Modeling \( p\text{CO}_2 \) variability in the Gulf of Mexico

**Challenge:** Oceans act as receivers of large carbon loading from terrestrial run-off and as vast carbon reservoirs via the ocean “carbon pump.” Thus, a better understanding of the oceans’ role in regulating the global carbon cycle is crucial. Our objectives were to 1) produce model simulations of \( \text{CO}_2 \) flux at the air–sea interface in the Gulf of Mexico - current estimates are based largely on observational analyses and subject to large uncertainty; and 2) constrain the relationship between \( \text{CO}_2 \) fluxes, river plume dynamics, and dominant oceanic processes.

**Methods:** A three-dimensional coupled physical–biogeochemical model was used to simulate and examine temporal and spatial variability of sea surface partial pressure of \( \text{CO}_2 \) \((p\text{CO}_2)\) in the Gulf of Mexico. The model was driven by realistic atmospheric forcing and observed freshwater and terrestrial nutrient and carbon input from major rivers to produce a multi-year model hindcast (2005–2010). NASA and other satellite data (MODIS, AVISO) were used in the tuning and validation of the model (see also Xue et al., 2013, *Biogeosciences*, 10, 7219–7234).

**Key Findings:** Model results revealed seasonality in surface \( p\text{CO}_2 \) and showed that, despite spatial and temporal variability, the Gulf of Mexico was a net \( \text{CO}_2 \) sink, with a flux of \( \pm 0.84 \times 10^{12} \) mol C yr\(^{-1}\). This is comparable to estimated inorganic carbon export through the Loop Current.

*Model simulated time-series of spatially averaged \( p\text{CO}_2 \) in the Gulf of Mexico, overlaid with in situ observations (in black). Control run (in blue) included all processes, and no-biology run (in magenta) included only physical and chemical effects.*

**Significance:** This is the first comprehensive physical-biogeochemical coupled model simulation of air-sea flux of \( \text{CO}_2 \) in the Gulf of Mexico. The findings highlight the role of biological uptake as an important driver for the \( \text{CO}_2 \) sink and provide critical information for North American and global carbon budgets.

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