SIBClim - Sea Ice Biogeochemistry in a Climate Change Perspective

A comparative study and modeling of biogeochemical cycles (C, N, P, Si, Fe, S) in Arctic and Antarctic sea ice, assessing their impact on CO_2 exchange and DMS emission at the ocean-atmosphere interface of polar seas

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PROJECT SUMMARY

This present research aims to assess to which extent ice-covered polar oceans contribute to processes regulating the Earth's climate. It involves a new multidisciplinary consortium combining the required expertise of glaciologists, biologists, geochemists and ecosystem-modelers of the Université Libre de Bruxelles (ULB).

The main goal of the project is to study, to understand and to quantify the physical and biogeochemical sea ice associated processes that govern the emissions of marine gases of climatic significance. These processes are indeed presently unknown and therefore not considered in Oceanic Biogeochemical Climate Models (OBCMs). In this context, particular attention will be paid to Carbon Dioxide (CO_2) and Dimethyl Sulphide (DMS), both actively involved in the sea ice microbial metabolism. On a global level, CO_2 is well known for its efficient greenhouse gas behavior, while DMS has the recognized potential to stabilize the climate against warming by controlling the incident solar energy *via* the production of aerosols and cloud condensation nuclei. It has now been demonstrated that iron can play a crucial role in controlling phytoplanktonic productivity and the biological carbon pump in the Southern Ocean. This iron limitation remains to be assessed for the Arctic Ocean. The work programme will thus focus on the biogeochemical cycle of iron (origin, bio-availability and fate) in the sea ice environment and its interactions with the carbon and sulphur cycling. The geographical domain will include, for comparison, both the Arctic and the Antarctic oceans where the mechanisms controlling the carbon production and the relative importance of anthropogenic and marine sulphur compounds in cloud formation processes are quite contrasted.

The research methodology will be interdisciplinary and combine field investigations, process-oriented studies both "in situ" and in the laboratory, and modeling work in order to quantify key biological, geochemical and physical interactions between sea ice, the ocean and the atmosphere and to elucidate the controlling mechanisms. Cores collected during field surveys will be used to characterize the distribution of Fe, CO_2, DMS and other related physico-chemical and biological parameters in sea ice. Chemical transformation of iron during melting of sea ice and the associated biological and chemical processes will also be studied in the field. Investigations on the mechanisms regulating iron bio-availability and on the iron isotopes bio-signature will be conducted under laboratory-controlled conditions on cultures of polar micro-organisms. This research will involve the development of new methodologies including, for example, extraction and gas chromatography for determination of gaseous DMS and multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS) for iron isotope analyses.

Modeling effort will involve the development of a new biogeochemical model describing the interactions between the C, N, P, Si, Fe, S cycles in sea ice (SIMCO). Its parameterization will rely on the results obtained during process studies described above. The online coupling of the SIMCO model with the existing, and currently being improved, model for the surface water of the Southern Ocean (SWAMCO) will allow us to assess CO_2 and DMS fluxes between the ocean and the atmosphere in polar oceans. The resulting ice-ocean model would then be available to the scientific community for further implementation of Ice-Oceanic Biogeochemical Climate Models.

The long-standing experience of each partner involved in this project makes it an ideal combination to unravel the complex interplay of physical, chemical and biological processes in evolving sea ice, and to evaluate their potential impact on climatic changes.

GENERAL OBJECTIVE

This research focuses on carbon, iron and sulphur biogeochemical interactions between sea-ice, ocean and atmosphere and their controlling mechanisms. The main goal is to assess the role of ice-covered regions of the northern and southern polar oceans in regulating the earth's climate through these various processes.

SPECIFIC OBJECTIVES

The research methodology involves and combines the following items which are the specific objectives of the research project:

1. Quantify the importance and pathways of terrigenous iron deposition and storage in pack and landfast sea ice by measuring trace elements in ice cores from both the Arctic and the Antarctic.

2. Develop and calibrate an operational technique for gaseous DMS measurements in sea ice, combining dry-extraction, helium trapping and gas chromatography techniques.

3. Assess relationships between the different chemical forms of iron, DMS (+DMSP), inorganic and organic nutrients, microbial communities and the ice physical properties in pack (seasonal) and landfast (coastal) sea ice cores from both the Arctic and the Antarctic.

4. Evaluate the level of bioavailability of terrigenous iron in sea ice by performing laboratory-controlled process studies simulating sea-ice formation and melting. These will combine dissolution kinetics with estimates of iron physiological uptake based on radioactive tracers using various algal communities.

5. Develop and apply novel multi-collector inductively coupled plasma mass spectrometry techniques (MC-ICP-MS) on algal cultures and natural samples to explore the feasibility of using stable isotopes of iron to trace its origin and evolution in the trophic chain after initial incorporation into ice micro-algae.

6. Measure *in situ* the evolution of physical, chemical (including photochemical) and biological properties of sea ice on melting, both in the Arctic and in the Antarctic during international polar expeditions.

7. Elaborate a mathematical model describing the biogeochemical cycles of C, N, P, Si, Fe and S in sea ice and the CO_2 and DMS exchanges with the atmosphere and the ocean and calibrate it in the Southern Ocean.

PARTNERSHIP

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Delphine LANNUZEL (Ph.D. grant recipient)
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WORK CONTENT

The present research consists of the following WorkPackages (WPs) and tasks:

WP1: Distribution of Fe, CO_2, DMS and other related physico-chemical and biological parameters in natural sea ice

Task 1.1: Field sea ice cores database acquisition (GLACIOL)
Task 1.2: Physico-chemical measurements (GLACIOL, LOCGE)
Task 1.3: Microbial communities: biodiversity and viability (ESA)

WP2: Laboratory-controlled study of mechanisms regulating iron bio-availability (cultures and sea ice tank experiments)

Task 2.1: Study of the mechanisms and kinetics of iron dissolution (LOCGE)
Task 2.2: Speciation of iron in sea ice pores and surface sea water (LOCGE)
Task 2.3: Fate of dissolved iron (ESA)

WP3: Origin and biological pathway of iron in natural sea ice through isotopic signature

Task 3.1: Analytical development (LOCGE)
Task 3.2: Iron isotopes bio-signature (LOCGE, ESA)
Task 3.3: Iron isotopes signature from source to sink (LOCGE)

WP4: Field study of iron, sulphur and biological interactions during the process of ice melting

Task 4.1: Chemical transformation of iron upon melting (LOCGE)
Task 4.2: Microbial processes (including biological uptake of iron and release of DMSP and its subsequent transformation in DMS) upon ice melting (ESA, GLACIOL)

WP5: Coupled ice-ocean biogeochemical model

Task 5.1: Implementation of the biogeochemical model for sea ice: SIMCO (ESA)
Task 5.2: Online coupling of SIMCO to SWAMCO (biogeochemical model for the Southern Ocean upper layer) (ESA)
Task 5.3: Model calibration and validation (ESA)

Field Study Site

Chemical transformation of iron upon ice melting and the associated biological and chemical processes will be studied in the field during two polar expeditions:

- The sea-ice covered area at the limit of Chuchki and Beaufort Sea in the Arctic ocean, as part of the research program at Point Barrow, planned in 2005, under invitation of Dr. H. Eicken and Dr. M. Jeffries (University of Alaska, Fairbanks).
- The drifting sea-ice station ISPOL-1 (icebreaker RV Polarstern anchored to a sea ice floe) in the Central-Western Weddell Sea (60°S, 40°W) planned in austral spring 2003, under invitation of Dr. G. Dieckmann (Alfred Wegener Institute, Germany).