# ROLE OF THE OCEANS IN GLOBAL CYCLES OF CARBON AND NUTRIENTS

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## Summary

With an ever-changing climate, the globe has been warming up throughout the past 100 years, most likely a factor of greenhouse gases. The so-called greenhouse effect is in itself not a bad thing for Humans since it is a natural process that prevents the world from freezing. Afterall, without heat-absorbing greenhouse gases in the atmosphere, the average surface temperature would be 30°C colder than it is today. The problem lies in the fact that the amounts of greenhouse gases, notably $CO_2$, have been increasing markedly over the past century, due to human activities such as the burning of fossil fuels and the clearing of forests, also called deforestation, and they are continuing to rise at such a rate that they are expected to produce even more significant worldwide warming in the next century.

The oceans provide the main natural control of the heat-retaining properties of the atmosphere. Of particular importance here are the ocean processes that affect the $CO_2$ content of the atmosphere in that the oceans provide an enormous potential sink, or depository, for man-made emissions of $CO_2$. Previous changes in ocean dynamics and productivity have already had a major influence on atmospheric $CO_2$, contributing to natural climate changes in recent times.

The expertise and resources required for a worldwide investigation of such systems are beyond the research capabilities of any one nation. Effort has therefore been brought together in an international research programme: the Joint Global Ocean Flux Study (JGOFS), under the auspices of the Scientific Committee on Oceanic Research (SCOR). JGOFS is an established core project of the International Geosphere-Biosphere

Programme (IGBP), the main interdisciplinary and international framework to address the critical unknowns related to global change. The roles of carbon and associated nutrients, namely, nitrogen, phosphorus and silicon are at central stage.

## 1. Introduction

The JGOFS community has long realized that the world's oceans are the sleeping giant of carbon dioxide ($CO_2$) control. There are 20 times more carbon dissolved in seawater than found on land (in plants, animals and soil), and the release of just two per cent of that stored in the oceans would double the level of $CO_2$ in the atmosphere. Furthermore, each year around 15 times more $CO_2$ are taken up and released by natural marine processes than the total that is produced by the burning of fossil fuel, deforestation, cement production and other human activities.

The global carbon cycle is regulated by the oceans which cover around 60 per cent of the Earth's surface in the northern hemisphere and over 80 per cent in the southern hemisphere. The amounts of $CO_2$ entering and leaving the oceans over an annual cycle are usually close to a balance. However, air-sea exchanges are controlled by many different processes, and these operate over a very wide range of space and time scales, with multiple direct and indirect links to climatic factors. As a result, the effects of global warming on the individual components of the ocean carbon cycle vary greatly in terms of phasing and magnitude, affecting the potential for significant ocean-atmosphere feedback interactions. Depending on the availability of $CO_2$, these feedback mechanisms could either speed up or slow down temperature changes until a new equilibrium is established.

Ocean circulation patterns and other physico-chemical conditions, such as temperature and wind speed, govern $CO_2$ solubility, gas transfer rates across the sea surface and the bulk transport of carbon within the oceans. Superimposed on, and strongly influenced by, these effects are two basic biological processes: carbon fixation by photosynthesis, whereby plants use $CO_2$ and solar energy to produce complex organic compounds, and $CO_2$ release through respiration, whereby the breakdown of organic materials provides metabolic energy transfers which are essential for life.

Photosynthesis is limited to the sunlit, upper ocean while respiration occurs throughout the water column. The organisms involved in the latter are mostly near-invisible. Several million phytoplankton, bacteria, protozoa and other forms of life, unseen except with a microscope inhabit a simple glass of water scooped from any ocean. Yet together, such species have changed the Earth: over geological periods of time, marine plankton have been responsible for the vast accumulation of carbon in the oceans and in sediments and accountable for the heat budget of the planet, too. These drifting microscopic plants that provide the primary link between ocean biology and the atmosphere release oxygen into the atmosphere, making the Earth habitable for animals.

The role of the continental margins is particularly important in the transfer of materials, including carbon (C), nitrogen (N) and phosphorus (P). A simple definition of continental margins is, 'those provinces of continents and of the ocean which are associated with the boundary between these two first-order features of the Earth'.

Although the continental margins occupy less than 10 per cent of the total sea surface, they are disproportionately important because they are regions of active biogeochemical interactions between land and the open sea. These regions provide a pathway for receiving, transferring and transporting large amounts of natural and anthropogenic terrigenous materials from land to the open seas. The rate of biological production of the continental margin per unit area can be several times higher than that in the open ocean, due to nutrient inputs from land, coastal upwelling, cross-shelf exchanges, and so forth. In addition, the growth of various types of marine organisms in shallow waters accounts for about half of the calcium carbonate production in the marine environment (see also , Continental Margins and Marginal Seas).

The physical and biogeochemical processes occurring in the continental margins make these regions important especially as concerns the intense air-sea exchange of $CO_2$, $N_2$, $N_2O$, $CH_4$, dimethyl sulfide (DMS) and other gases. The high biological productivity, combined with the shallow water depths of the margins and terrigenous inputs of organic matter, makes this region the site of high organic matter deposition and associated benthic remineralisation. It has been estimated that up to 50 per cent of the annual primary production of the continental margins may reach the sea floor, where much of it is remineralised in a reduced, anoxic, sediment environment. This is very different from what takes place in the open waters where less than one per cent of the primary production reaches the sea floor. Sedimentary processes are markedly different from water column processes and thus can greatly affect chemical mass balances in the oceans.

Further, the sediment accumulation rates on the continental margins can be orders of magnitude higher than in open ocean regions. Therefore, locally, especially in basins with anoxic bottom water, these sediments may contain high resolution records of physical or biogeochemical processes that have occurred at the margins in response to variability in the environmental conditions.

Studies of coastal oceans are directly relevant to societal needs. Coastal regions are densely populated and are subject to human exploitation for space and food. These regions are responsive to environmental changes caused by natural processes and human activities (see , Continental Margins and Marginal Seas and , Role of the Oceans in the Global Climate System). Many important commercial and subsistence marine fisheries are based in the continental margins, where biological production tends to be much greater than in the open ocean. The exploitation of marine organisms by Humans results in the removal of biomass from the sea and may also have an impact on the functioning of the marine ecosystem with resulting implications for carbon fluxes.

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## Biographical Sketch

Born in Changhwa, Taiwan, on 22 April 1949, **Prof. Chen-Tung Arthur Chen**, his wife and two daughters are currently residing in Kaohsiung, where he has been Professor at the Institute of Marine Geology and Chemistry since 1986. After receiving his B.Sc. degree in Chemical Engineering from National Taiwan University in 1970, Prof. Chen was awarded his Ph.D. degree in Chemical Oceanography from the University of Miami in 1977. In the same year, he was appointed Assistant Professor in the College of Marine Sciences of Oregon State University, where he was later promoted to Associate Professor in 1981. He served as visiting professor at National Sun Yat-Sen University (NSYSU) in Kaohsiung, Taiwan, and as Chargé de recherche (CNRS), Université Pierre et Marie Curie in Paris during 1984-1985. During this period, he founded the Institute of Marine Geology at NSYSU, and served as its director until 1989 when he was made Dean of the College of Marine Sciences, a position he held until 1992.

Prof. Chen has sat on numerous international committees, including the Scientific Committee on Oceanic Research and the World Ocean Circulation Experiment. He also served as one of the executives of the Scientific Steering Committee of the Joint Global Ocean Flux Study (JGOFS) between 1992-1995. Just prior to that, he had helped to form the Joint JGOFS / LOICZ Marginal Seas Task Team in 1991, and served as its chairman until 1995. Prof. Chen is at present one of the editors of *Oceanography Journal* and associate editor of *Marine Chemistry*. Besides having more than 150 of his own scientific papers published, Professor Chen was awarded the highly-coveted Biowako Prize for Ecology from Japan in 1997.