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# Testing an integrated river–ocean mathematical tool for linking marine eutrophication to land use: The *Phaeocystis*-dominated Belgian coastal zone (Southern North Sea) over the past 50 years

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## Abstract

The RIVERSTRAHLER model, an idealized biogeochemical model of the river system has been coupled to MIRO, a complex biogeochemical model describing diatom and *Phaeocystis* blooms in the marine domain, to investigate the link between changing human activities over the past 50 years and coastal eutrophication in the eastern Channel and Southern Bight of the North Sea with a focus on the Belgian coastal zone (BCZ). The whole area, submitted to the influence of two main rivers (Seine and Scheldt) is invaded each spring by massive blooms of *Phaeocystis* colonies which impact on the structure and functioning of the coastal ecosystem. For the present application MIRO is implemented in a simplified multi-box description of the coastal zone and is run over the last 50 years using average 1989–1999 meteorological conditions (global solar radiance and temperature) and RIVERSTRAHLER simulations of Seine and Scheldt nutrient loads as forcing conditions. Model validation is obtained by visual and statistical comparison of nutrients, Chl *a,* diatom and *Phaeocystis* simulations with data collected in the central BCZ (51°26.05 N; 02°48.50 E) over the 1992–1998 period.

The simulated *Phaeocystis* and diatom trends (yearly average and maxima reached) in BCZ, over the past 50 years are discussed with respect to changing nutrient loads, especially $NO_3$ and $PO_4$. Historical reconstruction back to the fifties suggests that *Phaeocystis* colonies were already blooming in BCZ in the early 1950's and were sharing almost equally with diatoms, the bulk of annual primary production. Over the 1960–1992 period, the increased loads of both N and P were beneficial to both *Phaeocystis* colonies and summer diatoms with however a little advantage to the latter. Since 1989, the decrease in P loads subsequent to the removal of $PO_4$ in washing powders and the maintenance of elevated $NO_3$ loads had a positive feedback to both diatoms and *Phaeocytis* production with however a significantly larger impact on diatoms than on *Phaeocytis*. This is due to the fact that *Phaeocystis* has strong affinity for low $PO_4$. Consequently *Phaeocystis* development is mainly controlled by $NO_3$ loads. We conclude that future management of nutrient emission reduction aiming at decreasing *Phaeocystis* blooms in BCZ without impacting on diatoms would target decrease of $NO_3$ loads by both the rivers Seine and Scheldt.


*Keywords:* Eutrophication; Diatoms; *Phaeocystis*; Modeling; Southern North Sea; Scheldt

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## 1. Introduction

Due to their impact on the marine biota and the environment, *Phaeocystis* colony blooms in the North-European coastal seas are generally reported as undesirable (Lancelot, 1995). Historical records of *Phaeocystis* blooms in the Eastern Southern Bight of the North Sea trace back to the end of the 19th century (Cadée and Hegeman, 1991). Nowadays, these blooms are recurrent and occur after an early-spring diatom bloom controlled by dissolved silicate availability (Rousseau et al., 2002). *Phaeocystis* colonies grow on nitrogen and phosphorus and form with diatoms the bulk of phytoplankton biomass during the growing season but their magnitude varies from year-to-year (Lancelot et al., 1998). Attempt has been made to relate long-term fluctuations of *Phaeocystis* blooms in the Southern Bight of the North Sea to changes either in climate (Owens et al., 1989) or in anthropogenic nitrogen and phosphorus river loads (Cadée and Hegeman, 1991), but the outcome is still unclear.

Over the past 50 years, several quantitative and qualitative changes in nutrient delivery by the NW European rivers to the Channel and the North Sea have been recorded (OSPAR, 2000; Soetaert et al., 2006), due to changing land use and human activity on the watershed. The link between the variations over the past 50 years in watershed agricultural, domestic and industrial activities and the nitrogen, phosphorus and silica delivery to the sea, has been recently established for the river Seine (Billen et al., 2001) and the river Scheldt (Billen et al., 2005), based on results obtained with the idealized RIVERSTRAHLER model. This model was developed for establishing the link between the biogeochemical functioning of large river systems and the constrains set by the meteorological conditions, the morphology of the drainage network and the human activity on the watershed (Billen et al., 1994; Garnier et al., 1995; Billen et al., 1999; Garnier et al., 2002; Garnier and Billen, 2002). As a general trend, the annual RIVERSTRAHLER fluxes of nutrients delivered to the North Sea show after 1965, a severe depletion of silica with respect to nitrogen compared with the requirements of coastal diatoms (Brzezinski, 1985), and a clear shift from nitrogen to phosphorus potential limitation after 1990 (Billen et al., 2001; Billen et al., 2005; Cugier et al., 2005).

In this paper we use the RIVERSTRAHLER nutrient fluxes of Billen et al. (2001, 2005) as nutrient load forcing of the marine biogeochemical MIRO model (Lancelot et al., 2005) to reconstruct the interannual variations of nutrient enrichment and diatom and *Phaeocystis* blooms in the Belgian Coastal Zone (BCZ) over the past 50 years. BCZ, located in the Southern Bight of the North Sea (Fig. 1), is a relevant site to investigate links between phytoplankton blooms and continental forcings. This area is a highly dynamic system with water masses resulting from mixing of English Channel Water inflows from Atlantic origin (Pingree and Maddock, 1977; Salomon and Breton, 1993) and freshwater inputs from the Scheldt river (Fig. 1; Brockmann et al., 1988). Overall the nutrient enrichment of BCZ mainly results from inputs of the river Scheldt but also of the English

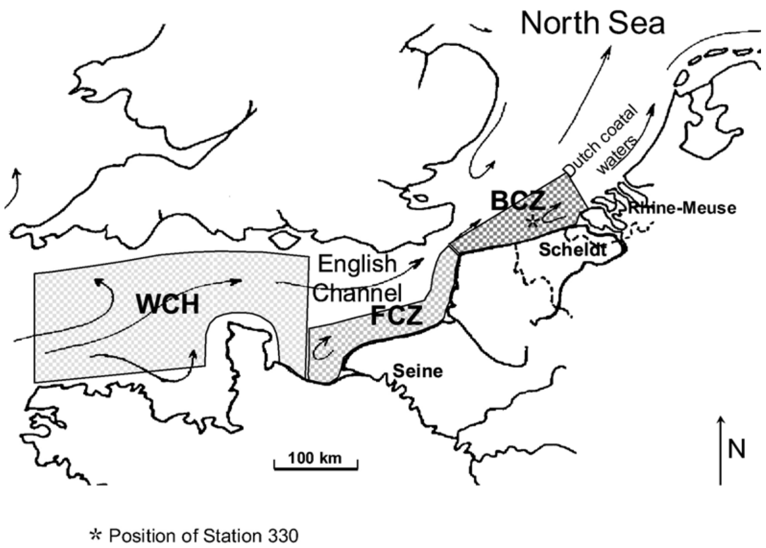


Fig. 1. Map showing the multi-box implementation geographical domain of MIRO, the location of Seine and Scheldt rivers and of the station 330 in BCZ, as adapted from Lancelot et al., 2005.