Rock Glacier Surface Change Detection Based on UAV- and Tristereo Pléiades Data (Agua Negra, Argentina)

Melanie Stammler[1], Rainer Bell[1], Xavier Bodin[2], Jan Blöthe[3], and Lothar Schrott[1]

[1]Department of Geography, Bonn University, Bonn, Germany (stammler@uni-bonn.de), [2]Université Savoie Mont-Blanc, CNRS, EDYTEM, Chambéry, France, [3]Institute of Environmental Social Sciences and Geography, University of Freiburg, Freiburg, Germany

Motivation

- Permafrost thaw and degradation contribute to river runoff in the semi-arid Andes of Argentina; essential for water usage.
- Periglacial ice in e.g. rock glaciers, block- and talus slopes (e.g. Halla et al. 2021) gains in relevance as glacial storages are diminishing (Masiokas et al. 2020, Arenson et al. 2022).
- Thawing/freezing processes and/or permafrost degradation often cause surface changes: increased process-understanding on vertical surface change magnitude and pattern is necessary.

Objectives

- Vertical surface change quantification by UAV-DEM of Difference (DoD) of talus-derived Dos Lenguas and a rock glacier in the Agua Negra glacial forefield.
- Creation of Pléiades-DoD and comparison to UAV-based DoD.
- **Analysis of data source combination (UAV and Pléiades) for investigating surface change signals over larger spatial areas**, e.g. periglacial-glacial system (de)coupling.

Methods

- Repeated Phantom 4 RTK + tristereo panchromatic Pléiades, see tab. 1.
- Structure from motion (SfM) for DEMs, DEMs of Difference (DoDs), fig. 2-5.
- DGPS for Ground Control Points (GCPs) and Check Points (CPs), see tab. 1-3.

Workflow

- Sparse cloud of all imagery (TimeSIFT, co-alignment; Cook a. Dietze 2019, De Haas et al. 2021)
- Separation by date, georeferencing
- Gradual selection; reprojection accuracy and reconstruction uncertainty (Sledz a. Ewertowski 2022)
- Dense point cloud generation

- Merging of tiled imagery (OSGeo4W)
- Sparse cloud per acquisition; tie point limit 10x UAV process and georeferencing
- Gradual selection; reconstruction uncertainty twice UAV process
- Dense point cloud generation

Results

Almost no vertical surface change between '22 and '23 on rock glacier in the Agua Negra glacial forefield (fig. 2).

Net negative vertical surface change balance on talus-derived Dos Lenguas rock glacier (fig. 3).

Pléiades data shows promising first results and needs further co-registration (fig. 4).

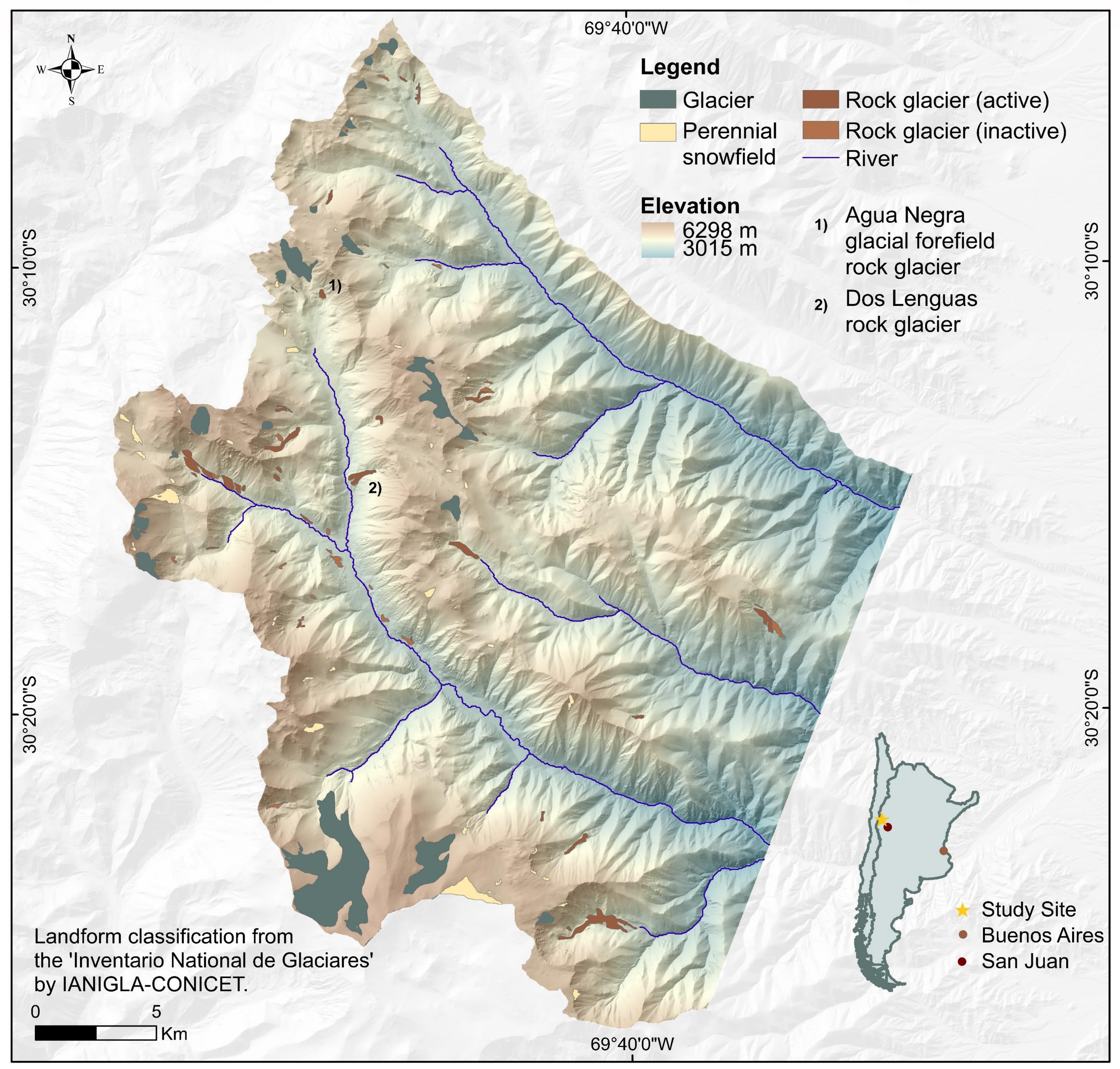

Figure 1: Distribution of (peri)glacial landforms in the high-alpine part of the study area. Landform classification based on the Inventario Nacional de Glaciares (IANIGLA-CONICET). Hillshade based on TanDEM X. Scan QR code for imagery from the field.

Table 1: Acquisition parameters for UAV flights on Dos Lenguas (DL) and Agua Negra glacial forefield (ANF), as well as for the Pléiades data acquisition for 2022 and 2023.

	DL		ANF	
UAV model	Phantom 4 RTK			
Mission type	TA*		2D	TA*
Date	**24.3.22**	**12.2.23**	**15.3.22**	**17.2.23**
Number of images	1509	2160	1682	1625
Flight altitude	40	50		
Overlap (vert. / horiz.)	65/65	70/70	60/60	70/70
Flight speed (m/s)	5		5.5	5
GCPs / CPs	15/5			

* Terrain awareness on TanDEM X (10m resolution)

	Pléiades	
Geometry	Tristereo (panchromatic + multi-spectral)	
Date	**8.2.22 - 22.2.22**	**13.2.23 – 20.2.23**
B/H	0.3-0.5	
Incidence angles (°)*	<20, e.g. 14.24, 10.11, 15.44	
Cloud cover (%)	<5	
GCPs / CPs	14/6	

*Combined incidence angles (roll and pitch)

Acknowledgements

This research is funded by the German Research Foundation (DFG). We are thankful for the Pléiades acquisition support by the Centre National d'Etudes Spatiales (CNES). Further, we want to thank the entire HyPerm team for their support during and outside of fieldwork.

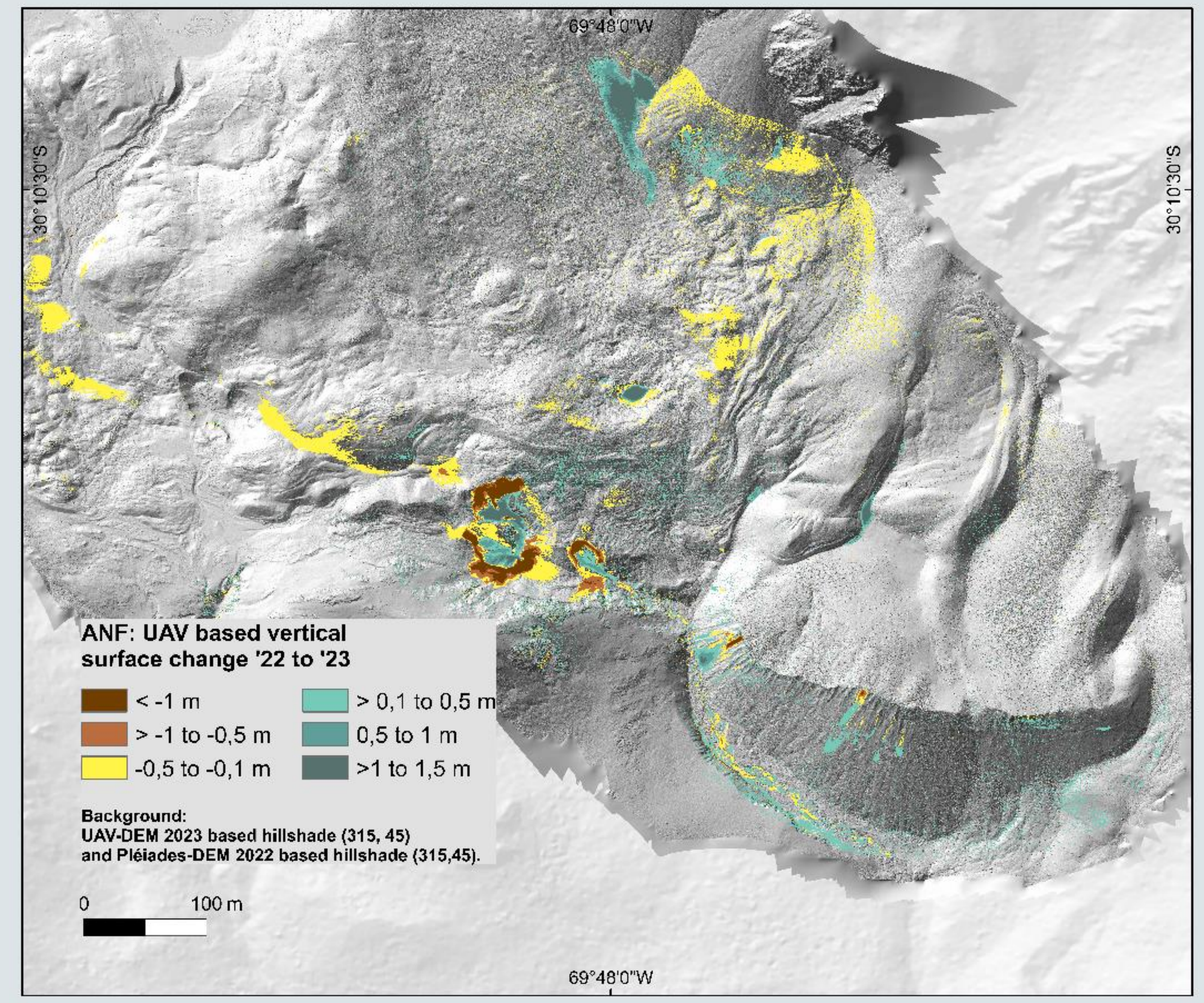

Figure 2: Vertical surface changes in the Agua Negra glacial forefield (ANF) between 2022 and 2023 based on UAV-DoD. Little change on rock glacier accompagnied by strong changes at thermokarst sinkhole (round structure), as well as along the river and due to snow patches.

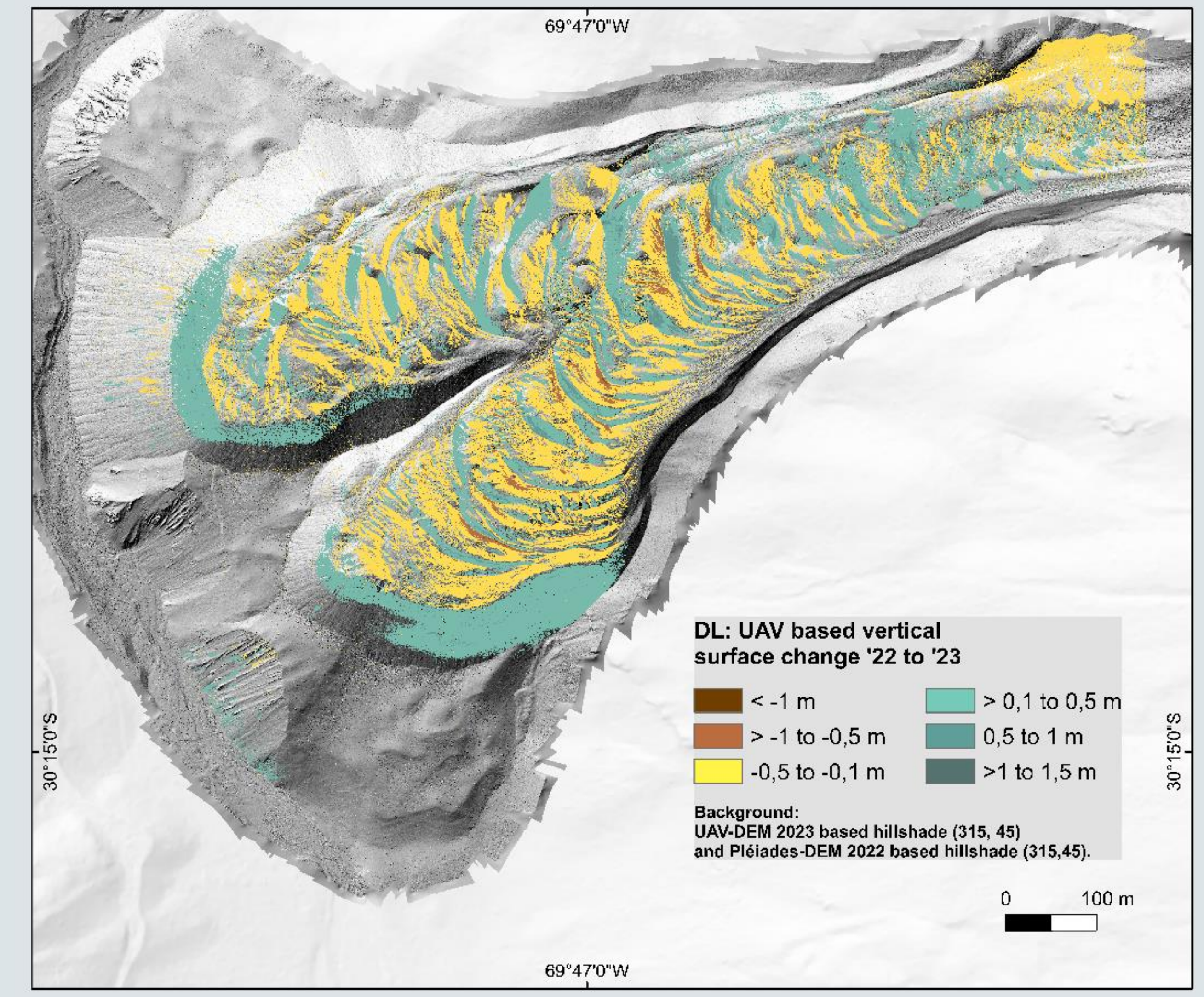

Figure 3: Vertical surface changes on Dos Lenguas (DL) between 2022 and 2023 based on UAV-DoD. Ridge and furrow pattern on the rock glaciers surface strongly visible, alongside gravitational mass movements at the rock glacier front.

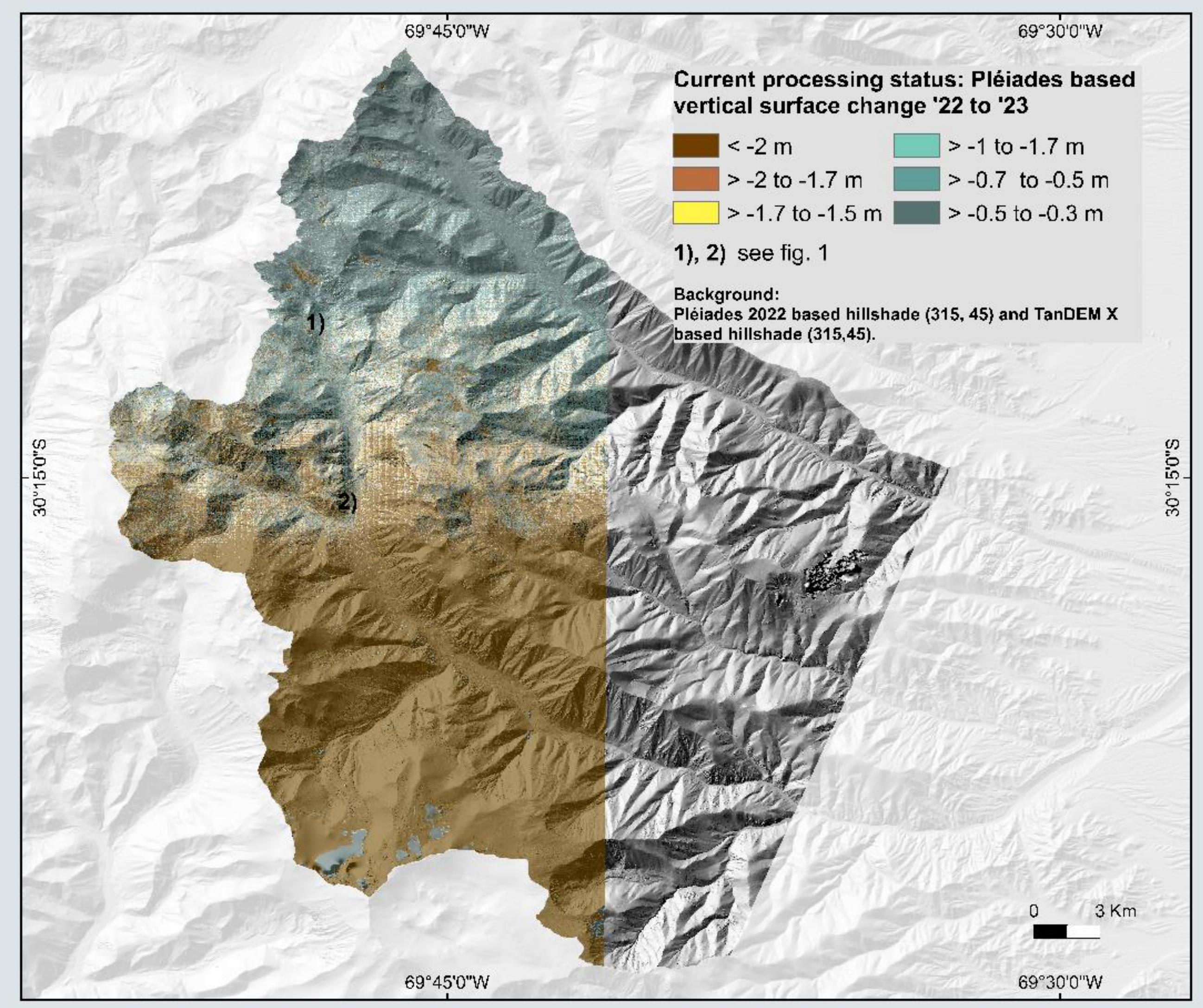

Figure 4: Current processing status of the Pléiades-based calculation of vertical surface changes in the Agua Negra catchment between 2022 and 2023. The DoD is calculated from the georeferenced, tristero, panchromatic Pléiades data. While glacial changes are already visible, the data includes a general tilt. Additional co-registration is needed for an analysis of the periglacial landforms.

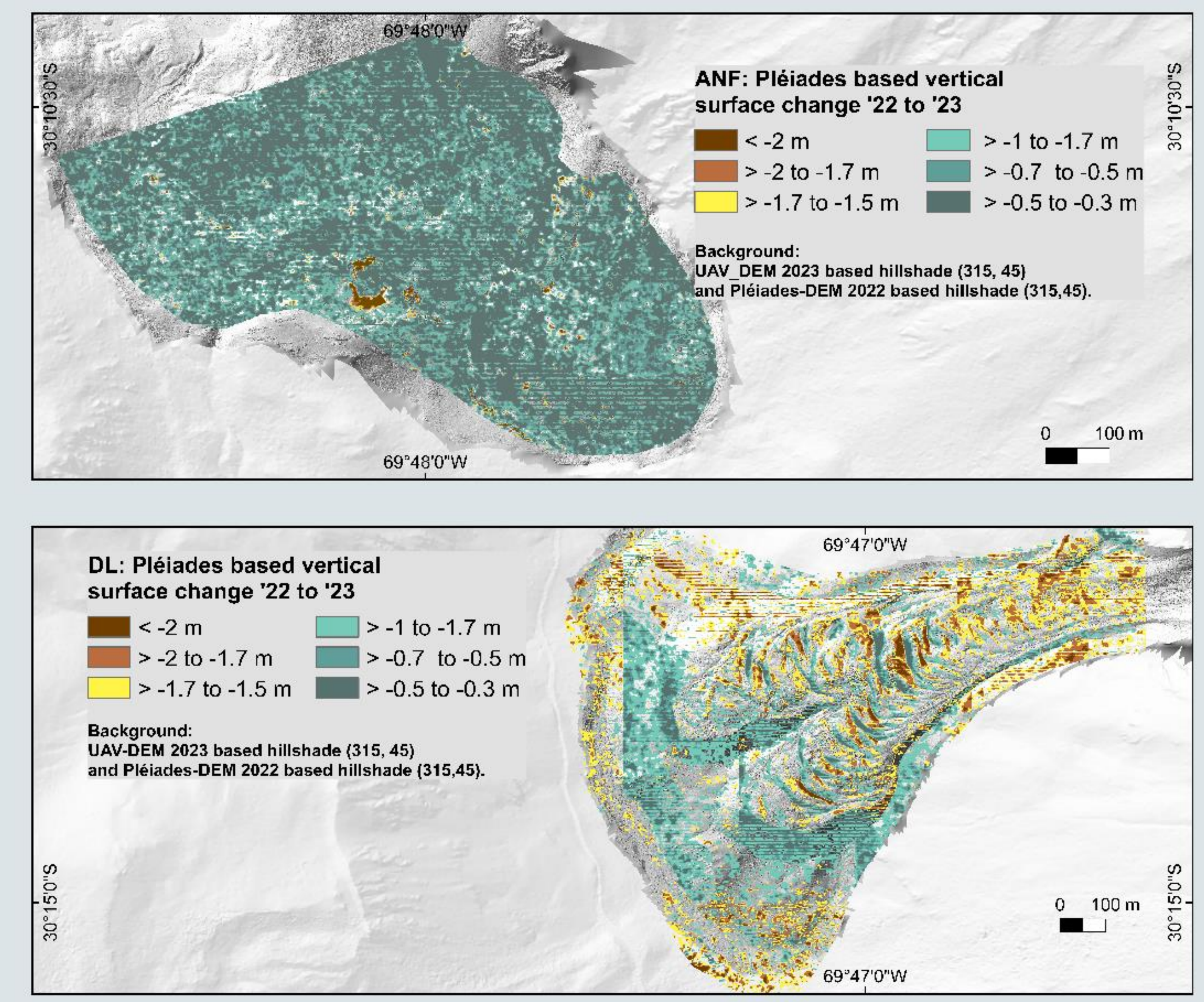

Figure 5: Current processing status showcased at the the locations ANF and DL. The thermokarst sinkhole (upper part, compare fig.2) and furrow and ridges (lower part, compare fig.3) are visible, however, at a shifted range of the vertical surface change (see legend of this figure).

Table 2: Ground control point (GCP) and check point (CP) based errors for Dos Lenguas (DL) and the Agua Negra glacial forefield (ANF) for 2022 and 2023. The maximum resolution of the DEM represents the highest resolution possible given the data and processing.

	DL		ANF	
Optimized* error GCPs (cm/pix)	1.2	1.1	1.0	1.8
Optimized* error CPs (cm/pix)	8.3	6.6	37.0	4.7
Max. resolution DEM (cm/pix)	**3.09**	**2.76**	**4.20**	**3.30**

* Optimization of image alignment including Fourier transform (‚fitting additional corrections')

Table 3: GCP and CP based errors and resolution of the DEM based on panchromatic, tristereo Pléiades data for the years 2022 and 2023. While Pléiades data for the entire catchment has been obtained, we showcase parts of the upper catchment.

	Pléiades	
Optimized* error GCPs (cm/pix)	0.1 *(to be discussed)*	
Optimized* error CPs (cm/pix)	4.0 *(to be discussed)*	
Max. resolution DEM (m/pix)	**1.03**	**1.03**

* Optimization of image alignment including Fourier transform (‚fitting additional corrections')

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Abstract

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Figure 1: North to south view along Agua Negra valley. Picture taken from Agua Negra glacial forefield. Pass road to Chile as well as Majadita glacier (in the back) visible. Own image, March 2022.

Figure 2: Agua Negra river looking south to north along Agua Negra valley. Dos Lenguas rock glacier in focus. Own image, March 2023.

Figure 3: DJI Phantom 4 and controller as used during field campaigns 2022 and 2023. Picture taken on Dos Lenguas looking northwards with Agua Negra glacier in the background. Own image, March 2022.

Figure 4: RTK equipment as used during field campaigns in 2022 and 2023. RTK base located in Agua Negra glacial forefield with southwards view along the valley. Majadita glacier is visible in the back. Own image, February 2022.

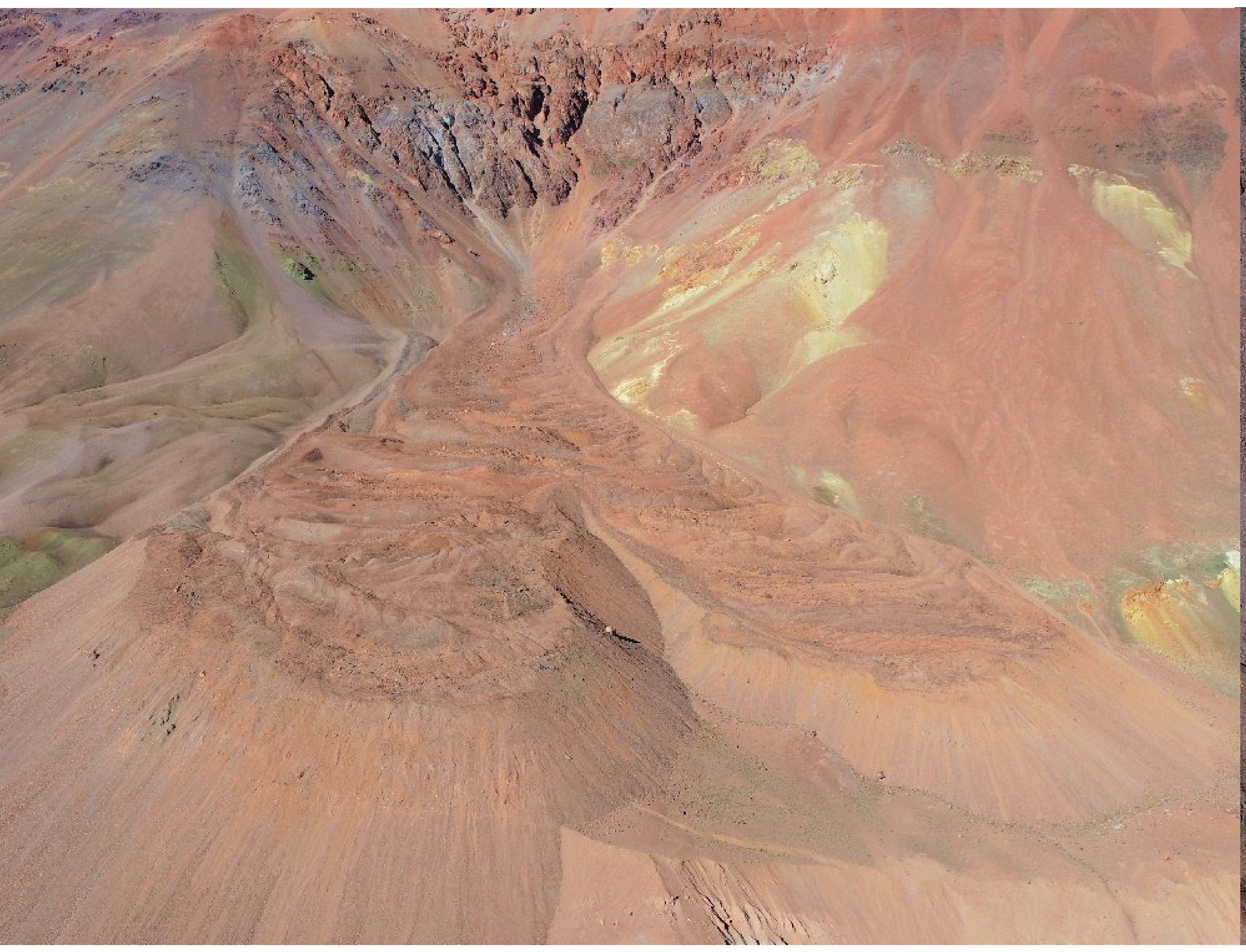

Figure 5: Dos Lenguas rock glacier photographed with DJI Phantom 4. Own image, March 2022.

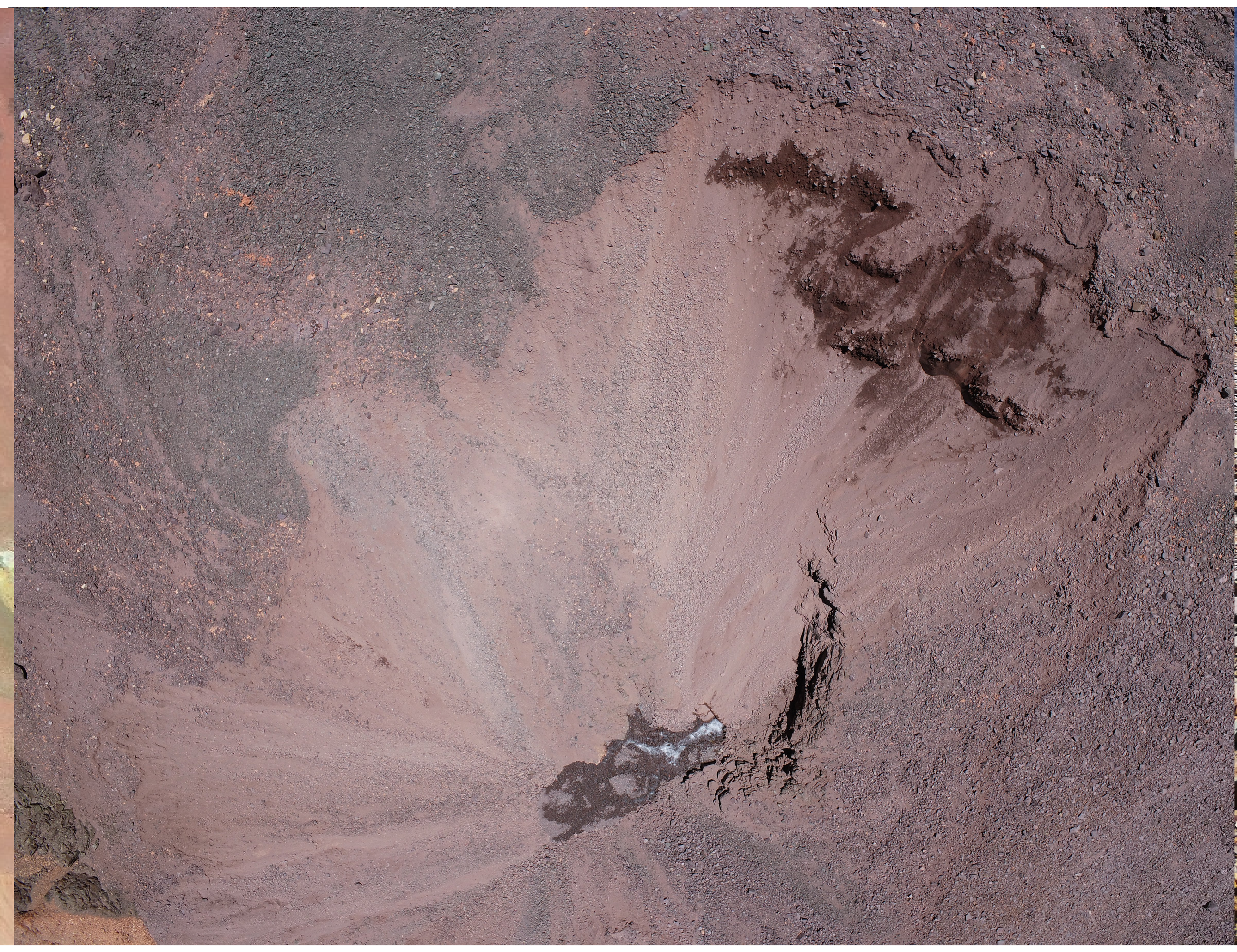

Figure 6: Thermokarst sinkhole loated in the Agua Negra glacial forefield. Predominant subsurface glacial meltwater flow visible above surface at this location. Feature clearly visible in figure 2 on poster (circular shape). Own image, February 2022.

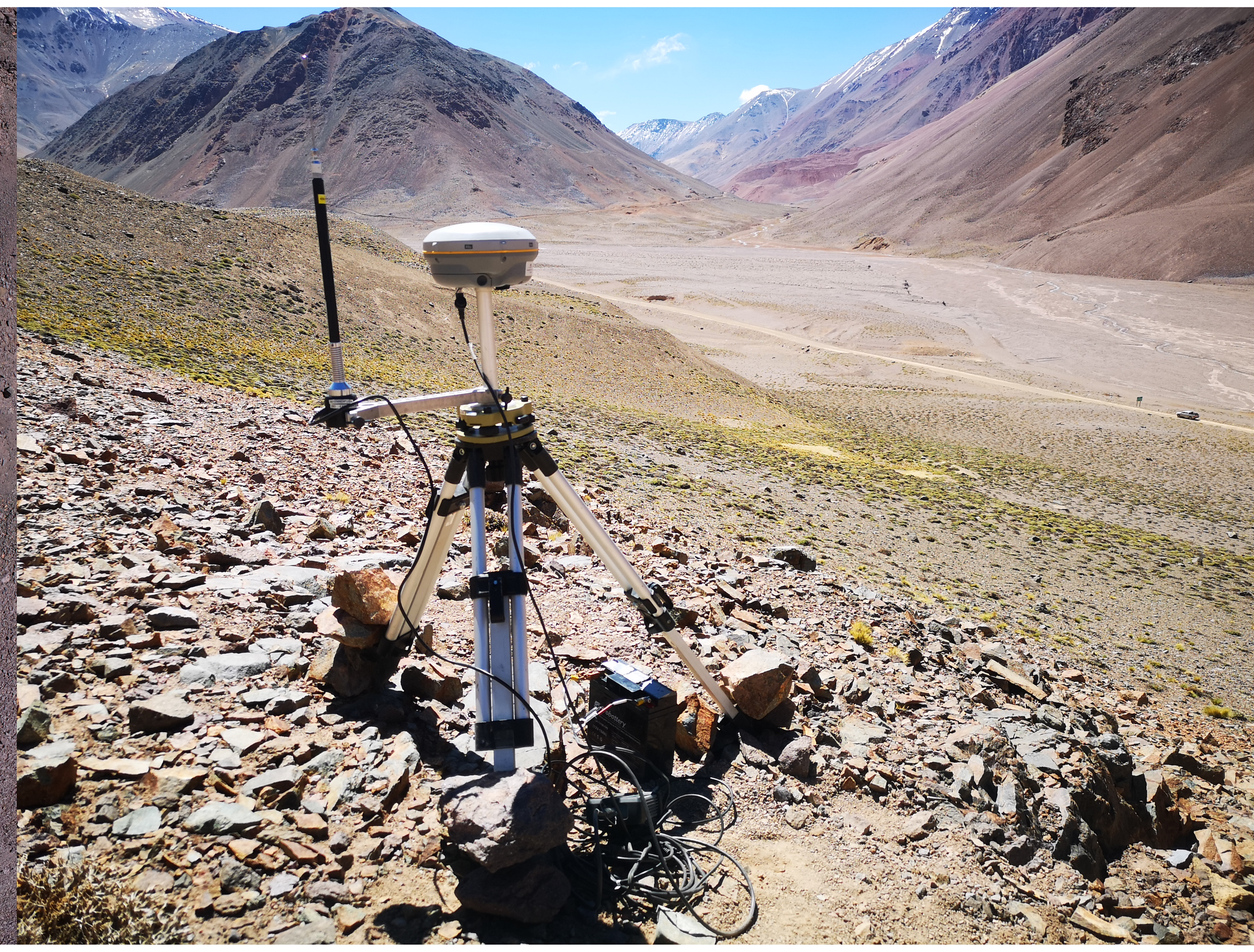

Figure 7: DGPS base as used during field campaigns 2022 and 2023. View towards Dos Lenguas (visible in the back). Own image, March 2022.

Figure 8: Southwards view along Agua Negra valley with protalus ramparts in back. Photo of geophysical measurement chosen as indicator of slope steepness. Own image, March 2023.

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Abstract

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