Quantifying Blue Carbon Stocks in Vegetation and Soils of Mangroves, Salt Marshes, and Salt Barrens in Tampa Bay, Florida

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Florida Mangroves and Coastal Habitats Integrated Mapping and Monitoring Joint Workshop

Saint Petersburg, Florida, USA

Nanos Gigantum Humeris Insidentes
(standing on the shoulders of giants)

FWC/FWRI Volunteers: Julie Christian, Dr. Kathy Guindon; Rebecca Lucas; Danielle Pavlik, Juley Polley, Regino Rodriguez, Dr. Randy Runnels; Jon Sneed; Alexandra Wilcox

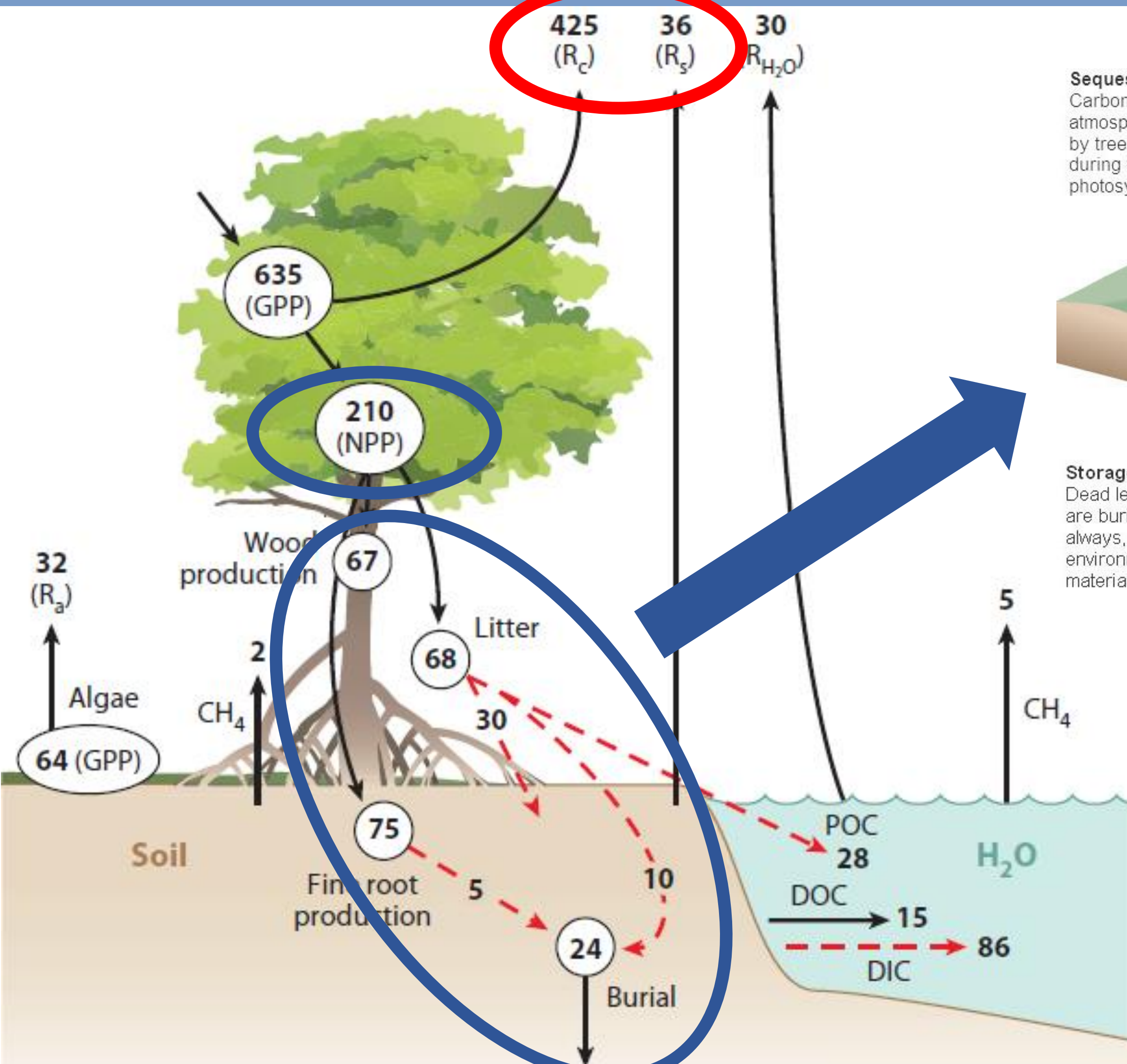
USGS: Dr. Kevin Kroeger, Christopher Moore; Nathan Smiley; Dr. Legna Torres-Garcia; Dr. Kimberly Yates

ESA: Dr. David Tomasko

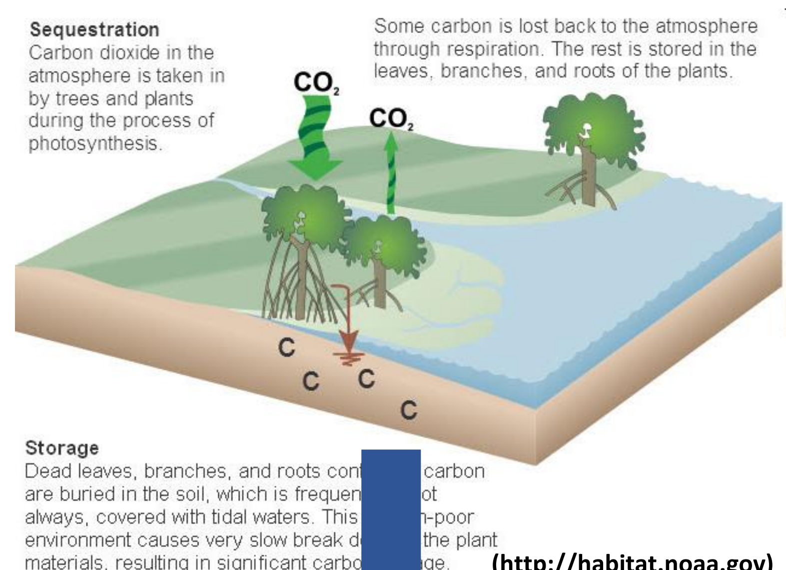
USFSP: Megan Burford; Jessica Rhyne; Dr. Donny Smoak

Funding, Guidance, Logistics, Partnerships, etc.

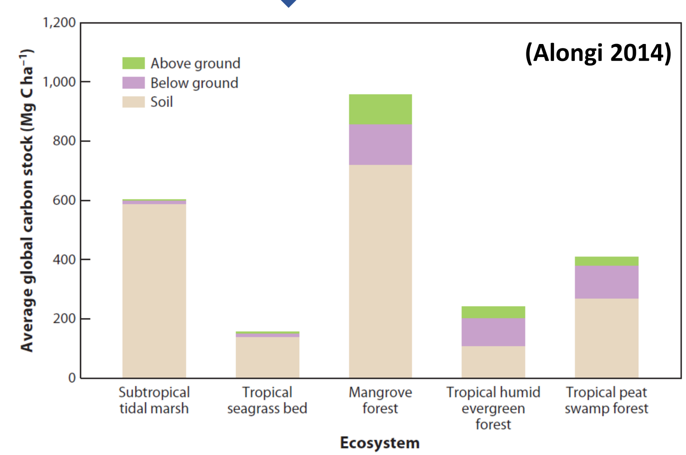
Carbon Cycling in Coastal Wetlands & Estuaries



(Alongi 2014)



(http://habitat.noaa.gov)



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Newly Approved Protocol for Wetland Carbon Finance 11/24/15

Coastal Wetland Restoration Can Now Earn Carbon Credits Globally

A landmark methodology has been approved for the restoration of coastal wetlands everywhere to generate finance on the carbon market.

WASHINGTON, D.C. – A new methodology to encourage coastal restoration across the globe has been approved by the Verified Carbon Standard (VCS). The *Methodology for Tidal Wetland and Seagrass Restoration* (VM0033) is the first globally applicable greenhouse gas accounting methodology for coastal wetland restoration, and will allow salt marsh, seagrass, mangrove, and other tidal wetland restoration projects to earn carbon credits.

Coastal wetlands (salt marsh, seagrass, mangroves, forested and other tidal wetlands) are some of the most productive

https://www.estuaries.org/restoration-methodology-approval

Approach:

19 total sites in Tampa Bay

- **2 Coastal Acidification**

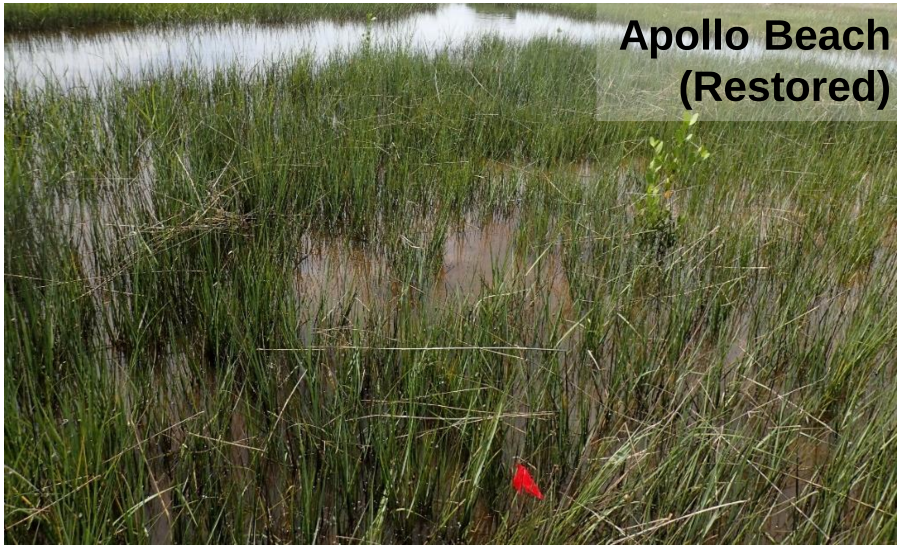
- **17 Blue Carbon**
  - **3 “Natural” salt marshes**
  - **3 “Natural” mangroves**
  - **3 Restored salt marshes**
  - **3 Restored mangroves**
  - **5 Salt barrens**

  - **Above- and below-Ground C stocks; Burial rate at 6 sites**

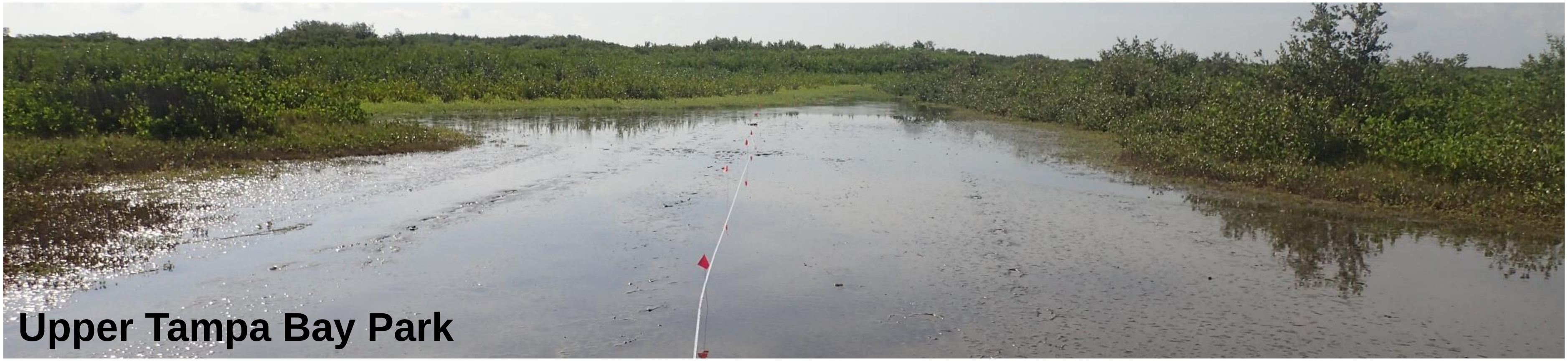
Tampa Bay Study Sites & Characteristics

Site Name	Habitat Type	Habitat State	Restoration Type	Year Completed	County	Bay Segment	Starting latitude	Starting longitude	Date Sampled
Haley House	Mangrove	Natural			Manatee	Lower Tampa Bay	27° 34.853' N	82° 33.820' W	8/7/2015
Weedon Island	Mangrove	Natural			Pinellas	Old Tampa Bay	27° 50.780' N	82° 36.092' W	7/10/2015
Fort De Soto	Mangrove	Natural			Pinellas	Lower Tampa Bay	27° 37.625' N	82° 42.909' W	10/2/2015
Bishop Harbor	Mangrove	Restored	Hydrologic restoration	2008	Manatee	Lower Tampa Bay	27° 35.955' N	82° 33.108' W	10/23/2015
E.G. Simmons Park	Mangrove	Restored	New wetland	1990	Hillsborough	Middle Tampa Bay	27° 44.533' N	82° 28.063' W	8/28/2015
Clam Bayou	Mangrove	Restored	Hydrologic restoration	2012	Pinellas	Boca Ciega Bay	27° 44.583' N	82°41.233' W	10/9/2015
Upper Tampa Bay Park	Salt Marsh	Natural			Hillsborough	Old Tampa Bay	28° 00.417' N	82° 37.995' W	7/24/2015
Little Manatee River	Salt Marsh	Natural			Hillsborough	Middle Tampa Bay	27° 40.738' N	82° 26.183' W	9/18/2015
Rocky Creek	Salt Marsh	Natural			Hillsborough	Old Tampa Bay	27° 59.658' N	82° 35.156' W	9/11/2015
Stock Enhancement Research Facility (SERF)	Salt Marsh	Restored	New wetland	1997	Manatee	Middle Tampa Bay	27° 38.720' N	82° 32.862' W	8/20/2015
Cockroach Bay	Salt Marsh	Restored	New wetland	1998	Hillsborough	Middle Tampa Bay	27° 41.581' N	82° 30.586' W	8/6/2015
Apollo Beach	Salt Marsh	Restored	New wetland	2013	Hillsborough	Hillsborough Bay	27° 46.804' N	82° 24.277' W	8/14/2015
Terra Ceia	Salt Barren	Natural			Manatee	Lower Tampa Bay	27° 34.893' N	82° 35.788' W	8/11/2015
TECO Power Plant	Salt Barren	Natural			Hillsborough	Hillsborough Bay	27° 47.145' N	82° 24.287' W	8/17/2015
Upper Tampa Bay Park	Salt Barren	Natural			Hillsborough	Old Tampa Bay	28° 00.475' N	82° 37.904' W	9/2/2015
Shell Point	Salt Barren	Natural			Hillsborough	Middle Tampa Bay	27° 43.311' N	82° 28.268' W	10/30/2015
Weedon Island	Salt Barren	Natural			Pinellas	Old Tampa Bay	27° 50.680' N	82° 36.627' W	11/6/2015

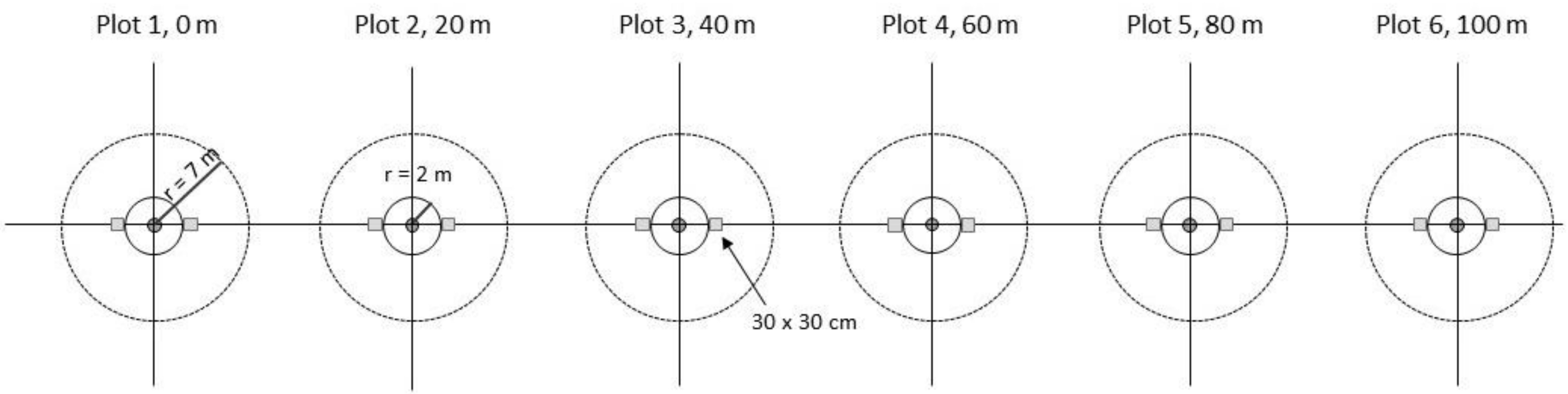
Blurred Lines:
Restored vs. "Natural" Ecosystems in Tampa Bay



Salt Barrens Do It Better



We Only Counted the Blue Carbon:
Transect and Study Design



Aboveground biomass sampled in 7 m radius plot:

- All live trees taller than 1.3 m
- Standing dead trees

Aboveground biomass sampled in 2 m radius plot:

- All seedlings (mangroves < 30 cm height)
- All scrubs (mangroves 30-130 cm height)

Aboveground biomass measured in 30 x 30 cm plot:

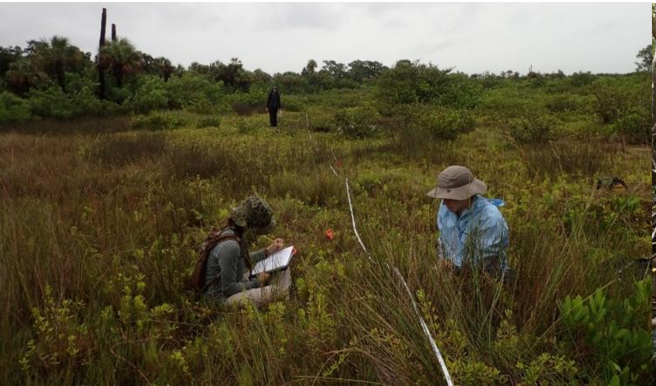
- Salt marsh vegetation

Fallen dead wood sampled along perpendicular transects:

- Large limbs (>7.5 cm diameter) from 2-12 m
- Medium branches (2.5-7.5 cm diameter) from 2-7 m
- Small branches (0.6-2.5 cm diameter) from 7-10 m

Belowground carbon:

- Sediment core collected in center of each plot



No Need To Russian To Anything:

Estimating Below-Ground Carbon Stocks

Find the Cost of Carbon Buried in the Ground:

Belowground Carbon Determination

Loss-on-ignition (LOI) = staged combustion (550° C and 950° C) process to determine sedimentary organic carbon content:

$$\%LOI = ((m_{dry} - m_{550})/m_{dry}) * 100$$

Salt marsh LOI equation from Craft et al. (1991):

$$\%C_{org} = 0.4 * \%LOI + 0.0025 * (\%LOI)^2$$

Mangrove LOI equation from Allen (1974) and Chmura et al. (2003):

$$\%C_{org} = \frac{\%LOI}{1.724}$$

Math Makes Everything Better:
Aboveground Biomass Calculations

Live Mangroves (>130 cm)

Black Mangroves (*Avicennia germinans*): $b_{AT} = 0.403 * d_{130}^{1.934}$

White Mangroves (*Laguncularia racemosa*): $b_{AT} = 0.362 * d_{130}^{1.93}$

Red Mangroves (*Rhizophora mangle*): $b_{AT} = 0.722 * d_{130}^{1.731}$

Mangrove Scrubs (<130 cm)

Black Mangrove Scrubs (*Avicennia germinans*):
$\ln(b_{AS}) = 2.134 + (0.895 * \ln(d_{30}^{2})) + (0.184 * \ln(CRWNV))$

White Mangrove Scrubs (*Laguncularia racemosa*):
$\ln(b_{AS}) = 1.095 + (0.659 * \ln(d_{30}^{2})) + (0.304 * \ln(CRWNV))$

Red Mangrove Scrubs (*Rhizophora mangle*):
$\ln(b_{AS}) = 2.528 + (1.129 * \ln(d_{30}^{2})) + (0.156 * \ln(CRWNV))$

(Smith & Whelan 2006; Kauffmann & Donato 2012; Howard et al. 2014)

Mangroves Aren't Everything:
Non-Mangrove Allometry

Species	Common name	Allometric equation	Source
Dalbergia ecastaphyllum	coin vine	$b = (d_{130})^{2.657} * e^{-0.968} * ln(d_{130})$	Schnitzer 2006, Howard et al. 2014 (general liana equation)
Lyonia lucida	fetterbush	$ln(b * 1000) = -1.186 + 1.863 * ln(d_b/10)$	Schafer 2010
Baccharis halimifolia, B. angustifolia	groundsel tree, saltwater false willow	$b = 0.2806 * d_b - 0.3843$	Appolone 2000 (B. halmifolia equation)
Iva frutescens	Jesuit's bark	$b = 0.686 * ht_m$	Appolone 2000
Schinus terebinthifolius	Brazilian pepper	$b = 0.16155 * (d_{130})^{2.310647}$	Aguaron and McPherson 2012 (general broadleaf equation)
Conocarpus erectus	buttonwood	$b = 10097.06 * (d_{130}/100)^{2.33}$	Abohassan et al. 2010
Acrostichum danaeifolium	leather fern	$b = (-0.4993 + 0.1086 * ht_{cm}) * 6.75/1000$ $b = (-85.950 + 0.7593 * ht_{cm}) * 6.75/1000$	Sharpe 2010*

We Even Learned Something:
Tampa Bay Salt Marsh Plant Allometrics

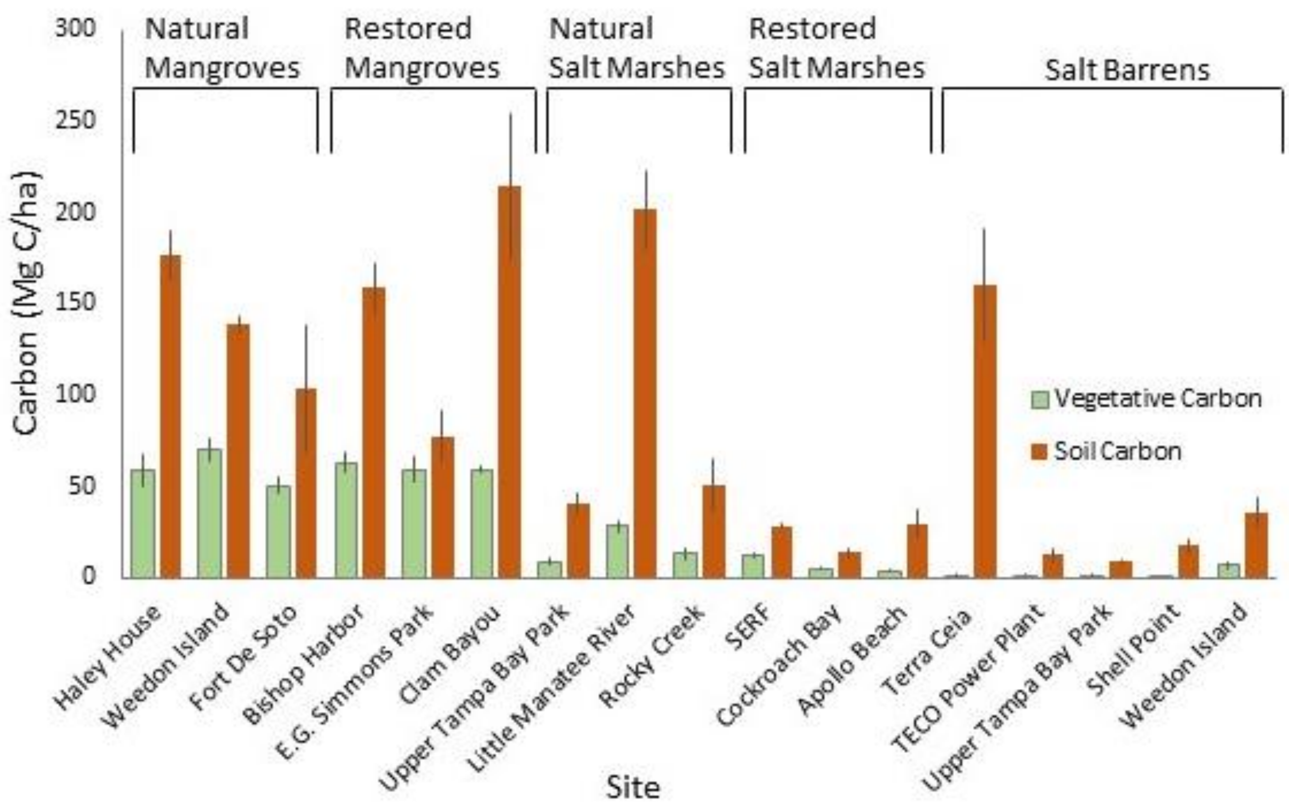
Species	Allometric equation*	R^2	n	Height range (cm)
Bacopa monnieri[1]	b = 0.0036ht - 0.0093	0.778	50	5.5-23.7
Batis maritima[2]	ln(b) = 1.7247ln(ht) - 5.3885	0.730	65	3.0-50.3
Blutaparon vermiculare[1]	b = 0.0121ht + 0.0464	0.723	50	4.4-48.9
Borrichia frutescens[1]	ln(b) = 1.9697ln(ht) - 6.8766	0.762	52	14.4-28.7
Fimbristylis castanea[1]	ln(b) = 2.0161ln(ht) - 9.5912	0.659	48	18.1-80.0
Fimbristylis cymosa[3]	ln(b) = 1.5244ln(ht) - 4.8064	0.463	56	14.1-37.2
Juncus roemerianus[1]	b = 0.0230ht - 0.6384	0.906	63	8.6-182.0
Limonium carolinianum[4]	ln(b) = 1.0071ln(ht) - 3.9246	0.755	59	6.2-83.4
Monanthochloe littoralis[1]	ln(b) = 1.4028ln(ht) - 5.4823	0.705	75	4.4-14.0
Paspalum distichum[1]	ln(b) = 1.9210ln(ht) - 6.6365	0.834	51	12.5-63.8
Rayjacksonia phyllocephala[1]	b = 0.1107ht - 0.9224	0.683	50	10.0-95.0
Salicornia virginica[2]	ln(b) = 1.5464ln(ht) - 6.3900	0.935	59	4.9-19.5
Schizachyrium scoparium[1]	b = 0.0031ht - 0.0358	0.918	48	11.8-98.0
Sesuvium portulacastrum[5]	ln(b) = 1.1760ln(ht) - 4.1677	0.779	53	5.9-94.2
Solidago sempervirens[1]	ln(b) = 1.2920ln(ht) - 4.9600	0.750	50	15.6-120.0
Spartina alterniflora[1]	ln(b) = 1.9492ln(ht) - 7.6267	0.767	53	17.0-82.0
Spartina patens[1]	ln(b) = 2.1380ln(ht) - 8.8881	0.679	53	15.5-51.2
Sporobolus virginicus[1]	ln(b) = 1.2473ln(ht) - 6.4324	0.553	50	4.8-32.3

[1] Total height of individual stems measured, including flower if present
[2] Total height, each vertical stem measured individually from ground stem
[3] Total height of whole plant, excluding flower if present
[4] Total height of whole plant, including flower if present
[5] Length of each significant branch measured individually

(Radabaugh et al. 2016)

How Much Blue Carbon Is There?

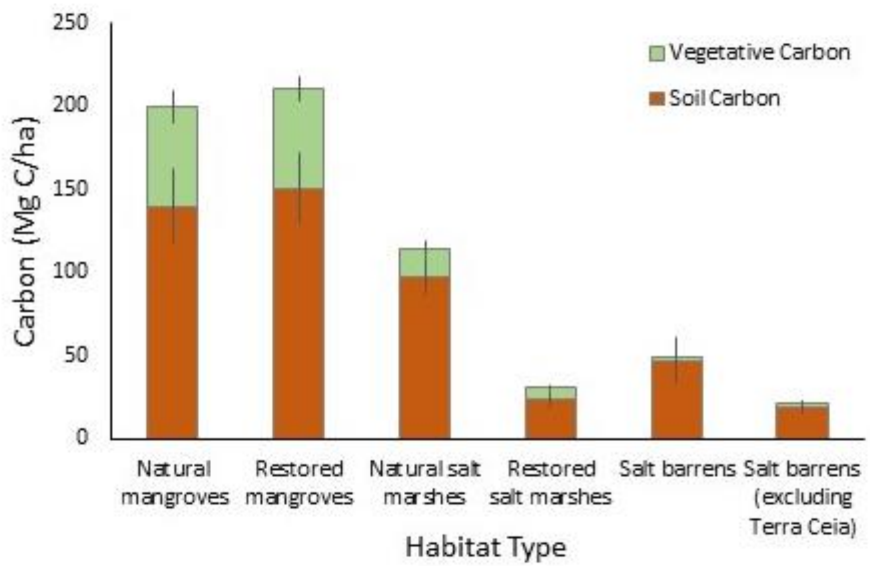
Above- and Below-Ground Carbon Stocks by Site



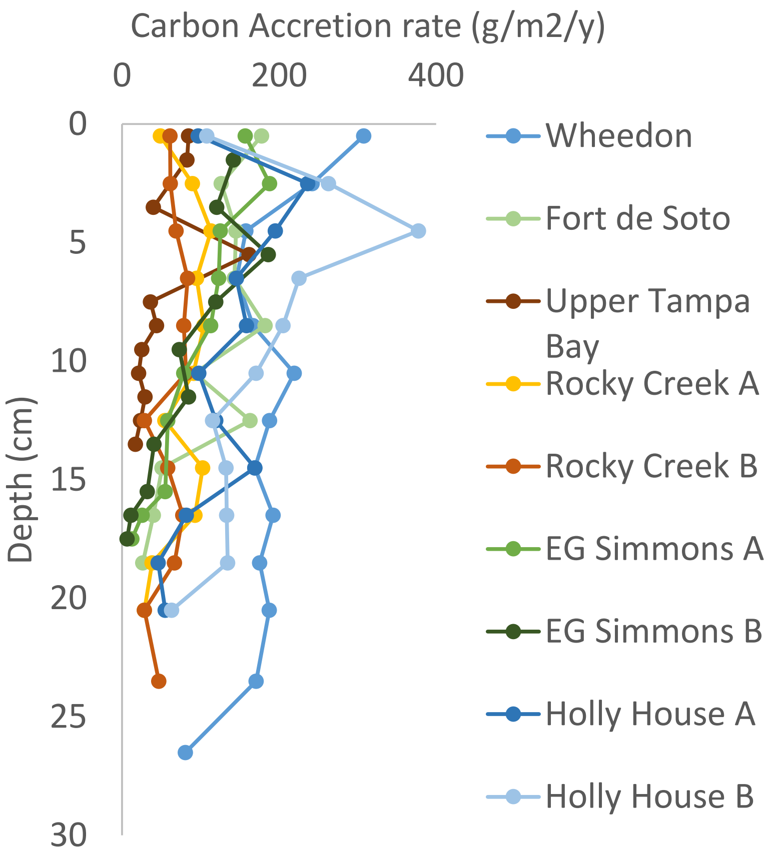
How Much Blue Carbon Is There?

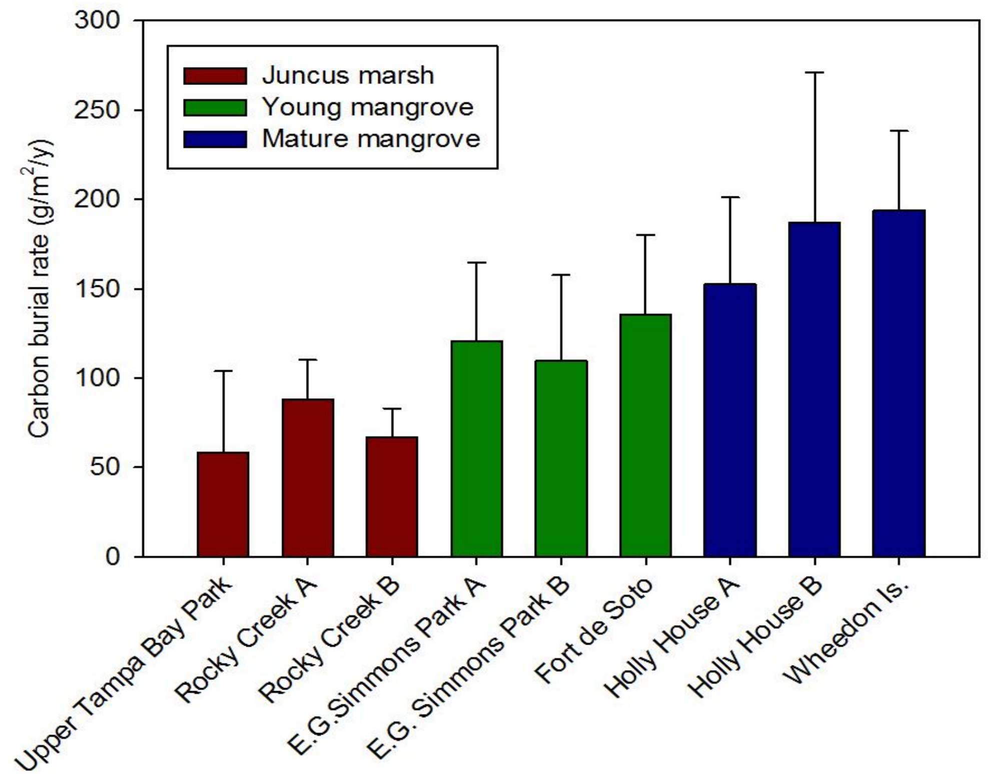
Carbon Stocks by Habitat Type

Site Name	Soil Carbon (MgC/ha)	Core depth (cm)	Vegetative Carbon (MgC/ha)	Total Carbon (MgC/ha)
Natural mangroves	139.5±22.3	14-90	59.8±9.3	199.4±25.5
Restored mangroves	150.3±21.2	13-90	60.5±7.1	210.8±18.9
Natural salt marshes	97.6±11.3	17-90	16.6±4.3	114.2±11.9
Restored salt marshes	24.0±4.7	4-46	7.0±1.4	30.9±5.0
Salt barrens	47.0±13.5	4-85	2.1±1.1	49.1±13.4
Salt barrens, excluding Terra Ceia	18.6±3.7	4-50	2.3±1.2	21.0±3.6
All mangroves	144.9±20.2	13-90	60.1±2.7	205.1±20.9
All salt marshes	60.8±28.6	4-90	11.8±3.6	72.6±32.0



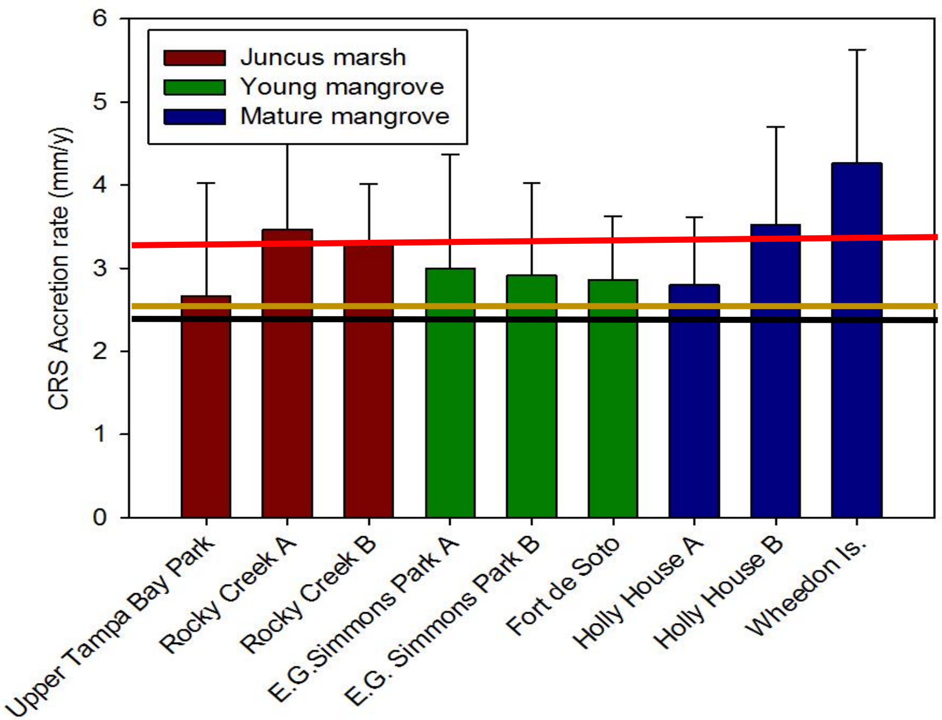
Digging Deeper in the Dirt:
Carbon Burial Rates in Tampa Bay

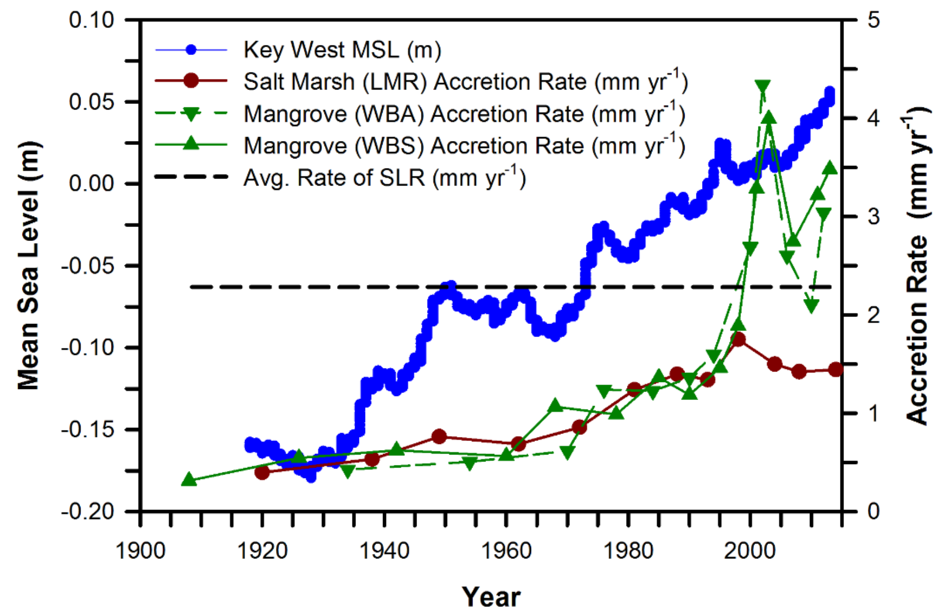




Carbon burial rates are higher in shallower sediments and mature mangroves have the highest carbon burial rates.

Can They Keep Up?
Sediment Accretion and Sea Level Relationships





Tampa Bay sea-level trends:

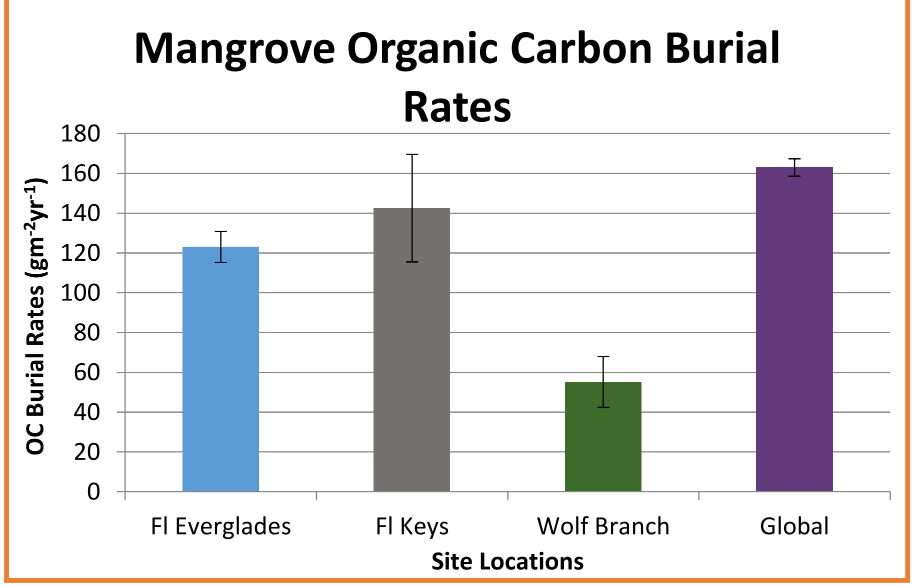
Clearwater 1973 – present
3.37 ± 0.62 mm y^{-1}

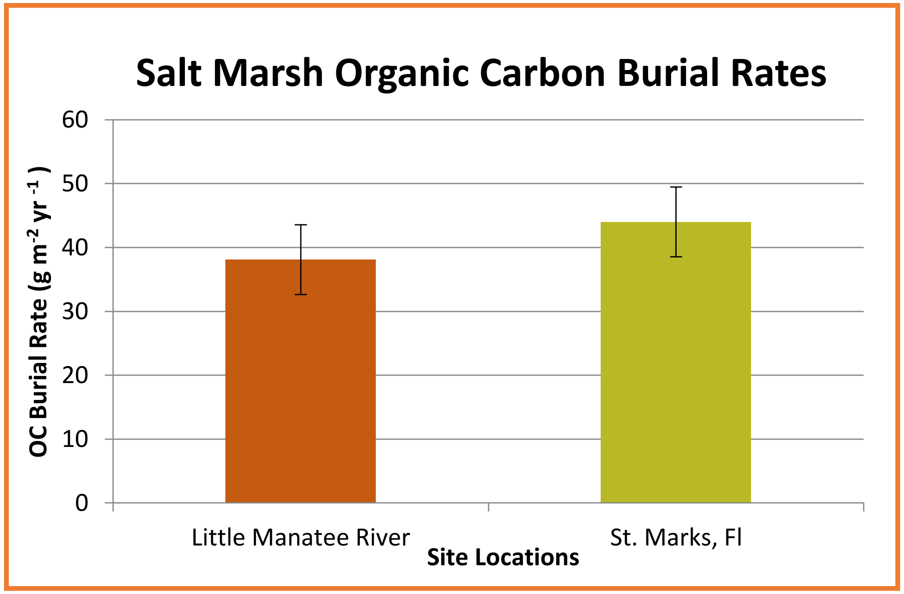
St. Petersburg 1946 – present
2.66 ± 0.25 mm y^{-1}

Key West
1913 – present
2.36 ± 0.54 mm y^{-1}

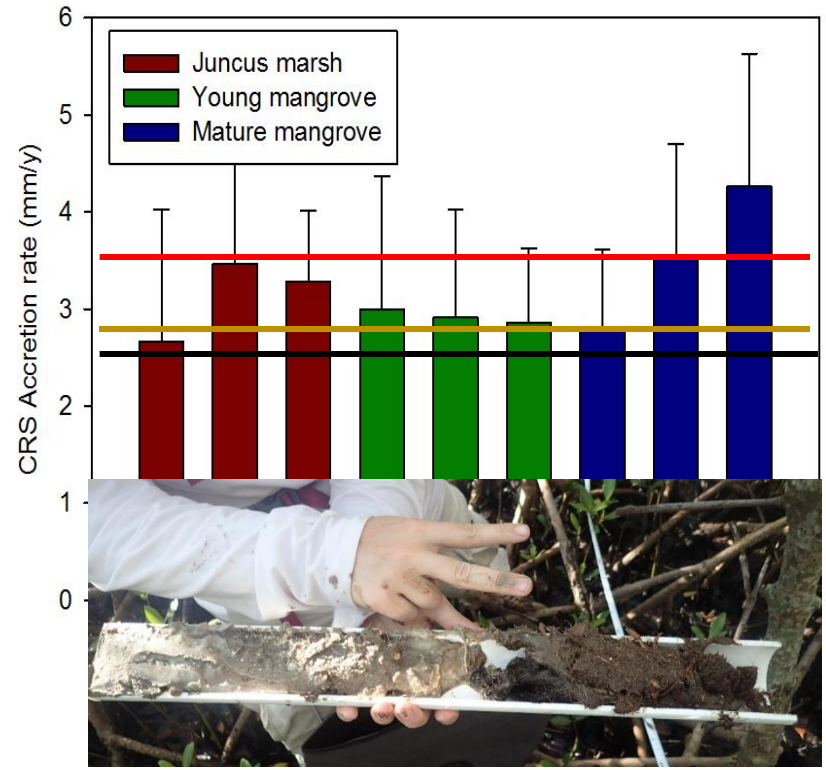
Nothing Compares 2 U:
Tampa Bay Blue Carbon vs. the World

Habitat	Location	Citation	Soil Carbon (MgC/ha)	Core Depth (cm)	Vegetative Carbon (MgC/ha)	Total Carbon (MgC/ha)	Total Carbon Range (MgC/ha)
Mangrove	Global	IPCC 2013	386 (55-1376)	100			
Mangrove	Tampa Bay, FL	This study	145	13-90	60	205	137-273
Mangrove	Merritt Island, FL	Doughty et al. 2015	57	30	66	122	
Salt marsh	Global	IPCC 2013	255 (16-623)	100			
Salt marsh	Tampa Bay, FL	This study	61	4-90	12	73	19-235
Salt marsh	Merritt Island, FL	Doughty et al. 2015	49	30	11	61	





Some Other Stuff We Think Might Be True:
Lessons Learned and Future Work



How Good Are Our Estimates?

- Spatial variability is important
- Methods are important

TB Blue Carbon Habitats are Critical Coastal Habitats

- Lower C production and burial
- Climate and sea-level rise tradeoffs?

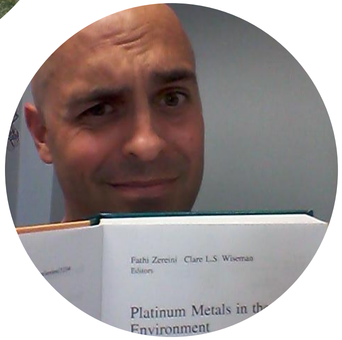
Where Do We Go from Here?
Measuring Blue Carbon from "Space"

USDA

ORGANIC CARBON BIOMASS, BURIAL, AND BIOGEOCHEMISTRY IN BLUE CARBON ECOSYSTEMS ALONG THE SOUTH FLORIDA COAST: CLIMATE CHANGE AND ANTHROPOGENIC INFLUENCES

SHORT TITLE: Marsh to Mangrove Habitat Switching: Increasing the Coastal Carbon Sink

Donny Smoak (USFSP)



Brad Rosenheim (USF CMS)

Ryan Moyer (FWC/FWRI)

Kara Radabaugh (FWC/FWRI)

Lisa Chambers (UCF)

David Lagomasino (NASA)

Meet the New Boss:
Understanding FL Blue Carbon in Space and Time

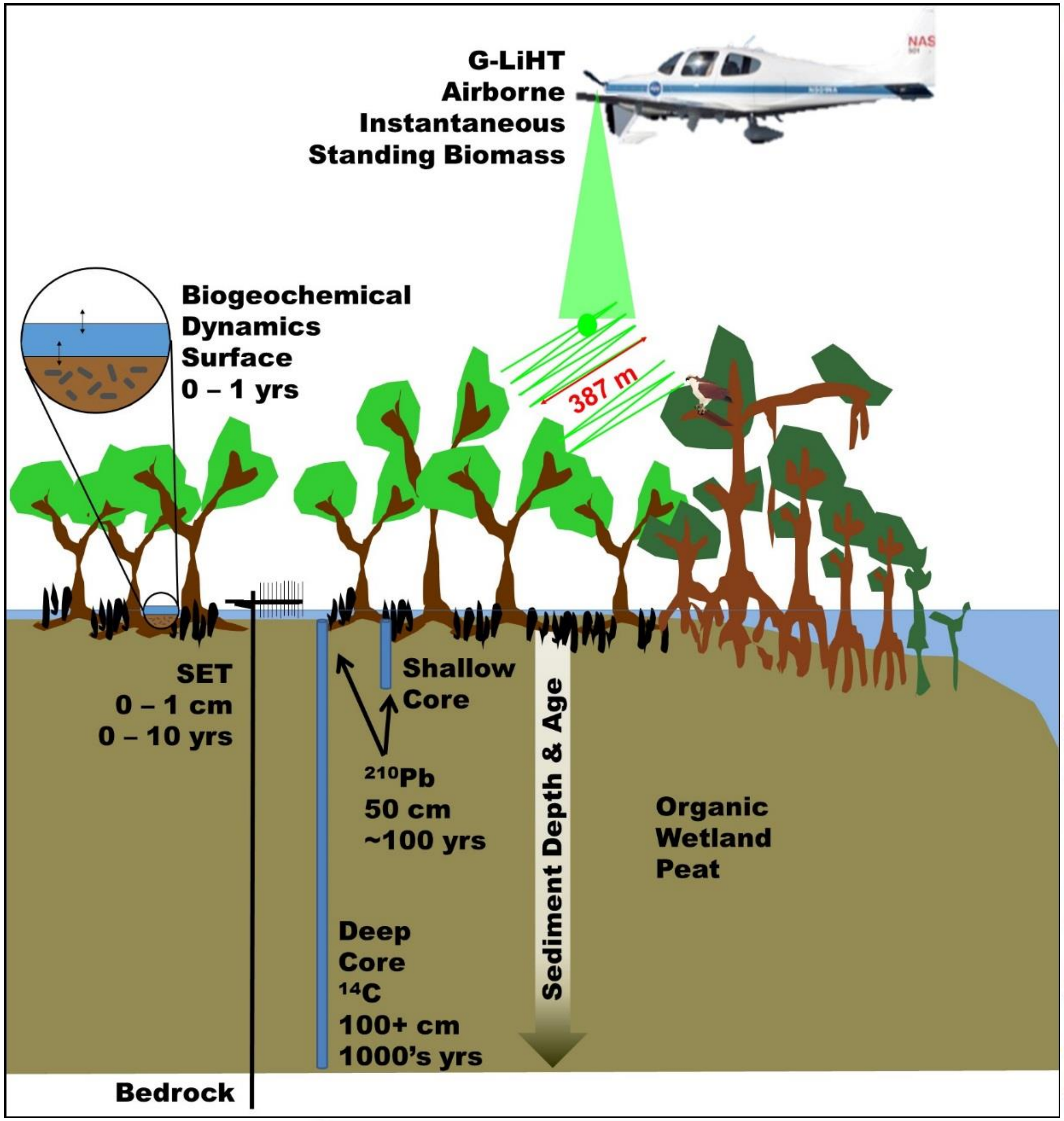


Fig. 3. Proposed focus area in Southwest Florida, including regions of existing G-LiHT data (black rectangles), proposed G-LiHT locations (white rectangles), and existing Sediment Elevation Tables (blue icons).

Thank You