PhD Title: Carbon Fluxes and Fates in the Flatwoods of North Florida

Inland waters—streams, rivers, lakes, ponds, and wetlands—are crucial to global carbon cycling, serving as the drainage network for the terrestrial biosphere (Cole et al., 2007; Regnier et al., 2013). Despite covering only 1% of Earth’s surface (Battin et al., 2009), they play a disproportionately active role in the carbon cycle (Battin et al., 2009; Cole et al., 2007). Of the 3.4 Pg-C/year delivered to streams from the terrestrial landscape (Drake et al., 2018; Raymond et al., 2016), only ~30% (0.95 Pg-C/year) returns to the oceans (Aufdenkampe et al., 2011; Kempe, n.d.; Regnier et al., 2022). The other 80% is buried in sediment, mineralized, or degassed to the atmosphere (Battin et al., 2009; Drake et al., 2018; Marx et al., 2017; Regnier et al., 2022). The global carbon cycle and the hydrologic cycle are intrinsically coupled (Abril & Borges, 2019; Battin et al., 2023; Zarnetske et al., 2018); the carbon discharged to oceans is the byproduct aquatic biogeochemical transformations and losses as water transitions from the terrestrial uplands to coastal marshes (Battin et al., 2009; Cole et al., 2007).

Streams are “active pipes” that “plumb” the terrestrial landscape by transporting, storing, and transforming terrestrial litterfall and debris (Cole et al., 2007). Stream CO2 emissions are equal to terrestrial net ecosystem productivity (Drake et al., 2018), yet less than half of terrestrial inputs are delivered to oceans (Aufdenkampe et al., 2011; Kempe, n.d.; Raymond et al., 2013; Regnier et al., 2022). The sum of stream CO2 emissions and ocean exports is greater than terrestrial input estimates. Of the aforementioned 3.4 Pg-C/year exported from the terrestrial landscapes, (hypothesized) 0.6 Pg-C/year is buried in sediment (Battin et al., 2009), 0.3 Pg-C/year is mineralized (Regnier et al., 2013), and 0.95 Pg-C/year is transported to oceans (Regnier et al., 2013), leaving a significant 1.5 Pg-C/year gap (Kirk & Cohen, 2023). This imbalance presents major uncertainties with the global carbon budget, especially when parsing stream carbon sources beyond the terrestrial biosphere.

Wetlands, in contrast, are functionally unique inland waters, serving as global carbon sinks rather than carbon sources (Abril & Borges, 2019). Wetland emergent vegetation both sequesters atmospheric CO2 and produces organic matter (OM) while hydric soils bury carbon for weeks to centuries (Mitsch et al., 2013). Although wetlands contribute to GHGs, wetland productivity and carbon burial offset emissions (Mitsch et al., 2013). Due to the accumulation of OM and saturated conditions, wetlands are global hotspots that transform carbon before exporting it downstream (Evenson et al., 2018; Marton et al., 2015), in addition to serving as significant carbon storage sinks.

Streams and wetlands are intricately linked: wetlands often serve as stream headwaters, streams facilitate longitudinal export between wetlands, and the surficial aquifer (SAq) supports lateral connectivity (Abril & Borges, 2019; Evenson et al., 2018; McLaughlin et al., 2014). Streams, wetlands, and the surficial aquifer (SAq) together form the “wetlandscape,” influencing the biogeochemical fingerprint of a watershed and affecting the degree of carbon storage and export (Evenson et al., 2018; McLaughlin et al., 2014; Zarnetske et al., 2018). Although current models confirm the SAq facilitates watershed connectivity, and inundation supports carbon storage (Evenson et al., 2018; McLaughlin et al., 2014; Zarnetske et al., 2018), few studies have systematically explored how the bidirectional exchange of carbon between inland waters- specifically wetland, riparian, and stream boundaries- shapes the global carbon cycle. Current estimates of carbon mass transfer separate the aquatic from the terrestrial. Wetlands, serving as intermediaries between terrestrial and aquatic systems, are challenging to distinguish remotely and are often excluded from carbon budgets (Cole et al., 2007; Drake et al., 2018), inadvertently omitting a significant source of stream carbon. Similarly, small headwater streams are often located in canopy-covered, distant areas, making them difficult to delineate both remotely and in the field (Drake et al., 2018; Marx et al., 2017). Yet, small streams, 3 orders and lower, drain 75% of watersheds (Marx et al., 2017). Difficulties associated with delineating the extent of inland waters, and the unknowns related to inland water processing, create keystone discrepancies. The “stream CO2 gap”, broadly assumed to be groundwater seepage add (Hotchkiss et al., 2015; Siemens & Villarreal, 2003), is massively provisional without first mapping the wetlandscape and its temporal and spatial influences (Kirk & Cohen, 2023).

The necessity for carbon budgeting and transfer models is to identify and quantify the significant players and key exchanges within the global carbon cycle(Cole et al., 2007). Improving our understanding of carbon sources and sinks, and how aquatic pathways link these elements, can enhance carbon flux estimates, provide insights for climate change mitigation, improve CO2 management, and aid in predicting feedback loops(Battin et al., 2023; Cole et al., 2007). Resolving discrepancies in the global carbon budget is challenging, but detailed observational studies across diverse landscapes are crucial for addressing these ambiguities (Battin et al., 2023). For my PhD dissertation, I will observe a low relief “wetlandscape” of North Florida. Through the of high-frequency datasets and water sampling, I aim to observe the temporal and spatial dynamics of stream carbon, investigate stream carbon sources, and explore how landscape hydrology influences stream carbon.

* *Chapter 1*: Observe the temporal and spatial dynamics of carbon within low-order, flatwood streams, aiming to differentiate between reactor and chimney pathways.
* *Chapter 2*: investigate the importance of the river corridor (RC) on stream carbon by estimating RC carbon fluxes to streams.
* *Chapter 3*: Holistically map flatwood stream carbon sources and fluxes, allowing me to draw detailed inferences on the “wetlandscape.”

My intention for this research is to emphasize the importance of aquatic-terrestrial ecotones while displaying the influence of landscape hydrology on regional, and in turn, global carbon cycling. Practically, this work will inform management decisions on how to optimize carbon storage on the watershed-level scale, ideally aiding in carbon-credit programs.