Cryospheric Hazards in the Río Volcán Basin, Chilean Central Andes: One Region, Multiple Phenomena

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Abstract

The Chilean central Andes are known for its variety of cryospheric landforms, which have included almost every kind of glacier since their first exploration back in the XIX century. However, there has been a severe reduction of the glacierized area since the 1950s, driven by climate change and enhanced due to the megadrought, which has endured for over a decade in the region. Such decline in glacier volume combined with temperature increasing and precipitation reduction can lead to different types of instabilities. In mountainous regions of high public affluence, glacial instabilities are considered as potential hazards leading to the loss of lives and infrastructure. Here we analyze the Río Volcán basin (-32.82°/-70.00°), located 40 km east of Santiago city in the international border with Argentina. The region is known for its closeness to the capital, which favors outdoor activities and hydroelectric power development. Elevation ranges from 3380 to over 6000 m a.s.l. at the San José Volcanic Complex, allowing conditions for coexistence of mountain glaciers, valley glaciers, rock glaciers and glaciarets. According to the public Chilean Glacier Inventory, there are more than 140 mapped cryoforms occupying an area of 57 km2 . Beside snow avalanches, there are multiple factor that provide ideal conditions for cryospheric hazards involving glaciers. Some of those factors are pointed out on the following: The presence of an active volcanic complex sets up the triggering agent for lahars and mixed snow/ice avalanche occurrence. There are three moraine-dammed glacial lakes with a cumulated area of up to 24 hectares in front of the El Morado glacier and two innominates. The lakes are still enlarging along with the glacier shrinkage, conforming three potential glofs in the region. Several debris-free glaciers have a very steep front, steeper than 30°, favoring the occurrence of ice falls and ice avalanches. There is a reported surge event in the Nieves Negras glacier, located at the south face of the San José volcano. The latter would have happened in the late 1940s according to literature. In addition, at least four glaciers showed abnormal advance rates in the early 1990s of up to 100 m/yr, along with the surge-like behavior of the Loma Larga glacier. Providing further knowledge of this complex region is key in order to enhance understanding and hazard management on a day to day basis.

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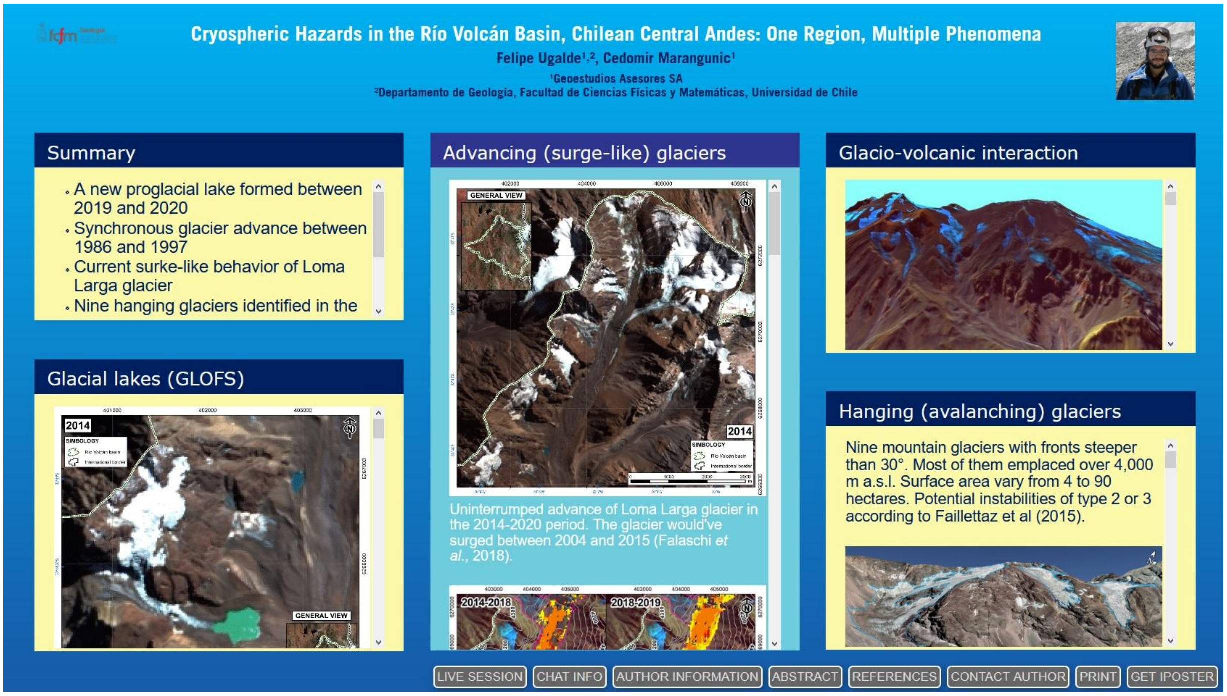

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PRESENTED AT:

ABSTRACT

The Chilean central Andes are known for its variety of cryospheric landforms, which have included almost every kind of glacier since their first exploration back in the XIX century. However, there has been a severe reduction of the glacierized area since the 1950s, driven by climate change and enhanced due to the megadrought, which has endured for over a decade in the region. Such decline in glacier volume combined with temperature increasing and precipitation reduction can lead to different types of instabilities. In mountainous regions of high public affluence, glacial instabilities are considered as potential hazards leading to the loss of lives and infrastructure.

Here we analyze the Río Volcán basin (-32.82°/-70.00°), located 40 km east of Santiago city in the international border with Argentina. The region is known for its closeness to the capital, which favors outdoor activities and hydroelectric power development. Elevation ranges from 3380 to over 6000 m a.s.l. at the San José Volcanic Complex, allowing conditions for coexistence of mountain glaciers, valley glaciers, rock glaciers and glaciarets. According to the public Chilean Glacier Inventory, there are more than 140 mapped cryoforms occupying an area of 57 km^2.

Beside snow avalanches, there are multiple factor that provide ideal conditions for cryospheric hazards involving glaciers. Some of those factors are pointed out on the following:

The presence of an active volcanic complex sets up the triggering agent for lahars and mixed snow/ice avalanche occurrence. There are three moraine-dammed glacial lakes with a cumulated area of up to 24 hectares in front of the El Morado glacier and two innominates. The lakes are still enlarging along with the glacier shrinkage, conforming three potential glofs in the region. Several debris-free glaciers have a very steep front, steeper than 30°, favoring the occurrence of ice falls and ice avalanches. There is a reported surge event in the Nieves Negras glacier, located at the south face of the San José volcano. The latter would have happened in the late 1940s according to literature. In addition, at least four glaciers showed abnormal advance rates in the early 1990s of up to 100 m/yr, along with the surge-like behavior of the Loma Larga glacier.

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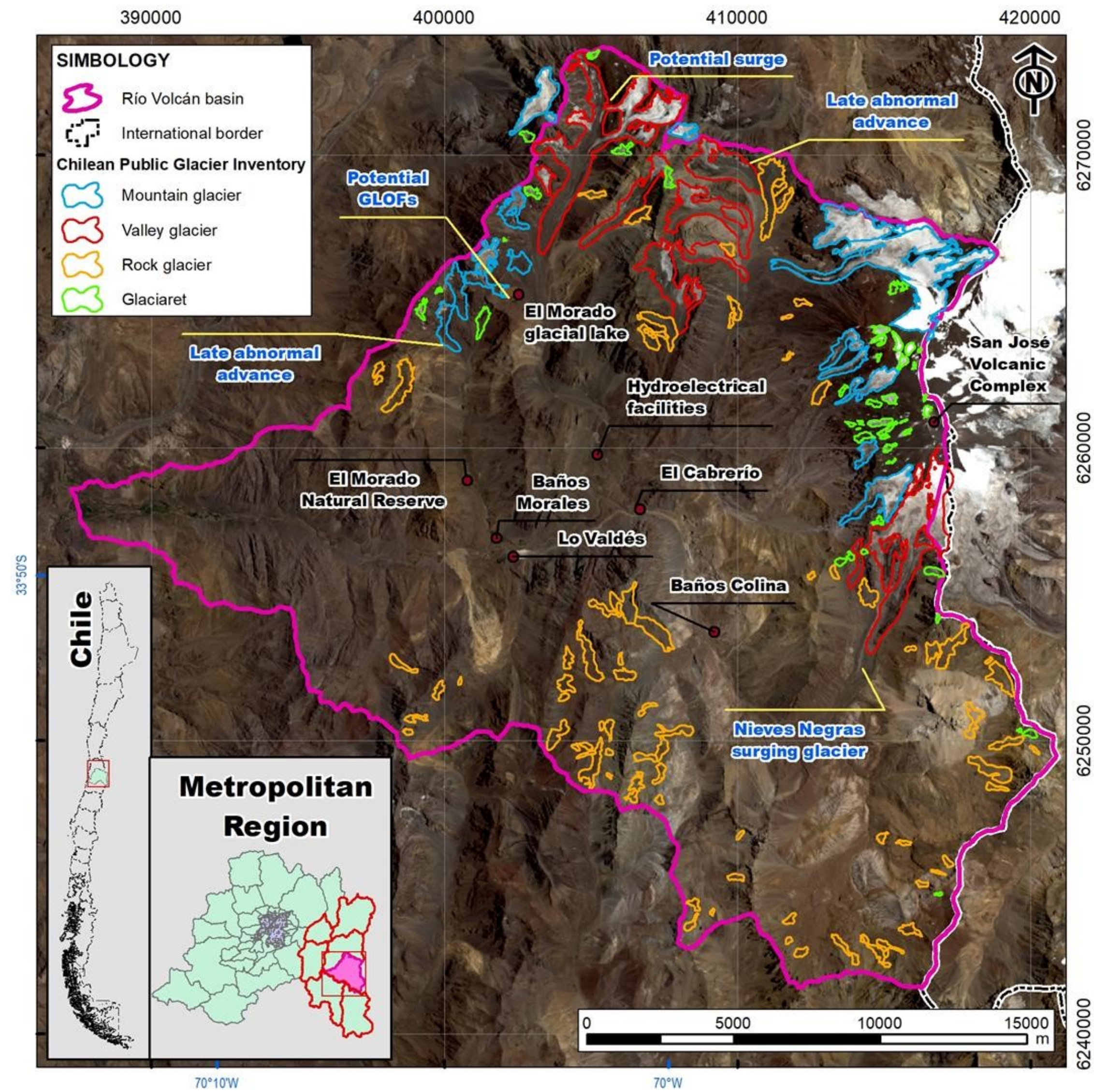
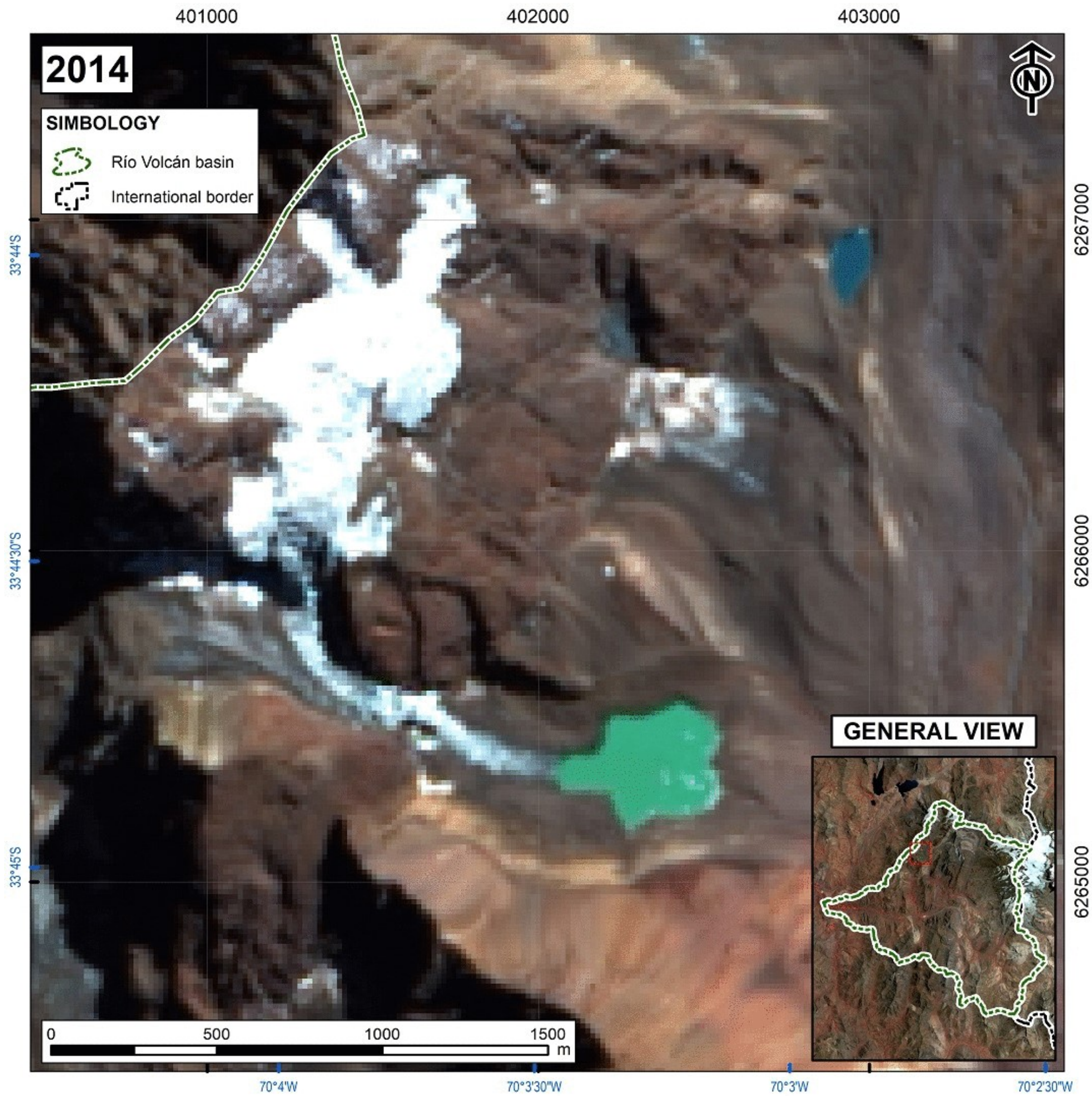
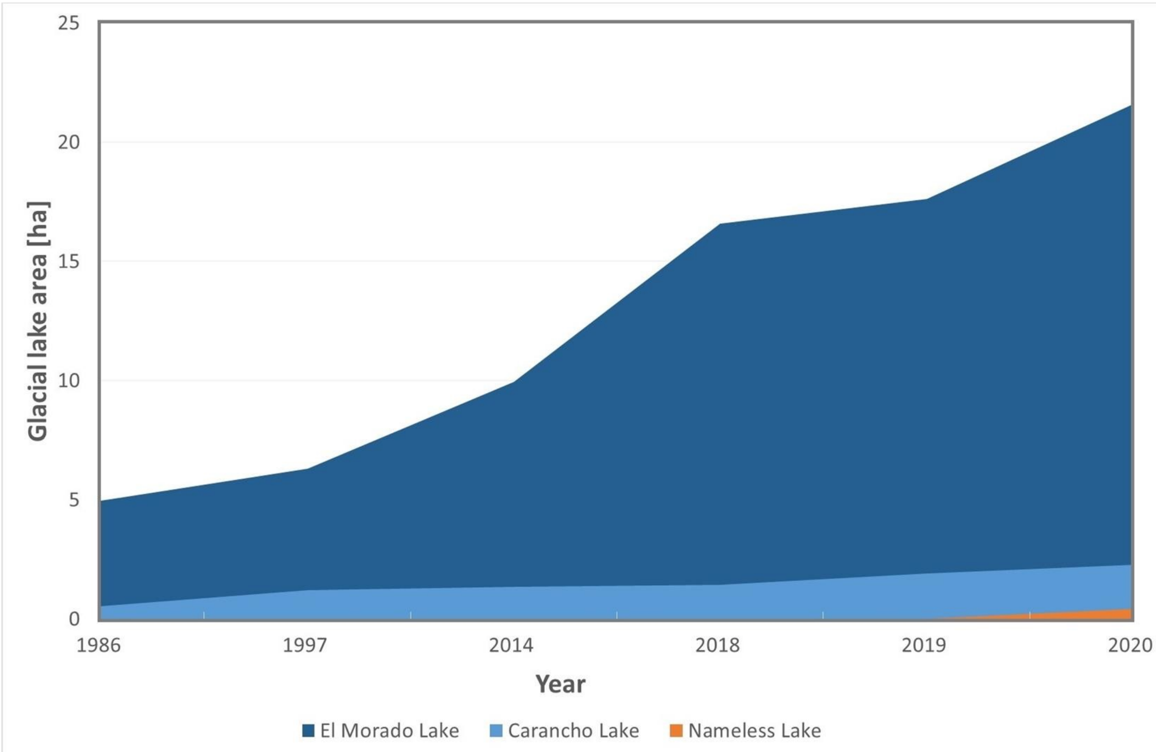


SIMBOLOGY
Río Volcán basin
International border
Chilean Public Glacier Inventory
Mountain glacier
Valley glacier
Rock glacier
Glaciaret
Potential surge
Late abnormal advance
Potential GLOFs
El Morado glacial lake
Late abnormal advance
San José Volcanic Complex
Hydroelectrical facilities
El Morado Natural Reserve
Baños Morales
El Cabrerío
Lo Valdés
Baños Colina
Nieves Negras surging glacier
Chile
Metropolitan Region
390000
400000
410000
420000
6270000
6260000
6250000
6240000
33°50'S
70°10'W
70°W
0 5000 10000 15000 m

GLACIAL LAKES (GLOFS)



The animation above shows three glacial lakes analyzed: El Morado (south), Carancho (north) and a nameless one in between. The latter, consisting on at least three small lakes, would've generated between 2019 and 2020 due to glacier shrinkage. By 2020, the cummulative area sums ~24 ha.



Glacial lakes growth through 1986 to 2020

El Morado glacier and proglacial lake. March 2019. Maximum depth of 64 m (Farías-Barahona *et al*., 2020)

Carancho glacial lake. March 2019

Carancho glacial lake. March 2020

Nameless glacier. March 2019

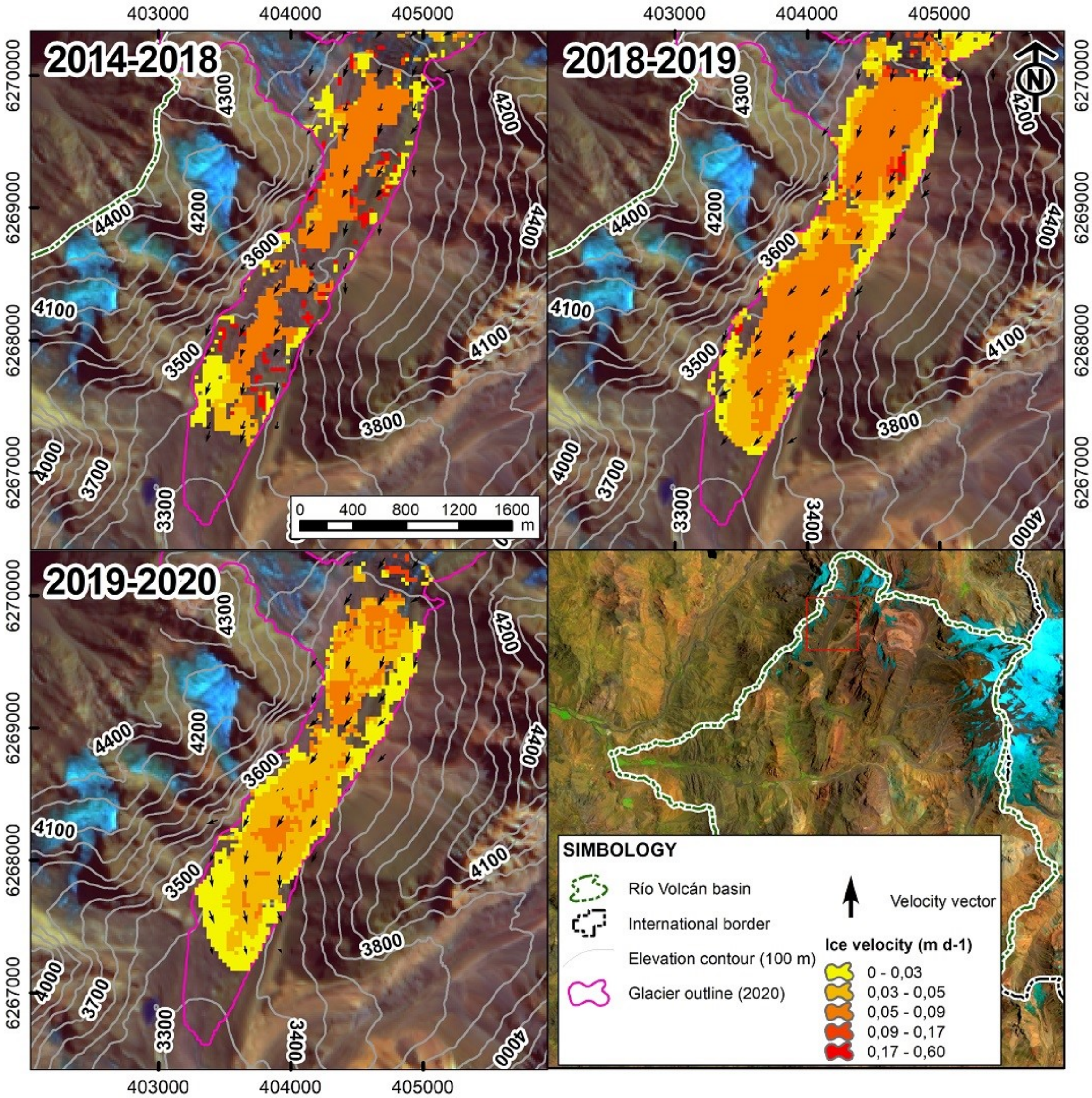
Nameless glacier. November 2020. Three small glacial lakes developed between 2019 and 2020

North lake, Nameless glacier. November 2020

[VIDEO] https://www.youtube.com/embed/JEUY4j_pYx4?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

ADVANCING (SURGE-LIKE) GLACIERS

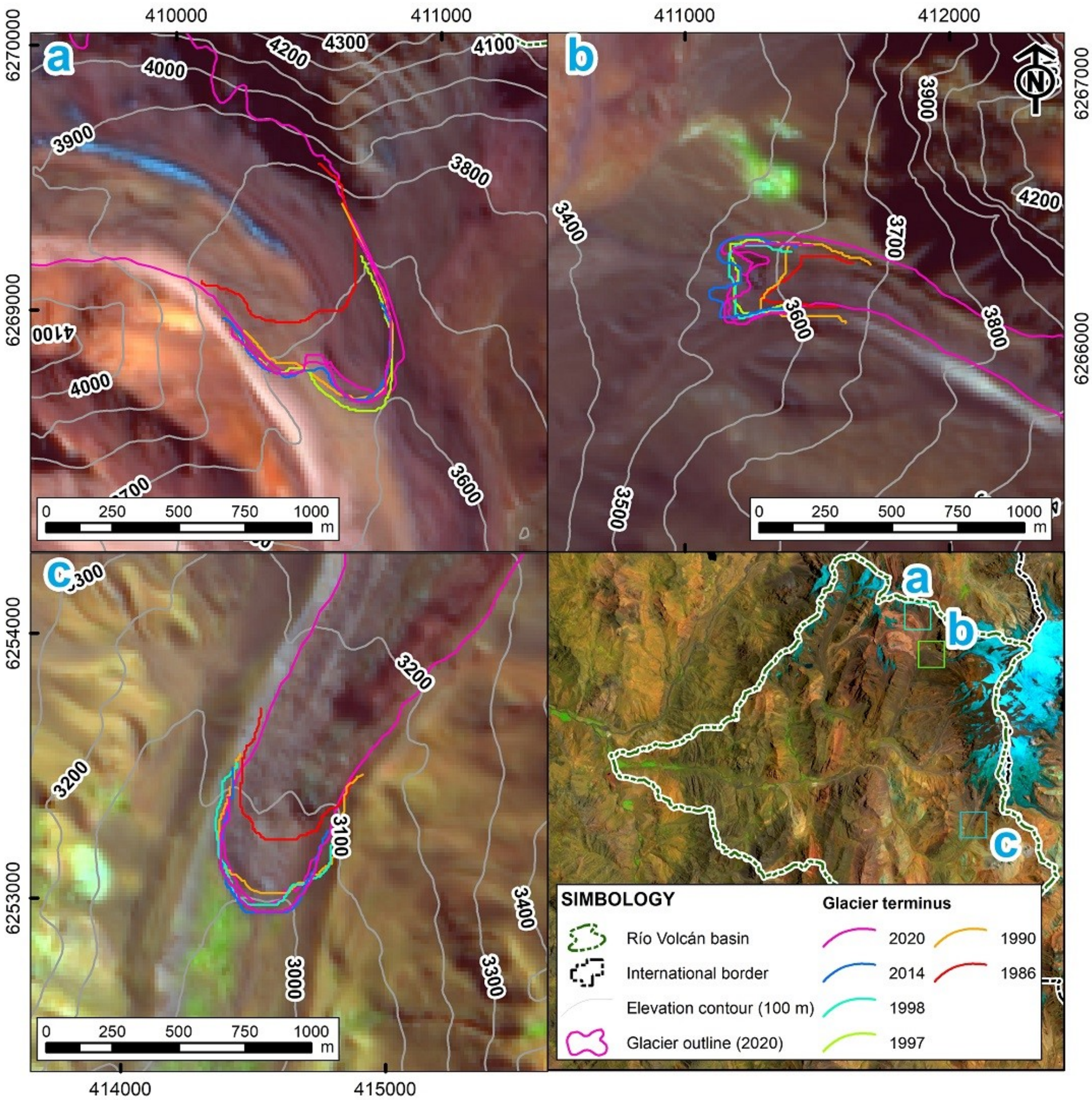
Uninterrumped advance of Loma Larga glacier in the 2014-2020 period. The glacier would've surged between 2004 and 2015 (Falaschi *et al*., 2018).



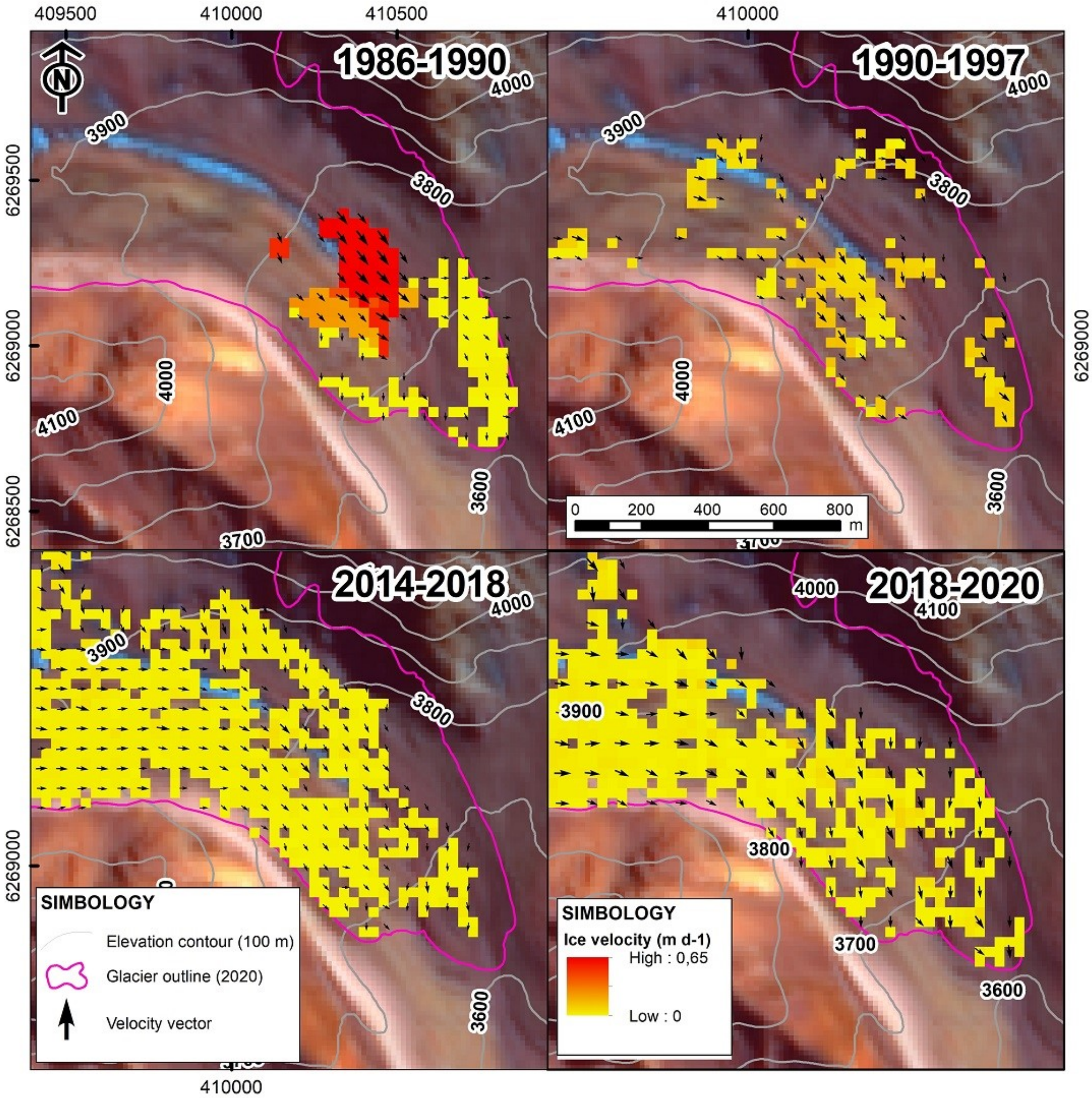
Loma Larga glacier velocities estimated for 2014-2018, 2018-2019 and 2019-2020 periods using CIAS software, after Kääb & Vollmer (2000) and Heid & Kääb (2012).

Video: Loma Larga glacier terminus on March, 2019

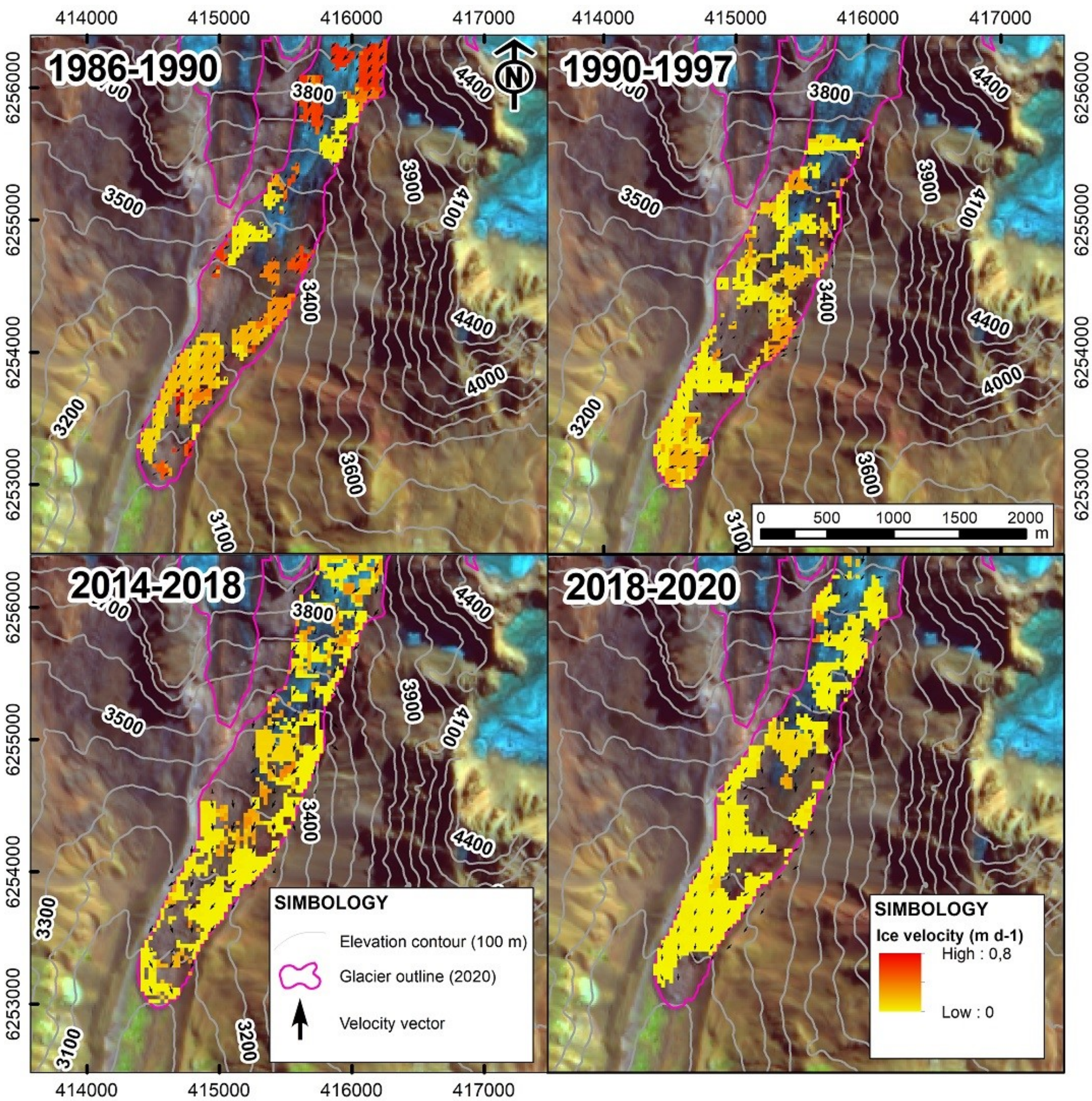
Terminus position



Glacier terminus from 1987 to 2020. a) Debris-covered glacier at Marmolejo valley. b) Marmolejo debris-covered glacier. c) Nieves Negras glacier



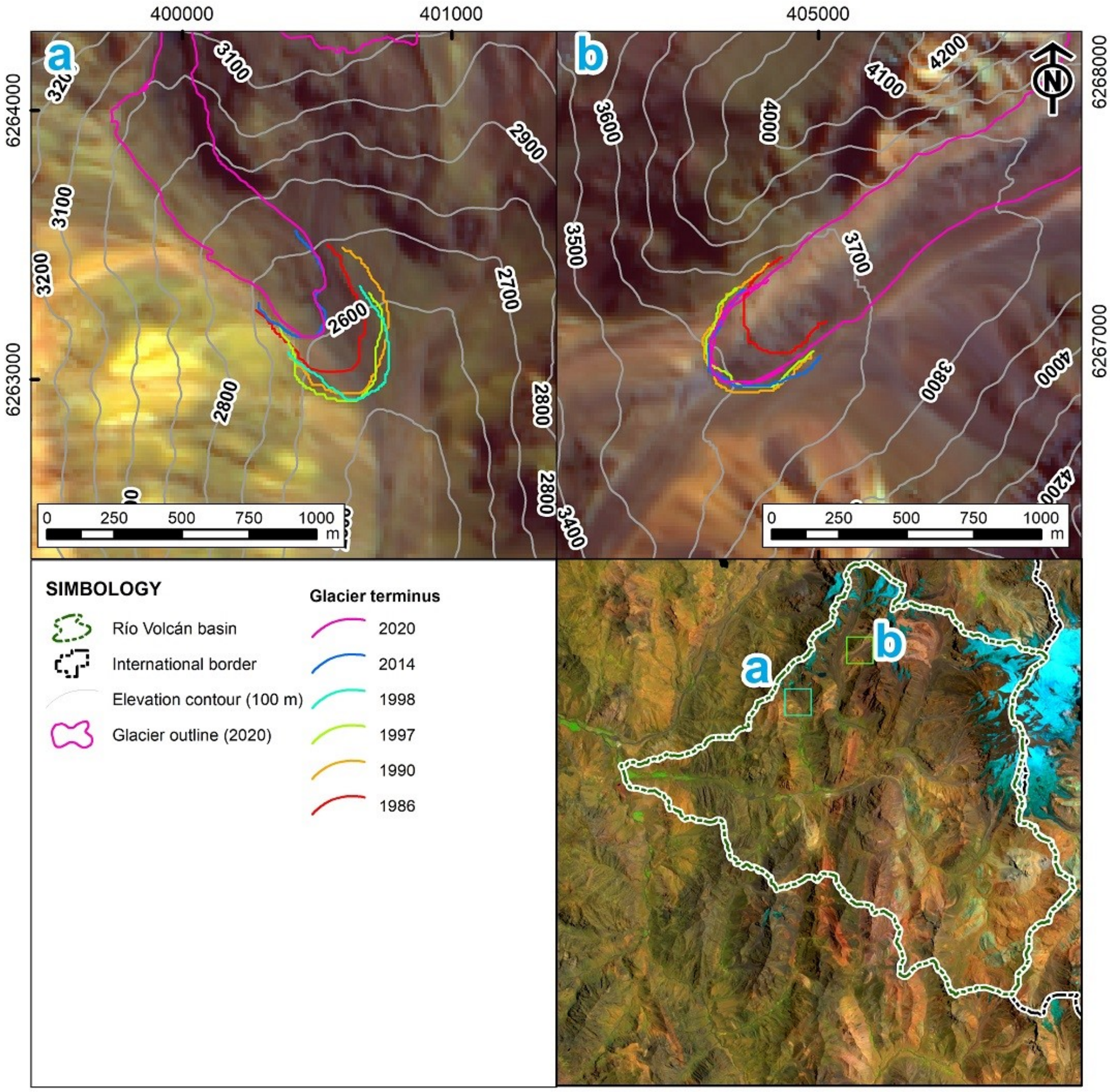
Debris-covered glacier velocities estimated for 1986-1990, 1990-1997, 2014-2018 and 2018-2020 periods



Nieves Negras glacier velocities estimated for 1986-1990, 1990-1997, 2014-2018 and 2018-2020 periods

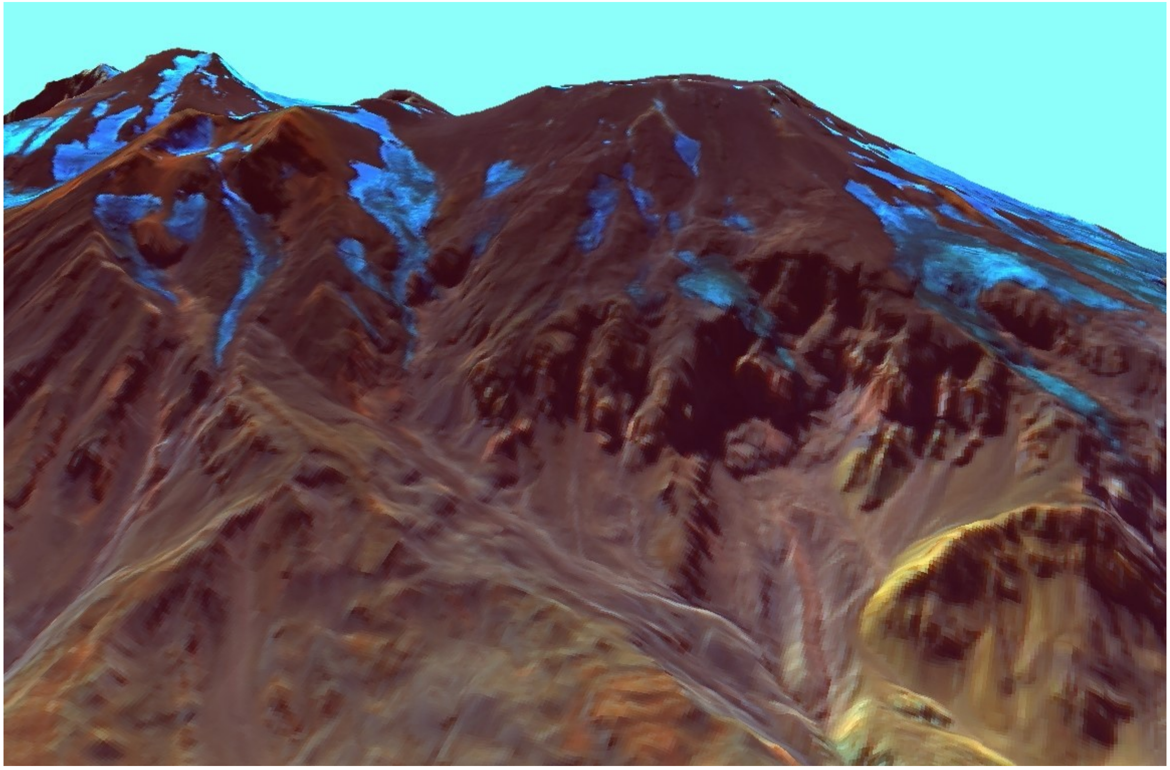
Nieves Negras glacier terminus. South flank of San José Volcano. December 2020.

[VIDEO] https://www.youtube.com/embed/3CdqBQhr1Tw?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0



Glacier terminus from 1987 to 2020. a) San Francisco glacier. b) Cortaderas debris-covered glacier.

GLACIO-VOLCANIC INTERACTION



Up to 60 uncovered snow and ice masses identified above the San José Volcanic Complex on its west face (including former Marmolejo volcano), occupying a total area of 16.1 km^2 and lying above 4,000 m a.s.l. on average. Generalized shrinkage trend according to Reinthaler et al. (2019). The latter image (north to the left) pictures the west face of San José volcano with the Marmolejo volcano summit beyond. March 14, 2020 Landsat 8 image (752) over an ALOS PalSAR digital elevation model.

Distribution

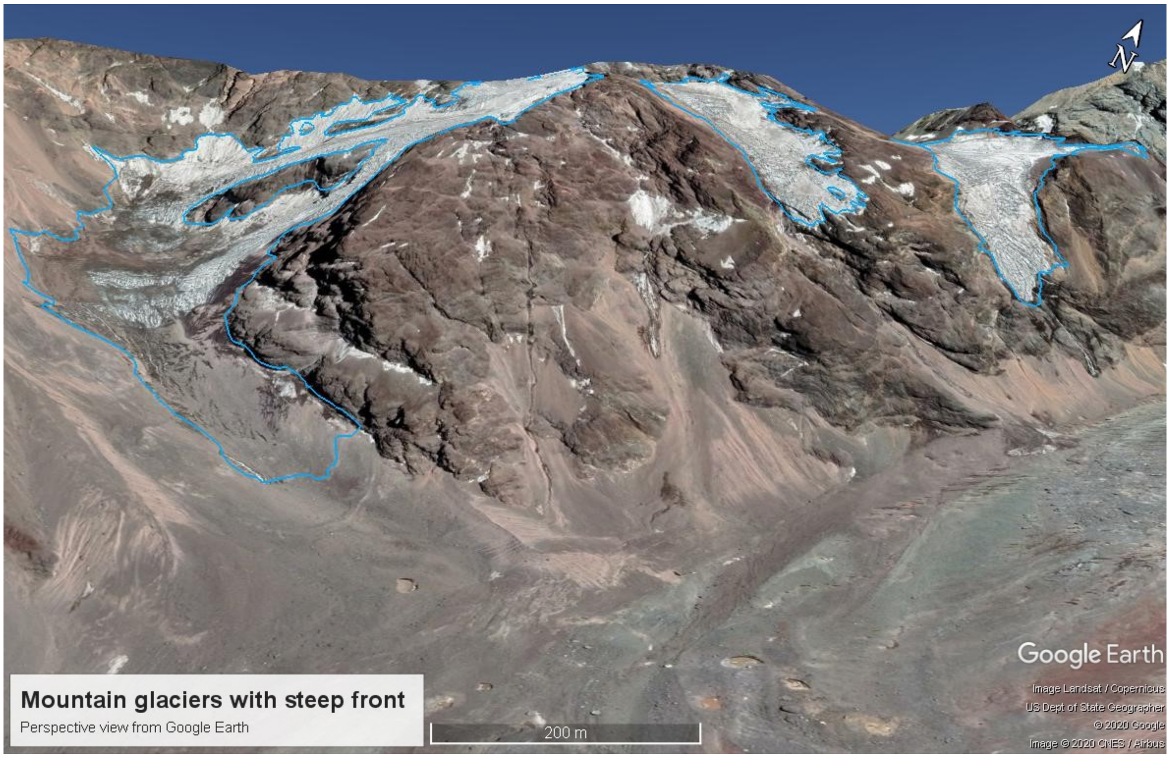
Distribution of snow and unconvered ice over a Landsat 8 image, March 14, 2020 (752). Due to the lack of precipitation of the 2019 rain season, imagery from summer 2020 allows to an accurate quantification of the number and extension of debris-free glaciers in the region.

Hanging and mountain glaciers on the west flank of San José volcano. October 2019.

South flank of San José volcano. Nieves Negras glacier at the bottom. December 2020.
No lahar deposits identified to date near San José volcano.

HANGING (AVALANCHING) GLACIERS

Nine mountain glaciers with fronts steeper than 30°. Most of them emplaced over 4,000 m a.s.l. Surface area vary from 4 to 90 hectares. Potential instabilities of type 2 or 3 according to Faillettaz et al (2015).



Google Earth view: Perspective sight of three glaciers with hanging fronts and margings.

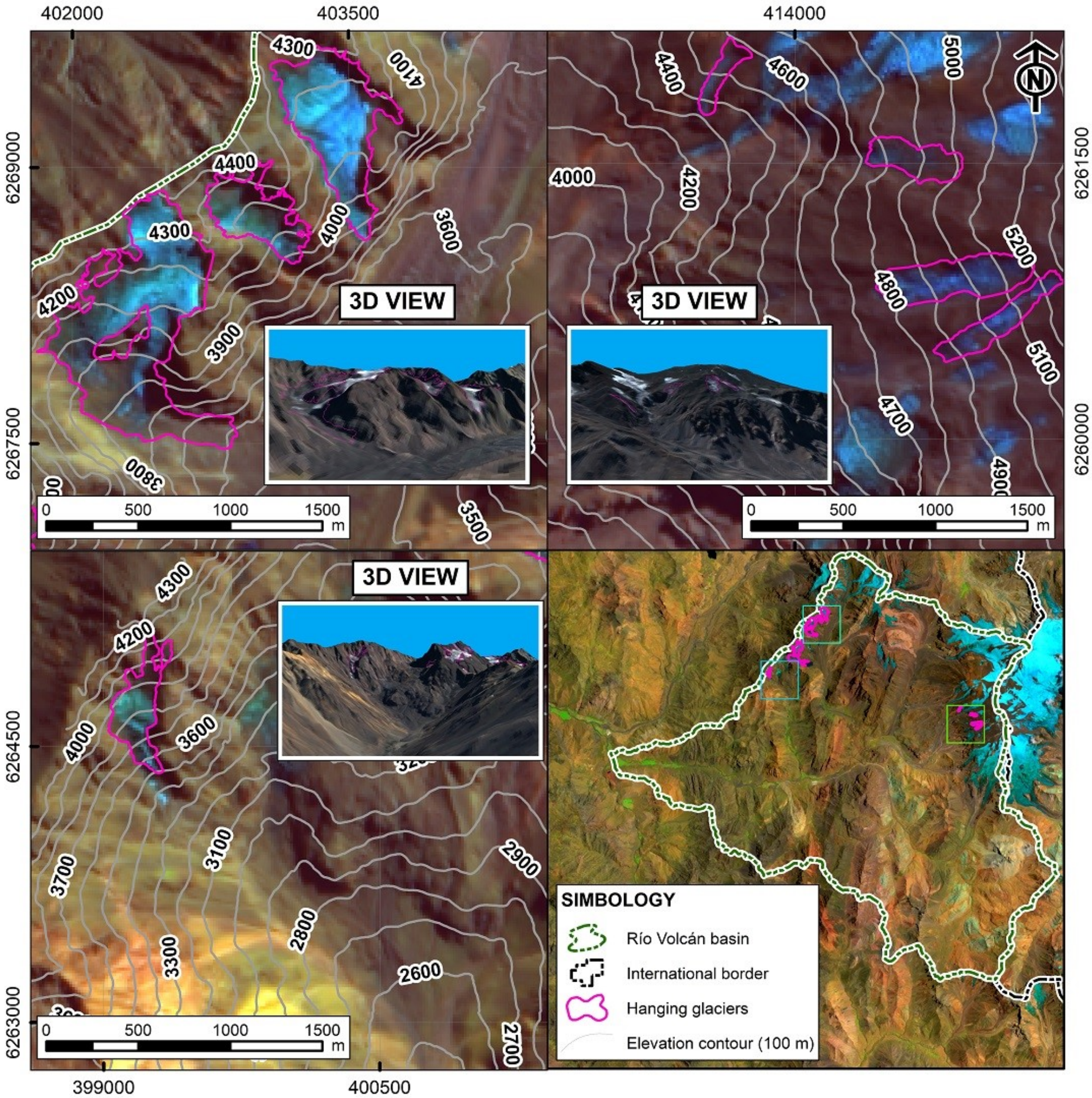
East view from the three hanging glaciers pictured before (inside the red elipses).
November 2020

East view from the hanging portion of El Morado glacier (inside the red elipse). March 2019

East view from the hanging portion of El Morado glacier. November 2020

East view from the hanging portion of the Carancho glacier. November 2020

Distribution



Upper left: Carancho glacier and two other hanging glacier in the NE direction. Upper right: hanging glaciers at the west face of San José volcano. Lower left: hanging glacier above the San Francisco glacier.

SUMMARY

- A new proglacial lake formed between 2019 and 2020
- Synchronous glacier advance between 1986 and 1997
- Current surke-like behavior of Loma Larga glacier
- Nine hanging glaciers identified in the study area
- More than 15 km^2 of uncovered ice above San José volcanic complex on its west flank

AUTHOR INFORMATION

Chilean geologist. I work at Geoestudios Asesores SA (Chile) and also I'm doing my master's thesis on cryospheric hazards at the Geology Deparment, Faculty of Physics and Mathematical Sciences, University of Chile.

Further research: https://www.researchgate.net/profile/Felipe_Ugalde2 (https://www.researchgate.net/profile/Felipe_Ugalde2)

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