Geophysical Research Abstracts
Vol. 18, EGU2016-15637, 2016
EGU General Assembly 2016

Scale effects impeding palaeoclimate reconstructions from mountain glaciers

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Lewis Glacier on Mt. Kenya lost more than 80% of its area since its last stadial in the late 19th century (L19). Can we reconstruct climate conditions sustaining Lewis Glacier in its L19 extent? First, we optimized a physical based energy and mass balance model to the modern-day glacier extent with in situ observed climate observations. Second, from this record we constructed synthetic climate scenarios (based on coupled parameter perturbation applying a simple weather generator concept) as input for the mass balance model. These scenarios reflect the observed variability in precipitation and air temperature over recent decades, reproduce the observed mass balance variability for the modern-day glacier extent, and quantify the glacier's sensitivity to climate.
Using the mass balance model as optimized for the modern-day glacier on the L19 extent, driven by climate perturbations most favourable to glaciation, results in negative mass balances. This would traditionally be interpreted to mean that even the extremes of the present-day climate are incapable of reproducing the L19 conditions.
Alternatively or additionally, the modelling suggests that the L19 Lewis Glacier could be sustained if a favourable climate perturbation is applied in conjunction with a modification of the gradients used to extrapolate the climate observations over the glacier surface from those optimized for the very small modern-day glacier. Such a modification might be justifiable, where the modern-day glacier is so small that it is unlikely to generate significant microclimatological effects that would be expected for the larger L19 extent, when e.g. the glacier filled its cirque reducing long-wave emissions from surrounding terrain drastically. In a general sense this finding indicates that extracting proxy climate conditions from a particular glacier geometry, using a modelling system optimized on a dramatically different geometry, may invalidate the approach, particularly if changes in boundary layer dynamics are substantial and not resolved in the model. This issue might warrant further investigation given that palaeoclimate reconstructions based on mountain glacier fluctuations inherently involve these scale contrasts; yet they are rarely considered in the tools used.