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Interactive comment on "Effect of precipitation seasonality on annual oxygen isotopic composition in the area of spring persistent rain in southeastern China and its palaeoclimatic implication" *by* Haiwei Zhang et al.

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Anonymous Referee #1 Received and published: 19 December 2018 The manuscript "Effect of precipitation seasonality on annual oxygen isotopic composition in the area of spring persistent rain in southeastern China and its palaeoclimatic implication" by Zhang et al. investigates the precipitation seasonality of the Chinese monsoon. For this the authors identify regions where precipitation associated with the Chinese monsoon makes the gross of the annual precipitation amount and regions where non-monsoonal precipitation also contributes significantly to the annual precipitation amount. A special

focus is on the so called "spring persistent rain (SPR) region", southeast China, where precipitation in March and April/May contributes also significantly (20% to 45%) to the annual rainfall amount. Then, the authors discuss the evolution of monthly precipitation _18O values and its correlation to precipitation amount for four regions, where seasonal precipitation amounts differ significantly; again a special focus is on southeastern China, where non-monsoonal precipitation contributes significantly to the annual precipitation amount. Based on the observation that precipitation amounts and precipitation _18O values in the SPR region correlate with El Nino and La Nina phases the authors investigate in detail the observed relationship by studying back trajectories and correlation coefficients between various quantities. Finally, the authors discuss implications for palaeoclimate reconstructions using speleothem _18O time series.

The submitted manuscript discusses an important aspect of the Chinese monsoon in highlighting the effect of precipitation seasonality on precipitation-weighted _18O (_18Opw) values that will influence the interpretation of _18O-based reconstructions (e.g. speleothems) of the Asian Monsoon. I personally find this an exciting topic that will eventually stimulate also similar studies in other regions, where year-round precipitation can modulate _18Opw values. However, while the manuscripts outline and topic is generally sound and in the scope of Climate of the Past, there are some aspects and sections of the manuscript that need to be improved/strengthen and extended, respectively. These are detailed in my general and specific comments. Therefore, my recommendation is that the manuscript needs major revisions before being considered for publication in Climate of the Past.

Answer# Thank you very much for your approval of this subject. We will revise the manuscript according to your constructive comments and suggestions.

General comments Statistical Analyses: The statistical results that are presented in Table 2 and Table 3 need to be redone and/or better explained. In the submitted manuscript it is basically not possible to understand how the correlation coefficients were calculated. While it is clear that you calculated correlation coefficients for annual averages it is not stated what months you are using. This is even more important for the correlations between meteorological parameters (_18Opw, precipitation amounts and ratios, respectively) and the MEI. It is often stated that these are correlated to the El Nino phases, but what is this phase? Is it from January to December? Is it the year before an El Nino occur or the year after? All this information should be accessible in the table caption for Table 1 and Table 2.

Answer# Agree. We will redo the statistical analyses that presented in Tables 2 and 3. In the current manuscript. the temporal coverage of annual rainfall is from January to December, the EASM rainfall is from May to September, the NSM rainfall is from October to next April, the d18Opw is from January to December, the MEI is from October to next June. In the revision, we will redefine the temporal coverage for these parameters and clearly state them in the captions of the Tables 2 and 3. We will also calculate the correlations between the different phases of El Nino/La Nina and the meteorological parameters, and clearly explain how the correlations were done.

To strengthen your conclusions, I strongly encourage you to calculate also the correlation coefficients between the meteorological parameters (_18Opw, precipitation amounts and ratios, respectively) and the ENSO index.

Answer# Actually we have calculated the correlation coefficients between these meteorological parameters and Nino 3.4 SST, some of correlations are weaker than those with MEI. Some study considers that the MEI can provide a more complete description of the ENSO phenomenon than a single variable ENSO index such as Southern Oscillation Index (SOI) or Nino 3.4 SST (Wolter and Timlin, 2011), therefore, we only show the results in terms of the MEI. This was stated in line 124-127. In the revision, we will also show the correlation coefficients between the meteorological parameters and Nino 3.4 SST.

Furthermore, I left wondering why you calculated the lag-1 correlation coefficient in Table 2. Is there any physical rationale for these calculations?

Answer# In the current manuscript, the temporal coverage of the NSM rainfall is from October to next April and the d18Opw is from January to December. There is a four-month overlapping (January-April) between 1-yr lag d18Opw, NSM rainfall and EASM/NSM ratio. Therefore, we also calculated the correlation coefficient between 1-yr lag d18Opw, NSM rainfall and EASM/NSM ratio. Bur there is no physical sense between 1-yr lag d18Opw and EASM. Actually, we have also calculated the contemporary correlations between d18Opw (Jan-Dec) and EASM rainfall (May-Sep), NSM rainfall (current Jan-April plus current Oct-Dec) and the corresponding EASM/NSM ratio, significant correlations can be also observed between them. But we did not show these results in the manuscript. In the revision, we will evaluate these correlations and show the results, the definition of the temporal coverage and the calculation will be clearly stated in the caption of Table 2 and in the new manuscript.

In the manuscript you mention that the trajectories of the westerlies are changing between an El Nino and La Nina phase. I am wondering if you tested also correlations between the meteorological parameters and NH mid-latitude modes (e.g. the Arctic Oscillation (AO)?). This is because a recent study highlights the importance of the location of the westerlies for the Asian Monsoon [Zhang et al., 2018]. Furthermore, another study mentions the correlation between the AO and the East Asian and precipitation anomalies southern China [He et al., 2017]. Therefore, I would find it exciting if the authors could also investigate whether there is a relationship between the AO and the meteorological parameters in southeastern China and the spring persistent region or not. This would certainly strengthen the manuscript and yield a more complete picture of the processes that affect precipitation amounts and _18Opw in the study region.

Answer# Thank you very much for this helpful suggestion. We will also calculate the correlations between the AO and these meteorological parameters (d18Opw, precipitation amounts and ratios, respectively), the results will be also discussed in the new manuscript.

Back trajectory analyses: The investigation of the back trajectories to unveil the differences of the moisture sources for La Nina and El Nino phases in the SPR region is in principle solid for the analysed years of 1988/98 and 1991/1992, respectively. However, while the analysed back trajectories reveal differences in the moisture sources (which appear to be consistent with the observed variations in _18Opw from the Changsha GNIP station) it is not possible to conclude from these alone that variations in the moisture source could explain the observed variations in _18Opw. This is because no information is given or presented on the mean state of the moisture sources and if the back trajectories changes in a similarly for other El Nino and La Nina phases. Moreover, it is not discussed where the moisture is taken up that forms the precipitation in SPR region (i.e. is the moisture from a distal or close source). To strengthen the conclusions of the back trajectory analyses I suggest that you should perform back trajectory analyses for the complete period of the Changsha GNIP station and for the period shown in Figure 6. Furthermore, perform back trajectory analyses for El Nino and La Nina phases shown in Figure 6 and compare it to the back trajectories of for the years 1988/98 and 1991/1992. These analyses facilities to better constrain the differences and/or similarities between the mean state and El Nino/La Nina phase of the back trajectories; the comparison of the back trajectories for multiple El Nino/La Nina phases allow to better constrain whether the presented back trajectories represent a "normal" response to El Nino/La Nina phase or not. Explain the differences to the other regions that receive precipitation from the East Asian Monsoon. Furthermore, I suggest that the authors perform analyses of where the moisture is taken up. This is possible with HYSPLIT and would further strengthen the results of the manuscript and allow for more robust conclusions on the processes that govern the _18Opw variability. These analyses may also be used to estimate the sensitivity on the precipitation history along a specific trajectory applying a multi-box Rayleigh model and using precipitation amount and atmospheric moisture (similar to the study of [Rozanski, 1985]). You could use the model output of the IsoGCM simulation for this. Together, these analyses would yield a more fundamental insight into the processes that control the _18Opw variability

in the SPR region, in turn allow using this knowledge to reconstruct past changes of the atmospheric circulation by using e.g. speleothem _18O time series.

Answer# Agree. In the current manuscript, our back trajectory analysis only considers air mass movement without considering moisture content, and no information is given on where these air masses picked up. Now we know how to do the trajectory analyses after our special efforts on HYSPLIT. We will reanalyze the moisture source trajectory for the complete period of the Changsha GNIP station and also for the period shown in Figure 6. The changes in moisture source trajectory during multiple El Nino/La Nina phases and their effects on the d18Opw will be discussed.

Figure 1 and 2: Figure 1 and 2 do show very similar results and I suggest to show Figure 2 in the supplement (for comparison to the revised Figure 1) and instead modify Figure 1. For this I would show seasonal precipitation ratios instead of seasonal precipitation amounts in Figure 1. Include an additional panel, which shows the annual precipitation amount for reference. Furthermore, show the location of the GNIP station in the panel of the annual precipitation amount and the location of caves in the panels of the precipitation ratios. Based on the ratios define some criteria where the SPR and monsoon region are, instead of the different symbols in Figure 2.

Answer# Agree, we will combine these two figures together and redraw a new figure 1.

Specific comments Line 41: Explain in more detail why it is a unique synoptic and climate pattern.

Answer# Agree, we will explain it and give the references.

Line 63-64: Please indicate these regions in Figure 1

Answer# Agree, we will indicate these regions in the new figure 1.

Line 65-67: Please reference the published stalagmite records you list.

Answer# Agree. We will add the corresponding references.

Line 83-86: Please detail where (in which region? Everywhere?) the various mechanisms/ processes are proposed to modify _18O values.

Answer# Agree. We will extend this part in detail.

Line 141-142: Have you developed the cluster analyses tool or did someone else do it? If you developed it, please explain it in more detail. If not, please reference the original work.

Answer# We follow the reference Stein et al. (2015), it will be given in the revision.

Line 145-146: What data have you used for the analyses?

Answer# It is monthly precipitation datasets encompassing 160 meteorological stations in China during the period 1951-2014, which was described in line 101-104. We will make it clear in the revision.

Line 147-149: Refer to Figure 1 and indicate the different regions in Figure 1.

Answer# Agree, we will revise it.

Line 150-157: Indicate the boarders between the areas with different precipitation seasonality in Figure 1.

Answer# Agree, we will redraw a new figure 1.

Line 164-168: You state that the EASM starts later and is weaker during El Nino years. Then you write that the EASM precipitation amount over southeast China is reduced when the SPR starts late. I left wondering if these two parts of the sentence are linked or not? Do you want to say that the SPR starts late too during El Nino years or are these two observations independent of each other? I suggest to revise this text to make clear what you want to say.

Answer# We want to say that the EASM starts later (late May to early June) and the SPR lasts longer (until late May) during El Nino years. These two parts are linked. We

will reorganize this part and make it clear.

Line 169-173: What occurs during La Nina years? The opposite?

Answer# Yes, the opposite happens during La Nina years, we will clearly state it.

Line 173-174: This last concluding sentence is an important observation and I would summarize it in more detail, especially the link to El Nino/La Nina (the latter is missing at the moment and should be included).

Answer# Agree, we will summarize it in detail.

Line 175: I would reorder Section 3.2. Start with the discussion of the precipitation pattern first, followed by the discussion of the _18Op values and then by the effect of precipitation on _18Op or _18Opw.

Answer# Agree. We will reorganize it.

Line 177: Refer to Table 1 when you mention the GNIP stations for the first time. Line 186: Refer to a figure here. Line 187-189: Please give a reference for this statement or prove some details for it.

Answer# Agree. We will give the references.

Line 191: Rayleigh (1896) is a wrong reference here, because you reference to a statement and not to a Rayleigh model (multi-box mass balance model).

Answer# Agree. We will remove the reference Rayleigh (1896) and give a correct one.

Line 207: The reference to Figure 3b seems to be wrong here?

Answer# The reference should be Table 1, it will be corrected.

Line 207-209: What and how many meteorological stations have you used? What were the selection criteria?

Answer# We only used the data from the nearest meteorological station (one station) to each GNIP station. Every meteorological station has 64-yr data (1951-2014), it should be convincing.

Line 213: Have you defined SEC before?

Answer# Yes, in line 167.

Line 216: See the general comment on the back trajectory analyses.

Answer# Please see the response to the general comment on the back trajectory analyses.

Line 236: Please give a reference for the cluster analyses.

Answer# The reference Stein et al. (2015) will be given here.

Line 258-261: This sentence seems to be at the wrong place and I would move it to the beginning of this section (line 250). It kind of is also related to Equation 1 and 2, respectively. So it may repeat the conclusions from Line 247-249 already?

Answer# Agree. We will reorganize this paragraph.

Line 266-269: How is this statement linked to El Nino and La Nina to which you refer at the beginning of this section (Line 162-264)?

Answer# Their statements linked to El Nino and La Nina are different; we will state this clearly in the revision.

Line 270-273: The results from Cai et al. (2017) do at least not fit to your results presented in Figure 4. In your back trajectory analyses there is a change in the moisture source and the ratio between the Indian and Pacific Ocean trajectory is nearly 50:50. Please state this hear already.

Answer# We will reanalyze the moisture source trajectory and rewrite the discussion section according to the results.

Line 306-310: Have you done some cross-comparison between the model and the

precipitation data? If yes, please state this here and show it in a supplementary file. Otherwise, I suggest to do some cross-comparisons and include it. Show comparisons between observed and modelled precipitation amount as well as precipitation _18O.

Answer# Yes, we have compared the IsoGSM data with the GNIP data, consistent variations in monthly precipitation amount and d18O can be found between them. But we did not show the results in the manuscript. We will evaluate the IsoGSM data and state it clearly in the revision.

Line 323: Modify Figure 5a in highlighting the El Nino and La Nina years.

Answer# Agree, we will redraw figure 5.

Line 326-328: What is the meaning of this observation? See also my general comment on statistical analyses.

Answer# The temporal coverage of the NSM rainfall is from October to next April and the d18Opw is from January to December. There is a four-month overlapping (January-April) between 1-yr lag d18Opw, NSM rainfall and EASM/NSM ratio. Therefore, we calculated the correlation coefficients between 1-yr lag d18Opw, NSM rainfall and EASM/NSM ratio. Please see the detailed response to the general comment on statistical analyses. We will redefine the temporal coverages of these parameters and redo these statistical analyses.

Line 370-376: I am not fully convinced by this conclusion. Our observations show that there seems to be a relationship between ENSO and _18Opw in the SPR region. However, your back trajectory analyses clearly show that there are differences between El Nino and La Nina moisture trajectories. Possibly, the suggested additional analyses (see general comments) will clarify this and either strengthen or modify this final conclusion.

Answer# Yes, we also think the moisture source and pathway might impact the changes in d18Opw. In the current manuscript, our back trajectory analysis only considers air mass movement without considering moisture content, and no information is given on where these air masses picked up. We will reanalyze the moisture source trajectory in the revision, then quantify the effects of moisture source and precipitation seasonality on d18Opw. The discussion and conclusions will be adjusted according to the new results.

Figure 1: - The combination of red and green colours should be avoided to make it easier/possible for colour-blind readers to identify differences and symbols. I suggest to only use black symbols for locations such as in Figure 1b. - The scale for the precipitation amount of panel a and b should be similar. - Identify/highlight/name the regions that you mention in the manuscript.

Answer# Agree. We will redraw figure 1 according to your helpful suggestions.

Figure 2: - Highlight the boarders between the different precipitation pattern - Refer in the figure caption what precipitation data was used or refer to a section in the paper for more information.

Answer# Agree. We will combine figures 1 and 2 as a new figure 1, the boarders between the different precipitation patterns will be shown in the new figure 1. The precipitation data will be stated clearly in the caption.

Figure 3: - Clearly state in the figure caption how you calculated the mean values. E.g. Figure 1a shows the mean _18O (or _18Opw?) values – the y-label is different to the figure caption! – using monthly _18O values (or _18Opw?) from all GNIP stations in the northern MRC region, as grouped in Table 1, etc. - What is the standard deviation of the mean _18O value (_18Opw?)? To estimate it, you may use _18O-anomalies only, to account e.g. for different altitutes. - Please state how many measurements were used to calculate the mean values. Was it only one year or many years and were the datasets continuous. This allows to better constrain the robustness of the comparisons. - What meteorological stations were used (Figure 3c) and was it only one station or many? What was the criteria to select them? - You could combine

Figure 3b and c for a better comparison between the datasets. For example show the comparison of 2 regions in Figure 3b and the comparison of the remaining 2 regions in Figure 3c.

Answer# The calculation of d18Opw (including the measurements, standard deviation of the mean 18O value) and the selection of the meteorological stations in figure 3c will be clearly stated in the caption of figure 3. The figures 3b and 3c will be combined for a better comparison according to your suggestion.

Figure 4 - See my general comments.

Answer# We will reanalyze the moisture source trajectory, a new figure 4 will be given.

Figure 5 - Avoid the use of green and red colours in the same figure panael (e.g. Figure 5b) (see above). - Please give details what you mean with ENSO events? What years and months have you used for your calculations? - What months were used to calculate the EASM and NSM ratio?

Answer# We will change the colors of the curves in figure 5, the temporal coverages of ENSO events and the EASM/NSM ratio will be clearly stated in the caption.

Figure 6 - Label the different panels from a) to f) and refer in the text to Figure 6a, b etc. - I don't understand you write that the "The time series : : : lag : : : by 1 yr." at the end of the figure caption. Is this an observation? Did you shift the time series to make it look good? See also my general comment on this issue. - Please state what data you have used for the figures.

Answer# The different panels will be labelled accordingly. The temporal coverage of the NSM rainfall is from October to next April and the d18Opw is from January to December. There is a four-month overlapping (January-April) between the 1-yr lag d18Opw and the EASM/NSM ratio. That's why a good correlation can be also found between them. Please see the detailed response to the general comment on statistical analyses. We will redo these statistical analyses and redraw the figure 6. The data used for figure 6 will be clearly stated in the caption.

Table 1: - Include the period that the GNIP data is covering (e.g. 1987-1995) and the number of _18O measurements that you are using. - Are there seasons/months when no data is available? If so, please state it in the table caption, if not, state that year-round measurements are available.

Answer# We will add two columns showing the period and the number of the d18O measurements. The seasons/months without data will be also clearly stated in the table caption.

Table 2 and 3: - Please state in detail how the correlation coefficients are calculated. What months have you used? Is it always January to December? What datasets were used - Table 2: Why did you shift it by one year? What's the rationale of this? - See also my general comment on the statistical analyses.

Answer# The detailed calculation of the correlation coefficients will be clearly stated in the caption of Tables 2 and 3 in the revision. Please see the detailed response to your general comment on the statistical analyses.

Nomenclature for text, figures, axis: - If you refer to precipitation _18O values, use _18Opw - If you refer to precipitation-weighted precipitation _18O values, use _18Opw - If you refer to speleothem _18O values, use _18Os

Answer# Agree. We will correct them.

References: He, S., Y. Gao, F. Li, H. Wang, and Y. He (2017), Impact of Arctic Oscillation on the East Asian climate: A review, Earth-Science Reviews, 164, 48-62, doi: https://doi.org/10.1016/j.earscirev.2016.10.014. Rozanski, K. (1985), Deuterium and oxygen-18 in European groundwater sâ ËŸAËĞ Tlinks to atmospheric circulation in the past, Chemical Geology: Isotope Geoscience section, 52(3), 349-363. Zhang, H., M. L. Griffiths, J. C. H. Chiang, W. Kong, S. Wu, A. Atwood, J. Huang, H. Cheng, Y. Ning, and S. Xie (2018), East Asian hydroclimate modulated by the position of the westerlies

during Termination I, Science, 362(6414), 580, doi: 10.1126/science.aat9393.

Thank you very much for your recommendation.

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