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Roughness Parameterization Using Full-Waveform Airborne LiDAR Data

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Detailed topographic information is of high importance for studying and characterizing earth surface morphology and processes. Airborne LiDAR, also referred to as Airborne Laser Scanning, provides such a tool for the acquisition of highly detailed three-dimensional elevation information. This study examines the potential of the newest generation of LiDAR sensors, the full-waveform recording small-footprint airborne systems, for surface roughness characterization. Surface roughness maps are valuable datasets, for example to investigate landslide morphology and activity and are input layers for distributed models such as hydrological/hydrodynamic or energy balance models. Full-waveform LiDAR provides additional attributes for each detected echo (i.e. range measurement) with (i) the signal intensity characterizing the reflectance of the scanned surface and (ii) the echo width standing for the elevation distribution of the scatterers of a distinct target hit by the laser beam. Particularly, the echo width contains information on the vertical variation of the surface in the planimetric scale of the laser footprint size, which is generally in the sub-meter domain when using small-footprint airborne sensors (e.g. 0.2-0.5m diameter). The vertical resolution depends on the waveform digitizing interval, which is typically 1 ns.

This contribution introduces two LiDAR-derived surface roughness parameterizations in the sub-meter scale based on (i) the vertical distribution of the high density point cloud (>40 points/square meter) and (ii) the echo width using only laser points belonging to the terrain (bare Earth). Based on resultant roughness images the parameterizations are compared and discussed. The echo width is a suitable measure for surface roughness in the sub-meter scale showing comparable spatial patterns as the geometrical parameterization using very high density data. As a consequence the echo width roughness parameter allows for a sub-meter roughness description even with moderate point densities. For example, footprint diameters of 0.5m and a homogeneous point distribution of 4 laser points per square meter suffice to reach nearly full coverage and sampling of the surface. Further investigation will concentrate on the quantitative evaluation of the full-waveform derived roughness parameter using high resolution (<dm) in-situ data, such as terrestrial LiDAR data, and conventional roughness field measurements (e.g. manual indirect assessment of roughness classes based on the vegetation cover).

The proposed surface roughness parameterization offers an automatic and standardized procedure to derive objective and metric roughness data layers of large areas with full coverage using the full information provided by state-of-the-art LiDAR sensors. The most detailed scale possible with airborne LiDAR, the sub-footprint scale, can be approached in a cost-efficient manner with assessable quality.

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