The Potential of Low-Cost UAVs and Open-Source Photogrammetry Software for High-Resolution Monitoring of Alpine Glaciers: A Case Study from the Kanderfirn (Swiss Alps)

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Institute of Geography
University of Bern

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Introduction

ODM

Research Goals

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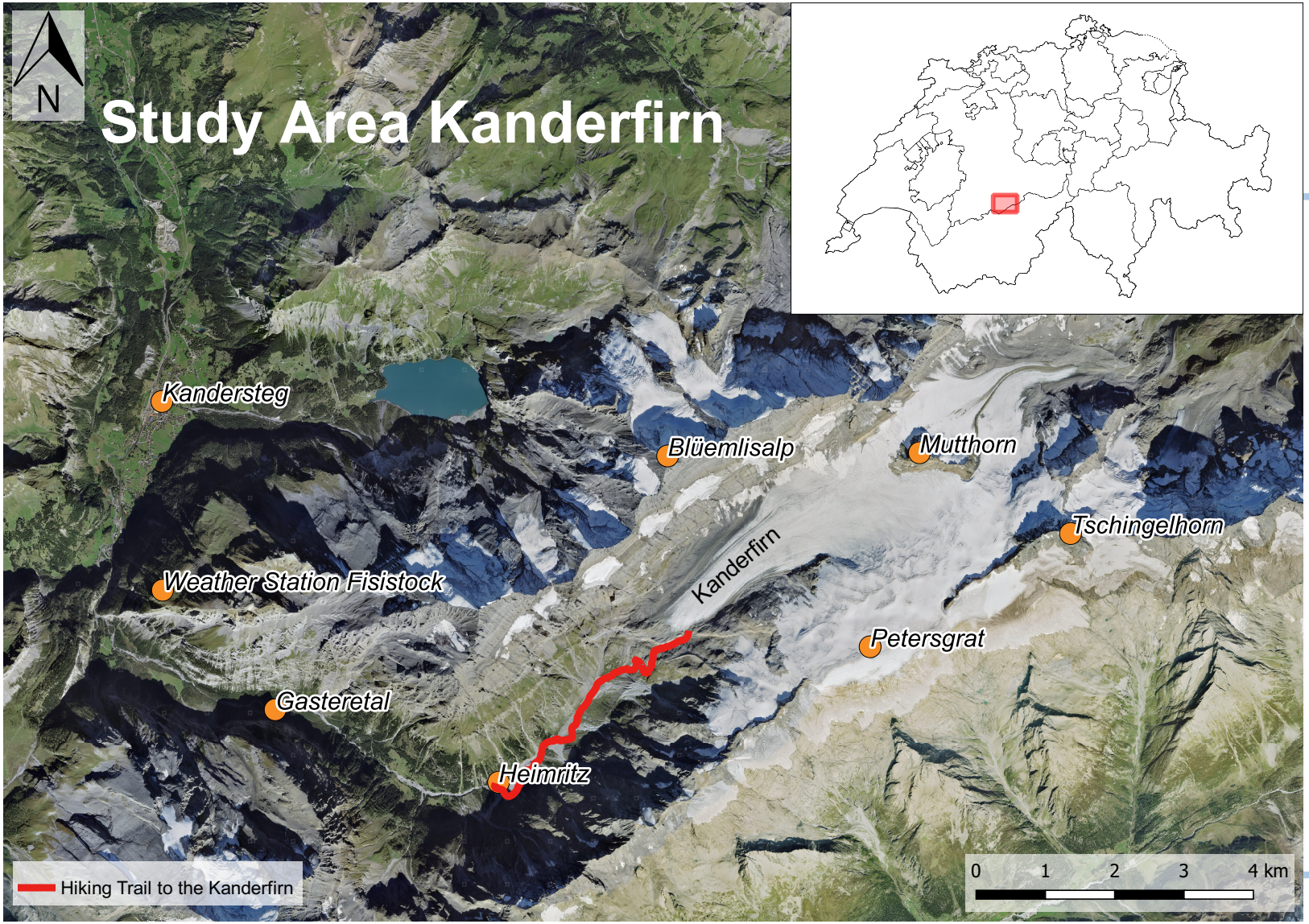
- Investigation of glacier surface changes (with regards to content)
- With **low-cost** UAVs and **open-source** photogrammetry software (methodical goal)

Study Area Kanderfirn



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Glacier Tongue:
2330 m ü. M.

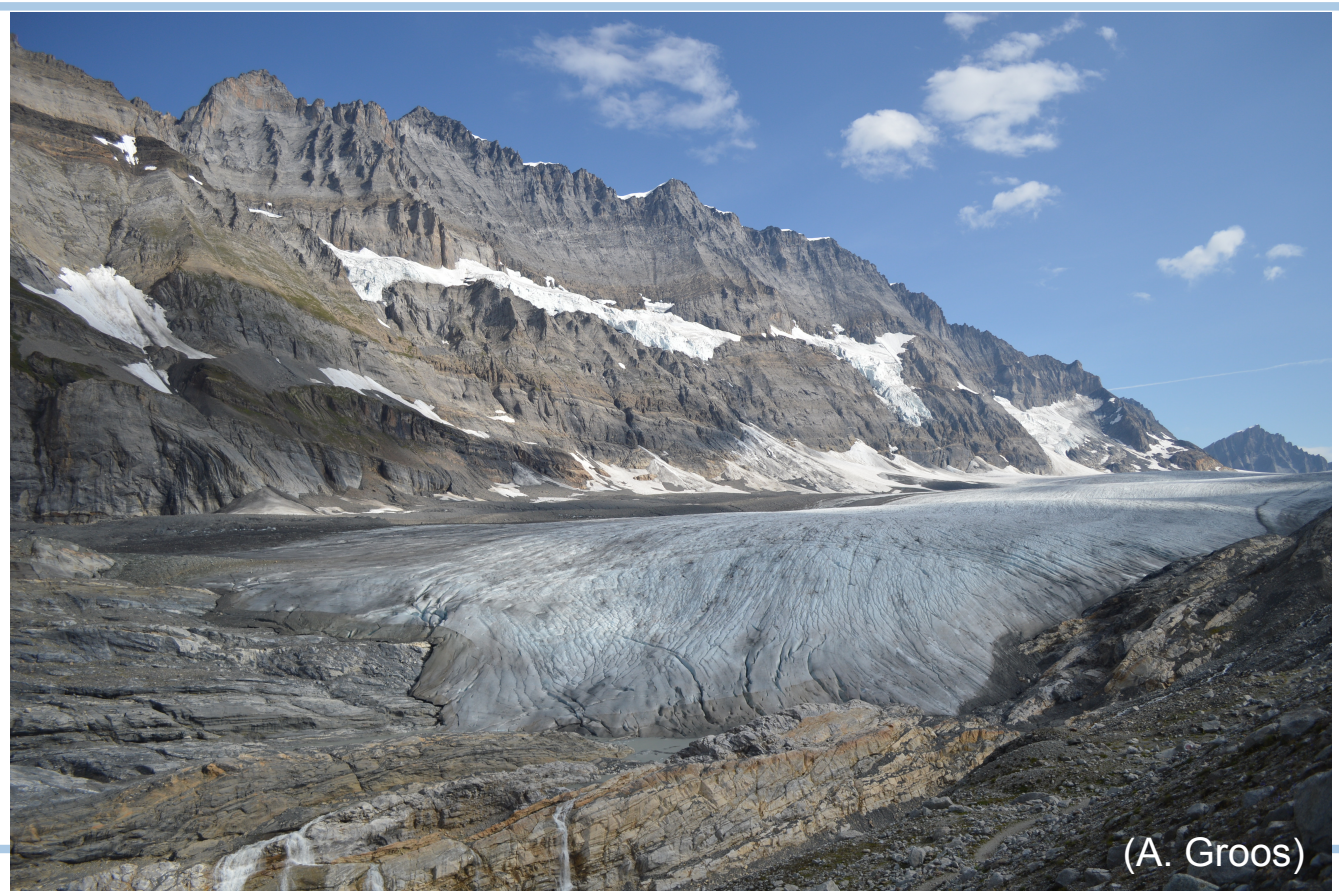
Petersgrat:
3202 m ü. M.

Area (2018):
11.9 km^2

Ø Temperature:
2.8 °C

Ø Precipitation:
826 mm

Study Area Kanderfirn



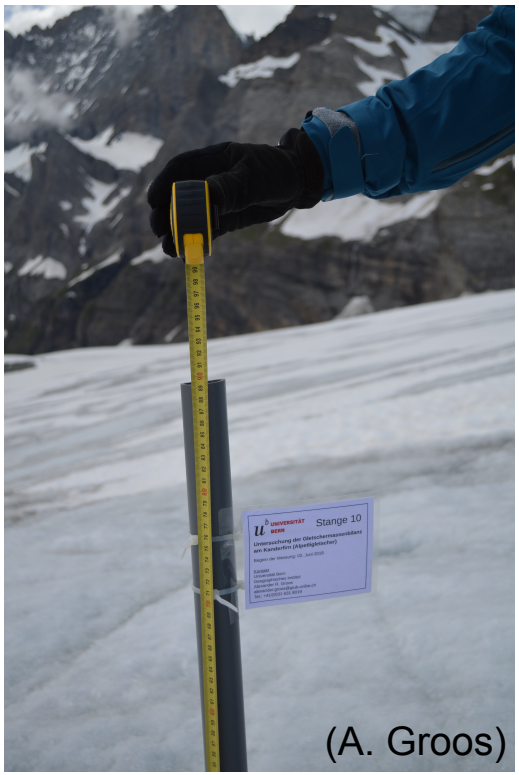
08. August 2018

Materials and Methods

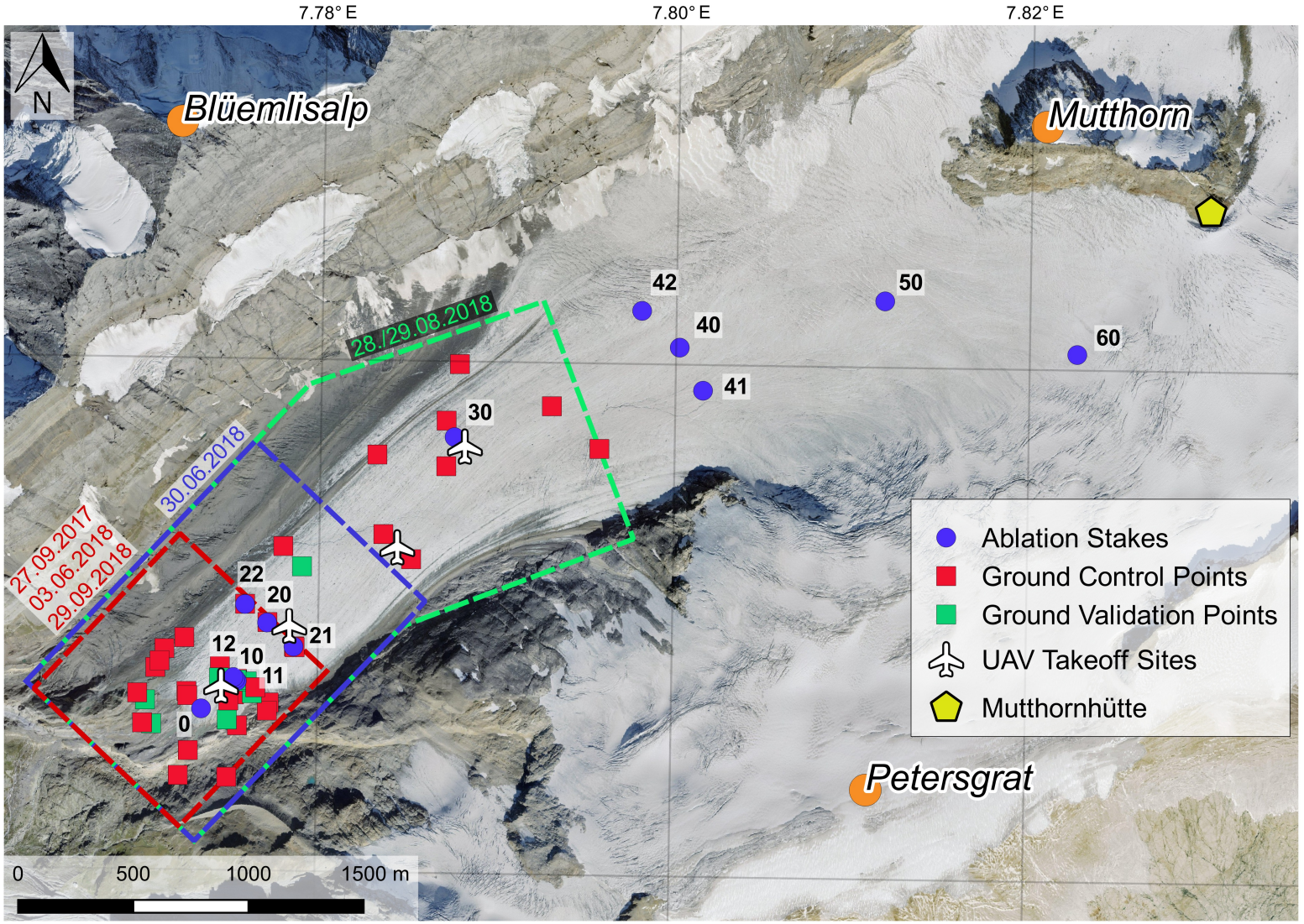
Materials and Methods


(T. Bertschinger)

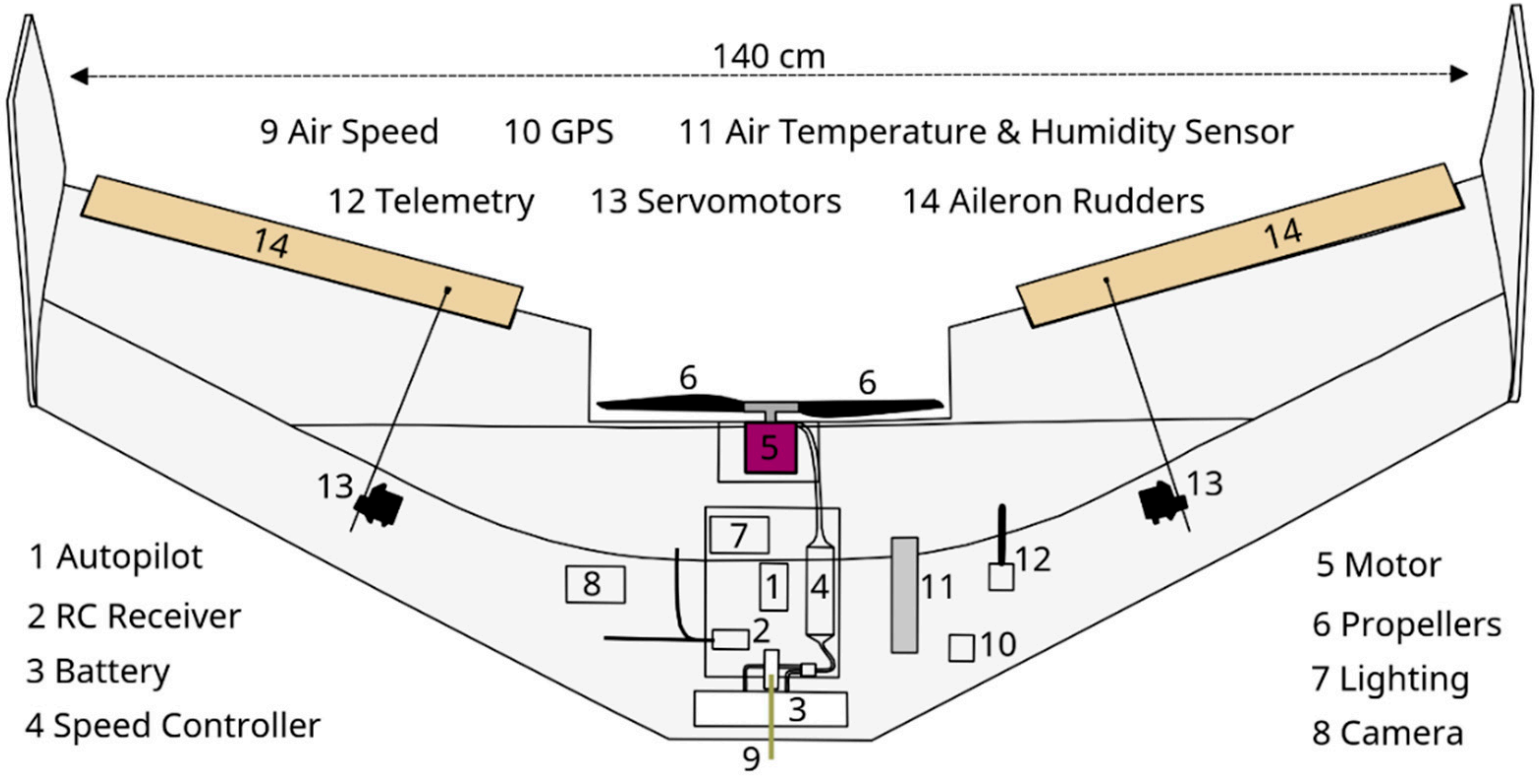

(A. Groos)

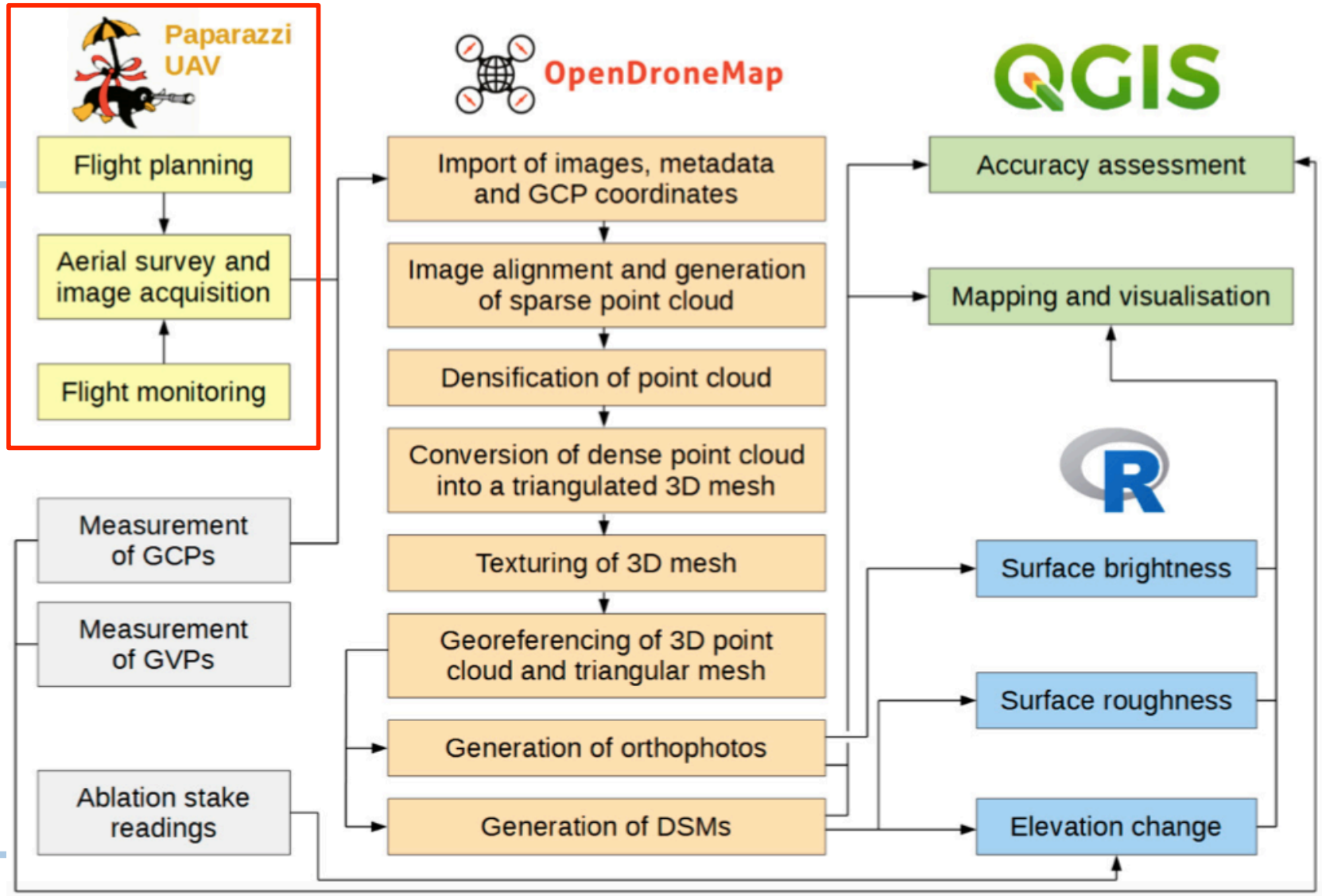


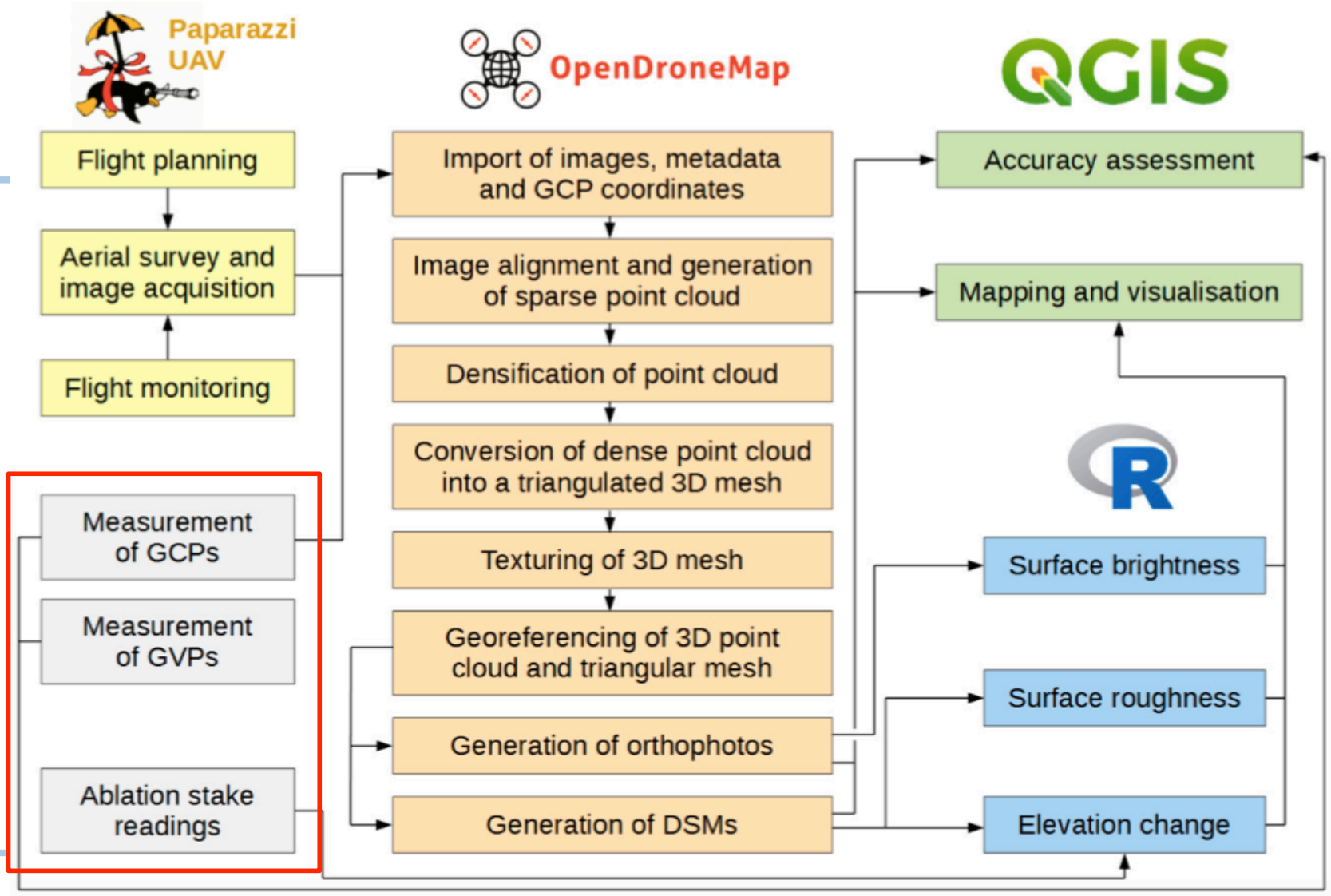
(A. Groos)


7.78° E
7.80° E
7.82° E
N
Blüemlisalp
Mutthorn
Petersgrat
42
40
41
50
60
30
22
20
21
12
10
11
0
28./29.08.2018
30.06.2018
27.09.2017
03.06.2018
29.09.2018
Ablation Stakes
Ground Control Points
Ground Validation Points
UAV Takeoff Sites
Mutthornhütte
0
500
1000
1500 m
46.48°N
46.46°N

Materials and Methods




Paparazzi UAV
Flight planning
Aerial survey and image acquisition
Flight monitoring
OpenDroneMap
Import of images, metadata and GCP coordinates
Image alignment and generation of sparse point cloud
Densification of point cloud
Conversion of dense point cloud into a triangulated 3D mesh
Texturing of 3D mesh
Georeferencing of 3D point cloud and triangular mesh
Generation of orthophotos
Generation of DSMs
QGIS
Accuracy assessment
Mapping and visualisation
R
Surface brightness
Surface roughness
Elevation change
Measurement of GCPs
Measurement of GVPs
Ablation stake readings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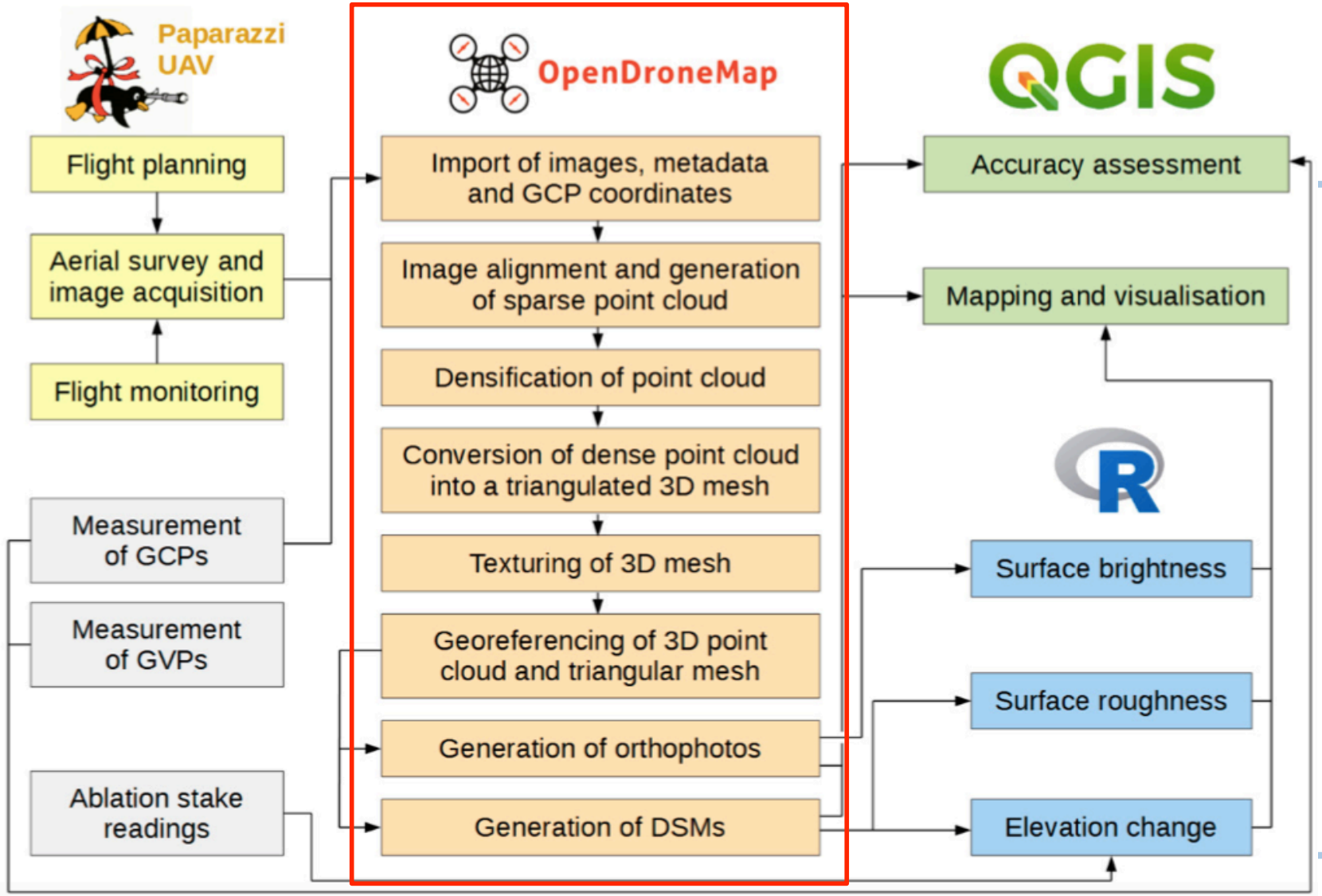
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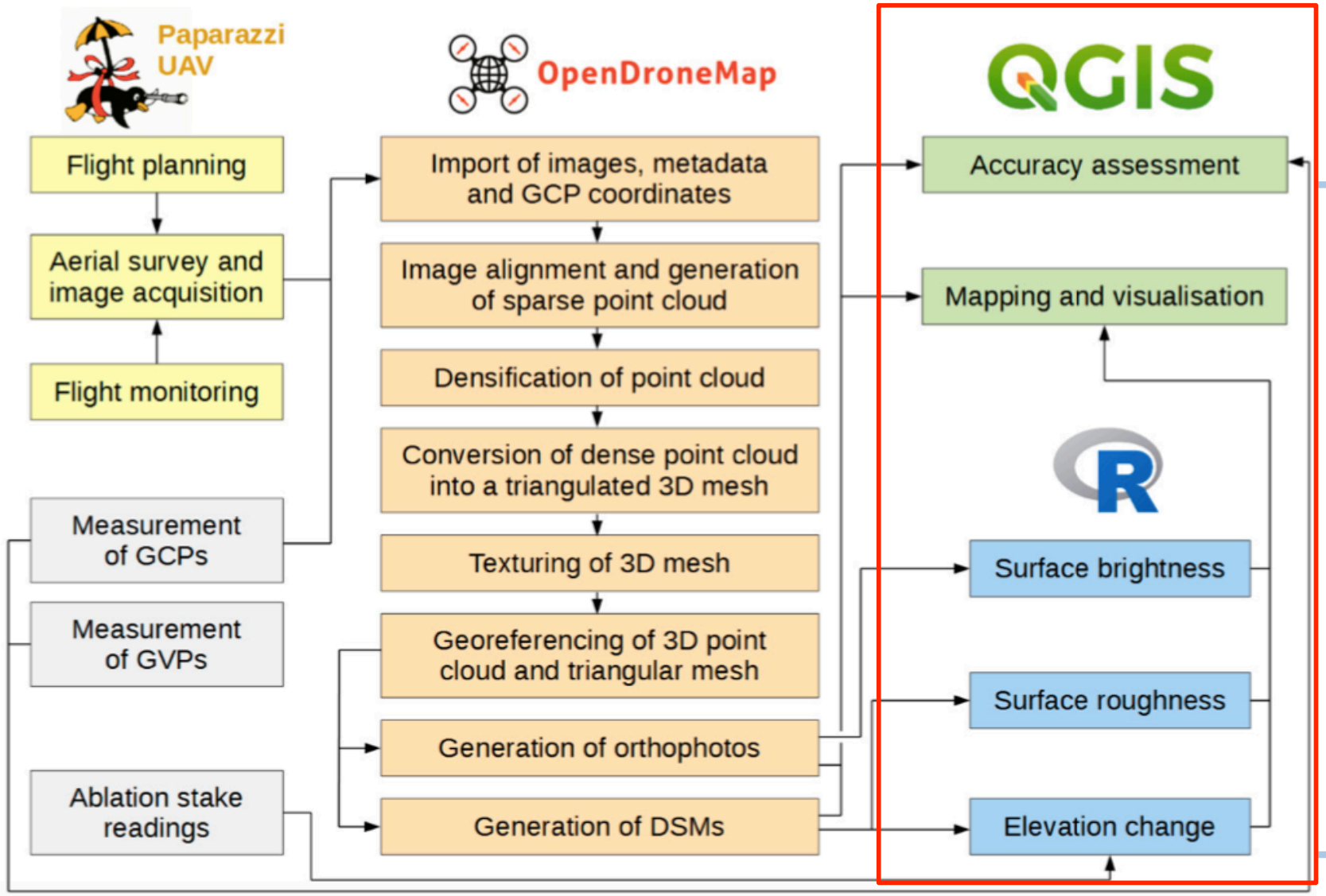
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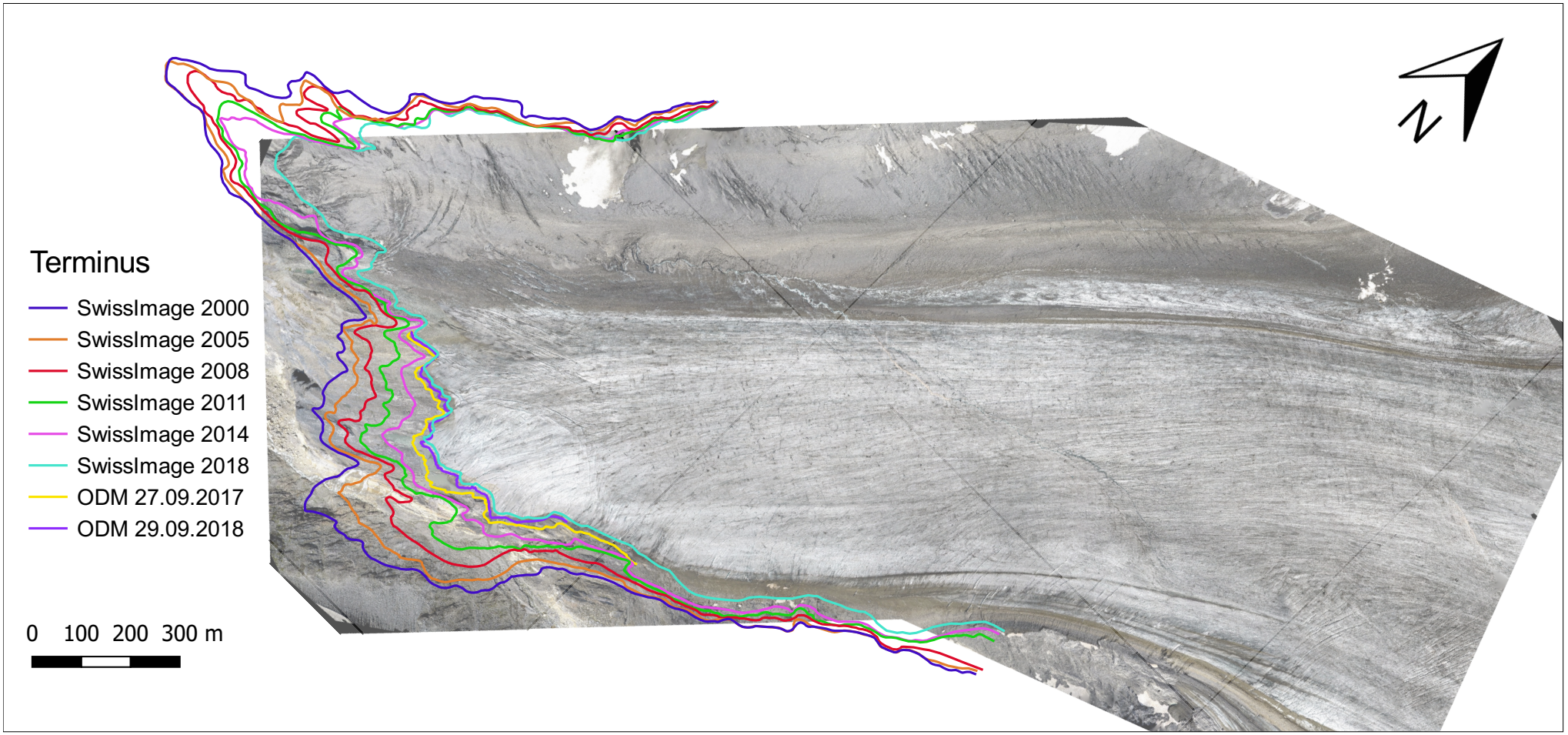
Surface brightness
Surface roughness
Elevation change

Results and Discussion

OpenDroneMap Orthophoto 28./29. August 2018



Results and Discussion

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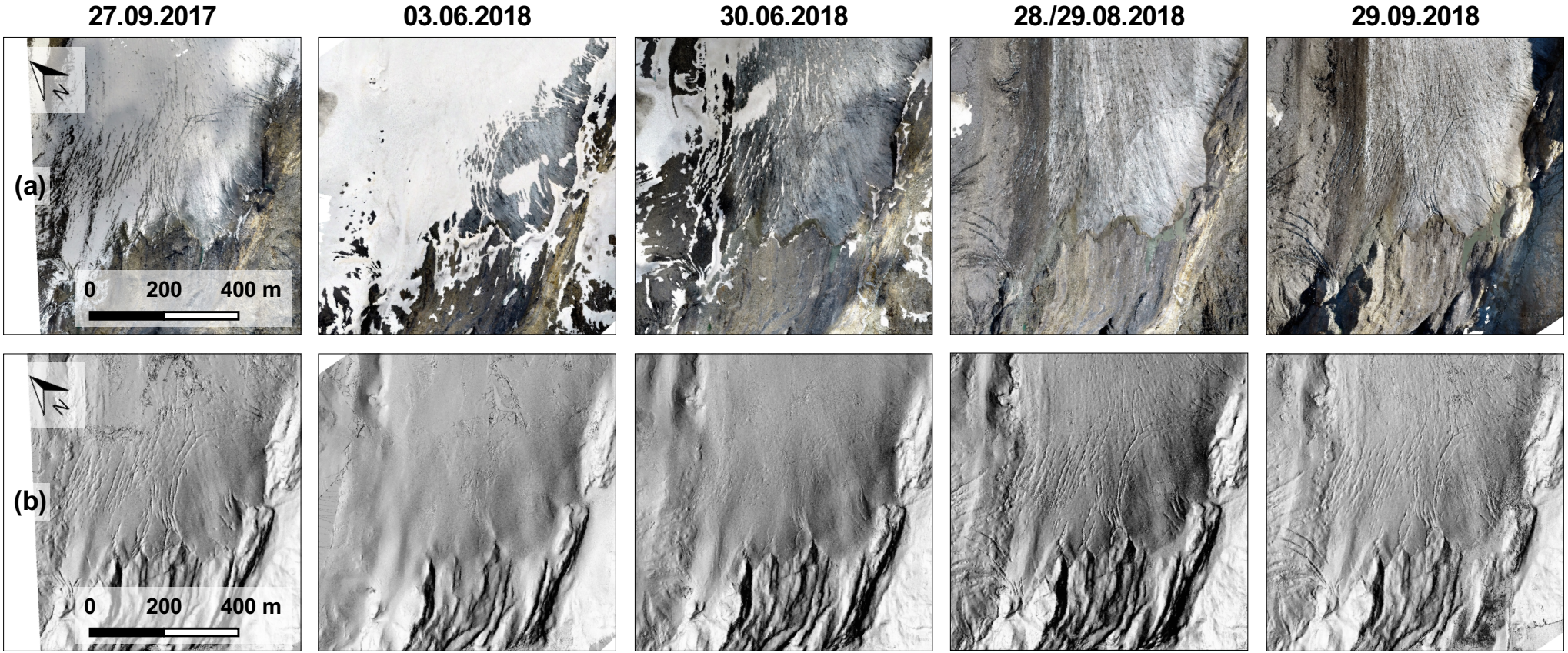
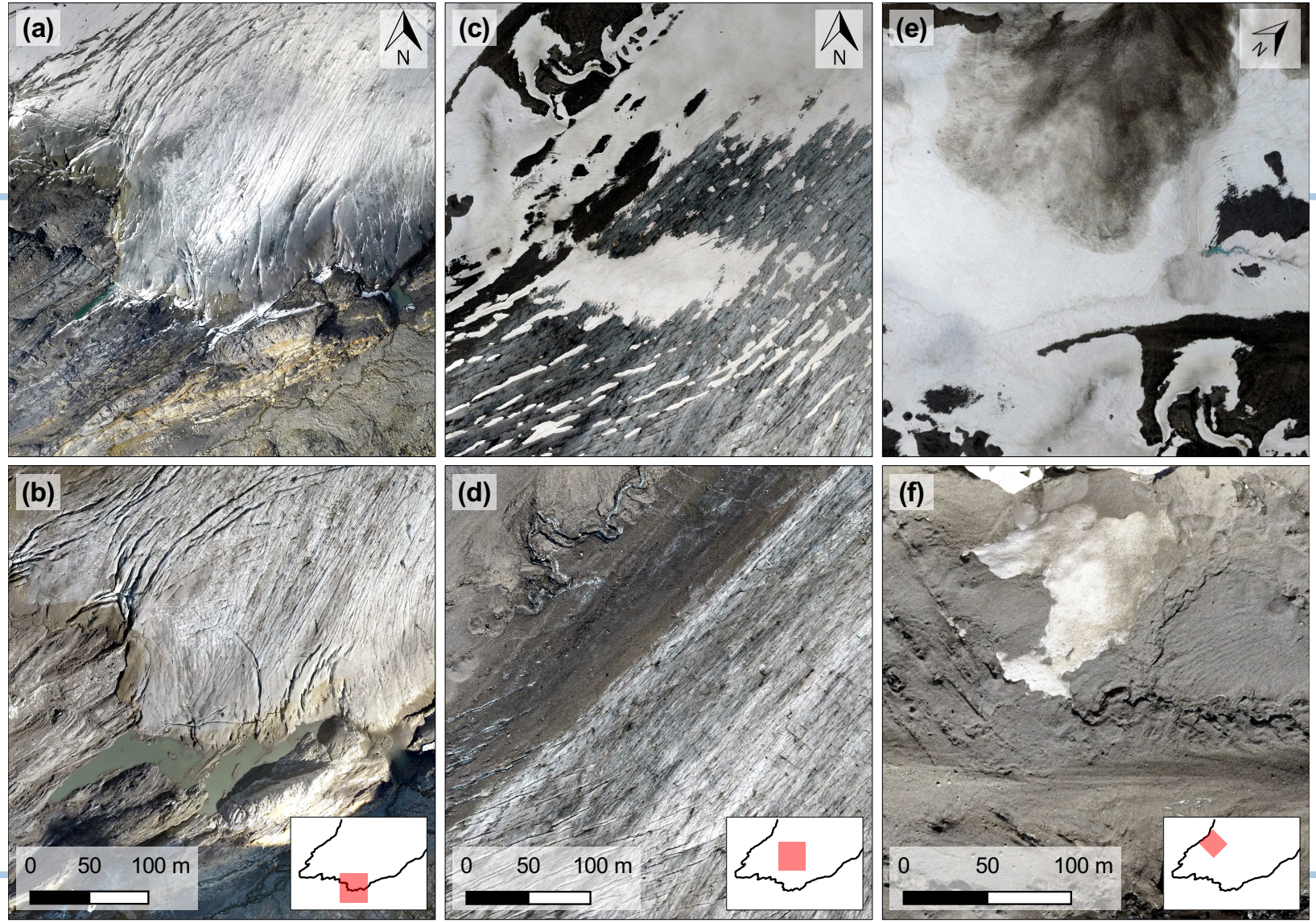
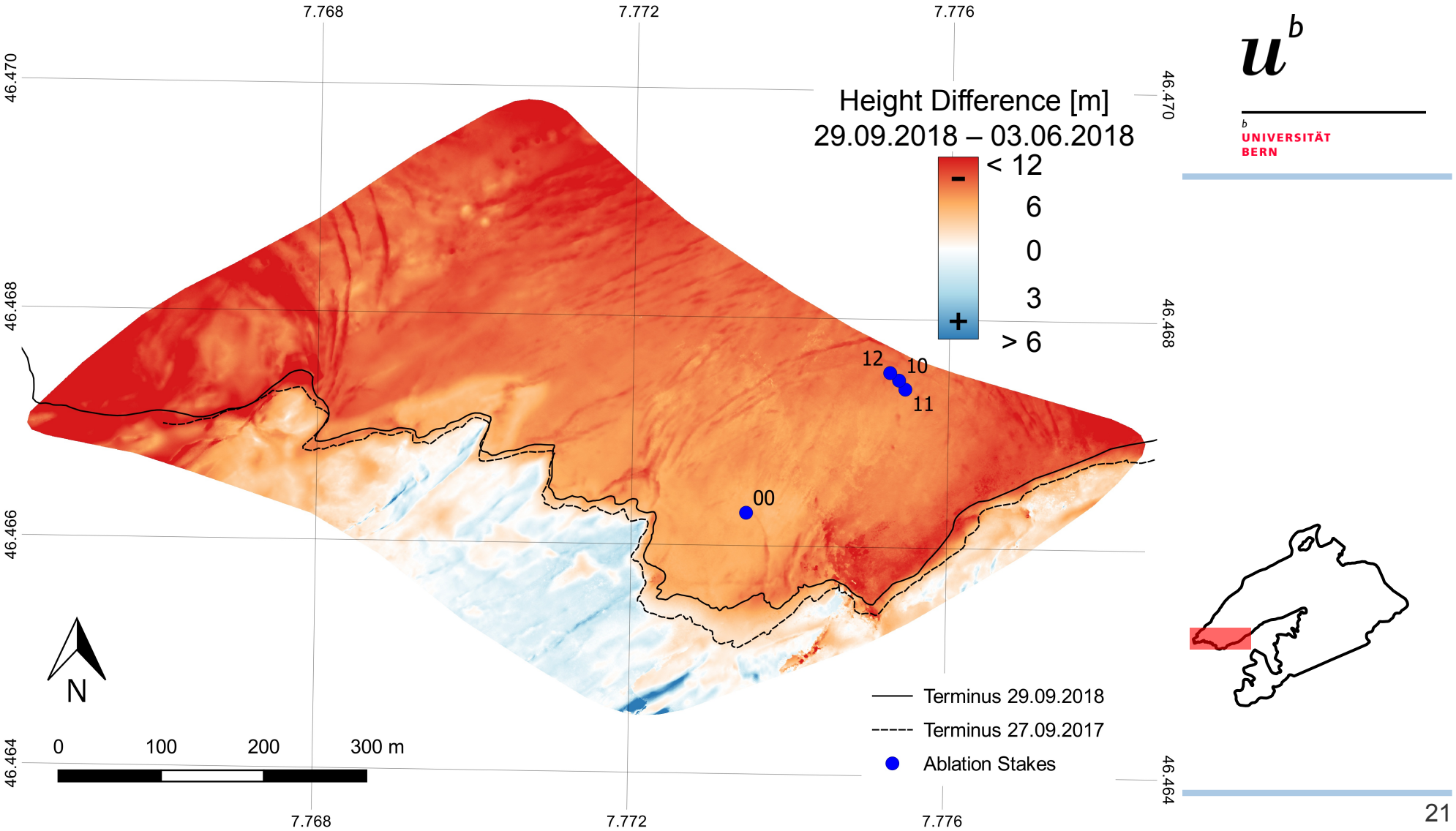
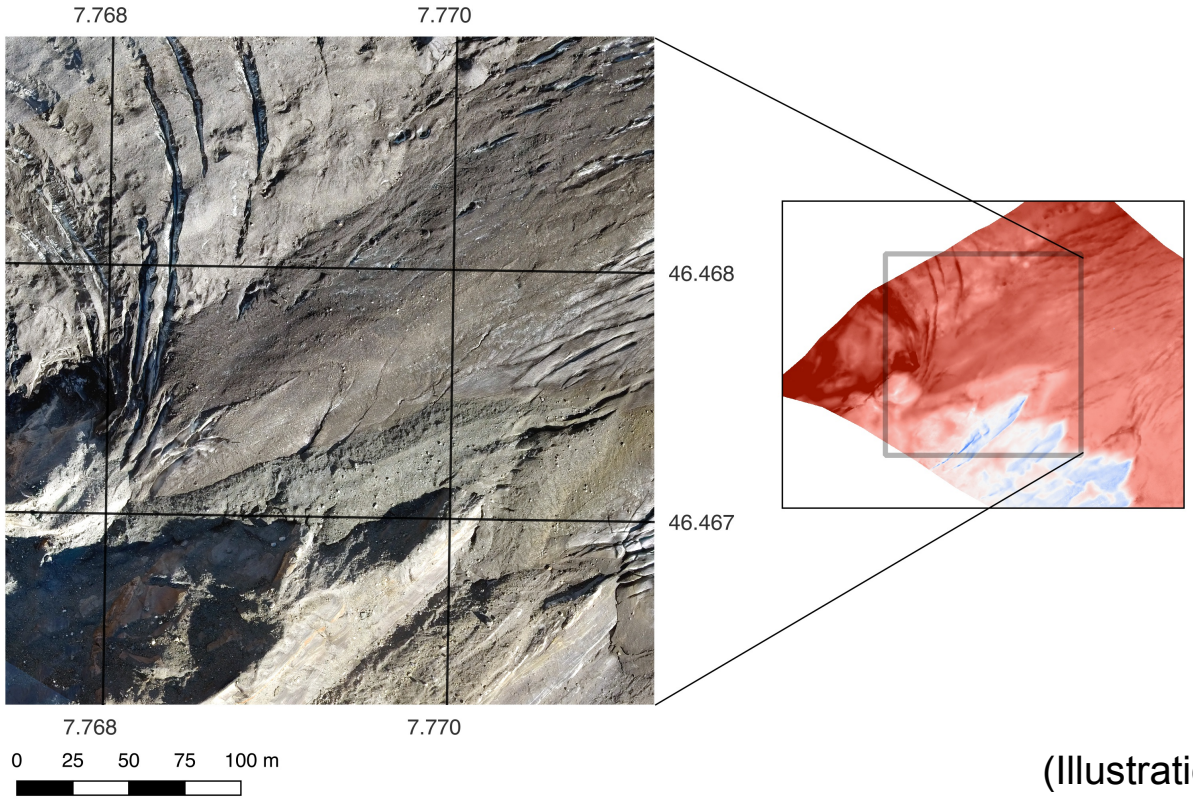



(a)
N
(c)
N
(e)
(b)
0 50 100 m
(d)
0 50 100 m
(f)
0 50 100 m

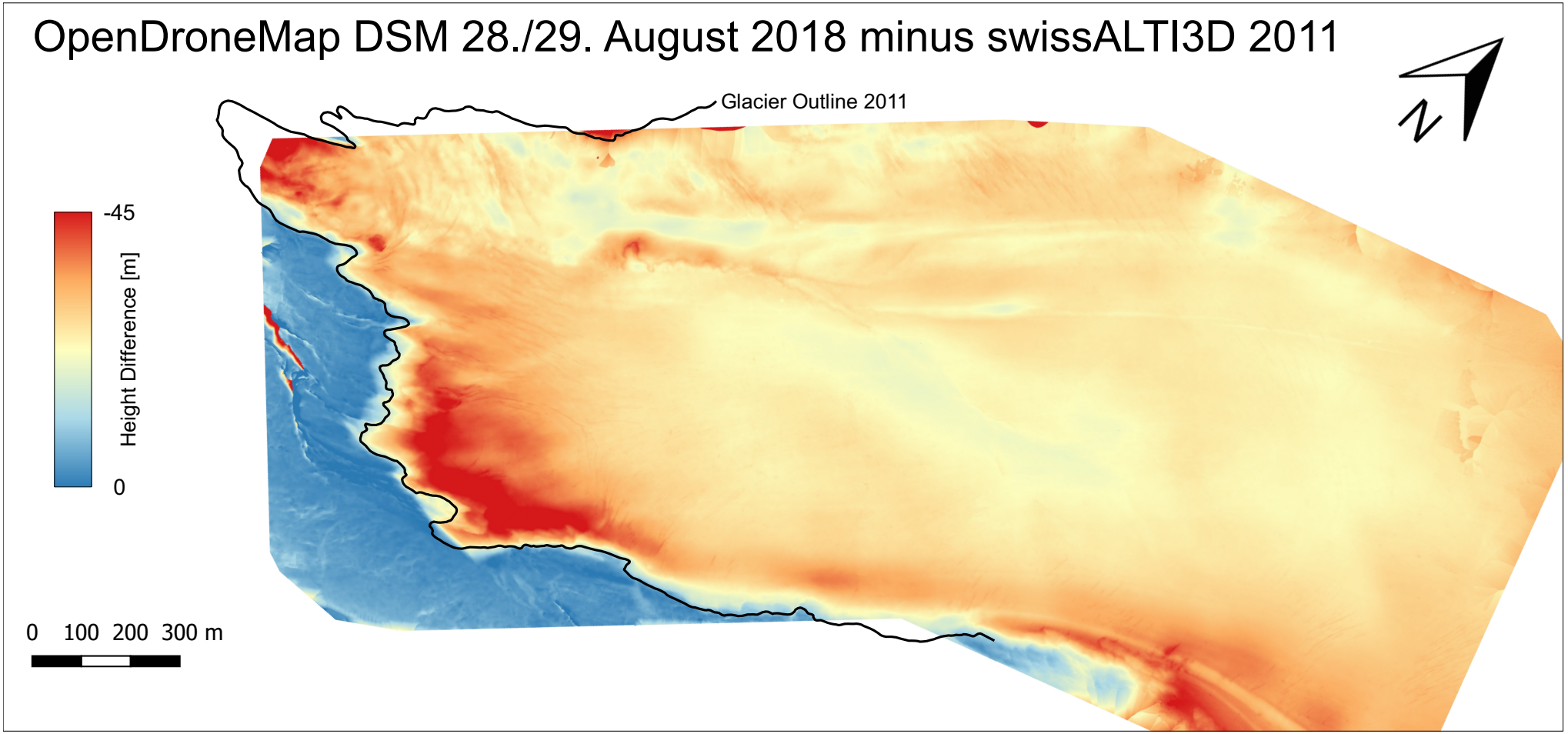

7.768
7.772
7.776
46.470
46.468
46.466
46.464
Height Difference [m]
29.09.2018 – 03.06.2018
< 12
6
0
3
> 6
12
10
11
00
N
0
100
200
300 m
Terminus 29.09.2018
Terminus 27.09.2017
Ablation Stakes

Results and Discussion



(Illustration by Céline Kummer)

OpenDroneMap DSM 28./29. August 2018 minus swissALTI3D 2011



Results and Discussion

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Date	Software	Version	GCPs	GVPs	XY RMSE (m)			Z RMSE (m)		
					GCP	GVP	Total	GCP	GVP	Total
27 September 2017	ODM	0.4.1	6	4	1.5	1.2	1.4	1.0	0.6	0.9
3 June 2018	ODM	0.4.1	6	4	0.8	0.7	0.8	0.7	0.8	0.7
3 June 2018	Pix4D	4.3.31	6	4	0.4	0.7	0.6	0.3	0.4	0.3
30 June 2018	ODM	0.4.1	9	3	1.9	0.5	1.7	2.3	1.2	2.1
28 /29 August 2018	ODM	0.4.1	22	5	1.6	1.0	1.5	2.1	0.9	1.9
29 September 2018	ODM	0.4.1	4	3	0.8	0.8	0.8	0.9	0.9	0.9
29 September 2018	Pix4D	4.3.31	4	3	0.3	0.4	0.3	0.2	0.7	0.5

Conclusions and Outlook

Conclusions

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- Self-built fixed-wing UAVs in tandem with open-source photogrammetry software are a powerful low-cost tool to obtain remotely sensed geodata in high spatial and temporal resolution
- Pronounced surface melting of the Kanderfirn during summer 2018: optical glacier surface structure transformations, negative height changes over the whole glacier tongue, brightness decreased, roughness increased
- ODM: high-resolution orthophotos and DSMs **but** the accuracy has not yet reached the one of proprietary software → worst point: georeferencing → work in progress!

Outlook

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> Continue monitoring of the Kanderfirn:
  - Longer time series
  - Overflight of the whole area at one point in time
  - Meteorological flights for boundary layer investigations
> Investigations in other areas of the world

Thank You!

Further Information

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- alexander.groos@giub.unibe.ch

- Groos, A. R., Bertschinger, T. J., Kummer, C. M., Erlwein, S., Munz, L., & Philipp, A. (2019). The Potential of Low-Cost UAVs and Open-Source Pho- togrammetry Software for High-Resolution Monitoring of Alpine Glaciers: A Case Study from the Kanderfirn (Swiss Alps). *Geosciences, 9*(8), 356.
  → **https://doi.org/10.3390/geosciences9080356**

Materials and Methods

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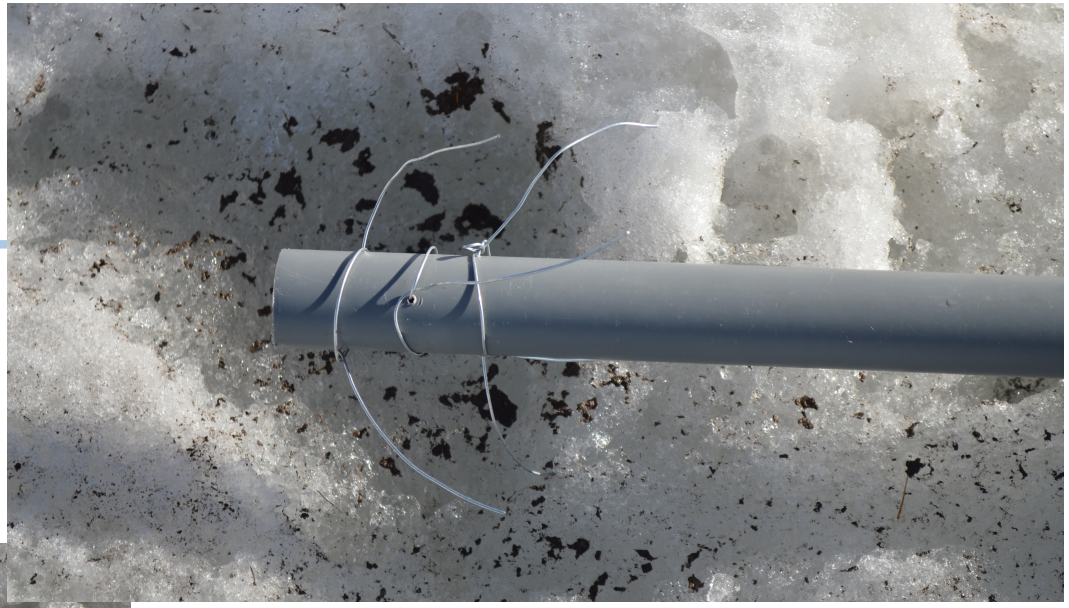
Date	Flight No.	Start Time (hh:mm)	Flight Time (hh:mm)	Flight Altitude (m a.g.l.)	Area (km^2)	Images (selected)	Resolution (cm / pixel)
27 September 2017	1	16:26	00:14	140 ± 10	0.7	1242 (314)	7.2 ± 0.5
3 June 2018	1	14:37	00:16	140 ± 10	0.7	913 (347)	7.2 ± 0.5
30 June 2018	1	15:03	00:16	120 ± 10	0.8	972 (249)	6.2 ± 0.5
30 June 2018	2	18:02	00:16	135 ± 20	0.8	952 (228)	6.9 ± 1.0
28 August 2018	1	13:27	00:15	120 ± 10	0.8	883 (210)	6.2 ± 0.5
28 August 2018	2	15:24	00:16	135 ± 20	0.8	935 (210)	6.9 ± 1.0
28 August 2018	3	17:14	00:17	135 ± 20	0.8	992 (217)	6.9 ± 1.0
29 August 2018	1	12:20	00:17	135 ± 20	0.8	1036 (213)	6.9 ± 1.0
29 September 2018	1	10:51	00:11	120 ± 10	0.8	668 (215)	6.2 ± 0.5
29 September 2018	2	16:15	00:01	120 ± 10	< 0.1	70 (0)	6.2 ± 0.5



Schlussfolgerungen

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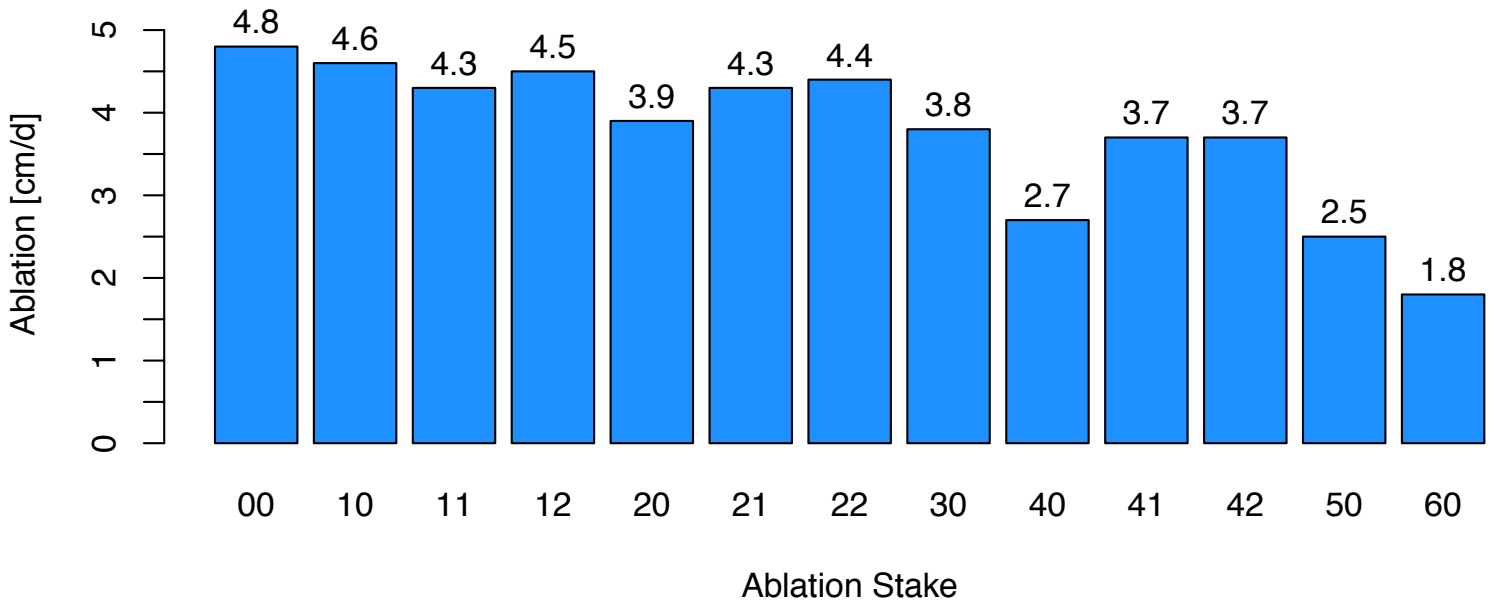
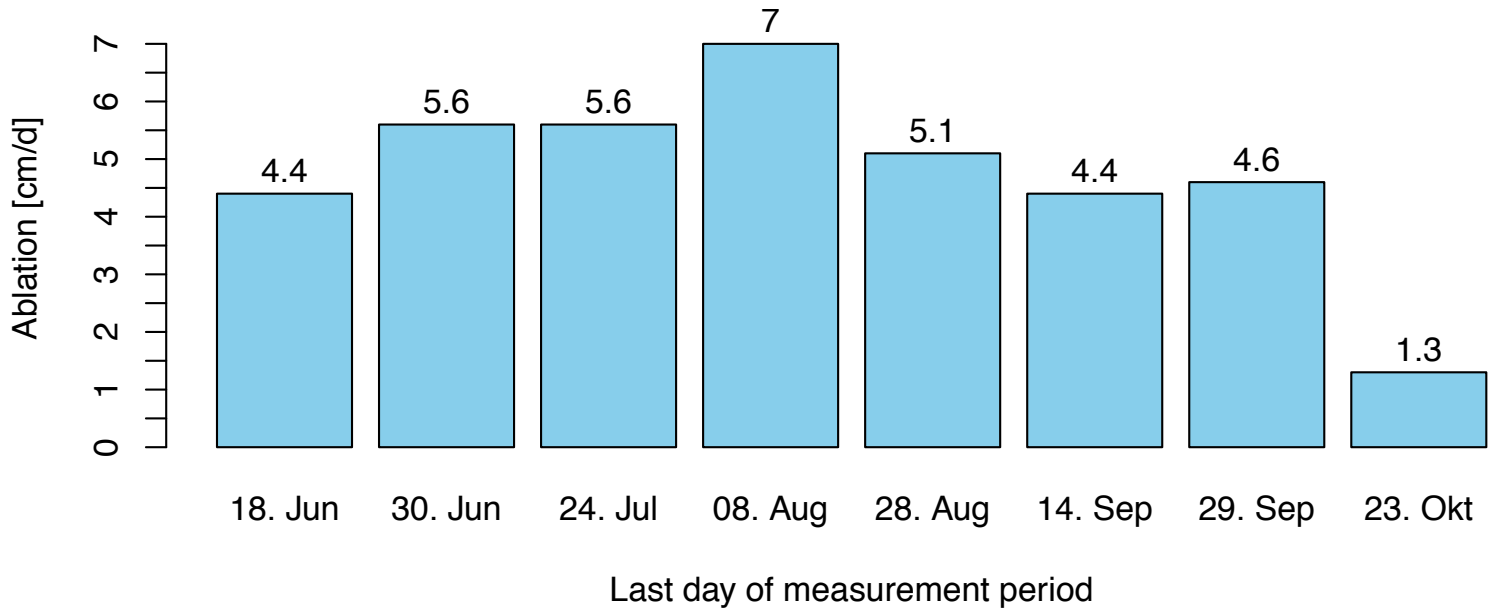
- Der Kanderfirn hat im Sommer 2018 an Höhe verloren. Die modellierte Oberflächenmassenbilanz ist ebenfalls deutlich negativ.
- Die aktuell erreichte Qualität der Orthophotos und DSMs lässt qualitative Schlussfolgerungen über Strukturänderungen der Gletscheroberfläche zu, eine Quantifizierung der Höhenänderung ist jedoch mit Unsicherheiten verbunden.
- Die Kombination von hochaufgelösten Höhenmodellen und dem Massenbilanzmodell bringt Vorteile. (Stärken einer Methode gleichen Schwächen der anderen aus)
- Potential zur Verbesserung: Flugplan, Prozessierung in OpenDroneMap, Inputdaten im Massenbilanzmodell, Masseneintrag von Lawinen....

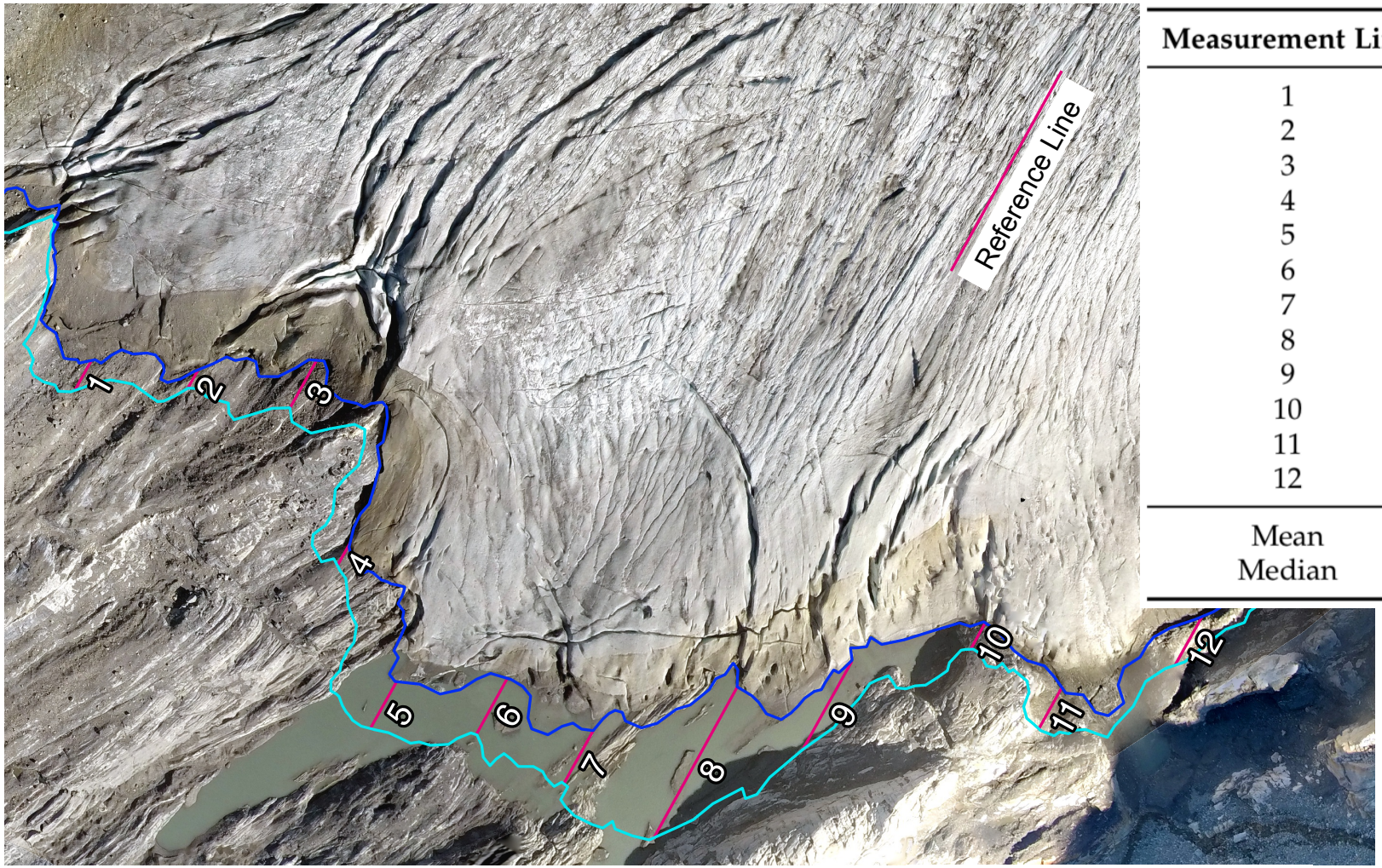
Stake	Lat (°N)	Lat (°E)	Elevation (m)	Start Date	End Date	Period (d)	Ablation (cm)	Ablation (cm d^{-1})
0	46.4663	7.7735	2363	30 June 2018 13:00	23 October 2018 11:40	114.9	549	4.8
10	46.4675	7.7754	2414	3 June 2018 15:00	23 October 2018 11:30	141.9	648	4.6
11	46.4674	7.7755	2413	3 June 2018 15:00	23 October 2018 11:25	141.9	610	4.3
12	46.4675	7.7752	2413	30 June 2018 11:50	23 October 2018 11:35	115.0	521	4.5
20	46.4697	7.7771	2444	30 June 2018 16:50	23 October 2018 11:00	114.8	443	3.9
21	46.4688	7.7786	2437	30 June 2018 16:15	23 October 2018 11:15	114.8	489	4.3
22	46.4704	7.7759	2446	30 June 2018 17:10	23 October 2018 11:05	114.7	509	4.4
30	46.4770	7.7875	2544	24 July 2018 14:15	23 October 2018 10:20	90.8	347	3.8
40	46.4807	7.8002	2633	8 August 2018 15:15	23 October 2018 09:50	75.8	204	2.7
41	46.4790	7.8016	2632	24 July 2018 15:30	23 October 2018 10:00	90.8	335	3.7
42	46.4821	7.7980	2641	8 August 2018 15:45	23 October 2018 09:45	75.8	284	3.7
50	46.4826	7.8118	2735	8 August 2018 16:30	23 October 2018 09:30	75.7	186	2.5
60	46.4806	7.8227	2843	9 August 2018 09:30	23 October 2018 09:00	75.0	136	1.8

Ablation Stake 00 - 60

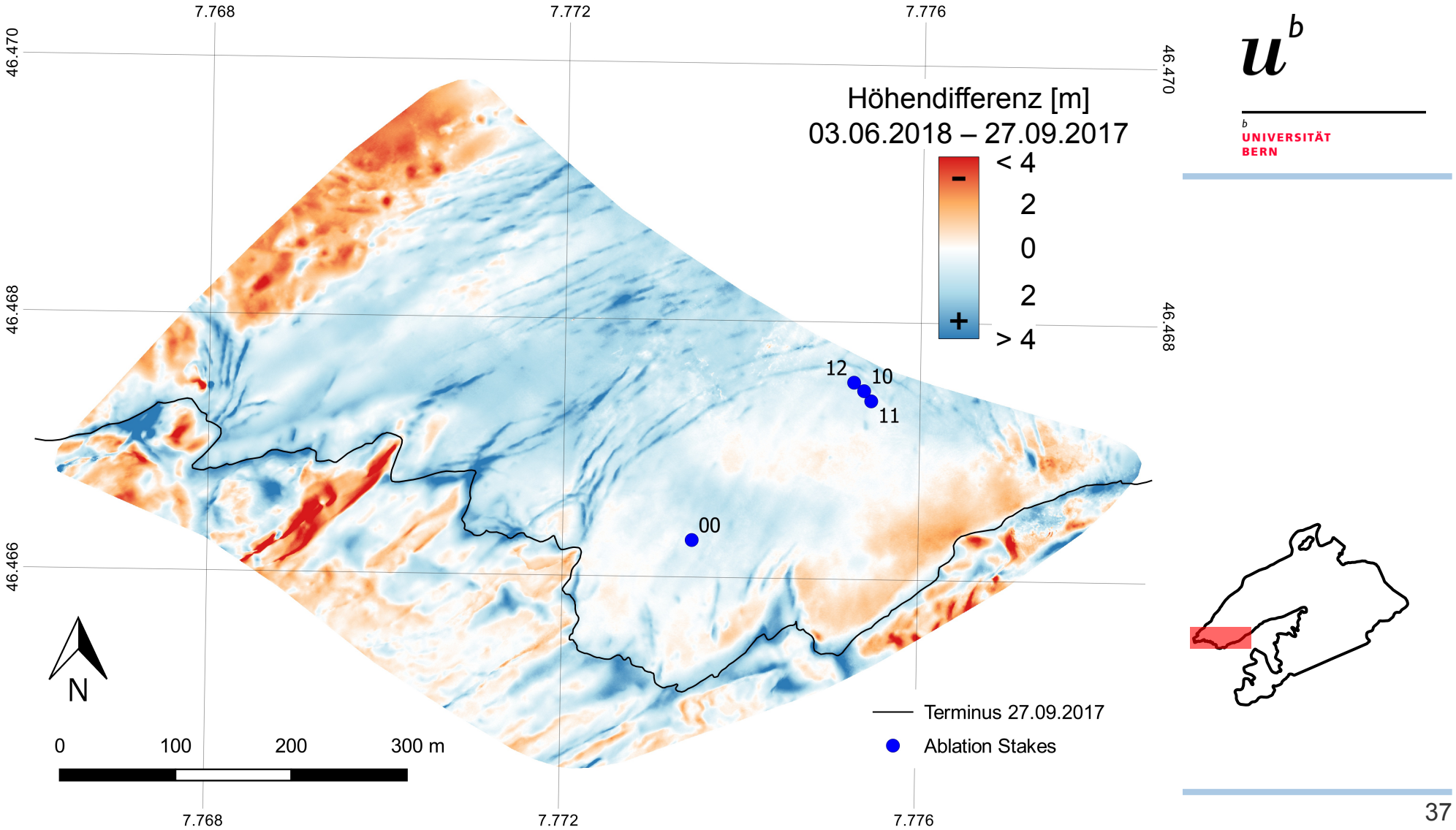


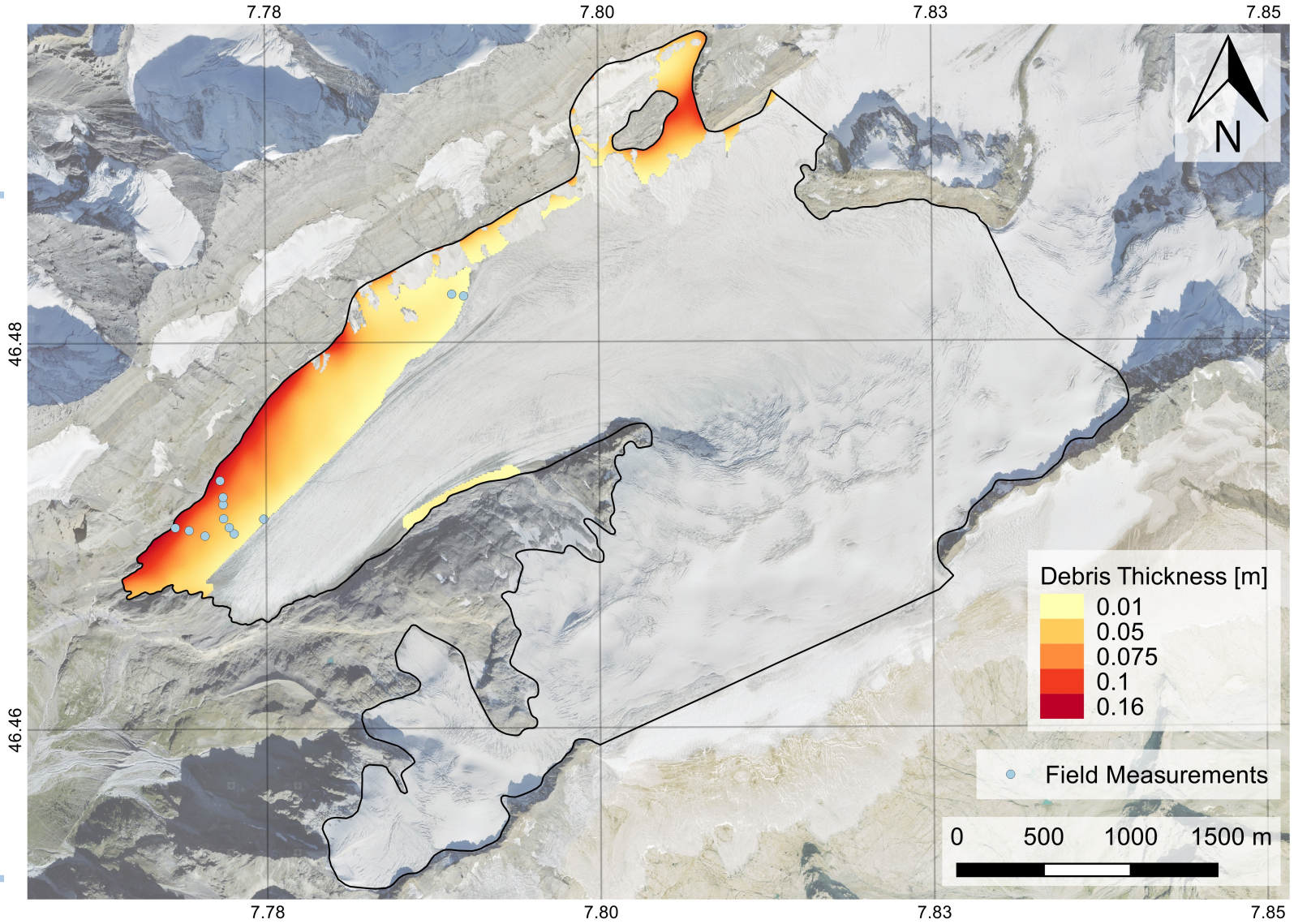
Ablation Stake 10

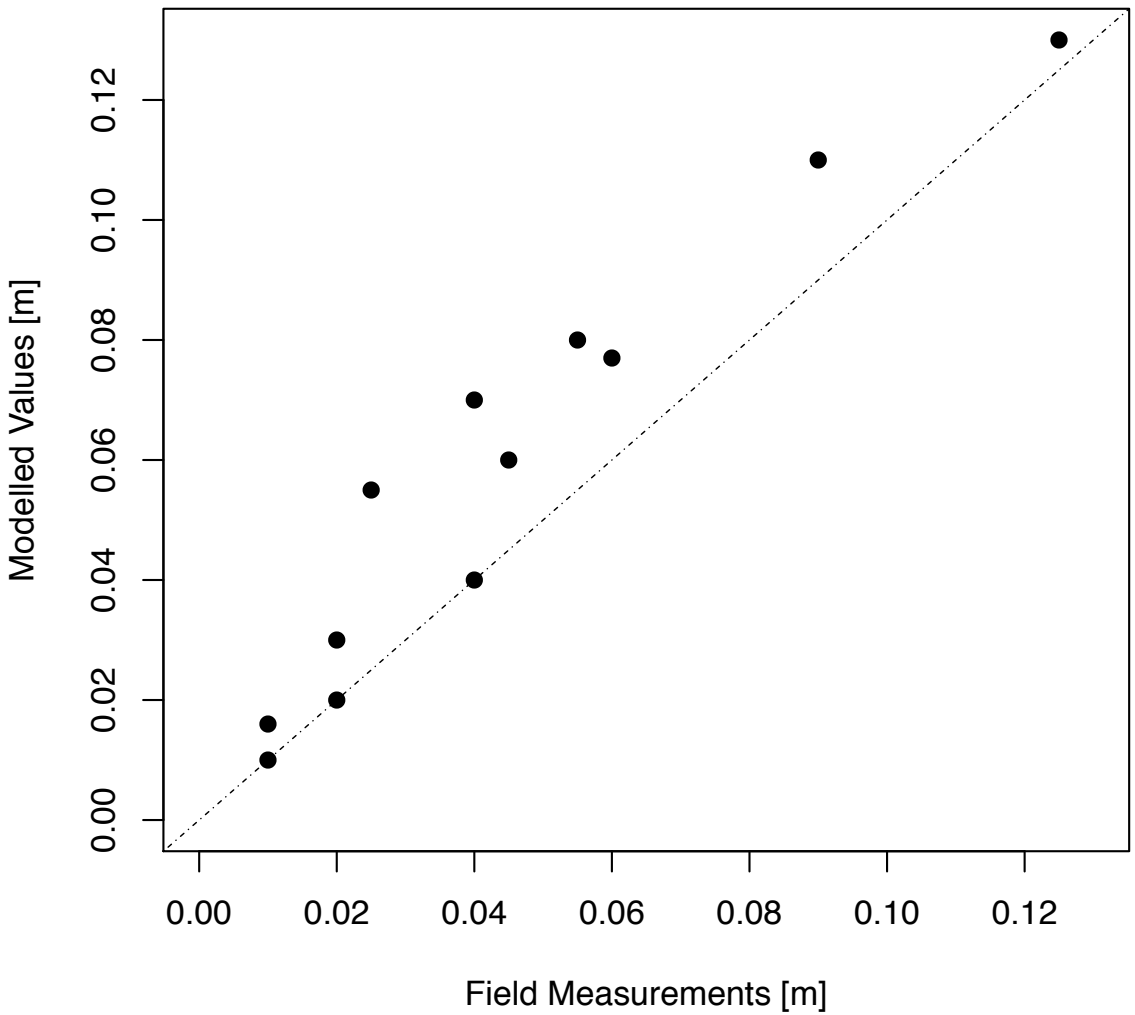


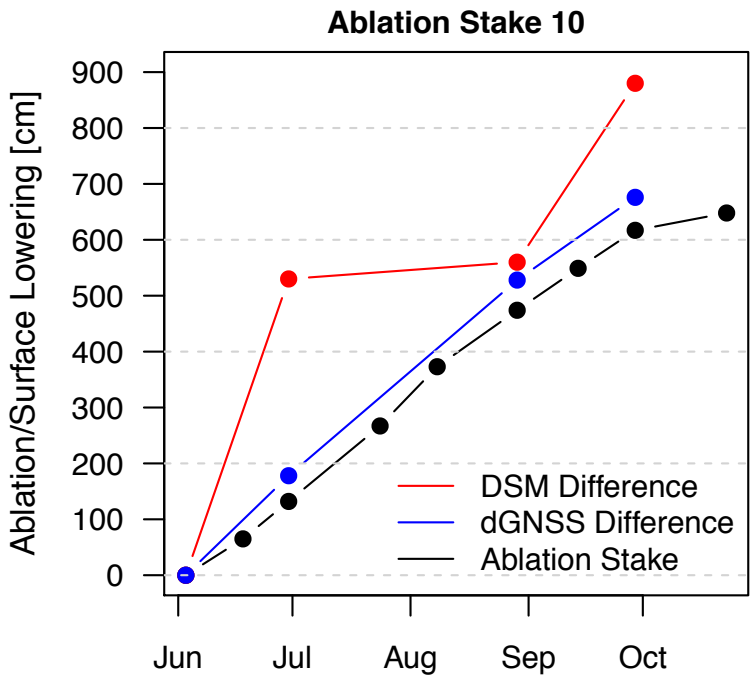


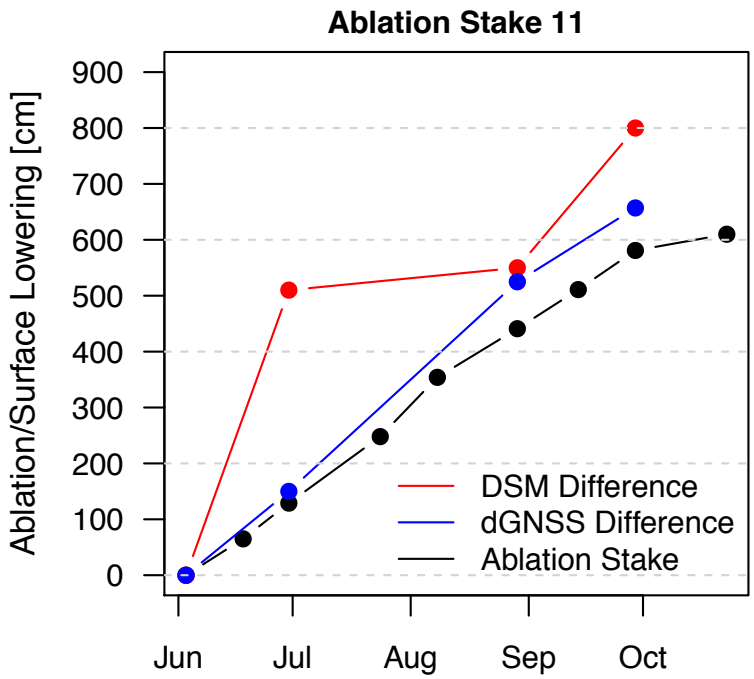
Measurement Line	Length Change (m)
1	10.3
2	6.4
3	16.4
4	7.4
5	16.2
6	19.4
7	18.2
8	52.0
9	30.5
10	9.4
11	14.2
12	16.5
Mean	18.1
Median	16.3

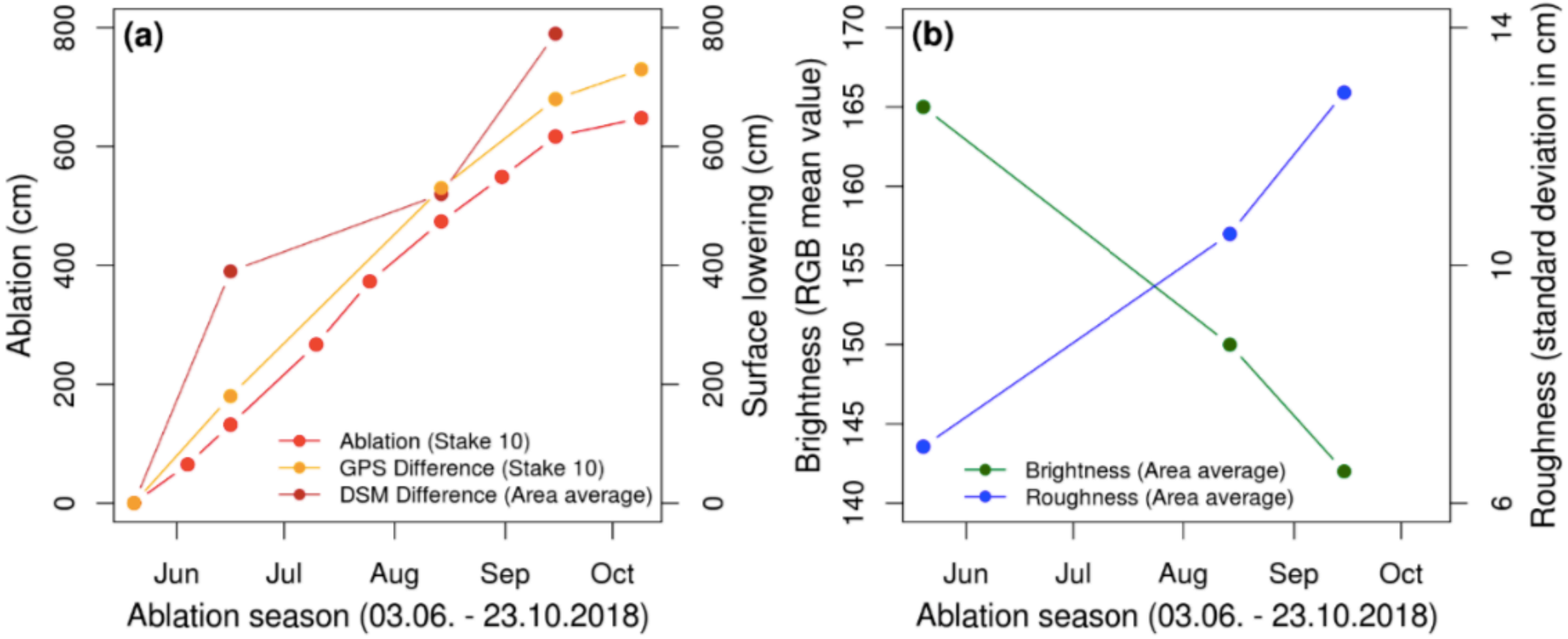

7.768
7.772
7.776
46.470
46.468
46.466
Höhendifferenz [m]
03.06.2018 – 27.09.2017
< 4
2
0
2
> 4
12
10
11
00
N
0
100
200
300 m
Terminus 27.09.2017
Ablation Stakes


7.78
7.80
7.83
7.85
46.48
46.46
N
Debris Thickness [m]
0.01
0.05
0.075
0.1
0.16
Field Measurements
0
500
1000
1500 m


Modelled Values [m]
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Field Measurements [m]
0.00
0.02
0.04
0.06
0.08
0.10
0.12


Ablation Stake 10
Ablation/Surface Lowering [cm]
900
800
700
600
500
400
300
200
100
0
Jun
Jul
Aug
Sep
Oct
DSM Difference
dGNSS Difference
Ablation Stake
03 June 2018 – 23 October 2018


Ablation Stake 11
Ablation/Surface Lowering [cm]
900
800
700
600
500
400
300
200
100
0
Jun
Jul
Aug
Sep
Oct
DSM Difference
dGNSS Difference
Ablation Stake
03 June 2018 – 23 October 2018


(a)
Ablation (cm)
Surface lowering (cm)
0
200
400
600
800
Ablation (Stake 10)
GPS Difference (Stake 10)
DSM Difference (Area average)
Jun
Jul
Aug
Sep
Oct
Ablation season (03.06. - 23.10.2018)
(b)
Brightness (RGB mean value)
Roughness (standard deviation in cm)
140
145
150
155
160
165
170
6
10
14
Brightness (Area average)
Roughness (Area average)
Jun
Jul
Aug
Sep
Oct
Ablation season (03.06. - 23.10.2018)