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Review on instrumental monitoring of fast-moving flow-like landslides in alpine and volcanic environment.

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Fast-moving flow-like landslides are among the most dangerous natural hazards that threaten people and infrastructures in mountainous areas. They include different processes in terms of physical and rheological properties, ranging from flash floods to debris flows. In volcanic environment, very similar processes can occur and the Indonesian word lahar is used to refer to rapidly flowing sediment-laden hot or cold mixtures of debris and water. In-situ monitoring of such processes is of great importance in order to improve the understanding of the mechanics, to better design mitigation measures and to calibrate numerical models. However, instrumental monitoring has to overcome multiples drawbacks: on one side, technical issues associated to the harsh environmental conditions and the energetic flow behaviour, on the other side the irregular occurrence, which normally requires a monitoring system switching between “event” mode and “no-event” mode to limit power supply and data storage.
During the last two decades, monitoring systems have strongly improved and quite a long time has passed since the last reviews on this topic (e.g. Itakura et al. 2005; LaHusen 2005; Arattano and Marchi 2008). In addition, their employment for early warning purposes is becoming more and more attractive due to the technological developments that progressively reduce sensor cost and size. We present an updated state-of-the-art of wired and wireless monitoring systems focussing the initiation mechanisms and the flow dynamics, both in mountainous and volcanic environment.
The most common sensors that study the initiation of fast-moving flow-like landslides are meteorological devices measuring principally rainfall and in some sites snowfall. In very specific instrumented catchments, the discharge upstream the initiation zone is measured. Moreover, there are sensors measuring the stress-strength conditions of the soil. Finally, video cameras are installed in few sites to observe the initiation mechanisms. Regarding the flow dynamics, the ground vibration produced by the flow is used in a growing number of sites to detect the process. Many types of sensors exist to measure the ground vibration (e.g. seismometers, geophones, accelerometers). In addition, infrasound sensors and devices measuring the flow depth (e.g. ultrasonic devices, radars or lasers) are installed along many torrents. Some monitoring systems also include sensors installed in the channel bed to measure pore fluid pressure, normal and shear forces, or even the entrainment. Moreover, load cells or strain gauges have been fixed at structures exposed to the flow to measure impact pressure. Finally, video cameras are commonly installed to gather complementary information on the flow behaviour.

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