



This discussion paper is/has been under review for the journal Natural Hazards and Earth System Sciences (NHESS). Please refer to the corresponding final paper in NHESS if available.

Brief Communication: A new testing field for debris flow warning systems and algorithms

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Received: 11 February 2015 – Accepted: 12 February 2015 – Published: 2 March 2015

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

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Abstract

Early warning systems (EWSs) are among the measures adopted for the mitigation of debris flow hazards. EWSs often employ algorithms that require careful and long testing to grant their effectiveness. A permanent installation has been so equipped in the Gadria basin (Eastern Italian Alps) for the systematic test of event-EWSs. The installation is conceived to produce didactic videos and host informative visits. The populace involvement and education is in fact an essential step in any hazard mitigation activity and it should envisaged in planning any research activity. The occurrence of a debris flow in the Gadria creek, in the summer of 2014, allowed a first test of the installation and the recording of an informative video on EWSs.

1 Introduction

The prediction and forecasting of landslides is a very broad issue that involves the work of researchers of many different disciplines and includes several diverse topics. Among the latter, a place is held for the early warning of landslides and the study and development of early warning systems (EWSs). Restricting further into the topic, a specific theme is represented by the early warning from rapid mass movements such as debris flows (Stähli et al., 2014).

There are two main categories of EWSs, namely the advance and the event EWSs (Hungr et al., 1987). Advance EWSs predict the occurrence of a debris flow by monitoring the hydro-meteorological conditions that might lead to its initiation (Keefer et al., 1987) whereas event EWSs detect the debris flow when it is already occurring (Badoux et al., 2008).

Event EWSs may use different types of detecting devices that range from simple electrified wires, broken by the passage of the flow, to more complex types of sensors that require the development of algorithms to interpret the sensor output and recognize the debris flow occurrence. The devices employed by EWS are usually the same used

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for monitoring and research in rheological and modeling studies and investigations on propagation processes (Arattano et al., 2006; Lin et al., 2005). They include a wide variety of sensors, such as stage sensors, seismic sensors, microphones, trip wires, video cameras (Arattano and Grattoni, 2000; Marchi et al., 2002; Suwa et al., 2011; Turconi et al., 2015; Zhang, 1993).

The event EWSs for debris flows usually detect the passage of a debris flow at a certain cross section where the sensor is installed, but they may also be able to detect in advance the arrival of the debris flow when specific types of devices are employed (Abancó et al., 2014; Koschuch et al., 2015; Schimmel and Hübl, 2015). The event EWSs that rely on the use of algorithms to process the monitoring data and recognize the occurrence of a debris-flow event, usually require long development and systematic testing. An instrumented site specifically designed for testing EWSs and their algorithms would be of great help to favor their development and improvement and also to undertake a first attempt toward a standardization of procedures and methods for such testing. The standardization of monitoring and warning procedures for debris flows is in fact a need that is particularly felt (Arattano et al., 2015). This need suggested to equip a specific testing field for event EWSs and warning algorithms in the instrumented area of the Gadria creek, on the North-Eastern Italian Alps.

The installation of a testing field for debris flow EWSs is also important because it may increase the public awareness on their functionality and effective performances. An EWS, in fact, cannot provide a complete safety for the people that it is devoted to protect, as a certain percentage of risk will always remain and false alarms will also be possible. Therefore the interested population needs to learn and understand the performance of an EWS and the service it may provide. The Gadria testing field might be used for guided visits that could connect public and researchers and help to reach such an understanding.

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2 The Gatria testing field for debris flow warning algorithms

Any EWS needs a period of calibration and tests that precedes its operational employment. This is particularly true for the event EWSs that make use of warning algorithms to process the output of the sensors employed for detection. In fact, the warning algorithms require to be systematically and extensively checked for verifying their capacity in correctly detecting the occurrence of a debris flow and measuring the needed parameters. The check must include the capability of the algorithm to avoid the detection of other types of phenomena that might produce false alarms (Coviello, 2015). Moreover, algorithms might need improvement on the basis of their first performances and also the improved versions should undergo a systematic phase of tests.

These needs have suggested the realization of a specific facility where the required tests could systematically be performed with the needed recurrence and continuity. The ideal location of such an installation would have been an already existing instrumented area for debris flow monitoring where events occurred with a high enough frequency to grant the possibility of a significant number of tests. The Gatria catchment, located in the Eastern Italian Alps (Comiti et al., 2014) provided a good opportunity.

The testing field has been realized in 2014 along a straight reach of the Gatria creek (Fig. 1). The reach was already equipped with different types of sensors for the monitoring of debris flows (Comiti et al., 2014), including raingauges, three video cameras shooting the channel, two radars for flow stage measurements and four geophones. The downstream boundary of the testing field is determined by the most upstream of the fixed video cameras. This video camera (Fig. 2a) is in fact an essential part of the EWS testing field installation, as it will be shown in the following.

About 150 m upstream of the video camera, a specific equipment was installed (Fig. 2b) that has been designed by the CNR IRPI researchers and constructed by the Company SIAP+MICROS (www.siapmicros.com), which also contributed to fund the research along with the EU-funded SedAlp project (www.sedalp.eu). This equipment is named ALMOND-F, which stands for “ALarm and MONitoring system for Debris-

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Flows". The ALMOND-F is designed to host different types of sensors and to implement different warning algorithms aboard. These algorithms can be directly uploaded on the ALMOND-F with a laptop computer. Finally, a flashing light (Fig. 2) has been installed on the bank of the torrent 75 m downstream of the ALMOND-F equipment and has been cabled together.

The flashing light is framed by the fixed video camera (Fig. 1) and is activated by the algorithm. This allows a visual verification of the efficacy of the algorithm under test. The activation of the flashing light is in fact recorded by the video camera, which also records the arrival of the debris flow. By analyzing the video recordings, it is possible to verify the moment when the light starts to flash and the contemporary occurrence of the debris flow. When the warning system is capable of providing an alarm in advance, as it occurs when it makes use of seismic sensors (Abancó et al., 2014), it becomes possible to appreciate visually the amount of time elapsed between the activation of the flashing light and the actual arrival of the debris flow.

An event EWS may also have a closure algorithm which recognizes when the event is finished and turns off the alarm. This would correspond to the restoring of the green light in case the EWS were connected to a traffic light to stop the vehicles and impede the access to an endangered stretch of road or railways. The flashing light of the Gatria EWS testing field also allows an easy check of such closure algorithms, visualizing the turning off of the flashing light and the correspondent flow that is occurring in the channel at that moment.

3 An educational and informative site

The chance to shoot videos that show the activation and deactivation of the flashing light is particularly useful for showing decision makers, practitioners and the general public the performance of an EWS and to make them aware of its functionality. The involvement and the education of the interested populace are important goals and essential steps in almost any hazard mitigation activity. These goals should not be

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pursued as something separated by the research activities carried out in the field or in the laboratory. On the contrary, they should be kept in mind during all the phases of the research and possibly integrated with the research activity.

The Gatria testing field was designed with this in mind and can be considered a first attempt of such integration. In fact, it has an importance and an utility that goes beyond the simple mechanical test of new algorithms. This latter, in fact, might have been pursued from a mere technical point of view, without the need of a video camera and a flashing light, but by simply designing and installing the ALMOND-F equipment and then analyzing the recorded data in a laboratory. By including a flashing light framed by a video camera, however, makes much more evident and understandable the functionality of a warning system and its performances. Decision makers, practitioners and the general public could not analyze complex files of data and the formulas of an algorithm, but can certainly recognize if a flashing light was correctly activated and then if it was correctly turned off.

The Gatria testing field, thanks to the described structure, is therefore an important source of didactic videos (Dutto et al., 2015). It is also a possible destination for educational trips, carried out for information and divulgation purposes, and it may be a font of news that can be published on popular magazines widely circulated, as it has recently occurred (Bignami, 2015).

4 First tests performed in the Gatria EWS testing field

The Gatria EWS testing field has provided a chance, in 2014, to test a new warning algorithm, developed by the researchers of CNR IRPI. The algorithm is designed to detect debris flows through the use of geophones. A first version of the algorithm, which uses the Signal-to-Noise Ratio (SNR) as a warning parameter, was implemented aboard the alarm and monitoring unit of the Gatria EWS testing field at the beginning of the 2014 summer season.

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The warning algorithm processes the amplitude signal (Arattano et al., 2014) provided by three vertical 1-D, 10-Hz geophones. These geophones are installed at three different locations, some tens of meters apart along the channel (Fig. 1) and connected to the ALMOND-F equipment that records the data. The warning algorithm makes use of the signal of three geophones to reduce the possibility of false alarms. It is in fact required by the algorithm that a certain site specific threshold of the SNR is exceeded on two geophones to issue the alarm (turn on the flashing light).

On 15 July 2014 a debris flow occurred in the Gadria creek and provided a chance for the test of the warning algorithm. Both the opening and closure algorithms performed well. The recorded video shows the activation of the flashing light about three minutes before the arrival of the debris flow main front. When the flashing light turned on, the Gadria Creek was affected by a turbulent wave with intense bed load transport. After the passage of the 8 surges composing the debris flow event, the flashing light was correctly turned off, as it is possible to observe in the recorded images (Fig. 3). No other surge followed the turning off of the flashing light.

Within the 51 days of tests carried out during the 2014 summer season, 2 false alarms were detected by the system. The relative data were recorded by the monitoring equipment. The recorded video of the July debris flow event and the monitoring data concerning the false alarms have provided precious information regarding the performances of the algorithm. This latter will be consequently improved to reach better performances and reduce the number of false alarms. The improvements are currently under development and an improved version of the algorithm will be tested in 2015.

5 Conclusions

A testing field for debris flow warning systems has been instrumented in the Gadria basin. The installation provides a site where different types of warning systems and algorithms for debris flows can be tested. It encompasses a specifically designed alarm and monitoring equipment that can be linked to different types of sensors and im-



plement different algorithms aboard. A flashing light framed by a video camera and activated by the algorithm under test allows a visual verification of the performance of this latter. The importance of the installation is also due to the chance that it may offer to increase the public awareness about the functioning of an EWS and the hazard mitigation that it may allow. This goal could be pursued through the realization of didactic videos, guided visits and the spreading of informative news on the debris flow events that occur in the Gadria Creek. So far, such instrumented basin has provided some first important indications for the enhancement of the algorithms currently under investigation.

Acknowledgements. This study is funded by the European Territorial Cooperation Alpine Space Programme 2007–2013 – SedAlp project, by the Autonomous Province of Bolzano and by the Company Siap +Micros S.r.l. The monitoring station of the Gadria basin is managed by the Autonomous Province of Bozen-Bolzano (Department of Hydraulic Engineering).

References

- Abancó, C., Hürlimann, M., and Moya, J.: Analysis of the ground vibration generated by debris flows and other torrential processes at the Rebaixader monitoring site (Central Pyrenees, Spain), *Nat. Hazards Earth Syst. Sci.*, 14, 929–943, doi:10.5194/nhess-14-929-2014, 2014.
- Arattano, M. and Grattoni, P.: Using a fixed video camera to measure debris-flow surface velocity, in: 2nd International Conference on Debris-flow Hazards Mitigation: Mechanics, Prediction, and Assessment, edited by: Wieczorek, G. F. and Naeser, N. D., Balkema, Rotterdam, Taipei, 16–18, 2000.
- Arattano, M., Franzi, L., and Marchi, L.: Influence of rheology on debris-flow simulation, *Nat. Hazards Earth Syst. Sci.*, 6, 519–528, doi:10.5194/nhess-6-519-2006, 2006.
- Arattano, M., Abancó, C., Coviello, V., and Hürlimann, M.: Processing the ground vibration signal produced by debris flows: the methods of amplitude and impulses compared, *Comput. Geosci.*, 73, 17–27, doi:10.1016/j.cageo.2014.08.005, 2014.
- Arattano, M., Cavalli, M., Comiti, F., Coviello, V., Macconi, P., and Marchi, L.: Standardization of methods and procedures for debris flow seismic monitoring, in: *Engineering Geology for So-*

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- Badoux, A., Graf, C., Rhyner, J., Kuntner, R., and McArdell, B. W.: A debris-flow alarm system for the Alpine Illgraben catchment: design and performance, *Nat. Hazards*, 49, 517–539, doi:10.1007/s11069-008-9303-x, 2008.
- Bignami, L.: Droni, fibre ottiche, sensori chimici: i metodi per prevenire crolli e smottamenti sono sempre più efficaci, *Focus*, Madison, 104–108, 2015
- Comiti, F., Marchi, L., Macconi, P., Arattano, M., Bertoldi, G., Borga, M., Brardinoni, F., Cavalli, M., D’Agostino, V., Penna, D., and Theule, J.: A new monitoring station for debris flows in the European Alps: first observations in the Gadria basin, *Nat. Hazards*, 73, 1175–1198, doi:10.1007/s11069-014-1088-5, 2014.
- Coviello, V.: Debris flow seismic monitoring and warning, PhD thesis, Politecnico di Torino, Torino, Italy, 120 pp., 2015.
- Dutto, F., Arattano, M., Bacenetti, M., Chiarle, M., Contrafatto, C., Giardino, M., Longo, F., Perotti, L., Racca, F., Rocci, L., and Turconi, L.: Interactive, 3-D simulation of natural instability processes for civil protection purposes, in: *Engineering Geology for Society and Territory*, vol. 7, edited by: Lollino, G., Arattano, M., Giardino, M., Oliveira, R., and Peppoloni, S., Springer International Publishing, Switzerland, 125–130, 2015.
- Hungr, O., Morgan, G. C., VanDine, D. F., and Lister, D. R.: Debris Flow Defenses in British Columbia, in: *Debris Flows/Avalanches: Process, Recognition, and Mitigation*, vol. 7, Reviews in Engineering Geology, Geological Society of America, 201–222, 1987.
- Keefer, D. K., Wilson, R. C., Mark, R. K., Brabb, E. E., Brown, W. M., Ellen, S. D., Harp, E. L., Wieczorek, G. F., Alger, C. S., and Zatzkin, R. S.: Real-time landslide warning during heavy rainfall, *Science*, 238, 921–925, doi:10.1126/science.238.4829.921, 1987.
- Koschuch, R., Jocham, P., and Hübl, J.: One year use of high-frequency RADAR technology in Alpine mass movement monitoring: principles and performance for torrential activities, in: *Engineering Geology for Society and Territory*, vol. 3, edited by: Lollino, G., Arattano, M., Rinaldi, M., Giustolisi, O., Marechal, J.-C., and Grant, G. E., Springer International Publishing, Switzerland, 69–72, 2015.
- Lin, M.-L., Wang, K.-L., and Huang, J.-J.: Debris flow run off simulation and verification – case study of Chen-You-Lan Watershed, Taiwan, *Nat. Hazards Earth Syst. Sci.*, 5, 439–445, doi:10.5194/nhess-5-439-2005, 2005.

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Schimmel, A. and Hübl, J.: Approach for an early warning system for debris flow based on acoustic signals, in: *Engineering Geology for Society and Territory*, vol. 3, edited by: Lollino, G., Arattano, M., Rinaldi, M., Giustolisi, O., Marechal, J.-C., and Grant, G. E., Springer International Publishing, Switzerland, 55–58, 2015.

Stähli, M., Sättele, M., Huggel, C., McArdell, B. W., Lehmann, P., Van Herwijnen, A., Berne, A., Schleiss, M., Ferrari, A., Kos, A., Or, D., and Springman, S. M.: Monitoring and prediction in Early Warning Systems (EWS) for rapid mass movements, *Nat. Hazards Earth Syst. Sci. Discuss.*, 2, 7149–7179, doi:10.5194/nhessd-2-7149-2014, 2014.

Suwa, H., Okano, K., and Kanno, T.: Forty years of debris-flow monitoring at Kamikamihorizawa Creek, Mount Yakedake, Japan, in: *5th International Conference on Debris-Flow Hazards Mitigation: Mechanics, Prediction and Assessment*, edited by: Genevois, R., Hamilton, D. L., and Prestininzi, A., Casa Editrice Università La Sapienza, Roma, 605–613, 2011.

Turconi, L., Coviello, V., Arattano, M., Savio, G., and Tropeano, D.: Monitoring Mud-flows for investigative and warning purposes: the instrumented catchment of Rio Marderello (North-Western Italy), in: *Engineering Geology for Society and Territory*, vol. 3, edited by: Lollino, G., Arattano, M., Rinaldi, M., Giustolisi, O., Marechal, J.-C., and Grant, G. E., Springer International Publishing, Switzerland, 85–90, 2015.

Zhang, S.: A comprehensive approach to the observation and prevention of debris flows in China, *Nat. Hazards*, 7, 1–23, doi:10.1007/BF00595676, 1993.



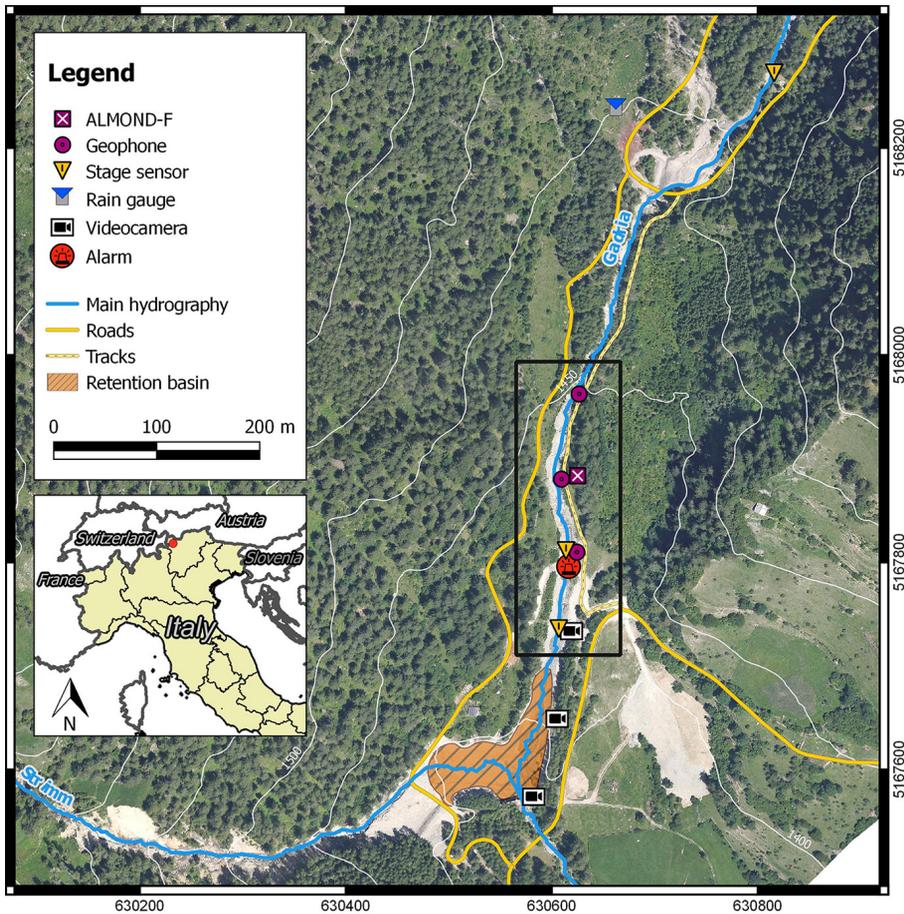


Figure 1. The Gadria testing field (black rectangle) for debris-flow warning systems and algorithms. Background image coordinate system: WGS 1984 UTM Zone 32N.

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Figure 2. (a) The most upstream of the fixed video cameras (red circle) of the Gadria instrumented area, which is part of the EWS testing field installation, the arrow indicates the position of the flashing light; (b) the ALMOND-F equipment allowing the implementation of different types of warning algorithms; (c) detail of the equipment.

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Figure 3. On 15 July 2014 a debris flow occurred in the Gatria creek that was recorded by the video camera. The closure algorithm correctly turned off the flashing light at the end of the process. Frames from the video camera part of the EWS testing field (Fig. 2a), time in the upper-left corner of each frame is in UTC+1 (local time): **(a)** the creek before the process (flashing light off); **(b)** arrival of the main front (flashing light on); **(c)** a secondary surge (flashing light still on); **(d)** the end of the process (flashing light off).

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