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Interactive comment on "Causal networks of biosphere–atmosphere interactions" *by* Christopher Krich et al.

Christopher Krich et al.

ckrich@bgc-jena.mpg.de

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1 Response to reviewer 2

The presented manuscript presents an interesting and novel approach to better understand biosphere-atmosphere interactions. The paper is clearly of interest for the scientific community and fits well in the scope of the Biogeosciences journal. While moving on from the classical correlation approach is needed and of great interest, because causality is modern topic and no so broadly used, the paper needs to do a better effort to introduce the topic in an easy way to the community in order to be published. Actually, it is difficult for me to review the results of the paper until the methods are more clearly exposed to the reader.

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Discussion paper

We thank the reviewer for the support of the topic. The accessibility of the method has been criticised also by reviewer 1. In a revised version of the manuscript we will aim for an improved accessibility of the method. Please refer to your specific comment for further details.

These are my specific comments:

- **Introduction: I miss a paragraph showing the limitations of the classical correlations analysis, when the failed, when causality approaches did better and why**...

  We see the benefits the reviewer aims for by requesting such a paragraph. We do not claim correlation analysis to be wrong, if applied correctly. The issues arise, if one moves beyond certain boundaries within the interpretation of the results. A correlative analysis does not fulfill requirements for a causal interpretation. Any method which brings us closer to causal interpretability of a dependence structure increases the information content of the analysis. This is our motivation to test a causal inference method that is more sophisticated than the mere use of correlations.

  This argument will be further motivated, first by citing literature which showed an improved interpretability using causal methods rather than correlation (cf. Detto 2008, but also Runge2019 and others), and second by further highliting the differences of the estimated dependence structure using lagged correlation and PCMCI (cf. Fig. 1 or Fig. 4 and F1).

- **Methods: In general, as I said, the methods are hard to follow. I suggest to simplify/restructure the section to facilitate its understanding. The section 2.1.2 is probably the most confusing to me, I recommend to include a flowchart to visualise the algorithm.**

We will improve the accessibility of the method by adding an introductory paragraph to the method section. Here we explain how PCMCI relates to existing methods which will help the reader to gain a more intuitive understanding of aim and concept of PCMCI. A detailed description including mathematical notations will be then given in the following subsections. Further a graphical visualisation will also be considered.

- **Results: Line 5, page 12, replace "stonger" by stronger.**

  Thanks for noticing and pointing out this spelling mistake.

- **Discussion: Lines 7-11: After reading the paper, I am still not convinced that using a linear in-dependence test is the way to proceed. I think you have to demonstrate it with an example. Perhaps, you can run your artificial dataset tests using a non linear rank independence test (spearman's correlation) and compare the results. These results could be added to an appendix to better support your statements if that's the case.**

  In a revised manuscript we will include analysis using Gaussian-process regression and distance correlations. Preliminary, results suggest, that those outcomes are indeed very similar.

  For example, Fig. 1 is comparable to Fig. 5 from the manuscript. The difference is that Fig. 1 is calculated using Gaussian-process regressions and distance correlations as independence test (GPDC). The two figures show a similar seasonal behaviour and even good agreement in detected links. Note that GPDC only yields positive link strengths. Further, the strength values estimated with GPDC are rather weak due to the low number of data points and the larger sensitivity of that method to the sample size.

  An other example is given in Fig. 2. Here the figure is not one-to-one comparable with Fig. 6 of the manuscript because significances of an analysis using GPDC have been too (due to too low sample sizes) low to perform the same analysis.

Instead we plotted the link strengths of radiation, temperature and precipitation on NDVI at lag 0 and 1. At lag 0, GPDC detects some influence of temperature (and radiation) in boreal regions. At lag 1 precipitation influences mostly arid regions.

Caption Fig. 1:
Same as Fig. 5 of the manuscript but the analysis was performed using a non-linear independence test. The number of significant occurrences of a link is given by its width. The link strength, given by the link color, is calculated by averaging the significant links of the towers. The link's lag is shown in the centre of each arrow, sorted in descending order of link strength. The resulting graphs are shown for April 2014 till March 2015. The significance threshold is 0.01

Caption Fig. 2:
Influence of climatic drivers on NDVI as calculated by PCMCI in conjunction with the non linear independence test GPDC. The first and second columns show the estimated causal influences of climatic drivers on NDVI at lag 0 and 1, respectively.

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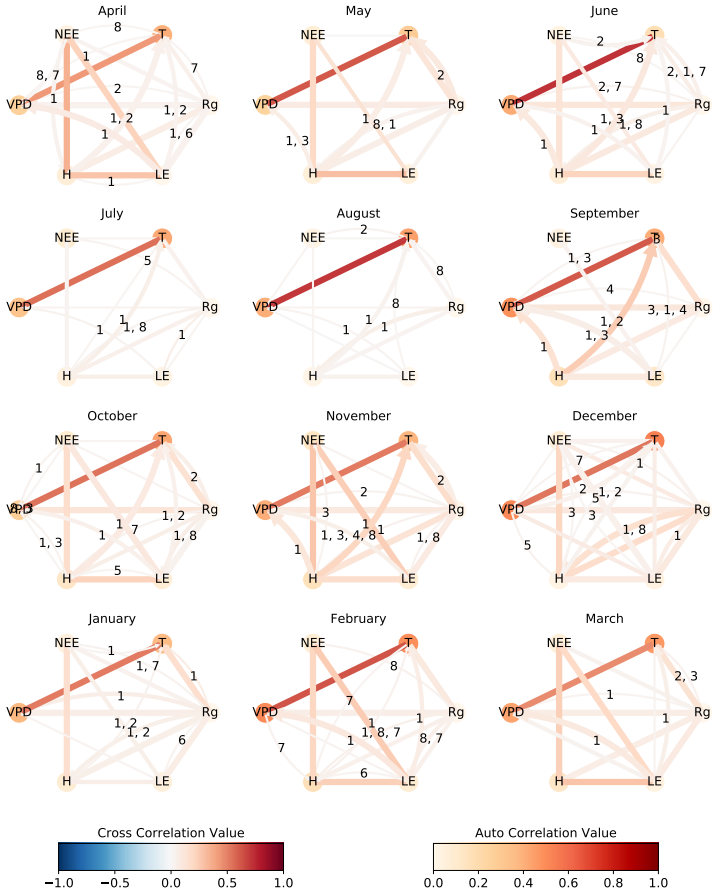

Fig. 1.

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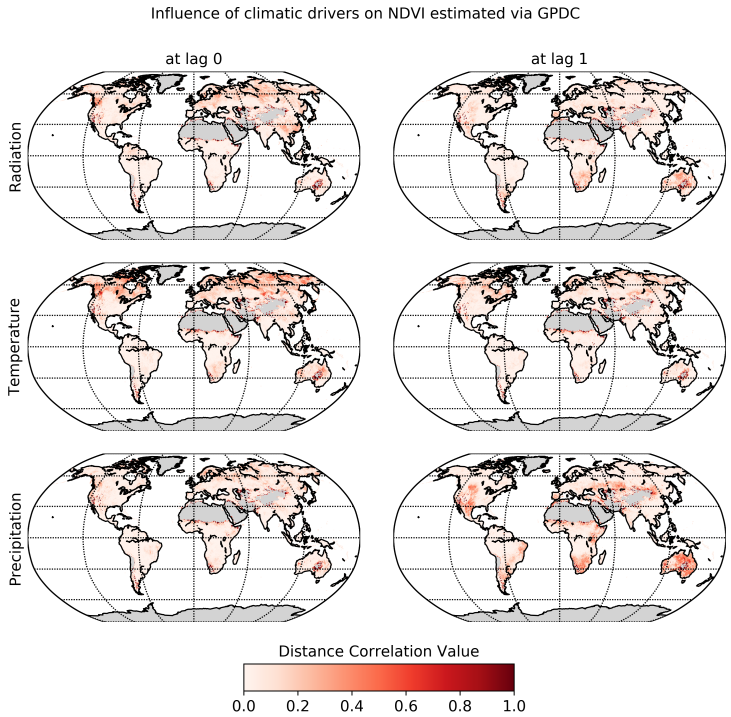

Fig. 2.

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