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High frequency seismic monitoring of debris flows at Chalk Cliffs (CO), USA

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A growing number of studies adopt passive seismic monitoring techniques to investigate slope instabilities and landslide processes. These techniques are attractive and convenient because large areas can be monitored from a safe distance. This is particularly true when the phenomena under investigation are rapid and infrequent mass movements like debris flows. Different types of devices are used to monitor debris flow processes, but among them ground vibration detectors (GVDs) present several, specific advantages that encourage their use. These advantages include: (i) the possibility to be installed outside the channel bed, (ii) the high adaptability to different and harsh field conditions, and (iii) the capability to detect the debris flow front arrival tens of seconds earlier than contact and stage sensors.

Ground vibration data can provide relevant information on the dynamics of debris flows such as timing and velocity of the main surges. However, the processing of the raw seismic signal is usually needed, both to obtain a more effective representation of waveforms and to decrease the amount of data that need to be recorded and analyzed. With this objective, the methods of Amplitude and Impulses are commonly adopted to transform the raw signal to a 1-Hz signal that allows for a more useful representation of the phenomenon. In that way, peaks and other features become more visible and comparable with data obtained from other monitoring devices.

In this work, we present the first debris flows seismic recordings gathered in the Chalk Cliffs instrumented basin, central Colorado, USA. In May 2014, two 4.5-Hz, three-axial geophones were installed in the upper part of the catchment. Seismic data are sampled at 333 Hz and then recorded by a standalone recording unit. One geophone is directly installed on bedrock, the other one mounted on a 1-m boulder partially buried in colluvium. This latter sensor integrates a heavily instrumented cross-section consisting of a 225 cm2 force plate recording basal impact forces at 333 Hz, a laser distance meter recording flow stage over the plate at 10 Hz, and a high definition video camera (24 frames per seconds). This combination of instrumentation allows for a comparison of the amplitude and spectral response of the geophones to flow depth, impact force, and video recordings.

On July 4, 2014 a debris flow event occurred in the basin that was recorded by the whole monitoring system. Both geophone installation methods and channel bed characteristics largely influenced the seismic records. One geophone exhibits a broad frequency response during all debris flow surges, while the energy recorded by the other one is mainly concentrated in the 40-80 Hz band. Furthermore, erosion and entrainment processes have a crucial effect on the recorded waveforms. The presence of channel bed sediment damps the Amplitude waveforms during the first surges, when the flow is not yet erosive. The typical proportionality between the Amplitude curve and the flow stage is observed only after the entrainment of the channel bed sediment by the debris flow, when the flow is directly on bedrock. The processing of the signal with the Impulse transformation displays the same damping effect when a high threshold is adopted. However, the use of a high threshold entails the disappearance of the first surge and causes a less effective early detection of the flow. On the contrary, the adoption of a lower threshold impedes the observation of sediment damping effect.