University of Gdansk, Institute of Oceanography

The ecohydrodynamic model as a tool for studying processes in coastal waters of the Gulf of Gdansk

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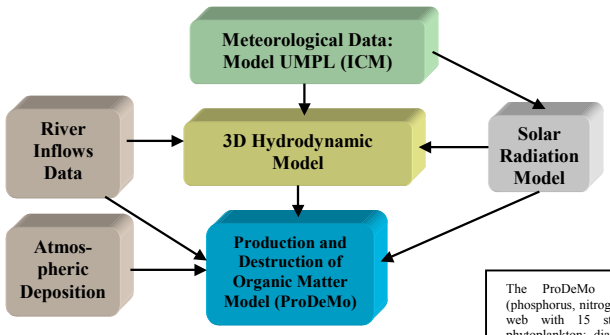
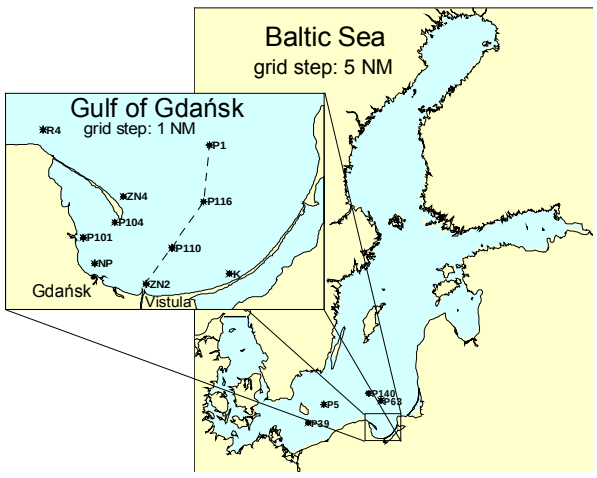
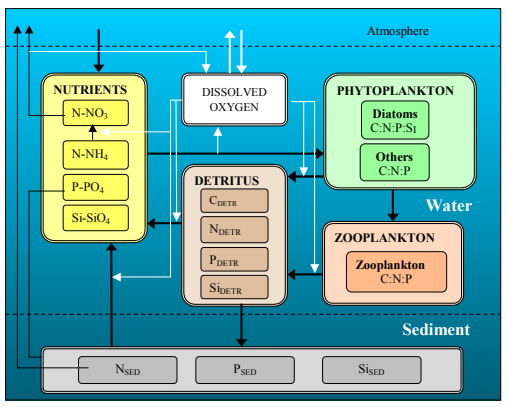


A 3D coupled hydrodynamic – ecological model: ProDeMo (**Pro**duction and **De**struction of Organic Material **Mo**del) has been formulated and applied for the whole Baltic Sea and the Gulf of Gdańsk. The ProDeMo model contains both inflow of matter and energy into the sea environment including discharges of rivers and atmospheric deposition. Hydrological and biological conditions of the Gulf of Gdańsk are strongly influenced by the Vistula River.



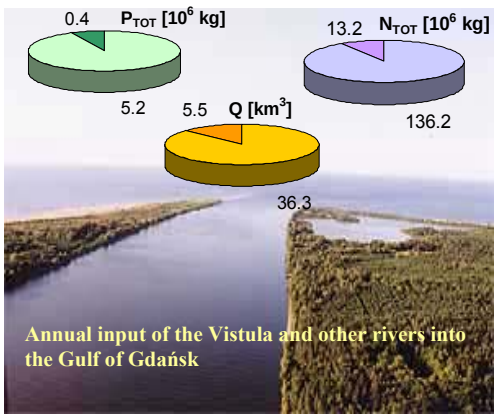


The ProDeMo model describes the nutrients (phosphorus, nitrogen, silicon) cycles through the food web with 15 state variables. Two groups of phytoplankton: diatoms and non-diatoms as well as zooplankton has been considered in the present version. The following processes are included in the ProDeMo:

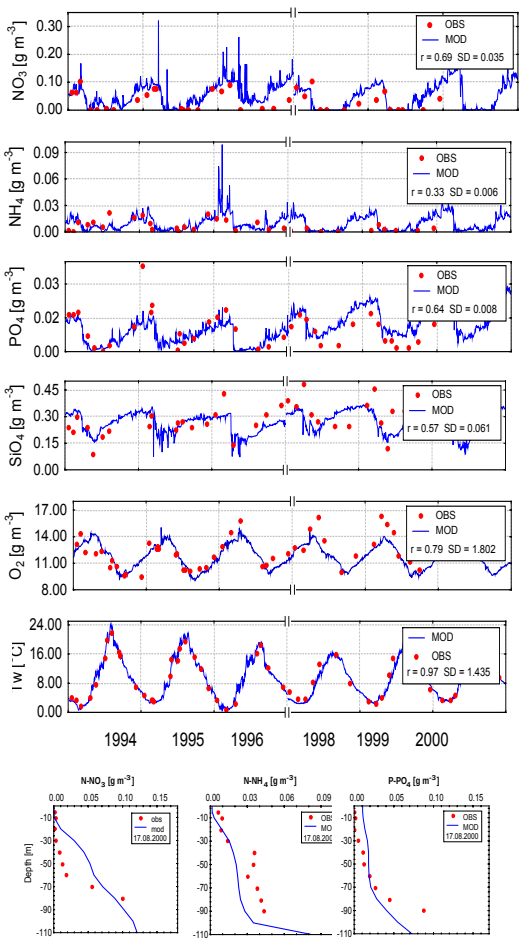
1) nutrient uptake by phytoplankton,
2) phytoplankton grazing by zooplankton,
3) phytoplankton respiration,
4) phytoplankton decay,
5) sedimentation,
6) nutrients release from sediment,
7) atmospheric deposition,
8) denitrification,
9) mineralization,
10) zooplankton respiration,
11) sedimentation of phosphorus adsorbed on particles,
12) detritus sedimentation,
13) zooplankton decay.

The model also describes processes influenced the dissolved oxygen:

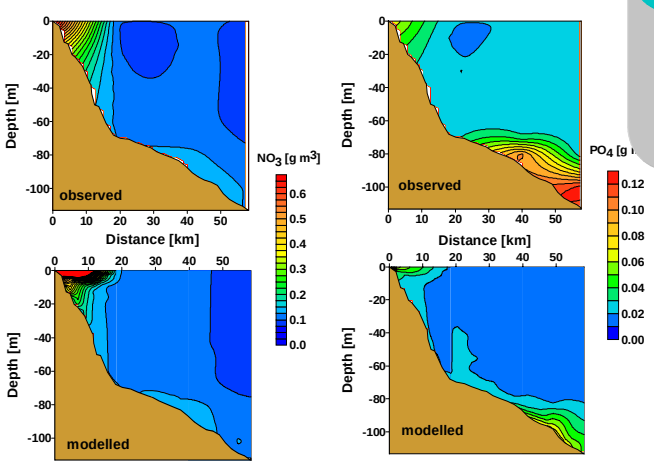
14) reaeracja,
15) flux to atmosphere due to the oversaturated conditions,
16) zooplankton respiration,
17) phytoplankton respiration,
18) assimilation,
19) mineralization,
20) nitrification.

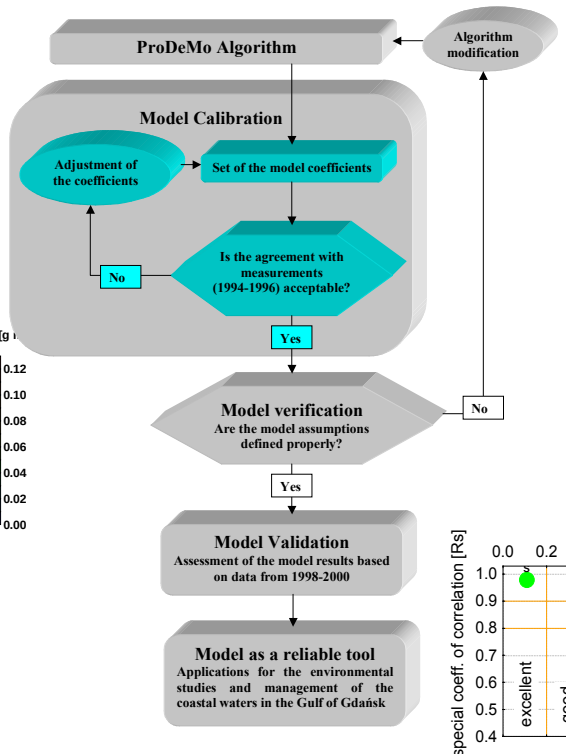


The hydrodynamic model is based on the POM (Princeton Ocean Model). The numerical application of the model has been embedded on two nested grids: 1 NM for the Gulf of Gdańsk in 5 NM for the Baltic Sea. Calculations in those two areas are parallel and the exchange of information on the common border takes place on each time step. All the model variables calculated on the border of one area serve as a boundary condition for the other area. A "sigma" transformation approach was applied in the model, making it possible to divide the vertical profile in each point of the sea, irrespectively of its depth, into

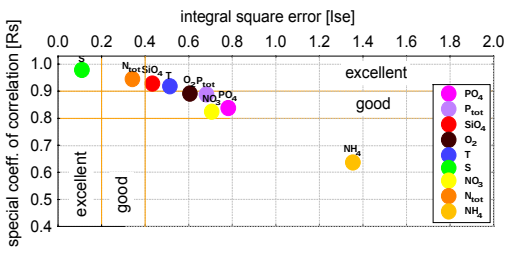


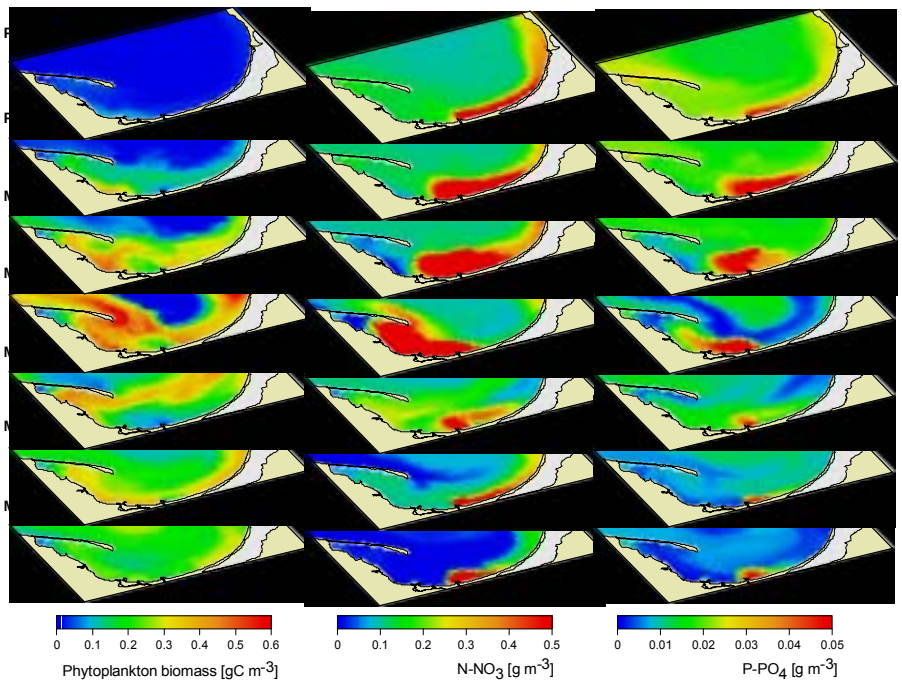
Distributions of N-NO_3 and P-PO_4 in cross-section through the Gulf of Gdańsk (4th March 1995)





In order to get the proper agreement between modelled simulations and observed data, the calibration procedure has been done by comparing results of the model with measured nutrient concentrations for 1994-1996 period and the adjustment of the model parameters. The model has properly described the seasonal distribution of nutrients, temperature and dissolved oxygen. Also the vertical distributions of the modelled parameters follows the observations, however better agreements have been achieved in the upper layer than in the layer below the halocline (60-70 m). Correlation coefficient versus total quadratic error diagram shows that the majority of the compared parameters lie in the good range except ammonium nitrogen. The model was subjected to a verification for three years time series in 1994-96. Finally observations from 1998-2000 allowed to validate of the model. Obtaining evidences permit to consider this model as reliable tool for studding the coastal processes in the Gulf of Gdańsk.

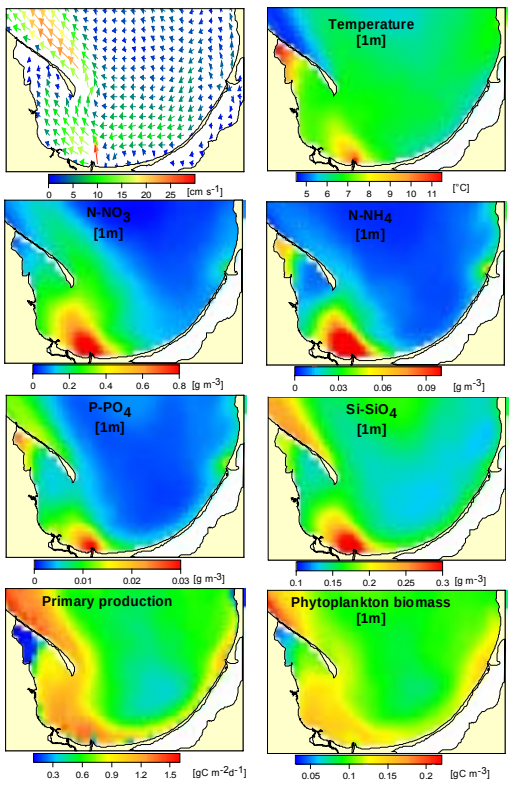




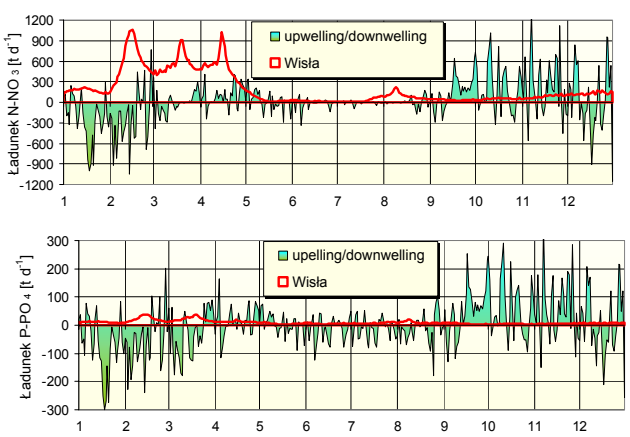
The model has been applied to study various effects of the Vistula River discharge on the environmental state of the coastal waters:

- pathways of the Vistula River waters in the Gulf
- temporal and spatial dynamics of nutrients
- blooms and seasonal variations of phytoplankton biomass
- upwelling and its consequences for vertical nutrient fluxes and rate of the primary production

The model was also able to observe the dynamics of the phytoplankton blooms. During the presented sequence of phytoplankton, nitrate nitrogen and phosphate phosphorus patterns (22 February – 27 March 1995) the main direction of the Vistula River waters flowed along the coast towards eastern parts of the Gulf with one exception (12 March). The phytoplankton growth started near the coasts of Gulf of Gdańsk and than bloom moved to the open sea. The model has also given an evidence that higher values of phytoplankton biomass were observed in the areas of higher content of nitrate nitrogen and phosphate phosphorus originating from the Vistula River.

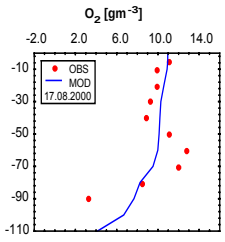


The ProDeMo model has been applied to study the consequences of the hydrodynamics of the Gulf of Gdańsk on the nutrient and phytoplankton distributions. During the spring conditions (high values of nitrogen and phosphorus loads) the influence of the Vistula River waters on the nutrient concentrations reached even the open waters of the Gulf of Gdańsk (towards North the Hel Peninsula). It has been observed that during the studied period: 11 April – 10 May 2000, the main pathway of the Vistula River water was the North-West direction.



The model has simulated the special dynamic behaviour of the Gulf of Gdańsk: the Hel upwelling. According to the model results (mean values during the 11 April – 10 May 2000) the area of the Hel upwelling showed much higher primary production rate caused by additional fluxes of nutrients from the bottom layer. The comparison between the Vistula River loads of inorganic nitrogen and phosphorus and the upwelling/downwelling fluxed shows that during the autumn the upwelling gave higher loads to the upper layer than the Vistula River. In contradiction, during the spring time the upwelling phenomena was rather week while the Vistula River discharged very high loads of nitrogen and phosphorus.

The presented applications have proven the ability to use the ProDeMo model as a reliable tool to study the environmental processes in coastal waters of the Gulf of Gdańsk.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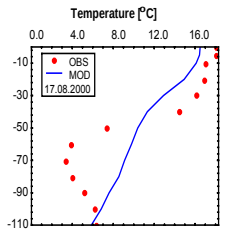
2.0
6.0
10.0
14.0
-10
-30
-50
-70
-90
-110
OBS
MOD
17.08.2000


Temperature [°C]
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4.0
8.0
12.0
16.0
-10
-30
-50
-70
-90
-110
OBS
MOD
17.08.2000