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Modelling changes of the marine carbon cycle on glacial-interglacial and millennial timescales and its role on atmospheric CO2

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Measurements of air trapped in ice cores show changes in atmospheric CO_2 contentrations of 80 ppmv on glacial-interglacial timescales and intra-glacial variability of 20 ppmv on millennial timescales. Using highly idealized (box or zonally averaged) models, it has been suggested that the ocean accounts both for glacial to interglacial changes of atmospheric CO_2 as well as for the intra-glacial variability. Here I re-assess both problems with a global coupled climate model (UVic ESCM) containing state-of-the-art 3D ocean circulation, ecosystem and carbon cycle modules. Simulated variations of atmospheric CO_2 in response to changes in North Atlantic Deep Water (NADW) formation are consistent with the observed amplitude but they strongly depend on the amount and duration of the freshwater forcing. Modelled glacial-interglacial changes of about 20 ppmv largely underestimate the observed variability. The processes leading to these modelled changes, particularly deep ocean ventilation, air-sea gas exchange and productivity, are analysed. The potential role of missing processes such as increased productivity through iron fertilisation and calcium carbonate compensation within the sediments are discussed. I conclude that we are still a far way from understanding the natural variability of the carbon cycle and that the simulation of both glacial-interglacial and millennial variability remains a key challenge for Earth System Models.