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Mesoscale Eddies and the Coastal Carbon Cycling in the California Upwelling System

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Eastern Boundary Upwelling Systems (EBUS) are sites of intense biogeochemical cycling and among the most productive marine ecosystems in the world, and thus one of the hotspots of the global carbon cycle. Upwelling brings carbon-enriched deep water to the surface, which is subsequently warmed, leading to recently upwelled waters having very high surface pCO_2. At the same time, the upwelled nutrients stimulate phytoplankton growth which in turn creates organic matter that can be exported laterally and vertically and also reduces surface ocean pCO_2. This interplay of upwelling and biological consumption together with offshore transport and strong mesoscale turbulence leads to a highly variable mosaic of the oceanic carbon system, which makes the quantification of the net carbon budget in EBUS challenging. Here we investigate the coastal ocean carbon budget for one of the four major EBUS, namely the California Upwelling System (CUS), with a particular focus on the role of mesoscale eddies and their contribution to the lateral, vertical and air-sea fluxes of carbon. To this end, we made an eddying and a non-eddying CUS simulation based on a 5km horizontal resolution version of the Regional Ocean Modeling System (ROMS), coupled to a nitrogen-based nutrient-phytoplankton-zooplankton-detritus (NPZD) model, including a formulation of the ocean carbon cycle. We first evaluate our model by comparing surface pCO_2 from the control simulation to a seasonal climatology based on the Lamont-Doherty Earth Observatory (LDEO) and the Monterey Bay Aquarium Research Institute (MBARI) databases. We then analyze the lateral, vertical and air-sea exchange fluxes of carbon in both CUS simulations. Overall, our results show a small net air-sea CO_2 flux in the central CUS compared to the net community production and the lateral and vertical export carbon fluxes. This suggests that the air-sea flux of CO_2 in the CUS represents only a small component of a very dynamic carbon cycle dominated by large lateral and vertical carbon exports. The comparison of the eddying and non-eddying CUS simulations reveals that eddies substantially reduce the CO_2 outgassing in the nearshore area due to eddy-driven leaking of DIC. Further offshore, the CO_2 uptake is slightly decreased as eddies tend to reduce productivity. Finally, we examine the impact of mesoscale eddies on the lateral transport of carbon in the central CUS and we document their contribution to the temporal variability of the surface pCO_2.