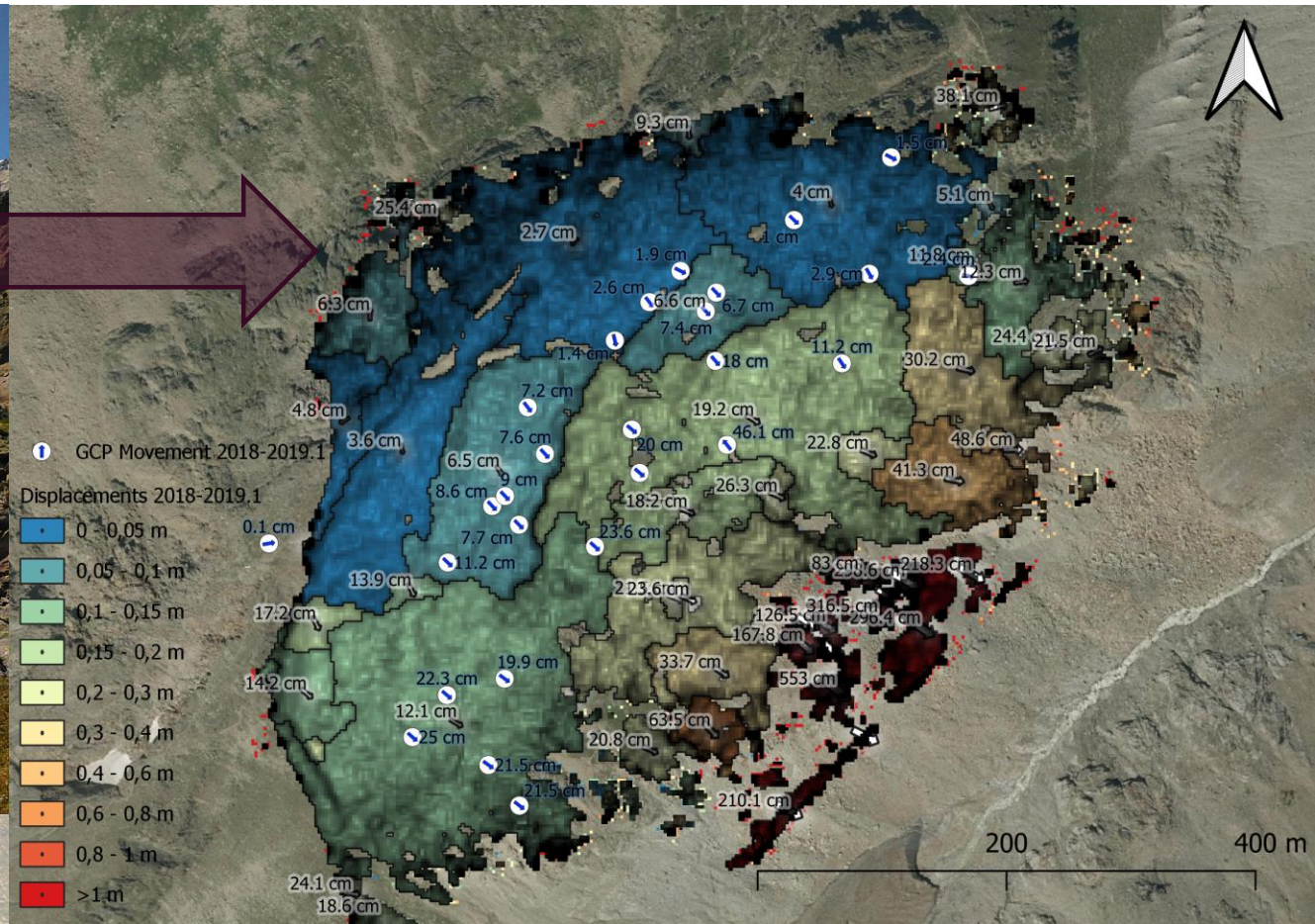
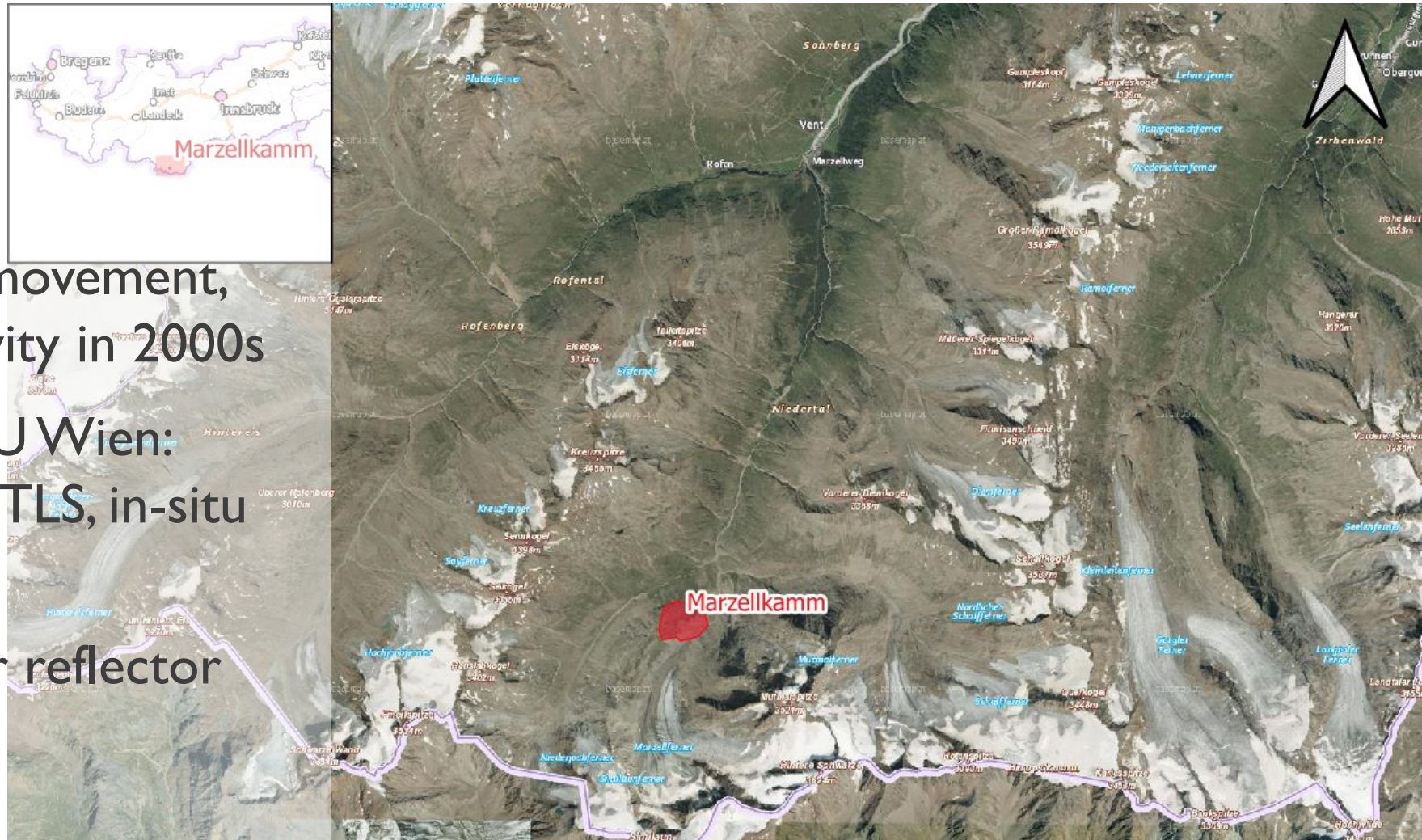
FROM UAV-PHOTOGRAMMETRY TO DISPLACEMENT RATES: MONITORING SLOPE DEFORMATIONS IN ALPINE TERRAIN



EGU DISPLAY, APRIL 8 2020
CHRISTIAN DEMMLER (SKY4GEO E.U., BFW)

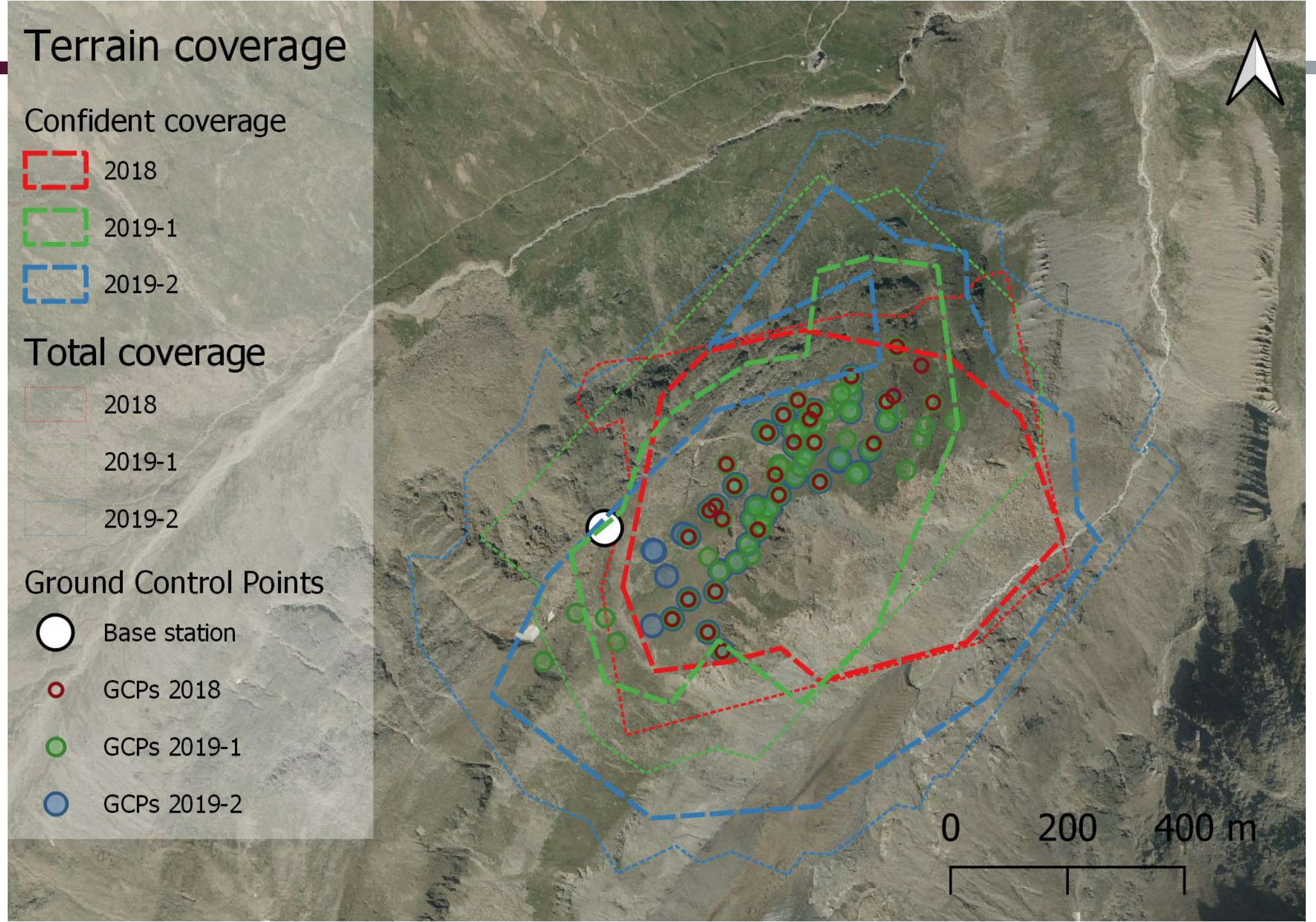
SITE: MARZELLKAMM

- Test Site in Ötztal, south of Vent
- Deep seated mass movement, phases of large activity in 2000s
- Monitored by BOKU Wien: GNSS, Total Station, TLS, in-situ measurements
- GBA: INSAR corner reflector installed



PHOTOGRAMMETRIC MISSIONS

- Three missions flown
- DJI Drones:
  Phantom 4 (2018) – GSD ~4cm (100m above ground), 1366 images, 0.46km²)
  Phantom 4 RTK (2019.1) – GSD ~2cm (75m above ground), 1202 images, 0.44km²)
  Mavic 2 (2019.2) – GSD <2cm (80m above ground, 3830 images, 0.51km²)
- GCP referenced (+RTK)


Terrain coverage
Confident coverage
2018
2019-1
2019-2
Total coverage
2018
2019-1
2019-2
Ground Control Points
Base station
GCPs 2018
GCPs 2019-1
GCPs 2019-2
0
200
400 m

MOTIVATION

Aims

- Derive area displacement rates
- Identify regions of homogenous movement

Issues

- Ground control point distribution
- Model periphery
- Accuracy assessment

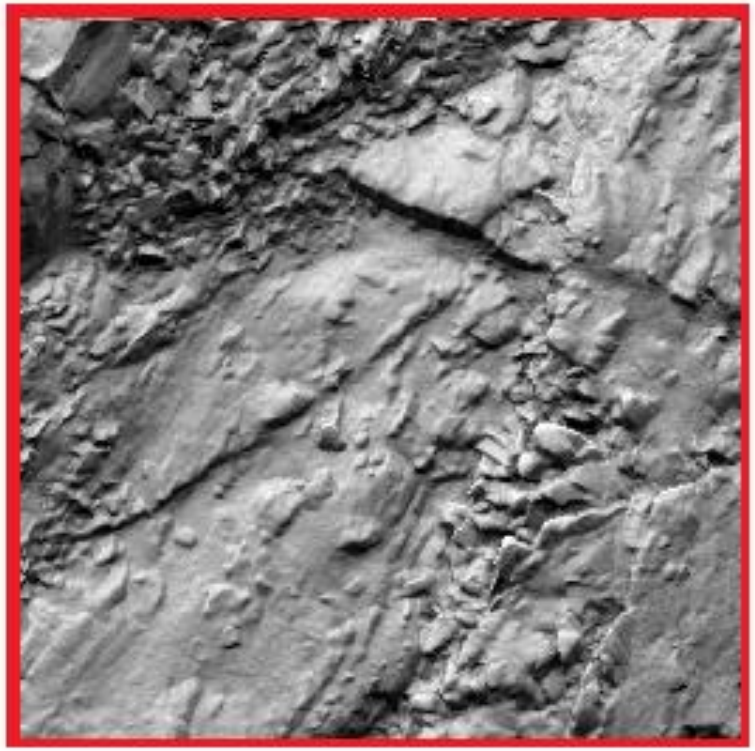
IMCORR ALGORITHM

- Fast-Fourier-Transformation of 2D Raster (harmonics domain)
- Phase shifting (X/Y) to fit best correlation
- Sub-pixel fitting possible

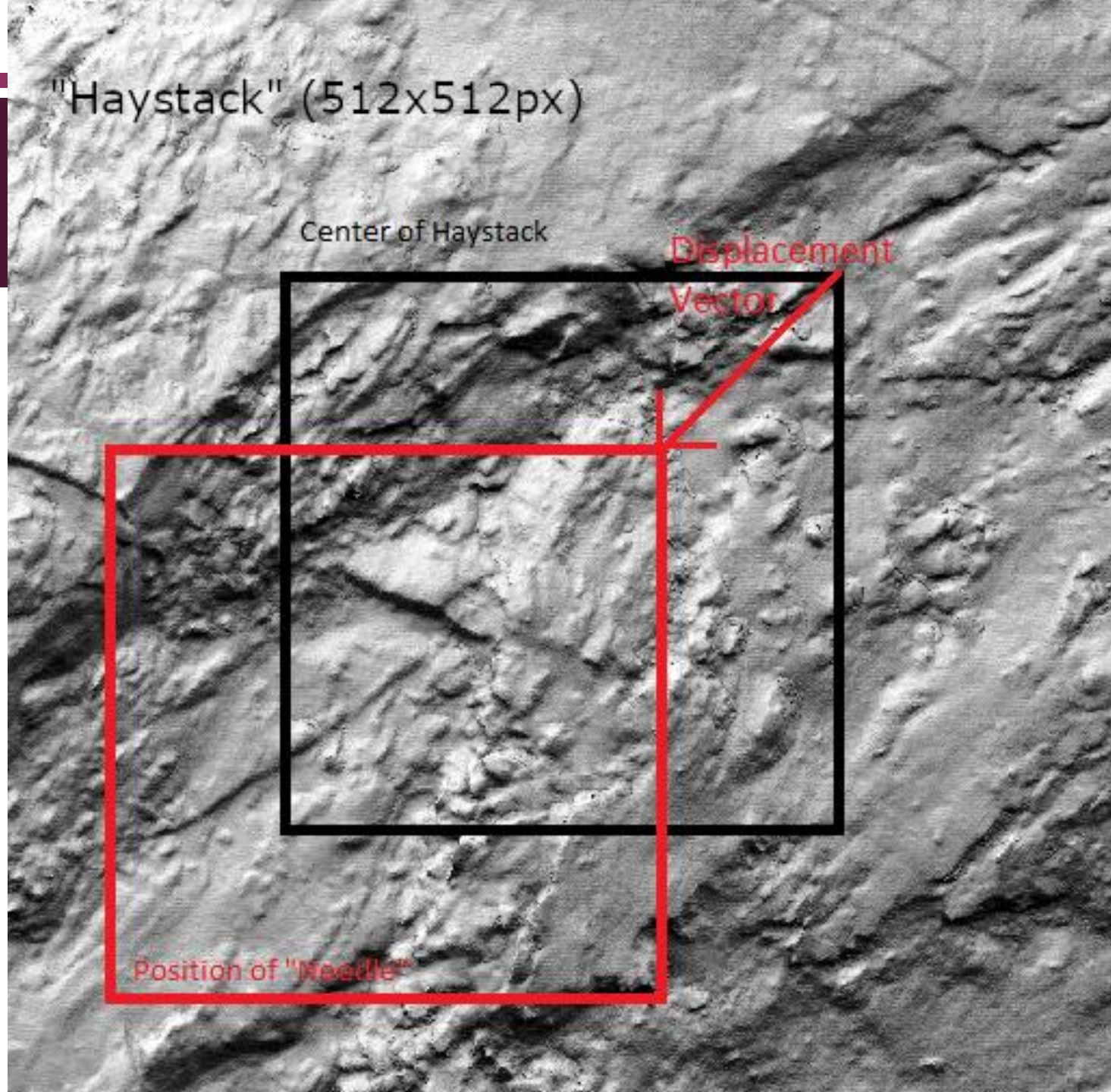
Input alternatives:
Hillshade
Orthophoto
Roughness
(…)

IMCORR ALGORITHM

"Needle" (256x256px)



Note: Actual FFT-transformed signal not shown



PROCESSING

Point cloud + DEM

- Agisoft Metashape:
  Creation of pointclouds and DEM

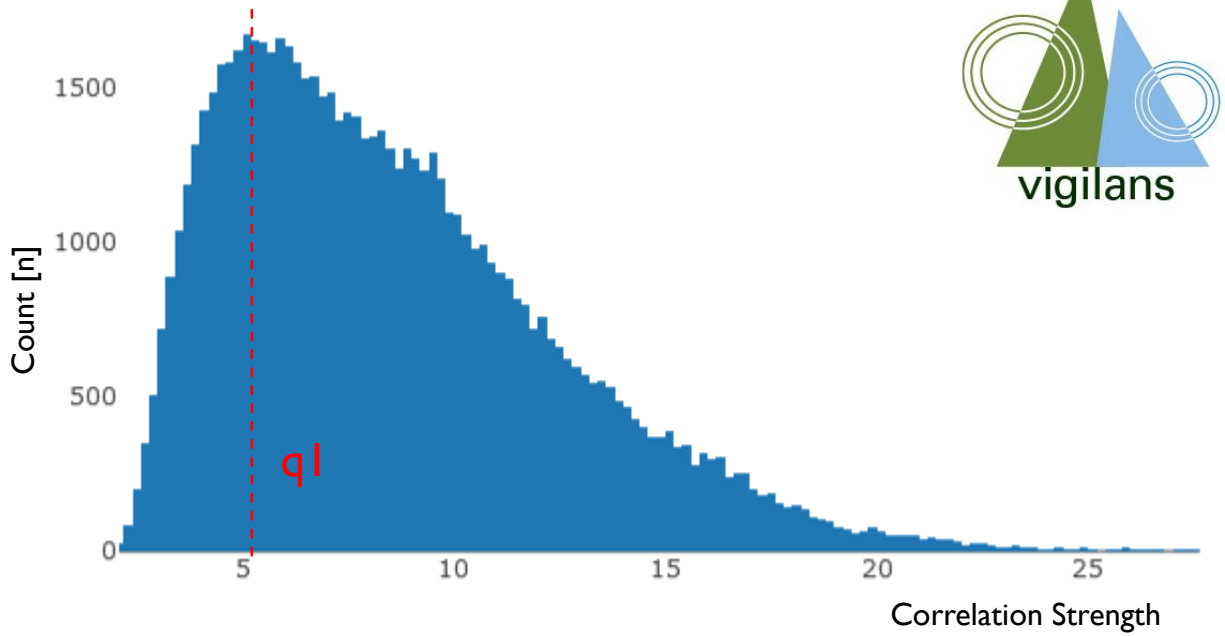
Hillshade raster
IMCORR vectors

- SAGA-GIS:
  Creation of hillshades
  IMCORR

Displacement vectors and derived rasters

- QGIS (+ GDAL,SAGA-GIS):
  Filtering
  Identification of homogenous regions

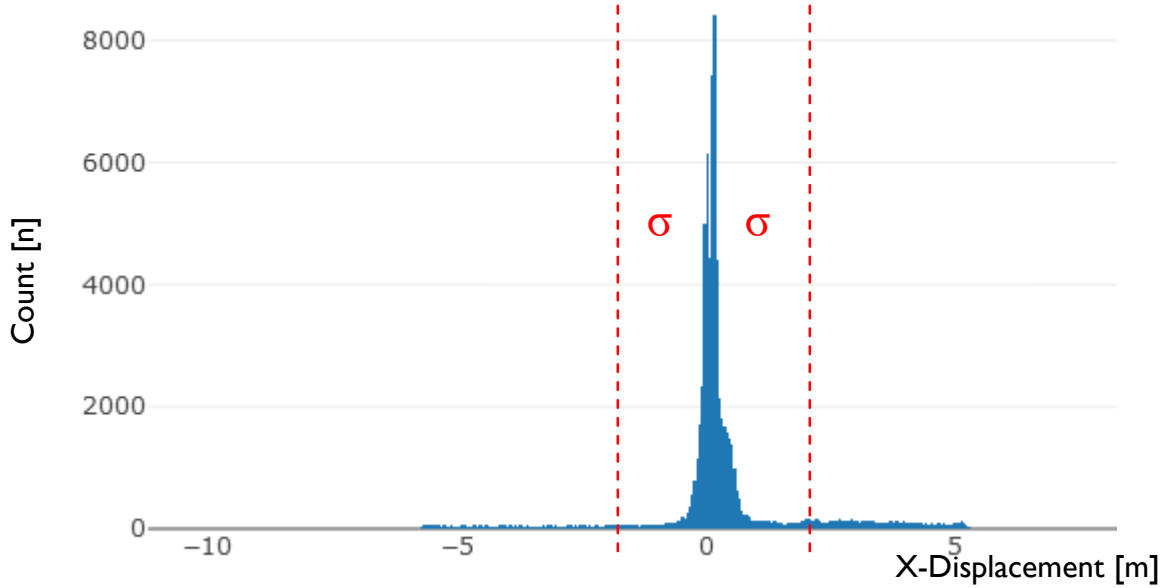
IMCORR STEP 1

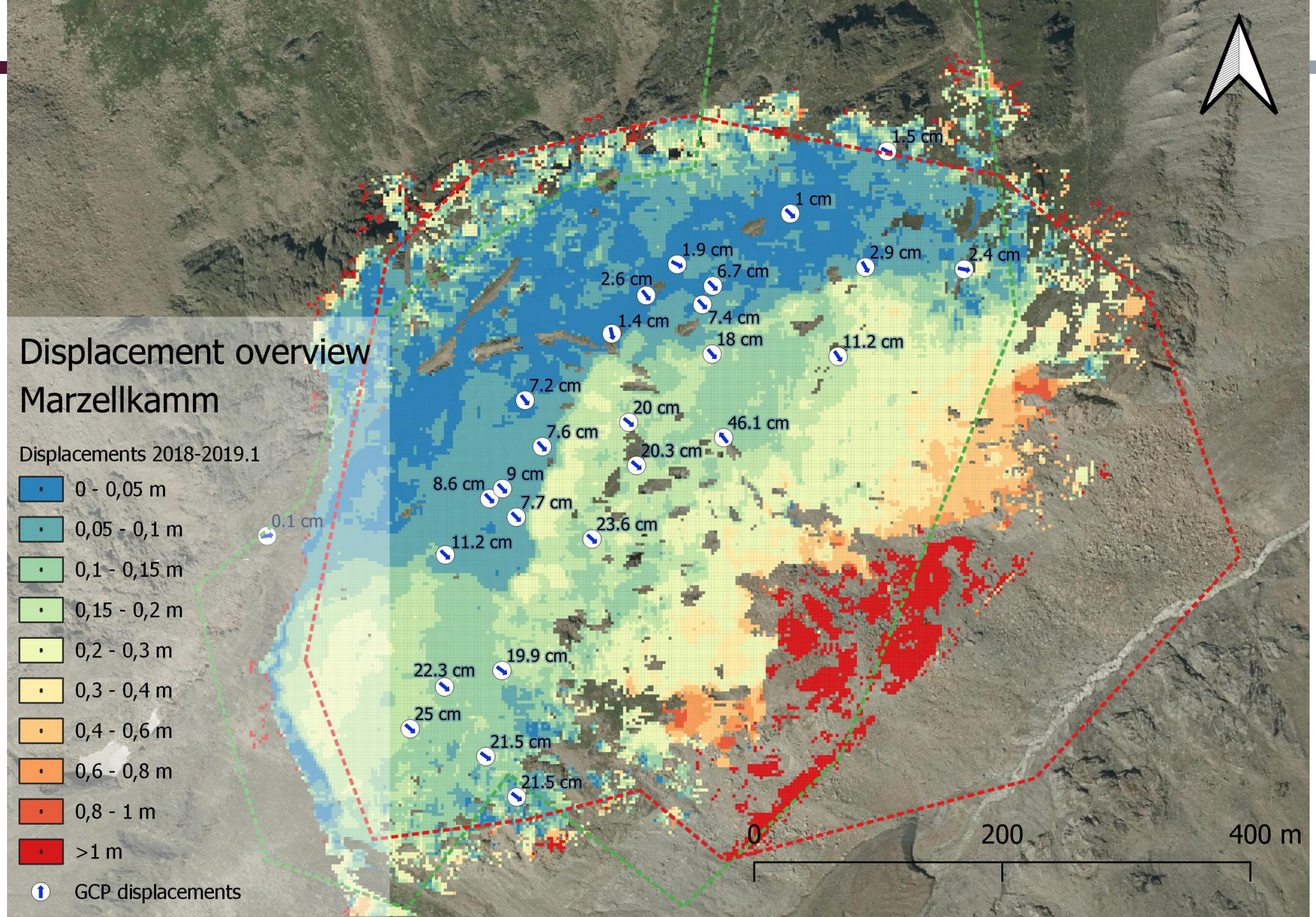


Correlate DEMs

Filter out weak and unplausible correlations
(low strength, very large movements)

-> Holes: large, incoherent surface movement

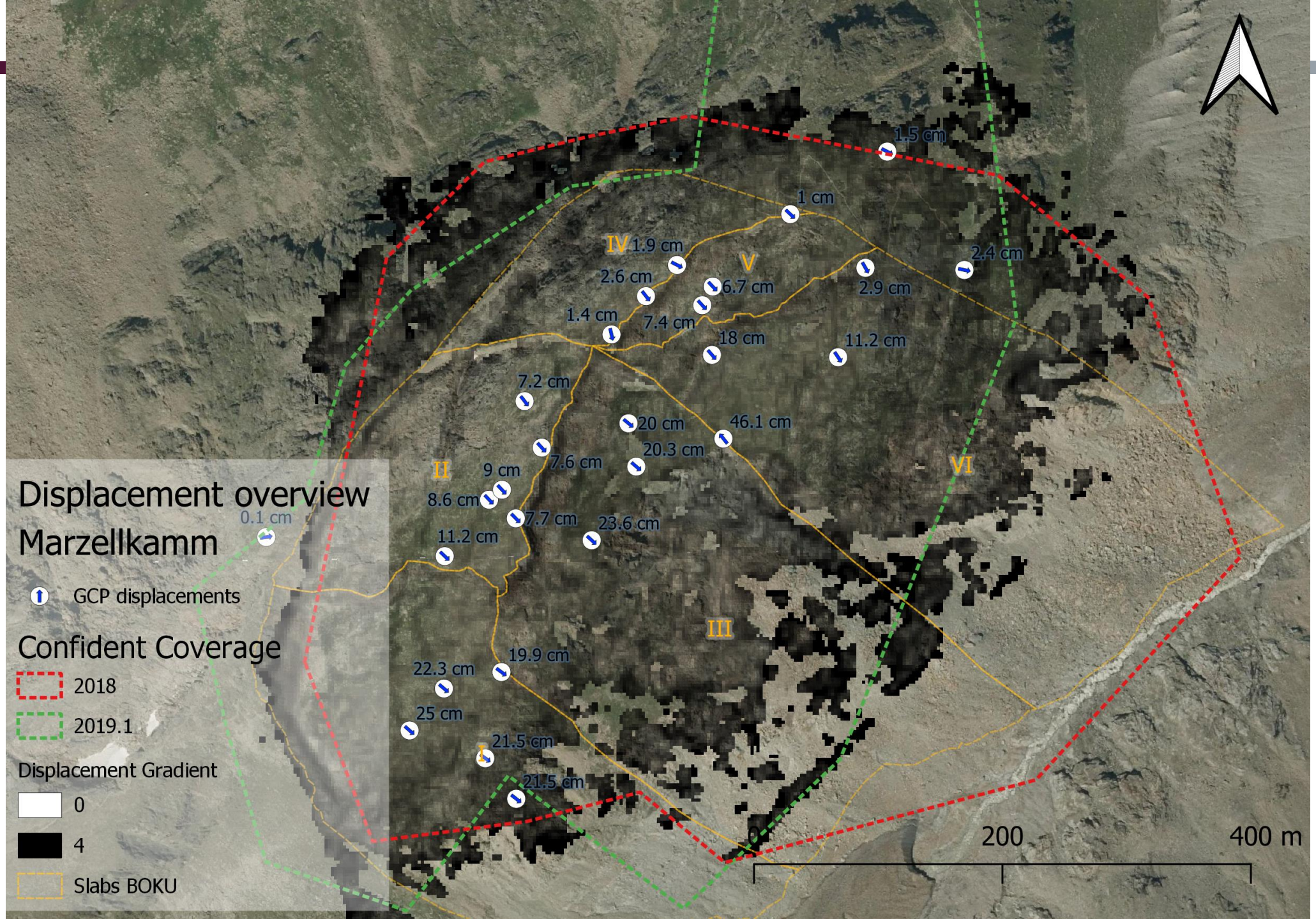


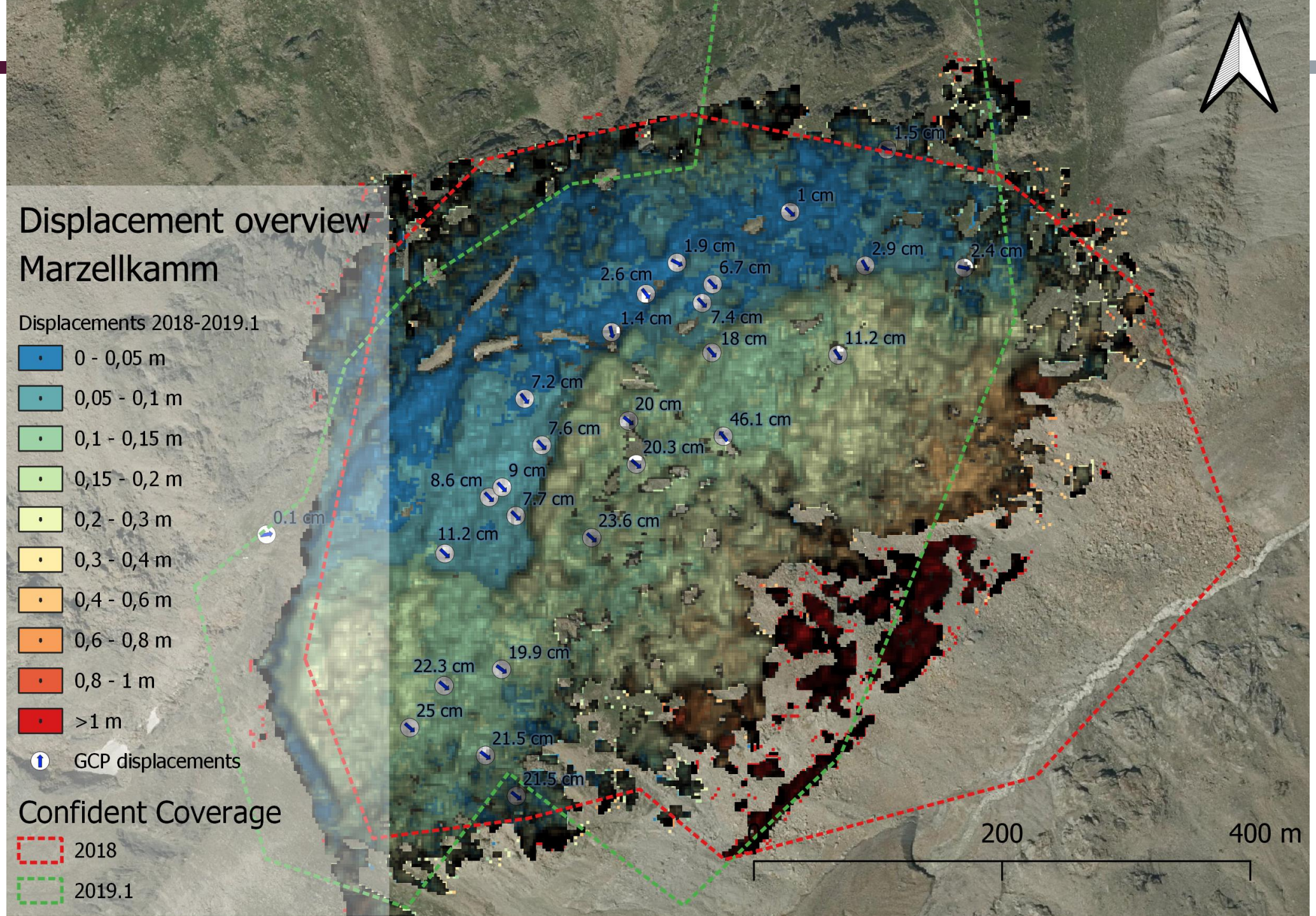

Displacement overview
Marzellkamm
Displacements 2018-2019.1
0 - 0,05 m
0,05 - 0,1 m
0,1 - 0,15 m
0,15 - 0,2 m
0,2 - 0,3 m
0,3 - 0,4 m
0,4 - 0,6 m
0,6 - 0,8 m
0,8 - 1 m
>1 m
GCP displacements
1.5 cm
1 cm
1.9 cm
2.9 cm
2.4 cm
2.6 cm
6.7 cm
1.4 cm
7.4 cm
18 cm
11.2 cm
7.2 cm
20 cm
46.1 cm
7.6 cm
20.3 cm
8.6 cm
9 cm
7.7 cm
0.1 cm
23.6 cm
11.2 cm
19.9 cm
22.3 cm
25 cm
21.5 cm
21.5 cm
0
200
400 m

IMCORR STEP 2

Transformation: XY Displacement to gradient

Bright: homogenous region – coherent slab?
Dark: inhomogenous region – border between slabs?


Displacement overview
Marzellkamm
GCP displacements
Confident Coverage
2018
2019.1
Displacement Gradient
0
4
Slabs BOKU
0.1 cm
1.5 cm
1 cm
IV
1.9 cm
V
2.6 cm
6.7 cm
2.9 cm
2.4 cm
1.4 cm
7.4 cm
18 cm
11.2 cm
7.2 cm
20 cm
46.1 cm
20.3 cm
7.6 cm
II
9 cm
8.6 cm
7.7 cm
23.6 cm
11.2 cm
VI
III
19.9 cm
22.3 cm
25 cm
21.5 cm
21.5 cm
0
200
400 m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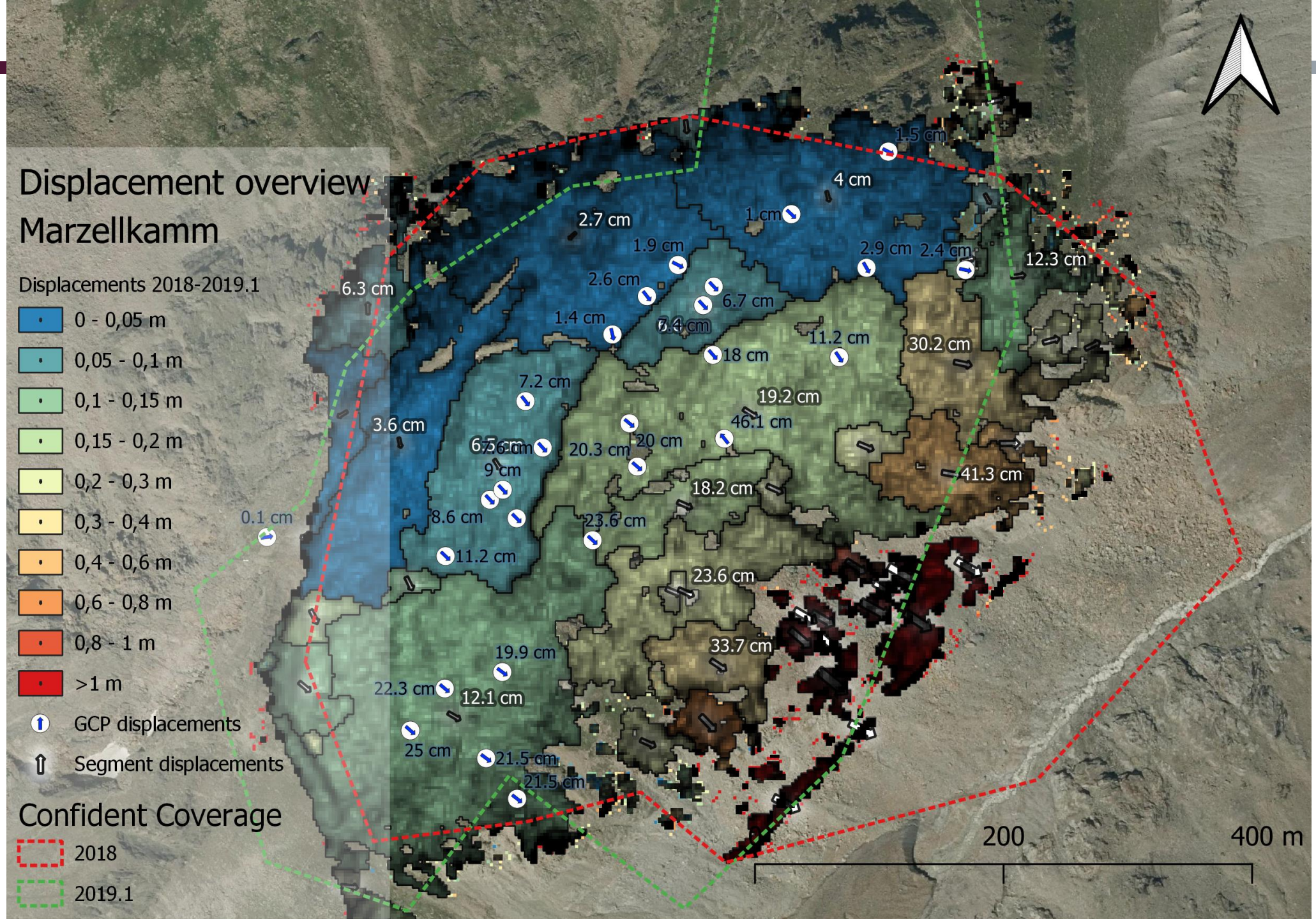
0,3 - 0,4 m
0,4 - 0,6 m
0,6 - 0,8 m
0,8 - 1 m
>1 m
GCP displacements
Confident Coverage
2018
2019.1
1.5 cm
1 cm
1.9 cm
2.9 cm
2.4 cm
2.6 cm
6.7 cm
1.4 cm
7.4 cm
18 cm
11.2 cm
7.2 cm
20 cm
46.1 cm
7.6 cm
20.3 cm
8.6 cm
9 cm
7.7 cm
0.1 cm
23.6 cm
11.2 cm
19.9 cm
22.3 cm
25 cm
21.5 cm
21.5 cm
200
400 m

vigilans

IMCORR STEP 3

- Segmentation (Watershed – treat dark regions as separating ridges)
- Combine Displacement information within segment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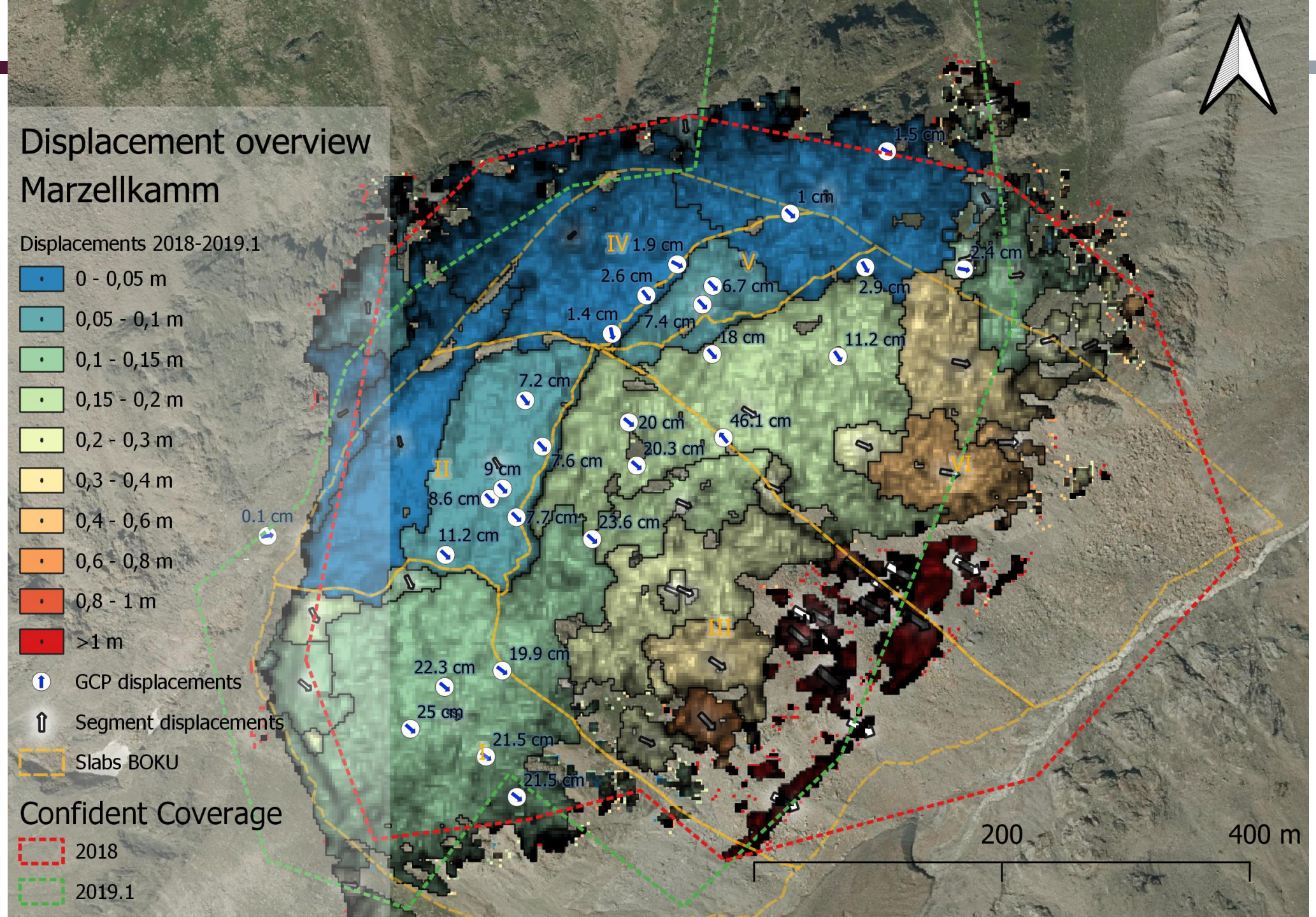
0 - 0,05 m
0,05 - 0,1 m
0,1 - 0,15 m
0,15 - 0,2 m
0,2 - 0,3 m
0,3 - 0,4 m
0,4 - 0,6 m
0,6 - 0,8 m
0,8 - 1 m
>1 m
GCP displacements
Segment displacements
Confident Coverage
2018
2019.1
1.5 cm
4 cm
2.7 cm
1 cm
1.9 cm
2.9 cm
2.4 cm
12.3 cm
6.3 cm
2.6 cm
6.7 cm
1.4 cm
6.4 cm
11.2 cm
30.2 cm
18 cm
7.2 cm
19.2 cm
3.6 cm
46.1 cm
20 cm
20.3 cm
9 cm
41.3 cm
18.2 cm
0.1 cm
8.6 cm
23.6 cm
11.2 cm
23.6 cm
33.7 cm
19.9 cm
22.3 cm
12.1 cm
25 cm
21.5 cm
21.5 cm
200
400 m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0,2 - 0,3 m
0,3 - 0,4 m
0,4 - 0,6 m
0,6 - 0,8 m
0,8 - 1 m
>1 m
GCP displacements
Segment displacements
Slabs BOKU
Confident Coverage
2018
2019.1
I
II
III
IV
V
VI
0.1 cm
1.5 cm
1 cm
1.9 cm
2.6 cm
6.7 cm
2.9 cm
2.4 cm
1.4 cm
7.4 cm
18 cm
11.2 cm
7.2 cm
20 cm
46.1 cm
20.3 cm
9 cm
7.6 cm
8.6 cm
7.7 cm
23.6 cm
11.2 cm
19.9 cm
22.3 cm
25 cm
21.5 cm
21.5 cm
200
400 m

Pre-Processing

Agisoft: Generation of High-Quality Point Cloud

Based on Point Cloud:

- DEM
- Analytical Hillshade (Ambient Occlusion)

Derivation of displacement rates

IMCORR matching:

128x128px in 256x256px using Hillshade.
sampling DEM for Z-values

Filtering erroneous matching:
Strength > q1, X/Y-Displacements within 2σ

Grouping / Segmentation

Combination of x/y-Displacement:
z = sqrt(slope(XDISP)^2 + slope(YDISP)^2)

Watershed Segmentation of Displacement raster, threshold = 1.0

Sampling of Displacements per segment (Average of X, Y, Z Displacement)

DISCUSSION POINTS AND OUTLOOK

- Advantages/Disadvantages of larger IMCORR window
- Filtering outliers – statistical approach vs. Handfiltering
- Adapting for vertical movements – „IMCORR3D“?