HYDROPHYSICAL AND BIOLOGICAL CHARACTERISTICS IN THE KURILO-KAMCHATKA CURRENT AND OYASHIO REGION

Vadim Navrotsky, T.Zadonskaya ,
Pacific Oceanological Institute FEB RAS,
V.Darnitsky, V.Chuchukalo, L.Bokhan, V.Napazakov,
TINRO-Center

navrotskyv@poi.dvo.ru

Main points

- Hydrology: spatial structure – different seasons, multiyear averaging
- Biology (zooplankton): differences in species structure depending on hydrology

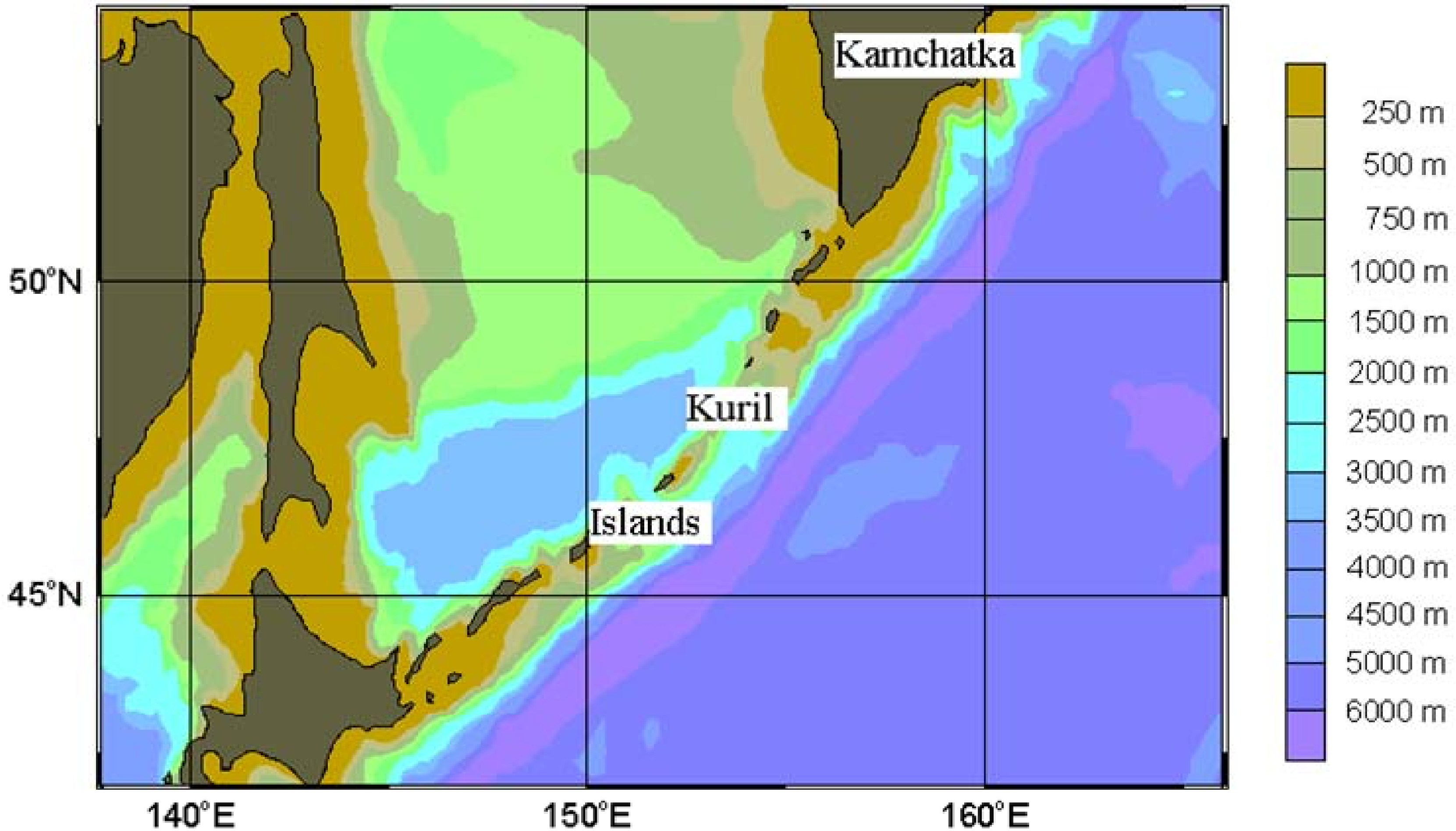


Fig. 1. Map of the region, showing bottom topography along p-la Kamchatka and Kuril Islands

Geography:The chain of 30 islands and 80 underwater volcanoes from Hokkaido till cape Lopatka (p-la Kamchatka). Along the islands and south-eastern part of Kamchatka the Pacific bottom is a trough about 8 km deep with many underwater mountain summits. Many straits, some of them having depths 1000-2000 m (Bussol and Krusenshtern) connect Pacific to the Okhotsk Sea (see Fig.1).

Interaction of tides and other mesoscale and large scale processes with the bottom and shore-line inhomogeneities causes topographic upwellings and topographic eddies, which are observed directly by measuring hydrologic parameters in the sea and remotely from satellites.

The information used for the analysis was taken from data bases of TINRO-Center and Pacific Oceanological Institute of Russian Academy of Sciences, as well as from Japanese cruises, performed in 1984-1999 in accordance with an agreement between Russia and Japan.

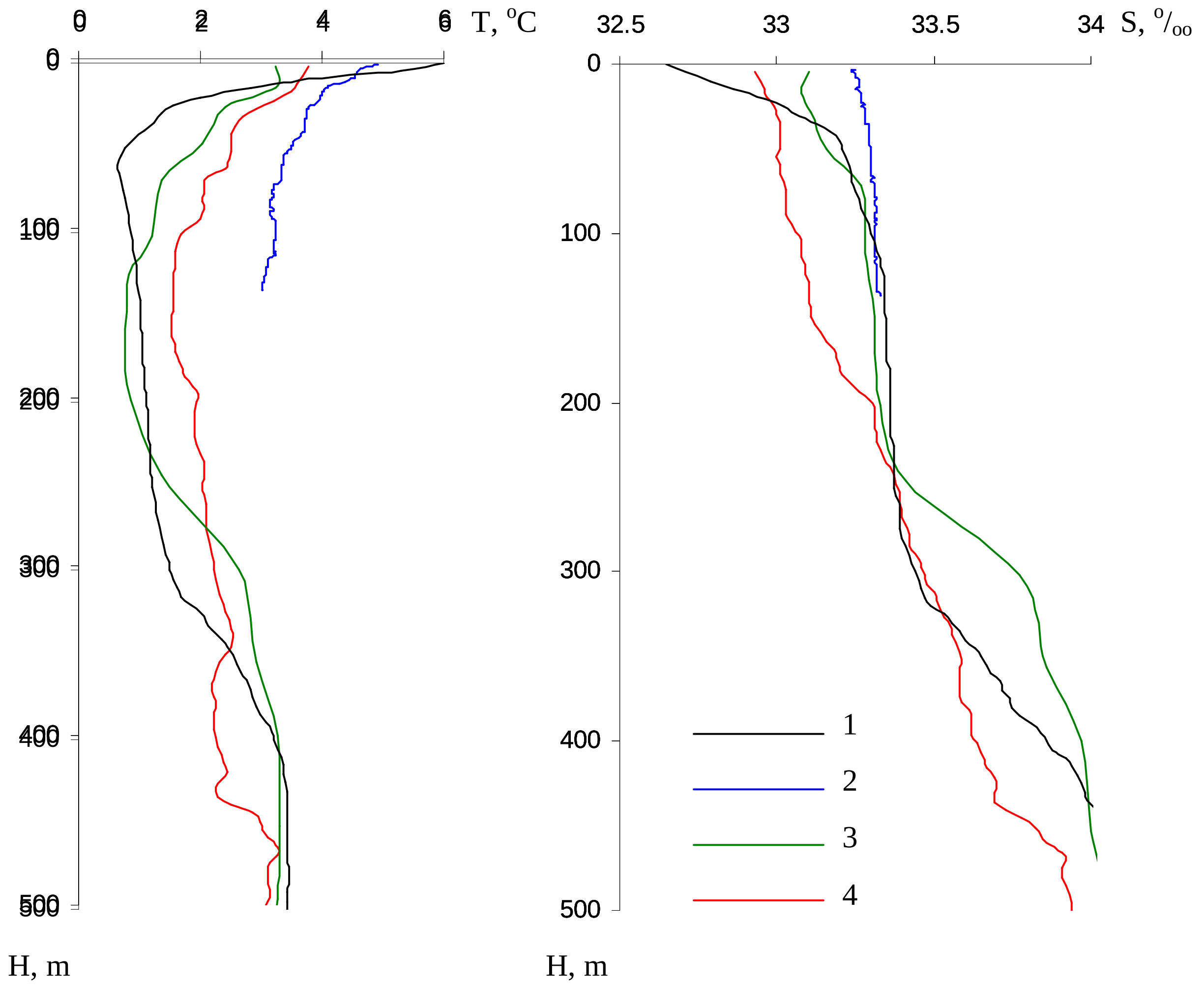


Fig. 2. Vertical structure of temperature and salinity in different parts of the region (summer): 1 – Eastern Kamchatka; 2 – Northern Kurils; 3 – Central Kurils; 4 – South Kurils

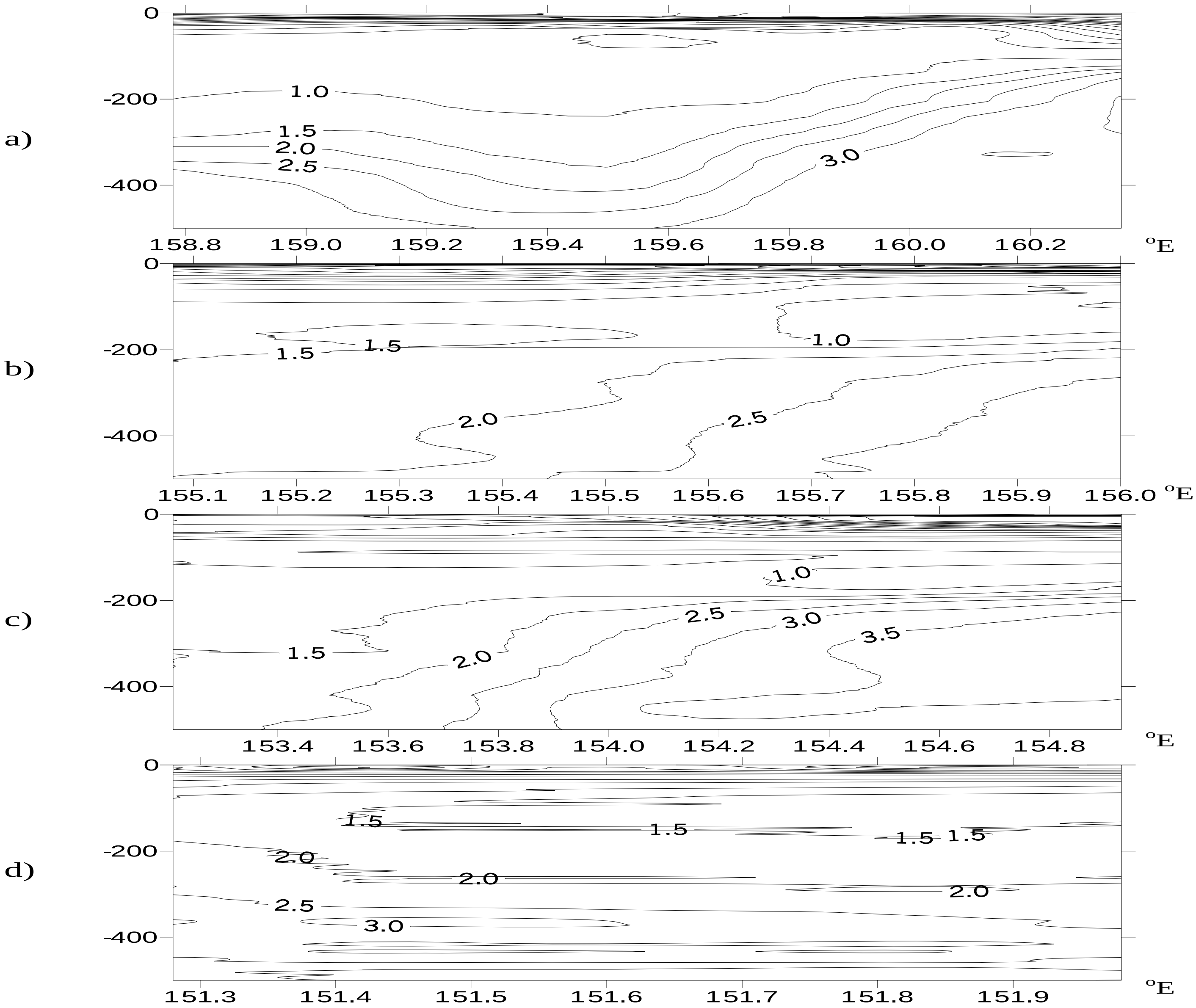


Fig. 3. Vertical sections of temperature normal to shore: a) Eastern Kamchatka, b) Northern Kurils, c) Central Kurils, d) Southern Kurils.

In the Kamchatka waters we have rather monotonous run of isotherms, but in the Northern Kurils waters we see large horizontal gradients, and that is due to the interchange between Pacific and Okhotsk Sea waters. In the Central Kurils region the influence of eddies leads to existence of closed maxima or minima in the parameters horizontal distribution. Especially high spatial variations of horizontal gradients are observed in the South Kuril area because of dynamical mixing of Oyashio and Kuroshio waters.

The surface water is formed in summer in the adjacent Pacific, reaching near the Kuril islands the depths 30-35 m with T about 8°. In winter time this water mass is destroyed by convective, tidal and wind mixing, and cold intermediate water appears actually as surface layer. This seasonal rebuilding is characteristic for subarctic waters in the North-Western Pacific. While moving from the open ocean to the shelf, the cold intermediate layer becomes thicker (from 100 m to 200 m), minimum temperature in the core becomes 1° higher.

The warm intermediate layer has steady parameters in the ocean, but when approaching to the shore it becomes thinner, practically disappears, and the cold water reaches bottom.

Horizontal gradients between ocean and shelf waters change with seasons: in autumn and winter shelf waters are colder, than in deep ocean, in spring and summer they are warmer.

The main features of horizontal structure can be seen in Figs.4 – 11, showing temperature and salinity horizontal structure at different levels.

The most important and visible effects on temperature and salinity distribution in the region are produced by meanders and eddies, originated in the Kuril current. Its deep stream corresponds to minimum temperature of the cold intermediate layer, and lenses of cold water are observed in the eddies and meanders. In general, the cold water stripe is observed all along the islands.

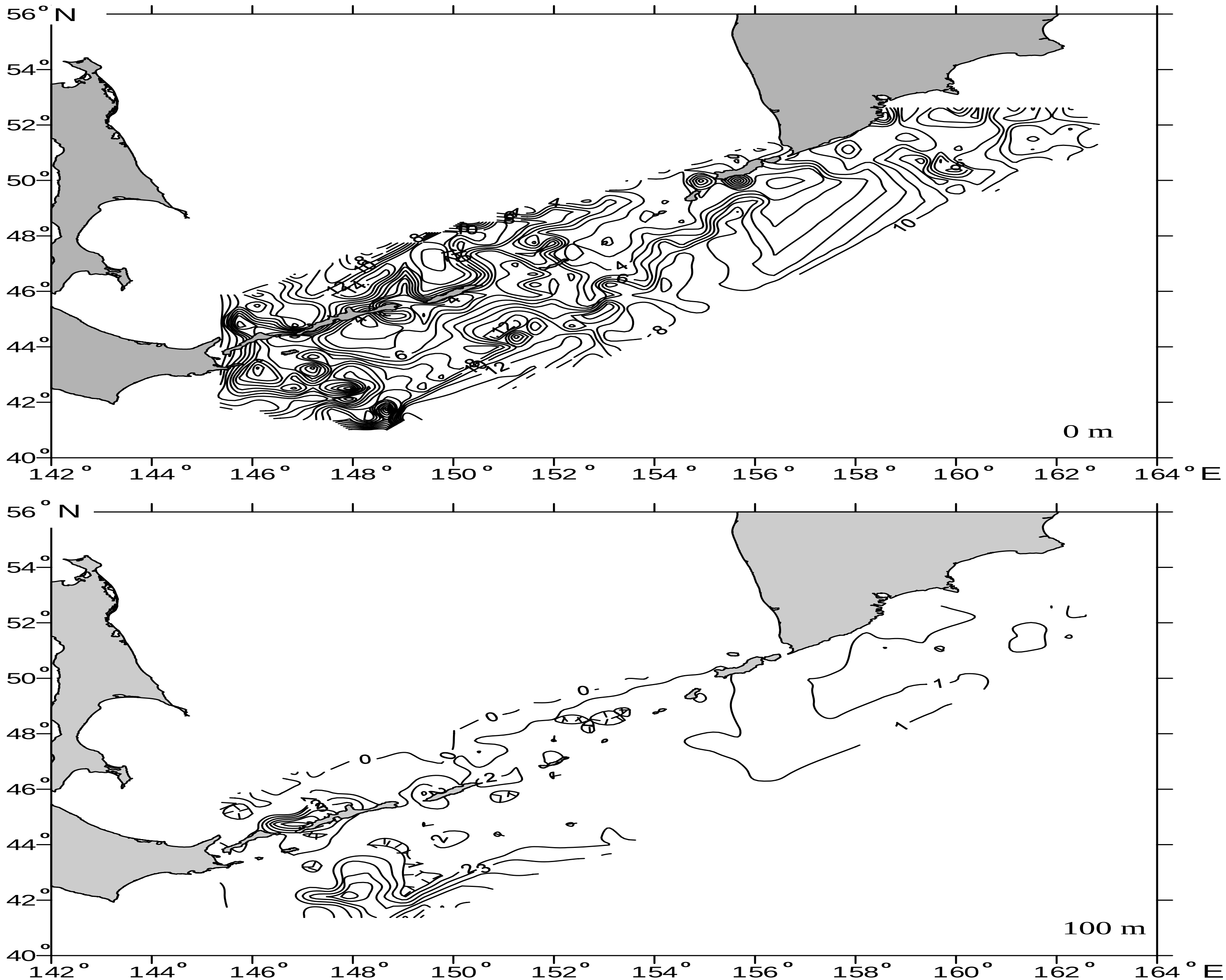


Fig. 4. Horizontal distribution of temperature at 0 and 100 m. Summer.

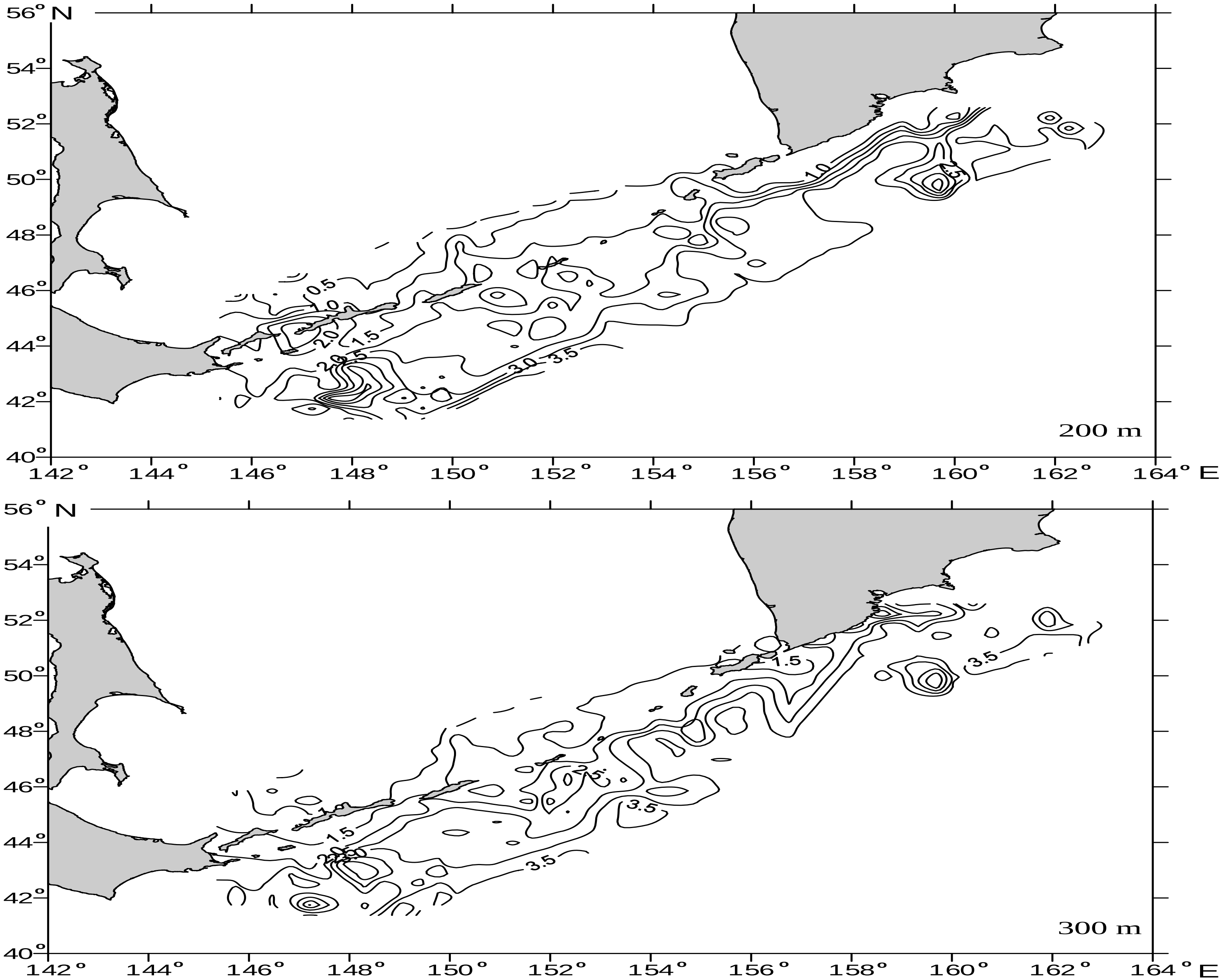
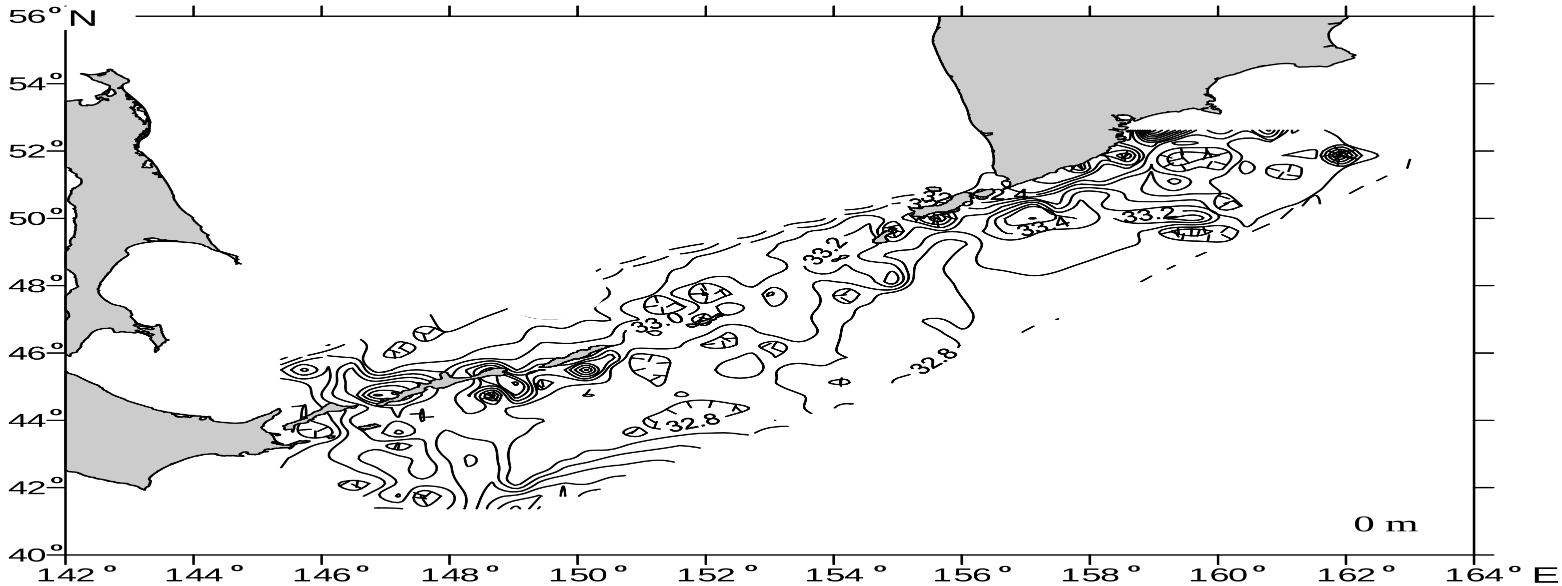


Fig. 5. Horizontal distribution of temperature at 200 and 300 m. Summer.



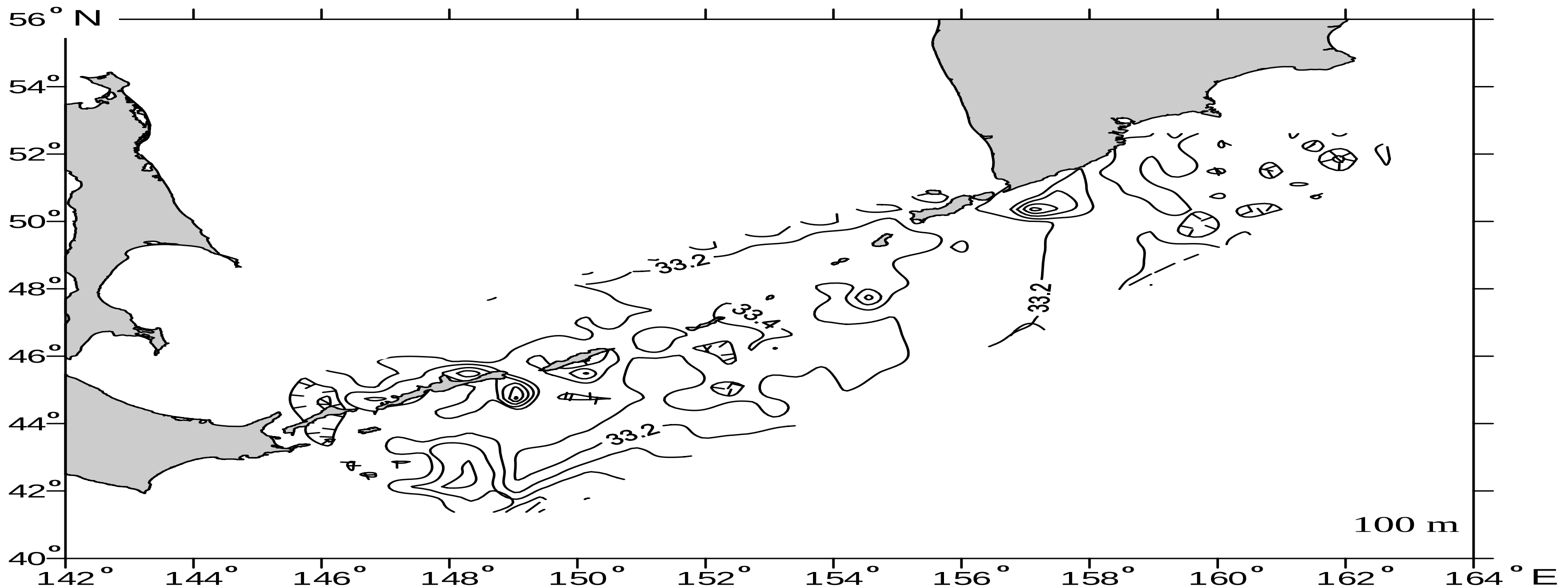


Fig. 6. Horizontal distribution of salinity at 0 and 100 m. Summer.

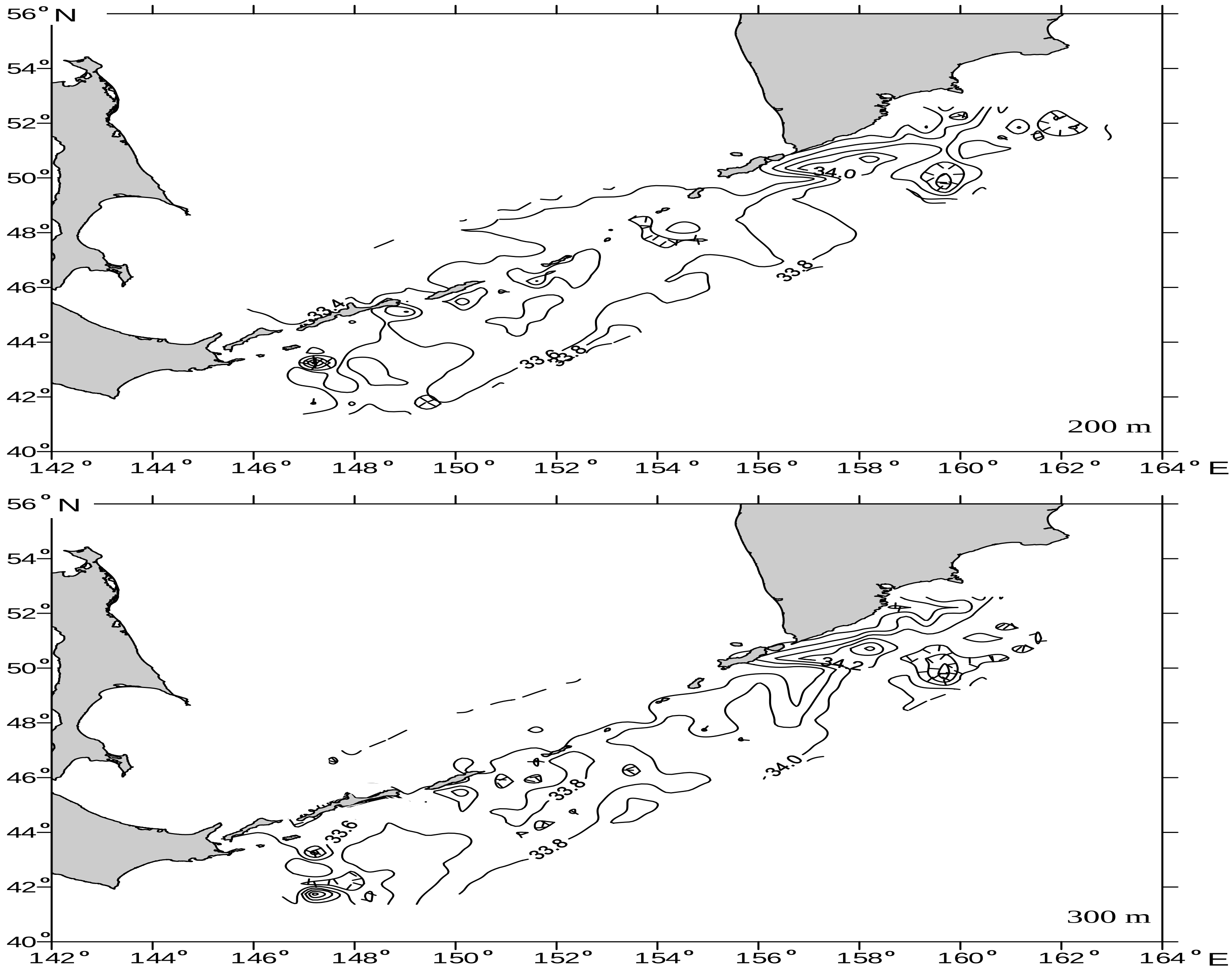


Fig. 7. Horizontal distribution of salinity at 200 and 300 m. Summer.

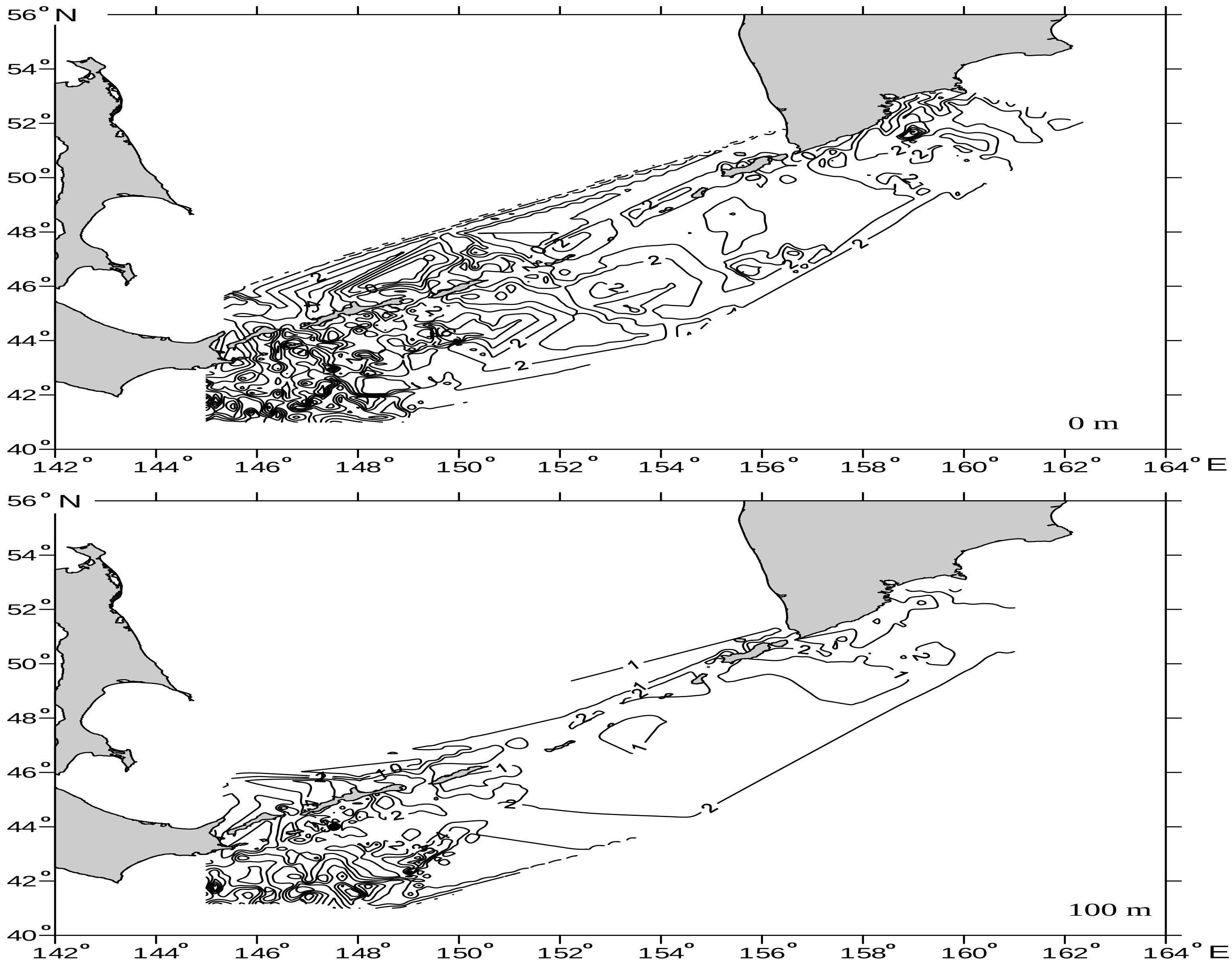


Fig. 8. Horizontal distribution of temperature at 0 and 100 m. Winter.

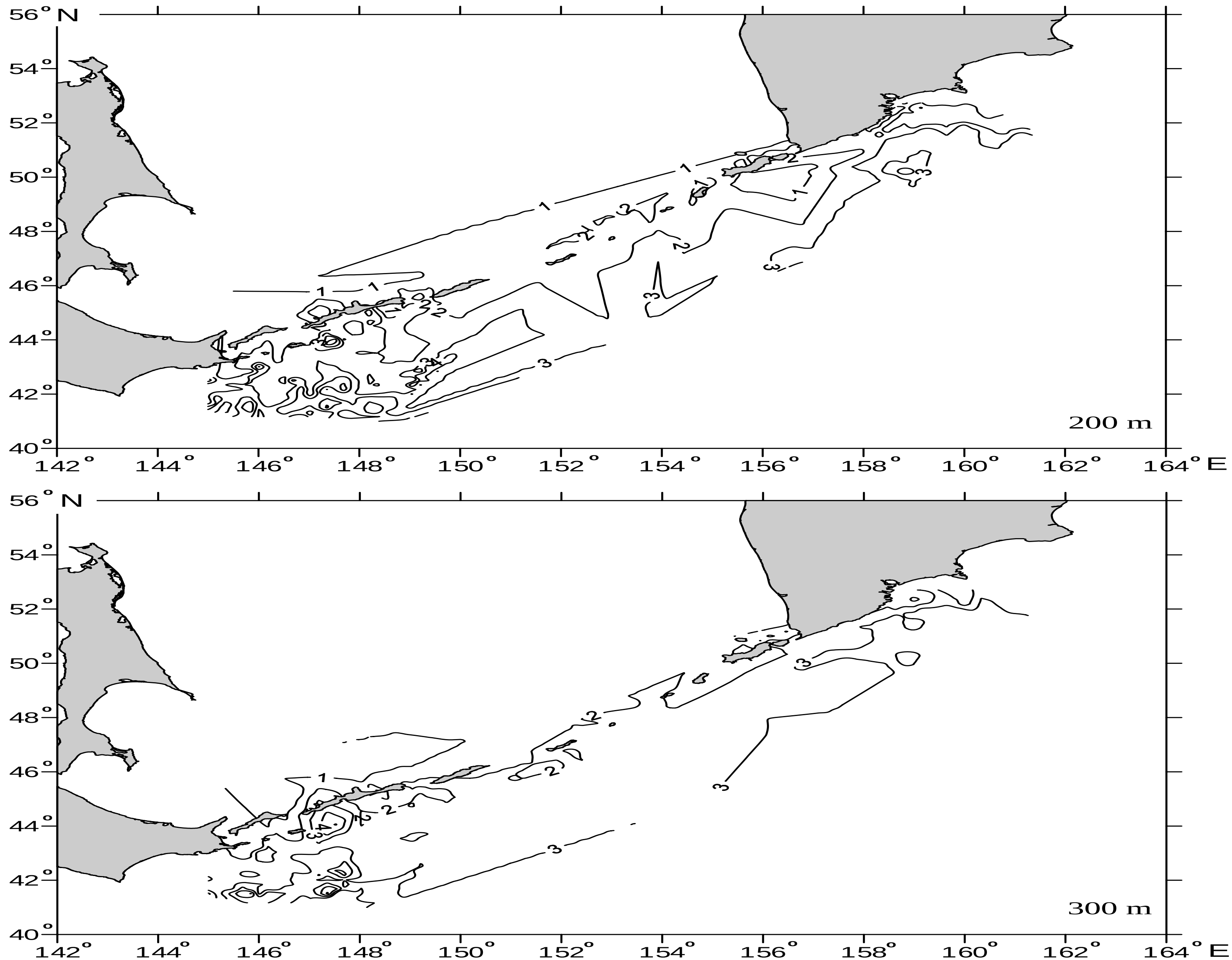
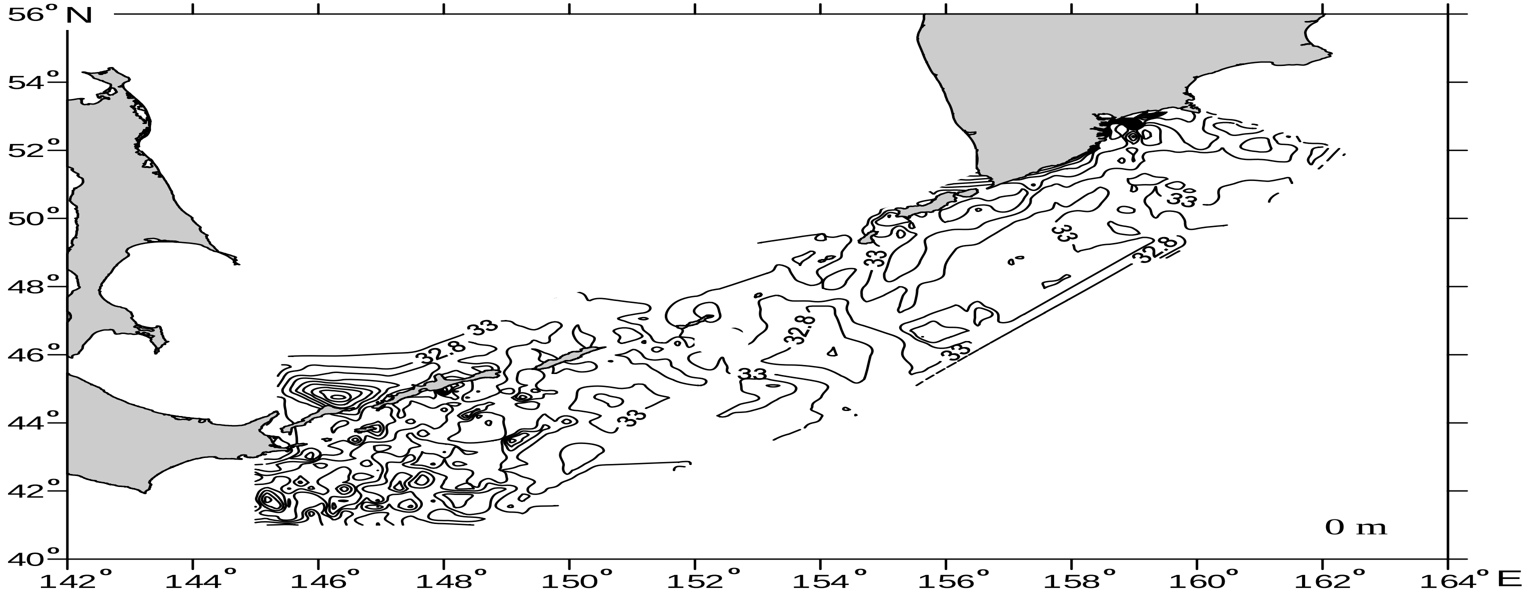


Fig. 9. Horizontal distribution of temperature at 200 and 300 m. Winter.



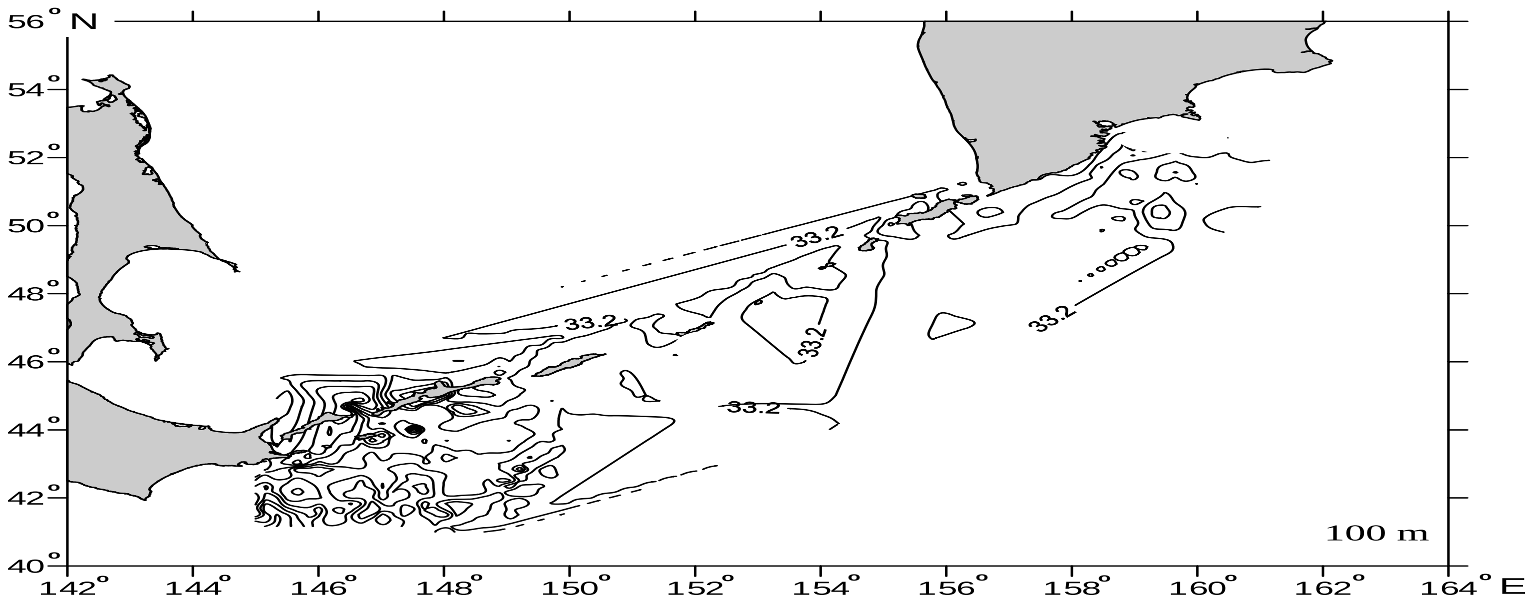


Fig. 10. Horizontal distribution of salinity at 0 and 100 m. Winter.

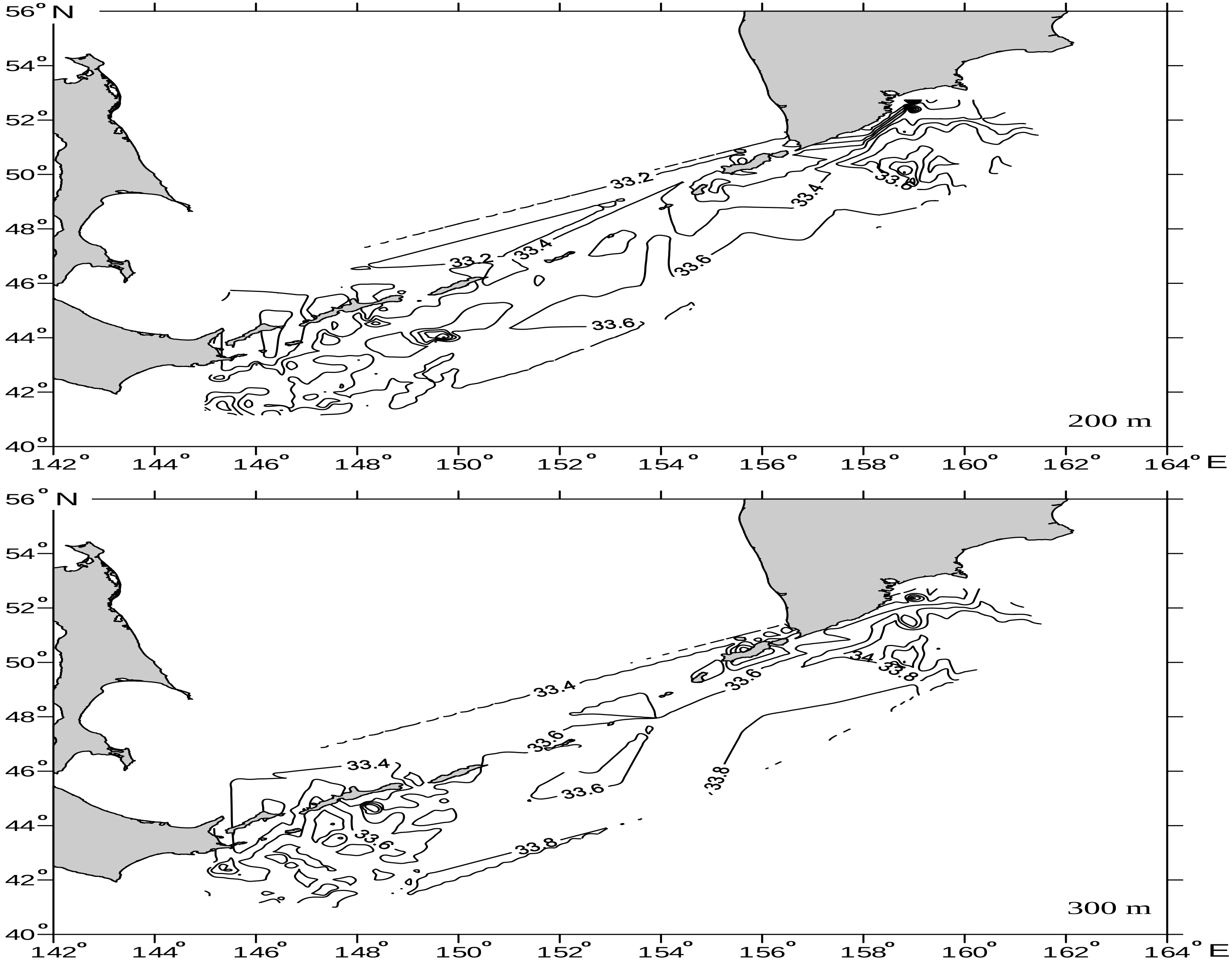


Fig. 11. Horizontal distribution of salinity at 200 and 300 m. Winter.

The large horizontal gradients of temperature lead to formation of shelf-slope front, but its exact position varies depending on the outcome of the Okhotsk Sea waters through the Kuril Straits. Mixing of Kuril current waters with colder waters of the Okhotsk Sea south of the Bussol Strait leads to the front destruction, partly to the Oyashio current formation, and can explain sometimes reported appearance of extremely cold, but lower salinity layers about 100 m thick and 150 km long [Talley, 1991].

Waters of Oyashio in the southern part of the Kuril Islands are different from waters in the northern part due to modifying effect of the Okhotsk Sea waters. The resulting horizontal structure of coastal waters along Kamchatka and Kuril islands is very complicated and changeable, as we can see in Figs.4 - 11and in Fig.12 (the last map was constructed by Bulatov and Lobanov (1983) on the base of meteorological satellite information).

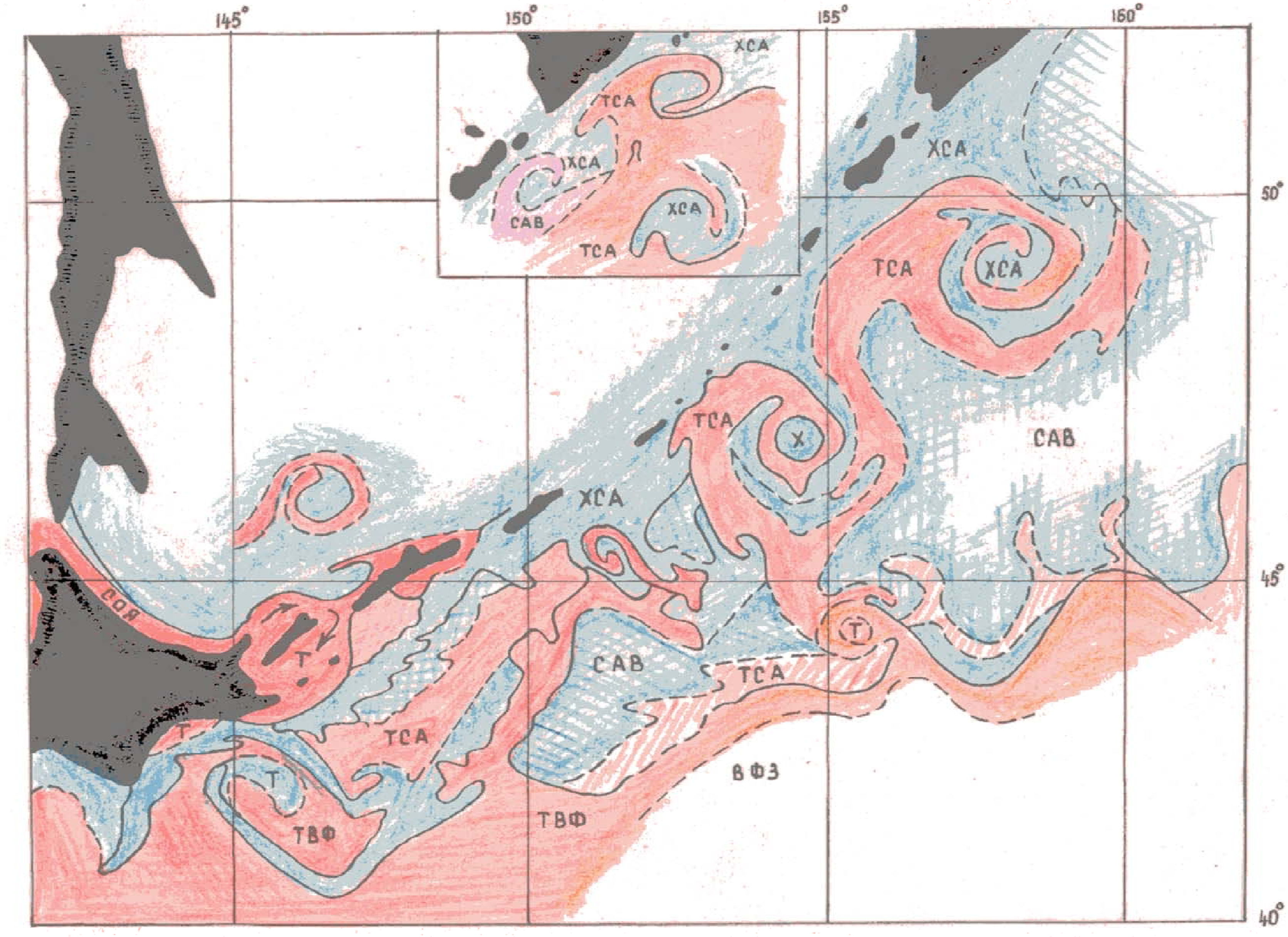


Fig. 12. A satellite image of eddies in the Pacific along the Kuril Islands (after Bulatov, Lobanov, 1983).

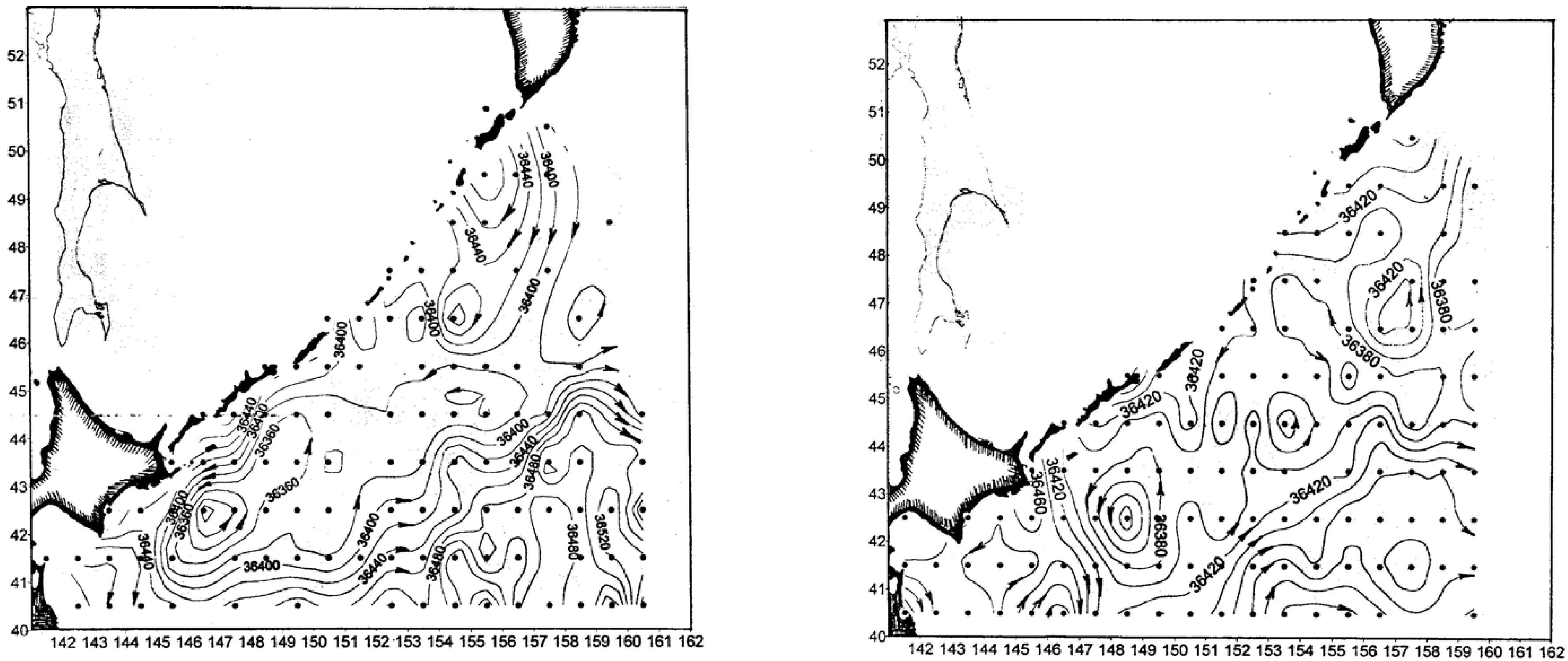


Fig. 13. Climatic geostrophic currents for winter (left) and spring (right).

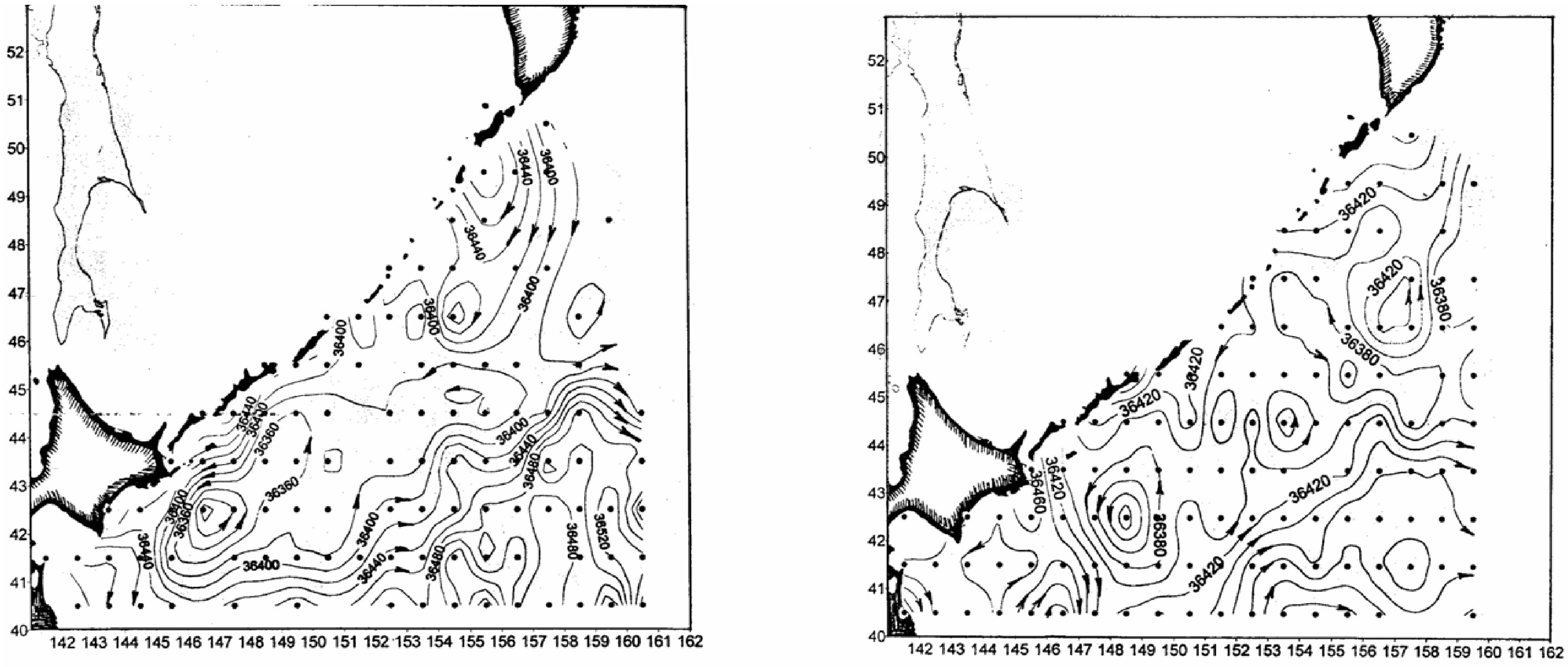


Fig. 14. Climatic geostrophic currents for autumn (left) and summer (right).

In all the schemes, except for autumn, the flow is observed along Kuril Islands and Hokkaido. It is the western part of the subpolar cyclonic circulation in the North-Western Pacific and consists of the Kuril current and Oyashio current, but there is no distinct boundary between these currents. In autumn the Oyashio is formed mainly by waters from the Okhotsk Sea, flowing out through the Bussol and Friz straits, but in winter and summer the Kuril current contributes appreciably, and the flow is almost continuous from Kamchatka till the Oyashio-Kuroshio frontal zone. In autumn the Kuril current is divided into two parts near the Krusenshtern strait. One branch flows into Okhotsk Sea, the other turns to the south-east.

Depending on season Oyashio can form several branches, but actually they may be the result of meanders and eddy formation, as can be seen in satellite snapshots (see Fig.12). The north-eastern part of Kuroshio reaches 40°N and is seen as separate anticyclonic eddies, leading to average eastern flow.

The region is characterized by intense eddy activity: about 10 vortex cores may be observed in winter, about 8 in spring, with minimum 4 cores in summer. The eddies position changes considerably in different years and seasons, so that dynamic charts give only general idea about their role in the region.

Calculations of velocities and integral flows at several characteristic sections in the region have shown, that minimum of Kuril and Oyashio currents is observed in summer, maximum is observed in winter.

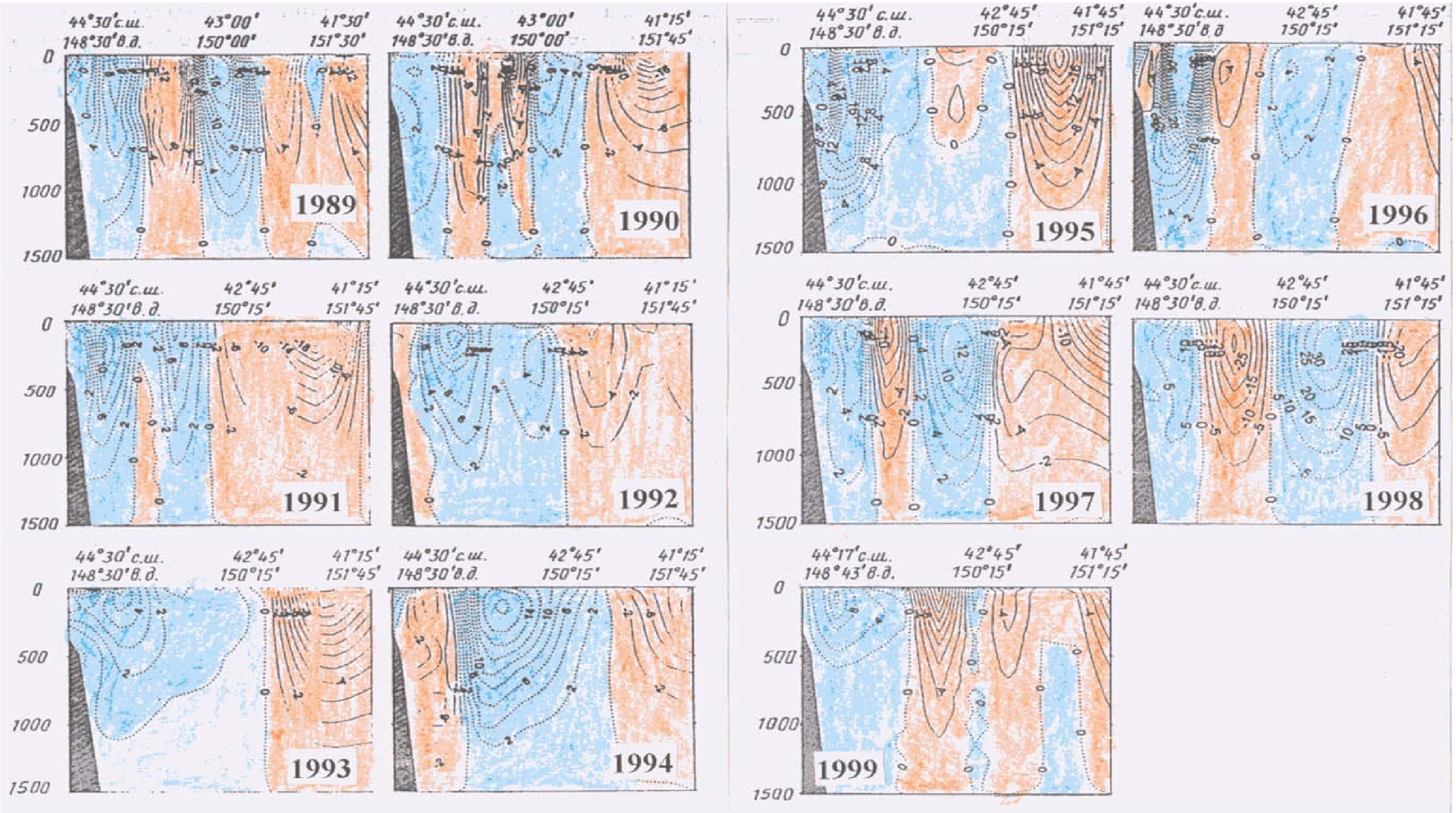


Fig. 15. Velocity structure changes of the Oyashio current through the Iturup section in August (1989-1999). Cold waters of Oyashio are blue. (After Zhigalov et. al., 2002).

The changeability of Oyashio was studied by Sekine (1988) for the period 1954-1984. It was shown that its boundary can fluctuate between south and north positions with periods from 3-4 till 10-11 years. In Fig.15 are shown results of calculations of geostrophic currents through the section from the middle part of Iturup till 41°N, 152°E for 11 years (Zhigalov et al., 2002). Oyashio is well marked from surface till bottom in the shelf and slope zone till the depths 1300-1500 m. The flow width varies considerably from one year to another – from 100 till 275 km. During the years 1989, 1990, 1997, we can see two streams, but in 1991, 1992, 1994, 1995 there is only one stream.

Comparison of integral transport changes (Fig.16) and velocities (Fig.15) leads to the conclusion that values of water transport in Oyashio current are more related to its velocity, than to its width.

It is interesting to note that intraannual changes of Oyashio position and velocity can be of the same order as interannual ones (Sekine, 1988). It means that seasonal and synoptic scales in boundary currents are not less important than the annual scale. (Darnitsky, Bulatov, 2000).

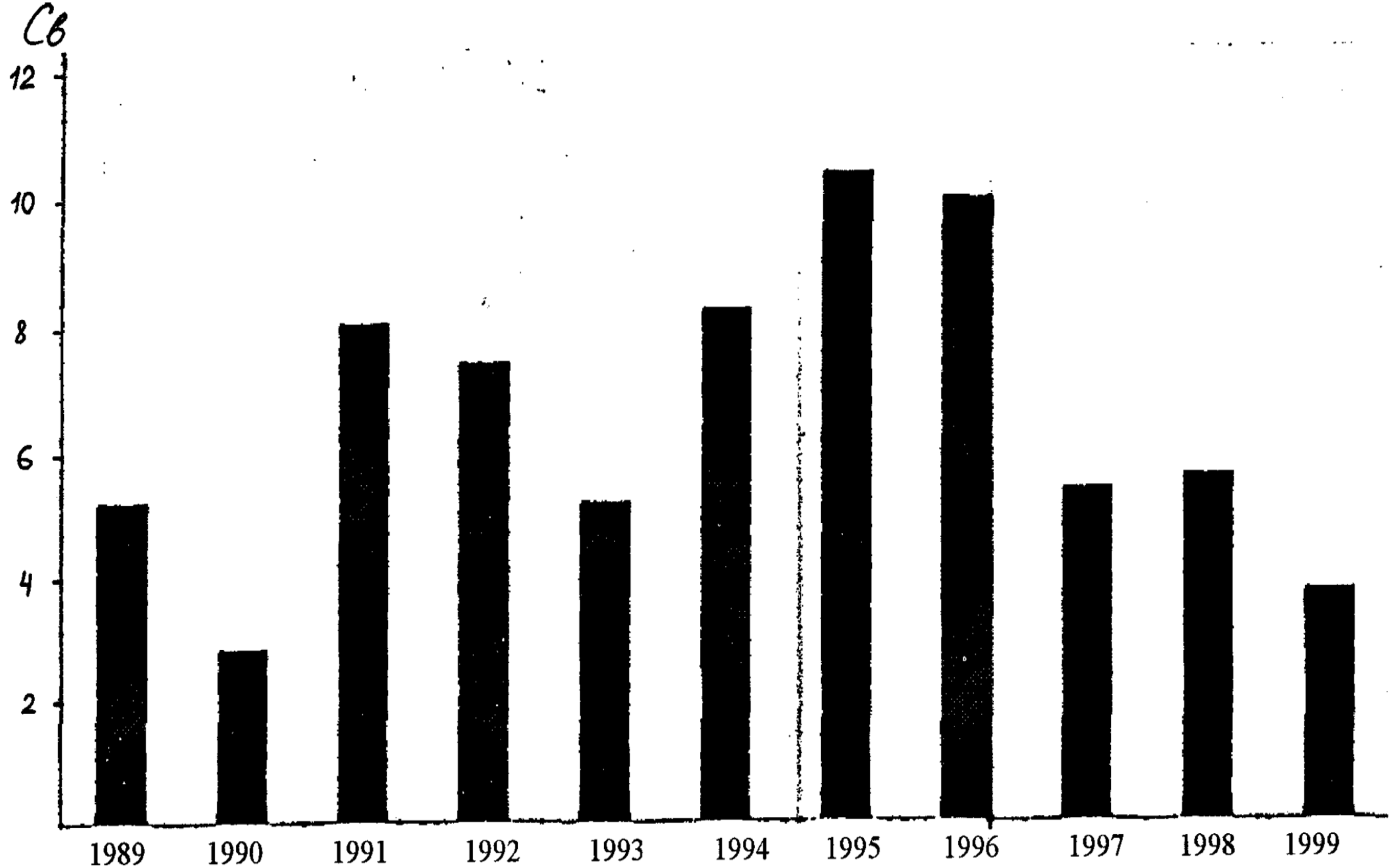


Fig. 16. Interannual changes of the Oyashio current transport (0 – 1500 db). (After Zhigalov et al., 2002).

Analysis of satellite images has shown that the chain of anticyclonic eddies along the Kurils can be traced from Japan till Kamchatka with distances 120-180 miles between their centers. Their distance from the islands changes from 60-80 till 150 miles, but nonetheless they affect considerably dynamics and hydrology of coastal waters. Interaction of the eddies with Oyashio stream leads to cold water penetration into the ocean and warmer water penetration into the shelf zone. These anticy-clonic eddies can disintegrate into chaotic streamers of cold and warm water during two or three weeks and appear again after 10-15 days. It follows, that appearance one or two streams of the Oyashio current may be determined by the eddies evolution along the Kuril Islands.

Direct measurements of currents (Ponomarev et al., 1996) give strong support to the conclusion about the role of eddies in the region. Though the resulting current may look rather random in fixed moments, it becomes evident from averaged data, that we have two kinds of eddies: those, that are generated in shallow waters in the result of tide and mean flow interaction with bottom topography and islands, and those that are generated in deep waters and move along the Kuril trough (Kozlov, Gurulev, 1994). Their interaction leads to intense Pacific-Okhotsk Sea water exchange and to high diversity of environment conditions for biota, which is the object of the next section.

To describe biological state of the region we should use too many parameters, beginning from hydrochemical ones till fish populations biomass. But actually we have a rather representative parameter, namely plankton biomass (or concentration), that is not very difficult to determine and not so dependent on the specific regional and economic conditions as, for example, fish catches do.

The value of plankton biomass integrates effects of many physical, chemical and biological processes, including long-term and short-term climate conditions and at the same time it defines the structure and amount of fish production, which is the final objective of most of our efforts in the ocean. But fish catches depend on many changeable factors (economical, political, technical, weather etc.) not always having relation to real fish stocks.

Spring vegetation of phytoplankton in the investigated region begins in April in the open waters and reaches it maximum in May-June, when its biomass at some arias can mount to 1500-2000 mg/m3. In the shelf zone the vegetation begins about 1 month later. In July the phytoplankton biomass in oceanic waters is generally 120-400 mg/m3, but in coastal waters it remains high during summer and autumn till November. In the beginning of November it is not more than 150 mg/m3 in shore waters, 60 mg/m3 in oceanic waters, and is about an order less in December.

The main representatives of the net phytoplankton are Thalassiothrix longissima, Thalassiosira, Coscinodiscus, Rhizosolemia, Chaetoceros, Ceratium.

Table 1

Biomass of main species of zooplankton in neritic zone along the Eastern Kamchatka, mg/m^3

Zooplankton species	Summer of 80-ies		Autumn of 90-ies		Winter of 80-ies
	Shelf w.	Open w.	Shelf w.	Open w.	Open waters
Oithona similes	-	70	22	20	26
Pseudocalanus minutus	60	23	80	15	15
Neocalanus plumchrus	316	100	70	10	12
Neocalanus cristatus	122	41	36	11	12
Calanus glacialis	47	-	35	-	-
Eucalanus bungii	182	90	70	76	-
Metridia pacifica	24	25	13	6	52
Euphasia pacifica	-	13	-	76	147
Thysanoessa inspinata	-	-	-	22	33
Th. longipes	-	24	-	39	55
Th. Raschii	10	-	114	-	-
Th. Inermis	-	-	50	4	-
Calyptopis (Euphausiacea)	23	-	-	-	-
Themisto pacifica	29	10	-	49	77
Parasagitta elegans	328	219	288	293	418
Larvae Cirripedia	12	-	-	-	-
Larvae Polychaeta	15	-	-	-	-
Biomass of leading species	1168	615	778	621	847
Part of total biomass, %	97	96	96	95	97

Biomass of zooplankton in shelf waters near the eastern shore of Kamchatka in summer-autumn period is higher, than in the open waters, though its biomass in the first half of nineties was much lower than in the eighties.

Very important is the fact, that interannual variability of plankton is higher, than seasonal variability. Among small zooplankton prevailing were naupleas of Oythona similis, Pseudocalanus minutus and larvae of molluscs. In the middle fraction prevailed copepoid stages of Eucalanus bungii and Neocalanus plumchrus, and adult Oithona similis and Pseudocalanus minutus. Biomass of large zooplankton is always much higher, than total mass of small and middle fraction.

Biomass variations of all groups in the large fraction are considerable in seasonal and especially in interannual aspects. Though in winter time the mass species of crustacea sink to deeper waters, rather high biomass of large zooplankton is registered in winter in the upper layer 0-200 m. Average values for many years, as reported by Shuntov (2001), are given in Table 1.

It is interesting to note that plankton species structures in shelf zones of the Bering Sea and near the Kamchatka east shore are very similar, though relative role of some species is different. Such similarity of fauna can be explained by similar effects of cold Kamchatka current, which defines abiotic conditions of the regions.

High diversity of physical conditions in the region leads to high diversity of biota and extremely high bioproductivity of waters. The main information of phyto and zooplankton structure was obtained by Japanese and Russian scientists (Marukava, 1921; Aikawa, 1933, 1936; Bogorov, Vinogradov, 1960; Vinogradov, 1968; Brodski, 1955, 1957; Kun, 1975; Bokhan, Zuyenko, 1995; Volkov, 1996; Kobary, Ikeda, 1999; Shuntov, 2001).

Due to the thin shelf zone, oceanic and near-shelf species of plankton prevail in all arias, except the South Kuril strait, where neritic group is more pronounced. Vegetation of phytoplankton between 40° and 50°N begins in May - first half of June. In the Kuril Islands area prevail diatoms, and biomass in some cases reaches 8000 mg/m3.

Seasonal succession goes slowly and periods of mass species vegetation are overlapped. Biomass values of phytoplankton from the Okhotsk Sea side and from the Pacific side are similar. The phytoplankton abundance is observed as in direct measurements with the help of nets, so in remote satellite measurements of chlorophyll concentration. Long-term average biomasses of phytoplankton and zooplankton in different seasons are given in Table 2.

Table 2

Long-term average structure of plankton in the Kuril Islands region, mg/m^3

Plankton structure	Pacific waters						Okhotsk Sea waters		
	Shelf waters			Open waters			Open waters		
	Summer	Autumn	Winter	Summer	Autumn	Winter	Summer	Autumn	Winter
Phytoplanc-Ton	414	13	0,9	329	5	2	505	12	4
Zooplanc-Ton	2172	571	292	1062	462	485	906	434	353
Small zoo-plancton fraction	336	168	43	77	50	56	89	69	42
Middle zoo-plancton fraction	135	94	17	62	52	35	65	40	24
Large zoo-plancton fraction	1701	309	232	923	360	394	752	325	287
Including: Euphaus	277	109	106	144	52	150	258	56	57
Amphyp.	88	25	37	51	22	33	36	50	59
Copep.	633	48	24	266	47	42	240	54	49
Sagittas	619,9	122	37	417	203	149	168	150	117
others	83	5	28	45	36	20	50	15	5

It is seen from the table that in shelf waters zooplankton concentration is higher in summer time, and it is due to meroplankton, eggs, nauplials and euphausid larvae. Mass species structures in the Okhotsk Sea and Pacific waters are similar and not very different from the structure near the Kamchatka shore.

In the southern part of the region (south of 45°N) subtropic fauna becomes noticeable: copepodes Calanus sinicus, C. pacificus, Calocalanus pavo, Paracalanus parvus, Mecinocera clausie. Considerable amount of salpas is observed, that where absent in the North Kurils area. But the main role in biomass of zooplankton here belongs to boreal and subarctic species (see Table 3).

Table 3

Long-term average structure of zooplankton mass species in epipelagic waters of the Pacific near the Kuril Islands, mg/m^3

Zooplankton species	Shelf waters			Open waters		
	Summer	Autumn	Winter	Sum	Atumn	Winter
Oithona similis	72,5	16,3	15,4	34,2	17,2	25
Pseudocalanus minutus	136,8	62,3	18,4	19,4	15,8	17,5
Neocalanus plumchrus	479,3	13,3	11,4	116,3	22,7	22,4
N.cristatus	32,9	3	4	74,6	15	9,4
Eucalanus bungii	130,4	35,7	-	53,3	4,9	0,2
Metridia pacifica	24,6	41,7	7,4	32,7	38,4	30,5
Euphausia pacifica	135,5	41	84,3	77,4	30,3	100,6
Thysanoessa inspinata	4	1,2	17,9	15,5	6,3	34,3
Th.longipes	21,7	2,1	-	36,8	10,4	8,1
Th.inermis	-	65,2	3,7	2,6	6	1,7
Th.raschii	55,9	-	-	0,2	1,3	-
Furcilia (Euphausiacea)	70,4	0,8	0,4	10	0,2	3,7
Themisto pacifica	79,3	25,1	29,3	36,6	17,4	22,9
Sagitta elegans	619,9	123	6,9	417	203,2	148,9
Aglantha digitale	16	0,6	-	14,8	3	1,7
Larvae Polychaeta	1	0,2	-	1,6	3,4	2,5
Part of total biomass,%	86,6	75,6	68,4	88,7	85,6	88,5

An idea on interannual variations of plankton biomass and some species can be derived from Table 4.

Variations are very high, but their mechanism is not clear yet. We can suppose, that they are related to variations of environment, especially to the conditions of spawning and fry survivement. But extremely complicated space-time structure of the conditions variations prevents from finding more or less exact relations between environment parameters and bioproductivity. It was shown that spawning of plankton community is highly dependent on warm waters of Soya current and Kuroshio branches. But after successful spawning the larvae can be advected into cold waters, where their forage reserve is not developed yet.

Table 4

Interannual variations of plankton biomass in the layer 0-200 m during 5 years near the Kuril Islands, mg/m^3

Plankton species	Okhotsk Sea					Pacific ocean				
	1991	1992	1993	1994	1995	1991	1992	1993	1994	1995
Phytoplankton	79	040	47	70	00	95	07	88	25	24
Euphausids	04	28	68	16	91	02	01	43	37	64
Amphypods	2	2	7	2	04	4	13	0	4	2
Sagittae	59	33	40	89	99	22	10	5	89	45
Kopepods large fraction										
Neocalanus cristatus	2	9	4	6	5	7	9	7	48	6
N.plumchrus	45	93	5	71	20	48	0	3	18	41
Eucalanus bungii	2	1	0	2	6	5	1	3	09	1
Metridia okhotensis	1		9	4	84		,7	,4	0	,4
M.pacifica	7		1	2	3	3		1	5	5

Though we did not mean to expound the situation with nekton in the region (that is a separate and very extensive problem), some idea about the level and changeability of the most productive species can be derived from Fig.17. The most striking features in the figure are very high peaks in 1978-1980 and in 1985-1990. The first peak may be related to widely discussed climate regime shift in 1977-1978, but the other is explained by migration from subtropical waters. General raise from 1960 is due not so by fish abundance, but mainly by the relevant technique and strategy developments.

Shuntov (2001) and Dulepov (2002) analyzed the data for the last 20 years and came to the conclusion that the Kuril Islands region is one of the most productive in the North Pacific. It is important to note, that high interannual variability has different directions at different parts of the region. To relate the biota variations to fluctuations of climate and oceanographic conditions we should have much longer and more detailed observations of biological parameters, and to forecast climate and oceanographic conditions we should have much more detailed models of the processes.

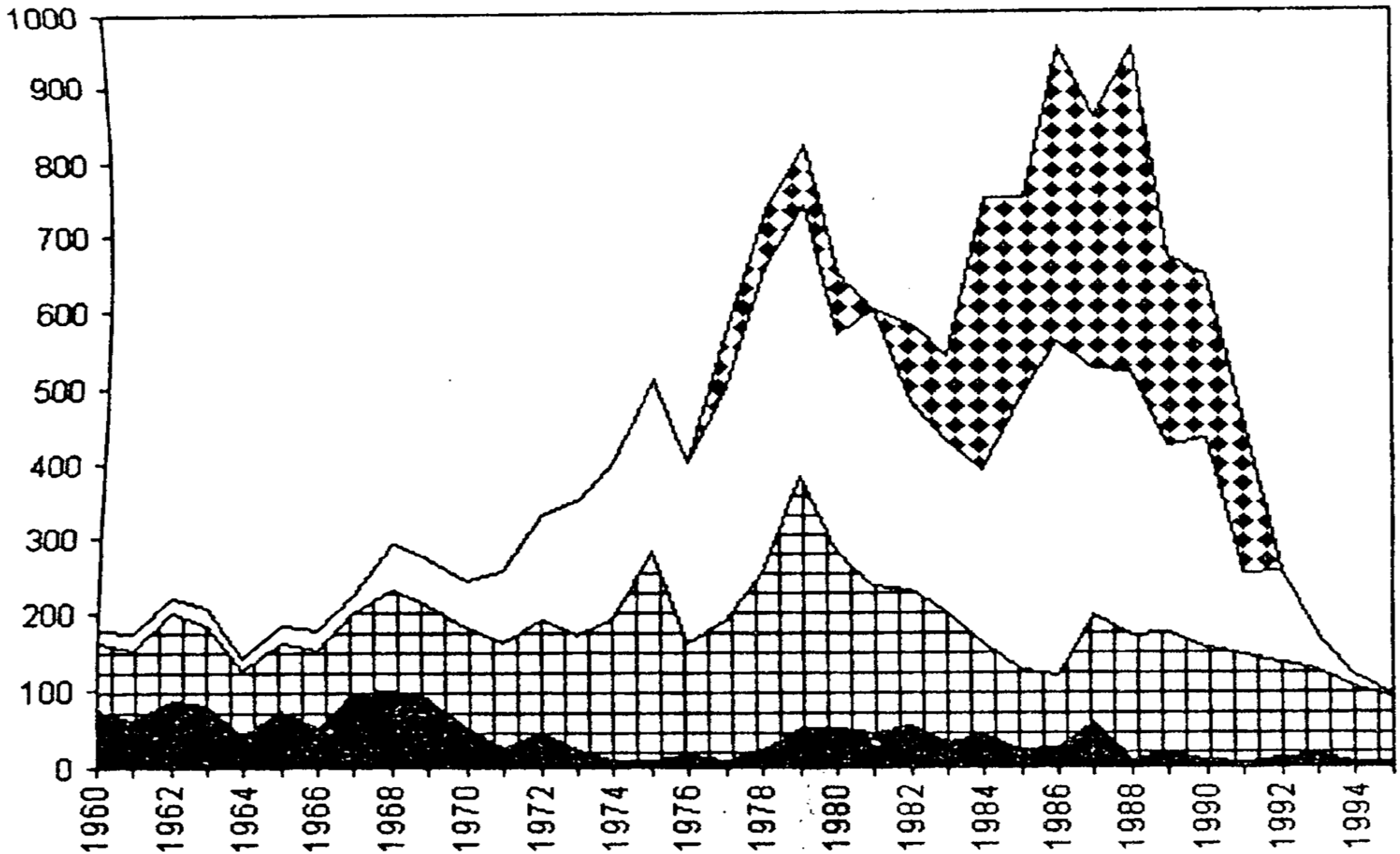


Fig. 17. Total catches of fish and non-fish objects in the South Kuril region in the economic zone of Russia (thousands tons). (After Ivanov, Sukhanov, 2002).

Conclusions

- Though geographically the discussed region is rather monotonous, the oceanographical conditions are extremely variable, and we should not refer to it as to one integrated region, which characteristics can be obtained by spatial averaging.
- High diversity of physical conditions in the region leads to high diversity of biota and extremely high bioproductivity of waters.
- We believe that correspondent ecosystems are practically not sensitive to global climatic changes, because local thermal and dynamic conditions prevail in formation spatial and temporal variability of ecosystem parameters.