Monitoring and Recognition of Debris Flow Infrasonic Signals

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Abstract: Low frequency infrasonic waves are emitted during the formation and movement of debris flows, which are detectable in a radius of several kilometers, thereby to serve as the precondition for their remote monitoring. However, false message often arises from the simple mechanics of alarms under the ambient noise interference. To improve the accuracy of infrasound monitoring for early-warning against debris flows, it is necessary to analyze the monitor information to identify in them the infrasonic signals characteristic of debris flows. Therefore, a large amount of debris flow infrasound and ambient noises have been collected from different sources for analysis to sum up their frequency spectra, sound pressures, waveforms, time duration and other correlated characteristics so as to specify the key characteristic parameters for different sound sources in completing the development of the recognition system of debris flow infrasonic signals for identifying their possible existence in the monitor signals. The recognition performance of the system has been verified by simulating tests and long-term in-situ monitoring of debris flows in Jiangjia Gully, Dongchuan, China to be of high accuracy and applicability. The recognition system can provide the local government and residents with accurate precautionary information about debris flows in preparation for disaster mitigation and minimizing the loss of life and property.

Keywords: Debris flow; Infrasound; Interference noise; Monitoring; Signal recognition

Introduction

Debris flows are a common type of natural disaster in mountainous regions, with enormous hazardous nature of strong power of eroding, transporting, accumulating and alluviating. As an important non-structural hazard mitigation measure, debris flow early-warning monitor technique has been proved effective in natural disaster reduction and prevention projects (Zhong et al. 2011), while infrasound monitoring technique is the one based on the physical properties of
debris flows as a main-line research that boasts of development potential, greatly concerned in the academic and engineering world in recent years (Kogelnig et al. 2011, 2014).

Low frequency infrasonic waves result generally from many major natural disasters (tsunami, hurricanes, volcanic eruptions, earthquakes, landslides, debris flows, etc.) (Cochran and Shearer 2006; Matoza et al. 2007; Ripepe et al. 2010; Arattano et al. 2012; Zhu et al. 2013). Because of their low frequency, infrasonic waves have strong penetration, small attenuation in air to travel in the atmosphere for long distance. Therefore, long-distance passive monitoring of infrasonic sound sources is possible (Garcés et al. 1999; Mutschlecner and Whitaker 2005; Evers 2008) for analyzing the relationship of infrasound to some disastrous events so as to improve people's disaster prevention abilities. With its research into a maturity period, infrasonic sound monitoring found applications in the investigation of volcano eruptions (Johnson 2003; Matoza et al. 2009; Ripepe et al. 2010), avalanches (Scott et al. 2006, 2007; Comey and Mendenhall. 2004; Ulivieri et al. 2011), earthquakes (Le Pichon et al. 2005; Lin and Yang 2010; Lü et al. 2012; Yang et al. 2014), nuclear explosions (Christie et al. 2001; Krasnov and Drobzheva 2005; Qin et al. 2013), and atmospheric environment studies (Brachet et al. 2009; Drob et al. 2009; Le Pichon et al. 2010). A lot of work has been done by scholars on debris flow seismic sound monitoring with the help of many ground vibration detectors, such as accelerometer, velocimeters, seismometers, geophones (Arattano 1999; Marchi et al. 2002; Itakura et al. 2005; Jakob et al. 2005; Badoux et al. 2009), but infrasound monitoring is still seldom used (Kogelnig et al. 2014) and mostly involved in analyzing of and comparison between debris flow infrasonic signals of different types and scales in reference to their characteristics and influencing factors. 

Zhang et al. (2004, 2008) designed and developed Debris-Flow Infrasound Alarm (DFW-I and DFW-I III) which can give alarm 10-30 minutes prior to the arrival of debris flows, but its in-situ monitoring is of high probability of false alarm owing to its inability to get rid of the interference of environmental noises (Kogelnig et al. 2011). To reduce the false alarm probability, Zhang and Yu (2010) achieved comprehensive utilization of the devices of intelligent remote-sensing rain gauge, ultrasonic mud potentiometer, debris flow infrasound alarm (DFW-I III) and pherope, and made improvement of the instrument as a debris flow early warning system in advance warning accuracy. To update field monitoring of debris flows, scholars collected from different debris flow gullies a large amount of infrasonic signals for researching on their characteristics and the major influencing factors concerned (Chou et al. 2007, 2013; Hübl et al. 2008; Kogelnig et al. 2011; Li et al. 2012). By analyses of infrasonic signals in Jianguia Gully, Chou et al. (2007) concluded that the viscous debris flow ranged in the main infrasonic frequency between 5~10 Hz with peak-frequency decreasing by a rate of about 0.002 Hz/(m³/s) versus the discharge increments. And according to the analyses of infrasonic signals from debris flows that occurred in Mt. Huoyen, Taiwan (Chou et al. 2007, 2013), their peak-frequencies were relevant to soil properties, discharges and debris flow types: the peak-frequencies (>10 Hz) of dilute debris flows were higher than those (<10 Hz) of viscous debris flows, and the main frequencies of the former (5~15 Hz) ranged wider than those of the latter. Analyses by Hübl et al. (2008) on the acoustical signals of debris flows from Jiangjia Gully indicated the existence of two main frequencies, one was plotted in the infrasonic band of 8~12 Hz, and the other of 28~32 Hz in audible sound band. Monitoring tests were conducted by Kogelnig et al. (2014) in the catchment torrents of Lattenbach, Tyrol (Austria), Illgraben, Valais (Switzerland), the MiDui and GuXiang Glacier, Tibet (China) on debris flow infrasound monitoring by means of seismic sound and flow depth to compare and verify his gauged infrasonic signals, and he pointed out the great potential of debris flow monitoring by means of infrasound, especially when integrated with seismic sound. Li et al. (2012) developed Debris-Flow Infrasound Monitor (DBF-IS), but it still embodies no obvious improvement in early-warning accuracy due to its simple mechanics similar to DFW-I III unable to exclude the influence of interference noises. However, it is expected to see reports on such positive results as applied to field monitoring and identifying debris flow infrasonic signals.

What we can see from the above work is that