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Groundwater noble gas paleothermometry record of 9°C LGM cooling in Eastern France

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Constraining the evolution of past continental climates is key for evaluating modern estimates of climate sensitivity and, in turn, for improving predictions of future climate change. The Last Glacial Maximum (LGM; ~26–18 ka) represents a benchmark period for evaluating the sensitivity of global temperatures to the net radiative forcing **[1]**. However, reliable quantitative proxies of continental paleotemperatures are scarce and often associated with large uncertainties, which has limited our understanding of the dynamics of past climate changes on land.

Here, we present a new noble gas temperature (NGT) record of the last ~40 kyr from the Albian aquifer, Eastern Paris Basin (latitude ~48°N, France). These data indicate that mean annual temperatures were ~ 5°C between 42–30 ka, before cooling to ~2°C between 28–25 ka. Then, post-glacial warming between 25 and 10 ka led to Holocene temperatures of ~11°C, indistinguishable from the average modern ground surface temperature in Eastern France. The implied LGM cooling (ΔNGT_{LGM} = 9.1±0.9°C, relative to the Late Holocene) is consistent with previous studies of noble gas paleothermometry in Europe, but larger than estimates of low-to-mid latitude LGM cooling **[2]**, hence supporting a predicted amplification of LGM cooling with latitude. Comparing our ΔNGT_{LGM} with Eastern France LGM cooling estimates from current-generation climate model simulations **[3]** provides some proxy-derived evidence that most simulations do not react sensitive enough to the glacial cooling in Western Europe during the LGM.

At last, we present a compilation of European ΔNGT_{LGM} that, once combined with other continental proxies of paleo-temperatures at high and low altitude, will allow providing a comprehensive assessment of spatial gradients (lapse rate, latitudinal and continental amplification) across Europe, for different climate states (past, present, future). We also note that the strong correlation between NGTs and water stable isotopes may help to calibrate regional paleothermometry applications (e.g., speleothem records), although the exact temperature sensitivity of water stable isotopes in precipitation remains uncertain.

[1] Parrenin, F. et al. (2013). *Science*, *339*(6123), 1060-1063. **[2]** Seltzer, A. M. et al. (2021). *Nature*, *593*(7858), 228-232. **[3]** Kageyama, M. et al. (2021) *Climate of the Past*, *17*(3), 1065-1089.