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An ice-sheet wide framework for englacial attenuation and basal reflection from ice penetrating radar data

Thomas Jordan (1), Jonathan Bamber (1), Chris Williams (1), John Paden (2), Martin Siegert (3), Philippe Huybrechts (4), Olivier Gagliardini (5), and Fabien Gillet-Chaulet (6)

(1) Bristol Glaciology Centre, School of Geographical Sciences, University of Bristol, Bristol, UK, (2) Center for Remote Sensing of Ice-Sheets, University of Kansas, Lawrence, USA, (3) Grantham Institute and Earth Science and Engineering, Imperial College, University of London, London, UK, (4) Department of Geography, Vrije Universiteit Brussels, Brussels, Belgium, (5) Le Laboratoire de Glaciologie et Géophysique de l'Environnement, University Grenoble Alpes, Grenoble, France, (6) Le Laboratoire de Glaciologie et Géophysique de l'Environnement, Centre National de la Recherche Scientifique, Grenoble, France

Radar-inference of the bulk material properties of glacier beds, most notably identifying basal melting, is, in general, derived from the basal reflection coefficient. Unambiguous determination of basal reflection is primarily limited by uncertainty in the spatial variation of the englacial attenuation of the radio wave. Arrhenius temperature models predict that, over the extent of an ice-sheet, the depth-averaged attenuation rate can vary by a factor of $\sim$ 6-8. However, existing 'bed-returned power' radar algorithms for basal reflection assume stationarity in the depth-averaged attenuation rate. These radar algorithms are therefore only applicable to local regions of ice-sheets, and are suspected to yield erroneous values for basal reflection.

Here we introduce an automated, Greenland wide, framework for radar-inference of englacial attenuation and basal reflection. To demonstrate its efficacy we apply it to recent, (2011-2014), Operation Ice Bridge data. A central feature is the use of a prior Arrhenius temperature model to estimate the spatial variation in radar attenuation as a first guess input for the radar algorithm. Specifically, this estimate is used to test for sample regions where the assumption of stationarity is valid within some specified tolerance, and to modify the bed-returned power method for local attenuation variation within each sample region.

The radar algorithm is validated in a number of different ways. Firstly, we demonstrate regions of solution convergence for two different input temperature fields; the steady-state temperature fields for the SICOPOLIS and GISM ice-sheet models. Secondly, we show that, for regions of data coverage overlap, the algorithm is repeatable for different field campaign years. Thirdly, we illustrate that, for the coverage achieved, the predicted range for the basal reflection coefficient is $\sim$ 20 dB, which is consistent with the predicted range for the basal material interface ($\sim$15 dB) and our uncertainty estimate ($\sim$5 dB). Finally, using the attenuation rate solution as a proxy for depth-averaged temperature, we demonstrate agreement with ice core temperature profiles and the known temperature biases of the ice-sheet models.

In future work the new algorithm will be applied to $\sim$ 10 years of Operation Ice Bridge data from the Greenland Ice-Sheet. The overall goal is produce digital data products for basal reflection and basal melt that will accompany the next generation of Greenland bed elevation data products.