Earthquake-induced surface deformations in a small mud volcano: multi-temporal high-definition measurements using TLS and UAS-SfM

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Tectonic signals are often found in mud volcanoes which are formed both in the land and undersea areas. Earthquakes often enhance the activities of mud volcanoes, including the surface deformations, mud eruptions, and gas emissions. Extensional stresses by upcoming underground pressures of liquid mud and gas may result in the formation of surface ruptures on mud volcanoes. Subtle changes of such surface deformations can be detected by the use of high-definition topographic measurements, including terrestrial laser scanning (TLS) and unmanned aerial system-based structure-from-motion multi-view stereo photogrammetry (UAS-SfM). The Murono mud volcano, located in Niigata Prefecture in north-central Japan, is an ideal test site for the measurements because of its small size and frequent deformations by strong earthquakes in this region. The spatiotemporal variations in the surface morphology have been explored in the mud volcano using TLS. While the TLS approach is suitable for accurate three-dimensional measurements of the surface morphology, the UAS-SfM approach is capable of acquiring visual images of the ground surface from which cracks can be readily extracted and mapped with a certain accuracy. The fusion of TLS and UAS-SfM point cloud data enables to enhance the accuracy of the UAS-derived data. We demonstrate a case study of the crack mapping using these data, as well as a result of numerical simulation of crack formations based on the pressure distribution by earthquakes.

Keywords: TLS, SfM-MVS photogrammetry, UAS, Point cloud, Digital Elevation Model, Cracks

