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Deliverable D2.4: Description of the procedure to generate the ADA and VEAM

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

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Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
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EXECUTIVE SUMMARY

The main goal of this document is to provide the description of the procedure to generate Active Deformation Areas (ADA) starting from Sentinel-1 interferometric products. The ADA are the inputs for assessing landslide vulnerability applying the so called Vulnerable Elements Activity Maps (VEAM) procedure.

This deliverable is a technical report that will contain a technical explanation about the methodology aimed at deriving ADA and VEAM products. The methodology will be adapted, corrected and modified following the inputs given by its final user (Valle d'Aosta Civil Protection) and on the basis of the potential constrains of the interferometric products.

The Activity 2.4 is led by UNIFI which is in charge of the definition of the methodology and of the generation of the VEAM products for the Valle d'Aosta Region.

REFERENCE DOCUMENTS

N°	Title
RD1	DoW Part B

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1.INTRODUCTION

The Landslide activity maps and the Vulnerable elements activity maps (VEAM) are the main outputs of the WP2 “Tools to support the Early Warning for Landslides geohazard”.

The generation of Landslide activity maps relies on the definition of hotspots of active landslide motions (Active Deformation Areas – ADA) with a 6-days temporal repeatability, fully exploiting the unique characteristics of the Sentinel-1 constellation. The ADAs will provide the spatial distribution and the magnitude of ground deformation over the Valle d’Aosta Region, updating the state of activity of already known phenomena or mapping new potential slope movements. The ADAs will also indicate if an already moving landslide is changing its behavior, i.e. accelerating. This information is of crucial importance for landslide management practices.

Vulnerable elements activity maps will be derived starting from the interferometric products, specifically from the ADAs. The aim of this task is to assess the impact of detected and/or assessed geohazard on road networks and built-up areas. The VEAM will consist in a simplified color scale map indicating those structures and infrastructures with a greater probability to suffer for the impact of a geo-hazard and those structures and infrastructures affected by the dynamic of an active geohazard.

The proposed methodology is designed to be easily and semi-automatically applied, in order to follow the 6-days repeatability of the Sentinel-1 constellation.

The technical report will contain the description of:

- methodology for Active Deformation Areas generation;
- methodology for Vulnerable Elements Activity Maps generation.

2.METHODOLOGY FOR ACTIVE DEFORMATION AREAS GENERATION

The generation of ADAs for the Valle d’Aosta Region follows two subsequent phases:

1. definition of ADAs at regional/basin scale (small scale procedure);
2. frequently updated monitoring of selected ADAs (detailed scale procedure).

The first phase allows defining the areas with the highest activity in terms of ground motions, related to slope deformation, within a sector of the Valle d’Aosta Region (Figure 1). This sector has been selected because of the presence of several landslides affecting the steep slopes of the valleys (Valtournanche, Ayas Valley and Lys Valley) included within the area of interest. The starting point of this procedure is a deformation map, derived from Sentinel-1 images and analyzed by means of a PSI (Persistent Scatterers Interferometry) approach based on Devanthéry et al., 2014, and through the use of software tools developed by CTTC in the framework of the Safety project. The first deformation map will be produced starting from Sentinel-1 images acquired from January 2015 (firsts regular acquisitions of Sentinel-1A over the area) to April 2018. The deformation map will be updated every 6 months to highlight changes in the deformation patterns at basin scale. The PSI dataset will be analyzed, using the methodology proposed by Barra et al. (2018), in order to semi-automatically extract ground motion areas (i.e. ADAs) from a large number of measurement points.

These data will be used to define a priority list of active areas with potential interest for the Regional Civil Protection and for risk management authorities. The ADAs defined at basin scale will be used to perform a near-real-time monitoring of the motions at detailed scale, based on single interferogram analyses performed every 6 days.

The selection of the most representative and noteworthy ADA is performed on the basis of four main criteria:

- ADA assessment based on:
  - ✓ quality Index
  - ✓ presence, within the ADA, of already mapped landslides (contained into the IFFI - Italian landslide inventory - database of the Valle d'Aosta Region);
  - ✓ availability of validation data on site, such as GPS (Global Positioning System) stations or GBInSAR (Ground Based Interferometry) platforms.
- magnitude and spatial coverage of the deformation;
- direct or induced potential impact on structures and infrastructures;

The second phase of this task relies on the near-real-time monitoring of the previously defined ADAs. In particular, the classical D-InSAR (Differential Interferometric SAR) approach will be used to derive, at every new acquisition of the Sentinel-1 sensor, an estimation of the ground displacement occurred in the time span between two acquisitions. This approach will be used for two main reasons: the capability to follow fast motions, within the technical boundaries of the methodology, and the lowest machine time needed with respect to a complete PSI analysis performed at every new acquisition of the satellite. Thus, the deformative evolution of every ADA will be followed exploiting the 6-days repeatability of the Sentinel-1 constellation.

At every new acquisition of Sentinel-1, an update of the selected ADA will be implemented. Both the magnitude of the deformation and the spatial development of the active motion will be derived. It is worth noting that this methodology is aimed at detecting accelerations in an already set up slope deformation, using Sentinel-1 as a real monitoring platform, following the example presented by Raspini et al. (2018) for the Tuscany Region.

The product of this activity will be a detailed scale characterization of the selected ADAs, providing useful information for risk management and civil protection activities. The results of this monitoring will be delivered every 6 months, accordingly with the structure of U-Geohaz project. During this activity a continuous exchange of information between the technical team and the Valle d'Aosta regional authorities will be established. The authorities in charge will be promptly informed on the presence of intense variations in the behavior of the monitored landslides, potentially indicating the triggering of slope failures.

The deformation occurred in the selected areas will be automatically extracted; then, all the 6-days information will be merged to reconstruct the spatial behavior of the areas of interest during the monitored period. The size of the deformation and its magnitude will be used to develop detailed scale impact scenarios and intensity evaluations for every monitored landslide, that, cross-compared with exposure of elements at risk, will lead to the estimation of vulnerability for the different ADAs.

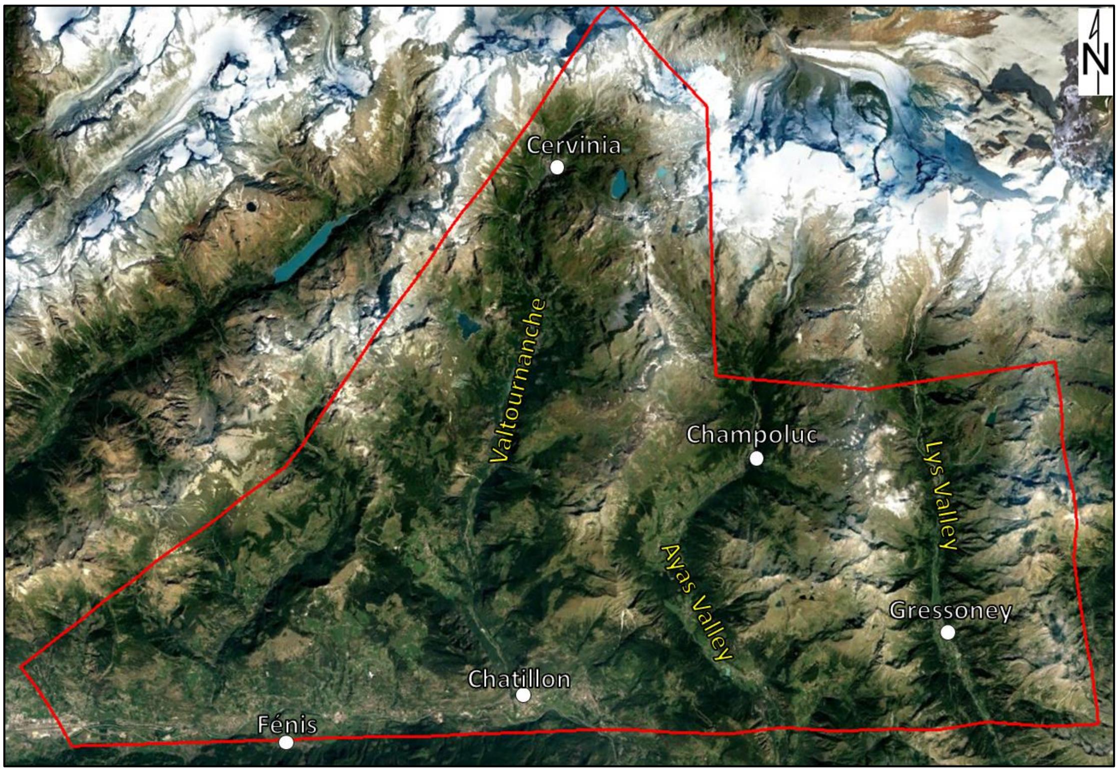

Figure 1 – Localization of the area of interest.

3.METHODOLOGY FOR VULNERABLE ELEMENTS ACTIVITY MAPS GENERATION

The vulnerability of a structure is defined as the expected degree of loss experienced by the elements at risk for a given magnitude of hazard (Glade, 2005). Its assessment is quite complex and depends on several parameters such as building conservation, type of construction, typology of landslide, kinetic energy at impact, presence of landslide mitigation measurements and so on (Fell 1994).

The vulnerability of structures depends also on the exposure of the elements at risk, i.e. the number of lives or the value of the properties exposed to the risk. The first parameter is extremely difficult to assess because population is a mobile asset (Lee and Jones, 2004); thus, exposure of persons requires the calculation of conditional probability of presence of people in buildings, depending on the time of the day in which the landslide might occur (Van Western et al., 2006). For this reason, human lives exposure is a parameter rarely implemented in landslide risk practices, especially at regional or basin scale. The economic value of elements at risk is simpler to estimate, because relies on information easier to reach.

Several authors presented different vulnerability estimation procedures, depending on the working scale, the type of landslides involved and on the availability of different input data. As a general law, vulnerability is a combination between the intensity of the event and the exposure of the elements at risk.

Landslide intensity can be expressed by several parameters including volume, velocity, depth, run-out, and area extent (Lee and Jones, 2004). Considering the characteristics of the Valle d'Aosta Region landslides, i.e. large rockslides that evolves into channelled debris flows, we choose to estimate, for the areas of interest, the intensity of the phenomena as a product between geometrical and dynamic parameters. This in accordance with the definition of intensity given by Li et al. (2010).

For the aims of the project, we will use the Gravitational Process Path (GPP) model developed by Wichmann (2017) to evaluate the runout area and the process path of the potential debris flows. These phenomena could be generated from the unstable areas detected and monitored by means of interferometric data. The interferometric data act as a fundamental input for the model, determining the size and the volume of the source area that could be updated depending on the results produced within the project. The GPP model has been chosen for two main reasons: i) it requires a few inputs (a Digital Terrain Model and simple source area characteristics) and ii) is implemented as a tool of the free-to-use GIS (Geographic Information System) SAGA (System for Automated Geoscientific Analyses, Conrad et al., 2015). The GPP model simulates the movement of one or multiple mass points called "particles" from the initiation site (source area) to the deposition area. The model allows estimating, through the use of empirical, stochastic and physically based approaches, the maximum velocities reached by the debris, the stopping position and the height of the deposited materials (Wichmann, 2017).

Although more sophisticated and complete models exist at the slope scale, capable of simulating in detail runout, entrainment and deposition of a debris flow sediment, they are not usable at the basin scale, where several shallow landslides can be triggered at the same time and where the prediction must encompass an entire valley or river basin. The GPP model, in such cases, is a very good compromise between accuracy and efficiency and feasibility.

These parameters will be used to quantitatively estimate the intensity of the monitored landslides, information needed to calculate the vulnerability of the areas of interest. It is worth noting that the source areas of the phenomena could be frequently updated depending on the outcomes of the interferometric analyses, also because GPP model runs are easily generated, fast and semi-automatic, once calibrated.

Exposure will be evaluated giving an economic value to the different classes of elements at risk (administrative buildings, monuments, hospital complexes, highways, local roads, etc…), as suggested for example by Catani et al. (2005), Remondo et al. (2008) and Pellicani et al. (2014). An example of this kind of exposure evaluation is illustrated in Table 1.

The final output of the methodology proposed will be a colour scale map, indicating the different values of vulnerability for the structures potentially affected by the run out of a landslide generated starting from a source area detected by means of interferometric analyses. This product will be regularly updated every 6 months.

Table 1 – Examples of exposure values for different types of buildings and infrastructures (modified after Catani et al., 2005). The values have been derived for the Arno River basin in the Tuscany Region (Central Italy).

Type of building/infrastructure	Exposure (€/m^2)
Abandoned/ruined building	10
Building under construction	100
Campground/resort	100
Cemetery	100
Civil Complex	4000
Greenhouse	10
Hospital complex	4000
Industrial/commercial building - factory	1000
Local road	50
Monument	100
Power station/power substation/power shed	2000
Provincial road	50
Public/social/administrative building	3000
Railway/railway station	2000
Religious building	4000
School complex	4000
Shed	100
Silo	10
Sport facilities	100
Stable/barn/breeding farm	10
State highway/provincial highway	100
Toll road/highway	200

CONCLUSIONS

This deliverable has briefly presented the methodologies to derive Active Deformation Areas and Vulnerable Elements Activity Maps for the Valle d'Aosta test site. These methodologies are the core of the WP2 "Tools to support the Early Warning for Landslides geohazard".

The generation of the ADAs follows two subsequent phases: i) a regional/basin scale procedure for the selection of the most representative ADA and ii) a detailed scale monitoring of the selected ADA thanks to the 6 days repeatability of Sentinel-1.

The generation of vulnerability maps depends on the definition of the exposure of the elements at risk (through an evaluation of their economic value) and on the intensity of potential landslide events, whose source areas have been derived from the analysis of the interferometric data. In particular, the evaluation of landslide intensity will be based on run out modeling products.

This document presents a preliminary assess of the methodologies that will have to be tuned during the project, adapting them to the results obtained, and calibrated depending on the potential constrains of the interferometric products and on the inputs given by the final users of U-Geohaz.

REFERENCES

Barra, A., Solari, L., Béjar-Pizarro, M., Monserrat, O., Bianchini, S., Herrera, G. et al. (2017). A Methodology to Detect and Update Active Deformation Areas Based on Sentinel-1 SAR Images. Remote Sensing, 9(10), 1002.

Catani, F., Casagli, N., Ermini, L., Righini, G., & Menduni, G. (2005). Landslide hazard and risk mapping at catchment scale in the Arno River basin. Landslides, 2(4), 329-342.

Conrad, O., Bechtel, B., Bock, M., Dietrich, H., Fischer, E., Gerlitz, L., et al. (2015). System for automated geoscientific analyses (SAGA) v. 2.1. 4. Geoscientific Model Development, 8(7), 1991.

Devanthéry, N., Crosetto, M., Monserrat, O., Cuevas-González, M., & Crippa, B. (2014). An approach to persistent scatterer interferometry. Remote Sensing, 6(7), 6662-6679.

Fell, R. (1994). Landslide risk assessment and acceptable risk. Canadian Geotechnical Journal, 31(2), 261-272.

Glade T, Anderson M, Crozier M. (2005). Landslide hazard and risk. Chichester: John Wiley & Sons Publisher Ltd.

Lee, E. M., & Jones, D. K. (2004). Landslide risk assessment. Thomas Telford.

Li, Z., Nadim, F., Huang, H., Uzielli, M., & Lacasse, S. (2010). Quantitative vulnerability estimation for scenario-based landslide hazards. Landslides, 7(2), 125-134.

Pellicani, R., Van Westen, C. J., & Spilotro, G. (2014). Assessing landslide exposure in areas with limited landslide information. Landslides, 11(3), 463-480.

Remondo, J., Bonachea, J., & Cendrero, A. (2008). Quantitative landslide risk assessment and mapping on the basis of recent occurrences. Geomorphology, 94(3-4), 496-507.

Van Westen, C. J., Van Asch, T. W., & Soeters, R. (2006). Landslide hazard and risk zonation-why is it still so difficult?. Bulletin of Engineering geology and the Environment, 65(2), 167-184.

Wichmann, V. (2017). The Gravitational Process Path (GPP) model (v1.0) - a GIS-based simulation framework for gravitational processes. Geosci. Model Dev., 10, 3309-3327.