Towards a comprehensive C-budgeting approach of a coccolithophorid bloom in the northern Bay of Biscay: results from PEACE project

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Introduction

During coccolithophorid blooms, carbon (C) cycling in the photic zone is driven by the production and the degradation of organic matter (primary production and community respiration), as well as the production and the dissolution of biogenic calcium carbonate ($CaCO_3$). Organic and inorganic metabolisms lead to a transfer of carbon to depth and both impact the flows of carbon dioxide (CO_2) in the water column and the CO_2 flux across the air-sea interface. Furthermore, due to complex dynamics of coccolithophores, the impact of metabolic C fluxes on CO_2 fluxes is variable in time, depending on the stage of the bloom development, and mainly on the ratio of calcification to primary production (CAL:GPP). Understanding and quantifying C cycling of coccolithophorid blooms in natural conditions is a prerequisite to correctly validate biogeochemical models aiming at predicting feedbacks related to ocean acidification, which incorporate knowledge obtained from perturbation laboratory experiments.
We carried out a trans-disciplinary cruise on board the R/V *Belgica* at the continental margin of the Bay of Biscay, in the midst of a coccolithophorid bloom, during which ^{14}C primary production (GPP_p), ^{14}C calcification (CAL) and O_2-based pelagic community respiration rates (PCR) were determined in the water column.

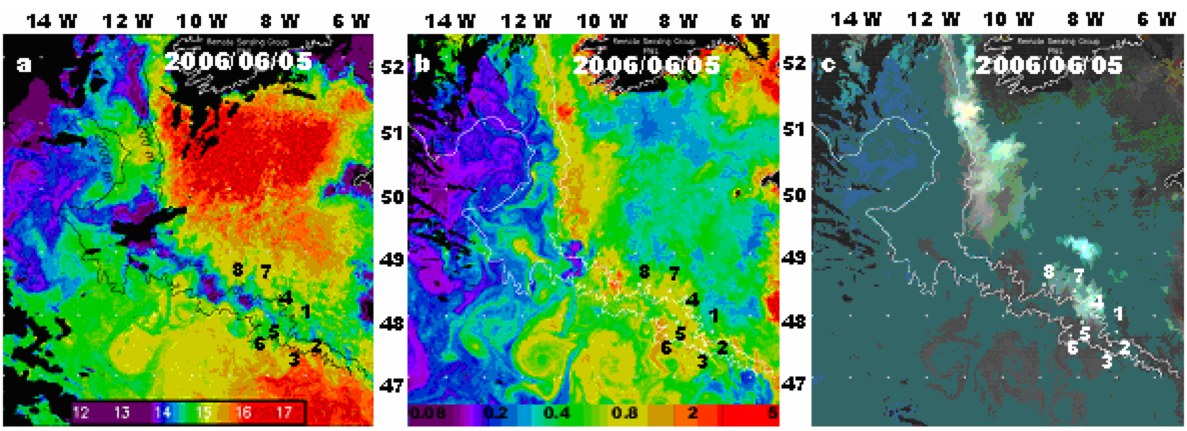

Figure 1. **a-** AVHRR sea surface temperature (SST) in the northern Bay of Biscay, showing the location of the stations, the 200 m and 2000 m isobaths, **b-** MODIS chlorophyll-a (Chl-a) and **c-** Reflectance satellite images.

Results and discussion

The time series of remotely sensed parameters reveals a rise of SST accompanied by a shoaling of the thermocline to 25 m depth during the period of the cruise. This situation is favourable for

coccolithophorid development, as indicated by the elevated reflectance and moderate (~1 µg L^{-1}) Chl-a concentration and nutrient exhaustion.
In agreement with Margalef's Mandala (Margalef, 1997), the degree of stratification was hypothesized to control the biological processes and allowed the reconstruction of the succession phases of the coccolithophore-dominated bloom. Bloom aging was characterized by a decrease in Prymnesiophyte biomass relative to other phytoplankton groups. With increasing stratification from early coccolithophorid bloom stations (1-2-5) to the later stages (station 8), GPPp decreased as CAL increased over the shelf, leading to a significant CAL:GPPp ratio for later stages of the bloom. The aging of the bloom resulted in a lower GPPp:PCR ratio and an evolution from net phytoplanktonic community autotrophy to net heterotrophy.
A C-budget was computed along a gradient from the productive (station 2) to the high reflectance zone (station 8). Surface waters remained as a net sink for atmospheric CO_2, although total alkalinity data indicated that calcification had a large impact on surface carbonate chemistry. However, net autotrophy was only found for the early phase of the bloom (station 2) where the potential export was of the same magnitude as the aphotic C demand. In other cases, the C export was null or negative and insufficient to sustain aphotic C demand.

Conclusions

Our classical C-budgeting approach suffers from several caveats. Firstly, steady state is assumed but C production and degradation are decoupled in time and space, as well as biomineralization and dissolution. Secondly, the dissolved production (GPPd) is not considered here. The importance of GPP_d and its potential fate to be transformed into transparent exopolymer particles (TEP) could constitute a significant C flux (12% of the POC, Harlay *et al.*, 2009) to sustain the heterotrophic C demand in the twilight zone, as suggested by Koeve (2005).
The estimate of GPPd from the particulate nitrogen to carbon ratio in surface waters, based on the parameterization by Joassin *et* al. (2008) and the computation of C budget based on GPP_{tot} (GPPtot = GPPd + GPPp) contributes to the budgeting of C fluxes to the twilight zone by providing a net export of the same magnitude as the aphotic demand (Harlay *et al. in prep*).

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