Geophysical Research Abstracts
Vol. 19, EGU2017-9528, 2017
EGU General Assembly 2017

Self-affine subglacial roughness: consequences for radar scattering and basal thaw discrimination from radio-echo sounding

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Subglacial roughness can be determined at variety of length scales from radio-echo sounding (RES) data; either via statistical analysis of along-track topography, or inferred from basal radar scattering. Past studies have demonstrated that subglacial terrain exhibits self-affine (power-law) roughness scaling behaviour, but existing radar scattering models don't take this into account. Here we introduce a self-affine statistical framework that, for the first time, enables a consistent integration of roughness determined from subglacial topography with basal radar scattering. Using RES data from northern Greenland, we demonstrate that radar scattering is strongly topographically controlled by the Hurst (roughness power-law) exponent. Notably specular reflections are confined to regions with lower Hurst exponent, with diffuse scattering more typical in regions with higher Hurst exponent.

Considering this relationship, we then assess the consequences of our self-affine roughness framework for the discrimination of basal thaw from RES. Unambiguous discrimination of the basal thermal state of ice sheets from RES is a complex, and currently unsolved, problem, with conventional basal reflection analysis greatly limited by uncertainty in radar attenuation. To mitigate the ambiguity of reflection analysis, the presence of a specular bed echo - as occurs for reflection from electrically deep subglacial lakes - has been proposed to serve as a necessary criteria for positive discrimination of basal thaw. Via a comparison between our RES-derived data and a recent prediction for the basal thermal state, we demonstrate that predicted thawed regions in northern Greenland exhibit an overall more diffuse scattering signature than frozen regions. This is in contradiction with the prior use of high reflection specularity as necessary criteria for the presence of basal thaw, and indicates that radar scattering is best viewed as being under direct topographic, rather than thermal, control.