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Reconstructing the evolution of ice sheets, sea level and atmospheric CO2 during the past 3.6 million years

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Understanding the evolution of, and the interactions between, ice sheets and the global climate over geological time is important for being able to constrain earth system sensitivity. However, direct observational evidence of past CO_2 concentrations only exists for the past 800,000 years. Records of benthic d^{18}O date back millions of years, but contain signals from both land ice volume and ocean temperature. In recent years, inverse forward modelling has been developed as a method to disentangle these two signals, resulting in mutually consistent reconstructions of ice volume, temperature and CO_2. We use this approach to force a hybrid ice-sheet – climate model with a benthic d^{18}O stack, reconstructing the evolution of the ice sheets, global mean sea-level and atmospheric CO_2 during the late Pliocene and the Pleistocene, from 3.6 Myr ago to the present day. The resulting reconstructions of CO_2 and sea level agree well with the ice core record and different sea-level proxies, indicating that this model set-up yields useful information for colder-than-present climates. For the warmer-than-present climates of the Late Pliocene, different proxies for both CO_2 and sea level are contradictory, making model validation difficult. During the early Pleistocene, 2.6 – 1.2 Myr ago, we simulate 40 kyr glacial cycles with CO_2 ranging between 270 – 280 ppmv during interglacials and 210 – 240 ppmv during glacial maxima. After the Mid-Pleistocene Transition (MPT), when the glacial cycles change from 40 kyr to 80/120 kyr cyclicity, these values change to 260 to 280 ppmv during interglacials, and 180 – 200 ppmv during glacial maxima.