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Interactive comment on "Spatio-temporal consistent bias pattern detection on MIROC5 andFGOALS-g2" *by* Bo Cao et al.

Bo Cao et al.

martincao12@gmail.com

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This paper presents a new method for detecting and analyzing spatial-temporal consistent bias pattern in climate models. A good introduction is given about the general context, the methods used for climate model evaluation and their limitations in section 1. The method is presented clearly in the method section and the results of the application on precipitation from MIROC5 and FGOALS-g2 compared to the precipitation from GPCP data set are presented in section 3. A very short summary and discussion is found in section 4. The method proposed here is relatively original and could become a useful tool for the analysis of climate data (not only model outputs) through the analysis of anomalies. However, the discussion is very short and lacks comments about the limitations of the method. I think the paper should undergo

major revisions before being accepted.

Thank you for taking your time and effort in reviewing our manuscript and we appreciate your insightful comments for improving the manuscript.

General comments:

Q.1-1

My main concern is that the authors seem to have compared directly time series from observations and freely evolving climate models. The limitations associated with this issue should be treated with care and properly discussed.

Response: Thank your very much for your comments on the Method. We answer this question in more details in Q.1-6.

Q.1-2

Other possible applications of the method as suggested below should be considered in order to propose a more robust analysis of the method and its limitations.

Response: Thank your very much for your comments on the Method and its limitations. We answer this question in more details in Q.1-7 and Q.1-8.

Q.1-3

The introduction could be slightly improved by adding a couple more information about the context, some perspectives and a few more references.

Response: Thank your very much for your comments on Introduction. We answer this question in more details in Q.1-5.

Q.1-4

The form of the text is understandable and the number of grammar errors limited although the paper could be improved by having it checked (once again ?) by an English native speaker (which the reviewer is not).

Response: Thank you very much for the suggestion on improving the readability of the paper. We will make the manuscript proofread and improved by an English native speaker.

General comment about the introduction :

Q.1-5

Climate models biases spatio-temporal consistency or "stationarity" has important implication for the validity of climate model bias corrections methods (in this regards, see publication by Krinner and Flanner, 2018). This might be worth mentioning in the introduction.

Response: We will include the discussion on Climate models biases spatio-temporal consistency (Krinner and Flanner, 2018) in the Introduction.

General comment about the method and its application :

Q.1-6

1) It is unclear to me whether the matrix of biases (or residuals) for MIROC-5 and

FGOALS-g2 were obtained by directly comparing time series of the model to the monthly time series of GPCP data set or to the monthly climatology of GPCP? In any case, it is challenging or even questionable to directly compare the time series of freely evolving climate models to an observational time series due to the independence between the two time series as freely evolving climate models own their inner variability. Differences for a given month should therefore in any case not being called a "bias". Possibly, the fact that the bias detection algorithm is applied on a long climate period with thresholds on the size of the area and the length of the period to identify "bias families" allows for the method to identify actual biases of the climate model but this issue should be handled with care, more deeply explored and discussed. In my opinion, the application of the method proposed in this paper is more straightforward and easier to justify for the detection of biases in climate simulation (GCM or RCM) nudged towards meteorological reanalysis and directly compared to time series from observations (discussion of surface climate biases mostly in this case) or for the detection and analysis of climate anomalies as suggested by the authors in their discussion.

Response: The results shown in this manuscript is obtained by comparing the simulation outputs of climate models to observational time series of GPCP. The methodology for evaluating the effectiveness of the proposed clustering method in this paper is to check whether the bias patterns found by our algorithm are consistent with those found by existing studies. Towards this goal, in our case studies we intended to use the same climate model outputs and precipitation data as reported in the existing studies. Take the double ITCZ bias as an example. Both Oueslati et al. (2015, https://doi.org/10.1007/s00382-015-2468-6) and Siongco et al. (2015, https://doi.org/10.1007/s00382-014-2366-3) adopted GPCP for analyzing the double ITCZ bias in CMIP5 models. Adam et al. (2018, https://doi.org/10.1007/s00382-017-3909-1) performed their double ITCZ bias analysis using GPCP, the Climate Prediction Center (CPC) merged analysis precipitation (CMAP) product (Xie and Arkin 1996),

and the analyzed precipitation of the European Center for Medium-Range Weather Forecasts (ECMWF) Interim Reanalysis (Dee et al. 2011). However, only the results of GPCP were reported in their paper and others were omitted. Thus, we consider using GPCP in this case is proper. Note that it is very possible that meteorological reanalysis data are more suitable than observations for analyzing biases in other cases as suggested by the referee. Our proposed method works the same way for both meteorological reanalysis data and direct observations.

Q.1-7

2) Why focusing particularly on these two climate models and only on precipitation? Extending the analysis on other climate models would increase the robustness of the results and the conclusion drawn from them, while applying it to other climate variables (e.g. temperatures) would open possibilities for exploring links between biases among different variables (e.g. temperatures and precipitation) as the method is meant to be a tool for a better understanding of the sources of the climate model biases as the authors mentioned. If an extent of the application and the analysis on other climate models and/or other climate variables, the authors should at least justify why they restrained their analysis to these two climate models and to precipitation.

Response: The reason why we chose MIROC-5 and FGOALS-g2 is that there are a number of papers studying these two models, based on which we can check the effectiveness of the proposed approach. MIROC-5 and FGOALS-g2 are only used as case studies. We will modify the title of the paper (also as suggested by Q.2-3) and clarify the choice of models in the manuscript.

We did the experiments on temperatures and found meaningful bias patterns as well. We did not include the results mainly for space concerns. We will add this set of experiments to enhance the robustness of the proposed method in the manuscript.

Exploring the links between biases among different variables is indeed very useful. It requires measuring the correlations between bias patterns among different variables, which is our current undergoing research. We will discuss it more in the Summary and Discussion.

Q.1-8

3) Applied on monthly values as it is in this paper hampers the method from detecting model biases that evolve with the daily cycle (which is often the case for temperatures and precipitation). Would the method proposed in this paper be able to deal with this type of biases? If this is not explored by a short application of the method on data at a higher time resolution, this should at least be briefly mentioned and discussed.

Response: Our proposed clustering method is designed to find the bias patterns that steadily appear in a region over a period of time. Comparing to climate data, meteorological data (usually at a higher time resolution) is more dynamic, which cannot be handled by our proposed method. We will discuss it as a limitation of our method in the Summary and Discussion.

More particular, minor comments:

Q.1-9

Title : If the method is meant to become a useful tool for climate models analysis a more general and “attractive” title should be considered, for example “Spatio-temporal consistent bias pattern detection method : application on MIROC5 and FGOALS-g2 precipitation”

Response: The paper indeed focuses on a general clustering technique with MIROC5

and FGOALS-g2 used as case studies. We will modify the title to reflect the focus of this paper.

Q.1-10

P1 L18 : I would rather recommend the use of AOGCM or CGCM (used but nor defined in P2) acronym when speaking precisely of coupled atmosphere-ocean general circulation models.

Response: We will use the CGCM acronym for coupled atmosphere-ocean general circulation models throughout the manuscript.

Q.1-11

P1 L20 : May-be add a more general reference about biases and evaluation of climate models (e.g. Flato et al., 2013 from IPCC AR5).

Response: We will add the reference Flato et al.(2013) on P1 L20.

Q.1-12

P1 L22 : Since it is a widely spread and studied bias, may-be, add one or two more references about the double ITCZ.

Response: We will add more references about the double ITCZ on P1 L22.

P2 L30 : “Highlight” or “evidence” may be more appropriate here than “discover” ?

Response: We will change the sentence on P2 "...multivariate spatio-temporal clustering (MSTC) to discover recurring climate regimes from model outputs..." to "...multivariate spatio-temporal clustering (MSTC) to evidence recurring climate regimes from model outputs..."

Q.1-13

P3 L13-28 : A brief summary of the method (already present in the abstract) as well as of the results might not relevant at this point in the paper. At this point, readers might just want to know about what they will find in the different sections of the paper.

Response: We will rewrite this part to remove the repeated information (a brief summary of the method and results), and provide the organization of the paper and just the highlights our method.

Q.1-14

P4 L8 : Which statistical tests will be available for users to determine significance of the biases?

Response: The proposed method does not have any restrictions on which statistical tests should be chosen. Currently, we support the commonly used t-test.

Q.1-15

P7 L7 : How were the values of the parameters determined? Did you performed some sensitivity tests?

Response: We chose the values of the parameters by considering both the number and size of the resultant bias patterns. For example, δ_a defines the minimum number of grid points that must appear in a bias instance. A large δ_a value may filter out too many bias instances, whereas a small δ_a value may lead to tiny bias instances. For a given dataset, we tried a range of δ_a values and chose the one that traded off well. We will provide more guidelines on parameters in the README file.

Q.1-16

P8 L8 "Positive residuals are plotted in red and negative residuals are plotted in blue". I think this sentence should only appear in the caption of the figure.

Response: We will delete the sentence from L8 on P8 and only keep it in the caption of the figure.

Q.1-17

P9 L13 "In longer time series, the percentage will be even lower, which indicates that analysis or similarity calculations based on the entire series could be misleading" → I am not entirely sure about this statement, and it should in my opinion be explained more clearly if it is a meaningful result.

Response: Here we would like to emphasize that the discovered bias patterns are indeed local patterns temporally. If we take the global view of the entire time series, the discovered bias patterns only span a small portion of it and can be easily neglected under this circumstance. We will explain this result more clearly in the manuscript.

Q.1-18

P9L21 "One mainly consists of negative biases while the other mainly consists of positive biases. As a result . . .." This result might simply just be the consequence of the model and observational time series being completely independent and disconnected. As already mentioned, I think the authors should deal more carefully with this issue.

Response: It is true that the two opposite bias patterns in the specific region are simply coincidences. In the manuscript, we pointed out these two opposite bias patterns as an example of the patterns that could not be found if the entire time series had been considered. We will clarify this limitation on possible interpretations in the manuscript.

References :

Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W. J., Cox, P., Driouech, F., Emori, S., Eyring, V., et al.: Evaluation of Climate Models. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Climate Change 2013, 5, 741–866, 2013.

Krinner, G. and Flanner, M.G., 2018. Striking stationarity of large-scale climate model bias patterns under strong climate change. Proceedings of the National Academy of Sciences, 115(38), pp.9462-9466. https://doi.org/10.1073/pnas.1807912115

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