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Slope Stability Monitoring of the Urban Boundary Layer of Hills in Athens City by Means of MTInSAR

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In many urban areas of the world, the issues associated with rocky slope instability are numerous, ranging from first-time rapid rockfalls to reactivated slow rock mass slides and from minor, localized failures to broader catastrophic events. A variety of factors, such as the topography, geological - geotechnical structure of the formations and environmental conditions control the occurrence of slope failures (Chowdhury and Flentje, 2011). The growth of urban population is responsible for inevitable expansion of urban centres adjacent to hazardous hilly regions. As a result, stability concerns arise for the safety of humans and the infrastructure. The need to predict and prevent these slope failures is critical. Despite the extremely slow rates of hillslope movements, imperceptible to the optical observation, the cumulative displacement over a period of time may cause considerable risk to manmade structures and increase vulnerability. Although authorities have general restrictions prohibiting building on slopes exceeding a certain degree of incline, other effects triggering slope instability should also be considered in mass movement assessments when projecting a complete urban growth plan.

In recent years, integrated remote sensing techniques based on space-based SAR interferometry techniques could become the key method to identify and predict slope instabilities. Since 90's differential repeat-pass interferometry radar (DInSAR) based on SAR images processing has proven an interesting tool for the measurement and observation of ground deformation (Massonnet and Rabaute, 1993). Nowadays, using large stacks of SAR images acquired over the same area, long deformation time series can be analysed using multitemporal differential SAR interferometry techniques which overcome several limitations of repeat-pass interferometry. The most important advantage of the method is the ability to construct maps of yearly rates of ground displacement or the change to the rates at millimetric scale. Space-based SAR interferometry techniques could become an effective tool for prediction of slope instabilities and identification of locations, where potential slope failures may appear and human interventions could cause instability (Di Martire et al. 2012, Burns S.F. 2015).

The main purpose of this study is the slope stability monitoring of Athens city hills. In the case of Athens progressive residential development has been taking place bellow the shadow of steep rocky hills of the city centre. It is worth mentioning that some of the most renowned ancient monuments in the city are founded on these hills.
The Athens Basin represents a complex neotectonic asymmetric graben bounded by NNE-SSW marginal faults (Papanikolaou et al., 2004). The basin is surrounded by the mountains of Aegaleo, Parnitha, Pendeliko and Hymettus. The southern and south-western part of the basin is open towards the Saronikos Gulf forming a shoreline of about 47 km. A number of historical hills are distributed within the basin, Acropolis, Nymphs, Philopappou, Pnika, Areopagus, Lycabettus and Tourkovounia. Based on the comparative evaluation of the geological maps and the available literature it is summarized that the Athens hilltops are formed by light to dark grey, thickly bedded to massive and occasionally medium bedded, recrystallized Upper Cretaceous limestone with numerous joints and karstic cavities. These limestone masses are a member of the upper calcareous horizon of the lithostratigraphic series of the alpine formations that were overthrusted the "Athens Schist" formation that constitute the basement of many parts of Athens Basin. The limestones overlie a marly horizon which covers the Athens Schist series, including schists, shales, sandstones, marls and limestones (Koukis and Sabatakakis, 2000). In places the limestone hills are covered by post-alpine deposits. The neotectonic structure of the broader Athens area comprises a number of major tectonic fractures with E-W and NW-SE strike direction (Papanikolaou et al., 2004). It can be determined that the limestone outcrops were subjected to a NNE-SSW tensile tectonic stress field which formed faults, mainly normal throughout the calcareous mass. Although the limestones have excellent mechanical characteristics they are fractured by numerous joint sets and are intensively weathered forming karstic fissures often 0.5 to 2 m wide and in case of Tourkovounia the voids reach 15m width (Karfakis and Loupasakis, 2006). The karstificated fractured zones represent areas of slope instability and may cause differential settlements of structures and even the failure of the foundation of residences.

Taking into consideration all these points Athens hillslopes' monitoring is an indispensable and essential issue due to its nature to provide support for slope stability risk assessment in urban and suburban cases.
The current research work aims to examine the contribution of high resolution radar satellite images and specifically TerraSAR-X stripmap in the mapping of low rate land displacement over the urban boundary layer of hills in Athens city by means of MTInSAR for the period 2012-2016. In addition, DEM and DEM-derived spatial models have been created and used. Analysis of the results shows that generally the urbanised slopes in Athens hills are stable. Patterns of displacement are locally observed and are of minor importance. Nonetheless, a more detailed knowledge of the local conditions of the limestone outcrops is needed by fieldwork. The methodologies applied proved an effective way to describe the potential behavior of the rock mass with respect to the probability of occurrence of slope displacements.

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