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THE COMPARISON OF THE FORECASTED AND MEASURED CURRENTS IN THE DEEP PART OF THE SOUTHERN BALTIC SEA IN 1999

Abstract

This paper presents results of the investigation carried out in frame of research project of Institute of Meteorology and Water Management Maritime Branch in Gdynia (IMWM-MB) in the year 2000. The goal of the project was to determine the conformity of the sea current forecasts for the layer 8 - 12 meters of the open sea part of the Southern Baltic Sea, as produced by the hydrodynamic model of the Baltic Sea - HIROMB [5], with the measurements. Contrary to the results of previous experiments as in the case of the POLRODEX ones [7, 8, 9], during present study it was expected to detect behaviour of the model far from the influence of the boundary like coastline as well as bottom friction in the shallow water areas.

The analysed data were collected during five routine cruises of r/v Baltica organized by IMWM-MB since February until September 1999 [10], when cruise track started from the Gdańsk Deep, next along the northern border of the Polish EEZ, ending in the Bornholm Deep area usually. On the basis of the current vectors recorded by means of the ship mounted ADCP as the 250 m average values in the layer 7.5 to 12.5 meters, mean values related to the model grid have been calculated and statistically assessed. These mean vectors have been used for comparison of forecasted values. Consequently, the sets of values of the differences between measured and predicted currents were statistically evaluated both regarding the direction and the module of the currents as well as the current vector components (V_x, V_y) separately.

1. Introduction

High Resolution Operational Model for the Baltic – HIROMB was primarily developed by Bundesamt für Seeschifffahrt und Hydrographie (BSH) in co-operation with Swedish Meteorological and Hydrological Institute (SMHI). The model is based on the modified BSH operational model [5], with the atmospheric forcing from HIRLAM model. Among other parameters, the model predicts the sea currents in the nodes of 3 nm by 3 nm horizontal grid in 24 vertical layers. During the last period of its operational phase the model was a subject of several validation and verification exercises, both in general and regional scales regarding different predicted parameters [1]. Some of works concerned accuracy of prediction of surface flow in space [2, 3] and the temporal changes of the currents observed on different depths [4, 11] as well. Also the spatial distribution of the differences between predicted and measured currents under surface layer within central part of the Gulf of Gdańsk were studied on the basis of the measurements carried out during POLRODEX'96 [8] and POLRODEX'97 [9] experiments. Those observations of the flow field have been carried out by means of RDI's BBADCP (Broad Band Acoustic Doppler Current Profiler) [9], and the method of linear interpolation of vector components in the nodes of the model grid vectors was applied for the quasi-synoptic flow field reconstruction [6]. Thus predictions were compared to the interpolated values. During present work the method of interpolation was not applied, although a method of vector averaging was applied.

2. Materials and methods

Similarly to the POLRODEX experiments, the data for the study was collected during cruises of r/v Baltica organized by IMWM-MB since February until September 1999 [10]. The cruise routes began from the Gdańsk Deep, next followed the northern border of the Polish Exclusive Economical Zone (EEZ) and ended in the Bornholm Deep area usually. Most of the parts of the route covered relatively deep areas. The maximum depth of the sea varied from 110 m to 95 m, however the route sometimes crossed the shallow water Słupsk Bank area located in the central part of the EEZ.

The currents were recorded by means of the ship mounted ADCP device as the 250 m average values in the layers from 7.5 meters depth down to the bottom. For further study data of one layer 7.5 to 12.5 meters were selected only (Fig. 1), to be compared with predicted currents in the layer 4 - 12 m of the model.

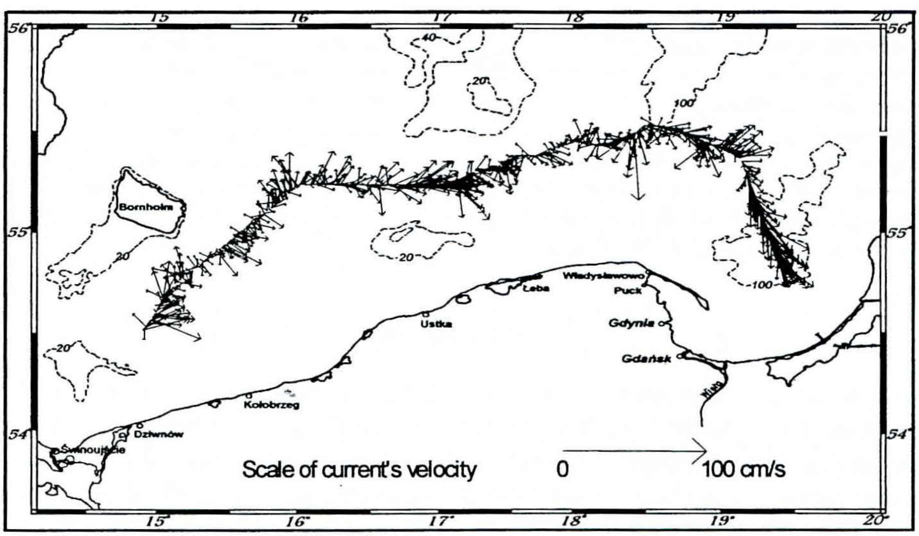

Fig. 1. Current vectors as recorded by means of ADCP in the layer 7.5 – 12.5 m during cruise of r/v Baltica in February 1999

Next, the recorded current vectors have been pooled within 3 Nm by 3 Nm squares of the middle points overlaying selected nodes of the model grid as separate data sets (Fig. 2). For each of the data sets, the mean values of the current vectors components (Vx and Vy) were calculated, as well as standard deviations and standard errors of the averages. The standard error of average value had been obtained as the result of division of standard deviation by the square root of data number.

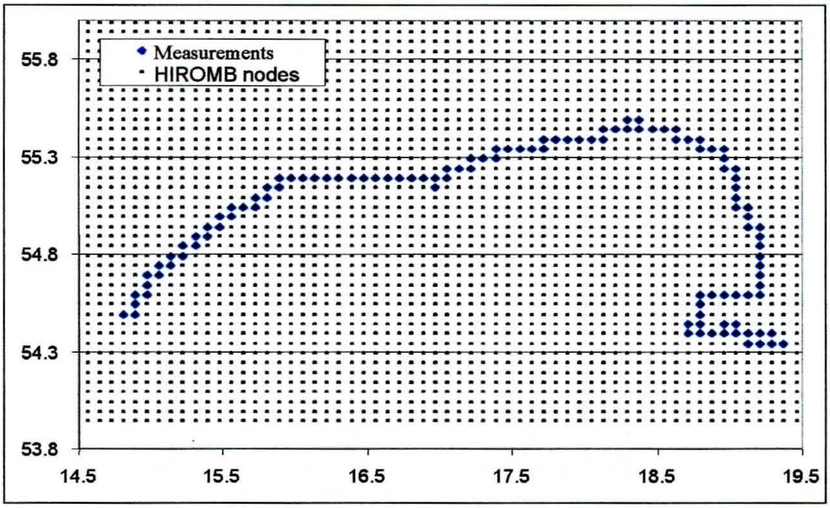

Fig.2. An example of the locations of data sets overlying the HIROMB grid nodes

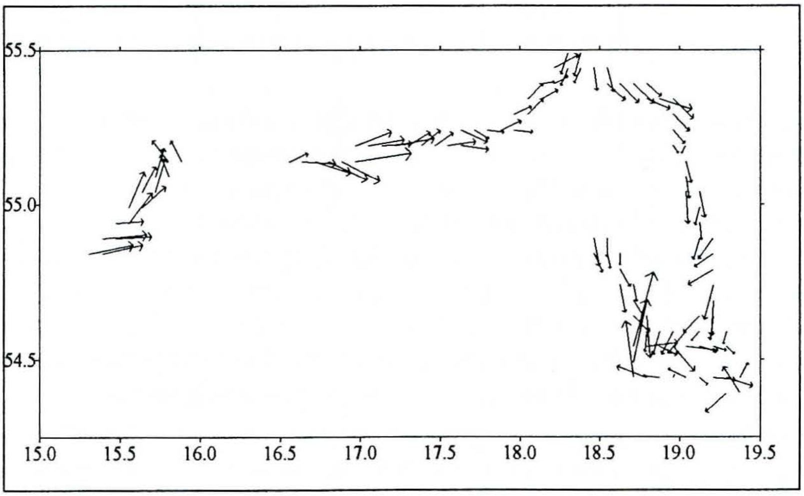

Fig. 3. An example of the measured current vectors as averaged within 3 Nm by 3 Nm squares

Finally, for selected nodes of the grid, we obtained mean values of current vector direction and module (Fig. 3), called as "measured" later in the paper. As it can be noted in the above figure, these sparsely distributed vectors still reflect main features of the circulation patterns in the Baltic Sea waters well, in comparison with much more dense raw data distribution.

For the final analysis, only the data within ±3 hours time span regarding the time of the forecast was selected. Such data were compared with the 6 and 24 hours forecasts separately. The error of the forecasted current direction was calculated as the deviation in degrees of direction of the forecasted current to the left and right sides in relation to the direction of the measured one. Thus we obtained values within the range ±180°, where, respectively, a positive sign means a clockwise deviation and a negative an anticlockwise deviation. The error of the current velocity was calculated as the difference between measured and forecasted vector modules.

3. Results and discussion

In order to check the representativeness of calculated mean current vectors, the statistical analysis of their North (Vx) and East (Vy) components averaging was carried out as first. All the calculated average values for each node were combined into one file, and the statistical analysis followed (Table 1). The statistical distribution of the averaged vector components (Fig. 4) was considered as to be a normal one.

Table 1. The statistical parameters of the distribution of the averaged current components

Vector components	N	Average	Median	Minimum	Maximum	Standard deviation
V_x [cm/s]	495	2.75	3.0	-39	57	10.1
V_y [cm/s]	495	-1.10	-1.0	-28	39	9.64

Such spectrum of variability of the currents data has been assumed as being very prompt for further analysis, while the data itself represented different conditions of the water dynamics. However, it has to be noted that in the case of the East components (V_x) the maximum number of averages was related to small values, i.e. in the range -5 to 10 cm/s, while the range of maximum number of the North component (V_y) average values was slightly wider (-10 to 10 cm/s). This asymmetry is seen in Table 1, where median of V_x stands 3.0 cm/s and -1 cm/s for V_y respectively. Besides this, the range of the East component values is wider by ±10 cm/s comparing to the North component, what suggests prevailing occurrence of both easterly and westerly currents during cruises.

Figure 5 exhibits a very narrow range of standard deviations variability of the averaged current vector components, where the most values lay within 0.0 to 0.75 cm/s range. The range of variability of standard errors is even narrower (Fig. 6). Assuming an average value of the standard error of the component means as less than 0.25 cm/s, we obtain the average error vector of 0.4 cm/s and 45° direction, which can be neglected during further analysis. On the other hand, these results confirm good accuracy of the current detection by means of the ADCP device. Only in some cases, mostly when the flow changed its direction, more significant errors (> 2.3 cm/s) had occurred. However, the number of such cases is less then 5% of the population of the averages.

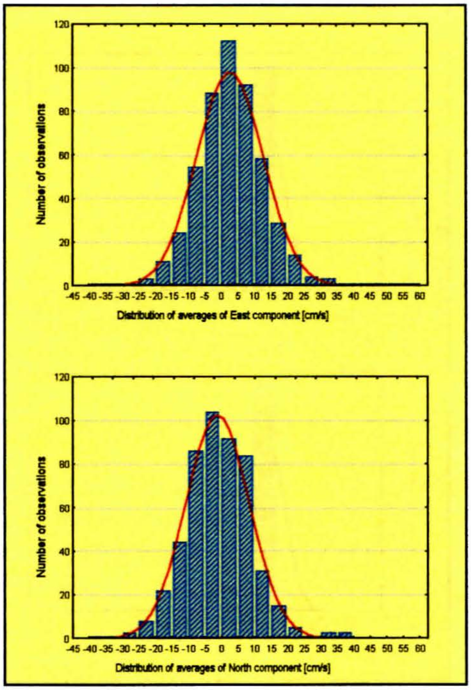

Fig. 4. Statistical distribution of the means of the measured current vector components in the nodes of HIROMB model in selected layer in 1999

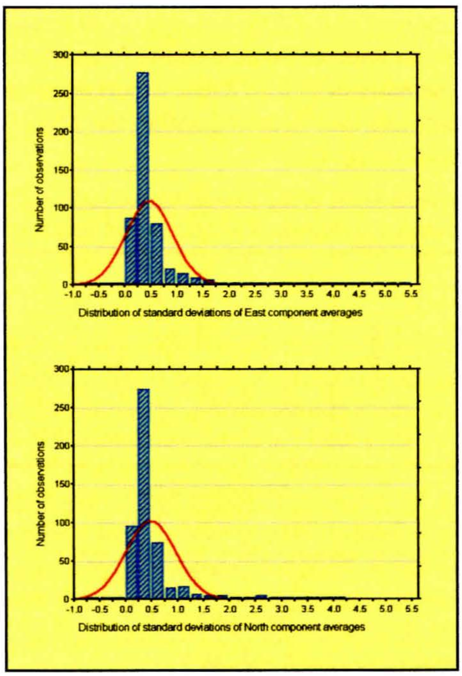

Fig. 5. Statistical distribution of standard deviations values of current vector components averages in the nodes of HIROMB

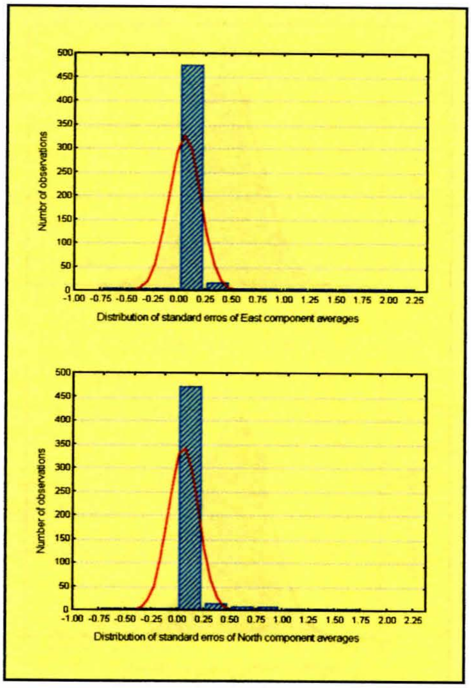

Fig. 6. Statistical distribution of standard errors of current vector components averages in the nodes of HIROMB

Results of statistical analysis of the differences for both forecasts are presented in Table 2. They show, in general, an underestimation of the forecasted current velocity, similarly to the results found on the basis of POLRODEX experiments investigations. As of 75 % cases of the velocity differences they occurred within the range 0 to - 15 cm/s both in the case of 5 h and 24 h forecasts (Fig. 7).

Table 2. Statistical parameters of the forecasted and measured currents comparison. Current velocity is expressed in cm/s, while direction in degrees

	N	Average	Conf. Level -95%	Conf. level +95%	Median	Minimum	Maximum	Standard deviation	Standard error of average
Forecast + 6 h									
Direction deviation	214	20.2	8.0	32.4	21.6	-179.9	179.5	90.4	6.2
Velocity difference	214	7.7	6.7	8.8	6.3	-8.8	46.6	7.6	0.5
Forecast + 24 h									
Direction deviation	114	8.12	-10.6	26.9	8.1	-178.1	177.8	101.14	9.5
Velocity difference	114	9.13	7.8	10.4	7.4	-2.8	37.9	7.09	0.76

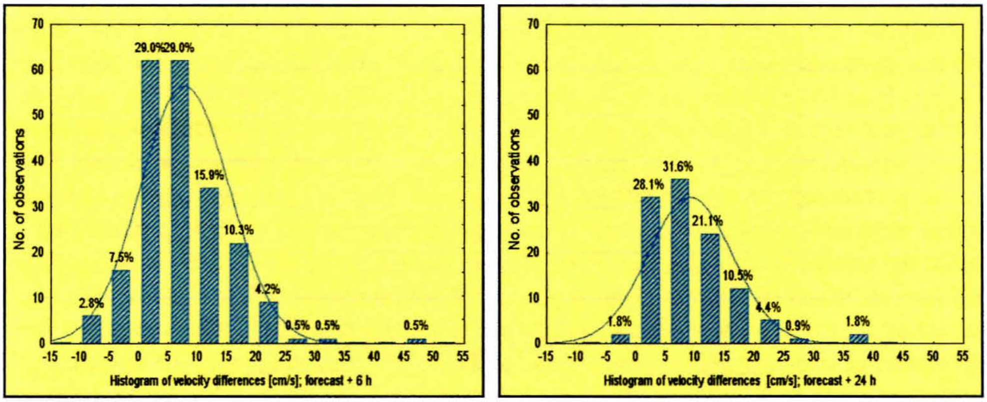

Fig. 7. Statistical distribution of the forecasted currents velocity deviation from measured ones

The forecasted current speed was sometimes even greater from the mean. However, the maximum difference reached even more than 40 cm/s, what means that the forecasted current was significantly underestimated (Table 2). For both forecasts, the average values of the differences were similar and low, i.e. equal ca. 8 cm/s.

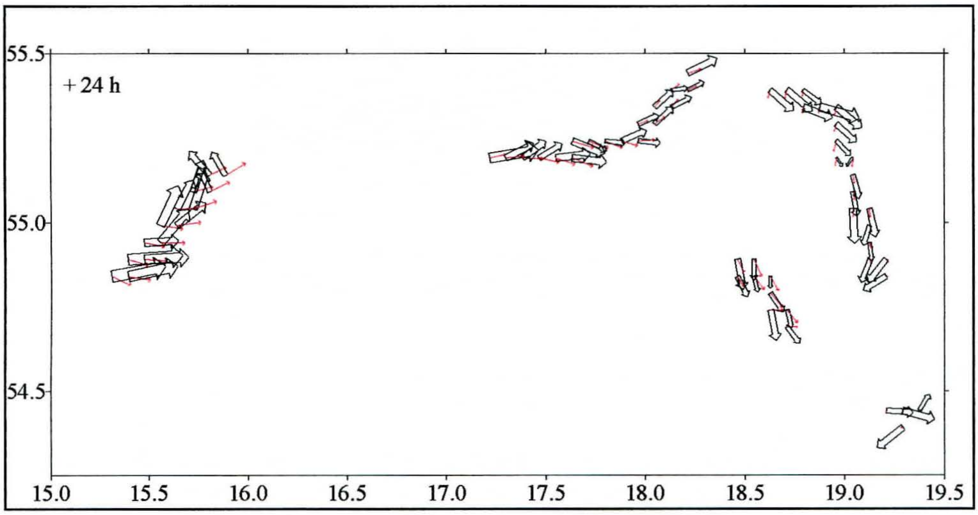

Fig. 8. An example of the current vectors represented as mean vectors in the nodes of HIROMB model (thick arrows) and the currents forecasted (thin arrows) +24 hours during cruise in March 1999

The presented above, example of horizontal distribution of measured and predicted currents during one of the cruises (Fig. 8) shows good accordance both regarding current vectors modules and directions. On the other hand, not all analysed cases were so good as the presented one, sometimes forecasted currents differed significantly (Fig. 9) from the measured ones. Analysing the last figure, it is important to note, that in the central part of area of investigations (western edge of the Słupsk Bank) the maximum depth is only *ca.* 25 m. It is likely, that these factors could influence on the distribution and magnitude of measures and forecasted currents as well.

Analysing the current direction, we found better accordance of the forecasted values with the measured ones, than during the POLRODEX experiments. Here, for both forecasts (+6 h and +24 h) the average deviations of the direction were only ca. 20 and 8 degrees respectively. It has to be considered that it may be the result of adding negative and positive values (median is 21.6 and 8.1 respectively), as the deviations by almost 180° were also observed. In the case of +6 hours forecast (Fig. 10), the prevailing clockwise shift of maximum number of deviations can also be observed (ca. 25°). It is likely that it may be the result of combining the data within ±3 hours time span and what is comparable with forecast time (+6 hours). There is practically no deviation shift in the case of +24 h forecast or it is relatively small in comparison to the +6 h forecast, which suggests less importance of data aggregation in time regarding that case. Although the deviation of direction is much smaller in the case of 24 h forecast (ca. 8.12 cm/s), the error of the average is much greater (9.5 cm/s).

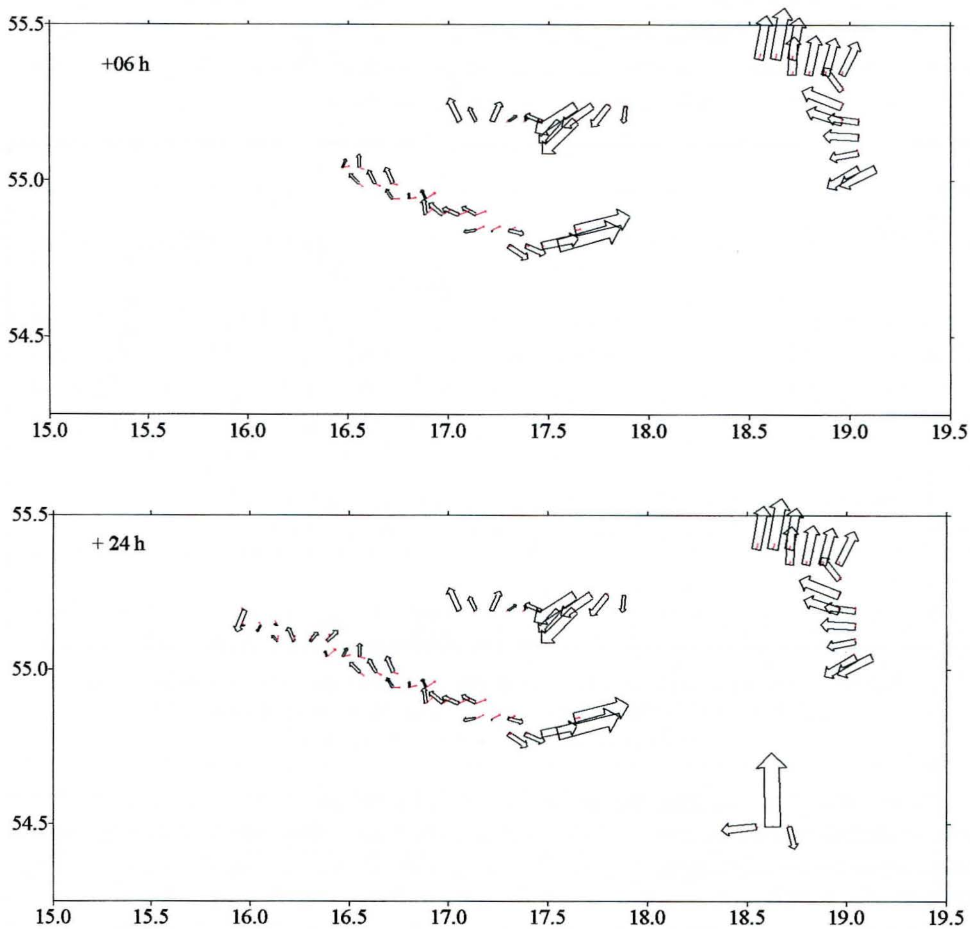

Fig. 9. An example of the current vectors represented as mean vectors in the nodes of HIROMB model (thick arrows) and the forecasted currents (thin arrows) during cruise in August 1999; case +6 h and +24 hours

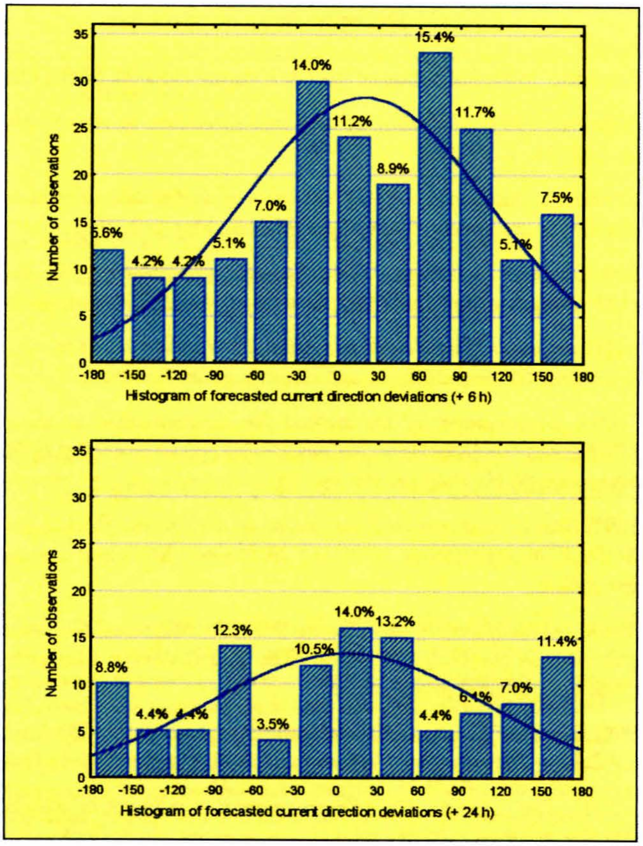

Fig. 10. Statistical distribution of the direction deviations of +6 h and +24 h forecasted currents from the measured ones

4. Conclusions

As the main conclusion of the analysis, it is possible to assume good model behaviour in general, and that the current field prediction is better in the case of high current velocities than during weak current occurrence or very turbulent water movement.

The comparison of the deviations of predictions in relation to the observed (averaged) current velocity results with the conclusion that most of the greater deviations have been observed in the cases of weak currents, i.e. less then 10-15 cm/s. In the situation when the water flow is stronger and the circulation patterns are better expressed, the accordance of the forecasts with the nature is better; however the problem of resolving mesoscale eddies still exists. Another possible reason of observed errors this could be an effect of bottom influence on currents distribution in shallow areas.

The results of presented work showed also the value of collected ADCP field data regarding verification of the hydrodynamic models. On the basis of the experience gained and thanks to developed software it is possible to carry out similar analysis for another version of the model in the future.

References

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