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The variable ocean carbon sink

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The ocean is a major sink for human-emitted carbon dioxide (CO_2) currently absorbing it at a mean rate of about 2.5 PgC/yr equivalent to roughly 25% of the total CO_2 emissions. Thereby the ocean provides a valuable ecosystem service to humanity, however, despite its crucial role in the global carbon cycle substantial discrepancies exist with regards to its sink variability in time and space estimated by various methods. Understanding the source and magnitude of this variability that is superimposed on the long-term sink trend is essential in order to quantify the future contribution of the ocean in removing excess carbon from the atmosphere. Recent observation-based estimates, benefitting from the collection of surface ocean fugacity of CO_2 (fCO_2) measurements within the Surface Ocean CO_2 Atlas (SOCAT) database, illustrate that regionally- and globally-integrated ocean CO_2 fluxes significantly exceed variations suggested by state-of-the-art ocean biogeochemistry models. This is particularly visible in the Southern Ocean, i.e. the most important ocean basin for the uptake of anthropogenic CO_2, where observation-based flux estimates suggest a significant strengthening of the CO_2 sink of 0.35 ± 0.23 PgC/yr/decade in the 2000s following a decade of sink reduction. This suggests a more dynamical climate modulated carbon cycle than previously recognised, particularly on decadal timescales. The oceanic uptake of anthropogenic CO_2, however, does not only help to regulate the atmospheric CO_2 concentration but it further substantially alters the marine carbon cycle. Today, using the SOCAT database, we can confirm past model predictions and theoretical considerations highlighting substantial changes in the amplitude of the marine partial pressure of CO_2 (pCO_2). Over the past decades, the seasonal surface ocean pCO_2 amplitude has increased at a rate of 2.2 ± 0.4 μatm/decade in response to the increasing concentration of anthropogenic CO_2 in the ocean and changes in the ocean buffer capacity. These strengthening seasonal pCO_2 variations highlight the inevitable and far-reaching consequences of anthropogenic CO_2 emissions on marine organisms, as they are exposed earlier to higher levels of ocean acidification, possibly inducing the transition across critical thresholds harmful to ocean ecosystems and fisheries.