Reply to the anonymous Referee #2

General comments

Referee #2: *In this interesting study the authors make an attempt to investigate the combined effects of mid- and late-Holocene orbital forcing and changes in solar activity on the oxygen isotope composition of precipitation. It is striking that purely orbital-driven simulations for the time slices 6 and 5 k show very similar results, but differs if solar activity forcing is added. The results of these simulations are certainly of some interest for paleoclimatologists working on speleothems and/or lake records in central Europe.*
However, while the authors present the results of nine ECHAM5-wiso simulations, only little attempts have been made to include climate archive proxy data from central Europe for a more comprehensive data-model comparison. However, this is not a major short-coming per se, provided that the strength and weaknesses of the model simulations are critically accessed.

We thank the second anonymous reviewer for the review that helped to improve our ms. More comprehensive data-model comparisons were already investigated in some recent works within the DAPHNE project (e.g. Langebroek, Werner, & Lohmann, 2011; Lohmann et al., 2012; Wackerbarth et al., 2012). In these studies time slices of the Mid Holocene and of the Late Holocene were simulated, the results were compared with proxy data, and the results were additionally used to generate artificial speleothem records for further comparison.
In this study we were more interested to analyse potential interferences of orbital and solar forcing on $\delta^{18}O$ in rainfall. The study was motivated by the calcite $\delta^{18}O$ record of the Bunker cave, which does not seem to be driven by orbital forcing, only.

Referee #2: *Although I am not an expert in this field, I wonder whether the results are possibly an artifact of the climate model simulations. It is well known that climate models have considerable weaknesses and uncertainties when simulating the hydrological cycle which will also affect modeled stable isotopes. I would like to see a discussion on possible biases in these climate model simulations, particularly in central Europe! This is crucial before the proxy quality of Holocene stable isotope records from Europe is challenged by the results of these.*

We agree with the reviewer that model biases have to be carefully checked. In tow previous studies (Werner et al., 2011; Langebroek et al., 2011) we have shown that simulated present-day $\delta^{18}O$ in precipitation values are in good agreement with observational data, e.g. from the GNIP network (IAEA/WMO, 2006). This holds especially true for Europe, and we refer to Langebroek et al. (2011) for an detailed discussion of this issue (Fig. 1; this comment).

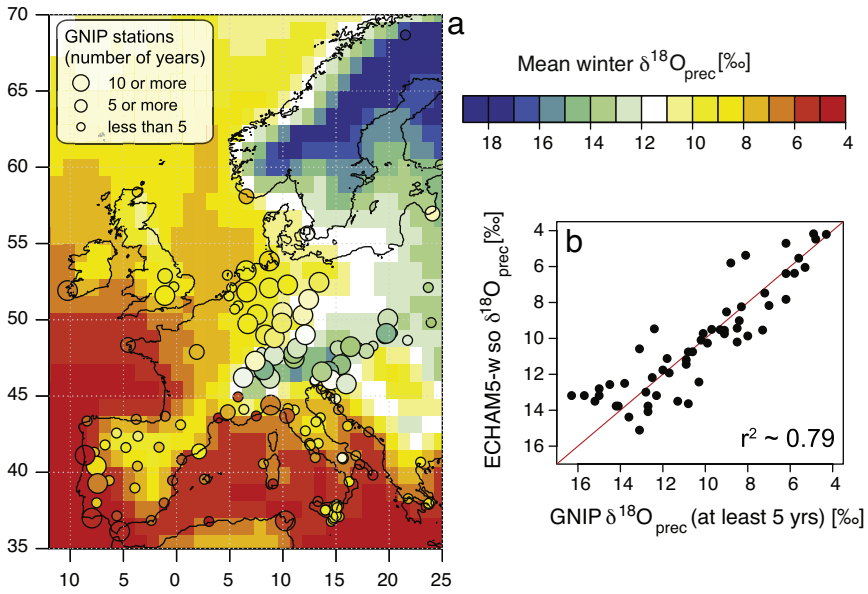

Figure 1 (a) Winter mean $\delta^{18}O_{prec}$ of GNIP stations (colored circles) and ECHAM5-wiso (background pattern) in T106 resolution (~1.1°x1.1°). ECHAM5-wiso values are averaged over 1959–1999. Larger circles indicate longer time series of GNIP measurements. (b) Correlation between GNIP $\delta^{18}O_{prec}$ of stations that include at least 5 years of data and corresponding ECHAM5-wiso $\delta^{18}O_{prec}$ values. The red line indicates the 1:1 line. Edited after Langebroek et al. (2011).

Referee #2: *Statements such as "Our results indicate that a quantitative interpretation of single del18O Holocene proxy records in terms of regional climate variability remains difficult" are correct, but this is certainly also true for single climate model simulation!*

This is of course true and is also mentioned in the revised ms.

Referee #2: *Furthermore, the geographical position of a climate proxy site is also of crucial importance for constructing quantitative time series based on oxygen isotopes. There are also areas where the changes are quite consistent.*

We fully agree with this statement. In our prior studies we have already shown that the Bunker Cave is a sensitive region for investigating atmospheric circulation patterns like the NAO (Fohlmeister et al., 2012; Langebroek et al., 2011; Lohmann et al., 2012; Wackerbarth et al., 2012).

Detailed comments

Page 3792, Line 23: *should be ". . .correspond to. . ."*
Modified as suggested.

Page 3792, Line 23: *". . .such high frequency. . ."*
Modified as suggested.

Page 3794, line 9*: better ". . .,variations in the amount of precipitation. . ."*
Modified as suggested.

Page 3794, lines 14-15: *"Like for other terrestrial records, regional effects may also influence the oxygen isotope records of speleothems (Scholz et al., 2012." I find this sentence a little bit awkward, as paleoclimate research on speleothems aims at reconstructing regional climate variability and teleconnection patterns. The palaeoclimatologists are well aware of this.*
We agree and the sentence is modified.

Page 3799, line 4: *should be ". . .European speleothems is dominated by winter climate. . ."*
Modified as suggested.

Page 3805, line 6: *Should be . . ., mixing and partial rainout. . .".*
Modified as suggested.

Page 3808, line 22: *should be ". . .findings from. . ."*
Modified as suggested.

References

Fohlmeister, J., Schröder-Ritzrau, a., Scholz, D., Spötl, C., Riechelmann, D. F. C., Mudelsee, M., Wackerbarth, a., Gerdes, a., Riechelmann, S., Immenhauser, A., Richter, D. K., et al.: Bunker Cave stalagmites: an archive for central European Holocene climate variability, Climate of the Past Discussions, 8(3), 1687–1720, doi:10.5194/cpd-8-1687-2012, 2012.

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Langebroek, P. M., Werner, M. and Lohmann, G.: Climate information imprinted in oxygen-isotopic composition of precipitation in Europe, Earth and Planetary Science Letters, 311(1-2), 144–154, doi:10.1016/j.epsl.2011.08.049, 2011.

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Wackerbarth, A., Langebroek, P. M., Werner, M., Lohmann, G., Riechelmann, S. and Mangini, A.: Simulated oxygen isotopes in cave drip water and speleothem calcite in European caves, Climate of the Past Discussions, 8(4), 2777–2817, doi:10.5194/cpd-8-2777-2012, 2012.

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