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Subglacial roughness of the Greenland Ice Sheet: relationship with contemporary ice velocity and geology

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The nature of the subglacial environment of the Greenland Ice Sheet (GrIS) is poorly constrained, both in its bulk (e.g. geology, sediment and presence of water) and interfacial properties (e.g. roughness and geotechnical bed properties). There is, therefore, limited understanding of how spatially heterogenous subglacial properties relate to ice-sheet motion. Here, via analysis of two decades worth of CReSIS radio-echo sounding (RES) data, we present a new systematic analysis of subglacial roughness beneath the GrIS. Subglacial roughness, defined here in general terms as the relative variation in bed elevation, is quantified from RES using two independent methods. First, we use the variability of along-track topography (enabling assessment of roughness anisotropy), and second, we infer roughness from the electromagnetic scattering of the bed-echo (enabling assessment of finer-scale information).

Here, we present a new systematic, ice-sheet-wide, analysis of subglacial roughness beneath the GrIS. We depict the spatial distribution of subglacial roughness and quantify the relationship with ice velocity (in magnitude and flow-direction). In fast flowing regions 'topographic roughness' exhibits strong anisotropy, and an exponential scaling relationship with ice velocity parallel, but not perpendicular, to flow direction. We demonstrate that spatial variation in this relationship can be explained by an interplay between geology and topographic-constraint on ice flow in major outlet regions. In many slow flowing regions both roughness methods indicate spatially coherent regions of smooth bed, which, combined with analyses for underlying geology and lithology, we conclude is likely due to the presence of a hard bed. In this vein, this study provides scope for a spatially-variable hard bed–soft bed boundary constraint for ice-sheet models.