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Terrestrial Laser Scanning (TLS) over volcanic areas: experiments on Vesuvius, Stromboli and Vulcano (Italy)

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Geomorphological changes of areas affected by crustal deformation, eruptive events, gravitative instabilities, landslide and glacier evolution, and other phenomena, can be detected and quantified using high-accuracy digital surface models. The comparison between multitemporal models provides a space-time description of geophysical processes, and can be used to estimate deformation patterns, displacements, surface variations, volumes involved in mass movements, and other physical features. Several techniques, including GPS kinematic methodology, digital aerial and terrestrial photogrammetry, airborne and terrestrial laser scanning, satellite-based and ground-based interferometric radar and optical satellite imagery systems, are suitable surveying methods that provide appropriate spatial resolution.

Terrestrial Laser Scanning (TLS) allows an accurate and cost-effective representation of the topographical details of the observed surface. For this reason, TLS is currently used in geologic survey, engineering practice, cultural heritage, and mobile mapping. Besides the geometric data, the point cloud provided by a TLS observation contains radiometric information, i.e. the intensity of the received pulses, that can be used for classification purposes. Moreover, some instruments are equipped with a calibrated camera to add RGB color data to the intensity data. Since a TLS survey, including the corresponding data processing and analysis, can be carried out in relatively short time, an operational procedure can be planned and executed. The TLS and other remote sensing techniques, like digital photogrammetry, can be integrated to profit from the strength of each single technique and overcome the corresponding weakness, leading to a better modeling of the observed system.

We show the results of observations on three Italian volcanoes by using a TLS recently implemented in the monitoring system of the INGV. The most complete set has been acquired on Mt. Vesuvius crater in May 2005, October 2006 and June 2009. The whole crater was measured with several overlapped scans and the corresponding digital surface models were generated and registered into the UTM-WGS84 reference frame. The comparison between the models leads to an evaluation of the occurred changes. The deformation maps showed a progressive mass loss due to rock-falls in an area of about 5000 m^2 with a corresponding accumulation at the bottom of the crater. The volume loss which occurred from 2005 to 2009, was computed by subtraction of volumes defined with respect to reference planes parallel to the caldera walls and was estimated to be 20300 m^3. Some results were also interpreted on the basis of micro-seismic and meteorological data in order to plan a monitoring technique where seismic signals related to rock-fall and/or signals of intense rainfalls are used as alarms for fast TLS surveys able to characterize the corresponding changes of the caldera walls. The proposed methodology, in particular the simple but effective approach used in the estimation of volume uncertainties, can be applied to each rock slope instability phenomenon, regardless to the particular environment.

Two measurements were carried out at Vulcano in April 2009, by surveying the whole “La Fossa” crater and the “La Forgia” unstable slope, and in April 2010, by re-surveying again the “La Forgia” slope. All measurements were acquired with several overlapped scans. The comparison between the two measurements at “La Forgia” shows small change in the morphology that will be further investigated by new measurements; new measures will also be carried out to image again the “La Fossa” crater.

Measurements at Stromboli were aimed at testing the capability of the technique in very difficult surveying conditions: the 2007 lava fan in the Sciara del Fuoco, an inaccessible and unstable area of the Stromboli volcano. In such a condition, TLS observes the fan only with high incidence angles and from distances longer than La Fossa case. In addition, the lava fan consists in black porous lavas, characterized by a bad reflectivity.