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Climate of the Past Discussions

Interactive comment on "Assimilation of Pseudo-Tree-Ring-Width observations into an Atmospheric General Circulation Model" *by* Walter Acevedo et al.

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Answer to reviewer #1

Acevedo et al.,

November 10, 2016

We wish to thank you so much for your constructive review and very detailed comments. It would be our pleasure to do all the modifications and make the improvements you have suggested, in the next version of the manuscript. We answer your comments (*italic*) point by point (**Bold**):

My major comment for this paper is that while the language is very concise and direct, it is perhaps too concise; many sections of the paper leave the reader wanting more detail or are a bit confusing because they are so brief. For example, in the introduction, I felt as if I didn't have a clear grasp on what new problem the authors were looking to solve, existing gaps in the literature, and how they addressed these in a novel way.

There are also a lot of references to previous studies but without any additional information and the reader is left feeling lost. I have made notes in my comments below about the specific sections where more detail is needed. Very few equations describing the experimental design are given to orient the reader to the various components of the DA strategy and how you altered it for your specific set of tests. There are also some major relevant references that have come before this study that are missing and not discussed, which I have pointed out in my line-by-line comments below.

We completely agree. Therefore, we have reviewed the methods in more detail and added additional text to the introduction and methods as well as the results and the discussions (We expanded the manuscript from 26 pages to 32 pages). Data assimilation equations are also added in the methods. Subsections "Rationale, Kalman Filter, Ensemble Kalman Filter, Time Averaged Ensemble kalman Filter, OSSE, TRW forward models and VSL from the Fuzzy Logic Viewpoint" are fully explained and added to the new version. We hope that the new version of the manuscript with all additional subsections and explanations is now clear for the readers.

In particular, I think this paper needs to cite and discuss previous findings of Dee, Steiger, Emile-Geay and Hakim 2016 (JAMES):

Dee, Sylvia G., et al. "On the utility of proxy system models for estimating climate states over the common era." Journal of Advances in Modeling Earth Systems (2016).

They have already employed 3 different proxy system models with DA and it would be helpful here to discuss how your study is different from the findings that have recently been outlined in that paper. It's clear that you are performing different tests in this study, but you have to acknowledge that this is not the first piece of work to include forward proxy models with DA (as written you assert this).

We agree on this and the point that it is not the first study considering the forward proxy models with DA. We have also cited the paper by Dee et al. (2016) in the new version and modified the Introduction accordingly, acknowledging this study. Given that this novel paper Dee et al. (2016) was published first

on 10th August 2016, we missed that during the production process of our manuscript. This paper is a perfect reference and back-up for our similar strategy in paleoclimate reanalysis.

From a science perspective, and as I've highlighted below, I think there are some design problems with the VS-Lite application: namely, you used prescribed soil moisture fields when you can instead use time-varying precipitation. Why use a climatological average that is not time-varying for DA when you can use dynamically-updated precip? This makes no sense to me, and I feel it detracts from your results.

The soil moisture used in our experiments is not just a climatological average but a monthly climatology, meaning that the soil moisture value does depend on the month and is therefore time varying, allowing the seasonal competition of limiting factors to develop. Using SPEEDY precipitation as input for VS-Lite model is indeed a possibility to add time variability to the soil moisture, however this would imply to use the CPC Leaky Bucket Huang et al. (1996) Model in order to generate moisture time series out of temperature and precipitation time series. We consider that this approach would reduce the consistency of the simulations, given that the moisture values considered by SPEEDY parametrizations would be still the climatological ones and not the ones produced by the CPC Leaky Bucket Model.

In general, with some revisions to the text giving more description, more background, and much more motivation, this paper should be suitable for publication in CoP. Note: The way this manuscript is numbered makes it challenging to give line by line comments. Can you please revise this?

Thanks for the comment. We have used the CoP's LATEX template for compiling

the manuscript. Maybe this issue can be suggested to the Editorial Support, providing a new template for CoP.

Page 1, Line: 4: appeared = appears (active voice) 13: revise "the so called" to "the usage of paleoclimate proxy records." 14: Revise: "Nonetheless, these natural archives. . ." 16: Revise: "is still an open question" to "can often remain opaque." 17: Delete "To the," rephrase "At present, many. . .. 18: comma after hindcasts, 22: and cite Dee et al., JAMES 2016 in addition to other citations.

Done!

Page 2 5: rephrase last sentence "Finally, the use of a particle filter has been tested..." 11: cite Dee et al., 2015 (JAMES) PRYSM along with Evans (review of existing forward models). 12-15: Need to cite and discuss previous findings of Dee, Steiger, Emile-Geay and Hakim 2016 (JAMES) here: Dee, Sylvia G., et al. "On the utility of proxy system models for estimating climate states over the common era." Journal of Advances in Modeling Earth Systems (2016).

Done!

17: comma after AC15, delete now, comma after scenario. "were" = "where." 20-25: Back to my major comment above: to a person who is not already quite familiar with the technical details of Data Assimilation, these objectives are opaque. We need more background and you haven't yet defined prior, posterior, etc. There hasn't been any prior introduction of the DA equations so all of this comes out of nowhere.

Done!

25: filed = 'field' 28: yes it has already been explicitly investigated, in Dee et al., 2016

−− as I mentioned, you'll have to discuss this and potentially change the language in your introduction accordingly. 29: rephrase "the TRW forward model, and the climate model.."

We have deleted this sentence and acknowledged Dee et al., 2016.

Page 3 3: rephrase: "accuracy, relatively user-friendly implementation, and computational expense." 5: what do you mean by "adjoint model"? This is not clear. 9: rephrase "have historically been prohibitively expensive...", hyphen in high- dimensional. Change "However" to "Thus" 10: toy models is this a common phrase in DA? You have not defined it. I think you should change to "perfect model studies," which is a more widely recognized term for this type of study. Or, "pseudoproxy tests."

We changed the text accordingly.

13: If I am a person unfamiliar with DA, how do I know what the 'observation operator' is? We could really use some equations here: lay out the DA equations for us so we know what the 'observation operator' is. The DA community will follow you, but most others will not. 13: You have not defined "TA" yet.

Several sections ans subsections have been added to the manuscript to cover your comment. We also reordered many parts of the manuscript to describe every detail of the methodology.

15: grammar is incorrect in last part of this sentence. Perhaps you mean: "We study the impact of....using the assimilation of TA linear observations as a reference." 19:

what is fuzzy logic? Please cite and explain in detail. 2.2.1 Spell out "V-S-Lite Model" 20: change "limiting factors" to "model inputs for VSL are ..." and put parentheses around (T, M). 21: 'variables' (add s) and rephrase "variables influence tree growth..." delete period after gm, just continue sentence "using a piece-wise" and put colon after Tolwinski citation:

Done!

Page 4 1: no indent, no capitalization of Where, change to "denote minimum thresholds for temperature and moisture below which there is no grown, and TU and MU are upper thresholds above which tree growth is optimal" 2: are you sure it's optimal and not too hot/dry?

Done! TU and MU are defined as optimal growth limits and not the hottest or driest limits.

2.2.2 the reader does not know what Fuzzy Logic is because you have not introduced it in the text, nor have you cited it. We need more context. 9: delete 'have, the' ... and what is PLF? Have you defined this yet? 10-15: this is too brief and we need more motivation here about your experimental design and what you're testing.

We added a complete section describing the Fuzzy Logic concept.

Page 5 1: delete 'the' before version 32 1-7: be a bit careful here with text this reads awfully similar to Molteni 2003 6: rephrase "The latter makes SPEEDY..." 7: change 'presented in this paper' to 'necessary for this study' 15-16: not enough information

for a non-DA specialist. 21: 'where' = were 23: huge = large, change 'are' to 'were' – also, what is the fallout of this? 24: change 'as the following' to 'as follows:' 25: delete comma after deviation 2.3.3. change to 'Simulations' instead of Runs characteristics, which is not grammatically correct.

Done. We think that the new section added will cover some basics of the DA implementation.

Page 6, Line: 2 consist = 'consists' 6 'from the equilibrium' not enough detail. Do you mean it's already spun up, or it's a control simulation? Be more clear. 7 should not be a new paragraph, change 'affordability' to 'efficiency' 8 "minimum" and "product" Triangular norms come out of no where, we need an explanation, description, citation, and to not be lost by the first use of these terms 10 150 year (no 's') and, by 'nature' run do you mean 'control' run? I have never seen the term 'nature' run. change wording. 11 change month to 'months' 12 nature = control, when you say 'different ensemble runs' are these the ensemble of climate state vectors or 'prior' for the DA? be clear. Change 'driving' to 'forcing SPEEDY' 16 change 'added to the clean' to 'imposed on the TA observations' also I think you should spell out TA and not abbreviate. It's a short acronym and it's confusing when there are already so many other acronyms flying around. Delete comma after 'observations so as to obtain'..

Done

17 10 seems like a very high and unrealistic SNR for a pseudo proxy test. See previous literature on this topic, and the Smerdon et al. 2012 review.

Thanks a lot for this comment. We have redone the offline DA using VSL-min for

24 different SNR values (from $SNR =$ 0.03 to 11) and plotted the time-averaged global RMSEs. We have added Figure 11 and a subsection for SNR to the manuscript. As can be seen the plot shows an elbow around value $SNR = 1$ and reaches the Free run at around $SNR = 0.03$ where almost all of the observations are neglected in DA..

20 So, this seems very unsatisfying. Even though SPEEDY has a climatological mean soil moisture field, precipitation, by contrast, is varying. You can run VSLite with Precipitation and a parameterization that goes from precip to soil moisture people run VS Lite this way all the time, and I don't think it make sense not to in this case. I would redo all the pseudo proxy analysis with time-varying precipitation instead of time- invariant climatological mean soil moisture....I have seen this mistake before with VSLite and it causes an unphysical response for the trees.

We already answered this on page 2 of this answer.

30 citation needed after 'internal variability'

Done!

Page 7, Line: 1 rephrase to "Our results are presented in three sections: 1)..." 2-4 This is confusing what do you mean by the word 'selection'? Elaborate. Add 'the' before 'temperature' 8 rephrase "disentangled to some extent by considering atmospheric variability to be a superposition.." 24 change but present... to "stationary and fluctuate over longer time scales. These low- frequency"... 25 occur should be 'occurs' 26 reverse order of wording to read 'modes of variability' 27 which annular modes? this is a very offhand reference. 28 change to 'displacements of the jet stream' 29 no comma

after SPEEDY, nature=control

Done.

Page 8, Line: 2 again I think nature should be control throughout. Larger comment for Section 3.2.1: We need more information on the experimental design perhaps a graphic showing a schematic of your experimental design and the PSM vs. no PSM simulations, online vs. offline, showing the full scope of the research you performed for this paper. What is the point of the control run in this context? It's just not very clear in the current text. How did you use it?

Figure 1 is illustrating the schematic of our experiment. Here we refer to the figure 1 in the new manuscript and import the Appendix in the main part of the paper along with figure 1.

15 change 'there exists a DA skill' awkward wording, revise for clarity 18 rephrase to 'proxy record locations', and the comma after Northern hemisphere should be a semi-colon (;) 20 no comma after 'skill' 24 rephrase: "constrain temperature with considerably larger skill than TRW sites in South Africa. This finding may prove useful for the design of optimal TRW chronology networks...." 25 you need to cite Comboul et al., 2015 here which is also about optimizing observing networks in paleoclimate data, and discuss their findings (using coral pseudo proxies) in relation to yours: " CITATION: Comboul, Maud, et al. "Paleoclimate Sampling as a Sensor Placement Problem." Journal of Climate 28.19 (2015): 7717-7740. 29 citations are out of chronological order, change last bit of sentence from 'is currently' to 'is generally termed 'offline Data Assimilation.' 30 rephrase end 'using assimilation, the prior...'

Done.

Page 9, Line: 1 can you remind the reader about the differences between the two pseudo proxy schemes here ? MIN vs PROD? Give us a brief description to re-orient, as well as your hypothesis for how the two will differ. 5 delete comma after VSL-Min, add 'as a TRW observation ...' 6 rephrase "analysis, as demonstrated in Figure 6b. The expected value of the RMSE shifts significantly toward lower values.." 8 change present to 'shows' 10 revise "performs with slightly better skill" Note: there's no discussion of the pseudo proxy design here..... 17 What is TA DA???? Just write it out. 18 change to 'applied in parallel and independently of any specific..." 25-30 again cite Comboul et al., here: Comboul, Maud, et al. "Paleoclimate Sampling as a Sensor Placement Problem." Journal of Climate 28.19 (2015): 7717 7740.

Done.

there is an official term for this kind of work, and it's optimal sensor placement (OSP)much literature here in the pseudo proxy community and forward modeling/proxy system modeling that you need to work through in this discussion. Also, be careful with your language here.....is this really a fair statement to make when you didn't use time-variant soil moisture? if you are going to make the claim that your method can be used to design OSSEs you should probably give a walk-through, thorough example of this and associated caveats. Show a map of where the trees capture the most climate variability, etc. Also, the claim that you can apply this method to any proxy with 'stable time resolution' needs to be clarified. Do you mean annual resolution? It would be difficult to do this with lower frequency climate data like sediment cores or speleothems. So, this comment seems a bit far-reaching.

We have explained that in the new version of the manuscript. We cited the OSP Ancell and Hakim (2007); Hakim and Torn (2008); Mauger et al. (2013); Comboul et al. (2015) here with a discussion on the caveats.

Page 10, Line: 5 delete comma after provided, delete 'the' before results, delete "huge amount of" 6-7 revise language for clarity'undiscriminated' I think you mean 'indiscriminate' ? 9 change 'In addition to the classical DA approaches used in paleoclimate studies..." 10 and cite Dee et al., 2016 as well, which also uses this approach AND PSMs... 18 change "In this conditions" which is grammatically incorrect to "Under these conditions..." 19 what is meant by 'climatological levels?' 20 delete 'model' after SPEEDY, and the phrase "it is not surprising to enter the offline ..." is confusing and needs to be revised for clarity 22 delete "In this state of affairs" and change to Thus, it seems unlikely ... 23 constraint = constraints 24 this is too brief and we need examples of course there is climate variability on time scales longer than 1 year. The obvious one is ENSO, but you need to give more examples and more citations. 25 rephrase "Accordingly, we expect that it should be possible to obtain...." and change 'skills' to skill. 27 rephrase "It is not clear if whether we can employ this technique with SPEEDY to properly estimate..." 28 comma after In particular,

Done.

Page 11, Line: 4 rephrase "conducted with SPEEDY support results obtained..." 9 delete colon (:) 10 rephrase "contained in them and the..." 11-15 it's not clear from the current text what point you're making here. Revise for clarity. 18 'response saturation'what is this? The paper is jargon-y, as I mentioned. We need more description of these terms. 22 be careful here.....VSLite is not very Gaussian either. There is a brief discussion of this in Dee et al., 2016 in the TRW section. What is the fall out of this? General: we need a concrete summary of your findingsthere isn't a

conclusion section that gives us a summary and broader implications of your work. Needs to be added.

The comments are considered in the new manuscript. "response saturation" is changed to "the threshold, for temperature or moisture, after which the growth response does not change". Non-Gaussianity of the VSL is also a challenge for EnKF. A complete subsection have been added at the end of the manuscript to cover a summary and broader implications of our work.

Page 12 Appendix you need to spell out the meaning of OSSE on first usecannot abbreviate.

We moved the appendix to the main text after figure 1.

References

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