Supplementary Material for Doughty, A.M., Kelly, M.A., Russell, J.M., Jackson, M.S., Anderson, B.A., Chipman, J., Nakileza, B., and Dee, S.G., 2020, Modeling glacier extents and equilibrium line altitudes in the Rwenzori Mountains, Uganda, over the last 31,000 yr, *in* Waitt, R.B., Thackray, G.D., and Gillespie, A.R., eds., Untangling the Quaternary Period: A Legacy of Stephen C. Porter: Geological Society of America Special Paper 548, https://doi.org/10.1130/2020.2548(09).

Supplementary Methods

Model output contains uncertainties related to the equations, assumptions, and input climate values we use. The ice-flow model is based on the shallow-ice approximation and does not include full-stokes equations of all glacier stresses and strains. In comparison studies, the shallow-ice approximation has produced similar ice extents and thicknesses as a full-stokes model (Le Meur et al., 2004). We assume that the shallow-ice approximation will perform well in the complex topography of the Rwenzori Mountains and that characteristic sliding velocities did not change through time.

The input modern climate data are sparse and could be improved with increased weather monitoring stations. Precipitation data come from rain gauges monitored each month in the 1950s, and complications included playful leopards tipping the gauges and high evaporation rates (Osmaston, 1989). Modern temperature data come from a few years of measurements on Mt. Stanley showing relatively minor seasonal changes in temperature (Lentini et al., 2011). Although Loomis et al. (2017) advocate for a steeper lapse rate during the Last Glacial Maximum, we chose use the modern lapse rate for all simulations through the past 31 kyr. We use the modern lapse rate in the transient simulations because we do not know how the lapse rate changed through time. We suggest that future steady-state or equilibrium simulations use the steeper LGM lapse rate from Loomis et al., (2017).

We modeled CE 1995 glacier extents (Fig. S2) using all of the same climate input data as the transient simulations, but with a ΔT of -1°C and a ΔP of 0% change from modern climate conditions. Comparing the simulated glacier extents (blue) with the mapped glacier extents (red outline, Kaser and Osmaston, 2002) we can see that the model produced a surplus of ice on Mt. Stanley and a deficit of ice on Mt. Baker. Despite this difference, we consider the agreement between the mapped and simulated CE 1955 glacier extents to be close, and we did not adjust our input climate data to improve the fit.

Using a modern lapse rate of 0.0058°C/m (Loomis et al., 2017) and a temperature of -0.41°C at 4750 m asl (Lentini et al., 2011), we can estimate modern temperatures at all elevations, which results in a sea-level temperature of ~27.14°C. To estimate temperatures across the model domain (T_E), we multiply the lapse rate by the elevation of each grid cell (z) plus the sea-level temperature.

$$T_E = -0.0058 * z + 27.14 \qquad \text{(Eq. 1)}$$

TABLE S1: ELA values (m asl) for the Rwenzori for the Lake Mahoma Stage (Last Glacial Maximum) and CE 1955.

	Mt. Stanley / west	Mt. Speke / southwest and north	Mt. Baker / east and central	Reference
Last Glacial Maximum	4040	3780	3600	Kaser and Osmaston (2002)
	4050	3780	3600	Osmaston (1989)
	4250		3500	Osmaston (2004)
			<3720	This Study
CE 1955	4720	4660	4600	Osmaston (1989)
	4780			This Study

TABLE S2: Monthly values for modern precipitation and temperature.

	Precipitation (monthly proportions)[1]	Temperature (°C)[2]	Incoming shortwave radiation (W m^{-2})[2]
Jan	0.044	-0.41	117.8
Feb	0.054	-0.41	117.8
Mar	0.095	-0.19	127.5
Apr	0.114	-0.19	127.5
May	0.089	-0.19	127.5
Jun	0.064	-0.19	127.5
Jul	0.061	-0.4	121.5
Aug	0.097	-0.4	121.5
Sept	0.105	-0.49	115.6
Oct	0.118	-0.49	115.6
Nov	0.1	-0.49	115.6
Dec	0.059	-0.49	115.6

[1]New et al., 2002
[2]Lentini et al., 2011

TABLE S3. Modern climate and location information for the Rwenzori Mountains, Mt. Kenya, and Kilimanjaro. The modern glacierized extent reflects the local humidity regime (Osmaston and Harrison, 2005).

Variable	Rwenzori	Mt. Kenya	Kilimanjaro
Latitude	0.3858°N	0.1521°S	3.0674°S
Longitude	29.8717°E	37.3084°E	37.3556°E
Max. elevation	5,109 m asl	5,199 m asl	5,895 m asl
Rainy season	March-June, Sept.-Oct.	March-June, Sept.-Oct	March-June, Nov.
Annual precipitation above 4500 m asl	1800 mm a^{-1} (Osmaston, 1989)	<900 mm a^{-1} (Mizuno, 1998)	<600 mm a^{-1} (Røhr and Killingtveit, 2003)

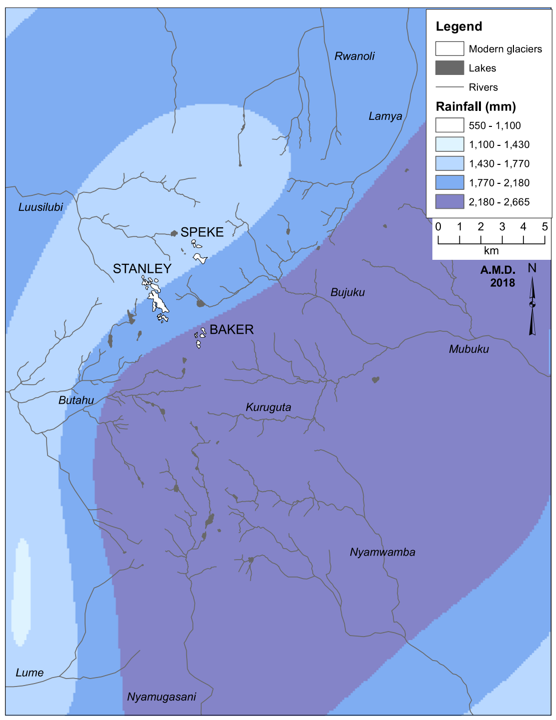

Figure S1. Annual total precipitation surface for the Rwenzori Mountains based on measurements and interpretation from Osmaston (1989).

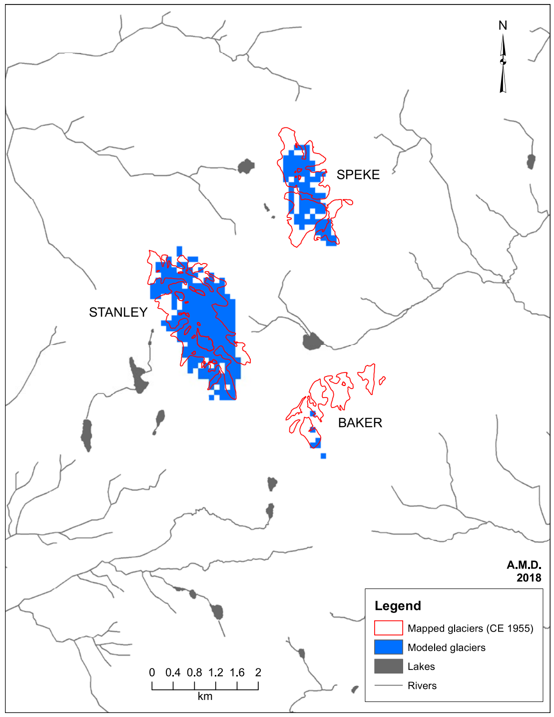

Figure S2. Map comparing modeled glacier extent (blue area, with ΔT = -1°C and ΔP = 0%) with CE 1955 glacier outlines (red outlines; Kaser and Osmaston, 2002). The modeled and mapped glacier extents provide a form of validation of modern input climate resulting in modeled glacier extents similar to those mapped in CE 1955.

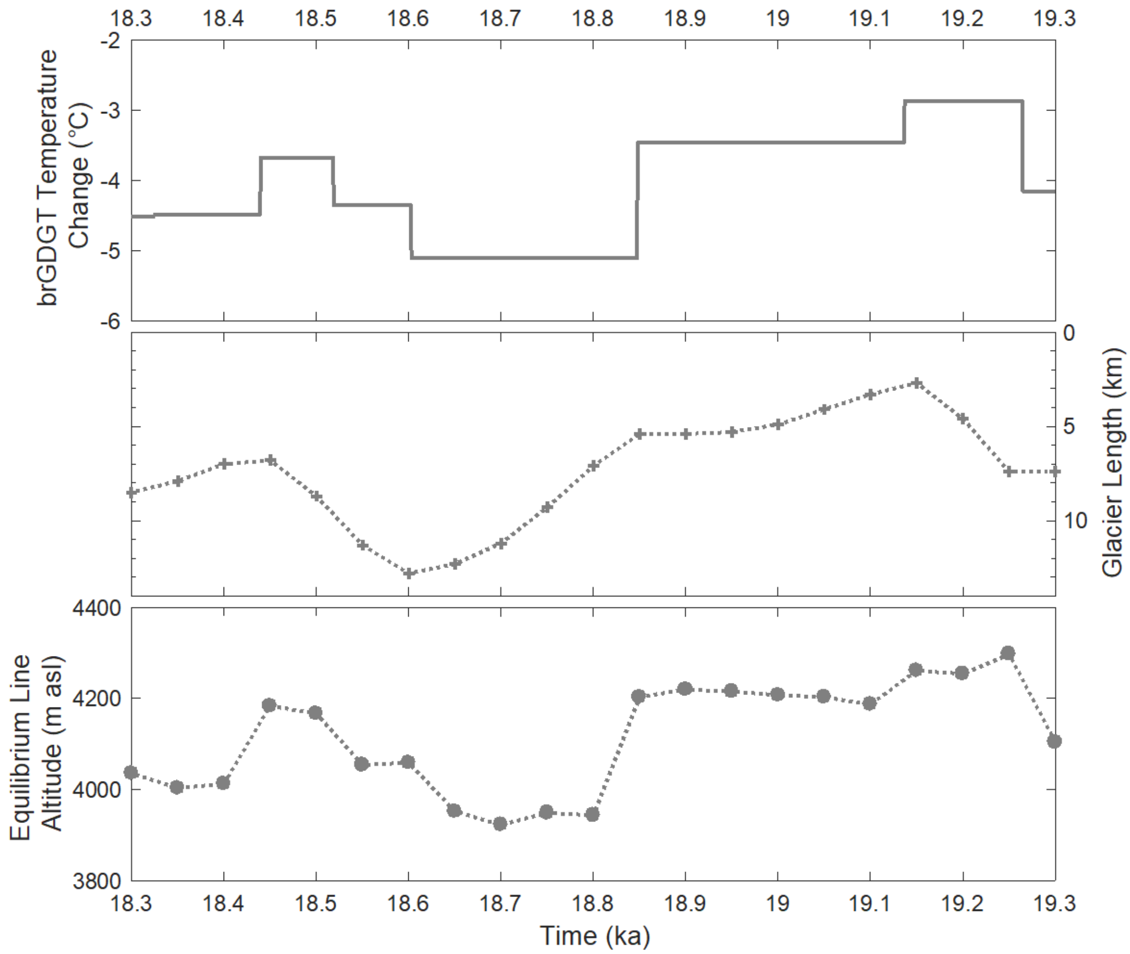

Figure S3. Plot comparing the timing of temperature forcing (top panel), glacier length change (middle panel), and Equilibrium Line Altitude (bottom panel) in 'MeanP-10' that shows a 250-year lag between the beginning of a cool event at 18.85 ka (top panel) and the modeled maximum glacier advance at 18.6 ka (middle panel).