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Investigating spatially coherent changes in European speleothem δ18O time-series

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Speleothems can provide valuable archives of past environmental conditions on the continents. They can be dated precisely using U-Series disequilibria techniques, or in some cases by lamina counting. Oxygen isotope ratios in speleothem calcite are widely used to infer past climatic conditions.

In general speleothem δ18O values are typically dominated by the δ18O signal of the precipitation above a cave site. Therefore, coeval speleothems represent different parts of the same hydrological cycle and should, consequently record spatially coherent δ18O variations. Here we present a new study, in which speleothem δ18O time-series from different locations in Europe are collated to investigate coherent δ18O variations, applying principal component analysis (PCA). The temporal focus of our study was the past 2,000 years, an interval that includes two relatively strong phases of climate change, namely the Medieval Warm Period (MWP) and the Little Ice Age (LIA).

The first of two time slices investigated covers the interval from 2.0 until 0.8 ka BP (BP = 1950 cal. years) and the second, the period from 1.2 to 0.05 ka BP. The seven speleothem δ18O time-series, which were tested for spatial coherence during the analysed time slices originate from caves in Austria, Germany, Ireland, Romania, Northern Spain, Sweden and Northern Turkey, respectively. The 1st principal component (PC 1) derived for the first time slice (2.0-0.8 ka BP) explains 36.0 $\pm$ 8.9 % (1-sigma) of the total variance (TEV) and is anti-correlated with the speleothem δ18O time-series in Central, Northern and Eastern Europe, including Turkey and correlated with the speleothem δ18O time-series from Ireland and Northern Spain. The mean Spearman rank coefficient between PC 1 with the speleothem δ18O time-series is +/- 0.6, respectively. For the second time slice (1.2-0.05 ka BP) the 1st PC (TEV = 30.9 $\pm$ 4.3 %) shows a significant correlation with the speleothem δ18O time-series from Austria, Germany, Romania, Northern Spain and Sweden – the speleothem δ18O time-series from Central and Northern Europe are anti-correlated with PC 1 – the mean Spearman rank coefficient is c. -0.7 – whereas the time-series from Romania is correlated with PC 1 (mean = c. 0.6). The 2nd PC (PC 2) (TEV = 24.2 $\pm$ 3.7 %) shows a positive correlation with the speleothem δ18O time-series from Ireland, Northern Spain and Turkey (mean = c. 0.6) and a negative correlation with the δ18O time-series from Germany (mean = c. 0.5). The speleothem δ18O time-series from Austria, Romania and Sweden show no significant correlation with PC 2.

Importantly, this study reveals that speleothem δ18O time-series from all over Europe show coherent variations over the last 2,000 years, which can be identified with PCA. The investigated time slices show that during the interval from 2.0 until 0.8 ka BP, the 1st principal component can mostly explain the variations of the speleothem δ18O time-series, whereas for the period from 1.2 until 0.05 ka BP, two principal components are necessary to explain the changes in the speleothem δ18O time-series. The reasons for these differences are likely to reflect the different climatic patterns associated with each time slice, and will be discussed in detail in the presentation.