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From bed topography to ice thickness: GlaRe, a GIS tool to reconstruct the surface of palaeoglaciers

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We present GlaRe, A GIS tool that automatically reconstructs the 3D geometry for palaeoglaciers given the bed topography. This tool utilises a numerical approach and can work using a minimum of morphological evidence i.e. the position of the palaeoglacier front. The numerical approach is based on an iterative solution to the perfect plasticity assumption for ice rheology, explained in Benn and Hulton (2010). The tool can be run in ArcGIS 10.1 (ArcInfo license) and later updates and the toolset is written in Python code.

The GlaRe toolbox presented in this paper implements a well-established approach for the determination of palaeoglacier equilibrium profiles. Significantly it permits users to quickly run multiple glacier reconstructions which were previously very laborious and time consuming (typically days for a single valley glacier). The implementation of GlaRe will facilitate the reconstruction of large numbers of palaeoglaciers which will provide opportunities for such research addressing at least two fundamental problems:

1. Investigation of the dynamics of palaeoglaciers. Glacier reconstructions are often based on a rigorous interpretation of glacial landforms but not always sufficient attention and/or time has been given to the actual reconstruction of the glacier surface, which is crucial for the calculation of palaeoglacier ELAs and subsequent derivation of quantitative palaeoclimatic data.

2. the ability to run large numbers of reconstructions and over much larger spatial areas provides an opportunity to undertake palaeoglaciers reconstructions across entire mountain, ranges, regions or even continents, allowing climatic gradients and atmospheric circulation patterns to be elucidated.

The tool performance has been evaluated by comparing two extant glaciers, an icefield and a cirque/valley glacier from which the subglacial topography is known with a basic reconstruction using GlaRe. Results from the comparisons between extant glacier surfaces and modelled ones show very similar ELA values on the order of 10-20 meter error (which would account for a 0.065-0.13 K degree variation on a typical -6.5 K altitudinal gradient), and these can be improved further by increasing the number of flowlines and using F factors where needed. GlaRe is able to quickly generate robust palaeoglacier surfaces based on the very limited inputs often available from the geomorphological record.