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Wind wave modelling over the Baltic Sea using WAM model and the coupled ocean circulation-wave POM model

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Abstract

This study presents a setup of the wind wave forecasting model WAM working over the Baltic Sea in operational mode. The work is a part of the PROZA project financed from the Polish Innovative Economy Programme and the European Regional Development Fund. The modelling results are verified against observations recorded with a directional waverider buoy. The results of the validation studies are presented in this paper. The agreement between the modelled and observed wave data obtained was quite good. The model setup is part of the system allowing for operational decision-making based on atmospheric and sea conditions.

In the next stage of the project we are seeking for improvement of the modelling accuracy by taking into account wave-current interactions. To this end a new version of POM with embedded wave sub-model has been implemented. Based on cross-comparisons against observed waverider buoy data and the results obtained with WAM, some adjustments of the parameters controlling the coupled circulation-wave POM were applied.

Introduction

The PROZA Project

It is essential in modern coastal management and engineering design to have access to most accurate description of the present state of the sea as well as to forecasts providing continuous predictions of the future prevailing condition of the sea including coastal zone for as far ahead as possible. Therefore, there is a growing need of information provided by the operational oceanography.

The project PROZA, entitled "Operational decision-making based on atmospheric conditions," is a Polish Innovative Economy Programme project co-financed from the European Regional Development Fund. One of its objectives is to develop a coupled wave-current model for the Baltic Sea and the Gulf of Gdańsk working in operational mode. The coupled wave-current nested models together with systematic routine measurements of the sea and atmosphere parameters will compose a basis of a hydrometeorological forecasting and warning system which is being developed within PROZA.

This study

This study presents the wind wave forecasting system for the Baltic Sea based on the WAM (WAve Model) Cycle 4.5.2 (WAMDI Group 1988) based on the setup developed within the EU-research project HIPOCAS (Cieślikiewicz and Paplińska-Swerpel 2008). WAM has been setup and validated in many places all over the world, including the Baltic Sea. In this paper we focus on operational aspects of the WAM based wind wave forecasting system for the Baltic Sea and the Gulf of Gdańsk which is under development in the Institute of Oceanography, University of Gdańsk (IOUG) within the PROZA project (see Fig. 1).

The significance of the interaction between sea wave and current effect on output wind wave field is still under discussion. Therefore the sensitivity of the modelled wind wave field to the coupling with currents and sea level is analysed with special attention. For this purpose the influence of wave-current interactions on the wind wave field modelled with the coupled ocean circulation-wave model POM (Princeton Ocean Model) recently developed based on Mellor et al. (2008), is examined in this study.

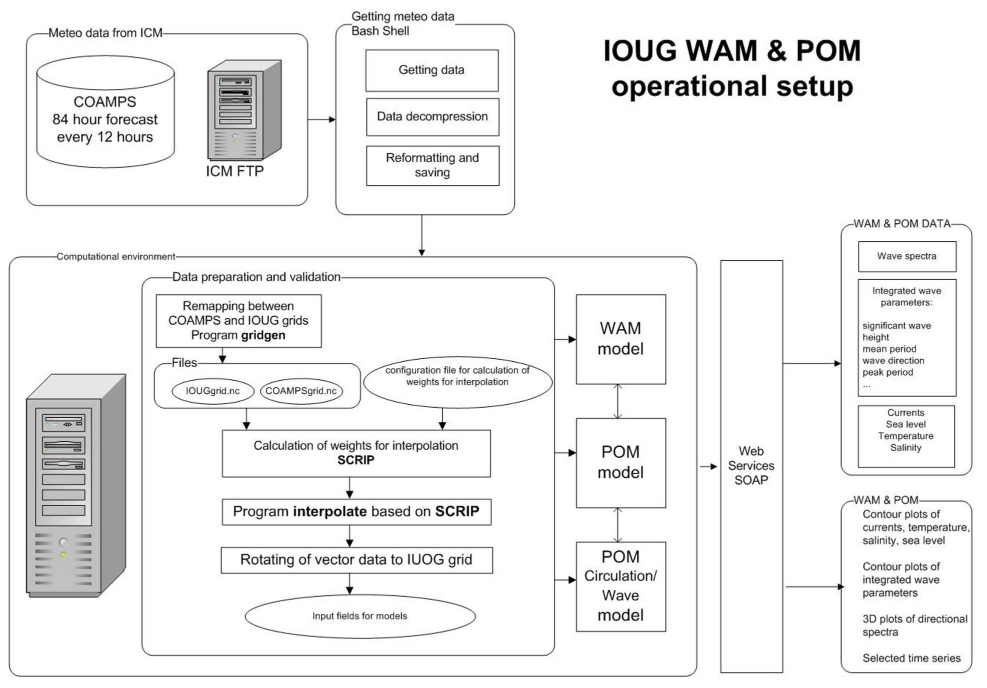

Figure 1: The operational setup of WAM model within PROZA project.

Methodology

Input data and setup of the models

As a meteorological input to WAM, the results of the atmospheric model COAMPS (Hodur, 1997; Jakubiak and Hodur 2011) operated at the Interdisciplinary Centre for Mathematical and Computational Modelling (ICM), Warsaw, which is the co-ordinator of PROZA, have been used. The results of the ICM model are in a form of one-hourly time series of wind field, on a 13 km x 13 km grid in the Lambert conformal conic projection coordinates. All the wave calculations described in the present work have been performed in the spherical grid in rotated longitude, latitude coordinate system with the resolution 5' x 5' (approximately 5 Nm in the modelled area). All observed wind and waves data, available within PROZA, have been used to verify the generated wind wave parameters in order to assess the quality of numerical output produced by WAM. Extensive validation studies, both of the input ICM wind data and the wind wave data modelled with WAM, have been done. The agreement between the modelled predictions and the measured data obtained within this study is quite good.

The WAM model is setup and runs on a powerful two quad-core processor PC workstation in IOUG. The bathymetry data for the Baltic Sea, used as input to the wave forecasting model, were provided by the Institut für Osteseeforschung in Warnemünde (IOW) (see Seifert and Kayser 1995). These data were subjected to a very careful examination and then adapted to the wave model requirements. The meteorological forcing data, used within the project, are 1-hourly gridded wind velocity fields provided by ICM together with forecasts given every 12 hours and going out 84 hours. The wind wave modelling area covers the whole Baltic Sea together with the Danish Straits (see Fig. 2).

Sea ice coverage in WAM and POM models

The sea ice is an important factor in wave modelling in the Baltic Sea. The sea ice cover delimits an area of wave generation, and thereby affects waves, even far away from the region of ice occurrence. In the WAM cycle 4.5.2 code, utilised in the project, the ice routines have been implemented. The ice data are obtained from the near-real-time passive microwave brightness temperature data acquired with the Special Sensor Microwave Imager/Sounder (SSMIS) on board the Defence Meteorological Satellite Program (DMSP) F13, F14, F15, and F17 satellites. The ice data are analysed daily using the ocean analysis component of COAMPAS called CODA. Fig. 2 presents an example of the modelled significant wave height H_s and wave direction distributions with the ice cover visible in the northern part of the Baltic Sea.

In the next stage of the project we are seeking for improvement of the modelling accuracy by taking into account wave-current interactions. To this end a new version of the POM with embedded wave sub-model (POM08) has been implemented. We will refer to this model as POM+wave in this study. Based on cross-comparisons against observed waverider buoy data and the results obtained with WAM some adjustments of the parameters controlling the coupled circulation-wave POM were applied. Namely, the values of two wave energy dissipation coefficients have been modified which substantially improved the agreement between the modelled wind wave characteristics and those recorded at five waverider buoys located in the Baltic.

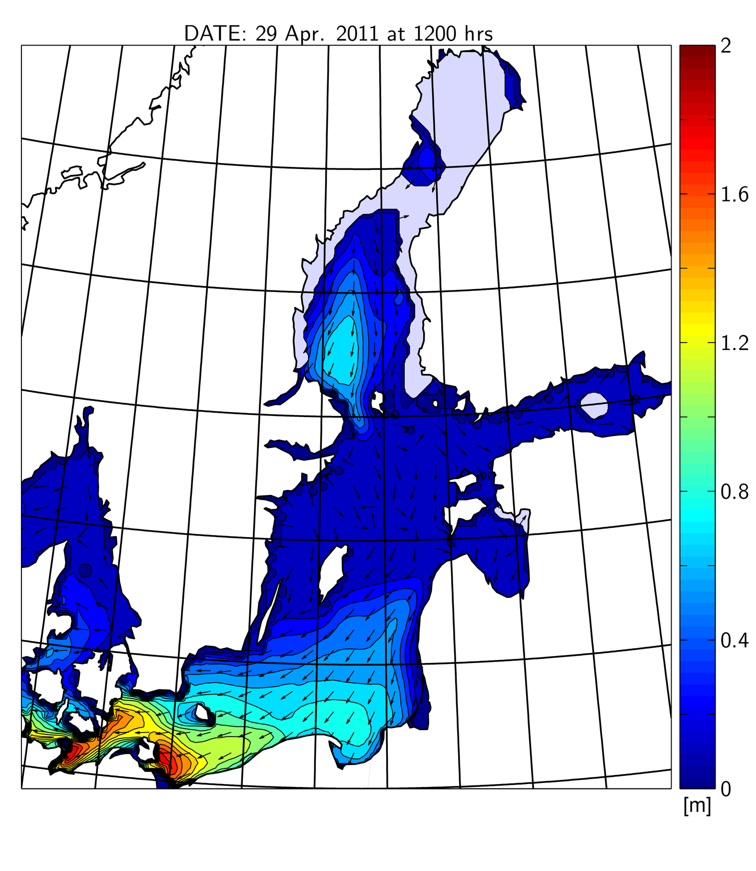

Figure 2: Contour plot of significant wave height H_s in meters and wave direction as shown by arrows. Ice cover is marked with grey-blue.

Results and Conclusions

Both WAM and POM+wave models have been verified using measurement data provided by the Swedish Meteorological and Hydrological Institute (SMHI) and the Finnish Meteorological Institute (FMI). The modelled integral wave parameters were compared with wave data measured during 2010–2012 in 6 locations presented in Fig. 3. The agreement between modelled and recorded wave parameters is good for all locations with H_s scatter index not exceeding 0.3. For brevity, the WAM model validation results against the open-sea Södra Östersjon buoy (see Fig. 3) is only presented here. Fig. 4 presents time series of both measured and modelled data for two selected storm periods as well as scatter plots of H_s and T_z for the whole validation period. Additional time series for a few consecutive storms are presented in Fig. 5.

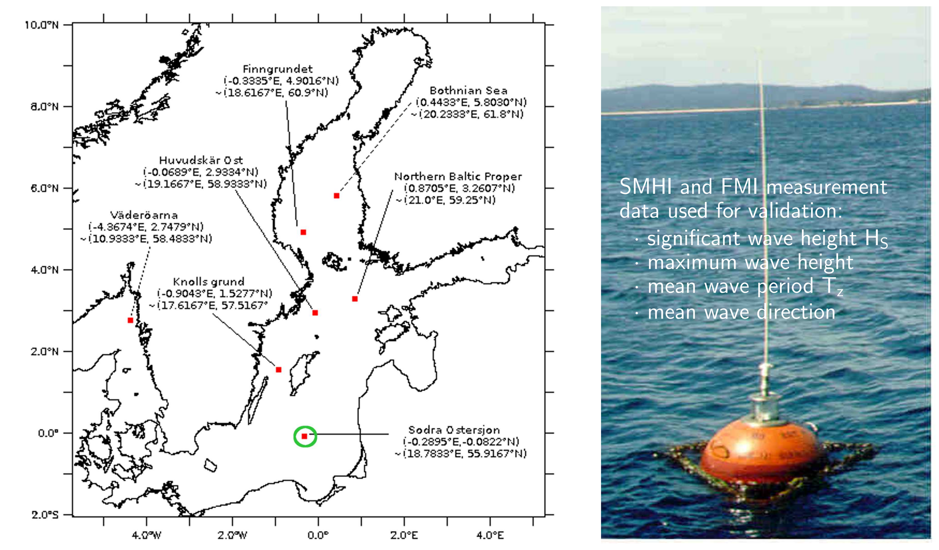

Figure 3: Location of buoys providing data for WAM and POM+wave validation.

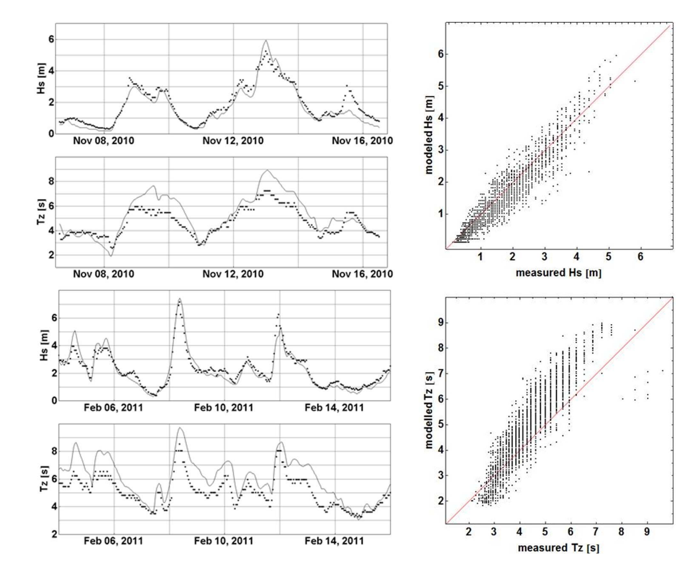

Figure 4: Left: H_s and T_z for two storms in 2010 and 2011; buoy measurements (dots) vs. WAM model output (solid line). Right: H_s and T_z scatterplots for the entire validation period.

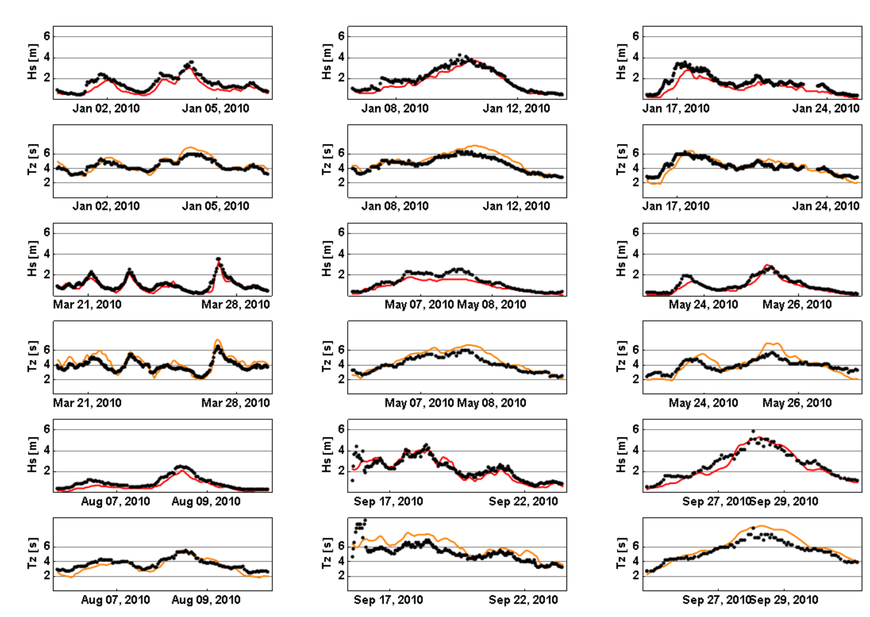

Figure 5: Time series of the significant wave height H_s and the mean wave period T_z for a few consecutive storms in 2010; buoy measurements (black) vs. WAM model output (red).

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