Cosmogenic ^{3}He-^{10}Be-^{14}C dating quantifies terrestrial climate response to global warming

B. GURALNIK[1,2], M.M. TREMBLAY[3,4,5], M. PHILLIPS[6], N. GRIBENSKI[7], P.G. VALLA[7], K. HIPPE[8], D.L. SHUSTER[3,4]

[1] Wageningen University, The Netherlands.
[2] Nordic Laboratory for Luminescence dating, Denmark.
[3] University of California, Berkeley, USA
[4] Berkeley Geochronology Center, Berkeley, USA.
[5] Scottish Universities Environmental Research Centre, UK.
[6] Institute for Snow and Avalanche Research, Switzerland.
[7] University of Bern, Switzerland.
[8] ETH Zürich, Switzerland.

The area of St. Gotthard (Switzerland) is a focal topographic divide of the Alpine complex. During the LGM, the Gotthard hosted the ice saddle between the two largest European ice caps (Rhone and Vorderrhein), while today it is the headwater of four major European basins (Rhone, Rhine, Reuss, and Ticino). Detailed in-situ ^{10}Be-^{14}C cosmogenic dating at the Gotthard Pass has previously constrained its terminal deglaciation to have occurred between 16-11 ka, and the ensuing annual snow cover to <2 m [1]. Here, we apply a new methodology (cosmogenic ^{3}He in quartz; QHe) to further constrain Holocene-averaged effective diffusion temperatures (EDT) for three selected sites at the Gotthard Pass, and then evaluate them against modern (2016-2017) high-resolution in-situ ground thermometry (following [3]).

Compared to quartz ^{10}Be-^{14}C concordia ages, the apparent quartz ^{3}He ages are younger by an order of magnitude. Coupled with proton-irradiated thermal kinetics of ^{4}He in quartz, such QHe age underestimates translate into Holocene-averaged EDTs in the range of 5-15 °C. These palaeo-EDTs anti-correlate with the amount of snow cover obtained from ^{10}Be-^{14}C age concordia, suggesting snow as a major modulator of near-surface temperature. In contrast, modern in-situ EDTs are in the 10-13 °C range, suggesting a relative and recent warming of some sites by up to 5 °C. Given the millenial-scale response times of the QHe system, we interpret the temperature mismatches between modern and ^{3}He paleothermometry as the evasive imprint of centennial-scale human-induced global warming on high-alpine terrestrial microclimate.

[1] Hippe et al. (2014) Quat. Geochron. 19, 14–26.
[2] Tremblay et al. (2014) EPSL 400, 195–205.
[3] Haberkorn et al. (2015) Geog. Ann A. 97, 579–597.