Spatial and Temporal Variability of $p$CO$_2$, Carbon Fluxes, and Saturation State on the West Florida Shelf


Objectives:

- The Gulf of Mexico (GOM) was identified as the single largest source of uncertainty in the North American carbon budget by the first State of the Carbon Cycle Report.
- While a number of observations have been made to address this uncertainty, large areas remain under sampled and poorly characterized in terms of air-sea exchange of carbon dioxide (CO$_2$), associated carbon fluxes and their variability, and controlling mechanisms.
- The West Florida Shelf (WFS)—a low bathymetric gradient calcium carbonate platform stretching between the Florida Panhandle to the Florida keys—is a source of uncertainty for determining the GOM carbon budget and how surface waters are being affected by increasing atmospheric carbon dioxide (CO$_2$) levels.
- In order to address some of this uncertainty, approximately 135,000 pCO$_2$ values collected on 97 research cruises between 1996 and 2016 were analyzed to determine the spatial and temporal distribution of pCO$_2$ over the WFS and defined subregions.
- The authors quantified the air-sea CO$_2$ fluxes and identified physical and biogeochemical processes that can control the fluxes.
- Comparisons of pCO$_2$ values and fluxes between different subregions and by season were investigated.
- Aragonite saturation state data were calculated to provide a synoptic evaluation of regional subregional spatial and seasonal trends.

New Science:

- WFS surface water shows a change from carbon sink to source from 1996 to 2016.
- The WFS emits 9.23 Tg C/year, with the south nearshore emitting the most at 9.01 Tg C/year and the north acting as a sink of -1.96 Tg C/year
- Offshore surface waters absorb CO$_2$, whereas nearshore surface waters emit CO$_2$ to the atmosphere.
- Importantly, pCO$_2$ of the nearshore seawater has been increasing at a rate approximately 2.5 times faster than atmospheric pCO$_2$ over the past 20 years – indicating that factors in addition to the atmosphere CO2 are influencing increases in nearshore seawater.
- Additionally, WFS aragonite saturation state, often used to monitor ocean acidification conditions, shows seasonal and geographic trends, with year-round supersaturated values ranging from 2 to 5.

Significance:

- Previous synthesis efforts suggest that the Gulf of Mexico air-sea CO$_2$ flux may dominate the net flux of the entire North American margin because of the GOM’s large size and strong signals, indicating the critical need constrain the fluxes in the GOM.
- The study provides data synthesis for the WFS—a large, important, and relatively unstudied portion of the GOM—that shows significant differences in surface patterns of pCO$_2$, CO$_2$ flux, and carbonate saturation state in the context of geographic, seasonal, and interannual variabilities.
• The data demonstrate that anthropogenic processes are superimposed on natural cycles of CO₂, which have been shifting the ocean chemistry over time.
• The subregional and seasonal variations in surface water pCO₂, CO₂ flux, and carbonate saturation state distributions have provided the basis to identify processes linked to measurable latitudinal, inner to outer shelf, and seasonal changes in coastal and ocean carbon chemistry (pCO₂, CO₂ sea-air flux) and to derive carbonate saturation state maps of Florida shelf waters.
• Additional data are needed to provide fundamental understanding of the coastal carbon cycle and to reveal the processes behind the observations that show that shelf water pCO₂ has increased at a rate faster than the atmospheric rate in the past 20 years.
• Future cruises that target data gaps and uncertainties for pCO₂ and carbonate saturation state are needed for the WFS, where significant declines in carbonate-dominated ecosystems, fishery habitats, and calcifying organisms are predicted for this century.

Figure 2: pCO₂ values (μatm) for the West Florida Shelf during the (a) winter, (b) spring, (c) summer, and (d) fall seasons.
Figure 3: CO₂ flux values (mol m⁻² yr⁻¹) for the West Florida Shelf during the (a) winter, (b) spring, (c) summer, and (d) fall seasons.