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VERIFICATION OF DRIFT MODELS OF RHODAMINE SPILL, LIFE-RAFT AND DUMMY-MAN DURING EXPERIMENT POLRODEX'97

Abstract

The part of the experiment POLRODEX'97 was a set of drift experiments including the rhodamine spill, life raft and dummy-man drifting experiment. The experiments have been realised in order to both verify the hydrodynamic model results and increase the knowledge on drifting object behaviour including the possibilities to model the object drift using the operational results of HIROMB model. The results of the drifting experiments are shown. Some deficiencies in operational hydrodynamic and meteorological models are named.

1. Introduction

The main idea of POLRODEX experiments is to collect the data necessary for validation and verification of operational models of the Baltic and its parts. The idea is facilitated with different activities like CTD stationing, current and wave measurements and drift experiments. The drift experiments are main test for the operational hydrodynamic and meteorological models – model results are usually used to be the driving force for operational drift models. The operational drift models play significant role in the rescue and combating activities at sea.

The three types of the drifting experiments have been realised during POLRODEX'97 experiment. They have been:

1) rhodamine drift experiment,
2) life raft drift experiment,
3) dummy-man drift experiment.

The drift experiment results are described in following chapters. The locations of the drifting experiments are shown in Fig. 1.

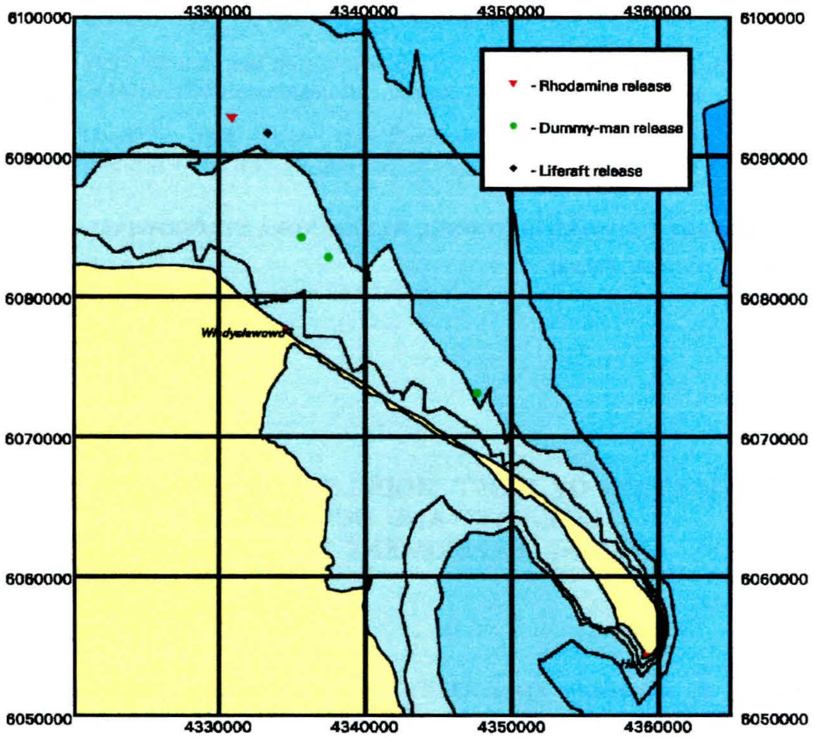

Fig. 1. Location of rhodamine, rescue-raft and dummy-man release

2. The rhodamine drift model verification

The rhodamine drift model verification has already been a part of POLRODEX'96 experiment [1, 2]. The rhodamine is chosen as a tracer because it follows the water movement having no wind side effect. Additionally the rhodamine can be quite well traced in the sea environment using fluorimeter technology [2]. The scheme for the rhodamine release as copied from previous POLRODEX'96 experiment as the "pumped balloon" technique has been found extremely successful [2]. The 1997 rhodamine release point was chosen at location 54°55'49.48"N, 18°21'43.83"E as point being nearby the Hel Peninsula but still well located in the HIROMB model computational grid. Rhodamine concentration has been traced (Fig. 2) from 22nd of September 10:00 to 23rd of September 1999, 10:00, when the rough sea conditions forced r/v "Doktor Lubecki" return to harbour. Well-determined weather conditions caused the rhodamine spill to drift more then 10 nautical miles away from release point during 25 hours of rhodamine tracing (Fig. 3). The topography dependant trajectory of the plum drift is also well documented in Fig. 3. The 25 hours of almost continuous rhodamine B spill tracing resulted in 16 snapshots of the plum, which allowed us to determine the variability of plum parameters, including position of the plum centre, peak concentration and plum semi-axes (Table 1).

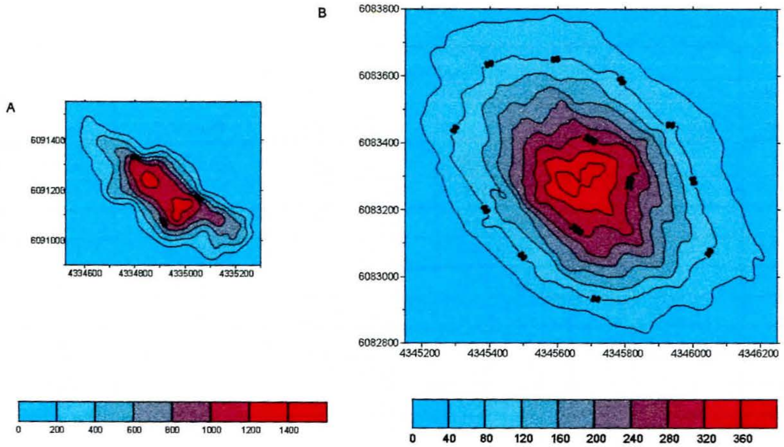

Fig. 2. Rhodamine concentration 6 (A) and 25 (B) hours after release [g/cm^3 x 10^{-11}]

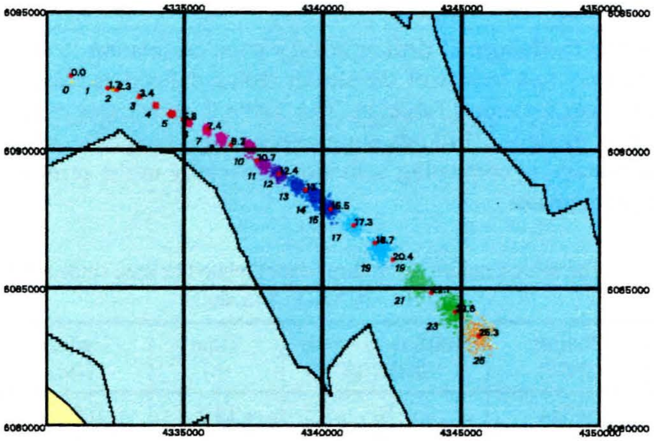

Fig. 3. Modelled and observed rhodamine B drift (red dots – plum centres for different snapshots, coloured clouds – modelled lums)

Table 1. The rhodamine plum parameters

Snapshot number	Maximum of rhodamine concentration				Plum semi-axis	
	Concentration g/cm^3*10^{-11}	Time [min]	Plum centre		major [km]	minor [km]
			Northing	Easting		
0		0	6092670	4330923		
1	11047.470	103.650	6092213	4332254	0.24	0.05
2	5230.404	140.100	6092157	4332593	0.38	0.12
3	3416.618	206.033	6091910	4333400	0.83	0.13
4	1408.234	352.567	6091084	4334963	0.42	0.17
5	1173.031	449.433	6090729	4335844	0.42	0.18
6	978.817	553.933	6090185	4336708	0.50	0.21

Table 1. (continued)

Snapshot number	Maximum of rhodamine concentration				Plum semi-axis	
	Concentration g/cm^3*10^{-11}	Time [min]	Plum centre Northing	Plum centre Easting	major [km]	minor [km]
7	935.935	645.300	6089618	4337627	0.60	0.24
8	789.897	748.100	6089133	4338429	0.61	0.27
9	763.487	824.500	6088518	4339384	0.56	0.28
10	688.812	930.083	6087846	4340291	0.65	0.33
11	637.974	1040.750	6087271	4341120	0.64	0.32
12	580.985	1125.233	6086630	4341890	0.71	0.32
13	484.336	1225.733	6086037	4342532	0.68	0.34
14	418.209	1330.633	6084838	4343923	0.52	0.43
15	426.933	1416.700	6084139	4344782	0.65	0.35
16	403.333	1519.083	6083284	4345619	0.61	0.37

The coordinates are given in WGS84 system.
Concentration was measured at 1 m water depth.

The modelled rhodamine B drift is in very good correlation to drift observed in nature. This results in very low values of the search radius defined as distance between modelled and observed plum location (Table 2). The Table 2 shows that during whole experiment resultant error of modelled drift has not exceeded 1 nautical mile, what is reasonable result giving big advantage in combating activities, especially in the primary phase – search and reaching the plum phase.

Table 2. The search radius variability (error) related to time since rhodamine release (CAROCS model)

Time (h)	Radius (NM)	Relative to whole drift (%)	Time (h)	Radius (NM)	Relative to whole drift (%)
1.71	0.074	10	13.7	0.829	16
2.33	0.239	25	15.5	0.738	13
3.43	0.243	17	17.3	0.737	12
5.86	0.571	24	18.75	0.583	9
7.48	0.684	24	20.4	0.478	7
9.21	0.797	23	22.1	0.145	2
10.75	0.928	23	23.6	0.309	4
12.46	0.961	21	25.3	0.582	6

During the POLRODEX'97 experiment the vertical mixing has been significantly higher than during measurements in 1996 showing that rhodamine sinks very slowly [2]. This resulted in different maximum concentration readings (Fig. 4) from concentrations stated in [3] and [2]. This phenomenon may be result of rough weather conditions, which caused extremely high mixing in upper sea layer, leading also to almost uniform vertical distribution of the rhodamine concentration. The measurements of vertical distribution of rhodamine concentration could not be done because of weather conditions, but above conclusion may be implication of the rhodamine concentration measurements which in each consecutive plum shows "losses" of total rhodamine amount.

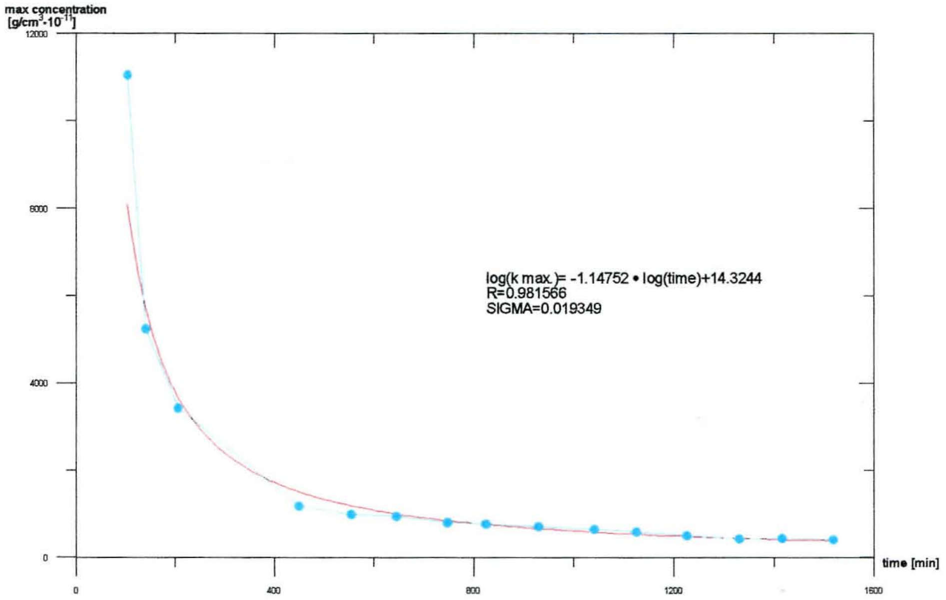

Fig. 4. The rhodamine maximum concentration change during the POLRODEX'97 experiment

3. The life raft drift model verification

Besides rhodamine drift also the life raft drift has been observed during POLRODEX'97 experiment. One of the ideas behind the life raft drift experiment was to prove if models may give advantages in rescue operations over the procedures proposed by International Maritime Organisation (IMO). IMO procedures are limited mainly to including the wind information into procedure for forecasting of the life raft drift. The procedure includes simple coefficient calculation of leeway not taking into account global basin characteristics – among others – bathymetry. Additionally IMO procedures relay on real wind information – information from the vessel has been taken as a basis for computations, but usually this information is not operationally available. The three trajectories are shown in Fig. 5 – observed drift, modelled with IMO procedures and modelled with CAROCS model (basing on HIROMB hydrodynamic fields). The same arbitrarily chosen wind-driven drift coefficient for both IMO and CAROCS procedures has been used (4.6 %). The forecasting procedures leaded to search radius as shown in Table 3. It is clear that use of operational drift models in this case may benefit in reducing the search area.

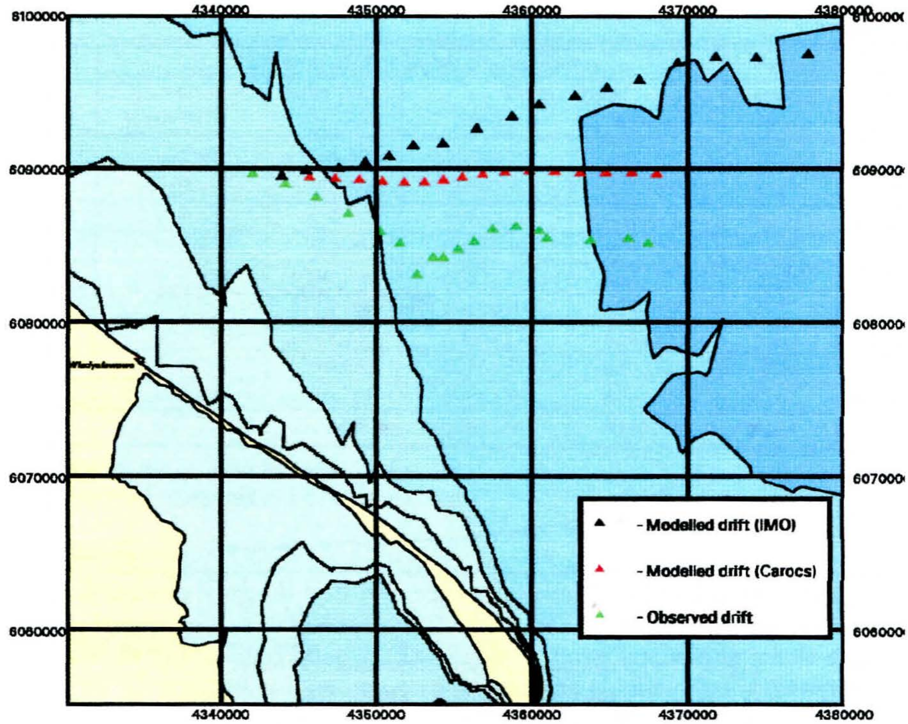

Fig. 5. Forecasted life raft drift according to IMO procedures, CAROCS model related to observed drift

Table 3. The search radius variability (error) related to time since life raft release (CAROCS model, IMO procedures)

Time (h)	Radius - IMO (NM)	Radius - CAROCS (NM)	Relative to whole drift – IMO (%)	Relative to whole drift - CAROCS (%)
1	0.297	0.322	25	26
2	0.997	0.738	42	31
3	1.629	1.317	45	37
4	2.489	1.958	51	40
5	3.092	2.283	54	40
6	4.526	3.267	67	49
7	3.989	2.634	58	38
8	4.658	2.711	64	38
9	5.019	2.536	66	33
10	5.293	2.360	66	29
11	5.482	2.057	64	24
12	5.782	2.004	62	22
13	6.332	2.159	62	21
14	7.641	2.589	73	25
15	7.754	2.446	65	21
16	7.732	2.317	58	17
17	8.645	2.471	62	18

4. The dummy-man drift model verification

The last drift experiment has been made with drifting human body model. The dummy-man drift experiment results are shown in Fig. 6. The wind-driven drift coefficient has been chosen as 1.4 %. The modelled drift differed from observed as it is shown in Table 4. Very good result is that search radius has not exceeded 0.7 nautical mile.

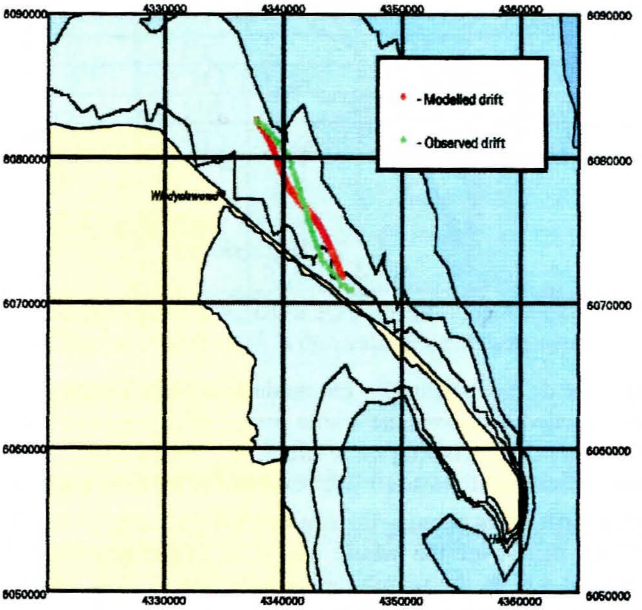

Fig. 6. Observed and forecasted dummy-man drift

Table 4. The search radius variability (error) related to time since dummy-man release (CAROCS model)

Time (h)	Radius (NM)	Relative to whole drift (%)	Time (h)	Radius (NM)	Relative to whole drift (%)
0.5	0.064	28	12	0.051	1
1	0.134	32	12.5	0.037	1
1.5	0.170	26	13	0.115	3
2	0.226	26	13.5	0.204	5
2.5	0.271	25	14	0.288	6
3	0.312	25	14.5	0.356	8
3.5	0.403	27	15	0.389	2
4	0.470	27	15.5	0.422	9
4.5	0.517	27	16	0.482	9
5	0.550	27	16.5	0.511	10
5.5	0.558	25	17	0.535	10
6	0.464	20	17.5	0.560	10
6.5	0.492	19	18	0.554	10

Table 4. (continued)

Time (h)	Radius (NM)	Relative to whole drift (%)	Time (h)	Radius (NM)	Relative to whole drift (%)
7	0.464	18	18.5	0.619	10
7.5	0.456	17	19	0.571	9
8	0.442	15	19.5	0.548	9
8.5	0.405	14	20	0.523	8
9	0.346	11	20.5	0.506	7
9.5	0.323	10	21	0.530	8
10	0.242	7	21.5	0.659	9
10.5	0.184	5	22	0.620	8
11	0.127	4	22.5	0.691	9
11.5	0.110	3	23	0.658	9

5. Conclusions

The drifting experiments during POLRODEX'97 experiment may be characterised as follows:

1) rhodamine drift experiment – the rhodamine plum search radius is less than 25 % of total modelled drift over the whole period of experiment with the use of wind drift coefficient 0.25 % (basing on results from POLRODEX'96 rhodamine tracing), the search radius stabilises at 10 % of total modelled drift after 18 hours since release;
2) life raft drift experiment – the life raft search radius is less than 50 % of the total modelled drift over the whole period of experiment with the use of wind drift coefficient 4.6 %, the search radius stabilises at 25 % of total modelled drift after 11 hours since release,
3) dummy-man drift experiment – the dummy-man search radius is less than 40 % of total modelled drift over the whole period of experiment with the use of wind drift coefficient 1.4 %, the search radius stabilises at 10 % of total modelled drift after 9 hours since release.

The above numbers shows clearly – the lower wind drift coefficient the better forecasted drift trajectories. It means that at the moment the problem in operational drift models is not the hydrodynamic models itself but what is more important – meteorological models. Their role is dual in the drift model – one is direct application to forecasting procedures through wind drift component, the second one is as a driving force for hydrodynamic models. Especially for the life raft drift experiment there is significant change in the modelled trajectories and observed trajectories due to very local spatial and temporal fluctuations in wind field at the very beginning of drift experiment. This leads to conclusions that the temporal and spatial resolution of meteorological models is of greatest importance for success of operational drift modelling.

Other problem, illustrated in Fig. 7, is that hydrodynamic models bathymetry still may be improved for better representation of coastal areas even in within the coarse 3 nautical mile grid. In order to reduce side effect of shifts shown in Fig. 7 locally positions of grid cells has been moved 2 nautical miles northward and 1 nautical mile eastward related to original grid positions. This may also be a solution for other coastal areas in the Baltic.

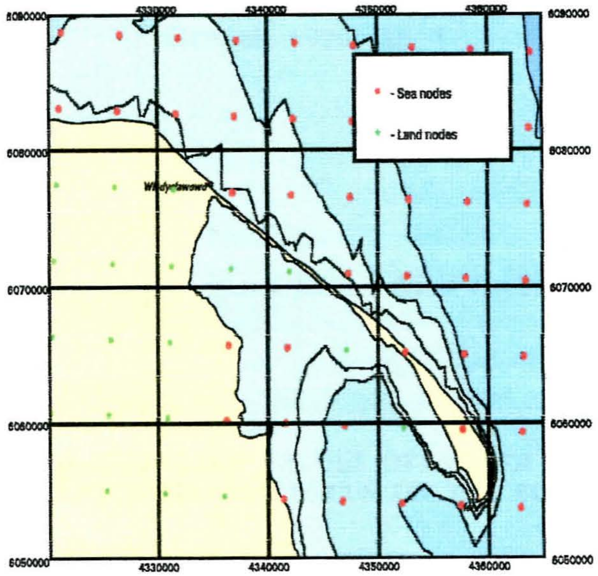

Fig. 7. The illustration of the shift in the model gridded bathymetry

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MEASURED AND PREDICTED VALUES OF WATER TEMPERATURE AND SALINITY WITH SPECIAL FOCUS ON THE SURFACE LAYER

Abstract

The Baltic is a stratified sea. The upper layer is under the influence of atmospheric and terrestial factors. The mechanisms of these external factors on the surficial and subsurface water layer are well recognised but the vertical exchange in the water body is still not sufficiently investigated. Field measurements at sea are time consuming and expensive. A model of the Baltic Sea distributed to and accessible by institutions investigating the Baltic Sea is advantageous because of easier exchange modelled data. The modelling, especially of the surface layer is important due to the fact that outside the coastal zone continuous measurements of physical parameters is difficult.

The comparison between measured in situ and modelled data serves as a tool for the corrections to HIROMB resulting in better approximation of real phenomena occurring in the Baltic Sea. Temperature and salinity values obtained on board r/v Baltica during the POLRODEX'97 expetriment were compared with modelled values. The analysis showed significant differences between in situ measurements and obtained from the HIROMB model.

1. Introduction

The paper presents comparison between water temperature and salinity values measured in situ from the board of r/v Baltica in the Gulf of Gdańsk and data generated in HIROMB model.

2. Material

The data for model verification were collected during two cruises in the Gulf of Gdańsk: 22-23 September 1997 (I) and 25-26 September 1997 (II). The area of in situ measurements was divided into subregions according to the period of CTD observations. The borders of the subregions were delineated in the middle of the distances between CTD stations. Depending on the time of observations, appropriate forecast of water temperature and salinity was used. Water temperature and salinity values were calculated by the HIROMB model using following forecasts in the case of I project period 12, 18 and 24 h forecast from 22 September was used and 6 h from 23 September 1997, in the case of II project period - 6, 12 and 18 h forecast from 25 September 1997. Figs. 1 and 2 present the respective networks of measurement stations during the I and II period of the study.

The in situ measurements were carried out at standard HELCOM levels, i.e. 0, 5, 10, 15, 20 m and every 10 m down to 2 m above the bottom.

Measurements were made at the irregular space net. In the first measurement period, stations were placed every 5 NM in meridional direction and every 20 - 25 NM in longitudinal direction. The arrangement of CTD stations in the second period was more complicated. The most dense net was at the Vistula river mouth, where the distances between neighbouring stations were approximately 3 NM. The distances between stations, moving from the coast to the deep water area increased from 5 to 10 NM. The distances between stations in longitudinal direction were equal to 10 - 15 NM. The analysis was carried out for 6 upper lavers of the model: 0-4, 4-8, 8-12, 12-18, 18-24 and 24-30 m.

Temperature and salinity, measured from the surface to the depth of 30 m, were compared with the forecast data. At present, the spatial resolution of the numerical model is 3 NM in the horizontal plane and 24 layers in vertical direction. The thickness of the layers varies from 4 m in the mixed layer and up to 20 m in the deepest parts of the investigated basin.

3. Methods

To compare the data generated by HIROMB model with measured values, correlation coefficients were calculated between the relevant parameters. The number of data used for calculations was 6-11 from the I experimental period and 4-6 from the II period.

Correlation coefficients between the measured and modelled by HIROMB values of sea water temperature and salinity were very low, from 0.1 to 0.4 at the confidence level of 0.05. Examples of correlation coefficients calculated for data from the I experiment period are shown in Fig. 3. Correlation coefficients were calculated by means of the „Statistica" programme.

The differences between the measured and modelled data were also calculated whereas the model data of one layer were compared to the measured data from this layer and two adjacent layers - above and beneath one, e.g. the data from model layer 4-8 m were compared with the in situ data from 5 m, 0 m and 10 m. The model layers referring to the levels of in situ measurements were analysed and discussed. The differences are presented as diagrams (Figs. 4-7) and horizontal distribution pictures (Figs. 8-19). The modelled temperature and salinity values are given in the regular grid nodes with the resolution of 3 NM. The distribution of the measured in situ values is irregular. Using „Surfer" programme the measured values were interpolated at the grid of the numerical model. After all, kriging was used, in particular quarters of a circle (due to the need of the special treatment of the area near the Vistula mouth), with the minimum number of five values for interpolation, semi-diameter (horizontal anisotropy) was equal to 1/3 of the length of the area along the parallel and the meridian.

After the interpolation of the measured values, the differences between the modelled and the interpolated values of the in situ measurements were calculated.

4. Discussion

Correlation coefficients between the measured and modelled by HIROMB values of sea water temperature and salinity were very low, from 0.1 to 0.4 at the confidence level of 0.05. Examples of correlation coefficients calculated for data from the I experiment period are shown in Fig. 3. One reason of the low correlation values was the low number of data for comparison.

The correlation between the measured and modelled data was calculated in order to check the consistency between the predicted and the actual data and to assess the extent of deviations for the modelled data. Unfortunately, this goal was not reached. It is only possible to say that the correlation is not statistically significant for the number of data used in calculations.

The differences between measured and modelled values of temperature and salinity fell in the I period within the range -0.15 to +3.87°C (Fig.4) and +0.48 to +3.82°C in the II (Fig.5). The respective differences in salinity were: -1.63 to 1.64 PSU (Fig.6) in the I period and -1.19 to +2.01 PSU in the II period (Fig.7).

The measured water temperature values were included between 14.98°C (W2 station) and 15.87°C (E station) in the first period of measurements. Generally, along the profile E-P1 in the eastern part of the Gulf of Gdańsk, the measured water temperature was slightly higher than along the profile in the western part (W-P118). This statement is true for the lower layers too.

The salinity distribution was more complicated. The lower values were measured in the shallow water area along the profile in the eastern part of the Gulf (E-E1-E2) and at the W3E station. In the first period of measurements, the surface salinity values were between 6.538 PSU (W3E station) and 7.304 PSU (P1 station).

In the second period of measurements, the surface water temperature in the investigated area was between 14.7°C (ZN2) and 15.7°C (P110). Similarly as in the case of temperature, the lowest salinity slightly exceeding 5.8 PSU, as well as temperature were measured near the Vistula river mouth. The highest value of surface salinity was measured at P101 station, where it was equal to approximately 7.6 PSU. In the second period of measurements it could be clearly seen that winds, surface and subsurface currents modify the Vistula water spreading.

Sea water temperature generated by HIROMB was generally higher than measured in situ. It means that the model insufficiently accounts for the cooling effect of the Vistula river water. Similar effect was observed in salinity values, the model produced higher salinity values than the measured values. Besides, there was certain asymmetry observed in horizontal distribution of differences; positive (+) differences of both - temperature and salinity - were found in the western part of the Gdańsk Deep while negative (-) were calculated for the values from the eastern part of this area.

5. Conclusions

Correlation coefficients between the measured and modelled by HIROMB values of sea water temperature and salinity were very low, from 0.1 to 0.4 at the confidence level of 0.05. Correlation between HIROMB data and measured in situ indicated that the values calculated by the model are not reliable.

The differences between modelled and measured data might result from the neglected influence of the Vistula river in the model.

Errors in bathymetry evaluation (shallow nearshore area of the Gulf of Gdańsk is probably not well depicted in the model) could be another important source of differences between the model and measured data.

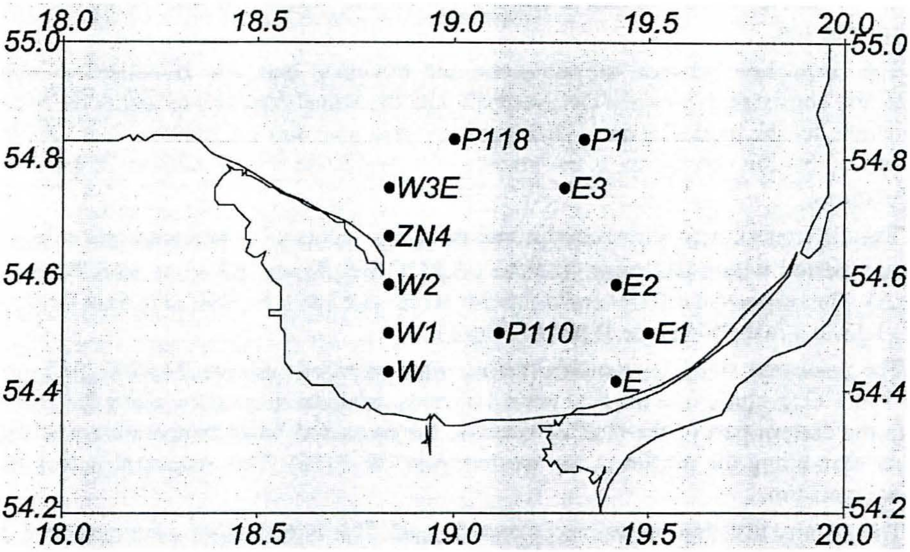


Fig.1. Network of measurements stations in Polrodex'97 experiment (22-23 September)

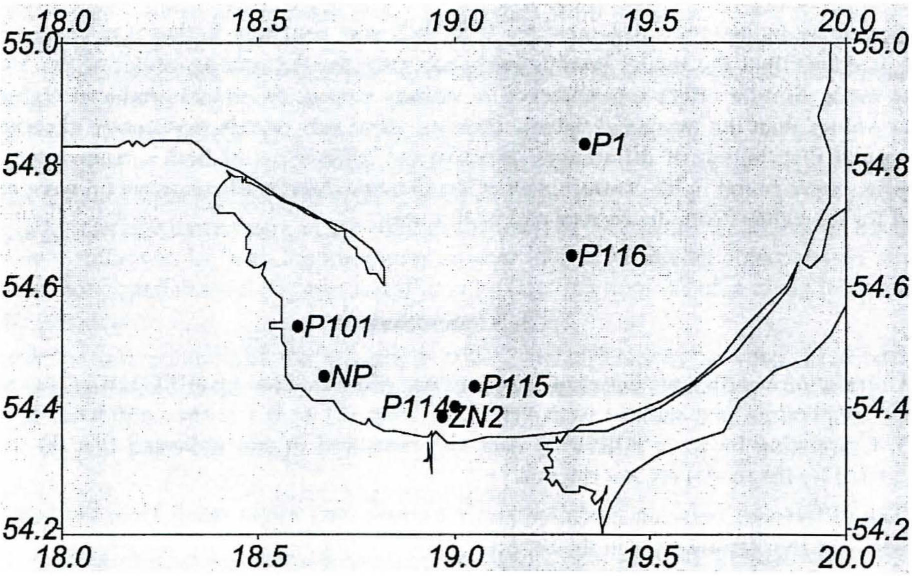
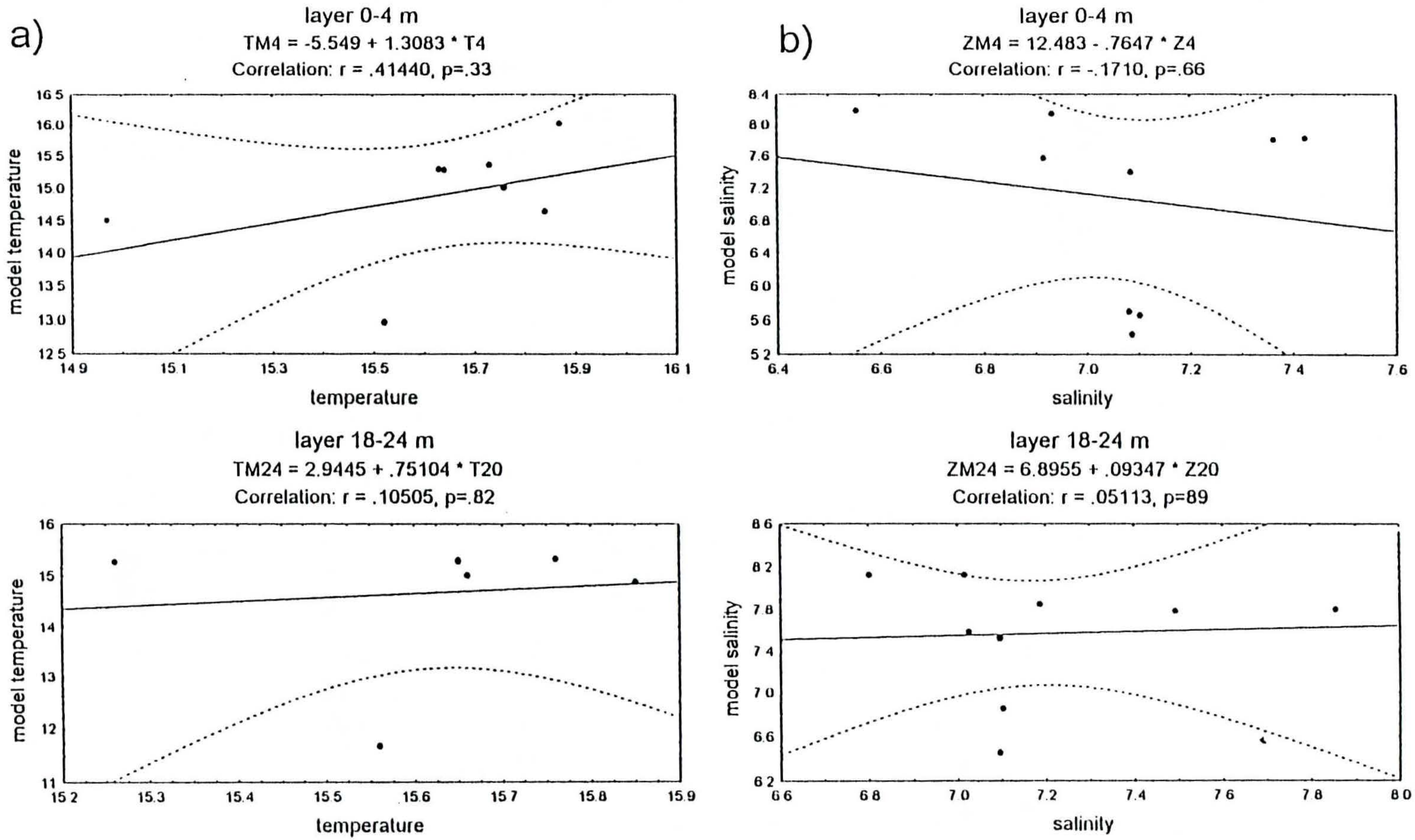


Fig.2. Network of measurements stations in Polrodex'97 experiment (25-26 September)



a)

layer 0-4 m
TM4 = -5.549 + 1.3083 * T4
Correlation: r = .41440, p=.33

b)

layer 0-4 m
ZM4 = 12.483 - .7647 * Z4
Correlation: r = -.1710, p=.66

layer 18-24 m
TM24 = 2.9445 + .75104 * T20
Correlation: r = .10505, p=.82

layer 18-24 m
ZM24 = 6.8955 + .09347 * Z20
Correlation: r = .05113, p=89

Fig. 3. Examples of regression function between measured and modelled walues of: a) temperature. b) salinity

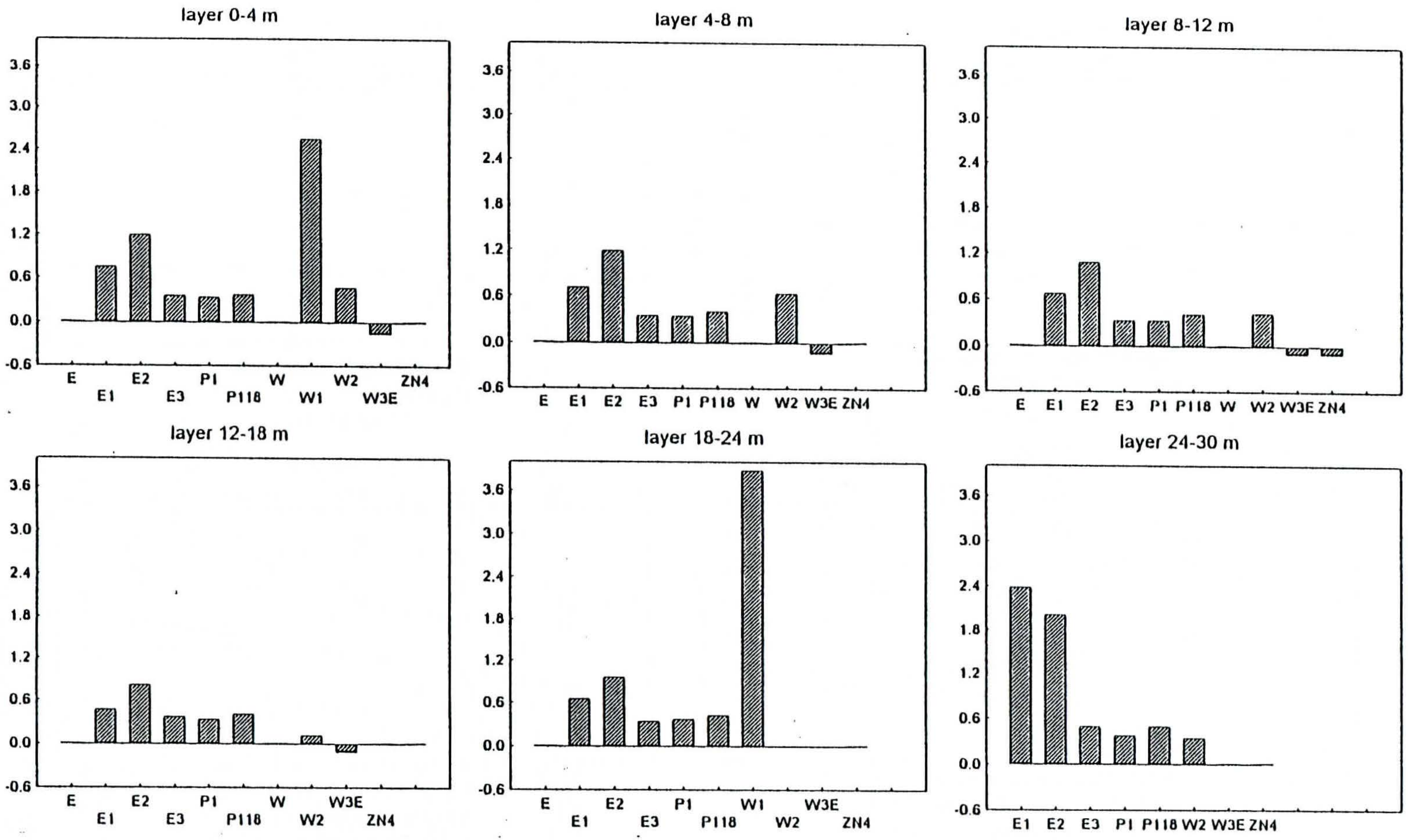


Fig. 4. Differences in temperature between measured and modelled values (22-23 September)

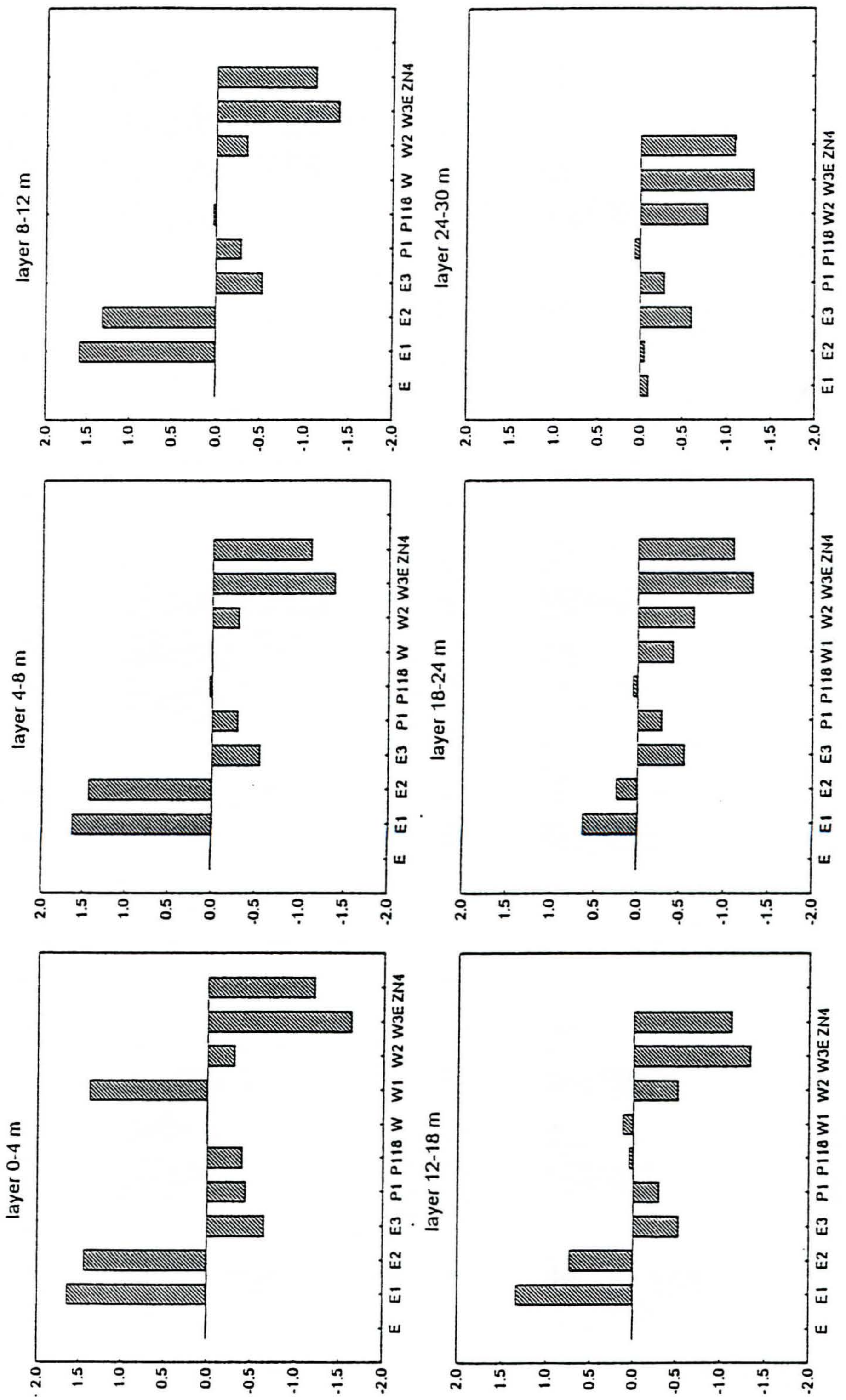


Fig. 5. Differences in salinity between measured and modelled values (22-23 September)

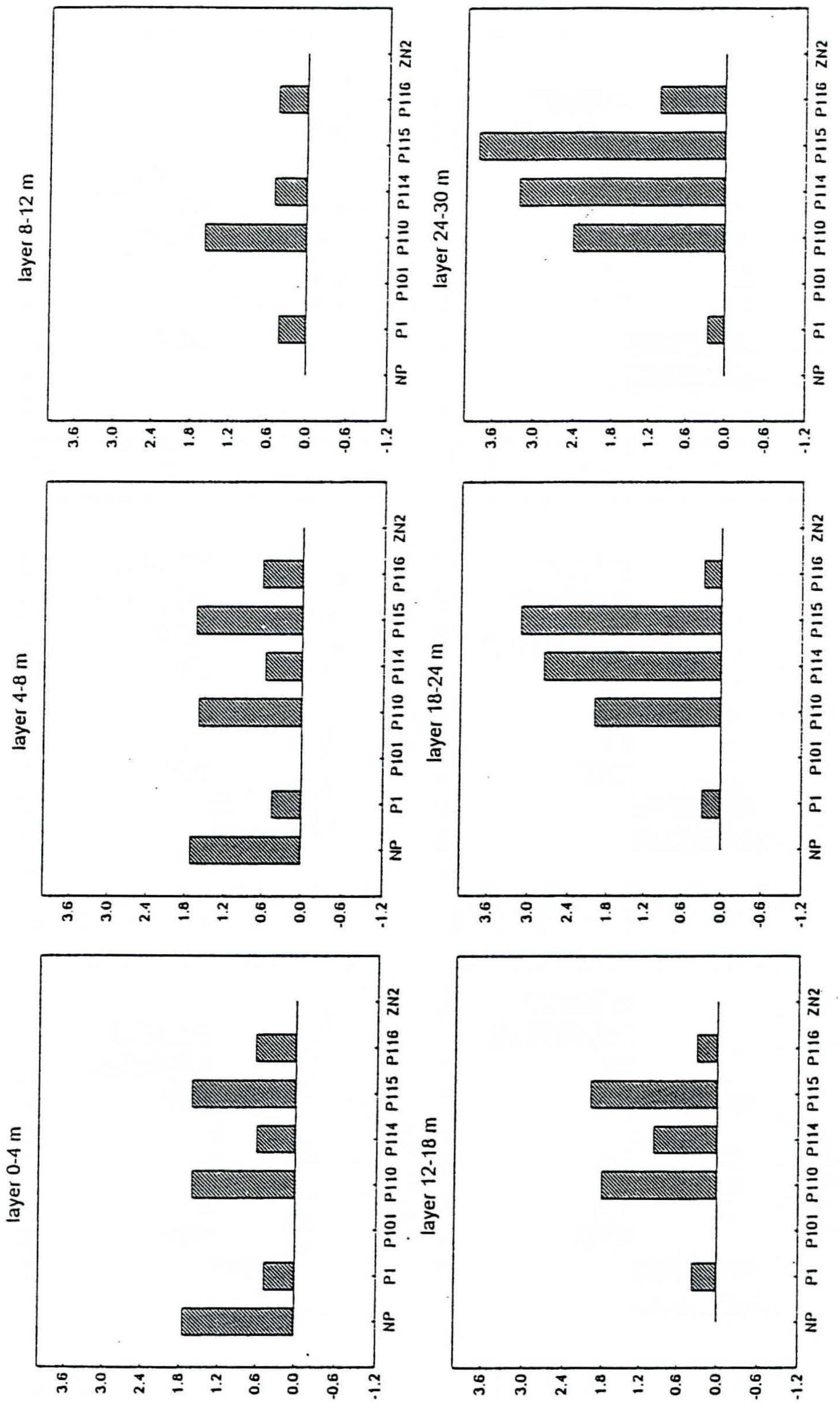


Fig. 6. Differences in temperature between measured and modelled values (25-26 September)

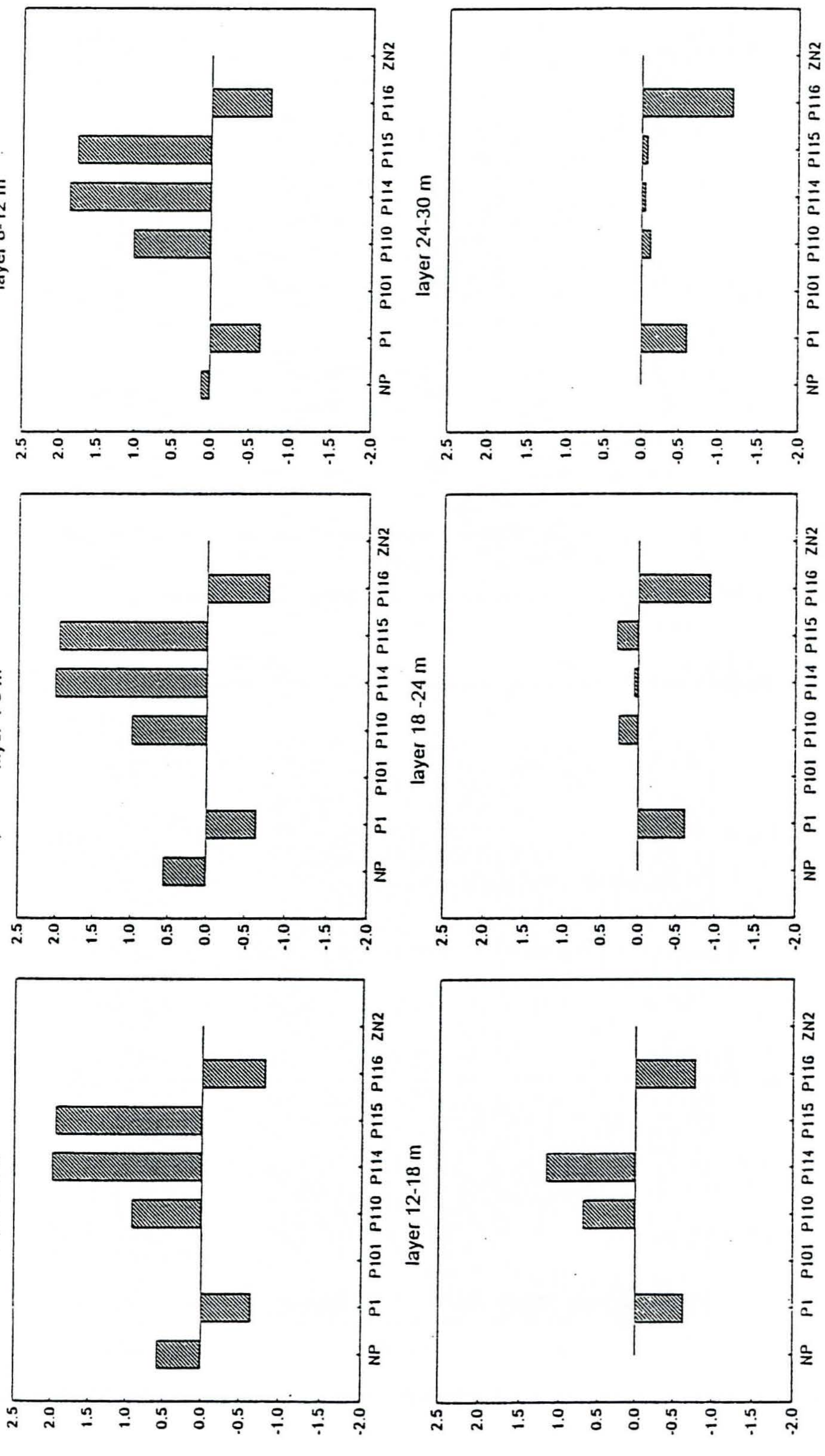


Fig. 7. Differences in salinity between measured and modelled values (25-26 September)

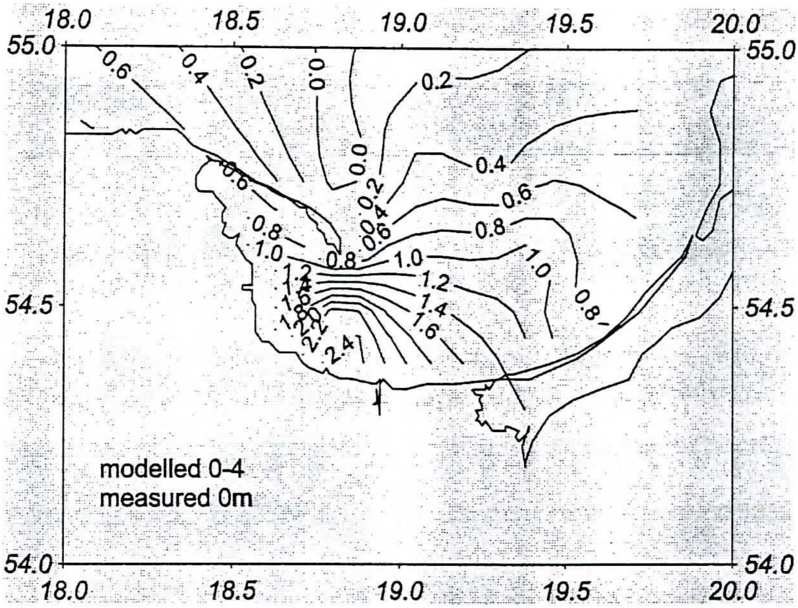


Fig. 8. Isolines of differences between measured and modelled temperature (22-23 September)

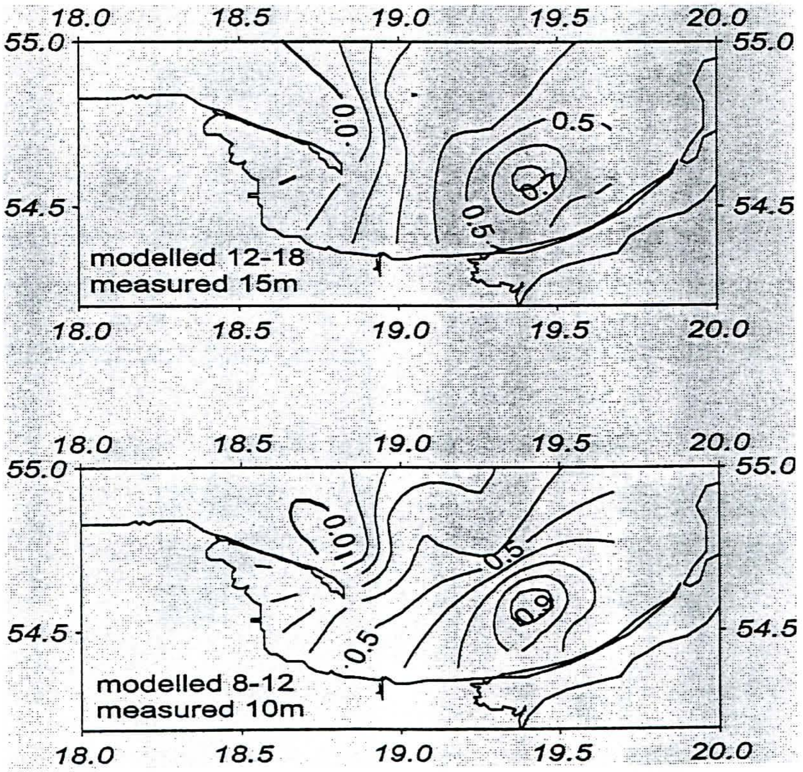


Fig. 9. Isolines of differences between measured and modelled temperature (22-23 September)