ITINERIS

Landslide Surveying and Monitoring Systems Surface Monitoring

Advanced technologies for monitoring and prediction of ground instabilities
Pisa, 09-12 December 2024

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

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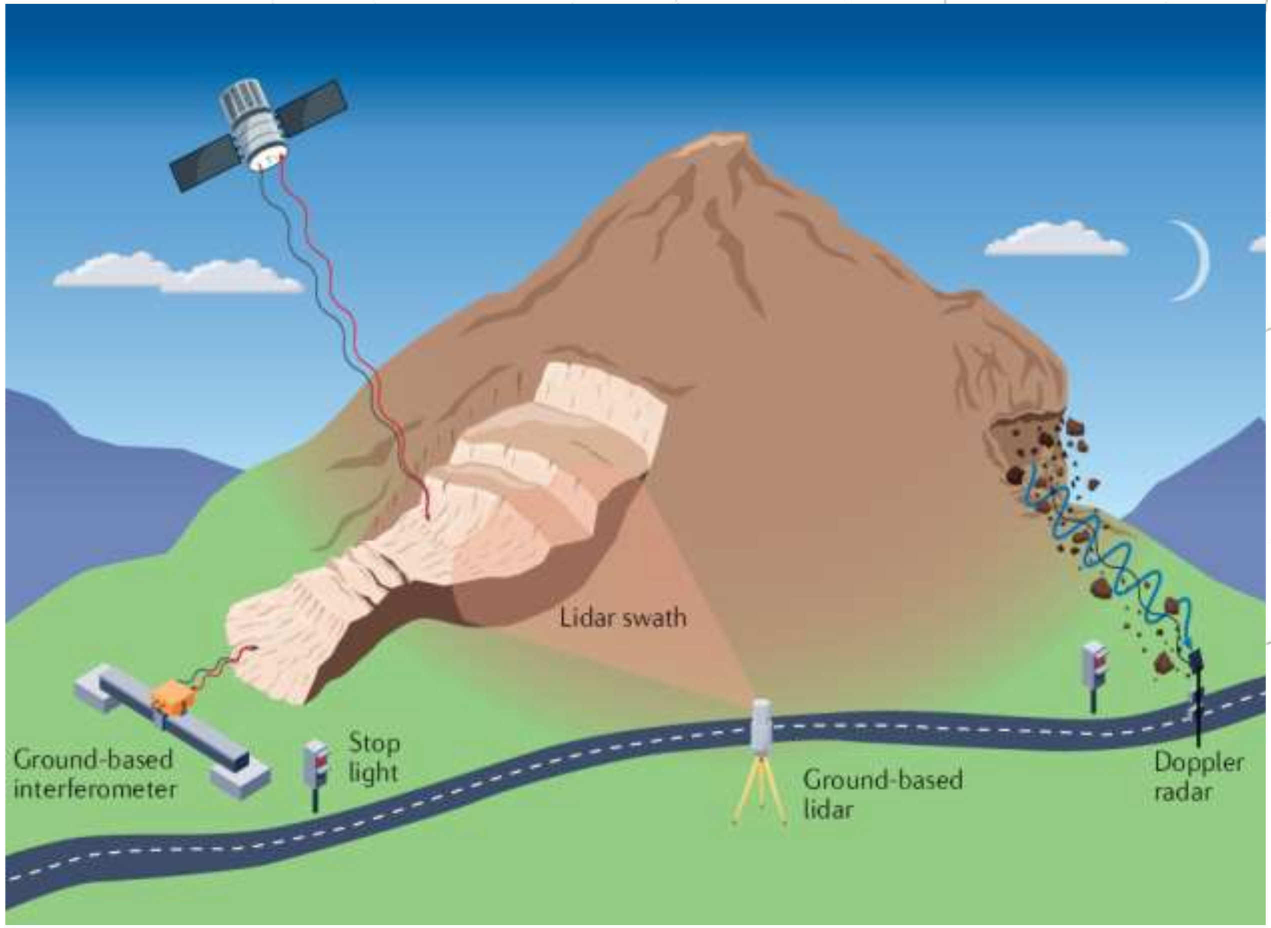
Ministero dell’Università e della Ricerca
Italiadomani

Surface monitoring objectives

- Define the areal extent of the unstable area
- Identify possible landslide retrogression or widening
- Determine the deformation field in different sectors of the affected slope
- Quantify the displacements and monitor their variation
- Promptly identify paroxistic movements in case of extremely rapid events

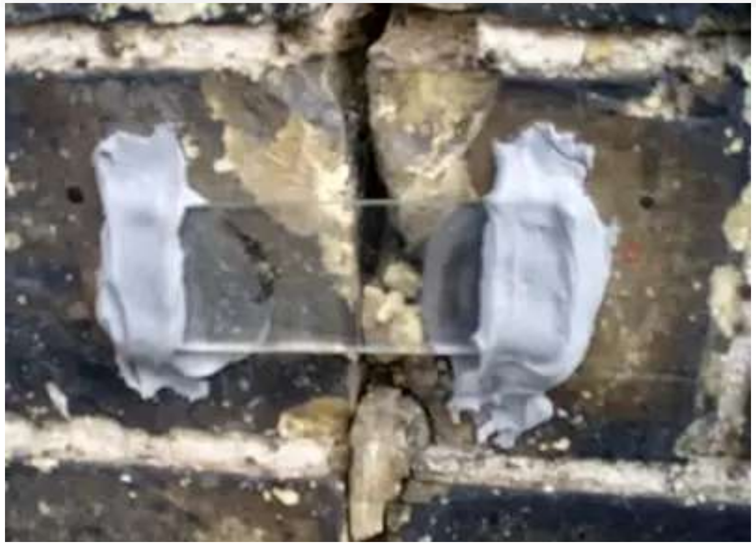


Surface monitoring devices

- Tell tale
- Crack gauges
- Distometers
- Rod extensometers
- Wire extensometers
- Tiltmeters
- GPS/GNSS
- Teodolite
- Robotized total station
- Radar Interferometry
- Lidar
- Optical photogrammetry
- Hyperspectral
- Infrared thermography
- Doppler radar
- ....

Manual monitoring of structural cracks

Steel ruler



Tell tale

Fixing screws and caliper

From:https://theconstructor.org/concrete/crack-width-measurement/21745/

Distometer

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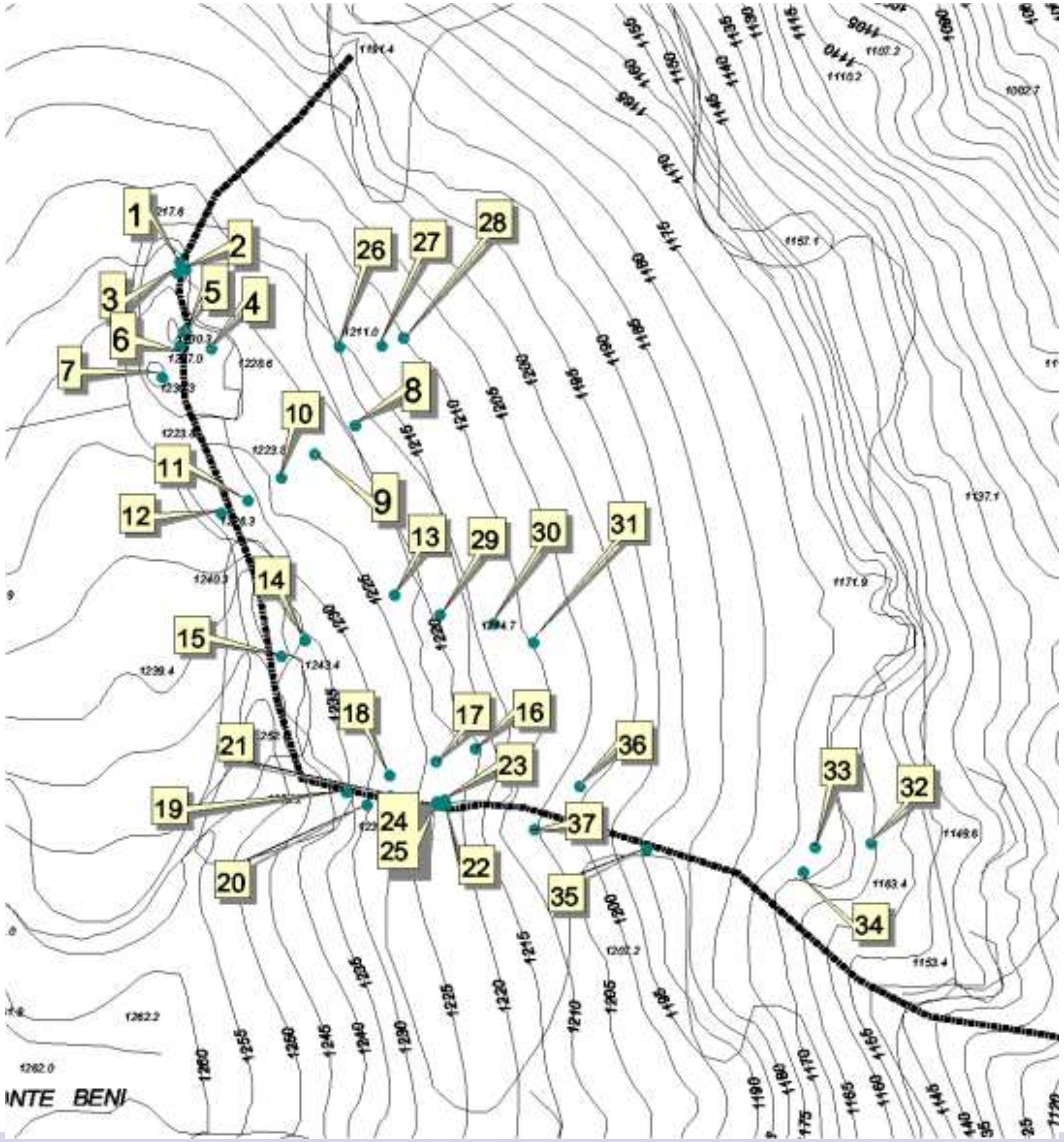
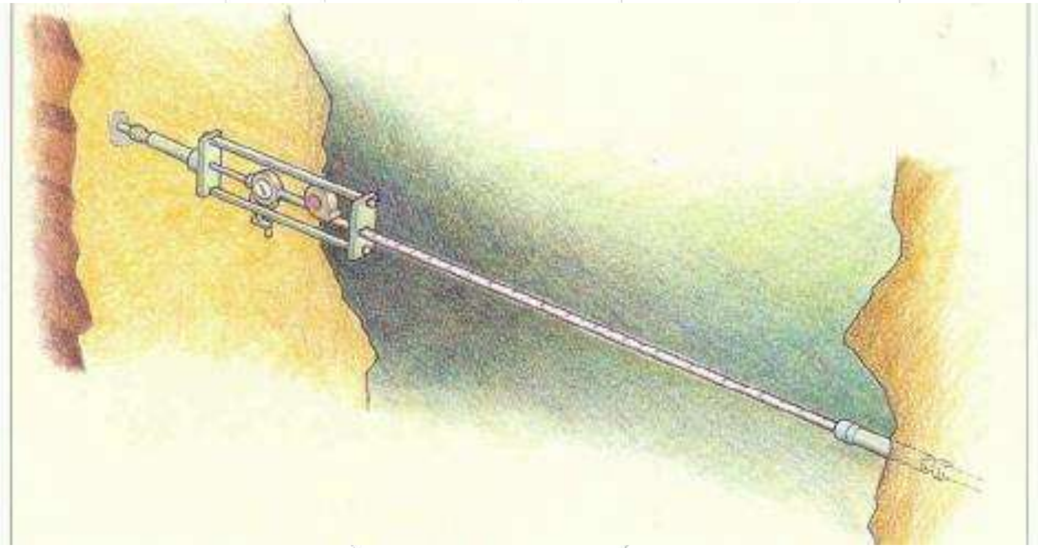
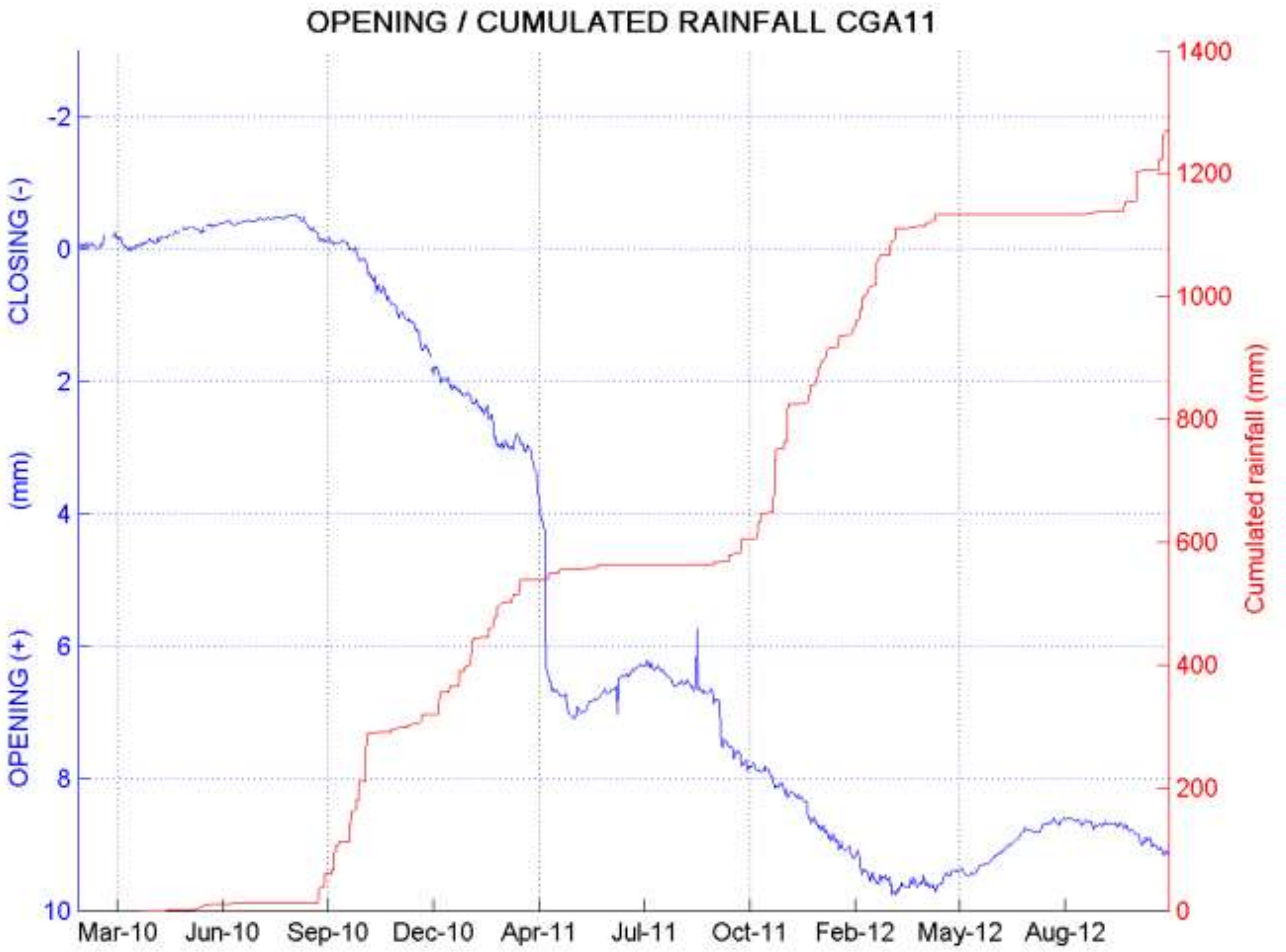
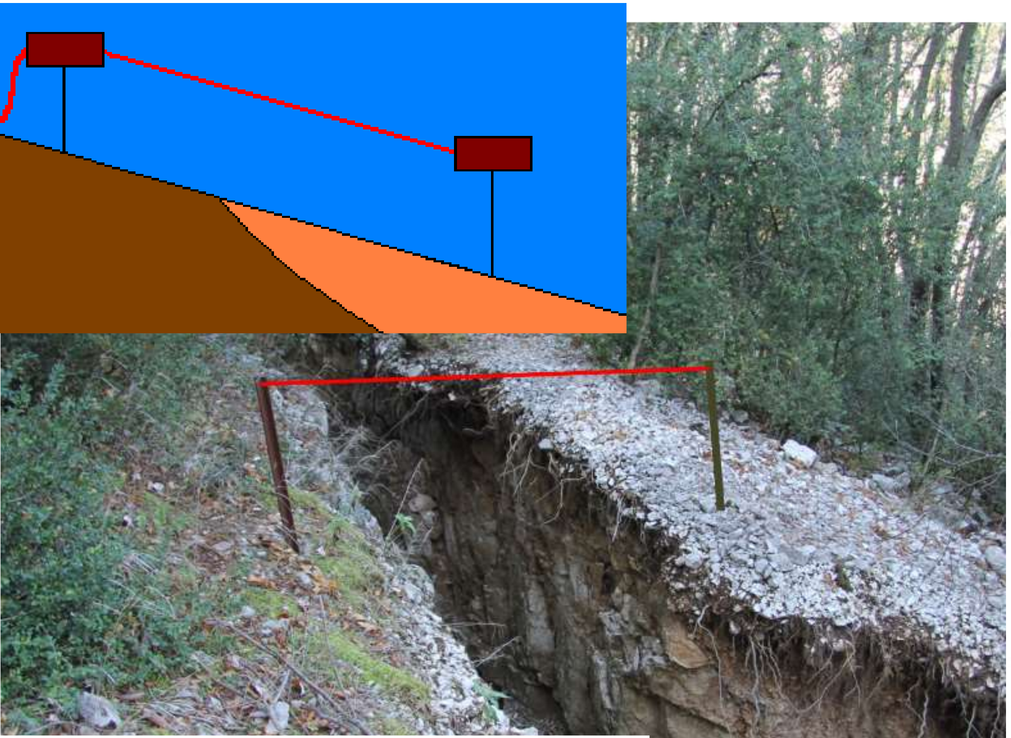


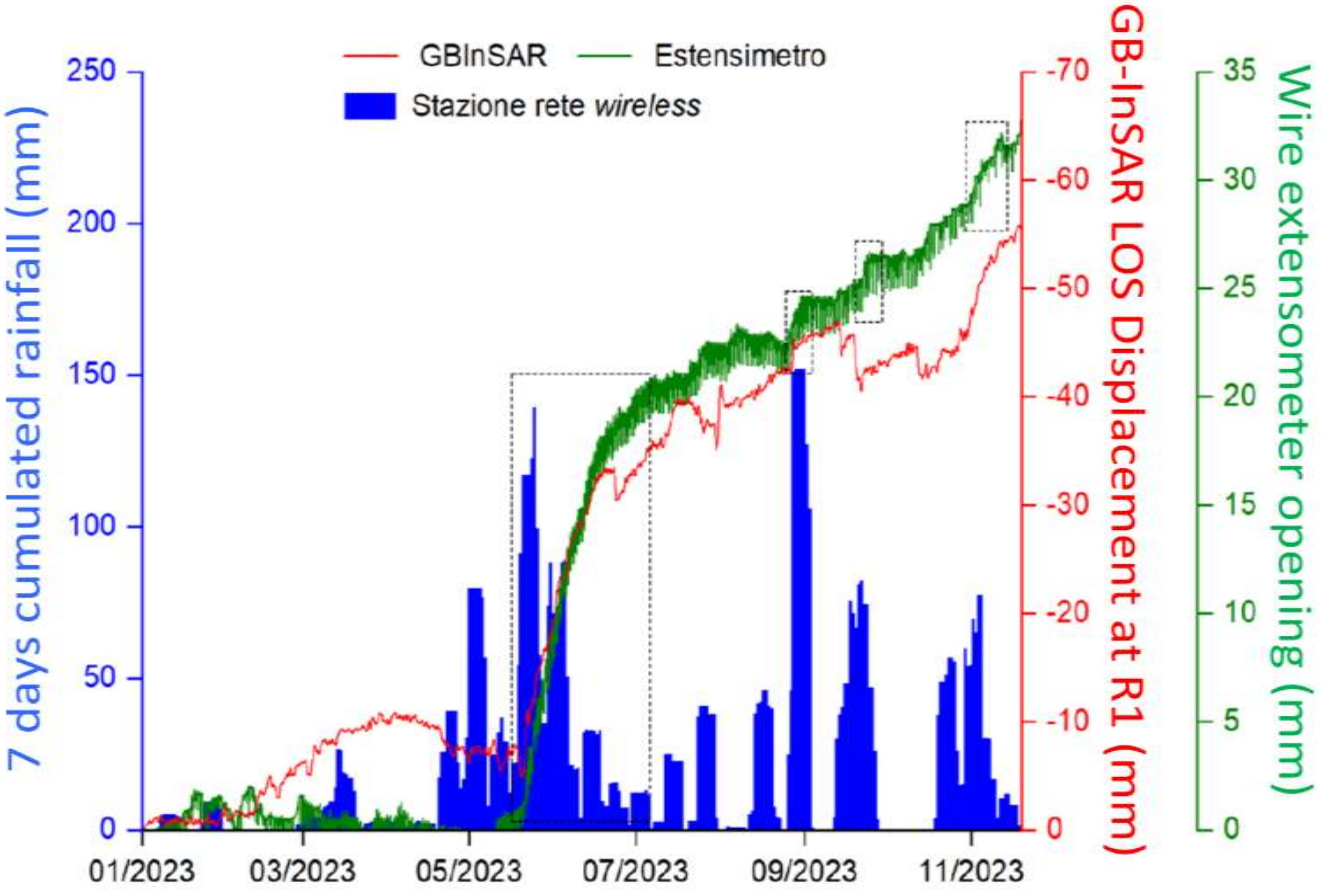


Crack gauges



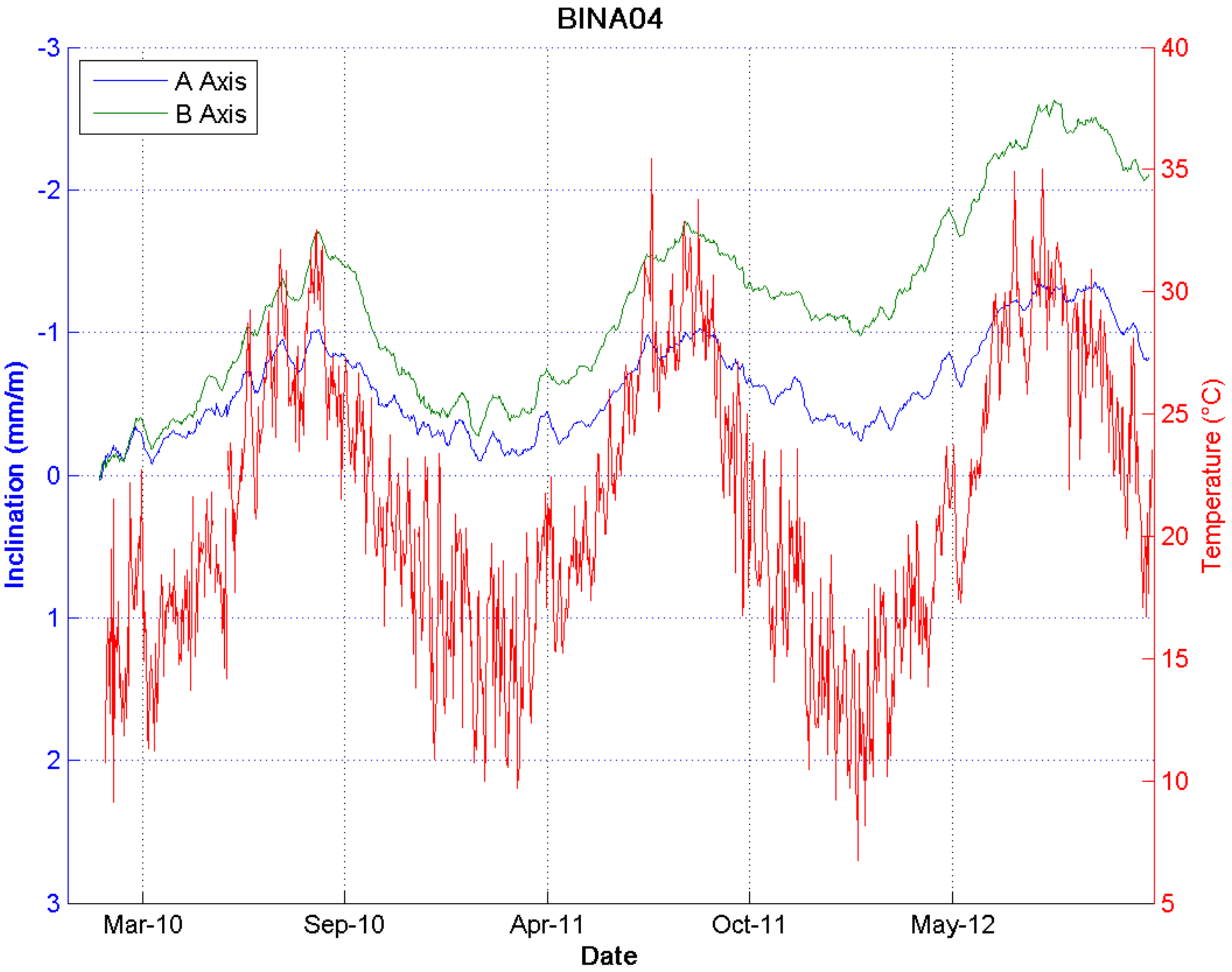
Wire extensometer



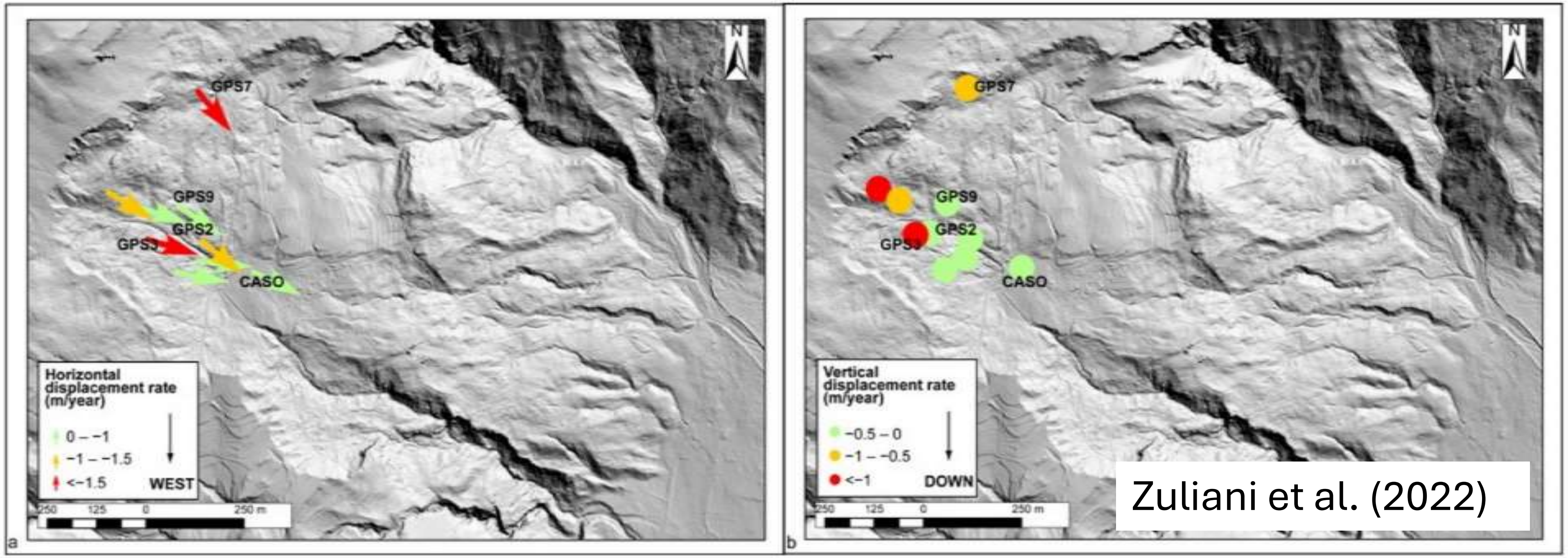


Tiltmeter


+Y
+X
TILTMETER
RANGE: -10°/+10°
SN 180274
CE


BINA04
A Axis
B Axis
Inclination (mm/m)
Temperature (°C)
Date
-3
-2
-1
0
1
2
3
40
35
30
25
20
15
10
5
Mar-10
Sep-10
Apr-11
Oct-11
May-12

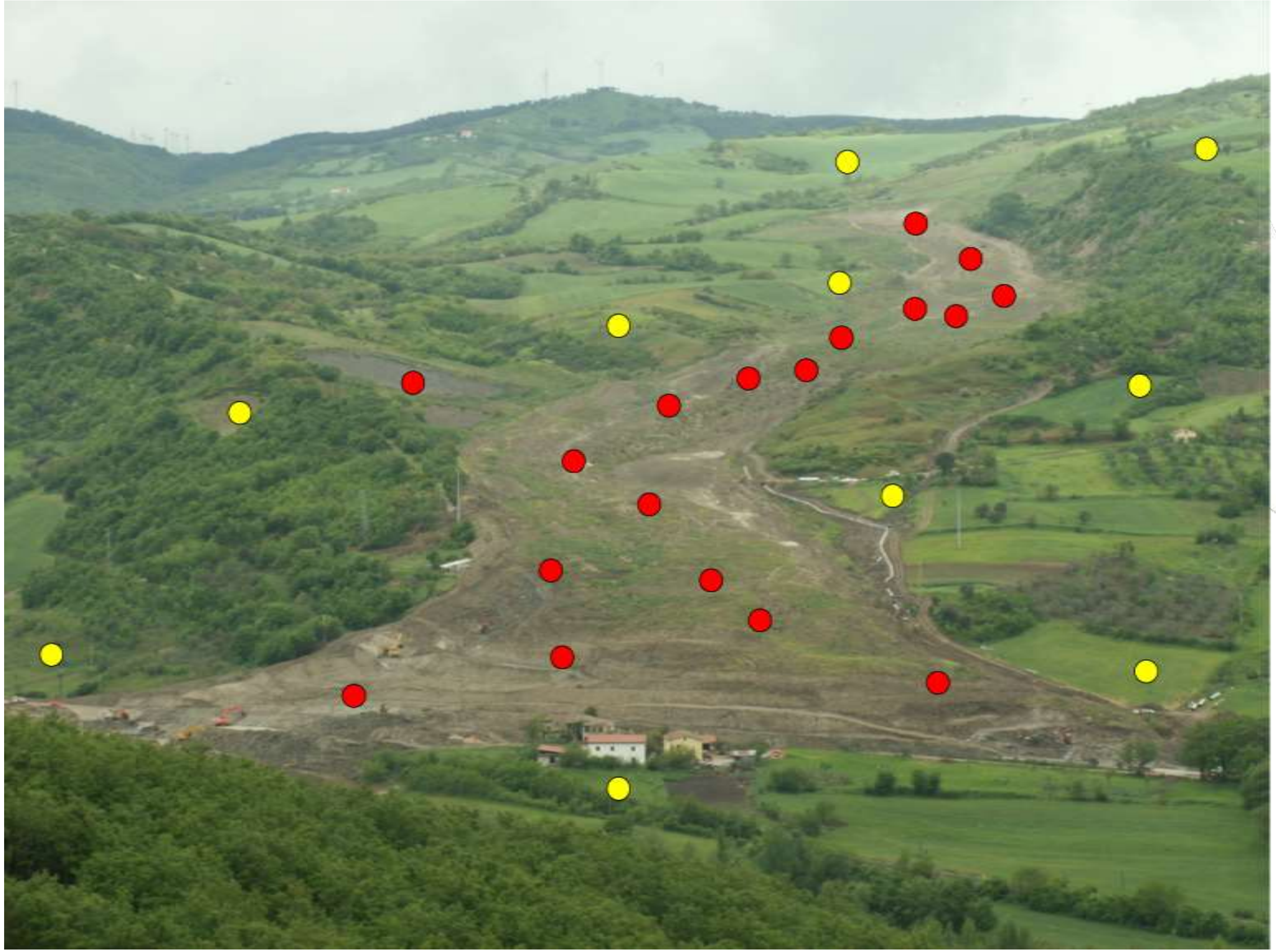
GPS/GNSS monitoring



Zuliani et al. (2022)

Topographic monitoring

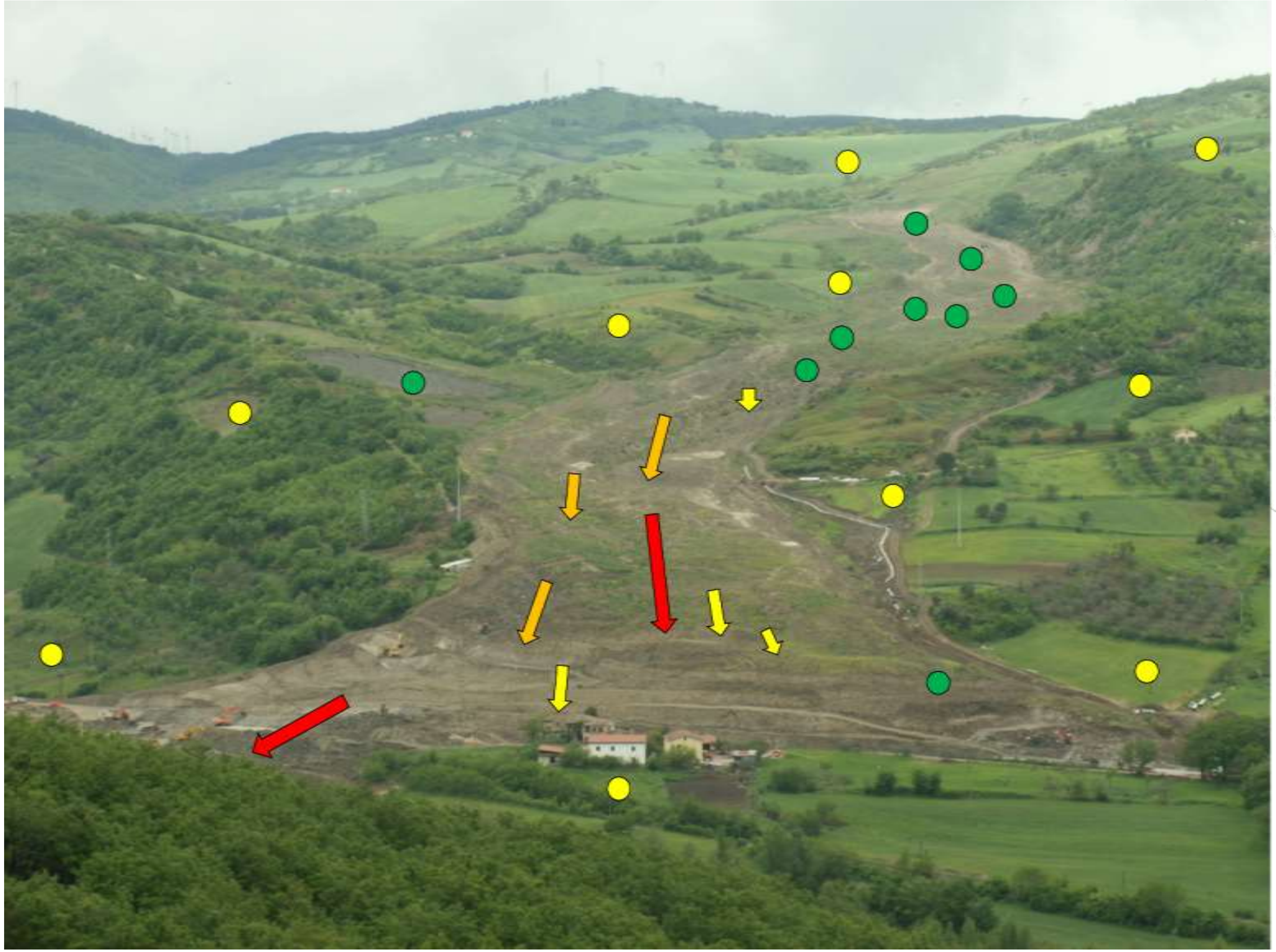
Topographic monitoring



Reference prisms

Monitoring prisms

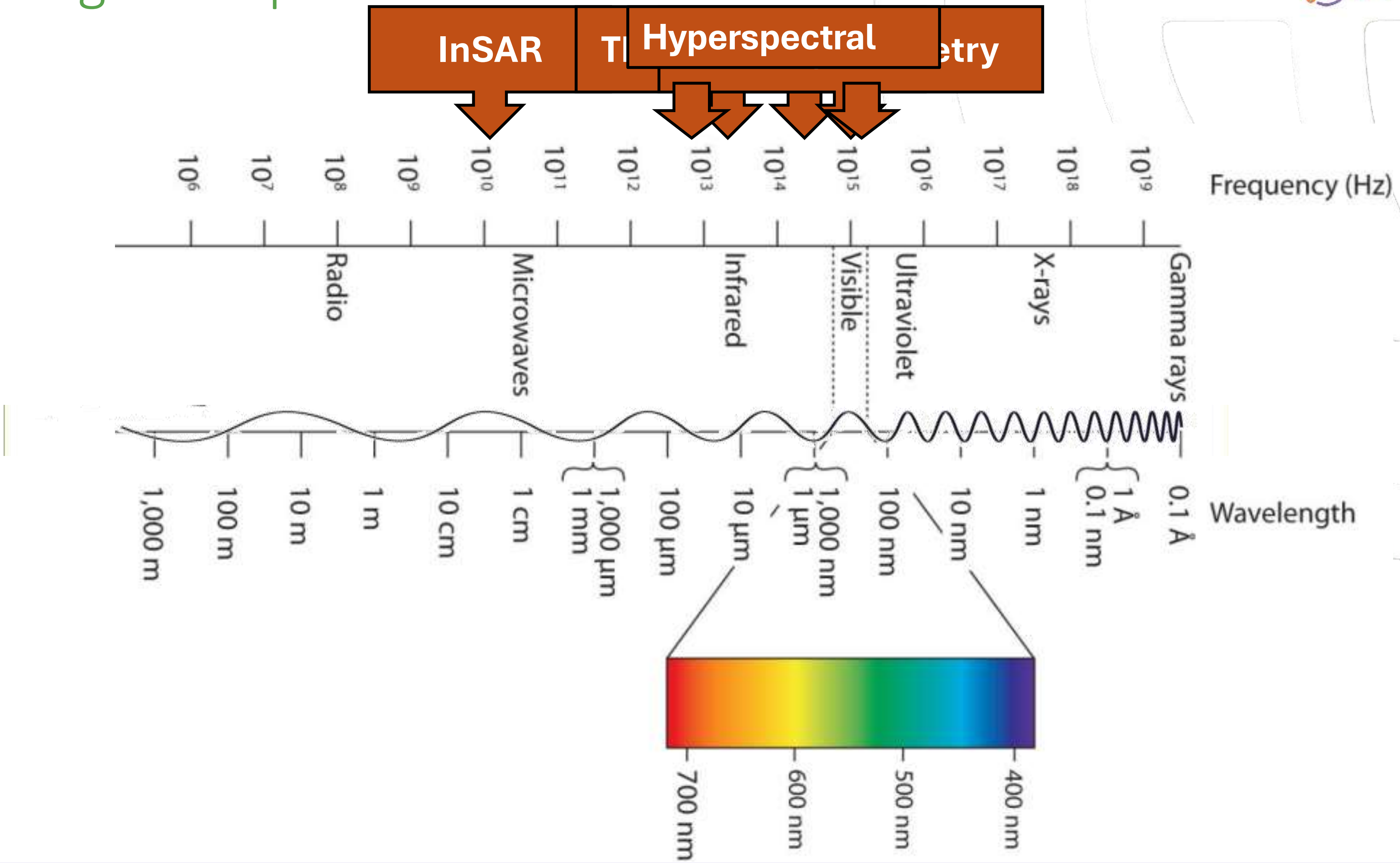
Topographic monitoring



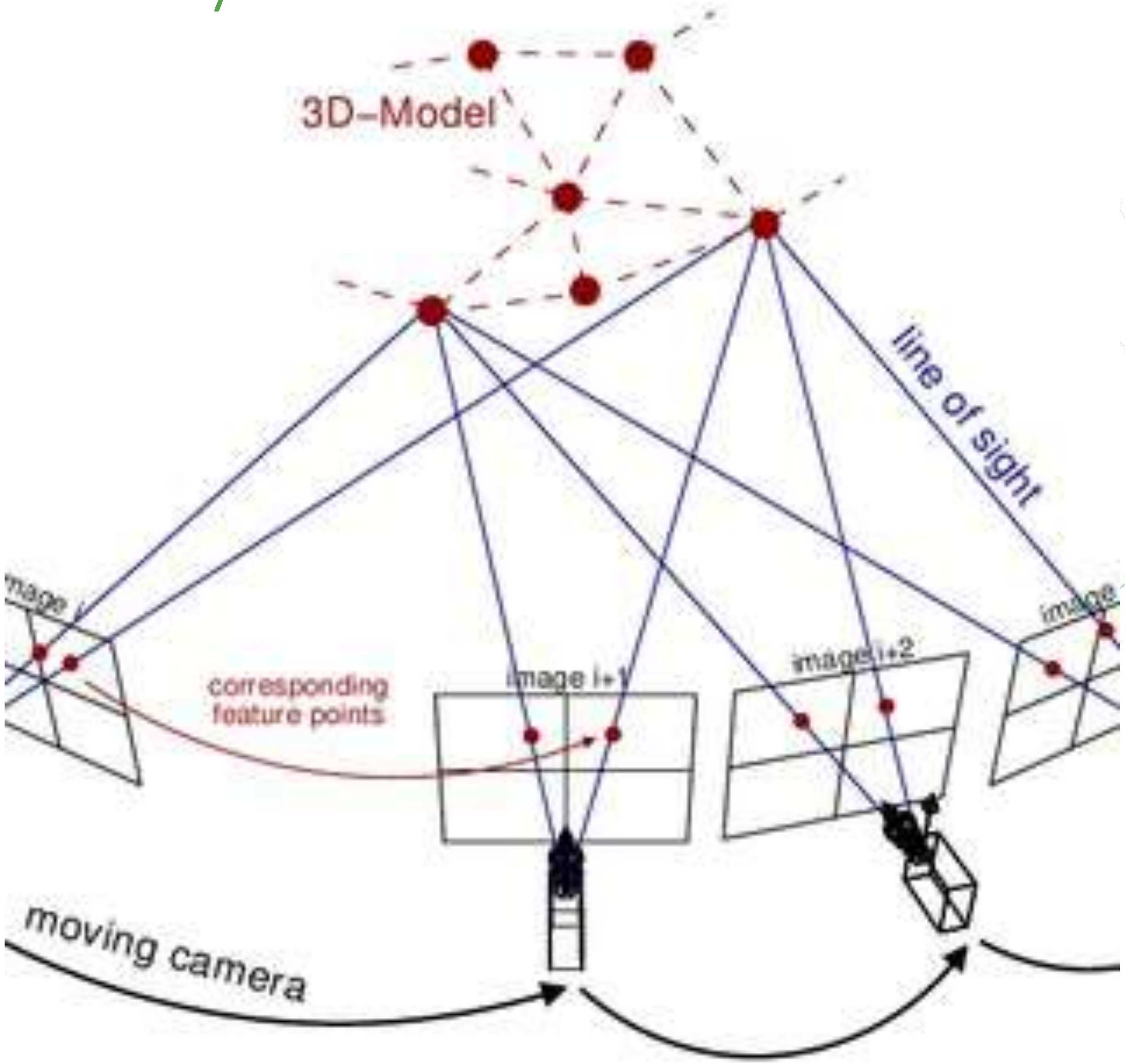
- Reference prisms
- Monitoring prisms
- 3D displacement vectors

Remote sensing

Electromagnetic spectrum



Optical photogrammetry



UAV - Unmanned Aerial Vehicle

- Aircraft piloted by remote control or onboard computers, commonly knows as drones.

Fixed-Wing

- Autonomy
- Range

Single/Multi-rotor

- Payload
- Feasibility

SATURN UAV series

SATURN 2

Payload: 10 kg

Autonomy: 30 min

Diameter: 120 cm

Vel max: 65 km/h

SATURN MINI

Payload: 1.5 kg

Autonomy: 30 min

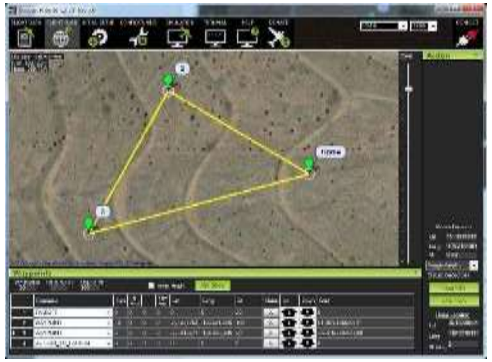
Diameter: 60 cm

Vel max: 90 km/h

SATURN 2

Work phases

1. Plan

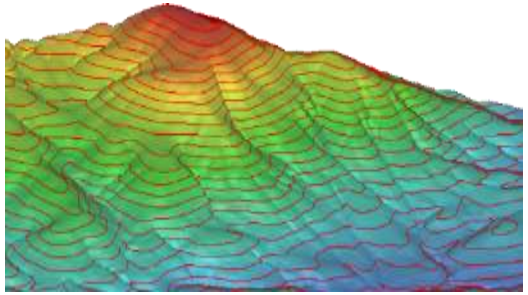


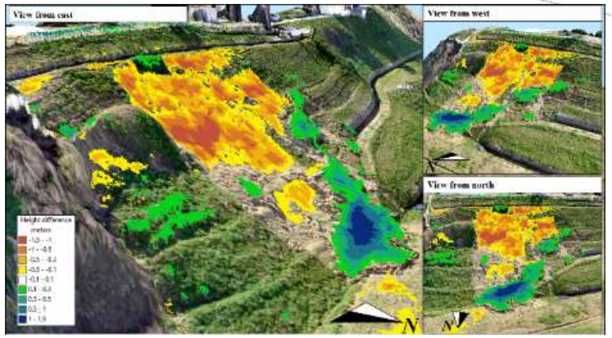
2. GCPs

3. Survey

4. Image geotag

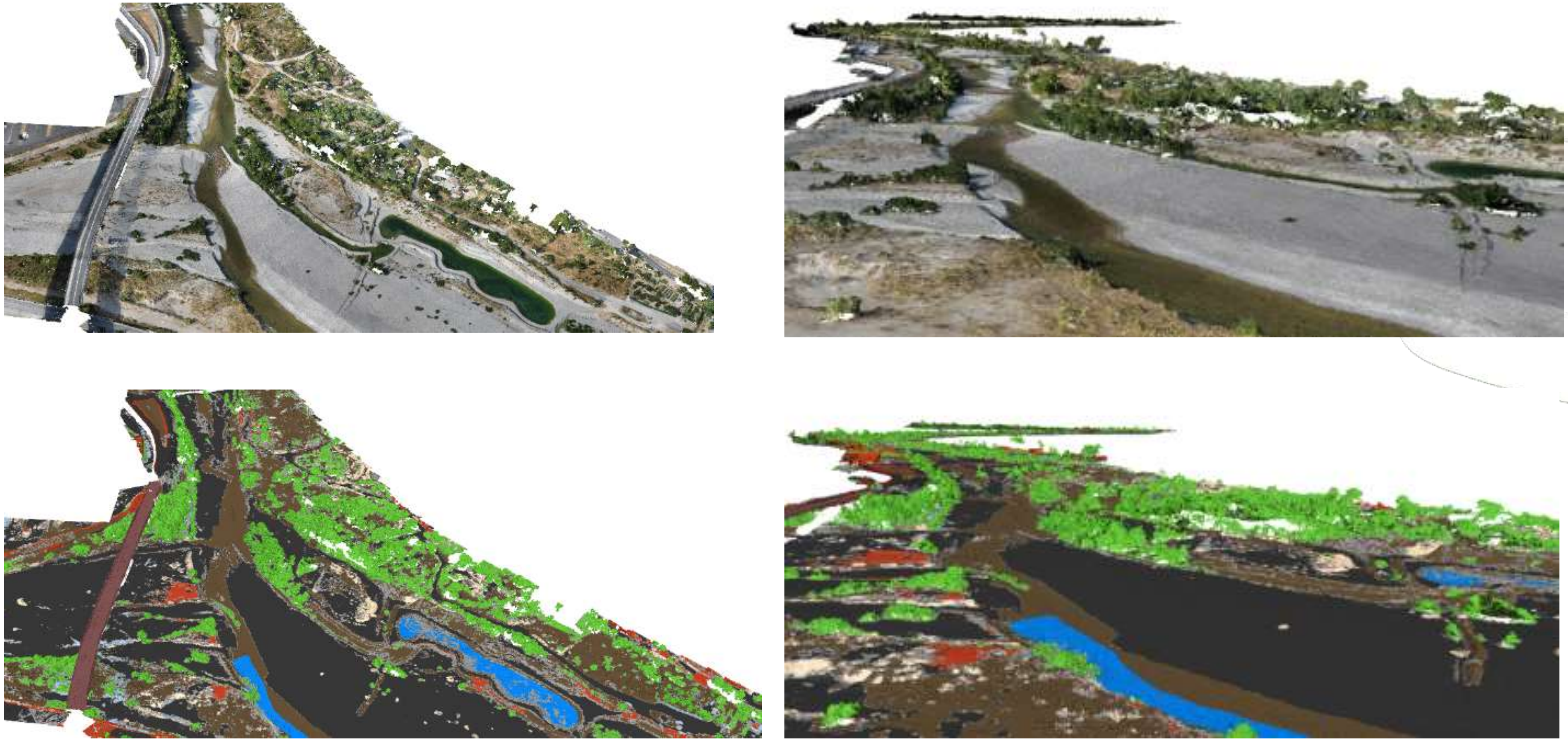
5. Processing





Vegetation Filtering

- Algorithms (e.g. automatic classification - Agisoft Metashape software)
- Manual filtering



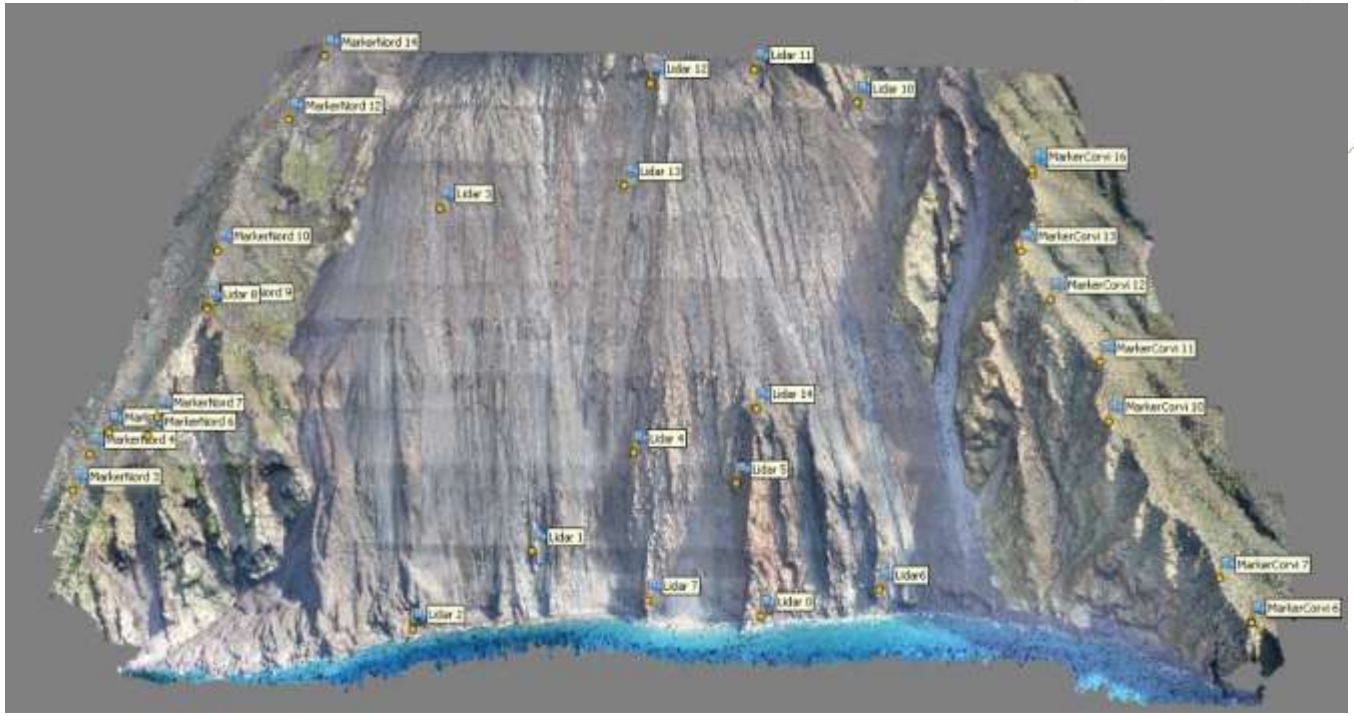
Stromboli Island

Sciara del Fuoco

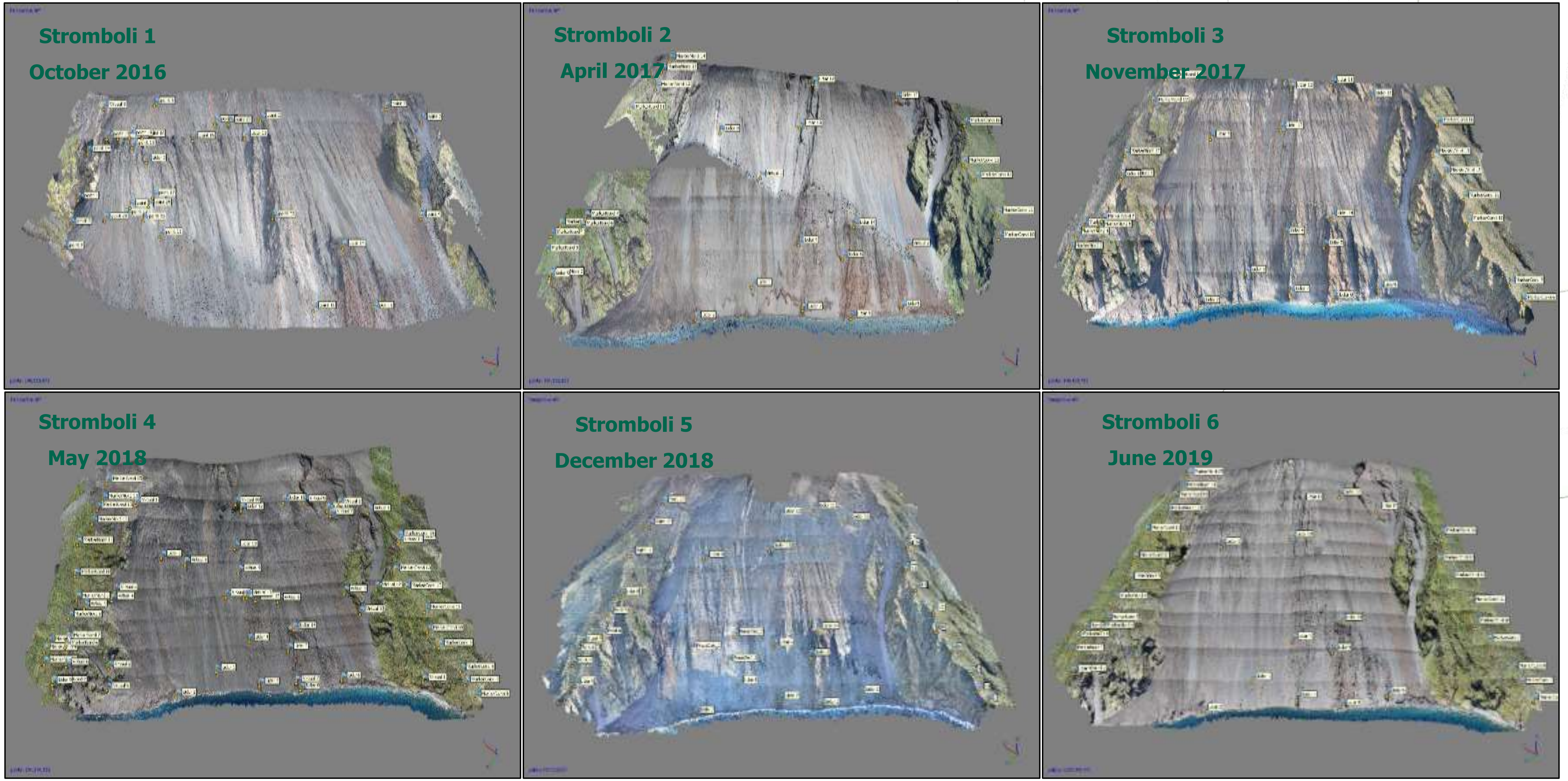
Ground Control Points positioning

UAV Survey

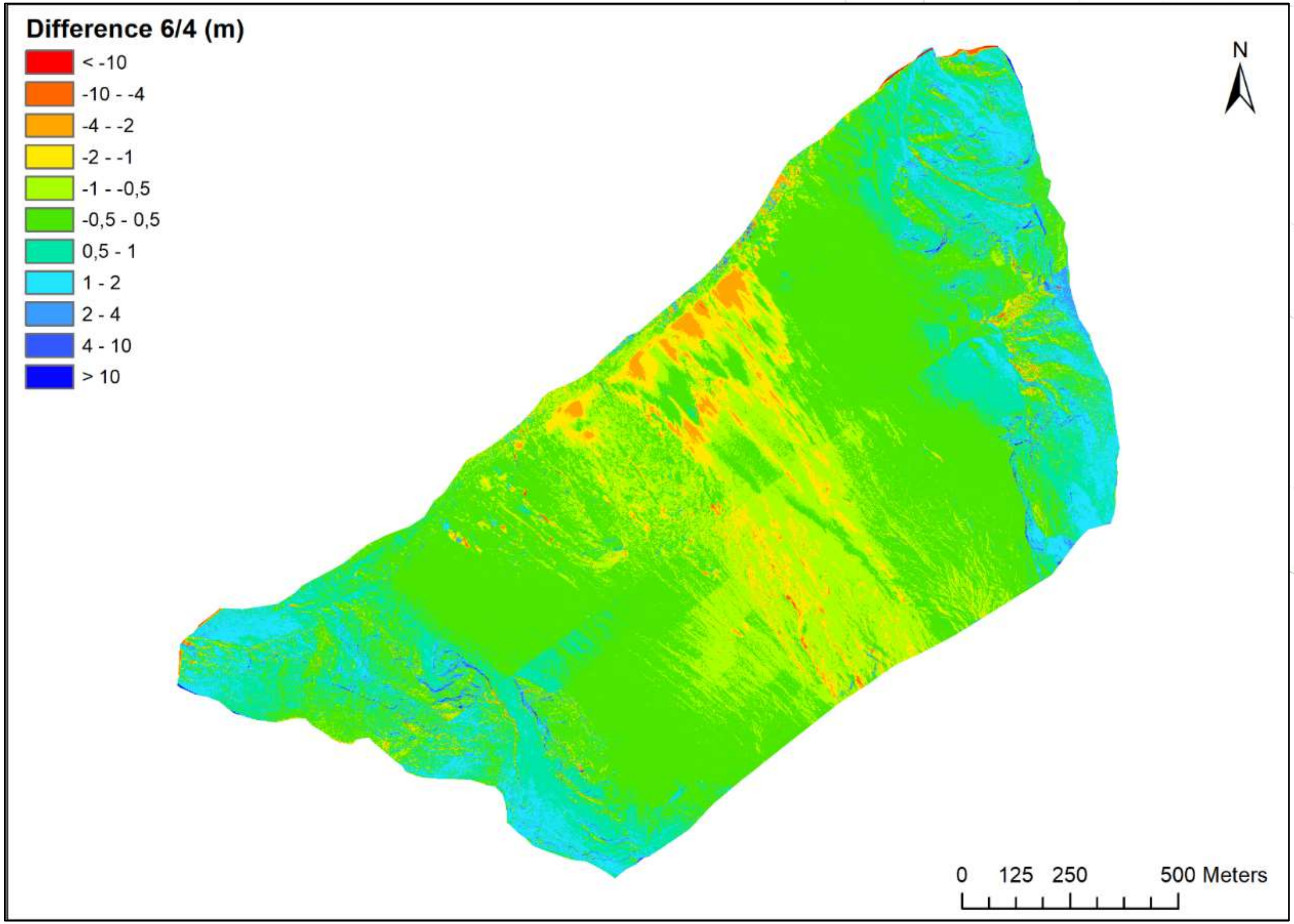
Processing
↓
3D Point cloud



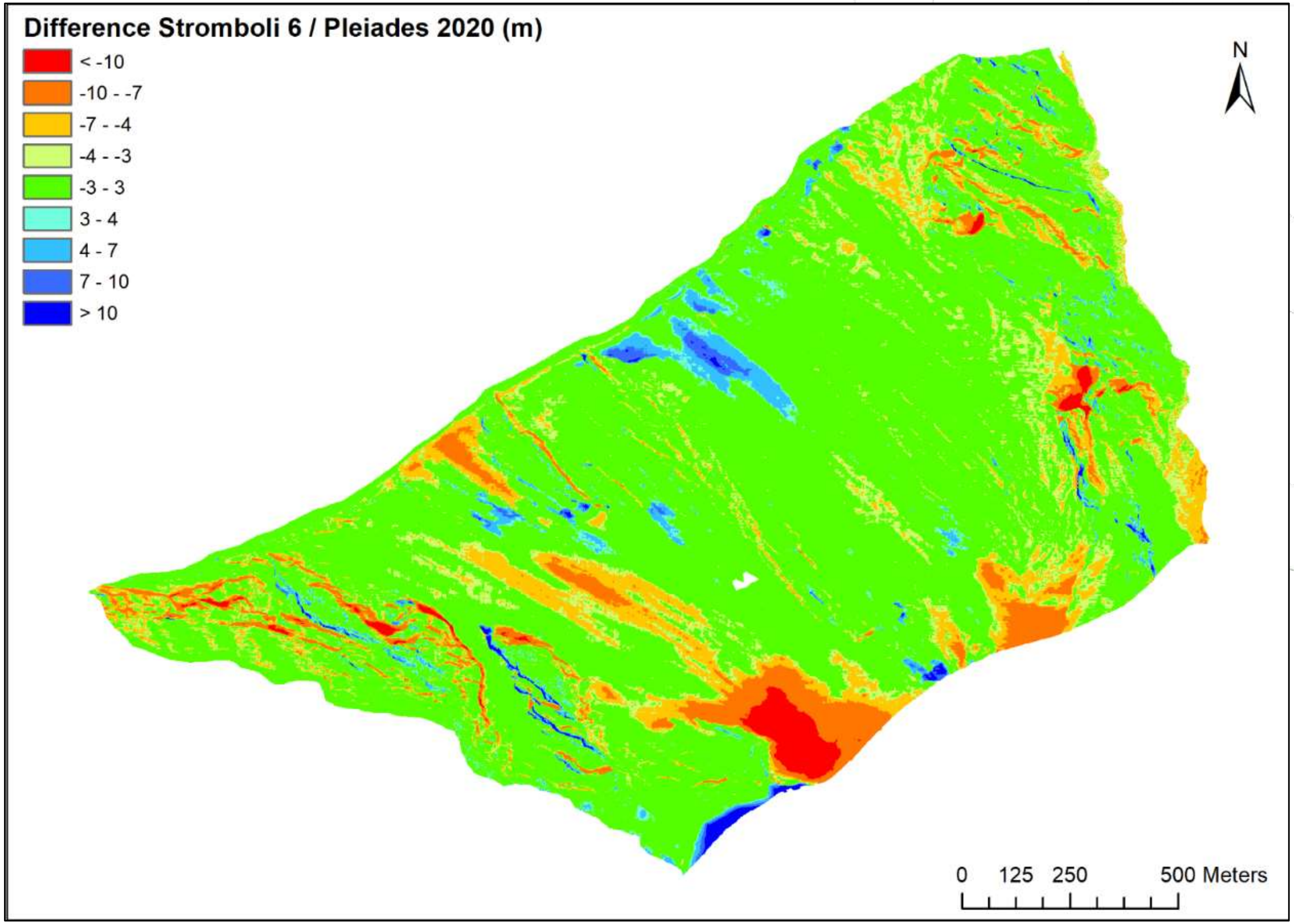
Multitemporal surveys



Multi-temporal analysis



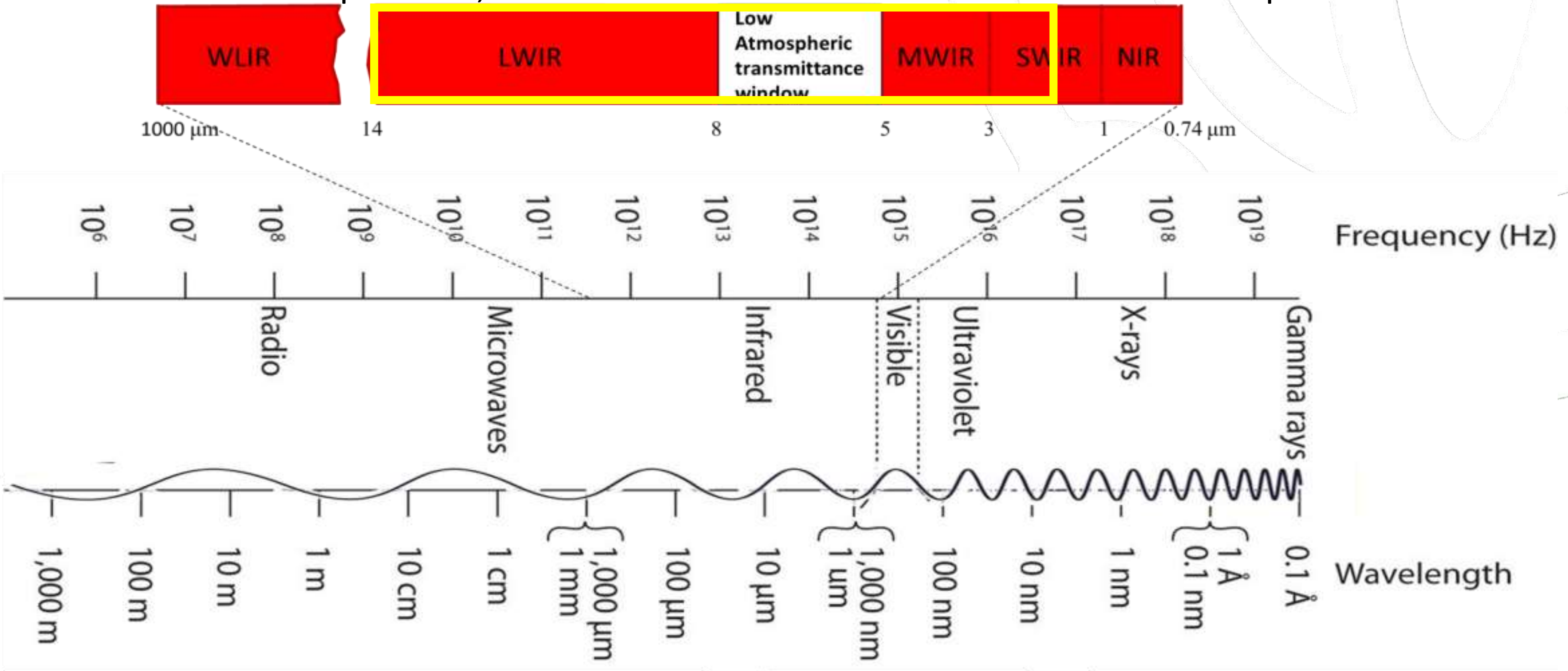
Multi-temporal analysis



Thermal Infrared

All matter with a temperature greater than absolute zero emits thermal radiation

At room temperature, most of the emission is in the Thermal Infrared spectrum



Stephan-Boltzman Law

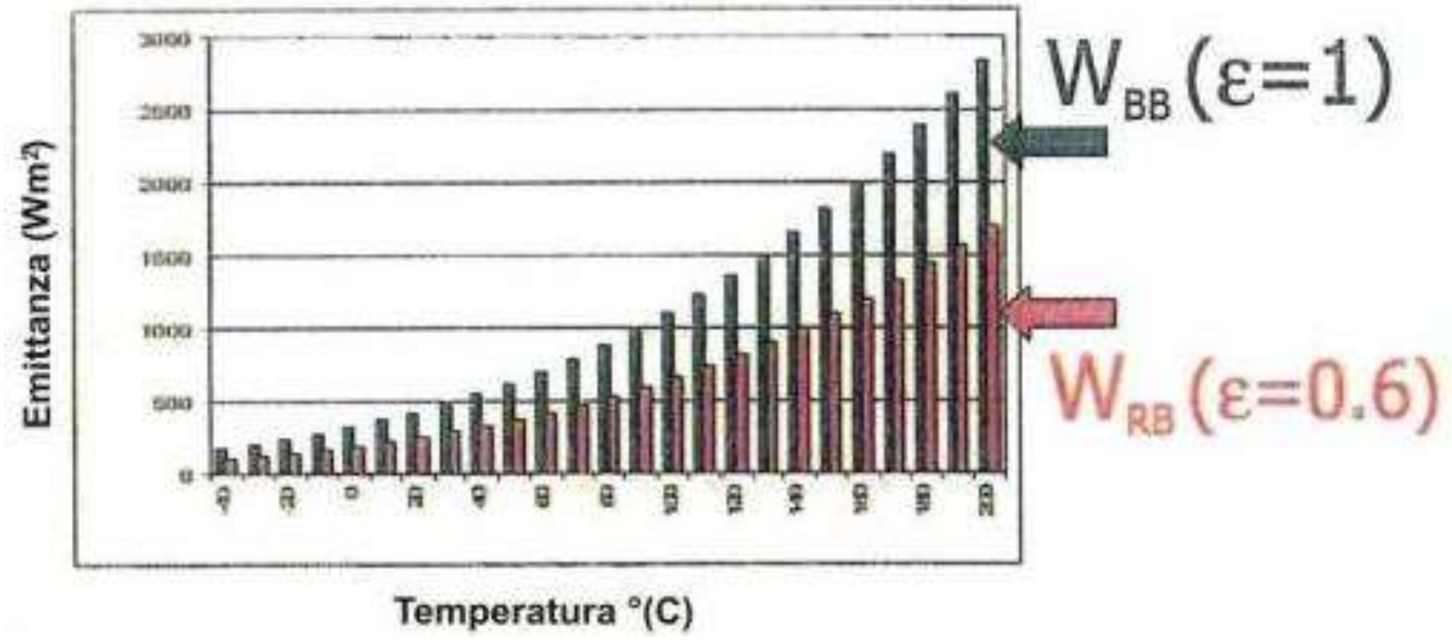
$$W = \varepsilon \sigma T4$$

W (Watt/m2) = Radiant Exitance

ε = Emissivity

σ = Stephan-Boltzmann Constant (5.67×10-8 Wm-2 K-4)

T = Absolute temperature (K°).



Material	Typical Average Emissivity ε over 8–14 μm[a]
Clear water	0.98–0.99
Wet snow	0.98–0.99
Human skin	0.97–0.99
Rough ice	0.97–0.98
Healthy green vegetation	0.96–0.99
Wet soil	0.95–0.98
Asphaltic concrete	0.94–0.97
Brick	0.93–0.94
Wood	0.93–0.94
Basaltic rock	0.92–0.96
Dry mineral soil	0.92–0.94
Portland cement concrete	0.92–0.94
Paint	0.90–0.96
Dry vegetation	0.88–0.94
Dry snow	0.85–0.90
Granitic rock	0.83–0.87
Glass	0.77–0.81
Sheet iron (rusted)	0.63–0.70
Polished metals	0.16–0.21
Aluminum foil	0.03–0.07
Highly polished gold	0.02–0.03

Thermal cameras

IR Resolution: 1024 × 768

Thermal Sensitivity/NETD: <20 mK @ 30°C (86°F)

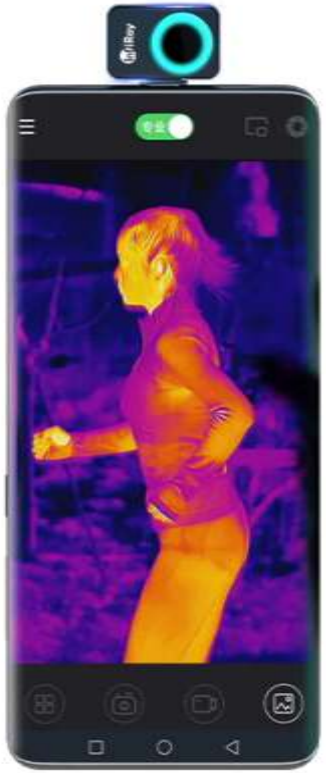
Field of view (FOV): 12° × 9°

Digital Camera: Field of view adapts to the infrared lens

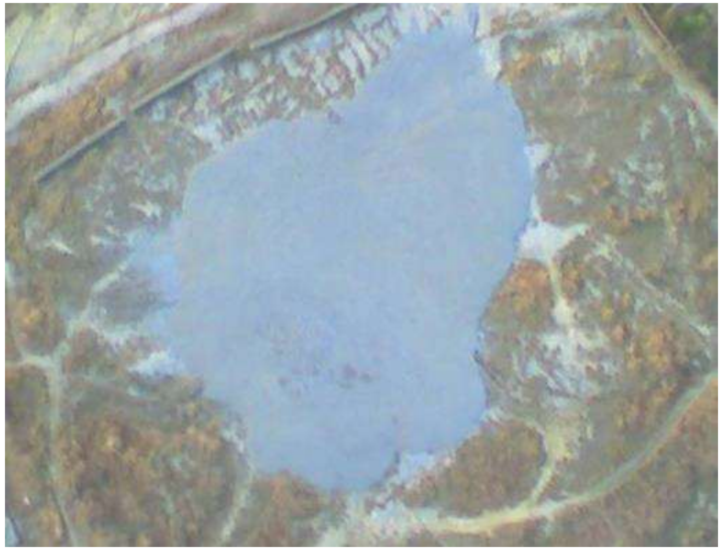
Spectral Range: 7.5–14 µm

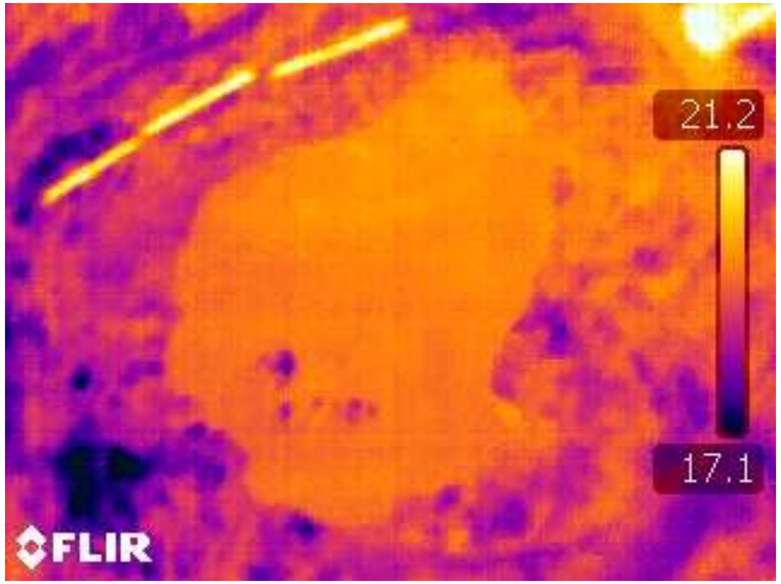
Object Temperature Range: -40°C to 2000°C (-40°F to 3632°F)

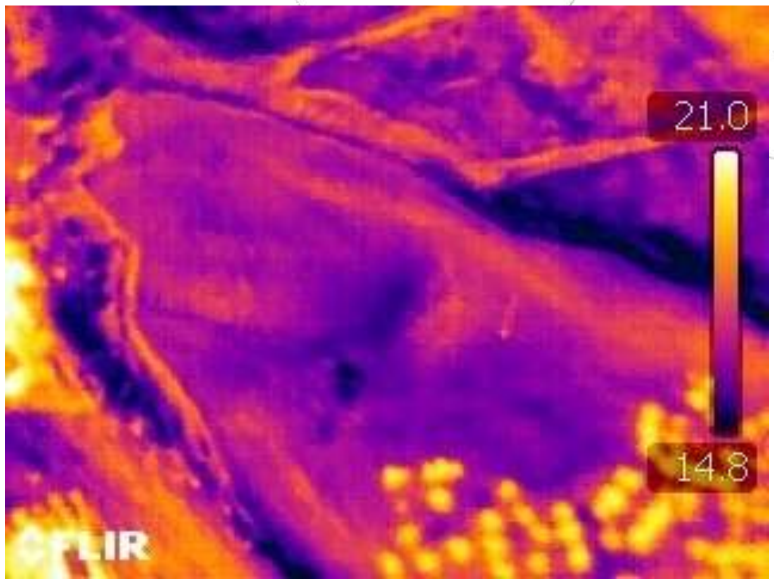
Display: Touchscreen, 4.3 in. wide screen LCD, 800 × 480 pixels



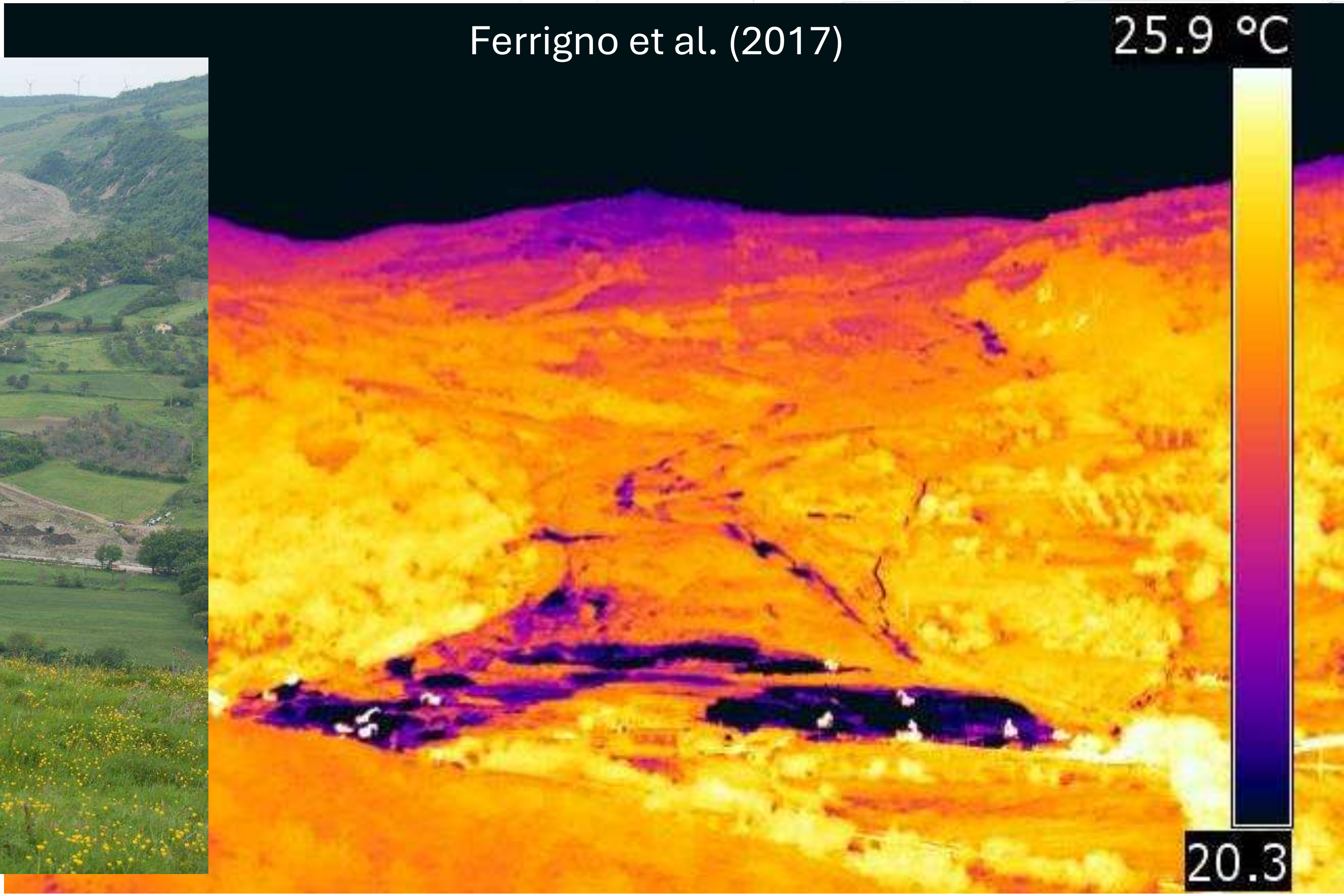
Environmental applications



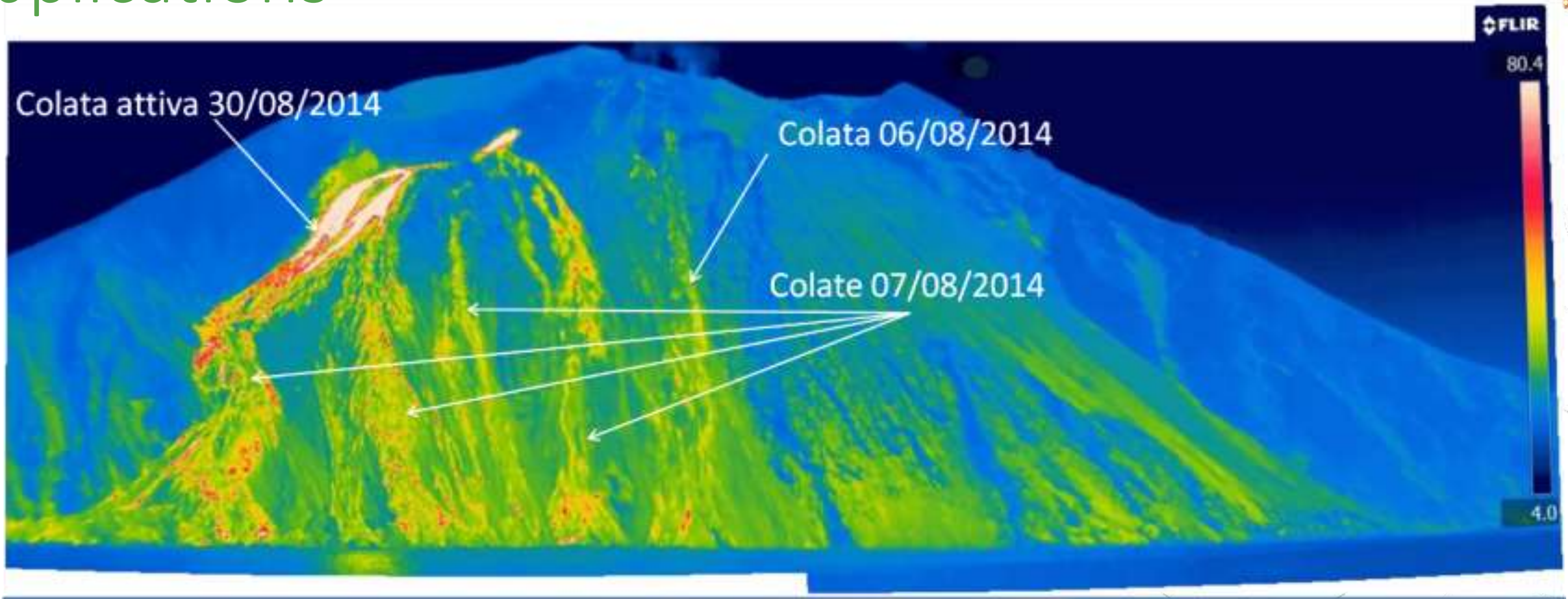




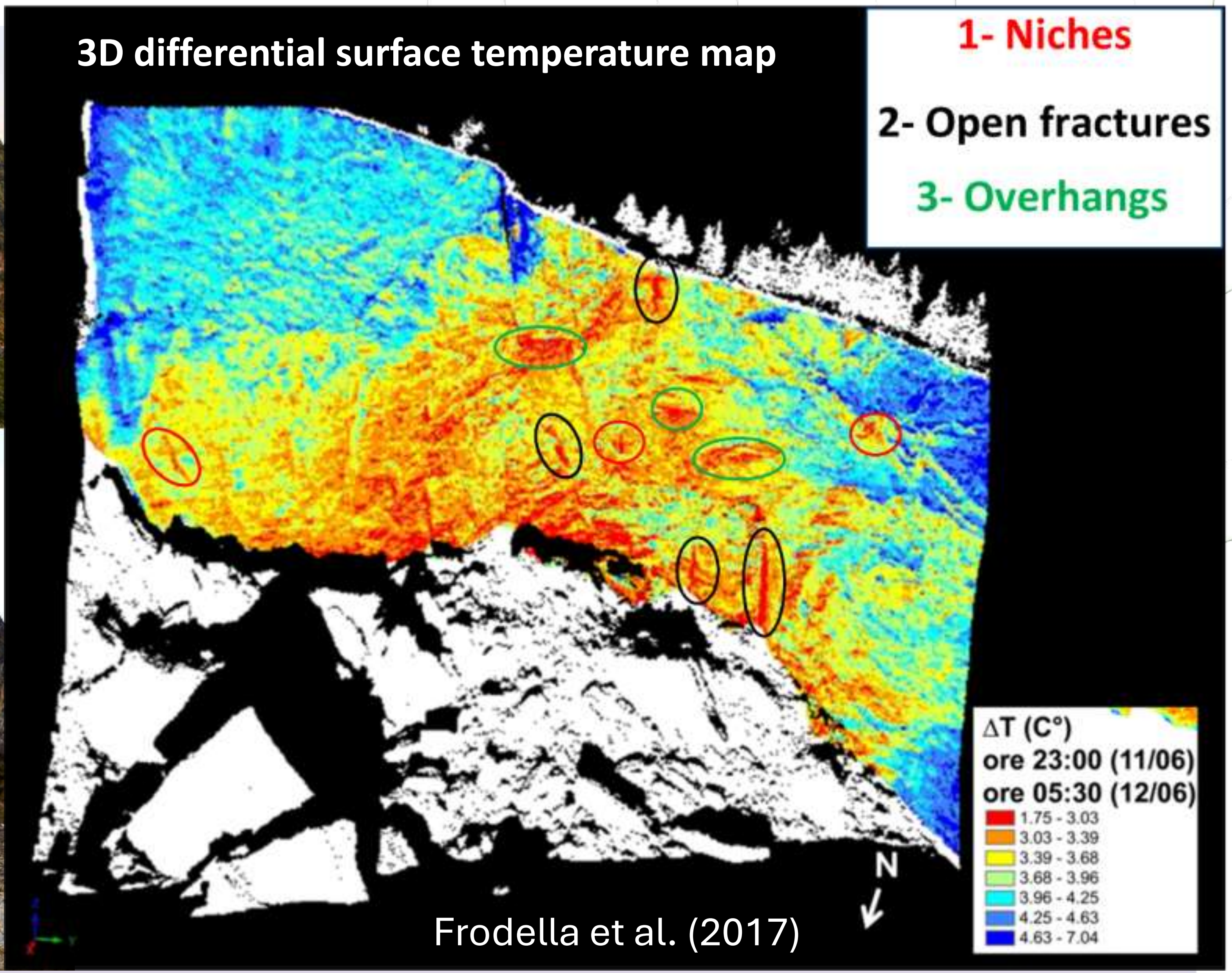
Landslide satureted areas



Volcanic applications



Rockfalls

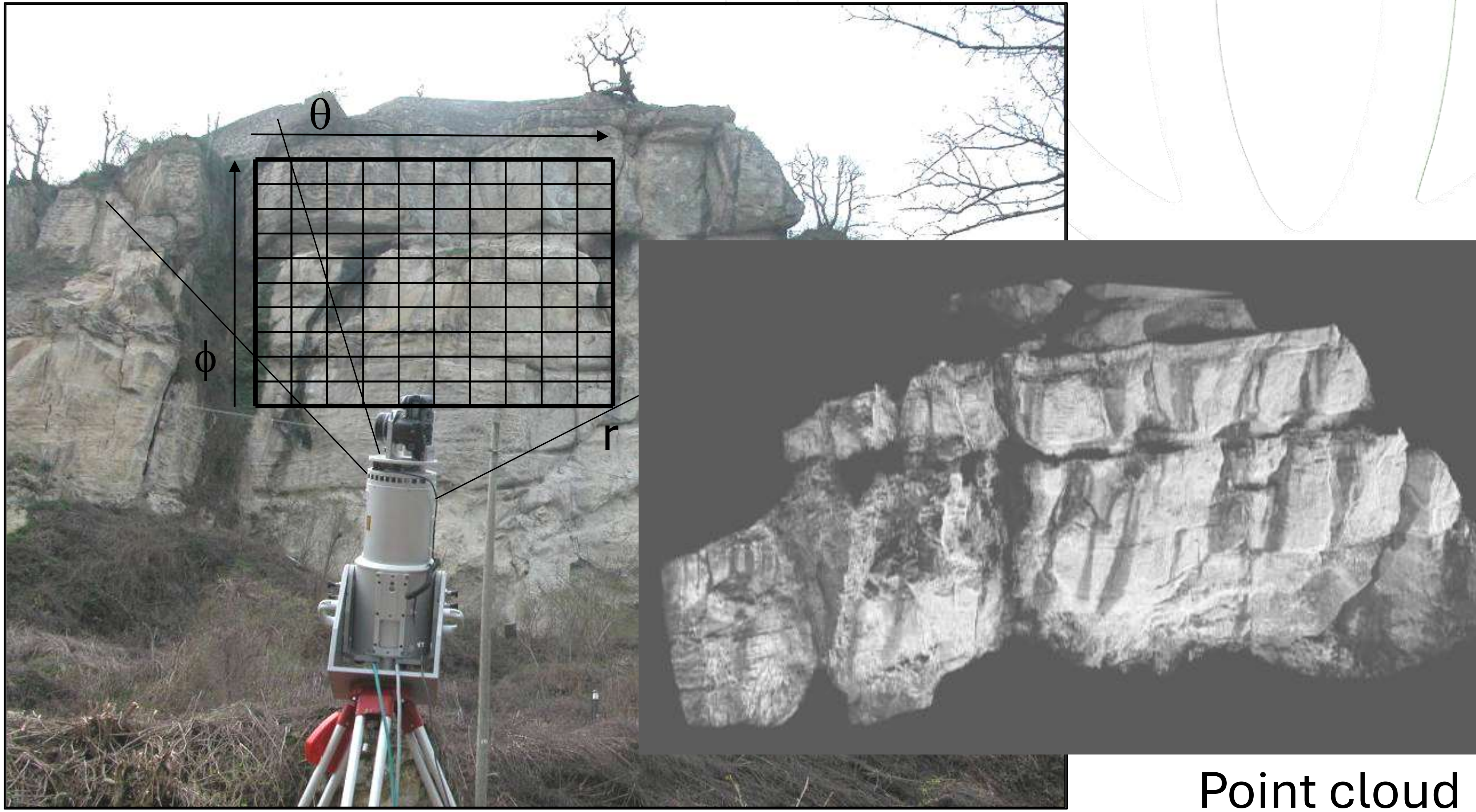

3D differential surface temperature map
1- Niches
2- Open fractures
3- Overhangs
ΔT (C°)
ore 23:00 (11/06)
ore 05:30 (12/06)
1.75 - 3.03
3.03 - 3.39
3.39 - 3.68
3.68 - 3.96
3.96 - 4.25
4.25 - 4.63
4.63 - 7.04
N
Frodella et al. (2017)

Laser scanning (LIDAR)

Time of Flight

Phase Difference

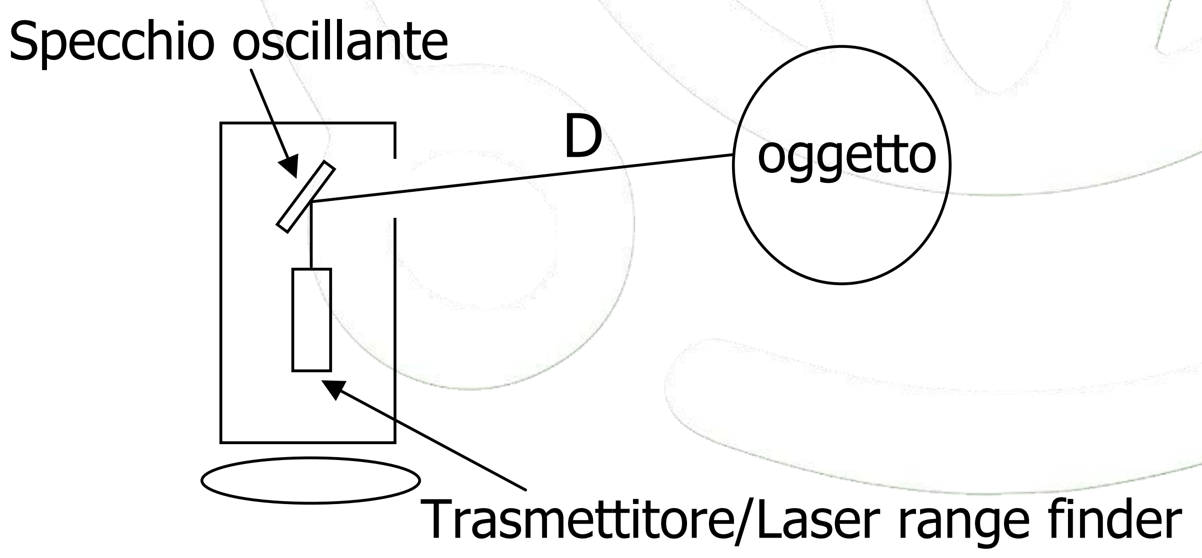
Optical Triangulation



Point cloud

Time of Flight (TOF)

- Short duration laser pulse
- With a stabilized quartz chronometer the time of flight (TOF) is measured
- The object distance is: D=(ct)/2
- Maximum range >100m
- eCntimetric accuracy
- Monitoring rate >> 10000 pts/s



Terrestrial laser scanners

Main technical specifications:

- Maximum range
- Scanning speed (acquisition rate)
- Field of view
- Angular (Spatial) resolution
- Accuracy
- Dimensions/weight
- Associability with other devices (GPS, Cameras)

Advantaged and drawbacks of Lidar

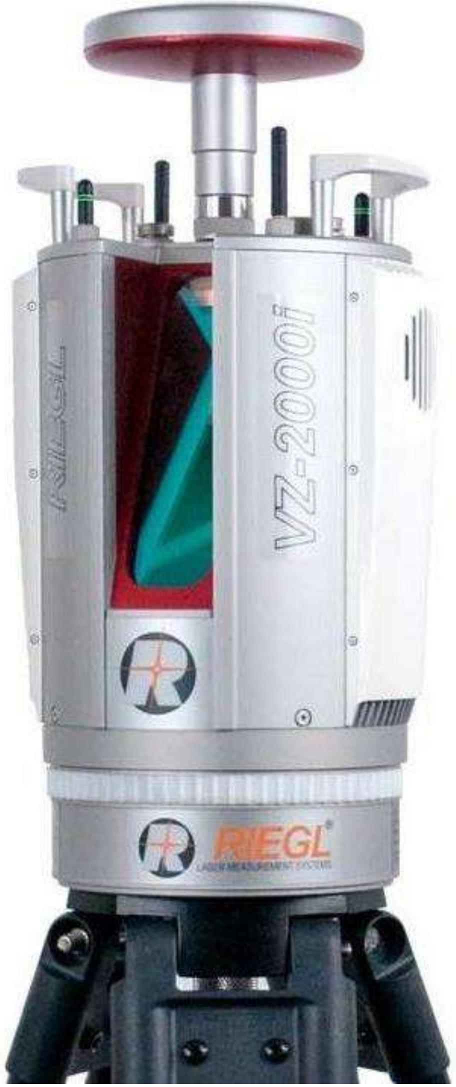
ADVANTAGES

- Ease of transportation
- Large scanning window
- High survey speed
- High spatial resolution
- High accuracy
- Real-time cloud production (emergency)
- Reflectivity (and RGB) values of the points
- Remote sensing (inaccessible or dangerous areas)
- Active sensor (not affected by external light conditions)
- Possibility to compare point clouds obtained at different times (monitoring)

DISADVANTAGES

- All objects present in the scenario are detected: filtering required
- Depends on environmental conditions (snow, rain, dust)
- Limited range (by instrument characteristics and object reflectivity)
- Need for power source (battery, power generator)
- (relative) difficulty in transporting the equipment
- High costs

Laser scanner RIEGL VZ-2000i

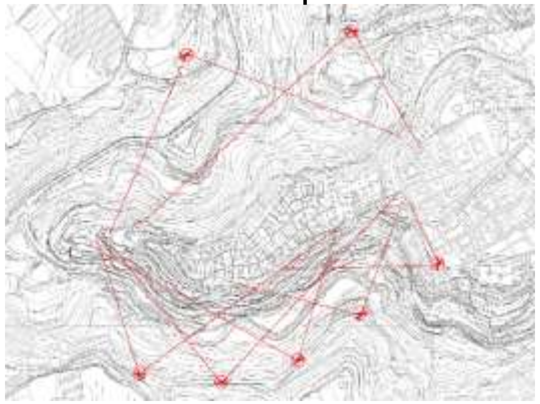


- Max range: 2500 m
- Max scan rate: 500.000 pts/sec
- Accuracy: 5 mm
- Precision: 3 mm
- Angular resolution: 0.0005°
- Wavelength: near infrared
- Beam divergence: 0.19 mrad
- Scan field: 100°(vertical), 360°(horizontal)
- Full waveform technology

TLS acquisition phases

1. Survey

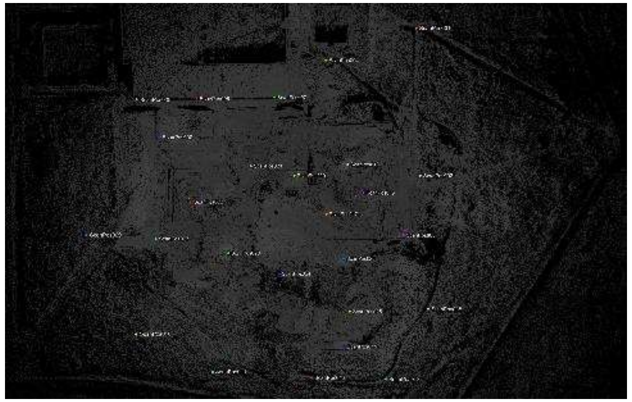
Define scans positions



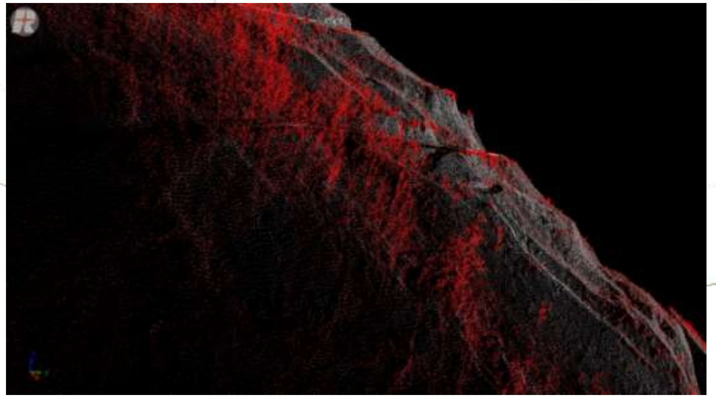
Place targets

Acquire scans

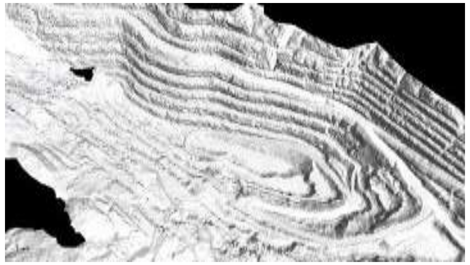
2. Registration and georeferencing

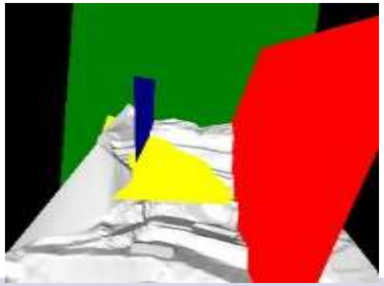


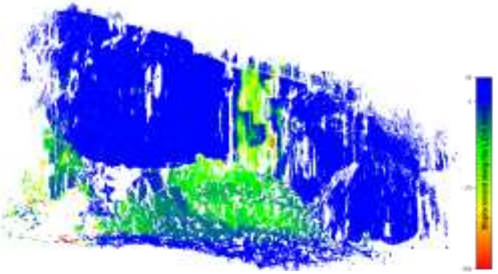
3. Vegetation filtering

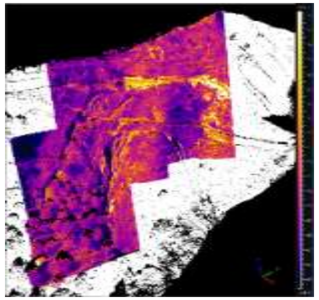


4. Data Processing









Survey planning and execution

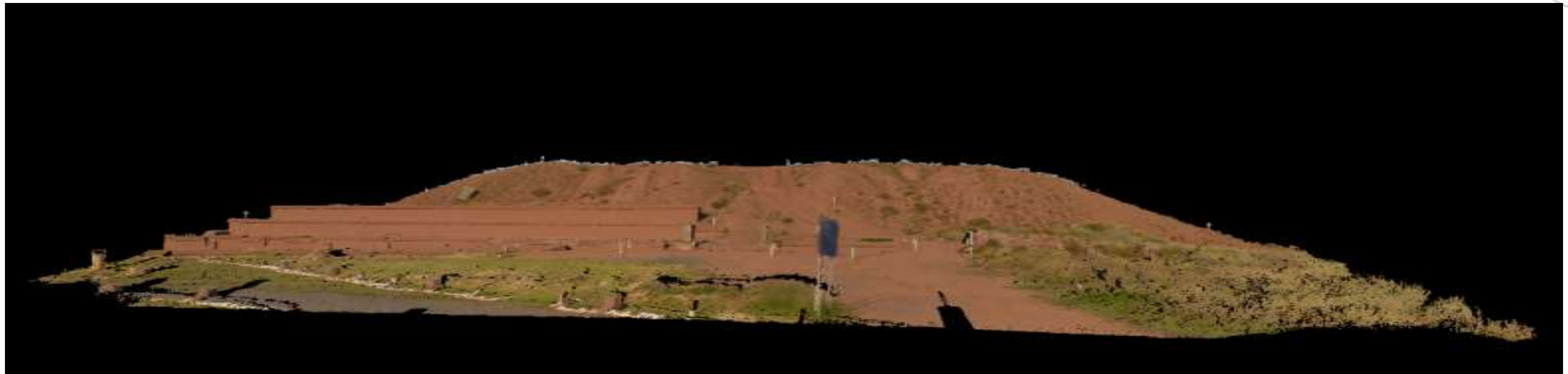
- Like all optical instruments they have their own field of view and do not detect hidden objects (shadow areas)
- Minimize the number of scanning positions (depending on the complexity of the scene, panoramic views and the max range of the instrument)
- Choice of reflector position (Gps – Topography)
- Make sure the stability of the instrument and the reflectors
- Survey with suitable angle of incidence with surfaces (density and reflectivity)
- Limit the number of useless points (pre-framing scans)
- Define a priori the maximum required resolution
- Plan the best time for digital images (optimal light)
- Monitor battery life (PC, Laser, Camera)

Registration and georeferencing

Scansione 1   Scansione 2   Scansione 3

tie points

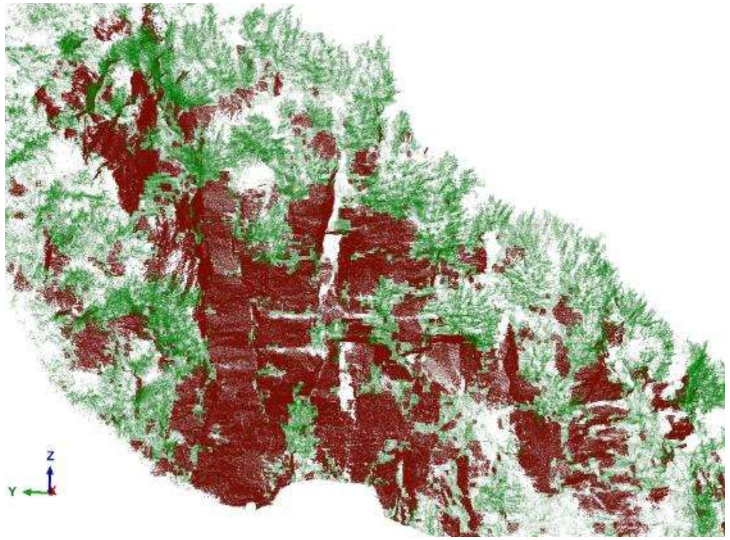
Global coordinates

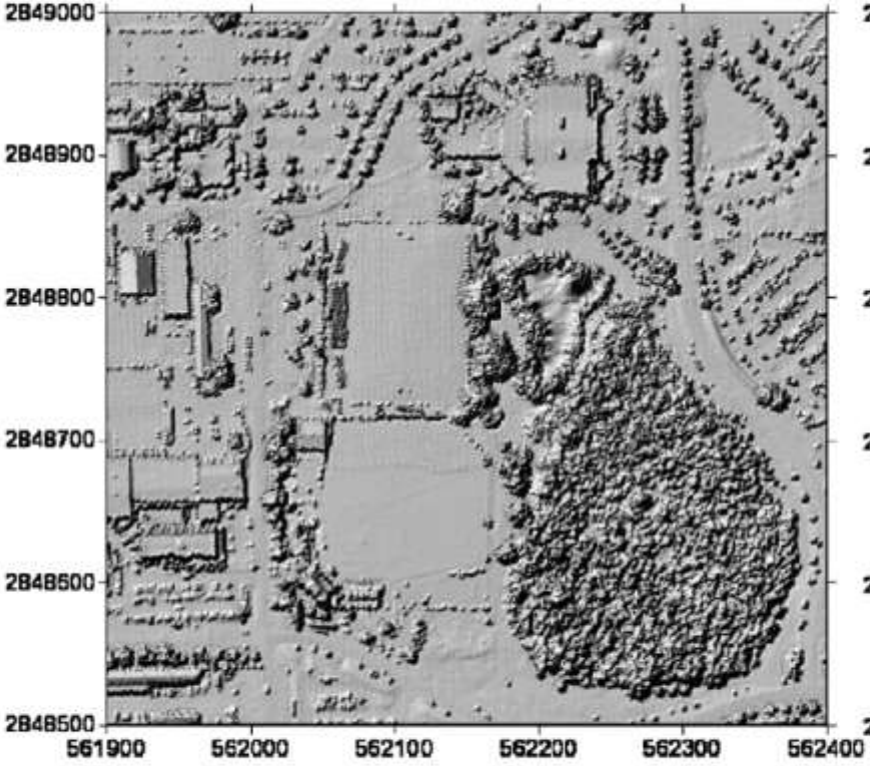


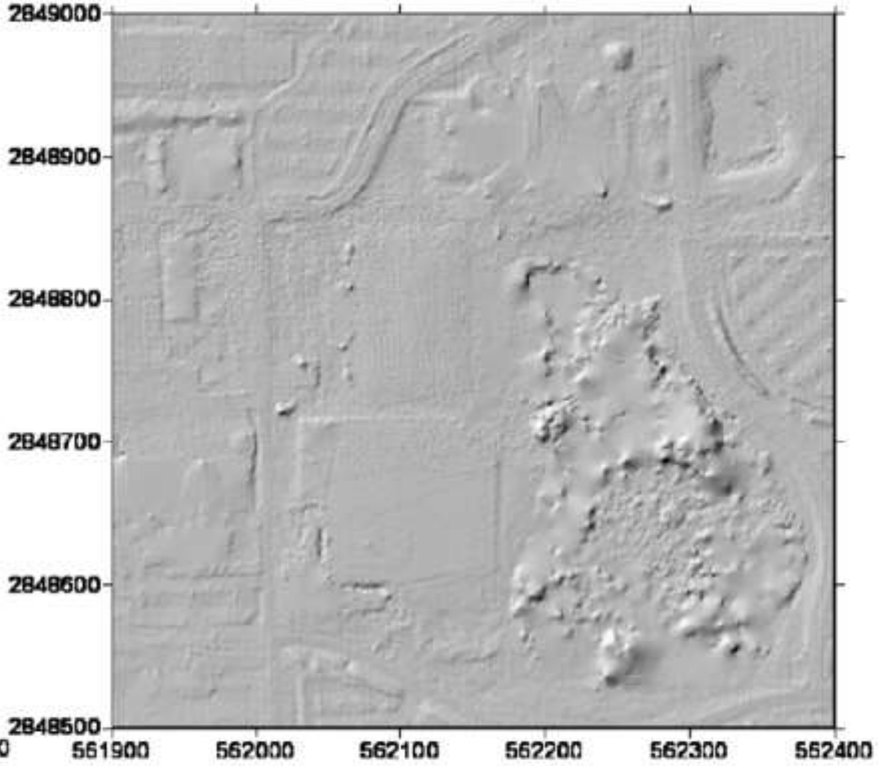
Tiwanaku Pyramid (Bolivia)

Vegetation filtering

- Full waveform technology (first and other targets removal)
- Algorithms (e.g. terrain filter, CANUPO classification)
- Manual filtering

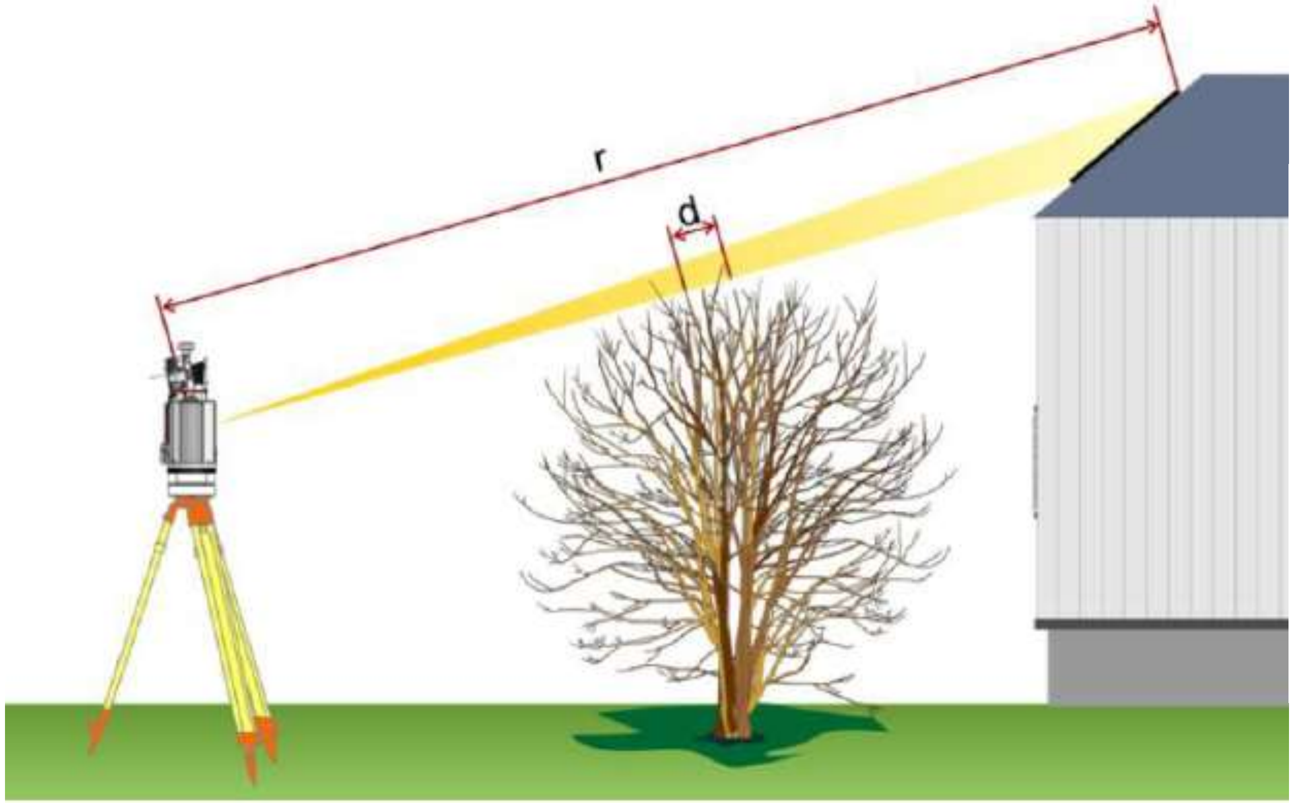


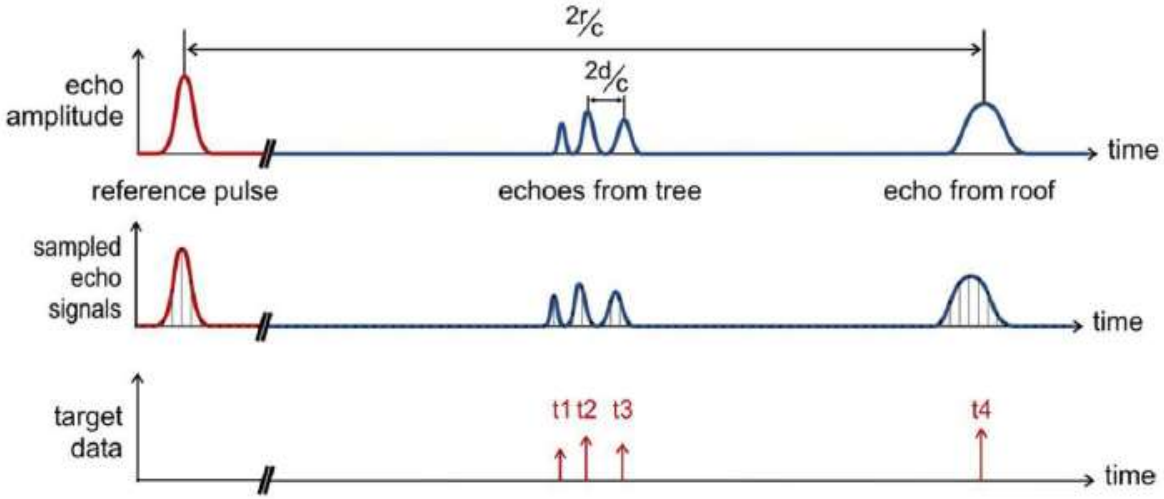




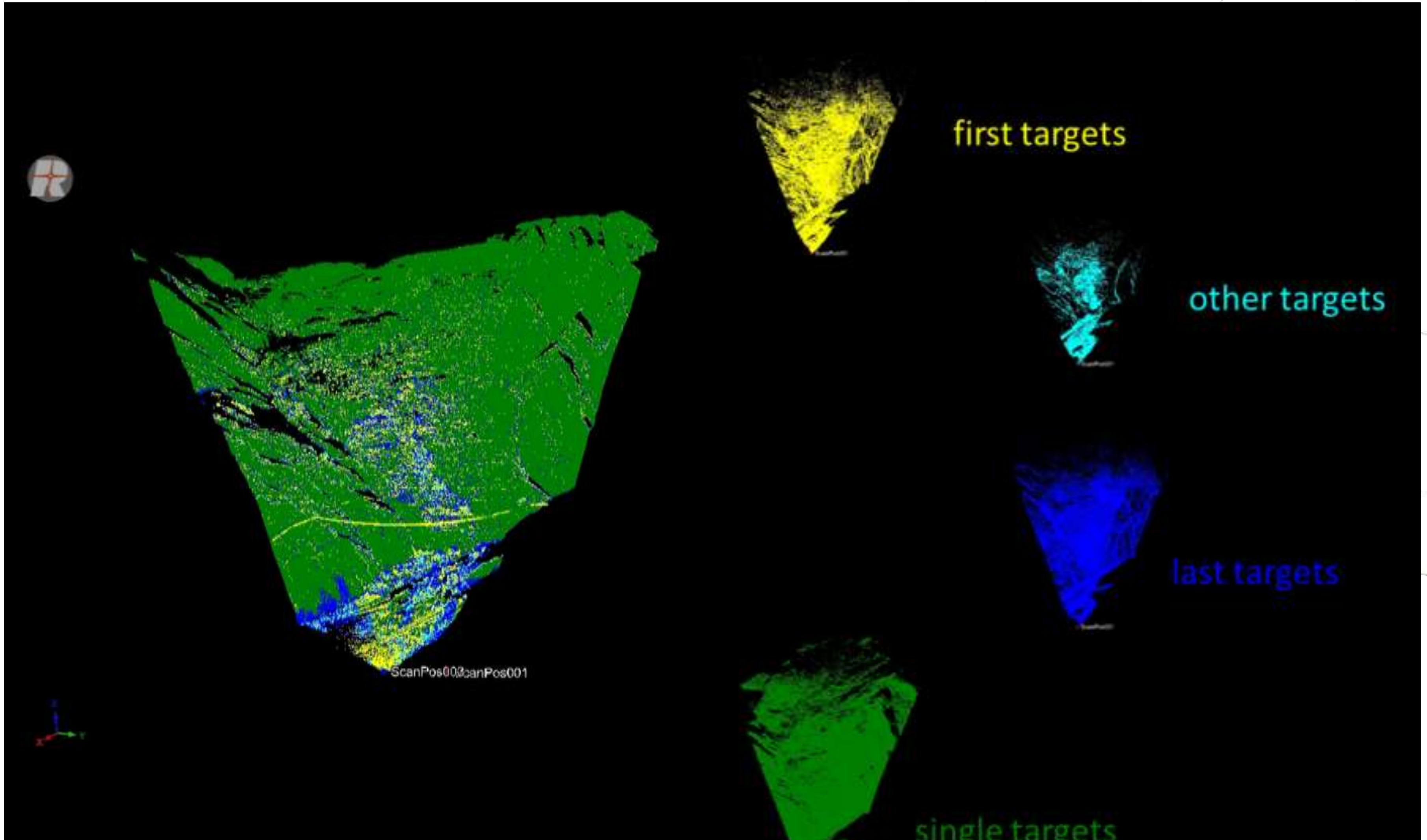
Zahng et al., 2003

Full waveform technology





Different targets

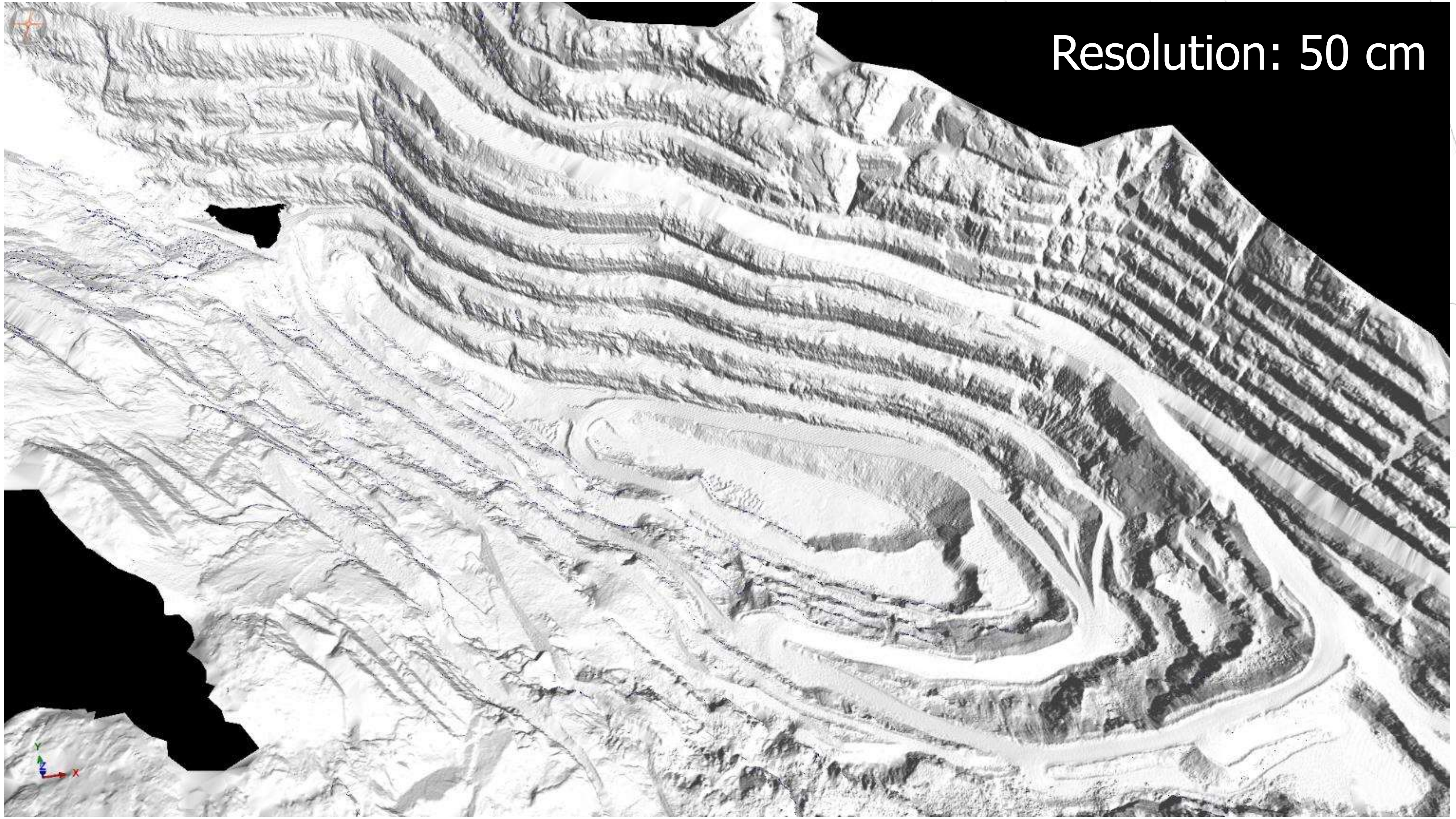


Xishancun landlside (Sichuan, Cina)

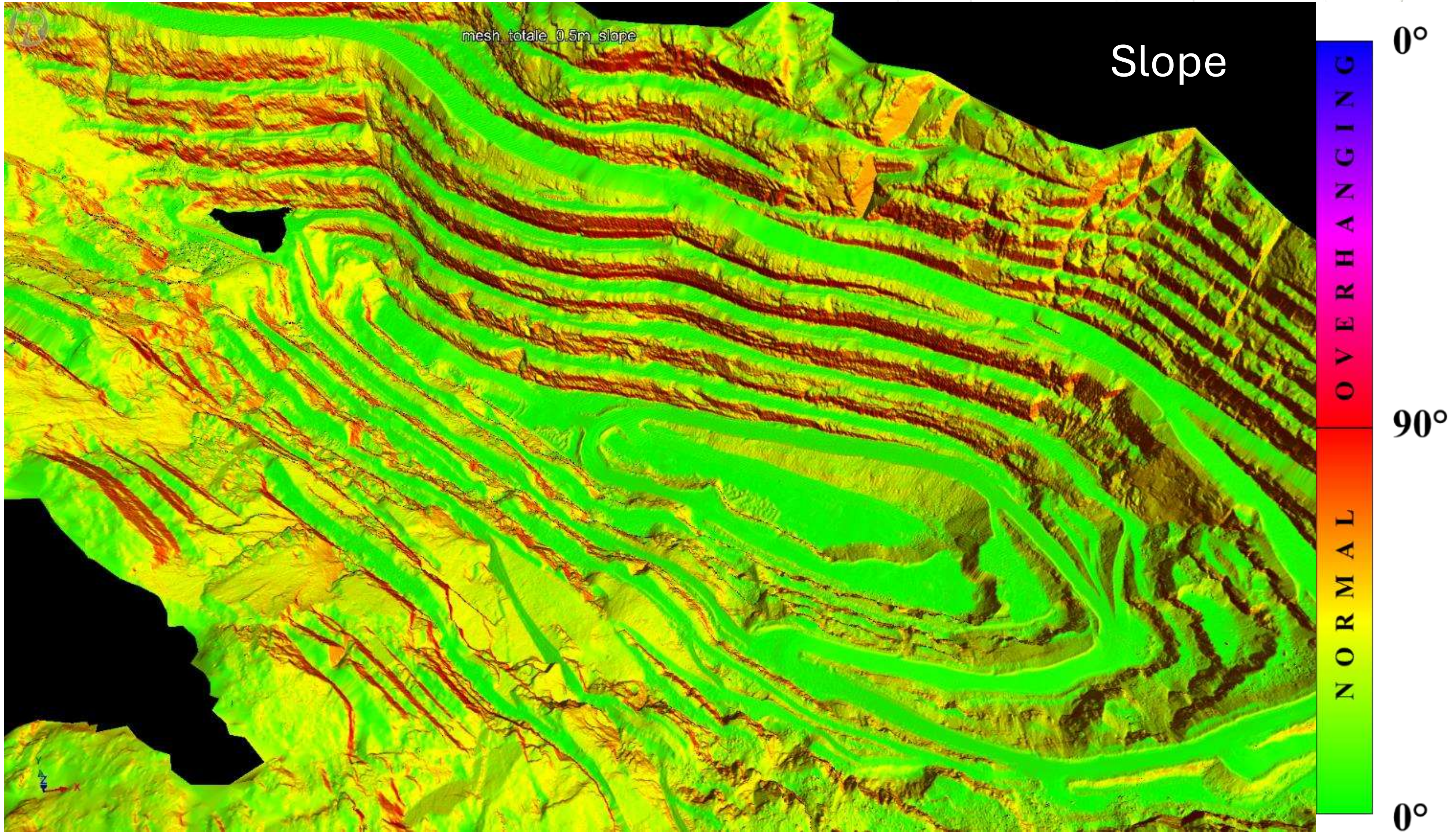
Point cloud processing

- Resample
- Mesh generation
- Mesh processing
- Decimation and smoothing
- Point cloud colorize and mesh Texturing
- Sections, profiles, polylines, measurements…
- Projection of data from other devices
- Classification and segmentation
- Export for processing with other software

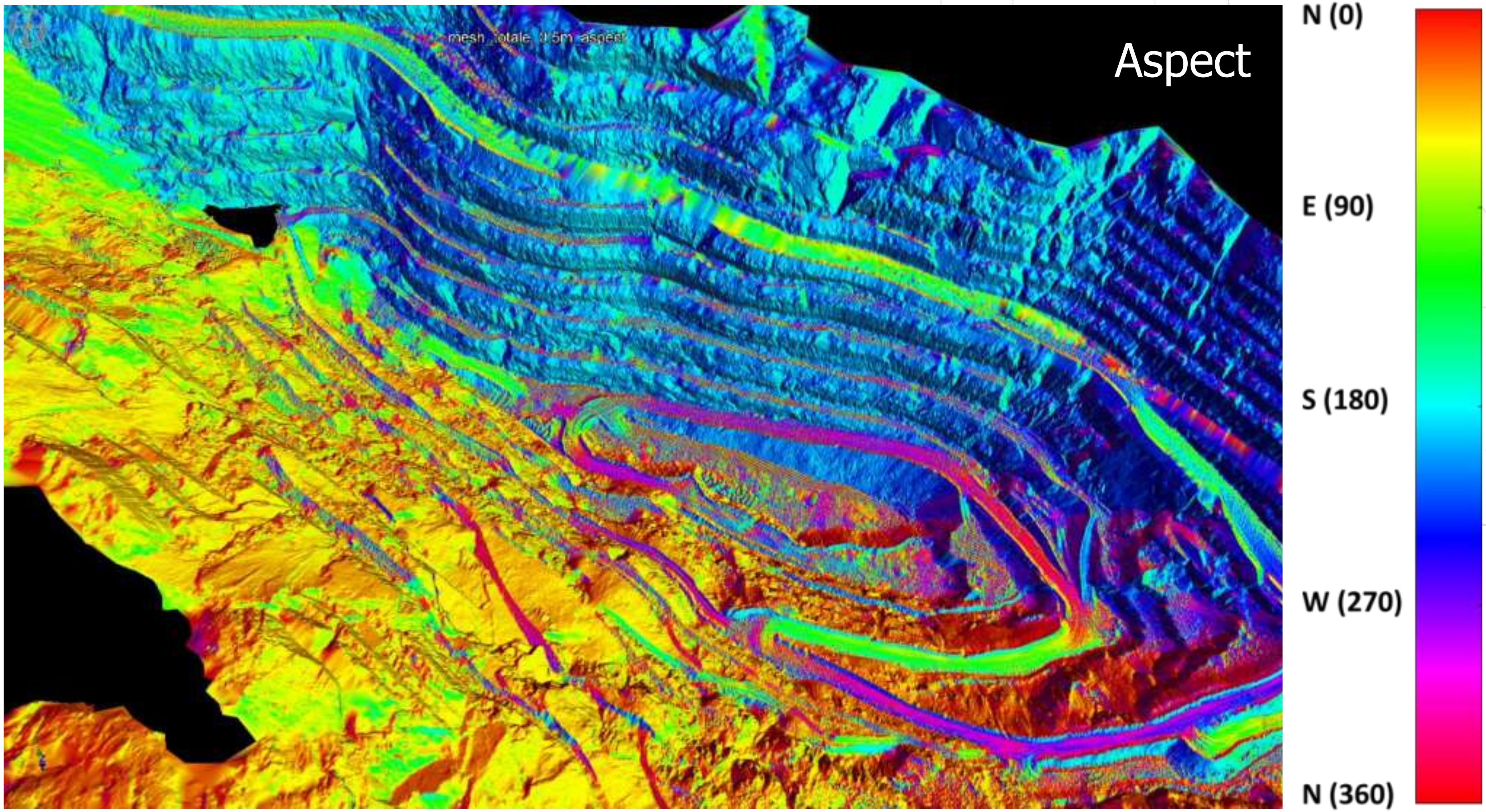
Mesh generation



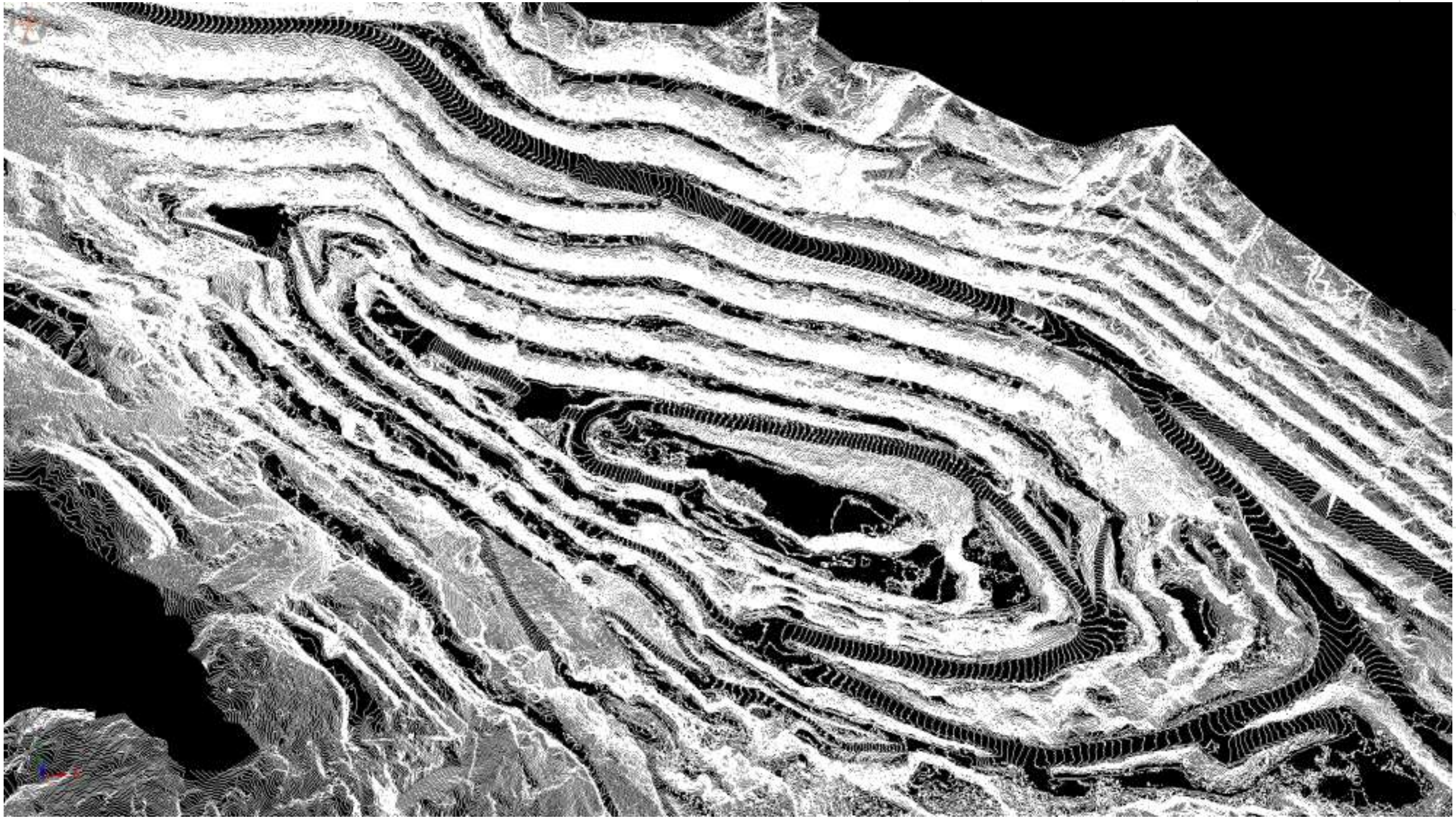
Mesh elaboration



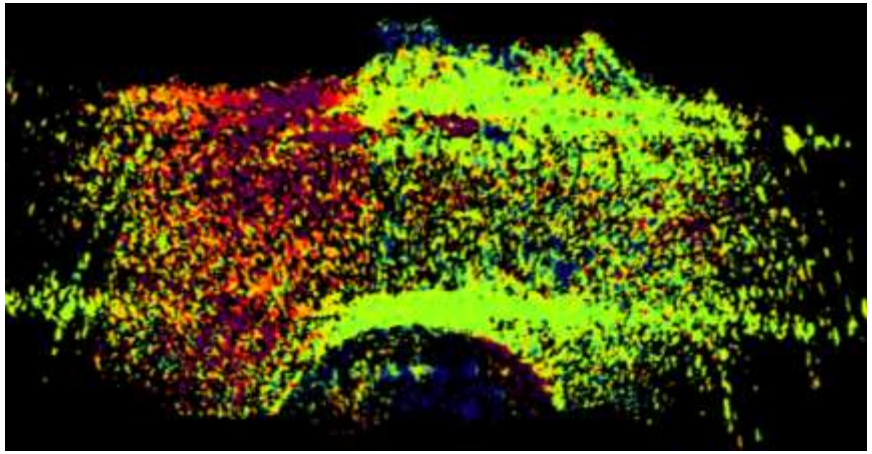
Mesh elaboration

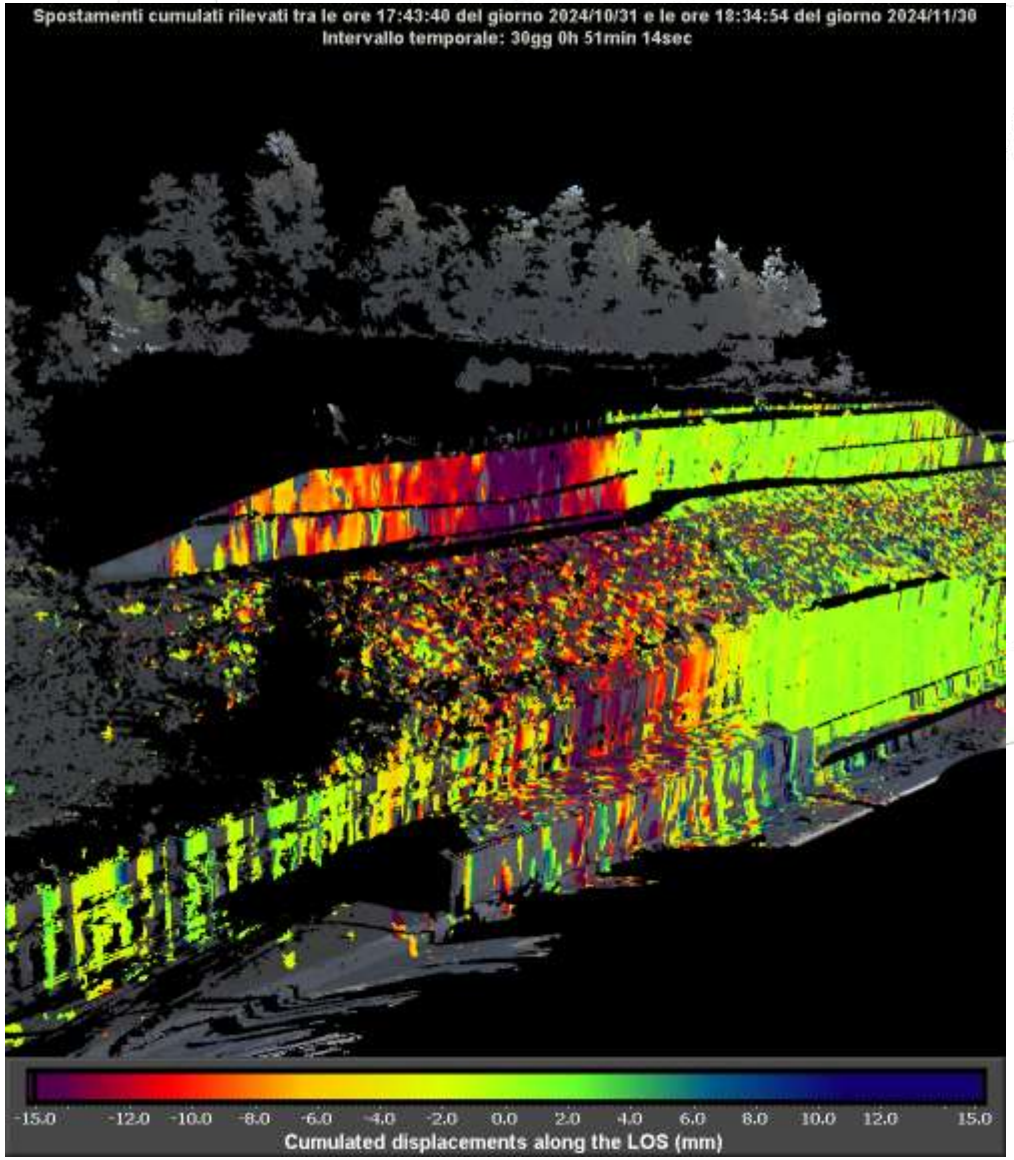


Contour lines



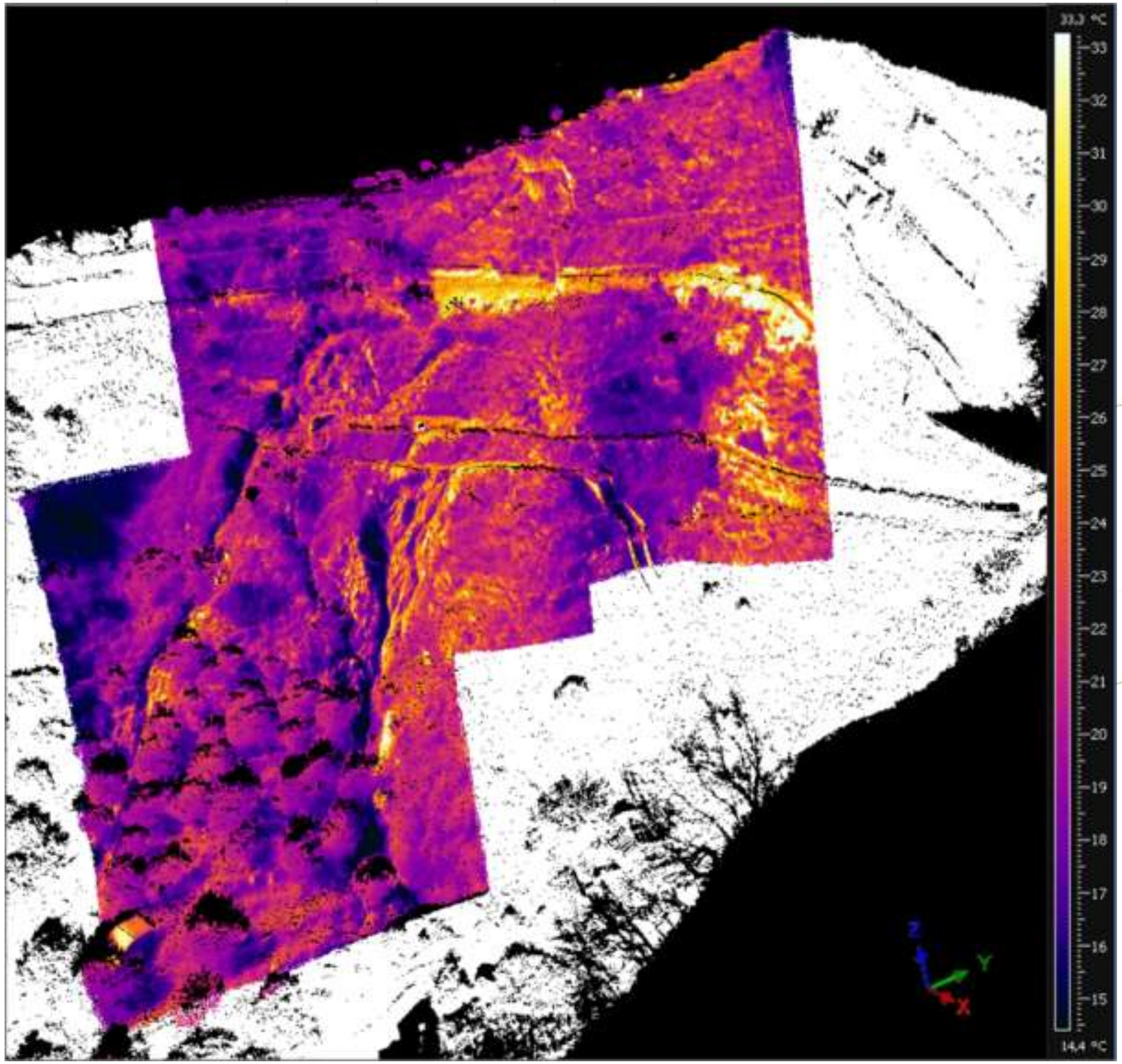
GB-InSAR data projection





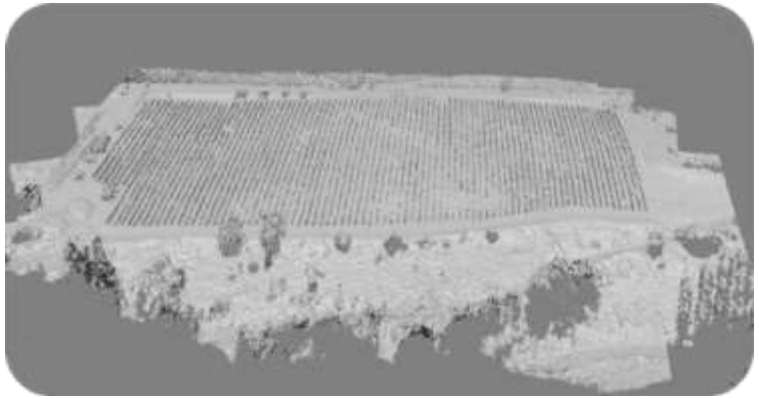
Thermal imagery progection

Calatabiano landslide (CT, Italy)



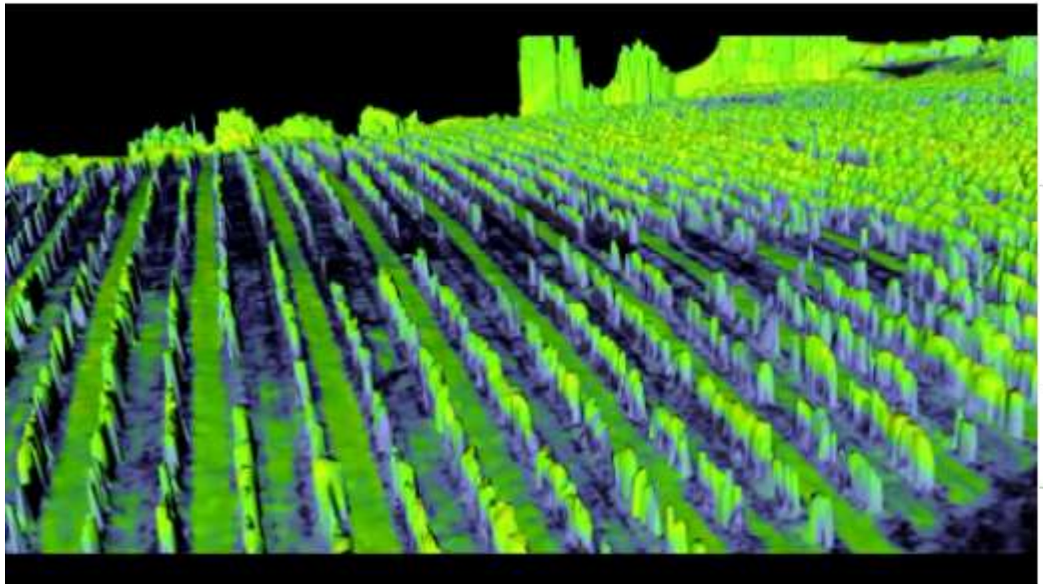
Multispectral data projection

High resolution DSM



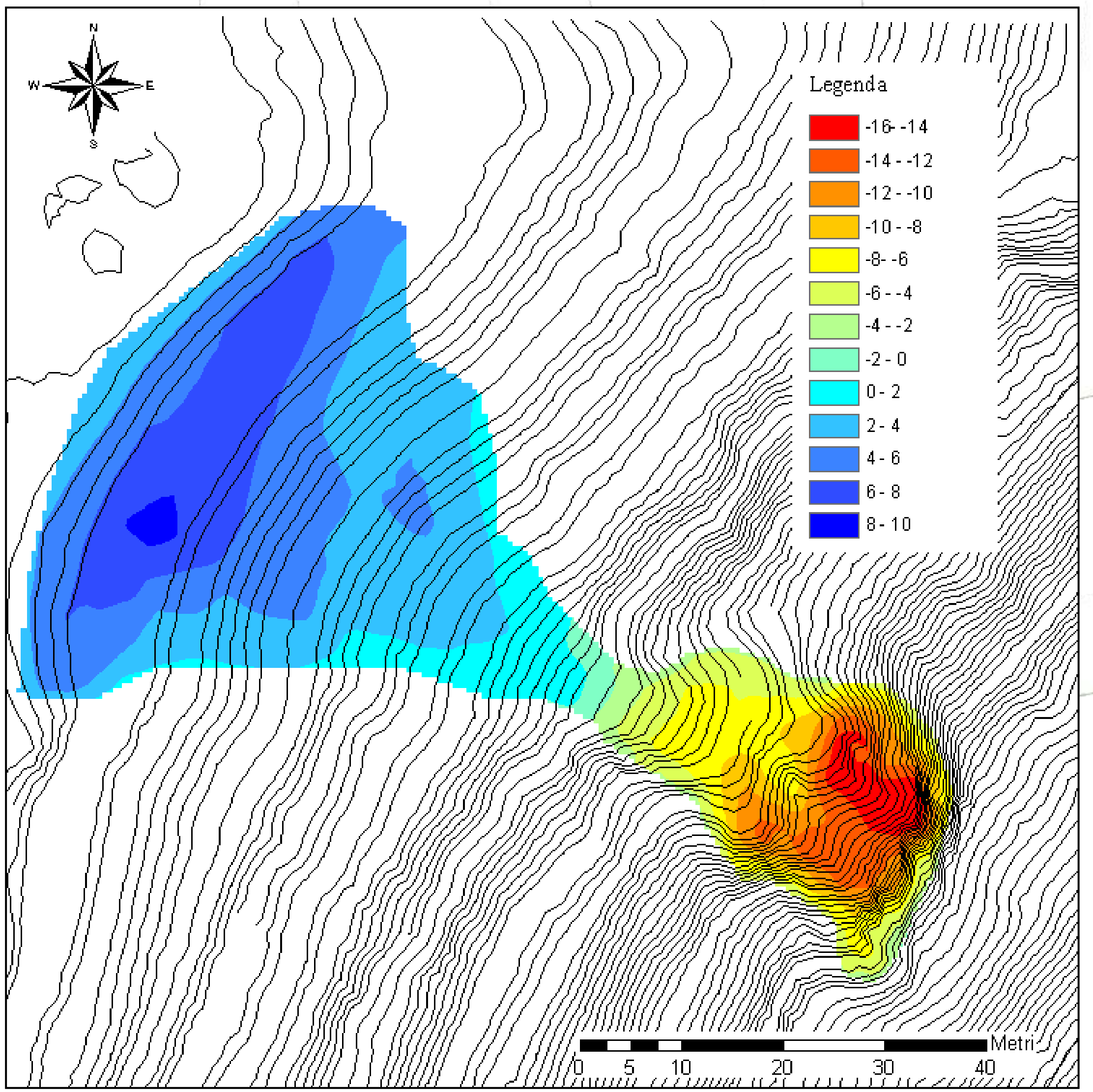
+

Multispectral survey

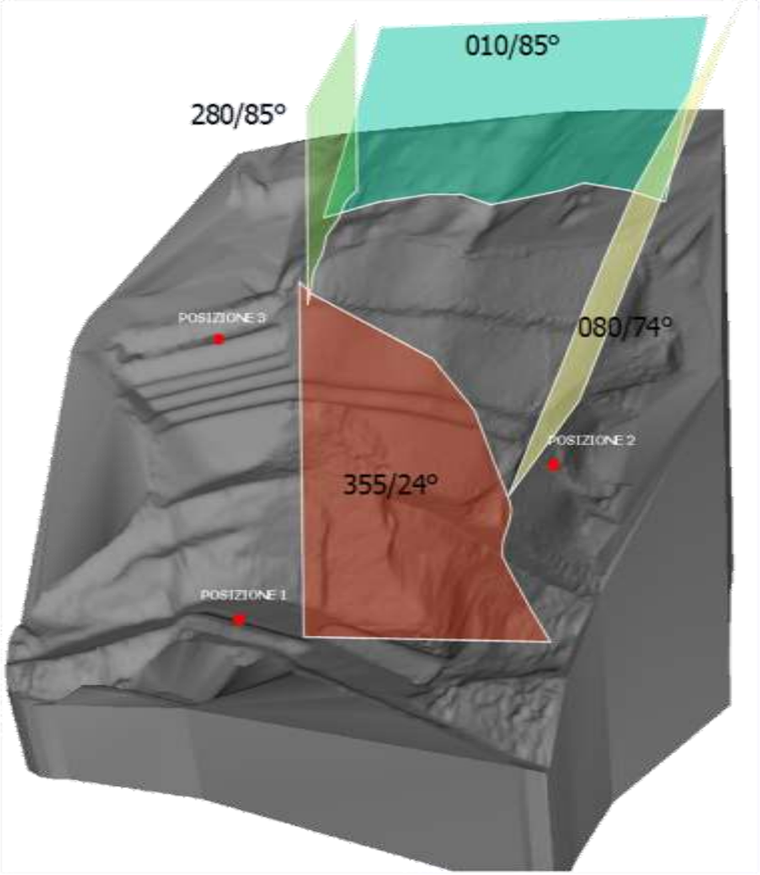


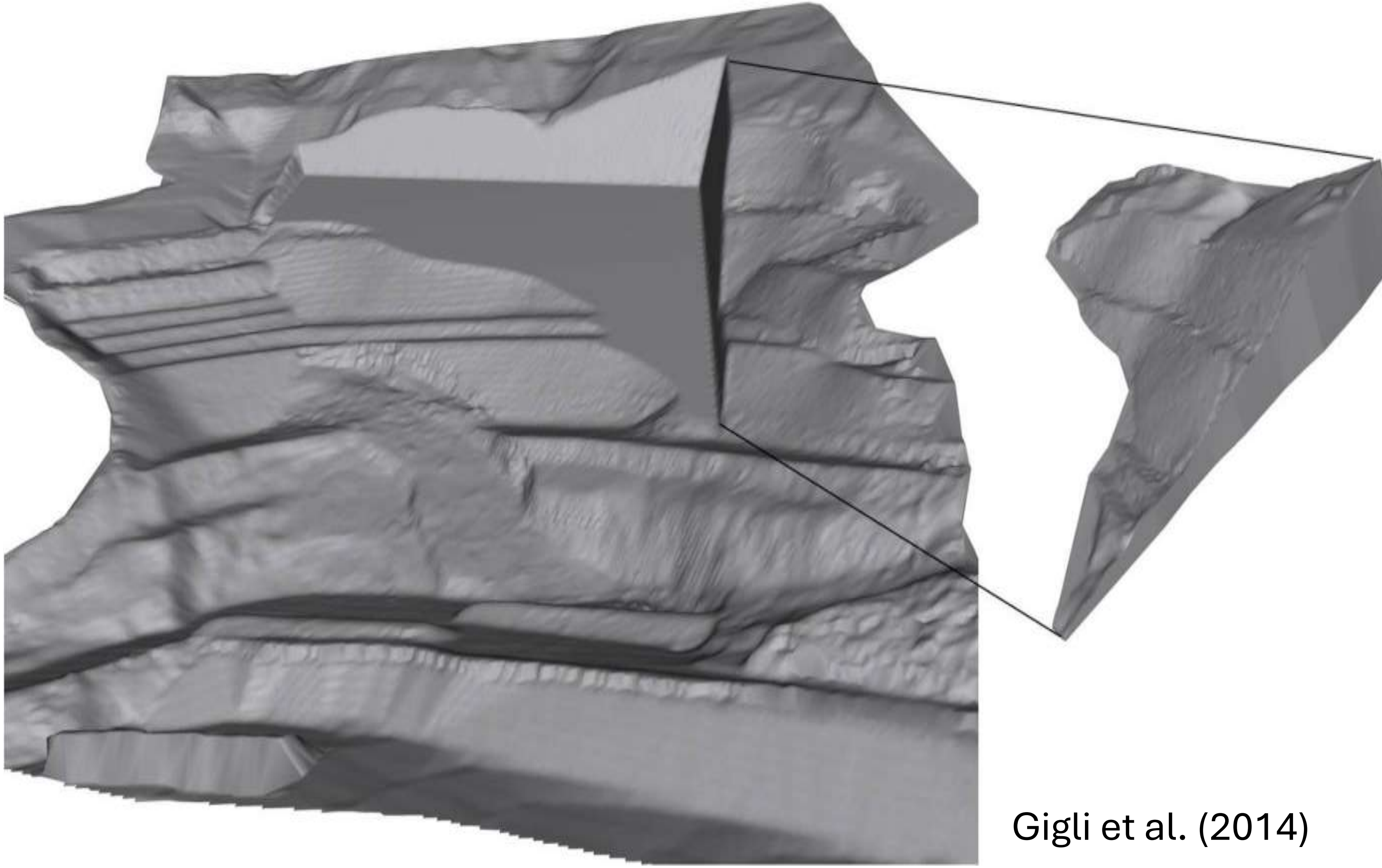
Highly detailed phenological analysis

Morphological changes



3D Volume extraction

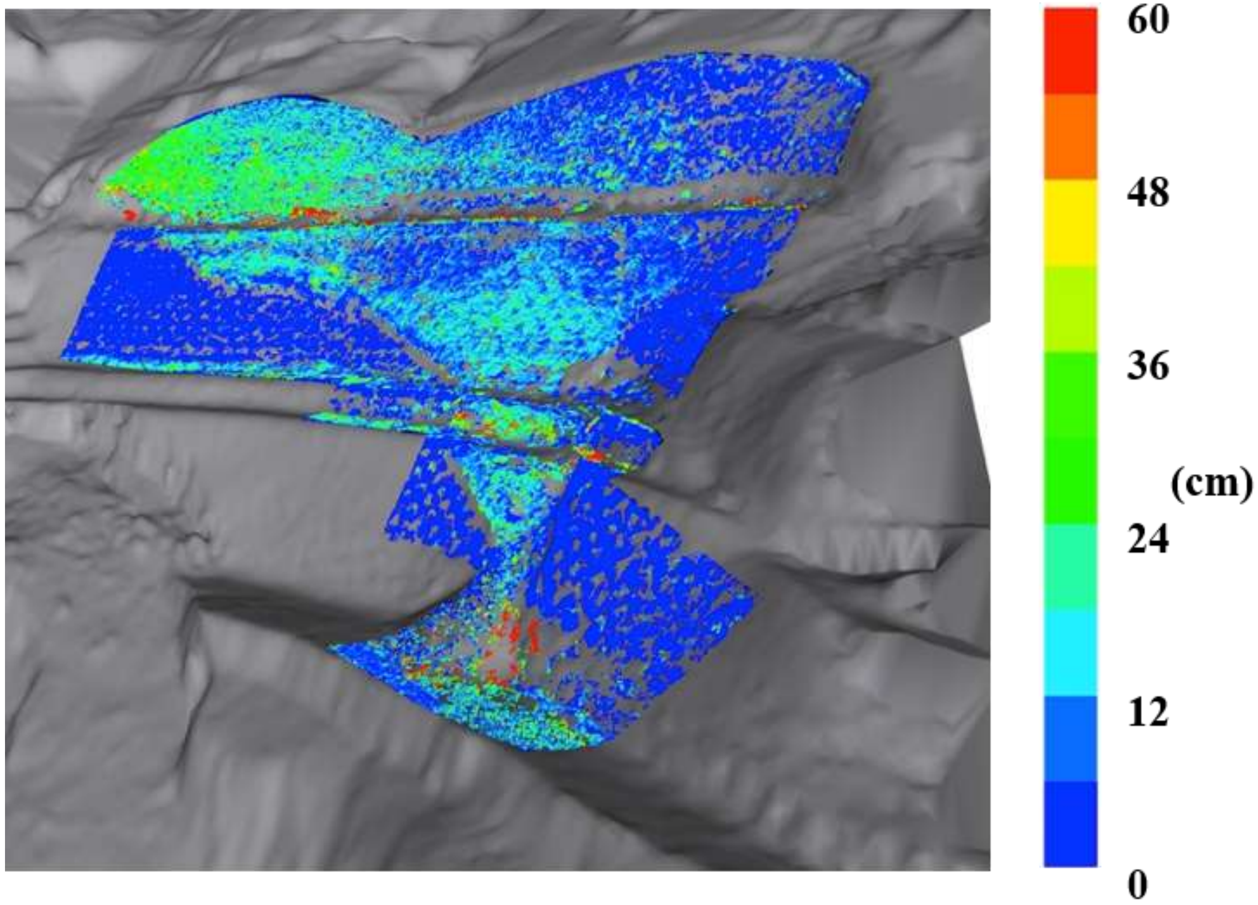




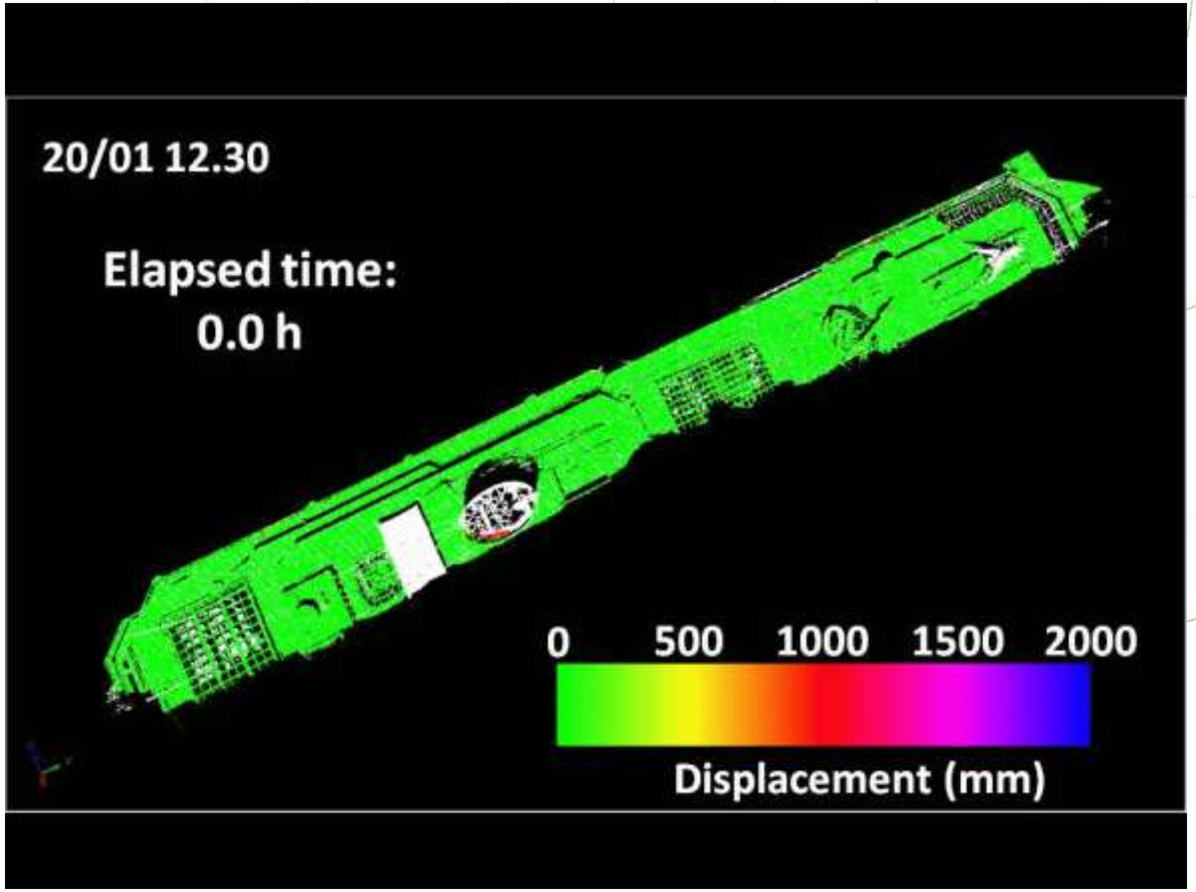
Calculated volume:
182.000 m^3

Gigli et al. (2014)

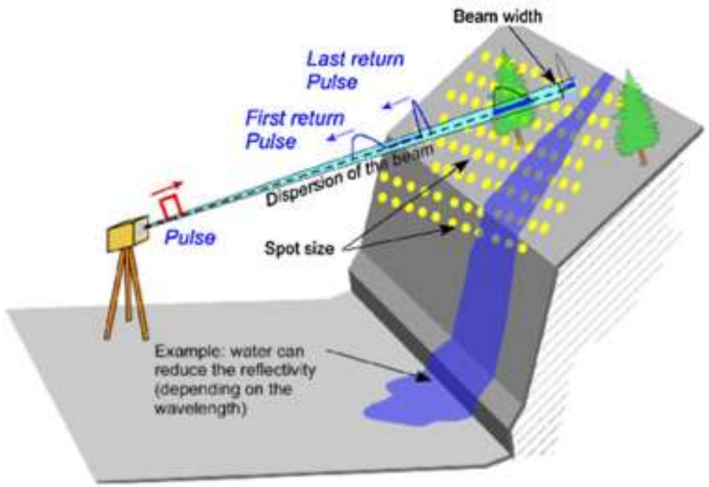
Multi-temporal monitoring



Gigli et al. (2014)



Photogrammetry vs TLS



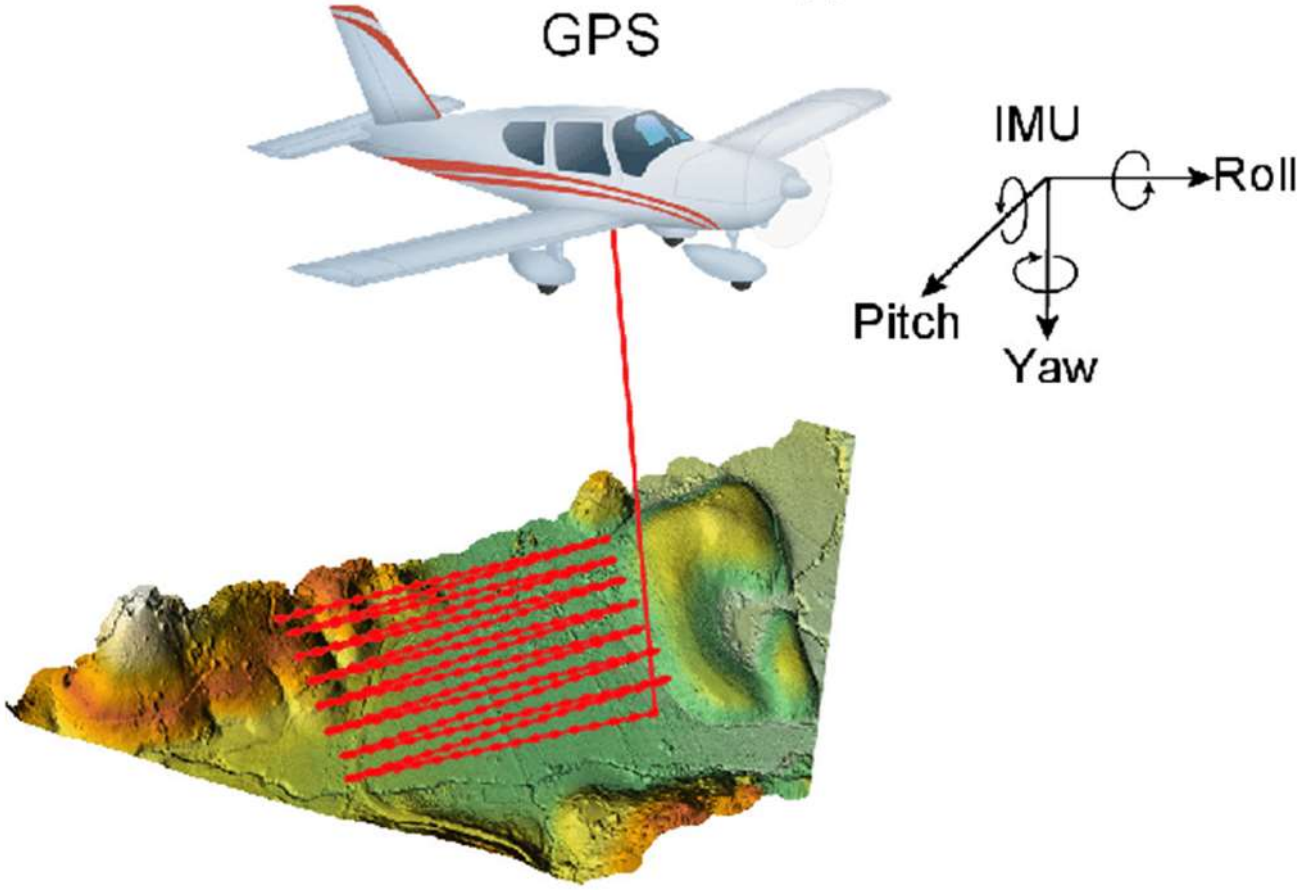
UAV-based photogrammetry:

- Cost effective
- Quick surveys
- Large area coverage

Terrestrial Laser Scanner:

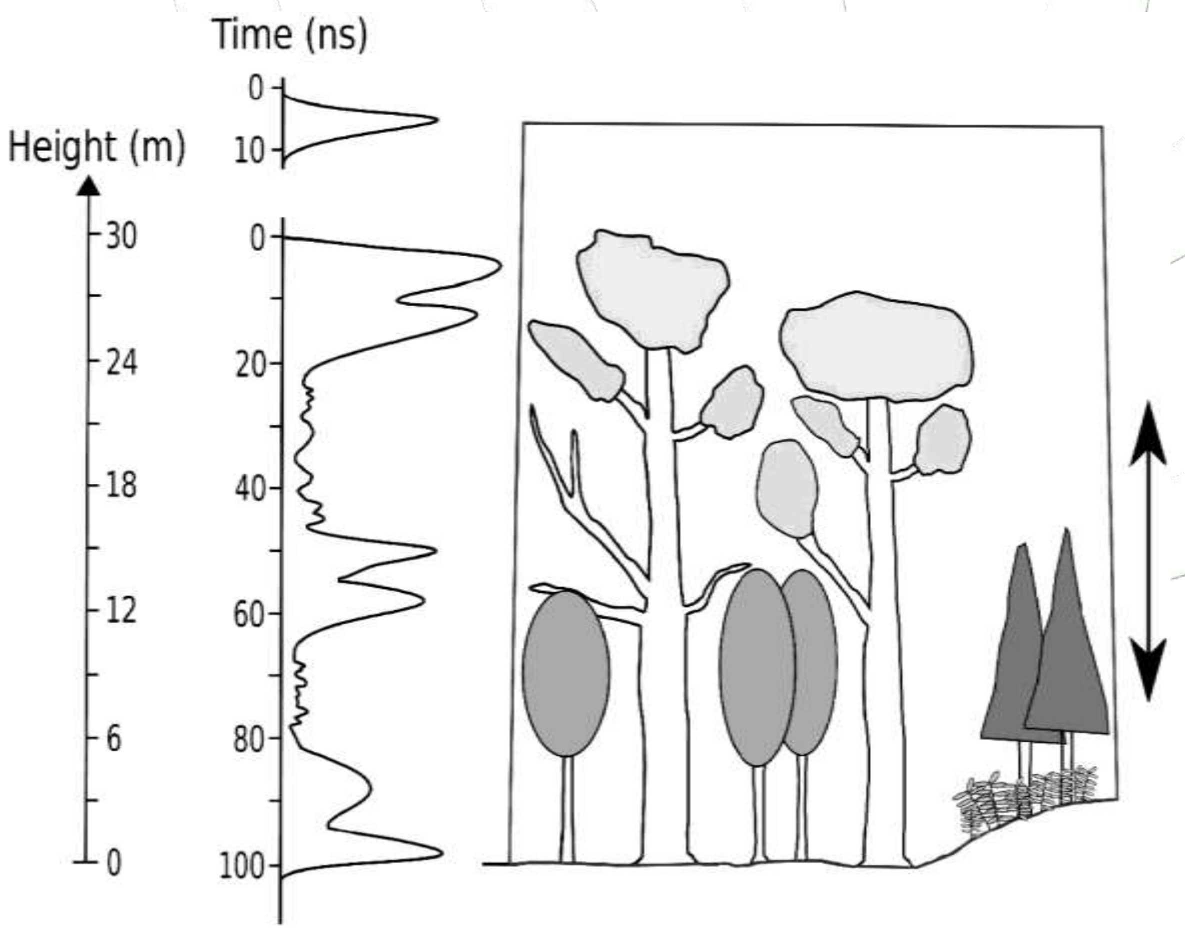
- High resolution
- High accuracy
- Penetrates trough high canopy areas

Aerial Lidar



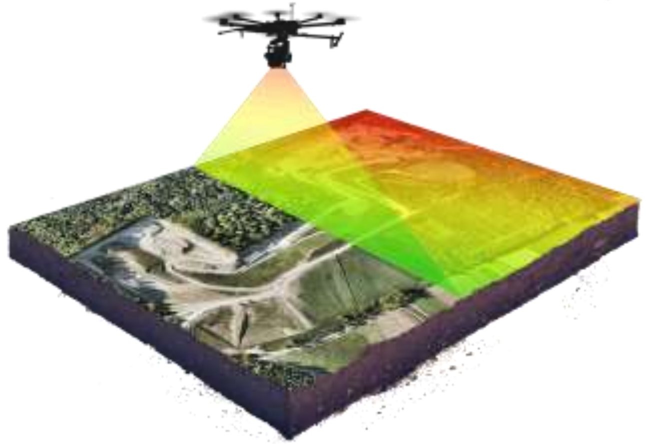
From: Shih et al. (2008)

Full waveform detection



Mallet & Bretar (2009)

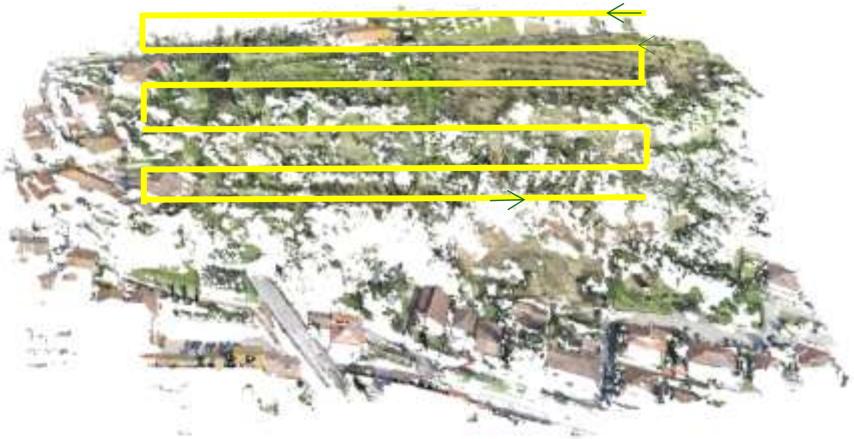
Laser scanner da drone RIEGL VUX – 1UAV



- Distanza di scansione: fino a 550 m
- Tasso di scansione: fino a 500.000 misure/sec
- Accuratezza: 10 mm
- Precisione: 5 mm
- Risoluzione angolare: 0.001°
- Lunghezza d’onda: infrarosso vicino
- Divergenza del fascio: 0.5 mrad
- Campo di scansione: 330°
- Tecnologia full waveform

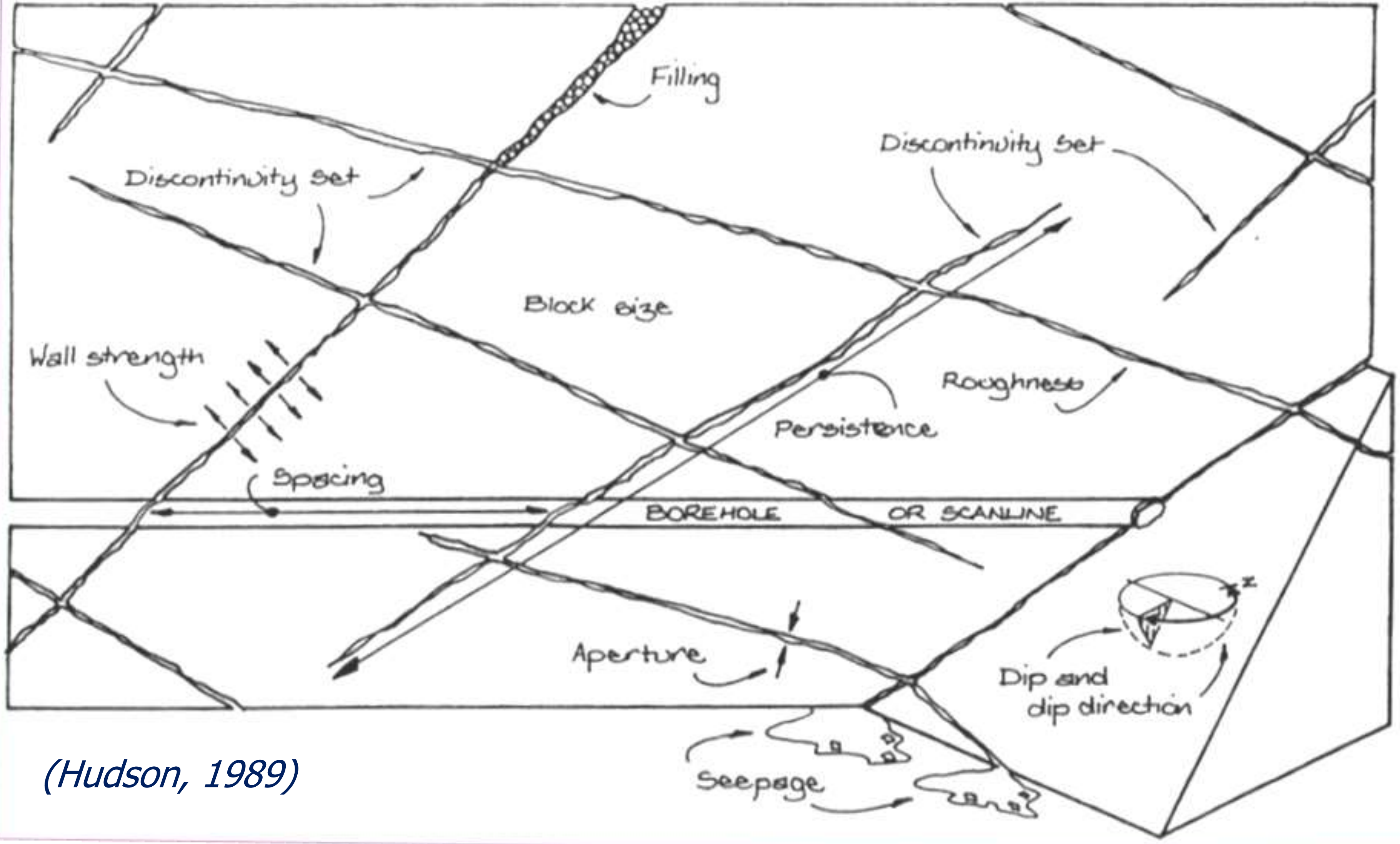
UAV LiDAR systems

UAV- based photogrammetry



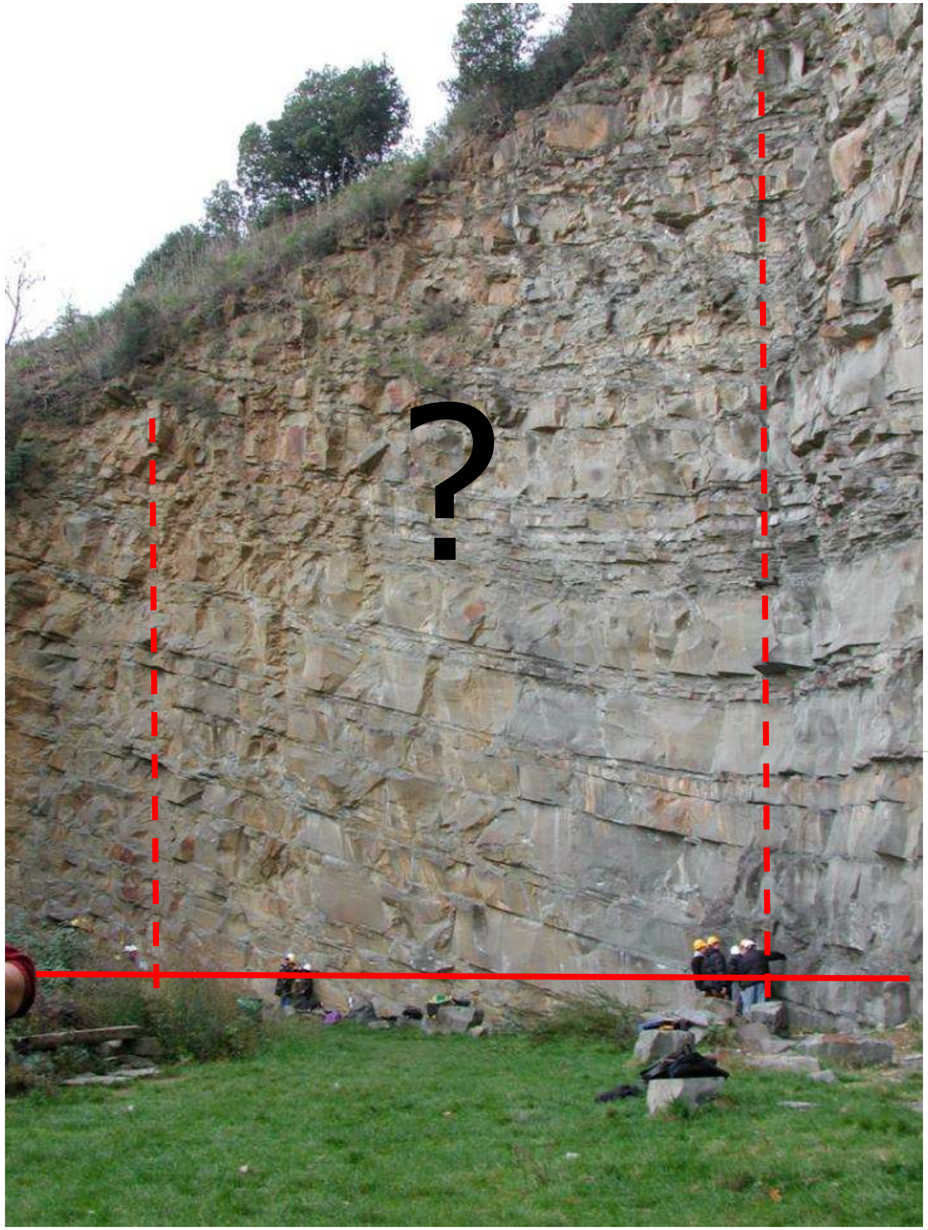
UAV LiDAR system

Rock mass characterization – ISRM parameters



(Hudson, 1989)

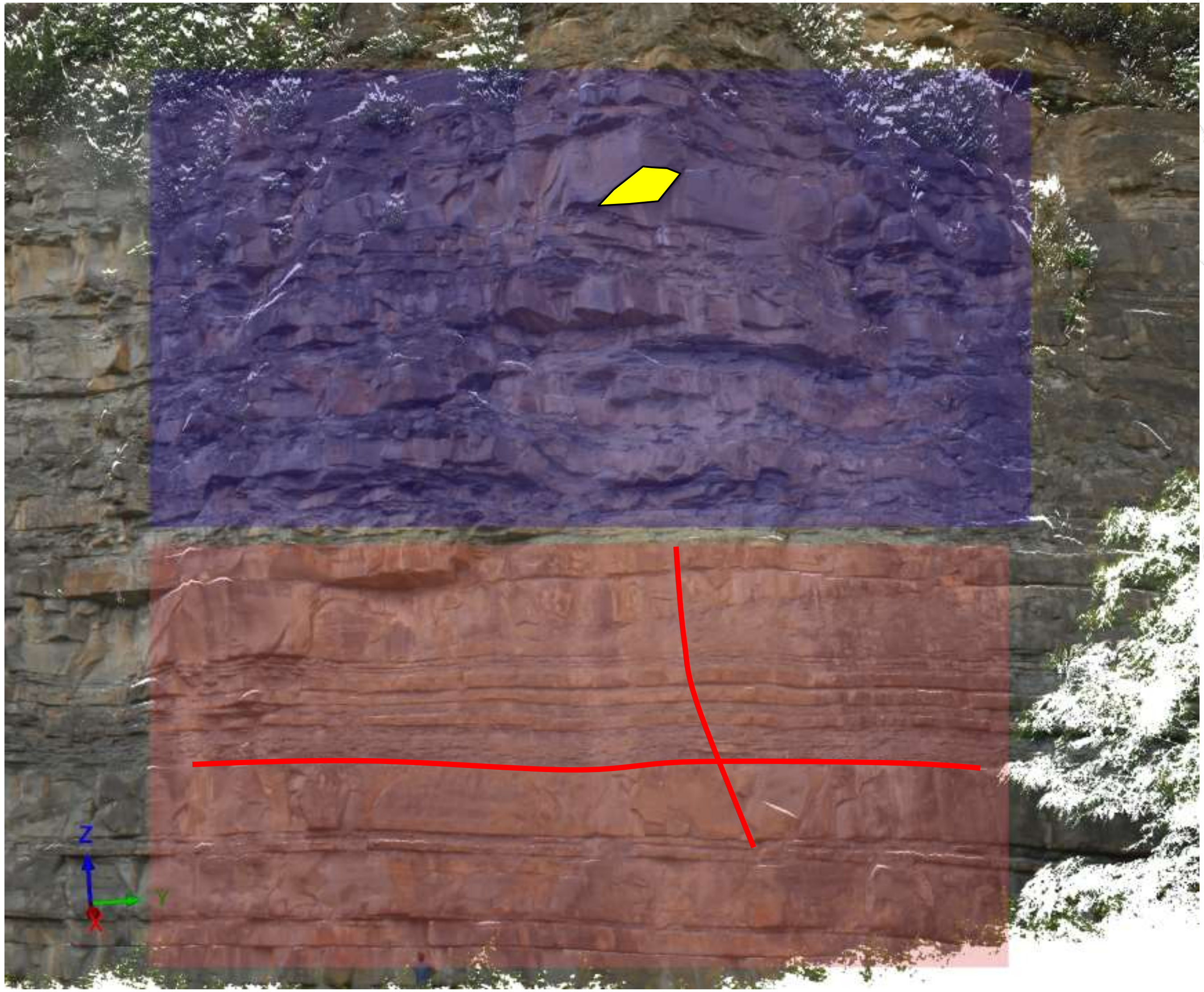
Traditional geomechanical surveys



DiAna (Discontinuity Analysis)

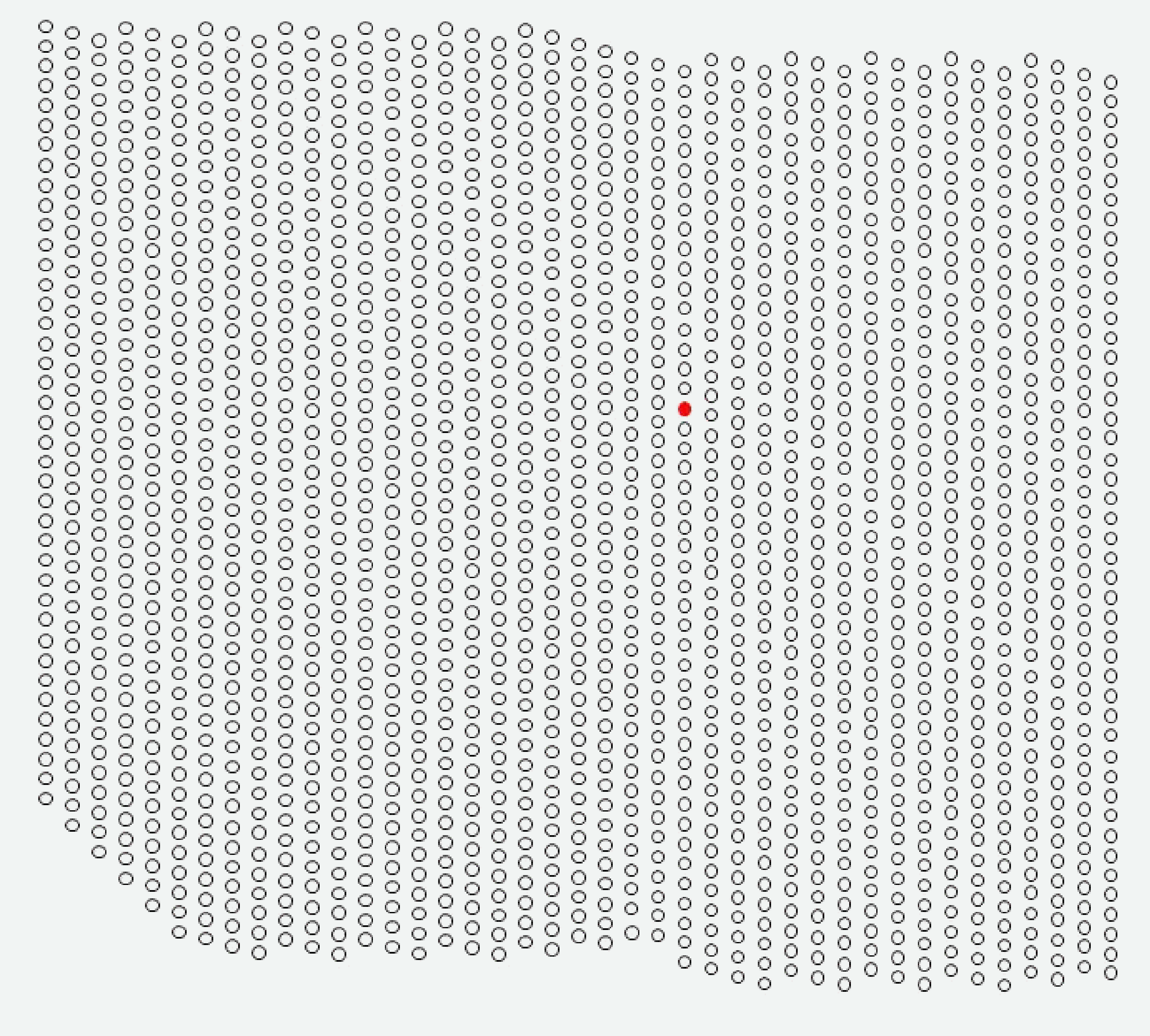
3D

2D



Discontinuity surface detection

Organized point cloud

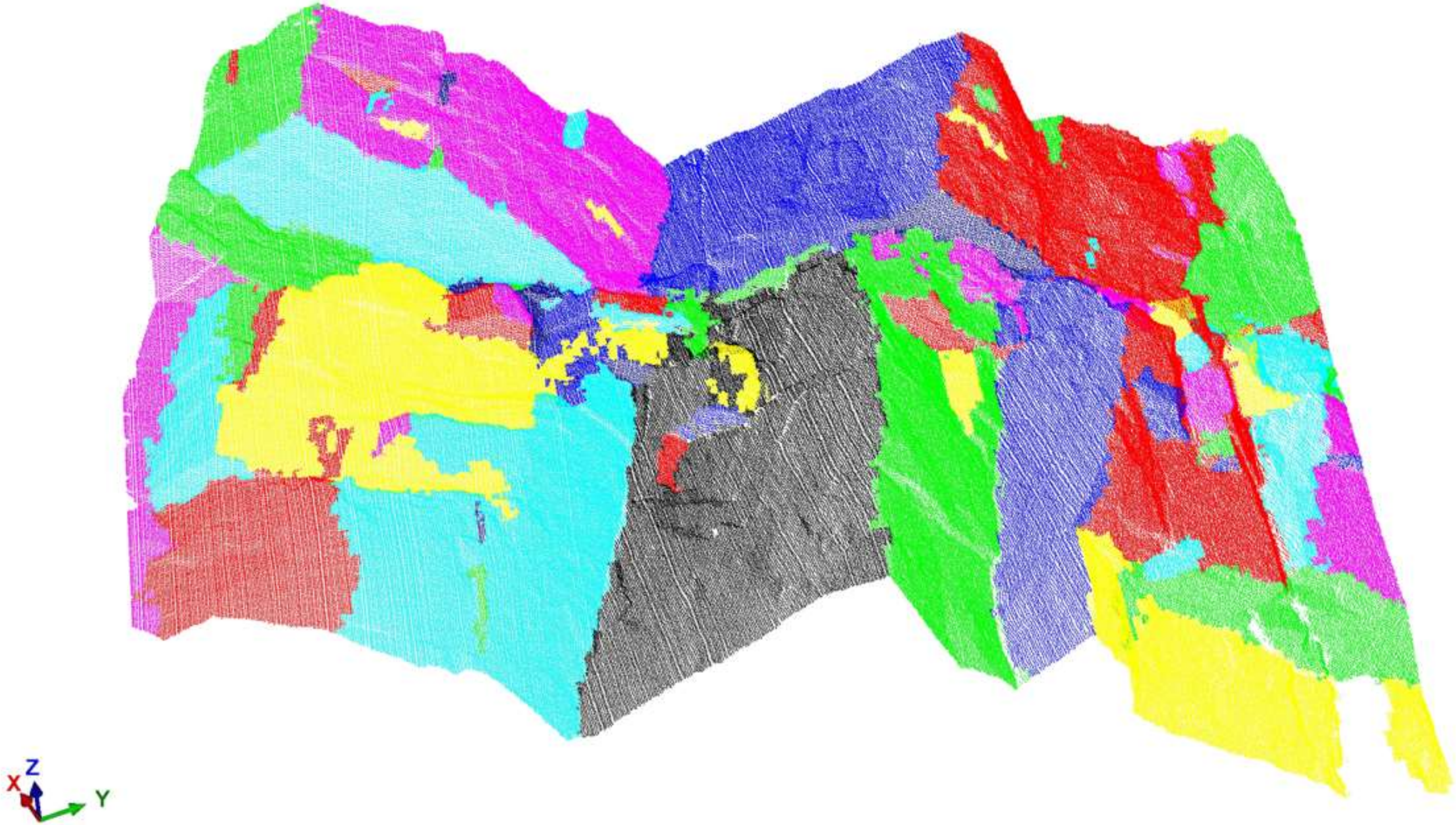


Input parameter

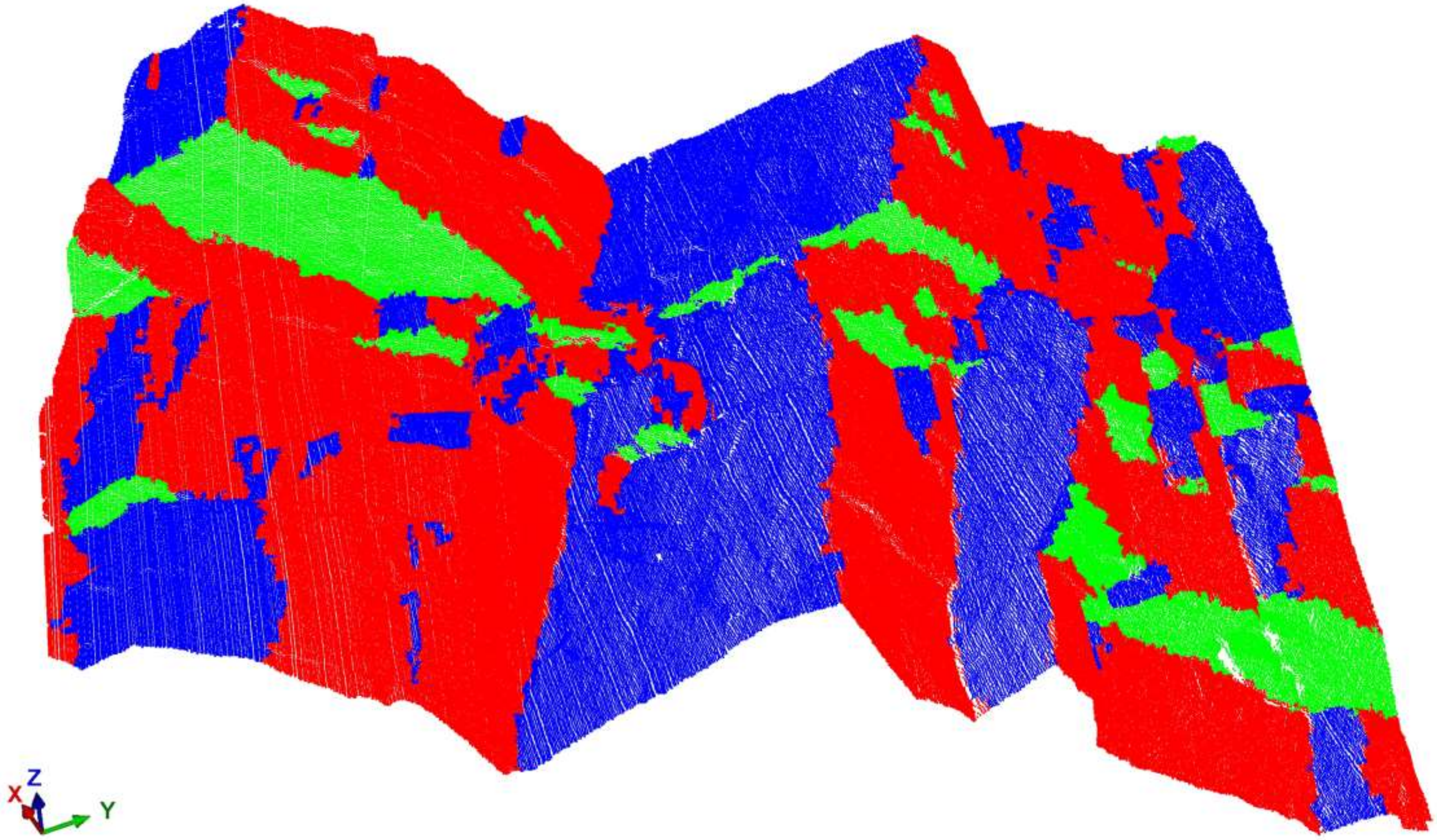
1) σ_{max} (m)

DiAna
Gigli & Casagli, 2011

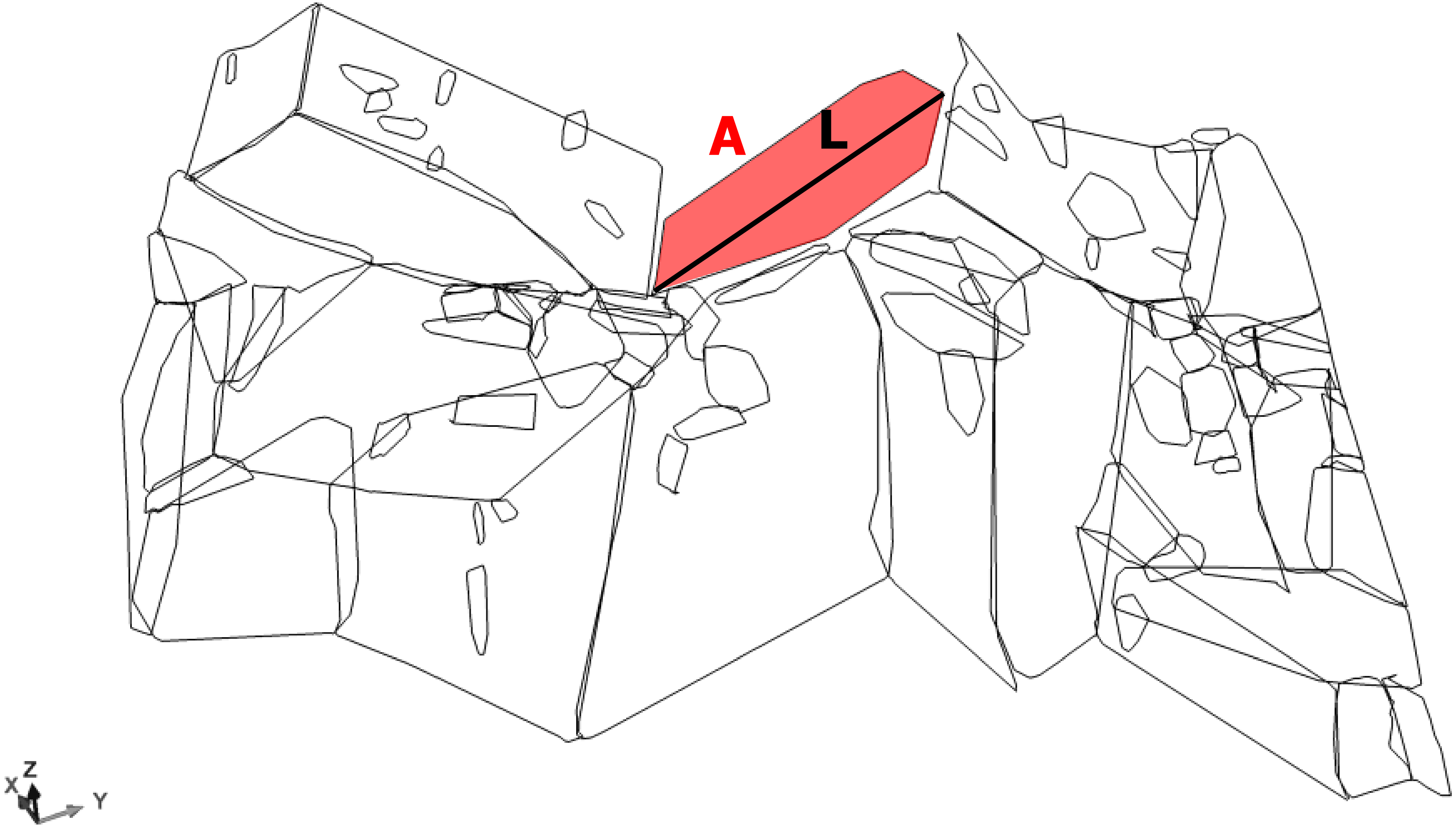
Joint extraction



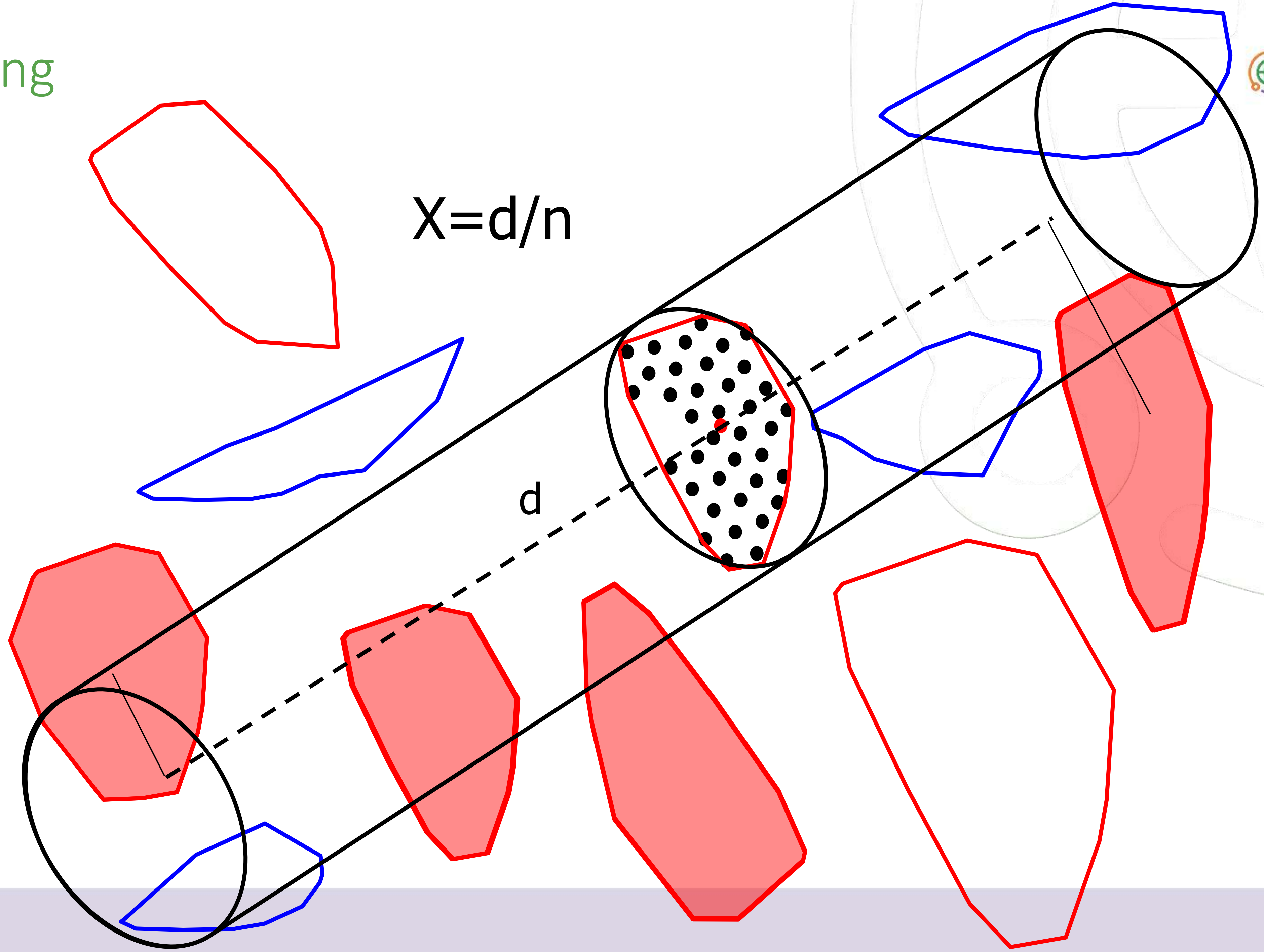
Discontinuity sets



Persistence

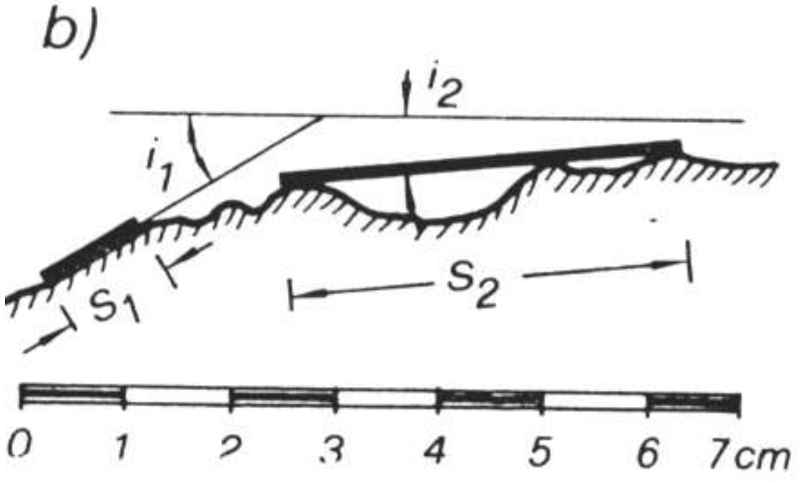


Spacing

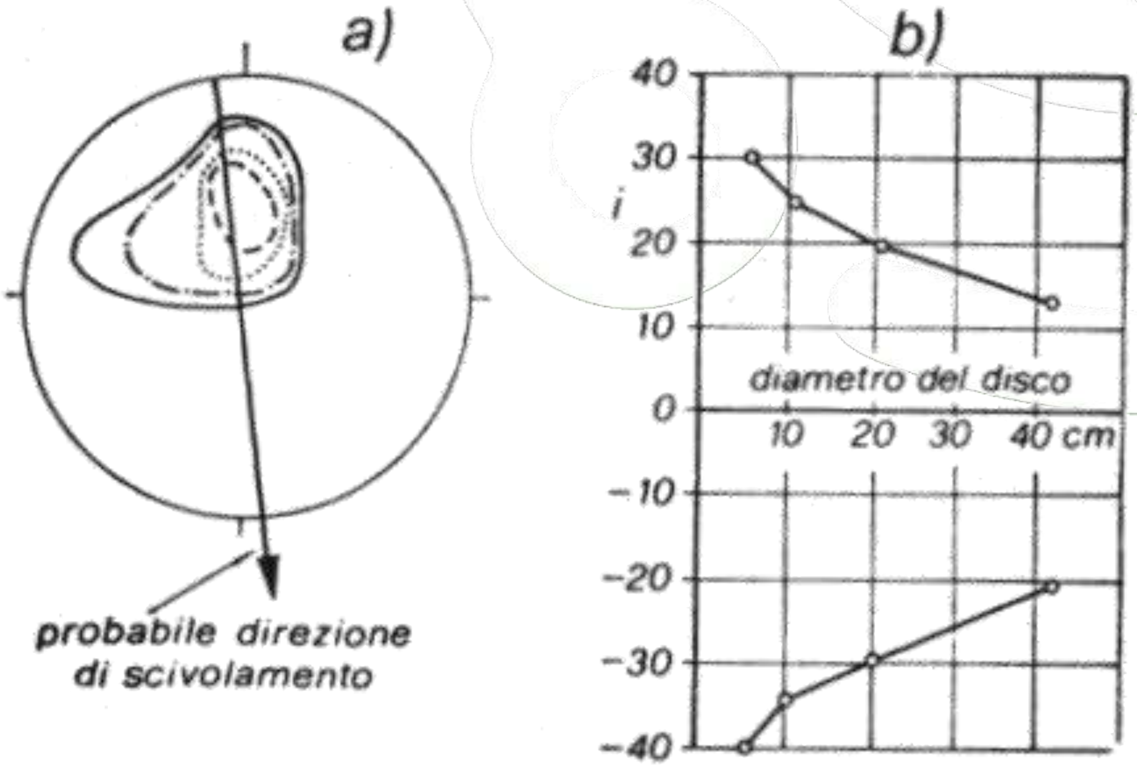


Roughness – Clinometric dish

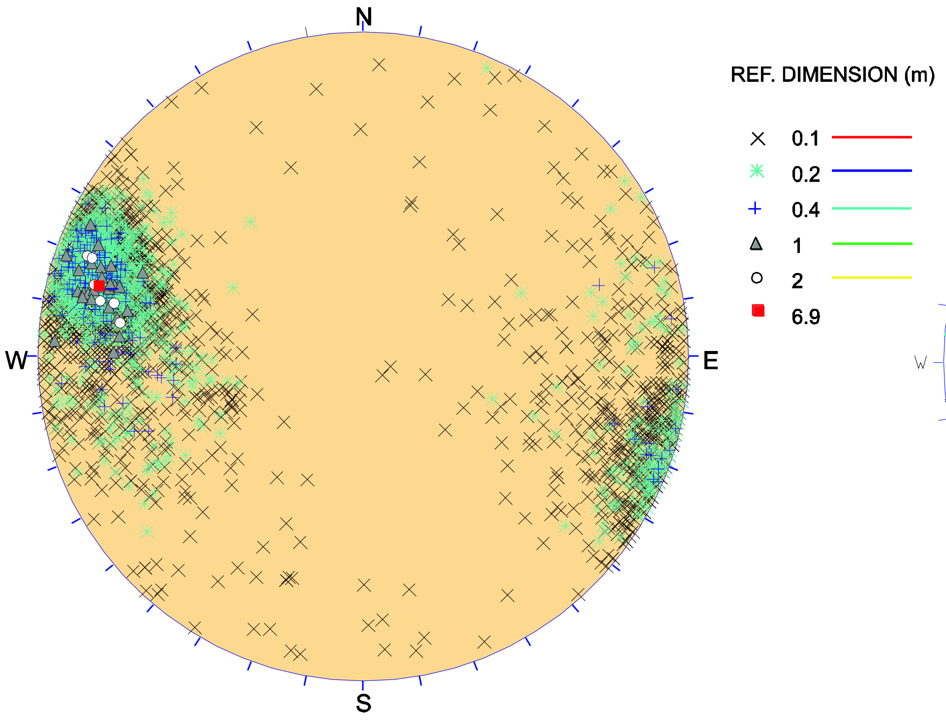
simbolo	ø disco cm	n° minimo di misure
———	5,5	100
-·—·—·	11	75
···········	21	50
- - - -	42	25

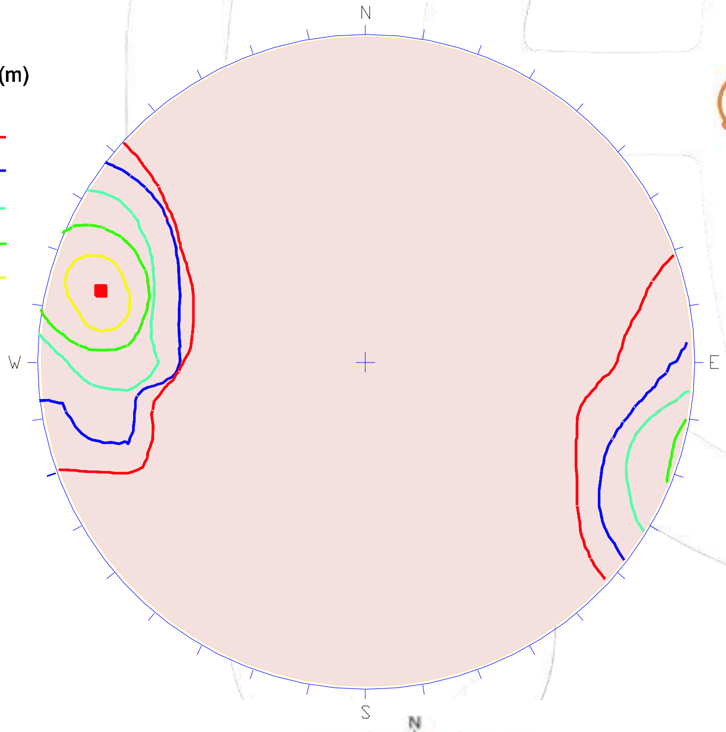


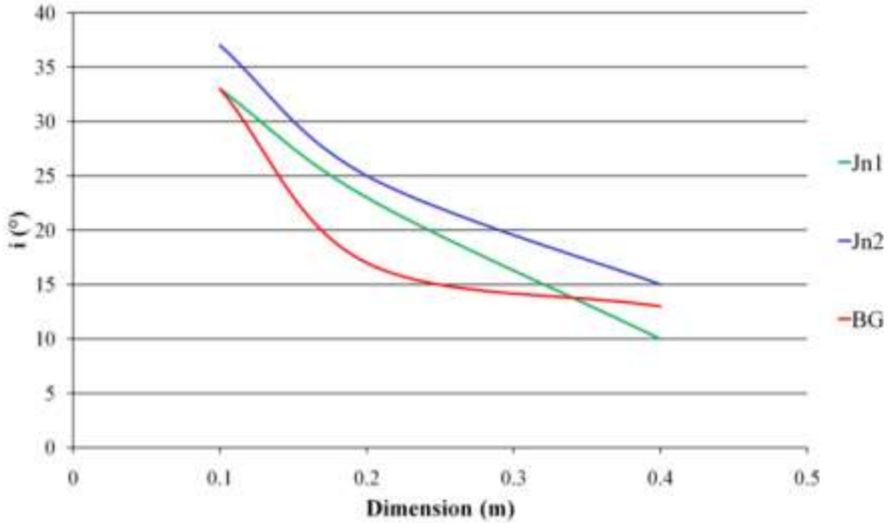
(ISRM, 1978)

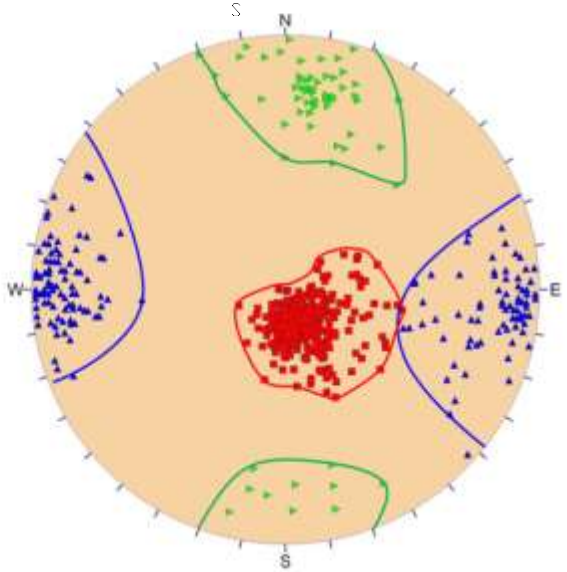


Roughness









Ref Dim=0.1m

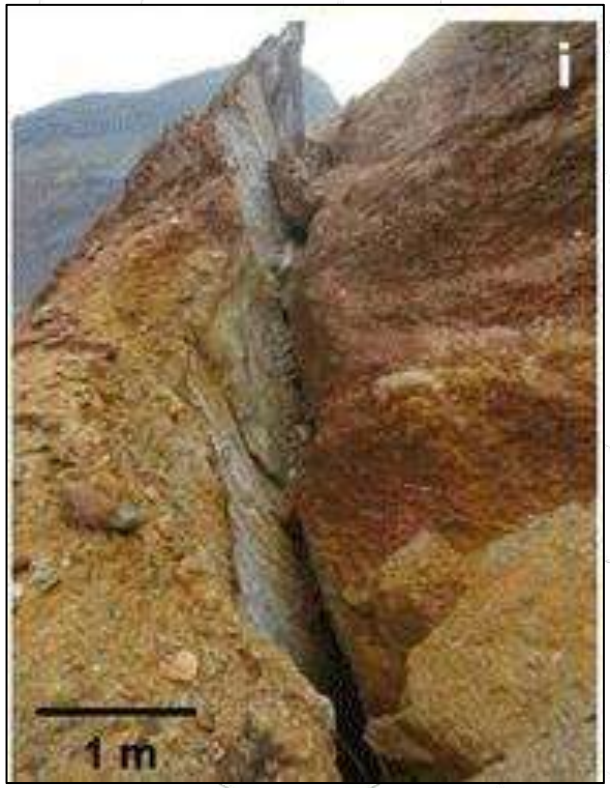
3D Kinematic analysis

Gigli et al. (2023)

3D Kinematic analysis

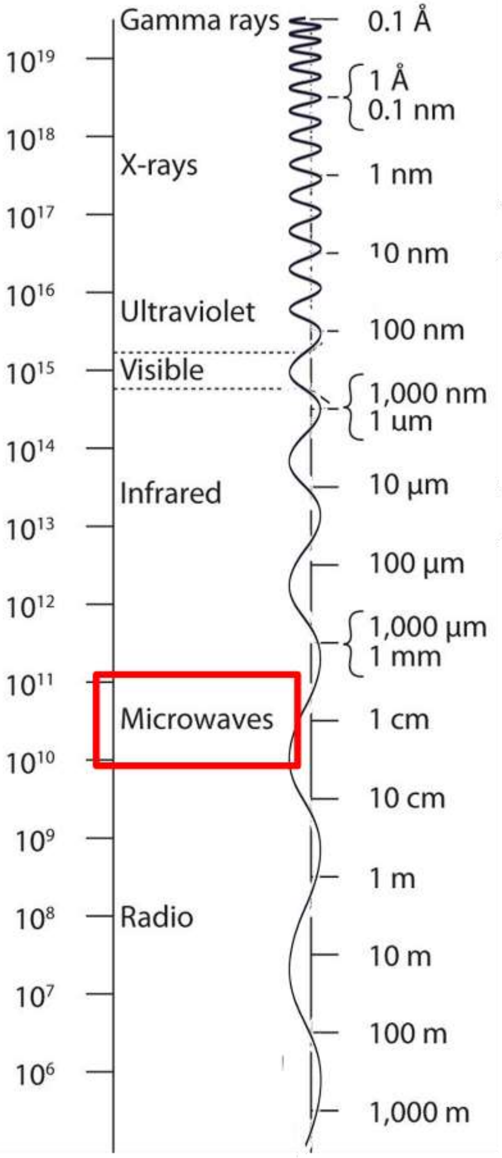
Ground Based Synthetic Aperture Radar (GB-InSAR)

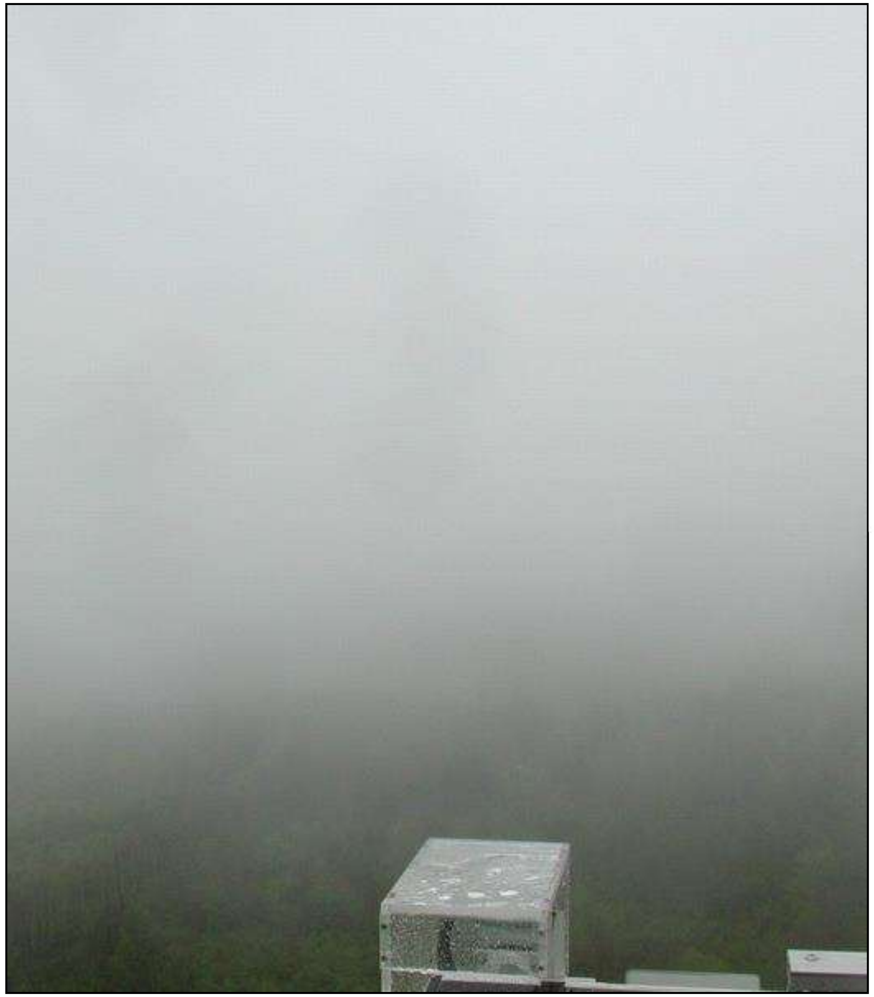
Pre-paroxistic displacements

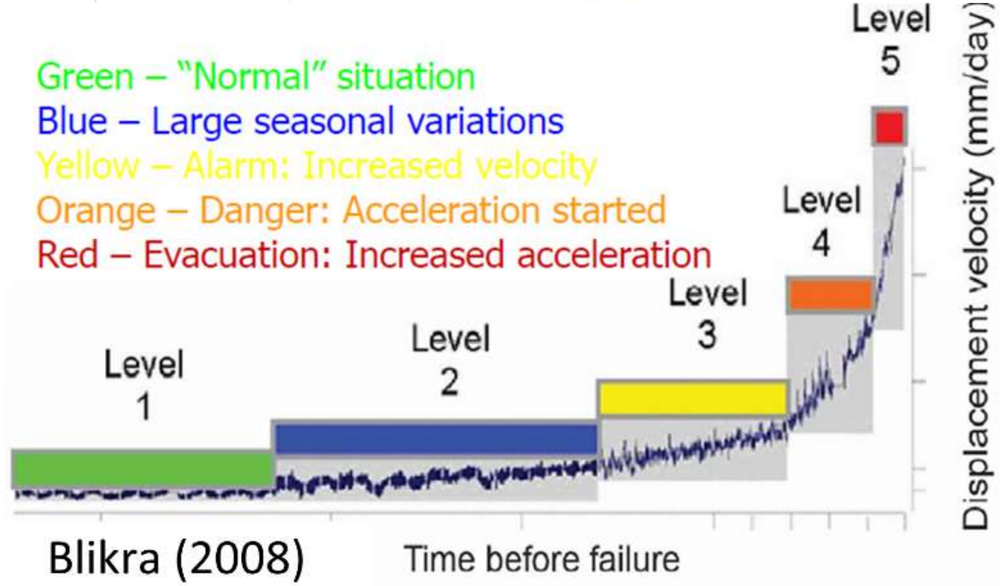


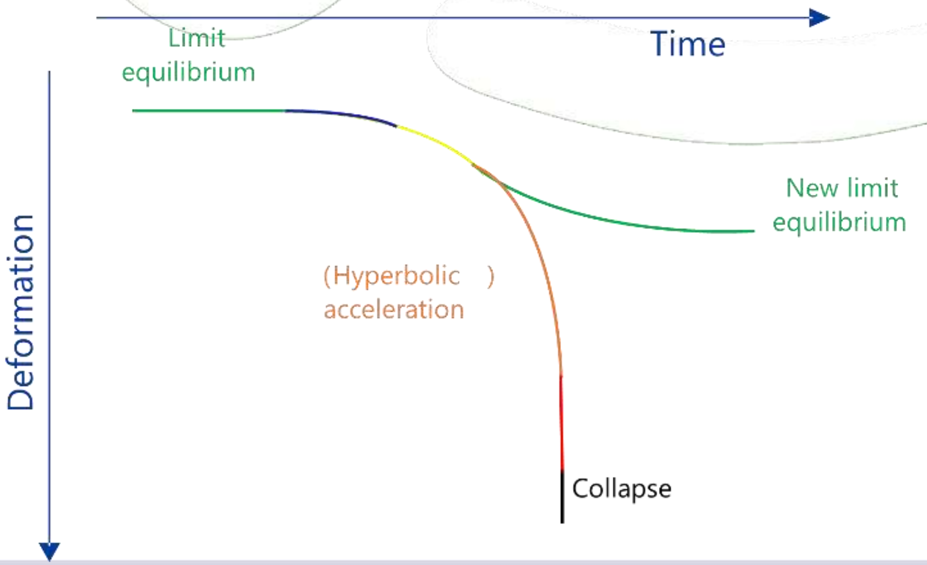
(Clayton et al., 2017)

Terrestrial Radar Interferometry

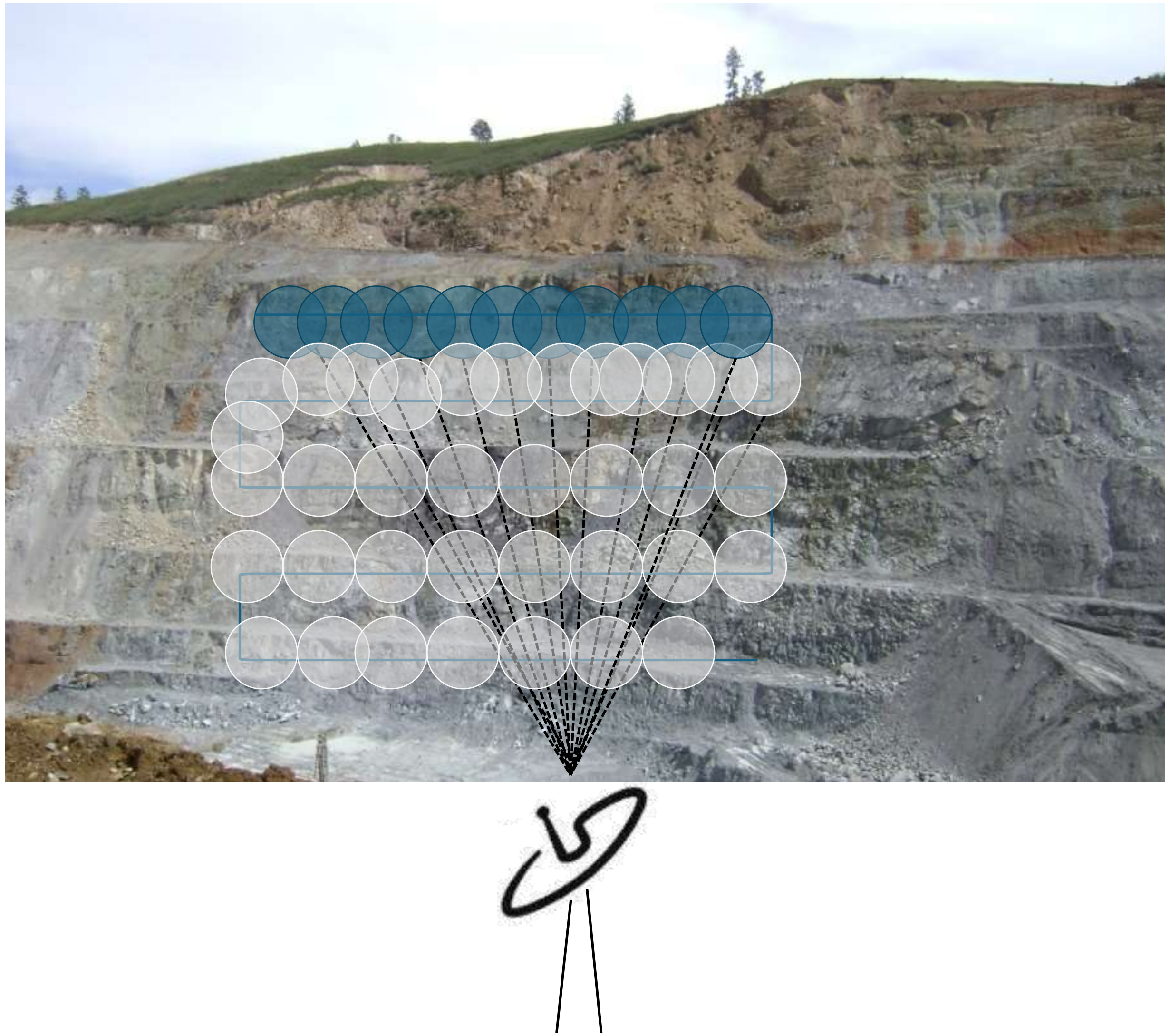


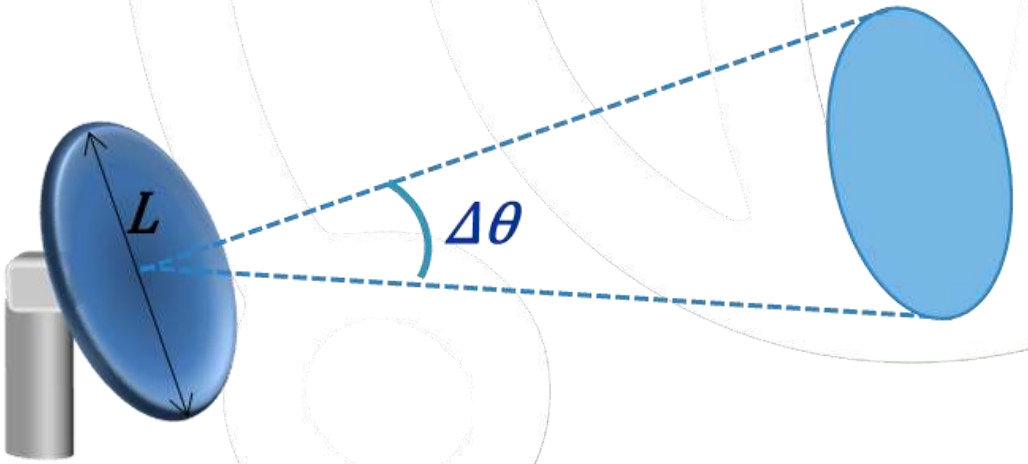






Real Aperture Radar (RAR)

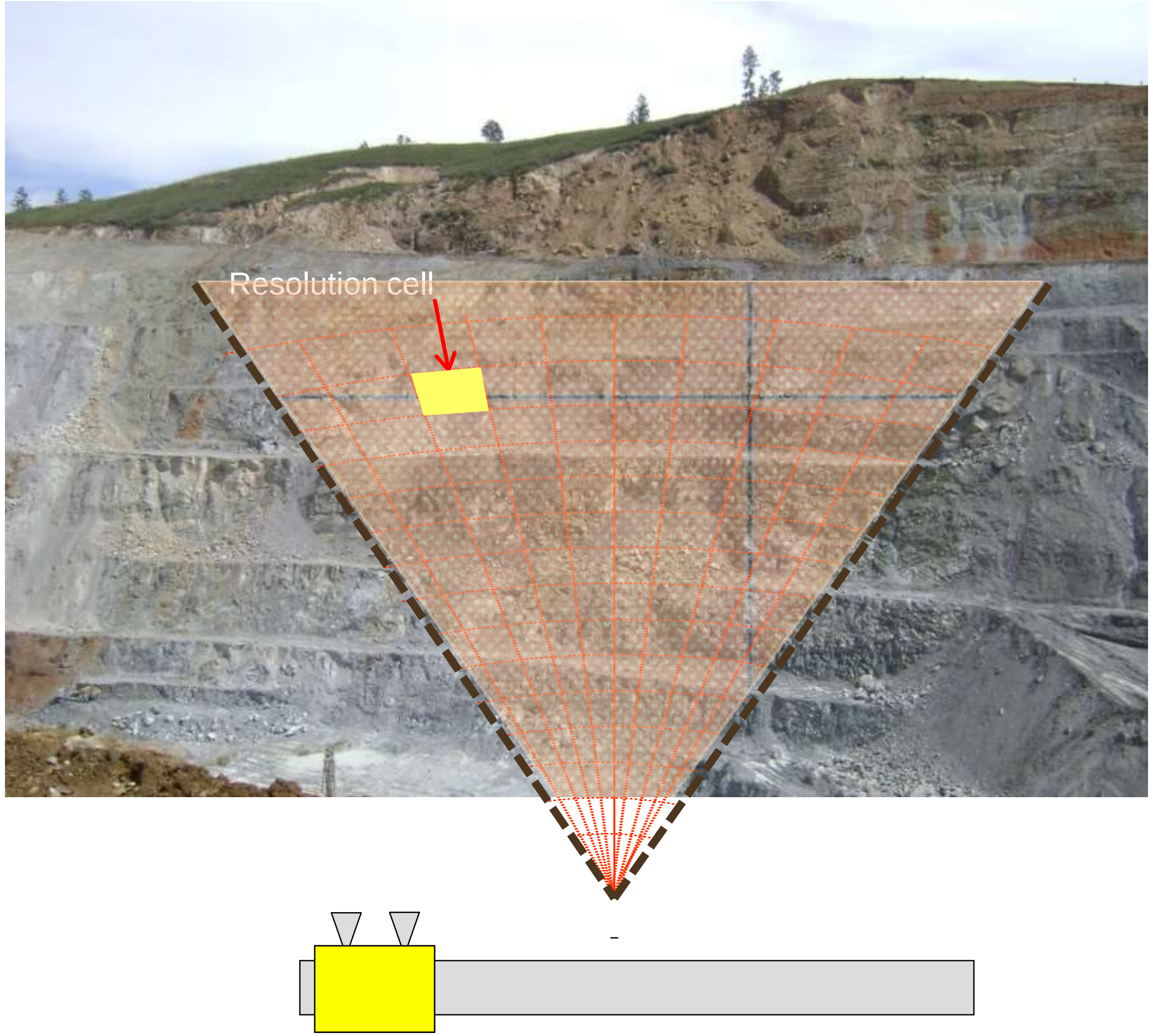


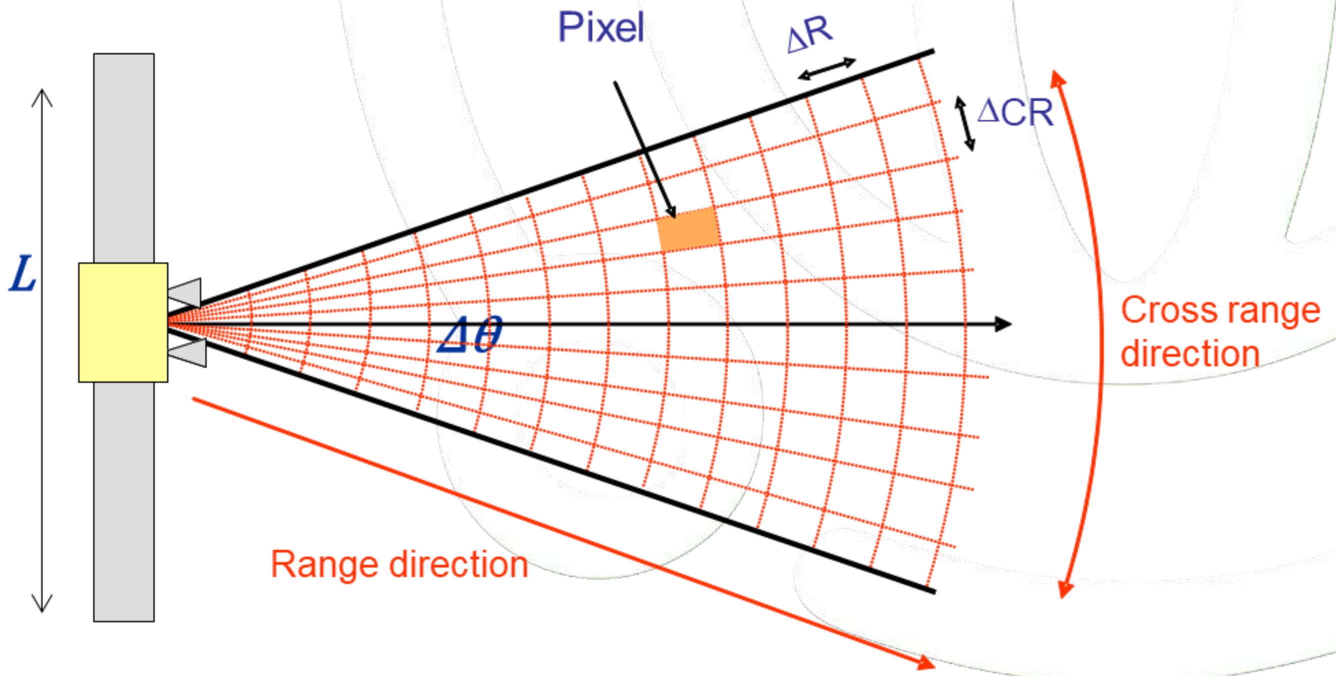


Pixel dimension is inversely proportional to antenna width:

$\Delta\theta = \lambda/L$

Synthetic Aperture Radar (SAR)





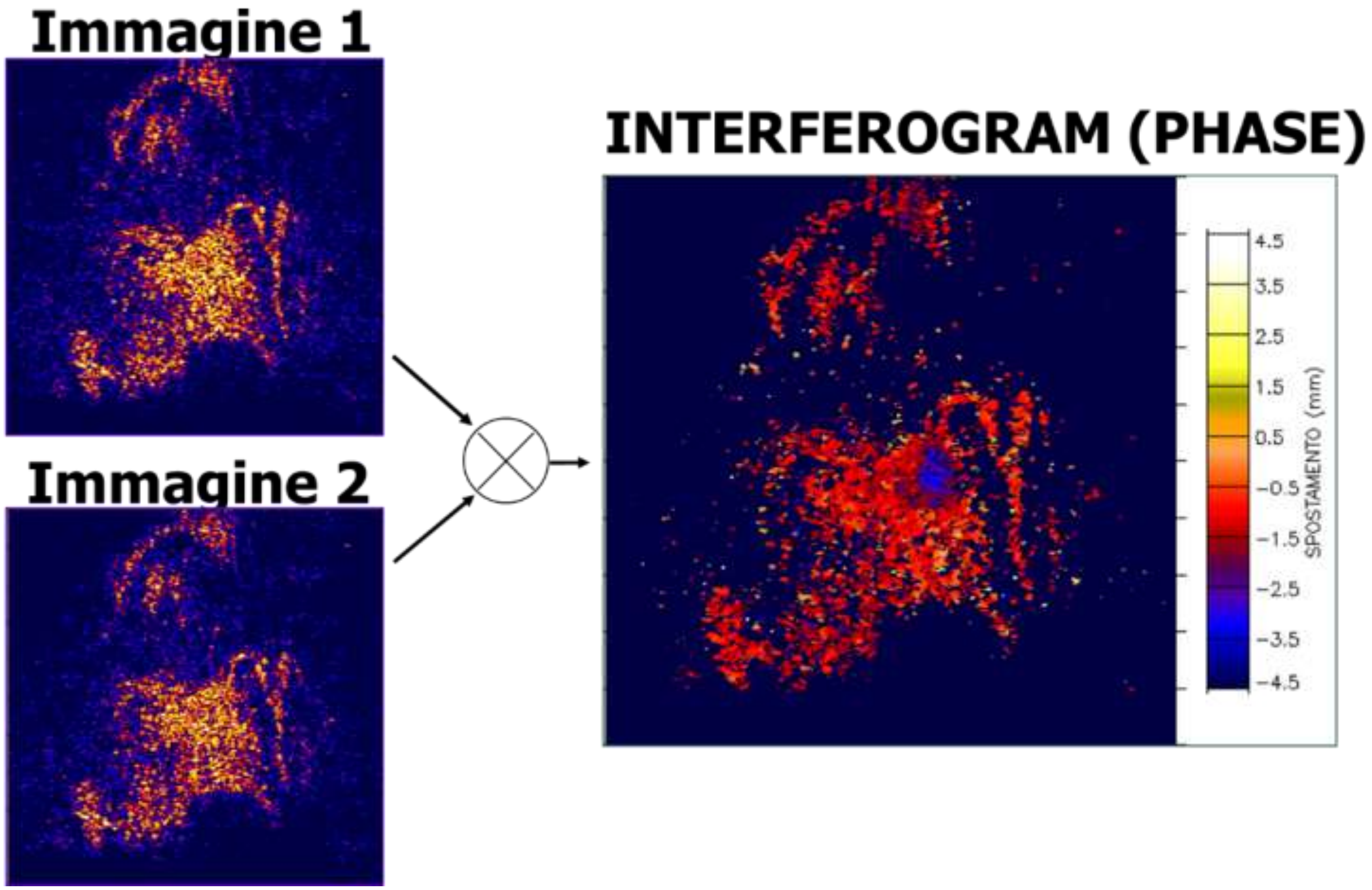
Range resolution:

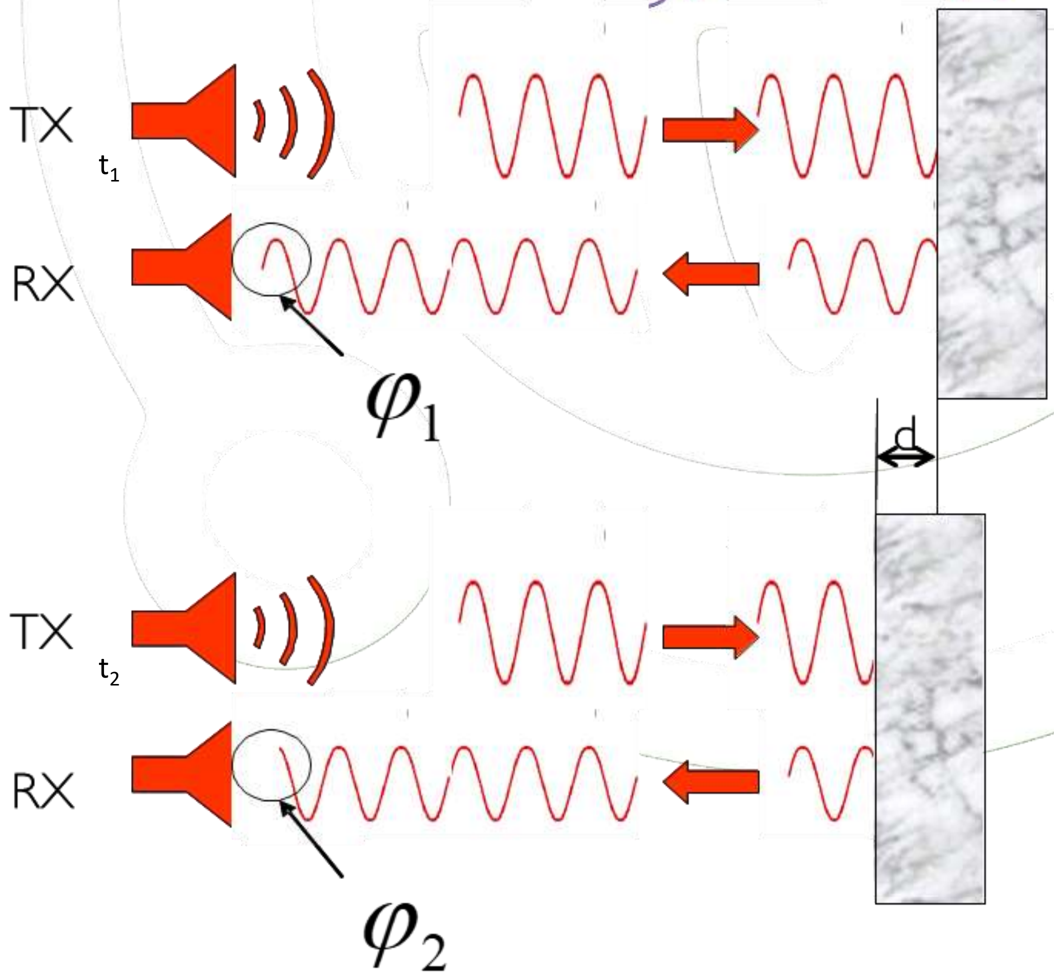
ΔR = c/2B (constant)

Azimut (Cross Range) resolution:

$\Delta\theta = cR/2Lf_c$

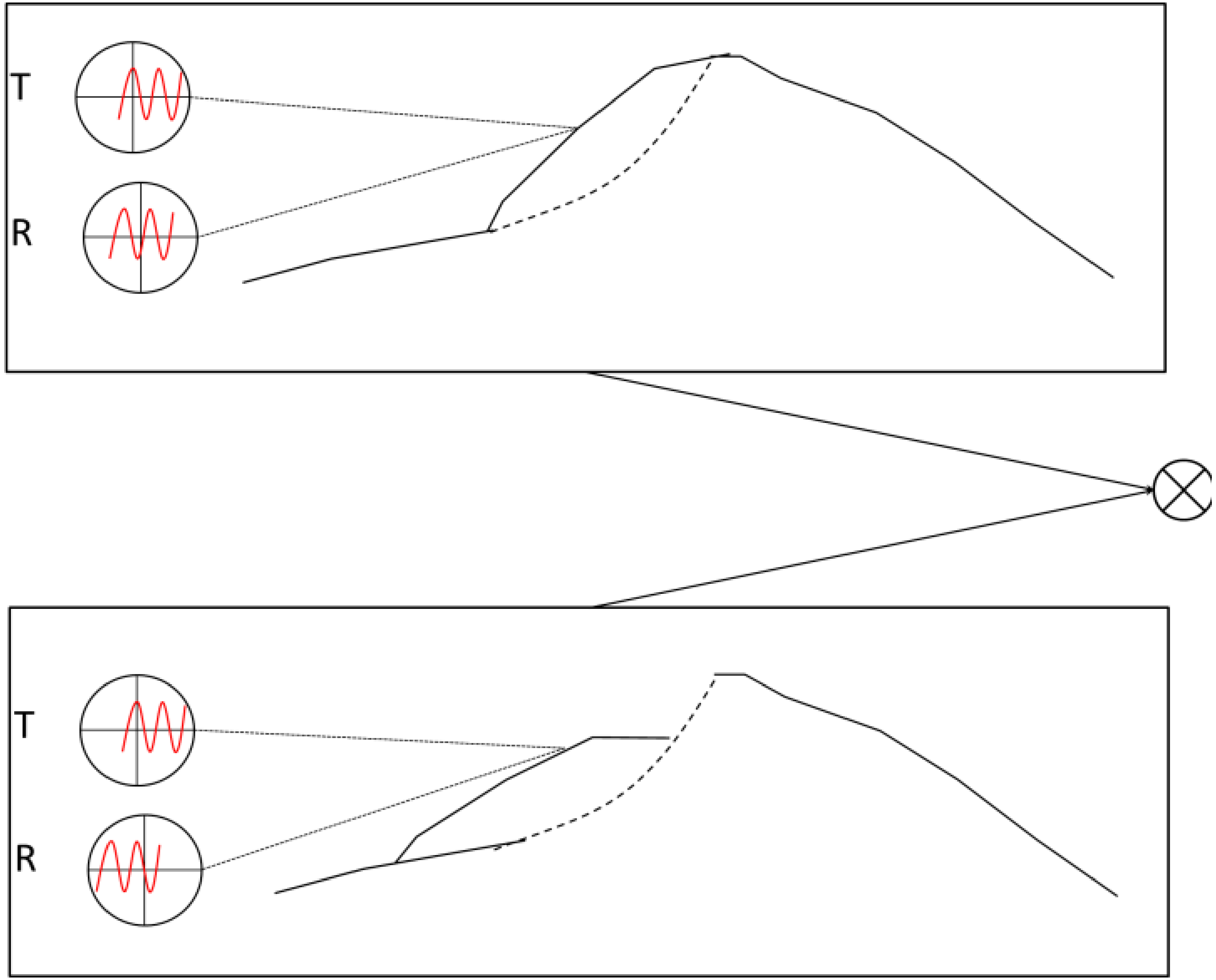
Interferometric Analysis

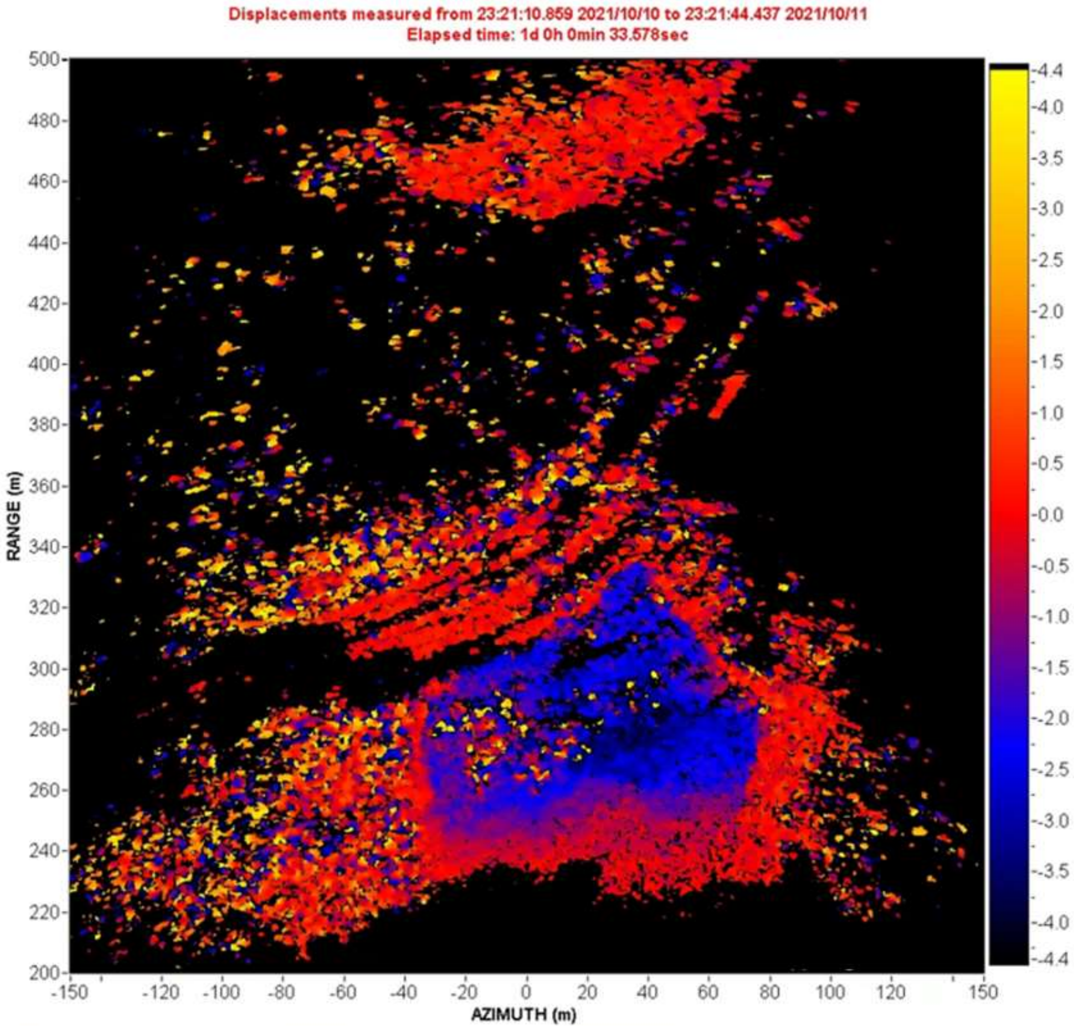




$$d = -\frac{\lambda}{4\pi}(\varphi_2 - \varphi_1)$$

Terrestrial Radar Interferometry





Casagli et al. (2010)
Tarchi et al. (2003)

Slope stability radar

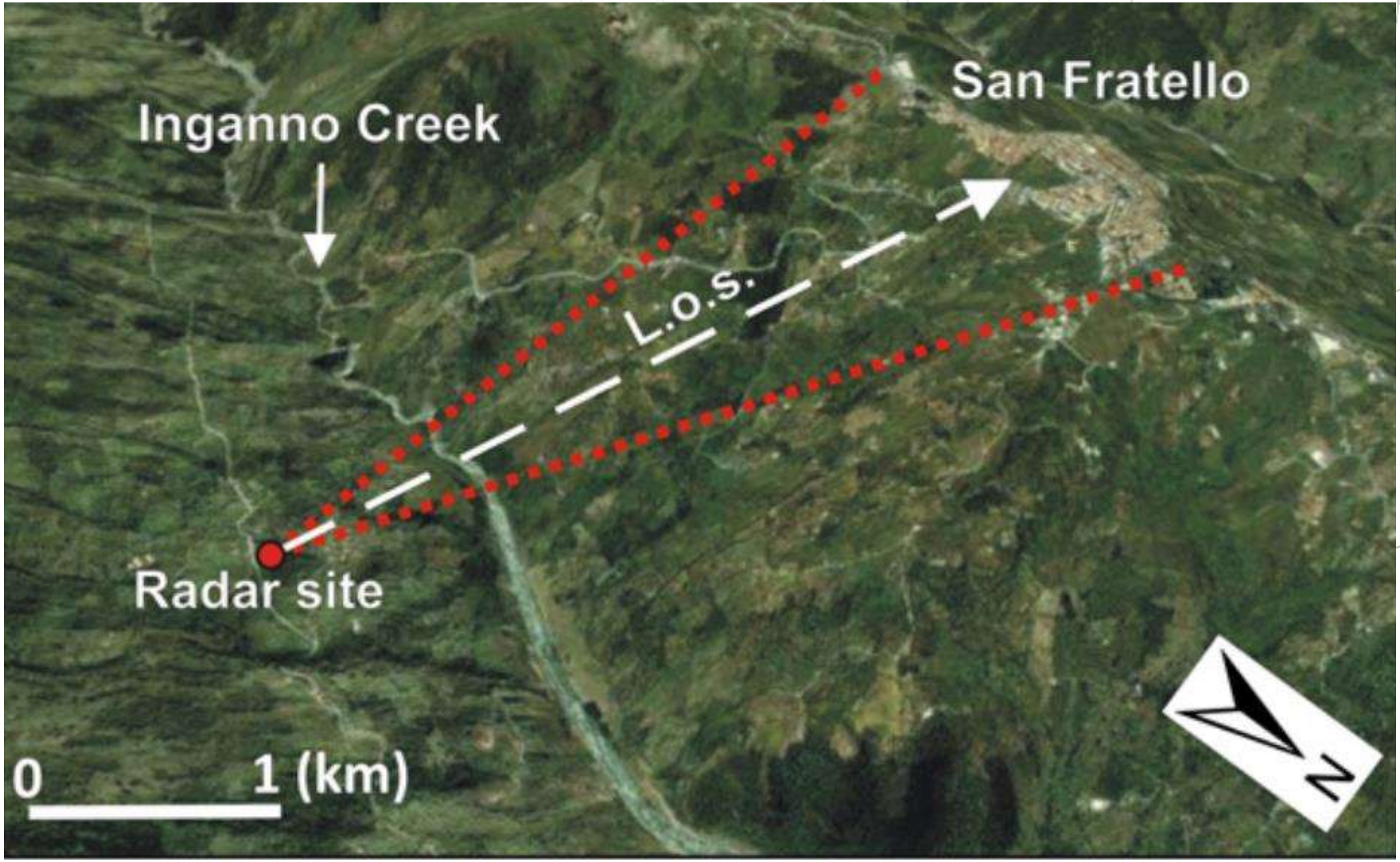
Slope stability radar

Main advantages

- Operation in all lighting conditions and in adverse weather conditions

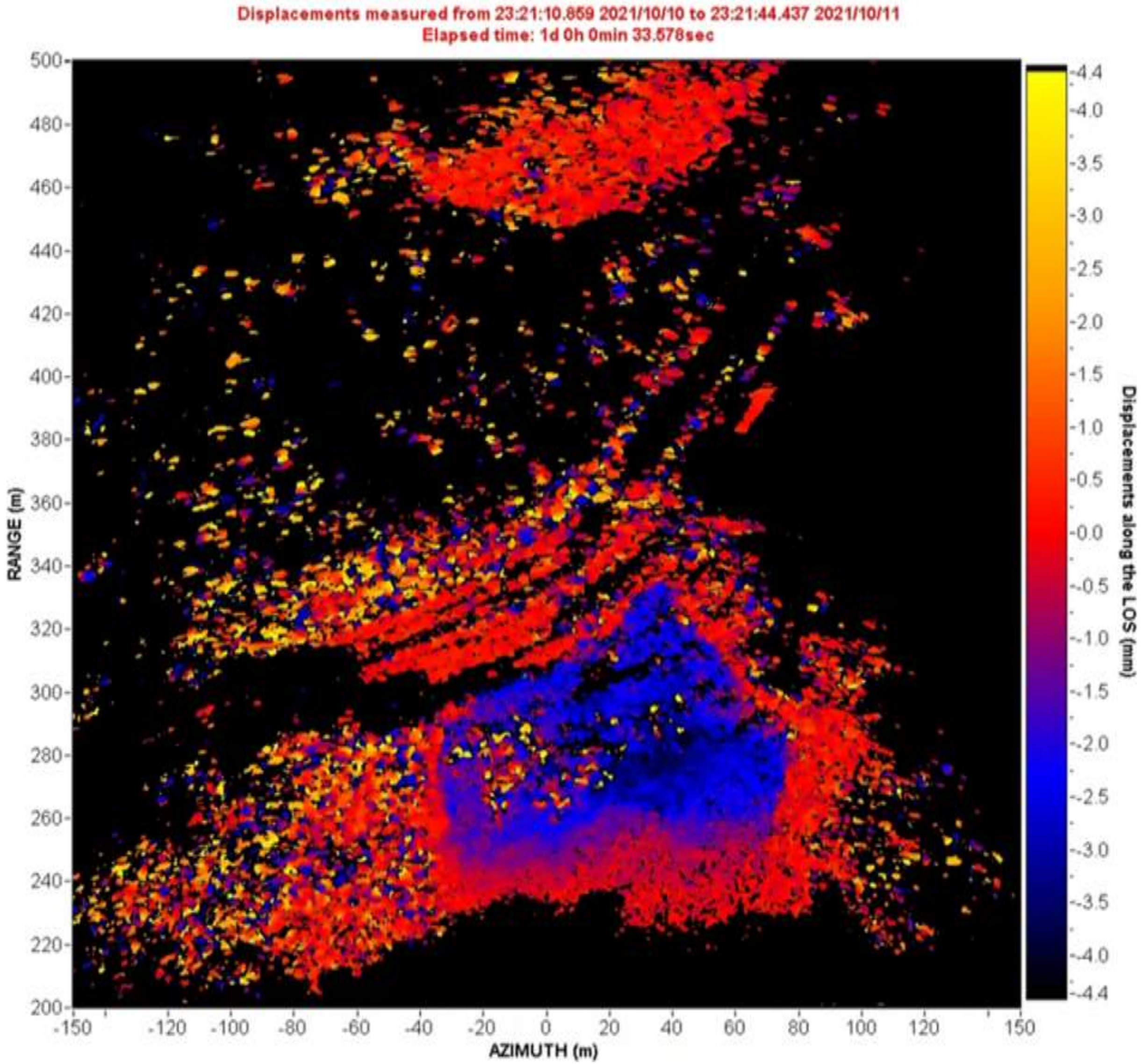
Main advantages

- Remote monitoring, up to distances of a few km



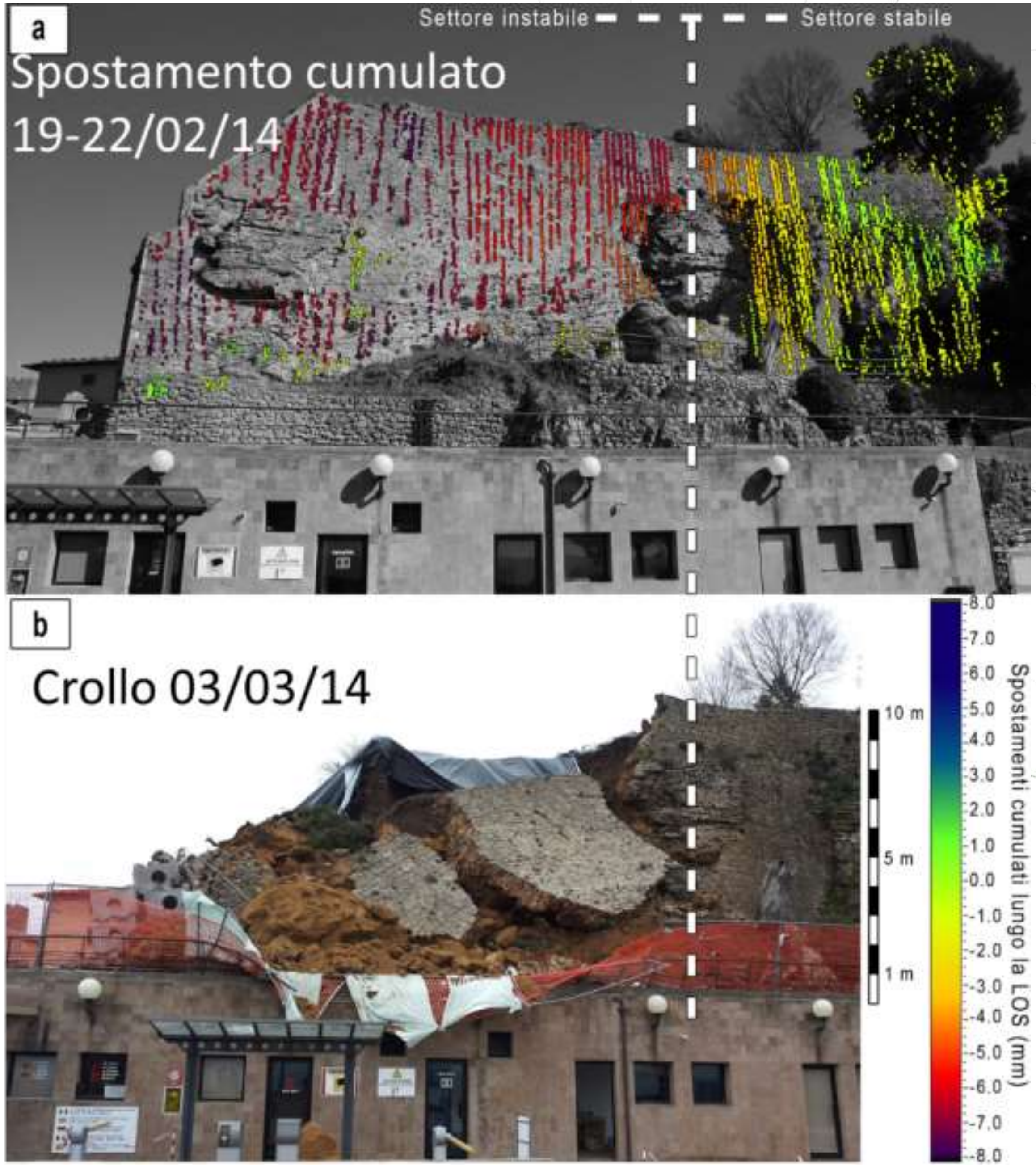
Main advantages

- Sub-millimeter accuracy



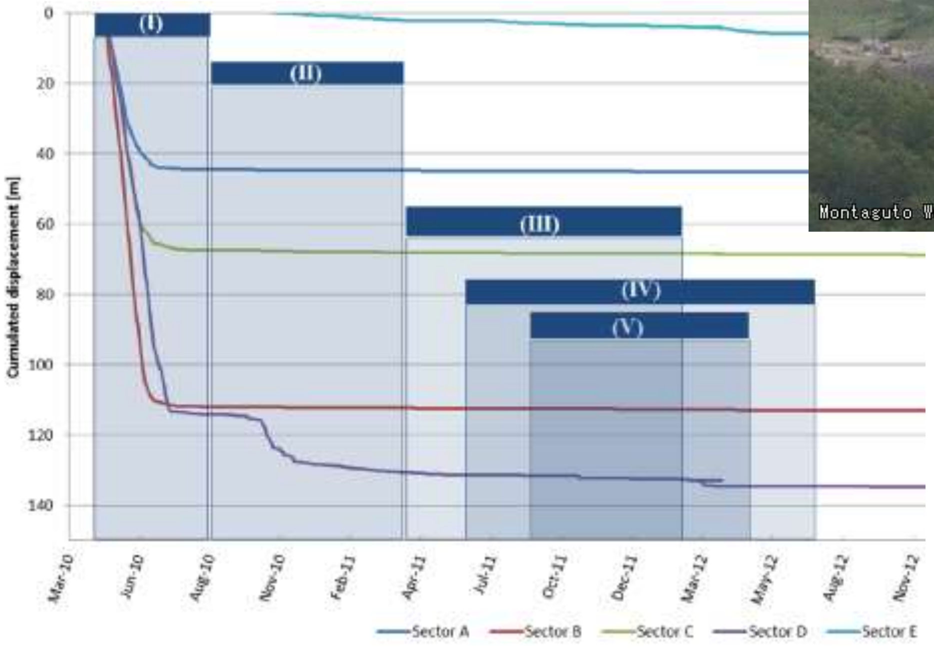
Main advantages

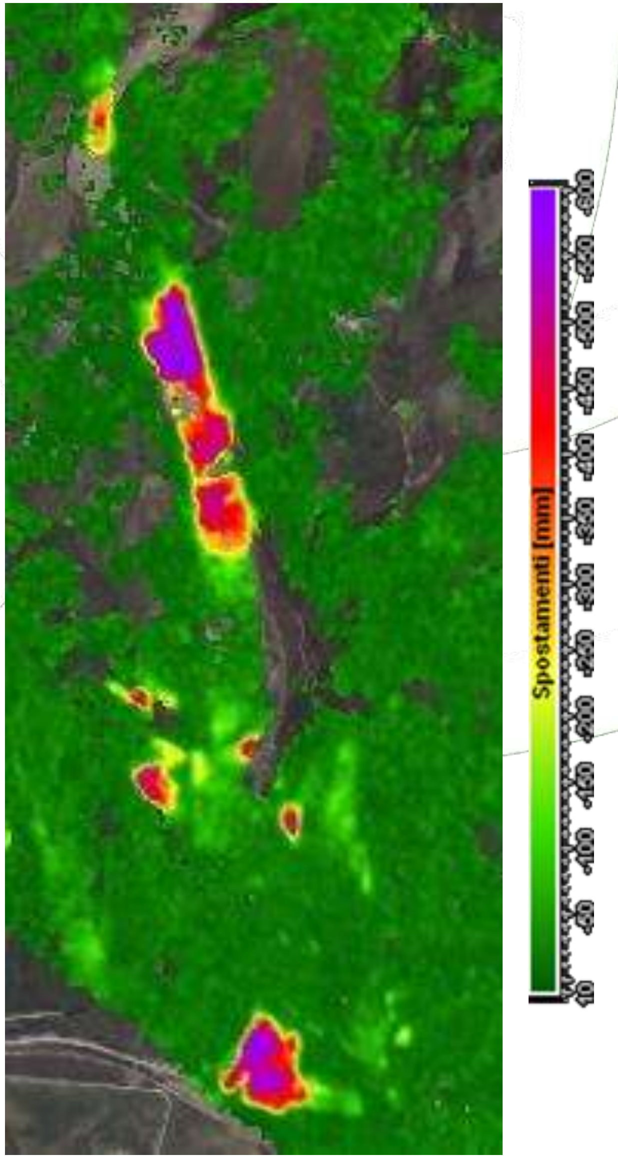
- Spatial resolution from decimetric to metric



Main advantages

- Areal monitoring

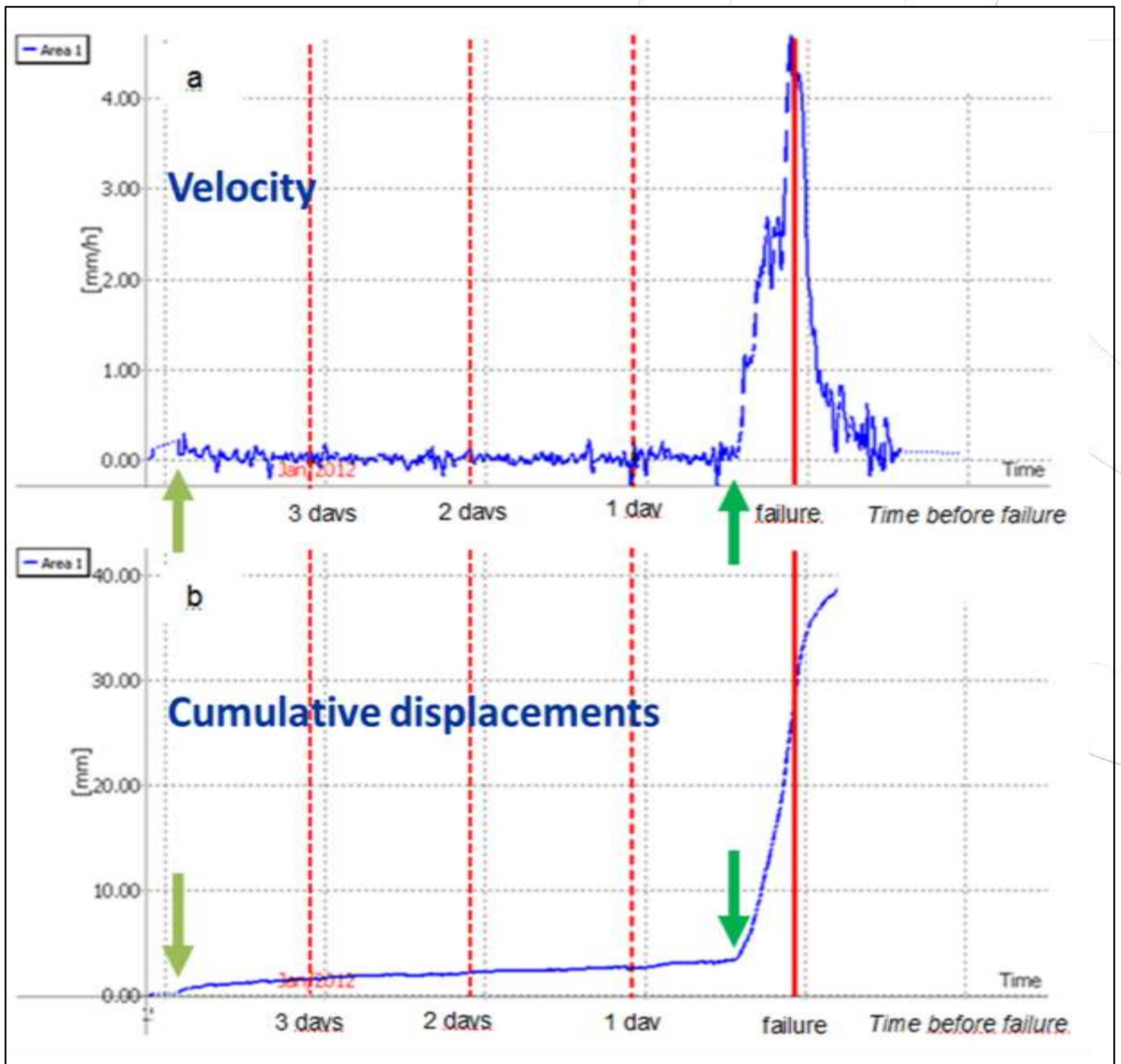




Ferrigno et al., 2017

Main advantages

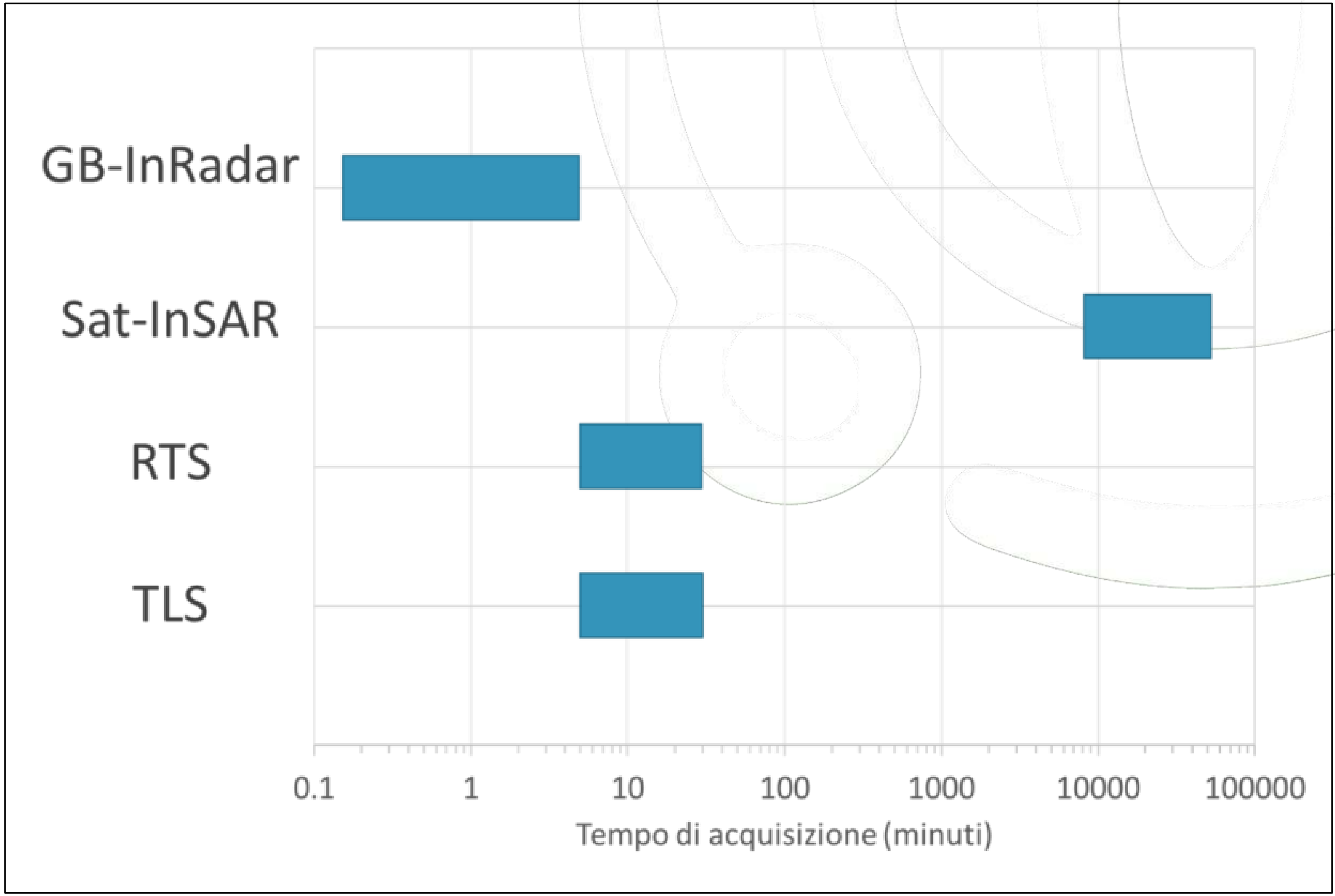
- Time histories of points of interest



Farina at al., 2012

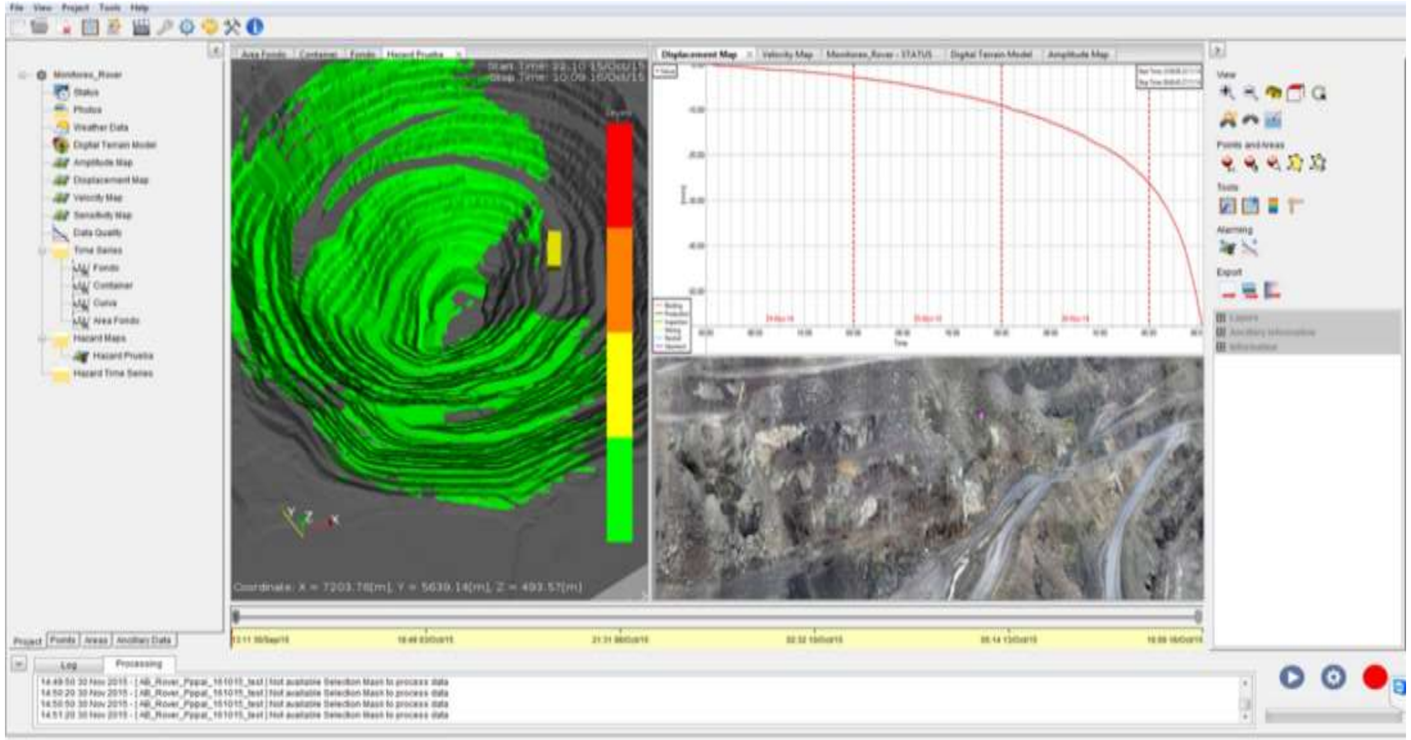
Main advantages

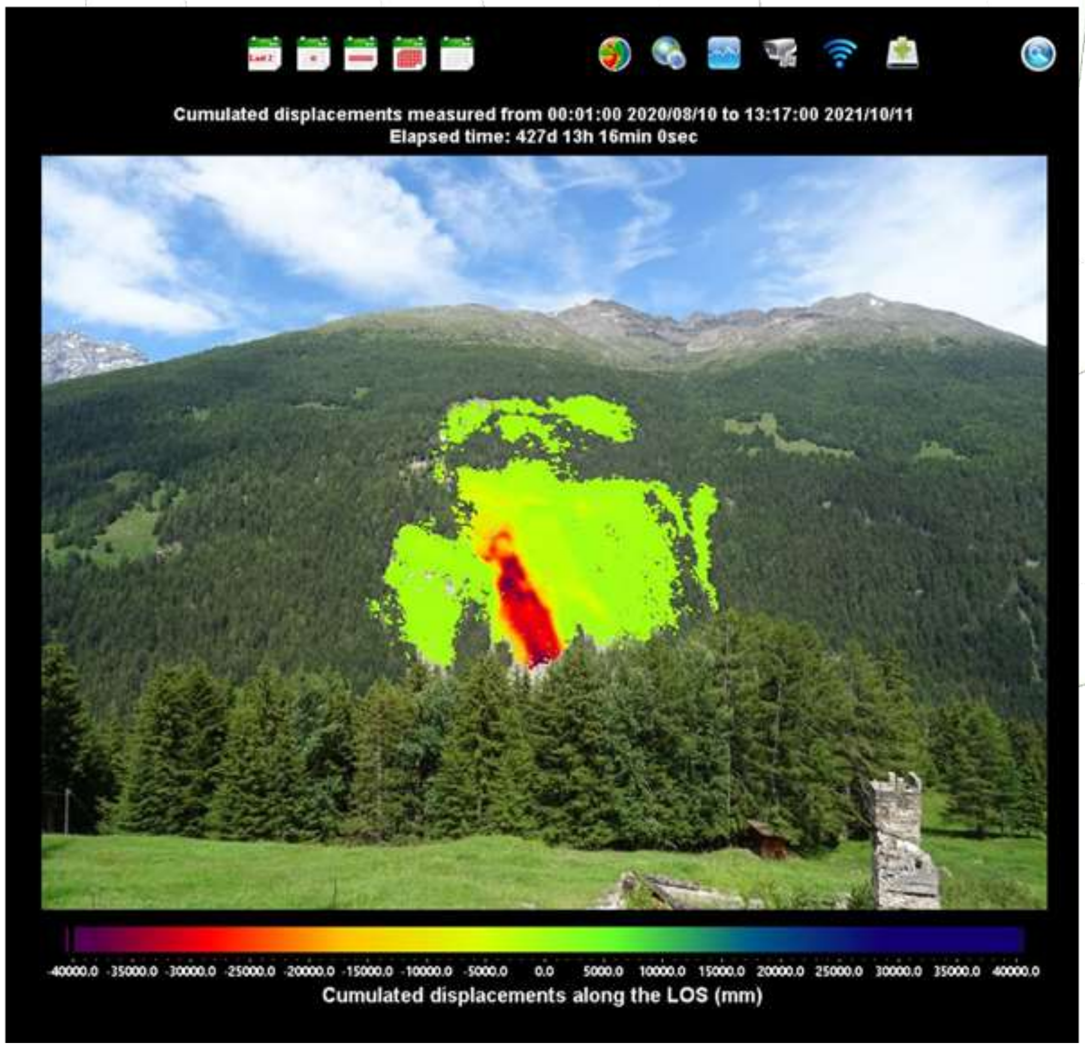
- High acquisition frequency



Main advantages

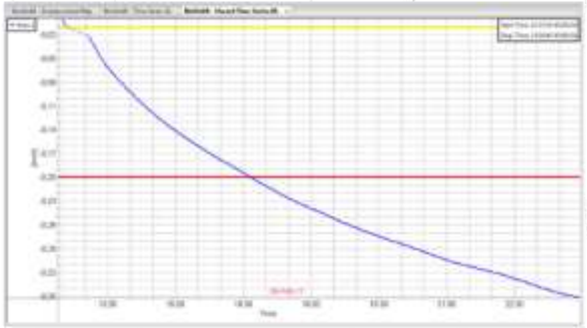
- Remote instrument management

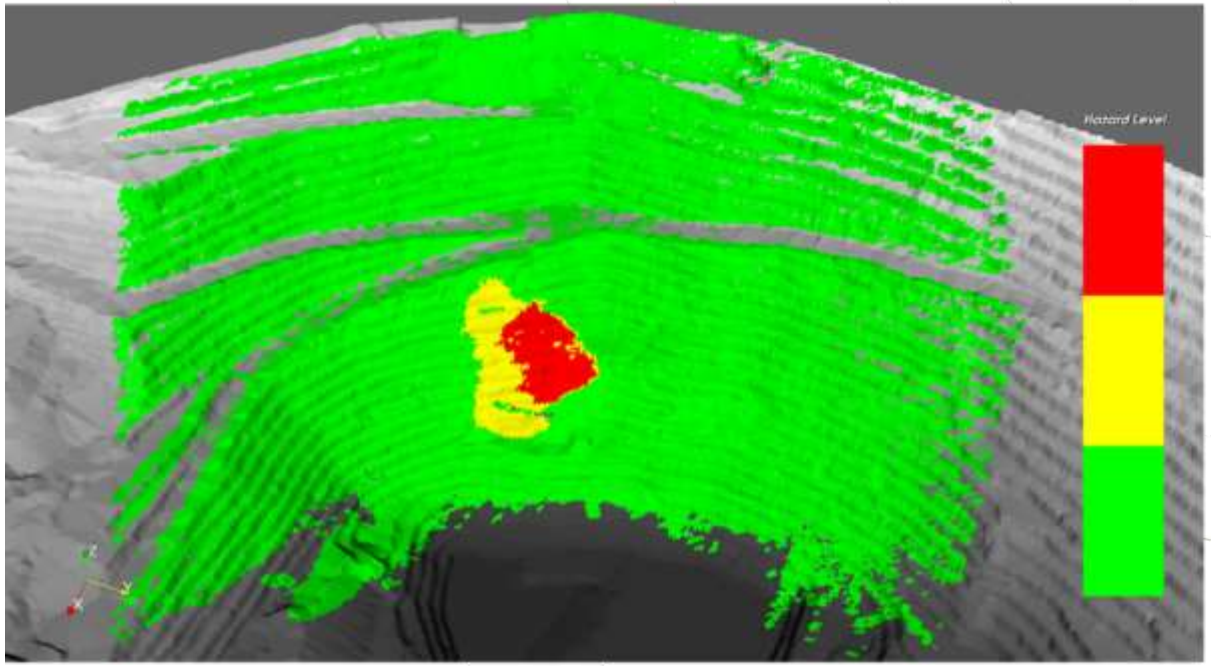




Main advantages

- Alarm maps and interfaceability in Early Warning systems





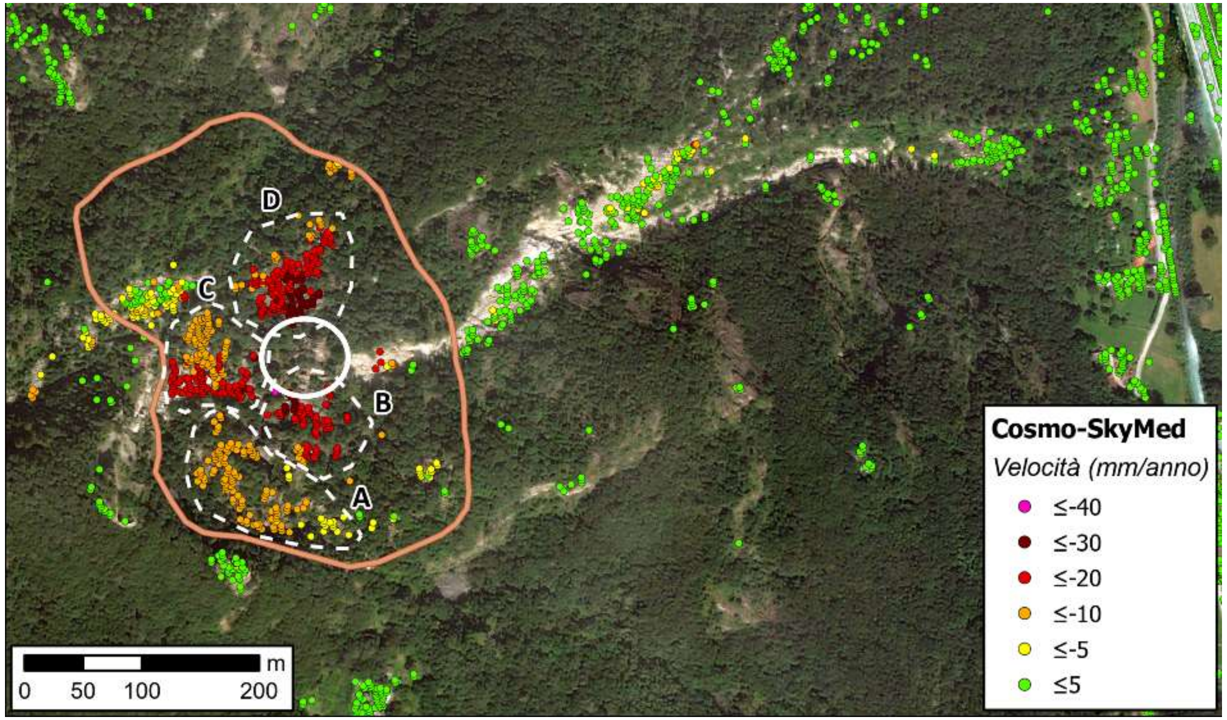
Main advantages

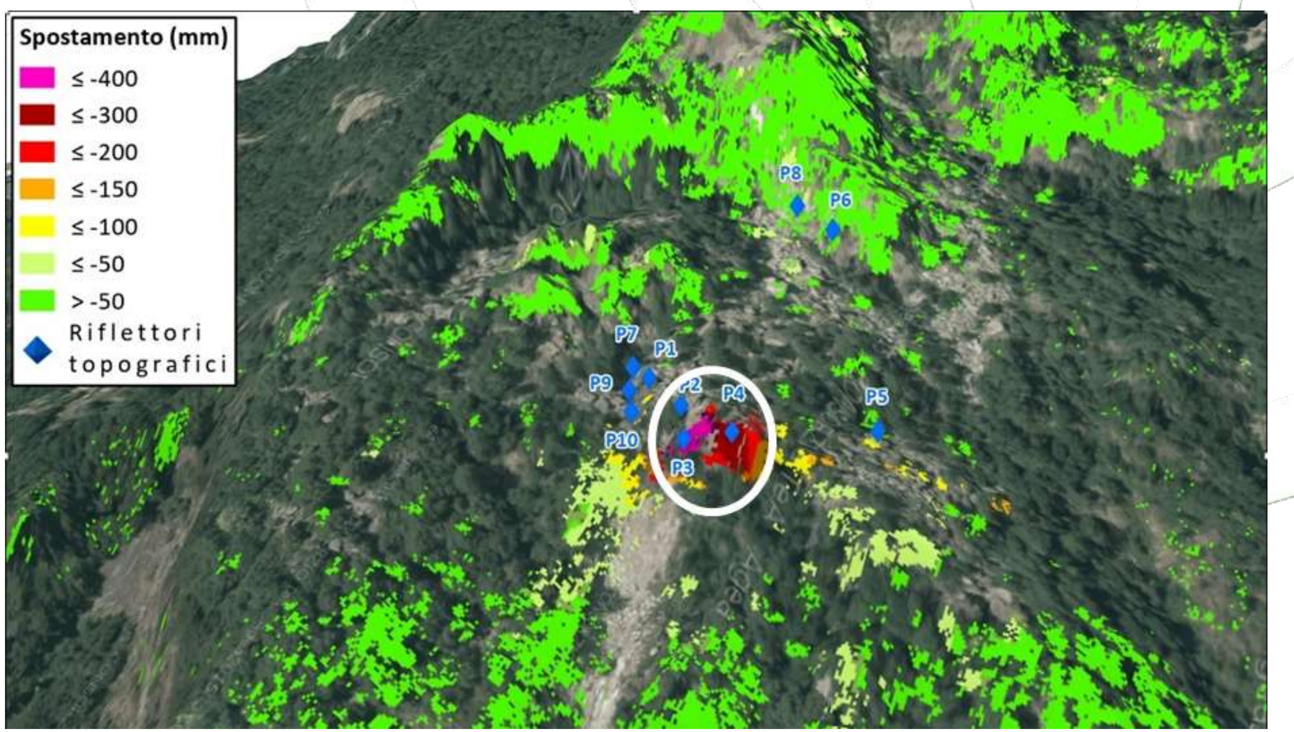
Complementarity with Sat-InSAR

Quincinetto rockslide

Main advantages

Complementarity with Sat-InSAR





Drawbacks

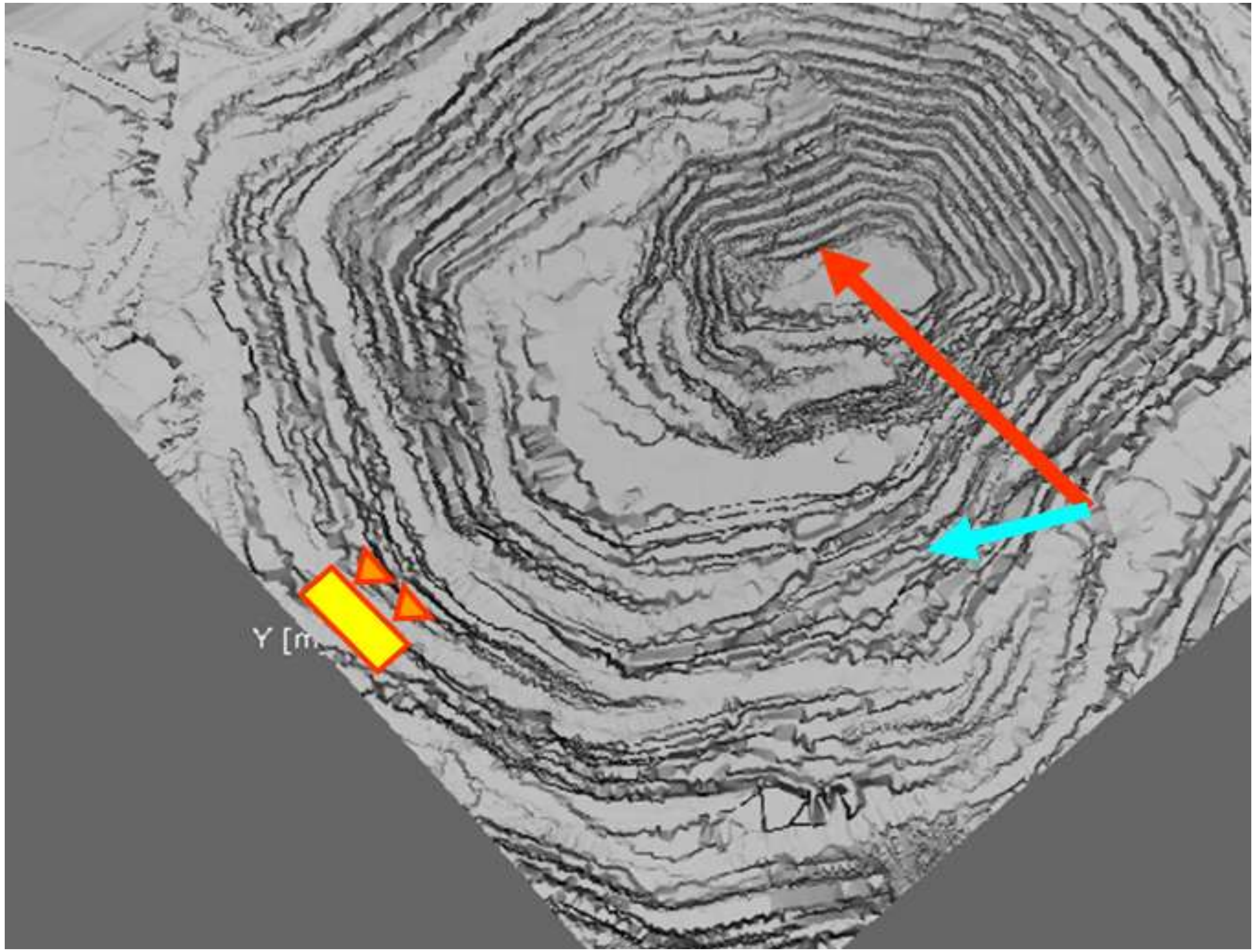
- instrumentation is heavy and bulky

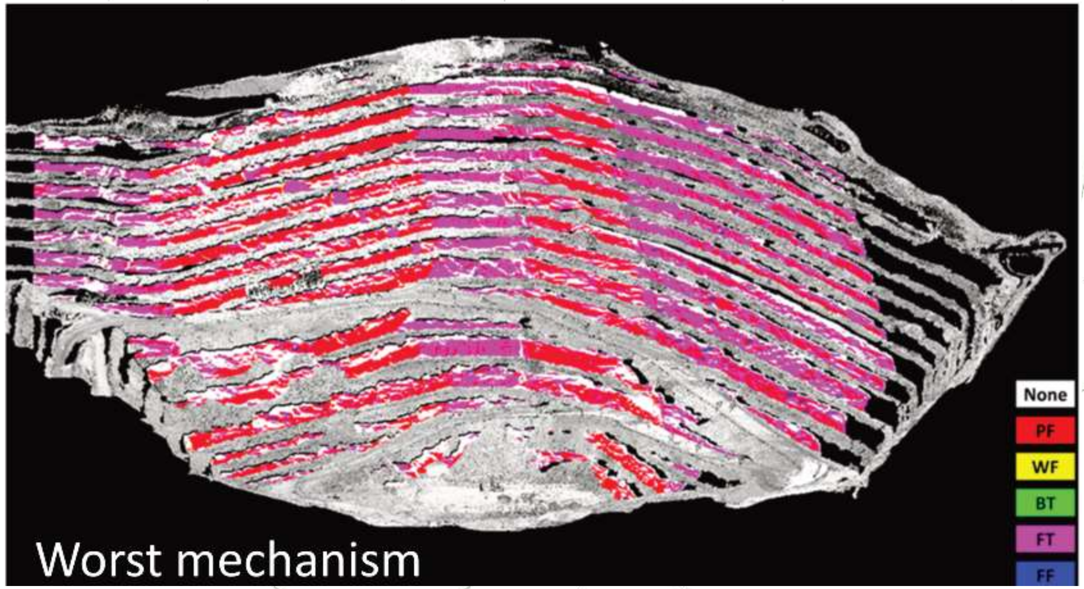
Drawbacks

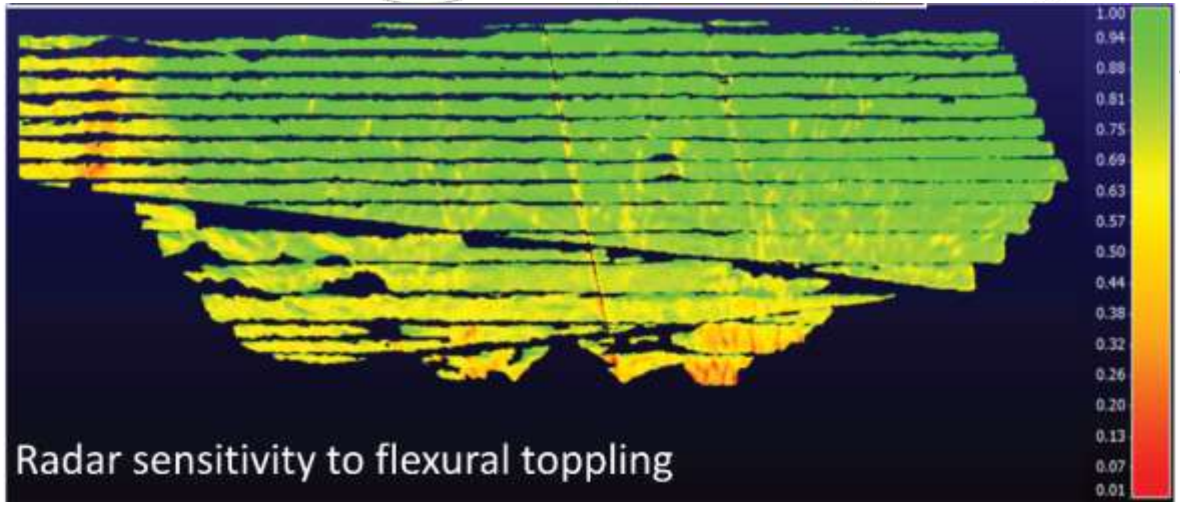
- Limited cone of view and operating distance for some applications

Drawbacks

- Line of Sight (LOS) displacements

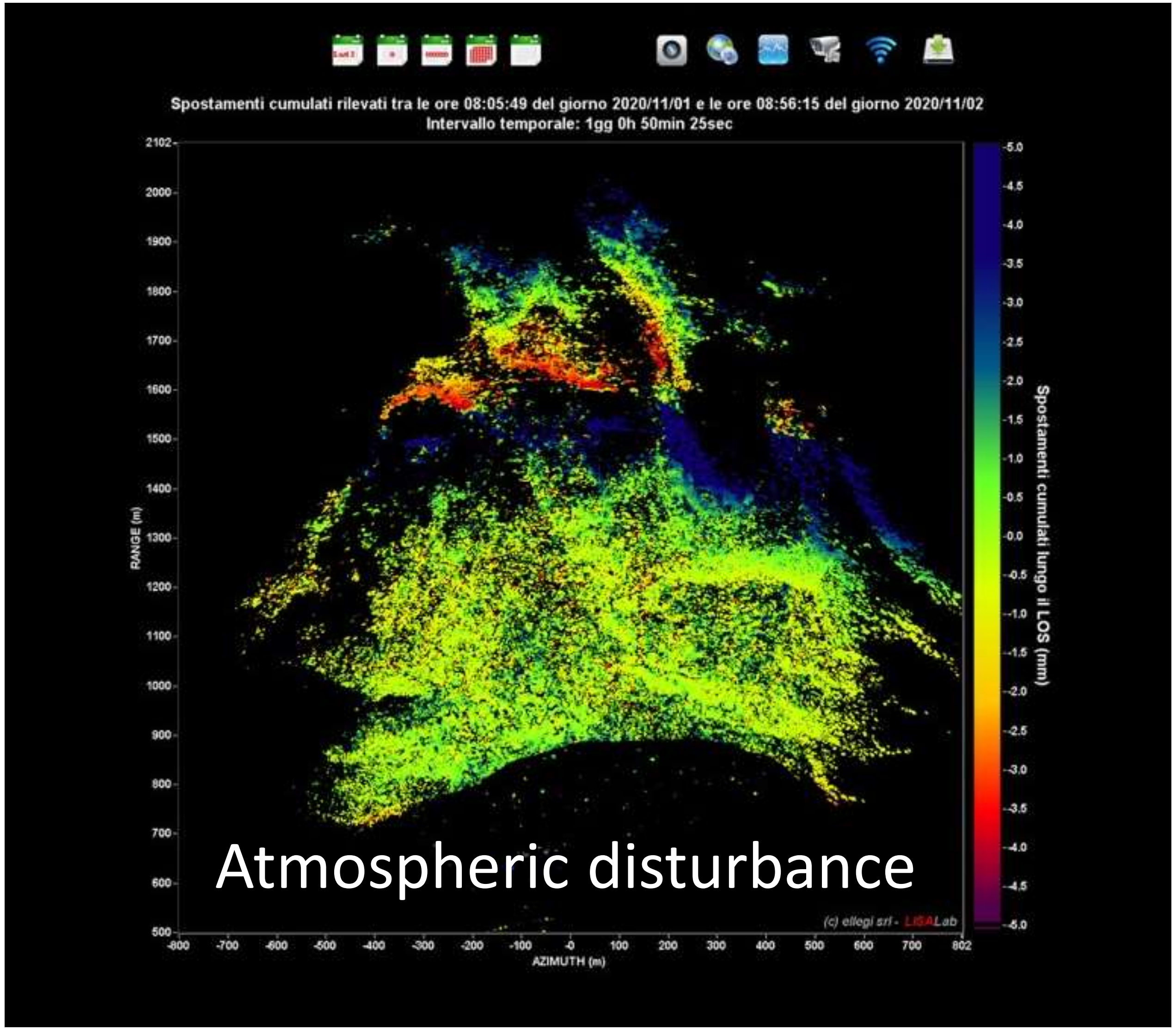


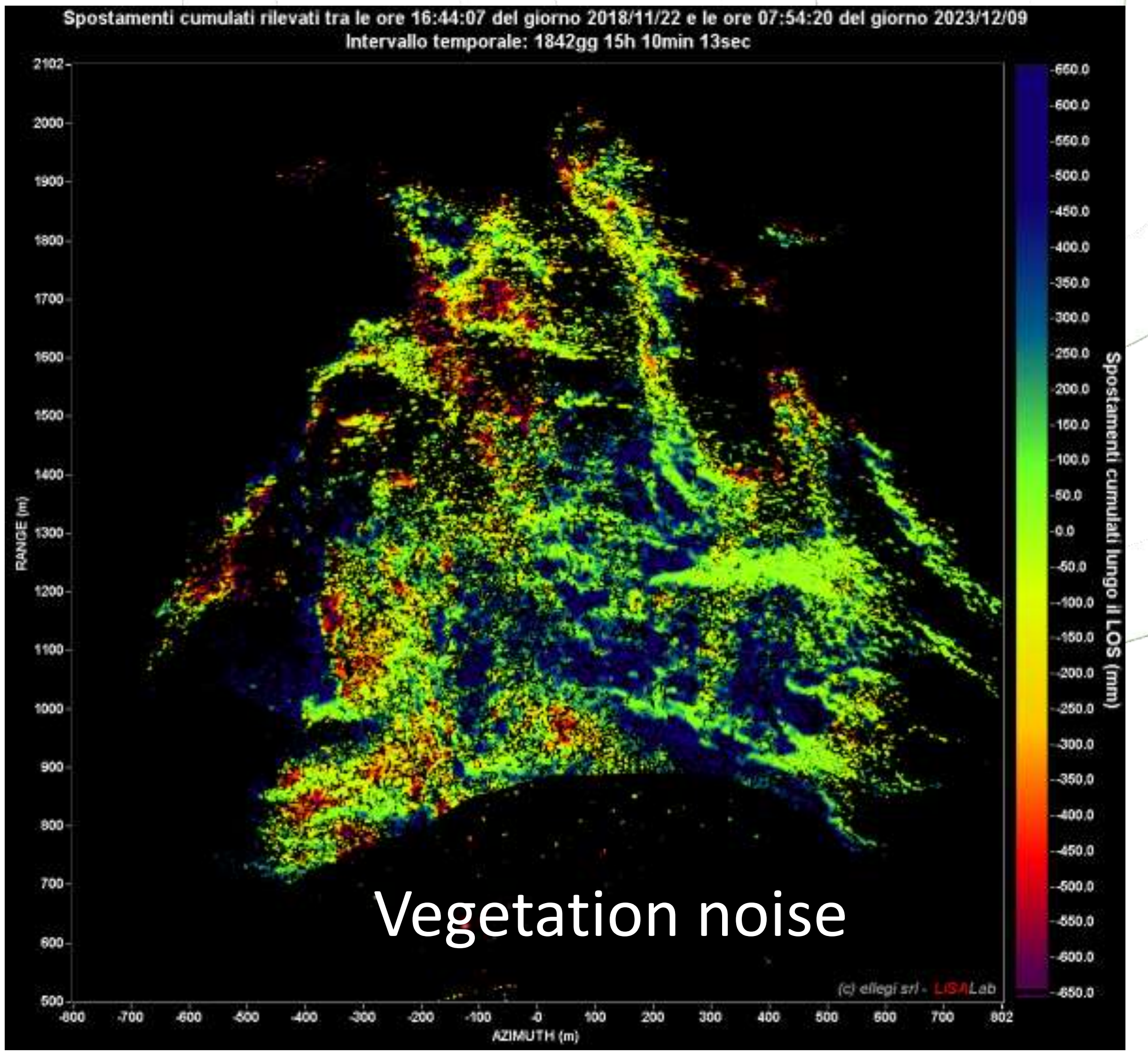




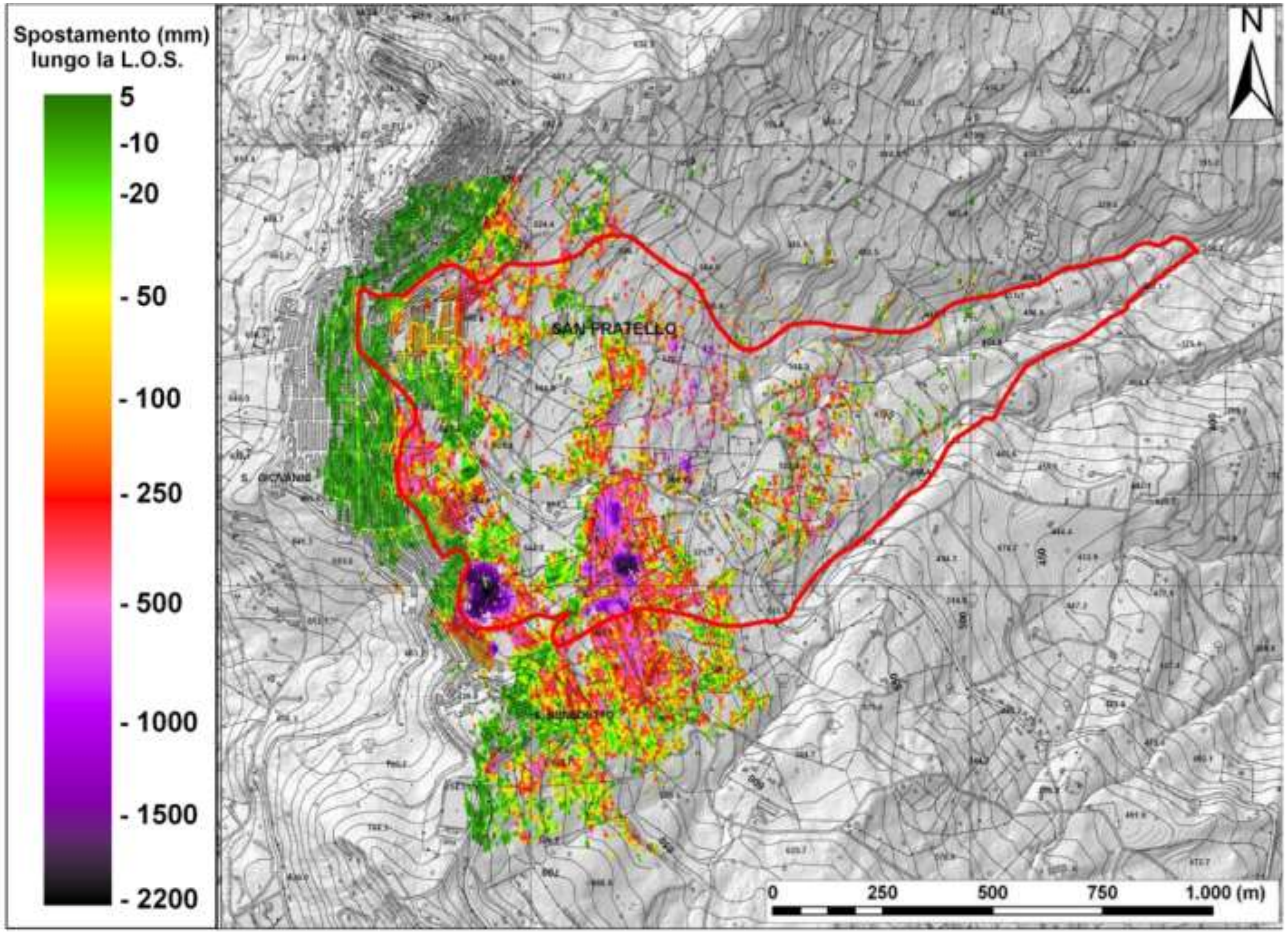
Drawbacks

Noise effects





Drawbacks

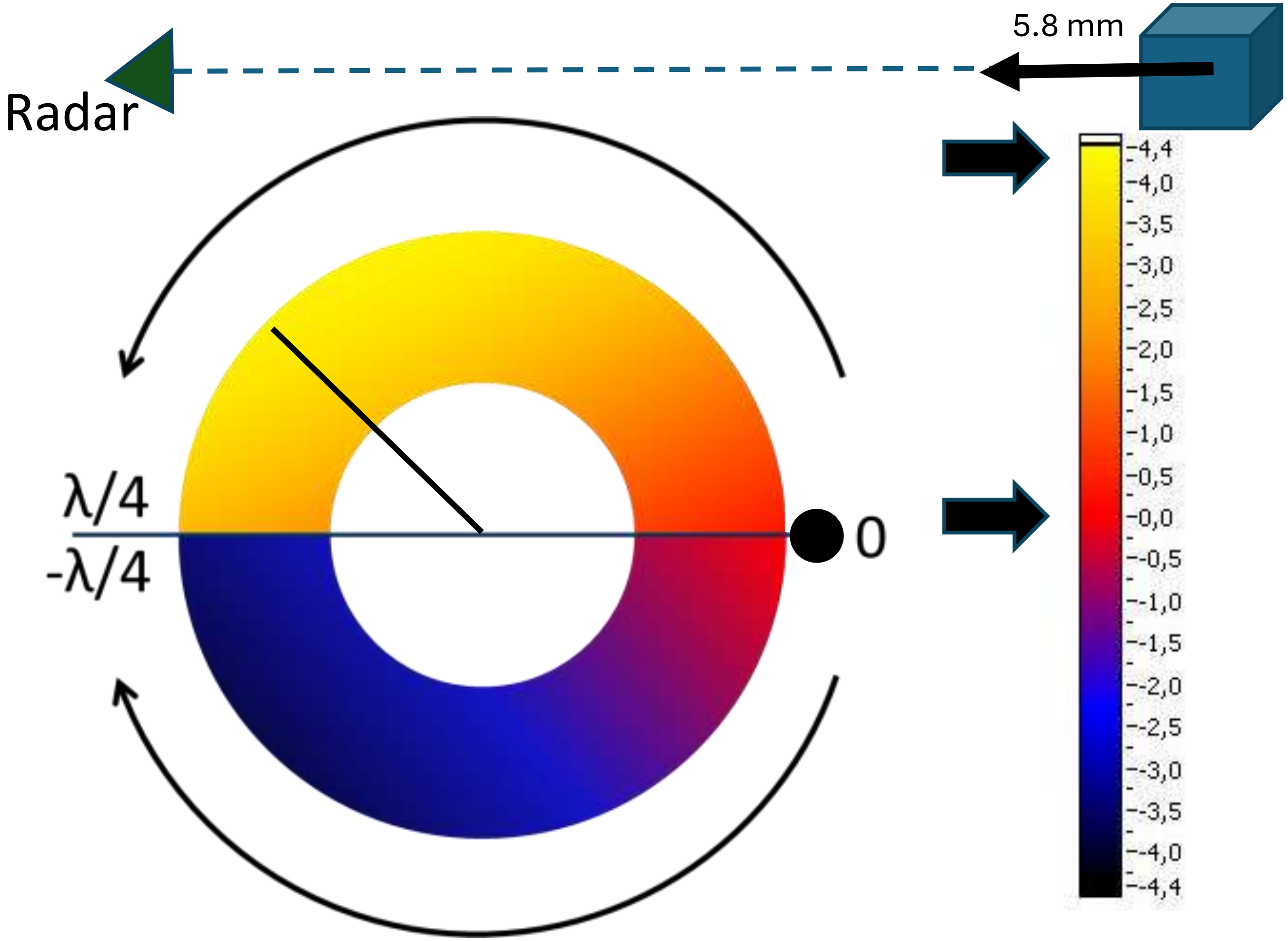


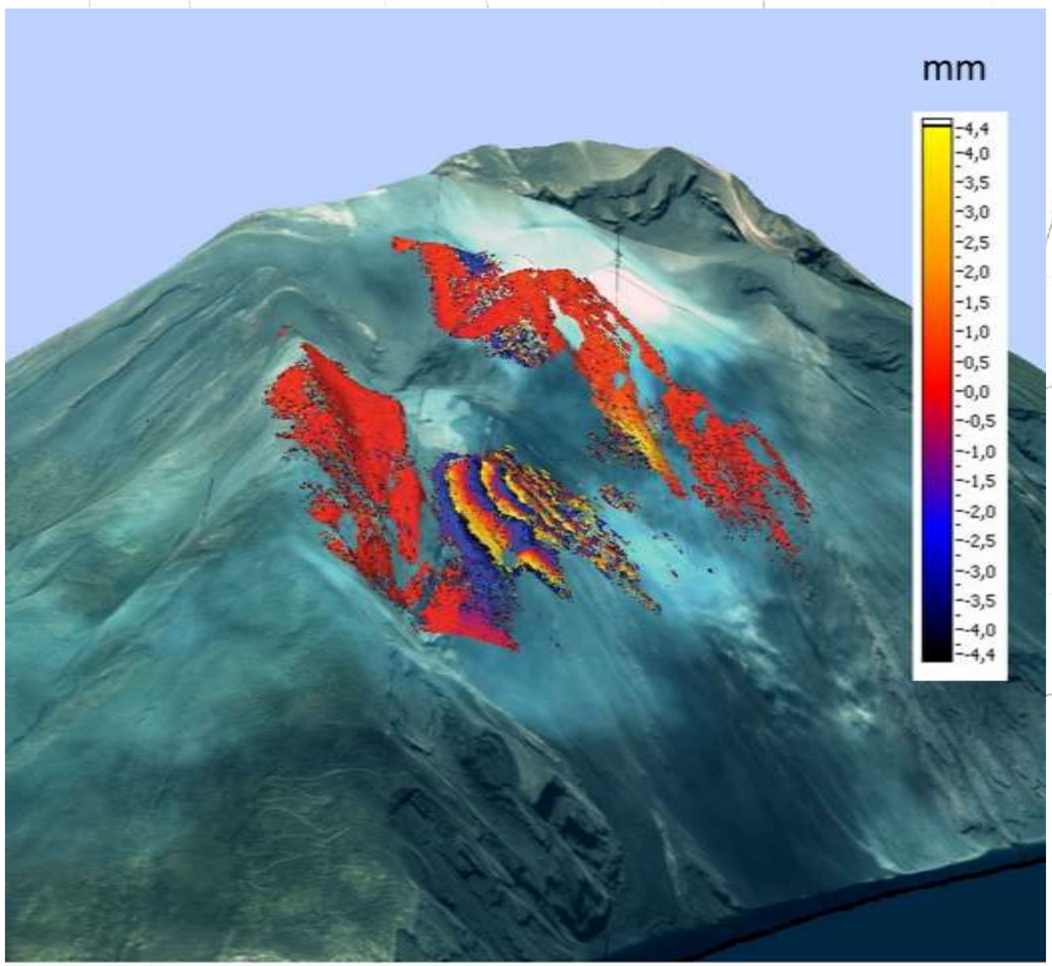
Spostamento cumulato 10 marzo 2010-1dicembre 2012

- Lack of data in vegetated areas

Drawbacks

Phase ambiguity





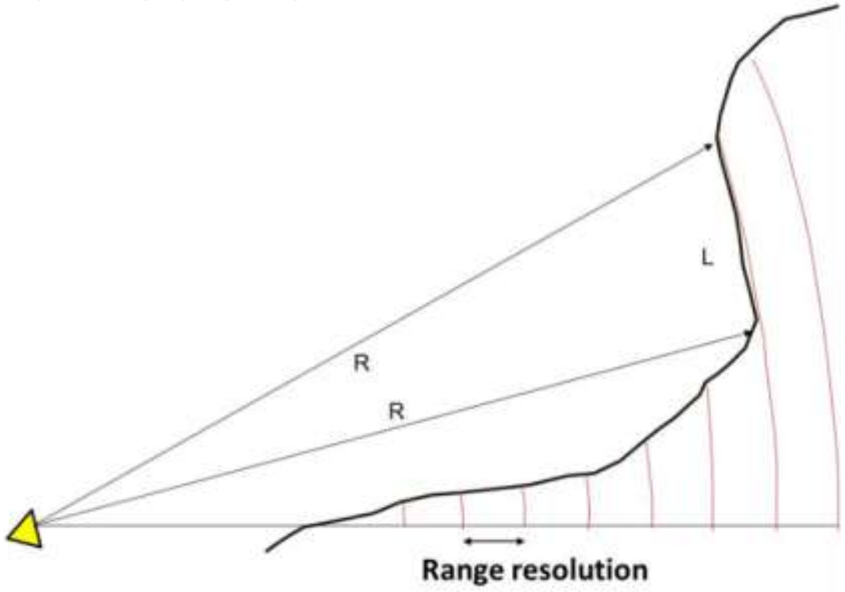
λ = 17,2 mm   λ/4 = 4,3 mm

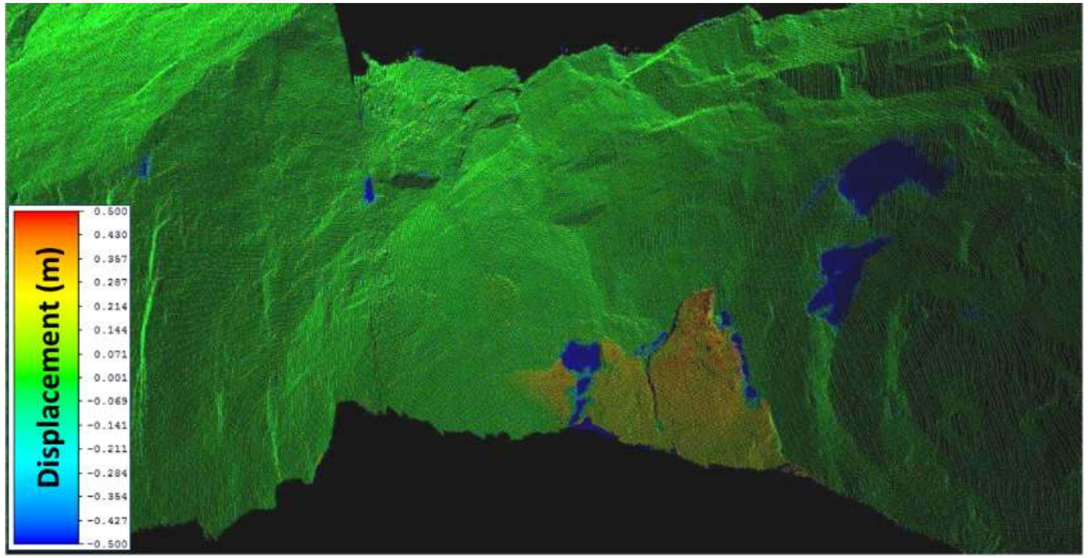
Drawbacks

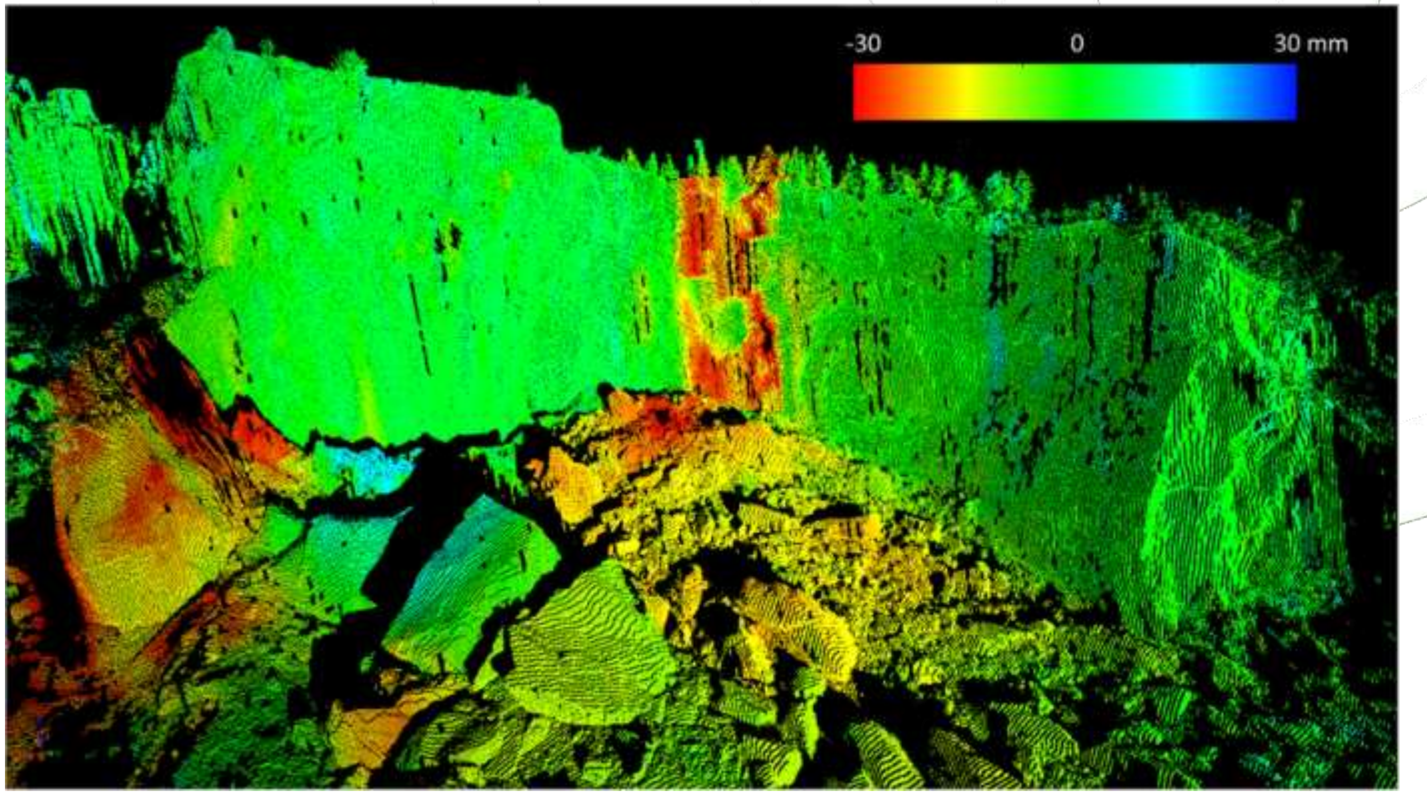
- Range ambiguity (only SAR)

Drawbacks

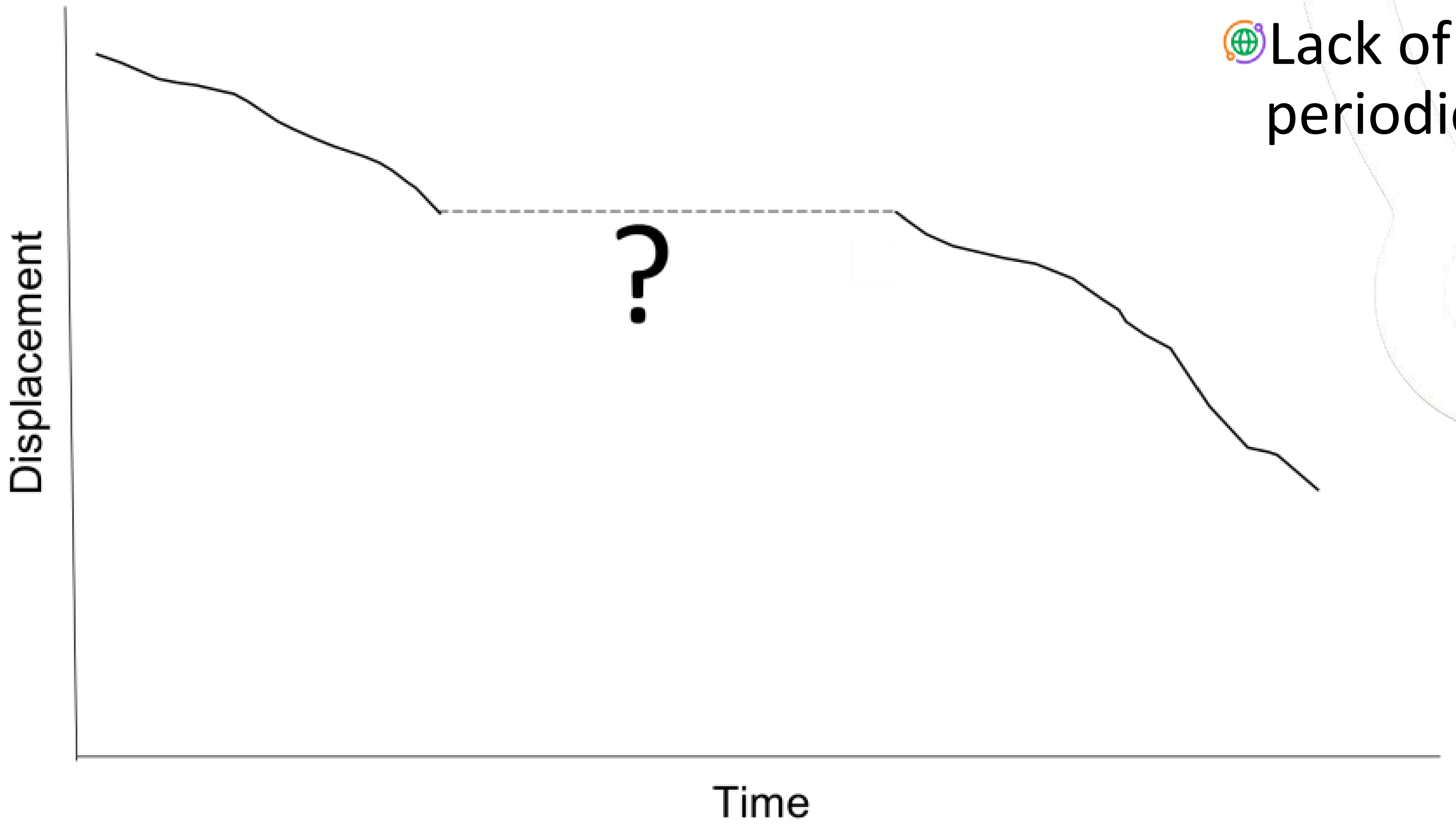
- Range ambiguity (only SAR)





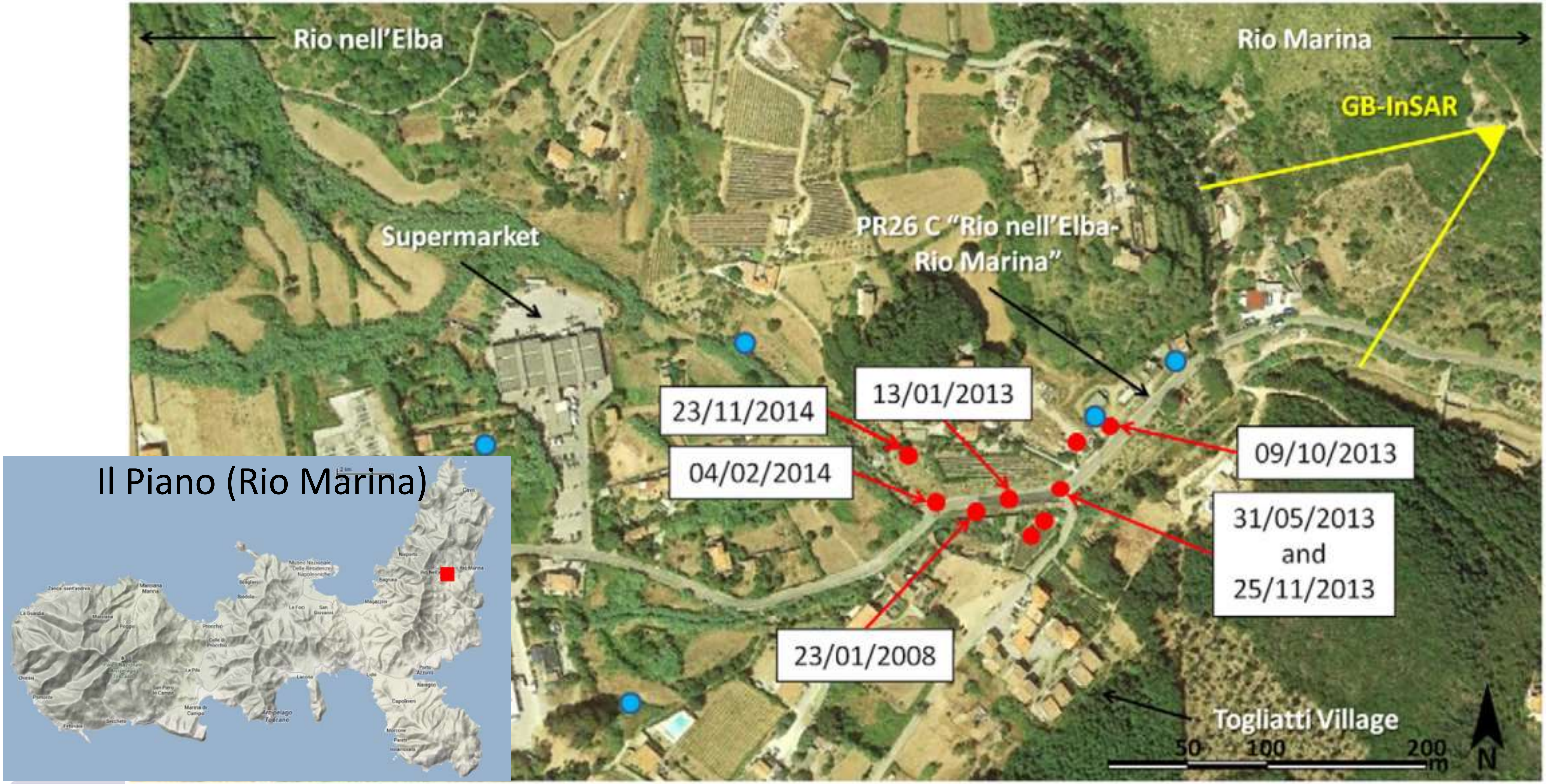


Drawbacks

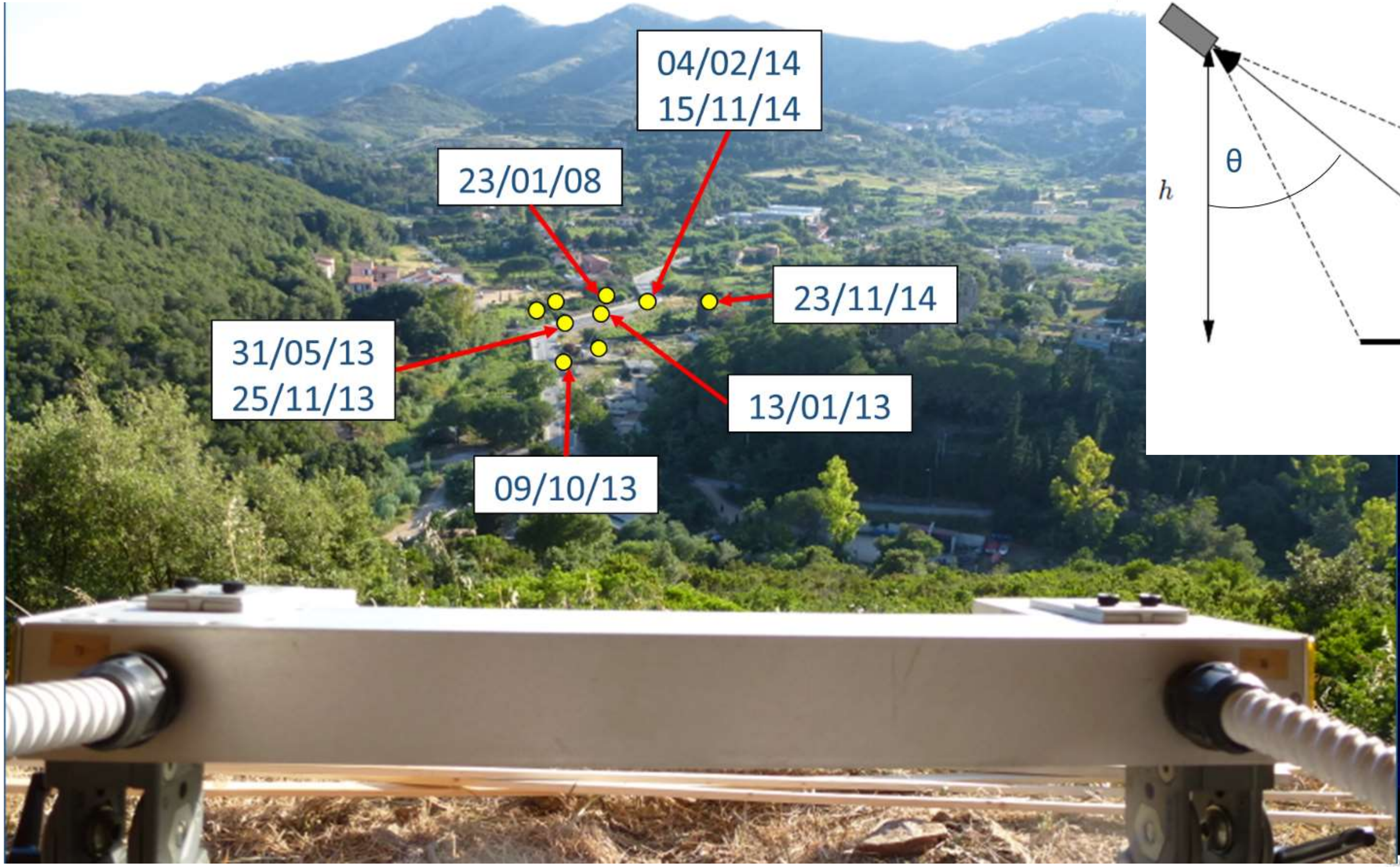


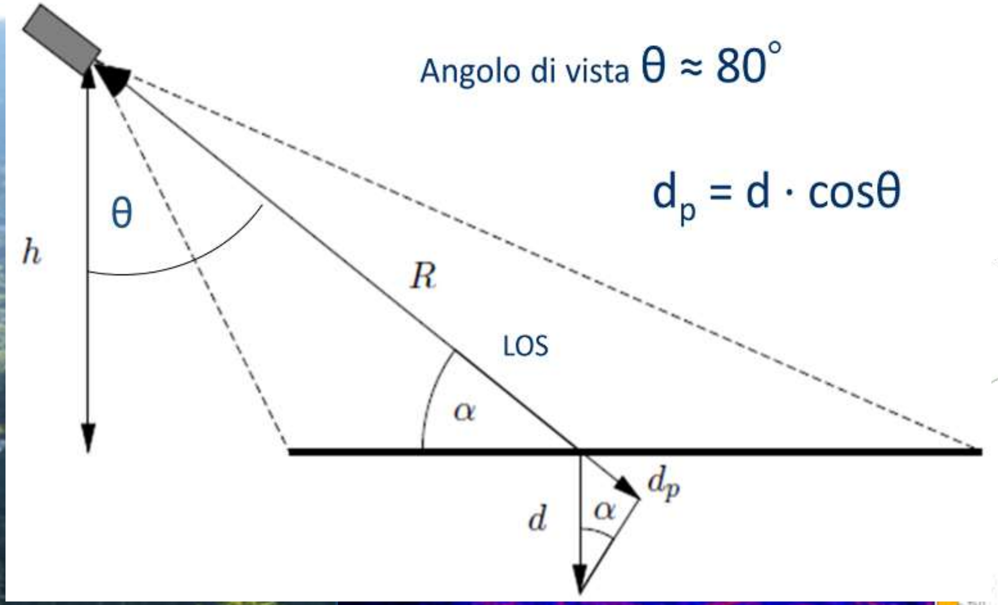
- Lack of information between periodic campaigns

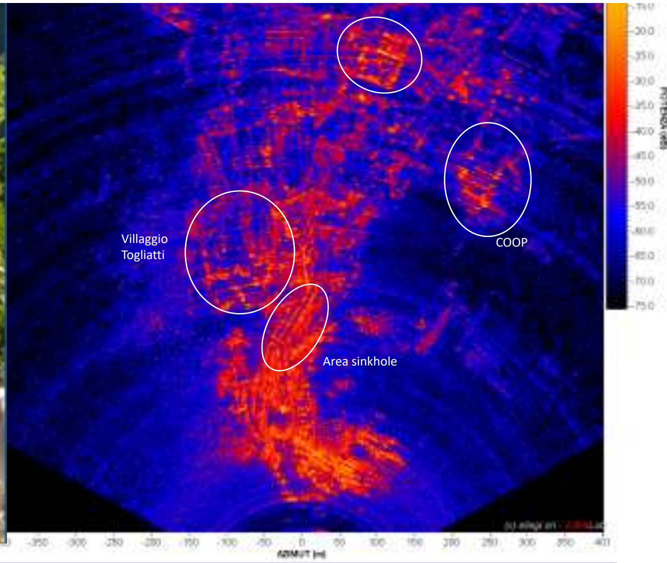
GB-InSAR sinkhole monitoring



Field of view







Subsidence simulation

Spostamento reale (d)	Spostamento proiettato (d_p)
1 mm	0.19 mm
5 mm	0.95 mm
10 mm	1.9 mm
50 mm	9.5 mm

Dimase, 2013

Subsidence simulation

Spostamento reale (d)	Spostamento proiettato (d_p)
1 mm	0.19 mm
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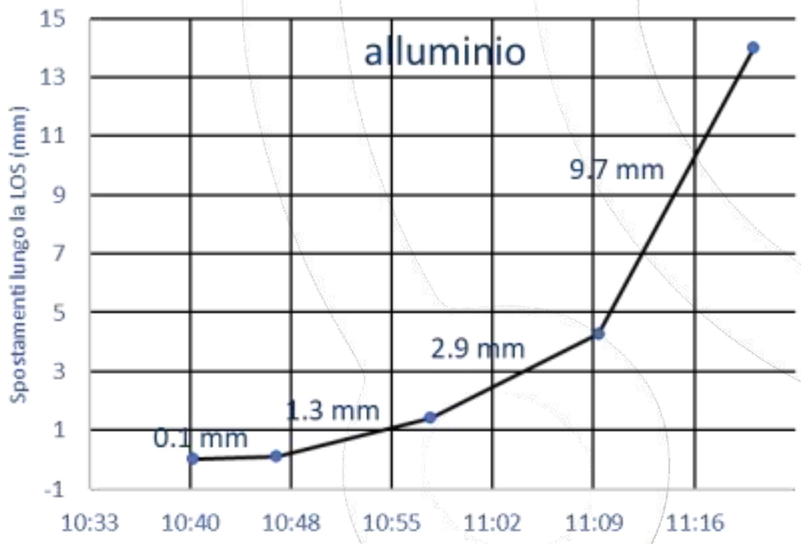
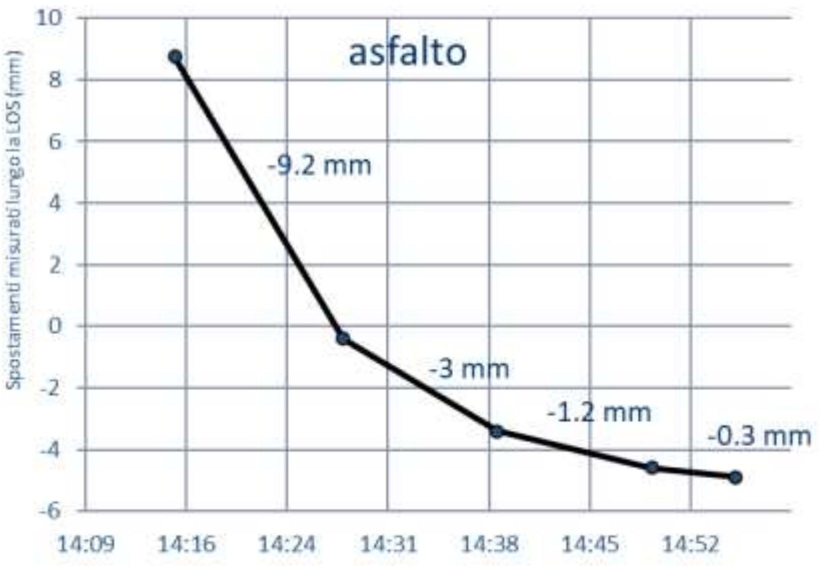
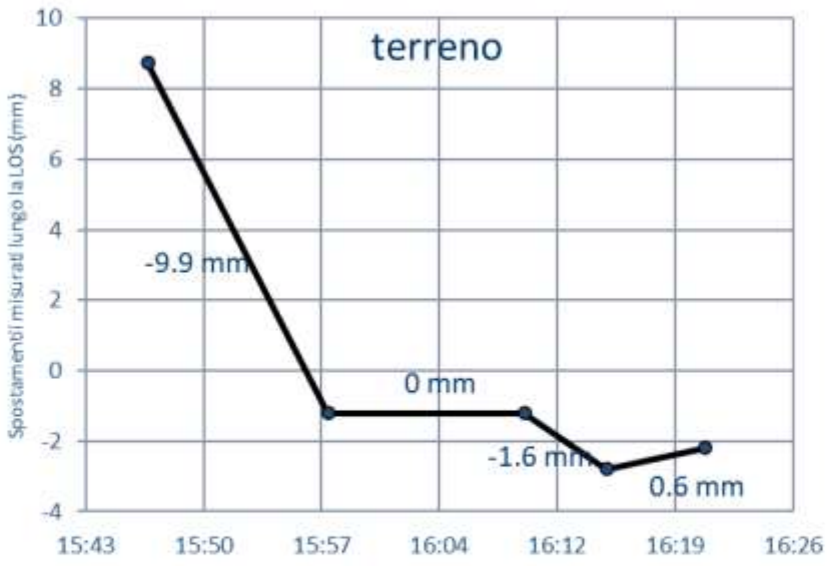
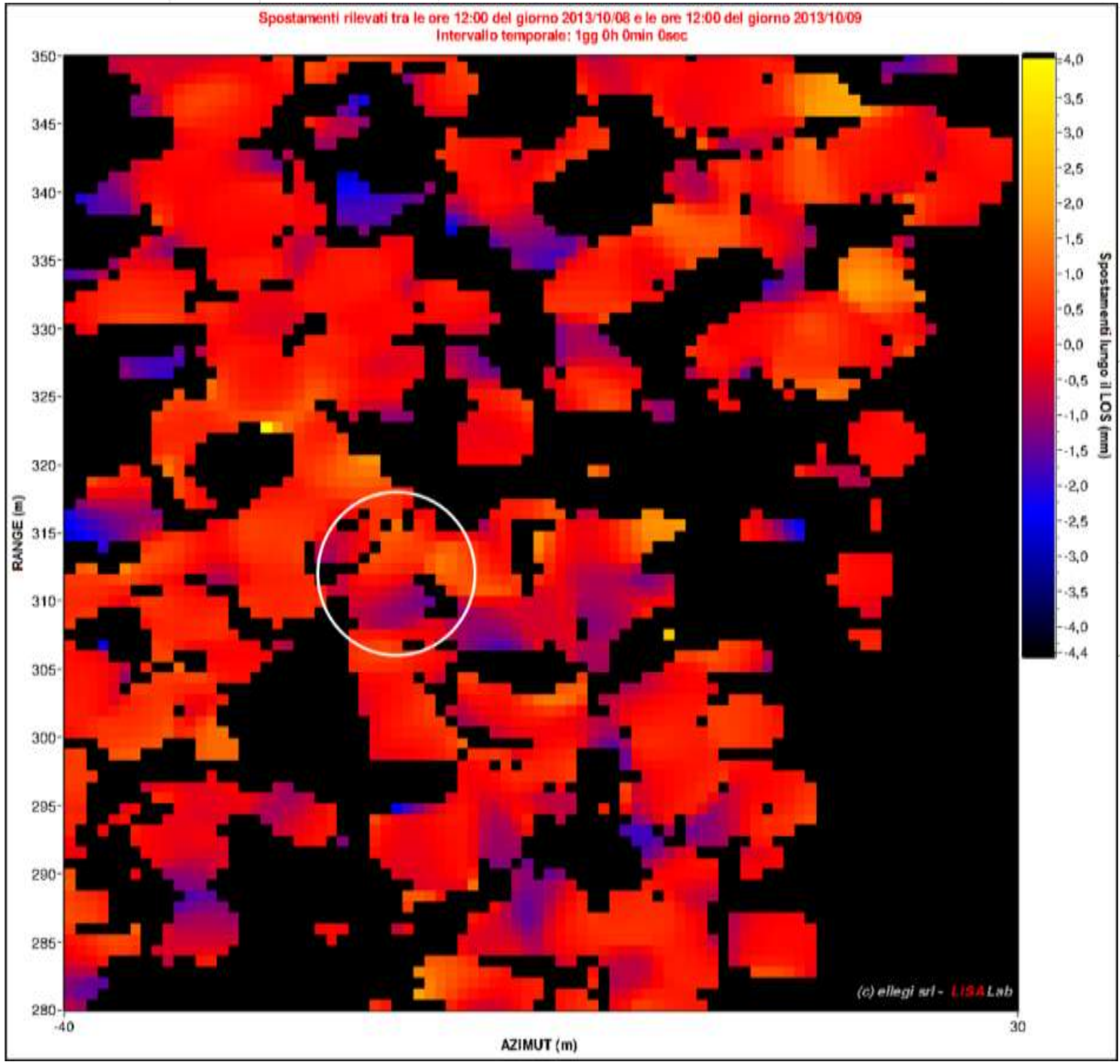


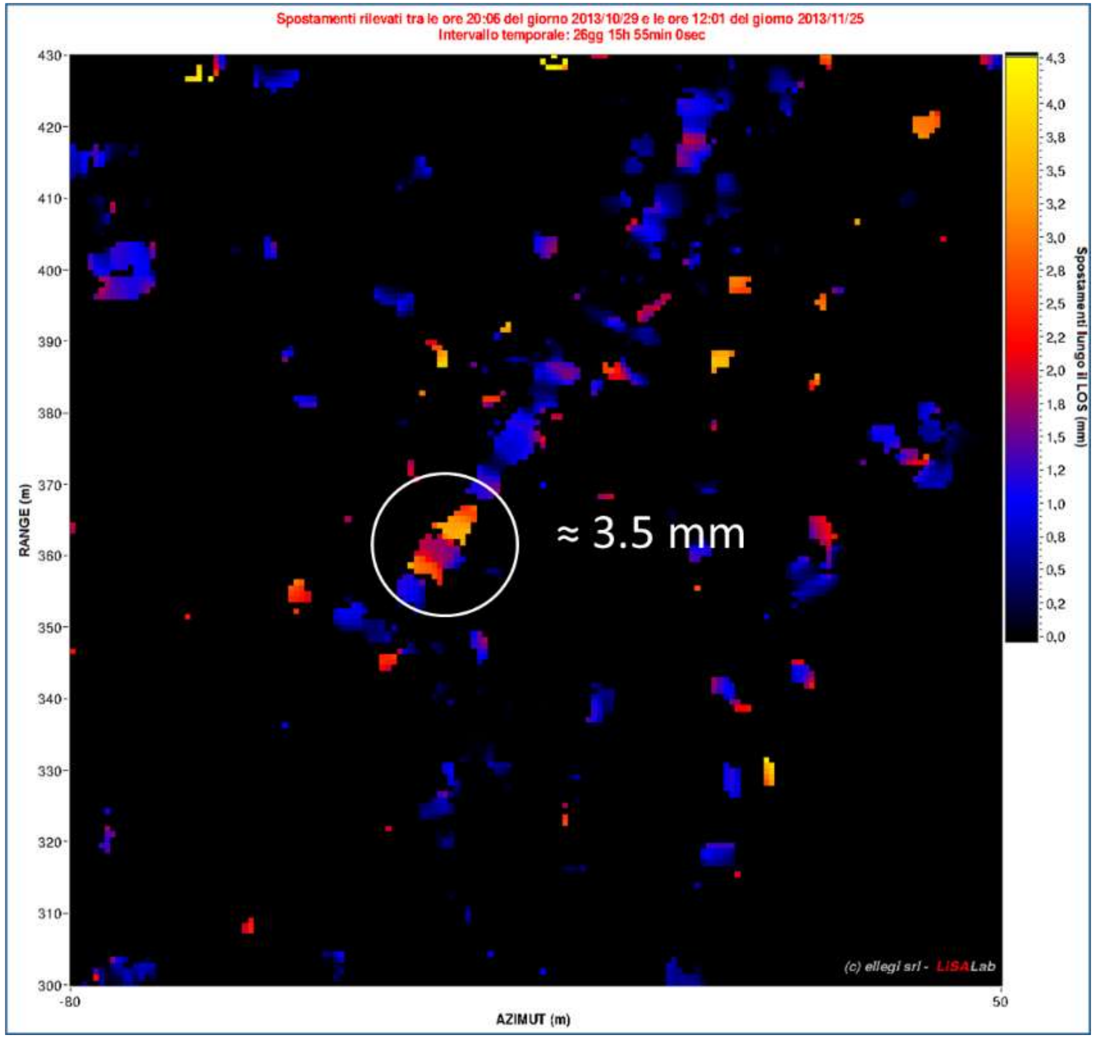




October 9 2013 sinkhole



November 25 2013 subsidence



$$d_p = d \cdot \cos\theta = 2 \text{ cm}$$

January 27 2014 sinkhole

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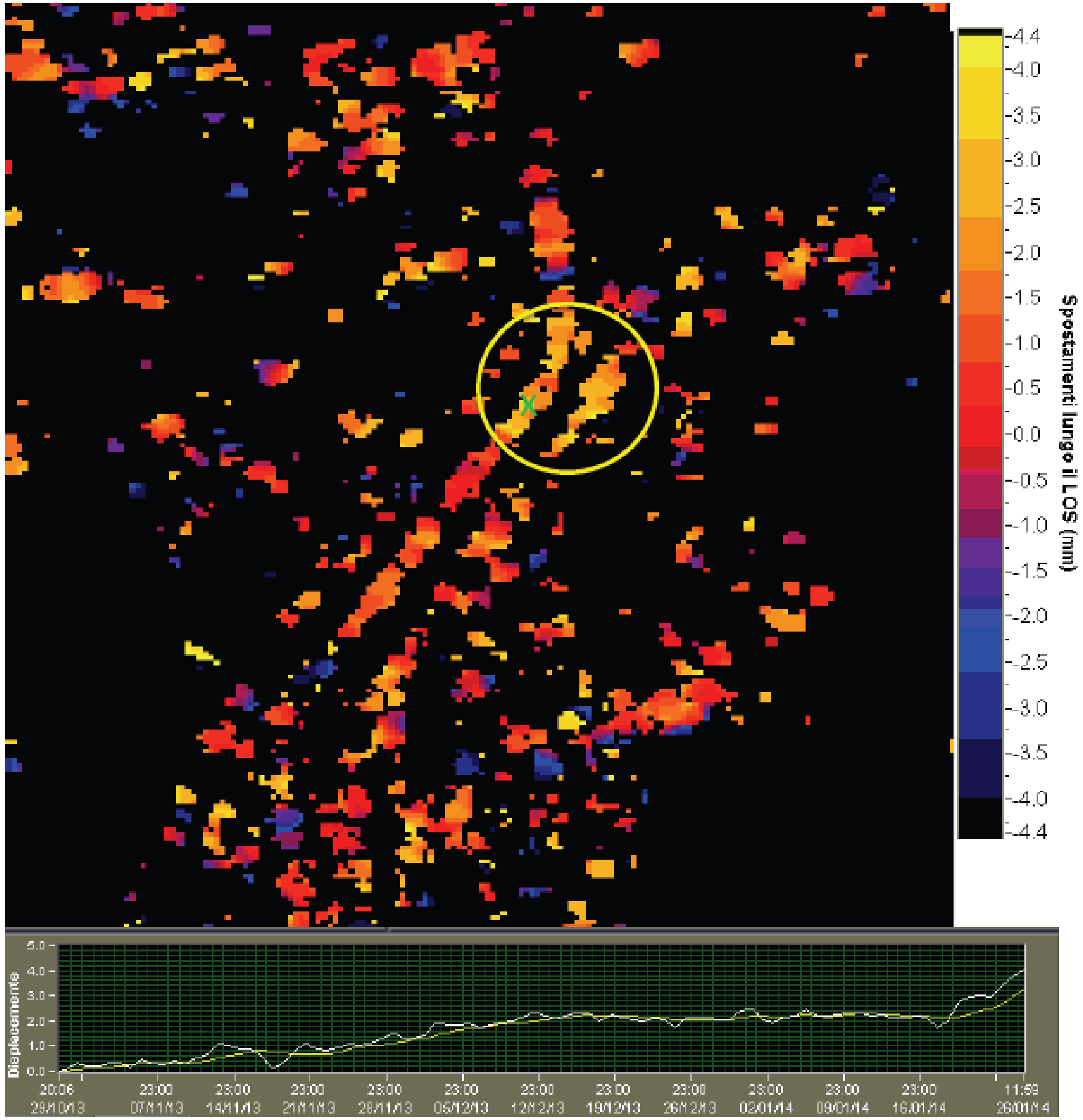


UNIVERSITÀ DEGLI STUDI FIRENZE

DST DIPARTIMENTO DI SCIENZE DELLA TERRA

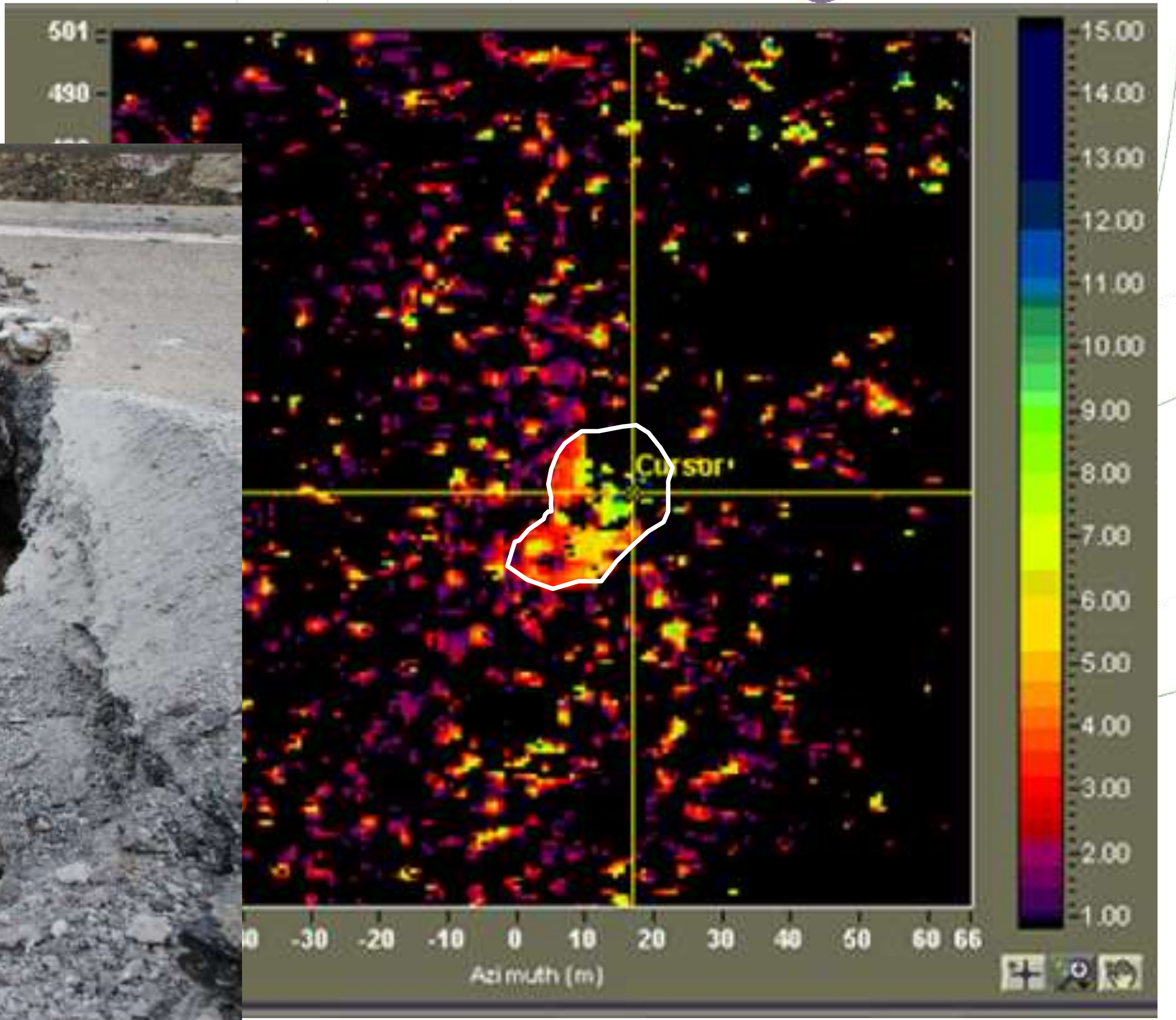
CENTRO DI COMPETENZA DEL DIPARTIMENTO DELLA PROTEZIONE CIVILE DELLA PRESIDENZA DEL CONSIGLIO DEI MINISTRI

NOTA DEL 27/01/2014 RELATIVA AL MONITORAGGIO MEDIANTE INTERFEROMETRIA RADAR DA TERRA IN CORRISPONDENZA DELL'AREA INTERESSATA DAI SINKHOLES FRA I COMUNI DI RIO MARINA E RIO NELL'ELBA

Dall'osservazione degli interferogrammi prodotti dal GBInSAR nel periodo compreso fra il 29/10/2013 e il 26/01/2014 si individua un'area che presenta una anomalia negli spostamenti in allontanamento dal sensore, compatibile con un movimento di subsidenza localizzata del terreno, con una tendenza all'incremento nell'ultima settimana (Fig. 1).

I dati interferometrici risultano, nel periodo considerato, affetti da un elevato rumore; tuttavia, la dimensione dell'area interessata e la sua localizzazione, in corrispondenza dell'asse stradale e prossima agli eventi che si sono manifestati negli anni passati (Fig. 2, 3), suggeriscono l'opportunità di effettuare un sopralluogo di verifica.

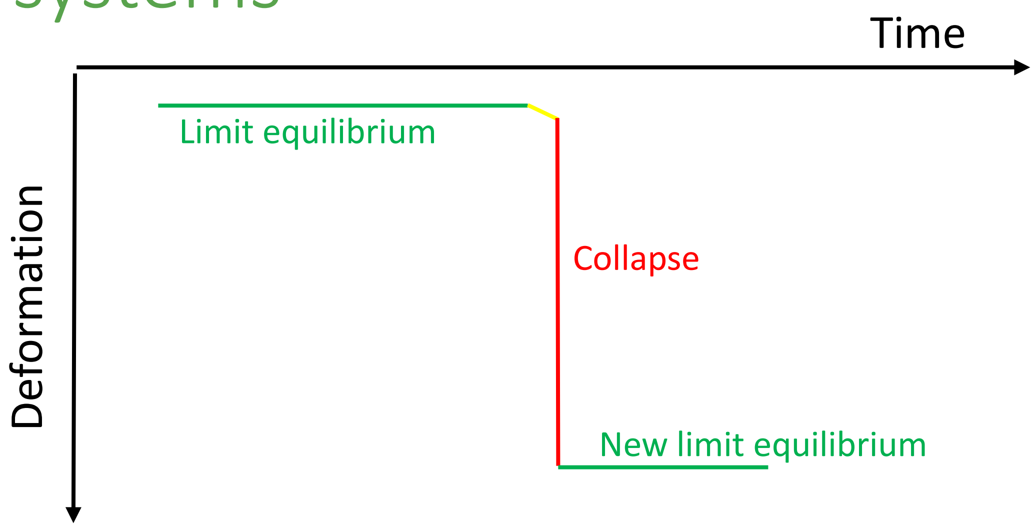
February 2 2014



(Intrieri et al., 2015)

Alarm systems

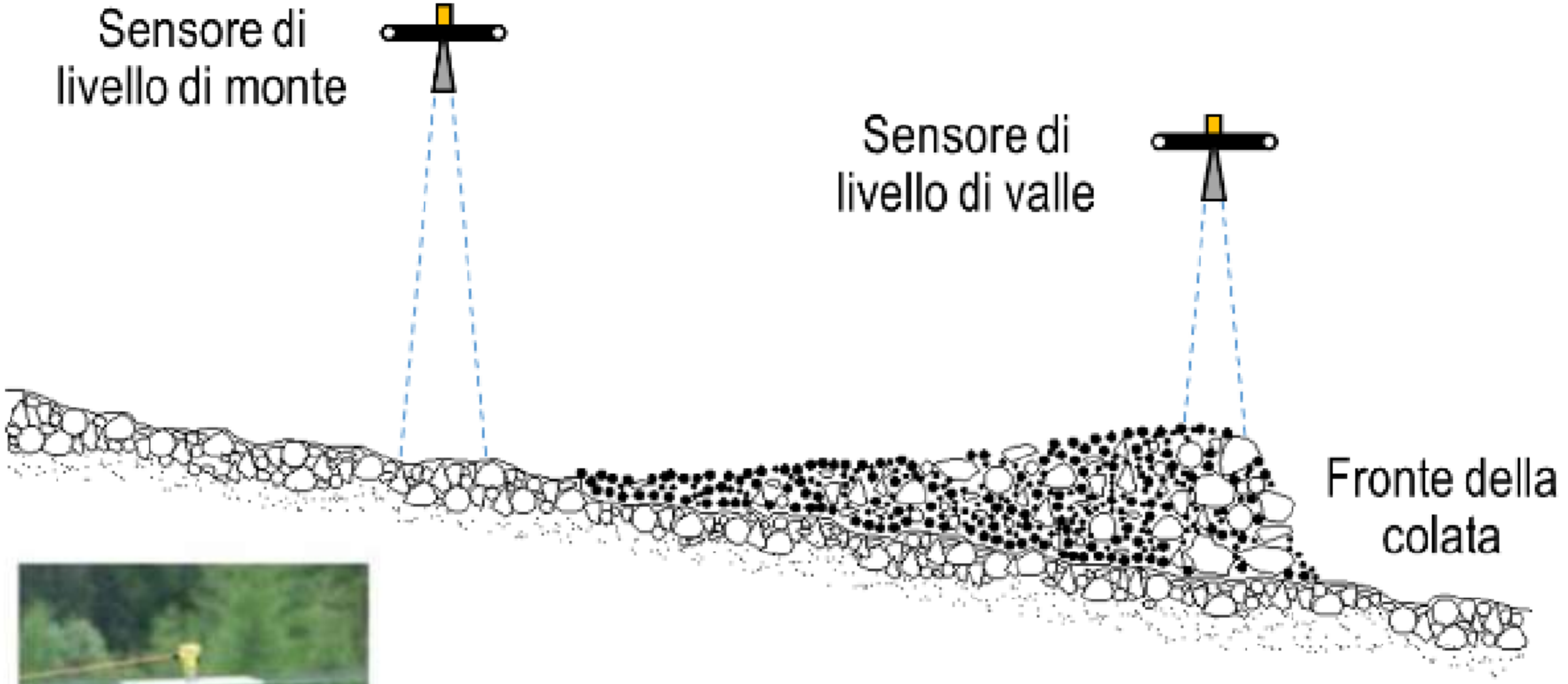
Alarm systems

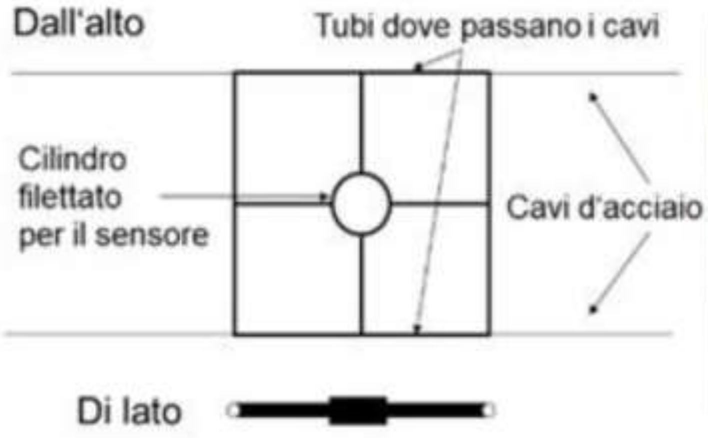


Velocity class	Description	Velocity (mm/s)	Typical velocity	Response[a]
7	Extremely rapid	5×10^{3}	5 m/s	Nil
6	Very rapid	5×10^{1}	3 m/min	Nil
5	Rapid	5×10^{-1}	1.8 m/h	Evacuation
4	Moderate	5×10^{-3}	13 m/month	Evacuation
3	Slow	5×10^{-5}	1.6 m/year	Maintenance
2	Very slow	5×10^{-7}	16 mm/year	Maintenance
1	Extremely Slow			Nil

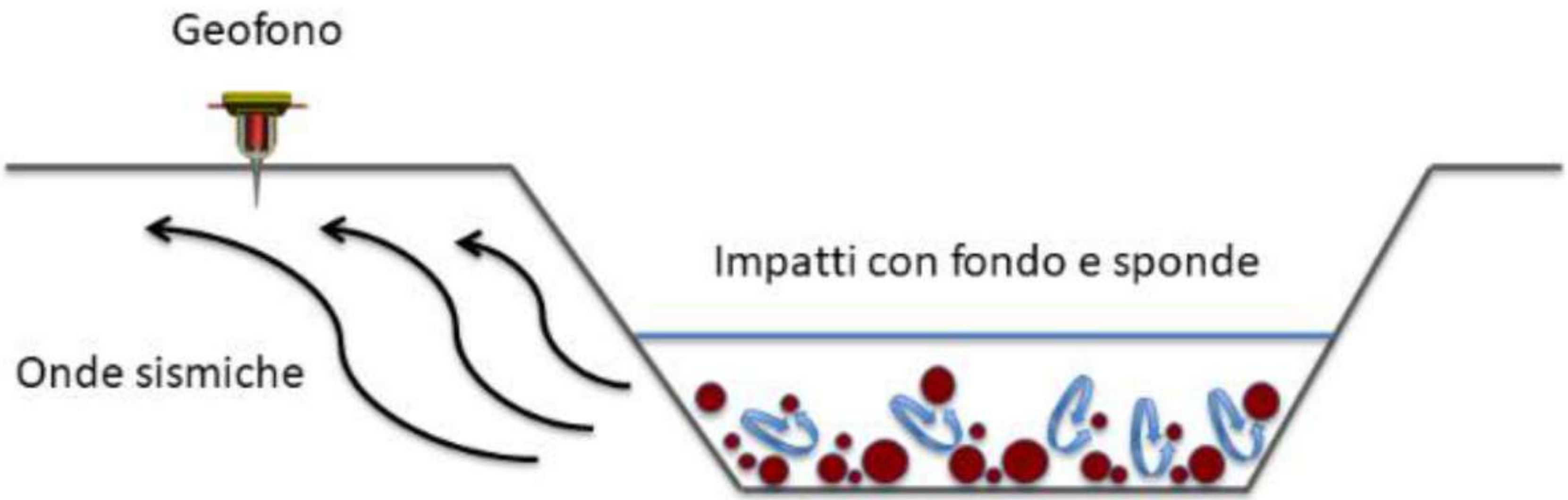
(Hungr et al., 2014)

Level measurement for debris flows





Geophones



Differential Monitoring of Stability

ITINERIS

Sensore inclinometrico triassiale	
Tipologia sensore	MEMS
Range	± 90°
Risoluzione	0.01°
Ripetitibilità	± 0.02°
Linearità	0.05% FS

Sensore piezometrico	
Tipologia sensore	Resistivo
Range	30 psi
Sensibilità	3.33 mV/psi
Risoluzione	0.02 psi
Ripetitibilità	0.05% FS
Linearità	± 0.05% FS

Sensore accelerometrico	
Tipologia sensore	MEMS 3 assi
Range	± 2 g
Sensibilità	0.001 mg/LSB
Livello di rumore	25 μg/√Hz

Sensore di temperatura	
Tipologia sensore	Termoresistenza al platino
Classe	A (DIN EN 60751/95)
Range	-50°C / +130°C
Resistenza	1 kΩ @0°C
Risoluzione	0.1°C
Tolleranza	± 0.15°C @0°C

DMS

Strumenti per il monitoraggio geotecnico di stabilità di versanti, scavi e opere dell'ingegneria geotecnica

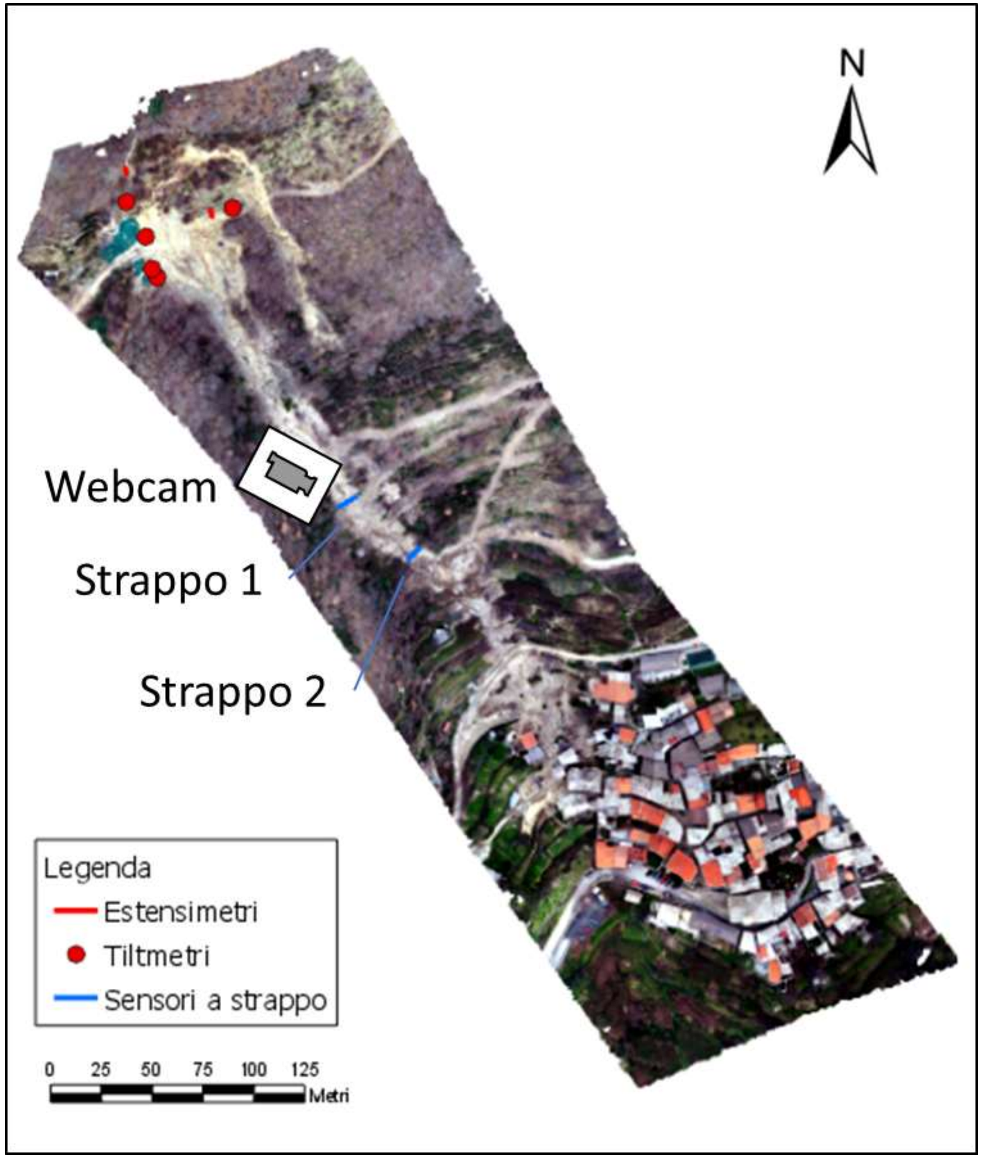
SCHEDA TECNICA

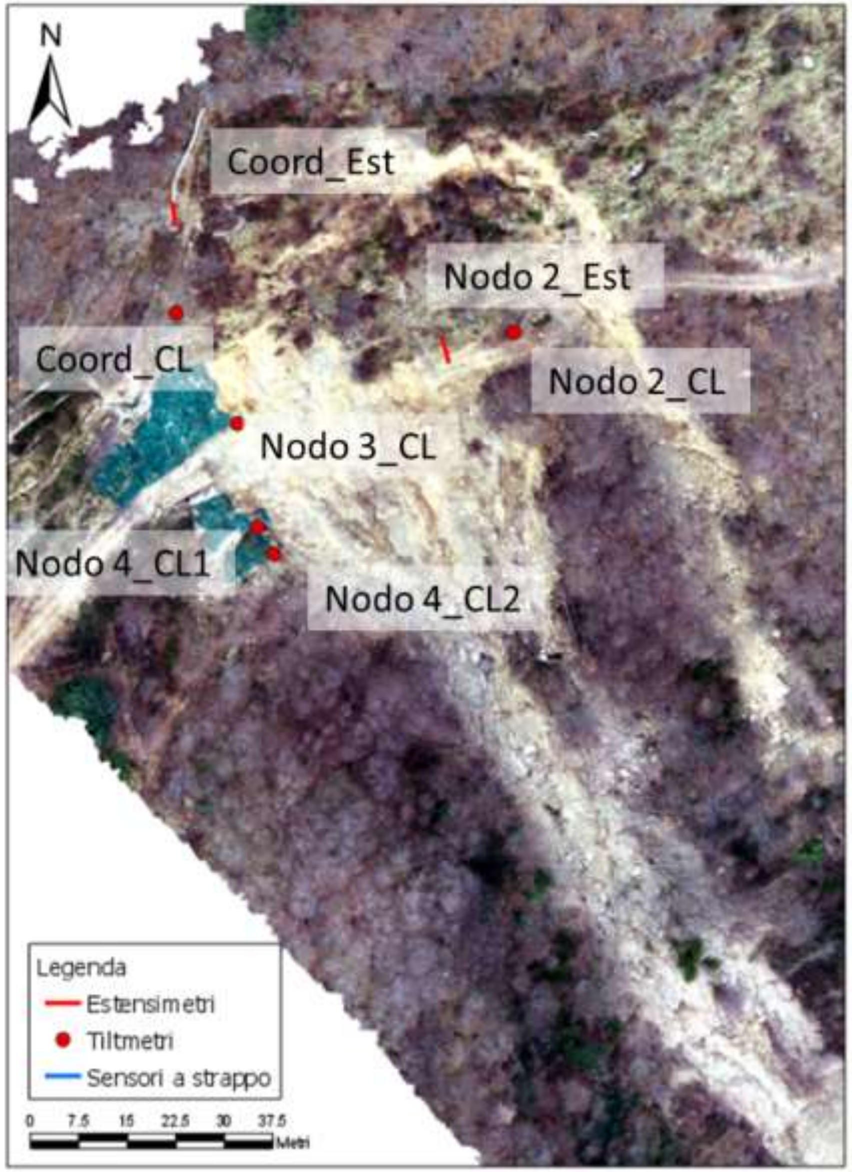
DMS-i SCOUT

CSG Geotechnical Monitoring

Wire sensors

Cenova landslide



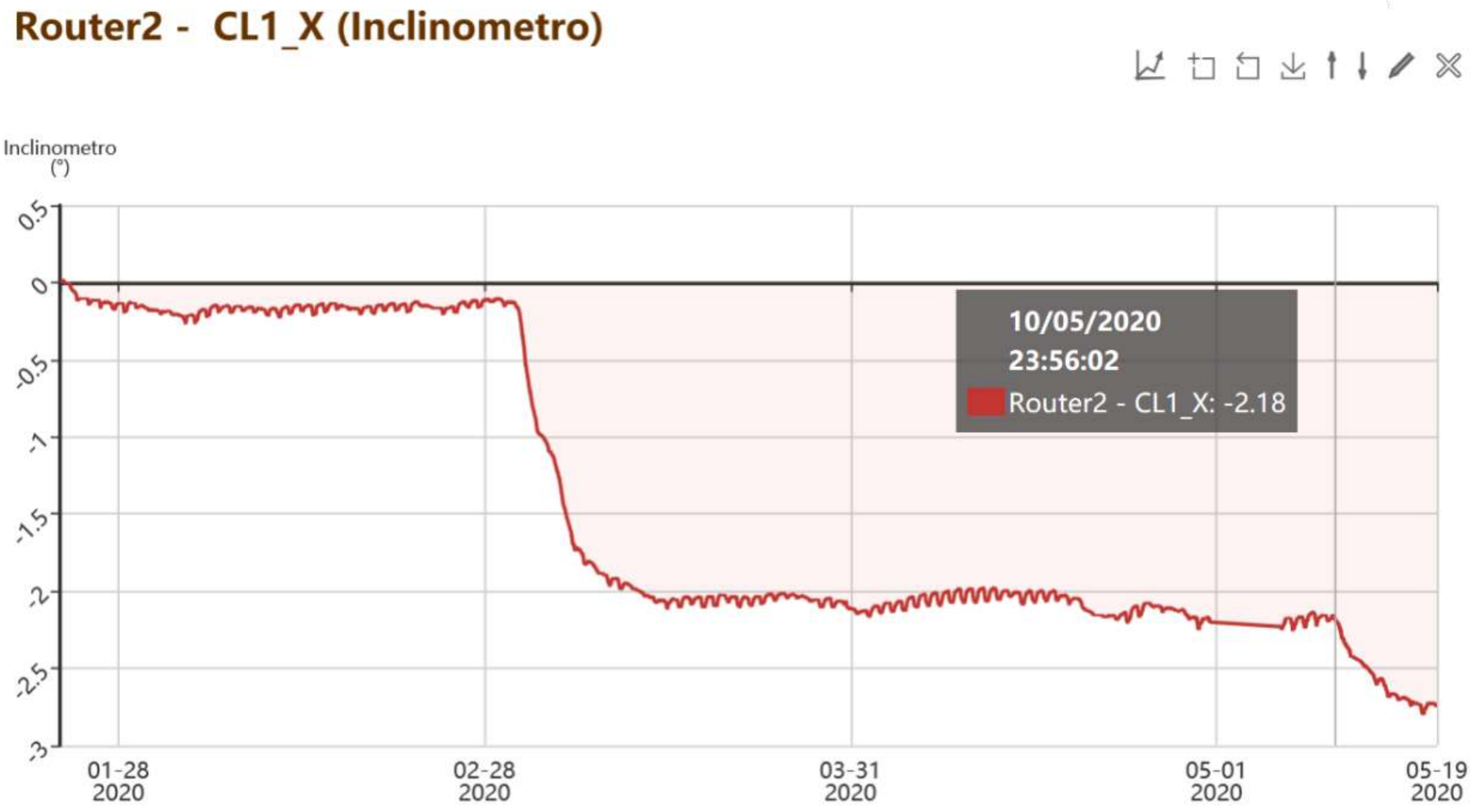


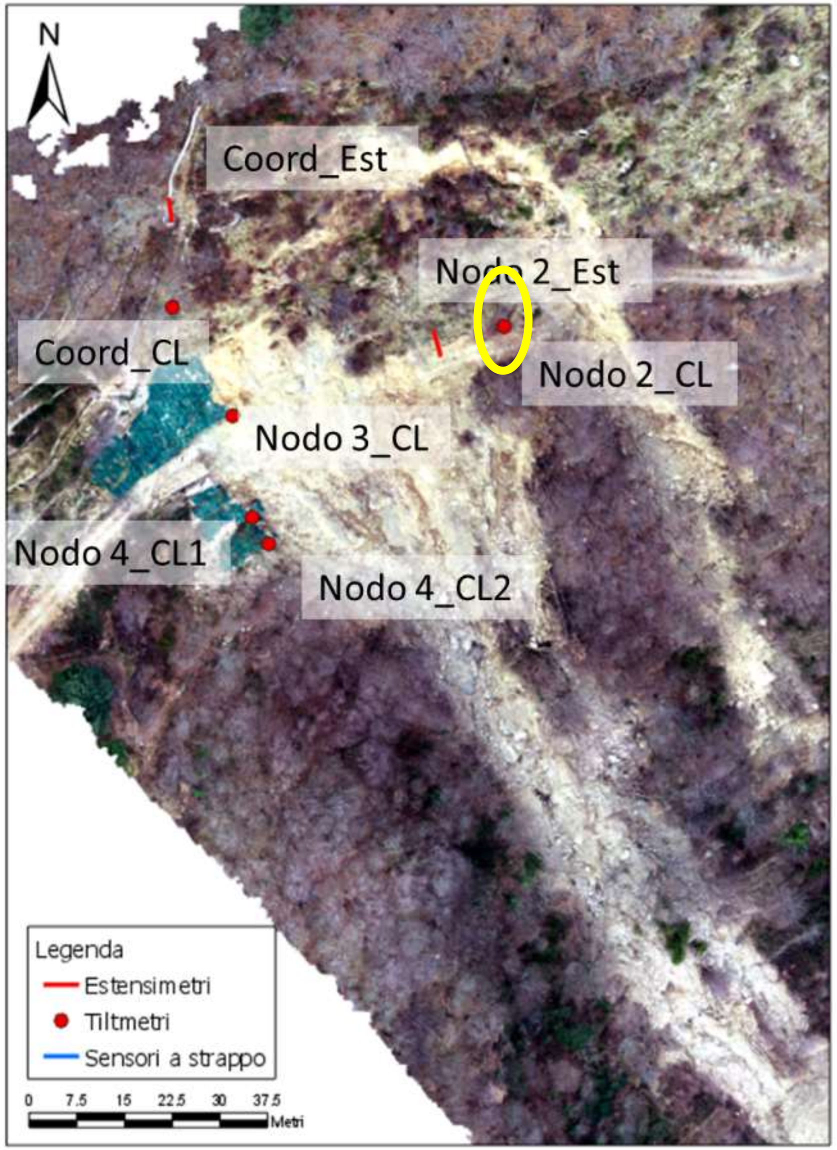
Cenova landslide

Cenova landslide

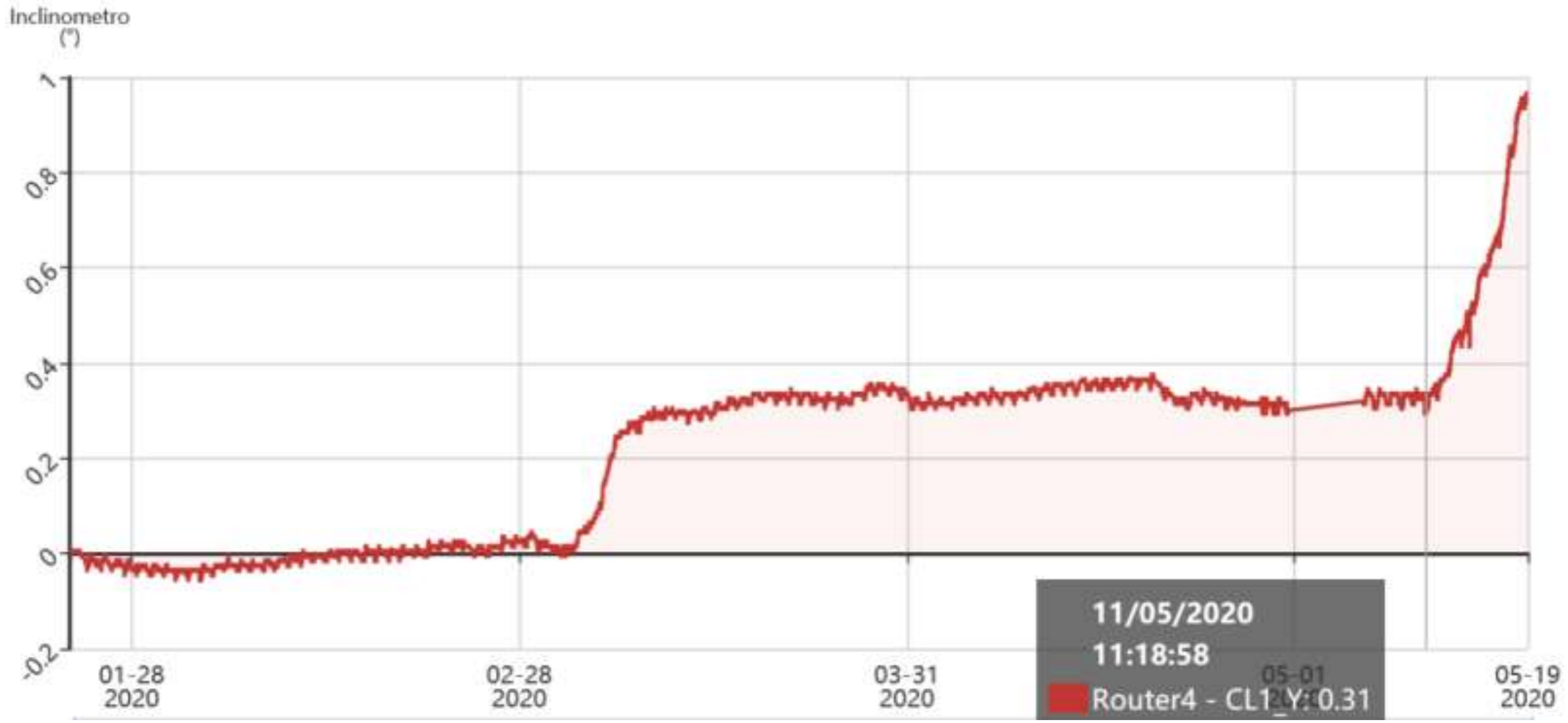
Cenova landslide

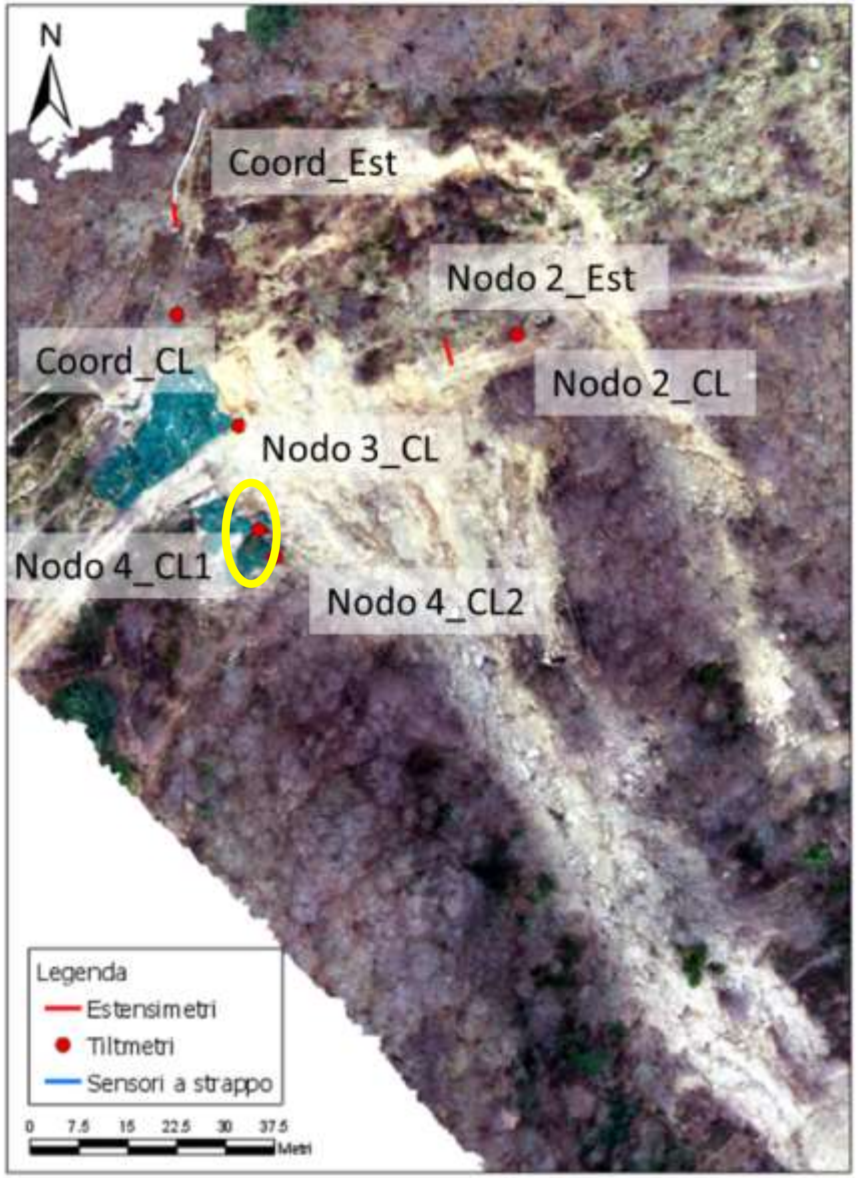
Tiltmeter – node 2





Tiltmeter – node 4





Wire sensor breakage

Strappo Nodo Valle Posta in arrivo ×

info@winetsrl.com lun 11 mag, 11:10 (8 giorni fa)

a me, massimiliano.nocentini, luca.lombardi, etavelli

Scattato il sensore a strappo valle Rete:Monitoraggio Cenova Imperia Nodo:CoordStrappo Sensore:Strappo Valore: 170.00 Soglia:> 0 Data:2020-05-11 11:05:27 Rete:Monitoraggio Cenova Imperia Nodo:CoordStrappo Sensore:Strappo Valore: 170.00 Soglia:< 221 Data:2020-05-11 11:05:27

Time Lapse webcam

Time Lapse webcam

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Time Lapse webcam

Time Lapse webcam

Time Lapse webcam

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Time Lapse webcam

Activation sequence

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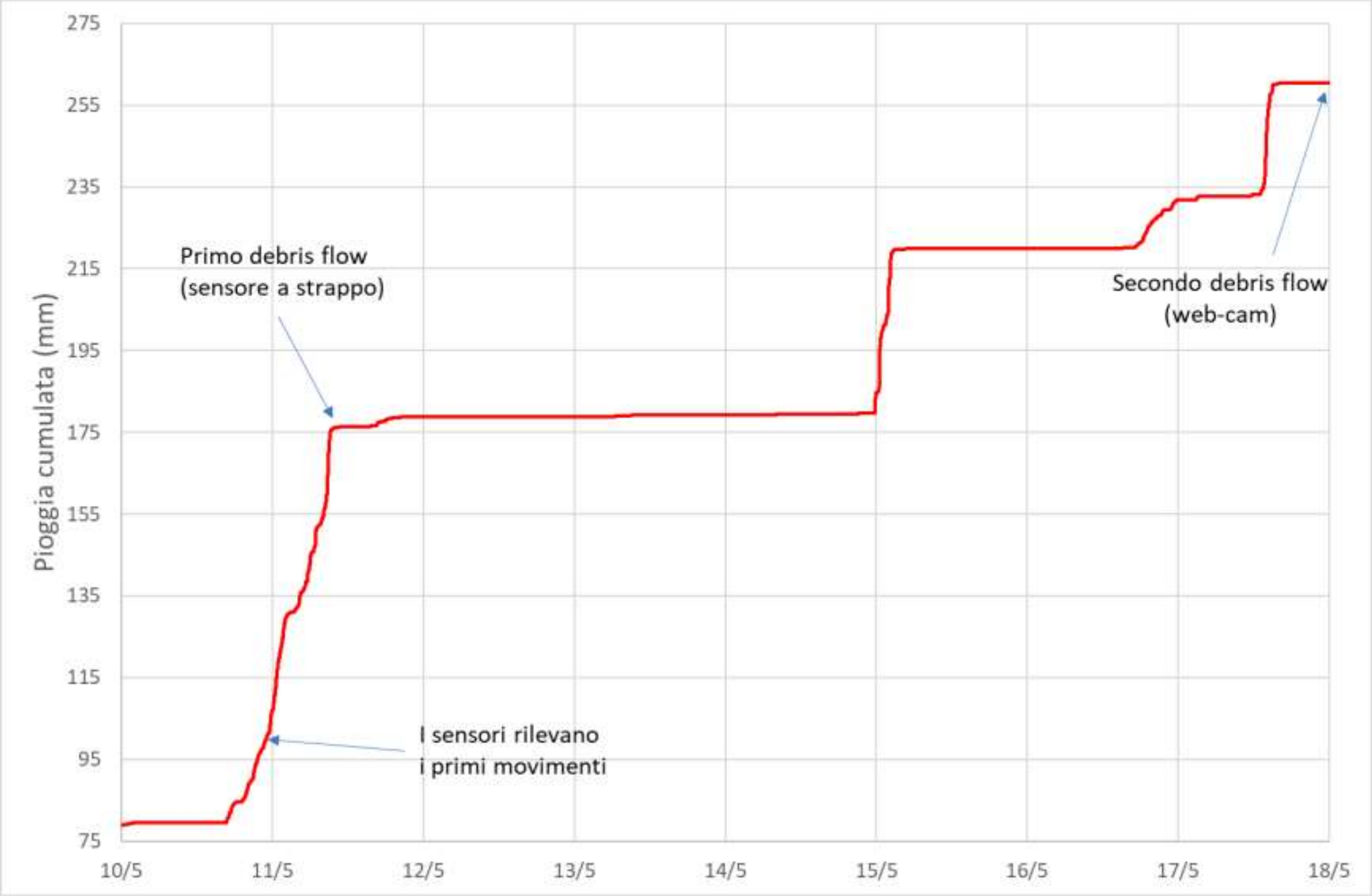
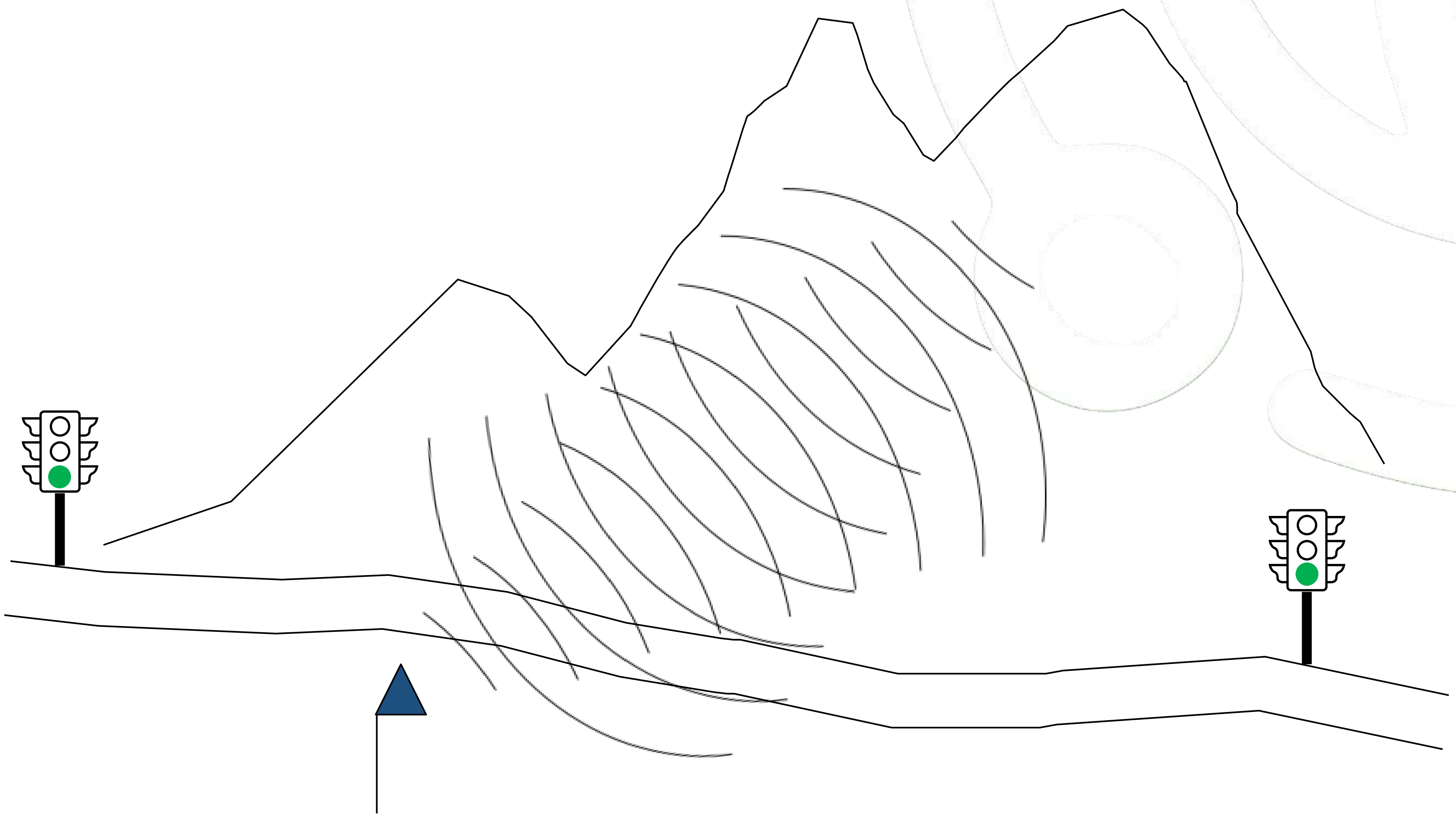
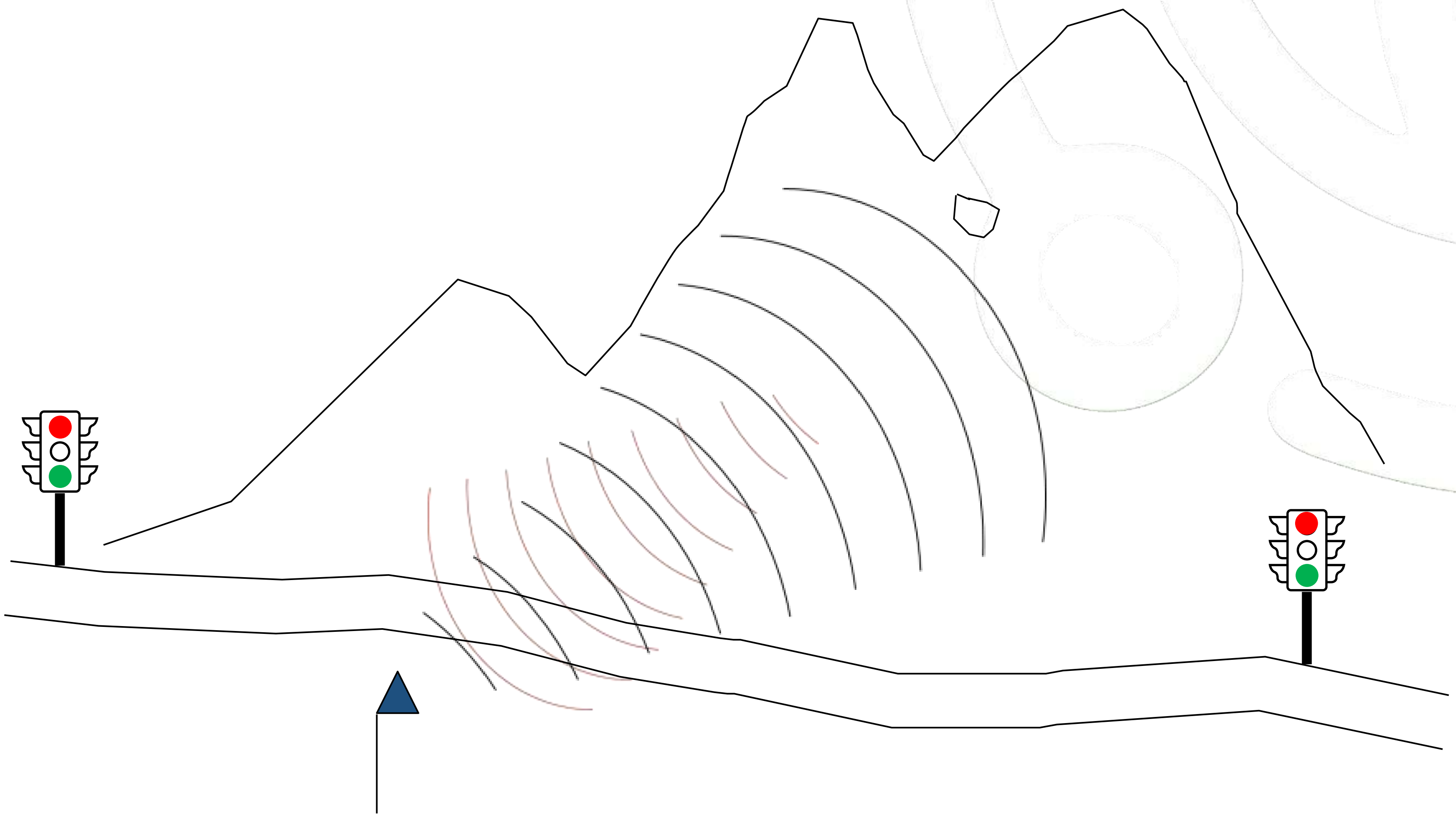


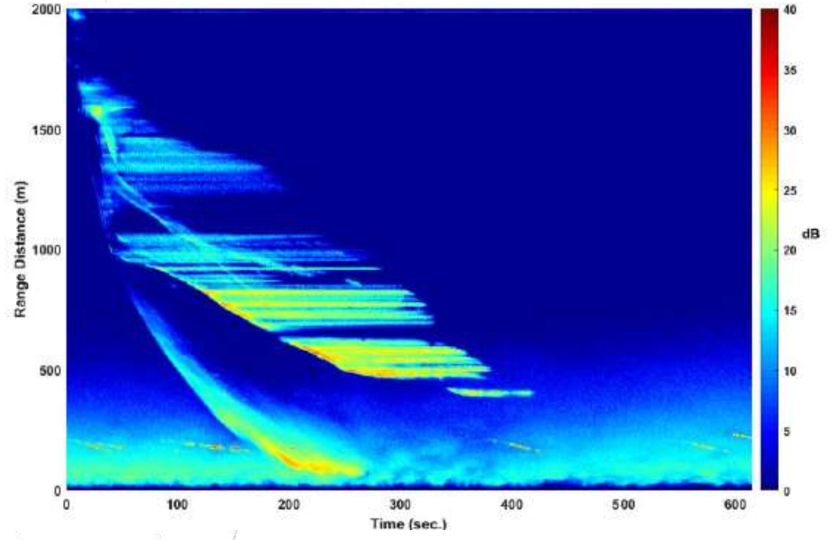
Doppler effect

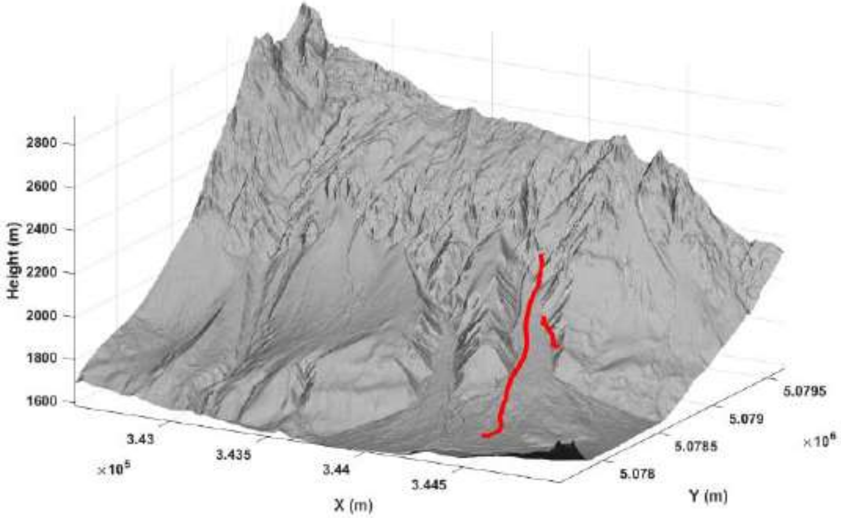


Doppler effect



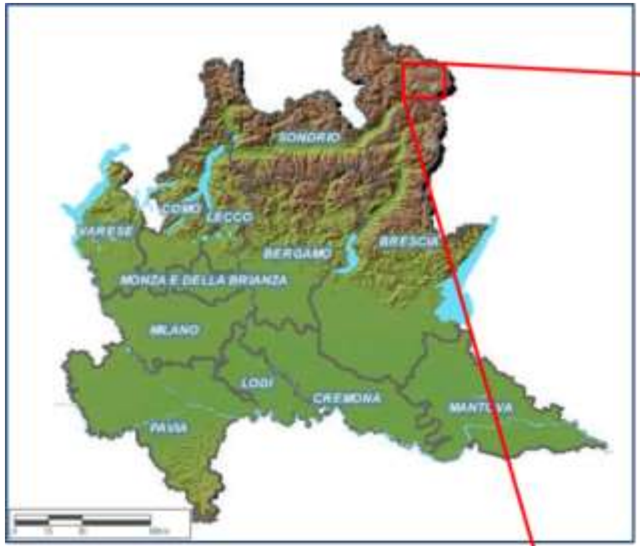
Doppler radar

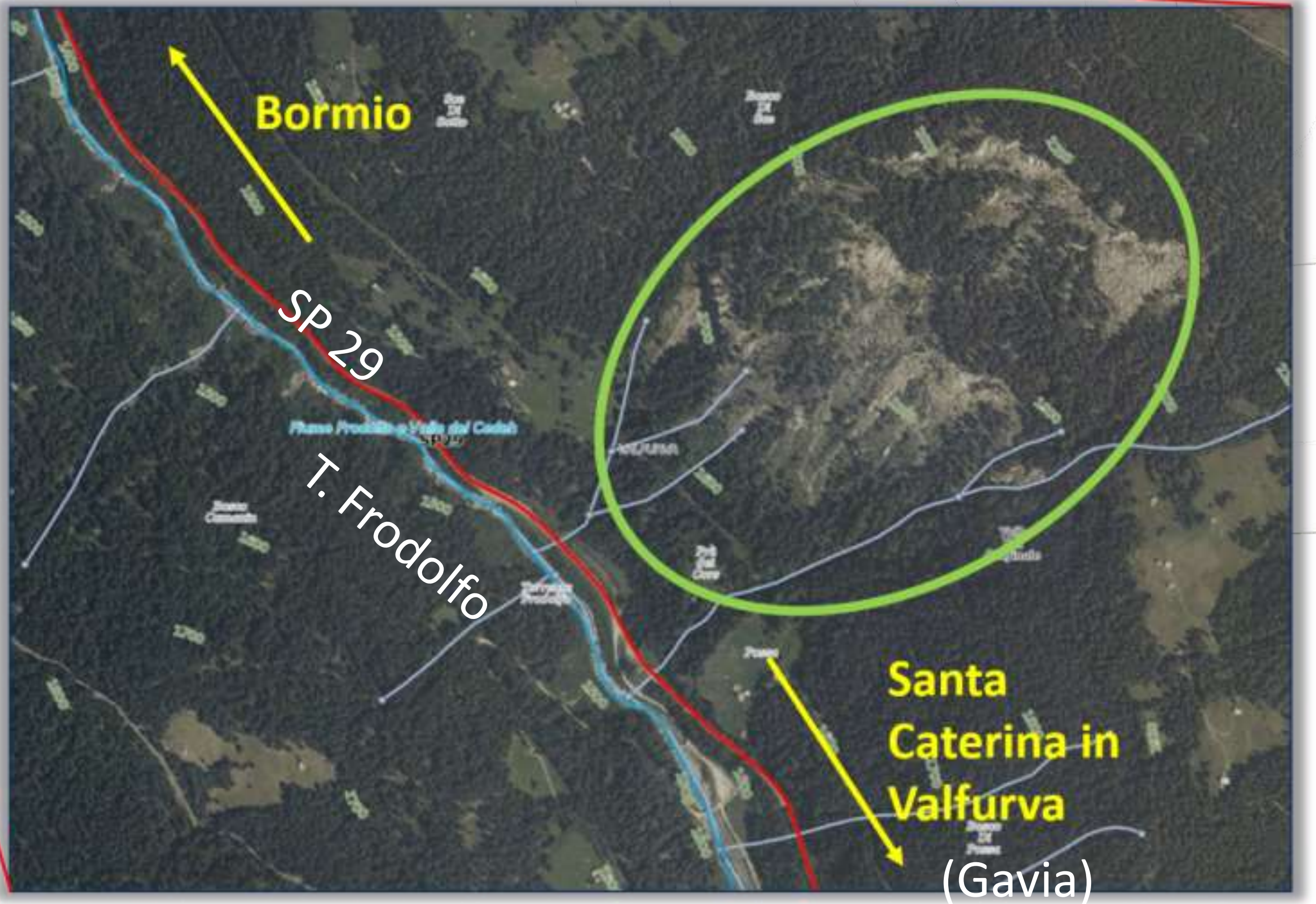




Viviani et al., 2020

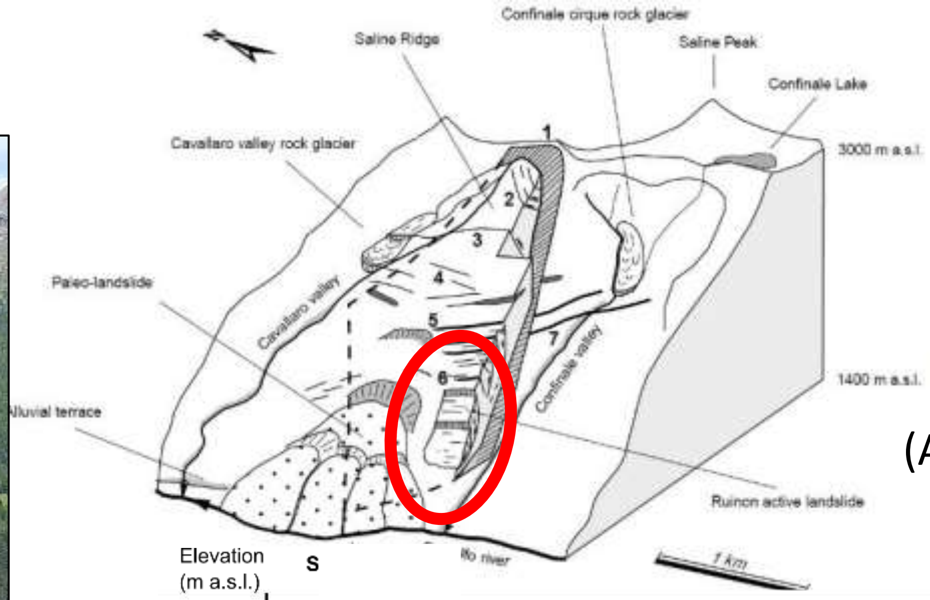
Ruinon landslide



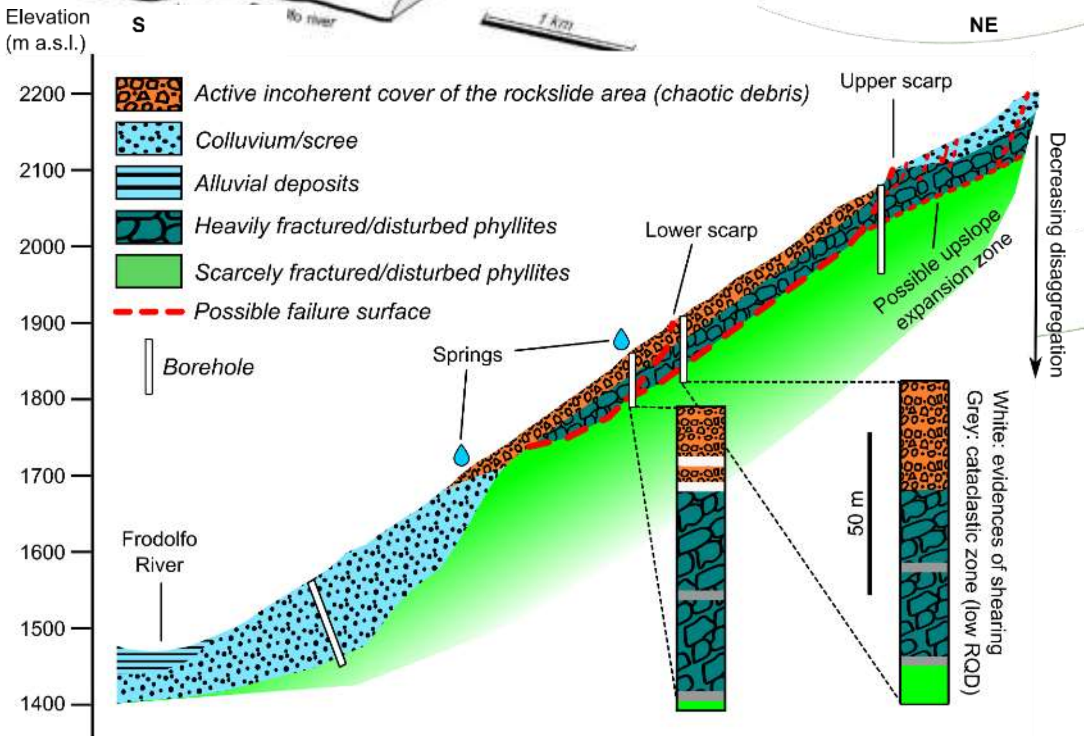


Volume: 20-30 Mm^3

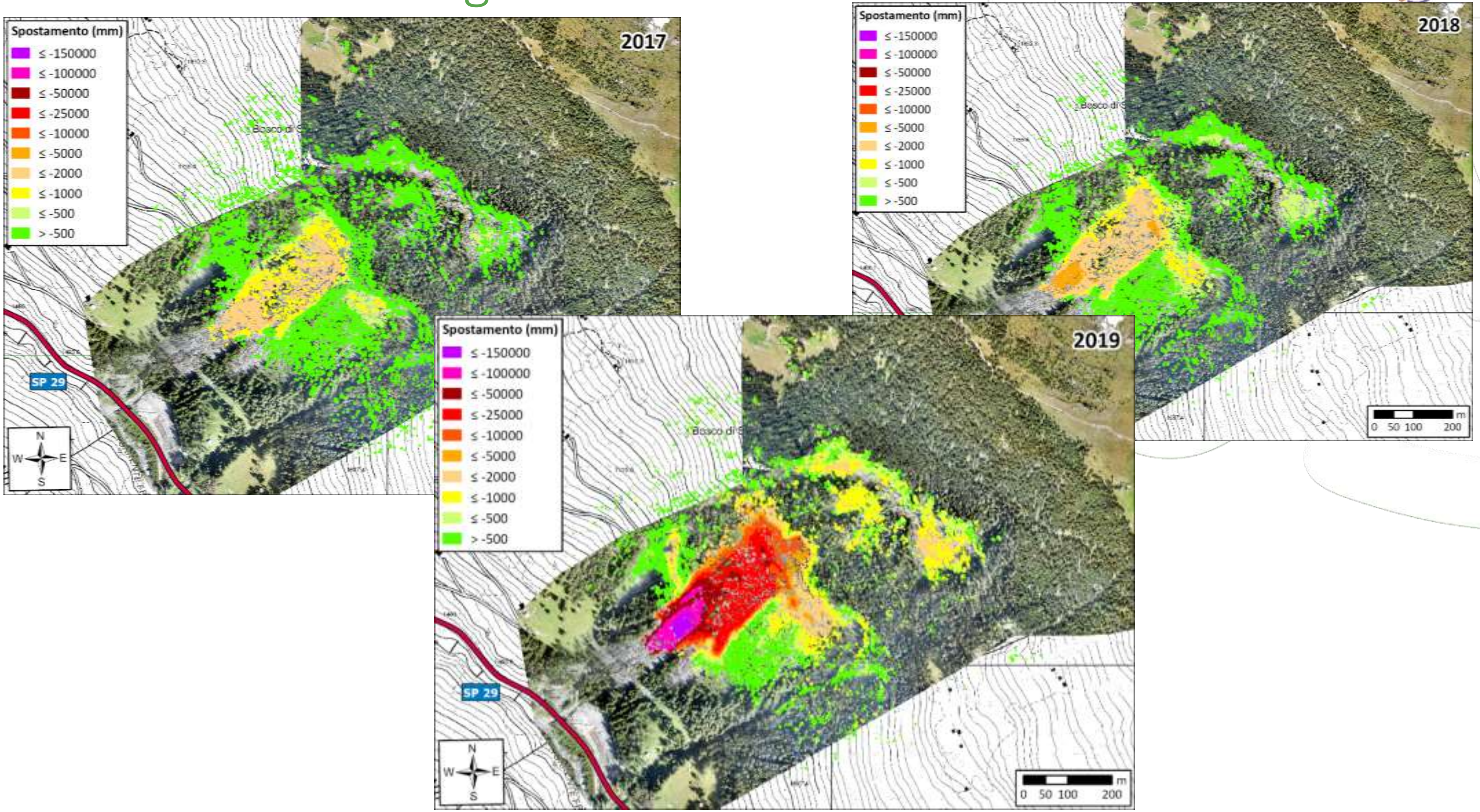
Ruinon landslide



(Agliardi et al., 2001)



GB-InSAR monitoring



Most critical sector

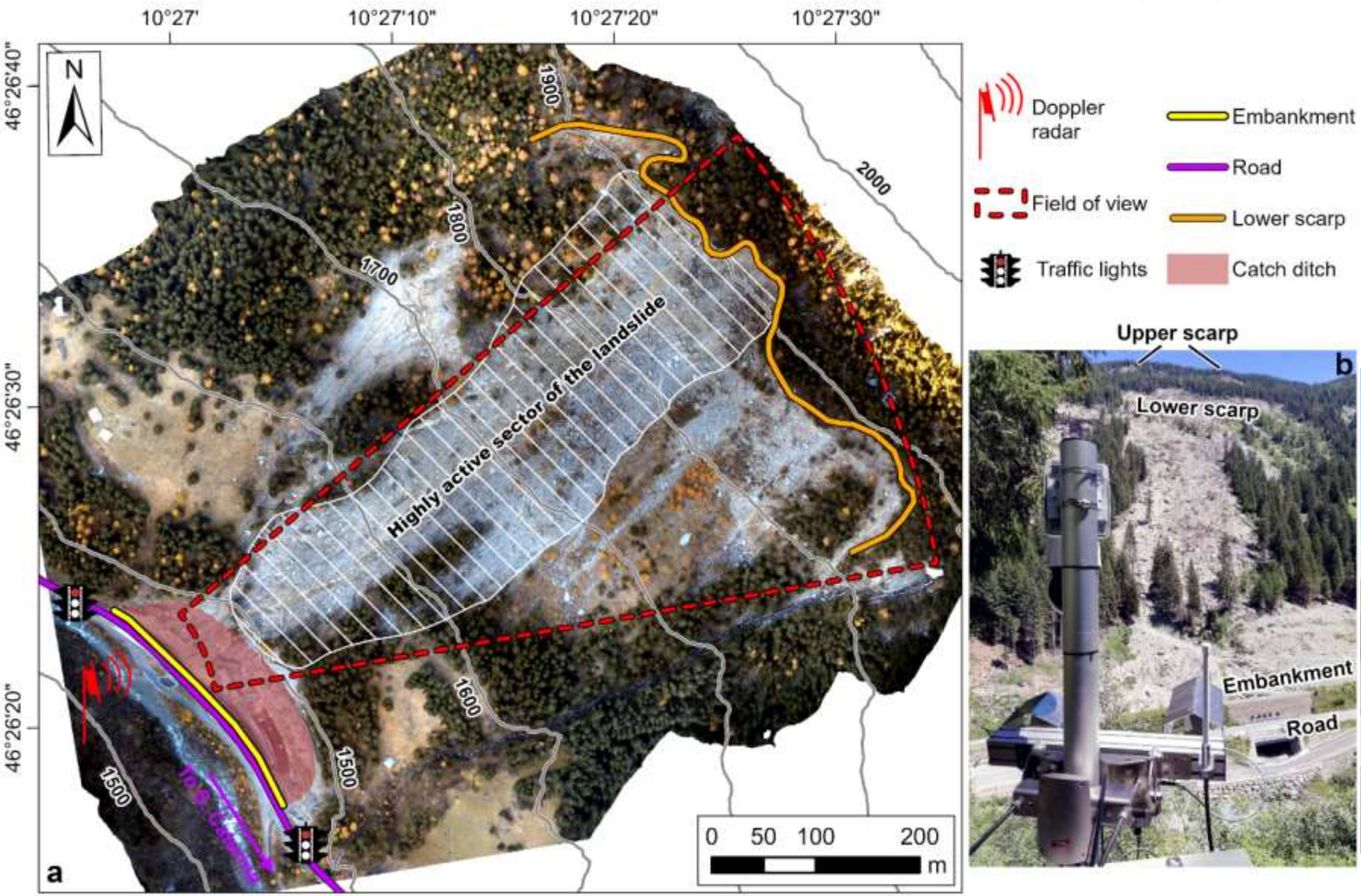
ITINERIS

Time lapse

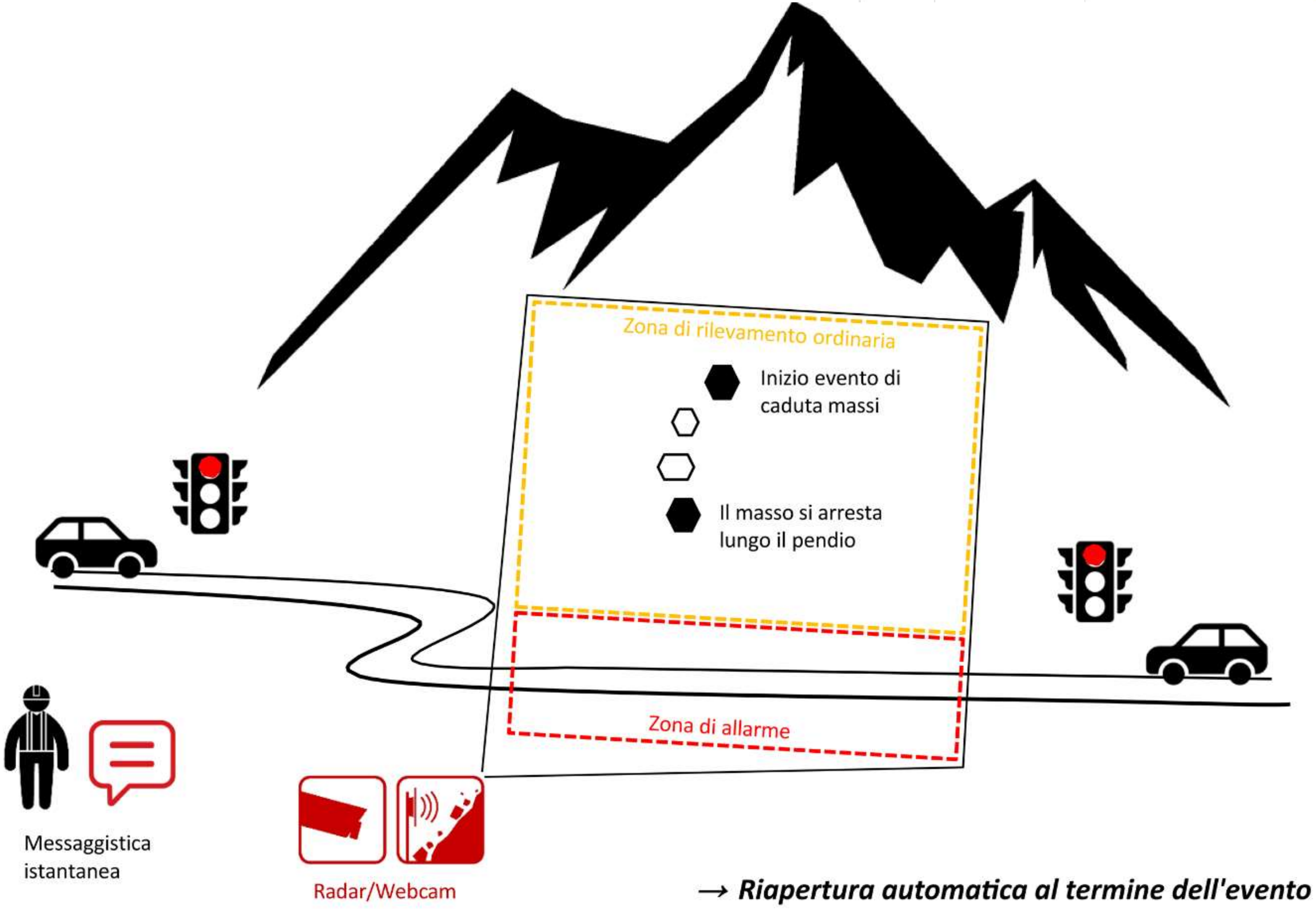
Unstable blocks

August 20 2019 rockfall

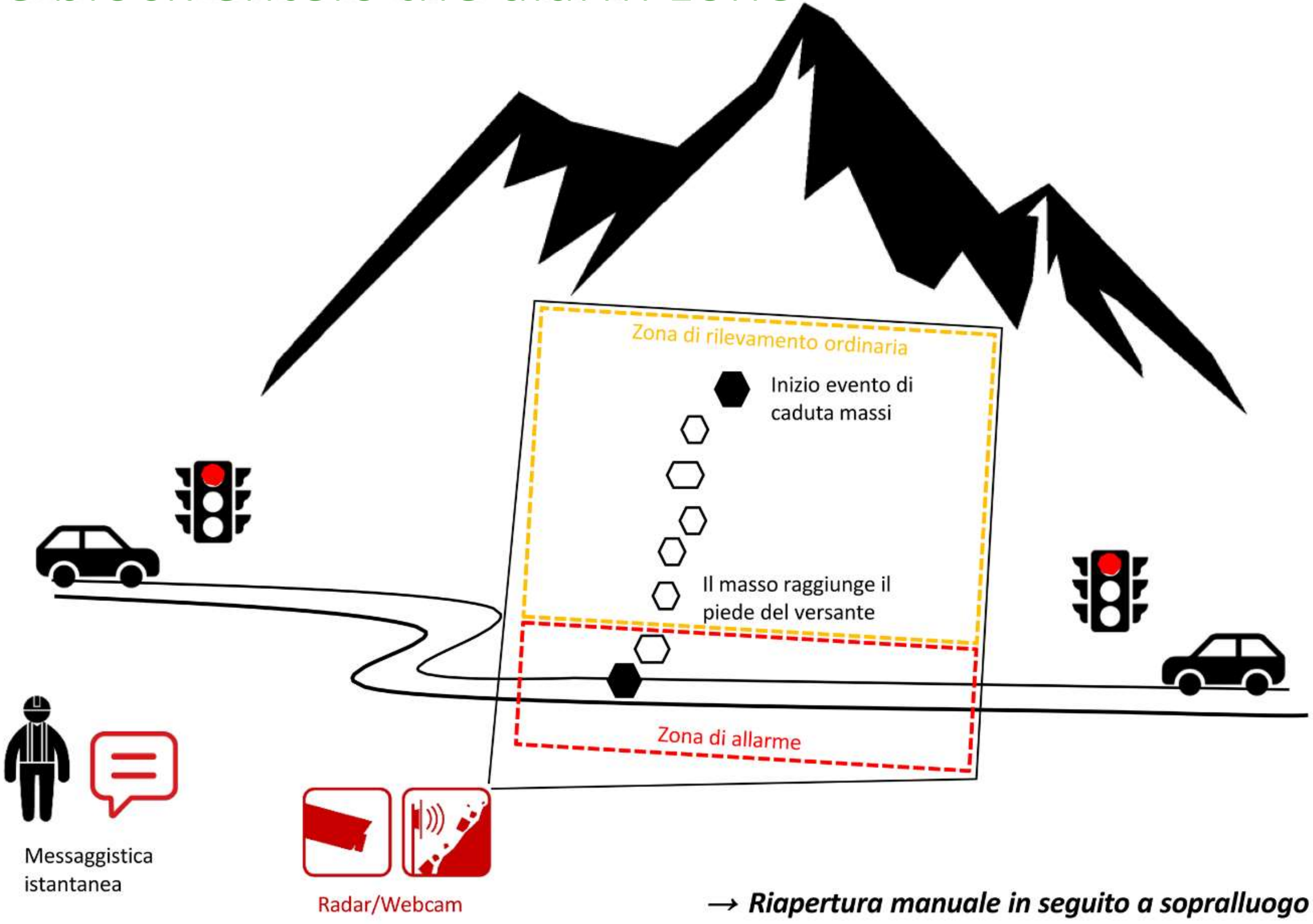
Alarm system configuration



Case 1: the block does not enter the alarm zone



Case 2: the block enters the alarm zone



September 12 2020 rockfall

L'evento rilevato alle ore 12.09.2020 09:58:48 ha interessato la zona di rilevamento ordinaria. SEMAFORO ROSSO.

09:58

Evento rilevato alle ore: 12.09.2020 09:58:45; distanza tra radar e punto di innesco: 637.06 m; distanza di propagazione: 449.69 m; classe di dimensione: 4.08; velocità media: 39.04 km/h.

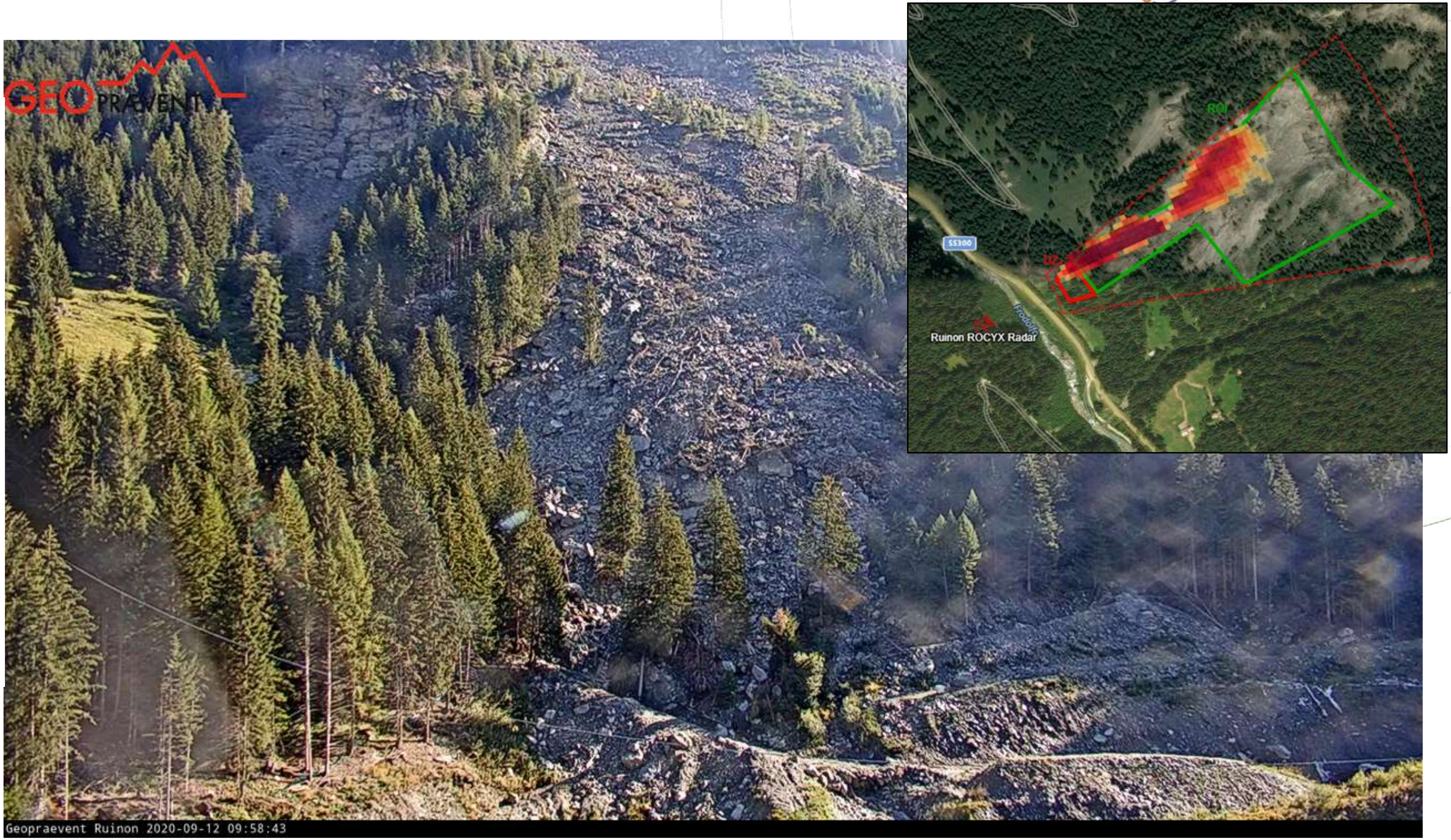
10:04

L'evento rilevato alle ore 12.09.2020 09:58:48 ha interessato la zona di allarme. SEMAFORO ROSSO – RICHIESTO RIPRISTINO MANUALE.

10:05

SEMAFORO VERDE ripristinato alle ore 12.09.2020 10:43:52.

10:43



October 1 2020 rockfall

ITINERIS

L'evento rilevato alle ore 01.10.2020 18:18:53 ha interessato la zona di rilevamento ordinaria. SEMAFORO ROSSO.

18:18

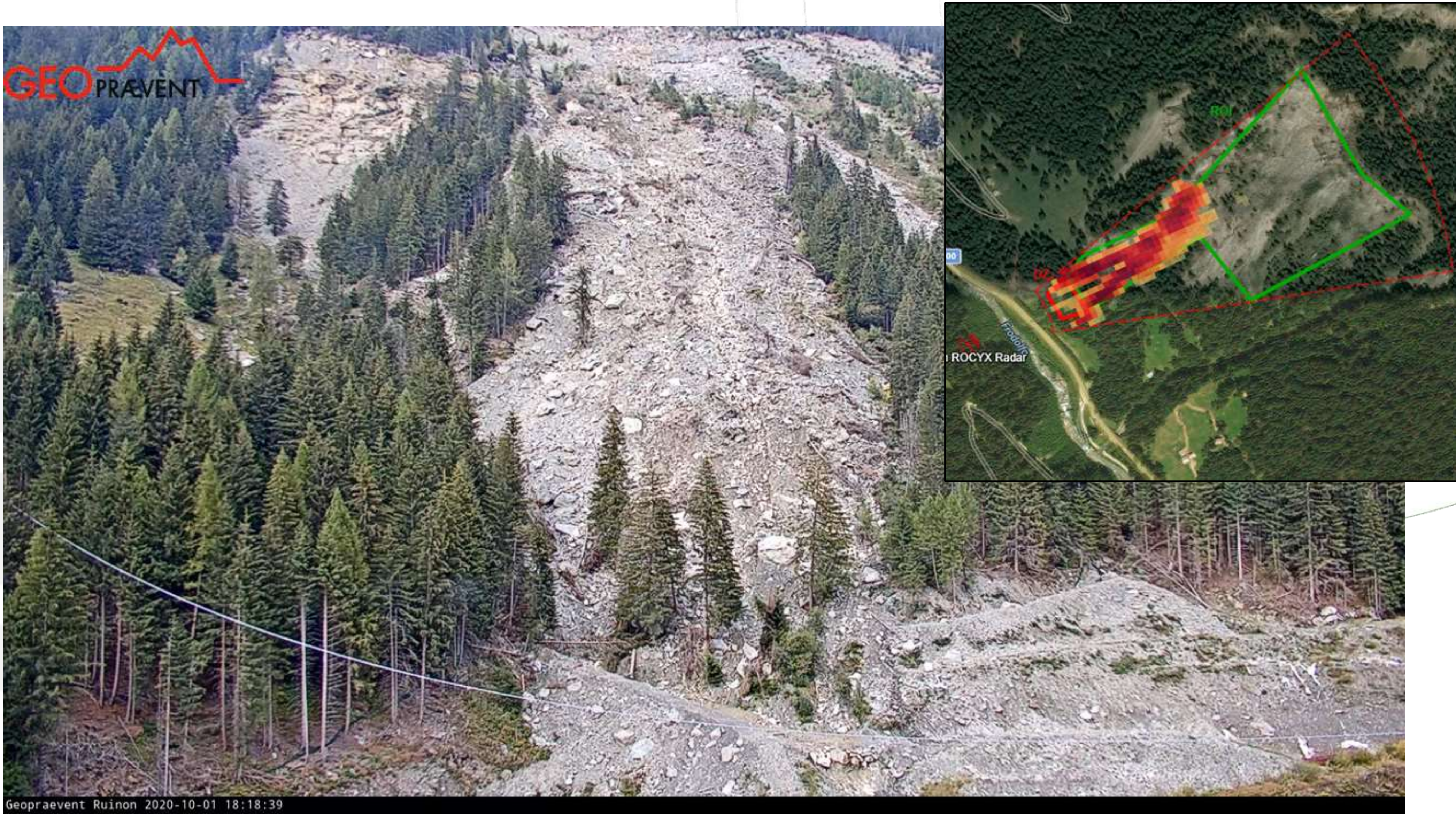
Evento rilevato alle ore: 01.10.2020 18:18:49; distanza tra radar e punto di innesco: 487.16 m; distanza di propagazione: 374.74 m; classe di dimensione: 3.78; velocità media: 48.64 km/h.

18:20

L'evento rilevato alle ore 01.10.2020 18:18:53 ha interessato la zona di allarme. SEMAFORO ROSSO – RICHIESTO RIPRISTINO MANUALE.

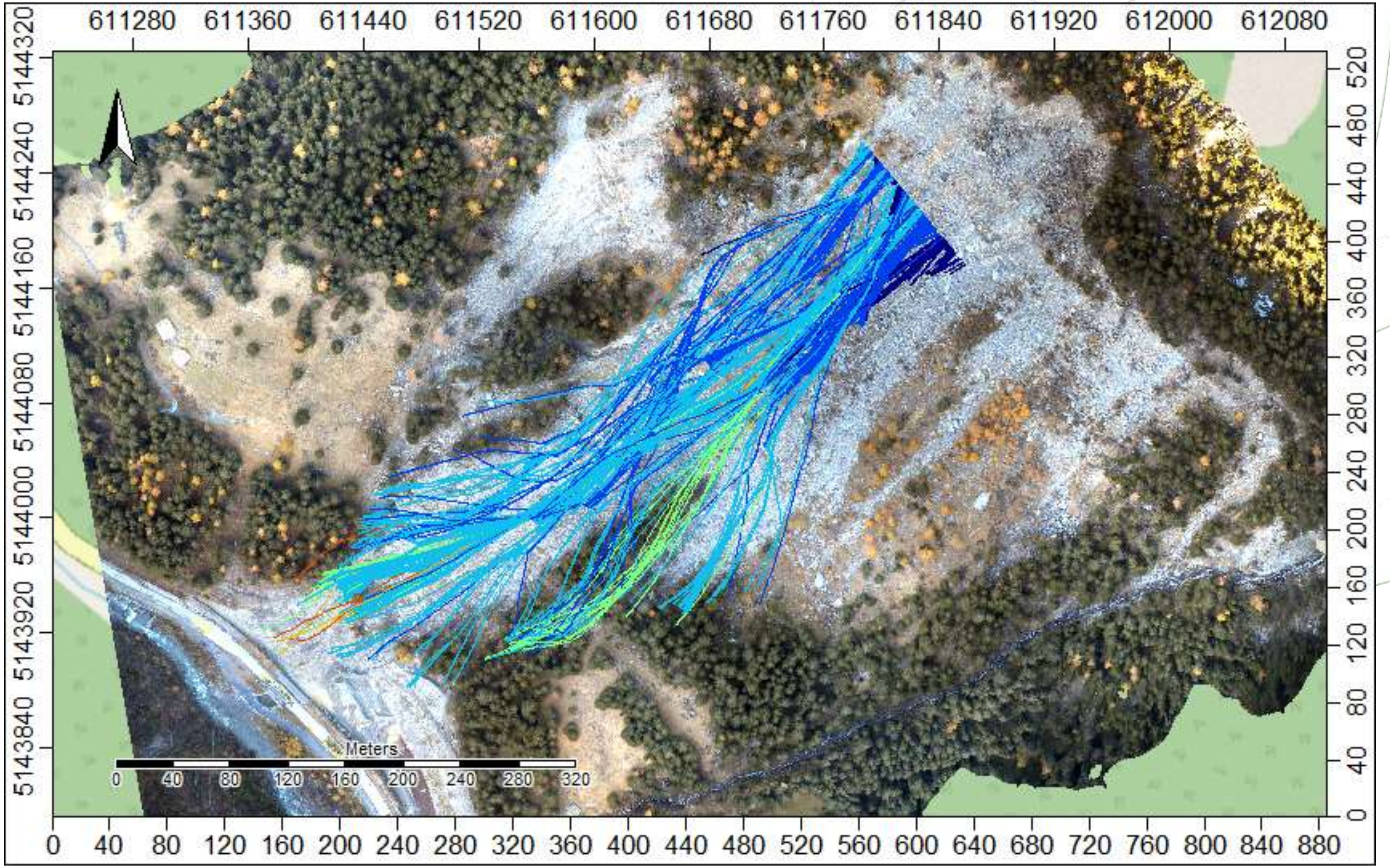
18:21

SEMAFORO VERDE ripristinato alle ore 01.10.2020 18:56:24.



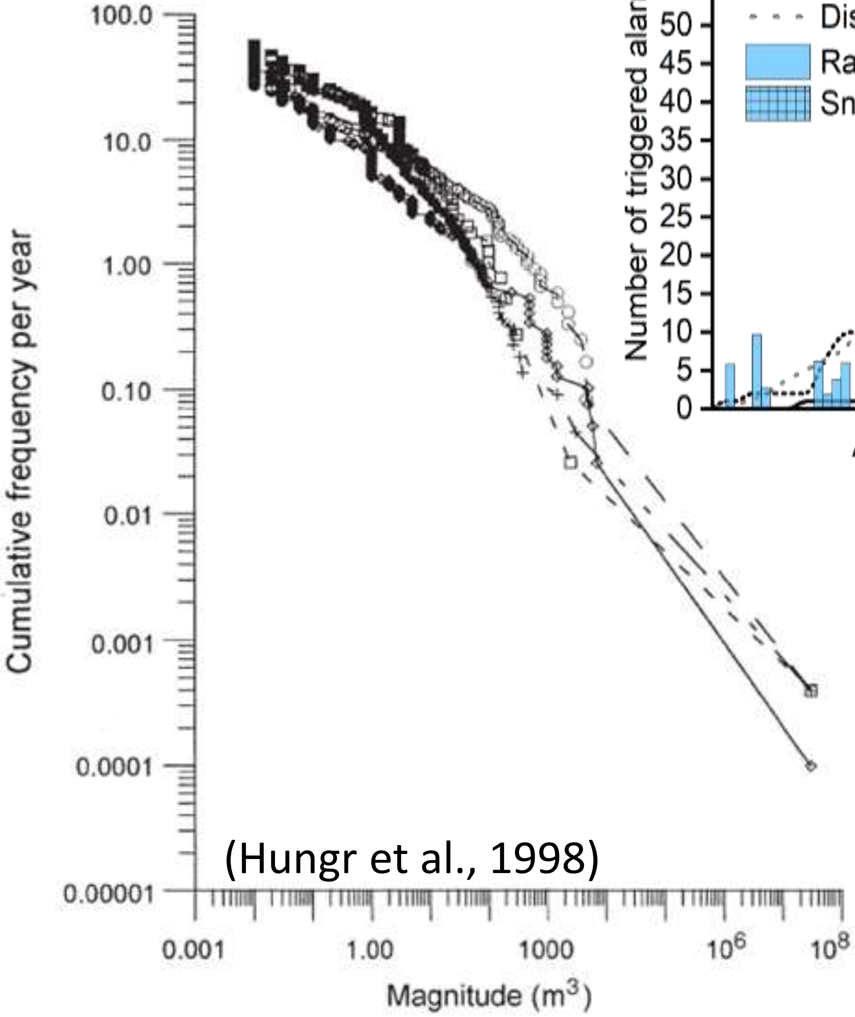
Numerical model calibration

Data evento	T_{reale}	$T_{simulazione}$
27 luglio	31	28-34
4 agosto	19	18-20
10 agosto	18	19-20
25 agosto	18	18
26 agosto	19	18-20
27 agosto	19	18-19
29 agosto	28	29-32
30 agosto	33	31-33
2 settembre	19	17-19
12 settembre	51	53-54
1° ottobre	48	48

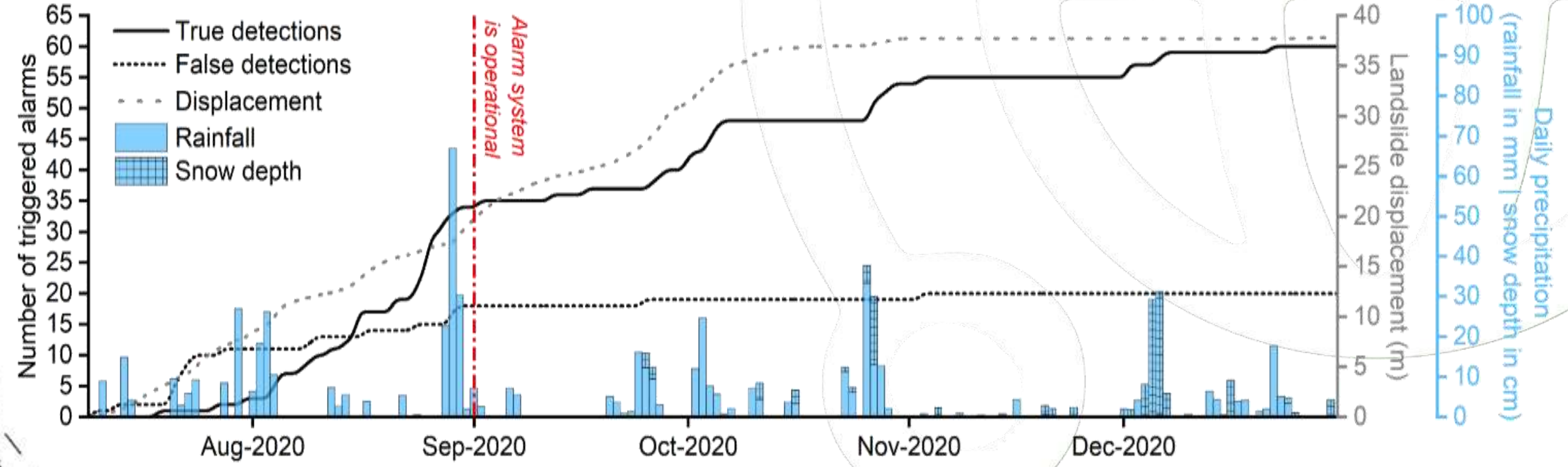


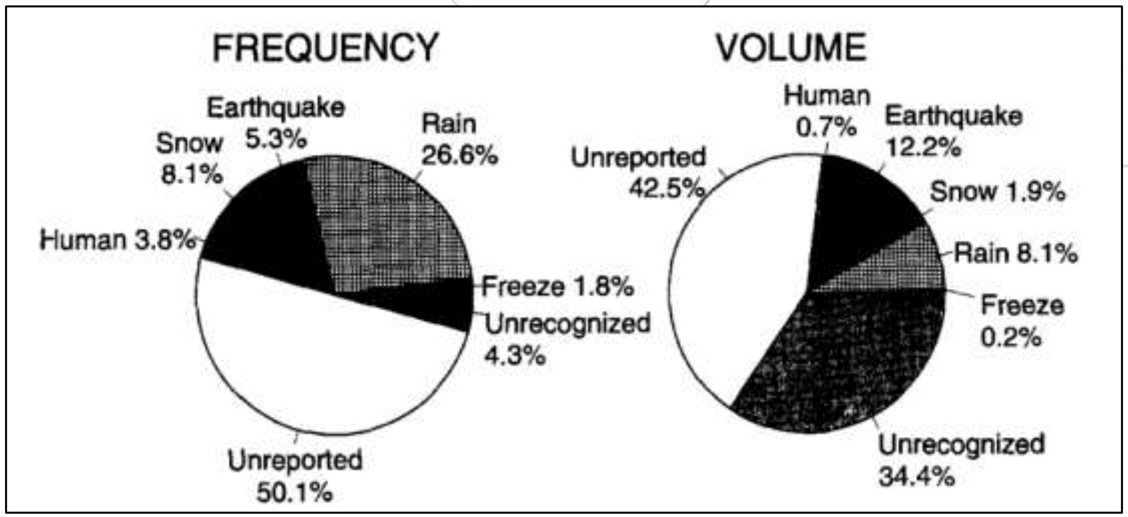
Rossi R., 2021

Analysis of causes and incidence



(Hungr et al., 1998)





(Wieczorek & Jager, 1995)

THANKS!

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 "Education and Research" - Component 2: "From research to business" - Investment 3.1: "Fund for the realisation of an integrated system of research and innovation infrastructures"

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

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