

★ The TASIO project studies how phytoplankton such as diatoms and coccolithophorids play a part in the regulation of atmospheric carbon dioxide, which has significance to important climate change studies as **Pedro Cermeño**, the coordinator of the project explains

The role of phytoplankton in the carbon cycle

Phytoplankton have evolved over many millions of years, interacting with other organisms to produce a great diversity of life-forms. This group is central to the oceans' ecological and biogeochemical services, as they constitute the basis of the marine food web and in addition are major drivers in the cycling of elements. Of particular interest to the Tasio project (Taxonomic composition and cell size of marine phytoplankton) are diatoms and coccolithophorids, which play key roles in the regulation of atmospheric carbon dioxide. Carbon uptake by phytoplankton, and its export as organic matter to the ocean interior (a mechanism known as the 'biological pump') lowers the partial pressure of CO₂ in the upper waters and facilitates the diffusive drawdown of atmospheric CO₂. However, precipitation of calcium carbonate by coccolithophorids increases the partial pressure of CO₂ and promotes outgassing from the ocean to the atmosphere (known as the 'alkalinity pump'). While these carbon fluxes have been, over the past 100 million years, modulated by the abundance of diatoms and coccolithophorids, resulting in biological feedback on atmospheric CO₂ and Earth's climate, the processes which determine the distribution of these phytoplankton groups remain poorly understood. "The objective of the Tasio project was to understand the mechanisms that control the distribution of phytoplankton in the oceans and its impact in the regulation of atmospheric CO₂ levels," said Tasio research scientist Pedro Cermeño.

"We were interested in mechanisms that control the distribution of phytoplankton in the ocean. This required us looking at the geographic distributions of two main groups of phytoplankton, the diatoms and coccolithophorids. These two groups are particularly important because they contribute a lot to the export of organic

carbon into the deep ocean. Phytoplankton take CO₂ up in the surface ocean to produce organic carbon through the process of photosynthesis. In the contemporaneous ocean, they are responsible for roughly half of the total carbon fixation on Earth. Part of this carbon is sequestered into the deep ocean

phytoplankton and their role in the carbon cycle. The team then applied a diagnostic analysis to a coupled atmosphere-ocean general circulation model to make projections about the response of diatoms and coccolithophorids in the next century and their potential impact on the sequestration of

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for quite long periods. In this way phytoplankton contribute to the regulation of atmospheric CO₂ and therefore the climate.”

Phytoplankton and the carbon cycle

The Tasio project's research analysed phytoplankton community composition across four latitudinal transects in the Atlantic Ocean to look at the processes controlling the biogeographic distributions of

atmospheric carbon. "In the first part of the project, we were working with data we already had from a database in the Atlantic ocean," said Pedro Cermeño. "Every year British scientists undertake Antarctic surveys. They take advantage of their ships' passage to and from Antarctica to conduct different experiments in the Atlantic ocean, creating an excellent database of phytoplankton community composition.

"They created this database and we used it

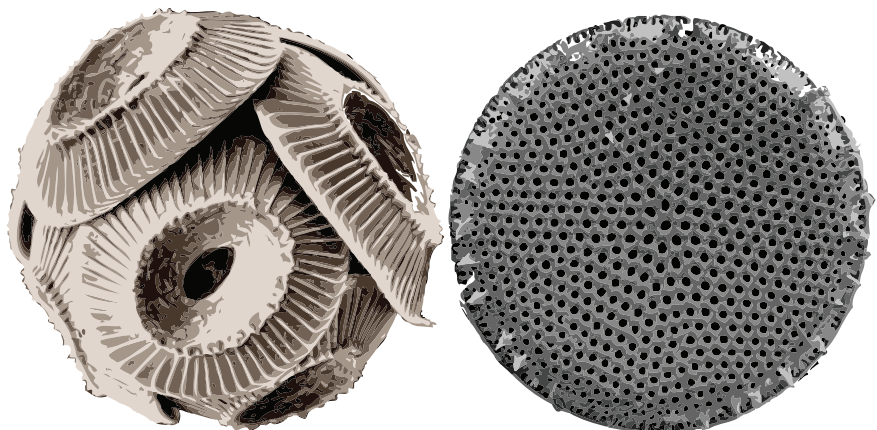
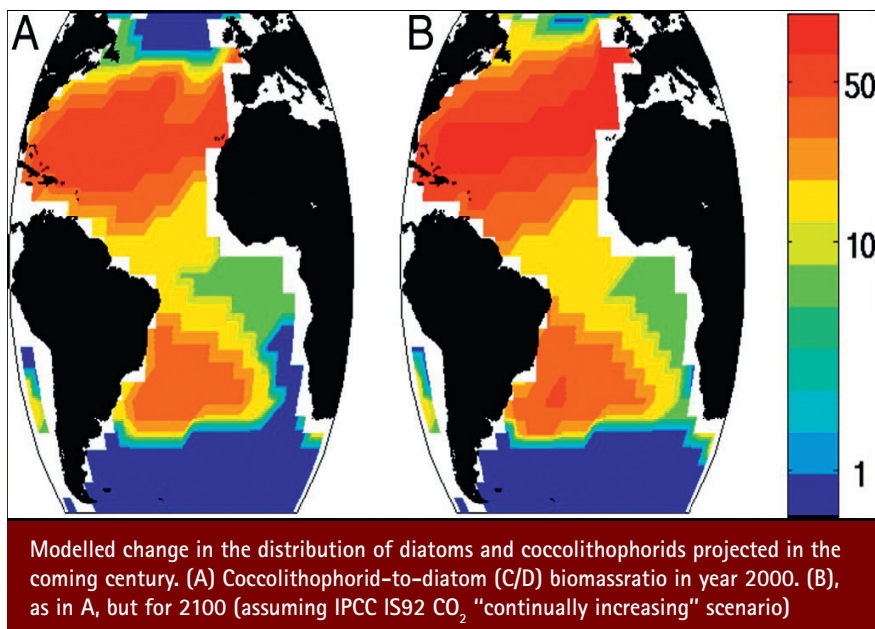


Diagram of coccolithophore (left) and the diatom (right)



to do our first analysis. What we saw was that the distribution of these two groups of phytoplankton is controlled by the rate of nutrient input to the system. If nutrients enter the upper oceans very quickly diatoms dominate, but if nutrients are supplied slowly, then coccolithophorids are selected."

Laboratory analysis showed that the distribution of phytoplankton is correlated with the injection of nutrients into the upper ocean. In nature, high latitude, temperate and upwelling systems receive substantial amounts of nutrients from deep waters via wind-driven vertical mixing, and diatoms take over. In contrast, phytoplankton inhabiting low latitude environments largely rely on slow nutrient diffusion from deep waters to sustain their standing stocks, and coccolithophorids dominate. "Strikingly, we have been able to replicate those results in the laboratory, using cultures of diatom and coccolithophore species."

When our field results were projected into the coupled atmosphere-ocean general circulation model, the project's model predicted a dramatic reduction in the nutrient supply to the photic layer as a result of increased thermal stratification. Moreover, by altering phytoplankton community composition, increased ocean stratification led to a decreased efficiency of the biological pump in sequestering atmospheric CO₂, implying a positive feedback in the climate system.

The mechanisms of regulation

Over millions of years, diatoms and coccolithophorids have responded to climatically forced changes in upper ocean

turbulence and nutrient exchange dynamics, leading to a feedback in the regulation of atmospheric CO₂ and Earth's climate. Consistent with the geological records, Tasio's results indicate that the relative distribution of diatoms and coccolithophorids is strongly dependent upon the mechanisms that supply nutrients into the upper mixed layer of the ocean. The project suggests that this mechanistic connection is the major factor responsible for the succession and domain shifts of these two phytoplankton functional groups in the ocean. If so, these taxonomic shifts, and their associated impact on net air-sea CO₂ exchange, would be linked mechanistically to the seasonal dynamics of the upper mixed layer, interannual variations in climatic forcing, contemporaneous trends in anthropogenic climate warming, and historical climate change. "The project has furthered our understanding of what mechanisms regulate the biogeography of phytoplankton in the sea," said Pedro. "There are two main mechanisms; one is dispersal with oceanic currents, which is an important mechanism because currents move phytoplankton over the ocean. The other vital factor is local environmental selection, such that the species that are better adapted to a given set of environmental conditions will dominate. The distribution of phytoplankton controls the biogeochemical cycles in the ocean and by using existing data we can predict the distribution of phytoplankton in future climatic scenarios, which has implications for our understanding of biogeochemical feedbacks in climate." ★

At a glance

Full Project Title

Taxonomic composition and cell size of marine phytoplankton (TASIO)

Project Objectives

To understand the distribution of marine phytoplankton and their role in the carbon cycle. To predict the response of diatoms and coccolithophores in a climate warming scenario.

Project Funding,

Partners and Collaborations

This research project was funded by a Marie Curie Outgoing International Fellowship within the 6th European Community framework Program (2007-2010). Emilio Marañón was the project coordinator in University of Vigo, Spain. The project was entirely developed at the Institute of Marine and Coastal Sciences, Rutgers University (USA) in collaboration with Dr Paul G. Falkowski. The modelling part of the project was developed at the Massachusetts Institute of Technology in collaboration with Drs Mick Follows and Stephanie Dutkiewicz.

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Pedro Cermeño took his undergraduate degrees in Biology and Marine Sciences at the Universities of Salamanca and Vigo, Spain. In 2006, he obtained his PhD degree in Biology at the University of Vigo, and took an appointment as Postdoctoral Associate at the Institute of Marine and Coastal Sciences, Rutgers University (USA). Currently, Pedro works as Research Scientist at the University of Vigo in marine microbial ecology and evolution.

