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Climate
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Discussions

Interactive comment on “Bunker Cave stalagmites: an archive for central European Holocene climate variability” *by* J. Fohlmeister et al.

J. Fohlmeister et al.

jensf@iup.uni-heidelberg.de

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We would like to thank the anonymous Referee 2 for the helpful and constructive comments and technical corrections suggested for our manuscript “Bunker Cave stalagmites: an archive for central European Holocene climate variability”. We will carefully take these comments into account when revising the manuscript. However, a few suggestions will be difficult (in particular points 2ii and 5) or even impossible (especially point 2i) to address.

Point 1: Does the modern drip behaviour reflect the palaeo-drip behaviour?

This is an important point. Indeed, the anthropogenic enlargement of the cave entrance is a basic and important problem when comparing the monitoring data with proxy data of the stalagmites. The cave was discovered during railway works (blasting) in 1860 AD. Some 60 years later a second entrance was opened at a lower, horizontally orientated cave level during street works. The stalagmites came from chambers near the second entrance. Each artificial entrance was later sealed by a door with an opening large enough to allow bats to enter and leave the cave. In the cave monitoring literature (e.g., Spötl et al., 2005; Mattey et al., 2008; Frisia et al., 2011; Tremaine et al., 2011), the importance of annual variations in cave ventilation has been discussed in great detail. However, based on the observations of those studies, this process seems to be best visible in the δ^{13}C values of cave CO2, dissolved inorganic carbon in the drip water and recent calcite precipitates (apart from other parameters, e.g. radon, not recorded in speleothems). Until now, the influence of cave ventilation was only shown to be important for δ^{13}C and seems to be restricted to this proxy. For speleothem Mg/Ca ratios or δ^{18}O values, no influence has been reported so far. The proxy data of the most recent section of Bu4 (the only stalagmite that was actively growing when the cave was opened) suggest that only δ^{13}C seems to respond to this event by a sharp increase. Anomalous shifts in δ^{18}O and Mg/Ca ratio are not observed implying that both proxies are unaffected by a potential change in the ventilation regime. Therefore, we can rely on the monitoring findings for both proxies in our study.

In the following, we focus on δ^{13}C. The opening of the cave might have increased the degree of cave ventilation, or in other words, the cave air parameters (pCO2, δ^{13}C values of cave pCO2) were likely shifted to values, which are closer to those of the free atmosphere. With respect to the δ^{13}C values of speleothem calcite, we focus on cave air pCO2 and its δ^{13}C value as well as on humidity and temperature. The recent cave temperature reflects the mean annual surface air temperature, which was certainly also the case before the cave was opened. The present-day cave humidity is between 90 to 95% throughout the year (Riechelmann et al., 2011). Before the cave was opened, cave air pCO2 was most probably higher than today since the exchange between cave air and the outside atmosphere was less effective. Such a change from a poorly to a better ventilated cave may be reflected in a strong increase in δ^{13}C values of speleothem calcite as convincingly demonstrated by Tremaine et al. (2011). This is in agreement with our interpretation of the observed steep increase in the δ^{13}C values of the top section of Bu4.

Under modern conditions, all four cave air parameters (temperature, humidity, pCO2 and δ^{13}C) do not show an obvious annual variability (Riechelmann et al. 2011). Therefore, we argue that under present-day conditions the monitoring chambers of the cave are equally well ventilated throughout the year, due to the two artificial entrances and the horizontal geometry of this part of the cave. Before the cave was opened, gas exchange between the cave interior and the free atmosphere was most likely provided by some small fissures at both levels of the cave. Both reasons, but especially the horizontal geometry of the interesting cave part gives us some confidence that no large sub-annual fluctuations occurred in the cave air parameters for the period before the cave was opened. This allows us to use the results of the cave monitoring for the interpretation of stalagmite proxies and minimises the influence of cave ventilation on the δ^{13}C values of speleothem calcite during previous periods.

Point 2i: Is there any unweathered remnant of the loess soil?

Unfortunately, we do not have found unweathered loess.

Point 2ii: Soil carbonate budget calculation

Establishing such a calculation, is very speculative without knowing the chemical composition of all end-members. In particular, the variation of the soil carbonate end-member seems to change with time, which makes such a calculation even more difficult. In addition, incongruent dissolution of Mg and Ca is difficult to quantify, leading to an even more inaccurate computation. We doubt that it is meaningful to perform a

budget calculation under such circumstances. However, measurements of strontium isotopes might help to tackle this problem. This is planned in the future.

Point 3: Correlation analysis

A correlation analysis did not yield high correlation coefficients. Therefore, we decided not to present these statistical data. We stated that there is an “overall similarity [. . .] of Mg/Ca and δ^{13}C for Bu4” (P: 1703; line 1-2) and between the detrended Mg/Ca record and smoothed δ^{18}O (P1704; lines 3-5). The general features are shown in Figure 4. However, this visual finding does not hold a full correlation analysis, mainly because some periods deviate from the general long-term behaviour. We will formulate the corresponding passages more clearly in the revised version of the manuscript.

Point 4: δ^{13}C behaviour between Bu1 and Bu4

In the manuscript, we calculated the mean δ^{13}C differences of both stalagmites for the recent past (1.3‰). We showed that about 0.5 to 0.6‰ of the total offset are due to differences in the carbonate dissolution system. This is indeed quite novel work. To our knowledge, so far no one has shown that differences in the δ^{13}C values of contemporaneously grown stalagmites can be related to differences in the carbonate dissolution system. Even more important: we are able to quantify this effect for Bu 1 and Bu 4. Our approach allows ascribing the remaining 0.7 to 0.8‰ to the extent of prior calcite precipitation (PCP) and to differences in kinetic isotope fractionation. As we stated in the manuscript, the sign of the difference is right. However, computing reliable numbers for kinetic isotope fractionation is much more difficult since the currently available models rely on at least one free parameter, which can be used to tune the respective models to the measured data (i.e., the mixing parameter, ϕ, in Mühlinghaus et al., 2009, and the parameter, γ, in Dreybrodt, 2008). In summary, feeding the models with the modern drip rate will show that the difference in the δ^{13}C values due to kinetic effects can be confirmed by the models. In the revised manuscript, we will present the requested numbers.

Point 5: Contribution to understanding the 8.2 ka event

Unfortunately, our stalagmites have low U concentrations. This results in a large dating uncertainty. Therefore, the precision of the age model is not good enough to contribute significantly to a better understanding of the 8.2 ka event and, in particular, not to its timing and duration.

However, from our multi-proxy study, we learn that the 8.2 ka event was not exceptionally dry in central Europe: it might even be concluded that the opposite was the case.

Final remark: Amend the Conclusions to better emphasise what is novel in the presented work

We agree that the conclusions might have been somewhat weakly expressed since only climate-related points were mentioned. However, one important point of the conclusions is that well-known European cold periods, such as the 8.2 ka event and the Little Ice Age, show a completely different behaviour with respect to their δ^{18}O values. To our best knowledge, this has not been shown before in one single record. We will emphasize these points more prominently in the revised version of the manuscript.

Furthermore, we will more prominently stress the new findings and approaches used in our analysis in the conclusions. For example, among the many speleothem paleoclimate studies published to date, only a few of them used a multi-proxy approach. Speleothem studies, which present a multi-proxy and multi-record approach, are not available to our knowledge. In addition, the application of the advanced and largely objective construction method for stacking of several records is new. A further novel approach of this study is our quantification of the differences in the δ^{13}C values between Bu1 and Bu4 due to the different degree of the carbonate dissolution system. We will

stress these novel aspects in more detail in the revised version of the manuscript.

Interactive comment on Clim. Past Discuss., 8, 1687, 2012.