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Earth system predictions of the carbon sinks and atmospheric CO_2 growth: new insights and lessons from DCPP

Tatiana Ilyina, Hongmei Li, Wolfgang Müller, and Aaron Spring
Max Planck Institute for Meteorology, Germany (tatiana.ilyina@mpimet.mpg.de)

Initialized predictions of near-term future climate have proven successful and predictive power for the global carbon cycle is also emerging. Through extending ESM-based decadal prediction systems, i.e. those contributing to Decadal Climate Prediction Project (DCPP) with the ocean and land carbon cycle components, it becomes possible to establish predictability of the carbon sinks and variations of atmospheric CO_2 concentrations. However, such predictions of the global carbon cycle still remain a cutting-edge activity of only a few modeling groups.

On interannual to decadal time-scales, atmospheric CO_2 growth rates exhibit pronounced anomalies driven by varying strengths of the land and ocean carbon sinks; these anomalies are linked to climate variability on decadal and interannual time scales. Is it possible to predict if atmospheric CO_2 changes slower of faster as expected from changes in emissions? This question is examined in a multi-model framework comprising prediction systems initialized by the observed state of the physical climate. The multi-model framework comprises ESM-based prediction systems that contributed to DCPP within CMIP6, as well as those which run with the CMIP5 forcing.

A predictive skill for the global ocean carbon sink of up to 6 years is found for some models. Longer regional predictability horizons are found across single models. On land, a predictive skill of up to 2 years is primarily maintained in the tropics and extra-tropics enabled by the initialization of the physical climate. Furthermore, anomalies of atmospheric CO_2 growth rate inferred from natural variations of the land and ocean carbon sinks are predictable at lead time of 2 years and the skill is limited by the land carbon sink predictability horizon. These predictions of the global carbon cycle and the planet's breath maintained by variations of atmospheric CO_2 are essential to understand where the anthropogenic carbon would go in response to emission reduction efforts addressing global warming mitigation. Such information is useful to verify the effectiveness of fossil fuel emissions reduction measures.