



A warm and humid phase revealed by the first early MIS 3 speleothem record from Germany

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Marine Isotope Stage 3 (MIS 3) is an exciting time span in climate history being characterised by numerous rapid climate oscillations (i.e., the Dansgaard-Oeschger (DO-) events). These events have been observed in various climate archives, such as Greenland ice cores, marine sediment cores and speleothems. So far, MIS 3 speleothem records from central Europe have been restricted to caves located beneath temperate Alpine glaciers or in areas near the Atlantic Ocean. MIS 3 was believed to be too cold and dry in more northern areas to enable speleothem growth. Here we present a speleothem from the central European Bunker cave, Germany, which grew during the early MIS 3 rejecting this hypothesis. U-series dating revealed two distinct growth phases between ~ 52 and 51 ka and ~ 47 to 43 ka. The first growth phase is characterised by a relatively fast growth rate (~ 100 to 300 $\mu\text{m/a}$) and the proxy data ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values as well as several trace elements) suggests sufficient supply of precipitation and the presence of soil cover above the cave. Prior to the growth stop, the $\delta^{13}\text{C}$ values increase significantly suggesting a trend towards drier and/or colder conditions. The timing of the hiatus between the two growth intervals is in agreement with the Heinrich stadial 5. For the second growth phase, we observe a climatic and environmental deterioration with dryer conditions, indicated by rising Mg concentrations, less radiogenic Sr-isotope values and much slower growth rates (< 10 $\mu\text{m/a}$). The different climate conditions during the two distinct growth intervals are in good agreement with nearby pollen records from the Eifel, Germany. While the initial growth phase shows a more stable climate state, the $\delta^{13}\text{C}$ values show two significant decreases during the second growth phase, associated with DO-events 11 and 12. The timing of these shifts is in agreement with published MIS 3 speleothem data from Europe and China and ice core records data from Greenland. In contrast to the $\delta^{13}\text{C}$ record, the $\delta^{18}\text{O}$ record does not show any variations representing DO-events 11 and 12, suggesting no or only minor changes in the seasonality of the rainfall. In general, the precisely dated Bu2 record provides exceptionally highly resolved information on the climate and environment during the early MIS 3 in central Europe.