Pluri-annual time lapse survey applied to landslide monitoring: new highlights on short and long term dynamics

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Abstract

This study reports the results from 4 years of multi-parametric time laps survey on the "Vence" landslide (South eastern France). This landslide is active since the 1970s, jeopardinzing the safety of more than 20 houses. It develops in a sandy-clay Eocene layer overlying a highly fractured and faulted Jurassic limestone discordantly. The actual survey combined Electrical Resistivity Tomography (2 daily acquisitions), many boreholes monitoring of groundwater levels as well as inclinometer and temperature measurements, rainfall records and water spring chemistry measurements (available only for the last 2 years). Gaps in the data represent about 20% of the survey duration. However, the amount of data is sufficiently significant to address the question of the long term behavior of the sliding mass. Thus, we were able to study the landslide dynamic at various time scales.

At short time-scale (few days), the time laps survey enables us to follow mean resistivity variations after rainfall events in correlation with the consecutive rises of the groundwater level within the sliding mass. Firstly, the statistical data analysis highlights a global correlation between the rainfall rate, the piezometric elevation and the mean resistivity decrease. Secondly, by analyzing the resistivity variations of each tomogram point, we observed a time-dependant vertical clustering, representative of two hydrogeological answers to rainfalls events:

1. A few hours later, near the surface: small resistivity variations related to subsurface water infiltrations,
2. about 2 days later, deeper: strong variations highlight the influence of the drained limestone fault systems in the landslide water supply.

During some very strong rainfall events, irreversible deformation was recorded by inclinometers. However, it is necessary to consider the landslide answer at longer time scale as the amplitude of deformation is strongly dependent on the massif state prior the rainfall event (e.g. piezometric levels).

At long time-scale, we show a clear annual hysteris. The landslide behavior follows a cycle directly linked to the seasonal state of the geological system. Using Principal Component Analysis, we observed periods characterized by stable relations between all physical parameters (summer and winter) punctuated by short transitional phases (autumn and spring). During stable periods, the landslide dynamic answer (ground deformation) will follow the same pattern for rainfall events.

Understanding this long term behavior represent the main challenge to define the precursors of landslide re-activation and thus to provide safety alarm systems.