Decadal predictions of the variable ocean carbon uptake

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The global ocean, as a major carbon sink, absorbs about 25% of the contemporary anthropogenic CO_2 emissions; hence the carbon uptake by the ocean largely mitigates the CO_2concentration increase in the atmosphere and hence the global warming. Moreover, the strength of the carbon flux into the ocean, varies substantially from annual to decadal time-scale. Therefore, predicting the variable ocean carbon uptake and global carbon cycle is of essential value of tracing the fate of carbon and the corresponding climate and ecosystem changes.

By assimilating atmosphere and ocean physical observations into the decadal prediction system based on the Max Planck Institute Earth System Model (MPI-ESM), we reproduce the ocean carbon uptake variations in consistent with the data-based estimates. The retrospective predictions starting from the assimilation states show a predictive skill of 2 years in the ocean carbon uptake globally. Regionally the predictive skill is up to 5 years in the Southern Ocean and the North Pacific. To understand the mechanisms in maintaining the predictability of the ocean carbon uptake, we separate the ocean surface pCO_2, which is the main driver of the variability in carbon fluxes, into thermal and non-thermal components. The thermal component is affected by the solubility of CO_2via temperature variations, and the non-thermal component is affected by the ocean circulation and biology, i.e., is not first order affected by the temperature. We find that the thermal component contributes mainly to shorter-term (of <3 years) of predictive skill of the ocean carbon uptake, while the non-thermal component is responsible for longer-term (of >3 years) of predictive skill of the ocean carbon uptake.

Decadal prediction study of the global carbon cycle and corresponding ecosystem based on the ESMs is still at its early stage and facing a number of challenges arising from limited ocean biogeochemical observations and lack of proper initialization strategies. An extension of our predictions in the context of multi-model framework is in progress and this will facilitate deeper understanding of the mechanisms and further improvement of the predictive skill in the global carbon cycle.

Keywords: Decadal predictions, Ocean carbon uptake, Climate variability

