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# Validation of the 3D biogeochemical model MIRO&CO with field nutrient and phytoplankton data and MERIS-derived surface chlorophyll *a* images

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## Abstract

This paper presents results obtained with MIRO&CO-3D, a biogeochemical model dedicated to the study of eutrophication and applied to the Channel and Southern Bight of the North Sea (48.5°N–52.5°N). The model results from coupling of the COHERENS-3D hydrodynamic model and the biogeochemical model MIRO, which was previously calibrated in a multi-box implementation. MIRO&CO-3D is run to simulate the annual cycle of inorganic and organic carbon and nutrients (nitrogen, phosphorus and silica), phytoplankton (diatoms, nanoflagellates and *Phaeocystis*), bacteria and zooplankton (microzooplankton and copepods) with realistic forcing (meteorological conditions and river loads) for the period 1991–2003. Model validation is first shown by comparing time series of model concentrations of nutrients, chlorophyll *a*, diatom and *Phaeocystis* with *in situ* data from station 330 (51°26.00′N, 2°48.50′E) located in the centre of the Belgian coastal zone. This comparison shows the model's ability to represent the seasonal dynamics of nutrients and phytoplankton in Belgian waters. However the model fails to simulate correctly the dissolved silica cycle, especially during the beginning of spring, due to the late onset (in the model) of the early spring diatom bloom. As a general trend the chlorophyll *a* spring maximum is underestimated in simulations. A comparison between the seasonal average of surface winter nutrients and spring chlorophyll *a* concentrations simulated with *in situ* data for different stations is used to assess the accuracy of the simulated spatial distribution. At a seasonal scale, the spatial distribution of surface winter nutrients is in general well reproduced by the model with nevertheless a small overestimation for a few stations close to the Rhine/Meuse mouth and a tendency to underestimation in the coastal zone from Belgium to France. $PO_4$ was simulated best; silica was simulated with less success. Spring chlorophyll *a* concentration is in general underestimated by the model. The accuracy of the simulated phytoplankton spatial distribution is further evaluated by comparing simulated surface chlorophyll *a* with that derived from the satellite sensor MERIS for the year 2003. Reasonable agreement is found between simulated and satellite-derived regions of high chlorophyll *a* with nevertheless discrepancies close to the boundaries.


*Keywords:* Biogeochemical model; Eutrophication; MERIS chlorophyll *a*; English Channel; Southern Bight of the North Sea; Model validation

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## 1. Introduction

In order to manage effectively environmental problems, such as eutrophication, in the Southern Bight of the North Sea, it is necessary to establish a scientific understanding of cause–effect relationships between climatological and/or changing human activities and ecosystem response. The Belgian Coastal Zone (BCZ) in the Southern Bight of the North Sea is a highly dynamic system where waters of Atlantic origin are mixed with freshwater river inputs (Fig. 1). Eutrophication along the continental coastline of the Southern Bight of the North Sea leads to high-biomass algal blooms (mainly the Haptophycea *Phaeocystis globosa*) that spread over the entire area along a SW–NE axis in spring (Lancelot et al., 1987). Massive development of *Phaeocystis* colonies is regularly observed in the Southern Bight of the North Sea (e.g. Veldhuis et al., 1986; Lancelot et al., 1987; Riegman et al., 1992; Mills et al., 1994) and is sustained by freshwater inputs deficient in silicon but enriched in nitrogen and phosphorus (Rousseau et al., 2002b).

Due to the complexity of interactions between planktonic organisms, the link between nutrient inputs and coastal ecosystem function cannot be understood by simple correlation between events. Models describing ecosystem carbon and nutrient cycles as a function of environmental forcing are needed to help understand the dynamics of the ecosystem and assess the magnitude and extent of algal blooms and their response to changes in land-based nutrient inputs and climate (Lancelot et al., 2005). The biogeochemical MIRO model is specifically designed to study the link between anthropogenic nutrient loads and the magnitude and extent of diatom and *Phaeocystis* colony blooms in the Southern Bight of the North Sea. This model simulates carbon and nutrient cycles, resolving the complex biology of the bloom species and the coupling between the benthic and pelagic compartments that characterise this shallow coastal shelf sea ecosystem. To account for the impact of the hydrodynamics of the region, this biogeochemical model is coupled with a 3D hydrodynamic model developed for the region (Lacroix et al., 2004). Such a model can be used to investigate the relative effect of different factors on ecosystem dynamics by simulating scenarios. For example, the relative effect of a possible nitrogen and/or phosphorus river input reduction on diatoms/*Phaeocystis* distribution in the Southern Bight of the North Sea could be estimated by simulating scenarios of nutrient reduction.

However, particular attention must be paid to the validation of models and in an environmental management context the model should be shown to reproduce a series of observed annual cycles and their observed variability realistically (Radach and Moll, 2006) before being used for simulating future scenarios. The prediction capability of the model is thus tested through its ability to reproduce observations. In order to assess the model accuracy for simulation of the seasonal dynamics of nutrients and phytoplankton (diatoms and *Phaeocystis*), a high resolution time series of data is necessary. The data collected in the

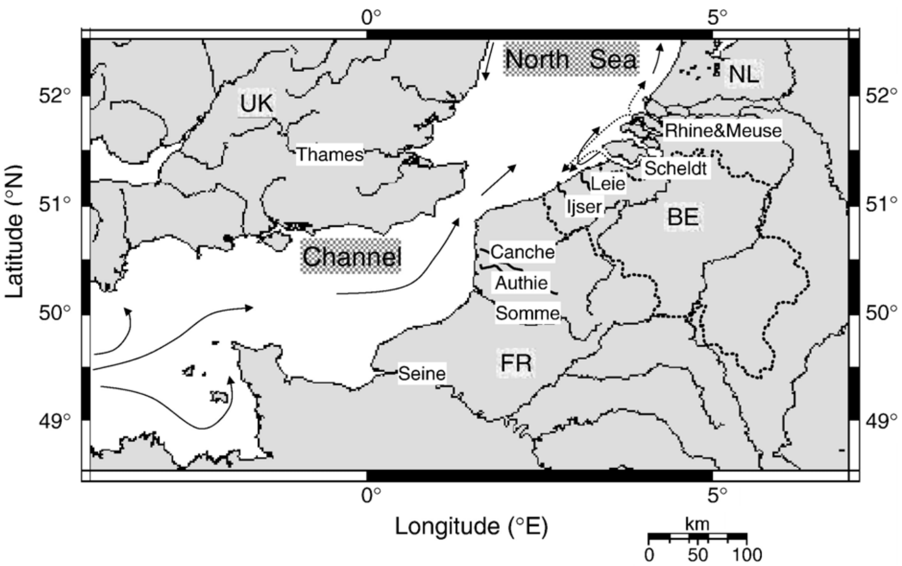


Fig. 1. Map of the Channel and the Southern Bight of the North Sea with schematic representation of the circulation (solid line) and dispersion (dotted line) (redrawn from Lacroix et al., 2004).