3.2 Short-period internal waves in the Kara Sea

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Introduction

The internal waves are one of the main reasons of the processes of water entrainment and pycnocline erosion in the fresh waters spreading zone in the Kara Sea. Instability and destruction of the internal waves on the shelf and in the coastal zone results in more intensive mixing of water masses and amplification of the turbulent diffusion of the heat and salts. Until present time there are only a few measurements of the short-period waves in the Kara Sea. Within the framework of Russian-Swedish expedition "Tundra-94" in the southwest part of the Kara Sea the measurements of water temperature oscillations in the pycnocline during about 1 hour with the discretization 4 sec were executed. The analysis of these measurements has shown the presence of the internal waves with periods 10-12 and 2-3 minutes (Zakharchuk and Presnyakova 1997). Within the framework of the joint Russian-German expedition 1997 onboard of the RV "Academik Boris Petrov" the measurements of temporary variability of water temperature and salinity were executed from anchored vessel not far from the Dikson Island. The recording of hydrological parameters was carried out with the discretization 1 sec during almost 4 hours. The analysis of these measurements has shown internal waves with well-expressed periods 9.5, 5.3 and 2-3.5 minutes. It was noted the packet character of the short-period waves (Gribanov et al. 1999).

Data

Within the framework of the joint Russian-German expedition 2001 onboard of the RV "Academik Boris Petrov" the measurements of temporal variability of water temperature and salinity using CTD-sonde "Neil Brown-MKIII" were executed. After water sampling the additional profiling was carried out and the horizon for device deploying was selected. At 22 stations the CTD-sonde was deployed for long term measurements from the anchored vessel directly within the pycnocline layer or within the layer with some peculiarity of the vertical thermohaline structure. Also to exclude the influence of the vessel body the depth of observation was chosen more than 4.5 m.
The mean duration of these records is about 1 hour (Tab. 3.1). The numbers of CTD-stations in the table are from this expedition and their locations are presented in this volume (Fig. 3.10, Chapter 3.1). Unfortunately the simultaneous measurements of currents are absent.

Table 3.1. The long-term measurements of the water temperature and salinity

№ station	Horizon, m	Duration, min	Length of averaging row	Note
3	6.0	71	230	Pycnocline
11	7.5	65	391	Pycnocline
23	4.5	31	95	Pycnocline, long-periodic trend
26	7.8	78	156	Pycnocline, long-periodic trend
28	14.9	69	138	Peculiarity, long-periodic trend
31	15.1	60	121	Pycnocline
35	19.7	67	202	Peculiarity
38	14.5	81	243	Pycnocline, long-periodic trend
43	11.0	69	207	Peculiarity
45	18.0	59	178	Pycnocline, long-periodic trend
46	19.0	69	209	Pycnocline
48	22.7	72	217	Peculiarity
52	14.3	63	190	Peculiarity, long-periodic trend
56	19.0	35	107	Peculiarity, long-periodic trend
59	31.2	52	158	Peculiarity
62	23.7	81	243	Peculiarity, long-periodic trend
65	10.3	69	207	Peculiarity
67	14.6	63	189	Peculiarity
68	11.6	63	191	Peculiarity
70	8.5	128	768	Pycnocline, long-periodic trend
80	6.1	61	185	Pycnocline, long-periodic trend
82	8.0	60	181	Peculiarity

The depth of sensors varied because the sound was put down from the vessel board. We assumed that the oscillations of values of water temperature and salinity are a linear superposition of oscillations caused by vertical displacements of sensors and by internal waves. Using data of registration of the immersion depth of the sensors and data of sounding on CTD-station executed before record, the oscillations caused by vertical displacements of sensors were filtered. The minimum values of internal waves periods should be more than maximum value of the Brunt-Väisälä period therefore source rows were smoothed by the running averaging. All oscillations with period less than Brunt-Väisälä period are referred to turbulent pulsing.

Results and discussion

The analysis of the long term records of water temperature and salinity have shown the existence of well pronounced short-period internal waves at the all CTD-stations. The salinity variations are about 0.3-0.5 psu per 10 min (in estuaries – up to 6-8 psu) and temperature variations reach values up to 0.5-1.0 °C per 10 min. The main periods of these waves are about 8-12, 5-6 and 2-3 minutes and amplitudes are from 0.5 to 3 m.
In Table 3.2 the estimations of the wave amplitudes and main periods are presented. These values are presented for temperature and salinity separately. The spatial distributions of these parameters are presented on Figure 3.10.

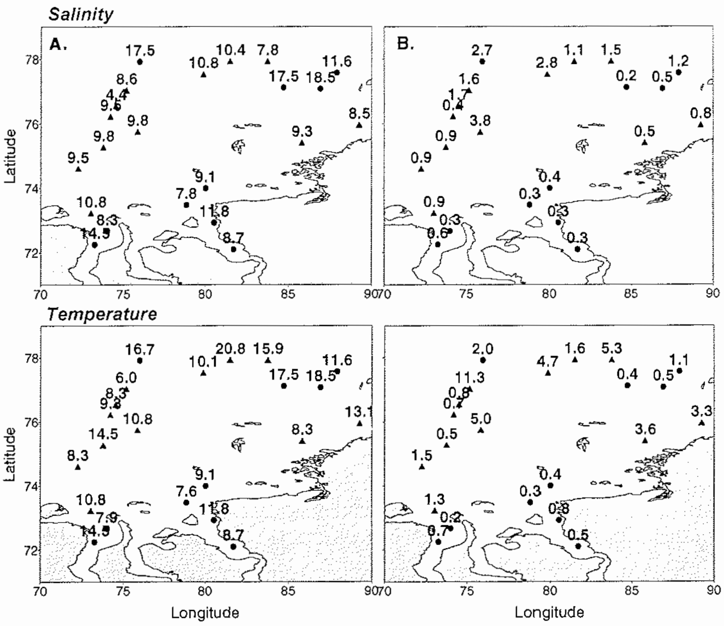

Fig. 3.10. The spatial distribution of the amplitudes (A) and periods (B) of internal waves for water temperature and salinity records.

• - measurements at the pycnocline layer;

▲ - measurements at the layer with some peculiarities.

It is necessary to note that the values of wave amplitudes and periods for temperature and salinity are the same (or closely) at the stations where measurements were executed at the pycnocline layer (Fig. 3.11). But these values are different at the stations where measurements were executed at the layer with some peculiarities (Fig. 3.12).

About the one half of the records has the well-expressed long-period trend (Tab. 3.1). The analysis of measurements on the daily and multidaily CTD-stations in the Kara Sea (the measurements were produced with a discretization 1 hour and more) has shown the presence of internal waves with tidal and subtidal (3-8 hours) periods (Gribanov et al. 1997; Pavlov et al. 1996). Thus the short-period waves exist on the background of the more long-period waves (Fig. 3.13).

Table 3.2: The estimations of the internal wave parameters.

№ station	Horizon, m	Salinity		Temperature	
		Wave amplitude	Wave period	Wave amplitude	Wave period
3	6	0.3	**11.8**: 5.1	0.8	**11.8**; 4.9
11	7.5	0.3	**8.7**: 5.0; 2.8	0.5	**8.7**; 2.4
23	4.5	0.3	**7.8; 4.2**; 2.0	0.3	**7.6; 4.2**; 2.0
26	7.8	0.4	**11.9; 9.1**; 5.5	0.4	**11.9; 9.1**; 5.5
28	14.9	0.8	**13.1; 8.5**; 5.2	3.3	**13.1**; 6.6; 3.8
31	15.1	1.2	**11.6**; 7.9; 6.0	1.1	**11.6**; 7.8; 6.0
35	19.7	1.5	18.5; **7.8**; 3.9	5.3	**15.9;** 10.1; 7.4; **5.8**; **4.3**; 3.5
38	14.5	0.5	**18.5**; 6.9; 4.8	0.5	**18.5**; 6.9; 4.8
43	11	0.5	**15.9; 9.3; 5.8**; 3.7; 3.2	3.6	**8.3**; **5.7**; 4.6; **3.2**
45	18	0.2	**17.5**; 10.8; 4.9	0.4	**17.5;** 10.4; 4.9
46	19	2.7	**17.5**: 10.1; 5.0	2.0	**16.7**: 10.1; 5.0
48	22.7	1.1	**10.4**; 5.8; **3.4; 2.8**	1.6	**20.8; 10.1**; 6.3; 4.2
52	14.3	2.8	**10.8**; 5.0; 2.9	4.7	**10.1; 5.5**; 3.9
56	19	1.6	**8.6; 5.8**; 2.3	11.3	7.8; **6.0**; 3.5; 2.3
59	31.2	1.7	6.5; **5.4; 4.4**; 2.1	0.8	**8.3**; 4.3; 3.3; 2.4
62	23.7	0.4	**13.9; 9.5; 6.4**; 5.2	0.7	**9.3**; 5.5; 4.3; 3.7
65	10.3	3.8	**9.8**; 7.1; **4.4**; 3.7; **2.8**	5	**10.8**; 6.9; **5.5**; 3.4; 2.8; **2.4**
67	14.6	0.9	**9.8; 6.0; 3.6**; 1.8	0.5	**14.5; 6.9; 3.6**; 1.8
68	11.6	0.9	**9.5; 6.7**; 3.5	1.5	**8.3; 6.4**; 3.5
70	8.5	0.3	13.9; **8.3**; 4.5; 3.4	0.2	12.8; **7.9**; 4.5; 3.4
80	6.1	0.6	**14.5**; 7.2; 4.2; 3.4	0.7	**14.5**; 7.1; 4.2; 3.4
82	8.0	0.9	**10.8**; 3.7; 2.8; 2.4; 2.0	1.3	**10.8**; 3.7; 2.8; 2.4; 2.0

At the some stations it was marked the nonlinearly temperature and salinity oscillations from the cnoidal waves caused by the bottom influence (Fig. 3.14) and up to soliton-like waves caused by the peculiarities of the vertical thermohaline structure (Fig. 3.15).

The strip-selected filtering has shown that the short-period oscillations of the water temperature and salinity with periods 2-5 minutes have the packet character and the periods of these packets are from 30 minutes up to 1 hour.

The analysis results give some possibility to conclude that in the Kara Sea the probability of the Kelvin – Helmholz instability occurring is very high for internal waves with periods 2-5 minutes. The dynamic instability and destruction of short-period internal waves results in the turbulence and formation of the fine thermohaline structure.

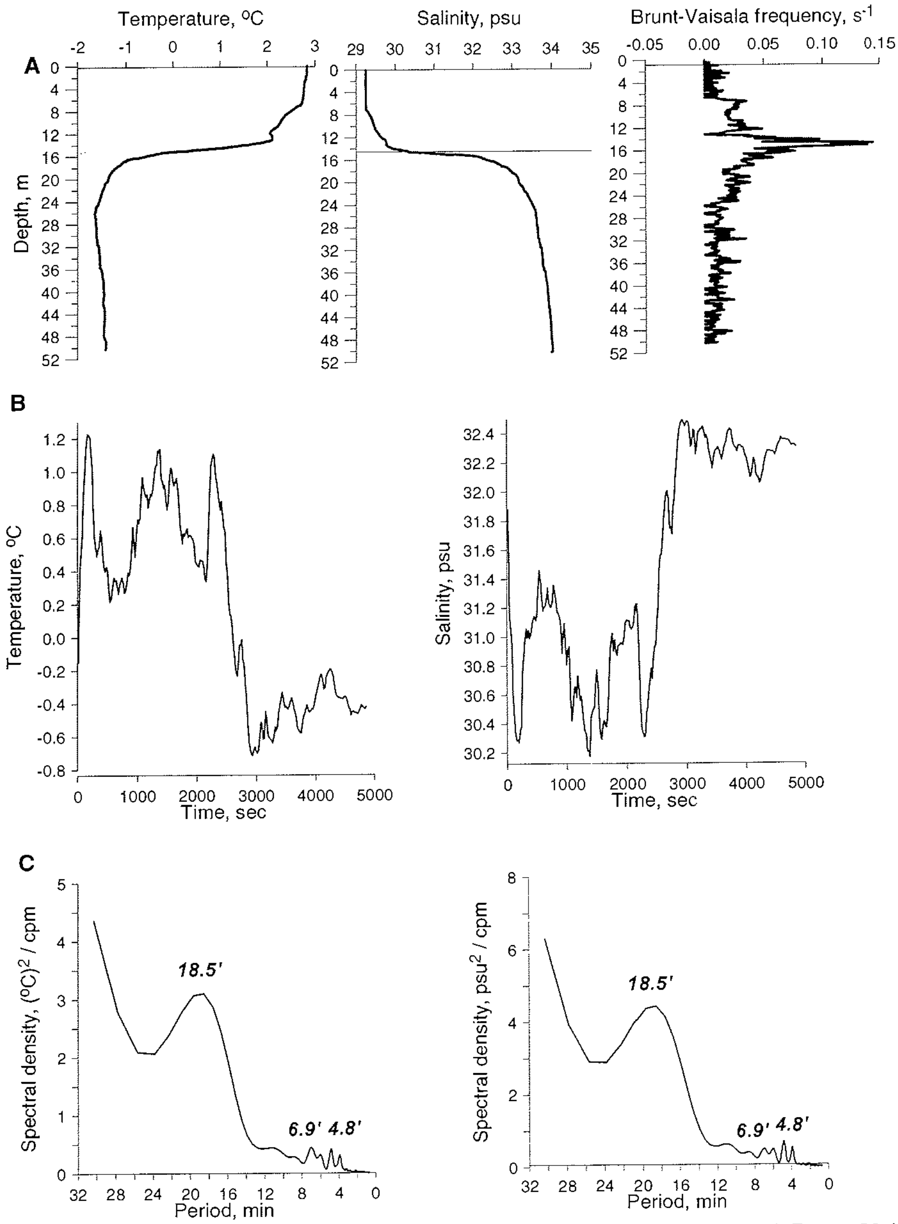

Fig. 3.11. Vertical distribution of the water temperature, salinity and Brunt-Vaisala frequency (A), oscillations of the temperature and salinity at the horizon 14.5 m (B) and spectra of these oscillations (C). Station No 38.

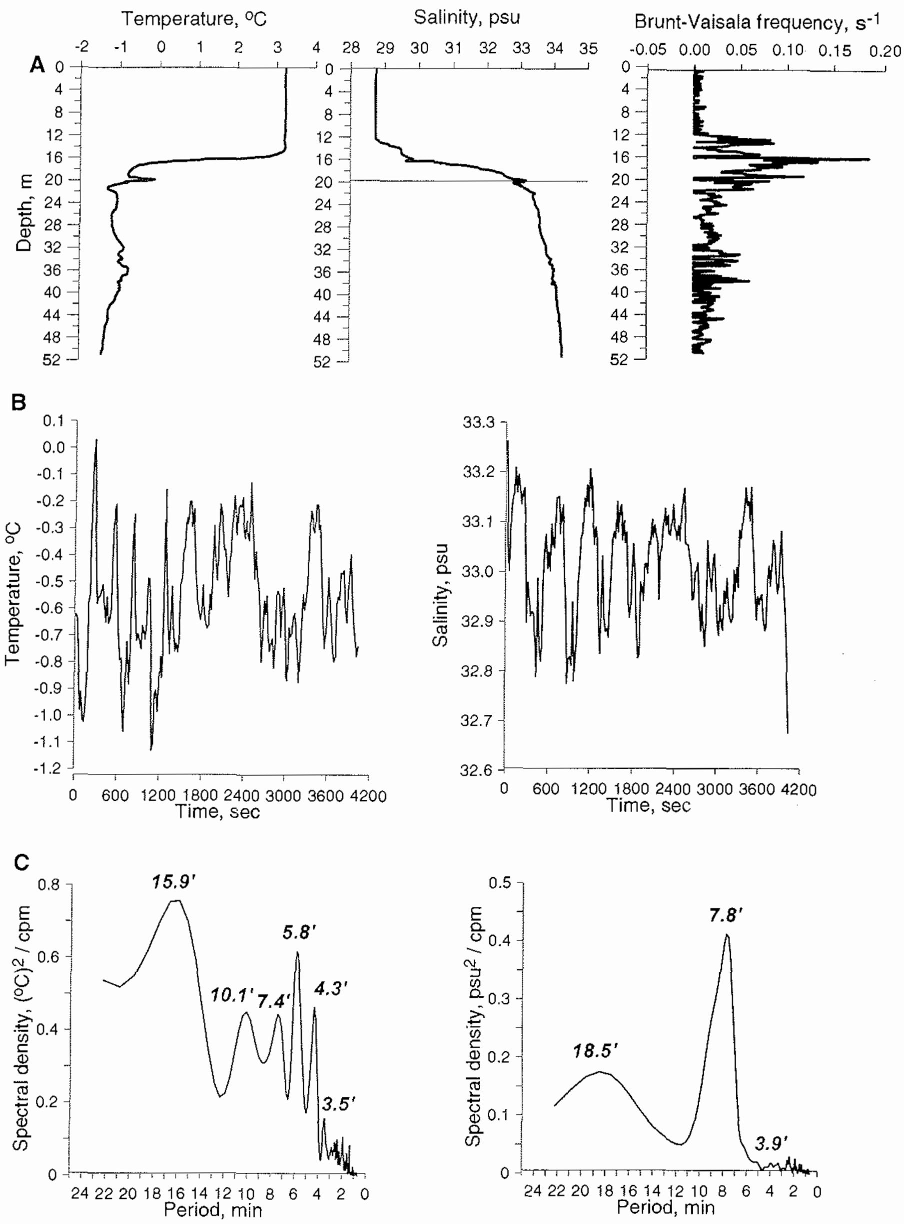

Fig. 3.12. Vertical distribution of the water temperature, salinity and Brunt-Vaisala frequency (A), oscillations of the temperature and salinity at the horizon 19.7 m (B) and spectra of these oscillations (C). Station No 35.

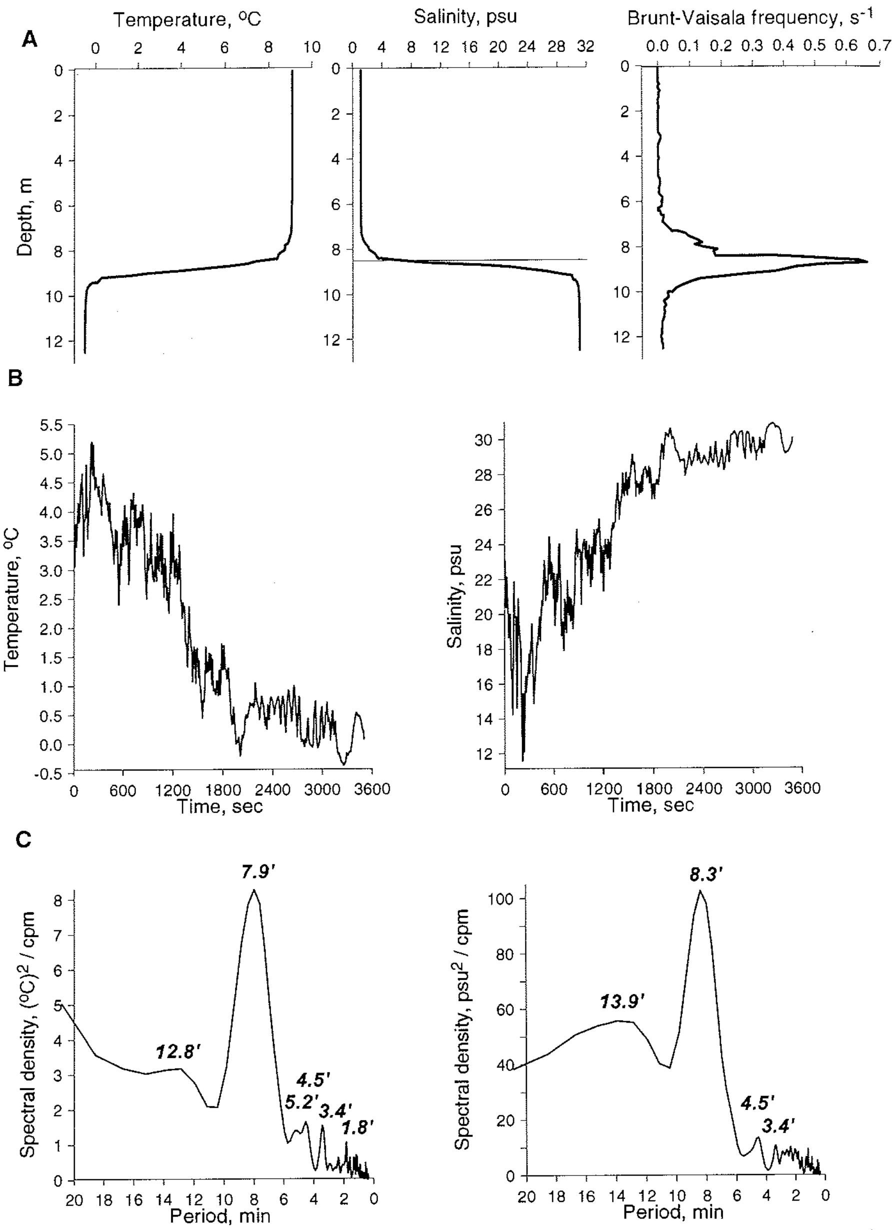

Fig. 3.13. Vertical distribution of the water temperature, salinity and Brunt-Vaisala frequency (A), oscillations of the temperature and salinity at the horizon 8.5 m (B) and spectra of these oscillations (C). Station No 70.

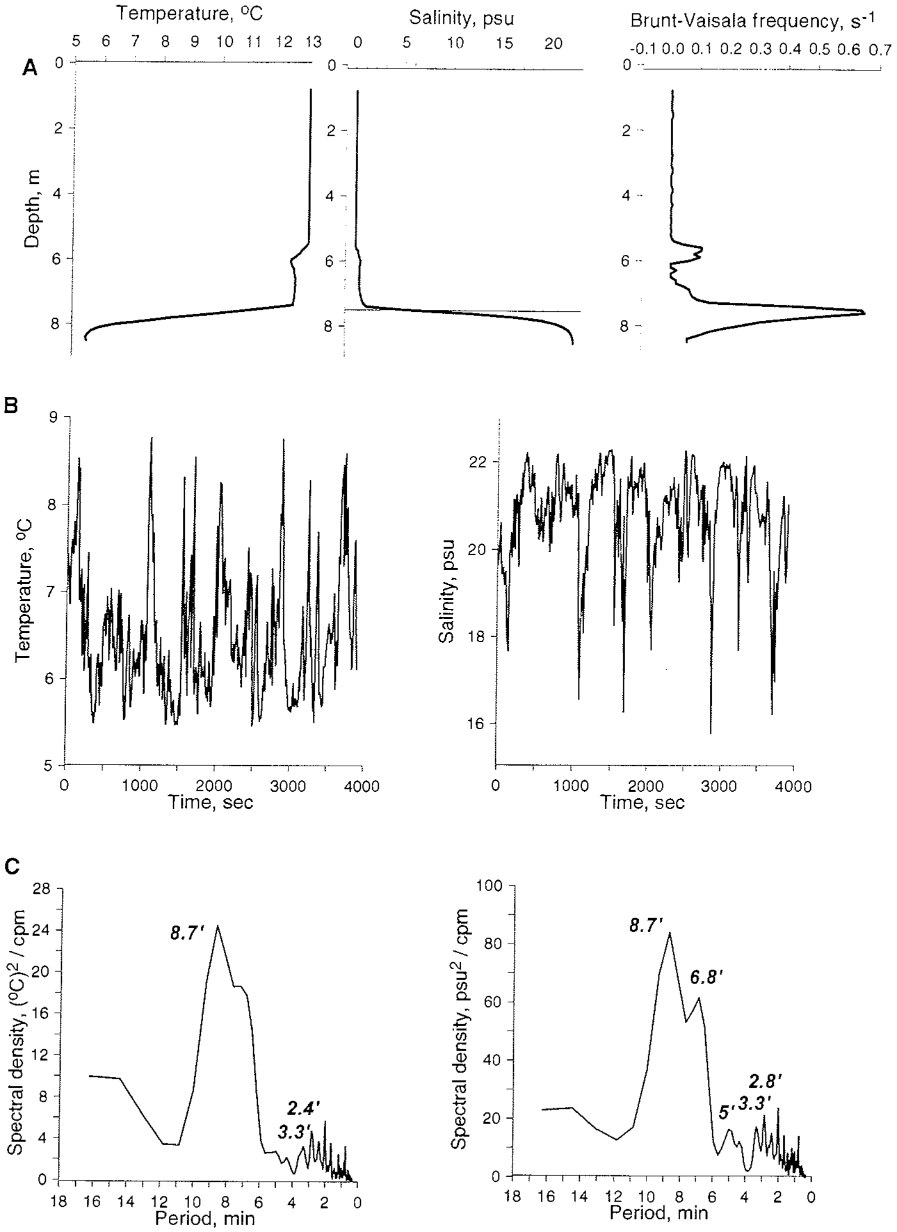

Fig. 3.14. Vertical distribution of the water temperature, salinity and Brunt-Vaisala frequency (A), oscillations of the temperature and salinity at the horizon 7.5 m (B) and spectra of these oscillations (C). Station No 11.

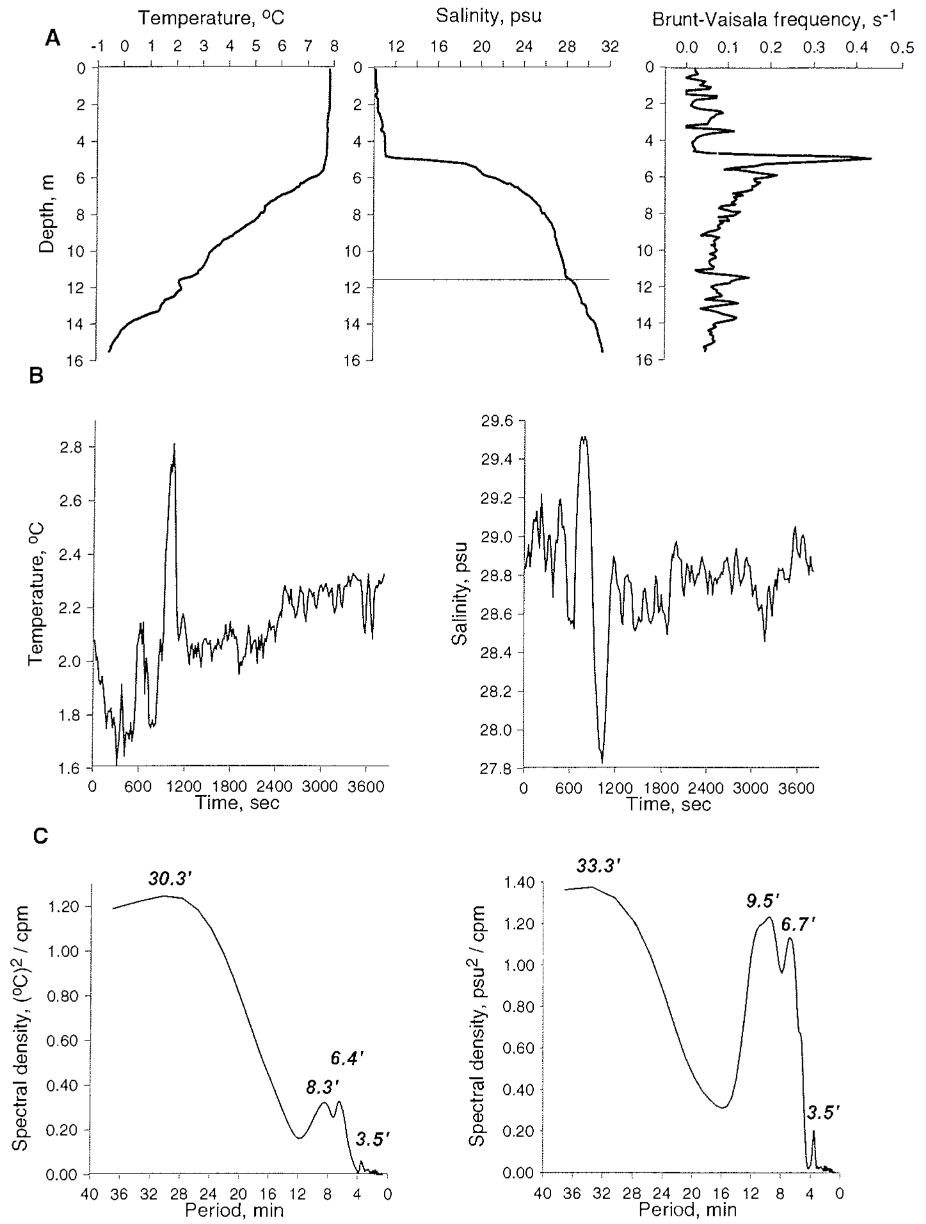

Fig. 3.15. Vertical distribution of the water temperature, salinity and Brunt-Vaisala frequency (A), oscillations of the temperature and salinity at the horizon 11.6 m (B) and spectra of these oscillations (C). Station No 68.