Multi-sensor technologies for EWS of landslides and man-made structures

DURATION: 2012 – 2013

TARGET COUNTRIES: France, Georgia, Italy

PARTNERS INVOLVED :
Coordinating Centre : CERG Strasbourg, France
Other Centres: Ghhd Tbilisi, Georgia
Other Partners: Delft University of Technology (TUD, T.A. Bogaard), National Research Council, Institute for the Dynamic of Environmental Processes (CNR-IDPA, S. Sterlacchini), National Research Council, Research Institute for Geo-Hydrogeological Protection (CNR-IRPI, S. Frigerio, L. Schenato), Centre National de la Recherche Scientifique, Institute de Physique du Globe de Strasbourg (CNRS-IPGS , J.-P. Malet), Restauration des Terrains de Montagne 04 (RTM, G. Guiter)

OBJECTIVES OF THE PROJECT

Global objective for 2012-2013 :
The purpose of the project is to test the use of multi-sensor technologies as possible early-warning systems for landslides and man-made structures, and the integration of the information in a simple Decision Support System (DSS). The final aim is the provision of timely and effective information that allows individuals exposed to hazard to take appropriate actions to avoid or reduce their risk and prepare for effective response. The observation techniques used are displacement sensors (such as low-cost GPS and tiltmeters), hydrological sensors (pore water pressure, temperature) and strain sensors (FO technology, possibly seismometers) for which some of the observations are transmitted automatically (GSM, web-services, etc.). Not all sensors will be tested at all the monitored sites, but the fluxes of data will be integrated in a simple DSS that will allow to manage the data, propose some interactive graphs, identify some thresholds and prospective hazard scenarios that could be used for pre-alert and alert. Finally (not within the scope of this 2-year project), the possibility of linking the fluxes of observation data to people in charge of the decision-making in case of major disaster will be considered.
In this project, particular attention will be paid to some new possibilities available in the field of distributed monitoring systems of relevant parameters for landslide and man-made structures monitoring (such as large dams and bridges), and among them the distributed monitoring of temperature, strain and acoustic signals by FO cables. This novel technology appears stable, very accurate, and has the potential to measure several independent physical properties. However, the operative implementation and performance testing of such technique has not still been evaluated in a quantitative approach.

The objectives of the project are:
1) To assess the applicability and limitations of FO cable technology in landslide and man-made structures monitoring based on both literature review and field experiments on relevant case studies in France, Georgia and Italy. Focus will be on the use of all physical variables that can be obtained using F0 (such as strain, temperature and acoustic signals) in order to provide timely and effective information on the dynamics of the structure.
2) To assess the use of arrays of multi-technique displacement sensors (tiltmeters, inclinometers, GPS, etc.) to monitor in real-time small ranges of displacement, on relevant case studies in France, Georgia and Italy.
3) To review the landslide and man-made structures EW systems already working in European countries in order to define to what extent multi-sensor technology can be incorporated in the EWs and what kind of added value can be provided.
4) To translate the observation and the analysed signals into a simple DSS able to visualize the data, identify some trends in the time series, and provide meaningful information usable to "foresee" a forthcoming possible catastrophic event.

The proposed activity associates three specialised centres (CERG, GHHD). The expertise of contributing academic partners (see above) guarantees the success of the research activities as they are already working closely together within European Projects. Co-funding to the research will be made available by each of the partners.

Specific yearly objectives :

2012 :
1) Analysis of the potential of FO cable technology for landslide monitoring (test site in France) through a 1 week field experiment.
2) Analysis of the potential of arrays of displacement sensors (tiltmeters, GPS, etc) with real-time data transmission for landslide monitoring (test site in France) and a large dam monitoring (test site in Georgia)
3) Development of a framework for a simple DSS system able to visualize the data, plot relevant information and identify trends and thresholds in the time series. Definition of the concept for the diagnostic.

2013 :
1) Analysis of the potential of FO cable technology for dam/bridge monitoring (test site in Luxemburg)
2) Consolidation of the data transmission equipment/procedure for real time monitoring in Georgia.
3) Creation of the DSS system, and implementation of all the data acquired, and test of the performance of the system.

EXPECTED RESULTS

2012 :
1) Organisation of a 2-days workshop to initiate the work
2) Literature review on FO cable technology and arrays of displacement sensors for landslide and man-made structures monitoring.
3) Field experiment to test FO cable technology at a landslide test site in France.
4) Implementation of tiltmeters and data transmission systems at the Georgia test site (large dam).
5) Framework/concept for the development of the simple DSS (specifications, visualization, etc).

2013 :
1) Organisation of a 2-days workshop to discuss the progress of the work
2) Field experiment to test FO cable technology at one landslide in France.
3) Consolidation of the arrays of equipment and data transmission system at the Georgia test site (large dam).
5) Development of the DSS prototype, integration of data and test of the system.
5) Diffusion of the results through joint publications

RESULTS OBTAINED PREVIOUSLY

The proposed activity will take advantages of previous results obtained within the activity of CERG members, on the test of FO technology for soil temperature monitoring on landslide (Krzeminska et al., in press) and in rivers (Westhoff et al., 2011) and on the use of arrays of GPS and extensometers on landslides with a near-real time data transmission (Malet et al., 2011) . It can take advantage of the CERG activity 'Real-Time Management of Emergency Phase in the aftermath of Natural Disasters ' which objective was to develop a beta-version of a DSS system able to manage data and communications.

References:
Krzeminska, D.M., Steele-Dunne, S., Bogaard, T.A., Rutten, M., Sailhac, P. Géraud, Y. 2011. High-resolution temperature observations to monitor soil thermal properties as a proxy for soil moisture condition in clay-shale landslide. Hydrological Processes, DOI: 10.1002/hyp.7980
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Peters, E.T. J.-P. Malet, T.A. Bogaard (2010). Multi-sensor monitoring network for real-time landslide forecasts in early warning systems. Pp. 335-340. Proceeding conference on Mountain Risks: bringing science to society (Ed. J.-P Malet, T. Glade, N. Casagli). Florence 2010. ISBN 2-9518317-1-5
Malet, J.-P., Ulrich, P., Déprez, A., Masson, F., Lissak, C., Maquaire, O., 2011. Continuous monitoring and near-real time processing of GPS observations for landslide analysis: a methodological framework. In: Margottini, C., Canuti, P. Sassa, K. (Eds): Proceedings of the Second World Landslide Forum, 3-7 October 2011, Rome, Italy, Springer (to be published in 2012).
Co-funding 2012 :
- TUD: KulturRISKProject funded by the European Commission by the Seventh Framework Programme - co-funding provided: 2000 €.
- CNR-IDPA/IRPI: CHANGES project funded by the European Commission by the Seventh Framework Programme - co-funding provided: 2000 €.
- CNRS / RTM : La Valette DSS System funded bt DTT Alpes-de-Haute-Provence - co-funding provided: 2000 €.

Co-funding 2013:
- TUD: KulturRISKProject funded by the European Commission by the Seventh Framework Programme - co-funding provided: 1000 €.
- CNR-IDPA/IRPI: CHANGES project funded by the European Commission by the Seventh Framework Programme - co-funding provided: 2000 €.
- CNRS / RTM : La Valette DSS System funded bt DTT Alpes-de-Haute-Provence - co-funding provided: 1000 €.

RESULTS OBTAINED IN 2012

Work package 1 (prepared by CERG Strasbourg, France, TUD, CNRS, RTM):

Applicability and limitations of fiber optic cable technology for landslide and man-made structure monitoring

Associated deliverables:
1.1 Review on the use of FO cable technology for landslide and man-made structures monitoring (CERG)
1.2 Field experiment to test in practice the use of FO technology to monitor temperature, strains and acoustic signals on a landslide site in France (CERG)

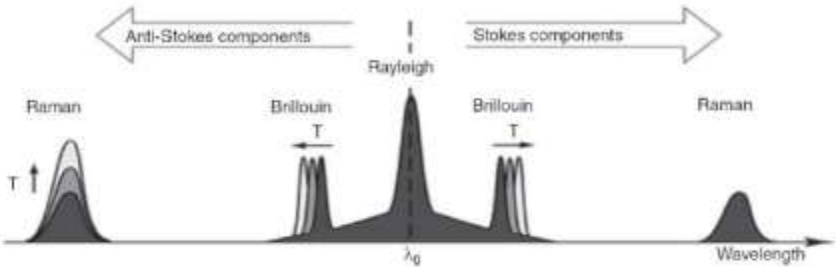
Applications and limitations of fiber optic (FO) cable technology for landslide research

First, a thorough literature review was done to assess the applicability and limitations of FO cable technology. This review was focused but not limited to application in landslide research. Fiber optic cables have been developed in the telecommunication business to send large amounts of information over large distances with the speed of light. Because of the commercial application, production costs are relatively low. Using Fiber optics for measurements has several advantages: it is for instance immune to electromagnetic interference and can used in a wide range of applications; using Fiber optic cables as distributed measurement devices gives the opportunity to gain knowledge in different both engineering and science.

The review assessed the physical properties that can be measured and the physical background. The possibilities to measure physical phenomenon are abundant and before searching for new applications, it is important to know what is possible with Fiber optic cables. The table below shows the Fiber Optic technique and the physical property of light to measure.

Fiber Optic technique	What is measured
Amplitude modulated	Measuring the intensity losses of the light
Phase modulated	Measuring differences in phase of a lightwave
Polarization modulated	Measuring the total polarization of the light
frequency modulated	Measuring the changes in frequency of the light

The main form of application of Fiber Optic relates to the backscatter of light and the temperature (and strain) dependence of the backscatter wave forms (see figure below). Lastly, also the attenuation of energy is looked at as that influences the total range over which a Fiber Optic technique can be applied.



The different operational fiber optic measurement techniques are compared below.

Scattering	Rayleigh	Raman	Brillouin
Temp. sensitivity [% °C^{-1}]	0.54	0.8	0.01
Temp. range [°C]	5 to 110	0 to 70	-30 to 60
Accuracy [°C]	1	0.01[2]	1
Spatial resolution [m]	1	0.25[3]	3-5
Fiber length range [m]	170	1000	51000
Measurement time [s]	2.5	40	4
Strain [μm]	-	-	100

A full list of current applications is then reviewed, showing that applications are mainly concentrated in engineered structures (like dams) and for temperature monitoring in natural conditions. Limited applications are found that apply strain related measurements in natural conditions: the second year of the APO-funded project will focus on this.

Applications of multi-sensor technology for the hydrogeophysial monitoring of landslides

Introduction
Hydrogeophysics typically consists in the combination of hydrological and geophysical methods for a better understanding of hydrogeological systems. Among key petrophysical parameters that can provide time-lapse sections of the topsoil, we consider the electric conductivity for its sensitivity to soil water contents.

The study site is the Super-Sauze landslide (French Alps) largely documented and monitored since several years. Triggered in the 1960s, the landslide is representative of slope instabilities developed in clay-shales (Fig. 1a). Previous studies highlighted the importance of material rheology, bedrock geometry and changes in pore water pressures as controlling factors of the landslide kinematics. The latter is known to vary seasonally, with two rapid groundwater recharge episodes (spring and autumn) and a progressive drainage from June to April but the relation between water table levels and precipitations remain poorly understood (Malet, 2003).

Recently, Travelletti et al. (2011) showed the possibility to monitor the hydrological response of a weathered clay-shale slope during a controlled rainfall experiment using time-lapse Electrical Resistivity Tomography (ERT). The high conductivity of the clayey soil generally results in poor resolution and sensitivity at depth. To avoid this problem, they used salt tracers and showed that it was possible to monitor water flows in the case of a simulated rainfall experiment, over short time periods.

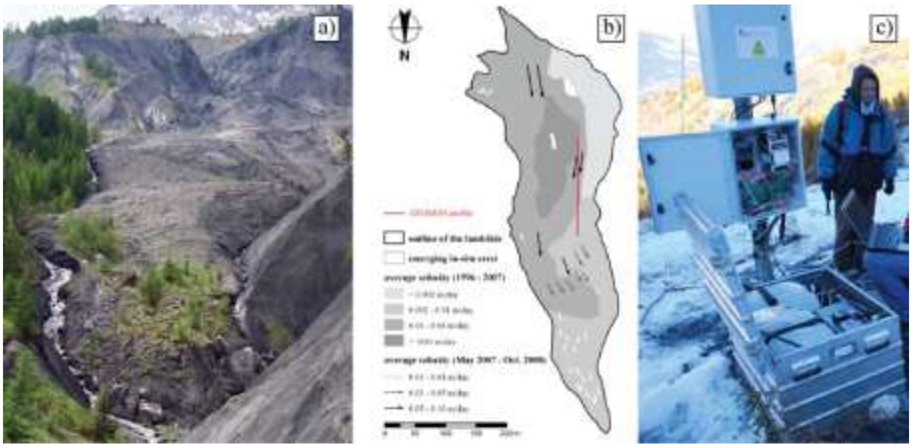
In the present work, we consider a new electrical monitoring experiment at the Super-Sauze landslide dedicated to long period of monitoring (one year) under natural meteorological conditions. The monitoring is carried out along a profile located in the upper part of the landslide (Fig. 1b) within an area characterized by high displacement rates and several soil surface facies (with or without cracks, with different grain sizes and soil water conductivity). We present the experimental set up, and then show the first results in terms of electric resistivity but also streaming-potential

(SP) and discuss about perspectives.

Setup of the GEOMON device on the Super-Sauze landslide

Contrary to most commercial systems that do not suit to permanent monitoring, the GEOMON4D resistivity monitoring system, developed by the Austrian Geological Survey (Vienna), was specifically designed for experiments needing high rate of data acquisition, records of full signal samples for noise detection, remote controlled management and automatic data transfer (Supper et al., 2002, 2003 & 2004). The device comprises 93 electrodes, separated in 24 injection and 69 potential electrodes. Their spacing, not regular, is 0.5, 1.0 or 2.0 m according to the cracking state of the topsoil for a total profile length of 113 m. 4300 quadripoles in a gradient array are acquired two times per day. SP measurements are also carried out every hour along the profile. The device is powered with a solar panel and an ethanol fuel cell (Fig. 1c) and the data are sent daily.

Wilkinson et al. (2010) show the importance of electrode movements in apparent resistivity measurement and propose to obtain displacement information directly from the resistivity data. Because our purpose is to monitor the underground water content through the electrical resistivity, we decided to monitor the electrode displacements independently. This is obtained by combining GPS campaign and time-lapse stereophotogrammetry. We equipped the 24 injection electrodes with 10 cm diameter white Styrofoam spheres on their top. Two high-resolution optical cameras were placed on stable crests nearby the profile; the cameras are spaced by 75 m and are able to monitor the displacement of the electrodes located 65 and 110 m downstream. The cameras are triggered every day at 12h, 14h and 16h so that the best picture (according to weather conditions and illumination) can be selected for the day. We monitor the electrode coordinate processing the pictures in four steps: (i) correction of the rigid camera movements (ii) detection of the white Styrofoam spheres centroid plane coordinates based on a colour detection algorithm (iii) correction of the lense distortion, and (iv) computation of the 3D global coordinate by stereo-restitution.



Multi-sensor instrumentation at the study site: a) Picture of the Super-Sauze landslide from 2006. b) Mean velocities and directions of horizontal displacements at the Super-Sauze landslide (modified from Amitrano et al., 2007). c) GEOMON4D device powered with a solar panel and an ethanol fuel cell.

The algorithm is tested on a period of one month in June 2012. During this period, we monitor the displacements of a permanent GPS antenna and show that the accuracy of the stereo-photogrammetry processing is 10 cm for the further electrode. Over this period, the profile had moved downhill between 50 cm and 76 cm. The obtained coordinate are then used in the ERT inversion.

In addition to the electrode displacements, other parameters are considered to correct possible effects on electrical resistivity changes as pointed by Travelletti et al (2011). Several hydrological sensors are set up along the profile to monitor soil temperature at several depths, groundwater conductivity, water temperature, and groundwater table level continuously at some places.

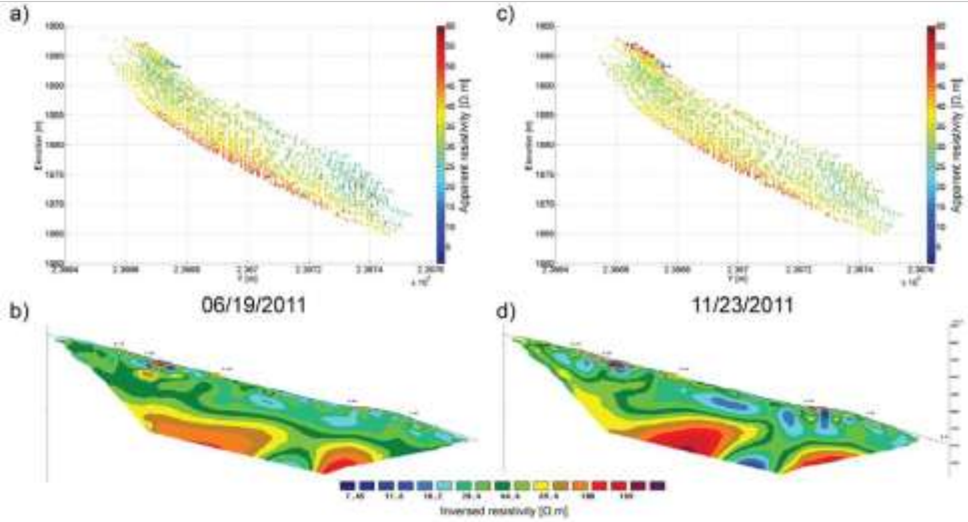
First results

They concern the electrical resistivity monitoring. Raw data are processed using three criteria:

- the measured voltage must be greater than 0.5 mV to ensure that the measure is not an ambient noise (e.g. magneto-telluric currents or sudden variations in streaming-potential);
- the error percentage between forward and reverse measurement must be lower than 15%, to ensure the good repeatability of the measurement;
- negative or null resistances are removed from the dataset.

This pre-processing permits to select 98% of the initial data to be inverted. The remaining 2% of the initial data is concentrated on a few quadripoles. Those low quality data appears to be more concentrated on dry periods and could be explained by a problem of contact between the electrodes and the ground due to shrinkage or swelling of the clay. This pre-processing allows verifying the coupling of the electrodes with the soil. Those problems can be periodically fixed when going back to the field.

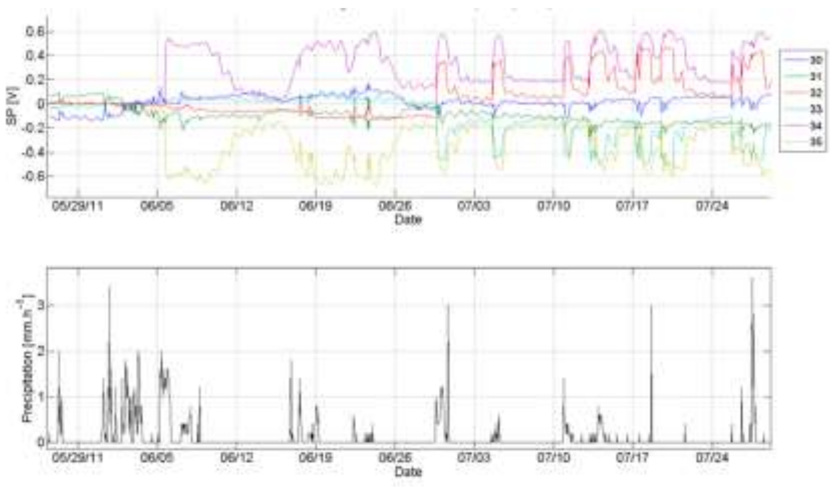
Among 500 slices, we show the results at two very contrasting days. The figure below shows two pseudo-sections and the corresponding inverted sections with RES2DINV. Both dataset have been inverted in five iterations with a misfit function lower than 5%.



Apparent and inversed resistivities at different dates. a) Apparent resistivity from the 19th June 2011. b) Inversed resistivity from the 19th June 2011. c) Apparent resistivity from the 23th November 2011. d) Inversed resistivity from the 23th November 2011.

Although the two datasets have been inverted separately and with the conventional parameters of RES2DINV, we observe resistivity differences mostly located in the landslide layer. This can be attributed to large changes in the soil water content in the soil around the profile. More generally, apparent resistivity variations are noticeable during the six months of data. Some of them, for small quadripoles, are clear response to rainfall, and others show long wavelength variation. This first interpretation is done without consideration on the effect of temperature and groundwater conductivity that have to be considered when estimating actual water content from the resistivity.
Besides, the systems also provides the SP monitoring along the same profile; the figure belowshows a few dipoles. Although unpolarizable electrodes were not used, it seems by visual inspection that SP signals are stable enough and provides useful information. Indeed, their variations present different intensities, durations and are linked to some rainfall events (Fig. 3): a clear correlations is observed, for instance, on the 5th June 2011. Precise modelling of the SP do to the rainfall infiltration and groundwater flows would be necessary. Possibly, soil saturation plays a crucial role in these behaviors: Indeed, Allegre et al. (2012) has shown that coupling coefficient greatly depends on the water stauration, with smaller values at saturation than at lower saturation (at least in sand). Thus, SP data may provide important information on the infiltration that follows rainfall; both the observed time lag and the existence of non-appearance of SP response to rainfall could be related to the complex relation between rainfall and soil water content in the top soil.

SP monitoring from the 25th May to the 26th July 2011.a) SP voltage for 6 consecutive dipoles. b) Precipitation observed in the same period.



To monitor water flows in a clayey landslide, we monitor the electrical resistivity of the soil with time-lapse ERT technique. To allow a possible interpretation of the tomograms as groundwater content images, we also measured continuously the different parameters that affect apparent electrical resistivity (electrode movement, temperature and groundwater conductivity). The first results using the dataset of May-July 2011 show that apparent and inverted resistivities present low variations correlated with rainfall and large variations correlated with the increase of groundwater table. The GEOMON4D monitoring system also provides SP data which could be used to obtain information on the infiltration processes and the topsoil saturation. They could be used with the resistivity data to determine and classify the amplitude and durations of rainfalls which may lead to infiltration.

Work package 2 (prepared by GHHD Tbilisi, Georgia, CNRS*):*

Description:
Applicability and limitations of arrays of multi-sensor for the monitoring of landslide and man-made structures / Leader: GHHD

Associated deliverables:
D.2.1 Review on the use of displacement sensors for landslide and man-made structures monitoring (GHHD, CNRS)
D.2.2 1st stage implementation of the arrays of displacement sensors and telemetry at the Georgia test site, and pre-analysis of data (GHHD)

Modification of Loughborough University technique which is using acoustic sensor with gravel coating around waveguide

The goal of acoustic monitoring is to record acoustic signals generated by preliminary displacement of geologic formations before activation of the fast phase of landslides. The similar technique based on the recording of the acoustics generated by displacement in the gravel coating around acoustic sensor was earlier developed by Loughborough University team, but it demands drilling of relatively deep borehole down to the sliding surface. This procedure is quite expensive. Our objective was to develop a cost-effective version of the mentioned method. The idea is to use two sensitive acoustic probes grounded on different depths, one on the depth of several meters and other close to the day surface. The former probe is the basic and the role of latter one is to distinguish signals of surface origin, which in this case are considered as noise.

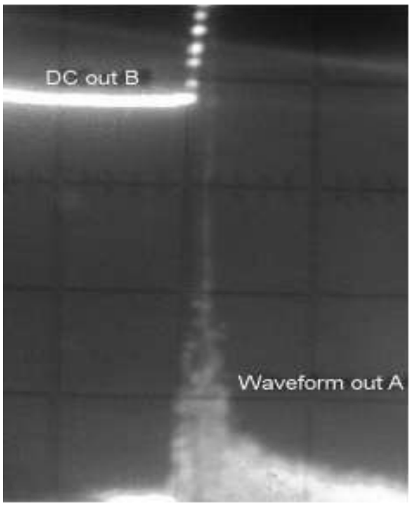
The probes are constructed from thick-wall stainless steel tube containing acoustic sensor (Fig.8). The length can be chosen according to the depth of investigation by screwing additional sections to the tube containing basic sensor. The length of these sections is 1.5 m; the maximal depth of probe is of the order of 4 m.

The upper part of the basic probe is manufactured as a cylinder rod with inclined cut. The precise finish of the cut surface guarantees good contact of acoustic sensor with probe tube. Investigation of various types of acoustic sensors in laboratory led to conclusion that for the frequency range of interest, i.e. frequencies generated by displacements in the gravel coating i.e. 5-25 KHz the best solution is the capacity capsule-microphone, glued with his sensitive membrane side to the surface of the upper end of the probe (Fig. 9b).

The whole electronic module, located in the upper part of the probe and consisting of capsule-microphone, filters and integrator schemes is seated into hermetic box to avoid environment impact. The hermetization of connection of electronic module to the probe tube is performed by the soft rubber in order to avoid damping and accordingly, decrease of acoustic signal amplitude (Fig.9c).

Electronic module consists of low-noise amplifier, buffer amplifiers of output for signal waveform A and precision peak-integrator and DC voltage output B for recording in the datalogger (Fig. 10 a,b). The integrator fixes in its memory the maximal value of obtained signal and after this the signal decays by the rate 5% per minute. Fixing on datalogger the readings with the sampling rate 1 per minute allow obtaining the necessary information on the variation of acoustic noise in the time domain.

Below is presented (Fig. 11) a real two-ray oscillogramm, where the acoustic burst arriving on the background of the ambient noise is visible as well as peak value of the signal from the output of the datalogger. It is evident that logger output fixes the peak output signal – the DC out B voltage increases rapidly according to the signal waveform out front.



A two-ray oscillogramm, where the acoustic burst arriving on the background of the ambient noise is visible as well as peak value of the signal from the output of the datalogger (clipped).

At present the system is tested in laboratory conditions.

Development of cost-effective telemetric system for real-time data communication from multi-sensor monitoring network to remote diagnostic centre

For the automation and telemetric data communication from multi-sensor monitoring network to remote diagnostic centre the GHHD and Institute of Geophysics prepared a technical project and the organization – "ALGO, ltd" was ordered to construct the real-time operating telemetric system. After laboratory testing the system was installed on the 360 m, 402 m and 475 m levels of the section 12 of the Enguri high arc dam for monitoring tiltmeter network data. The data acquisition and transmitting system (DAMWATCH) supports the collection of data in a form of an electronic data table and their transmission to the diagnostic centre in Tbilisi for the further processing and analysis of the material. Though the system was developed for dam monitoring, it can be used for monitoring any dynamical system (constructions, bridges, landslide areas etc).

The system consists of several terminal controllers (in accordance to the quantity of points) and a central controller that is connected with the GSM/GPRS Modem (Fig. 8). The diagnostic centre is equipped with a computer with a static IP address connected to Internet and supported by proper server programs. The number of the objects under monitoring and their geographic areas connected with one computer is limitless in the GSM/GPRS cover zones.
The terminal controller is a microprocessor with 3 similar inputs on the one hand and RS485 interface – on the other hand. The number of inputs may vary according to the tasks. The diagram of the figure 3 shows the controllers linked to a sensor that provide continuous measuring of the tilt X and Y components and the temperature T and their transformation into digital data. The terminal controllers are linked to the central controller by a RS485 bus-bar. The bus-bar is presented as a couple of overwound wires that are connected with all terminal and central controllers simultaneously. The permissible total length of the bus-bar is 1300 m. The maximal number of controllers connected to one bus-bar is 32.

The central controller receives information alternatively from the terminal controllers linked with the bus-bar, and then collects data in its memory and automatically transmits them by means of the modem in regular time intervals to the diagnostic centre database. The transmitting time intervals are defined according to tasks and vary from one minute to several days. An extraordinary transmission of data from the objects is possible as well. The transmission is fulfilled by means of GSM/GPRS service that is quite necessary for the monitoring processes.

The central controller in the data exchange process functions as FTP client by means of the GSM/GPRS modem, and the computer in the diagnostic centre is supported by FTP server and a special utility that provides the input of the data received from the client into the database. The central controller is operated and configured by SMS directives from the research centre.

The database records the arrival time and the ordinal number of the data. Moreover, it informs about presence or absence of electric power as for the central controller as well for each terminal controllers. In case of electric failure the controllers are fed from the local batteries. The memory size of the central controller is 262144 bytes. In case of 3 terminal controllers the average size needed by one datum is 105 bytes. Thus, in a minute data transmission regime the whole memory is sufficient to save information during 41 hours.
After processing the data we obtain information about the dam tilts in angle seconds or about its displacement against the dam axis according to the current technical and tectonic processes practically in real time – with delay depending on technical details. It is evident that the accurate data received in short time intervals from multi-sensor will give huge information about the technical state of the construction. There is no problem in applying this system for multi-sensor monitoring of landslides and debris-flows.

Work package 3 (prepared by CERG Strasbourg, France , CNR-IDPA, CNR-IRPI, CNRS):

Description:
Development of a simple DSS system to manage the dataflow and identify thresholds in the time series

Associated deliverables:
D.3.1. Review of existing DSS system used to manage data acquired on landslides and man-made structures (CERG, CNR-IDPA, CNR-IRPI, GHHD) - M+6
D.3.2. Guidelines for the development of a simple operational; DSS - Definition of functionalities (CERG, CNR-IDPA, CNR-IRPI, GHHD) - M+12

Translate of the observations and the analysed signals into a simple DSS able to visualize the data

On the basis of past experience, the priority is to design and make available solutions easy to use. Starting from this assumption, the proposed system has been designed in order to improve the capacity of local authorities to cope with natural disaster preparedness and response activities by acknowledging some important demands, needs, and policies from the expected final users. The system architecture (in terms of functionalities and characteristics) is based on the outcomes of some user's requirements meetings in which the stakeholders have specified their desiderata. Specifically, during these meetings, the actors that will interact with the system have been identified and the roles they play specified. The actors comprise the various types of stakeholders, system administrators, information providers, experts and any other external programs and data sources which interact with the system.
To this end, some system prototypes have been defined and submitted to the stakeholders and potential actors for their feedback and refinement. Based on the outcomes of this first step, the system architecture has been defined, including all components and considering their interactions. The system hereafter described provides tools able to identify and prepare people in charge to take actions, define the activities to be performed, be aware of available resources and optimize the communication system for data transfer and sharing. In this way, the system can help to plan in advance response and rescue to disaster-related emergency anticipating, as far as possible, the demand for disaster relief operations. This will rely on the main requirements and actions expected for each phase of the emergency concerning different risk scenarios. The signals derived from FO cables will be the input to give the start of the procedure managed by the system that is able to activate a flow of response actions according to pre-defined thresholds and on the base of the legislative framework in charge in each country involved in this project.

The system has been designed and tested in a Consortium of Mountain Municipalities (Valtellina di Tirano, Central Alps, Northern Italy) that has been affected by natural disasters over the past years, experiencing significant losses. Nowadays, the system is in full operation at a municipal and inter-municipal level, continuously updated by local end-users and it is expected to significantly improve the capacity of the community to face the negative effects of prospective disasters by organizing the delivery of timely response, rescue, relief and assistance activities. It is expected that the same system will be operational in a short time at Barcelonnette municipality, the largest town in the Ubaye Valley, given that many work phases (hazard and risk scenario definition, inventory of elements at risk, list of strategic resources and structures available for response and rescue, collection of Laws and Decrees concerning Civil Protection matters, etc.) have already be accomplished.

Dissemination of project results

Gance, J., Sailhac, P., Malet, J.-P., Supper, r., Jochum, B., Ottowitz, D., Grandjean, G. 2012. Electrical Monitoring of the Super-Sauze Landslide (French Alps). Near Surface Geoscience 2012 – 18th European Meeting of Environmental and Engineering Geophysics, Paris, France, 3-5 September 2012 [Poster presentation]

Bogaard, T.A., Wenker, K., Malet, J.-P. 2013. A search for applications of Fiber Optics in early warning systems for natural hazards. EGU 2013 General Assembly, Vienna, 7-13 April 2013.

ACTIVITIES PLANNED IN 2013 (split by partner)

Working package 1 (prepared by CERG Strasbourg, France TUD, CNRS, RTM*):*

Description: Applicability and limitations of FO cable technology for landslide and man-made structure monitoring / Leader: CERG

Associated deliverables:
D.1.3 Writing of a joint publication (CERG, TUD, CNRS, RTM) -M+24

Work package 2 (prepared by GHHD Tbilisi, Georgia, CERG Strasbourg, France, CNRS):

Description:
Applicability and limitations of arrays of multi-sensor for the monitoring of landslide and man-made structures / Leader: GHHD

Associated deliverables:
D.2.3 2nd stage implementation of the arrays of displacement sensors and telemetry at the Georgia test site (GHHD) - M+18
D2.4 Analysis of data, and integration in the DSS system (GHHD, CERG, & CNRS) - M+21

Work package 3 (prepared by CERG Strasbourg, France, CNR-IDPA, CNR-IRPI):

Description:
Development of a simple DSS system to manage the dataflow and identify thresholds in the time series

Associated deliverables:
D.3.3 Development of the DSS system (CERG, CNRS, CNR-IDPA) - M+18
D.3.4 Integration of all the data and test of the system to identify trends and thresholds (CERG, CNRS, RTM) - M+24
D.3.5 Writing of a joint publication (CERG, CNRS, CNR-IDPA) -M+24

Work package 4 (prepared by CERG Strasbourg, France*)*:

Description:
Project management

Associated deliverables:
D.4.3 Mid-term project meeting with all participants - M+14
D.4.4. Project reporting (CERG) - M+24