How to use interferometric data for landslide risk management

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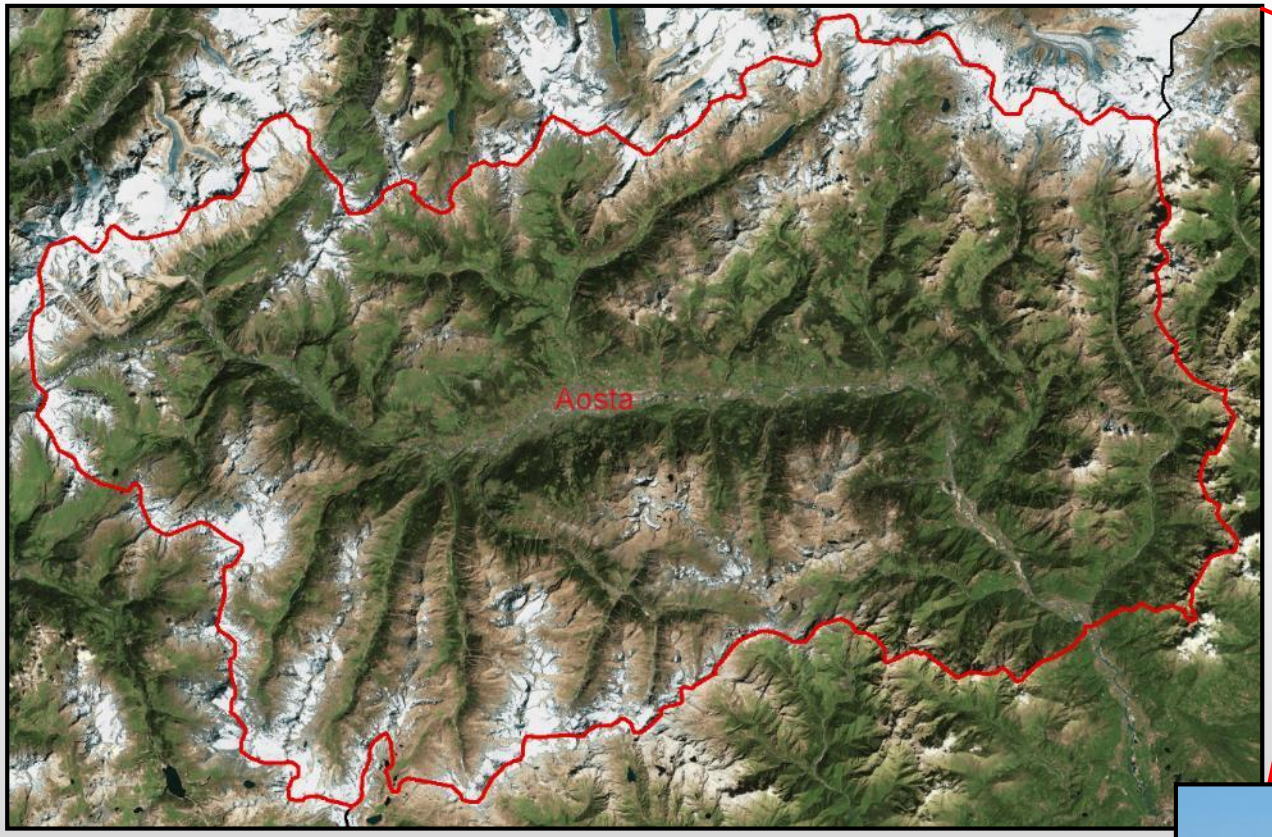
Aims & contents

- Present a methodology for landslide impact evaluation based on interferometric data, developed in the framework of U-Geohaz project
- Present the results of a 3-years monitoring project based on Sentinel-1 data, focusing on data management for Civil Protection aims

Satellite interferometry-based landslide impact assessment – an example from Valle d'Aosta Region

Valle d'Aosta region



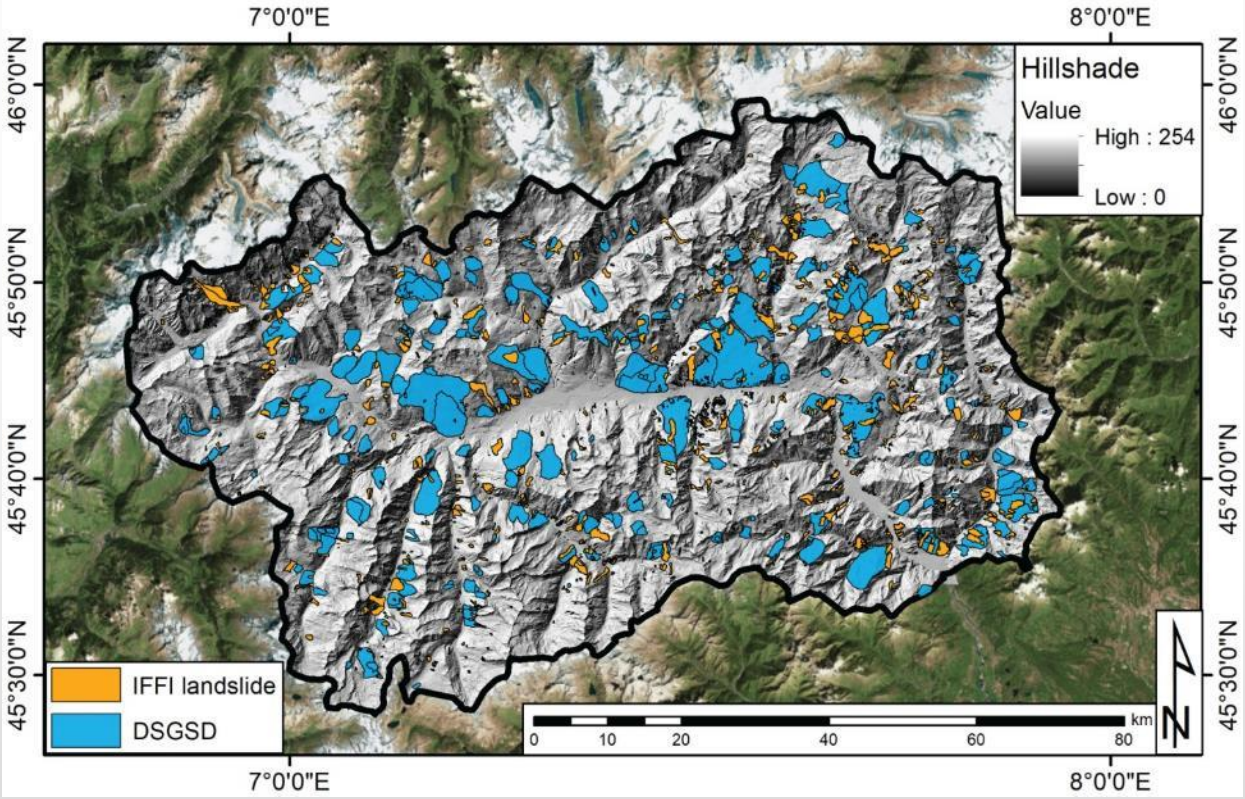
Surface = 3260 sqkm

Population = 126.687

Municipalities = 74

>50% of the territory is above 2000 m a.s.l.

Valle d'Aosta – Landslide risk



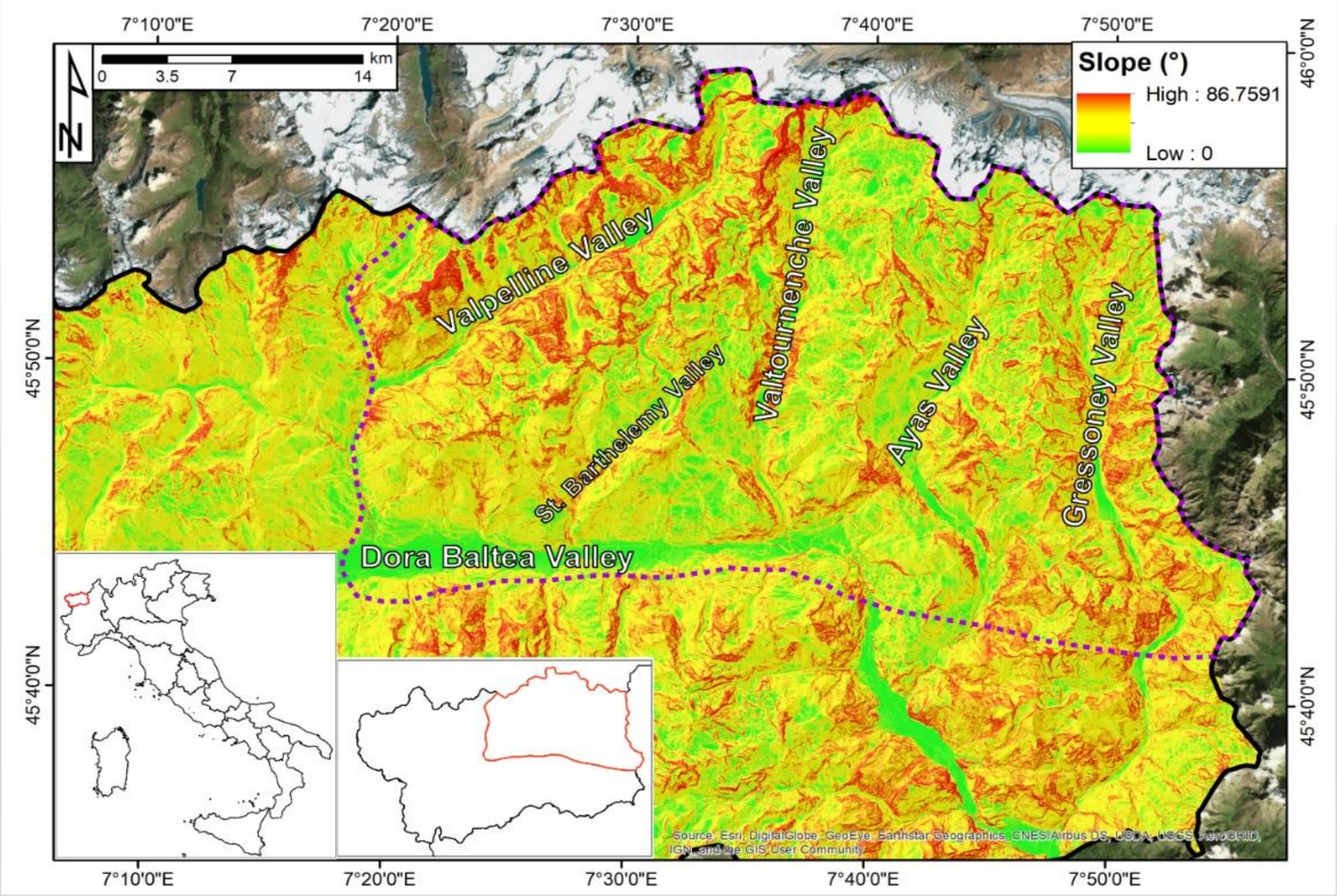
4400 landslides

134 landslides/100 sqkm

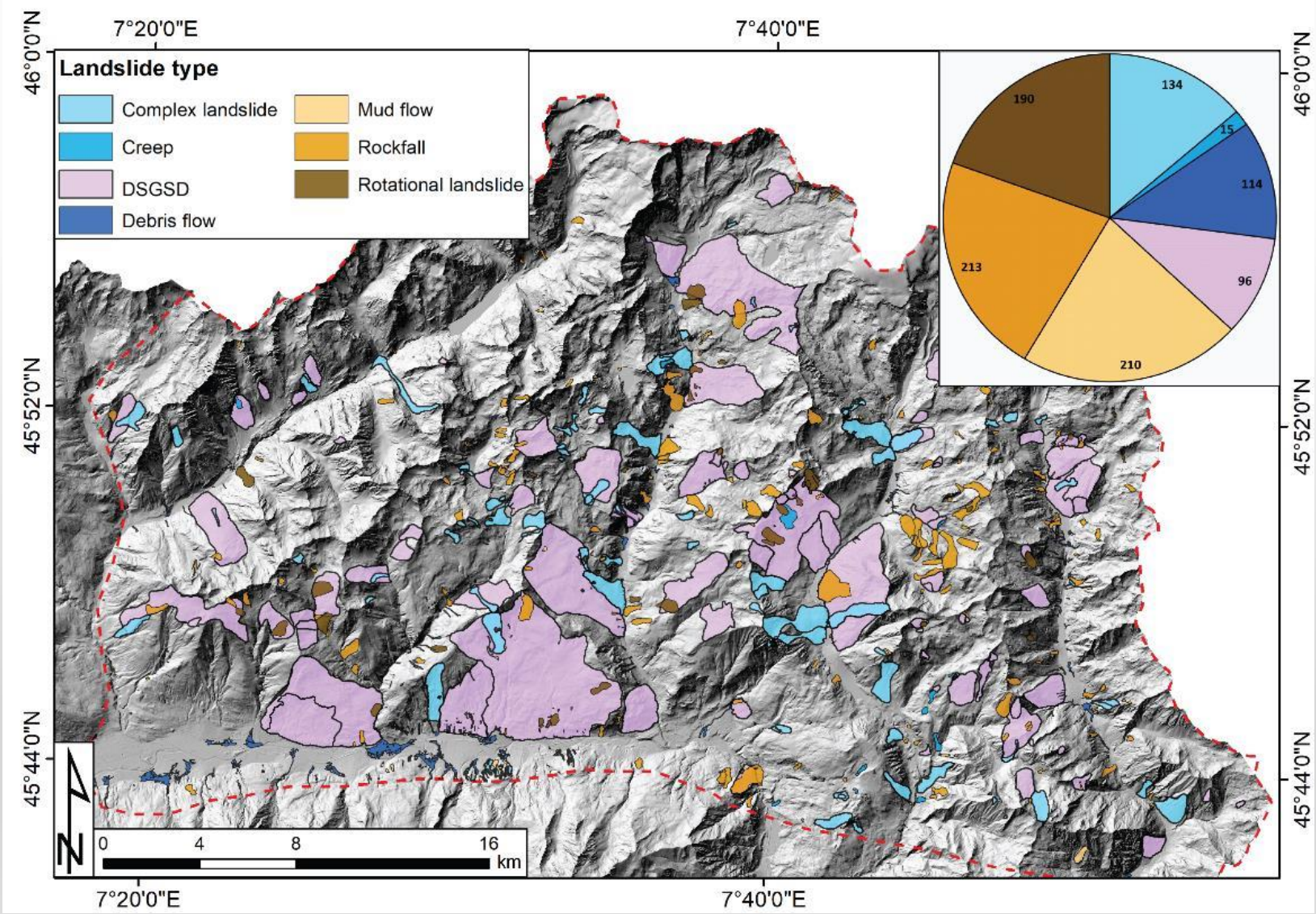
520 sqkm affected by landslides (16% of the total)

Rockfalls, complex and rotational landslides are common

Test area – NE Valle d'Aosta

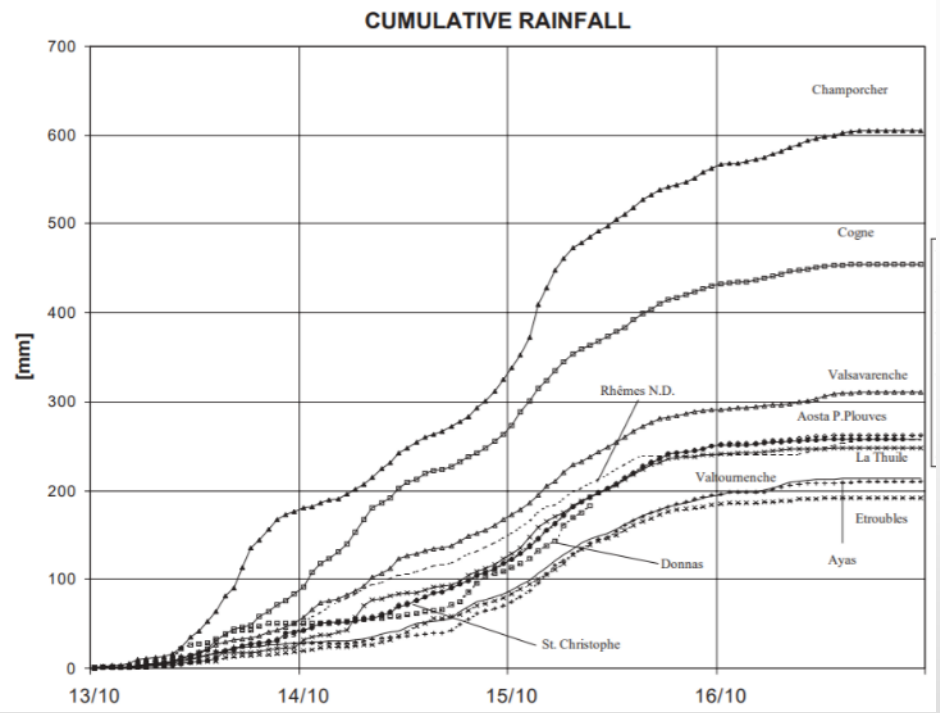


Test area – NE Valle d'Aosta



Landslide index = 20%, some DSGSD cover more than 10 km^2

Test area – Past events



13 to 16 October 2000 rainfalls:

385 landslides - 259 debris flows

17 people died

500 millions euros lost

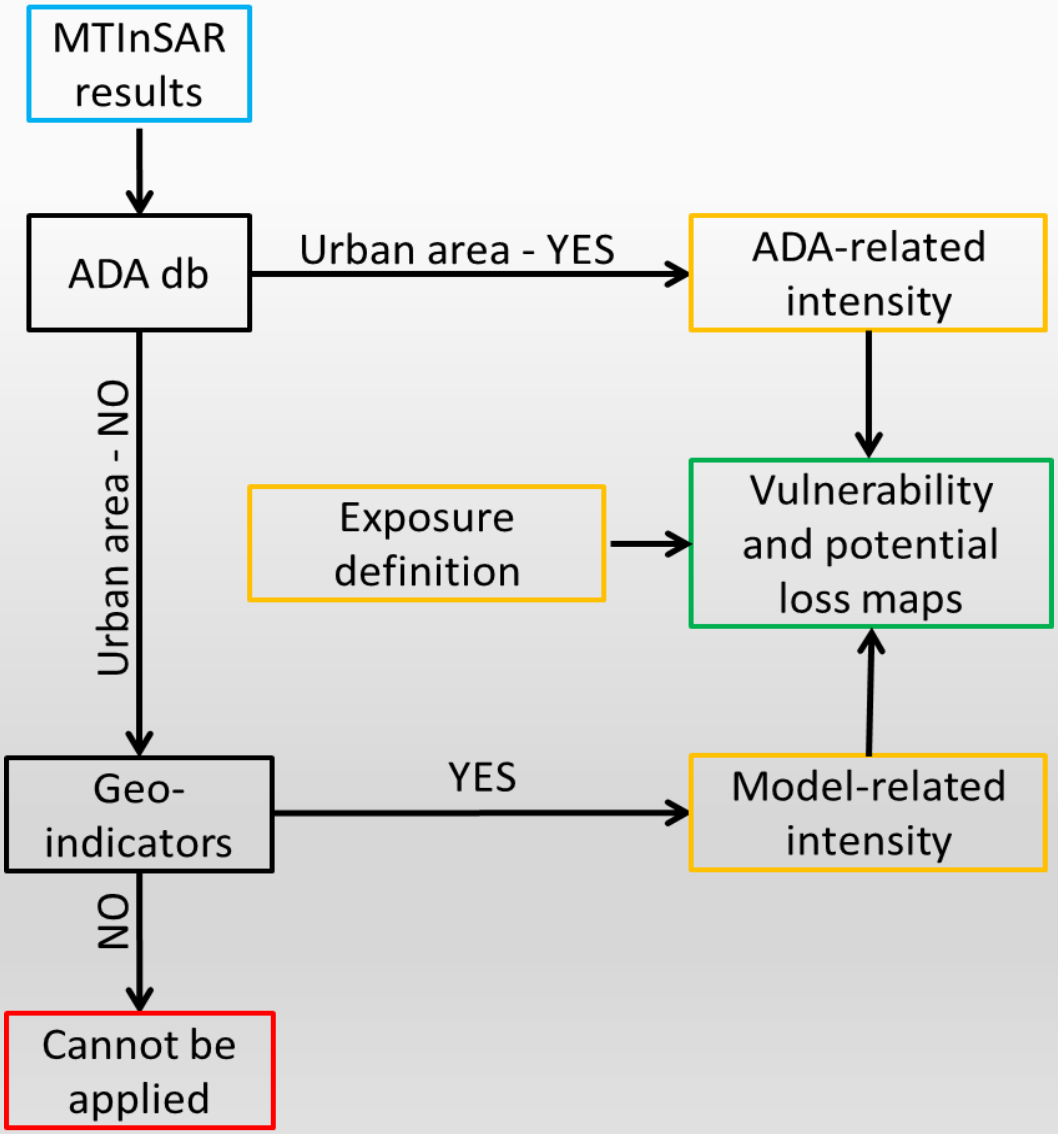
General concept

- Interferometric data are the core of the methodology and the starting point
- The final output should be a color-scale map showing «numbers» for each element at risk →quantitative estimation
- The methodology should work at regional scale with limited ancillary data
- The methodology should use common GIS tools or open-source software
- The methodology should be fast to apply

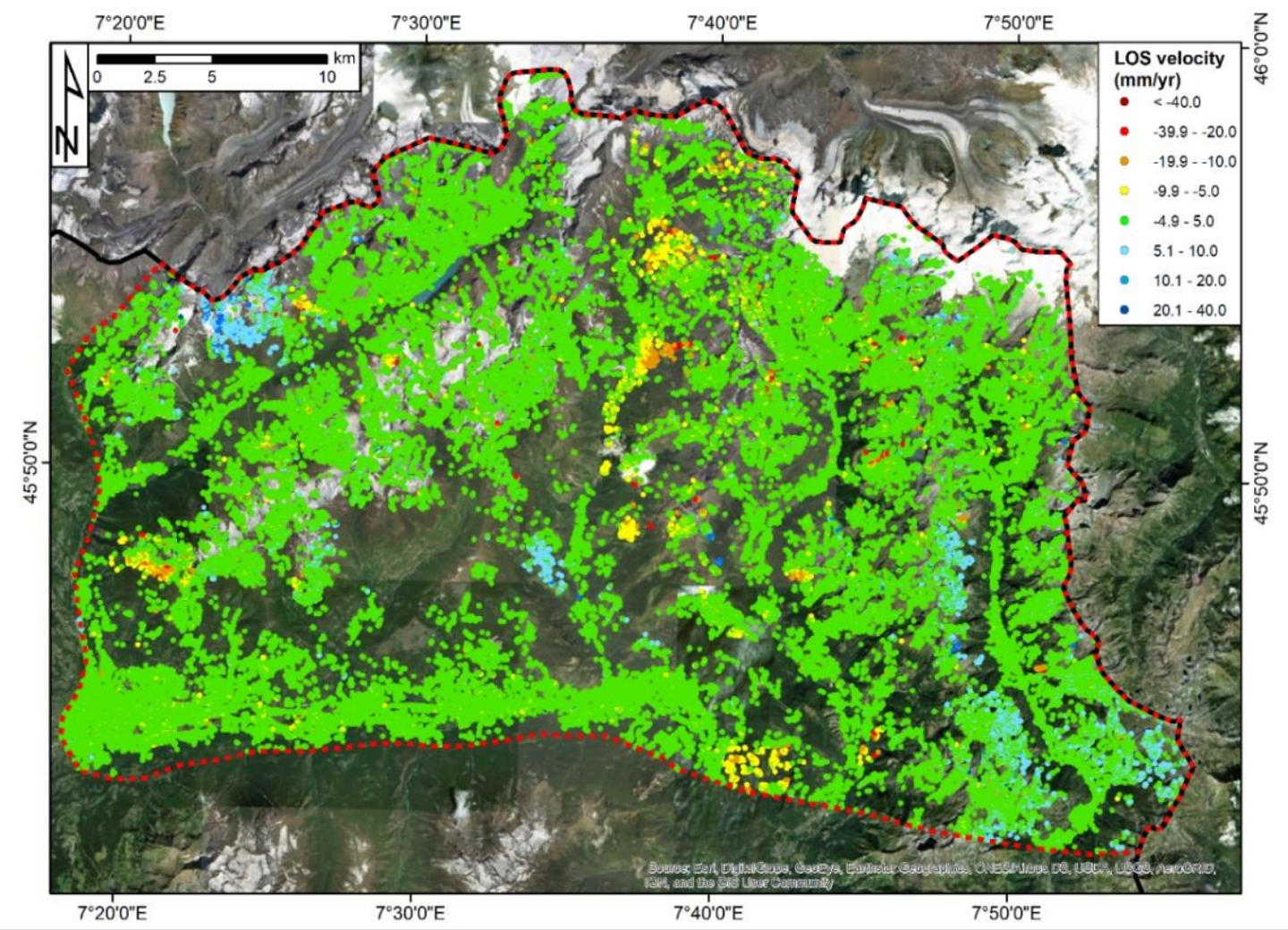
Some definitions

- Vulnerability: degree of loss of a given element at risk to the occurrence of a landslide of a given magnitude (Corominas et al., 2014)
- Exposure: a characteristic of the element at risk (person or structure) and it is referred to its location and economic value (Glade and Crozier, 2005)
- Intensity: an evaluation of landslide destructiveness (Hungr, 1997)
- Potential loss (or worth of losses): product between vulnerability (as a function of intensity) and exposure (Catani et al., 2005)

Work flow of the methodology

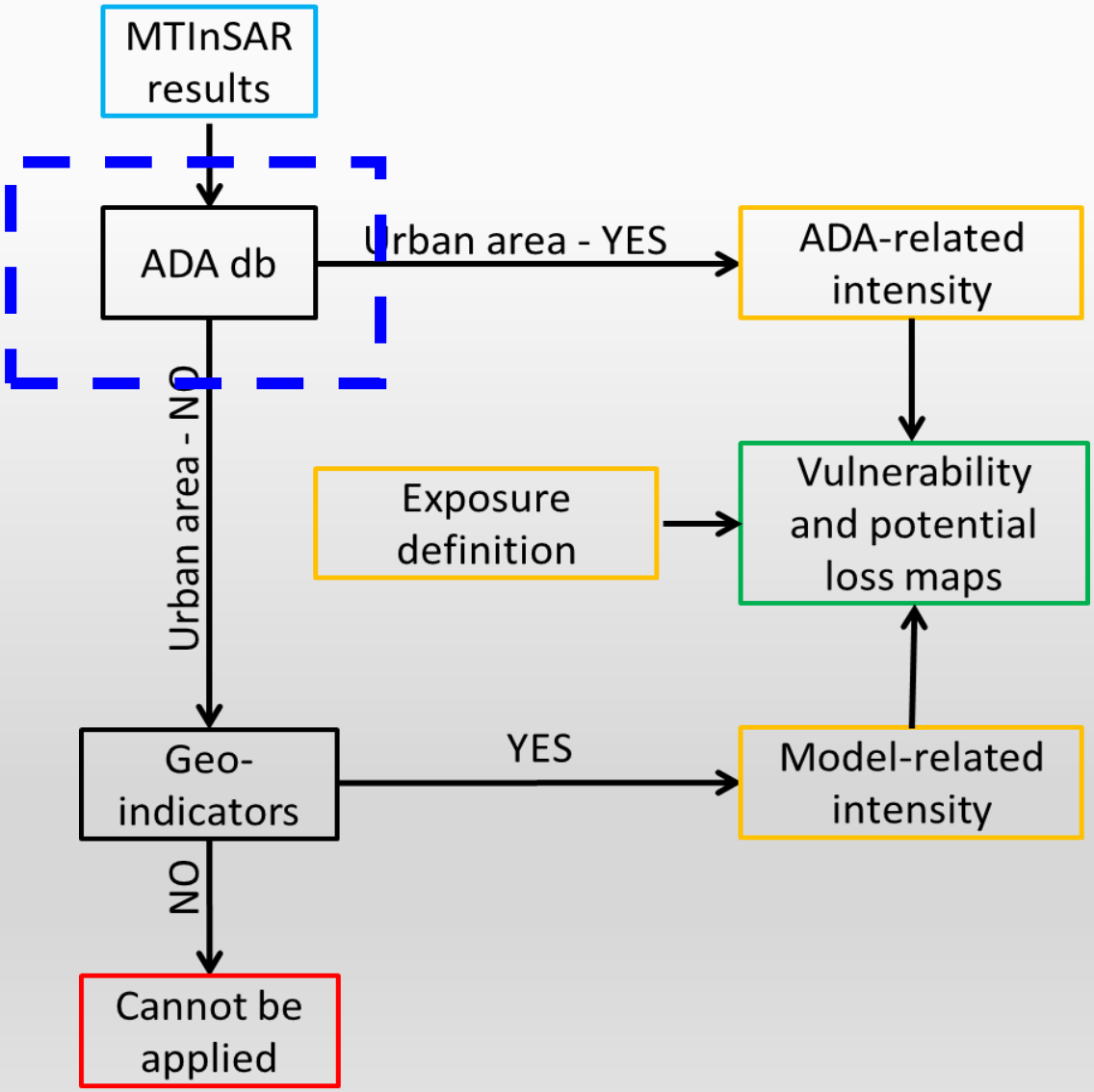


Deformation map – Starting point

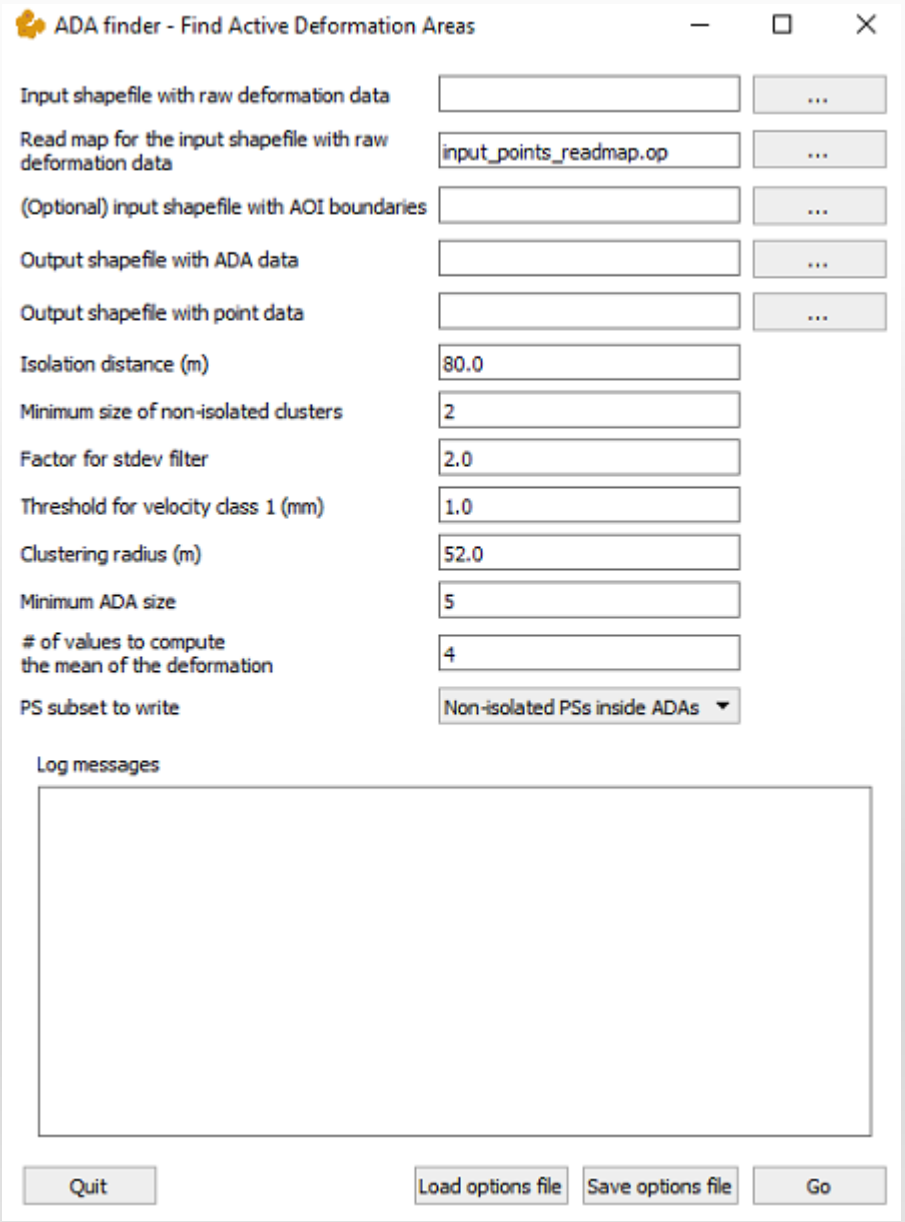


364451 PS → we need to group the fastest PS to reduce the time needed for interpretation

Phase 1 – ADA generation



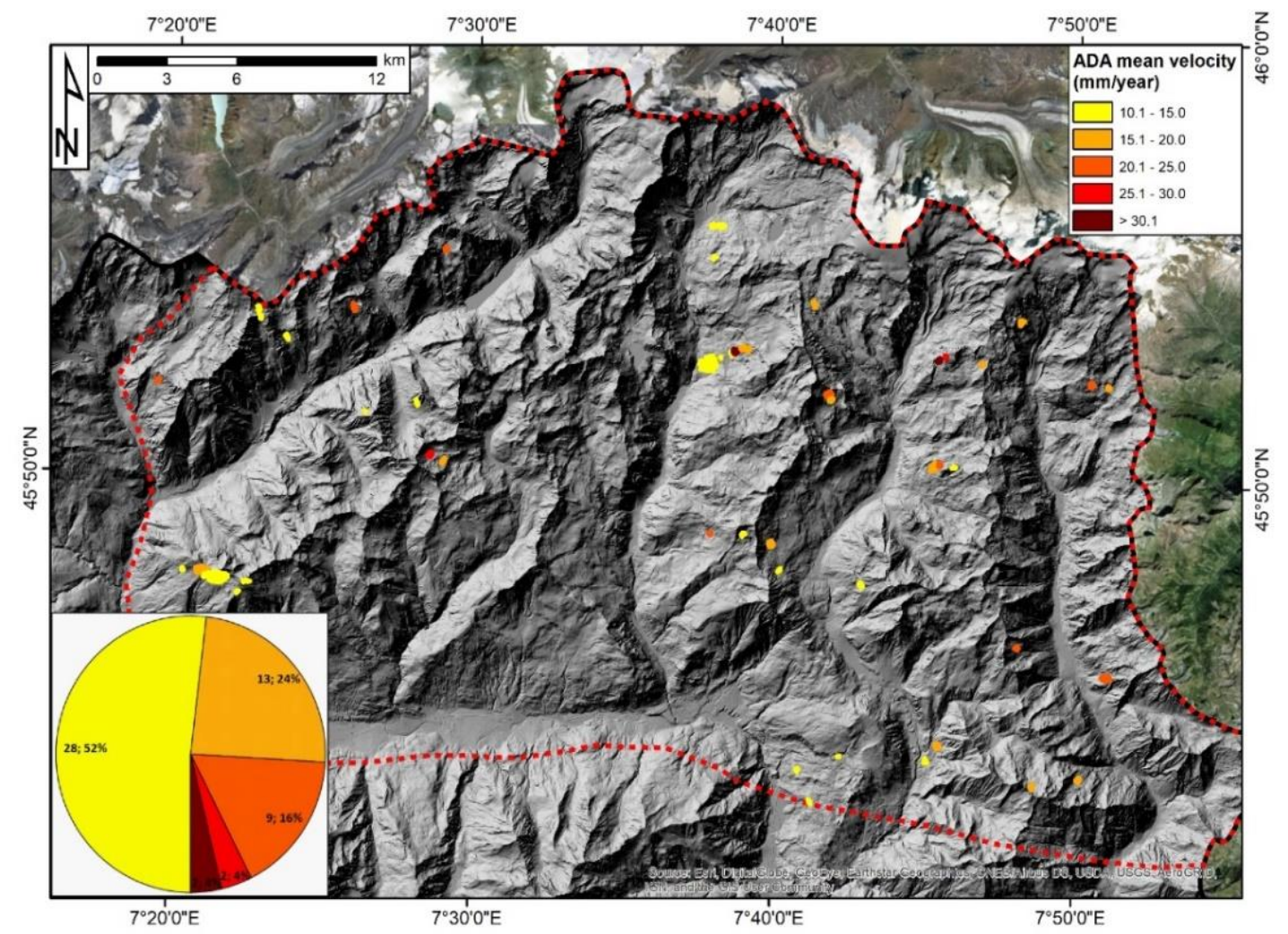
ADA database generation



- Isolation distance=100
- Stdv dev= 2 (velocity threshold=10 mm/yr)
- Clustering radious=28
- Minimum ADA size=5

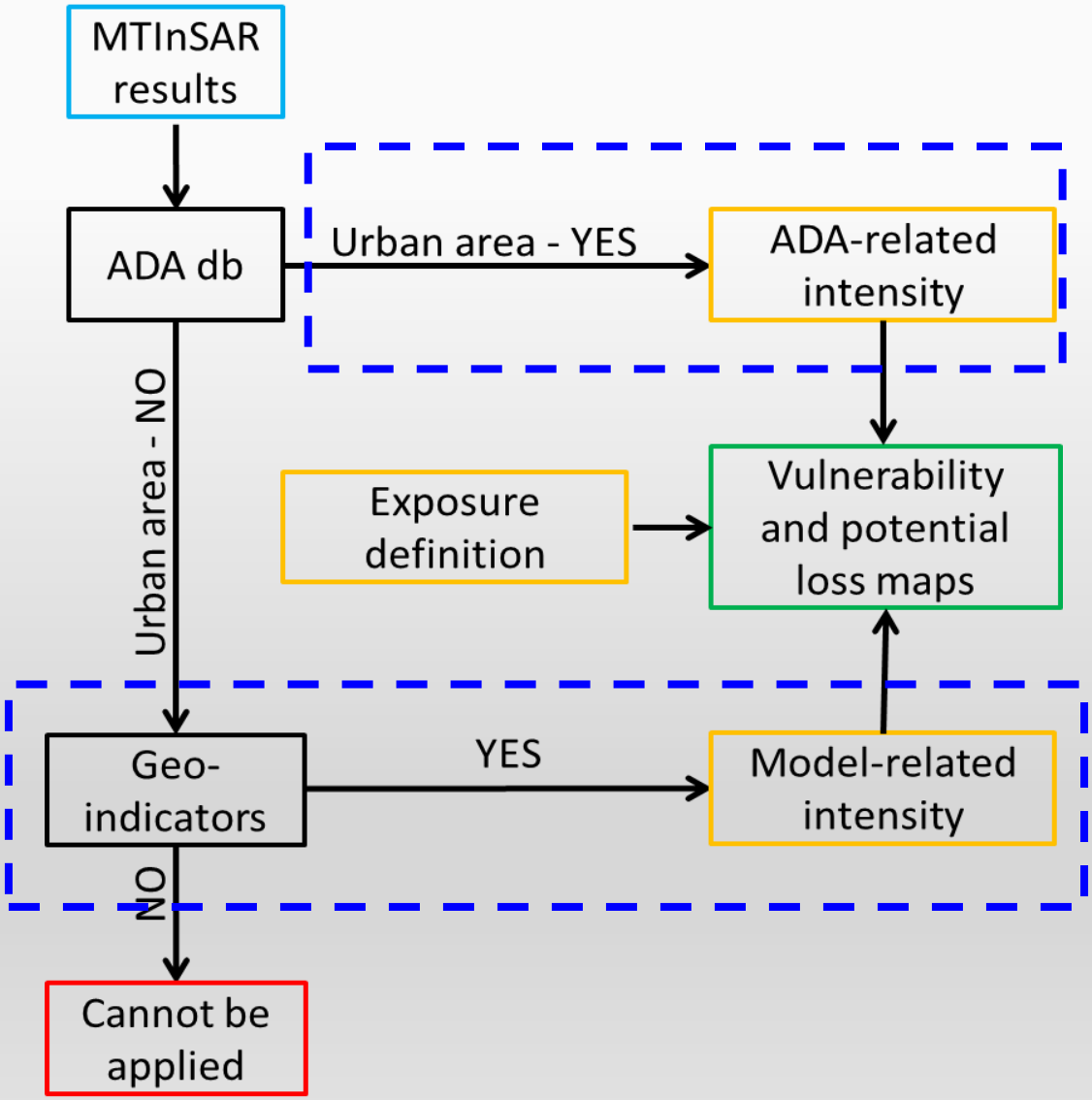
Time required to obtain the output= few seconds

ADA database



54 moving areas

Phase 2 – Intensity evaluation



Landslide intensity - concept

- Two ways to define landslide intensity starting from the ADA:

1. ADA-related intensity, if an ADA directly overlaps with a urban area, a building or a road

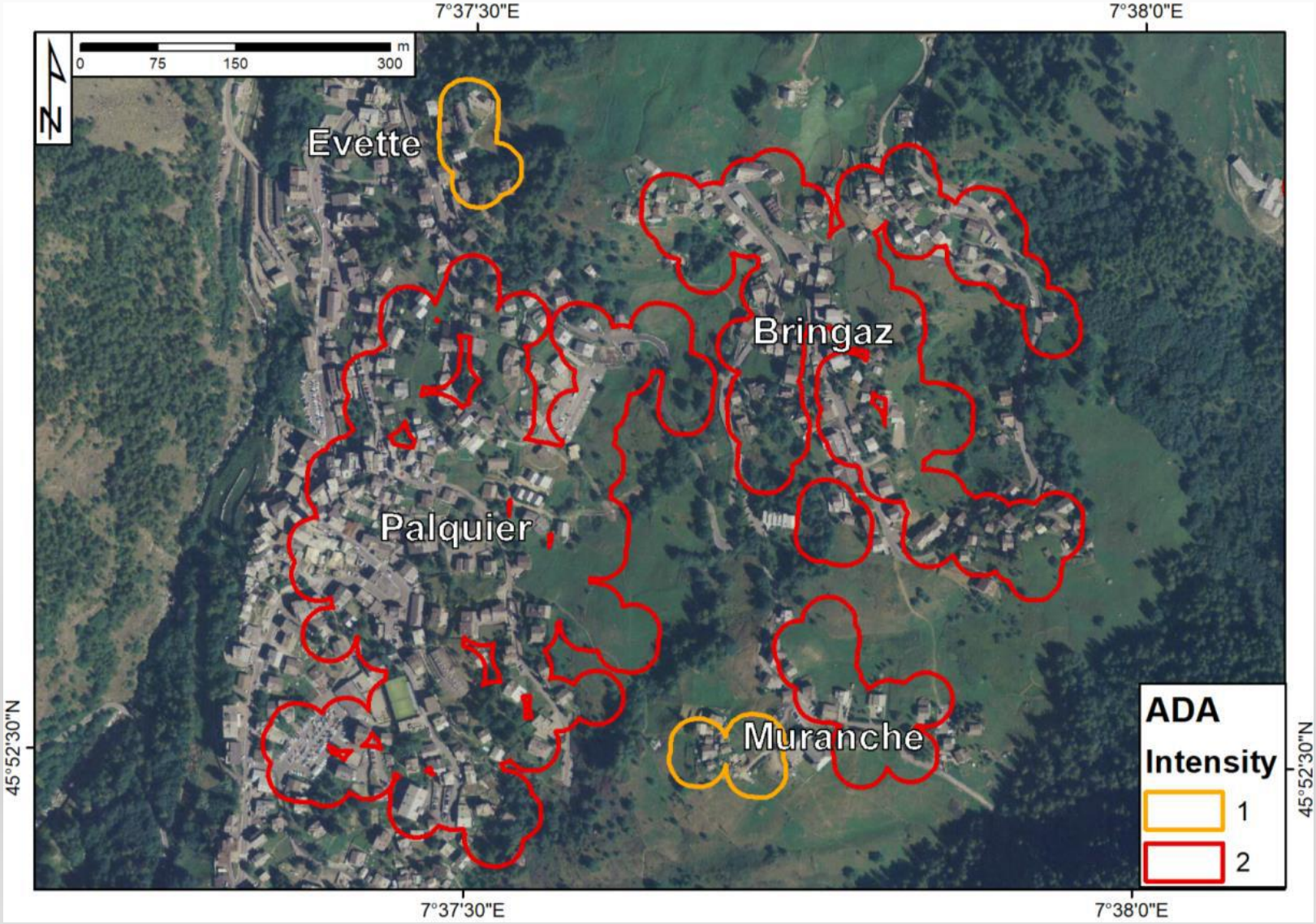
2. Model-related intensity, if an ADA does not overlap with a urban area but indicates the motion of a debris area

- Both approaches define intensity on the basis of three classes(I1,I2 and I3) depending on the variability of their outputs

ADA-related intensity

- Landslide intensity depends on the average velocity of each ADA directly intersecting an element at risk
- Intensity classes:
  1. I1: average velocity < 16 mm/yr
  2. I2: average velocity between 16.1 and 32 mm/yr
  3. I3: average velocity higher than 32.1 mm/yr
- The first limit (16 mm/yr) represents the passage between extremely slow and very slow landslides, as assumed by Cruden and Varnes (1996).

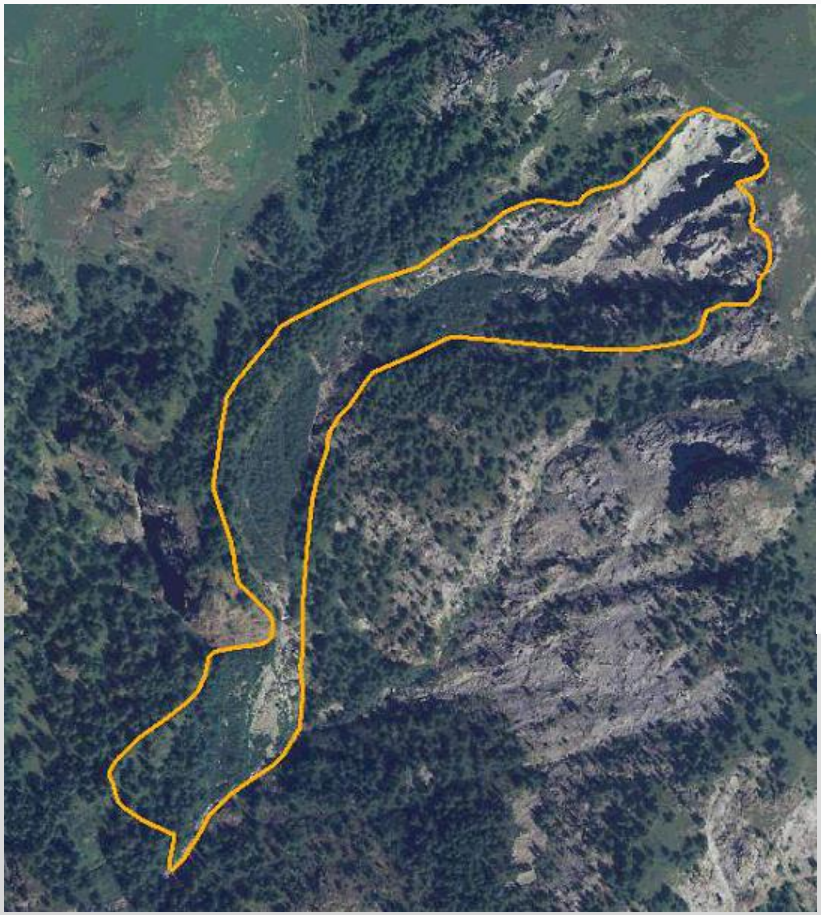
ADA-related intensity

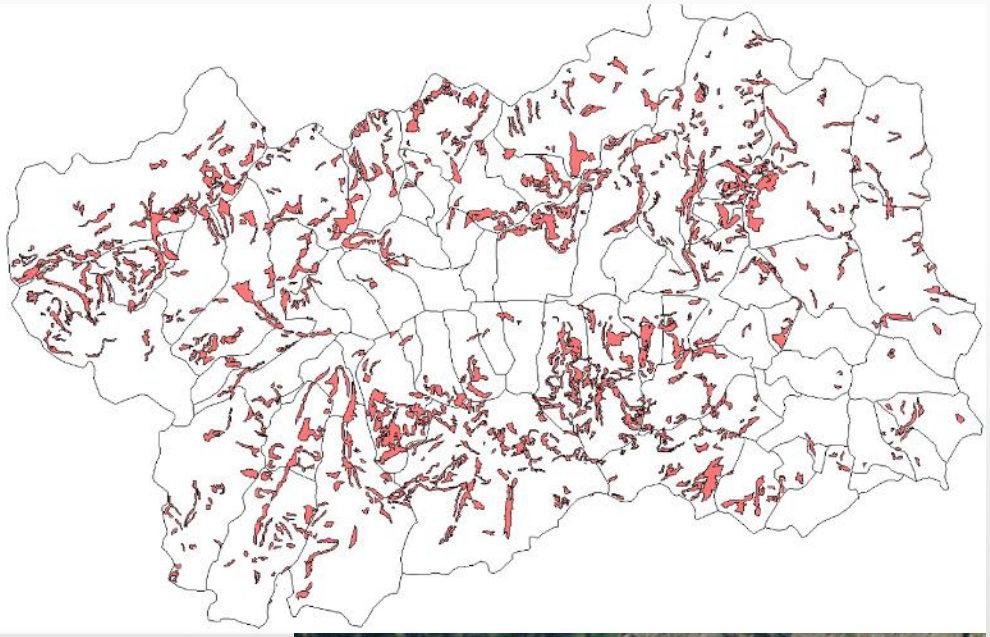


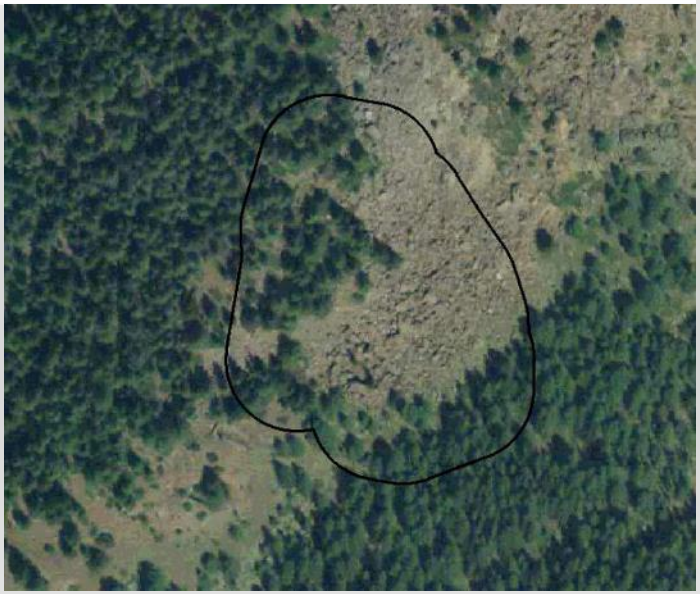
Model-related intensity

- Considering the low urban density of the area of interest and of Valle d'Aosta in general, we opted to use ADA in a different way
- ADA used as indicators of active mass wasting processes, involving unstable debris that could be source areas for catastrophic debris flows/debris avalanches
- A run-out model is used to evaluate the possible landslide evolution, in terms of landslide path and spatial distribution of the accumulation
- Extension of the concept of landslide intensity definition trough interferometric data

Geo-indicators







- Mapped debris flows
- Mapped debris deposits
- Presence of debris

Run-out model

GPP model

Geosci. Model Dev., 10, 3309–3327, 2017
https://doi.org/10.5194/gmd-10-3309-2017

Geoscientific Model Development
Open Access
EGU

The Gravitational Process Path (GPP) model (v1.0) – a GIS-based simulation framework for gravitational processes

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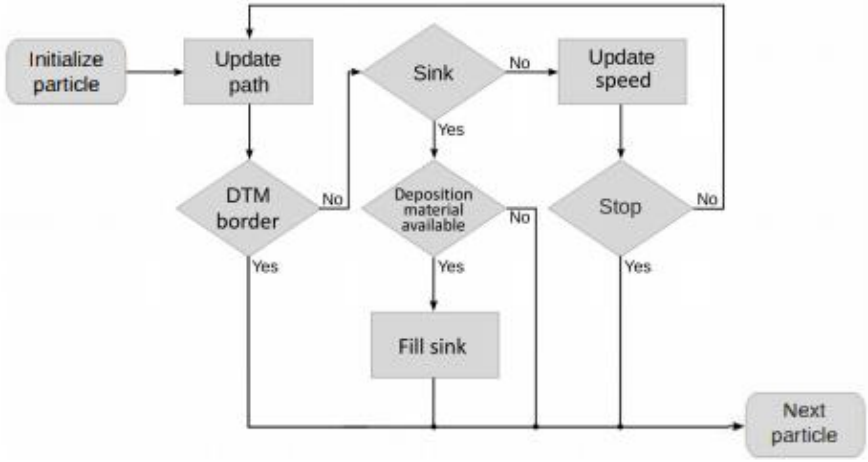
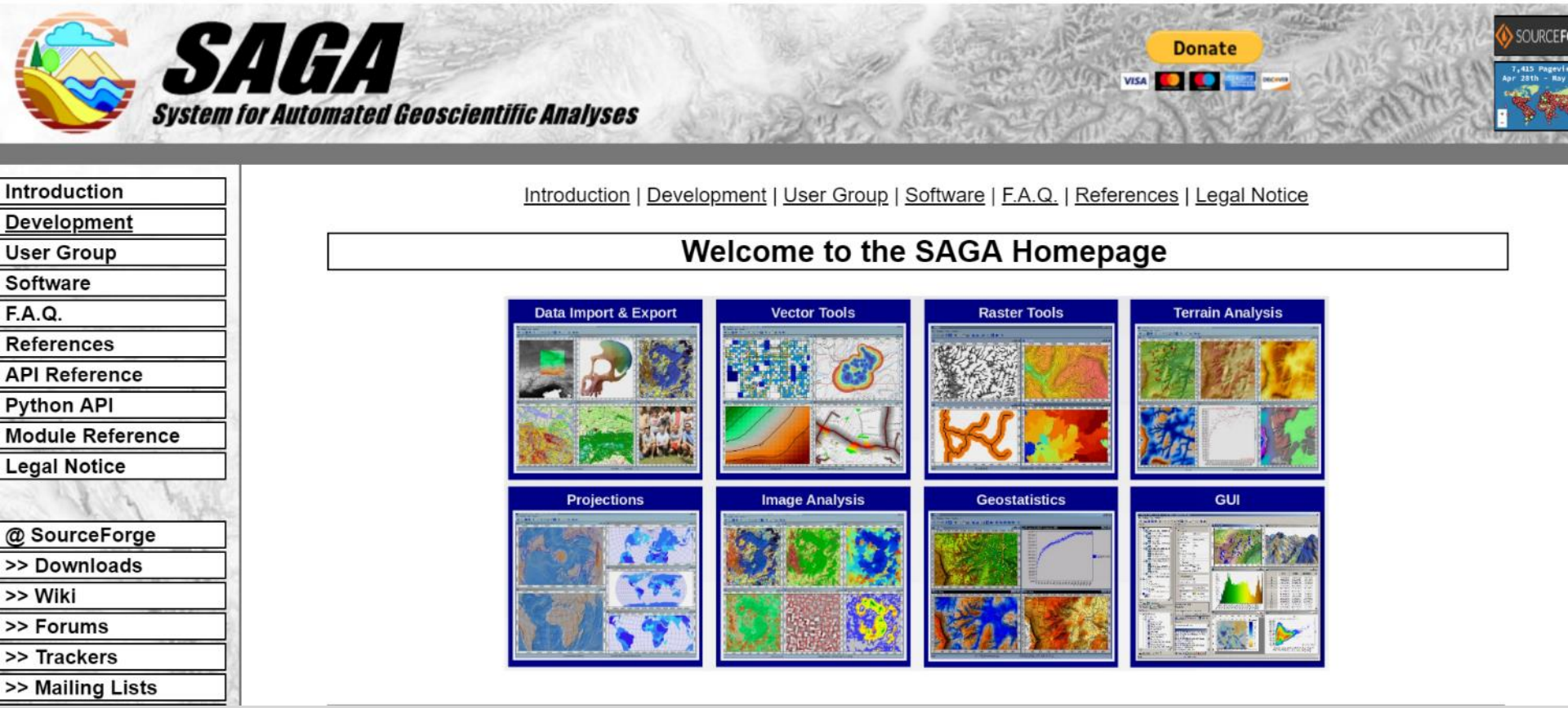


- Run-out & process path model for debris flow or avalanches
- Open source and implemented in SAGA GIS
- Requires a DEM as input (basic configuration)

- Allows deriving:
  - maximum velocity of the mass
  - stopping positions
  - height of the deposited material
- Different approaches: empirical, stochastic and physically based

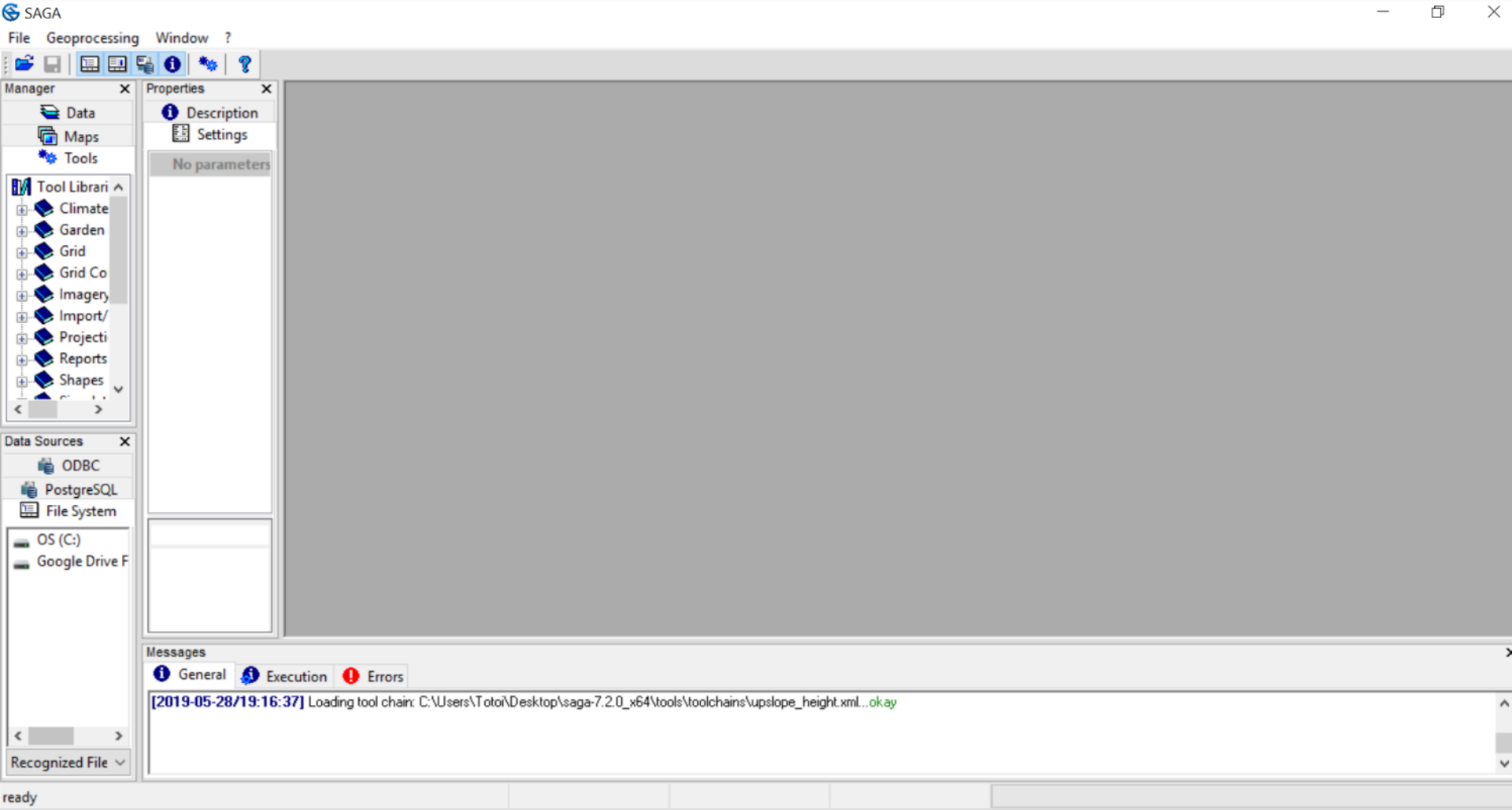
GPP model

http://www.saga-gis.org/en/index.html

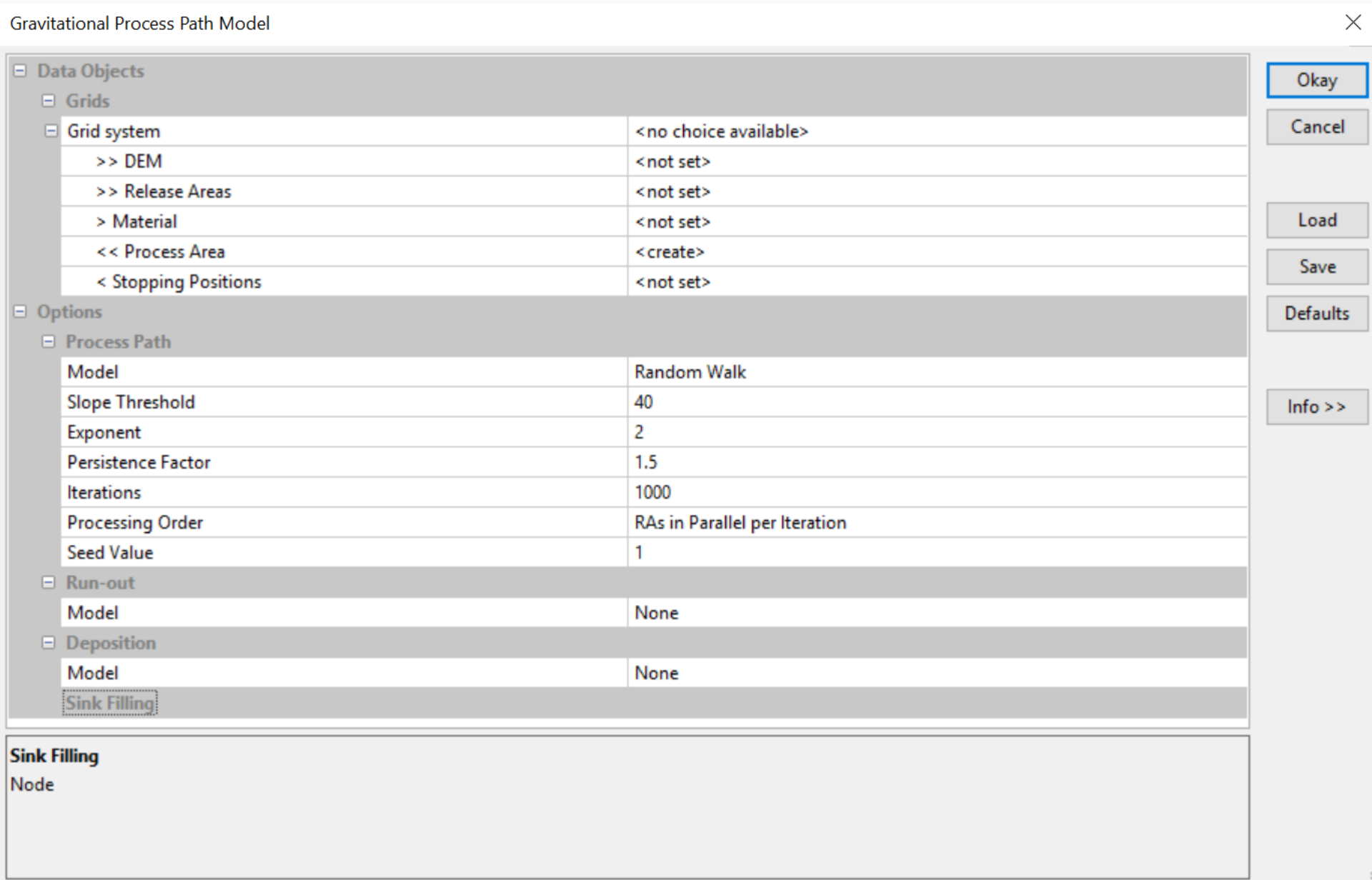


- Open-source GIS developed by a team of researchers from the Dept. of Physical Geography, Göttingen
- SAGA occupies 190 Mb
- It is very useful for geomorphological analysis

SAGA graphical interface



GPP user interface



GPP model

- Process path models
    1. Maximum slope (O'Callaghan & Mark, 1984)
    2. Random walk (Gamma, 2000)
- Run-out models
    1. Geometric gradient (Heim, 1932)
    2. Fahrböschung (Heim, 1932)
    3. Shadow angle (Hungr & Evans, 1988)
    4. One parameter friction model (Scheidegger, 1975)
    5. PCM (Perla et al., 1980)
- Deposition models (requires material height for starting cells)
    1. Sink filling (Gamma, 2000)
    2. On stop (Wichmann, 2017)
    3. Slope and on stop (Gamma 2000)

Model inputs

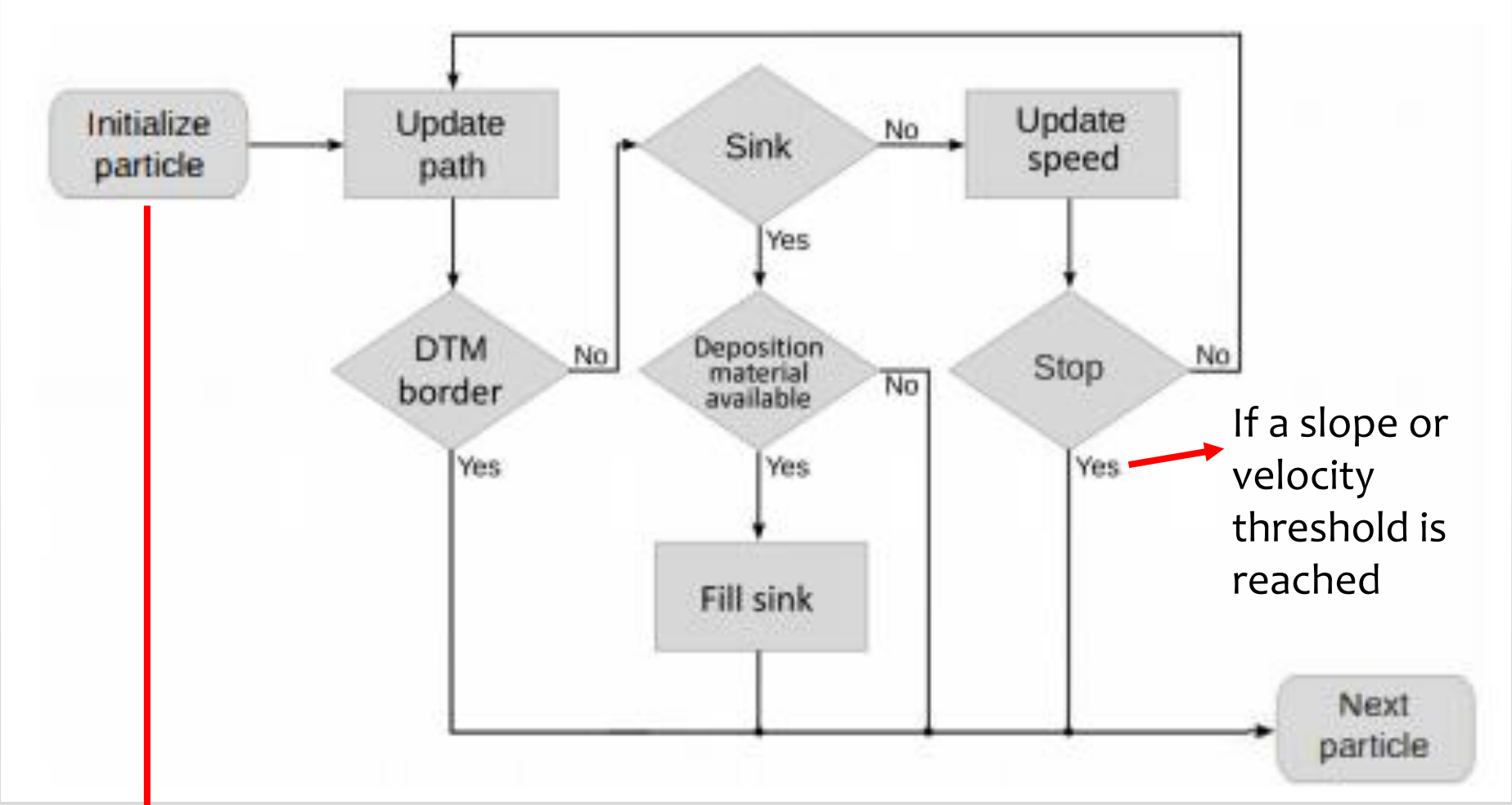
- In its simplest configuration, the GPP model only requires a DEM and one or more source areas (i.e. starting cells with altitude information)
- In our study, we used a more complex configuration in which:

1. The source areas are defined on the basis of the PS point distribution of each ADA and selected considering the distribution of moving points and the local morphology
2. The DEM resolution is 2m
3. The height of material for each starting cell is defined and obtained by Salvatici et al. (2018) using the Geomorphologically Indexed Soil Thickness model

Application of a physically based model to forecast shallow landslides at a regional scale

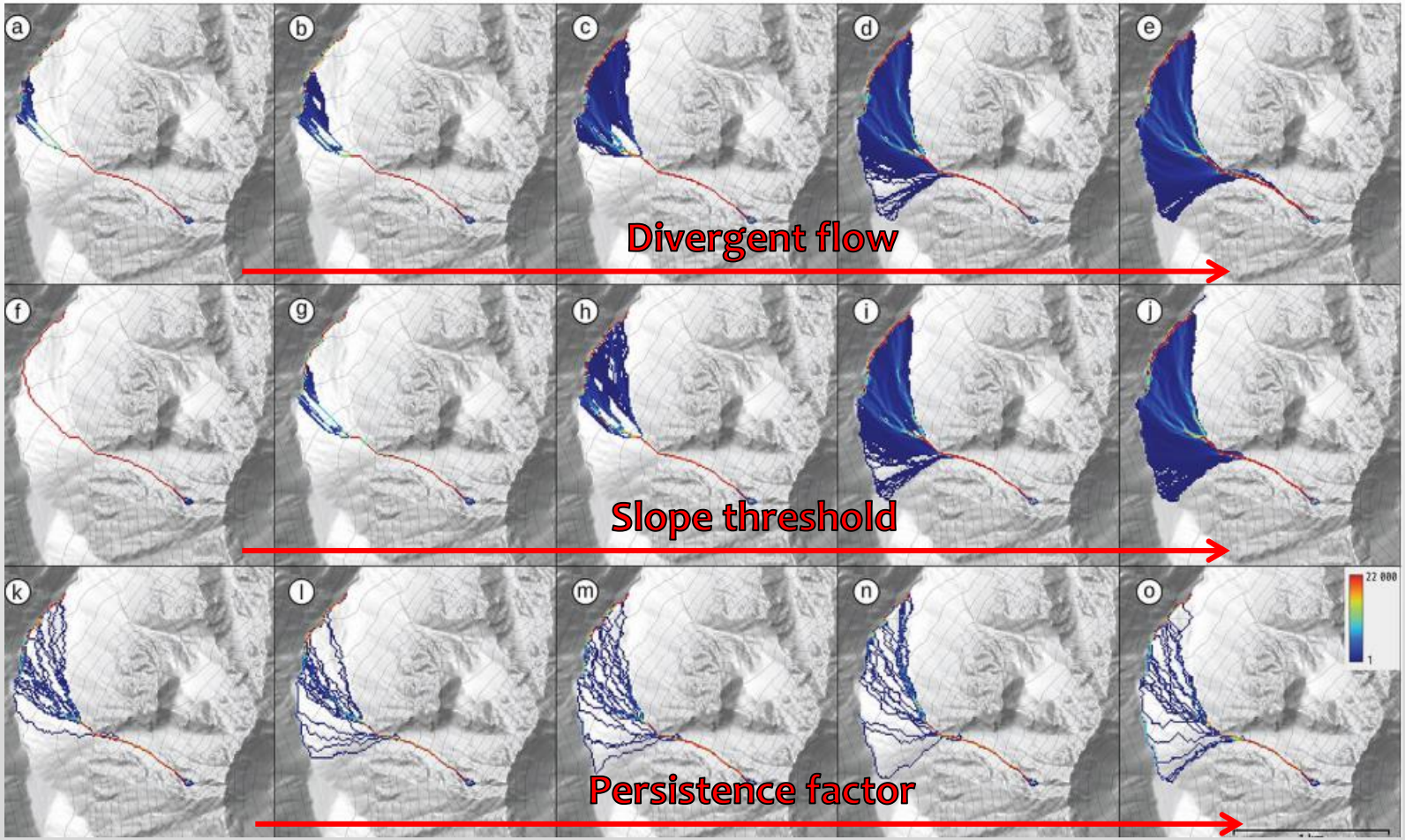
Teresa Salvatici[1], Veronica Tofani[1], Guglielmo Rossi[1], Michele D'Ambrosio[1], Carlo Tacconi Stefanelli[1], Elena Benedetta Masi[1], Ascanio Rosi[1], Veronica Pazzi[1], Pietro Vannocci[1], Miriana Petrolo[1], Filippo Catani[1], Sara Ratto[2], Hervè Stevenin[2], and Nicola Casagli[1]

Work flow of the process



Each starting cell is characterized by an elevation and (if available) a material thickness

Random walk model



- Defines how each particle “move” and how the flow will be
- 3 inputs parameters are needed. They are set at basin/flank scale

PCM model

- Two-parameter friction model
- It is a center-of-mass model in which two parameters that govern the motion of the particle must be defined: the sliding friction coefficient (μ) and the mass-to-drag ratio
- $\mu = 0.19 * a^{-0.24}$ where a is the catchment area
- The mass-to-drag ratio depends on the size distribution of the material and for debris flows made of granular materials and blocks is on average equal to 70

$$v_i = \sqrt{\alpha_i \cdot (M/D)_i \cdot \left(1 - e^{\beta_i}\right) + \left(v_{(i-1)}\right)^2 \cdot e^{\beta_i}}$$

and

$$\alpha_i = g\left(\sin\theta_i - \mu_i \cos\theta_i\right),$$

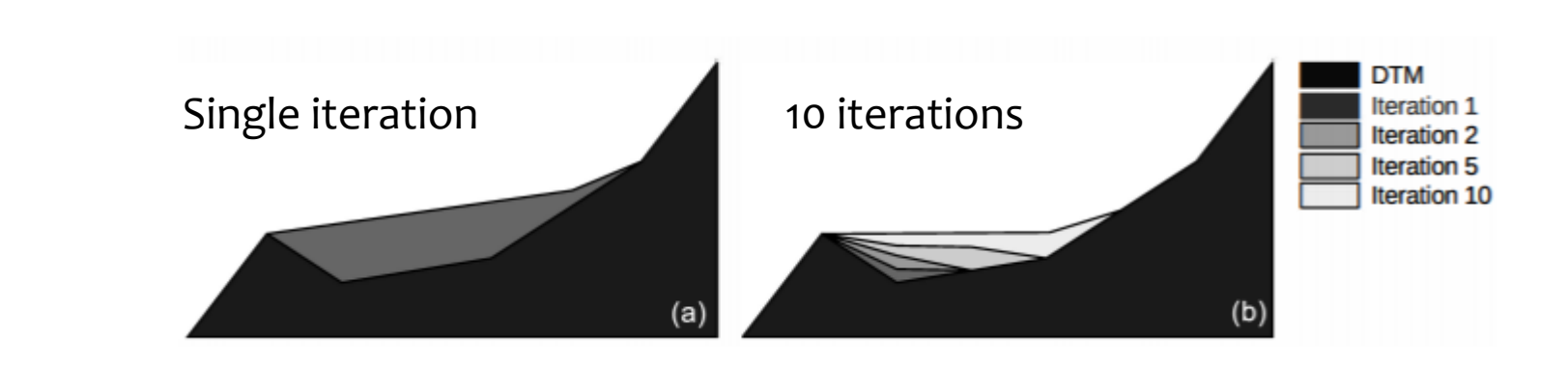
$$\beta_i = \frac{-2L_i}{(M/D)_i},$$

local slope

slope length between adjacent grid cells

The process stops as soon as the square root becomes undefined

Slope & On stop



Model	Slope & On Stop
Initial Deposition on Stop	20
Slope Threshold	20
Maximum Deposition along Path	20
Minimum Path Length	100

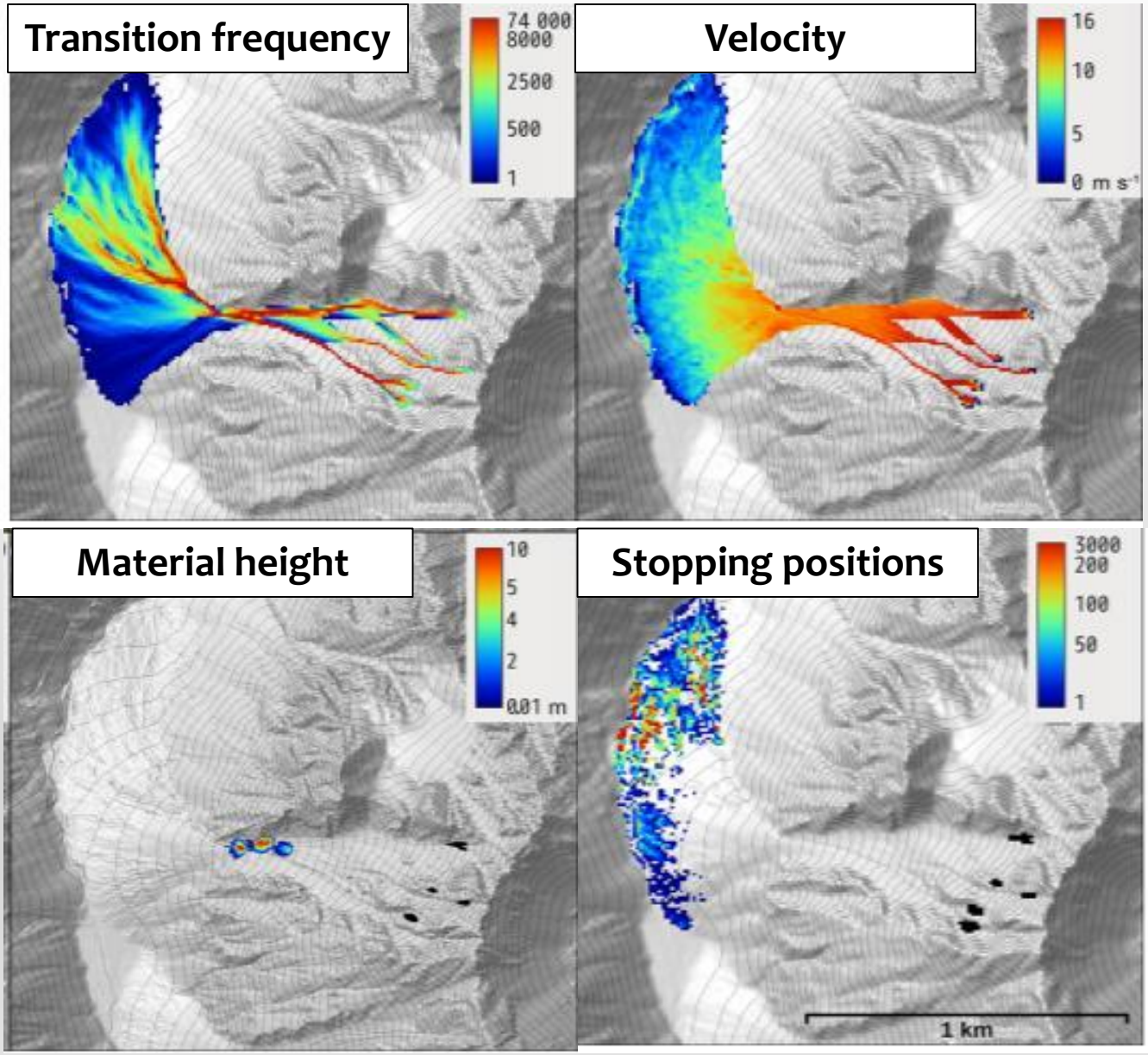
- The deposition starts once the slope drops below a specific threshold
- The amount of material deposited on the stopping cell (%) is controlled by the Initial Deposition on Stop parameter
- At a slope of zero, the Maximum Deposition along Path parameter controls the percentage of material that is deposited
- The Minimum Path Length, which describes the distance along the process path that must be exceeded before deposition sets in

In summary

What we have to do:

1. Select all the ADA that respect the “Geo-indicators” condition
2. Group them for macro-areas (same flank, basin, etc…)
3. Run the model on a known debris flow in the area of interest to calibrate the model.
4. Use the parameters to run the GPP using as source areas the ADA; multiple source areas can be defined within the same ADA, depending on the PS distribution and on the local morphology
5. If pt.3 is not achievable, select one ADA and launch multiple GPP runs until you obtain a reasonable result

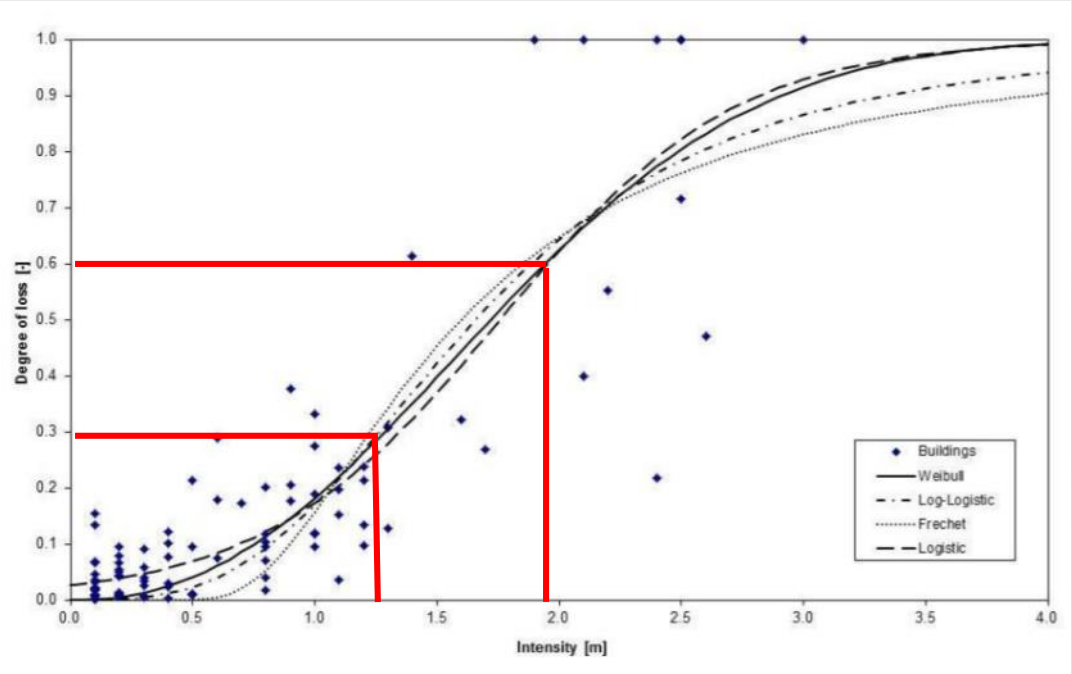
Outputs of the model



Intensity definition

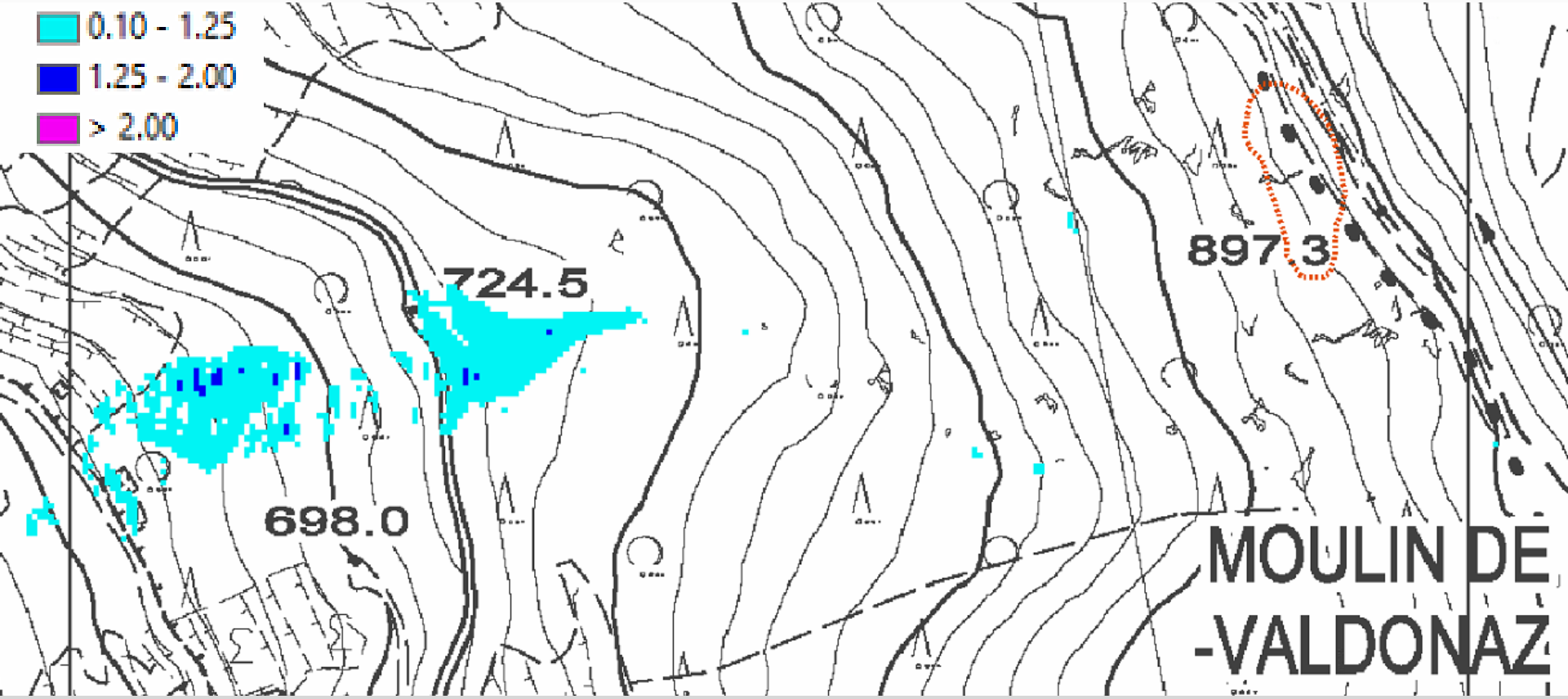
- The height of material at every cell as a proxy for landslide intensity
- Three classes of intensity:

1. I1: height of the material lower than 1.25 m
2. I2: height of the material between 1.26 and 2 m
3. I3: height of the material higher than 2.01 m

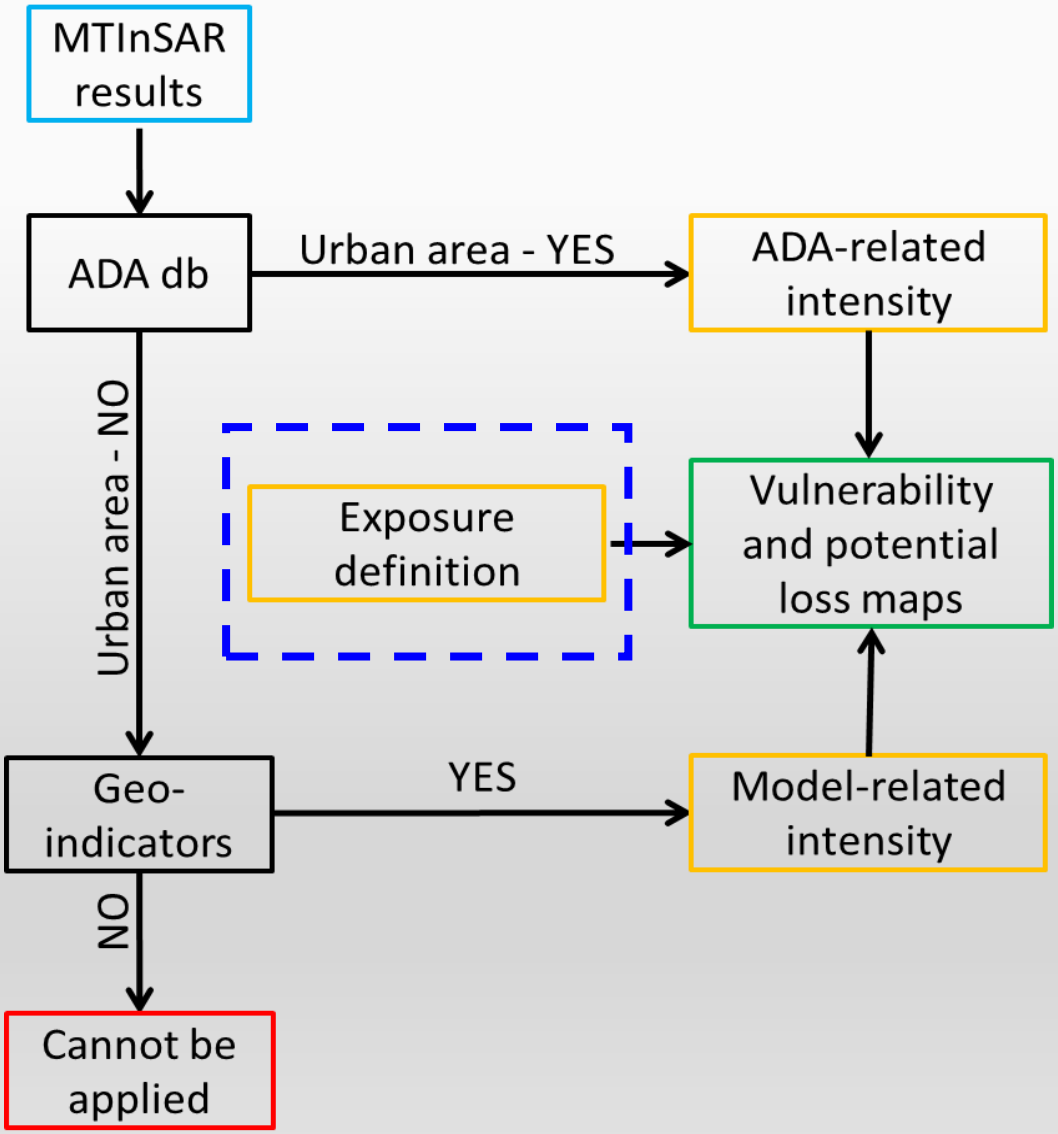


The values chosen are defined following the vulnerability functions derived by Papathoma-Kohle et al. (2015) using real debris flow events in South Tyrol (Austria)

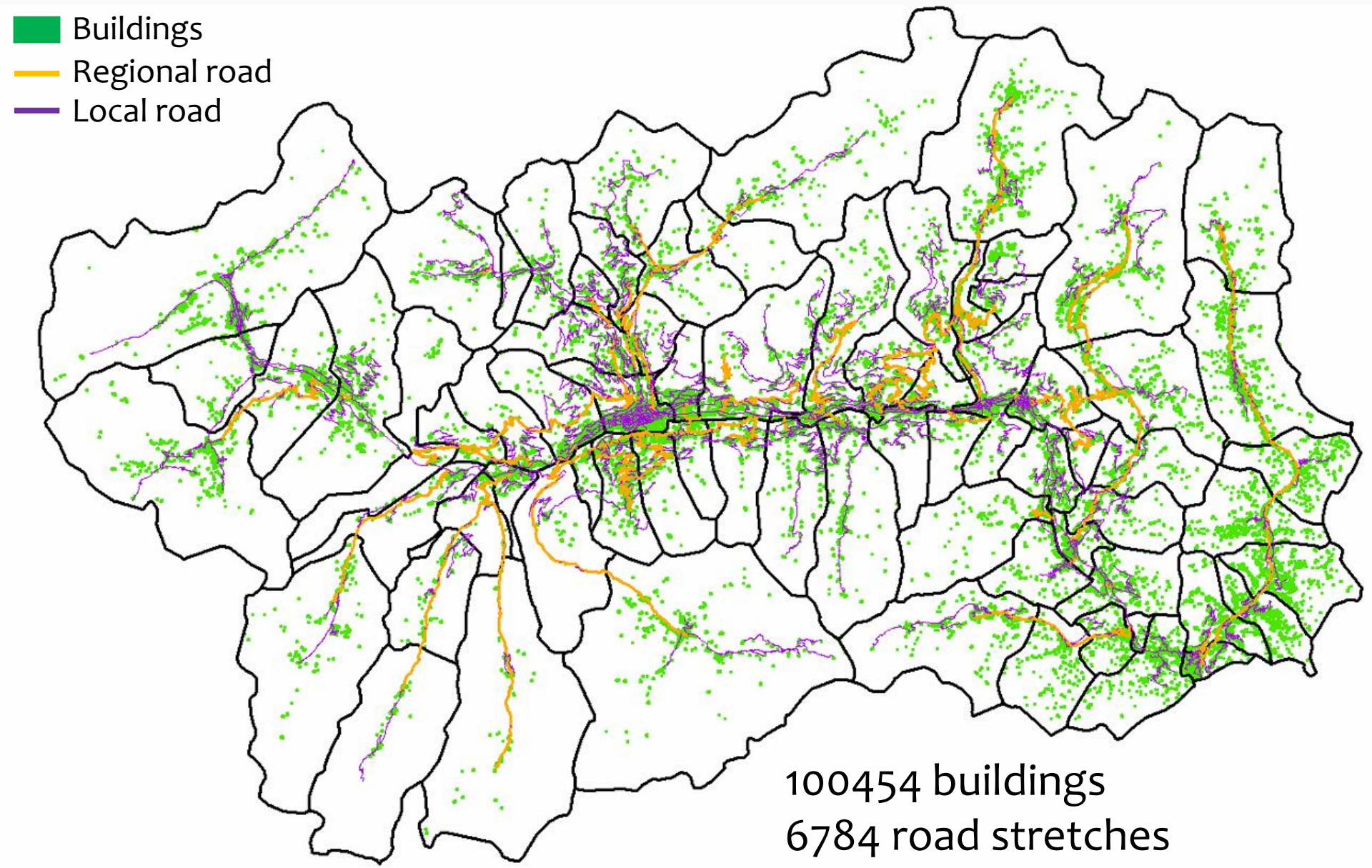
Model-related intensity



Phase 3 – Exposure definition



Elements at risk database



Exposure

- We defined exposure as an economic value of properties, not considering people occupancy
- We assigned the market values of a building at municipality scale. If not possible, we used the construction/renewal cost multiplied by 10
- For roads we used the construction cost of the road itself, not considering accessory costs
- Exposure of cultural heritages – including churches – is not defined (it is too much site-related)

Exposure values

Private houses

OMI database

Agenzia Entrate

Banca dati delle quotazioni immobiliari - Risultato

Spazio disponibile per annotazioni

Risultato interrogazione: Anno 2018 - Semestre 2

Provincia: AOSTA

Comune: AOSTA

Fascia/zona: Centrale/CENTRO STORICO - NORD

Codice zona: B1

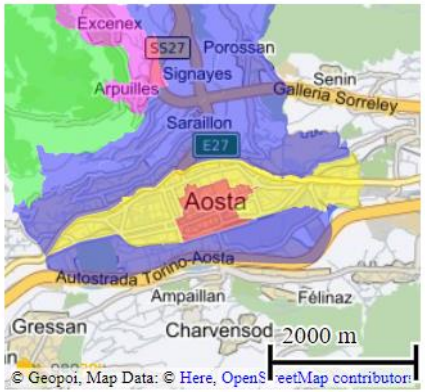
Microzona: 1

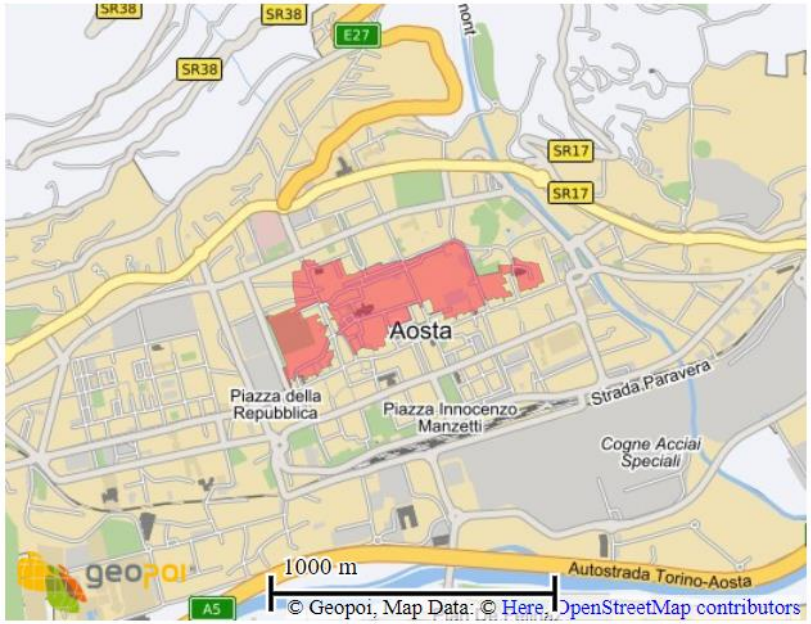
Tipologia prevalente: Abitazioni civili

Destinazione: Residenziale

Tipologia	Stato conservativo	Valore Mercato (€/mq)		Superficie (L/N)	Valori Locazione (€/mq x mese)		Superficie (L/N)
		Min	Max		Min	Max	
Abitazioni civili	Normale	1450	2100	L	6,8	9,9	L
Abitazioni civili	Ottimo	2500	3300	L	7,4	10,3	L
Abitazioni civili	Scadente	1200	1650	L	3,8	5,6	L
Abitazioni di tipo economico	Normale	1050	1350	L	4,7	6,7	L
Abitazioni di tipo economico	Scadente	940	1200	L	4,3	5,4	L
Box	Normale	1550	2200	L	4,7	6,9	L
Posti auto scoperti	Normale	500	700	L	3,2	4,1	L

We used the average market value for each municipality





https://wwwt.agenziaentrate.gov.it/geopoi_omi/index.php

Exposure values

Stores & warehouses

Agenzia Entrate

Banca dati delle quotazioni immobiliari - Risultato

Risultato interrogazione: Anno 2018 - Semestre 2

Provincia: AOSTA

Comune: AOSTA

Fascia/zona: Semicentrale/FASCIA SEMICENTRALE OVEST-NORD

Codice zona: C11

Microzona: 2

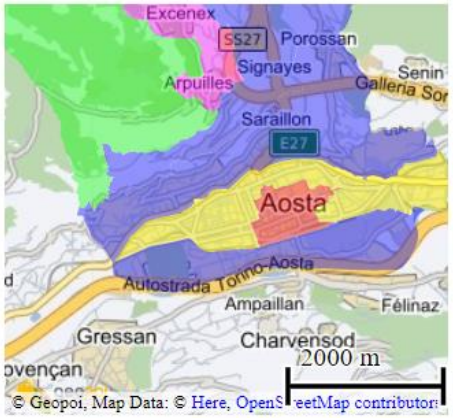
Tipologia prevalente: Abitazioni civili

Destinazione: Residenziale

Tipologia	Stato conservativo	Valore Mercato (€/mq)		Superficie (L/N)	Valori Locazione (€/mq x mese)		Superficie (L/N)
		Min	Max		Min	Max	
Magazzini	Normale	500	730	L	3,1	4	L
Negozi	Normale	1050	1500	L	8	12	L

Stampa Legenda

Spazio disponibile per annotazioni



https://wwwt.agenziaentrate.gov.it/geopoi_omi/index.php

Exposure values

Construction cost for hotels of different categories

1 o 2 stelle	**€/mc 155,00**
3 stelle	**€/mc 258,00**
4 stelle	**€/mc 355,00**
5 stelle	**€/mc 410,00**
5 stelle di lusso	**€/mc 460,00**

Construction cost for stables

5.2. Stalle e affini

5.2.1 Stalle aperte per stabulazione libera, con corsia di alimentazione interna, compresi recinto esterno, eventuale fienile (sullo stesso piano):

€/m^2 100,00

5.2.2 Stalle aperte a cuccette a stabulazione libera, con corsia di alimentazione interna, con eventuale fienile (sullo stesso piano) e pensilina di alimentazione interna:

€/m^2 120,00

Exposure values

Rete Anno 2007 [km]	Autostrade Anno 2007	Statali Anno 2007	Regionali Anno 2007	Provinciali Anno 2007	Comunali urbane Anno 2002	Comunali extraurbane Anno 2002	Vicinali Anno 2002
Piemonte	817	740	1.454	12.496	15.103	24.243	13.862
Valle d'Aosta	114	153	500	0	930	1.299	584
Lombardia	576	988	2.841	10.547	26.510	20.280	11.551
Liguria	375	135	903	3.889	5.287	7.630	6.246
Friuli Venezia Giulia	210	191	n.d.	2.209	4.304	5.377	4.092
Trentino Alto Adige	211	0	2.188	2.300	4.221	9.870	2.892
Veneto	485	808	2.878	6.820	14.041	20.166	8.370
Emilia Romagna	568	1.225	2.856	8.917	11.839	24.365	13.140
Toscana	424	967	2.576	9.857	9.609	17.896	18.199
Umbria	59	560	983	3.551	2.257	7.301	10.963
Marche	168	511	93	5.812	5.161	10.930	6.901
Lazio	470	547	3.536	6.854	7.182	22.665	12.511
Abruzzo	352	1.037	1.195	5.440	5.521	16.102	8.081
Molise	36	571	347	2.360	1.549	5.350	3.736
Campania	442	1.359	4.226	5.725	10.924	19.119	11.696
Calabria	295	1.424	340	7.721	9.522	22.257	10.909
Puglia	313	1.570	745	9.438	11.876	25.490	8.562
Basilicata	29	1.039	3.441	1.413	3.250	10.819	5.942
Sicilia	644	2.396	4.521	10.312	14.468	23.675	11.201
Sardegna	0	3.070	2.148	3.231	7.925	17.315	15.217
Lunghezza	6.588	19.921	37.771	118.892	171.479	312.149	184.655
Larghezza media (m)	30	18	18	12	9	9	4
Superficie totale (mq)	197.640.000	347.238.000	679.878.000	1.426.704.000	1.543.311.000	2.809.341.000	738.620.000
Costo (€/mq)	350	250	250	180	150	150	50
Larghezza media (m)	69.174.000.000	86.809.500.000	169.969.500.000	256.806.720.000	231.496.650.000	421.401.150.000	36.931.000.000
Totale escluse vicinali e comunali (€)				1.004.160.870.000			

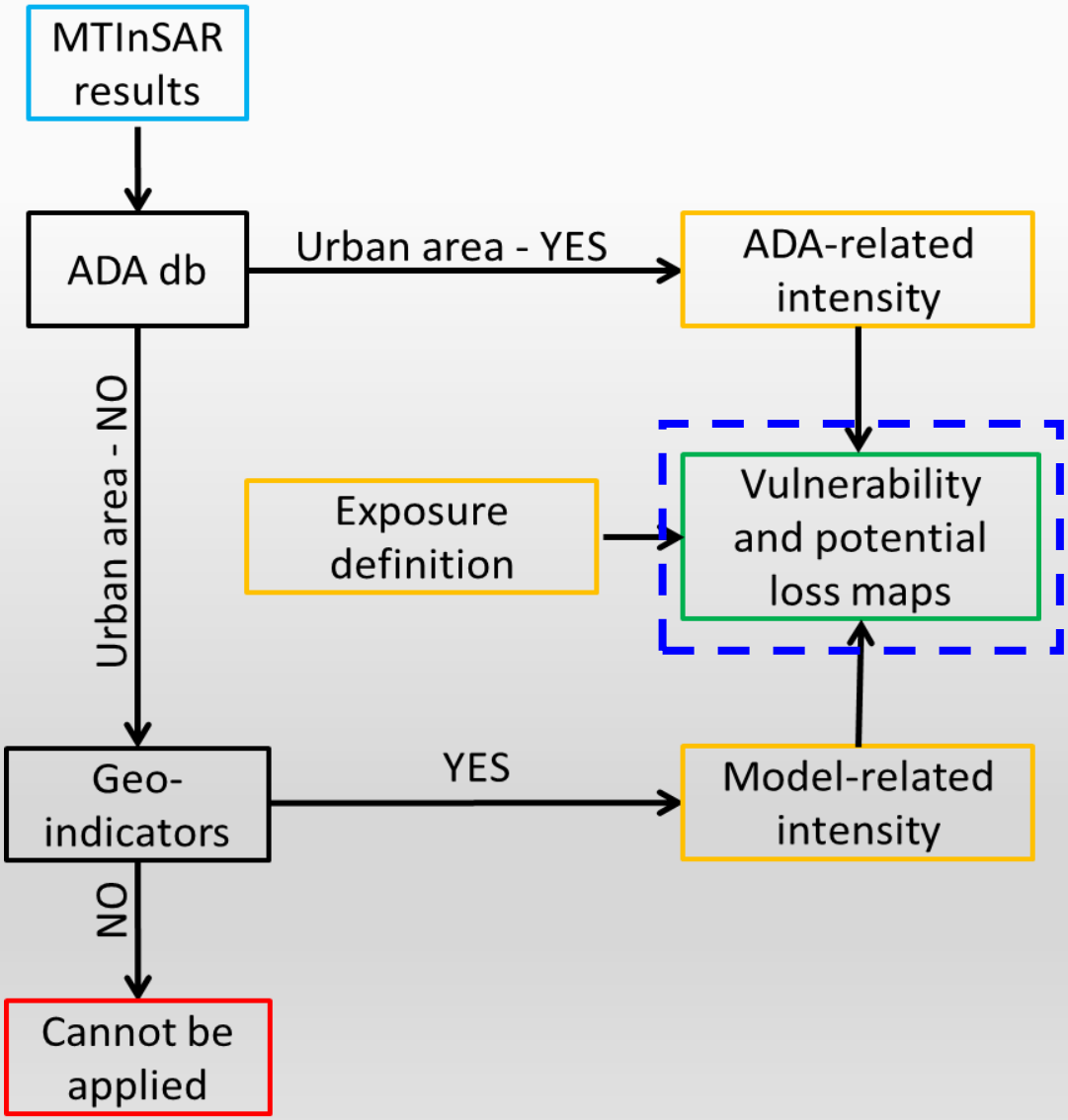
Construction cost for different types of roads. Source: ANAS

Exposure values

Type of building/road	E (€/sqm)
Barn	80
Camping	2600
Greenhouse	50
Hotel	1550 – 4600
Industrial laboratory	740 – 1000
Local road	50
Motorway	350
Municipal road	150
Office/service sector	1175 – 2600
Private house	1075 – 4350
Provincial road	180
School complex	4000
Shed	540-890
Commercial building (shop, restaurant, etc...)	865 – 2100
Shopping mall	1400 – 2200
Sport facilities	15-120
Stable	120
Regional/State road	250
Warehouse	680 - 1000

- If the value is a range the OMI database is used. The value is assigned depending on the municipality where the element at risk is found
- The value for private houses has a large variation because of the more or less touristic “level” of the municipality

Phase 4 – Vulnerability & potential loss



Vulnerability

- Vulnerability varies, as a function of landslide intensity, between 0 (no damage) and 1 (complete loss).
- Each value of vulnerability is defined by the typology of element at risk following a data driven approach
- Linear elements have the highest vulnerability values for each intensity class.
- If intensity is equal to zero, then vulnerability is null.

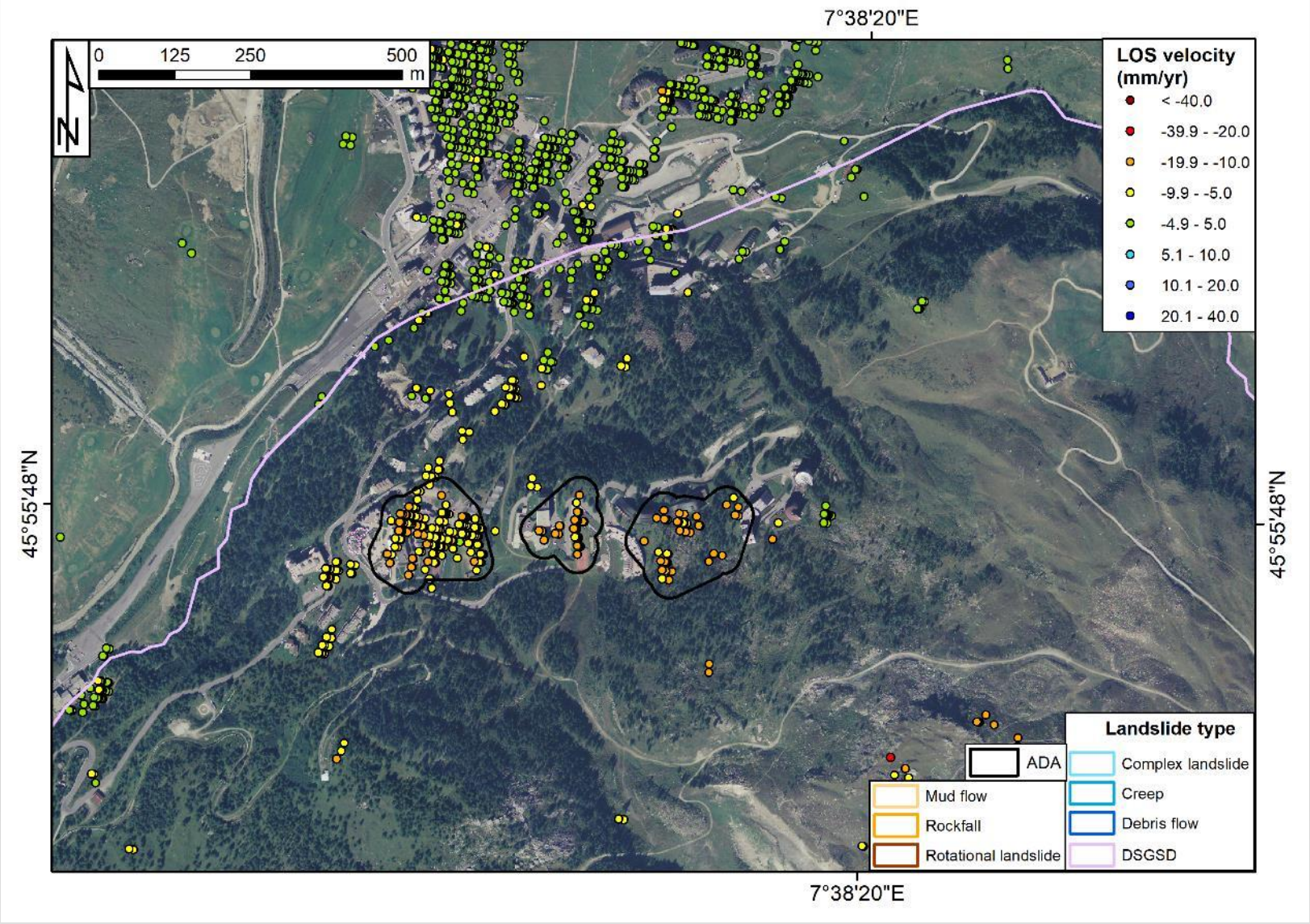
Vulnerability values

Type of building/road	V (I=1)	V (I=2)	V (I=3)
Barn	0.2	0.4	0.6
Camping	0.4	0.6	0.8
Greenhouse	0.2	0.4	0.6
Hotel	0.15	0.3	0.5
Industrial laboratory	0.1	0.2	0.5
Local road	0.6	0.8	1
Motorway	0.4	0.6	0.8
Municipal road	0.6	0.8	1
Office/service sector	0.1	0.3	0.6
Private house	0.2	0.35	0.6
Provincial road	0.6	0.8	1
School complex	0.3	0.5	0.7
Shed	0.2	0.4	0.6
Commercial building (shop, restaurant, etc...)	0.2	0.35	0.6
Shopping mall	0.2	0.35	0.6
Sport facilities	0.3	0.5	0.7
Stable	0.15	0.4	0.6
Regional/State road	0.4	0.6	0.8
Warehouse	0.2	0.4	0.6

Potential loss

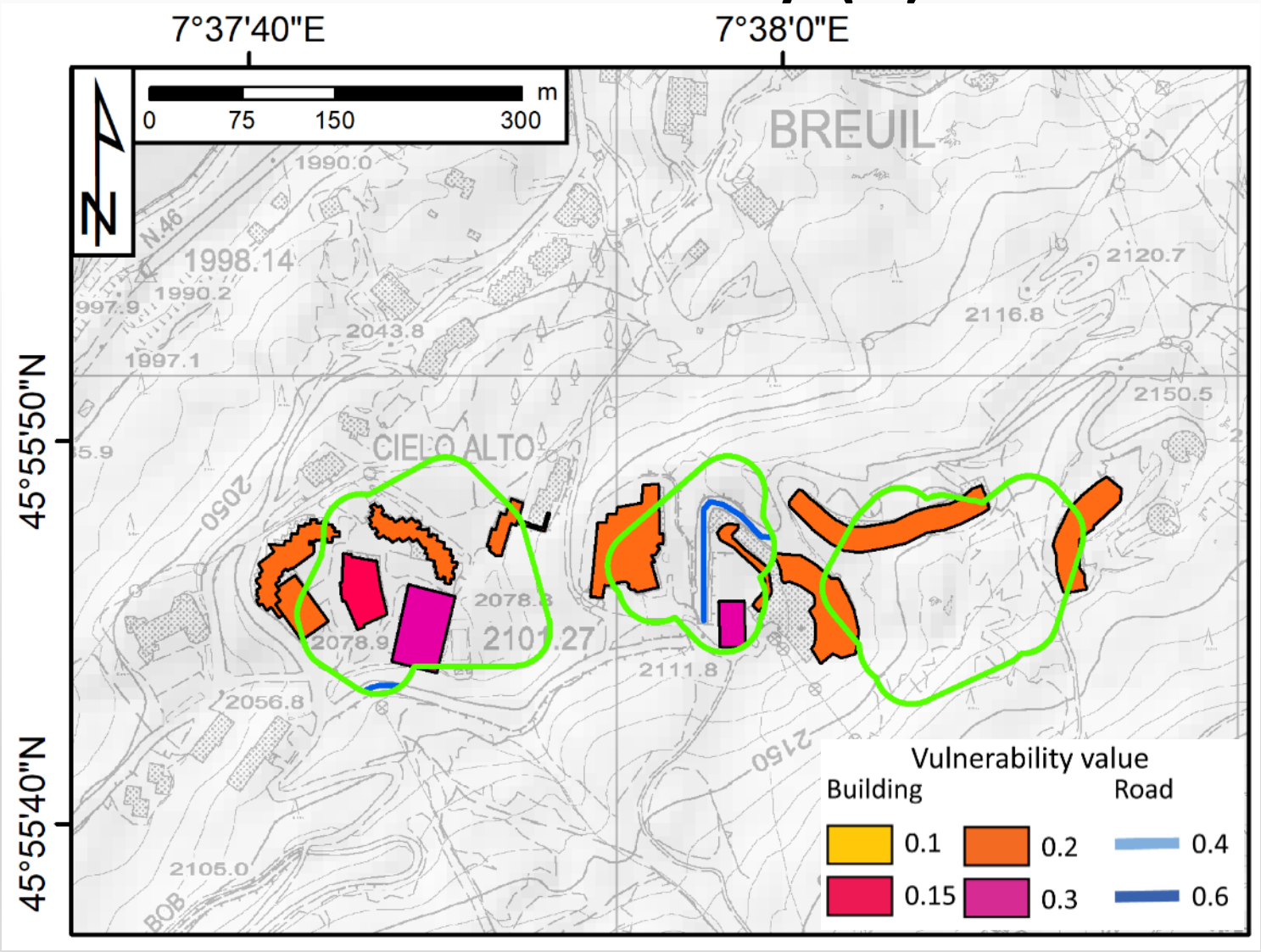
- D= I(fV)xE
- The potential loss is referred to the direct impact of a landslide on a building or road and it is expressed in quantitative terms (Euros for square meters)
- If one or both vulnerability and exposure are null, the potential loss is zero

ADA-related intensity (1)



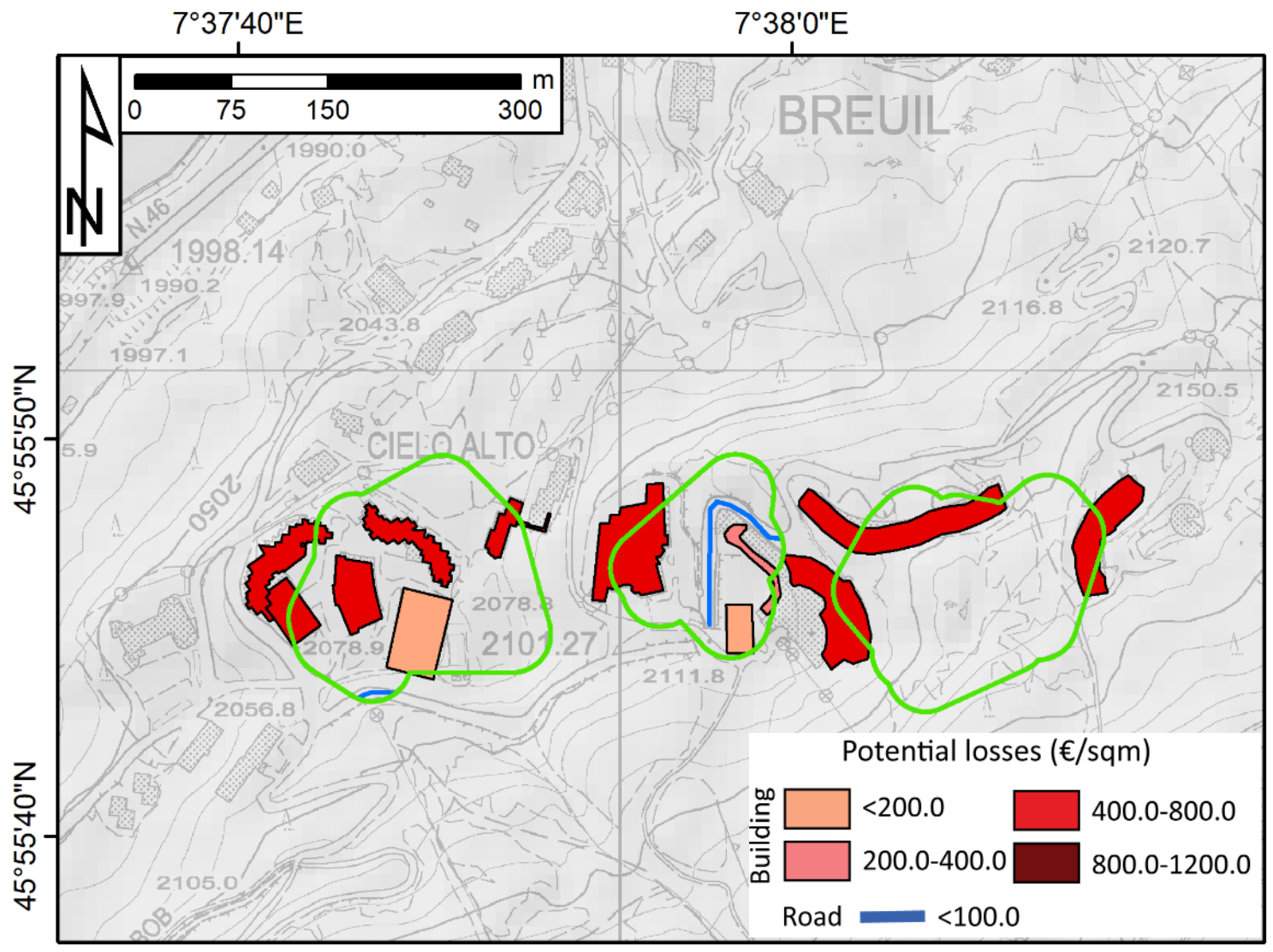
Cervinia, Valtournenche municipality. 3 ADA in the toe area of a large DSGSD

ADA-related intensity (1)



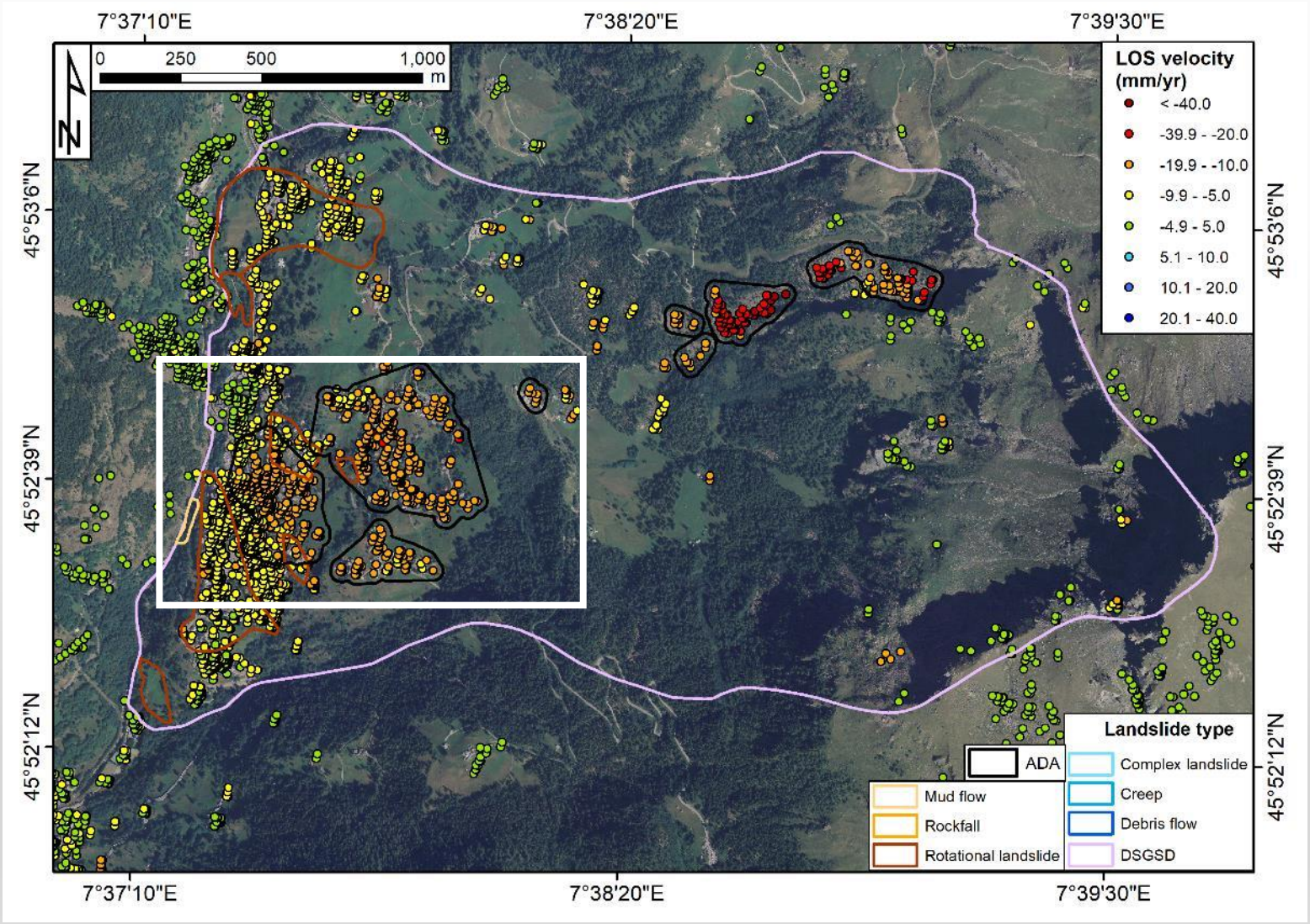
Residential buildings, a shopping mall, 2 tennis courts, an hotel and a restaurant. 1 local road

ADA-related intensity (1)



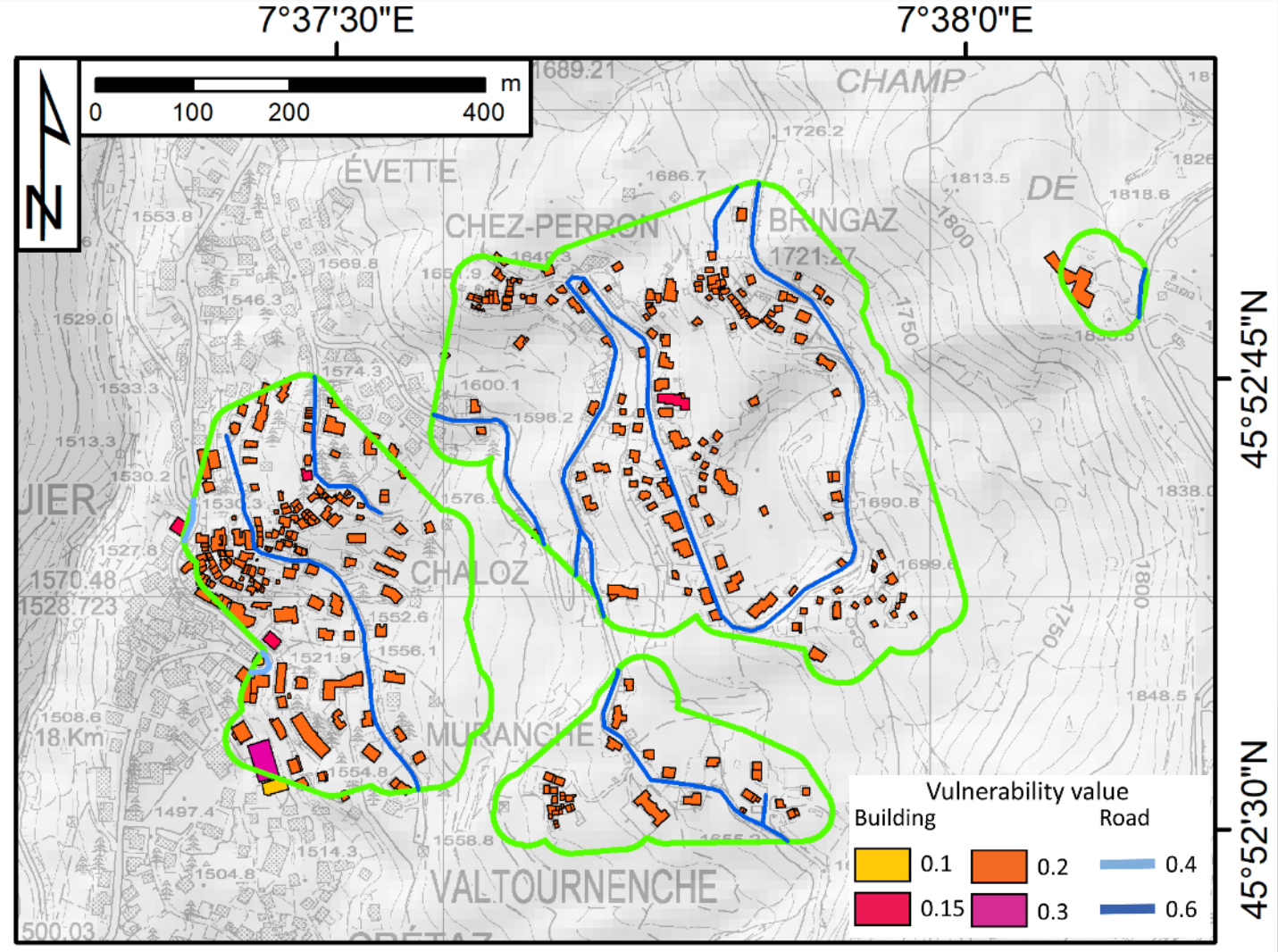
The highest potential loss is 525 €/sqm for a 4-stars hotel

ADA-related intensity (2)



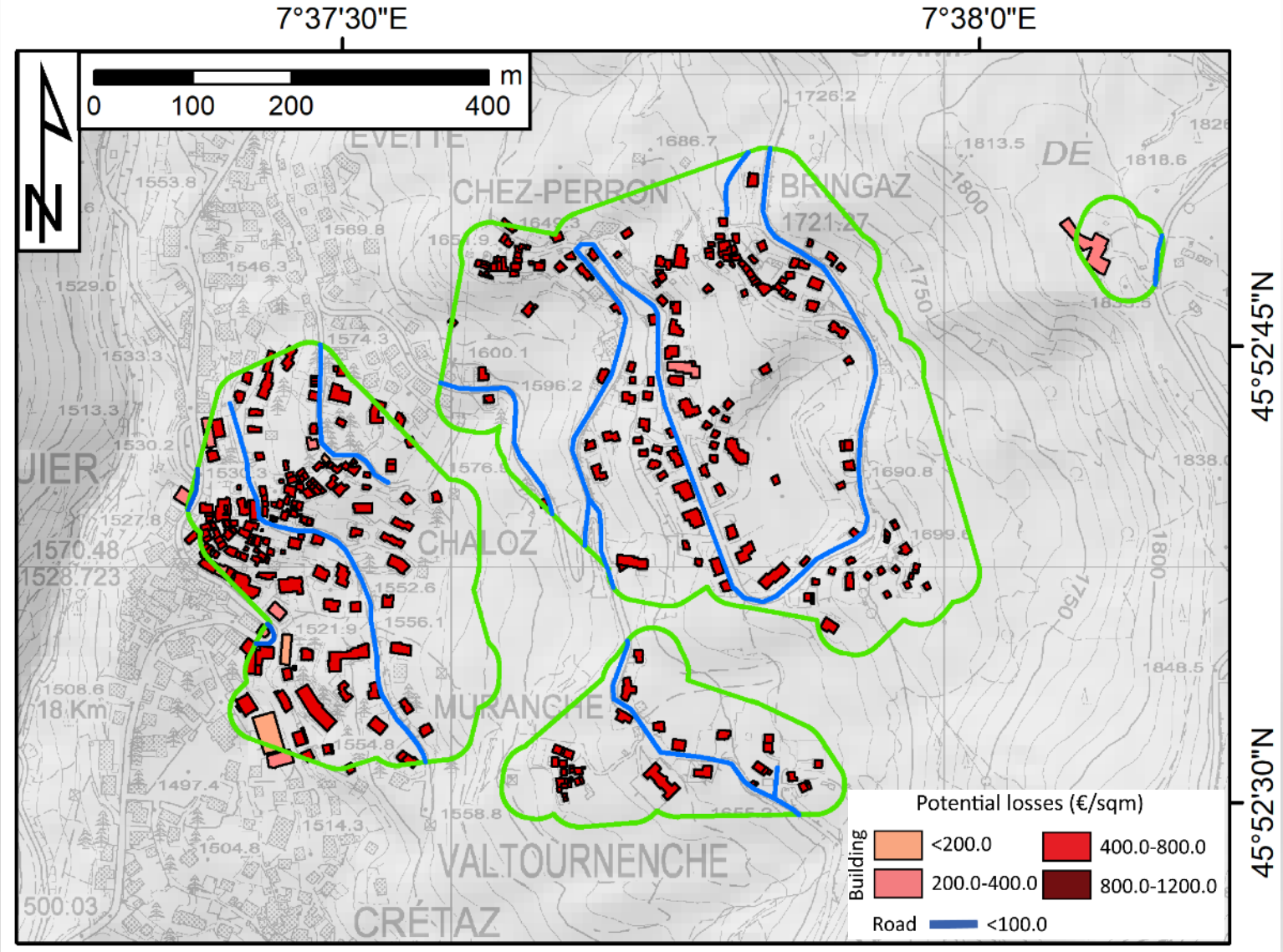
Chaloz village, Valtournenche municipality. Multiple ADA within a large DSGSD and various rotational landslides

ADA-related intensity (2)



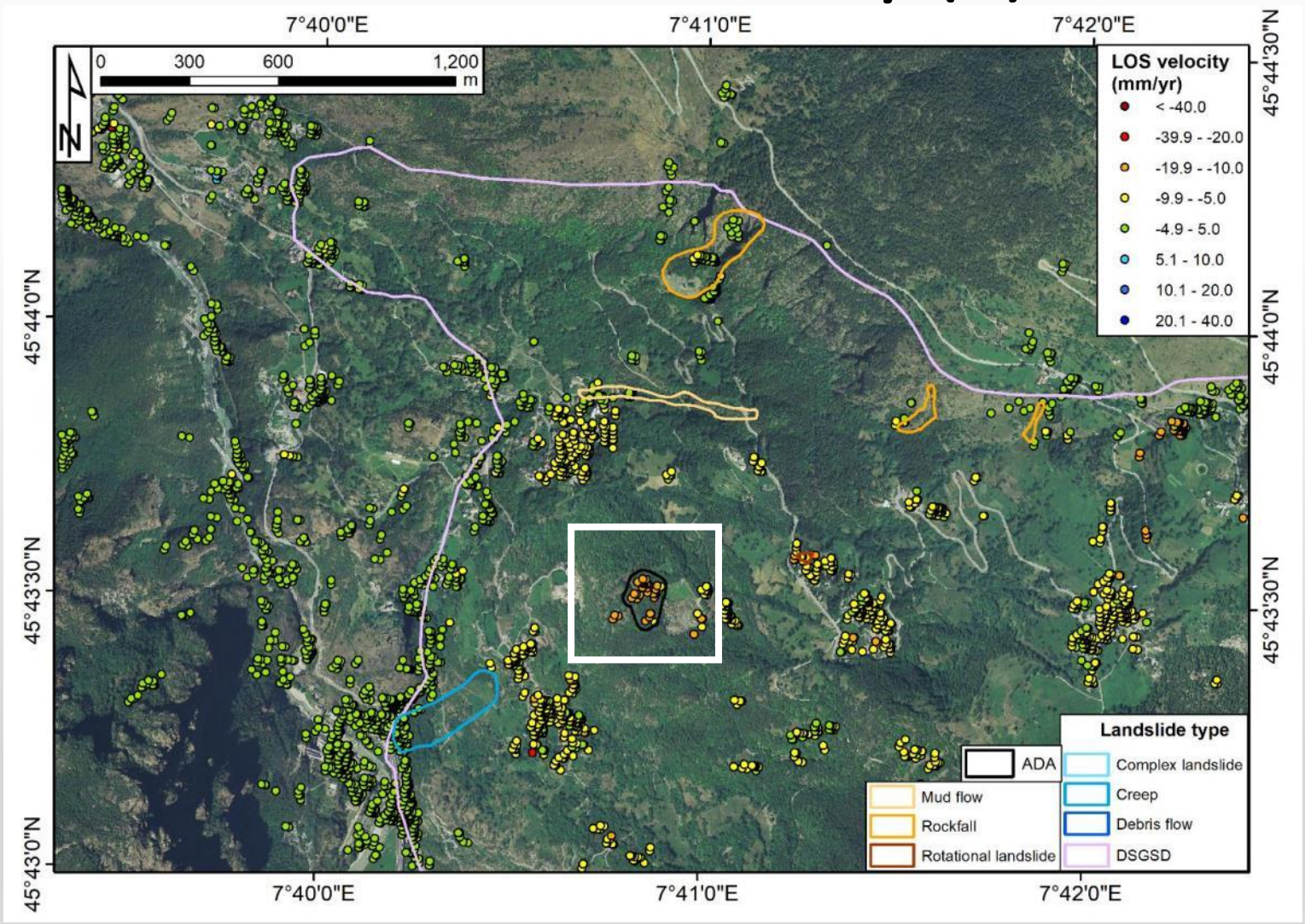
90% private houses, some shops, warehouses, four hotels, barns and a tennis court. Some local roads and a regional road

ADA-related intensity (2)



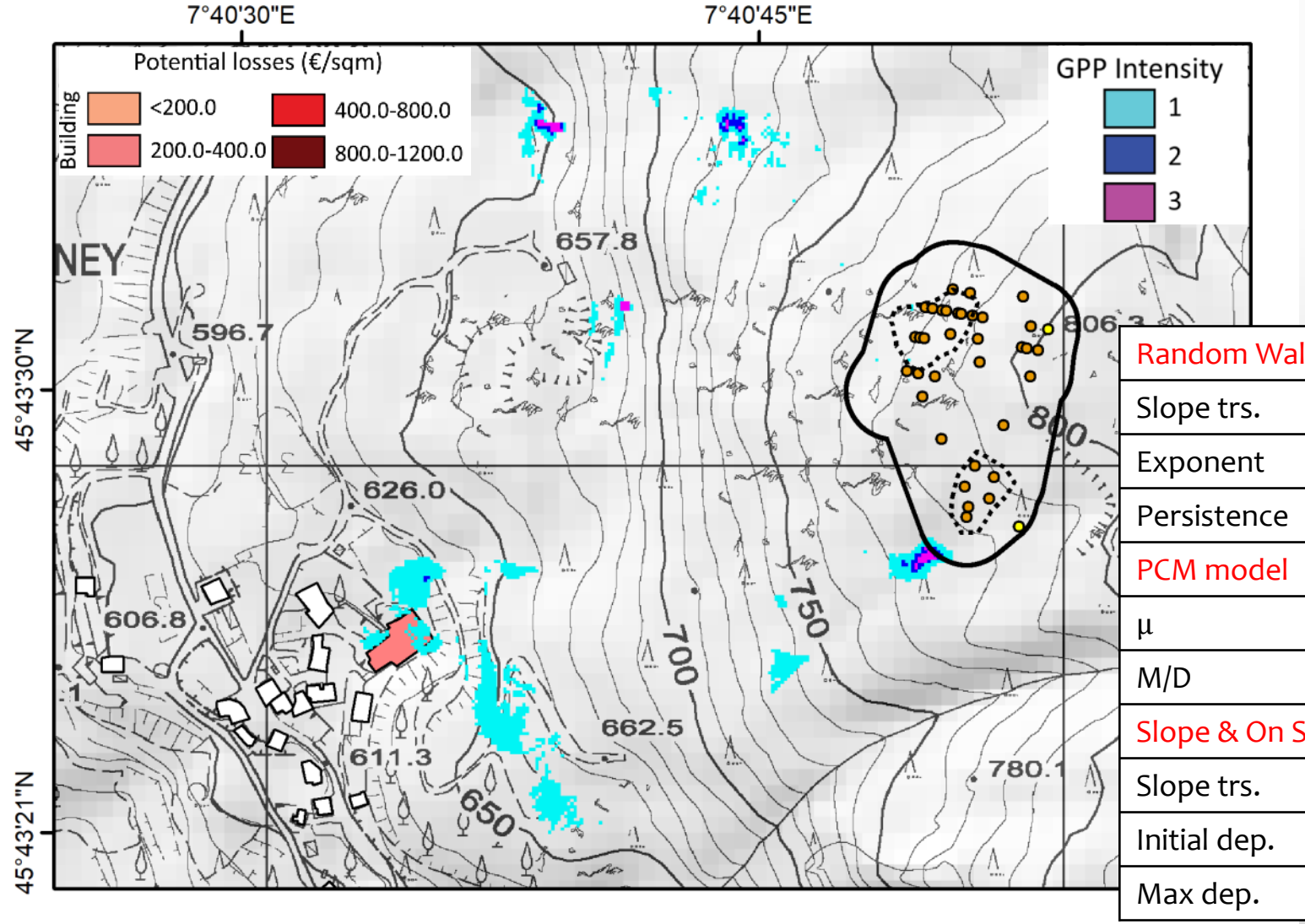
The highest potential loss is 490 €/sqm for private houses

Model-related intensity (1)



Ciseran village, Montjovet municipality. One ADA found within a debris area in a large DSGSD

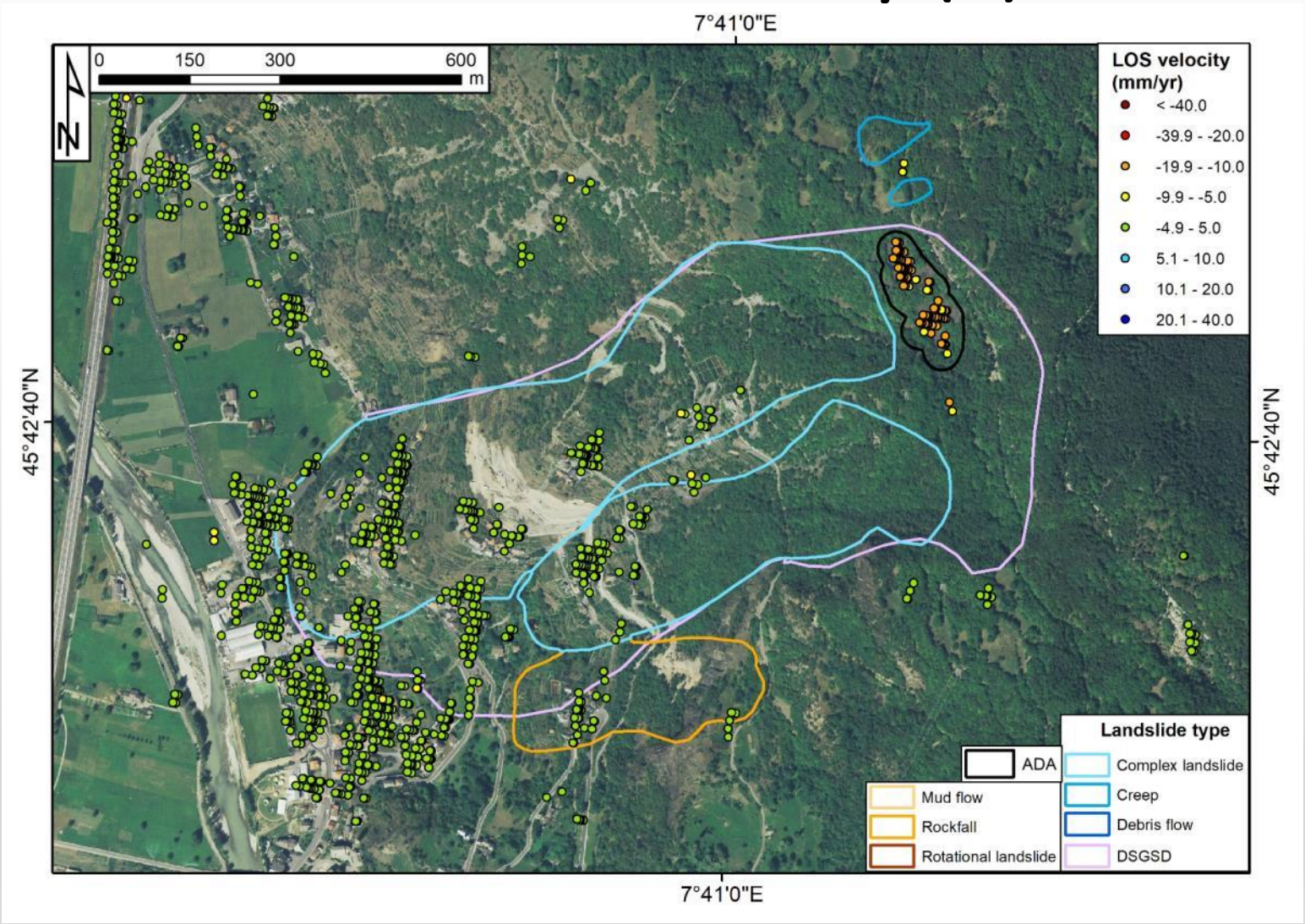
Model-related intensity (1)



Random Walk model	
Slope trs.	40°
Exponent	1.5
Persistence	1.5
PCM model	
μ	0.2
M/D	70
Slope & On Stop	
Slope trs.	15°
Initial dep.	10%
Max dep.	20%

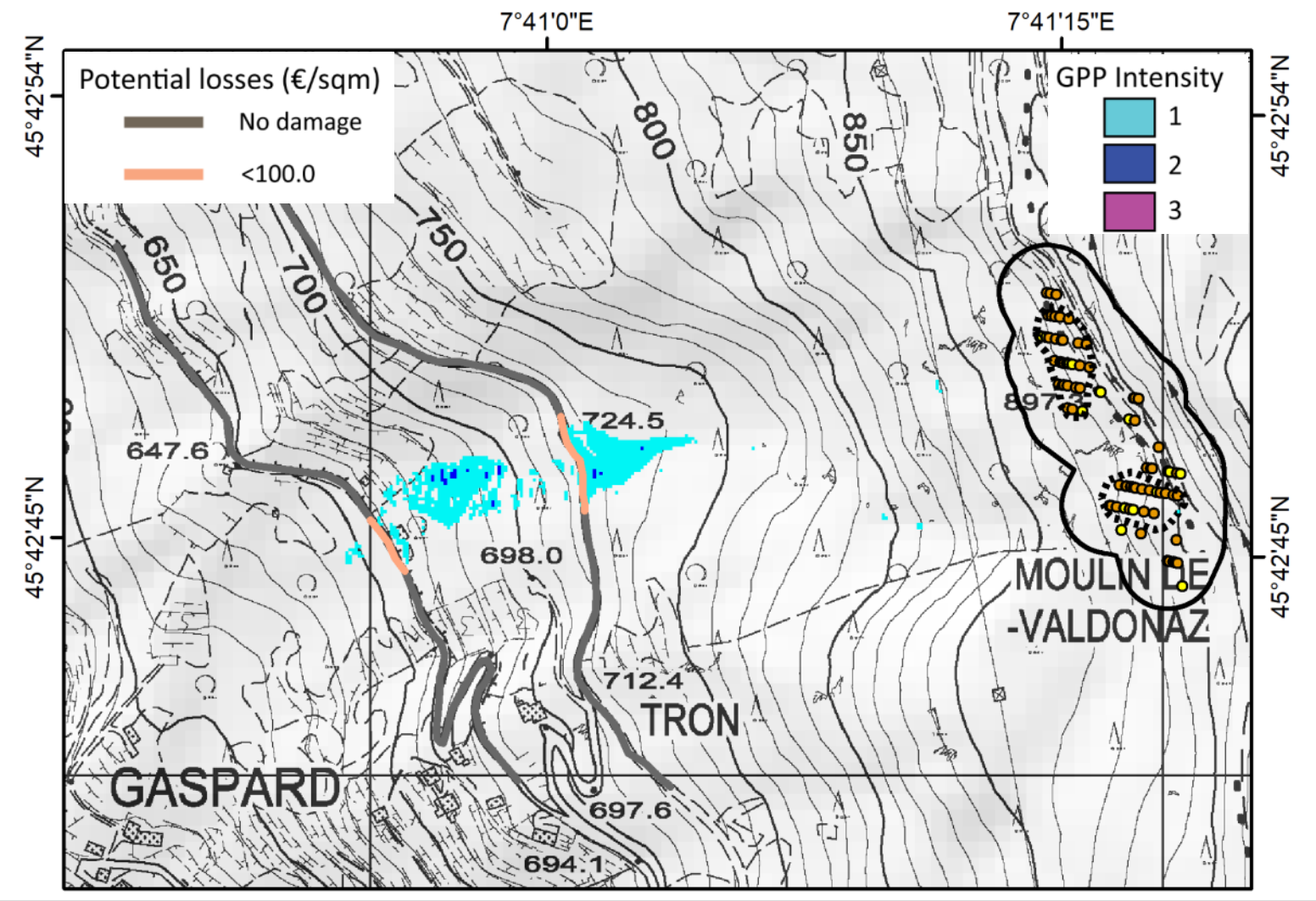
One private house could be hit by the debris flow with intensity 1.
V=0.2 and D=260€/sqm

Model-related intensity (2)



Tron village, Montjovet municipality. One ADA found within a debris area in a large DSGSD, crown area of 2 complex landslides

Model-related intensity (2)



Two local roads could be hit by the debris flow with intensity 1. V=0.6 and D=30€/sqm

Final considerations

- We expand the concept of PS hot-spots, using them as input for “quantitative” damage estimation
- Interferometric data are here used for:

1. ground movement hot-spots detection
2. as landslide intensity tool (“ADA-related” approach)
3. potential debris flow source areas detection (“model-related” approach)

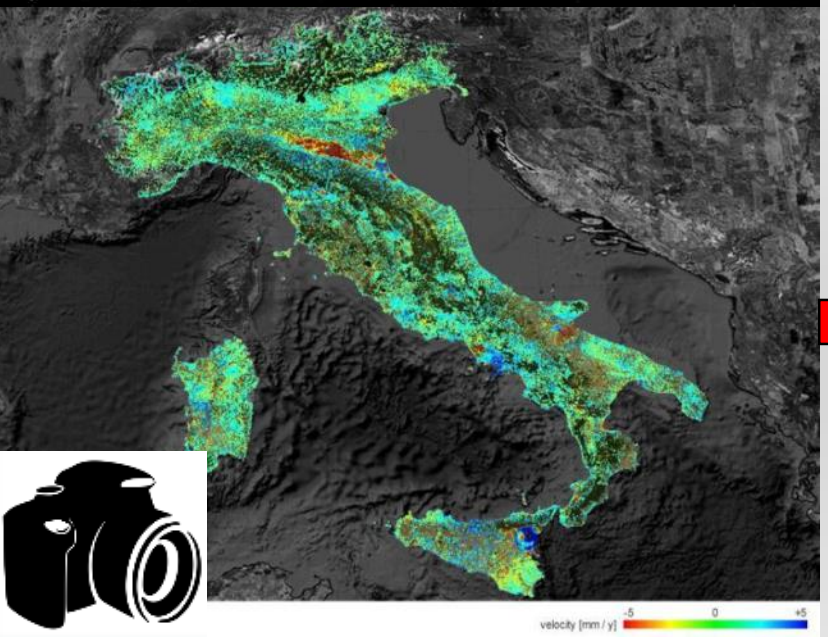
- The methodology is designed for regional scale studies with few ancillary data available
- The methodology is designed for a wider exploitation of interferometric products, not only as mapping tools but also as instruments for preliminary risk estimation

Limitations

- All the classical limitations of interferometric data (topography, snow, vegetation, fast motions…)
- Both vulnerability and exposure are estimated at medium to small scale. This is not a detailed scale analysis, it should be refined where possible
- The GPP model is a “worst-case” scenario forecasting, not a rheological model of a single phenomenon. So we can both underestimate or overestimate the reality
- No temporal occurrence information about the phenomena can be given, so it is not a quantitative risk analysis

Sentinel-1 satellite monitoring system of the Tuscany Region

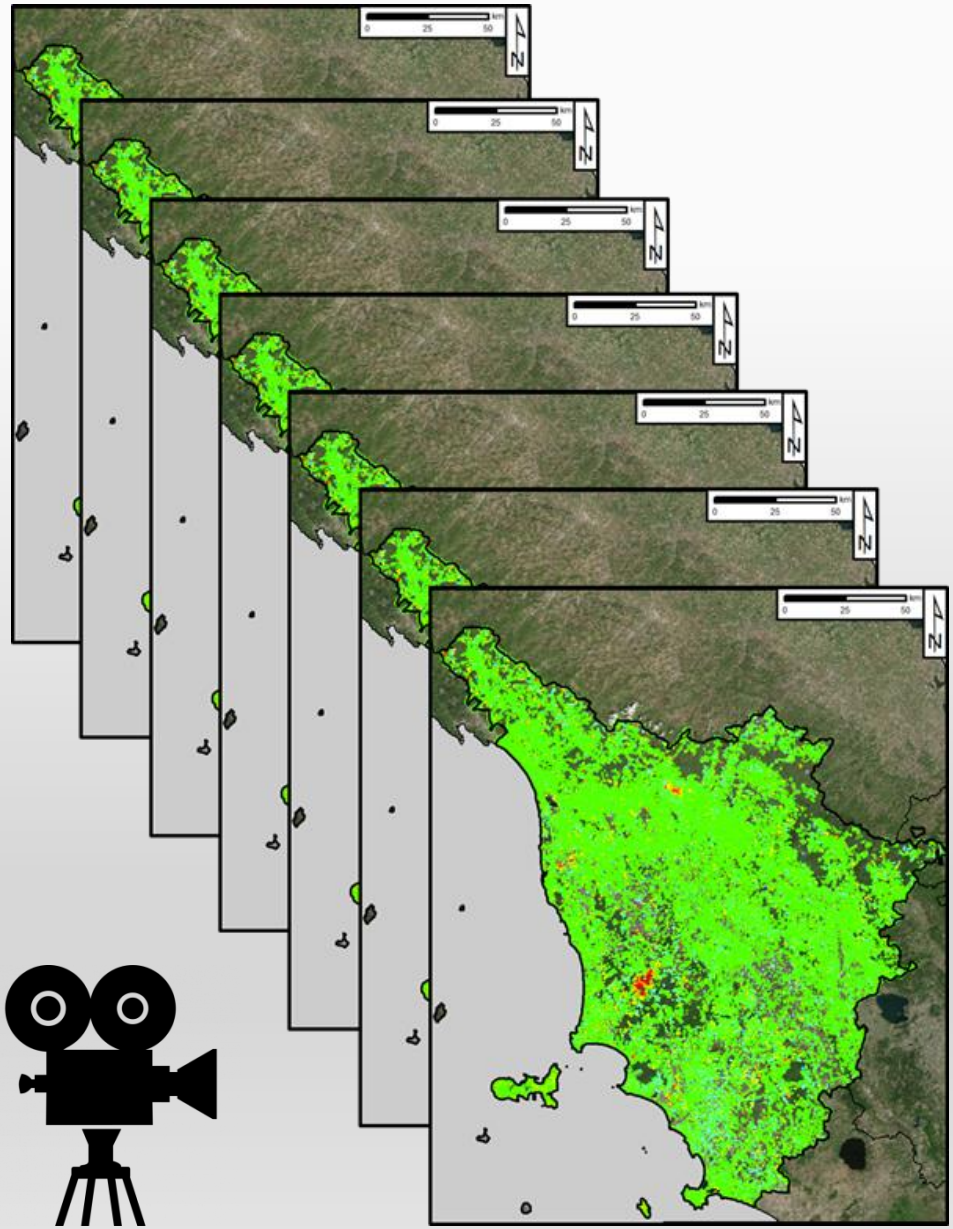
Technological background



a. Sentinel-1 is providing a continuous streaming of radar images free-for-all
b. "Science-oriented" acquisition plan → no data lost
c. Good compromise between acquisition band and resolution for regional-scale studies

d. Algorithms and calculus power are ready to process over wide areas
e. We already have the experience of previous "photographs" of entire nations
f. New cloud-computing capabilities

The concept

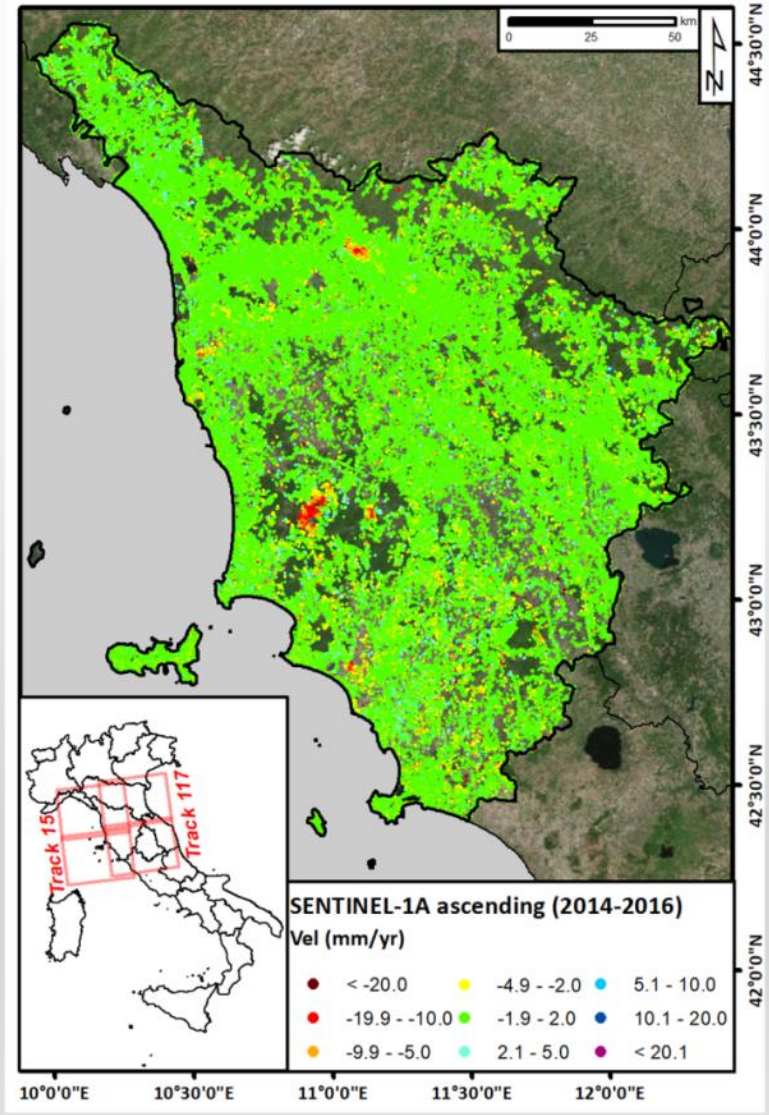


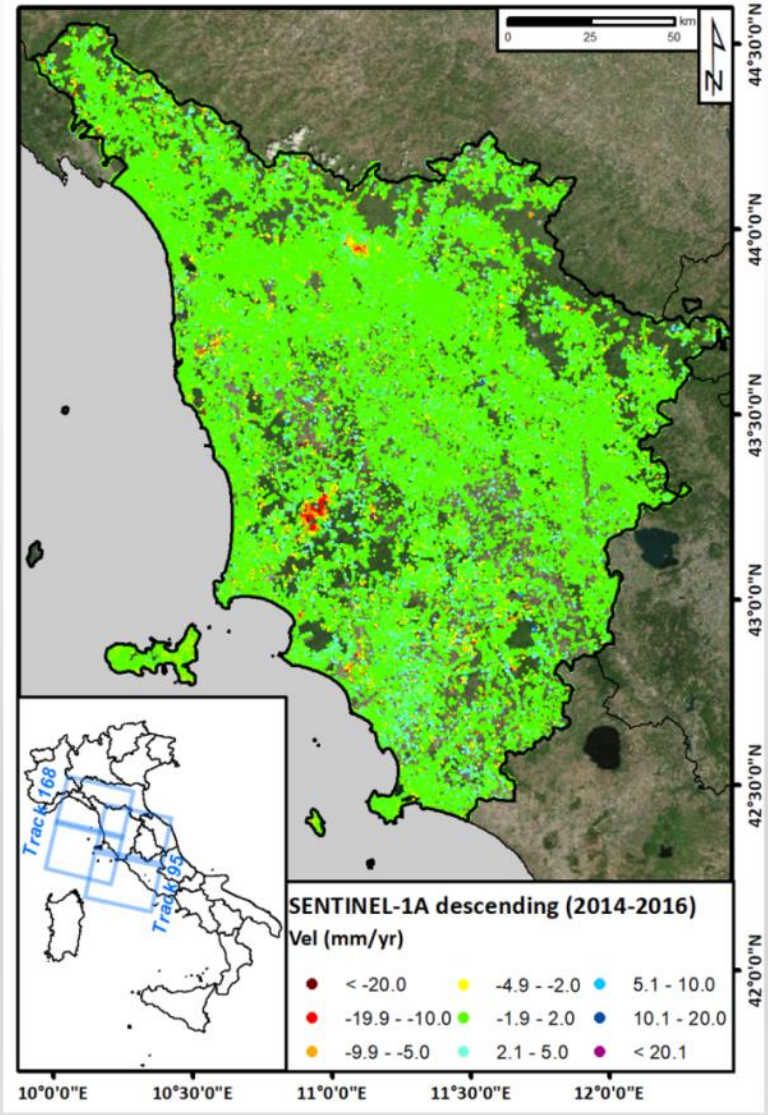
Transition from static satellite analysis to dynamic monitoring of ground displacement

Transition from «one-shot» delivery to a continuous streaming of information

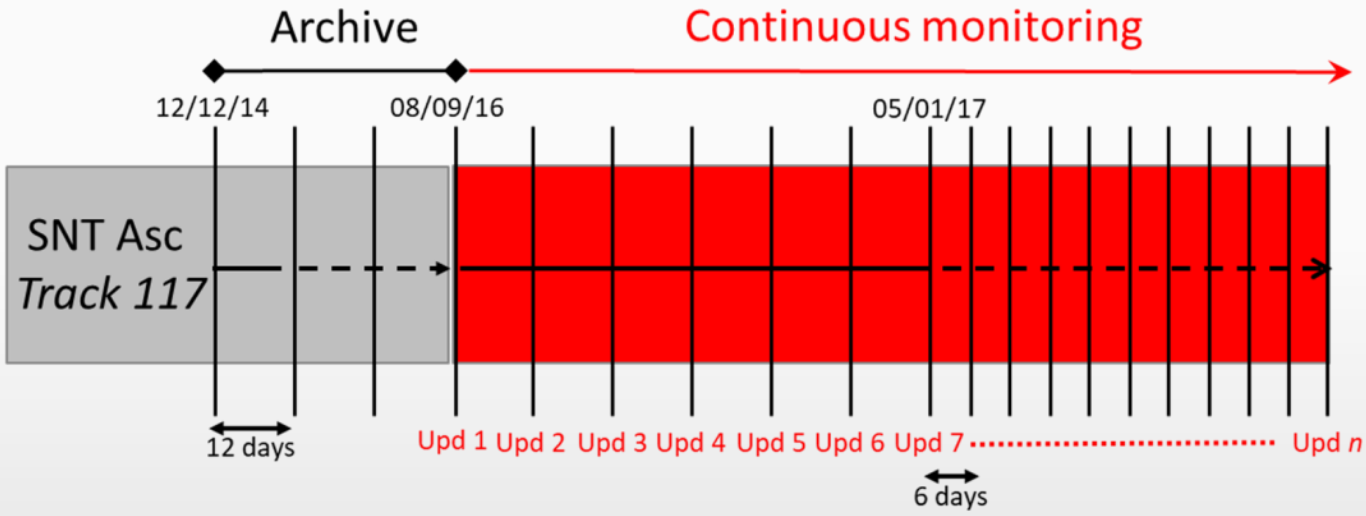
Systematic analysis of deformation time series, coupled with automatic tools for data mining and screening of large datasets

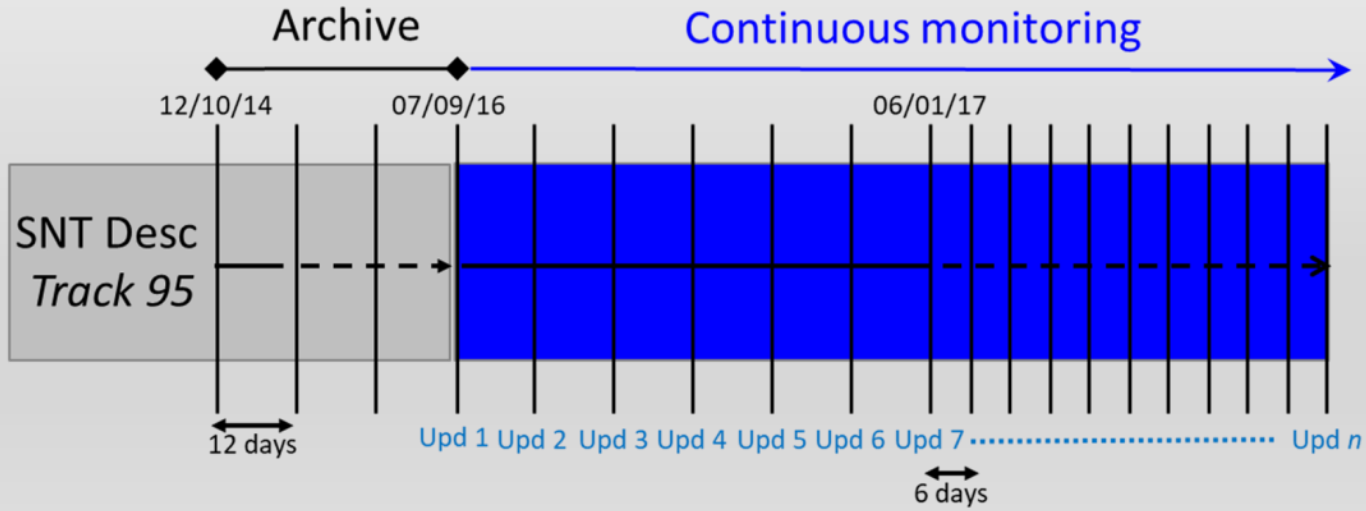
Deformation maps





Monitoring plan





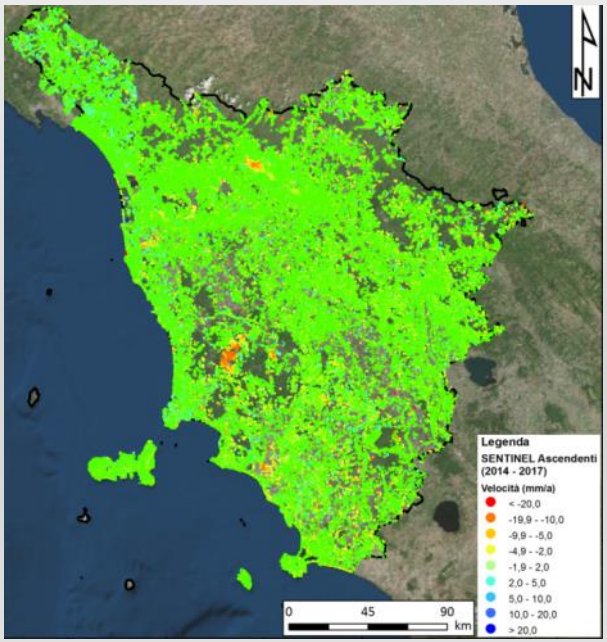
71 updates of the project – almost 3 years of monitoring

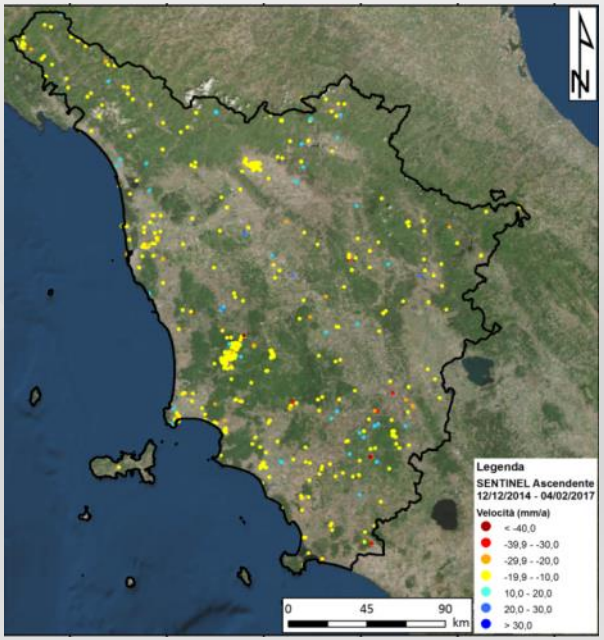
Our activities

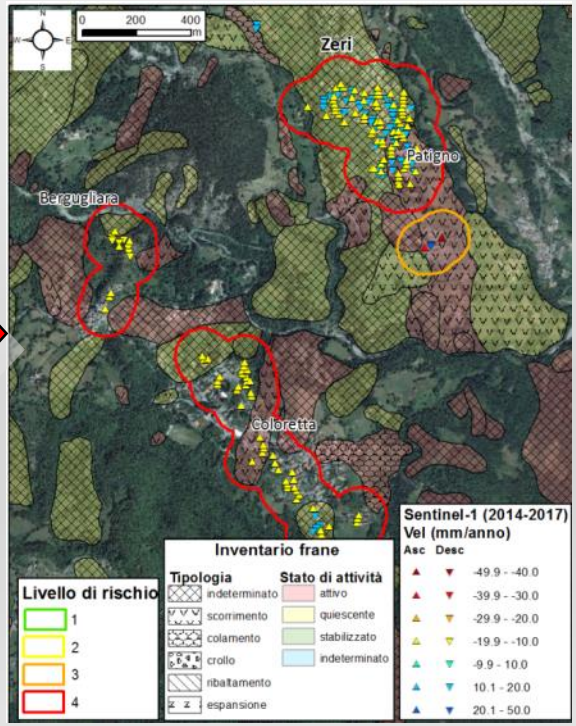
	PS Mapping	PS Monitoring
Typology	Single product	Continuous service
Time	deferred	«real»
Update	1 year	6 days
Purpose	Update of landslides inventory maps	Update of scenarios for geohazard risks

PS Mapping

- It is based on the concept of ADA – Hot spot analysis
- We perform the analysis every year
- We classify each moving area on the basis of its possible triggering cause (mining, subsidence, uplift, landslide, geothermal activity)

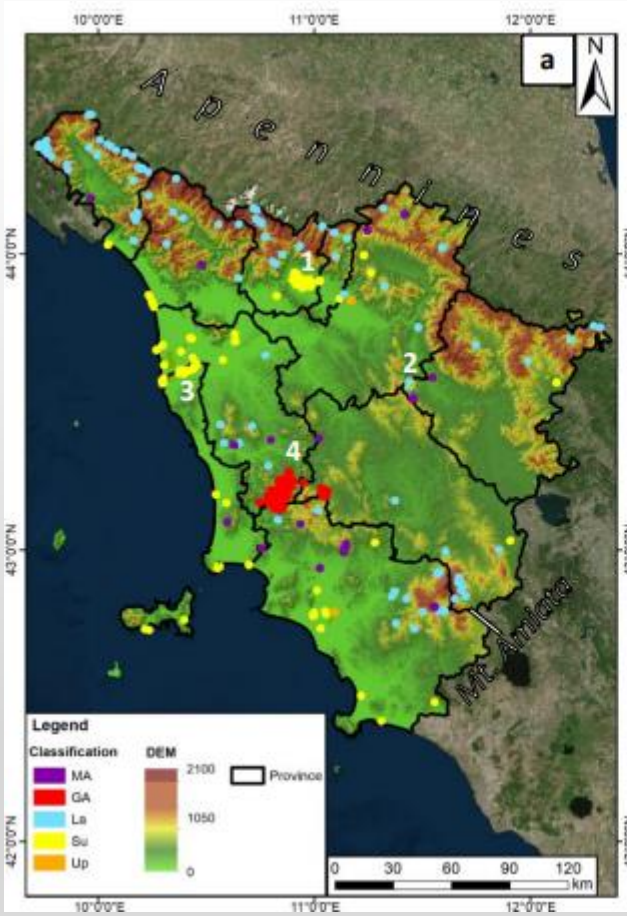




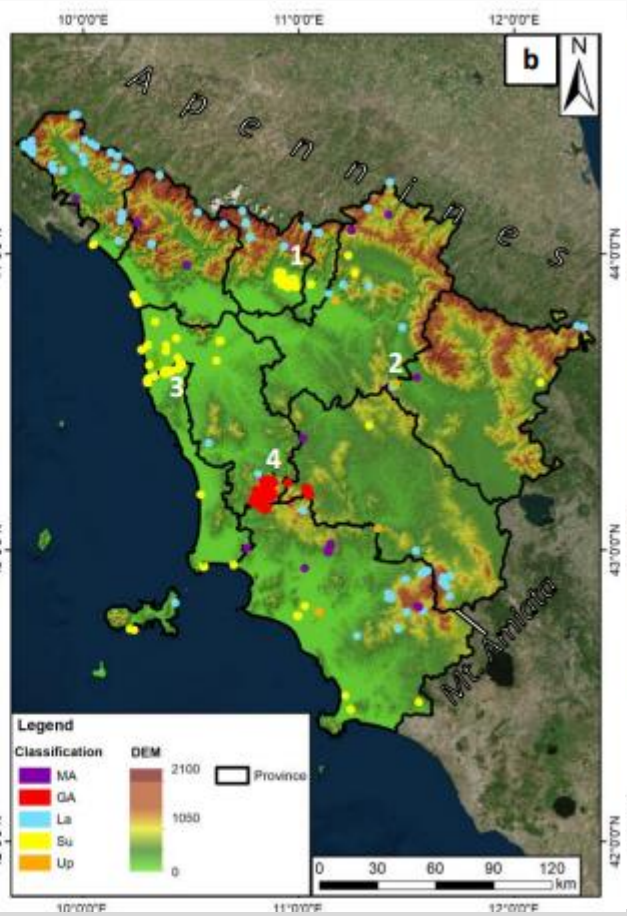


Multi-temporal results

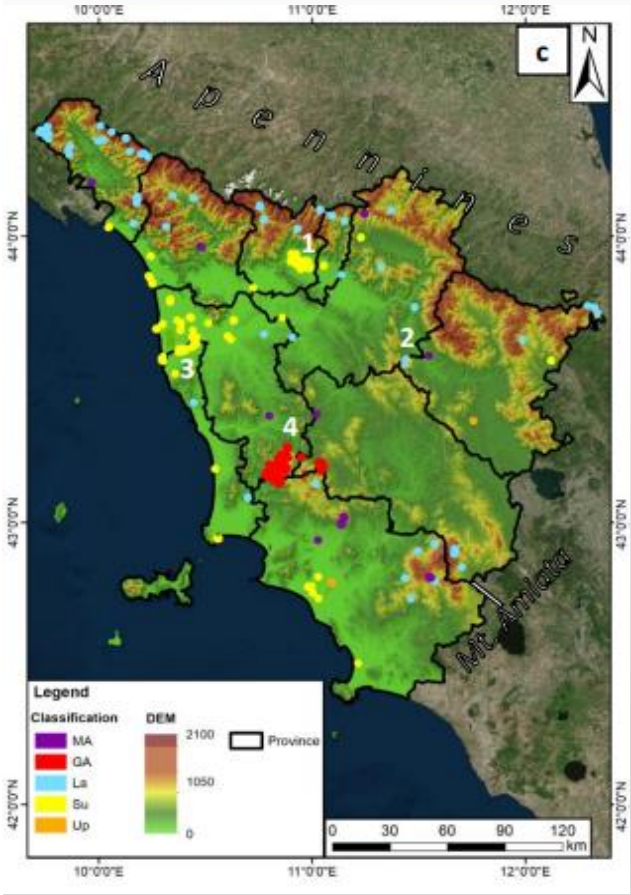
1st year



2nd year

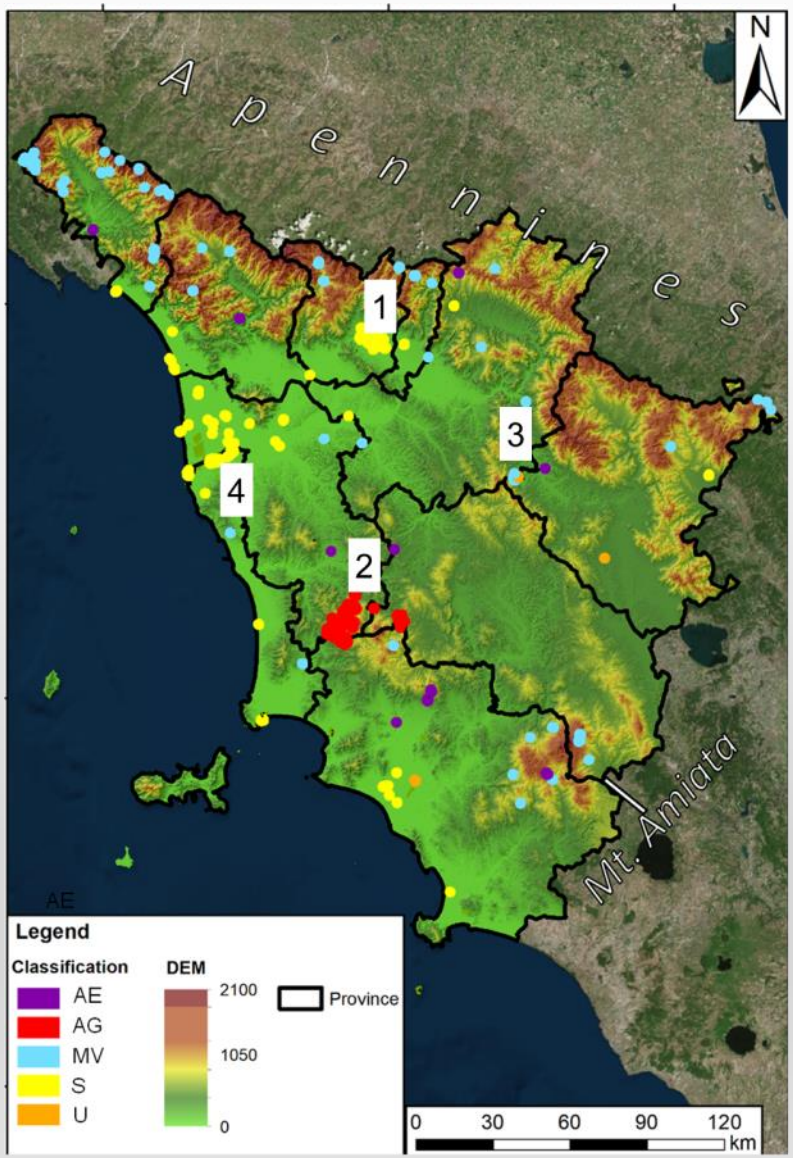


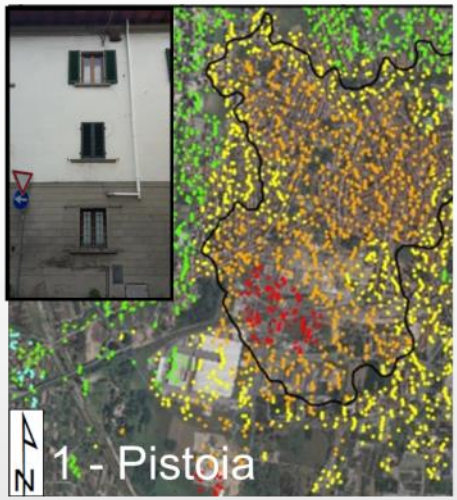
3rd year

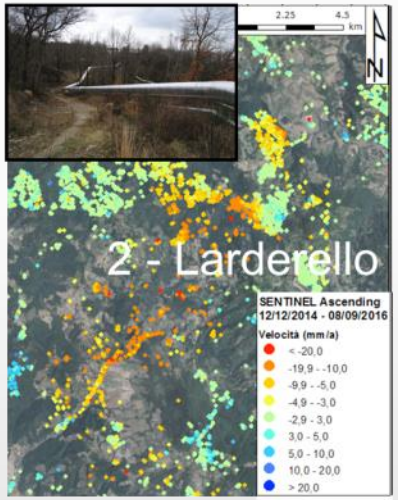


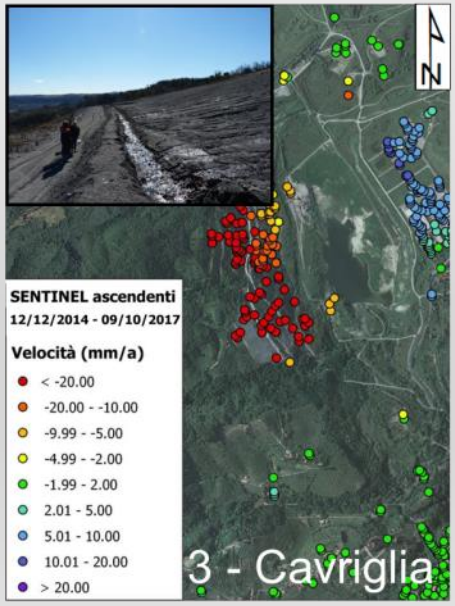
The filtering threshold is 10 mm/yr

Some examples

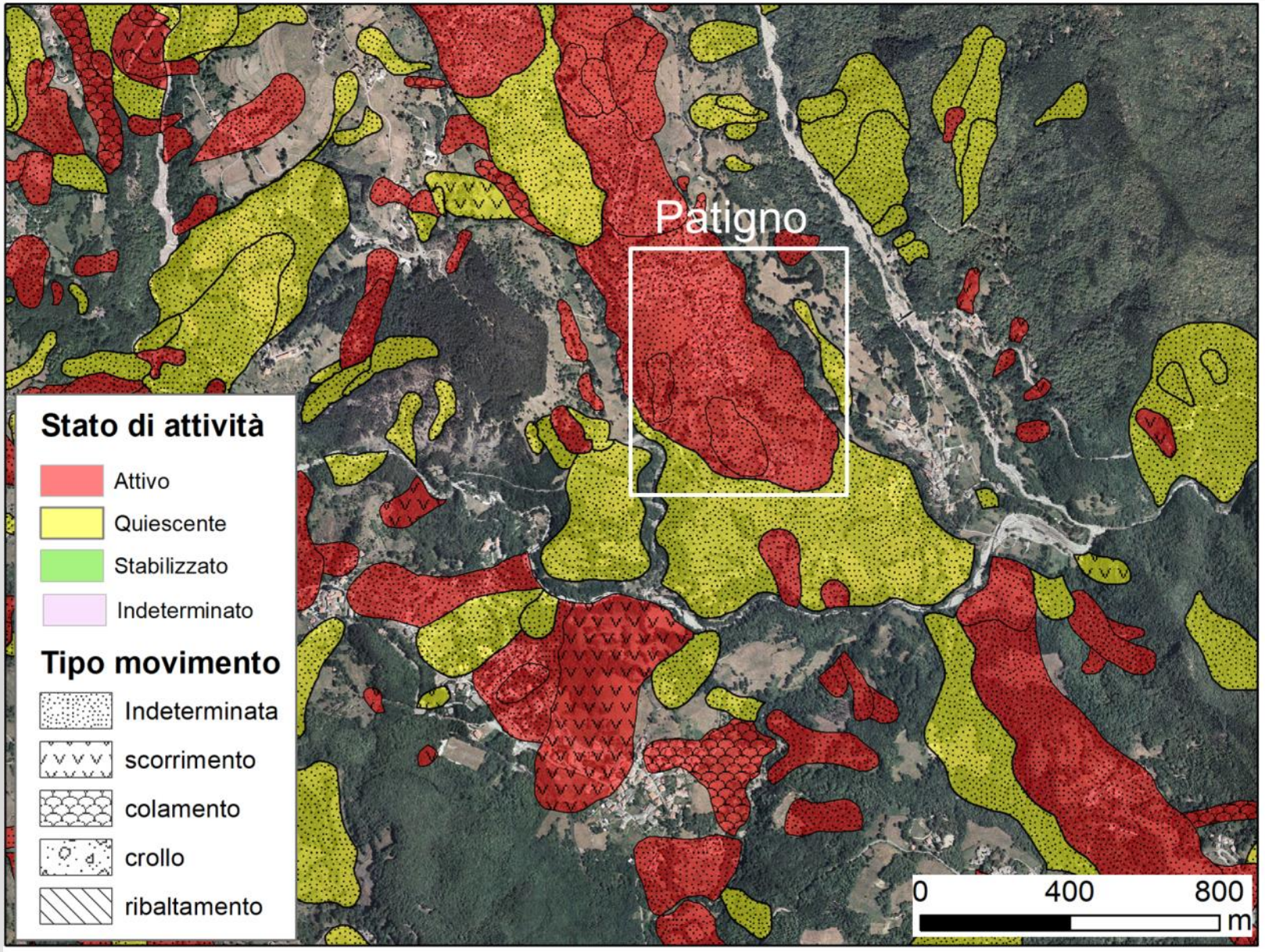




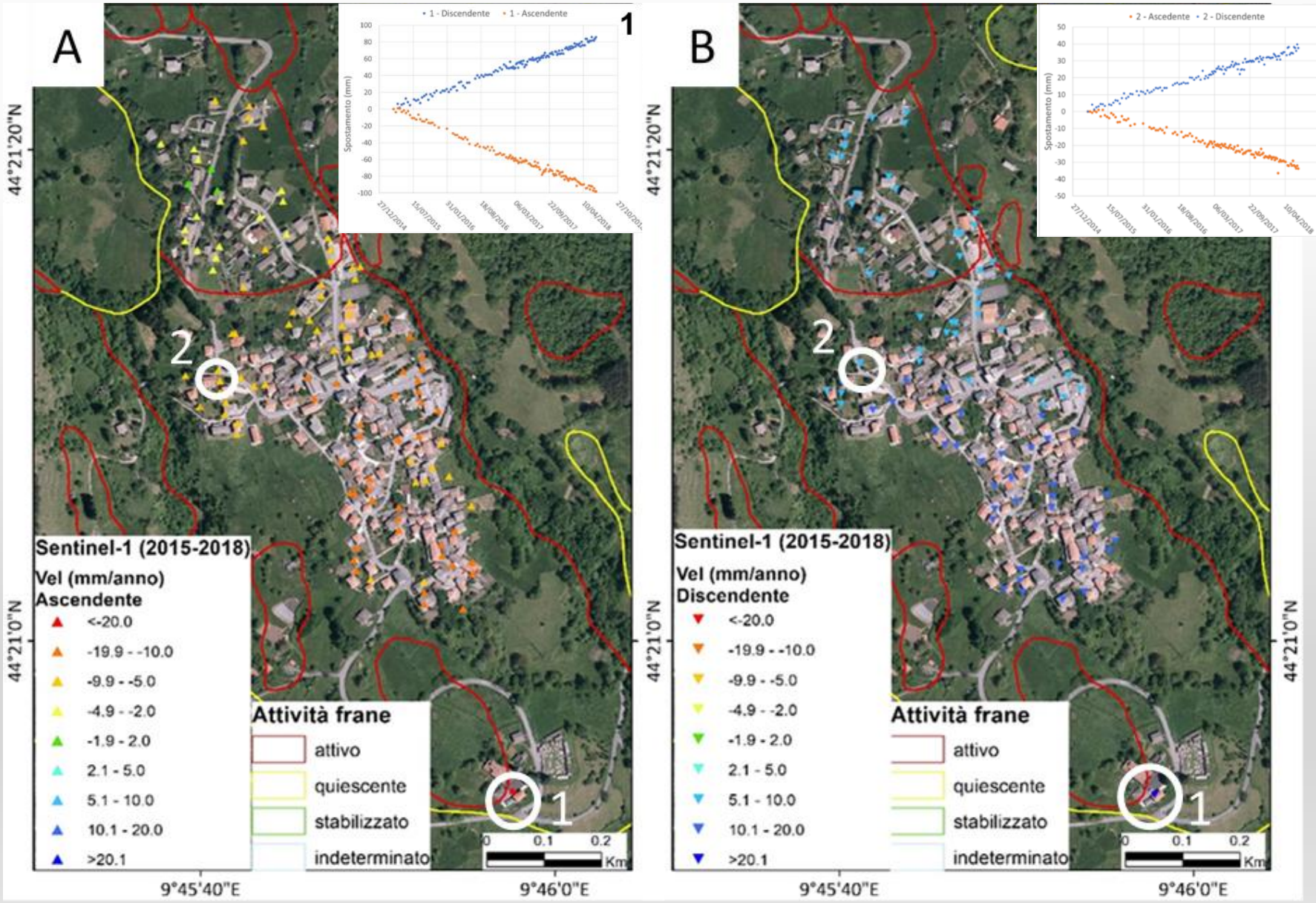




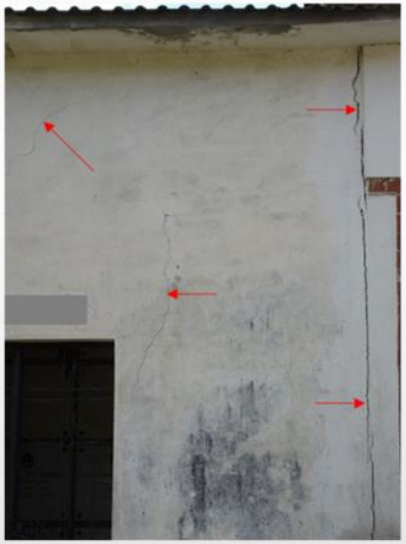
Patigno landslide



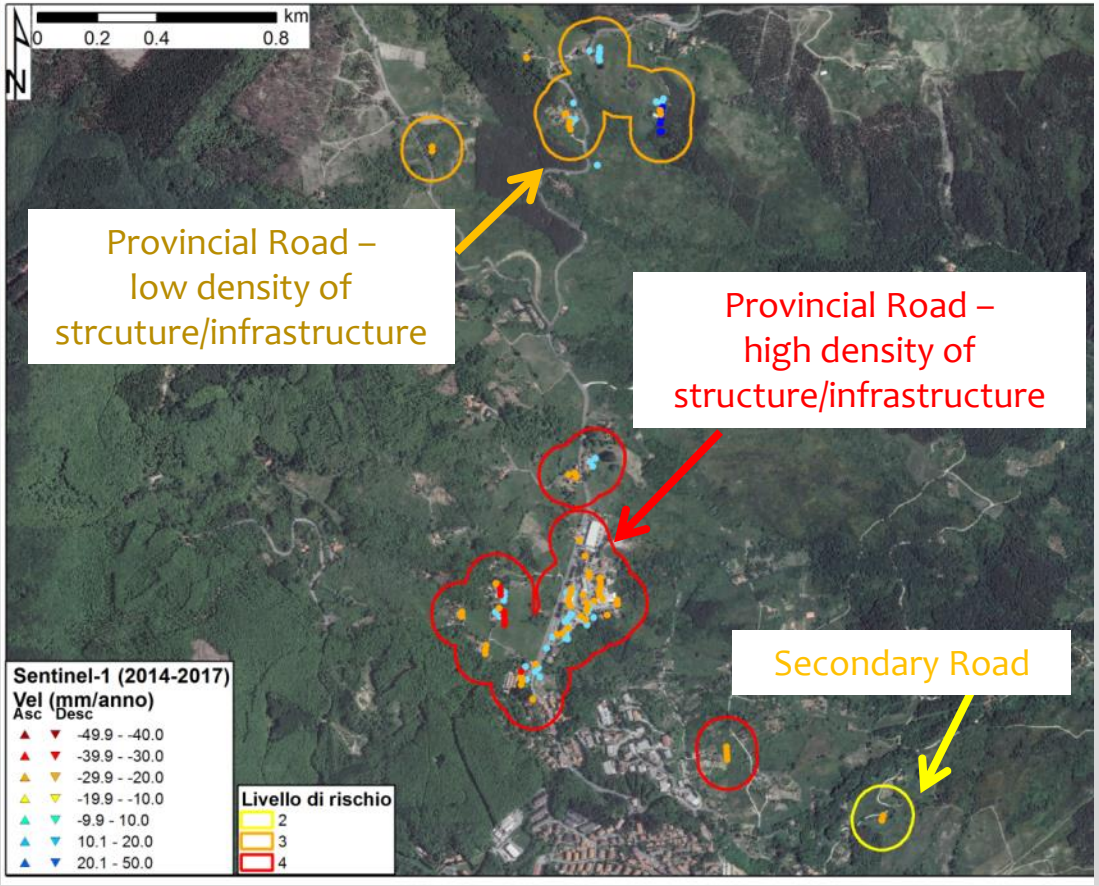
Patigno landslide



Patigno landslide



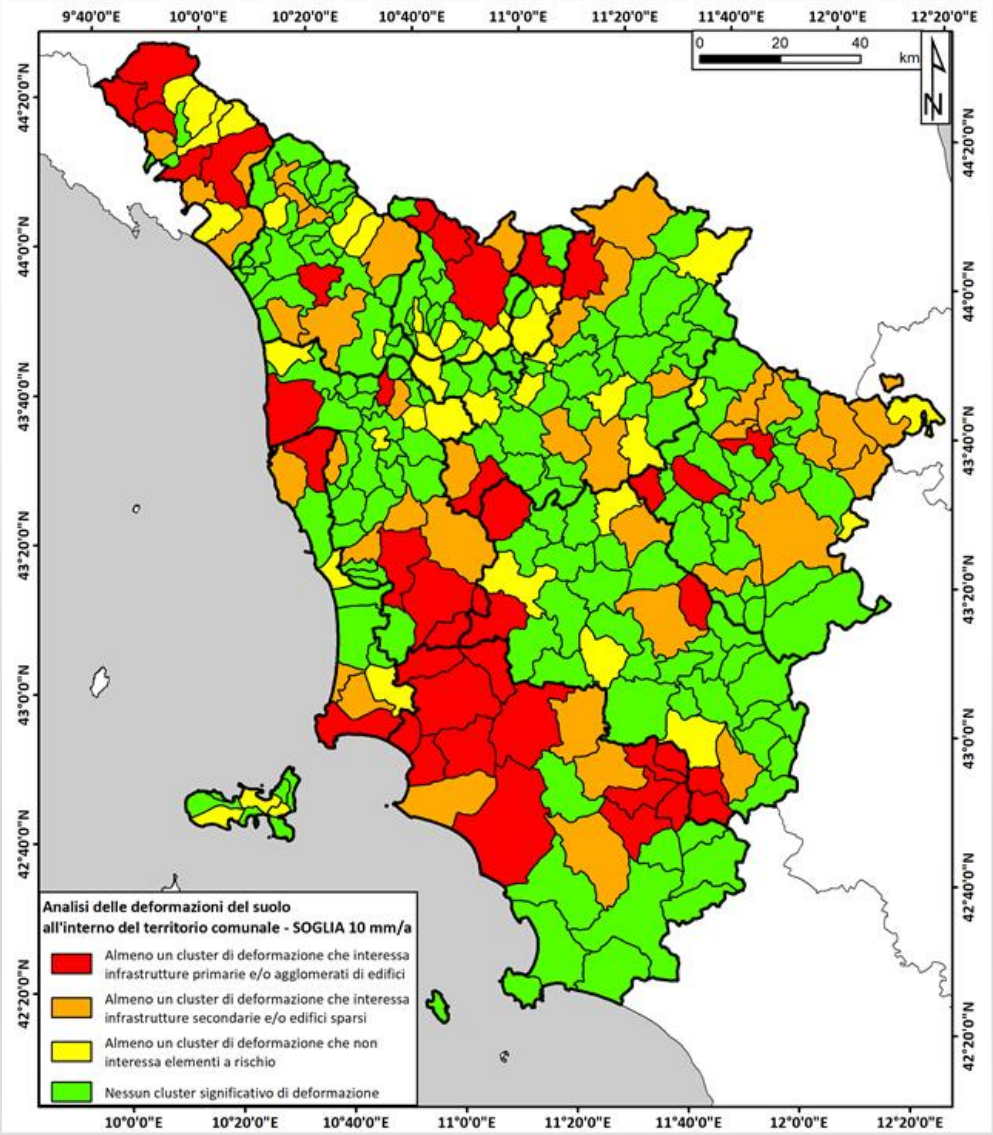
Municipality classification

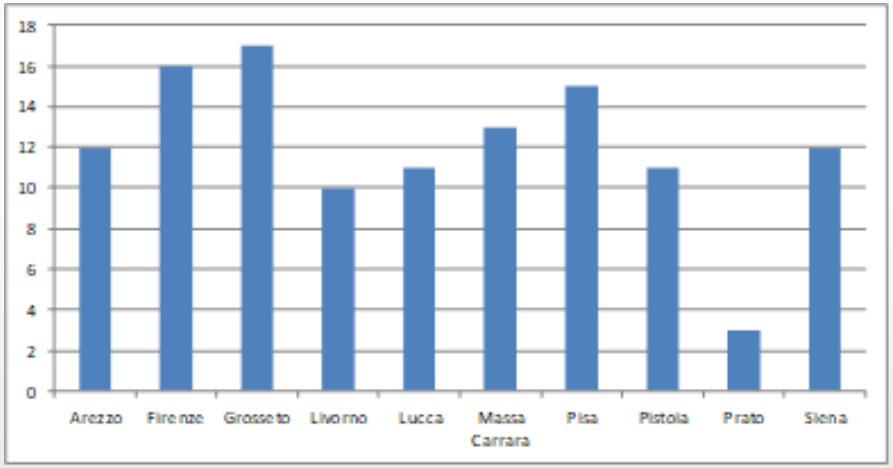


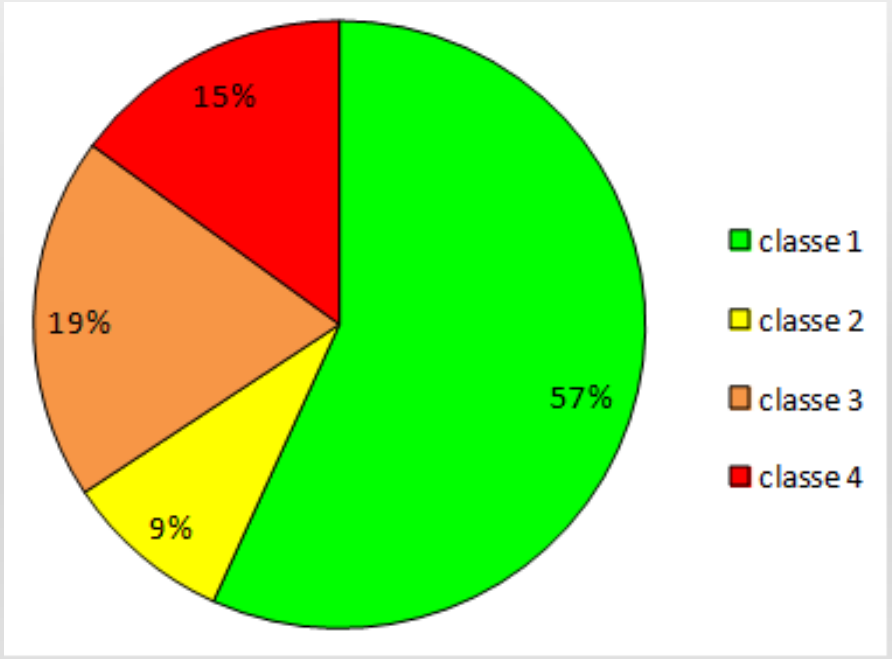
Class	Description
1	No relevant cluster
2	Isolated elements at risk (secondary road network, isolated buildings) within the clusters
3	Elements at risk (primary road network, isolated buildings) within the clusters
4	Several elements at risk (primary road network, villages, town) within the clusters

- Expeditious “risk” evaluation
- We only consider the type of element at risk – qualitative way

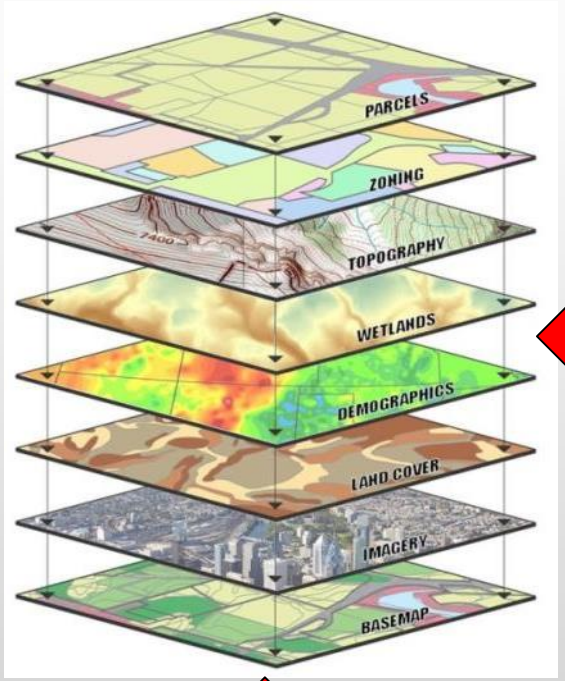
Final product



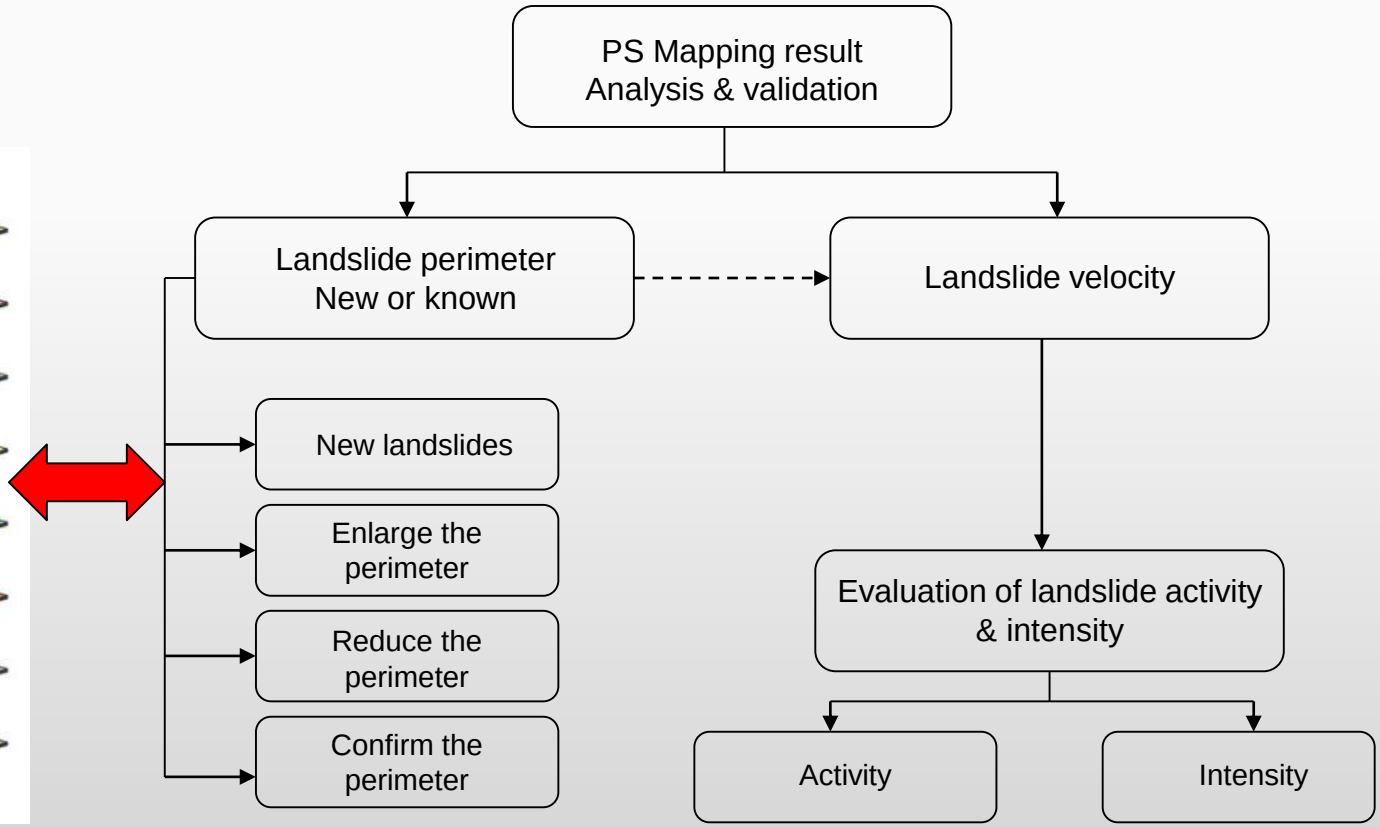




PS Mapping dissemination & use

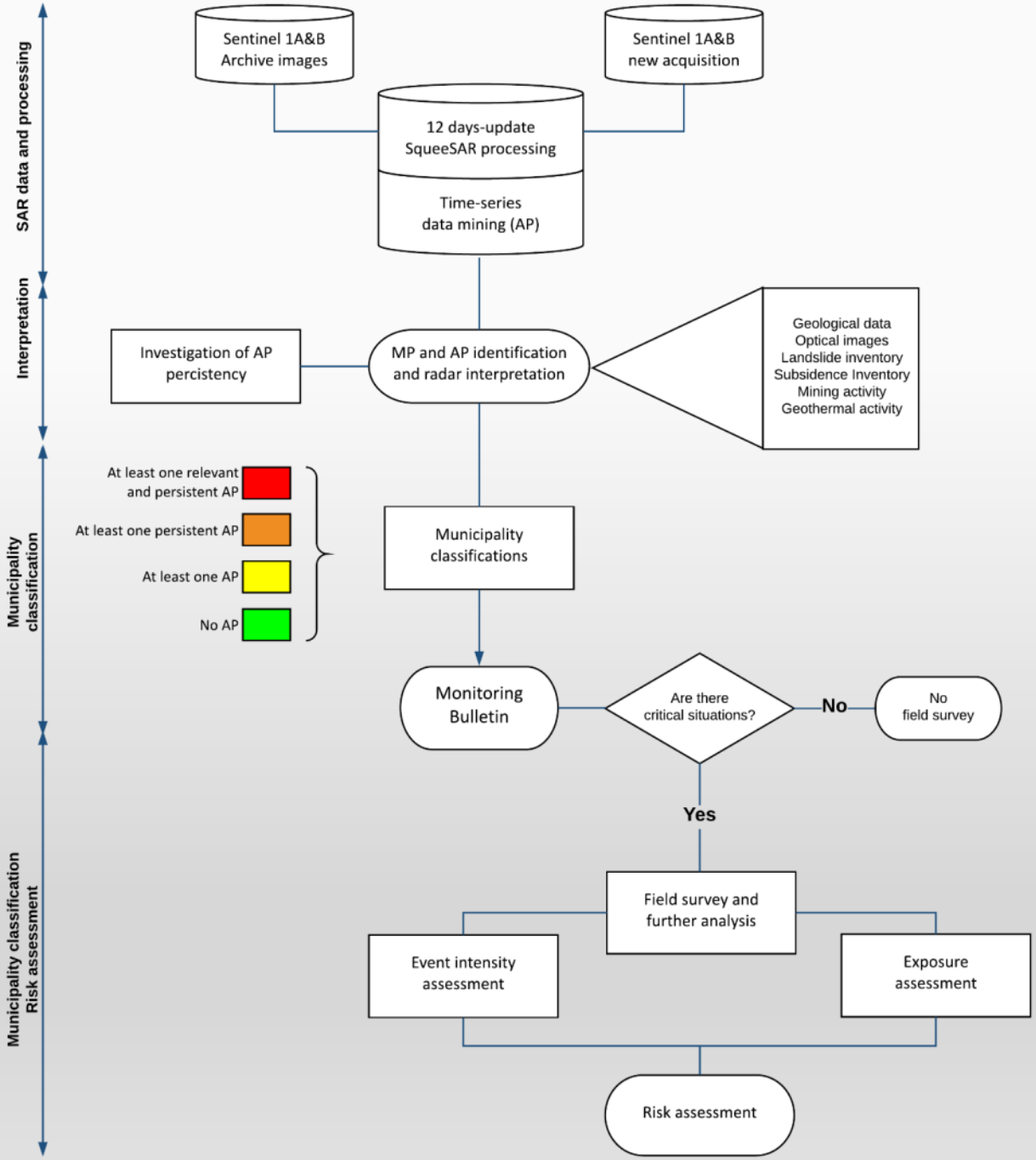


Survey



Operational document for landslide risk management of the Tuscany Region
Resolution n° 224 of 25/02/2019

PS Monitoring procedure



www.nature.com/scientificreports

Anomaly detection

Anomalouls point: PS with a change of deformation rate in the last 150 days

SCIENTIFIC REPORTS

OPEN

Continuous, semi-automatic monitoring of ground deformation using Sentinel-1 satellites

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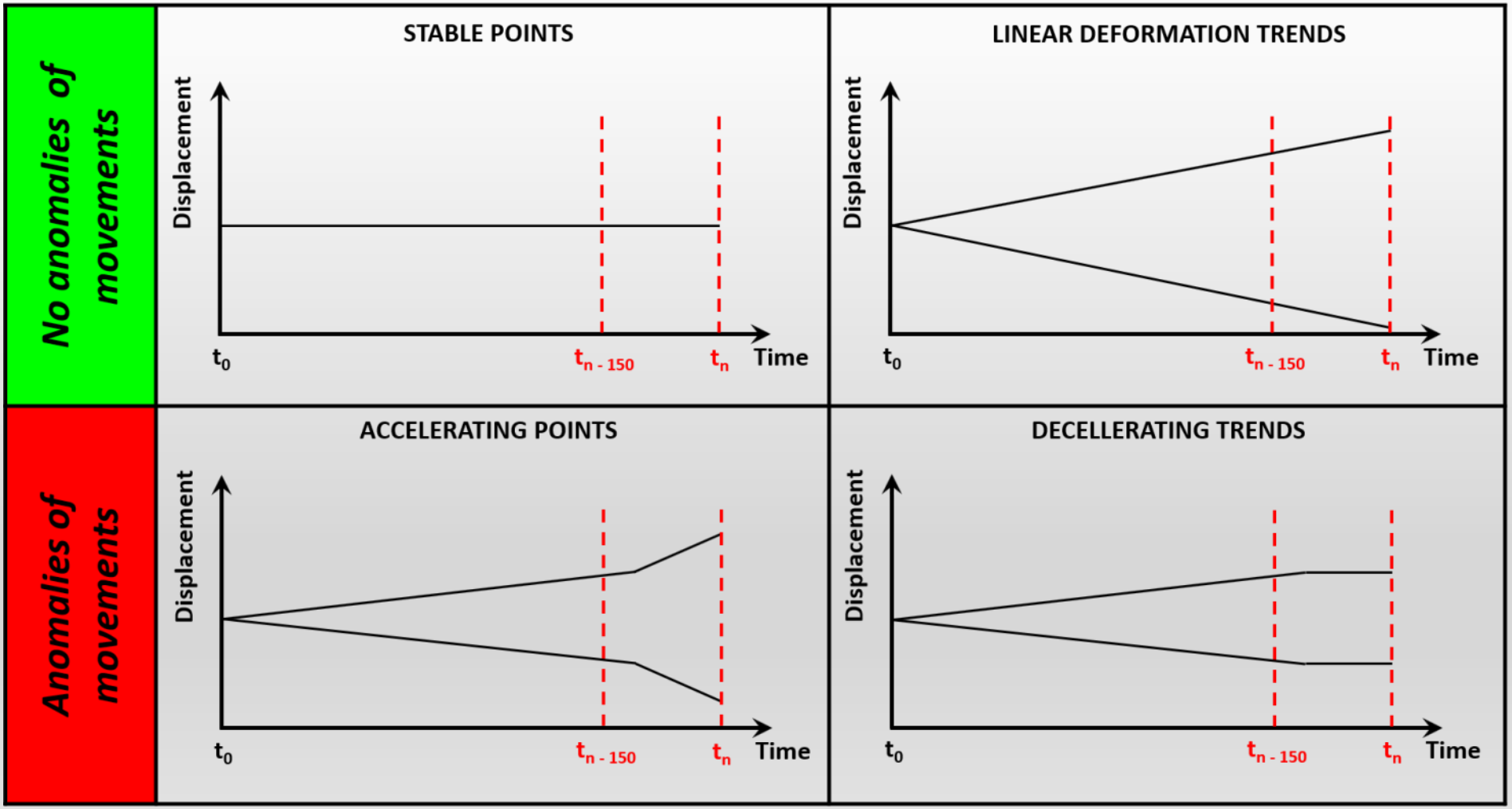
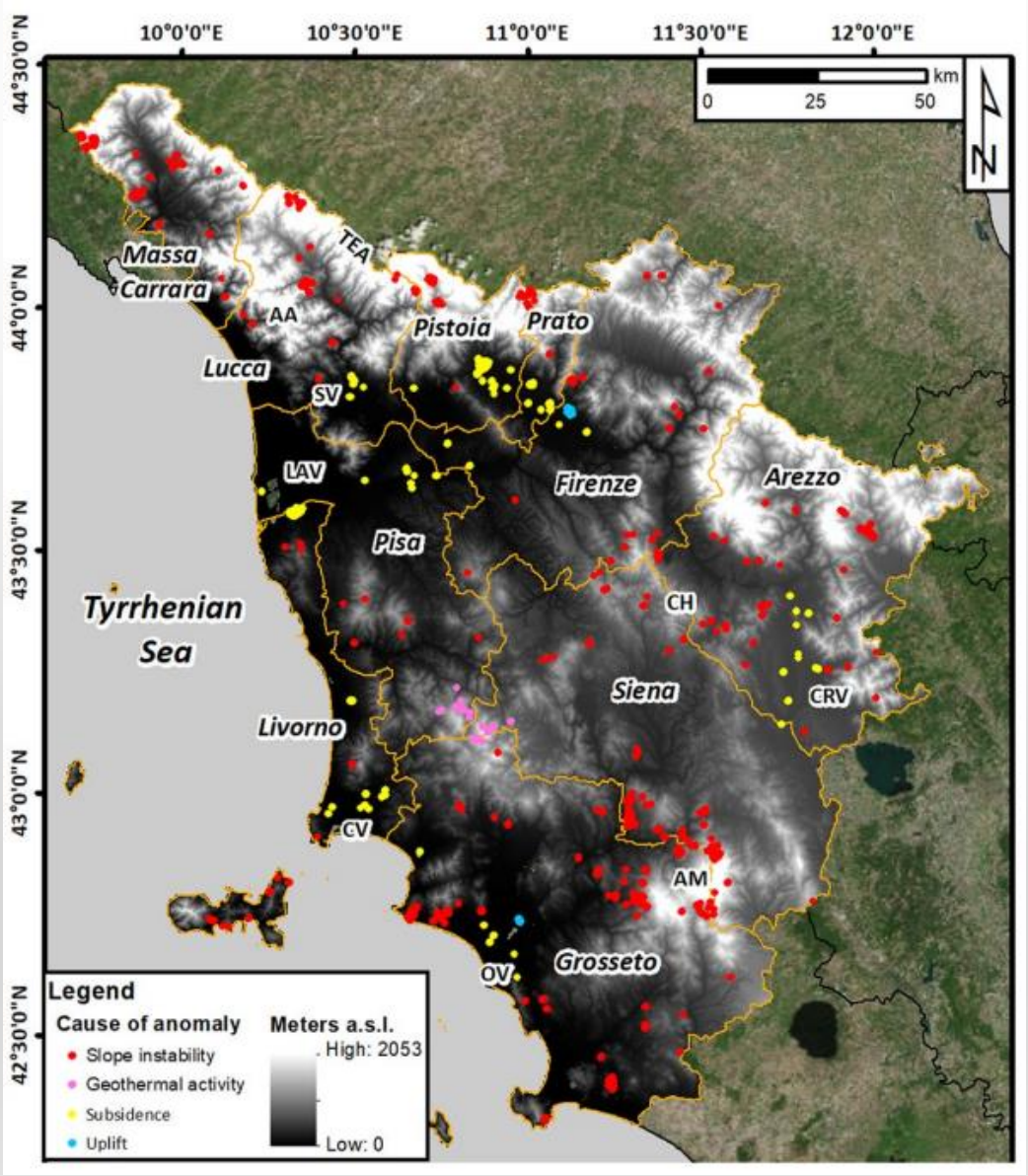
Federico Raspini[1], Silvia Bianchini[1], Andrea Ciampalini[1,3], Matteo Del Soldato[1], Lorenzo Solari[1], Fabrizio Novali[2], Sara Del Conte[2], Alessio Rucci[2], Alessandro Ferretti[2] & Nicola Casagli[1]



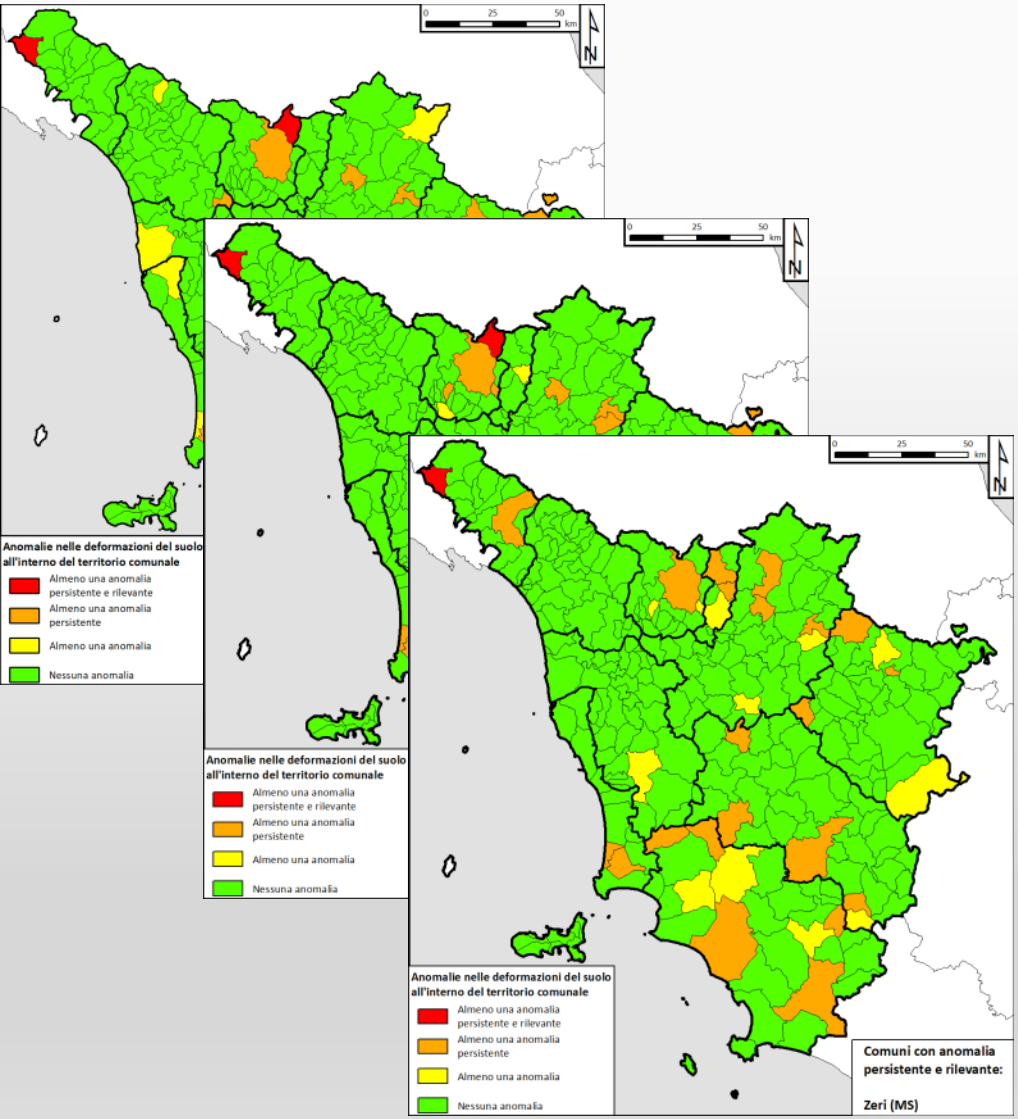
Anomalies database



- Every 2 SNT-1 images a new processing is performed →new deformation map and new anomalous points
- The data are then interpreted and the database updated
- We define for each anomaly:

1. cause (either if it can be true or not)
2. temporal persistency
3. spatial persistency

Monitoring bulletin



Class	Description
1	No anomaly within the municipality
2	At least one anomaly within the municipality
3	At least one persistent anomaly within the municipality
4	At least one persistent and relevant anomaly within the municipality

The bulletin is sent to the end users the same day or the morning after the delivery of the satellite data

Monitoring bulletin

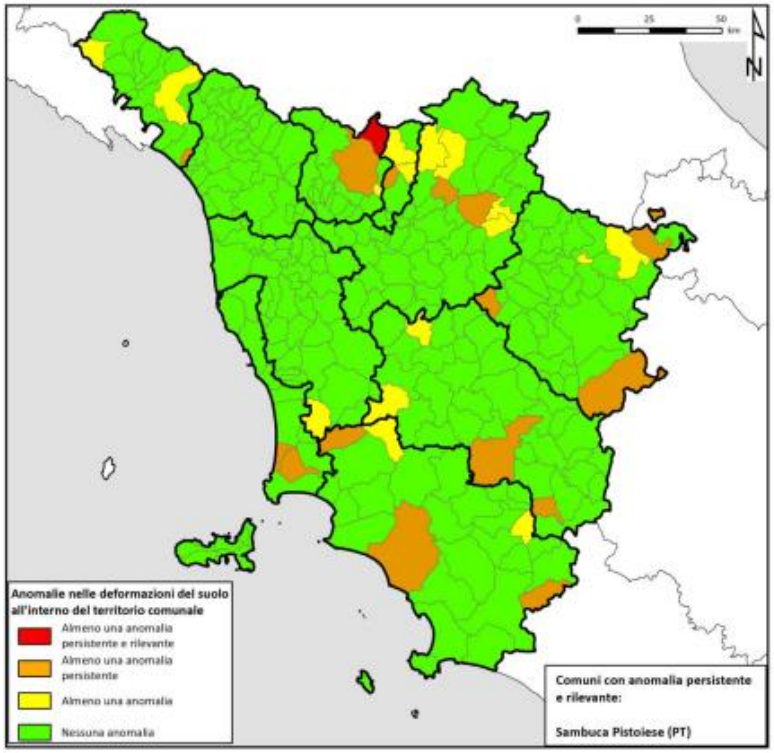
UNIVERSITÀ DEGLI STUDI FIRENZE

DST DIPARTIMENTO DI SCIENZE DELLA TERRA

CENTRO DI COMPETENZA DEL SERVIZIO NAZIONALE DELLA PROTEZIONE CIVILE

BOLLETTINO DI MONITORAGGIO RADAR SATELLITARE DELLE DEFORMAZIONI DEL TERRENO DELLA REGIONE TOSCANA

Periodo di riferimento dal 24/04/2018 al 05/05/2018



NOTE: Per anomalie si intendono cambi di *trend*, variazioni repentine e/o accelerazioni nelle serie temporali di deformazione di punti di misura all'interno del territorio comunale.

Sambuca Pistoiese (Pistoia)

Provincia	Comune	Località	Coordinate (WGS 1984 UTM Zona 32N)	Elemento a rischio	Causa	Persistenza
Pistoia	Sambuca Pistoiese (PT)	Carpineta	663011 E 4884116 N	Centri abitati, nuclei abitati e case sparse	Movimento di versante	3°, 4°, 5°, 6°, 7°, 8°, 9° e 10° aggiornamento

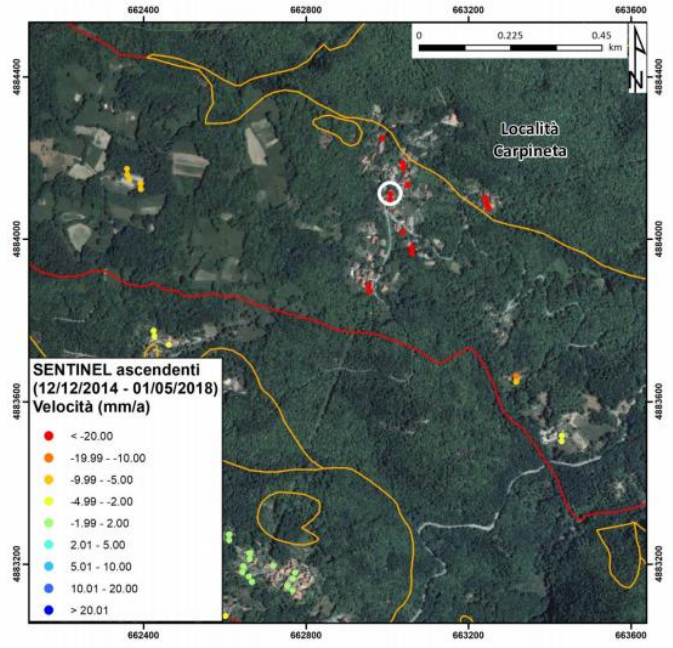


Figura 1 - Mappa di deformazione riferita all'area nel Comune di Sambuca Pistoiese (PT) in cui sono state registrate le anomalie nelle serie temporali. Il cerchio bianco si riferisce alla serie temporale riportata in Figura 2.

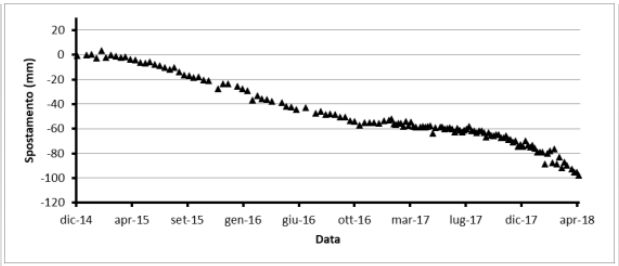
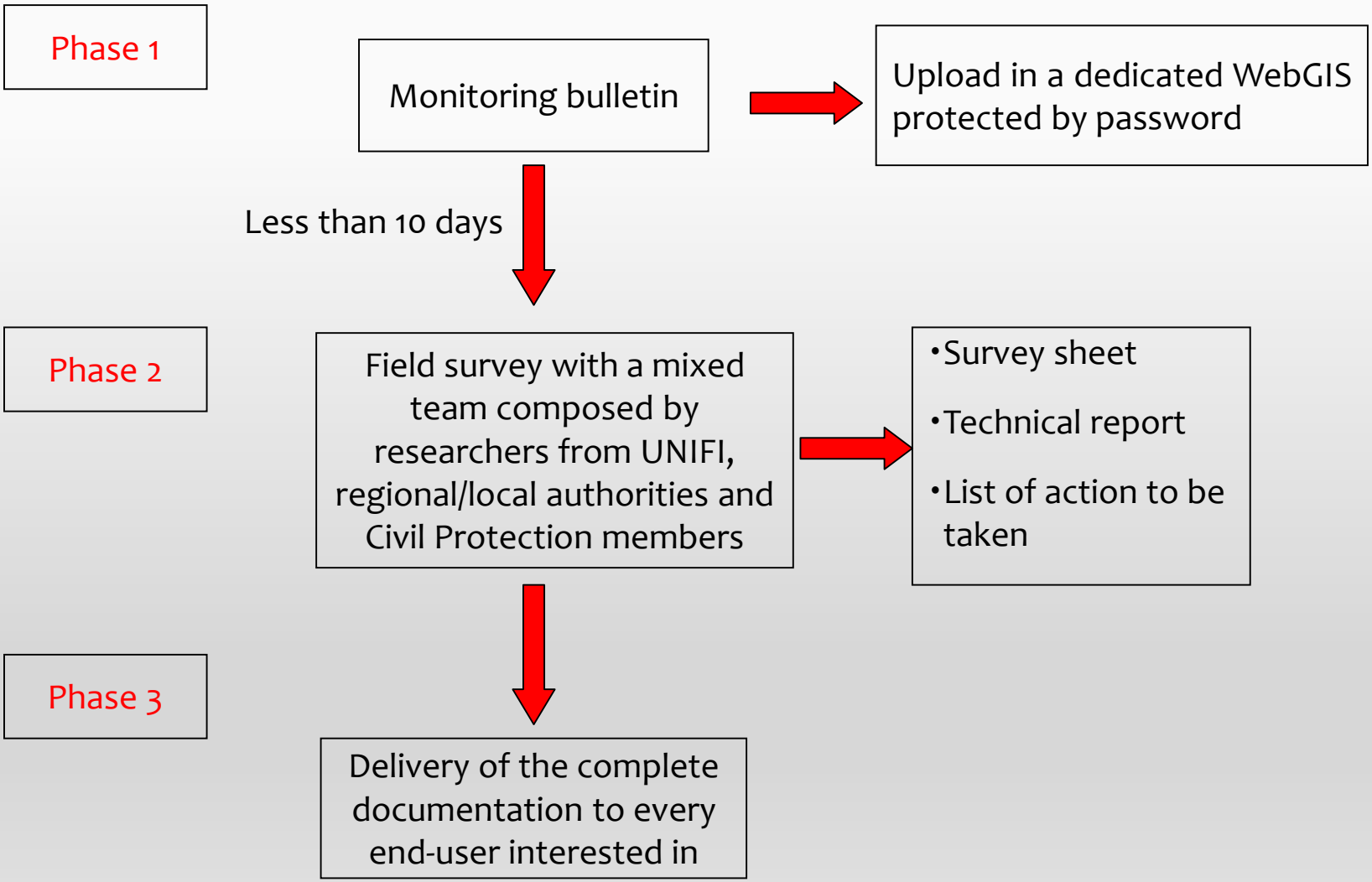
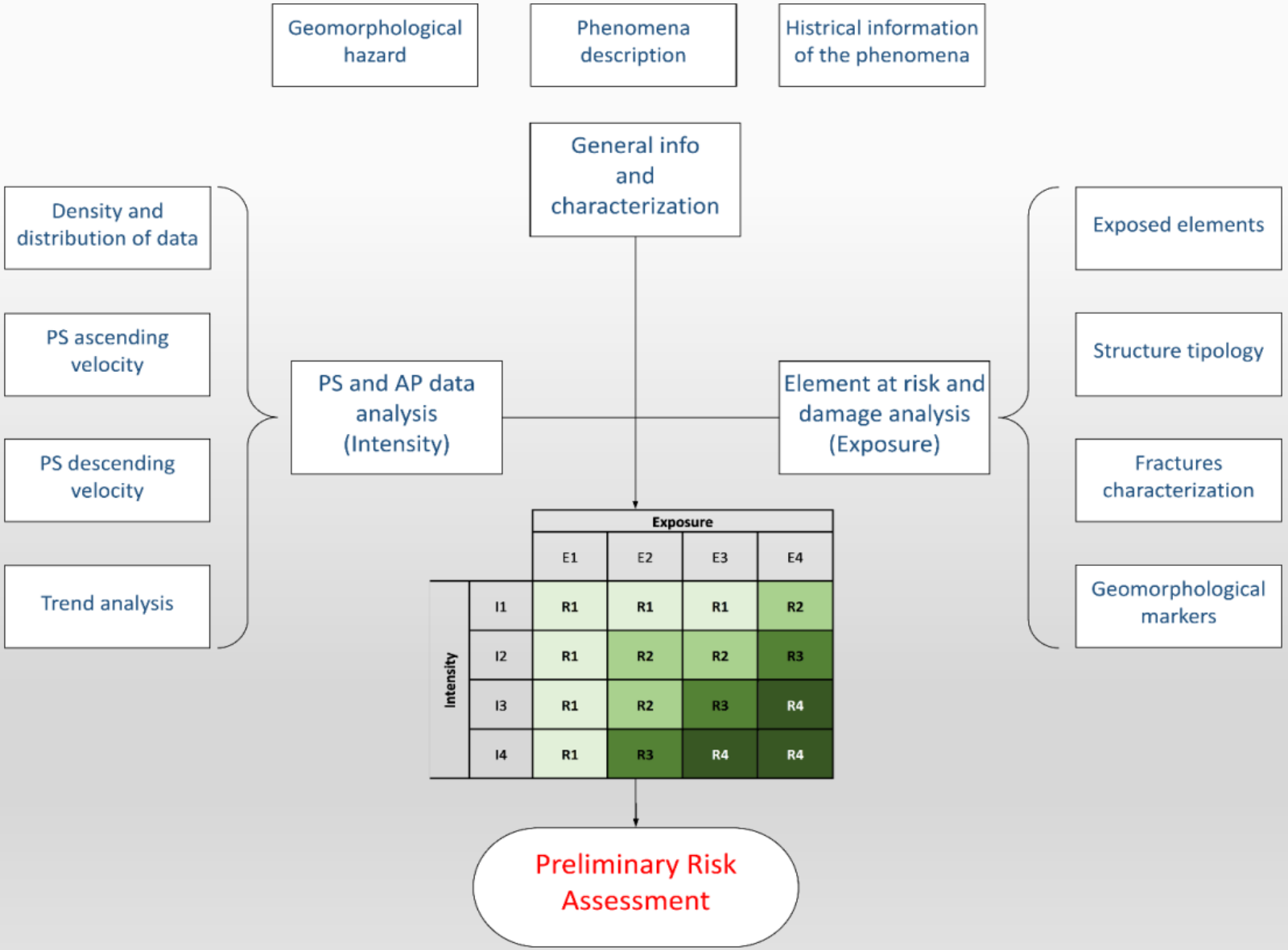


Figura 2 - Serie temporale di spostamento rappresentativa per l'area di indagine. Si evidenzia una nuova accelerazione a partire da febbraio 2018.

Post-bulletin procedure



Field sheet

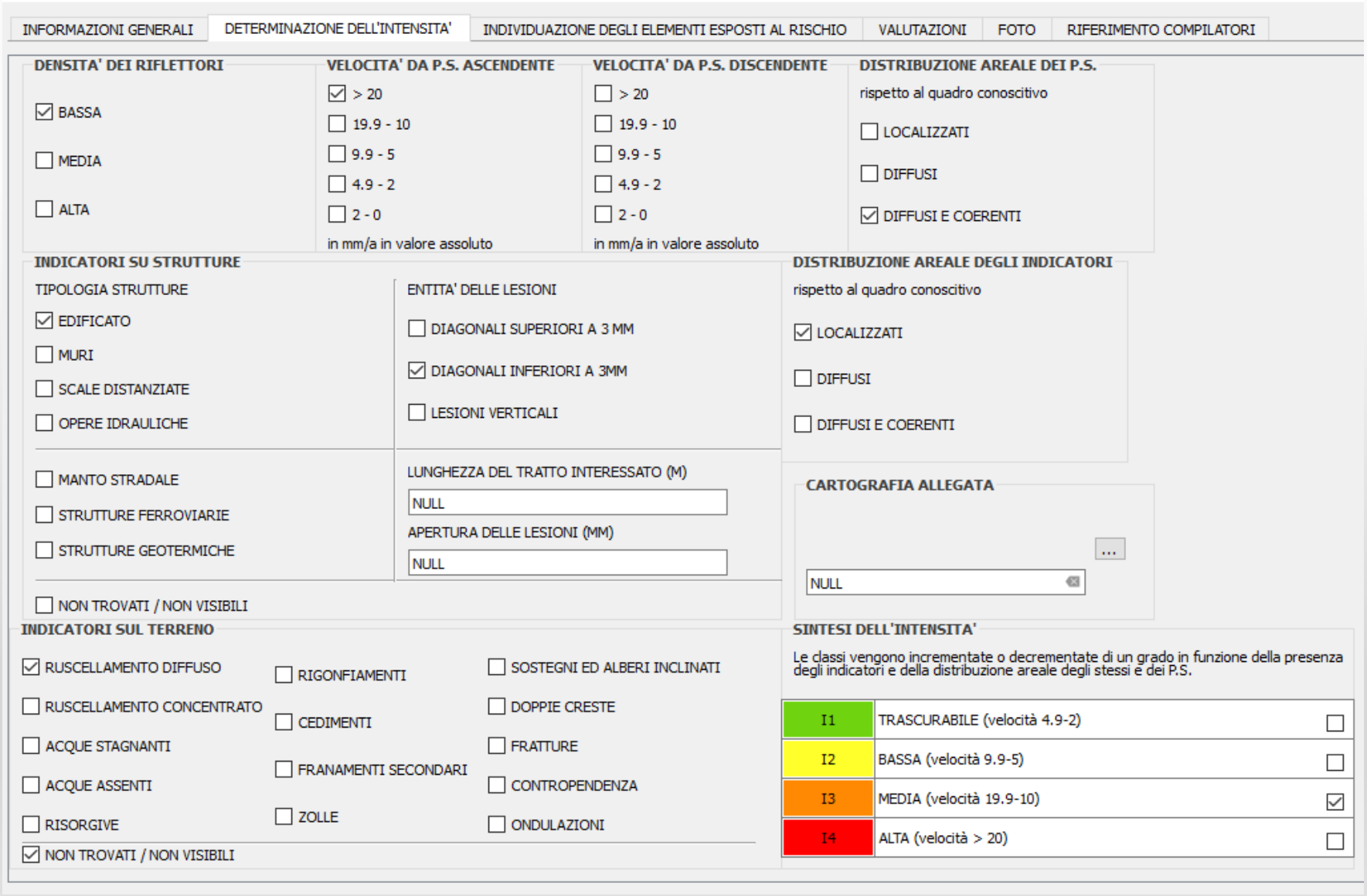

Geomorphological hazard
Phenomena description
Histrical information of the phenomena
General info and characterization
Density and distribution of data
PS ascending velocity
PS descending velocity
Trend analysis
PS and AP data analysis (Intensity)
Element at risk and damage analysis (Exposure)
Exposed elements
Structure tipology
Fractures characterization
Geomorphological markers
Exposure
E1
E2
E3
E4
Intensity
I1 R1 R1 R1 R2
I2 R1 R2 R2 R3
I3 R1 R2 R3 R4
I4 R1 R3 R4 R4
Preliminary Risk Assessment

Field sheet - Intensity

PS

BUILDINGS

TERRAIN



Field sheet - Exposure

INFORMAZIONI GENERALI | DETERMINAZIONE DELL'INTENSITA' | INDIVIDUAZIONE DEGLI ELEMENTI ESPOSTI AL RISCHIO | VALUTAZIONI | FOTO | RIFERIMENTO COMPILATORI

ELEMENTI ESPOSTI

- ☐ EDIFICATO
  - ☐ CASE SPARSE
  - ☐ NUCLEI
  - ☐ CENTRI ABITATI
    - ☐ RESIDENZALE
    - ☐ COMMERCIALE
    - ☐ INDUSTRIALE
    - ☐ EDIFICI STRATEGICI
    - ☐ BENI ARCHITETTONICI
    - ☐ MISTO
- ☐ DISMESSO
  - ☐ PERSONE RESIDENTI STABILMENTE
  - ☐ PERSONE RESIDENTI TEMPORANEAMENTE

PERSONE ESPOSTE

- ☐ 0
- ☐ < 10
- ☐ > 10

- ☐ INFRASTRUTTURE VIARIE
  - ☐ MINORI
    - ☐ VICINALI
  - UNICO ACCESSO A CENTRI/NUCLEI
    - ☐ SI
    - ☐ NO
  - ☐ SECONDARIE
    - ☐ PROVINCIALI
    - ☐ COMUNALI
    - ☐ REGIONALI
  - ☐ PRIMARIE
    - ☐ STATALI
    - ☐ AUTOSTRADE
- ☐ INFRASTRUTTURE FERROVIARIE
- ☐ INFRASTRUTTURE PORTUALI E AEROPORTUALI
- ☐ AREE GEOTERMICHE
  - ☐ RETI DI DISTRIBUZIONE
  - ☐ CENTRALI GEOTERMICHE
- ☐ OPERE IDRAULICHE
  - ☐ BACINO ARTIFICIALE
  - ☐ PONTI
  - ☐ DIGHE
  - ☐ ARGINI
  - ☐ MANUFATTI
- ☐ CAVE
  - ☐ AREA DI CANTIERE
  - ☐ RAVANETI

NOTE

NULL

SINTESI DELLA CLASSE DI ESPOSIZIONE AL RISCHIO

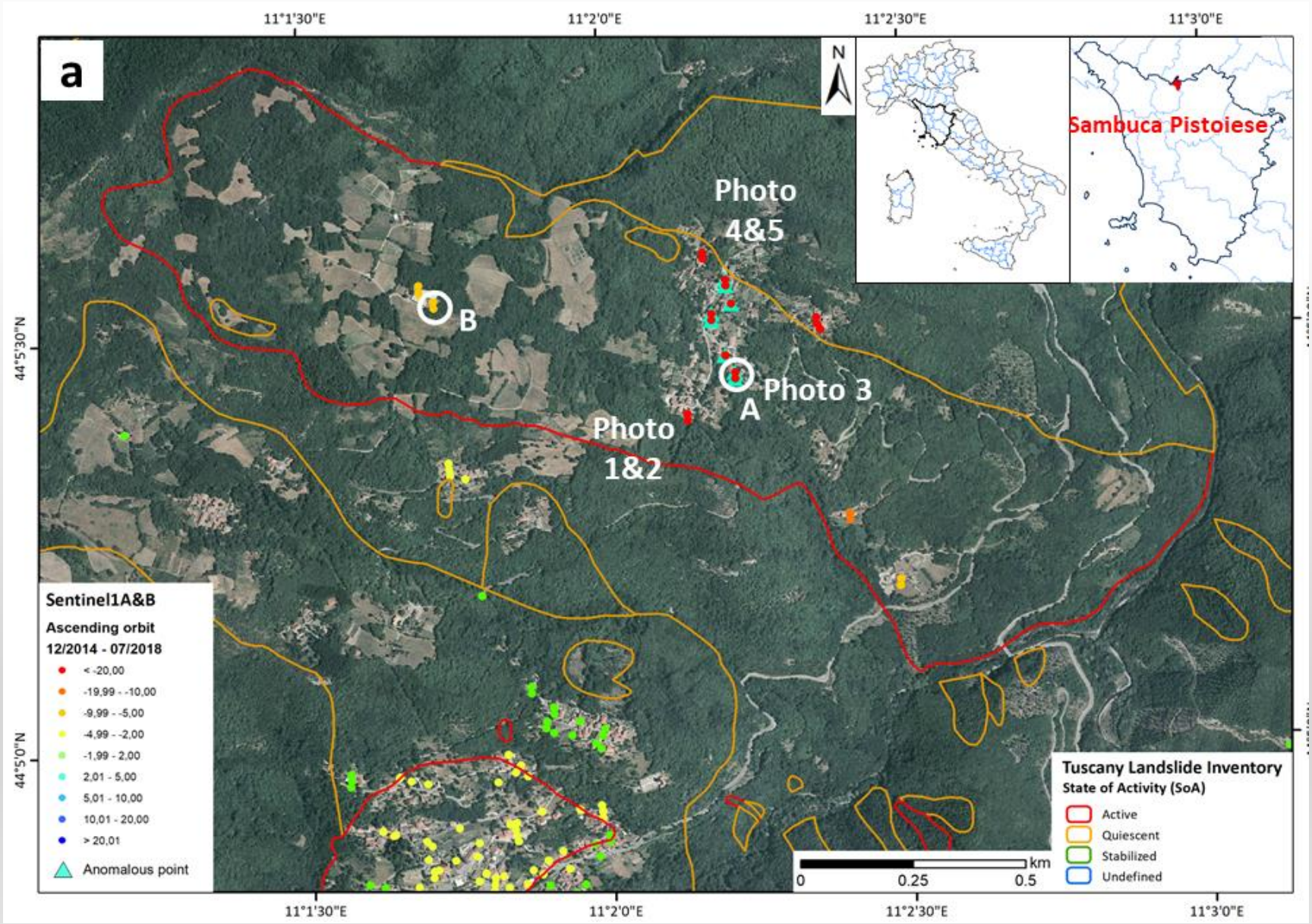
E1	NESSUN ELEMENTO ESPOSTO	☐
E2	VIABILITA' MINORE, EDIFICI SPARSI CON RESIDENTI <10, STRUTTURE COMMERCIALI	☐
E3	VIABILITA' SECONDARIA, NUCLEI, EDIFICI SPARSI CON RESIDENTI >10, INFRASTRUTTURE MINORI	☐
E4	VIABILITA' PRIMARIA, CENTRI ABITATI	☐

Actions to be taken

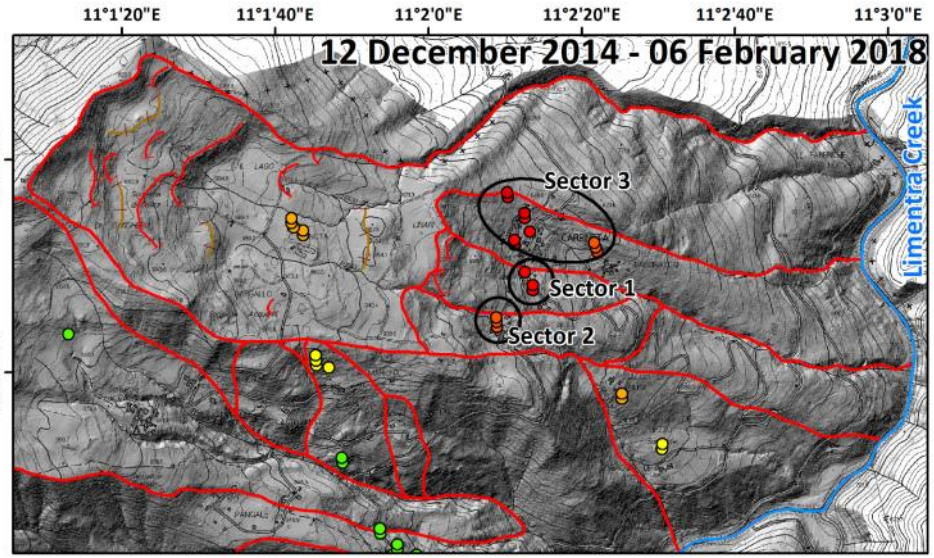
R1	No particular precautions have to be taken.
R2	- Installation of extensiometers or crackmeters - Systematic field surveys - Conventional topographical monitoring - Geo-engineering solutions
R3	- Installation of inclinometers - Installation of piezometers - Installation of rain gauges - Detailed studies - Environmental engineering techniques
R4	- Installation of GB-InSAR instrument - GPS topographical monitoring - Environmental engineering techniques

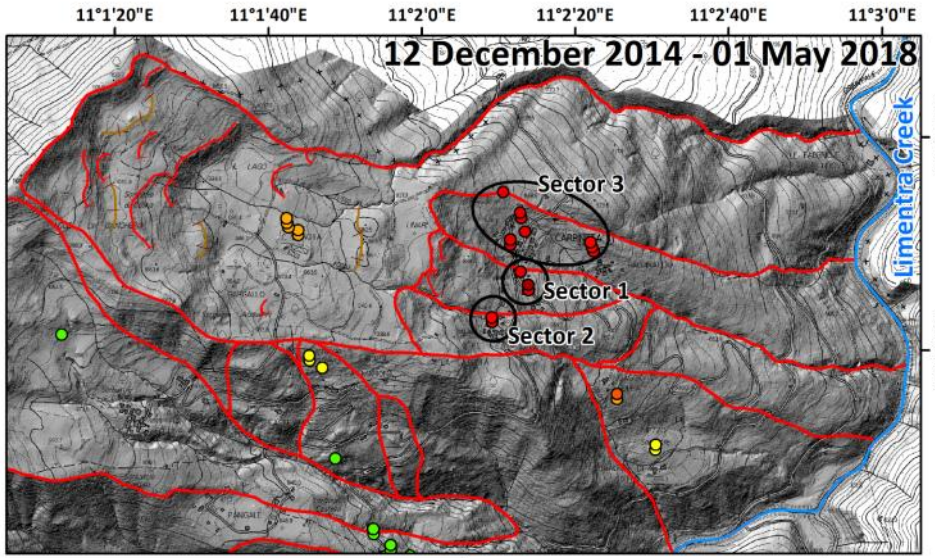
These are SUGGESTIONS, the municipality is not bound to any of these points. But if the local administration decides to take actions, it is a priority way to obtain regional funds

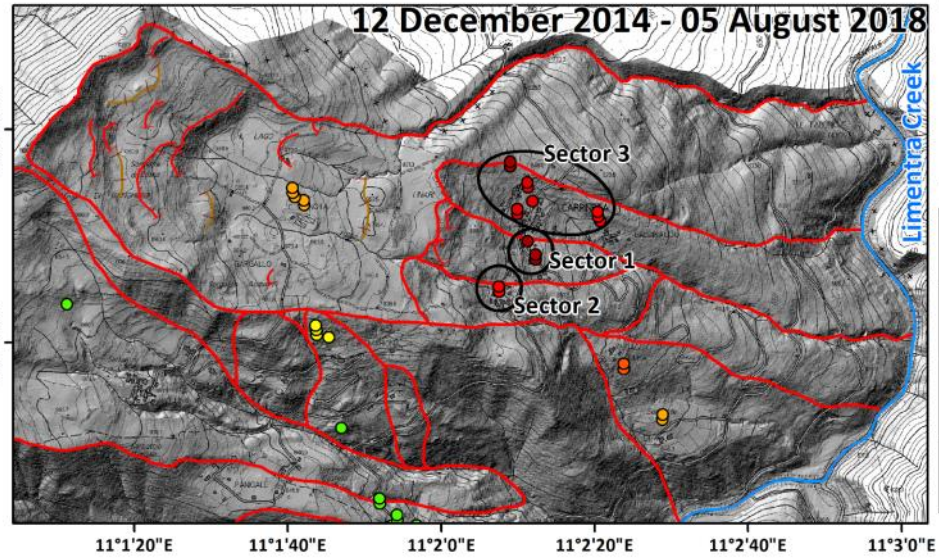
Sambuca Pistoiese

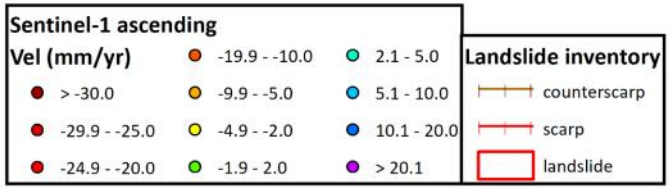


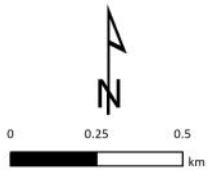
Sambuca Pistoiese - Acceleration





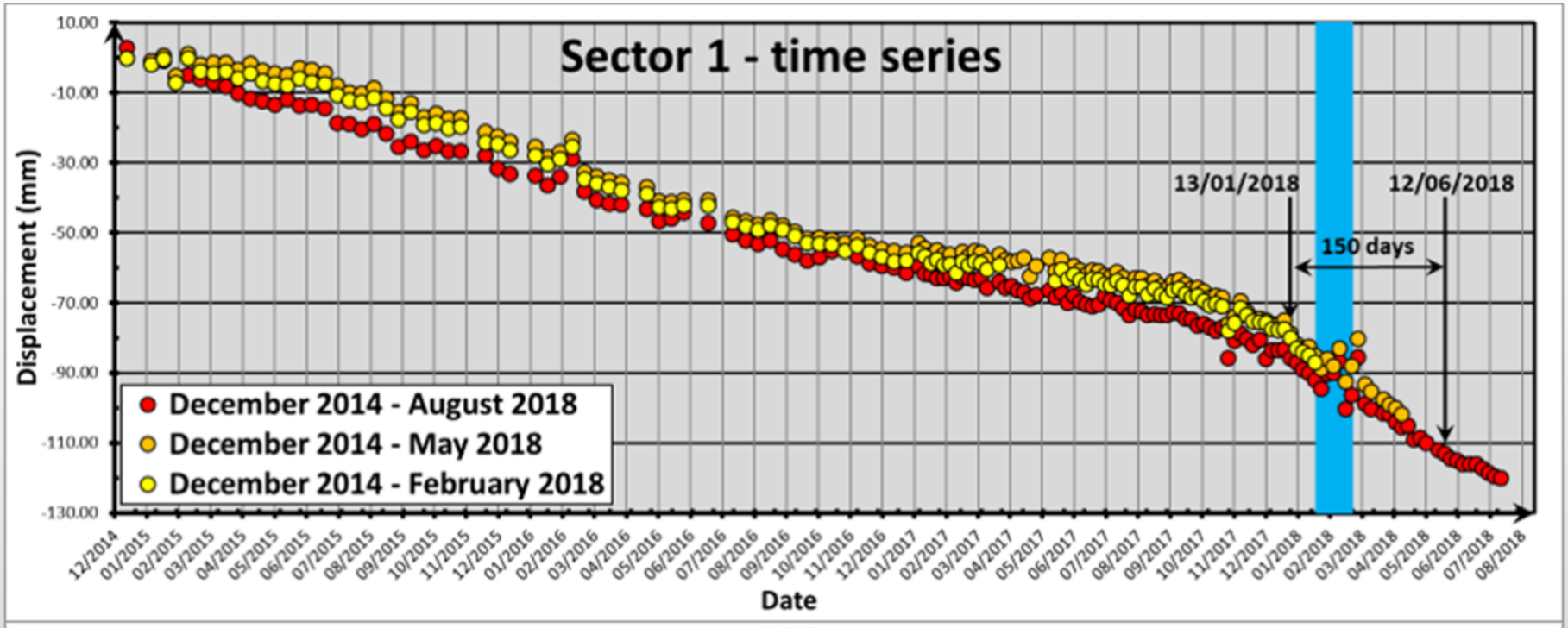






	12 December 2014 6 February 2018	12 December 2014 1 May 2018	12 December 2014 5 August 2018
Sector 1 Vel (mm/yr)	-24.6	-27.8	-30.2
Sector 2 Vel (mm/yr)	-19.4	-20.4	-22.1
Sector 3 Vel (mm/yr)	-23.9	-24.5	-26.4

Sambuca Pistoiese – Time series



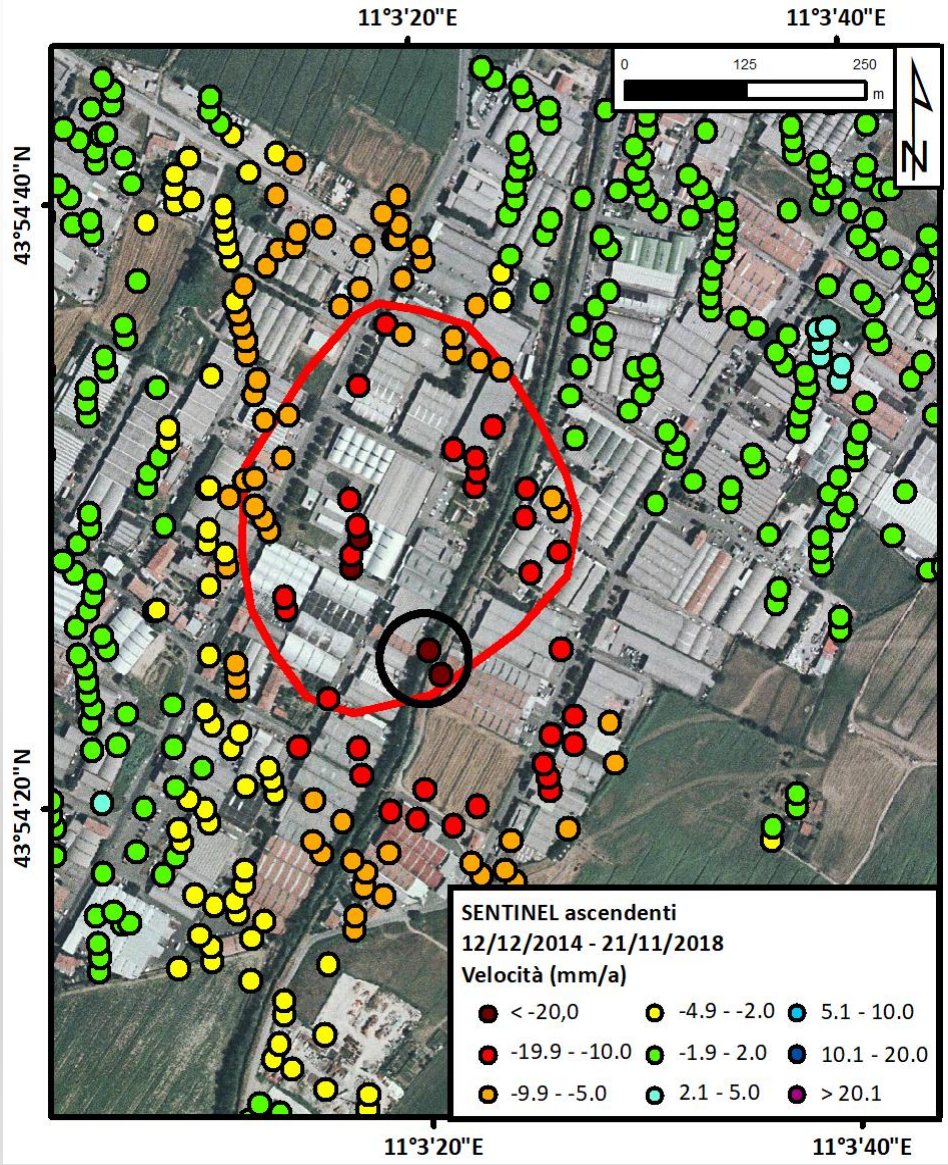
	Start of acceleration	Latency period	Appearance of anomaly	Disappearance of appearance	Persistency	Life length (days)
Sector 1	13/01/2018	4 acquisitions	06/02/2018	12/06/2018	126	150
Sector 2	12/02/2018	5 acquisitions	14/03/2018	06/07/2018	114	144
Sector 3	14/03/2018	3 acquisitions	01/04/208	05/08/2018	126	144

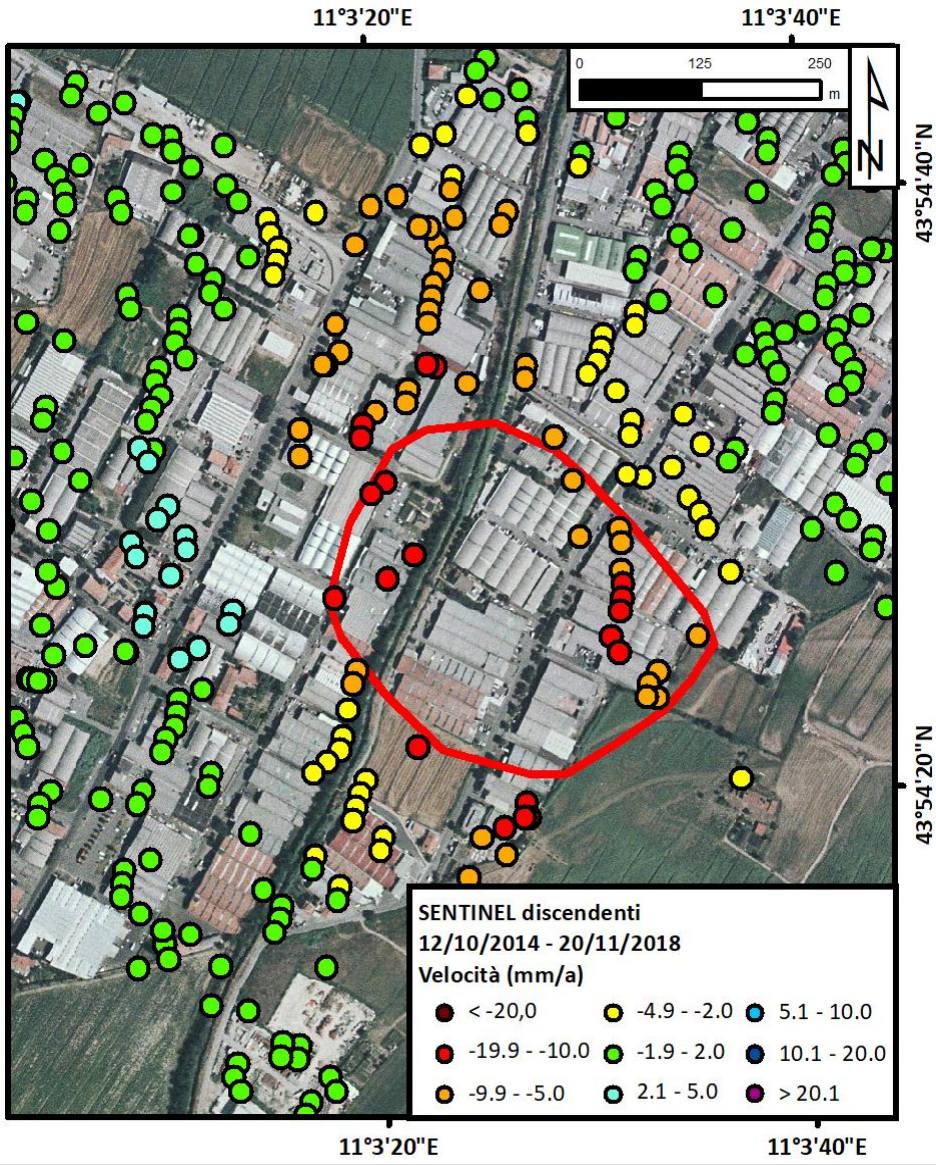
Sambuca Pistoiese - Survey

Further in situ investigations are needed to understand the landslide motion:

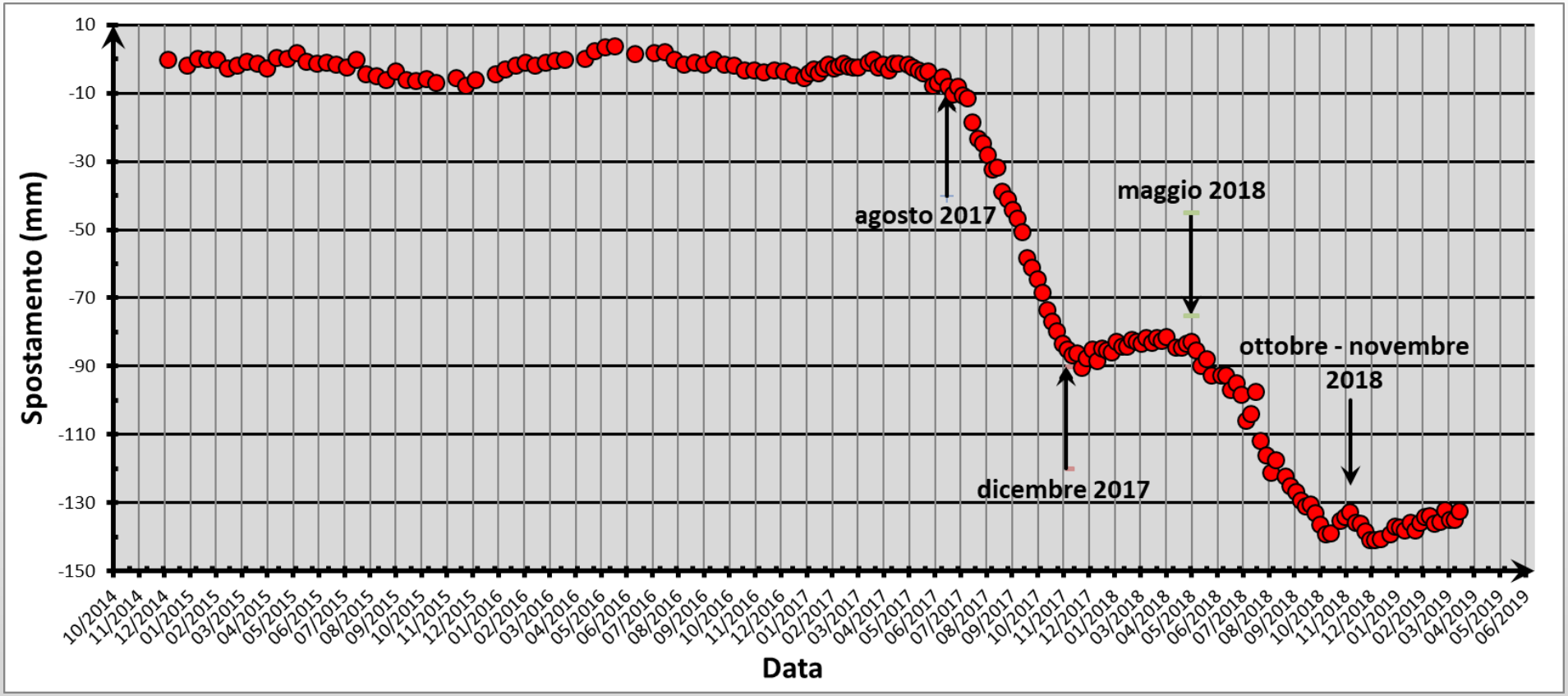
1. Boreholes
2. Inclinometers
3. Geotechnical parameters
4. Building fractures monitoring systems

Montemurlo


11°3'20"E
11°3'40"E
43°54'40"N
43°54'20"N
0
125
250
m
N
SENTINEL ascendenti
12/12/2014 - 21/11/2018
Velocità (mm/a)
< -20,0
-19.9 - -10.0
-9.9 - -5.0
-4.9 - -2.0
-1.9 - 2.0
2.1 - 5.0
5.1 - 10.0
10.1 - 20.0
> 20.1


11°3'20"E
11°3'40"E
43°54'40"N
43°54'20"N
0
125
250
m
N
SENTINEL discendenti
12/10/2014 - 20/11/2018
Velocità (mm/a)
< -20,0
-19.9 - -10.0
-9.9 - -5.0
-4.9 - -2.0
-1.9 - 2.0
2.1 - 5.0
5.1 - 10.0
10.1 - 20.0
> 20.1

Montemurlo – Time series



Three acceleration periods related to the illegal activity of water extraction from a unauthorized well

Montemurlo – Survey

Further in situ investigations are needed:

1. Hydrogeological parameters
2. Building fractures monitoring systems

Actions taken

REGIONE TOSCANA
UFFICI REGIONALI GIUNTA REGIONALE

ESTRATTO DAL VERBALE DELLA SEDUTA DEL 25-02-2019 *(punto N 32)*

Delibera *N 224* *del 25-02-2019*

Proponente
FEDERICA FRATONI
DIREZIONE DIFESA DEL SUOLO E PROTEZIONE CIVILE

Pubblicita'/Pubblicazione Atto soggetto a pubblicazione integrale (PBURT/BD)
Dirigente Responsabile Gennarino COSTABILE

DODS2019PT0108	Studio fenomeno franoso individuato con anomalia da PS nell'ambito dell'accordo di Programma con UNI	COMUNE DI SAMBUCA PISTOIESE	PT	42475	€ 85.000,00	€ 85.000,00	€ 34.000,00	€ 34.000,00	€ 17.000,00		30/05/19	31/12/21
DODS2019PT0106	Studio mirato alla verifica di fenomeni di subsidenza rilevati da anomalia PS	COMUNE DI MONTEMURLO	PO	42475	€ 161.585,08	€ 161.585,08	€ 64.634,03	€ 64.634,03	€ 32.317,02		30/05/19	31/12/21

The Tuscany Region financed for a total of 246k€ additional geological activities Sambuca Pistoiese and Montemurlo.

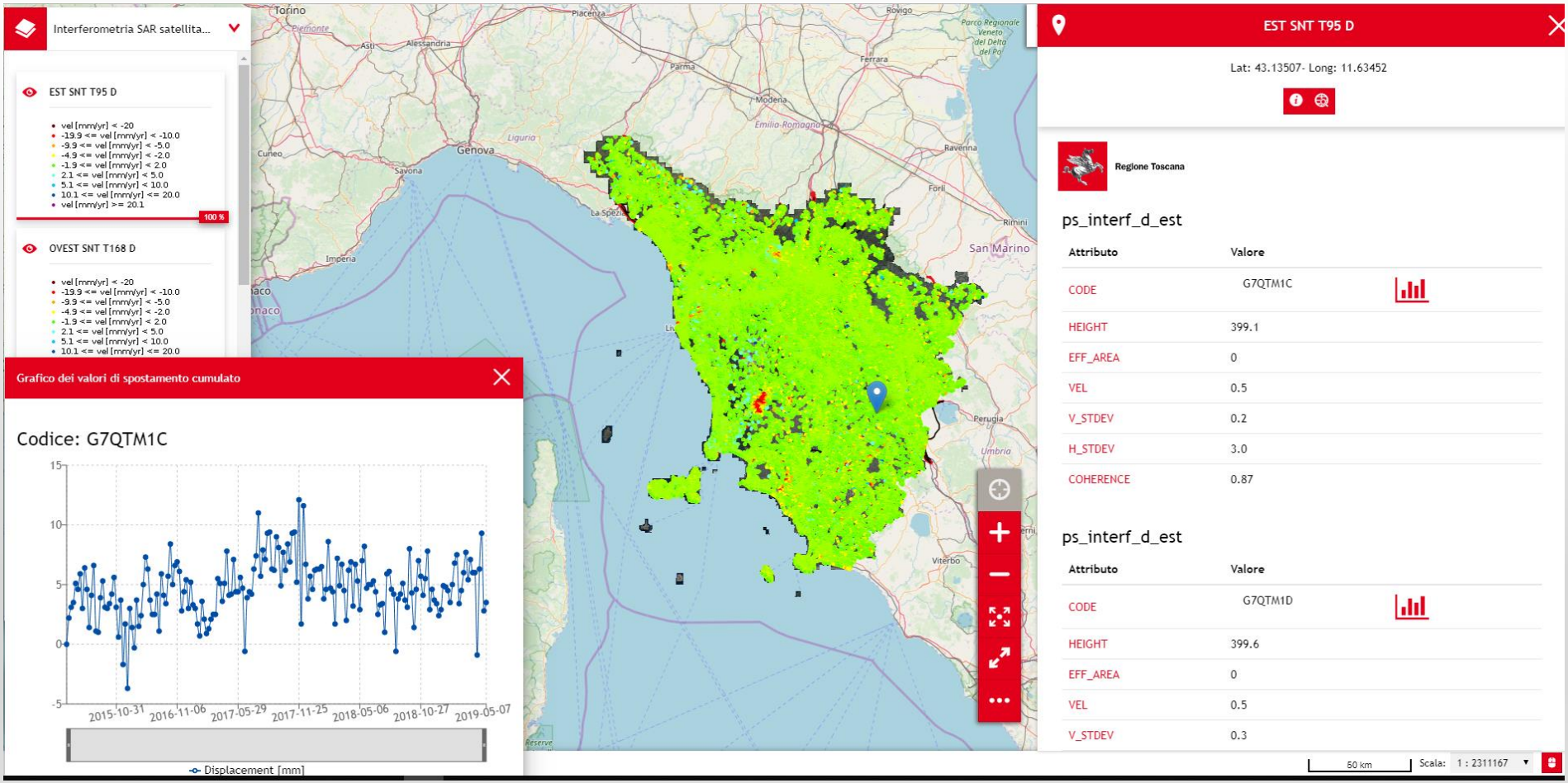
Dissemination of the results

We disseminate our results at different levels:

1. Scientific community: papers & conferences
2. Risk management entities (Tuscany Region – Geni Civili, Regional and National Civil Protection): periodic reporting, dedicated WebGIS (deformation maps + filtered/interpreted anomalies), bulletins, surveys
3. Municipalities: surveys results (including reports) and dedicated WebGIS (deformation maps ONLY)
4. Everyone (geologists, engineers, etc…): dedicated WebGIS (deformation maps ONLY) and courses

Open WebGIS

https://geoportale.lamma.rete.toscana.it/difesa_suolo/#/viewer/openlayers/326

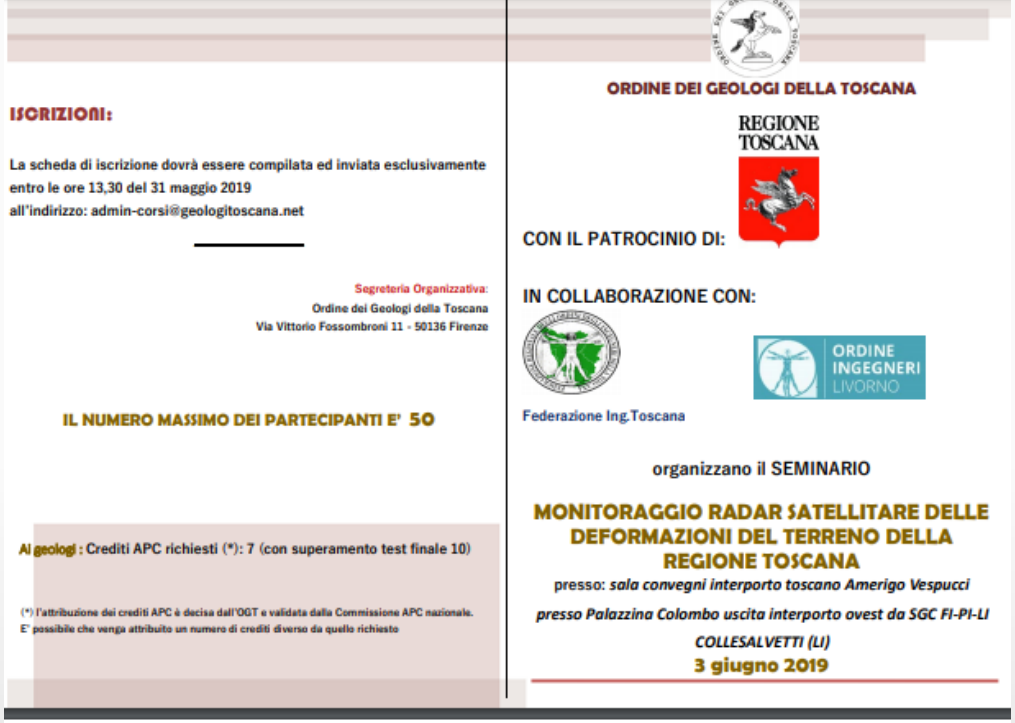


Open WebGIS

- The download is free and everyone can access to the portal. The user can upload its own shapefiles if needed (i.e. an area of interest contour, a landslide, etc…)
- We prepared, helped by 2 lawyers, specific terms of service
- A guideline about the use of the data and how they can be used and interpreted is available in the website
- In the guideline, the user can also found a disclaimer and a list of “bad practices”
- The anomalies of motion are not delivered to the public, being a really advanced product (risky as well…)

Courses

- We have already organized two courses (one in Firenze and one in Livorno) about the use of these data
- We start with the radar theory, giving to the technicians an overview on interferometric product and on how to read them



ISORIZIONI:

La scheda di iscrizione dovrà essere compilata ed inviata esclusivamente entro le ore 13,30 del 31 maggio 2019
all'indirizzo: admin-corsi@geologitoscana.net

Segreteria Organizzativa:
Ordine dei Geologi della Toscana
Via Vittorio Fossombroni 11 - 50136 Firenze

IL NUMERO MASSIMO DEI PARTECIPANTI E' 50

Ai geologi : Crediti APC richiesti (*): 7 (con superamento test finale 10)

(*) l'attribuzione dei crediti APC è decisa dall'OGT e validata dalla Commissione APC nazionale.
E' possibile che venga attribuito un numero di crediti diverso da quello richiesto

ORDINE DEI GEOLOGI DELLA TOSCANA

REGIONE TOSCANA

CON IL PATROCINIO DI:

IN COLLABORAZIONE CON:

ORDINE INGEGNERI LIVORNO

Federazione Ing.Toscana

organizzano il SEMINARIO

MONITORAGGIO RADAR SATELLITARE DELLE DEFORMAZIONI DEL TERRENO DELLA REGIONE TOSCANA

presso: *sala convegni interporto toscano Amerigo Vespucci*

presso Palazzina Colombo uscita interporto ovest da SGC FI-PI-LI

COLLESALVETTI (LI)

3 giugno 2019

Programma

Ore 8.45 – 9. 00
Registrazione dei partecipanti

Ore 9.00 – 9.30
Saluti e introduzione
Presidente Ordine dei Geologi della Toscana,
geol.Riccardo Martelli
Presidente Federazione Ingegneri della Toscana,
ing.Marco Bartoloni
Presidente Ordine degli Ingegneri Provincia di Livorno,
ing.Maurizio Malvalvi

Ore 9.30 – 11.00
L'interferometria radar satellitare: aspetti teorici e principi generali
Università degli Studi di Firenze
Relatori: prof.geol.Nicola Casagli,
geol.Matteo Del Soldato, dr.Lorenzo Solari

Ore 11.30 – 13.00
Il monitoraggio radar satellitare: analisi ed interpretazione dei dati
Università degli Studi di Firenze
Relatori: prof.geol.Nicola Casagli,
geol.Federico Raspini, dr.ssaSilvia Bianchini

Ore 13.00 – 14.30 – pausa pranzo

Ore 14.30 – 15.30
Il sistema informativo e la rappresentazione dei dati
LAMMA (in attesa di conferma)
Relatori: dr.Bernardo Gozzini, dr.Lorenzo Bottai, dr.Riccardo Mari

Ore 15.30 – 16.30
Protocollo di utilizzo dei dati del Monitoraggio Radar satellitare delle deformazioni del terreno in Regione Toscana
Regione Toscana
Relatore: geol.Vania Pellegrineschi (in attesa di conferma)

Ore 16.30 – 17.00
Tavola rotonda
Regione Toscana, geol.Vania Pellegrineschi
Ordine dei Geologi della Toscana, geol.Riccardo Martelli
Ordine degli Ingegneri di Livorno, ing.Maurizio Malvalvi
Università degli Studi di Firenze, geol.Federico Raspini
Lamma, dr.Bernardo Gozzini

Ore 17,00 – 18,00
TEST DI VERIFICA

Final considerations

- Image availability & computational power allow rethinking the concept of PS data for “one-shot” mapping activities
- In the Tuscany Region the system is now fully operative. It was not easy to tune but we start to obtain good results
- A key factor to correctly manage the amount of data is the constant exchange of information with regional and local entities
- The end users must have an active role in the dissemination of the results
- The dissemination itself requires precise guidelines and rules to avoid misinterpretation and uncorrect usage

Thank you for your attention

if you have any question: lorenzo.solari@unifi.it