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CONICET
U.N.CUYO
GOBIERNO
DE MENDOZA

Mariano Masiokas, Lidia Ferri, Laura Zalazar, Pierre Pitte, Lucas Ruiz, Mariano Castro, Hernán Gargantini, Melisa Giménez, Gustavo Costa, Rodolfo Crimi, Ricardo Villalba

On October 2010, the Argentinean Senate approved the Law 26639 for the “Preservation of Glaciers and Periglacial Environments”

✓This National law considers glaciers and periglacial features as strategic water reserves

- ✓ Declared these reserves as public goods

✓One important outcome of this law was the creation of the National Glacier Inventory (NGI) to identify and map all the glacier and periglacial landforms that act as strategic water reserves in the Argentinean Andes

✓The inventory was assigned to the Argentinean Institute for Snow, Ice and Environmental Research (IANIGLA) in collaboration with the National Secretary of Environment and Sustainable Development

What is included in the inventory

- Clean ice glaciers
- Debris-covered glaciers
- Permanent snow patches
- Rock glaciers

Area ≥ 0,01 km^2



Methods

The NGI was largely based on remote sensing techniques and datasets

The methodology followed international guidelines (e.g. from GLIMS) for the development of glacier inventories

Tipo de glaciar	Resolución espectral	Resolución espacial	Método
Glaciares descubiertos y manchones de nieve 	Multiespectrales Alos Aster Spot 4 Spot 5 Landsat	Media 10x10m 15x15m (visible) 20x20m 10x10m 30x30m (visible-IRC-IRM)	**Extracción automática** Clasificación supervisada por objetos Índice de nieve (NSDI) 
Glaciares de escombros y glaciares cubiertos 	Multiespectrales o pancromáticas HRC (CBERS2) SPOT 5 Prism (ALOS)	Alta 2,5 x 2,5m 2,5x2,5m y 5x5m 2,5 x 2,5m	**Digitalización manual** 

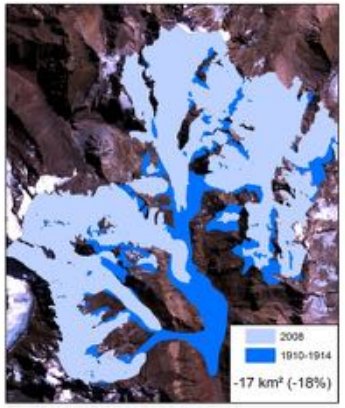
Methods

But also included field campaings to verify the mapping and classification of ice masses

The NGI project includes three types of studies

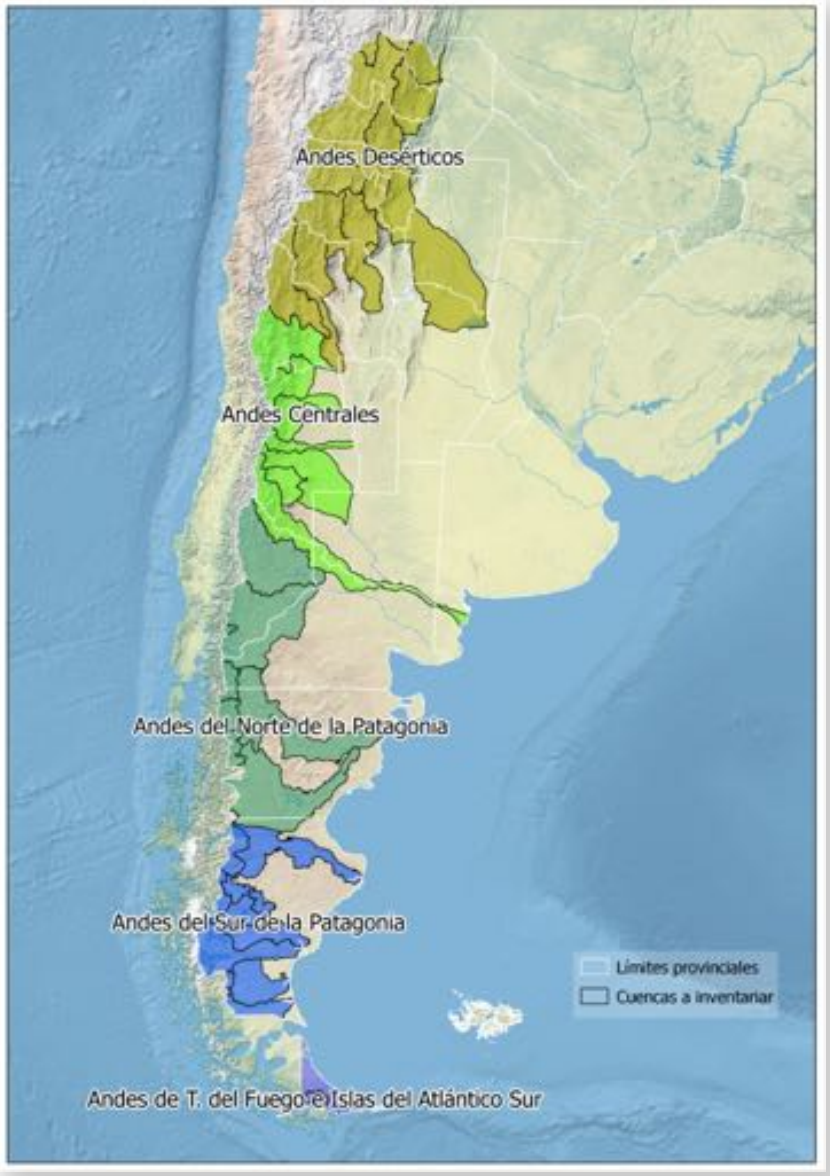
Level 1: Identification, mapping and characterization of all ice masses that act as water reserves in the country

Level 2: Assessment of recent glacier fluctuations on selected areas along the Argentinean Andes



Level 3: mass balance, meteorological and hydrological studies in selected glaciers in different regions of the Andes

Geographical organization



Due to the large extent of the Andes and the wide range of environments and conditions, the NGI was also organized in five major regions:

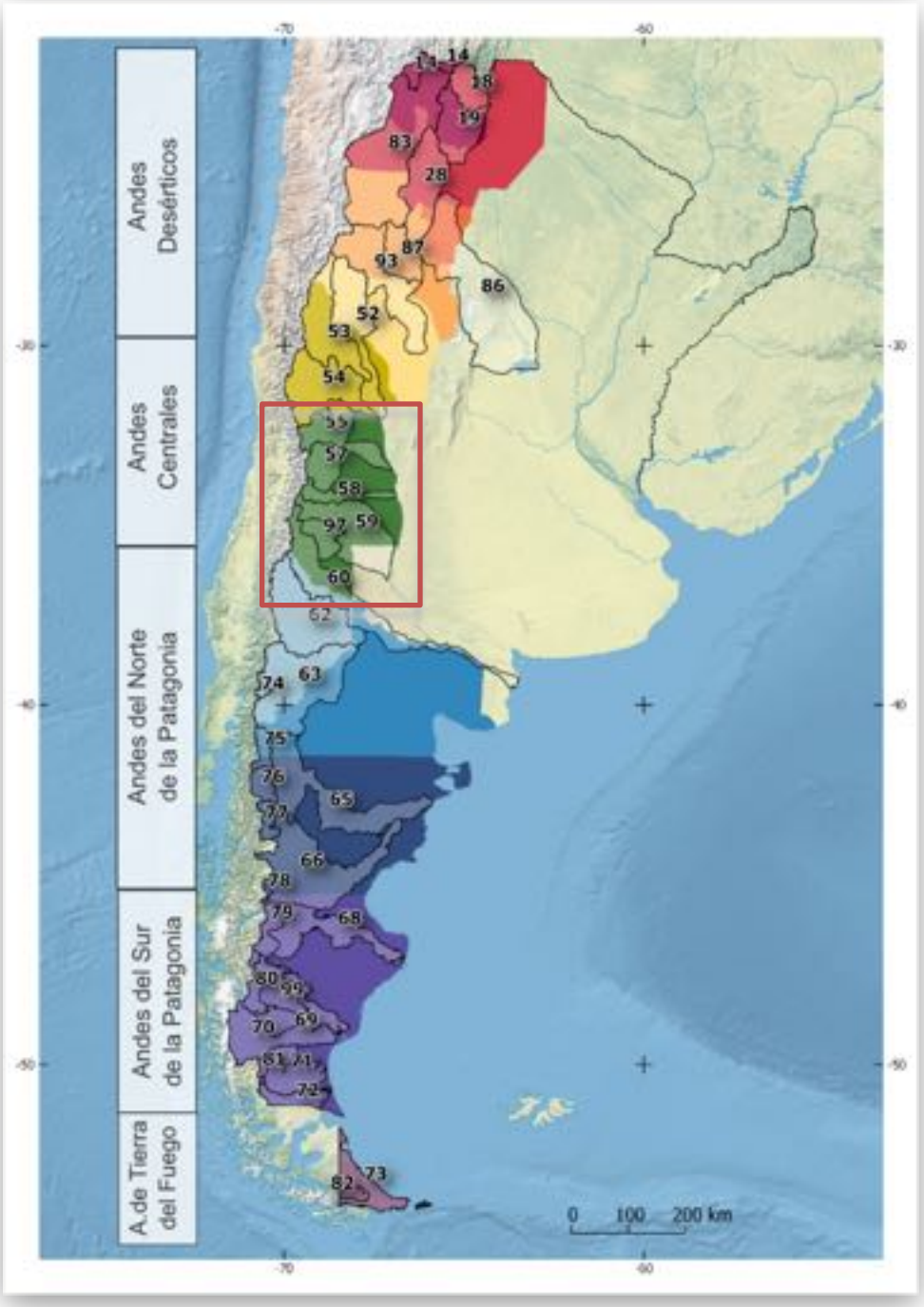
A) Desert Andes

B) Central Andes

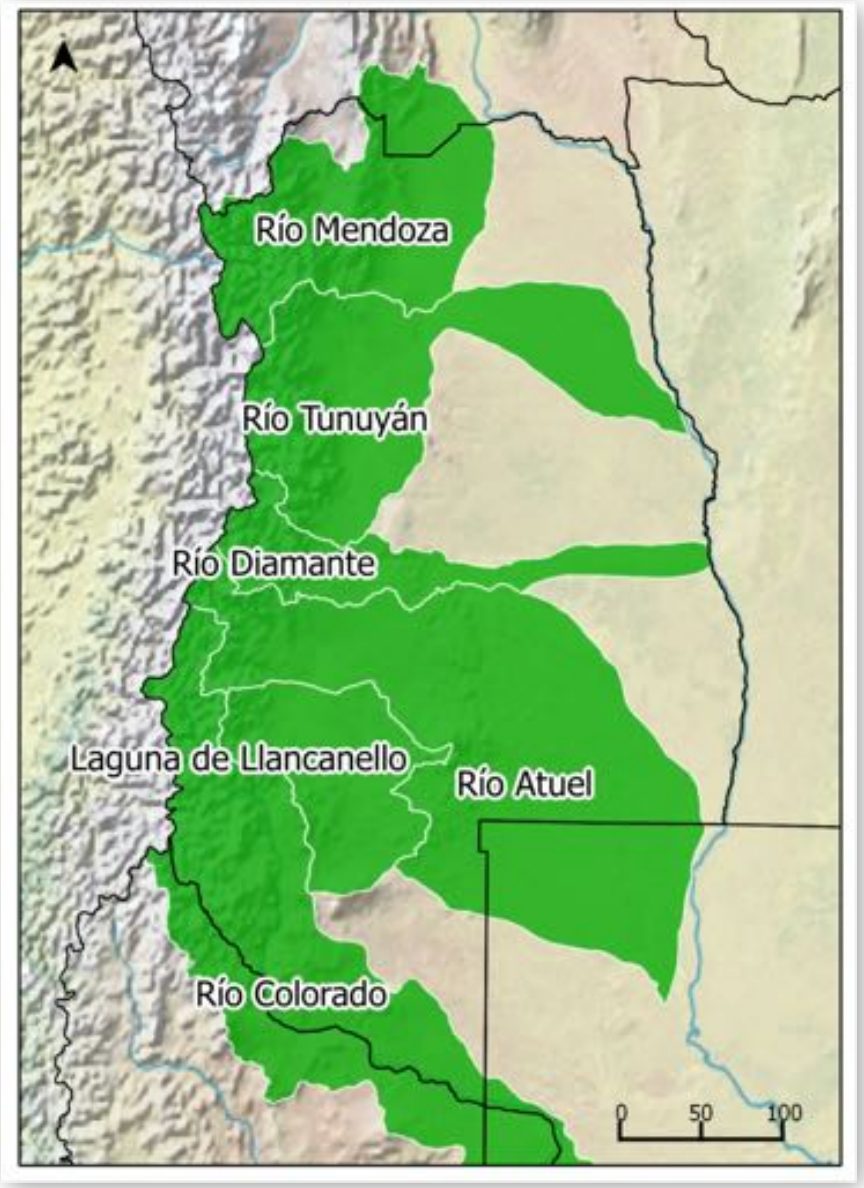
C) North Patagonian Andes

D) South Patagonian Andes

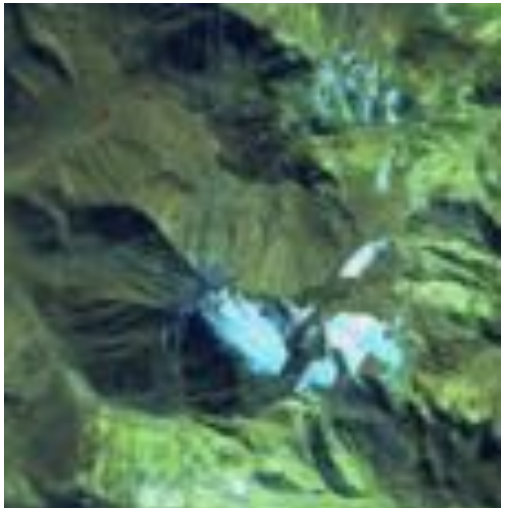
E) Andes of Tierra del Fuego



Within these regions the inventories were performed considering hydrological basins or specific sectors



Desert Andes (21°- 31°S)



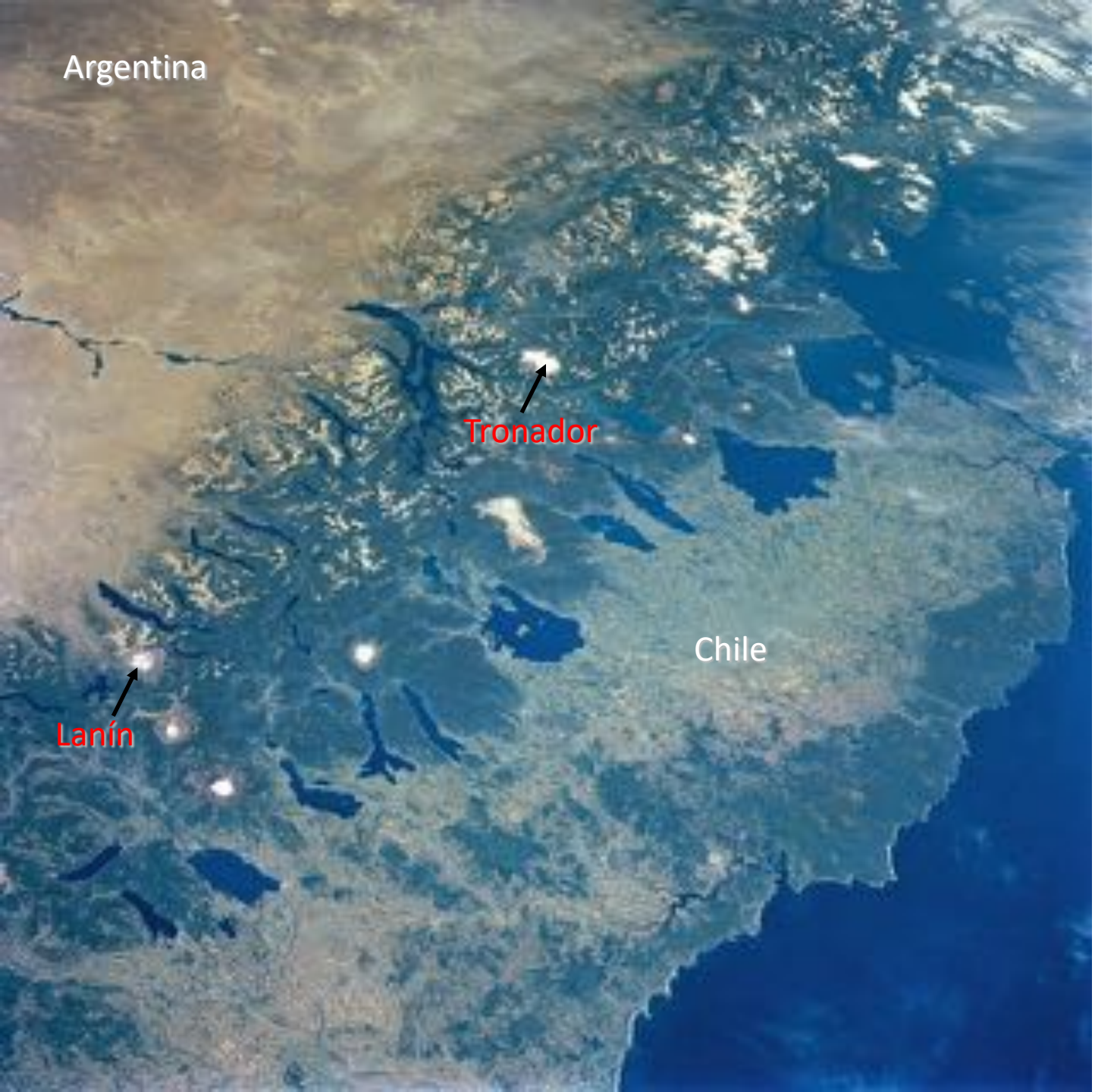
Central Andes (31°- 35°S)

Glaciar de escombros Morenas Coloradas

Fuente: D. Trombotto IANIGLA

North Patagonian Andes (35°- 45°S)

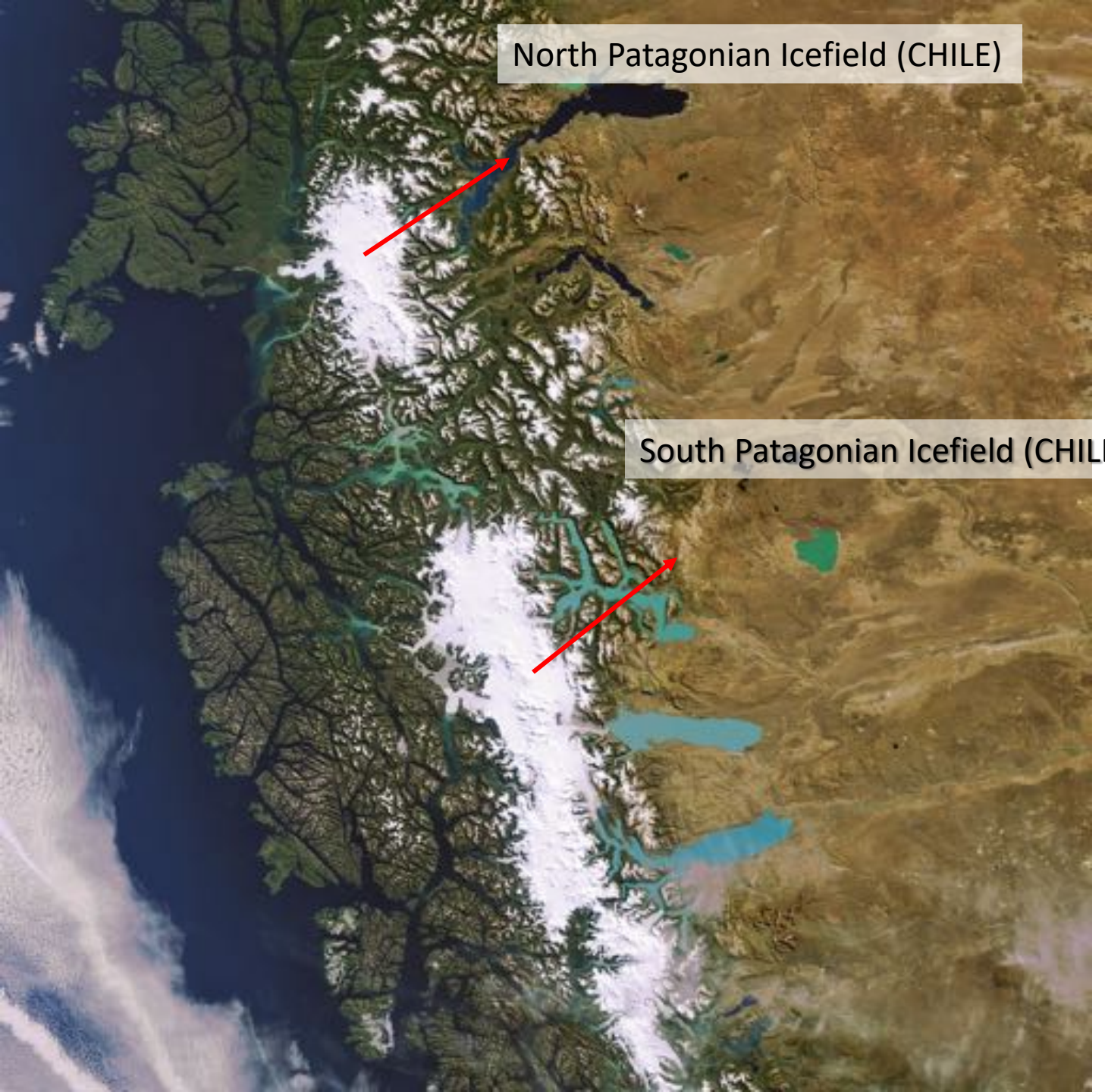
Monte Tronador

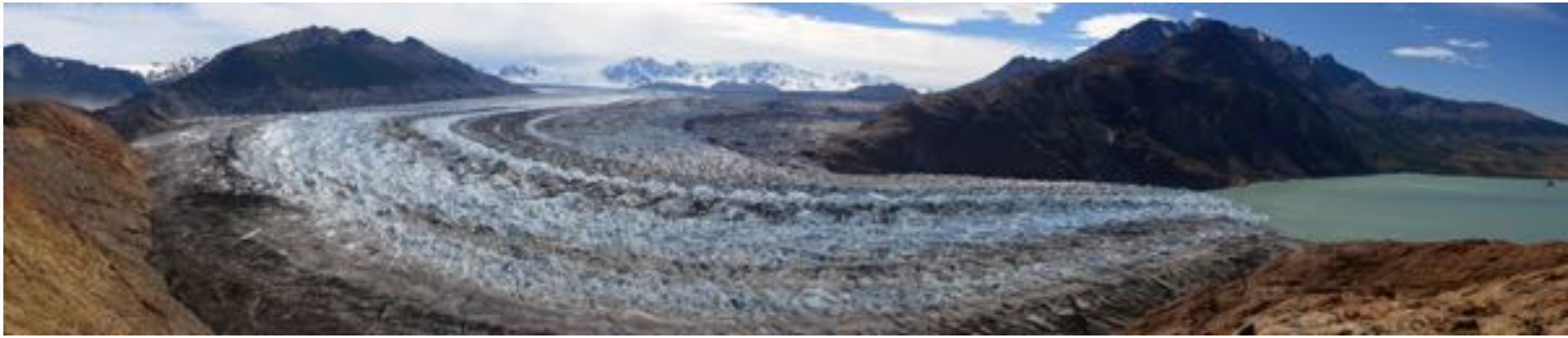

Argentina
Tronador
Chile
Lanín


Volcán Lanín

South Patagonian Andes (45°- 52°S)

Glaciar Upsala


North Patagonian Icefield (CHILE)
South Patagonian Icefield (CHILE-ARGENTINA)




Perito Moreno glacier

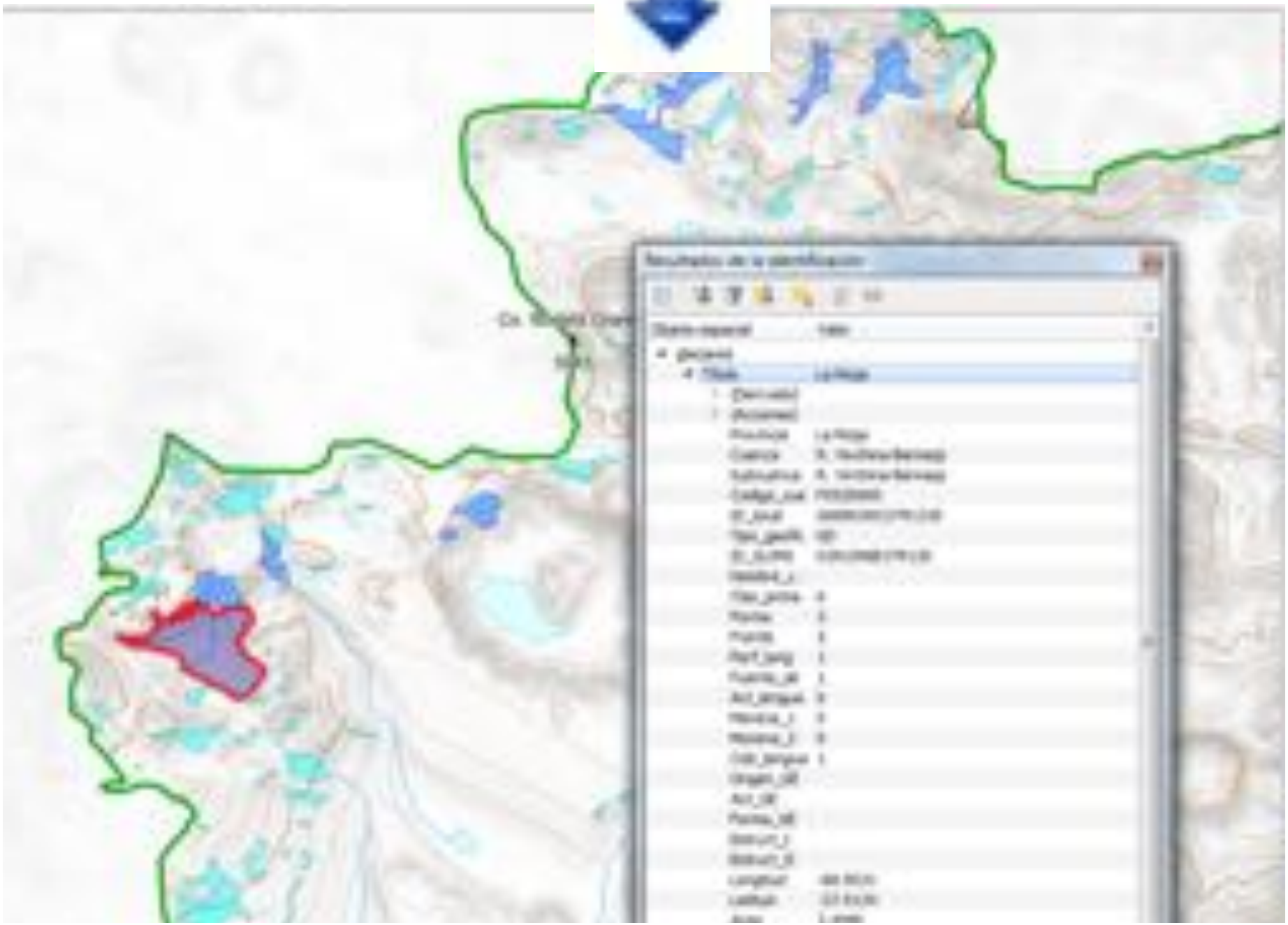
Tierra del Fuego (52º - 55ºS)

TIERRA DEL FUEGO

The first National Glacier Inventory
was published in May 2018

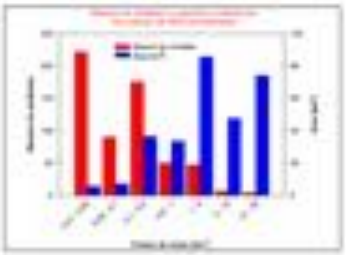
www.glaciaresargentinos.gob.ar

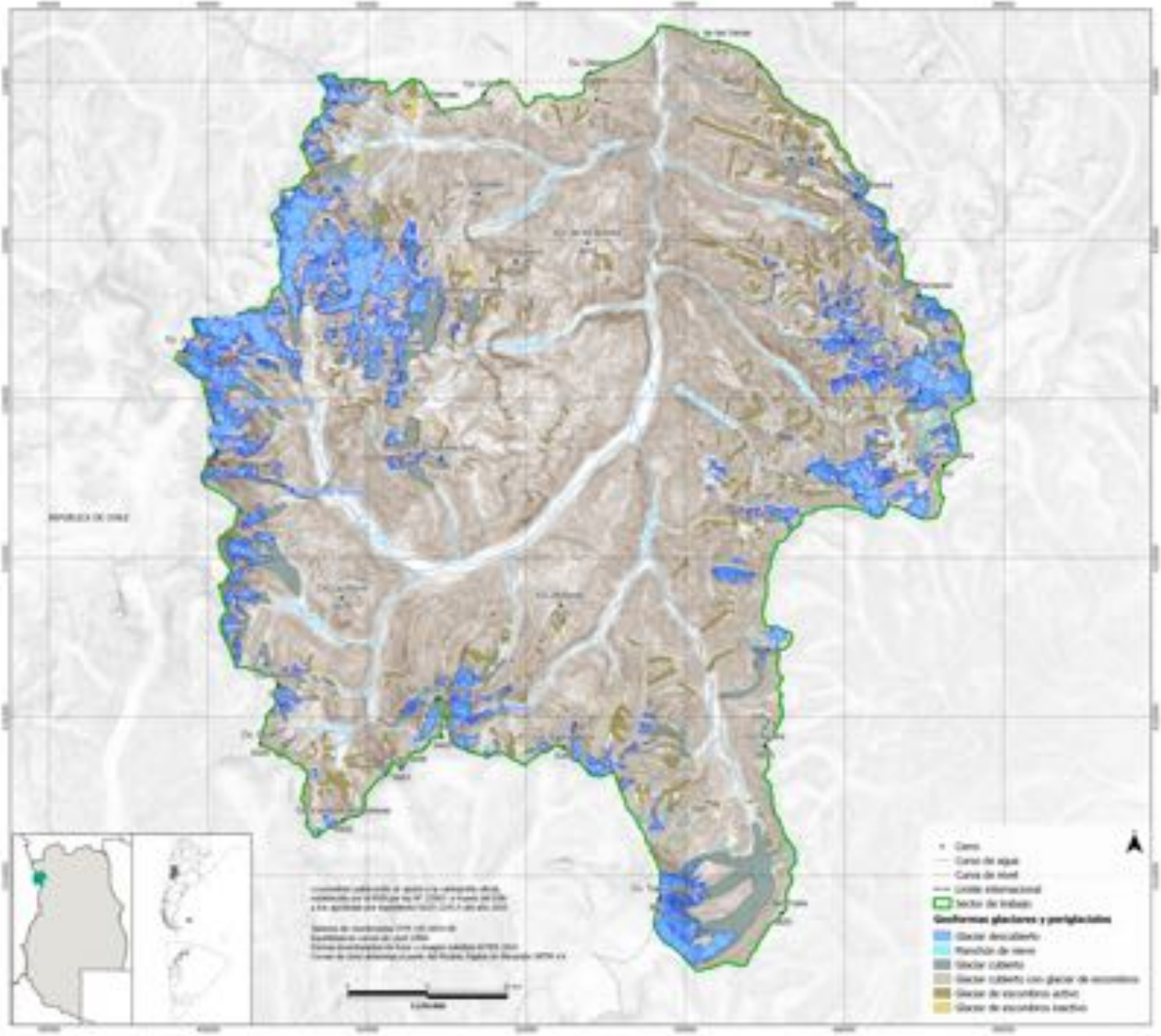
NGI database



Maps


INVENTARIO
NACIONAL
DE GLACIARES
Cuenca del río Mendoza
Subcuenca del río Tupungato
Provincia de Mendoza




Cerro
Curso de agua
Curva de nivel
Límite internacional
Sector de trabajo
Geoformas glaciares y periglaciales
Glaciar descubierto
Manchón de nieve
Glaciar cubierto
Glaciar cubierto con glaciar de escombros
Glaciar de escombros activo
Glaciar de escombros inactivo

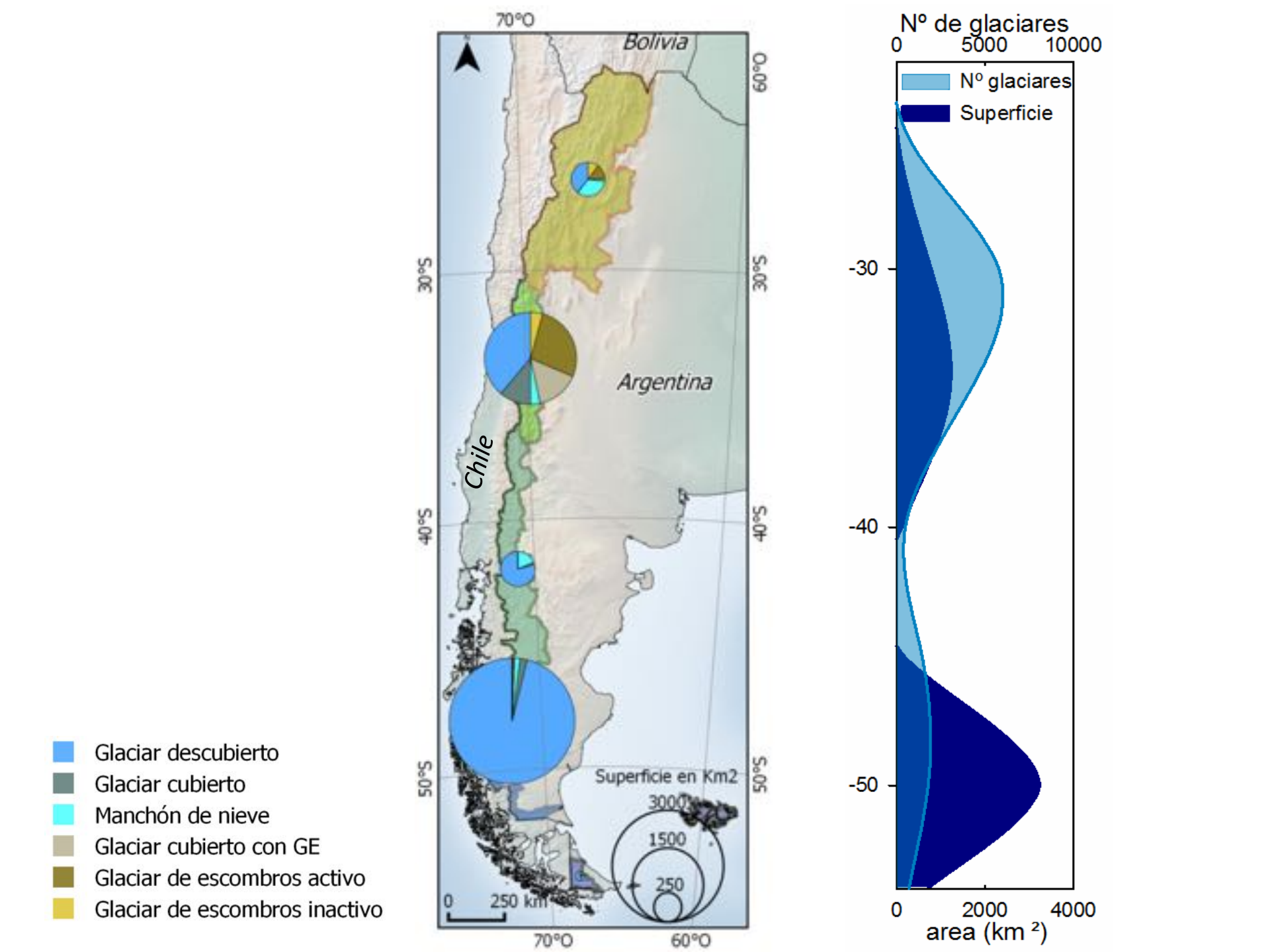
Reports and maps are available for 69 basins and sub-basins along the Andes

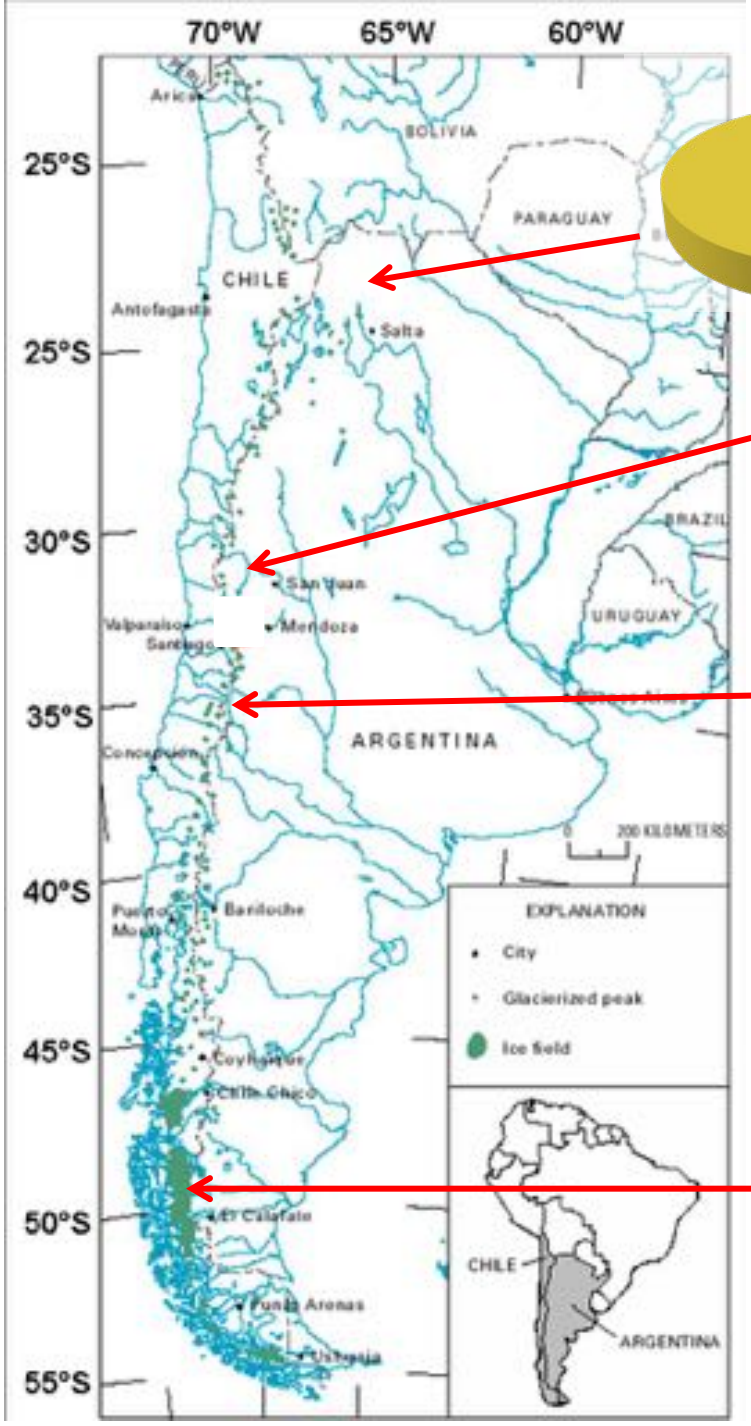
National totals

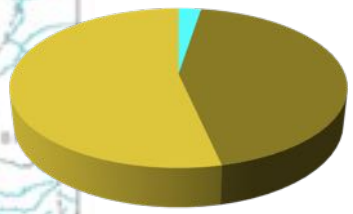
16078 ice bodies

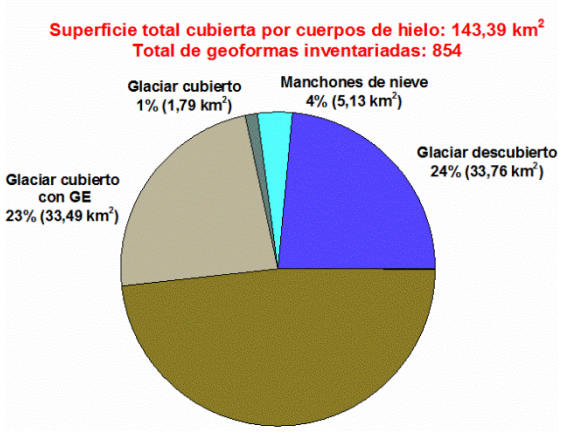
5768 km^2 in surface area

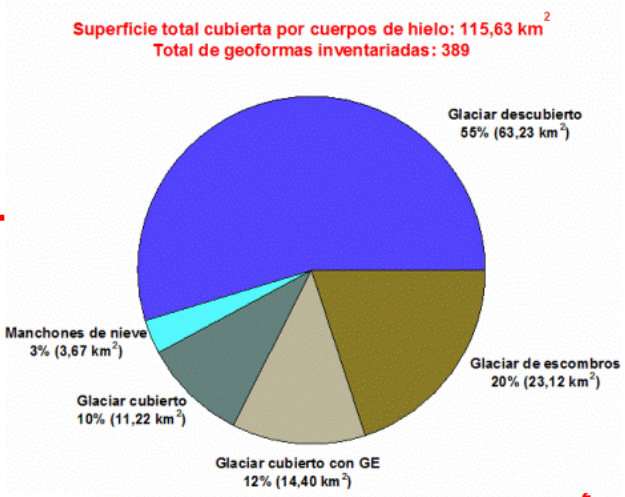
- Glaciar descubierto
- Glaciar cubierto
- Manchón de nieve
- Glaciar cubierto con GE
- Glaciar de escombros activo
- Glaciar de escombros inactivo


Glaciar descubierto
Glaciar cubierto
Manchón de nieve
Glaciar cubierto con GE
Glaciar de escombros activo
Glaciar de escombros inactivo
70°O
60°O
30°S
40°S
50°S
Bolivia
Argentina
Chile
Superficie en Km2
3000
1500
250
0
250 km
Nº de glaciares
0
5000
10000
Nº glaciares
Superficie
-30
-40
-50
0
2000
4000
area (km ²)

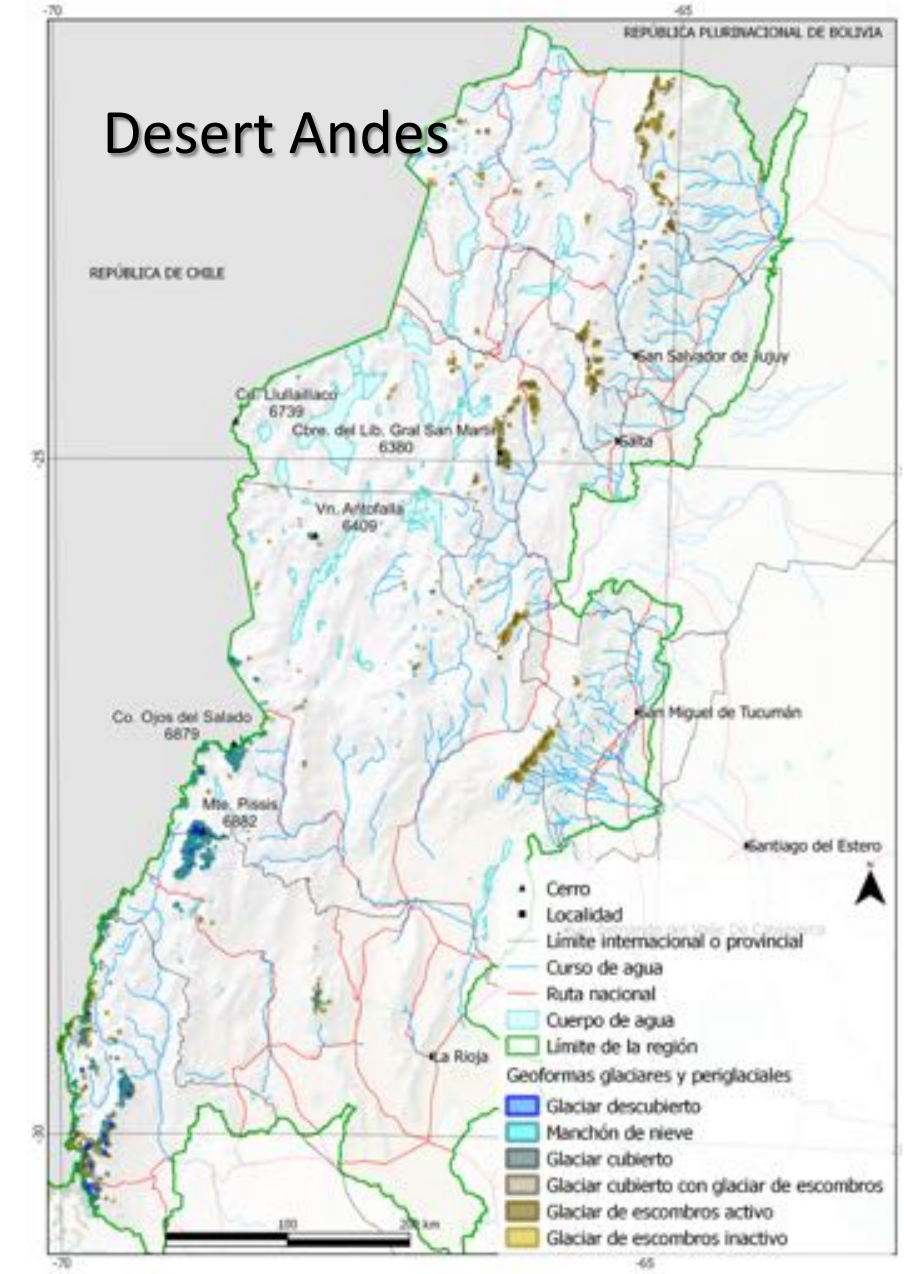

70°W
65°W
60°W
25°S
30°S
35°S
40°S
45°S
50°S
55°S
BOLIVIA
PARAGUAY
CHILE
Antofagasta
Salta
BRAZIL
San Juan
Mendoza
URUGUAY
Valparaiso
Santiago
ARGENTINA
Concepcion
200 KILOMETERS
Bariloche
Coyhaique
Chile Chico
El Calafate
Punta Arenas
Ushuaia
EXPLANATION
City
Glacierized peak
Ice field
CHILE
ARGENTINA

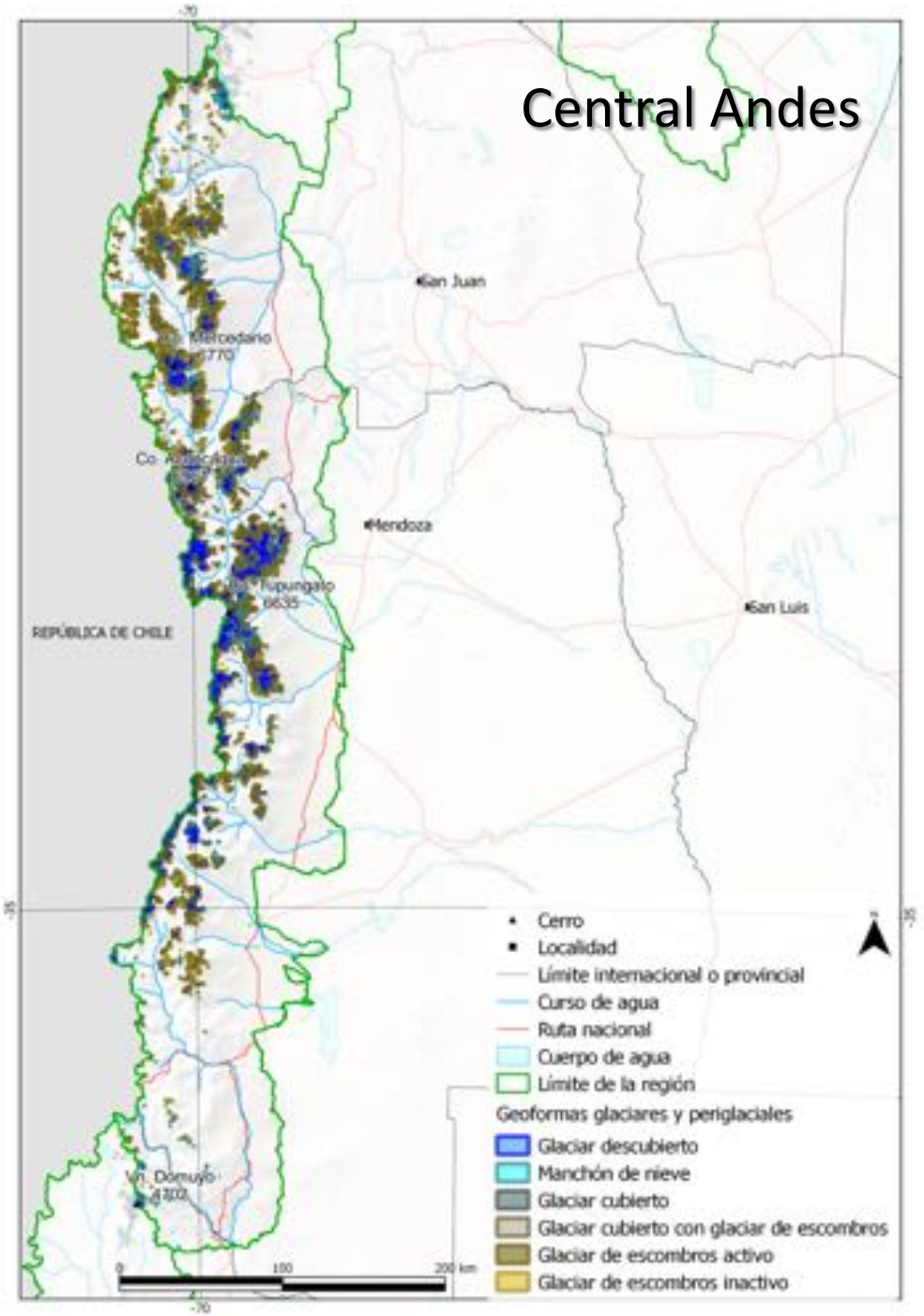


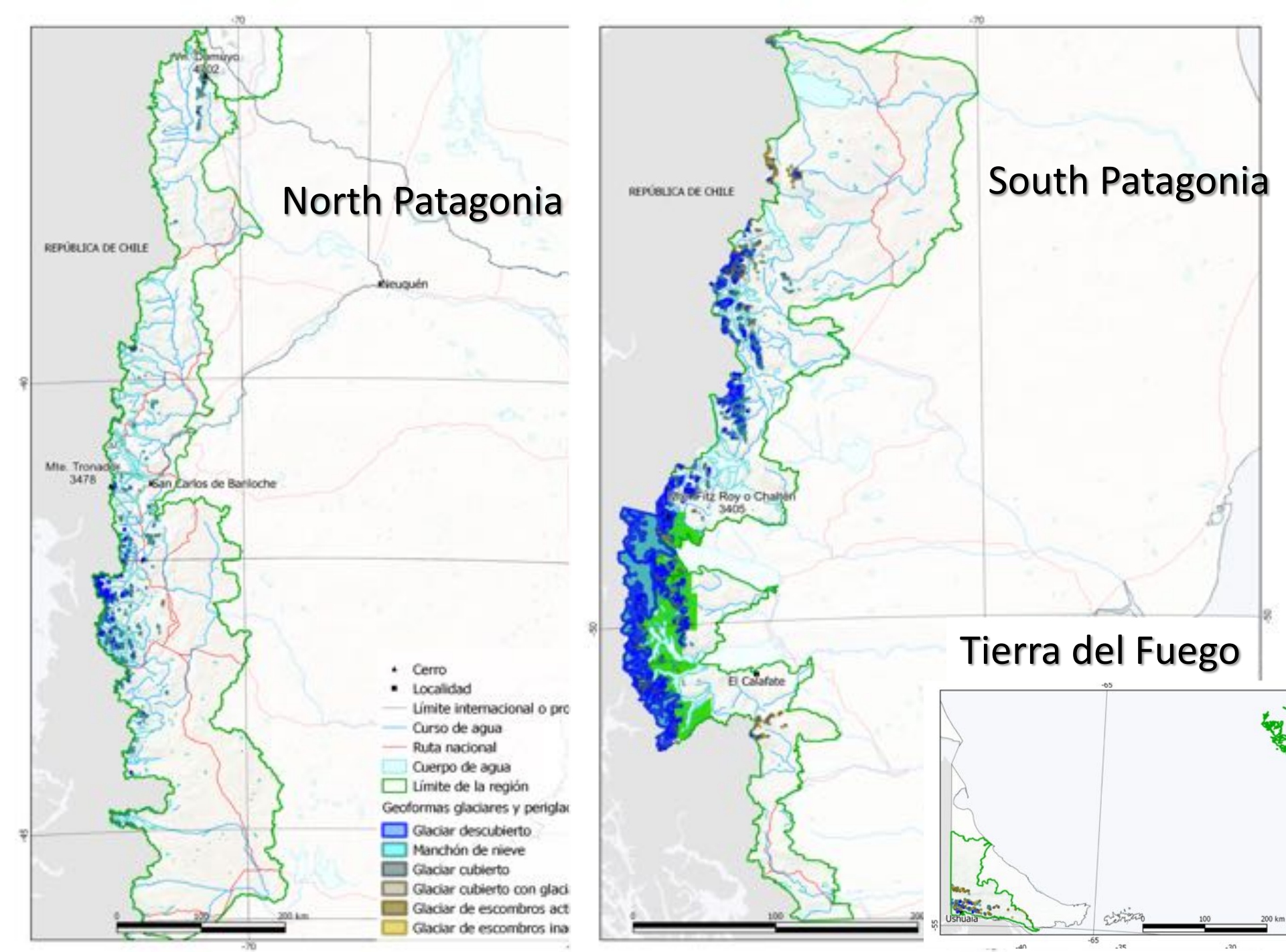

Superficie total cubierta por cuerpos de hielo: 143,39 km2
Total de geoformas inventariadas: 854
Glaciar cubierto
1% (1,79 km2)
Manchones de nieve
4% (5,13 km2)
Glaciar descubierto
24% (33,76 km2)
Glaciar cubierto
con GE
23% (33,49 km2)


Superficie total cubierta por cuerpos de hielo: 115,63 km2
Total de geoformas inventariadas: 389
Glaciar descubierto
55% (63,23 km2)
Manchones de nieve
3% (3,67 km2)
Glaciar de escombros
20% (23,12 km2)
Glaciar cubierto
10% (11,22 km2)
Glaciar cubierto con GE
12% (14,40 km2)


Superficie total cubierta por cuerpos de hielo: 606 km2
Total de geoformas inventariadas: 194
Glaciar descubierto
99% (599,08 km2)
Glaciar cubierto
0,77% (4,69 m2)
Manchones de nieve
0 ,37% (2,23 km2)


Desert Andes
REPÚBLICA PLURINACIONAL DE BOLIVIA
REPÚBLICA DE CHILE
San Salvador de Jujuy
Cro. Llullaillaco
6739
Cbre. del Lib. Gral San Martín
6380
Salta
Vn. Antofalla
6409
Co. Ojos del Salado
6879
San Miguel de Tucumán
Mte. Pissis
6882
Santiago del Estero
La Rioja
Cerro
Localidad
Límite internacional o provincial
Curso de agua
Ruta nacional
Cuerpo de agua
Límite de la región
Geoformas glaciares y periglaciales
Glaciar descubierto
Manchón de nieve
Glaciar cubierto
Glaciar cubierto con glaciar de escombros
Glaciar de escombros activo
Glaciar de escombros inactivo
100
200 km


Central Andes
San Juan
Mercedario
6770
Mendoza
Tupungato
6635
San Luis
REPÚBLICA DE CHILE
Vn. Domuyo
6300
Cerro
Localidad
Límite internacional o provincial
Curso de agua
Ruta nacional
Cuerpo de agua
Límite de la región
Geoformas glaciares y periglaciales
Glaciar descubierto
Manchón de nieve
Glaciar cubierto
Glaciar cubierto con glaciar de escombros
Glaciar de escombros activo
Glaciar de escombros inactivo
0
100
200 km

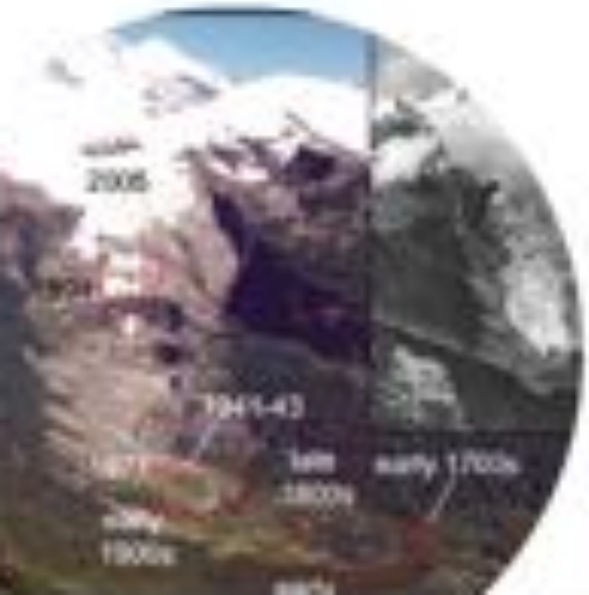

North Patagonia
South Patagonia
Tierra del Fuego
REPÚBLICA DE CHILE
Neuquén
Mte. Tronador
3478
San Carlos de Bariloche
Fitz Roy o Chaltén
3405
El Calafate
Ushuaia
Cerro
Localidad
Límite internacional o prc
Curso de agua
Ruta nacional
Cuerpo de agua
Límite de la región
Geoformas glaciares y periglac
Glaciar descubierto
Manchón de nieve
Glaciar cubierto
Glaciar cubierto con glaci
Glaciar de escombros act
Glaciar de escombros ina

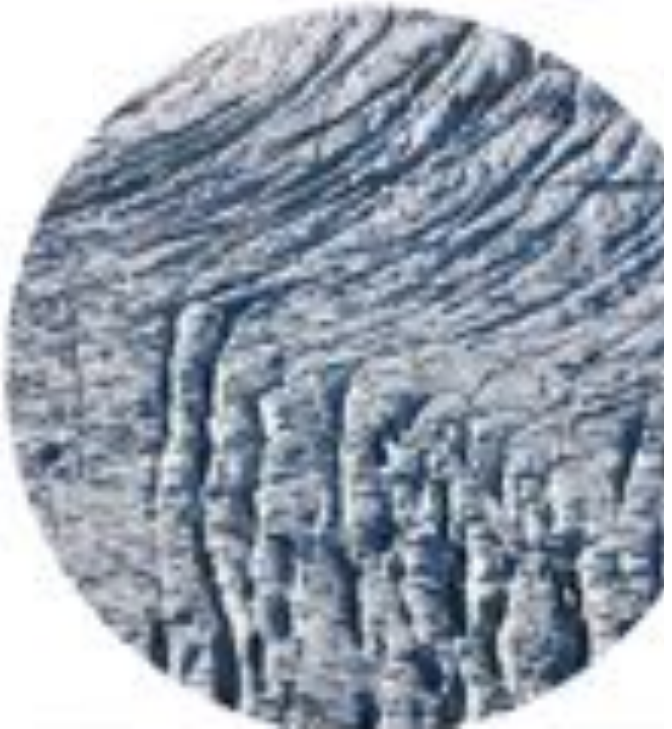
Next steps

- Publication of Level 1 results in the scientific literature, dissemination of results, incorporation of NGI data on scientific analyses

- Initiation of Level 2 studies (fluctuations of glaciers)

- Continuation and expansion of Level 3 studies now including rock glacier sites






INVENTARIO
NACIONAL
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CONICET
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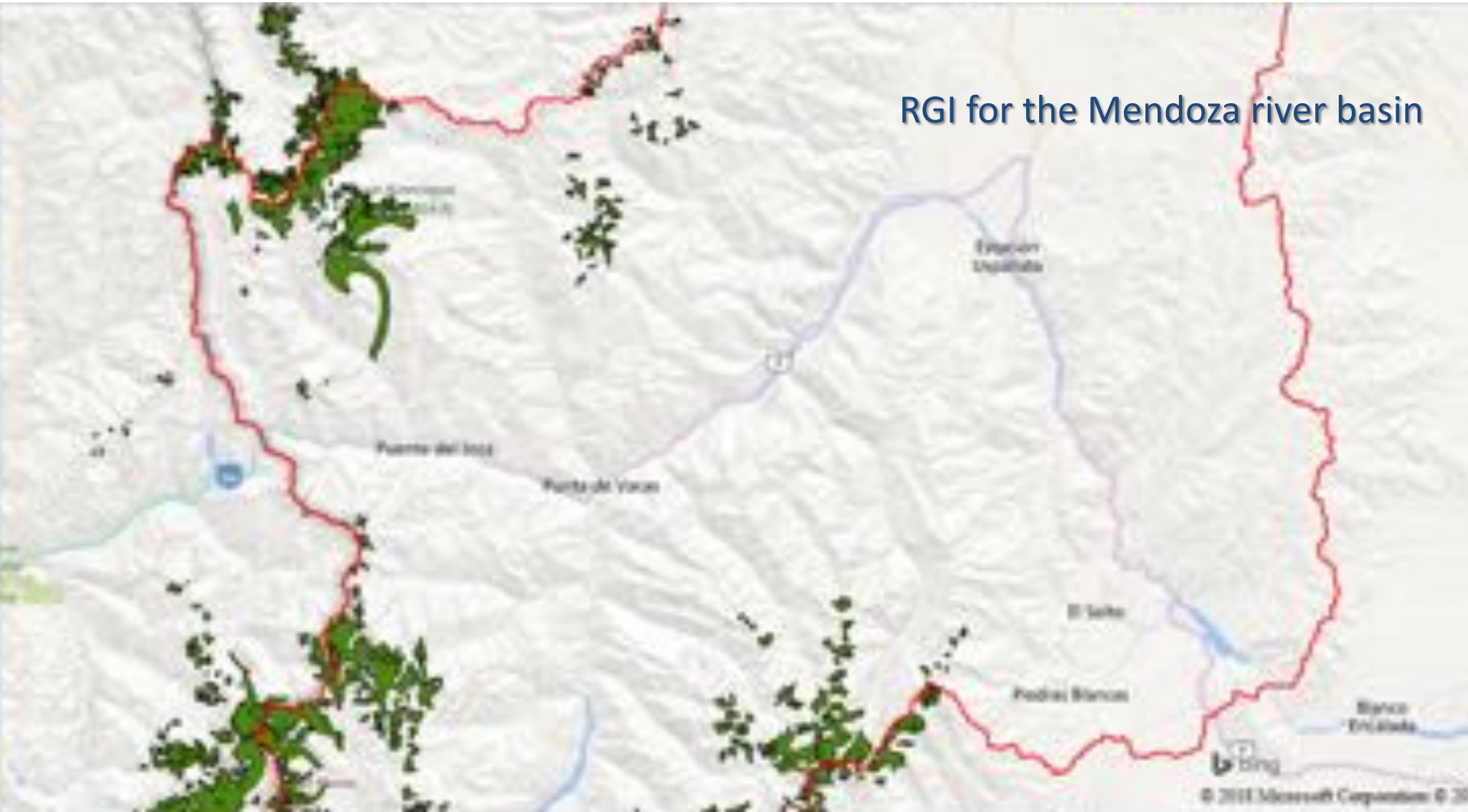
Some aplications of the results

Comparison with the Randolph Glacier inventory

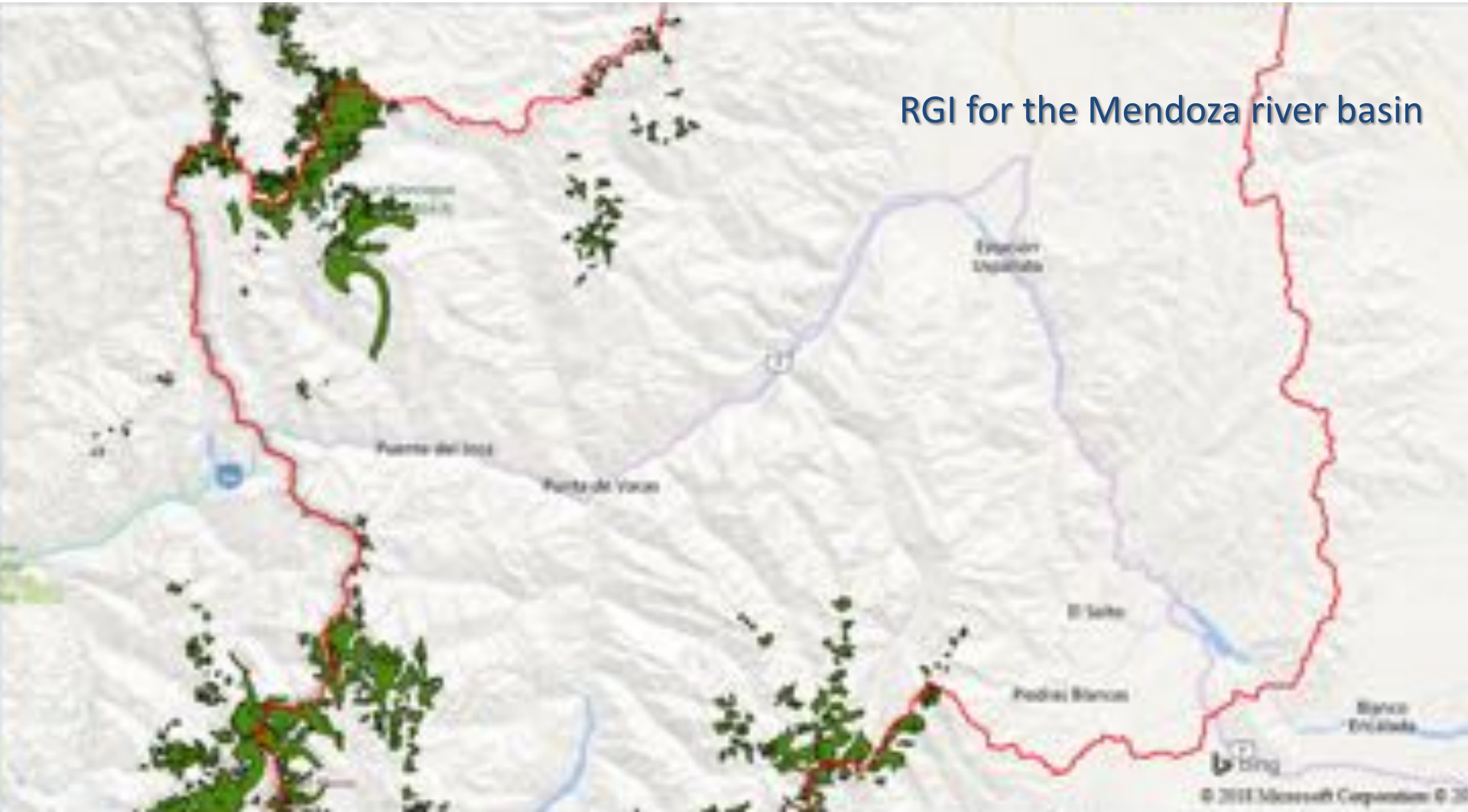


Randolph Glacier Inventory, GLIMS

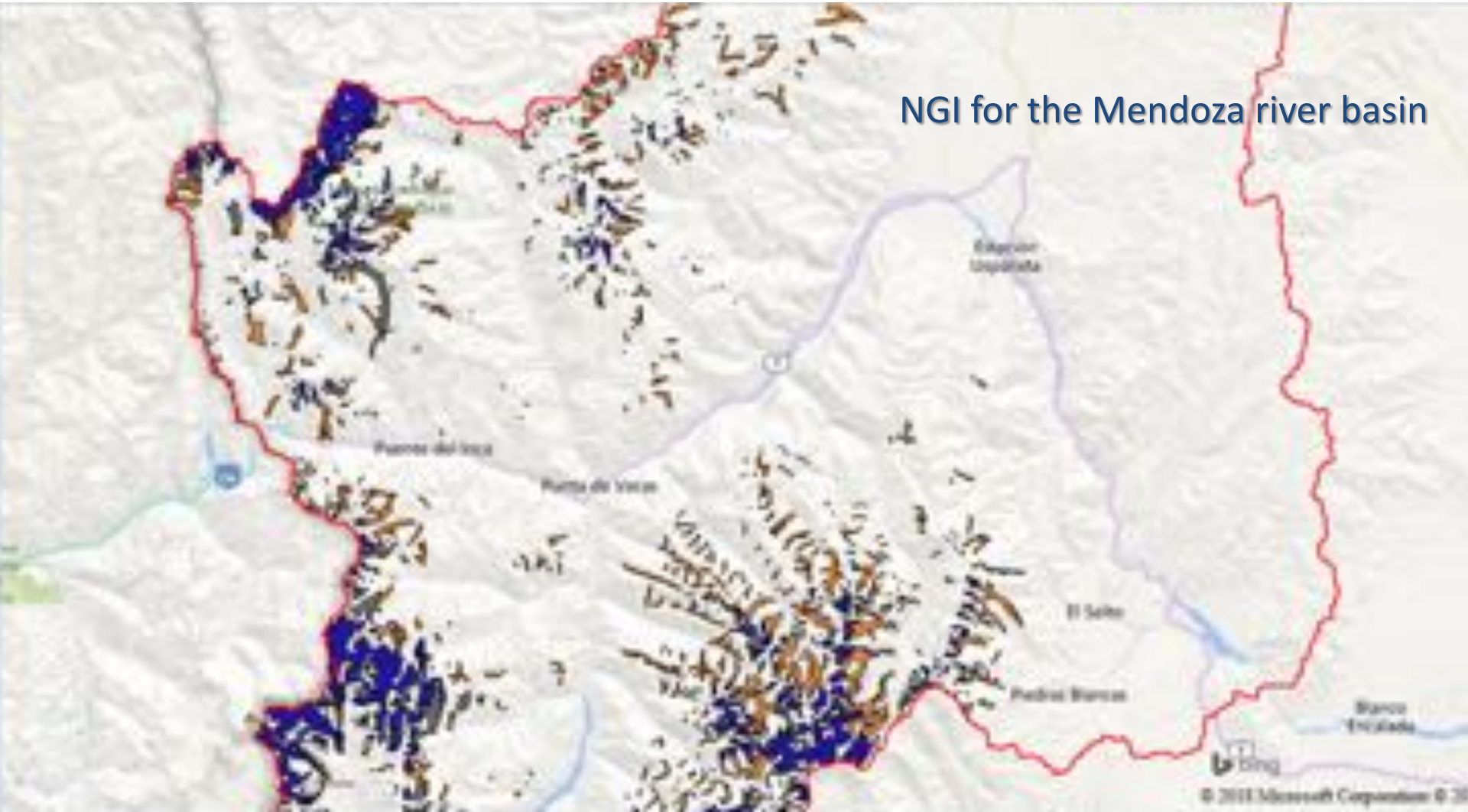
Regularly updated and freely available for the entire Andes

Some aplications of the results

Comparison with the Randolph Glacier inventory

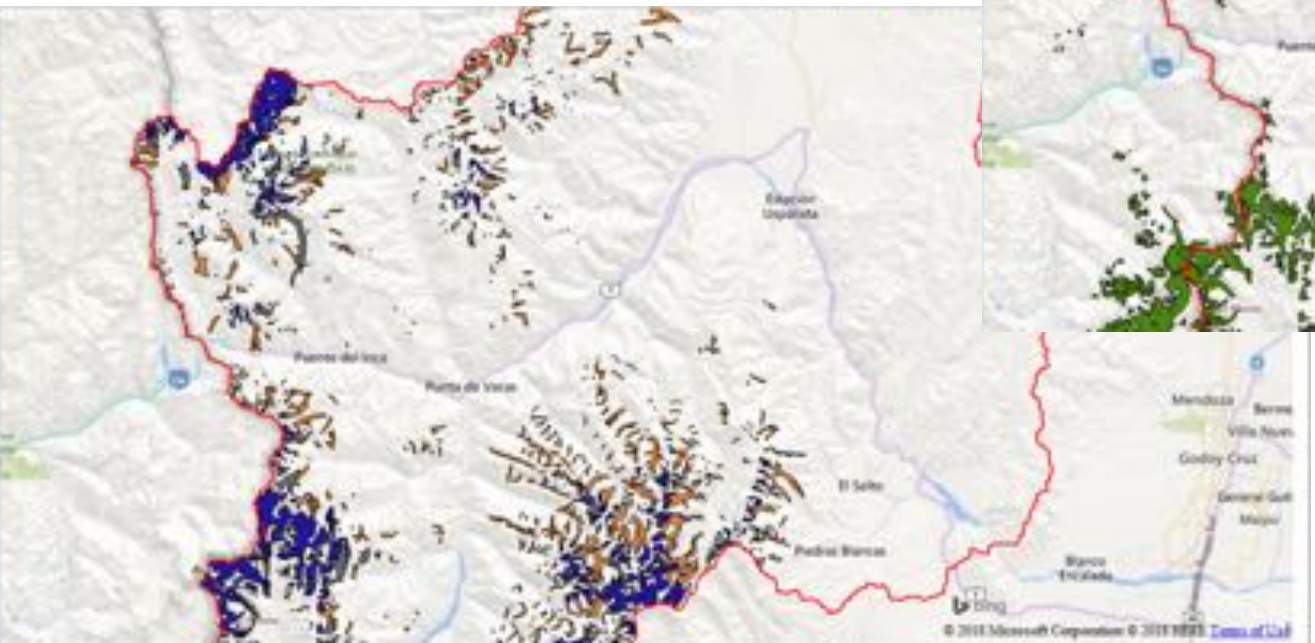


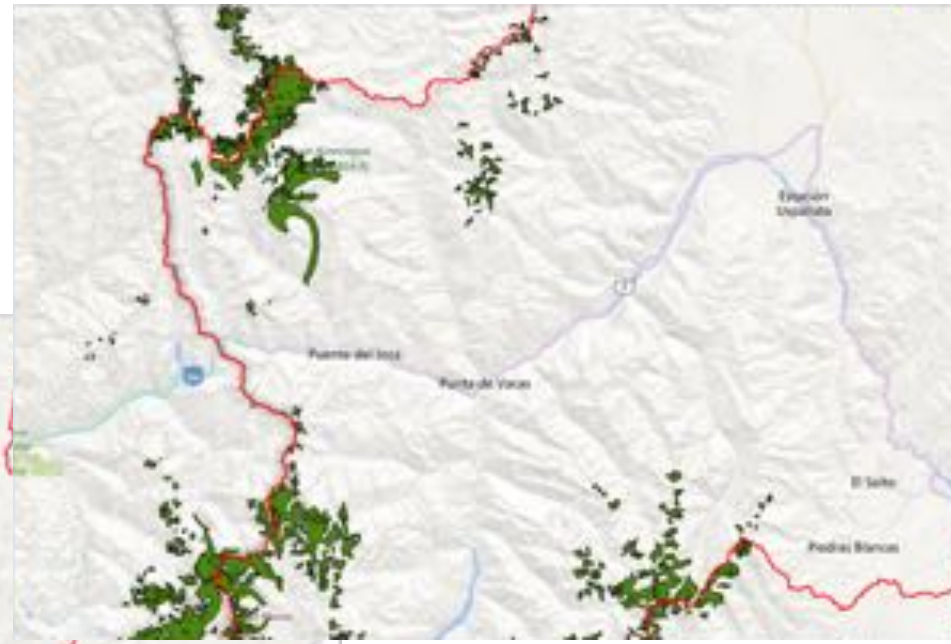
Some aplications of the results



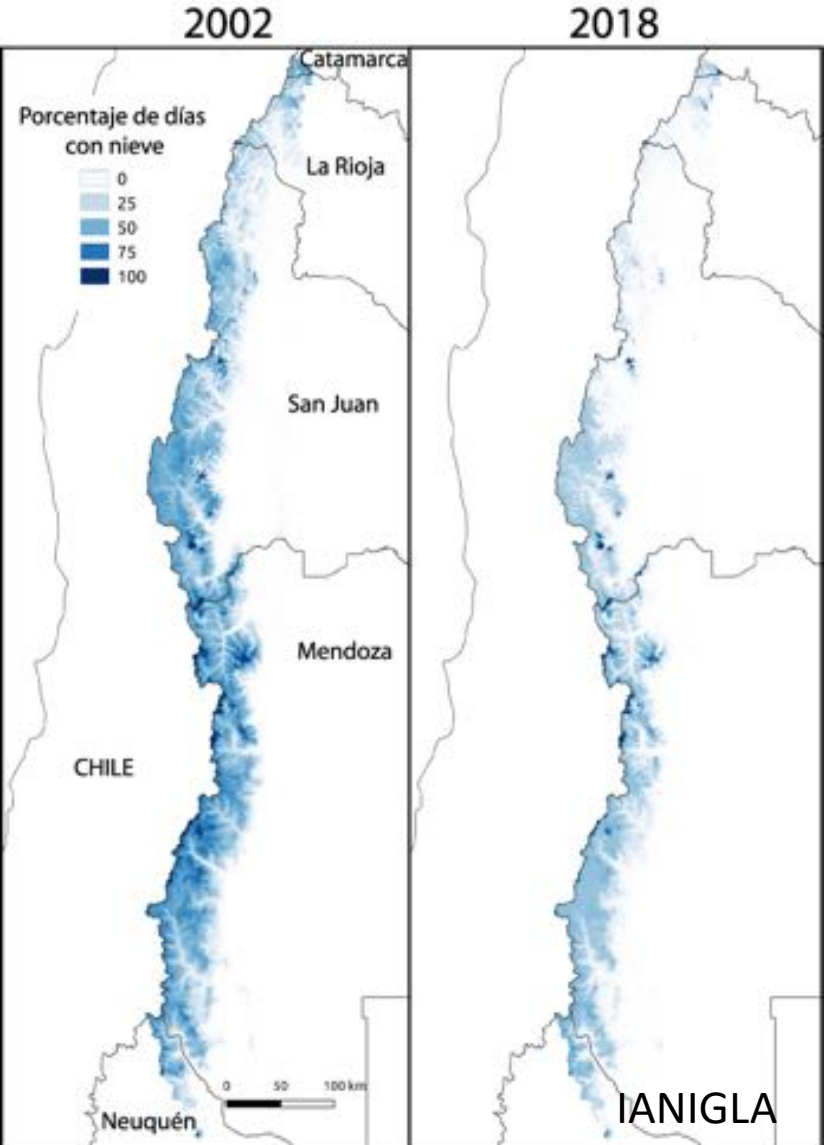
Some aplications of the results

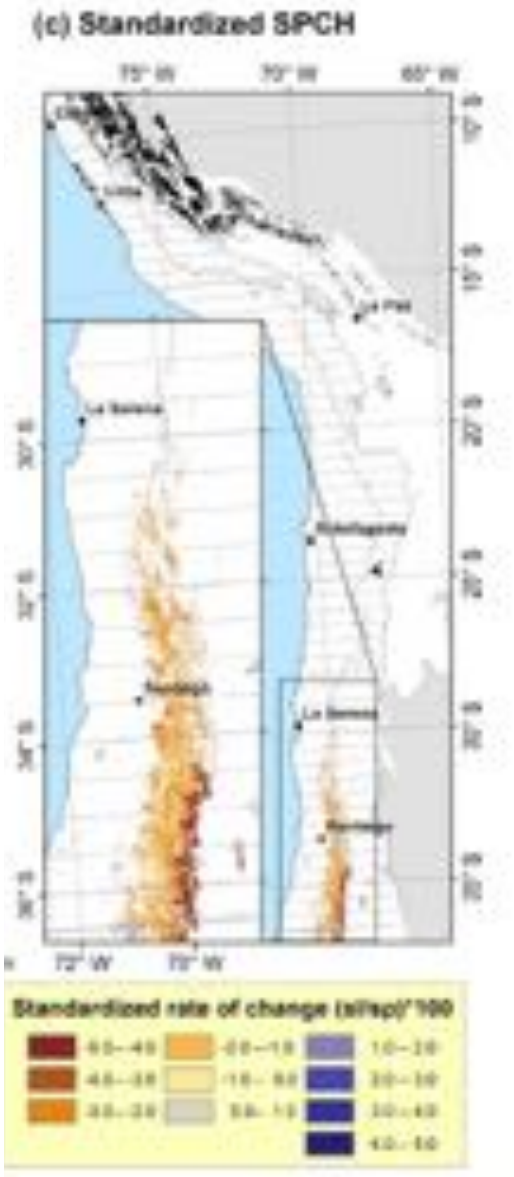
Together with improved estimates of the hydrological contribution of glaciers to a given basin, the inclusion of rock glaciers in these national initiatives could also help improve global inventories such as the RGI





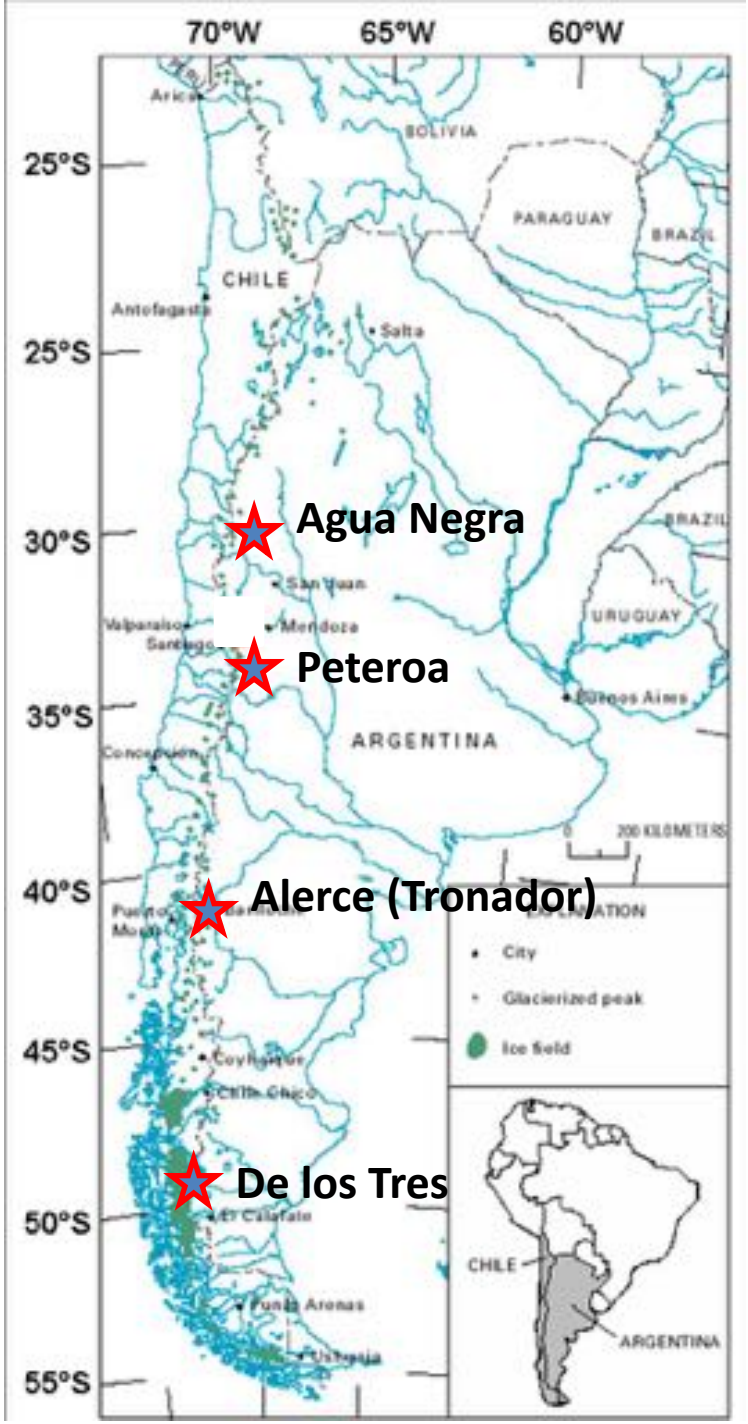
Improved hydrological assessments of mountain water availability are particularly relevant on the Argentinean (drier) side of the central Andes, where the recent lack of snow is particularly noteworthy





IANIGLA

Saavedra et al. 2016



As part of Level 3 of the NGI, we started a program to monitor the mass balance and hydro-meteorological variations of four selected glaciated sites along the Andes in Argentina

Nivel 3 del ING

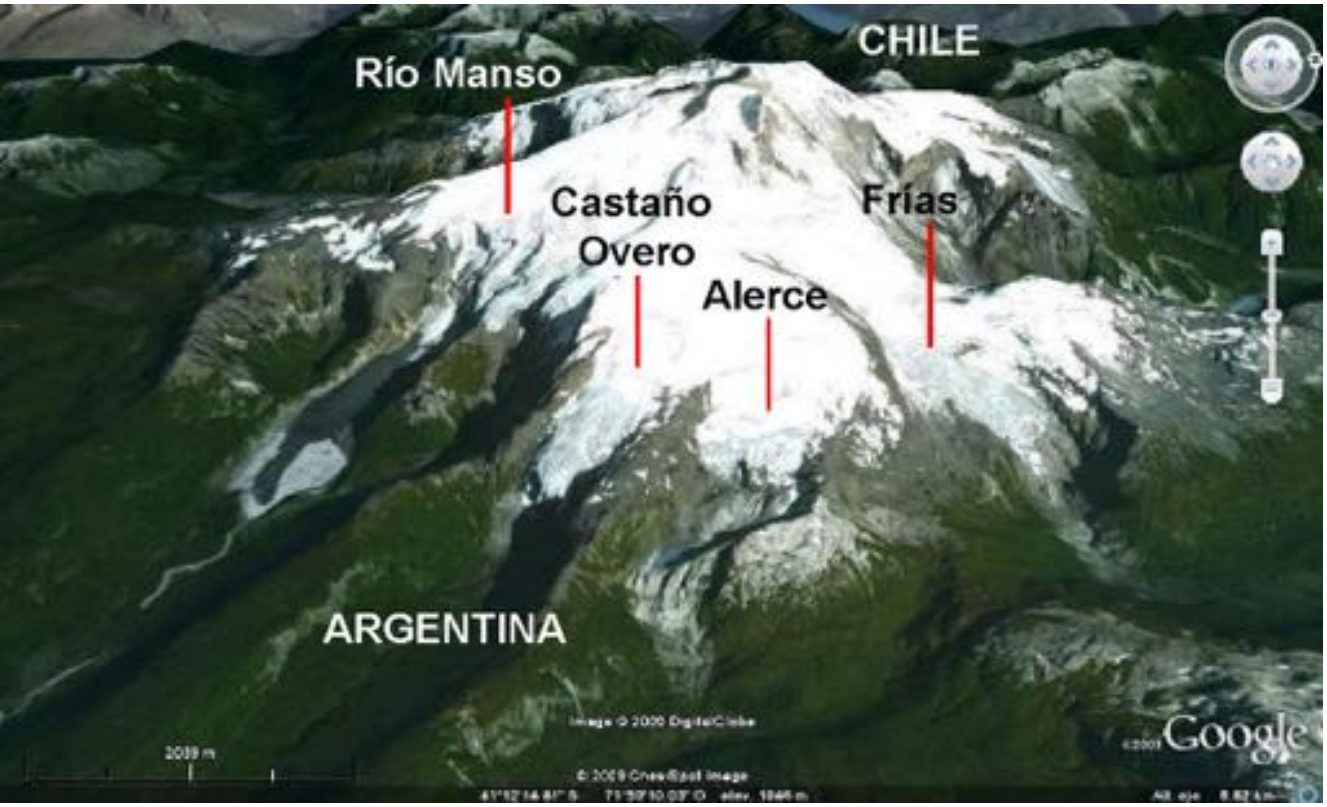
Accumulation at glaciar de los Tres (south Patagonia)

Installation of ablation stake at glaciar Alerce (north Patagonia)

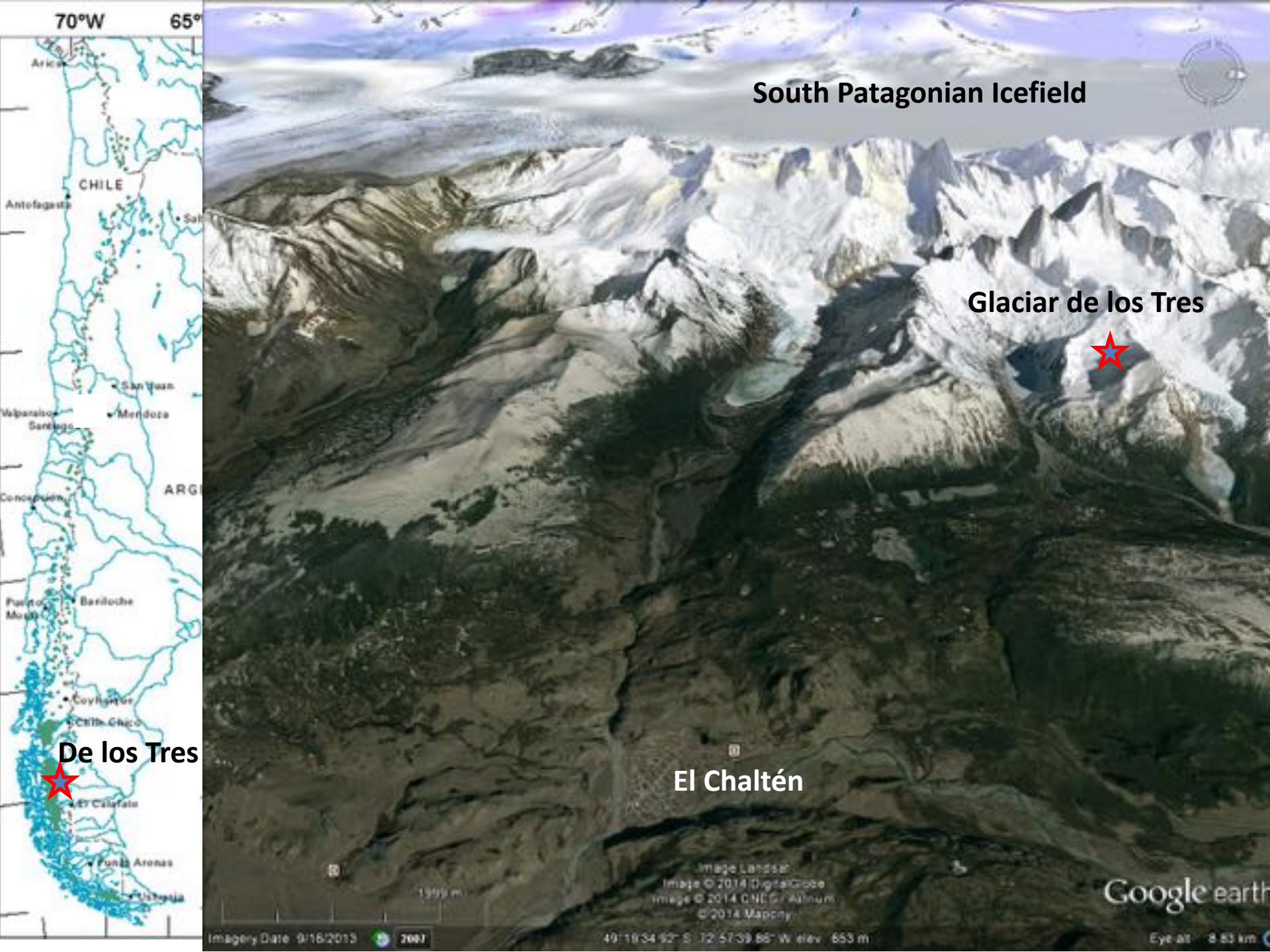

70°W
65°W
60°W
25°S
30°S
35°S
40°S
45°S
50°S
55°S
BOLIVIA
PARAGUAY
BRAZIL
CHILE
Antofagasta
Salta
Agua Negra
San Juan
Mendoza
URUGUAY
Buenos Aires
ARGENTINA
Concepción
200 KILOMETERS
Bariloche
EXPLANATION
City
Glacierized peak
Ice field
El Calafate
Punta Arenas
Ushuaia
CHILE
ARGENTINA


Glaciar Agua Negra
Paso Internacional Agua Negra
Google earth

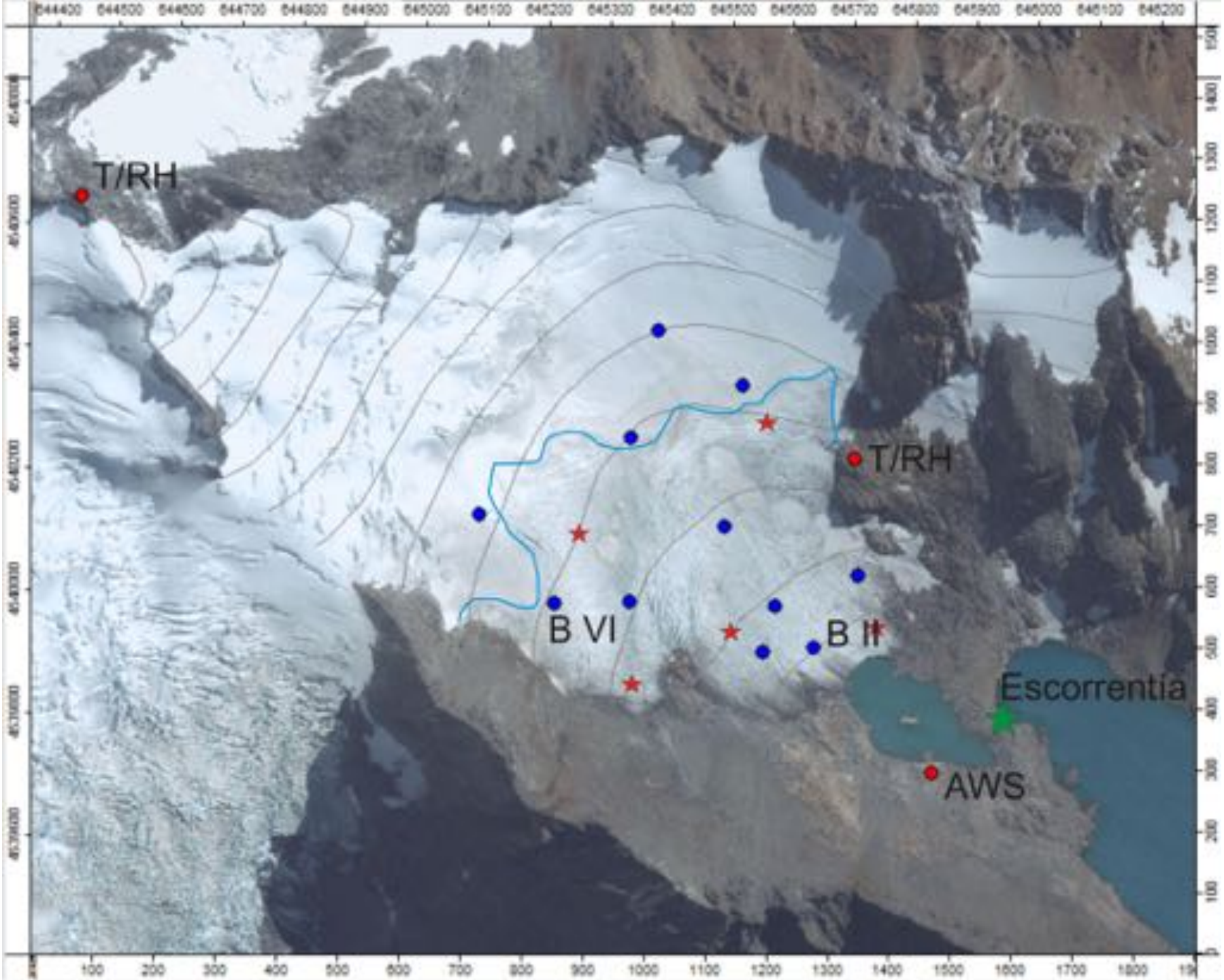
Monte Tronador (41°S) North Patagonian Andes



AWS La Almohadilla

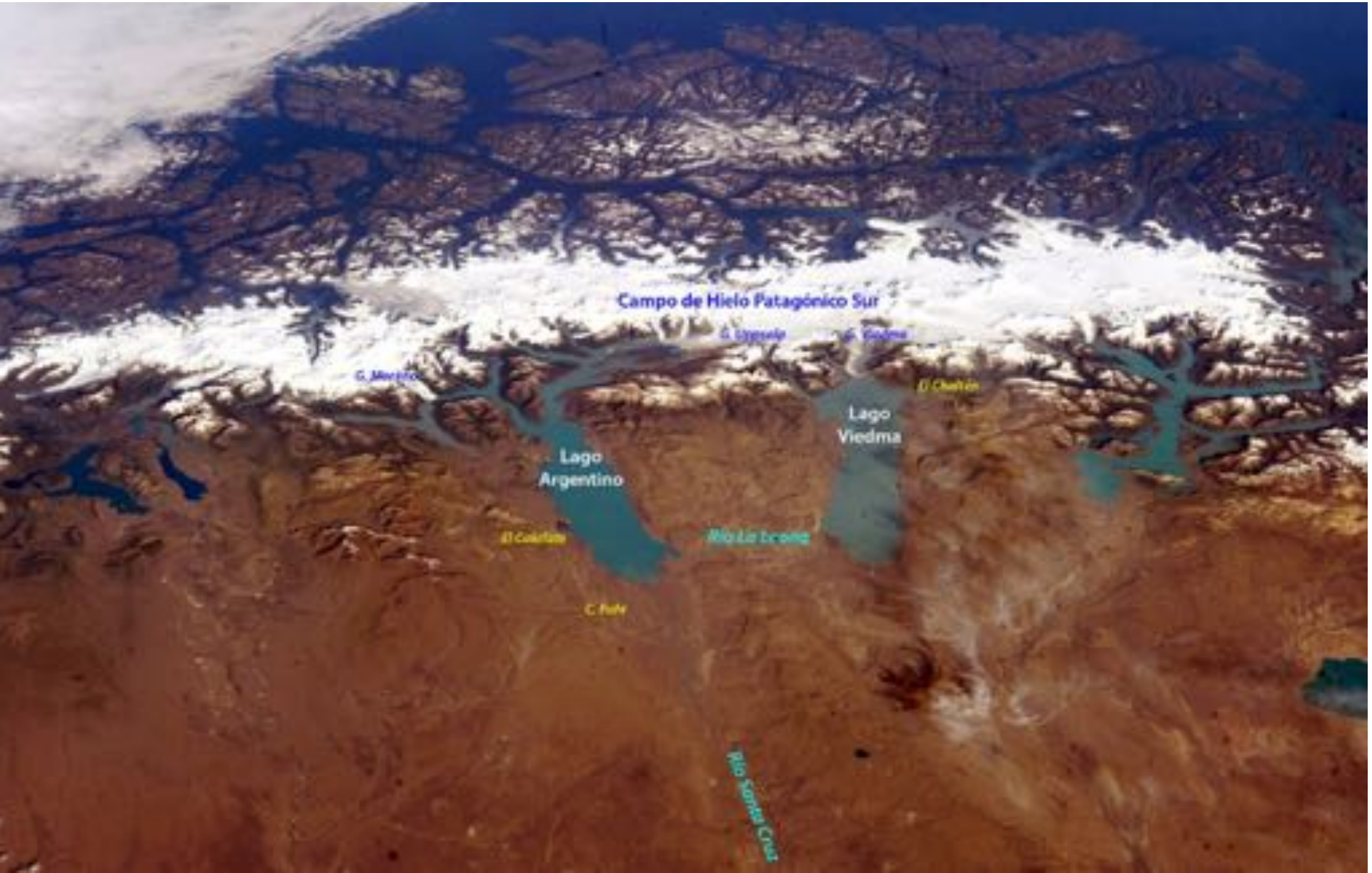

70°W
65°
CHILE
Antofagasta
San Juan
Mendoza
Valparaíso
Santiago
Concepción
Puerto Montt
Bariloche
Coyhaique
Chile Chico
El Calafate
Punta Arenas
Ushuaia
De los Tres
South Patagonian Icefield
Glaciar de los Tres
El Chaltén
Image Landsat
Image © 2014 DigitalGlobe
Image © 2014 CNES / Astrium
© 2014 MapCity
Google earth
Imagery Date: 9/16/2013
49°19'34.62" S 72°57'39.86" W elev 653 m
Eye alt 8.83 km

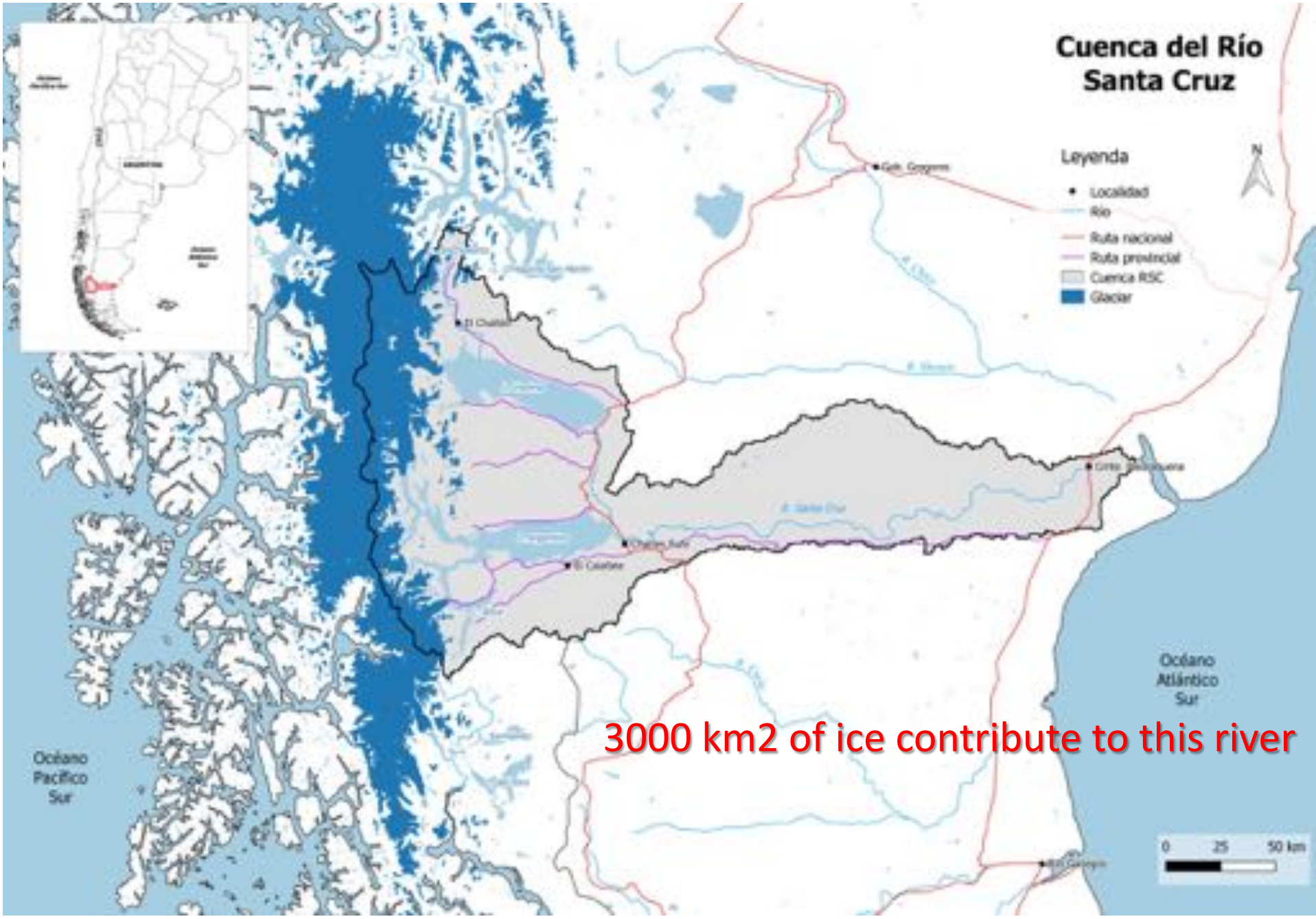

Cerro Fitz Roy
Glaciar de los Tres


T/RH
T/RH
B VI
B II
Escorrentia
AWS

AWS Aónikenk, Glaciar de los Tres
Installed april 2014

Proposal for an integrated hydro-meteorological monitoring system in the upper Santa Cruz river basin

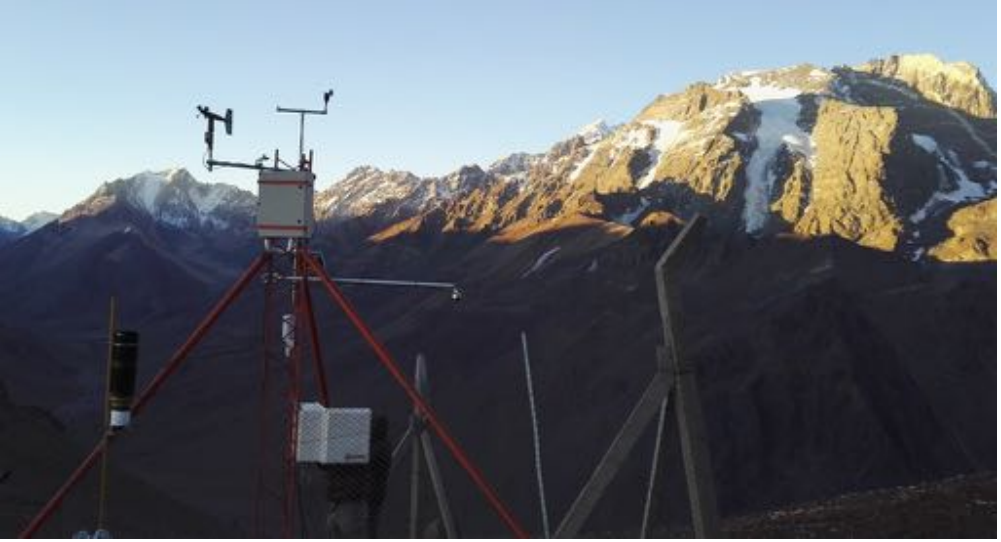



Cuenca del Río
Santa Cruz
Leyenda
Localidad
Río
Ruta nacional
Ruta provincial
Cuenca RSC
Glaciar
N
Océano
Pacífico
Sur
Océano
Atlántico
Sur
3000 km2 of ice contribute to this river
0
25
50 km

Real time meteorological monitoring of the upper Mendoza river basin

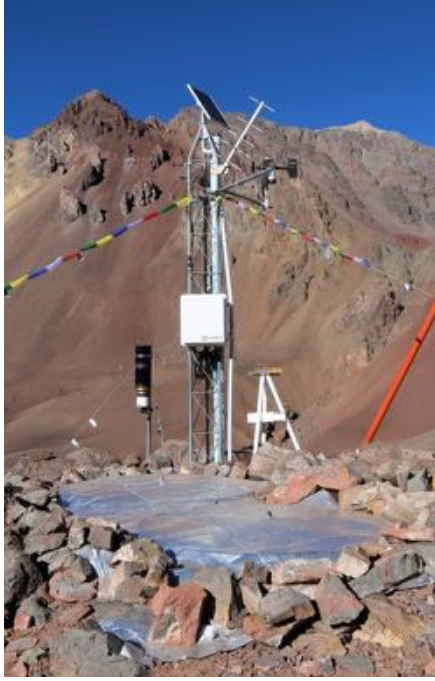
Installed and transmitting hourly data

To be installed this Spring



Cristo Redentor (32,8251°S, 70,0703°O, 3840 msnm)

Plaza de Mulas - Aconcagua (32,6539°S, 70,0651°O, 4370 msnm)



Morenas Coloradas (32,8251°S, 70,0531°O, 3347 msnm)

Las Cuevas (32,8130°S, 70,0531°O, 3190 msnm)

¡Muchas Gracias!

The sporadic GLOF created by glaciar Perito Moreno has a noticeable impact on the Santa Cruz river

http://www.youtube.com/watch?v=Dfl4DAtHkYQ

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Southern Patagonia's Perito Moreno Glacier, Lake Argentino, and Santa Cruz River hydrological system: An overview

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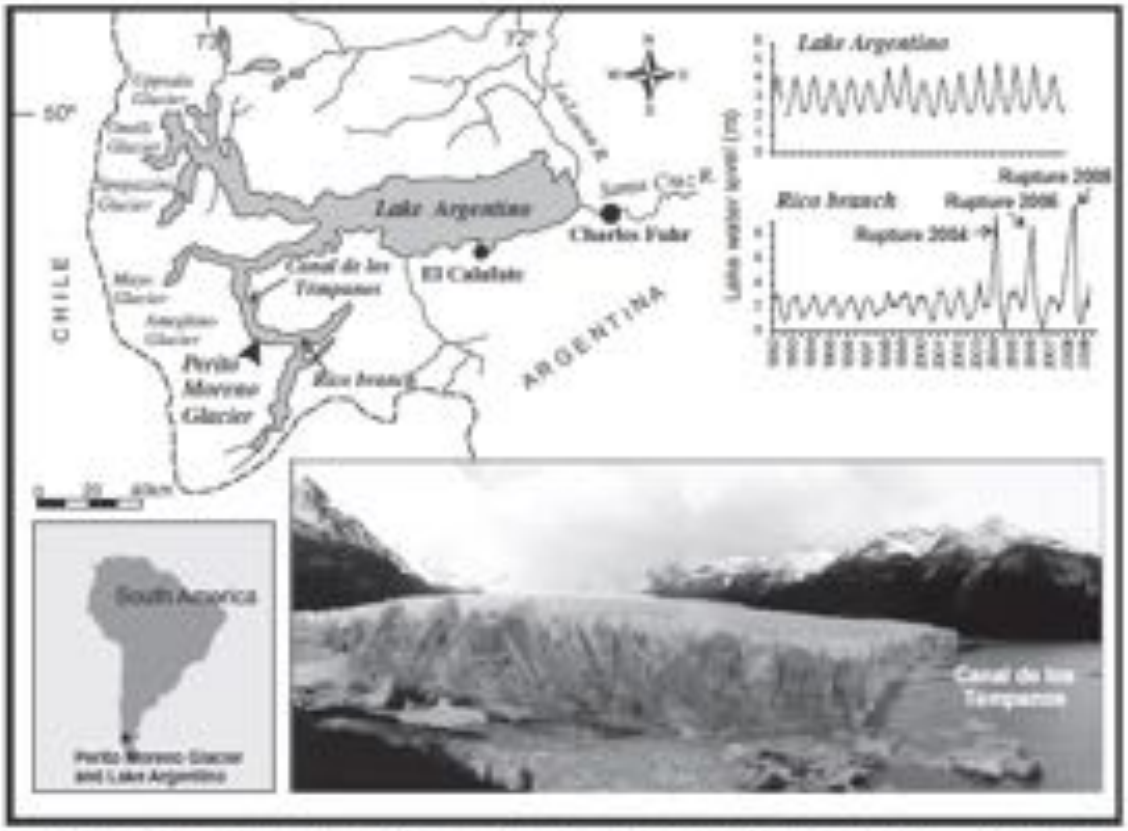
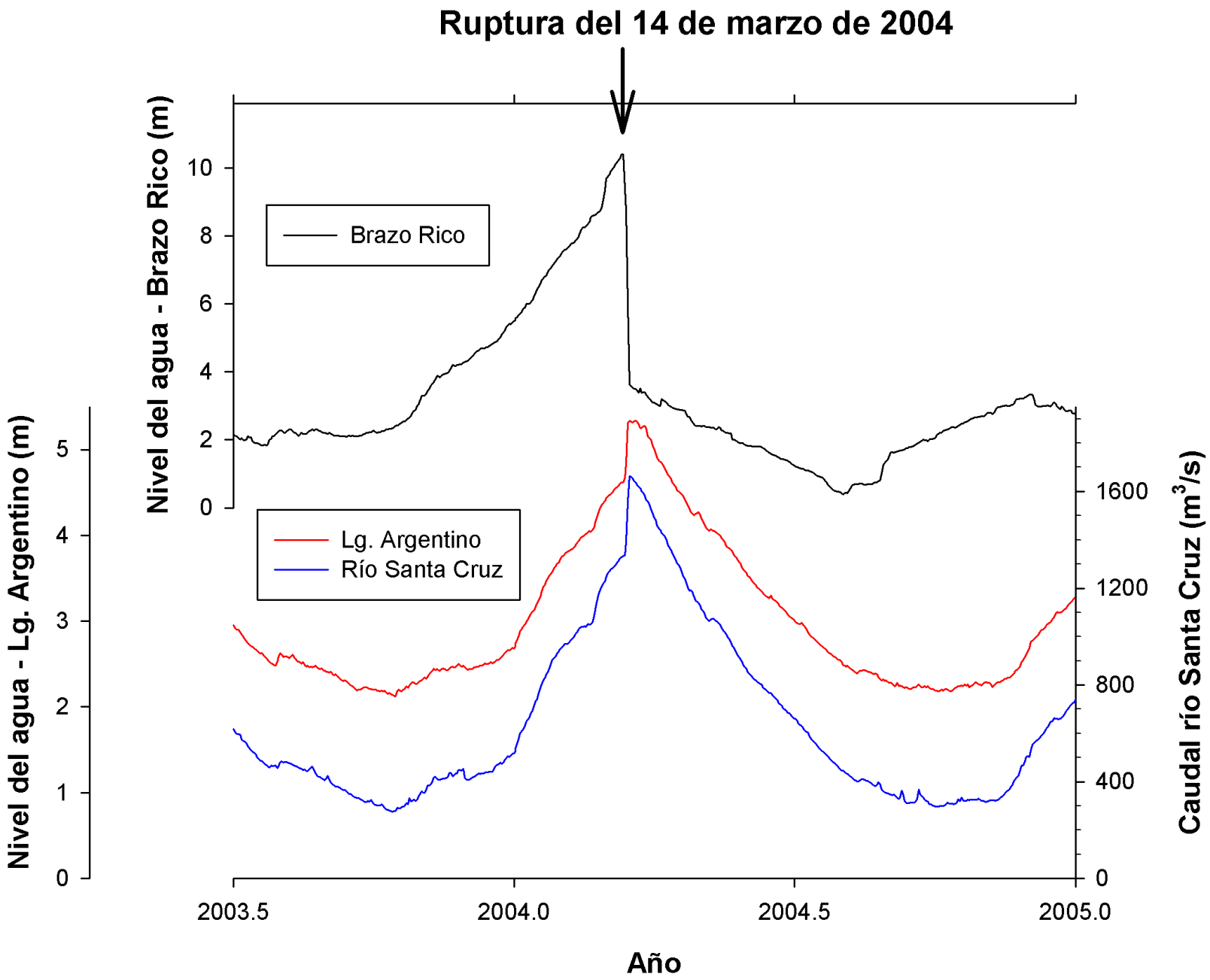
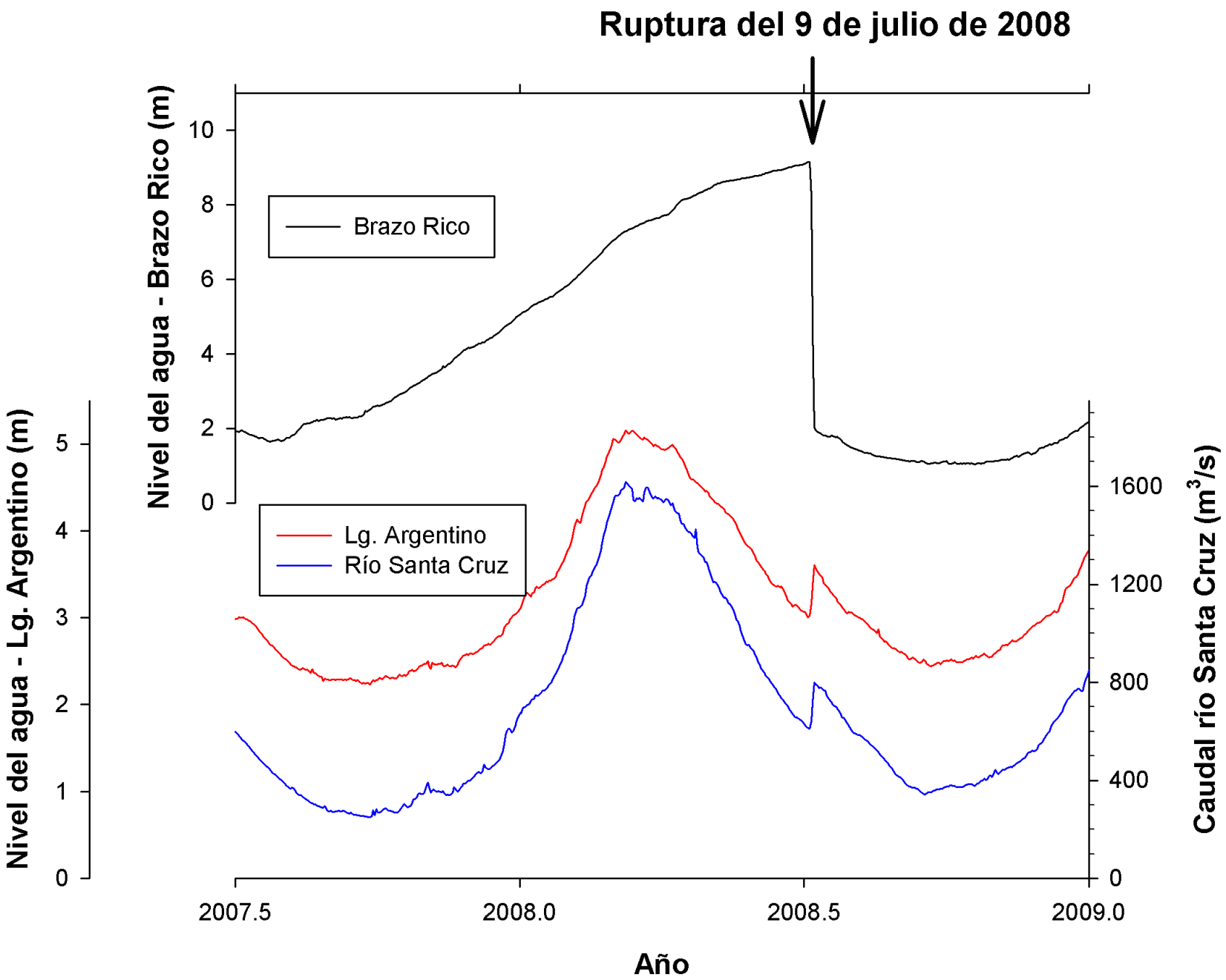
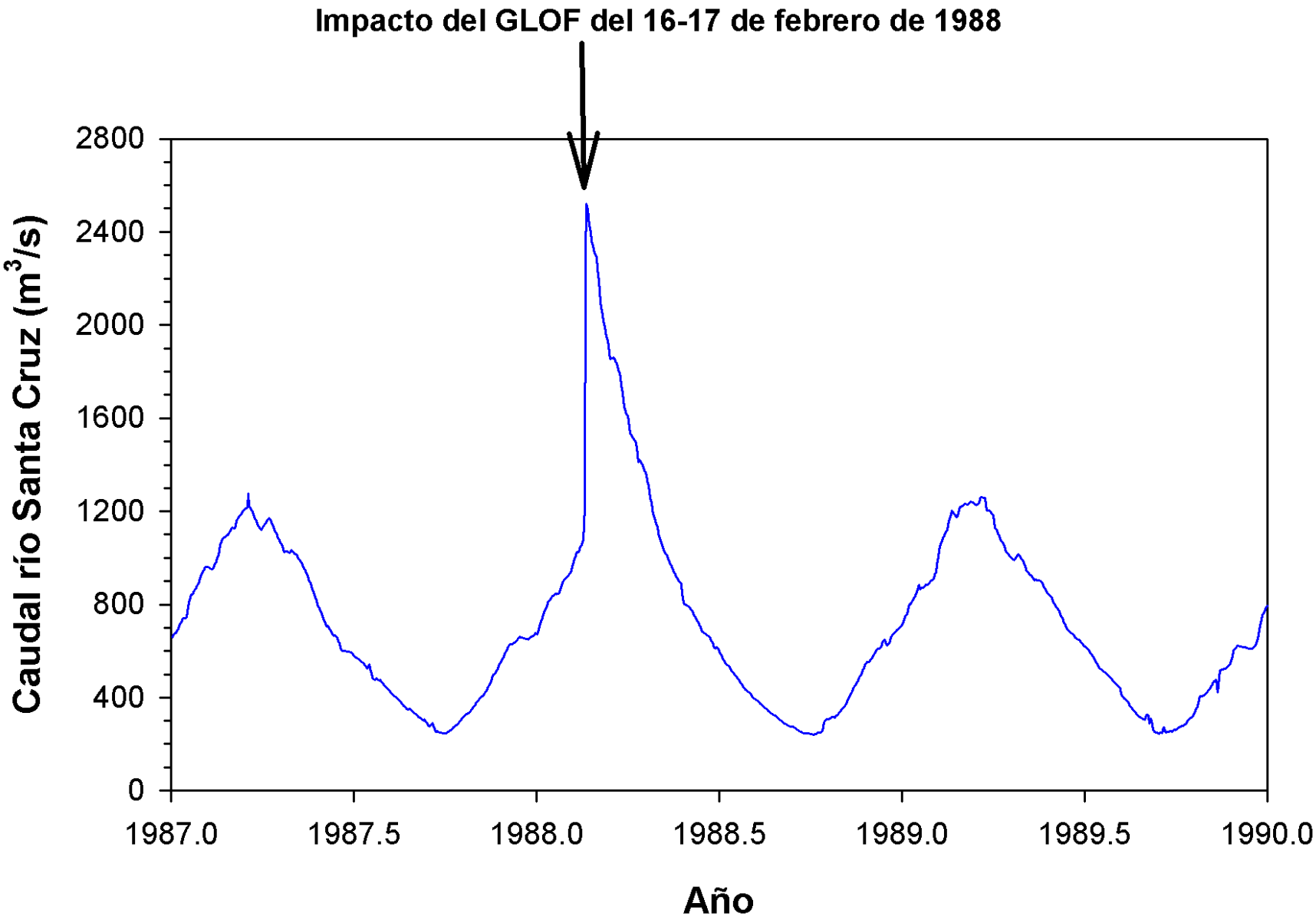


Fig. 1. A picture of the Perito Moreno Glacier terminus, a map of the hydrological system integrated by the glaciers, Lake Argentino, and the head waters of the Santa Cruz River, South America's map (lower left side) shows the location of the area in the southern Argentine Andes. The inserts in the upper right hand corner show the water level gage height variability (period 1942–2009 La Rica Rico branch) notice the water level reached behind the ice dam during the last 3 ruptures) and the corresponding modulated level in Lake Argentino.


Ruptura del 14 de marzo de 2004
Nivel del agua - Brazo Rico (m)
Brazo Rico
Lg. Argentino
Río Santa Cruz
Nivel del agua - Lg. Argentino (m)
Caudal río Santa Cruz (m3/s)
Año
2003.5
2004.0
2004.5
2005.0


Ruptura del 9 de julio de 2008
Nivel del agua - Brazo Rico (m)
Brazo Rico
Nivel del agua - Lg. Argentino (m)
Lg. Argentino
Río Santa Cruz
Caudal río Santa Cruz (m3/s)
Año
2007.5
2008.0
2008.5
2009.0


Impacto del GLOF del 16-17 de febrero de 1988
Caudal río Santa Cruz (m3/s)
2800
2400
2000
1600
1200
800
400
0
1987.0
1987.5
1988.0
1988.5
1989.0
1989.5
1990.0
Año