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Geoscientific Model Development Discussions

Interactive comment on "Detecting causality signal in instrumental measurements and climate model simulations: global warming case study" *by* Mikhail Y. Verbitsky et al.

Anonymous Referee #1

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This paper presents a method to detect causality in climate time series. This method is based on principles of recurrences in dynamical systems. While interesting a priori, many points need to be improved and/or discussed.

Major points The literature review does not seem complete and misses crucial contributions. The paper is about attribution (of climate change), through the identification of causal links. There is an ample published literature on the subject, including in climate sciences. For instance, google scholar shows:

Hannart, A., Pearl, J., Otto, F. E. L., Naveau, P., & Ghil, M. (2016). Causal counterfactual theory for the attribution of weather and climate-related events. Bulletin of the

American Meteorological Society, 97(1), 99-110. (J. Pearl, who made the theory of causality, is a co-author of that paper)

Runge, J., Petoukhov, V., Donges, J. F., Hlinka, J., Jajcay, N., Vejmelka, M., ... & Kurths, J. (2015). Identifying causal gateways and mediators in complex spatio-temporal systems. Nature communications, 6, 8502.

A report of the US Academies of Science (National Academies of Sciences Engineering and Medicine 2016) also mention causality.

Although I do like dynamical systems, the transition from a 2-D discrete Hénon attractor to a "real world" problem sounds like a leap of faith. There are many numerical problems with the application of embedding methods ("à la" Takens). The main one is that there is no bound to the necessary embedding dimension, so that the low dimensional example that is treated is not sufficient to be convincing. The authors never mention questions linked to the so called "curse of dimensionality" to treat causality. When they treat the Hénon attractor, they use variables of the dynamical system, and do not need to evaluate embedding to make reconstructions. The climate application uses observables of the climate system (northern hemisphere temperature and CO2), which might not give a straightforward connection to variables of the underlying system. Therefore all interpretations might be misleading.

In Eqs (1-5), the systems have dimensionless variables, so that the choice of the range for epsilon is easy. The normalization of CO2 and temperature for figure 2, to compute Eq. (1) is not explained. The authors do not explain how they embed the climate time series. Their results are not reproducible from the text and figures.

I do not quite agree with the interpretation of Fig. 2b. The slopes of sigma(epsilon) are significantly positive for both ways (T and CO2). Therefore both observable interact with each other, in rather well physically understood way. The discussion on the slope to define the strength of the unidirectional interaction is irrelevant because it depends on the units of the variables and the shape of their probability distribution (from eye-

balling Eq. (1)). The authors should compare how curves depart from a horizontal line when dealing with heterogeneous variables. If this type of analysis was done between a proxy for solar activity and temperature, I would expect a horizontal line. Is it the case?

What is the added value of the MCD analysis over the CMIP5 simulations and all the literature on attribution? The trend in observations cannot be obtained with control simulations and simulations with natural forcings. Only simulations with increasing CO2 can reproduce the recent trend. The analysis of this manuscript "just" reflects this known result. Such diagnostics (either visual, as reported by the IPCC or statistical in this manuscript) are relevant to measure causality. They do not state by which mechanism this causality operates: only first principles of physics can do that!

Specific points

Fig. 1 caption: alpha=0 and beta=0.3 is when x is the cause of u. The legend says the opposite (x depends on u). Please clarify or correct.

References National Academies of Sciences Engineering and Medicine (ed) (2016) Attribution of Extreme Weather Events in the Context of Climate Change. The National Academies Press, Washington, DC

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