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Predictions of multi-year variations of the ocean carbon sink

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The ocean currently absorbs about 25% of the anthropogenic carbon emissions to the atmosphere. Without the important oceanic carbon uptake, the increase of atmospheric CO_2 concentration and the corresponding global warming would be much higher than the contemporary rate. However, temporal evolution of the oceanic carbon sink does not simply follow the trajectory of the fossil fuel CO_2 emission increase. Instead it shows prominent interannual to decadal variations. Can the multi-year variations of the ocean carbon sink be captured by an earth system model (ESM)? And how predictable are these variations?

To address these questions, we use the decadal prediction system based on the Max Planck Institute's ESM (MPI-ESM) in which the ocean biogeochemical component is represented by the Hamburg Ocean Carbon Cycle Model (HAMOCC). We only assimilate 3-dimensional fields of atmospheric and physical ocean observations into the MPI-ESM decadal prediction system. We first explore the potential predictability of the ocean carbon uptake by comparing the initialized simulations with the assimilation. We find a high potential predictive skill of 4-7 years in the western subpolar gyre region of the North Atlantic, where high predictive skills of ocean temperature and meridional circulation are confirmed in decadal prediction systems. Further investigation reveals that the improved predictive skills of carbon uptake in the western subpolar gyre region of the North Atlantic is mainly maintained in winter and can be attributed to the improvement of ocean physical states by initialization (see Li et al., 2016).

We further assess the predictive skill based on the observational estimates of the air-sea CO_2 flux. We find high predictive skills in the North Atlantic and the North Pacific Oceans, and low predictive skills in the tropical ocean. We note that large uncertainties among different data-based products due to temporal and spatial gaps in observations, as well as different techniques used to derive those observational products (Rödenbeck et al. 2015), impose challenges to interpret the predictive skill. Physical processes, such as those determining ocean circulation and the physical state of the ocean are investigated to further disentangle the mechanisms that maintain the predictability of the ocean carbon sink. This decadal prediction study of the oceanic carbon uptake contributes to understanding of the near-future evolution of the global carbon cycle and the corresponding climate change.

References:
1. Li, H., et al. (2016), Decadal predictions of the North Atlantic CO_2 uptake, Nature Communications, 7, 11076.
2. Rödenbeck, C., et al. (2015), Data-based estimates of the ocean carbon sink variability – first results of the Surface Ocean pCO_2 Mapping intercomparison (SOCOM), Biogeosciences, 12, 7251-7278.