Maciej Kałas, Kazimierz Szefler
Maritime Institute, Gdańsk, Poland

ON THE POSSIBILITY OF FORECASTING WATER LEVEL ON THE BASIS OF THE HIROMB MODEL

Abstract

The following paper presents a comparison of water level data taken during the POLRODEX'97 experiment by some Polish water level gauges situated around the Gulf of Gdańsk with results computed for this period using the High Resolution Operational Model for the Baltic Sea (HIROMB). Additionally sea level changes near the oil-drilling platform BETA were computed using data from pressure sensors and compared with results of the model. It is found that observed and computed values of sea level change are in good agreement.

1. Introduction

One of the main goals of the POLRODEX field experiments, carried out since 1996, is to obtain meteorological and hydrological data from the coastal zone as well as from the open sea for needs of calibrating and validating various operational forecasting models. The output data from these models are used to run a computer system to serve protection of navigational conditions, aiding oil and chemical spill combat activities, for rescue actions, etc. The Polish hydrological service used or implemented for using some empirical statistical and hydrodynamic-numerical 2D models [4, 5, 6]. The hydrodynamic-numerical model HIROMB developed in co-operation between several Baltic countries and run at the SMHI is a full 3D model. It delivers daily forecasts of currents, water level changes, sea temperature and salinity, ice concentration and thickness [1, 2]. Polish institutions contribute significantly to the development and validation of this forecasting system, especially during the annual experiments carried out at sea near the Polish coast.

The POLRODEX'97 experiment was carried out on the Gulf of Gdańsk and neighbouring sea areas in September 1997 and allowed collecting a lot of valuable hydro-meteorological data. One of the objectives was to assess the quality of sea level forecasts given by the HIROMB model for the eastern part of the Polish coast. For this aim, water level data from some gauges situated around the Gdańsk Bay owned by the Institute of Meteorology and Water Management, Maritime Branch in Gdynia were used. Positions of the gauges are shown in Fig. 1. Additionally, sea level changes near the oil drilling platform BETA were computed using data from pressure sensors placed there for the time of the experiment.

2. Sea-level data from the HIROMB model

HIROMB is the result of a combined effort of scientists from several Baltic countries working under the agreement, also called HIROMB. At present the HIROMB model is run pre-operationally at the SMHI, and from there were obtained results of its forecasting computations. As current meteorological input data, the model uses forecast information from the limited area atmospheric model HIRLAM [3].

Horizontal resolution of the HIROMB model is now approximately 3 Nm, and it is divided vertically into 26 layers, with the finest resolution of 4 m in the upper subsurface layer. In the Polish zone, because of the limited depths, the model has now 14 levels from the surface to the bottom in the deepest parts of the Gdańsk Deep. The horizontal grid-net points of the HIROMB model for the Gulf of Gdańsk area are shown in Fig. 1 (blue circles).

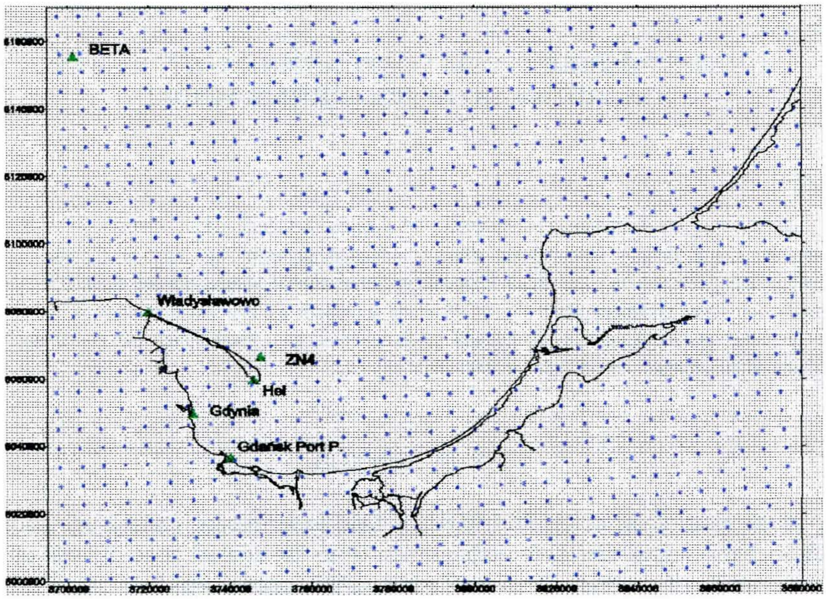

Fig. 1 Points of sea level measurements and numerical grid of the HIROMB model

As well as many hydrological parameters (ice conditions, salinity, temperature, currents), the model calculates water level in each node of the horizontal grid for 24 hours ahead – to the noon of the next day. The predicted data are daily available 00, 06, 12 and 18 hours ahead. For the analysis and comparison with observations, sea level data from these times and from the nearest grid points of the numerical model were used. The curves of computed values of sea levels for four points near the coastal stations and two near the open sea points (shown in Fig.1) are presented in Fig. 2.

We can see a very good consistency of sea level curves taken from all model grid points, lying near the observation points is visible. To the values obtained from model computations, 500 cm was arbitrarily added for agreement with the 0 point used in sea level measurements on Polish coast. This is connected with the Amsterdam 0 level and assigned a mean sea-level height of 500 cm (there are no negative values). This results in a systematic error for all curves, but it is hard to estimate it without precise levelling or using a long time series of statistical data.

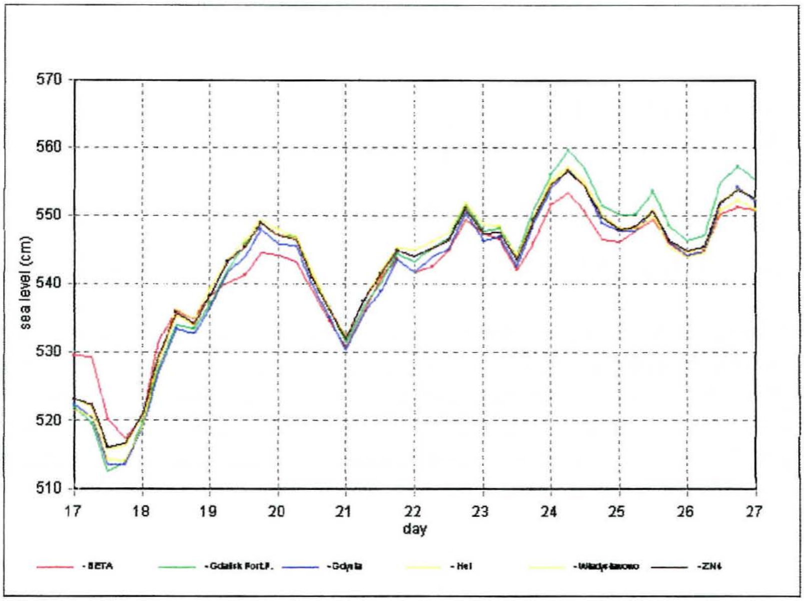

Fig. 2 Sea level changes computed at the nearest grid points in the Gulf of Gdańsk

3. Sea-level data measurements during POLRODEX'97

3.1 Data from sea level gauges around the Gulf of Gdańsk

In the daily hydrological service run at the Institute of Meteorology and Water Management there are continuous recordings of sea level data from about a dozen sea level gauges located along the Polish open sea coast and estuarine waters. For the purpose of the experiment, data from four stations lying on the coasts around the Gulf of Gdańsk were used: Władysławowo, Hel, Gdynia and Gdańsk Port Północny (Fig.1). The curves of sea level changes recorded by these gauges during experiment are presented in Fig. 3 (thin lines).

The data for sea level changes are available every 4 hours (from 00, 04, 08, 12, 16, and 20 UTC), so for the needs of comparison with values computed from the model, the data from 06 and 18 UTC were interpolated.

3.2 Data from drilling platform BETA

During POLRODEX'97 there was a possibility to make water pressure measurements at an open sea station – on the drilling platform BETA situated about 40 Nm north off Cape Rozewie. This was done by way of CTD measurements. Extracting the pressure of the water column above the sensors (water temperature and salinity over the sensors were also measured) and taking into account temporal changes of atmospheric pressure, it is possible to obtain a time series of water level changes Δh:

$$\Delta h = \frac{P - P_a}{\rho \cdot g}$$

where:

P – pressure measured by sensor
P_a – atmospheric pressure (taken from observations)
g – acceleration of gravity
ρ – density of sea water, dependent on temperature T and salinity S, Mamaev formula [7]:

$$\rho = 1.000082 - 3.5 \cdot 10^{-6} T - 4.69 \cdot 10^{-6} T^2 - 2.0 \cdot 10^{-6} T \cdot S + 8.02 \cdot 10^{-4} S$$

It is now also technically possible to obtain the absolute height for values of water level (it needs precise levelling); even time changes of the water level at open sea are very valuable for model validation. To these computed values - Δh 500 cm was arbitrarily added (as in the case of data obtained from model), to obtain agreement with the 0 point from the sea level gauge measurements. The curve of calculated in this way sea level changes at the oil platform is presented in Fig. 3 (thick line).

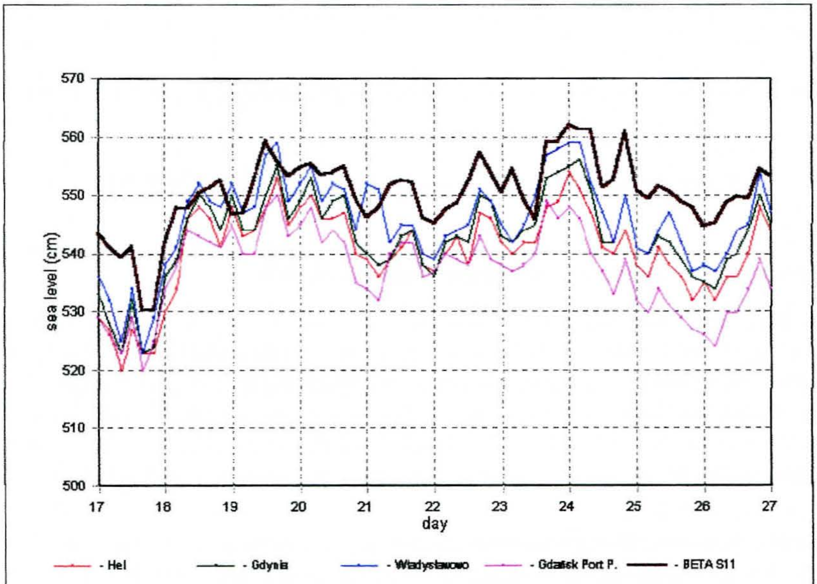

Fig. 3 Sea level changes during experiment: from sea level-gauges along the Gulf of Gdańsk (thin lines) and recorded at open sea (thick line)

4. Comparison between observed and computed values of sea level changes

Detailed comparison of curves for observed and predicted values of sea level changes during the experiment is shown in Fig. 4, where pictures a) – d) show the data for coastal stations, and e) – the data from the open sea station – drilling platform BETA. Unfortunately, it was not possible to compute real sea level changes for point ZN4.

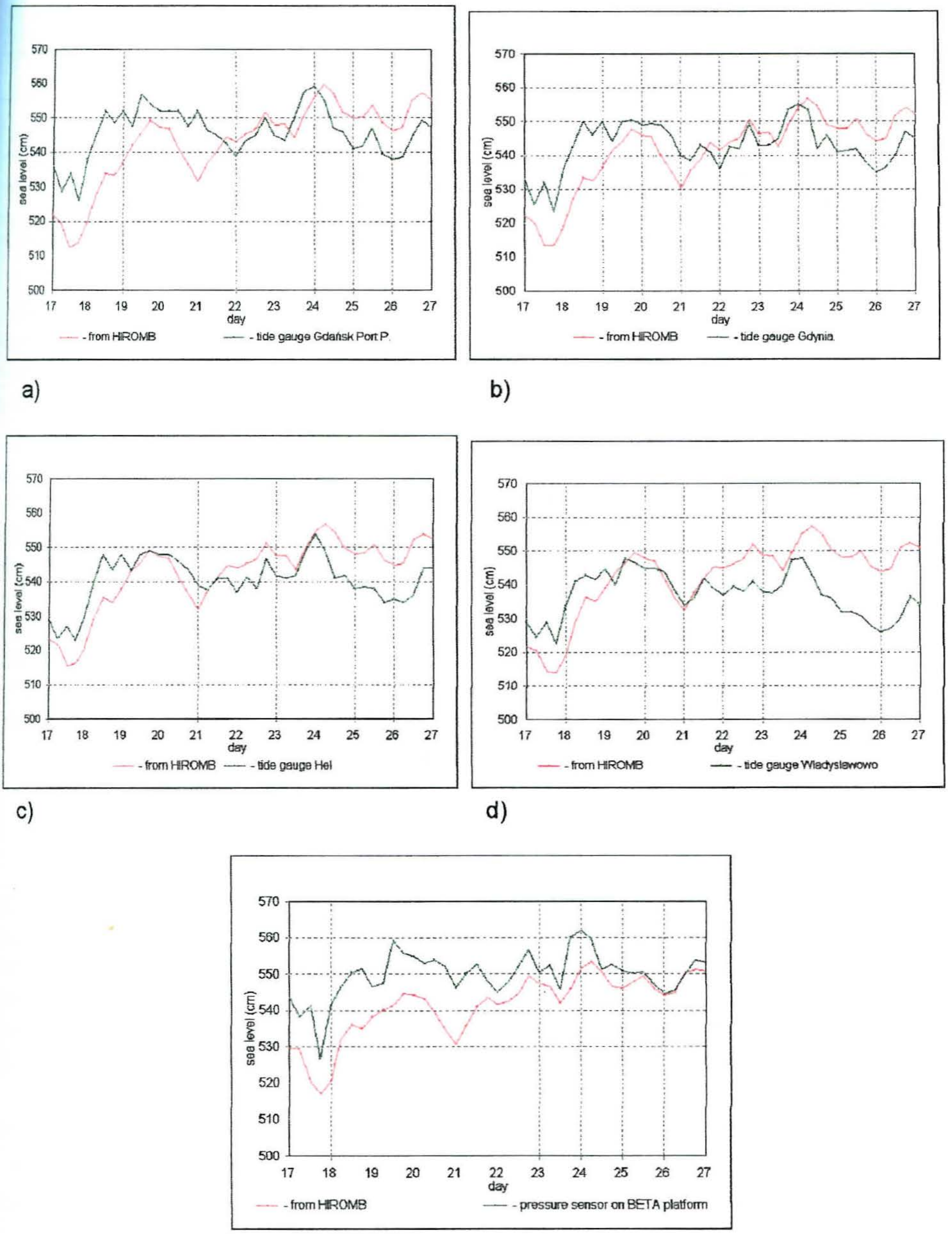

Fig. 4. Sea level changes near coastal stations - a) – d) and at open sea - e)

This set of figures shows a very good agreement between the shapes of observed and computed curves of sea level change for all analysed points, both on the coasts and at open sea. This is confirmed by a short statistical analysis of the data, presented in Table 1. In the table are shown: number of analysed data – N, maximum D_{MAX} and minimum D_{MIN} values of differences between observed and computed sea-level data (in cm), mean square deviation – MSD (in cm) and coefficient of correlation – R.

Table 1 Correlation parameters between observed and computed sea level data

Tide-gauge	N	D_{MAX}	D_{MIN}	MSD	R
Gdańsk Port Północny	48	21.60	1.73	9.99	0.84
Gdynia	48	18.48	0.90	9.24	0.83
Hel	48	16.13	0.04	9.01	0.87
Władysławowo	48	21.03	0.01	9.46	0.68
BETA – open sea	46	21.20	0.34	9.69	0.90

As can be seen, a relatively small number of data was taken into account. Nevertheless, the results of statistical analysis confirm the very good agreement between the two sets of sea level data, as was previously concluded from the figures (Fig. 4 a-e) for the coastal stations and for the open sea point (here the coefficient of correlation is the highest, but the mentioned earlier reservation about exact levelling must be borne in mind).

The values of maximum differences between observations and computations seem to be relatively high, in some cases they exceed 20 cm; the highest value is for Gdańsk, the lowest is for Hel. They can be connected with local conditions in which sea level recordings are usually performed. It can be helpful to use the nested model with closer lying grid points. On average, the values of minimum differences are quite small, only in case of the point Gdańsk Port Północny the value exceeds 2 cm. The values of mean square deviation are quite similar (about 9 cm) and do not exceed 10 cm. The values of correlation coefficients are quite high – between 0.83 and 0.90, only for Władysławowo this value is lower – 0.68, which may be the result of greater divergence of curves showing the data for this point in the second part of the investigated period (Fig. 4d).

5. Discussion and conclusions

As was shown above, there is a broad range of possibilities for the use of the HIROMB model for forecasting sea level changes not only at some fixed points, connected with sea level stations on the coasts, but also along the coast and on the open sea. Basing on the above analysis, it seems that the agreement between observations and data from the model is very good, especially with respect to the trend of changes. More detailed explanation needs adjustment of levelling for both sets of data. It should be correlated for all seacoasts as well as for the sea areas.

A comparatively short period was used for the analysis of HIROMB results. For a more detailed assessment of the model, sea level data from long periods of time should be used.

Predicted values of sea level change, obtained from computations with numerical models such as HIROMB, can be very helpful for forecasting storm surges, which are connected with active depressions over the Baltic Sea area. It is not only very interesting, but there is a strong need to test the HIROMB model for such extreme hydrological situations. Till now there was no possibility to make investigations for such events on the Polish coast.

As it is known from previous testing of various forecasting models, they can give significant differences between observed and computed values, especially for hydrological situations connected with rapid changes of sea level at the coast. Forecasts obtained from hydrodynamic-numerical models basically depending on the outdistance time of forecast meteorological input data can be very helpful for early prediction of such events, often connected with storm floods on the coast. The same can be said about periods with low sea level, the duration of which can be quite long and which can significantly disturb navigation on waterways and shallow areas of the sea.

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