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The temperature and precipitation reconstructions on Swiss stalagmites with a special emphasis on altitude gradient using noble-gases, δO-18 and δD of fluid inclusions

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We present the results of an application of 'Combined Vacuum Crushing and Sieving (CVCS)' system (e.g., allowing to crush samples to defined grain size in vacuum) for the first time to stalagmites grown in cold climates during the last glacial-interglacial transition, but at different altitudes.

Recently, concentrations of dissolved atmospheric noble gases in fluid inclusions of stalagmites were used to reconstruct past ambient cave temperatures, the annual mean temperature and hydrological conditions when the water was trapped. To reconstruct temperatures from noble gases (noble gas temperature: NGT) in water-filled inclusions, we processed samples from Swiss stalagmites M6 from Milandre cave (400 m.a.s.l) and GEF1 from Grotte aux Fées cave (895 m.a.s.l) covering the climatic transitions Allerød–Younger Dryas–Holocene.

Water content. The amount of water extracted per unit mass of calcite fabric (e.g., 'water yield': WT) was shown to be a measure of the total water content. The data shows that the WT systematically changes with $\delta^{18}O_{calcite}$ of the calcite. We therefore conclude that WT records can be linked on changes in drip rates and thus can be used to track changes of past precipitation even in cold regions.

Noble gases. Noble gas analysis shows that the annual mean temperatures in Milandre cave were 2.2$\pm$2.0°C during the late Allerød and dropped to 0$\pm$2°C at the Younger Dryas. Such temperatures close 0°C indicate that drip water supply stopped in response to the formation of permafrost conditions around the cave preventing further stalagmite growth. However, one late Holocene sample gave a cave temperature of 8.7$\pm$1.4°C agreeing generally with present day annual mean temperature. The annual mean temperature of 5.7$\pm$1.3°C from GEF1 was determined for the early Holocene. The observed data show systematic variations with sample elevation, e.g., higher temperature from lower altitude and vice versa. Combining the isotopic composition of water in fluid inclusions ($\delta^{18}O_{water}$, δD_{water}) and the NGTs allows determining the δ^{18}O–T relation ('laps rate') in the past as both δ^{18}O and T scale with altitude. This calibration is key as paleo–temperatures are often reconstructed from δ^{18}O, δD data whereby it is implicitly assumed that the modern $\Delta(\delta^{18}O_{water}, \delta D_{water})$–$\Delta$T relation is also valid for the past. Our study makes an argument that noble gas analysis in stalagmites can also be a new route to address this fundamental hypothesis of past climate reconstruction.