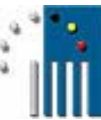


# Biogeochemical Investigations of Coccolithophore Blooms along the Continental Margin of the Northern Bay of Biscay: Highlights of the PEACE Project

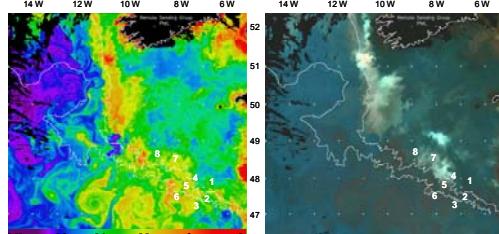
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## Introduction

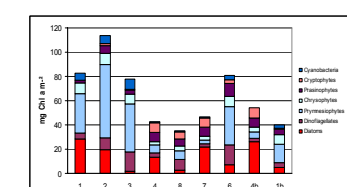
Recent studies have demonstrated that changing ocean chemistry due to **ocean acidification** poses a growing threat for marine organisms such as corals, coccolithophores and many others that form calcareous skeletons. Its biogeochemical feedbacks and impact on the oceanic carbon cycle are yet to be quantified. **Coccolithophores** are the major calcifying phytoplankton in the sub-polar and temperate regions of the world's ocean. They produce furthermore **transparent exopolymer particles (TEP)**, which are known to promote aggregate formation. Combined with the **CaCO<sub>3</sub> ballast effect**, large-scale coccolithophore blooms could thus contribute to the export of organic carbon to deep waters on relatively short time scales. During the Belgian **PEACE project**, we have conducted yearly interdisciplinary biogeochemical surveys, assisted by remote sensing, along the continental margin of the **northern Bay of Biscay** where coccolithophore blooms dominated by *Emiliania huxleyi* are frequently and recurrently observed (Figure 1). Rates of various processes governing the coccolithophore ecosystem dynamics have been determined and associated biogeochemical parameters analysed. The overall objective is to evaluate the role in climate regulation of calcification, primary production and export processes during coccolithophore blooms. Here we report the principal results obtained during the 2006 campaign.



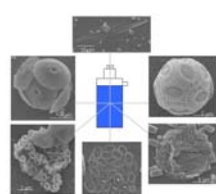
**Figure 1.** Remote sensing images taken on 5 June 2006, showing MODIS chlorophyll (left) and Reflectance (right). The bright blue-white areas on the reflectance image, indicate the high coccolithophore scattering. Sampling locations of the Belgica BG06/11 cruise (29 May – 10 June 2006) are also indicated. Stations 1 and 4 were revisited during the second leg.

## Nutrients, chlorophyll and phytoplankton

Phytoplankton development in surface waters had led to the depletion in inorganic nutrients (data not shown). Depth-integrated chl-a partitioning (Figure 2), based on HPLC pigment data, showed that stations 1, 2, 3, and 6 were characterized by a high coccolithophore biomass (Prymnesiophytes). Station 1b (revisited after one week) exhibited a decrease in chl-a, indicating the decay of the bloom. In contrast, stations 4 (and especially 4b) and 7 were dominated by diatoms and to a lesser degree cryptophytes. Stations 6 and 8 had higher relative contributions of dinoflagellates. Figure 3 shows the SEM micrographs of samples taken at station 2 where the highest abundance of coccolithophores were observed.



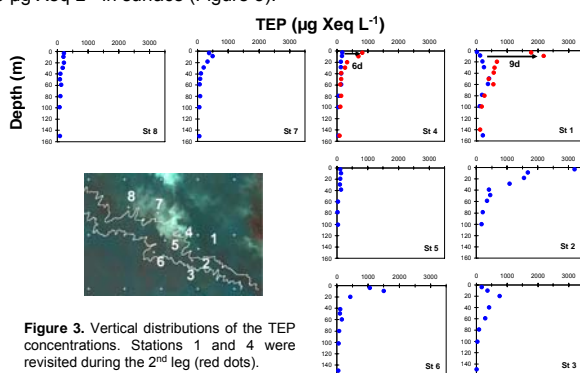
**Figure 2.** Phytoplankton biomass: depth-integrated chl-a partitioning based on HPLC pigment data.



**Figure 3.** SEM photographs showing hetero- and holococcolithophore species, as well as pennate diatoms (apical picture), that were sampled at station 2.

## Transparent exopolymer particles (TEP)

TEP concentrations were measured spectrophotometrically according to the semi quantitative method of Passow and Alldredge (1995) with alcian blue staining. TEP profiles were relatively similar each year with highest concentrations observed at surface and subsurface. A general decrease in TEP was observed below 40-60m. Higher concentrations were measured during the 2006 cruise with values ranging between 100 to 2000  $\mu\text{g Xeq L}^{-1}$  in surface (Figure 3).

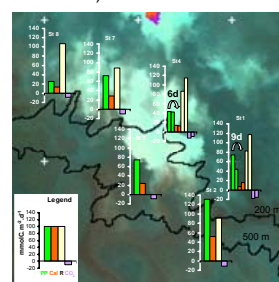


**Figure 3.** Vertical distributions of the TEP concentrations. Stations 1 and 4 were revisited during the 2<sup>nd</sup> leg (red dots).

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## Net ecosystem production and calcification

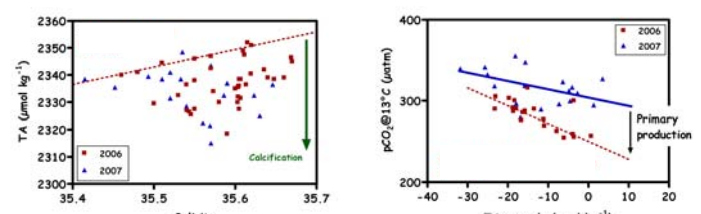
<sup>14</sup>C primary production and calcification rates obtained for the June 2006 cruise are summarised in Figure 4 where pelagic community respiration rates and air-sea CO<sub>2</sub> fluxes are also indicated. The averaged primary production on the continental shelf was 50  $\text{mmolC m}^{-2} \text{d}^{-1}$  compared to 103  $\text{mmolC m}^{-2} \text{d}^{-1}$  on the slope, in accordance with the remotely sensed surface chl-a distribution (Figure 1, left). A decrease in chl-a concentration was observed between the two legs for station 1 (and 1b), which was accompanied by a decrease in primary production (from 74  $\text{mmolC m}^{-2} \text{d}^{-1}$  to 43  $\text{mmolC m}^{-2} \text{d}^{-1}$ ). We measured in addition dissolved esterase activity and the related lysis rates using



the method described in Riegman et al. (2002). The highest lysis rate was observed at station 1b (1.34  $\text{d}^{-1}$ ), associated with low chl-a concentration in surface waters, which corresponded probably to the grazing/viral lysis activity and the decline of the coccolithophore bloom at this station. These results suggest a **patchy** distribution of phytoplankton with various properties regarding organic and inorganic carbon production.

## Surface-water carbon dioxide dynamics

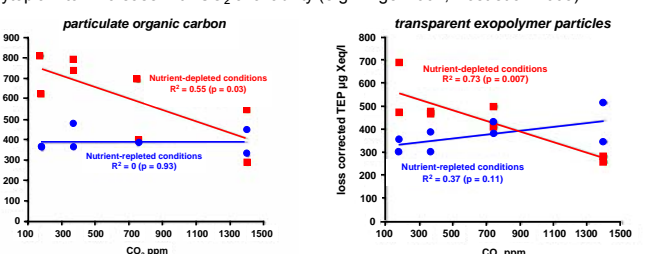
Carbon dioxide (CO<sub>2</sub>) data were obtained in the northern Bay of Biscay in June 2006 and May 2007 during coccolithophore blooms. Total alkalinity (TA) showed non conservative behaviour with respect to salinity, highlighting strong TA drawdown related to calcification (Figure 5). The TA anomalies were negatively correlated to pCO<sub>2</sub> due to the production of CO<sub>2</sub> during calcification ( $\text{Ca}^{2+} + 2\text{HCO}_3^- \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2$ ). The slope of the correlation was different during both years since the cruises were carried out at different stages of the phytoplankton bloom, highlighting the contribution of primary production to CO<sub>2</sub> dynamics during coccolithophore blooms.



**Figure 5.** Dissolved inorganic carbon chemistry of surface waters.

## Influence of pCO<sub>2</sub> on TEP dynamics

To describe the influence of CO<sub>2</sub> concentration on coccolithophores, specifically on the kinetics of polysaccharide exudation and TEP production, chemostat studies were performed on board the ship during the June 2006 cruise. Preliminary results indicate a response of the plankton community to CO<sub>2</sub> at low flow rates, when nutrients were depleted. Then, the net production of particulate organic matter, such as POC and TEP, decreased significantly with increasing CO<sub>2</sub> (Figure 6). This result differs from our expectations and previous publications, which showed that biomass production by marine phytoplankton increase with CO<sub>2</sub> availability (e.g. Engel 2002, Rost et al. 2003).



**Figure 6.** Production of POC and TEP in response to changing CO<sub>2</sub> concentration under nutrient replete or depleted conditions. Incubations of natural water samples taken at station 2 were carried out at an irradiance of 200  $\mu\text{mol m}^{-2} \text{s}^{-1}$  (PAR) with a 16h:8h light:dark cycle, and two different flow rates (0.6 and 0.13  $\text{d}^{-1}$ ). Temperature were kept at  $16 \pm 2^\circ\text{C}$ .

## Concluding remarks

Understanding of carbon dynamics of calcifiers such as coccolithophores under natural conditions is an essential pre-requisite for a robust and credible implementation in mathematical models to allow the projection of a plausible future evolution of carbon biogeochemistry under global change, in particular in relation to ocean acidification. This can be achieved with a transdisciplinary approach combining integrated field and laboratory studies as in the PEACE project.

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