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Millennial-scale climate variability: Insight from the theory of nonlinear vibrations

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The most fundamental problem in understanding climate variability at the millennial time scales is perhaps the fact that the millennial band is near the middle of a wide gap in the spectrum of external forcing on the climate system. This state of affairs tends to support theories that invoke unforced (free) oscillations within the climate system in order to explain millennial variability. Our contribution will be twofold. First, we will discuss some basic notions from the theory of nonlinear vibrations that possibly contain some of the essential physical elements underlying the occurrence of free oscillations in the climate system. Particular emphasis will be put on self-sustained oscillations, which occur when the damping force is a nonlinear function of the system's motion. Among the class of self-excited oscillators, the relaxation oscillator of van der Pol, which corresponds to the strongly nonlinear limit, will be given due consideration. Second, we will discuss the self-sustained oscillations that occur in a zonally averaged model of the ocean circulation – a major component of the climate system. In this model, the occurrence and period of the flow oscillations vary with the energy available for vertical mixing. It will be shown that the variations of the period of flow oscillation with mixing energy are consistent with a scaling from van der Pol theory. Whether this theory and the numerical solutions of the ocean model have any relevance to the issue of climate change in the millennial band will be discussed.