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On the potential role of marine calcifiers in glacial-interglacial dynamics

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The well-known Vostok and EPICA ice-core data have revealed a highly asymmetric ('sawtooth') cycle in Antarctic temperature and atmospheric CO_2 concentration during the last 800,000 years. Both CO_2 and temperature decrease over 100,000 years going into a glacial period, then steeply increase over less than 10,000 years at the end of a glacial. There does not exist wide agreement about the causes of this cycle or about the origin of its sawtooth shape. Here, we explore the possibility that a biologically driven oscillator plays a role in the dynamics of the cycle. A highly idealized model describing the interaction between calcifying organisms and ocean alkalinity reveals the potential for an internal oscillation of the ocean carbonate cycle which has several interesting features: (i) it produces an oscillation in global ocean alkalinity (and thus atmospheric carbon dioxide) with the characteristic sawtooth shape observed in the ice-core record, (ii) the oscillation is due to an interaction between marine calcifiers and ocean alkalinity, (iii) the period of the oscillations depends upon the chosen parameter values (which partly reflect ecological interactions between calcifiers and non-calcifiers), but the period is in a range consistent with the observed glacial-interglacial variations, (iv) the model predicts "spikes" of enhanced calcifier productivity at the glacial-interglacial transitions, consistent with sedimentary records, and (v) the oscillation slowly damps out if unforced, but can be sustained through forcing by an external (e.g., Milankovitch) cycle. Thus, we suggest that ecological processes might contribute actively to the observed glacial-interglacial cycles.