Acquisition of UAV based LiDAR Point Clouds and Change Detection for Monitoring purposes

Frederic Petrini-Monteferri, Laserdata GmbH

User Workshop
7.12.2021
Webconference

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LASERDATA GmbH project inputs (1)

- **WP 2: Space and Airborne Remote Monitoring**

Task 2.3: Refinements and Final Development of Monitoring System

System developed in cooperation with the University of Innsbruck / Department of Geography

- **Carrier platform RiCOPTER**
- **VUX-1LR LiDAR Sensor**

Processing System Chain:

- **Flight planning**
- **Trajectory correction**
- **Flight strip adjustment**
- **Project oriented managing of UAV LiDAR data (RiPROCESS, RiPRECISION, Laserdata LIS)**

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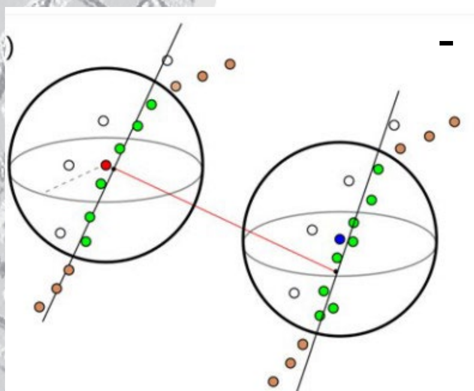
LASERDATA GmbH project inputs (3)

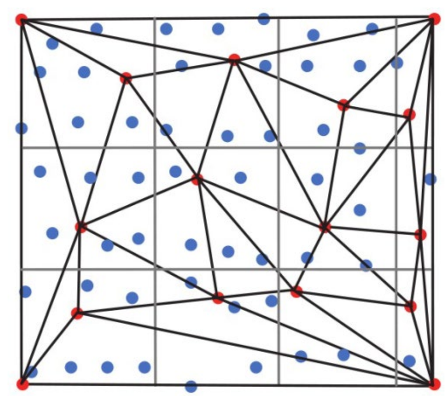
- **WP 4: Monitoring Data Analysis and Modelling**

Task 4.5: Validation and Refinement of Data Analysis and Change Detection Methods:

Adaptation of the analysis system to UAV based change detection and quantification

- **Integration of additional packages (e.g. structural geology)**
- **Derivation of pole plots, joint planes, discontinuity spacings**
- **Change detection tools based on**
  - **Point cloud to point cloud comparison**
  - **Point cloud to TIN comparison**
  - **Raster to raster comparison**
  - **Break line detection tools**





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European Commission

Research Fund for Coal & Steel

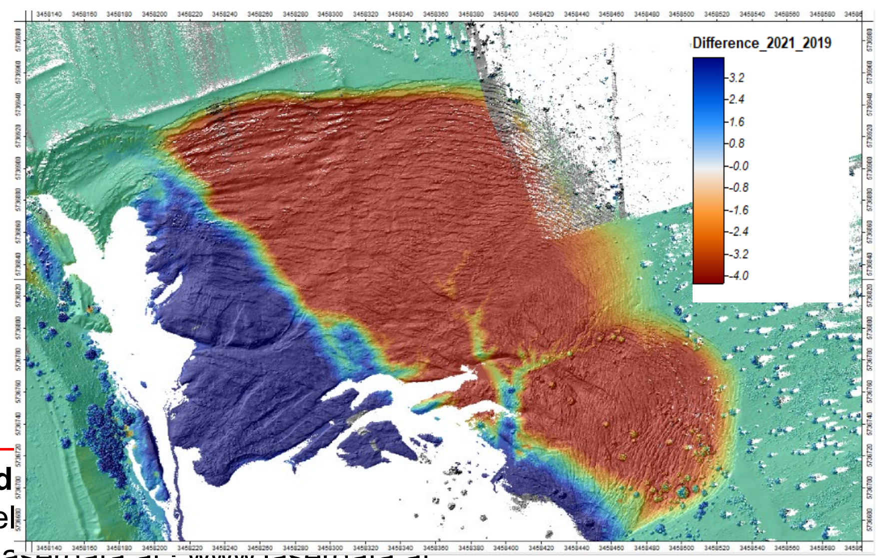
LASERDATA GmbH project inputs (3)

- **WP 6: Monitoring System Application**

  Task 6.2: Initial Application of the Monitoring Systems at Test Site Cottbuser Ostsee

  Task 6.3: Final Application of the Optimized Monitoring Systems at Test Site Cottbuser Ostsee

  - **UAV based flight campaigns and data analysis**



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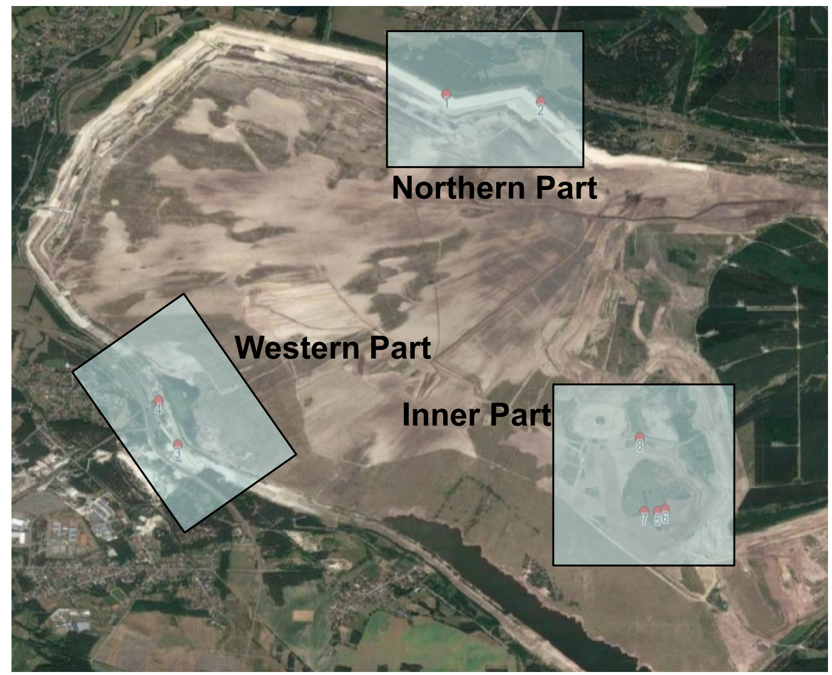
Drone based LiDAR data acquisition

UAV based flight campaigns at LEAG test site Cottbuser Ostsee

- 1st campaign: special permission to fly had to be acquired from the aviation authority Berlin-Brandenburg
- 1st campaign: based on UAV descriptions and licenses, pilot certificates, insurance documents, declaration of consent from LEAG, specific operational risk assessment documents as well as planned starting locations and distances to restricted areas.
- 2nd campaign: renewal of declaration of consent from LEAG for data acquisition was sufficient



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- **Data acquisitions on 26.11.2019 and 7.10.2021**
  - **7 flights from 8:00 a.m. to 16:00 p.m. each campaign**
  - **Flight height approx. 40m AGL**
  - **Flight speed: 8m/s**
  - **Pulse repetition rate 820kHz**
  - **Average footprint on the ground: 3 to 6cm**
  - **From 1 flight of inner part on 7.10.2021 no point cloud could be produced**

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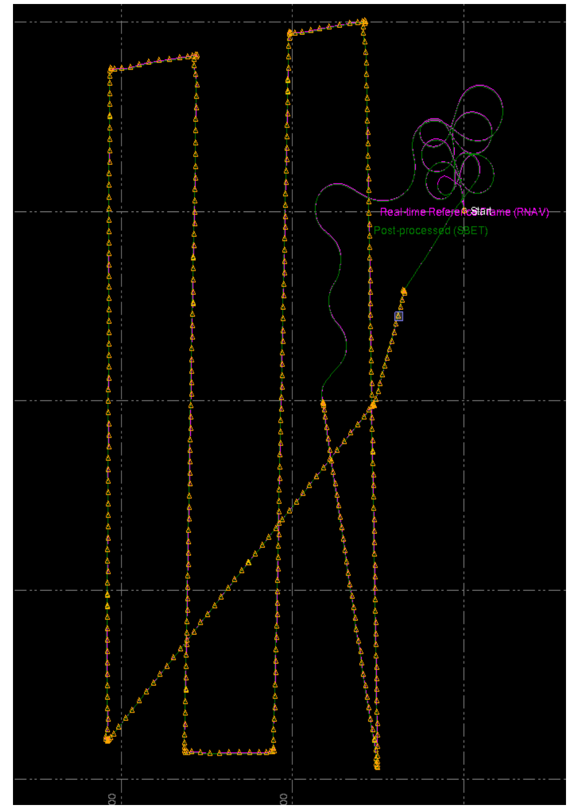
- **Data processing – Trajectory correction**

  - **The trajectories acquired by the Applanix AP20 System (Integrated Inertial Measurement and GNSS Unit) on board the RiCopter MultiCopter were processed with Applanix POSPAC.**

  - **Trajectory post-processing was aided by 1s-Interval RINEX data of the SAPOS-reference station in Cottbus (0014). The same workflow was conducted for all seven flights conducted during the campaigns 2019 / 2021.**

  - **Estimated trajectory accuracies: approx. 2cm**



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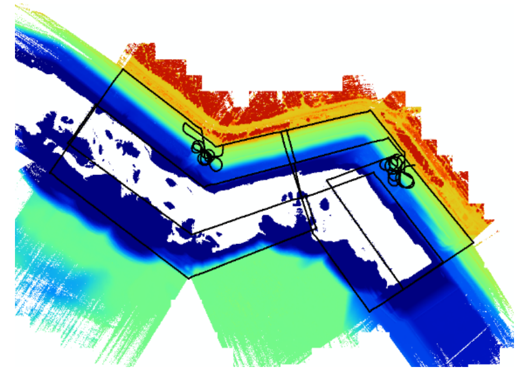
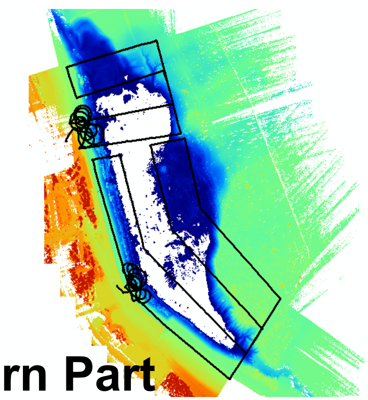
- **Basic Point Cloud Processing with Riegl RiProcess**

  - **The three sub areas of the project (north = 2 flights, west = 2 flights, inner = 3 flights) were organized in three RiProcess projects for each flight campaign 2019 and 2021.**

  - **point extraction into WGS84 Geocentric Coordinates was applied, using a Full-Wave-Form decomposition method implemented in the Package RiAnalysis within RiProcess.**

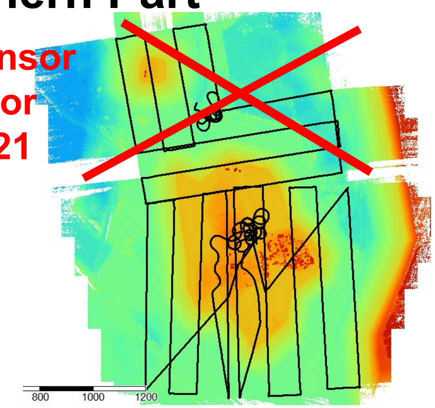


Northern Part



Western Part

Sensor error 2021



Inner Part

- ❖ **2019 roughly 1.2 billion points**
- ❖ **2021 750 million due to higher water level (no data areas) and one flight with sensor error**

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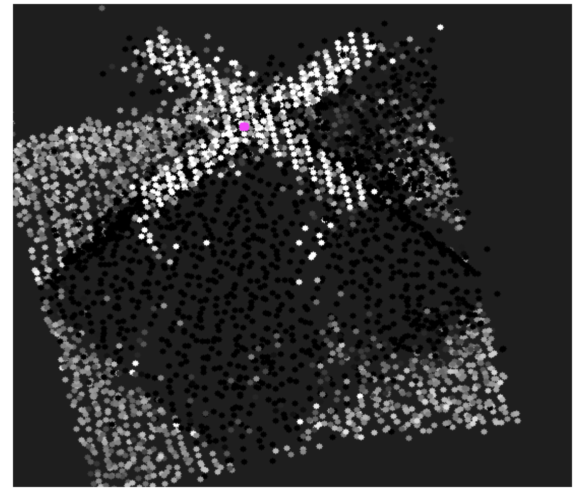
- **Strip Adjustment and Georeferencing**

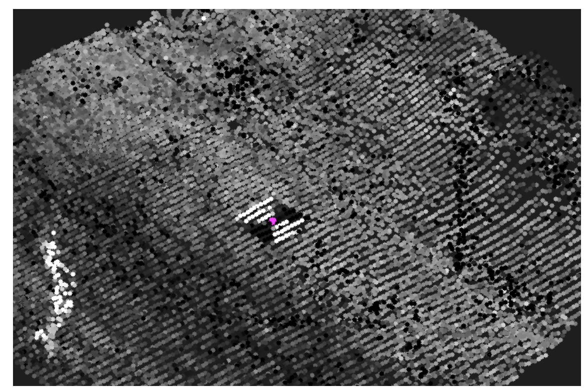
  - **For the three sub areas a strip adjustment was conducted using the package RiPrecision in RiProcess (2019/2021).**

  - **The three sub areas were merged into a single project and fine geo-referenced considering the pass point positions given by LEAG in ETRS89 coordinates. In LIS Pro 3D, the point clouds were cleaned and outliers were removed (2019/2021).**

  - **Mean distance to tiepoints: 4 cm**



Tiepoints examples



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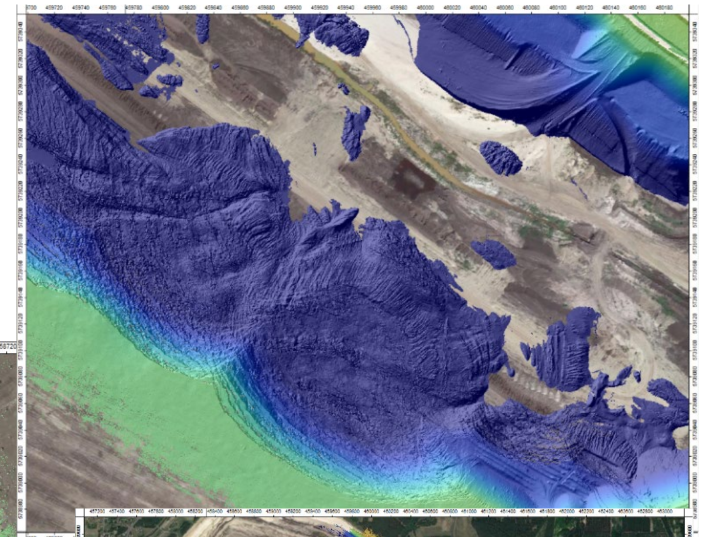
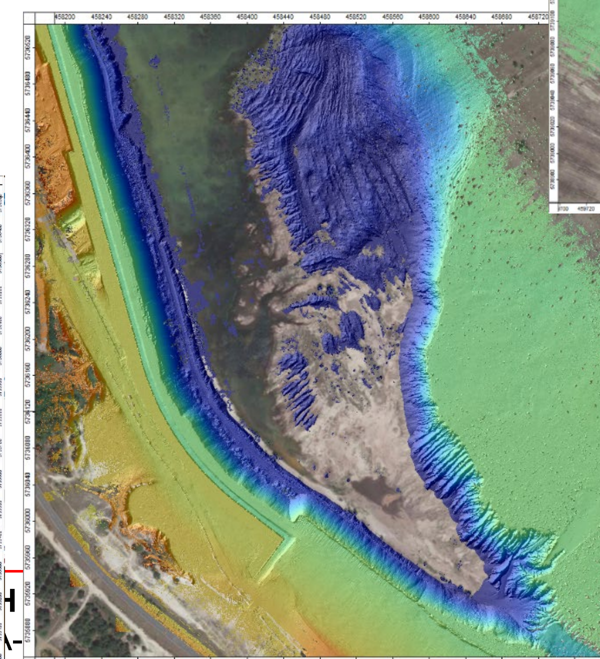
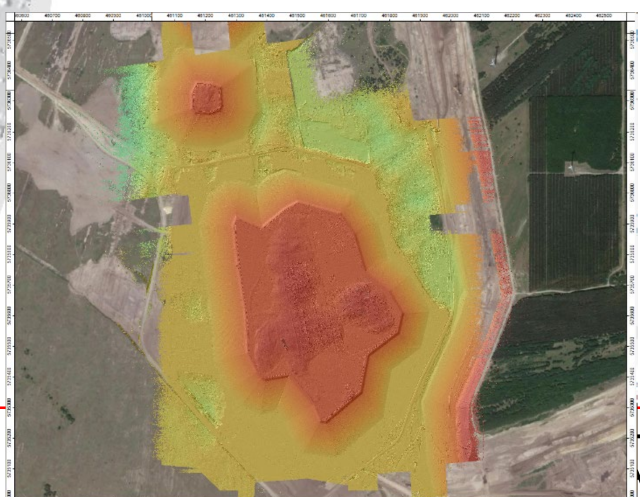
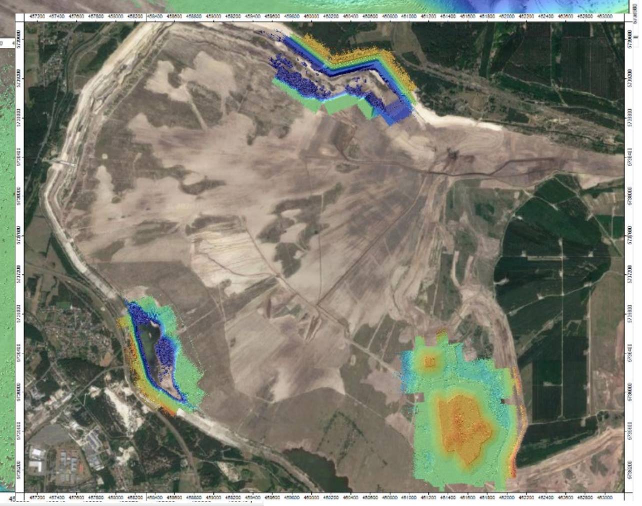
- **Point cloud classification, DTM generation**
  - **For the three sub areas each, a slope adaptive ground classification is performed within LIS Pro 3D (2019/2021).**
  - **Point Cloud to raster conversion with 25cm resolution**
  - **Export to GeoTIFF**









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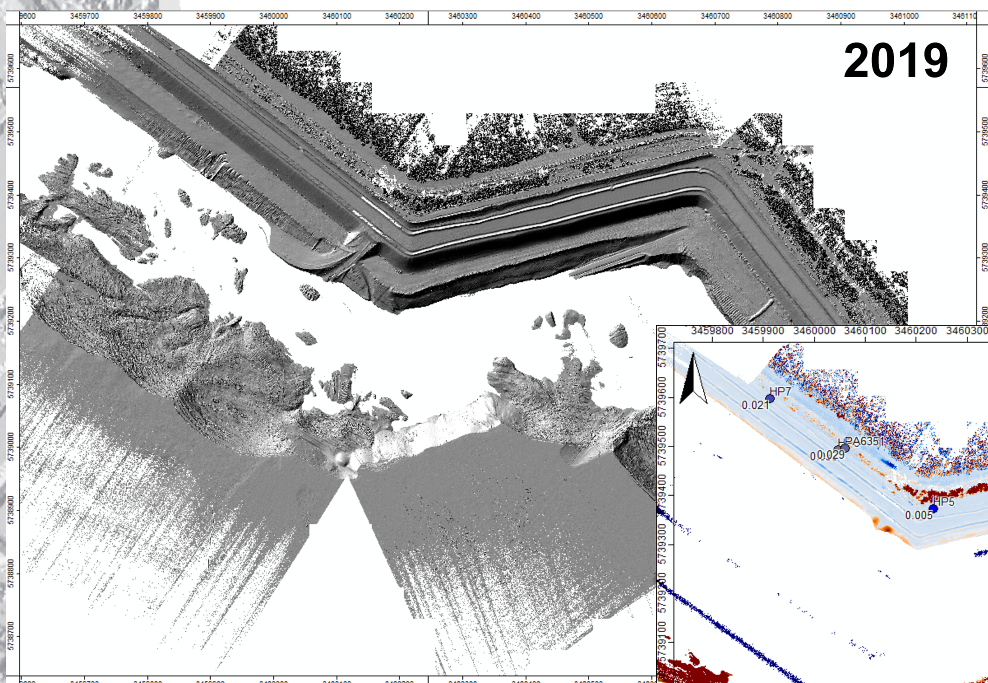
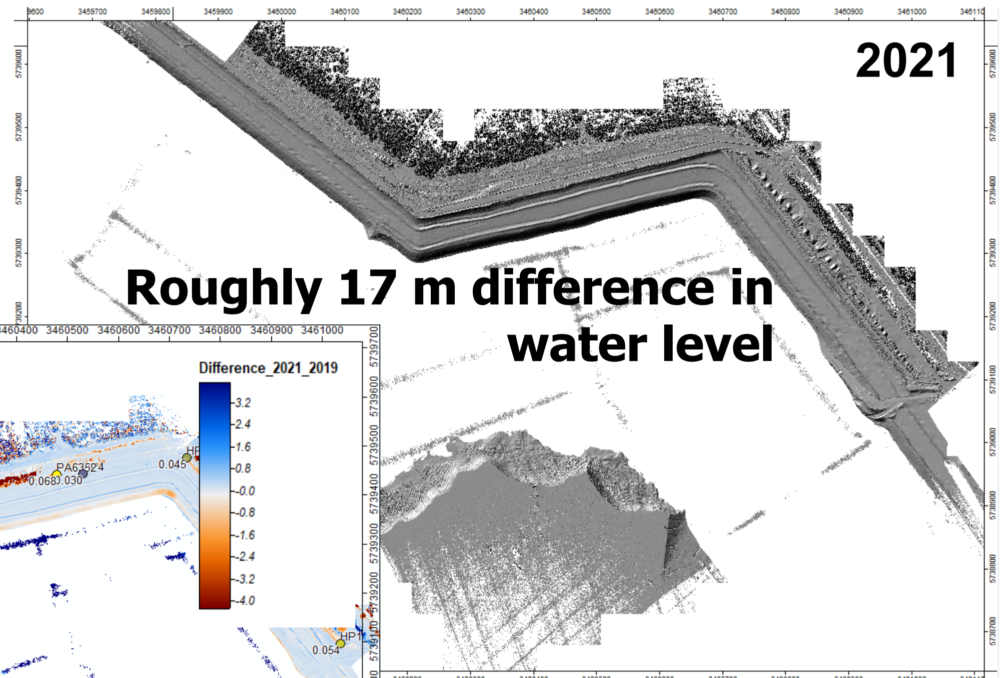
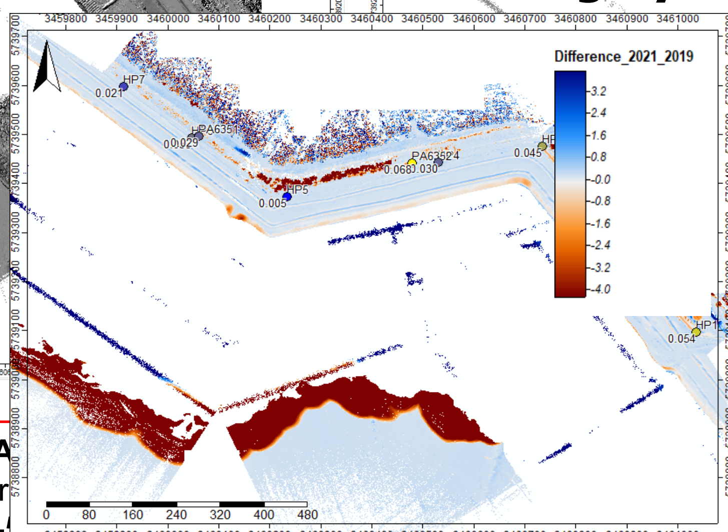
- **Differences 2019-2021**
  - **- Northern Area**





Roughly 17 m difference in water level



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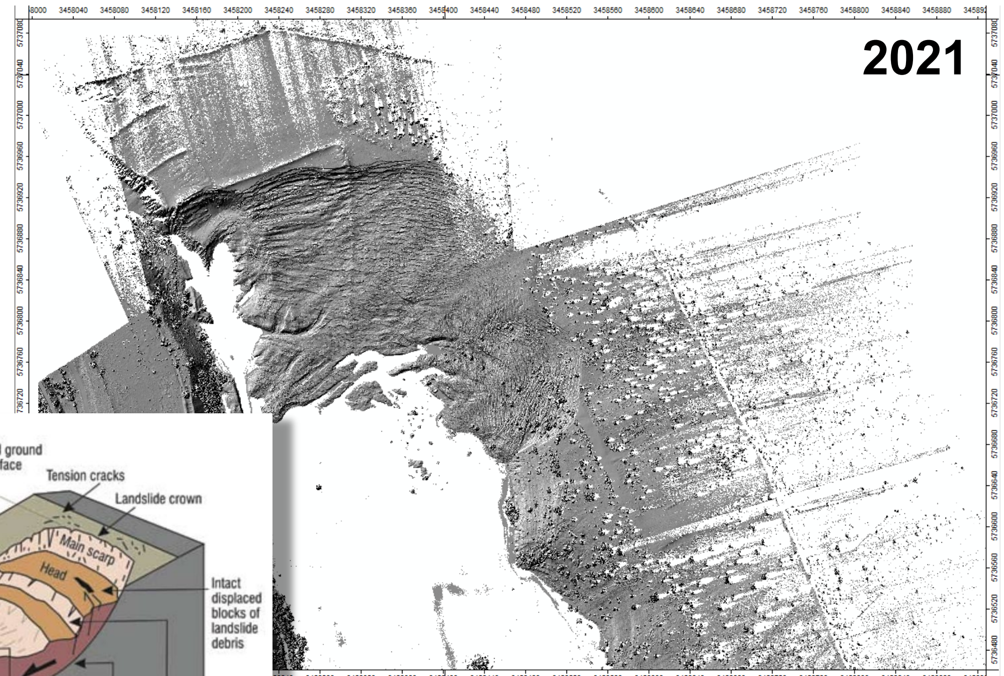
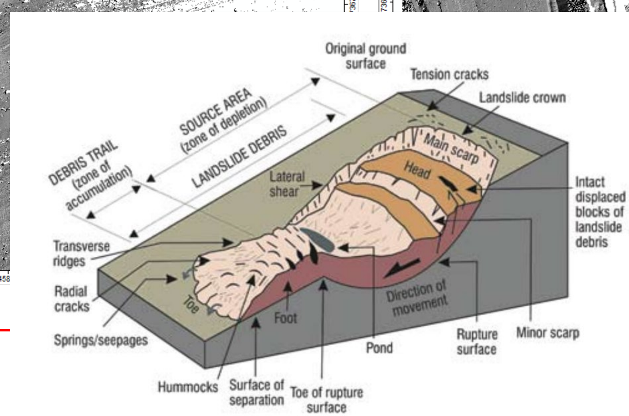
- **Differences 2019-2021**

  - Western Area (Detail 1)





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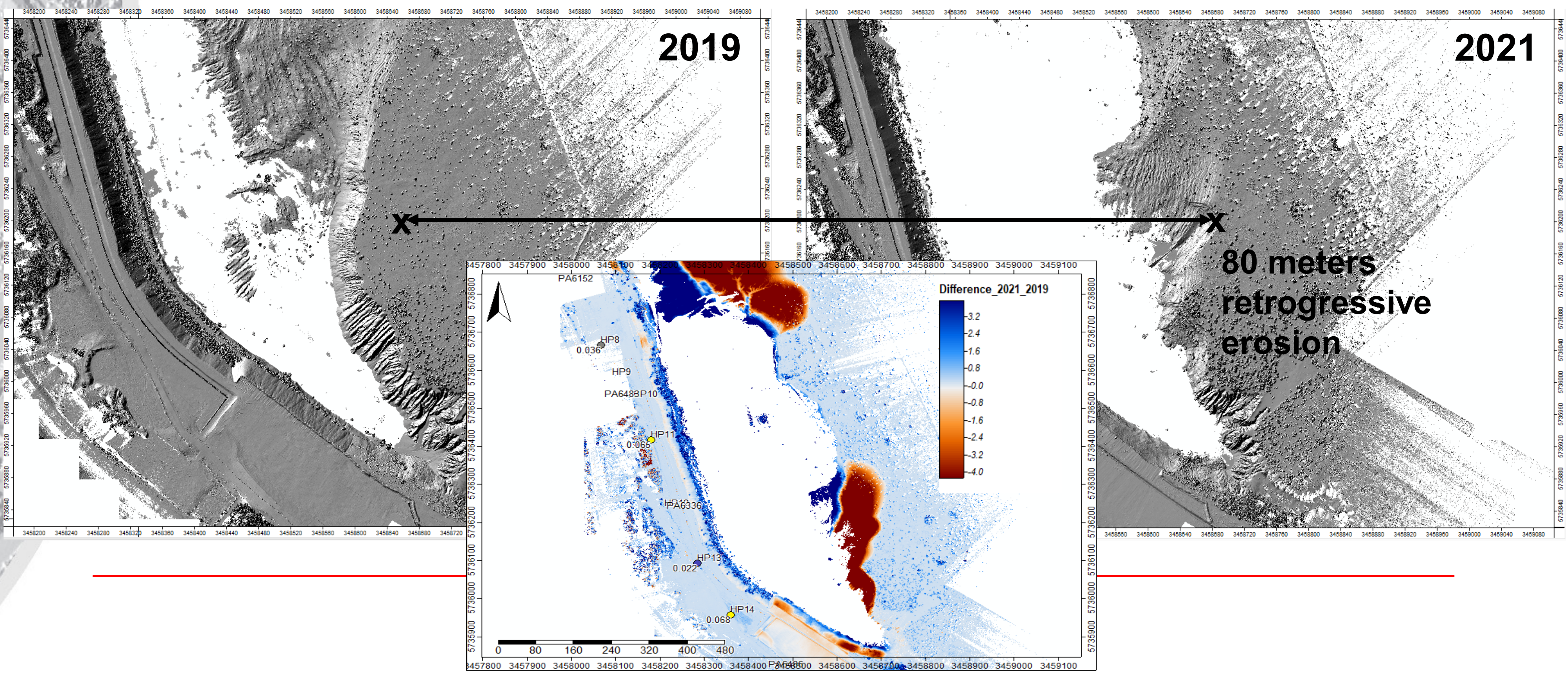
- **Differences 2019-2021**

  - Western Area (Detail 2)



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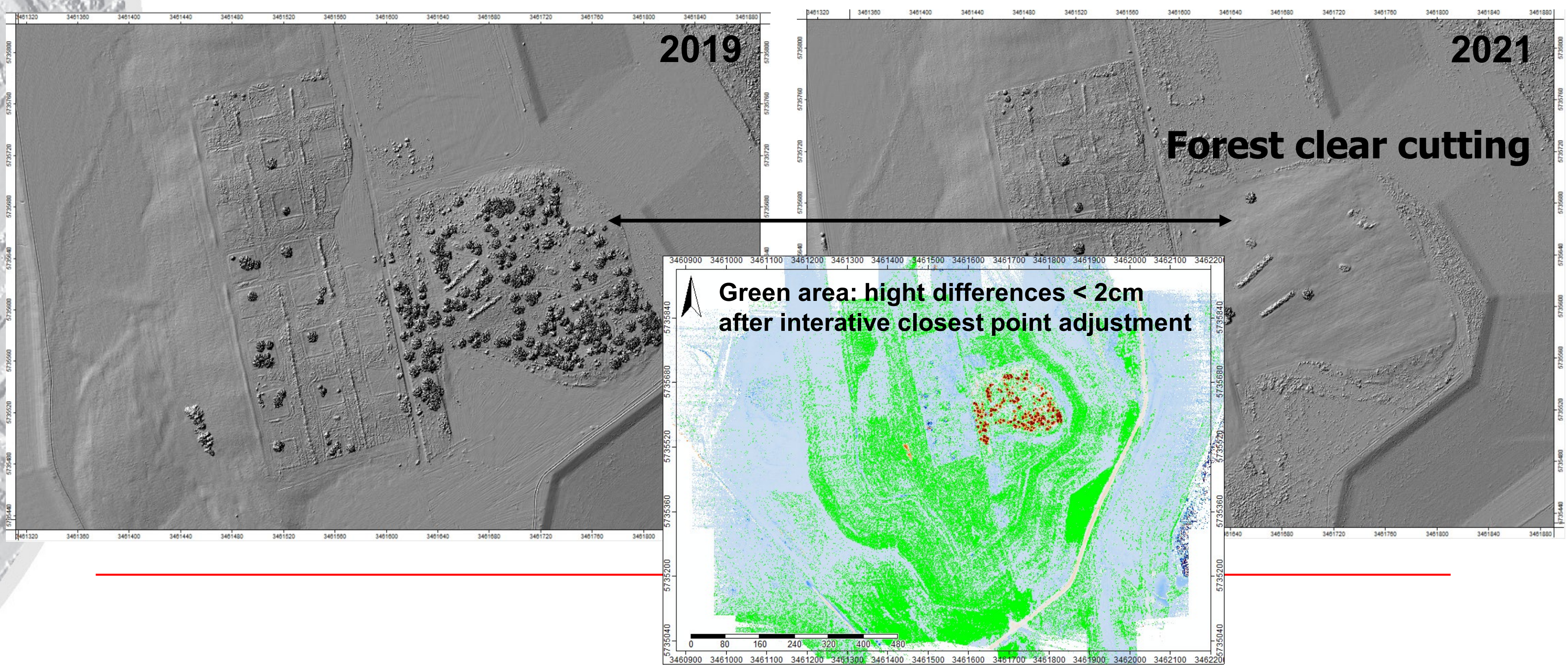
- **Differences 2019-2021**

  - Inner Part



Actual Studies

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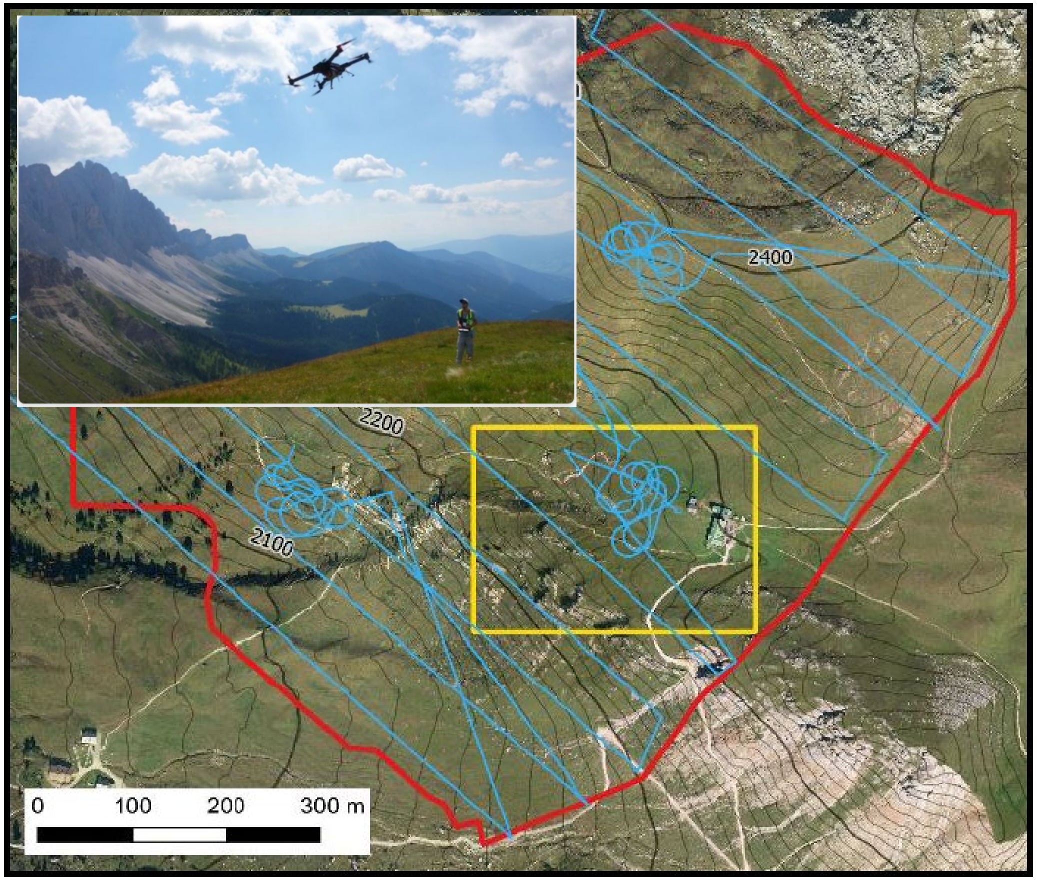
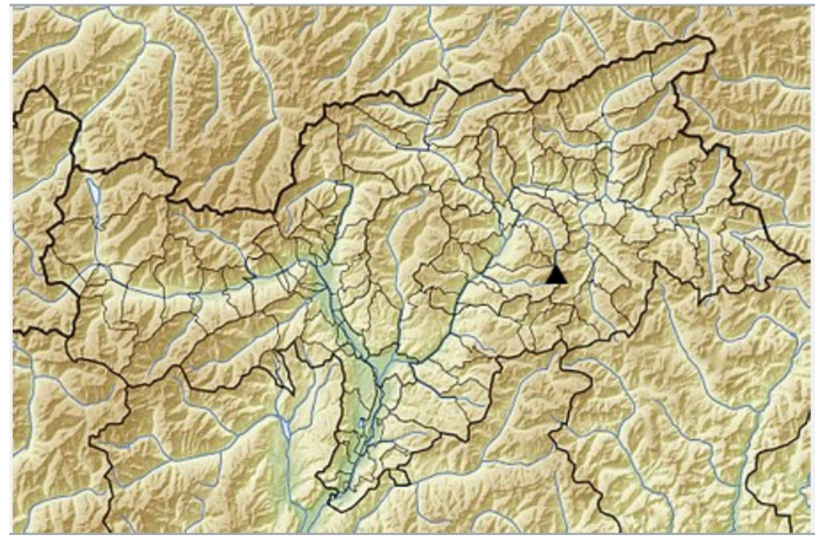


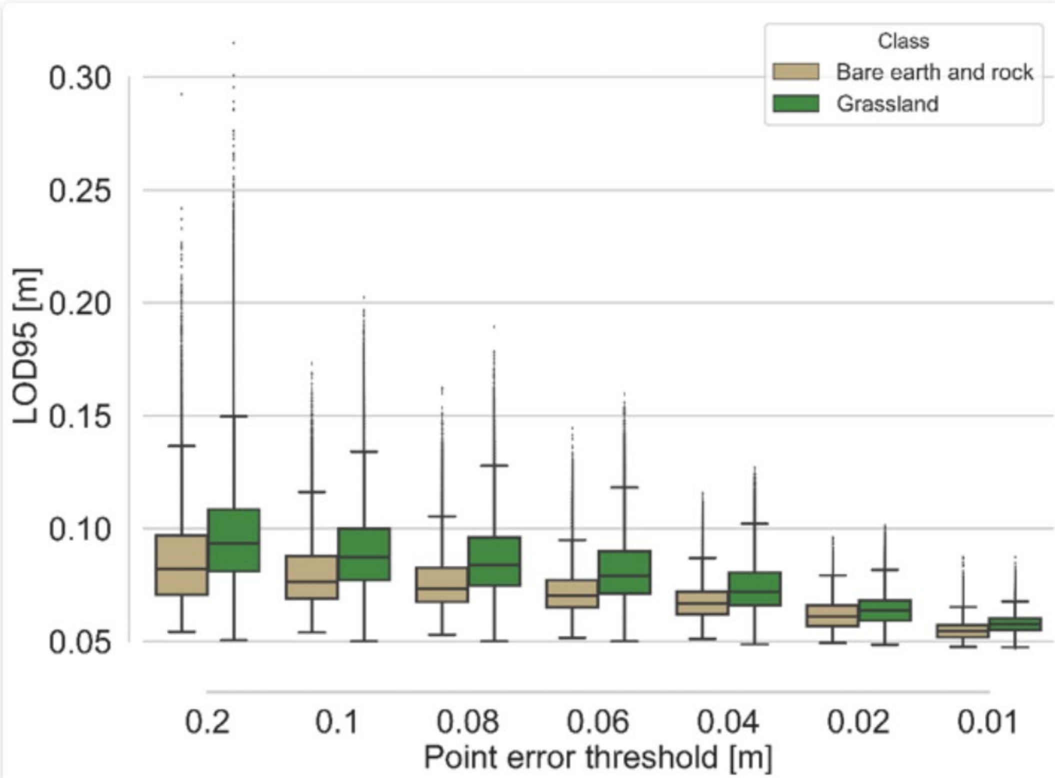
Figure 1. Test site Zendleser Kofel (South Tyrol, Italy) showing the ULS data coverage (red), the flight trajectories from 2019 (blue) and the rectangular test site subset (yellow). Orthophoto and contours: Autonomous Province of Bozen - South Tyrol, 2020)



Zendleser Kofel (South Tyrol) UAV flight campaigns during summer 2019 and 2020

Mayr, A.; Bremer, M.; Rutzinger, M. (2020): 3D point errors and change detection accuracy of unmanned aerial vehicle laser scanning data. In: ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., V-2-2020: 765-772.

Actual Studies



- The level of detection (at the 95%-confidence interval; LOD_{95}) indicates the magnitude of observable changes (e.g. by erosion) using multitemporal point clouds. The LOD_{95} is partly related to the registration error and the surface roughness.

- At some points, additional uncertainties related to laser footprint effects (modelled as a function of range, incidence angle, and beam divergence) affect the LOD_{95} negatively.

- Removing such erroneous points with a point error threshold improves the LOD_{95}; though this comes at the cost of increasingly incomplete point clouds (depending on the threshold).

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Actual Studies

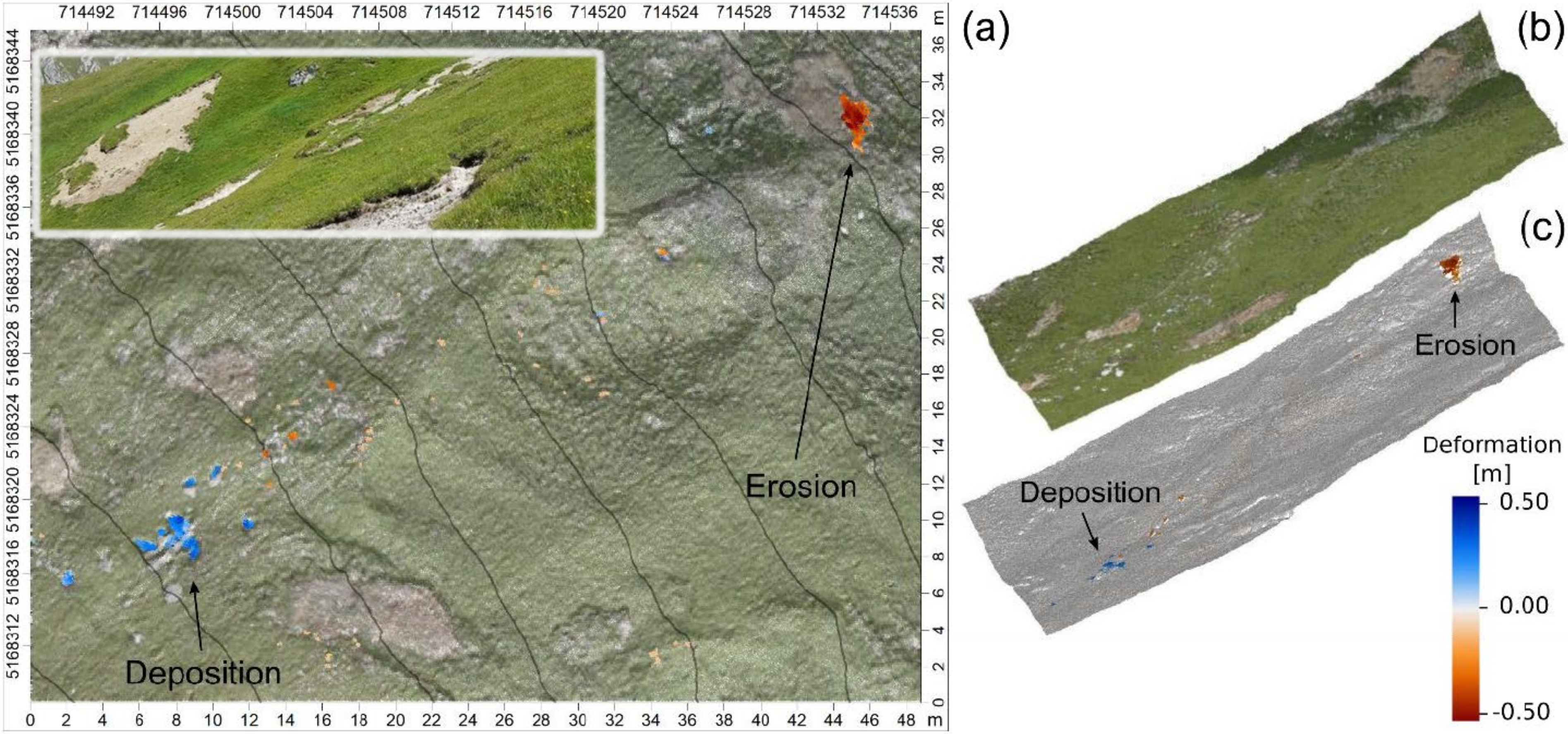
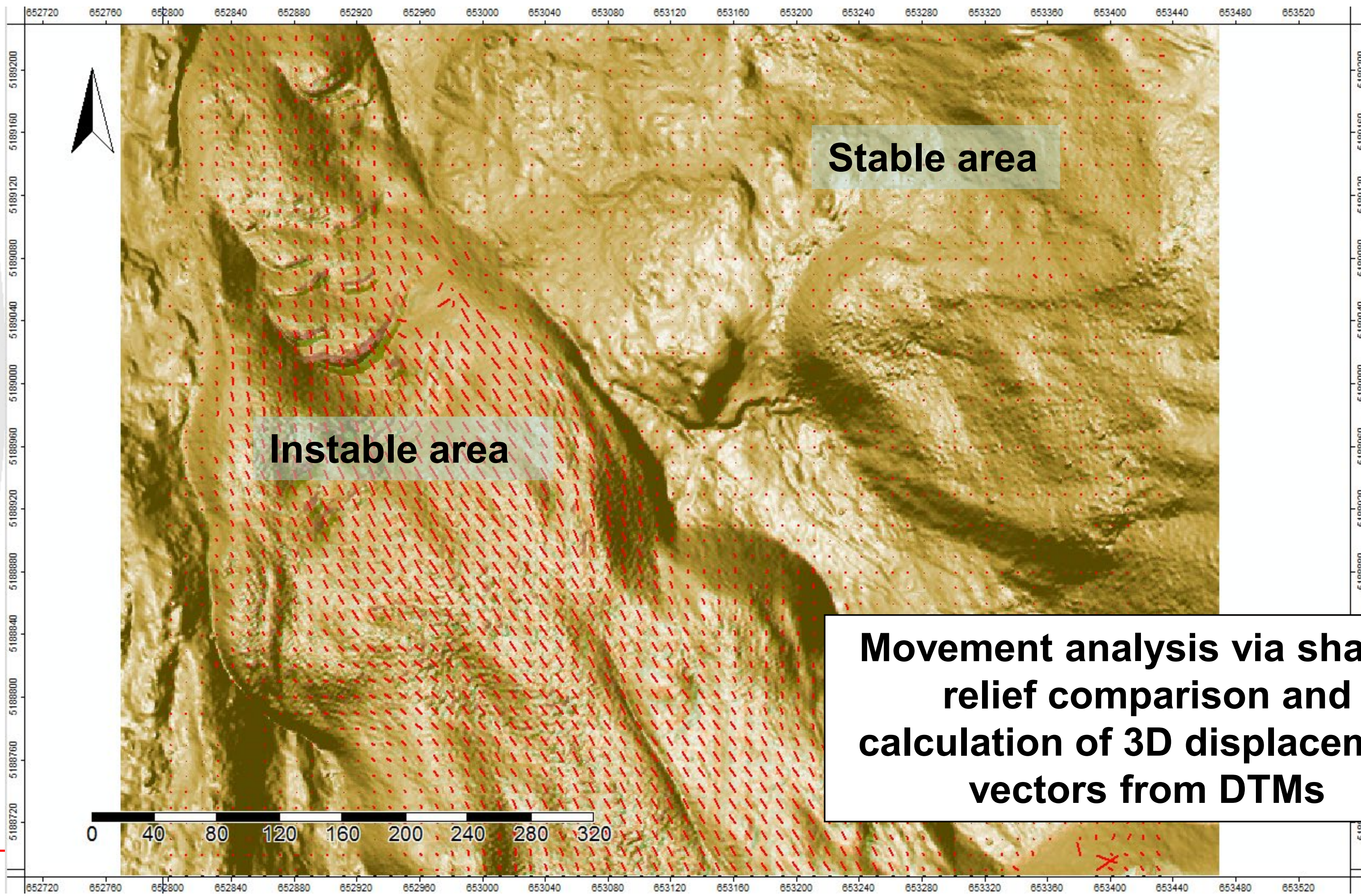


Figure 9. Subset of the test site with surface deformation (3D point cloud distance) due to secondary erosion and deposition of eroded material. (a) Planimetric view of the point cloud coloured by deformation exceeding the LOD_{95}, with RGB coloured point cloud, shaded relief and 5-m contours as background. (b) Oblique view of the RGB-coloured point cloud subset. (c) Oblique view of the point cloud subset, coloured by deformation exceeding the LOD_{95}.

Multi-temporal analyses

Raster to Raster comparison approach (IMCORR)



Movement analysis via shaded relief comparison and calculation of 3D displacement vectors from DTMs

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Multi-temporal analyses

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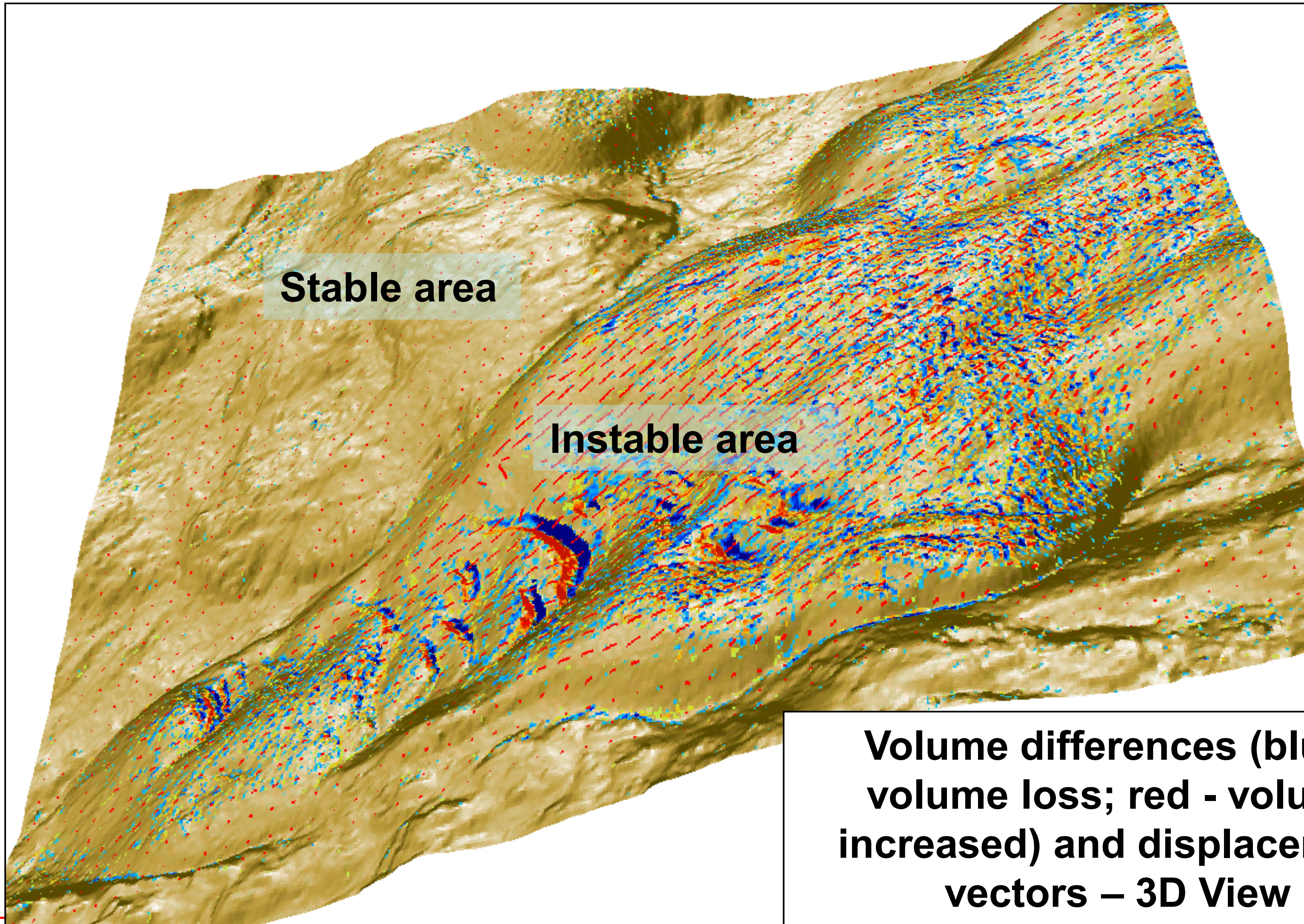

Volume differences (blue - volume loss; red - volume increased) and displacement vectors – 3D View

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Multi-temporal analyses

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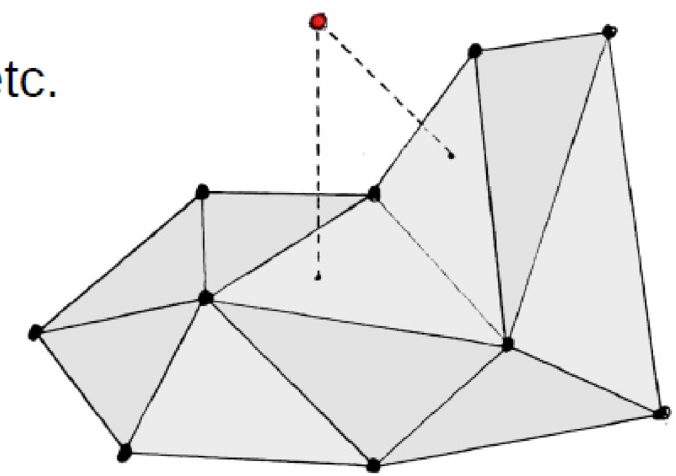
Pointcloud to TIN comparison approach

Calculates distance between a point from point cloud A and a TIN created from point cloud B:

- along plumb line
- shortest distance

Drawback:

The TIN is 2.5D, so we miss overhangs etc.



Multi-temporal analyses

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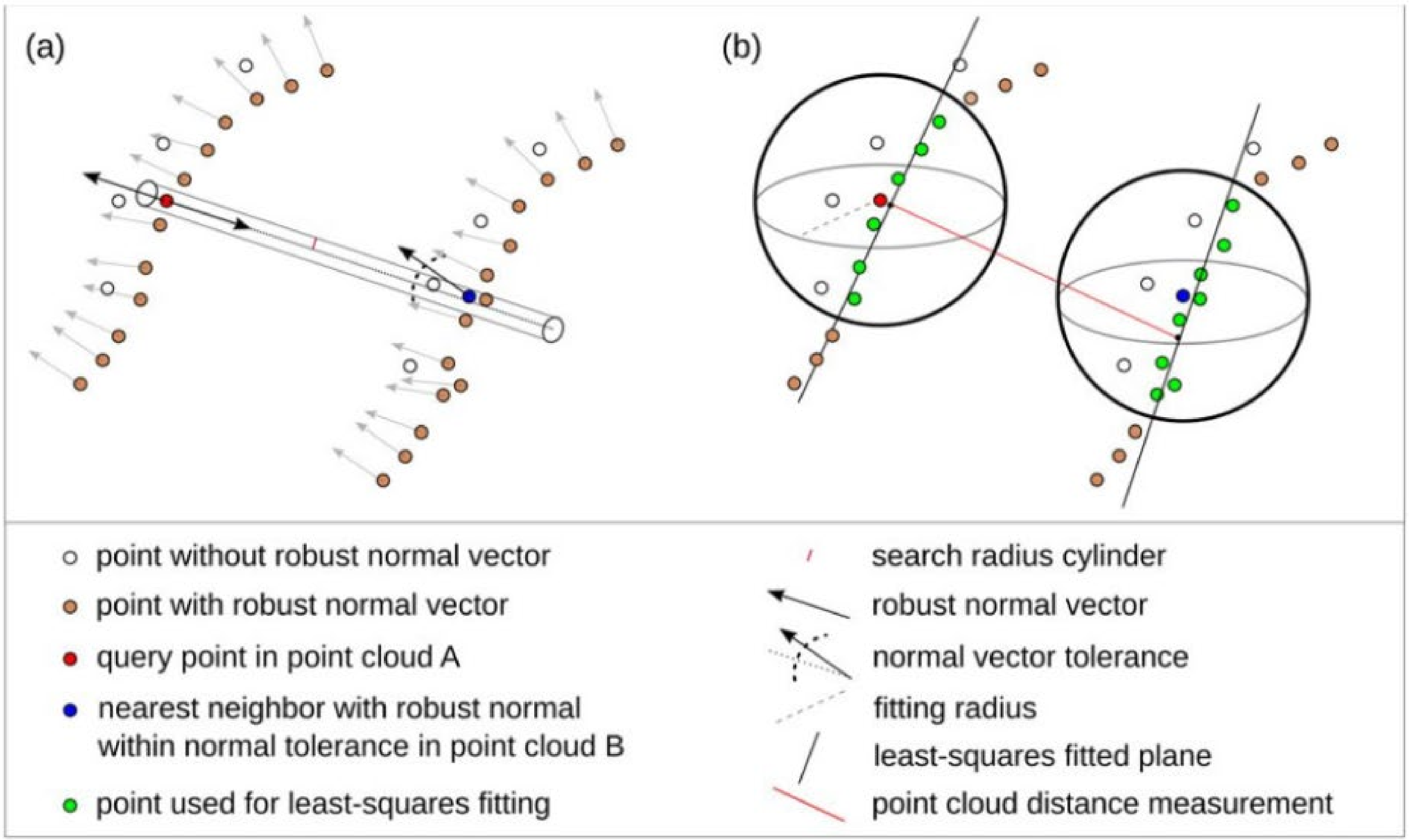
Pointcloud to Pointcloud comparison approach

3D distance calculation approach



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Multi-temporal analyses

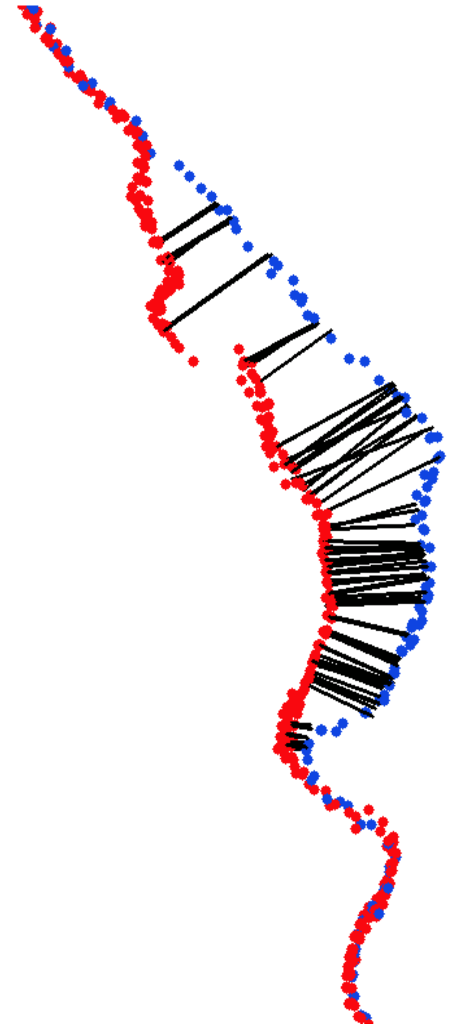
Pointcloud to Pointcloud comparison approach

Point Cloud Viewer, profile with 0.5 m swath width

Blue points: point cloud from T1

Red points: point cloud from T2

Black lines: measurement vectors from point cloud T1 to point cloud T2



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Multitemporal analyses

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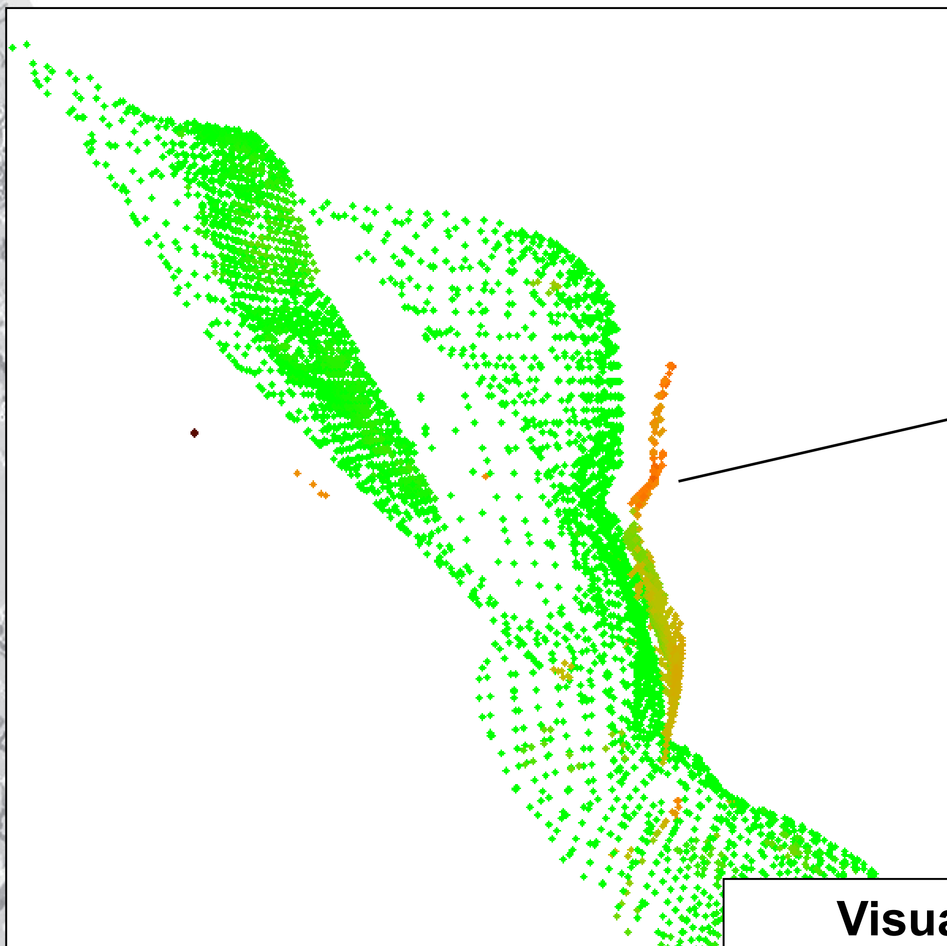
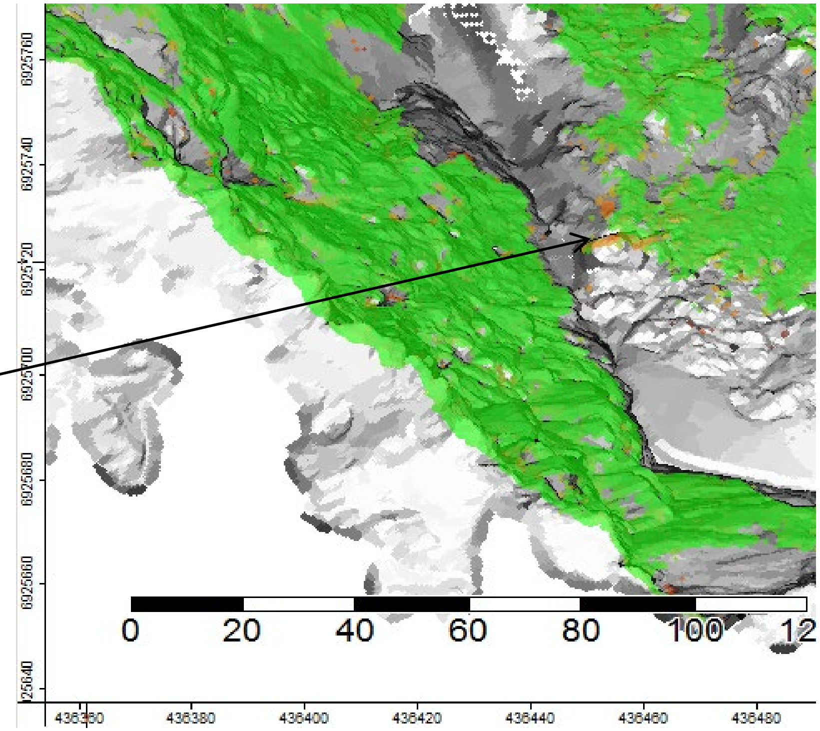
Example: Norwegen - Photogrammetry Point Cloud and TLS LiDAR





Visualisation of 3D point distances between the datasets – example moving block

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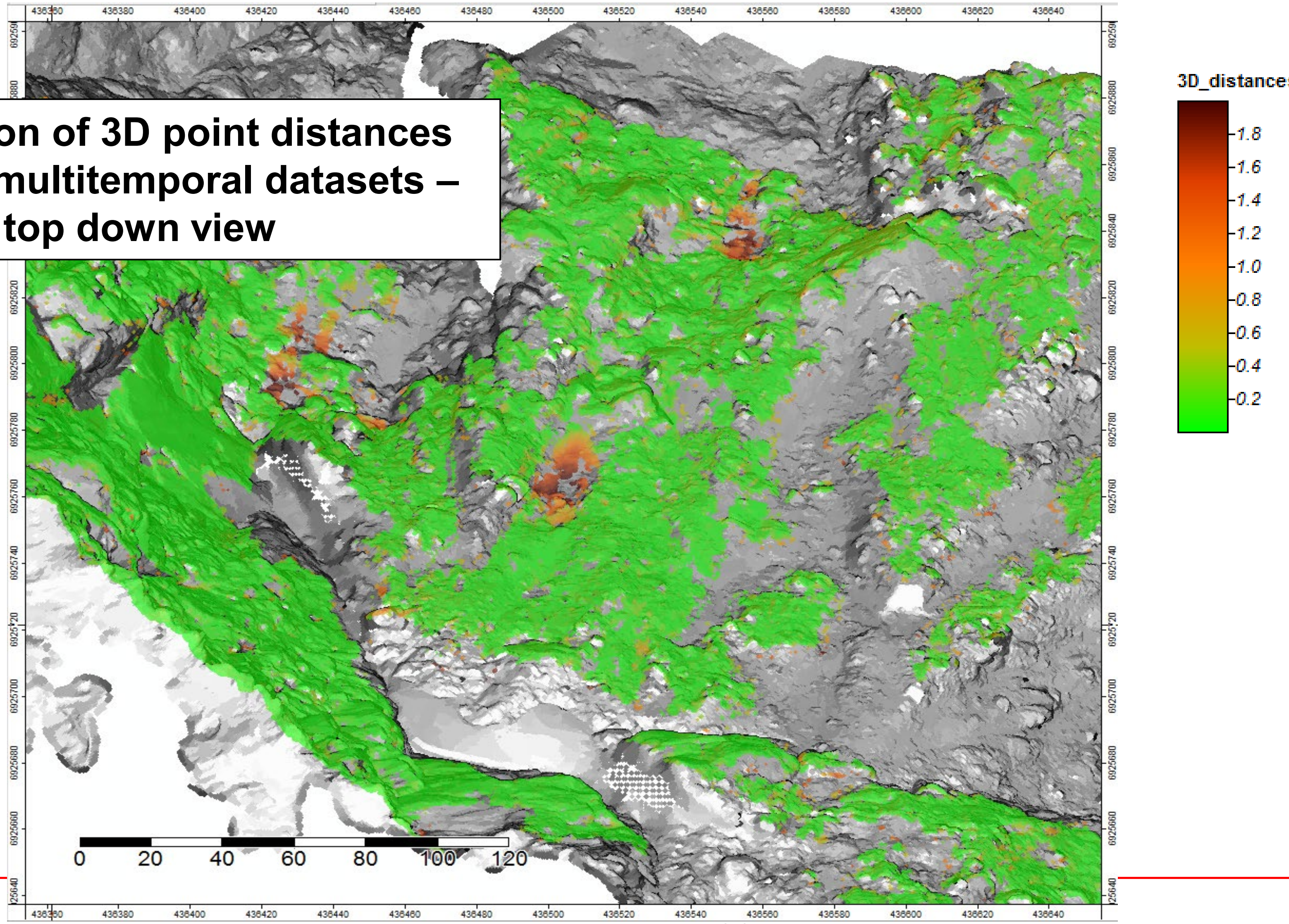
Multi-temporal analyses

Example: Norwegen - Photogrammetry Point Cloud and TLS LiDAR

Calculation of 3D point distances between multitemporal datasets – top down view



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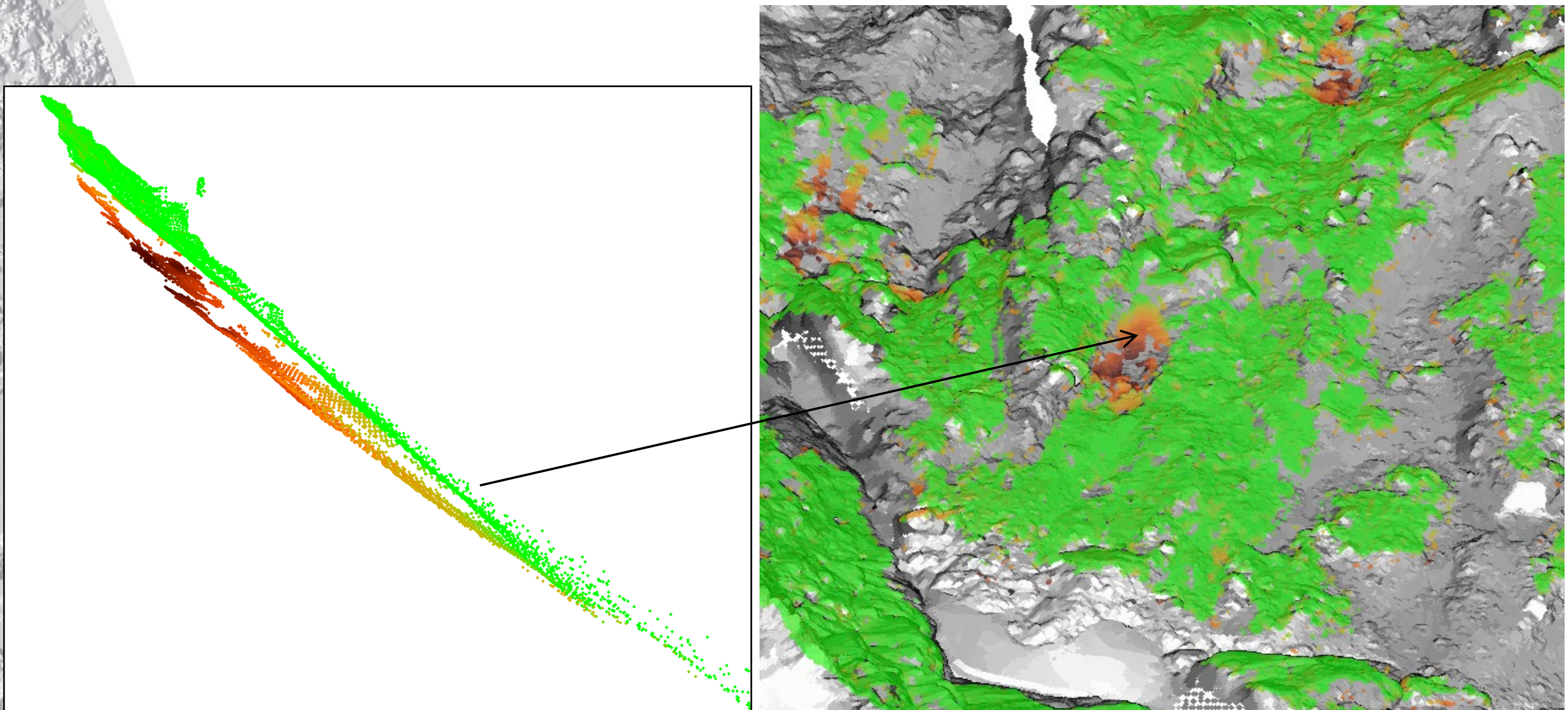
Multi-temporal analyses

Example: Norwegen - Photogrammetry Point Cloud and TLS LiDAR



Visualisation of 3D point distances between the datasets – example height differences

Multi-temporal analyses

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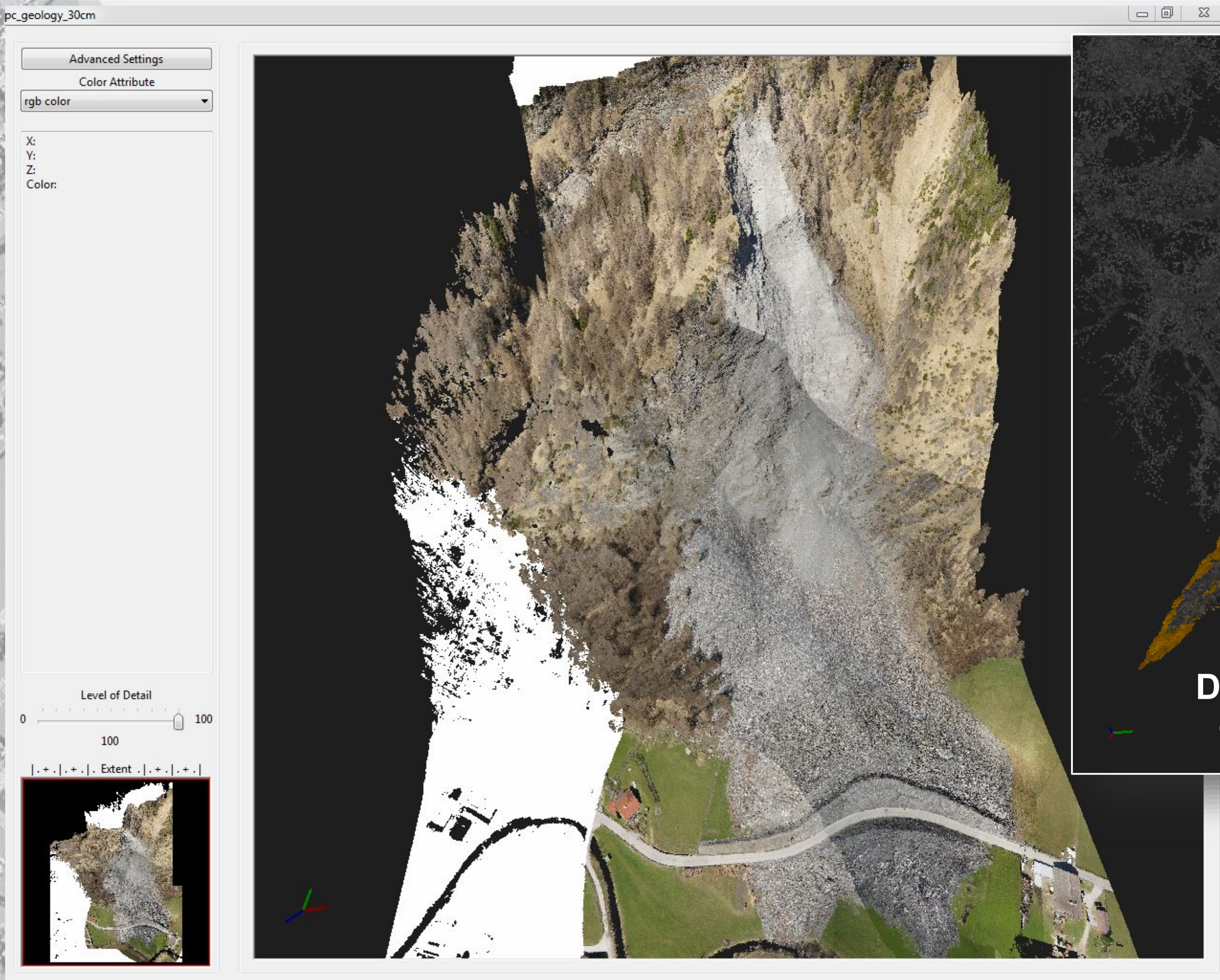
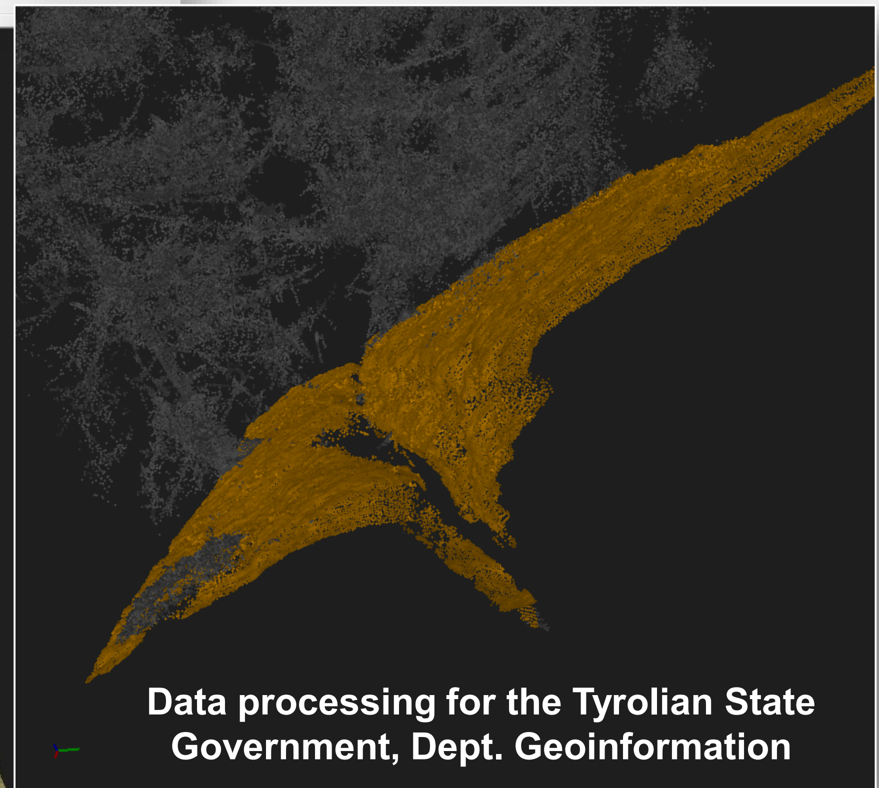
Rockslide Vals, Tyrol, UAV based multitemporal LiDAR





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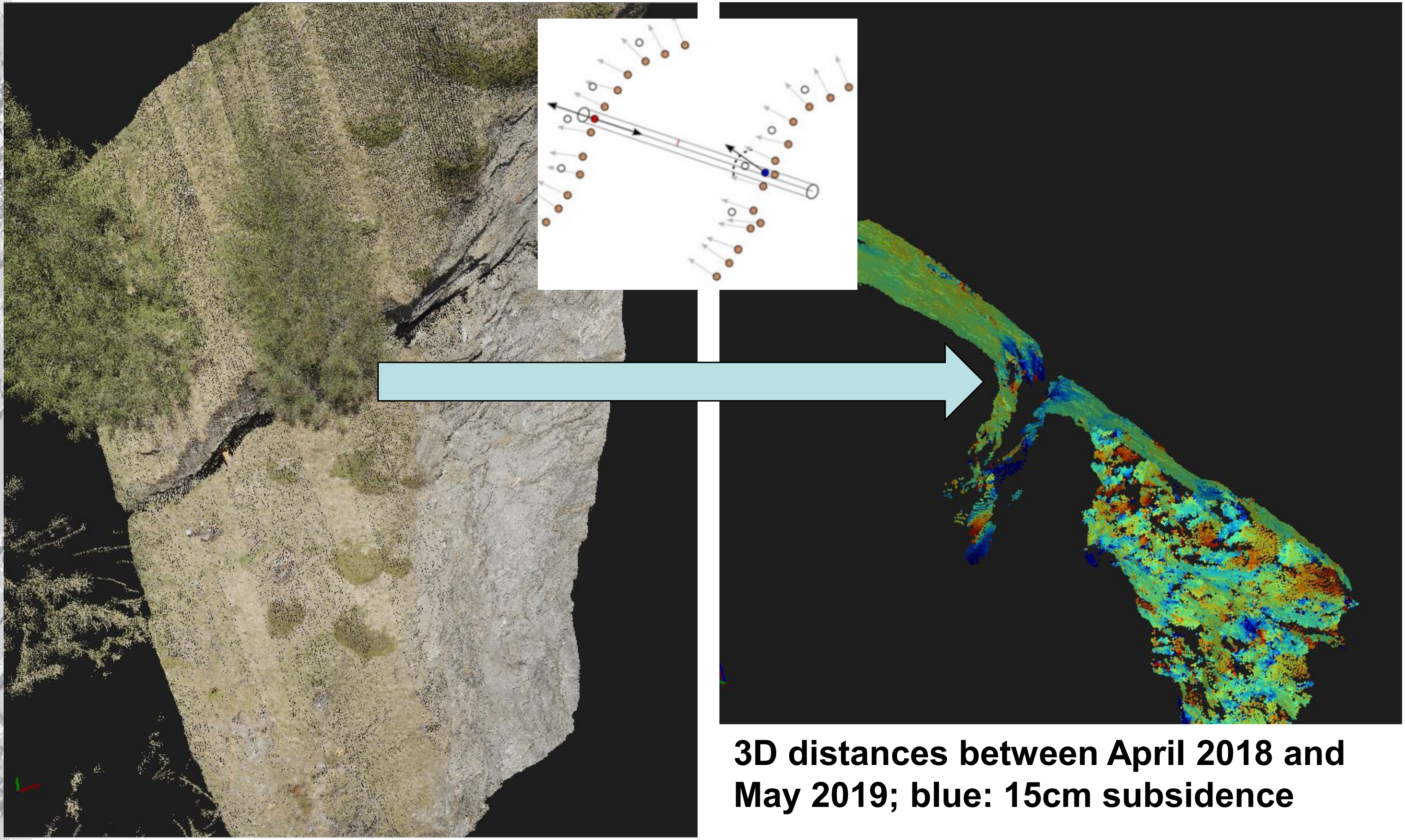
Rockfall Vals (Tyrol) UAV based multitemporal LiDAR data



3D distances between April 2018 and May 2019; blue: 15cm subsidence

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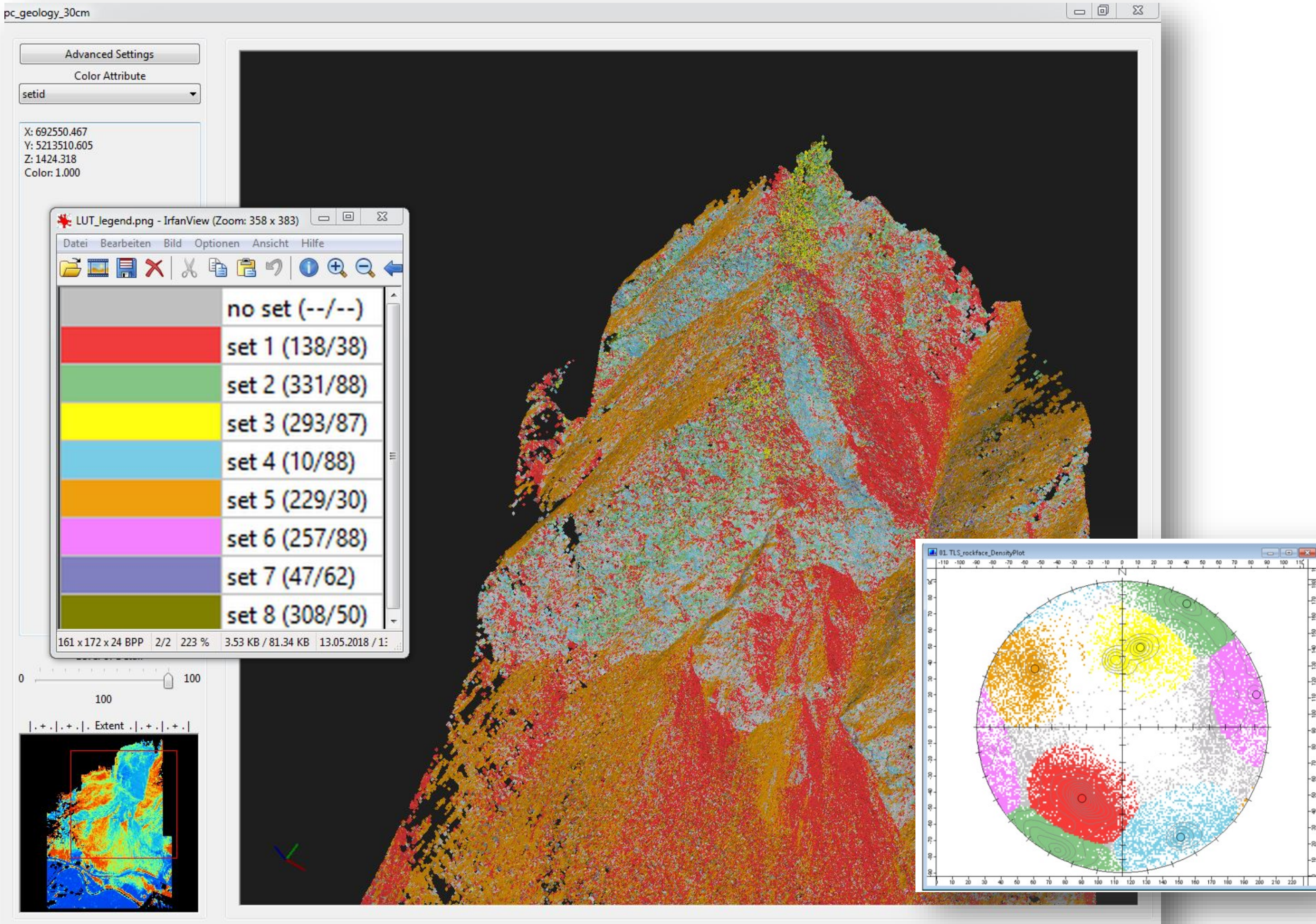
Structural Geology Analysis - Discontinuity sets



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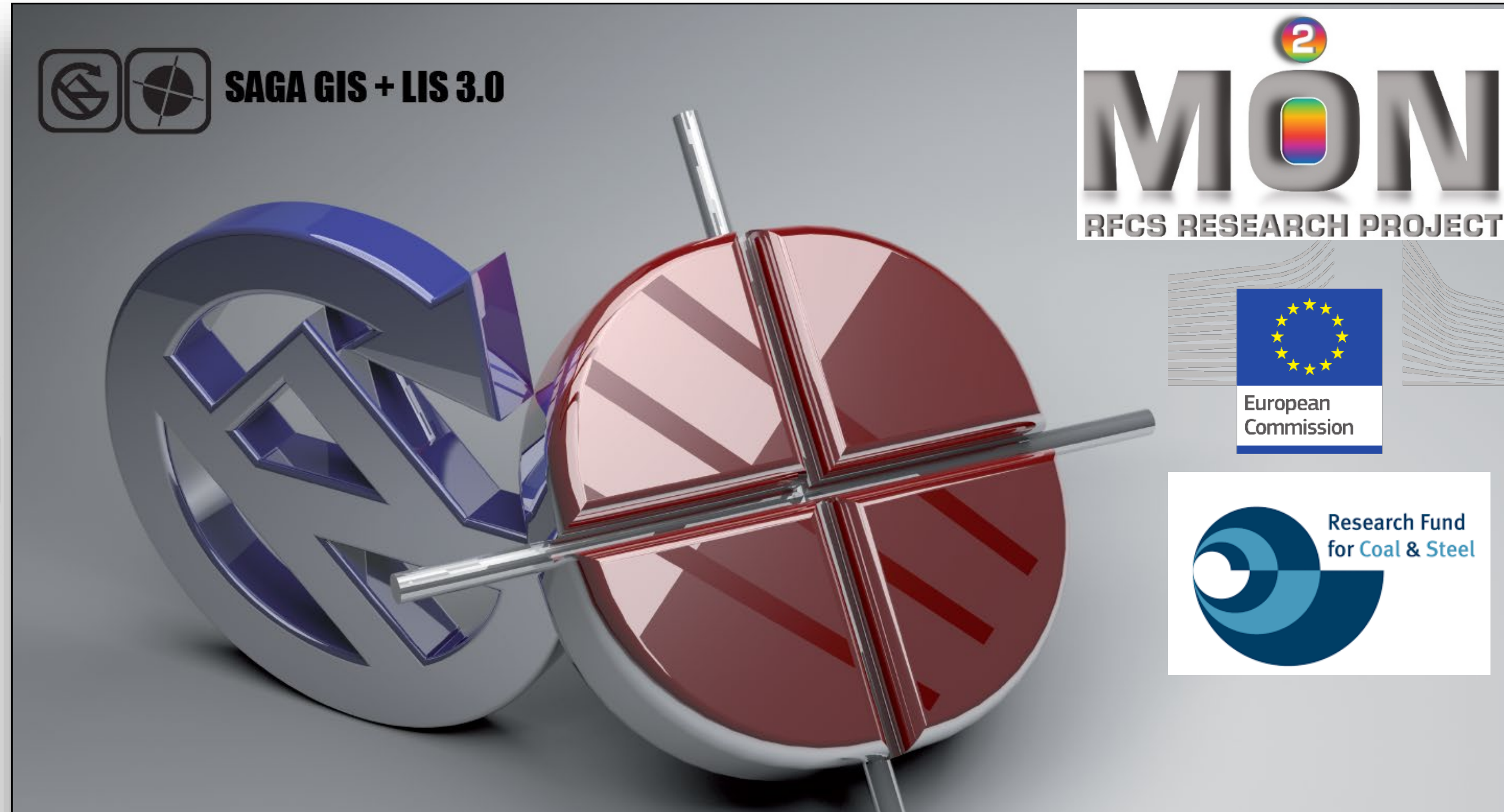

Thank you for your attention

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