Surface roughness and polarimetric SAR signatures of geologic units in the Canadian Arctic

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ABSTRACT

This study reports the relationship between the surface roughness and polarimetric SAR signatures of geologic units in the Canadian Arctic using C-band RADARSAT-2 quad polarimetric data. Extensive glacial activity and freeze-thaw processes in the Arctic have resulted in different surface roughness depending on rock type and its resistance to weathering. In this work, we investigate how surface roughness is related to geology and how polarimetric SAR signatures can be characterized depending on different surface roughness. The study areas are the Tunnunik impact structure (centred at 72°28'N, 113°56'W) on Victoria Island, N.W.T., and the Haughton impact structure (75°22'N, 89°41'W) on Devon Island, Nunavut (Osinski et al. 2001 and 2013). These meteorite impact structures exhibit highly localized geological features, complex geology, and exposure of multiple subsurface lithologies (Tornabene et al. 2005), which can facilitate and supplement geologic mapping in the Canadian Arctic. First, we estimated surface roughness by applying the semi-empirical radar scattering model by Oh (2004) and compared it to surface roughness measurements of high-resolution topography data acquired in the field. Topography data were collected from a total of 11 and 19 sites in the Tunnunik and Haughton impact structures, respectively, using a tripod mounted LiDAR scanning system. The surface roughness (i.e. Root Mean Square (RMS) height) values were underestimated for weathered rock surfaces, which is due to the saturation feature of the model at ks>3 (where k=wavenumber and s=RMS height). Based on our measurements, we suggest a modified scattering model for rough and blocky rock surfaces. We also produced three-dimensional polarimetric SAR signature plots of co-polarization responses simulated at various linear, elliptical, and circular polarization bases for different geologic units with a variety of surface roughness. For example, very smooth glacial sediments showed a concentric peak at the HH polarization (where ellipticity angle = 0° and orientation angle = 0°) resulting in a significant variation at linear polarizations, while rough carbonate rock units showed very little variation. This suggests that the variation of linear co-polarization responses is highly related to surface roughness and offers a promising new parameter for characterizing surface roughness in addition to pedestal heights (i.e. normalized ratio of the minimum to the maximum response).

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