SEASONAL VARIABILITY OF OCEANOLOGICAL CONDITIONS IN THE SOUTHERN PART OF THE OKHOTSK SEA FROM CTD SURVEYING ON STANDARD SECTION CAPE ANIVA – CAPE DOKUCHAEV

George Shevchenko and Valery Chastikov

Sakhalin Research Institute of Fisheries and Oceanography
196 Komsomolskaya street, Yuzhno-Sakhalinsk, Russia, 693023
e-mail: shevchenko@sakhniro.ru

Introduction

Observations on standard oceanological sections give us the unique data for investigation of seasonal and interannual water temperature and salinity variations because of regular, repeated surveying. During the 1950 – 1989 Sakhalin Hydrometeorology Agency carried out regular CTD surveying on the system of standard sections on the shelf of Sakhalin Island. Since 1990 to the present day CTD surveying supplemented by zooplankton sampling are carried out by Sakhalin Research Institute of Fishery and Oceanography (SakhNIRO). These measurements are carried out with lower frequency (usually two times per year), mainly in the southern part of the Okhotsk Sea (red rectangle that shown in the Fig.1).

The most important and informative among these sections is section Cape Aniva – Cape Dokuchaev (AD) in the southern part of the Okhotsk Sea. The AD section is crossing the southern part of the Okhotsk Sea from the southeastern end of Sakhalin Island to the northeastern end of Kunashir Island (Fig.2). This section also is crossing zones of two most important currents in this region – East Sakhalin Current that originates from the northern end of Sakhalin Island, and Soya Warm Current that is transporting the warm and salt Japan Sea waters to the area of South Kuril Islands (see Fig.1, 2).

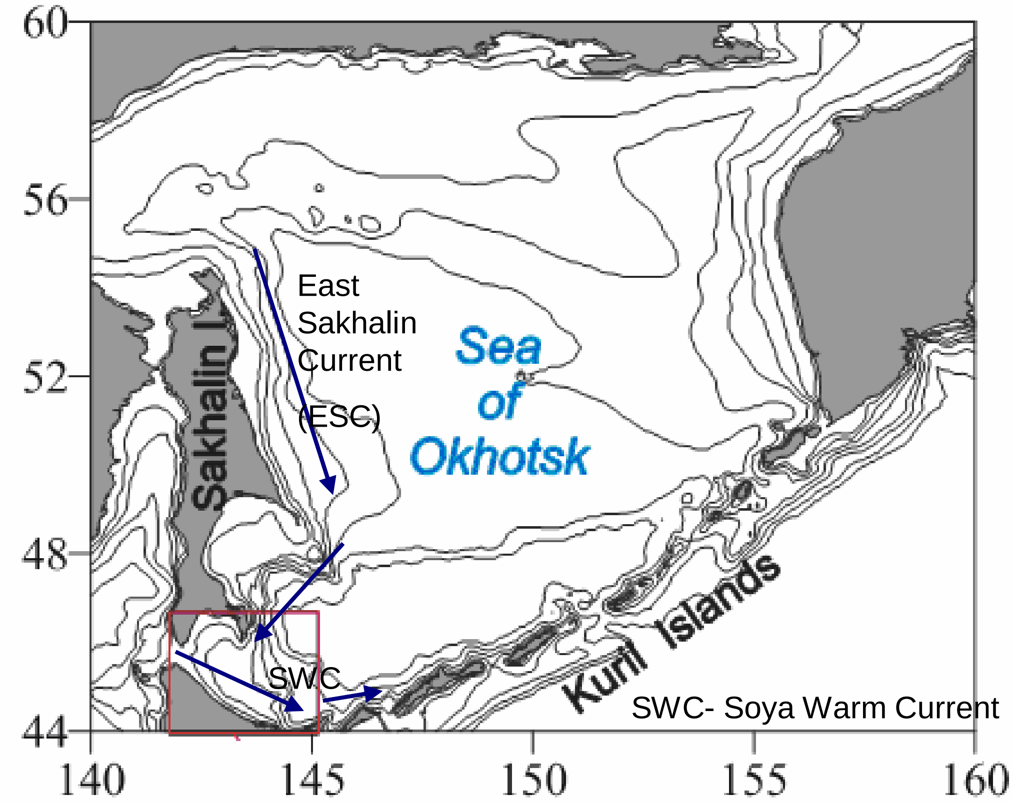


Fig.1. Southern part of Okhotsk Sea (marked by red rectangle) – the area of SakhNIRO fish resources and CTD surveying.

Data

Multiyear CTD-data were collected in NiroPro database and used for analysis of seasonal changes in oceanological conditions in the southern part of the Okhotsk Sea. CTD-data of 22 SakhNIRO expeditions (1990-2004) were analyzed with the goal of temperature and salinity anomalies determination and estimation of their influence on zooplankton community state. We also analyzed mean monthly SST satellite data in two 1°x1° squares (1982-2004) that crossed AD section in the northern and southern parts. Also we analyzed ADP current data obtained by Patritia-3 mooring (duration about 3 months in the fall season of 2004 not far from Cape Aniva) and Leya-2 mooring (duration more the 1 year, mooring located close to Cape Dokuchaev).

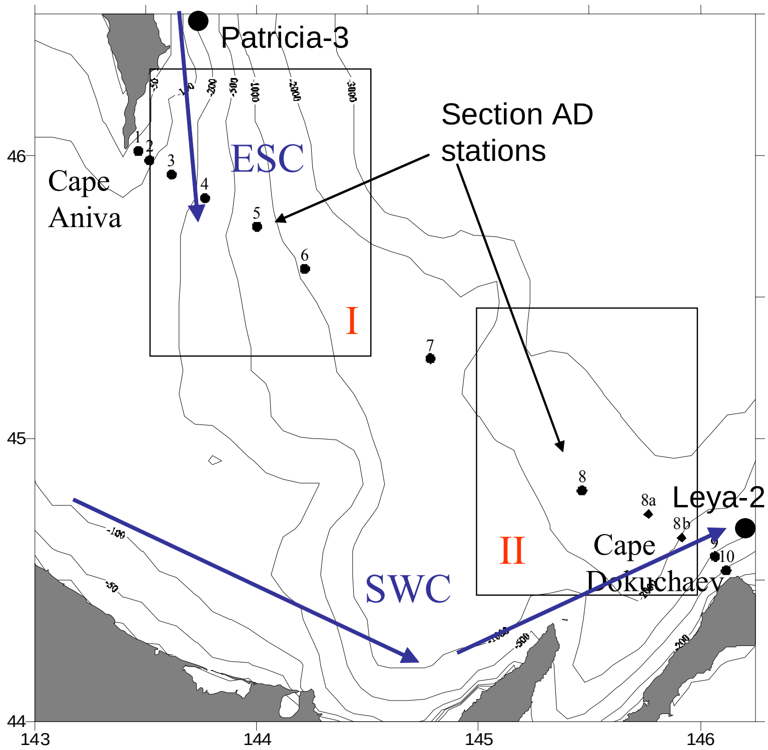


Fig.2. Stations of AD section (main stations are shown by circles and additional station 8a,b are shown by rhombs). Mean monthly SST data (1982-2004) were collected in two 1°x1° squares in the northwestern (I) and southeastern (II) parts of the section. The location of Patricia-3 and Leya-2 moorings is shown too.

Results and discussion

Multiyear mean temperature and salinity distributions on the AD section in May were analyzed to describe oceanological conditions in spring (Fig.3). We found that influence of Soya Warm Current in May is relatively weak in spite of an intensive flux of the Japan Sea waters in the La Perouse Strait. Cold intermediate layer is well-expressed: 0° isotherm is at the depth of 30 m in the northwestern part of the section and at the depth of 50 m in the southeastern part. At the depth more than 200 m we did not find waters with negative temperature. In the upper 50-meters layer low salinity waters were found been formed a as result of sea ice melting. Long-sections salinity gradients were relatively small.

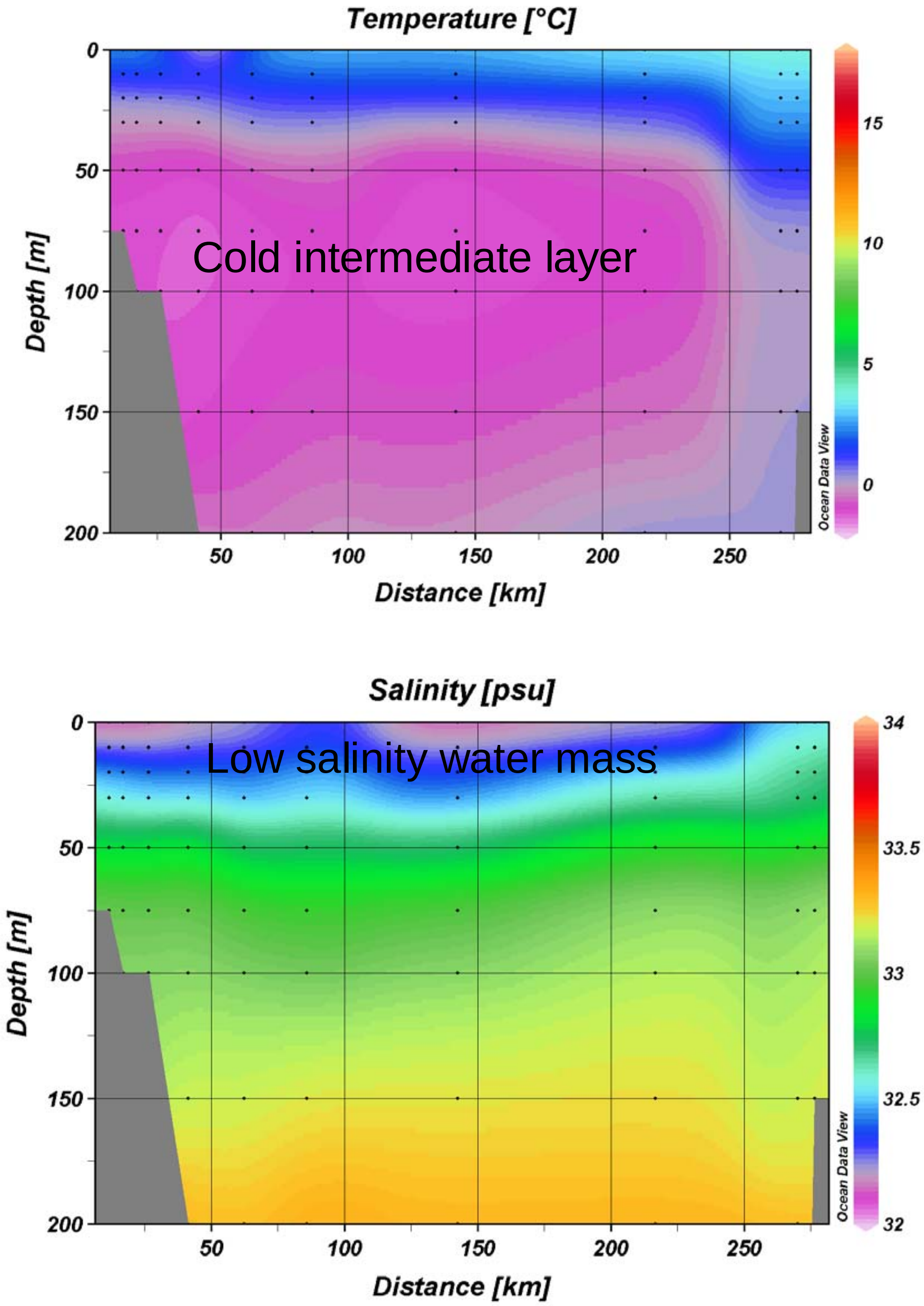


Fig.3. Multiyear mean water temperature (upper picture) and salinity (lower) distributions on the AD section that were calculated for spring (May).

Influence of the Soya Warm Current is very significant in the southwestern part of the AD section in summer (Fig.4); the Japan Sea warm waters were observed in the upper 200-meters layer on the shelf of Kunashir Island. At the same time, we found cold intermediate water with temperature -1.3°C on the shelf of Sakhalin Island. Spatial long-section salinity gradients are also very strong, difference between the first and last stations of AD section in the upper layer reached 2‰ (we see low salinity water mass in the northern part of the section).

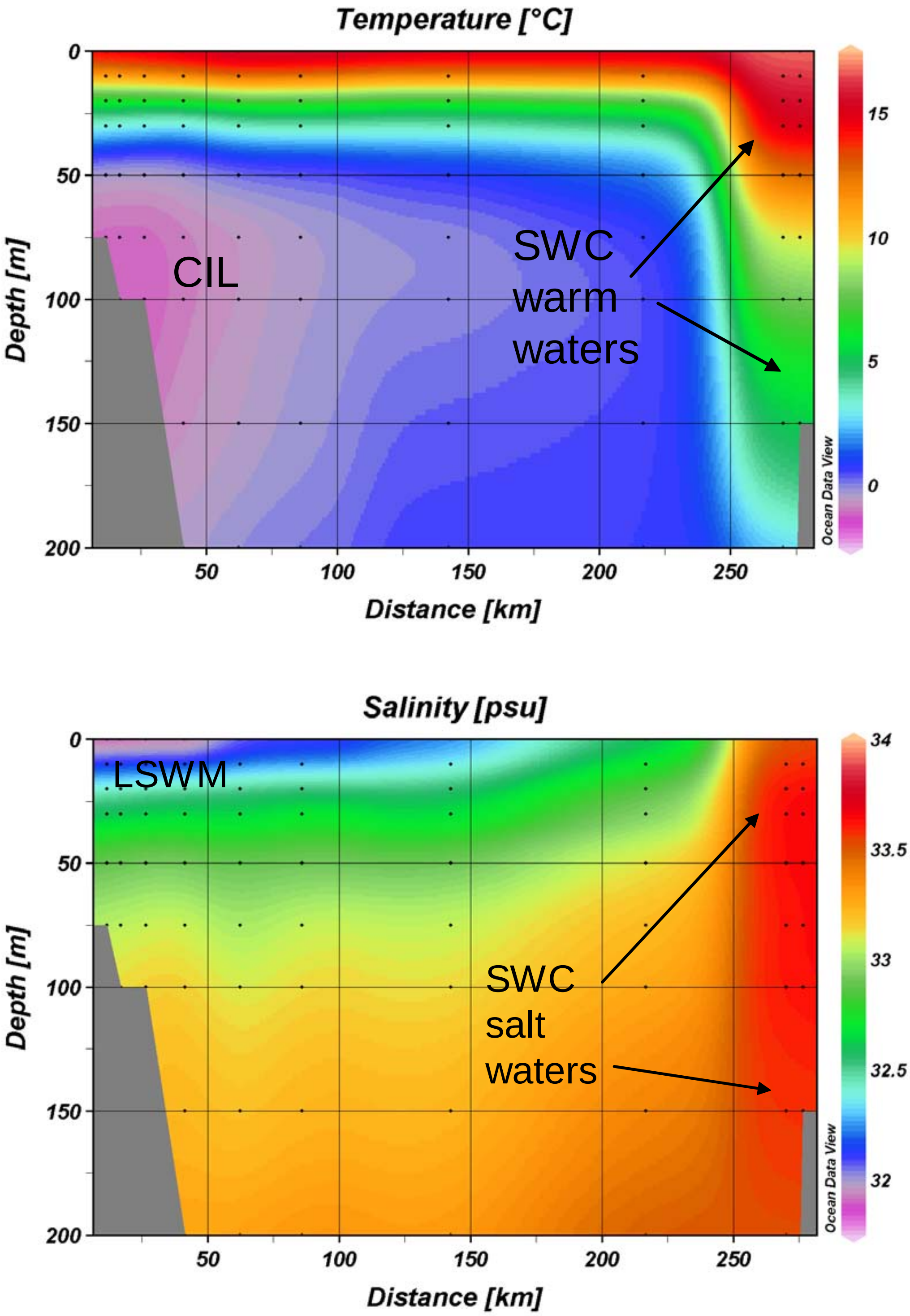


Fig. 4. Multiyear mean water temperature (upper picture) and salinity (lower) distributions on the AD section that were calculated for summer (August).

Autumn intensification of the East Sakhalin Current is the main factor affecting marine ecosystem. This current is transporting relatively warm and fresh Amour River waters to the southern part of the Okhotsk Sea in fall season (about 1000 kilometers from the northern end of Sakhalin Island). Cold intermediate layer which was well presented in the period of maximal warming-up (the later half of August – first half of September) was destroyed in November. Water temperature reached 3°C on the Sakhalin shelf at the depth of 100 m, where cold waters with temperature -1.3°C were observed earlier,. At the same time, influence of the Japan Sea warm waters is significant on the shelf of Kunashir Island.

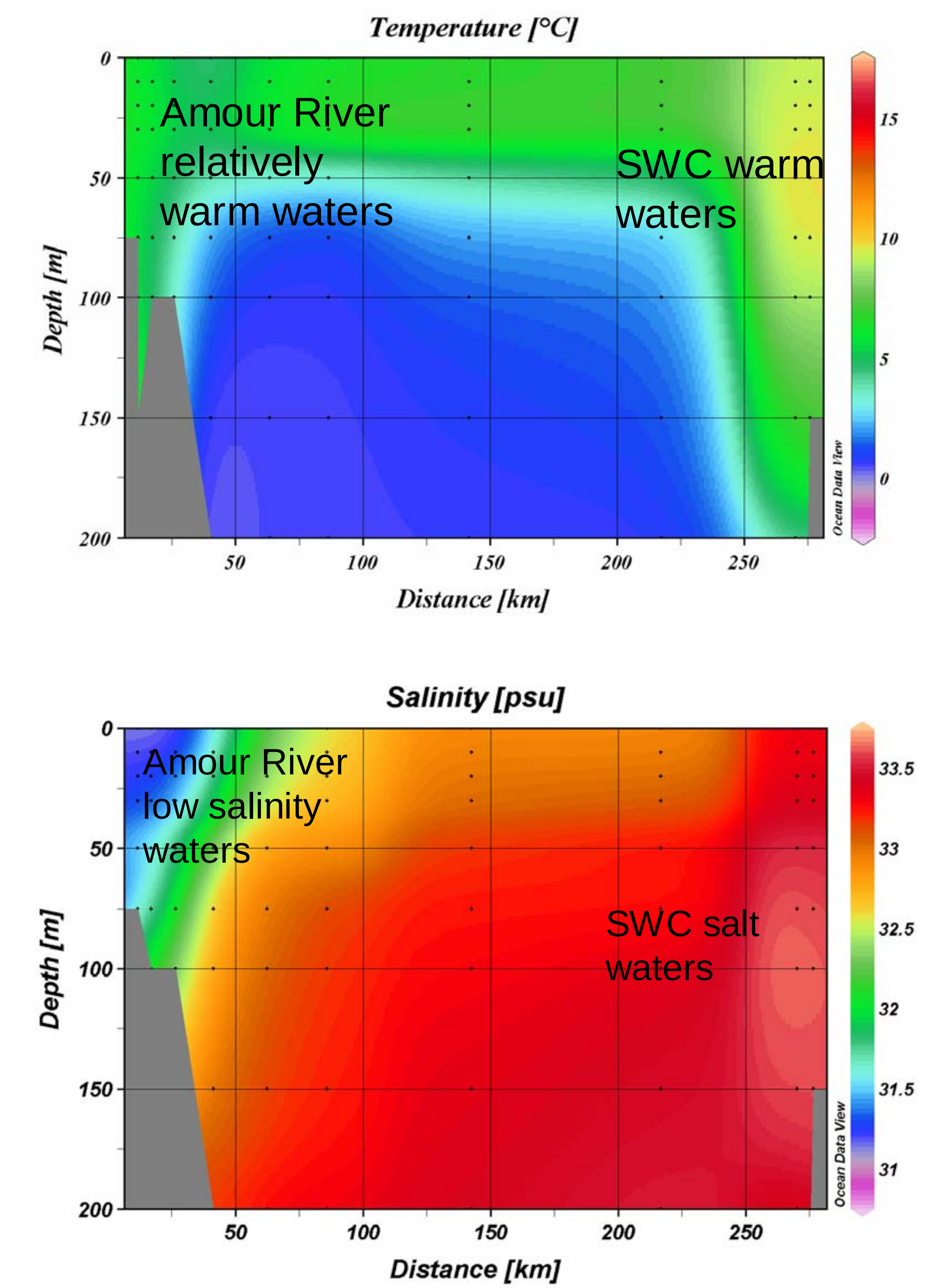


Fig. 5. Multiyear mean water temperature (upper picture) and salinity (lower) distributions on the AD section that were calculated for summer (August).

We can see autumn intensification of the East Sakhalin Current from the ADP Patricia-3 mooring's data that are presented in Fig.6. The north-going component of the currents increased rapidly in the middle of October 2004. We observed the same picture of autumn amplification of south-directed currents on the northeastern Sakhalin shelf (Rybalko, Shevchenko, 2004; Shevchenko, 2004).

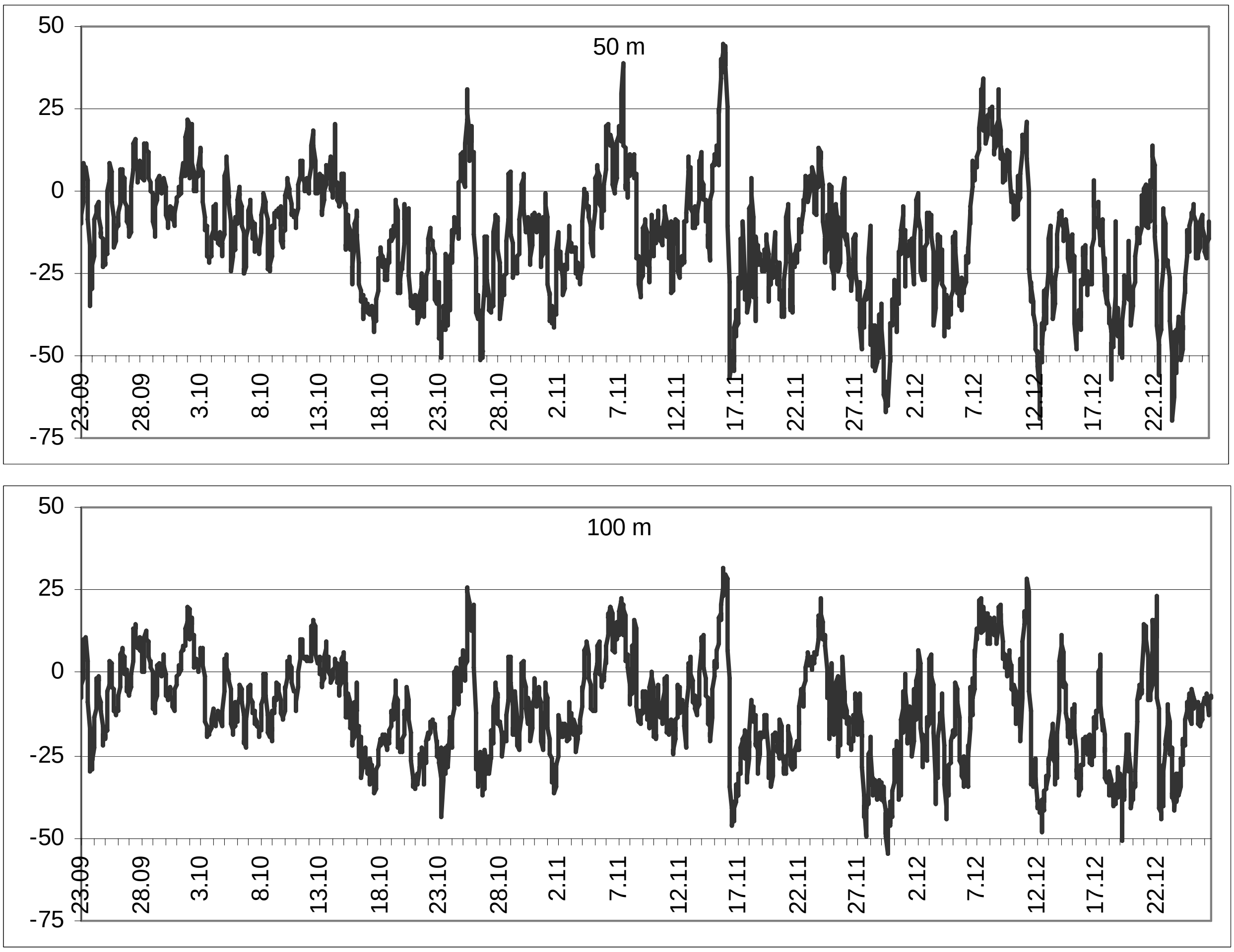


Fig.6. North-going constituents of current velocity that were measured by Patricia-3 ADP mooring in the middle and near-bottom layers.

We obtained the very interesting results relating to seasonal changes in currents from Leya-2 mooring. Mean monthly velocity vectors in the middle layer are shown in the Fig.7. In summer time we can see east-southeast directed currents with velocity about 10 cm/sec. In the autumn we see amplification of currents (velocity 20-25 cm/s) and some counterclockwise turning. The cause of amplification probably is the seasonal changes in atmospheric processes (so-called winter monsoon with strong northwesterly winds). However it is difficult to explain counterclockwise turning.

In a winter time we see south-directed currents. It means that a flux from the Okhotsk Sea to Pacific Ocean dominated in the cold season. This result is in a good agreement with these of winter intensification of the cyclonic circulation in the Okhotsk Sea obtained from altimetry data (Shevchenko, Romanov, 2005).

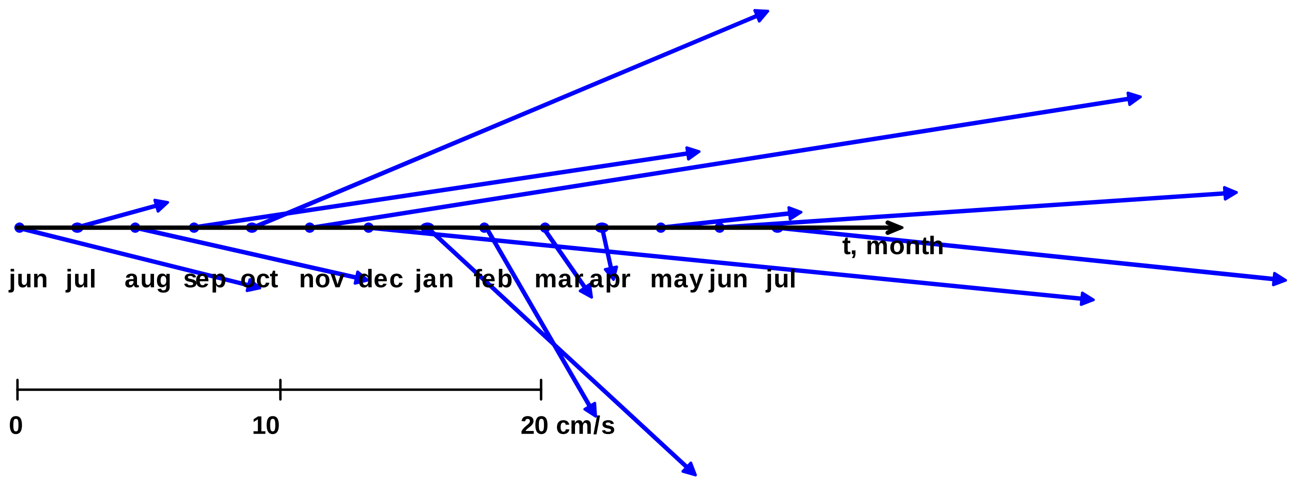


Fig.7. Mean monthly vectors of the current velocity in the middle layer near Cape Dokuchaev (Leya-2 ADP mooring, June 2003 – July 2004.

Let us consider extremal situations: the highest temperature and anomalies on the AD section. To determinate extremal situations, we used multiyear mean values and standard errors that were calculated for different layers using the database NiroPro.

The first one was observed in the end of May 1992. There were significant negative water temperature anomalies (greater than standard error) and positive salinity anomalies in the northwestern part of the section (Tab.1). We calculated norms and anomalies for different parts of the section separately because of great difference between them. In the area adjacent to Kunashir Island significant negative temperature anomalies were found too, however they were less than standard error.

Table 1. Temperature and salinity anomalies in May 27, 1992 in comparison with multiyear mean values according to (Pishchalnik, Bobkov, 2000) in the different layers. Positive anomalies greater than standard error (in denominator) are marked by yellow color (negative anomalies are marked by blue color)

Layer, m		0-20	0-30	0-50	0-100	0-200	20-100	30-100	50-100	100-200
Northwestern part of AD section (stations 1-7)										
27.05 .1992	T,°C.	-1,72 / 1,30	-1,74 / 1,30	-1,38 / 1,18	-0,79 / 0,84		-,56 / 0,74	-0,38 / 0,66	-0,16 / ,52	
	S, ‰.	+0,36 / 0,31	+0,41 / 0,32	+0,45 / 0,34	+0,38 / 0,31		+0,38 / 0,30	+0,36 / 0,29	+0,31 / 0,27	
Southeastern part of AD section (stations 8-10)										
27.05 .1992	T,°C.	-1,63 / 1,76	-1,79 / 1,90	-1,66 / 1,92	-1,24 / 1,92	-0,99 / 1,89	-1,15 / 1,99	-1,01 / 1,97	-0,83 / 1,97	-0,64 / 1,80
	S, ‰.	+0,17 / 0,26	+0,18 / 0,25	+0,17 / 0,25	+0,15 / 0,23	+0,06 / 0,21	+0,14 / 0,22	+0,13 / 0,22	+0,13 / 0,21	+0,06 / 0,17

SST satellite data that were collected in squares I and II (it is interesting that the difference between these squares was small) show that the spring 1992 was relatively cold, but not coldest (Fig.8). Let us look on the vertical distributions of temperature and salinity (Fig.9). We can see cyclonic eddy off the coast of Sakhalin Island which was a cause of upwelling of the relatively cold and salt waters in the upper layer that gave the temperature and salinity anomalies observed.

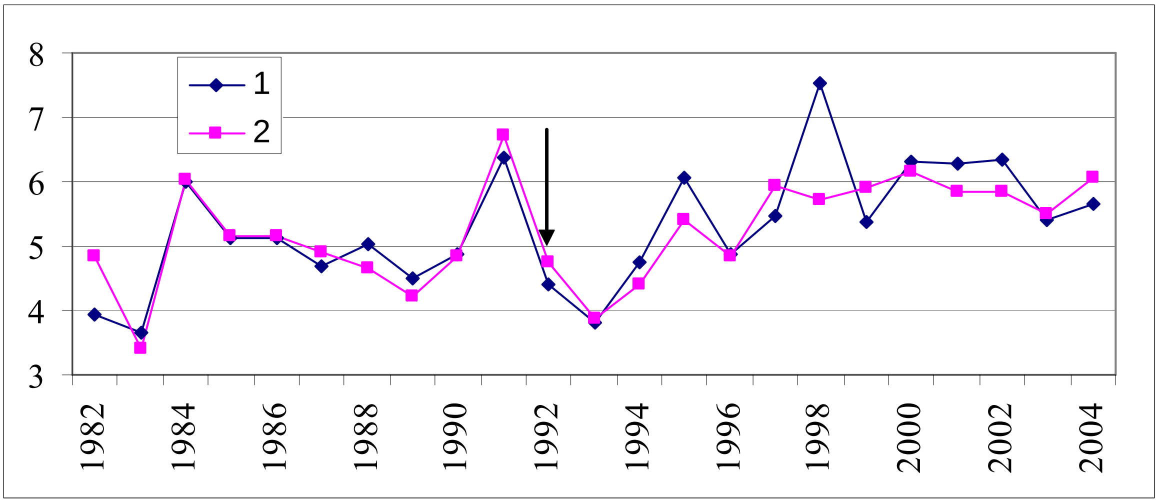


Fig.8. Average SST values for spring (May + June) in the squares I and II.

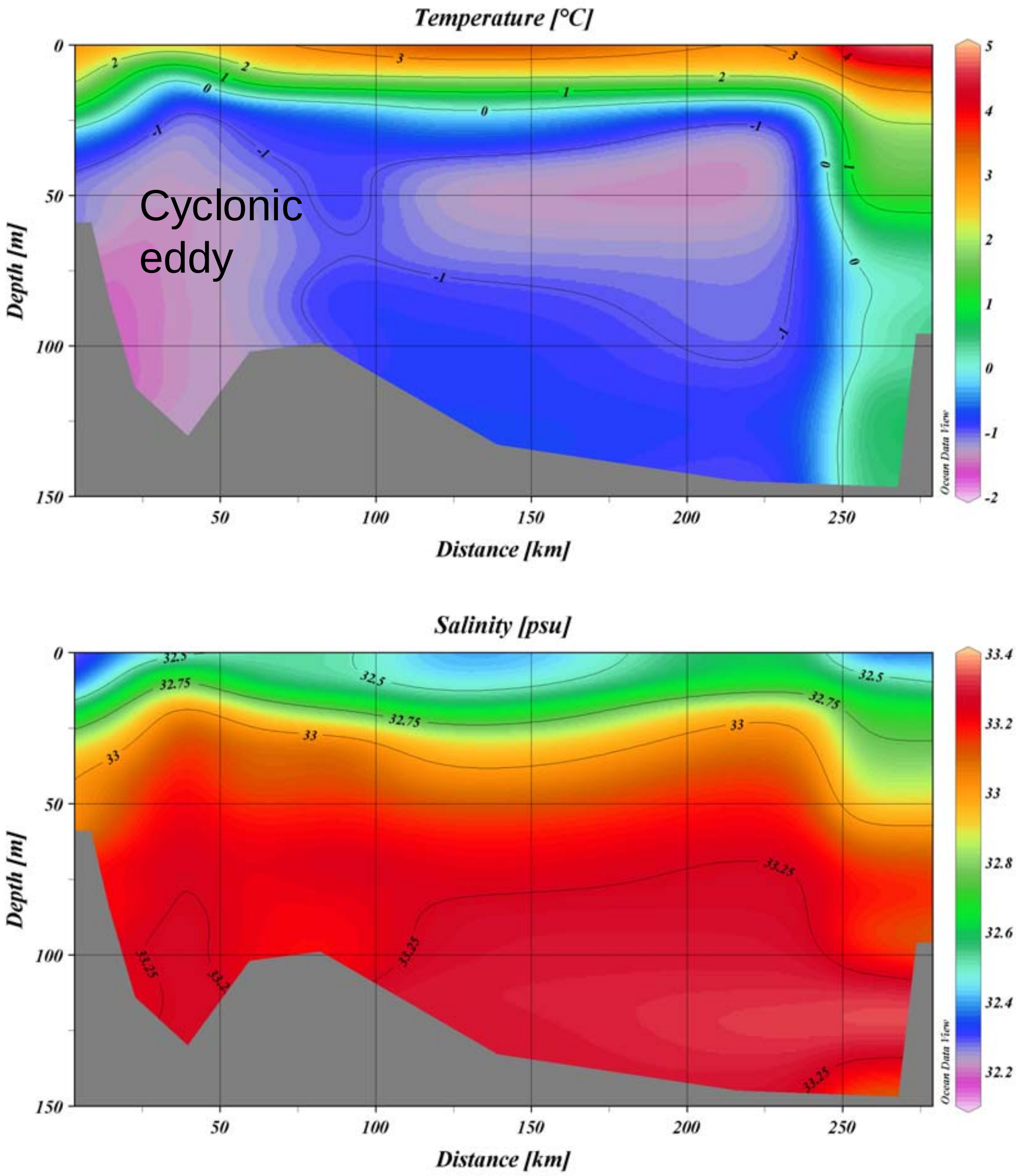


Fig.9. Temperature and salinity distribution on the AD section in May 27, 1992.

Table 2. Temperature and salinity anomalies in June 16, 1999 in different layers.

Layer		0-20	0-30	0-50	0-100	0-200	20-100	30-100	50-100	100-200
Northwestern part of AD section (station 1-7)										
16.06 .1999	**T**,°C.	+2,02 1.29	+1,62 1.32	+0,84 1,23	+0,28 0,88	+0,13 0,75	-0,16 0,78	-0,30 0,70	-0,28 0,54	-0,03 0,61
	S, ‰.	-0,01 0,27	-0,03 0,27	-0,03 0,26	-0,01 0,23	-0,01 0,21	-0,02 0,22	-0,01 0,21	0,00 0,20	-0,01 0,19
Southeastern part of AD section (stations 8-10)										
16.06 .1999	**T**,°C.	+4,14 1,25	+4,14 1,63	+4,28 2,10	+2,86 2,21	+1,60 1,83	+2,54 2,46	+2,32 2,46	+1,45 2,33	+0,28 1,44
	S, ‰.	+0,47 0,32	+0,50 0,34	+0,50 0,36	+0,32 0,34	+0,17 0,28	+0,28 0,34	+0,24 0,34	+0,14 0,32	+0,02 0,21

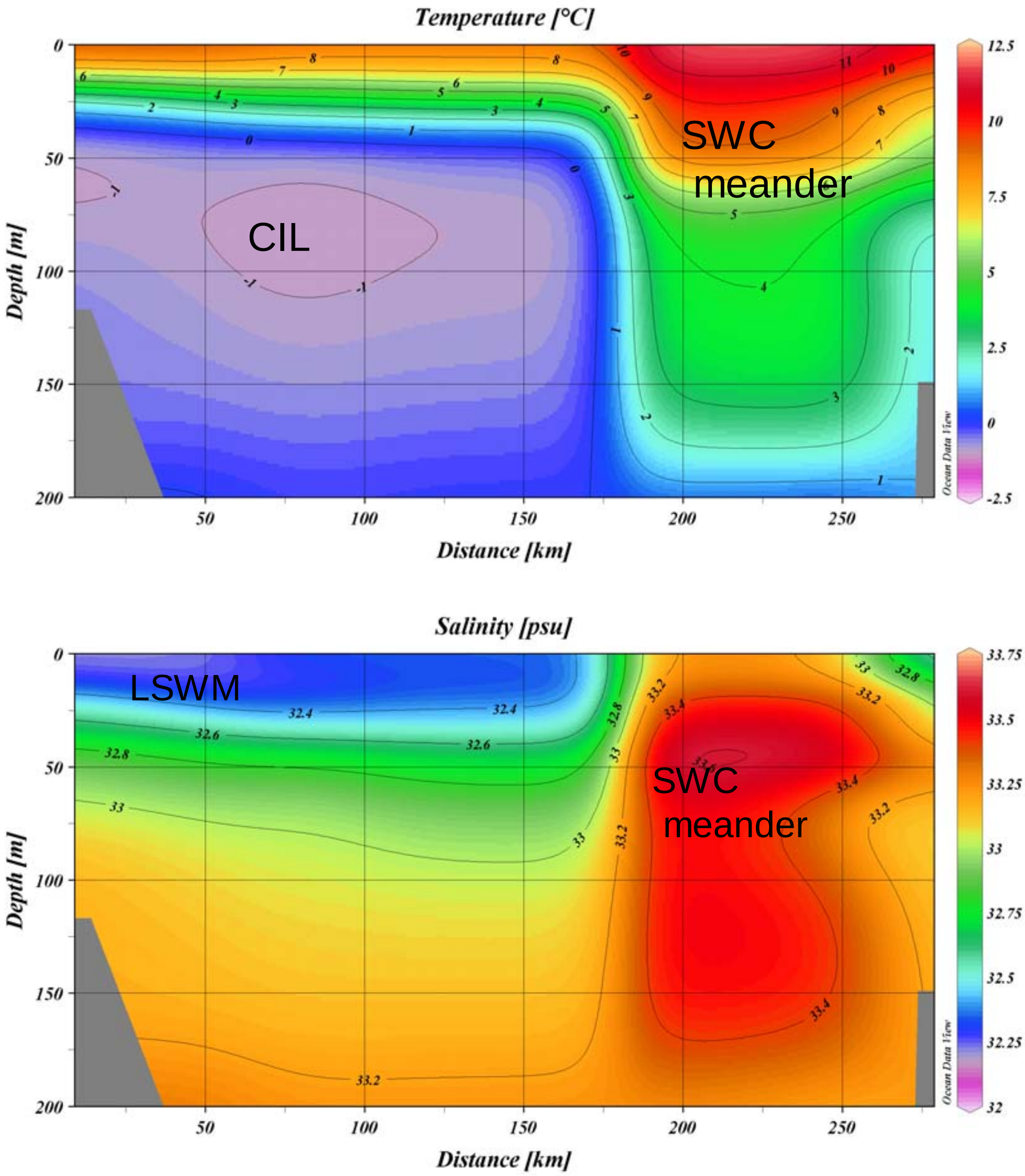


Fig.10. Temperature and salinity distribution on the AD section in May 27, 1992.

Another interesting situation was observed in the middle of June 1996. We see the large positive anomalies in the upper layer in both pats of the section: in the southern part they reached more than 4 degree C (Tab.2). In this part unusually strong positive salinity anomalies (more then 0.5 ‰) were found too.

The vertical distributions of temperature and salinity on the AD section in June 1996 show the typical for Soya Current warm and salt waters off the coast of Kunashir Island, from the forms of isotherms and isohalines we can conclude that anti-cyclonic eddy (probably Soya meander) was formed on the South Kuril shelf (Fig.10). There is only one case from 22 expeditions when maximal temperature and salinity were found far from the Kunashir coast.

The next interesting situation was observed in the same 1996 year, in August. We found the large positive water temperature anomalies in the southern part of the section. According to satellite data, summer 1996 was warmest in the southern part of the Okhotsk Sea since 1982. Large positive SST anomalies were observed from satellite data in the whole western part of the sea and adjacent area of the Pacific Ocean.

Table 3. Temperature and salinity anomalies in August 9, 1999 in different layers.

Layer		0-20	0-30	0-50	0-100	0-200	20-100	30-100	50-100	100-200
Northwestern part of AD section (stations 1-7)										
09.08.1999	T,°C.	+1,09 / 1.96	+0,76 / 2,00	+0,34 / 1,59	+0,17 / 1,06	+0,18 / 0,77	-0,06 / 0,84	-0,08 / 0,66	+0,01 / 0,53	+0,19 / 0,38
	S, ‰.	-0,10 / 0,25	-0,08 / 0,26	-0,06 / 0,23	-0,05 / 0,21	-0,04 / 0,18	-0,04 / 0,19	-0,03 / 0,18	-0,04 / 0,18	-0,03 / 0,16
Southeastern part of AD section (stations 8-10)										
09.08.1999	**T,°C.**	+2,25 / 2,20	+2,34 / 2,24	+2,83 / 2,14	+3,94 / 1,92	+3,04 / 1,54	+4,36 / 1,85	+4,63 / 1,78	+5,05 / 1,70	+2,09 / 1,15
	S, ‰.	+0,17 / 0,32	+0,20 / 0,31	+0,26 / 0,27	+0,27 / 0,23	+0,12 / 0,21	+0,30 / 0,20	+0,30 / 0,19	+0,29 / 0,19	-0,03 / 0,20

We can see the residual eddy influence on the vertical distribution of temperature and salinity. As we see from Fig.11, this summer was warmest in the southern part of the Okhotsk Sea, however, a cold intermediate layer was observed near the Sakhalin slope.

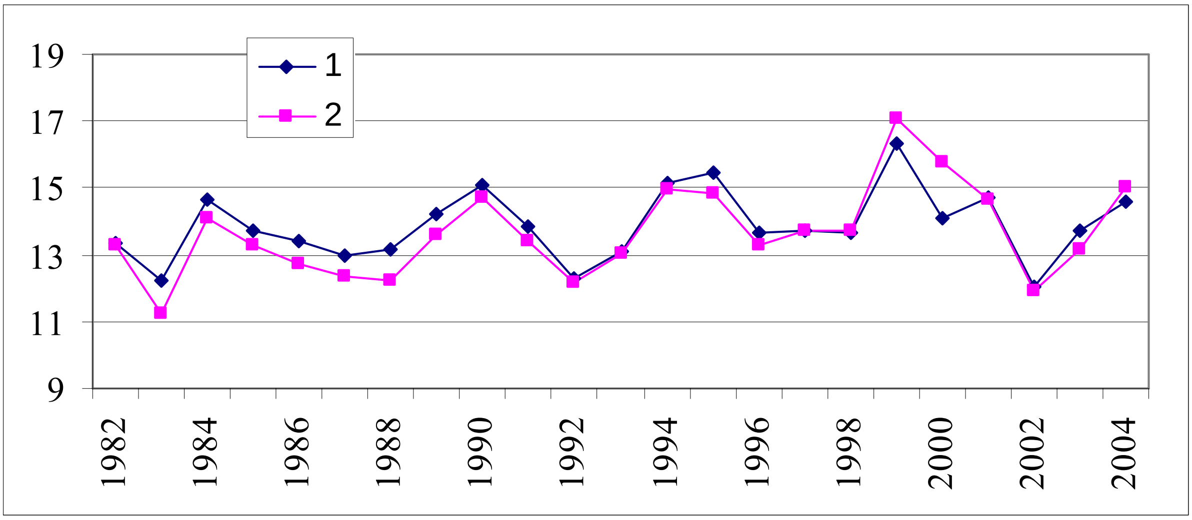


Fig.11. Average SST values for summer (July + August + September) in the squares I and II.

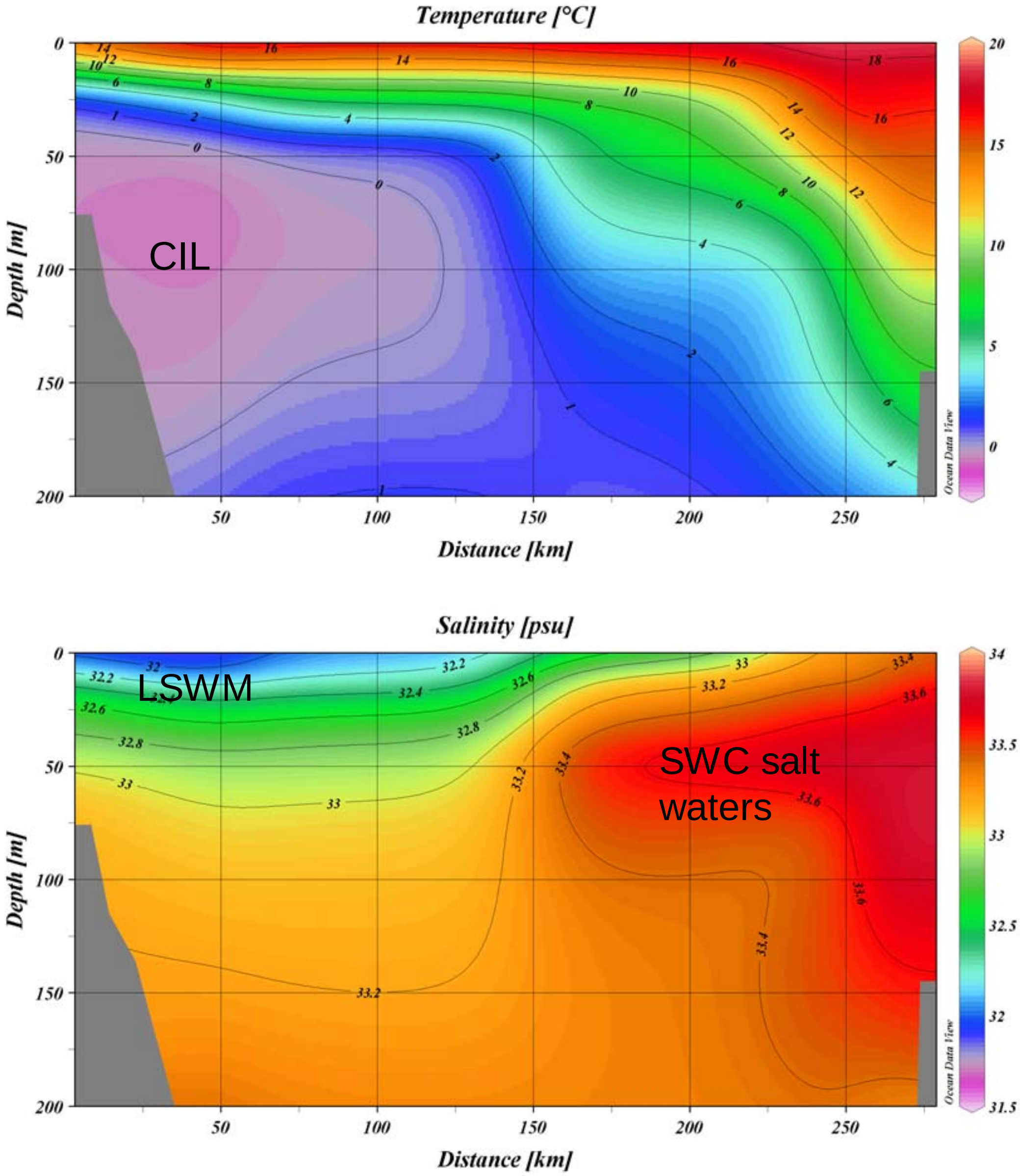


Fig.12. Temperature and salinity distribution on the AD section in August 9, 1999.

The next (last) example is the situation in November 1998. Large positive anomalies of temperature and salinity were found in the northern part of the section. Salinity anomalies that reached 0.5‰ are especially interesting. According to satellite data, there was the warmest autumn since 1982 in the study area. It is very interesting that the difference between two squares in contrast to spring and summer seasons was significant and increased during last years. This result partly agreed to these of (Itoh, Ohshima, 2000) – they show that the area of Soya warm waters is narrow in summer and wider in autumn. However increasing of difference is unclear, it is a great question of our investigation. Probably, this question is connected with another question – what is a cause of velocity vector turning in autumn.

Table 4. Temperature and salinity anomalies in November 10, 1998 in different layers.

Layer	0-20	0-30	0-50	0-100	0-200	20-100	30-100	50-100	100-200
Northwestern part of AD section (stations 1-7)									

10.11 .1998	**T**,°C.	+1,46 1,05	+1,44 1,10	+1,96 1,32	+1,97 1,37	+1,39 1,06	+2,10 1,46	+2,20 1,50	+1,99 1,43	+0,72 0,71
	S, ‰.	+0,55 0,39	+0,53 0,37	+0,45 0,34	+0,33 0,27	+0,21 0,21	+0,28 0,24	+0,25 0,23	+0,22 0,20	+0,07 0,13
Southeastern part of AD section (stations 8-10)										
10.11 .1998	**T**,°C.	+1,34 2,23	+1,24 2,22	+1,36 2,29	+1,23 2,12	+1,18 2,04	+1,21 2,10	+1,23 2,08	+1,10 1,96	+1,12 1,94
	S, ‰.	+0,37 0,50	+0,33 0,49	+0,24 0,46	+0,13 0,35	+0,07 0,32	+0,07 0,31	+0,05 0,29	+0,03 0,24	0,00 0,27

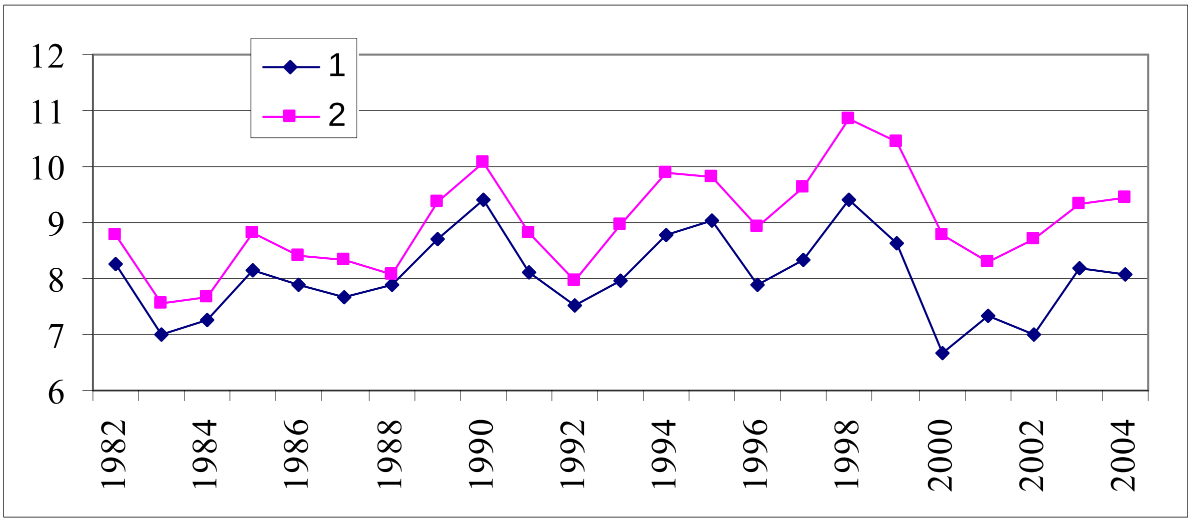
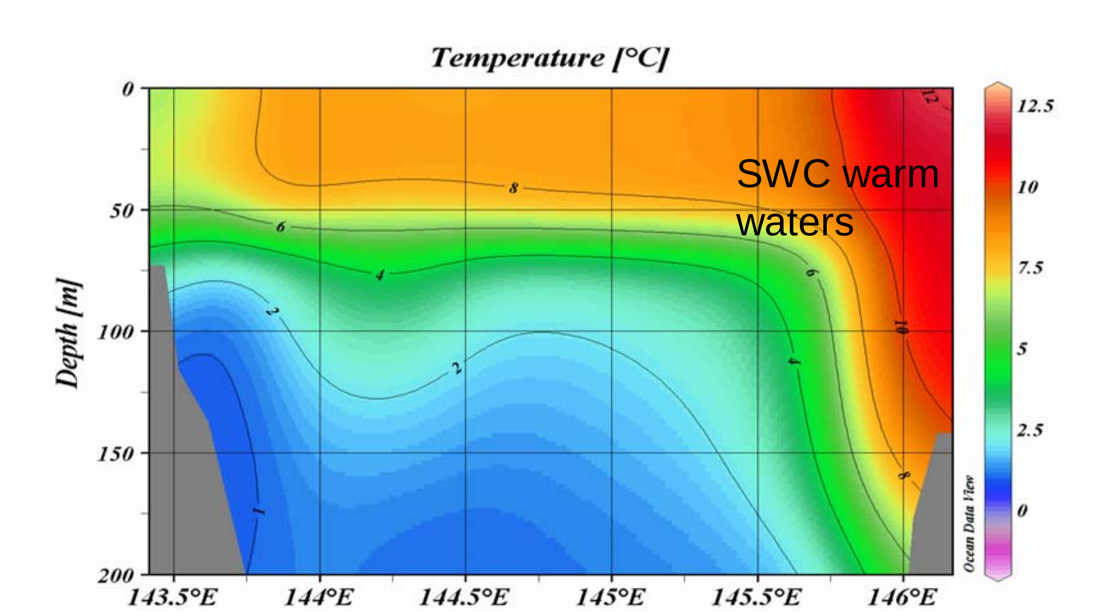


Fig.13. Average SST values for autumn (October + November + December) in the squares I and II.



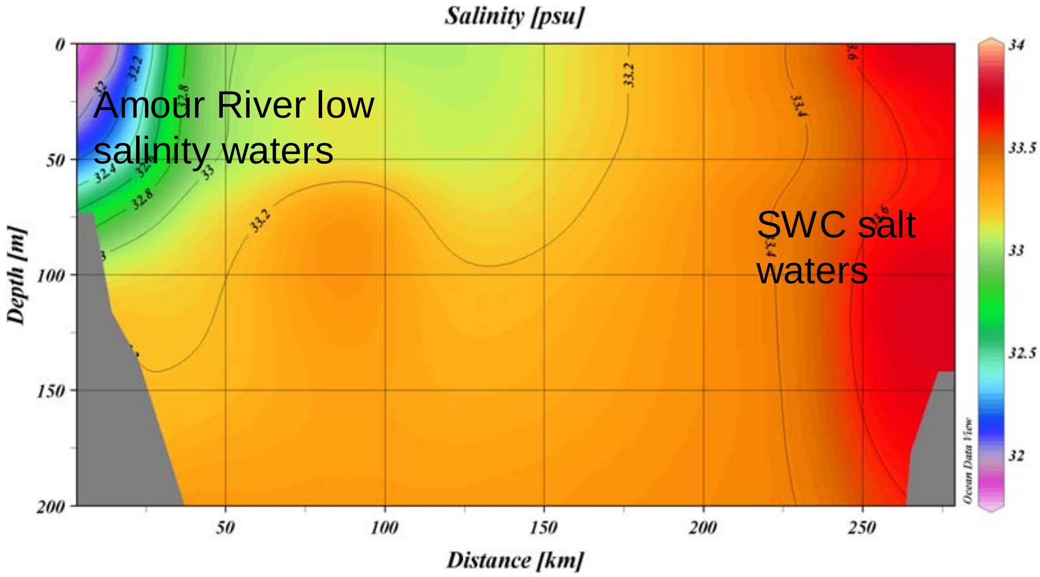


Fig.14. Temperature and salinity distribution on the AD section at November 10, 1998.

Conclusion

We obtained from the analysis of seasonal variability of oceanological conditions on the AD section the following results:

Spring. Influence of Soya Warm Current waters is weak. Low salinity (melt) water mass in the upper layer and cold intermediate layer were found well-expressed. Long-section salinity gradient is relatively small.

Summer. Warm and salt Soya Warm Current waters were found in the upper 200 m on the shelf of Kunashir Island. Cold intermediate layer with temperature -1.3°C is located near Sakhalin Island.

Autumn. The main oceanologicaql factor in autumn is an amplification of the East Sakhalin Current that is transporting low salinity Amour River water along the eastern Sakhalin coast. In the same time, influence of warm and salt SWC waters is significant; they occupy wider area than in summer time.

Water temperature anomalies can reach 4-5°C and salinity anomalies - 0.5-0.6‰. Maximal anomalies were connected with cyclonic or anti-cyclonic eddies that crossed AD section.

From mooring data we found an amplification of currents and counter-clockwise turning of vectors in autumn on the shelf of Kunashir Island. In the winter time the flux from Okhotsk Sea to Pacific Ocean was observed.

References

Itoh M., Ohshima K. Seasonal Variations of Water Masses and Sea Level in the Southwestern Part of the Okhotsk Sea // J. Oceanogr. 2000. 56. 643-654.

Pishchalnik V.M., Bobkov A.O. Oceanographycal Atlas of Sakhalin shelf. – Sakhalin University. – 2000 (In Russian).

Rybalko S.I., Shevchenko G.V. Seasonal and spatial variability of sea currents on the Sakhalin northeastern shelf // J. Pacific Oceanography. - 2003. - Vol. 1. - No. 2. - P. 168–178.

Shevchenko G.V. Calculation of extreme current velocities by the composition distribution method (using the example of the Piltun-Astokh oil field on the northeastern shelf of Sakhalin)// Russian Meteorology and Hydrology J. – 2004. – No 1. – P.33-47. (English translation).

Shevchenko G. and Romanov A. Seasonal variations of surface circulation in the Okhotsk Sea from Topex/Poseidon satellite altimetry data// Proceedings of the 20th international symposium on Okhotsk Sea & Sea Ice. - Mombetsu, Hokkaido, Japan, 2005, pp. 289-294.