Processing strategy of Continuous GPS (CGPS) observations for the French Landslide Observatory OMIV

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ABSTRACT

The French Landslide Observatory (OMIV - *Observatoire Multi-disciplinaire des Instabilités de Versants*) is a national research structure clustering six research institutes in earth sciences under the auspices of INSU (*Institut National des Sciences de l'Univers*). Six continuously active landslides in France are monitored by the OMIV research group; they have been chosen according to their past history of monitoring, to the hazard/risk they may create and to the scientific challenges they raise up. The six studied landslides are: (1) the Avignonet landslide (30 km South of Grenoble), (2) the Super-Sauze landslide (5 km South to Barcelonnette), (2) the La Clapière (100 km North of Nice), (4) the Séchilienne landslide (25 km East of Grenoble), (5) the Pégairolles landslide (40 km North of Montpellier), and (6) the Villerville landslide (10 km South of Le Havre).

These landslides show various displacement rates (ranging from a few centimetres to several meters per year) and kinematic regimes. The objective of this work is to evaluate the performance of PPP (Precise Point Positioning) and DD (Double Difference) processing techniques on GPS observations acquired at the landslides. The PPP approach is a positioning method used to calculate precise positions using a single receiver from un-differenced phase measurements, precise clocks and precise satellite orbits. The PPP method is different from the DD positioning method which eliminates most errors using one or more reference stations with known positions. Position time series of several GPS located on landslides are computed with the NRCan (Natural Resource Canada) PPP software, the GINS (*Géodésie par Intégrations Numériques Simultanées*) PPP software and the GAMIT/GLOBK DD software. Evaluation of the results will be discussed. Time series of positions are available at: http://www.ano-omiv.cnrs.fr/

I. Introduction

A. *The French Landslide Observatory OMIV*

The French Landslide Observatory (OMIV - Observatoire Multi-disciplinaire des Instabilités de Versants) is a national research structure clustering six research institutes in earth sciences (EOST in Strasbourg, OSUG/ISTerre in Grenoble, OCA/GeoAzur in Nice; THETA-Chrono-Environnement in Besançon, OREME-GM in Montpellier; UCN-LETG in Caen) under the auspices of INSU (Institut National des Sciences de l'Univers) (Malet et al., 2016).

The objectives of OMIV are:

- (1) to conduct geo(morpho)logic, hydrologic, geodetic and seismic observations for the long-term understanding of landslide processes, and
  - (2) to maintain robust, long-lasting multi-parameter datasets freely available for the geoscience community. Six continuously active

landslides in France are monitored by the OMIV research group; they have been chosen according to their past history of monitoring, to the hazard/risk they may create and to the scientific challenges they raise up.

The six studied landslides are: (1) the Avignonet landslide (30 km South of Grenoble), (2) the Super-Sauze landslide (5 km South to Barcelonnette), (2) the La Clapière (100 km North of Nice), (4) the Séchilienne landslide (25 km East of Grenoble), (5) the Pégairolles landslide (40 km North of Montpellier), and (6) the Villerville landslide (10 km South of Le Havre) (Figures 1, 2). These landslides show various displacement rates (ranging from a few centimetres to several meters per year) and kinematic regimes (e.g. continuous displacement of nearly constant rate or succession of periods of acceleration/deceleration).

Figure 1. Location of landslides monitored in France by the OMIV Landslide Observatory

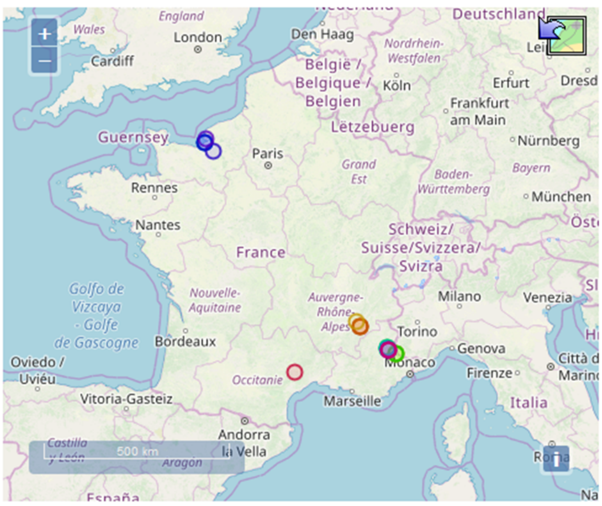

Figure 2. Location of landslides monitored by GPS/GNSS techniques in France by the OMIV Landslide Observatory

The objective of the French National Landslide Observatory OMIV is to provide long-term monitoring of three categories of landslide parameters:

- Kinematic observations (surface and in-depth displacements).
- Hydro-meteorological observations.
- Seismological observations.

Monitoring is essential to understand the mechanics of landslides, and predict their behavior in time and space. Scientists at the OMIV Observatory monitor selected landslides in order to learn more about the physical processes that trigger landslides or control their movement, develop original landslide investigation methods and hydro-mechanical models of slope deformation. For the survey, a multi-technique monitoring strategy is proposed (Figure 3).

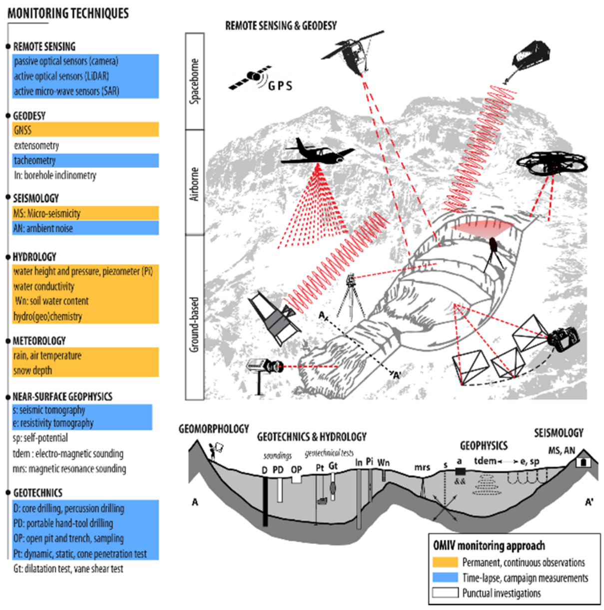

Figure 3. Multi-technique monitoring strategy at OMIV Landslide Observatory (http://ano-omiv.cnrs.fr).

B. *Continuous monitoring with GPS/GNSS*

In this paper, we focus on GPS/GNSS technique to monitor the displacement, and quantify displacement rate and regime. Since many years GPS, techniques is largely s used in geosciences for tectonic purposes (Dixon, 1991; Genrich et Bock 1992), landslide monitoring (Ding et al. 2000; Malet et al., 2002; Squarzoni et al., 2005; Peyret et al., 2008; Benoit et al., 2014), glacier monitoring (Benoit et al 2015).

Deploying continuous GPS/GNSS (cGPS) monitoring of landslides is not yet widely employed because of high cost of receivers/antennas and also because of the infrastructure of retrieving data and processing them in near-time. Malet et al. 2002 perform a first experiment for GPS monitoring in the French Alps at the Super Sauze, France. This experiment provided interesting results and initiate cGPS monitoring for landslides.

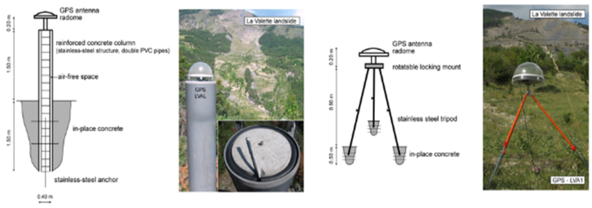

Figure 4. Permanent GNSS antenna on a pillar at the toe of La Valette landslide (Southern French Alps) and on-site GNSS antenna on the landslide. (http://ano-omiv.cnrs.fr).

Two types of measuring devices are developed in our sites. We use permanent GPS network on or close to the landslide (Figure 4). GPS receivers can be of two types: expensive geodetic (2-frequencies) devices or 1-frequency (L1 only) device. The latter ones are a low cost solution (Geomon) provided by InfraSurvey company (Demierre et al. 2016; Figure 5).

Figure 5. Geomon low-cost GNSS receiver and its solar panel on the Super-Sauze landslide (Boetzlé, 2015).

Depending on the size of the landslides, most of them are equipped with 2 to 4 permanent antennas located on the landslide (Ferhat et al. 2015; Malet et al., 2016). The requested accuracy of the estimated horizontal and vertical coordinates has to better than 1 – 2 cm.

II. Geodetic tasks for the observatory

A. *Global strategy of the OMIV geodetic task*

The GPS receivers are operated by local Observatory. Data are most of the time downloaded in near real-time or in some very few cases manually. Data are then stored on local server in order to be processed by the EOST team of OMIV group in Strasbourg (Figure 6).

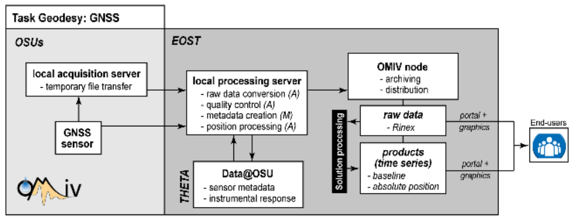

Figure 6. Global flowchart of GPS/GNSS data acquired at the French landslide Observatory OMIV (http://ano-omiv.cnrs.fr).

B. *Processing of GPS data*

The raw data are stored in proprietary format and then converted into RINEX format. Quality check on the data is the preliminary task for the geodetic analysis. In order to achieve a good precision for the daily positions of the different antennas located on the landslides, two strategies have been used.

The first one was a differential processing using the classical Double-Difference techniques with the GAMIT/GLOBK software. The second one is the PPP technique, Precise Point Positioning. The main results are expressed in term of time series of position but also in term of baseline changes relative to an antenna on a pillar outside but very close to the landslide.

III. Comparisons of DD and PPP techniques

A. *GPS Processing in double differences*

The double differencing (DD) technique has been operated with the GAMIT/GLOBK software (Hering et al. 2003a, b). This solution offers precise results and stable for daily estimates. But this latter technique is more adequate to permanent GPS stations whose displacements are low, i.e few cm/yr. Daily solution does not differ much from one day to another. But the displacements occurring on a landslide may be important, and more precisely highly variable and frequent from a day to another with some possible high acceleration due to precipitation for example. This is why an adequate processing was required for monitoring moving antennas on a landslide.

As an example, Figure 7 shows an example of anomalous estimates using a DD technique for baseline changes in October 2011 for the Super-Sauze landslide, Southern French Alps (Figure 8). This is why PPP techniques was explored.

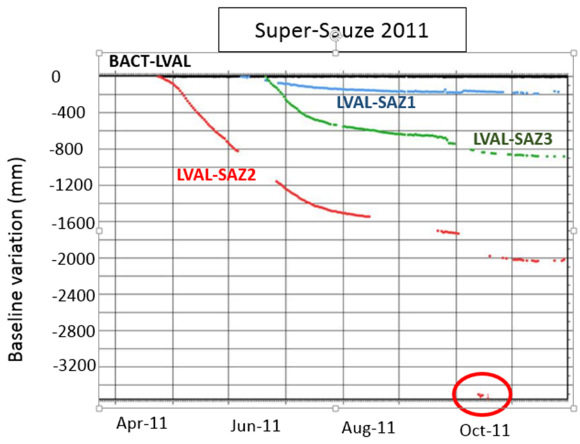

Figure 7. Example of anomalous estimation of baseline changes at Super-Sauze landslide (French Southern Alps) (Boetzlé, 2015).

Figure 8. The 1-km long La Valette landslide in the French Southern Alps (http://ano-omiv.cnrs.fr).

B. *PPP processing*

For a number of years, precise point positioning (PPP, Zumberge et al., 1997; Wang, 2013) algorithms using un-differenced observations have been available in some GPS analysis softwares. Users now have the option of processing data from a single station to position with cm-precision within the reference frame provided by the International GNSS Service orbit products (IGS). Point positioning eliminates the need to acquire simultaneous tracking data from a reference (base) station or a network of stations. PPP technique enables estimates of daily positions in the reference frames defined through the orbits. These daily estimates are not supposed of small order of movements from day to day.

C. *Evaluation of different PPP softwares*

We selected two PPP softwares: SCRS-PPP (Canada) and GINS (France). GINS software is developed by the GRGS/CNES (France) and the SCR-PPP is developed at the National Resources Canada (NRCAN (Canada).

The two PPP softwares were chosen because both can process RINEX data, provide solutions in the appropriate International Terrestrial Reference Frame and provide automation procedures with shell or batch programs.

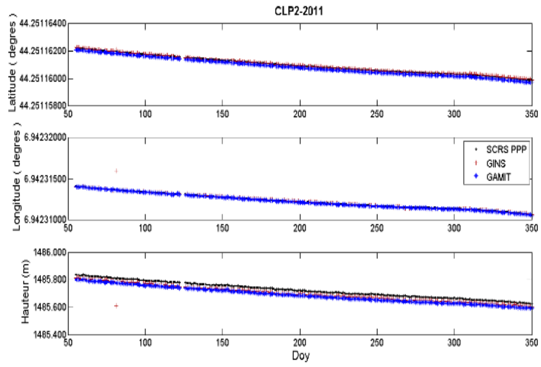

Figure 9. Comparison of time series obtained through SCRS-PPP, GINS and GAMIT/GLOBK softwares for a rapid landslide (Boetzlé, 2015).

Figure 9 shows daily positions estimated at la Clapière (Southern French Alps, Figure 10) using all three sofwares, i.e GINS, SCRS-PPP and GAMIT/GLOBK softwares. Time series of positions exhibit similar behavior. We observe a quite good agreement for this very rapid landslide (Table 1). The DD solution obtained with GAMIT/GLOBK serves a reference solution and we compute differences relative to this DD solution (Table 1).

Table 1. Differences between two PPP softwares (NRCAN, GINS) and GAMIT DD solutions

La Clapière CLP2	Statistics in cm	
	latitude	longitude
mean	4.3	1.5
rms	0.4	1.0
Min/max	2.6/5.7	0.0/7.2

Figure 10. La Clapière landslide in the French Southern Alps (http://ano-omiv.cnrs.fr).

For a slow moving landslide such as Villerville (VLRB site), differences between PPP and DD solution are higher, but still acceptable. Moreover we observed a bigger scatter for the GINS software, because we used a preliminary version of the GINS software (Maisse, 2014).

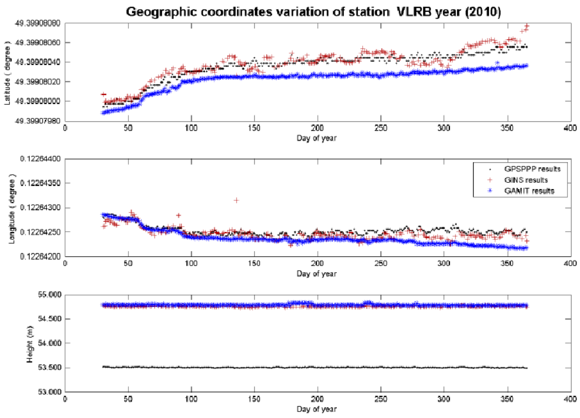

Figure 11. Comparison of time series obtained through SCRS-PPP, GINS and GAMIT/GLOBK softwares for a slow moving landslide at Villerville, France. (Boetzlé, 2015)

IV. CONCLUSIONS

The French Landslide Observatory (OMIV - Observatoire Multi-disciplinaire des Instabilités de Versants) is a French-research initiative clustering five research institutes in earth sciences. The six studied landslides are studied (Avignonet, Super-Sauze, La Clapière, Séchilienne, Pégaroilles, Villerville). Concerning GNSS processing techniques, we evaluate the difference between DD (Double Differencing) and PPP (Precise Point Positioning). Historical calculations for our GPS networks located on active landslide were performed with the GAMIT/GLOBK software. For rapid movement of the landslide, classical DD Double Differencing exhibits sometimes anomalous results, especially in case of acceleration of movement. This is why an alternative way for computing automatically solution of for slow or rapid motion has been explored. PPP technique offers an interesting solution for landslide monitoring. We employ PPP calculation for 6 continuously active landslides equipped with GPS/GNSS sensors. We adopted the NRCAN PPP software for analyzing GPS data acquired on landslides.

V. ACKNOWLEDGMENT

Metadata of all OMIV GNSS sensors are described with the DOI FR-18008901306731-2018-09-28.

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