4th July 2025

ESA Climate Climate Change Initiative (CCI+)

Permafrost project Phase 2.

'Monitoring high-altitude permafrost in the Dry Andes.' (and a bit more)

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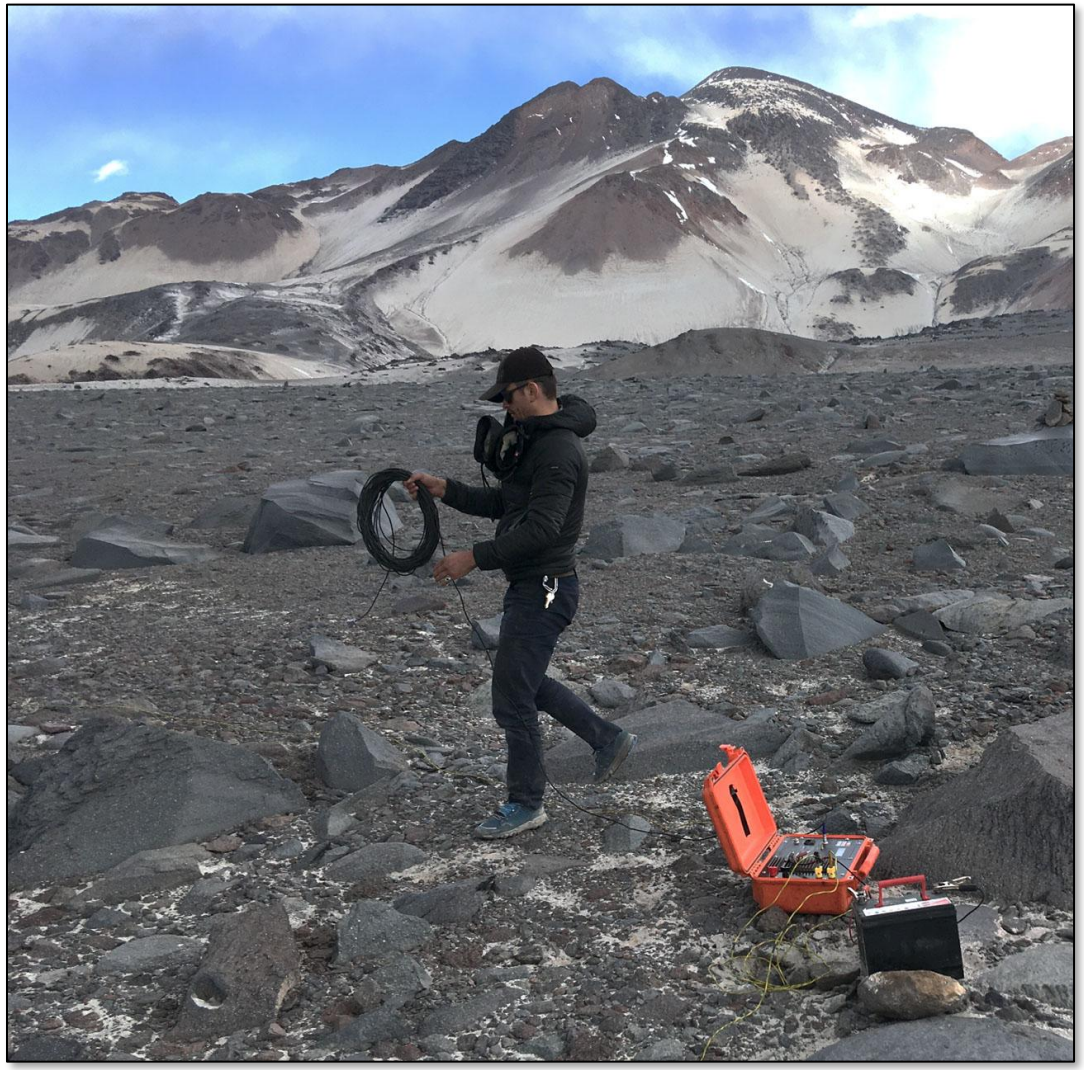
Hydraulic and Environmental Eng. Dep.,
Pontifical Catholic University Of Chile (PUC).

Bio

- Postdoc Project at **PUC**, Chile.
  - Part **PermaChile** field monitoring network and **PermaIntern/SEDNA** internship Project.
  - High mountain hydrology focusing on periglacial environments.

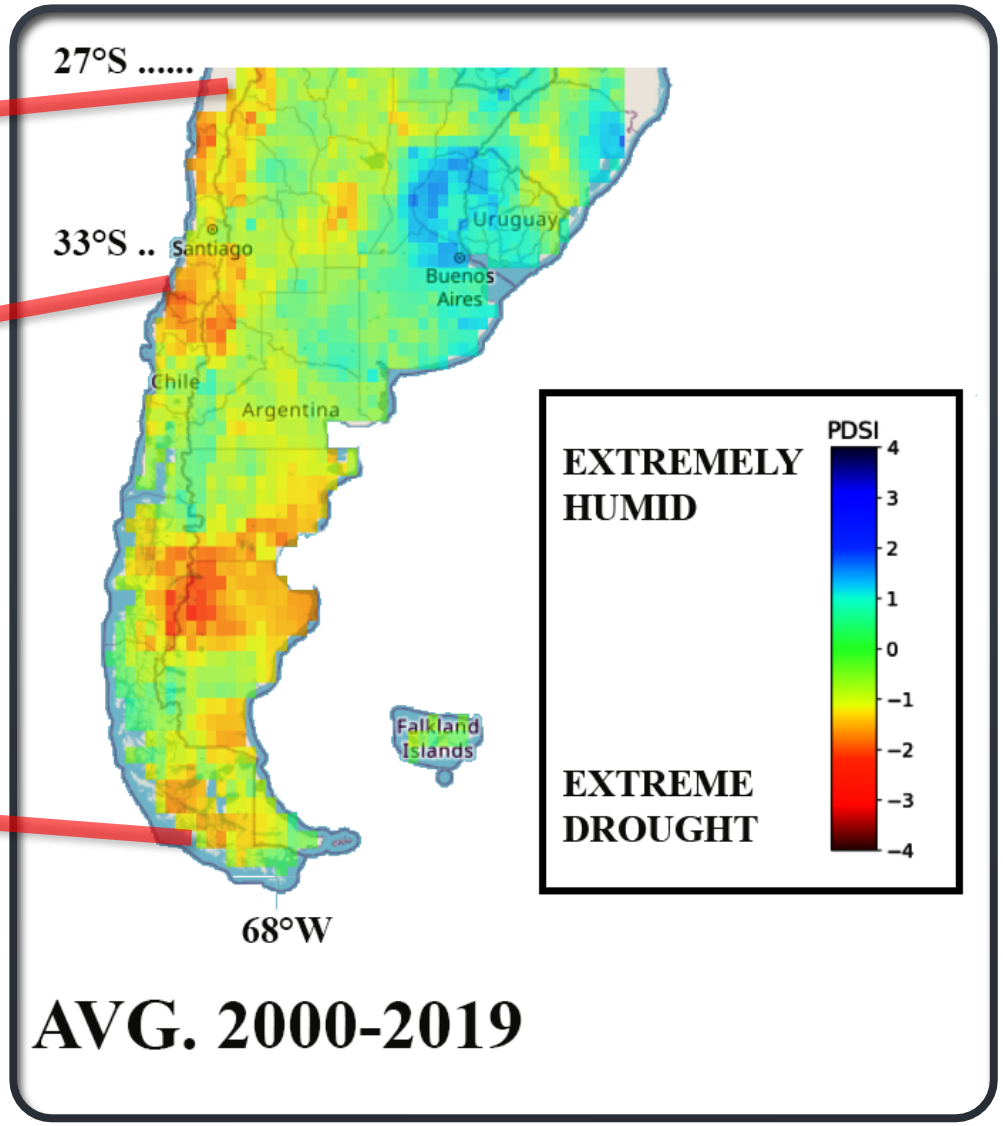
How will permafrost degradation affect headwater catchment hydrology?



Dry headwaters, **27°S**
>5000 m a.s.l.

Snow-dominated
Catchment, **33°S**
>3600 m a.s.l.

Wet tundras
at **51°S** and **54°S**
800 - 1,200 m a.s.l.



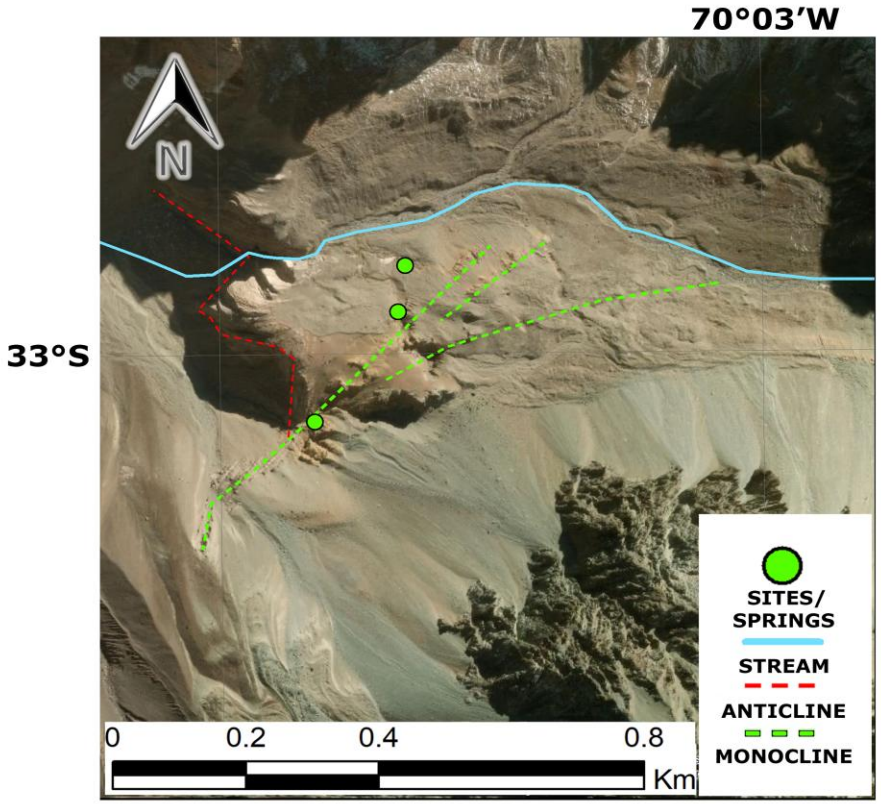
Comment from a user perspective.

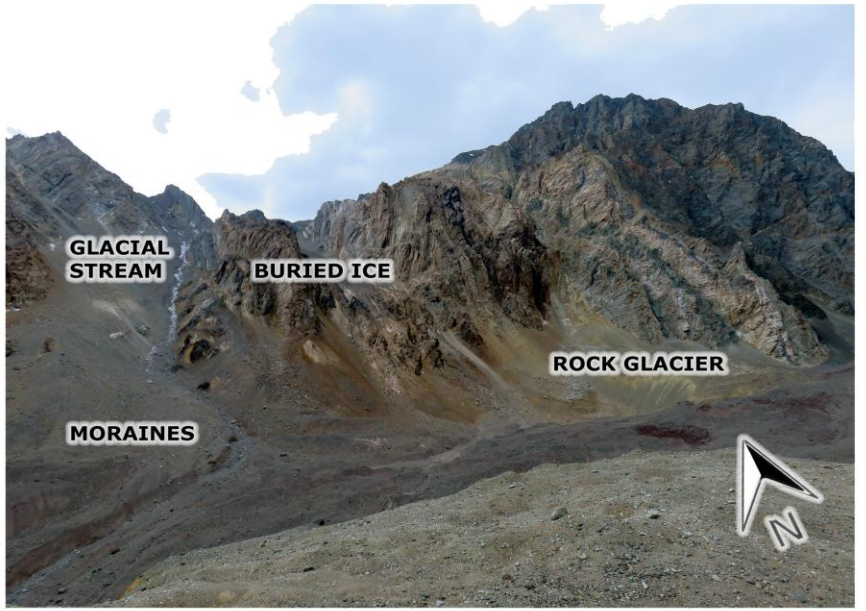
- I require GT products to assess the thermal structure of mountain aquifers.
- Evolution of the thermal structure of aquifers to parameterize groundwater response times.
- I have used **GlobPermafrost** products to locate accessible field areas for further surveying.

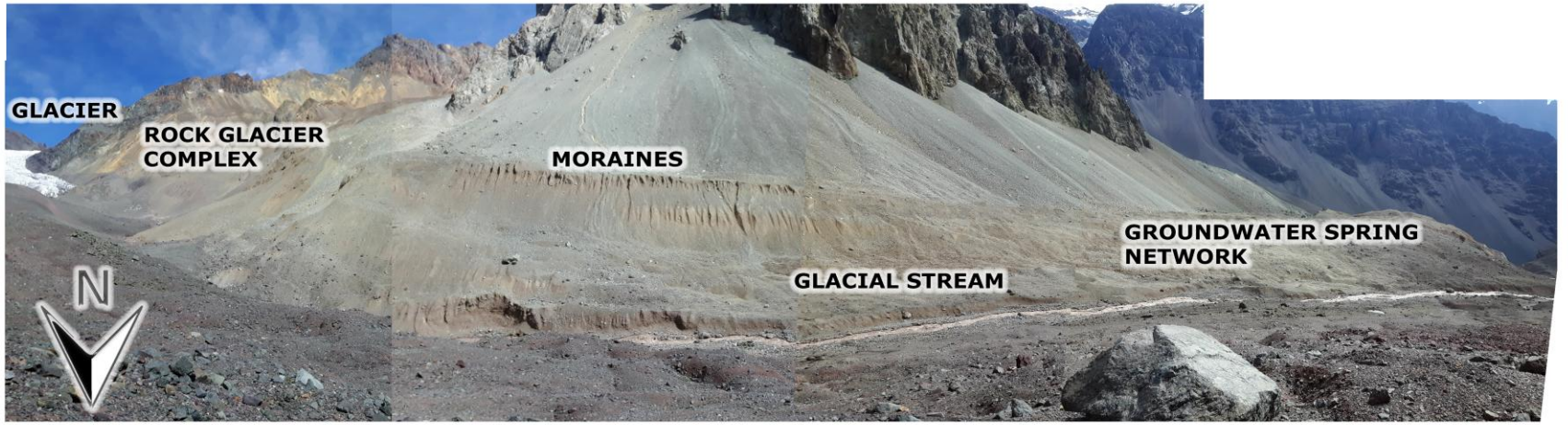
Central Andes, Chile.

- Mining operations above 4,000 m a.s.l.
- Water supply component connected to cryosphere concerns.
- Protected areas.
- Infrastructure related to winter sports above 3,000 m a.s.l.

Complex settings at 33°S, above 3,000 m ASL



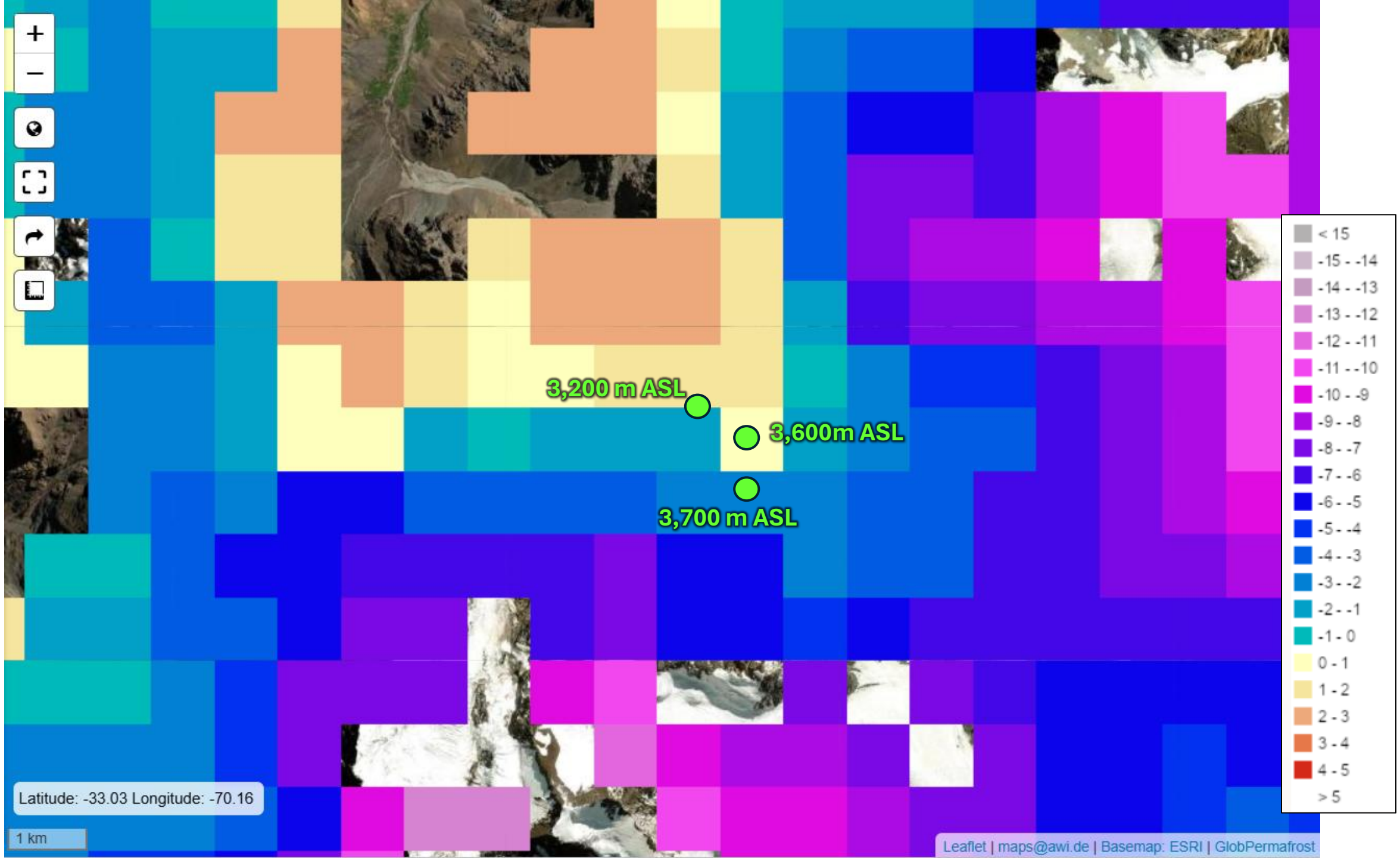




Pereira et al., (2021). Permafrost evolution in a mountain catchment near Santiago de Chile. *Journal of South American Earth Sciences*, *109*, 103293.

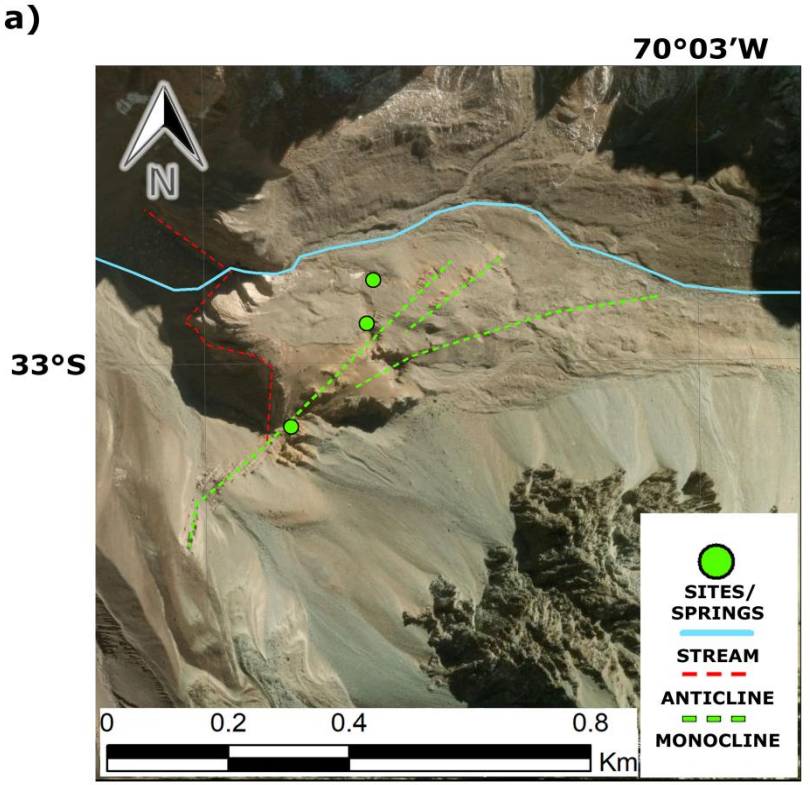
Pereira et al., (2023). Hydrological connections in a glaciated Andean catchment under permafrost conditions (33° S). *Journal of Hydrology: Regional Studies*, *45*, 101311.

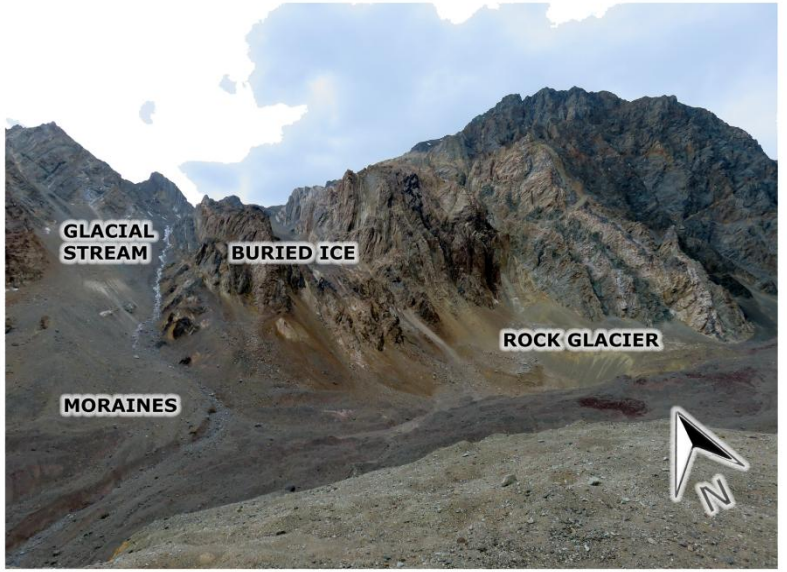

3,200 m ASL
3,600m ASL
3,700 m ASL
Latitude: -33.01 Longitude: -70.15
1 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


3,200 m ASL
3,600m ASL
3,700 m ASL
< 15
-15 - -14
-14 - -13
-13 - -12
-12 - -11
-11 - -10
-10 - -9
-9 - -8
-8 - -7
-7 - -6
-6 - -5
-5 - -4
-4 - -3
-3 - -2
-2 - -1
-1 - 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Latitude: -33.03 Longitude: -70.16
1 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


3,200 m ASL
3,600m ASL
3,700 m ASL
1
0
Latitude: -33.05 Longitude: -70.13
1 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost

Positive average temperatures at -15cm

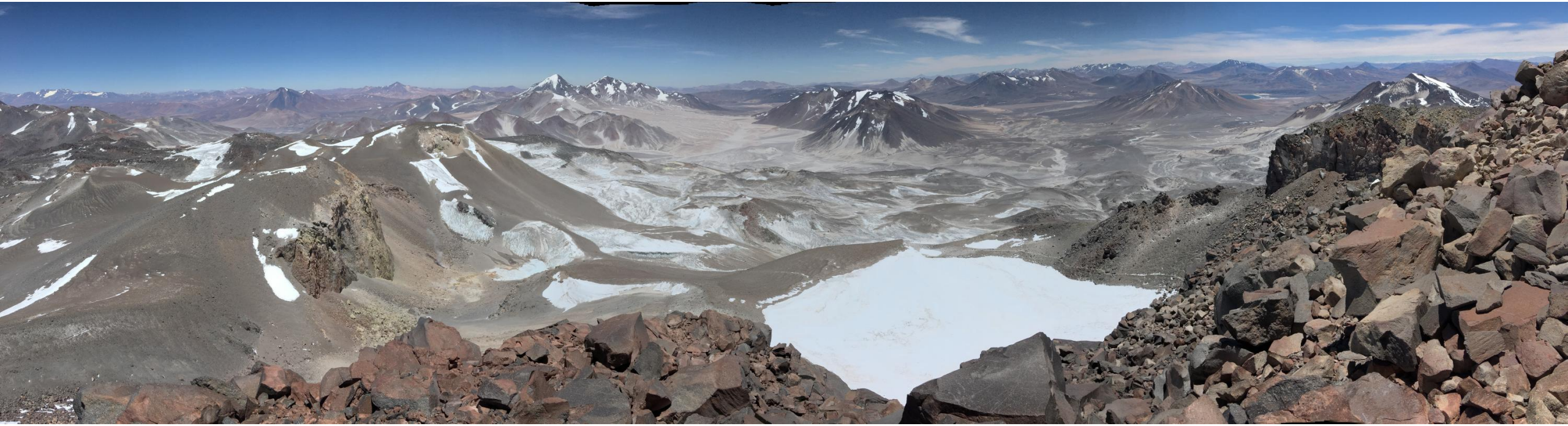




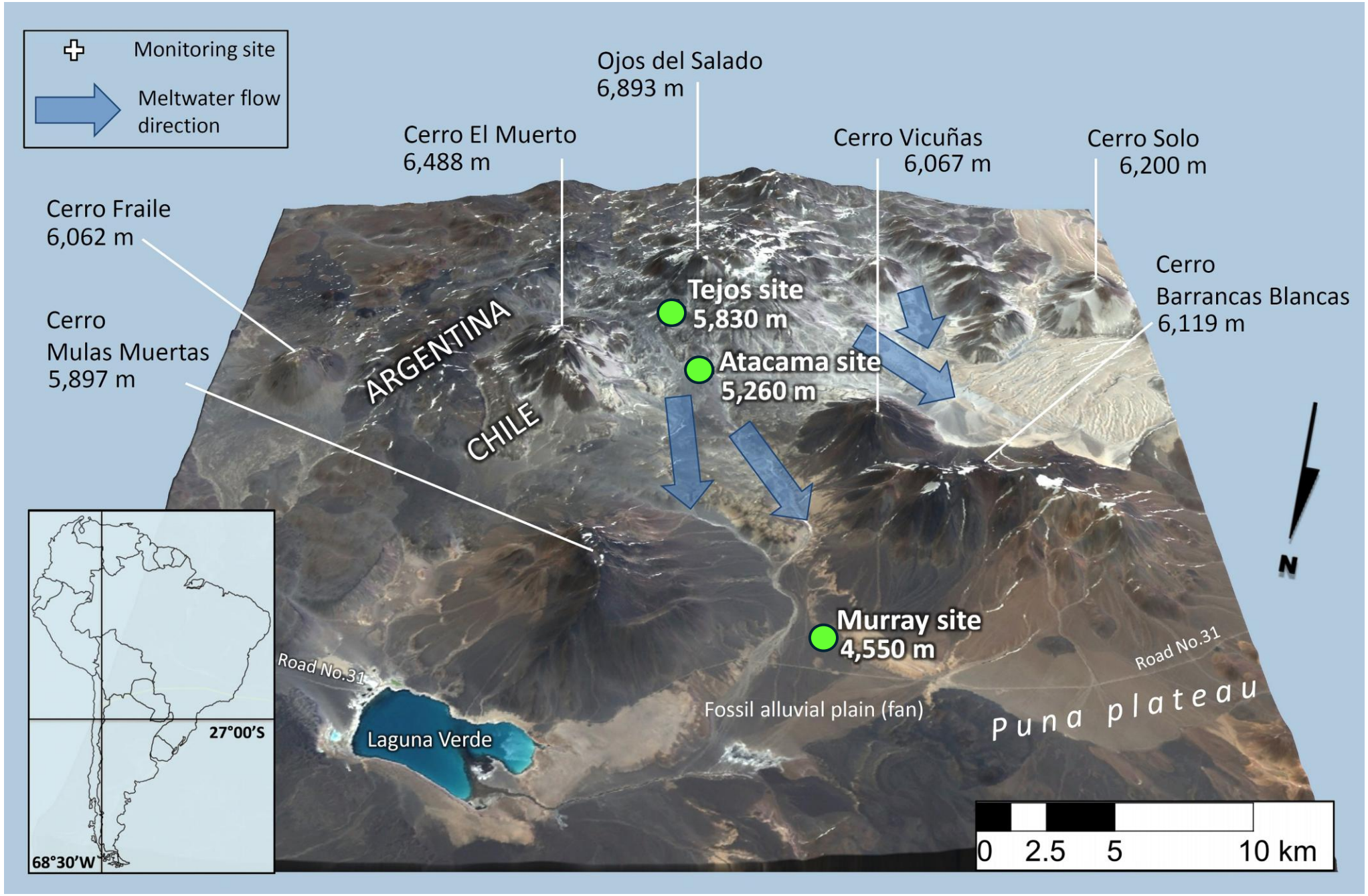
Ground surface temperature measurements (2018–2020). Freeze-thaw cycles constitute thermal weathering conditions of a periglacial environment.

	Mean Temperature (°C)	Freeze-thaw cycles	Clear sky %
3700 m a.s.l.	2.23 ± 1.0	69	51 ± 13
3600 m a.s.l.	3.98 ± 2.14	48	50 ± 11
3200 m a.s.l.	7.78 ± 0.77	40	48 ± 10

Dry Andes, Ojos del Salado massif (6,800 m ASL)



From summit (6,800 m ASL) and at the crater...

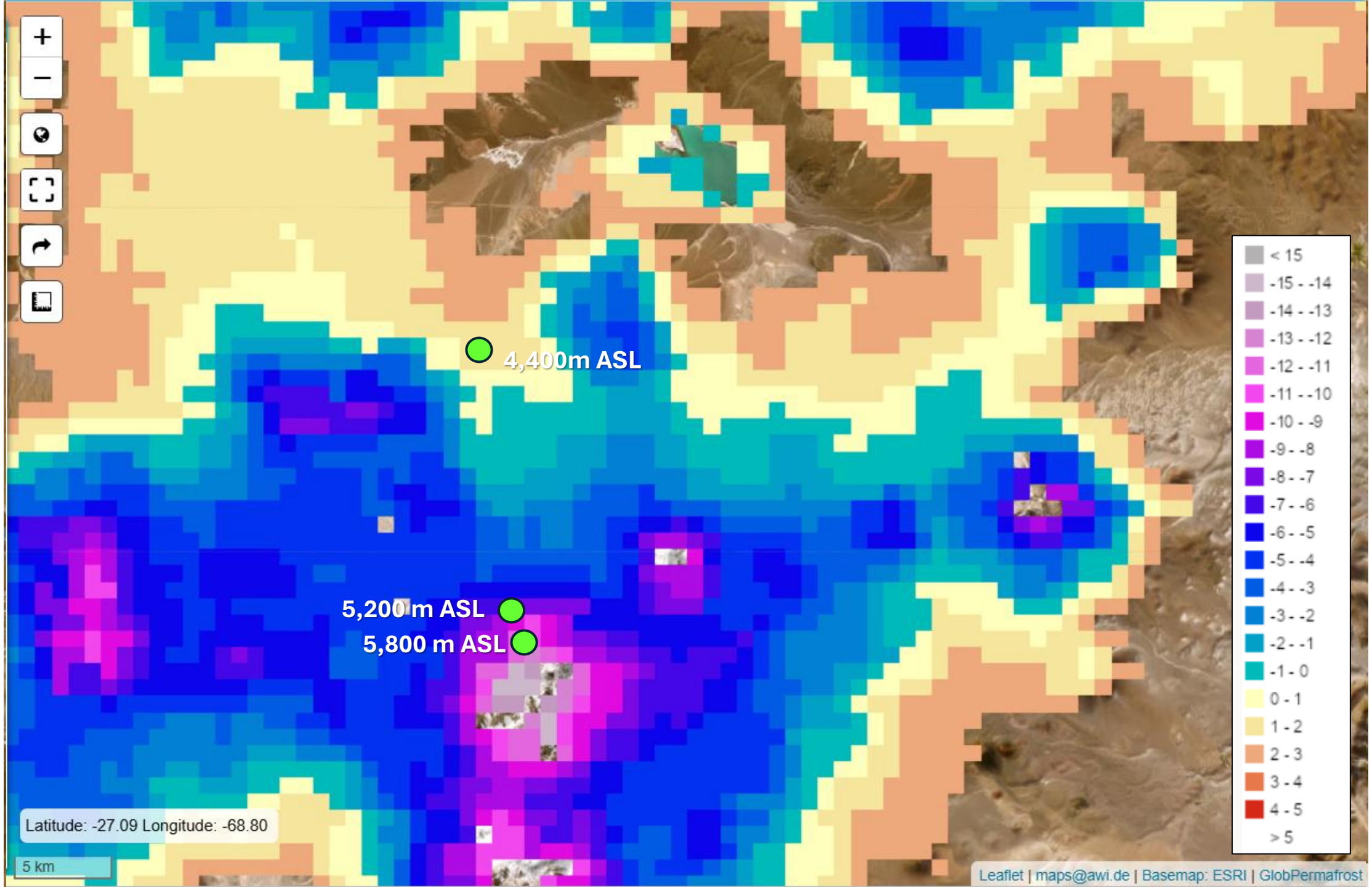


Ruiz-Pereira et al., 2025

Assessing permafrost structures in headwater aquifers

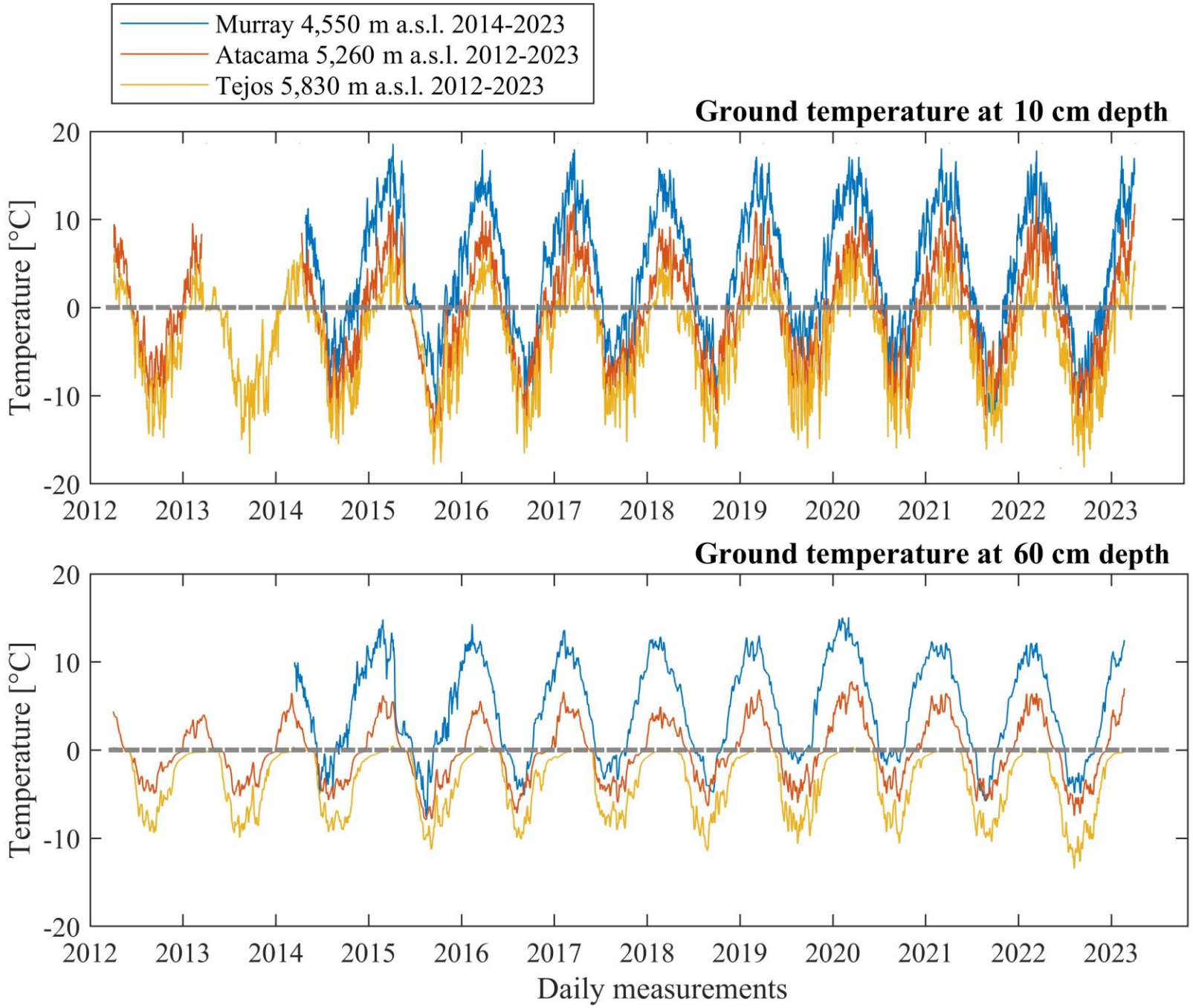
Andean Geology 52-2


4,400m ASL
5,200 m ASL
5,800 m ASL
Latitude: -27.20 Longitude: -68.79
5 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


4,400m ASL
5,200 m ASL
5,800 m ASL
< 15
-15 - -14
-14 - -13
-13 - -12
-12 - -11
-11 - -10
-10 - -9
-9 - -8
-8 - -7
-7 - -6
-6 - -5
-5 - -4
-4 - -3
-3 - -2
-2 - -1
-1 - 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Latitude: -27.09 Longitude: -68.80
5 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost

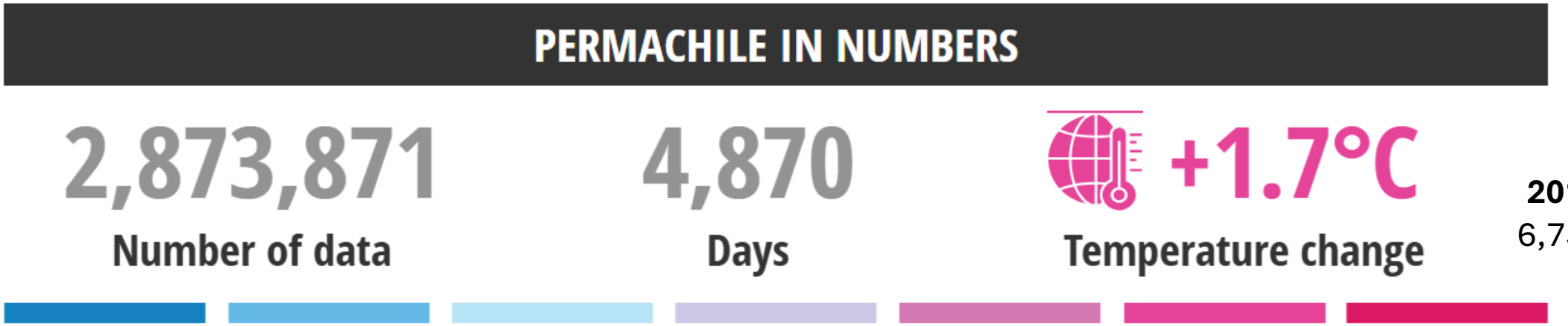
Ground Temps.

- 2012-2025.

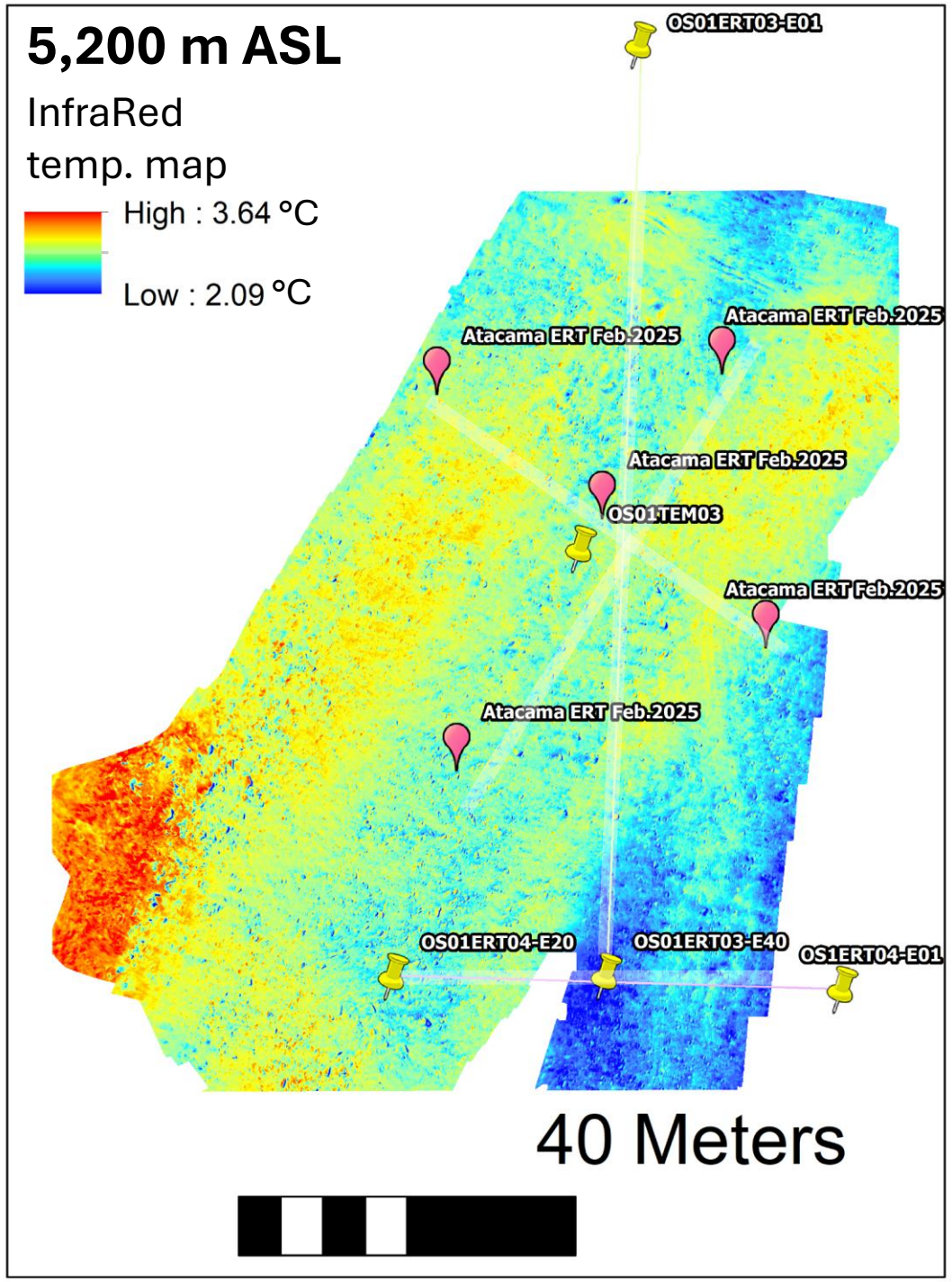


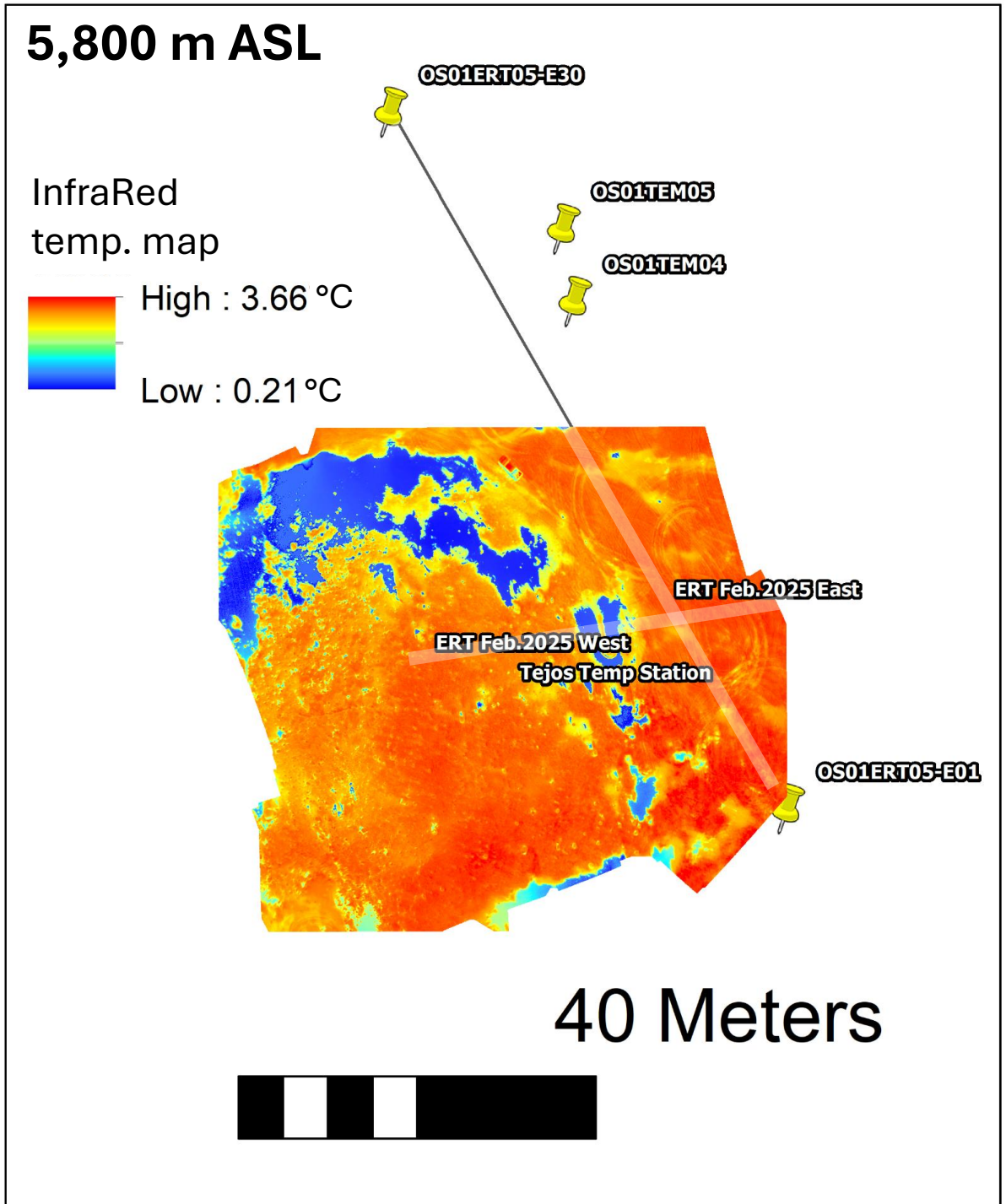
Field temperatures 2012-2025.

	5,800 m ASL 10cm	5,800m ASL 35cm	5,800m ASL 60cm	5,200m ASL 10cm	5,200m ASL 35cm	5,200m ASL 60cm	4,400m ASL 10cm	4,400m ASL 35cm	4,400m ASL 60cm
Median temperature 2012-2025	-3.57	-3.51	-3.31	-0.2	-0.02	0.08	4.1	4.74	4.98
Deviation	6.04	4.77	3.88	6.59	4.90	3.80	8.02	6.66	5.62
MAGT 2000-2016 GlobPermafrost	**(-9)**			**(-6)**			**(+1)**		




4,400m ASL
5,200 m ASL
5,800 m ASL
1
0
Latitude: -27.16 Longitude: -68.80
5 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


5,200 m ASL
InfraRed
temp. map
High : 3.64 °C
Low : 2.09 °C
OS01ERT03-E01
Atacama ERT Feb.2025
Atacama ERT Feb.2025
Atacama ERT Feb.2025
OS01TEM03
Atacama ERT Feb.2025
Atacama ERT Feb.2025
OS01ERT04-E20
OS01ERT03-E40
OS1ERT04-E01
40 Meters


5,800 m ASL
InfraRed
temp. map
High : 3.66 °C
Low : 0.21 °C
OS01ERT05-E30
OS01TEM05
OS01TEM04
ERT Feb.2025 East
ERT Feb.2025 West
Tejos Temp Station
OS01ERT05-E01
40 Meters

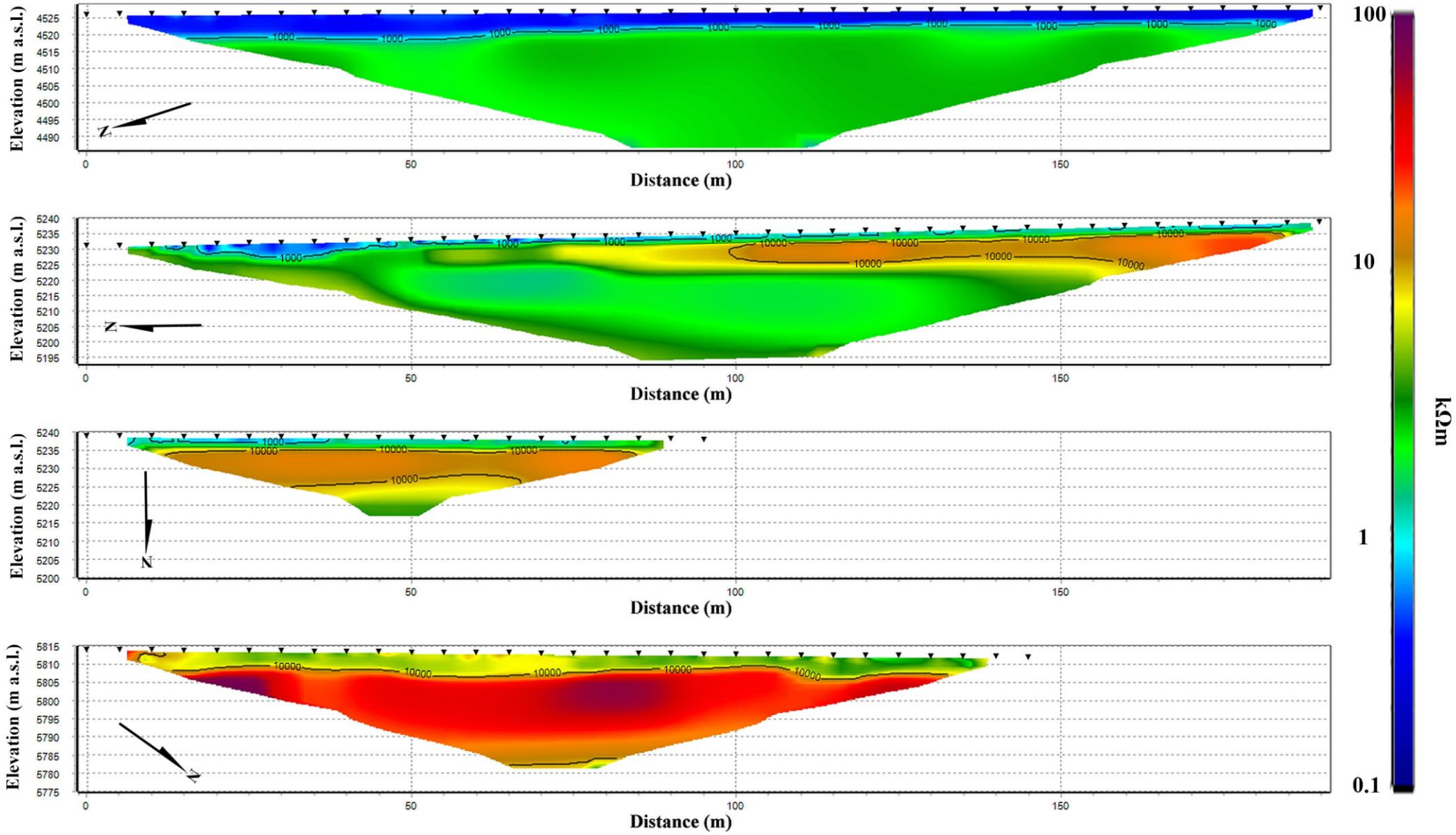
Electrical resistivity tomography.

4,400m
NO PF

5,200m
PF ✓

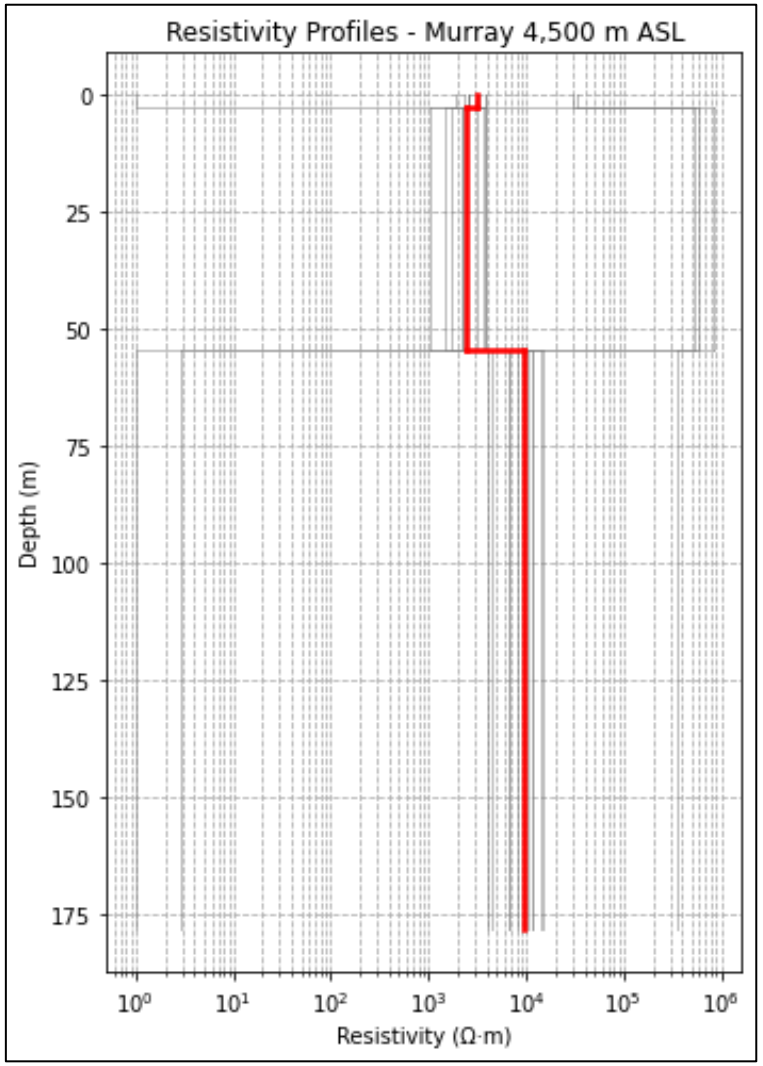
5,200m
PF ✓

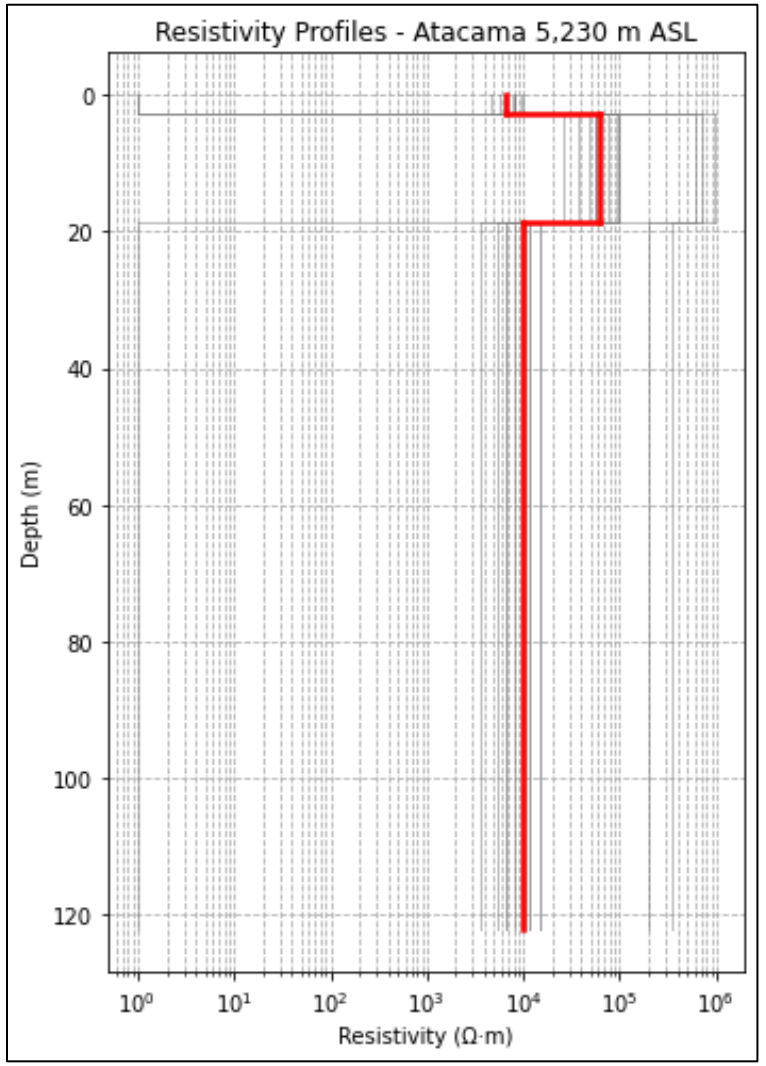
5,800m
PF ✓

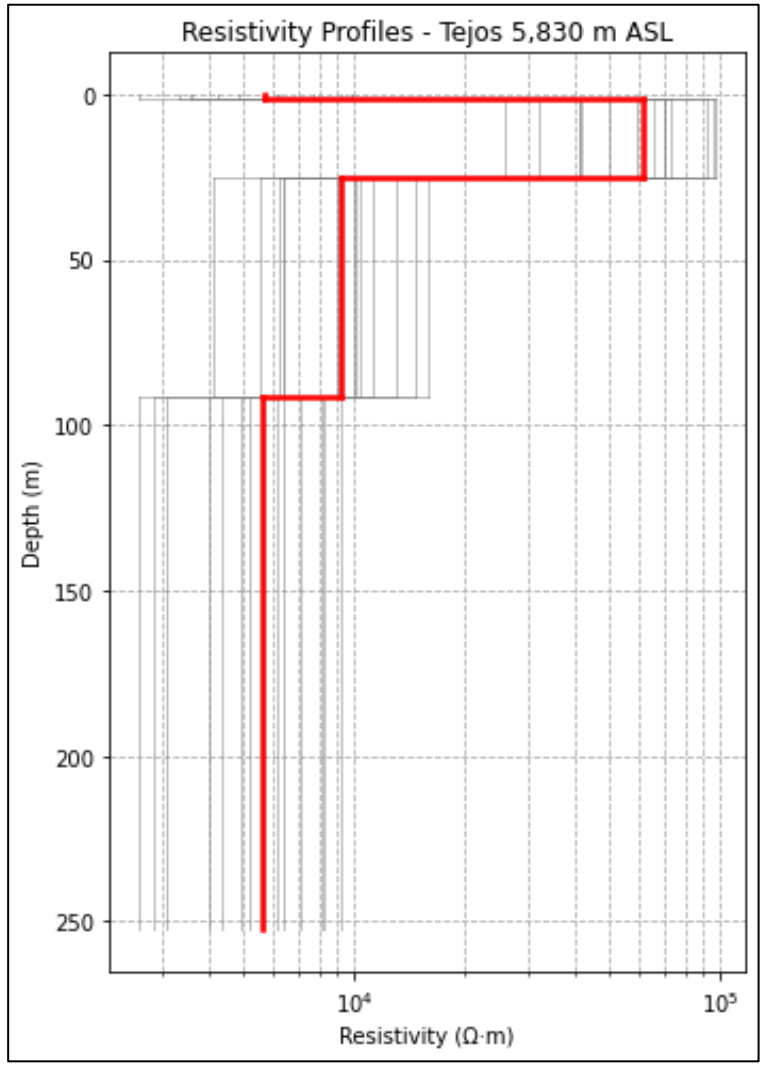


Ruiz-Pereira et al., 2025, Andean Geology 52-2

TEM subsurface surveys (50m loop)



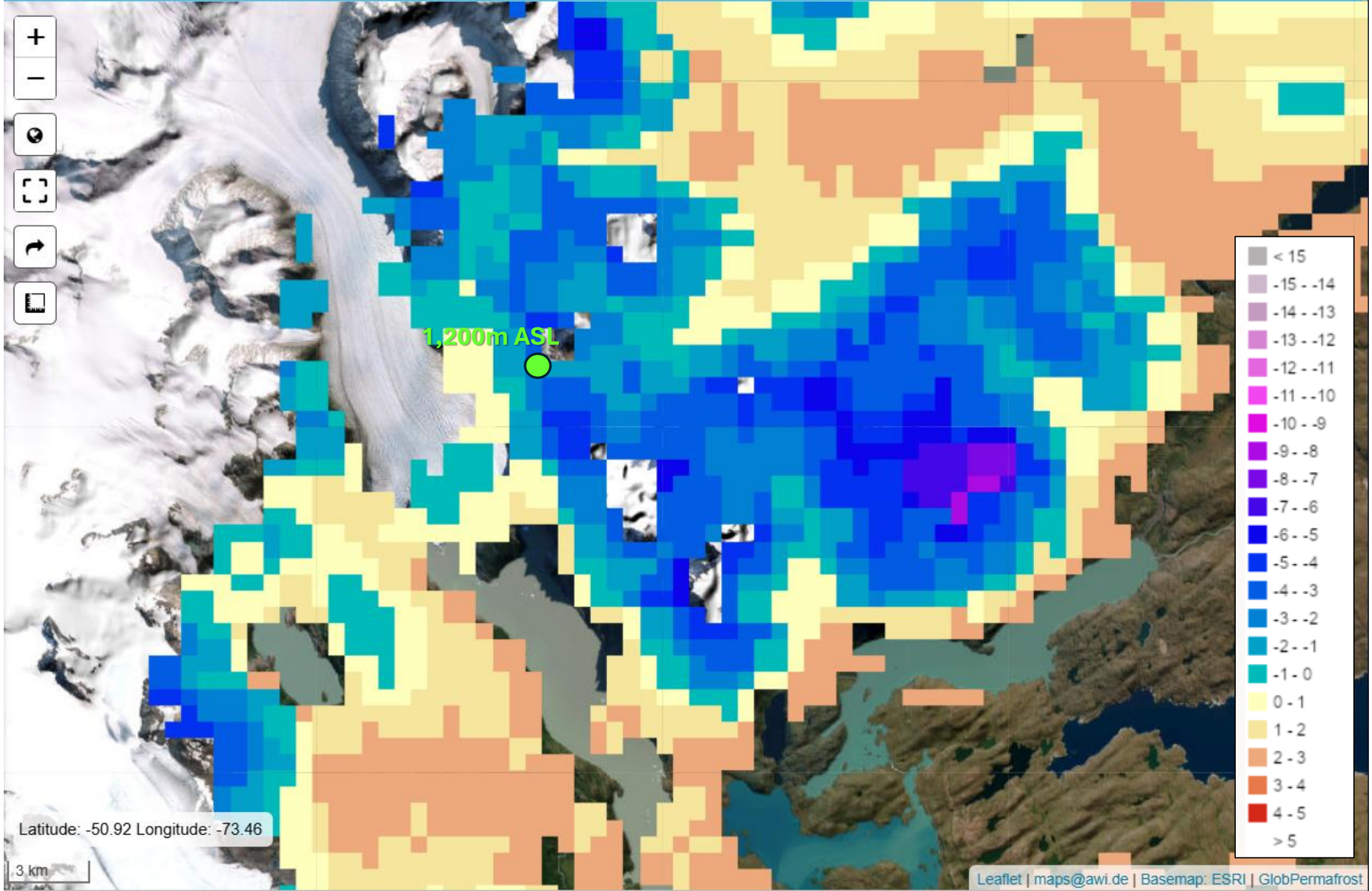


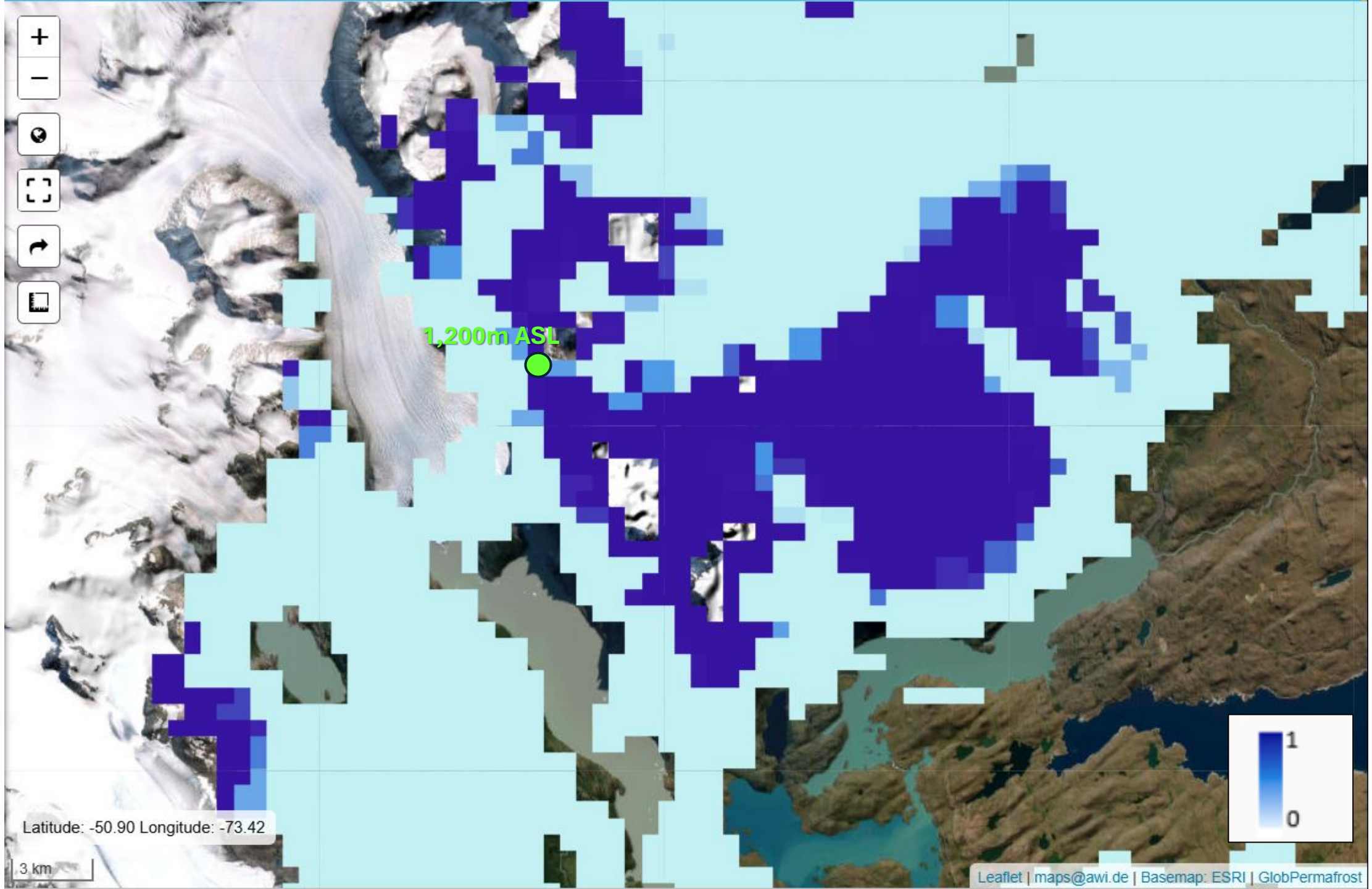


Southern continental Patagonia.

- Ongoing monitoring at **1,200 m ASL**.
- MAGT 2020-2024: **0.55 ± 2.66 °C**
- Cryogenic depth around 2m.

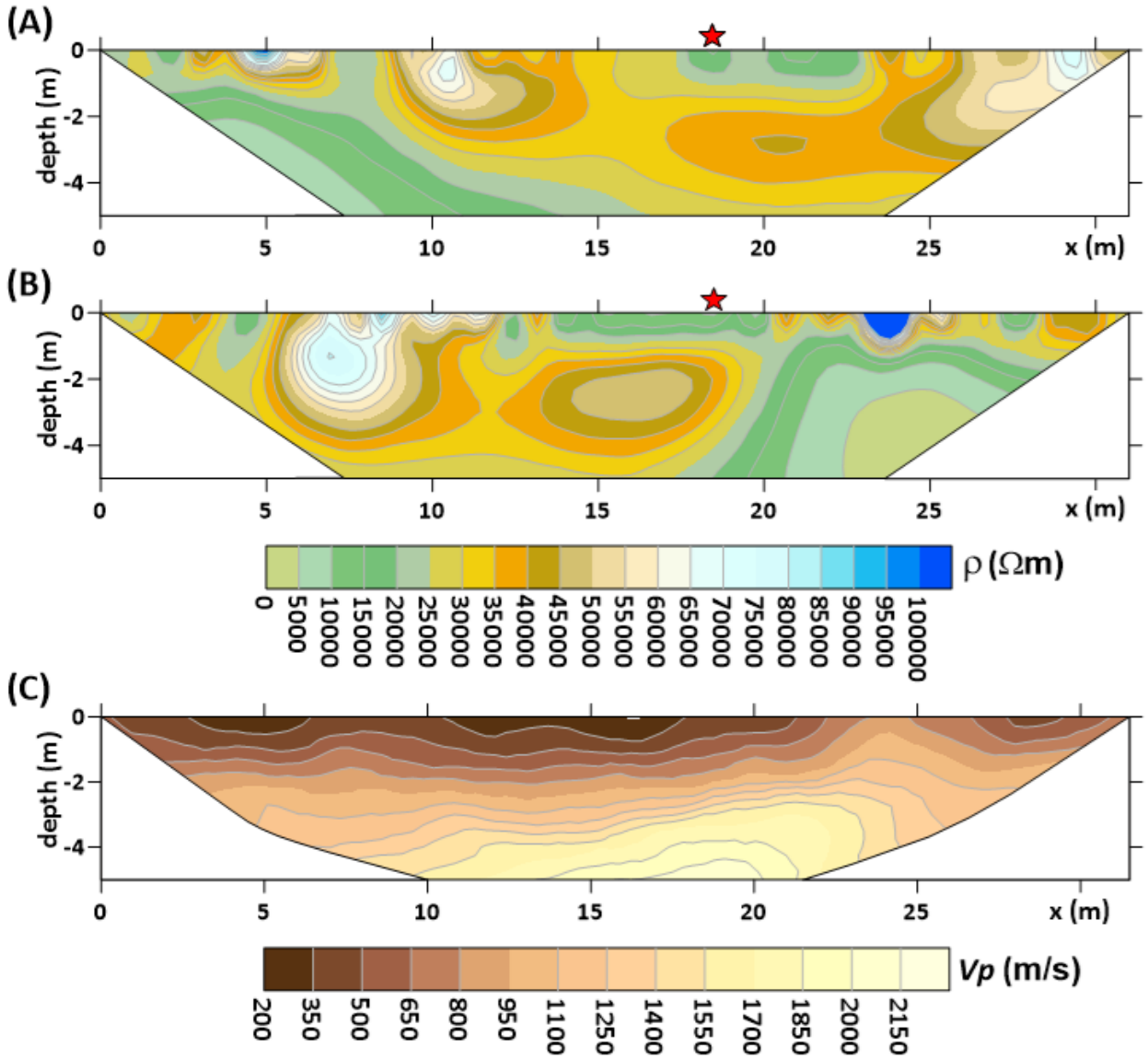

1,200m
ASL
Latitude: -50.93 Longitude: -73.46
3 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


1,200m ASL
< 15
-15 - -14
-14 - -13
-13 - -12
-12 - -11
-11 - -10
-10 - -9
-9 - -8
-8 - -7
-7 - -6
-6 - -5
-5 - -4
-4 - -3
-3 - -2
-2 - -1
-1 - 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Latitude: -50.92 Longitude: -73.46
3 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


1,200m ASL
Latitude: -50.90 Longitude: -73.42
3 km
1
0
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost

Gardner pass, Torres del Paine, 51°S, 1,200m ASL

Work along with U. of Padova:
Mirko Pavoni
Alberto Carrera
Jacopo Boaga



Gardner pass, Torres del Paine, 51°S, 1,200m ASL

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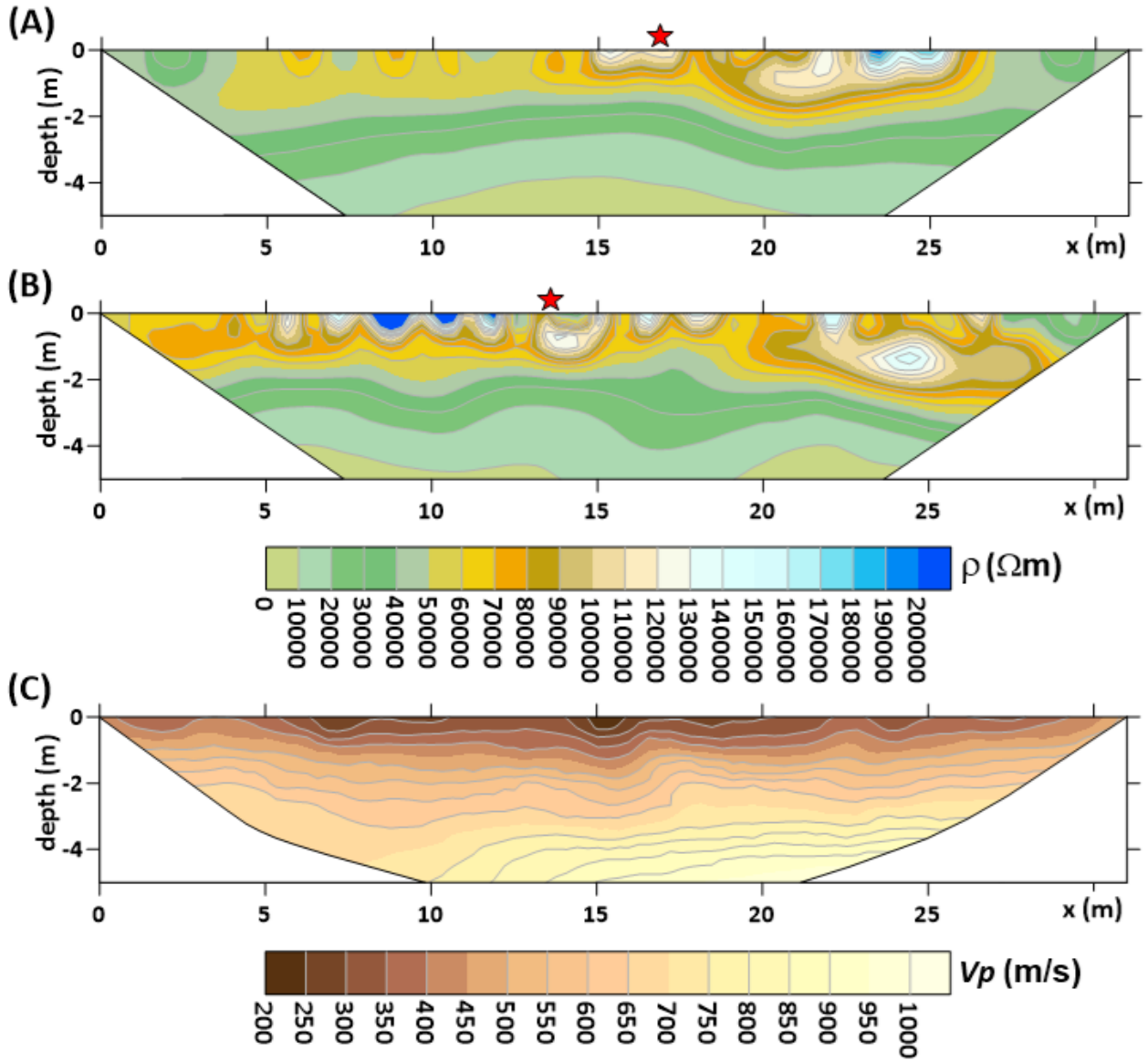
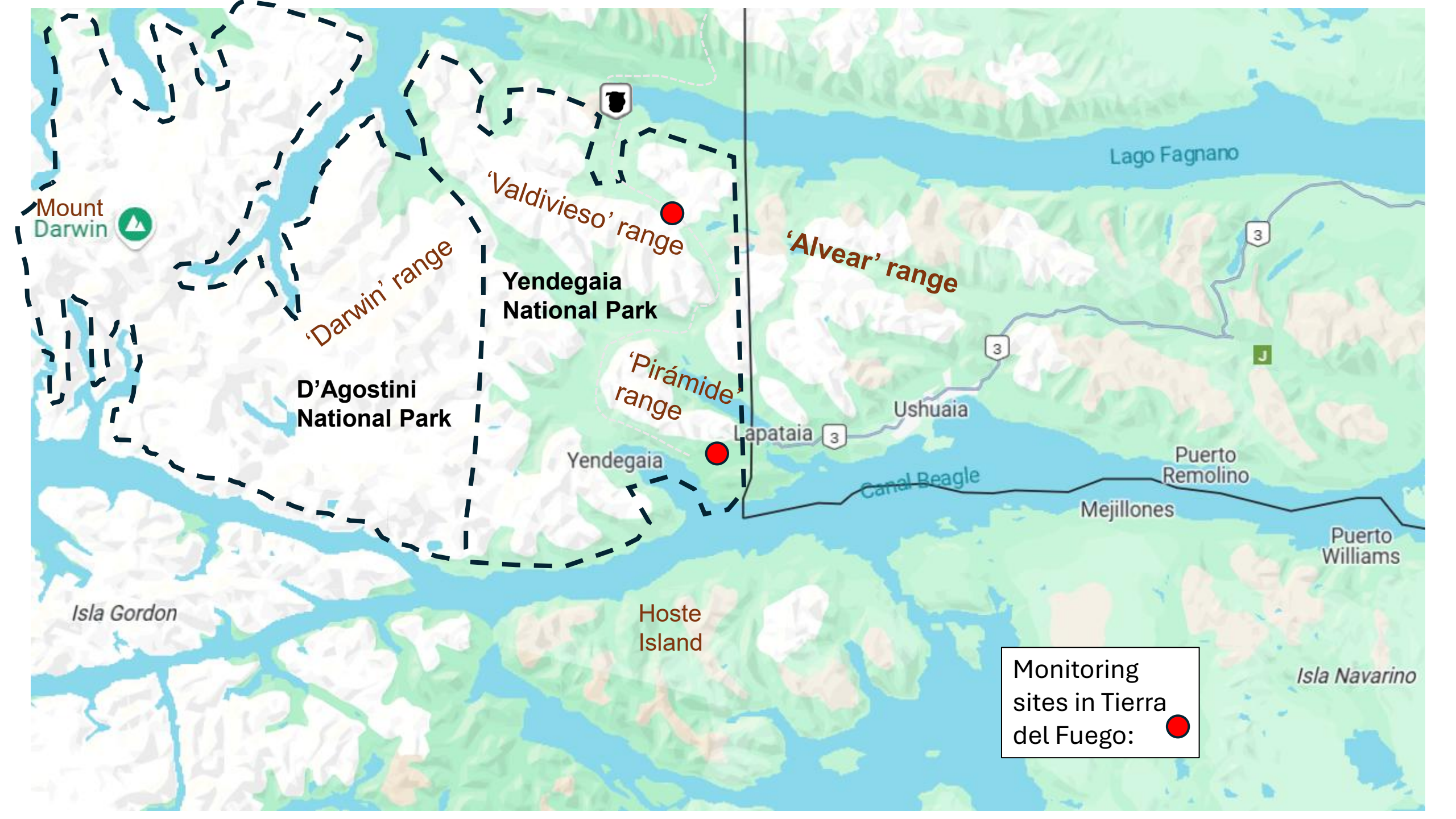
Jacopo Boaga



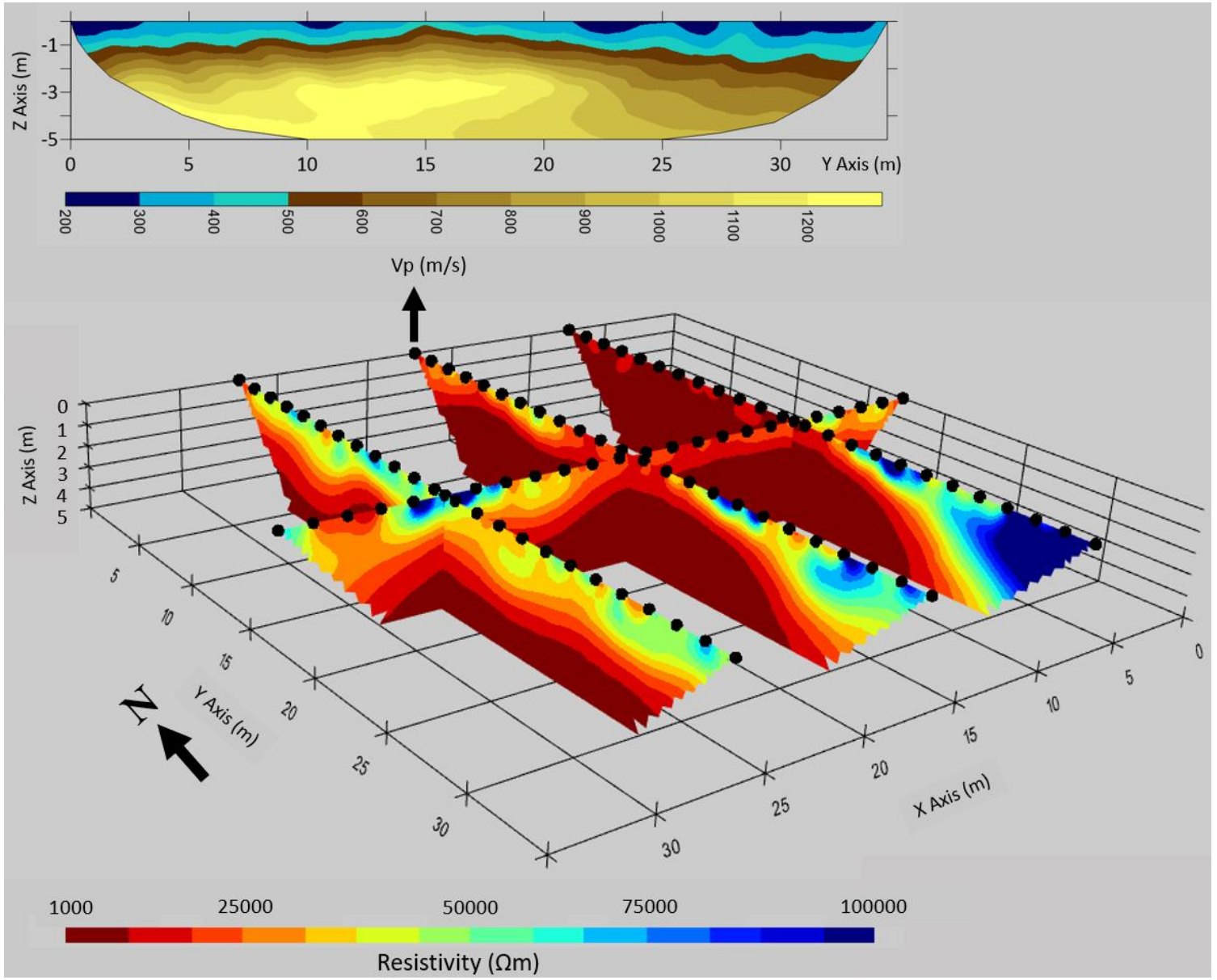

Mount Darwin
'Darwin' range
'Valdivieso' range
Yendegaia National Park
'Pirámide' range
'Alvear' range
D'Agostini National Park
Yendegaia
Lago Fagnano
Ushuaia
Lapataia
Canal Beagle
Puerto Remolino
Mejillones
Puerto Williams
Isla Gordon
Hoste Island
Isla Navarino
Monitoring sites in Tierra del Fuego:

Tierra del Fuego island, 54°S >800 m ASL.

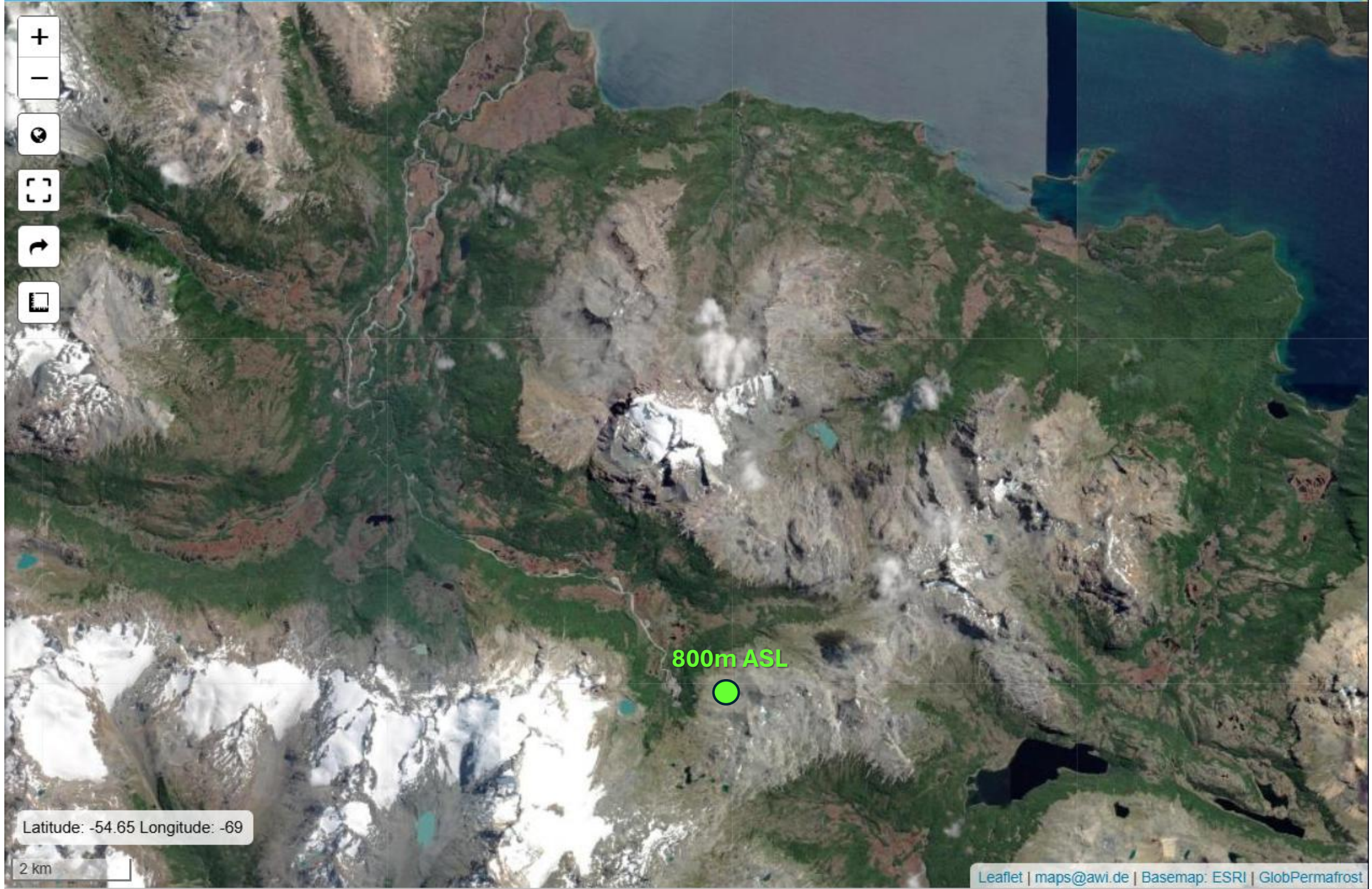
Clear indications of periglacial processes.

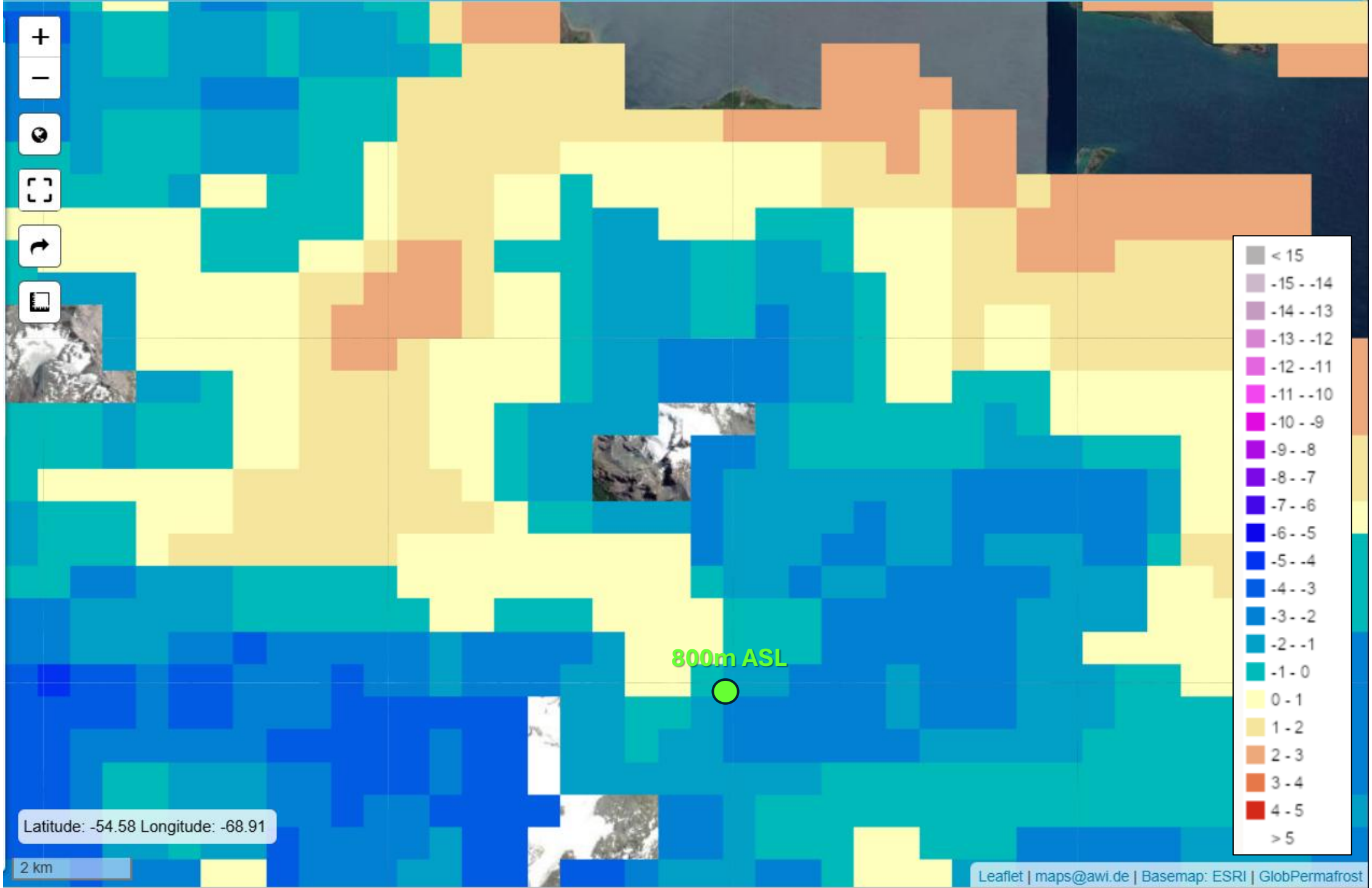
ERT and SR

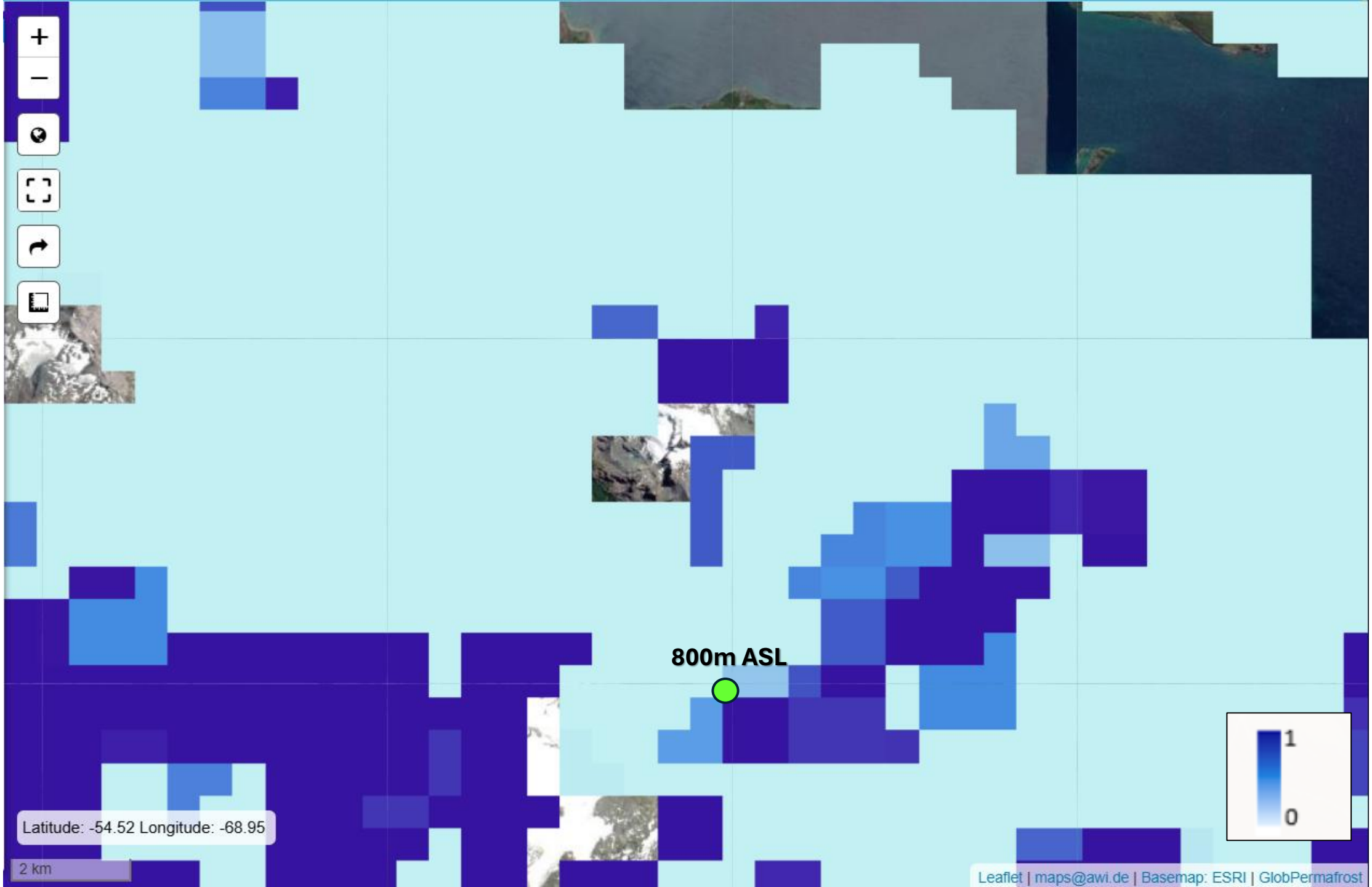
- Shallow, high resistivity bodies.
- Compatible with frozen sediments.

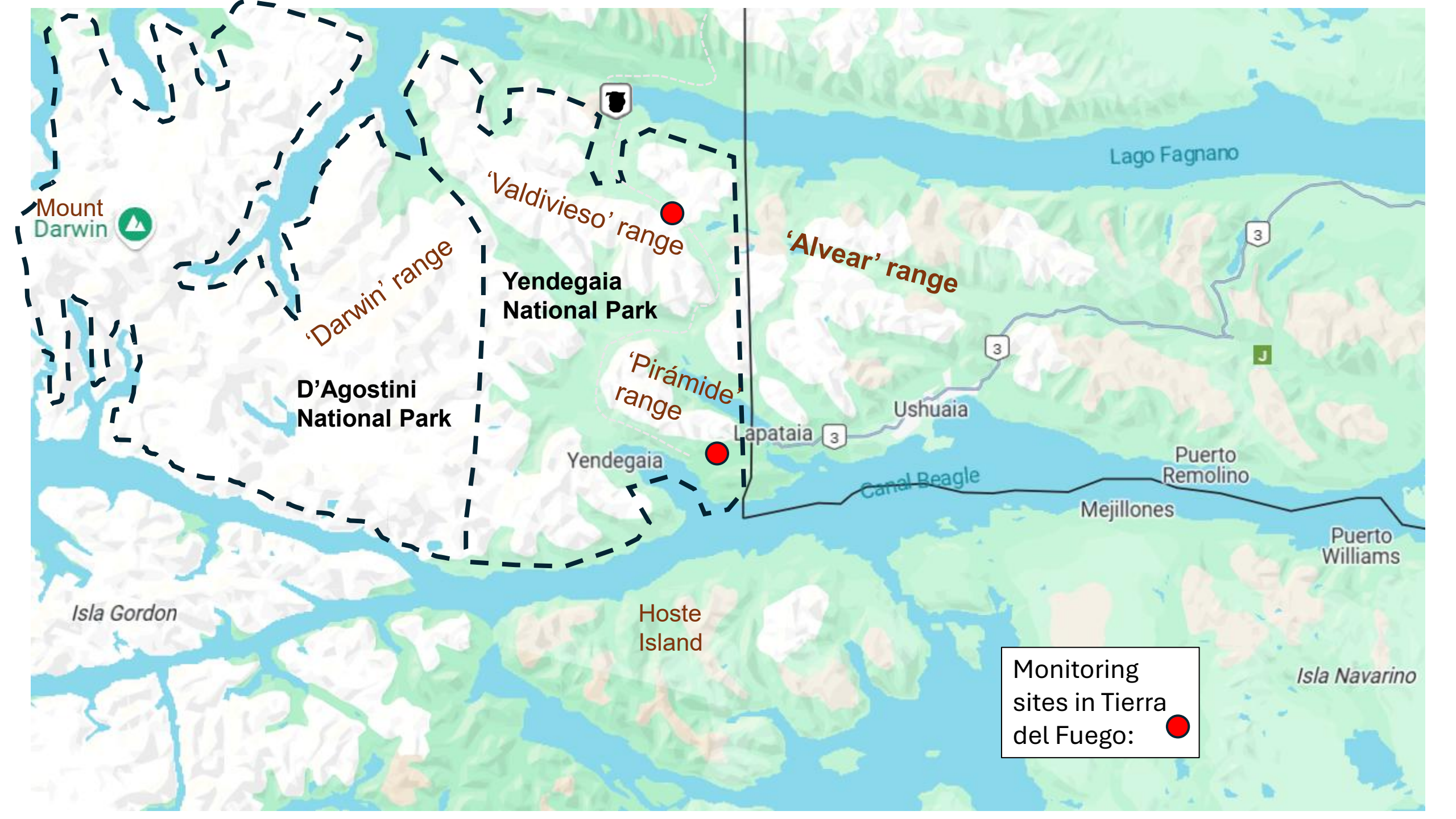


Work along with U. of Padova:
Mirko Pavoni
Alberto Carrera
Jacopo Boaga


800m ASL
Latitude: -54.65 Longitude: -69
2 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


800m ASL
< 15
-15 - -14
-14 - -13
-13 - -12
-12 - -11
-11 - -10
-10 - -9
-9 - -8
-8 - -7
-7 - -6
-6 - -5
-5 - -4
-4 - -3
-3 - -2
-2 - -1
-1 - 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Latitude: -54.58 Longitude: -68.91
2 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


800m ASL
1
0
Latitude: -54.52 Longitude: -68.95
2 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost

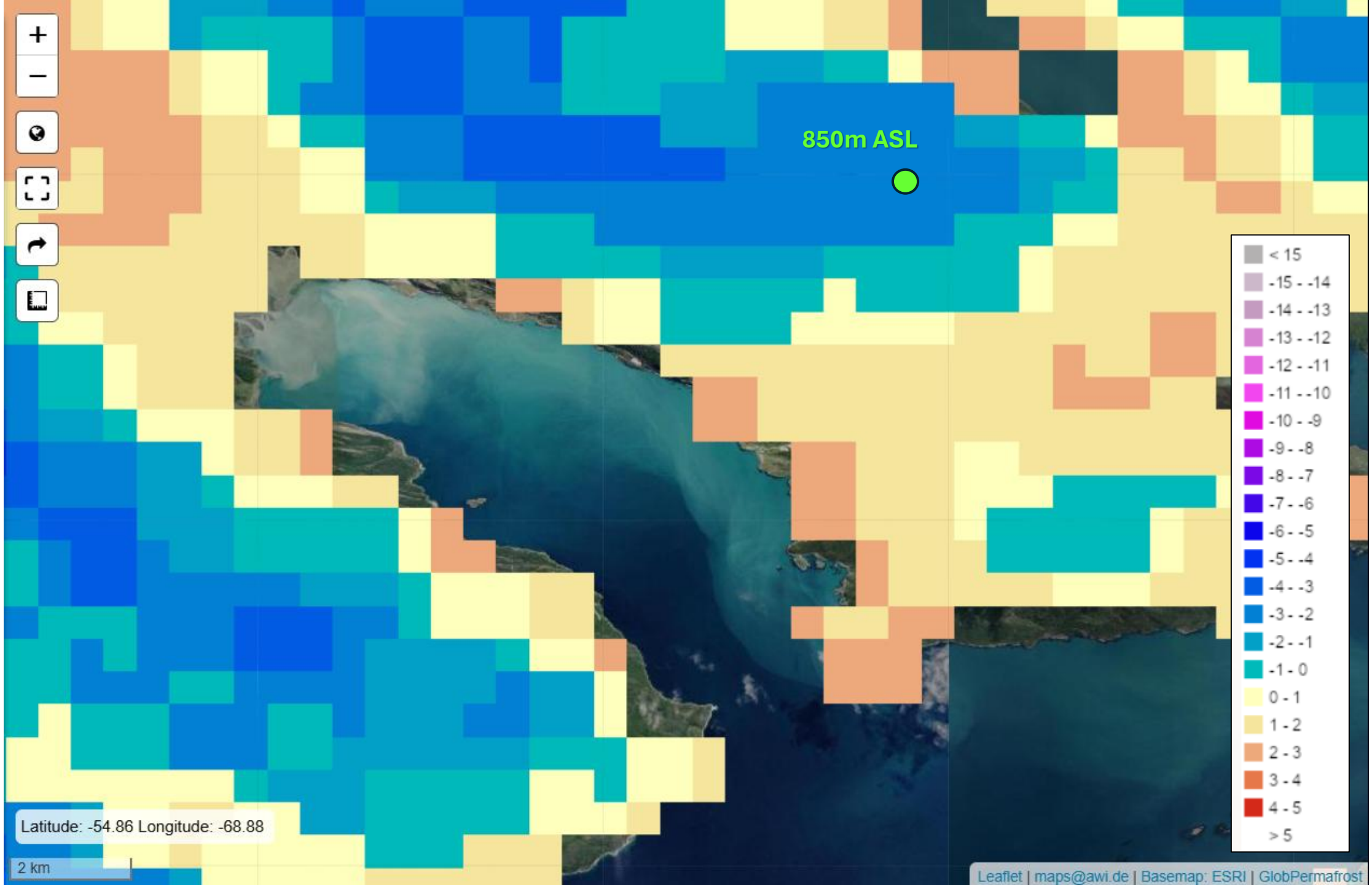

Mount Darwin
'Darwin' range
'Valdivieso' range
Yendegaia National Park
'Pirámide' range
'Alvear' range
D'Agostini National Park
Yendegaia
Lago Fagnano
Ushuaia
Lapataia
Canal Beagle
Puerto Remolino
Mejillones
Puerto Williams
Isla Gordon
Hoste Island
Isla Navarino
Monitoring sites in Tierra del Fuego:

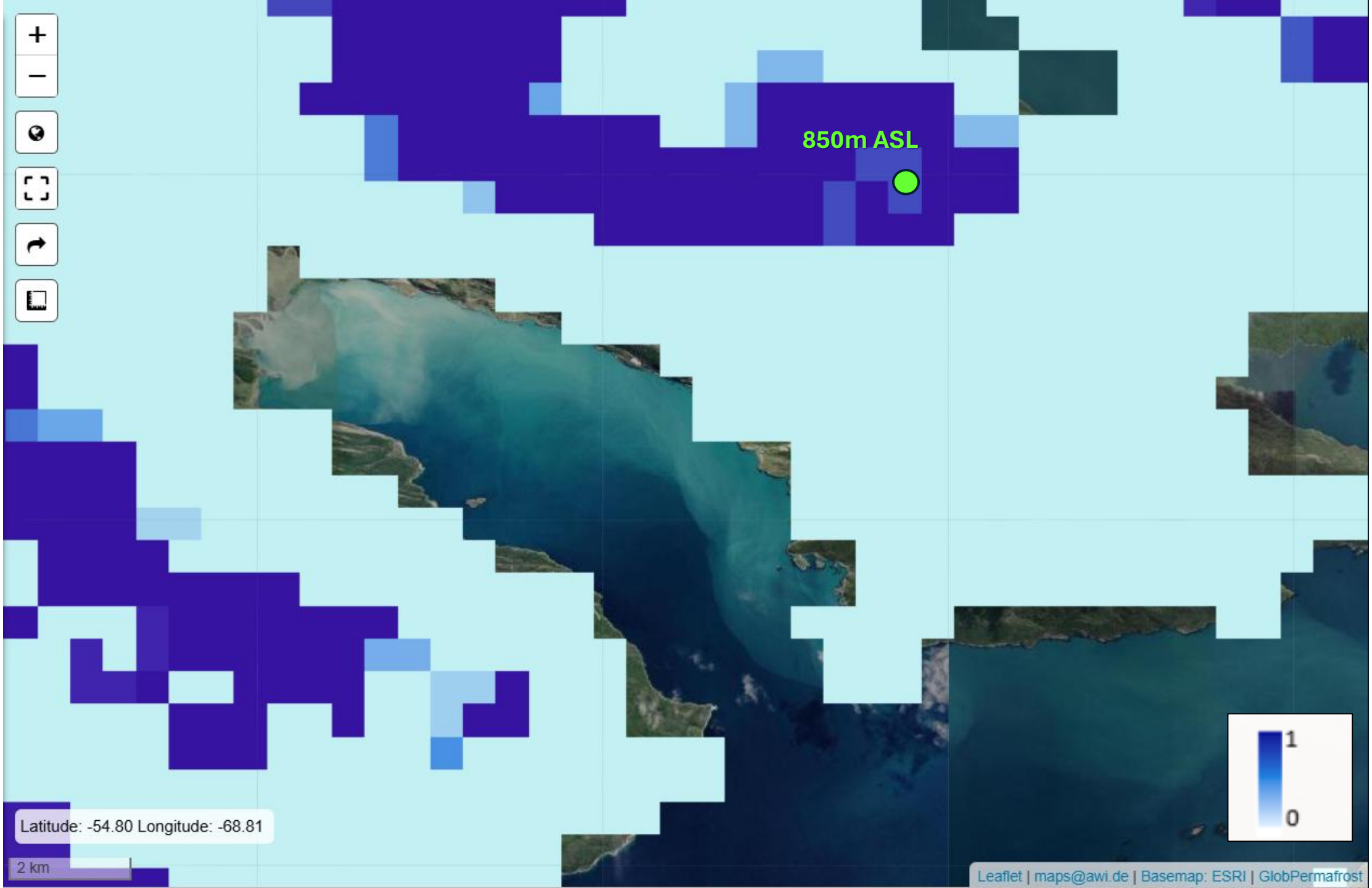
Cóndor mountain: post-glacial cirque

Cóndor in 1945.

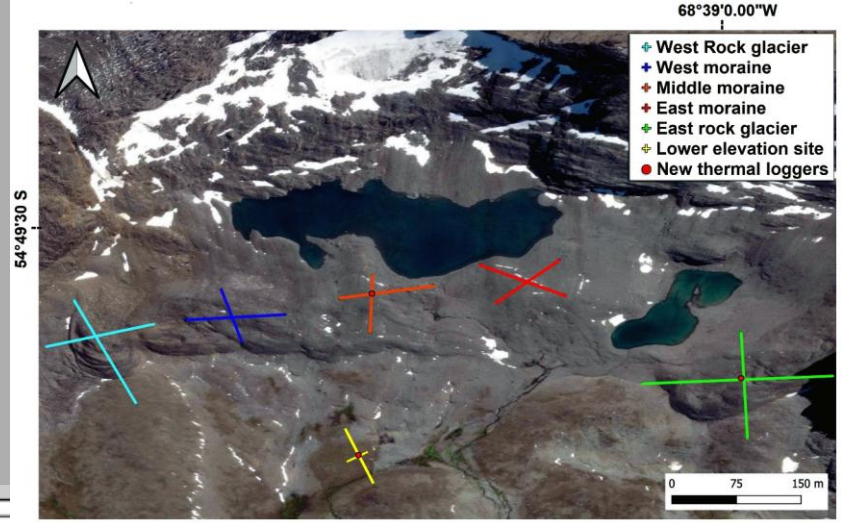
AI ‘reimagination’ from Trimetrogon image

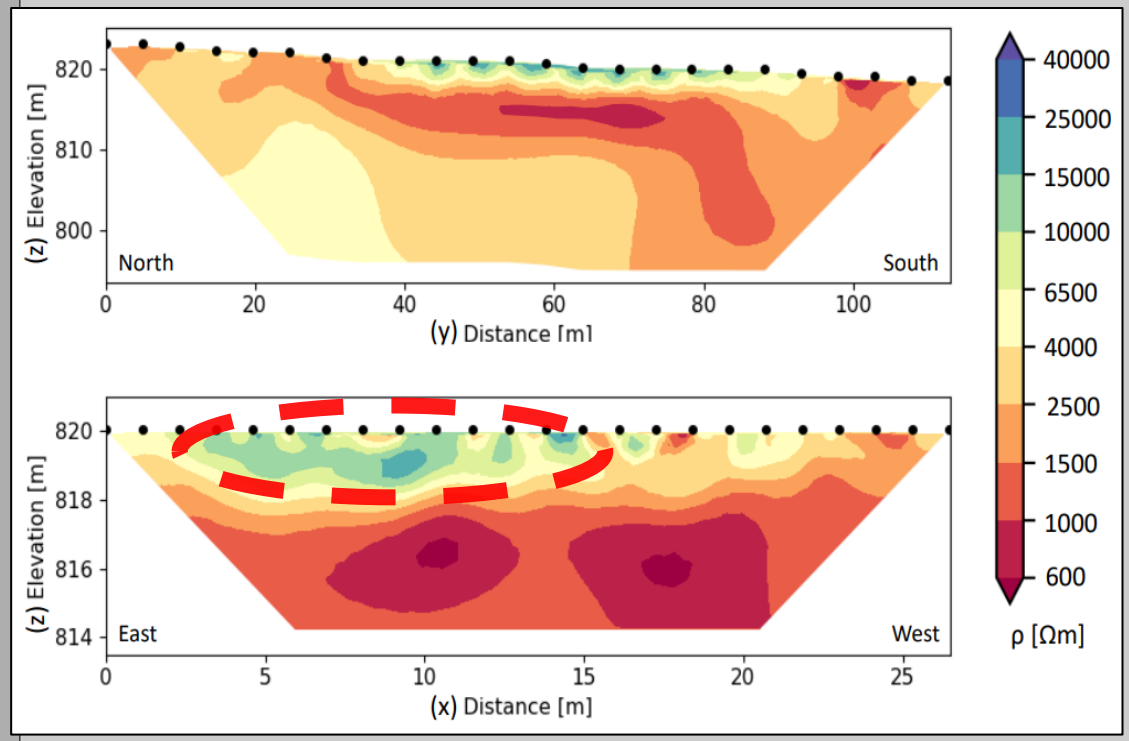

850m ASL
Latitude: -54.90 Longitude: -68.88
2 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost

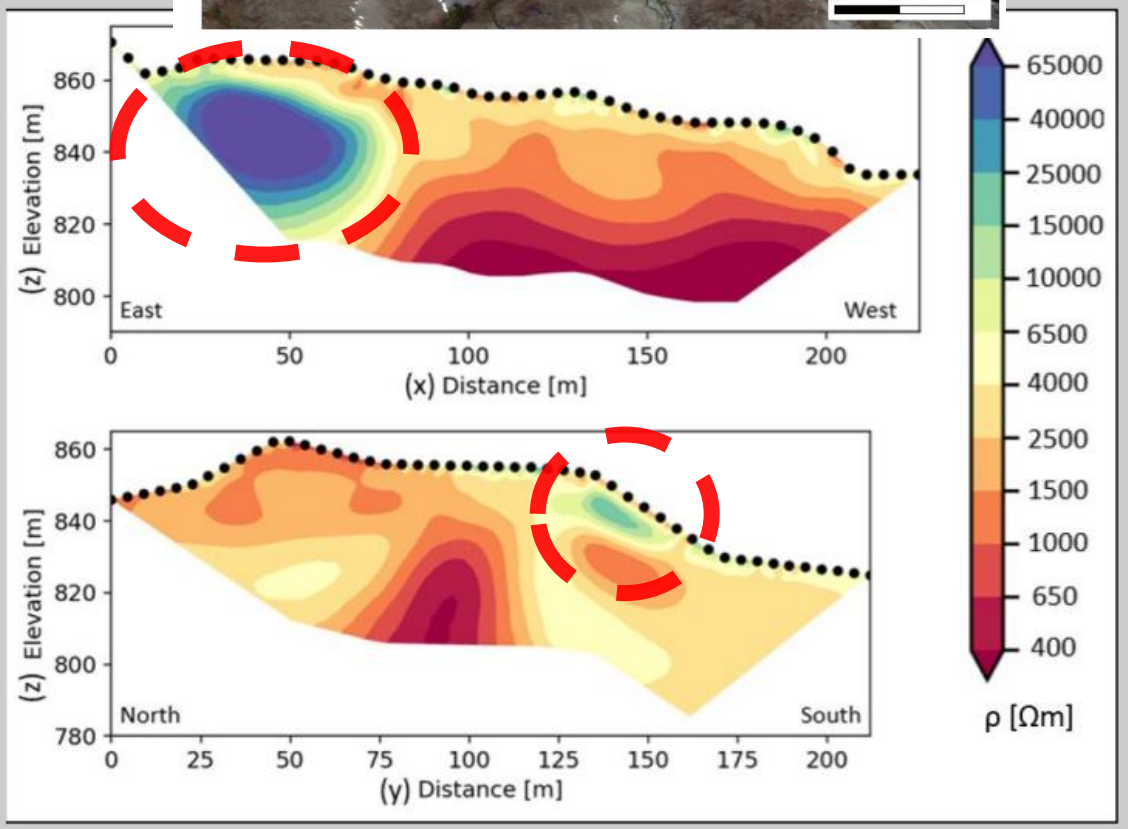

850m ASL
< 15
-15 - -14
-14 - -13
-13 - -12
-12 - -11
-11 - -10
-10 - -9
-9 - -8
-8 - -7
-7 - -6
-6 - -5
-5 - -4
-4 - -3
-3 - -2
-2 - -1
-1 - 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Latitude: -54.86 Longitude: -68.88
2 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost


850m ASL
1
0
Latitude: -54.80 Longitude: -68.81
2 km
Leaflet | maps@awi.de | Basemap: ESRI | GlobPermafrost

Subsurface evidence: ***rock glaciers, moraines and sediment slopes.***







Credit: Mirko Pavoni & Jacopo Boaga, University of Padova.

Comment & outlook.

Does the MAGT deliver a good output compared to local measurements?

Yes, but at moderate elevations. Added effect of radiation and extreme aridity can change the estimation.

In very windy locations, like mountain passes, probability may underestimate cold intensity.

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- **27° dry tundra:** Overestimation of T°, good P(permafrost) prediction.
- **33°S dry tundra:** Overestimation of T°, *worse* P(permafrost).
- **51°S wet tundra:** good P(permafrost) prediction.
- **54°S wet tundra:** good P(permafrost) prediction.

Thanks.

spruiz@uc.cl

www.permachile.com