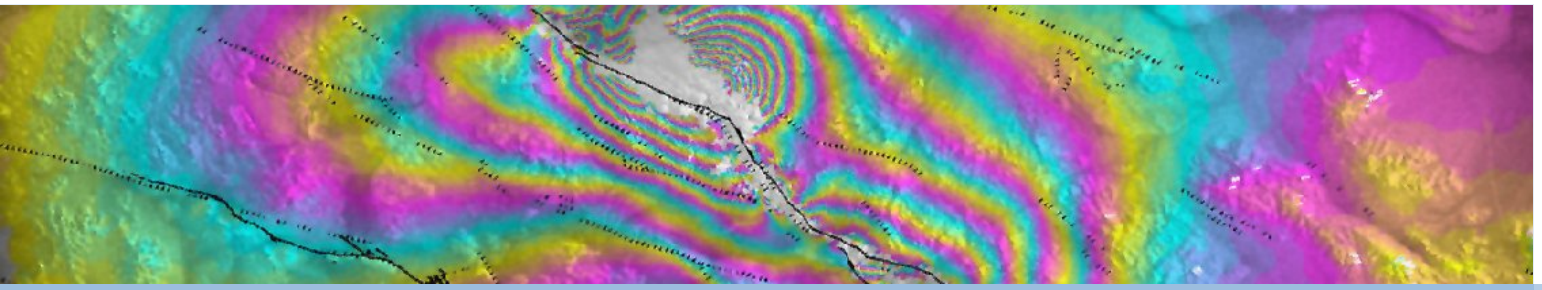

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10th Swiss Geoscience Meeting,
Bern 17. November 2012

Deformation- and radiometric mapping with terrestrial radar interferometry

From radar-geometry to high resolution 3d-surface maps

Rafael Caduff[1,2], Andrew Kos[3], Fritz Schlunegger[1]

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[3] Institut für Geotechnik, ETH-Zürich / Terrarsense Switzerland AG, Werdenberg

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Mountains – Up and Down

Where? How Fast?

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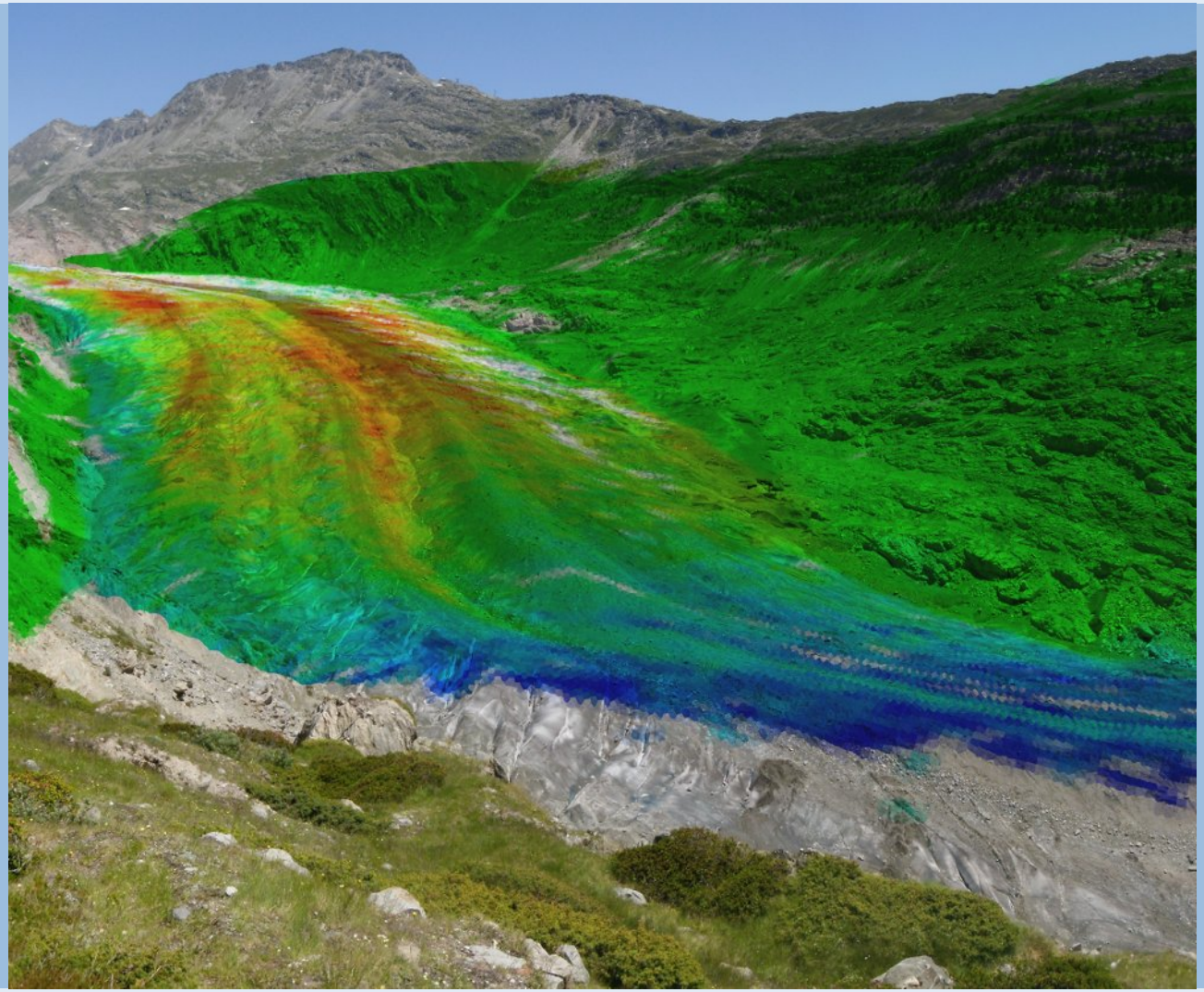
Mountains – Up and Down



GPRI-Measurements
Aletsch-Glacier

27.06.2011
14:47 – 15:07

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Outline

- Introduction
- Data Acquisition
- Data Processing
- 3D-referencing
- Visualization
- Examples

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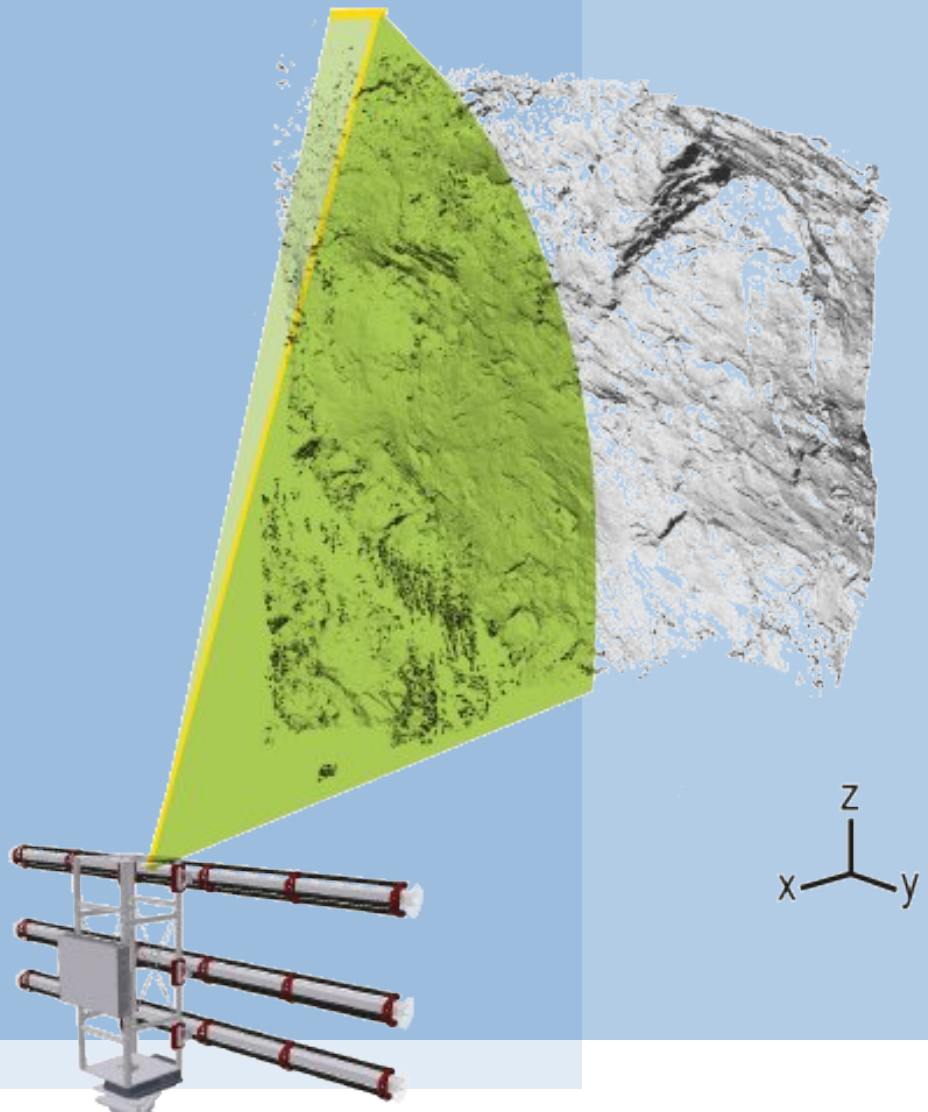
Acquisition
Hardware: Gamma Portable Radar Interferometer

- > Introduction
- > Data Acquisition
- > Data Processing
- > 3D-referencing
- > Visualization
- > Examples



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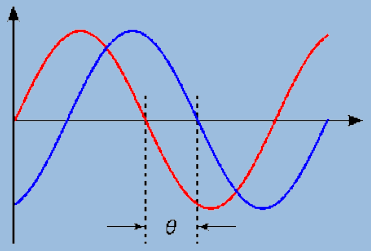
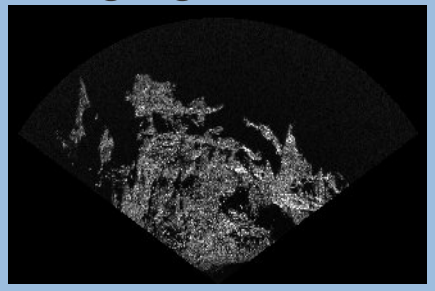
Acquisition
Hardware: Ground based radar systems

> Active remote-sensing technique operating at microwave frequencies

> Acquisition of magnitude (M) and phase (φ) of the backscattered signal



> Imaging radar: Day / Night / Through-cloud operation



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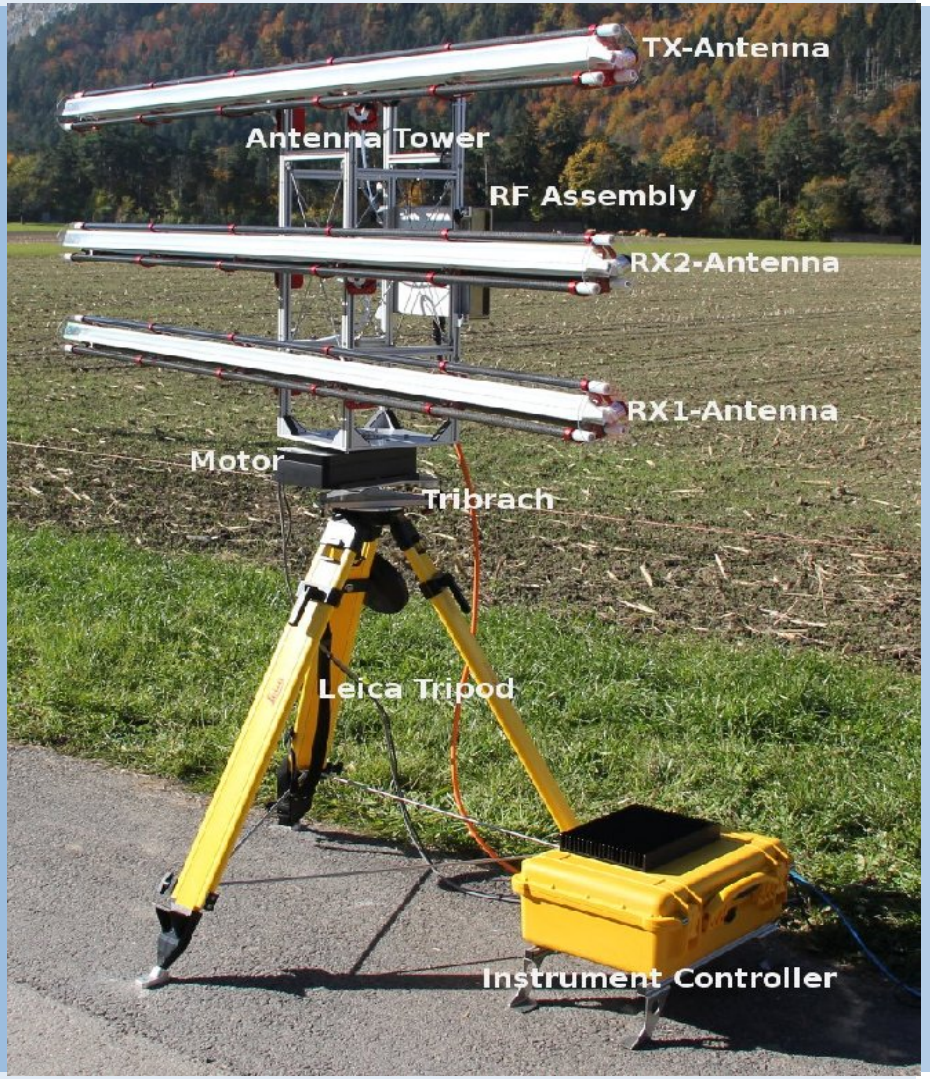
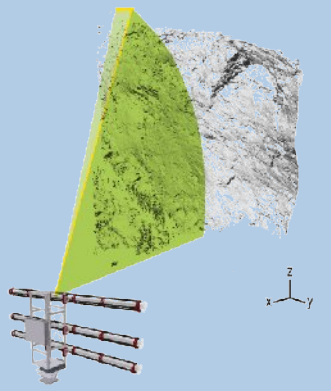
Acquisition
Hardware: Gamma Portable Radar Interferometer





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Acquisition
Hardware: Gamma Portable Radar Interferometer

> Resolution

Range resolution as function of Operation Frequency (Ku-Band allocation: 17.1-17.3 GHz, λ = 1.75 cm)

1.0 m (constant)

Azimuth-resolution as function of antenna length (2 m) and range distance

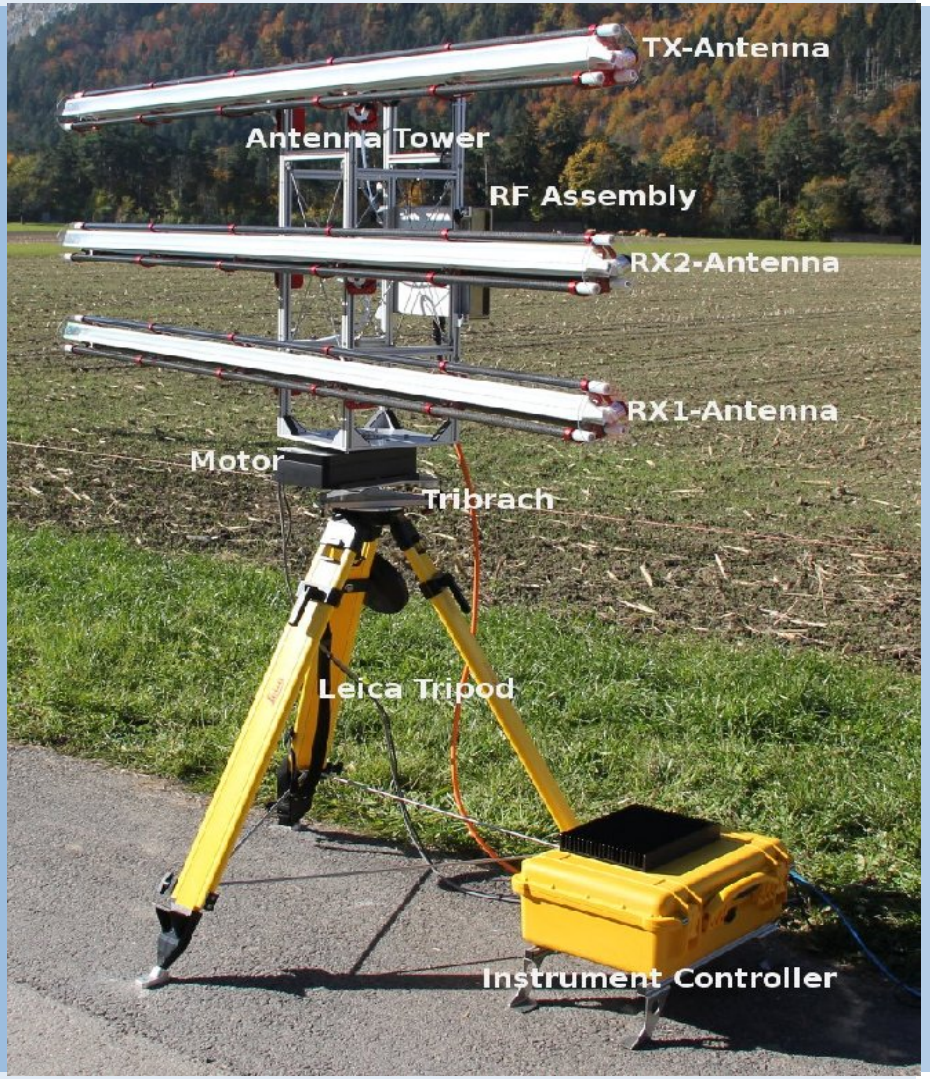
8 m @ 1 km

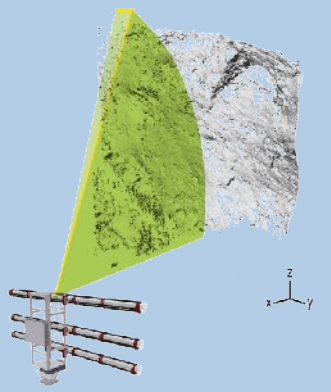
> LOS-Precision

Precision as function of operation frequency and atmospheric influences

(0.125 mm @ 1 km)

1 mm nominal





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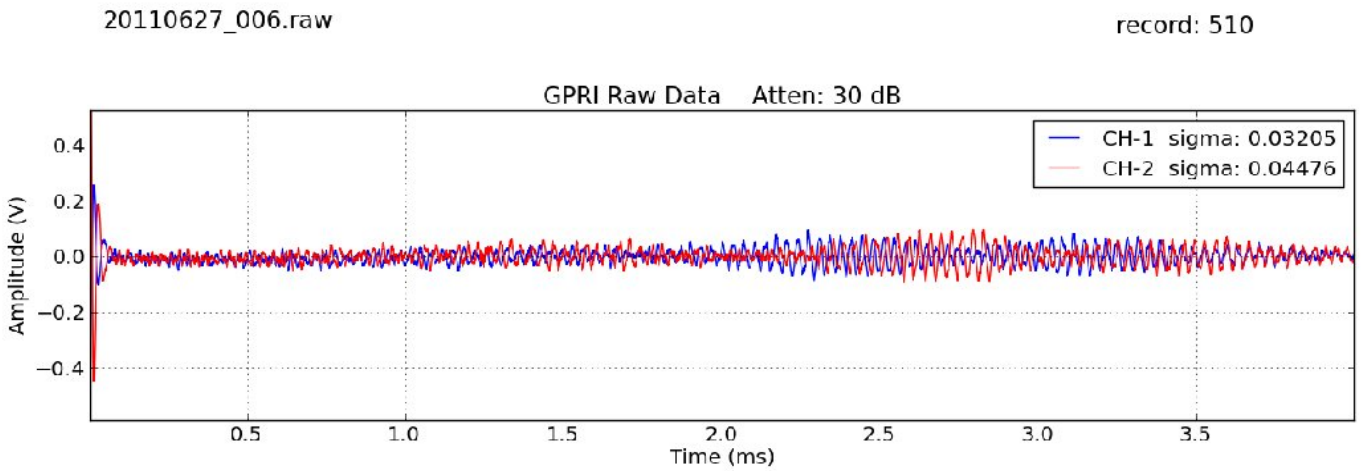
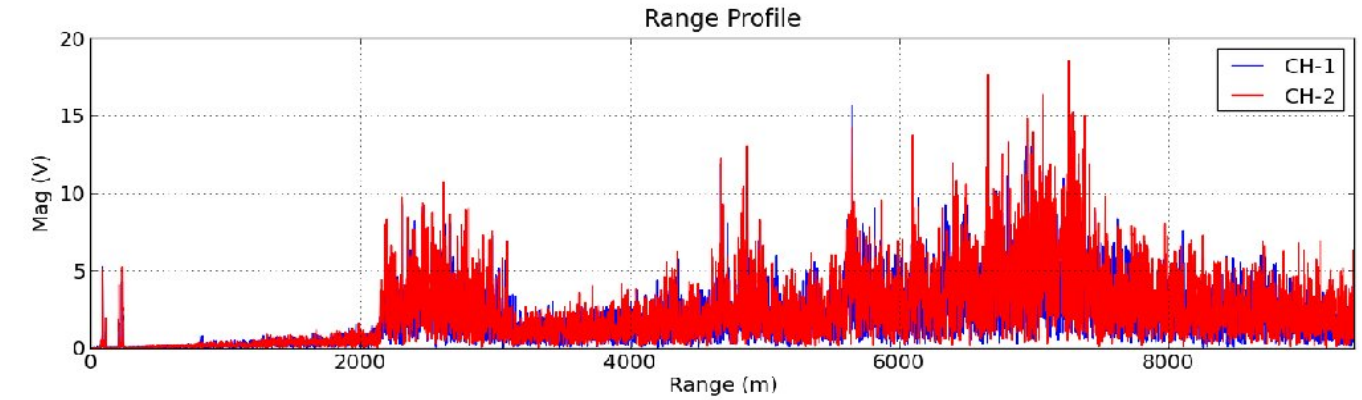
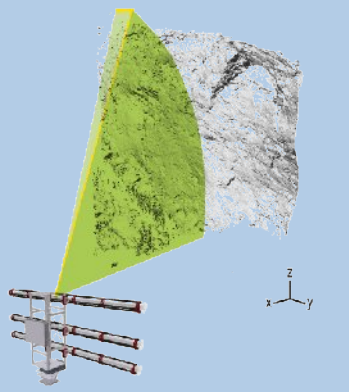
Acquisition
Range Profile of Single Azimuth Aquisition







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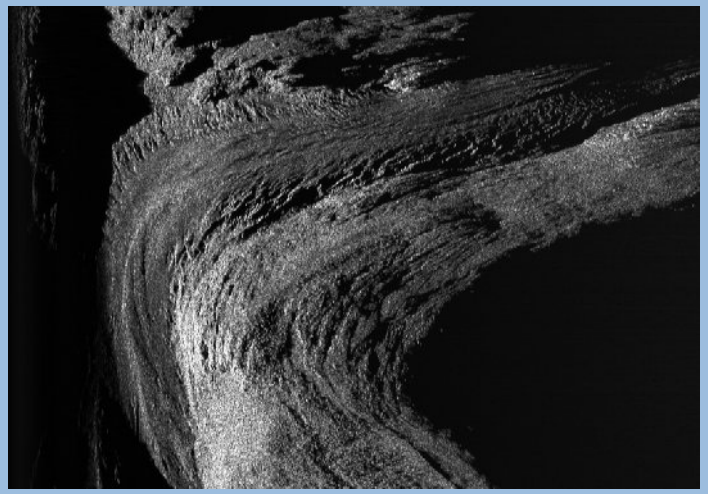
Acquisition
Image Geometries

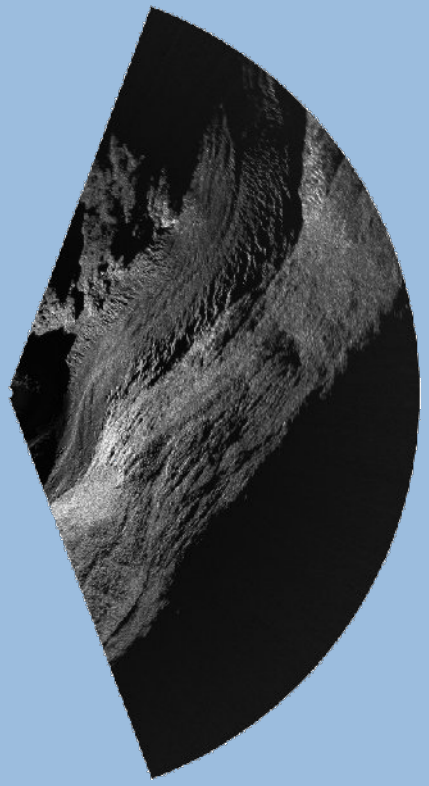
> Polar Geometry

Data Storage and Processing
Image_X: Range
Image_Y: Azimuth



> Rectangular Geometry

≠ Map Geometry



- > Introduction
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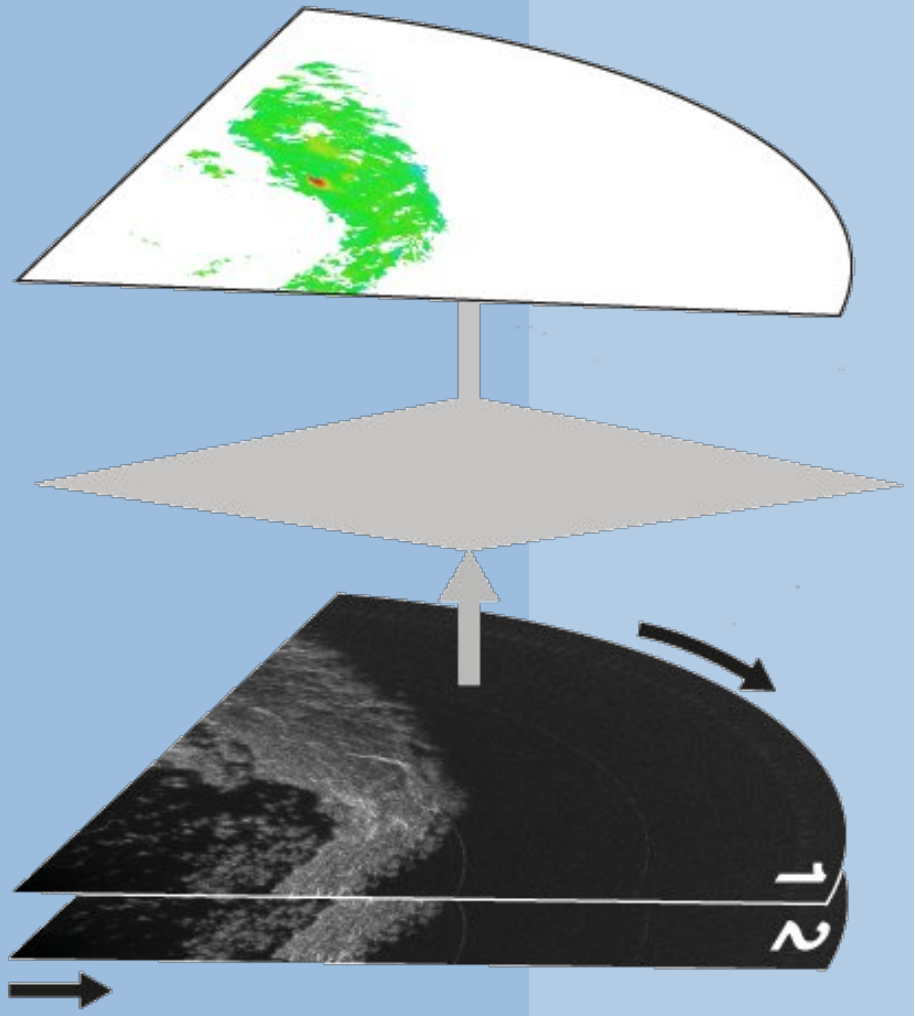

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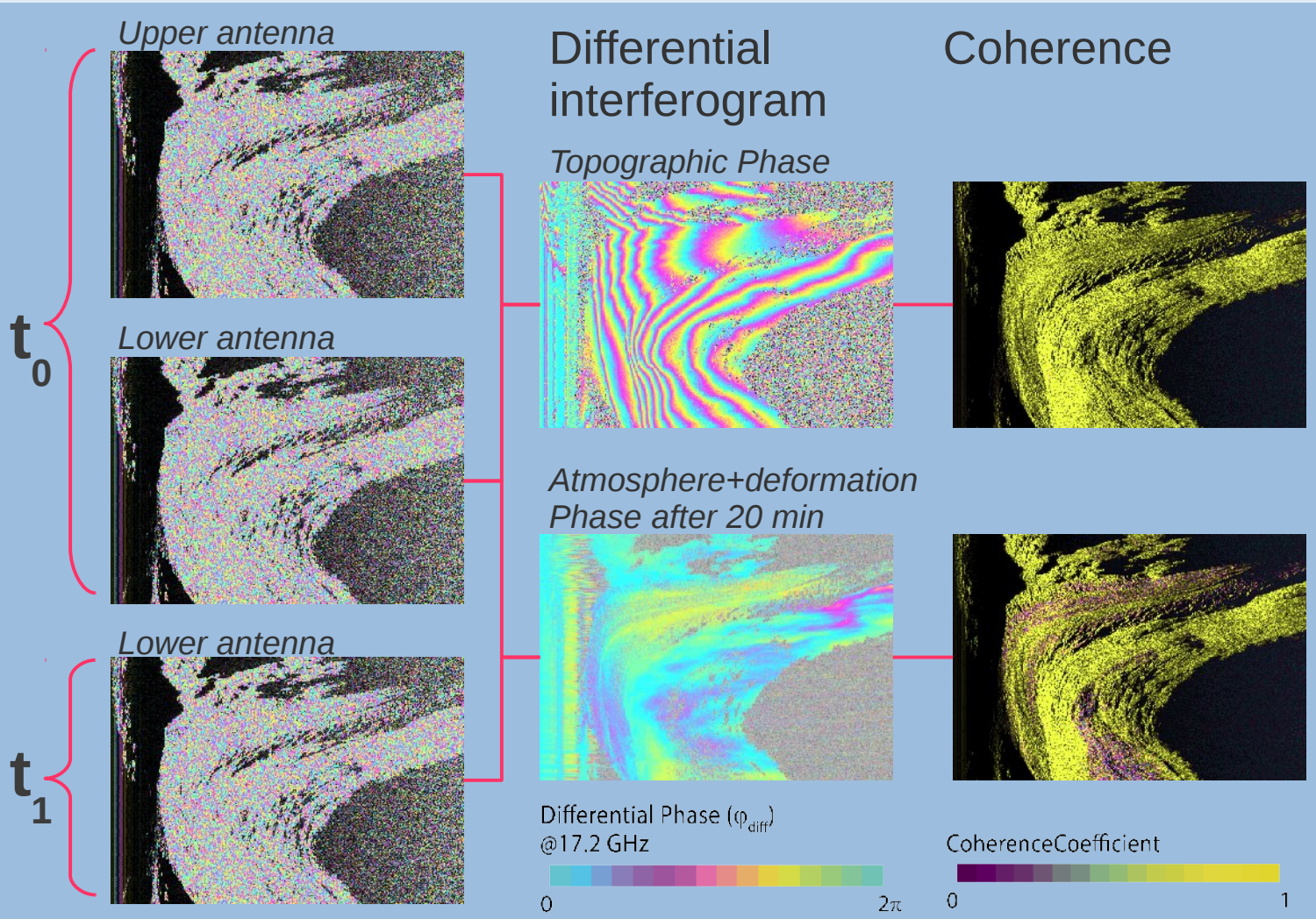
Data Processing
Differential Interferometry



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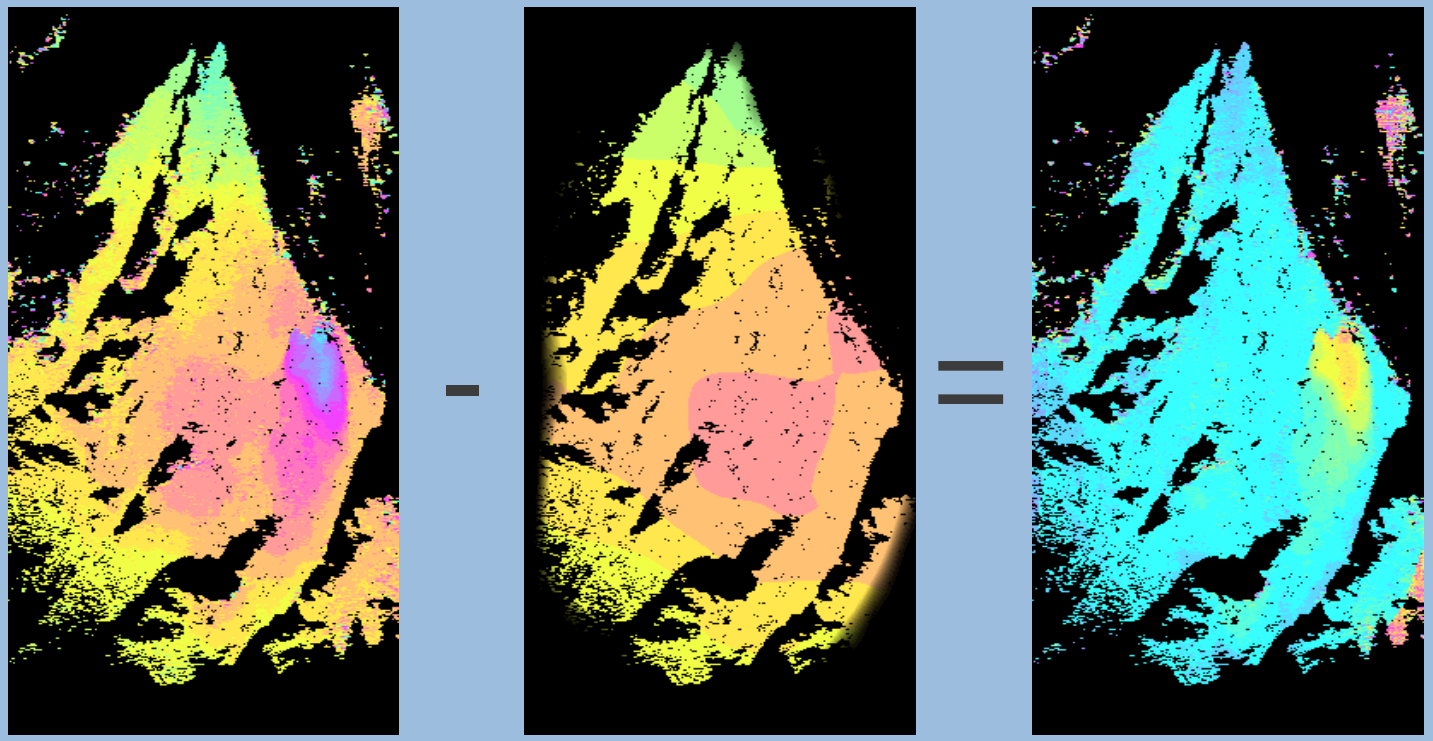
Data Processing
Atmospheric Phase Removal

> **Differential Interferogram**
Deformation Phase + Atmospheric Phase

> **Simulated Atmospheric Phase**
Interpolation over masked areas

> **Filtered Interferogram**
Deformation Phase



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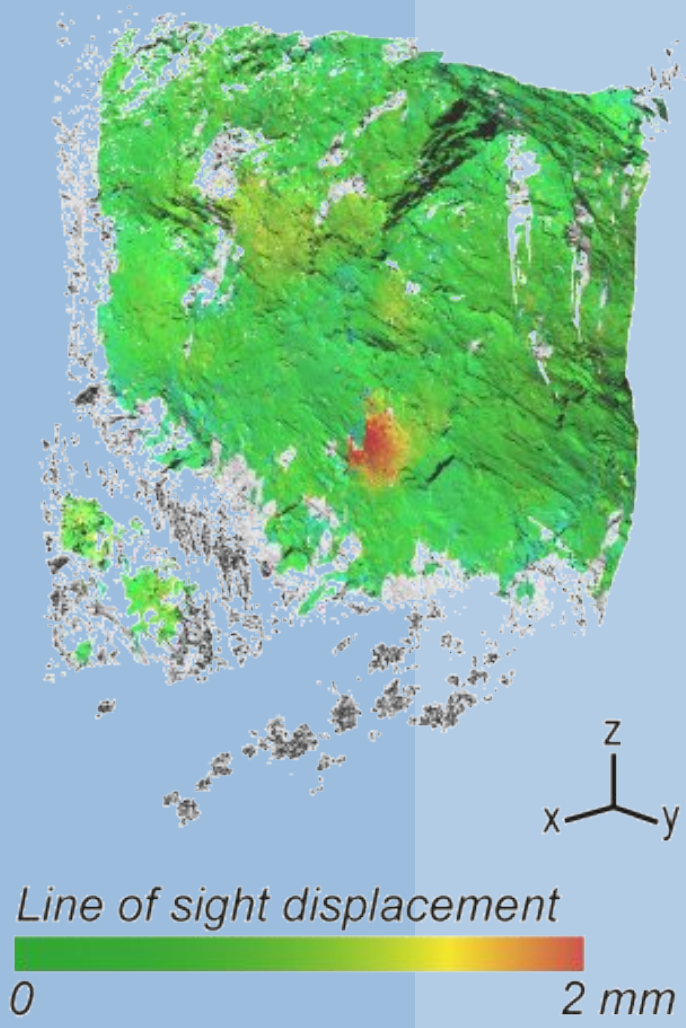

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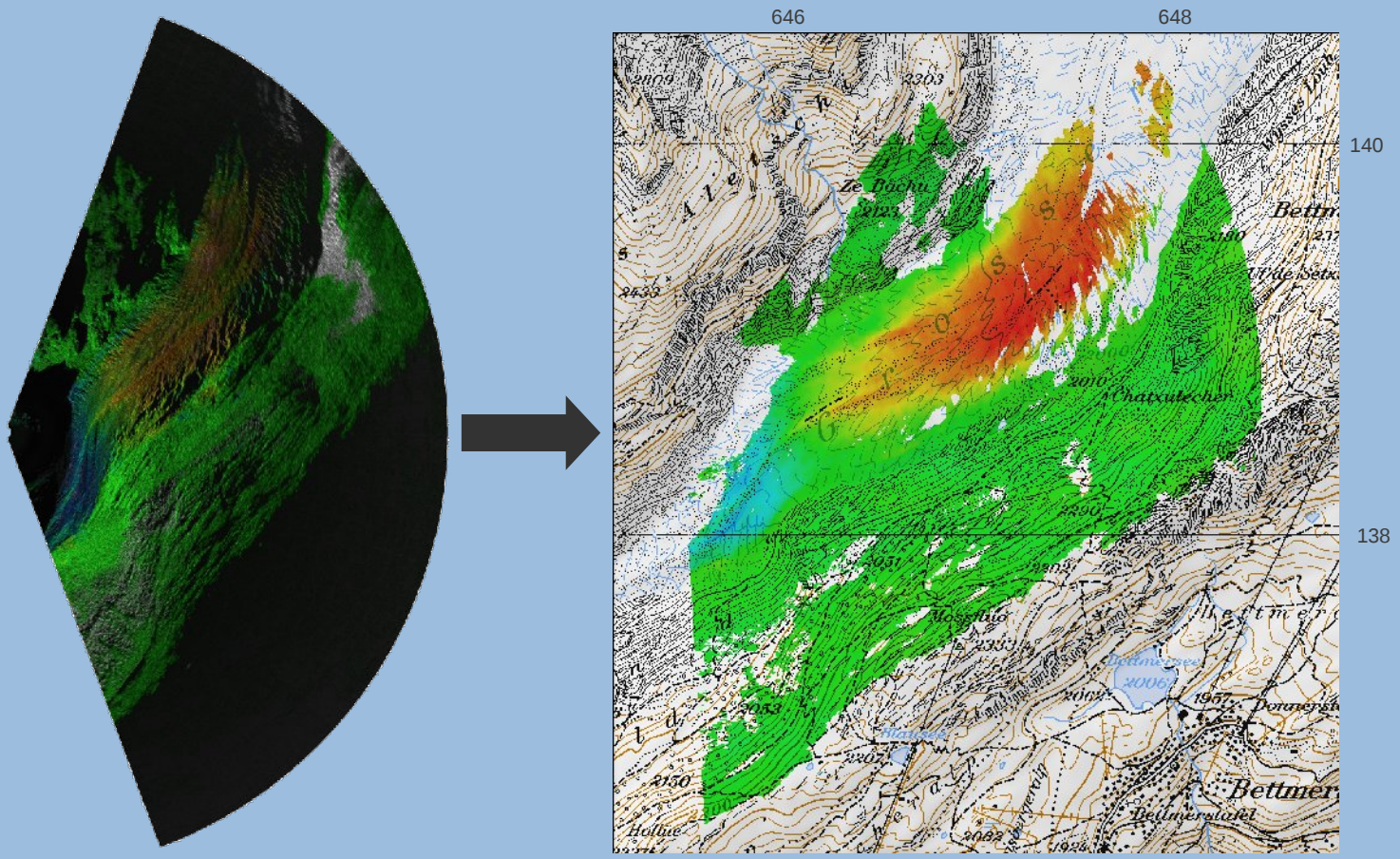
3D-Referencing
Map-geocoding for landscape scale



Topographic background: LK50 (c) swisstopo

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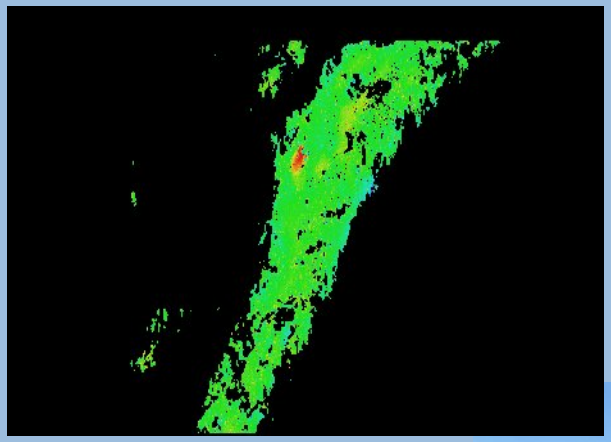
3D-Referencing

Map-geocoding not suitable for vertical landscape



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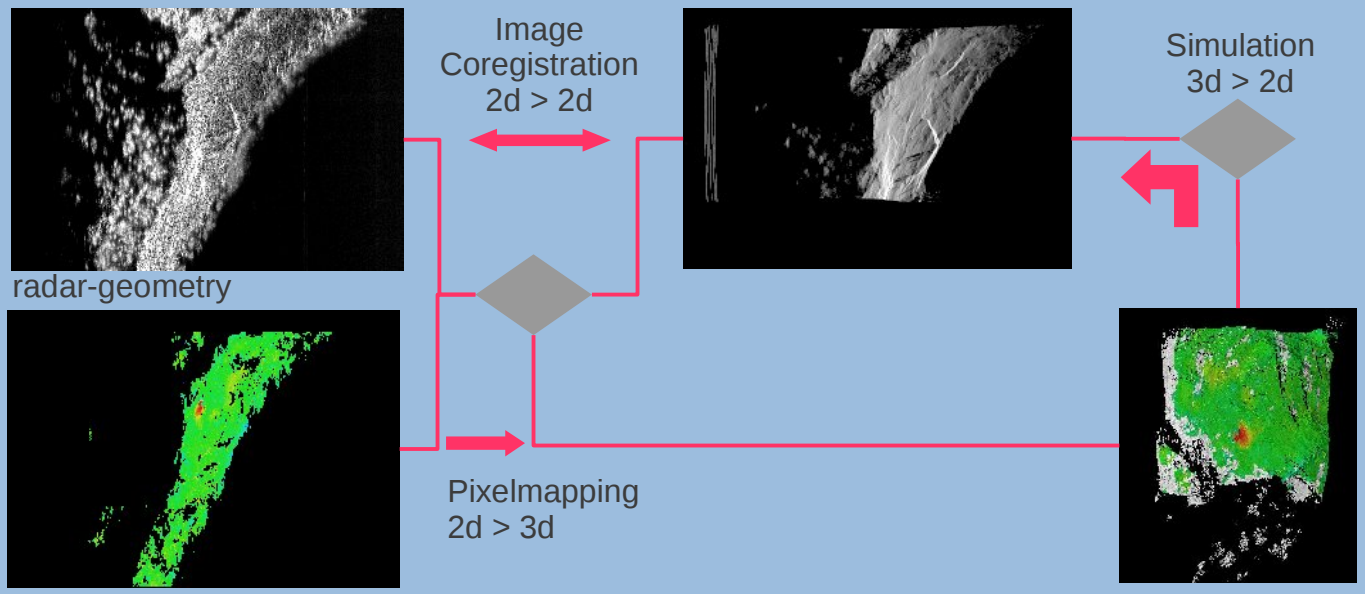
3D-Referencing

Map-geocoding not suitable for vertical landscape

> Mapping of radar-pixels to 3D-point via radar-simulation

Radar-data still in radar-geometry
Only pixel-map is stored
3D-points are attributed via relation or information stored directly in 3D-point cloud



I/O - 3D point-cloud
Open File Formats for Point-Clouds:
Attributed
ASCII or bin

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3D-Referencing
Vertical geometries

> Vertical Projection on Existing Point-Clouds

3D-Information can be obtained from different sources:

- Existing DEM
- LIDAR (ALS or TLS)
- Photogrammetry
- Structure from Motion

> Projection Precision

Precision as function of input data-resolution and topography

Together with TLS in the order of 1 radar pixel

> Direct attribution of 3D-triplets or relational storage for large radar data sets

For localization purposes or as input for modeling

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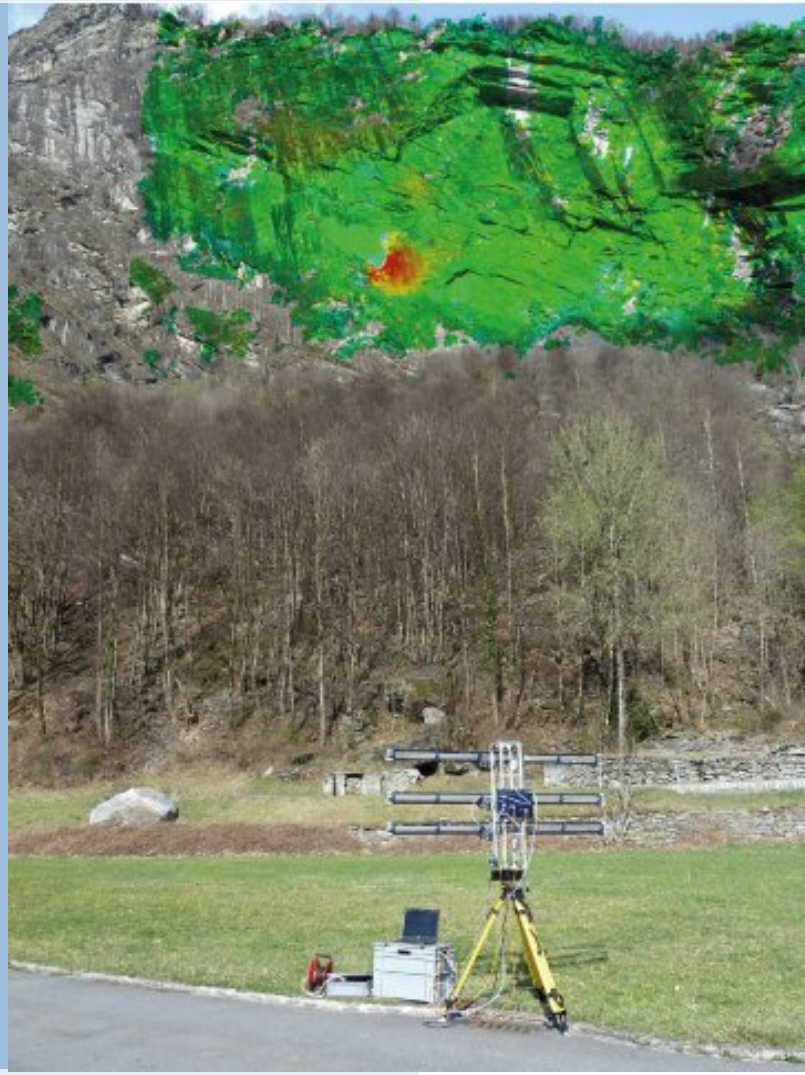

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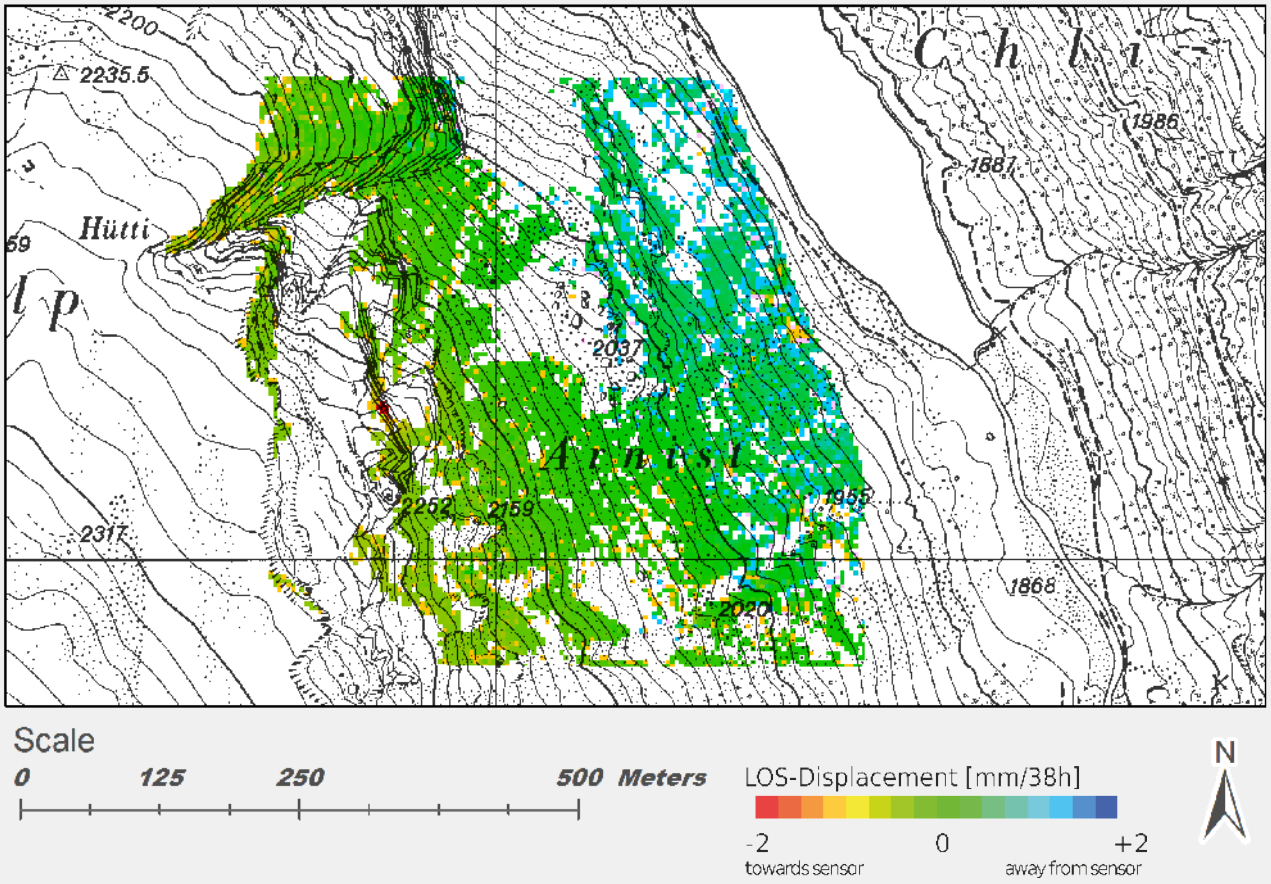
Visualization

Map geometry not always suitable for localization



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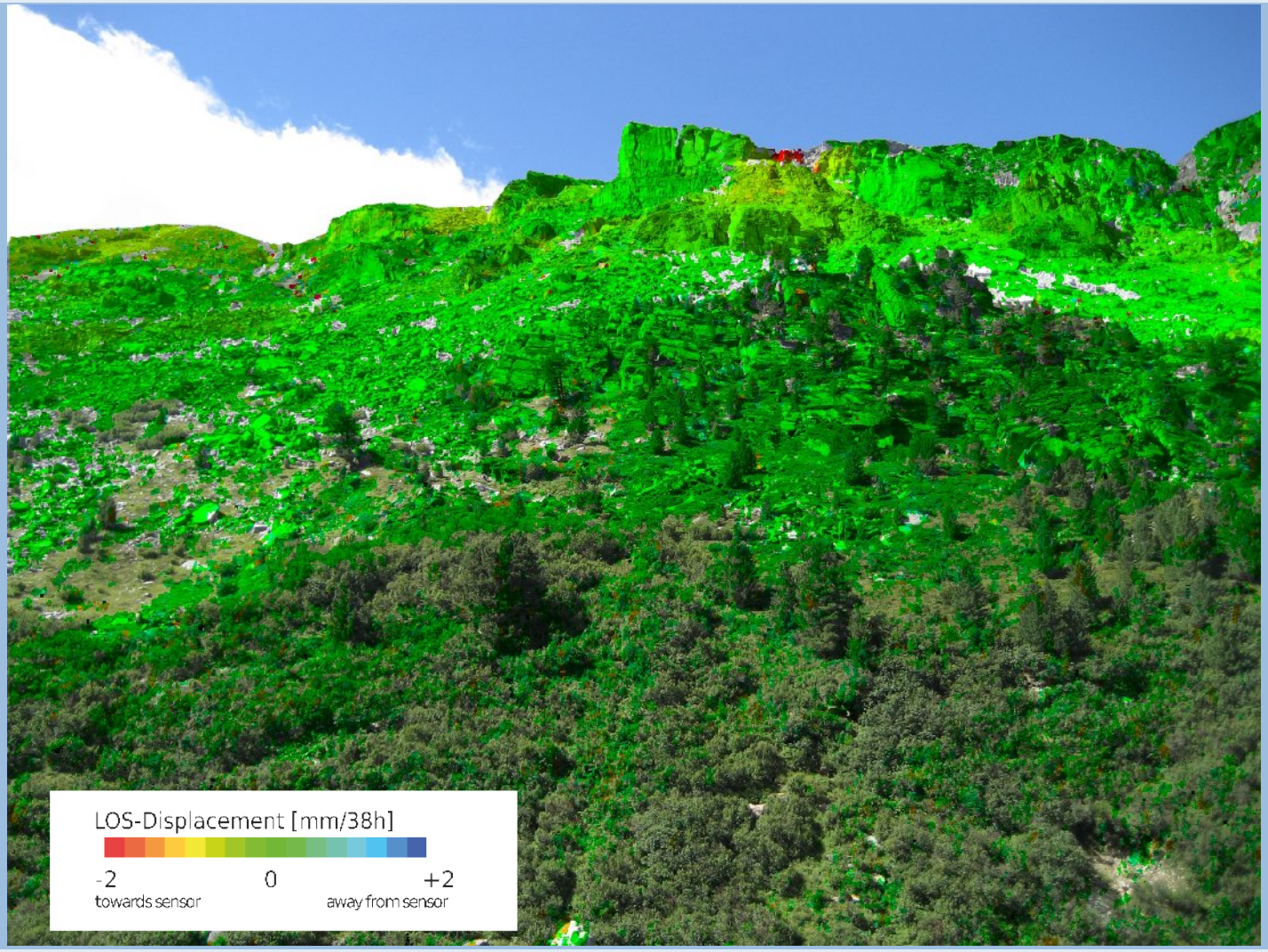
Visualization

Terrestrial photograph as “natural” way of observing



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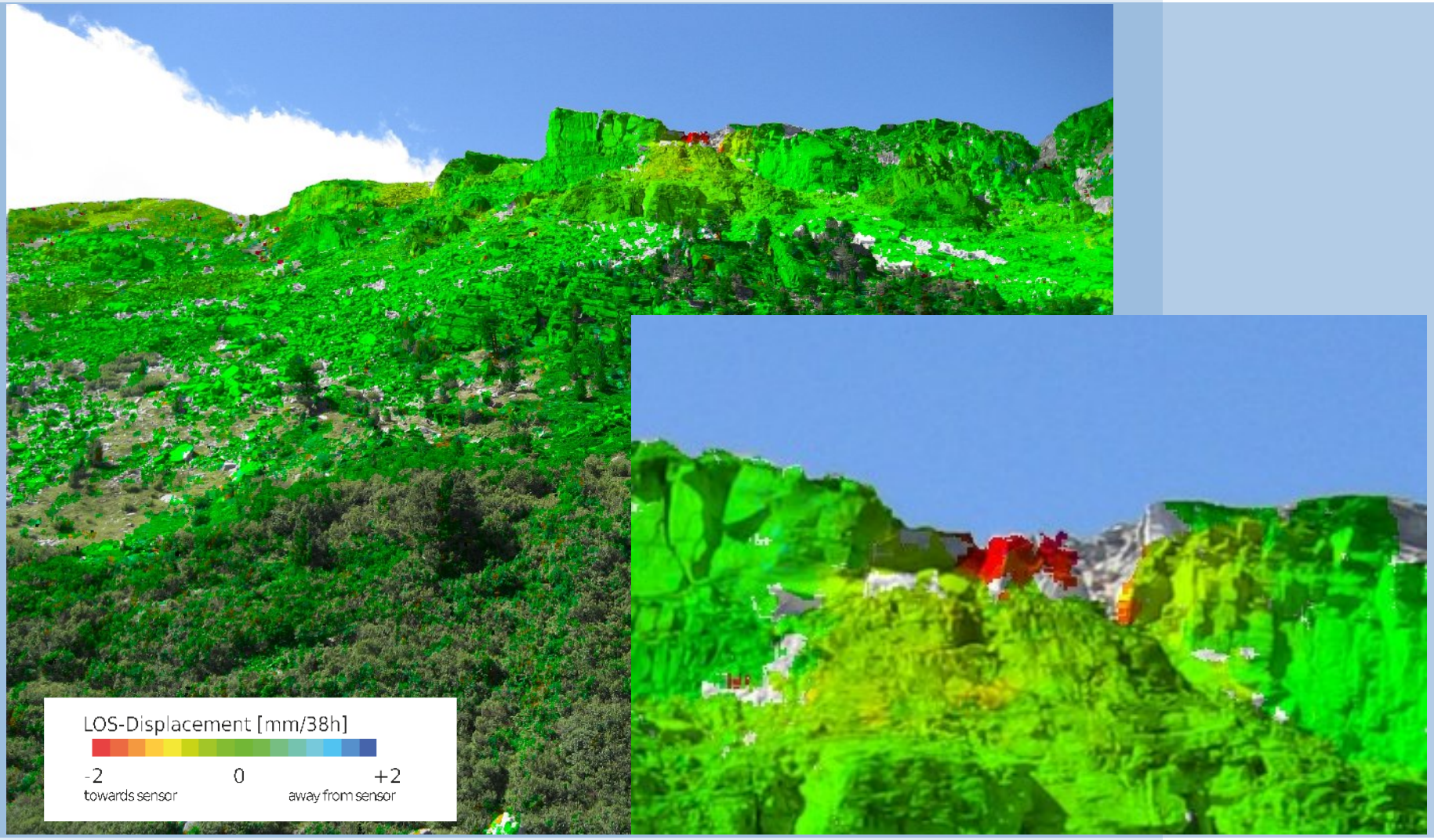
Visualization

Separation of moved and stable objects



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Visualization
Image rendering

> Photogrammetric Acquisition

+ Advantage of determination of camera-parameters and point elevations
+ Image projection possible
+ High resolution and precision
- - Demanding in further resources (expensive cameras, software ...)

> Structure from Motion

+ Feasible with every digital (compact) camera
+ Mostly Free and Open Source
- Little control of the reconstruction process
- Camera parameter not as accurate as with photogrammetry

> Natural way of seeing the terrain through terrestrial photographs allows quick and precise localization of moving objects

> Introduction
> Data Acquisition
> Data Processing
> 3D-referencing
> Visualization
> Examples

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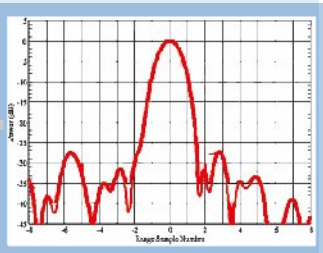
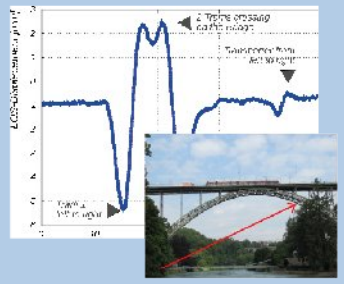
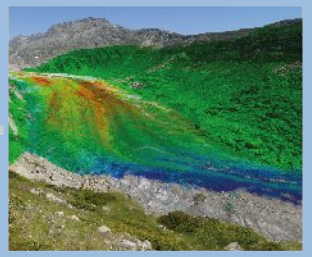
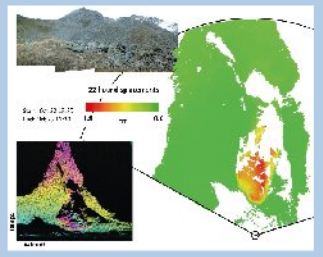
Examples
Timescale and possible applications

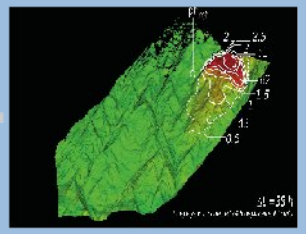
Radiometry	Radiometric measurements on all kind of surface cover				
infrastructure and Buildings	Infrastructure Dynamics (1d)	(Deformation monitoring)			
Snow-/Glaciers		Ice-/Snow Velocity	Decorrelation on warm ice	Decorrelation and out of measurement range *(d >> λ)*	
Rockglaciers				Decorrelation and out of measurement range *(d >> λ)*	
Landslides, Rockslides, Block-movements etc.		Very fast Movements		Measurements possible, if no vegetation present	
Temporal baseline	**ms**	**m**	**h**	**d**	**y**











"continuous-measurements" "repeat-measurements"

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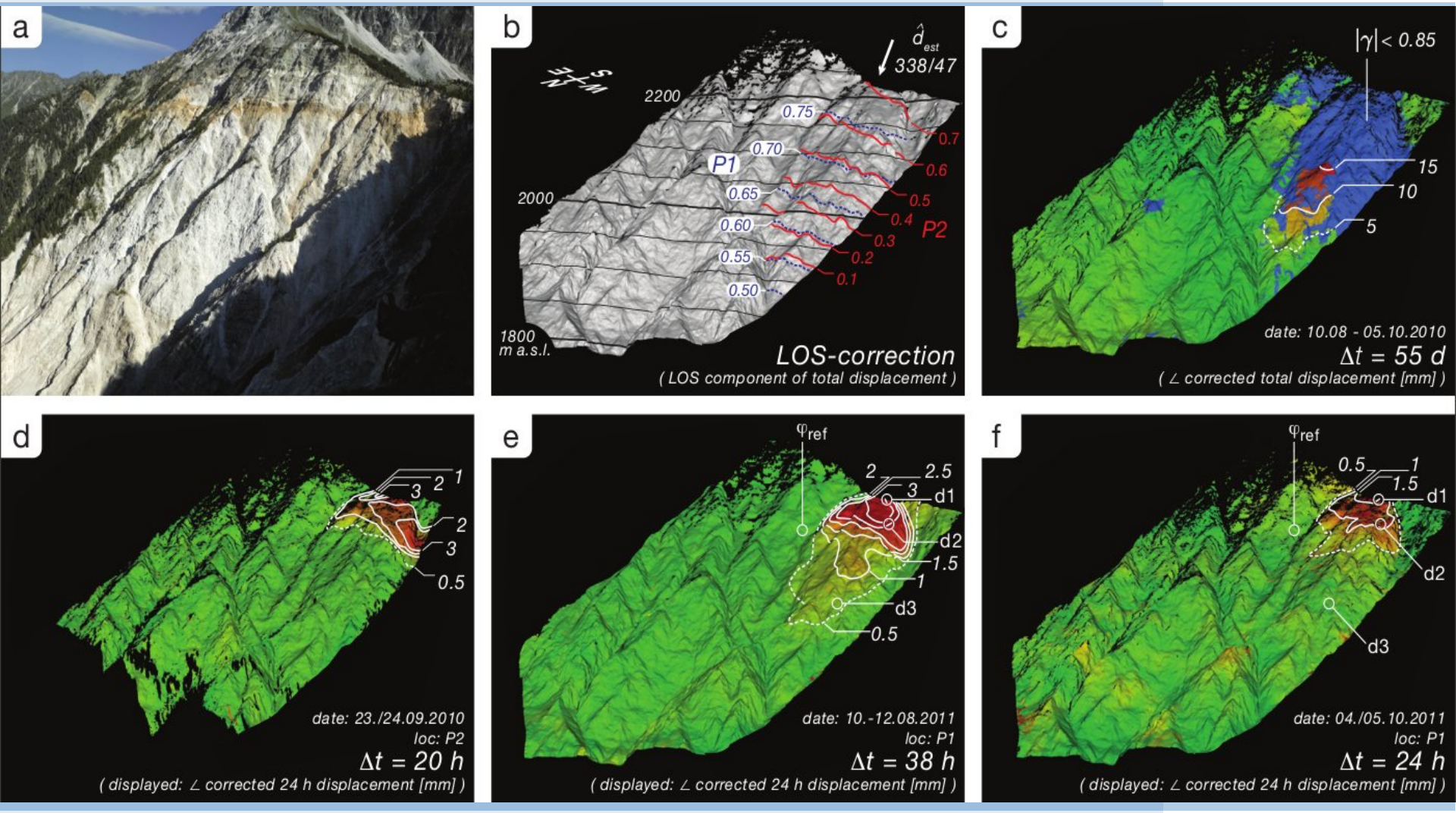
Examples
Illgraben Escarpment: Slope Instability



Caduff et al. (submitted)

Thank You for Your Attention!

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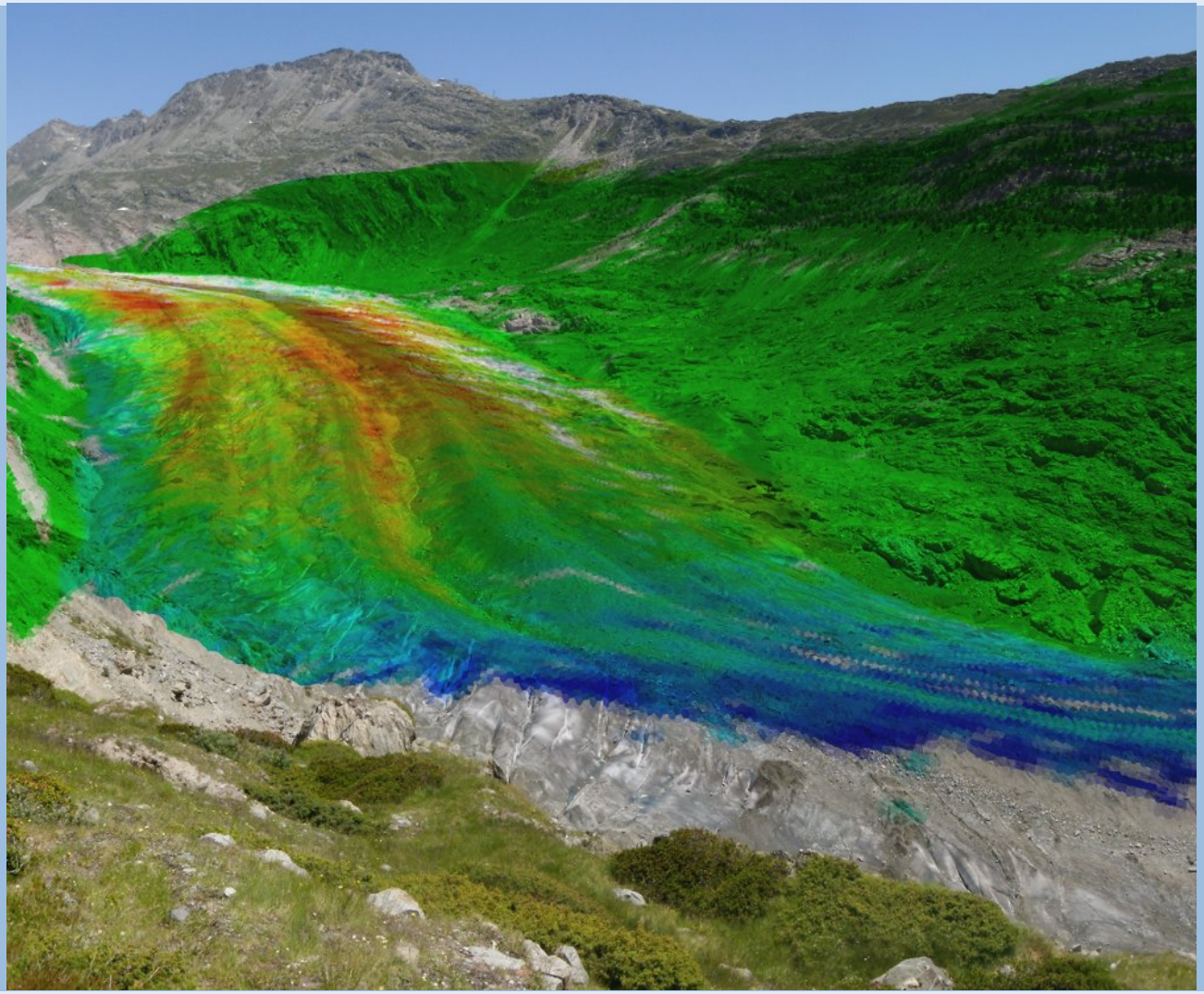

GPRI-Measurements
Aletsch-Glacier
27.06.2011

LOS-Displacement [mm/20 min]

-2.5 towards sensor | 0 | +2.5 away from sensor

GAMMA REMOTE SENSING

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich