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Landscape roughness analysis of Mt. Etna volcanic complex detected via fractal geometry

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During the last years several aspects relevant to volcanic activity have been analyzed in fractal context. These studies have been aimed at identifying the power laws that govern the magma fragmentation processes and/or the classification of different geological processes. In this work we exploit the algorithm proposed by Di Martino et al. (2012) that allows retrieving the fractal dimension of a natural surface starting from its corresponding Synthetic Aperture Radar (SAR) image. Such an algorithm is based on an analytical model that links the stochastic characterization of a single SAR amplitude image to the fractal dimension of the observed surface, modeled via a fractional Brownian motion (fBm) process. The considered SAR image processing provides – as an output product – the pixel by pixel map of the fractal dimension of the scene observed by the sensor. Previous works demonstrated that the fractal dimension of lava flows is strictly connected to the natural surface roughness. Moreover, Pepe et al. (2012) showed the possibility of characterizing the single volcanic structures by means of the fractal dimension values retrieved from the corresponding SAR images. In the present work we consider a data-set of Cosmo-SkyMed high resolution images acquired over the Mt. Etna volcanic complex (South Italy), spanning the 2009 – 2011 time period. Starting from the SAR amplitude images of the considered data-set, we generated the corresponding fractal dimension maps that were subsequently co-registered each other, thus retrieving the fractal dimension time-series of the Mt. Etna volcano. Then, by averaging the so-computed fractal dimension maps with respect to time we generated a map of the mean fractal dimension of the investigated area. This procedure allows significantly improving the quality of the final fractal dimension map, as the average operation reduces the noise (due to the speckle effect on SAR images) present on each fractal map. Besides, the so-obtained mean fractal dimension map was quantized in order to identify and aggregate areas that are homogeneous from a fractal viewpoint, i.e. areas having a similar surface roughness. The comparison with the geological map of Mt. Etna volcanic complex reveals that the level of roughness is strictly connected with the lava flow age. More specifically, the roughness of lava flows, which is measured by the fractal dimension, decreases with the increasing of time. In other words, our analysis demonstrates that the volcanic depositional processes of the lava flows produce surfaces with high fractal dimension (roughness), whereas the exogenous phenomena, as the erosion processes, significantly reduce the fractal dimension associated with eruptive mechanisms.
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