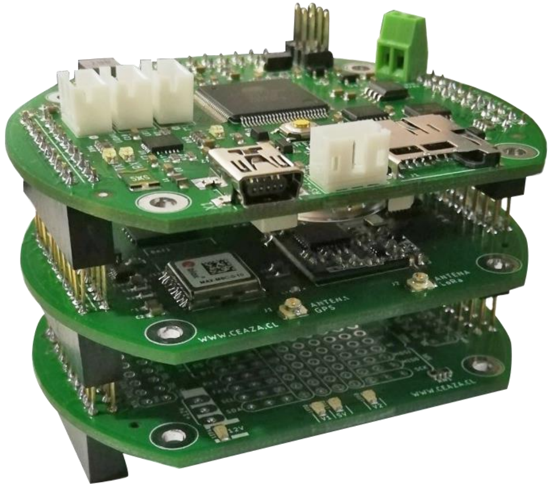
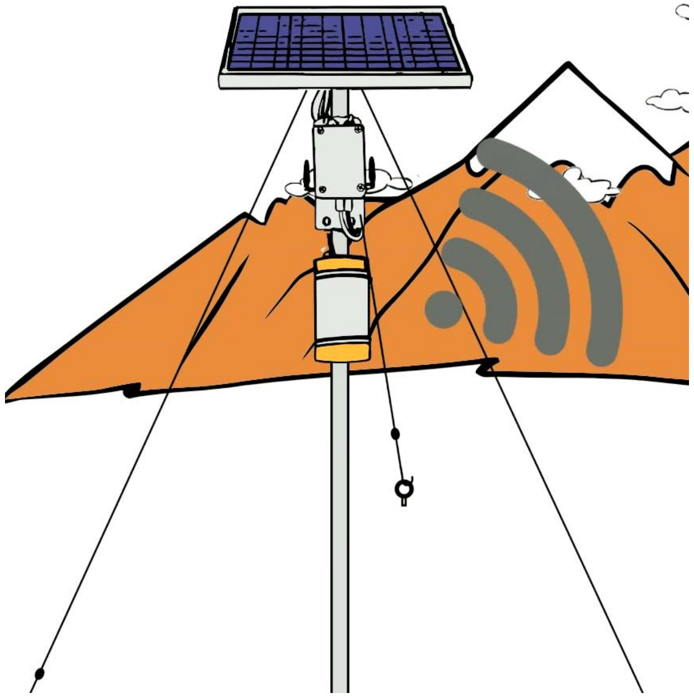
Agencia Nacional de Investigación y Desarrollo

Ministerio de Ciencia, Tecnología, Conocimiento e Innovación

Gobierno de Chile

Snow water equivalent, snow height and air temperature monitoring network for high mountain prototype based on open hardware development





Concurso IDeA I+D 2022

CHAPTER 1

SCIENTIFIC AND TECHNOLOGICAL CONTENT

Problem/Opportunity and Proposed Solution

- Climate change and a long-lasting drought are heavily impacting the water availability in Central and Northern Chile (see Fig. 1). Therefore, there is an urgent need for mitigation and adaptation processes that include efficient management systems. These decision support systems need accurate data and information, especially for the high-mountain region, since most of the water accumulation occurs in the mountain range in the form of snow. However, there is a lack of information about the snow cover at high altitudes, mostly due to the high costs of these devices.

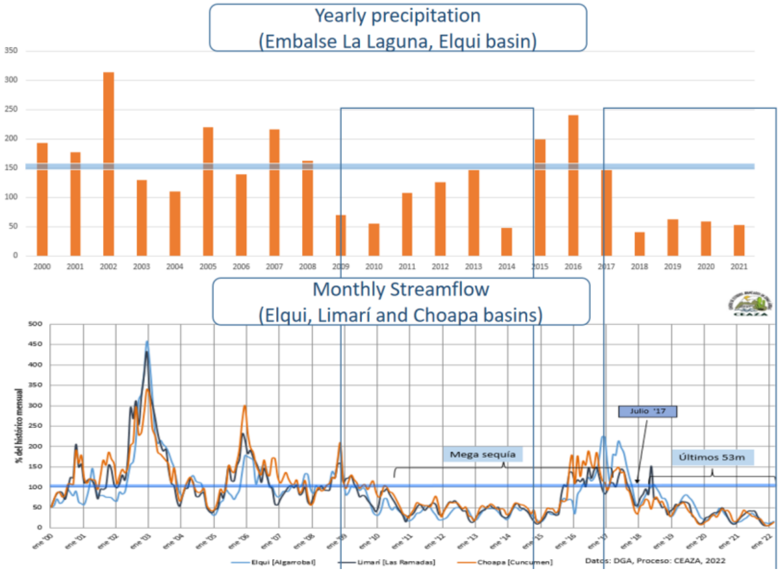


Fig.1 Yearly precipitation at the reservoir “La Laguna” (Elqui river basin) and monthly streamflow (Elqui, Limarí and Choapa river basins).

As a solution to the problem, we propose to:

1. Design and implement low-cost sensors to monitor snow-related parameters (air temperature, snow depth, snow water equivalent)
2. Develop highly technologically advanced small wireless weather stations (nodes).
3. Implement experimental operational networks of snow parameters in three basis of the Coquimbo Region.

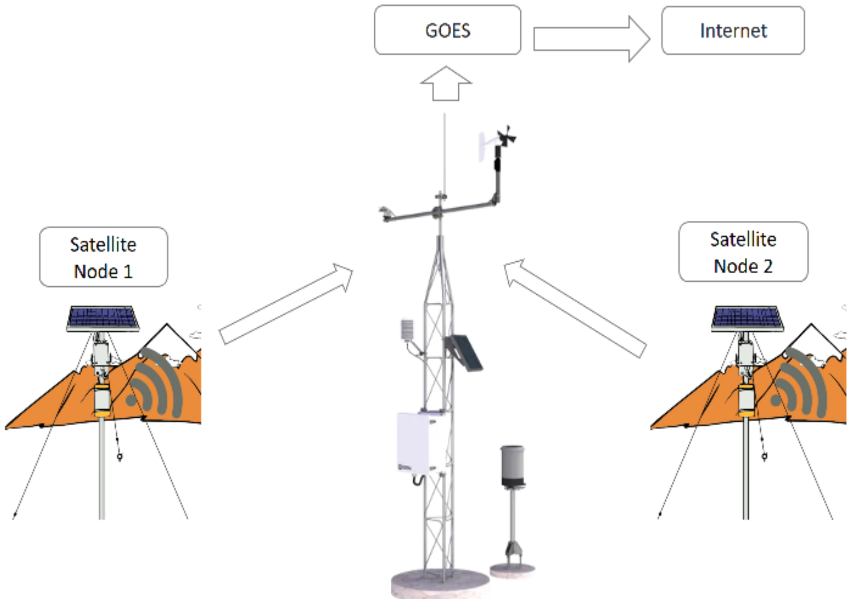


Fig.2 Proposed field network architecture. The existing GOES satellite channel infrastructure of CEAZA’s mountain AWS will be shared with data obtained from near snow monitoring nodes (up to 5 km by direct view).

State of the Art Analysis

The industrialized countries operate their own snow monitoring networks, but even in those places there is still low density of monitoring sites, despite the need for more accurate data for operational diagnosis and forecast models. The data scarcity is mostly due to the resources involved in operating weather stations in such harsh environments (see Fig.1).

Taking advantage of new technologies of open-source electronic platforms, some scientist from different fields have been investing time and resources to crate their own devices to take samples and gather data. But there is still a large gap between self-developed hardware and scientific grade equipment. There are also some examples of devices with more advances RTLs, which so far still don't reach the operational level (LOCUS-2) shown in Fig.2.

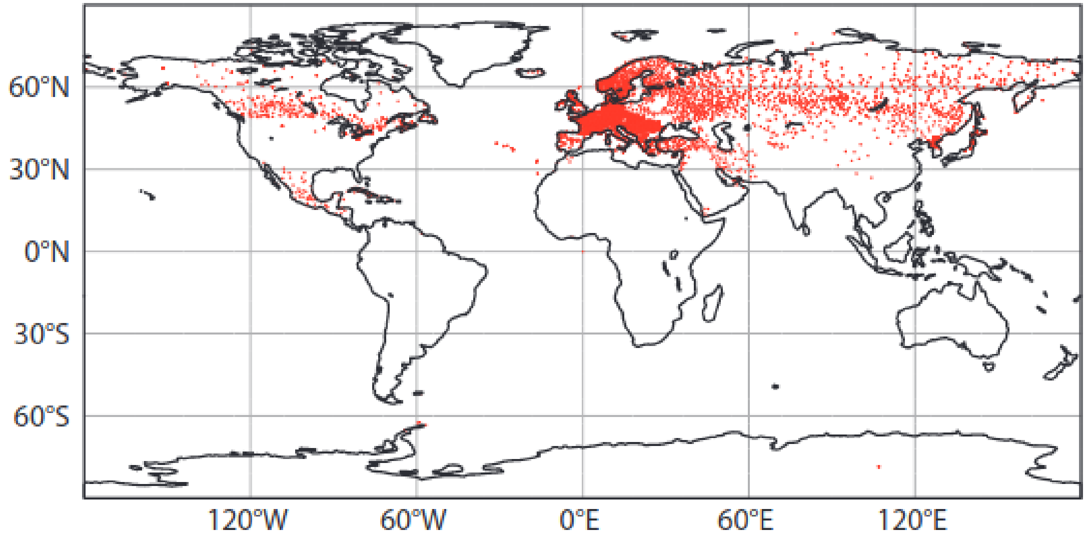


Fig1. World coverage of public snow weather stations availability on WMO GTS
Source: (WMO & ECMWF, 2022)

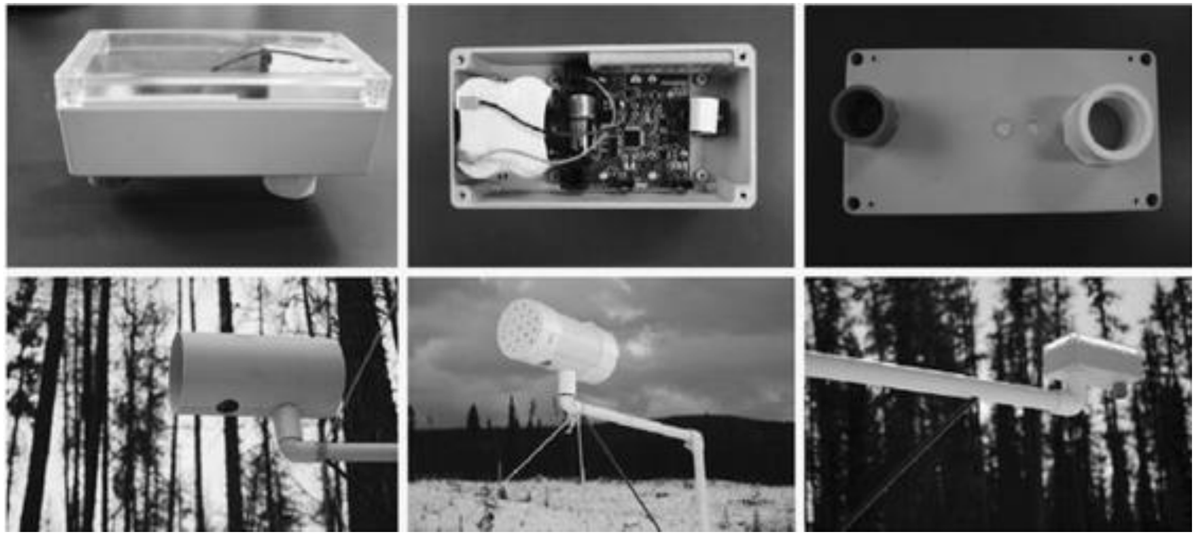


Fig.2 (top) Side, top, and bottom views of the LOCUS-2. (bottom) Examples of LOCUS-2 sensors installed in the field: (left) sensors in forested sites were oriented N–S to minimise the entry of direct sunlight in the PVC cover, whereas (center) sensors in open areas were fully covered; also, (right) some sensors were installed without a protective cover.
(From Varhola et al., 2010)

Previous Results

Fig.1 Electronics of node prototype

Fig.2 Prototype node implemented in 2021 summer season near Tascadero AWS

Previously, in the project "Design and implementation of low-cost measurement nodes for mountain range monitoring to support water management" (ANID, Proyectos I+D. Ciencia Territorio 2019 cod. R19F10002), a portable prototype node was developed by the CEAZA team (see Fig.1), capable of recording and transmitting by radio measurements of snow height and air temperature. The prototype was successfully tested: it achieved continuous datalogging in the mountains for one year (see Fig.2) using only low power consumption (TRL 5).

Fig.3 Air temperature prototype

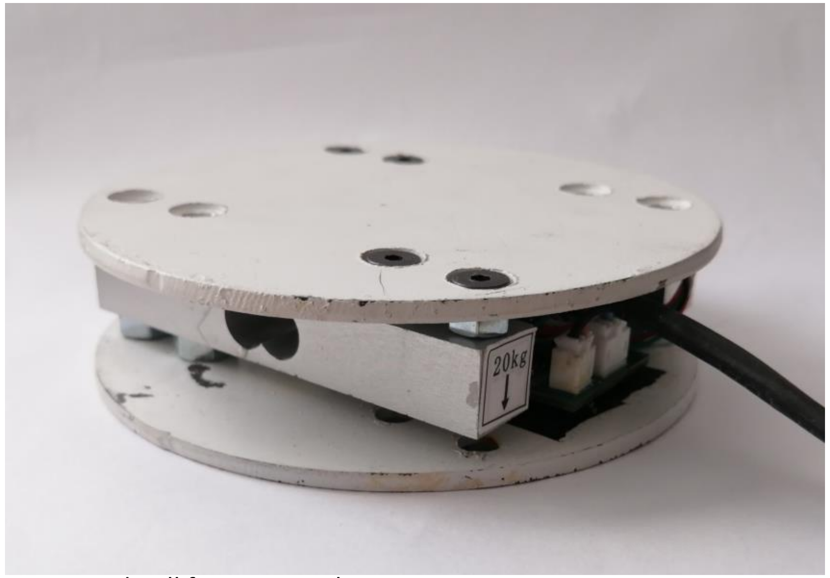


Fig.4 Load-cell for snow scale prototype

In addition, concept tests were carried out with self-developed electronics instruments to measure air temperature (Fig.3) and snow water equivalent (Fig.4) at TRL 3.

As a scientific result, a draft paper explaining the design and validation process of the main electronic board of the node has been accepted for publication in the International Journal of Research in Engineering and Science (IJRES) (scheduled for Jul. 2022)

Hypotheses and Objectives

General objective	Results	Specifics objectives
Implement an experimental snow monitoring network with cost-effective and self-developed telemetry technologies that allows overcoming the uncertainties of the snowpack water accumulation in the Andes Mountains	Implemented system in 3 experimental sites	Selection and setup of 2 validation sites in high Andes with scientific AWS and sensors
		Implementation and operation of 3 experimental wireless telemetry networks in three basins of the Coquimbo Region
	Operational node prototype validated under snow working condition	CEAZAnode prototypes design, implementation and field validation
	Prototypes of low-cost and low-consumption snow parameter measurement sensors	Snow sensors prototypes design and implementation and field validation

The hypothesis of this project is:

"The spatial and temporal density of snow monitoring in the mountains can be improved through the design and implementation of devices that meet the criteria of low cost, reliability and ease of operation“

Research and Development Methodologies

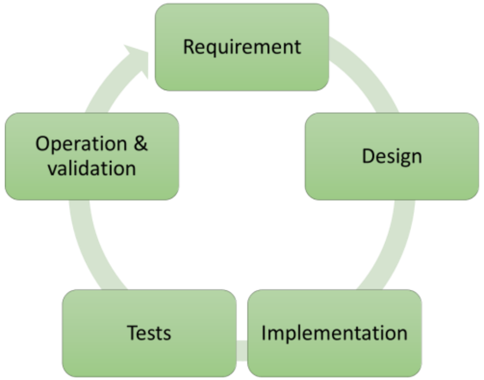


Fig.1 Adapted continuous improvement cycle

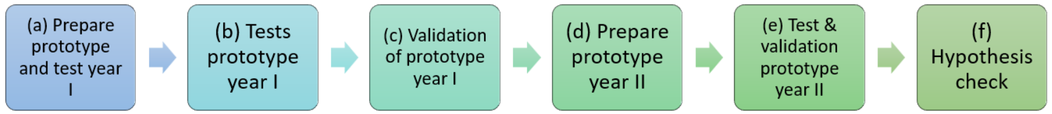


Fig.2 Products development process stages

The development methodology in this project is based on two cycles of continuous improvement adapted for this work, as can be seen in Fig1.

In step (a), two validation sites will be prepared in the mountains (Fig.2). The first prototypes to be tested in the field will be developed and prepared. In step (b), the prototypes will be implemented in the validation sites (see Fig.3) and will be left running throughout the winter season.

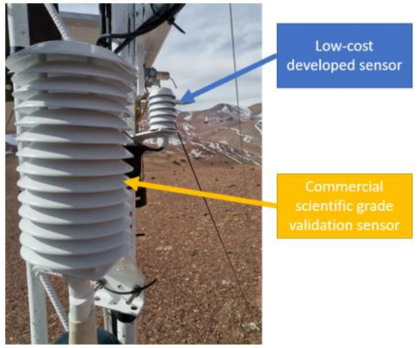


Fig.3 Low-cost developed air temperature sensor compared to commercial scientific grade air temperature sensor at validation site in "El Tapado" AWS under real operational conditions.

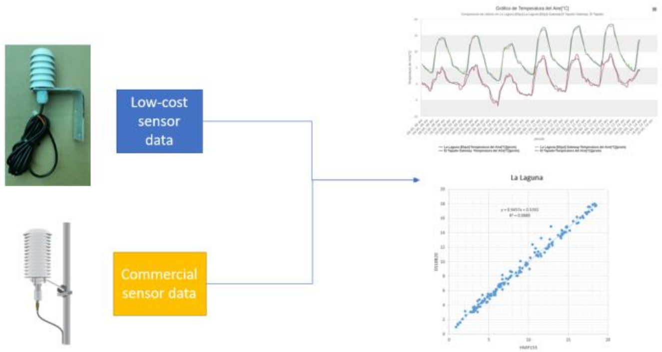


Fig.4 Data comparison example from sensors implemented at validation sites in "El Tapado" and "La Laguna" AWS. The same proposed validation process for this project.

At the end of the winter, the prototypes and their data will be collected, where in step (c) the development data will be compared with the reference sensors (see Fig.4) and functional, practical and operational improvements on the prototypes will be identified. Then, in step (d) improved prototypes will be designed, tested and manufactured, which will be implemented as a network in step (e) before the winter. At second year spring season, at stage (f), all prototype logs will be collected to verify product reliability, network performance, and low-cost achievement relative to commercial monitoring stations.

Activity program

ACTIVITY PERIOD

MONTHS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

RESULT	OBJECTIVES	ACTIVITY	ACTIVITY MANAGER	MILESTONE	START OF THE ACTIVITY (month)	ACTIVITY PERIOD (months)	MILESTONE ACHIEVEMENT (month)
1. Implemented telemetry network in 3 experimental sites	1.Selection and setup of 2 validation sites in high Andes with scientific AWS and sensors						
		1.1. Site selection of validation AWS	Shelley MacDonell		1	3	
		1.2. Setup and implementat validation sites with scientific grade HS, SWE and temperature sensors	Cristian Orrego	Milestone 1 - Validation sites functional and gathering data	3	6	8
		1.3. Maitenance of validation sites	Adrian Gallardo		6	19	
		1.4. Data gathering and validation	Cristian Orrego	Milestone 2 - Validation sites online and data available in CEAZAmet platform	7	18	24
	2. Implementation and operation of 3 experimental wireless telemetry networks in three basins of the Coquimbo Region						
		2.1. Network planning and sites selection	Cristian Orrego		1	3	
		2.2. Season 1 network implementation	Adrian Gallardo	Milestone 3 - Season 1 sucessful network data transmition thought winter (v2023 nodes)	6	7	12
		2.3. Season 2 updated network implementation	Adrian Gallardo	Milestone 4 - Season 2 sucessful network data transmition thought winter (v2024 nodes)	13	13	24
		2.4. Network operation	Cristian Orrego		4	21	
		2.5. Report generation and datasharing	Cristian Orrego		6	19	
2.Operational node prototype validated under snow working condition	3.CEAZAnode prototypes design, implementation and field validation						
		3.1. Requeriment and design of CEAZAnode prototype 2023	Cristian Orrego		1	3	
		3.2. implementation and testing of CEAZAnode prototype 2023	Adrian Gallardo	Milestone 5 - Prototype v2023 operational nodes (laboratory and field testing)	4	9	12
		3.3. Requeriment and design of CEAZAnode prototype 2024	Cristian Orrego		13	3	
		3.4. implementation and testing of CEAZAnode prototype 2024	Adrian Gallardo	Milestone 6 - Prototype 2024 operational nodes (laboratory and field tested)	16	9	24
		3.5 Difusion and transference of nodes by publishing, seminar participations and workshop conducting	Cristian Orrego		13	12	
3.Prototypes of low-cost and low-consumption nival parameter measurement sensors	4. Snow sensors prototypes design and implementation and field validation						
		4.1. Requirement and design of the temperature, snow height, weight and SWE sensors version 2023	Cristian Orrego	Milestone 7 - v2023 sensor prototypes laboratory validated	1	3	3
		4.2. Build, calibrate and testing of the temperature, snow height, weight and SWE sensors version 2023	Adrian Gallardo		4	8	
		4.3 Requirement and design of the temperature, snow height, weight and SWE sensors version 2024	Shelley MacDonell	Milestone 8 - Sensor v2024 prototypes field validated	12	3	24
		4.4. Build, calibrate and testing of the temperature, snow height, weight and SWE sensors version 2024	Adrian Gallardo		15	10	

CHAPTER 2

Technology development and transfer strategy and estimation of the social, environmental and territorial impact.

Product, process or service to develop

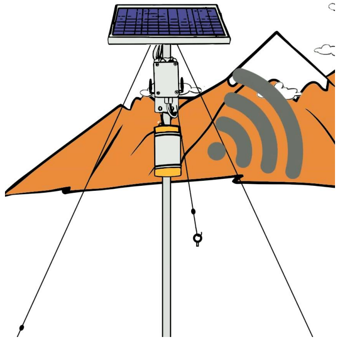


Fig1. Node equipped with low-cost instruments

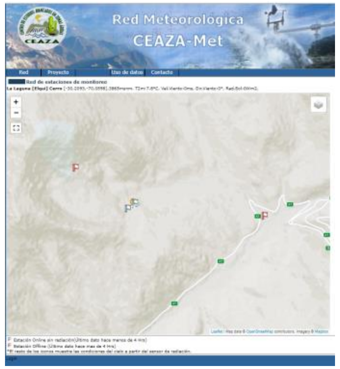


Fig2. Online prototype monitoring network

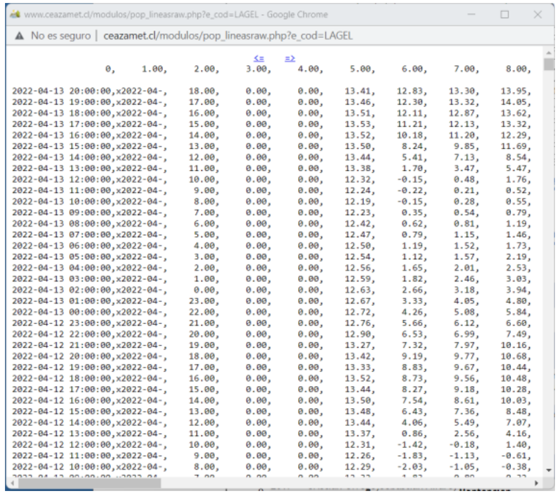


Fig3. Freely available RAW data from each network for studies purposes

Provincia	Lugar	Altura de nieve al 31 de Julio
Elqui	El Tapado (4306msnm)	10 a 15cm
Limarí	Tascadero (3427mnsm)	0 a 6cm
Choapa	Casa del Canto (3570msnm)	0cm

Fig4. Monthly resume report included in climate bulletin

This project offers a solution by a three-step development approach:

I. low-cost electronics measurements instruments (called “sensors” in the project context) for SWE, SH and air temperature observations. From RTL3 to RTL5

II. Improve portable easy to use and low-cost mountain-range instrumentation node, from RTL5 to RTL6.

III. Two experimental networks at high mountains created with the new nodes and the sensors developed and implemented near two existing AWS from the existing CEAZA network in Coquimbo region. Reporting SWE, SH and air temperature

The data of monitored snow parameters collected from the experimental network will be freely available from a sister platform to the CEAZAmet meteorological network with 1-hour time resolution. This data should be useful as input for water resource managements decision makers, scientific purposes for hydrological studies of Coquimbo region.

Associated Entities

In Chile, the main agents involved in the process of water management and distribution are the Water Management Associations (*Juntas de Vigilancia*), this entities have the important roll of control, dispatch and decide how much water will be given to water rights holders given the current and expected future water availability. In this role the most significant intervention, transference and data report impact in the water management system it is with them. In this Project "*Juntas de Vigilancia*" from the three basins of the Coquimbo Region were included:

1. JV del Río Elqui y sus Afluentes, Elqui Province
2. JV del Río Grande y Limarí y sus Afluentes, Limarí Province
3. JV del Río Illapel y su Afluentes, Choapa Province

In each of this basins we will implement a prototype network

Junta de Vigilancia RÍO ELQUI y sus Afluentes

Junta de Vigilancia Río Grande y Limarí y sus afluentes

JUNTA DE VIGILANCIA RIO ILLAPEL

JUNTA DE VIGILANCIA RIO ILLAPEL Y SUS AFLUENTES

Development strategy and business or overcrowding

There's 3 levels of products associated with the project proposal and so is the strategy.

1. The sensors: Because these devices will be at RTL5, future development projects will be needed to further develp them into higher technological levels.
2. The nodes (CEAZAnode): These devices will be at RTL6. Future projects are planned to take them to finals step in the commercialization process. Although these devices be ready at the end of the proposed project to be transferred to other intuitions with similar data capturing needs. This also will allow the expansion of the network.
3. The network: After the project ending, a snow monitoring network will be functional in an experimental manner. A future step will be to expand the network to monitor additional snow catching area and install other networks in other zones.

It is expected also that when the first RTL 8 and 9 products are ready (4-5 year from now), the core development team should be incorporated into the core CEAZA team. This would be a large step up in the technological level of the institution and a large achievement in view of the future of technological development. Hardware development will be a central knowledge area in years to come, as many problem with management are related to data gathering and transformation.

CHAPTER 3

Scientific and technological capabilities and collaboration mechanisms

Resource Distribution

ITEM	FONDEF	INSTITUCIONAL	ENTIDADES ASOCIADAS	TOTAL
GASTOS EN PERSONAL	78.220.500	10.944.000	8.400.000	97.564.500
EQUIPAMIENTO	26.713.208	49.763.088	5.000.000	81.476.926
INFRAESTRUCTURA Y MOBILILARIO	4.000.000	7.200.000	18.800.000	30.000.000
GASTOS DE OPERACIÓN (considera gastos en los ítems Material fungible, Software, Subcontratos, Pasajes y Viaticos, Propiedad intelectual, Seminarios, Publicaciones y difusión, Capacitación, Otros gastos de operación)	43.030.000	1.200.000	0	44.230.000
GASTOS DE ADM. SUPERIOR 12% Máx.	20.000.000			20.000.000
TOTAL	**171.963.708**	**69.107.088**	**32.200.000**	**273.270.796**
PORCENTAJE				

Research Team

- Ing. Cristian Orrego, director, is the CEAZA's meteorology group coordinator and system manager of CEAZAmet network. Also has been working in hardware prototyping for the last 5 years, will be also the firmware developer of the prototypes and network designer.

- Ing. Adrian Gallardo, deputy director, is an electronic engineer, with experience in hardware electronic design, embedded systems implementations and scientific monitoring networks. Also have experience in electronic devices testing and certifications.

- PhD. Shelley MacDonell, researcher in glaciology with experience in the interactions between the climate, cryosphere and hydrology. Her main role will participate in the experiment design and validation.

- PhD. Simone Schauwecker, postdoctoral researcher with experience in climate-cryosphere interactions. She will participate in design, requirement definition and data validation activities.

- PhD. Álvaro Ayala, postdoctoral researcher with experience in numerical models of the cryosphere with a focus on runoff generation. He will participate in design and requirement definition activities. Also, as field tester of the prototypes.

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