Microseismic and meteorological monitoring of Séchilienne (French Alps) rock slope destabilisation

Stella Coccia, Jannes Kinscher, Aurélien Vallet

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Stella COCCIA (INERIS) [1], Jannes Kinscher (INERIS)[1], Aurélien Vallet (BRGM)[2]

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Rockfalls and deep-seated gravitational slope deformations are recognized as a major natural hazard across the mountainous regions with strong economical and social impacts on regional land settlement and transportation policies. In recent years these geohazards are increasing as a result of climate change and rapid expansions of human habitats and critical infrastructure. Unfortunately, the physical mechanisms and trigger of slope destabilization are rather complex and strongly site variable and thus, difficult to predict. As a result, some of the current researches aim to design efficient monitoring techniques able to detect changes in the slope conditions in order to anticipate catastrophic failures. Microseismic, meteorological and geodetic monitoring approaches are tested in this context.

Here, we present ongoing investigations on the microseismic and the meteorological monitoring approach for Séchilienne case study (south-east of Grenoble city), being the most instrumented French hazardous slope for more than 20 years. The Séchilienne slope is characterised by a deep progressive deformation controlled by the network of faults and fractures and induced by rainfall (Vallet et al. 2015b). A particularity of this landslide is the absence of a well-defined basal sliding surface (Leroux et al, 2011). Two microseismic networks have been installed. A permanent seismic network, installed in May 2007 (Helmstetter and Garambois, 2010) by the the Multidisciplinary Observatory of Versant Instabilities (OMIV), to supplement the geodetic and geotechnical monitoring system operated since 1985 by the French "Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement" (CEREMA) (Durville et al., 2009). Later in November 2009, a temporary microseismic network was set up by the National French Institute for risks and environment (INERIS). It consists of experimental in-depth probes and it is only one of the components of the INERIS experimental multi-parameter system, placed along the West border of the very active zone of the landslide (Dunner et al., 2010).

MICROSEISMIC MONITORING

Observations from the permanent and temporary network both indicate that microseismic monitoring is a useful tool in order to survey slope activities as rock falls and other destabilizations mechanisms. Accordingly, two major microseismic crisis (with more than 100 events a day) have been recorded during significant rock fall activity in 2012 and 2013.

Beyond data qualification and quantification of the seismic rate, location of the corresponding microseismic sources is the second step in microseismic analysis but is quite complex above all with temporal networks with no dense stations number and poor azimuthal coverage. In addition, the location is a challenging task mostly because of: the lack of clear seismic phase arrivals times and strong heterogeneities in the local velocity structure.

In this study, we tested the potential of an amplitude based location approach (Kinscher et al. 2015) with some data coming from the 2013 activity. Results of this approach are consistent with previous location results (available on http://omiv.osug.fr/SECHILIENNE/SISMO/data.html) obtained by using a beam-forming approach (Lacroix & Helmstetter, 2011) (Figure 1). Even though amplitude based location seem to be somewhat less precise than the beam-forming approach, it provides automatic event location in quasi real time, which could significantly improve local hazard monitoring. Other efforts are currently done to better resolve internal destabilization dynamics of these rockfalls by using the high frequency component sensors installed in boreholes.

METEOROLOGICAL MONITORING

Rainfall threshold is a widely used method for estimating minimum critical rainfall amount (rainfall index) which can yield a slope failure. Vallet et al. (2015b) showed that a threshold definition based on rainfall and effective rainfall coupled with antecedent and precedent rainfall index is the most appropriate approach for the Séchilienne landslide. Indeed, the displacement velocity of the Séchilienne instability is mainly controlled by the hydrodynamic behaviour of the landslide hydrosystems (Vallet et al. 2015a, b). Moreover, previous works (Helmstetter and Garambois, 2010 and Klein et al, 2014) showed a potential weak correlation between local microseismicity and rainfall.

To better understand the relationship between microseismic activity and rainfall, effective rainfall, in addition to precipitation, was considered for threshold definition as being the input signal of the landslide hydrosystems. Literature reviews show that most of the threshold studies are subjective and not optimal. Support vector machines (SVM), a supervised learning method, is used for establishing an optimal and objective threshold for the Séchilienne landslide. The calculation of the SVM threshold is in progress: all our microseismic data from 2009 to 2014 are used

[1] COCCIA Stella, INERIS, Nancy, France (54042), stella.coccia@ineris.fr
[2] VALLET Aurélien, BRGM, Besançon, France (25000), A.Vallet@brgm.fr

and precipitation data coming from the Mont Sec weather station (CEREMA station). This station includes a rain gauge and a snow gauge and is located on the same slope of our microseimic network.

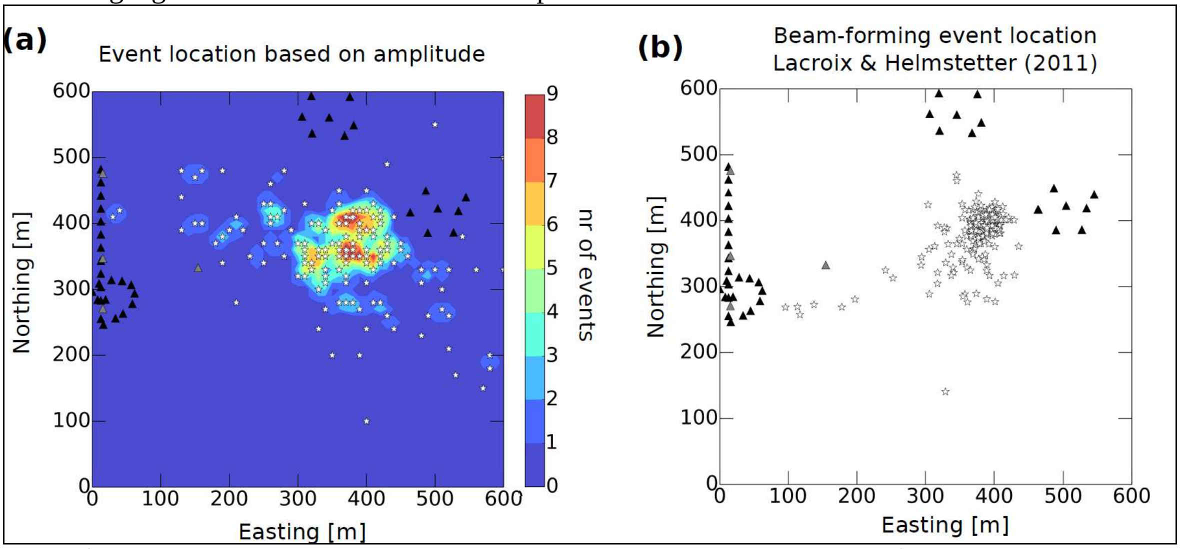

Figure 1: Example of event location results using an amplitude based (a) (Kinscher et al 2015) and a beam-forming based (b) (Lacroix & Helmstetter 2011) approach for ~ 250 events detected on the 20/10/2013. Black triangles refer to seismic stations of the permanent OMIV network, while gray triangles mark station positions of the temporal INERIS network.

CONCLUSION

We present current investigations aiming to improve microseismic and meteorological data analysis of the Séchilienne rock slope. We provide a new automatic location tool providing event location in real time, whose results are consistent with previous location ones (OMIV web page) and the in situ observations. Complex slope failures are predisposed and triggered by hydrogeological conditions. Our combination of microseismicity with groundwater recharge is ongoing and detailed results will be present in the next future.

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