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Deep Sea Memory of High Atmospheric CO_2 Concentration

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Carbon dioxide removal (CDR) from the atmosphere has been proposed as a powerful measure to mitigate global warming and ocean acidification. Planetary-scale interventions of that kind are often portrayed as “last-resort strategies”, which need to weigh in if humankind keeps on enhancing the climate-system stock of CO_2. Yet even if CDR could restore atmospheric CO_2 to substantially lower concentrations, would it really qualify to undo the critical impacts of past emissions? In the study presented here, we employed an Earth System Model of Intermediate Complexity (EMIC) to investigate how CDR might erase the emissions legacy in the marine environment, focusing on pH, temperature and dissolved oxygen. Against a background of a world following the RCP8.5 emissions path (“business-as-usual”) for centuries, we simulated the effects of two massive CDR interventions with CO_2 extraction rates of 5 GtC yr-1 and 25 GtC yr-1, respectively, starting in 2250. We found that the 5 GtC yr-1 scheme would have only minor ameliorative influence on the oceans, even after several centuries of application. By way of contrast, the extreme 25 GtC yr-1 scheme eventually leads to tangible improvements. However, even with such an aggressive measure, past CO_2 emissions leave a substantial legacy in the marine environment within the simulated period (i.e. until 2700). In summary, our study demonstrates that anthropogenic alterations of the oceans, caused by continued business-as-usual emissions, may not be reversed on a multi-centennial time scale by the most aspirational geoengineering measures.

We also found that a transition from the RCP8.5 state to the state of a strong mitigation scenario (RCP2.6) is not possible, even under the assumption of extreme extraction rates (25 GtC yr-1). This is explicitly demonstrated by simulating additional scenarios, starting CDR already in 2150 and operating until the atmospheric CO_2 concentration reaches 280 ppm and 180 ppm, respectively. The simulated massive CDR interventions eventually bring down the global mean pH value to the RCP2.6 level, yet cannot restore a similarly homogenous distribution – while the pH of the upper ocean returns to the preindustrial value or even exceed it (in the 180 ppm scenario), the deep ocean remains acidified. The deep ocean is out of contact with the atmosphere and therefore unreachable by atmospheric CDR.

Our results suggest that the proposition that the marine consequences of early emissions reductions are comparable to those of delayed reductions plus CDR is delusive and that a policy that allows for emitting CO_2 today in the hopes of removing it tomorrow is bound to generate substantial regrets.