

INTERNATIONAL COLLOQUIUM CLIMATE CHANGE IN MAGELLAN
AND ANTARCTIC REGIONS: EVIDENCE AND CHALLENGES FOR
THE FUTURE SESSION 3. RESEARCH HIGHLIGHTS FROM THE
CHILEAN FJORDS: WATER COLUMN AND SEDIMENTS

COLOQUIO INTERNACIONAL DEL CAMBIO CLIMÁTICO EN LAS REGIONES MAGALLANES
Y ANTÁRTICA: PRUEBAS Y RETOS PARA EL FUTURO. SESIÓN 3. INVESTIGACIONES
DESTACADAS DE LOS FIORDOS CHILENOS: COLUMNA DE AGUA Y SEDIMENTOS

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The Chilean fjords, located between 41° and 56° S, cover an area of roughly 241,000 km² characterized by an extensive coast line composed by a large number of islands, fjords, sounds, basins and gulfs which were formed by glacial erosion during the Quaternary and tectonic sinking of the central Chilean valley. The complex topography limits or controls the exchange of waters between coastal regions and the open ocean, creating micro-environments with oceanographic conditions that sustain unique ecosystems. These are characterized by complex marine–terrestrial–atmospheric interactions that result in high biological production. Strong seasonal climatic changes (e.g. solar radiation, wind, and precipitation) as well as different physical regimens (mixing and/or stability of the water column) impose an external influence on phytoplankton biomass, primary production, and species composition. Diatoms are the most frequent and abundant group year-round, dinoflagellates are only important on some occasions when they form blooms, and nanoflagellates have the highest abundances in summer and autumn in the most southern area. Thus, high spatial and temporal heterogeneity of phytoplankton assemblages exists.

The fjord region lies mostly under the influence of the main Southern Hemisphere atmospheric circulation pattern, the Southern Westerlies, which in turn, are closely linked to changes within the tropical climate system and climate conditions in coastal Antarctica. High annual rainfall in the fjord region (1,000–7,000 mm year⁻¹) and high mean annual river discharges (~2,500–3,500 m³ s⁻¹) greatly enhance the supply of terrigenous sediment which leaves its mark in the sedimentary record. The river regimen varies with latitude, and three kinds of regimens can be found, i.e. winter-centered pluvial (to the north of 43° S), summer-centered nival (to the south of 47° S), and mixed pluvial-nival (43°–47° S).

A typical estuarine circulation pattern characterizes the area, determined by an offshore surface flow of freshwater over an onshore flow of oceanic water. The surface freshwater layer separates from the marine layer by a strong pycnocline, resulting in overlapping brackish and marine characteristics in the fjord ecosystem. The productivity of the Chilean fjords is influenced by the combined effect of important contributions of dissolved silicon from freshwater discharge (river runoff and glacial melting)

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as well as the vertical entrainment of Subantarctic Water loaded with macronutrients (nitrate and orthophosphate) from the adjacent oceanic area.

The sediments in the fjord region accumulate at high sedimentation rates (up to 0.8 cm yr⁻¹, at the sediment surface). The terrigenous organic matter content in the sediments increases from the oceanic area to the heads of the fjords due to local river discharges. Sediments influenced by glaciers have very low organic matter due to dilution by the large amounts of inorganic matter contributed by glaciers. Both freshwater and marine microfossils are abundant in sediment cores, allowing assessment of variability in freshwater input through time which in turn is tied to precipitation on land and river runoff into the fjords.

Most of the oceanographic information for the Chilean fjords and channels (from Puerto Montt at 42°S to Cape Horn at 56°S) comes from the CIMAR Program (Cruceros de Investigación Marina en Áreas Remotas; Marine Research Cruises in Remote Areas). This is an ongoing program of the Comité Oceanográfico Nacional (CONA; National Oceanographic Committee) which started with its first cruise in 1995. In all CIMAR cruises, the water column and the surface sediments were sampled intensively, and in some occasions sediment cores were also collected. This yielded a large database on the physical (temperature, salinity, light penetration, currents, tides), chemical (dissolved oxygen, nutrients), and biological (phytoplankton, chlorophyll-a, zooplankton, red tides) characteristics of the water column, and characterization of the sediments in terms grain size, porosity, carbon, nitrogen, trace metals, stable and radioactive isotopes, and organic components. In the past six years several international cruises have taken place in the Chilean fjords and adjacent oceanic area, aimed at the recovery of high-resolution long sediment cores that encompass the time period since the Last Glacial Maximum: JAMSTEC Beagle expedition 2003; Palmer cruise NBP0505 2005; PACHIDERME cruise 2007; and Mirai MR08-06 leg 2 in 2009 which also included present-day observations of water column chemistry and biology, and pelagic-benthic coupling.

In this talk I will present data from ongoing research in the Chilean fjords and adjacent oceanic area, including the water column and the sediments. Some of the themes I will address include: 1) Sea-

sonal changes in marine primary production; 2) Fjords as sinks of CO₂; 3) Recent shifts in spawning areas of southern hake and anchovy; 4) Fluctuations (present and past) in temperature, precipitation and river discharges into the Inner Sea of Chiloé and Northern Patagonia fjord system, and their impact on biological productivity and phytoplankton species composition; 5) Temperature evolution from high-resolution marine sediment cores from Southern Patagonia and the Strait of Magellan; and 6) Holocene storm track record from Lake Tamar.

Challenges

Intense use of the area began in the 1980s with activities related to aquaculture, fisheries, tourism, and human settlements. Aquaculture is one of the activities that has experienced largest growth and development in the last decade, especially in Regions X (De los Lagos, 39°15'–44°04' S) and XI (Aysén, 43°38'–49°16' S). Salmon farming is one of the most important export commodities of the country. This activity may generate accumulation of organic matter promoting exhaustion of oxygen, change of natural nutrient cycles, methanogenesis and sulfide production, thus altering the chemical composition of the sediments and the ecological structure of the macrobenthos.

The southern region of the Chilean fjords contains enormous potential, including fresh water reserves of worldwide importance such as the Patagonian Ice Fields: the Northern Patagonian Icefield (NPI, 46–47° S), Southern Patagonian Icefield (SPI, 48–52° S), and the Darwin Mountains Icefield in Tierra del Fuego (DMI, 54–55° S). These notable volumes of pristine waters are associated with an enormous hydroelectric potential that has become an attractive asset inciting investment by energy-generating companies in the region. Nevertheless, possible environmental damages associated with inappropriate management of the affected ecosystems can result in environmental liabilities incompatible with sustainable development of the region. A suitable understanding of the oceanic and climate conditions and the capacity to forecast these are key elements for strengthening the increasing development of this region. Consequently, the growth projected for aquaculture and the fishing industry (artisanal and industrial) as well as possible interventions related

to the hydroelectric potential of the Patagonia necessitates studies of the highest scientific/technical level in order to meet the new challenges. In this context, it is vital for science and technology to position themselves with *long-term monitoring programs* (as the COPAS Sur-Austral program) in crucial areas for these unique ecosystems and, in turn, with potential risks for projections of intensive use by activities such as aquaculture, mining, and energy.

Some problems and threats identified are:

- Ignorance of the fragility, resilience, and load capacity of the ecosystems given anthropogenic pressure and global change
- Ignorance of the relative importance of species, habitat, and priority areas for implementing effective protective plans for the zone's biodiversity
- Limited forecasting of changes in the distribution and abundance of fishing resources
- Limited forecasting of the cyclic patterns and prevailing tendencies in terms of the availability and quality of the hydric resources
- Limited use of relevant scientific information in the decision-making processes of both the public and productive sectors. Poor communication between the generators of information (scientists) and social and/or productive actors
- Ignorance of the zone and its marine ecosystems on the part of the productive sector, resulting in lost opportunities for orderly and sustainable development.

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