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Formulation of a reduced order model of the climatic system by combining classical simulation methods with artificial intelligence techniques

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The climate is a multivariable dynamic complex system, governed by equations which are strongly nonlinear. The space-time modes of climatic variability extend on a very broad scale and constitute a major difficulty to represent this variability over long time-scales. It is generally decided to separate the dynamics of the slow components (ice sheets, carbon cycle, deep oceans) which have a time scale of about thousand of years and more, from those of the fast components (atmosphere, mixed layer, earth and ice surface) for which the time scale is for about some years. In this framework, the time-evolution of the slow components depends on the statistics of the fast components, and the latter are controlled by the slow components and the external forcing particularly astronomical ones characterised by the variation of the orbital parameters: Obliquity, precession and eccentricity. The statistics of the fast components of the climate could in principle be estimated with a general circulation model of the atmosphere and ocean. However, the demand on computing resources would be far too excessive.

Given the complexity of the climatic system, the great number of dynamic equations which govern it and its degree of nonlinearity we are interested in the statistical reduction rather than an analytical one. The order reduction problem is equivalent to approximator construction. We will focus on neural networks because they constitute very powerful estimators in presence of non-linearity. The training of this network would be done using the output of the climate model of intermediate complexity "LoveClim" developed and available in the Institute of Astronomy and Geophysics G.Lemaître in Belgium as a first step of statistical reduction. The output of the model are first reduced using different methods of reduction order going from linear ones as principal component analysis (PCA) and empirical orthogonal functions (EOF) to non linear ones as Non Linear Principal component analysis (NLPCA) taking on account the non linear dependences between data.

The choice on the one hand of the values of the orbital parameters and on the other hand the number of simulations has been chosen using an optimal experimental plan. This method allow us to maximise the information about the model considering the variation of its parameters in a minimum experiences. A great number of these simulations have been done already and the next step will be to apply all the reduction methods.

These methodologies have been applied on two simple models. First, the Lorenz attractor, a simple model which takes into account the main characteristics of the complex dynamics of the climate system. Second, a model of the terrestrial insolation determined by the three orbital parameters varying in time, has been analysed using PCA and EOF reduction methods. In this case, five dominant modes have been found to be sufficient. These first results justify the use of the several methods and prove their efficiency in the case of these simple models and encourage us to apply them to the outputs already computed with LoveClim.