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Analysis of the fractal dimension of volcano geomorphology through Synthetic Aperture Radar (SAR) amplitude images acquired in C and X band.

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Abstract
In the last two decades several aspects relevant to volcanic activity have been analyzed in terms of fractal parameters that effectively describe natural objects geometry. More specifically, these researches have been aimed at the identification of (1) the power laws that governed the magma fragmentation processes, (2) the energy of explosive eruptions, and (3) the distribution of the associated earthquakes. In this paper, the study of volcano morphology via satellite images is dealt with; in particular, we use the complete forward model developed by some of the authors (Di Martino et al., 2012) that links the stochastic characterization of amplitude Synthetic Aperture Radar (SAR) images to the fractal dimension of the imaged surfaces, modelled via fractional Brownian motion (fBm) processes. Based on the inversion of such a model, a SAR image post-processing has been implemented (Di Martino et al., 2010), that allows retrieving the fractal dimension of the observed surfaces, dictating the distribution of the roughness over different spatial scales. The fractal dimension of volcanic structures has been related to the specific nature of materials and to the effects of active geodynamic processes. Hence, the possibility to estimate the fractal dimension from a single amplitude-only SAR image is of fundamental importance for the characterization of volcano structures and, moreover, can be very helpful for monitoring and crisis management activities in case of eruptions and other similar natural hazards. The implemented SAR image processing performs the extraction of the point-by-point fractal dimension of the scene observed by the sensor, providing - as an output product - the map of the fractal dimension of the area of interest. In this work, such an analysis is performed on Cosmo-SkyMed, ERS-1/2 and ENVISAT images relevant to active stratovolcanoes in different geodynamic contexts, such as Mt. Somma-Vesuvio, Mt. Etna, Vulcano and Stromboli in Southern Italy, Shinmoe in Japan, Merapi in Indonesia. Preliminary results reveal that the fractal dimension of natural areas, being related only to the roughness of the observed surface, is very stable as the radar illumination geometry, the resolution and the wavelength change, thus holding a very unique property in SAR data inversion. Such a behavior is not verified in case of non-natural objects. As a matter of fact, when the fractal estimation is performed in the presence of either man-made objects or SAR image features depending on geometrical distortions due to the SAR system acquisition (i.e. layover, shadowing), fractal dimension (D) values outside the range of fractality of natural surfaces ($2 < D < 3$) are retrieved. These non-fractal characteristics show to be heavily dependent on sensor acquisition parameters (e.g. view angle, resolution). In this work, the behaviour of the maps generated starting from the C- and X-band SAR data, relevant to all the considered volcanoes, is analyzed: the distribution of the obtained fractal dimension values is investigated on different zones of the maps. In particular, it is verified that the fore-slope and back-slope areas of the image share a very similar fractal dimension distribution that is placed around the mean value of $D=2.3$. We conclude that, in this context, the fractal dimension could be considered as a signature of the identification of the volcano growth as a natural process.
The COSMO-SkyMed data used in this study have been processed at IREA-CNR within the SAR4Volcanoes project under Italian Space Agency agreement n. I/034/11/0.

References
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