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An explanation of the 100 kyr ice age cycle using a simple box model

A.C. Fowler (1), R.E.M. Rickaby (2), and E.W. Wolff (3)

(1) University of Limerick, Limerick, Ireland (fowler@maths.ox.ac.uk), (2) University of Oxford, Oxford, U.K. (rosr@earth.ox.ac.uk), (3) British Antarctic Survey, Cambridge, U.K. (ewwo@bas.ac.uk)

We have developed a conceptually simple box model, similar in philosophy to those of Saltzman, with a view to explaining the 100 kyr period of the most recent ice age signals. Here we explain in detail how and why the various components of the model have been constructed, and we show how the model can be analysed in order to explain its behaviour. We find that the model can explain the 100 kyr cycles as a self-sustaining oscillation, and in addition we can explain the 40 kyr –100 kyr transition, and indeed the post-Eocene cooling, through the variation of weathering rate over geologic time.

The central component of the model is an ocean carbon balance, which receives input from the weathering of silicates and carbonates, and loses $CaCO_3$ by the burial of calcareous biomass. It is therefore necessary to also balance calcium and biomass, and thence phosphorus, which we take to be rate limiting. Charge balance is effected through estimates of the conservative ions Na^+, Cl^-, etc. To this ocean chemistry model we add a simple ice sheet model of the Weertman/Oerlemans/Ghil type, and we allow for rapid deglaciation through an enhanced wastage rate associated with the growth of proglacial lakes like Agassiz.

The oscillations which result are due to the interaction of the hysteretic ice sheet growth (allowing for the elevation-accumulation feedback), and a similar hysteresis in the proglacial lake volume. The effect of this on the atmospheric carbon is controlled by the lowering of the carbonate ion which results when the ice sheet meltwater flows into the ocean.