

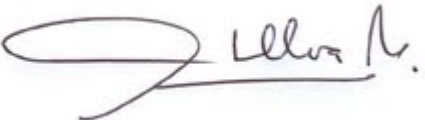



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1.1 Executive Summary

Chile is on the southeastern border of the Pacific Ocean, the largest biome on the planet. The Pacific accounts for most of the biological production in the oceans, which in turn represents half of the total primary production on Earth. The Pacific is also the largest ocean basin, and its circulation is a major controlling element of global climate. Grand ocean-atmosphere dynamics in the Pacific, such as the warm El Niño and cold La Niña alternation, particularly cause substantial changes in ecosystem structure and functioning in the Eastern South Pacific (ESP), but also have global ecological and economic impacts. Ongoing climate change is becoming apparent, with potentially major consequences on ecosystems, socio-economic systems, food availability, human health, and even governance. Chile, as a Pacific rim country, will be particularly susceptible to these changes, yet the ESP region is still much less explored and understood than the rest of the Pacific.

An integrated scientific view of the processes that drive short and long-term changes in the structure and functioning of marine ecosystems in the ESP is at the core of the Millennium Institute of Oceanography (IMO). IMO particularly seeks to help place Chilean science at the forefront of understanding the ESP. IMO is organized around four interconnected research lines each with ambitious goals:

- 1) Mesoscale processes: To characterize physical mesoscale (and sub-mesoscale) structures and processes in the ESP and their impact on open-ocean and transitional (coast-ocean) ecosystems;
- 2) Ocean variability: To determine how large-scale perturbations impact the transport and gradients in physical-chemical water properties and the dynamics of the ESP;
- 3) Adaptations to a changing ocean: To gain new understanding about the adaptations of key planktonic groups to chemical changes taking place in the ocean (e.g. acidification, deoxygenation, desertification) and the impact of such changes on biogeochemical cycling;
- 4) The deep ocean: To explore the pelagic environment of the deep and ultra-deep ocean.

IMO scientists include ecologists, microbiologists, physical oceanographers, chemical oceanographers, biological oceanographers, ecosystem modelers, science-outreach specialists, and special equipment-developers. A network of scientific collaborators provides a strong support to IMO research, understanding the global context of our themes. During 2016, IMO included 25 researchers in different categories, 13 postdocs, 43 undergraduate and graduate students, up to 24 research technicians, and 4 administrative staff. Funding sources used for IMO came from ICM (45%) and increasing share has come from externally funded projects secured by IMO researchers, including national (e.g. FONDECYT, FIP, CIMAR) and international funding agencies (The Agouron Institute, the Gordon and Betty Moore Foundation - Marine Microbiology Initiative) (55%), not including individual grants or external fellowships to postdocs and students.

During 2016, IMO led one major national oceanographic cruise, participated in a leading role in a second large scale expedition, executed two time series, and provided the essential personnel and equipment for a third research cruise convened as an emergency response by the Chilean government:

- IMO researchers conducted the MOPEX cruise to characterize mesoscale and sub-mesoscale activity in the coastal upwelling zone and coastal transition zone (CTZ) off Valparaíso. This represents the second iteration of one of the major field expeditions the IMO committed to in its founding.
- IMO played a lead role, including providing the essential oceanographic equipment, for the CIMAR-22 cruise, in collaboration the Chilean National Commission of Oceanography (CONA) and other Chilean institutions. The cruise investigated the region between the Chilean coast and the oceanic Desventuradas Islands and the Juan Fernandez Archipelago.

- IMO operated two long-term studies, one coastal (off Valparaíso) and one oceanic using moorings (in the Juan Fernández Archipelago)
- In May of 2016, the Chilean Government convened an emergency scientific commission to study the devastating toxic algal bloom in front of Chile. While this theme was outside of IMO's research lines, the IMO responded by providing all essential oceanographic equipment and highly trained personnel to facilitate this effort, in the REDTIDE cruise to the coast of Chiloé. This demonstrates IMO's commitment and capability to respond rapidly to support other marine science in Chile.
- An IMO researcher participated in a major international oceanographic cruise (Polar Stern N° 97) to the far south Pacific, to study the Cape Horn Current.
- IMO researchers continued to conduct smaller field surveys, as well as experimental work ranging from laboratory to field scales, and advanced on processing the massive amount of samples and data obtained in the three major cruises in 2015.

Some highlights of the major achievements in each research line:

Research Line 1: We discovered that intrathermocline eddies are most important for controlling the vertical depth of the oxygen minimum zone (OMZ) in front of Chile, while internal waves and surface eddies are dominant in front of Peru.

Research Line 2: In addition to documenting changes to the South Pacific High and upwelling favorable winds, we found that the total volume of the ESP Intermediate Water has greatly expanded.

Research Line 3: We documented that local adaptation and phenotypic plasticity determine resiliency or susceptibility to ocean acidification among marine invertebrates. In phytoplankton, we found that one of the most cosmopolitan species exhibits surprisingly close, even intertwined (reticulate) phylogeny with close relatives that show restricted ecological distributions.

Research Line 4: We have succeeded in getting zooplankton net samples as deep as 3500 m and bottle samples as deep as 5200 m, showing progress in ability to regularly sample the deep sea. Deep water communities we are finding exhibit a higher diversity and biomass than would be expected for oligotrophic systems.

IMO has continued to strengthen and expand its activities in education and training. IMO continued the tradition of leading and supporting the internationally recognized course Ecology and Diversity of Marine Microorganisms (ECODIM). IMO also provided more basic courses outside of academic programs, such as an intensive R course. IMO trains from postdoc to undergraduate level. In 2016, IMO hosted 13 postdocs, two receiving full IMO support while the rest received external grants. Directly participating in IMO were 14 PhD students, 20 M.Sc. students, and 8 undergraduates, with direct IMO scholarships provided to 1 PhD student, 7 Masters students, and 7 undergraduate students, while others received CONICYT scholarships or financing through projects of IMO researchers. As for advanced "on-the-job" field training, IMO graduate students and postdocs participated extensively in the research cruises.

IMO has continued increasing its outreach coverage and developing new activities and products. Major media advances have been the strengthening of the educational website "Sumérgete" (Submerge), expanding reach of the Muestra Audiovisual Científica Itinerante - MACI (Itinerant Scientific Audiovisual Exhibition), completion of the educational cartoon series "La Receta Científica de Tony Tonina" (Tony Tonina's Scientific Recipe), and the new TV series for the general public "Exploradores: del átomo al cosmos" (Explorers: From the atom to the cosmos) created by IMO and Fundación Ciencia y Vida in collaboration with TVN and Imago.

1.2 Resumen Ejecutivo

Chile se encuentra en la frontera sureste del Océano Pacífico, el bioma más grande del planeta. El Pacífico aporta con la mayor parte de la producción biológica en los océanos, la que a su vez representa la mitad de la producción primaria total en la Tierra. El Pacífico es también la cuenca oceánica más grande, y su circulación es un elemento importante en el control del clima global. Las grandes dinámicas océano-atmósfera en el Pacífico, como el cálido El Niño y la fría alternancia de La Niña, causan cambios sustanciales en la estructura y funcionamiento del ecosistema en el Pacífico Sur Oriental (PSO), pero también tienen impactos ecológicos y económicos globales. El cambio climático en curso se hace evidente, con consecuencias potencialmente importantes sobre los ecosistemas, los sistemas socioeconómicos, la disponibilidad de alimentos, la salud humana e incluso la gobernanza. Chile, como país del Pacífico, será particularmente susceptible a estos cambios, sin embargo, la región del PSO es todavía mucho menos explorada y entendida que el resto del Pacífico.

Una visión científica integrada de los procesos que impulsan cambios a corto y largo plazo en la estructura y el funcionamiento de los ecosistemas marinos en el ESP está en el corazón del Instituto Milenio de Oceanografía (IMO). IMO busca particularmente ayudar a colocar la ciencia chilena en la vanguardia de la comprensión de la PSO. El IMO se organiza en torno a cuatro líneas de investigación interconectadas, cada una con objetivos ambiciosos:

- 1) Procesos de mesoescala:** Caracterizar estructuras y procesos físicos de mesoescala (y sub-mesoescala) en el PSO y su impacto en ecosistemas de mar abierto y de transición (costa-océano);
- 2) Variabilidad del océano:** Determinar cómo afectan las perturbaciones a gran escala el transporte y los gradientes en las propiedades físico-químicas del agua y la dinámica del PSO;
- 3) Adaptaciones a un océano cambiante:** Obtener una nueva comprensión de las adaptaciones de los principales grupos planctónicos a los cambios químicos que tienen lugar en el océano (por ejemplo, acidificación, desoxigenación, desertificación) y el impacto de tales cambios en los ciclos biogeoquímicos;
- 4) El océano profundo:** Explorar el ambiente pelágico del océano profundo y ultra profundo.

Los científicos del IMO incluyen ecólogos, microbiólogos, oceanógrafos físicos, oceanógrafos químicos, oceanógrafos biológicos, modeladores de ecosistemas, especialistas en divulgación científica y desarrolladores de instrumental especial. Una red de colaboradores científicos proporciona un fuerte apoyo a la investigación del IMO, entendiendo el contexto global de nuestros temas. Durante el año 2016, el IMO incluyó 25 investigadores en diferentes categorías, 13 postdoctorales, 43 estudiantes de pregrado y posgrado, 24 técnicos de investigación y 4 funcionarios administrativos. Las fuentes de financiamiento para el IMO provienen de la ICM (45%) y de una creciente proporción de proyectos financiados con fondos externos obtenidos por investigadores del IMO, incluidos organismos nacionales (FONDECYT, FIP, CIMAR) y organismos internacionales de financiamiento (The Agouron Institute, Gordon y Betty Moore Foundation - Marine Microbiology Initiative) (55%), sin incluir donaciones individuales o becas externas a postdoctorales y estudiantes.

Durante el año 2016, el IMO lideró un gran crucero oceanográfico nacional, participó en un destacado papel en una segunda expedición a gran escala, ejecutó dos series de tiempo y proporcionó el personal y el equipo necesarios para un tercer crucero de investigación convocado como respuesta de emergencia por el gobierno chileno:

- Los investigadores del IMO llevaron a cabo el crucero MOPEX para caracterizar la actividad de mesoescala y sub-mesoescala en la zona costera de afloramiento y la zona de transición costera (CTZ) frente a Valparaíso. Esto representa la segunda iteración de una de las expediciones de campo principales con que el IMO se comprometió en su fundación.
- El IMO desempeñó un papel de liderazgo, incluyendo el suministro del equipo oceanográfico esencial, para el crucero CIMAR-22, en colaboración con la Comité Oceanográfico Nacional (CONA) y otras instituciones chilenas. El crucero investigó la región entre la costa chilena y las islas oceánicas Desventuradas y el Archipiélago de Juan Fernández.

- El IMO llevó a cabo dos estudios a largo plazo, uno costero (frente a Valparaíso) y otro oceánico utilizando anclajes (en el Archipiélago de Juan Fernández)
- En mayo de 2016, el Gobierno de Chile convocó una comisión científica de emergencia para estudiar la devastadora floración de algas tóxicas frente a Chile. Si bien este tema estaba fuera de las líneas de investigación del IMO, éste respondió proporcionando todo el equipo oceanográfico esencial y personal altamente capacitado para facilitar este esfuerzo, en el crucero REDTIDE a la costa de Chiloé. Esto demuestra el compromiso y la capacidad del IMO en responder rápidamente para apoyar otras ciencias marinas en Chile.
- Un investigador del IMO participó en un importante crucero oceanográfico internacional (Polar Stern N ° 97) en el extremo sur del Pacífico, para estudiar la Corriente del Cabo de Hornos.
- Los investigadores del IMO continuaron realizando estudios de campo más pequeños, así como trabajos experimentales que van desde el laboratorio hasta las escalas de terreno, y avanzaron en el procesamiento de la cantidad masiva de muestras y datos obtenidos en los tres grandes cruceros en 2015.

Algunos puntos destacados de los principales logros en cada línea de investigación:

Línea de investigación 1: Descubrimos que los remolinos intratermoclina son los más importantes para controlar la profundidad vertical de la zona mínima de oxígeno (ZMO) frente a Chile, mientras que las olas internas y remolinos de superficie son dominantes frente al Perú.

Línea de Investigación 2: Además de documentar los cambios en la Alta del Pacífico Sur y los vientos favorables a la surgencia, encontramos que el volumen total del del Agua Intermedia del PSO se ha expandido considerablemente.

Línea de Investigación 3: Documentamos que la adaptación local y la plasticidad fenotípica determinan la resiliencia o susceptibilidad a la acidificación de los océanos entre los invertebrados marinos. En el fitoplancton, encontramos que una de las especies más cosmopolitas exhibe una filogenia sorprendentemente estrecha, incluso entrelazada (reticulada) con parientes cercanos que muestran distribuciones ecológicas restringidas.

Línea de Investigación 4: Hemos logrado obtener muestras de zooplancton de hasta 3500 m de profundidad y muestras con botellas hasta 5200 m, mostrando el progreso en la capacidad de muestrear regularmente el mar profundo. Las comunidades de aguas profundas que estamos encontrando exhiben una mayor diversidad y biomasa de lo que se esperaría de los sistemas oligotróficos.

IMO ha seguido fortaleciendo y ampliando sus actividades en materia de educación y formación. IMO continuó con la tradición de dirigir y apoyar el curso internacionalmente reconocido Ecología y Diversidad de los Microorganismos Marinos (ECODIM). IMO también proporcionó cursos más básicos fuera de los programas académicos, como un curso intensivo de R. IMO entrena desde el nivel de postdoc hasta de pregrado. En 2016, el IMO acogió 13 postdoctorales, dos recibieron apoyo completo del IMO, mientras que el resto recibió subvenciones externas. Participaron directamente en el IMO 14 estudiantes de doctorado, 20 estudiantes de maestría y 8 estudiantes de pregrado, con becas directas del IMO a 1 estudiante de doctorado, 7 estudiantes de maestría y 7 estudiantes de pregrado, mientras que otros recibieron becas de CONICYT o financiamiento a través de proyectos de investigadores del IMO. En cuanto al entrenamiento de campo avanzado "en terreno", los estudiantes graduados del IMO y postdocs participaron extensivamente en los cruceros de investigación.

El IMO ha seguido expandiendo la cobertura y creando nuevos productos de divulgación.. Los principales avances de los medios de comunicación han sido el fortalecimiento de la página web educativa "Sumérgete", ampliando el alcance de la Muestra Audiovisual Científica Itinerante - MACI, realización de la serie educativa "La Receta Científica de Tony Tonina" La recopilación científica de Tony Tonina), y la nueva serie de televisión para el público en general "Exploradores: del átomo al cosmos" creada por el IMO y la Fundación Ciencia y Vida en colaboración con TVN e Imago.

2. Introduction

a) Description of the Institute

The Millennium Institute of Oceanography (IMO, Instituto Milenio de Oceanografía) is a center of excellence established at the end of 2013 with the aim of researching and exploring the open and deep ocean. Its vision is to become an internationally recognized institute in oceanographic research and education, leading exploration in the central and eastern area of the South Pacific Ocean, with impact on the country and society in general. IMO's commitment is to provide an intellectually stimulating environment for the production and dissemination of scientific knowledge that generates new understanding about the ocean, from a creative, daring and collaborative perspective.

IMO's mission is: i) to conduct pioneering and interdisciplinary research in oceanography, addressing scientific problems in an integrative and collaborative manner; ii) to develop and apply new technologies and platforms for observational and experimental work in the ocean, including the use of the new Chilean research vessel Cabo de Hornos, and to reach unexplored areas of the South Pacific; iii) to increase human resources in ocean sciences in Chile and South America, through higher education and training in research based on direct observation and experimentation in the sea, and by attracting ocean scientists from all over the world to work in Chile; and iv) to inform and create awareness among the general public and decision-makers about the importance of the ocean, its conservation and its relationship to humans and global change.

This Annual Report is a summary of the third year of activities and the second as a legal Non-Profit Private Corporation.

b) Research Lines:

IMO established the following 4 initial research lines:

I. Mesoscale Processes: The focus of this research line is the characterization of physical mesoscale (and sub-mesoscale) structures and processes in the eastern South Pacific Ocean (ESP) and their impact on open-ocean and transitional (coast-ocean) ecosystems. Mesoscale structures include eddies and fronts of different types, but probably other types of poorly characterized structures associated with seamounts, ridges, and oceanic islands. The research strategy is based on field and satellite observations as well as on numerical modeling.

II. Ocean Variability and Change: The main focus of this research theme is to analyze the impact of climate variability and climate change on the circulation, transport of volume, heat and fresh water, stratification of the upper water column of the South Pacific Ocean, especially the Eastern South Pacific and the Humboldt Current system, including coastal upwelling. The research strategy is based on field and satellite observations as well as on numerical models. Since large-scale physical variability and change also impact meso- and sub-mesoscale physical processes and the chemical and biological characteristics of the ocean, this research theme is also a cross-sectional one.

III. Adaptation to a Changing Ocean: The objective of this research line is to gain new understanding about the adaptations (at the genomic, physiological, behavioral and community-structure level) of key planktonic groups to chemical changes taking place in the ocean (e.g., acidification, deoxygenation, desertification) and the impact of such changes on biogeochemical cycling. The research strategy is based on laboratory and fieldwork. For lab work, isolation of selected species of key plankton functional groups across environmental gradients and single-stressor (perturbation) experiments are being carried out in order to understand their response to variations in pCO₂/pH, O₂ and nutrients. Based on these results, genome analysis of selected species and multi-stressor experiments will be carried out. For fieldwork, observations and experiments are being carried out in IMO-organized and other oceanographic expeditions. Also, culture-independent genetic/genome analysis of representative species will test associations among genomic variation,

variability in physiology, and changes in water chemical properties. On-board experiments will expose distinct onshore and offshore plankton communities to single and multiple stressors.

IV. The deep Ocean: The objective of this research line is to explore the deep and ultra-deep ocean, determining the pelagic-community ecology and physical/biogeochemical characteristics of the bathyal (> 1000 m), abyssal (>4,000 m) and hadal (>6,000 m) waters of the eastern South Pacific. Special emphasis will be on mechanisms that contribute to the maintenance of endemic communities and the connectivity among the different deep biomes (i.e., islands, seamounts, trenches, etc.). IMO will organize as well as participate in major research expeditions to study the deep and ultra-deep waters of the eastern South Pacific, including the Atacama Trench. Appropriate sampling, observational, and experimental technology will be implemented and developed, accordingly.

The original research lines were maintained during 2016, but research line 2 was slightly modified to make it a more cross-sectional theme, as it permeates and underpins the other three research lines.

c) Organization of research team:

During 2016, its third year, IMO consisted of 36 researchers: the 8 original associate researchers, 2 senior researchers, 10 adjunct researchers, 3 young researchers and 13 postdocs. The associate researchers: Osvaldo Ulloa –Director-, Rubén Escribano -Deputy Director-, Carmen Morales, Oscar Pizarro, Wolfgang Schneider, and Cristian Vargas (from University of Concepción, UdeC), Peter von Dassow (Pontifical Catholic University of Chile, PUC) and Samuel Hormazábal (Pontifical Catholic University of Valparaíso, PUCV). They are distributed in Concepción, Santiago, and Valparaíso, respectively. IMO also worked with up to 24 professionals/technicians and assistants, 4 administrative staff, as well as 42 students (8 undergraduate, 20 M.Sc., and 14 Ph.D.). The adjunct researcher Dr. Laura Farías (UdeC) is no longer part of IMO and Dr. Julio Sepúlpeva (U. Colorado, Boulder) has joined the Institute as an adjunct researcher.

The institute's functioning and budget allocation are organized around the 4 research lines, an outreach team (led by Pablo Rosenblatt, Director of Outreach), a central administrative office based at UdeC (led by Atilio Morgado, Executive Director), and a Development and Technology Transfer team (established in 2015); this team is led by Ing. Víctor Villagrán. IMO also has two senior researchers: Prof. Juan Carlos Castilla, (PUC) and Dr. Gerrit van den Engh (MarCy, USA), both as advisors to the institute.

The 4 research lines combine and share scientific and technical personnel, laboratories, and equipment. Carmen Morales and Samuel Hormazabal lead Research Line 1; Wolfgang Schneider and Oscar Pizarro lead Research Line 2; Peter von Dassow, Cristian Vargas and Osvaldo Ulloa lead Research Line 3; and Rubén Escribano and Osvaldo Ulloa lead Research Line 4.

All the associate researchers define collectively annual research priorities for each line -as well as for education, outreach, and technology development and transfer- and the budget is allocated according to these priorities. Central to IMO's research activities are the organization of and participation in oceanographic expeditions and field experiments.

3. Scientific and technological research

a) Current status of research lines:

Major field research campaigns contribute simultaneously to more than one research line, and are also the principal instances where the research lines come together. In 2016, IMO participated in 2 Chilean large oceanographic cruises, MOPEX and CIMAR-22, and it continued with research

activities at the mooring station in the Juan Fernández Archipelago and the time-series station STOV off Valparaíso, as well as beginning data analysis from the two major research cruises in the end of 2015, CIMAR22 and LowpHox (Fig. 1). The IMO also contributed highly trained personnel from all research lines, as well as major equipment, to the emergency research “cruise REDTIDE” called for by the Chilean President in May 2016, to investigate the massive harmful algal bloom that occurred in front of Chiloe and in inland seas (not shown in Fig. 1), demonstrating our capacity to respond rapidly to support the national marine science community.

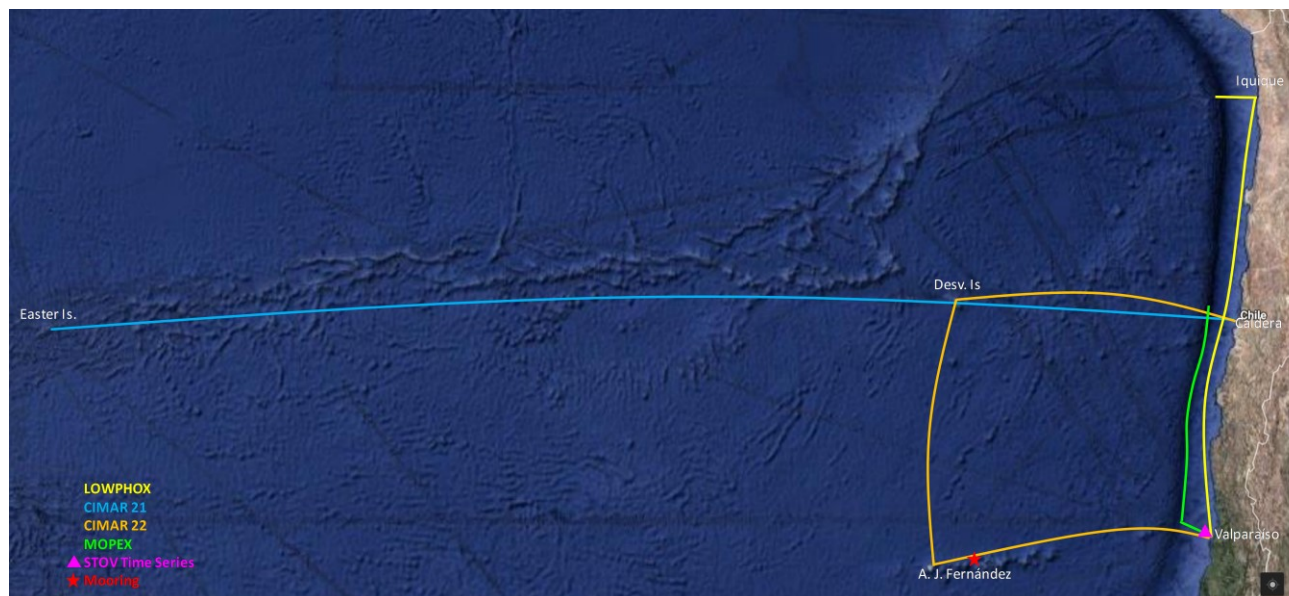


Fig. 1: IMO oceanographic expeditions 2015 y 2016. Not shown in Fig. 1 are IMO participation in various smaller field expeditions in specific projects, or in international-led cruises.

I. Mesoscale Processes

During 2016, integrated IMO research on this theme was dedicated to:

- a) The characteristics and evolution of mesoscale eddies, which are generated off the coast of central Chile and propagate NW, reaching the surroundings of the Juan Fernández Archipelago (JFA) and beyond. The approach included satellite time-series observations, a mooring around the JFA (Sep. 2015 – Nov. 2016), and a seamount-dedicated cruise (Sep. 2015) with data analyses carried out during 2016. Additionally, numerical experiments of different types were applied.
- b) The characteristics and evolution of frontal areas and their association with mesoscale eddies in the shelf-break area off central Chile. The approach included field observations (STOV time series off Valparaíso; 2015-2016), satellite time-series, and an opportunity cruise off Valparaíso (MOPEX, Sep. 2016) with sample analyses carried out during 2016-2017. In addition, a glider section was completed in the area of the STOV time series immediately after the cruise.

IMO investigators developed a series of collaborative studies, in some cases with the support of international investigators, to accomplish research objectives on this theme (see Section 2b). The most relevant and integrated IMO activities in 2016 were:

- Continuation of the oceanographic time series off Valparaíso (STOV) to study mesoscale processes, with monthly sampling including physical, biogeochemical and biological data. Led by IMO investigators S. Hormazabal and M. Cornejo, with institutional support from the PUCV, and including the participation of IMO postdocs (A. Murillo/P.A. Auger) and graduate/undergraduate IMO students,

as well as international collaboration with A. Rodriguez and A. Ramos (U. Las Palmas de Gran Canaria, Spain).

- An oceanographic survey (MOPEX, Sept. 2016) to characterize mesoscale and sub-mesoscale activity in the coastal upwelling zone and coastal transition zone (CTZ) off Valparaíso, including physical, biogeochemical, and biological samplings. Analyses of samples and data were completed, for the most part, in 2016. IMO investigators S. Hormazabal, M. Cornejo, R. Escribano, P. Hidalgo, and C. Morales collaborated through this CONICYT-financed ship-time, with the support of technicians and graduate/undergraduate IMO students.
- Retrieval of an IMO oceanographic mooring in the JFA area (Nov. 2016), equipped with several autonomous devices to register mesoscale activity around oceanic islands. IMO investigators S. Hormazabal, O. Pizarro, and C. Morales collaborated in this task with the support of several funding sources and the participation of IMO students and technicians. Data analysis began in 2017.
- Implementation of combined biophysical-biogeochemical models (ROMS-PISCES, NEMO, ROMS-IBM) focused on the Chile-Peru coastal and/or CTZ, including the JFA area, to resolve spatio-temporal variability in circulation and mesoscale activity, and to explore physical-biogeochemical-biological coupling in these systems. IMO researcher C. Parada, A. Belmadani, and postdoc P.A. Auger have lead this task, with the partial collaboration from O. Pizarro, S. Hormazabal, and/or C. Morales. Other researchers (O. Artal, C. Conejeros, A. Sepulveda, and B. Ernst, UdeC) and IMO students have actively participated in this task, besides several international collaborators (V. Echevin, T. Gorges, O. Aumont, A. Chaigneau, and F. Colas - IRD-France; N. Maximenko - U. Hawaii – USA; V. Combes - OSU-USA; and E. Di Lorenzo -GATech - USA). In addition, sensitivity experiments with ROMS to study the influence of high-frequency atmospheric forcing on mesoscale eddy properties in the ESP have been performed, lead by A. Belmadani and O. Artal (UdeC).

The most relevant and integrated scientific achievements in IMO Theme 1 during 2016 are:

Mesoscale activity and their biogeochemical and ecological impacts in the coastal upwelling and coastal transition zones in the ESP.

- Oceanic striations off central Chile coincide with polarized mesoscale eddy tracks and the offshore formation of new eddies. Vorticity produced by topographically steered unstable offshore meridional flow triggers striations as beta-plumes in the subtropical front. Eddy vorticity, advection, and striation shear instability participate to maintain eddy streets and striations in this region (Belmadani et al. 2017, submitted in 2016). These results concern both Themes 1 and 2.
- Data from in situ profiles (World Ocean Database and Argo buoys) in the ESP indicated that intra-thermocline eddies (ITEs) are involved in the vertical variability of the oxygen minimum zone (OMZ) in the coastal waters off Chile and in the CTZ off Peru-Chile, whereas waves and/or surface eddies are more relevant off northern Peru (P.A. Auger, S. Hormazabal, C. Morales, and graduate student A. Bustamante; prepared in 2016 and submitted in 2017).
- Satellite data analysis of sea surface chlorophyll, wind, temperature and height revealed that the interannual variability of surface chlorophyll in the CTZ is not explained by mesoscale activity off Chile, although offshore production remains connected to coastal production. The effect of El Niño Southern Oscillation was shown (P.A. Auger, A. Belmadani, A. Montecinos, J. Bento, C.E. Morales, S. Hormazabal; in preparation for International Journal of Remote Sensing in early 2017).
- The impact of an ITE-Front interaction on the structure of planktonic communities in coastal upwelling and CTZ off Concepción were analyzed using field and satellite data. This interaction enhanced the cross-shelf exchange of diatom taxa but in both, coastal and oceanic directions, in contrast to the usual view of eddies as offshore vehicles of organic matter (C.E. Morales, IMO doctoral student V. Anabalón, J. Bento, S. Hormazabal, M. Cornejo, and N. Silva (data re-analyses in 2016 and in preparation for Journal of Geophysical Research in early 2017).
- Annual and inter-annual fluctuations of micro-phytoplankton community structure in the coastal upwelling zone off Concepción (central Chile) was determined using in situ time series data off Concepción. The main results point to significant changes in oceanographic conditions (2002-2006 and 2007-2009) associated with a decrease, though not significant, in diatom biomass

during the second period (IMO doctoral student V. Anabalón, C.E. Morales, H. González, W. Schneider, E. Menschel, and R. Escribano, *Progress in Oceanography*, 2016). Also, gross primary production and diatom abundance were negatively impacted with the changes during the last period (2007-2013) and an alteration of diatom dominance, and phytoplankton size-structure was detected (B. Jacob, R. Quiñones, F. Tapia, G. Daneri, P. Montero, W. Schneider, H. Gonzalez, M. Sobarzo, and C.E. Morales; prepared in 2016 and submitted in 2017).

- Phytoplankton community structure in the coastal upwelling and CTZ off central Chile have been analyzed using both in situ and satellite approaches to characterize size composition and functional groups (PFG). A modified version of the PHYSAT method to detect PFG in highly productive waters has been developed and validated with field data (M. Correa-Ramirez, C.E. Morales, R. Letelier, S. Hormazabal, and V. Anabalón, prepared in 2016 and submitted to *Remote Sensing of the Environment* in 2017). Two doctoral theses are also developing this topic (J.A. Corredor-Acosta and E. Velasco-Vinasco) under the guidance of C.E. Morales and S. Hormazabal and in collaboration with Drs. M.A. Correa-Ramirez (INVEMAR, Colombia), R. Letelier (OSU-USA) and R. Brewin (PML, UK).

Mesoscale activity and ocean circulation associated with the Juan Fernandez Ridge System (JFRS).

- Temporal and spatial variability of the ocean circulation and mesoscale activity in the JFRS was characterized through modeling. Ocean circulation around the islands is dominated by anticyclonic relative vorticity and positive anomalies of temperature and salinity at the subsurface layer. These characteristics are associated with ITEs, and submesoscale structures can play an important role in the vertical transport of nutrients to the euphotic zone in this system (C. Conejeros, C. Parada, A. Montecinos, V. Combes, B. Ernst, in preparation 2016-2017).

- Model-simulation experiments showed a high level of retention associated to low eddy kinetic energy and anticyclonic eddies, allowing the retention of jack mackerel pelagic larvae for at least 4 months in the ESP seamount region. We discussed the relevance of seamounts playing a double role as spawning and nursery regions from a conservation and biodiversity viewpoint (C. Parada, A. Gretchina, S. Vasquez, A. Belmadani, V. Combes, B. Ernst, E. Di Lorenzo, J. Porobic, A. Sepulveda; submitted in 2016 and currently in press).

- Model-simulation experiments have been used to explore the impact of mesoscale eddies on larval distribution, vertical migration and growth. Results show that there is a significant interaction between mesoscale eddies, von Karman vortices, and mesoscale wakes, and differential vertical migrational patterns which contribute to enhance patchiness and impact pelagic larval growth in the JFRS (undergraduate IMO student C. Medel, C. Parada, O. Pizarro, C.E. Morales, and C. Conejeros, submitted to *PIO* in 2016; accepted in 2017).

- A long-lived anticyclonic eddy in oceanic waters in the surroundings of the JFA was found to have an impact on the biogeochemical characteristics of the water column, with subsurface waters (150-450 m depth) having suboxic and even anoxic levels, implying a strong impact on the nitrogen cycle in the region (M. Cornejo, M., Bravo, L., Ramos, M., Pizarro, O., Karstensen, J., Gallegos, M., Correa-Ramirez, M., Silva, N., Farías, L., Karp-Boss, L.; *Biogeosciences*, 2016).

Mixing processes in the ESP

- Microstructure measurements (vertical resolution ~2 mm) and temperature, salinity and oxygen profiles (vertical resolution 1 m) were used to characterize the influence of diapycnal mixing in modulating the thickness, depth and oxygen concentration of the OMZ in the STOV area and over seamounts in the JFRS. Mixing in the upper limit of the OMZ is mainly caused by vertical wind shear, whereas the lower limit is dominated by double diffusion processes, producing an increase in the diffusive oxygen flow. In the OMZ core, the dissipation of turbulent kinetic energy diminishes and no significant diffusive flows favoring diapycnal mixing are present, except during the generation period of ITE's and during the interaction between cyclone and anticyclone eddies over seamounts (IMO graduate student L. Valencia, S. Hormazabal, A. Rodriguez; in preparation for *Progress in Oceanography*).

II. Ocean Variability and Change

During 2016, integrated IMO research on this theme was dedicated to:

- a) Intensification of the South Pacific gyre circulation due to climate change
- b) Eastern South Pacific Intermediate Water Mass under climate variability
- c) ENSO dynamics and its impact on the Humboldt Current system
- d) Variability of the Oxygen Minimum Zone of the eastern South Pacific

The most relevant and integrated IMO activities in 2016 were:

- Participation in the international Polar Stern cruise N°97 (16 Feb – 8 Apr 2016) which among others targeted the virtually least known current in the Eastern South Pacific, namely the Cape Horn Current. W. Schneider collaborated in this cruise leading the physical oceanography group.
- Collaboration in the oceanographic surveys REDTIDE, May 2016, and MOPEX, September 2016, providing CTDO/Rosette operations and processing CTDO data.
- Collaboration with Theme I (S. Hormazabal and C. Morales) in field activities: (a) IMO oceanographic mooring in the Juan Fernandez Archipelago (33°40' S 78° 50'W, maintained from Sep 2015 to Nov 2016). The mooring was equipped with several sensors (4 CTD-MicroCATs with oxygen sensors and 2 150 kHz ADCPs) to analyze ocean variability in the region. (b) a glider section off Valparaiso (33°S) to complement observations from the ship-based monthly time series (STOV) and the MOPEX cruise carried out during September 2016 (see Theme I activities).
- Integration of a new Postdoc Fraucke Albrecht: Working title “Anthropogenic influence on the change of the subtropical gyre circulation in the South Pacific in the 20th and 21st century”. Dr Albrecht was originally integrated as IMO Postdoc in 2016 and during that year she applied for a CONICYT postdoctoral scholarship which was recently awarded.

The most relevant scientific achievements in Theme 2 during 2016 were:

- Changes in Eastern South Pacific Intermediate Water (ESPIW) distribution and volume: Update of the ESPIW mass distribution with new Argo information. Change in volume of ESPIW was +50% compared to the 1990s. Changes in ESPIW could be linked to an Intensification of Ekman Pumping velocity from 2000 on (Freddy Hernández-Vaca [graduate student IMO], Wolfgang Schneider, José Garcés-Vargas, prepared in 2016 and submitted in January 2017).
- Cooling and salinity increase of the water column on the shelf of central Chile: Intensification of the South Pacific High (SPH) led to a strengthening of upwelling favorable winds along the coast of central Chile thus cooling the waters of the continental shelf. A southward displacement of the SPH reduced precipitation and consequently increased salinity this way reducing the stratification of the water column contrarily of what would be expected under a scenario of global warming (Wolfgang Schneider, David Donoso, José Garcés-Vargas and Rubén Escribano. Submitted 2016 and published January 2017).
- ENSO impact on the Humboldt Current System (HCS): We confined the extent of the HCS to be limited by the 20° S and 45 °S parallels, the coast of Chile and the 85 °W meridian, and scrutinized the period 1992-2015. Zonal averages of sea surface temperature (SST), absolute dynamic topography, meridional geostrophic velocity, and alongshore winds were computed separately for the sum of El Niño (7 events), La Niña (5 events), and neutral periods (8). During El Niño (La Niña) events, on average, SST was 0.25 °C warmer (colder) than during neutral conditions; this temperature difference could be confirmed and extended to the upper 100 m of the water column by comparing CTD in-situ measurements along the latitude 27 °S obtained in October 1999 (La Niña) and repeated by IMO in October 2015 (El Niño). Significant differences were found in the alongshore wind magnitude being 0.6 m/s stronger in the southern region during El Niño than during La Niña thus impacting on the intensity of coastal upwelling. (Freddy Hernández-Vaca [graduate student IMO] and Wolfgang Schneider, work in progress to be submitted during the first semester of 2017).

- The role of the North Pacific High (NPH) during the 2015/16 El Niño: We hypothesize that a (not expected) strengthening of the NPH at the end of 2015 broke the anticipated Godzilla El Niño 2015/16 (Wolfgang Schneider, Aldo Montecino, and Rubén Escribano, work in progress to be continued in 2017).
- Spin-up of the subtropical ocean gyre in the South Pacific: In the recent years a spin-up of the subtropical ocean gyre in the South Pacific has been recognized in analysis of sea-level height, temperature and salinity profiles, sea surface temperature and wind data. Until now it is not clear whether this spin-up is decadal variability or whether it is a long-term trend introduced by anthropogenic forcing. Dr Frauke Albrecht's study aims to analyze whether and how anthropogenic forcing influences the position and the strength of the gyre in the 20th century. To determine that, different variables of an ensemble of the Coupled Model Intercomparison Project (CMI Phase-5) are being analyzed. The study includes the experiments 'historical' and 'historicalNat'. The 'historical' experiment is supposed to simulate the climate of the 20th century and the 'historicalNat' experiment covers the same time period, but only includes natural forcing. Comparing the outcomes of these two experiments information about the anthropogenic influence on the subtropical gyre of the South Pacific is obtained. Results are part of a work in progress: “Anthropogenic Influence on the Changes of the Subtropical Gyre Circulation in the South Pacific in the 20th Century” by Albrecht, Pizarro, Montecinos & Schneider. Preliminary results were sent to the International WCRP/IOC conference 2017 on Regional Sea Level Changes and Coastal Impact.
- Vertical propagation of extratropical Rossby waves: The question of how energy is redistributed in the ocean has renewed the interest in the processes leading to mid-latitude subthermocline variability at low frequency. We investigated a process dealing with the planetary energy budget in the eastern South Pacific where an efficient oceanic teleconnection takes place, linking the remote surface equatorial momentum forcing with the subthermocline in the Southeastern Pacific, through the vertical propagation of low-frequency, long-wavelength extra-tropical Rossby waves (ETRW). A high-resolution model is used to document the vertical energy flux associated with these waves at interannual to decadal timescales. Simulation reveals that the vertical energy flux associated with the El Niño Southern Oscillation forms ETRW beams below the thermocline that account for a large fraction of the total vertical energy flux at interannual timescales. The energy beams experience dissipation processes in the ocean below 2000 m that is interpreted as resulting from vertical turbulent diffusion, constituting an energy pathway between the surface and the deep ocean. Vertical energy propagation at decadal timescales is also evidenced in the model. Results were submitted to Journal of Geophysical Research by Vergara, Dewitte, Ramos and Pizarro, in 2016.
- Seasonal variability of the oxygen Minimum zone: The extensive oxygen minimum zone (OMZ) embedded in the eastern South Pacific plays a major role in the regional biogeochemical cycling. Along with international collaborators (Boris Dewitte and his group from the Complex Coupled Systems at LEGOS/Toulouse) and the PhD students (Matías Pizarro; IMO student and Oscar Vergara LEGOS) we have used a high-resolution coupled physical/biogeochemical model simulation to investigate the seasonal variability of the OMZ off Peru and central Chile. The results indicate that the seasonal variations of the OMZ can be interpreted as resulting from the seasonal modulation of the mesoscale activity in both regions. Along the Peruvian coast, despite the increased seasonal low DO water upwelling, the DO peaks homogeneously over the water column and within the Peru Undercurrent (PUC) in austral winter, which results from mixing associated with the increase in both the intraseasonal wind variability and baroclinic instability of the PUC. The coastal ocean acts therefore as a source of DO in austral winter for the OMZ core, through eddy-induced offshore transport that is also shown to peak in austral winter (Vergara et al. 2016). Off central Chile cross-shore eddy fluxes of DO related to mesoscale eddies modulate the mean offshore extension of the OMZ and together with the alongshore flux of DO related to the Peru-Chile Undercurrent dominate the seasonal variability of the southern tip of the OMZ in the eastern South Pacific (Matias Pizarro-Koch, work in progress to be submitted during the first semester of 2017). Preliminary results from our glider time series off 36.5°S were published during 2016 in the Bulletin of The American Meteorological Society: “Underwater glider observations in the oxygen minimum zone off central

Chile” by Pizarro et al., 2016. In this work glider sections from different period of the years are shown to illustrate the seasonal variability of the OMZ and the strong influence of mesoscale eddies in its variability in this region.

- A decadal SST mode in the tropical to sub-tropical South Pacific Ocean: Recent studies have reported a slowdown in the warming of global sea surface temperature (SST) since the 90s with a strong imprint in the tropical and subtropical eastern Pacific. Whether or not this so-called hiatus is the result of the internal variability of the climate system or is a response to external forcing has remained elusive. Along with our collaborators Boris Dewitte (UCN-Chile, LEGOS-IRD, France) and Ken Takahashi (IGP, Peru), we revisit available long-term SST data sets over the 20th and 21st centuries and show the existence of a decadal mode in the tropical to sub-tropical South Pacific that propagates from the coast of Peru up to Australia. This mode has a period of ~45 years and features a westward propagation of SST anomalies near 12°S that takes ~30 years to travel from the coast of Peru to Australia. The mechanism involves the positive Wind-Evaporation-SST feedback in the central South tropical Pacific and a negative feedback over the SPCZ region consisting in a negative wind stress curl anomalies forcing upwelling that subsequently depresses the thermocline along the equator and reverse the cycle in about 15 years. While the existence of such a mode offers predictive value at decadal scale for the regional climate at both side the Pacific ocean, its characteristics are diversely simulated by state-of the art coupled models. Work in progress to be submitted during the first semester 2017 (Boris Dewitte, Ken Takahashi, Aldo Montecinos & Oscar Pizarro).
- Study of quasi-zonal jets in the eastern South Pacific: Quasi-zonal jets or striations have been ubiquitously detected in the world ocean using satellite and in situ data as well as numerical models. Belmadani (young IMO researcher) along with the IMO student E. Concha and international collaborator (A. Chaigneau [LEGOS/IRD], F. Colas [LOCEAN/IRD], N. Maximenko [IRPSO, University of Hawaii] and E. Lorenzo [Georgia Tech.]) and E. Concha (IMO student) analyzed the role of mesoscale eddies in the generation and persistence of striations in the eastern South Pacific. A 50 year climatological integration of an eddy-resolving numerical ocean model is used to assess the long-term persistence of striations. Results reveal that striations coincide with both polarized eddy tracks and the offshore formation of new eddies in the subtropical front and coastal transition zone. Eddy vorticity advection and striation shear instability participate to maintain eddy streets and striations in this region. Results have been recently published (see Belmadani et al., 2017).

III. Adaptation to a Changing Ocean

The main objective of this research line is to gain new understanding about the adaptations (at the genomic, physiological, behavioral and community-structure level) of key planktonic groups to physical-chemical changes taking place in the ocean, such as Deoxygenation or Low Oxygen (O₂) conditions, Ocean Acidification (OA), Ocean warming and Desertification, and how such changes impact marine biogeochemical cycles. Upon this framework, during 2016 IMO researchers were focused in data analysis from time-series observations combined with experimental results and sample and data analysis from research cruises.

Low O₂ conditions are one of the main drivers of plankton community structure and biogeochemical cycling in the Eastern South Pacific. In this regard, our work has been focused on a) the assessment of zooplankton responses to low O₂ conditions upon upwelling-driven variability (mostly in the coastal zone), b) the evaluation of the O₂ sensitivity of biogeochemical rates down to the ultra-low (<10 nM) levels of O₂ found in oxygen minimum zones (OMZs) and anoxic marine zones (AMZs), and c) the analysis of parameters in carbon biogeochemical cycle measured during the LowpHox cruise (Nov-Dec 2015). Major scientific activities are summarized as:

- The time series observations at the coastal zone off Concepción were maintained until May 2016, in association with the development of the El Niño 2015-2016 conditions in the Pacific. Samples and data from these observations have been analyzed during this year.
- Experimental work testing the effect of low-oxygen (hypoxia) on some target species of zooplankton from the upwelling was conducted at the Marine Biology Station of the University.

- Analysis and interpretation of data on rates of ammonium and nitrite oxidation in the seasonal OMZ off Concepcion, which were determined under manipulated O₂ levels between 5 nM and 20 μM using a highly sensitive oxygen-sensing technique.
- Zooplankton analyses in terms of species identification, size spectra and metagenomics were also performed from samples from LowpHoX cruise. These data come from a high-resolution vertical and temporal sampling of zooplankton associated with the OMZ off northern Chile.
- Analysis of samples and data derived from LowpHoX cruise. All organic and inorganic carbon pools have been quantified, and isotopic composition of dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), and particulate organic carbon (POC) has been determined.
- Organization of a Synthesis Workshop focused on integrating information on carbon cycle dynamic in the OMZ and AMZ of northern Chile.

Regarding adaptations to changes in marine carbon chemistry (OA), several micro/mesocosm perturbation experiments were conducted during 2016. The characterization of carbonate system in different coastal and open ocean environments was also continued. Major scientific activities are summarized as:

- Experiments with different strains of coccolithophores, including *Gephyrocapsa muellerae*, *G. ericksonii*, and *Reticulofenestra parvula* upon high pCO₂ conditions.
- We have carried out a 10-days mesocosm experiment with natural phytoplankton assemblages from corrosive upwelling waters (pCO₂= ~650 μatm) (Lavapie Point, Central-Southern, Chile) exposed to higher pCO₂ conditions (pCO₂= 1600 μatm).
- A time series of carbonate system in coastal waters off Antofagasta focused in the characterization of pH/pCO₂ variability, and subsequent laboratory experiment on the effect of such variability in copepod (*A. tonsa*) egg production.
- A short research cruise during summer conditions in the upwelling system off Concepcion, aiming to characterize the influence of upwelling events in the carbonate system in this environment.
- A one-day research cruise in late winter conditions the upwelling system south of Coquimbo, characterizing carbonate system parameters and whether phytoplankton were limited by iron.

Regarding ocean desertification, we analyzed samples from two previous cruises studying community structure changes along the coastal to open ocean productivity gradient, and near oceanic islands and seamounts.

- The picoplankton community from the coastal to ultra-oligotrophic ocean was characterized by flow cytometry (counts of pico-cyanobacteria, eukaryotic picophytoplankton, heterotrophic bacteria) using samples from the CIMAR-21 cruise (2015) from the Chilean coast to Easter Island and Salas-y-Gómez island.
- Zooplankton samples from previous cruises (CIMAR-21 and Seamounts cruises) were processed for automatic identification and assessment of biomass size spectra. Isotopes composition of C and N were also analyzed for size-fractionated zooplankton.

One of our long-term goals is to understand processes of adaptation in marine plankton. This work involves phylogenetic, genomic, and experimental analyses.

- Using the cosmopolitan coccolithophore *Emiliania huxleyi* and congeneric species with more restricted distributions as models, we have been relating thermal reaction norms to organelle and nuclear phylogenies to understand how adaptation to different temperature regimes occurred.
- Work continues on the relating genomic capacities to biochemical function in the pico-cyanobacterial genus *Prochlorococcus*, focusing on the uncultured representatives of this organism found in AMZ waters, which are basal to the group.
- We completed a first synthesis of single-cell genomics and phylogenomics of uncultured rare and common AMZ bacteria and archaea, with metagenomic and metatranscriptomic datasets from the AMZ. This work is revealing AMZ metabolic pathways and the organisms involved.

- Horizontal gene transfer is well known as a mechanism for adaptation in bacteria and archaea, but its possible role in eukaryotes is controversial. We conducted an exploratory project, financed by the Moore Marine Microbial Initiative, experimentally testing whether natural marine eukaryotic picoplankton had the propensity to accept and express exogenous DNA, one of the major limiting steps in horizontal transfer.

Some scientific achievements/highlights for this theme:

- Two key aerobic processes, ammonium oxidation and nitrite oxidation, persist even at low O₂ levels of 5–30 nM (~0.01% air saturation). Activity at these low O₂ concentrations allows ammonium and nitrite oxidation to persist at oxic/anoxic boundaries and within anoxic waters if oxygen intrudes at sufficient frequency (Bristow et al. 2016).
- In the last two decades, wind-driven upwelling has been increasing in the coastal zone off central/southern Chile, as impacted by a large-scale process characterized by a southward displacement of the south Pacific gyre (see Themes 1 and 2). Physical effects in the upwelling zone are cooling down of the water column, increased surface salinity and reduced stratification (Schneider et al. 2016). Increased upwelling has been accompanied by a reduction in phytoplankton biomass due to lower abundance of large size diatoms (Anabalón et al. 2016). The zooplankton community has changed its taxonomic composition (Medellín-Mora et al. 2016), and copepod biomass (main components of zooplankton) becomes reduced under increased advection affecting secondary production in the upwelling zone (Escribano et al. 2016). The growth of an important zooplankton species, the “krill” *Euphausia mucronata* exhibits a strong dependence with upwelling intensity, such that greatly augmented upwelling may even reduce it, or animals tend to shrink (Riquelme-Bugueño et al. 2016).
- Low pH/high pCO₂ had no significant impact on growth, Chl-a, cellular abundance, gross photosynthesis, dark respiration, in some functional groups, such as the diatom *S. pseudocostatum*. However, dissolved organic carbon (DOC) concentration and DOC/POC ratio was significantly higher at high pCO₂, indicating that a greater partitioning of organic carbon into the DOC pool was stimulated by OA (Jacob et al. 2016).
- Low pH conditions during upwelling may have significant negative impact in the reproductive output of neritic small copepods (Aguilera et al., in prep.).
- We have uncovered the reticulate phylogenies underlying the relationship between the cosmopolitan coccolithophore *Emiliania huxleyi* and close relatives with restricted distributions (Bendif et al. 2016).
- Negative response ratios are observed in marine organisms models (mussels, gastropods, and planktonic copepods) exposed to pCO₂ changes far from the average and extreme pCO₂ levels experienced in their native habitats. This variability in response between populations reveals the potential role of local adaptation and/or adaptive phenotypic plasticity in increasing resilience of species to OA impacts (Vargas et al. 2017).

IV. The deep and ultra-deep ocean ecosystem

We have continued making efforts to sample organisms and obtain oceanographic data in the open/deep-ocean off Chile during 2016. Zooplankton and fish samples from offshore areas and deep water (>1000 m) have been obtained through national cruises and in collaboration with fishermen for deep fishes. Actions are summarized as:

- During September 2016, we carried out the MOPEX cruise onboard the R/V Cabo de Hornos. In this cruise, we deployed a zooplankton net as deep as 3500 m and the oceanographic rosette went down to 5200 m in waters off central Chile. Highly valuable samples were obtained for taxonomic, biochemical analyses and molecular analyses.

- By the end of 2016 we carried out a large-scale cruise CIMAR-22 in collaboration the Chilean National Commission of Oceanography (CONA) and other Chilean institutions. The cruise covered the region between the Chilean coast and the oceanic Desventuradas Islands and the Juan Fernandez Archipelago. Deep zooplankton samples for taxonomic, biochemical and molecular analyses were obtained.
- We continued sampling deep fishes (>1000 m) from fishermen catches to analyze their parasite composition and assess prevalence of parasitic infections in relation with biogeographic patterns of fishes in the region.
- We have started working with the company Global Ocean Design (San Diego, California, USA) on the design of a Sea Lander that will allow us to sample the ultra-deep ocean (>6,000 m) from any of the Chilean vessels. Sea Landers are the most cost-effective way to get to deep and ultra-deep mid-water or benthic locations. They can carry traps, samplers, and sensors and travel on a free-falling mode to any depth. Sea Landers remain independent of the ship and surface, release an expendable weight on command, and actively assist in their location and recovery. We expect to acquire such equipment in order to study the Atacama Trench in the coming years.

Highlights of scientific achievements:

- Metabolic processes mediated by zooplankton in seamount regions located in oligotrophic areas are strongly dependent on size-structure and taxonomic composition. Changes in these community parameters forced by environmental factors may greatly affect C cycling in these seamount systems (Frederick et al. submitted).
- Nitrogen cycling mediated by zooplankton may play a key role in fueling regenerated primary production in open ocean blue water of the western south Pacific where diazotrophic processes are main sources for N. These findings derived from experimental work during OUTPACE cruise of January 2015 are to be published in a special issue of Biogeoscience for this French initiative where IMO has contributed through one of our PhD students.
- Analyses of zooplankton and their biochemical condition over the oceanographic zonal gradient across the Pacific (Chilean coast to Easter Island) have allowed us to identify distinct biogeochemistry regions in the south Pacific basin, characterized by different sources of C and N sustaining the biological communities. These regions also reflect distinct biogeochemical processes controlling nutrient sources and cycling along the zonal gradient (Manuscript in preparation).
- The assessment of deep-water pelagic communities reveals an impressive biological diversity and biomasses greater than expected for oligotrophic ecosystems. Our current efforts have concentrated in identifying organisms from surface blue water and deep zooplankton components. Molecular tools and traditional taxonomy are the basis for this task.
- New species and the need for revising current biogeographic patterns of fish parasites from the South America region have become key issues from the analyses of deep-water fishes and their associated parasite organisms (Luque et al. 2016, Cardenas et al. submitted).

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Schneider, W., Donoso, D., Garcés-Vargas, J., Escribano, R. (2017). Water-column cooling and sea surface salinity increase in the upwelling region off central-south Chile driven by a poleward displacement of the South Pacific High. *Progress in Oceanography*, 151, 38-48.

Vergara, O., Dewitte, B., Montes, I., Garçon, V., Ramos, M., Paulmier, A., Pizarro, O. (2016). Seasonal variability of the oxygen minimum zone off Peru in a high-resolution regional coupled model. *Biogeosciences*, 13(15), 4389-4410.

b) Publications:

A total of 28 journal articles were published in year 3, of which 20 were authored or co-authored by IMO associate researchers (2.5 per associate researcher). From the latter, 70% were in Q1 journals and 55% in the top 10% of the Impact Factor (IF) distribution for the discipline or

multidisciplines (Annex 3). Moreover, 35% included more than one IMO associate researcher as author/coauthor, reflecting increased collaboration.

The 28 total ISI-type IMO publications represent an increase from the 22 publications in year 2, but did not reach the 37 publications in year 1. A similar trend is observed for the publications considering only the associate investigators. However, the number of publications in the top 10% of the IF distribution in year 3 is similar to that in year 1 (but higher in term of relative numbers) and greater than that in year 2, reflecting our efforts to publish in the very best journals of the discipline or in highly ranked multidisciplinary journals. Moreover, the total and relative number of articles in which more than one associate researcher was a co-author increased significantly in year 3. Only 3% of joint articles were published in year 1. This figure increased to 13% in year 2, and to 35% in year 3. Our strategy to prioritize high-impact and collaborative publications among IMO associate researchers is thus starting to show its fruits.

When possible, we have continued to publish in high-ranked journals that are open access or to pay an extra fee to the publisher to make them open access.

Summary table

Category of Publication	MSI Center Members	Number of Publications coauthored by students	Total Number of Publications
ISI Publications or Similar to ISI Standard	Associate Researchers	6	20
	Other Researchers	3	8
SCIELO Publications or Similar to SCIELO Standard	Associate Researchers	0	0
	Other Researchers	0	0
Scientific Books and chapters	Associate Researchers	0	0
	Other Researchers	0	0
Other Scientific Publications	Associate Researchers	0	0
	Other Researchers	0	0
Total of Publications		9	28

Other achievements:

Development and Technological Transfer Area: In May 2016 we travelled to the United States to visit research centers and enterprises with the objective of prospecting existing technologies, especially those used for the exploration of the deep ocean. We identified the main technological challenges to address the scientific objectives of our institute. We established contact with groups of specialists that will support the development of the required solutions.

We also contacted the different research groups within the Institute through lectures and informative meetings. The objective of these activities was to boost development and technological transfer. With the support on an IMO researcher, we proposed an I+D project (Research + Development) that was presented to the COPEC, Chile foundation. The Project entitled “Laboratorio robótico para mantención y caracterización de células vivas en suspensión” (Robotic Laboratory for the maintenance and characterization of live cells in suspension) did not go beyond the initial stage. The argument was the need to have a basic prototype.

During 2016, we actively participated in national meetings and workshops related with topics of entrepreneurship and technological transfer. We also worked in the development of the Hub for technological transfer as a complied beneficiary. Along with the Outreach Area and in the frame of

the initiative of Explora Bio Bio “Technological Challenges”, we designed and built a mini-Lander prototype. This device is a type of low-cost small-scale submarine vehicle built with common used material and its objective is to promote the interest for science and technology among students. The project included induction Workshops for teachers and students from schools of the Bio Bio region.

The Submarine Robotic Group created by IMO, which include engeniers student of distincts discipline (e.g. electronic, aerospace, mechanic, civil and marine biologists) was awarded an internal project from the University of Concepcion which will enable us to continue developing ROV vehicles in the frame of business entrepreneurship.

Finally, during the second semester of 2016 we designed a laboratory experiment to assess the performance of the instrumentation used in oxygen minimum zones. This topic constitutes one of the basic research lines of IMO and the participation of one of the associate researchers of our institute.

- **Patents:** Untill now we have no Patents.
- **Intellectual property:** Untill now we have no Intellectual Properties.
- **Congress Presentations:** All associate researchers participated giving talks in international congresses, workshops and symposia and several talks were as guest speakers or key note speakers in highly relevant events about general oceanography, biogeochemistry, marine ecology and climate variability. Adjunt and young researchers were also active participants in international scientific events. At national there were many presentations y IMO researchers, although graduate and even undergraduate students of IMO had a remarkable involvement in national events, including the Chilean National Congress of Marine Sciences and the National Congress of Physical Oceanography and Atmospheric Research.

Summary Table

Type of presentation	National Events [Number]	International Events [Number]
A. Associate Researchers		
Conferences, oral communications, poster communications, others (specify)	12	13
Invited presentations (not included in above row)	1	9
B. Other researchers (Adjunct Researchers, Senior Researchers, Young Researchers, Postdoctoral Researchers and Students)		
Conferences, oral communications, poster communications, others (specify)	33	14
Invited presentations (not included in above row)	4	4

- **Organization of Scientific Events:** At international level IMO organized a special conference of Dr. Trevor Platt from Plymouth Marine Laboratory, UK, during the opening ceremony of IMO in May 2016. At national level, IMO researcher P. Hidalgo was member of the organizing committee of the Chilean National Congress of Marine Sciences. This event, co-sponsored by IMO, took place at University of Concepción with the participation of national researchers and students of Chile involved in marine sciences, and with the presence of international invited scientists as key note speakers. A summary is shown in **Annex 4**.
- **Scientific Editorial Boards:** Our Principal Researcher Dr. Osvaldo Ulloa continued as Review Editor for Frontiers in Marine Science.

- **Awards:** Our Outreach Director, MSc. Pablo Rosenblatt, was awarded TRIBUTE AWARD Prize, for the audiovisual production quality and education and science promotion, at international show VERCIÊNCIA 2016, Palace Centro Cultural Banco Do Brasil, Rio de Janeiro, Brazil, 17-10-2016.

4. Education and Capacity Building

a) Education and Capacity Building:

Young researchers, including graduate and undergraduate students, postdocs and several of our technicians which essentially have a researcher profile, play an essential role in developing new ideas in projects and activities directly linked to IMO's research themes. IMO provides for them:

- i) advanced research opportunities in terms of access to all IMO research facilities and equipments,
- ii) participation in IMO oceanographic cruises, advanced courses, workshops, and meetings,
- iii) funds in the form of scholarships and fellowships to allow them to initiate or complete their thesis or projects, as well as to attract new students,
- iv) partial support to attend national and international congresses or advanced courses, and
- v) complete support in the purchase of materials and reagents needed for their thesis work or project development.

IMO promotes the effective interaction between researchers and students through thesis co-tutoring and participation in IMO cruises. In the case of IMO postdocs, they participate as members of graduate and undergraduate thesis committees and they are also strongly encouraged to seek collaboration between IMO researchers through their own work. Recently formed Ph.D's from Chile and abroad are encouraged to get their research funds through CONICYT-FONDECYT postdoctoral fellowships before or during their time with IMO.

b) Achievements and results

The main IMO's educational activities, achievements and results during 2016 were the following:

- **IMO incorporation of postdoctoral researchers**

During 2016, IMO hosted 13 postdocs, 2 of which started during 2016 and received full IMO grants, the rest were recipients of external grants, mostly CONICYT/FONDECYT. One of the new postdoc, Frauke Albrecht, incorporated during 2016 originally received a full IMO grant, but she obtained a FONDECYT grant for 2017-2019. The IMO selection processes of postdocs with IMO grants for 2016 finished at the end of 2015 and, as in previous IMO call, all associate researchers participated in this process and selection candidates were agreed by majority. The selection criteria considered the needs in each IMO research theme, the potential for increased interaction between IMO researchers through the selected candidates, and the scientific quality and potential of the individual candidates. Among the 13 postdocs working full time with IMO researchers during 2016, 6 of them came from foreign countries (UK, U.S.A., France, Spain, and Germany). During 2016, 4 postdocs (Drs. Deborah Steele, Isabel Andrade, Anthony Bertagnolli and Barbara Jacob) finished their contract and association with IMO, while 2 postdocs (Pierre-Amael Auger and Ramiro Riquelme) were employed by IMO as young researchers.

- **IMO involvement in graduate and undergraduate Programs**

During 2016, IMO continued to be linked to different undergraduate (4) and postgraduate programs (6), including teaching basic and advanced courses, practical work, and thesis guidance:

- Undergraduate Programs in Marine Sciences: Marine Biology at UdeC and PUC, Geophysics at UdeC, and Oceanography at PUCV

- Postgraduate Programs in Marine Sciences: M. Sc. in Oceanography at UdeC and PUCV, M.Sc. in Ecology of Aquatic Systems at U. Antofagasta, Ph.D. in Oceanography at UdeC, Ph.D. in Environmental Sciences at UdeC, and Ph.D. in Biological Sciences at PUC.

During 2016, 43 students were directly linked to IMO: 8 in undergraduate, 21 in M. Sc., and 14 in Ph.D. Programs. IMO researchers are or were co-tutoring 50% or more students in each of these categories.

IMO makes a call for undergraduate scholarships twice a year and the decision criteria is strongly based on the academic records of the candidates, the needs of each IMO research theme, and the potential for interaction through co-tutoring their thesis work and/or professional qualification. In the case of graduate students, IMO associate researchers are asked twice a year to propose candidates, including first year and older students developing their thesis. First year students who applied to a CONICYT scholarship but did not get it are strongly considered for support if they have very good academic records and, in some cases, they were linked to IMO from their undergraduate formation. IMO support extends for up to 1 year and these students are asked to apply again to external funds. Graduate students finishing their thesis work are also supported for periods of less than 1 year if they have completed an important part of their thesis requirements. IMO also supports students with partial grants when IMO researchers make a contribution to these grants through other funding sources available to them.

In 2016, IMO awarded scholarships to a total of 15 students, 7 of undergraduate level and to 8 of graduate level (7 M.Sc. and 1 Ph.D.). In addition, 6 of the 24 graduate students from IMO received a CONICYT scholarship during 2016 whereas the rest had full or partial support from other funding sources (eg. institutional scholarships or through projects from IMO researchers).

- **IMO organization of training**

Advanced courses:

Ecology and Diversity of Marine Microorganisms (ECODIM): This international course was held at the Marine Station of the Department of Oceanography of the University of Concepcion, in Dichato, on 11/30 January 2016. Lecturers from France, Switzerland, the United States and Chile interacted with 15 students coming from Argentina, Brazil, Ecuador, Egypt, Colombia, Cuba, Peru and Chile. ECODIM offered the Symposium Exploring the deepest and most mysterious regions of the ocean on January 15. This activity was held at the Main Campus of the University of Concepcion, was open to the scientific community, and transmitted via streaming.



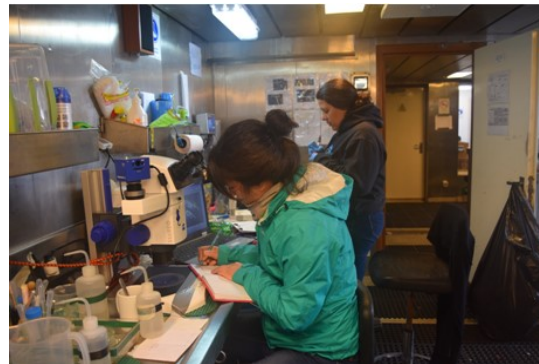
Participants in the Ecology and Diversity of Marine Microorganisms (ECODIM) course carried out in the University of Concepcion Marine Station, Dichato, Chile during January 2016.

Basic Courses:

Course in R programming: An intensive course in R, a functional language and environment to statistically explore and analyse data, was carried out by the IMO researcher Carolina Parada and postdoc Frauke Albrecht during August 2016. The course was mainly focused to satisfy requirement expressed by IMO graduate students and postdocs. The course was attended by 15 students.

- **Field Training:**

During 2016, 2 oceanographic cruises organized by researchers allowed an active involvement of students and/or postdocs. During the MOPEX **cruise**, a total of 8 graduate students and 3 postdoc participated whereas during the CIMAR 22 **cruise**, 5 graduate students participated. These cruises allow them to gather samples and data for the preparation of their thesis work and/or research. In addition, several types of samples were obtained for the analyses of other students and postdocs that did not participated in the cruise.



MOPEX cruise group (left) and IMO students at CIMAR 22 cruise (right).

A summary is shown in Annexes 5.1 y 5.2

5. Networking and other collaborative work

a) **Networking:**

We have strengthened international collaboration with researchers from the Instituto Oceanográfico Español (IOE), Spain, and the Scripps Institute of Oceanography (SIO), USA, for sample and data analyses, equipment development derived from cruises realized during 2016 and those upcoming in the next few years. With IOE an international course on the use of isotopes of C and N to assess food webs in marine systems was organized and carried out in Concepción as sponsored by IMO. As result of this collaboration a proposal for a formal networking project between IMO and IOE has been submitted to CONICYT of Chile as to collaborate for investigating food webs and sources of C and N in deep ocean communities. A formal MOU between University of Concepción and SIO was agreed and recently signed by both Institutions. IMO research is one of the important components for such agreement.

Collaboration with the Mediterranean Institute of Oceanography (MIO) of University of Marseille, France continued during 2016 through data processing and analysis of experimental work on nutrient cycling mediated by zooplankton excretion carried out in the OUTPACE cruise in oligotrophic waters of the western south Pacific. This work will be published in a special issue of Biogeoscience planned for mid 2017.

Additional collaboration with France continued in the framework of the UMI3614 “Evolutionary Biology and Ecology of Algae”, the international research unit of the CNRS partnered with Université Pierre et Marie Curie (Paris VI), Pontificia Universidad Católica de Chile, and the Universidad Austral de Chile, as well as the larger CNRS-financed international research network International Research Network "Diversity, Evolution and Biotechnology of Marine Algae" (GDRI N° 0803), involving French, Chilean, and Brazilian researchers. IMO Associate Researcher P. von Dassow is part of both networks. These collaborations have supported ongoing phylogenetic analysis of coccolithophores (Bendif et al. 2016), population genetics work (to be submitted in 2017), research in press on phytoplankton community fluctuation in an estuary (Alves-de-Souza et al., in press in *Journal of Plankton Research*), and, in 2016, a shared UPMC Master M2 thesis (Florian Freytet, tutors Laure Guillou of CNRS and von Dassow of IMO) analyzing sequences of parasitic Syndiniales from anoxic waters.

During 2016 IMO has actively contributed to international networking programs involved in ocean dynamics, biogeochemical processes, climate variability and marine ecosystem health and sustainability, and ocean observations. IMO researcher and deputy director, R. Escribano continues to be member of the SCC of IMBeR Program (Integrated Marine Biosphere and ecosystem Research which has now entered a second phase as sponsored by Future Earth and SCOR. Within IMBeR R. Escribano has re-organized the Upwelling Working Group becoming chair of it. IMO has also become an active participant of the Ocean Climate Variability Program (CLIVAR) sponsored by the WCRP. In CLIVAR R. Escribano is a co-chair of the Eastern Boundary Upwelling Systems (EBUS) Research Focus Program. EBUS RF constitutes an international joint effort to integrate biogeochemical, ecosystem and climate models to understand and predict responses of upwelling systems to climate change. Regarding ocean observations IMO continued to be participant in the Chilean consortium formal member of POGO (International Partnership for Observation of the Ocean). Also IMO associate researcher, C. Morales has been the national representative for SCOR (Scientific Committee for Oceanic Research).

At regional scale IMO has been an active member of the ANTARES network for oceanographic time series of America sponsored by IAI (Interamerican Institute for global change). In ANTARES IMO organized a time series workshop in Concepción, December 2016, focused on climatic indexes and in situ time series observations in coastal stations of several Latin American countries.

In the framework of Research Theme 3, our collaboration network strategy in IMO has carried out an outstanding number of networking activities and joined several international cooperation programs during this period. IMO has maintained a permanent involvement in joint activities with the Ocean Acidification International Coordination Centre (OA-ICC). OA-ICC is focused in bringing together scientists to promote, facilitate, and communicate research. One of the IMO's PI (C. Vargas) is a member of the Executive Council of the Global Ocean Acidification Observing Network (GOA-ON) from its launch in 2012. GOA-ON is a network for the detection and attribution of OA and ecosystem response, and involves participants from 30 nations. Dr. Vargas is also member of the Scientific Committee of the International Ocean Carbon Coordination Program (IOCCP). IOCCP is a global network of ocean carbon observations for research, international agreements on standards and methods, and links to the global observing systems. IMO has been involved in the founding of the Latin-American Ocean Acidification Network (LAOCA), a network to coordinate research efforts that are being developed in this region, with focus on OA, and generation of information for decision-makers and governments. LAOCA is actually involving scientists from Argentina, Brazil, Chile, Colombia, Peru, Ecuador, Mexico and Costa Rica. One of the IMO's PI, has been not only one of the founder, but also member of the Executive Council in LAOCA.

Given the similarities that exist between Mexico and Chile, in terms of oceanographic conditions (Oxygen Minimum Zones, OMZs), as well as the type of marine ecosystems, we will reinforce a

strong collaboration with colleagues from the Autonomous University of Baja California, Ensenada, Mexico (Dr. Eugenio Carpizo and Martin Hernández-Ayon), focused in carbonate chemistry research, and impact of ocean acidification in marine organisms. Two research visits of Dr. Vargas in Ensenada, Baja California, in the framework of capacity building activities for Latin-American students through LAOCA have reinforced our collaboration with Mexican colleagues.

Finally, we have also host colleagues from different institutions such as from Plymouth Marine Laboratory (UK), Exeter University (UK), but also providing internship opportunities abroad for our graduate students.

*Summary in **Annex 6.1.***

- b) **Other collaborative activities:** Some of our researchers (C.A. Vargas) are members of the technical advisory groups for several governmental agencies, such as the Technical Advisory Group on Climate Change for the **Under-Secretary of Fisheries** and Chilean representative for the **National Atomic Energy Agency (CChEN)** upon international agencies and programs (INT7019) of the International Atomic Energy Agency (IAEA). Summary in **Annex 6.2.**

6. Outreach and connections with other sectors

The IMO Outreach team is an interdisciplinary group of scientists, educators, designers, audiovisual producers, communicators, students and engineers with the objective of disseminate knowledge and culture about the sea and marine science, through face-to-face activities, the creation and implementation of multiplatforms, digital tools and audiovisual products, which are presented to schools and the society. The team promotes awareness and empowerment related to the ocean in broader society, through new informational and educational products.

During 2016, our team continued developing and improving strategies and tools to take the scientific knowledge about the ocean to the school and the community, focused on the concept of the great wealth of our oceans.

1. Proyección al Medio Externo - PME (*Outreach activities Projects*):

i. “Sumérgete: una travesía por el Océano Pacífico” (*Submerge: A travel through the Pacific Ocean*) (www.sumergete.cl)

First created in 2015, this website is an educational platform of Marine Sciences, oriented to primary and secondary students, where students can access different “classrooms”, each one representing a marine environment of the Pacific Ocean. The users can browse the “classrooms” discovering the organisms living there, as well as some characteristics and importance of the environment and the impact that humans have on it. Videos and other audiovisual material are available YouTube channel, and news of Outreach team activities and selected news from the scientific world are published weekly on the site’s Facebook fanpage. A complete redesign of the web occurred in 2016. “Sumérgete” now has 3 “classrooms”: Intertidal, Coastal Ocean, and Oceanic Islands, with the latter developed in 2016 collaboration with the Millennium Nucleus of Ecology and Sustainable Management of Oceanic Islands (ESMOI). Alliances were also made for the creation of a Southern Ocean “classroom” with the Chilean Antarctic Institute (INACH) and a Fjord “classroom” with the Center for Research in Ecosystems of Patagonia (CIEP).



Homepage www.sumergete.cl



Jornada Concurso Sumérgete a Explorar

A partnership with PAR Explora Biobío, called "Submerge to Explore" in 2016 created a completion. a call was made to teachers of second cycle of Basic Education, to register groups of maximum 10 students, who had the opportunity to participate in four instances or challenges: Photomontage of marine food traps; Tales of the Sea; Video about "us on the Ocean" and a Cómico "SuperMar". In total, 295 students participated, from 18 schools in 14 communes of the Biobío region. Winning groups from each challenge, totaling 40 students from 4 communes, visited the Marine Biology Station of the Universidad de Concepción in Dichato.

ii. **Muestra Audiovisual Científica Itinerante - MACI** (*Itinerant Scientific Audiovisual Exhibition*)

This activity "takes the ocean to school", in the Biobío Region, and includes a display of audiovisual material, and practical and playful work with students of the three levels of education in Chilean educational system: first cycle of Basic Level (from 1st to level 4th), second cycle of Basic Level (from 5th to 8th grade) and High School (1st to 4th level). MACI informs students of the ocean, as well as its importance for our country and impact on the planet, through simple language and associating MACI with the school curriculum.

A 3 year partnership with PAR Explora Biobío to develop 10 MACI events annually in 2016, doubling the number with respect to 2015 and reaching a coverage of 3000 students. In 2016, partnerships with Univesidad de Antofasta, PAR Explora Antofagasta, the Pontificia Universidad Católica de Valparaíso, and the Universidad de Magallanes allowed MACI to begin in other Regions of Chile, with two in Antofagasta, one in Valparaíso, and two in Magallanes. MACI was pre-selected by the CTI program initiatives of valuation of the technological sciences and innovation to be taken to schools in Los Ríos region in a pilot plan.

iii. **"IMO en la Escuela" (IMO in the School)**

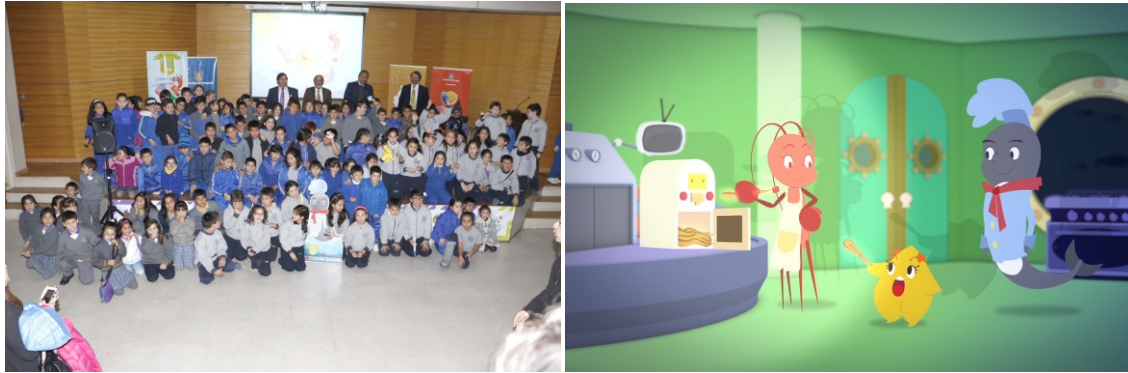
This initiative consists in the intervention of a scientist in a School, with a talk / workshop about Marine Sciences, focused on primary and secondary students, to stimulate and/or reinforce curricular learning, complementing with alluring scientific topics and the guidance of student scientific groups about marine subjects. "IMO en la Escuela" aims to stimulate the curiosity and interest of children about the ocean and ocean science.

In 2016, eleven talks / workshops were held under this initiative. Six of them in the Biobío Region, and five in the Metropolitan Region, reaching more than 500 schoolchildren. Adjunt Researcher, Dr. Pamela Hidalgo, the Academy of Sciences of the Colegio Salesiano in Concepción for the second consecutive year, with students participating in provincial and regional school congresses.

2. **"La Receta Científica de Tony Tonina"** (*Tony Tonina's Scientific Recipe*)

This is a 10 chapter television cartoon series for education, focused to first cycle of Basic Education children. Each chapter addresses a specific topic of Natural Sciences, extracted from the scholar curriculum. The series is about Tony Tonina, the chef of the Restaurant "Sabores Submarinos", who, passionate about cooking and discovering the mysteries of science, is dedicated to cooking great preparations of his magic recipe book.

During 2016, the chapters were completed, the series was officially launched at the Interactive Center for Arts, Sciences and Technology (CICAT) of the Universidad de Concepción. It was broadcast on channel 9 Biobío TV, achieving a reach of 25,000 to 30,000 viewers per chapter. With a total of 300 thousand spectators for the series. The series also has an interactive video game application: where students are motivated to answer scientific questions associated with the school curriculum. This videogame is divided by the different courses of first cycle of Basic Education. See the website www.tonytonina.cl and the associated YouTube channel.



The series launch, September 9, 2016

3. “Exploradores: Del átomo al cosmos” (*Explorers: From the atom to the cosmos*)

In 2016, IMO and Fundación Ciencia y Vida have co-led the project "Explorers: from the Atom to the Cosmos", in co-production with the channel 24 Horas de TVN and IMAGO. The objective of the series is to inform Chileans about the centers of excellence in science. The first season included the participation of the following centers: Center for Astrophysics and Related Technologies (CATA), the Millennium Institute for Research in Depression and Personality (MIDAP), Institute of Complex Engineering Systems (ISCI), Center for Climate Science and Resilience (CR)², Interdisciplinary Center for Neuroscience of Valparaíso (CINV), Center for Biotechnology and Bioengineering (CeBIB), Center for Aging and Regeneration (CARE), and the Center for Electrical and Electronic Engineering (AC3E), as well as the IMO in a special chapter where Senior Researcher Dr. Juan Carlos Castilla discussed challenges and crises relevant to current marine science and oceanography. Each chapter was seen by more than 300 thousand spectators, and so is judged a great success, and so will be followed with a new season in 2017.

4. Others

During 2016, we also participated in various scientific outreach events. Such as: An activity for Asperger children at the Universidad de Concepción; In the “Month of the Sea” with talks for the schools and general community; In the Congress of Marine Sciences with an institutional stand; On “Cultural Heritage Day”, at the Universidad de Concepción; In an urban intervention for the “Day of the Oceans”; At the “ChileVA Scientific Camps” with two workshops of Oceanography; In various scientific fairs, both communal and school; In different instances of the provincial and regional school congresses of Explora; In the “Day of the Science in Family”, at the Universidad de Concepción; At the “Feast of Science” in Antofagasta; Several field activities to students from different communes, in the Marine Biology Station of the Universidad de Concepción, in Dichato; In the “Open Doors University” at the Universidad de Concepción; In the “Congress of the Future for Young People”, with a promotional booth and an IMO postdoc talk; In the “Technological Challenges” of PAR Explore Biobío.

5. Some of the milestones in 2016, which had significant media coverage were:

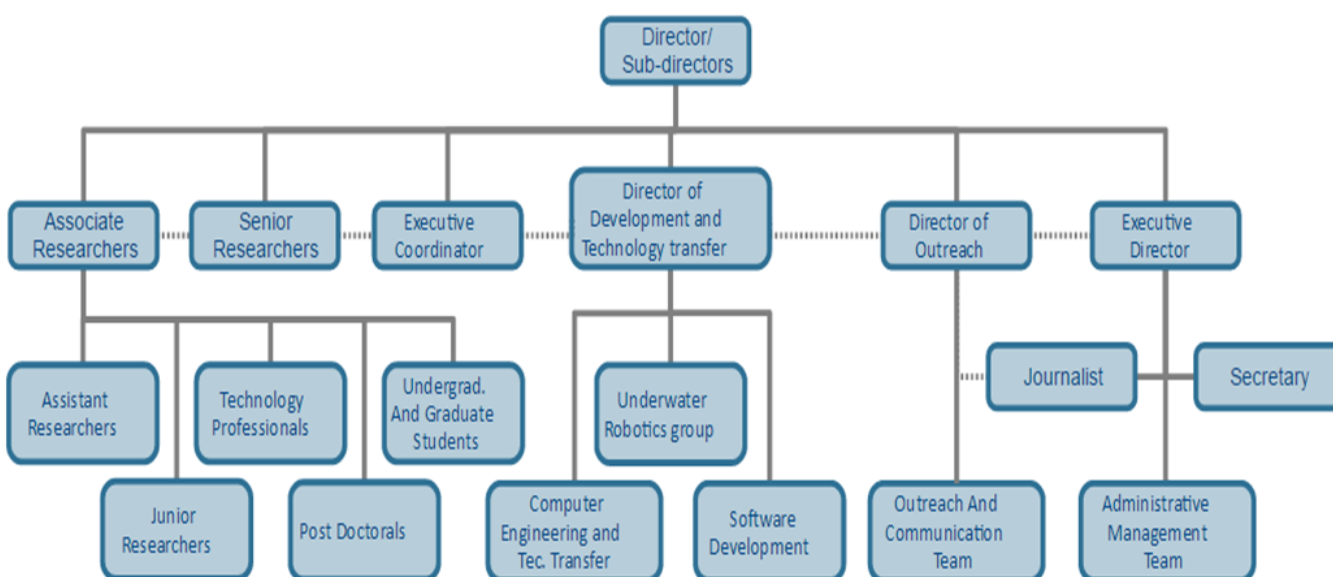
The inaugural ceremony of the IMO held in May, which achieved a cover in *Diario Concepción*, in addition to mentions in newspapers such as “*Diario El Sur*” and in various national media such as “*El Ciudadano*”, and sites such as “*Innovacion.cl*”, “*Mundo Acuicola*”, “*Aqua.cl*”, among others; The

launch of the children's animation series "La Receta Científica de Tony Tonina" in September, which captured the attention of national scale media such as "La Cuarta", "El Mercurio", "TVN" and "EMOL.cl". At the regional level, the "Velvet" Magazine, Regional Channel "Canal 9", "Radio UdeC", "Panorama UdeC", among others, echoed the information; The IMO's oceanographic expeditions: MOPEX and participation in CIMAR 22 reached national media such as "Las Últimas Noticias", "Hoy por Hoy", "El Mercurio" and regional media such as "Diario Concepción", "Biobio Chile" and specialized media such as "Aquaculture World", "Aqua.cl", as well as "Panorama UdeC".

7. Administration and Financial Status

a) **Organization and administration:**

The following chart shows the organizational and operational structure during 2016.



The administration team was is comprised of Mr. Mario Baltazar as Chief Accountant, and Mrs. Olga Pérez as the Assistant Accountant, both of whom are full time professionals, together with IMO's Executive Secretary, Mrs. Mabel Marcó and the Executive Director Mr. Atilio E. Morgado. The number of professionals ranged between 17 to 24, collaborating in laboratoy, sample and data analysis, field task, including cruises and marine operations and equipment operation. Some of them contributed also to R&D and Outreach activities.

During 2016, administrative demands rose with increasing transactions related to projects obtained by the Institute and activities, such as the CIMAR 22 and MOPEX cruises, the Moore Foundation Experimental Model Systems grant, and an increasing number of Outreach projects.

Another main task of administrative and technical staff in 2016 was organizing and conducting the ceremony officially inaugurating our Institute held on May 23, 2016, at the Art House of the University of Concepcion. The ceremony was presided over by the Vicerrector of the University and attended by representatives of the scientific and academic community, regional authorities and members of IMO. Our Director Dr. Osvaldo Ulloa, presented the objectives of the Institute and the landmarks that have been achieved so far. Dr. Juan Carlos Castilla, our senior researcher, offered the Conference "Chile es Mar y Profundo". Dr. Trevor Platt, professor at the Plymouth Marine Laboratory was our special guest for this ceremony. Dr. Platt has been involved in the development of oceanography in Chile since the late 1970s and his presence was highly appreciated given the positive impact that his work has had in the formation of professionals in this area. Dr. Platt offered the Conference Chile on the World Stage of Oceanography. Dr. Platt was recognized by the University of Concepcion with the honorific title of Distinguished Visiting Professor.

Finally, IMO administrative and technical staff were also engaged in providing resource management and technical support to the “Crucero Marea Roja” (RedTide Cruise) aboard *Cabo de Hornos* research vessel, as was requested from Chilean Economy Ministry to face the scientific research about the microalgae bloom emergency occurred in Chiloé Island, South of Chile, during february and march 2016, and reaching the “Los Lagos” and “Los Ríos” regions.

A summary of administrative and technical staff by gender is presented below.

Category	Female	Male	TOTAL
Assistant & Technicians	11	13	24
Administrative Staff	2	2	4
TOTAL	13	15	28

- b) **Financial Status:** The 2016 financial status, the different fund sources and their percentage of use, for the Millenium of Oceanography Institute are detailed in the Annexes 9.1 to 9.3

8. Annexes

Annex 1.- Institute Researchers

1.1 Associate Reaserchers

Full Name	Research Line	Nationality	Gender	Date of birth	Profession	Academic Degree	Affiliation	Current Position	Relation with Center
Oscar Roberto Pizarro Arriagada	1,2,4	Chilean	M	28-03-1963	Oceanographer	D	UdeC	Associate Professor	2
Peter von Dassow	All	American	M	31-03-1974	Oceanographer	D	PUC	Assistant Professor	2
Oswaldo Iván Ulloa Quijada	3,4	Chilean	M	21-05-1961	Marine Biologist	D	UdeC	Full Professor	2
Heraclio Rubén Escribano Veloso	All	Chilean	M	16-04-1957	Marine Biologist	D	UdeC	Full Professor	2
Carmen Morales Van De Wyngard	1,2	Chilean	F	16-07-1955	Biologist	D	UdeC	Associate Professor	2
Wolfgang Schneider	2,4	German	M	16-02-1954	Oceanographer	D	UdeC	Full Professor	2
Cristian Antonio Vargas Galvez	1,3,4	Chilean	M	26-12-1972	Marine Biologist	D	UdeC	Assistant Professor	2
Samuel Ernesto Hormazábal Fritz	1,2	Chilean	M	08-12-1967	Oceanographer	D	PUCV	Associate Professor	2

1.2 Young Researchers

Name	Research Line	Nationality	Gender	Date of birth dd/mm/yy	Profession	Academic Degree	Affiliation	Current Position	Relation with Center
Victor Miguel Aguilera Ramos	2,3	Chilean	M	01-11-76	Marine Biologist	D	University of Antofagasta	Assistant Professor	2
Marcela Alejandra Cornejo D'Ottone	1	Chilean	F	20-07-77	Oceanographer	D	Pontifical Catholic	Associate Professor	2

Name	Research Line	Nationality	Gender	Date of birth dd/mm/yy	Profession	Academic Degree	Affiliation	Current Position	Relation with Center
							University of Chile		
Ali Reda Belmadani	1, 2	Finland	M	04-06-79	Oceanographer	D	University of Concepción	Assistant Professor	2
Pierre Amael Auger *	1: Mesoscale Processes	French	M	07-09-1984	Engineer	D	Millennium Institute of Oceanography	Postdoctoral fellow	1
Ramiro Antonio Riquelme Bugueño *	1: Mesoscale Processes. 3: Adaptations to a Changing Ocean. 4: The Deep Ocean	Chilean	M	07-09-1978	Marine Biologist	D	University of Concepción – IMO	Assistant Professor *	2

1.3 Senior Researchers

Name	Research Line	Nationality	Gender	Date of birth dd/mm/yy	Profession	Academic Degree	Affiliation	Current Position	Relation with Center
Juan Carlos Castilla Zenobi	All	Chilean	M	19-08-40	Biologist	D	PUC	Professor	2
Gerrit van den Engh	All	Holland	M	06-03-49	Biologist	D	MarCy	Senior researcher	2

1.4 Other Researchers

Name	Research Line	Nationality	Gender	Date of birth dd/mm/yy	Profession	Academic Degree	Affiliation	Current Position	Relation with Center
Aldo Manuel Montecinos Gula	2: Ocean Variability	Chilean	M	24-07-1965	Oceanographer	D	University of Concepción	Associate Professor	2
Carolina Eugenia Parada Veliz	1: Mesoscale Processes	Chilean	F	02-10-1970	Oceanographer	D	University of Concepción	Assistant Professor	2
Julio Sepúlveda Arellano	2: Ocean Variability 3: Adaptations to a Changing Ocean	Chilean	M	25-02-1977	Marine Biologist	D	University of Colorado Boulder	Assistant Professor	2
Laura Farías	3: Adaptations to a Changing Ocean	Argentinian	F	07-07-1963	Oceanographer	D	University of Concepción	Assistant Professor	2
Marcelo Enrique Oliva Moreno	4: The Deep Ocean.	Chilean	M	17-03-1952	Biologist	D	University of Antofagasta	Full Professor	2
Pablo Rosenblatt Guelfenbein	All.	Chilean	M	06-01-1955	Biologist	M	Millennium Institute of Oceanography	Adjunct Researcher	2
Pamela del Carmen Hidalgo Diaz	3: Adaptations to a Changing Ocean	Chilean	F	07-06-1966	Other	D	University of Concepción	Adjunct Professor	2
Ricardo Hernán De Pol Holz	2: Ocean Variability.	Chilean	M	17-10-1973	Marine Biologist	D	University of Concepción -	University Teacher	2

Name	Research Line	Nationality	Gender	Date of birth dd/mm/yy	Profession	Academic Degree	Affiliation	Current Position	Relation with Center
							University of Magallanes		
Rodrigo Alonso De la Iglesia Cabezas	3: Adaptations to a Changing Ocean	Chilean	M	26-12-1978	Biologist	D	Pontifical Catholic University of Chile	Associate Professor	2
Víctor Enrique Villagrán Orellana	All.	Chilean	M	02-03-1973	Engineer	M	University of Concepción	Ing. Chief Laboratory MidGEO	2
Alejandro Andrés Murillo Cordova	1: Mesoscale Processes	Chilean	M	20-01-2015	Biologist	D	University of Concepción	postdoctoral fellow	1
Pierre Amael Auger *	1: Mesoscale Processes	French	M	07-09-1984	Engineer	D	Millennium Institute of Oceanography	postdoctoral fellow	1
Deborah J. Steele	1: Mesoscale Processes. 3: Adaptations to a Changing Ocean.	United Kingdom	F	18-11-1986	Biologist	D	Millennium Institute of Oceanography	postdoctoral fellow	2
Paulina Aguayo	3: Adaptations to a Changing Ocean	Chilean	F	31-12-1980	Marine Biologist	D	Millennium Institute of Oceanography	postdoctoral fellow	1
Anthony Bertagnolli	2: Ocean Variability. 3: Adaptations to a Changing Ocean.	American	M	15-09-1982	Biochemist	D	Millennium Institute of Oceanography	postdoctoral fellow	2
Alvaro Alfredo Muñoz Plominsky	3: Adaptations to a Changing Ocean	Chilean	M	24-04-1984	Biologist	D	University of Concepción	postdoctoral fellow	2
Carlos Andrés Henríquez Castillo	3: Adaptations to a Changing Ocean. 4: The Deep Ocean.	Chilean	M	06-05-1983	Biochemist	D	University of Concepción - IMO	postdoctoral fellow	2
Pedro Echeveste De Miguel	3: Adaptations to a Changing Ocean. 4: The Deep Ocean..	Spanish	M	03-08-1981	Biologist	D	Pontifical Catholic University of Chile	postdoctoral fellow	1
Sara Zamora Terol	. 4: The Deep Ocean.	Spanish	F	23-03-1980	Biologist	D	University of Concepción	postdoctoral fellow	2
Frauke Albrecht	2: Variabilidad Oceánica.	German	F	02-01-1980	Geosciences	D	University of Hamburg Germany	Postdoctoral fellow	1
Isabel Margarita Andrade Cornejo	1: Mesoscale Processes	Chilean	F	22-10-1979	Marine Biologist	D	Pontifical Catholic University of Valparaíso	postdoctoral fellow	2

Name	Research Line	Nationality	Gender	Date of birth dd/mm/yy	Profession	Academic Degree	Affiliation	Current Position	Relation with Center
Bárbara Jacob Valderrama	3: Adaptations to a Changing Ocean	Chilean	F	02-11-1972	Fishing And Aquaculture Engineer	D	University of Concepción	postdoctoral fellow	2
Ramiro Antonio Riquelme Bugeño *	1: Mesoscale Processes. 3: Adaptations to a Changing Ocean. 4: The Deep Ocean	Chilean	M	07-09-1978	Marine Biologist	D	University of Concepción – IMO	Postdoctoral fellow *	2
Atilio Morgado	All	Chilean	M	23-05-1960	Mar. Biol.	M	Millennium Institute of Oceanography	Adjunct Researcher	2

NOMENCLATURE:

[Gender] [M] Male [F] Female	[Academic Degree] [U] Undergraduate [M] Master [D] Doctoral	[Relation with Center] [1] Full time [2] Part time
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* These two researchers changed from IMO Postdoctoral Fellows to IMO Young Researchers during 2016.

Annex 2. Research Lines

N°	Research Line	Research Line Objectives	Description of Research Line	Researcher	Research Discipline	Starting Date [dd/mm/yy]	Ending Date [dd/mm/yy]
1	Mesoscale processes	What is the role of mesoscale activity in governing energy and matter transfer and ecosystem dynamics in open ocean ecosystems	<p>Mesoscale eddies are characteristic of the southeastern Pacific (SEP) and connect areas with coastal upwelling with oligotrophic oceanic waters, as well as meso- and epipelagic domains. Eddies create unique and relatively isolated environments with distinct biological communities and chemical conditions, depending on the nature of the water trapped, the characteristics and path of eddies and their interactions with winds and topography.</p> <p>Seamounts, submarine mountain ranges and oceanic islands in the southeastern Pacific can also create or strengthen mesoscale activity and consequently increase biological production around them.</p> <p>Our hypothesis is that mesoscale eddies generated in the coastal area create conditions of deficient O₂/low pH in the open sea (or the opposite in areas with minimal oxygen), with corresponding changes in the structure of communities and biochemical cycles, and that differ significantly from those found in adjacent oceanic waters. To address this research theme, we will carry a field experiment to study the characteristics and evolution of mesoscale eddies generated in the sea beyond central Chile (~36 °S) and that are propagated to the northwest, reaching to around the Juan Fernández Archipelago. The field experiment will include time-series observations by satellite teledetection (e.g. ocean altimetry and color), an anchorage in the vicinity of the Juan Fernández Archipelago, and sections with a sailplane, as well as cruises oriented to processes.</p> <p>To study the evolution of the physical-chemical and biological conditions of one of these eddies we will visit it on three occasions as it advances from the coast to the open ocean. On this occasion we assess changes in chemical characteristics (e.g. dissolved organic carbon and organic particulates and dissolved inorganic matter, O₂, pH/pCO₂ and nutrients), community structures, gene expression and biogeochemical activity (e.g. primary production, nitrogen fixation, respiration and others) within and beyond the eddies.</p> <p>Also, we will carry out onboard perturbation experiments; applying individual and multiple stress factor in contrasting waters.</p> <p>Using numeric experiments, we will analyze the structure of these eddies and they ways in which they are generated and transported, in particular in the minimum oxygen zones (ZMO) around oceanic islands and submarine associated with the submarine Nazca and Juan Fernández mountain ranges.</p>	<p>Carmen Eliana Morales Van De Wyngard</p> <p>Samuel Ernesto Hormazábal Fritz</p> <p>Ali Reda Belmadani</p> <p>Carolina Eugenia Parada Veliz.</p> <p>Marcela Alejandra Cornejo D'Ottone.</p> <p>Juan Carlos Castilla Zenobi.</p> <p>Isabel Margarita Andrade Cornejo.</p> <p>Oscar Roberto Pizarro Arriagada.</p> <p>Peter von Dassow</p> <p>Cristian Antonio Vargas Galvez.</p> <p>Alejandro Andrés Murillo Cordova.</p> <p>Heraclio Rubén Escribano Veloso.</p> <p>Ramiro Antonio Riquelme Bugueño.</p> <p>Pierre Amael Auger</p>	<p>Ecology and environmental sciences.</p> <p>Oceanography</p> <p>Meteorology and climatology.</p> <p>Marine biology.</p> <p>numerical methods and computer science.</p>	26-12-2013	

2	Ocean Variability and Change	How large scale perturbations impact the transport and gradients in physical chemical water properties	<p>The subtropical cell controls the large-scale transport of heat, freshwater, carbon, nutrients and dissolved O₂ through the southeastern Pacific basin. These processes modulate chemistry and biology and the regional component of the climate variability.</p> <p>Models and field observations have shown that in the context of climate warming, the subtropical celda of the South Pacific is reinforced as a response to changes in surface winds on a large scale on the tropical Pacific. As well, it is expected that global warming directly affects the South Pacific by strengthening the degree of productivity. As the temperature of the upper layers increases, the stratification of oceanic water is reinforced, affecting the mixing of water masses and vertical diffusiveness in subtropical regions. In contrast, stronger coastal winds could increase vertical mixing and upwellings of eastern currents.</p> <p>It has been argued that coastal upwelling and transport by the Humboldt Current have intensified in recent decades and has been getting stronger on the scale of decades. This in turn has been modifying the properties of waters that participate in the subtropical cell and in an increase in the physical, biochemical and ecological gradients between the coastal and oceanic environments. The lower O₂ content of the warmer ocean waters and the higher gradients between upwelling and stratified oceanic waters contributes to expanding waters low in O₂/pH and high in pCO₂, which affects biological communities and the biogeochemical cycles in these waters.</p> <p>To address this issue, new and novel observations will be combined with advanced regional numeric models. The observations come from expeditions and regular transects with gliders between the coast and the Juan Fernández Archipelago. The data will include temperature, salinity, O₂ and other biochemical variables (e.g. pH, pCO₂, nutrients, gases, and organic and inorganic carbon, including their isotopes: ¹²C, ¹³C, ¹⁴C, and ¹⁵N). We will also make a high-resolution analysis of the microstructure and the indices of turbulent mixing that allow calculating the vertical flows of salts, heat and relevant biogeochemical properties. These high-resolution data, together with historic data will allow for assessing annual and more frequent changes in meridional transport and in the physical and chemical properties in the thermocline and intermediate waters.</p> <p>This data will be used in refining models and in validating their outcomes. Different simulations will generate outcomes that will be introduced into regional models to assess the mechanisms that affect coastal upwelling, the generation of mesoscale eddies, regional circulation and the modification of water masses.</p>	<p>Oscar Roberto Pizarro Arriagada.</p> <p>Wolfgang Schneider</p> <p>Ricardo Hernán De Pol Holz.</p> <p>Carolina Eugenia Parada Veliz.</p> <p>Samuel Ernesto Hormazábal Fritz</p> <p>Carmen Morales Van de Wyngard</p> <p>Peter von Dassow</p> <p>Víctor Miguel Aguilera Ramos.</p> <p>Aldo Manuel Montecinos Gula</p> <p>Ali Reda Bel Madani</p> <p>Heraclio Rubén Escribano Veloso.</p> <p>Víctor Enrique Villagrán Orellana</p> <p>Pierre Amael Auger</p> <p>Frauke Albrecht</p>	<p>Biochemistry.</p> <p>Ecology and environmental sciences.</p> <p>Oceanography</p> <p>Meteorology and climatology.</p> <p>Marine biology.</p> <p>numerical methods and computer science.</p>	26-12-2013	
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3	Adapting to a Changing Ocean	<p>How Key functional plankton groups adapt to changing ocean chemistry and impact biogeochemical cycling</p>	<p>The strong and dynamic horizontal chemical gradients in the southeastern Pacific (SEP), from ultra-oligotrophic waters to coastal upwelling, exhibit highly variable combinations of low O₂ and pH/high pCO₂ and include strong vertical changes in O₂ concentrations, from saturation levels at the surface to undetectable levels in the nucleus of minimum oxygen zone (MOZ). These gradients cover a wide range of spatial-temporal scales. The responses of plankton communities and the feedback between community function and biogeochemical dynamics can depend in large measure on adaptations and capacities of acclimatization of key components, which can vary significantly among oceanic habitats. Moreover, the biological responses to multiple stress factors can be additive, synergetic or antagonistic. Our hypothesis is that the genomic variability among marine species is related to the differential functional responses to multiple stress factors and these determine the persistence or the modification of ecological/biogeochemical functions as the chemistry of the ocean changes.</p> <p>It is postulated that community functioning in highly stable environments like the South Pacific gyre is less robust in the context of changes in chemical conditions compared to that of highly variable environments, such as the oceanic coasts.</p> <p>Field and laboratory work will be undertaken to address this theme. In the first fieldwork undertaking, key representatives of functional plankton from areas with gradients of pCO₂, pO₂ and nutrients will be isolated. In association with this activity, a new collection of phytoplankton will be initiated at the PUC in coordination with the Roscoff Culture Collection.</p> <p>Perturbation experiments will be conducted with single stress factors on selected species, focusing on physiological variability in response to variations in pCO₂/pH, and O₂, and allow for improving the design of experiments with multiple stress factors. Based on these results, we conduct genomic analysis of species/genera (e.g. low O₂ – <i>Prochlorococcus</i>; low pH/high pCO₂ – <i>Coccolithophore</i>).</p> <p>For fieldwork, our Institute will conduct observations and experiments during expeditions. In situ estimations will be made of physiological/metabolic rates and communities, gene expression and particle flows (in particular associated with the carbon cycle, which in minimum oxygen zones is relatively unknown).</p> <p>As well, culture-independent genomic analysis of representative species will allow for putting to the test the associations between genomic and physiological variations. The composition and functioning of the communities will be analyzed and compared to the genomic population among the specific representatives of functional plankton groups.</p>	<p>Peter von Dassow.</p> <p>Osvaldo Iván Ulloa Quijada.</p> <p>Cristian Antonio Vargas Galvez.</p> <p>Laura Farías.</p> <p>Pamela del Carmen Hidalgo Diaz.</p> <p>Víctor Miguel Aguilera Ramos.</p> <p>Ricardo Hernán De Pol Holz.</p> <p>Alvaro Alfredo Muñoz Plominsky.</p> <p>Rodrigo Alonso De la Iglesia Cabezas.</p> <p>Heraclio Rubén Escribano Veloso.</p> <p>Alejandro Andrés Murillo Cordova.</p> <p>Bárbara Gianella Jacob Valderrama.</p> <p>Gerrit van den Engh.</p> <p>Víctor Enrique Villagrán Orellana</p> <p>Pedro Echeveste De Miguel.</p>	<p>Numerical methods and computer science.</p> <p>Biochemistry.</p> <p>Marine biology.</p> <p>Biophysics.</p> <p>Microbiology</p> <p>Oceanography</p>	26-12-2013	
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4	the deep Ocean	<p>what are the community structures and the biogeochemical characteristics of the deep and abyssal waters of the ESP</p>	<p>The ecosystems of deep SEP waters are practically unknown. Exploration of mesopelagic (>500 m) and abyssopelagic communities (>3000 m) represent unique opportunities to discover new forms of life, species and genes for science, as well as a major challenge for oceanography in the South Pacific basin.</p> <p>This initiative will allow for identifying the mechanism through which communities are able to distribute themselves widely and colonize unique habitats like the Atacama Trench and the Nazca, Salas & Gómez and Juan Fernández ranges. Our hypothesis is that the ranges contribute significantly to the dispersion of species and the gene flows in the coast-ocean direction, driven by the circulation of water masses and mixing associated with the meso and large scale physical dynamics.</p> <p>To address this theme we will carry out deep water samplings, including a MOCNESS net (maximum depth of 6,500 m) with an underwater video profiler (UVP), conductivity, temperature and fluorescence sensors and stratified sampling nets.</p> <p>The underwater video profiler provides profiles of the distributions of particle sizes, while the net samplings will be divided into fractions for examining live animals, DNA analysis and taxonomic studies.</p> <p>Water samples will also be taken for molecular and genomic analyses of microbial communities (viruses to protists). In situ incubation systems will be developed to estimate microbiological activity/rates. Quantitative and qualitative assessments will also be made of fish parasites and plankton as biomarkers of the dispersion of host species and the colonization of habitats. Individual and biogeochemical models will be used to analyze the mechanisms that contribute to maintaining endemic communities and the connectivity among different islands, seamounts and other oceanic regions.</p> <p>The expeditions will be conducted jointly with international counterparts. Molecular analysis of selected plankton will be centered on DNA microsatellites and mitochondrial DNA to relate sampled populations and species in the coast-ocean direction and in the vertical dimension.</p> <p>As well, the biogeochemical conditions of the deep ocean will be characterized, including measurements of carbon, and pH/pCO₂ reserves and saturation states of calcite and aragonite (Ω). Inorganic carbon isotopes (¹²C, ¹³C, ¹⁴C), dissolved organic carbon and age determination (DO¹⁴C) will also be included with the aim of learning about biogeochemical rates and the mixing of water masses in deep water ecosystems.</p>	<p>Heraclio Rubén Escribano Veloso.</p> <p>Oswaldo Iván Ulloa Quijada.</p> <p>Marcelo Enrique Oliva Moreno.</p> <p>Pamela del Carmen Hidalgo Diaz.</p> <p>Wolfgang Schneider.</p> <p>Oscar Roberto Pizarro Arriagada.</p> <p>Peter von Dassow</p> <p>Cristian Antonio Vargas Galvez.</p> <p>Alejandro Andrés Murillo Cordova.</p> <p>Pablo Rosenblatt Guelfenbein.</p> <p>Ramiro Antonio Riquelme Bugueño.</p> <p>Víctor Enrique Villagrán Orellana.</p> <p>Sara Zamora Terol.</p> <p>Gerrit van den Engh.</p>	<p>Numerical methods and computer science.</p> <p>Biochemistry.</p> <p>Marine biology.</p> <p>Biophysics.</p> <p>Microbiology</p> <p>Oceanography</p> <p>Ecology and Environmental Sciences</p>	26-12-2013	
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Annex 3.- Publications (Total or partially financed by MSI)

3.1.- ISI Publications or Similar to ISI Standard

3.1.1 Associate Researchers:

1. Anabalón, V., **Morales, C.E.**, González, H.E., Menschel, E., **Schneider, W.**, **Hormazábal, S.**, Valencia, L., **Escribano, R.** (2016) Micro-phytoplankton community structure in the coastal upwelling zone off Concepción (central Chile): Annual and inter-annual fluctuations in a highly dynamic environment. Progress in Oceanography 149: 174-188. Q1*, IF: 3.512, Research Line 1
2. Bendif, E. M., Probert, I., Díaz-Rosas, F., Thomas, D., van den Engh, G., Young, J., **Von Dassow, P.** (2016). Recent reticulate evolution in the ecologically dominant lineage of coccolithophores. Frontiers in Microbiology, 7: 784. Q1, IF: 4.165, Research Line 3
3. Bristow, L.A., Dalsgaard, T., Tiano, L., Mills, D.B., Bertagnolli, A., Wright, J.J., Hallam, S.J., **Ulloa, O.**, Canfield, D.E., Revsbech, N.P., Thamdrup, B. (2016). Ammonium and nitrite oxidation at nanomolar oxygen concentrations in oxygen minimum zone waters. Proceedings of the National Academy of Sciences of the United States of America Volume 113: 10601–10606. Q1*, IF: 9.423, Research Line 3
4. Cornejo D'Ottone, M., Bravo, L., Ramos, M., **Pizarro, O.**, Karstensen, J., Gallegos, M., Correa-Ramirez, M., Silva, N., Fariás, L., Karp-Boss, L. (2016) Biogeochemical characteristics of a long-lived anticyclonic eddy in the eastern South Pacific Ocean. Biogeosciences 13: 2971-2979. Q1*, IF: 3.7, Research Line 1
5. **Escribano, R.**, Bustos-Rios, E., Hidalgo, P., **Morales, C.E.** (2016) Non-limiting food conditions for growth and production of the copepod community in a highly productive upwelling zone. Continental Shelf Research 126: 1–14. Q2, IF: 2.011 Research Line 1
6. González, H.E., Graeve, M., Kattner, G., Silva, N., Castro, L., Iriarte, J.L., Osmán, L., Daneri, G., **Vargas, C.A.** (2016) Carbon flow through the pelagic food web in southern Chilean Patagonia: relevance of *Euphausia vallentini* as a key species. Marine Ecology Progress Series 557: 91–110. Q1, IF: 2.361, Research Line 3
7. Jacob, B., **Von Dassow, P.**, Salisbury, J., Navarro, J., **Vargas, C.A.** (2016) Impact of low pH/high pCO₂ on the physiological response and fatty acid content in diatom *Skeletonema pseudocostatum*. Journal of the Marine Biological Association of the United Kingdom, 97: 225–233. Q3, IF: 1.094, Research Line 3
8. Lagos, N. A., Benítez, S., Duarte, C., Lardies, M. A., Broitman, B. R., Tapia, C., Tapia, P., Widdicombe, S., **Vargas, C.A.** (2016) Effects of temperature and ocean acidification on shell characteristics of *Argopecten purpuratus*: implications for scallop aquaculture in an upwelling-influenced area. Aquaculture Environment Interactions 8: 357–370 Q2, IF: 1.985, Research Line 3
9. Medellín-Mora, J., **Escribano, R.**, **Schneider, W.** (2016) Community response of zooplankton to oceanographic changes (2002–2012) in the central/southern upwelling system of Chile. Progress in Oceanography 142: 17–29. Q1*, IF: 3.512, Research Line 3
10. Pérez, C.A., Lagos, N. A., Saldías, G. S., Waldbusser, G., **Vargas, C.A.** (2016) Riverine discharges impact physiological traits and carbon sources for shell carbonate in the marine intertidal mussel *Perumytilus purpuratus*. Limnology and Oceanography 61: 969–983. Q1*, IF: 3.66, Research Line 3

11. Peters, B., Babbin, A., Lettmann, K., Mordy, C., **Ulloa, O.**, Ward, B., Casciotti, K. (2016) Vertical modeling of the nitrogen cycle in the eastern tropical South Pacific oxygen deficient zone using high-resolution concentration and isotope measurements. Global Biogeochemical Cycles 30: 1661–1681. Q1*, IF: 4.495, Research Line 3
12. **Pizarro, O.**, Ramírez, N., Castillo, M., Cifuentes, U., Rojas, W., Pizarro-Koch, M. (2016) Underwater glider observations in the oxygen minimum zone off central Chile. Bulletin of the American Meteorological Society 1783 -1789. Q1*, IF: 7.929, Research Lines 1 and 2
13. Riquelme-Bugueño, R., Gómez-Gutiérrez, J., **Escribano, R.**, Ruz, P., Hidalgo, P., **Schneider, W.** (2016) First measurements of euphausiid growth rates in the northern Humboldt Current (23°S). Revista de Biología Marina y Oceanografía 51: 435-440, Q4, IF: 0.475 Research Line 3
14. Riquelme-Bugueño, R., Silva-Aburto, J., **Escribano, R.**, Peterson, W.T., **Schneider, W.** (2016) Growth of the Humboldt Current krill in the upwelling zone off central Chile. Journal of Marine Systems 163: 1–11. Q2, IF: 2.174 Research Line 3
15. Rokitta, S.D., **Von Dassow, P.**, Rost, B., John, U. (2016) P- and N-starvation trigger the same cellular responses to promote senescence in eukaryotic phytoplankton. Frontiers in Marine Science 3: 109, NA IF: NA, Research Line 3
16. Saldías, G., Largier, J., Mendes, R., Pérez Santos, I., **Vargas, C.A.**, Sobarzo, M. (2016) Satellite-measured interannual variability of turbid river plumes off central-southern Chile: Spatial patterns and the influence of climate variability. Progress in Oceanography 146 , 212–222. Q1*, IF: 3.512, Research Line 3
17. **Schneider, W.**, Donoso, D., Garcés-Vargas, J., **Escribano, R.** (2016) Water-column cooling and sea surface salinity increase in the upwelling region off central-south Chile driven by a poleward displacement of the South Pacific High. Progress in Oceanography 151: 38–48, Q1*, IF: 3.512, Research Line 2
18. Silva, C., Andrade, I., Yáñez, E., **Hormazábal, S.**, Barbieri, M.A., Aranis, A., Böhm, G. (2016) Predicting habitat suitability and geographic distribution of anchovy (*Engraulis ringens*) due to climate change in the coastal areas off Chile. Progress in Oceanography 146: 159–174. Q1*, IF: 3.512, Research Line 1
19. **Vargas, C.A.**, Contreras, P., Pérez, C., Sobarzo, M., Saldías, G., Salisbury, J. (2016) Influences of riverine and upwelling waters on the coastal carbonate system off Central Chile and their ocean acidification implications. Journal of Geophysical Research: Biogeosciences 121: 1468-1483. Q1, IF: 3,318, Research Line 3
20. Vergara, O., Dewitte, B., Montes, I., Garçon, V., Ramos, M., Paulmier, A., **Pizarro, O.** (2016) Seasonal variability of the oxygen minimum zone off Peru in a high-resolution regional coupled model. Biogeosciences 13: 4389-4410, Q1* IF: 3.7, Research Lines 1 and 2

* In the top 10% of the Impact Factor (IF) distribution.

3.1.2 Other researchers:

1. Biteen, J.S., Blainey, P.C., Cardon, Z.G., Chun, M., Church, G.M., Dorrestein, P.C., Fraser, S.E., Gilbert, J.A., Jansson, J.K., Knight, R., Miller, J.F., Ozcan, A., Prather, K.A., Quake, S.R., Ruby, E.G., Silver, P.A., Taha, S., **van den Engh, G.**, Weiss, P.S., Wong, G.C.L., Wright, A.T., Young, T.D. (2016) Tools for the Microbiome: Nano and Beyond. ACS Nano 10 (1), pp 6–37 ,Q1* IF: 13,334 Research Line 1,2,3,4
2. **Fierro, P., Hidalgo, P.**, Pino-Pinnuer, P., Marchant, M. (2016) First record of copepod Neomormonilla minor (Giesbrecht, 1891) for the Humboldt Current System off Chilean coastal zone (Mormonilloida: Mormonillidae) Crustaceana Volume 89, Issue 1, Pag. 19 – 28 Q4 IF: 0,664
3. Hinckley, S., **Parada, C.**, Horne, J., Mazur, M., Woillez, M. (2016) Comparison of individual-based model output to data using a model of walleye pollock early life history in the Gulf of Alaska. Deep-Sea Research Part II-Topical studies in Oceanography Vol.132, Pag. 240–262 Q1 IF: 2,137
4. J.L. Luque, F.B. Pereira, P.V. Alves, **M.E. Oliva** and J.T. Timi (2016) Helminth parasites of South American fishes: current status and characterization as a model for studies of biodiversity. Journal of Helminthology Page 1 of 15, Q2 IF: 1,63 Research Line 4
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7. **Parada, C.**,Frusher, S., Bustamante, R.H., Di Lorenzo, E., Bernal, P., Cryer, M., Dunn, A., Garreaud, Gutierrez, M., Jennings, S., **Montecinos, A.**, Neira, S., Quiñones, R.A., Takahashi, K., Yannicelli, B. (2016) South Pacific Integrated Ecosystem Studies meeting: toward conservation and sustainable use of marine resources in the South Pacific. Fisheries Oceanography 25 (Suppl. 1): 1–4, Q1 IF: 2,73
8. Torreblanca, M.L., Pérez-Santos, I., San Martín, B., Varas, E., Zilleruelo, R., **Riquelme-Bugueño, R.**, Palma, A.T. (2016) Seasonal dynamics of zooplankton in a northern Chile bay exposed to upwelling conditions. Revista de Biología Marina y Oceanografía Vol. 51, N°2: 273-291 Q4 IF: 0,475 Research Line 3

3.2.- SCIELO Publications or Similar to SCIELO Standard

3.2.1 Associate Researchers: No publications

3.2.2 Other researchers: No publications

3.3.- Scientific Books and Chapters

3.3.1 Associate Researchers: *No publications*

3.3.2 Other researchers: No publications

3.4.- Other Publications:

3.4.1 **Associate Researchers:** No other publications

3.4.2 **Other researchers:** No other publications

3.5.- Collaborative publications:

Category of Publication	1 researcher		2 researchers		3 researchers		4 or more researchers	
	Nº	%	Nº	%	Nº	%	Nº	%
ISI Publications or Similar to ISI Standard	19	%	8	%	0	%	1	%
SCIELO Publications or Similar to SCIELO Standard	0	0%	0	0%	0	0%	0	0%
Books and chapters	0	0%	0	5%	0	0%	0	0%
Other Publications	0	0%	0	0%	0	0%	0	0%
Total of publications	19	68%	8	29%	0	0%	1	3%

Annex 4.- Organization of Scientific Events

Scope	Title	Type of Event	City	Country	Responsible Researcher
International	IAI-ANTARES13 Workshop	Workshop	Dichato	Chile	Heraclio Rubén Escribano Veloso
National	Introduction to the statistical program R Workshop	Workshop	Concepción	Chile	Frauke Albrecht Geb. Gorenflo
National	Time Series Analysis Workshop	Workshop	Valparaíso	Chile	Samuel Ernesto Hormazábal Fritz
National	Chile on the World Stage of Oceanography	Conferece	Concepción	Chile	Oswaldo Ulloa Quijada
International	The International course Ecology and Diversity of Marine Microorganisms, ECODIM	Course	Concepción	Chile	Oswaldo Ulloa Quijada

Annex 5.- Education and capacity building

5.1 Capacity Building inside MSI Centers

MSI RESEARCHER	NUMBER												TOTAL NUMBER PER MSI RESEARCHER		
	Undergraduate students			Graduate students						Postdoctoral researchers					
	F	M	T	Masters			Doctoral			F	M	T	F	M	T
S. Hormazábal	0	0	0	0	2	2	0	0	0	1	1	2	1	3	4
R. Escribano	0	0	0	2	0	2	4	0	4	1	2	3	7	2	9
O. Pizarro	0	1	1	2	0	2	0	1	1	1	0	1	3	2	5
O. Ulloa	1	0	1	1	0	1	0	1	1	0	4	4	2	5	7
C. Morales	0	0	0	0	0	0	1	0	1	1	0	1	2	0	2
W. Schneider	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
P. Von Dassow	0	0	0	0	2	2	0	1	1	0	1	1	0	3	3
C.Vargas	0	0	0	2	0	1	0	0	0	1	0	1	2	0	2
O.Pizarro /A.Montecinos	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
C.Morales / S. Hormazabal	0	0	0	0	0	0	2	0	2	0	0	0	2	0	2
C.Morales/ C.Parada	1	1	2	0	0	0	0	0	0	0	0	0	1	1	2
C.Vargas/Pablo Rossenblatt	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
S.Hormazabal / M.Cornejo	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
R.Escribano/ M.Oliva	0	0	0	1	1	2	0	0	0	0	0	0	1	1	2
O.Pizarro/S.Hormazabal	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
S.Hormazabal/C.Morales	0	0	0	2	0	2	0	0	0	0	0	0	2	0	2
O.Ulloa/P.V.Dassow	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
R.Escribano /P.Hidalgo	1	0	1	2	2	4	2	0	2	0	0	0	5	1	6
P.Hidalgo/ V.Aguilera/ R.Escribano	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
C.Morales/M.Cornejo	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
O.Ulloa /P.Hidalgo	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
Total	5	3	8	14	7	21	10	4	14	5	8	13	34	22	56

Annex 5.2. - Short-term Traineeships of MSI students

Student name	Institution	Country	Advisor	Project Description	Starting Date [dd/mm/yy]	Ending Date [dd/mm/yy]
Valentina P. Valdes Castro	Institut Meiterraneen d'Océanologie (MIO)	France	Dr. François Carlotti	Results of the Oceanographic cruise OUTPACE (Oligotrophic to ultraoligotrophic Pacific experiments)	15-12-2015	30-03-2016
July Andrea Corredor	Plymouth Marine Laboratory	England	Dr. Robert Brewin	Marine Remote Sensing Scientist	01-12-2016	31-01-2017

¹ : Foreign Students coming to IMO in the context of collaboration/networking; Country of origin is detailed.

External

Student name	Institution	Country	Advisor	Project Description	Starting Date [dd/mm/yy]	Ending Date [dd/mm/yy]
Albane Ruaud ¹	Institut Supérieur des Sciences Agronomiques, Agroalimentaires, Horticoles et du Paysage (Agrocampus Ouest) Rennes.	France	Dr. Peter von Dassow	Specialization in cell analysis techniques isolated by flow cytometry. (Optional Independent Research Internship in interstitial year, program Master of Science in Biology)	19-02-2016	17-08-2016
Laura Galezowski ¹	Université Pierre et Marie Curie, Paris VI	France	Dr. Peter von Dassow	Comparing thermal performance curves of different strains of <i>Emiliana huxleyi</i> , the most common coccolithophore, with closely related species (Master stage M1 research internship).	01-18-2016	24-04-2016

Student name	Institution	Country	Advisor	Project Description	Starting Date [dd/mm/yy]	Ending Date [dd/mm/yy]
Kyle Fukui	Independent	USA	Dr. Peter von Dassow	Independent Fulbright Scholarship for graduating students (US Department of State), project title: "The Effects of Micro Abiotic Factors on E. huxleyi Populations"	03-03-2016	30-11-2016

Annex 6.- Networking and other collaborative work

6.1 Networking

NOMENCLATURE:

[Network Scope]

[N] National [I] International [LA] Latin American

Network Name	Network Scope	Network Participants [Number]				Institutions
		From the Center		External		
		Researchers	Postdocs/ Students	Researchers	Postdocs/ Students	
Red Pop	LA	1				Museums and centers of Latin American.
MBARI – IMO collaboration	I	1				IMO - MBARI (Monterey Bay Aquarium Research Institute)

Network Name	Network Scope	Network Participants [Number]				Institutions
		From the Center		External		
		Researchers	Postdocs/ Students	Researchers	Postdocs/ Students	
ANTARES	I	3	4/8	75	Bedford Institute of Oceanography (Canada) Dalhousie University (Canada) DIMAR (Colombia) La Salle fundation (Venezuela) IMaRS (USA) IAFE (Argentina) INIDEP (Argentina) INPE (Peru) INOCAR (Ecuador) IOUSP (Brazil)	
					SIO (USA) UABC (Mexico) USB (Venezuela) CONABIO (Mexico) IMARPE (Peru) CIOH (Colombia)	

Network Name	Network Scope	Network Participants [Number]				Institutions
		From the Center		External		
		Researchers	Postdocs/ Students	Researchers	Postdocs/ Students	
IAI CRN 3094	I	2	1/4	10		FUNDEP (Brasil) USP (Brasil) UBA (Argentina) INIDEP (Argentina) IAFE (Argentina) UABC (Mexico) CONABIO (Mexico) EDIMAR (Venezuela) IMARPE (Perú) INOCAR (Ecuador)
HUB APTA (Andes Pacific Technology Access)	N	8		9		Catholic University of the North, University of Antofagasta. University Federico Santa Maria University, University Mayor, University Adolfo Ibáñez, University of Santiago, University of Concepcion, Catholic University of the Holy Concepcion, University of Tarapacá, University of Atacama, University of La Serena. Scientific and Technology Center for Mining Research.

Network Name	Network Scope	Network Participants [Number]				Institutions
		From the Center		External		
		Researchers	Postdocs/ Students	Researchers	Postdocs/ Students	
UMI 3614 "Evolutionary Biology and Ecology of Algae:	I	1	1	5	4	Centre National de la Recherche Scientifique (CNRS) (France), Université Pierre et Marie Curie Paris VI – Sorbonne Universites (UPMC) (France), Pontificia Universidad Católica de Chile, Universidad Austral de Chile
GDRI 803 "diversity, evolution and biotechnology of marine algae"	I	1		>40		Station Biologique de Roscoff, France (CNRS and UPMC) Observatoire Oceanique de Banyuls, Banyuls, France (CNRS and UPMC) Pontificia Universidad Catolica De Chile, Santiago, Chile Universidad Austral De Chile, Valdivia, Chile Universidad De Los Lagos, Osorno, Chile L'universidad De Concepción, Concepción, Chile Universidad Católica De La Santísima, Concepción (UCSC) Concepción, Chile Universidad De Magallanes, Punta Arenas, Chile Universidade De Sao Paulo, São Paulo, Brazil Universidade Federal Do Rio De Janeiro, Rio De Janeiro, Brazil Universidade Do Estado Rio De Janeiro, Rio De Janeiro, Brazil

Annex 6.2.- Other collaborative activities

Activity Name	Co-Participant Institution(s)	Participants [Number]				Products [Type & Number]
		MSI center		External		
		Researchers	Postdocs/Students	Researchers	Postdocs/Students	
Teaching Network	National Scholar Teachers	1				
Collaboration network with Interactive Center of Sciences, Arts and Technologies (CICAT).	CICAT		6	1		Conferences and workshops, 8
Multi-institutional network of PAR Explora Biobio	PAR Explora Biobio		5	1		Co-funding projects, 2
Popularization of science and technology in Latin America and the Caribbean	RedPOP	1	8	3		Seminar: Four looks of Science Outreach, 1
GIRS (Interest Group in Underwater Robotics)	University of Concepción	4		3	6	Protptype
A day in the beach	PAR Explora Biobío.					Practical activity
National Television Scientific Committee	Televisión Nacional de Chile - TVN	1				Initiatives to include science in television
Ocean Communicators United Telecon	Partnership for Observation of the Global Oceans (POGO)	8				Regional changes in the Pacific Ocean
Collaboration Network with CIEP	Research Center for Patagonia Ecosystems	1				Virtual Classroom "Canales y Fiordos",1
Collaboration Network with DAEM de Quillón	Education Administration Department of Quillón					Itinerant Scientific Audiovisual Show (MACI), 1
Collaboration Network with DAEM de Talcahuano	Education Administration Department of Talcahuano					Itinerant Scientific Audiovisual Show (MACI), 1

Collaboration Network with ESMOI	Núcleo Milenio de Ecología y Manejo Sustentable de Islas Oceánicas	1				Virtual Classroom "Islas Oceánicas", 1
Collaboration Network with INACH	Chilenean Antarctic Institute	1				Virtual Classroom "Océano Austral", 1
Invention Patent Drafting	Cristian Muñoz (Independent)	2				Filing of Patent Application, 1
Collaboration Network with DAEM de Coihueco	Education Administration Department of Coihueco		4			Itinerant Scientific Audiovisual Show (MACI) and field trip, 2
Talk to Children Group with Asperger Concepción	Children Group with Asperger Concepción		3			Talk, 1
Collaboration Network with Universidad de Magallanes	University of Magallanes	1				Didactical material and talks, 2
Collaboration Network with PAR Explora Antofagasta	University of Antofagasta	2				Didactical material and talks, 2
Collaboration Network with Pontificia Universidad Católica de Valparaíso	Pontifical Catholic University of Valparaíso	1				Didactical material and talks, 2

7. - Outreach

7.1. - Outreach activities throughout the period

Event Title	Type of Event	Scope	Target Audience	Date	Country	Region	N° of Student from the Center	N° of Attendees	Duration in days	Participating Researchers	Responsible for the activity
Itinerant Scientific Audiovisual Show (MACI) Talcahuano	Exhibition	National	Primary students	30-03-16	Chile	Bío Bío	4	200	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Chiguayante	Exhibition	National	Primary students	05-04-16	Chile	Maule	4	300	1		Tamara Luna
IMO in the School	Conference	National	Secondary students	28-04-16	Chile	Bío Bío	1	25	1	Alejandro Andrés Murillo Cordova.	Tamara Luna
May Challenge "Sumérgete a Explorar" contest	Contest	National	Primary students	01-05-16	Chile	Bío Bío	0	100	30		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) Valparaíso	Exhibition	National	Primary students	03-05-16	Chile	Valparaíso	2	100	2	Marcela Alejandra Comejo D'Ottone.	Tamara Luna y Marcela Comejo
Exhibition for Association of children with Asperger	Exhibition	National	General Community	07-05-16	Chile	Bío Bío	2	70	1		Tamara Luna y Bárbara Léniz

Activities in the Month of the Sea	Conference	National	Secondary students Primary students	12-05-16	Chile	Bío Bío	1	50	1		Bárbara Léniz
IMO in the School	Conference	National	Secondary students Primary students	13-05-16	Chile	Metropolitana de Santiago	1	50	1	Pedro Echeveste De Miguel.	Tamara Luna
Activities in the Month of the Sea	Conference	National	Primary students	19-05-16	Chile	Bío Bío	4	45	1		Bárbara Léniz
Congress of Marine Sciences	Exhibition	National	Undergraduate students General Community Scientific Community	23-05-16	Chile	Bío Bío	0	200	4		Bárbara Léniz
Activities in the Month of the Sea	Conference	National	General Community	24-05-16	Chile	Bío Bío	2	15	1	Heraclio Rubén Escribano Veloso.	Bárbara Léniz
Cultural Heritage Day in UdeC	Exhibition	National	General Community	29-05-16	Chile	Bío Bío	4	200	1		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) San Carlos	Exhibition	National	Primary students	31-05-16	Chile	Bío Bío	5	200	1		Tamara Luna
IMO in the School	Conference	National	Primary students	01-06-16	Chile	Bío Bío	0	50	1		Carlos Henríquez
IMO in the School	Conference	National	Secondary students	01-06-16	Chile	Metropolitana de Santiago	1	10	1	Pedro Echeveste De Miguel.	Pedro Echeveste
June Challenge “Sumérgete a Explorar” contest	Contest	National	Primary students	01-06-16	Chile	Bío Bío	0	100	30		Bárbara Léniz
IMO in the School	Conference	National	Primary students	02-06-16	Chile	Bío Bío	0	150	1		Bárbara Léniz

Itinerant Scientific Audiovisual Show (MACI) Antofagasta	Exhibition	National	Undergraduate students	02-06-16	Chile	Antofagasta	0	10	1	Víctor Miguel Aguilera Ramos.	Tamara Luna
IMO in the School	Conference	National	Primary students	06-06-16	Chile	Bío Bío	2	50	1		Bárbara Léniz
Climate Change workshop	Seminar	National	Secondary students	08-06-16	Chile	Bío Bío	0	60	1		Carlos Henríquez
World Oceans Day	Exhibition	National	General Community	08-06-16	Chile	Bío Bío	3	500	1		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) Coihueco	Exhibition	National	Primary students	14-06-16	Chile	Bío Bío	4	200	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Cabrero	Exhibition	National	Primary students	16-06-16	Chile	Bío Bío	4	200	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Quillón	Exhibition	National	Primary students	29-06-16	Chile	Bío Bío	5	150	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Antofagasta	Exhibition	National	Primary students	03-08-16	Chile	Antofagasta	1	250	2	Víctor Miguel Aguilera Ramos.	Tamara Luna
Conference in San Carlos, in collaboration with MUSELS.	Conference	National	Primary students Secondary students	03-08-16	Chile	Bío Bío	1	300	1	Ramiro Antonio Riquelme Bugueño.	Bárbara Léniz
Oceanographic workshops in ChileVA! Science Camp	Exhibition	National	Secondary students	10-08-16	Chile	Bío Bío	9	150	1	Alejandro Andrés Murillo Cordova. Sara Zamora Terol.	Bárbara Léniz

Opean Door A-21 school Talcahuano	Exhibition	National	Primary students Secondary students	11-08-16	Chile	Bío Bío	2	300	1		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) Talcahuano	Exhibition	National	Secondary students	19-08-16	Chile	Bío Bío	3	150	1		Tamara Luna
Outreach activity with MUSELS	Exhibition	National	Secondary students	22-08-16	Chile	Bío Bío	1	40	1		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) Talcahuano	Exhibition	National	Primary students	23-08-16	Chile	Bío Bío	4	200	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Coihueco	Exhibition	National	Primary students	25-08-16	Chile	Bío Bío	5	270	1		Tamara Luna
IMO in the School	Conference	National	Primary students	26-08-16	Chile	Metropolitana de Santiago	1	35	1	Pedro Echeveste De Miguel.	Tamara Luna
Oceanographic workshops in ChileVA! Science Camp	Exhibition	National	Secondary students	31-08-16	Chile	Bío Bío	9	150	1	Alejandro Andrés Murillo Cordova.	Bárbara Léniz
School Scientific Meeting	Conference	National	Secondary students	06-09-16	Chile	Bío Bío	0	50	1	Alejandro Andrés Murillo Cordova.	Alejandro Murillo
Itinerant Scientific Audiovisual Show (MACI) Ránquil	Exhibition	National	Primary students	06-09-16	Chile	Bío Bío	5	100	1		Tamara Luna
"La Receta Científica de Tony Tonina" launch	Launching event	National	Primary students General Community	09-09-16	Chile	Bío Bío	5	200	1	Paulina Andrea Aguayo Venegas. Pablo Rosenblatt Guelfenbein.	Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) Mulchén	Exhibition	National	Primary students	26-09-16	Chile	Bío Bío	4	200	1		Tamara Luna

IMO in the School	Conference	National	Primary students	30-09-16	Chile	Metropolitana de Santiago	0	65	1	Pedro Echeveste De Miguel.	Tamara Luna
Family Science Day UdeC	Exhibition	National	General Community	02-10-16	Chile	Bío Bío	2	250	1		Bárbara Léniz
Science Party	Exhibition	National	Primary students General Community	02-10-16	Chile	Antofagasta	0	50	1	Víctor Miguel Aguilera Ramos.	Victor Aguilera
IMO in the School	Conference	National	Primary students	06-10-16	Chile	Bío Bío	1	40	1	Alejandro Andrés Murillo Cordova.	Bárbara Léniz
Curanilahue School Science Fair	Exhibition	National	General Community Primary students Secondary students	06-10-16	Chile	Bío Bío	1	400	1		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) San Rosendo	Exhibition	National	Primary students	06-10-16	Chile	Bío Bío	3	150	1		Tamara Luna
VI Fair of School Scientific projects	Exhibition	National	Primary students Secondary students	12-10-16	Chile	Bío Bío	2	200	1		Bárbara Léniz
Activity in Marine Biology Station, Dichato	Field and conference	National	Primary students	13-10-16	Chile	Bío Bío	3	43	1		Bárbara Léniz
Open doors UdeC	Exhibition	National	Secondary students	18-10-16	Chile	Bío Bío	2	50	2		Bárbara Léniz
1st Fair of Scientific and Environmental Outreach	Exhibition	National	Primary students Secondary students	20-10-16	Chile	Bío Bío	1	150	1		Bárbara Léniz
IMO in the School	Conference	National	Primary students	20-10-16	Chile	Bío Bío	0	30	1		Bárbara Léniz

Speaking with Scientists	Exhibition	National	Secondary students	25-10-16	Chile	Bío Bío	2	20	1		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) Punta Arenas	Exhibition	National	Primary students	25-10-16	Chile	Magallanes y Antártica Chilena	0	90	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Puerto Natales	Exhibition	National	Primary students	26-10-16	Chile	Magallanes y Antártica Chilena	0	90	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Quillón	Exhibition	National	Secondary students	03-11-16	Chile	Bío Bío	4	100	1		Tamara Luna
Day of Oceanography	Field and conference	National	Primary students	16-11-16	Chile	Bío Bío	0	40	1		Bárbara Léniz
Fair at Congress of the Future for Young people	Exhibition	National	Secondary students	17-11-16	Chile	Metropolitana de Santiago	0	300	2	Alejandro Andrés Murillo Cordova. Pedro Echeveste De Miguel.	Bárbara Léniz
Conference at Congress of the Future for Young people	Conference	National	Secondary students	18-11-16	Chile	Metropolitana de Santiago	0	250	1	Alejandro Andrés Murillo Cordova.	Alejandro Murillo
Science Fair Llico	Exhibition	National	Primary students Secondary students	22-11-16	Chile	Bío Bío	2	100	1		Tamara Luna
Itinerant Scientific Audiovisual Show (MACI) Llico	Exhibition	National	Primary students	22-11-16	Chile	Bío Bío	4	100	1		Tamara Luna
Visit to Marine Biology Station, Dichato	Field and Conference	National	Primary students	29-11-16	Chile	Bío Bío		40	1		Bárbara Léniz
Itinerant Scientific Audiovisual Show (MACI) Yungay	Exhibition	National	Primary students	30-11-16	Chile	Bío Bío	3	100	1		Tamara Luna

Visit to Marine Biology Station, Dichato	Field and Conference	National	Primary students	14-12-16	Chile	Bío Bío	1	50	1		Bárbara Léniz
A day in the Beach	Field and Conference	National	Primary students	15-12-16	Chile	Bío Bío	0	30	1		Bárbara Léniz
Technological Challenges from Explora	Workshop	National	Secondary students Public Services	21-12-16	Chile	Bío Bío	0	30	1		Tamara Luna
A day in the Beach	Field and Conference	National	Primary students	29-12-16	Chile	Bío Bío	0	25	1		Bárbara Léniz

7.2. - Products of outreach

Name of Product	Product Objective	Target Public	Type of Product"	Scope
www.sumergete.cl	Educational web platform of Marine Sciences. It is a journey through the different environments of the South Pacific Ocean. It aims to provide information about the environments, their resources and inhabitants, the most important physical and chemical characteristics. For this it has videos, illustrations and audios, among others.	High school students. Primary students. General Community	Web Design	National
MACI (Itinerant Scientific Audiovisual Show)	Aim to show the ocean and its characteristics, the importance for our country and the global impact, to children with a language close to the school community. It consists of an exhibition of audiovisual products, accompanied by practical and playful work with children, to reinforce the learning.	High school students. Primary students	Audiovisual show	National
Tony Tonina Scientific Recipe	Educational children's animated series, which deals with the contents of Natural Sciences of the primary school curriculum of Basic Education. Its objective is to be a tool for teachers, who seek to complement and reinforce learning.	Primary students	TV Show	National
Interactive application of the Tony Tonina Scientific Recipe	Video game where children should get the ingredients, through entertaining mini games, then cook the creative recipes of the magic book. To comply with the preparation, they must answer scientific questions associated with the school curriculum. This videogame is divide by the different courses of first cycle of basic education.			

<p>Program "Explorers: from the atom to the cosmos" Canal TVN 24 hours</p>	<p>Each chapter will have in situ the participation of the director of each scientific center, who will have the opportunity to deepen in the work carried out by his institution and contextualize it within the national and international contingency in order to give the citizens a complete overview of the relevance of the investigations currently being carried out in the country. Their testimony in the studio will be complemented by three reports on different investigations that are carrying out, rescuing the scientific-technological value and the human aspect that moves the search for knowledge.</p>	<p>Scientific Community. Community in General.</p>	<p>Annual Television Series</p>	<p>National</p>
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7.3.- Articles and Interviews

ype of Media and Scoupe	Local / Regional		National		International		Total
	N° Interviews	N° Articles	N° Interviews	N° Articles	N° Interviews	N° Articles	
Written	0	13	2	7	0	0	22
Internet	0	62	4	56	0	1	123
Audiovisual	2	4	3	1	0	0	10
Total	2	79	9	64	0	1	155

Annex 8. - Connections with other sectors:

Activity and Objective	Expected Impact	Obtained Results	Type of Connection [Number]	Type of Activity [Number]	Institution Name	Institution City, Region & Country	Agent Type [Number]	Economic Sector
Project Evaluation and analysis of the necessary requirements for the implementation of a monitoring network of aquaculture concessions groups.	Determine the necessary requirements to implement an on-line monitoring network for aquaculture concession pools.	Project in Development	2	2	Subsecretaría de Pesca y Acuicultura (SOOAA), FIPA N° 2016 - 68	Valparaíso, Chile	2	Development of Studies
Oceanographic-Operational Meteorological Portal (POMEQ)	Development and implementation of a Web Portal and Mobile Application for the deployment of operational meteorological-oceanographic information.	Project in Development	2	2	CORFO InnovaChile 15BP-45408	Valparaíso, Chile	2	Project Implementation
Project Connectivity between the surge system of the Guajira and the Archipelago of San Andrés, Providencia and Santa Catalina, as an input of a platform of permanent deployment of oceanographic information for use in conservation and fishing	Development of a platform for the permanent deployment of oceanographic information for use in conservation and fisheries.	Project in Development	2	2	Instituto de Investigaciones Marinas y Costeras INVEMAR	Santa Marta, Magdalena, Colombia	3	Development of Studies

NOMENCLATURE:

[Type of Connection] [1] Services Contract [2] Cooperation Agreement

[Type of Activity] [1] Development of Studies [2] Project Implementation [3] Training [4] Prospective Activity [5] Scientific Training
[6] Installation of Scientists [7] Others (specify at the table foot other type of activity)

[Agent Type] [1] Industry and Services [2] Organizations and Public Services [3] Educational Sector

9. Financial Status**9.1 Total incomes:**

Funds	Accumulated incomes to last year [\$]	2016 Incomes		Total income to 2016 [\$]
		Amount \$	Percentage of resources used by the Center [%]	
MSI IC 120019	1.749.821.000	840.000.000	100	2.589.821.000
MSI - PME (Outreach)	28.999.862	15.003.751	100	44.003.613
MSI - RFC (Networking)		2.935.000	100	2.935.000
FONDECYT 1151299	44.250.000	59.000.000	100	103.250.000
FONDECYT 1130511	79.254.600	9.540.000	100	88.794.600
FONDECYT 1141106	92.380.000	49.783.000	80	132.206.400
FONDECYT 1130254	82.500.000	58.000.000	75	126.000.000
FONDECYT 3150507		23.700.000	80	18.960.000
FONDECYT 3160611	3.700.000	6.732.000	100	10.432.000
FONDECYT 3160665	3.700.000	23.092.843	100	26.792.843
FONDECYT 11150914		34.800.000	100	34.800.000
FONDECYT 11150914		30.480.000	100	30.480.000
EXPLORA ED 190157	3.700.000	26.230.000	100	29.930.000
CONA – CIMAR 22		356.400.000	100	356.400.000
CONICYT – TIEMPO BUQUE		178.200.000	100	178.200.000
MOORE FOUNDATION	2.325.000	113.948.720	97	112.855.258
AGOURON INSTITUTE	88.952.980	88.952.979	40	124.534.172
Private funds IMAGO		50.000.000	100	50.000.000
FIP 2014-042	48.750.000	15.000.000	100	63.750.000
NÚCLEO MILENIO NC 120086	52.123.600	20.000.000	100	72.123.600
TOTAL	2.280.457.042	2.001.798.293	96	4.196.268.486

9.2 Outcome structure (Only SMI funds)

ITEM	Accumulated expenses to last year [\$]	2016 Expenses [\$]				Total expenses to 2016 [\$]	%
		Operative	Networking	Outreach	Total		
Honoraria Researchers	327.041.172	245.573.560	0	0	245.573.560	572.614.732	24,06
Honoraria students and other personnel	272.669.657	200.244.008	0	7.348.799	207.592.807	480.262.464	20,18
Tickets and travel expenses	140.828.451	101.846.156	2.635.161	507.355	104.988.672	245.817.123	10,33
Materials/supplies	240.256.970	104.290.691	104.723	199.360	104.594.774	344.851.744	14,49
Goods and equipment	272.344.887	75.232.164	0	0	75.232.164	347.577.051	14,60
Infrastructure	6.320.538	3.238.216	0	0	3.238.216	9.468.754	0,39
Administrative expenses	98.054.407	60.872.323	0	0	60.872.323	158.926.730	6,68
Publications and subscriptions	16.635.468	8.963.829	0	0	8.963.829	25.599.297	1,08
Consultancies	37.050.312	29.450.638	0	379.200	29.829.838	66.880.150	2,81
Overhead	50.100.000	25.200.000	0	0	25.200.000	75.300.000	3,16
Insurance costs	34.027.106	16.846.550	195.109	249.393	17.291.052	51.318.158	2,15
Legal personality expenses	1.700.000	0	0	0	0	1.700.000	0,07
Others	0	0	0	0	0	0	0,00
Total Expenses (\$)	1.497.028.968	871.758.135	2.934.993	8.684.107	883.377.235	2.380.406.203	

9.3 Financial accounting (Only SMI funds)

ITEM	2016[\$]				TOTAL TO 2016
	Operative	Networking	Outreach	Total [\$]	
Income	840.000.000	2.935.000	15.003.751	857.938.751	2.636.759.613
Outcome	871.758.135	2.934.993	8.684.107	883.377.235	2.340.406.203
Annual balance	-31.758.135	7	6.319.644	-25.438.484	Total balance 296.353.410

Annex 10. Researcher Exchange

10.1 Researchers from the center going abroad 2016

Researcher type	Name	Type of activity	Duration	Country he traveled	Funding (Millennium / External / Mixed)
Associated Research	H. Rubén Escribano	REDOC Mision Meeting	12 days	Francia	Mixed
Associated Research	H. Rubén Escribano	Zooplankton International Congress	9 days	Noruega	Mixed
Associated Research	H. Rubén Escribano	Project Meeting I.A.I. Mar del Plata	7 days	Argentina	Mixed
Associated Research	H. Rubén Escribano	CLIVAR QINGDAO Meeting	12 days	China	Mixed
Associated Research	Osvaldo Ulloa	Visits Oceanographic Institutions	8 days	USA	Mixed
Associated Research	Osvaldo Ulloa	ISME Montreal Conference	9 days	Canadá	Mixed
Associated Research	Osvaldo Ulloa	SCOR en GOA Meeting y Conference en Kochi	17 days	India	Mixed
Associate researcher	Cristián Vargas	2nd Latin-American Ocean Acidification Workshop	5 days	México	External
Associate researcher	Cristián Vargas	Technical Workshop in Carbonate System Measurements	5 days	México	External – IOCCP
Associate researcher	Peter von Dassow	Analysis of population genetics data of the coccolithophorid <i>Emiliana huxleyi</i> in the Southeast Pacific Ocean	7 days	Francia	Mixed
Adjunt Research	Pamela Hidalgo	OUTPACE-FONDECYT Workshop	12 days	Francia	Mixed
Adjunt Research	Pamela Hidalgo	Zooplankton International Congress	9 days	Noruega	Mixed

10.2 Researchers from abroad coming to the Center

Researcher name	Nationality	Type of activity	Duration	Country from traveling	Funding (Millennium / External / Mixed)
Gerrit Van den Eng	Dutch	Researcher/teacher in Flow Cytometry Advanced Workshop	15 days	USA	Mixed
Angel Rodriguez Santana	Spanish	Research Experiment on mixing processes off Valparaíso	10 days	Spain	Mixed
Antonio Ramos	Spanish	Glider Experiment off Valparaíso	10 days	Spain	Mixed
Albane Ruaud	French	Independent Research Internship	150 days	France	IMO
Kyle Fukui	USA	Independent Research Fellow	271	USA	External