Introduction: Landslide Monitoring and Warning

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Abstract

The Session Landslide Monitoring and Warning: Monitoring Techniques and Technologies, and Early Warning Systems, as a part of WLF4 Volume 3 Advances in Landslide Technology, collected the contributions that deal with techniques and technologies employed in landslide monitoring and establishing of early warning systems with the aims to reduce or completely eliminate landslide risk. These techniques and technologies include a wide spectra of monitoring equipment united in monitoring sensor networks including modern advanced remote sensing technologies based on satellite observations of Earth surface.

Keywords

Landslide monitoring • Early warning • Landslide prediction • Remote sensing techniques • Case study

Introduction

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Forty one contributions from 17 countries (Austria, Canada, China, Chinese Taipei, Croatia, Czech Republic, France, Hungary, India, Italy, Japan, Korea, Mexico, Poland, Slovenia, Spain and Switzerland) have been submitted and, after review process, accepted for publishing in this Session. These contributions can be divided in the following four general topics:

- Landslide Monitoring and Early Warning Systems for Landslide Occurrence Prediction;
- Landslide Monitoring and Early Warning Systems at Regional Level;
- Remote Sensing and Landslide Monitoring;
- Case Studies of Landslide Monitoring and Early Warning Systems.

In this introduction to the Volume 3 Session 2 Landslide Monitoring and Warning: Monitoring Techniques and Technologies, and Early Warning Systems, a short summary of each of the accepted papers is presented within previously defined general topics.

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Landslide Monitoring and Early Warning Systems for Landslide Occurrence Prediction

Bozzano et al. (2017) in their paper "Multisensor Landslide Monitoring as a Challenge for Early Warning: from Process Based to Statistic Based Approaches" discussed approaches to forecast the slope evolution, providing alert levels suitable for managing infrastructures in order to mitigate the landslide risk and reduce the "response" time for interventions. Two different strategies can be defined as an observation-based approach (OBA) and a process-based approach (PBA), this last one comprehensive of semi-empirical approaches (SEA) and a statistical-based one (SBA). The results experimental results of testing of different kind of sensors encourage improving the SBA, based on data clouding, and testing them more extensively, at a national scale, by selecting test sites for experiencing their suitability for intervention strategies.

Vinodini Ramesh et al. (2017) in their paper "Wireless sensor networks for early warning of landslides: experiences from a decade long deployment" described design and development an integrated wireless sensor network system for real-time monitoring and early warning of landslides. The paper discusses the detailed requirements and design criteria considered in the design and development of the Intelligent Wireless Probe (IWP), to capture the relevant landslide triggering parameters. The network of IWPs is used to derive the local or regional contribution of geological, hydrological, and meteorological factors towards the initiation of a potentially imminent landslide. This heterogeneous sensor system provides the capability for gathering real-time context aware data to understand the dynamic variability in landslide risk. The results from the experimental sites showed that this system has contributed in enhancing the reliability of landslide warning, reduced false alarm rate, and provides the capability to issue warnings in local, slope and regional levels.

Design and validation of wireless communication architecture for long term monitoring of landslides was presented by Kumar et al. (2017). For developing of the most appropriate communication architecture for an landslide monitoring system the authors considered the following factors that could deliver long term monitoring and real-time early warning of landslides: frequency of data collection from spatially distributed heterogeneous sensors based on their impact on the landslide initiation; acceptable tolerance limit of latency for each type of data packet arrival; adaptive bandwidth requirement for efficient dana transfer with respect to balance energy in each wireless sensor nodes; adaptive routing of the data based on the propagation, terrain and climatic effects; remote maintenance using node level reconfiguration and network level reconfiguration; secured real time data transfer; and scalable to multi-site deployments. The authors developed communication architecture in two landslide prone areas, where one of the architecture is functional for the last ten years. This architecture has supported in collecting real time data from more than 150 geophysical sensors in adaptive frequency rate, remote configuring the sensor sampling rate, remotely triggering new software updates, providing prioritized service delivery based on the landslide alert level and data dissemination based on the warning levels.

Guntha et al. (2017) presented scalable, secure, fail safe, and high performance architecture for storage, analysis, and alerts in a multi-site landslide monitoring system. The authors' monitoring system is high performance, scalable, robust, and secure system; featuring multi-site landslide data capture, replication, storage, monitoring, and processing functionalities. The scalability and performance is achieved by real-time streaming of compressed data, in-memory processing, bulk storage, and retrieval through partitioned tables. The security is achieved through authenticating and encrypting streamed data and keeping only minimal raw data on site. The fail-safety is achieved through automated reconnection, and persisting and cross-tracking data at each processing step. The high performance in analysis and alerts are achieved by series of hierarchical and temporal aggregate tables.

Zhu et al. (2017) presented a proposal for a self-adaptive data acquisition technique and its application in landslide monitoring. The developed device can automatically adjust its data output rate from very low frequency to high one to capture the high-speed process then the physical variable sensed is dramatically changing. Such technique has the potential to reduce the energy consumption, bandwidth resources and data transmission burden in some practical energy conservation monitoring applications. A preliminary application of the proposed method was successfully carried out in one slope monitoring in China.

Yu et al. (2017) introduced the general framework of a new landslide early warning technology in China in the paper "A New Landslide Early Warning Technology-Escorting for Life". The new technology should have three advantages: efficiency, cost-effective, and easy to operate. It should be an effective alternative, supplement and upgrade of the traditional method, able to function with greater efficiency, speed and flexibility.

Lévy et al. (2017) introduced the method for prediction of displacement rates at an active landslide using joint inversion of multiple time series. The paper describes the development of FLAME (Forecasting Landslides induced by Acceleration Meteorological Events) model that can analyze of the relationship between displacements and precipitations using a statistical approach in order to predict the surface displacement at active landslide. FLAME is an Impulse Response model (IR) that simulates the changes in landslide velocity by computing a transfer function between the input signal (e.g. rainfall or recharge) and the output signal (e.g. displacement). The model is applied to forecast the displacement rates at the Séchilienne Landslide south-east of Grenoble in the French Alps.

Sasahara (2017) presented time-prediction method of the onset of a rainfall induced landslide based on the monitoring of shear strain and pore pressure. Monitoring of deformation and soil–water characteristics in a sandy slope model under artificial rainfall was conducted to establish a prediction method for shear deformation of the slope due to rainfall infiltration and the onset of a rainfall-induced landslide. A hyperbolic relationship between the shear strain and the pore pressure at the same depth was identified from the analysis of the monitored data. A time-prediction method of the shear strain in the slope was established based on regression analyses of the shear strain—the pore pressure relationship at any given time before the failure of the slope—and the time—pore pressure relationship at the same time.

Iwata et al. (2017) introduced an improvement of Fukuzono's model for time prediction of an onset of a rainfall-induced landslide. Fukuzono's model showed that the logarithm of the velocity of the surface displacement is proportional to the logarithm of the acceleration of the surface displacement and proposed the method for predicting a failure time by the extrapolation of the curve plotted an inverse of velocity of the surface displacement against time. The failure time in the proposed improvement was predicted from the intercept and the slope of the line calculated by following methods: calculating from two monitoring data at different times; extrapolating the straight line by least squares method using the previous monitoring data; making the relationship between the velocity and the acceleration of the surface displacement by least square method using the previous monitoring data.

Hiraoka et al. (2017) described a full scale model test for prediction collapse time using displacement of slope surface during slope cutting work. In the paper in order to predict the time of slope failure during an experimental testing on a full-scale model slope the slope surface were monitored during slope excavation. The surface displacements rapidly increased with the elapsed time after excavation and the relationship between the displacements and the elapsed time follow an exponential function just before the collapse. The authors analyzed the inverse velocity of slope surface displacement and identify the warning signal 2 min before the collapse.

Arioso et al. (2017a) introduced the classification of microseismic (MS) activity in an unstable rock cliff. According to the outcomes of previous studies presented in the scientific literature and to careful analysis of the collected data of microseismic monitoring of a 300 m high unstable rock face, the authors conducted manual classification of recorded signals according to two main classes: a first one grouping events related to the stability conditions of the slope (referred to as MS and local events), and a second one clustering all disturbances (referred to as spikes, mixed event and unclassified noise). The authors attempt to develop a classification routine in order to cluster possibly all the signals manually classified as MS events, and at the same time having few false positives. The development of classification algorithm involved analysis of parameters in both time and frequency domains, also supported by spectrograms and Radon transform computations, correlation with meteorological datasets, and polarization assessment of the 3-component recordings along with principal component analysis.

Szalai et al. (2017) presented method of prediction of the process of a slowly moving loess landslide by Electrical Resistivity Tomography (ERT). The aim of the research was to determine the fracture system of the study site. It seems to be the only possibility to get information about the landslide and its further evolution due to the homogeneous composition of the loess. The mass movement was expected to occur in the direction of the identified crack openings. The applicability of the ERT technique for such a supposedly dense fracture system was studied by numerical modelling and the results have been verified in the field. It was shown that it is especially important to carry out the field measurements following dry periods; otherwise the interpretation may become extremely difficult if not impossible.

Kim et al. (2017) presented the pilot construction of a sensor-based landslide early warning system developed for mitigating human damage in Republic of Korea. A sensor-based landslide early warning system in landslide highly-prone site of urban areas as a part of integrated prevention system for sediment-related disasters was suggested. The system mainly consisted of sensors, network system, and monitoring system and it had been partly revised for the improvement of its effectiveness through three-year testbed monitoring. The suggested system would effectively mitigate human damage by sediment-related disasters through sending landslide early warning information to residents at a landslide highly risky area directly.

Wang et al. (2017) presented an early warning system of unstable slopes based on multi-point MEMS tilting sensors and water contents. Surface tilt angles of a slope are monitored using this method, which incorporates a Micro Electro Mechanical Systems (MEMS) tilt sensor and a volumetric water content sensors. In several case studies, including a slope failure test conducted on a natural slope using artificial heavy rainfall, the system detected distinct tilt behavior in the slope in pre-failure stages. The development of this low-cost system results with a significantly reduced cost compared with current and comparable monitoring methods. Given the cost reduction, slopes can be monitored at many points, resulting in detailed observation of slope behaviors, but the potentially large number of monitoring points for each slope does induce a financial restriction.

Huang (2017) in his paper entitled "Early Warning of Long Channel and Post-controlled Debris-flow Gully in Southwest China" presented a new approach for debris flow forecasting, initiation prediction and real-time mass movement monitoring, particularly for a long channel debris flow that already controlled by check dams. The proposed early warning system for debris flow occurrence forecasting, employed the rain gauges, ultrasonic sensors and video recording sensors as the main sensors in the system. The proposed system was established in the Niujuangou Gully in Southwest China.

Landslide Monitoring and Early Warning Systems at Regional Level

Manconi et al. (2017) in their paper entitled "How many rainfall-induced landslides are detectable by a regional seismic monitoring network?" analyzed the seismic waveforms of 1058 landslides induced by rainfall in Italy, spanning the period between 2000 and 2014. Seismic data are gathered by several European research infrastructures and collected in the European Integrated Data Archive of the Observatories and Research Facilities for European Seismology. Such analyses may provide important insights for the development and calibration of automatic landslide identification algorithms, which might be then used to verify the validity of landslide forecasting procedures based on rainfall thresholds.

Rosi et al. (2017) presented the set-up of a fully functional landslide warning system, based on rainfall thresholds, developed in Tuscany region (Italy), an area characterized by a heterogeneous distribution of relieves and rainfalls. The established system can use both real time and forecasting rainfall data and can identify the most hazardous rainfall of each rain event. In the last part of the paper the authors present the updating of the thresholds using an enhanced calibration dataset, to enhance the performances of the early warning system and to account for the changes on territory and on rainfall distribution.

Renuga Devi et al. (2017) described a tool for developing a landslide early warning system—Artificial Neural Network (ANN) based rainfall forecasting model used in the study area in Tamil Nadu in India. The paper proposes a reliable rainfall forecast mechanism using only temporal and spatial rainfall intensity data recorded at rain gauge stations located close to the landslide risk sections in Coonoor, India. Several Artificial Neural Network (ANN) based rainfall forecasting models were developed to forecast rainfall one day in advance at Coonoor. Mean Square Error (MSE) and Correlation Coefficient (CC) are considered as the performance measures to compare the forecasting ability of the ANN models. Wavelet Elman model, which had all the input predictors, emerged as the best model. Time Delay Neural network (TDNN) resulted in high correlation coefficient when the number of input predictors was limited. Results prove that the proposed wavelet Elman network has a forecasting accuracy better than all other ANN models and is an appropriate network to choose when the number of input predictors increases.

Pecoraro et al. (2017) in their paper "Regional landslide early warning systems: comparison of warning strategies by means of a case study" compared the performance of two regional landslide warning models in the Campania Region (Italy) designed considering different algorithms. The evaluation of the performance of the different models is conducted applying the EDuMaP method, which is based on the computation of a duration matrix reporting the time associated with the occurrence of landslide events in relation to warning events, in their respective classes.

The use of a hybrid landslide warning model for rainfall triggered shallow landslides in Korean mountain was presented in Singh Pradhan et al. (2017). The authors used a physically based approach to evaluate the factor of safety of the hillslope for different hydrological conditions and to prepare warning map of probable landslide occurrence using ensemble approach of in Mt Umyeon, southern of Seoul in Korea. National wide landslide inventory data was used to prepare C-D landslide thresholds. An ensemble model was designed, in which an FS distribution of 'alarm' warning level was incorporated with important conditioning factors (hydrology, forest, soil and geology) using maximum entropy based machine learning algorithm.

Remote Sensing and Landslide Monitoring

Barra et al. (2017) in their paper entitled "Sentinel-1 data analysis for landslide detection and mapping: first experiences in Italy and Spain" presented the differential interferometric SAR (DInSAR) technique as a powerful tool to detect and monitor ground deformation. The potential of DInSAR to detect and monitor landslides has been extensively documented in the literature, mainly using the C-band data from the European Remote Sensing (ERS-1 and-2), Envisat and Radarsat missions. In this paper the data processing and analysis strategy and presentation of deformation and measurement results obtained during monitoring of landslides in Italy and Spain are presented.

Tessari et al. (2017) presented the study of the effectiveness of Sentinel-1A Synthetic Aperture Radar (SAR) data in monitoring scarcely urbanized slopes affected by slow-moving instabilities in the study area Rovegliana, located in the North-Eastern sector of the Italian pre-Alps. In situ surveys and Advanced Differential SAR Interferometry (A-DInSAR) processing of ERS, ENVISAT and COSMO Sky-MED SAR data pointed out that the instabilities are active with constant velocities up to 10 mm/year. Comparing results from historical interferometric data, GPS measurements and interferometry processing of Sentinel SAR data acquired in the period 2015–2016, make it possible to verify that Sentinel data, characterized by short revisiting time, can be used as useful tool to define the spatio-temporal evolution of the recorded instabilities, overcoming the limits of applying interferometric techniques caused by temporal decorrelation due to the presence of vegetation cover, increasing the possibility to obtain significant information about landslide dynamics from SAR data.

Huntley et al. (2017) presented the results from coherent points analyses and differential stacking of RADARSAT-2 InSAR persistent scatterer interferograms covering used in the monitoring over a part of the Thompson River valley, south of Ashcroft in British Columbia, Canada. The successful application of Coherent Points Analysis and Differential Stacking of persistent scatterer interferograms suggests both techniques are suitable for monitoring unstable terrain in other remote settings where infrastructure, natural resources, the environment, local communities and public safety are at risk.

The remote sensing mapping and monitoring of the Capriglio Landslide, Emilia Romagna Region, in Northern Italy was presented by Bardi et al. (2017). The paper describes the main results of the landslide mapping and monitoring activities, conducted after the landslide occurrence in the spring 2013, after heavy and persistent rainfall occurred between January and April resulted in the triggering of about 1400 landslides in the region. With the aim of supporting local authorities in the hazard assessment and risk management, an integrated analysis of various remote sensing data was developed, in order to generate a multi-temporal mapping of the landslide. Satellite and aerial post-event images were analyzed, together with the results of field surveys, to accurately map the landslide extension and evolution. Moreover, on May 2013, a GB-InSAR (Ground Based Interferometric Synthetic Aperture Radar) monitoring campaign was started in order to assess displacements of the whole landslide area and to support early warning activities.

Chen et al. (2017) presented results of the deep-seated landslides monitoring using ALOS/PALSAR Satellite imagery in the disaster area of 2009 Typhoon Morakot in Taiwan. Central Geological Survey of Taiwan has identified 56 sites with important protected targets including village, reservoirs, roads or bridges in the disaster area of Typhoon Morakot. The authors used a multi-temporal InSAR model to estimate the surface deformation rate of 56 sites. The deformation rate pattern from TCP-InSAR can be compared to the LiDAR-derived DEM that it represents the long-term surface features and evaluate their activities.

Case Studies of Landslide Monitoring and Early Warning Systems

Carri et al. (2017) presented the case study of landslide modeling, monitoring and establishing of triggering alarm at an active landslide at the A16 Highway in Italy. The site has been instrumented with a series of automated sensors, both innovative and traditional, which monitor different physical parameters. Following the trends of data, the weekly/monthly average displacements and the possible causes (heavy rainfall, raising of the water table), it is possible to study the mechanical behavior of the landslide and establish preliminary warning thresholds and triggering alarm. The obtained knowledge permits to automate all the processing procedure and control the situation on the highway in near real time.

Mazzanti et al. (2017) in described experimental landslide monitoring site of the Poggio Baldi Landslide, Santa Sofia, North Apennine, in Italy. On 19th March 2010, a 4 million m^3 landslide was reactivated in Poggio Baldi. After this reactivation the landslide monitoring was started using permanent inclinometers, piezometers and extensometers. The Experimental Landslide Monitoring Site has been developed in 2015 mainly for research purposes and several multi-temporal surveys have been performed by using different remote sensing techniques, such as Terrestrial Laser Scanning (TLS), Global Positioning System (GPS), Unmanned Aerial Vehicles (UAV) Photogrammetry, Digital Image Correlation (DIC), Terrestrial Interferometric SAR (TInSAR). The Experimental Landslide Monitoring site demonstrated to be a great opportunity for both research and training purposes.

Krkač et al. (2017) described the method of landslide movement prediction of based on monitoring results using the random forests technique, a machine learning algorithm based on regression trees. The prediction method was established based on a time series dana gathered by two years of monitoring on landslide movement, groundwater level and precipitation by the Kostanjek Landslide monitoring system (Zagreb, Croatia). Because of complex relations between precipitations and groundwater levels, the process of landslide movement prediction is divided into two separate models: model for prediction of groundwater levels from precipitation data; and model for prediction of landslide movements from groundwater level data. In a groundwater level prediction model, 75 parameters were used as predictors, calculated from precipitation and evapotranspiration data. In the landslide movement prediction model, 10 parameters calculated from groundwater level data were used as predictors. The validation results show the capability of the model to predict the evolution of daily displacements, from predicted variations of groundwater levels, for the period up to 30 days.

Nolesini et al. (2017) described possibilities of remote 3D mapping and GB-InSAR monitoring at the Calatabiano Landslide in Southern Italy. The landslide triggered in the Calatabiano Municipality (Sicily Island, Southern Italy) after period of heavy rain in October 2015 caused the rupture of a water pipeline transect of the aqueduct supplying water to the City of Messina. The landslide monitoring system was installed in November 2015, based on the combined use of advanced remote sensing techniques such as Ground-Based Interferometric Synthetic Aperture Radar (GB-InSAR), Terrestrial Laser Scanning (TLS) and Infrared Thermography (IRT). The installed monitoring system allowed analysis of the landslide geomorphological and kinematic features in order to assess the landslide residual risk; and support the early warning procedures needed to ensure the safety of the personnel involved in the by-pass realization and the landslide stabilization works. The authors presented preliminary results of the monitoring activities and a 3-D mapping of the landslide area.

Alberti et al. (2017) presented the results statistical analysis of displacement rate for definition of EW thresholds applied to two case studies Italian Alps: Mont de La Saxe Landslide affects the upper part of Valle d'Aosta region (Courmayeur) and the Ruinon Landslide is sited in upper Lombardia Region (Valfurva, Santa Caterina). Both landslides are sited into a larger deep-seated gravitational slope deformation (DSGSD) and they are deeply monitored with different systems: GB-InSAR, monitoring optical targets, a GPS network and multi-parametric borehole probes. The authors used statistical approach for analysis of displacement rate derived from monitoring activity to support the choice of threshold values for the management of Early Warning System, by considering also the minimization of false alarms.

The ground based wireless instrumentation and real time monitoring system installed at the Pakhi Landslide, Garhwal Himalayas, Uttarakhand, India was described by Prasanna Kanungo et al. (2017). Landslide Observatory with wireless instrumentation for real time monitoring of ground deformation and hydrologic parameters has been established using the measurement sensors that include in-place inclinometers (IPI), piezometers, wire-line extensometers and an automatic weather station (AWS). The real time data is being monitored to establish warning thresholds.

Caduff and Strozzi (2017) presented the use of terrestrial radar interferometry monitoring during a Landslide Emergency 2016 in Ghirone, Switzerland. In early spring 2016 an exceptionally high rock-fall activity in a slope above the Village of Ghirone, Blenio-Valley Ticino, Switzerland was observed. Local authorities then decided setting up a monitoring campaign using terrestrial radar interferometry and the monitoring campaign was started in March 2016. Using inverse velocity extrapolations, a failure forecast could be done pointing to a potential failure event in the same day. A refined post-processing of the radar data showed that the simplified real-time processing approach was suitable for the situation.

The results of monitoring of slope movements with GEASENSE GNSS probes of the Stogovce Landslide in Slovenia was described in Verbovšek et al. (2017). GEASENSE GNSS probes were installed in the landslide body below the new road crossing the landslide, have also measured movements in range of several cm/month in the 2012-mid 2015 period, with cumulative movement of 45 cm. Depth to the slip surface was identified from 13 to 25 m, and groundwater occurs in most of the boreholes, approximately half meter above the slip surface. The displaced material has been also detected by the calculation of surface difference in GIS, from the 2010 and 2014 LiDAR DEMs.

Shi et al. (2017) presented the newly developed distributed fiber optic sensing technology (DFOS) used for monitoring of the Majiagou Landslide near Three Gorges reservoir, China. Distributed fiber optic sensing technology (DFOS) offers a number of attractive advantages over conventional monitoring methods, such as better integration capability, higher accuracy and long-term stability, which are very suitable for the acquisition of multi-field information in a slope. The fundamental principles of some typical DFOS technologies were introduced, and the details about the DFOS based monitoring system for the acquisition of multi-fields information, including stress, temperature, seepage and deformation were described.

Arosio et al. (2017b) in their paper entitled "Seismic noise measurements on unstable rock blocks: The case of Bismantova rock cliff" presented the use of passive seismic for the characterization of potentially unstable rock blocks in the Pietra di Bismantova site, a wide slab of calcareous sandstone located in the Northern Apennines of Italy. Ambient vibrations recordings with broad-band 3-component seismometers were carried out on potentially unstable areas such as 5 rock blocks and 1 rock column located close to the top of the 100 m-high cliff. Seismic noise recordings were processed with a standard sequence and noise spectra and spectral ratios have been evaluated. The presented preliminary results are promising: in some cases a significant frequency peak can be observed, indicating resonance effects due to the vibration of the rock pillars and, for the most favorable case, noise polarization analysis presents vibration direction values at given frequency in a limited angle range, reasonably corresponding to the direction of maximum displacement.

Blahůt et al. (2017) in their paper entitled "Monitoring giant landslide detachment planes in the era of big data analytics" presented the monitoring results movements across detachment planes of the giant San Andrés Landslide on the northeastern lobe of El Hierro in the Canary Islands obtained over a two year period from October 2013 to October 2015. The monitoring results and analyzes contrast markedly with suggestions that the giant landslide is inactive and demonstrate that its reactivation is a possibility which cannot be dismissed categorically. Big data analytics have been used to identify interdependence between the recorded movements and a range of climatic and geophysical variables such as seismic data, tidal data, and geomagnetic data. The authors concluded that the recorded movements correlate only weakly or moderately with climatic and seismic parameters but strongly to the horizontal and vertical intensity of the magnetic field.

The geophysical model and displacement of the active slope at Jastrzębia Góra cliff in Northen Poland was described by Kamiński and Zientara (2017). Digital photogrammetric analysis and electrical resistivity tomography (ERT) techniques were used to identify the structure of a landslide and determine its dynamics. Two photogrammetric high-resolution models were generated from airborne laser scanning data that enabled comparison and identify displacements of the landslide surface.

Fusco and De Vita (2017) presented the results of hydrological monitoring of ash-fall pyroclastic soil mantled slopes in Campania in Southern Italy. Ash-fall pyroclastic deposits that mantle mountain slopes around the Mount Somma-Vesuvius are frequently involved in debris flows under high intensity and prolonged rainfall, thus representing a principal geohazard for settlements located alongside the footslope areas. Since 2011, the field monitoring activities were carried out in a test area of the Sarno Mountains to assess hillslope hydrological processes that predispose and lead to slope instability. The analysis of pressure head time series, recorded along four hydrological years (Jan. 2011–Dec. 2014) in the whole thickness of the ash-fall pyroclastic soil cover, showed a composite variability, from the daily to the seasonal time scales, related to rainfall patterns and evapotranspiration regime as well as to unsaturated flow dynamics. The results obtained by the proposed approach can be conceived as a fundamental basis to understand hydrological processes at slope scale, to set and calibrate hydrological numerical and slope stability models for estimating rainfall thresholds triggering slope instabilities.

Analysis of hydro-meteorological monitoring data collected in different contexts prone to shallow landslides of the Oltrepò Pavese in northern Italy was presented by Bordoni et al. (2017). The paper presented the results of the continuous monitoring of two slopes of the Oltrepò Pavese (Northern Apennines), representative of different contexts usually affected by shallow landslides. The first monitored site is representative of high gradient slopes with silty soils. The second one represents slopes with low-medium slope gradient and clayey soils. Hydrological monitoring allowed to identify the responses of the soils to different rainy or dry periods, focusing in particular on the conditions which could predispose landslides triggering.

Song and Cho (2017) presented a study of surveying and deformation monitoring of the coal waste dump slope and the natural ground slope under the waste dump at Dogye village in Samcheock city.

Gangwon Province, Korea. To investigate the behaviors of the waste dump slope and the natural slope under the waste dump, wire sensors and a rain gauge were installed at the crest of the waste dump slope, and inclinometers were installed in the natural slope of the ground under the waste dump. According to the monitoring results, the deformation at the crest of the waste dump slope steadily increased and then converged over time due to the effect of the infiltration of rain into the ground after rainfall.

The monitoring of soil movement characteristics of in the land creeping area located in Hadong-gun, Gyeonsangnam-do in Republic of Korea was presented by Kang et al. (2017). Soil bulk density, particle size distribution, porosity and hardness have been periodically measured as soil physical properties of the study site important for creeping process. These soil factors would be used as indirect index for vegetation restoration.

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References

Alberti S, Crosta GB, Rivolta C (2017) Statistical analysis of displacement rate for definition of EW thresholds applied to two case studies. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)

Arosio D, Boccolari M, Longoni L, Papini M, Zanzi L (2017a) Classification of microseismic activity in an unstable rock cliff. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)

Arosio D, Corsini A, Giusti R, Zanzi L (2017b) Seismic noise measurements on unstable rock blocks: the case of Bismantova rock cliff. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)

Bardi F, Raspini F, Frodella W, Lombardi L, Nocentini M, Gigli G, Morelli S, Corsini A, Casagli N (2017) Remote sensing mapping and monitoring of the Capriglio landslide (Parma Province, northern Italy). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing

culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Barra A, Monserrat O, Crosetto M, Cuevas-Gonzalez M, Devanthéry N, Luzi G, Crippa B (2017) Sentinel-1 data analysis for landslide detection and mapping: first experiences in Italy and Spain. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Blahůt J, Rowberry M, Balek J, Klimeš J, Baroň I, Martí X (2017) Monitoring giant landslide detachment planes in the era of big data analytics. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Bordoni M, Meisina C, Valentino R, Bittelli M, Chersich S, Musetti M, Persichillo MG (2017) Analysis of hydro-meteorological monitoring dana collected in different contexts prone to shallow landslides of the Oltrepò Pavese (northern Italy). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Bozzano F, Esposito C, Fantini A, Fiorucci M, Martino S, Mazzanti P, Prestininzi A, Rivellino S, Rocca A, Scarascia Mugnozza G (2017) Multisensor landslide monitoring as a challenge for early warning: from process based to statistic based approaches. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Caduff R, Strozzi T (2017) Terrestrial radar interferometry monitoring during a landslide emergency 2016, Ghirone, Switzerland. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Carri A, Grignaffini C, Segalini A, Capparelli G, Versace P, Spolverino G (2017) Study of an active landslide on A16 Highway (Italy): modeling, monitoring and triggering alarm. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Chen R-F, Lee C-Y, Yin H-Y, Huang H-Y, Cheng K-P, Lin C-W (2017) Monitoring the deep-seated landslides by using ALOS/PALSAR satellite imagery in the disaster area of 2009 Typhoon Morakot, Taiwan. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Fusco F, De Vita P (2017) Hydrological monitoring of ash-fall pyroclastic soil mantled slopes in Campania (southern Italy). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Guntha R, Kumar S, Hariharan B (2017) Scalable, secure, fail safe, and high performance architecture for storage, analysis, and alerts in a multi-site landslide monitoring system. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Hiraoka N, Kikkawa N, Sasahara K, Itoh K (2017) A full-scale model test for predicting collapse time using displacement of slope surface during slope cutting work. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Huang J (2017) Early warning of long channel and postcontrolled debris-flow Gully in Southwest China. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Huntley D, Bobrowsky P, Charbonneau F, Journault J, Macciotta R, Hendry M (2017) Innovative landslide change detection monitoring: application of space-borne InSAR techniques in the Thompson River valley, British Columbia, Canada. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Iwata N, Sasahara K, Watanabe S (2017) Improvement of Fukuzono's Model for time prediction of an onset of a rainfall-induced landslide. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Kamiński M, Zientara P (2017) Geophysical model and displacement of active landslide—an example from Jastrzębia Góra cliff (Northen Poland). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Kang M-J, Lee C-W, Woo C-S, Kim D-Y, Seo J-P, Kwon H, Park J-H, Kim K-D (2017) Monitoring soil movement characteristics of an area subject to land creeping in the Republic of Korea. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Kim D, Lee C, Woo C, Seo J, Kang M, Kwon H (2017) The pilot construction of a sensor-based landslide early warning system for mitigating human damages, Republic of Korea. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Krkač M, Mihalić Arbanas S, Arbanas Ž, Bernat Gazibara S, Sečanj M (2017) Prediction of the Kostanjek landslide movements based on monitoring results using random forests technique. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Kumar S, Venkat Rangan P, Vinodini Ramesh M (2017) Design and validation of wireless communication architecture for long term monitoring of landslides. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Lévy C, Gendrey S, Bernardie S, Chanut M-A, Vallet A, Dubois L, Duranthon J-P (2017) Prediction of displacement rates at an active landslide using joint inversion of multiple time series. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Manconi A, Gariano SL, Coviello V, Guzzetti F (2017) How many rainfall-induced landslides are detectable by a regional seismic monitoring network? In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Mazzanti P, Bozzano F, Brunetti A, Caporossi P, Esposito C, Scarascia Mugnozza G (2017) Experimental landslide monitoring site of Poggio Baldi landslide (Santa Sofia, N-Apennine, Italy). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Nolesini T, Frodella W, Lombardi L, Nocentini M, Bardi F, Intrieri E, Carlà T, Solari L, Dotta G, Ferrigno F, Casagli N (2017) Remote 3D mapping and GB-InSAR monitoring of the Calatabiano landslide (Southern Italy). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Pecoraro G, Piciullo L, Calvello M (2017) Regional landslide early warning systems: comparison of warning strategies by means of a case study. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Prasanna Kanungo D, Kumar Maletha A, Singh M, Sharma N (2017) Ground based wireless instrumentation and real time monitoring of

Pakhi landslide, Garhwal Himalayas, Uttarakhand (India). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Renuga Devi S, Arulmozhivarman P, Venkatesh C (2017) ANN based rainfall prediction—a tool for developing a landslide early warning system. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Rosi A, Segoni S, Battistini A, Rossi G, Catani F, Casagli N (2017) Definition of a fully functional EWS based on rainfall thresholds, the case of study of Tuscany Region. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Sasahara K (2017) Time-prediction method of the onset of a rainfall-induced landslide based on the monitoring of shear strain and pore pressure. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Shi B, Jiang H, Sun Y (2017) DFOS technology-based landslide monitoring: the Majiagou landslide case study (China). In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Singh Pradhan AM, Kang H-S, Kim Y-T (2017) Hybrid landslide warning model for rainfall triggered shallow landslides in Korean mountain. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Song Y-S, Cho Y-C (2017) Field monitoring to measure deformation of a mine waste-dump slope. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Szalai S, Prácser E, Szokoli K, Tóth Á (2017) Prediction of the process of a slowly moving loess landslide by electrical resistivity tomography. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Tessari G, Floris M, Achilli V, Fabris M, Menin A, Monego M (2017) Testing Sentinel-1A data in landslide monitoring: a case study from North-Eastern Italian pre-Alps. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Verbovšek T, Kočevar M, Benko I, Maček M, Petkovšek A (2017) Monitoring of the Stogovce landslide slope movements with GEASENSE GNSS probes, SW Slovenia. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Vinodini Ramesh M, Pullarkatt D, Geethu TH, Venkat Rangan P (2017) Wireless sensor networks for early warning of landslides: experiences from a decade long deployment. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Yu H, Yu N, Wang Y, Yu L, Yu Z (2017) A new landslide early warning technology-escorting for life. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Wang L, Nishie S, Uchimura T, Towhata I, Su L, Tao S (2017) An early warning system of unstable slopes by multi-point MEMS tilting sensors and water contents. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)
Zhu X, Xu Q, Qi X, Liu H (2017) A self-adaptive data acquisition technique and its application in landslide monitoring. In: Mikoš M, Arbanas Ž, Yin Y, Sassa K (eds) Advancing culture of living with landslides, vol 3. Springer International Publishing, Switzerland (this volume)

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