



# Agencia Nacional de Investigación y Desarrollo

Ministerio de Ciencia,  
Tecnología, Conocimiento  
e Innovación

## SUBDIRECTORATE FOR CENTERS AND ASSOCIATIVE RESEARCH DEPARTMENT OF INITIATIVES FOR STRATEGIC TARGETING

RESEARCH CENTERS OF EXCELLENCE IN PRIORITY AREAS  
FONDAP

### FINAL REPORT

*CENTER FOR CLIMATE AND RESILIENCE RESEARCH (CR)<sup>2</sup>*

*15 11 00 09*

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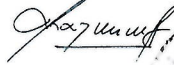

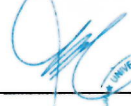
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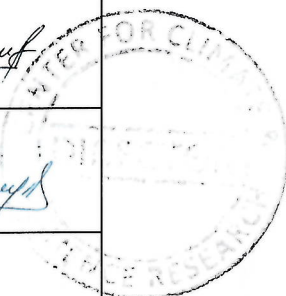
**I. PRESENTATION**

**PERIOD COVERED:** From: 7th December 2021

To: 6th December, 2022

Note: This is the final report of the last five years (2018-2022)

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DATE: 12/04/2023

## II. EXECUTIVE SUMMARY

It is the only section where all the condensed information of the 10-year period will be included. This section must mention the goals and the more significant achievements of the Center and the most important actions undertaken in each one of the activities (research, outreach, formation, etc.). Brief information must be given on those undertaken actions that did not have conclusive results or whose results will only be able to be verified in the future. This summary must be sufficient to present the work of this Center to the evaluation committee as well as the scientific community.

One decade ago (2013) the Center for Climate and Resilience Research, (CR)<sup>2</sup>, was created with three overarching goals: (i) deepen our understanding of the climate system, processes, and impacts throughout Chile confronting its socio-ecological complexities, (ii) strengthen the emerging community of natural and social scientists in Earth System Science in Chile, and (iii) contribute to the definition of climate change adaptation and mitigation measures for building societal resilience in collaboration with stakeholders. For its mid-term evaluation (2018) we further committed to become a major player in (iv) developing climate and resilience science in Chile, (v) strengthen our role in the training of new scientists and (vi) contribute to our country's goals of achieving low-carbon, sustainable development consistent with the Paris Agreement.

This final report gives us the opportunity to show the fulfillment of these goals, synthesize our main results and reflect on how the center has evolved and what is our aggregated impact on society. Indeed, the dedicated effort of our researchers, support staff and students made possible that (CR)<sup>2</sup> became a well-recognized national leader and international reference in climate and resilience research by both producing high-quality disciplinary studies and developing novel interdisciplinary modes of research and collaboration, inside and outside the center. Based on research, (CR)<sup>2</sup> has actively informed and contributed to the management and public policies in Chile in the fields of climate change mitigation and adaptation, reached out the general public, trained students at under and post graduate levels, and established strong alliances with other research groups and networks at national and international level.




Figure 1: Key numbers of (CR)<sup>2</sup> scientific production and outreach during 2013-2022

Some basic metrics of the decade-long center's performance are depicted in Figure 1. Our science contributions are reflected in the author- and co-authorship of more than 696 research articles in international, peer-review journals (53% of them in Q1), 124 book chapters, and participation in over 871 scientific congress and conferences in Chile and abroad (including 63 invited keynote presentations). About 17% of the scientific papers are coauthored by researchers from different Research Lines (RL) at the center, a rough metric of interdisciplinary work. More qualitatively, **knowledge generation by (CR)<sup>2</sup> has progressed deep and far** and here we provide a succinct list of scientific highlights during the past decade:

- The central Chile Mega Drought (MD), the ongoing dry spell since 2010, is unprecedented in Chile's history and with no analogues in four century reconstructions. It is caused by the superposition of natural variability and climate change, thus providing a grim prospect of our future climate. The MD has had detrimental effects in diverse socio-environmental sectors exacerbated by the system's memory and the attending warming.
- Southerly winds have increased within coastal areas off central-south Chile during recent decades resembling the projected trend due to climate change. The strengthening of the upwelling favorable winds tends to decrease the sea surface temperature and dissolved oxygen and increase nitrate and the outgassing of CO<sub>2</sub> in the coastal zone. This explains the weak cooling trend along the Chilean coast in contrast with the marked warming inland.
- An increased number of large forest fires, even outside the summer, signals the establishment of a new fire regime in Chile, instigated by warm-dry conditions, human-induced ignitions, spreading of alien vegetation and the continuous, vast expanses of mono-species forest plantations. Nonetheless, integrating genetic, functional, and demographic diversity across heterogeneous landscapes should make timber productivity and conservation compatible under a changing climate.
- The interlink between poverty, water and energy (in)security in urban and rural settings has been assessed, emphasizing heterogeneities in needs and capacities as well as varieties and multiplicities of threats affecting them, which are projected to increase in a changing climate, thus calling for urgent adaptation measures. The water-energy-food nexus has been also analyzed in the context of climate risk in a semi-rural area from central Chile.
- The diagnosis of climate governance of elements (water, land, fire and air) in Chile, offers a comparative view of the main gaps within each element and in their interaction spaces, based on the principles such as reactive adaptation measures; increasingly unequal distribution of both the burdens caused by the impacts of climate change and the access to services provided by the elements; the ineffectiveness of participatory mechanisms; deficiencies in the availability, quality or accessibility of data.
- Drying, more heat waves and increasing southerly winds were linked to the expanding range and severity of Harmful Algal Blooms (HABs, known as a red tide) in the coastal waters of the Chilean Patagonia, and area heavily used for aquaculture. Public efforts to prevent poisoning and deaths related to HABs have been highly effective, but HABs can trigger complex socio-ecological crises.
- Deteriorated air quality in south-central Chile is strongly related to emissions from the residential sector. The use of firewood is an expression of energy poverty or socio-cultural factors. Model simulations for current climate under different emission trajectories for the period 2010-2050, as well as analysis of climate model projections for center-south Chile suggest that the main cities in this area, already suffering from air pollution problems, will continue to exceed the PM2.5 daily air quality standard in the future.

Further scientific findings of our different research lines and integrative themes are synthesized next in section III. But for a center of the size, complexity and orientation of (CR)<sup>2</sup> is also relevant to describe **how we reach and communicate our science** to fulfill our broader societal contribution. The center was initially composed by a group of 27 researchers distributed in five research lines (RL). Those RL were aligned with the PIs (Principal Investigators) main topics and included *Climate Dynamics*, *Ecosystem Services*, *Biogeochemistry*, *Human Dimension* and *Data & Modelling*. Administration and communications were handled by a small team. Much of the work was conducted within the RL, fulfilling our first goal (to deepen



our understanding of the climate system) by publishing scientific articles and guiding student's theses at undergraduate and graduate levels through various disciplines of the natural and social sciences. The simultaneous of the Central Chile Mega Drought with major socio-environmental impacts fueled our interdisciplinary work. The drying along much of our country is one of the most eloquent manifestations of climate change afflicting socio-environmental systems and providing a grim prospect of the projected Chile's future climate. Collaborative efforts among the **RL** helped to quantify and understand the MD and based on scientific results we release a succinct report intended to inform the society and decision makers ([CR2 2015](#)). A second collaborative effort aimed at characterizing the manifestations of the Anthropocene -an epoch dating from the beginning of significant human impact on the Earth system- in Chile, whose main findings were also synthesized in second comprehensive but accessible report to society and decision makers ([CR2 2017](#)). These and our future reports to society and decision-makers became communication milestones of our scientific activity. Addressing these two broad themes required work from social to biophysical sciences and were instrumental to fulfill our second goal (strengthen the emerging Earth System Science in Chile) in ways that became **the seal of the (CR)<sup>2</sup>: interdisciplinary work and informing the society at large with knowledge usable by public policy**. Given the profound impacts of climate change in Chile, research on the Mega Drought and the Anthropocene in Chile further contributed to assess adaptation and mitigation measures for building societal resilience, part of our third goal.

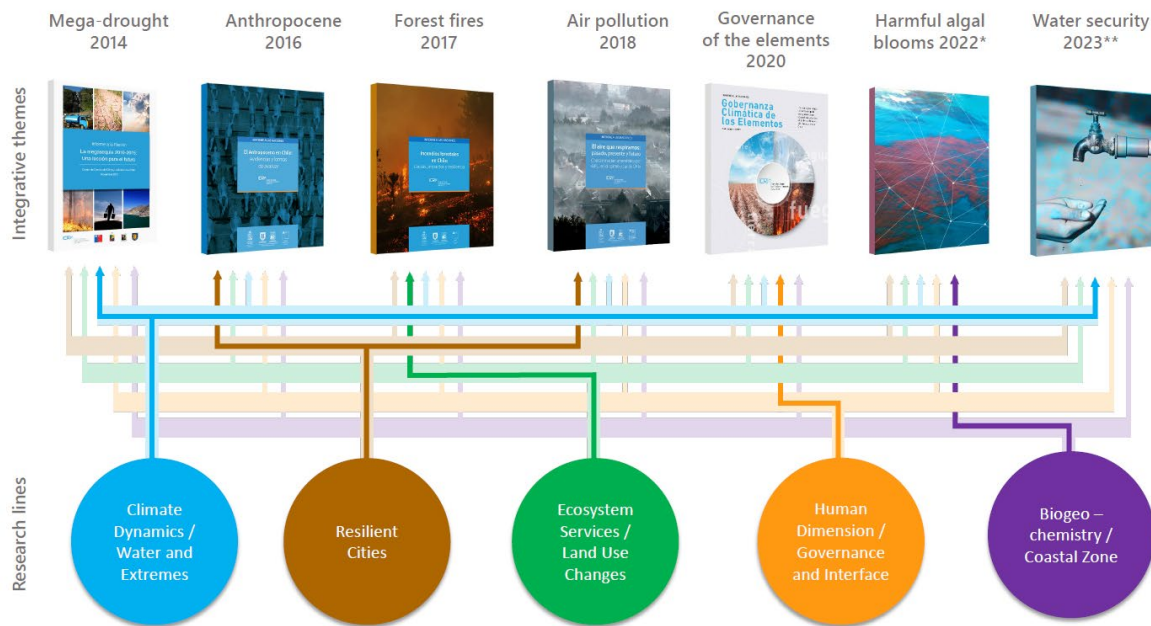
To advance our science and societal contribution, a more systematic approach was needed and undertaken in the transition from the first- to the second five-year funding cycle. First, the **RL** were reorganized moving away from the previous mono-disciplinary composition and focusing on more tangible issues, along with a growth in the number of scientists. Currently, our 60 researchers are affiliated to one (or two) **RL**: Water Extremes (**WEx**), Coastal Zones (**CZ**), Land Use Change (**LUC**), Governance and Science-Policy Interface (**GovSPI**) and Resilient Cities (**RC**). Second, the Management (7 members) and Communications (4) and Data & Computing (D&C, 4) teams were also expanded. Communications support and create a variety of products and events (see below) and D&C provides support for numerical modelling, massive databases and development and maintenance of our twelve web-based climate services platforms. Another key step was the formation of the Dialogue and Transdisciplinary team (3 members) that has facilitated and supported much of scientific collaborative work both inside and beyond (CR)<sup>2</sup>. In particular they develop and Interdisciplinary Manual (available [here](#)) addressing barriers and ways-forward. More recently, we began to systematize efforts on university education.

A third and key action was to focus our collaborative efforts on complex climate-related issues affecting the country with major societal impacts. They have provided not only a link with tangible national problems but also a broad -yet tractable- multi-, inter- and even trans-disciplinary research questions. These so-called **integrative themes** have been led by one or two **RLs**, but all of them contribute rather equally ([Figure 2](#)). The scientific knowledge emerging from this targeted research is presented in dozens of articles which are summarized into more accessible language in the so-called "[Reports to the Nation\(s\)](#)" documents that include **public-policy recommendations**. In doing so, we advance our goal of building societal resilience -in collaboration with stakeholders- and developing climate and resilience science in Chile. These reports, along with web-based supporting materials, have received considerable attention from the general public, the media and specialized audiences, and the five editions became a trademark of our center.

After addressing the initial integrative themes and releasing their corresponding reports (the [central Chile Mega Drought](#) and the [Anthropocene in Chile](#)) we investigated the drivers and impacts associated with the changes of the [new forest fire regime](#) in our country (2017) and the past, present and future [air pollution](#)



[problems of Chile](#) (2018). In 2020 we released a report towards an anticipatory, socio-ecosystemic and evidence-based Climate [Governance of the Elements](#) *water, air, fire and land*. In late 2022 we completed our work [Harmful Algal Blooms](#) (2022) which is a global problem with major socio-environmental manifestations in southern Chile. In parallel, many researchers have been working on water scarcity & security in Chile which addressed not only the decrease in precipitation but also the increase in consumption along our country. The corresponding report will be released by the end of 2023. In addition to the **RL** and Integrative Themes, two transversal initiatives, climate change economics and transformation, were launched in 2020. The group in climate change economics worked on understanding the magnitude and impacts of the current megadrought. The work on transformation produced a first common framework on the concept of transformation built in a participatory process, for adaptation, with the publication of a working document.




**Figure 2.** (CR)<sup>2</sup> Integrative themes and their tight connection with the research lines.

Complementing our National Reports, (CR)<sup>2</sup> has prepared more than 500 of "[Policy briefs](#)" and "[Analyses](#)" that address contingency scientific issues and seek to contribute to the adaptation and mitigation of climate change in Chile. Collectively they have attracted over 300.000 visits in our web site. "[Climate capsules](#)" have also been a successful outreach product aimed at analyzing scientific concepts present in public discourse. Further, "[Constitutional bulletins](#)" have been developed to contribute to the constituent process on climate change issues. These documents are available on the (CR)<sup>2</sup> website. The presence in media and social networks has increased exponentially and can be seen in the statistics of annual press appearances from 2013 to date (over 400 per year).

**(CR)<sup>2</sup> contributions to public policy** have markedly increased in the past few years. After conducting a project on the need and feasibility of a climate change law in Chile, the Chilean Ministry of the Environment (MMA) announced the start of legislative processing of the framework law on climate change. The **GovSPI** team accompanied this legislative discussion process, with the creation of the *Climate Change Law Observatory* in Chile and participation in the technical table of the Senate Environment Commission. This law was signed by the government last year. Moreover, the recommendations contained





in our last National Report (climate governance of the elements) made their way into the Constitutional Convention, which concluded with the consecration in the draft text of the principle of fair climate action, the recognition of the climate and ecological crisis, and the duty of the state to develop public mitigation and adaptation policies. The final text of the new constitution was rejected in a national referendum but a new process is underway and many of the ideas around environmental issues, including coping with climate change, are likely to be preserved. Our researchers also co-chaired the land-use group on the scientific evidence for the design of NDCs presented by Chile to COP25. Additional scientific evidence developed by researchers from different (CR)<sup>2</sup> research lines has been presented to recommend the diversification of climate action away from forest plantations from a nature-based solutions (NbS), considering native forests, wetlands, peatlands and oceans. A series of recommendations were made by working groups and scientific committees in the context of the organization of the COP25 in 2019. In particular, a proposal for an Integrated Ocean Observing System, crucial for the monitoring of the ocean in the context of climate change.

Another unifying and highly relevant initiative led by (CR)<sup>2</sup> was the creation of the **Chilean Atlas of Climate Risk (ARClim)**, solicited in 2018 by the MMA and involving the work of 27 research groups in Chile. ARClim is a web-based platform with nation-wide, municipal-level information on climate hazard, exposure and vulnerability for 54 impact chains grouped in 12 social, environmental and economic sectors (e.g., human welfare, biodiversity, agriculture). In addition to ARClim, our center has developed **12 Climate Services**, including widely used web-based hydro-climate explorers for reconstructed, historical, future (simulated) and real time data. Other databases are related to air pollution and air pollutants emissions. In doing so, (CR)<sup>2</sup> has developed, compiled and merged datasets generated by our own research and instruments and third-party data, facilitating the work of a broad audience of researchers and practitioners making it all available at the (CR)<sup>2</sup> web.

Most researchers at (CR)<sup>2</sup> are University professors, which has facilitated the **center's role on the formation of the next generation of scientists and professionals** in the ample arch of Climate and Resilience disciplines. More than 100 under- and post-graduate students have completed their thesis in themes carried out by the center and many more students have participated as research assistants. Many of them have received a stipend or travel support but perhaps the greatest opportunity for them is the access to a network of researchers and support staff, thus expanding their horizon into interdisciplinary, collaborative works at an early stage of their careers. Likewise, we have benefited from the participation of 22 postdoctoral fellows, bringing new ideas and methods and gaining a broad vision of Climate and Resilience in Chile. In addition to students and Postdoc, the center has engaged in multiple formation initiatives targeting professional and early-career scientists. Details are provided in section 3.2, but here we highlight the **certificate program (Diploma) on Climate Change and Low-Carbon Development**, a joint effort with the Energy Center, that has been offered since 2017 providing knowledge and tools to over 200 professionals. On the other hand, the center has organized **three summer schools for master, doctoral students and postdoctoral fellows**. In 2021 we began with "Integrative Assessment of Climate Change: Water Scarcity", then in 2022 by "Cities and short-lived climate forcings: complexity, challenges, and opportunities"; both versions virtually. The third version "With feet in the sea: Towards the co-design of resilient coasts. Climatic risks and responses in the coastal zones", was carried out in person in Concepción in Jan 2023. Several dozens of students and researchers have teamed up in these schools.

We must acknowledge the **fruitful collaboration with other research centers in Chile and abroad**. Some of the interaction has followed formal commitments, as the MOU signed with the SCRIPSS Institution of Oceanography, University of California San Diego, and the joint operation of the [Andean Snow](#)



Observatory with IANIGLA-Argentina. Other collaborations are more spontaneous and focus on specific themes, as the effort with CAPES and CHIAHM (in Chile) to address economical aspects of climate change. Also noteworthy is the recent creation of CEODOS-Chile, a consortium of excellence research centers (CR2, IDEAL, COPAS, CIEP, among others) devoted to the oceanographic investigation along the Chilean coast. In the case of LUC RL, we will strengthen collaborative research initiative among three FONDAP/ANID Centers: Institute of Ecology and Biodiversity (IEB), the Center of Applied Ecology and Sustainability (CAPES) and (CR)<sup>2</sup>. One of our strategic goals is to become an international reference center. In this respect, we highlight (CR)<sup>2</sup>'s role as Technical Secretariat of the UN global campaign, Race to Resilience (R2R) aiming at catalyzing action by non-state actors that builds the resilience of 4 billion people from groups and communities who are vulnerable to climate risks. Another important external project is the “Carbon neutrality observatory”, that aims at providing independent monitoring and information on Chile’s CO2 reductions, and our long-term participation in AQ-WATCH (Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health).

In closing this executive summary, we must acknowledge the support received from ANID through its FONDAP grant that supported nearly all the (CR)<sup>2</sup> operation. Unfortunately, to date the continuity of the FONDAP program of centers of excellence is still under a high level of uncertainty, despite of which we have develop ambitious and concrete plans for the center next decade.

### III. RESULTS FOR THE SECOND FIVE-YEAR PERIOD

#### 3.1. Research

The most relevant scientific achievements of the Center must be summarized. In this section, it is important to indicate the scientific interaction and synergies that have been outlined between the respective research lines. Include in this section the Center scientific impact to the local, national and international community. The information regarding Center's productivity must be included at the Center Reporting System.

##### a. Main research findings

The dedicated effort of our researchers, support staff and students made possible that (CR)<sup>2</sup> became a well-recognized national leader and international reference in climate and resilience research by both producing high-quality disciplinary studies and developing novel interdisciplinary modes of research and collaboration, inside and outside the center. Based on this research, (CR)<sup>2</sup> has informed and contributed to the management and public policies in the fields of climate change mitigation and adaptation.

Our science contributions are reflected in the author- and co-authorship of more than 871 research articles in international, peer-review journals (53% of them in Q1), 124 book chapters, and participation in over 871 scientific congress and conferences (including 63 invited keynote presentations). About 17% of the scientific papers are coauthored by researchers from different RLs, a rough metric of interdisciplinary work. More qualitatively, knowledge generation by (CR)<sup>2</sup> has progressed deep and far, as described in some detail in the next sections for each Research Line (5), Integrative Theme (4) and Cross-cutting initiatives (2). Here we provide a **succinct list of scientific highlights** in this period, reflecting the aggregated efforts of our center:

**1. The central Chile Mega Drought (MD)**, the continuous and ongoing dry spell (average rainfall deficit 25-40%) since 2010 is unprecedented in Chile's history (1900-present) and with no analogues during the last millennium according to a precipitation tree-ring reconstruction (Garreaud et al., 2017). It emerged from the superposition of natural variability and climate change (Garreaud et al., 2019), thus providing a grim prospect of our future climate (Bozkurt et al., 2019). Given its temporal and spatial extent, the Mega Drought has had detrimental effects in diverse socio-environmental sectors (e.g., vegetation, agriculture, drinking water, coastal sediments; Figure 1) exacerbated by the system's memory and the attending warming. Within the MD, the years 2019 and 2021 qualified as hyper-drought, with rainfall deficit in excess of 80%, putting ecosystems and human-systems at the brink of a collapse (Arroyo et al., 2021).

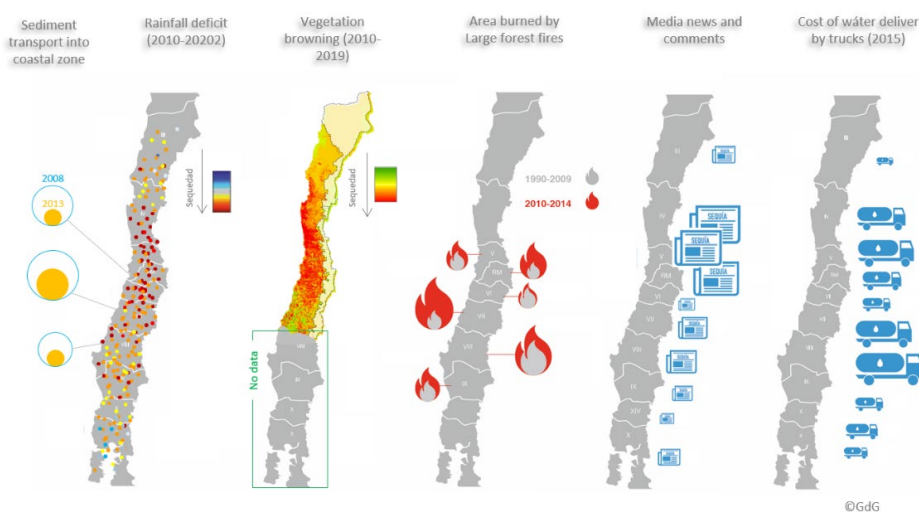
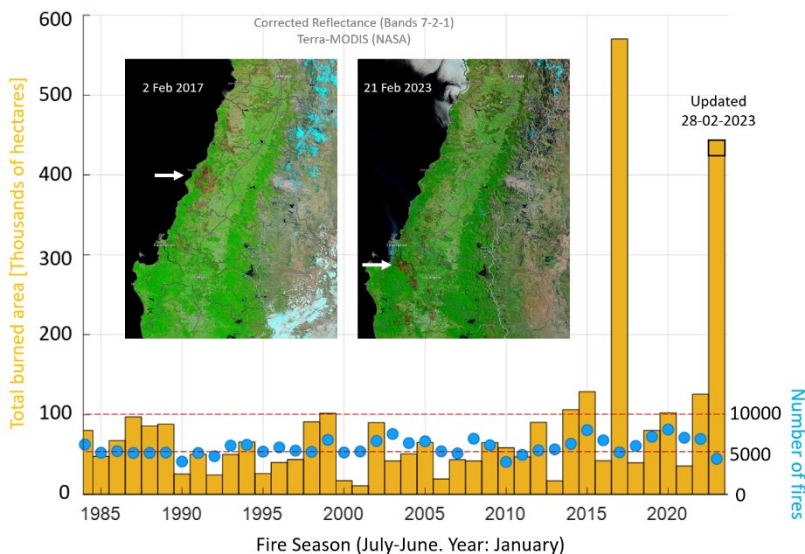


Figure 1. Some of the impacts of the Central Chile Mega Drought (2010-2022)



**2. Southerly winds have increased within coastal areas off central-south Chile** during recent decades resembling the projected trend due to climate change, driven by the strengthening and poleward expansion of the SE Pacific subtropical anticyclone. The strengthening of the upwelling favorable winds (Aguirre et al., 2021b) tends to decrease the sea surface temperature (Falvey & Garreaud 2014), and dissolved oxygen (de la Maza & Farías, 2023) and increase nitrate and the outgassing of CO<sub>2</sub> in the coastal zone (Aguirre et al., 2021a). The augmented upwelling explains the weak cooling along the coastal zone in sharp contrast with the marked warming inland.

**3.** There is a substantial increase in the number of large forest fires (>10.000 ha), even outside the summer, signaling the establishment of **a new fire regime in Chile** (e.g., Figure 2), instigated by warm-dry conditions, human-induced ignitions, spreading of alien vegetation and the continuous, vast expanses of mono-species forest plantations (see review in Gonzalez et al., 2020). Integrating genetic, functional, and demographic diversity across heterogeneous landscapes should make timber **productivity and conservation compatible** with new conditions under a changing climate (Gómez & González 2022).



**Figure 2.** Number of forest fires and area burned in Chile. The inset shows fire scars after two mega fires

**4. The interlink between poverty, water and energy (in)security in urban and rural settings** has been assessed, emphasizing heterogeneities in needs and capacities as well as varieties and multiplicities of threats affecting them (Urquiza & Billi, 2020), which are projected to increase in a changing climate, thus calling for urgent adaptation measures. Strategically concrete research efforts for producing contributions to climate adaptation and risk assessment for Chilean cities and for the Latin America and Caribbean (LAC) region, in terms of the mitigation goal for black carbon, region are summarized in Gallardo et al. (2019) and Huneus et al. (2020b), and in document for establishing the Chile Nationally Determined Contribution to the Paris Agreement in terms of the mitigation goal for black carbon (Gallardo et al 2020a,b)

**5. Deteriorated air quality in central-southern Chile is strongly related to emissions from the residential sector.** The use of firewood for heating and cooking represented about 94% of PM<sub>2.5</sub> emissions in 2017. The use of firewood in central and southern Chile is an expression of energy poverty, evidencing the poor thermal insulation of homes and the difficulties of the general population in accessing clean and high-quality energy services (Huneus et al., 2020b). Model simulations for current climate under different

emission trajectories for the period 2010-2050, as well as analyses of climate model projections (CMIP5) for center-south Chile suggest that the main cities in this area, already suffering from air pollution problems, will continue to exceed the PM2.5 daily air quality standard in the future, even if all the emission reductions until 2050.

**6. The diagnosis of climate governance of elements in Chile (air, water, fire, land)**, offers a comparative view of the main gaps within each element and in their interaction spaces, based on the principles such as reactive adaptation measures; increasingly unequal distribution of both the burdens caused by the impacts of climate change and the access to services provided by the elements; the ineffectiveness of participatory mechanisms; deficiencies in the availability, quality or accessibility of data. In the national report on the **Climate Governance of the Elements** (Billi et al., 2021) an integrated, anticipatory, socio-ecosystemic and evidence-based governance of water, air, fire and land is presented on the basis of three principles shown in Figure 3.

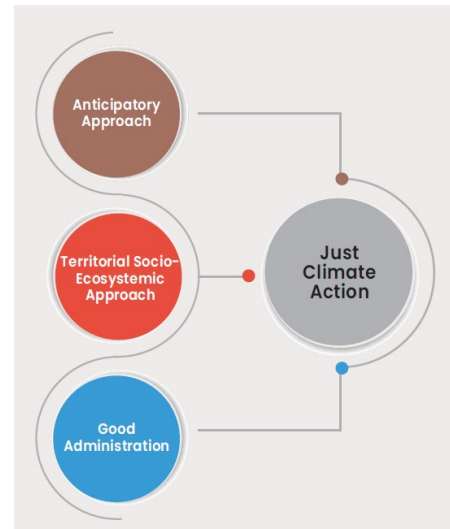


Figure 3. Principles of the CGE

**7. Drying trend, more frequent heat waves and increasing southerly winds were linked to the expanding range and severity of Harmful Algal Blooms (HABs, popularly known a red tide, adjunct picture of Comau fjord)** in the coastal waters of the Chilean Patagonia (Jacques-Coper et al., 2023; Díaz et al., 2021; Muñoz-León et al., 2018). This is an area where abundant freshwater resources, diverse water bodies and other




Picture 1: Fjord of Comau during February 2021 under a red-tide event

oceanographic conditions have permitted an accelerated and heavy expansion of aquaculture (farmed salmon and mussels). Public efforts to prevent poisoning and deaths related to HABs have been highly effective, but HABs can also trigger complex socio-ecological crises. Moreover, HABs governance has been generally fragmented, reactive and disorganized, relying on particular efforts made by some institutions, the private sector, the scientific community and civil society (Ugarte et al., 2022).

**b. Synergy and collaboration among research lines**

For the second five-year period, synergy and collaboration between the different research lines and disciplines of the center are found in two main lines of work. First, in publications produced by the center (ISI, NON-ISI, books and chapter books). In the case of ISI publications, of a total of 518 publications, 77 are





the result of collaboration between researchers from two or more research lines ([Annex N° 9.2.a](#)). In the case of **non-ISI** articles, out of a total of 162 publications, 47 are the result of collaboration between researchers from two or more lines ([Annex N° 9.2.b](#)). Finally, in the case of the **books** and **book chapters**, out of a total of 90 publications, 10 are the result of collaboration between researchers from two or more research lines ([Annex N° 9.2.c](#)).

Specifically, regarding the publications reported in 2022, several of them account for collaborations. In the case of **ISI** publications, of a total of 112 publications, 13 are the result of collaboration between researchers from two or more lines. More specifically, three are the result of collaboration between researchers from three lines and 10 from two lines. In the case of **non-ISI** articles, out of a total of 28 publications: 4 are the result of collaboration between researchers from two lines, and 3 from collaboration between researchers from three research lines. Finally, in the case of the reported **books** and **book chapters**, out of a total of 36 publications, 2 of them are the result of collaboration between researchers from two research lines.

A second effort that has implied synergy and collaboration among researchers and research lines, which already involves researchers with different disciplinary backgrounds, is sought to be carried out mainly within the Integrative Questions. During the second five-year period, the Center has developed five Integrative Questions: Forest Changing fire regimes (concluded in 2020); Atmospheric Pollution (concluded in 2021); Climate Governance of the Elements (concluded in 2021); Harmful Algal Blooms (concluded in 2022) and Water Security (will conclude in 2023). In addition to delivering “reports to the nation” that serves as accessible input for policymaking, the Integrative Questions has involved the development of an important integrative work that involves researchers of all five research lines of the center sought to answer inter-and even trans-disciplinary research questions relative to societal resilience and changing climate ([Annex N° 9.2.d](#)).

During 2022 the integrative question about Harmful Algal Blooms (HAB) was successfully completed and the consequent Report to the Nations titled “Red tides and global change: Elements for Integrated Governance on Harmful Algal Blooms” ([Ugarte et al., 2022](#)) was released in November. The objective of this report is to contribute scientific evidence to develop more effective strategies for the prevention, mitigation and adaptation of HAB, improving the way in which these events are responded to and advancing towards greater resilience of the coastal areas of Chilean Patagonia, based on a transdisciplinary perspective and transformative climate governance approach.

The report is organized into chapters that merge information about the dynamics in the ecosystem, as well as the resulting social and economic consequences. Finally, the report offers policy recommendations oriented to the State and scientific community in terms of monitoring and proper risk communication.

A last collaborative effort during 2022 is the establishment of a renewal committee with the purpose of discussing and generating the proposal for its renewal of the Center. This renewal committee consists of 19 members including researchers from different disciplines and research lines but also professional staff ([Annex N° 9.2.e](#)), has met from April to December 2022 to decide on the guidelines and direction of the renewal effort as well as to produce a working proposal that will inform the renewal proposal of the Center, when the appropriate funding call is announced. The proposal highlights the need for an interdisciplinary approach to advance knowledge and to interface with society in an effective and prompt manner that enables the integration of a wide range of competencies and knowledge, while encouraging work among different disciplinary, organizational, and socio-cultural spheres. This means maintaining those processes and products which allows it (as the integrative questions) and seeking its deepening.



### c. Water and Extremes (WEx)


The main achievements of the WEx line focus on the regional detection of climate change, diagnosis and projections of extreme events and climate impacts on water resources across Chile. We continue working on one of our research milestones that corresponds to the identification, description and understanding of the present mega drought (MD) that has afflicted the highly populated region of central Chile (30-40°S) since ~2010. The duration, intensity ([Álvarez-Garretón et al., 2021](#)) and spatial extent ([Boisier et al., 2018](#)) of the MD make it an unprecedented event in the context of the last millennium ([Morales et al., 2020](#)). Moreover, instrumental ([Masiokas et al., 2019](#)) and tree-ring streamflow records ([Muñoz-A et al., 2020](#)) demonstrate the extraordinary adverse effects of the MD in river flows even affecting the marine productivity in the coastal zone ([Massoti et al., 2018](#)). The intensity and maintenance of the MD emerge from the superposition of natural and human forcings ([Garreaud et al., 2020](#); [Garreaud et al., 2021](#)), so the last decade provides a grim preview of the future hydroclimate for the region. It is expected that central Chile rainfall, river flow and snowpack continue to decrease 25-40% relative to present toward the end of this century ([Bozkurt et al., 2018b](#); [Barría et al., 2019](#)), an information of high relevance for planning Chile's future. A similar direction is projected for the mass balance of extratropical Andean glaciers ([Scheiter et al., 2021](#)). Already this MD has produced severe regional socio-ecological impacts such as the decline of the sclerophyllous forest ([Venegas-González et al., 2022](#)) and a drastic drop in honey production triggering migration south and conflicts with the locals ([Gajardo-Rojas et al., 2022](#)).

In addition to the MD, other extreme events (EEv) addressed by the research line include large forest fires ([McWethy et al., 2021](#)), sudden stratospheric warming ([Lim et al., 2021](#)), and the impact of atmospheric rivers ([Valenzuela and Garreaud, 2019](#); [Carvajal et al., 2021](#)). Within the complex risks management of EEv ([Kreibich et al., 2022](#)), rare summer atmospheric rivers have a large negative potential impact over the supply of drinking water in Santiago Chile's capital ([Valenzuela et al., 2022](#)), by significantly increasing the level of suspended sediment triggered by landslides in the semiarid basin ([Vergara et al., 2022a](#)). Moreover, regional deglaciation in this region is also significantly contributing to the increase of the occurrence of extreme turbidity events due to present warming and heatwaves ([Vergara et al., 2022b](#)) imposing challenges to large-scale drinking water plants. The need for rapid adaptation to the drier and warmer condition in central Chile requires a stringent evaluation of diverse measurements ([Aldunce et al., 2021a](#)), learning from each other ([Aldunce et al., 2021b](#)) and considering transformative strategies ([Aldunce and Guevara, 2021](#)). To anticipate and inform, [Álvarez-Garretón et al. \(2023\)](#) developed a new approach to diagnose if water allocation scheme in Chile is compatible with long-term water security at catchment scale. Moreover, [Gimeno et al. \(2022\)](#) developed models to determine the impact of different forest policy scenarios on water provision, and [Winckler et al. \(2022\)](#) a web-based tool for common users (ARClim) to provide an atlas of climate change-related risk assessments spanning over 50 environmental and productive sectors in Chile.

In addition, because of its global importance we have continued working on the Niño Southern Oscillation (ENSO), which is a major player in SA's climate ([Cai et al., 2020](#)). [Hernández et al. \(2022\)](#) determine the key aspects of the hydrological propagation and temperature responses to ENSO at watershed level across south-central Chile, and we continue enhancing regional proxies of ENSO past behavior using the widths ([Crispín-DelaCruz et al., 2022](#)) and isotopes content ([Rodríguez-Catón et al., 2022](#)) in Andean tree-rings.

To put present day climate anomalies in perspective, the group utilized different paleo-climate proxies. [Morales et al. \(2020\)](#) developed a gridded annual soil moisture reconstruction for most of South America (SA) since the year 1400 determining that the frequency of widespread severe droughts and extreme






pluvials since the 1960s is unprecedented. [Villa-Martínez and Moreno \(2021\)](#) and [Henríquez et al. \(2021a,b\)](#) determined the timing for the Last Glacial Termination (LGT) and deglaciation of the Patagonian Andes and a multimillennial context to the current precipitation changes in this region. Finally, [Moreno et al. \(2022\)](#) developed a detailed spatiotemporal description of the glacier and ecosystem evolution in northwestern Patagonia since the LGT, and [Soteres et al. \(2022a\)](#) pose that the global covariation of mountain glaciers during this period was linked to variations in atmospheric CO<sub>2</sub> promoted by the interplay of the Southern Westerlies - Southern Ocean system. Finally, for more recent times during the late Holocene, [Price et al. \(2022\)](#) developed detailed chronologies of Neoglaciation on Andean glaciers from Northern Patagonia to assess its dynamics with respect to temperature and aridity conditions.

#### **d. Coastal Zone (CZ)**

The Coastal Zone research line (CZRL) aims at studying how natural and anthropogenic forcing affects coastal processes of relevance to healthy ecosystem functioning as well as to Chilean society. In this context, research efforts have been conducted mainly on the monitoring (including unique observational efforts) and characterization of key mechanisms occurring in defined regions of the vast Chilean coastal zone (including Antarctica), addressing their multi-scale variability patterns, trends, and future projections. These novel scientific contributions have advanced and substantially improved the understanding on subjects from inter-disciplinary perspectives, thus laying pivotal foundations needed for evidence-based decision making towards resilient coasts.

The examination of southerly, upwelling-favorable wind events off central Chile at the synoptic scale has revealed main aspects of the daily and weekly variability of oceanographic conditions. Active upwelling events produce an increase in nitrate, partial pressure of CO<sub>2</sub>, and air-sea fluxes, and a decrease in sea surface temperature, dissolved oxygen, and pH; the opposite conditions are observed during relaxed wind periods ([Aguirre et al., 2021b](#)). Evidence shows that southerly winds have increased within coastal areas off central-south Chile (35°–42°S) during recent decades ([Aguirre et al., 2018](#); [Aguirre et al., 2021a](#)), a behavior that resembles the projected trend for future warming scenarios due to climate change ([Aguirre et al., 2019](#)). This loss of oxygen, called deoxygenation, is one of the most important current impacts on the ocean and is being recorded at accelerated rates in coastal waters off central Chile ([de la Maza & Farias, 2023](#)). The consequences are already being reflected in massive fish mortality and even in changes in the food chain of marine species. In north-central Chile, intensified seasonal upwelling affects the scallop physiology through local seawater acidification, deoxygenation, and cooling; all this impacts negatively on the industry of scallop aquaculture, its production, and economic indices ([Ramajo et al., 2022](#)). In addition, new progress has been made on the climatology and spatiotemporal variability of greenhouse gases (GHG). Measurements of cycling and exchange of GHG with the atmosphere throughout the eastern South Pacific have contributed to the characterization of their climatological spatial distribution, reaching better resolution than that derived from global models (e.g., [Daniel et al., 2013](#), [Yevenes et al., 2018](#), [Farias et al., 2015a, 2017](#)). Furthermore, the over-20-years-long time series of Station 18 off Concepcion (36°30,80'S; 73°7,75'W) has allowed the study of the variability of biological and oceanographic processes associated with the sources and sinks of greenhouse gases (such as N<sub>2</sub>O and CH<sub>4</sub>), the phytoplankton biomass cycles, and the development of hypoxia. Numerous oceanographic databases on GHG have been made publicly available ([Farías et al., 2019e](#); [Farías and Faúndez, 2020a, 2020b](#)).


The inter-annual variability of oceanographic conditions and phytoplankton composition is strongly modulated by ENSO ([Aparicio-Rizzo and Masotti, 2019](#)). Collaborating with the WEx research line, we



learnt that the recent extended mega-drought produces a reduction of nutrients loads, their transport to the sea, and ultimately phytoplankton biomass, probably impacting negatively on ecological processes and the productivity of this region (Masotti et al., 2018). Extending the geographical scope of this research, the role of nutrients and phytoplankton dynamics has been also addressed in the Peruvian upwelling systems (Paul et al., 2022).

Climate change is an ongoing phenomenon in this region (Bozkurt et al., 2020), which is key for the study of related impacts. Thus, dedicated future projections were developed (Bozkurt et al., 2019a). In this changing context, the CZRL focuses also on the diversity, identity, and activity of phyto-, bacterio- and virio-plankton during different productivity scenarios (Alarcón-Schumacher et al., 2019; Alcamán-Arias et al., 2021; Cifuentes-Anticevic et al., 2021; Alarcón-Schumacher et al., 2021; Alcamán-Arias et al., 2022a). A higher diversity of the bacterio-plankton community during phytoplankton blooms is due to the new source of fresh organic matter (Alcamán-Arias et al., 2018, Fuentes et al., 2019). There is a shift in the major viral groups infecting phytoplankton and bacterio-plankton blooms in late summer. Advances have been made on the characterization of novel bacterial psychrotolerant strains associated to the iron cycle (Muñoz-Villagrán et al., 2022), as well as the diversity and activity of ammonia-oxidizers and diazotrophic organisms in summer surface waters (Alcamán-Arias et al., 2022a, b). Due to a projected acceleration in climate change in the Western Antarctica Peninsula, this information is valuable for predicting the composition and functional changes in polar microbial communities (Arroyo et al., 2022).

The Chilean CZ faces a complex interaction of anthropogenic, geophysical, biogeochemical, and climate-driven perturbations. During the last decades, it has experienced changes in atmospheric sea level pressure, alongshore winds, sea surface temperature, chlorophyll-a, rainfall, river discharge, relative mean sea level and wave climate (Winckler et al., 2020). The CZ is also strongly affected by weather extreme events and climate trends that impact socio-economic activities. Research on extreme events is also a joint effort with the WEx research line. Barrett et al. (2020) and Vicencio et al. (2021) address the physical and environmental conditions behind the tornado outbreak in 2019. Demortier et al. (2021) reveal the main atmospheric drivers of heat waves (HWs) in south-central Chile, which might particularly impact the CZ and air-sea interactions. Intraseasonal teleconnections induced by the MJO and extra-tropical variability can act as remote precursors for HWs (Jacques-Coper et al., 2021) and eventually the propagation of wildfires, HABs in Northern Patagonia (Jacques-Coper et al., 2023), and extreme precipitation in Northern Chile (Rondanelli et al., 2019). These results offer innovative monitoring possibilities. An [open web platform](#) was launched to track HW precursors, seeking to provide guidance to public authorities concerning decision making for risk mitigation. Moreover, knowledge on the forecasting of favorable conditions for extreme weather events has been actively transferred to the National Weather Service and the Navy Weather Service. Besides, focusing on southwestern Patagonia, the geographical distribution of marine HWs and marine cold-spells and their relation to the persistence of the giant kelp ecosystem was analyzed for 1982-2020 (Mora-Soto et al., 2022), highlighting this region as a possible climatic refugium for these algae. For the Antarctic Peninsula (AP), after seminal work by CZ members, research has focused on some of the atmospheric dynamical aspects of HWs. The importance of atmospheric rivers in explaining extreme temperature events was documented (Bozkurt et al., 2018a). Moreover, Marín et al. (2022) shows that blocking days are more common over the Drake Passage and AP in recent years, and they produce significant increases in atmospheric river frequency and intensity as well as extreme temperature events over the leeward side of the AP (Bozkurt et al., 2022). The importance of synoptic scale tropical forcing in triggering Pacific-wide circulation anomalies behind the extreme temperature events in AP has been shown (Rondanelli et al., 2019; Clem et al., 2022). *Risks and climate change adaptation: Climate*



change is putting at risk several ecosystem services, health, economy, and wealth in Chile. With a broader focus, in addition to the information exposed by the IPCC ([Castellanos et al., 2022](#)), two studies address a list of key risks in Central and South America related to food and water security, coastal protection, and biodiversity, among others, as well as the feasibility and potential of adaptation solutions (Ramajo et al., 2022; Hagen et al., 2022). In this context, aiming at an improved and integrated analysis of physical, biochemical, and socio-economic variables and processes by the research community, the “[\(CR\)2 Coastal Platform](#)” has been designed from a multi-disciplinary perspective and is being implemented stepwise.

Transdisciplinary investigation diversifies the scopes in climate change research. The complex nature of the processes related to socio-ecological impacts of climate change is being assessed in the coast of Arauco province, Biobio region, using an approach focused on coastal commons ([Cid et al., 2022](#)). This research is delivering knowledge on local perspectives on climate change and local strategies for organizing the governance of such commons. *Science-policy interface*: The CZRL greatly sustained a major part of the research involved in the Integrative Question on HABs (2020-2022; see corresponding section), which culminated with a synthesis Report to the Nations ([Ugarte et al., 2022](#)).


#### **e. Land Use Change (LUC)**

The objective of the LUC research line is to develop scientific evidence for the design and construction of diversified heterogeneous landscapes, that have a direct application to decision-making. During the last 10 years LUC has increasingly oriented its research towards a diversity of topics including landscape design, forest fires, water yield in forested watersheds, restoration, carbon stocks, drought impacts on forest vigor and growth and economics and policy related to these topics.

Relevant research contributions of LUC in the 2018-2021 period included the influence of the megadrought on fire regimes ([González et al. 2018](#)); the report to the Nations on fire ([González et al. 2020](#)) that integrated researchers from all research lines (see IQ on fire); modelling of fire risk on highly flammable rural-urban interphase (RUI) areas across south-central Chile ([Miranda et al. 2020a](#)) and the use of deep fire topology for understanding the role of landscape spatial patterns in wildfire occurrence, using artificial intelligence ([Pais et al., 2021](#)).

Research in the previous years also addressed climate change impacts such as the Megadrought on the decline in vigor and productivity (browning) of native forests in central Chile ([Miranda et al., 2020b](#)). Vulnerability of long-lived endangered forests, and resilience to drought expressed as tree growth patterns was also studied ([Urrutia-Jalabert et al.; 2020 2021](#)). The influence of forest native cover versus exotic plantations in water yield, its policy implications, and modelling under climate change scenarios was addressed by [Álvarez-Garretón et al. \(2019\)](#) and [Galleguillos et al. \(2021\)](#). On the economics of natural resources [Ponce et al. \(2021\)](#) assessed the implementation of climate adaptation options and trade-offs between agriculture and household-level water demand. [Vásquez et al. \(2021\)](#) studied the willingness to consume goods at present or postpone it for the future, using data from a contingent valuation survey. ([Zamorano and Moreno, 2021](#)) contributed to the establishment of restoration priorities for the provision of ecosystem services in Patagonia.

The estimation that ~4,800 million tons of carbon are stored in Patagonian peatlands published as a letter in Science ([Hoyos-Santillán et al., 2019](#)) contributed to the inclusion of peatlands in Chile’s NDCs in 2020. The main research results that were published in 2022 are the following. [Gómez-González \(2022\)](#) from a thorough revision of cases worldwide on forest plantations and concludes that integrating genetic, functional, and demographic diversity across heterogeneous landscapes should make timber productivity and conservation compatible under a changing climate. [Miranda et al. \(2022a\)](#) Developed a



comprehensive landscape fire scars database, mapping historical burned area and fire severity in Chile. This data has been made publicly available (Miranda et al., 2022b). Pozo et al. (2022) assessed the socio-economic and land-cover drivers of wildfire activity and its spatiotemporal distribution in south-central Chile. They documented that fire density was associated with increased road access, as well as with the percentage of land covered by agriculture, exotic tree plantations, and native forest, as well as population density, proportion of indigenous population, but such relations varied considerably among counties that were analyzed. González et al. (2022a) documented that one of the important impacts of forest fires is that they trigger exotic pine invasion and increase the threats to endangered *Nothofagus alessandrii* remnant forest stands in the Maule region, documenting a new impact of the 2017 megafire.


On research dealing with water in forested landscapes and policy, Gimeno et al. (2022) developed a modeling approach for the assessment of the effect of forest policies in water provision in a drought-prone rural catchment in south-central Chile. This paper was done in collaboration with Manuschevich, D. and Zambrano-Bigiarini, M. from the Water Extremes Research Line. Jones et al. (2022) made a literature review of forest restoration and hydrology, which indicates that mature and old-growth forests have high evapotranspiration and consistent water yield, provided by moderated peak discharges and sustained low flows, while water yield is low from managed forest plantations, especially during dry periods. The early stages of native forest restoration may provide greater water yield and increased low flows compared with managed plantations (e.g., those presented in Lara et al. 2021).

In relation to water use in agriculture under climate change scenarios, Pizarro et al. (2022) documented that improved irrigation management for table grapes in central Chile as a case study, the water use efficiency (WUEi) increases from 49.5% to 55.7%. The calibrated model shows that under all the tested climate change scenarios, by mid-21<sup>st</sup> Century improved irrigation management can cope with climate change impacts for this crop in Central Chile.

Carbon stocks across different environments, disturbance regimes, and stand age in long-lived *Fitzroya cupressoides* forests was documented by González et al. (2022b). Old growth *Fitzroya* stands that may reach 1,500 years store 487–539 Mg C ha<sup>-1</sup> in the Andean range compared to 242 – 315 Mg C ha<sup>-1</sup> for stands that are up to 1260 years old. Lopatin et al. (2022) found that disturbance (harvesting of mosses and surface peat, grassing) alters the relationships between soil carbon pools and aboveground vegetation attributes in an anthropogenic peatland in Northern Patagonia. They document that these disturbances, even if small-scaled, will significantly alter their future carbon sequestration capacities by decreasing their live and poorly decomposed components.

Progress of Research on forest policy and economics, España et al. (2022) found that during the 1998-2013 period government subsidies increased the forested area of this program participants (mainly exotic pine and eucalypts plantations for timber production) by approximately 13% compared with the counterfactual scenario without such subsidies. Campos-Requena et al. (2022) used a choice experiment to characterize consumer preferences heterogeneity. This is a methodological paper based on attributes of seafood (mussels) affected by ocean acidification. F. Vasquez is the corresponding author of this paper that contributes to both CZ and LUC research lines, since the analysis is relevant to different ecosystems.

Integration with other research lines during 2022 has been strengthened through various initiatives. Collaborative work of (CR)<sup>2</sup> researchers on fire, heat waves and air pollution has started to be done, having a first outcome as an analysis in (CR)<sup>2</sup> web site. M. Galleguillos, M. González, A. Miranda and F. Vasquez LUC researchers participated in the Committee in charge of developing the proposal for (CR)<sup>2</sup> renewal to be submitted to the next ANID call (date undetermined), and also through the participation of



two LUC researchers in the Integrative Question (IQ) on Water Security. F. Vasquez from LUC is in charge of the IQ on Climate Change Economics, promoting integration with researchers from other lines.

LUC has made an important contribution to the scientific dissemination of its research through notes and opinions, published in high circulation electronic newspapers, newspapers, as well as public radio. Some of the researchers were invited to present at different Senate and government Commissions (e.g., A Lara was invited to be a member of CONAF (Chilean Forest Service) Directive Council. In this way, this research line has tightened the links and enhanced its outreach and contribution to relevant policy and laws regarding LUC, and communication to the public.


#### **f. Resilient Cities (RC)**

Over the last five years, the RC line has been engaged in the conceptualization and execution of different inter and transdisciplinary contributions on diverse dimensions of urban processes under a context of past, present and future climate and governance changes. Aside from addressing intertwined climate menaces (e.g., warming and drying), the team has assessed and quantified intrinsic drivers of change as well as emerging expressions (air pollution, inequality) of these “complex systems of systems”. In practice, RC strategically concreted research efforts for producing contributions to climate adaptation and risk assessment for Chilean cities and for the Latin America and Caribbean (LAC) region. Actually, it delivered two national policy briefs (i.e., National reports, [Gallardo et al. 2019](#); [Huneus et al., 2020b](#)) and a document for establishing the Chilean Nationally Determined Contribution to the Paris Agreement in terms of the mitigation goal for black carbon ([Gallardo et al 2020a](#), [Gallardo et al 2020b](#)). Additionally, the RC has been involved in the preparation of international instruments for policy making on climate change (e.g., [Szopa et al., 2021](#)). In this sense, the visibility and incidence of the RC together with its cross-edge research have been instrumental for strengthening the center’s standing.

Part of the RC effort has been devoted to finding a politically, culturally, and otherwise suitable framework for understanding urban resilience in the context of climate variability and change. The line has approached how the social dimension in climate change is generally understood ([Billi et al., 2019](#), [Azócar et al., 2021](#)) and evaluated the perception in the framework of development and sustainability as seen by diverse social actors ([Morales et al., 2019](#)). In other work, various aspects of governance were discussed ([Urquiza et al., 2019a](#); [Allendes et al 2021](#), [Billi and Labraña 2022](#)). RC has progressed in addressing resilience examining the urban metabolism-resilience relationship ([Fragkou and Urquiza, 2021](#)), and proposing an integrated analytical framework and methodological pipeline to streamline urban resilience analyses ([Urquiza et al., 2021](#)). Resilience indexes have also been developed for urban continental settlements ([Neira et al., 2020](#)) of all Chilean communes ([Billi et al., 2021c](#)). Moreover, long-term resilience in past social systems at global scale ([Freeman et al., 2021](#)).

Facilitated by the ARClim project (<https://arclim.mma.gob.cl/>; [Urquiza et al., 2020](#)), RC led the characterization of urban risk. Through the collaboration with local decision-makers, RC produced a benchmark contribution ([Amigo et al., 2021](#)) assessing the interaction between resilience and multiple urban risk (heatwaves, water (in)security, fires, floods) in one the major coastal city in central Chile. Meanwhile, the interlink between poverty, water and energy (in)security for the LAC region has been addressed, emphasizing heterogeneities in needs and capacities as well as varieties and multiplicities of threats affecting them ([Urquiza & Billi, 2020](#)). The water-energy-food nexus has been also analyzed in the context of climate risk in a semi-rural area from central Chile ([Calvo et al., 2020a](#)). The team has addressed challenges to cope with energy poverty ([Urquiza et al., 2019b](#); [Valencia et al., 2021](#)) as well as evaluated territorial energy vulnerability to enhance a just urban energy transition either in Chile ([Calvo et al., 2021a](#))






or LAC (Calvo et al. 2021b). The energy poverty work has been extended by characterization of the firewood market in southern Chile (Álamos et al., 2021b) and by exploring the impact of social and energy inequalities on national pollution mitigation measures, and in turn on the energy transition (Calvo et al. 2022). The use of simulation projections from the Coupled Model Intercomparison Project Phase 5 (CMIP5) by (Rojas et al., 2019) and the analysis of high-resolution climatic-gridded datasets by (Tudela et al., 2022) have enabled the evaluation of present and future risks posed by rapidly changing climate on food security. Such perspective on climate impact-drivers has been complemented by characterizing the vulnerability of pre-industrial Chilean socio-ecological systems to changing climate conditions (e.g., Tully et al., 2019, Ugalde et al 2021; Lima et al. 2022, McRostie et al 2022).

Work on urban footprint, with focus on urban climatology, has progressed by reconstructing historical intensities of heat islands in over 33 midsize Chilean cities for the period 2008-2018, but also by evaluating the relationship between surface temperature distribution and urban design (Smith et al 2022; 2021; Quintana-Talvac et al., 2021). In RC has also provided further insights into the intertwined relationship between social inequalities, environmental segregation and thermal islands in Santiago (Sarricolea et al 2022) as well as in other LAC cities (Smith & Henríquez, 2019a, 2019b).

Past and current evolution of air quality has been an RC area of interest. (Gallardo et al., 2018a) addressed the evolution for the relationship between mobility and air quality in Santiago over the last 30 years. (Barraza et al; 2017) attested for the increasing importance of mobile sources in the aerosol loading over Santiago and discussed the efficiency of mitigation measures. Meanwhile, (Menaes et al 2020) and (Seguel et al 2020) accounted for a shift in the oxidative capacity in Santiago over the last two decades. Research efforts have gone beyond Santiago, and the team has delivered contributions tackling air quality issues in northern (Jorquera et al. 2018a, Barraza et al. 2021, Zanetta-Colombo et al 2022) and southern Chile (Jorquera et al 2018b; Solís et al. 2022). Researchers also participated in works for the better assessment of commitments to the Paris Agreement to reduce black carbon emissions. For instance, (Daskalakis et al., 2022) evaluated the global impact of biomass burning on atmospheric composition in remote tropical Pacific. RC's scientific endeavor was enriched with the implementation of cutting-edge approaches (e.g., machine learning, artificial intelligence) for improving the spatial resolution of satellite observations of nitrogen dioxide (Parraguez, 2022), forecasting particulate matter pollution episodes (Menaes et al., 2021) as well as particulate matter extreme concentrations (Morawska et al., 2021). Additionally, the development of novel chemostratigraphic and dendrochemical proxy records added a new dimension for portraying the evolution of anthropogenic-driven air pollution from sub-decadal to millennial timescales in Chile (Muñoz et al., 2019; Gayó et al., 2019), but also laid the foundations for a pioneering approach to evaluate the feedback between environmental injustice, governance, attainment plans, just transition and sacrifice zones (Gayó et al., 2022).

The line has made available several science-based inputs for the better management of air quality. For instance, from validation of downscaled estimates for short-lived climate forcers (SLCF) emerges the recommendation to use local inventories in establishing mitigation scenarios in South America (Huneus et al., 2020a). RC also delivered a detailed national inventory for residential, mining, energy, and industry emissions (Álamos et al 2022). Whereas (Osses et al. 2022a) provide an historical inventory for national mobile emissions over the period 1990-2020, which combinewith other inventories from South America (e.g., Gómez et al 2018) and global data, affords a comprehensive emission inventory for the region (Castesana et al., 2022).



The team has also evaluated the impacts of the COVID-19 pandemic in urban areas. (Valdés-Salgado et al., 2021, Huneus et al., 2020b) explored the inequity effect of the pandemic in terms of emission and health impacts in Chile. The impacts of mobility restrictions on pollutant emissions were portrayed at global scale (Sokhi et al., 2021), as well as changes in photochemical regimes in Santiago (Toro et al., 2021) and three Latin American cities (i.e., Bogotá, Santiago, and São Paulo; (Seguel et al., 2022).

During the period 2018-2022, the RC's teamwork contributed to different studies regarding climate and climate impacts (e.g., Boisier et al., 2018; Ancapichún et al 2021; Gajardo-Rojas et al 2022, Reyes-Macaya et al. 2022) in a coordinated effort with other (CR)2's lines as well as in collaboration with other national or international groups (e.g., Bauer et al., 2019; Alfonso et al., 2019; Rowe et al., 2019, Lapere et al., 2020; Pizarro et al 2021; Brovkin et al. ,2021; Cazorla et al., 2022).


#### **g. Governance and Science-Policy Interface (GovSPI)**

During the last five years, the GOVSPI team has been focused on develop a climate governance conceptual framework in the global south perspective, characterized by vulnerability, less capacities and financed, as it was discussed in “Exploring the contours of climate governance: An interdisciplinary systematic literature review from a southern perspective” (Sapiains et al., 2021a) and in “Scientists and climate governance: A view from the South” (Ibarra et al., 2022). The research team, early on, laid the foundations of the problem of climate governance in a southern hemisphere country that is particularly vulnerable to the impacts of climate change (e.g., (Barria et al., 2019) and developed a reflection of the various climate governance models for Chile that ultimately gave rise to our own content (e.g., (Arriagada et al., 2018). In this perspective, one of the main scientific contributions in national terms was: Report to the Nations of Climate Governance of the Elements (CGE): Towards an Integrated, anticipatory, socio-ecosystemic and evidence-based climate governance of water, air, fire, and land (Billi et al., 2021), launched in August 2021. The diagnosis of climate governance of elements in Chile, offers a comparative view of the main gaps within each element and in their interaction spaces, based on the principles described above, like: reactive adaptation measures; increasingly unequal distribution of both the burdens caused by the impacts of climate change and the access to services provided by the elements, which affects the most vulnerable communities in environmental, social, and economic terms; the ineffectiveness of participatory mechanisms; deficiencies in the availability, quality or accessibility of data. The report offers specific recommendations for addressing the identified gaps and moving towards a new governance and management model for the elements, suitable for the challenges posed by climate change in the short, medium and long-term and propose a governance and management model that adopts climate change as a central axis and purpose, considering the mitigation and adaptation challenges in an integrated manner, and inspired by the CGE principles suggested in this report.

For that, GovSPI research line proposes principles (just climate action, anticipatory approach, territorial socio-ecosystemic approach, and good management), right (heathy environmental right, human right to water, access to energy right), state and private obligations (obligation of all GHG emitters to assume or bear the costs of preventing; obligation of State bodies to incorporate instruments and actions that promote the mitigation of climate change and the; Good management obligation of the State) and instruments (integrated climate basin, climate refuge zone, climate emergency).

At the same time, some recommendations are proposed to the constitutional Assembly, in view to establish climate change as a transversal element of society and nature, and an integrated climate change governance of nature elements and principles. The new constitution developed by the Assembly included the just climate action principle promoted by GovSPI research line. For that, the team research line





prepared an incidence strategy which included some presentation in Assembly, policy brief: Boletín especial N° 1 | Cambio climático y nueva Constitución (Billi et al., 2021d) and follow-up of the constitutional discussion.


In terms of incidence, the research line developed the first report concerning the need to have a climate national act in Chile: “Contenidos mínimos y lineamientos metodológicos para la evaluación económica y social de una ley de cambio climático para Chile” (Moraga et al., 2016). Then, the work of the Observatory for the Climate Change Law (Observatory, hereafter), which started in 2018 has continued and has resulted, probably, in the most significant contribution of (CR)<sup>2</sup> to its science-policy interface. The Observatory was created after the government announced that it would begin discussions on a climate change law in 2018. During 2020, the Observatory’s site generated material related to the legislative discussion on the Climate Change Framework Law Bill that entered the National Congress in January 2020. For example, minutes were prepared for each of the sessions held (15 audiences) that were published in a weekly newsletter during the period of the bill’s general discussion, in which several (CR)<sup>2</sup> researchers participated as guests to provide their expert opinion (Ariel Muñoz, Maisa Rojas, Laura Gallardo, Pilar Moraga, Marcelo Mena). After this stage was completed and the bill was approved by the senate in general. At this moment, the individual articles are being discussed. The Minister of the Environment proposed to the Senate Environmental Committee to rely on technical support, which would later translate into pre-legislative meetings held between the senators’ advisers, the Ministry of the Environment’s technical team, and the (CR)<sup>2</sup> team (Maisa Rojas, (CR)<sup>2</sup> Director; Pilar Moraga, Principal Researcher; and Andrea Rudnick, (CR)<sup>2</sup> Executive Director). Note that all senate sessions are transmitted live via the congress’s television channel.

During 2021 the research line participated as technical support in the climate change bill senate discussion. The executive director (Andrea Rudnick), scientific director (Maisa Rojas) and GovSPI Principal Investigator (Pilar Moraga), were member of technical committee which supported the legislative discussion on the environmental commission senate sessions and preparatory sessions. In this context, this team responded to questions and proposed legislative solutions. This task finished in August 2021 and the climate change law was approved in March 2022. Today, the ministries and subnational governments developed climate instruments to reach the legal goal: net zero emissions by 2050.

Complementing the work of (Palma-Behnke et al., 2019) on the technical aspects of Chilean’s net-zero emissions target, P. Moraga led a participatory and multi-stakeholder project, including various GOVSPi researchers, and under the auspices of the Chilean Senate, to identify the legal reforms required to implement this net-zero target (Moraga et al., 2020).

Research by GovSPI members has advanced the understanding of the relationship between climate change and its perception. (Sapiains et al., 2020b) addresses this in the context of forest fires in Valparaíso and (Azócar et al., 2021) carry out a comparative study on climate change perception among Latin American countries. The paper: Are Citizens Ready for Active Climate Engagement or Stuck in a Game of Blame? Local Perceptions of Climate Action and Citizen Participation in Chilean Patagonia (Sapiains et al., 2022) explores to what extent these structural transformations are also associated with cognitive and relational changes in the population, especially in terms of community participation.

In parallel, the team contributes to different areas concerning climate litigation in: Climate litigation in Chile: between the constitutional and the environmental jurisdiction path (Moraga Sariago, 2021), human rights and climate transition to net zero emissions in: El rol de los derechos humanos en la transición hacia una economía baja en carbono en Chile (Moraga and Bórquez 2022), participation and prevention




pollution planning (Cordero and Insunza, 2021), emission trading system impacts (Benavides et al., 2021) and audience segmentation in climate change and natural environment (Sapiains et al., 2021b), forestry's and indigenous territories (Blanco-Wells, 2021), among others.

The research team line lead by Cecilia Ibarra, developed the “climate capsules”, an example of interdisciplinary action research and dynamic science-policy interface. Aiming at given scientific answers to major topics from national public discourse on climate change in 100 words (plus a 500-word extended version), this ‘dose of science’ is an important effort to both working interdisciplinary and promoting outreach. This action research allowed us to identify gaps on knowledge production on climate change in Chile while positioning certain topics in the public debate. The project consisted on identifying key concepts from the public discourse (particularly, from speeches addressing issues related to climate change by the President of Chile and the Minister of Environment). Those concepts were analyzed in order to identify potential for providing a descriptive definition of each concept based on (CR)2 experts’ backgrounds and research. The results were the release of these ‘climate capsules’ tackling the following topics: ocean CO2 absorption in Chile, electro- mobility, fresh water running into the ocean, decarbonisation, black carbon and the differences between drought and water scarcity, loss and damages. The capsules were published on both (CR)2 website and the Climate Change Act Observatory [website](#) and disseminated through related social media, and the team followed the circulation with basic statistics for views (e.g. Google Analytics, Twitter statistics, etc.). This action research resulted in an effort for developing transdisciplinary work to produce the capsules and the management of an inter-areas work. Climate capsules are a project in progress. National government speeches on climate change decreased in Chile after the 18th of October, nevertheless, the evaluation so far is to continue with the project. During 2020, the team is expected to produce a paper reflecting on this experimental device and the lessons learned from it.

#### **h. IQ: Water Security (WSec)**

The main objectives of this IQ are to assess WSec over the last six decades (1960-2020) in Chile, considering the climatic and societal factors that have influenced WSec; to project WSec under climate change (2020-2060); and to provide adaptation recommendations. During 2022, 14 researchers (including postdoc, adjoint, associated, full-time and principal researchers) from different research lines (7 from WEx, 4 from GovSPI, 2 from LUC and 1 from CZ) and 4 postgraduate students, have tackled complementary aspects of WSec, based on three scales of analysis: national, catchment and local scales. At the national scale, the WSec team led by Camila Álvarez and Juan Pablo Boisier, achieved a major milestone with the award of a ~290.000 USD research fund (ANID/FSEQ210001) for a 1.5-year period (January 2022 - June 2023), focused on droughts in Chile. This project has boosted and complemented the WSeq IQ by: i) incorporating external researchers from Center of Advanced Studies in Arid Zones (CEAZA), the Helmholtz-Zentrum for Environmental Research (UFZ), the University of Avignon, and the University of Grenoble; ii) posing new research questions regarding the impacts of irrigation technology on total water use, the historical and projected glacier melting along the Chilean Andes, and the impacts of water abstraction on groundwater resources; and iii) developing a platform to transfer products and knowledge developed within the WSeq IQ to a broad community.

Other scientific achievements of the WSec IQ include publications tackling—from specific to more complex—aspects of WSec. At the national scale, an interdisciplinary team led by Camila Álvarez (WEx), Juan Pablo Boisier (WEx) and Marco Billi (GovSPI) assessed the water allocation scheme in Chile and concluded that the Water Code, recently updated in January 2022, is not compatible with water security



since the safeguarded environmental flows are insufficient to fulfill environmental requirements, while placing the basins under extreme risk of water scarcity if the total withdrawals allowed by law are exerted. The authors provided specific policy recommendations to overcome these limitations ([Álvarez-Garretón et al., 2023](#)). Within an international collaboration, and by providing evidence from central Chile as a case study, members of the WSec IQ team (Mauricio Zambrano and Camila Álvarez, WEX) published an article in *Nature* showing that risk management has reduced vulnerability to drought globally, although the impacts of these events are still increasing given the challenges posed by their greater magnitude ([Kreibich et al., 2022](#)). At the catchment scale, WSec IQ members analyzed the critical situation of drinking water provision in the Metropolitan Region and provided basic recommendations to address water scarcity. To facilitate reaching the community, this study was reported as a (CR)<sup>2</sup> analysis, in Spanish, and in plain language. Regarding WSec at the local scale, a team led by Chloe Nicolás-Artero (GovSPI), Gustavo Blanco (GovSPI) and Noelia Carrasco (CZ) proposed a typology of modes of access to drinking water in rural areas of Chile, identifying the dimensions that explained their heterogeneity. Three modes of access were identified: collective (network service), individual (domestic water intakes) and combined (multiple systems). The latter reflects a hybridization of practices accessing water at the domestic level, which tends to increase as a consequence of the decrease in water availability due to climate change ([Nicolás-Artero et al., 2022a](#)). A second article evidenced how some of the geolegal devices created to deal with events of water and environmental crises make access to drinking water precarious and contribute to the overexploitation and contamination of water resources ([Nicolás-Artero, 2022a](#)).


Several other products and articles are under development by the research team. During 2023, the insights from all these integrative scientific advances will be consolidated in a Report to the Nations that should be published in November 2023.

#### **i. IQ: Harmful Algal Blooms (HABs)**

During almost two and half years, the HABs team conducted multiple studies aimed at improving the understanding of this phenomenon in the context of climate change. Using an interdisciplinary approach and with a preventive focus, we produced different types of scientific knowledge to inform policymaking and help to build more resilient coastal communities. Our interdisciplinary cutting methodologies included stakeholder maps, focus groups, semi-structured interviews, surveys applied massively in different territories of Chilean Patagonia, and transdisciplinary workshops; as well as the raising of observed trends and projections of all kinds of climatic threats (variables and processes) that could play a key role in the appearance and frequency of HABs.

In terms of main results, we analyzed the trends and causes associated with the natural and anthropic factors that favor HABs, their socio-environmental impacts and the responses and governance mechanisms that have been implemented. Concerning causes, novel insights into the role played by the synoptic-to-intraseasonal variability of the coupled ocean-atmosphere within the Inner Sea of Chiloé system was described ([Jacques-Coper et al., 2023](#)). Current advances in scientific information on HABs have allowed the characterization of the climatic and oceanographic variability in which specific phytoplanktonic blooms occur ([Díaz et al., 2021](#); [Rodríguez-Villegas et al., 2021](#)), and the understanding of different natural and anthropogenic drivers ([Díaz et al., 2023](#)).

Considering the health aspects of the problem, public efforts to prevent poisoning and deaths related to HABs have been highly effective. However, it is also clear that HABs can trigger complex socio-ecological crises affecting not just the human health but also generating multiple economic, social and psychological impacts that are not totally understood ([Mascareño et al., 2020](#)). The survey applied in Patagonia



illustrates this. It showed that around 79% of the people have experienced at least one HABs, 66% consider that it is quite or very likely that, in the next five years, an event of this type will occur in the place where they live; and 63% consider that they are little or not at all prepared to face its socioeconomic impacts. Moreover, these results suggest that the health issue still requires more attention as 80% state their communities are little or not at all prepared to face the impacts on health. This might be related to the difficulties in accessing health services if the person is poisoned, rather than to the possibility of consuming contaminated products.

In relation to governance and responses capacities, existing technical observation and monitoring capabilities have made it possible to implement processes of adaptation and reduction of vulnerabilities of coastal human communities, with potential to also improve the protection of ecosystems and their services. Advances in coordination and articulation of social sectors linked to the management of HABs have made it possible to build important action networks for dialogue and decision-making, highlighting the creation of territorial-based "red tide" round tables. The political institutions have had the capacity to correct and use new learning, improving its management and responses to HABs events. However, HABs governance has been generally fragmented, reactive and disorganized, relying on particular efforts made by some institutions, the private sector, the scientific community and civil society without stable, continuous and financially supported coordination.


Overall, although previous responses have contributed to minimizing HABs impacts, it is unclear that only improving how things have been done (i.e., incremental changes) could be sustained in the long-term without reaching adaptation limits. It is necessary to consider transformational changes in the governance system to progressively increase the resilience of coastal communities. In doing that, responses that integrate scientific and local knowledge have been recognized and valued positively by the communities affected by HABs and should be deemed crucial of any future strategies.

Finally, a permanent hallmark of this report was the collaboration with colleagues from different public and academic sectors, along with social organizations. Many of them coauthored the report of the nations (<https://www.cr2.cl/fan/>, Ugarte et al., 2022), allowing the strengthening and expansion of national cooperation and contributing to transdisciplinary science. Thus, one of the milestones of the HABs research was the launch of the report to the nations in November 2022 in a small city of Chiloé (Quellón), selected for the purpose of giving back to the communities for the collected information.

#### **j. IQ: Changing Fire Regimes (CFR)**

This integrative research aimed to assess the main drivers, impacts, responses and trends of fire regimes under climate change and variability in central and south-central Chile. During 2018-2020 an interdisciplinary team led by Mauro González (LULC) and Rodolfo Sapiains (GovSPI), which included 33 investigators from different lines of research of the Center (WEx, LUC, GovSPI, CZ), addressed the social, economic and ecosystems damage and loss of fires as well as the institutional challenges of prevention, adaptation, and resilience to altered fire regimes. The main findings – including policy recommendations – were consolidated in the Report to the Nations presented to the public in January 2020.

Since the release of the Report, several papers have been published supporting its main results and conclusions. To reach a wider audience, informative material was prepared to the public (e.g., [Policy Briefs](#), [Media publications](#), [Opinions](#), [Interviews](#), [Talks](#), [video](#), etc.). The Report to the Nations and published papers have had an important international scientific contribution. For instance, Mauro González and Paulina Aldunce contributed to the IPCC sixth assessment report (AR6), IPCC Cross-Chapter Box DISASTER (Arfanuzzaman et al., 2022), with a case study in a socio-natural disaster such as the 2017



megafire in central Chile. Also, the publication of the book “Adaptation to Climate Change Risks in Ibero-American Countries - RIOCCADAPT Report”, includes a chapter about “Wildfires” – and the Impacts and lesson learned after the Megafire in 2017 in central Chile (Bilbao et al., 2020). The Report to the Nations (González et al., 2020) also contributed to a chapter to of a national report to understand the causes and impacts of fire on native forests in Chile (Lara et al., 2019). In October 2022, CR2 together with the Chilean Forest Service (CONAF) and the Center of Fire and Resilience of Socioecosystems (FireSES), organized the Workshop "Forests and communities at risk of forest fires: lessons and challenges" with the assistance of students, professionals from state agencies, NGOs, leader of local communities affected by fires, and scientist from research institutions.


During the last decades, climate and land use changes have led to an increase of megafires in Mediterranean-type climate regions all over the world. Similarly, Chile have experienced an extraordinary increase in fire activity associated with a severe drought since 2010 (Garreaud et al., 2017; González et al., 2018). For instance, the catastrophic fires of the 2016-2017 season broke all previous records with more than half a million hectares burned (570.000 ha), being recognized as a major catastrophe unprecedented in the last 50 years (Bowman et al., 2019; Lara et al., 2019; González et al., 2020).

Different interacting factors are likely responsible of the sustained increase in the annual area burned and contemporary mega-fires in Chile (Urrutia-Jalabert et al., 2018a; Pozo et al., 2022). Climate conditions (e.g., droughts, heat waves and high wind events), patterns, types and number of fuels and land-use change (e.g., expanding RUI and forest plantations) seem to predispose landscapes to mega-fires (Gómez-González et al., 2018, 2019; González et al., 2018; McWethy et al., 2018; Miranda et al., 2020). In the cases of forest exotic plantations, previous studies in other regions of the world support our main findings that its expansion during past decades have increased fuels across landscapes to the point where these areas are capable of fostering larger and more severe fires (Gómez-González et al., 2019; McWethy et al., 2018; de la Barrera et al., 2018; González et al., 2018; Moreira et al., 2020). Moreover, most of the fires occur in wildland/rural urban interface areas, where social impacts are higher. These interface areas are rapidly increasing due to population growth and expansion of more flammable ecosystems. Overall, in south-central Chile (32°-43° S) the wildland-urban interface comprises 4% of the territory but concentrate near 60% of the fires (González et al., 2020).

Under a scenario of extreme fire weather that favors large fires, it is recognized that current fire management policies are not capable of coping with the problem and a paradigm shift is needed. As a way to get out of this firefighting trap, fire researchers suggest moving from a strong focus on reactive fire suppression to a greater focus on mitigation to avoid or lessen socio-ecological damage and loss (Moreira et al., 2020).

#### **k. IQ: Atmospheric Pollution (AP)**

The Report to the Nation “The air we breathe: past, present and future. PM<sub>2.5</sub> air pollution in central and southern Chile” (Huneus et al., 2020b) discusses the impacts and the role played by the residential sector and its PM<sub>2.5</sub> emissions considering not only the physical-chemical factors, but also the socio-cultural, economic, and institutional dimensions of the problem. This interdisciplinary study integrates multiple databases, numerical simulations, interviews, and workshops with multiple stakeholders to characterize not only current air quality, but also the evolution of air pollution since pre-Columbian times, including the socio-economic and technological factors that influence its past, present and future evolution. In addition to the report, an interactive web platform (<http://contaminacion.cr2.cl/>) was created to allow policy makers and the public to explore the simulations performed for the report.



Deteriorated air quality in central-southern Chile is strongly related to emissions from the residential sector. A high resolution (approximately 1 km) national emission inventory including the main pollutants associated with the residential, transport, energy, and industry sectors for the period 2015-2017 was created for this work. This national emission inventory represents the first inventory with spatially distributed anthropogenic emissions from multiple sectors estimating both criteria pollutants as well as greenhouse gases (Álamos et al., 2022). According to this inventory, at the national level, the use of firewood for heating and cooking represented about 94% of PM<sub>2.5</sub> emissions in 2017. The use of firewood in central and southern Chile is an expression of energy poverty, evidencing the poor thermal insulation of homes and the difficulties of the general population in accessing clean and high-quality energy services. Improving air quality to comply with current environmental regulations requires an energy transition towards less polluting fuels that also considers socio-cultural conditions and their heterogeneity throughout the territory. Multiple sociocultural and sociotechnical barriers were identified to achieve this transition, highlighting: (a) the precariousness of the dwellings, which do not retain heat inside the homes; (b) limitations in the availability and storage of dry firewood; and (c) the cultural attachment to firewood and multifunctional artifacts, such as the wood stove. Additional challenges are territorial energy vulnerability related to the limited availability of other fuels, the deregulation and informality of the firewood market, and low social participation.


Furthermore, model simulations for current climate under different emission trajectories for the period 2010-2050, as well as analysis of climate model projections (CMIP5) for center-south Chile suggest that the main cities in this area, already suffering from air pollution problems, will continue to exceed the PM<sub>2.5</sub> daily air quality standard in the future, even if all the emission reductions until 2050, considered in the best scenario were applied today.

Our work estimates that about 4,500 annual deaths are associated with PM<sub>2.5</sub> air pollution, a higher number than the official estimate, which only considers the cardiopulmonary effects in the adult population under 80 years of age. Our estimate includes, in accordance with the recommendations of the World Health Organization (WHO), the entire population regardless of age, and all-natural causes (except external or unnatural causes, such as accidents, crimes, etc.). According to our calculations, these methodological differences suggest that the official estimate could be underestimating mortality by ~ 50%.

In view of all the above and considering: (a) emission projections, (b) simulations of pollutant dispersion, and (c) sociocultural, economic, and political barriers, it is clear that current efforts to improve air quality are insufficient. Adding to the picture a generally unfavorable scenario for air quality due to climate change, the necessity arises to accelerate efforts to improve the quality of life of the population, reduce avoidable deaths, and move towards a more sustainable energy usage.

Due to the Pandemic at the time this work was concluded and its link with air pollution, preliminary analyses exploring the potential relationship between COVID-19 and chronic exposure to PM<sub>2.5</sub> were included in the report. Health statistics and air quality data available until the end of June were considered in this analysis. Results suggest that in general, a higher incidence and mortality rate from COVID-19 in those communes with the highest chronic exposure to PM<sub>2.5</sub> and PM<sub>10</sub>. At the communal level, the incidence rate increased by 2.7% and 1.9% for every microgram per cubic meter increase of PM<sub>2.5</sub> and PM<sub>10</sub>, respectively. Similarly, the mortality rate increased by 1.9% and 1.3% for each microgram per cubic meter increase in PM<sub>2.5</sub> and PM<sub>10</sub>, respectively.





Based on the research results and considering reviewer suggestions in the last annual (CR)<sup>2</sup> report, a set of concrete recommendations were presented that contribute to the management of air quality in the country and overcome the identified barriers.

The report was launched on September 7, 2020, in an online event with an opening speech by the Chilean Minister of Energy at the time, Juan Carlos Jobet. In addition to this event, a short video was prepared as well as infographic material summarizing the main results, conclusions and recommendations from the report. In addition, a summary for policy makers was made and translated to English. All of these products are available on (CR)<sup>2</sup>'s website (<http://contaminacion.cr2.cl/>).

Papers summarizing the main findings presented in the report have already been published; articles by (Gayó et al., 2022), (Labraña et al., 2022) and (Labraña et al., 2021) complement the historical dimension of the pollution history in Chile while Álamos et al. (2022), Osses et al. (2022a) and Calvo et al. (2022) describe the methodology and present the national emissions and their trajectories used in the report.

Beyond the unprecedented collection of new data (e.g., emissions, simulations), and the amalgamation of social and physical dimensions of the problem, this work sets a robust ground for providing evidence-based mitigation and adaptation options in Chilean urban settlements between 30° and 45°S.

## I. Transformation


In the second semester 2020 it was decided to integrate the Transformation Approach (TA) in the research and in the interface science-policy/society of the (CR)<sup>2</sup>. This has been led by one of the Associated Researchers of the Center and one assistant personnel working part time. The objectives defined and achieved for this integration were twofold. First, the alphabetization of the conceptualization of transformation, this because some confusion about how Transformation is understood and applied existed, as the TA applied to climate change was relatively new among Chilean researchers and practitioners. Second, to integrate the TA in the interdisciplinary work of the Center, specifically through the work conducted in the “Climate Governance of the Elements”; and the Integrative Questions of “Harmful Algal Blooms” (HABs) and “Water Security” (WSec). To achieve these objectives, it was crucial that the interaction and synergies developed with the center Research Lines and Integrative Questions.

For the alphabetization of the TA two publication (Salgado, M. and Aldunce, P., 2021; Aldunce, P., et al., 2021c) addressed not only the conceptualization of Transformation but also key elements to guide research such as the transformation domains, positive and negative trajectories of transformation, among others. Also, the analysis of concrete examples of transformation actions and processes was included.

For the integration of the TA in the interdisciplinary work of the Center, the first step was to develop a conceptualization of “Transformative governance” (Billi et al., 2021). Some key research fundings for governance research were that transformative actions are insufficient in terms of legislative and institutional framework, and territorial management. Therefore, transformative actions on multiple scales and domains that address the drivers of climate change are urgently needed, concrete recommendations of how this can be achieved were given (Billi et al., 2021; Salgado, M. and Aldunce, P. 2021).

Related to the research conducted for the HABs and WSec, an important contribution is the “Transformations Actions Data Base” that include examples from the literature and from the cases studies that were conducted as part of these two integrative questions (Aldunce, P., et al, 2022). Some key contributions that emerged are that both incremental and transformational actions have been implemented, but with a weak presence of the latter (Aldunce, P. et al, 2022; Aldunce, P. and Guevara, G. 2021; Ugarte, A., et al, 2022). Therefore, to increase the ambition of transformational actions is urgent, in





which all actors are included, and collective action is promoted to ensure positive transformative trajectories.

#### **m. Climate Change Economics**

In the last two years (2021-2022), the Center created a research team in climate change economics with a focus on water economics and estimating the economic impacts of extreme climate/weather events, including droughts and HABs. Felipe Vásquez (adjunct researcher from RL LUC) led the team (since the associate researcher Rodrigo Arriagada left the Center to work at the Ministry of Environment), and we added two researchers (Ph.D. Francisco Fernández and M. Sc. Francisco Hernández) as research assistants. Additionally, we joined forces with two research centers (CAPES and SECOS, Roberto Ponce and Marcela Jaime) to strengthen the capacity for climate change economics. In this period, we have accomplished the following (with some overlapping with LUC):

- 1) Scientific productivity: a) papers:** between 2021-2022 we published 13 papers related to climate change economics (3 in water resource economics, 5 on land use and biodiversity, 1 in marine resource economics, and 2 on individuals time preferences for environmental goods).
- b) working papers:** we have 4 working papers that will be submitted to international journals in the first semester of 2023 (**W1:** The Economics of long-run droughts: Lessons from the Central Chile Megadrought. **W2:** Estimating Residential Water Demand under Systematic Shifts between Uniform Price (UP) and Increasing Block Tariffs (IBT). **W3:** Are price changes more effective than nudging to reduce water use? **W4:** A Review of the Economic Valuation of Harmful Algal Blooms (HAB): Methodological Challenges, Policy Implications, and an application).

**2) Extension:** We organized two cycles of seminars in 2021 and conferences at the annual meeting of the Society for Benefit-Cost Analysis (SBCA) in 2021 and 2022 (sessions with researchers, students, and policymakers).

**3) Human capital.** We contributed to 3 master dissertations (1 was defended in January 2022, and 2 will be finalized in March 2023) and one Ph.D. dissertation (expected to finish in 2023). Although the Center did not financially support these dissertations, Felipe Vásquez was their advisor or actively participated in the research development.

### 3.2. Formation of human resources in the discipline

This section must include a summary of the activities accomplished to achieve training of human resources. It is important to indicate the influence and participation of the Center in Doctoral Programs (and postgraduate training) of the sponsoring and associated Institutions, as well as their synergies, i.e.: number of thesis with co-advisors. Include in this section the local and national impact of training advanced human resources. The information relative to the number of doctoral student trained, number of undergraduate and graduate students, and number of thesis presented under this program must be included at the Center Reporting System.

Most researchers at (CR)<sup>2</sup> are University professors, which has facilitated the center's role on the formation of the next generation of scientist and professional in the ample arch of Climate and Resilience disciplines. Overall, between 2018 and 2022, 239 students participate in the center, specifically 105 undergraduate, 98 master's and 36 doctoral students. They actively collaborate in the execution of research projects through their thesis work, being key in the future follow-up of the studies that are currently being carried out.

Specifically, for the year 2022, a total of 127 students are enrolled in CR2, which are distributed as follows:

Table 1: Finished thesis and in process for the year 2022.

Year 2022	
<b>37 finished thesis</b>	<b>90 thesis in process</b>
15 undergraduate	36 undergraduate
18 master	35 master
4 doctorate	19 doctorate

As for postdoctoral fellows, a total of 26 postdoctoral students participated during the period 2018-2022. In particular, 6 of them correspond to the year 2022, of which 4 have received funding from (CR)<sup>2</sup>. Below is the complete list of postdocs:


Table 2 List of postdoctoral researchers in the period 2018-2022

Name	Research line	Start year
Rocío Urrutia	ECO	2015
Francisco Barraza	Resilient Cities	2015
Camila Tejo	Land Use Change	2015
Jonathan Barichivich	Land Use Change	2016
Camila Álvarez	Water and Extremes	2016
Cecilia Ibarra	Governance	2016
Lucy Belmar	Coastal Zone	2017
Raúl Valenzuela	Water and Extremes	2017

Sebastián Crespo	Water and Extremes	2018
María Estrella Alcamán	Coastal Zone	2017
Alejandro Miranda	Changing Fire Regimes	2021
Vincent Lemaire	Atmospheric pollution	2018
Macarena Valdés	Atmospheric pollution	2019
Christina Ridley	Coastal Zone	2019
Rocío Pozo	Changing Fire Regimes	2019
Julio Labraña	Atmospheric pollution	2019
Álvaro González	Water and Extremes	2019
Jorge Hoyos-Santillán	Land Use Change	2019
Felipe Raglianti	Atmospheric pollution	2019
Tania Villaseñor	Transversal	2019
Marco Billi	Governance, Water Integrative Theme, Red Tide	2020
María del Pilar Aparicio	Coastal Zone	2020
Danny Eduardo Carvajal	Land Use Change	2020
Ana María Ugarte	Coastal Zone	2019
Chloé Nicolas-Artero	Governance and science-policy interface	2021
Roxana Bórquez	Governance and science-policy interface	2021

As part of the training of advanced human capital directly related to the center's objectives, the following training activities are highlighted:

- **Diploma in Climate Change and Low Carbon Development.** This seeks to provide conceptual and methodological tools to understand and address, with a comprehensive vision, the problems related to climate change and sustainable development. In 2022, its 6th version was given, where the main challenges of environmental governance in Chile were addressed, to face current and future problems of climate change. In addition, Chile's commitments in the Paris Agreement, the scope of the climate change bill and other legal reforms that concern environmental justice in the country, such as the Water Code and the new Constitution, were analyzed. In its 2022 version, 26 students participated, of which 15 (57.7%) are women and 11 (42.3%) are men. It should be noted that in the period 2018-2022, the Diploma has had a total of 108 students.
- **Diploma on Climate Action and Municipal Management.** The diploma for municipal officials was carried out during August 2021, and whose objectives were to provide knowledge about the



causes and consequences of climate change; identify mitigation and adaptation needs at a municipal and territorial scale; provide tools for project evaluation, modeling of socio-ecological systems and planning for local action, and finally; deepen the integration of climate change in municipal management. The diploma course had the participation of 84 municipal officials.

- **Project of Development and implementation of an institutional strengthening and capacity-building program at the subnational level, in the context of the preparation of the Climate Strategy for Resilient Development and Low Emissions by 2050.** Initiative of the year 2021, whose objective was to develop a program to strengthen technical capacities for climate change management aimed at CORECCs (Regional Climate Change Committees) and promote a dialogue between the authorities convened. More than 450 people belonging to the CORECC from the different regions of the country participated in this event.
- **Municipal Climate Risk Diagnosis Workshop, ARClim (Climate Risk Atlas).** Joint initiative between the Ministry of the Environment (MMA), with the support of the European Union, (CR)<sup>2</sup> and fiiS (International Festival of Social Innovation) in 2021, which sought to promote conceptual and practical capacities on the use of the ARClim platform, for the diagnosis of climate risk at the municipal level and addressed municipal officials of the communes of the Municipal Environmental Certification System (SCAM) of the MMA. It should be noted that in 2020 online practical training was carried out on the ARClim platform. More than 200 people from the public sector were trained. The training workshops focused on explaining the functionalities and limitations of the platform, reviewing the risk maps and the threat explorer through videos and practical exercises.
- **Participation of (CR)<sup>2</sup> in the III International Conference on Education and Sustainable Development 2021.** In its online format, it brought together more than 3,000 participants per day. Over three days, the conference convened more than 50 speakers, presenting topics such as project-based learning, nature, art and culture, and citizen science for sustainability, in panels, webinars, and masterclasses.
- **The Summer School (CR)<sup>2</sup>.** It is an initiative focused on those who are beginning their scientific career (master students, doctoral students, and postdoctoral fellows), as well as researchers and professionals with experience and interest in the subject matter addressed by the School. 2021 began with "Integrative Assessment of Climate Change: Water Scarcity", which had 24 students; then in 2022 "Cities and short-lived climate forcing: complexity, challenges, and opportunities" was held, with 18 students, both versions virtually. The third version "With feet in the sea: Towards the co-design of resilient coasts. Climatic risks and responses along the coastal zones", was carried out in person in Concepción in January 2023 with the participation of dozens of students and researchers.
- **Program of "Education in Climate Change and Sustainable Development".** Participation of (CR)<sup>2</sup> in this program 2021. Its objective was to develop educational resources on these topics, to strengthen education on climate change and develop inquiry methodologies and project-based learning in Latin America. Chile, México, Colombia, Ecuador and Perú participate in the project. Program in which the Universidad de Chile participates, through the IBSE (Inquiry-Based Science Education) program, from the Instituto de Estudios Avanzados en Educación (Institute for Advanced Studies in Education), the Siemens International Foundation and the UNESCO OCE.

- **UAbierta** (Open University). Participation of researchers from (CR)<sup>2</sup> in free workshops through the online platform, on the real problems that climate change produces in different parts of the world and how society should adapt to these changes. This initiative began in 2020, and by 2022, six versions have been carried out, where 8,619 people have been able to develop the course.
- **General Training Courses.** The (CR)<sup>2</sup> researchers participate in different General Training Courses, which are taught to undergraduate students of the Universidad de Chile: "Climate change and sustainability", provides general knowledge on climate change and sustainability through an interdisciplinary perspective, which allows understanding the problems and impacts of climate change on the environment and on society. Next, the number of students per year since the program was taught will be indicated: 88 (2020), 102 (2021) and 28 (2022). The course "Energy Poverty in Chile: Approaches and Perspectives" seeks to generate a transdisciplinary discussion on the concept of energy poverty. Regarding the number of students who have developed the program, there are 52 (2020), 51 (2021) and 50 (2022). Finally, "Inter and transdiscipline to face global environmental change", is a new course that was taught in 2022 and had 46 students. Its objective was to show future professionals the type of knowledge generation processes that are required. to address some of today's complex challenges.
- **Air Pollution Forecast Modeling.** Summer school 2020 organized between (CR)<sup>2</sup> and the PAPILA project. The activity had 70 attendees from different countries. The topics addressed were the development of emissions inventories, as well as the implementation of mitigation policies that have a positive impact on air quality.

As for the Latin American Education Network for the Environment (Redlama), it is an initiative that has been aimed at bringing scientific knowledge on environmental sciences and climate change closer to the school community, through an interdisciplinary perspective that allows contributing to the development of critical thinking through tools and didactic material that facilitate learning. In 2021 it completed its seventh version under the eaves of (CR)<sup>2</sup>, however, in 2022 the (CR)<sup>2</sup> signed a collaboration agreement with the Museo del Agua (Water Museum) of the Universidad de O'Higgins, with the purpose that this initiative continue to grow and develop.

It is important to highlight the Interdisciplinary Program Energy, Water and Sustainability (ENEAS) of the Universidad de Chile, in which a large number of researchers (CR)<sup>2</sup> participates. The program developed the Spring School "Energy, water and sustainability" with the aim of addressing energy and water issues to contribute to the sustainable development of the country.

Some initiatives that are being worked on are: i) MOOC "Climate Change: An interdisciplinary perspective from the Global South", the course is aimed at undergraduate students and professionals from various areas, its objective is to provide general knowledge that allows understanding the functioning of the Earth system, anthropogenic forcing and its impacts on the climate system as a whole. ii) Training in water management from a gender perspective for the General Water Directorate (DGA, for its acronym in spanish Dirección General de Aguas), which seeks to strengthen knowledge on the matter, both for the public service and for the leaders of user organizations, in order to reduce the gender gaps.


### 3.3. National and international collaboration

This section must include ongoing or already conducted actions contributing to national or international networking (strengthening and internalization of activities), including their local and national impact.

(CR)<sup>2</sup> has benefited from fruitful collaboration with other research centers in Chile and abroad. Some of the interaction has followed formal commitments, as the MOU signed with the SCRIPSS Institution of Oceanography, University of California San Diego, and the joint operation of the [Andean Snow Observatory](#) with IANIGLA-Argentina. Other collaborations are more spontaneous and focus on specific themes, as the effort with CAPES and CRHIAM (in Chile) to address economical aspects of climate change. The latest integrative theme, Harmful Algal Blooms and Climate Change, involved several researchers from universities and researchers outside (CR)<sup>2</sup> as well as colleagues at National Agencies, like Instituto de Fomento Pesquero (IFOP). Also noteworthy is the recent creation of CEODOS-Chile, a consortium of excellence research centers ((CR)<sup>2</sup>, IDEAL, COPAS, CIEP, among others) devoted to the oceanographic investigation along the Chilean coast. Details on specific collaborations are provided in Annex 9.6 and here a few are highlighted to display their wide arch of disciplines and institutions.

#### a. Highlighted National Collaboration Networks

- **CAPES** ("Center of Applied Ecology and Sustainability") – **IEB** ("Corporation Institute of Ecology and Biodiversity"). The objective of the alliance between these three research centers is to create a collaborative research line entitled "Socio-ecological changes in ecosystems in transition due to global change".
- **SECOS** ("Millennium Institute in Coastal Socioecology") – **CAPES** ("Center of Applied Ecology and Sustainability"). The project "**Elements**" aims to make visible the process and the works co-created in the initiative of the same name. "Elements" seeks to generate, through collaborative work between scientists and artists, a process of reflection and co-creation, to raise awareness about the current environmental crisis, which values scientific knowledge and artistic practices in the search and implementation of solutions and in the creation of new imaginaries of our future, mobilizing us to action.
- **Itrend** ("Disaster Resilience Institute"). "**Semi-Automatic Mapping of Historic Fire Scars**". The objective of this alliance is to contribute to the development of disaster resilience triggered by natural and anthropic hazards, with an emphasis on the field of forest fires, through the articulation of capacities in the subject matter of prevention and combat of forest fires. The work carried out includes the definition of the perimeter and severity of the fires that will allow understanding the behavior of the fire, evaluating its frequency, simulating the fires, evaluating natural and non-natural barriers to fires, quantifying their impacts and to plan the restoration of areas, among other applications.
- **The Millennium Nucleus Understanding Past coastal upWelling systems and Environmental Local and Lasting impacts (UPWELL, NCN19\_153)**. This 3-year project addresses the long-term co-evolution between social and biophysical systems in coastal urban centers along northern and central Chile over the last 12,000 years. This project emerges from the integrative articulation by researchers from "Resilient cities" (Eugenia Gayó) and "Coastal Processes" (Laura Farías, Catalina Aguirre) lines. Specifically, UPWELL provides a temporal dimension that complements and enriches the understanding of phenomena that are addressed in both lines, either in relation to natural and anthropogenic change factors, long-term transformations in littoral urban centers as well as adaptation strategies to a changing climate. Besides, it will strengthen international




collaborations with South Africa, Spain, Portugal, Peru and the USA, but also outreach and student engagement.

- **Energy, water and sustainability (ENEAS) Interfaculty Programme** at (Universidad de Chile). It sought to enhance the creation, promotion and coordination of interdisciplinary research initiatives, teaching and relationship with the environment, related to the sustainable use of natural resources. The program aims to develop, articulate and disseminate scientific knowledge that can be used for decision-making, contributing to the development of public policies on energy, water and related to the exploitation of other natural resources, with the aim of promoting sustainable development of the country, addressing challenges of climate change and respecting, at the same time, cultures, communities and various territorial configurations. In this context, the program encourages the development of integrated training processes, considering interdisciplinary approaches at different academic levels and moving towards initiatives for transdisciplinary training. Several (CR)<sup>2</sup> researchers are part of ENEAS.
- **Andean Observatory Project.** The first objective of this project was to install an Andean observatory in central Chile, that allows to: understand the processes that modulate the observed and projected variability in the Andean cryosphere of central Chile, downwind of the largest city in Chile; observe and document the changes registered in various meteorological, physicochemical and hydrological parameters; provide quality information and knowledge to support decision making at the local, regional and global levels; and dissemination of science. This project was implemented as part of a collaboration with Valle Nevado (VN) ski center. (CR)<sup>2</sup> contributes with: Andean refuge, instrumentation, installation and maintenance, campaigns to measure key variables, process of integrating the international network of Andean observation Global Atmospheric Watch (GAW), and scientific research related to climate simulations, pollutant transport processes, among others. The VN ski center contributes with land (approximately 35 m<sup>2</sup>) in Cerro Tres Puntas (~ 3.678 masl), authorization to install additional instruments in the vicinity of the refuge, free access to the land throughout the year, program of operation of machinery in the vicinity of Cerro Tres Puntas, that may affect measurements.
- **Observatory of Atmospheric Rivers (ORA).** This is a suite of atmospheric measurements systems deployed at the University of Concepción since 2022 and oriented to understand the fine scale structure (microphysics) and dynamics of Atmospheric Rivers landfalling in south-central Chile. These systems account for most of the precipitation and extreme events. The current ORA includes a micro-rain radar, a ceilometer, a disdrometer and automatic weather stations, operating continuously. Intensive Observing Periods include radiosonde launches and special oceanographic measurements. Many WEX researchers are involved in ORA, which also include the Departments of Oceanography and Astronomy at UdeC and IANIGLA-Argentina.

#### b. Highlighted International Collaboration Networks


- **Race to Resilience campaign.** (CR)<sup>2</sup> assumed last year the technical secretariat of the global campaign "Race to Resilience", of the United Nations Framework Convention on Climate Change, the same role that the University of Oxford performs in the sister initiative, "Race to Zero". Race to Resilience - launched at the beginning of 2021 - seeks to catalyze a radical change in climate resilience, where people and nature are expected not only to survive climate shocks and stresses, but to thrive despite them. (CR)<sup>2</sup>'s work is divided into two parts: coordinating experts to evaluate the initiatives coming into Race to Resilience and creating a metric framework to measure





progress. Both the metrics and the review of initiatives will be worked on with international groups.

- **Net Zero Research Fund of Scotiabank Canada.** (CR)<sup>2</sup> together with the Centro de Energía (Energy Center) of the Universidad de Chile were one of the ten entities benefited by the Net Zero Research Fund (NZRF), initiative launched this year globally by Scotiabank as part of its climate commitments, through which it seeks to promote research to move towards a low-carbon economy. The project will develop annual estimates of Greenhouse Gas (GHG) emissions from the energy sector (with a lag of 1 year) and the carbon budgets of the energy sector, which will provide more frequent and updated information for the independent monitoring of compliance with Chile's mitigation commitments. This is to respond to the current information gaps, in which Chile produces biennial GHG inventories and must report the progress of its NDC every two years, in accordance with its GHG inventory. The observatory will be useful as an early warning to identify possible deviations from mitigation objectives and guide public policies and productive sectors to fulfill with Chile's carbon neutrality.
- **ANDEX, Regional hydroclimate initiative for the Andes.** ANDEX is proposed as a GEWEX Regional Hydroclimate Project (RHP) aiming at understanding, modeling, and predicting the dynamics of the water and energy cycles over the Andes cordillera, at a wide range of temporal and spatial scales, and their linkages with the surrounding oceans, land surface and major river basins. From its inception in late 2017 to present day, a small team of scientists with the help of the GEWEX IPO carried out diverse activities that led to the present implementation plan. René Garreaud was cochair of ANDEX from 2018 to 2022 and he is now part of the steering committee. Also involved are Juan Pablo Boisier and Camila Alvares, both from WEX. continues as co-president of ANDEX.
- **Agreement for scientific and educational cooperation.** It was signed between the Center for Western Weather and Water Extremes, SCRIPPS Institution of Oceanography, UC San Diego and (CR)<sup>2</sup>. The purpose was to further the development of basic scientific and applied research with goals of advancing research in ocean and atmospheric science, gaining a more fundamental understanding of the oceans and atmosphere, and benefiting society at large. The forms of cooperation included: exchanging researchers, scientists, faculty members, and graduate students; exchanging scientific information in fields of mutual interest; exchanging scholars for lectures, talks, conferences, colloquia, symposia and sharing of experiences; implementing cooperative research programs; making facilities and equipment of one party available to researchers from the other party; encouraging direct contacts between researchers; permitting other forms of research cooperation by mutual arrangement; and jointly apply to funding to strengthen the cooperation.
- **International consortium that applied a project to the call of the Horizon 2020.** Research and Innovation Framework Programme from the European Commission named "Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health (AQ-WATCH)". This project was awarded to the AQ-WATCH consortium starting towards the end of 2019. The project has co-developed and co-produced tailored products and services derived from space and in situ observational data. The purpose of these products and services is to improve air quality and their capabilities will be demonstrated in three different populated regions of the world to establish their potential for their on-going widespread adoption beyond the lifetime of the project. A prototype production chain will be initiated by proposing to three "prime users" chosen in



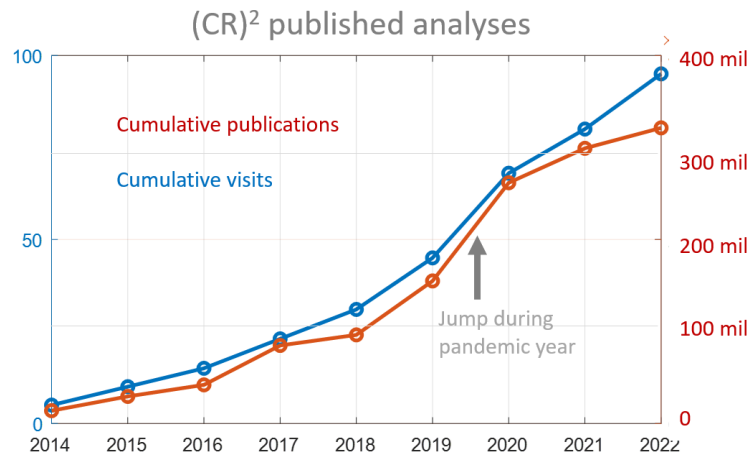
different parts of the world (Colorado, USA; Santiago, Chile; Beijing, P.R. China) and a range of prototype products/services to help mitigate air pollution and their effects on health has been developed. Some of the scientific partners are: Max Planck Institute for Meteorology from Germany, Centre National de la Recherche Scientifique from France, the Finnish Meteorological Institute, University Corporation for Atmospheric Research from USA, among others. There are also other relevant partners such as the State of Colorado, Beijing Municipality and the Unconventional Renewable Energies Trade Association (ACERA) of Chile. Therefore, the project also strengthens (CR)<sup>2</sup> relations with the private sector and contributes with the interface between science and its application in a productive sector.

- **Agreement with the Centre National de la Recherche Scientifique.** Together with several universities in France, Brazil, Canada and Japan have created an international research network on “Justice and Environmental Law”. The purpose of the agreement is to coordinate scientific activities falling within justice and environment including organization of conferences, lectures, seminars, symposiums, theme-based workshops; encourage the exchange of Information and documentation on the scientific theme; identify common research projects; encourage permanent training initiatives and promote pedagogical operations.
- **Prediction of Air Pollution in Latin America (PAPILA).** This is a Marie Skłodowska-Curie Research and Innovation Staff Exchange project (H2020-MSCA-RISE-2017,777544, 2018-2022). This project aims at improving air quality forecasting for current and future conditions in Latin America, having Santiago as one of the pilot studies.
- **AEROSOL ROBOTIC NETWORK (AERONET).** The AERONET project is a federation of ground-based remote sensing aerosol networks established by NASA and PHOTONS (PHotométrie pour le Traitement Opérationnel de Normalisation Satellitaire; Univ. of Lille 1, CNES, and CNRS-INSU) and is greatly expanded by networks and collaborators from national agencies, institutes, universities, individual scientists, and partners. For more than 25 years, the project has provided long-term, continuous, and readily accessible public domain databases of aerosol optical, microphysical, and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases.
- **Justice and Environmental Law.** International Research Network to consolidate and deepen a fruitful cooperation between France, Brazil, Japan, and Chile. The above, considering the long-standing and well-established collaboration between their researchers in the field of environmental law, that gave rise to numerous researchers and professors crossed mobilities, to different workshops, seminars, and conferences, to join publications and co supervision of thesis. Centre National de la Recherche Scientifique, Aix-Marseille Université, Université de Pau et des Pays de L'Audour, The Université de Toulon, Université Laval, Universidades de Brasília, WASEDA University and Universidad de Chile.
- **Tropospheric Ozone Assessment Report, phase II 2020-2024.** TOAR-II is an activity of the International Global Atmospheric Chemistry Project (IGAC) developed by more than 200 experts from over 35 countries. The objective is to provide an up-to-date scientific assessment of the tropospheric ozone's global distribution and trends in the troposphere. Currently, a (CR)<sup>2</sup> researcher, Rodrigo Seguel, is serving as a member of the Steering Committee, contributing together with the community to develop scientific questions and analyses.

### 3.4. Outreach

Include here transfer or training activities that ties the Center with the external community such as elementary or high schools, institutions, companies, etc. Mention the local and national outcomes, impact and their indicators.


(CR)<sup>2</sup> devotes a significant effort in outreach, targeting multiple stakeholders and the general public but focusing on professionals in state agencies and private organizations, high-level policy makers and undergraduate and graduate students in universities. Outreach is undertaken and systematized by a dedicated communication team (four professionals) but nearly all researchers are involved in this effort, providing material, participating in media interviews and co-organizing events and forums. Complementing our seven National Reports, (CR)<sup>2</sup> has prepared more than 300 of "[Policy briefs](#)" and "[Analyses](#)" that address contingency scientific issues and seek to contribute to the adaptation and mitigation of climate change in Chile. The analysis began to be published as early as 2014 and now they totalize near 100, as seen in the next figure. Collectively they have attracted over 300.000 visits to our web site, and -in average- they are visited more than 3000 times. "[Climate capsules](#)" have also been a successful outreach product aimed at analyzing scientific concepts present in public discourse. Further, "[Constitutional bulletins](#)" have been developed to contribute to the constituent process on climate change issues. These documents are available on the (CR)<sup>2</sup> website. The presence in media and social networks has increased exponentially and can be seen in the statistics of annual press appearances from 2013 to date (over 400 per year).



#### a. Media publications

Press management is a key component of (CR)<sup>2</sup> communications team's daily work. Approximately, 2,500 press appearances were registered during the last five years: 79% correspond to publications in national media, while 11% are appearances in regional media. Another 11% corresponds to appearances in international media. Regarding the publication's formats, most of them were made on websites (72%), followed by 15% in print media. Appearances on television reached 7%, while on radio they represented 6%.

Comparing the four most popular press topics of each year from 2018 to 2022, "climate change" is the one that stands out. That's an outcome of the positioning strategy developed by (CR)<sup>2</sup> communications team, being one of its main objectives to establish (CR)<sup>2</sup> and its researchers as a reliable source of information on climate change related issues for news media and journalists.



Between 2018 and 2022, and in addition to “climate change”, the main topics of (CR)<sup>2</sup> press clipping were: “mega-drought”, “extreme weather events”, “water scarcity”, “forest fires” and “air pollution”. That reflects a generalized concern in Chile on climate change impacts and, also, how relevant are (CR)<sup>2</sup> Reports to the Nations to explain and address those issues. The designation of former (CR)<sup>2</sup> director Maisa Rojas as Chilean Ministry of the Environment was also a relevant topic in 2022 press clipping.

In recent years, new topics have emerged in the mass media coverage on climate change, like the “Climate Change Law” and the “Proposal for a new Chilean Constitution”, both being public policies needed to mitigate and adapt to climate change. “Climate Change Law” appears like a relevant topic because between 2020 and 2022 the legislative discussion to implement a Framework Law on Climate Change for Chile took place, and (CR)<sup>2</sup> was an active actor in that process. Also, during 2022 the environmental and climate change aspects of a new constitution were debated in national and foreign media, being the third most present press topic related to (CR)<sup>2</sup> (7%).


International events also had an impact on press issues related to (CR)<sup>2</sup>. For example, UNFCCC COP was the most relevant topic in 2019, and continued to be an important theme during 2021 and 2022 due to the active participation of (CR)<sup>2</sup> researchers in COP26 and COP27. The launch of the Sixth IPCC’s Assessment Report (AR6) was the second most relevant press topic for the center in 2021, having four (CR)<sup>2</sup> researchers as authors of the working groups I and II contributions to the report. (More details on press appearances can be found in the Annual Communications Annex).

#### **b. Outreach platforms**

- **Websites.** During the last five years, (CR)<sup>2</sup> has developed, designed and maintained several websites in addition to the (CR)<sup>2</sup> website in Spanish and English: The Climate Change Law Observatory Website, The RedLama website, the Climate Change and Low Carbon Resilient Development Diploma website, the (CR)<sup>2</sup> Summer School websites, and the International Conference on Climate Change Education websites.

Since 2018, (CR)<sup>2</sup> website had increased its numbers of visits, starting with 96,711 visits in 2018; 238,898 in 2019; 372,621 visits in 2020; 450,483 in 2021 and 417,845 visits to the website in 2022. A slight decrease can be seen between 2021 and 2022, that could be associated with the preference of audiences to consume content on social networks instead of websites.

- **Social networks.** (CR)<sup>2</sup> started its second period with two institutional social networks: Facebook and Twitter. In 2019 an Instagram account was created, and in 2020 content were developed for a LinkedIn account. In contrast to what happens with the website, social networks have maintained a sustained increase during the last five years. By now, the institutional LinkedIn account has the largest number of followers among all the (CR)<sup>2</sup> social networks, reaching 12,939 followers at the end of 2022. That’s 43% followers more than 2021. Twitter is the second most important social network for (CR)<sup>2</sup>, with 11,668 followers by 2022 (in 2018, the account had 3,452 followers). Regarding Instagram, the institutional account reached 10,377 followers in 2022. In 2019 it had 1,761 followers and that number increased to 5,029 in 2020 and to 7,553 followers in 2021. Finally, (CR)<sup>2</sup> Facebook page started the five years period with 4,333 followers that increased to 9,005 in 2022. (More details on websites and social media can be found in the Annual Communications Annex).



c. **Outreach products** (All available on [www.cr2.cl](http://www.cr2.cl), under the “Divulgación” tab)

- **Policy briefs.** One of (CR)2 signature products are policy briefs. They are aimed to offer national public policy recommendations based on scientific papers and research carried out by the center. The most read policy brief in (CR)2 website is “The impact of native forest and forest plantations on the water supply in Chile” published in 2019 (5,867 visits), followed by “Water crisis in the Petorca basin: a combination of mega-drought and water management” published in 2020 (1,999 visits) and “Water rights in Chile: A discordant look at natural processes” also from 2020 (1,586 visits). Some of (CR)2 policy briefs are available in the National Congress Library website, which is a source of information for the Chilean Senate and the House of Representatives and other policymakers as well.

- **Analyses.** This product is focused on reaching academic audiences, but it does not exclude other audiences like policymakers and the general public. Its goal is to deepen into current phenomena on social and exact sciences, mainly happening in a national level. Since 2018 we have produced 75 analyses with more than 240 thousand visits on the web. The most read analysis is “River water is not lost when it reaches the sea” published in 2020 (9,290 visits), followed by “Chilean Altiplano: When it rains, it pours” also from 2020 (7,462 visits), and “A winter storm in the middle of summer? Understanding the extraordinary event of late January 2021 in central Chile” published in 2021 (3,674 visits). Like policy briefs, some of (CR)2 analyses are available on the National Congress Library website.


- **Constitutional bulletins.** As part of the dissemination actions of the Governance of the Elements Report to the Nations, constitutional bulletins were created in 2021 and 2022. They reflect relevant issues for the proposal of a new Chilean constitution and delivered recommendations for their incorporation. The most read bulletin was “Climate governance of river basins. Proposals for the New Constitution” published in January 2022 (709 visits), followed by “The climate emergency” published in 2021 (627 visits) and “Climate Governance of the Elements: A proposal on the current national institutionalism of climate change” also from 2021 (420 visits).

- **Climate capsules.** The climate capsules are products aimed to social media and web audiences. Their objective is to clarify, using a few words and appealing graphics, scientific concepts that are present in mass media and public opinion. Sometimes, these concepts are misused and can confuse people. The most read climate capsules were all published in 2019: “What is decarbonization?” (20,923 visits), “What happens in Chile, drought or water scarcity?” (11,678 visits) and “Is the water that reaches the sea lost?” (9,945 visits)

- **Infographics.** Infographics developed by (CR)2 communications team summarize relevant information on papers and research carried out by the center, and on the Reports to the Nations. Visuals are attractive to younger audiences and to social media followers and have educational potential. More than 10,000 visits to the “Infographics” section are registered in (CR)2 website and they are one of the most shared contents in (CR)2’s Twitter and Instagram accounts.

- **Scientific papers brochures.** This product is specially designed for social networks and consists of a series of images and posts (Twitter threads, Instagram cards, for example) that explain a relevant aspect of a scientific paper from a (CR)2 researcher. Between 2021 and 2022, eight brochures were developed on topics like climate governance, heat-waves, Antarctic research, among others.

- **(CR)2 tales.** This new product is aimed to engage younger audiences on scientific research. “Ofelia: Lost in the greenery” was written by José Barraza, (CR)2 scientific disseminator, based on a research on the browning trends of the Mediterranean sclerophyllous forests of central Chile (Miranda et al., 2020).



- **Videos.** Five videos have been developed during the last five years as part of the dissemination strategy of each of the Reports to The Nations. These are brief animation videos (1-2 minutes) aimed to younger and social media audiences. (CR)2 has presented the videos in different platforms, as Metro stations in Santiago (public subway transportation system), and public TV channels like Educa TV and UChile TV, and education websites like Tantaku, among others. Also, they are key materials to science fairs and other outreach activities aimed at students. The most watched video in (CR)2 Youtube channel is the one on the Anthropocene (22,869 views). The video on the Chilean mega-drought holds the fourth place and the video on forest fires reached the fifth place.

- **Rocadictos.** “Rocadictos” is a joint initiative of the University of Chile Radio, the Geology Department, and the Geophysics Department of the University of Chile, and (CR)2 to promote earth sciences in mass audiences. The radio program started in 2019 with Macarena Troncoso as panelist and Michelle Ferrer as part of the editorial team. Cecilia Ibarra replaced Macarena in 2022 as panelist. The show had different (CR)2 researchers as guests, talking about different issues like climate change, meteorology, oceanography, climate governance, among diverse topics.

The most relevant outreach products are translated into English, such as policy briefs, climate capsules, constitutional bulletins, and some analyses. These products, in addition to the translations of the Reports to the Nations, are available on (CR)2 English website.

#### **d. Outreach activities**

(CR)<sup>2</sup> has organized, co-organized and participated in approximately 700 outreach activities in the last five years, including seminars, webinars, conferences, science fairs and other events aimed to impact society. Some of these activities are highlighted below:


- **Launch of the Reports to the Nations.** Five Reports to the Nations have been launched from 2018 to 2022: Anthropocene, Forest Fires, Air Pollution, Governance of the Elements and Harmful Algal Blooms. With each report, and in addition to a launch event, different products are created to reach specific audiences such as policymakers, social media audiences, local communities, among others. These products include videos, infographics, climate capsules, policy briefs, seminars and others that have been described in the “Outreach products” section.

- **COPs side-events.** Since 2013, (CR)2 has actively participated in the UNFCCC COPs. In the last five years, some of the highlights have been the organization of four side-events and the participation of researchers in 18 events at COP25 in Madrid (2019), and the organization of eight side-events at COP27 in Sharm el-Sheikh (2022) with participation as speakers of nine researchers from the center. These events are opportunities to establish relationships with global institutions, international decision makers, and other relevant actors for (CR)2 international projection.

- **International Conference on Climate Change Education (CIECC).** This initiative was born in 2019 as a joint project from the University of Chile, (CR)2, CIAE, the Office for Climate Education from France, UNESCO, and Siemens Stiftung, among other institutions that joined the organization team during the years. Its main objective is to strengthen climate change education in the Latin American region, offering a space for educators to share their teaching and learning experiences. Four versions of the conference have been held, with a participation of (CR)2 researchers as speakers and as part of the organization team.

- **Seminars and webinars.** As part of the dissemination actions of (CR)2, numerous seminars and webinars have been held to address the center's research topics. Among the events held, are highlighted: the “Science for evidence-based decision-making” webinar cycle started in 2022, the “Mega-drought economic





assessment" webinar series held in 2021, the ARClim seminars for mass audiences and public service officials held in 2020 and 2021, the cycle of webinars "Social laboratory for the community construction of constitutional bases for a resilient society to climate change: a perspective from Patagonia" that sought to discuss the incorporation of climate change in the proposal for new Chilean Constitution with a focus on the Magallanes region, the webinar series "Science with impact for the development and resilience of coastal zones" in 2021 organized by the FONDAP centers CIGIDEN, (CR)2, CEDEUS, and SECOS Millennium Institute to provide a scientific, institutional, and political view of disaster risk management, adaptation, and local governance in coastal areas, and the "Launch of (CR)2 Climatic Services Platforms and Databases" in 2018 focusing on supporting climate change public policies. Four platforms were presented: "Climate Visualizer", "Weather Visualizer", "Climate Simulations Platform for Continental Chile" and "The Catchment attributes and meteorology for large sample studies – Chile dataset" (CAMELS-CL).

- **Presentation of results of the study on atmospheric pollutants in Quintero.** During the second week of October 2022, three seminars were held to present the results of the project "Study of atmospheric pollutants, determinants and impacts in the Quintero-Puchuncaví Bay" to the Quintero community. These activities were crucial to develop a relationship of trust with the community that has historically been neglected by the authorities in one of the most recognized "sacrifice zones" in Chile.

- **Science fairs and Lollapalooza 2018.** (CR)2 has participated in every year's version of the Science Week of the Ministry of Science and also in the biannual science fairs of the Faculty of Physical and Mathematical Sciences of the University of Chile. These events are aimed to elementary and high school students. In 2018, the center participated at the 8th edition of Lollapalooza Chile, within the framework of the "Green Village", a space that seeks to inform, raise awareness and provide alternatives to festival attendees, so that they can change habits and make more responsible consumption decisions. Lollapalooza Chile brought together more than 250 thousand people in three days.



### 3.5. Contribution to public policies


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

While the ultimate goal of a research center is to generate knowledge, (CR)<sup>2</sup> has done so with two distinctive elements: an interdisciplinary approach and continuous communications with stakeholders. Since we focus on large, complex climate-related and resilience questions, many of our results are of direct interest to national and regional public agencies (e.g., Ministry of Environment and Municipalities). In aggregated form, **(CR)<sup>2</sup> has made substantial contributions to public policy** in areas of climate-related hazard, mitigation, adaptation and resilience. First and foremost, after conducting a project on the need and feasibility of a climate change law in Chile, the Chilean Ministry of the Environment (MMA) announced the start of legislative processing of the framework law on climate change. The **GovSPI** team accompanied this legislative discussion process, with the creation of the *Climate Change Law Observatory* in Chile and participation in the technical table of the Senate Environment Commission. This law was signed by the government last year. Moreover, the recommendations contained in our last National Report (climate governance of the elements) made their way into the Constitutional Convention, which concluded with the consecration in the draft text of the principle of fair climate action, the recognition of the climate and ecological crisis, and the duty of the state to develop public mitigation and adaptation policies. The final text of the new constitution was rejected in a national referendum but a new process is underway and many of the ideas around environmental issues, including coping with climate change, are likely to be preserved.

Our researchers also co-chaired the land-use group on the scientific evidence for the design of NDCs presented by Chile to COP25, clarifying the role of the ocean, forest and peatlands in carbon sequestration. Additional scientific evidence developed by researchers from different (CR)<sup>2</sup> research lines has been presented to recommend the diversification of climate action away from forest plantations from a nature-based solutions (NbS), considering native forests, wetlands, peatlands and oceans. A series of recommendations were made by working groups and scientific committees in the context of the organization of the COP25 in 2019. In particular, a proposal for an Integrated Ocean Observing System, crucial for the monitoring of the ocean in the context of climate change.

We next offer a synthesis of the many collaborations and specific activities aimed at strengthening public policies assisting our country's goals of achieving low-carbon, sustainable development consistent with the Paris Agreement, and developing societal resilience to climate-related hazards in Chile:


- **Technical advice to the Draft Framework Law on Climate Change.** Three researchers from the center participated in the Technical Board that reviewed 847 indications during the First Constitutional Procedure of the project. Specifically, during the processing in the Senate Committee on the Environment and National Assets, which took place between July 2020 and August 2021, and which was approved practically unanimously in October 2021. Among the main improvements to the project are the strengthening of principles such as an ecosystem approach, climate equity and justice, transparency and citizen participation, climate management at the regional and municipal level, financial instruments, among others.
- **Project of Development and implementation of an institutional strengthening and capacity-building program at the subnational level, in the context of the preparation of the Climate Strategy for Resilient Development and Low Emissions by 2050.** Initiative that regards the role and challenges of regional governments in the development of public policy on climate change by 2050, in connection with national and local authorities. The purpose is to identify: The main issues



of concern for each region, in terms of mitigation and adaptation; the capacities they have; and the main barriers to fulfill the tasks entrusted in the current draft Framework Law on Climate Change (PLMCC), in particular in the preparation of regional climate change plans. For more details, see section 3.2.

- **IPCC sixth assessment cycle:** Four researchers (Maisa Rojas, Laura Gallardo, Paulina Aldunce, Laura Ramajo) have been strongly engaged in the recent IPCC process, contributing as authors to chapters in contributions of Working Groups I and II to the IPCC Sixth Assessment Report (AR6). Additionally, five researchers (Martin Jacques, Fabrice Lambert, Catalina Aguirre, Eugenia Gayo and Marco Billi) have served as delegates of the Chilean government to IPCC during the approval process of the Summary for Policymakers of the AR6. Their participation was ratified by the Chilean Ministry of Environment and the IPCC Secretariat.
- **Chilean Science Committee on Climate Change (Comité científico):** In 2019, the Cr2 led this advisory body to the Ministry of Science, Technology, Knowledge and Innovation in the areas of climate change to link the national scientific community with the challenges of the organization of COP25. It was presided by Maisa Rojas, and other two researchers coordinated cross-cutting working groups on Oceans (Laura Farias) and Adaptation (Paulina Aldunce). This committee has continued well-beyond the COP25, and CR2 researchers (Anahí Urquiza, Laura Fariás) are still active members engaged in making available scientific evidence on climate change in Chile for decision-makers.
- **Advice to Municipality of Quintero on AQ issues.** This collaboration (FONDEQUIP projects) has aimed to carry out monitoring campaigns, to characterize the air quality in Quintero Puchuncaví Bay and to strengthen the alliance through the exchange of capacities, experiences, information, and tools, with a view to generating greater scientific evidence on air quality in this so-called sacrifice zone (in terms of volatile organic compounds, trace metals, among other pollutants), ensuring a synergistic approach between scientific information and the design of public policies.
- **Support to GORE of Magallanes (Regional Government).** The Regional Government of the Magallanes Region has requested (CR)2 support for the preparation of the National Development Strategy, which consists of the development of a climate governance model for the Magallanes Region, around the concept of "Climate Refuge", which is transversal to the strategy and in a binational perspective (Tierra del Fuego and Patagonia). This alliance has sought to strengthen the collaboration through the exchange of capacities, experiences, information, and tools, with a view to strengthening the monitoring, reporting and verification of the Regional Government, the preparation of annual compliance indicators and evaluation, for the Environment (MMA).
- **Advice to IFOP ("Fisheries Development Institute").** This collaboration has sought to raise and integrate information, scientific research, knowledge spreading/dissemination and researcher training, particularly in aspects related to the coastal zone, oceanography, climatology and, in particular, harmful algae blooms, and their relationship with climate variability, and impacts, vulnerability and adaptation to climate change.
- **Advice to The Ministry of National Defense.** Through the Undersecretariat for the Armed Forces (SS.FF.AA.), resolved to update the National Policy for the Use of the Coastal Zone, for which it requested support from (CR)<sup>2</sup> in the methodological design for updating said public policy. In the proposal were included subjects about climate change and disaster reduction, among others.

- **Public consultation on the regulation of projects of pollutant emission reductions.** (CR)<sup>2</sup> participated in the public consultation on the regulation that establishes the obligations and procedures related to the evaluation, verification, and certification of projects of pollutant emission reductions to offset taxed emissions.
- **Public consultation about the Long-Term Climate Strategy.** (CR)<sup>2</sup> participated in this public consultation. Along this same line, Maisa Rojas and Andrea Rudnick participated in the Advisory Committee for Climate Action of the Ministry of the Environment (MMA), instance in which the MMA was advised on the instrument development processes for climate change management.
- **Development of Atlas of Climate Risks for Chile (ARClim).** Mandated by the Ministry of Environment and financed by GIZ Germany and jointly developed by the Global Change Centre of the Universidad Católica de Chile. This project included the analysis of climate and environmental threats for 12 priority sectors of the country to support development of public policies based on information on climate impacts and risks, exposure and sensitivity of different sectors to municipal level.
- **Advice to Senate Joint Committee on the Environment and National Assets.** (CR)<sup>2</sup>, in 2020, received the invitation from the Senate Joint Committee on the Environment and National Assets to serve as scientific advisers in the review of the observations received from Chilean senators to the draft Framework Law on Climate Change, analyzing the 847 indications made by the senators and the Government with the support of experts from the center. The president of the Commission indicated that the experts were able to participate in all sessions, saying: *“The important thing is that we have a technical and scientific reference in this matter to have coherence, independent of the political positions that we will manifest as a government, opposition or as a bloc, so as not to fall into contradictions”*. During the sessions with the parliamentary advisers and the sessions with the senators, innumerable recommendations from (CR)<sup>2</sup> were accepted. All sessions were transmitted live via the Senate Television Channel. It is a clear recognition of (CR)<sup>2</sup> status of the most authoritative institutions in the country in climate change, trusted by all parties to give technical and impartial assistance to all parties involved in the discussion.
- **Advice to National Forestry Corporation (CONAF) from the Ministry of Agriculture.** As a result of the research carried out under the integrative theme Changing fire regimes, an approach was made to the CONAF authorities, to the CONAF Forest Fire Protection Manager to identify opportunities for collaboration. In September 2020, a virtual workshop was held between CONAF and (CR)<sup>2</sup>, whose objective was to exchange experiences regarding the work that both institutions are currently carrying out in relation to forest fire prevention. As a result of the workshop, both institutions agreed on the need to initiate a formal collaboration process.
- **Advice to Ministry of Science, Knowledge, Technology, and Innovation.** In July 2020, (CR)<sup>2</sup> provided comments to the public consultation of the Policy of Open Access to Scientific Information and Research Data of the National Research and Development Agency (ANID).
- **Advice to Ministry of Agriculture.** In March 2020, the Chilean Comptroller's Office declared native forest management plans illegal to conduct large scale clear cuts to develop agricultural crops (especially avocado plantations), because among other things these plans went in the opposite direction to the Native Forest Law, which sought to recover and protect these types of



ecosystems. However, the National Agricultural Society presented a protection appeal arguing that the agricultural crops had the same and even more socio-environmental benefits than native vegetation. Given this context, Ariel Muñoz and Duncan Christie from (CR)<sup>2</sup> led a valuable work to face the problem of the elimination of native forest on the slopes of hills of central Chile, by presenting scientific evidence arguing the multiple ecosystem goods and services that supports these ecosystems. They developed a scientific report that summons 76 scientists (of which 10 were at (CR)<sup>2</sup>) and that contains solid evidence about the value of these ecosystems. Also, Muñoz, Christie and 9 other scientists became part of the cause to support the Chilean Comptroller, being represented by lawyers from the NGO FIMA. The scientific report was presented in the form of third-party contributors supporting the opinion of the Comptroller's Office and rejecting the SNA Protection Appeal. During December 2020, the court rejected the protection appeal of the National Agricultural Society and supported the original pronouncement from the Chilean Comptroller's Office.

- **Regional climatic simulations for the Antarctic continent and Chilean island territory project.** Through high spatial resolution climate projections, this project, mandated by the Ministry of Environment, analyzed the impact of climate variability on temperature, precipitation and melting of the ice surface in the Chilean Antarctic territory. In parallel, the study establishes the variation of precipitation and temperature for Rapa Nui and the Juan Fernández Archipelago towards the end of the century. The relevance of these territories lies, in the case of Antarctica, that it greatly influences the regulation of the climate of Chile and the planet. The increase in temperature and precipitation projected in the study affects the amount of ice that melts contributing to the increase in sea level, increasing the risk of flooding the coasts in the long term. On the other hand, the Chilean island territory presents different conditions to the continental territory, with different biodiversity, climate and soil characteristics, where specific plans are required. An interactive platform was designed to support the design of public policies and allow the creation of adaptation and mitigation plans consistent with future climate variations.
- **Black carbon mitigation in the update of Chile's nationally determined contribution.** The Ministry of Environment, through the United Nations Environmental Program, requested (CR)<sup>2</sup> to establish mitigation scenarios for black carbon consistent with the overall greenhouse gas mitigation efforts to be carried out by the country. In this work, mitigation measures for long-lived greenhouse gases were evaluated in terms of their potential for reducing black carbon over the period 2010-2050, using the analysis framework of the Long-Range Energy Alternatives Planning System – Integrated Benefits Calculator (LEAP-IBC). The final report was delivered early 2020.



#### IV. OTHER RELEVANT ASPECTS

Analyze the effects that the creation of the Center produced on:

- ✓ **Modifications in the originally proposed research activities**, including changes in parameters like: quantity and quality of publications, development of new research areas, anticipated termination of initially proposed research goals, and achievement of variable degrees of successful multidisciplinary work in the different research lines, among others.
- ✓ The **problems** that could not be addressed.
- ✓ **Main constraints** to reach the proposed research goals.


##### *a. Modifications to the original proposed activities*

As commented in the executive summary and result of the second five-year period (sections II and III), the dedicated effort of our researchers, support staff and students made possible that **(CR)<sup>2</sup> became a well-recognized national leader an international reference in climate and resilience research** by both producing high-quality disciplinary studies and developing novel interdisciplinary modes of research and collaboration, inside and outside the center. Based on research, (CR)<sup>2</sup> has informed and contributed to the management and public policies in the fields of climate change mitigation and adaptation, reached out the general public, trained students at under and post graduate levels, and established strong alliances with other research groups and networks in Chile and abroad.

Given its size (ca 60 researchers, 15 support staff and dozens of students) and broad objectives, our center has undergone some minor transformations during the last decade. In terms of organization, the most important change was in the transition from the first to second 5-year periods, when we change our research lines (**RL**) to Water Extremes (WEx; formerly Climate Dynamics), Coastal Zones (CZ, formerly Biogeochemistry), Land Use Change (LUC, formerly Ecosystem Services), Governance and Science-Policy Interface (GovSPI, formerly Human Dimension) and Resilient Cities (RC). The new **RL** are more interdisciplinary in composition and focus on more tangible problems relative to the initial lines. Equally important, the whole center was committed to tackle large, relevant climate-related problems in Chile, by selecting integrative questions investigated in depth during about two years each. These integrative questions included the past, present and future air pollution problems of Chile (2018), an anticipatory, socio-ecosystemic and evidence-based climate governance of the elements water, air, fire and land, Harmful Algal Blooms (2022), which is a global problem with local manifestations, and water scarcity & security in Chile (2023). These questions have underpinned much of the interdisciplinary work that became a seal of our center, along with the broad outreach that we did on them, including the Reports to the Nation, policy briefs and analysis. The collaborative work of researchers and the support teams (communications, transdisciplinary, computing, education) was the key for success in this five-year period, none of which was envisioned at the beginning of (CR)<sup>2</sup>.

One of the broad questions stated during the center creation was scarcity and variability of water in norther-central Chile. This issue moved its geographical focus to south-central Chile for two reasons. Northern Chile is a hyper-arid region (including the Atacama Desert) that has deal with water scarcity for all its history (and pre-history), and where climate change can't decrease water resources any lower. The real problem there is allocation of scarce water resources, given their intensive use for mining. By the contrary, southern Chile (35-45°S) has a temperate, humid climate, and we have shown (Boisier et al. 2018) that is here where the drying trend is clearer and more connected to climate change. The historically abundant resources there somehow augmented its vulnerability to droughts given the lack of water management experiences and infrastructure. In between these two regions, central Chile (32-36°S) is where most of the population is concentrated and has received the direct impact of the Mega Drought (2010-present) jeopardizing the moderate to low water resources for the humans, environment and economic sectors.





Another unforeseen experience during (CR)2 was that technological approach and solutions have a limit in efficiency. This was hinted during our study on the air pollution in Chile (Hunneus et al. 2020). The change in fuel quality and stringent restriction to the vehicles had a major success in reducing particulate matter in Santiago, Chile's capital. But further improvements seem to require socio-cultural behaviors in the way people move around the city. Even more clear is the situation in southern Chile where most air pollution comes from residential sources because the use of coal and other fuels, with profoundly cultural and economic roots. Likewise, the report on governance of the elements illuminated that they require a holistic view rather than separate approaches.

*b. Main constraints to reach research goals.*

Most of our goals were reached with the available resources (people, data, computing) but we can mention a few examples where external factors hinder our advance:

- Biophysical observations in Chile are abundant but highly disperse and often with no meta-data. That requires substantial work from (CR)2 in systematizing different datasets. This problem eventually became an opportunity and many of our newly assembled datasets were made public in web-based platforms that have given enormous visibility to our center (e.g, the Chilean Climate Explorer).
- The same applies (and is exacerbated) for socio-economic datasets and observations, hindering our assessment of adaptation and resilience efforts. Much of this came in evidence during our analysis of the economic impacts of the Central Chile Mega Drought.
- A key missing dataset is the level of underground water in Chile. The Ministry of Public Work has hundreds of observation wells, but the continuity and quality of this data is questionable. We are doing an effort to construct a robust dataset of ground water in Chile which is utterly important as this resource is buffering the reduction of surface water during the megadrought (specially for agriculture and potable water) but with an uncertain future.
- During the last few years our efforts have focused on climate-related extreme events. By definition, these events have a long recurring period (once in a decade or so) rendering them hard to detect and characterize in records spanning a few decades. Consider, for instance, the hyper drought -years with more than 70% rainfall deficit- observed in central Chile during 1924, 1968, 1998, 2019 and 2021. Very few biophysical and almost no socio-economic data is available for the first events in the 20<sup>th</sup> century.
- Lastly, our center lacks earth-system models. These models couple atmosphere, hydrosphere, biosphere, and eventually social aspects, and allow to test hypothesis on grand questions. A few international centers do have this capability, and we plan to access them in the future.

*c. Unexpected difficulties*

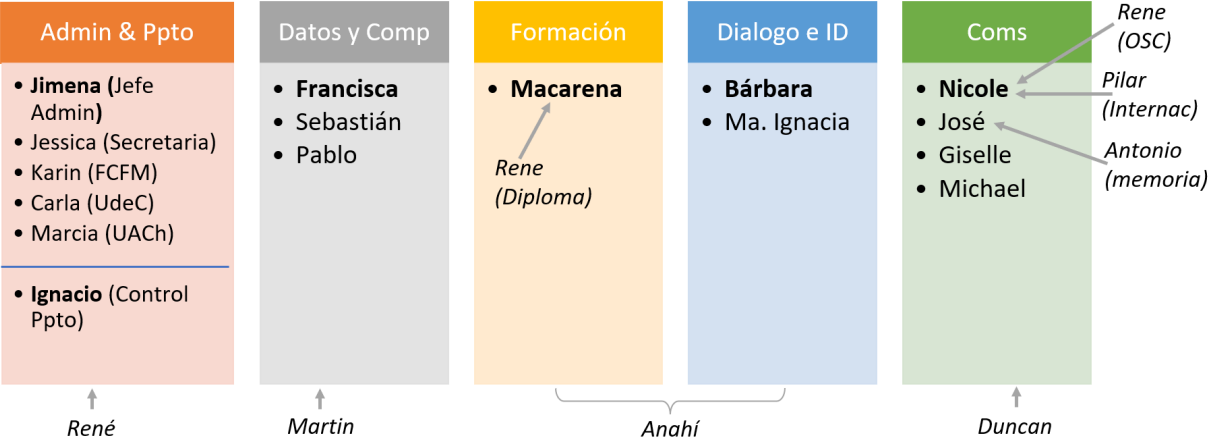
The National Research and Development Agency (ANID) has not confirmed the continuity of the program or its priority areas. Nor has ANID carried out an evaluation that allows the country to assess the impacts of a scientific policy that is already a decade old, in order to strengthen those positive aspects and improve the dimensions that require adjustments.

The uncertainty of continuity of the program has been kept since 2020 and to date no itinerary of the FONDAP program has been anticipated or published. In the first semester of 2022 there was a tender for a 1-year bridge financing, which would allow the FONDAP centers to continue their operation during the

year 2023, while the priority areas and the continuity of the program are defined. Although the spirit of (CR)2 is to continue carrying out research excellence with a long-term perspective, this scenario generates questioning within the members of the center and makes it a priority to search for other funds/financing to achieve the permanence of the institution. We are not waiting for a second bridge project.

In October 2021, Andrea Rudnick, who was Executive Director of the center since 2018, rendered her resignation to embark on a new job challenge. Although this news generated an impact in the team, the activities and initiatives have continued their normal course. To face this change, Susana Bustos, a Civil Engineer by profession, was appointed as Acting Executive Director, who since 2015 has worked in various areas of the center (budget management, coordination of national and international projects, generation of indicators, etc.). At the same time, Ignacio Ruz, Industrial Civil Engineer, has been hired, who will support various tasks during the transition period. A tender is expected to be made to cover the position during the first quarter of 2022.

Unfortunately, Mrs. Susana Bustos took a sabbatical year in 2023. We are operating with no executive director, which puts more pressure on the PI board and especially the Director, which are now more connected with the day-to-day demands of the center.





## V. CENTER PROJECTIONS

Analyze the Center projections after 10 years of funding.

We live in a time when manifestations of climate change are evident at global and regional scales, involving the slow change in climate conditions but also -and more problematic- an increased occurrence of climate extreme that trigger socio-environmental catastrophes. In the case of Chile, for instance, we entered into a new regime of forest fires (with megafires burning > 100.000 ha not seen before), in part due to extreme weather and the sclerophyllous forest was at the brink of collapse after hyper droughts (within the megadrought!) in 2019 and 2021. Both, the gradual changes and adverse episodes have an enormous impact in our country, whose economy largely relies on the exploitation of natural, climate-sensitivity resources (agriculture, mining, aquaculture) and where large portion of the population lives in socio-economic conditions that made them particularly vulnerable to climate-related hazard. In this context, there are formidable and pressing questions: How regional climate change will unfold in the decades to come? how effective the current adaptation/transformation measures are? and how the country can advance in mitigation, following the just climate action?

Over the last decade, the dedicated and talented effort of our researchers, support staff and students made possible that (CR)<sup>2</sup> became a well-recognized national leader an international reference in climate and resilience research, addressing the aforementioned grand questions. Based on interdisciplinary research, (CR)<sup>2</sup> has informed and contributed to the management and public policies in the fields of climate change mitigation and adaptation and reached out to the general public. Nonetheless, many questions need to be revisited and new questions have arisen, especially on changes of climate-driven extreme environmental events (e.g., mega fires, HABS, coastal extremes among others), as well as governance and social response to these events.

Given the scientific success of (CR)<sup>2</sup> in its first decade, the human/technical capacity built within and around the center and the complex, grand challenges that our country faces (climate wise at least!), it is quite reasonable that the center should continue in the next decade. No less important is the high esteem that our center has gained in the academia, political and social sphere in Chile along with increasing international recognition.

Projecting the (CR)<sup>2</sup> for the next decade is a major task that is being tackled collectively by a group of 15 researchers from all RIs (**the renovation committee**), with participation and full support from our staff and PIs. The work of this committee began in early 2022 and deliver an all-embracing proposal in early 2023. To do so, the committee maintained regular meetings with the full center, other academic units in Chile and abroad, and stakeholders of the public and private sector. We believe this ample and in-depth discussion of research initiatives and priorities (within and outside the center) was an effective way to innovate and increase the new capacities of the (CR)<sup>2</sup>. The **renovation guidelines** are confidential but, given the need for a research center devoted to study the specifics of the climate/earth system in Chile (and beyond) and to inform public policy on adaptation and mitigation measures for building societal resilience, it seeks to maintain most of our research group during the next decade. While keeping some of the (CR)<sup>2</sup> pillars, emerging and relevant topics were identified, new geographical areas were targeted, and novel tools, methods and collaborations were committed.

Unfortunately, to date, the continuity of the FONDAP program for large, long-standing Centers of Excellence is still under a high level of uncertainty, and we are currently transiting “bridge projects” that allow us to keep the center but not fully project (CR)<sup>2</sup> for the next decade. We are ready though!



## VI. FULFILLMENT OF THE INSTITUTIONAL COMMITMENT

Describe the support received by the hosting Institution such as physical space, funds, personnel (including hiring), scholarships, and contributions to the doctoral program.

All institutions made their financial contributions on time, and according to the agreements. All the (CR)2 support units are located in the Geophysics Department (DGF), Facultad de Ciencias Físicas y Matemáticas (FCFM), Universidad de Chile, in Santiago, Chile. The three directors of the center (Gallardo, Rojas, Garreaud) are professors at this department, and have their office there. The DGF has all the facilities and space to host the administration and support teams of (CR)2. Some of the DGF technical staff also support CR2 activities, especially regarding instrumentation and field work. The FCFM also provides a general project unit and a legal area to support the center's administration and centralize all the purchases, contracts and tenders involving the center. The DGF also hosts many postdocs and students from Water and Extreme. Last year, two of our full-time researchers were hired as affiliated professors at DGF.

Moreover, the FCFM has large computing facilities, including a central storage and supercomputer (Leftratus) in the National Laboratory for High Performance Computing ([NHLPC](#)). This laboratory hosts many of our computers, platforms and web services, providing a robust infrastructure for the (CR)2 needs in data and computing.

Most researchers at Governance and Public Policy as well as Resilient Cities are professors at Facultad de Derecho (Law School), Facultad de Arquitectura y Urbanismo and Facultad de Ciencias Agrarias, Universidad de Chile. These units provide office space and laboratories for our affiliated researchers and students.

In a similar manner, Universidad Austral de Chile (UACH) supports many of the researchers in Land Use Change and Universidad de Concepción (UdeC) supports many of the researchers in Coastal Zones. In all these places there is excellent collaboration and synergy between (CR)2 affiliated, students and the rest of the faculty, as we all understand that (CR)2 uses resources but also provides a wealth of knowledge, instrumentation and academic opportunities beyond the center personnel.



## VII. ADVISORY COMMITTEE

Indicate the way in which the committee contributed to the development of the Center. Discuss the most relevant problems found in carrying out this endeavor.

During both funding cycles (CR)<sup>2</sup> has been accompanied by an international and national advisory panel. They have advised us in many areas, including the strengthening of scientific cooperation networks, diversifying funding sources, consolidation as an internationally recognized climate and resilience research center. The annual results and strategic plans (bi or triennial) have been evaluated by the panels and helpful comments have been received by the Principal Investigators of the center. Panels members are regularly invited and -time permitting- participate in the center's annual meetings. The exception was during the pandemic period, in which we met with them virtually.

The process of electing the new members of the national and international advisory panel was done in a collegiate manner within the academic committee of the center. Names were proposed by each principal investigator, and then a process of discussion of the most suitable names for the center was carried out, considering the agreed mission and vision, and positioning strategy of the center. In the case of the national advisory panel, a balance was sought between representatives of the public sector, private sector, academia, and civil society. In the case of the international advisory panel, a balance was sought between the various scientific specialties of the center, together with a greater representation of Latin American experts. In both cases a gender balance was sought.

The current members of the National panel are Bárbara Saavedra (Director of the Wildlife Conservation Society (WCS) in Chile); Juan Carlos Aravena (Director of the GAIA Antarctic Research Center); María Luisa Méndez (Director of Centro de Estudios de Conflicto y Cohesión Social - COES), Rafael Palacios (Executive Vice-President of Asociación Chilena de Desalinización (ACADES), Strategy and Public Opinion Manager CADEM); and Carolina Urmeneta (Director of Circular Economy, Global Methane Hub). They have served on the panel since 2018.

The current members of the international panel are Mónica Araya (Climate Champions Team COP26, Costa Rica); François Gemenne (Université de Liège, Belgium); Karen O'Brien (University of Oslo, Norway); Alexandra D. Syphard (Chief scientist, Vertus Wildfire Insurance Services, United States); Ken Takahashi (IGP, Perú); Carolina Vera (Universidad de Buenos Aires, Argentina). They have served on the panel since 2018.

One of the important points that have been highlighted by the panels is the level of incidence reached by the center, its role in the effort to make open and integrated databases available, the space for dialogue and well-being that is perceived within the center, which provides favorable conditions to achieve the transition from monodiscipline to interdiscipline. Furthermore, the potential and need to move towards transdiscipline and respond to the challenge of promoting science transformation processes in Chile have been highlighted.

It is also suggested to integrate science into neighborhoods and communities, which would allow for profound transformations in civil society; and along the same line, in order to involve different actors, the need arises to provide public institutions with advanced human capital, that can monitor progress in the different territories, as another relevant point.

## VIII. PRODUCTS GENERATED BY THE PROJECT

Using the ANID Center Reporting System list all Center publications, congress and seminar presentations, courses, materials and other activities of dissemination during the funding period taking into account the following:


REPORT ONLY PUBLISHED MATERIAL (Except for books, all backup documents must be uploaded in the CONICYT center reporting system. Only publications that acknowledge the FONDAP program will be considered).


**PLEASE NOTE:** The number of products generated by (CR)2 is very large. For instance, even considering the last five years we have more than 500 ISI publications. All of them, including their DOI links, are freely available at <https://servicios.conicyt.cl/centros/> Furthermore, previous reports list the products generated in each year (until 2021). **In sake of space and following previous reports, here we only list the products generated during the last year (2022).**


### 8.1. ISI Publications. (2022 only!)

1. Barret M, Gandois L, Thalasso F, et al. A combined microbial and biogeochemical dataset from high-latitude ecosystems with respect to methane cycle. *Sci Data*. 2022;9(1):674. doi:10.1038/s41597-022-01759-8
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#### 8.4. Patents N/A


- ✓ Include all patents generated by the FONDAP Center.

#### 8.5. Congress presentations (2022 only)

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


*Event; City-Country, Presentation name; Reseacher; Dates*

1. THE ECONOMICS OF THE CIRCULAR ECONOMY TRANSITION, Chile, Santiago/Zoom, ""Impacts in Chile of a Transition to Green Copper"", roryan, 2022-12-05 0. 2022-12-05 00:00
2. XXVIII Reunión anual Sociedad de Ecología de Chile. , Chile, Pucón, Evaluación de la efectividad de herbicidas para la eliminación de Pinus radiata D. Don., en el contexto de la restauración de bosques nativos en la precordillera de Nahuelbuta, Chile., alara, 2022-12-05 0. 2022-12-07 00:00
3. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Impactos de la sequía en bosques y ríos de la transición semiárida-mediterránea en Chile central , amunoz, 2022-12-03 0. 2022-12-05 00:00
4. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Reconstruyendo crecidas de ríos de Chile central a partir de anillos de crecimiento de árboles , amunoz, 2022-12-03 0. 2022-12-05 00:00
5. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Potencial de nuevas especies para estudios dendrocronológicos en Chile central, amunoz, 2022-12-03 0. 2022-12-05 00:00
6. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Respuesta del bosque esclerófilo a la hipersequía del año 2019 utilizando diferentes metodologías retrospectivas, amunoz, 2022-12-03 0. 2022-12-05 00:00
7. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Influencia de la variabilidad climática local y cobertura nieve en el crecimiento radial de los bosques esclerófilos de altura, amunoz, 2022-12-03 0. 2022-12-05 00:00
8. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Respuesta de crecimiento de Beilschmiedia miersii frente a eventos de sequía extrema., amunoz, 2022-12-03 0. 2022-12-05 00:00
9. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Patrón de anillos de crecimiento blancos en árboles de Araucaria araucana: resultados preliminares, amunoz, 2022-12-03 0. 2022-12-05 00:00
10. XXXIII Reunión Anual Sociedad de Botánica, Chile, Putaendo, Registros dendroquímicos para el estudio del régimen de incendios en bosques de Araucaria en la Cordillera de Nahuelbuta, amunoz, 2022-12-03 0. 2022-12-05 00:00
11. XLII CONGRESO NACIONAL Y XXVII INTERNACIONAL DE GEOGRAFÍA DE LA SOCIEDAD CHILENA DE CIENCIAS GEOGRÁFICAS, Chile, Santiago , Análisis de las inequidades e islas de calor y frescor en el Gran Concepción: incorporando la noción de resiliencia climática urbana, psarricolea, psmith, 2022-11-28 0. 2022-12-02 00:00
12. Congreso Latinomaricano de Sociología Rural, México, Oaxaca, Ecologías de la reparación: Saberes, tecnologías y prácticas de reparación en el Humedal Río Cruces, sur de Chile, gblanco, 2022-11-27 0. 2022-12-02 00:00
13. IAL IPA 2022 Lakes, Memories of the Past, Argentina, Bariloche, Vegetation and climate evolution in Central Isla Grande de Chiloé (42°S) during the last glacial maximum and the last glacial termination., pmoreno, 2022-11-27 0. 2022-12-01 00:00
14. IAL IPA 2022 Lakes, Memories of the Past, Argentina, Bariloche, Environmental changes during the past millennium in northwestern Patagonia (41°S) inferred from a high-resolution diatom record, pmoreno, 2022-11-27 0. 2022-12-01 00:00
15. IAL IPA 2022 Lakes, Memories of the Past, Argentina, Bariloche, Reconstruction of the southern westerly




winds core intensity during the Late Holocene based on aeolian particles of lacustrine sediments of Southern Patagonia (~51°S), pmoreno, 2022-11-27 0. 2022-12-01 00:00

16. IAL IPA 2022 Lakes, Memories of the Past, Argentina, Bariloche, Environmental changes during the past millennium in northwestern Patagonia (41°S) inferred from a high-resolution diatom record, pmoreno, 2022-11-27 0. 2022-12-01 00:00
17. IAL IPA 2022 Lakes, Memories of the Past, Argentina, Bariloche, Fires and rates of change in the temperate rainforests of northwestern Patagonia since ~18 ka, pmoreno, 2022-11-27 0. 2022-12-01 00:00
18. IAL IPA 2022 Lakes, Memories of the Past, Argentina, Bariloche, A diatom perspective on the evolution of the Southern Westerly Winds over southwestern Patagonia since -14 ka, pmoreno, 2022-11-27 0. 2022-12-01 00:00
19. IAL IPA 2022 Lakes, Memories of the Past, Argentina, Bariloche, Limnogeology by the end of the last ice age in Isla Grande de Chiloé, northwestern Patagonia, pmoreno, 2022-11-27 0. 2022-12-01 00:00
20. Congres GIS Démocratie et Participation, Francia, Paris, Vers une Constitution Ecologique ? Succès et limites d'une coalition pour l'écologie politique dans la Convention Constitutionnelle chilienne, amailet, 2022-11-23 0. 2022-11-25 00:00
21. Journées Climat et Impacts, Francia, Paris, L'Indicateur composite de sécurité hydrique : un outil pour mesurer l'impact du changement climatique sur l'accès à l'eau potable, cnicolas, 2022-11-23 0. 2022-11-25 00:00
22. 6to Congreso Oceanografía Física, Meteorología y Clima, Chile, Pto Montt, Observatorio de Ríos Atmosféricos, rgarreaud, 2022-11-22 0. 2022-11-25 00:00
23. 6to Congreso Oceanografía Física, Meteorología y Clima, Chile, Pto Montt, Cambio Climático en nor patagonia , rgarreaud, 2022-11-22 0. 2022-11-25 00:00
24. XIV Congreso Nacional de la Ciencia del Suelo, Chile, Valdivia, Evaluación de la humedad de suelo estimada mediante productos grillados en la zona centro-sur de Chile, hzabrano, mgalleguillos, 2022-11-22 0. 2022-11-25 00:00
25. VI Congreso de Oceanografía física, meteorología y clima del Pacífico sur oriental, Chile, Puerto Montt, ¿Por qué están cambiando las precipitaciones máximas estacionales en Chile continental?, mlagos, 2022-11-22 0. 2022-11-25 00:00
26. VI Congreso de Oceanografía Física, Meteorología y Clima del Pacífico Sur Oriental, Chile, Puerto Montt, Reconstrucción de la altitud de la isoterma 0°C en Patagonia norte durante los últimos 1000 años utilizando anillos de árboles, dchristie, 2022-11-21 0. 2022-11-25 00:00
27. VI Congreso de Oceanografía Física, Meteorología y Clima del Pacífico Sur Oriental, Chile, Puerto Montt, Cuatro siglos de variaciones de la humedad del suelo en Chile Mediterráneo (30°-37°S) en base a anillos de crecimiento de árboles y arbustos, dchristie, 2022-11-21 0. 2022-11-25 00:00
28. 6º Congreso de Oceanografía Física, Meteorología y Clima del Pacífico Sur Oriental. Grupo de Trabajo Dinámica Océano-Atmósfera (DOCA), Chile, Puerto Montt, Taller "Sistema de observación del océano en Chile", augarte, 2022-11-21 0. 2022-11-25 00:00
29. FLORACIONES DE ALGAS NOCIVAS: CIENCIA Y EXPERIENCIAS, Chile, Puerto Varas, Percepciones locales de las FAN: Voces desde la Patagonia chilena, augarte, 2022-11-21 0. 2022-11-21 00:00
30. 6º Congreso de Oceanografía Física, Meteorología y Clima del Pacífico Sur Oriental. Grupo de Trabajo Dinámica Océano-Atmósfera (DOCA), Chile, Puerto Montt, Altitud de la isoterma 0°C sobre la zona costera del Biobío: estimación y variabilidad temporal, cqijada, 2022-11-21 0. 2022-11-25 00:00
31. XV Congreso Latinoamericano de Apicultura, Perú, Cuzco, Avances en la comprensión de los impactos del Cambio Climático en la Apicultura Chilena, dchristie, 2022-11-16 0. 2022-11-19 00:00
32. XV Congreso Latinoamericano de Apicultura, Perú, Cuzco, Secos desde siempre: las lecciones de la apicultura en el Desierto de Atacama, dchristie, 2022-11-16 0. 2022-11-19 00:00
33. XV Congreso Latinoamericano de Apicultura, Perú, Cuzco, Impactos y adaptación al cambio climático de la apicultura en la Patagonia chilena, dchristie, 2022-11-16 0. 2022-11-19 00:00

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34. V Congreso Latinoamericano y Caribeño de Ciencias Sociales “Democracia, justicia e igualdad”, Uruguay, Montevideo, Mega-sequía en Chile: ¿Pueden las comunidades rurales revertir la escasez hídrica?», Mesa “Cambio Climático: conflictos y experiencias locales, cnicolas, 2022-11-16 0. 2022-12-18 00:00
  35. XV CONGRESO LATINOAMERICANO DE APICULTURA FILAPI 2022, Perú, Cusco, Crisis hídrica en Chile central: Impactos sobre las fuentes de agua, el bosque y la apicultura, amunoz, 2022-11-16 0. 2022-11-19 00:00
  36. 12° Encuentro de Diseño Urbano, Chile, Concepción, Islas de calor y de frescor medidas por satélite, y su relación con los niveles socioeconómicos. El caso del área metropolitana de Concepción, psarricolea, psmith, 2022-11-09 0. 2022-11-11 00:00
  37. XIV Congreso Meteorológico Argentino (CONGREMET), Argentina, Buenos Aires, Olas de calor conjuntas en Chile y Argentina: los eventos de enero de 2022 en un contexto climatológico, mjacques, csegura, 2022-11-07 0. 2022-11-11 00:00
  38. Academic Collaboration Chile Sweden (ACCESS), Chile, Punta Arenas, Resiliencia Urbana, Igallardo, 2022-11-06 0. 2022-11-09 00:00
  39. Seminario Internacional de Ingeniería y Operación Portuaria, Chile, Valparaíso, Proyecciones del oleaje para fines de siglo en las costas del Pacífico Sureste, caguirre, 2022-10-26 0. 2022-10-28 00:00
  40. Seminario Internacional de Ingeniería y Operación Portuaria, Chile, Valparaíso, Sistema de simulación numérica para la costa de Chile central mediante el acoplamiento de modelos numéricos, caguirre, 2022-10-26 0. 2022-10-28 00:00
  41. Políticas de mitigación y adaptación al cambio climático: Actores, interrelaciones, desigualdades, y conflictos en Chile, Chile, Santiago, El rol de la ciencia en la gobernanza climática: una mirada desde el Sur, cibarra, 2022-10-26 0. 2022-10-26 00:00
  42. Hacia un análisis multinivel de la gestión del agua en América Latina, México, Tuxtla Gutiérrez, La distribución de agua por camiones aljibes : una normalización de la emergencia., cnicolas, gblanco, 2022-10-24 02:00, 2022-10-27 02:00
  43. COLOQUIO INTERNACIONAL Hacia un análisis multinivel de la gestión del agua en América Latina , México, San Cristobal de las Casas, Camiones aljibes: normalizar la emergencia en Chile, cnicolas, 2022-10-24 0. 2022-10-27 00:00
  44. Visita Centro Huinay, Chile, Huinay, Cambio Climatico en nor patagonia , rgarreaud, 2022-10-23 0. 2022-10-26 00:00
  45. 2022 Toronto Conference on Earth System Governance, Canadá, Toronto, Co-constructing integrated climate governance: a territorialized approach for the meta-governance of the Valparaíso Region, Chile, rborquez, 2022-10-19 19:00, 2022-10-23 19:00
  46. 2022 Toronto Conference on Earth System Governance, Canadá, Toronto, Co-constructing integrated climate governance: a territorialized approach for the meta-governance of the Valparaíso Region, Chile, mbilli, amaillet, rborquez, gazocar, 2022-10-19 0. 2022-10-21 00:00
  47. XII Congreso Internacional de la Asociación Española de Climatología (AEC), España, Santiago de Compostela, Modelo de simulación del clima urbano para apoyar la toma de decisiones de planificación sensible al clima en Chile, psmith, 2022-10-19 0. 2022-10-21 00:00
  48. 12 Congreso de la Asociación Española de Climatología, España, Santiago de Compostela, ISLAS DE CALOR DE SUPERFICIE Y SU RELACIÓN CON LOS NIVELES DE INGRESO Y LAS ZONAS CLIMÁTICAS LOCALES. EL CASO DE CUATRO CONURBACIONES DE COSTERAS DE CHILE, psarricolea, psmith, 2022-10-19 0. 2022-10-21 00:00
  49. Research Challenges for a Sustainable Energy Transition, Chile, Santiago/zoom, Opportunities to reduce CO2 emissions of urban transportation in Chile by alternative decarbonization pathways with co-benefits of improved public health, roryan, 2022-10-19 0. 2022-10-19 00:00
  50. SISC2022: “Governing the future”, Italia, Rome, Measuring Increased Resilience: The Race to Resilience Campaign, challenges and opportunities to monitor the impact of global adaptation efforts, rborquez,



- mbilli, paldunce, 2022-10-18 19:00, 2022-10-20 19:00
51. International Atmospheric River Conference 2022, Chile, Santiago, Quantitative Precipitation Forecast Performance Along Central-Southern Chile, rvalenzuela, 2022-10-11 0. 2022-10-11 00:00
  52. The International Atmospheric River Conference 2022, Chile, Santiago, Atmospheric Blocking Patterns around the Antarctic Peninsula and Their Influences on Temperature and Moisture Transport, dbozkurt, 2022-10-10 0. 2022-10-14 00:00
  53. The International Atmospheric River Conference 2023, Chile, Santiago, Potential aerosol transport to the Antarctic Peninsula driven by an atmospheric river event in austral summer 2022, dbozkurt, nhuneus, 2022-10-10 0. 2022-10-14 00:00
  54. The International Atmospheric River Conference 2024, Chile, Santiago, Dusty atmospheric rivers over Europe, dbozkurt, 2022-10-10 0. 2022-10-14 00:00
  55. The International Atmospheric River Conference 2025, Chile, Santiago, Impact of Winter Atmospheric Rivers on the Snowpack in the Headwaters of the Euphrates and Tigris Basin, dbozkurt, 2022-10-10 0. 2022-10-14 00:00
  56. The International Atmospheric River Conference 2026, Chile, Santiago, Impact of Atmospheric Rivers in the Mixing Layer on the Southeastern Pacific Ocean, dbozkurt, mjacques, 2022-10-10 0. 2022-10-14 00:00
  57. The International Atmospheric River Conference 2027, Chile, Santiago, Impact of Atmospheric Rivers in the Mixing Layer on the Southeastern Pacific Ocean, dbozkurt, mjacques, 2022-10-10 0. 2022-10-14 00:00
  58. The International Atmospheric River Conference 2028, Chile, Santiago, A case study of climate sensitivity of AR-induced precipitation to warm sea surface temperatures, mlagos, dbozkurt, rrondanelli, 2022-10-10 0. 2022-10-14 00:00
  59. The International Atmospheric River Conference 2029, Chile, Santiago, Zonal Atmospheric Rivers, rgarreaud, 2022-10-10 0. 2022-10-14 00:00
  60. The International Atmospheric River Conference 2030, Chile, Santiago, Effects of atmospheric rivers in the coastal ocean off Chile, mjacques, 2022-10-10 0. 2022-10-14 00:00
  61. The International Atmospheric River Conference 2031, Chile, Santiago, Quantitative Precipitation Forecast Performance Along Central-Southern Chile, rvalenzuela, rgarreaud, rrondanelli, 2022-10-10 0. 2022-10-14 00:00
  62. The International Atmospheric River Conference 2032, Chile, Santiago, Influence of atmospheric rivers on extreme high temperature events over the Antarctic Peninsula, rrondanelli, dbozkurt, mjacques, 2022-10-10 0. 2022-10-14 00:00
  63. The International Atmospheric River Conference 2033, Chile, Santiago, Mechanism for the influence of MJO in precipitation in precipitation over Chile., fmatius, rrondanelli, 2022-10-10 0. 2022-10-14 00:00
  64. Polar-CORDEX, Noruega, Bergen, Cooling the coldest continent: The 4 of December 2021 total solar eclipse over Antarctica, dbozkurt, rgarreaud, rrondanelli, tcarrasco, 2022-09-28 0. 2022-09-30 00:00
  65. EBUS Conference 2022, Perú, Lima, ENSO Driving Change of the Oxygen Minimum Zone Off Chile (18°S-38°S) in a Regional Coupled Biogeochemical Model, caguirre, 2022-09-19 0. 2022-09-23 00:00
  66. EBUS Conference 2022, Perú, Lima, South Pacific Subtropical High variability and changes in upwelling favorable winds along the Humboldt Current System, caguirre, 2022-09-19 0. 2022-09-23 00:00
  67. 5TH INTERNATIONAL SYMPOSIUM ON THE OCEAN IN A HIGH CO2 WORLD, Perú, Lima, Effects of upwelling in calcification, growth and mortality of Chilean scallop (*Argopecten purpuratus*) cultured in Tongoy bay (30°12'S, 71° 34'W)., lramajo, 2022-09-19 0. 2022-09-16 00:00
  68. Seminario Doctorado en Procesos e Instituciones Políticas 2022, "Democracia, Gobernanza y Normatividad. Enfoques emergentes, Chile, Santiago, Democracia epistémica y post-verdad en tiempo de diferenciación funcional: algunas reflexiones para el caso de la política ambiental, mbilli, 2022-09-14 0. 2022-09-14 00:00
  69. 5TH INTERNATIONAL SYMPOSIUM ON THE OCEAN IN A HIGH CO2 WORLD, Perú, Lima, Science and Industry: how are they addressing the impacts of Ocean Acidification on Aquaculture and Fisheries, lramajo, 2022-09-12 0. 2022-11-18 00:00


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70. International Global Atmospheric Chemistry (IGAC) conference, Reino Unido, Manchester, Assessing Black Carbon and Particulate Matter from mobile measurements in Quintero, Chile, z Fleming, 2022-09-10 0. 2022-09-15 00:00
  71. iCACGP-IGAC2022 Atmospheric Chemistry Conference, Reino Unido, Manchester, Obtaining a high-resolution OMI-NO2 product over South America using a Generative Adversarial Network, sparraguez, 2022-09-09 18:00, 2022-09-14 19:00
  72. European Society for the History of Sciences (ESHS) Conference, Bélgica, Bruselas, Chilean climate scientists' involvement in public policy from a historical perspective, cibarra, 2022-09-07 0. 2022-09-10 00:00
  73. VI Convection-Permitting Climate Modeling Workshop, Argentina, Buenos Aires, Sensitivity of convective precipitation to warming in the extratropical Andes, mlagos, 2022-09-07 0. 2022-09-09 00:00
  74. MEDECOS Conference, Sudafrica, Langebaan, Widespread synchronous decline in a Mediterranean forest driven by accelerated aridity, sgomez, 2022-09-04 18:00, 2022-09-08 18:00
  75. MEDECOS Conference, Sudafrica, Langebaan, Seed dormancy decay in an endemic pyrophyte driven by anthropogenic disturbance, sgomez, 2022-09-04 18:00, 2022-09-08 18:00
  76. MEDECOS Conference, Sudafrica, Langebaan, Effects of afforestation of tree-less habitats on the productivity of neighbouring cork oak habitats, sgomez, 2022-09-04 18:00, 2022-09-08 18:00
  77. SEMINARIO CALIDAD DEL AIRE EN AYSÉN, Chile, Online, Ciencia ciudadana con sensores de bajo costo, z Fleming, 2022-08-26 0. 2022-08-26 00:00
  78. 47th Apimondia Apicultural Congress, Turquía, Estambul, Developing the first national diagnosis of the drought impact on honey production in Chile, amunoz, 2022-08-24 0. 2022-08-28 00:00
  79. CALACS Conference 2022, Canadá, Toronto, Climate Governance of the Elements: towards a comprehensive framework and preliminary insights from Chile, mbilli, aurquiza, rborquez, 2022-08-23 0. 2022-08-26 00:00
  80. ISME18 2022, Suiza, Luasanne, Taxonomic, functional and environmental interactions in hot springs microbial mats., bdiez, 2022-08-14 0. 2022-08-19 00:00
  81. Academy of Management , Estados Unidos, Seattle, Moving from intention to action: Insights on Firms' Active pro-Environmental Behavior, fvasquez, 2022-08-05 0. 2022-08-08 00:00
  82. Inauguración Año Académico 2022, Programa de Doctorado Interdisciplinario en Ciencias Ambientales, Chile, Valparaiso, Interdisciplina para el ""Antropoceno"", egayo, 2022-08-04 0. 2022-08-04 00:00
  83. XXIII Congreso Red Apícola Nacional, Chile, Talagante, Santiago, "Impactos y adaptación al cambio climático en la apicultura en Chile", amunoz, 2022-07-22 0. 2022-07-23 00:00
  84. IGU Conference Time for geographers, Francia, Paris, La ley sobre Servicios Sanitarios Rurales: una doble transición reveladora de desigualdades socio-espaciales, cnicolas, 2022-07-18 01:00, 2022-07-22 01:00
  85. IGU Conference Time for geographers, Francia, Paris, De la difficulté de divulguer et valoriser les connaissances produites sur l'appropriation de l'eau par les groupes dominants, cnicolas, 2022-07-18 01:00, 2022-07-22 01:00
  86. Congreso UGI-IGU, Francia, París, Planificación urbana sensible al clima: Justicia climática y calidad de vida en la ciudad, psmith, 2022-07-18 0. 2022-07-22 00:00
  87. Journée d'etudes COINCIDE - Universite Sorbonne Paris I, Francia, Paris, Les eaux dans le projet de Constitution chilienne, cnicolas, 2022-07-12 01:00, 2022-07-13 01:00
  88. Congrès Association Francaise de Science Politique, Francia, Lille, « Única solución, EcoConstitución ». Succès et limites d'une coalition pour l'écologie politique dans la Convention Constitutionnelle chilienne, amailet, 2022-07-05 0. 2022-07-07 00:00
  89. Tercer Foro Internacional Vanguardia en la Educación FIVE 2022, México, Ciudad de México, La urgencia de la Adaptación y Transformación para enfrentar el cambio climático ¿Estamos a tiempo?, paldunce, 2022-06-29 0. 2022-07-01 00:00
  90. IV AmeriDendro Conference, Canadá, Montreal, A 389-yrs precipitation changes in the Northern South



- American Altiplano reveals an increase in extreme drought events since mid 20th century, dchristie, 2022-06-27 0. 2022-06-30 00:00
91. IV AmeriDendro Conference, Canadá, Montreal, Austrocedrus chilensis tree-rings as a natural encyclopedia: itinerant and interactive exhibition as an educational tool for students, dchristie, 2022-06-27 0. 2022-06-30 00:00
  92. IV AmeriDendro Conference, Canadá, Montreal, Spatio-temporal analysis of soil moisture variations explains the tree-growth decline of multiple species in Mediterranean ecosystems of Chile, dchristie, 2022-06-27 0. 2022-06-30 00:00
  93. IV AmeriDendro Conference, Canadá, Montreal, Drought and Inca rituals in the summits of the Andes of Atacama, dchristie, 2022-06-27 0. 2022-06-30 00:00
  94. AmeriDendro, Canadá, Montréal, Reconstructing Maximum flows using tree rings in Semiarid-Mediterranean climate transition of Chile, amunoz, 2022-06-27 0. 2022-06-30 00:00
  95. Business Association of Latin American Studies , Portugal, Carcavelos, Moving from intention to action: Insights on Firms' Active pro-Environmental Behavior, fvasquez, 2022-06-09 0. 2022-06-13 00:00
  96. EGU General Assembly 2022, Austria, Vienna, Atmospheric blocking patterns around the Antarctic Peninsula and their influences on temperature and moisture transport, dbozkurt, 2022-05-27 0. 2022-05-27 00:00
  97. Las organizaciones comunitarias rurales en los servicios de agua potable: Desafíos y perspectivas, Chile, Santiago, La seguridad hídrica doméstica en Chile: un enfoque multidimensional, cnicolas, 2022-05-26 01:00, 2022-05-26 01:00
  98. EGU General Assembly 2022, Austria, Vienna, Atmospheric rivers drive exceptional Saharan dust transport towards Europe and subsequent snow melt in the Alps, dbozkurt, 2022-05-26 0. 2022-05-26 00:00
  99. Las organizaciones comunitarias rurales en los servicios de agua potable: desafíos y perspectivas, Chile, Online, Propuesta de estudio de calidad de agua potable rural en sectores abastecidos por sistema APR, zfleming, 2022-05-26 0. 2022-05-26 00:00
  100. Ciencia en simple, Chile, Coyhaique, Cómo restaurar un ecosistema, czamorano, 2022-05-25 0. 2022-05-25 00:00
  101. XLI Congreso de Ciencias del Mar "Las Ciencias del Mar en tiempos de cambio", Chile, Concepción, "Variación espacio-temporal de las Floraciones Algales Nocivas (FAN) en Patagonia. Potenciales forzantes climático-oceanográficos", maparicio, 2022-05-23 0. 2022-05-27 00:00
  102. XLI Congreso de Ciencias del Mar "Las Ciencias del Mar en tiempos de cambio", Chile, Concepción, "Oceanographic drivers of micro-phytoplankton community at central Chile", maparicio, 2022-05-23 0. 2022-05-27 00:00
  103. Presentación Informe a las Naciones, Chile, Concepción, "Informe a las Naciones sobre FAN: una mirada integrativa desde el CR2 a la Patagonia", maparicio, 2022-05-23 0. 2022-05-27 00:00
  104. XLI Congreso de Ciencias del Mar "Las Ciencias del Mar en tiempos de cambio", Chile, Concepción, Modulación sinóptica-intraestacional de la biomasa fitoplanctónica en el Mar Interior de Chiloé, Patagonia Noroeste (42.5o-43.5oS, 72.5o-74oW), Chile, mjacques, 2022-05-23 0. 2022-10-27 00:00
  105. XLI Congreso de Ciencias del Mar "Las Ciencias del Mar en tiempos de cambio", Chile, Concepción, Floraciones algales nocivas (FAN) en Chiloé, enero-febrero 2021: ¿podríamos haberlas anticipado?, mjacques, 2022-05-23 0. 2022-10-27 00:00
  106. XLI Congreso de Ciencias del Mar "Las Ciencias del Mar en tiempos de cambio", Chile, Concepción, Proyecciones del oleaje para fines de siglo en las costas del Pacífico Sureste, caguirre, 2022-05-23 0. 2022-05-27 00:00
  107. XLI Congreso de Ciencias del Mar "Las Ciencias del Mar en tiempos de cambio", Chile, Concepción, Variabilidad del Anticiclón del Pacífico Sureste y cambios en los vientos favorables a la surgencia en el Sistema de Humboldt, caguirre, 2022-05-23 0. 2022-05-27 00:00
  108. XLI Congreso de Ciencias del Mar "Las Ciencias del Mar en tiempos de cambio", Chile, Concepción,



- Proyecciones de variables climáticas favorables para el desarrollo de Floraciones Algales Nocivas en la Patagonia, caguirre, 2022-05-23 0. 2022-05-27 00:00
- 109.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Concepción, Actualización del Atlas de Oleaje de Chile, caguirre, 2022-05-23 0. 2022-05-27 00:00
- 110.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Concepción, Sistema de simulación numérica para la costa de Chile central mediante el acoplamiento de modelos, caguirre, 2022-05-23 0. 2022-05-27 00:00
- 111.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Concepción, El Niño Oscilación del Sur y su relación con el volumen de la Zona de Mínimo Oxígeno (18-38° S): una perspectiva de modelación físico-biogeoquímica, caguirre, 2022-05-23 0. 2022-05-27 00:00
- 112.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Concepcion, Variación espacio-temporal de las Floraciones Algales Nocivas (FAN) en Patagonia. Potenciales forzantes climático-oceanográficos, imasotti, 2022-05-23 0. 2022-05-27 00:00
- 113.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Concepción, Oceanographic drivers of micro-phytoplankton community at central Chile, imasotti, 2022-05-23 0. 2022-05-27 00:00
- 114.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Concepción, “Informe a las Naciones sobre FAN: una mirada integrativa desde el CR2 a la Patagonia”, imasotti, 2022-05-23 0. 2022-05-27 00:00
115. EGU General Assembly 2022, Austria, Wien, Assessment of water provision under different future land use scenarios in the Cauquenes Catchment, Chile, hzambrano, mgalleguillos, dmanushevich, 2022-05-23 0. 2022-05-27 00:00
116. EGU General Assembly 2022, Austria, Wien, Increasing sediment connectivity and decreasing water availability: the anthropogenic impacts of exotic tree plantations on a Mediterranean catchment in central Chile, hzambrano, mgalleguillos, 2022-05-23 0. 2022-05-27 00:00
117. EGU General Assembly 2022, Austria, Wien, hydroMOPSO: A versatile Particle Swarm Optimization R package for multi-objective calibration of environmental and hydrological models, hzambrano, rmarinao, 2022-05-23 0. 2022-05-27 00:00
118. EGU General Assembly 2022, Austria, Wien, On the selection of precipitation products for the regionalisation of hydrological model parameters, hzambrano, 2022-05-23 0. 2022-05-27 00:00
119. Simposio Floraciones de Algas Nocivas en Chile: construyendo un camino hacia ICHA 2025. XLI Congreso Ciencias del Mar, Chile, Concepción, Percepciones locales de las FAN en zonas costeras y desafíos para la gobernanza climática, augarte, 2022-05-23 0. 2022-05-27 00:00
- 120.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Talcahuano, Intensificación de la hipoxia: variabilidad interanual y decadal de la hipoxia en un sistema de surgencia costera frente a Chile Central. , lfarias, 2022-05-22 0. 2022-08-26 00:00
- 121.XLI Congreso de Ciencias del Mar “Las Ciencias del Mar en tiempos de cambio”, Chile, Talcahuano, Seasonal to high-frequency hypoxia variability in a coastal upwelling system off Central Chile and its potential risks for marine resources.. , lfarias, 2022-05-22 0. 2022-08-26 00:00
- 122.Pre ALAS Concepcion 2022, Chile, Concepcion, Escapando de la ciudad: efectos de la pandemia covid-19 en suelos y aguas rurales de Chile, cnicolas, 2022-04-28 01:00, 2022-07-28 01:00
- 123.Seminaire Projet COINCIDE - Universite Paris I, Francia, Paris, L'eau dans la Convention Constitutionnelle, cnicolas, 2022-04-07 01:00, 2022-04-07 01:00
- 124.Seminaire Projet COINCIDE - Universite Paris I, Francia, Paris, L'eau dans la Convention Constitutionnelle, cnicolas, 2022-04-07 01:00, 2022-04-07 01:00
- 125.Fourteenth International Conference on Climate Change: Impacts & Responses , Otro, online, Innovation in Climate Responses from the South: Report on Climate Governance of the Elements - (CR)2, rborquez, 2022-04-06 18:00, 2022-04-07 18:00

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126. Fourteenth International Conference on Climate Change: Impacts & Responses , Otro, online, Responding to Climate change as Emergency: Governing the Climate Emergency, rborquez, paldunce, mbilli, 2022-04-06 18:00, 2022-04-07 18:00
  127. Séminaire du réseau Sciences Humaines et Sociales appliquées aux questions de l'eau « EAU & DROITS » « Aspects sociologiques, juridiques, démographiques et historiques des questions de l'eau » , Francia, Chatou, Le droit de l'eau au Chili : une source de transformation sociale ou de pérennisation de l'ordre établi ? , cnicolas, 2022-04-05 01:00, 2022-04-05 01:00
  128. Hackatón por el Cambio Climático en la región Antártica y Subantártica , Chile, Virtual, Cambio Climatico en PAtagonia y Magallanes, rgarreaud, 2022-03-27 0. 2022-03-27 00:00
  129. Workshop ""El rol de los territorios en la adaptación al cambio climático"", Chile, Coyhaique, Agua y territorio en el contexto de cambio climático, czamorano, 2022-03-24 0. 2022-03-24 00:00
  130. Hydrocerrado. Nouvelles frontieres de l'irrigation en Amerique Latine, Francia, Montpellier, S'approprier l'insaisissable. Eau et expansion agricole dans le Chili semi-aride (1950-2022), cnicolas, 2022-03-08 03:00, 2022-03-08 03:00
  131. XIV Congreso Chileno de Investigación Operativa, Chile, Talca, Automatización del proceso de obtención de cicatrices de incendios mediante herramientas de inteligencia artificial y sistemas de información geográficos, amiranda, 2022-03-06 0. 2022-03-08 00:00
  132. Ocean Sciences Meeting 2022, Otro, Online, CORRELATION BETWEEN ENSO PHENOMENA AND SHORELINE CHANGES DEFINED FROM MID-RESOLUTION SATELLITE IMAGERY IN VALPARAISO REGION, CHILE (1984-2021), caguirre, 2022-02-28 0. 2022-03-04 00:00
  133. Taller de capacitación Grupo de Trabajo de Proyecciones Marinas y Oceánicas (GTPMO) Nuestro clima cambiante:, Ecuador, Virtual, Nuestro Clima Cambiante, rgarreaud, 2022-02-26 0. 2022-02-27 00:00
  134. International Southern Hemisphere Meteorology and Oceanography Conference 2022, Nueva Zelanda, Virtual, The Southern Blob (Key Note Talk), rgarreaud, 2022-02-10 0. 2022-02-24 00:00
  135. International Southern Hemisphere Meteorology and Oceanography Conference 2022, Nueva Zelanda, Virtual, The central Chile Megadrought: Change or Variability?, rgarreaud, 2022-02-10 0. 2022-02-20 00:00
  136. 13th International Conference on Southern Hemisphere Meteorology and Oceanography, Nueva Zelanda, Christchurch, Temperature and precipitation projections for the Antarctic Peninsula over the next two decades: Contrasting global and regional climate model simulations, dbozkurt, rrondanelli, 2022-02-08 0. 2022-02-12 00:00
  137. International Conference on Southern Hemisphere Meteorology and Oceanography, Nueva Zelanda, Online, Past Atmospheric Particulate Matter Reconstruction based on Dendrochemistry, flambert, 2022-02-08 0. 2022-02-12 00:00
  138. Noveno Encuentro de la Red Chilena de Ciencia Tecnología y Sociedad, CTS-Chile, Chile, Santiago, Lazos afectivos y relaciones de cuidado con las infraestructuras, cibarra, 2022-01-12 0. 2022-01-14 00:00
  139. SOCHIAS meeting 2022, Chile, Virtual, Consequences of climate change globally and in Chile, rgarreaud, 2022-01-10 0. 2022-01-12 00:00
  140. American Geophysical Union (AGU) Fall Meeting, Estados Unidos, New Orleans, Oxygen stable isotopes in tree rings reveal 300 years of precipitation variability in the South American Altiplano, dchristie, 2021-12-13 0. 2021-12-17 00:00
  141. AGU fall meeting 2021, Estados Unidos, New Orleans / Online, How well are RCMs representing extreme indices in the SAM region?, mlagos, 2021-12-12 0. 2021-12-17 00:00
  142. XXII Congreso Nacional de Arqueología Chilena, Chile, Puerto Montt, Sequía y Rituales Incas en las Cumbres de los Andes Atacameños, dchristie, 2021-12-06 0. 2021-12-10 00:00



## 8.6. Organization of Scientific Meetings (2022 only)

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

*Type; Name; City-Country, Participants*

1. Workshop; Las organizaciones comunitarias rurales en los servicios de agua potable: desafíos y perspectivas. Santiago, Chile. 5/26/2022 al 5/26/2022. 35 Participantes
2. International congress ; Session Faire une géographie des dominants: enjeux méthodologiques et épistémologiques. París, Francia 7/18/2022 al 7/18/2022. 30 Participantes
3. International congress; International Atmospheric River Conference 2022. Santiago, Chile 10/10/2022 al 10/14/2022. 150 Participantes
4. National congress; Encuentro Nacional Monitoreo y Sensores para Salud Ambiental. Santiago; Chile. 11/17/2022 al 11/20/2022. 100 Participantes
5. Workshop; Effective Climate Planning: Biosphere responses to climate change and variability at multiple scales in north-central Chile (WECP). Concepción Chile. 5/23/2022 al 5/27/2022. 50 Participantes
6. International congress; Paleoclimate Model Intercomparison Project, 30th anniversary; Online Francia 12/2/2021 al 12/3/2021. 100 Participantes
7. International congress; Latin American Students' sessions at the Annual conference of the Society for Benefit Cost analysis (SBCA). Washington DC. Estados Unidos, 3/14/2022 al 3/25/2022. 50 Participantes
8. International congress; Cities and short-lived climate forcers: complexity, challenges, and opportunities. Santiago Chile 18-01-2022 al 1/27/2022. 35 Participantes



### **8.7. Collaborative Activities (2022 only!)**

- ✓ List the scientific visits of Center members to international institutions
- ✓ List the scientific visits of foreign researchers to the Center in Chile.

*Type of collaboration; Researcher, Institution, Country, Visit to, Dates*

1. Internacional, Josefa Antón Botella, Universidad de Alicante, Alicante, España, Santiago, Chile, 4/4/2022 to 4/14/2022.
2. Internacional, Fernando Santos, Universidad de Alicante, Alicante, España, Santiago, Chile, 4/4/2022 to 4/14/2022.
3. Internacional, Mauricio Osse, CNRS Toulouse, Santiago, Chile, Toulouse, Francia, 7/1/2022 to 7/31/2022.
4. Internacional, Paul Szejner, Universidad Nacional Autónoma de Mexico, Ciudad de Mexico, México, Valdivia, Chile, 7/1/2022 to 8/3/2022.
5. Internacional, Steve Leavitt, University of Arizona, Tucson, Estados\_ Unidos, Valdivia, Chile, 10/24/2022 to 10/28/2022.
6. Internacional, Maximilano Viale, IANIGLA -, Mendoza, Argentina, Concepción, Chile, 4/15/2022 to 4/22/2022.
7. Internacional, Marty Ralph, Anna Wilson, Thomas Corrignam, C3WE - Scripps, UCSD, San Diego, California, Estados\_ Unidos, Santiago, Chile, 10/6/2022 to 10/15/2022.
8. Nacional, Rene Garreaud, Dpto Oceanografía, UdeC, Santiago, Chile, Concepción, Chile, 7/15/2022 to 7/20/2022.
9. Nacional, Rene Garreaud, SERNAGEOMIN Los Lagos, Santiago, Chile, Puerto Varas, Chile, 4/20/2022 to 4/30/2022.
10. Internacional, Sebastian Diez, University of York, York, Reino\_ Unido, Santiago, Chile, 5/16/2022 to 5/24/2022.
11. Internacional, Mohammed Mead, Imperial College London, London, Reino\_ Unido, Santiago, Chile, 11/16/2022 to 11/25/2022.
12. Internacional, Nicolas Zanetta, Universitat Heidelberg, Heidelberg, Alemania, Santiago y Calama, Chile, 9/26/2022 to 2/28/2023.
13. Internacional, Javiera Machuca, Universitat Heidelberg, Heidelberg, Alemania, Santiago y Calama, Chile, 9/26/2022 to 2/27/2023.
14. Internacional, Benjamin Herfort, Universitat Heidelberg, Heidelberg, Alemania, Santiago, Chile, 7/18/2022 to 7/19/2022.
15. Internacional, Karen O'Brien, Universidad de Oslo, Oslo, Noruega, Santiago, Chile, 3/29/2022 1:00, 4/25/2022.
16. Internacional, Guy Brasseur, Max Planck Institute for Meteorology, Hamburgo, Alemania, Santiago, Chile, 10/16/2022 to 11/5/2022.
17. Internacional, Cathy Li, Max Planck Institute for Meteorology, Hamburgo, Alemania, Santiago, Chile, 10/18/2022 to 11/18/2022.
18. Internacional, Robert Skelton, South African Environmental Observation Network (SAEON), Cape Town, Sudafrica, Valdivia, Chile, 10/16/2022 to 10/29/2022.



19. Internacional, Rodrigo Seguel, Karlsruhe Institute of Technology (KIT); Instituto Max Planck [MPI] de Química; Heidelberg University; Centro Aeroespacial de Alemania (DLR), Santiago, Chile, Heidelberg, Mainz, Eggenstein-Leopoldshafen, Munich, Alemania, 6/3/2022 to 11/18/2022.
20. Internacional, Rodrigo Seguel, Ionicon Analytik, Santiago, Chile, Innsbruck, Austria, 6/12/2022 to 6/14/2022.
21. Nacional, Juli Pausas, CSIC-CIDE- Universidad de Valencia, Valencia, España, Puerto Real, España, 8/27/2022 18:00, 8/29/2022 18:00
22. Internacional, Carlos Zamorano Elgueta, Oregon State University, Coyhaique, Chile, Portland, Estados Unidos, 8/12/2022 to 8/22/2022.
23. Internacional, Serrana Ambite, PEDECIBA, Montevideo, Uruguay, Valparaíso, Chile, 4/13/2022 to 4/22/2022.



### 8.8. Postdoctoral Fellows

- ✓ List postdoctoral fellows working in the Center during the reported period regardless of their funding sources.

List of postdoctoral researchers active in the year 2022

Name	Research line	Start year
Christina Ridley	Coastal Zone	2019
María del Pilar Aparicio	Coastal Zone	2020
Danny Eduardo Carvajal	Land Use Change	2020
Ana María Ugarte	Coastal Zone	2019
Chloé Nicolas-Artero	Governance and science-policy interface	2021
Roxana Bórquez	Governance and science-policy interface	2021

✓



### 8.9. Students (2022 only!)

- ✓ Attach an abstract and the subject index.
- ✓ Include digital copies of the corresponding thesis registrations.

*Student name, Program, Thesis name*

1. Santiago, Ancapichún, Doctorado, Rol del océano y el clima en la modulación del gradiente latitudinal del radiocarbono atmosférico en el Hemisferio Sur
2. Claudio, Alvarez, Doctorado, Relaciones entre isótopos de oxígeno, crecimiento radial y variabilidad climática en bosques de altura a través de gradientes ambientales en los Andes tropicales y templados
3. Pablo, Vergara, Doctorado, Efecto de la temperatura sobre la actividad transcripcional y metabolismo energético de la cianobacteria termal *Fischerella thermalis*
4. Javier, Tamayo Leiva, Doctorado, Decoding the mobilome of marine microbial communities and their composition in response to local environmental conditions
5. Sara, Arenas Uribe, Magíster, Cambios temporales de la comunidad fitoplanctónica del sistema estuarino Reloncaví asociado a condiciones oceanográficas, hidroclimáticas y biogeoquímicas
6. Aaron , Grau, Magíster, Evaluación de la provisión de agua bajo distintos escenarios de uso del suelo mediante un enfoque de modelación interdisciplinar en la cuenca del río Cauquenes en desembocadura.
7. Lucas, Glasner, Magíster, Eventos hidrometeorológicos de lluvia sobre nieve en los Andes de Chile central
8. Ignacio, Laengle, Magíster, Distribucion espacial y temporal de gases contaminantes generados por sector transporte en las regiones de Chile
9. Luis, Gomez Parada, Magíster, Caracterización meteorológica de los episodios extremos de contaminación por material particulado fino en Coyhaique, Patagonia, Chile
10. Mirko , Del Hoyo, Magíster, Solar irradiance forecasts in the Atacama Desert using analog ensembles and a cloud assimilation technique
11. Felipe, Matus, Magíster, Diagnósticos dinámicos del efecto de la oscilación Madden-Julian en la precipitación en Chile
12. María Jesús, Rapanague, Magíster, Proyecciones de la actividad de incendios forestales en Chile centro-sur bajo escenarios futuros de cambio climático
13. Kevin, Basoa, Magíster, Dispersión de aerosoles y carbono negro en Chile central y sur en verano e invierno de 2016: el rol de la quema de leña
14. Catalina , Valenzuela Roa, Magíster, Rol de las JJVV de Punta Arenas frente al futuro de la ciudad en contexto de cambio climático y constitucional
15. Tomas, Caballero, Magíster, Análisis de la precipitación pre-altiplánica de verano en el norte de Chile
16. Orlando, Macari Rosales, Magíster, Elaboración de un índice de condición ecosistémica que incorpore el factor edáfico, como instrumento para la determinación de costos de medidas de restauración
17. Bastian, Fonfach Badinela, Magíster, Evolución del estatus hídrico y fotosintético en *Vitis vinífera* L. cultivar País en el secano del Maule y su correlación con parámetros espectrales
18. Andrea, Villavicencio Astete, Magíster, Evaluación de proyectos para una recuperación económica sostenible en Chile
19. Javiera, Gárate, Magíster, Percepciones locales sobre el problema socioecológico generado por el



desecamiento de la laguna de Aculeo en la comuna de Paine, Santiago

20. Tomas Ignacio, Gomez Zavala, Magíster, Identificación de patrones de gran escala conducentes a la formación de condiciones de río atmosférico en Chile continental
21. Pablo , Luna García, Magíster, Efectos de las plantaciones forestales sobre el régimen de incendios: Una revisión sistemática
22. Maria Alejandra, Bravo Diaz, Magíster, Detección de Pinus radiata a partir de imágenes capturadas por drones utilizando redes neuronales convolucionales
23. Anibal, Cerda, Pregrado, Diseño, construcción e implementación de una estación meteorológica de bajo costo basada en Arduino
24. Jessica Andrea Abigail, Figueroa Martínez, Pregrado, Sistema de aprovisionamiento de Leña en Valdivia bajo un escenario de Transición Socio – Técnica
25. Javiera, Ramírez, Pregrado, Relación entre olas de calor y variación de caudal en cuencas cordilleranas debido al derretimiento de hielo y nieve
26. Álvaro Esteban, Constanzo Gatica, Pregrado, Olas de calor y eventos cálidos no persistentes en las Islas Shetland del Sur: caracterización climática, sinóptica y teleconexiones
27. Contanza Catalina, Gonzalez Mena, Pregrado, Estado actual de la Observación Oceanográfica en Chile
28. Fernanda, Pino, Pregrado, Patrones de teleconexión de la precipitación invernal en Chile central y su variabilidad decadal
29. Bastián, Calderón Morales, Pregrado, Inundación por desborde de cauce natural en el centro urbano de la comuna de Colina: Análisis del riesgo y sus componentes
30. Barbara Escarlen, Lara Riquelme, Pregrado, Estructura y relaciones espaciales de un bosque adulto floreado del tipo forestal Coihue- Raulí- Tapa en Panguipulli, Región de los Ríos
31. Álvaro Ignacio, Martínez-Conde, Pregrado, Impacto hidrológico de plantaciones forestales en cuencas de la región del Maule: Huenchullami, Purapel y Perquilauquén.
32. Matías Alfonso, Palma Manterola, Pregrado, Aumento de resolución de datos satelitales espacio-temporales a través del modelo Random Forest para el estudio de aguas subterráneas en Chile
33. Cristian, Figueroa Mendoza, Pregrado, Cambio de estructura y patrones de establecimiento en un bosque de Araucaria araucana y Nothofagus pumilio en la Reserva privada Nasampulli, Región de la Araucanía, Chile
34. Mauricio , Herrera Diaz, Pregrado, Análisis espacio-temporal de la eficiencia del uso del agua en bosques templados siempreverdes y turberas de Chiloé mediante productos satelitales
35. Marco, Arratia Salinas, Pregrado, Relación entre riqueza arbórea modelada a través de percepción remota con características del paisaje donde están insertos los fragmentos de bosque nativo, ubicados en un ecosistema en peligro crítico de colapso de la zona centro sur de Chile
36. Manuel Jose, Suazo Alvarez, Pregrado, Variabilidad de la altitud de la isoterma 0°C y su influencia en la sensibilidad hidro-climática (34°S a 46°S)
37. Valeria, Arancibia, Pregrado, Análisis de las temperaturas de emisión superficial: islas de calor y frescor en el periodo 2002-2022, y su relación con las zonas climáticas locales y los grupos socioeconómicos en la conurbación La Serena-Coquimbo, Chile

## 8.10. Funding Sources (2022 only)

✓ List all funding sources including FONDAP.

1. B. Diez, FONDECYT, Biogeography and macroecology at the edge of life: a metagenomic approach to unravel pat-terns and causes of latitudinal diversity gradients in viruses, Co-Investigador, 4/1/2022 .
2. bdiez, Milenio Intituto, Millennium Institute Center for Genome Regulation , Co-Investigador, 6/1/2022 .
3. R. Garreaud, FONDEF, SISTEMA DE MONITOREO FENOLÓGICO SATELITAL Y DE CAMPO PARA LA EVALUACIÓN EN TIEMPO REAL DE LOS EFECTOS DE LA VARIABILIDAD CLIMÁTICA Y EVENTOS EXTREMOS SOBRE LA VEGETACIÓN NATIVA DE CHILE CENTRAL, Co-Investigador, 3/1/2022 .
4. R. Valenzuela, Anillo, Compound and Cascading Climate Extremes in Chile, Co-Investigador, 3/1/2022 .
5. R. Valenzuela, Ciencia Pública, Volando en El Tiempo, Director, 3/3/2022 .
6. R. Valenzuela, Fondos de Universidades (Sólo si son concursables), Sistema Articulado de Investigación en Cambio Climático y Sustentabilidad de Zonas Costeras de Chile , Co-Investigador, 3/1/2022 .
7. G. Azocr, FONDECYT, Gobernanza Adaptativa Ante Mega Incendios Forestales: El Caso del Sistema Socioecológico de Empedrado, Cauquenes, Constitución y San Javier, Investigador Responsable, 10/1/2019 .
8. Z. Fleming, FONDECYT, Integrated Assessment of Air Pollution in Contrasting Geographies of Chile, Investigador Responsable, 1/11/2022 .
9. P. Aldunce, FONDECYT, Transforming adaptation to drought and extreme precipitation in a changing climate: Chañaral and Aconcagua Valley, Chile, Investigador Responsable, 3/4/2022 1:00
10. paldunce, International Development Research Centre: IDRC, Visioning justice-informed adaptation through indigenous peoples? knowledge systems in Chile and Peru, Co-Investigador, 12/17/2021 1:00
11. R. Urrutia, Ciencia Pública, Un viaje a través del tiempo, desde que el alerce tiene memoria, Co-Investigador, 3/10/2022 .
12. M. Billi, Fuente Internacional (Indicar Fuente en Observations), Bridging the Water Adaptation Gap: a Comparative Inter- and Transdisciplinary Perspective of Regional Risks and Vulnerabilities in Drylands in Canada and Latin America, Investigador Responsable, 4/30/2022 18:00
13. P. Smith, FONDECYT, ¿Qué nos depara el Antropoceno Urbano?: Aportes de los modelos espaciales predictivos al sistema urbano chileno, Co-Investigador, 1/31/2022 .
14. psmith, FONDECYT, Clima urbano en conurbaciones costeras de Chile: propuesta de justicia socioambiental desde una planificación sensible al clima, Co-Investigador, 1/31/2022 .
15. M. Billi, Fuente Internacional (Indicar Fuente en Observations), H5537, Co-Investigador, 3/1/2021 .
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**IX. ANNEXES**

**9.1. (CR)<sup>2</sup> Data, Computing and Climate Services. PDF in digital format.**

**9.2. Interdisciplinary aspects. PDF in digital format.**

**9.3. Annual communications report. PDF in digital format.**

**9.4. (CR)<sup>2</sup> Extended Meeting 2022. PDF in digital format.**

**9.5. Collaborative networks. PDF in digital format.**