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# A multi-approach strategy in climate attribution studies: Is it possible to apply a robustness framework?

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ABSTRACT

Attribution studies investigate the causes of recent global warming. For a few decades the scientific community generally adopted dynamical models – the so-called Global Climate Models (GCMs) – for such an investigation. These models show the essential role of anthropogenic forcings in driving the temperature behaviour of the last half century. In the last period even other (data-driven) methodological approaches were adopted for attribution studies. This allows the scientific community to compare the results coming from these different approaches and to possibly increase their robustness. For such a purpose, the paper explores the possibility of applying a robustness framework, so far used only in the case of multi-model GCM ensembles, to a strategy including models from different methodological orientations, assessing such an application especially in the light of the independence issue.

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## 1. Introduction

At present, climate change represents one of the most urgent issues to deal with inside the framework of environmental sciences. Due to its multiple implications at different levels, e.g. socio-economic and scientific, getting reliable results is becoming more and more important.

In the realm of climatic researches, attribution studies investigate the causes of recent global warming, by evaluating the relative contributions of multiple causal factors to a change (for instance, in global temperature) in the climate system. These investigations were initially performed through simple linear regression analyses or other empirical methods: see, for instance, Wigley et al. (1990), North and Kim (1995).

After these pioneering empirical studies, for a few decades the scientific community adopted solely the method *via* Global Climate Models (GCMs) for attribution investigations. GCMs are the standard dynamical tools for catching the complexity of climate system and simulating its behaviour.[1] In particular, in the framework of this virtual laboratory we are able to perform attribution experiments in order to understand which factors have mainly influenced the behaviour of some variable of climatic importance, such as the global temperature (Hegerl and Zwiers, 2011). In doing so, GCMs show a fundamental role of anthropogenic forcings in driving the temperature behaviour of the last half century.

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[1] See Pasini (2005) for a conceptual introduction to GCMs, and McGuffie and Henderson-Sellers (2014) for more technical details.

Then, some scientists began to investigate other (data-driven) methodological approaches, borrowed by other disciplines: artificial intelligence for neural network (NN) modelling, econometrics for Granger causality analyses. This permits to compare the results coming from these distinct approaches and to possibly increase their robustness in order to uphold the hypothesized causal pattern involved in recent global warming. In what follows we always refer to the long-term mean of the global temperature.

This paper is neither intended to provide an in-depth analysis of the different methods or modelling strategies involved, nor to present new results. Rather its aim is highlighting the importance of pluralism in studying complex systems and the possible value of intercomparing results coming from different approaches (also by means of established techniques such as robustness analysis). This is especially significant when a certain degree of scientific uncertainty still existing (e.g. in how to represent a system) risks to become an easy justification to avoid decisions and actions. This is of course the case of the climate system and global warming issue.

The fact that decisions and actions concerning climate change policy require more than only technical (scientific) information (e.g., prediction of climate change made by GCMs) is becoming increasingly acknowledged. Not only the social, economic and ethical dimensions should be taken into account; an interdisciplinary cooperation is also required through which developing new theoretical frameworks and epistemic strategies that are suitable to investigate and interact with highly complex systems such as the climate.

## 2. Attribution studies in dynamical modelling

Causation is one of the underlying theoretical topics of the climate change debate, which is called into question in relation to attribution. There is mainstream consensus among scientists on the fact that the recent global climate change has to be put in relation with greenhouse gases emission due to human activities. However, when we come at the issue of reaching a causal judgment a number of questions have to be considered: (i) both external forcings and internal variability influence the climate behaviour. At present, probably GCMs have not yet shown a satisfying ability in simulating the behaviour of some patterns – such as El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) and the Atlantic Multi-decadal Oscillation (AMO) – which dominate the internal variability of global temperature, even if recent results are very promising (Guemas et al., 2014; Stoner et al., 2009); (ii) experiments cannot be performed. What could be undertaken are only experiments on artificial microenvironments, whose outcomes are mostly not applicable to real world situations; (iii) the climate system seems to respond not immediately but quite fast (about a decade, see Ricke and Caldeira, 2014) to the modifications in emissions of greenhouse gases, but there is a more extended time delay (several decades) between the gas emissions in the atmosphere and the full manifestation of their impacts on the planet, depending on the kind of impacts; (iv) complex causality and the issue of emergence have to be taken into consideration. The former is due to nonlinearity and feedback mechanisms. Phenomena and properties which many regard as emergent are due to the fact that the global climate-biosphere system is a complex system arising out from the interactions between atmosphere, hydrosphere, cryosphere and biosphere, and that the interactions between these subunits often lead to a behaviour that is not manifest if each part is considered as an isolated entity. Another layer of complexity, that is crucial in the policy dispute, is adjoined by the (emergent) properties of coupled socio-natural systems.

It should also be noted that the dynamical structure of GCMs is very complex and, at least in principle, their specific simulation results could crucially depend on the delicate balance of fluxes between subsystems, the relative strength of feedbacks and the different parameterization routines. The representation of the climate system must be necessarily approximated and reflects the common present knowledge of the processes considered important. Thus, the final modelling results about the attribution of climate behaviour could be influenced by some uncertainties in our representation of the dynamics and fundamental processes or by the exclusion of some feedback which could be recognised as important in future.

Ensemble runs greatly contribute to soften these problems and a big technical work is in progress on these aspects inside the modelling community. In an ensemble, climate models are evaluated not only individually but also by intercomparing them. Models making different assumptions about the physical processes operating in the climate system are involved. The existence of different accounts of the same phenomenon, and the fact that such models are used together, is however pragmatically accepted here in response to a situation of (partial) scientific uncertainty on how to represent this system and in the prediction of future climatic conditions. The plausibility of such models depends on the fact that they are grounded in recognized physical principles and include representations of key climatic processes. Despite all of them are seen as providing a plausible account of the climate, there is nevertheless no model that has demonstrated a marked superiority over the others. These different models are therefore used together as 'complementary' tools, in particular in projection studies, for probing how climate may change in the future (Parker, 2006).

An issue which is frequently called into question here is the kind of epistemic support which can be derived by 'robustness analysis'. Using a set of different models for investigating the same phenomenon or system implies in fact the adoption of a strategy whose underlying logic is understandable even intuitively: if the same conclusion is obtained by analyses undertaken under multiple and mutually independent 'means of determination' – these can include models, tools of identification, measurements procedures, tests, levels of description, etc. – it is unlikely that this reflects an artifact of a particular 'perspective' (see, for instance, Wimsatt, 1981, 1987). Given certain circumstances, the agreement among different models is therefore seen as to increase the reliability of their results.

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