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assessment for urban areas”**

Deliverable D2.9: Guidelines for the Integration of the Products in CPAs

**A deliverable of WP 2: Tools to support the Early Warning for Landslides
geohazard**

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EXECUTIVE SUMMARY

The aim of this deliverable is to provide guidelines for the implementation of U-Geohaz products in Civil Protection procedures. The goal is to properly integrate, use and interpret these products as a support to early warning system for landslides in mountainous environments.

The Activity 2.9 is led by UNIFI, in charge of the interpretation and validation of interferometric-derived products for the Valle d'Aosta Region.

REFERENCE DOCUMENTS

N°	Title
RD1	DoW Part B

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1.INTRODUCTION

Since last decade of the 20th century, the use of remote sensing techniques for geological hazard prevention, mapping and monitoring has grown significantly contributing to disaster risk reduction, impact assessment and disaster response for urban areas.

The increase of technological potentials of satellite radar interferometric data has changed the game rules providing operational tools for prevention purposes, crisis management and recovery tasks monitoring. In particular, the Earth Observation (EO) missions of the Copernicus program, funded by the European Union, has allowed scientist to make a significant step forward of the EO potentialities. Sentinel satellites can contribute to monitor a broad range of geological hazard types such as slow-moving landslides.

The integration of this new EO potentialities with traditional instruments and short-range remote sensing techniques mounted on drones or terrestrial platforms allowed the development of operational downscaling procedures. It is possible to monitor geohazards at different geographical levels, from regional to very local applications.

Nowadays, interferometric data are used in a wide variety of fields, including risk and emergency management. Considering this, it is important to create approaches and products that could be integrated into Civil Protection procedures. Satellite interferometric product are ready to be used as operational tools, not only as one-shot scientific applications.

Following the short revisiting time of 6-12 days of Sentinel-1 satellite and availability of SAR images, a regional monitoring of ground movements in almost “near real-time” is now conceivable. This is possible thanks to the last advancements in multi-temporal interferometric tools and computational power (through cloud platforms). This approach marks the passage from a static ‘picture’ of the regional deformation scenario to a weekly-updated ‘movie’ that can be useful for civil protection practices.

This deliverable will provide an overview on the operational use and integration of the satellite radar interferometric products as a support to early warning system for slow-moving landslides in the Civil Protection Authorities (CPA) practices.

2. OVERALL EXPLOITATION OF INSAR PRODUCTS IN CPA

In the framework of CPA practices, the need for intervention criteria as much objective and rational as possible is raising and becoming crucial for correct disaster risk reduction strategies.

Geohazard management and mitigation strategies involve the correct choice of the monitoring system (remote sensing vs in situ), the selection of the geohazards to be prioritized (in terms of allocated resources) and the development of a real-time or near-real time monitoring cycle involving local authorities and citizens. Therefore, there is a risk that some potentially hazardous and critical areas will be neglected, while too many resources were invested in not so hazardous areas.

The exploitation of satellite InSAR products allow selecting and highlighting the fastest moving areas at regional scale where attention must be paid. The detection of ADA (Active Deformation Areas) is a useful semi-automatic hot-spot like analysis which represents a good operative solution for reducing the time and efforts needed to inspect a whole interferometric dataset composed by thousands or millions of points. On these « priority » areas further investigations must be carried out in order to validate the data (e.g. to avoid « false positive » alarms) and to continue the surveillance on the territory (Figure 1).

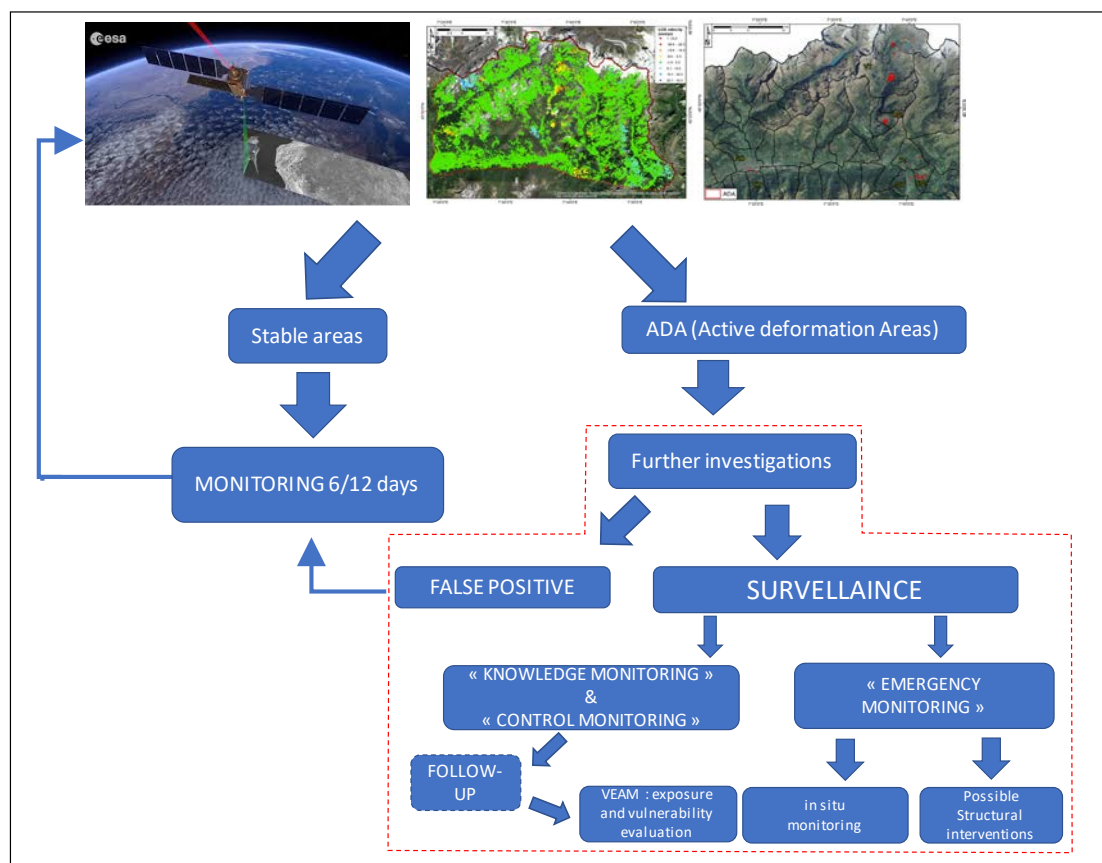


Figure 1 – Flowchart about the use of satellite InSAR products for geohazard management and mitigation strategies.

This active surveillance involves different levels of monitoring: (i) « knowledge monitoring » and « control monitoring » to follow-up studies and investigate possible critical situations, as well as to evaluate vulnerability, exposure impact and potential loss (included in the concept of VEAM : Vulnerable Elements at Risk Mapping) ; (ii) « emergency monitoring » that can lead to further in situ analyses or to the planning of 'structural' interventions of risk mitigation (Figure 1).

3. ADVANTAGES AND CONSTRAINTS OF INSAR PRODUCTS FOR CPA

The use of Persistent Scatterers Interferometry (PSI) data for Civil Protection usage is characterized by a series of advantages and drawbacks, which can be summarized as follow:

1) Main advantages:

- Wide area coverage: monitoring over large areas (up to regional/national scale);
- All climatic conditions;
- Data availability in inaccessible areas;
- Good cost/benefits ratio;
- Data promptness
- High update frequency (thanks to Sentinel-1 short revisiting time).

2) Main constraints:

- Presence of "false positive";
- Need of calibration and ground validation;
- Some areas are not covered (due to vegetation, snow, geometrical distortions);
- Only slow-moving phenomena can be detected (e.g. not applicable to rockfall/topples, flows).

In order to sketch and summarize the different levels of satellite monitoring, we defined 3 different "sub-types":

1) Preliminary evaluation: « KNOWLEDGE MONITORING »

2) Temporal evolution of critical situations: « CONTROL MONITORING »

3) Early warning: « EMERGENCY MONITORING »

By considering these issues and different features with respect to other techniques (in comparison with both traditional in situ or remote sensing such as GB-InSAR tool) a score of effectiveness can be assigned to PSI data according to the above-mentioned monitoring levels.

Concerning the first level, the use of PSI is quite reliable and so highly recommended for all the considered features (spatial coverage, temporal and spatial resolutions, data density, precision,

cost/benefits ratio). Conversely, for a detailed level of monitoring for early warning aims, PSI data are characterized by a lower score of effectiveness with respect to these features (Figure 2).

	Monitoring for preliminary evaluation	Monitoring for the temporal evolution of critical situations	Monitoring for early warning
Features	« <i>KNOWLEDGE MONITORING</i> »	« <i>CONTROL MONITORING</i> »	« <i>EMERGENCY MONITORING</i> »
Spatial coverage	High	Good	Good
Temporal resolution	High	Good	Low
Data density	High	High	High
Spatial resolution	High	Good	Medium-Low
Precision	High (mm)	High (mm)	Low (need validation)
Budget/year/km²	Very Low 40€/km ²	Very Low 40€/km ² Vs. 36.000 €/km ²	Not applicable

Range of effectiveness

<i>very good</i>	<i>acceptable</i>	<i>Not acceptable</i>	<i>Not applicable</i>
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Figure 2 – Example of score of effectiveness of PSI data according to the 3 different monitoring levels by CPA of VdA Region (Italy).

4. THE NEED OF AN INTEGRATED NETWORK

Due to the previously introduced critical issues, it is worth to highlight that a robust regional monitoring within CPA framework requires more networks and techniques to be integrated in order to obtain the most reliable and complete information. The use of PSI data allows tracing a useful and valid “path” across the three levels of monitoring, as shown in Figure 3.

Satellite InSAR monitoring makes possible to perform a real and effective “screening” of the territory at regional scale in order to identify the most critical situations, provide a “priority list” and to monitor landslide occurrence or ground motion acceleration.

Obviously, as with medical screening, there are many false positives that require direct insights and further in situ investigations. This is why a management procedure system and integrated network is necessary.

The monitoring procedure system allows an integrated monitoring/analysis that is useful for civil protection purposes, giving the various instruments a specific role in each data monitoring phase.

TOOLS	Monitoring for preliminary evaluation	Monitoring for the temporal evolution of critical situations	Monitoring for early warning
<i>Some remote sensing and in situ traditional techniques</i>	« KNOWLEDGE MONITORING »	« CONTROL MONITORING »	« EMERGENCY MONITORING »
Satellite PSI			
GbInSAR			
Robotic total station			
GNSS (autom.)			
Inclinometers (manual)			
Inclinometers, in situ sensors (automatic)			

Figure 3 – Table of comparison of different tools for the 3 levels of monitoring.

5. POSSIBLE PROCEDURAL PHASES: EXAMPLE FROM VARCP

The Valle d'Aosta Civil Protection (VARCP) is structured according to the Italian laws and it is based on the first response to the emergencies by the municipalities. The regional administration coordinates the response to the emergencies either in the case the Municipalities cannot give an effective response to local emergencies, or in the case of complex and extended events. In addition, the regional administration oversees the forecast and prevention activities, issuing civil protection warnings (e.g. in the case of meteorological or avalanche hazards).

Geohazard management is a particularly well-developed activity and it is managed by the distributed regional civil protection system adopting the “support function” organizational framework. Regarding landslide management, the civil protection system relies on the support provided by the Regional Geological survey (one of the administrative and technical structures of the RAVA – Regione Autonoma Valle d'Aosta), which oversees active geohazards monitoring (mainly landslides). The other fundamental support is provided by the meteorological and rainfall forecasts issued by the Regional Functional center which takes also care of landslides and rockfalls inventories.

The warning and early warning procedures are codified and approved by the regional government Resolution n. 26/2014, according to the Directive of the Prime Minister 27/02/2004. According to the above-mentioned Resolution and to the regional organization, the Geological survey is in

charge of the follow up of the active landslides and of the technical reports in case of new instabilities.

In this framework, when a new slope instability occurs the civil protection operation center dispatches an alert to the Geological survey, activating, where required, a survey aimed to evaluate the level of the residual risk. If the risk level is still high, civil protection measures, i.e. evacuation procedures or road closing, will be undertaken. In the case of an acceleration registered by an instrumented landslide, the Geological survey will issue a warning to the VARCP operative center, alerting at the same time the municipalities involved who activate of the civil protection plans.

In both cases, it's self-evident that the interferometry radar technology is a great opportunity for the operational services of VdA, greatly improving the monitoring capabilities of the territory.

The ground & satellite-based procedure is made of three levels of analysis and monitoring (Figure 4):

- 1) at regional scale by remote sensing tools (subdivided in phase 1 and 2);
- 2) at local scale by both remote sensing and on-site tools with discontinuous measurements;
- 3) local monitoring on site, as continuous measurement service.

More in detail, according to this monitoring network, the different actions that are carried out in each level are shown in Figure 5.

At level 1, the remote sensing tools are exploited. The phase 1 involves the fast detection of the areas characterized by the highest ground motions rates (e.g. the ADA or anomalous areas derived from satellite PSI data). The phase 2 requires a validation from other remote sensing tools: 1) control of possible alterations of the topographic surface (e.g.: due to snow presence) by comparison with optical satellite images (Sentinel 2) or webcams; 2) the extension of the point-wise information derived from PS benchmarks to confirm the presence of a landslide; 3) the acquisition of InSAR data acquired from other satellites (e.g. very high resolution X-band products); 4) comparison and integration with data from databases and thematic data such as geological information, IFFI databases, susceptibility studies; 5) check of the vulnerability and exposure and potential loss (VEAM products).

At level 2, there is an operational validation on site, which allows defining a priority score and leads to further surveys and discontinuous measurements such as: 1) data acquisition from geotechnical databases (data from on-site surveys); 2) reconnaissance with helicopter; 3) surveys with drones; 4) risk scenarios with runout modelling; 5) GNSS network installation discontinuous campaigns. If the elements at risk targets are structures or infrastructure managed by private companies, the specific authority is alerted. After these validation actions, a possible shift to the LEVEL 3 of monitoring network is possible.

At level 3, the monitoring is on site and at very local scale by means of continuous measurements. It is dedicated to specific sites characterized by high risk levels and by a high priority of Civil Protection.

According to this monitoring system, the network of remote sensing and on-site tools that are now active in Valle D'Aosta Region within VARCP is show in Figure 6. There are 6 sites at level 3 of monitoring, while the screening at regional scale for level 1 is assured by PSI data obtained every 12 days from the systematic and periodic elaboration and interpretation of Sentinel-1 SAR images.

Network	LEVEL 1	LEVEL 2	LEVEL 3
SCALE	Regional	LOCAL	LOCAL
Integration tools	REMOTE	REMOTE+ON SITE DISCONTINUOUS	ON SITE CONTINUOUS+CONTACT
Temporal resolution	12 days	12 days (PSI) + periodic	continuous
System tool	PSInSAR integrated	PSInSAR Integrated GNSS discontinuous, GBInSAR discontinuos, inclinometers, RTS	RTS, GBInSAR, GNSS continuous, DMS
Aim	- Preliminary screening and evaluation - Study - Planning	Operational validation of data from Level 1 on site, for potential activation of LEVEL 3	Civil protection
Coverage	Areal	Punctual	Punctual

Figure 4 – Monitoring network on 3 levels in VARCP.

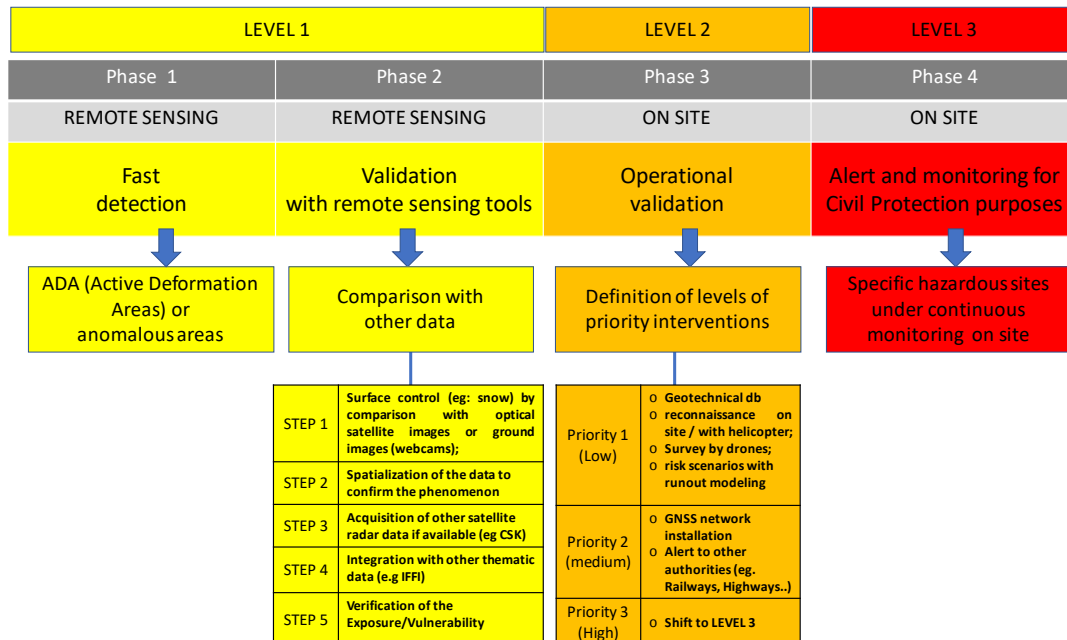


Figure 5 – Actions in the different phases and levels of the monitoring network in VARCP.

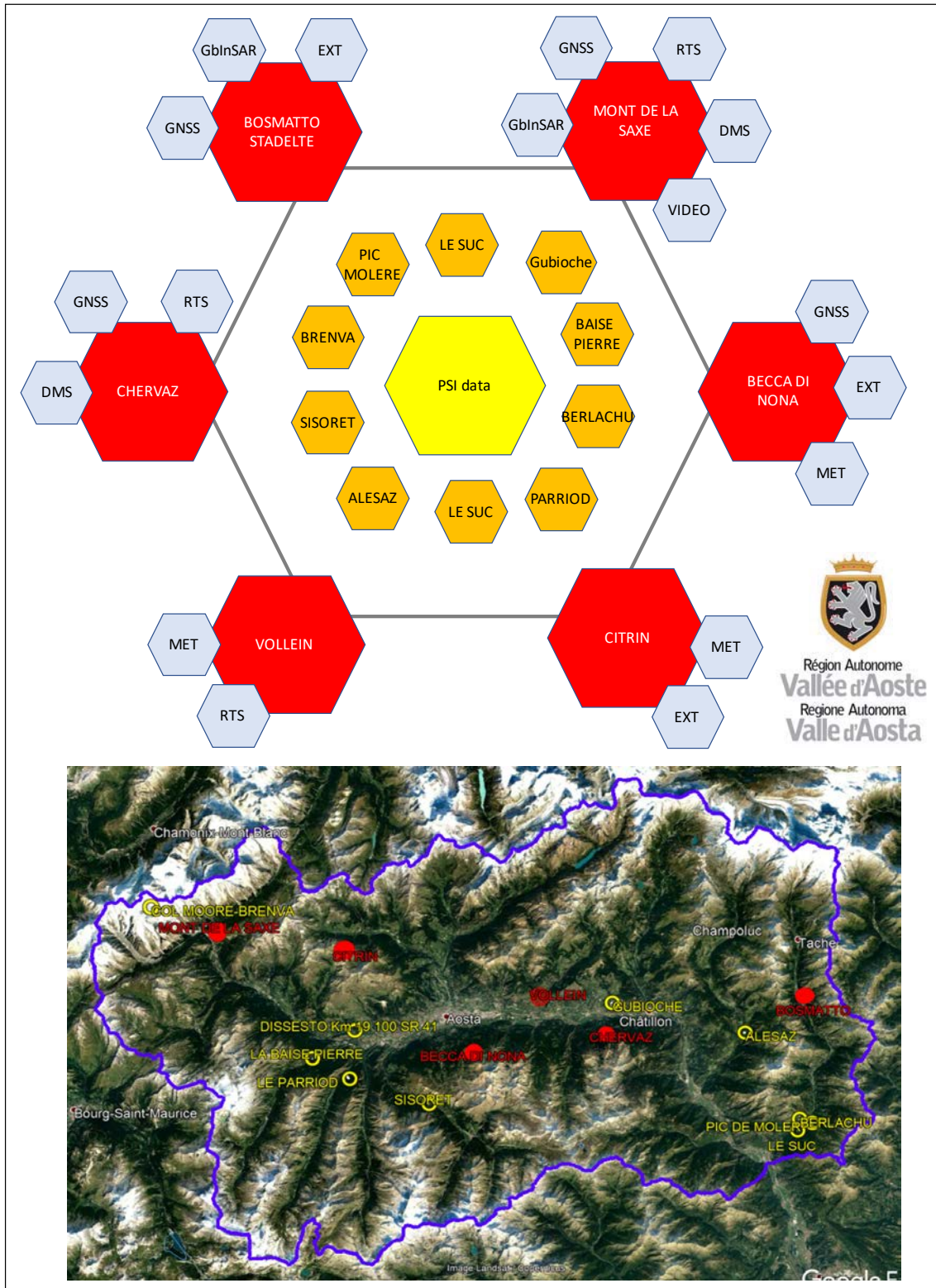


Figure 6 – Active monitoring network in VARCP, VdA Region (Italy).

6. CONCLUSIONS

This deliverable presents some general guidelines for the implementation of PSI products in Civil Protection systems and an example of how this is made by the VARCP.

The procedural integration of the InSAR products in the CPA (Civil Protection Authorities) strategies allows supporting disaster risk management, moving them from tools for the scientific community to operational tools able to meet the needs of local and regional organizations and authorities in charge of geohazard mitigation.

Nowadays the satellite InSAR monitoring makes possible to perform a real and effective “screening” of the territory at regional scale in order to identify the most critical situations, provide a “priority list” and to monitor landslide occurrence or ground motion acceleration.

Due to critical intrinsic constraints of InSAR data to be taken into account, it is worth to highlight that a robust regional monitoring within CPA framework requires more networks and techniques to be integrated in order to obtain the most reliable and complete information.

The monitoring network needs to be structured in different levels of detail and analysis, giving the various instruments and tools a specific role in a given data monitoring phase. The VARCP monitoring plan is a very good example of PSI data integration as baseline for further and targeted analyses at local scale.