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Late Pleistocene and Holocene Climatic Variability in the Carpathian-Balkan Region

ABSTRACTS VOLUME

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A stochastic vision of the paleoclimate. Modelling and predictibility

Ionel Haidu

Université de Lorraine, Laboratoire LOTERR - EA 7304, UFR SHS - Metz, France, ionel.haidu@univ-lorraine.fr

The objective of the paper is related to the use of stochastic methods to appreciate if the recent climate trend is similar to the decennial trends of the last thousands years.

If not, it means that the present climate change is unprecedented.

If yes, it means that the extraordinary climatic events of the recent years are a natural expression of climate variability, but the memory of several generations and of instrumental series, more than 100 years old, cannot point it out. The first hypothesis is an "alarming" possibility, while the latter is a "relaxing" one.

Background

There are uncertainties in the process of detecting a climate change. First, one may propose, like Klemes (1974), that no historical time can be stated for sure as stationary or not by the mathematicians. This is due to the short duration of instrumental series as compared to the "statistic infinity" which they are expected to represent. The opposite question, raised by Kite (1989), is to know how long a sub period of a historical series should be in order to identify a local stationary state.

At mean latitudes, the alternance of glacial and interglacial periods throughout the Quaternary clearly indicates that temperature averages have varied between two states, cold and warm, for geologic ages. This signifies a **non-stationary state**. At least at the average level of the series, the number of variations is equal to the number of stationary breaks. But at the level of peculiar sub periods, either glacial or interglacial stages, these have lasted enough to be considered as **stationary** from the point of view of the average temperature.

If one changes the time scale to the annual level, and if one makes reference to the period of instrumental observations, of about 150 to 200 years, the bibliographic results are contradictory. The last decade is an exception, as many authors have pointed out the manifestation of global warming for the last 10 years. The annual hydro climatic series, studied by the water resources managers, are independent of time and can be considered as **stationary** or "very close" of being stationary on average (Yevjevich, 1972; Salas *et al*., 1980; Kottegoda, 1980; Vandewiele, 1988). For 23 series of intermediate duration (96 to 1164 years) and analyzed at annual resolution, Hipel and McLeod (1994) have discovered the same type of result. On the basis of the data collected, the water resources managers assumed a hydrologic stationarity, as any trend cannot firmly established (Matalas, 1997). The trends encountered are suitable to be described as realizations of stochastic processes. In order to describe this type of process, it is reasonable to propose an **ARIMA type of stationary model**.

The papers of historical Climatology at annual scale (Guiot - 1991, Mann et al. - 1998, Mann et al. - 1999, Mann et al. - 2000, Crowley - 2000, Briffa et al. - 2001, Jones et al. - 2001, Robertson et al.

- 2001, Luterbacher et al. - 2002, Mann - 2002) have recently produced many chronological reconstitutions, the “proxy” series, which allow the modeling.

The “proxy” series at annual scale describe the climate of the last millennium. They reveal certain statistic features of the climate: great oscillations, significant “breaks”, sequential trends. Great oscillations such as the Little Ice Age and the Mediaeval Optimum seem to be as important as the last century warming. Three scientific reasons justify the necessity of a stochastic vision on the climate of the last millennium: the “proxy” series are more complicated than the instrumental series, the classic ARIMA model is not enough to describe the palaeoclimate and a new approach is necessary to allow modeling and prediction.

Methodology

The study of the climate variation trends is an issue of high interest nowadays, as the scientific literature indicates contradictory and higher oscillations than the normal ones, in different regions of the Earth. The numerous studies published recently did not lead to a certain conclusion regarding the increase or decrease of climatic elements (except for the temperature) at regional level. Often, the interpretation of different cited trends is influenced by the utilised work method and the way of defining the components of the time series. There is neither a humanimous opinion on the definition of trends, nor an adequate methodology for the analysis of chronological series depending on the duration of the series, the statistic and physical features of the analysed process. Thus, the stochastic prediction is not possible on the basis of classical models.

The modeling of a climatic time series, either having an instrumental origin or “proxy”, should begin by verifying the stationary or non-stationary state of its main statistic features. Therefore the study is mainly quantitative but the expected results should be qualitative.

For instrumental series (of 100-200 years) which do not have such obvious type of features (or there are none), the adequate stochastic models are the ARIMA type where (I) means a polynomial trend or the differentiation order. The classic ARIMA approach has several inconvenients: on the one hand, one cannot visualize the average oscillations during decades or centuries, on the other hand, false structures may be numerically created in the time series. The stationarity, reflected by the (I) part of the model, is a compulsory approach (Box et Jenkins - 1976; Brockwell et Davis – 1987; Kendall et Ord – 1990; Hipel et McLeod – 1994) in the field of time series analyses, before the series diagnosis by ACF or PACF. Usually, this determines the global tendency or makes a successive differentiation. Most of the times, the result is a false non-correlated stationary process (white noise), which makes a second inconvenient.

The moving averages are not adequate for stochastic modeling, too. The effect of an algebraic operation on the random series is well known in Climatology and Hydrology (Slutzky - 1927, Yule - 1927, Klemes et Klemes - 1988, Kendall et Ord - 1990, Hipel et McLeod - 1994). The accumulation, the moveable mean etc may sometimes create false structures in the time series. The conclusion is that one should intervene in the (I) part of the ARIMA model.

A) Stochastic approach of a continuous mean level

From a stochastic point of view, and depending on the dynamics of the mean level, the chronological series may be approached in two different ways. They may be either considered a phenomenon where the mean level has a continuous regime, or a phenomenon where the mean level has a discontinuous regime. The approaches based on the hypothesis of continuity are better known: non-correlated stationary processes (white noise), stationary processes and non-stationary processes. The second approach implies the presence of sudden shifts (jumps) in the evolution of the series mean level. One will use the non-parametric tests of independence of Wald-Wolfowitz, the stationarity tests of Kendall, the “run” tests for randomness and the Spearman test for serial independence etc.

B) Stochastic approach of a discontinuous mean level

Our aim is to find a model which makes the relation between the exigencies of stochastic modeling and those of physical significance. This is why we will discuss in this section the stochastic approach of a discontinuous mean level. The issue of segmenting the hydro-climatic series in order to emphasize the presence of climatic shifts has raised the interest of many scientists. The main question is that regarding the position of the break within an oscillating time series. Indeed, the position of the break point will depend on the type of data, the duration of the series, its amplitude and variability. A short comparison of these tests indicates that position of the breaks varies depending on the type of test which was chosen. The break may be found on a peak summit or at the bottom of a valley, but it can also be found between the highest peak and the lowest bottom.

There are two groups of tests which help one to verify the existence of stationary breaks in a time series. A first group is made up by tests which indicate the breaks between local means: M-K-S (combined type), Pettit (1979), Hubert (1989; 2000), Yamamoto and others (1986), Perreault (1999). The second type groups the tests which indicate the changes in direction of local trends: CUSUMS by Page (1954) and M-K-S (normal / onward).

The continuous contribution of Sneyers (1975, 1992-a et 1992-b) in order to explore the capability of different statistic tests for climate change detection is very important and well recognized by the scientific community. Many scientist used M-K (Kendall 1938 and Mann 1945) test in order to check the hypothesis of nonstationarity, but Sneyers is much more precise regarding the capability of this test. We can deduce from his explanation that the M-K statistics is a test against trend. As in the case of CUSUM, a change in the slope of progression way of this statistics implies an abrupt change in the mean. The M-K test is much more appropriate for a sequential analysis than the corresponding Spearman test.

In order to recognize a possible abrupt climatic change, Goossens and Berger (1987) recommend the Mann-Kendall rank statistics. This rank-based Mann-Kendall-Sneyers test (M-K-S) for detecting monotonic trends in time series data is still very present in many studies: Demarée (1990), Demarée and Nicolis (1990), Yue et al. (2001).

Some partial results

The observation series are yet too short if one wants to speak about the climate. We can consider that the analyzed climatic phenomenon has an infinite duration, while the human being dispose only of a “window”, limited to the period of instrumental observations, of only 100-200 years, sometimes more. The appearance of longer series, 500 to 1000 years for proxy, imposes a reexamination of ancient models. Certain statistic tests (Haidu et Mercier – 1996, Haidu – 1997) indicate that many of the instrumental climatic series are stationary on average and variability, but there are sub series which are significantly non-stationary. Through a certain method of segmentation, significant shifts of stationarity can be highlighted. They delimit distinct sub series from a statistical point of view, having duration between several decades and about 200 years.

I have analysed the following "proxy" series: grape harvest in eastern France-500 years (Fig. 1), punctual dendroclimatic series in Norway-600 years (Fig.2), Central European "multi-proxy" series (900 years), Canadian regional dendroclimatic series (300 years), the NH millenial Mann series, Jones series and Esper series. The adequate statistical tests display that a “proxy” series is stationary from the point of view of mean and variance, but the “proxy sub series” are significantly non-stationary. However, there are many other series that are to be analysed, too, in order to have regional, hemispherical or global results.

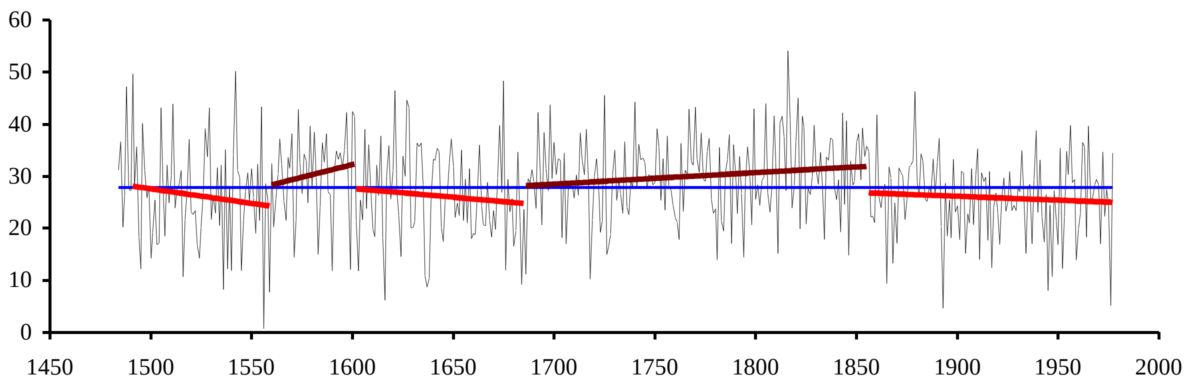

Fig. 1 Grape harvest data (Le Roy Ladurie, 1983), completed with sequential means. The opposite sequential trends separated by abrupt shift are highlighted.

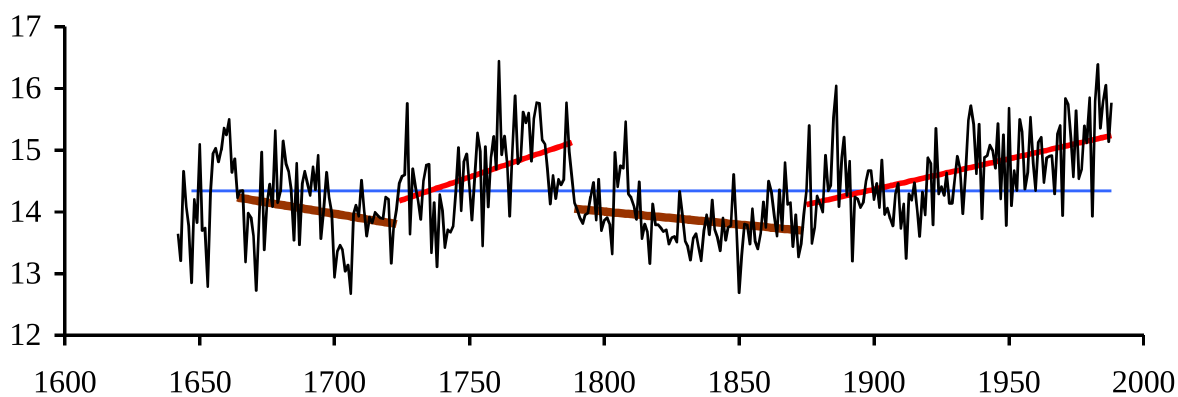

Fig. 2 Dendrological temperature reconstruction for Canada (Szeicz and MacDonald, 1995). The opposite sequential trends separated by abrupt shift are highlighted.

My partial results show that the climate has varied between two "stochastic states" in the last millennium. The duration of these states varies between several decades up to one or two centuries. The model tries to explain how much the sequential trends will increase and whether these trends can be reversible. It is possible that abrupt change exists between opposite trends. Many “proxy” series manifest this specific feature.

Maybe the present "stochastic state" of the climate is unusual, given by human impact, or maybe it is not. The results of the study will offer a new perspective to the climatic predictability problem. In the above-presented examples, the main question is the following: two statistical states separated by breaks should be taken into account by a unique stochastic modeling?

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