Geophysical Research Abstracts
Vol. 14, EGU2012-5973, 2012
EGU General Assembly 2012

Towards the optimisation of landslide monitoring using short-period seismometers.

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Traditional geotechnical and geodetic monitoring of landslides can be restricted due to a number of factors e.g. destruction of the monitoring instrumentation due to the landslide movement, need for permanent installations etc. Additionally, in the absence of boreholes, they provide limited information on the landslide failure plane, which is vital for the effective design of slope stabilisation works.
Short period seismometers (SPS) are a monitoring technology aimed in recording weak energy signals that travel in forms of seismic waves without the need for permanent or specialised installation with a full array consisting of one 3-component and three 1-component seismometers. Their sensor-to-source distance threshold for signal location concerning ML -1.0 down to -2.0 events (natural or man-made) is at 10km and 3km respectively, when monitoring at night time (low signal-to-noise ratio), (Wust-Bloch & Joswig, 2006). This makes SPS a favourable option for landslide monitoring. In addition, the location of the seismic sources can highlight the location of the landslide failure plane.
The aim of this project was to quantify the ability of SPS to detect and locate small seismic sources ML < 1, as those detected during the movement of a landslide, under unfavourable geological conditions e.g. cohesionless soils instead of solid rock. Sands, for example, have high attenuation resulting in the loss of even stronger seismic signals very quickly.
We deployed three SPS arrays on a geological site consisting of unsaturated sand and clay approximately 20 km South from Natal (NE Brazil). An equilateral triangle geometry was used: the 3D sensors were placed in the metacentre of the triangle while the 1D sensors were placed at the corners at radial distances 25m, 50m, and 100m from the 3D sensors. Three explosions, each produced by a different amount of explosives, were triggered at 20, 40, 60, 80, 100, 150 and 200m away from the 3D sensors. For better coupling with the soil, the explosives were buried at a depth of $\sim$30cm. The “true” locations of all sensors and explosives were a priori determined using a portable GPS device.
At a next step, we estimated the locations of the explosives using the recorded signals and two different location software: Hypoline and Hypo71. The resulting locations were then compared with the “true” locations and an error for each location was estimated.
It was revealed that this error depends on the distance of the explosives from the sensors and the magnitude of the explosion. The maximum source-to-receiver distance that allows for an accurate source location was found in the order of a few tens of meters in the case of sand and clay soil.
Our results help to improve the design of effective monitoring strategies of landslides using SPS by providing at a first step a threshold (to act as a guideline) for the source-to-receiver distance above which the error in the location of seismic sources becomes significant. These results are specific for sand and clay soils and are valid for an equilateral triangle array geometry, but the methodology followed could be repeated for other soil types and receiver array geometries.

References:
Wust-Bloch, G.H. and Joswig, M. [2006] Pre-Collapse Identification of Sinkholes in Unconsolidated Media at Dead Sea Area by ‘Nanoseismic Monitoring’ (graphical jackknife-location of weak sources by few, low-SNR records). Geophys. J. Int. 167, 1220-1232.