Ocean deoxygenation: degrees of reversibility in an atmospheric carbon dioxide removal (CDR) scenario

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The use of carbon dioxide removal techniques has gained increasing interest over the past decade. Its potential to reduce the carbon burden in the atmosphere, allowing for a net-zero or net-negative CO_2 emissions, makes these techniques extremely attractive as a way to counteract both past and future anthropogenic led greenhouse effects. Despite the potential, uncertainty remains regarding environmental responses to a reduction of carbon forcing from the atmosphere, especially for the oceans, which are subjected to processes acting in a multitude of timescales. In the current work we explore decadal and centennial ocean oxygen responses to an idealized CDR implementation, part of the Carbon Dioxide Removal Model Intercomparison Project (CDRMIP). This experiment simulates an overshoot scenario, with a CO_2 ramp-up followed by a ramp-down at the same rate, and provides baseline information that can aid scientific and political discussions. Using an 8-member ensemble of Earth system models, we found that the degree of oxygen reversibility on these timescales is highly dependent on the ocean depth and region. Considering the total ocean oxygen content no reversibility is possible, while the surface of the ocean and waters at depths up to 1300m can both return and overshoot their pre-industrial oxygen concentrations. Deeper waters, however, show a strong deoxygenation signal even after a century of idealized CDR implementation. This response time lag and hysteresis appear to be associated to the apparent oxygen use, in specific related to ventilation and circulation processes. Such outcomes highlight the long-term impacts of human activities and the uncertainties still associated with the use of CDR affecting, in case of the ocean oxygen, the marine ecosystem and biogeochemistry.