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Novel insights into Eastern France past hydroclimate evolution since the last glacial period from dissolved noble gas isotope systematics in the Grès du Trias Inférieur aquifer

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Paleoclimate proxies from the last glacial period record past temperatures, greenhouse gas levels, and atmospheric circulation, showing how the climate system responded to natural forcings. By analyzing how quickly and strongly climate changed in response to factors such as CO2 variations, one can identify feedback mechanisms, tipping points, and rates of change. This helps improve climate models and provides context for understanding current human-driven climate change and predicting future climate dynamics and evolution. However, reliable proxies for continental paleoclimates remain scarce and often qualitative, limiting our understanding of the spatial structure of past climate changes on land. Here, we present a new reconstruction of past hydroclimate changes over the Last Glacial Interglacial Transition (LGIT) based on fossil groundwater extracted from the Grès du Trias Inférieur aquifer (Eastern France). This dataset includes water stable isotopes, 14C and 4He dating, noble gas paleotemperatures (NGT) from dissolved noble gas concentrations, as well as paleowater table depth reconstructions from heavy noble gas isotope systematics. Age constraints indicate groundwater ages ranging from 1,980 years (at Escles, in the Vosges) to >40,000 years (at several locations). Our NGT data indicate that the mean annual surface temperature was ~2–3 °C during the last glacial period, warming to ~8 °C at present, matching modern mean annual ground surface temperatures in the mid-mountain recharge area of the Vosges. Combined with water stable isotopes, NGTs indicate water stable isotope–NGT transfer functions that are consistent with values recently derived from nearby aquifers (Bekaert et al., under review). The magnitude of the observed glacial–interglacial cooling (~5.5 °C) is, however, slightly lower than suggested by other NGT records, but compatible with pollen-based paleoclimate reconstructions from near the study area (Fénisse et al., in prep). Paleowater table depth reconstructions indicate no major change over the LGIT, consistent with outputs of the isotope-enabled transient climate experiment (iTraCE) from fully coupled transient Earth system model simulations (Brady et al., 2019). We discuss the implications of this work for the applicability of the noble gas-based paleowater table depth reconstructions across Europe and offer perspectives on the use of 4He, 3He, and 40Ar accumulation rates in sedimentary basins.