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THE TEST OF APPLICATION OF WAM MODEL FOR THE WIND WAVE FORECASTING OF THE BALTIC SEA

Abstract

The following presents a test of implementation of WAM - a third generation wind wave model for oceans, for computations of wave conditions on the Baltic Sea. This work presents an actual state of implementations of this model for existing in the Maritime Institute data base for bathymetry, input meteorological forces and computation possibilities, and point sout future potential of its development and implementation for operational forecasting.

Special attention was given to areas near the Polish coast, where field experiments POLRODEX were performed. The computations were made for homogenous wind fields, as well as for wind fields connected with real meteorological situations.

1. Introduction

WAM (WAve Model) is a third generation wave model based on energy equations. It solves the wave transport equation explicitly without any presumption on the shape of its spectrum and shows the physics of wave evolution for the full set of degrees of freedom 2D spectrum. Its theoretical background is based on works, among many others: [5, 6, 8, 9, 10, 11, 17]. The model was jointly developed by WAM Group at the Max-Planck Institut für Meteorologie in Hamburg, in co-operation with some European meteorological and computational institutions [18]. It was implemented in meteorological centres: DWD [1] , DKRZ [4], ECMWF [3] also in UKMO and NOAA. This model is also developed in Polish institutes connected with maritime management: the Institute of Hydro-Engineering (IHE PAS) [12, 14, 15, 16] and the Maritime Institute [10].

Authors of the model assume that the model runs for any given grid-set with a prescribed bathymetry data set. The grid resolution can be arbitrary in space and time. The propagation can be done on a geographic or Cartesian grid. The model outputs are: significant wave height, mean wave direction and frequency, swell height and mean direction, wind stress fields corrected by including the wave induced stress and the drag coefficient at each grid point at chosen output times, and also 2D wave spectrum at chosen grid points and output times. The model can run for deep or shallow water and can include depth and current refraction. The integration in the model can be interrupted and restarted at any time. Subgrid squares can be run in a nested mode. In a coarse grid run the spectra can be output at the boundaries of a subgrid. They can be interpolated in space and time to the boundary points of the fine subgrid and the model can be rerun on the fine mesh grid.

The model computes 2D wave variance spectra at all grid points. These spectra can be saved for a restart at the end of a run. It gives possibility to choose specific points and dates to output detailed 2D spectra. These spectra are represented by a variable number of logarithmically spaced frequencies, extending from an arbitrarily chosen minimum frequency, and by variable number of equally spaced directions, started from North. Also mean wave height, directions and frequency and mean wave swell height and direction can be output.

2. WAM model system

The model system consists of three major program parts:

a) pre-processing programs
b) processing programs
c) post-processing programs

The model has been written in FORTRAN and was extensively documented, i.e. each routine contains a header describing the purpose, method and interface of the routine and the externals used. It was designed to run for a CRAY computer with UNICOS operating system, but we have adopted it for use on our works-station H-P 9000 J282 with UNIX system. Detailed parts of the system, programs, input/output files are showed on Fig.1.

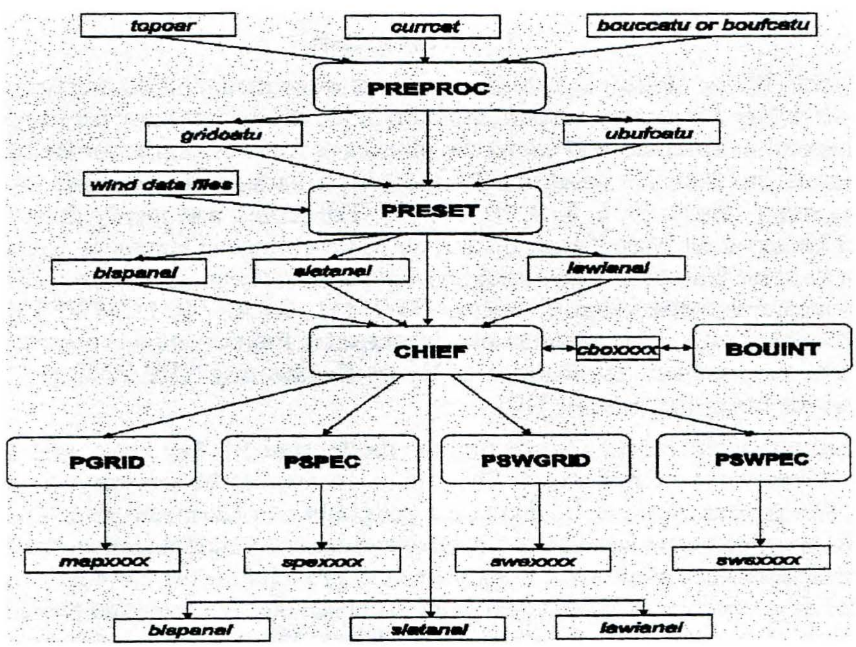


Fig.1. Diagram of WAM computation system; bold – programs, italic - input/output files

2.1. Pre-processing programs

In this section two programs are provided: **PREPROC** and **PRESET**.

Program **PREPROC** generates all time independent information for the wave model. It creates topographic grids required for the model using the sea depth data from input file *topoar*. If nested grids are generated in the model, the information for the output, input and interpolation of boundary spectra is precomputed and stored in separate files for the coarse and fine (sub) grid models – *bouccatu* and *boufcatu*.

In this program the frequency and angular arrays are generated too. If the current refraction option is activated, this program expects a current data set (from *currcat* file) and interpolates the data onto the model grid. It is expected in future to develop the model to use results received from daily forecasting of HIROMB as real time field data.

The output data for next steps of computation are stored in files *gridcatu*, *ubufcatu* and *bouccatu* (the last if nested grid option is used).

Program **PRESET** generates an initial wave field for cold start. At this stage of running the model the wind field data are implemented. The program uses the first wind file from assumption period as an input file. This file can consist both of a homogenous wind field and real wind field data.

In the computational process the same initial JONSWAP spectrum is used at all sea points or the initial spectra are computed from the local initial winds in accordance with fetch laws, with a $\cos^2$ directional distribution.

Results of computation are stored in files *blspanal*, *lawianal* and *slatanal* in the format of the model restart files. Thus in the first run of the system it is necessary to run program **PRESET**, but in case of restart we can run the main program **CHIEF** immediately.

2.2. Processing programs

This is the main section of the system. Two programs are provided: **CHIEF** and **BOUINT.**

Program **CHIEF** is the basic part of the system, where all wave parameters are computed. It is constructed as a shell program of the stand alone version of the wave model calling some computational procedures. All time dependent variables and user defined parameters are fixed, the input wind field data are transformed into the model formats, and the transport equation is integrated over a chosen period.

The program uses the output files of **PREPROC** and **PRESET** or a former run as initial values. A set-up of wind input files is provided by the user. The model computations can be integrated with independently chosen propagation, source term, wind input and output time steps. In our running of the model we chose 360 s as the propagation time step, 180 s as the source time step and 3 h as the time step on input wind file and output data as well as output and restart files.

A number of model options and parameters like: Cartesian or spherical propagation, deep or shallow water, without or with depth or current refraction, without or with nested grids and others can be selected by the user in the program input.

The model results are saved in four files:

- gridded output fields (*mapxxxx* files) of: significant wave height, mean wave direction and frequency, friction velocity, wind direction, peak wave frequency, drag coefficient and normalised wave stress.
- swell gridded output fields (*swexxxx* files) of: swell height, mean swell and wind wave direction and mean swell frequency.
- spectra at selected grid points (*spexxxx* files)
- swell spectra at selected grid points (*swsxxxx* files).

Program **BOUINT** interpolates the boundary output spectra from a coarse grid model run in time for the fine grid boundary input. This program has to be applied if nested grids are used.

2.3. Post-processing programs

The system contains four post-processing programs, used to show results of model computation: **PGRID** – for gridded output file, **PSWGRID** - for swell gridded output file, **PSPEC** - for spectra output file and **PSWPEC** - for swell spectra output file. The results are in digital form, but using some graphical programs they can be shown in the form of maps or plots.

3. Implementation of WAM model for the Baltic Sea conditions

As was mentioned above, WAM is a modern model for analysing and forecasting wave fields on seas and oceans. There is a strong need for operational, numerical wave forecasts in the Polish economic zone, especially along waterways, anchoring areas, at entrances to harbours. Wave forecast is important not only for navigational purposes, but also for rescue actions and for combatting oil and chemical spills. A long-term analysis of wave parameters in the coastal zone can be helpful for planning coastal protection, especially along cliffs and dunes. In the Polish hydro-meteorological service until now no good numerical models are used for wind wave predictions. The forecast information for waves fields is available only from HYPASS model results, calculated for a coarse grid in our area in SMHI, but its resolution is too low for our needs. Hence we have decided to implement the WAM model as a modern, free of charge system, available to the entire research and forecasting community and tested with good result in some European centres. This system is characterised by easy implementation of bathymetric data in any area of the sea as well wind and current input data, according to the time step at which they are received. The model also allows to analyse detailed information about wave spectra at any point. Fig. 2 shows an exemplary set of points from which we can get the spectral data, and a pattern of bathymetry, used as input data for the model computations.

For the computations we have adopted the system, which we received by courtesy of Prof. Hasselmann from the Deutsches Klimarechnenzentrum GmbH. We have made some changes in the source code to implement it on our work-station, using our bathymetry and hydro-meteorological data, and to avoid the huge amount of disk transmissions to minimise CPU time.

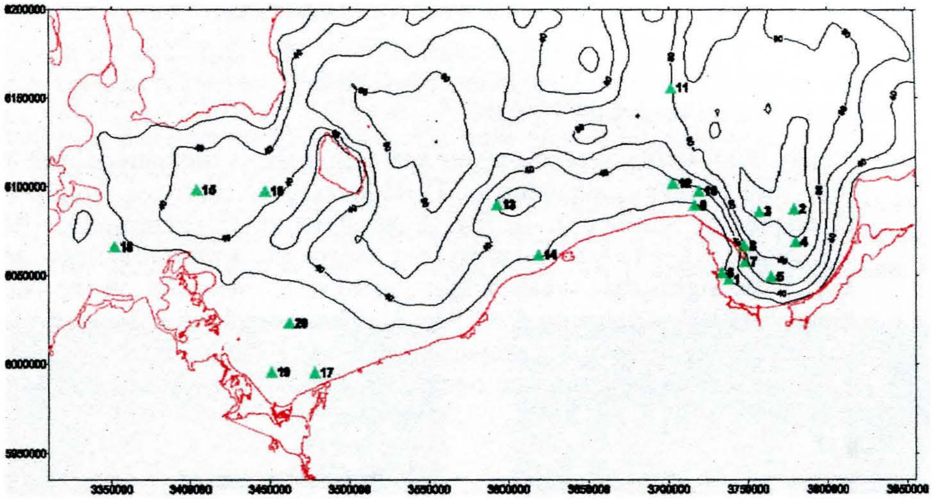


Fig. 2. Output points for spectra of WAM model – green triangles.
Pattern of bathymetry for southern part of the Baltic Sea – black solid line

3.1. Implementation of bathymetric data for the Baltic Sea

We have tried to use several nets with bathymetric data in the model, but for practical purposes (mainly to reduce the computational time) we have decided to use data for the whole area of the Baltic Sea in grid-net resolution 6 6 Nm. It gives a good enough resolution for the whole area of the sea.

This data set was generated with a base of 1 Nm. bathymetry grid-net usually used in the hydrodynamic model - HIROMB. This will allow us to implement it in full version of finest resolution as nested grids for smaller areas of the sea, like the Gulf of Gdańsk. If accuracy is needed, we have the possibility to use more detailed bathymetric data: 0.250.25 Nm for some small areas near the Polish coast and at entrances to harbours. The implemented grids for bathymetry of the Baltic Sea, on the Gulf of Gdańsk are shown in Fig. 3.

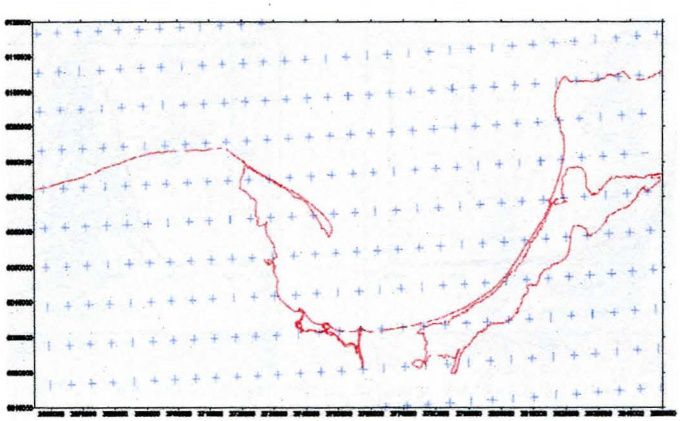
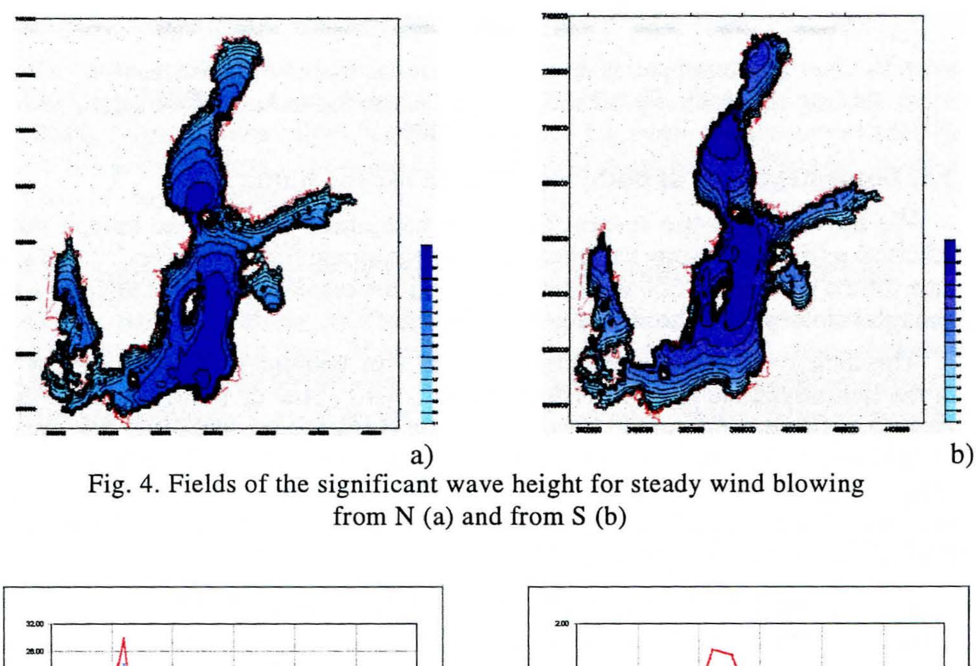


Fig. 3. Grids for bathymetric data (in the Gulf of Gdańsk area) – blue crosses

3.2. Data for meteorological forces over the Baltic Sea

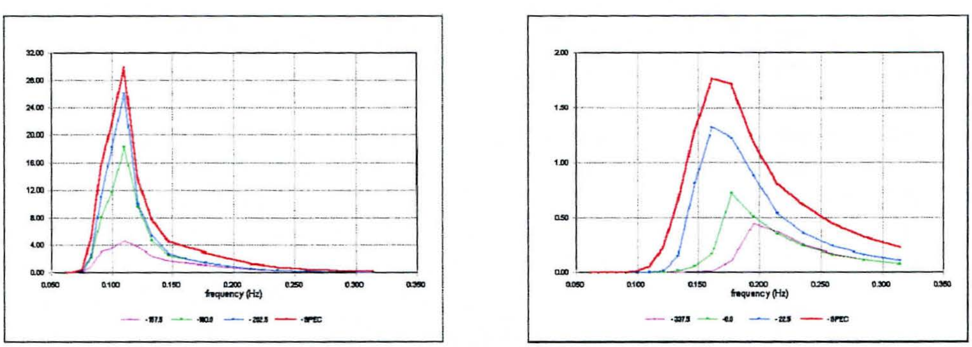
For the needs of wave field computations over the Baltic Sea we have used two kinds of wind fields (the format data of all input wind files is adapted to basic net actual used bathymetry):

— steady wind fields over the whole sea area. Like in the pattern system we take into account gale wind of 18.45 m/s speed, blowing from 8 main directions of wind rose. In Fig. 4 we show as an example two fields: significant wave height for wind from North and South directions, and in Fig. 5 the significant wave height spectrum at one point on the Gulf of Gdańsk (P104 – point no 6 on Fig. 2). These results can be used mainly for testing models and comparing with data from other models. The agreement with the computations by Krylov method was quite good [13].



a) b)

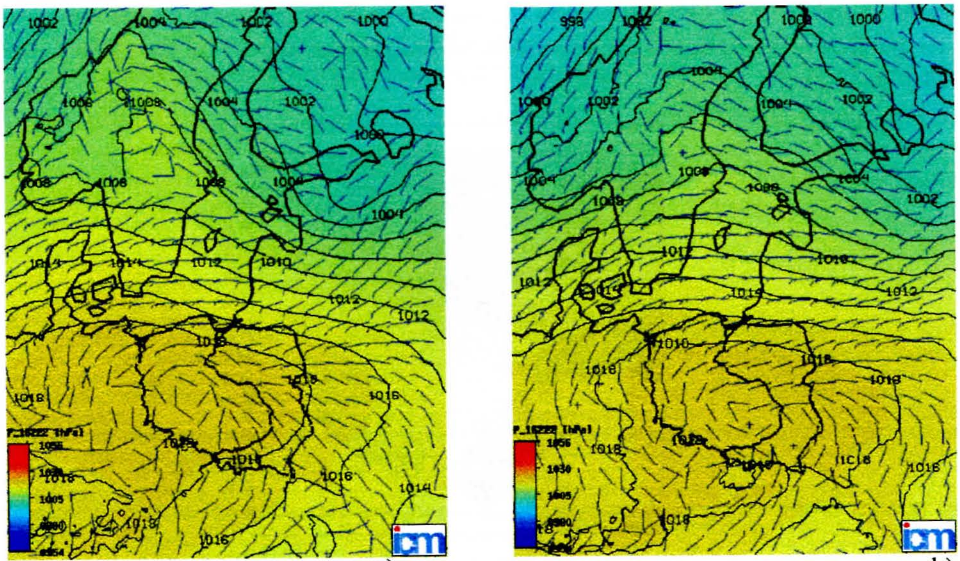
Fig. 4. Fields of the significant wave height for steady wind blowing from N (a) and from S (b)



a) b)

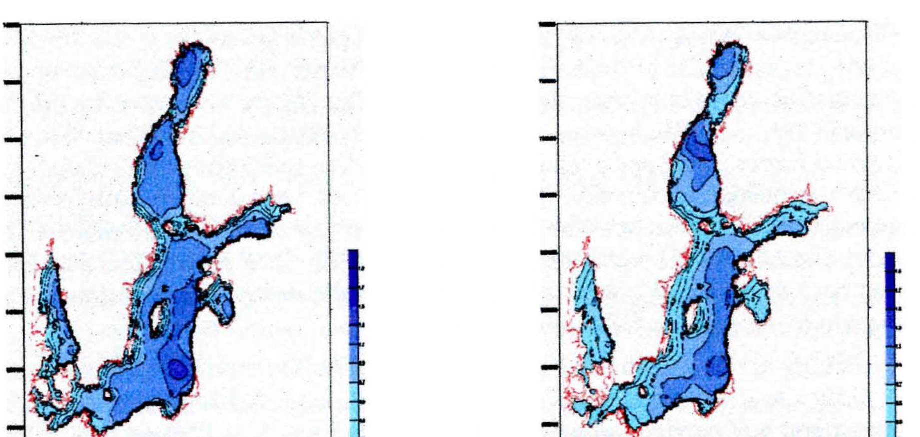
Fig. 5. Directional frequency spectra of the significant wave height for steady wind blowing from N (a) and from S (b) estimated for point No. 6 in Fig.2 (SPEC – total energy for all directions)

— real wind fields predicted at the Interdisciplinary Centre of Modelling (ICM UW), Warsaw University, computed using a mesoscale model of atmosphere [7]. The data in grid-net resolution 0.150.15 meridian degree are received daily via Internet. At present there are available daily data for two components of wind fields both from analytical times (every three hours) and for forecasting times (every one hour). Examples of this wind and atmospheric fields (for 20.08.98 00 and 06 UTC) and corresponding fields for significant wave height (for 20.08.98 03 and 06 UTC) taken from the period of POLRODEX'97 experiment are presented in Fig. 6 and 7.



a) b)

Fig. 6. Fields of real wind and pressure situations
a) 20.08.98 00 UTC, b) 20.08.98 06 UTC



a) b)

Fig. 7. Fields of significant wave height for real wind situations
a) 20.08.98 03 UTC, b) 20.08.98 06 UTC

3.3. Data for current fields

The WAM system has an option for current refraction. The source of the currents and waves is the same external force – wind field, it allows to take into account this important factor influencing the character of the wind wave field in different parts of the sea.

We co-operate with scientists of Baltic countries with the objective of developing a hydrodynamic-numerical model for the Baltic Sea (HIROMB), therefore we can receive daily forecasting data obtained from computations with this model. At present this model is in operational service at SMHI [2]. An example of a forecasted current field in the Gulf of Gdańsk area is shown in Fig. 8. In the nearest time it is planned to use these data as input files in the WAM model (as shown by the system scheme in Fig. 1).

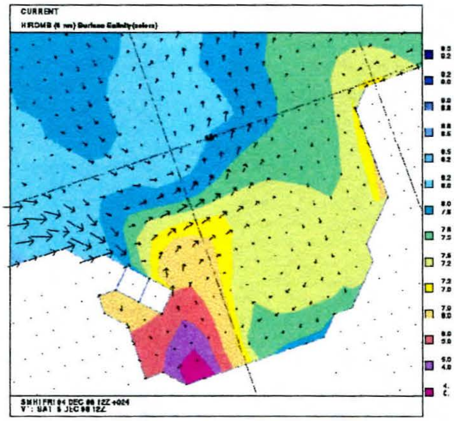


Fig. 8. An example of current field predicted by HIROMB model

4. Conclusions and possibility of further development of the model

The carried out texts show that there are real possibilities to use the WAM model not only for scientific purposes in simulation or verification of field experiments, but it can also be adopted to operational needs. Similar efforts were made by the German Service DWD [1]. We have good access to daily forecasted data describing meteorological forces (wind and pressure fields) as well as to hydrodynamic data (currents) which are needed to run this model. We can use very detailed bathymetric data, especially for the areas near the Polish coast. It is therefore quite possible to develop model computations by using nested grid calculations to obtain forecasts for small areas near the coast. We think about arriving at the best possible option in the code program to shorten the CPU time.

Looking at the results, they seem quite realistic. However, at present there is no possibility to compare them with data obtained from field measurements. Such a comparison was carried out by DWD (the Wave Rider was situated near Zingst) [1] and by IHE PAS (Wave Rider buoys were situated in the Pomeranian Bay and near Lubiatowo) [15, 16]. The results of comparisons show a very good correlation between observations and computations by the WAM model.

References

[1] Behrens A., 1998, *Wave model results for the Baltic Sea – A comparison between the second generation model HYPAS and the third generation model WAM – C4* (prepared for publication).

[2] Funkquist L., P. Ljungemyr, 1997, *Validation of HIROMB during 1995-96.* SMHI Oceanogr. no 67.

[3] Günther, H. at all, 1992, *Implementation of a third generation ocean wave model at the European Centre for Medium Range Weather Forecasts.* Technical Report No 68.

[4] Günther, H., S. Hasselmann, P.A.E.M Jansen, 1992, *The WAM model Cycle 4.0. User Manual.* DKRZ, Technical Report No 4.

[5] Hasselmann, S, K. Hasselmann, J.H. Allender, T.P. Barnett, 1985, *Computations and parameterisations of the non-linear energy transfer in gravity wave spectrum. Part I: A new method for efficient computations of the exact non-linear transfer integral.* J. Phys. Oceanogr. 15, 1378.

[6] Hasselmann, K., 1974, *On the spectral dissipation of ocean waves due to the white capping.* Bound. Layer Met. 6, 107.

[7] Jakubiak B., M. Kałas, 1998, *Assessment of numerical wind forecast in the Polish part of the Baltic Sea during the experiment POLRODEX'97.* (Prepared for publication).

[8] Jansen, P.A.E.M., 1989, *Wave induced stress and the drag of air flow over sea waves.* J. Phys. Oceanogr. 19, 745.

[9] Jansen, P.A.E.M., 1991, *Quasi-linear theory of wind wave generation applied to wave fore-casting.* J. Phys. Oceanogr. 21, 1631.

[10] Kałas M., A. Staśkiewicz, 1998, *The possibility of implementation of WAM model as a forecasting model for the Baltic Sea,* Report Maritime Institute No. 5387. (In Polish).

[11] Komen, G.J., S. Hasselmann, K. Hasselmann, 1984, *On the existence of a fully developed windsea spectrum.* J. Phys. Oceanogr. 14, 1271.

[12] Naguszewski A., 1997, *Adaptation of forecasting model for wind waves WAM for the Polish coastal zone,* Report Institute of Hydro-Engineering. (In Polish).

[13] Paszkiewicz Cz., 1988, *Wind waves of the Baltic Sea,* AMW, Gdynia. (In Polish).

[14] Paplińska B., 1997, *Verification of wind wave forecasting model WAM with measuring data,* Report Institute of Hydro-Engineering. (In Polish).

[15] Paplińska B., 1998, *Analysis of wind waves near Lubiatów and Pomeranian Bay on basis for measurements 1996/97 – comparison with model calculations (WAM program),* Report Institute of Hydro-Engineering. (In Polish).

[16] Paplińska B., 1998, *Case study of wave dependent drag coefficient in the Baltic Sea.* Contribution to Atmospheric Physic (in pres.).

[17] Snyder R.L., F.W. Dobson, J.A. Eliott, R.B. Long, 1981, *Array measurements of atmospheric pressure fluctuations above surface gravity waves.* J. Fluid. Mech. 102, 1.

[18] *WAMDI Group, 1988, A Third Generation Ocean Wave Prediction Model.* J. Phys. Oceanogr. 18, 1775.