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Villerville landslide field trip

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Fig. 1: Main active zones along the coast of Pays d’Auge (Lissak, 2011).

Fig. 2: Morphological setting of Pays d’Auge cliffs (modified from Flageollet & Helluin, 1987).
Fig. 3: Geological profile of the present coastal slope of Villerville (modified from Flageollet & Helluin, 1987).

Fig. 4: Monitoring network at ‘Cirque des Graves’ Villerville.
Fig. 5: Development of the Villerville-Cricqueboeuf landslide in relation to the groundwater table and effective annual rainfall data.

Fig. 6: Geomechanical slope stability analysis (Maquaire, 1990)

Fig. 7: Hazard zoning map PPR (in progress). Legend in Fig. 9.
Fig. 8: Hazard assessment: case of Villerville town

Fig. 9: Hazard zoning map PPR 2007 (in progress)

- G1: Low hazard.
- G2: Medium hazard.
- G3: High hazard.
Role of hydrological process in landslides occurrence: Villerville-Cricqueboeuf landslides (Normandy coast, France)

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ABSTRACT: In Normandy, along the Calvados coast, the 12 km long Pays d’Auge section is periodically affected by rotational and translational landslides. In January 1982, major landslides (3m high scarp) have caused several damages to property. In this paper, we focus our attention on the relationship between precipitation and groundwater fluctuations linked to Villerville – Cricqueboeuf landslide crises. Through these preliminary results coming from comparative analysis of twenty years of survey we have reached first insight in the groundwater level threshold for these landslides and have got a better understanding of the internal coastal slope behaviour.

1 INTRODUCTION

Calvados coastal slopes are frequently affected by landslides for several centuries particularly at the Pays d’Auge coast (Fig. 1). These two actives landslides (Varnes 1978) called Cirque des Graves near Villerville and Fosses du Macre near Cricqueboeuf are slow moving landslides but reactivated by spectacular crises (Maquaire 2000). In the Cirque des Graves landslide, the first time failure occurred the 10/11 January 1982. Several houses have been partially or totally destroyed and the departmental road has been cut at different points (Flageollet & Helluin 1987). After this first major event, three crises occurred in February 1988, January 1995 and March 2001. These reactivations caused different damages and the extension of the active zone (Maquaire 2000). All reactivations occurred in winter after freezing and heavy rainfall period.

Therefore, the field survey focus, since 1984 on the hydrological characteristics of the landslide to understand the hazard process. A field monitoring network was set up initially in 1984 but only completed in 2007.

Climate forcing is known as one of the major landslide triggers (Van Ash 1999) and this paper aims to illustrate the relationship between climatic conditions - groundwater changes - displacements but specific threshold cannot be defined yet.

Both study areas (Villerville-Cricqueboeuf) are located on the Pays d’Auge plateau which is bordered by very high cliffs (up to 140 m). The geologic structure and topography are heterogeneous. The main scarps of these rotational and translational landslides are several meters height, defined in Cenomanian chalk resting on Albian glauconic sand (Fig. 2). At the toe, the scarp is more gentle and relatively straight (Maquaire 1990, Flageollet & Helluin 1987).

Both instable zones are characterized by superficial material composed of blocks, debris of chalk, flints and loess (Fig. 2).
The slope morphology and the geologic structure increase landslide susceptibility. Frequent water resurgences and springs along the slope could be explained by a complex and dispersed underground network of deep water tables and subsurface water tables. The groundwater system discharges into the sea which and in such contribute to the slope erosion. The role of sea erosion on the slope instability is an important factor but not studied in this paper. Normandy is characterized by an oceanic climate with an annual precipitation which varies from 600 to 1150 mm with an average of 870 mm (period 1949-2007).

2 MONITORING AND METHODS

The 1982’s first time failure introduced studies to the rotational and translational landslide mechanisms of this area. In 1984 a first field monitoring system has been installed.

To analyse hydro-climatic conditions of displacements, the actual network (Fig. 3) is constituted by eighteen cemented ground benchmarks to evaluate surface displacements, three inclinometers, twenty-one wells and ten piezometers in order to analyze landslide kinematic and groundwater level variations.

Four piezometers are equipped with automatic water level recorders. Also the pore pressure and the climatic data will be recorded continuous.

Only the surficial displacements are measured with discrete intervals (1 time per month) and have been interrupted several years until January 2008.

3 RESULTS

3.1 Piezometry - Precipitation

Figures 4 to 6 present groundwater variations and field pluviometry since 1974. We can see that Danestal piezometer, which is located 17 kilometers from the landslide area, has similar behaviour as the local wells in and close to the landslide area. The groundwater fluctuations are correlated with high effective rainfall here Precipitations minus Evapotranspiration (P-ETP). Figure 4 shows the correlation between water table elevations and landslide reactivation. All important events are linked to groundwater rise. We can also define a first approach for a groundwater level threshold.
Figure 4 shows the correlation between water table elevations and landslide reactivation. The four crises are linked to groundwater rise. We can also define a first groundwater level threshold (108-109 m alt.).

The annual level is around 12 meters depth; for the first time failure, in January 1982, the groundwater table reached the highest and exceptional level ever known (4 m higher than annual average). The following reactivations (1988, 1995 and 2001) needed lower groundwater level rises (3 m). A statistical analysis was used to evaluate the groundwater tendency for 30 years and distinguish the recharge and discharge periods (every 4 years). The recharge periods are linked to acceleration periods (Fig. 4).

Figure 5. Groundwater behaviour standard cycle in Pays d’Auge.

Figure 6. Well comparative piezometry in wells at 4 locations (1985-1988).
The annual groundwater behaviour can be defined by an annual standard cycle and be divided into two steps (Fig. 5): a clear water level rise from September to March, and a water level decrease from March to September (Dupont et al. 2008). The groundwater level rise is in close relation with prolonged rainy periods and groundwater recessions correspond to the summer seasons with generally water deficits (Maquaire 1997).

Relationship between piezometry and precipitation are known and established with positive effective rainfall (P-ETP) (Fig. 7) and with exceeding rainfall (effective rainfall minus active storage of the soil). At first, we have considered a theoretical soil active storage of 100 mm to calculate the water budget and to estimate the pluviometric exceeding that feed directly the groundwater. Next we will evaluate the real infiltration conditions (Tacher 2005) to evaluate these threshold values.

The figure 7 shows that the correlation between water tables fluctuations and precipitations is better with effective rainfall (circles) than total rainfall (squares) but to estimate threshold value we need to know precisely the rainfall water needed by the soil and run-off. Although at different locations (Danestal, Le Ramier) the groundwater level fluctuations in all observation points react on the same moment but the amplitude variations are completely different for each one of them (Fig.6). For example, on the field area, the water table variations of the well “Les Houx” are more important (2 m versus 80 cm) and shorter than “Le grand Large” fluctuations. These adjustments are linked to the aquifer characteristics and the internal structure of the slope. The groundwater level rise lags behind the rainfall event because of damping character of the unsaturated soil; infiltration and percolation (Bogaard, 2001, Bogaard & Van Asch 2002). The water table response depends on the depth of the groundwater and on the cumulated rainfall. Subsurface groundwater tables are more reactive than the deep water tables. The water table in “Les Ramiers” increases around six days after beginning of the rainfall (Maquaire 1990).

We can evaluate pluviometric thresholds needed to increase the groundwater level with the figure 8 that shows the connection between groundwater level rising and rainfall. For 70 mm rainfall, the groundwater level increases 10 cm. This rise is only possible if the pluviometric threshold is exceeded. During drainage periods with a limited rainfall, the water level quickly stabilizes and decreases.

3.2 Piezometry –Rainfall – Displacement

As other landslides like La Frasse landslide (Noverraz 1990), displacements amplitude and occurrence depends on seasons and climatic conditions (Maquaire, 1990). Suspended or very slow-moving landslides can be reactivated in periods of heavy rainfall and are characterized by phases of acceleration and deceleration. This kind of behaviour has been observed in slow-moving earthflow (Lateltin & Bonnard 1995) or in rotational and translational landslides (Corominas et al 1999).

Horizontal and vertical surface displacements were measured using standard tacheometry together with the directions of these displacements. Annual rainfall, groundwater rise and cumulated displacements of benchmarks are clearly correlated (Fig. 9). The 2001 event is clearly visible and related to the important rainfall peak. On the contrary there are limited displacements in the dry years (2004, 2005) because of a low rainfall amount. The landslide kinematic follows the seasonal trend: with acceleration in winter and early spring and deceleration during the drainage periods (Malet et al. 2004, 2003). The March 2001 event occurred when the precipitations in the years 2000 and 2001 were exceeding the long-term average values (134 mm in January 2001 versus a 60 mm monthly average and
137 mm versus 28 mm monthly average in March 2001).

Along the year, we can say that displacements are heterogeneous. The most active zone is at the lower part of the slope, (benchmarks n° 68, 203, 58, (Fig. 3). Displacement is higher at the slope toe and decrease to upstream and to the east flank. As expected, point n°68 located near the long-shore has moved around 4 meters since 1985 (vertical displacement) contrary to points 63, near the east flank or 59 (upstream) which are affected by lower displacements. Recession by sea erosion could not explain spatial variability and temporal distribution of displacements but it is one of triggering factors.

Figure 9. Cumulated displacements Villerville Camping 1985-2008, effective rainfall and Danestal groundwater level at the same period.
4 CONCLUSION AND DISCUSSION

The historical comparison of hydrological events confirms the temporal variability of the mass landslides and an indubitable correlation between rainfall, groundwater and displacement. These movements are defined by characteristic parameters: such as temporal variability linked to a long rainy period and a regional groundwater recharge period. All triggering factors play a role at different geographical and temporal scales, that why all parameters have to be studied at different scale. In terms of risk prevention we have to put forward the most important parameters acting on the slope instability. Cricqueboeuf landslides, outside exceptional crises, evolve with continuous slow displacements particularly in winter season occurring important damages. In this context the field survey is now completed (since January 2008) by monthly and permanently displacements recorders. Add to tacheometer method, displacements are registered with DGPS and with the installation of new benchmarks to cover the majority of the landslide. Water level is for several points permanently registered by electronic data recorder and linked to meteorological data with local pluviometers. We try to determine water evolution by quantitative approach in order to analyze landslide movement frequency in response to rainfall events to evaluate precisely triggering thresholds and to determine precursor signs for alert system.

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REFERENCES


Multi-technique permanent monitoring of a slow-moving coastal landslide in Normandy.

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ABSTRACT: The ‘Cirque des Graves’ and the ‘Fosses du Macre’ landslides in Normandy (France) are slow-moving rotational and translational coastal landslides characterized by surface displacement of a few cm per year. The permanent landslide activity generates important economical and physical damages (building perturbations and destruction) in this area where the land pressure associated to coastal tourism is increasing. For these reasons, the landslides have been progressively monitored since 1984. Previous researches have demonstrated the efficiency of traditional instrumentation and the use of Global Positioning System (GPS) techniques to detect very low amplitude movements. Surface displacements correlated with rainfall and groundwater level analysis allowed to identify hydro-climatic thresholds initiating seasonal movements. A continuous monitoring at several points on the landslide allows to specify: 1) the slope kinematics, 2) the relationship between rainfall, groundwater level and velocity, 3) the temporal evolution of the different landslide sectors/areas. To establish a near real-time warning system, the monitoring network is based on the combination of data collection on the triggering factors and on the slope response in terms of kinematic. The state of the recent monitoring network is detailed and some preliminary results on the kinematics and on the triggering factors are presented.

1 INTRODUCTION

The coastal slopes of the department of Calvados (Normandy) are frequently affected by landslides causing significant damages on constructions and infrastructures.

This paper outlines the field monitoring investigation carried out at the ‘Cirque des Graves’ and the ‘Fosses du Macre’ landslides to identify critical threshold in the mobility of the landslides.

The first monitoring network was implanted in 1984 after the major event of January 1982 (Maquaire 1990) and completed in 2001 and 2008. The kinematics of these slow moving landslides is analyzed for several years with daily observations of displacement and groundwater level in order to identify critical thresholds for the onset of major acceleration. Traditional methods such as total stations and distance-meters are commonly used to quantify the kinematics and its possible correlation with hydrological and climatic characteristics. Many landslides are monitored to define critical thresholds and to point out the relation between groundwater levels and slope velocity (Angeli et al. 1999, Angeli et al. 2000, Petley et al. 2005, Ayalew et al. 2005, Corsini et al. 2005). Most of these areas are instrumented with a network of benchmark distributed along the slope at the surface, and with inclinometers and piezometers in depths. New monitoring techniques such as permanent GPS, ground-based laser scanning, ground-based SAR and ground-based photographs are used to either increase the accuracy of the displacement measurements or to obtain an image of the displacement field (Malet et al. 2002, Coe et al. 2003). On Normandy landslides, the monitoring network has been designed to record daily displacement rates, direction and amplitude, groundwater fluctuations and rainfall amounts.

The monitoring of unstable slopes influenced by hydrological factors necessitates high temporal resolution acquisitions to define the spatial and the temporal pattern of the hazard. The aim of the paper is to present the continuous monitoring network implanted at high spatial and temporal resolution to define specific thresholds for triggering surface displacements associated with rainfall and climatic triggering factors.
2 ‘FOSSES DU MACRE’ AND ‘CIRQUE DES GRAVES’ LANDSLIDES

2.1 Area of issues

The Normandy coastal slopes are important touristic areas with increasing land pressure. Consequently unstable slopes affect many private properties, tourist infrastructures and networks. The coastal main road (RD513), joining Honfleur to the East and Trouville to the West, is partially affected and in case of landslide events may disconnect many villages.

![Figure 1. Location of the study area on the North-eastern part of the Pays d’Auge coast.](image)

Study areas (the ‘Cirque des Graves’ and the ‘Fosses du Macre’ landslides) are located on the high cliffs of the Pays d’Auge plateau (up to 140 m) between Trouville and Honfleur (Fig. 1). Both landslides cover approximately 8 ha surrounding the village of Villerville. Both can be defined as active, slow-moving, rotational landslides according to the Cruden and Varnes (1996) classification.

The morphology is typical of rotational landslides (Varnes 1978, Buma 1996) with successive sliding blocks, often with counter slopes, separated by scarps of several decimeters to meters high. The oldest scarps are completely hidden by vegetation and/or modified by human intervention (Flageollet & Helluin 1987) and correspond to the Cenomanian chalk panels (Fig. 3) sliding on the Albian sands which overlay Kimmeridgian marls. The toe of the landslide is characterized by a chaotic morphology with shallow clayey flows overtopping sandy limestones.

2.2 Landslides behaviour history

The landslides are officially considered as active since an important reactivation that occurred in January 1982; however the slopes were not stable since the last two centuries without any major crisis identified (Ballais et al. 1984). Since the first major reactivation of 1982, the slopes are permanently affected by seasonal slow movement (0.05-0.10 m.yr\(^{-1}\)). Three other main acceleration occurred (February 1988, January 1995 and March 2001) in close relation with the hydro-climatic conditions. These multiple phenomena have generated many new scarps of several meters high and tensile cracks which are still evolving. The principal part of the ‘Cirque des Graves’ landslide is affected by horizontal displacement rate between 0.005 to 0.1 m.yr\(^{-1}\). The toe of the landslides is affected by superficial failure and the development of muddy flows characterized by a high velocity (around 1 m.yr\(^{-1}\)). The whole mass is affected by a combination of superficial and deep movements, including possible retrogression, enlargement or advancement of the limits of the landslide during major acceleration.

2.3 Hydro-climatic triggering factors

The historical comparison of hydrological events confirms the temporal variability of the landslides and the indubitable correlation between rainfall, groundwater and displacement. Annual displacements are characterized by a long rainy period and the groundwater recharge period in winter season.

3 METHODS OF DISPLACEMENT AND HYDRO-METEO MONITORING

3.1 Surface displacement monitoring

Since 1984, the ‘Cirque des Graves’ landslide is investigated using a monitoring network recently update for a better understanding of the moving processes and triggering factors. The landslide kinematic is estimated using traditional geodetic instruments and topographical landmark fixed on the moving part of the slope. The GPS techniques have been increasingly employed to monitor landslide movements (Gili et al. 2000, Malet et al., 2002, Squarzoni et al. 2005) and vertical subsidence of areas (Baldi 2009). The results of previous researches indicated that GPS is a viable alternative to other commonly used monitoring strategies.

The network is composed of 24 cemented benchmarks implanted according to the vegetation and the accessibility constraints and to the specific geomorphological features. Between 1984 and 2008, the benchmark positions were measured by non-continuous acquisitions with a total station. Since 2008, the 3-D positions of benchmarks are measured by non-permanent GPS campaigns (Trimble R5). The protocol consists of repeated GPS observations of the benchmarks and horizontal tiltmeter surveys to characterize the angular surface displacement. The
GPS observation time (e.g. real-time kinematic survey) for each benchmark is 17 minutes.

Since July 2009, to increase the temporal resolution of information and to implement an early warning system, three permanent GPS stations (Trimble NetRS) are installed to provide continuous observation of movements (Fig. 2, Fig. 4, Fig. 5). These GPS stations are part of the French Observatory of landslides (OMIV, http://eost.ustrasbg.fr/omiv). The GPS reference station VLRV has been set up on the stable part of the slope, outside the landslide. Two other permanent GPS receivers (VLRH and VLRB) are located on the active part of the landslide, on two subsequent nested chalk panels (Fig. 5). The baseline distance between VLRV- VLRH and VLRV- VLRB is respectively 465 m and 480 m.

The GPS data are processed daily using the Gami/GlobK software, taking into account tropospheric and ionospheric models, and including additional GPS observations from a regional network of permanent station to constrain the solution. An automated routine has been developed to process all the data by the OMIV-EOST team in Strasbourg, as a duty of the French Observatory of Landslide (OMIV). In a context of an early warning system network, these sensors designed by the AlertSolutions Company allow a daily solution by internet with a data acquisition at a 6 min temporal resolution.

3.3 Hydrological and meteorological array

The kinematic monitoring is completed by a permanent monitoring of water-level, pore water pressure and rainfall data at several positions on the landslide to define the interaction between these variables.

Water level is for several points permanently registered by electronic data recorder and linked to meteorological data with local pluviometers. On the ‘Cirque des Graves’ landslide seventeen piezometers (Fig. 2) including three continuous groundwater sensors (SD4, I2, PZ1), one multi-parameter datalogger CR1000 (water and soil temperature, water conductivity, raingauge; SD6), and one pore water pressure sensors (Geobeads, C3) were installed.

We try to determine water evolution by quantitative approach in order to analyze landslide movement frequency in response to rainfall events to evaluate precisely triggering thresholds and to determine precursor signs for an alert system.

4 RESULTS

4.1 Landslide displacement and spatio-temporal variability of velocity

The GPS data acquired from the repeated campaigns are processed using Trimble Geomatic office software. These monthly records helped us to define the cumulative displacement over two years and to spatialize the activity of the ‘Cirque of Graves’ landslide.

The position point accuracy for GPS measurements are estimated at 0.007 m for X, 0.012 m for Y and 0.013 m for Z using the standard deviation. Over the period of November 2008 - August 2010, we recorded cumulative displacement from a few millimetres to a few centimetres (Fig. 3).
Between 2008 and 2010 significant movements occurred with substantial horizontal displacement at the toe and in the middle part of the landslide. Cumulative displacement vectors reveal the spatial heterogeneities in the magnitude of movements with four distinct areas (Fig. 3, Fig. 4), (1) the lowest part of the slope is the most active part with superficial displacement of outcrop marls; (2) the central part, upstream of area 1, is affected by displacements of more than 0.15 m cumulated displacements, (3) the eastern edge of the active area is principally characterized by very low horizontal displacements (benchmarks 163, 164 eastern part) between few centimetres and millimetres per year. (4) And the western part of the landslide is affected by the moderate movement rates of few centimetres.

Previous studies have highlighted the beginning of the landslide activity by the toe of the slope (Maquaire 1990). The permanent GPS measurements can now confirm this theory.

Figure 3. Vector map of the cumulated displacements measured between 2008 and 2010

Figure 4. Displacement pattern and direction of movement (cross-section located on Fig. 2). The profile indicates the principal slip surface and the schematic displacement vectors at the surface: 1) Displacement vector, 2) Vertical component of velocity, 3) Horizontal component, 4) Sliding surface, 5) GPS receiver.

Figure 5. GPS baselines between VLRV (local reference station) – Caen (regional reference station, and VLRV-VLRH; VLRV-VLRB since January 2010. The baseline VRLV – CAEN allows to determine the accuracy on the GPS solutions, which is estimated at ca. 0.05 cm in all directions.
The major interest of a continuous monitoring by GPS is the increase of measurement accuracy to define the spatial variability of the sliding chalk blocks composing the landslide. The methodology to process the data and the accuracy is detailed in Déprez et al. (submitted).

The first results highlight the heterogeneities in time and magnitude of displacement between the two stations (VLRB and VLRH) since January 2010 (Fig. 5, Fig. 8). We can record over 0.06 m of cumulative displacement for the VLRB station located at the toe of the landslide and 0.02 m for VLRH station (Fig. 5). The accuracy of the baseline length estimated at ± 0.005 m (Deprez 2010).

Two acceleration periods are observed for the both stations, in January and at the end of February 2010. A third acceleration was recorded in April for VLRB station.

For the February acceleration, VLRH began to record a displacement about two days after the VLRB station recording. A displacement lag time of about 2 or 3 days between the stations (Fig. 5) can be explained by a required lag time between the two nested chalks panels to move downstream one after another.

In addition to records of surface deformations, we have put in place since July 2010 three Geobeads probes in C3 (Fig. 2).

4.2 Triggering factors

The continuous records in SD4, SD6, I2 (Fig. 2) highlight the influence of precipitation on the groundwater fluctuation.

For example, during a rainy period as November 2009 in SD4 piezometer, since the beginning of precipitation the groundwater level has increased for nine days. The groundwater still increased (Fig. 2, Fig. 7) three days after the end of precipitations and the level began to progressively decrease four days after the last rainfall event until a new episode. As considered in the previous research, after one year of continuous monitoring we can estimate an approximate critical threshold of cumulative rainfall with a minimum of 5 days precipitations for a considerable groundwater increases (Maquaire 1990, Lissak et al. 2009).

Concerning the pore pressure (in C3) linked to precipitations, for the first three months recording (July 2010-Sept 2010) no clear response to the infiltrating precipitation could be recorded because few rainfall episodes occurred for this period.

Nevertheless, the permanent monitoring allows us too to estimate the chalk panel activity response to rainfall and groundwater variations (Fig. 8). To define rainfall–velocity of landslide critical thresholds (Keefer 1987) GPS observations are linked to the groundwater variations at SD4 and SD6 piezometer and to the rain gauge data implanted near SD6 (Fig. 8). Observations from the GPS receivers and hydro-meteorological station show the beginning of blocks movements correspond to a period of groundwater recharge after several rainy days. This is the case for acceleration of the 26th (VLRB) and 28th February (VLRH) 2010 (Fig. 5, Fig. 8). The rise in the groundwater level is observed since de 21th February, three days after the beginning of (effective) precipitations. Displacements are measured from February 25th to VLRB station and from 27-28th for VLRH while rainfall cease on
February 28th and water level decrease since March 3rd.

Figure 8. Cumulated horizontal displacements of VLRB and VLRH stations and pluviometry between July 2009 and August 2010.

After one year of a continuous survey we can estimate an approximate critical water level threshold about 65.90 alt. at SD4 correlated to several days of cumulated rainfall for a few millimetres accelerations of a block at the toe.

At the end of March, the third acceleration of about 0.01m of displacement was observed only for the VLRB station. The station is located on the landslide toe which is directly in contact with the sea during high tides. A few days before the VLRB acceleration, the tidal coefficients were high. During the same periods South-North winds were recorded with a speed of 30-35 km/h (Fig. 9).

Figure 9. Extract from the wind map of March 25, 2010 (Meateciciel.fr) few days before VLRB acceleration to illustrate the wind conditions before and during the acceleration period.

The wind direction (Fig. 9) did not allow the oversize wave phenomenon. Now we are only able to highlight the efficiency of the rainfall on the movement triggering. But may be the sea action on the landslide toe could be proved during the next episode to explain the activity of the VLRB station when VLRH is stationary.

5 CONCLUSION

A monitoring system measuring spatial and high temporal resolution data is required for this type of slope movement because of the low amplitude displacement and heterogeneities of velocity. The data acquisition should be very precise to differentiate low seasonal accelerations and precursor signs of crisis. The Cirque des Graves device is introduced through a warning system in an area where the issues are high and where it is necessary to define critical thresholds of triggering factors.

First, the device monitoring allow us to highlight the most active areas by punctual campaigns, secondly the accelerations lag time between nested panels with continuous GPS survey. The continuous monitoring with hydro-meteorological stations and permanent GPS receivers provide several type of information. On the one hand, the chronology of velocity with the beginning of the displacement by the toe of the landslide during acceleration period, hence the lag between the different compartments of the landslide body to be moved linked to triggering factors. On the other hand, the device is used to define rainfall critical thresholds related to the groundwater increase and to the slope movement. The maximum correlation between rainfall and piezometry occurs after 5 days precipitation. This is also the time required to start the displacement process. Triggering factors and the slope velocity should be recorded at a very fine time steps to establish a warning system and to differentiate the precursors of crises of the seasonal activity. But for this type of (very low) movement it is also a need to acquire a long period of data to characterize precisely their activity.

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