

## ***Interactive comment on “South Pacific Subtropical High from the late Holocene to the end of the 21st century: insights from climate proxies and general circulation models” by Valentina Flores-Aqueveque et al.***

**Valentina Flores-Aqueveque et al.**

vfloresa@uchile.cl

Received and published: 19 October 2019

Answer to Referee #1

1. I am concerned about the use of such a small sample of models (4 models) to draw conclusions about changes in the SPSH. I cannot see why the authors could not use at least 6-8 models that have Last Millennium simulations, even excluding non-CMIP5 models HadCM3 and CSIRO Mk3L. R: We started with seven CMIP5/PMIP3 models but in order to carry out an adequate and rigorous comparison we had to discard the

C1

other three due to the impossibility to compare the first ensemble member (r1i1p1) of models for which the (1) Last Millennium simulation, (2) the historical simulation, and (3) the RCP8.5 scenario, were available in open access mode. Even though we understand four model could be a small sample, these four are the only models that fit the criteria described in the methodology, in particular the open access principle. We are aware of the uncertainties generated, but our results show consistencies in the responses to the forcing. This fact can be observed in the new Figure 3 (previously Figure 2), in which we include the results for each model in addition to the model ensemble mean.

2. When comparing models for LIA, CWP and RCP8.5, it may not be informative to consider only the multi-model mean. If there is large model disagreement, the model mean change does not represent the changes of each model. Instead, calculating changes in a given variable for each model and then comparing these, e.g. using a scatter plot or box and whisker plot, may be more informative. The model spread also provides a measure of uncertainty. (See also specific comment for page 13 below). R: A boxplot and whisker plot would not be statistically meaningful therefore not the best way to show models dispersion in consistency with our sample. As boxplot provides a five-number summary, n=4 models do not meet the minimum requirements for its application. In fact, the minimum recommended sample size for boxplot is n>20. Although, we agree that the multi-model mean may not very informative, consequently for a better visualization of the results, we modify the previous Figure 2 (now, Figure 3) to include the results for each model in addition to multi-model mean.

3. The model evaluation compared with observations or reanalysis should be included earlier in the paper as it provides the justification for using the models to examine past and future climate. That is, swap the order of section 3.2 and 3.3. Then include a few sentences at the end of the model evaluation section about the strengths and weaknesses of models (also add a figure comparing observations and model climatologies). R: We rearrange the order of both sections and included a new paragraph of synthesis

C2

about the comparison of our results and previous studies. We also added a new figure (Figure 1) including observations and models climatology.

#### Specific Comments

Page 3, Section 1.1: It would be helpful to include a Figure or schematic showing the regional climatological circulation in austral summer and winter. A new figure (Figure 1) showing the ERA-Interim climatology for the period 1979-2009, highlighting the main climatic features (SLP, winds) was added.

Page 3, line 12: “exceeding 45S” – does this mean extending poleward of 45S? It is not clear. The phrase “exceeding 45°S” was replaced by “extending poleward of 45°S”

Page 4, line 25-28: There is reasonable evidence of a period of synchronous cooling between Northern and Southern Hemispheres, although this does not imply that the signal is synchronous on a regional scale. For example, Neukom et al. (2014) state that “simultaneous cold anomalies in both hemispheres are identified between 1571 and 1722”. Perhaps provide some qualification here, or explain the difference between Southern Hemisphere and South American scale responses. R: A text about the work of Neukom et al. (2014) was included in section 1.2. In addition text was modified highlighting the difference between hemispheric and regional scales.

Page 5, line 19: Why did you only use 4 CMIP5/PMIP3 models when there are many more (8+) models available with the required simulations? You should comment on the limitation of relying on such a small number of models. R: To answer the first part of this question please referred above in the answer for comment 1. To answer the second part, a few sentences in ‘Concluding remarks’ about the need of future complementary analyses for reducing the uncertainties were included.

Page 6, line 21: You could also cite the new PAGES2K study here (PAGES2K Consortium, Nature Geosciences, 2019). Thanks for the recommendation. The new reference was added.

#### C3

Page 8, line 12: I am not sure what is meant by “increment” The word “increment” was changed by “increase”

Page 11, line 5: How can SLP fields move poleward? The sentence was replaced by “higher values of SLP would tend to move poleward”

Page 11, line 33: Do you mean the 4 models evaluated in this study, or a larger sample of CMIP models? The sentence was clarified by adding the phrase “the four models analyzed here”

Page 12, line 18: “long-term trends”: do you mean spurious (incorrect) long term trends, or actual anthropogenic climate change trends? R: Swart et al. (2015) found spurious long-term trends in all (6) reanalysis they studied. The term “spurious” was included before “long-term trends” to clarify.

Page 12, line 27: Denniston et al. (2016) is a study of the ITCZ in the Indo-Pacific region, so the position of the ITCZ in that study is not directly relevant to the ITCZ over South America. R: The work of Denniston et al. (2016) was cited here only for characterizing the latitudinal range on movement of the ITCZ in a general way. In addition, we also consider it to complement the observations of Yan et al. (2015) as both authors point out a change in the latitudinal range (contraction-expansion) of the tropical rain belt. While Yan et al. (2015) takes the western Pacific region and Denniston et al. (2015) the Indo-Pacific region, the feature can be interpreted independently of its longitudinal location because the consequence of this effect must be considered to understand the influence of the tropical dynamics at higher latitudes.

Page 13, line 8 onwards: the lack of signal in the LIA and CWP comparison based on models may be due to model disagreement. If you are comparing the multi-model mean values only, you may be smoothing out changes in individual models. An alternative way to show the changes might be a scatter plot or box and whisker plot of changes for each individual model (for example, change in location of ITCZ or Hadley Cell edge versus area average change in precipitation). This would be even more informative if

#### C4

more than 4 models were used. R: As we explained in the answer to Comment 2, a sample size of  $n < 20$  is not recommended for boxplot and whisker plot. For this reason and to improve the model disagreement comparison, we include as supplementary figure (Supplementary figure 2) the difference of mass stream function between LIA and CWP (LIA-CWP) for the annual mean, DJF and JJA for each individual model. This figure also displays the zonal mean precipitation, zonal mean winds, subtropical ridge position and latitudinal position of maximum zonal winds at 200 hPa.

Page 15, line 1-5: How do the model biases impact on the simulated changes in past and future climate? Do they reduce confidence in the results? R: When analyzing past and future changes with respect to historical simulations, we would be considering the same biases and our main point of interest is how different aspects of circulation vary within the same model. If there are systematic biases in the models, these would be reproduced in historical simulations -which we compared with reanalysis- as well as in past simulations (last millennium) and future projections. Moreover, the aim of this work is to establish a relative comparison of SA climate under a cold period (LIA), a warm period (CWP), and warmer conditions (RCP8.5) rather than a quantification of these changes. We include a few sentences in 'Concluding Remarks' developing this idea.

Page 15, line 23: You could also comment on the need to improve model performance in the simulation of Southern Hemisphere circulation to provide more robust projections. R: Thanks for the advice. We included a few sentences about that in Concluding Remarks.

Figure 2: I found it difficult to distinguish the red and magenta lines. Perhaps use different colors? R: We changed magenta for a brighter color (fuchsia) and we darkened the color red to increase contrast between both. In addition, color blue was replaced by cyan.

Figure 3: These plots are quite small with very small labels and legends. It is also hard

C5

to see the overplotted contour lines. I suggest plotting the zonal mean precipitation and winds in a separate set of plots to make it easier to see (there should be space for more figures as the paper currently only has 4 figures). R: Due to the close relation between the Hadley Cell, the zonal mean winds and the zonal mean precipitation we determined that these variables must be presented in the same plot. However, to facilitate image viewing we change the color blue (LIA) by cyan which is more contrasting and we enlarge labels and legends.

Figure 4: In this study, you do not find a shift in the Atlantic ITCZ and find a southward shift in the Pacific ITCZ as temperatures increase (according to line page 15, lines 15-20) so I am not sure why the ITCZ is plotted south in both sectors during LIA compared with CWP? R: Figure 6 (formerly Figure 4) shows a scheme resulting from the integration of both, paleoclimate records and model results. As can be read on section 3.4 models fails in representing tropical dynamics which is a known weakness of simulation models. However, reconstructions based on paleoclimate records are consistent among them and in agreement with the expected physical mechanisms exposed in literature (e.g., Sachs et al., 2009; Lee et al., 2011; Schneider et al., 2014). For this reason, Figure 6 displays an ITCZ located in a northern/southern position during the CWP/LIA.

Supplementary Figure 1: The green and magenta lines appear to be in the same location? R: Unfortunately, the scale prevents to appreciate better the small variations provided for the models in the position of the ITCZ during the LIA and the CWP in the figure 1S. However, as the display of the inter-hemispheric temperature differences is priority, we included a global scale map.

Supplementary Figure 2: The ERA-Interim climatology and the model climatology should be given in the main paper as this is an important part of evaluating model skill. Also, what are the stars? Also, the austral summer and winter lines appear to be swapped or wrongly labelled. R: We added the model climatology and we include it in the main paper (from now Figure 1). In figure caption the meaning of stars (= maximum

C6

value of slp) was added, and the labels of summer (red) and winter (blue) lines were corrected.

Technical Corrections Page 2, line 9: replace “interplays” with “interplay” R: The word “interplays” was replaced.

Page 2, line 16: replace “During last decades” with “During recent decades” R: The word “last” was replaced by “recent”.

Page 2, line 25: delete “derived” R: The word “derived” was deleted.

Page 3, line 6: replace “these evidences” with “this evidence” R: The phrase “these evidences” was replaced by “this evidence”.

Page 3, line 25: replace “to higher probability” with “with higher probability” R: The word “to” was changed by “with”.

Page 5, line 2: replace “associated to” with “associated with” (and elsewhere) R: The phrase “associated to” was replaced by “associated with” throughout the entire text.

Page 5, line 5: at the end of this line, I think “LM” is meant to be “LIA”? R: Yes, thank you. The right initials are “LIA”.

Page 5, line 10: replace “several” with “numerous” or “many” R: “Several” was changed by “many”.

Page 5, line 12: replace “uniform period: : .” with “period of uniformly positive temperature trends” for clarity. R: The sentence was replaced.

Page 6, line 6: replace “spanning time” with “time period” R: “Spanning time” was changed by “time period”

Page 13, line 24: this sentence is unclear. R: The sentence was changed to: “On the other hand, Yan et al. (2015), based on paleohydrology records of western Pacific and climate models, proposed that during the LIA a contraction of the tropical rain belt

C7

(i.e., the latitudinal range over which the ITCZ seasonally moves) occurs, instead of a meridional shift as has been described.”

Page 15, line 12: figure 5 is actually figure 4. R: Yes, in fact is figure 4. This error was corrected.

References: Please indent or add space between references to separate. R: Indent was added to references.

Please also note the supplement to this comment:

<https://www.clim-past-discuss.net/cp-2019-69/cp-2019-69-AC2-supplement.pdf>

---

Interactive comment on Clim. Past Discuss., <https://doi.org/10.5194/cp-2019-69>, 2019.

C8

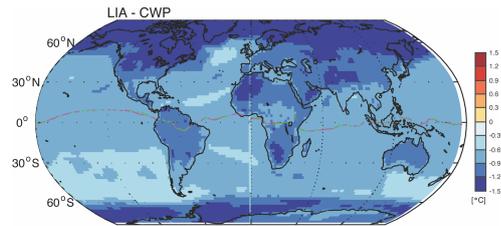


Figure S1: Model ensemble mean temperature difference between the LIA and the CWP. Note that models reproduce a small temperature variation (0.2°C) between both periods in most of the Pacific Ocean. Magenta line: ITCZ position during the CWP; green line: ITCZ position during the LIA.

Fig. 1.