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A field and glacier modelling based approach to determine the timing and extent of glaciation in southern Africa

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Moraines identified at high-altitude sites in southern Africa and dated to the last glacial maximum (LGM) indicate that the climate in this region was cold enough to support glaciers. Small glaciers are very sensitive to changes in temperature and precipitation and the identification of LGM moraines in southern Africa has important palaeoclimatic implications concerning the magnitude of temperature change and the seasonality of precipitation during the last glacial cycle. This paper presents a refined time-frame for likely glaciations based on surface exposure dating using Cl-36 at sites in Lesotho and reports results of a 2D glacier energy balance and ice flow modelling approach (Plummer and Phillips, 2003) to evaluate the most likely climatic scenarios associated with mapped moraine limits. Samples for surface exposure dating were collected from glacially eroded bedrock at several locations and yield ages within the timescale of the LGM. Scatter in the ages may be due to insufficient erosion of the bedrock surface due to the small and relatively thin nature of the glaciers.

To determine the most likely climatic conditions that may have caused the glaciers to reach their mapped extent, we use a glacier-climate model, driven by data from local weather stations and a 30m (ASTER) DEM (sub-sampled to 10m) representation of the topographic surface. The model is forced using modern climate data for primary climatic controls (temperature and precipitation) and for secondary climatic parameters (relative humidity, cloudiness, wind speed). Various sensitivity tests were run by dropping temperature by small increments and by varying the amount of precipitation and its seasonality relative to present-day values. Results suggest that glaciers could have existed in the Lesotho highlands with a temperature depression of $\sim$5-6 ºC and that the glaciers were highly sensitive to small changes in temperature. The additional accumulation of mass through wind redistribution appears to have been important at all but a few sites, suggesting that this must be taken into account when trying to determine a regional climate signal from small glaciers. Our dating and glacier-climate model simulations reinforce the idea that small glaciers existed in the Lesotho Highlands during the LGM, under climatic scenarios that are consistent with other proxy records.

Plummer, M.A. and Phillips, F.M. (2003) 2-D numerical model of snow/ice energy balance and ice flow for paleoclimatic interpretation of glacial geomorphic features. Quaternary Science Reviews, 22, 1389-1406.