MODELLING NITROGEN FLUXES IN A SEMI-ENCLOSED ENVIRONMENT (THE BLACK SEA) : TRANSPORT VERSUS BIOGEOCHEMICAL PROCESSES AND QUANTIFICATION OF THE EXCHANGES AT THE SHELF BREAK

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Abstract

A three-dimensional coupled biogeochemical-hydrodynamical model has been developed to get a better understanding of the biogeochemical functioning of the Black Sea. The influence on the ecodynamics of hydrodynamical and biogeochemical processes is quantified. Nitrogen inputs from the rivers, from the sediments and from the deep sea are estimated and compared in terms of potential fertilization. The exchanges between the north-western shelf and the deep sea are quantified. The results illustrate a highly complex spatial variability of the phytoplankton annual cycle and thus, stress the importance of using a 3D model to capture the essential physical-biological interactions that explain the data.

Keywords : Black Sea, Circulation Models, Primary Production, Mesoscale Phenomena, Ocean Colours.

Recent decades have seen a degradation of the environmental quality in various basins of the world's oceans, caused by eutrophication and pollution problems, with an amplitude depending on the ability of the damaged marine area to be able to adapt to new circumstances. As a result of their small inertia related to their geometry, the various semi-enclosed seas and enclosed inland bodies are particularly sensitive to natural and anthropogenic perturbations of their environment. Also, among the various basins of the world's oceans, the environmental degradation in the Black Sea, and in particular of its north-western continental shelf into which rivers such as the Danube flow, is the most severe, as reflected by the dramatic changes in its ecosystem and living resources. The management of the basin in a sustainable development perspective requires the identification and modelling of the Black Sea's physical and biogeochemical structures and processes that determine the mixing, transport and distribution of pollutants and biogeochemical constituents discharged by the rivers.

Model

The GHER General circulation model which has been used in this study of the Black Sea seasonal ecohydrodynamics is three-dimensional, non-linear, baroclinic and uses a refined turbulent closure scheme (the classical k-l model) (*e.g.* 1, 2, 3, 4). The ecosystem model is defined by a simple nitrogen cycle based on the functional role played in the trophic dynamics by planktonic populations. It is described by a limited number of aggregated variables sufficient to reveal the cogent effects of the three-dimensional time dependent macroscale and mesoscale hydrodynamics on biological fields. Six compartments are defined: the phytoplankton and zooplankton biomasses without reference to species, total detritus (lumping together dissolved and particulate organic matter), nitrate, ammonium and benthic detritus. In the transitional layer between oxygenated and anoxic waters, redox reactions prevent nutrients issued from the deep waters to reach the surface layer, thus constituting one of the main mechanisms whereby the Black Sea basin act as 'nutrients traps'. This implies that the modeling of the pelagic ecosystem will be made without the representation of the complex chemical processes occurring in the deep waters.

The model is forced by monthly mean climatological forcing functions. In particular, this includes the large scale free surface gradients along the Bosphorus strait, the wind stress at the air-sea interface and the outflow of the Danube and the Dnepr rivers on the north-western shelf. The spin-up time of the hydrodynamic model is of about 10 years. The ecosystem model is solved conjointly with the hydrodynamic model. After two years of integration, quasi-equilibrium is almost obtained for the ecosystem model, and the results of an additional annual simulation, which are representative of a situation typical of the mean Black Sea's climatological state, are compared with in-situ and satellite observations collected in the area.

Discussion

The nitrogen cycle in the north-western shelf waters and in the open sea is analysed and compared. The results illustrate a highly complex spatial variability in the phytoplankton annual cycle imparted by the horizontal and vertical variations of the physical and chemical properties of the water column.

In particular, the frontal instabilities of the main boundary current and the seasonal variability of the north-western shelf circulation, induced by seasonal variations in the Danube discharges and wind stress intensity which result in an important modification of the transport of nutrient rich Danube waters, have been found to play a key role in the space-time distribution of the primary production. Annual nitrogen fluxes computed on the shelf area and in the deep sea show the relative importance of transport versus biogeochemical processes. Computing the nitrate fluxes through the shelf break, it has been found that, with respect to the deep sea the margin acts as a source of nitrate most of the time. In agreement with observations, the model results indicated a rapid and efficient recycling of particulate organic matter in the oxygenated layer of the water column. More than 90% of the particulate organic nitrogen produced in the euphotic zone is shown to recycle in the upper 100 m of the water column and about 79% in the euphotic layer.

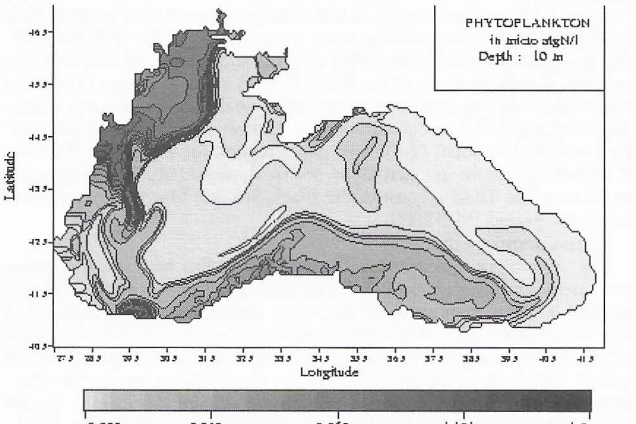

Figure 1 : Simulated phytoplankton distribution at 10 m at the end of May (in micro atgN/l)

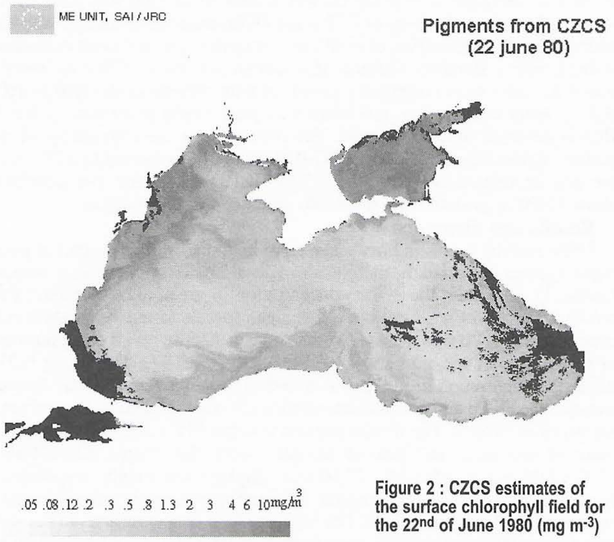

Figure 2 : CZCS estimates of the surface chlorophyll field for the 22nd of June 1980 (mg m^{-3})

The comparison of the phytoplankton biomass computed by the model with satellite-derived estimates of the surface chlorophyll field suggests that the model reproduces quite well the seasonal plankton productivity cycle in the different areas of the Black Sea but underestimates the phytoplankton biomass in the Danube's discharge area.

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