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Review

Earth climate identification vs. anthropic global warming attribution☆

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ABSTRACT

Based on numerical models and climate observations over past centuries, the Intergovernmental Panel on Climate Change (IPCC) attributes to human activity most of the warming observed since the mid-20th century. In this context, this paper presents the first major attempt for climate system identification – in the sense of the systems theory – in the hope to significantly reduce the uncertainty ranges. Actually, climatic data being what they are, the identified models only partially fulfill this expectation. Nevertheless, despite the dispersion of the identified parameters and of the induced simulations, one can draw robust conclusions which turn out to be incompatible with those of the IPCC: the natural contributions (solar activity and internal variability) could in fact be predominant in the recent warming. We then confront our work with the approach favored by IPCC, namely the "*detection and attribution related to anthropic climate change*". We explain the differences first by the exclusion by IPCC of the millennial paleoclimatic data, secondly by an obvious confusion between cause and effect, when the El Niño index is involved in detection and attribution.

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1. Introduction

The climatic process is a highly complex system, on which scientists experienced in systems theory have much to say. This concerns particularly the global climate modeling and the attribution of the recent warming to human activity. This analysis involves climatic observations, present and past, direct and indirect. Then, a preferred approach would rely on dynamical systems identification, a theory which is well known to all systems scientists, but has not been applied so far to the climate science.

Actually, bibliographic searches based on the key words *system identification, climate, global warming,* return strictly nothing related to identification of the climatic process. But if the key words *detection and attribution* are added, there are now dozens of papers regarding the attribution of climate change to human activity. Conversely, the sole couple of keywords *detection and attribution* addresses references exclusively relates to anthropogenic climate change.

In fact, it appears that "Detection and Attribution" (D&A) is an emerging theory, born in the early 21th, dedicated exclusively to the anthropic attribution of climate change. This last point is clear through the title of the following major publication: "Good practice guidance paper on detection and attribution *related to anthropogenic climate change*", by Hegerl et al. (2010). The lack of reference to identification is puzzling, knowing that the D&A has close relationships with it, and that the respective findings are mutually inconsistent.

This paper describes the first significant work on the identification of the climate system. It summarizes some findings from our book "*Climate Change, identification and projections*" (de Larminat, P., ISTE/Wiley, 2014). It adds news developments about its relationship with the D&A, and further elaborates on the differences between our conclusions and those of the IPCC.

The latest IPCC Assessment Report is the fifth (AR5, 2013): 1550 pages, 9200 publications quoted. A synthesis is made in the Summary for Policy Makers (SPM, 2013). One of its main conclusions is that "*it is extremely likely that human influence has been the dominant cause of the observed warming since the middle of the 20th century*". It is mainly supported by Chapter 10 of AR5: "*detection and attribution - from global to regional*". But these conclusions are infirmed by those based on identification: from the millenary climate observations, it appears that the recent warming is due primarily to natural causes (solar activity and random variations), and that one cannot reject the hypothesis that the human contribution be negligible.

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The purpose of this paper is to clarify the causes of this contradiction. It is organized as follows.

Section 2 presents the climatic data. Inputs: representative signals of human, solar and volcanic activities; output: the global surface temperature.

Section 3 describes the fundamental features of the Earth's climate system and the mathematical structure of an identifiable model.

The main results of identification are presented in Section 4, obtained by the Output Error method (OE), as well as the conclusions of the statistical analysis (reported in appendix) and hypothesis testing.

Section 5 presents and criticizes outcomes of the D&A: first, the observation periods (from a few dozens to about one hundred years) are too short and therefore lead to underestimate the internal variability, increasing the risk of a false detection of the human contribution in global warming.

Furthermore, this recent period is characterized by the simultaneous increase of global temperature and of atmospheric content in CO2, while the major past climate events (Medieval Warm Period, Little Ice Age) are the only ones that may allow highlighting the solar contribution. Finally, D&A studies which involve the El Nino index make a fundamental methodological error, namely confusion between cause and effect in the climate process. The general conclusions are drawn in Section 6.

2. Input-output data of climatic process

2.1. Causes and effects

The Earth's climate is a complex natural system on which we can observe a large amount of signals, among which it is not always easy to distinguish which are causes and which are effects. For systems scientists, the question of causality makes sense only if the concerned system (or subsystem) is clearly delimited; knowing that for coupled systems, the same signal often is both a cause for a subsystem and an effect for another. The answer is unambiguous when the causality can play only in one direction, for example between solar activity and terrestrial climate. It is much less obvious when it comes to variables internal to the climate system, such as the phenomena of oceanic oscillations and the associated ENSO (El Niño South Oscillation) index. We will further comment on this point in Section 5.

One of the available means to assess the relative contributions of the different causes is the theory of dynamical systems identification, in particular the branch dedicated to the determination of causal models from observed input output signals. Typical causal dynamic models correspond to linear transfer functions, rational or not, and more generally to state-space models.

Concerning the whole climate system, it is clear that the global temperature is an effect. The major independent causes – on what temperature has no action in return – are the solar activity, the volcanism and, to a large extent, human activities.

The issue of available climate data is crucial, both for identification and for detection and attribution. The reader must therefore get a precise idea of the datasets that we have gathered and used. Knowing the large time scales involved in the climate system, identification requires input-output data whose period widely exceeds those of the 'historical' measures – which, according to climatologists, start between 1850 and 1880. Paleoclimatology allows reconstructing past climate data from substitution measures or proxies (tree rings, isotopes stored in sediments, ice cores, etc.) The accessible reconstructions, available in public data bases (NOAA, NASA, Hadley Center, etc.) are far from overlapping perfectly, and are not always well connected to the historical data.

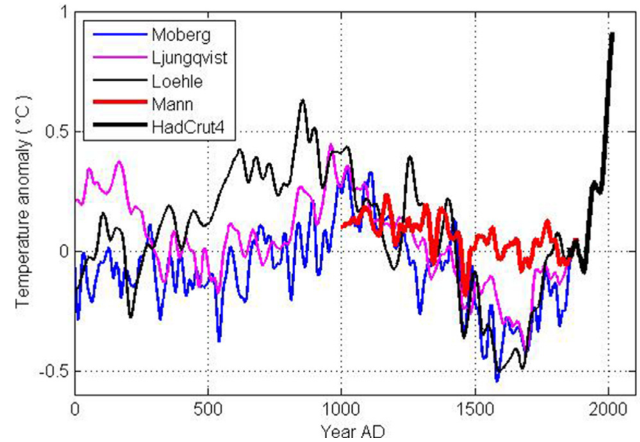

Fig. 1. Four reconstructed temperatures.

2.2. Global mean temperature

As an output, the global climate indicator is the mean surface temperature. Fig. 1 presents a catalogue of four reconstructions: Ljungqvist (2009); Loehle (2007); Moberg et al. (2005); Mann, Bradley, and Hughes, (1999). All four, except Mann, are quoted in the AR5 (Chapter 5: paleoclimate archives). They are aligned on – and extended by – modern measurements from 1850 (HadCrut4: thick black curve).

The further coming back in time, the more rare and inaccurate the proxies are. Some series start at the (symbolic) year 1000. For reasons of accuracy and availability, we will exploit temperatures reconstructions reduced to the second millennium. Moberg and Mann reconstructions are restricted to the northern hemisphere, Ljungqvist and Loehle to extra tropical zones. Nevertheless, the differences between modern temperatures of the northern and southern hemispheres are much lower than the observed disparities between the reconstructions above, which allow considering that the North/South or other climatic differences are dominated by errors due to proxies and reconstruction techniques.

We note that the curve of Mann, called *Hockey Stick Graph*, deviates significantly from others, which will reflect on the results of the identification.

2.3. Anthropic indicator: CO_2 atmospheric concentration

Human activity has an impact on the emissions of greenhouse gases (GHG), industrial aerosols, land use changes, etc. From C, the atmospheric concentration of CO_2, we define a global indicator of human activity as:

$$u_1 = \log_2(C/C_0)$$

where C_0 is the preindustrial concentration (*ante* 1750), about 280 *ppm* (*parts per million*).

Several reasons motivate this formula. First, the action of CO_2 is reportedly predominant. Also, others anthropogenic actions are cross-correlated and may tend to mutually compensate. Moreover, the CO_2-induced greenhouse effect is widely admitted to follow a logarithmic law. Finally, CO_2 doubling is often considered as the unit of variation; hence the interest of the base 2 logarithm.

Fig. 2 shows the signal u_1, resulting from the connection of modern atmospheric measures with the archives extracted from Arctic or Antarctic ice cores (source: NOAA and CDIAC). Note that $u_1 = 0.5 \leftrightarrow C = C_0 + 41\,\%$

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