

Geosci. Model Dev. Discuss., referee comment RC1
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Comment on gmd-2021-196

Anonymous Referee #1

Referee comment on "Quantifying Causal Contributions in Earth Systems by Normalized Information Flow" by Chin-Hsien Cheng and Simon A. T. Redfern, Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-196-RC1>, 2021

The manuscript 'Quantifying Causal Contributions in Earth Systems by Normalized Information Flow' by Cheng and Redfern addresses an important scientific question: how do we best measure causal relationships in coupled systems. While a good part of the manuscript is well-written and while I generally find the topic exciting and worth publicising, I found it impossible to assess for myself if the presented method is indeed the advance it is claimed to be. This might be a result of me being unfamiliar with the cited Liang papers. In any case, I therefore stopped with a detailed review of the paper after section 3.1, because I felt I was unable to follow the detailed arguments and maths purely based on the material presented, and I unfortunately lack the time to read up on all of the cited literature myself. I thus conclude that a major revision to the introduction of the method is essential (at least) before I could recommend publication. I also feel that a clearer and more intuitive discussion of the results and examples would be a massive step forward in terms of increasing the potential impact of this paper. Below, I list a few detailed comments that I hope the authors will find helpful.

Major points:

- I indeed think that the comparison to other work could be extended (see also other comments in the public discussion). Next to the references included, this should also involve the following citation:

Runge et al. Detecting and quantifying causal associations in large nonlinear time series datasets. *Science Advances* 5, eaau4996 (2019).
<https://advances.sciencemag.org/content/5/11/eaau4996.abstract>

- page 3: the motivation of the IF and nIF formulas (2) to (4) needs to be clarified. What is the intuition behind them? Given how central it is to the paper, a reference to Liang 2014 is not sufficient. In this context, a comparison to other methods might be particularly insightful. A discussion, which may well be focused on the 'big picture', would certainly also be useful for the general reader who may be less accustomed to think about concepts such as 'transfer entropy' and 'causality'. In particular, a better explanation of why the method is different from a simple linear correlation (which can be causal or not) is required. Overall, I suggest a significant extension to section 2.1 (a page or more, stepping through the equations; describing them intuitively, maybe even using examples for each variable).

Further corrections:

- page 1, L.14/15: do you maybe mean: ..., 'especially concerning a network of teleconnections'?
- page 2: the first two sentences are duplicates. Please revise.
- page 2 l. 23: would downtune to: 'yet established'
- page 2 l.28 you mean: 'good quantitative measures of causal strength'? How would you define good here? Would be careful/thoughtful about the wording.
- page 3. L. 18/19: I don't understand the reasoning for using $m \text{ abs}(nIF)$ here. Could you clarify?
- do you think only a linear and second order comparison is sufficient to establish a benchmark? How about other, e.g. non-parametric forms, which can capture more complex non-linear relationships?
- Can you clarify why a calibration factor might be needed in reality? What does that tell us about the correctness/suitability of the approach?
- page 4, l. 2/3: isn't the second term an important self-feedback aspect? I think this is quite a broad approximation that would require a problem-specific justification.
- page 4, l. 9: at this point it is still unclear to me why the magnitude would imply a strength of causality, or wrt l.5 why IF represents a 'trend of uncertainty'. This has to be introduced more carefully and intuitively. I am sure that should be possible and is key to improve the accessibility of this paper.
- l. 31: in such a case
- l. 32: and how about the corresponding feedback of methane ON temperature?
- page 5: the entire discussion of the cases in Figure 1 and the test case should be extended and could be written much more clearly. I really have difficulties to follow. I suggest you motivate each problem and give real examples (even if you don't calculate them – maybe point to citations). In Figure 1- are X and Y multidimensional in most cases I assume? If yes, this should be visualized as well compared to case (a).
- Figures 2, 3 and 4 are hard to decipher in terms of size of the labels.