重建 2009 年小林村山崩事件之歷程

Reconstruction of the kinematics of landslide and debris flow through numerical modeling supported by multidisciplinary data: the 2009 Siaolin landslide, Taiwan

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Abstract.

Typhoon Morakot struck southern Taiwan in the summer of 2009, causing the region's most severe flooding since the 1950s. In the early morning of August 9 (local time), a rainfall-triggered landslide and debris-flow extinguished the township of Shiaolin Village, Kaohsiung. A simulation of the landslide/debris-flow can be used to examine its complex kinematic characteristics. A landslide/debris-flow simulation is conventionally performed using constrained digital terrain models, filed mappings of channel cross-sections or laboratory measurements of slope material properties. Here, we employ seismological and near-surface magnetic data in a novel way to validate and reinforce our simulation of the catastrophic Shiaolin debris avalanche. Seismic waves induced by the landslide were registered by the Taiwan Central Weather Bureau Seismic Network (TCWBSN), allowing its time of occurrence to be precisely identified as 6:16 a.m. A near-surface high-resolution magnetic survey accurately depicts the flow direction of the debris around the Shiaolin Village township at a scale of several hundreds of meters. This survey indicates that structures in the northern half of the village were dislocated to the bank of the Cishan River, and the remaining structures stayed at the southern half without being moved. This suggests that this catastrophic event unfolded in two stages. In the first stage, the debris avalanche itself swiped away half the village. In the second stage, a debris-blocking dam was

breached about 30 minutes after it was formed. Following the breach, a muddy flow with an enormous peak flow of around 10^5 m^3/s covered the entirety of the village. This study thus demonstrates that seismological data, near-surface magnetic and geological mapping, and hydrological modeling can jointly lead to realistic reconstructions of debris avalanche events.

1. GEOLOGICAL BACKGROUND OF THE SIAOLIN LANDSLIDE

Typhoon Morakot struck southern Taiwan in the summer of 2009, causing the region's most severe flooding since the 1950s. In the early morning of August 9 (local time), a rainfall-triggered landslide and debris-flow extinguished the township of Siaolin Village, Kaohsiung. The interviews of many survived villagers could shed light on some parts of the story about the landslide catastrophe (Lee et al., 2009). Scientifically, a simulation of the landslide/debris-flow can be used to examine its complex kinematic characteristics. A landslide/debris-flow simulation is conventionally performed using constrained digital terrain models, field geological mappings of channel cross-sections or laboratory measurements of slope material properties. Here, we employ seismological and near-surface magnetic data in a novel way to validate and reinforce our simulation of the catastrophic Siaolin debris avalanche.

Siaolin is identified from a high-resolution aerial photograph taken before Typhoon Morakot (Figure 1). Changes in elevation before and after Typhoon Morakot (Figure 1) were derived from two digital terrain models (DTMs) with a precision of five meters by the Agriculture and Forestry Aerial Survey Institute (AFASI) of Taiwan. Based on the DTMs before and after Typhoon Morakot, the major landslide body (cool colors in Figure 1) had an extent of 57 hectares, and the volume of the landslide was about 23.87 million m^3. According to extensive field investigation, the sliding block was mainly composed of Pliocene shale and Quaternary colluvium. The sliding surface may have been located along the interface between the fresh and weathered Pliocene shale. The volumes of the deposits (warm colors in Figure 1) on the unnamed creek and the west bank of the Cishan River were estimated to have loose-measure volumes of 10.91 and 4.53 million m^3, respectively. Most of the deposits laid down in the Cishan River, which had dammed the river for a short time after the debris avalanche, were washed away. The deposits that were washed away had an estimated volume of 10.83 million m^3, assuming that the loose-measure