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Review

The role of the North Atlantic overturning and deep-ocean for multi-decadal global-mean-temperature variability by C. F. Schleussner, J. Runge, J. Lehmann and A. Levermann

This paper proposes analysis of multi-decadal variability in an ensemble of CMIP5 models. The analysis is essentially based on *statistical methods*.

Global mean temperature variance is decomposed into contributions from the *atlantic meridional overturning circulation* and *Northern Hemisphere sea-ice extent* by means of a "graph-theoretical statistical approach" and the contribution to global mean temperature variability in the model ensemble mean is found to be relevant (8%). Further analysis reveals the dominance of the feedbacks between atlantic meridional overturning circulation and sea-ice (5% of the global mean temperature variance).

Substantial variations in North Atlantic deep ocean heat content are found to be associated with multi-decadal atlantic meridional overturning circulation variability with trends that are of the order of observed changes over the last decade and consistent with the reduced global mean temperature warming trend over this period. Specific dynamics underlying the multi-decadal variance and the analysed correlations cannot be identified with the adopted techniques.

The paper is clear and legible, the scientific topic addressed by the authors is a relevant one, the proposed research work is well documented: I think the paper can be published in the present form as it proposes useful scientific information, although it falls short of capturing the essential dynamics of the considered processes. I propose below to the attention of the authors some comments and considerations which may be taken into consideration in further work.

Statistical spread of models

The spread of the considered models is not "normal" i.e. resulting from a "central limit" situation (a spread due to the superposition of many small, decorrelated agents): some models just *do not adequately represent relevant processes*. In such a situation, ordinary statistical treatment – like, for example, direct ensemble averaging – may be inappropriate: model results must be appropriately "weighted". I understand weighting is difficult in cases in which observations for direct comparison are unavailable, but some kind of metrics must be introduced.
I am currently analysing the representation of seasonal cycle and associated processes in CMIP (and other) models: in this case *comparison with observations is possible and* reveals that some models are just *unable to represent correctly* (meaning with the observed time-space modulations) *the observed seasonal cycle* and, as a consequence, such models are *inadequate for studying* long term variations of the cycle itself.
I believe that, in general, particular attention should be devoted to the analysis of the *statistical (non)homogeneity* of the ensemble *with respect to the specific processes which are under analysis instead of assuming that additional information may be recovered from othermodels "statistically nonhomogeneous" with respect to the considered one (and possibly incorrect!)*.
Comparison, based on adequate metrics, of models in their ability to capture , although with statistical spread, the essence of specific processes is a necessary, preliminary step in the adoption of statistical "ensemble" procedures.

“Modes of variability”

Another problem, connected with the above outlined one, consists in giving a precise dynamical meaning to the expression “mode of variability”. If the mode in question is just a (statistically meaningful) peak in some probability density estimation, there is no guarantee we are dealing with a dynamical process operating *locally in the pdf itself*: multi-modal distributions (with statistically meaningful peaks) can arise from strongly *nonlocal* (nonlinear) interactions: stochastic resonance, for example, can produce this type of statistical phenomenology.

“Graph-theoretical statistical approach”

I am not familiar (in the sense I have never personally used) the “graph-theoretical statistical approach” used in the paper: I understand (I hope!) how such methods work, but I have not enough direct experience to address the problem of reliability of the proposed statistical estimations.
If allowed to offer a guess based on a very long experience on other estimation methods, I would say that the proposed procedure can probably capture (almost) linear cause-effect relationships, but I am sceptical the same holds for (strongly) nonlinear processes. Have these methods been tested on known (something like KdV, say) nonlinear dynamics?

Meridional fluxes

In the past, in discussing the role of meridional ocean circulations, some sort of compensation between atmospheric and oceanic fluxes (particularly of heat, but not only) has been, more than once, invoked in connection with *adjustment* theories or, simply, for general stability requirements of the atmosphere-ocean system. Has this issue been considered? Specifically: are meridional oceanic and atmospheric transport processes correlated in the considered models?

How is multi decadal variability “generated”?

The authors conclude that “While this would in principle allow for a self-sustained oscillatory behaviour of the coupled atlantic meridional overturning circulation – deep ocean system, our results are inconclusive about the role of this feedback in the model ensemble.” As considered above, the process in question is not necessarily an “oscillation”.