Ground Based SAR and Terrestrial Laser Scanner data for the analysis of the Formigal landslide; the GALAHAD project test site in the Spanish Pyrenees

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An old, dormant landslide in the ski resort of Formigal at Sallent de Gállego (Huesca), Central Pyrenees, Spain, was partly reactivated in 2004 as a result of excavation works at its toe for the construction of a car park, thus endangering the car park and a newly built section of the road to El Portalet mountain pass, at the French border. Bedrock in the landslide area consists predominantly of weathered shales/slates and sandstones with some occurrences of limestone layers, all of Devonian to Carboniferous age, overlaid by colluvial deposits containing some calcareous boulders in a sandy clay matrix. The reactivated landslide sector has an extent of 0.25 km^2; it shows small hummocks and ponds, and it is mainly covered with grass vegetation, with calcareous boulders locally outcropping. This landslide is being monitored as part of the EU 6th Framework Programme's GALAHAD Project.

Soon after the landslide reactivation, a first monitoring campaign was carried out including the installation of inclinometers and extensometers and the use of GPS and Total Station, in addition to the geomechanical characterization of the landslide materials (Aramón, 2005). Inclinometer readings indicated the presence of a roto-traslational failure surface at a depth of 7 to 16 m. This campaign was followed by the implementation of stabilization measures at the toe of the reactivated landslide sector, which considerably slowed down the landslide movement. Later on, in the framework of the GALAHAD Project, surface displacement monitoring was performed during 2006 using mainly state-of-the-art terrestrial remote sensing systems. These included a C-band, VV polarization, 2 m linear scan length, ground-based interferometric SAR (GB-SAR) (Luzi et al., 2006) providing hourly interferograms for mapping displacements over a 53-day period, and a long-range Optech Ilris 3-D terrestrial laser scanner (TLS), acquiring multi-temporal, 3-D dense point cloud coordinates in two surveys from two different viewpoints, three months apart (see e.g. Abellán, et al., 2006). Simultaneously to these measurements and extending over a longer period of time, RTK-based differential GPS (D-GPS) monitoring was carried out using a Leica System 1200, collecting multi-temporal XYZ coordinates over 97 stations both for determining displacement rates and for georeferencing the GB-SAR and TLS data. The maximum accumulated modulus of displacement measured by D-GPS amounted to 22.6 cm over a 6-month period embracing the shorter GB-SAR and TLS monitoring campaigns, with displacement velocities changing with time.

Displacements shown on the GB-SAR multi-temporal differential interferograms, including also those for corner and active SAR signal reflectors precisely located at a number of GPS stations, showed a good agreement with those obtained by D-GPS over the common 53-day measurement period, with an average difference of ± 1.68 cm and a standard deviation of ± 1.51 cm for average maximum displacements of about 8 cm. Processing of the TLS-acquired data is still in progress.

Preliminary meteorological analysis appeared to show generally a good correlation between the landslide higher velocity periods and intense rainfall events. Further analysis, also investigating the possible correlation with snow melting, is envisaged to be performed once the TLS-based movement measurements are available. The results of the analysis are intended to be used for building a landslide forecasting model.

References

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