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Roughness of fault surfaces: implications of high resolution topography measurements at various scales

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The topography of active faults surfaces should control the heterogeneity of stress concentration, and therefore earthquake nucleation and rupture propagation. We have used 3D portable laser scanners to map, at various spatial scales, exposed slip planes in limestones of the Magnola normal fault system (Apennines, Italy). At the field scale, digital elevation models of the fault roughness were obtained over surfaces of 5 $m^2$to 200 m^2 at a resolution of 2 cm. At the laboratory scale, the three-dimensional geometry was measured on two slip planes using a laser profilometer with a pixel resolution of 0.025 mm. Using several independent signal processing tools (Fast Fourier Transform, correlation function, wavelets), we demonstrate that the roughness of these surfaces exhibit a self-affine topography, observed over a wide range of scales. Moreover, the scaling exponent depends on the direction along the fault. It is smaller in the direction of slip (parallel to the mechanical striation) than perpendicular to it. We observe this difference both at the field scale and at the laboratory scale.