picture similar to the situation in recent years was also noted in 1998, which probably suggests the cyclical nature of such variations.

Conclusion

Multiyear mean distributions of temperature and salinity in different months of the navigation season (June – November) were constructed. In spring (June), the warmest low salinity waters with are distributed in the northern and western parts of the study area; the Poronai River runoff plays an important role in their formation. Colder and saltier water comes from the northeast, transported by the East Sakhalin Current.

In summer, freshened water continues to flow from north to south along the coast of the island, forming a local lens in the area of Cape Svobodny.

A second stream of this water is also forming from the top of the Bay to southeast. Warm low salinity water is deepened in the northern part of the region to a depth of 20 m under the influence of the southerly wind (summer monsoon). Cold salty water is observed at the depth more than 30 m.

In autumn, as a result of the intensification of the ESC, modified low salinity water from the Amur River runoff (less than 31 psu) enters the study area. This water fills the northern and western shallow-water zones; the border with saltier water runs along the slope. In October, the deepening of warm low salinity surface water to a depth of 30 m and beginning of degradation of the cold intermediate layer (which remained during the period of maximum heating in August) was detected. In November, the deepening reaches a depth of 50 m, the modified water spreads along the Sakhalin coast further south.

Calculation of SST anomalies using satellite data for the spring and summer months showed that over the past two decades an unstable thermal regime in the spring. Significant SST anomalies can have a negative effect on the timing of release of salmon juvenile from fish hatcheries and their survival in the early marine period of life. In summer interannual fluctuations in temperature conditions are less significant; thermal regime in the last decade was stable, which is favorable for spawning approaches of pink salmon.

The spatial distribution of the first mode EOF is identical to the distribution of water temperature in the surface layer according to ship survey data and is characterized by higher values in the northern and western shallow and southeastern deep-water parts of the study area. Its amplitude shows cyclical variations with a period of 6–7 years, expressed in the modulation of the annual harmonic. In the amplitude of the second mode, of great interest is the climatic shift that occurred in 2010 and expressed in a change in its sign from positive to negative.

The obtained results are important for studying the living conditions of pink salmon, chum salmon and other types of fish on the southeastern Sakhalin shelf.