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Seasonal variabiltiy of the surface ocean carbon cycle: a global synthesis

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Here we present a synthesis of surface ocean pCO_2 and air-sea CO_2 flux seasonality for a modern climatology and their decadal trends between the 1980s and 2010s, as part of the REgional Carbon Cycle Assessment and Processes Phase 2 (RECCAP2) project. Working with both surface ocean pCO_2-observation products (pCO_2 products) and global ocean biogeochemistry models (GOBMs), our main findings are: (i) Over biome scales, both pCO_2 products and GOBMs confirm increases in the seasonal amplitude of pCO_2 and integrated CO_2 fluxes between 1985-1989 and 2014-2018. (ii) For the 2014-2018 climatology, GOBMs exhibit a systematic bias with too-weak biologically-driven seasonal variability in surface dissolved inorganic carbon (DIC), such that the pCO_2 seasonal cycle in subtropical biomes is spuriously large and both the amplitude and phase of seasonal pCO_2 variations diverge from those in the pCO_2 products in subpolar and circumpolar biomes. (iii) Decadal increases in pCO_2 seasonal cycle amplitude in subtropical biomes are attributed to being largely driven by reducing CO_2 buffering capacity and increasing sensitivity to temperature due to increasing anthropogenic carbon (C_{ant}) content insurface waters for both the pCO_2 products and GOBMs. In subpolar and circumpolar biomes, the seasonality change for GOBMs is dominated by C_{ant} invasion, whereas for pCO_2 products modulations of the climate state are equally important. (iv) Considered together, the subtropical biomes exhibit decadal increases in CO_2 flux seasonality that are larger during winter than summer, consistent with the mechanism described by Fassbender et al. (2022) and potentially promoting a negative feedback in the climate system by increasing the CO_2 uptake in winter, by virtue of surface winds being stronger in winter than summer. (v) Large ensemble simulations with ESMs were applied to confirm the validity of biomes as aggregation domains for identifying forced signals. Despite compromises to DIC seasonality impacting pCO_2 seasonality, the chosen biome-scale is appropriate for representing the decadal rate of increase of pCO_2 seasonality for both GOBMs and pCO_2 products.

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