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Quantifying the astronomical contribution to Pleistocene climate change: A non-linear, statistical approach

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The existence of an action of astronomical forcing on the Pleistocene climate is almost undisputed. However, quantifying this action is not straightforward. In particular, the phenomenon of deglaciation is generally interpreted as a manifestation of instability, which is typical of non-linear systems. As a consequence, explaining the Pleistocene climate record as the addition of an astronomical contribution and noise—as often done using harmonic analysis tools—is potentially deceptive. Rather, we advocate a methodology in which non-linear stochastic dynamical systems are calibrated on the Pleistocene climate record. The exercise, though, requires careful statistical reasoning and state-of-the-art techniques. In fact, the problem has been judged to be mathematically 'intractable and unsolved' and some pragmatism is justified.

In order to illustrate the methodology we consider one dynamical system that potentially captures four dynamical features of the Pleistocene climate : the existence of a saddle-node bifurcation in at least one of its slow components, a time-scale separation between a slow and a fast component, the action of astronomical forcing, and the existence a stochastic contribution to the system dynamics. This model is obviously not the only possible representation of Pleistocene dynamics, but it encapsulates well enough both our theoretical and empirical knowledge into a very simple form to constitute a valid starting point.

The purpose of this poster is to outline the practical challenges in calibrating such a model on paleoclimate observations. Just as in time series analysis, there is no one single and universal test or criteria that would demonstrate the validity of an approach. Several methods exist to calibrate the model and judgement develops by the confrontation of the results of the different methods.

In particular, we consider here the Kalman filter variants, the Particle Monte-Carlo Markov Chain, and two other variants of Sequential Monte Carlo methods (SMC), such as $(SMC)^2$ and Approximate Bayesian Computation-SMC. The presentation concludes on general considerations about the interest of the Bayesian approach in this context.