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Introducing ToE-MIP: Time-of-Emergence Model Intercomparison Project

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Invasion of anthropogenic carbon and heat into the ocean results in a cascade of biogeochemical and physical changes. In this study, we use 3 initial condition large ensembles (ICLE) experimental design with an Earth System Model (ESM) to estimate the timing, sequence and model-dependence of emergence of anthropogenic signals above natural background variability for a suite of biogeochemical variables under 21st century climate change. We focus on emergence of the ocean carbon sink and its components: a calcium carbonate pump, a soft-tissue pump, and a solubility pump. We find that the chronology of emergence remains broadly consistent amongst the models. First, emergences the calcium carbonate pump, second, emergence of solubility pump (approximated by the air-sea carbon fluxes), and finally, emergence of the soft tissue pump. The three ICLE models are GFDL-ESM2M, CanESM2 and CESM1-BGC. Our hypothesis is that changes in the calcium carbonate pump emerge first, as these are the most strongly linked to the depletion of carbonate ion. Air-Sea carbon fluxes emerge at intermediate time scales, as there is a competition on solubility between rising atmospheric pCO_2, rising ocean temperatures which acts to reduce solubility, and the nonlinearity of pCO_2 at high DIC concentrations (i.e. the Revel factor). Finally, the soft tissue pump emerges due changes in the physical state (e.g. heat, mixed-layer depth) of the ocean which take the majority of the 21st century to become emergent.