The marine carbon cycle from North to South along the Galathea route:
an ongoing project investigating the global carbon cycle.

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In August of this year, a Danish research vessel embarked on a global 9-month research cruise: The Galathea Expedition. The cruise track can be seen at www.galathea3.dk. Onboard are projects investigating a wide variety of topics related to the ocean, ranging in focus from viruses to whales and dealing with physical, chemical and biological processes. The largest project on the expedition, studying “The marine carbon cycle from North to South along the Galathea route”, is a multidisciplinary effort focusing on obtaining a better understanding of the carbon cycle in the upper ocean and in the lower atmospheric boundary layer, and the role of the ocean in climate change.

This IMBER-endorsed project is compiling a global dataset describing the upper ocean processes controlling ocean-atmosphere carbon exchange, which will increase our understanding of how physical, chemical and biological processes in the sea influence the carbon dioxide (CO_2) content of the atmosphere. The oceanic carbon reservoir is about 50 times greater than the amount of carbon stored in the atmosphere as CO_2. Due to the intense gas exchange through the air-sea interface, oceanic carbon storage will ultimately determine future atmospheric CO_2 concentration. Today, oceanic carbon uptake amounts to about one-fourth of the anthropogenic carbon emissions and, therefore, the ocean helps reduce the rate of atmospheric CO_2 increase. As CO_2 is a strong greenhouse gas, this oceanic carbon uptake counteracts the climatic influence from anthropogenic carbon emissions. Predicting future rates of oceanic CO_2 uptake requires knowledge relating to the magnitude of oceanic carbon uptake today and processes regulating this uptake.

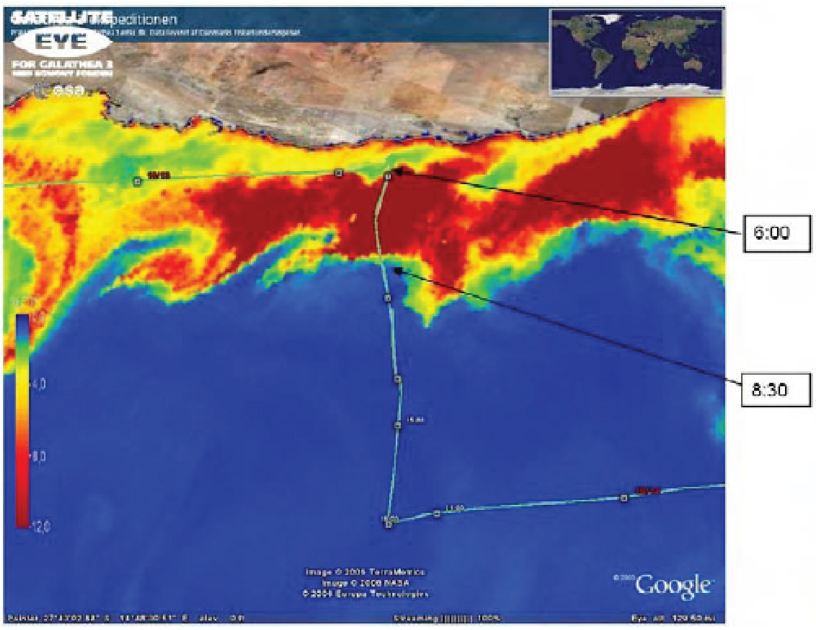

Figure 1. On October 13, 2006 the Galathea 3 Expedition crossed the upwelling zone off the Namibian coast. At 6 a.m. the ship sailed into the high concentration of algae (dark red area) and at 8:30 a.m. the ship sailed out of the area again (blue).

The marine carbon cycle is regulated through interplay among physical, chemical and biological processes. The fate of the biologically fixed carbon depends on the complexity of the food web. Large phytoplankton cells are normally efficiently transferred up a short classical food chain, while small phytoplankton cells, on the other hand, fuel a much more complex microbial food web. The biological pump, where carbon can be transferred from surface to deeper ocean layers, is believed to be most active in regions where large cells dominate. In this project, detailed studies of the structure of the food chain and related processes from the smallest algae to fish are combined with measurements of the CO_2 flux between the atmosphere and the ocean, and information on the physical and chemical characteristics of the sea. So far, few studies have combined measurements of all three types of processes in order to describe atmosphere-ocean carbon exchange and no such studies have been carried out on a global scale using the same methods. Therefore, this study provides a unique opportunity to compare the roles and contributions of different ocean regions in physical, chemical and biological processes in the global carbon and nutrient cycles.

Over the entire cruise track, continuous measurements of salinity, temperature, chlorophyll *a* are carried out on surface water. In addition, point measurements are made, and samples collected, at different depths down to 4000 m. Parameters studied include salinity, temperature, bulk and size-fractionated chlorophyll *a*, nutrients, primary production, algae physiology (e.g., fast repetition rate fluorescence for determination of photosynthetic capacity of the phytoplankton) and plankton size and species composition, to provide information on the hydrographic conditions and the biological activity deeper in the water column. Molecular studies and analysis of stable isotopes are used to assess the relative importance of nitrogen fixation compared with upwelled nitrogen in fuelling carbon flow in the pelagic foodweb and eventually carbon sequestration.

Remineralisation experiments are carried out onboard to evaluate the possible effects of changes in temperature and size composition of the particulate organic carbon pool on the export of carbon deeper into the water column. Net and pump collection of zooplankton, as well as trawling for zooplanktivore fish, are also carried out at selected intervals. On some transects, an undulating platform is towed from the ship to collect samples from 0 to 400 m.

The partial pressure difference between CO_2 in the atmosphere and CO_2 in the seawater is to be measured from Greenland in the north to Antarctica in the south. The measurements around Greenland show under-saturation of CO_2 in the cold Arctic waters, especially in the fjord systems, which have a high uptake of atmospheric CO_2 due to under-saturation. The warmer waters around the equator are more or less in equilibrium with the atmosphere but upwelling zones are large emitters of CO_2. Following is an example of data obtained in an upwelling zone.

On October 13, 2006 the ship crossed the upwelling area off the coast of Namibia, where cold and nutrient-rich water comes to the surface (Figure 1). The upwelling water also has a high CO_2 content. When this water reaches the surface, the pressure drops and it is warmed by the atmosphere. Warm water can contain less CO_2 and, therefore, the emission of CO_2 is high in this region and some of the highest values ever reported of CO_2 partial pressure in the ocean ever reported (over 800 µatm) were measured in this area (Figure 2). In the “high algae concentration area” (the red area on Figure 1) we see that the partial pressure of CO_2 decreases; however, there is still an out-gassing. The decrease is probably caused by uptake of CO_2 by the large algae biomass. When the ship leaves the “high concentration algae area” (around 8.30 a.m.) the CO_2 partial pressure measured in the water decreases to below the partial pressure of the atmospheric CO_2 indicating that the ocean is taking up CO_2 (Figure 2).

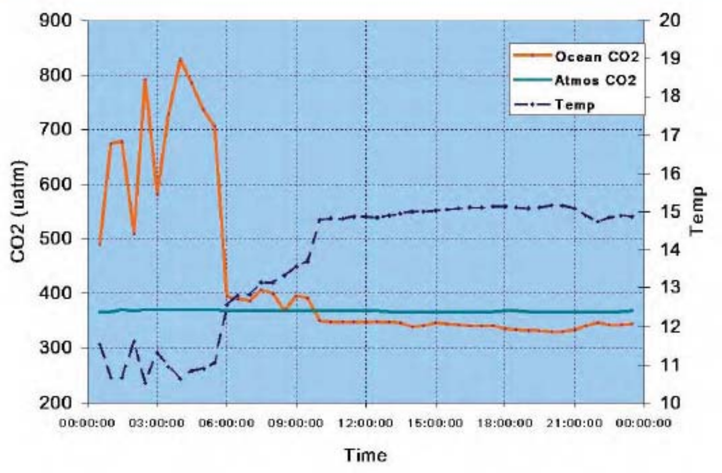

Figure 2. CO_2 partial pressure from seawater (orange), CO_2 partial pressure in the atmosphere (green) and temperature in seawater (blue) on October 13, 2006 when passing through the cold and nutrient-rich water of the upwelling area off the Namibian coast and into warmer nutrient-deplete water.

Each of the activities in the project involve expertise from research teams from various institutions, including Aarhus and Copenhagen Universities, The National Environmental Research Institute of Denmark and Risoe National Laboratory. The results from each of the activities are expected to provide new and important information related to processes influencing the cycling of carbon and the climate on Earth. However, the aim of this project is to combine and coordinate results from different scientific disciplines to develop a comprehensive understanding of the interaction between the processes involved in the carbon cycle and the spatial variability on a global scale.

For further information contact project leader, Katherine Richardson, at Richardson@biology.au.dk.

The project is financially supported by The Danish National Science Research Council, Nordea, The Villum Kann Rasmussen Fund (Denmark) and Knud Hoejgaard's Fund (Denmark).