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How to measure the thickness of dirty, wet Himalayan glaciers with low-frequency radar

Hamish Pritchard (1), Christoph Mayer (2), and Astrid Lambrecht (2)

(1) British Antarctic Survey, Cambridge, UK (hprit@bas.ac.uk), (2) Bavarian Academy of Sciences and Humanities, Munich, Germany

High Mountain Asia holds 90,000 glaciers of which only around ten have any ice thickness measurements at all, and on any one glacier these tend to be sparsely distributed and not well suited to calculating glacier ice volume. Existing regional ice volume estimates come from indirect methods (based on area-volume scaling or modelled ice flux) that are poorly constrained in this region and so have a wide spread (e.g., 1670 to 6500 km3 (Bolch et al., 2012; Huss and Faranotti, 2012)). Sufficiently extensive measurements of ice thickness can be used to calculate ice volumes directly, or can be used to calibrate and hence improve the indirect estimates. Unfortunately, measuring ice thickness on such glaciers on a useful scale is difficult. They are often remote with very rough, water-logged and debris-covered ablation areas, a lossy environment for radar and quite different to clean and cold polar glaciers that lend themselves well to rapid radar surveying by snowmobile or aeroplane. A possible solution is to develop a low-frequency, helicopter-borne radar that can access remote mountain valleys and penetrate to the beds of the thickest of these mountain glaciers. But the lower the frequency, the longer the dipole and the more cumbersome the radar: what frequency do we need to detect the bed? Here we report results from pilot studies on the ground in the Langtang Valley and on Ngozumpa, Nepal's largest glacier, that show how bed detectability depends on frequency both in terms of signal attenuation and clutter, and what this means for a planned regional-scale glacier thickness surveys.