QUANTIFYING THE SURFACE ROUGHNESS OF THE 2014–2015 HOLUHRAUN LAVA FLOW USING RADAR AND LIDAR REMOTE SENSING. G. D. Tolometti1, C. D. Neish1, G. R. Osinski1, A. Kukko2, J. R. C. Voigt1, C.W. Hamilton3. 1University of Western Ontario, London, ON (gtolomet@uwo.ca), 2Centre of Excellence in Laser Scanning Research, Finnish Geodetic Institute, 3Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ.

Introduction: In this work, we study the surface roughness of the 2014–2015 Holuhraun lava flow-field in Iceland as a planetary analogue. We seek to use this lava flow to improve our understanding of the types of volcanic eruptions that have occurred on Mars. Measuring surface roughness at different scales (e.g., cm vs. m) ultimately provides information about the processes involved in volcanic eruptions, which is vital for inferring the emplacement styles of lava flows on other planetary bodies [1]. Using UAVSAR L-Band (λ = 24 cm) quad-pol radar data and a backpack mounted kinematic mobile LiDAR scanning (KLS) system, we analyze the surface roughness of the 2014–2015 Holuhraun lava flowfield. From this data, we seek to make more refined interpretations about the emplacement of lava flows on Mars, since Holuhraun exhibits analogous flow morphologies and roughness textures to Martian lava flows [2].

Surface Roughness of Lava Flows: On terrestrial lava flows, decimetre to metre-scale surface roughness features are typically associated with disrupted surfaces associated with increases in shear stress and viscosity (e.g., clinkered 'a`ā) or mechanical fracturing of a quenched crust (e.g., ‘rubbly pāhoehoe’) [2]. Centimetre-scale features are typically associated with viscoelastic deformation of the lava crust (pāhoehoe ropes or spinose clinkers) [2]. As a result, analyzing lava flow surface roughness at the decimetre to centimetre-scale is important for planetary analogue research attempting to infer the volcanic history of other planetary surfaces.

A field deployment, funded by the Canadian Space Agency (CSA) and in collaboration with the NASA Goddard Instrument Field Team (GIFT), was conducted in 2019 to study the diverse surface roughness of lava flows at the 2014–2015 Holuhraun lava flow field. Five lava flow types were identified and studied in detail: rubbly, spiny, ‘undifferentiated’, pāhoehoe, and shelly. The ‘undifferentiated’ type is a combination of lava flow textures and morphologies, mapped by Voigt et al. [4] using aerial remote sensing data and field observations. The surface roughness of the lava flows is not homogenous across the entire lava field. For example, the spiny lava flow exhibits lava-rise pits, polygonal plates (similar to the platy-ridged lava flow textures on Mars [2]), as well as tumuli and lobate units with toes, which are located along the western margin of the lava field.

Data and Methods: To compare decimetre and centimetre-scale roughness, we correlate the circular polarization ratio (CPR) from the UAVSAR data with roughness statistics from the LiDAR data to study relationships between decimetre and centimetre-scale surface roughness at the Holuhraun lava flow-field.

Radar Remote Sensing: A total of two UAVSAR flight paths, collected in May 2015, were processed from the UAVSAR site (https://uavsar.jpl.nasa.gov/cgi-bin/data.pl) using the Interactive Data Language (IDL). The CPR and total backscatter (S1) of the two images were calculated at a spatial resolution of 8 m/pixel and incidence angles ranging from 50°–53°. The two flight paths were calibrated, projected and speckle filtered (low-pass) before CPR values were extracted from the data. CPR of each lava flow type at Holuhraun was extracted using the zonal statistics tool in ArcGIS.

Kinematic Mobile Scanning LiDAR System: High-resolution topography data (2.5–5 cm/pixel) was collected using the AKHKA-R3 backpack-mounted KLS system developed by Harris et al. [3]. The LiDAR instrument measures the topography of geologic features (e.g., lava flows) at resolutions comparable to radar wavelengths. It is capable of covering large areas (>2500 m²) with a vertical accuracy of ~5 mm. Surfaces are scanned along traverses by a Reigl VUX-1-HA laser line at 1 million points and 120 lines/sec, and the ground range values to the scanner are also measured. A GPS/GNSS receiver antenna attached to the LiDAR instrument provides absolute global positioning in the field. Products of the LiDAR scans are dense point clouds representing the surface in 3D. Post field processing converted the point cloud data into digital elevation models (DEM) using CloudCompare and ESRI ArcGIS programs. LiDAR scans of the five different lava flow types at Holuhraun were obtained during the field deployment. Over 12 scans (~80 × 80 m grids) were collected to analyze different types of lava flow surfaces. Each DEM contained over a million data points with 2.5–5 cm/pixel resolution.

The roughness statistics - RMS slope (Cs) and Hurst exponent (H) - were calculated from the DEMs using an IDL script. The RMS slope is the standard deviation of slope points along a defined profile length. It provides information about the roughness of surfaces because the greater the slope points along the profiles, the more irregular the surface. For H, values range from 0 to 1. If H approaches 0, it indicates that the surface becomes
smoother as the scale increases. If H approaches 1, the surface maintains its roughness despite a change in scale.

**Preliminary Results:** We plotted the CPR values from the UAVSAR L-Band data and Cs (at a reference scale of 5 cm) from the KLS LiDAR system to determine whether correlations are present between decimetre and centimetre-scale surface roughness. Figure 1 shows aerial and UAVSAR data of the Holuhraun lava field, LiDAR data of a spiny lava type (red circle in Figure 1), and CPR and Cs values from a rubbly and spiny lava type as well as a buried lava flow. The ‘buried’ datum represents the 1921 Askja lava flow buried by volcanic sediments deposited by aeolian processes. The buried lava is rough under radar because the L-Band wavelength is able to penetrate through the sediment [5] and scatter off the 1921 lava surface. The sediment, however, does make the surface smoother at the centimetre-scale, hence the low Cs (~3.2°). At the decimetre-scale, the lava flows all appear relatively similar (CPR 0.42–0.55), but their surface roughness is significantly different at the centimetre-scale. The distribution of Cs values for the spiny lava is a result of local heterogeneity in surface roughness. The spiny lava with Cs of 13.4° is a series of tumuli and toes along the lava field margin while the other two points (12.2° and 15.6°) are spiny surfaces with inflation pits and polygonal plates. More LiDAR data is currently under analysis to add to the plot in Figure 1. With more data, we will work to determine if the different lava flow surface textures can be differentiated using LiDAR and RADAR data.

**Acknowledgments:** Special thanks to the CSA for funding the 2019 field deployment and this research, as well as to NASA GIFT scientists for their expertise and logistical assistance in the field.


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**Figure 1.** (a) Aerial image mosaic (15 cm/pixel) of the Holuhraun lava flow acquired by Loftmyndir. The red circle marks where the LiDAR data in (c) was collected in the field. (b) CPR datasets calculated from quad pol radar data collected from two UAVSAR flights in May 2015. (c) Section of a Digital elevation model (DEM) of a spiny lava flow with polygonal plates. Pixel resolution is 5 cm/pixel. The entire LiDAR DEM covers an 80 x 80 m grid. The margins of the plates and their rift zones are easily distinguishable in the data. Collapsed inflated pits are areas with elevation points <775 m (marked as green to blue colour). (d) Cs and CPR data from the spiny, rubbly, and buried 1921 Askja lava flow plotted to observe correlations between decimeter and centimeter-scale roughness.