Coupling of Surface Ocean Heat and Carbon Perturbations under Global Warming

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The ocean is the principal integrator in the climate system on multi-decadal to centennial timescales, modeling anthropogenic climate change by absorbing approximately 30% of anthropogenic carbon (C_{ant}) emissions. Under global warming, coupled climate model simulations and theoretical arguments indicate that the capacity of the ocean to absorb C_{ant} will be reduced relative to what would be absorbed for an unperturbed physical state of the ocean, with this constituting a positive ocean carbon-climate feedback. Recent studies emphasize the importance of the North Atlantic and/or the Southern Ocean in sustaining such feedbacks. Here we use simulations with an Earth system model under a "business-as-usual" (historical/RCP8.5) concentration pathway to show that the coupling of heat and carbon in surface waters of the low-latitude shallow overturning circulation plays a first-order role in sustaining global ocean carbon-climate feedbacks. For an approximately 2°C average warming over 45°S-45°N, solubility perturbations alone would be expected to produce an 8% increase in surface ocean pCO_2. The fact that the increase in pCO_2 is only 2% by the end of the 21st century indicates that the response is more nuanced than just a solubility response. The amplitude of the surface warming prescribes a reduction of surface DIC concentrations of approximately 6 mmol/kg/°C, resulting in an 8% reduction in surface DIC concentrations relative to what one would expect in the absence of warming by the end of the 21st century. The reduction by 8% in surface DIC concentrations over 45°S-45°N constitutes a positive carbon-climate feedback. The consistency of this 8% reduction in average surface ocean DIC concentrations and the time-integrated reduction by 8% in spatially integrated CO_2 uptake by the ocean over the same latitude band indicates that it is the perturbations to the buffering capacity of seawater rather than perturbations to ocean ventilation rates that determine the amplitude of the carbon-climate feedbacks over 45°S-45°N. This stands in contrast to the drivers of carbon-climate feedbacks over the high latitudes, which tend to be driven by ocean circulation changes perturbing the natural carbon cycle.

Keywords: Carbon cycle, Earth system model, Carbon-climate feedback

