Nat. Hazards Earth Syst. Sci. Discuss., 3, 2757–2775, 2015
www.nat-hazards-earth-syst-sci-discuss.net/3/2757/2015/
doi:10.5194/nhessd-3-2757-2015

Natural Hazards and Earth System Sciences Discussions
Open Access

Brief Communication: On the rapid and efficient monitoring results dissemination in landslide emergency scenarios: the Mont de La Saxe case study

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Received: 17 March 2015 – Accepted: 31 March 2015 – Published: 21 April 2015

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Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

Straightforward communication of monitoring results is of major importance in emergency scenarios relevant to large slope instabilities. Here we describe the communication strategy developed for the Mont de La Saxe case study, a large rockslide threatening La Palud and Entrèves hamlets in the Courmayeur municipality (Aosta Valley, Italy). Starting from the definition of actions and needs of the Landslide Management Team, including scientists, technicians, civil protection operators, decision makers, and politicians, we show that sharing and disseminating ad hoc information simplifies the understanding of the landslide evolution, as well as the correct communication of the level of criticality.

1 Introduction

Large Slope Instabilities (LSI) include a wide range of landslide phenomena, from slow slope deformations to rapid and catastrophic rockslides. LSI geometry, as well as failure mechanisms, is deeply influenced by the background geological and hydrogeological conditions. One of the most critical issues related to LSI is their attitude to potentially evolve into gravitational events of impulsive nature, involving a partial or total portion of the instable mass (e.g. rock falls and/or rock avalanches). In this context, the identification of surface displacements and/or deep-seated deformation represents often the key information for a proper understanding and interpretation of the phenomenon (Wieczorek and Snyder, 2009).

In the last two decades, monitoring systems ranging from in-situ to remote sensing techniques, allowed to retrieve information on LSI deformation at unprecedented spatial and temporal resolution. Among several, displacement monitoring is probably one of the most common approaches used to increase the background knowledge of an instable slope, as well as to eventually control its evolution into impulsive events (Balis et al., 2011). When a high hazard potential is recognized, intensive monitoring is preferred, allowing for the recognition of displacement trends, and eventually for the identification of precursors of a partial or complete landslide failure. Thus, intensive monitoring provides an important support to survey inhabited centers and infrastructures surrounding the instable mass (Xu et al., 2011). Monitoring networks of this kind consist of precise and automated instruments, capable to achieve accurate measurements of surface displacements at very high sampling rates, e.g. in near real time (minutes to hours) or even in real-time (Intrieri et al., 2012): these are the base elements for the application of Early Warning Systems (EWS, Manconi and Giordan, 2014; Michoud et al., 2013). In this scenario, EWS relevant to displacement monitoring usually consist of 3-levels of attention (Intrieri et al., 2013): (i) an ordinary level, when displacements are below predefined thresholds (ii) a pre-alarm level, used when the landslide shows displacements above the seasonal oscillation, and (iii) an alarm level, which identifies a critical activation of the instable area. The application of complex monitoring networks to large landslides is documented in several reference papers (Brückl et al., 2013; Giordan et al., 2013; Lu et al., 2014; Malet et al., 2002; Tarchi et al., 2003). However, strategies of divulgation and dissemination of such a monitoring results, especially in emergency scenarios, are yet lacking of standards and best practices.

In this work, we describe a real case study, the Mont de la Saxe rockslide, a large and complex instability located in Val d'Aosta, northern Italy. We focus the attention on the characteristics of the monitoring procedures, as well as on the communication strategy developed to comply with the actions and needs of the different actors involved.

2 The Mont da La Saxe rockslide: a complex LSI emergency scenario

The Mont de La Saxe rockslide (hereinafter La Saxe) is a large instable slope located in the Aosta Valley region, northern Italy (Fig. 1). La Saxe rockslide is located in meta-sedimentary sequences cropping out along the left hand flank of the valley. These rocks belong to Ultra-Helvetic basal decollèment units located south of the Mt. Blanc crystalline massif and are made of very low-grade, intensely deformed Middle

Jurassic meta-sedimentary sequences, including limestones and marls, argillaceous schists, black schists, micaschists, and calcschist with quartz–arenite levels (Perello et al., 1999; Leloup et al., 2005). In the area affected by the rockslide, the dominant black argillaceous schists prevalently dip to the SE, into the slope, with dip angles ranging between 20 and 60° due to the effect of tectonic deformation events (Crosta et al., 2014, 2015). La Saxe instability has an estimated total volume of more than 8×10^6 m^3. The landslide is extended between 1400 and 1870 m a.s.l., over an area of about 150 000 m^2, with maximum horizontal length of about 550 m, maximum width of about 420 m, and average slope gradient of 37°. The upper scarp is about 200 m wide and it is characterized by a steep rock wall some tens of meters high, locally oriented along sub-vertical schistosity planes (Crosta et al., 2014).

An automatized near real time monitoring network (see details in Fig. 1) has been installed and developed starting from 2009, when the high level of criticality of the La Saxe rockslide for La Palud and Entrèves hamlets was officially recognized. The monitoring network permitted to detect and monitor the evolution of several landslide sectors characterized by different kinematic behaviors. Starting from 2014, the Mont de La Saxe landslide has been classified as national emergency, and the local authorities are supported by the Italian National Civil Protection Department. Thus, a specific Landslide Management Team (LMT) has been created to cope with the emergency activities.

Starting from the management system of the monitoring network, we defined a specific communication strategy aimed at supporting the decision makers during the critical phases of the landslide evolution, and to share the information with all the stakeholders. The main goals of our communication strategy are: (i) update all LMT members in near-real-time with essential information, (ii) deliver specific periodic (or on-demand) reports calibrated for each LMT role, summarizing the evolution of the LSI in a defined time period, (iii) fully exploit the potential of the data available, and divulgate the correct information on the landslide evolution to all people involved in the emergency scenario.

In the following, we describe the details of the strategy, as well as how we applied it to the management of La Saxe emergency.

3 The La Saxe Landslide Management Team

The management of a complex monitoring network to control LSI evolution is a difficult task, chiefly during emergency conditions. Usually, a specific working group of people (i.e. LMT) is set up with the aim of controlling the landslide evolution, to plan civil protection activities, as well as organize initial remedial activities. LMT members have to accomplish different actions, depending on their specific role and on the phases associated to the evolution of the landslide. In La Saxe case study, the team is composed of multiple stakeholders, including scientists, civil protection authorities, and technicians. By considering the different background knowledge, needs, and duties of the LMT components, we identified three different categories:

i. ROLE-1, composed of authorities such as the mayor, alderman and other politicians that often do not have a specific technical background on landslide hazard. This people are usually the terminal of a decision chain, and have the responsibility to eventually activate measures reducing direct risks to people and/or infrastructures. According to the not-specific background knowledge of people composing the ROLE-1, their principal need is to clearly understand the criticality level of the current situation by accessing to clear and meaningful information before tacking decisions concerning their personal or the public safety (Garcia and Fearnley, 2012).

ii. ROLE-2, composed of engineers, geologists, and others technicians that have a specific background knowledge and experience on landslides. Their tasks are mainly related to the exhaustive technical analysis of the landslide to support ROLE-1 in their decisions. This may include the analysis and comparison of

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different data sources, as for example surface deformation, deep-seated displacements, rain/snow precipitation data, groundwater variations, etc. In addition, ROLE-2 is usually responsible of the design of mitigation and/or protection measures. For this reason, they need to fully access the monitoring results, in order to clearly understand the recent landslide evolution, as well as to plan their activities accordingly.

iii. ROLE-3, mainly composed of engineers and geologists, which have a specific preparation and large experience on landslides monitoring and on EWS. Their tasks are aimed to develop and run efficiently the monitoring network, analyze and validate the data and the results, therefore to support the other members of the LMT in the different phases of the landslide evolution.

A common issue in standard approaches of data sharing is related to representation of the monitoring results. In particular, x–y plots employed for the restitution of time series (i.e. time in abscissas and the measured physical quantities on ordinates) might be of difficult reading and understanding for people not used to deal with this kind of graphical representations. In complex emergency conditions, incorrect reading of monitoring results can lead to misunderstandings and unnecessary concerns (Mileti and Sorensen, 1990). Figure 2 shows how the potential of divulgation decays depending on the complexity of the representations used. For this reason, the graphic representation of monitoring results should be carefully calibrated by considering the background of the LMT recipients. The low level of complexity of the representation helps population and ROLE-1 to better understand the current status of the landslide phenomenon according to their specific interest. On the contrary, ROLE-2 and ROLE-3 can afford more complex and detailed representations, and thus better evaluate the recent landslide evolution and its possible effects on the hypothesized scenarios.

In Table 1 we present a schematic diagram summarizing the duties, actions and needs of LMT members acting in the La Saxe emergency scenario. In general, the results obtained via the monitoring network of La Saxe landslide are analyzed and

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shared by generating specific products considering two main temporal ranges: (i) near-real-time (described in Sect. 3.1) and (ii) periodical and/or on-demand basis (Sect. 3.2).

We would like also to stress that the LMT concept developed for Mont de La Saxe can be considered a general schematic representation. In each specific context, there might be some changes, and thus duties, needs and actions of the different LMT members might have some overlaps. However, after the definition of LMT components, it is possible to focus on one of the most important points for the management of an emergency related to a natural hazard, i.e. the straightforward access to the available information, the data sharing, and the efficient communication of the actual status of the phenomenon.

3.1 Near-real-time divulgation

The dissemination of the monitoring results in near real time to La Saxe LMT members is based on the use of the ADVICE algorithm (Allasia et al., 2013). This procedure has been developed to perform a set of actions in near real time, including: (i) data acquisition and transfer protocols, (ii) data collection, filtering, and validation, (iii) data analysis and restitution through a set of dedicated software, (iv) recognition of displacement/velocity threshold, early warning messages via SMS and/or emails, (v) automatic publication of the results on a dedicated webpage. One of the main advances of the ADVICE method is that all the operations can be performed without installing dedicated software for the processing, exploitation, and management of the monitoring results. The access to the webpage relevant to the monitoring results of La Saxe has been structured with multiple levels, corresponding to the three different LMT roles. Thus, the information is presented according to the specific background knowledge of each user. For example, ROLE-1 members have access only to the Synthesis page. This front-end view has been developed as a cockpit to supply with the most relevant information, and to provide a rapid and straightforward overview on the actual landslide status. The Synthesis page contains: (i) the main meteorological parameters, (ii) the RTS displacement maps and plots with the indication of predefined threshold levels (Fig. 3),

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(iii) the last images acquired by the webcams. In this page, people not used to deal with time series plots may benefit of interpolated maps of the three-dimensional displacements produced in near real time, which facilitate the understanding of the recent development of the phenomenon (Manconi et al., 2013). On the other hand, ROLE-2 members have access to additional information derived from the monitoring network. The monitoring data available (meteorological parameters, RTS, GPS, GB-SAR, and piezometers) are organized in a set of different representations, which mainly depend on the time window considered (e.g. monthly or weekly time series plots/displacement maps). Among the available representations, Fig. 4 shows an example of integration of data retrieved via different monitoring instruments. Displacement rates measured by RTS and GB-SAR are interpolated in a unique representation generated via the ©3DA approach. Moreover, in order to allow the interaction of the users with the website, ROLE-2 members have access to interactive features, such as the dynamic time series plot. This tool is extremely important, mainly because it allows to explore the available dataset directly, and also to compare different data sources. Instead, ROLE-3 develops and controls all the data processing form the measurement to the publication. For this reason, they need tools to check the system status and to identify eventual malfunctioning of the monitoring network and/or of the ADVICE system. In the case of the La Saxe case-study, specific messages are issued (via SMS and e-mail) when the data on the webpage is not up-to-date, indicating at which step the procedure encountered a problem. This allows promptly acting and restoring the system.

ROLE-2 and ROLE-3 members benefit also of early warning messaging produced by the ADVICE system when predefined thresholds on surface displacements are overcome. Messages are sent via SMS and/or e-mail just few instants after the processing and publication online of the results relevant to the last measurement cycle. All the information provided via ADVICE, as well as additional data retrieved from other sources, joined with the in-depth knowledge of the landslide process, allows ROLE-2 and ROLE-3 members to evaluate and validate a potential situation of direct risk for the population and/or the infrastructures, and eventually transmit this information to ROLE-1 members.

3.2 Periodic/on-demand updates

To fully understand and interpret the landslide evolution, the availability of near real time monitoring results is not sufficient. For this reason, our divulgation strategy consists also of periodic and/or on-demand reports (bulletins), which also take into account the definitions of actions and needs of the different LMT components. A first bulletin typology is mainly dedicated to ROLE-2 LMT members. This bulletin is issued quarterly, and considers all the data retrieved via the different monitoring instruments operating in the La Saxe area. The main goals of the quarterly bulletin are: (i) to supply a complete description of the results obtained by the monitoring network in the considered time period, (ii) to identify and validate eventual trend changes with respect to the previous three months and to the same period of the previous years, (iii) to audit the results, in order to suggest eventual updates and integrations to the current monitoring network. During specific emergency conditions, this kind of bulletins can be issued also over shorter time periods and eventually on-demand.

In addition, a specific informative bulletin for the ROLE-1 members has been developed and tested. This bulletin is issued weekly during the most critical phase of the landslide evolution, and consists of a simplified visualization summarizing the displacement results obtained via the RTS in the previous 7 day period. Since the content, as well as the representation selected for this bulletin is intended for a straightforward divulgation to a large amount of people, this bulletin can also be considered to inform the population about the landslide status.

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4 Discussion and conclusions

The divulgation of scientific data is a complex task (Garcia and Fearnley, 2012) evidenced that often there is a real need to improve the relationship between the scientific community (and single researchers) and other stakeholders, in order to "produce usable science". This is a critical issue, in particular during emergency conditions, when one of the main aspects commonly recognized is the distance between scientist and other involved stakeholder. This notion refers to making scientific research findings useful for societal or individual well-being and especially useful for decision makers. To accomplish this goal, scientists should make their research results accessible to the public, while using simple language that allows the general community to understand the information.

Our recent experiences in the management of emergency scenarios relevant to large slope instabilities, as well as other natural and anthropic hazards (Lollino et al., 2014; Manconi et al., 2012, 2013b; Giordan et al., 2013), evidenced the need of integrated monitoring networks. However, the large amount of data retrieved may cause several problems if a proper approach for the sharing and correct divulgation of the results is missing. In this work, we have shown the communication strategy applied to the La Saxe rockslide emergency scenario. Starting from the background and needs of the final receivers, we proposed and discussed a straightforward methodology aimed at sharing the landslide monitoring network results in an efficient manner. At the moment of writing, the entire La Saxe monitoring infrastructure and workflow from the acquisition to the divulgation of the results is operative. By collecting all the data relevant to the La Saxe monitoring network in a unique web-based platform, comparative analysis of heterogeneous and complex information relevant to landslide displacements has been facilitated, in terms of time and effort. Following the results of this case-study, our aim is to define a standard approach to share the monitoring results, in order to disseminate the information about the recent evolution of the landslide, as well as the level of criticality, within all the people involved (scientists, technicians, civil protection operators, decision makers, politicians, press, population). To this end, near-real time results of the same dataset have been represented according to the characteristic of the final users, to adapt the information to the final receivers. Moreover, the auditing provided with quarterly bulletins permitted to describe and comment the recent landslide evolution, identify criticalities and lacunas of the monitoring network, and thus adapt instruments and eventually sampling policies along with the evolution of the landslide phenomenon. The application of dedicated products for the divulgation of the monitoring results helps for a proper understanding and evaluation of the landslide evolution. Decision makers can access in near real time to straightforward representations of the monitoring data, and thus can evaluate promptly the current situation. Moreover, simplified summaries revised by LMT experts (weekly bulletins) provide an efficient tool to discuss and interact with the population threatened by the landslide risk. This allows acting with prompt countermeasures, which represent one of the key steps for the successful management of the most critical emergency phases. The presented experience and the results obtained on the Mont de La Saxe landslide showed how a dedicated communication strategy could help to correctly manage complex emergencies. In the last years, this approach has been attempted in several monitoring contexts: (i) the Montaguto earthflow, southern Italy (Giordan et al., 2013), (ii) San Giovanni Profiamma, Foligno (PG), central Italy, where in April 2013 a landslide interrupted the important road that connects Rome to the Adriatic Sea through central Apennines (SS3 Flaminia), (iii) monitoring activities related to the recovering of the Costa Concordia vessel wreck, near the coast of the Il Giglio Island (Manconi et al., 2013b). However, the Mont de La Saxe case study is an important and representative application for its peculiarities in terms of complexity of the phenomenon, highly exposed value and heterogeneity of the actors involved in the emergency. For this reason, this experience evidences that similar communication strategies have to be considered for the efficient management of monitoring activities relevant to landslide scenarios, as well as of other natural and/or anthropic hazards.

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Table 1. Landslide management team components relevant to the La Saxe emergency scenario. Duties, needs and actions for each role are also defined.

	LMT members	Duties	Needs		Actions	
			NRT	Periodic	NRT	Periodic
ROLE-1	Local politicians and Decision makers	Responsible of the civil protection procedures (e.g. evacuation of risky areas)	Synthetic view of the current landslide status	Easy-to-catch summary of the landslide evolution	Promptly inform population on an immediate risk	Educational programs to increase the risk perception among the population
ROLE-2	Landslide experts	Provide a geological model of the landslide phenomenon and hypothesize scenarios of partial and/or total failure	Synoptic view on results of the entire monitoring results	In-depth analysis and auditing on the monitoring results	Validate monitoring results according to the interpretative model	Update the geological model and scenarios according to the monitoring results
ROLE-2 ROLE-3	Geological Service of the Aosta Valley Region	Responsible of the EWS and coordinator/supervisor of the LMT Design and implementation of mitigation strategies	Synoptic view on results of the entire monitoring network and results Early warning relevant to changes of the landslide status	In-depth analysis and auditing on the monitoring results	Analysis and comparison of different monitoring data sources	Maintenance/update of the monitoring network
ROLE-3	Geohazard Monitoring Group	Processing, validation, and dissemination of monitoring results	Alerts on proper functioning of the monitoring network	Total control on the monitoring data flow, from measurements to dissemination	Maintenance of the Early Warning System	Generation of reports/bulletins for the other LMT members, with detailed analysis of monitoring results

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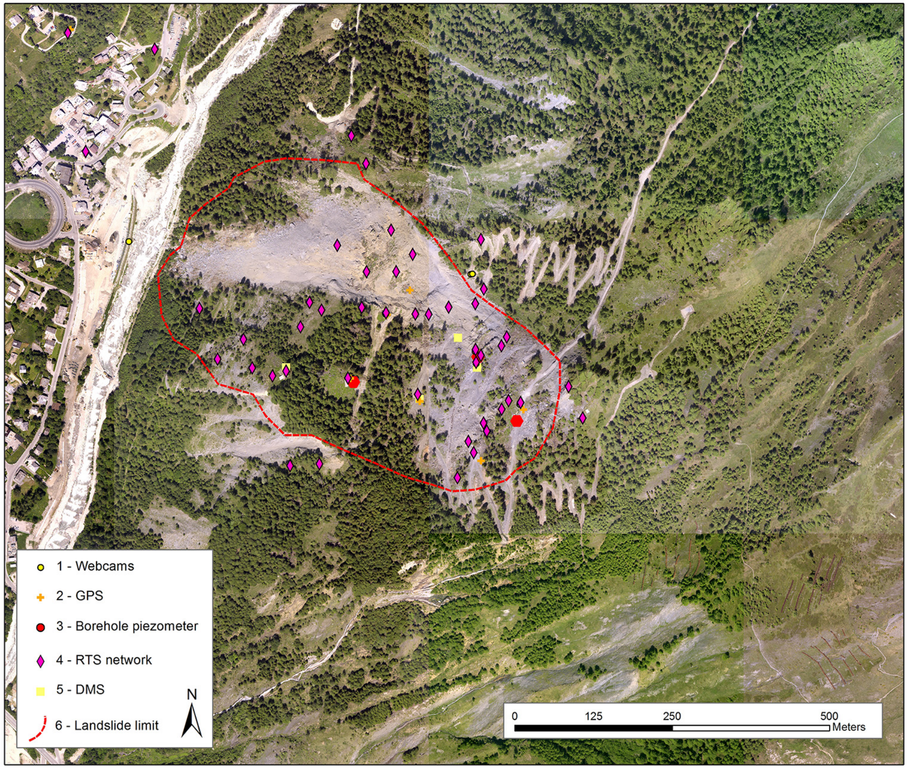

Figure 1. La Saxe intensive monitoring network. The actual automatized network is composed by: (1) webcams, (2) GPS devices, (3) borehole piezometers, (4) Robotic Total Station (surveying 36 optical targets), (5) DMS^{TM} columns (Lovisolo et al., 2003; Blikra et al., 2013) and a GBinSAR that control all the instable area.

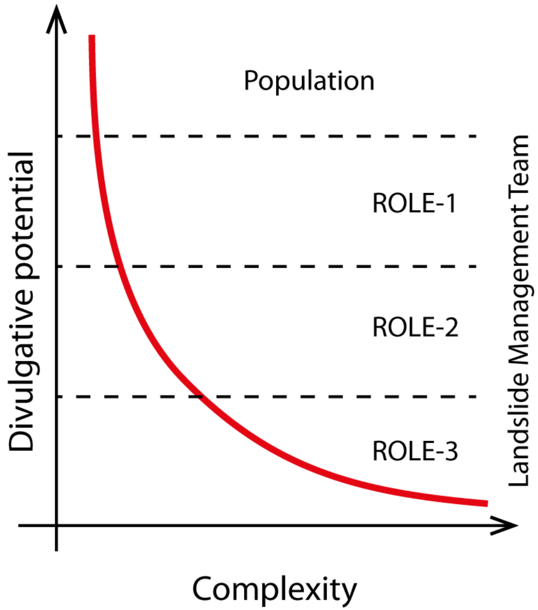

Figure 2. Communication strategy of monitoring results. The graph depicts how the potential of divulgation decays when the complexity of the graphical elaborates increases.

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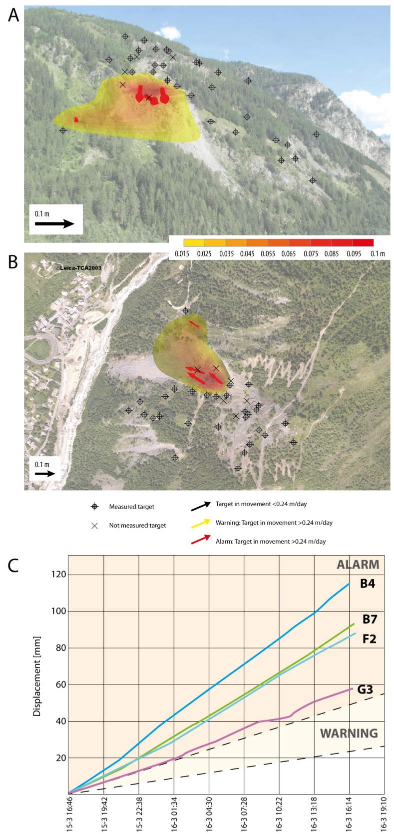

Figure 3. Examples of rendering of the RTS dataset published on the synthesis web page of the Mont the La Saxe monitoring network. These visualizations are aimed to share the last RTS data and to show which is the most landslide active area. The representations have been developed to represent the entity of displacement in relation to the predefined displacement thresholds (yellow = warning, red = alarm).

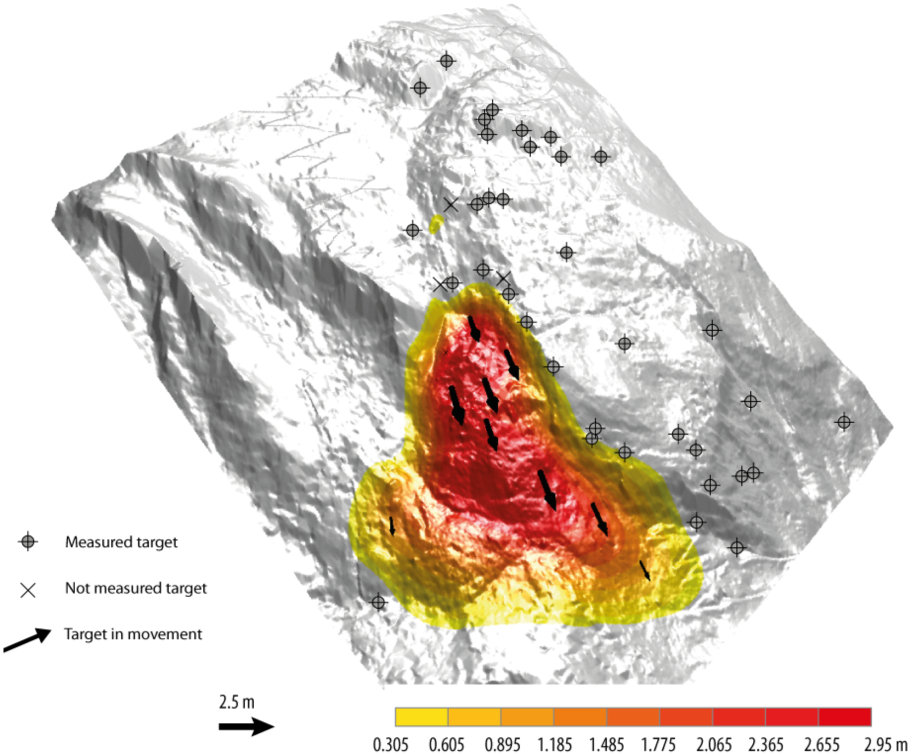

Figure 4. Map representing the displacement registered along the Line of sight direction using the RTS and GB-SAR data. In this way the LOS component measured by the two instrumentation is plotted in the same displacement map that can be used to have a more complete situation of the recent evolution on a series of point also represented by conventional plots. This solution gives the possibility to have high resolution and compensate RTS measures with several points derived from GB-SAR and located in the most inaccessible sectors where the installation of RTS target is not possible.

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3, 2757–2775, 2015