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Biogeochemistry and carbon mass balance of a coccolithophore bloom in the northern Bay of Biscay (June 2006)

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Harlay J.[1], Chou L.[2], Van Oostende N.[3,4], Sabbe K.[3], and Borges A.V.[1]

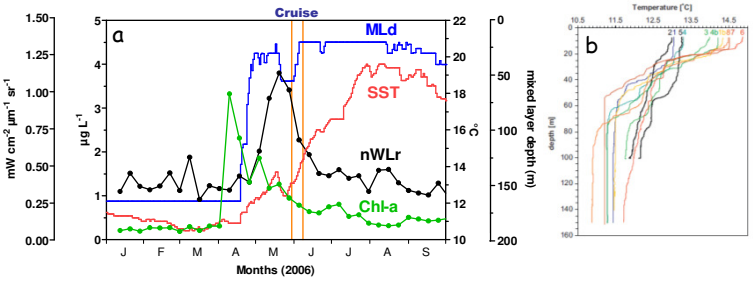

Fig. 1: **a**-Time series of remotely sensed weekly Chl-a concentrations and normalized water-leaving radiance @555 nm (nWLr), modelled daily mixed layer depth (MLd) and SST in the study area from January to September 2006. **b**-Vertical profile of temperature. Black profiles correspond to the stations (2 and 5) located on the continental slope.

Chl-a and nWLr are Level-3 SeaWiFS data (http://reason.gsfc.nasa.gov/Giovanni/) and MLd and SST were simulated with Met Office National Centre for Ocean Forecasting for the North-East Atlantic 1/8° model (http://www.nerc-essc.ac.uk/godiva/).

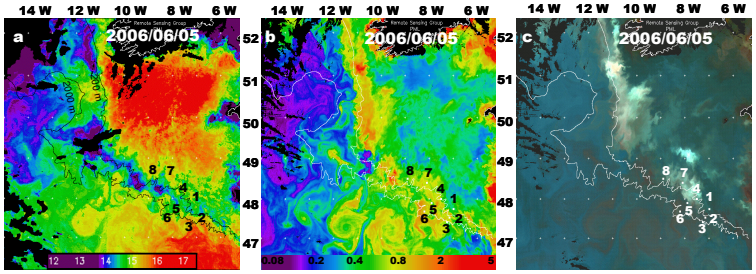

Fig. 2: **a**- AVHRR sea surface temperature (SST) in the northern Bay of Biscay, showing the location of the stations, the 200 m and 2000 m isobaths, **b**- MODIS chlorophyll-a (Chl-a) and **c**- Reflectance satellite images.

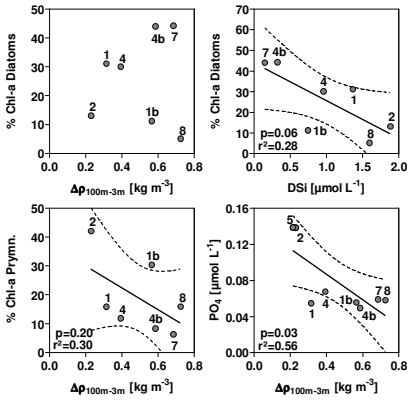

Fig. 3: Depth integrated over the top 30 m Chl-a relative percentage for diatoms (% Chl-a Diatoms), Prymnesiophytes (% Chl-a prym.), and PO_4 concentration versus the difference of density at 3 m depth and at 100 m depth ($\Delta\rho_{100m-3m}$) in northern Bay of Biscay in June 2006, and %Chl-a Diatoms versus averaged DSi concentration.
The linear regression and the 95% confidence intervals (dashed lines) are represented together with the determination coefficient (r^2). Plain regression lines are based on all stations, dashed regression lines are based on the continental shelf stations (excluding the continental slope—stations 2 and 5). Numbers refer to the sampling station.

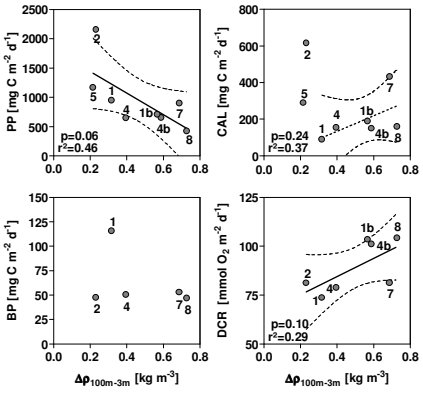

Fig. 4: PP, CAL, BP (mg C m^{-2} d^{-1}) and DCR (mmolO_2 m^{-2} d^{-1}) versus the difference of density at 3 m depth and at 100 m depth ($\Delta\rho_{100m-3m}$) in northern Bay of Biscay in June 2006.
The linear regression and the 95% confidence intervals (dashed lines) are represented together with the determination coefficient (r^2). Plain regression lines are based on all stations, dashed regression lines are based on the continental shelf stations (excluding the continental slope—stations 2 and 5). Numbers refer to the sampling station.

INTRODUCTION

Primary production (PP), calcification (CAL), bacterial production (BP) and dark community respiration (DCR) were measured along with a set of various biogeochemical variables, in early June 2006, at several stations at the shelf break of the northern Bay of Biscay. The cruise was carried out after the main spring diatom bloom that, based on the analysis of a time-series of remotely sensed chlorophyll-a (Chl-a), peaked in mid-April (Fig. 1).

ENVIRONMENTAL SETTINGS

Vertical profiles of temperature acquired during the cruise (Fig. 1b), as confirmed by remotely sensed sea surface temperature (SST, Fig. 2a) indicated the occurrence of enhanced vertical mixing (due to internal tides) at the continental slope, while adjacent waters on the continental shelf were stratified. The surface layer of the stratified water masses (on the continental shelf) exhibited high Chl-a concentration (Fig. 2b) and was depleted of inorganic nutrients. Dissolved silicate (DSi) levels probably did not allow significant diatom development.

WORKING HYPOTHESIS

We hypothesize that mixing at the continental slope allowed the injection of inorganic nutrients that triggered the blooming of mixed phytoplanktonic communities dominated by coccolithophores (*Emiliania huxleyi*), as shown by high reflectance patches (HR, Fig. 2c), that were favoured with regards to diatoms due to the low DSi levels (Fig. 3). Based on this conceptual frame, we used an indicator of **vertical stratification ($\Delta\rho_{100m-3m}$)** to classify the different sampled stations, and to reconstruct the possible evolution of the bloom from the onset at the continental slope (triggered by vertical mixing) through its development as the water mass was advected on-shelf and stratified.

RESULTS

The increase of CAL for stations over the shelf (excluding stations 2 and 5) is characteristic of coccolithophore bloom development from high-PP and low-CAL during the early bloom phase to low-PP and high-CAL during stationary and declining bloom phases (Fig. 4). Such a change was accompanied by an increase of heterotrophic processes, as featured by the increase of DCR with stratification, although there was no pattern of BP with stratification.
We established a carbon mass balance of net community production (NCP) at each station by integrating in the photic layer PP, CAL and DCR C fluxes. This allowed computation at each station of the contribution of PP, CAL and DCR to CO_2 fluxes in the photic layer, and how they changed from one station to another along the sequence of bloom development (as traced by the stratification indicator).

Table 1: Metabolic CO_2 fluxes [mmol C m^{-2} d^{-1}] based on a mass balance where the ^{14}C incubations are assumed to correspond to gross primary production (GPPp), where DCR is the sum of autotrophic and heterotrophic respiration based on O_2 incubations converted to C units using a respiratory quotient of 1, and where CAL is the rate of calcification based on ^{14}C incubations. Metabolic CO_2 fluxes related to CAL were computed as +0.6×CAL, following Frankignoulle et al. (1994).

Station	CO_2 fluxes (mmol C m^{-2} d^{-1})					C fluxes (mmol C m^{-2} d^{-1})	
	Related to PP	Related to CAL	Related to DCR	Net metabolic CO_2 flux	Net air–sea CO_2 flux	Export of organic C	Aphotic C demand
2	−180.0	30.9	81.3	−67.9	−11.4	98.7	89.0
1	−79.3	4.5	73.7	−1.0	−−17.8	5.5	98.2
4(HR)	−54.0	7.8	78.9	32.6	−13.4	−24.9	66.9
1bis	−59.2	9.5	103.5	53.8	−16.1	−44.4	159.0
4bis(HR)	−54.6	7.5	101.2	54.1	−10.7	−46.6	168.5
7(HR)	−75.1	21.7	81.4	28.0	−10.2	−6.4	35.1
8(HR)	−35.5	8.0	104.3	76.8	−8.5	−68.8	72.3

The **early bloom phase** (stations 2 and 1) was characterized by **high PP and CAL** values (Table 1). The net metabolic CO_2 fluxes (-67.9 mmol C m^{-2} d^{-1} at station 2) had the same direction as the air–sea CO_2 flux (-11.4 mmol C m^{-2} d^{-1}). At station 2, the NCP was positive, indicating a **net autotrophic status** leading to a positive potential C export (+98.7 mmol C m^{-2} d^{-1}) that was of the same order of magnitude as the aphotic pelagic C demand (89.0 mmol C m^{-2} d^{-1}).
At the stations representative of **more developed and declining bloom conditions** (stations 4, 4bis, 7 and 8), **PP and CAL were lower** than the early bloom phase (stations 2 and 5), and NCP was neutral or negative, indicating a balanced or a net **heterotrophic status** (ranging from +5.5 to -68.8 mmol C m^{-2} d^{-1}).

CONCLUSIONS

The pCO_2 measurements indicated that surface waters acted as a net sink for atmospheric CO_2 during all phases of the bloom. Hence, CAL related to coccolithophore blooms had the potential to decrease the sink of atmospheric CO_2 but did not reverse the direction of the flux. Net community autotrophy was only found for the early phase of the bloom. During the maturing and declining phases of the bloom, potential export from the photic layer could not meet the aphotic C demand. This suggested the importance of extracellular production of carbon to sustain the bacterial demand in the photic and aphotic layers.

References:
Frankignoulle et al. (1994). Limnology and Oceanography 39, 458-462.

Acknowledgments:
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Affiliations:
1. Université de Liège (ULg) - Chemical Oceanography Unit
2. Université Libre de Bruxelles (ULB) - Laboratoire d'Océanographie physique et Géochimie des Eaux
3. Ghent University (UGhent) - Protistology & Aquatic Ecology
4. Princeton University - Dept. Geosciences