RASTOOL-DoS

Satellite Interferometry (InSAR) in Disaster Risk Management (DRM)

InSAR based procedure in Valle d'Aosta Region (Italy)

Ing. Patrick Thuegaz
Geol. Davide Bertolo
Aosta Valley Geological Survey

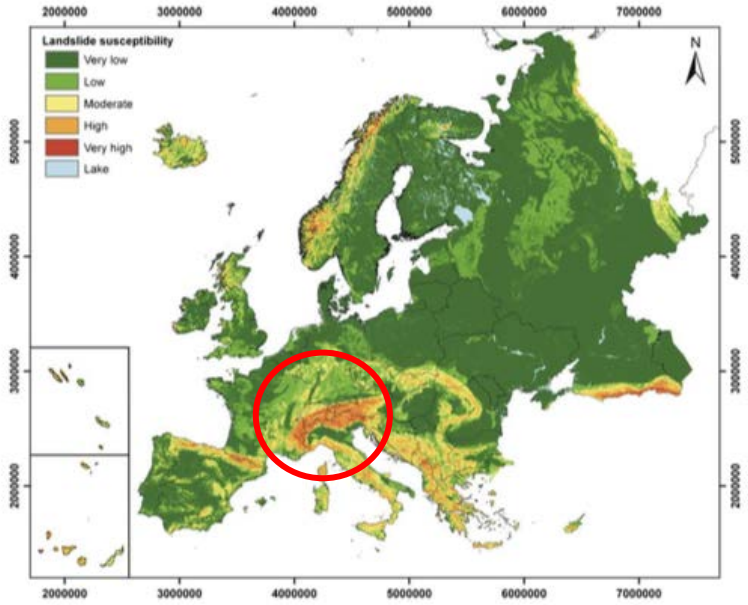
Online Information Day

06/06/2025

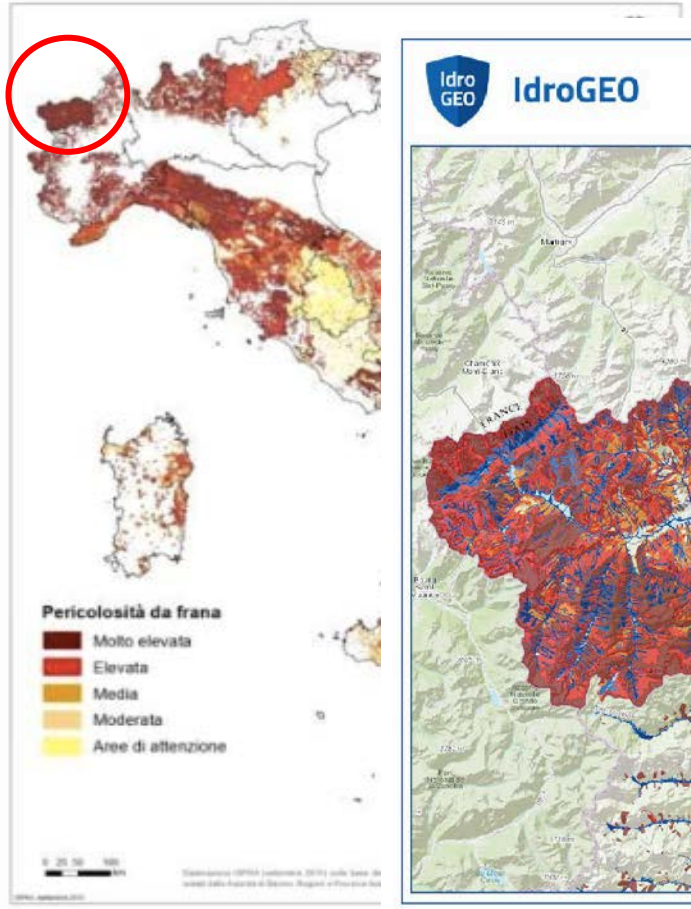
Project co-funded by the European Union, Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO)

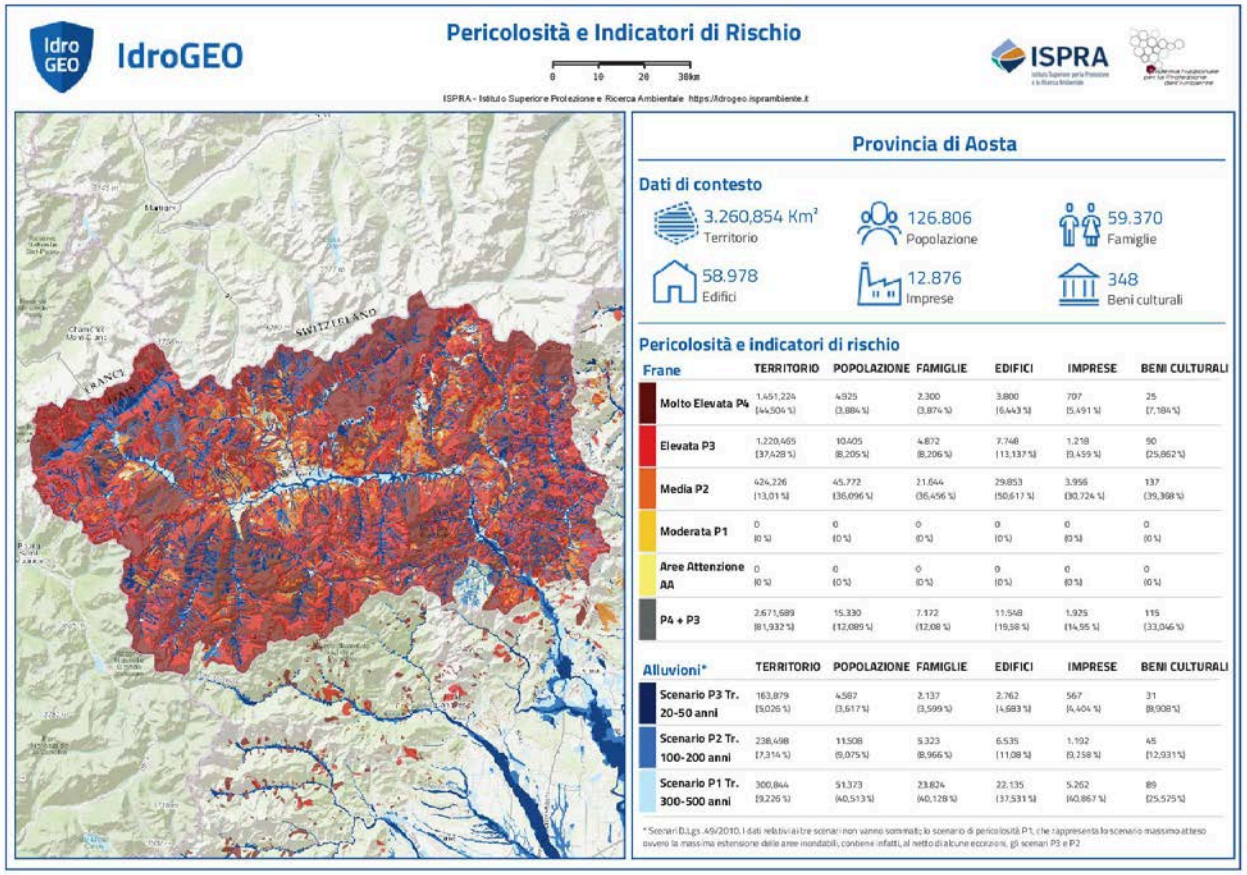
UCPM-2024-KAPP-PP - 101193210

Aosta Valley - Italy



Landslide susceptibility map of Europe (Van Den Eeckhaut et al., 2011)





The smallest Italian region (3262 km²)

6,334 Recorded Landslides in Catalogues 350 in April 2025

40 out of the 82 Alpine peaks over 4,000 meters in elevation are located in the Aosta Valley

11 Landslides under discontinous monitoring

6 LANDSLIDES UNDER CONTINUOUS MONITORING (Activating a Civil Protection Plan)

First installations of the monitoring system: 1997
Implementation of the integrated regional system: 2020-2022

Aosta Valley Geological Survey

+ **Geological site inspections** in case of instability phenomena;

+ t**opographic surveys** for risk mitigation interventions (total station, GNSS, UAS, scanning station);

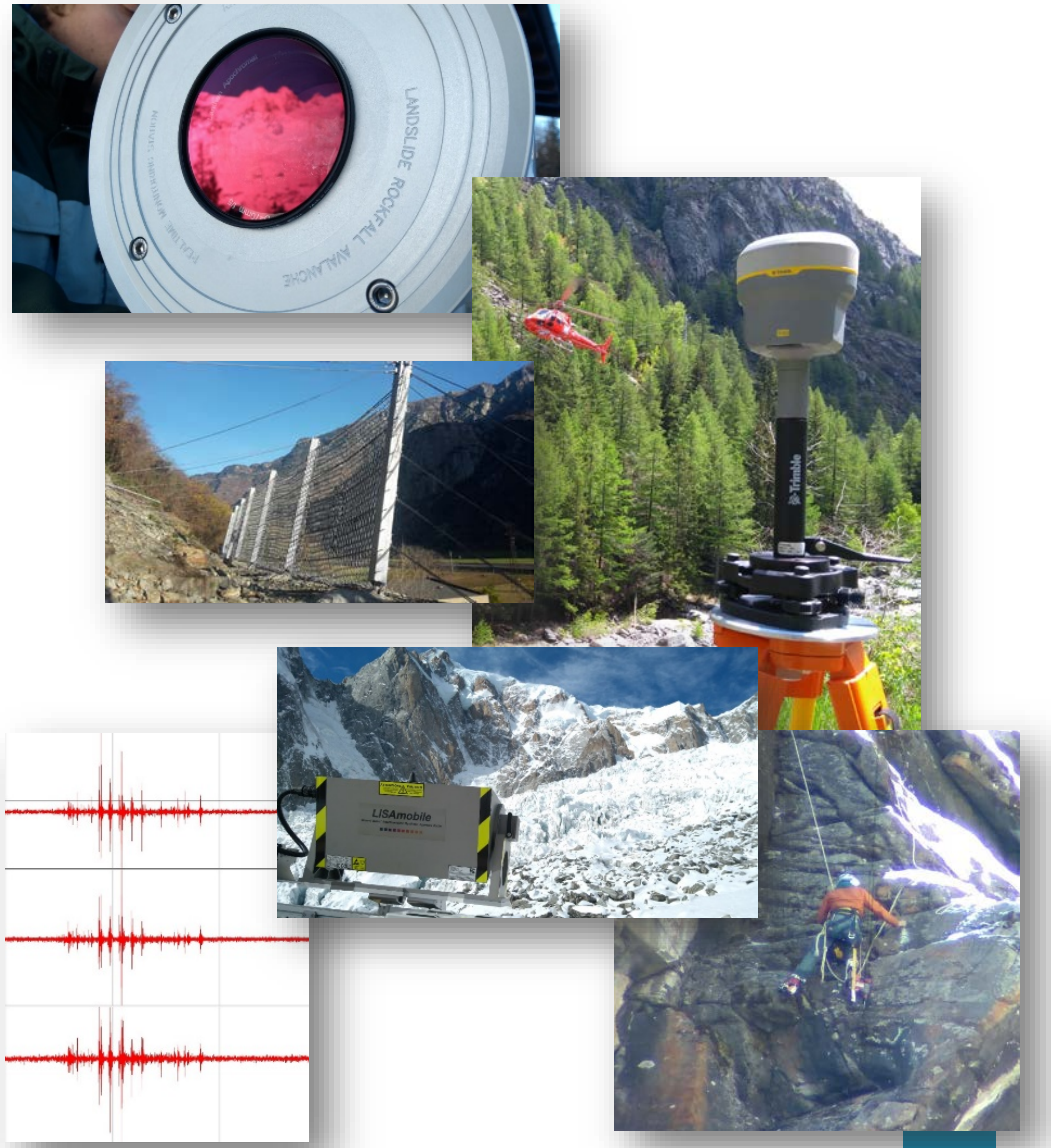
+ **monitoring of large landslides** in the region (**third level landslides**);

+ High-resolution **satellite optical image analysis** to support hydrogeological events (floods, landslides, debris flows)

+ support for the **development of new methods** and **technologies** for monitoring and surveying the territory;

+ regional **seismic network**;

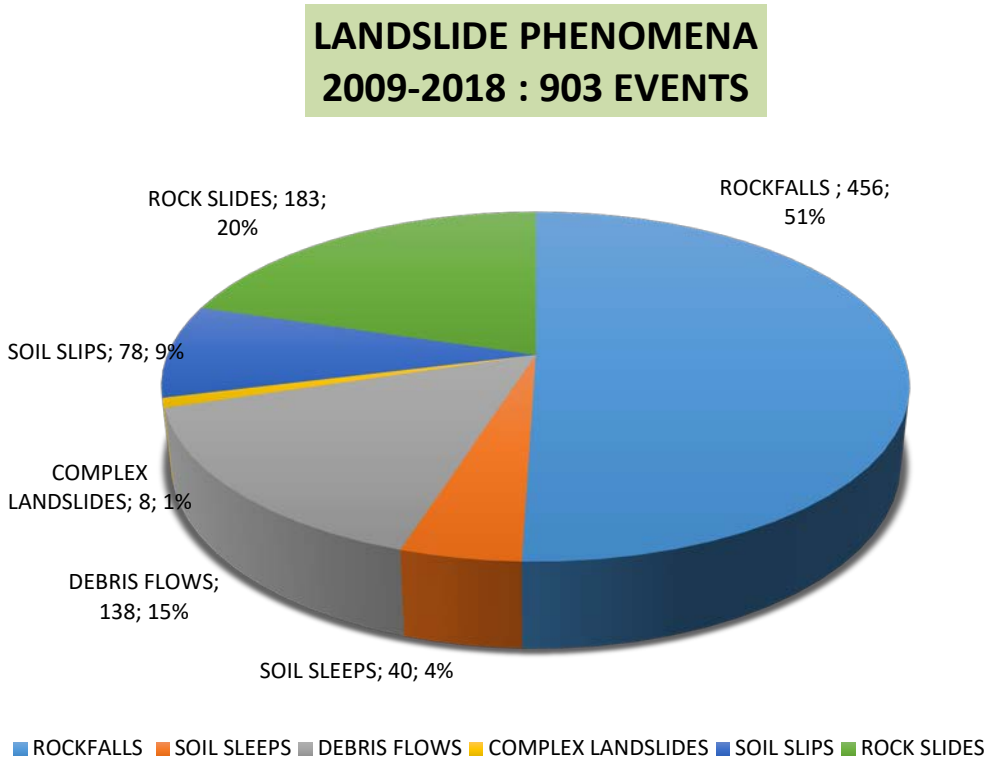
+ survey and monitoring of the territory following acceleration signals from **satellite InSAR** sensors (**second level events**).



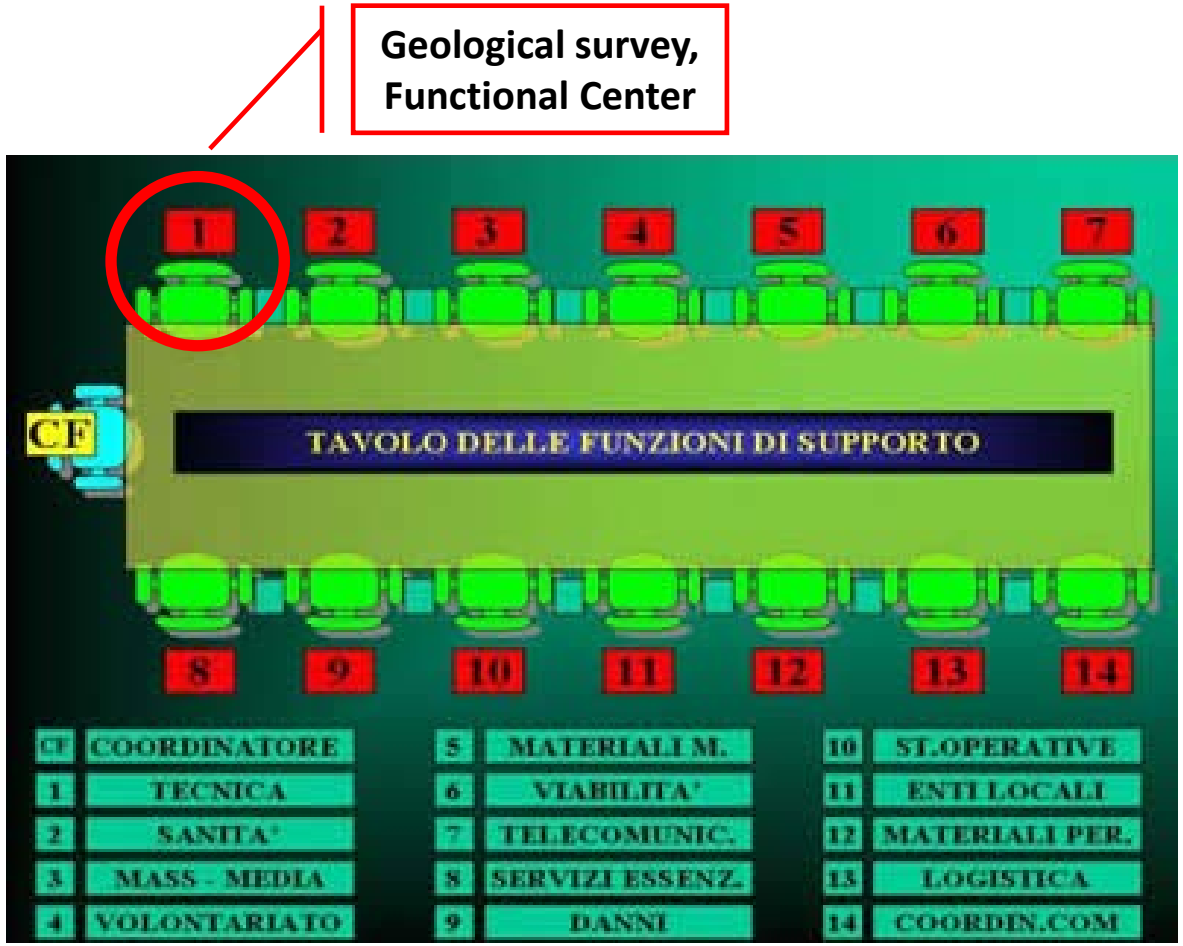
Civil Protection organization in Aosta Valley

Therefore, concerning the Landslides, the geological survey is involved in all **the four classical civil protection activities**:

- **FORECASTING**: Remote and in-situ (field) Monitoring
- **PREVENTION**: Land management, Emergency Planning and civil works;
- **EMERGENCY/RELIEF**: Support to the civil protection and the municipalities in case of events;
- **EMERGENCY OVERCOMING**: Remediation civil works, Survey, Monitoring.



Civil Protection organization in Aosta Valley



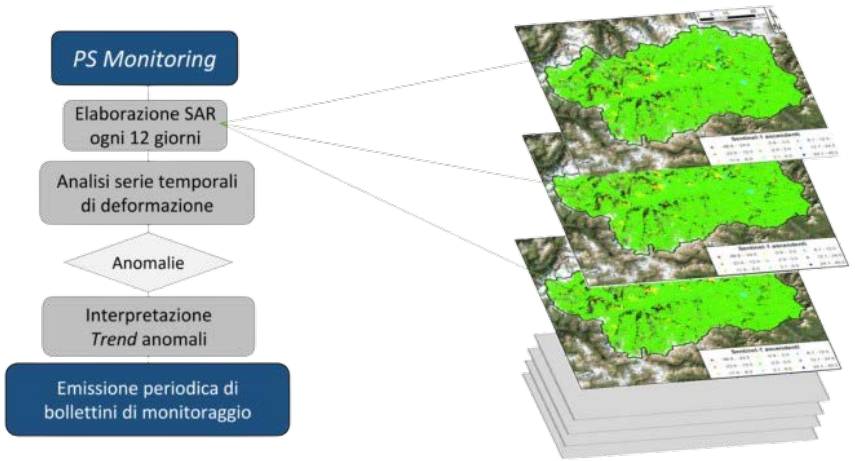
In Italy, civil protection is a streamlined institution that coordinates various public bodies that normally operate under ordinary conditions (Police, Fire Brigade, Technical Services).

The geological services and the functional center are **Civil protection support functions** that are integrated in forecasting, prevention, rescue, and the emergency overcoming.

Aosta Valley & UNIFI - 2018

AGREEMENT BETWEEN THE **AUTONOMOUS REGION AOSTA VALLEY** AND THE CIVIL PROTECTION CENTER OF THE **UNIVERSITY OF FLORENCE** FOR THE CONTINUOUS SATELLITE RADAR MONITORING OF GROUND DEFORMATIONS IN THE AOSTA VALLEY REGION

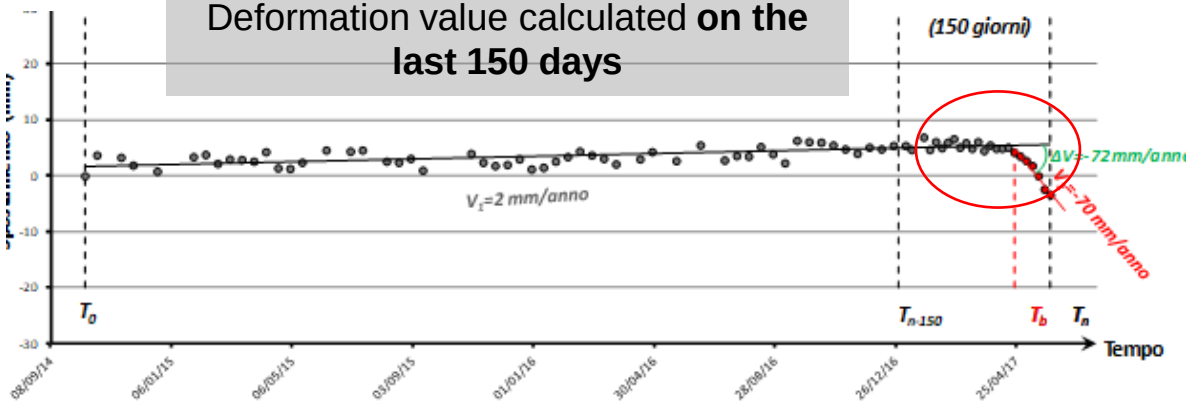
PS Monitoring: Workflow

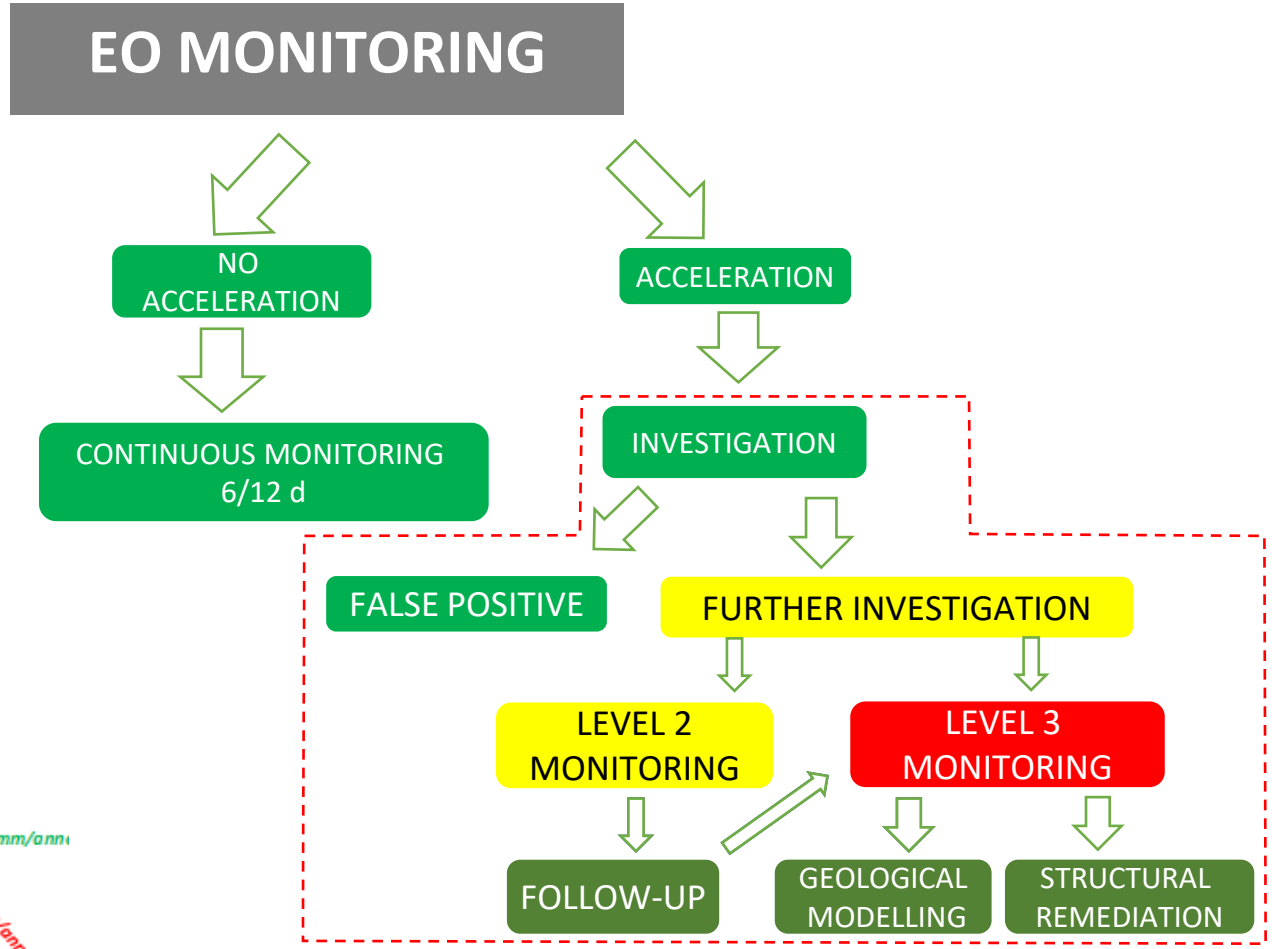


TREND VARIATION THRESHOLD (REGIONAL CUSTOMIZED)

$\Delta V > 10$ mm/y

Deformation value calculated **on the last 150 days**





EO Screening Workflow

Technical Note

Integration of Satellite Interferometric Data in Civil Strategies for Landslide Studies at a Regional Scale

Silvia Bianchini [1,*], Lorenzo Solari [2], Davide Bertolo [3], Patrick Thuegaz [3] and Filippo Catani [4]

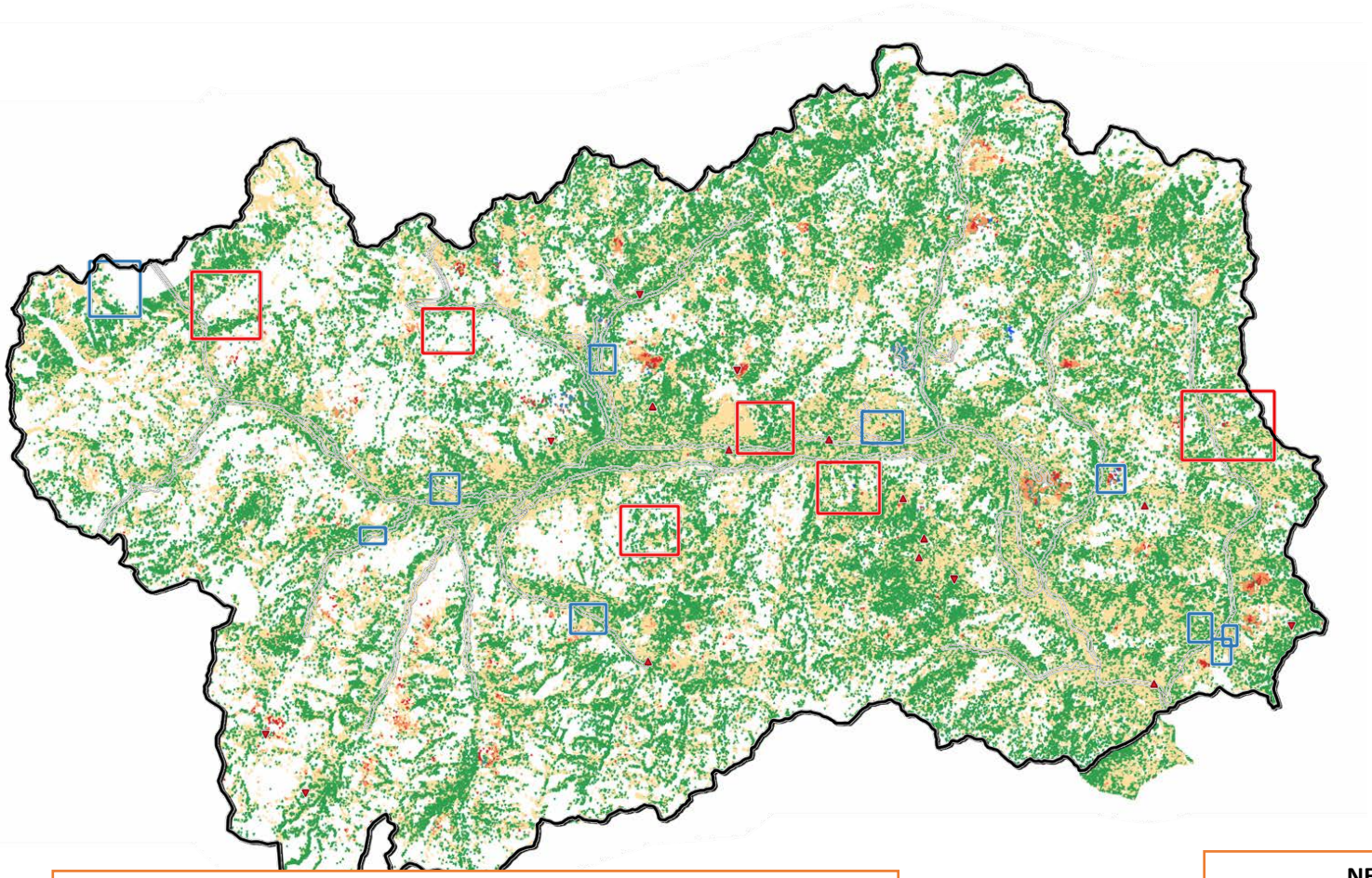
Level 1	Level 2	Level 3
Regional Near-real time + Deferred time Remote sensing 12 days + twice/year • PSI («PS mapping» + «PS monitoring») • Preliminary screening (new deformations and acceleration of existing phenomena) • Environmental planning	Local Near-real time Remote sensing + on site discontinuous 12 days + periodic update • PSI anomalies («PS monitoring») • GNSS discontinuous • GBInSAR discontinuos • Inclinometers • RTS • Investigation of potentially critical situations • Validation of data from Level 1 • Potential upgrade to level 3	Local Real Time on site continuous continuous • GNSS continuous • GBInSAR continuous • GPS • DMS • RTS • Alert and monitoring • Civil Protection
Phase 1: Identification of PSI clusters Phase 2: Remote double check + On-site control validation	Definition of further monitoring and/or remediation activities	Specific hazardous sites under continuous early warning monitoring

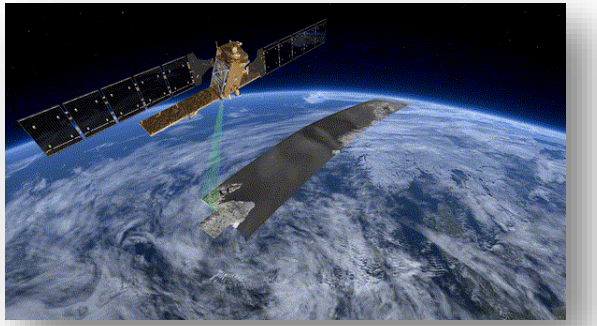
PREVENTION BY LAND MANAGEMENT

POTENTIAL PREVENTION BY REMEDIATION WORKS

NO PREVENTION EARLY WARNING

EO Screening Workflow





FORMER GROUND DEFORMATION MONITORING NETWORK
CONDUCTED USING TRADITIONAL METHODS
10 SITES UNDER ATTENTION LEVEL (BLUE)
6 CRITICAL SITES (RED)

NEW GROUND DEFORMATION MONITORING NETWORK
INTEGRATED WITH PS InSAR
FIRST-LEVEL NETWORK: REGIONAL INSAR COVERAGE
SECOND-LEVEL NETWORK: 10 SITES UNDER ATTENTION LEVEL
THIRD-LEVEL NETWORK: 6 CRITICAL SITES

Anomalies detection

PHASE 1	PHASE 2	PHASE 3	PHASE 4
REMOTE	REMOTE	FIELD	FIELD
ANOMALIES DETECTION	REMOTE VALIDATION	OPERATIVE VALIDATION	LEVEL UPSCALING

1. Automatic « trend breaking » identification. The service provider issues the layer including the accelerating PS, i.e. the so called « ANOMALIES »

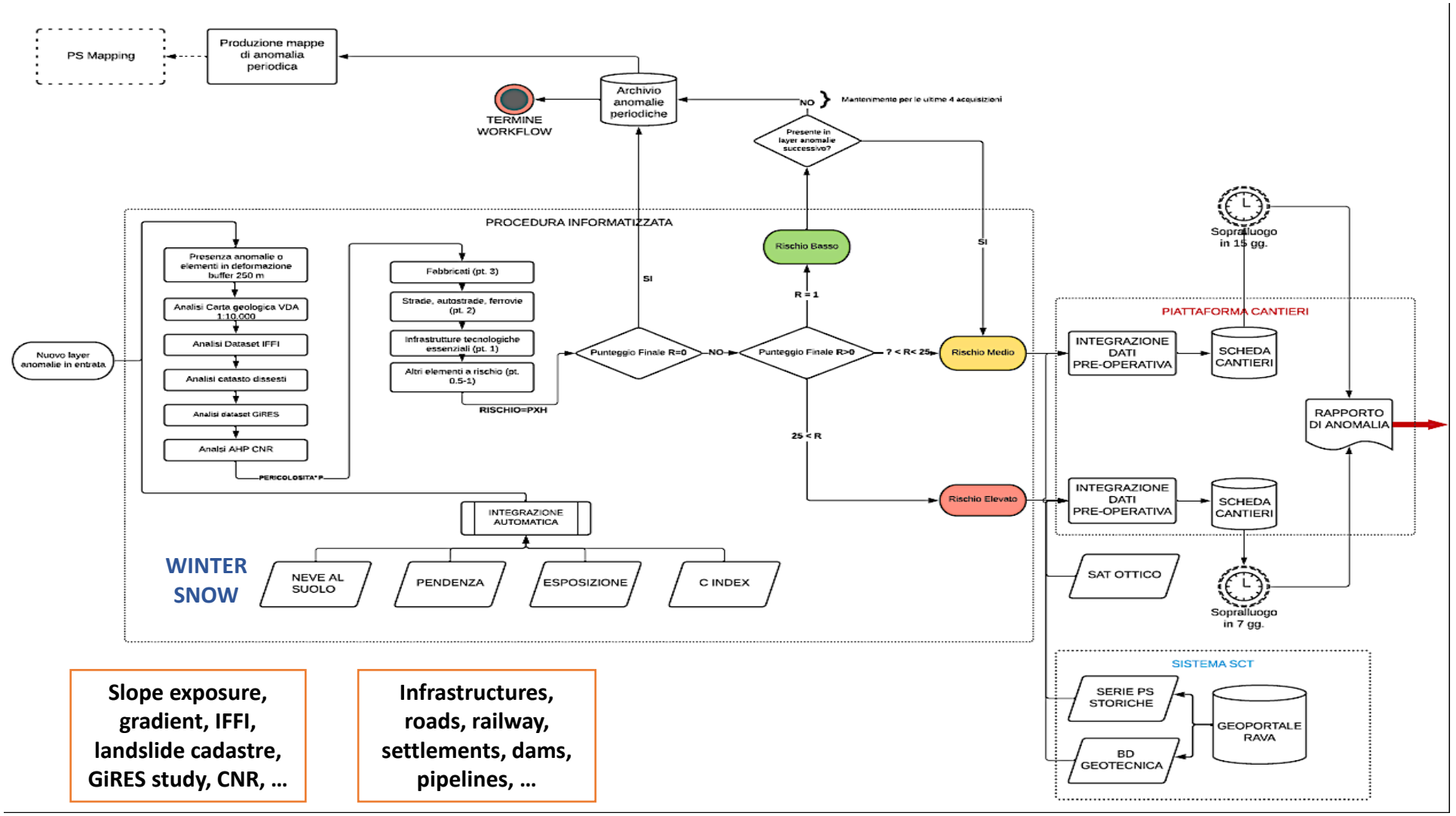
Anomalies validation

PHASE 1	PHASE 2	PHASE 3	PHASE 4
REMOTE	REMOTE	FIELD	FIELD
ANOMALIES DETECTION	**REMOTE VALIDATION (anomalies validation)**	OPERATIVE VALIDATION	EW CIVIL PROTECTION MONITORING

STEP 1: Control of potential alterations of the topographic surface (e.g.: by snow or human activity) by comparison with optical satellite images (Sentinel 2 and Planetscope) or ground images (webcams);
STEP 2: Data spatialization for phenomenon confirmation;
STEP 3: Comparison with PSInSAR data acquired from other satellites, if available, e.g.: Cosmoskymed;
STEP 4: Integration with database data:
- Detailed scale geological maps (1:10.000);
- Landslides National Inventory IFFI;
- Regional inventory of slope instabilities (includes also rockfalls and other);
- Study of susceptibility to rockfalls on regional roads.

STEP 5: Verification of the presence of **targets** (From Hazard to Risk);

Anomalies validation



Slope exposure, gradient, IFFI, landslide cadastre, GiRES study, CNR, …

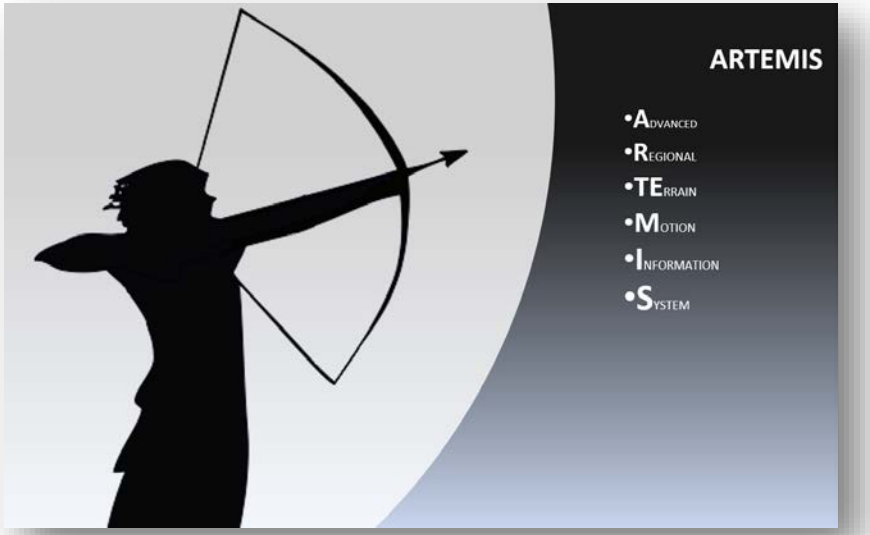
Infrastructures, roads, railway, settlements, dams, pipelines, …

Advanced Regional TErrain Motion Information System

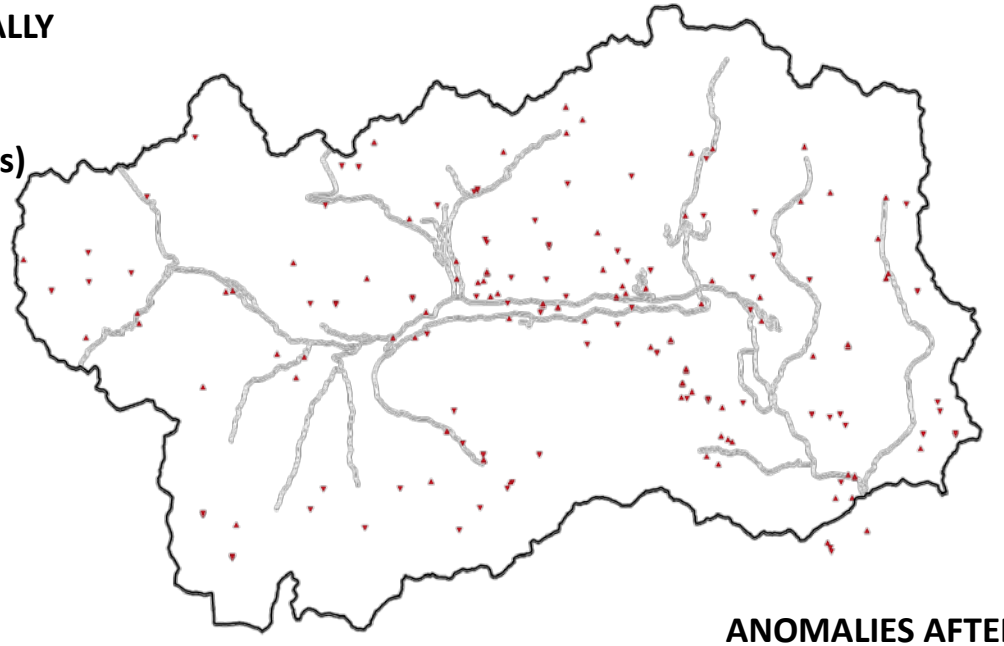
EGU22-12393
https://doi.org/10.5194/egusphere-egu22-12393
EGU General Assembly 2022

ARTEMIS – An operational tool to manage the information provided by Persistent Scatterers Monitoring at a regional scale.

Davide Bertolo, Michel Stra, and Patrick Thuegaz
Geological Survey - Regione Autonoma Valle d'Aosta, Difesa del Suolo, QUART, Italy (d.bertolo@regione.vda.it)

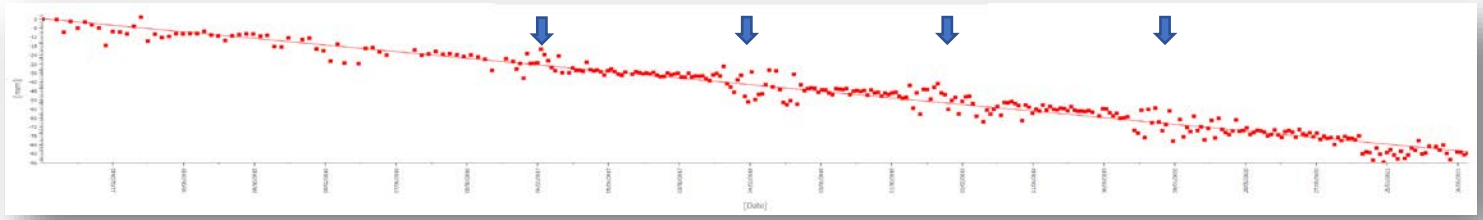


INPUT PRODUCT: AUTOMATICALLY DETECTED ANOMALIES APPROXIMATELY 200 (Ascending+Descending orbits)



ANOMALIES AFTER ARTEMIS PROCESSING

WINTER –SNOW EFFECT



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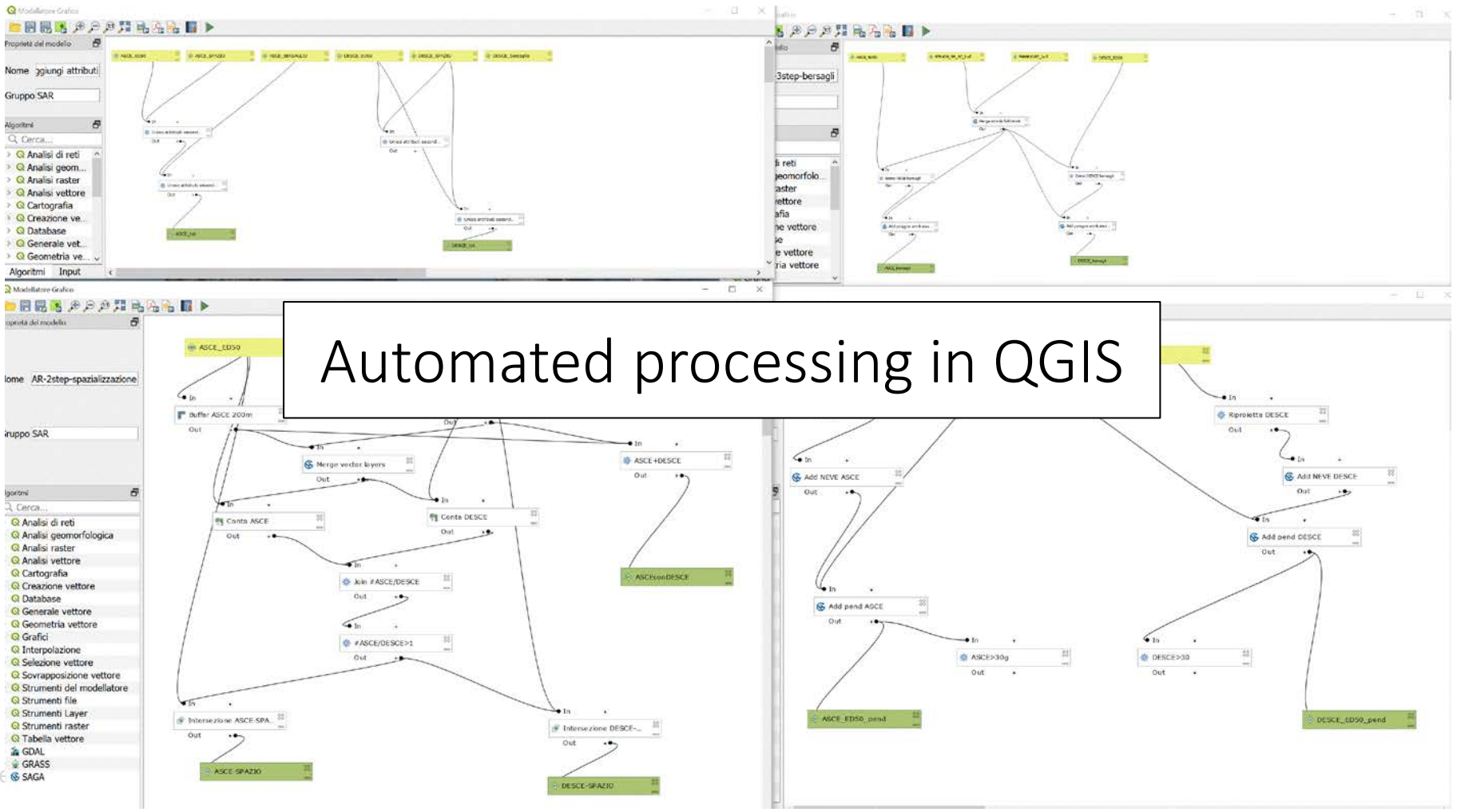

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PHASE 1	PHASE 2	PHASE 3	PHASE 4
REMOTO	REMOTO	FIELD	FIELD
ANOMALIES DETECTION	REMOTE VALIDATION	**OPERATIVE VALIDATION**	EW CIVIL PROTECTION MONITORING

PHASE 3 is activated at the end of the automatic procedure, which provides THREE LEVELS OF PRIORITY OF ACTION, BASED ON RISK: LOW, MEDIUM, HIGH. Depending on the level of risk some actions are taken

LOW RISK: COMPARATIVE EVALUATION WITH FURTHER ANOMALY LAYERS
MEDIUM RISK OR HIGH RISK
FIRST : RISK MEDIUM → WITHIN 15 days since the output. HIGH RISK → within 7 days.

- *PRE-OPERATIONAL DATA INTEGRATION;*
- *FIELD INVESTIGATIONS (Deformation signs in the terrain or infrastructures, cracks, etc.);*
- *POSSIBLE DRONE/HELICOPTER SURVEYS;*
- *POSSIBLE RUNOUT AND EVENT SCENARIOS MODELLING.*

POSSIBLE INCLUSION IN THE LEVEL 2 NETWORK:

- ***Discontinuous instrumental on-site follow up (e.g.: GNSS, RTS, Inclinometers, strain gauges);***
- *If the targets are infrastructures owned and exploited by other bodies and/or companies: REPORT TO THE OWNER (Regional DOT, Hydropower companies, Motorways, Railway Companies, etc.);*
- *Possible upgrade to the 3rd level network should the follow-up higlights the need.*

HIGH PRIORITY– LEVEL 3 NETWORK INCLUSION

- ***CONTINUOUS EW** monitoring*
- ***GEOLOGICAL AND DETAIL RUNOUT MODELLING***
- ***CIVIL PROTECTION PLAN***

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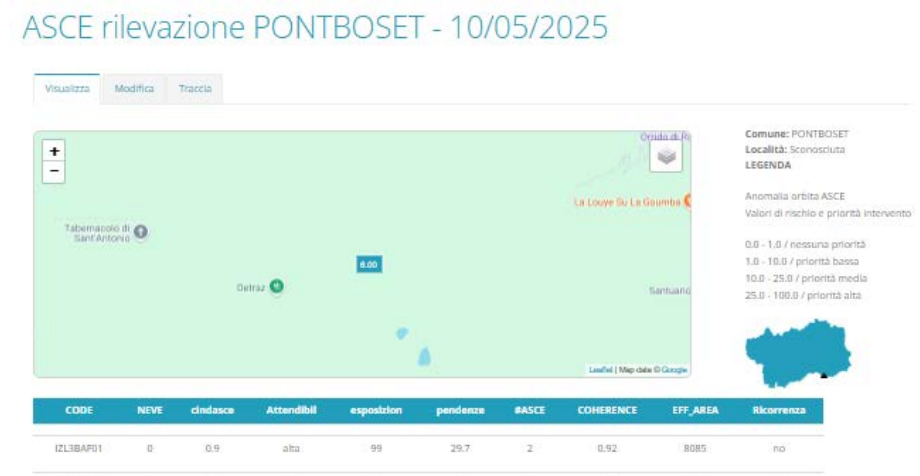
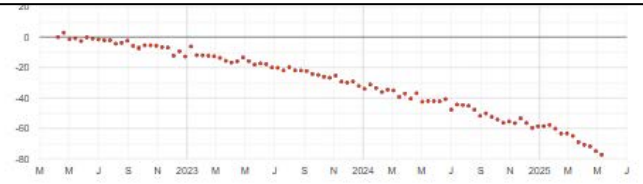
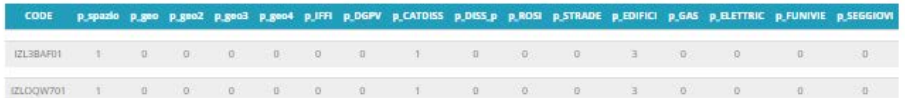
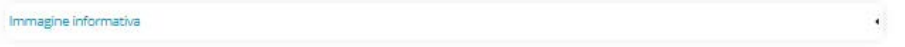
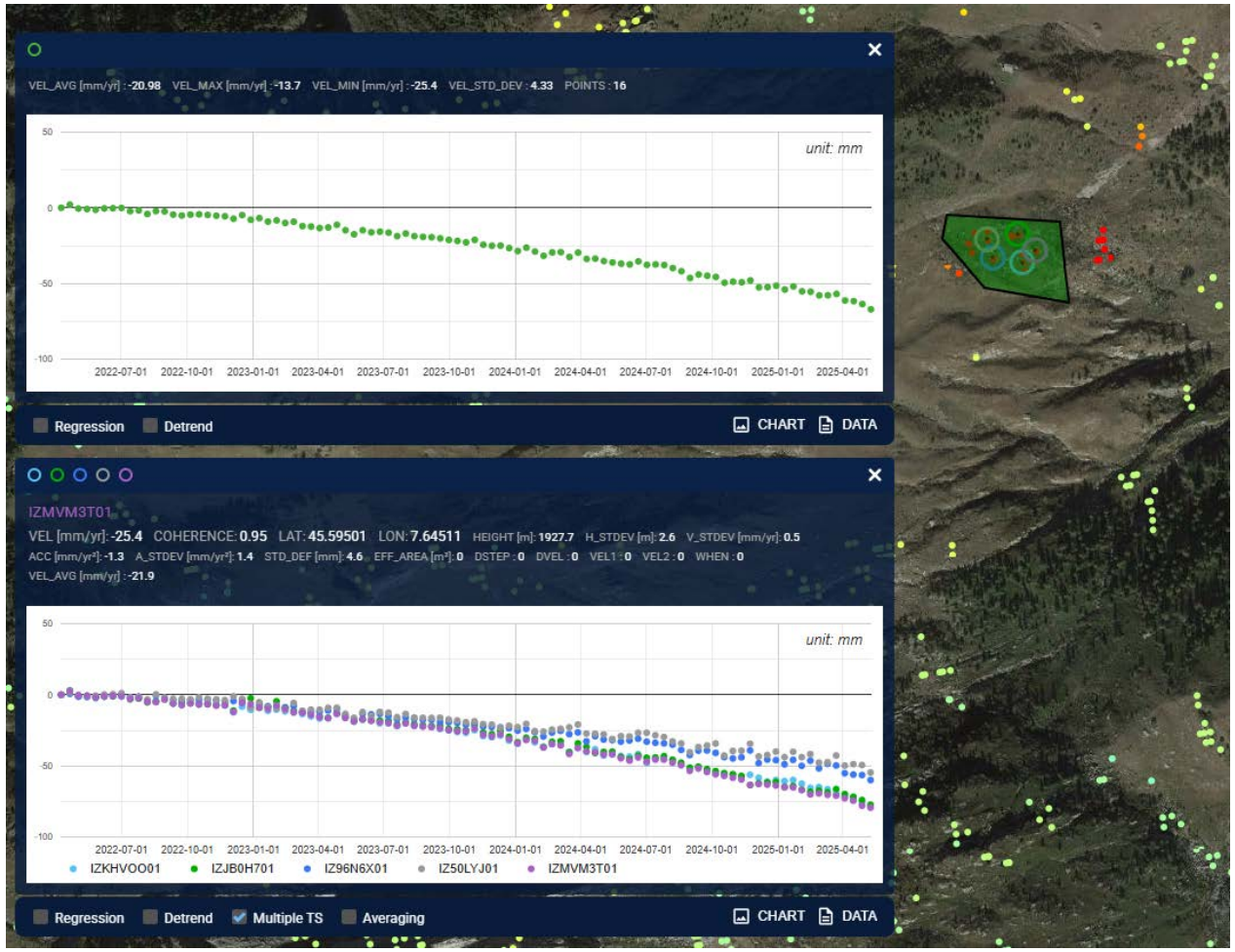


Tracking of the evaluation process on a dedicated regional web app for documentation and the possible issue of information to the Municipality (BULLETINS)









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Région Autonome Vallée d'Aoste — Regione Autonoma Valle d'Aosta

Crea Scheda sopralluogo

☰ Menu

Titolo *

Rilevazione satellitare *

- Selezionare un valore -

Dati rilevazione associata

Comune

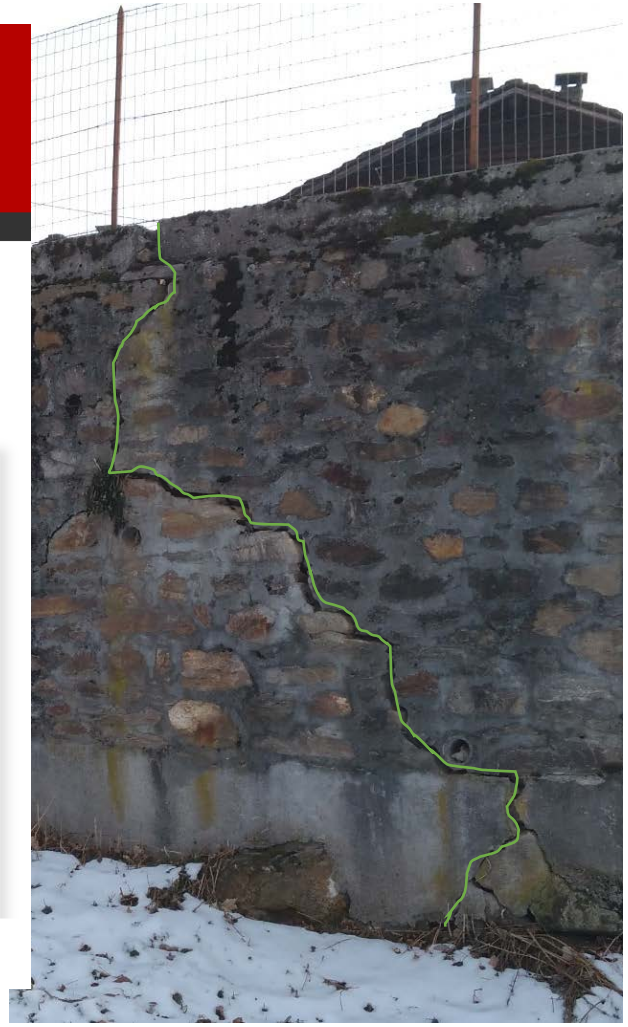
Località

Codice punto

Data rilevazione

Valore di rischio

Salva | Anteprima



Dati sopralluogo

Rilevatore

- Nessuno -

Data sopralluogo

05/03/2021

Formato: 05/03/2021

Ricorrente *

No

Tipologia di elementi a rischio

- [x] Puntuale
- [ ] Lineare
- [ ] Areale

Elemento a rischio

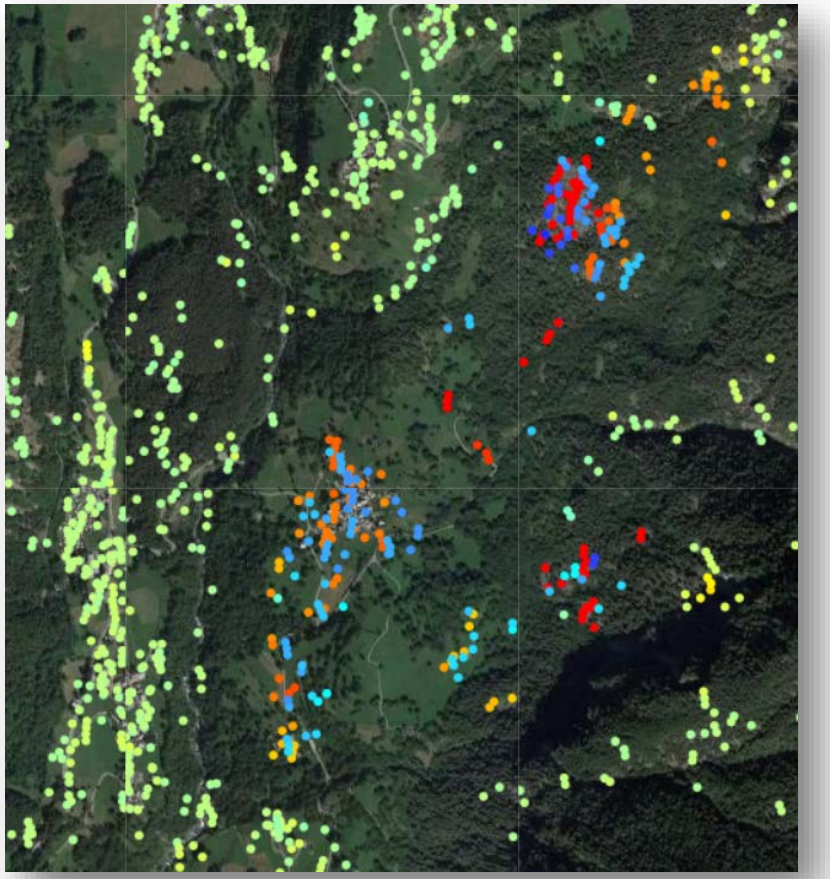
Distanza elemento a rischio (m)

Deformazioni elementi antropici

- [ ] Strade
- [ ] Muri
- [ ] Recinzioni

Salva | Anteprima

Case study: Alesaz (Challand-Saint-Anselme)

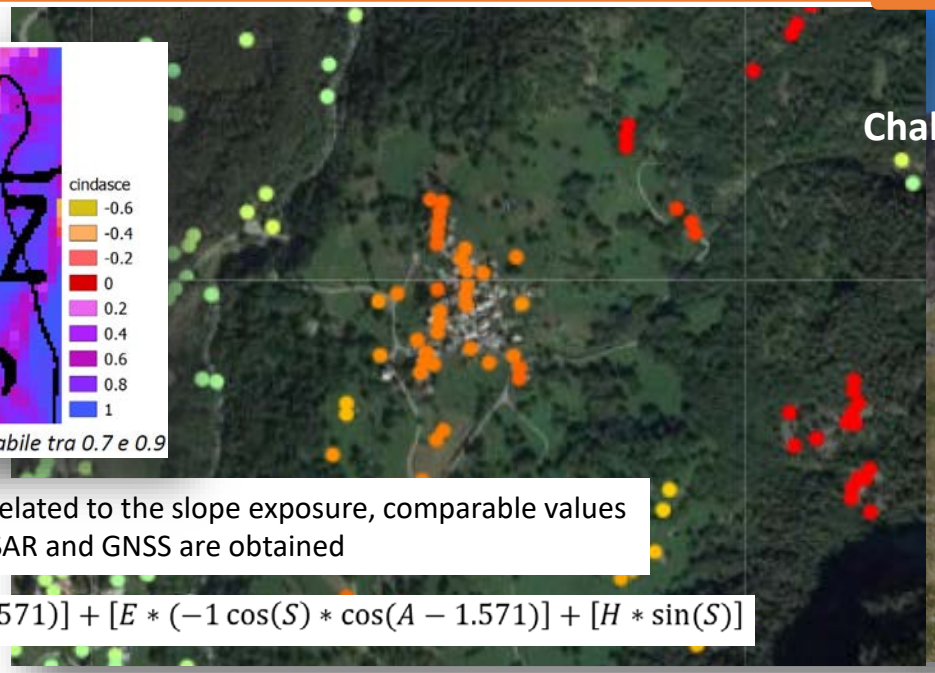


Case study: Alesaz (Challand-Saint-Anselme)

Coerenza spostamenti GNSS/PS su baseline lunga ***luglio 2019 – luglio 2023*** *[m]*

Punto	VEL_{LOS} [m/y]	C-index	VEL_{SLOPE}	Punto GNSS prossimo	Δ3D annuale [m/y]	Coerenza GNSS/PS Δ3D/ VEL_{SLOPE}	Coerenza GNSS/PS Δ3D/ VEL_{LOS}
CBG9C44	-0,0094	0,88	-0,0106	ALL2	0,0085	80,2%	**90,4%**
C9GTBIQ	-0,0116	0,53	-0,0219	ALL4	0,0130	59,3%	**89,2%**
CB5JJ8I	-0,0096	0,76	-0,0126	ALL6	0,0097	76,9%	**99,0%**

Fig. 13. *Mappa C-index del sito di Alesaz. Il valore è variabile tra 0.7 e 0.9*



By applying a correction factor related to the slope exposure, comparable values between SAR and GNSS are obtained

$$C = [N * \cos(S) * \sin(A - 1.571)] + [E * (-1\cos(S) * \cos(A - 1.571)] + [H * \sin(S)]$$


RASTOOL-DoS