Coupling a watershed model of the Seine river with a 3D ecological model of the English Channel in order to study eutrophication problems

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Introduction

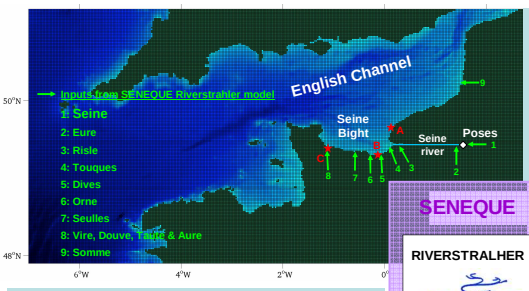
Eutrophication of the Seine river/estuary/bay continuum of the French coast of the English Channel is a subject of growing concern. Because of huge nutrient inputs from the Seine river, with an excess of nitrogen over phosphorus and silica, chlorophyll concentrations reach very high level and episodic blooms of toxic dinoflagellates are regularly observed. In order to better understand the relationship between these ecological processes and the human activities in watersheds flowing into the bay (the main of which is the Seine river), two models have been developed and used in connection : 1/ a model describing nutrient (N, P, Si) transfer processes at the scale of the whole Seine Basin as well as secondary ones (SENEQUE/RIVERSTRAHLER, Thieu et al, 2009), allowing human activity (agricultural practices, waterscape management, urban wastewater treatment, etc.) to be related to fluxes delivered to the sea, 2/ a 3D hydrodynamic (MARS model, Lazure & Dumas, 2008) and an ecological model (Cugier et al. 2005) of the English Channel reproducing the spatio-temporal variations of thermo-haline stratification, nutrients transport and phytoplanktonic development in the plume of the Seine river.

This coupled model was validated and used to simulate two scenarios of human activity in watersheds and the impacts at the coastal zone :

1/ As planned by the Water Framework Directive (WFD), the setting to the standards of water-treatment (SWT) plants for cities of more than 2000 inhabitants, mainly leading to reduction of point source phosphorus inputs.

2/ in addition to the previous scenario, the establishment of organic farming all over the watershed, leading to reduce diffuse nitrogen inputs (SWT+ORGFARM).

Studied area and modelling tools



The river model is based on a description of the geomorphology of the whole drainage network according to the Strahler classification

The 3D ecological model of the English Channel has a horizontal spatial resolution of 2 km and describe the Seine Estuary up to Poses where it is connected to the Seneque-Riverstrahler model for the Seine basin (1). Secondary basins are also modelled with Seneque (2-9) and coupled to the English Channel model.

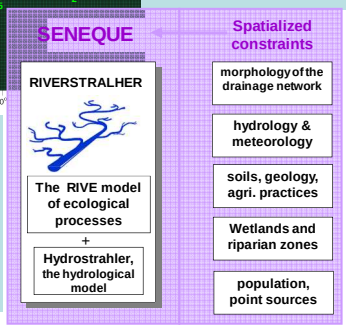


Figure 1: The Seneque-Riverstrahler model is connected to the ecological model MARS.

Validations

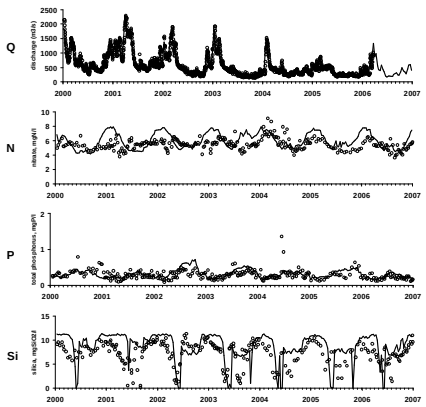


Figure 2: Discharge, nitrate, total P and DSi as observed (dots) and calculated (lines) by Seneque/Riverstrahler from 2000 to 2007 at Poses show a good agreement for the 8 years.

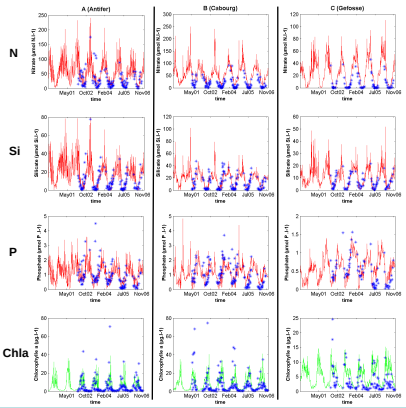


Figure 3: Comparisons between simulated nutrients (red line), chlorophyll a (green line) and measurements (blue dots) at 3 stations (A, B, C) in the Seine bight (see figure 1 for location)

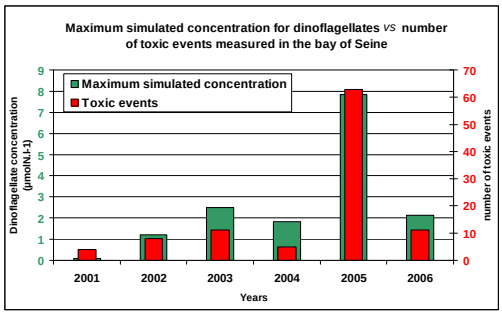


Figure 4: Comparison between simulated annual maximum concentration for dinoflagellates and the number of toxic events link to *dynophysis* observed each years in the Seine bight.

Results of scenarios

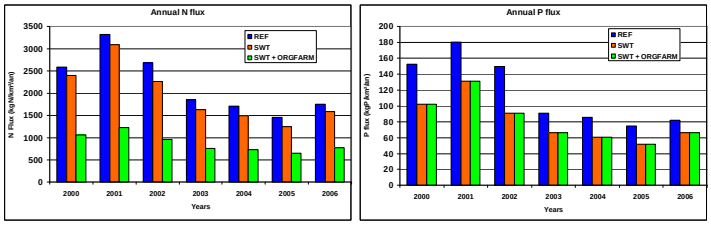


Figure 5: Impact of each scenario on the annual fluxes of nitrogen and phosphorus at Poses for the reference (REF) and two scenarios. The SWT scenario (setting to Standards the Water Treatment plants) leads to a decrease by 20 to 50 kgP/km²/yr. The organic farming scenario (ORGFARM) permits a two fold reduction of nitrogen fluxes.

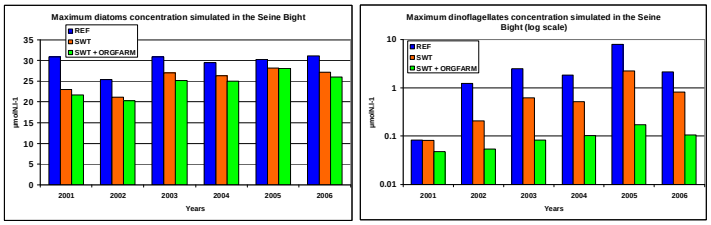


Figure 6: Impact of each scenarios on the annual maximum concentration of diatoms and dinoflagellates in the Seine Bight (REF: reference situation, SWT: setting to Standards the Water Treatment plants ; ORGFARM : ORGanic FARMing all over the watershed)

Conclusions

The simulations show good agreements with measurements at the outlet of the rivers as well as in the adjacent marine area. The two studied scenarios lead to a reduction of nutrient inputs : for phosphorus in SWT scenario (-30 % of P in average for Seine river) and for phosphorus and nitrogen in SWT+ORGFARM scenario (-60 % of N in average for Seine river). In both cases, diatom maximums are reduced in the Seine Bight but remain at high values (between 20 to 30 µg.l-1 of chlorophyll *a*). On the other hand, the impact on dinoflagellates is very strong. The maximum concentrations are 3 to 5 times lower for SWT scenario and 20 to 40 times lower when both SWT and the organic farming are implemented all over the watersheds. This second scenario, exploring organic farming all over the watersheds, remains theoretical because irrealistic for political and economical reasons; it however allows to evaluate the role of agricultural practices on eutrophication of coastal areas of the English Channel. Nevertheless, the STW scenario, as planned by the WFD , shows that a significant impact on dinoflagellates should be expected (and thus, on potentialy toxic species) without having effects on the primary productivity of the bay (due to diatoms).

Bibliographie :

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