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Characterising soil surface roughness with a frequency modulated polarimetric radar

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Soil surface roughness is considered crucial for soil erosion as it determines the effective surface exposed to the raindrop impact. It regulates surface runoff velocity and it causes runoff concentration. But a comprehensive characterisation of the shape of the soils' surface is still difficult to achieve. Photographic systems and terrestrial laser-scanning are nowadays able to generate high resolution DEMs, but the derivation of roughness parameters is still not clear.

Spaceborne radar systems are used for about 3 decades for earth survey. Spatial soil moisture distribution, ice sheet monitoring and earth-wide topographic survey are the main objectives of these radar systems, working generally with frequencies <10 GHz. Contrasting with this, technologies emitting frequencies up to 77 GHz are generally used for object tracking purposes. But it is known, that the reflection characteristics, such as intensity and polarisation, strongly depend on the properties of the target object.

A new design of a frequency modulated continuous wave radar, emitting a right hand shaped circular polarization and receiving both polarization directions, right and left-hand shaped, is tested here for its ability to detect and quantify different surface roughness.

The reflection characteristics of 4 different materials 1) steel, 2) sand (0,5-1 mm), 3) fine (2-4 mm) and 4) coarse (15-30 mm) rock-fragments and different roughness as well as moisture content are analysed. In addition, the signals are taken at 2 different angles to the soil's surface (90° and 70°). For quantification of the roughness, a photographic method (Structure-from-Motion) is applied to generate a detailed DEM and random roughness (RR) is calculated. To characterise the radar signal, different ratios of the reflected channels and polarisations are calculated.

The signals show differences for all substrates, also clearly visible between sand and fine rock fragments, despite a wavelength of 1 cm of the electromagnetic waves. A systematic change of the signals with changing roughness is also observed. Measurements show a significant influence of the angle of observation.

Soil moisture shows also an influence on the reflected signal, but is quite well differentiable to the effects of the shape of the soil's surface.

The results show that polarimetric radar technology may be suitable to characterise the surface of soils, but still faces a big lack of knowledge on how to quantify and differentiate the different signals, how to handle variable observation angles, and finally how to characterise roughness.