Comisión Nacional de Investigación Científica y Tecnológica – CONICYT

FONDAP Centers of research Program

Annual Progress Report

Guidelines:

The report should be written following the format specified hereafter. Both a printed (report and excel spreadsheets) and an electronic version must be sent to the following address:

PROGRAMA CENTROS DE EXCELENCIA FONDAP
CONICYT
Moneda 1375, Floor 9
Providencia
Santiago

E-mail: mcamelio@conicyt.cl
projas@conicyt.cl
Phone: (56 – 2) 2435 43 27

For future inquiries, please contact:

María Eugenia Camelio
FONDAP Program Acting Director
E-mail: mcamelio@conicyt.cl

I. TABLE OF CONTENTS

II. PRESENTATION

PERIOD REPORTED: 1st Year ☐ 2nd Year ☐ 3rd Year ■ 4th Year ☐ 5th Year ☐

PERIOD COVERED: From: January 21/2015 To: January 20/2016

NAME OF THE CENTER		CODE 15 11 00 09
DIRECTOR OF THE CENTER Laura Gallardo Klenner	E-MAIL laura@dgf.uchile.cl lgallard@u.uchile.cl	SIGNATURE
DEPUTY DIRECTOR René Garreaud Salazar	E-MAIL rgarreau@dgf.uchile.cl	SIGNATURE
SPONSORING INSTITUTION Universidad de Chile		
ASSOCIATED INSTITUTION(S) (if applicable) Universidad de Concepción Universidad Austral de Chile		
CENTER WEBSITE ADDRESS http://www.cr2.cl/		

RESEARCH LINES

N°	Research Line	Objective	Principal Researcher	Associated Researcher(s)
1	Biogeochemistry (BGC)	✓ Estimate emissions of climatically active tracers (CATs) ✓ Identify and quantify novel biogeochemical processes mediating CATs cycling in surface waters ✓ Characterize the regional interactions between urban areas and adjacent ecosystems	Laura Farías	Ricardo De Pol Roberto Rondanelli
2	Climate Dynamics (CD)	✓ Analyze interdecadal climate variability in Chile ✓ Diagnose of contemporaneous climate trends ✓ Project hydrological response to climate change	René Garreaud	Duncan Christie Patricio Moreno
3	Human Dimensions (HD)	✓ Identify ways to build resilience for climate change ✓ Diagnose the institutional framework ✓ Perform economic evaluation of climate change in Chile ✓ Define adaptation measures ✓ Contribute to the strengthening of institutional capacities	Pilar Moraga	Paulina Aldunce Laura Nahuelhual*
4	Ecosystem Services (ECO)	✓ Design optimal landscape arrays for the combined production of goods and services ✓ Define time frames, rates, and costs of the recovery of water provision as an ES from ecological restoration ✓ Assess reduced precipitation predicted by climate models for Central and Southern Chile on water provision as an ES from watersheds	Antonio Lara	Susana Gómez Mauro González
5	Modeling and Observing Systems (MOS)	✓ Implement and develop modeling and observation platforms to assess climate change and variability and to define probable scenarios ✓ Establish a test-bed, and transference of Climate Services ✓ Develop integrated observing systems	Laura Gallardo	Axel Osses* Maisa Rojas Fabrice Lambert

NB. The asterisk (*) indicates researchers who have become adjoint (other) researchers in 2016.

III. EXECUTIVE SUMMARY

Provide a brief overview of the vision, goals, plans and performance of the Center. Report on the progress made towards reaching the original goals of the Center and provide an overview of the most significant accomplishments during the reported period. Please indicate the research highlights. Describe any significant changes from the original proposal. (**Maximum length: 2 pages**).

The Center for Climate and Resilience Research (CR2) has produced in 2015 two major milestones in terms of its societal impact. First, it has launched a first Report to the Nation on the extended drought ("mega drought") experienced in Chile in the period 2010-2015. This report was delivered to her Excellency Michelle Bachelet at the Governmental Palace (*La Moneda*) on November 2nd, and launched to the public later that week. Second, it has defined the minimum contents and analyzed the feasibility of a potential Climate Change Law for Chile. This project led by CR2 has included an extensive participation of policy makers and experts in different fields, counting with the support of the parliamentary group promoting the legislation. The corresponding results will be launched in April 2016.

Our first approach to interdisciplinary studies has resulted already in one published paper, two papers in revision, and several manuscripts plus a well-received report to the nation (CR2, 2015), in which our main results have been summarized for policy makers and the public in general. According to these studies, the 2010-2015 drought has no analog in the paleo records for the last 1000 years, and it is extraordinary in terms of geographical extension reaching ~40°S, and in terms of temporal extension (~5 years). Moreover, roughly 25% of the drought experienced over the last half decade in central and southern Chile cannot be explained by natural variability, i.e., a distinct anthropogenic signal has emerged in the rainfall record. The impacts derived from this drought are not only relevant to water provision for agriculture and human consumption but also to the fire regimes, and coastal productivity. In general, governmental and private responses assume that droughts are either extraordinary or short-lasting phenomena. However, future climate scenarios and various climate proxies suggest a progressive aridification of central and south-central Chile due to the increased occurrence of long-term droughts. This, and the existence of a multiplicity of authorities (>40) that respond to droughts, typically via economical subsidies, building damns, and providing water trucks in a rather discoordinated manner result in suboptimal economic and social responses, which are no longer appropriate to address the recurrent water shortage Chile will be facing over the next decades.

A legal body to frame climate variability and change for Chile has gained support among Chilean parliamentarians and other stakeholders crossing political borders. This support has been triggered by the CR2 led project, in collaboration with a NGO (ADAPT Chile) and the Ministry for the Environment, that is assessing the viability of such a law, and defining the basic contents of it, and proposing an appropriate institutional framework for Chile.

The characterization of coastal processes affecting climatically active tracers has continued leading, for instance, to the identification of hot spots and moments for nitrous oxides. Likewise, land use change studies have been carried out documenting and quantifying the general pattern of landscape homogenization towards the reduction of native forests, mainly due to their conversion to exotic pine and eucalypt commercial

plantations for some regions in Chile. Also, CR2 has taken a regional leading position in determining the impact of short-lived climate pollutants, black carbon in particular on the Andean cryosphere. Further, alternations between centennial wet/cold and warm/dry periods in Southern Patagonia during the Holocene associated with variability of the Southern Annular Mode type have been identified.

Our scientific progress in 2015 should be further enhanced in 2016 as computational and measurement platforms will be in full operation. Such is the case for the oceanographic and atmospheric buoy bought in 2015 that has been recently launched and that will be in operation starting in March 2016. Such is also the case regarding computer and storing power allowing diverse modeling simulations at high resolution, and the provision of web-based services including the soon to be launched "climate explorer" and other climate services. Moreover, concurrent research projects and budget rearrangements have made available new instrumentation for characterizing coastal clouds, robust meteorological stations to better capture changes along the high Andes, aerosol optical depth in urban and non-urban environments, and ^{14}C dating and registration.

Acknowledging that the mega drought interdisciplinary study took nearly two years to be completed, we decided to jointly address the other two CR2 transversal issues, namely urbanization and land use changes, under the common umbrella of the Anthropocene. Part of our efforts starting in 2016 will quantify and qualify the Anthropocene in Chile according to drivers (emissions, population, motorization, cultural and institutional changes, etc.). Other efforts will focus upon the consequences of these drivers in terms of changes in vulnerability and risk, and upon the regional climate. Projections of drivers and its consequences should also be assessed. A second plenary meeting to be held in mid-March 2016 should be functional to define a more detailed working plan for this new interdisciplinary effort.

In 2015, we have seen a substantial increase in scientific productivity with 45 published papers that explicitly acknowledge CR2, and about 20 that although authored by CR2 researchers and relevant to CR2 themes, they do not explicitly acknowledge CR2. We also see the first signs of a growing recognition by our peers as indicated by quotations. In fact, we have accumulated 443 citations between 2013 and 2015. Even though a substantial part of this productivity and recognition builds upon previous individual and group achievements and concurrent projects, a distinct CR2 identity starts to emerge. In terms of advanced human resources, in 2015 we had 14 post-doctoral fellows, 60 graduate students, and 20 undergrads. During the reported period, 17 students graduated, and we have offered doctoral theses to start in 2016. Moreover, 5 new post-doctoral positions are being announced.

All in all, CR2 has completed its third year having achieved a first integrated study on the mega drought producing both new knowledge, and having a distinct impact among policy makers. Furthermore, we have enabled new CR2 branded research, and contributed to the development of new human and instrumental resources, which consolidate us as a relevant and important center of excellence.

IV. ADMINISTRATIVE ASPECTS

1. Budget execution

Describe and justify any budgetary modifications (itemized) of the original proposal.

Table 1. Budget execution for 2015.

Year 3	Income			Expenses			
Item	CONICYT in MCLP	Universities in MCLP	Total in MCLP	CONICYT in MCLP	Universities in MCLP	Total in MCLP	Comments
Personnel	$ 135.916		$ 135.916	$ 135.916		$ 135.916	
New Hires	$ 24.000	$ 27.400	$ 51.400	$ 4.000	$ 33.100	$ 37.100	Dr. Lambert got a position at the Catholic University starting in March 2015. He keeps his connection with CR2 a regular associate researcher. The
Post-doctoral f	$ 91.000		$ 91.000	$ 14.249		$ 14.249	The delay in obtaining work visas for foreign researchers , resources were re-allocated to internationalization (F. Albrecht , C. Ramallo , A. Mazzeo , C.
Support Staff	$ 150.000	$ 8.500	$ 158.500	$ 175.108	$ 8.500	$ 183.608	In order to hire research assistants and engoneers for developing several products, we increased the budget under
Traveling	$ 58.000		$ 58.000	$ 56.140		$ 56.140	Minor adjustments were necessary
Per-diem	$ 25.000		$ 25.000	$ 24.453		$ 24.453	
Domestic	$ 10.000		$ 10.000	$ 7.414		$ 7.414	
International	$ 15.000		$ 15.000	$ 17.308		$ 17.308	
Tickets	$ 33.000		$ 33.000	$ 31.687		$ 31.687	
Domestic	$ 12.000		$ 12.000	$ 10.923		$ 10.923	
International	$ 21.000		$ 21.000	$ 20.764		$ 20.764	
Internationaliz	$ 35.000		$ 35.000	$ 40.134		$ 40.134	
Operational co	$ 80.000	$ 26.213	$ 106.213	$ 116.515	$ 20.513	$ 137.028	Operational expenses increased since we organized three coordination meetings with participation of all CR2
Capital goods	$ 105.586	$ 20.000	$ 125.586	$ 159.358	$ 12.500	$ 171.858	According to the request in letter budget adjustment , 3 meteorological stations and one meteorological balloon were bought
Infrastructure							
General expen	$ 25.000		$ 25.000	$ 25.000		$ 25.000	
Administrative	$ 37.400		$ 37.400	$ 41.427	$ 7.500	$ 48.927	
Publication and	$ 3.000		$ 3.000	$ 2.175		$ 2.175	
Bank bonds	$ 1.000		$ 1.000				
Consulting ser	$ 6.000		$ 6.000	$ 1.770		$ 1.770	
Administrative e	$ 40.500		$ 40.500	$ 40.500		$ 40.500	
Unforeseen exp	$ 21.090		$ 21.090	$ 1.200		$ 1.200	See notes above.
Total M$	**$ 813.492**	**$ 82.113**	**$ 895.605**	**$ 813.492**	**$ 82.113**	**$ 895.605**	

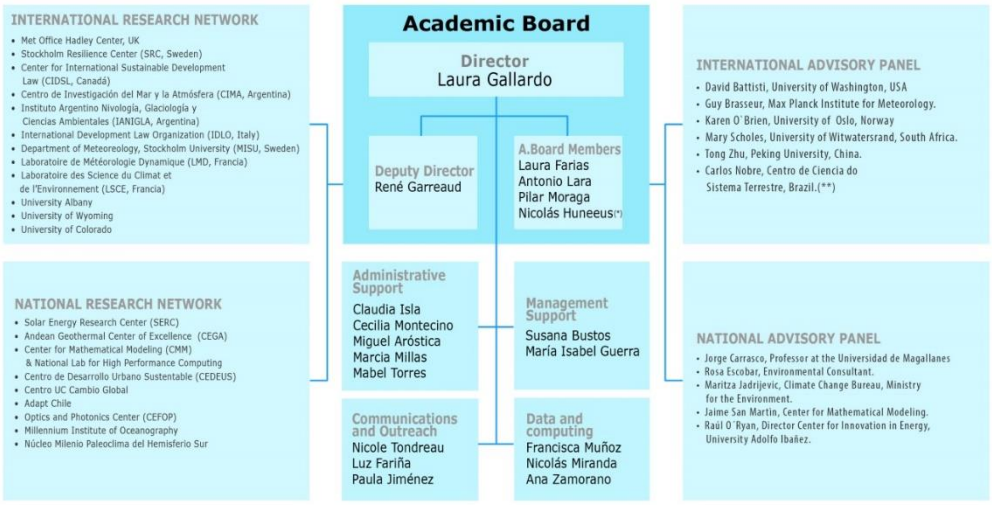
2. Accomplishment of institutional commitments

Describe any difficulty (ies) encountered regarding this aspect.

All institutions made their financial contributions on time, and according to the agreements.

3. Organizational Chart

Present an organizational chart of the Center depicting its main links to associated institutions and other units within the same institution.



Research Areas				
Human Dimensions	**Climate Dynamics**	**Ecosystem Services**	**Biogeochemistry**	**Modeling and Observing Systems**
Principal Investigator Pilar Moraga	Principal Investigator René Garreaud	Principal Investigator Antonio Lara	Principal Investigator Laura Farias	Principal Investigator Laura Gallardo
Associate Researchers Laura Nahuelhual Paulina Aldunce	Associate Researchers Duncan Christie Patricio Moreno	Associate Researchers Mauro González (Dep-PI) Susana Gómez	Associate Researchers Ricardo De Pol (Dep-PI) Roberto Rondanelli	Associate Researchers Axel Osses Maisa Rojas Fabrice Lambert Nicolàs Huneeus
Adjoint Researchers Anahí Urquiza Rodrigo Arriagada Gustavo Blanco	Adjoint Researchers Rodrigo Villa Mauricio Zambrano Paulo Herrera	Adjoint Researchers Carlos Jara Mauricio Galleguillos Christian Little	Adjoint Researchers Beatriz Diez Italo Masotti Eugenia Gayó	Adjoint Researchers Nancy Hitschfeld Mauricio Osses Pablo Saide
Post-doctoral Fellows	Post-doctoral Fellows Catherine Van den Hoof Cinthya Ramallo Deniz Bozkurt Jie Chang	Post-doctoral Fellows Carlos Zamorano Camila Tejo Rocío Urrutia	Post-doctoral Fellows Mariela Yévenes Juan Pablo Boisier Caitlin Frame	Post-doctoral Fellows Frauke Albretch Andrea Mazzeo Catalina Aguirre Paola Arias
Support Personnel	Support Personnel	Support Personnel Rodrigo Bravo *(Field Assistant)*	Support Personnel *(Lab Assistant)* Gerardo García Sandra Sanhueza	Support Personnel Francisca Muñoz *(Data and Computing Manager)*
Research Assistants	Research Assistants	Research Assistants	Research Assistants	Research Assistants
Graduate Students	Graduate Students	Graduate Students	Graduate Students	Graduate Students

** During 2015, Nicolás Huneeus has been acting as principal investigator of the line Modeling and Observing Systems*
*** Carlos Nobre has not had in 2015 an active role as part of the international advisory panel. We are evaluating their participation for the next period.*

4. Personnel

Provide a table indicating all personnel involved in the operation of the Center during the reported period, including names, position within the center (e.g. associate researcher, post doc, student, technician, etc.) and the number of hours committed to the Center.

In addition, in no more than one page, provide a brief academic biography for each new researcher recruited by the Center.

In the following pages we present lists of personnel indicating dedication, affiliation, and other details.

A. Principal and associate researchers

Table 2. Principal and associate researchers, indicating weekly dedication (hours per week), research area and institutional affiliation.

Name	Last Name	Category	Dedication	Reasearch Area[1]	Affiliation[2]
Laura	Farías	Associated Researcher Principal Investigator	26	BGQ	UDEC
Laura	Gallardo	Associated Researcher Principal Investigator	44	MOS, T	UCH
René	Garreaud	Associated Researcher Principal Investigator	26	CD	UCH
Antonio	Lara	Associated Researcher Principal Investigator	26	ECO	UACH
Pilar	Moraga	Associated Researcher Principal Investigator	26	HD	UCH
Paulina	Aldunce	Associated Researcher	12	HD	UCH
Duncan	Christie	Associated Researcher	12	CD	UACH
Ricardo	De Pol	Associated Researcher	12	BGQ	UMAG
Susana	Gómez	Associated Researcher	12	ECO	UBB
Mauro	González	Associated Researcher	12	ECO	UACH
Nicolas	Huneeus	Associated Researcher	12	MOS	UCH
Fabrice	Lambert[3]	Associated Researcher	17	MOS	PUC
Patricio	Moreno	Associated Researcher	12	CD	UCH
Laura	Nahuelhual[4]	Associated Researcher	12	HD	UACH
Axel	Osses[5]	Associated Researcher	12	MOS	UCH
Maisa	Rojas	Associated Researcher	12	MOS	UCH
Roberto	Rondanelli	Associated Researcher	12	BGQ	UCH

[1] BGQ: Biogeochemistry; CD: Climate Dynamics; ECO: Ecosystem Services; HD: Human Dimensions; MOS: Modeling and Observing Systems.

2 UCH: Universidad de Chile; UDEC: Universidad de Concepción; UACH: Universidad Austral de Chile; UMAG: Universidad de Magallanes; UBB: Universidad del Bío Bío; PUC: Pontificia Universidad Católica de Chile.

3 Dr. Lambert started in March a full time position at the Catholic University reducing his commitment to 12 hours per week. Thus his yearly averaged dedication was 17 hours per week.

4 Dr. Nahuelhual has taken a leading position in a new Center of Excellence starting in 2016. She will remain as an adjoint researcher for CR2 to continue her work on vulnerability maps.

5 Dr. Osses remain as an adjoint researcher in 2016.

B. Adjoint researchers

Table 3. Adjoint (other) researchers. Adjoint researchers, i.e., researchers that supported specific research activities or guided theses in collaboration with CR2 associate researchers. In general, they receive monetary incentives.

Name	Last Name	Dedication	Research Area	Affiliation	Activity
Rodrigo	Arriagada	6	HD	PUC	A priori economic evaluation of environmental policiess
Gustavo	Blanco	6	HD	UACH	Resilience conceptualization, guiding the theses
Beatriz	Díez	6	BGQ	PUC	Extremophils and biogeochemical cycles
Mauricio	Galleguillos	6	ECO	UCH	Teledection, hydrology and ecosystems
Eugenia	Gayo	6	BGQ	UDEC	Isotopes, climate and human settlements
Paulo	Herrera	6	CD	UCH	Sustainable underwater management
Nancy	Hitschfeld[6]	6	MOS	UCH	Urban canopy representations
Carlos	Jara	6	ECO	UACH	Biodiversity and climate zoologic indicators
Christian	Little	6	ECO	UACH	Forest and watersheds in southern Chile
Italo	Masotti	6	BGQ	UV	Ocean primary produtivity and dimethyl sulfide fluxes
Mauricio	Osses	6	MOS	UTFSM	Emission scenarios: compilation and assessment
Pablo	Saide	6	MOS	UCH	Simulations of pyro aerosois in central Chile
Anahí	Urquiza	6	HD	UCH	Vulnerability and water resources and markets
Rodrigo	Villa[6]	6	CD	UMAG	Paleo envirormental records of climate variability in Southerm Patagonia
Héctor	Zambrano	6	CD	UFRO	Meteorological and hydrogical indeces for watersheds during the mega drought

[6] Dr. Hitschfeld and R. Villa did not receive a CR2 incentive in 2015

C. Post-doctoral fellows

Table 4. Post-doctoral fellows, indicating weekly dedication (hours per week), research area and institutional affiliation. When funded by CR2, all contracts are signed under Universidad de Chile.

Name	Last Name	Dedi-cation	Research Area	Affilia-tion	Start Date	Status	Sponsoring Researcher	Funding Source	Research Topic
Catalina	Aguirre	44	MOS	UCH	2015	Active	Maisa Rojas	Fondecyt postdoc 3150329	Viento costero de Chile central: la influencia de la surgencia y proyecciones futuras
Frauke	Albrecht	22	MOS	UDEC	2013	Active	Gary Shaffer/Nicolás Huneeus	Fondap CR2 15110009	Future sea level rise along the coast of Chile
Paola	Arias	44	MOS	UCH	2013	Active	Maisa Rojas	Fondecyt postdoc 3140570	Variability of the South American monsoon circulation
Juan Pablo	Boisier	44	CD	UCH	2015	Active	Roberto Rondanelli	Fondecyt postdoc 3150492	Projected precipitation changes in the South-East Pacific and in Chile: Assessment of uncertainties and physical processes
Deniz	Bozkurt	44	MOS	UCH	2014	Active	Rene Garreaud	Fondecyt postdoc 3150036	Regional climate processes and future hydroclimate of Central Chile
Jie	Chang	44	CD	UCH	2015	Active	Patricio Moreno	ICM Paleoclima	Quantifying the Southern Hemisphere terrestrial temperature changes from the last millennium to the glacial times by using both traditional and novel palaeolimnological techniques.
Caitlin	Frame	44	BGQ	UDEC	2015	Active	Laura Farías	Fondap CR2 15110009	Production, destruction, and transport of the trace greenhouse gases nitrous oxide (N2O) and methane (CH4) in the environment.

Andrea	Mazzeo	44	MOS	UCH	2015	Active	Nicolás Huneeus	Fondap CR2 15110009	Regional climate forcing by aerosols over and downwind Santiago, with emphasis on absorbing aerosols, using a combined modeling and observational approach
Cinthya	Ramallo	44	CD	UCH	2015	Active	Rene Garreaud	Fondap CR2 15110009	Estudio de la caracterización hidrológica de años secos
Camila	Tejo	44	ECO	UACH	2015	Active	Mauro Gonzalez	Fondecyt postdoc 3160707	Ecological relevance of the canopy of the giant alerce (*fitzroya cupressoides*) and its consequences for management and conservation
Rocío	Urrutia	44	ECO	UACH	2015	Active	Antonio Lara	Fondecyt postdoc 3160258	Vulnerability of *Fitzroya cupressoides* or Alerce to climate change (warmer and drier summers in southern Chile) using ecophysiological tools
Catherine	Van den Hoof	44	CD	UCH	2013	Active	Rene Garreaud	FONDAP/FONDECYT	Coupling between air temperature and precipitation changes
Mariela	Yévenes	44	BGQ	UDEC	2015	Active	Laura Farías	Fondecyt Postdoc 3150162	Reactive nitrogen sources and their cycling in river catchment areas subjected to a strong land use change and a water deficit drainage, the case of central-southern chilean rivers.
Carlos	Zamorano	44	ECO	UACH	2015	Active	Antonio Lara	Fondap CR2 15110009	A spatial multicriteria approach to identify active-passive forest restoration areas for biodiversity conservation, water provision, and carbon sequestration

D. Students

Table 5. Current doctoral fellows (19), indicating thesis title, weekly dedication (in hours per week), research area and institutional affiliation.

Name	Last Name	Tutor's	Affiliation	Research Area	Dedication	Thesis Title/Subject
Jose Ignacio	Arroyo	Beatriz Díez	PUC	BGQ	44	Ómica de tapetes microbianos de fuentes termales
Maria	Alcamàn	Beatriz Díez	PUC	BGQ	44	Efectos de la temperatura en el metabolismo del nitrógeno de cianobacterias termófilas: tasas, estrategias y expresión génica
Santiago	Ancapichùn	Ricardo De Pol	UDEC	BGQ	44	Variabilidad climática en la cuenca del Pacífico en reconstrucciones paleoclimáticas de los últimos 1000 años
Sergio	Guajardo	Beatriz Díez	PUC	BGQ	44	Comunidades virales asociadas a cianobacterias termófilas en el sistema hidrotermal Porcelana
Maria del Pilar	Aparicio	Italo Masotti	UV	BGQ	44	Impacto relativo de la surgencia costera y la descarga de los ríos sobre la productividad en el Sistema de Corriente de Humboldt entre 21º y 42ºS, Chile
Carla	Henriquez	Patricio Moreno	UCH	CD	44	Cambios en la intensidad y posición de los Vientos del Oeste inferidos a partir de múltiples indicadores estratigráficos en Patagonia norte (41°S) y Patagonia sur (51°S) desde el Último Máximo Glacial.
Monica	Bello	René Garreaud	UCH	CD	44	Circulación Oceanica en Bahia de Coquimbo (30S)
Oscar	Pesce	Patricio Moreno	UCH	CD	44	Comportamiento de los Vientos del Oeste entre los 40° S y 52°S desde la Última Terminación Glacial.
Mario	Romero	Mauro González	UACH	ECO	44	Recuperación del bosque siempreverde bajo distintas intervenciones antrópicas en la Cordillera de la Costa de la región de Los Ríos
Angela	Bustos	Antonio Lara	UACH	ECO	44	Restauración de bosques de alerce (*Fitzroya cupressoides*)
Gastón	Sotes	Susana Gómez	UDEC	ECO	44	Evaluando en la planta invasora Centaurea melitensis el efecto de los tricomas glandulares sobre la eficiencia en el uso de recursos, la competencia y la interferencia
Marco	Cortès	Antonio Lara	UACH	ECO	44	Ecología de la Restauración de los relictos Araucaria araucana en la Cordillera de la Costa de Chile

Andrea	Leiva	Antonio Lara	UACH	ECO	44	Por definir
Francisco	Tello	Mauro González	UACH	ECO	44	Por definir
Alejandro	Miranda	Antonio Lara	UACH	ECO	44	Cambio de uso del suelo y restauración ecológica
Rodrigo	Santander	Laura Nahuelhual	UACH	HD	44	Exposición a eventos climáticos y políticas públicas: un análisis espacial en la región de Los Ríos
Noemi	Kugler	Pilar Moraga	UCH	HD	44	El concepto de daño en el contexto del cambio climático
Melisa	Dìaz	Laura Gallardo	UBA	MOS	44	Dinámica de los aerosoles atmosféricos en el Área Metropolitana de Buenos Aires
Priscilla	Nowajewski	Maisa Rojas	UCH	MOS	44	Climate dynamics by obliquity forcing in planetary atmospheres

*Table 6. **Master fellows**, indicating thesis title, weekly dedication, research area and institutional affiliation.*

Name	Last Name	Tutor's	Affiliation	Research Area	Dedication	Thesis Title/Subject
Cynthia	Escares	Laura Farías	UDEC	BGQ	44	Ciclaje de óxido nitroso (N20) en aguas superficiales y en cultivos monoclonales de Microalgas Marinas: un estudio sobre interaccion potencial de nitrificantes con picoeucariontes fotosintéticos.
Dharma	Reyes-Macaya	Ricardo de Pol	UDEC	BGQ	44	Geometría de masas de agua frente al margen continental chileno durante el pleistoceno tardío
Giovanni	Testa	Italo Masotti	UDEC	BGQ	44	Seasonal primary production in the central-southern Chilean upwelling
Josefa	Verdugo	Laura Farías	UDEC	BGQ	44	Contenido e intercambio de gases de efecto invernadero en aguas del Bahía Chile, Antártica; el caso del CH4 y N2O y de los procesos biogeoquímicos que los consumen"
Macarena	Troncoso	Laura Farías	UDEC	BGQ	44	Gradientes troficos extremos en la cuenca del Pacifico sur oriental y su relación con el reciclaje e intercambio de gases invernaderos
Pamela	Pizarro	Roberto Rondanelli	UCH	BGQ	44	Frecuencia de neblina y nubosidad baja en el valle central de Chile"
Sebastián	García-Loyola	Laura Farías	UDEC	BGQ	44	Variabilidad temporal de los parámetros físicos y biogeoquímicos de la columna de agua bajo distintos forzantes atmosféricos, un estudio basado en observación y modelación unidimensional
Valeria	Moreno	Roberto Rondanelli	UCH	BGQ	44	Hydrological Cycle and Atmospheric Shorwave Absorbption
Victor	Merino	Ricardo de Pol	UDEC	BGQ	44	Edad de reservorio del radiocarbono en el océano Pacífico Sur Oriental
Sergio	Gonzalez	René Garreaud	UCH	CD	44	Variabilidad Espacial de Temperaturas Nocturnas sobre la Cordillera de Nahuelbuta, Zona Centro-Sur de Chile
Camilo	Barahona	René Garreaud	UCH	CD	44	Precipitaciones asociadas a Bajas Segregadas en el Hemisferio Sur
Carolina	Morano	Rodrigo Patricio Villa	UMAG	CD	44	Desarrollo de registros paleoecologicos de alta resolución temporal durante los últimos 3000 años en Patagonia Sur

Cristian	Pino	Paulo Herrera	UCH	CD	44	Aplicación del modelo Hydrogeosphere en la cuenca del río San José, región de Arica y Parinacota, Chile
David	Jaramillo	Duncan Christie	UACH	CD	44	Photosynthetic functioning on the roof of the world: Polylepis tarapacana along an altitudinal gradient in the Central Andes
Enzo	Simi	Patricio Moreno	UCH	CD	44	Vegetación, clima y paleofuegos en la región de Aysén desde la Última Terminación Glacial.
Fabiola	Cid	Patricio Moreno	UCH	CD	44	Variabilidad natural e inducida en ambientes lacustres de Patagonia Noroeste a escala multidecadal durante los últimos 3000 años
Juan Pedro	Guerrero	Patricio Moreno	UCH	CD	44	Por determinar
Lucia	Gonzalorena	Patricio Moreno	UCH	CD	44	Historia postglacial de la vegetación de Lago Tarumán, en la zona centro-occidental de Isla Grande de Chiloé: inferencias paleoambientales a partir de un registro palinológico de alta resolución
Andres	Ceballlos[7]	Mauricio Galleguillos	UCH	ECO	44	Efecto de la dinamica de paisajes forestales sobre la Biodiversidad de plantas vasculares
Constanza	Becerra	Christian Little	UACH	ECO	44	Rol de los bosques nativos ribereños en la provisión de agua en calidad como servicio ecosistémico
Guillermo	Barrientos	Carlos Jara	UACH	ECO	44	Crecimiento y Mortalidad de ninfas del Género Meridialaris (Insecta: Ephemeroptera: Leptophlebiidae) en escenarios simulados de Calentamiento Global
Waldo	Iglesias	Mauro González	UACH	ECO	44	Historia de incendios en la Reserva Nacional Malleco
Lorenzo	Palma	Antonio Lara	UACH	ECO	44	Análisis descriptivo cualitativo de las percepciones de los habitantes de la localidad de Cauquenes, respecto al servicio ecosistémico, provisión de agua, desarrollo y resiliencia ligadas a las plantaciones forestales exóticas
Ignacio	Vera	Carlos Jara	UACH	ECO	44	Comunidades de macroinvertebrados bentónicos como bio-indicadores de resiliencia para el diseño de la restauración de ecosistemas de agua dulce.
Humberto	Bernasconi	Susana Gómez González	UBB	ECO, BGQ	44	Análisis de las comunidades bacterianas del suelo en el marco de las principales consecuencias del cambio climático: La sequía y los incendios

[7] *He got his undergraduae exam this year too so he appears in two lists..*

Alice	Junqueira	Anahí Urquiza	UCH	HD	44	Estudios del Futuro y Políticas Públicas para el desarrollo sustentable: análisis de la experiencia MAPS Chile
Carlos	Ardissoni	Paulo Herrera	UCH	CD	44	Determinación del caudal de extracción sustentable y análisis de la pertinencia del concepto del mito del balance hídrico en el acuífero del Valle de Azapa.
Dana	Jimenez	Laura Nahuelhual	UACH	HD	44	Evaluación de la distribución del agua en cuencas de la comuna de Río Bueno (región de Los Ríos) a través del concepto de huella hídrica
Denis	Alegrìa	Paulina Aldunce	UCH	HD	44	Análisis bibliométrico del concepto de “resiliencia” en la literatura científica en el contexto del cambio climático y su actual aplicación en políticas públicas
Hugo	Pizaña	Anahí Urquiza	UCH	HD	44	Transformaciones socioterritoriales en el espacio rural. Análisis desde una observación sistémica en el marco del Proyecto Ciudades Rurales Sustentables implementado en Chiapas, México
Issa	Ramos	Paulina Aldunce	UCH	HD	44	Percepción sobre cambio climático y sus principales impactos en habitantes del Valle del Aconcagua
Marco	Billi	Anahí Urquiza	UCH	HD	44	Comunicación ambiental y proyectos energéticos renovables no convencionales: análisis de contenido en medios de comunicación de masa chilenos
María Fernanda	Rojas	Gustavo Blanco Wells	UACH	HD	44	Crisis hídrica y estrategias desde comités de agua rural para obtener y preservar el agua en el sur de Chile. Tres casos de la Región de Los Ríos
Mindy	Fuentes	Pilar Moraga	UCH	HD	44	La incorporación del fenómeno del cambio climático al marco normativo de los instrumentos de planificacion terriorial que regulan las zonas costernas en Chile
Pamela	Maldonado	Paulina Aldunce	UCH	HD	44	Evaluación participativa de prácticas de adaptación a la sequía: un aporte a la construcción de resiliencia
Andrea	Orfanoz	Laura Gallardo	UCH	MOS	44	Estratificación vertical y transporte de contaminantes urbanos viento abajo de Santiago de Chile
Benjamin	Del Favero	Nicolas Huneuss	UCH	MOS	44	Escenarios meteorológicos favorables para el transporte potencial de carbono negro cordillera arriba

Hernaldo	Leyton	Nicolas Huneuss	UCH	MOS	44	Estudio de Sensibilidad de Modelo Químico Atmosférico CHIMERE en Santiago
Maria José	Meneses	Nicolas Huneuss	UCH	MOS	44	Modelación de Transporte de Black Carbon en la Cordillera de los Andes Central:Evaluación de desempeño WRF-Chimere
Matias	Bravo	Laura Gallardo	UCH	MOS	44	Obtención de Dosel Urbano para Simulación WRF
Patricio	Velásquez[8]	Laura Gallardo	UCH	MOS, BGQ	22	Registros de ozono en Tololo* El estudiante ha decidido suspender su trabajo en esta tesis y buscará un nuevo tema y profesor(a)

[8] *Patricio Velásquez decided to terminate this theme so he is expected to start over his thesis with another advisor.*

*Table 7. **Undergraduates** who got their exams in 2015, indicating thesis title, weekly dedication, research area and institutional affiliation.*

Name	Last Name	Tutor's	Affiliation	Research Area	Dedication	Thesis Title/Subject
Jaime	Alcorta	Beatriz Díez	PUC	BGQ	44	Mastigocladus sp. CHP1 como modelo de cianobacteria termófila de la Subsección V: Fisiología, filogenia y genómica comparativa
Ivo	Balic	Paulo Herrera	UCH	CD	44	Modelación numérica de los efectos de la variabilidad climática sobre la utilización sustentable del acuífero de la cuenca del Río San José, Arica.
Felipe	Flores	Duncan Christie	UACH	CD	44	Eficiencia multidecadal en el uso del agua en especies arbóreas de los Andes semiáridos inferida a través de cronologías de isótopos δ13C en anillos de crecimiento
Camila y Javiera	Espinoza, Jara	Susana Gómez	UBB	ECO	44	Temperatura y plantaciones forestadas como causantes de incendios forestales
Andrés	Ceballos	Mauricio Galleguillos	UACH	ECO	44	Combinación de información topográfica estructural lidar y teledetección hiperespectral para estimar la diversidad Florística Vascular de un bosque mediterráneo caducifolio en la precordillera andina del Maule, Chile.
Karla	Leal	Mauro González	UACH	ECO	44	Evaluación del proceso de restauración inicial luego de la reconversión de plantaciones de Eucalyptus globulus Labill a bosques siempreverdes en la Reserva Costera Valdiviana, Región de Los Ríos, Chile
Yasna	Salazar	Mauro González	UACH	ECO	44	Caracterización de los legados biológicos y su influencia en la diversidad de plantas en bosques de Nothofagus afectados por la erupción del Cordón Caulle (2011), Parque Nacional Puyehue, Chile.
Marcos	Buchi	Mauro González	UACH	ECO	44	Reconstrucciòn de un bosque adulto tallado de alerce en la depresiòn intermedia de la regiòn de los lagos

E. Support personnel

In the following list we show the people who have supported the center's activities without pursuing a thesis. Students are listed separately.

Table 8. Administrative personnel in charge of management, secretarial, and accounting duties.

Name	Last Name	Role	Affiliation	Dedication
Miguel	Aróstica	Secretary/Accountant	UCH	44
Susana	Bustos	General Coordinator/Manager	UCH	22
Claudia	Isla	Secretary	UCH	44[9]
Marcia	Millas	Secretary/Accountant	UACH	22
Cecilia	Montecino	Accountant	UCH	44
Mabel	Torres	Secretary/Accountant	UDEC	22
María Isabel	Guerra[10]	General Coordinator/Manager	UCH	44

[9] *Between April and September*
[10] *Between January and March*

Table 9. Communication's and outreach personnel. The whole team works under the direction of Nicole Tondreau

Name	Last Name	Role	Affiliation	Dedication	Months
Nicole	Tondreau	Journalist	UCH	44	March-December
Luz	Fariña	Journalist	UCH	44	Jan-Feb, December
Paula	Jiménez	Secretary	UCH	22	July-December[11]
Cristóbal	Bustamante	Designer	UACH	22	June-November
Giselle	Ogaz	Designer	UCH	44	December

Table 10. Computing and data management team. This team is under the leadership of Francisca Muñoz.

Name	Last Name	Role	Research Area	Affiliation	Dedication	Period
Nicolás	Miranda	Data manager	T	UCH	44	July-December
Francisca	Muñoz	Data Manager	T/MOS	UCH	44	All year
Roxana	Sanguineti	Technical edition	T/MOS	UCH	44	July-December
Ana	Zamorano	Digitization	T	UCH	44	July-December

[11] *Funded externally by the Prosperity Fund from the British Embassy for the Climate Change Law project*

Table 11. Research engineers who have working for extended periods supporting investigators and who are not pursuing a degree

Name	Last Name	Role	Responsible Researcher	Research Area	Affiliation	Dedication	Funding
Claudio	Alvarez	Technician	D. Christie	CD	UACH	44	CR2
Dámare	Araya	Research Engineer	P. Aldunce	HD	UCH	44	F
Gabriel	Araya	Research Engineer	P. Moraga	HD	UCH	22	CR2
Alejandra	Carmona	GIS Engineer	L. Nahuelhual	HD	UACH	44	CR2
Raúl	Fuentes	Research Engineer	R. Rondanelli	BGQ	UCH	22	F
Gerardo	García	Laboratory Assistant	L. Farías	BGC	UDEC	44	CR2
Adolfo	Henríquez	Research Engineer	L. Gallardo	MOS	UCH	22	CR2/CMM
Gloria	Lillo	Research Engineer	P. Aldunce	HD	UCH	44	CR2
David	Lobos	Field Assistant	A. Lara	ECO	UACH	44	CR2
Sol	Mockievi	Research Engineer	P. Moraga	HD	UCH	44	CR2/P
Bárbara	Morales	Research Engineer	A. Urquiza	HD	UCH	44	Other
César	Ordóñez	Research Engineer	N. Huneeus	MOS	UCH	22	CR2/F
Carolina	Ruiz	Field Assistant	A. Lara	ECO	UACH	44	CR2
Roxana	Sanguineti	Research Engineer	L. Gallardo	MOS	UCH	44	CR2
Fernanda	Skewes	Research Engineer	P. Moraga	HD	UCH	44	P
Felipe	Toledo	Research Engineer	R. Rondanelli	BGQ	UCH	11	F
Claudia	Villarroel	Research Assistant	R. Garreaud	CD	UCH	6	CR2

5. Changes in research personnel

Describe any changes in the principal and associate researchers relative to the original project.

A. Principal researchers

There are no changes to report regarding principal researchers.

B. Associate researchers

Regarding associate researchers, there are two main changes; **Dr. Axel Osses (MOS)** has decided to reduce his engagement at CR2 taking a position as adjoint researcher in 2016 and **Dr. Laura Nahuelhual (HD)** has taken a position as Principal Researcher for a Center of Excellence on Antarctic Research. She will therefore collaborate with us only as an adjoint researcher in the coming years.

Also, we have proposed the inclusion of **Dr. Eugenia Gayó** and **Dr. Raúl O'Ryan** as associated researchers under biogeochemistry and human dimensions respectively:

- **Dr. Eugenia Gayó** is a very active young researcher who blends in her research on paleoclimate tools from biogeochemistry (isotopic analysis) and from archeology to address the timing of early settlements in Northern Chile. In her proposal to CR2, she decided to focus over the next couple of years on the early fingerprints of the Anthropocene in Chile. This is very welcome because the Anthropocene will be our next interdisciplinary endeavor. Also, her work will facilitate the interaction between our biogeochemistry group and the rest of the CR2, particularly with human dimensions, which in turn addresses one of the observation raised by our evaluators. Up to now, Eugenia Gayó had collaborated with us as an adjoint researcher.
- **Dr. Raúl O'Ryan** is a senior researcher with a vast experience in Economics and Public Policy whom we have asked to strengthen our research in climate change economics. Particularly now that Laura Nahuelhual has shifted her focus of interest around ecosystem services in sub Antarctic environments. Over the next few years, Dr. O'Ryan will develop tools to allow a more integrated assessment of climate change policies and instruments, evaluating not only environmental, but social and economic impacts of mitigation and adaptation strategies. Initially top-down models will be developed, however bottom-up analysis to examine how investment projects that help mitigate and adapt to climate change can reduce socio-environmental conflicts will also be undertaken. Also, he proposes to enrich policy proposals in developing contexts by incorporating

uncertainty into the models used, for example a probabilistic approach to evaluate policies contained in Chile's Intended Nationally Determined Contributions.

Dr. Ricardo de Pol has taken a new position at Universidad de Magallanes in mid-2015. He maintains his association to the Center.

C. Adjoint researchers

In addition to the researchers listed in Table 2, during 2015 two new researchers have started collaborating with us:

- **Dr. Mauricio Osses** (Modeling and Observing Systems, Universidad Federico Santa María) has been working on new emission estimates for black carbon from mobile and stationary sources in Santiago. In 2016 he will extend this work to include past and future scenarios with emphasis on short-lived climate pollutants and precursors.
- **Dr. Mauricio Zambrano** (Climate Dynamics, Universidad de La Frontera) has continued his studies on hydrology in water catchment areas in the Andes. He is also assessing changes in temperature and changes in water availability during the mega drought.

In 2016, we will see the incorporation of **Dr. Marcela Munizaga** (Civil Engineering, U. of Chile) an expert in urban transportation issues, and **Dr. Natalia Escudero** (Architecture, U. of Chile) an expert in urban mobility with whom we are collaborating together with the Municipality of Santiago on urban resilience and sustainability. **Dr. Ariel Muñoz** (Geography, P. Catholic University of Valparaíso) who specializes in dendrochemistry, will collaborate with Modeling and Observing Systems and Biogeochemistry assessing dendrochemical signals of the Anthopocene in Central Chile.

D. Post-doctoral fellows

New post-doctoral fellows who arrived in 2015 are:

- **Cinthya Ramallo** (CD, U. of Chile): She studies the daily distribution of rainfall during wet and dry years in central Chile. A major point is that intense storms can occur independent of the average condition of a given year.
- **Dr. Caitlin Frame** (BGQ, U. Concepción): She studies the production, destruction, and transport of the trace greenhouse gases nitrous oxide (N_2O) and methane (CH_4) in the environment. N_2O, a strong greenhouse gas, is produced by microbial nitrogen cycle transformations in soils and aquatic environments and its concentration in the atmosphere has expanded over recent human history, largely as a result of agricultural fertilizer use.
- **Dr. Andrea Mazzeo** (MOS, U. of Chile): He is simulating the dispersion of aerosols in the atmosphere of Santiago under various conditions, looking at the export of

pollutants from Santiago to the Andes cordillera. In particular, he is analyzing events for which there are vertically resolved measurements.

- **Dr. Camila Tejo**[12] (ECO, U. Austral: In her project "Ecological Relevance of the Canopy of the Giant Alerce (*Fitzroya Cupressoides*) and its consequences for management and conservation" she will characterize the canopy by means of microclimate studies (moisture and temperature), C and N fluxes (via litterfall, stemflow and throughfall) and aerial soil chemistry, collecting samples from March 2016 to August 2018 in the Alerce Costero National Park and Reserva Costera Valdiviana (and other neighboring Alerce forests in the X and XIV regions).
- **Dr. Rocío Urrutia-Jalabert**[12] (ECO, U. Austral): She will assess the the vulnerability of *Fitzroya cupressoides* or Alerce to climate change (warmer and drier summers in southern Chile) using ecophysiological tools. Specifically, the research will focus on the vulnerability of the water conductance system to dry conditions and on the impacts of these conditions on the availability of carbon for the species. She will focus on adult trees and saplings to compare their vulnerability. Moreover, she will also work on refining the climate signal contained in alerce tree ring carbon isotopes sampling wood at an intra-annual level. Their study areas are the Alerce Costero National Park, the Central Depression close to Puerto Montt and the Alerce Andino Park for some of the objectives.
- **Dr. Carlos Zamorano** (ECO, U. Austral): He is identifying forest areas of passive and active restauration for biodiversity conservation and ecosystem services provision in Southern Chile. He is working on modeling the impact of grazing by domestic cattle on the degradation of native forests, focusing on regeneration of forest species, soil properties and ecosystem services.

A search for five new post-doctoral fellows for 2016 is on its ways.

E. Other personnel changes

We faced several changes in support and administrative personnel in 2015. First, our general coordinator between late 2013 and early 2015 María Isabel Guerra had to leave her position due to personal reasons. This resulted in the need of re-locating the working load among the director and the accounting assistant, Cecilia Montecino. Also a secretary was hired in early March but she did not manage to cope with her responsibilities. Her position was then taken by Miguel Aróstica, who in spite of not being an executive secretary has been able to support secretarial duties but we may make a new call to engage an executive secretary. Only in late 2015, Susana Bustos, an industrial engineer took a half time position to support the development of projects for the center. In 2016 she will have an 80% dedication adding also management duties.

In addition to this, Dr. Nicolás Huneeus has acted as director for Modeling and Observing Systems. This has resulted in a better functioning of the research area, and a balanced representation of the area in the Academic Board. Also, for the director it has implied more time for research.

In early 2016, Dr. René Garreaud will take a sabbatical in Yale University. During that time, Dr. Huneeus will replace him as acting subdirector if CONOCYT agrees.

[12] *She obtained a 3 year post-doctoral fellowship from CONICYT/FONDECYT starting in November 2015*

6. International and National Advisory Boards

Describe their tasks, the frequency of meetings, and usefulness of the advice provided to the Center. Also, report on the availability of the committee to assist the Center.

The International Scientific Panel provides guidance to our leading team of principal investigators, to promote collaboration between $(CR)^2$ and other centers around the world, and participates in our annual meetings and in activities involving students and stakeholders. The active members of our committee are:

- Dr. David Battisti, Tamaki Chair and Professor of Atmospheric Sciences, University of Washington, USA.
- Dr. Guy Brasseur, Max Planck Institute for Meteorology, Germany
- Dr. Mark Howden, Theme Leader - Adaptive Primary Industries, Enterprises and Communities, CSIRO, Australia.
- Dr. Carlos Nobre, Instituto Nacional de Pesquisas Espaciais, Centro de Ciência do Sistema Terrestre (CST), Brazil
- Dr. Karen O'Brien, Professor at the Department of Sociology and Human Geography at the University of Oslo, Norway
- Dr. Mary Scholes, Professor in the School of Animal, Plant and Environmental Sciences and Assistant Dean for Postgraduate Studies in the Faculty of Science, University of the Witwatersrand, South Africa.
- Dr. Tong Zhu, Chair Professor of Environmental Sciences, Cheung Kong Scholar Program at Peking University, China.

Unfortunately, Prof. O'Brien and Nobre haven't been able to collaborate with us.

Other advisory board members have been keen to support us, and Professors Battisti, Brasseur, Howden, Scholes and Zhu will visit us in mid-March 2016 as we will hold a plenary meeting to define questions and methods to address the Anthropocene in Chile, with emphasis on urbanization and land use changes.

In 2015, Dr. Brasseur visited during 2015 on periods of several weeks as part of his Abate Molina prized awarded in early 2015. In addition to seminars, this has led to joint publications and research proposals:

- Brasseur, G. P., and L. Gallardo, Climate Services: Lessons Learned and Future Prospects, submitted to Earth's Future.
- The joint Atmospheric Chemistry and Surface Hidrology: Impacts in Chile and in the Andes (CHICHA). CONICYT Chile – BMBF Germany, Convocatoria 2015.

Also, he accompanied us in a symposium on air quality forecasting and management organized by the Ministry for the Environment.

Our National Advisory Panel is to promote the connection with various institutions and sectors. The members in 2015 have been:

- Jorge Carrasco, former Director of the Climatology Division at the Chilean Weather Office (DMC, Dirección Meteorológica de Chile), and currently affiliated with University of Magallanes.
- Rosa Escobar, private consultant with expertise in environmental studies for the mining industry. She acted also as director for the regional office of the National Commission for the Environment (Now Ministry for the Environment).
- Maritza Jadrijevic, Officer at the Ministry for the Environment, Climate Change Bureau, Ministry for the Environment.
- Raúl O'Ryan, former Officer at the United Nations Development Program in Santiago and now Director for Innovation and Energy, Universidad Adolfo Ibáñez
- Jaime San Martín, Researcher and former Director for the Center for Mathematical Modeling

Jorge Carrasco, Rosa Escobar, Maritza Jadrijevic, Raúl O'Ryan, and Jaime San Martín have actively participated in the different meetings held in Roca Negra (January 2015), Santiago (June 2015) and Valdivia (November 2015). Also, either verbally or in written they have provided insightful comments, and recommendations.

V. OBJECTIVES AND RESULTS ATTAINED (Maximum 25 pages)

1. RESULTS OBTAINED RELATIVE TO CENTER OBJECTIVES

a. Considering the objectives established in the project. Refer also to those objectives that have not been accomplished, justifying the reasons. Organize your report describing the most significant outcomes for the following aspects:

   i. Main research findings
   ii. Synergy and collaboration among research lines. Also, please explain how FONDAP funding has transformed the individual and collaborative research within the Center?
   iii. Formation of advanced human capital directly related to the Center´s objectives: Also, please explain how FONDAP funding has transformed the training of young researchers?
   iv. Collaborative networks both at the national and international level. Also, please explain how FONDAP funding has transformed collaborative research between the Center's researchers and national and international researchers?
   v. Dissemination and exploitation of results
   vi. Outreach to society. Please explain the impact of the FONDAP Center in terms of outreach to the general public.

b. Please explain the impact of the FONDAP Center in terms of contribution to policy makers and other targeted groups.

c. Describe unexpected difficulties encountered and indicate how they were dealt with.

A. Main research findings

Our research findings of the third year are summarized here in bullet points. These are further explained in section 2, and in concurrent peer-reviewed publications.

- High-emitting structures of nitrous oxides (N_2O) have been documented in upwelling areas in the South East Pacific
- It has been demonstrated that nitrogen fixation in hot springs is more active than previously thought.
- The observed large variability in oceanic surface ^{14}C reservoir effect during the Holocene was attributed to changes in the wind-driven upwelling of old subsurface waters, and thus to local climate change.
- Anthropogenic climate change -mediated by circulation anomalies- accounts for about a quarter of the precipitation deficit during the current (2010-2015) mega drought in central Chile.
- The duration and spatial extent of the mega drought are extraordinary in the historical record and unparalleled in 1.000 year reconstructed precipitation based on tree-ring growth records.
- Alternations between centennial wet/cold and warm/dry periods in Southern Patagonia during the Holocene associated with SAM-like variability.
- A general pattern of landscape homogenization towards the reduction of native forests, mainly due to their conversion to exotic pine and eucalypt commercial plantations was documented for Southern Chile
- Contrary to what was previously thought, the rate of conversion of native forests to exotic forest plantations has increased in the period 1999-2008 when compared to 1987- 1999 in vast areas of south-central Chile.
- Residence time of carbon for *Fitzroya cupressoides* forests estimated in 1368–1393 years are the highest reported for any species worldwide and they act as ongoing biomass carbon sinks that allow biomass and carbon to be accumulated for millennia.
- Despite the paucity of systematic observations along the Andes, a few studies have detected BC on snow and glaciers in the Andes. These, in addition to existing and projected emissions and weather patterns, suggest a possible contribution of BC to the observed retreat of the Andean cryosphere.
- Using paleoclimate data and model simulations it was shown that iron fertilization of the earth's oceans and the resulting enhanced biological productivity and carbon export to the deep ocean is a minor geoengineering tool to reduce current carbon dioxide levels
- Depending on this steric/dynamic component estimate, the total mean sea-level rise along the coast of Chile is estimated between 34 cm and 52 cm for the RCP4.5 scenario and between 46 cm and 74 cm for the RCP8.5 scenario.

B. Synergy and collaboration among research lines

The number of published papers in 2015 represents roughly 50% of all articles produced by CR2 since its start in early 2013. This increase with respect to previous years is partially reflected in the number of co-authored papers by individuals pertaining different research areas, and more importantly crossing disciplinary boundaries. Still the majority of our papers are disciplinary or at best multidisciplinary. This is illustrated in Figure 1.

		P. Individual	Cooperacion	Linea	L Gallardo	N. Huneuss	A. Osses	M. Rojas	G. Shaffer	JP. Boisier	R Garreaud	P Moreno	D Christie	P Herrera	R Villa	L Farias	M Yevenes	M Cornejo	R DePol	B. Diez	R Rondanelli	E. gayo	I. Massotti	A Lara	C Little	S Gomez	M Gonzalez	M. Gallegillos	P Moraga	P Aldunce	L Nahuelhual	A Carmona	Borquez	F Lanbert
	L Gallardo	5	61%		**2.0**	0.2	1.0				0.2					0.3			0.3		0.5												0.2	0.5
	N. Huneuss	2	40%		0.2	**1.2**					0.2																						0.2	0.2
	A. Osses	2	50%		1.0		**1.0**																											
	M. Rojas	5	36%					**3.2**			0.7	0.7			0.2				0.2															
	G. Shaffer	2	NA						**2.0**																									
*	JP. Boisier	2	NA	**13.1**						**1.3**	0.3										0.3													
	R Garreaud	18	15%		0.2	0.2		0.7		0.3	**15.2**	0.2			0.2				0.2		0.3												0.2	0.2
	P Moreno	10	18%					0.7			0.2	**8.2**			0.7				0.2															
	D Christie	8	8%										**7.3**											0.3			0.3							
	P Herrera	0	NA											**0.0**																				
	R Villa	2	N/A	**33.7**				0.2			0.2	0.7			**0.7**				0.2															
	L Farias	9	14%		0.3											**7.8**		0.5	0.3															0.3
	M Yevenes	0	NA														**0.0**																	
	M Cornejo	1	NA													0.5		**0.5**																
	R DePol	10	16%		0.3			0.2			0.2	0.2			0.2	0.3			**8.5**															0.3
	B. Diez	1	NA																	**1.0**														
	R Rondanelli	5	23%		0.5					0.3	0.3										**3.8**													
*	E. Gayo	2	100%																			**2.0**												
*	I. Masotti	1	100%	**26.0**																			**1.0**												
	A Lara	7	31%										0.3											**4.8**	1.0		0.8							
	C Little	2	50%																					1.0	**1.0**									
	S Gomez	1	NA																							**1.0**								
	M Gonzalez	5	23%										0.3											0.8			**3.8**							
*	M. Gallegillos	3	0%	**17.3**																								**3.0**						
	P Moraga	1	NA																										**1.0**					
	P Aldunce	3	0%																											**3.0**				
	L Nahuelhual	2	NA																												**1.5**	0.5		
	A Carmona	1	NA																												0.5	**0.5**		
	Borquez	2	40%	**8.2**	0.2	0.2					0.2																						**1.2**	0.2
	F Lanbert	4	39%	**2.5**	0.5	0.2					0.2					0.3			0.3														0.2	**2.5**
																																		90.0

Figure 1. This figure summarizes the contributions of different authors to CR2 publications (with acknowledgements) since 2013. The more numbers outside the diagonal the more papers with authorships in more than one research line.

The growth in productivity is shown in Figure 2. After 3 years, one can see a change in the number of total publications produced by the center. The only exception refers to Human Dimensions but that could be partially explained by the type of literature they produce, i.e., typically books that take longer than peer-reviewed articles. Still, we are aware of the possibilities and the need to improve the statistics for this group. It is also interesting to notice that the Modeling and Observing System group is the areas with the largest relative growth in the period.

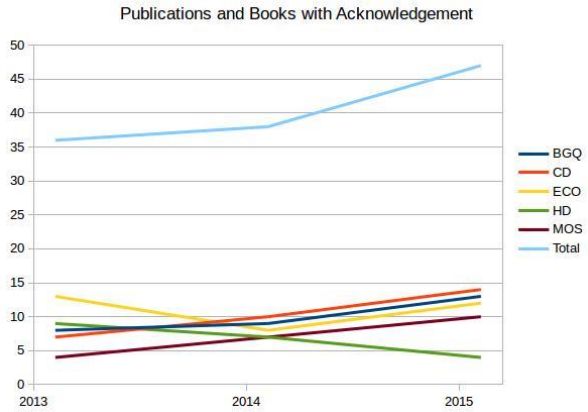


Figure 2. This figure shows the total number of publications per research line between 2013 and 2015, as well as the total of papers and books produced by CR2. This refers only to publications with explicit acknowledgment to FONDAP 15110009.

Interestingly, the issues addressed in our publication do refer to the themes declared in early 2012. This is illustrated in Figure 3.

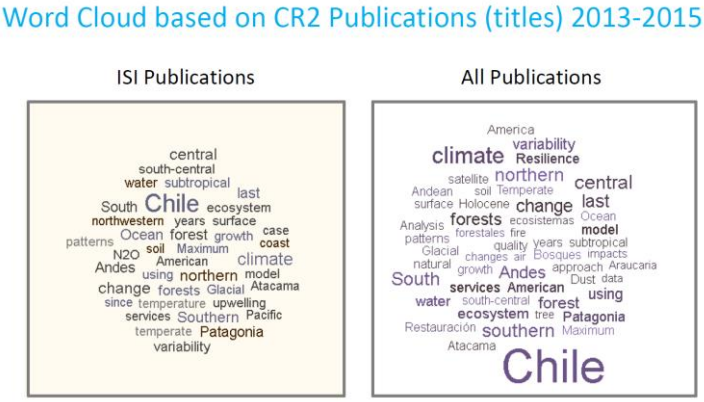


Figure 3. Word clouds based on our publication's titles.

As stated earlier, the mega drought study resulted already in a published paper and a number of manuscripts for which collaboration within and among research areas took place. A number of "mega drought" themes for manuscripts have identified so far are listed in Table 13. From the list it becomes apparent the role played by the mega drought coordinator, Dr. Garreaud, in triggering and directing the research. Also, the majority of papers are framed within disciplinary boundaries, and only a couple attempt to stretch beyond those boundaries. Nevertheless, the effort put into building a coherent story involving several research areas is already an achievement, and a significant step forward in advancing towards interdisciplinary studies.

A much less encouraging story is reflected in the number of theses with advisors in more than one research area. Actions must be taken to prioritize this type of work in 2016.

Table 12. Lists of manuscripts produced around the mega drought integrative theme. One of these articles has already been published. Another is under review, and the rest will be submitted jointly to one journal to be determined. The main author is outlined in bold letters.

Title (Status)	Contributors adscribed to:					
	BGQ	**CD**	**ECO**	**HD**	**MOS**	**Other**
Anthropogenic and natural contributions to the Southeast Pacific precipitation decline and recent mega-drought in central Chile, *Geophysical Research Letters*. (Published)	Rondanelli	**Boisier**, Garreaud			Muñoz	
On the assessment of adaptation practices: a transdisciplinary exploration of drought measures in Chile. Environmental Science and Policy (In revision)				**Aldunce** Lillo	Rojas	Adler Vidal
Análisis comparativo del diseño institucional de cambio climático en Chile y México: convergencias, fortalezas y debilidades, (Parlatino), In revision				***Moraga*** *Araya Meckievi*		
The process of building interdisciplinary climate studies in Chile: the mega drought case (Idea)	*Farías*	***Garreaud***	*Lara*	*Moraga*	***Gallardo***	
Rivers discharge and their influence on phytoplankton biomass during drought period in central coastal areas of Chile	***Masotti*** *Farías Yévenes Aparicio-Rizzo*	*Garreaud*				
Fire promotors and inhibitors: fire protection as a new ecosystem service provided by native forests.		*Garreaud*	***Gómez-González*** *González Díaz Little Lara*			*Delgado-Boquerizo Paula*
Impact of increasing temperatures on MD		Garreaud **Zamorano**				
Dynamics of the Central Chile mega drought	*Rondanelli*	**Garreaud** Boisier				

For the next integrative theme, i.e., the Anthropocene, we intend to try a bottom up approach in which people propose research projects to be incorporated into one or more focal areas, namely, drivers, impacts and risks, and projections. This is somewhat different from the approach used in the mega drought study, where specific questions were posed to the research areas. A short exercise around characterizing the Anthropocene and its consequences on climate and vulnerability was carried out last November in a meeting emphasizing the need for interdisciplinary approaches. We also intend to allocate extra research resources for those who actually propose projects that cross disciplinary boundaries. A meeting to be held in mid-March in Central Chile

together with our advisory panel will be key in defining a research agenda for the next 18 months or so. The previous approach was advantageous in terms of efficiency but some people felt left out as their own research agendas did not fit into the integrative theme. The current approach may allow a better allocation of research interests but it may be less efficient.

C. Formation of advanced human capital directly related to the Center´s objectives

At the moment of writing this report we have graduated 4 PhDs, 32 MSc and 27 undergraduates, of whom 1, 8, and 9 graduated in 2015. Although the number of doctoral students is still small, the majority of the themes of the corresponding theses are directly relevant to research CR2 objectives. A similar situation is apparent in master degrees. Also, post-doctoral fellowships have been shaped within the framework of our scientific goals. However, there is still room for better directing these works towards CR2 key objectives, and certainly for interdisciplinary research. In fact, in our current call, one of the criteria to select doctoral students and post-doctoral fellows will be the collaboration of more than one research line.

D. Collaborative networks both at the national and international level

At the national level we have collaborated with centers and institutions including governmental agencies as presented in Subsection G. Nationally, we highlight:

- **CR2 and Chilean Weather Office**. As part of the agreement previously signed:
    - We have now completed the design of a new Climatological Bulletin for the Chilean Weather Office. The design considered a review multiple bulletins, and definition of new contents, as well as the automatization of its production. Now, figures included in the bulletin are produced automatically and fully consistent with the Weather Office data bases. Moreover, the new system is connected to a high-level visualizer that allows the production of interactive graphs. These interactivity features will be of great use once the Weather Office will enable on-line climate services. This work was under the leadership of **Francisca Muñoz**, and counted with the collaboration of **Roxana Sanguineti** (MSc Meteorology) and the communication's team. Of course, the new contents, and features of the bulletin were thoroughly discussed with the Weather Office personnel. The new bulletin will be officially launched in March or April 2016.
    - A training hands-on course on statistical methods for characterizing monitoring networks was held for two Weather Office officials in order to transfer this capability to the Weather Office.
    - A joint paper describing ozonesonde data from Rapa Nui (Easter Island) was completed and submitted: Gallardo,L., Henríquez, A., A. M. Thompson, Velásquez, P., Rondanelli, R., Carrasco, J., and. The first twenty years (1994-2014) of ozone soundings from Easter Island (27ºS, 109ºW,51 m.a.s.l). Tellus B (In Review).

- **CR2, Center for Mathematical Modeling and Ministry of Public Works**. A broad collaboration agreement was signed among these entities to develop studies that should support the strategic planning of this Ministry. In 2016, detailed studies will be defined.
- **CR2 and Municipality of Santiago**. A collaboration agreement intended to develop climate services was signed between these institutions. In addition to tailored climate data, we want to focus our collaboration around instruments to quantify and qualify climate vulnerability, and to collaborate with this emblematic municipality in terms of sustainable urban mobility and trasportation. This collaboration will be coordinated by **Dr. Anahí Urquiza** and **Dr. Laura Gallardo**. In this framework, Dr. Brasseur gave a talk at the Municipality. Also, later in the year, we have been invited to participate in the Chilean Mayor's Forum on Climate Change.
- **CR2 and SERC**: Together with the Center of Excellence for Solar Research we have proposed to University of Chile a course on "***Cambio Climático y Desarrollo Bajo en Carbono. Un desafío Interdisciplinario".*** This course is oriented to professionals in the public and private sectors with a duration of one semester or 282 hours. In the curriculum we involve CR2 researchers from all areas. **Dr. Anahí Urquiza** is the general coordinator for the program, and **Dr. Laura Gallardo** is in the academic committee.
- **CR2, CEGA, IEB*:*** Together with the Andean Geothermal Center of Excellence (CEGA), and the Institute for Ecology and Biodiversity (IEB) we have developed an outreach program oriented to promote the involvement of girls in natural science (http://www.julietaexploradora.cl/el-proyecto-julieta-en-la-tierra-de-las-ninas/). **Dr. Laura Gallardo** acts as the deputy director for this project.
- **CR2 and Center for Global Change.** In 2015, together with the Center for Global Change from the Catholic University we applied for the development of the adapation chapter of the National Communication of Chile to be presented in 2016. The CR2 team is coordinated by **Dr. Paulina Aldunce**.

We received multiple visitors in 2015 and from different countries in Europe (France, Germany, Spain, Switzerland), North America (Canada, United States), South America (Argentina, Colombia), and Oceania (Australia). We visited six different research facilities in Peru, France, Sweden, Colombia and the Netherlands. Of course, we visited many more places in connection with our nearly 50 participations in conferences and symposia abroad. In addition to collaboration among individual researchers, this has led for instance, to an agreement between CR2 and the Bolin Centre for Climate Research in Sweden to exchange young researchers and students for weeks- to months-long visits.

Also, we have applied to CONICYT calls for international collaboration. In 2015, we submitted at least three proposals (CR2 researchers in parenthesis):

- Joint Studies on Climate Change and Variability along the Andes. Principal Investigator. In Collaboration with Argentinean Institutions (CIMA/IANIGLA). REDES CONICYT. Gallardo, Rojas, Huneeus, Garreaud, Christie, Zamorano

- Towards a first emission inventory in South America. REDES CONICYT. Huneeus, Gallardo, Osses
- The joint Atmospheric Chemistry and Surface Hidrology: Impacts in Chile and in the Andes (CHICHA). CONICYT-BMBF. Gallardo, Huneeus, Rondanelli.

Initiatives started in 2014 were continued or completed in 2015. Such is the case for *The Chilean Coastal Orographic Precipitation Experiment* (CCOPE) pilot project, led by Dr. Justin Minder from University at Albany, USA. CCOPE-2015 took place over the coastal Nahuelbuta Mountains of Chile during May-August of 2015 to improve understanding of orographic precipitation processes over coastal mountain ranges, particularly the role of aerosols, shallow convection, and shallow warm-rain processes. To this end, we deployed a network of rain gauges, two rain radars, disdrometers and radiosondes. CCOPE has the support from CR2, University at Albany, State University of New York, University of Colorado, NOAA/ESRL, University of Wyoming and Universidad de Concepcion, Chile.

Also, in addition to the 11 ICHSMO International Conference on Southern Hemisphere Meteorology and Oceanography chaired by our deputy director and co-organized by CR2, we co-chaired symposia under the *IV Congreso Internacional de Servicios en los Neotrópicos* in Colombia and the 26th General Assembly of the International Union of Geodesy and Geophysics, Earth and Environmental Sciences for Future Generations in the Check Republic. It is worth noticing that Dr. Gallardo was invited to give one of the 6 Union Lectures in the IUGG conference, when she talked about Atmospheric Chemistry in the Anthropocene.

The Project funded by the British Embassy to address the question of Climate Change legislation has also led to a number of exchanges with distinguished UK scholar and policy makers, including Sir David King.

E. Dissemination and exploitation of results

In addition to numerous standard presentations for the national and international communities in seminars and conferences, we were keen to take part in multiple meetings and seminars oriented to the general public and stakeholders. We highlight the following instances:

- ***11th International Conference on Southern Hemisphere Meteorology and Oceanography (ICSHMO).*** From October 5th to 9th, the American Meteorological Society ICSHMO conference (held every 3 years) took place in the Faculty of Physical and Mathematical Sciences, University of Chile. The conference reviewed the state of atmospheric and oceanographic sciences of the South Hemisphere and brought more than 200 international scientist and total of 330 abstracts. René Garreaud led the event's organization, with strong support from Roberto Rondanelli, and several others CR2 members acted as session's chairs.
- ***Climate law week***. Developed from 28 September to 1 October in the context of the project "Proposal for a legal and institutional framework to address climate change in Chile" by Adapt-Chile and (CR)2. During four days, several events with local, national and foreign decision makers and stakeholders were held. We highlight the international seminar where the former President of Chile, Ricardo Lagos Escobar,

was the keynote speaker. The event took place at the Faculty of Law of the University of Chile and was organized by Pilar Moraga.

- ***Launching the Report to the Nation "The mega-drought 2010-2015: a lesson for the future".*** On November 6 the report was officially launched at the Faculty of Physical and Mathematical Sciences, University of Chile. High level authorities were present at the event: Ennio Vivaldi, President of the University of Chile; Carlos Estévez, Chair of the National Water Authority; and Reinaldo Ruiz, Presidential Delegate for Water Resources, among other representatives of the government, the academic community and the business sector.

F. Outreach to society

During 2015, CR2 had significant and continuous presence in media: 232 original press appearances were achieved, overcoming the number reached in 2014 (89 appearances). Both records exclude secondary media and institutional websites. Most of these appearances were in written press (111), which is consisting with the previous year trend. The rest corresponds to websites (67), TV (28) and radio (24).

Main themes linked to CR2 in the media were extreme weather events, climate change (often in connection with the above), COP21 and the mega-drought report. The latter received extensive press coverage, especially the delivery of the document to President Michelle Bachelet. Thus, foreign press agencies like EFE and Associated Press offered the theme within its daily news content.

Informative news, like stories and articles, were the predominant genre of (CR)2 press publications during 2015. In fact, they displaced the interview as main genre prevailed in 2014.

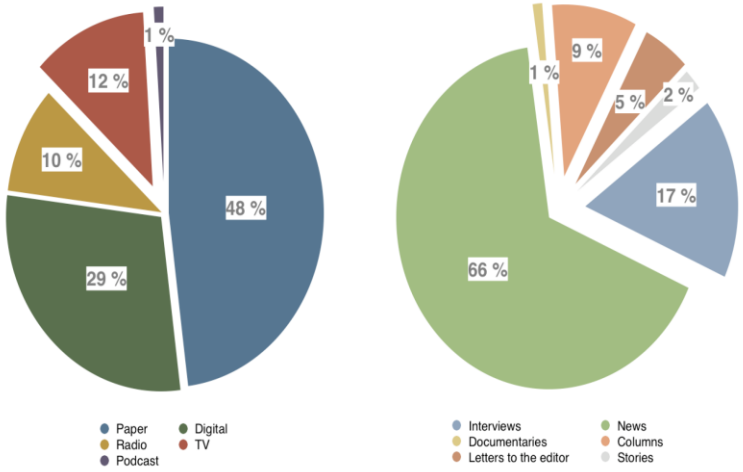


Figure 4. The left panel shows the percentage of media appearances in 2015 per media type. The right panels shows the format of the appearances. For details see Annex 4 "In the media", and attached summary brochure.

(CR)2 website kept a high number of visits comparable to the previous year. In social networks, Facebook and Twitter institutional profiles doubled their number of

followers in 2015 (1,667 and 1,169 followers respectively). These sites are consolidated as informative channels of equivalent or more importance than that of the website.

In terms of communication products, there was an emphasis on the development of video, highlighting the one that summarizes the interdisciplinary work made in mega-drought. Our own audiovisual production also increased during COP21 of Paris, where several interviews for broadcast on institutional channels were filmed. We continued the streaming transmission of seminars held in Santiago.

Outreach actions focused on the implementation of Explora-CONICYT project "Julieta en la tierra de las niñas" (Julieta in the land of the girls) which promotes the interest for earth sciences in girls aged 7-11 years, conducted in partnership with the Andean Geothermal Center of Excellence FONDAP-CONICYT (CEGA).

Other focus was through the implementation of the project "Proposal of a legal and institutional framework to address climate change in Chile" that settled the need of a law on climate change for Chile in the parliamentary agenda (creation of the "Climate parliament") and in the Ministry of Environment. A "climate week" was organized in collaboration with the British Embassy, and NGO ADAPT Chile, in which several high level national and international profiles participated including former president Ricardo Lagos, Sir David King, and the undersecretary for the Environment, Marcelo Mena. It is worth noticing that prior to the project addressing the climate law, there were no media mentions in this respect. Thus CR2 and it climate law project have added a new subject to the agenda.

Finally, we highlight the workshop "Comunica tu ciencia" (Communicate your science) organized by the communication officers of (CR)2, CEGA (both FONDAP-CONICYT centers of excellence), Millenium Nucleus of Paleoclimate, Millenium Nucleus for Metals Tracing along Subduction, and the Institute for Ecology and Biodiversity (Millenium Scientific Initiative). In that occasion, a group of doctoral and post-doctoral fellows of these centers received basic media training and also some tips to improve their communication skills with different audiences.

G. Contribution to public policies

In 2015, we have carried out multiple activities that contribute to the presence and recognition of CR2 as a viable partner for collaboration. Among those we highlight:

- **Meeting her Excellency Michelle Bachelet.** The majority of the center's principal investigators held a nearly two hours meeting with Mrs. Bachelet last November 2nd at the governmental palace. In addition to presenting our report to the nation on the Mega Drought, we had the opportunity to talk about the then upcoming COP 21 meeting and the general position of Chile in the international negotiations, and general matters affecting science and technology in Chile.
- **Presentation in Congress.** Dr. Garreaud also presented the Report to the Nation in an especially dedicated session of the Chilean Congress in the Commission for Water Scarcity and Drought
- **Launching of the Climate Caucus.** Within the framework of the Climate Change Law project, a caucus of deputies and senators was launched in late September. Dr. Pilar Moraga and Dr. Gallardo had then the opportunity to exchange points of view with the parliamentarians.

Whether these encounters will lead or not to new public policies or legislation is difficult to assess. Nevertheless, it is obvious that our capacity to influence the decision making process has reached a new status. In fact, Dr. Gallardo has now been invited to participate in the **Presidential Commission on Resilience to Natural Disasters** in Chile whose purpose is to define research needs and priorities regarding these phenomena including the climate variability and change perspectives, and with a strong emphasis on interdisciplinary research. This commission must provide a report in mid-2016, which together with other reports on mining, health and technology will state the bases for public policies to be driven by the recently announced Ministry for Science and Technology.

Many other activities are taking place that also cement the base for an impact for influencing policy making in the sense of providing a scientifically authoritative opinion. For instance, since April 2015, Dr. Lara, Eng. Cruz and Dr. Aldunce collaborated with La Bolsa del Clima de Santiago, a Chilean private initiative dedicated to the development of climate market instruments and associated capacity building, training and certification processes. This work has been requested by the National Climate Change Strategy for the Vegetation Resources (Estrategia Nacional de Cambio Climático y Recursos Vegetacionales, ENCCRV) led by the Chilean Forest Service (CONAF, Ministry of Agriculture). Also, a document sent to the highest authorities to present the evidences that demonstrate the inconvenience to pass a law for the renewal of D.L. 701, created during the military dictatorship, that has provided subsidies for fast growing forest plantations for the last 40 years. Moreover, several CR2 researchers including Dr. Aldunce and Dr. Rojas participated in the evaluation of the National Action Plan for Climate Change, and the proposition of a new Plan, which is now under review.

2. RESULTS ACHIEVED PER RESEARCH LINE

Briefly describe the main results per research line achieved during the period.

A. Biogeochemistry

A set of the Biogeochemistry group's findings in 2015 refer to the mega drought studies. A decadal assessment (2000-present) revealed that droughts have severely impacted fresh water discharge of the main rivers off central Chile as Maipo, Mataquito, Maule, Itata and Biobío rivers (32-37°S), as shown in (CR2, 2015). Satellite (MODIS satellite images) and hydro chemical analyses showed decreasing trends in plume area of rivers and in nutrient export to the coastal area (nitrate and phosphate) as precipitation and river discharge were reduced. Significant correlations were found between fresh water discharges and the riverine plume areas (r: 0.6 to 0.76) and between fresh water discharges and phytoplankton biomass associated to plume areas measured as chlorophyll-a (r: 0.4 to 0.53) as reported in a manuscript by (Masotti et al., 2016).The nutrients levels, that support the phytoplankton communities, were also correlated with exported nitrate and phosphate (r: 0.35 to 0.61). Therefore, similar to phytoplankton biomass, nutrient loading showed a reduction of 25% to 75% for nitrate and phosphate, respectively, mainly in months of maximum discharge (austral winter). This study also identified a marked latitudinal gradient of the drought impact on the

primary producers. The Maipo river in the Santiago basin, which is already highly intervened, was the most affected by the drought with major consequences on the phytoplankton biomass.

We also examined the impact of El Niño Southern Oscillation (ENSO). In fact, more frequent and extended nutrient rich plumes were recorded during El Niño years and less so during La Niña years. This is of relevance for the phytoplankton fertilization in coastal waters. During El Niño, discharge increases were found, which can be benefitial to primary producers when upwelling decreases. Instead, in La Niña years intensified upwelling is present and the river discharges are apparently not the primary factor. This natural regulation is less notorious in presence of a mega drought especially in Maipo river during 2009 until 2014 (Masotti et al., 2016).

Temporal variability in biogeochemical variables (including nitrous oxide and methane) was re-evaluated from time series (TS) stations off Concepcion (COPAS TS; Farías et al., 2015) and Valparaiso by Masotti and collaborators. Besides a seasonal variability is observed in oxygen, nitrous oxide, methane, nutrients and chlorophyll-a (Chl-a) as a consequence of upwelling process (austral spring–summer) in COPAS TS and Valparaiso TS. Also, a clear inter-annual variability was particularly evident by the occurrence of N_2O hotspots. These are structures located below the mixed layer (15–50m depth) with gas saturation levels of up to ~5000% (Farias et al., 2015). These hotspots consistently took place during the upwelling-favorable periods in 2004, 2006, 2008, 2010 and 2011, in waters with hypoxia and some nitrite accumulation. As a result, this causes a substantial N_2O emission to the atmosphere of up to 260 μmol m^{-2} d^{-1}. (Farias et al., 2015) indicated that N_2O hotspots are transient events or hot moments, which may occur more frequently than they are observed. If so, this upwelling area is producing and emitting greater than expected amounts of N_2O. These phenomena will be further studied by the deployment of the POSAR platform (buoy with biogeochemical and oceanographic sensors) close to COPAS ST that will allow to study daily, weekly an intraseasonal variability, and therefore, to study how variables respond to local forcing as wind direction and intensity, heat and precipitation. These driving variable/factors (e.g., the meridional wind component which causes the coastal upwelling phenomenon) seem to be changing in the central Chilean zone, and they may have an impact on fertilization and gas exchange with the atmosphere.

The CR2 team participated in the CIMAR 21 expedition to the eastern South Pacific (Valparaiso to Eastern Island, October 2016). We took our recently implemented system (own technological development) for continuous measurement of nitrous oxide and methane in surface oceanic waters to estimate the air-sea fluxes in the region. We also collected samples for studying the very fine vertical distribution (each meter) of the variables in the water column in order to determine the origin of gases in the South Pacific gyre. We also participate in LOWPHOX cruise in order to investigate the impact of ocean acidification on nitrifying activity, preliminary results suggest that OA does not seem affect nitrification but N_2O yielding rates (Frame et al., manuscript).

Another interesting finding is that nitrogen fixation is more active than previously thought. For example, it can occur in extremophilic environments as hot springs (Alcamán et al. 2015) as well as polar ecosystems (Díez et al, manuscript). New expeditions to Antarctica will allow a better description of this phenomenon.

The effect of climate conditions on the sensitivity and resilience of pre-hispanic societies in the hyper arid Atacama Desert was evaluated by studying the weathering of surface lithic archeological remains (Ugalde et al., 2015), ^{14}C reservoir effects in archeological shell middens as well as by implementing socio-environmental models (Latorre et al., 2016). Further, observed large variability in oceanic surface ^{14}C reservoir effect during the Holocene (last 11,500 years) –inferred by dating simultaneously marine (shells) and terrestrial (plant remains) materials recovered from archeoloigical shell middens- is attributed to changes in the wind-driven upwelling of old subsurface waters, and thus to local climate change. These changes had, in turn, significant impact on the local prehistoric habitants (Chinchorro culture) as upwelling is the main factor accounting for local marine primary productivity along the coastal of northern Chile (Latorre et al., 2016).

In this same vein, (Gayo and Santoro, 2015) show that paleo demographic trends either at sub-continental or regional scales followed closely the environmental variability induced by ENSO over the past 15,000 years. Actually, model simulations showed that major population expansions (crushes) are coeval to significant positive (negative) productivity anomalies detected along the coastal and inland Atacama Desert. These results point to an active and coordinated response of hunter-gatherers and agrarian groups to variations in ecological and hydrological conditions, which in turn suggests that pre-Hispanic societies from the arid Andean slope are susceptible to changes in ENSO activity at different spatial-temporal scales and cultural contexts.

A study of how mineral dust flux impacted carbon cycle (exported carbon and atmospheric CO_2 concentration) during Holocene and Last Glacial Maximum (LGM) conditions was made based on a compiled and modeled dust flux datasets. Regional changes in dust input stimulated heterogeneity LGM carbon export and the higher LGM dust loads compared to Holocene conditions resulted in only a weak reduction in atmospheric CO_2 of <10 ppm (Lambert, et al., 2015). Finally, as part of a long-term collaborative effort with ECO, CD and MOD, we have finished the collection and analysis of annual tree ring samples from the Anthropocene (1850-2010 AD) from 4 different latitudes covering the entire Chilean territory. These samples were radiocarbon dated and will help exploring the changes in the latitudinal gradients in atmospheric radiocarbon content, a proxy of large-scale climate change (De Pol et al, manuscript). In addition to better characterizing transport processes, these analyses will be functional to characterize the Anthropocene. Preliminary analyses clearly show thermonuclear explosions in the mid XX century and the dilution or Suess effect due to increasing CO_2 mixing ratios.

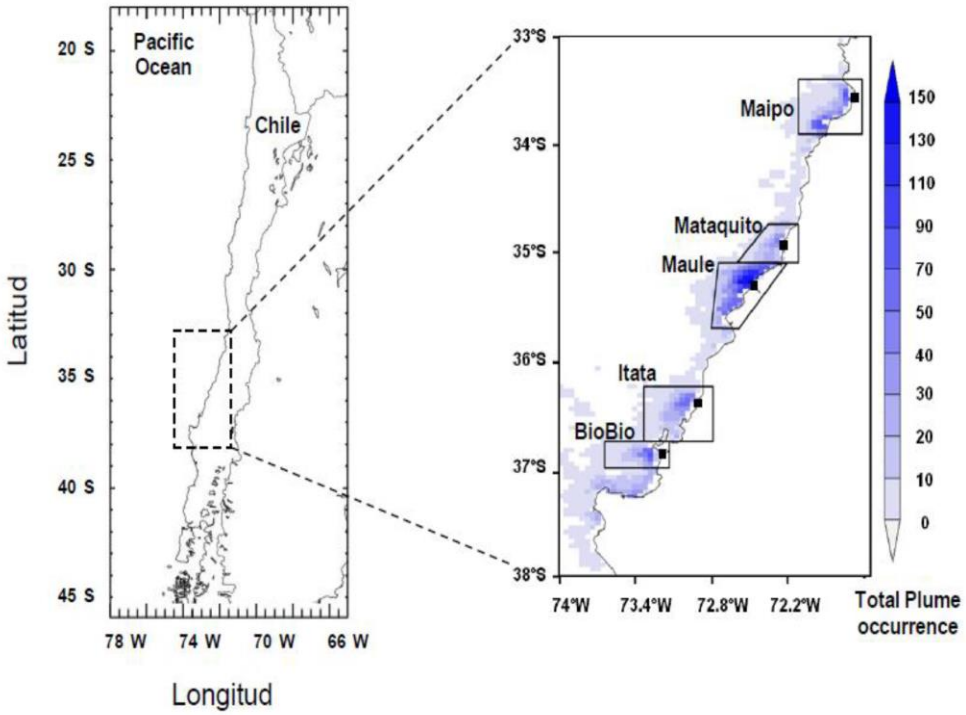


Figure 5. River locations in central Chile, violet color show the river plume influenced area around the Maipo, Mataquito, Maule, Itata and Biobío rivers from MODIS data (2000-2014).The scale is number of weeks in all study period.

Within the framework of a concurrent FONDECYT grant, we are studying the variability of cloud liquid water on the coastal fog forests of northern Chile. We have acquired a Fog Monitor, and we have started analyzing satellite proxies of cloud liquid water, effective particle radius and cloud coverage. Simulations with WRF are carried out to characterize the mesoscale circulation associated with the cloud formation. During 2016 we expect to perform one observational campaign and to deploy the equipment in the Talinay hill as well as to install some of the meteorological instrumentation. The seasonal and diurnal evolution of Central Chile Fog has been documented by Pizarro (2016, thesis).

Dynamical aspects affecting extreme precipitation events have also been explored. In particular, we studied the so-called Atacama storm. In fact, in March 2015 a powerful and extreme storm hit the Atacama desert producing precipitation in areas that are usually considered hyper arid (less than 5 mm annual precipitation). Several aspects of the storm such as the role of a coastal South American SST anomaly (Bozkurt et al., 2016) and the connection to extreme temperatures in Central Chile (Barrett et al.) as well as global teleconnection implications (Rondanelli, 2016), have been studied using observations and modeling. A report is being prepared for the decision makers at the Ministry of Public Works in which we summarize the main meteorological

characteristics of the storm. Further, we contributed to the analysis of the mega drought phenomenon (Boisier et al., 2015b).

In collaboration with the Modeling and Observing Systems team, we have continued the collection of valuable data on Aerosol Optical Depth (AOD), water vapor and derived particle size distribution. These data are being directed towards establishing a connection between the diffuse and direct partition of global horizontal radiation in connection with AOD (del Hoyo, 2016, thesis), and the impact of humidity on aerosol growth. During 2016, the network of sunphotometers will be expanded by deploying new instruments: one near the Paranal observatory in Northern Chile and a second one downwind from Santiago in the Andes. These instruments have been acquired through a 3-year ANILLO project (Black Carbon in the Andean Cryosphere) led by Raul R. Cordero (Universidad de Santiago). Also, low cost sun-photometers to allow higher spatial resolution observations of AOD are being developed in collaboration with Electrical Engineers. Further we have collaborated in the analysis of a measuring campaign trying to address the impact of Santiago in the Andean cryosphere (Cordova et al., 2015).

B. Climate Dynamics

During the third year of our center, the Climate Dynamics group has consolidated several research efforts at the time of beginning new initiatives. First and foremost, we have considerably deepened our understanding of the ongoing mega drought (MD) that has afflicted central Chile (30-40S) since 2010. The MD has been the longest multiannual dry period in the instrumental record, and their consequences are readily discernible in surface and underground water reservoirs (CR2, 2015). Moreover, a tree-ring (*Austrocedrus Chilensis*) based reconstruction of central Chile precipitation (developed by D. Christie and colleagues, see also (Alvarez et al., 2015) indicates that the current MD doesn't have analogues in the last 1000 years and it emerges as an extreme event in a drying trend initiated about a century ago. Likewise, the last century emerges as a particularly dry period in the central Andes (Altiplano) that probably will continue during the rest of the 21st century (Neukom et al., 2015).

During the years that compose the MD have features near neutral El Niño Southern Oscillation (ENSO) conditions in the equatorial Pacific but the Pacific Decadal Oscillation (PDO) has been in its negative (cold) phase that favors dry conditions in central Chile. Nonetheless, the recent work by (Boisier et al., 2015b) has proven that anthropogenic climate change explains at least a quarter of the longevity and intensity of the MD. The attribution of part of the MD to anthropogenic climate change is a major scientific finding (e.g., Figure 6) with important societal implications (e.g. (Pino, 2015)). Although we don't know when, the natural variability will flip its sign favoring wetter conditions but even then, the mean central Chile precipitation in the coming decades is predicted to remain about 10% below the historical values before of the previous century. The frequency of multi-year droughts has been small in the past but we also expect an increase in this type of phenomena during the rest of the 21st century (Mega Drought Report). The actual mechanism linking climate change and central Chile droughts are mostly related to the weakening of the subtropical jet stream and will be a key subject of study during 2016.

The temperature trends not only in Chile but along the whole western coast of South America have been documented by (Vuille et al., 2015)**.** They found that air

temperature along the coast has been decreasing since the 80'S in connection with the cooling of the SE Pacific, which in turn has a natural and anthropogenic effect (van den Hoof and Garreaud, 2015). No indication of such hiatus of the warming was found inland and over the Andes cordillera, including vast sectors of Central Chile. Thus, the MD also occurs during the warmest decade on record in central Chile, exacerbating the water deficit due to increased losses by evaporation and evapo-transpiration.

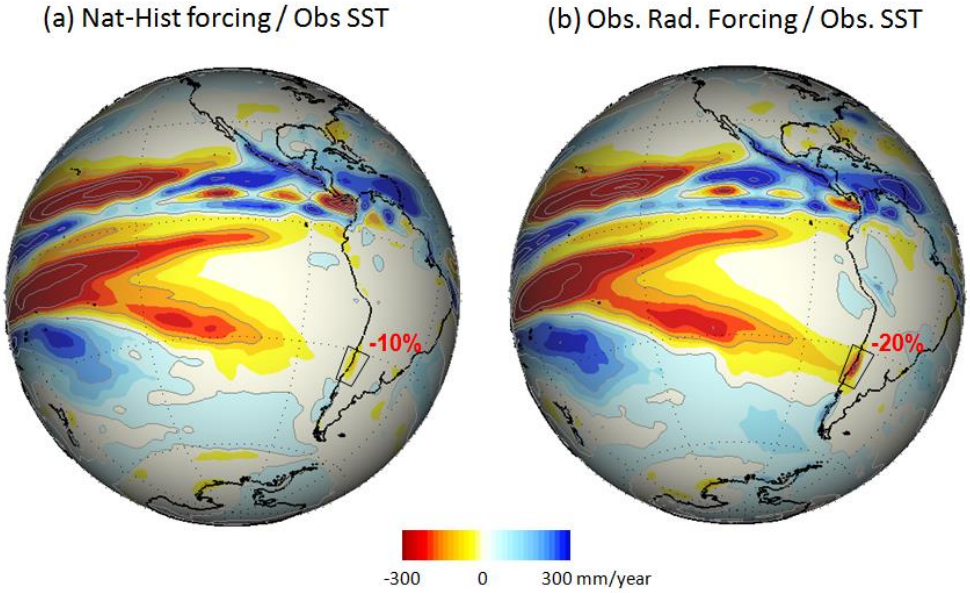


Figure 6. Rainfall anomalies for the period MJJAS 2010-2014 respect to long-term mean (1950-2000) showing the drought in central Chile, as simulated by a numerical model in which the sea surface temperatures are prescribed. The simulations only differ in the greenhouse gases (GHG) concentration. The left panel is a simulation with GHG fixed to pre-industrial values, and the MD has an anomaly around 10%. The right panel is with observed GHG and the MD has an anomaly around 20%, closer to the observed value.

Concerning the deep past, the team headed by P.I. Moreno has continued its study of century to millennium-scale variability employing sediment cores taken from small lakes in southern Chile. Climate variability in Patagonia is largely controlled by the intensity of the Westerly wind belt (e.g.,(Garreaud, 2013)), a circumpolar feature with impacts across much of the Southern Hemisphere and with implications for CO2 degassing from the Southern Oceans. Following the initial work in Lake Cipreses (Moreno et al., 2014) that documented variations in the last 3.000 years, we are now in the preparation of a climate/enviromental synthesis for the last 12.000 years. It is suggested that the current trend toward the positive phase of the Southern Annular Mode resembles oscillations that have taken place repeatedly in the last millennia in the southern mid-latitudes. The deep-paleo group has also contributed a radiocarbon chronology of the last glacial maximum and its termination in the northwestern Patagonia (Moreno et al., 2015b) as well as better understanding of the vegetation and climate change, and volcanic disturbances in that region during the last 10.000 years (Henriquez et al., 2015b; Moreno et al., 2015a).

The Climate Dynamics group has made contributions in other topics as well:

- The impact of the topography on the precipitation and temperature fields in southern Chile has been the subject of research reported in (Viale and Garreaud, 2015);(Minder et al., 2015); González (2015, thesis). In the same line, the impact of sea surface temperatures off the Chilean coast upon inland precipitation has been documented in case and climatological studies (Bozkurt et al., 2016).

- Major forest fires have increased significantly during the MD. When close to urban areas, these fires can affect negatively the air quality of these cities, as dramatically observed in Santiago (the Chilean capital) in January 2013 and documented in (Rubio et al., 2015).

- Rainfall decrease in the South American Altiplano and Amazonia has been projected based on modeling results for the 21st century by (Neukom et al., 2015) and (Boisier et al., 2015a) respectively.

C. Ecosystem Services

During 2015 much progress was done in the study and understanding of the spatial and temporal patterns of land-use change that addresses one of three main research topics of (CR)^2 , i.e. rapid land use change. A. Miranda (Ph.D. student) as part of his dissertation led an article on the study of land use change patterns in Araucanía Region in South Central Chile (Miranda et al., 2015). This study documented a general pattern of landscape homogenization towards the reduction of native forests, mainly due to their conversion to exotic pine and eucalypt commercial plantations and the main process between 1975 and 2008 in the Araucanía Region (Figure 7). Moreover, conversely of what was previously thought, the rate of conversion of native forests to exotic forest plantations has increased between the period 1999-2008 and the period 1987- 1999.

We also continued our research on fire regimes and on the increase in the burned area due to the mega drought, led by M. González. Burned area for the fire seasons 2012-13 and 2014-15 exceeded 100.000 annually, what is unprecedented for two successive years in the entire available fire record starting in 1977. In a manuscript in preparation on the relationships between the climatic drivers and fire regimes, we document that in Central Chile under a stronger Mediterranean-type climate, burned area is significantly related with higher precipitation during the previous year of the fire season, mainly occurring in the austral summer, and rainfall is especially related to ENSO (Urrutia et al, in preparation). In this region, burned area is also related to drought occurrence in the same year as fire season. Conversely, further south, in south-central Chile under higher precipitation regimes and lower Mediterranean effects, the number of fires and burned area are mainly related to drought and higher spring-summer maxima temperatures during the fire season (Urrutia et al, in preparation). Additionally,

in this region, fire occurrence is positively correlated with the Southern Annular Mode (SAM), (higher SAM implies decreased precipitation and increased fire).

The biophysical factors promoting or inhibiting directly or indirectly the occurrence of fire on the broad area covering central and south-central Chile has been assessed (Gómez-González et al., 2016). This study used a statistical analysis from GIS-based data including fire occurrence, topography, drought, land use, land cover and human impacts. This research concludes that human impacts, drought and exotic forest plantations promote the occurrence of fire, whereas native forest cover inhibits it. Therefore, the protection against wild fires is an additional ecosystem service provided by native forests, and the restoration of these forests may reduce the probability of fire, both directly due to their lower flammability compared to exotic pine or eucalypt plantations or indirectly reducing the drought conditions (e.g. increasing soil moisture).

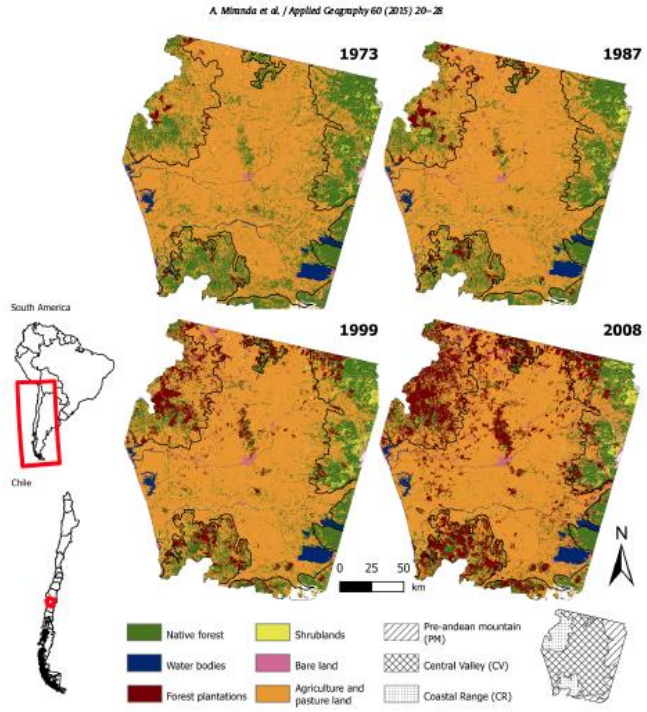


Figure 7 Land use change in the Araucanía Region between 1975 and 2008 (Miranda et al., 2015)

We continued the study of the resilience of ecosystems to natural disturbances (e.g. human set fires, logging, grazing by cattle) and natural disturbances, such as volcanism as a basis for the design of restoration. These studies included the ecosystem response of tephra fall from the Caulle volcano located in Puyehue National Park (c. 41°S) that erupted in June 2011 as part of a long term collaboration with colleagues from the Forest Service and Oregon State University. Resilience of the disturbed stands varied with forest type. Sites dominated by the deciduous *Nothofagus pumilio*, which was leafless at the initial phase of the eruption (austral winter) survived and leafed out

vigorously the following year (2012). Conversely, stands of the evergreen *Nothofagus dombeyi* experienced much greater mortality (Swanson FJ, 2016).

The definition of priorities for the restoration of native forests that have been degraded by grazing is being studied by (Zamorano-Elgueta et al., 2016). They are using a multicriteria approach and methods that integrates the assessment of land-use change from Landsat images, as well as the evaluation of forest structure, composition and degradation status. Areas of high restoration priority are defined as those with relative high biodiversity and potentials for water provision and maintenance of soil fertility as ecosystem services, integrated with socioeconomic feasibility, judged from land tenure regime, accessibility and willingness to restore.

R. Urrutia made a significant contribution to the understanding of carbon balance and carbon stocks of temperate forests, providing key information for the assessment of carbon sequestration as an ecosystem service. In her paper published in the high impact journal PLOS One, she documented that *Fitzroya cupressoides* dense stands that are endemic to Chile and adjacent Argentina include stands that are probably the oldest dense forest stands in the world, with long-lived trees and high standing biomass (Urrutia-Jalabert et al., 2015b). These stands with trees older than 1,450 years in the Andean Range have 448–517 Mg of Carbon ha^{-1} with a very low annual productivity (2.22–2.54 Mg C ha^{-1} $year^{-1}$). Estimated mean wood residence time was a minimum of 539–640 years for the whole forest in the Andes and 1368–1393 years for only *Fitzroya* in this site. Our biomass estimates for the Andes place these ecosystems among the most massive forests in the world. Residence time estimates for *Fitzroya* are the highest reported for any species and carbon dynamics in these forests are the slowest reported for wet forests worldwide (Urrutia-Jalabert et al., 2015a). Although primary productivity is low in *Fitzroya* forests, they probably act as ongoing biomass carbon sinks on long-term timescales due to their low mortality rates and exceptionally long residence times that allow biomass to be accumulated for millennia. These results indicate the importance of carbon sequestration as a key ecosystem service of *Fitzroya* stands.

L. Palma finished his M.Sc. Thesis on the socio-economic valorization of native forests from the perspective of ecosystem services by the rural inhabitants in Nirivilo and Purapel watersheds in the Maule Region (South Central Chile). This study benefited by the collaboration with G Blanco (adjoint researcher from H.D.) as a member of his Thesis Committee. The main findings from this study include the perception that "forests" are constituted by commercial exotic pine and eucalypts plantations, and greatly do not know native forests nor their species that have been extensively replaced by plantations since the 1970s (Palma 2015). There has been a monetarization of the decisions of rural inhabitants that are more interested on plantations because they see them as a source of employment and money, and do not show major interest on native forests. This contrasts with the broader knowledge and higher interest for native forests among rural inhabitants of other regions, located southwards, where these ecosystems are more abundant and still maintain an economic importance (e.g. firewood, timber).

D. Human Dimensions

During 2015, a significant part of our efforts focused on the "mega drought". A map of public and private agencies was generated. Also, the type of responses to the mega drought were analyzed and the population perception of drought and climate

change. Vulnerability maps were produced characterizing the effects of the rainfall changes upon food production in a region of Chile. Further, the relation between temperature and rainfall changes and food production was analyzed for Central and Southern Chile. In Southern Chile, a specific study compared the spatial distribution beneficiaries of public policies with that of extreme events as projected by regional climate simulations. Finally, the analysis of pros and cons of adopting a Climate Change Law for Chile, and if so the basic contents and possible institutional approaches to be addressed in it, was a central activity for this research line in 2015.

A map of actors, including their identification and description has been completed (Aldunce et al., 2015). The total of interviews declared the existence of the drought, several recognized impacts to their personal and professional life (Ramos, in preparation). The majority of the drought responses (measures) are carried out by government agencies (50%), followed by the private sector (29%) and the civil society (21%). The majority of the measures are engineering and infrastructure projects and the minority of responses are related to build social resilience, for example through education processes. More than 150 people were interviewed and 3 workshops were held at the local level in 6 counties: La Pintana, Paine, Los Andes, Rinconada de Los Andes, San Felipe and Santa María in Central Chile. In these groups, the Index for the Usefulness of Adaptation Practices (IUPA) was applied to account for the perceived effectiveness of the measures (Aldunce et al., 2016). Enablers such as autonomy in the decision making process emerged as key factors, whereas barriers such as integration with other policy domains, programs or projects were identified. Here, the transdisciplinary and action-research approaches were used, i.e., approaches that aim not only at generating scientific production but also to a platform of social learning for the different social actors involved and for informing policy processes.

Vulnerability maps with respect to changes in climate parameters (rainfall and temperature) and its consequences on water and food provision (potatoes, wheat and maize) were developed for the Maule region in central Chile. This is an area with a Mediterranean climate, highly exposed to the mega drought, characterized by severe land use changes and a high proportion of family farming. Exposition was characterized by rainfall deficit and surplus with respect to the climatological average, and susceptibility as losses in biomass and yield of crops. The adaptive capacity was estimated from the combination of economic, social and institutional variables and proxies. It was concluded that this region's vulnerability has grown between 1997 and 2013.

Another study aiming to identify and describe the effects of variability of climate elements and of the extreme events on cereal yields for each region of Chile was made (Rivera 2015, thesis). The analysis relied on historical climate data and productivity of maize and wheat at the regional level for the period 1980-2013. As a first step climate variability indexes were calculated based upon mean precipitation and mean maximum and minimum temperature for the growth season of each year (September to March) and annual productivity of maize and wheat. A negative effect due to the scarcity of rainfall on wheat crops in the central-south area was identified, unlike the case of maize because the high irrigation implementation for this crop. However, for maize a negative effect of high temperatures on productivity was detected. For extreme weather events, crops and regions affected by a particular climate element were identified. In these cases

a small negative effect was observed. This could be partly attributed to suitable adaptation measures for the present climate conditions. However, future research should consider and take special consideration of the negative effects that the intensification of extreme events according to the climate change projections will have in these regions.

Further, the Chilean public policy related to climate change in the agriculture and forestry sectors was analyzed for the Los Ríos regions in Southern Chile (Santander 2015, thesis). We explored whether the current spatial distribution of instruments linked to programs of national climate agenda in Los Rios Region responds to exposure levels associated with extreme temperatures and rainfall. This was done by crossing alphanumeric data bases, and comparing it with regional climate projections (Rojas 2012). The results indicate that only 34.5% of the regional area receives over 84% of the benefits, and these concentrate mostly in three communes, reaching a rate of 6.3 beneficiaries per hectare. However, effects of extreme events are concentrated in the Andean areas where the rate of beneficiaries per hectare varies between 0 and 0.7. Thus public policies around agriculture and forestry sectors are not adequately regionalized.

Within the framework of the project "Proposal for a Legal and Institutional Framework to Address Climate Change in Chile", funded by the Prosperity fund of the British Embassy, the necessity and viability of climate change legislation for Chile has been assessed. Also, an outline and a recommendation for basic contents of such a law to support the country's Intended Nationally Determined Contribution (INDC), presented before the United Nations Framework for the Climate Change Convention (UNFCCC) and prior to the 21st Conference of the Parties (COP) in Paris 2015 has been studied. A Steering Committee comprised of members of the implementing institutions, i.e., CR2, the NGO Adapt-Chile (http://www.adapt-chile.org/web/) and the Chilean Ministry for the Environment lent technical, policy and legal expertise. Additionally, an Expert Committee was created, and a variety of stakeholders have been interviewed in order to determine the status of discussions on the necessity and viability of specific climate legislation, to validate the proposed content of this legislation, and to evaluate the evolution and developments at the COP 21. The involvement of the Parliament by means of the creation of a Climate Caucus ("Bancada Climática"), composed by 10 parliamentarians from different political sectors, both senators and deputies, who promoted a resolution of the Chamber of Deputies, sent to the President of the Republic, requesting the drafting of a bill on climate change. Also, these parliamentarians and the project's team have met to analyze the country's position before COP21. These activities have led to reports such as (Moraga and Araya, 2015), and manuscripts, as well as to many presentation including those held at the COP21 in Paris during a side events.

E. Modeling and observing systems

Last year a white paper was prepared addressing the potential impacts of carbonaceous aerosols, particularly black carbon, on the Andean cryosphere (Molina et al., 2015). This was done under the international umbrella of the Pollution and its Impact on the South American Cryosphere initiative (PISAC, http://www.mce2.org/activities/pisac). Also, a one week long measurement campaign was conducted to explore if BC from Santiago had the potential to reach the Andean cryosphere during intense pollution events. This campaign was conducted in Santiago and the neighboring Maipo Valley between 18th and 25th of July 2015 during which the

city's air quality conditions reached critical levels twice according to Chilean environmental regulations. Measurements were carried out at three sites; downtown Santiago, the entrance of the valley (and outskirts of Santiago) and 12 km inside the Maipo Valley. In each of these sites both surface and vertically distributed measurements were conducted. In general, BC concentrations inside the valley, both at the surface and in the vertical, were dominated by emissions within the valley and BC was limited to shallow layers above the ground. However, on both days with critical air quality levels, wind blowing from the city and deeper BC layers were observed inside the valley. Furthermore, on these days observations at the entrance of the valley and those taken inside were coupled contrary to the other days where they were decoupled. This deeper BC layer and the coupling of observations at the entrance and inside the valley suggest that pollutants are transported inside the Maipo Valley and thus could potentially reach the snow and ice covered areas in the Andes. Consistent findings have been identified by Orfanoz (2016) who uses a numerical model to characterize the vertical stratification and export of Santiago pollutants towards the Andes. These results contradict part of the findings reported in (Cordova et al., 2015) and stress the need to extend the observations in the area. Preliminary results of our campaign are depicted in Figure 8.

Also, another measuring campaign was conducted in October 2015 to measure the truck traffic across the Andes. This is an additional activity to further understand and quantify the impact of BC on the Andean cryosphere. During the four-day campaign a total of 47 trucks on highway driving cycle were measured. Each one of these trucks was followed from Santiago to the pass "Los Libertadores" by another car equipped with instruments measuring variable such as position, air temperature, pressure and ambient BC concentration. Preliminary results reveal the important difference in emission depending on nationality of the truck; foreign trucks emit a larger proportion of BC than Chilean trucks which can be related to the sulfur levels in diesel fuel or to lower pollution abatement technology in neighboring countries.

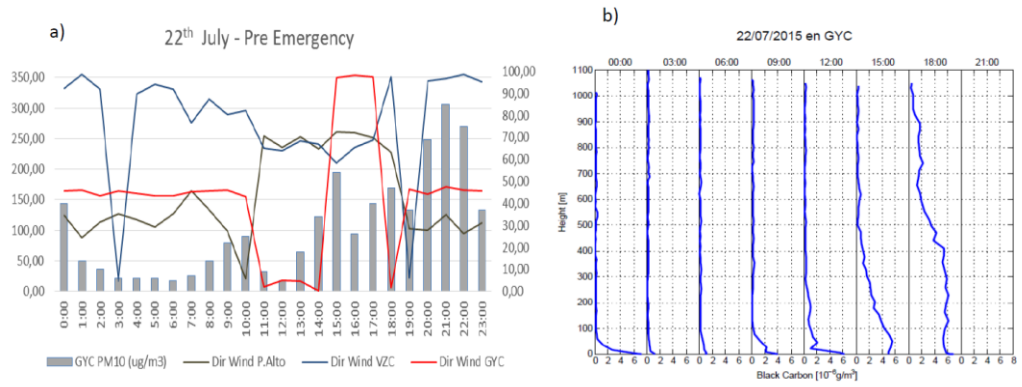


Figure 8. (a) Surface measurements of PM10 concentration in the Maipo Valley (grey bars) for the 22nd of July and 10m wind direction at Puente Alto (green), at the entrance of the valley (blue) and inside the valley (red). (b) Profiles of BC concentration inside the valley for the 22nd of July.

In terms of air pollution in urban areas, (Saide et al., 2015) expanded the air quality prediction system previously developed for Santiago to be applied in eight additional cities in Chile. The system is being used by the Chilean Ministry for the Environment not only to warn population but also to take contingency-based emission restrictions to try to avoid severe pollution events.

The team also continued its work regarding the development of tools for analysis and design of monitoring system. (Henriquez et al., 2015a) developed a variational method that complements the statistical method previously published (Osses et al., 2013). These methods have been transferred to the Chilean Weather Office and are now being applied to precipitation and temperature records.

Using paleoclimate data and model simulations it was shown that iron fertilization of the earth's oceans and the resulting enhanced biological productivity and carbon export to the deep ocean is a minor geoengineering tool to reduce current carbon dioxide levels (Lambert et al., 2015). In fact, reduced atmospheric pCO2 values by at most 20 ppm during the comparatively very dusty Last Glacial Maximum were reported. The data collected may provide boundary conditions in the next simulation round of the Paleoclimatic Model Intercomparison Project (PMIP4).

A modeling system able to project future sea level rise and developed in the previous year was applied to the Chilean coast for the RCP4.5 and RCP8.5 scenarios. The system includes sea level change due to the steric/dynamic component, the contribution from land ice loss and the glacial isostatic adjustment. Two different estimates of the steric/dynamic component are considered. Depending on this steric/dynamic component estimate, the total mean sea-level rise along the coast is between 34 cm and 52 cm for the RCP4.5 scenario and between 46 cm and 74 cm for the RCP8.5 scenario (Albrecht, 2015). This paper completes one of the specific objectives of the center.

Further, the climatic forcing of glacier expansion in the mid-Holocene was examined by evaluating modeled glacier equilibrium line altitude (ELA) and climate conditions during the MH (6000 BP) compared with pre-industrial time (PI, year 1750) in the mid latitudes of the Southern Hemisphere, specifically in Patagonia and the South Island of New Zealand. In response to climatic changes, glaciers in both analyzed regions have an ELA that is 15-33 m lower than PI during the MH. The main causes of this difference are the colder temperature during the MH, reinforcing previous results that mid-latitude glaciers are more sensitive to temperature change compared to precipitation changes (Bravo et al., 2015).

In its role to provide and support the establishment of databases and computing systems the CR2 has continued its efforts to increase its computing resources. On the previous years, efforts were mainly focused in building up the physical infrastructure and computing power to host and run different and multiple numerical models. At present a total of 7 different models are installed and running at the CR2 Rocks cluster (compiled with Intel licenses), and also Matlab is available for parallel computing. In addition, necessary purchases and formalities were made to connect CR2 storage servers with the NLHPC cluster, providing up to 50 teraflops of computing power to CR2 scientist, with fast access to storing results. Moreover, this year, important investments were made to increase the storage capacities at CR2. On one hand, the storage at CR2 was increased from 60T to 100T and on the other hand we are contributing to the building of an

archiving center composed by a robot and multiple data tapes. This archiving center is being build within the framework of the QUIMAL project of the laboratory of astroinformatics, it will be hosted at the Center of Mathematical Modeling and managed by the NLHPC. Contribution of CR2 to this project was not only limited to acquiring tapes but also with hardware needed in this archiving center and the necessary connectivity to insure fast access to the tapes. Alongside the above, a server exclusively for Web Sites and Climate Services, and a 10GbE switch were bought. The former will help tackle the current demand for services, but above all the future needs (e.g. data visualization applications, data sharing, web services, etc.) whereas the latter allows access to the data and ensures movement of large volumes of data at the maximum speed allowed by the system taking thus advantage of the investment made in infrastructure.

Regarding climate services, a consistent climate data base, a climate explorer (See Annex) have been developed in collaboration with Climate Dynamics. Also, specific projects are being developed at the Municipality level via the pilot activities with the Municipality of Santiago. Moreover, the Climatological Bulletin of the Chilean Weather Office was re-designed and automatized.

References not listed in VII

Aldunce, P., G., L., Adler, C., Vidal, M. and M., R. 2016. On the assessment of adaptation practices: a transdisciplinary exploration of drought measures in Chile. In: Environmental Science and Policy (In revision)

Barrett, B., Campos, D., Vicencio, J. and Rondanelli, R. 2016. Extreme temperature and precipitation events in March 2015 in central and northern Chile(ed. Manuscript).

Bozkurt, D., Rondanelli, R., Garreaud, R. D. and Arriagada, A. 2016. March 2015 Northern Chile floods: Impact of warmer Eastern Pacific coastal SST anomaly. In: Manuscript.

Gayo, E. M. and Santoro, C. M. 2015. Fechados radiocarbonicos como datos paleodemograficos: una aproximacion para evaluar la interaccion humano-ambiente en los Andes Centro-sur durante los ultimos 13.000 años. In: XX Congreso de Arqueologia Chilena. .

Gómez-González, S., González, M., I. Díaz, Delgado-Baquerizo, M., Paula, S. and co-authors 2016. Fire promotors and inhibitors: fire protection as a new ecosystem service provided by native forests. Manuscript.

Latorre, C., De Pol-Holz, R., Carter, C. and Santoro, C. M. 2016. Using archeological shell middens as a proxy for past local coastal upwelling in northern Chile. Quaternary International.

Masotti, I., Aparicio-Rizzo, P., Yévenes, M., Farias, L. and Garreaud, R. 2016. Rivers discharge and their influence on phytoplankton biomass during drought period in central coastal areas of Chile.

Minder, J., Snider, J., Kingsmill, D., Garreaud, R., Massmann, A. and co-authors 2015. The Chilean Coastal Orographic Precipitation Experiment Pilot Project (CCOPE-2015): Overview and preliminary results. In: 11 International Conference on Southern Hemisphere Meteorology and Oceanography. Santiago, Chile. 5-9 October 2015.

Rondanelli, R. 2016. Extreme tropical forcing at the onset of El Niño. An extreme case of an atmospheric teleconection. In: Manuscript.

van den Hoof, C. and Garreaud, R. D. 2015. Influence of Precipitation on Diurnal Temperature Range Variability in South America and Implications for Climate Change Projections. In: 11 International Conference on Southern Hemisphere Meteorology and Oceanography. Santiago, Chile. 5-9 October 2015.

Zamorano-Elgueta, C., Geneletti, D. O., L. Cayuela, J. M., Benayas, R. and Lara, A. 2016. Restoring forests for biodiversity and ecosystem services: A spatial multicriteria approach to identify priority areas.Manuscript

VI. SUGGESTIONS FROM PREVIOUS EVALUATION

Describe how the suggestions provided by the evaluation panel and the FONDECYT Council in its previous evaluation report were taken into account by the Center.

The overall rating given by the evaluators was very good. However, remarks were made. Hereby we respond those that appeared most relevant and for which actions have been adopted.

A remark was made in terms of adding economics to Human Dimensions. This has been partially addressed by incorporating as adjoint researchers Dr. Arriagada and Dr. O'Ryan. The former has been key in the evaluation of the Climate Change Law project. The latter has been proposed as a new associate researcher emphasizing the economical evaluation of public policies, for instance regarding Chile's intended contribution to the Climate Convention. Unfortunately, Dr. Nahuelhual has taken a position as principal investigator in another center of excellence. Still she will keep her connection to CR2 for continuing the development of vulnerability maps combining social and natural variables.

Recognizing the productivity and high quality research provided by Biogeochemistry, there was some concern regarding their integration into the rest of the research within CR2. The addition of Dr. Gayó, who combines isotopic tools and archeological studies to address paleo climatic records as well as understanding of the cultural and natural processes involved in the early settlements in Northern Chile will certainly facilitate a more straight forward interaction with other groups. Also, the 14C dating effort sustained by Dr. De Pol-Holz will play a central role in characterizing the Anthropocene facilitating again the collaboration across disciplinary boundaries. A similar result is expected with the operation of the bouy to be made operational in early 2016. Thus, all in all, the group is making a serious effort for integration.

For Climate Dynamics, although outstanding in quality and number of products some of them crossing disciplinary boarders, there was a call to further improvement by integrating some other issues, in particular when collaborating with biogeochemistry. This is in fact a path but also, the leadership played in the mega drought study will certainly result in a broader impact of this group's research.

The call for Ecosystem Services was also in terms of integration with other research lines. The incorporation of Dr. Urrutia-Jalabert who studies carbon in long standing millennial forests strengthen the opportunity for increased collaboration with biogeochemistry. Also, questions regarding fire regimes and emissions of black carbon along Chile, including wood burning in urban centers, is being explored with modeling and observing systems. A stronger connection with Human Dimensions may be enhanced in the framework of the Anthropocene studies to be started in March.

In the case of Modeling and Observing Systems the potential for stronger collaboration and improved science scores was called upon. The new organization within the research line resulted in fact in an improved productivity with 10 publications adscribed to this group in 2015, including one white in which the center's director was the leading author, and other papers either published or submitted in which she made significant contributions.

Other comments addressed the low number of doctoral students. To address this and at the same time promote more integration among research lines, a call is being made in which cross-cutting issues focused on the center's objectives are to be preferred.

Other suggestions such as communicating our science to the general public and using the media has been well received, and actually adopted in 2015. The learning process of developing integrated studies is being assimilated and fully considered for the development of our next interdisciplinary team. In fact, we will write a paper describing the pros and cons of the approach used in connection with the mega drought assessment.

All in all, our performance in 2015 has been much better than in the previous years in all respects. Part of this is based on the quality and engagement of our researchers in all categories. Part of this follows from the germination of seeds planted early on in the center's establishment. Of course, internal and external reviews, as well a receptive leadership has been key to our advancements. Still, there are many aspects to be improved to much more to be learnt, taught and spread.

VII. PRODUCTS GENERATED BY THE PROJECT

In what follows, complete the attached Excel spreadsheets taking into account the following:

REPORT ONLY PUBLISHED MATERIAL INCLUDING THOSE WITH AN OFFICIAL DOI POINTER (e.g., with EARLY ONLINE ACCESS).

EXCEPT FOR BOOKS, ALL BACKUP DOCUMENTS MUST BE PRESENTED IN DIGITAL FORMAT. DO NOT SEND PRINTED COPIES.

ONLY PUBLICATIONS THAT ACKNOWLEDGE THE FONDAP PROGRAM WILL BE CONSIDERED.

1. ISI Publications

- ✓ For each publication, if applicable, the main author and the corresponding author must be indicated using the following terminology:
  - [1] For main author (example: Toro[1], J.)
  - [2] For the corresponding author (example: Toro[2], J.)
  - [3] For main and corresponding author (example: Toro[3], J.)
- ✓ Include a digital copy of each **PUBLISHED** paper.

A. With explicit acknowledgements

1. **Albrecht, F.**, and ***Shaffer, G.***[13] (2015), Regional Sea Level Change along the Chilean Coast in the 21st century, *Journal of Coastal Research*, *Accepted*.
2. **Alcamán, M. E.,** C. Fernández, A. Delgado, B. Bergman, and **B. Díez** (2015), The cyanobacterium Mastigocladus fulfills the nitrogen demand of a terrestrial hot spring microbial mat, The ISME journal.
3. **Aldunce, P.** (2015), Stakeholder participation in building resilience to disasters in a changing climate, Environmental Hazards, Accepted.
4. **Álvarez, C.,** T. T. Veblen, **D. A. Christie**, and A. González-Reyes (2015), Relationships between climate variability and radial growth of Nothofagus pumilio near altitudinal treeline in the Andes of northern Patagonia, Chile, Forest Ecology and Management, 342, 112-121. doi: 10.1016/j.foreco.2015.01.018.
5. **Arias, P**. A., R. Fu, C. Vera, and **M. Rojas** (2015), A correlated shortening of the North and South American monsoon seasons in the past few decades, *Climate dynamics*, 1-21.
6. **Boisier, J. P.**, P. Ciais, A. Ducharne, and M. Guimberteau (2015), Projected strengthening of Amazonian dry season by constrained climate model simulations, *Nature Climate Change*, *5*(7), 656-+. doi: 10.1038/nclimate2658.

[13] *At the time of the design of the paper, Dr. Shaffer was an associate researcher.*

7. **Boisier, J. P., R. Rondanelli, R. D. Garreaud, and F. Muñoz** (2015), Anthropogenic and natural contributions to the Southeast Pacific precipitation decline and recent mega-drought in central Chile, *Geophysical Research Letters*.
8. **Bravo, C., M. Rojas**, B. Anderson, A. Mackintosh, E. Sagredo, and **P. Moreno** (2015), Modelled glacier equilibrium line altitudes during the mid-Holocene in the southern mid-latitudes, *Climate of the Past Discussions*, *11*, 603-636.
9. **Cabezas, J**., **M. Galleguillos**, A. Valdés, J. P. Fuentes, C. Pérez, and J. F. Perez-Quezada (2015), Evaluation of impacts of management in an anthropogenic peatland using field and remote sensing data, *Ecosphere*, *6*(12), art282.
10. Castro-González, M., O. Ulloa, and **L. Farías** (2015), Structure of denitrifying communities reducing N 2 O at suboxic waters off northern Chile and Perú, *Rev. biol. mar. oceanogr*, *50*(1), 95-110.
11. Castro-González, M. and **L. Farías** (2015), Influence of O_2 and substrate availability on N_2O cycling by denitrification in the upper boundary of oxygen minimum zone off northern Chile, *Journal of Marine Research*, *73*, 20.
12. Córdova, A. M., J. Arévalo, J. C. Marín, D. Baumgardner, G. B. Raga, D. Pozo, C. A. Ochoa, and **R. Rondanelli** (2015), On the transport of urban pollution in an Andean mountain valley, *Aerosol Air Qual. Res., doi*, *10*.
13. Cuyckens, G., **D. A. Christie**, A. Domic, L. Malizia, and D. Renison (2015), Climate change and the distribution and conservation of the world's highest elevation woodlands in the South American Altiplano, *Global and Planetary Change*.
14. Delgado-Baquerizo, Manuel, Maestre, Fernando T., Gallardo, Antonio, Eldridge, David J., Soliveres, Santiago, Bowker, Matthew A., Prado-Comesaña, Ana, Gaitán, Juan, Quero, José L., Ochoa, Victoria, Gozalo, Beatriz, García-Gómez, Miguel, García-Palacios, Pablo, Berdugo, Miguel, Valencia, Enrique, Escolar, Cristina, Arredondo, Tulio, Barraza-Zepeda, Claudia, Boeken, Bertrand R., Bran, Donaldo, Cabrera, Omar, Carreira, José A., Chaieb, Mohamed, Conceição, Abel A., Derak, Mchich, Ernst, Ricardo, Espinosa, Carlos I., Florentino, Adriana, Gatica, Gabriel, Ghiloufi, Wahida, **Gómez-González, Susana**, Gutiérrez, Julio R., Hernández, Rosa M., Huber-Sannwald, Elisabeth, Jankju, Mohammad, Mau, Rebecca L., Miriti, Maria, Monerris, Jorge, Morici, Ernesto, Muchane, Muchai, Naseri, Kamal, Pucheta, Eduardo, Ramírez, Elizabeth, Ramírez-Collantes, David A., Romão, Roberto L., Tighe, Matthew, Torres, Duilio, Torres-Díaz, Cristian, Val, James, Veiga, José P., Wang, Deli, Yuan, Xia and Zaady, Eli (2016), Human impacts and aridity differentially alter soil N availability in drylands worldwide, *Global Ecology and Biogeography*, *25*(1), 36-45.
15. Díaz-Hormazábal, I., **González, M.E.** Análisis espacio-temporal de incendios forestales en la región del Maule, Chile, *Bosque,* Aceptada
16. **Farías, L.**, **V. Besoain, and S. Garcia-Loyola** (2015), Presence of nitrous oxide hotspots in the coastal upwelling area off central Chile: an analysis of temporal variability based on ten years of a biogeochemical time series, *Environmental Research Letters*, *10*(4). doi: 10.1088/1748-9326/10/4/044017.
17. Fernández, C., M. Lorena Gonzalez, C. Munoz, V. Molina, and **L. Farías** (2015), Temporal and spatial variability of biological nitrogen fixation off the upwelling

system of central Chile (35-38.5 degrees S), *Journal of Geophysical Research-Oceans*, *120*(5), 3330-3349. doi: 10.1002/2014jc010410.

18. Fink, H. G., C. Wienberg, **R. de Pol-Holz**, and D. Hebbeln (2015), Spatio-temporal distribution patterns of Mediterranean cold-water corals (Lophelia pertusa and Madrepora oculata) during the past 14,000 years, *Deep-Sea Research Part I-Oceanographic Research Papers*, *103*, 37-48. doi: 10.1016/j.dsr.2015.05.006.
19. García-Plazaola, J. I., R. Rojas, **D. A. Christie**, and R. E. Coopman (2015), Photosynthetic responses of trees in high-elevation forests: comparing evergreen species along an elevation gradient in the Central Andes, *Aob Plants*, *7*. doi: 10.1093/aobpla/plv058.
20. **González, M. E., and A. Lara** (2015), Large fires in the Andean Araucaria forests: when a natural ecological process becomes a threat, *Oryx*, *49*(3), 394-394.
21. **González, M. E.**, Donoso, P.J., Szejner, P (2015), Tree-fall gaps and patterns of tree recruitment and growth in Andean old-growth forests in south-central Chile, *Bosque*, *36*, 11.
22. **González, M.E.**, Szejner, P., Donoso, P.J., Salas, C.(2016), Fire, logging and establishment patterns of second-growth forests in south-central Chile: implications for their management and restoration, Ciencia e Investigación Agraria, 42(3), 427-441.
23. **Henríquez, A., A. Osses, L. Gallardo, and M. D. Resquín** (2015), Analysis and optimal design of air quality monitoring networks using a variational approach, *Tellus Series B-Chemical and Physical Meteorology*, *67, 25385*. doi: ARTN 25385 10.3402/tellusb.v67.25385.
24. **Henríquez, W. I., P. I. Moreno,** B. V. Alloway, and G. Villarosa (2015), Vegetation and climate change, fire-regime shifts and volcanic disturbance in Chiloe Continental (43 degrees S) during the last 10,000 years, *Quaternary Science Reviews*, *123*, 158-167. doi: 10.1016/j.quascirev.2015.06.017.
25. **Lambert, F**., A. Tagliabue, G. Shaffer, F. Lamy, G. Winckler, **L. Farías**, **L. Gallardo, and R. de Pol-Holz** (2015), Dust fluxes and iron fertilization in Holocene and Last Glacial Maximum climates, *Geophysical Research Letters*, *42*(14), 6014-6023. doi: 10.1002/2015gl064250.
26. Landais, A., Masson-Delmotte, V., Stenni, B., Selmo, E., Roche, D. M., Jouzel, J., **Lambert, F**., Guillevic, M., Bazin, L., Arzel, O., Vinther, B., Gkinis, V. and Popp, T. (2015), A review of the bipolar see-saw from synchronized and high resolution ice core water stable isotope records from Greenland and East Antarctica, *Quaternary Science Reviews*, *114*, 18-32. doi: 10.1016/j.quascirev.2015.01.031.
27. Lopatin, J., **M. Galleguillos**, F. E. Fassnacht, A. Ceballos, and J. Hernandez (2015), Using a Multistructural Object-Based LiDAR Approach to Estimate Vascular Plant Richness in Mediterranean Forests With Complex Structure, *Ieee Geoscience and Remote Sensing Letters*, *12*(5), 1008-1012. doi: 10.1109/lgrs.2014.2372875.
28. **Masotti, I.**, S. Belviso, L. Bopp, A. Tagliabue, and E. Bucciarelli (2015), Effects of light and phosphorus on summer DMS dynamics in subtropical waters using a global ocean biogeochemical model, *Environmental Chemistry*.

29. Miranda, A., A. Altamirano, L. Cayuela, F. Pincheira, and **A. Lara** (2015), Different times, same story: Native forest loss and landscape homogenization in three physiographical areas of south-central of Chile, *Applied Geography*, *60*, 20-28. doi: 10.1016/j.apgeog.2015.02.016.
30. Molina, L. T., **Gallardo, L.**, Andrade, M., Baumgardner, D., Borbor- Córdova, M., **Bórquez, R.**, Casassa, G., Cereceda-Balic, F., Dawidowski, L., **Garreaud, R., Huneeus, N., Lambert, F**., McCarty, J. L., Mc Phee, J., Mena- Carrasco, M., Raga, G. B., Schmitt, C. and Schwarz, J. P. (2015), Pollution and its impacts on the South American Cryosphere (PISAC), *Earth's Future*, n/a-n/a. doi: 10.1002/2015ef000311.
31. **Moreno, P. I**., B. V. Alloway, G. Villarosa, V. Outes, W. I. Henríquez, **R. de Pol-Holz**, and N. J. G. Pearce (2014), A past-millennium maximum in postglacial activity from Volcan Chaiten, southern Chile, *Geology*, *43*(1), 47-50. doi: 10.1130/g36248.1.
32. Neukom, R., M. Rohrer, P. Calanca, N. Salzmann, C. Huggel, D. Acuña, **D. A. Christie**, and M. S. Morales (2015), Facing unprecedented drying of the Central Andes? Precipitation variability over the period AD 1000–2100, *Environmental Research Letters*, *10*(8), 084017.
33. Pino, P., V. Iglesias, **R. Garreaud**, S. Cortés, M. Canals, W. Folch, S. Burgos, K. Levy, L. P. Naeher, and K. Steenland (2015), Chile Confronts its Environmental Health Future After 25 Years of Accelerated Growth, *Annals of global health*, *81*(3), 354-367.
34. **Rojas, M.,** Mac-Lean, C., Morales, J., Monares, A and R. Fustes (2015), Climate Change Education and Literacy at the Faculty of Physical and Mathematical Sciences of the University of Chile, *Int. J. Global Warming*.
35. Rubio, M. A., E. Lissi, E. Gramsch, and **R. D. Garreaud** (2015), Effect of Nearby Forest Fires on Ground Level Ozone Concentrations in Santiago, Chile, *Atmosphere*, *6*(12), 1926-1938.
36. **Saide, P. E.,** M. Mena-Carrasco, **S. Tolvett**, P. Hernández, and G. R. Carmichael (2015), Air quality forecasting for winter-time PM2. 5 episodes occurring in multiple cities in central and southern Chile, Journal of Geophysical Research: Atmospheres.
37. Swanson FJ, J. J., Crisafulli C, **González ME, Lara A** (2016), Puyehue-Cordon Caulle eruption of 2011: tephra fall and initial forest responses in the Chilean Andes, *Bosque*, *37*.
38. Titschack, J., D. Baum, **R. de Pol-Holz**, M. López Correa, N. Forster, S. Flögel, D. Hebbeln, and A. Freiwald (2015), Aggradation and carbonate accumulation of Holocene Norwegian cold-water coral reefs, *Sedimentology*.
39. Ugalde, P. C., C. M. Santoro, **E. M. Gayo**, C. Latorre, S. Maldonado, R. De Pol-Holz, and D. Jackson (2015), How Do Surficial Lithic Assemblages Weather in Arid Environments? A Case Study from the Atacama Desert, Northern Chile, *Geoarchaeology*, *30*(4), 352-368. doi: 10.1002/gea.21512.
40. **Urrutia-Jalabert, R**., Y. Malhi, and **Lara** (2015), The Oldest, Slowest Rainforests in the World? Massive Biomass and Slow Carbon Dynamics of Fitzroya cupressoides Temperate Forests in Southern Chile, *PloS one*, *10*(9), e0137569. doi: 10.1371/journal.pone.0137569.

41. **Urrutia-Jalabert, R.,** Malhi, Y., Barichivich, J., **Lara, A**., Delgado-Huertas, A., Rodríguez, C.G., Cuq, E. (2015), Increased water use efficiency but contrasting tree growth patterns in Fitzroya cupressoides forests of southern Chile during recent decades. *Journal of Geophysical Research G: Biogeosciences*. in press: doi 10.1002/2015JG003098
42. Valenzuela, D., C. M. Santoro, J. M. Capriles, M. J. Quinteros, R. Peredo, **E. M. Gayo**, I. Montt, and M. Sepúlveda (2015), Consumption of animals beyond diet in the Atacama Desert, northern Chile (13,000–410BP): Comparing rock art motifs and archaeofaunal records, *Journal of Anthropological Archaeology*, *40*, 250-265. doi: 10.1016/j.jaa.2015.09.004.
43. Veblen TT, G. M., Stewart G, Kitzberger T, Brunet J (2015), Tectonic ecology of the temperate forests of South America and New Zealand, *Journal of Botany*.
44. Viale, M., and **R. Garreaud** (2015), Orographic effects of the subtropical and extratropical Andes on upwind precipitating clouds, *Journal of Geophysical Research: Atmospheres*, *120*(10), 4962-4974. doi: 10.1002/2014jd023014.
45. Vuille, M., E. Franquist, **R. Garreaud**, W. S. Lavado Casimiro, and B. Cáceres (2015), Impact of the global warming hiatus on Andean temperature, *Journal of Geophysical Research: Atmospheres*, *120*(9), 3745-3757. doi: 10.1002/2015jd023126.

B. Without explicit acknowledgement

These are ISI publications that are of relevance to CR2 research and partially or fully supported by FONDAP 15110009 but lacking an explicit acknowledgement.

1. Alloway, B. V., N. J. G. Pearce, G. Villarosa, V. Outes, and **P. I. Moreno** (2015), Multiple melt bodies fed the AD 2011 eruption of Puyehue-Cordon Caulle, Chile, *Scientific reports*, *5*. doi: 10.1038/srep17589.
2. Aracena, C., R. Kilian, C. B. Lange, S. Bertrand, F. Lamy, H. W. Arz, **R. De Pol-Holz**, O. Baeza, S. Pantoja, and C. Kissel (2015), Holocene variations in productivity associated with changes in glacier activity and freshwater flux in the central basin of the Strait of Magellan, *Palaeogeography Palaeoclimatology Palaeoecology*, *436*, 112-122. doi: 10.1016/j.palaeo.2015.06.023.
3. **Arias, P. A**., J. A. Martínez, and S. C. Vieira (2015), Moisture sources to the 2010–2012 anomalous wet season in northern South America, *Climate dynamics*, 1-24.
4. **Arriagada, R. A**., E. O. Sills, P. J. Ferraro, and S. K. Pattanayak (2015), Do Payments Pay Off? Evidence from Participation in Costa Rica's PES Program (vol 10, e0131544, 2015), *PloS one*, *10*(8). doi: 10.1371/journal.pone.0136809.
5. Avesani, D., **P. Herrera**, G. Chiogna, A. Bellin, and M. Dumbser (2015), Smooth Particle Hydrodynamics with nonlinear Moving-Least-Squares WENO reconstruction to model anisotropic dispersion in porous media, *Advances in Water Resources*, *80*, 43-59. doi: 10.1016/j.advwatres.2015.03.007.
6. Ayres-Peres, L., P. Araujo, **C. Jara**, A. Palaoro, and S. Santos (2015), How variable is agonistic behavior among crab species? A case study on freshwater anomurans (Crustacea: Decapoda: Aeglidae), *Journal of Zoology*, *297*(2), 115-122.

7. Ceballos, A., J. Hernandez, P. Corvalan, and **M. Galleguillos** (2015), Comparison of Airborne LiDAR and Satellite Hyperspectral Remote Sensing to Estimate Vascular Plant Richness in Deciduous Mediterranean Forests of Central Chile, *Remote Sensing*, *7*(3), 2692-2714. doi: 10.3390/rs70302692.
8. Cuenca, P., **R. Arriagada**, and C. Echeverría (2016), How much deforestation do protected areas avoid in tropical Andean landscapes?, *Environmental Science & Policy*, *56*, 56-66.
9. Franco A., Moffat R., Toledo M., **Herrera P.** Numerical sensitivity analysis of thermal response tests (TRT) in energy piles. Renewable Energy. 86, 985-992
10. Gonzalez S.M, Avila L.A., Silva J.T., **Blanco-Wells G**. (2015) Comunidades indígenas: Entre la adaptación a alteraciones climáticas locales y el abandono de la agricultura. Revista de Antropologa Iberoamericana, 10, 27-48
11. Hernández, J., G. A. Lobos, I. Matus, A. del Pozo, P. Silva, and **M. Galleguillos** (2015), Using Ridge Regression Models to Estimate Grain Yield from Field Spectral Data in Bread Wheat (Triticum Aestivum L.) Grown under Three Water Regimes, Remote Sensing, 7(2), 2109-2126. doi: 10.3390/rs70202109.
12. Jara, I. A., R. M. Newnham, M. J. Vandergoes, C. R. Foster, D. J. Lowe, J. M. Wilmshurst, **P. I. Moreno**, J. A. Renwick, and A. M. Homes (2015), Pollen–climate reconstruction from northern South Island, New Zealand (41° S), reveals varying high-and low-latitude teleconnections over the last 16 000 years, *Journal of Quaternary Science*, *30*(8), 817-829.
13. Lopatin, J., **M. Galleguillos**, F. E. Fassnacht, A. Ceballos, and J. Hernandez (2015), Using a Multistructural Object-Based LiDAR Approach to Estimate Vascular Plant Richness in Mediterranean Forests With Complex Structure, *Ieee Geoscience and Remote Sensing Letters*, *12*(5), 1008-1012. doi: 10.1109/lgrs.2014.2372875.
14. Molina-Montenegro, M. A., C. Galleguillos, R. Oses, I. S. Acuña-Rodríguez, P. Lavín, J. Gallardo-Cerda, C. Torres-Díaz, **B. Diez**, G. E. Pizarro, and C. Atala (2015), Adaptive phenotypic plasticity and competitive ability deployed under a climate change scenario may promote the invasion of Poa annua in Antarctica, *Biological Invasions*, 1-16.
15. **Moreno, P**., B. Alloway, G. Villarosa, V. Outes, W. Henríquez, **R. De Pol-Holz**, and N. Pearce (2015), A past-millennium maximum in postglacial activity from Volcán Chaitén, southern Chile, *Geology*, *43*(1), 47-50.
16. Perez-Quezada, J. F., S. Olguín, J. P. Fuentes, and **M. Galleguillos** (2015), Tree carbon stock in evergreen forests of Chiloé, Chile, *Bosque (Valdivia)*, *36*(1), 27-39. doi: 10.4067/s0717-92002015000100004.
17. Reyes-Mendy, F., **R. A. Arriagada**, S. Reyes-Paecke, and A. Tobar (2014), Policy statement coherence: A methodological proposal to assess environmental public policies applied to water in Chile, *Environmental Science & Policy*, *42*, 169-180. doi: 10.1016/j.envsci.2014.06.001.
18. Rodríguez-Echeverry, J., C. Echeverría, and **L. Nahuelhual** (2015), Impacts of anthropogenic land-use change on populations of the Endangered Patagonian cypress Fitzroya cupressoides in southern Chile: implications for its conservation, *Oryx*, *49*(03), 447-452. doi: 10.1017/s0030605314000945.

19. Rodriguez-Marconi, S., R. De la Iglesia, **B. Diez**, C. A. Fonseca, E. Hajdu, and N. Trefault (2015), Characterization of Bacterial, Archaeal and Eukaryote Symbionts from Antarctic Sponges Reveals a High Diversity at a Three-Domain Level and a Particular Signature for This Ecosystem, *PloS one*, *10*(9), e0138837. doi: 10.1371/journal.pone.0138837.
20. **Saide, P.E**., Peterson, D.A., Da Silva, A., Anderson, B., Ziemba, L.D., Diskin, G., Sachse, G., Hair, J., Butler, C., Fenn, M., Jimenez, J.L., Campuzano-Jost, P., Perring, A.E., Schwarz, J.P., Markovic, M.Z., Russell, P., Redemann, J., Shinozuka, Y., Streets, D.G., Yan, F., Dibb, J., Yokelson, R., Toon, O.B., Hyer, E., Carmichael, G.R. Revealing important nocturnal and day-to-day variations in fire smoke emissions through a multiplatform inversion. *Geophysical Research Letters* 42, 3609-3618
21. **Saide, P.**, S. Spak, R. Pierce, J. Otkin, T. Schaack, A. Heidinger, A. Silva, M. Kacenelenbogen, J. Redemann, and G. Carmichael (2015), Central American biomass burning smoke can increase tornado severity in the US, *Geophysical Research Letters*, *42*(3), 956-965.
22. Sierra, J. P., **P. A. Arias**, and S. C. Vieira (2015), Precipitation over Northern South America and Its Seasonal Variability as Simulated by the CMIP5 Models, *Advances in Meteorology*, *2015*, 1-22. doi: 10.1155/2015/634720.
23. Toledo, C., E. Muñoz, and **M. Zambrano-Bigiarini** (2015), Comparison of Stationary and Dynamic Conceptual Models in a Mountainous and Data-Sparse Catchment in the South-Central Chilean Andes, *Advances in Meteorology*, *2015*.
24. Weller, D., C. Miranda, **P. Moreno**, **R. Villa-Martínez**, and C. Stern (2015), Tephrochronology of the southernmost Andean Southern Volcanic Zone, Chile, *Bulletin of Volcanology*, *77*(12), 1-24.

2. Non ISI Publications

- ✓ For each publication, if applicable, the main author and the corresponding author must be indicated using the following terminology:
  [1] For main author (example: Toro[1], J.)
  [2] For the corresponding author (example: Toro[2], J.)
  [3] For main and corresponding author (example: Toro[3], J.)
- ✓ Include a digital copy of each **PUBLISHED** paper.

1. CR2, G., R., Aldunce, P., Araya, G., Blanco, G., Boisier, J. P., Bozkurt, D., Carmona, A., Christie, D., Farías, L., Gallardo, L., Galleguillos, M., González, M., Herrera, P., Huneeus, N., Jiménez, D., Lara, A., Latoja, D., Lillo, G., Masotti, I., Moraga, P., Nahuelhual, L., Paredes, P., Ossandón, J., Rojas, M., Urquiza, A., Yévenes, M., Zambrano, M. 2015. Mega drought report to the nation. Center for Climate and Resilience Research, 26 pp. CR2 publication available at www.cr2.cl
2. Smith-Ramírez, C., **González, M.E.**, Echeverría, C., **Lara, A.** (2015). Estado actual de la Restauración ecológica en Chile, perspectivas y desafíos. Anales del Instituto de la Patagonia, 43, 11-21

3. **Urquiza, A.,** Morales, B. 2015. La observación del problema ambiental en un contexto de diferenciación functional. Revista Mad, 64-93.
4. **Urquiza, A.,** Cadenas, H. 2015. Sistemas socio-ecológicos: elementos teóricos y conceptuales para la discusión en torno a vulnerabilidad hídrica. Revista Orda
5. LeQuesne. C., **Rojas, M. & Christie, D.A. 2015**. Anillos de crecimiento de Austrocedrus chilensis: un archivo natural del cambio climático. Revista del Jardin Botánico Chagual.
6. **Nahuelhual, L**., Laterra, P., Villarino, S., Mastrángelo, M., **Carmona, A.,** Jaramillo, A., Barral, P., Burgos, N. Mapping of ecosystem services: Missing links between purposes and procedures. Ecosystem Services. 13, 162-172
7. **Moraga, P., Araya, G.** La Gobernanza del Cambio Climático. Propuesta de Marco Legal para abordar el Cambio Climático en Chile. CR2 publication available at www.cr2.cl
8. **Aldunce P, Bórquez R, Indvik K, Lillo G**. Identificación de actores relacionados a la sequía en Chile. CR2 publication available at www.cr2.cl

3. Books and book chapters

- ✓ Include a hard copy of every **PUBLISHED** book.
- ✓ Include a digital copy of the front page of the chapter in the case of a book chapter.

1. **Pilar Moraga**, Mathilde Boutonnet, Jean-Cristophe Saint-Pau, Néstor Cafferatta, Mauricio Tapia, Sebastián Ríos, Aida Kemelmajer, Mustapha Mekki, Gonzalo Medina, Carlos Japiassú, Francoise Russeau, Juan Pablo Aristegui, 2015. Principio precautorio en el derecho comparado. Editores: Pilar Moraga, Mathilde Boutonnet, Jean-Cristophe Saint-Pau. 210 pp. Editorial LOM. Santiago, Chile.
2. Adler, C., **Aldunce, P., Indvik, K., Alegría, D., Bórquez**, R., Galaz, V. 2015. Chapter 43, Resilience. In Research handbook on climate governance, Eds. Karin Bäckstrand and Eva Lövbrand. Edward Elgar Publishing Limited, Cheltenham, UK.

4. Patents

✓ Include all patents generated by the FONDAP Center.

Does not apply.

5. Congress presentations

✓ Include abstracts of all presentations. Attach a digital copy of the front page of the congress/workshop book.

See Excel Tables

6. Organization of Scientific Meetings

✓ List all congresses, courses, conferences, symposia, or workshops organized by the FONDAP Center.
✓ Include abstracts of all presentations. Attach a digital copy of the front page of the congress/workshop book.

See excel files

7. Collaborative Activities

✓ List the scientific visits of Center members to international institutions

✓ List the scientific visits of foreign researchers to the Center in Chile.

See excel files

8. Postdoctoral Fellows

✓ List postdoctoral fellows working in the Center during the reported period regardless of their funding sources.
✓ Provide current affiliation and positions held by former postdoctoral fellows that left the Center during the reported period

See excel files

9. Students

✓ List titles of theses framed in the project completed during the reported period. Attach an abstract and the subject index.
✓ List titles of theses in progress, framed in the project, during the reported period. Include digital copies of the corresponding thesis registrations.

- ✓ Provide current affiliation and positions held by former students that graduated during the reported period

✓ See excel files

10. Funding Sources

- ✓ List all funding sources including FONDAP.

In order to stress the fact that CR2 acts as a center to which individual and larger projects contribute, we show here the table of concurrent funding available to our researchers.

No.	FUNDING SOURCES	STARTING YEAR	ENDING YEAR	TOTAL AMOUNT (M$)
1	FONDECYT 1151125 (Roberto Rondanelli)	2015	2018	155.000
2	FONDECYT 1120965 (Duncan Christie)	2012	2015	200.000
3	FONDECYT 1121106 (Duncan Christie)	2012	2015	209.600
4	FONDECYT 1130410 (Antonio Lara)	2013	2017	200.000
5	FONDECYT 1140536 (Ricardo De Pol)	2014	2018	200.000
6	FONDECYT 1151187 (Laura Nahuelhual)	2015	2018	151.000
7	FONDECYT 1140531 (Laura Nahuelhual)	2014	2017	178.000
8	FONDECYT 1140637 (René Garreaud)	2014	2015	80.000
9	FONDECYT 1150873 (Nicolás Huneeus)	2015	2018	154.000
10	FONDECYT 1151427 (Fabrice Lambert)	2015	2018	163.259
11	FONDECYT 11121264 (Susana Gómez)	2012	2016	69.838
12	FONDEQUIP EQM140134 (René Garreaud)	2014	2015	160.000
13	FONDECYT 1150763 (Ricardo de Pol)	2015	2019	200.000
14	FONDECYT 3150162 (Mariela Yévenes)	2015	2017	73.175
15	FONDECYT 3150036 (Deniz Bozkurt)	2014	2016	46.031
16	REDES 130066 (Laura Gallardo)	2013	2015	20.000
17	FONDECYT 11150210 (Eugenia Gayó)	2015	2018	84.050
18	FONDECYT 11140394 (Paulina Aldunce)	2014	2017	77.868
19	FONCYT-Argentina PICT2013-1880 (Duncan Christie)	2015	2017	70.000
20	FONDECYT 3140570 (Paola Arias)	2013	2015	46.487
21	FONDECYT 3150492 (Juan Pablo Boisier)	2015	2017	69.127
22	FONDECYT 1130935 (Mauricio Galleguillos)	2013	2017	150.000
23	FONDECYT 3150329 (Catalina Aguirre)	2015	2015	23.766
24	FONDECYT 3140422 (Beatriz Diez)	2013	2015	49.692
25	FONDECYT 1150171 (Beatriz Diez)	2015	2019	200.000
	TOTAL FONDECYT			**3.030.894**

No.	FUNDING SOURCES	STARTING YEAR	ENDING YEAR	TOTAL AMOUNT (M$)
26	Inter-American Institute for Global Change Research (Laura Nahuelhual)	2013	2017	70.000
27	ICSHMO (René Garreaud)	2014	2015	14.000
28	Programa de Investigación Asociativa CONICYT SOC1405 (Eugenia Gayó)	2015	2018	195.000
29	NSF - EEUU + CR2 (CCOPE 2015) (René Garreaud)	2014	2015	70.000
30	VESPLAN (Laura Nahuelhual)	2013	2017	40.000
31	CONAF - Fondo de Investigación del Bosque Nativo (Carlos Zamorano)	2015	2016	45.000
32	FONDEF CA13I10102 (Mauricio Galleguillos)	2014	2016	150.000
33	Prosperity Fund ""Propuesta de marco legal e institucional para abordar el cambio climático en Chile" (Pilar Moraga)	2015	2016	73.500
34	CONICYT ABATE MOLINA (Laura Gallardo)	2014	2015	23.000
35	Convenio Universidad Austral de Chile- Forestal Mininco S.A. (Mauro González)	2014	2016	80.000
36	CONICYT y National Science Foundation - NSF DPI2014044 (Beatriz Diez)	2015	2017	150.000
	TOTAL OTROS			**910.500**

No.	FUNDING SOURCES	STARTING YEAR	ENDING YEAR	TOTAL AMOUNT (M$)
37	FONDAP 15110009 (Laura Gallardo)	2013	2018	5.581.000
38	Iniciativa Científica Milenio IC120019 (IMO) (Ricardo de Pol/Laura Farias)	2014	2023	4.500.000
39	Iniciativa Científica Milenio NC120066 Paleoclima del Hemisferio Sur (Maisa Rojas)	2014	2017	660.000
	TOTAL FONDAP Y MILENIO			**10.741.000**
TOTAL FONDOS				**14.682.394**

VIII. OTHER ACCOMPLISHMENTS

Report articles or notes published in the media (provide URL links, if available), awards, prizes, etc.

See our annual report on communications.

IX. SUGGESTIONS

What recommendations would you make to the FONDAP Program Office to improve the performance of the Center and the review process? Please describe.

We think it is important to separate role of Center's Director from that of Research Area director. This is not necessary to assure that the Director is an active researcher. In our case, Dr. Huneeus has taken the position of acting director of the Modeling and Observing Systems research area leading to improvements for the area team and also providing more research space for the Director. We would like this to be official.

It would be better to have the annual report in mid-December instead of mid-January. The current dates are not fully consistent with the budget execution that finishes in December, and they limit to some extent the participation of those researchers who have field campaign in summer. Perhaps, one could accelerate the reporting process by using web services, particularly regarding peer reviewed publications, and concurrent projects.

X. ANNEXES

1. International Advisory Board's Report

Please, provide as an annex the International Advisory Board´s Report

No such an annex is available this year.

2. National Advisory Board

Please, provide as an annex the National Advisory Board´s Minutes.

No such an annex is available this year.

3. Other Relevant Aspects

A. Mega drought report to the nation (bilingual)

B. Climate Explorer

C. Data bases, computer power and climate services

D. Communications in 2015

E. Peer reviewed publications (2015)

F. Finished theses (2015)

G. Participation in symposia and conferences