Modeling the biogeochemical and phytoplankton dynamics of an arid ecosystem: the coastal waters of the Eastern Red Sea (Saudi Arabia)

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Introduction:

Located on the Eastern side of the Red Sea, the coastal waters of Jeddah (Saudi Arabia) are characterized by numerous shallow micro-tidal hyper-saline lagoons in the North and, in the South, by a steep continental slope and waters as deep as 500-600 meters directly off-shore of the city. The biogeochemical dynamics of these ecosystems strongly rely on nutrient recycling due to very limited terrestrial inputs. The growing population around the city of Jeddah and the current lack of adequate waste water treatment plants may lead to large local releases of nutrients. Here, we investigate how sensitive these coastal waters are to such perturbations.

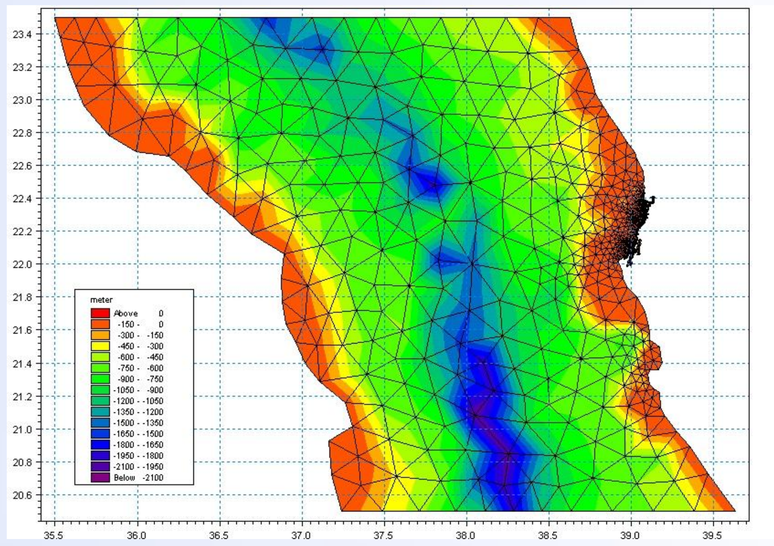

Figure 1: Geographical extent of the model and spatial resolution of the grid.

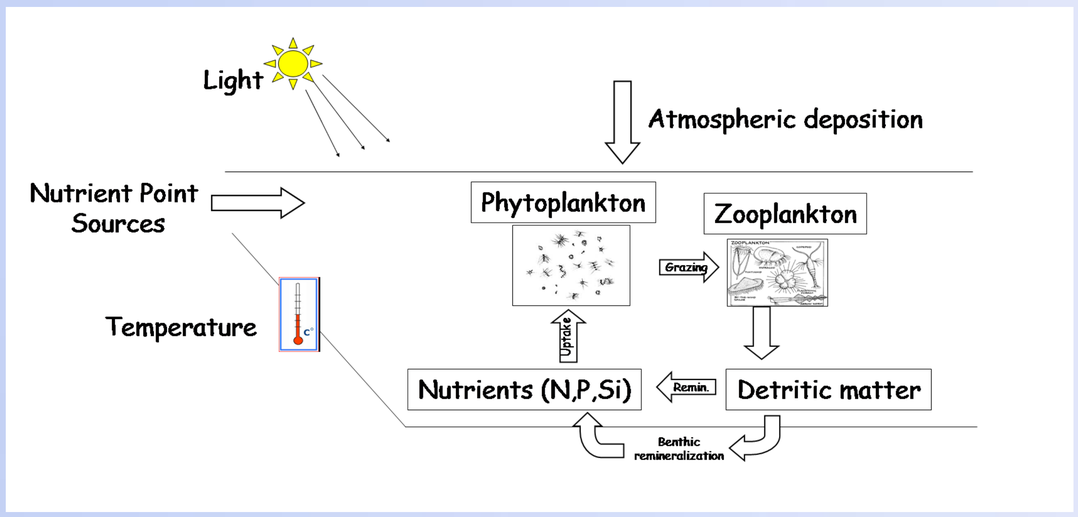

Figure 2: Conceptual scheme of the model.

Model Set-up:

A 3-dimensional, finite element model of a Northern section of the Red Sea was developed using an irregular mesh which provides a finer spatial resolution around the coastal waters (fig.1). The model couples a hydrological module with a biogeochemical module comprising nutrients (nitrogen, phosphorus and silica), 3 phytoplankton groups (diatoms, flagellates and cyanophyceaes), zooplankton as well as a representation of the water column and benthic remineralization of detritic organic matter (fig. 2).

Simulations:

One standard year long simulation using climatological forcings and boundary conditions was performed and used as reference run. Furthermore, scenarios of nitrogen and phosphorus enrichment at two locations in the neighborhood of Jeddah's urban area (fig.3) were run to assess the potential effect of untreated waste water release into the sea.

The water discharge was calculated based on the population of the urban area (3.6 M inhabitants) and an average water consumption of 200 liters per day.

The nutrient loads used for the simulations are derived from local sewage concentrations:

NH_4: 18 mg l^{-1}, NO_3: 3 mg l^{-1}, PO_4: 0.2 mg l^{-1}

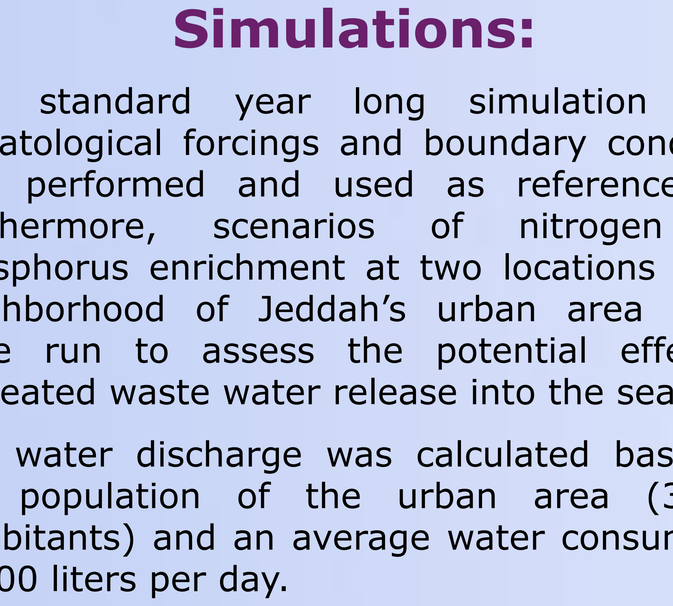

Figure 3: 3-dimensional representation of the bathymetry of the Red Sea and location of the point sources used for the simulations.

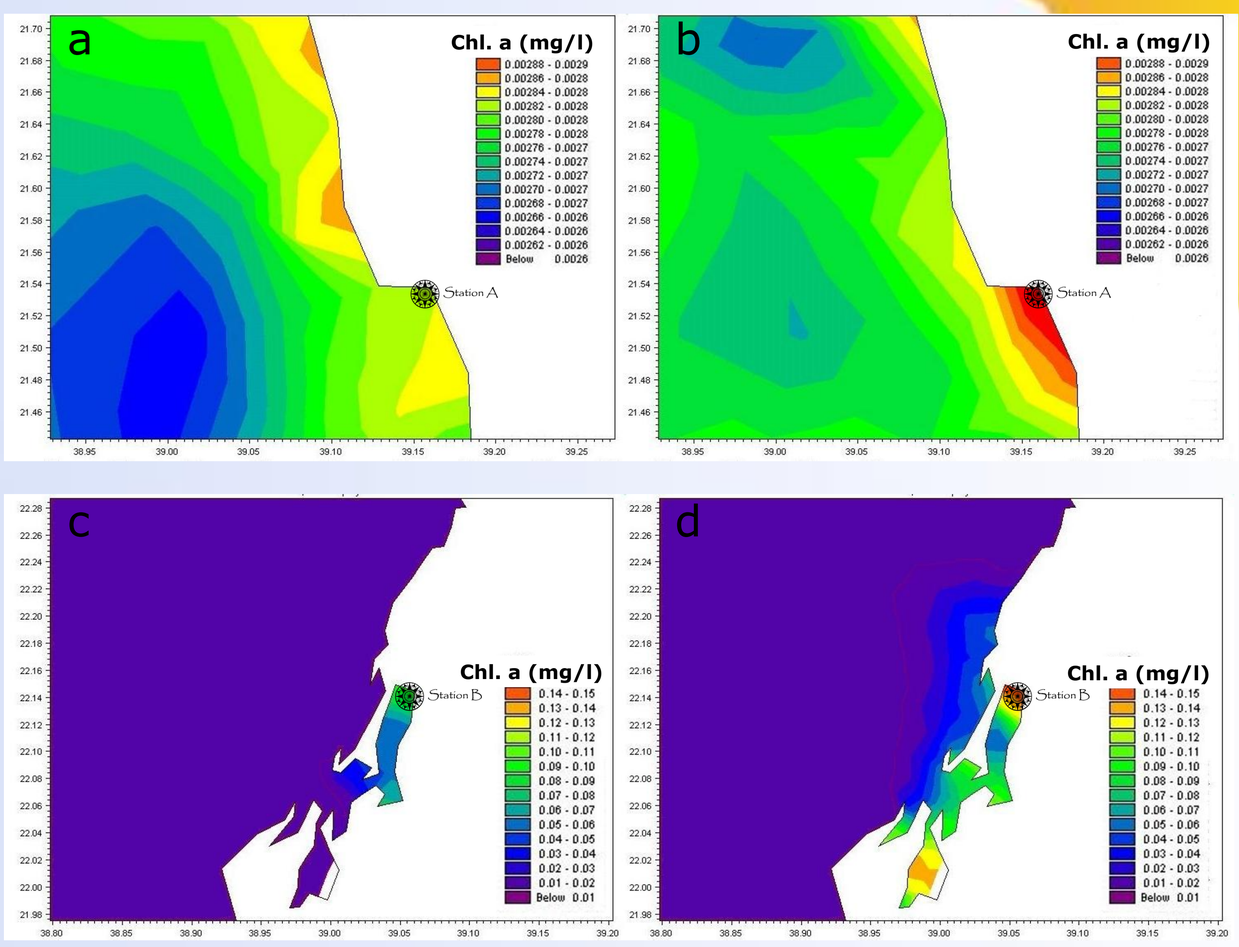

Figure 4: Average chlorophyll a concentrations over 3 month (March-May) around stations A (top panels) and B (bottom panels) in the reference run (left) and the nutrient enrichment simulations (right).

Results-Discussion:

The simulations reveal the influence of the local bathymetry (fig. 3) on the ecological response to local nutrient loads with a contrasted behavior between the Northern part of the model domain, where nutrient enrichment increases primary production 3 fold (from 160 gC m^{-2} yr^{-1} to 440 gC m^{-2} yr^{-1}) and the Southern portion, where phytoplankton dynamics are hardly affected by human pressure (fig. 4).

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