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Climate of the Past Discussions

Interactive comment on "Evaluating model outputs using integrated global speleothem records of climate change since the last glacial" *by* Laia Comas-Bru et al.

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Reply to Anonymous Referee 1

The paper compares isotopic simulations with ECHAM5-wiso for present day, last glacial maximum (LGM) and mid-holocene (MH) to speleothem records archived in the new SISAL database. They propose recommendations for an optimal model-data comparison, which can be useful for future such comparisons.

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The paper is well-written, although it could sometimes be made more concise. The figures are of good quality. Besides minor comments listed below, I have one major comment: the authors argue that it is useful for model evaluation to look at spatial patterns of absolute δ^{18}O for past climates (LGM, MH) rather than just looking at anomaly maps, in contrast with many previous studies. However, the argument is not convincing and the examples given argue rather for the contrary. I would suggest to remove this sub-section and remove this recommendation.

We thank the reviewer for their comments. We try to clarify what we are doing in response to these comments: the reviewer comments are in normal script, our explanations in blue italics and the rest of the text in blue normal script.

1 Major comment: what is the added value of looking at spatial patterns for past climates compared to looking at them for present-day?

The authors argue that it is useful for model evaluation to look at spatial patterns of absolute δ^{18}O for past climates (LGM, MH) rather than just looking at anomaly maps, in contrast with many previous studies. This allows to have more sites for model data comparison. However, what is the added value of looking at spatial patterns for past climates compared to looking at them for present-day? For present-day, spatial patterns would be the same to first order. At present, there are so many more sites available directly sampling precipitation (GNIP), so why bother with speleothem records for past climates?

Figures 7 and 8 show the spatial patterns of observed and simulated δ^{18}O for LGM and MH. The sub-figure a representing North and South America are common to both figures, and they actually show very similar patterns. The same figure for present day would also show very similar patterns. This is because δ^{18}O, temperature or precipitation changes between LGM, MH and present-day are much smaller than the magnitude of spatial variations along a transect covering such a wide range of latitudes. So these figures support my skepticism about the relevance of spatial patterns in absolute values for past climates. Figures 7b,c and 8b,c do not represent the same regions. But I'm sure that the maps for present-day would look very similar.

The corresponding text bears several slips of the pen and/or interpretation errors, that probably reflect that writing this sub-section was not comfortable:

– l 408: "δ^{18}O changes" should be replaced by "δ^{18}O patterns": the authors write "changes" because this is really what is interesting to look at, but actually the figures do not show it.

– l 412: "underestimates changes in precipitation": again, we cannot see changes from present-day to MH on this figure.

What you want to plot depends on the science question. If the science question is what controls spatial patterns in absolute values, then it is better to focus on present day values; past climates do not provide much added value. But if the science question is what controls the changes at paleo-climatic time scales, then it is necessary to look at anomalies between 2 climatic states.

So I recommend to remove section 3.4, or replace it by an analysis of spatial patterns of anomalies, and to modify accordingly the abstract, protocol and conclusions.

We agree that we need to make the case that using palaeodata over different transects is valuable for data-model comparisons in addition to looking at anomalies between two climatic states. We expect the gradients shown in Figures 7 and 8 to change over time due to the large ice-sheets during the LGM and the different insolation patterns at different latitudes during the MH. In some cases, the model will be able to simulate those gradients/patterns and in some other cases, the model will not – and this is valuable information.

We have therefore decided to modify the current Figures 7 and 8 to better showcase the changes that occur in the transects between the modern (1958-2013 CE), the MH and the LGM. As a result of this, we will remove the pollen-based reconstructions - which are not the focus of this paper - to only focus on focus on isotope data.

The two examples enclosed as Review Figures 1 and 2 will be part of these new figures. In the case of the Asian transect, we observe a fundamental change in the latitudinal gradient across time periods and in particular during the MH. The SE-NW gradient in the data is clearly not reproduced by the model, which systematically simulates more isotopically enriched precipitation between 20-35 N. On the other hand, the Asian-Oceania transects are fairly similar across time periods but the clear offset during the MH between the data and the model supports the fact that the model underestimates the intensification of the hydrological cycle during this period. We hope the reviewer will agree that this observation is clearer in the spatial transects than in the traditional anomaly plots shown in Figure 6.

We will rewrite section 3.4 to reflect the changes in the figures.

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2 Detailed comments

L157-158: I do not understand what this means. Where is the control simulations included in the LGM-MH difference?

Two different control simulations are available for the lgm and 6ka experiments and to avoid any potential offset between these control simulations being incorporated in the LGM-MH anomaly map (Figure 6c), we have calculated the LGM-MH anomalies as (lgm-PI$_{lgm}$) – (6ka-PI$_{6ka}$) instead of doing directly lgm-6ka. We will clarify this in the text with the following sentence:

We also calculated the anomaly between the LGM and MH (LGM-MH), taking account of the difference between their control simulations in the following way: (lgm-PI$_{lgm}$) – (6ka-PI$_{6ka}$).

L209: remove "non-equilibrium of"

We will do this.

L216: add a dot.

We will do this

L223: remove "with data ... baseline".

Removing "with data ... baseline" as suggested by the reviewer obscures what palaeoclimate simulations are being compared to: the data. We will clarify this sentence by writing:

Data-model comparisons are generally made by comparing (1) anomalies between a control period and a palaeoclimate simulation with (2) data anomalies with respect to a modern baseline.

L234-235: already said, remove.

We agree with the reviewer that this has already been mentioned in L156-158 and the text will be removed.

246: define pchip

We will add the definition of pchip (piecewise cubic hermite interpolation) in the text.

L295: clarify the rationale. Why can't there be a sampling bias in temperate regions towards the PMIP periods?

The previous sentence already suggested that the deviations could result from a sampling bias. However, we will rephrase this sentence to clarify this point:

These deviations could arise from sampling biases but it is unlikely that human sampling bias would be different in the tropics than in temperate regions. Differences between the deviation curves of both regions curves at least for the last 130ka (Figure

2b,c) suggest increased climate variability in the extra-tropics leads to increased deviation from expected stalagmite growth.

L296: clarify this sentence. What does even “at a global level” mean?

We will rephrase this sentence to:

Thus, the speleothem data provide a first-order assessment of climate changes on orbital time scales globally.

L300-302: can you explain briefly why higher latitude speleothems are more depleted than OIPC and low latitude speleothems are more enriched?

Here, we were interpreting the map patterns rather than doing a robust assessment of the observed trends. We believe that these patterns will probably not be significant and, as we do not see any reason why this may be the case, we will take this sentence out.

L305:“cave specific factors” cannot explain why you have such systematic differences common to wide regions.

We agree with the reviewer and refer to our answer above.

L317-319: should the reader conclude that ECHAM underestimates the interannual variability? If so, please state this clearly. Has such a bias already been described in a previous paper, for ECHAM or for other models? Explain briefly what could be the reason for this underestimate.

According to the AR5 IPCC report, although there has been substantial progress between CMIP3 and CMIP5 models in their ability to simulate precipitation extremes, there is a tendency to underestimate the sensitivity of extreme precipitation to temperature variability or trends and, in turn, its inter-annual variability. In particular, ECHAM5 underestimates this inter-annual variability in regions with prevalence of convective precipitation (i.e., the tropics), as well as in extratropical regions during the summer (e.g., in southern Europe) (see Eden et al., 2012). This is due to the fact that formation of convective precipitation acts on small scales and has a large random component, even for a given large-scale atmospheric state. In another study (Butzin et al., 2014), the authors found that for three Siberian GNIP stations δ^{18}O-variability was also underestimated. We will modify the manuscript to incorporate this information.

References not already listed in the manuscript:

Eden, J. M., Widmann, M., Grawe, D. and Rast, S.: Skill, Correction, and Downscaling of GCM-Simulated Precipitation, J. Climate, 25(11), 3970–3984, doi:10.1175/JCLI-D-11-00254.1, 2012.

Flato, G., Marotzke, J., and others:Evaluation of climate models, in: Climate Change 2013 – The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Change, I. P. C. C., Cambridge University Press, Cambridge, 741-866, 2013.

L321: move “processes” before “within”

We will revise this sentence to read:

(...) reflecting the impact of karst and in-cave processes that effectively act as a low-pass filter (...)

L325-328: this has already been said just above.

We agree with the reviewer. Both sentences will be merged to avoid duplication.

L359: replace "anomalies" by "MH values"?

We agree with the reviewer and we will make the suggested change in the text.

L422: remove "utilising"

We will rephrase this sentence to:

Our analyses illustrate a number of possible approaches for using speleothem isotopic data for model evaluation.

L440-447: this issue was not previously discussed. Add some quantification, or a map, showing what error we would make if we use only the fractionation factor for calcite?

While the impact of using one of another fractionation equation is minimal (i.e. smaller than the measurement uncertainty) for sites with MAT > 27.3C, the added *uncertainty is noticeable at sites with lower MAT. Changes of MAT across time periods could exacerbate these differences for individual sites thus making the calculated entity-based anomalies inaccurate. As requested by the reviewer, we will add a new supplementary figure (enclosed as Review Figure 3) to showcase that using the appropriate correction according to the speleothem's mineralogy is important. We will also revise the text accordingly.*

L473: remove "on a global basis". Or clarify what you mean. Even at a specific cave, if the speleothem acts as a low pass filter, time scales shorter than "quasidecadal" cannot be studied.

The temporal smoothing inflicted by the karst processes varies from site to site. There are sites where the transmission from the surface to the cave happens rapidly and as a result speleothems preserve yearly or even sub-annual variability. However, in using the database to construct regional signals, there will always be some sites that have a high temporal smoothing, and therefore you cannot use them for timescales shorter than quasi-decadal (as seen in Figure 4). We will revise the text to clarify this point.

L475-476: clarify. Do you mean that the model underestimates δ^{18}O changes?

Yes, the model underestimates the amplitude of δ^{18}O changes as recorded in the speleothems. For details we refer the reviewer to our answers on their comment on L317-319. We will rephrase this sentence to:

Using the traditional anomaly approach to data-model comparisons, consistency between the sign of observed and simulated changes in both the MH and the LGM exists. However, the ECHAM5-wiso model underestimates δ^{18}O compare to the speleothems.

L476-477: clarify.

We agree that this sentence is too broad and general and have decided to delete it.

L489: “constraining structural error on the model side”: what do you mean? There are plenty of sources of errors in the model: errors on forcings, missing processes in parameterization package, tunable parameters, coarse resolution... Which one are you refering to? “true uncertainties”: beware that errors are not the same as uncertainties. Anyway, in this paragraph, I suggest to focus only on uncertainties on the observation side, because this is what is useful to evaluate models. The question of quantifying uncertainties in models is set differently and is beyond the scope of this paper.

We will rephrase this sentence to:

There are many reasons why climate models do not simulate observed climate changes, including lack of key forcings, missing processes, structural errors, coarse resolution, etc. However, in this paper we focused on potential uncertainties on the speleothem data. Site-specific controls...

Figure captions:

Review Figure 1: Modern, Mid-Holocene (MH) and Last Glacial Maximum (LGM) transects for Asia. Maps at the top of each panel show the simulated δ^{18}Op from

ECHAM5-wiso. All transects show absolute δ^{18}O values. In the maps, filled circles are SISAL δ^{18}O averages for entities that cover both the MH and the modern reference period. Filled squares are SISAL entities that do not have a corresponding modern. Bottom plots of each panel show the simulated data extracted for each transect: black circles and whiskers are mean $\pm$2 standard deviation of the data extracted along longitudinal sections in between the two great circle lines shown in dashed grey lines in the top maps. The red line is the median of the extracted data. All data were extracted at steps of 1.12 degrees to coincide with the average model grid-size. These bottom panels also show SISAL δ^{18}O (circles for low-elevation sites, < 1,000 masl; triangles for high-elevation sites, > 1,000 masl).

Review Figure 2: Modern, Mid-Holocene (MH) and Last Glacial Maximum (LGM) transects for Oceania and SE Asia. Maps at the top of each panel show the simulated δ^{18}Op from ECHAM5-wiso. All transects show absolute δ^{18}O values. In the maps, filled circles are SISAL δ^{18}O averages for entities that cover both the MH and the modern reference period. Filled squares are SISAL entities that do not have a corresponding modern. Bottom plots of each panel show the simulated data extracted for each transect: black circles and whiskers are mean $\pm$2 standard deviation of the data extracted along longitudinal sections in between the two great circle lines shown in dashed grey lines in the top maps. The red line is the median of the extracted data. All data were extracted at steps of 1.12 degrees to coincide with the average model grid-size. These bottom panels also show SISAL δ^{18}O (circles for low-elevation sites, < 1,000 masl; triangles for high-elevation sites, > 1,000 masl).

Review Figure 3: Speleothem samples for the period 1958-2013 converted to their drip-water equivalent using the fractionation factors from Grossman and Ku (1986; black dots) and Tremaine et al. (2011; red dots). We used simulated mean annual temperature (MAT) for the years when samples are available for the conversion. Vertical lines indicate the offset thresholds for 0.1 and 0.3 with the former corresponding to the average isotope uncertainty in the SISAL database. Maximum offset occurs at low MAT and is 0.86.

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Review Figure 1:

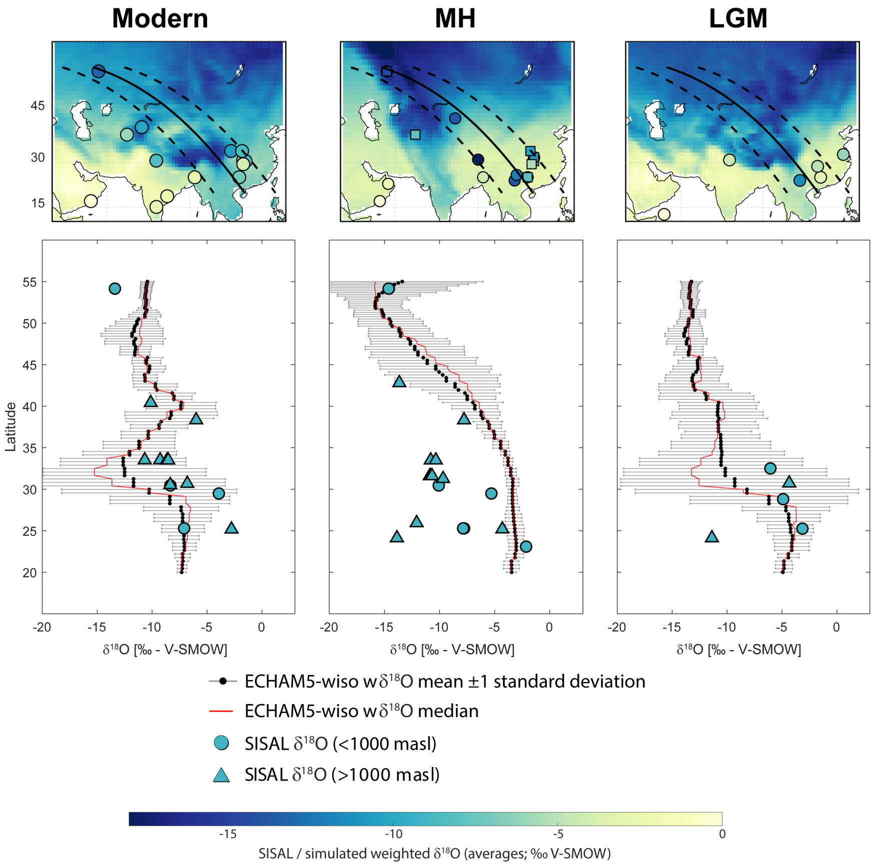

Fig. 1.

Review Figure 2:

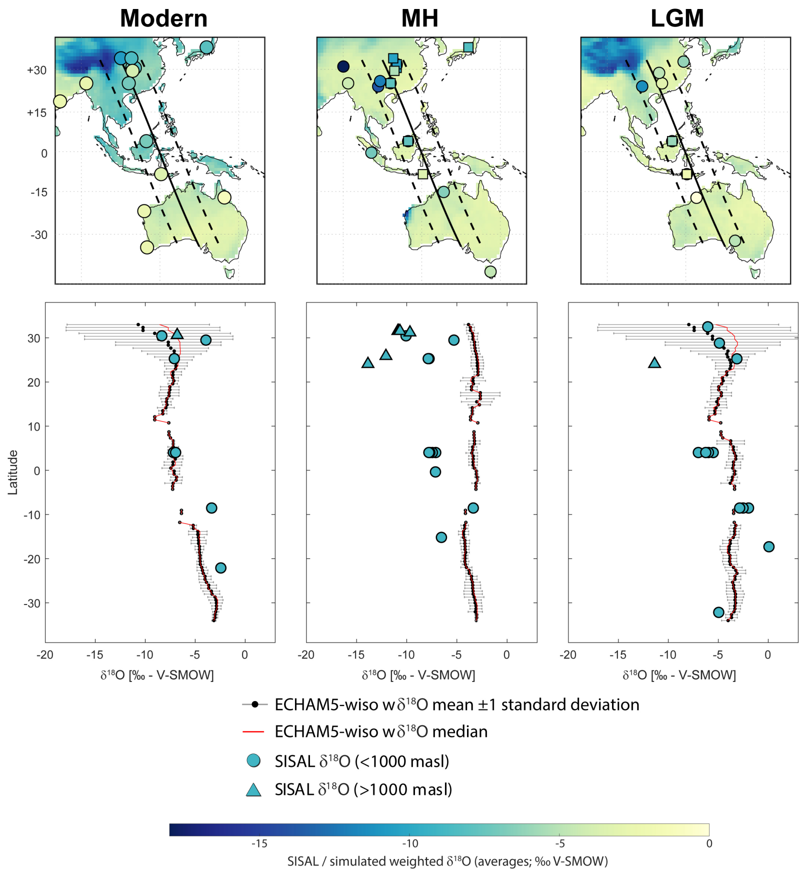

Fig. 2.

Review Figure 3:

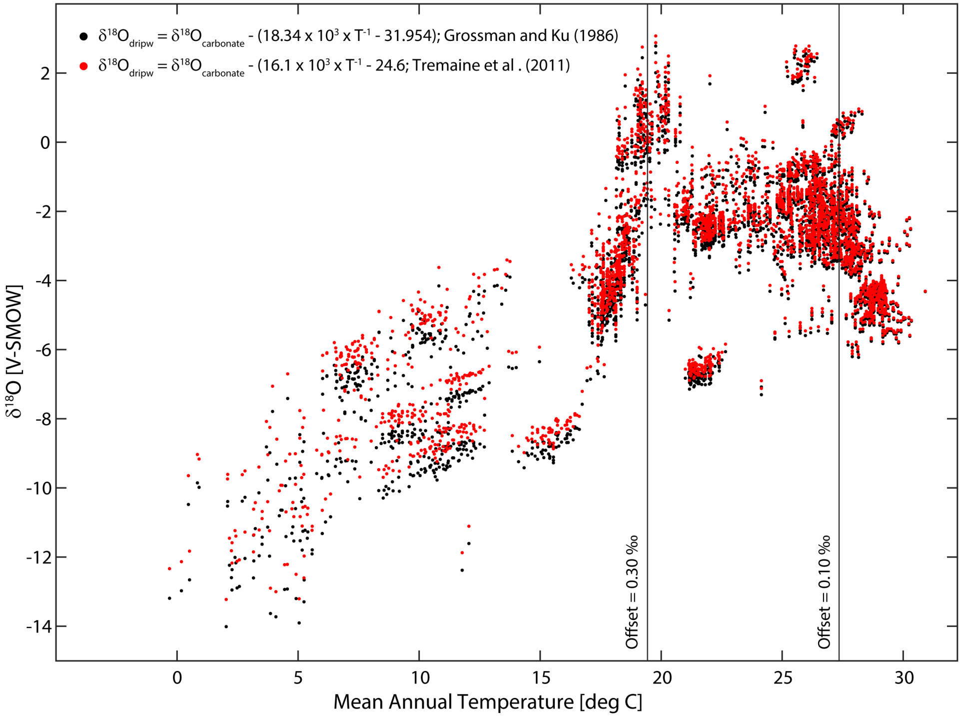

Fig. 3.

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