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On the functioning of the glacial-interglacial variability: deterministic excitation vs. stochastic resonance

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The mechanism of stochastic resonance (SR) in a bistable system was introduced [1] to explain the glacial-interglacial cycles in the Quaternary and is still regarded as a dynamical systems paradigm for those climate cycles. In the SR the stochastic forcing must satisfy a rather stringent condition; besides, glacial inceptions occur abruptly, as well as the glacial terminations. However, these conditions do not seem to be verified in the real climate system. Here it is shown that the alternative dynamical paradigm -that may be termed deterministic excitation (DE)- in which relaxation oscillations (ROs) are excited by the astronomical forcing in a purely deterministic framework, overcomes those limitations and may therefore provide a more plausible theoretical basis for the explanation of the glacial-interglacial variability.

In an excitable dynamical system a RO connects a basic state to an unstable excited state, which is then followed by a spontaneous, slow return to the original state. Such transition is self-sustained in a given parameter range of the autonomous system, otherwise it can be excited by an external deterministic time-dependent forcing (DE) or by noise (coherence resonance). Examples of DE in ocean dynamics are presented for the Kuroshio Extension in the North Pacific and for the Antarctic Circumpolar Current in the Southern Ocean.

A 4-dimensional nonlinear excitable spectral model of the wind-driven ocean circulation [2] is then used to briefly illustrate the main aspects of excitable climate dynamics, focusing on the occurrence of coherence resonance [3], on the DE of ROs under the action of an aperiodic forcing [4] and on the tipping points due to parameter drift [5]. Finally, a classical energy balance model is extended to obtain a minimal excitable model of the late Pleistocene ice ages [Pierini, in preparation]. The timing of the interglacials, determined by the DE caused by the variations of the Earth's orbital eccentricity and axial tilt and precession, is found to be in significant agreement with proxy data. (Support from the IPSODES-P.N.R.A. project is acknowledged)

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