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Evaluating the deep-ocean circulation of a global ocean model using carbon isotopic ratios

André Paul (1), Stephanie Dutkiewicz (2), Jake Gebbie (3), Martin Losch (4), and Olivier Marchal (5)

(1) MARUM - Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany (apaul@marum.de), (2) Department of Earth, Atmosphere and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA, (3) Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA, USA, (4) Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, (5) Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA, USA

We study the sensitivity of a global three-dimensional biotic ocean carbon-cycle model to the parameterizations of gas exchange and biological productivity as well as to deep-ocean circulation strength, and we employ the carbon isotopic ratios δ^{13}C and Δ^{14}C of dissolved inorganic carbon for a systematic evaluation against observations. Radiocarbon (Δ^{14}C) in particular offers the means to assess the model skill on a time scale of 100 to 1000 years relevant to the deep-ocean circulation.

The carbon isotope ratios are included as tracers in the MIT general circulation model (MITgcm). The implementation involves the fractionation processes during photosynthesis and air-sea gas exchange. We present the results of sixteen simulations combining two different parameterizations of the piston velocity, two different parameterizations of biological productivity (including the effect of iron fertilization) and four different overturning rates. These simulations were first spun up to equilibrium (more than 10,000 years of model simulation) and then continued from AD 1765 to AD 2002. For the model evaluation, we followed the OCMIP-2 (Ocean Carbon-Cycle Model Intercomparision Project phase two) protocol, comparing the results to GEOSECS (Geochemical Ocean Sections Survey) and WOCE (World Ocean Circulation Experiment) δ^{13}C and natural Δ^{14}C data in the world ocean.

The range of deep natural Δ^{14}C (below 1000 m) for our single model (MITgcm) was smaller than for the group of different OCMIP-2 models. Furthermore, differences between different model parameterizations were smaller than for different overturning rates.

We conclude that carbon isotope ratios are a useful tool to evaluate the deep-ocean circulation. Since they are also available from deep-sea sediment records, we postulate that the simulation of carbon isotope ratios in a global ocean model will aid in estimating the deep-ocean circulation and climate during present and past.