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Palaeoclimate dynamics : a voyage through scales

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Our knowledge of climate dynamics depends on indirect observations of past climate evolution, as well as on what can be inferred from theoretical arguments. At the scale of the Cenozoic, it is common to define a framework of nested time scales, the longest time scale of interest being related to the slow tectonic evolution, then variability associated with or controlled by the astronomical forcing, and finally the fastest dynamics associated with the natural modes of variability of the ocean and the atmosphere. For example, in a model, the astronomical modes of variability may be simulated with deterministic equations under fixed boundary conditions representing the tectonic state, and associated with stochastic parameterisations of the ocean-atmosphere (chaotic) modes of motion. Bifurcations or, more generally, qualitative changes in climate dynamics may be scanned by changing slowly the tectonic state, in order to provide explanations to observed changes in regimes such as the appearance of ice ages and their changes in length or amplitude. The above framework, largely theorized by B. Saltzman, may still be partly justified but is in need of a review. We address here specifically three questions:

1. To what extent astronomical variability interacts with natural modes of ocean - atmosphere variability ? Specifically, how does millennial variability (e.g.: Dansgaard-Oeschger events) fit the Saltzman scheme ?

2. The astronomical forcing is quasi-periodic, and we recently showed that it may produce somewhat counter-intuitive dynamics associated with the emergence of strange non-chaotic attractors. What are the consequences on the spectrum of climate variability ?

3. What are the effects of centennial climate variability on the slow variability of climate ?

These three questions are addressed by reference to recently published material, with the objective of emphasising research questions to be explored in the near future.