Multi-geophysical interpretation using fuzzy logic data fusion: application to landslides imagery

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Abstract

Geophysical methods, such as seismic or electrical tomography, provide crucial information in the study of landslides, whether to determine their internal structures or identify associated hydro-mechanical processes. These methods are non-intrusive and measure the velocity of compressional waves (Vp), shear waves (Vs) and electrical resistivity (Rho), three geophysical parameters able to define the physical properties of the soil and to identify anomalies related to tectonic structures (faults, fissures), lithological variations (sand, clay or calcareous) and hydrological properties (moisture, water flows). For these reasons, seismic and electrical imaging methods are commonly used to characterize the subsurface - and especially landslides - as shown in the scientific literature of recent decades. Conventional treatments consist of inverting the first P wave arrival times, the Rayleigh wave dispersion, and the apparent electrical resistivity to produce Vp, Vs and rho maps called tomograms. While the coupling of these methods provides additional information in terms of petrophysical properties, their combined interpretation is nevertheless complex because each geophysical method is sensitive to different soil properties. Each tomogram therefore reflects only a part of the physical reality of the medium. An innovative method, less complex than joint inversion, is here proposed to combine these three geophysical parameters represented on the tomograms and to convert them into different interpreted images of the subsoil. Knowing that the speed of the P waves, S and the electrical resistivity respectively provide information on stiffness, plasticity and water content, the combined images are calculated by the mean of belonging functions inferring these properties. These calculations are performed within the framework of the mathematical theory of fuzzy sets that maintains a certain level of objectivity and is capable of handling uncertainties. This approach is tested on several landslides located in the French Alps. The results obtained are then discussed in terms of reliability and compared to surface observations and borehole data.