106° Congresso Nazionale – Società Italiana di Fisica 14-17 Settebre 2020

Sezione IV - Geofisica e fisica dell'ambiente

Merging Digital Image Correlation (DIC) and Persistent scatterers interferometry (PSInSAR), to study paroxysmal acceleration in slow landslide

Combinare le tecniche di Digital Image Correlation e Persistent Scatterer Interferometry per lo studio di frane lente con accelerazioni parossistiche.

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Istituto di Ricerca per la Protezione Idrogeologica

Consiglio Nazionale delle Ricerche

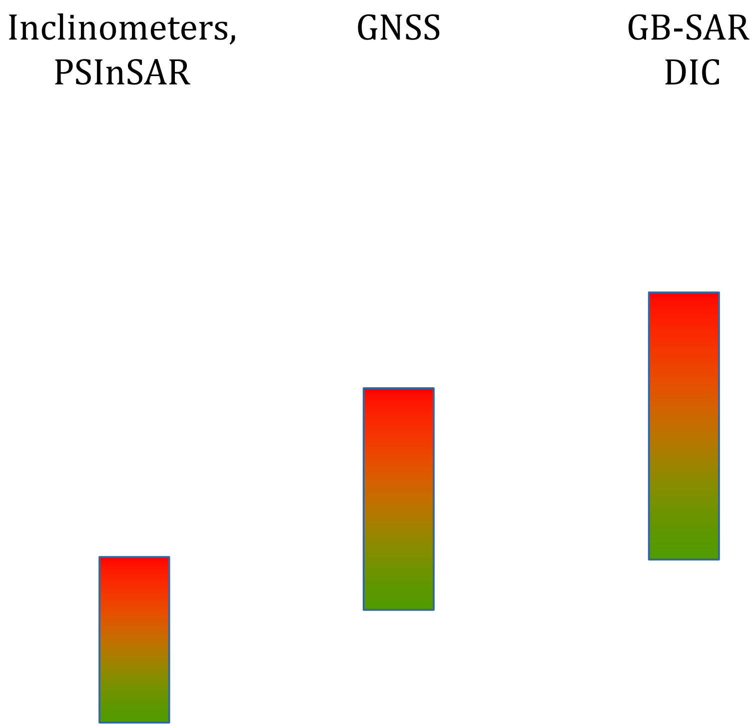
istituto per il rilevamento elettromagnetico dell'ambiente

The problem

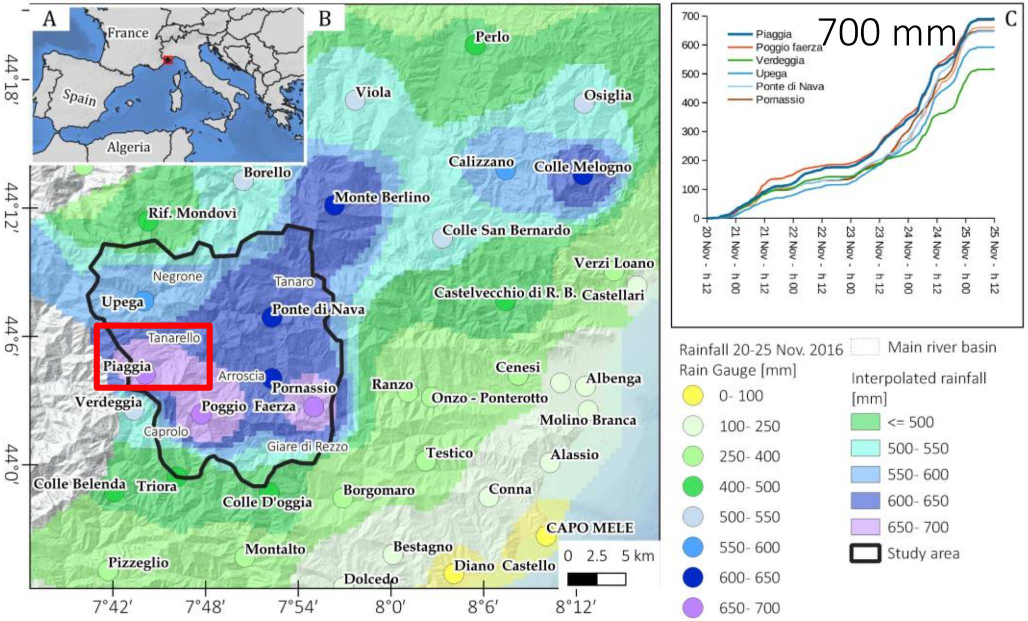
Extreme events like strong earthquake, intense rainfall, snow melting could reactivate or accelerate, sometimes up to a catastrophic failure, landslides that usually have very slow velocity. Many landslides before paroxysmal acceleration are not studied and monitored.
Remote sensing data could help into study these acceleration.

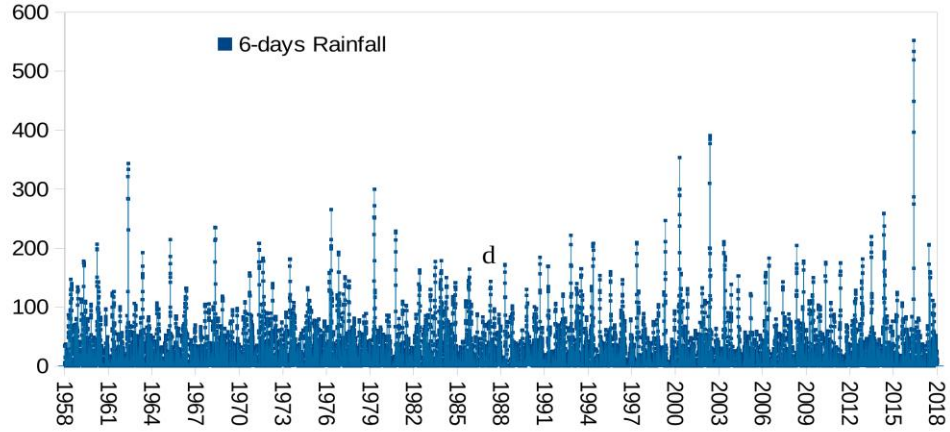
Velocity of a landside according to Cruden and Varnes classification (modified from Cruden and Varnes, 1996).

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		5×10^{3}	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		5×10^{1}	3 m/min	
5	Rapid			Escape evacuation possible; structures; possessions, and equipment destroyed
		5×10^{-1}	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		5×10^{-3}	13 m/month	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		5×10^{-5}	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		5×10^{-7}	15 mm/year	
1	Extremely SLOW			Imperceptible without instruments; construction POSSIBLE WITH PRECAUTIONS



20-25 November 2016 flood event

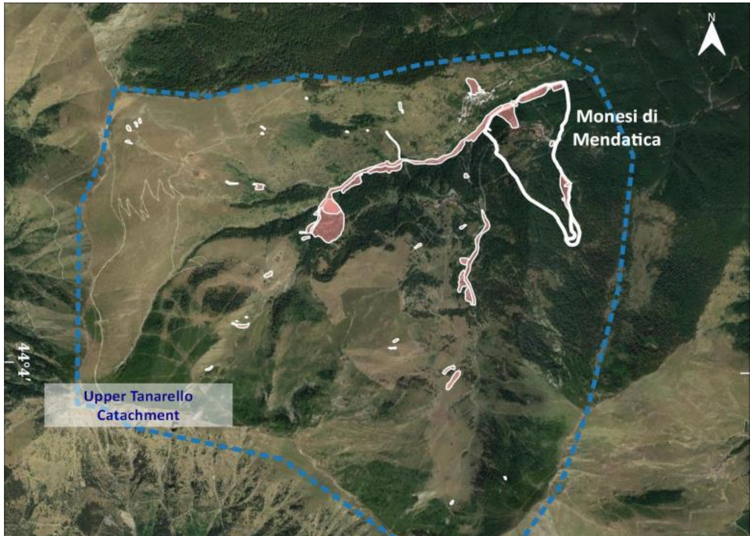




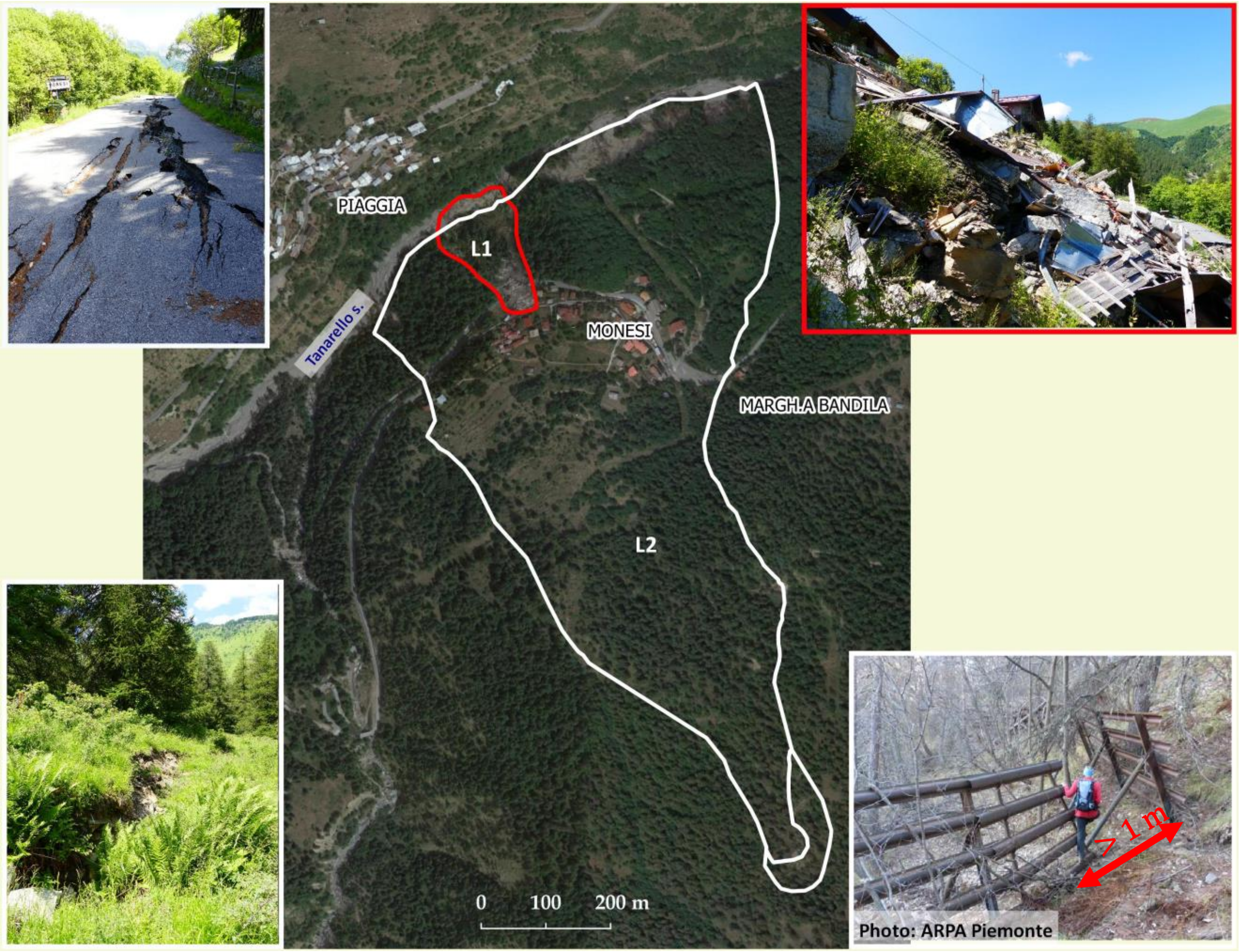
In the area of Ligurian Alps the most sever event in at least 70 years.

The upper Tanarello stream basin, between Piemonte and Liguria region was affected by many shallow landslides and reactivation of some deep landslides.

The village of Monesi di Mendatica was deeply affected by landslide reactivation.



20-25 November 2016 flood event



L1: Rotational landslide that collapsed destroyng road and buildings.

L2: Complex planar landslide, reactivation.

Field surveys show evidences that whole mass (10 m) slide toward NW of some meters in few days.

Several damages to the buildings, roads and walls.

20-25 November 2016 flood event

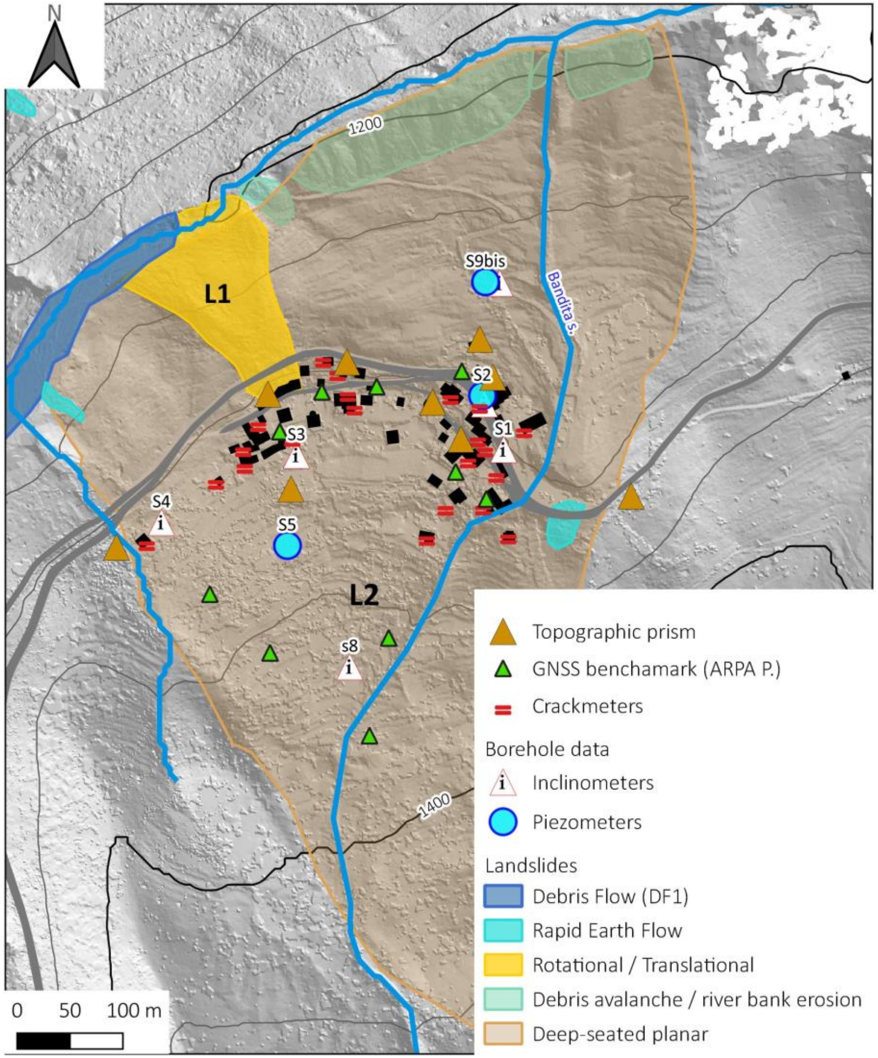
After the 2016 event a monitoring system was installed on landslides:

- GNSS
- Inclinometers
- Piezometers
- Topographic monitoring
- Crackmeters

However…

! Before and during the 2016 event the landslide mostly unknown !

Only remote sensing data helped us into assess the movement occurred before and during the events



Remote sensing data on Monesi landslides

Satellite

Multispectral

Sentinel-2: 10 m (2016; 2018) for DIC
Planet Scope: 3.7 m (2016; 2017) for DIC
Pleiades: 0.5 m (2016; 2017)

SAR

RADARSAT (2003-2009) processed with SqueeSAR, Regione Liguria

Sentinel-1 (2014-2019) processed with SqueeSAR, Regione Liguria

Aerial

Orthophoto AGEA, Regione Liguria
0.3 m SR (2016 pre event)

Google Earth

Helicopter

LIDAR (CNR-IRPI) 2017
Orthophto (0.1 m>) and DTM

UAV

Only on L1 landslides
HR DEM and orhtophto with SfM (2017), CNR-IRPI

GB-SAR

CNR-IRPI /CTTC

Monitoring L1

Digital Image Correlation (DIC) Technique

DIC is an image analysis technique whose purpose is to search for the patches in the master and slave images that maximize a given similarity function. DIC provides spatially-distributed maps of the two displacements orthogonal to the line of sight (LOS).

1 **Image selection**: first choice on images acquired in the same period of the year and/or at similar hour to guarantee a similar sun elevation and azimuth to minimise shadows changes. Discard images with different orthorectification, snow or cloud covered

2 **Monochromatic conversion:** RGB optical photographs into monochromatic images and image sharpening to enhance edge features.

3 **Co-registration:** we co-registered the images conducting a rigid translation according with the pixel offsets computed on a reference area assumed stable.

4 **Displacement calculation**: we calculated the NCC in a window that slides onto a regular grid that covered the whole image. Template overlapping allowed at increasing the spatial resolution of the maps.

5 **Outlier identification**: we refined the results adopting a statistical local metrics to identify and discard the outliers

We adapted the methodology and software (MATLAB) already tested for Planpincieux Glacier:

Journal of Glaciology

Classification and kinematics of the Planpincieux Glacier break-offs using photographic time-lapse analysis

Daniele Giordan[1], Niccolò Dematteis[1], Paolo Allasia[1] and Elena Motta[2]

Applied sciences

Article

Image Classification for Automated Image Cross-Correlation Applications in the Geosciences

Niccolò Dematteis, Daniele Giordan * and Paolo Allasia

ISPRS Journal of Photogrammetry and Remote Sensing

4D surface kinematics monitoring through terrestrial radar interferometry and image cross-correlation coupling

Niccolò Dematteis[a,b], Daniele Giordan[a,*], Francesco Zucca[b], Guido Luzi[c], Paolo Allasia[a]

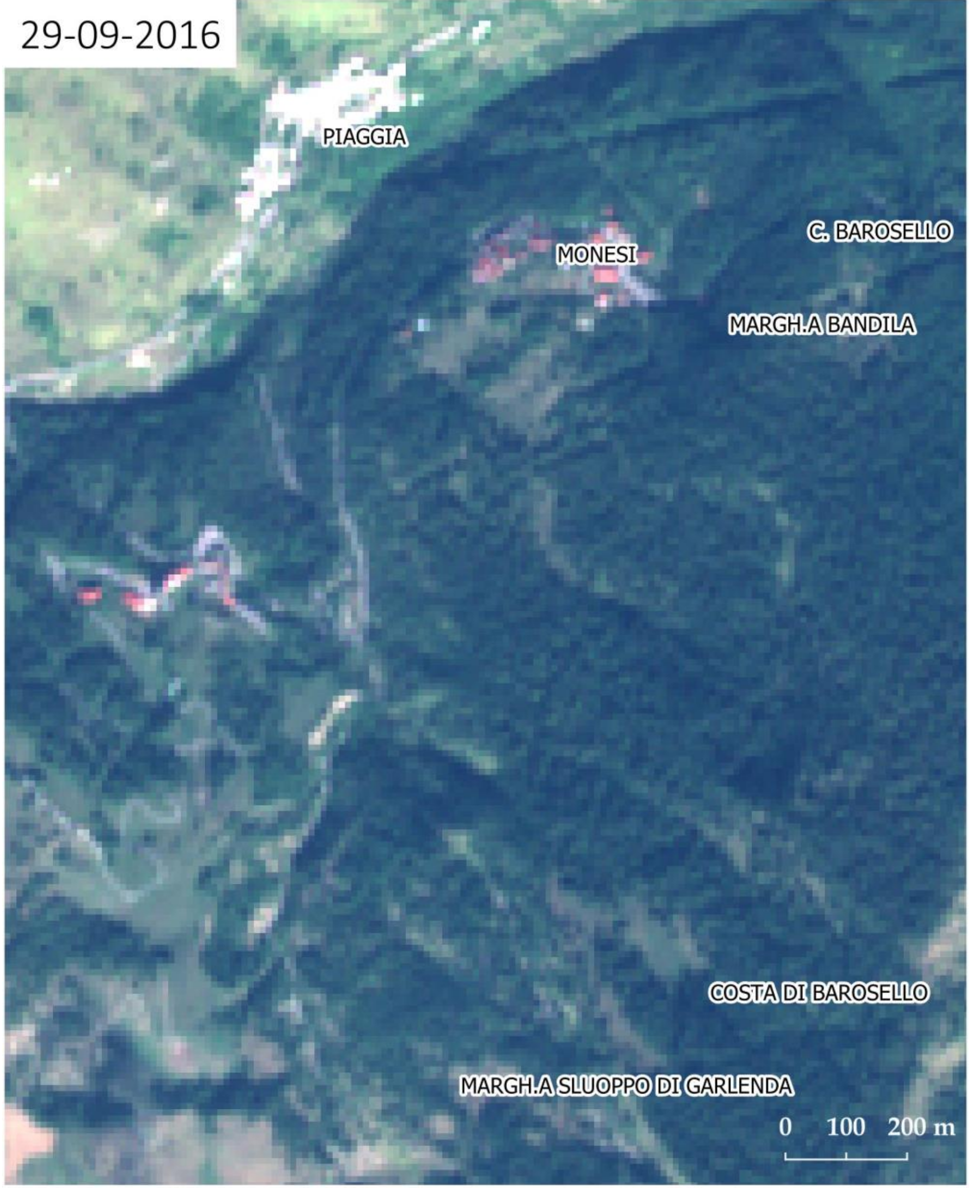
Sensors

Article

A Low-Cost Optical Remote Sensing Application for Glacier Deformation Monitoring in an Alpine Environment

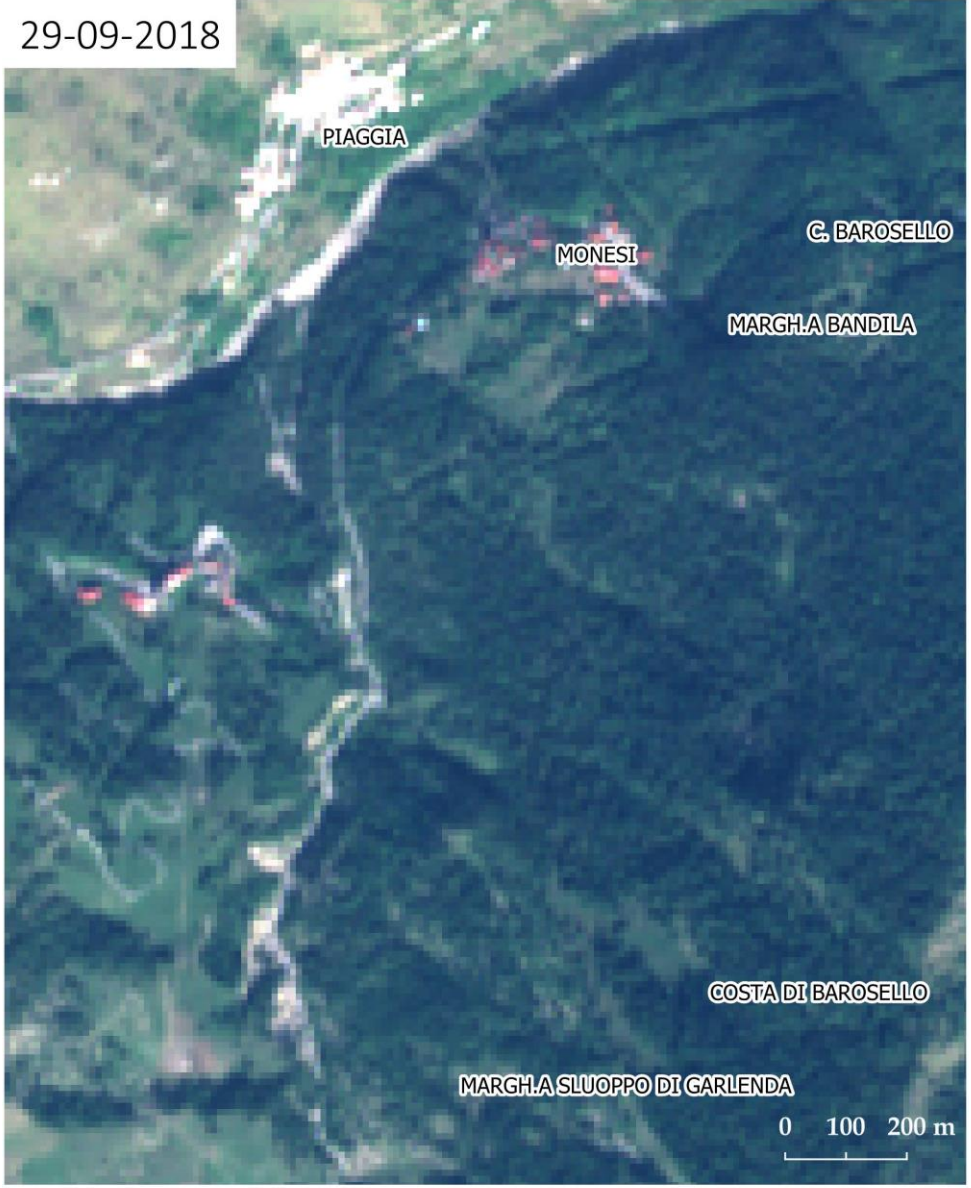
Daniele Giordan [1], Paolo Allasia [1], Niccolò Dematteis [1,*], Federico Dell'Anese [1], Marco Vagliasindi [2] and Elena Motta [2]

Sent-2: 10m SR



29-09-2016
PIAGGIA
MONESI
C. BAROSELLO
MARGH.A BANDILA
COSTA DI BAROSELLO
MARGH.A SLUOPPO DI GARLENDA
0 100 200 m

Sent-2: 10m SR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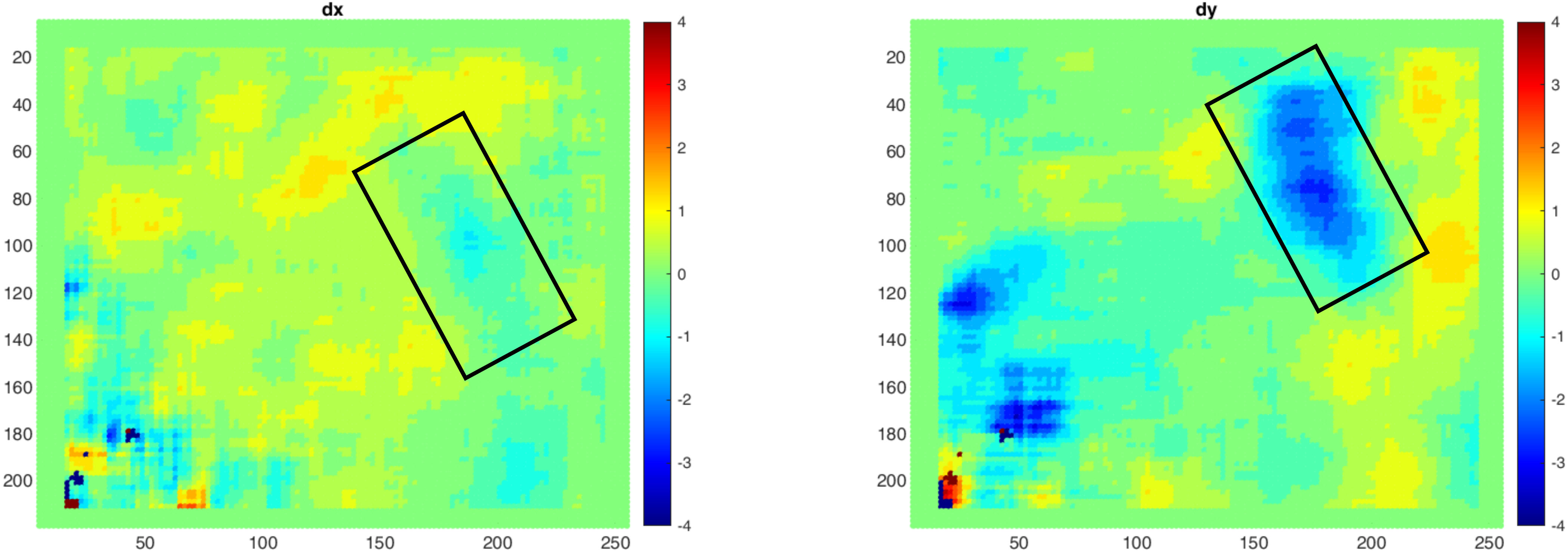
Digital Image Correlation (DIC) Technique

Sent-2: 10m SR

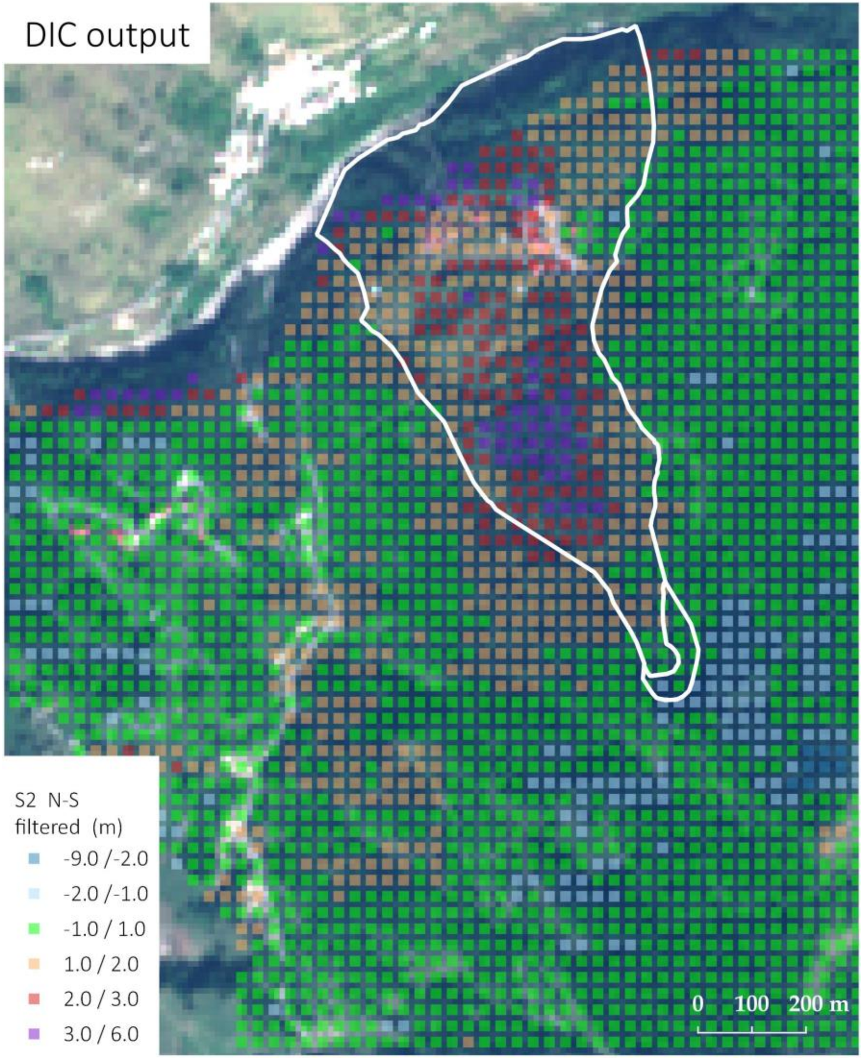
MatLAB output



Digital Image Correlation (DIC) Technique

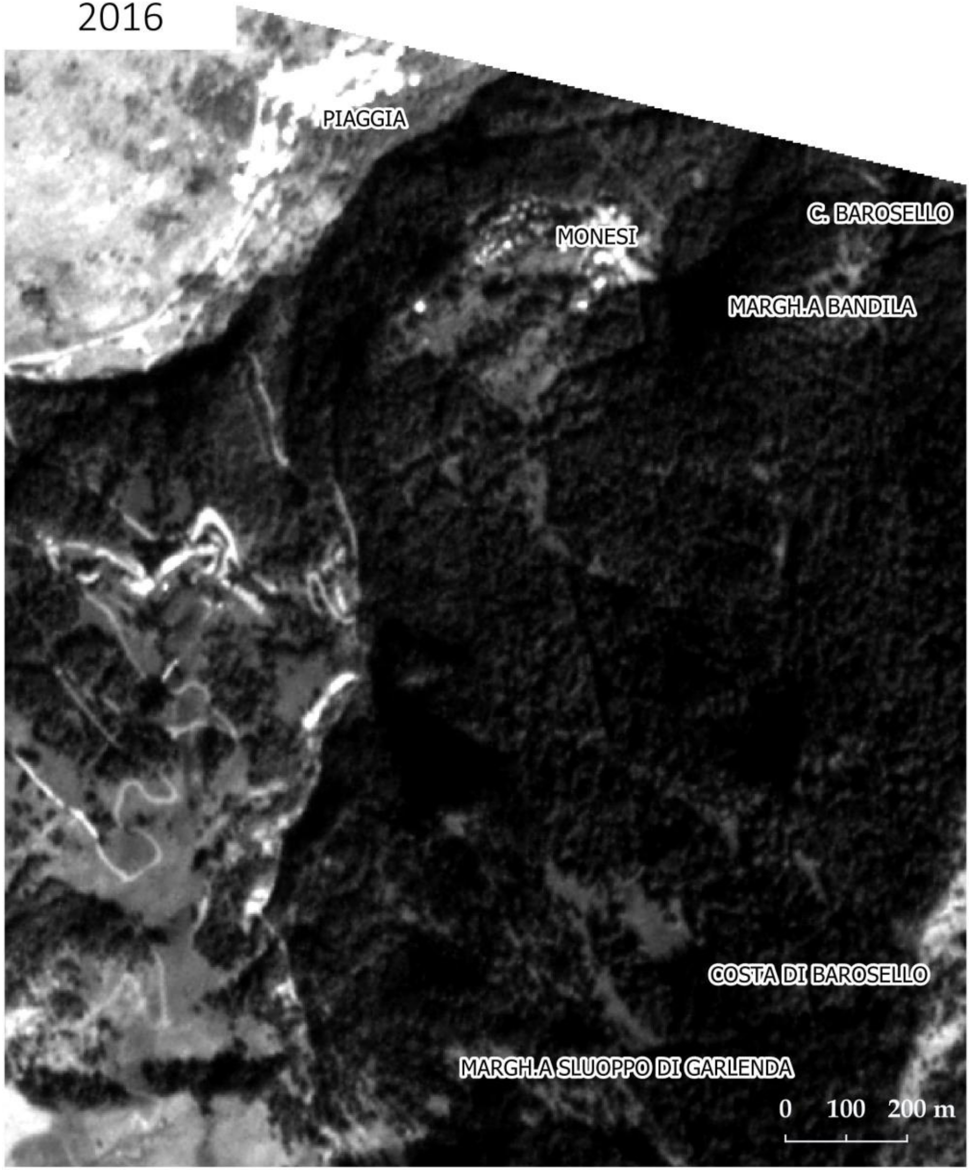
Sent-2: 10m SR

Results exported to GIS for filtering and comparison

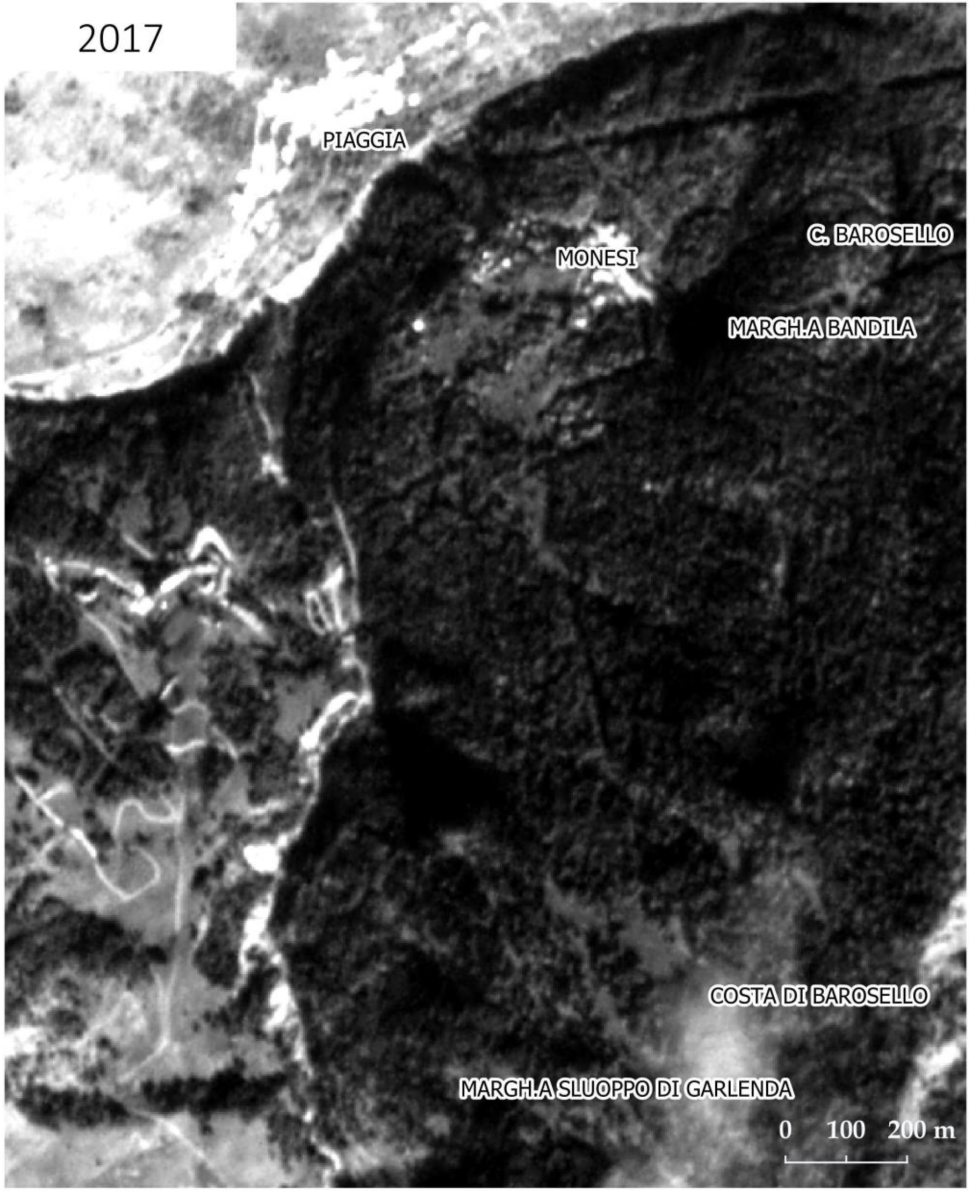


Planet Scope;
3 m SR

2016



Planet Scope;
3 m SR

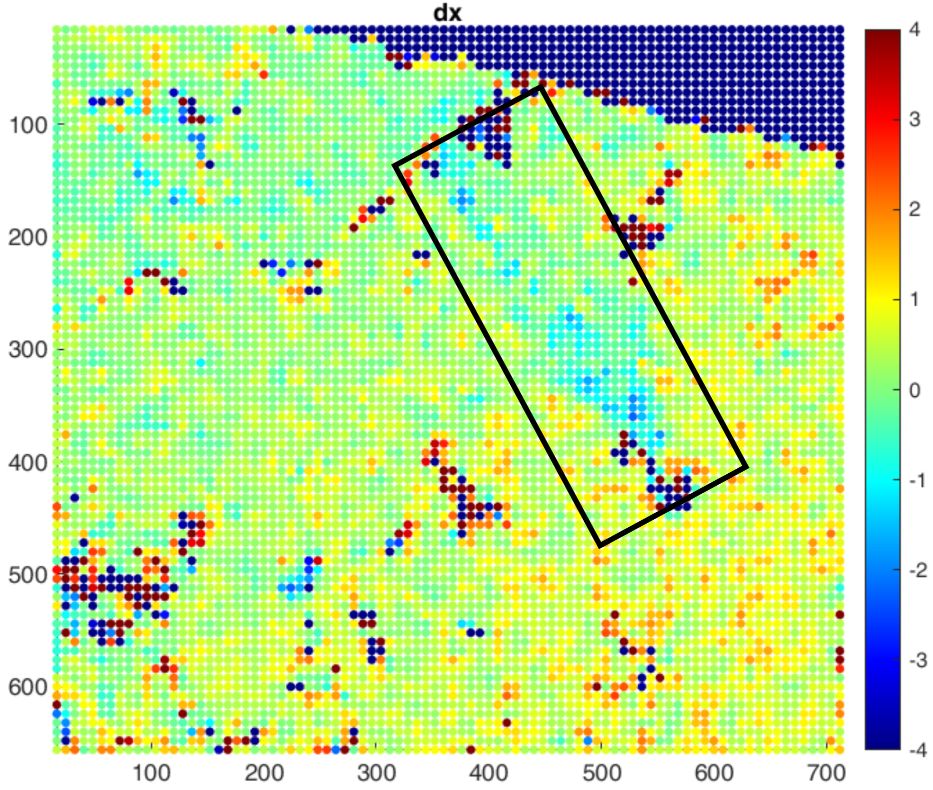


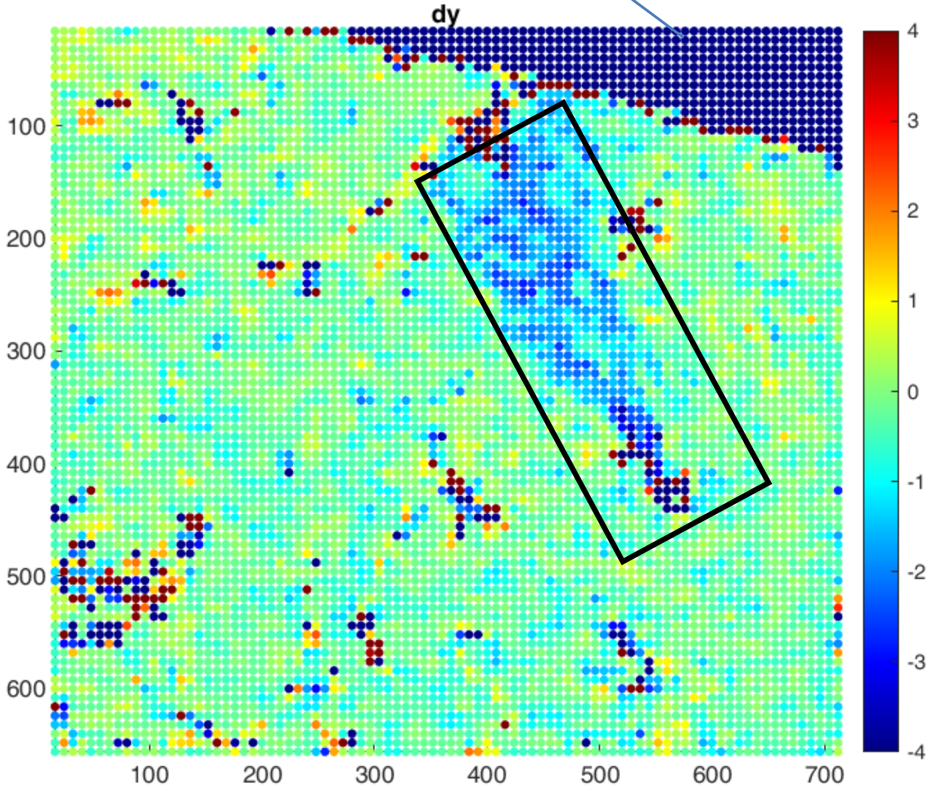
Digital Image Correlation (DIC) Technique

Planet Scope;
3 m SR

MatLAB output

No DATA



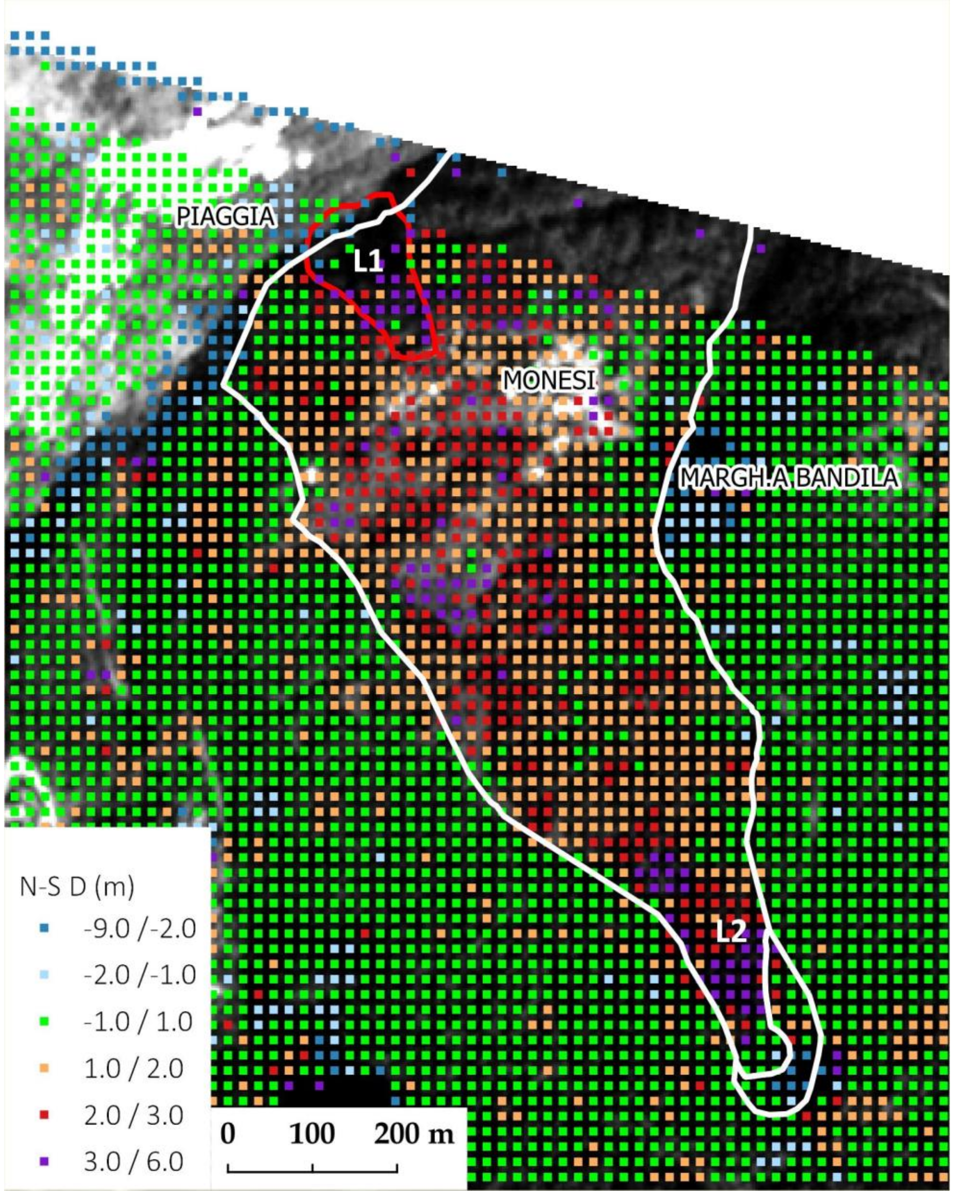


X (east-west) component is weak and most affected by noise

Noise / Outllayer

Planet Scope;
3 m SR

Results exported to GIS for filtering and comparison

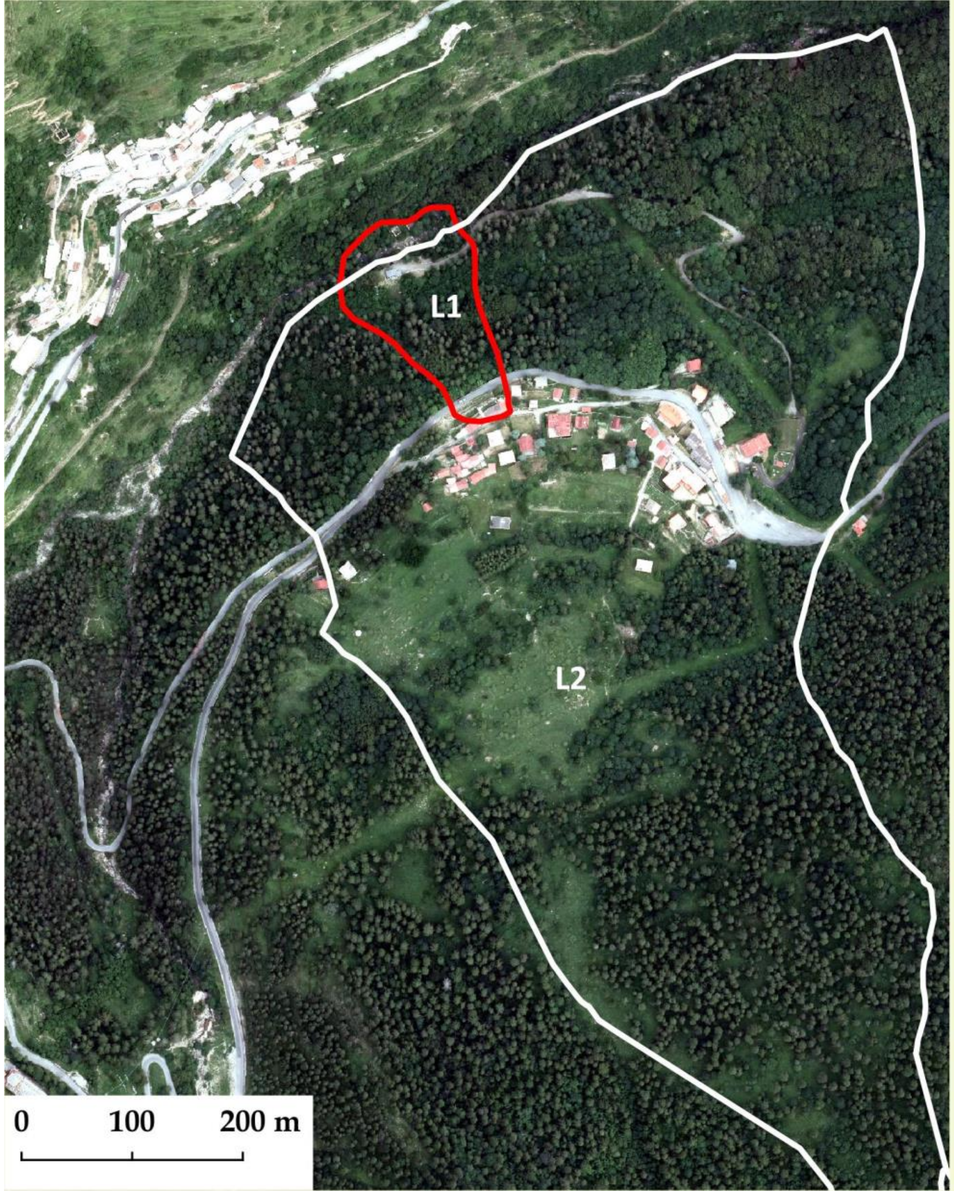


DIC from

Orthophoto LIDAR (2017)
Vs
Orthophoto Liguria (2016)

Spatial Resultion
0.3 m

In this case the effect of the shadow, the different conditions of light and some deformation in geocoding affect the results despite the very-high resolution



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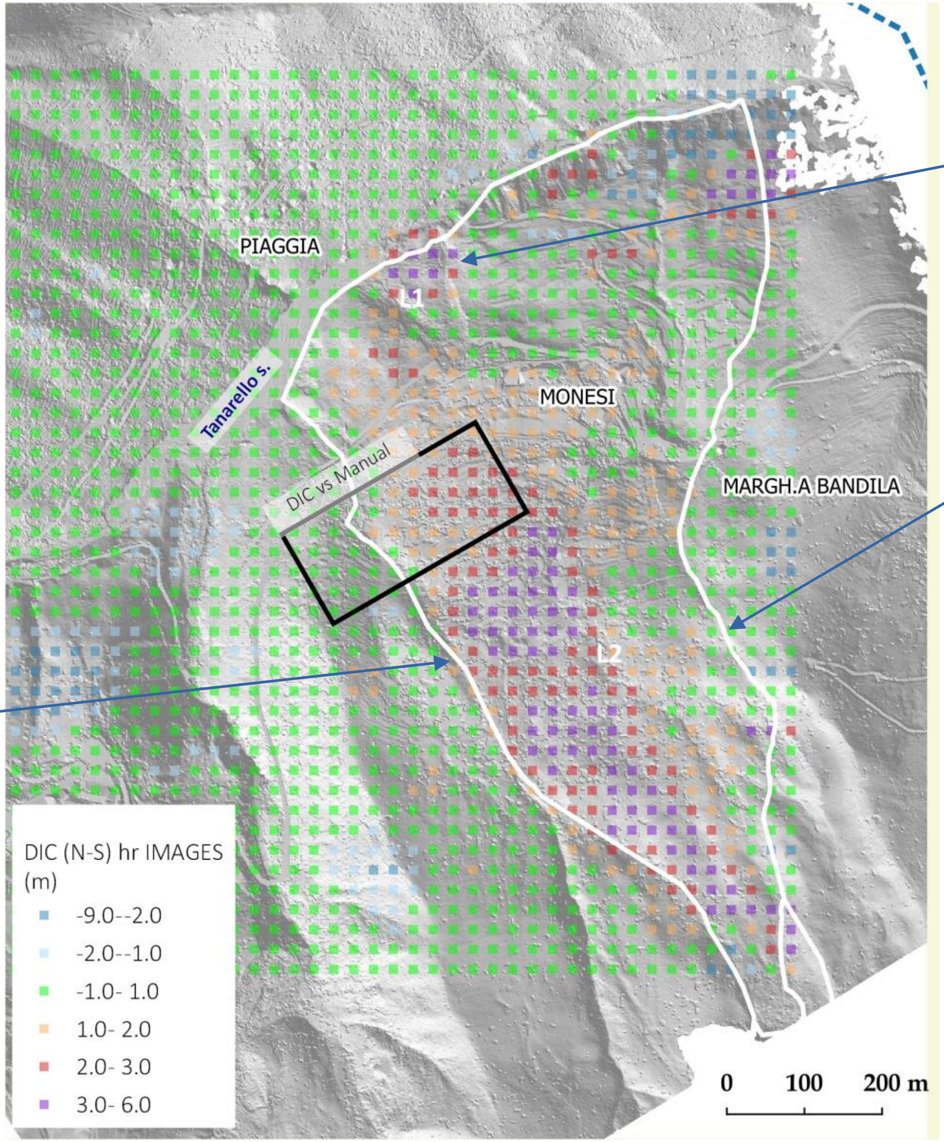
DIC from

Orthophoto LIDAR (2017)
Vs
Orthophoto Liguria (2016)

Spatial Resultion
0.3 m

Sharp
boundary



L1 and shallow landslide decorrelation

Smooth and uncertain boundaries
(dense forest areas)

Manual Mapping

Orthophoto LIDAR (2017)
Vs
Orthophoto Liguria (2016)

Spatial Resultion
0.3 m

2016 g.o. identification

2016

2017

Manual Mapping

Orthophoto LIDAR
(2017)
Vs
Orthophoto Liguria
(2016)

Spatial Resultion
0.3 m

2017 g.o.
identification

Manual Mapping

Orthophoto LIDAR (2017)
Vs
Orthophoto Liguria (2016)

Spatial Resultion
0.3 m

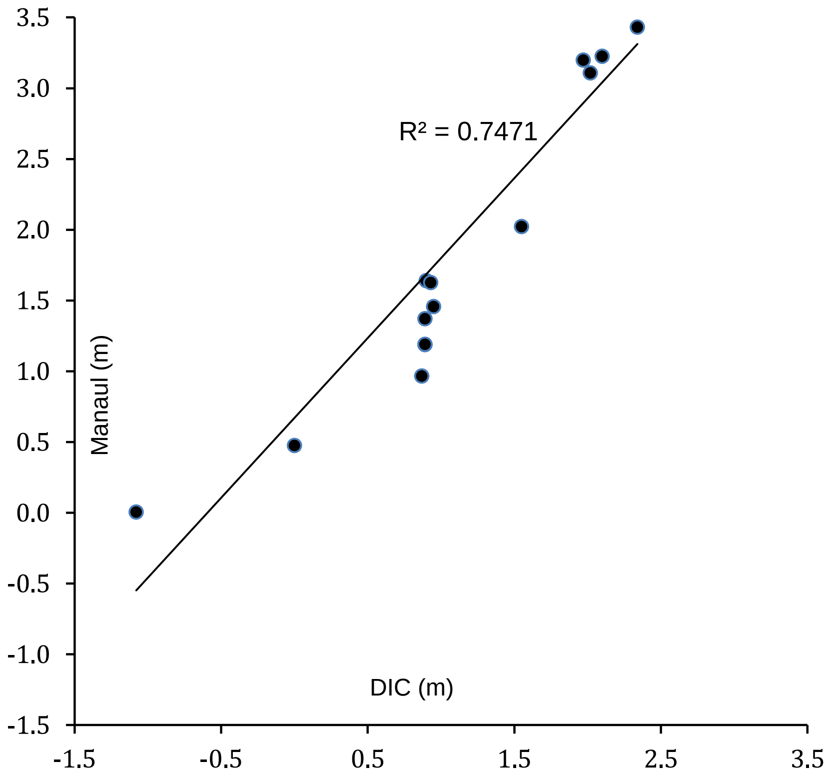
2017-2016
XY Displacement
Calculation

DIC vs Manual Mapping

The match of DIC with manual mapping is high despite several noise factors:

- land use decorrelation (e.g. shallow landslide);
- geocoding errors
- image deformations;
- Shadows
- forested areas
- differential offset (strip effects)
- Manual errors

DIC vs Manual Measure

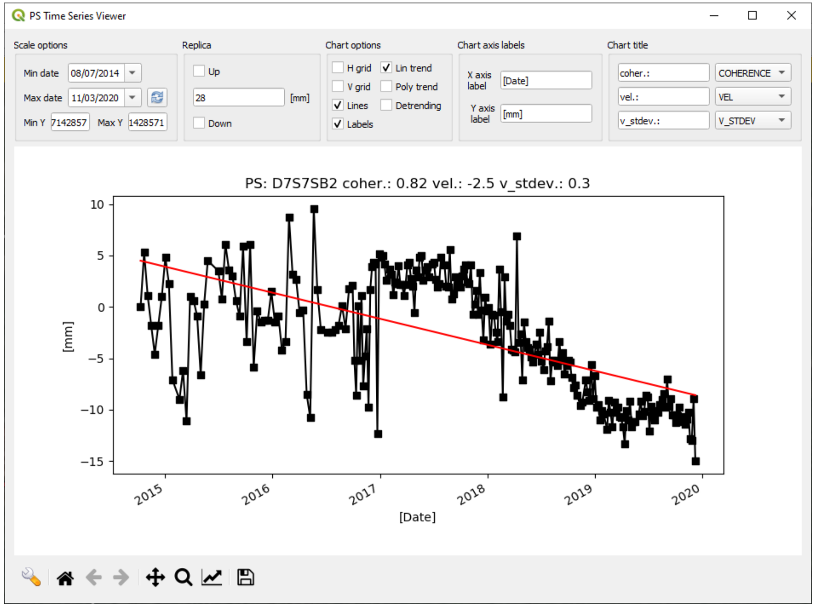


PSInSAR

Radarsat
Ascending and Descending geometries
2003-2019
Revisit time
24 days

Sentinel-1a/b:
Ascending and Descending geometries
2014-2019
Revisit time
10 days 2014-2016
5 Days 2016-2019

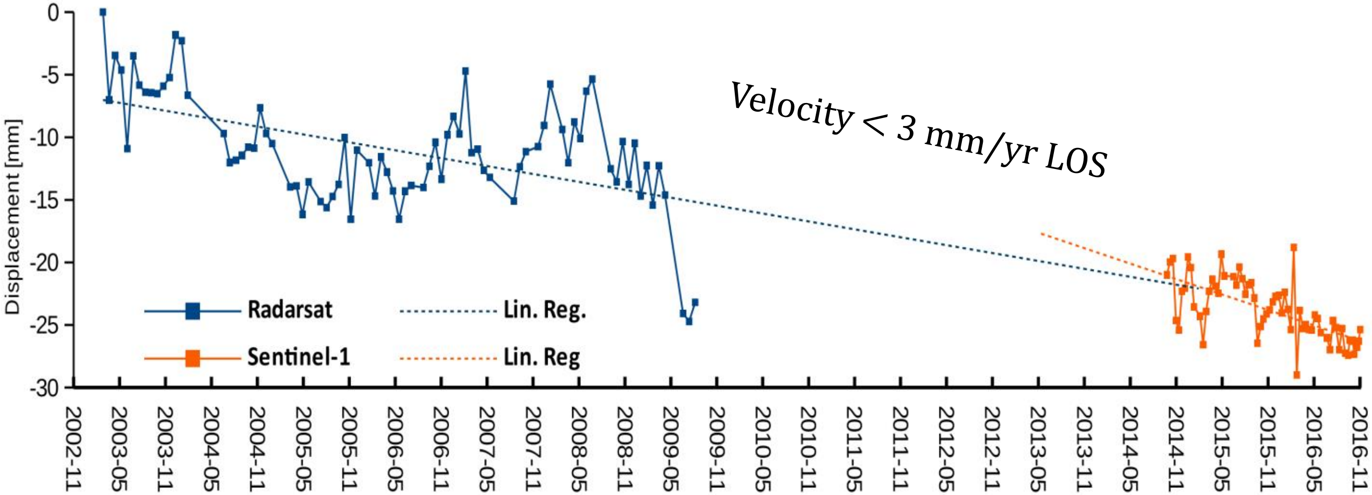
Processing SqueeSAR (Ferretti et al., 2011)
Regione Liguria

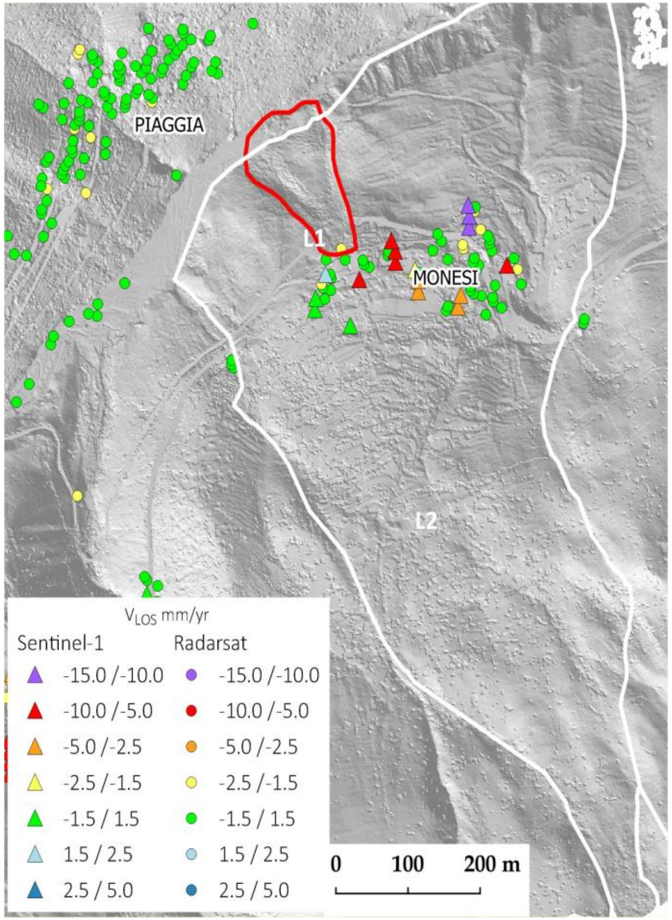


PSInSAR for pre- and post- event landslide activity assessment

Before the 2016 event the InSAR data is the only source to know landslide kinematics however:

1. Slope toward N – NNW velocity underestimated;
2. PS data only on the urban area.
3. Radarsat data TS noised
4. No data for 2000 flood events

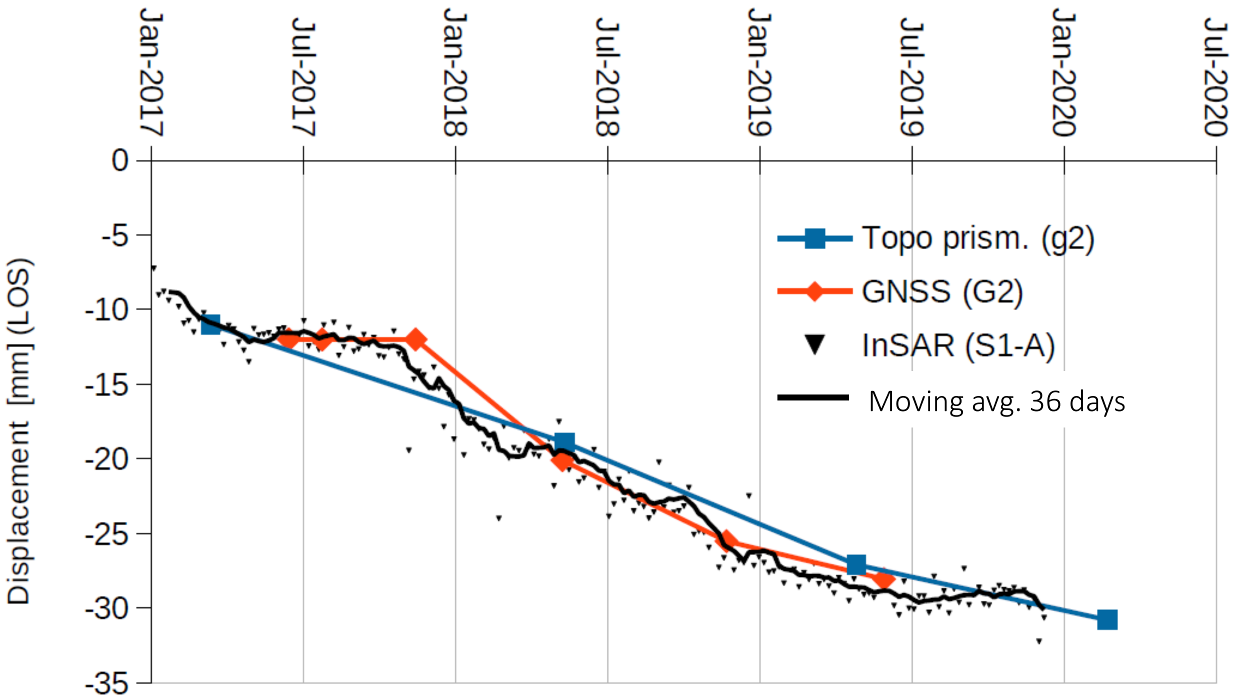


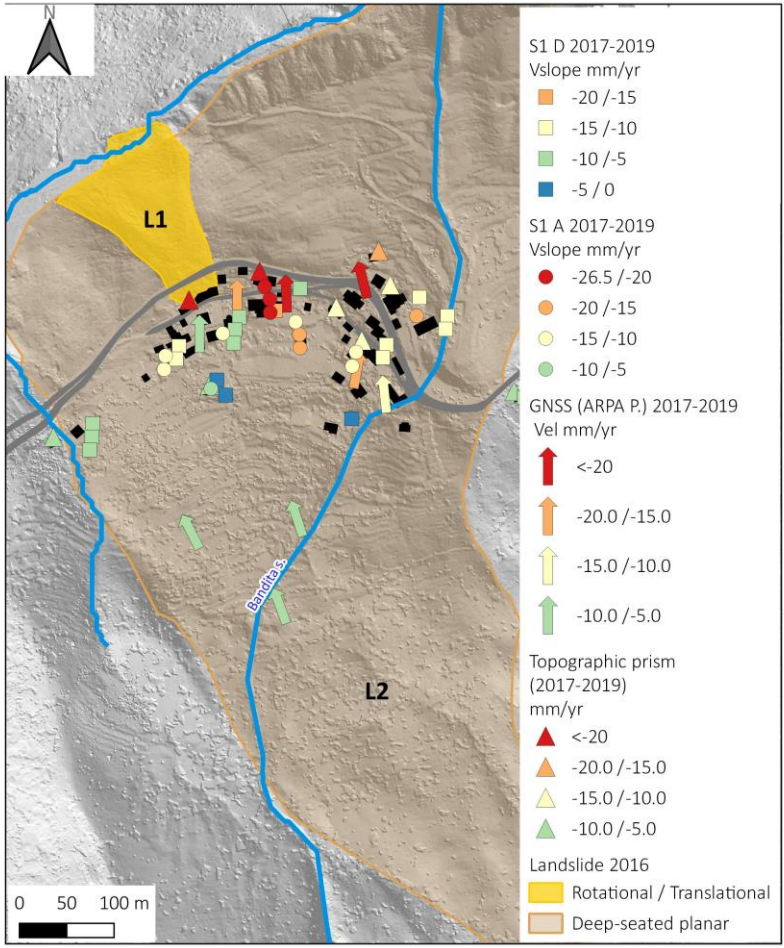


PSInSAR for pre- and post- event landslide activity assesement

Post-event Monitoring:

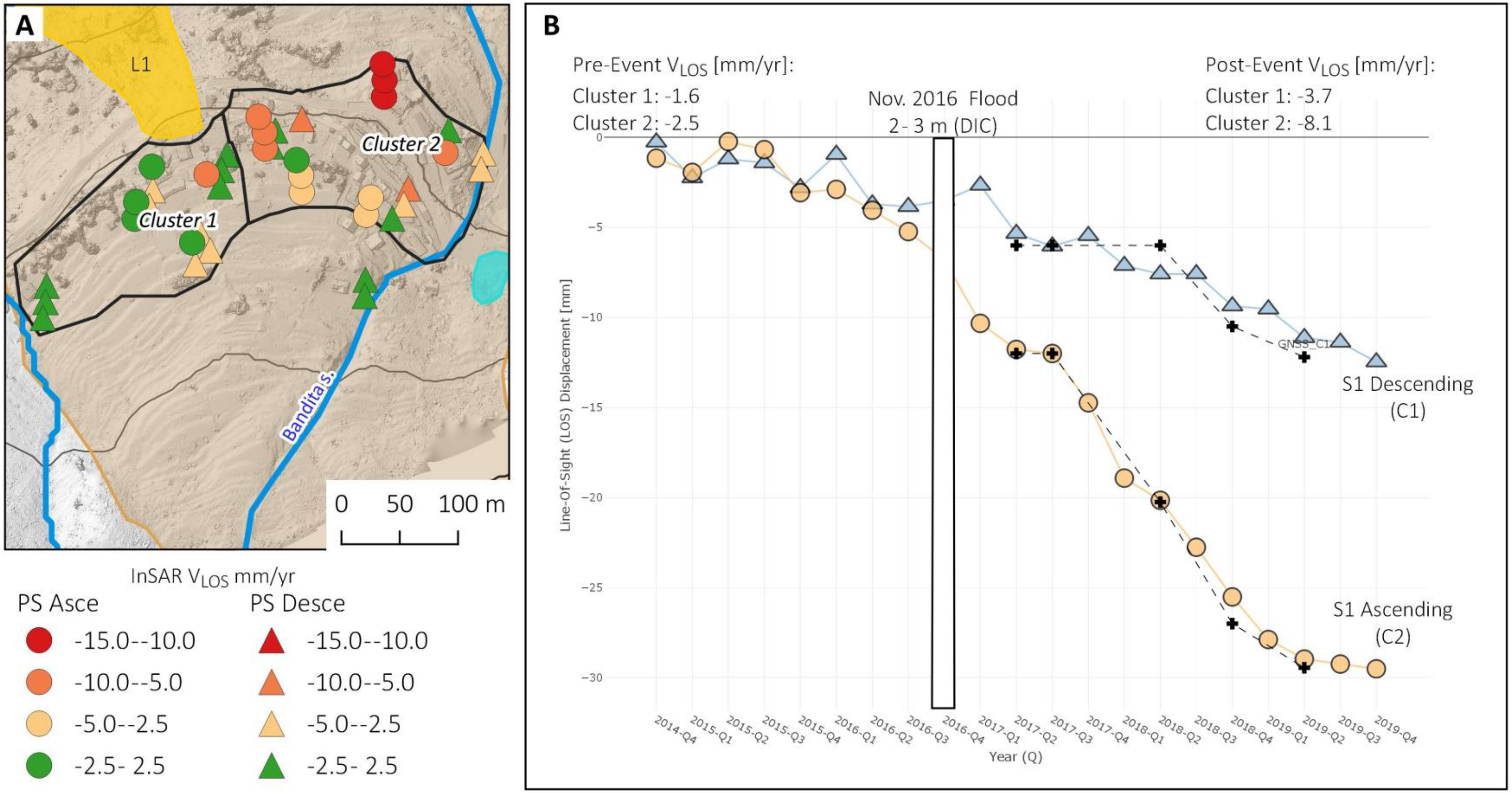
Sentinel-1 match with other ground based monitoring data both for velocity (Vslope) and time series



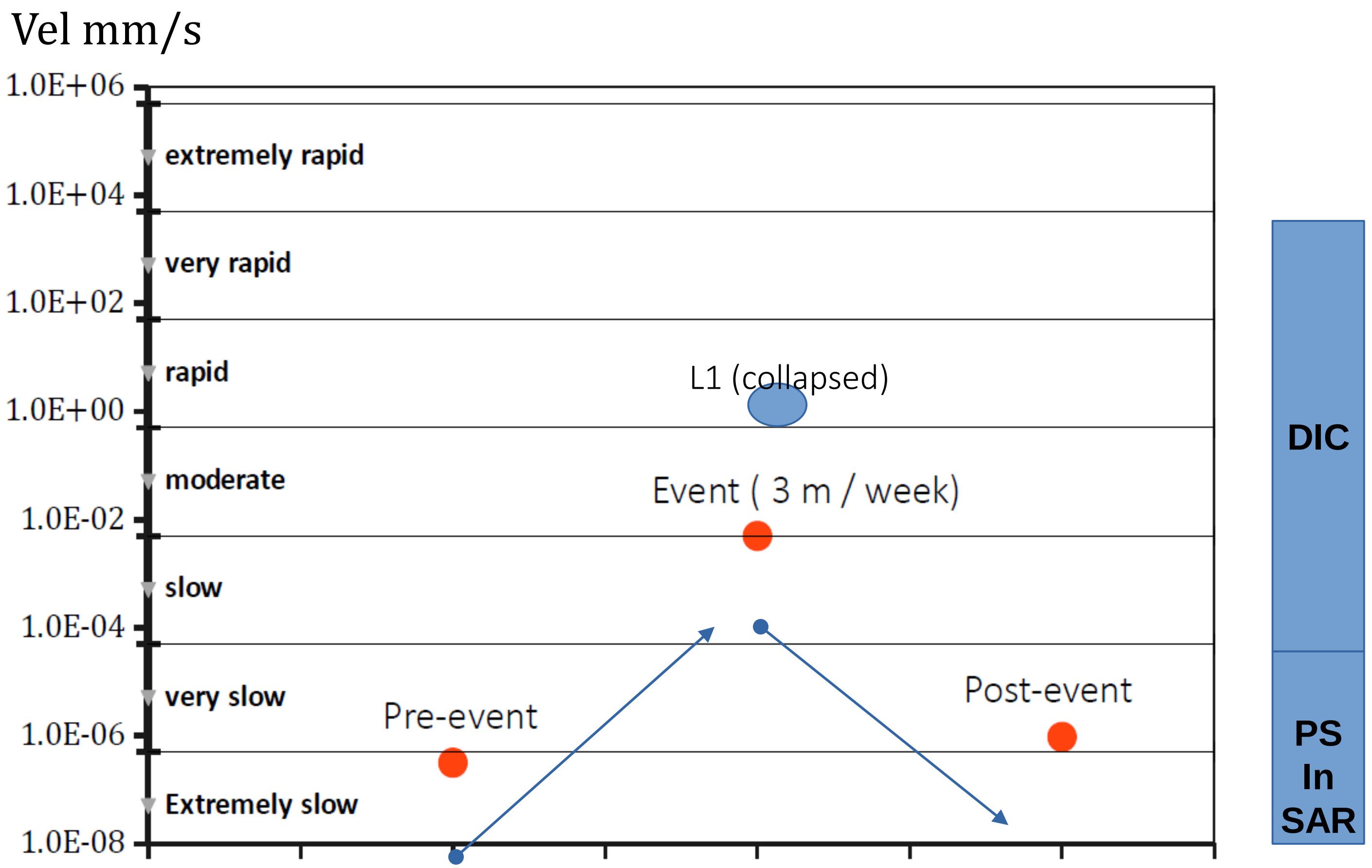


PSInSAR for pre- and post- event landslide activity assesement

InSAR data show a clear acceleration after the 2016 event



PSInSAR and DIC



Min/Max velocity detectable depends on:

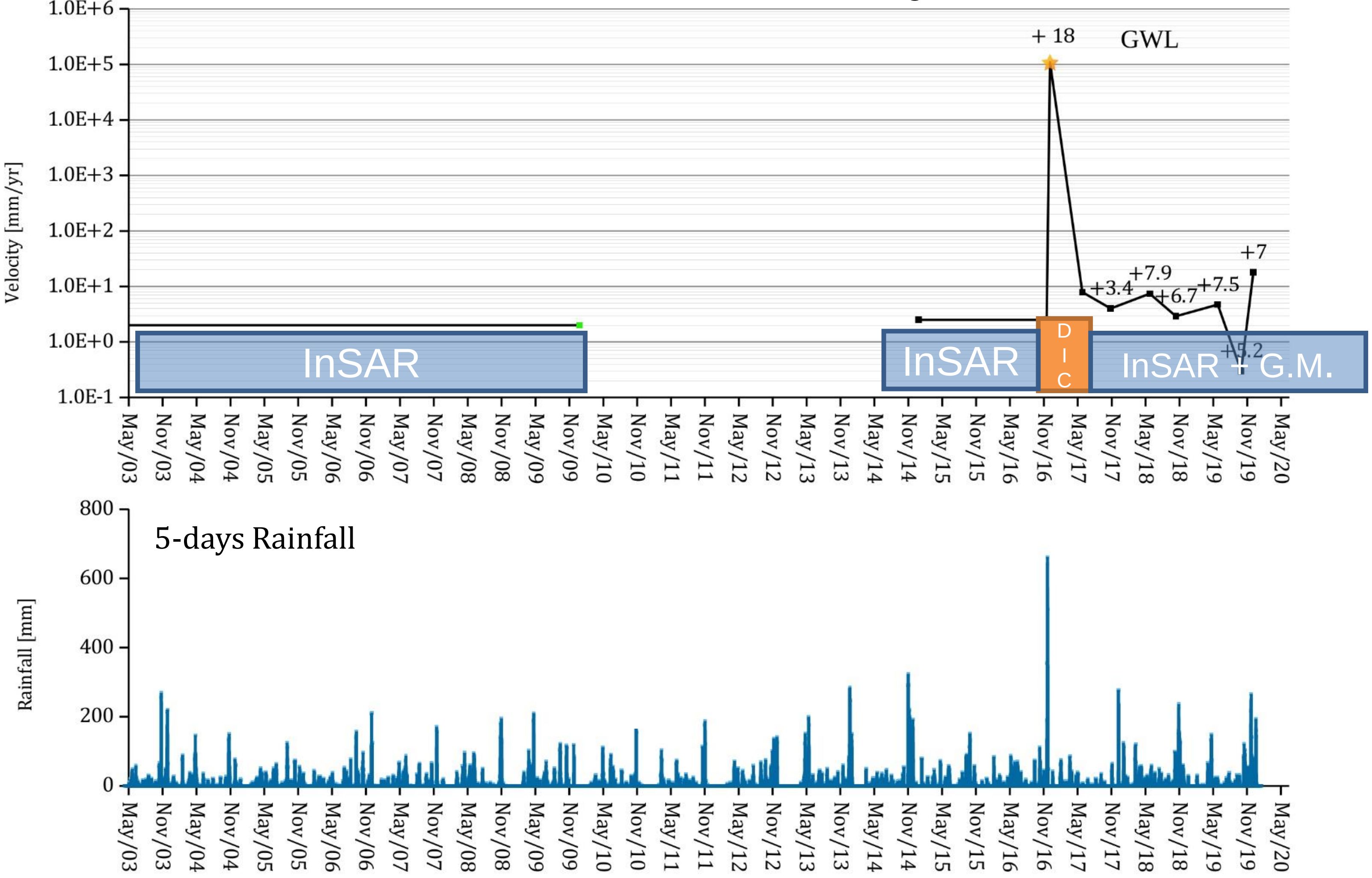
- Frequency of acquisition
- Spatial resolution
- Noise factor

MAX= ¼ λ,

S1 ~ 500 mm/yr

PSInSAR and DIC

And their contribute to landslide acknowledgments



Conclusions

PSInSAR

+ Many time its the only displacement data on extremely slow landslides;

+ The data from Sentinel-1 with high temporal sampling show time series with few noise that can be compared with other ground based instruments

+ Sensitive to vertical component

- It is limited by topographic and land-use constrain

- Only along LOS displacement

- The range velocity is limited for very slow landslides, paroxysmal accelerations are lost.

DIC

+Provide a displacement map of whole landslide areas,

+ It is the only displacement data for unmonitored landslides with paroxysmal accelerations

+ Could be used also with SAR amplitude images

- It is limited by image acquisition conditions and geocoding

- Only planar displacement (orthogonal to LOS)

- The range of velocity is more suitable for slow to moderate landslides

PSInSAR + DIC

> Spatial distribution of velocity

> Time series corrected with the paroxysmal acceleration

>Correlation with rainfall/groundwater both for slow and high velocity

> Important information for the landslides numerical modelling (*Notti et al., 2020 under revision*)


Thank you for your attention!