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SPACE-TIME CHARACTERISTICS OF MESOSCALE STRUCTURES IN THE NORTH- EAST GDAŃSK BAY

Abstract

Temporal and spatial variability of mesoscale structures in the North-East Gdańsk Bay is discussed. During measurements in September 1997, variability in the upper layer was determined by convective cooling processes. Measurements made in January 1998 show that between the two periods renewal of a whole halocline water took place in the Gdańsk Bay.

Temporal and spatial variability of mesoscale structure in the North-East Gdańsk Bay is discussed in the presented paper. Data of thermohaline structure along high-resolved sections overlapping the Russian part of the Gdańsk Bay are considered. The field measurements were carried out from board the ship "Professor Shtokman" in its 34, 35 and 37 cruises. Considered measurements were carried out in September 1997 and January 1998 during four surveys, three of them in September and one - in January. The measurements, made in September, had been carried out in the frame of POLRODEX '97.

The measurements were made with the scanning CTD - probe "Mark - 3", which was undulated between upper near-to-surface layer and sea bed. In the direction of a ship lag horizontal resolution varied, depending on the depth, in the range of 100-400 m, vertical resolution was about 0.2 m.

In the autumn 1997, three surveys had been performed in the following date intervals: 2-3, 23-29 of September. The schemes of ship tracks corresponding performed measurements are presented in Fig. 1a, b, c. At mentioned time intervals had been performed 5 and 32 transects respectively. In January 1998 the survey of thermohaline structure was repeated approximately on the same area in the Gdańsk Bay (Fig. 1d). It was performed during 17-21 of January and consists of 16 transects. During all considered phases, 53 transects had been performed.

The period of measurements in September was characterised by sharp changes in weather over the area under investigation. After a hot windless summer rather windy and not so hot weather begun. Therefore, we had the opportunity to investigate upper layer changes.

The space variability had been analysed for horizontal and vertical distributions of temperature, salinity, density fields. The maps of investigation area with temperature field are presented in Fig. 2. The upper layer is characterised by rather hot waters. Cold inhomogeneities near the west shore of the Sambian Peninsula were also observed. Apparently, this cold water in the upper layer was connected with upwelling phenomena. Another reason may be associated with a mesoscale eddy or long-period internal waves (IW).

In the beginning of September respectively cold water occupied rather wide depth interval bounded by thermocline at depth of about 30 m. It is clearly seen from temperature field at various levels in Fig. 2. The temperature distributions on depths 45 m, 60 m, 70 m at the end of summer (Survey 0) are characterised by low temperatures. The layers under thermocline were rather cold, because thermocline blocked vertical heat transfer. 20 days later the sharp temperature gradient had been smoothed and deepened. In September the depth interval with cold waters became more narrow. During Survey 1 (23-26 September) and Survey 2 (26-29 September) the temperature at depth of 45 m had been risen considerably. Near the shore the hot waters about 10-12 °C reached levels 60 m or upper boundary of the halocline.

It may be concluded that upper density gradient layer, associated with the thermocline, had been unlocked to the third decade of September, when POLRODEX '97 experiment performed. So the period of approximately 20 days may be treated as the period of reconstruction of vertical thermohaline structure. For this period vertical convection mechanism in a layer from upper surface to the upper boundary of halocline begun to function. Horizontal scales of temperature features on temperature maps on depths of 45m and 60m (Fig. 2) were about 7-40 km.

The sequence of vertical transects, corresponding more to different days of September, are presented in Fig. 3. This sequence permits to observe the temporal variability of thermohaline structure in the Gdańsk Bay during September, when the transformation of temperature distribution from summer type to winter type took place. From our measurements it could be seen that the heat loose in the upper layer was not uniform.

The first phase of this transformation was the cooling of upper layer and formation narrow domains with more cold water in near surface layer. Then these domains extended and filled in for patches with more hot temperature. Simultaneously the deepening of gradient layer with rather hot waters and gradient layer erosion took place. The further cooling occurred the same way: new narrow domains arose from the lower layers and then enlarged. It is important to notice that the deepening of the border of respectively hot waters was restricted by upper border of halocline. In the halocline, we can see cold water inhomogeneities with the temperature of about 3.6°C. Data obtained at the same time in the Gotland Deep were evidence of cold waters spreading from North-Eastern regions of the Baltic Sea.

The series of transects along the slope of the Gdańsk Bay were characterised with changes in temperature structure in the upper quasi-homogeneous layer (Fig. 3). In the halocline, oscillations of thermohaline parameters and deformations of vertical structure due to internal waves had been observed. Rather considerable waves with swings of about 10 m had been observed at some transects (Figs. 3, 5).

During POLRODEX '97 in the Russian part of the Gdańsk Bay the moorings had been installed along one of the transect. The underwater buoy was used to reduce noise. Time spectra revealed that the most energetic were waves near inertial frequency and frequency of approximately 1/11 hours^{-1}. The largest current velocities were observed in IW oscillations. Their magnitudes were about 20-30 cm/sec.

On the base of density field on some horizontal level, time – space spectrum depending on horizontal wave numbers and frequency had been evaluated. The level of 70 m, which characterised oscillations in upper boundary of halocline, had been considered. For the survey in the beginning of the September the data on 15 m level in a layer of thermocline had been considered too. The detailed analysis had been performed for the periods of 14 hours and 11 hours. Just at these periods the more power oscillations of sea currents were registered in the Gdańsk Bay. Note, that period 14 hours is close to the local inertial period for the latitude of the Gdańsk Bay.

The sections of time-space spectra for the periods of 14 hours and 11 hours, calculated on the base of Survey 1 data, are presented in Fig. 4. It occurs that the most energetic IW components spread along isobaths in the direction South-North. For the quasi-inertial IW there was a little phase velocity component in direction from the open sea to the shore . The waves with period of 11 hours were associated with horizontal scale of about 22 km. It is in a good agreement with dispersion relation for the first mode. The characteristic scale of quasi-inertial IW was about 6-7 km.

The main peculiarities of thermohaline structure in January were much higher temperature in the halocline and higher salinity near to the bottom layer. It can be seen in the temperature and salinity transects (Fig. 5) and from comparison of T-S correlation curves corresponding to September 97 and January 98 data (Fig. 6). The maximum salinity values in the bottom layer had risen from 11.6 psu to 13.2 psu.

Observed changes in the thermohaline structure of the Gdańsk Bay denote that the inflow of more hot and salt waters had taken place in the end of the autumn or in the beginning of winter. It is interesting to note that at the same depth levels in the Gotland Deep lower salinity had been observed at the same time.

Apparently the inflow was not so large and new waters could only to disturb the structure of thermohaline fields in the Gotland basin. In the Gdańsk deep the waters in halocline were renewed entirely.

Results

The temporal and spatial variability in the upper layer during autumn cooling had been determined by the convective cooling processes. The cooling of upper layer occurred non-homogeneously, at first inside convective domains.

In the regions adjacent to the sea shore between cape Taran and Yantarny, upwelling effects had been recorded. Regularly rather cold water masses were observed in the intermediate and near bottom layers at this region. The period of September 1997 was characterised with considerable transformation in the upper layer thermohaline structure.

At the slope area, isotherm and isopycnal surfaces deformations were observed which had wave nature.

At the frequency band of IW, quasi inertial waves (period about 14 hours) and waves with period about 11 hours appeared more powerful. Phase velocities of these waves were directed along isobaths. It denotes that energy spreads across isobaths. For the quasi inertial waves the spectral analysis testify to the energy transmission from the slope to the open sea.

For the period of last autumn months and first half of winter, a renew of whole halocline water had took place in the Gdańsk Bay. The inflow event included entirely the Gdańsk Bay and more slightly disturbed thermohaline structure of the Gotland Deep.

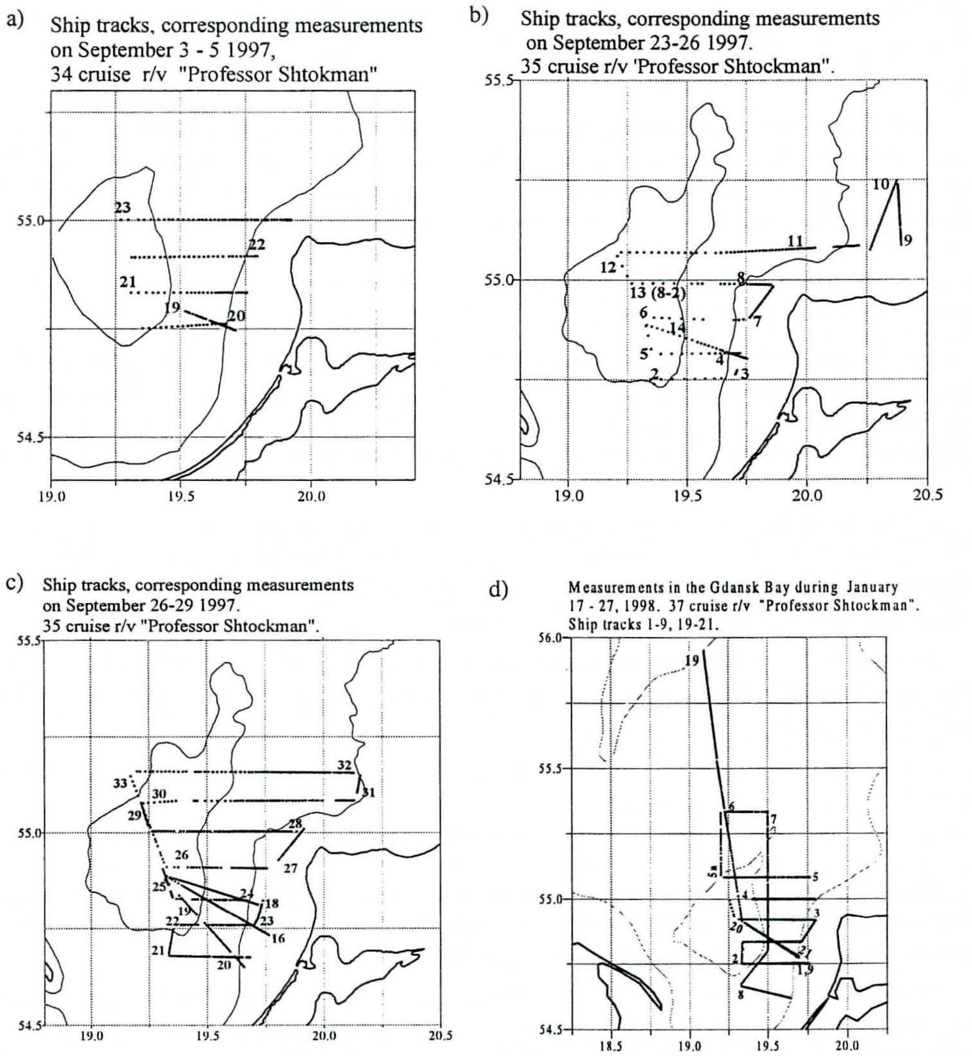


Fig.1. The schemes of ship tracks corresponding to measurements on three Surveys in September 1997 and on Survey in January 1998

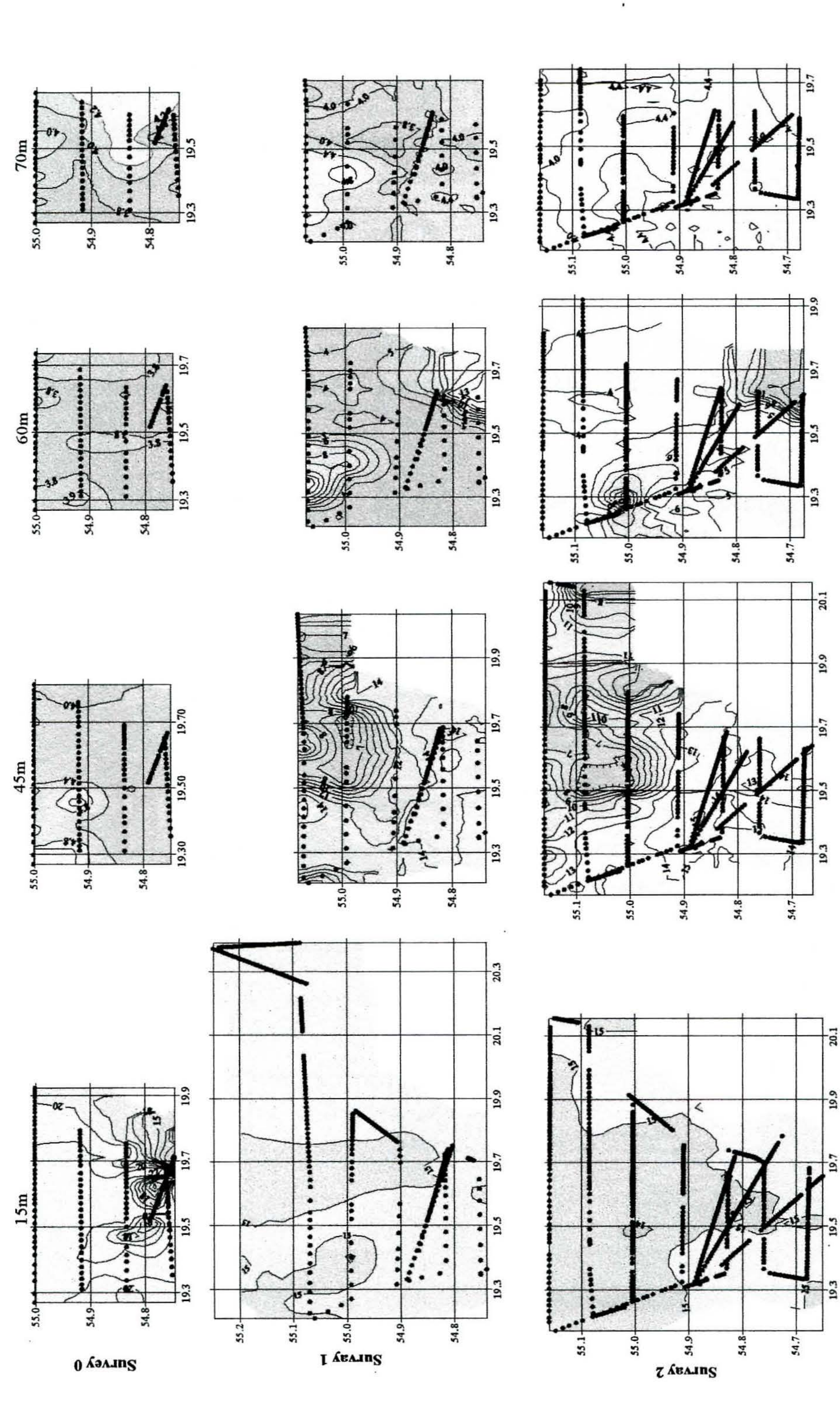


Fig. 2. The maps of investigation area with temperature field at depths 15 m, 45 m, 60 m, 70 m

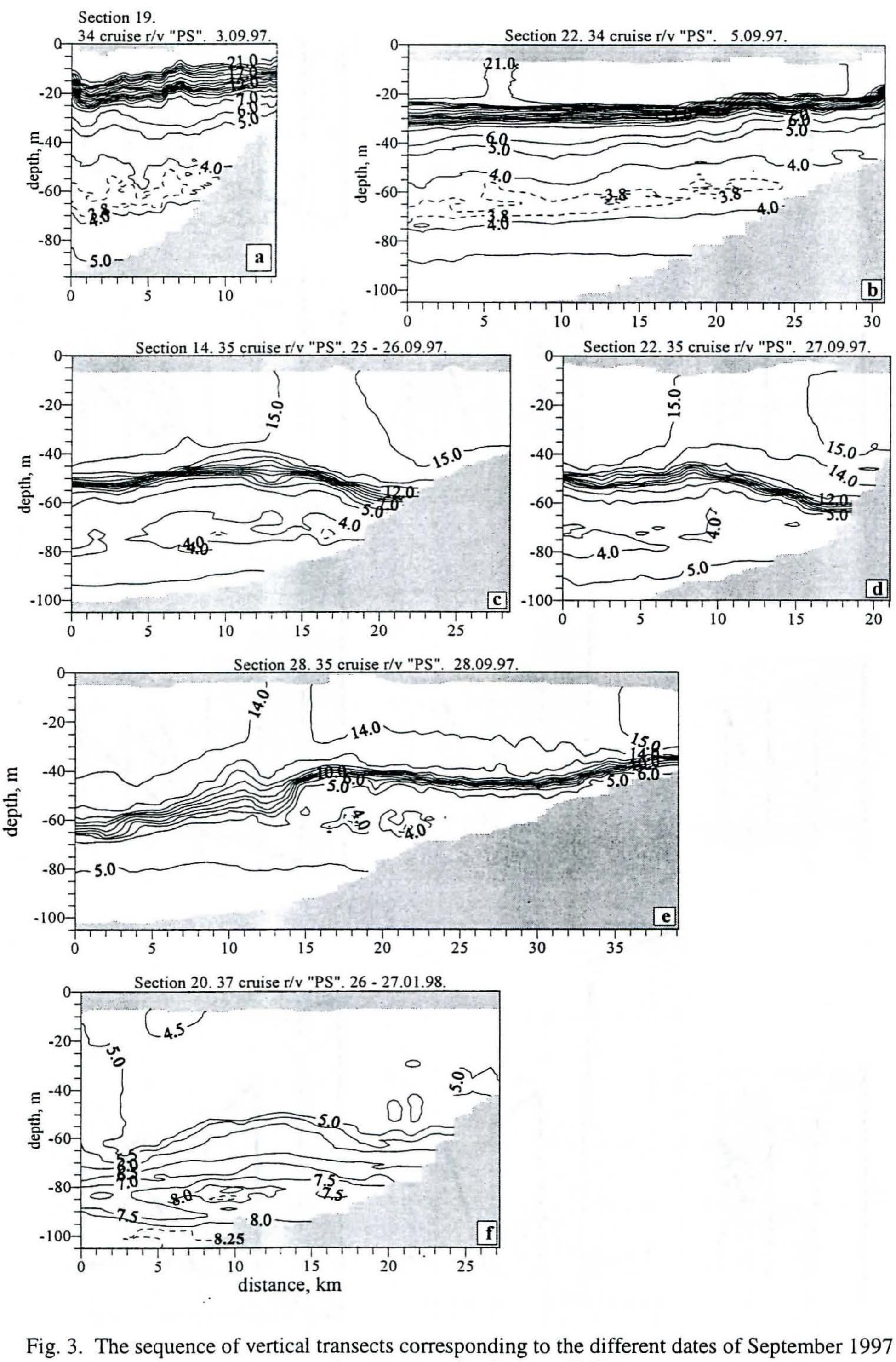


Fig. 3. The sequence of vertical transects corresponding to the different dates of September 1997 and one transect for January 1998

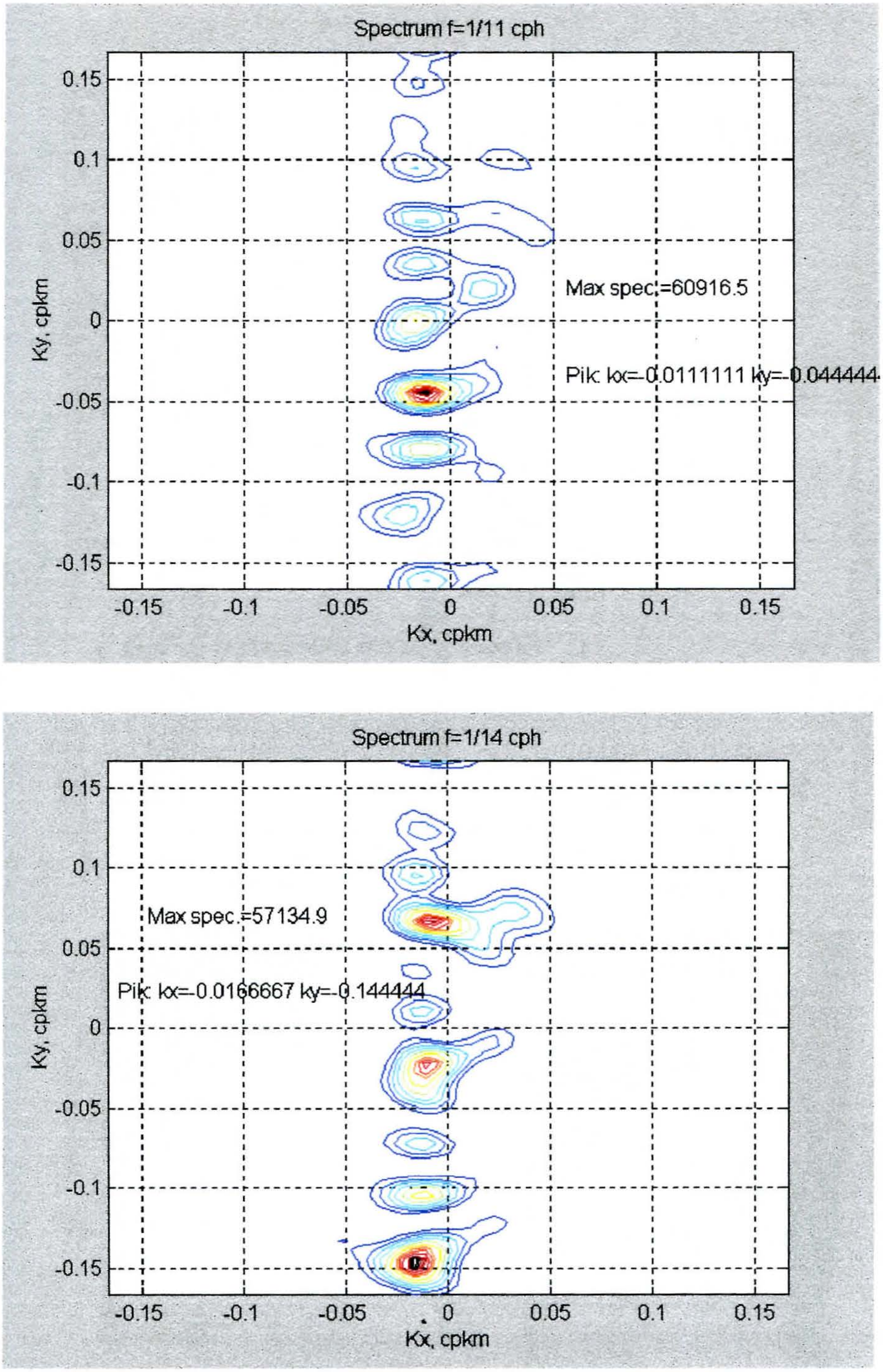


Fig. 4. The sections of time-space spectra for the periods of 14 hours and 11 hours, calculated on the base of Survey 1 data

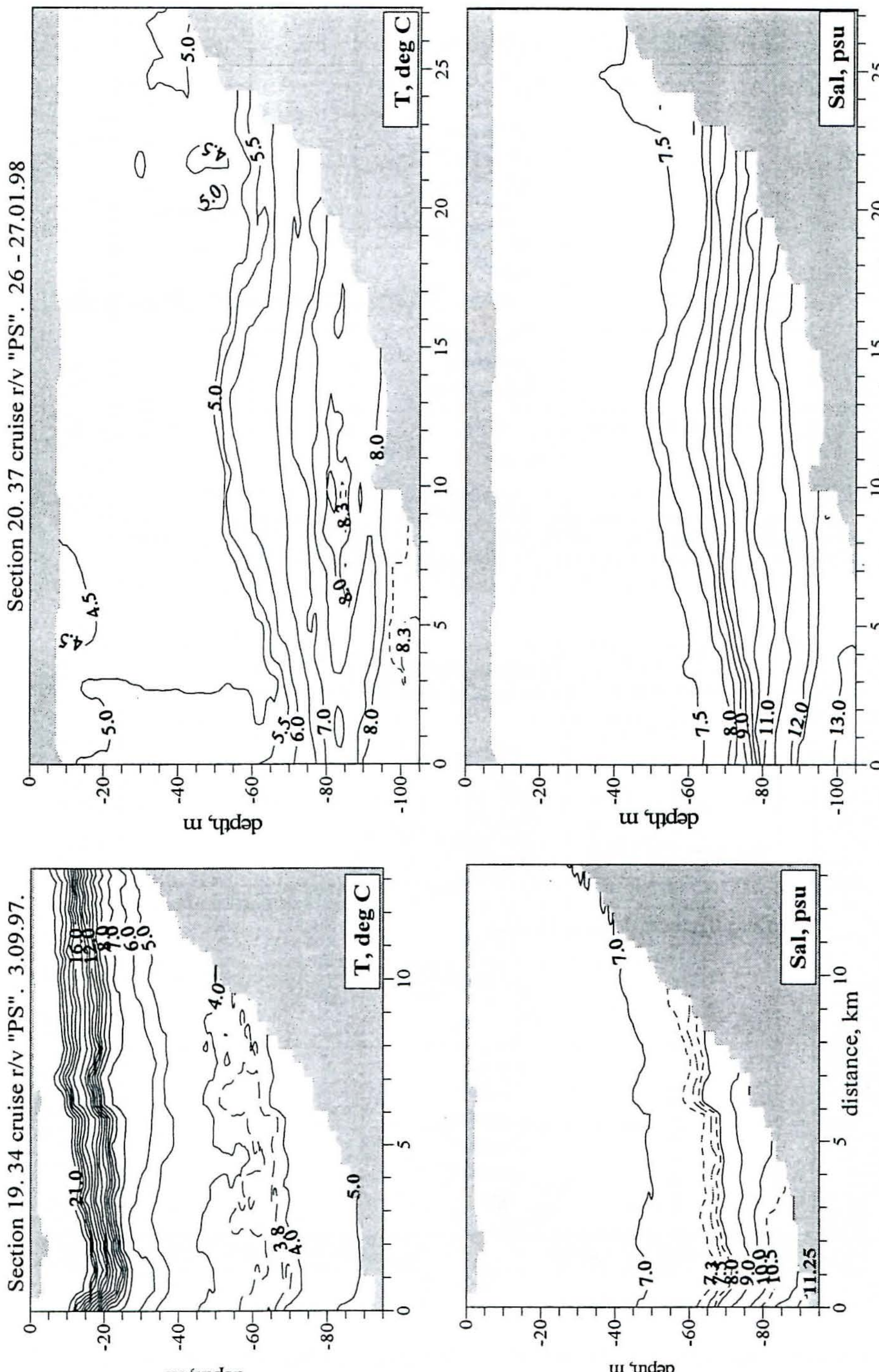
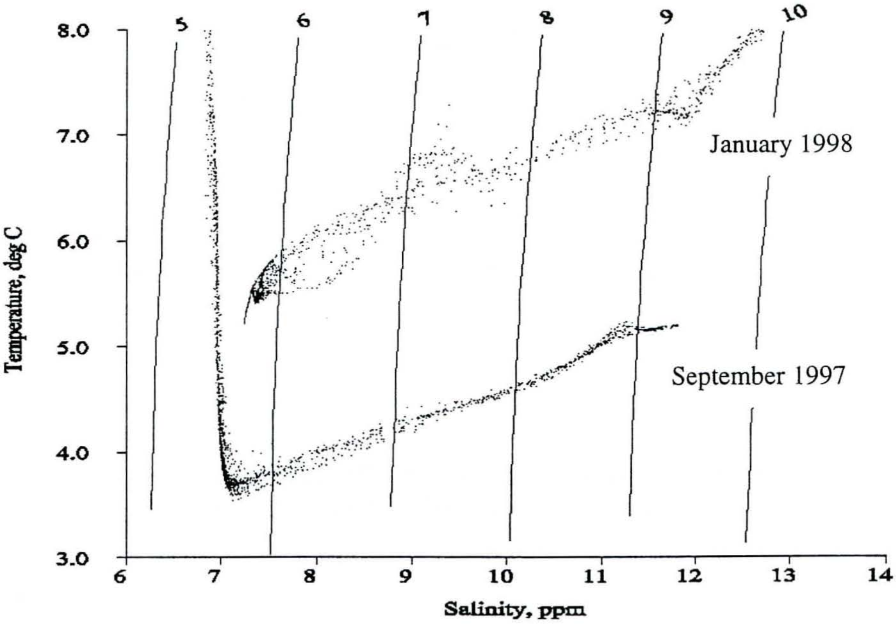


Fig. 5. Temperature and salinity transects, corresponding measurements to the end of summer (1997) and January 1998



Sections 20(34 cruise) and 1(37 cruise)

Fig. 6. T-S correlation's curves corresponding to September 97 and January 98 data