

Interactive comment on “Pre-industrial and mid-Pliocene simulations with NorESM-L – AGCM simulations” by Z. Zhang and Q. Yan

Anonymous Referee #2

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In the paper "Pre-industrial and mid-Pliocene simulations with NorESM-L - AGCM simulations" Zhang and Yan introduce the model setup employed for the generation of their Pliocene Model Intercomparison Project (PlioMIP) experiment 1. The corresponding PlioMIP experiment 2 has already been described by Zhang et al. 2012. This paper is a contribution to the GMD special issue "Pliocene Model Intercomparison Project: experimental design, mid-Pliocene boundary conditions and implementation". A brief introduction of the atmospheric component "CAM4" of the NorESM-L model is presented, the model setup and generation of the boundary conditions is described, and the general climatology of the mid-Pliocene simulation and two reference simulations is presented at the example of surface air temperature and precipitation.

The presentation of the additional pre-industrial reference simulation (that is not being

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asked for in the PlioMIP experimental guidelines) is very interesting and adds to the scientific value of the generally well-written and sound manuscript. I highly recommend the paper for publication after minor revisions.

For the preparation of the final version of the manuscript I have added an extensive list of remarks that the authors might want to address. The majority of my comments is related to the language. In my opinion, some parts of the text need to be corrected in order to make the scientific message being understood more easily. I myself am not a native speaker of the English language - therefore, sometimes my remarks might be too critical, and sometimes they might be not critical enough. My remarks regarding grammar therefore merely represent suggestions to the authors that they should cross-check carefully, maybe also by consulting a native speaker.

Some of my recommendations have already been mentioned by anonymous referee #1, but I list them here all for the sake of completeness. The here given page and line numbers refer to the printer-friendly version of the discussion paper.

Throughout the paper: Atmosphere general circulation model (AGCM) experiments and atmosphere ocean general circulation model (AOGCM) experiments are being referred to by the terms "Experiments I", "Experiment II", and "experiments I". In all cases the term refers to more than one experiment, therefore I would propose to be consistent with respect to the use of the "plural -s". Furthermore, I propose to be consistent with respect to the use of upper- or lower-case.

Throughout the paper: The abbreviation "SST" seems not to be defined in the manuscript. Of course, it is a standard abbreviation that the typical reader of this manuscript will be familiar with. Yet, sometimes the authors use this abbreviation, and sometimes they use the full term "sea surface temperature" (e.g. in the heading of subsection 3.1). I propose to define the abbreviation SST at its very first occurrences (which are in line 12 of the abstract and line 29 on page 1205 if I am not mistaken), and then consequently use the abbreviation. The same proposal holds for the term

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"surface air temperature", which is at various locations of this manuscript used in either its abbreviated or non-abbreviated form, this includes table 2, figure captions, and axis labels (e.g. in Fig. 4).

Throughout the paper (especially in section 4): When describing results from the simulations, the authors often use terms like "global annual mean SAT" or "zonal mean annual precipitation". Would it make sense to point out the time- and space-average nature of the data by reformulating those terms to e.g. "global mean annual average SAT", "globally and annually averaged SAT", or "zonally and annually averaged precipitation"?

Throughout the paper (especially in section 4 and figure captions): Throughout the paper different notations of physical units are used. For example, the authors use mm day^{-1} , mm d^{-1} and mm/d as unit for precipitation. I propose to choose one unit for precipitation and use this consistently for text, figure captions and axis labels.

Page 1204, lines 9-10: I think there is a grammatical error that complicates the understanding of this sentence. I suppose the sentence should be changed to "... and also assess the potential uncertainties in analyzing mid-Pliocene climate anomalies that might result from the choice of the SST forcing for the reference experiment (pre-industrial or present-day)."

Page 1204, lines 20-21: Instead of "... is thought to be an analog ..." I propose to write "... is thought to be a potential analog ...". Jansen et al. (2007) actually write in the here cited publication that "... the mid-Pliocene represents an accessible example of a world that is similar in many respects to what models estimate could be the Earth of the late 21st century." In the following sentences Zhang and Yan (2012) actually themselves write that the mid-Pliocene represents a "potential analog", so I would weaken the statement also here.

Page 1205, lines 1-6: Change "the potential analog" to "a potential analog". Change "attentions are paid" to "attention is paid". Change "The recent mid-Pliocene sim-

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ulation" to "A recent mid-Pliocene simulation". Change "in the Pliocene" to "of the Pliocene". Change "climate sensitivities" to "climate sensitivity". With respect to climate sensitivity to fast and slow feedbacks: Maybe add a short explanation and/or references that describe the difference between Charney sensitivity and Earth system sensitivity. Is my assumption, that there is more than one record of $\delta^{18}\text{O}$ available from the Philippines, correct? If that is the case, then change "The $\delta^{18}\text{O}$..." to "A $\delta^{18}\text{O}$...". Change "from the coral skeletons" to "from coral skeletons". Change "do not exist" to "did not exist".

Page 1205, lines 9-10: It is not clear to me which relationship of cause and effect between topography and ice-sheet changes that the authors want to point out here. Would it make more sense to write "the changes of orography related to changes in ice-sheets are the major reason ..."? As far as I understand, changes in the mid-Pliocene orography especially in high latitudes are less related to mountain building than to the reduction of the ice-sheets, or is that incorrect?

Page 1205, line 14: Change "is recently" to "has been recently".

Page 1205, line 17: "are coming out" sounds strange to me, I propose to change this phrase to "are being published".

Page 1205, line 18: Similarly, I propose to change "should be done" to "should be conducted".

Page 1205, lines 24-26: In order to clarify the sentence I propose a reformulation: Write for example "mid-Pliocene experiments performed with the atmosphere component of the low resolution version of the Norwegian Earth System Model (NorESM-L), the Community Atmosphere Model version 4 (CAM4)".

Page 1206, line 1: Maybe it makes sense to name here (for the sake of completeness) the atmospheric trace gas composition as the main cause for the difference between

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pre-industrial and present-day climate.

Page 1206, lines 8-11: I personally think this passage of the manuscript definitely needs to be rewritten. Would it make sense to write: "Section 2 introduces the CAM4 model. In addition to the information that has already been given by Zhang et al. (2012), in section 3 we present details on the source and implementation of the boundary conditions (including SSTs, topography, vegetation and ice-sheets) that have been used in the PlioMIP simulations. Section 4 gives an overview on general results of the climate simulations. In section 5 we conclude with a general discussion and summary."

Page 1206, line 14: Change "which is developed at" to "which is being developed at".

Page 1206, lines 15-16: I think the following reformulation of the sentence would make the included technical information much clearer: "The horizontal resolution used in the CAM4 model is T31 (approximately 3.75x3.75 degrees) at 26 vertical levels."

Page 1206, lines 16-18: I propose to change the sentence to "This model is identical to that used in the coupled PlioMIP simulations that have been presented by Zhang et al. (2012)".

Page 1206, lines 18-19: Similarly, I propose to change the following sentence to "However, two parameters that are specific for the NorESM-L are described here". Is this the message that the authors would like to give here? Furthermore I somehow miss the explanation on why these parameters are named here. Does this adjustment represent a deviation from a standard high-resolution-version of this model (which would probably be of minor relevance to PlioMIP), or is this a difference to the version of the setup used for the preparation of the simulations for experiment 2 as described by Zhang et al. (2012) (which would be of importance within the framework of PlioMIP)? I assume that the prior is the case - but at least to me that is not completely clear, in particular since the "However" seems to weaken the statement of the previous sentence (that the model versions between this study and Zhang et al. (2012) are exactly the same). It would be great if an explanation of this issue could be added to the final version of the

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manuscript.

Page 1206, line 19: Delete the "s" in "minimums relative".

Page 1206, line 22: Change "pre-industrial simulation with the CAM4" to "pre-industrial simulations with CAM4". It might be informative to additionally give a reference to a publication that describes the standard values of the mentioned parameters (if these are not given by Neale et al. (2010) and Eaton (2010)).

Page 1206, lines 23-25: The last two sentences of this page are difficult to read. Maybe reformulate them for example in the following way: "More information on the CAM4 model is given by Neale et al. (2010) and in the user guide (Eaton, 2010). A detailed introduction to NorESM is provided by Alterskjaer et al. (2011) and Zhang et al. (2012)."

Page 1207, line 5: Change "created by" to "described by".

Page 1207, line 6: If the proper reference to the "Reynolds SST climatology" is not Hurrell (2005), I would add it here.

Page 1207, line 7: I would give a more accurate time period that the climatology refers to. Is it comparable to the averaging period of the HadISST set?

Page 1207, line 9: I would change the sentence to "... are created with an anomaly method similar to the one suggest by the ..."

Pages 1207-1208: Some comments regarding the equations. First: Would it make sense to number the equations and then to refer to them in the text via their number (e.g. on page 1212, line 24-25)? Second: I would give a proper definition of all the "symbols" that are used within the three equations, e.g. a statement in the text that defines the meaning of "Modern_{Prism}". Third: I propose to use the index "Prism" in its upper-case form (i.e. PRISM) as defined before on page 1205, line 18. Fourth: Maybe it makes sense to stick to a specific name pattern for the symbols. Since pre-industrial SSTs are referred to as SST_{pre-industrial}, I would write e.g. ModernSST_{PRISM} instead

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of "Modern_{PRISM}". Fifth: I would avoid the space in "mid-Pliocene SST_{PRISM}" and write instead e.g. "midPlioSST_{PRISM}"; similarly for "mid-Pliocene Top_{PRISM}". Sixth: Would it make sense to call symbols referring to topography "Topo" instead of "Top"? The prior simply seems to be a more common abbreviation.

Page 1207, lines 13-14: Change the sentence to "Pre-industrial sea-ice area is identical to its local modern match."

Page 1207, lines 15-16: Change the sentence to "The generation of mid-Pliocene SST and sea-ice forcing (Fig. 1c and f) follows as well the anomaly method (eq. 2) described by Haywood et al. (2010)."

Page 1207, lines 19-20: Change the sentences to "Sea ice area follows mid-Pliocene monthly SSTs. Where SST is higher than $-1.8\text{ }^{\circ}\text{C}$, the sea ice coverage is set to 0."

Page 1207, lines 24-25: The authors state that the reference simulation uses local modern land-sea mask and topography conditions since the pre-industrial and modern versions are "almost" the same. If they are indeed not the same but slightly different, then it would make sense to shortly explain what these differences are.

Page 1208, line 1: Change "used here is same as" to "equals".

Page 1208, line 4: Change "anomalies method (Fig. 2)" to "anomaly method (Fig. 2 and eq. 3)".

Page 1208, lines 6-9: The two sentences sound a little complicated. Maybe such a reformulation will contribute to readability: "Compared to the modern condition, large changes of mid-Pliocene topography appear in particular on Greenland and at the margin of the Antarctic because of the reconstructed retreat of ice-sheets. The Colorado and Andes mountains are higher in the mid-Pliocene simulation." Does "Colorado mountains" refer to the Rocky Mountains?

Page 1208, line 14: Change "biom_veg_v1.2" to "biome_veg_v1.2". Would it make sense to speak of "the PRISM Pliocene vegetation and ice-sheet condition" rather than

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the "land cover condition"?

Page 1208, lines 18-22: I think also here is a complete reformulation needed to make the sentences more understandable. I propose to write: "Compared to the pre-industrial vegetation, in the mid-Pliocene simulation the percentage of bare land is reduced, while the percentage of tress increases (Fig. 3). The mid-Pliocene extent of ice-sheets is smaller on Greenland and at the margin of the Antarctic. The vegetation and ice-sheet conditions used in this study are identical to those used in the coupled PlioMIP simulations with NorESM-L (Zhang et al., 2012)."

Page 1208, line 23: Remove the "s" in "Experimental designs".

Page 1208, line 24: Change "above conditions" to "above described conditions". Additionally, replace the "," between "here" and "the pre-industrial" by a ":".

Page 1208, line 26: Change "experiment suggested" to "experiment as suggested". Change "the PlioMIP" to "the PlioMIP experimental guidelines".

Page 1209, line 2-3: Change the sentence "In this paper, ..." to "Other results described below are based on climatological means from the last 20 yr of each simulation." If I am not mistaken, the here chosen time period for the calculation of climatologies (20 yr) differs from the experimental guidelines of PlioMIP (where 30 yr are suggested). Is the number "20" a typo, or has the calculation of climatologies actually been carried out over 20 yr? If so, then I would point out this deviation from the experimental guidelines, since it might be of relevance for the model intercomparison.

Page 1209, line 8: Change "SAT 14.6 °C" to "SAT (14.6 °C)".

Page 1209, line 9-10: Change the sentence to "Both simulations are warmer than estimates of the pre-industrial SAT (about 13.5° C, Hansen et al., 2010), and ...". I did not understand the meaning of the word "but" here, and assume instead there should be an "and".

Page 1209, line 12-14: I would rephrase the sentences to: "The simulated zonal mean

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annual average SAT (Fig. 4b) of the pre-industrial and control experiment are similar. The results agree with the zonal mean EAR-interim temperature between 1979 and 2008 (Dee et al., 2011). If one takes a close look at Fig. 4b it looks like that indeed there is good agreement in the low- and mid-latitudes, but quite some disagreement close to the poles. Maybe it would be worth to address this shortly.

Page 1209, line 18: I assume that "on the Antarctic" should be replaced by "in the Antarctic".

Page 1209, line 19: I would rephrase the sentence "Such pattern ..." to "This is in agreement with the ERA-interim annual ...". When looking at the figure, the question came to mind whether the statement "there is generally good agreement between the simulation and the ERA-interim" really can be drawn from these plots. The large color range in the plots (showing absolute temperatures and precipitation) might hide differences that are actually not that small. Would the statement of "good agreement" still hold if one plotted anomalies between the simulation and the data-sets rather than absolute values?

Page 1210, lines 1-2: Change "In the two Poles" to "At the Poles". In Fig. 4c it actually seems that the value of 0.2 mm d^{-1} given for the zonal mean annual average precipitation at the poles is only correct in the Southern Hemisphere. For the Northern Hemisphere the value should be actually around 0.4 mm d^{-1} . Is that correct? If yes, then I would adjust this information in the text.

Page 1210, line 3: Change "coincides with" to "matches to".

Page 1210, lines 5-6: I personally would change "precipitation fields are" to "precipitation is".

Page 1210, line 9: I think the reference should be "(Table 2)" instead of "(Table 1)".

Page 1210, line 12: Delete "the".

Page 1210, line 13: Change the sentence "at tropics ..." to "... at the tropics in the
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mid-Pliocene simulation (Fig. 6)." I think the term "experiment" in this publication is already reserved for a set of mid-Pliocene and reference simulations. Also at other locations of the manuscript I would change "experiment" to "simulation" wherever this is appropriate.

Page 1210, lines 13-14: Add "the" before "equator" and "Southern Hemisphere".

Page 1210, lines 18-19: I propose to adjust the text to "reconstructed within the PRISM Project (Dowsett et al., 2009), and also agree with PlioMIP simulations of other groups ..."

Page 1210, lines 21-25: Change "also can be" to "is also"; at "anomalies fields" there is a spare "s", I propose to simply write "seasonal SAT anomaly"; instead of "northern winter" or "southern winter" I propose to use the terms "boreal winter" and "austral winter" - these terms are also used later in the manuscript; after "relative to the control experiment" add a reference to (Fig. 6); add a "the" before "Antarctic"; I propose to delete the "," after the temperature value in line 25.

Page 1211, line 2: Add a reference to Table 2 at the end of the line.

Page 1211, line 5: Change "The zonal mean precipitation shows that the mid-Pliocene ..." to "The zonal mean mid-Pliocene ...".

Page 1211, lines 6-7: Add a "the" before the each appearance of "tropics".

Page 1211, line 7: Add a reference to Fig. 7 after "relative to the control experiment." This also ensures that Fig. 7 is referenced, which is not the case throughout the first version of the manuscript.

Page 1211, line 8: Change the sentence "... precipitation anomalies map, larger annual ..." to "... precipitation anomaly map, a large annual average ..."

Page 1211, line 9-10: Would it be better to write "at the coast of the Arabian Peninsula" instead of "on the coast of Middle East"?

Page 1211, line 11: Write "reduction" instead of "deduction".

Page 1211, line 11-13: The term "Southern Indian" is not clear to me, a clarification is needed; change "the New Guinea island" to "New Guinea"; write "tropical Pacific" instead of "tropical pacific"; add another reference to Fig. 7 at the end of line 13.

Page 1211, line 14: I propose to change "at middle and high latitudes" to "at mid- and high-latitudes". If you follow this advice, please also adjust other occurrences of "high latitudes" and "middle latitudes" which appear in sections 4 and 5.

Page 1211, line 15-16: It is not clear to me to what the statement "have less regional variations" refers to. It would be good to clarify to which other state or quantity this comparison refers to.

Page 1211, line 18: To increase readability, I propose to delete the sentence "The annual precipitation increases by 4 mm d^{-1} there." and instead give the value of the precipitation anomaly in line 16 by changing "Norwegian Sea," to "Norwegian Sea (4 mm d^{-1})",

Page 1211, line 19-20: The sentence becomes clearer if it is reformulated: "The mid-Pliocene anomaly of global mean precipitation does not depend strongly on the choice of the reference simulation (i.e. the pre-industrial simulation or the control simulation).

Page 1211, line 22: Would it make sense to write "Southern Asia, especially on the Indian Subcontinent" instead of "South Asia"?

Page 1211, line 22-23: Do these anomalies really refer to annual average precipitation? The boreal summer anomaly shown in Fig. 7 is actually much larger. Could you also add a general description of the seasonal variation of precipitation? The respective subfigures of Fig. 7 do not seem to be addressed in the text.

Page 1211, line 23: Change "referenced" to "relative".

Page 1212, line 2: Change "described in the above sections" to "described above".

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Page 1212, line 3: Change "experiment agree with observations" to "experiment both agree with modern observations".

Page 1212, line 5: I propose to add "and during the winter season" after "particular at high latitudes".

Page 1212, line 5-6: The meaning of the sentence evades me. Did you mean to say: "The simulated general patterns of mid-Pliocene warming agree to our earlier coupled simulations"?

Page 1212, line 9: I propose to change the sentence to "The analysis of mid-Pliocene climate anomalies necessitates a reference experiment."

Page 1212, line 12-14: To clarify the sentence, I would rewrite it: "If on the other hand the pre-industrial experiment is chosen as the reference, the mid-Pliocene globally and annually averaged SAT increases by $2.7 \text{ }^\circ\text{C}$ ", which is 8% larger.

Page 1212, line 16-17: Change "However, on a regional scale, choosing reference experiment clearly influences the analyses of mid-Pliocene climate anomalies." to "On a regional scale, however, the choice of the reference simulation clearly influences the mid-Pliocene climate anomaly (Fig. 8)."

Page 1212, line 17-20: The sentence is difficult to understand. Would it make sense to rewrite the text passage to: "For example, if the pre-industrial experiment is chosen as the reference (instead of the control experiment), the mid-Pliocene globally and annually averaged SAT anomaly is increased (decreased) by 30% (55%) at mid (low) latitudes (Fig. 8)".

Page 1212, line 20: The meaning of "In Indian" is not clear, please refine.

Page 1212, line 21: Change "decuction" to "reduction".

Page 1212, line 22: Add a reference to Fig. 7 at the end of the sentence.

Page 1212, line 23: Change "The PlioMIP suggests" to "The PlioMIP experimental

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guidelines suggest"; change "reference experiment for" to "reference simulation of".

Page 1212, line 24-28: The meaning of the whole text passage is not clear to me. Would it be correct to write: "The mid-Pliocene SST forcing is created following the anomaly method, where the PRISM mid-Pliocene SST anomaly is added onto the local (i.e. group-specific) modern SST forcing. This experimental design is useful for the calculation of climate sensitivity considering the PRISM mid-Pliocene SST anomaly. It is also a common basis for future comparisons of PlioMIP AGCM simulations." As I pointed out, the meaning of the passage is not clear to me. Please clarify it.

Page 1213, line 1: Change "note, compared" to "noted, that compared"; add "(experiment 2, Zhang et al. 2012)" after "AOGCM simulations".

Page 1213, line 2: Change "anomalies" to "anomaly"; add "of this study (experiment 1)" after "AGCM simulations".

Page 1213, lines 3-9: Here is another passage that might be better understandable if being rewritten. I propose to change it like this: "All PlioMIP AGCM reference simulations are based on modern SSTs, but all AOGCM reference simulations rely on pre-industrial SST forcing. We indeed find a difference between our AGCM and AOGCM simulations (Zhang et al., 2012), and also in the simulations carried out by Chan et al. (2011). The simulations carried out by Kamae and Ueda (2012) and Contoux et al. (2012) on the other hand do not show such differences. This issue should be noticed and further assessed during the upcoming PlioMIP analysis and synthesis phase." Would it make sense to extend this discussion onto the data part of PlioMIP? As far as I understand, the mid-Pliocene warm phase as reconstructed within the PRISM project is as well influenced by variable climate forcing (due to the long averaging period), so the problem at the data side is somehow comparable to the issue that has been highlighted here. But maybe that would go beyond the scope of this manuscript.

Page 1213, lines 10-11: Change "atmosphere model (CAM4) of the NorESM-L in this paper" to "atmosphere component (CAM4) of the NorESM-L climate model".

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Page 1213, lines 12-13: Change "by the local modern SST fields" to "the standard CAM4 modern SST forcing".

Page 1213, lines 14-15: Change "condition" to "forcing (Fig. 8a)".

Page 1213, line 15: Delete "the".

Page 1213, line 19: Change "SSTs in the reference experiment" to "forcing in the reference simulation".

Page 1213, line 20: Add a "the" before "mid-Pliocene", change "anomalies" to "anomaly".

Page 1213, line 20-22: I propose to change the sentence to: "However, on a regional scale, the potential uncertainties linked to the choice of the SST forcing for the reference simulation should be noted and assessed in the upcoming PlioMIP analysis."

Page 1218, Table 1: I propose to change "Anomalies + local modern" to "PRISM topo ano. + local modern", and to define the abbreviation "ano." in the table's caption.

Page 1219, Table 2: Does "Surface temperature" refer to "surface air temperature"? If so, then please write "SAT" instead. In the caption, I propose to change "Global mean value" to "globally averaged climatologic parameters", or maybe simply to "globally averaged climatology".

Page 1220, Fig. 1: I propose to add the "unit" "E" to the tick labels of the longitude axis (I propose a similar change in Fig. 2,3,5,6,7, and 8). In the caption, change the last sentence to "The gray area identifies areas that are covered by sea-ice". Could you additionally add a statement on whether or not the sea-ice distribution is fractional, and could you give some information on the density of the ice-cover if that is possible?

Page 1221, Fig. 2: Would it make sense to also show the absolute mid-Pliocene topography for reference?

Page 1222, Fig. 3: I personally would use all plant types in their plural form, e.g. to

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write "shrubs and grasses" instead of "shrub and grass". With respect to Fig. 3 e and j: Is the ice-sheet distribution really fractional? If not, I would simply write "distribution of ice-sheets" instead of "for the percentage of land ice".

Page 1224, Fig. 5: It looks like some of the subfigure identifiers (e.g. "(a)") are formatted bold, while others are not. Could you check and fix this if needed, please also for Fig. 6 and 7?

Page 1225, Fig. 6: I think it is necessary to add some space between the maps and the zonal averages (or to alternatively change the location of tick marks), since the tick labels of the different axes get too close to each other. In particular, the "24" of the temperature axis and the "0" form a "240" that looks like it marks the respective degree longitude. In the last sentence of the caption, I propose to change "zonal mean values" to "zonal means".

Page 1226, Fig. 7: Also add here some space between the maps and zonal averages if that is possible.

Page 1227, Fig. 8: May it be that these results are only mentioned in the discussion and summary? Maybe it would be useful to give some additional information on the findings already in section 4. With respect to the right-hand-side plots: I suggest to add a zero-line. In the caption I propose the following adjustments: Change "Uncertainties in mid-Pliocene SAT anomolies, due to choosing SST fields in the reference experiment." to "Uncertainty in mid-Pliocene SAT anomaly introduced by the choice of the SST forcing." Change "Differences between" to "Differences between the". Change "the zonal difference" to "the zonal mean difference". Change "anomalies between" to "anomaly between".

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