Studying ice dynamics of the Morteratsch glacier complex (Switzerland) with UAV acquired photography and structure from motion (SfM) algorithms

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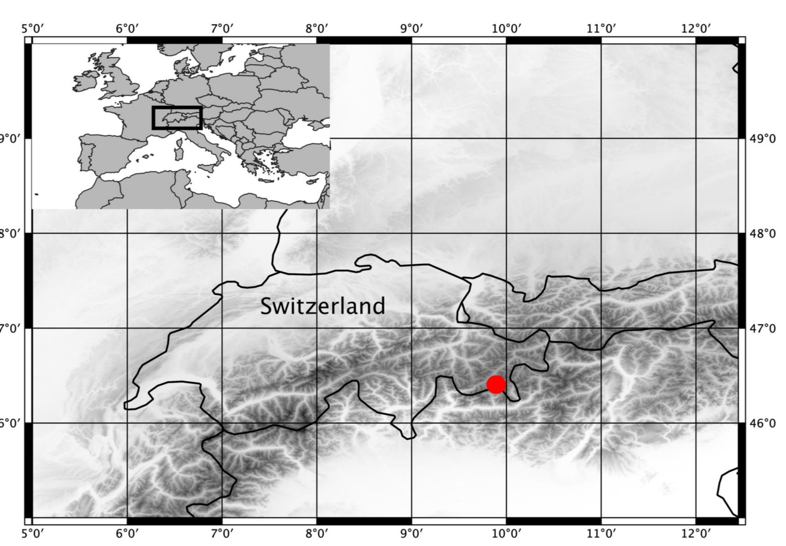
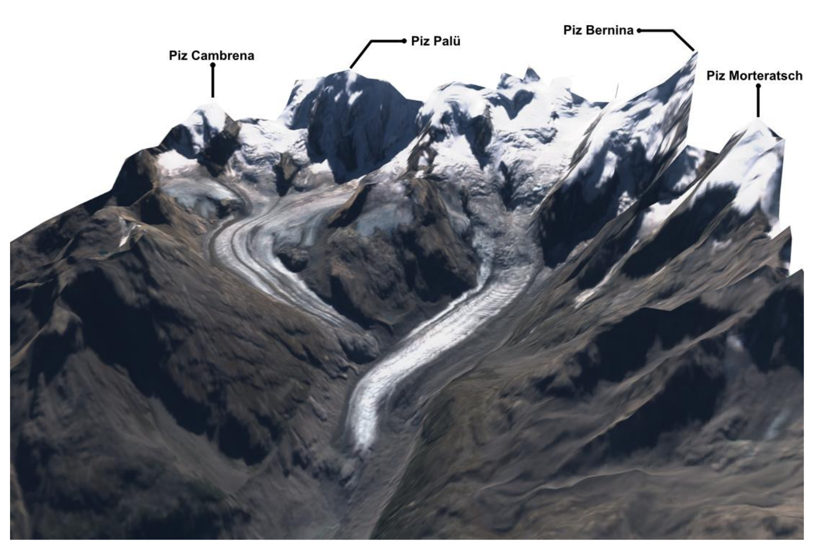
Introduction

Glacier variations are key indicators of climate change. Monitoring of glacier activity is mostly based on ground-based measurements and on satellite observations. However, these measurements lack the spatial and/or temporal resolution that is required for accurate interpretations. Therefore, Unmanned Aerial Vehicles (UAVs) are increasingly used to study glacier dynamics, bridging the gap between direct field observations and satellite images. In this research, we applied UAV acquired photography and SfM algorithms to study the glacier dynamics of the Morteratsch-Pers glacier complex (Switzerland)

Location

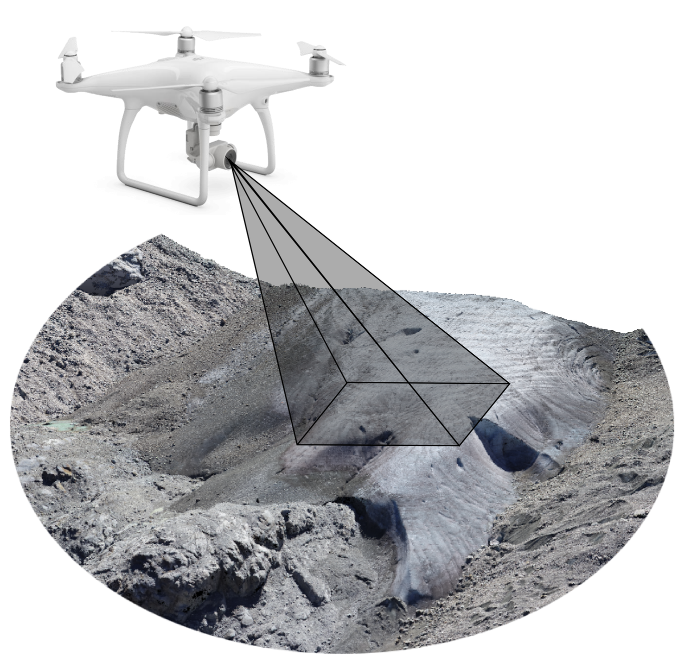
- Morteratsch and Pers glacier complex
- Bernina - Graubünden – Switzerland
- Area > 15 km^2
- Ice volume > 1 km^3
- Retreat of almost 3 km since 1878
- > 200 mass balance measurements since 2001

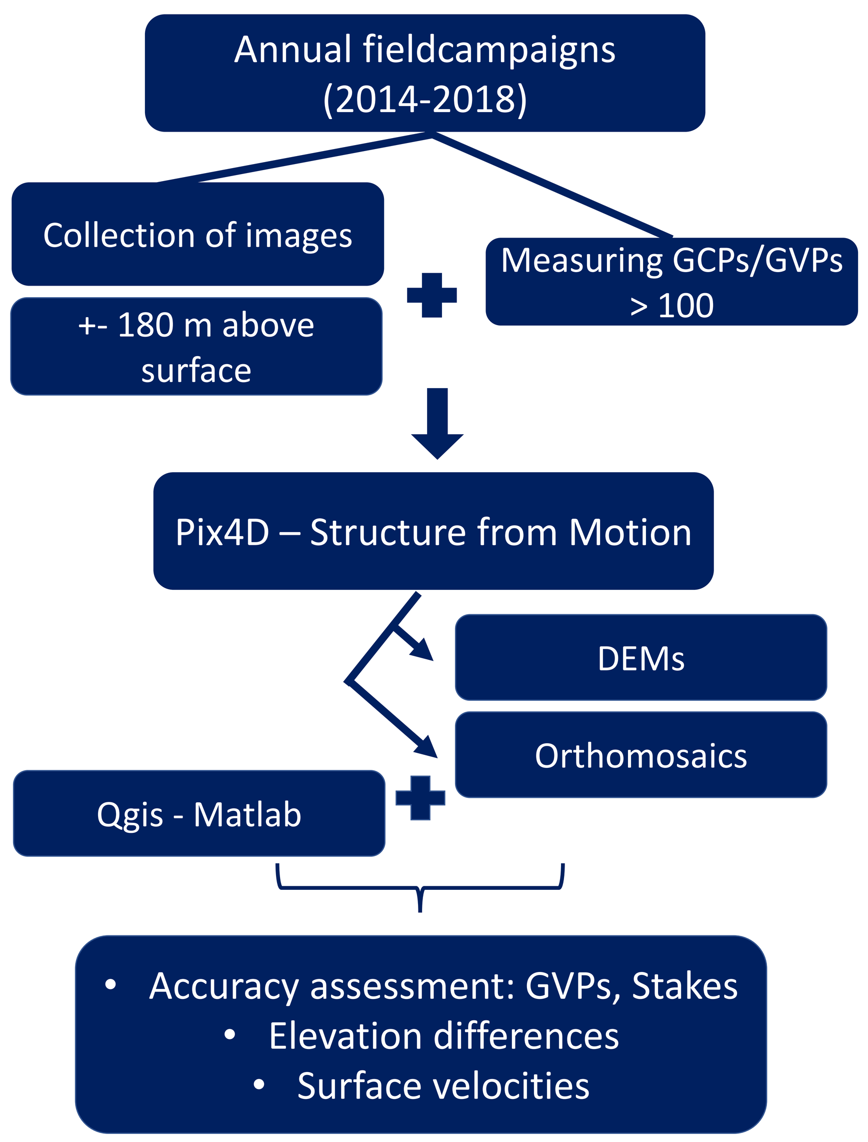




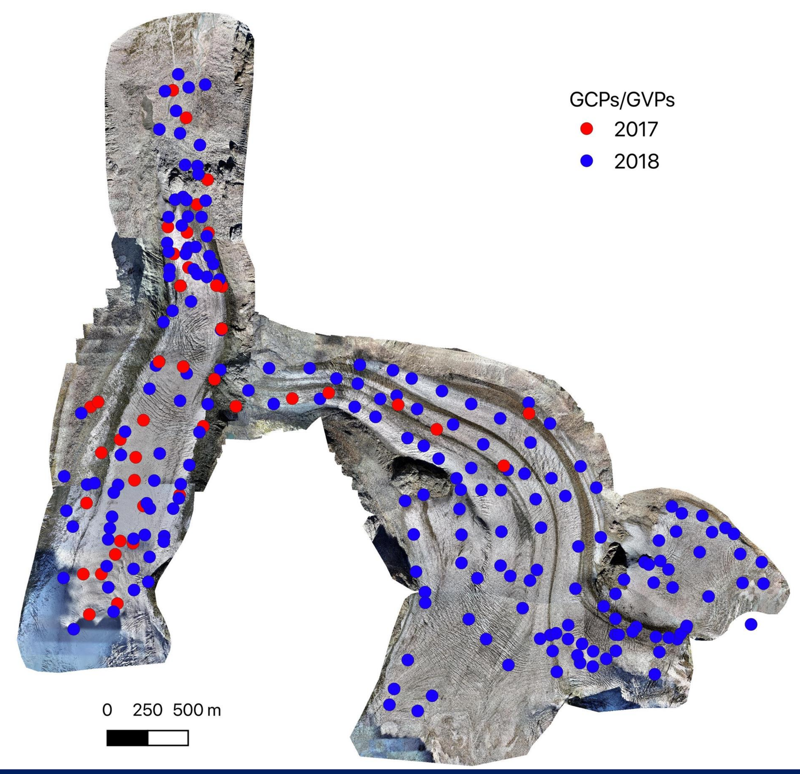
Methodology

- Phantom 4 Pro
- Ground Control Points (GCPs)
- Ground Validation Points (GVPs)
- Accuracy of +- 15 cm
- Pix4D / DJI GS Pro
- Qgis
- Matlab





Accuracy



- Early snow prevented a homogeneous and dense spreading of GCPs in 2017 (especially on the Pers glacier)
- Perfect conditions allowed a complete spreading of GCPs in 2018
- Accuracy of the GCP positions between 10-20 cm
- Elevation differences on stable terrain very close to zero
- 6 GVPs in 2017, 52 GVPs in 2018

=> Final DEMs have an accuracy of 10-20 cm

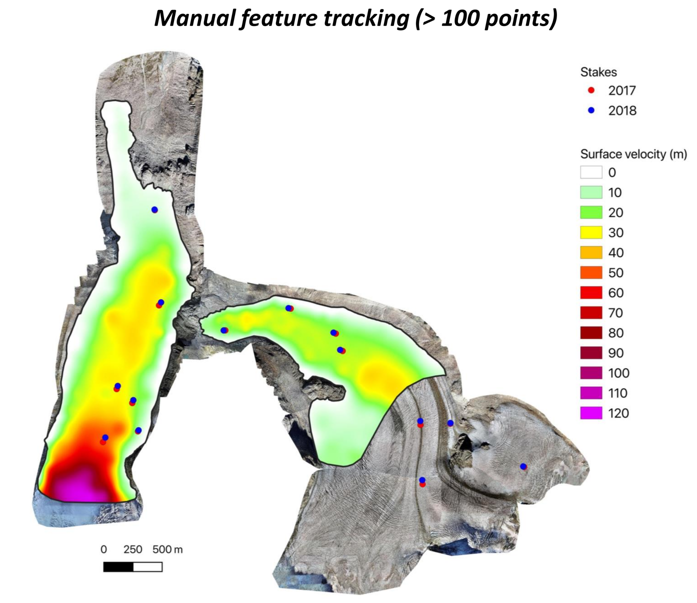
	GCPs (cm)				GVPs (cm)			
	Nr.	X	Y	Z	Nr.	X	Y	Z
'17	41	1.3	1.8	2.3	6	6.9	5.7	4.6
'18	107	2.1	2.4	3.7	71	2.4	3.7	5.2

Results

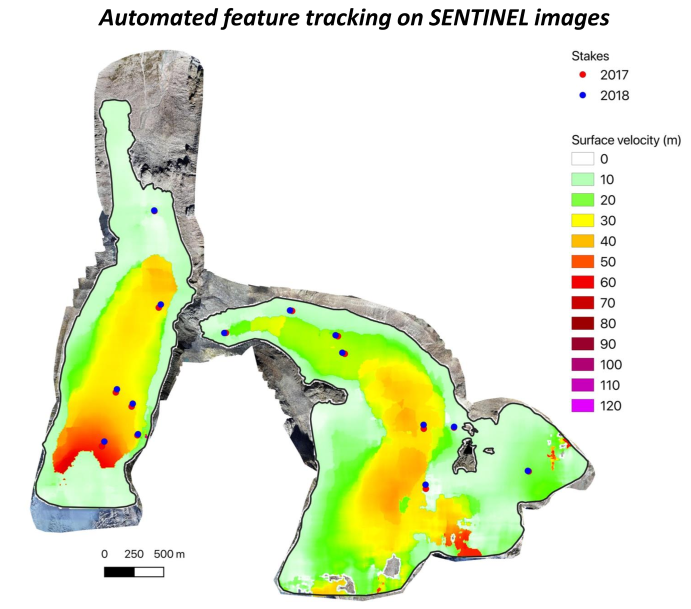
1. Surface velocity 2017-2018

- Ice velocity determined with automated/manual feature tracking (Imgraft)
- Very large shear at the valley walls reduces the ice velocity rapidly to zero
- Ogives move > 100 m/y and deform, the Morteratsch front is almost stagnant

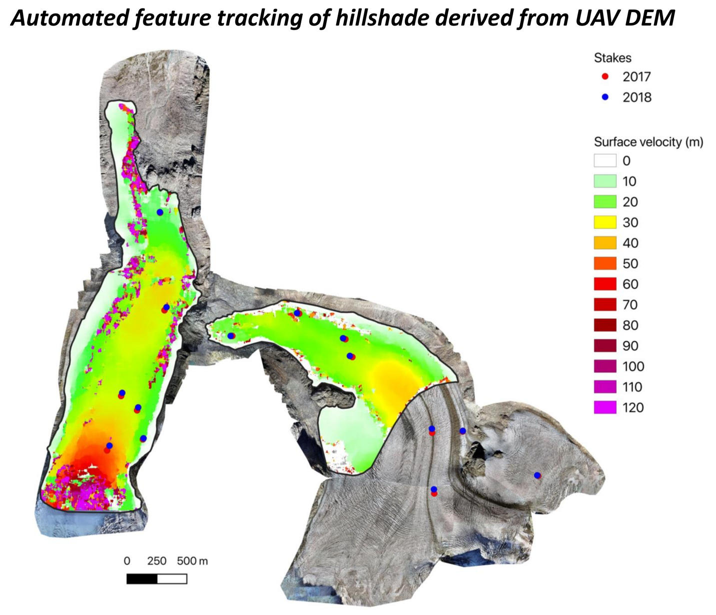
Manual feature tracking (> 100 points)

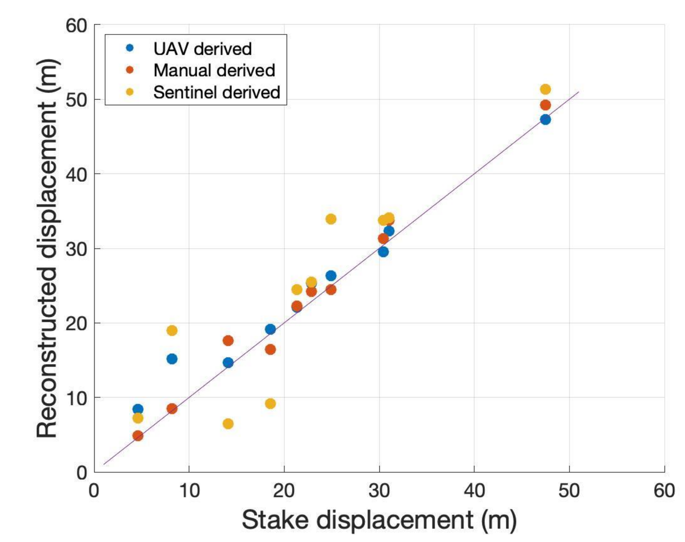


Automated feature tracking on SENTINEL images



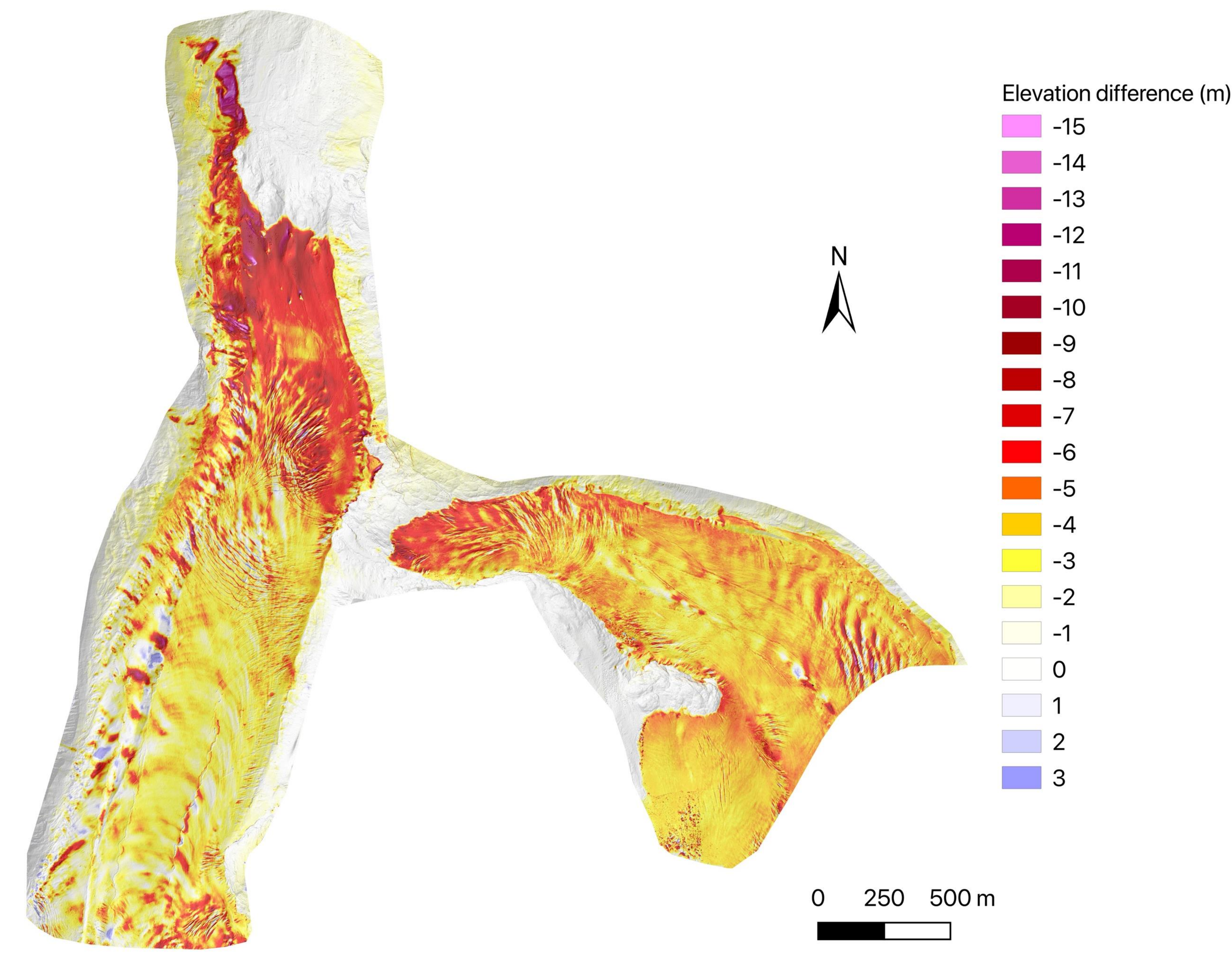
Automated feature tracking of hillshade derived from UAV DEM





2. Elevation difference 2017-2018

- Large spatial differences
- Elevation differences depend on elevation, aspect, debris cover, shadowing, movement, terrain characteristics etc.



Conclusion

- Confirmation that UAVs have a lot of potential in studying glaciers
- GCPs are necessary but not enough
- Glacier is thinning very rapidly and slowing down,
- Surface velocities are very heterogeneous and reach up to 120 meters/year

Outlook: Annual fieldwork will be performed, increasingly with a RTK drone
It is the goal to cover (parts of the) the accumulation area as well

References and contact

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