Debris flow cartography using differential GNSS and Theodolite measurements

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Giorgi Khazaradze[1*], Marta Guinau[1], Jaume Calvet[1], Gloria Furdada[1], Ane Victoriano[1], Mar Génova[2], Emma Suriñach[1]

(1) Grup Risknat, Departament de Geodinàmica i Geofísica, Facultat de Geologia, Universitat de Barcelona (UB), Martí i Franquès s/n, 08028 Barcelona, Spain
(2) Departamento de Sistemas y Recursos Naturales, Universidad Politécnica de Madrid (UPM), 28040 Madrid, Spain
(*) Corresponding author: gkhazar@ub.edu

Introduction

The presented results form part of a CHARMA project, which pursues a broad objective of reducing damage caused by uncontrolled mass movements, such as rockfalls, snow avalanches and debris flows. Ultimate goal of the project is to contribute towards the establishment of new scientific knowledge and tools that can help in the design and creation of early warning systems. Here we present the specific results that deal with the application of differential GNSS and classical geodetic (e.g. theodolite) methods for mapping debris and torrential flows. In the last decade more than ten debris-flow type phenomena have affected the region, causing considerable economic losses (García-Oteyza e tal., 2015; Furdada et al., 2016; Victoriano et al., 2016).

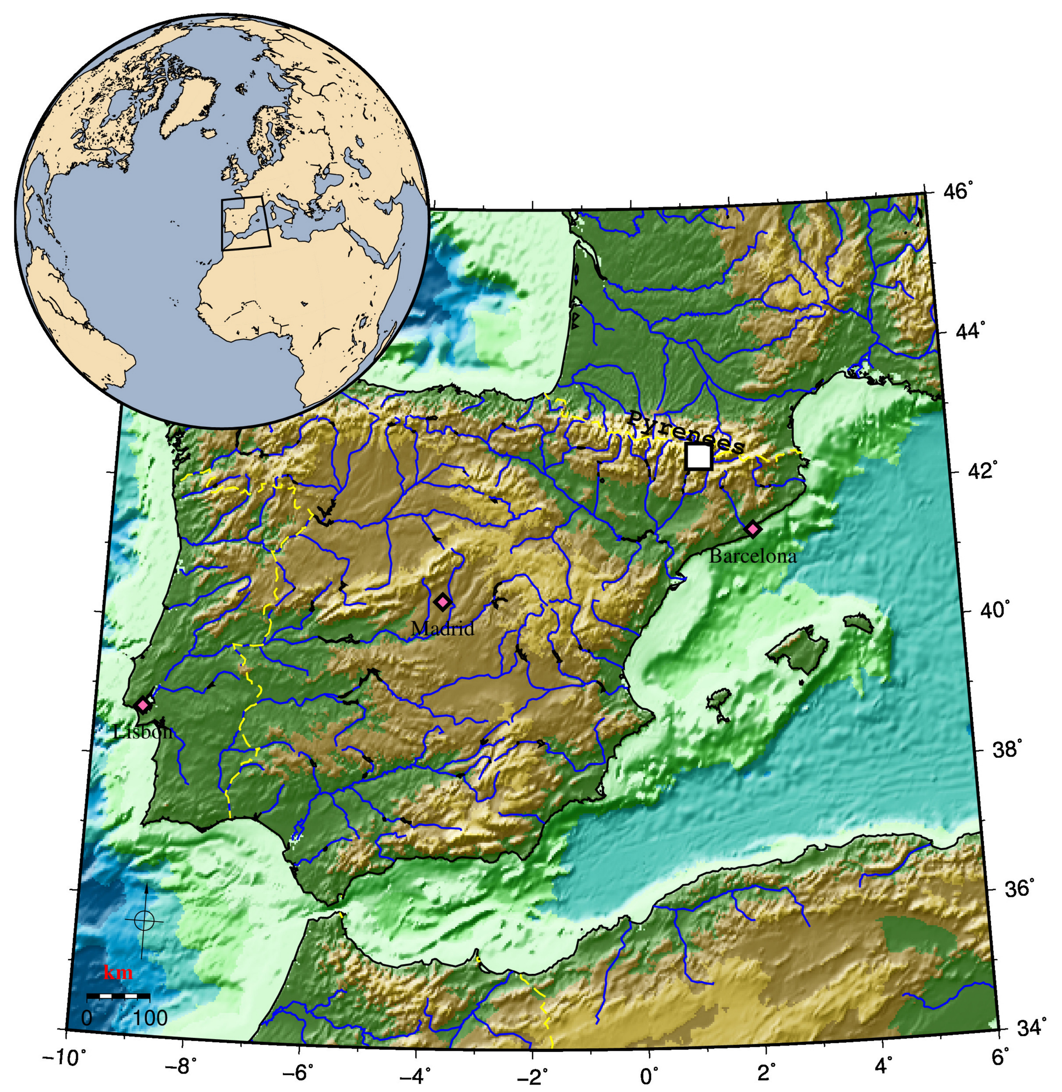


Figure 1: We investigate the Portainé stream located in the Pallars Sobirà region of Catalonia (Spain), in the eastern Pyrenees. White rectangle indicates the the location of the study area.

Field-Work

We have conducted 2 GNSS campaigns using various differential GNSS systems in March and in September of 2015. During the fieldwork we employed a multi-disciplinary approach, consisting of geomorphological, dendro-chronological (García-Oteyza, et al., 2015) and geodetic methods, with the main objective of mapping the river bed and reconstructing the history of the extreme flooding and debris flow events.

Figure 2: Investigative team at work.

Methodology

Geodetic studies included several approaches, using the classical and satellite based methods. The classical method consisted of angle and distance measurements using a theodolite. Specifically, we used somewhat outdated Geodolite 502 Total Station (TS). The control points were chosen within the river bed and measured using the reflecting prism with a fixed height pole of 2 meters. These type of measurements for relatively short baselines (les than 50 m) are precise (< 1 cm), although present several disadvantages: 1) lack of absolute coordinates; 2) time-consuming process involving two persons; 3) requirement for a direct line of sight. For this reason, we have conducted the pilot studies using the GNSS technique, where we have measured a set of the TS control points using the differential GNSS system. This measuring method is fast and can be conducted by one person. However, the fact that the study area is within the river valley, and that significant part of the riverbed is covered by trees, limits the visibility of the satellites and thus, results in significant positioning errors (> 1 m).

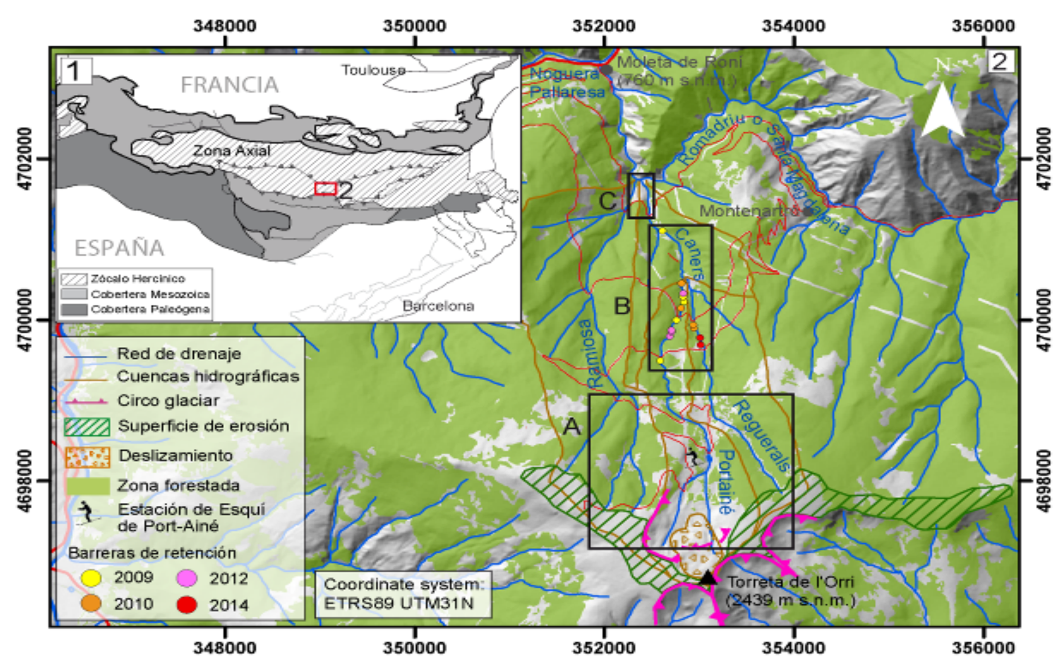


Figure 3: Detailed map of the study area. 1) Geologic map of the Pyrenees. 2) Geomorphologic map of the ravines of Portainé, Reguerals y Ramiosa rivers; A) Head waters; B) Intermediate section; C) Lower section where the three rivers merge with the river Romadriu. Sediment retention barriers are shown in thick pink colours. Map is based on Furdada et al., 2016.

GNSS Measurements: RTK

During the first campaign we have used the RTK positioning method using the SmartNet network (http://es.smartnet-eu.com) operated by Leica, which has an advantage of transmitting differential corrections for GPS and GLONASS. During the second campaign, we have had an access to the ICGC (http://www.icc.cat) CatNet permanent GPS network, which only provides GPS corrections.

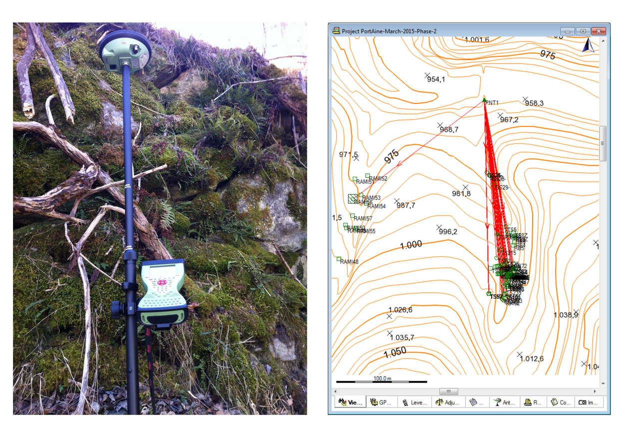


Figure 4: a) Leica Viva GS14 dual-frequency receiver with a CS15 controller used in the study. B) Map of the study area with a subset of measured points and baselines, plotted within the LGO 8.4 software.

We have used RTK positions and compared them with the results of the post-processing using the Leica Geo Office 8.4 software with IGS estimated final orbits. For this procedure, in addition to using the data from nearby CatNet CGPS stations, we have also used data from the base station(s) specifically setup near the study area during the campaign period.

Theodolite measurements

Classical geodetic survey was conducted using the theodolite measurements of 455 points within the river valley. Specifically we measured 280 points in March, 2015 and 175 points in September, 2015. All the data was consequently transferred to Excel spreadsheet and transformed to geographic coordinates using the in-house software.

For a successful realization of this transformation, we have surveyed minimum 3 control points using GNSS and estimated their positions with the LGO 8.4 software in a post-processing mode.

Figure 4: Theodolite measurements were conducted using the Geodolite 502 Total Station, which has an an angular precision of 6" and a distance accuracy of ±5mm+5ppm.

GNSS Measurements: Base Stations

Apart from conducting the RTK measurements using Leica system, we have also setup additional base stations in the beginning of each campaign. Suring the September 2015 campaign we setup two base stations, in order to check possible advantage of having two base stations, as opposed to the one.

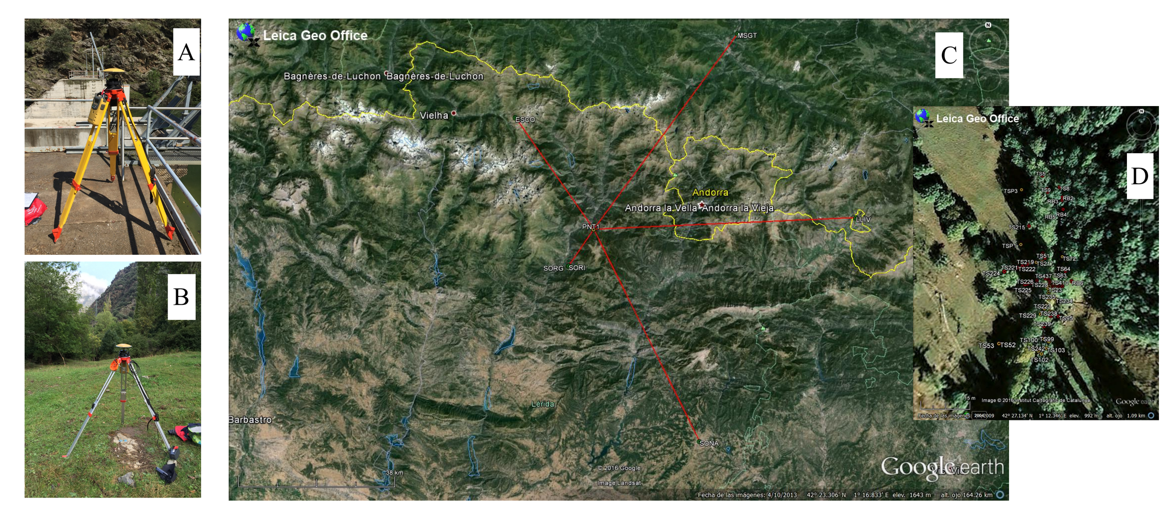


Figure 5: Two base stations were setup for the entire duration of campaigns. We used Topcon GB-1000 dual-frequency GPS-GLONASS receivers, with 1 second sampling. A) Base station PNT1 at the dam; B) Base station PNT2 in the middle section of the Portainé river. C) Location of the PNT1 base station, together with the GNSS reference stations used in post-processing. D) Zoom into the middle section.

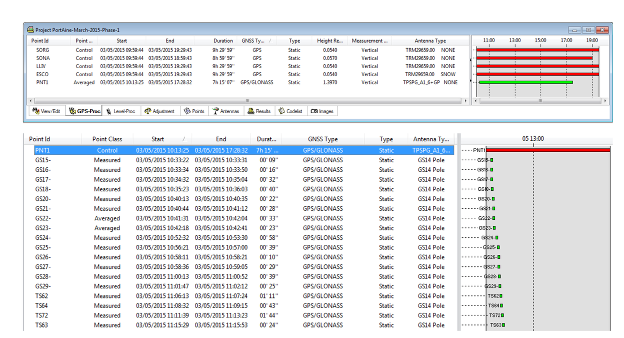
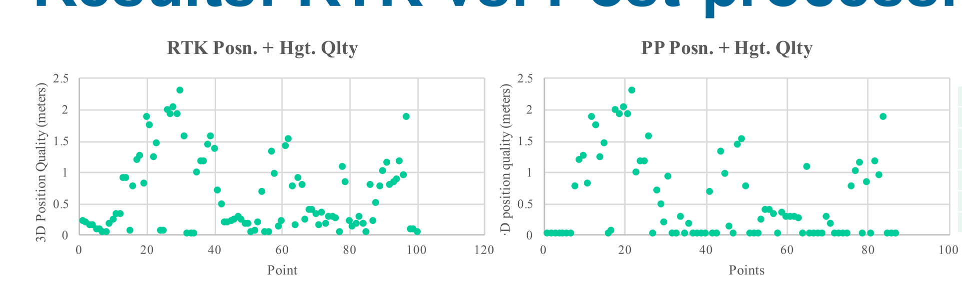
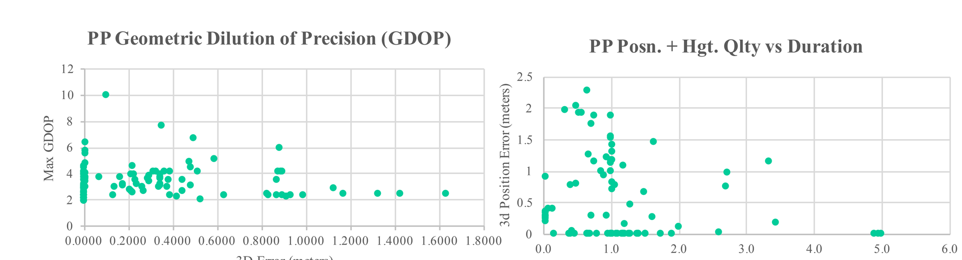


Figure 6: Post-processing was performed in two stages using the LGO 8.4 software, employing IGS final orbits: 1) precise positions of the base stations were estimated using the nearby continuous reference stations with 1 sec sampling data. 2) Survey data from the Leica receiver were processed using the fixed position of the base stations.

Results: RTK vs. Post-processing



Statistics	RTK	PP
Average (m)	0.621	0.538
Median (m)	0.327	0.256
St. Deviation	0.599	0.653
Variance	0.359	0.426
Range	2.278	2.278
# of Points	100	87

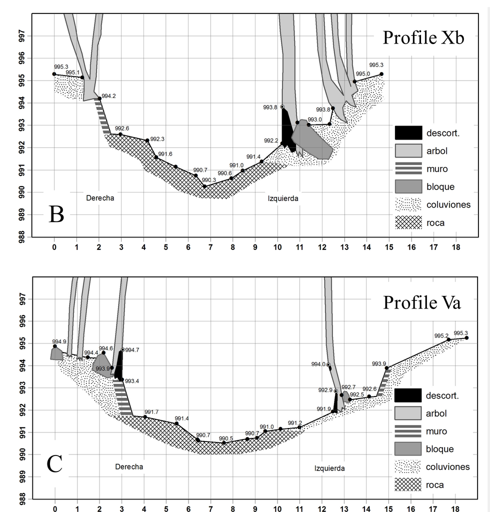


Obs. Duration (mins)	
Average (hours)	1.134
Variance	0.987
Range	4.967
Min	0.033
Max	5
# Points	86

Discussion

The main goal of this study was to map debris and torrential flows that have occurred in the last decade in the Portainé river valley (Figure 7). By employing the GNSS RTK technique for measuring different points within the riverbed, we were hoping to achieve sufficient precision (< 5 cm) in order to avoid more laborious classical geodetic measuring techniques with a theodolite.

However, after conducting two surveys, we saw that the precisions achieved using both the RTK and PP mode GNSS positioning were not sufficient and the work had to be conducted using the Total Station measurements. This conclusion is due to the two main factors: 1) Significant Dilution of precision (DOP) due to the trees and surrounding mountains (Piedallu & Gégout, 2005; Valbuena et al., 2010). 2) Due to the increased number of points that had to be observed (455 in total), the observations times were to be limited to 2 minutes.



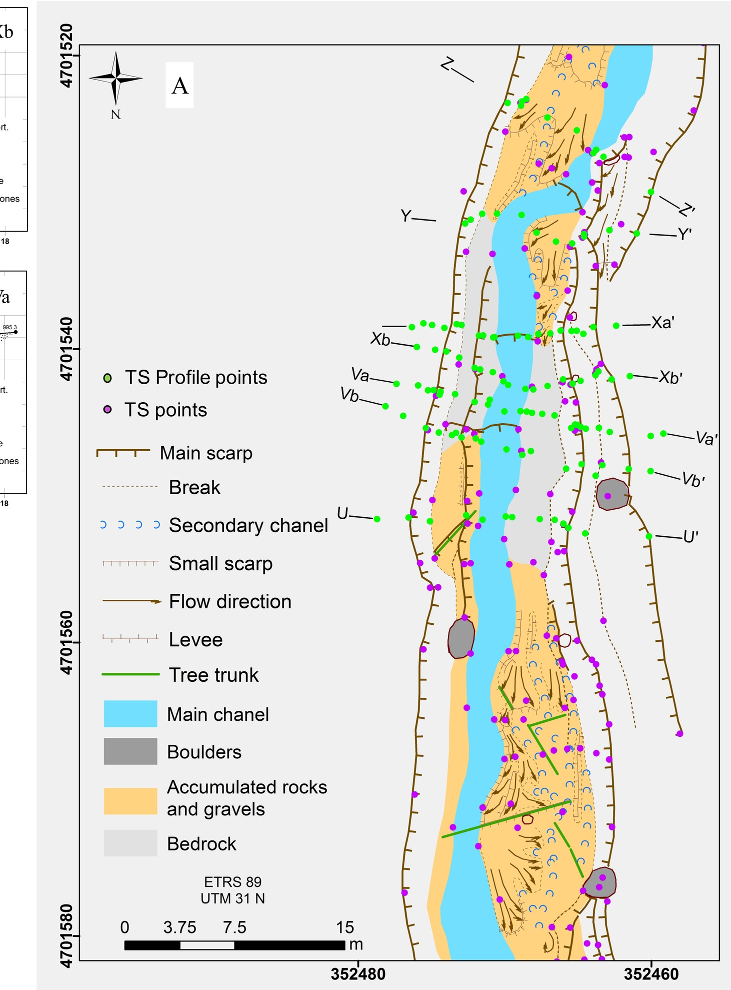


Figure 7: Mapping of the debris and torrential flow deposits. A) Middle section of the geomorphological map showing the river channel and the points measured with the total station (TS). Points belonging to the cross sections (green) are distinguished from the points (purple) that were used to map the landforms. B) Cross section Xb. C) Cross section Va.

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Acknowledgements

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