Dissolved inorganic carbon dynamics and air-sea carbon dioxide fluxes during coccolithophorid blooms in the Northeast European continental margin (northern Bay of Biscay)

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Keywords: coccolithophores, CO2, net community calcification,net community production

Introduction

Balch et al. (2007) evaluated global pelagic contemporary calcification from remote sensing data (mainly associated to coccolithophores) to 1.6 ± 0.3 Pg PIC yr^{-1} (1 Pg = 10^{15} g; PIC = particulate inorganic carbon). This would imply that coccolithophores would be the most important pelagic calcifier in the oceans, since other estimates of contemporary global pelagic calcification range between 0.7 Pg PIC yr^{-1} based on accumulation rates and sediment trap data (Milliman et al. 1999), and 1.4 Pg PIC yr^{-1}, based on the seasonal cycle of total alkalinity (TA) in the euphotic zone (Lee 2001). The development of coccolithophorid blooms affects the seawater carbonate chemistry, and air-sea CO_2 fluxes, through the organic carbon pump and the carbonate counter-pump. The ratio between calcification (carbonate counter-pump), and organic carbon production (organic carbon pump), the C:P ratio, depends on the life cycle (bloom development), and growth conditions of coccolithophores. At the onset of the coccolithophorid bloom, when nutrients are available for growth, organic carbon production dominates over calcification (C:P << 1, the so-called organic phase). At the end of the bloom, in nutrient depleted conditions, and high irradiances (due to stronger stratification), organic carbon production decreases and calcification increases (C:P ≤ 1, the so-called inorganic phase). Several manipulative experiments to test the effect of ocean acidification on coccolithophores have shown that while calcification would decrease, the export of organic carbon would increase mainly through increasing transparent exopolymer particles (TEP) production. For a credible implementation in mathematical models of such feed-back mechanisms to allow the projection of a future evolution of carbon biogeochemistry under global change, it is required to understand present day biogeochemistry and ecology of naturally occurring pelagic calcifying communities. In particular, the overall effect of phytoplankton communities on the C:P ratio, and the net effect on carbonate chemistry, and related air-sea CO_2 fluxes.

Cruises

Three cruises were carried out in the northern Bay of Biscay from 31/05 to 09/06/2006 (BG06/11 cruise), 10/05 to 24/05/2007 (BG07/12 cruise), and 07/05 to 23/05/2008 (BG08/12 cruise). Depths of sampling were chosen to cover surface waters, thermocline, and bottom waters down to the seafloor over the continental shelf and down to maximum 1400 m over the continental slope. Due to shorter ship-time, sampling during the June 2006 cruise was limited to the area around the La Chapelle Bank, while during the other two cruises sampling was also carried out further north along the continental margin (Fig. 1)

Results and discussion

During the three cruises in the northern Bay of Biscay, blooms of coccolithophores occurred, as indicated by patches of high reflectance on remote sensing images, phytoplankton pigment signatures, and microscopic examinations. Total alkalinity (TA) showed a non-conservative behaviour as a function of salinity due to the cumulated effect of net community calcification (NCC) during bloom development on seawater carbonate chemistry. The cumulated impact of NCC and net community

production (NCP) on DIC and the partial pressure of CO_2 (pCO_2) were evaluated. The decrease of DIC (and increase of pCO_2) due to NCC was overwhelmingly lower than the decrease of DIC (and decrease of pCO_2) due to NCP (NCC:NCP << 1). During the cruises, the northern Bay of Biscay acted as a sink of atmospheric CO_2 (on average ~-9.7 mmol C m^{-2} d^{-1} for the 3 cruises). The overall effect of NCC in decreasing the CO_2 sink during the cruises was low (on average ~12% of total air-sea CO_2 flux). If this is a general feature in naturally occurring phytoplankton blooms in the northern North Atlantic Ocean (where coccolithophorid blooms are the most intense and recurrent), and in the global ocean, then the potential feed-back on increasing atmospheric CO_2 of the projected decrease of pelagic calcification due to thermodynamic CO_2 "production" from calcification is probably minor compared to feed-backs related to changes of NCP.

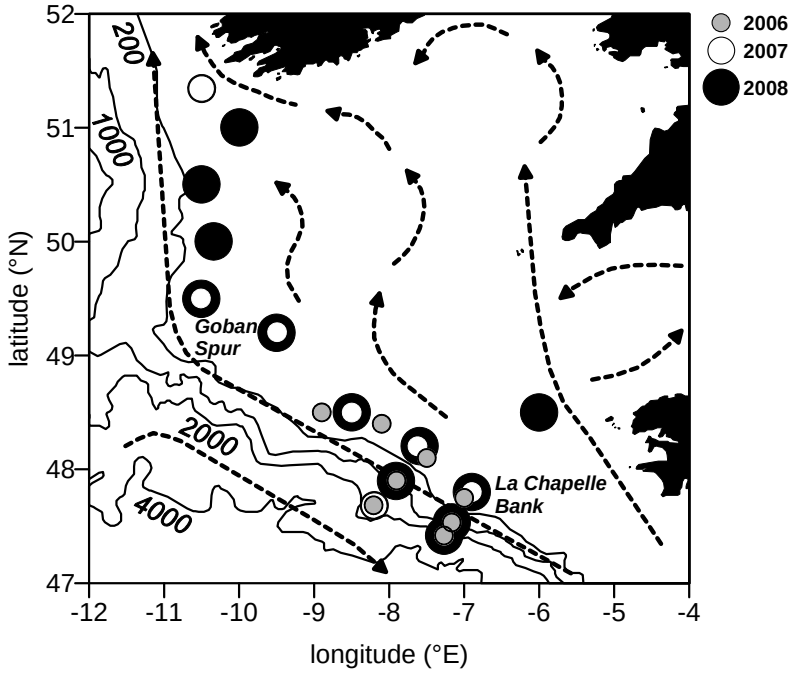

Figure 1. Map of the study site showing the sampling stations in June 2006, May 2007, and May 2008, the 200m, 1000m, 2000m and 4000m isobaths (solid lines), and the general residual circulation (dotted arrows).

Acknowledgements

We are grateful to the officers and crewmembers of the R.V. Belgica and to J. Backers, J.-P. De Blauw and G. Deschepper (Unit of the North Sea Mathematical Models) for their support during the cruises, to S. Groom (Remote Sensing Group from the Plymouth Marine Laboratory) for providing remote sensing images, to N. Van Oostende and K. Sabbe (Ghent University) for providing the HPLC and SEM data, and to A. Engel (Alfred Wegener Institute) for additional SEM data. This work was carried out in the frame of Belgian Science Policy project Role of pelagic calcification and export of carbonate production in climate change (PEACE, SD/CS/03A).

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