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The influence of different parameterisations of meteorological forcing and turbulence schemes on modelling of eutrophication processes in a 3D model of estuary

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1 Introduction

In numerical modelling of water ecosystems, the role of the weather is accounted for through the atmospheric fluxes of energy and gases at the water surface. They provide the upper boundary conditions for the hydrodynamic module in a water ecosystem model. This obviously requires the highest possible accuracy in specification of the air-water turbulent fluxes turbulence description in the water body. In this paper a three-dimensional coupled hydrodynamic-water quality model has been applied to the Dnieper-Boog estuary in the Black Sea. The influence of different parameterisations of meteorological forcing and turbulence closures on the hydrodynamics and water quality characteristics has been studied

2 Model

The hydrodynamics is simulated using the time-dependent, free surface, primitive equation model (*Margvelashvili et al.* [1997]). The based on WASP5 eutrophication kinetics (*Ambrose et al.* [1994]) the submodel of water quality simulates the transport and transformation reactions of four interacting systems: phytoplankton kinetics, the phosphorus cycle, the nitrogen cycle, and the dissolved oxygen balance.

Following Stanev and Beckers [1999] the studied domain has been divided into upper and bottom layers, each was with own sigma-coordinate system to describe effect of deep and narrow ship channel in the Dnieper-Boog Estuary (see Figure 1). Both parts were coupled on assumption of continuity of all parameters and fluxes through interface. .

The model was run with two different parameterisations of vertical turbulent mixing of momentum, heat, suspended and diluted matter. The algebraic closure of *Blumberg and Mellor* [1987] and two-equation $k-\varepsilon$ model with stability functions from *Burchard and Petersen* [1999] were compared.

Surface boundary conditions for hydrodynamic model are flux conditions for the momentum, temperature, and dissipation rate (for $k-\varepsilon$ closure), which depend on surface flux parameterisation schemes. The atmospheric fluxes were calculated from standard data on the wind speed and the air temperature/humidity/cloudiness using flux-calculation schemes of *Blackadar* [1979]. The refined formulations of the near surface flux parameterisation also was given according to *Zilitinkevich et al.* [2001]. The proposed technique accounts for generally essential difference between the roughness lengths for momentum and scalars and includes a newly discovered effect of the static stability in the free atmosphere on the surface layer scaling. Recommended by *Zilitinkevich et al.* [2001] correction functions depend, besides bulk Richardson number, on one more stability parameter, involving the Brunt-Väisälä frequency in the free atmosphere, and on the roughness lengths .

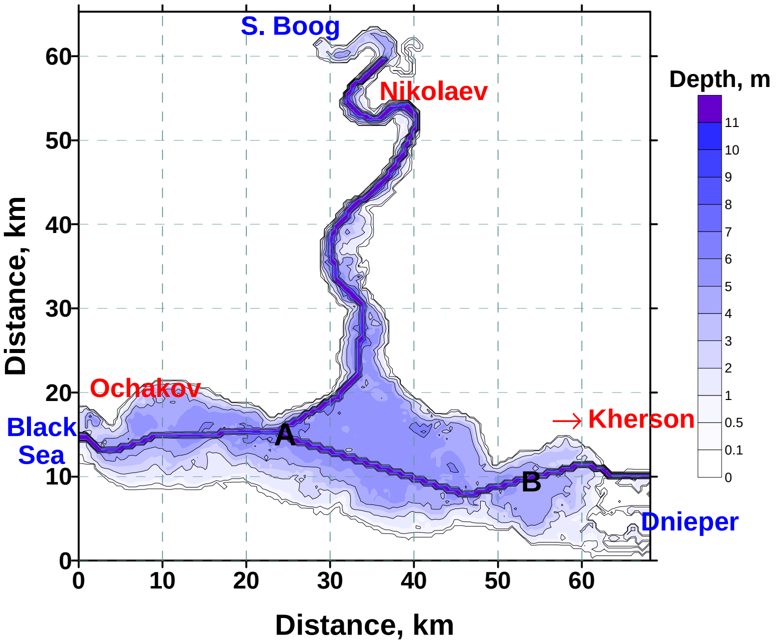

Figure 1: Dnieper-Boog Estuary.

3 Results and discussion

The model was applied to predict circulation and eutrophycation processes in period March-August 1998 for which data in the Dnieper-Boog Estuary were collected in frame of US-Ukraine joint programme. The Dnieper-Boog Estuary (see Figure 1) is the largest of all the Black Sea estuaries. Its limits are defined by the Dnieper delta on the East, the Kinburn strait in the West, the confluence of rivers Ingul and Southern Boog on the North. The average depth is of order 4-5m, but the estuary has narrow 12 m depth ship channel tha connects two ports of Nikolaev and Kherson with the Black Sea.

A set of runs were carried to study the influence of different parameterisations of meteorological forcing and turbulence closure schemes on modelling of eutrophication processes in the estuary. First run was carried out with $k-\varepsilon$ model and flux-calculation scheme of *Blackadar* [1979] (Scheme B). In Figure 2 the model results of computations of salinity and dissolved oxygen are compared with the survey data. As seen from figure the model reproduces observed distributions quite well. The figure show important role of man-made channel in the salt and other scalar fields transport. Second run was carried out with $k-\varepsilon$ model and flux-calculation scheme of *Blackadar* [1979] with refined formulations of *Zilitinkevich et al.* [2001] (Scheme ZB). The correlation for the April-August period between results of use of two fluxes schemes (ZB and B) for bottom salinity and NO3 in the point A (see Figure 1) is given in Figure 4. This figure shows sensitivity of salinity and water quality parameters to the flux of energy parameterization, especially for periods of weak wind and static stability in atmosphere surface layer. It can be explained by 3D nature of density and wind circulation and mixing processes in the estuaries. Third run was carried out with algebraic scheme used by Blumberg and Mellor [1987] and flux-calculation scheme of *Blackadar* [1979]. The comparison of temperature and salinity profiles calculated by these turbulence schemes in point B (see Figure 1) is given in Figure 5. Again the salinity and other variables in the coupled model demonstrated dependence on the turbulence closure (see also Chen and Annan [2000]).

The sensitivity of the eutrophication model to the details of physical environment arising from different parameterisations of atmosphere-water body interaction and turbulence models shows that precision of eutrophication modelling of depends on the quality of such parameterization.

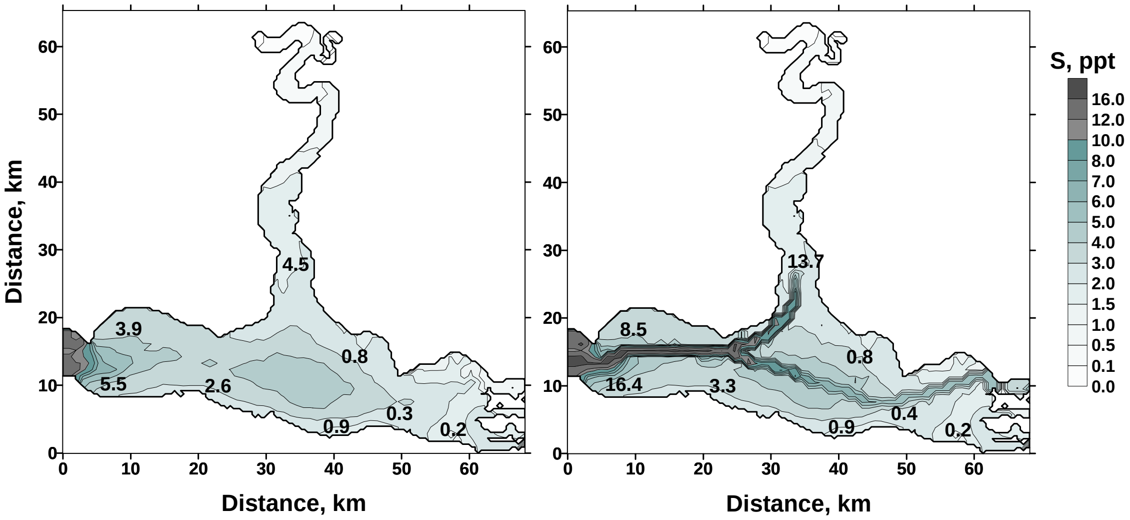

Figure 3: Comparison of measured 12-15 August 1998 and computed surface and bottom salinity, ppt.

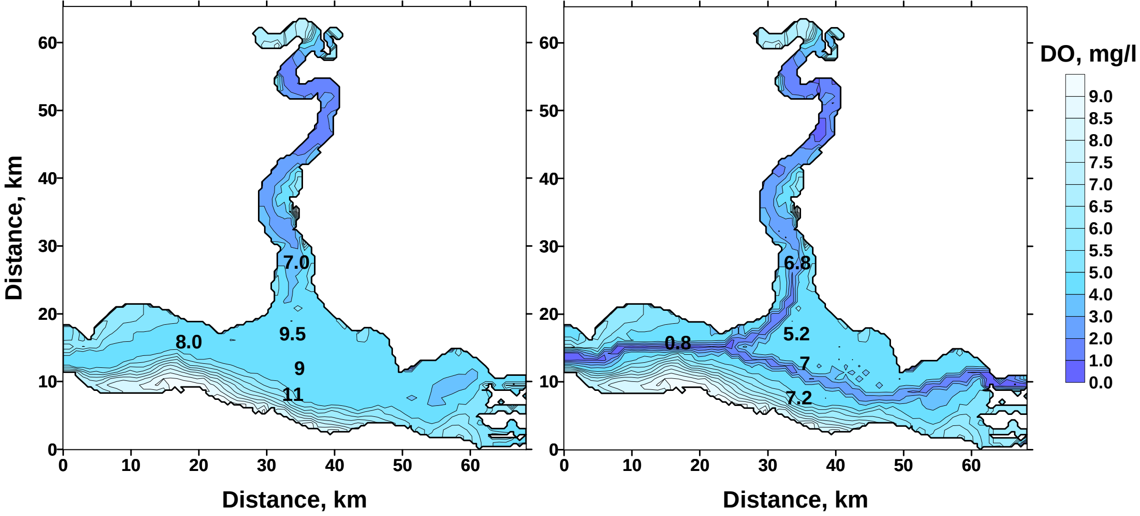

Figure 4: Comparison of measured 12-15 August 1998 and computed surface and bottom DO, mg/l.

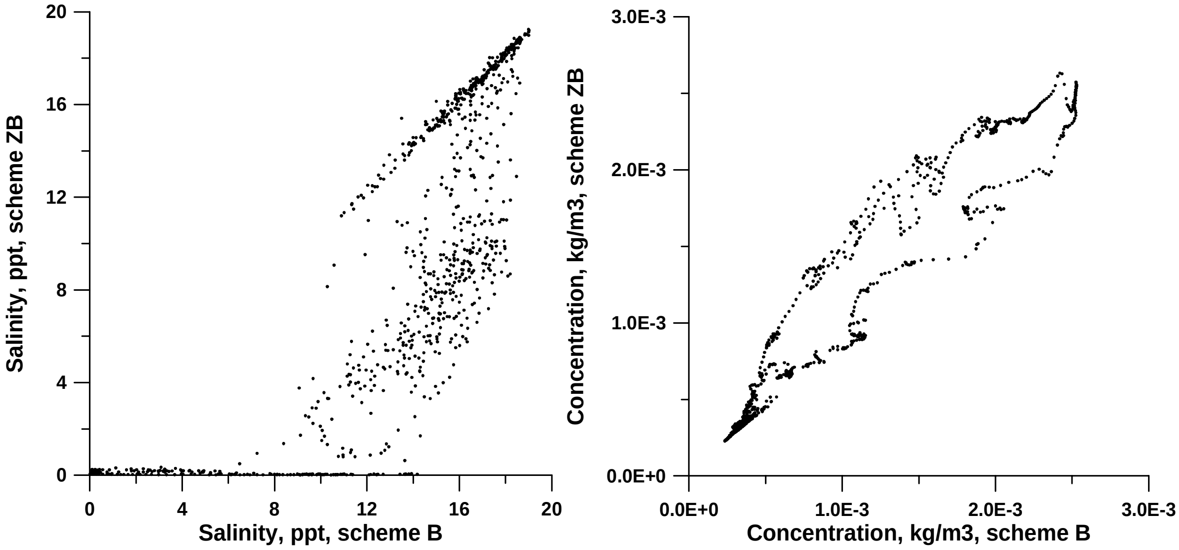

Figure 5: Bottom salinity and NO3 correlation for the two surface fluxes schemes: (ZB) and (B) in the point A (see Figure1) for the time period April-August.

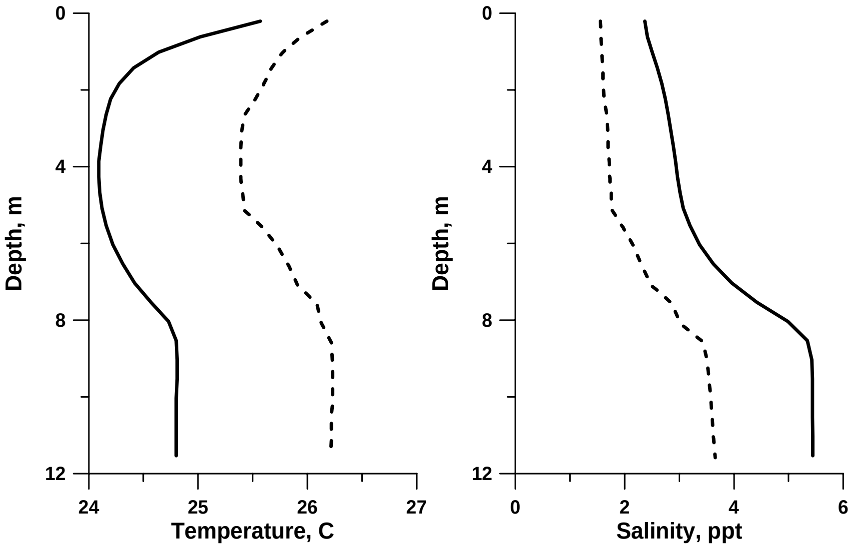

Figure 6: Temperature and salinity profiles for $k-\varepsilon$ turbulence closure (solid) and algebraic closure at the point B (see Figure 1) 13 August 1998. The Blackadar surface fluxes scheme is used.

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