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Multiscale roughness characterization from multiresolution remote sensing data acquired over the Asal-Ghoubbet rift, Republic of Djibouti

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Surface roughness is a key parameter in soil physics which controls many surface processes at a wide range of scales: microscopic and mesoscopic scales from 10 μm to 1 cm (soil particles or regolith), macroscopic scale from 1 cm to 1 m (clods, aggregates of rock or ice, micro-fractures or lava flows), and topographic scale from 1 m to several kilometers (faults, hills, craters or mountains).

While it is recognized that surface roughness is strongly scale-dependent, it is often expressed as an integrated parameter (root-mean-square height, correlation length, tortuosity index), which does not address the full range of spatial features present on the surface. In particular, the Hapke roughness parameter is defined as the mean slope angle of the facets composing the surface, integrated over all scales from the microscopic to the macroscopic scales. Yet its physical meaning is still a question at issue, as the scale at which it occurs is undefined in the model.

Photogrammetry has been shown to be an inexpensive and powerful method for topography reconstruction from optical data. We took advantage of a series of 21 Pléiades-1B images (video acquisition mode) to build a global digital elevation model (DEM) over the Asal-Ghoubbet rift, Republic of Djibouti. Additionally, we acquired close range data with a quadcopter equipped with a HD camera. Topography at four scales is available: 1 m with the satellite images (694 km), 1 cm with the drone flying at medium altitude ($\sim$100 m), 1 mm with the drone flying at low altitude ($\sim$10 m), and <1 mm with the handheld camera ($\sim$1.5 m). We have defined twenty-two sites, 20 $\times$ 30 m in dimension, corresponding to a wide range of volcanic and sedimentary terrains, from regolith-like structures to very rough lava flows, over which DEMs have been generated at two or more resolutions.

In order to investigate the contribution of each scale to the integrated roughness and to test the ability of the Hapke model to retrieve a roughness parameter that depicts well the ground truth, we applied two multiscale methods: fractal analysis and wavelet transform. The latter allows splitting the frequency band of a signal in several sub-bands, each of which corresponding to a spatial scale. By analyzing data acquired at Piton de la Fournaise Volcano, Réunion island, we showed that wavelet transform is a very powerful tool for characterizing roughness regimes over scales and that sub-centimeter surface features mostly explain the integrated roughness for meter-sized surfaces (Labarre et al., 2017, Icarus). This has to be confirmed on Djibouti terrains, for which we have a broader range of resolutions and larger areas.