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The Last Glacial N-Alps stack: precisely dated stalagmites from the northern part of the Alps

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U-Th dated speleothems from the Austrian Alps have been shown to trace the Last Glacial O isotope signal of Greenland ice cores very closely (cf. Spötl et al., QSR 2006) and therefore provide the opportunity to refine the chronology of the ice core records using a common climate proxy, but also to study regional similarities and differences. Stalagmite samples with high U and low detrital Th contents were collected from carefully selected cave sites. These caves are located at the northern rim of the Alps (Austria, Switzerland and southern Germany), which is characterized by a dominant advection of moist air masses from the N-Atlantic. This location is thus ideal to compare in detail Last Glacial rapid climate changes (Dansgaard-Oeschger or D-O events) recorded in Greenland ice, in N-Atlantic marine sediments, and in these European speleothems.

The N-Alps stack (consisting of several stalagmites) covers the time interval from 120 to 60 ka, i.e. D-O cycles 25 to 18 are well represented and will be completed by additional samples. Interestingly, major Greenland Stadials (GS) are also recorded, demonstrating that the caves were not frozen during these cold intervals. Some growth phases of individual stalagmites overlap, providing a test of internal reproducibility. Each of the stalagmites is precisely dated using state-of-the-art U-Th techniques and typical 2-sigma age uncertainties are in the range of 0.2 to 0.8 %, i.e. D-O events during the first half of the Last Glacial period can be dated to within a few hundred years. High-resolution (micromilled) O isotope profiles show distinct shifts of up to 4 permil during D-O transitions. Remarkable details regarding the fine structure of the Greenland O isotope curves are recorded in some of the samples (e.g. a short-lived warming during GS 22) due to an average temporal resolution of 4 to 21 years. The duration of GS 22 is significantly longer in our record compared to NGRIP and D-O Interstadial 18 lacks a clear signal, in spite of the high resolution. The latter is also the case in some highly-resolved stalagmite records from outside Europe. C isotopic compositions reveal a pronounced variability of up to 6 permil and high values typically coincide with cold and dry stadial conditions, while low values correspond to the relatively warm and wet interstadials, the latter most likely reflecting the development and biological activity of vegetation and soil above the caves. Transitions from interstadial to stadial conditions and vice versa are further expressed in the stalagmite petrography and some of the samples show regular lamination patterns, likely of seasonal origin. Detailed petrographic analyses thus can help to further constrain the duration of transitions and intervals, but also to detect changes in seasonality.

Our results demonstrate the sensitivity of the Alpine region to rapid climate changes during glacial intervals and the common climate forcing of Greenland and the European Alps in a N-Atlantic context. With regard to the timing of D-O transitions between 120 and 60 ka recorded in Greenland, the N-Alps stack suggests a shift by 1 to 2 ka towards younger ages compared to the ss09sea timescale. This shift is already indicated by the older portion of the GICC05 timescale.