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Cenozoic CO_2: from the deep ocean to the atmosphere

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CO_2 is thought to play a critical role in environmental change throughout the Cenozoic, yet despite recent progress, there is still much to learn on the Cenozoic evolution of the ocean-atmosphere CO_2 system. To address this, we present new reconstructions of deep ocean pH spanning the past 66 million years, based on the boron isotope composition of benthic foraminifera from multiple ocean basins. These data demonstrate close coupling between the CO_2 system of the deep ocean, the surface ocean, and the atmosphere. In combination with new reconstructions of deep sea carbonate saturation from benthic boron to calcium ratios, we place constraints on the evolution of ocean alkalinity, dissolved inorganic carbon, and seawater boron isotope composition. Together, these underscore the importance of whole ocean CO_2 system changes – driven by changes in the ratio of ocean alkalinity to dissolved inorganic carbon – in controlling Cenozoic climate. Our data also highlight intervals of dynamic changes in the carbon cycle, such as the transition into the Early Eocene Climatic Optimum, where we suggest a novel link between changes in ocean circulation, redox, and the carbon cycle. Overall, our data demonstrate the persistence of CO_2's control on the climate system across varying boundary conditions, and the influence of changes in both the long-term carbon cycle and shorter-term ocean biogeochemistry on Earth's climate.