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Ocean dynamics determine the response of oceanic CO2-uptake to climate change

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We investigate the mechanisms of the ocean's carbon uptake within the feedback loop of atmospheric CO2 concentration, climate change and oceanic CO2 flux. Two transient simulations from 1860 until 2100 are evaluated performed with a version of the Max Planck Institute Earth System Model (MPI-ESM) with the carbon cycle included. In both experiments observed anthropogenic CO2 emissions were prescribed until 2000, followed by the emissions according to the IPCC Scenario A2. In one simulation the radiative forcing of changing atmospheric CO2 is taken into account (coupled), whereas it is artificially suppressed in the other simulation (uncoupled).

In both simulations the oceanic carbon uptake increases steadily from about 1 GT C/yr in 1960 to about 4.5 GT C/yr in 2070. Afterwards, the rise weakens in the coupled simulation, leading to a reduced uptake rate of about 10% in 2100 compared to the uncoupled simulation. This includes a partial offset by higher atmospheric CO2 concentrations as a result of the land surface response to greenhouse warming, that is, reduced carbon uptake by soil and vegetation compared to the uncoupled simulation.

The smaller oceanic CO2 uptake in the coupled simulation is primarily due to changes in the oceanic circulation under global warming. The major decreases compared with the uncoupled simulation are found in the Southern Ocean between 35S and 60S (-45%) and in the North Atlantic (-30%), which are related to reduced convection and vertical mixing, accompanied with reduced meridional overturning in the North Atlantic. The tropical oceans show little response, except the low-latitude Atlantic (-20%). In the polar areas, climate change induces additional CO2 uptake, mainly due to sea ice melting (+20%).