Reply to the anonymous Referee #1

General comments

Referee #1*: The authors examine the temperature and d18O responses to different orbital and solar activity forcings during the Holocene using an isotopically equipped AGCM. This is an important idea. It is unique among isotope-GCM studies in examining the effects of different external forcings through explicit simulations. The contributions of these forcings are usually inferred from different proxy records; this paper attempts to fill a gap in trying to understand these relationships mechanistically. Other modeling studies have conducted similar experiments in forcing models with different orbital, solar and GHG characteristics. But, to the best of my knowledge, this is the first to try and understand their individual contributions and how they interact, and therefore uses the model to its full potential. The paper is generally well-written, aside from the odd awkard phrase.*
I have a major concern, however, which is that the 10-yr runs were simply too short. The main result of the paper is that the d18O response to different forcings is difficult to identify. But I suspect that this 'complexity', as the authors state, could be absent if longer time slices were used.

We thank the anonymous reviewer for the thorough review that helped to improve the ms. In particular, the question whether the 10-year experiments are long enough is of major importance. We have carefully checked this issue. Therefore we have performed a 40 years long control simulation (CTRL). Subsequently, we split up this simulation in four 10 years long ensemble members of CTRL. The ensemble members ens1 to ens4 represent one decade each and their mean values are compared with those of the 40-year control experiment using the Student's t-test. The mean values of the surface temperature, the precipitation, as well as δ^{18}O in precipitation do not differ significantly - neither at the location of the Bunker record, nor when comparing European or global means (Fig. 1, Tab. 1 in this comment). Thus, we argue that ten model years are long enough to calculate an adequate representation of mean δ^{18}O values in precipitation.
We also discussed internally the idea of long low-resolution experiments but have rejected the idea since we were more interested on the high resolution focussing on Europe and since high-resolution results in T106 for Europe looked promising in the previous study by Langebroek et al. (2011).

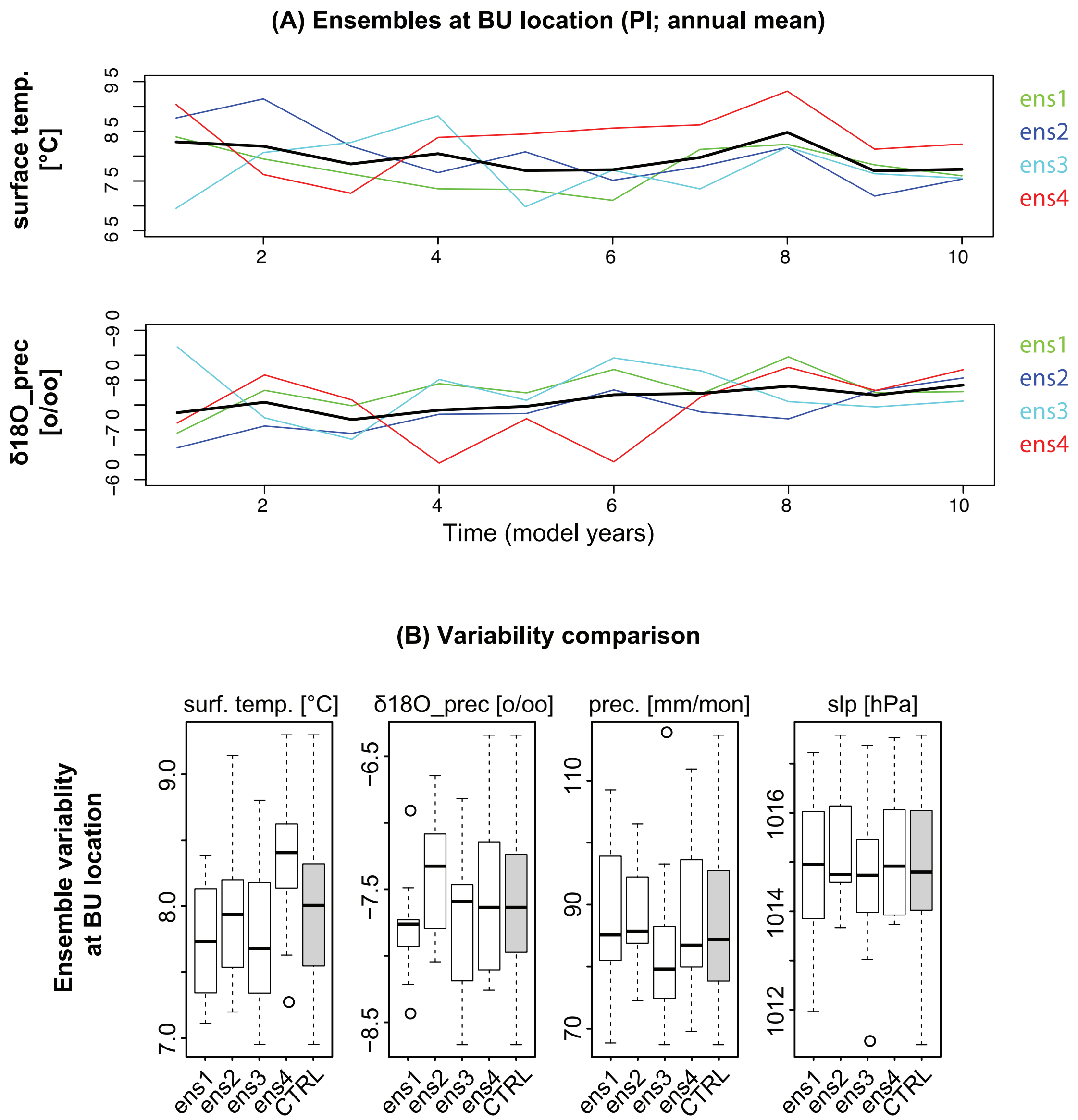

Figure 1. We have calculated a 40-year control experiment (CTRL) simulation for pre-industrial (PI) conditions. Subsequently, this experiment is spitted up into four 10 yeas rlong ensemble members (ens1-ens4). The bold black line show the ensemble means (A). The boxplots (B) show that the mean values at the location of the Bunker Cave (BU) do not differ significantly for various climate parameters. The boxplots summarise the smallest (largest) observation with the lower (upper) end of the whiskers, the lower (upper) quartile with the lower (upper) end of the box, and the median (bold black line), as well as outliers (circles) of a sample distribution.

Table 1. P-values derived from Student's t-test in order to compare the mean values of the single ten years long ensemble members with the 40 years long control simulation (CTRL). All values larger than α=0.05 means that the null hypothesis cannot be rejected and thus the mean values does not differ significantly from each other. The t-test is applied on time series from the Bunker Cave location, from mean values covering Europe (30°-70°N, -15°-45°E), and from global mean values.

Surface temp.	**BU**	**Europe**	**global mean**
ens1 vs CTRL	0.29	0.29	0.99
ens2 vs CTRL	0.85	0.85	0.91
ens3 vs CTRL	0.31	0.31	0.79
ens4 vs CTRL	0.07	0.07	0.89
δ^{18}O_prec			
ens1 vs CTRL	0.31	0.43	0.82
ens2 vs CTRL	0.21	0.69	0.07
ens3 vs CTRL	0.39	0.86	0.13
ens4 vs CTRL	0.55	0.56	0.63

Specific comments

Abstract: *Please give an indication in the abstract that the study was motivated by Bunker cave d18O interpretation*
Modified as suggested.

P3794-L20 or P3803-L20*: Please elaborate briefly on the standard interpretation of the Bunker cave d18O (i.e. in terms of dominance of summertime precipitation with higher d18O?) given that it is counter to the conventional d18O 'paleothermometer' intepretation*.
We agree that this information is important. According to the analysis of the speleothems from the Bunker cave Fohlmeister et al., (2012, this issue) have given a detailed interpretation of the observed variations in speleothem δ^{18}O. In particular they interpreted the variations as changes in both surface winter temperature and amount of winter precipitation as a consequence of predominant winter precipitation (Wackerbarth et al., 2010, 2012) as well as kinetic isotope fractionation during calcite growths. In summary, more negative δ^{18}O values represent warmer and more humid winters, whereas more positive δ^{18}O values reflect cold and dry winters. This is indeed counter to the conventional δ^{18}O 'paleothermometer' intepretation (Jouzel, 1999; Lachniet, 2009).

P3795-L12: *it is not clear what is meant by 'infer with each other'*
We modified this spelling error to 'interfere with each other'.

P3796-L11: *Mention the AOGCMs with water isotopes that do exist (GISS, HadCM3 of Tindall and Valdes, 2011, Glob. Plan. Change).*
Modified as suggested.

P3796-L21: *Please indicate whether only the SST and SIC fields from the EGMAM model were used as boundary conditions in the ECHAM5-wiso runs, or the stratospheric winds also.*

Modified as suggested. The climate model was forced by sea surface temperatures and sea-ice cover only, leaving the atmospheric circulation free to evolve.

P3799-L10: *Please add letter captions to Figure 2.*
Modified as suggested.

P3799-L26: *Please indicate the direction in which the ITCZ shifted and how this can be inferred from the changes in precipitation d18O.*
The shift from the ITCZ is here inferred from the temperature anomalies (Fig. 2 in the ms.). We will clarify this issue in the ms. However, speleothem data (Fleitmann et al., 2003) from the sensitive region of southern Oman, data from the Cariaco Basin (Haug et al., 2001), and model observations (Herold and Lohmann, 2009) recorded meridional shifts of the convergence zone and associated changes in precipitation source and amount. The mid to late Holocene trend is characterized by a continuous southward migration of the ITCZ caused by the precessional component of orbital insolation forcing. This finding is also captured in Fig.2 of the ms.

P3799-L23: *It is difficult to identify the stronger gradients over central Russia during 5K.*
We agree with this statement and have modified this issue in the revised ms.

P3800-L21: *Replace 'on the opposite' with 'conversely'?*
Modified as suggested.

P3802-L4: *'exits' to 'exists'*
Modified as suggested.

P3802-L26: *it is not clear what's meant by (sub) tropical - do you mean 'tropical and subtropical'?*
Yes, modified as suggested.

P3804-L22: *In the Discussion, please add additional comparison with the mid-Holocene results of LeGrande and Schmidt (2009). What were the similarities and differences?*
The results by LeGrande & Schmidt (2009) are already discussed at P3805-L26ff. However, we agree with a more detailed discussion of their results. Thus we added following paragraph to the revised version:
"In general the simulated spatial temperature and $\delta^{18}O$ patterns by LeGrande & Schmidt (2009) are quite similar to our simulations. Anomalies of the mid Holocene (6k) compared to PI show high latitude warming and low latitude cooling according to orbital forcing. This pattern is accompanied by changes in $\delta^{18}O$ following the conventional paleothermometer approach (Jouzel, 1999; Lachniet, 2009). In Europe, however, mid Holocene warming is in both models accompanied by a relative depletion of $\delta^{18}O$ values in the modelled precipitation. These patterns remain as a robust feature in both models. $\delta^{18}O$ anomalies are in general more similar than temperature differences, e.g. LeGrande and Schmitt (2009) found more significant cooling in low latitudes, which remains insignificant in our simulations."

P3804-L15: *'general stronger' to 'stronger general'*
Modified as suggested.

P3805-L15: *Doesn't the temperature effect in this case largely reflect the continental effect – the cooling moving eastward?*
We will specify this in the ms. The continental effect is a combination of both progressive cooling as well as progressive rainout of air masses as they traverse a continent (Lachniet, 2009).

P3805-L17: *change 'easterly' to 'westerly' or 'eastward'?*
Modified as suggested.

P3805-L25*: But in some cases, they often do correspond to temporal temperature changes (during winter in the continental interiors, for example) – so invoking them as generally consistent with the results here is inaccurate.*
We agree with this statement and will also discuss studies that show the correspondence between $\delta^{18}O$ and local temperature (e.g. Rozanski et al., 1992).

P3806-L5*: please elaborate on the agreement with LeGrande and Schmidt (2009). I think you've shown that the isotopic response can't (perhaps due to the run length, however) be associated with a corresponding temperature change. But you have not shown that it is the result of any broad circulation or moisture transport changes either.*
We agree that this passage is misleading and is rephrased as denoted in the comment above (P3804-L22).

P3810-L18: *This may be true, but it could simply be because of the short simulation length.*
See above.

P3818 - Fig 1.: *Please indicate what the DJF and JJA curves represent (orbital forcing?)*
Yes, orbital forcing is right. Modified as suggested.

References

Fleitmann, D., Burns, S. J., Mudelsee, M., Neff, U., Kramers, J., Mangini, A. and Matter, A.: Holocene forcing of the Indian monsoon recorded in a stalagmite from southern Oman., Science (New York, N.Y.), 300(5626), 1737–9, doi:10.1126/science.1083130, 2003.

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.

Haug, G. H., Hughen, K. A., Sigman, D. M., Peterson, L. C., R"ohl, U. and Röhl, U.: Southward Migration of the Intertropical Convergence Zone Through the Holocene, Science, 293(5533), 1304–1308, 2001.

Herold, M. and Lohmann, G.: Eemian tropical and subtropical African moisture transport: an isotope modelling study, Climate Dynamics, 33(7-8), 1075–1088, doi:10.1007/s00382-008-0515-2, 2009.

Jouzel, J.: Calibrating the isotopic paleothermometer, Science, 286, 910–911, 1999.

Lachniet, M. S.: Climatic and environmental controls on speleothem oxygen-isotope values, Quaternary Science Reviews, 28(5-6), 412–432, doi:10.1016/j.quascirev.2008.10.021, 2009.

LeGrande, A. N. and Schmidt, G. A.: Sources of Holocene variability of oxygen isotopes in paleoclimate archives, Climate of the Past, 5(3), 441–455, doi:10.5194/cp-5-441-2009, 2009.

Rozanski, K., Araguás-Araguás, L. and Gonfiantini, R.: Relation between long-term trends of oxygen-18 isotope composition of precipitation and climate., Science (New York, N.Y.), 258(5084), 981–5, doi:10.1126/science.258.5084.981, 1992.

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.

Wackerbarth, A., Scholz, D., Fohlmeister, J. and Mangini, A.: Modelling the delta O-18 value of cave drip water and speleothem calcite, Earth And Planetary Science Letters, 299(3-4), 387–397, doi:10.1016/j.epsl.2010.09.019, 2010.

Werner, M., Langebroek, P. M., Carlsen, T., Herold, M. and Lohmann, G.: Stable water isotopes in the ECHAM5 general circulation model: Toward high-resolution isotope modeling on a global scale, Journal of Geophysical Research, 116(D15109), 1–14, doi:10.1029/2011JD015681, 2011.