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A 150,000 year marine δ^{13}C synthesis and its use in Earth System modelling

Kevin Oliver (1), Babette Hoogakker (2), Simon Crowhurst (2), Gideon Henderson (3), Ros Rickaby (3), Neil Edwards (4), and Harry Elderfield (2)

(1) School of Ocean and Earth Science, National Oceanography Centre, University of Southampton, UK (K.Oliver@noc.soton.ac.uk), (2) Department of Earth Sciences, University of Cambridge, UK, (3) Department of Earth Sciences, University of Oxford, UK, (4) Department of Earth and Environmental Sciences, The Open University, Milton Keynes, UK

The isotopic composition of carbon, δ^{13}C, in seawater is used in reconstructions of ocean circulation, marine productivity, air-sea gas exchange, and biosphere carbon storage. We present a synthesis of δ^{13}C measurements taken from foraminifera in marine sediment cores over the last 150,000 years, comprising previously published and unpublished data from benthic and planktonic records throughout the global ocean. Data are placed on a common δ^{18}O age scale and filtered to remove timescales shorter than 6 kyr. Error estimates account for the resolution and scatter of the original data, and uncertainty in the relationship between δ^{13}C of calcite and of dissolved inorganic carbon (DIC) in seawater.

The presentation focuses on the use of the data synthesis as a modelling target, and for assimilation into Earth system models (ESMs), with two scientific questions used as examples: (1) changes in biosphere carbon storage; (2) changes in atmospheric pCO_2 on glacial timescales. We discuss problems of uneven sampling, and dealing with records which often contain greater errors in absolute δ^{13}C than in δ^{13}C changes. We also consider the use of ESM outputs such as temperature, DIC concentration, and alkalinity to inform the assimilation process.

Whereas planktonic data place a weak constraint on ESM simulations, due to large error estimates, benthic data provide a strong constraint, which coherent changes throughout much of the ocean on orbital timescales. Global deep ocean δ^{13}C is high during Marine Isotope Stages (MIS) 1, 3, 5a, 5c and 5e, and low during MIS 2, 4 and 6, which are temperature minima, with larger amplitude variability in the Atlantic Ocean than the Pacific Ocean. The ESM GENIE is able to adequately reproduce most aspects of the the last glacial maximum (during MIS 2) distribution under a variety of forcing conditions, indicating that further proxies are required to constrain the glacial carbon cycle problem. However, GENIE systematically overestimates the Atlantic-Pacific δ^{13}C difference; methods to account for systematic structural errors in models, such as this, are discussed.