SCIENCE ON BOARD SEDNA IV

Combined Effects of Ultraviolet B Radiation, Increased CO_2 and Climate Warming on the Biological Pump: A Temporal and Latitudinal Study

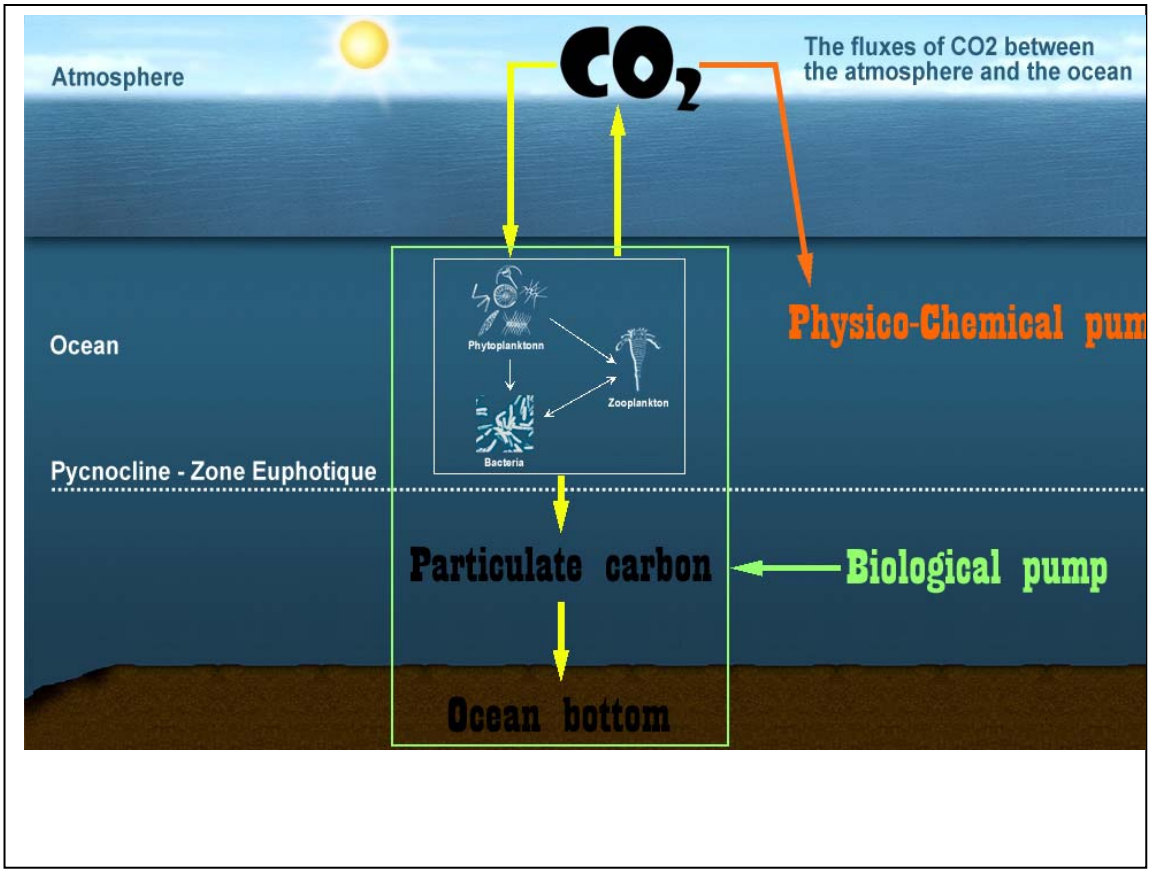
The *Sedna IV* Antarctic Mission is not only a well-known, worldwide, way to show the effects of global climate change to the general public through the media. This mission also represents an excellent and unique platform for development of scientific research. In addition to the study on human isolation, developed in collaboration with NASA and the University of British Columbia, a multidisciplinary, international study is presently taking place on board *Sedna IV*, as well as in the nearby Melchior Station.

Melchior is a former Argentine Antarctic field station, located on Observatory Island, 64°19.53’ S and 62°58.64’ W. Managed by the Argentine Navy, it was first opened on 31 March 1947 and remained operational during the summer for many years. The station was finally closed during the 1997–98 Antarctic season. Access to this station is part of Argentina’s much appreciated contribution to this program.

The Scientific Problem

Despite documented natural long-term cycles in concentrations of atmospheric CO_2, it is now widely accepted that the contemporary large and rapid increase of this gas is largely a result of human activity. CO_2 is considered to be one of the primary greenhouse gases of human origin causing climate warming, followed by methane, halocarbons, and nitrous oxide. Oceans play a key role in CO_2 dynamics. Recent estimates for the period from 1800 through 1994 show that the ocean sink of CO_2 represents ~48 % of human-generated fossil carbon burning and cement making emissions. Man-made emissions of CO_2 supposedly lead to increased flux of CO_2 between the atmosphere and the ocean. Physical processes partly control the fluxes of CO_2 between the atmosphere and the ocean. However, once in the upper layer of the water column, a significant fraction of this gas is fixed by plant photosynthesis, reaching ~45 Gigatons of carbon per year, of which ~16 is estimated to be exported to the deep ocean where it is immobilized

The main interest of the research program is the study of the biological incorporation of CO_2 into the water column, as well as cycling and export of carbon to the bottom of the ocean, a process known as the **biological pump**. This process is basically controlled by the balance of two key mechanisms: *photosynthesis* and *respiration*.



Photosynthesis is the process used by certain organisms to transform inorganic carbon (in the form of CO_2) into organic carbon. It occurs exclusively at depths reached by light, defined as the “euphotic zone.” This process is limited to plants, from microscopic (phytoplankton) to macroscopic (marcoalgae), and requires access to nutrient salts.

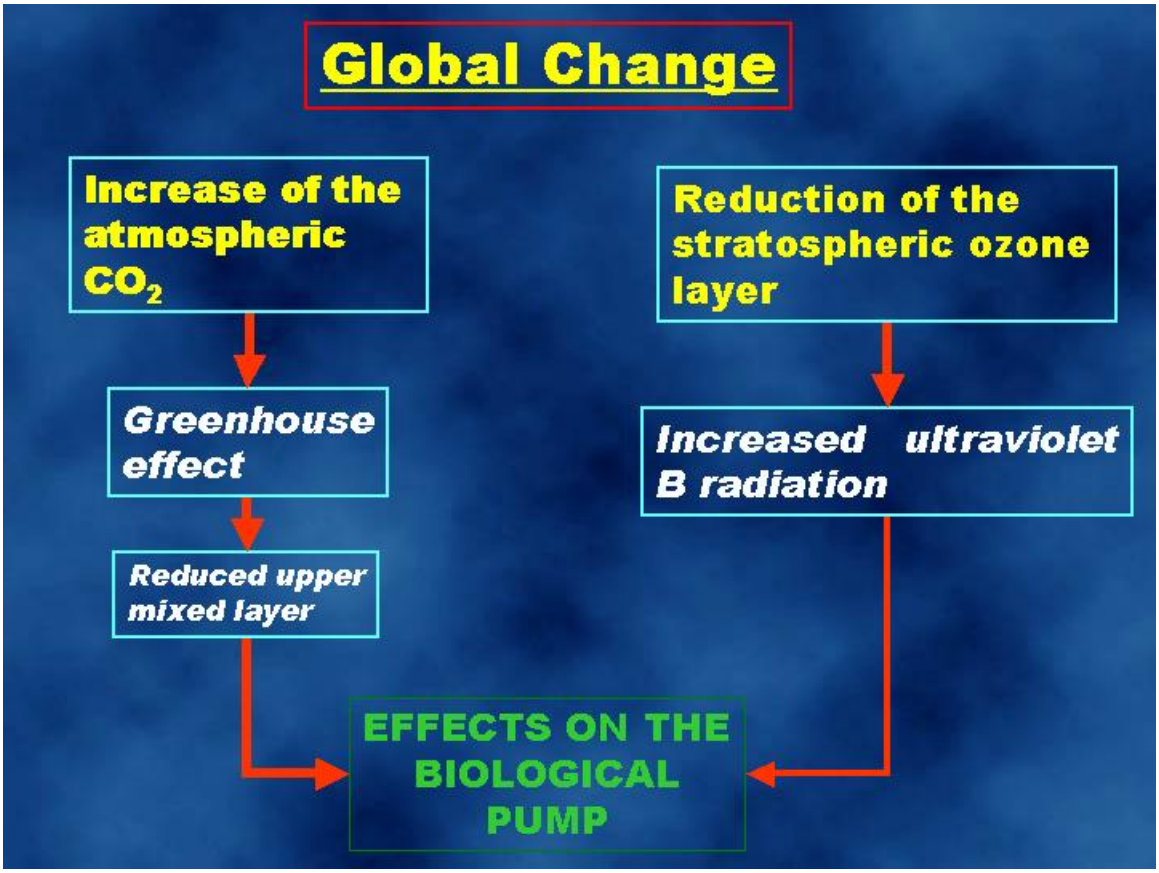
In contrast, *respiration* is a process that involves both plants and all consumers (from the smallest bacteria to the largest animals) throughout the water column.

Whether these two processes are balanced or not on the global ocean scale is still under debate. At present, several issues are the topic of great concern for the international scientific community. Among these issues are variations in CO_2 fluxes, such as the exchange of this gas between the atmosphere and the ocean; the effects of climate warming on the planet and ultraviolet B radiation (UVBR, 280-320 nm), which strongly influences photosynthesis and respiration in the upper layer of the oceans.

As it is well known UVBR, which is highly harmful for living organisms, has increased during the last decades due to the destruction of the stratospheric ozone layer, mainly in Polar regions. On the other hand, the increase of CO_2 levels in the atmosphere has contributed to the global rise of Earth’s temperatures.

The combined influence that increased UVBR and climate change will have on marine plankton communities is still unknown. This could modify the dynamics of carbon fluxes between the ocean surface waters and the deep ocean. These carbon fluxes depend not only on physical and chemical characteristics of seawater, but also on biological factors, namely the types of plankton communities present.

The present research project will study the combined effects of climate warming, the increase of CO_2 and UVBR on the planktonic community, as well as how the modifications that could result in the planktonic system will affect atmosphere-ocean CO_2 fluxes and export to the bottom of the ocean (the "*biological pump*").



Planktonic organisms, particularly photosynthetic ones, are found at relatively shallow depths, due to water column density stratification. Warmer and fresher waters lie over colder and saltier waters, generating a density gradient which is called a *pycnocline*. Pycnoclines limit the exchanges of small organisms, gases and chemical substances between both layers of water. Physical factors like winds mix the water above the pycnocline, thus forming an *upper mixed layer*.

Global warming is expected to reduce the average depth of the upper mixed layer, hence increasing the degree of exposure of the plankton community to UVBR. Therefore, the central questions to be answered through this research are:

(1) What will be the response of the *biological pump* on a global scale in a scenario of higher exposure to UVBR combined with global warming?

(2) Do we expect significant changes in CO_2 fluxes between the atmosphere and the ocean related to changes in the plankton community?

(3) What would be the magnitude of these changes, and the possible consequences for the rest of the marine ecosystem?

Field and Laboratory Work

In order to carry out this project, several research procedures are being conducted to obtain field and experimental data. These include keeping continuous records of environmental variables, such as visible and ultraviolet radiation at sea surface and vertical profiles of these variables in the water column, together with salinity and temperature profiles. Water samples are taken at specific depths and intervals both in the field and during mesocosm experiments. Mesocosms are parcels of the water column contained in large enclosures, usually larger than 1 m^3, which are considered to represent the characteristics of the natural systems under study.

These samples will be used to study a series of key variables: plankton composition and abundance, photosynthetic pigments, photosynthesis and respiration, photoprotective substances, water chemistry, particulate organic carbon (POC), particulate organic nitrogen (PON) and also the synergic effects of pollutants such as hydrocarbons. Several of these parameters will be monitored, once we are back in Canada, through highly complex equipment (HPLC, flow cytometer, etc.).

Finally, all the collected data will be integrated into mathematical models that will contribute to explaining the processes studied, as well as being a basis to describe possible future global change scenarios.

The general project is formed by five different fieldwork missions, starting with the SEDNA IV field mission. The research is divided in the following parts:

2005-2006-2007

Two latitudinal studies along inter-hemispheric Atlantic transects, based on samples taken along the course of the *Sedna IV* between Canada and Antarctica (already accomplished) and during its voyage back to Canada. One time-series study collecting samples and analyzing parameters during the wintering-over period at Melchior.

2007

A scientific cruise in winter 2007 on board the icebreaker A.R.A. Almirante Irízar (DNA-IAA) to study the dynamics of the biological pump in the Western Antarctic Peninsula and Northern Weddell Sea.

A mesocosms experiment at Melchior station (DNA-IAA) in December 2007 to study the effects of ultraviolet radiation and increased temperature on the biological pump.

A scientific cruise in January 2007 on board the Argentine oceanographic ship A.R.A. Puerto Deseado (DNA-IAA) in the area of the Western Antarctic Peninsula.

2008

A second mesocosms experiment in August 2008, similar to the one performed at Melchior in 2007, conducted in the Arctic at the Whapmagoostui-Kuujjuarapik Research Station (55° 17' N, 77° 46' W, Centre d'Études Nordiques, Université Laval).

The project is scheduled to be finished by the end of 2009. Five doctoral theses, several publications in specialized journals and presentations to scientific meetings are expected for that timeframe. The results will contribute to obtaining more knowledge about this issue, which is of general concern and will also raise the awareness of the general public regarding the protection of the planet.

Institutions

This project was made possible by the collaboration between Canadian and Argentine government agencies. This international collaboration began in 2001 between the *Université du Québec à Rimouski - Institut des Sciences de la mer de Rimouski* (UQAR-ISMER, http://www.uqar.qc.ca/campusRimouski/index.asp //) from Canada and the *Dirección Nacional del Antártico-Instituto Antártico Argentino* (DNA-IAA, http://www.dna.gov.ar/) from Argentina.

Three scientific institutions are part of this project: IAA, ISMER and the University of Victoria (http://www.uvic.ca). This is an International Polar Year project.

Funding

In Canada, the *Natural Sciences and Engineering Research Council* (NSERC), the *Ministère du Développement économique, de l'Innovation et de l'Exportation du Québec* (MDEIE) and *Développement Économique Canada* (DEC), granted the financial support for scientific activities and human resources.

Argentina provided the logistical support coordinated by DNA-IAA. This support included transportation of cargo and personnel from Argentina with Air Force aircraft to Marambio station at the northern tip of the Antarctic Peninsula (64°14'42"S 56°39'25"W). Also, the transfer to the icebreaker A.R.A. Almirante Irízar from the Argentine Navy by helicopter, as well as transfer of crewmembers to *Sedna IV* at Melchior in March 2006. In February 2006, the icebreaker delivered fuel and food to *Sedna IV* for the winter. Meanwhile, Navy personnel took care of repairs and maintenance of the Melchior facility, to be used as a field laboratory. The USA National Science Foundation (http://www.nsf.gov/) with the use of its icebreaker R/V Laurence M. Gould, generously transported an important part of the scientific cargo after a request by the DNA-IAA.

Last but not least, a major asset to the scientific project during the winter is the support from the *Sedna IV* crew. They provide not only supplies and a work force, but also companionship for the scientists on board.

Scientific Team

This is a multidisciplinary project, integrating physical, chemical and biological oceanographers. The team consists of a project leader, one scientific coordinator, five principal investigators, one research collaborator, two post-doctoral researchers and one doctoral student. Four additional doctoral students (from both Canada and Argentina) will be recruited in 2006 to complete the team, which will participate in the other parts of the project.

One of the Post-Doctoral researchers (Damián López) and the Doctoral student (Sébastien Roy) are presently in Antarctica as part of the wintering-over program at Melchior and on board the *Sedna IV*. The research group has extensive experience in ultraviolet radiation research, with a significant number of refereed publications in international journals. The participants of the project are:

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