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Consiglio Nazionale delle Ricerche

Innovative characterization and monitoring solutions for rockfall prone areas

Giordan Daniele

CNR IRPI - Geohazard Monitoring Group

GEOHAZARD MONITORING GROUP

Outline

OUTCROP CHARACTERIZATION → Ormea case study

ROCKFALL VOLUME ESTIMATION → Gallivaggio case study

ROCKFALL PRONE AREA ANALYSIS AND MODELLING → Villanova di Accumoli case study

INNOVATIVE ROCKFALLS MONITORING SOLUTIONS → LASMON PROJECT

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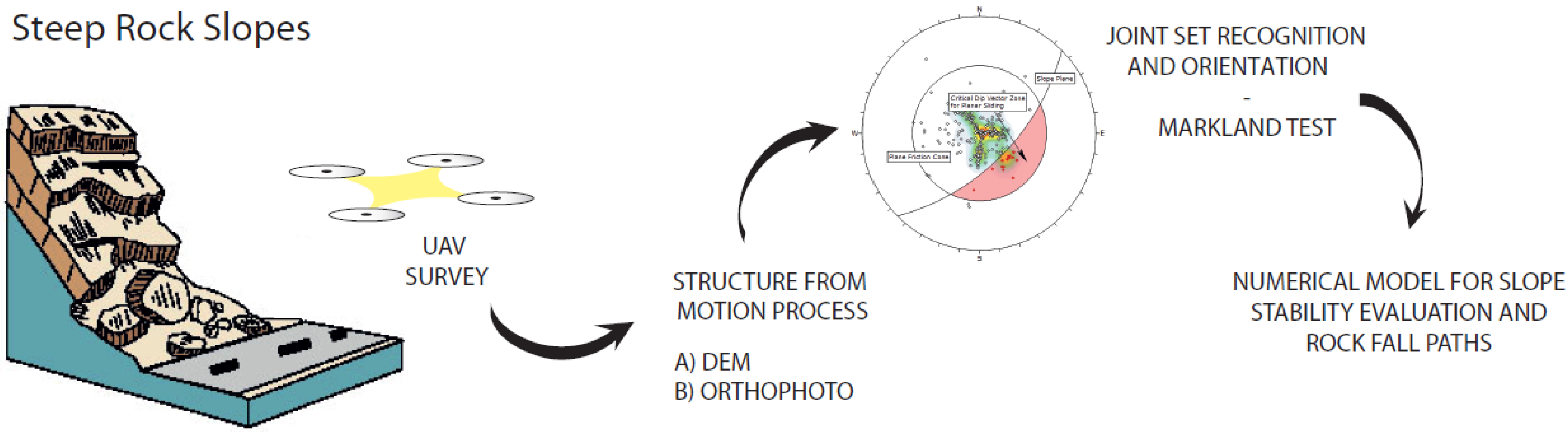
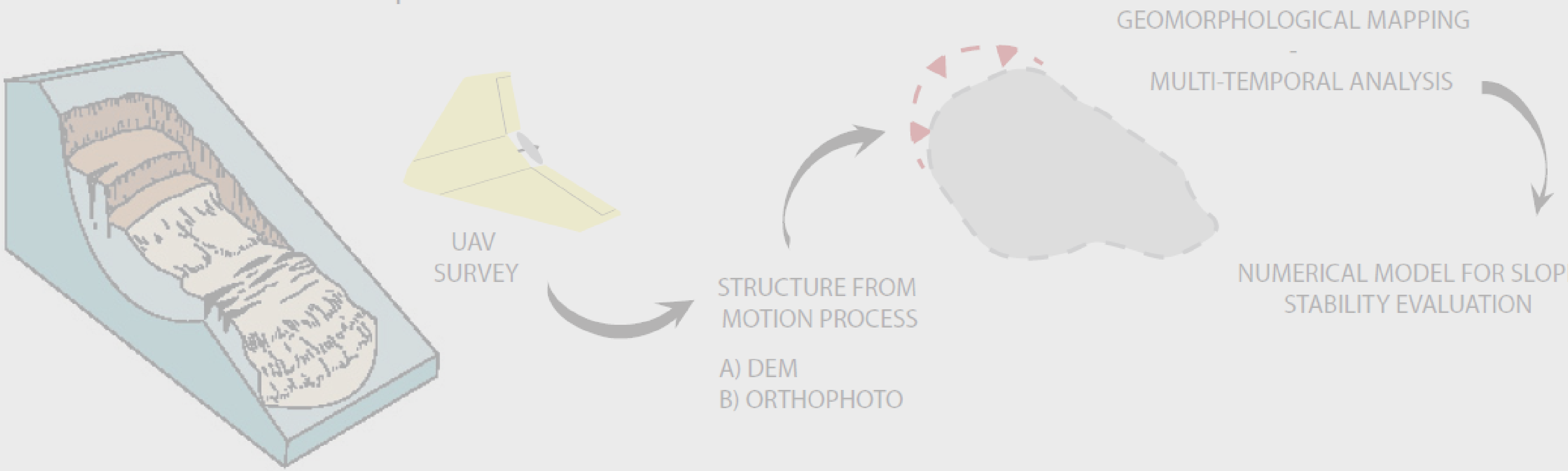
UAV LANDSLIDES INVESTIGATION WORKFLOW

Steep Rock Slopes



Gentle to Moderate Slopes



Giordan D. Manconi A., Tannant D., Allasia P. 2015 UAV: low-cost remote sensing for high-resolution investigation of landslides. Geoscience and Remote Sensing Symposium (IGARSS), 2015 IEEE International, 5344-5347.

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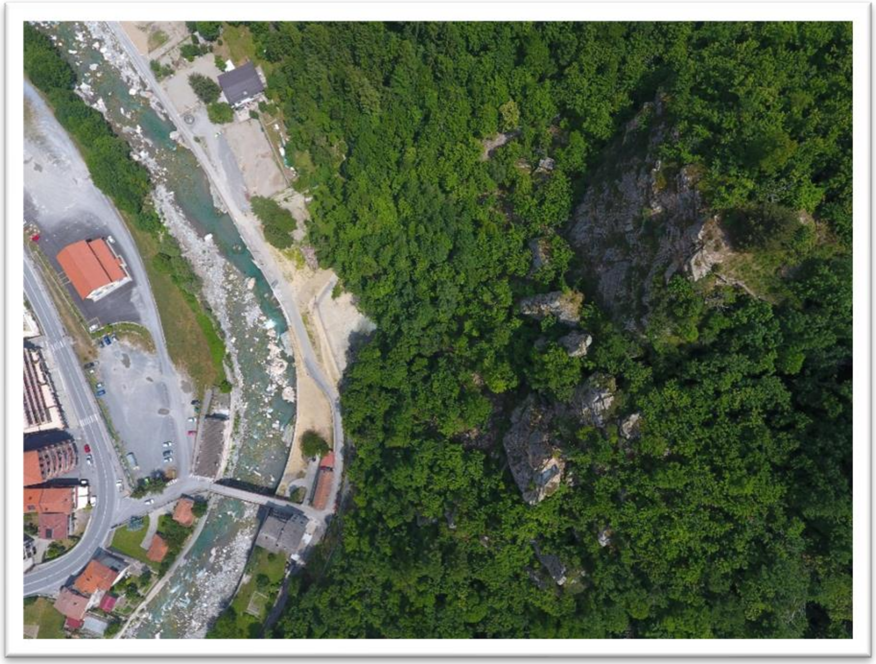
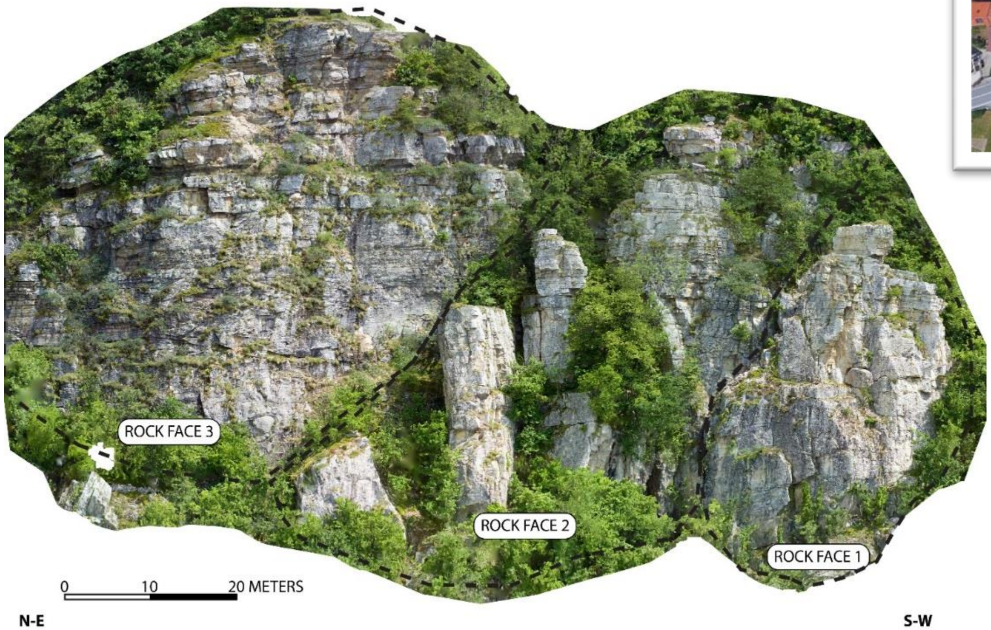
Ormea rock falls prone area





Menegoni N., Giordan D., Perotti C., Tannant D. 2019. Detection and geometric characterization of rock mass discontinuities using a 3D high-resolution digital outcrop model generated from RPAS imagery – Ormea rock slope, Italy. Engineering Geology, 252, 145-163

Ormea rock falls prone area

WORKFLOW FOR FRACTURED ROCK SLOPE ANALYSIS

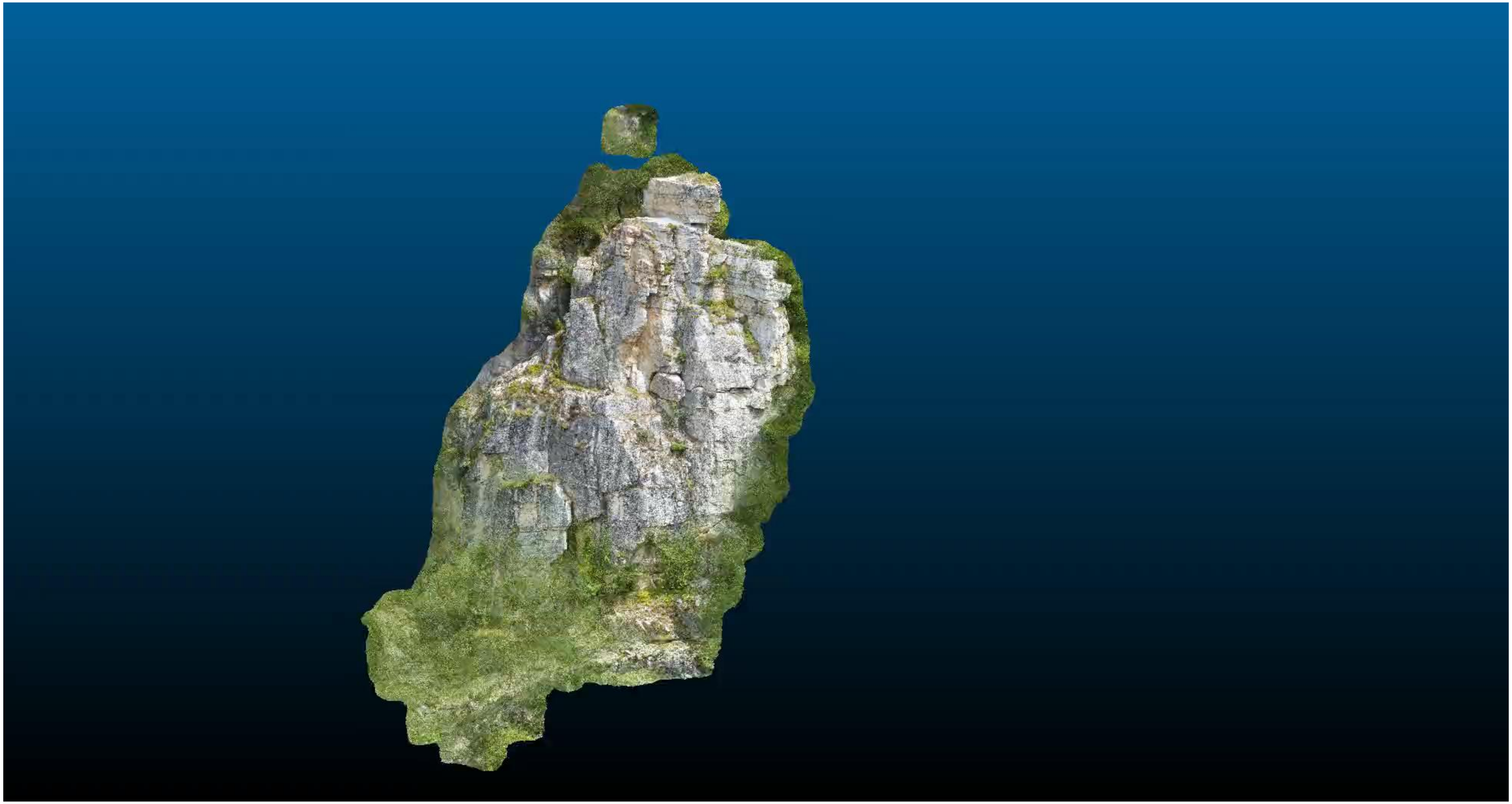
ULTRA-HIGH RESOLUTION RPAS ACQUISITION

STRUCTURE FROM MOTION

MANUAL DISCONTINUITY ANALYSIS

SLOPE STABILITY EVALUATION
(ROKA ALGHORITM)

Ormea rock falls prone area

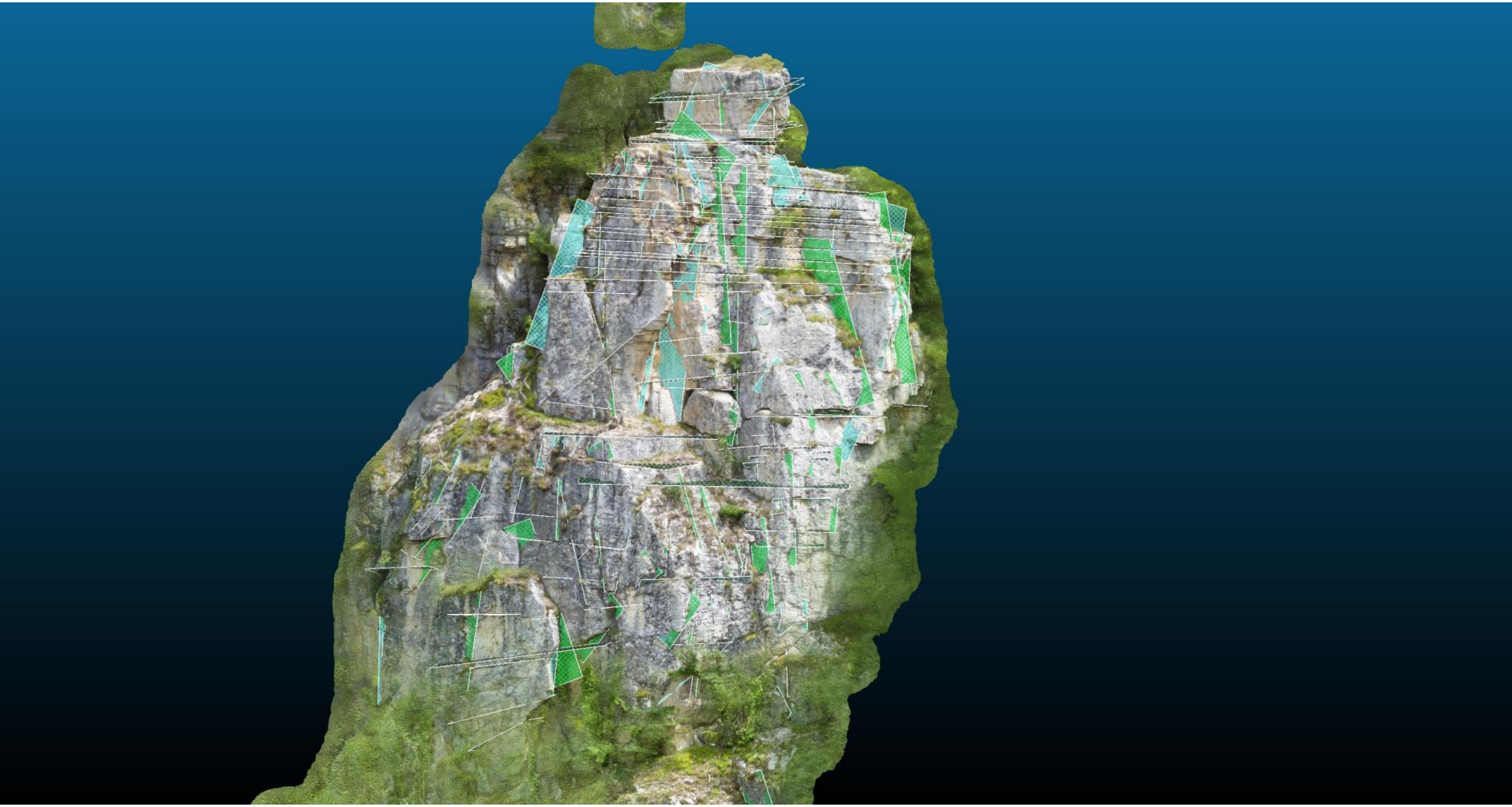


Mean resolution 5 mm/pixel

Ormea rock falls prone area

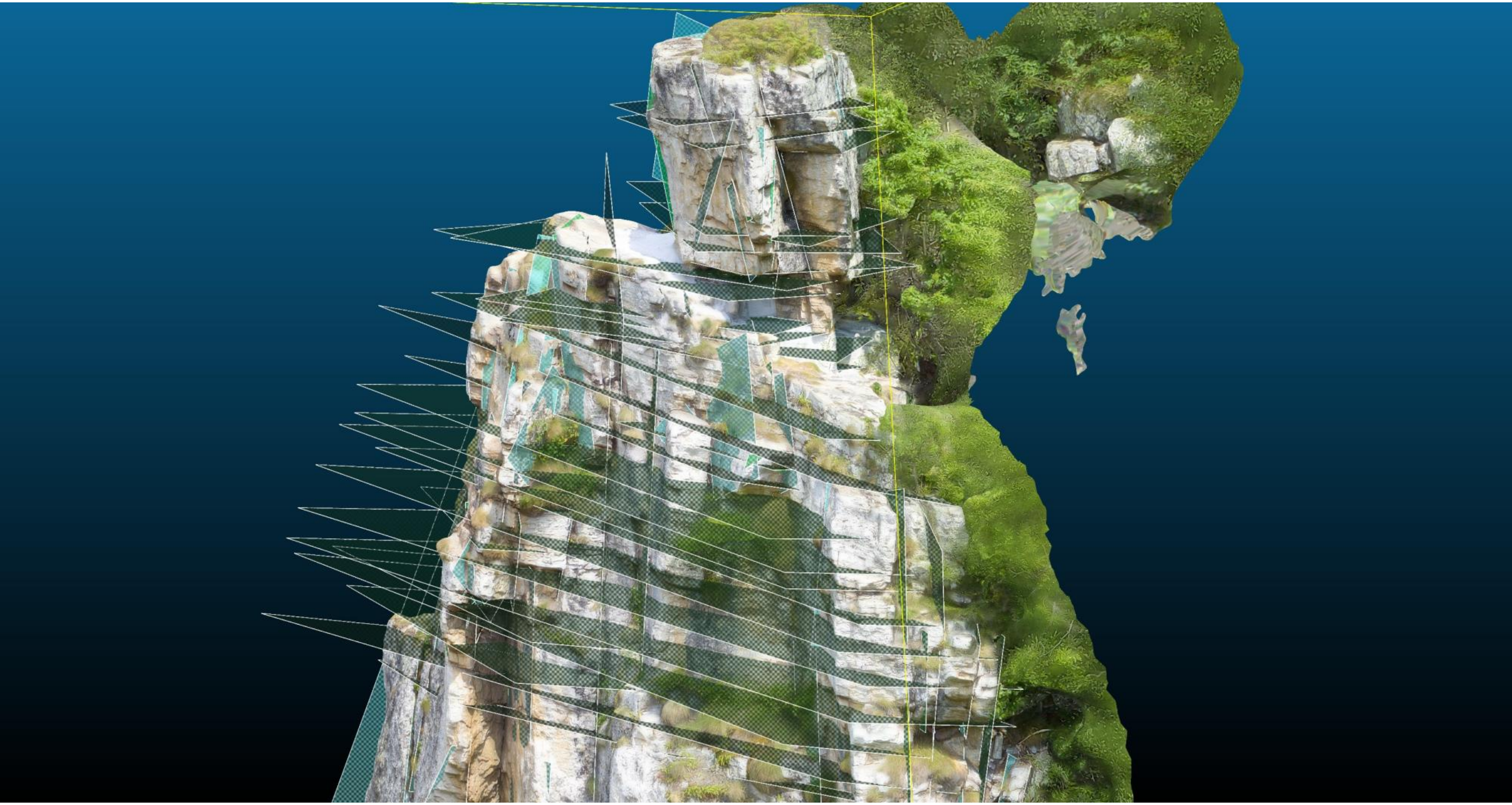
BEDDING

Ormea rock falls prone area



BEDDING + JOINTS

Ormea rock fall prone area



ROCK FACE 1:

Width: 30 m
Height: 60 m

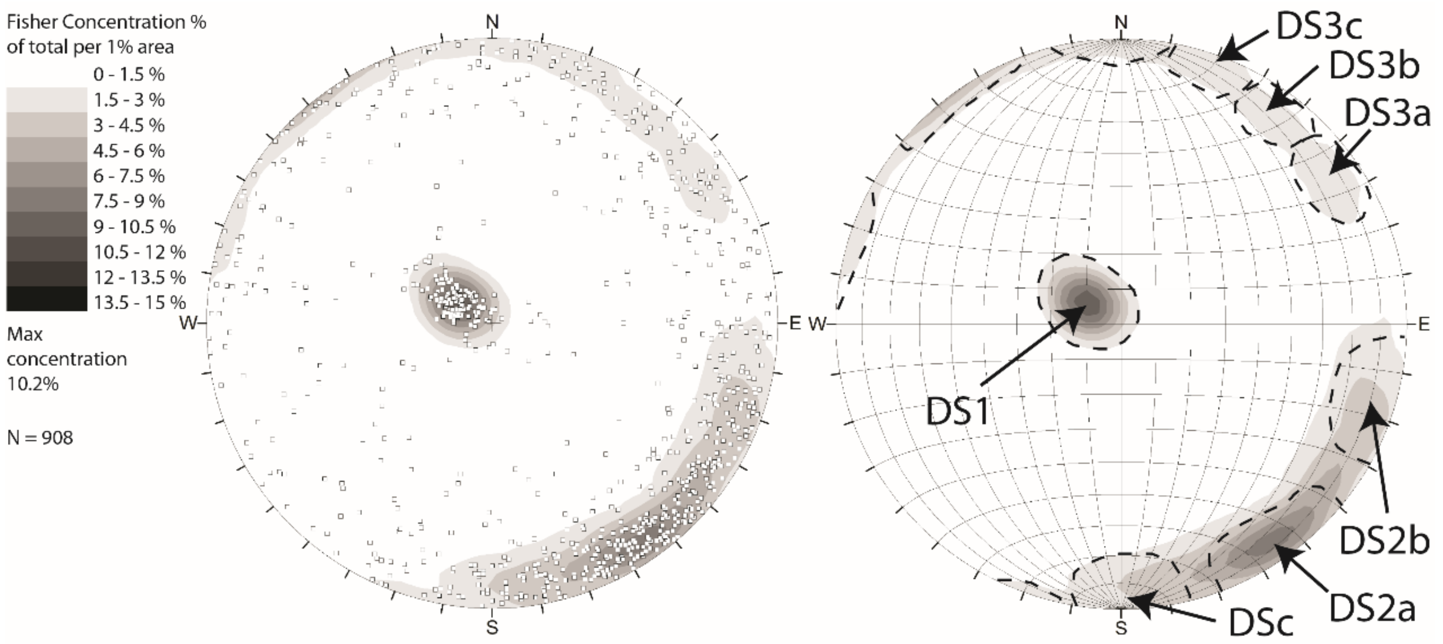
192 joints + bedding measures

Ormea rock fall prone area

Full area

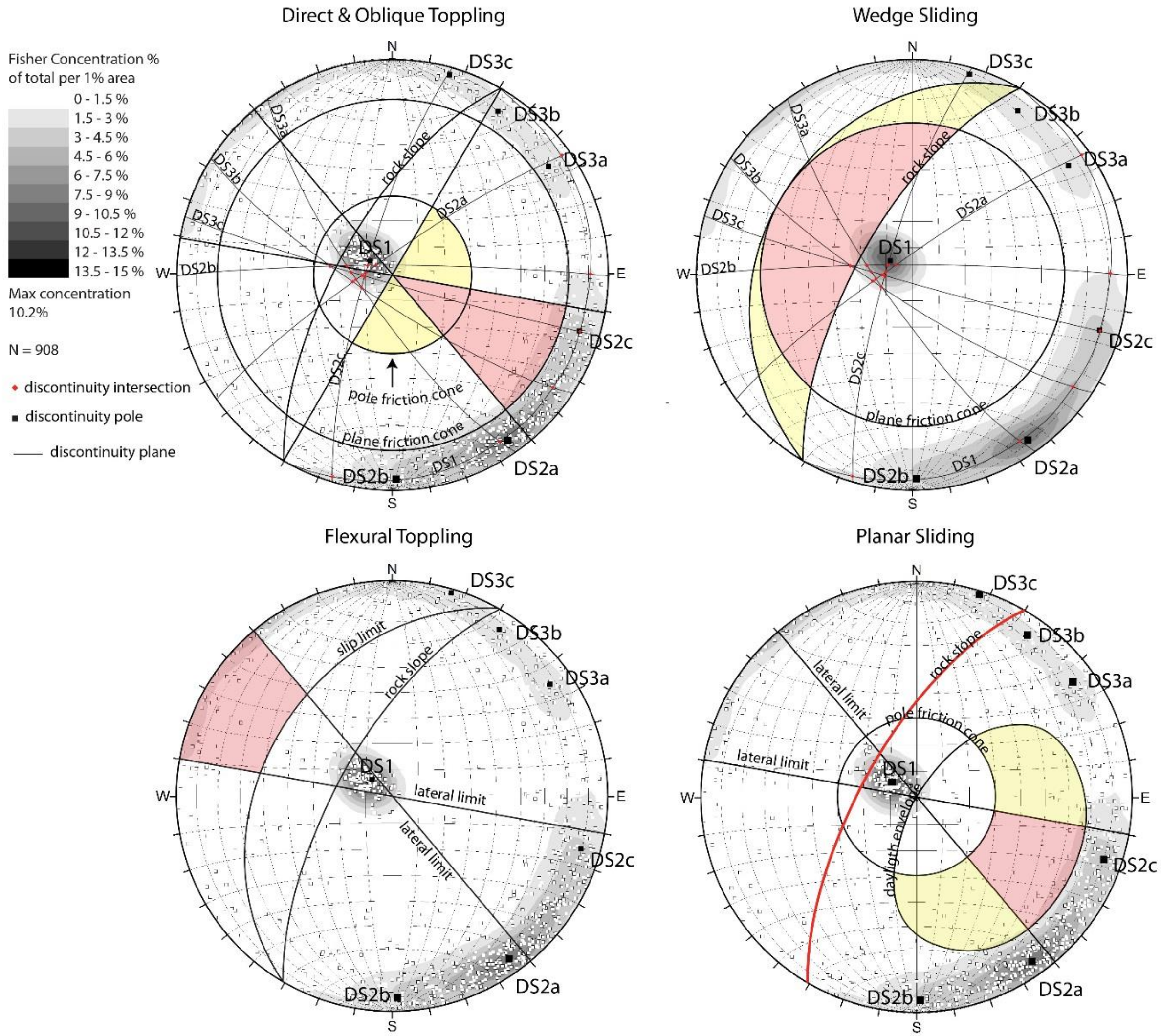
Width: 100 m
Height: 80 m

908 joints/bedding measures



The use of DOM is useful for a correct identification and interpretation of joints

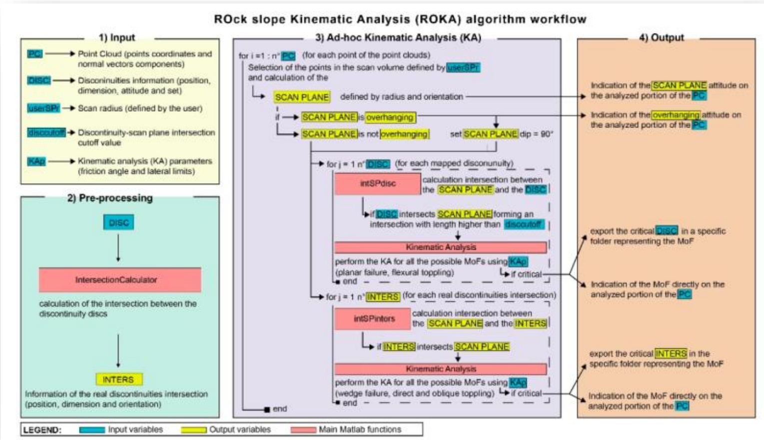
Ormea rock fall prone area



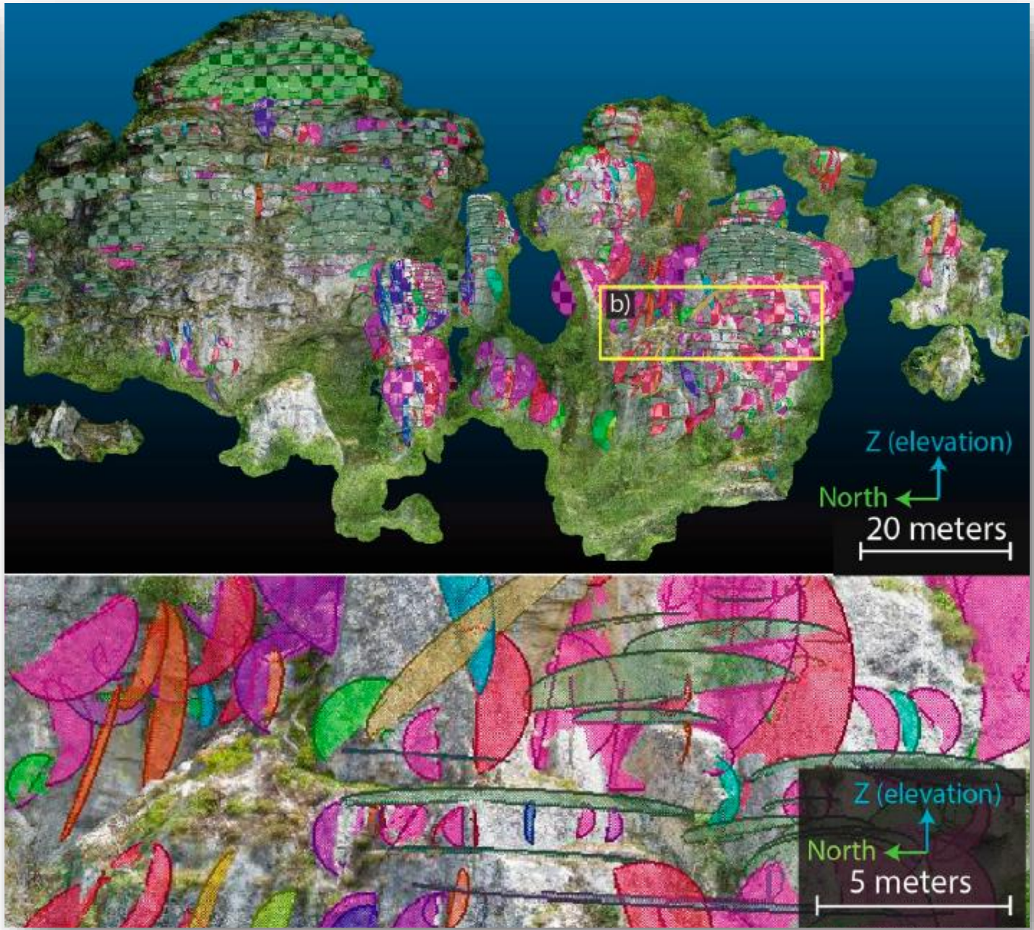
Markland tests for the identification of critical joints combinations

Ormea rock fall prone area

3D ROck Slope Kinematic Analysis (ROKA)



The open source ROKA code is able to detect critical joints combinations using a mobile window that checks all the possible discontinuity combinations according to Markland test



Menegoni N, Giordan D, Perotti C 2021 An Open-Source Algorithm for 3D ROck Slope Kinematic Analysis (ROKA). Applied Sciences, 11,1698

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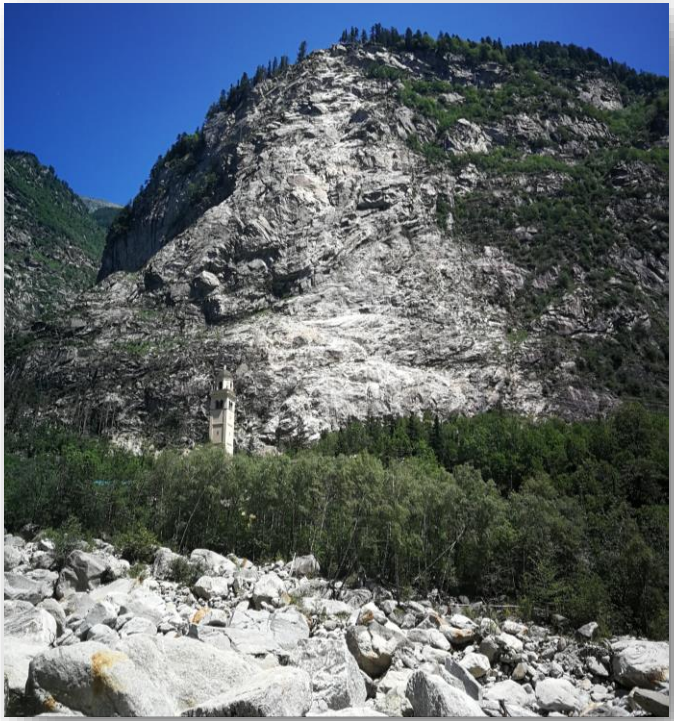
Gallivaggio rockfall (may 31, 2018)



Menegoni N, Giordan D, Perotti C 2020. Reliability and Uncertainties of the Analysis of an Unstable Rock Slope Performed on RPAS Digital Outcrop Models: the Case of the Gallivaggio Landslide (Western Alps, Italy). Remote Sensing. 12(10), 1635

Courtesy Prof. G. Crosta

Gallivaggio rockfall (may 31, 2018)

WORKFLOW FOR ROCKFALL VOLUME ESTIMATION

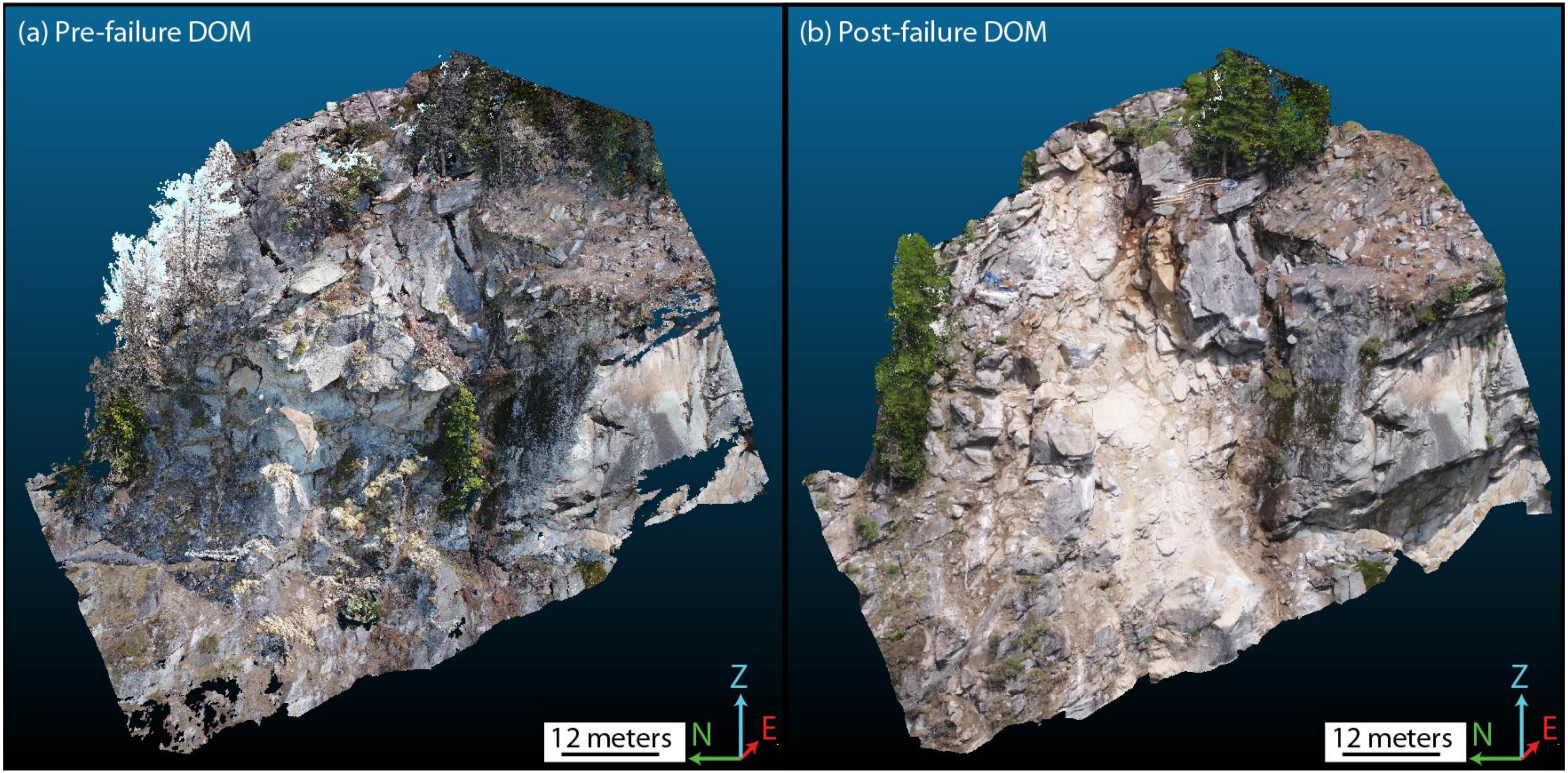
ULTRA-HIGH RESOLUTION RPAS ACQUISITION

STRUCTURE FROM MOTION

MANUAL DISCONTINUITY ANALYSIS

ROCKFALL VOLUME ESTIMATION

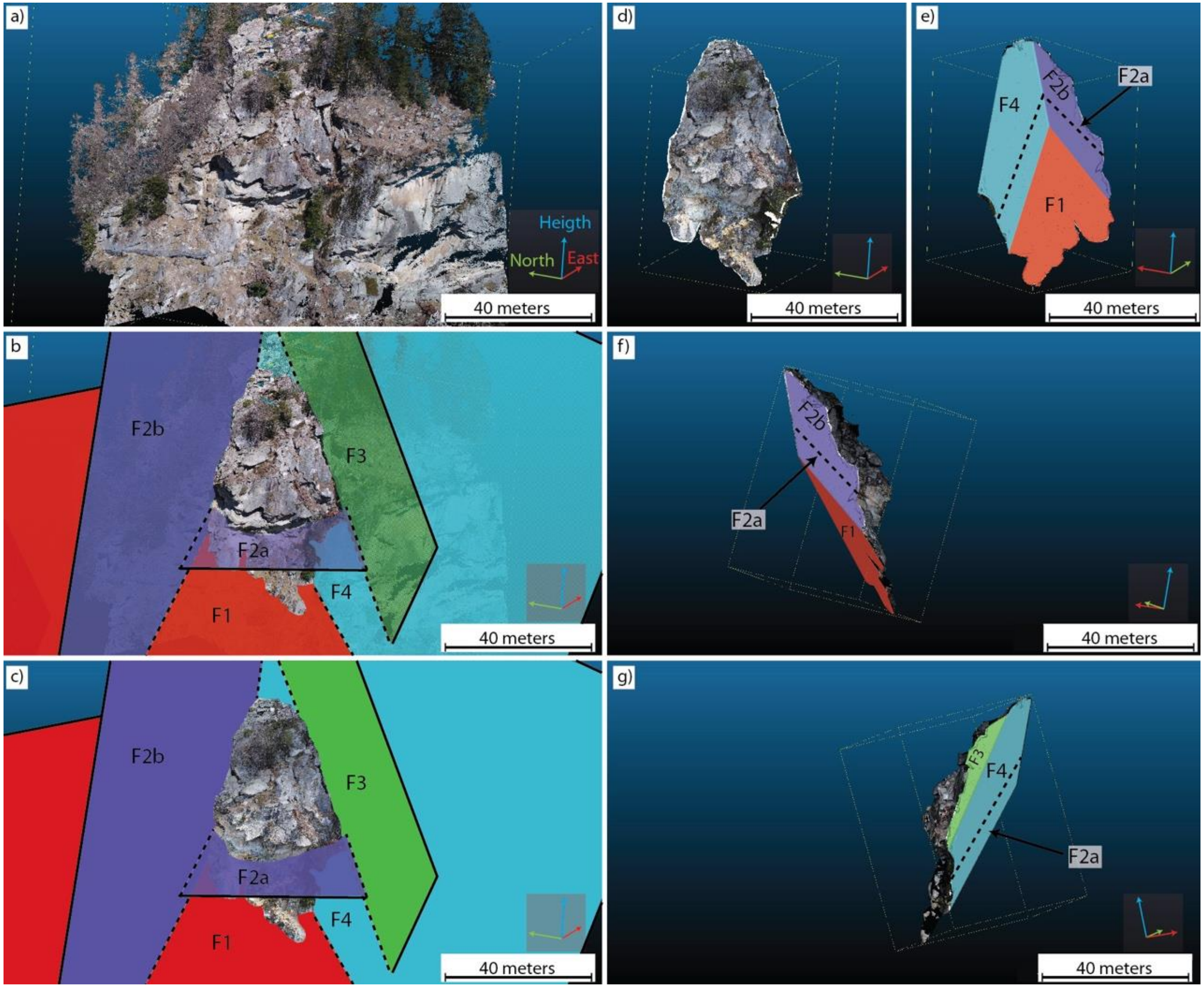
Gallivaggio rockfall



(**a**) before (April 17th 2018) and (**b**) after (May 30th 2018) the landslide

Menegoni N, Giordan D, Perotti C 2020. Reliability and Uncertainties of the Analysis of an Unstable Rock Slope Performed on RPAS Digital Outcrop Models: the Case of the Gallivaggio Landslide (Western Alps, Italy). Remote Sensing. 12(10), 1635

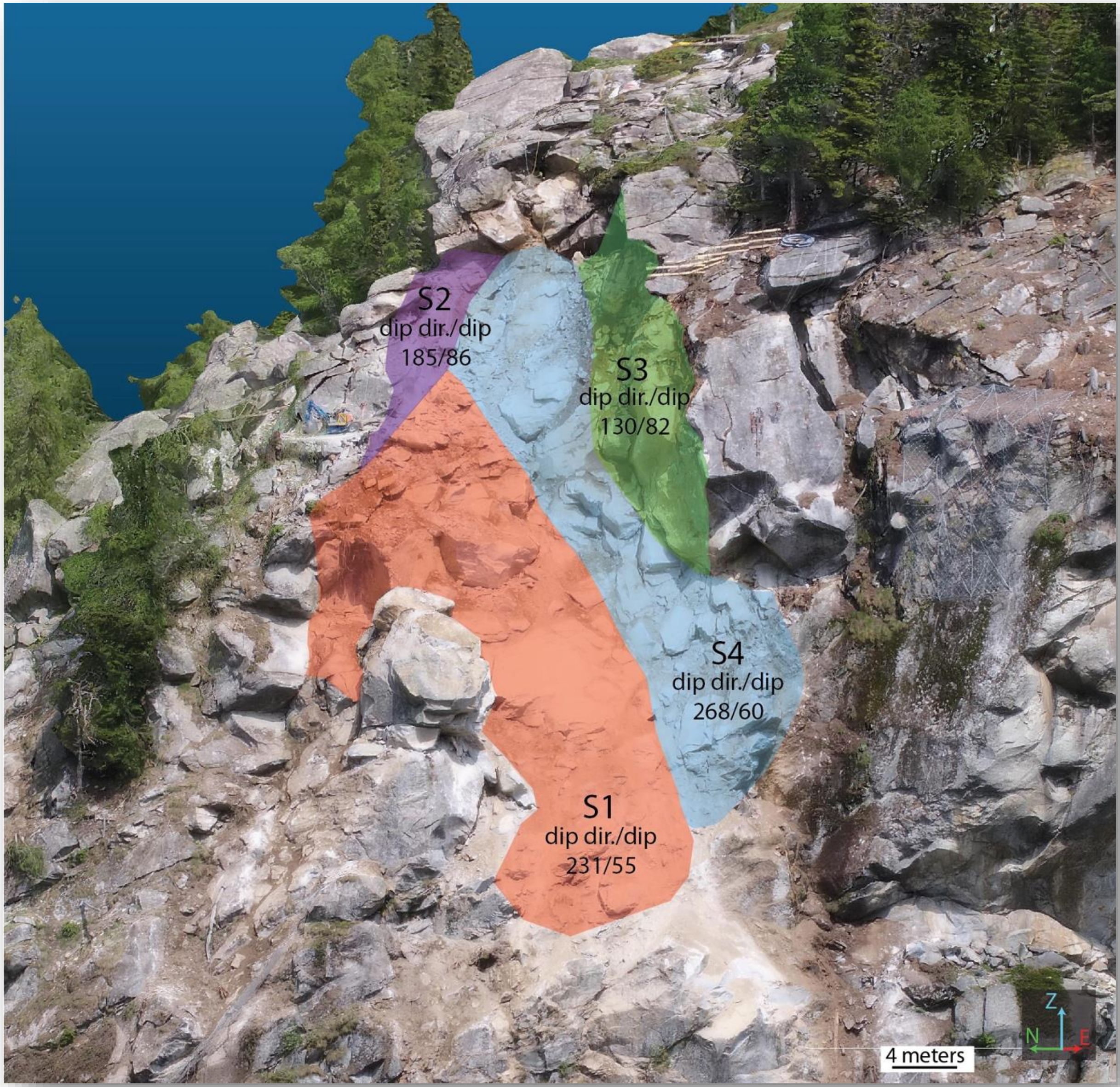
Gallivaggio rockfall



The estimated volume of the potentially unstable rock block was 8240 m^3

The volume of the fallen rock mass thus calculated was of ca 6730 m^3.

Gallivaggio rockfall

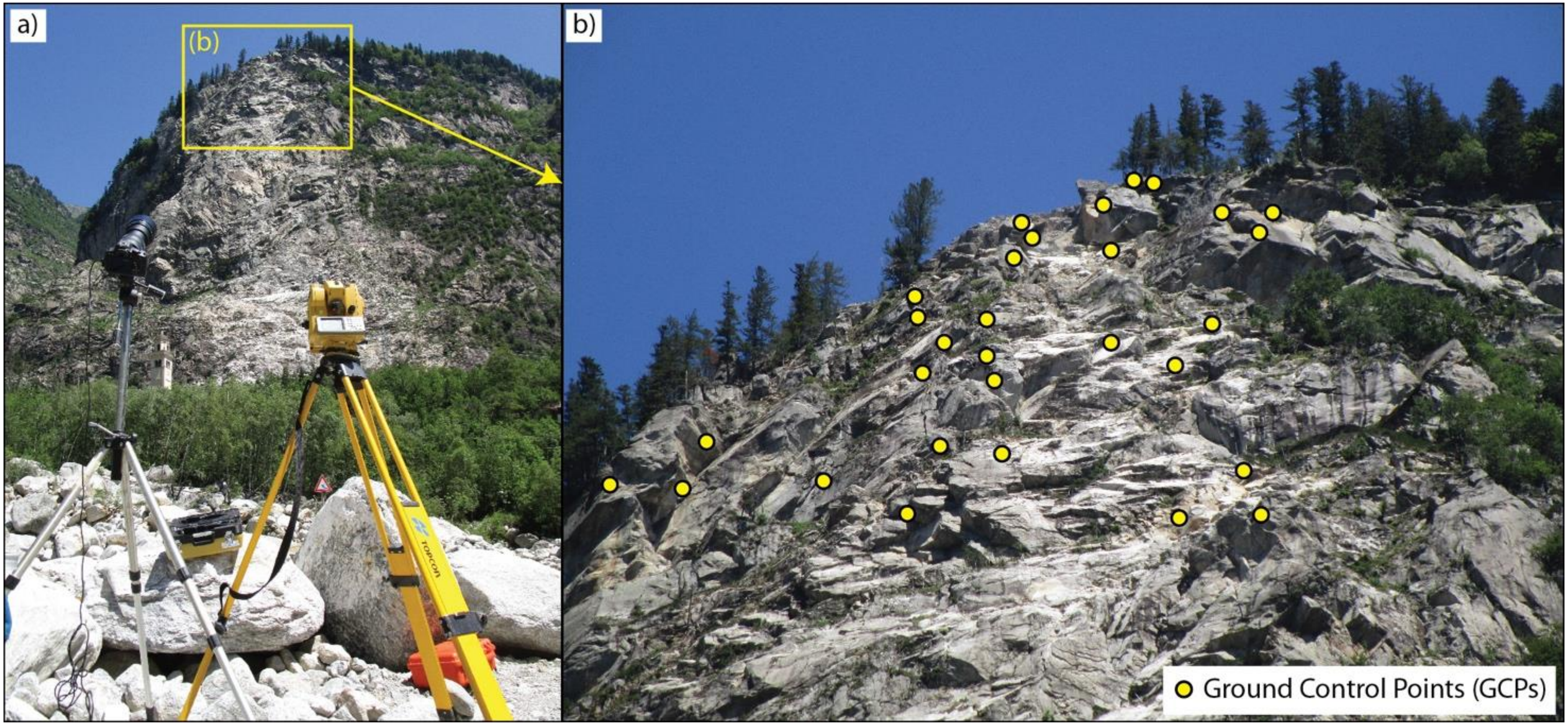


The volume of the lateral block still unstable is about 809 m^3.

The difference between the estimated and the real landslide volume is reduced to about 701 m^3 (~ 10% of the real collapsed volume).

The difference of the volume of the landslide calculated in the direct-referenced and GCP-referenced models (6730 m^3 vs 6864 m^3; ca. 1.7%).

Gallivaggio rockfall



The problem of the acquisition of Ground Control Points!

Menegoni N, Giordan D, Perotti C 2020. Reliability and Uncertainties of the Analysis of an Unstable Rock Slope Performed on RPAS Digital Outcrop Models: the Case of the Gallivaggio Landslide (Western Alps, Italy). Remote Sensing. 12(10), 1635

Villanova di Accumoli earthquake induced rockfall

Villanova di Accumoli is one of the most damaged town by the seismic sequence that hit the central part of Italy in the second half of 2016. The town was strongly damaged by the earthquake sequence and the area was also affected by the activation of several slope instabilities. Rock falls represented one of the most frequent instabilities that threatened in particular the viability and contributed to the loss of road connection in this mountainous area.

Villanova di Accumoli earthquake induced rockfall

WORKFLOW FOR ROCKFALL RISK ASSESSMENT

ULTRA-HIGH RESOLUTION RPAS ACQUISITION

STRUCTURE FROM MOTION

IDENTIFICATION OF SOURCE AREAS AND FALLEN BLOCKS

ROCKFALL TRAJECTORIES MODELLING

Villanova di Accumoli earthquake induced rockfall

UAV survey → Identification of unstable blocks → Numerical model of possible trajectories

In particular, the provincial road SP18 near Villanova di Accumoli was closed due to a 1 m^3 rock block that fell down from the slope and crossed the SP18, partially damaging it. During the emergency, it was decided to apply a numerical model to estimate the trajectories of the remaining instable rock masses and to define the possible places where to set up protection measures to safely re-open the road. Therefore, a survey with a multicopter was carried out to obtain (i) an accurate DSM of the source area and the slope (ii) the identification and characterization of other unstable blocks possibly not reachable in the field.

Villanova di Accumoli earthquake induced rockfall

STEP 1
OPTICAL RPAS ACQUISITION OF THE STUDIED AREA

The 6,500 m^2 area was covered by a total 161 photograms by a 34 Mpixel camera, obtaining a 1.5 cm/pixel Ground Sampling Distance (GSD).

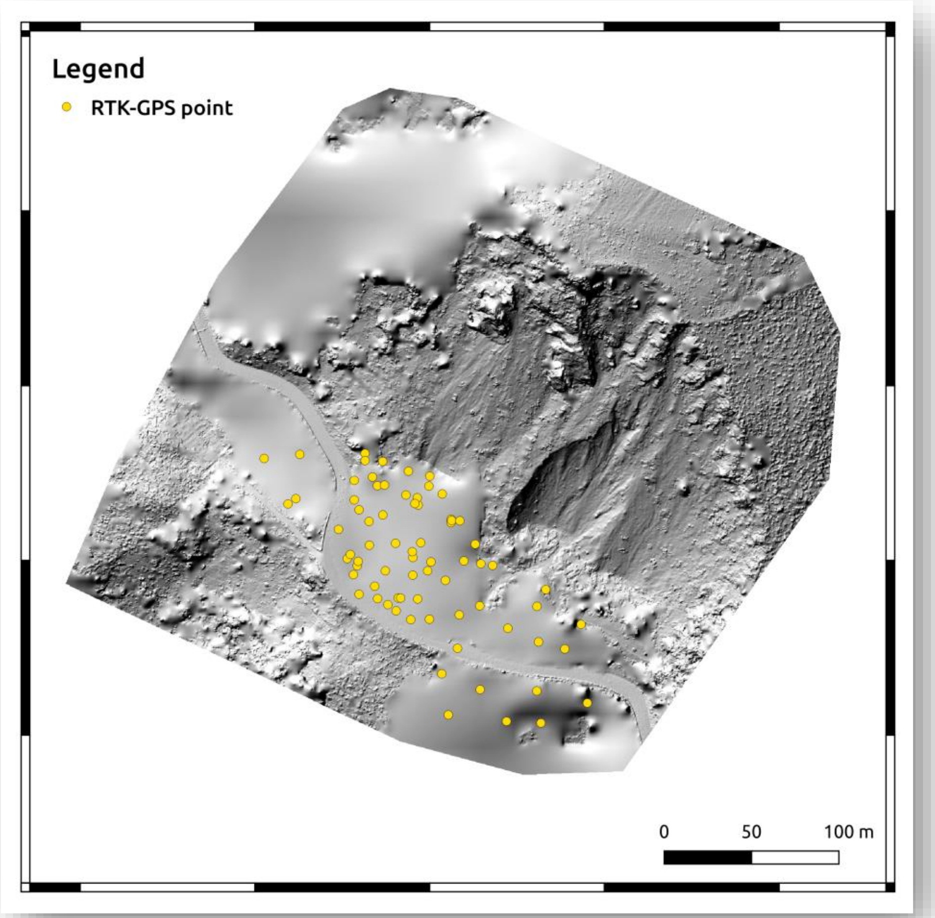
Santangelo M., Alvioli M., Baldo M., Cardinali M., Giordan D., Guzzetti F., Marchesini I., Reichenbach P. 2019. Brief communication: Remotely piloted aircraft systems for rapid emergency response: road exposure to rockfall in Villanova di Accumoli (central Italy) Nat. Hazards Earth System Science. Sci. 19, 325-335

Villanova di Accumoli earthquake induced rockfall

STEP 2
STRUCTURE FROM MOTION RESULT: ORTOPHOTO

The final orthophoto has a resolution of 2.5 cm, whereas the DSM has a resolution of 20 cm.

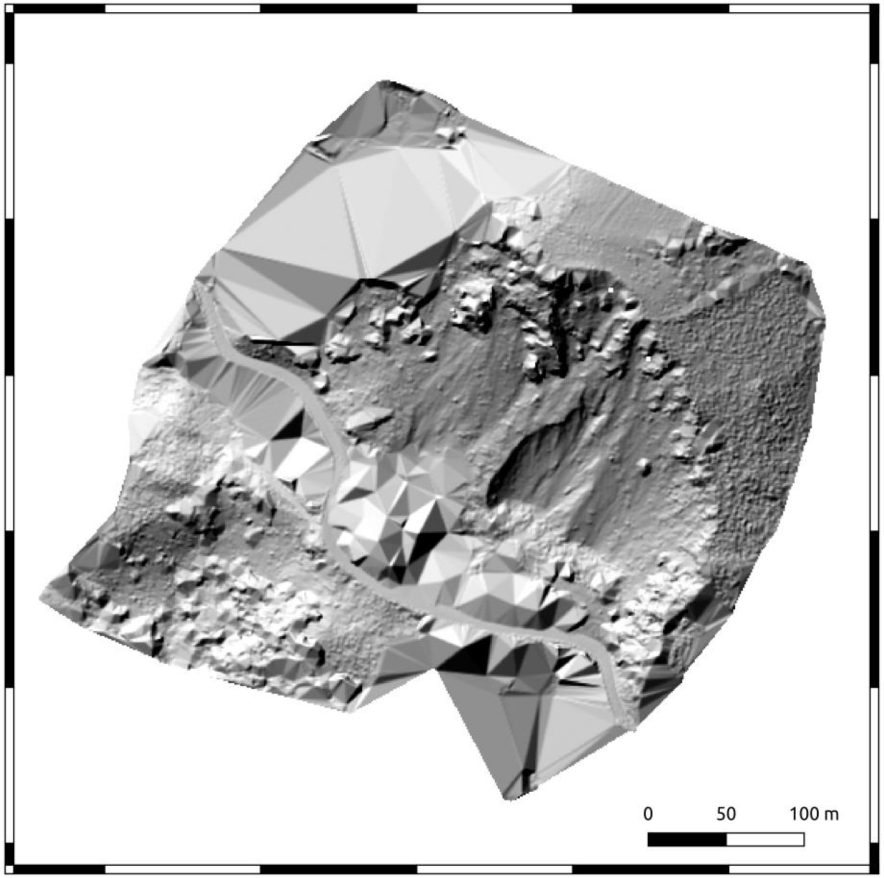
Villanova di Accumoli earthquake induced rockfall



STEP 3
STRUCTURE FROM MOTION RESULT: DTM

The DSM was then filtered by a three-step procedure including manual removal of sparse vegetation cover

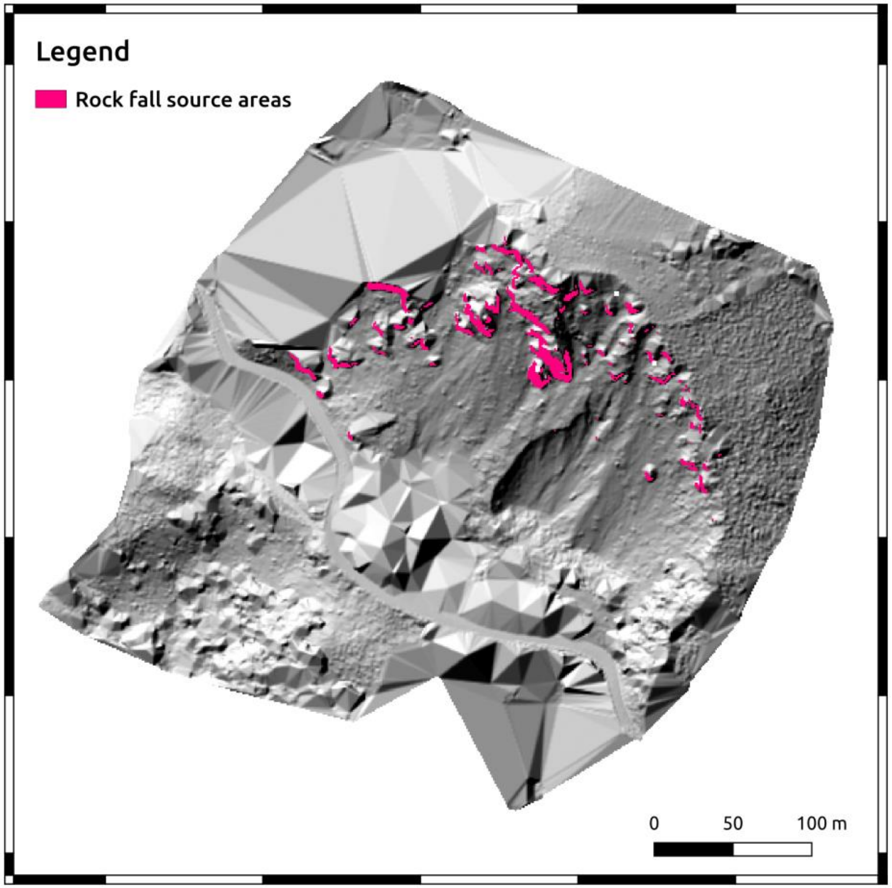
Villanova di Accumoli earthquake induced rockfall



STEP 4
GPS RTK ACQUISITION IN THE MOST VEGETATED AREAS

In the area covered by dense vegetation (the lower part of the slope) the DSM could not be manually filtered, which hampered to run the numerical model. This problem was addressed by carrying out a GPS RTK survey of the most vegetated area. A total of 73 points with less than 1m error were acquired and integrated in the DTM. The resulting integrated DTM has a resolution of 25 cm

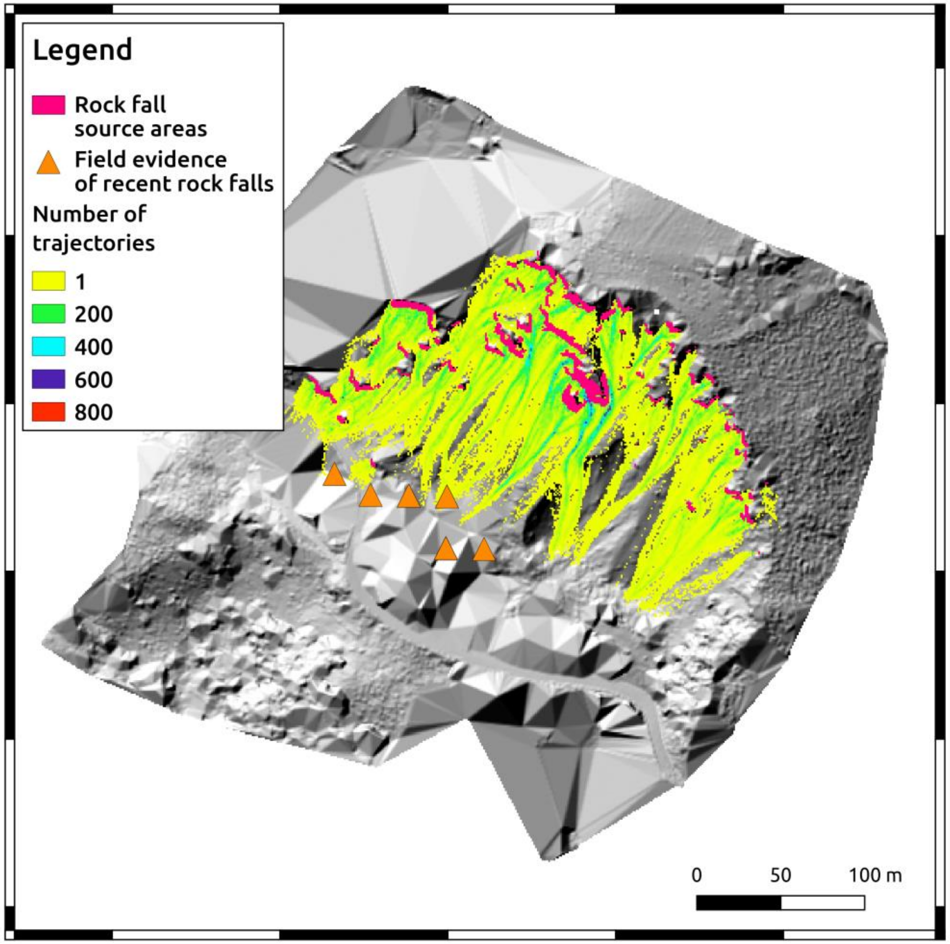
Villanova di Accumoli earthquake induced rockfall



STEP 5
ROCK FALLS SOURCE AREA RECOGNITION

The numerical model STONE was then applied to the source areas mapped by photo-interpretation of the RPAS orthophoto and by a morphometric threshold.

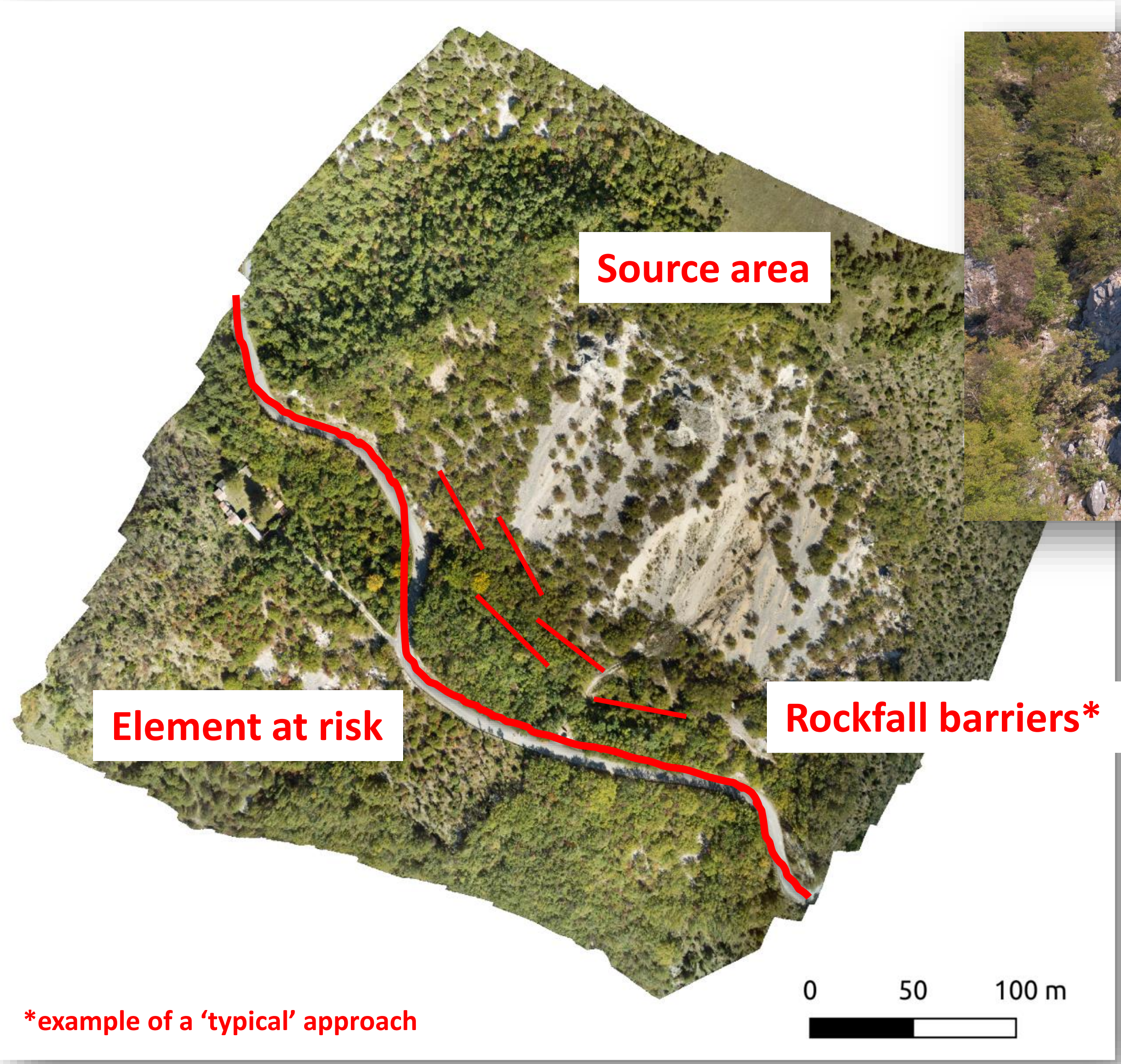
Villanova di Accumoli earthquake induced rockfall

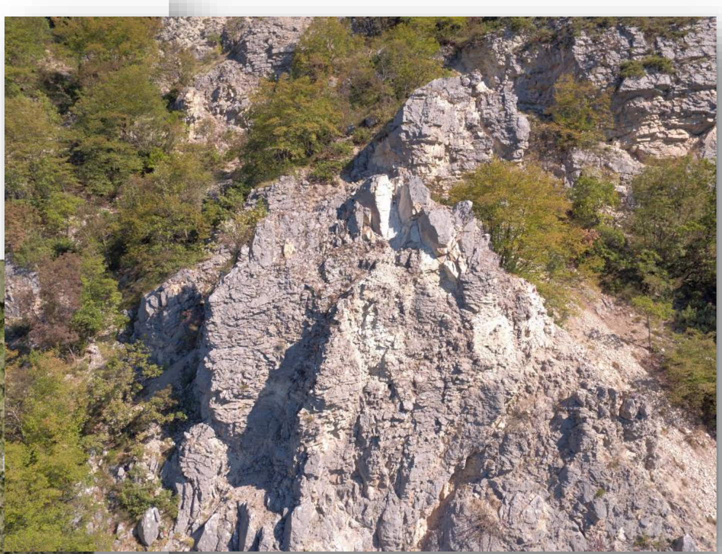


STEP 6
NUMERICAL MODEL FOR POTENTIAL ROCK FALLS TRAJECTORIES

STONE model produced a 1m raster showing the potential trajectories of the mapped instable rock masses. Results showed that only the part of the road hit by the rockfall was actually exposed to rockfall trajectories. Therefore only limited protection measures were suggested to reduce the exposition of the road.

Rockfall vs monitoring approaches





The target of monitoring activity is the system composed by the rockfall prone area and the active and passive elements installed to reduce the rockfall risk

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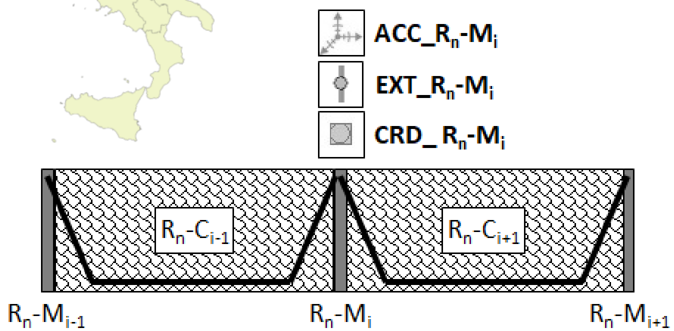
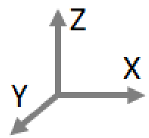
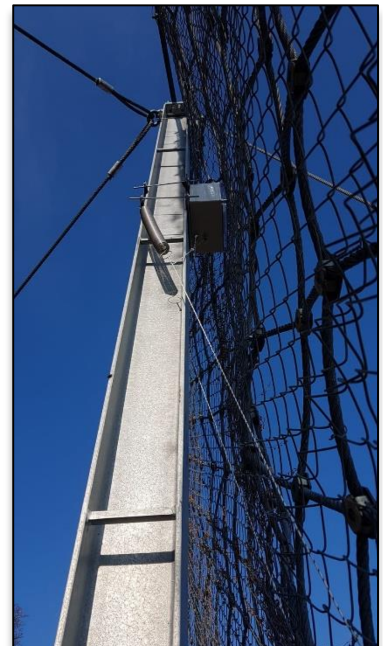
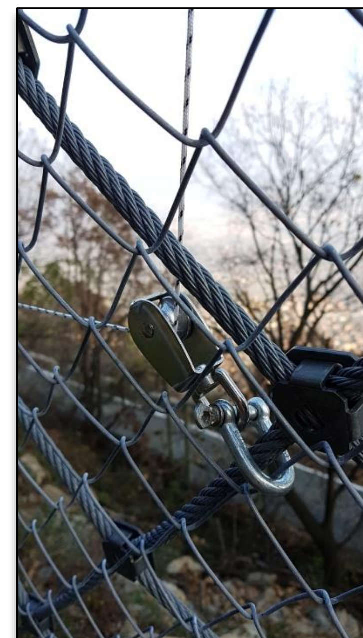
Dynamic rockfalls barriers monitoirng



Rete R_n







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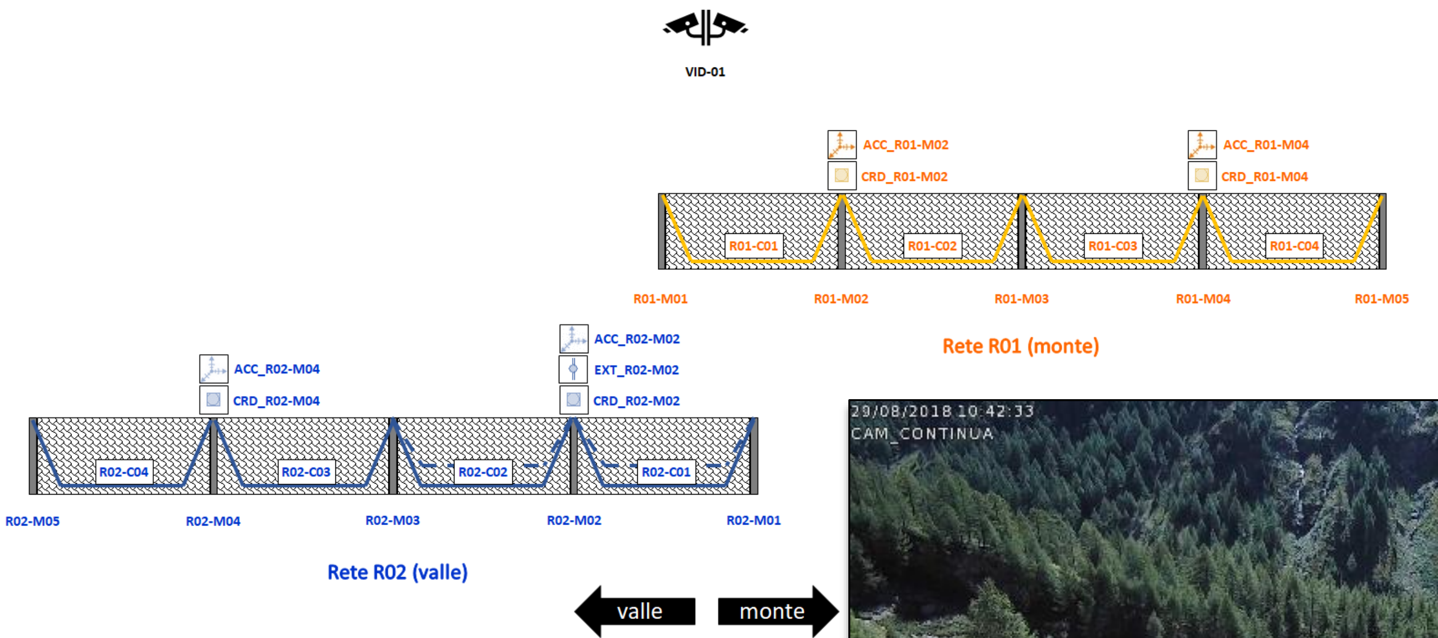

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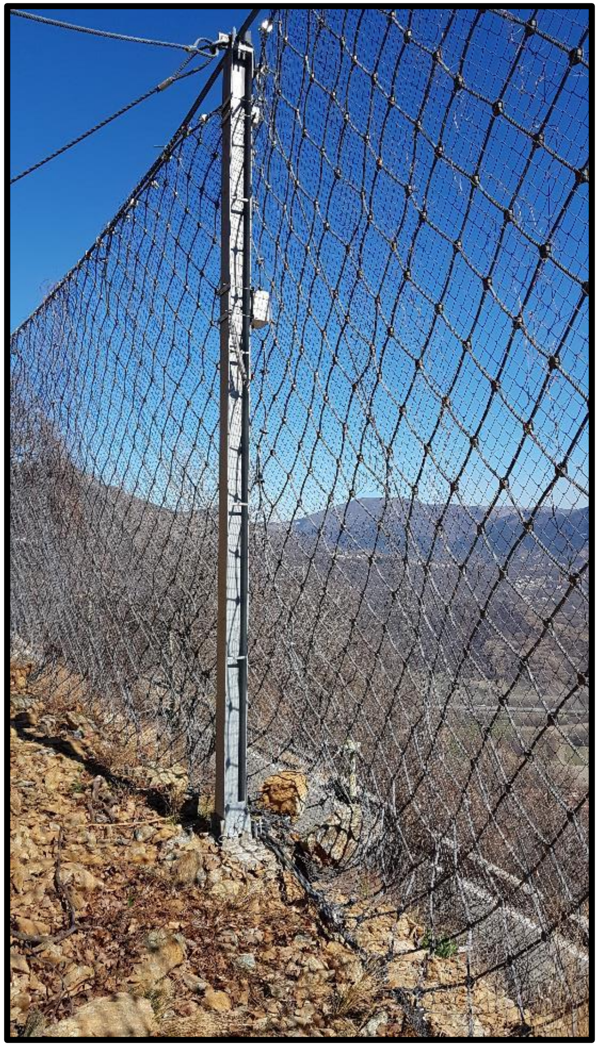

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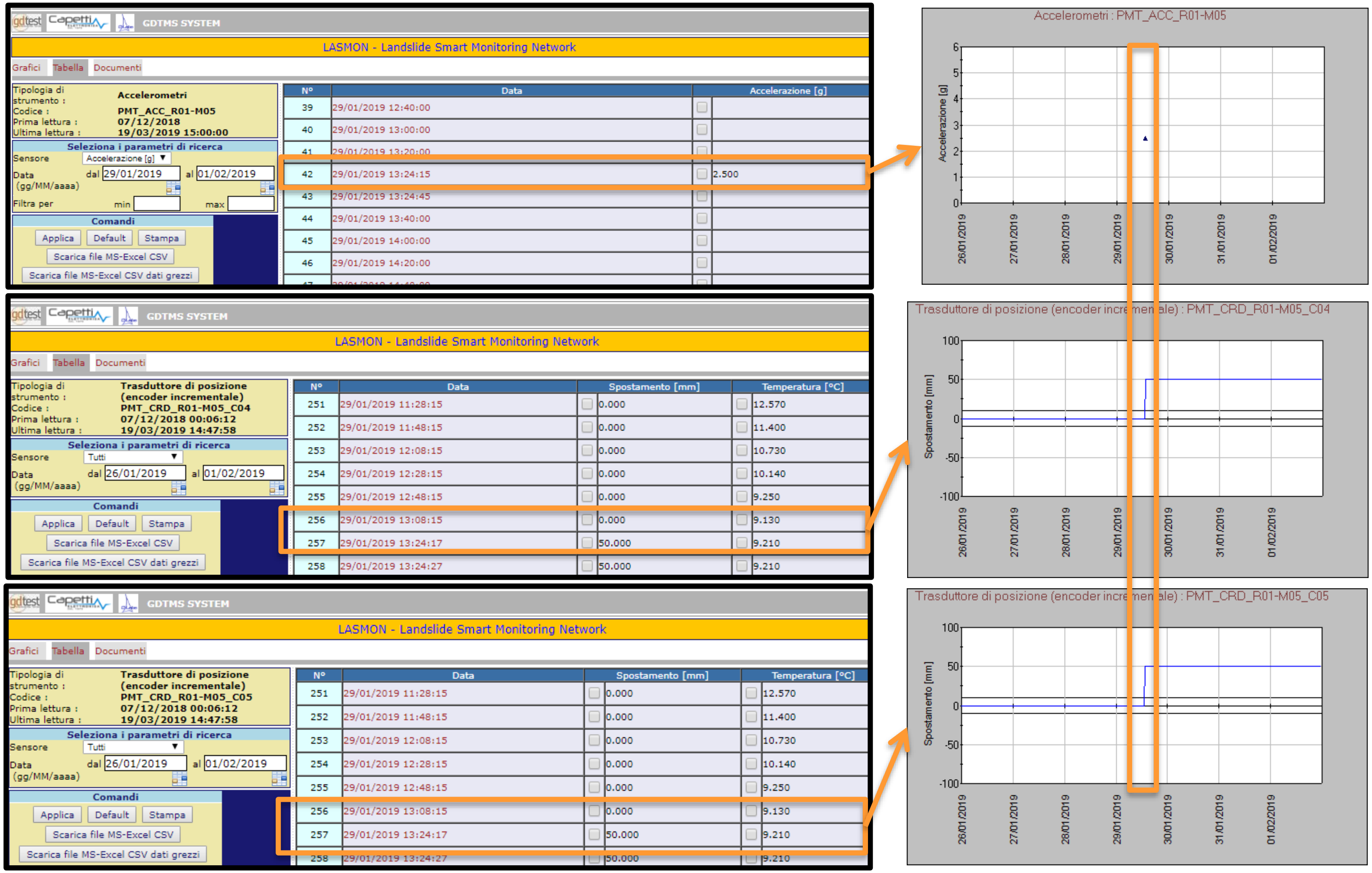

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Conclusion

The use of recent innovative solutions can be an useful support for the management of rockfall prone areas

UAV can be considered one of the most powerful systems for the creation of ultra high-resolution digital outcrop models and DSMs of studied areas

UAV can be used on demand even in dangerous areas without a direct access to the most critical sectors

On the other hand, the use of SMART NETWORK can be a great solution for the creation of complex monitoring network that can control many phisical parameters but also the integrity of rockfall protection active and passive infrastructures

Thank you for your attention

http://gmg.irpi.cnr.it