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Biennial report for Permanent Supersite/Natural Laboratory

GeoHazSA: Southern Andes Supersite

Coupled geohazards at Southern Andes: Copahue-Lanín arc volcanoes and adjacent crustal faults

History	*https://geo-gsnl.org/supersites/permanent-supersites/southern-andes-supersite/*
Supersite Coordinator	*Luis E. Lara, SERNAGEOMIN, CIGIDEN, Av. Santa María 0104, Santiago, CHILE*

1. Abstract

The Southern Andes (33°-46°S) are a young and active mountain belt where volcanism and tectonic processes pose a significant threat to the communities nearby. In fact, only recent eruptions caused evacuations of 250-3500 people and critical infrastructure is present there. The segment here considered corresponds to a low altitude orogen (<2000 masl on average) but characterized by a high uplift rate as a result of competing tectonic and climate forces. This Supersite focuses on a ca. 200 km long segment of the Southern Andes where 9 active stratovolcanoes (Copahue, Callaqui, Tolhuaca, Lonquimay, Llaima, Sollipulli, Villarrica, Quetrupillan and Lanín) and 2 distributed volcanic fields (Caburgua and Huelemolles) are located, just along a tectonic corridor defined by the northern segment of the Liquiñe-Ofqui Fault System (LOFS). Activity of the LOFS has been detected prior to some eruptions and coeval with some others. There are several tectonic and volcanic models to be investigated that derive from a strong two-way coupling between tectonics and volcanism, recently detected by either geophysical techniques or numerical modeling. Hazards in the segment derive mostly from the activity of some of the most active volcanoes in South America (e.g., Villarrica, Llaima), others with long-lasting but weak current activity (e.g., Copahue) or some volcanoes with low frequency but high magnitude eruptions in the geological record (e.g., Lonquimay). Since the beginning of the 20th century ~80 eruptions have been recorded in this area. Remote sensing techniques coupled with ground-based seismic methods allowed tracking of the effusive stage of the 2011-2012 Cordón Caulle eruption and geodesy became a current tool of volcano monitoring in SERNAGEOMIN, with remote sensing as the most promising method in terms of data cover and time series. The Supersite is especially active and there is evidence of both magmatic and non-magmatic ground deformation, mainly from InSAR data at Copahue and more recently Lonquimay, Llaima and Villarrica volcanoes. The growing network of continuous GNSS stations deployed in this segment is a perfect complement and is already revealing interesting patterns of crustal deformation likely related to current activity the LOFS and its possible interaction with volcanoes. A preliminary spatio-temporal analysis suggests postseismic relaxation after the Maule earthquake and as a driver for instability of the volcanic systems, athough all of these hypotheses remain to be confirmed

2. Scientists/science teams

<In the table below please list all scientists/science teams who used/received data >

Researcher/team 1	***Name, affiliation, address, e-mail, website/personal page of team leader***
Francisco Delgado	*Universidad de Chile, fdelgado@uchile.cl*
Pablo Euillades	*Universidad Nacional de Cuyo, pablo.euillades@ingenieria.uncuyo.edu.ar*
Luis E. Lara	*SERNAGEOMIN, luis.lara@sernageomin.cl, www.sernageomin.cl*
Loreto Córdova	*SERNAGEOMIN, loreto.cordova@sernageomin.cl, www.sernageomin.cl*

Scientists/science teams issues

This Supersite is not hosted by a single institution but in a number of institutes/universities and thus the capability is distributed and somewhat disperse. Scientists of the Supersite are also in charge of multiple programs and projects, which priorities are sometimes in conflict. This is not surprising being in fact the reality of developing countries with small science communities and institutions without permanent funding for emerging programs. Taking into account this situation, we have focused on a reduced number of case-studies, explored our best networking capacities and hired PhD students under our advice.

1. In situ data

<In the table below please list all in situ data types available for the Supersite>

Type of data	Data provider	How to access	Type of access
Seismic data (waveforms and time series)	*SERNAGEOMIN*	*Formal request*	*Limited to GSNL scientists upon request or registered public*
GPS time series	*SERNAGEOMIN*	*Formal request*	*Limited to GSNL scientists upon request or registered public*
Gas (DOAS, multigas)	*SERNAGEOMIN*	*Formal request*	*Limited to GSNL scientists upon request or registered public*

In situ data issues

Access to in-situ instrumental data in Chile is not straightforward, although the law recognizes the obligation of public agencies in providing information obtained with public funding. Since the last report, public agencies as SERNAGEOMIN are moving to a more open style and they have now protocols for data request, which are usually satisfied in time. There are still some challenges and technical issues in data storage and sharing because (for example seismic data from the monitoring network) is not designed for pattern recognition and retrospective analysis but mostly for real-time short-term forecasting. There are some cultural issues in terms of collaborative work between public agencies and third parties but some advance in the number of collaborative processes. In fact, young scientists and technicians are more able to share data being involved in join efforts aimed to better understand processes beyond the short-term response. Some ongoing undergraduate and graduate thesis are an example of such a change of paradigm.

2. Satellite data

<In the table below please list all satellite data types available for the Supersite>

Type of data	Data provider	How to access	Type of access

TerraSAR X	*DLR*	*Supersite data repository*	*Registered public, limited to GSNL scientists*
COSMO-Skymed	*ASI*	*Supersite data repository*	*Registered public, limited to GSNL scientists*
RADARSAT		*Supersite data repository*	*Registered public, limited to GSNL scientists*
Pleiades		*Supersite data repository*	*Registered public, limited to GSNL scientists*

Satellite data issues

No relevant data issues observed. Some format issue for CSK images was rapidly solved.

3. Research results

Research results are still in progress. There is advance in a PhD thesis (Fernanda López, Universidad de Concepción, advised by Luis E. Lara) focused on both the atmospheric effect and the problem of big data management. An undergraduate student is working on a similar topic (Universidad de Chile, advised by Francisco Delgado). Four undergraduate students are working under supervision of external researchers:

Andrés Parra (Geology, Universidad de Concepción), advisor José Luis Palma. Co-advisor: Franco Vera.
Javier Muñoz (Geology, Universidad de Concepción), advisor José Luis Palma. Co-advisor: Franco Vera.
Matias Fernandez (Master degree, Geophysics, Universidad de Concepción), advisor José Luis Palma. Co-advisor: Franco Vera ((SERNAGEOMIN).
Catalina Mellado (U. de O'Higgins), advisor Laura Becerril (SERNAGEOMIN)

Publications

1 article submitted

Peer reviewed journal articles
López-Pozo, F.; Abarca, R.; Lara, Luis E. Climatology of tropospheric delay in InSAR data 1 applied as tropospheric correction to volcanoes in 2 Los Andes. Submitted to Nature Scientific Data.
…
…
Conference presentations/proceedings
…
…

…

Research products

There are some preliminary research products mostly focused on Villarrica and Copahue volcanoes:

Villarrica:

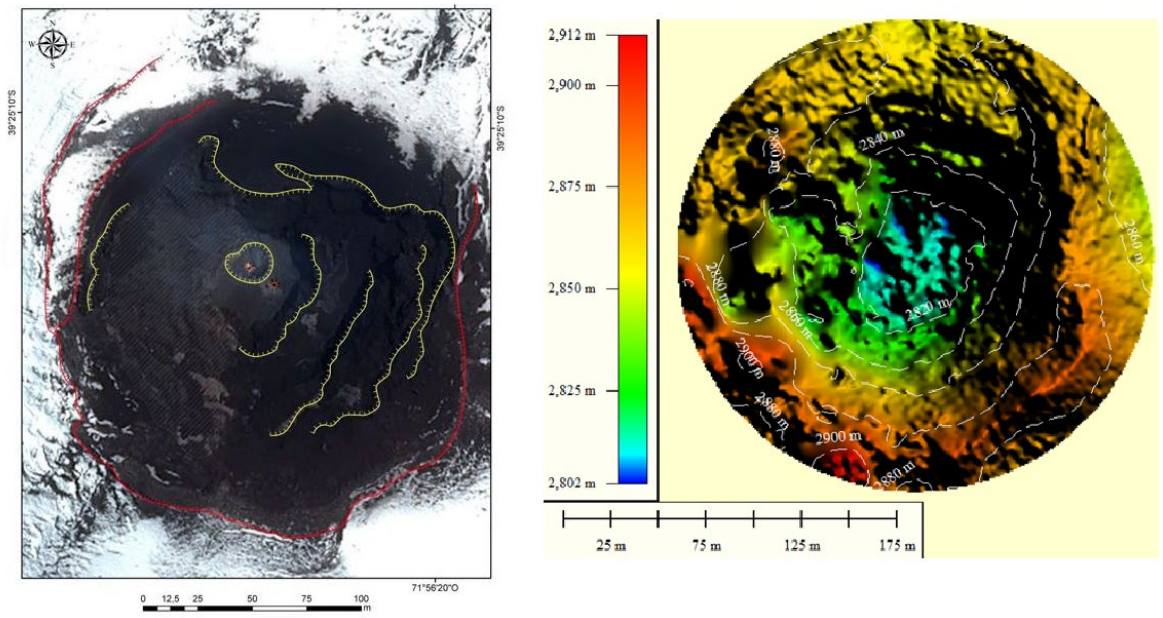
Pleiades imagery

This resource has proved to be very important for monitoring purposes and hazard assesment. During the last year we have learn about the use of the images with CNES and we also made the selection of volcanoes to monitor by this tecnique. The quota asigned was 1200 km2 per year; images in mono and stereo mode were asked for Villarrica (the most active volcano in Chile) and Copahue volcanoes and were used for volcano monitoring, mapping products or geological studies, and to build Digital Elevation Models (DEM) for modeling efforts.

(1) Images and DEM have supported monitoring work of OVDAS and helped for hazard assesment. Copahue has active fumaroles and a crater lake which dynamics is a key monitoring parameter. On the other hand Villarrica has an active lava lake that presented ash emissions during the last years. Photointerpretation has been done for determining morphological features, the dynamics of volcanic activity at the craters (level of the lava lake, degassing zones, surface textures, stability of crater walls, structures and vents, among others), as well as the dimensions of pyroclastic deposits.

(2) Pleiades images for Villarrica were used for monitoring the crater area, comparing between 2 acquisitions and another high resolution images (Skysat), since at the end of 2020 the volcano emitted ash and pyroclatic material that reached 2 km away of the crater and are being used to map historical lavas around the volcano, contrasting size and volumen of these products against published data, in order to re-calculate eruptive parameters as efussion rate. Final results are expected for March 2022.

(3) Digital Elevation Models were built in SERNAGEOMIN using Catalyst software and are being used by the Volcano Hazard Team to develop a methology to optimize the morphometric and morphological analysis of the valleys, which will serve as inputs for new modelling efforts of lahars and lava flows with final result the update of the hazard map of Villarrica and Copahue volcanoes. This work has started in Villarrica area with first products to be presented next year and the new hazard map published in 2023. All this is part of a collaborative work with Universidad de Concepción, where two undergraduate students and another master student are working in that.



Preliminary products prepared from Pleiades images for Villarrica volcano: Photo-interpretation of the crater rim, structures and vents to the left, and contour lines to determing depth of the lava lake and vents on the right.

On the other hand, an undergraduate student is working on a reanalysis of the 2015 eruption of Villarrica Volcano in order to propose a more reliable interpretation of the processes involving the lava lake and recorded deformation (supervised by Francisco Delgado).

Copahue:

CSK images were used for Copahue Volcano and a book chapter was published, although the specific images used in this study (2011-2012) were provided by CONAE.
https://www.sciencedirect.com/science/article/pii/B9780081029084001326

Research product issues

No relevant issues to report beyond our reduced capabilities when being a smalle research community with multiple tasks.

4. Dissemination and outreach

No dedicated dissemination or outreach activities were performed.

5. Funding

All the activities have been funded from grants and scholarships granted to members of the scientific team. Supersite Coordinator is partially funded by FONDAP 15110017 Center for Integrated Risk Management (CIGIDEN); PhD student Fernanda López has a Conicyt scholarship; CoI Tassara is part of The CYCLO Millenium Nucleous.

6. Stakeholders interaction and societal benefits

Only few interaction with stakeholders was performed, mostly because of the pandemics. However, Pleiades products on Villarrica volcano were used to generate information published on monthly Volcanic Activity Reports (RAV), available on our web page.

7. Conclusive remarks and suggestions for improvement

<In this section the Supersite Coordinator is asked to summarize the achievements and the issues, and to provide comments, impressions, remarks, and suggestions to improve the GSNL initiative and/or the specific Supersite activities.>

We still have an extremely complex scenario because the Supersite represents a small and dispersed scientific community. However, the Supersite partially solved this challenge shaping a collaborative network with participation of external researchers and graduate/undergraduate students.
Some remarkable advances are:

- *PhD student (Fernanda López) in her 3rd year, working on atmospheric correction and exploitation of time series. Her first article was recently submitted to Nature Scientific Data and currently she is working on a couple of drafts.*
- *Image analysis is now a regular operational due at the Volcano Observatory run by SERNAGEOMIN. Staff involved on that has been trained. Also experience and training has been performed for radar images.*
- *A growing number of external researchers from different universities are leading research with this images as basic input.*

As a personal view, I still envision this initiative as a challenge for collaborative work not related to a single institution or research team. Issues are of course those expected for a small scientific community with scarce institutional support, affiliated to institutions that accomplish their mission with small budget and many dues. Thus, our preliminary results both scientific and operational could serve as a trigger for a transition from small-scale studies to large-scale automatized processes with a big amount of data.