Coastal wetland carbon accounting:

using U.S. syntheses to build up the baseline

Lisamarie Windham-Myers
USGS National Research Program

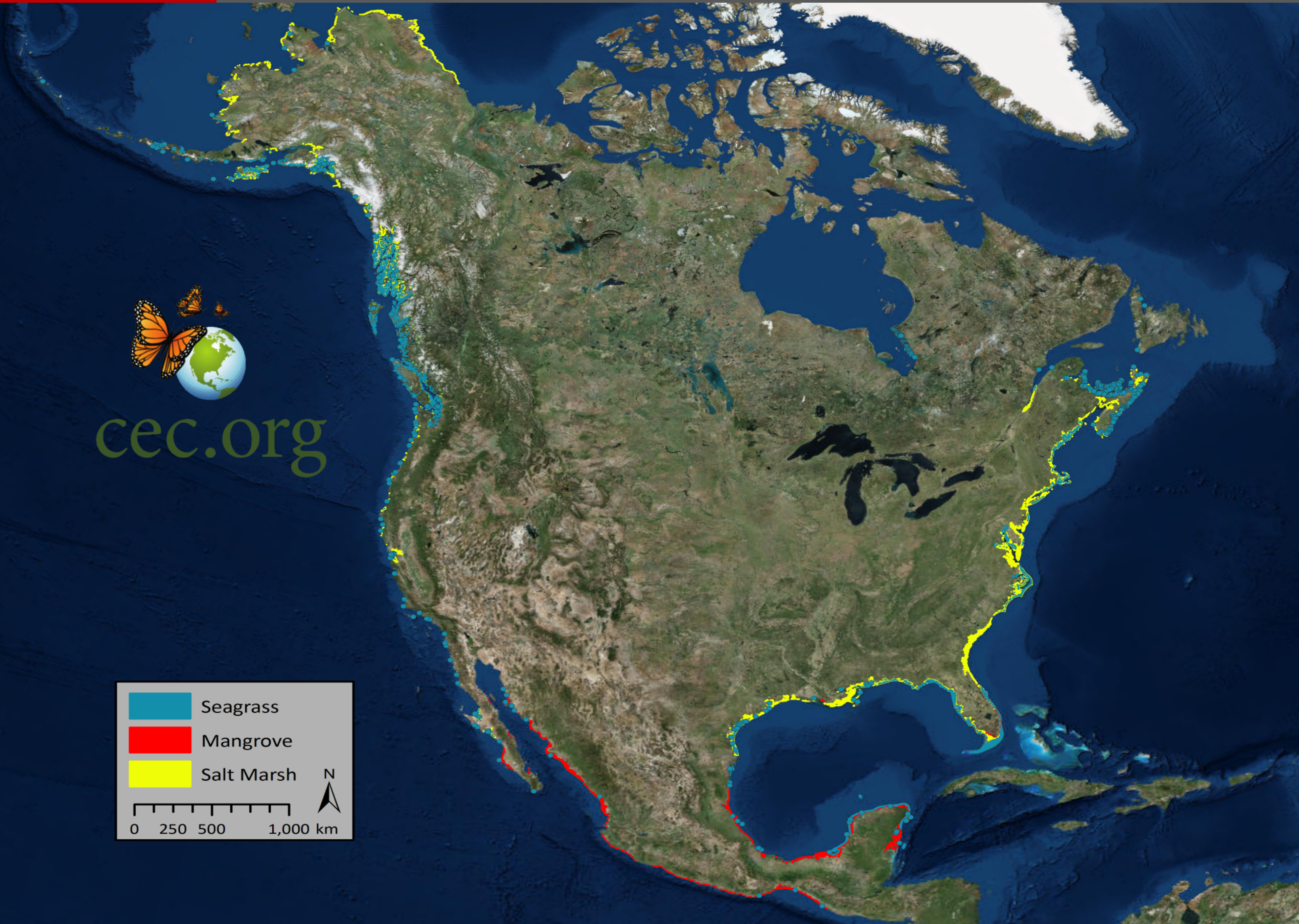
OCB Plenary, Woods Hole, MA; June 26, 2017

Acknowledgements to MANY colleagues:

NASA Carbon Monitoring System (18 PI's, >60 collaborators)

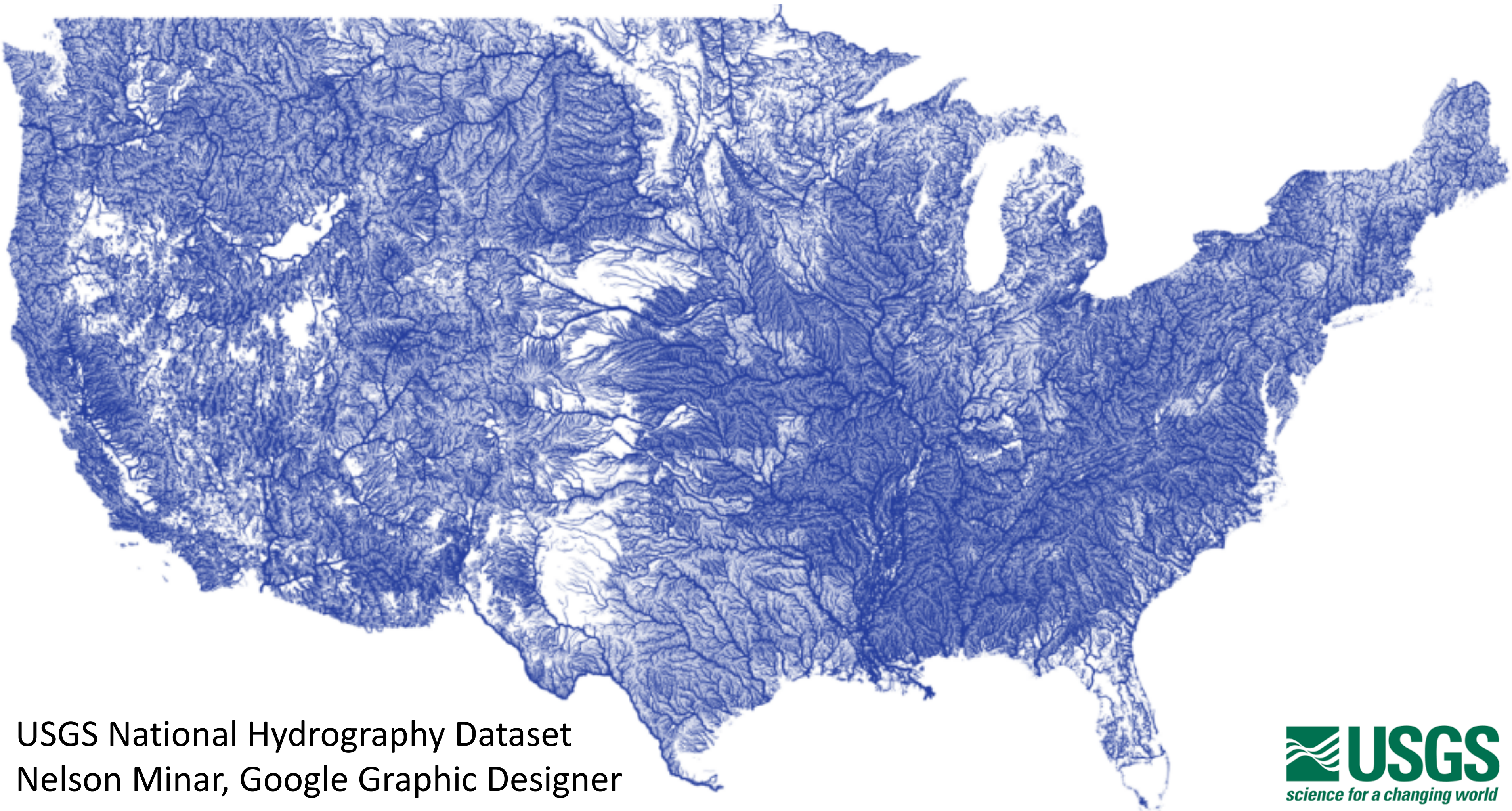
SOCCR-2: Tidal Wetlands and Estuaries (Chapter 15)

USGS LandCarbon Program and CEC


cec.org
Seagrass
Mangrove
Salt Marsh
N
0 250 500 1,000 km

Terrestrial:Aquatic Interfaces (TAIs)

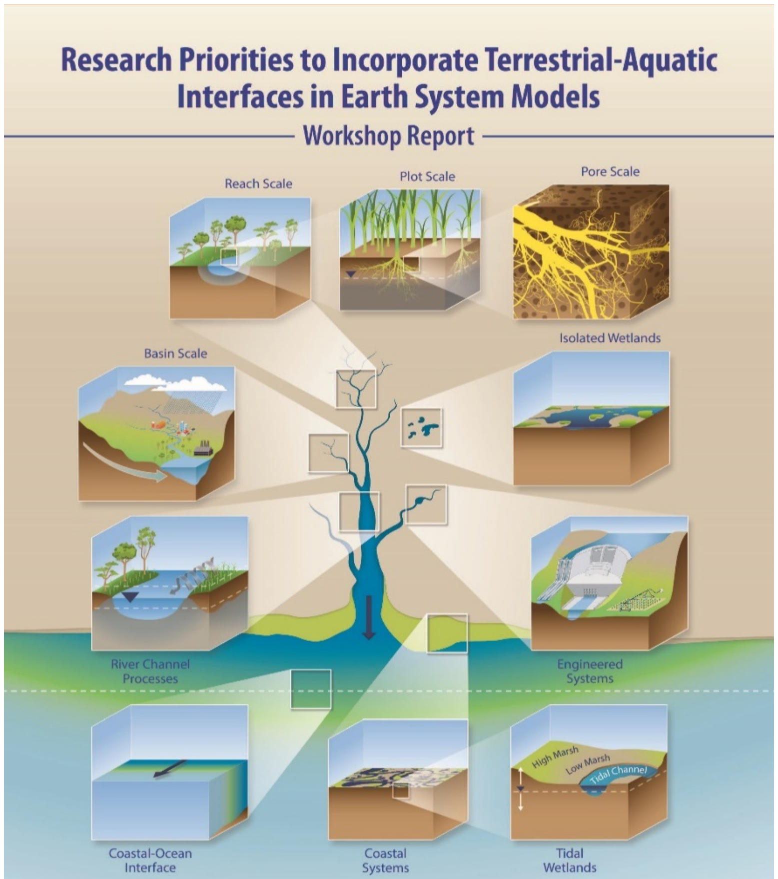
Small but spatially extensive

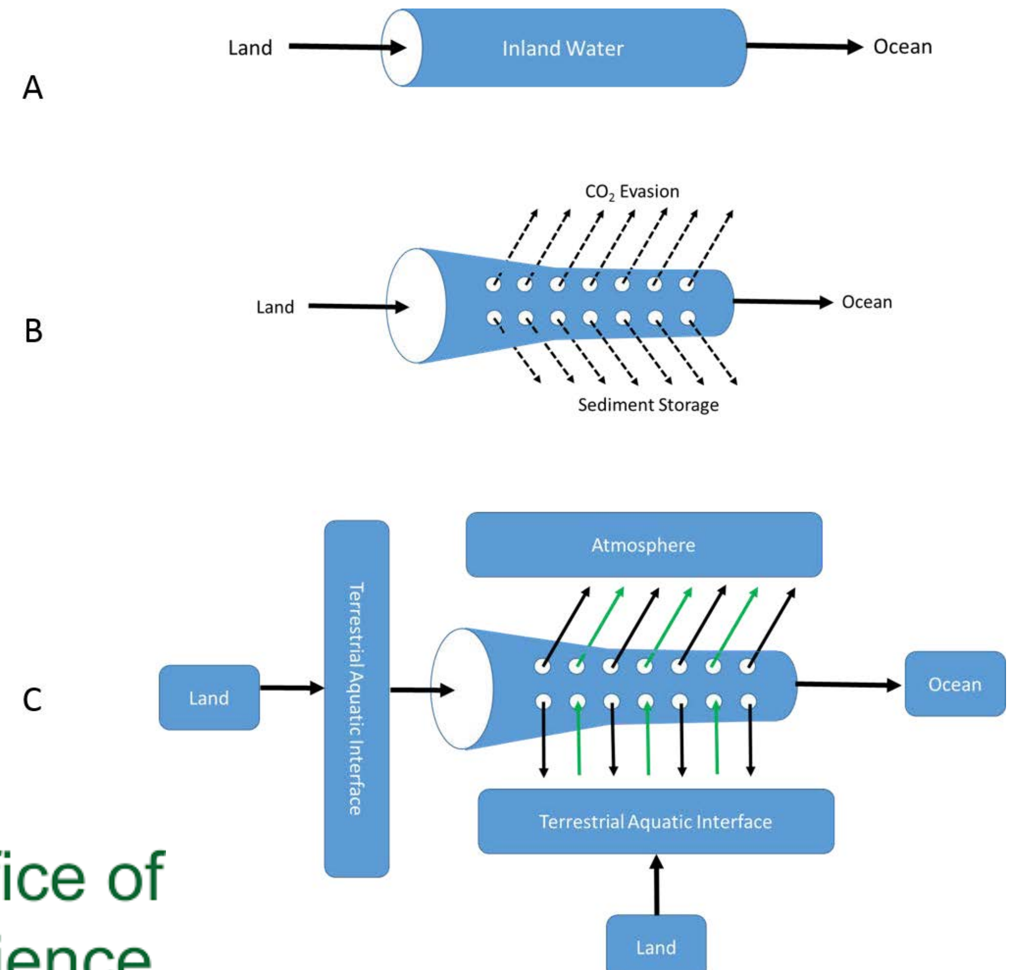


USGS National Hydrography Dataset
Nelson Minar, Google Graphic Designer

Terrestrial:Aquatic Interfaces (TAIs)

complex coupling of land and ocean

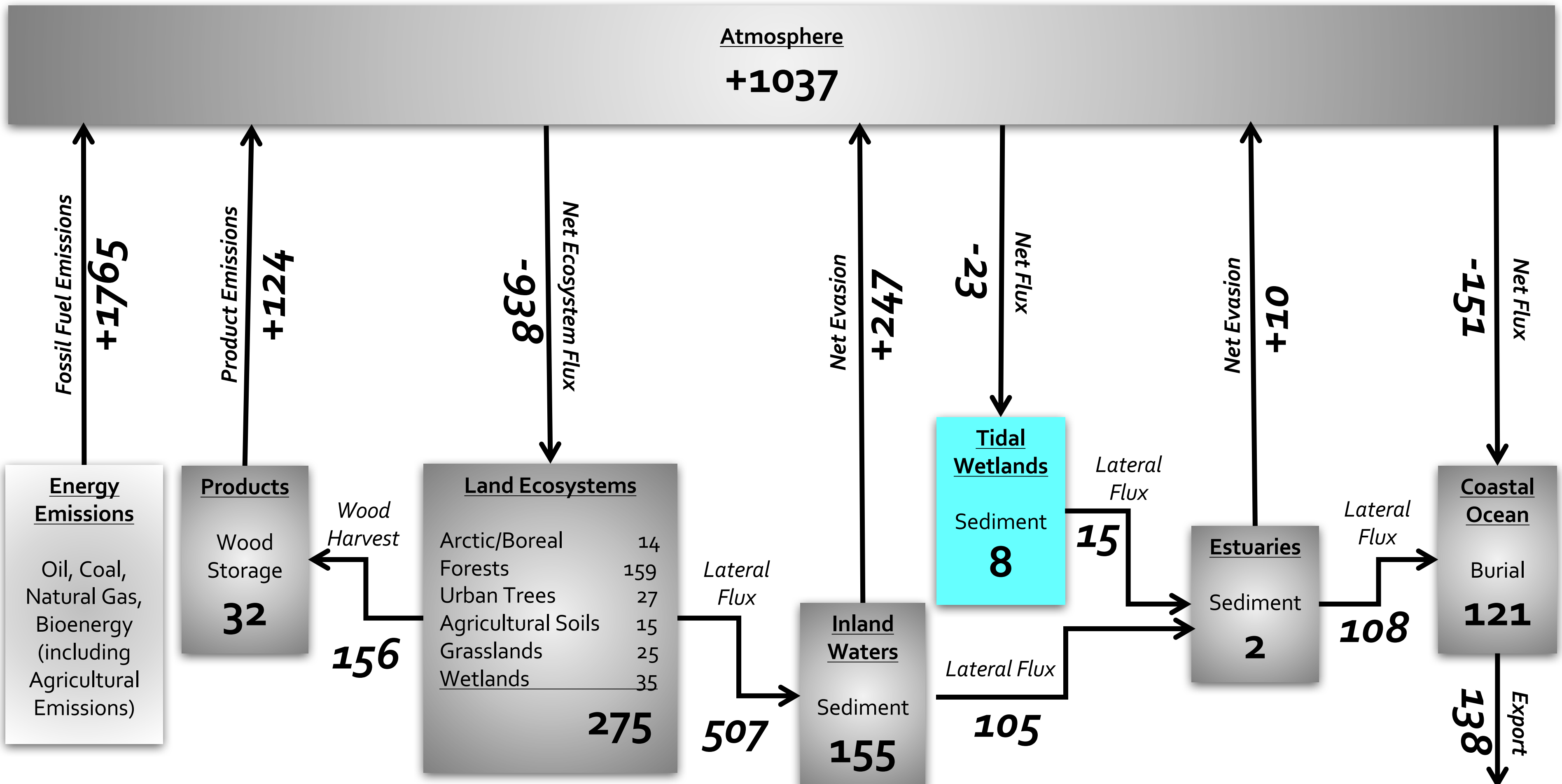




U.S. DEPARTMENT OF ENERGY | Office of Science

SOCCR-2: Coastal zones are net sinks of carbon

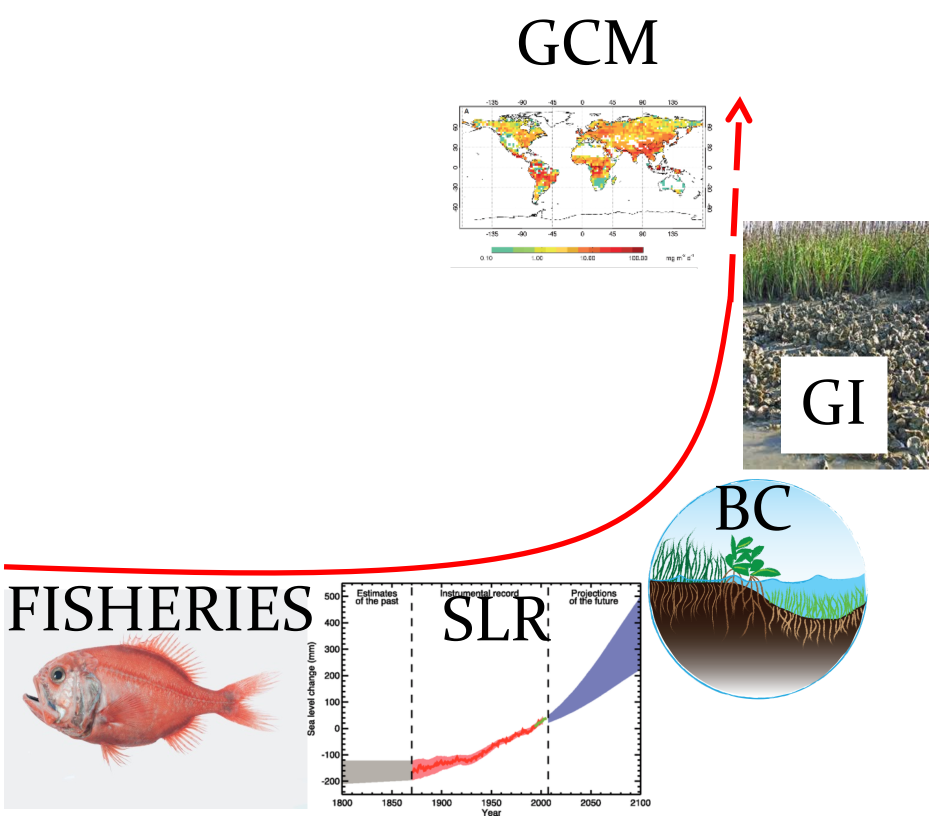
Tidal wetlands are small but significant sinks



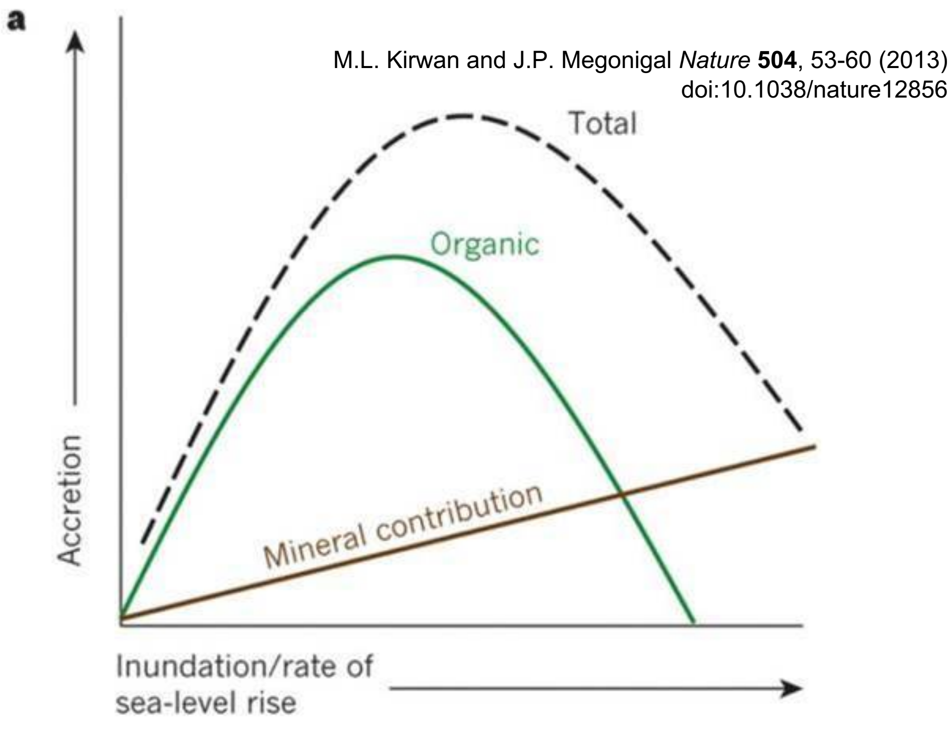
Daniel Hayes, Overview Chapter

Lots of baseline leading to new theories

A brief history of research on tidal wetland C fluxes



e.g. Positive influence of SLR on C sequestration **until** <u>tipping point</u>



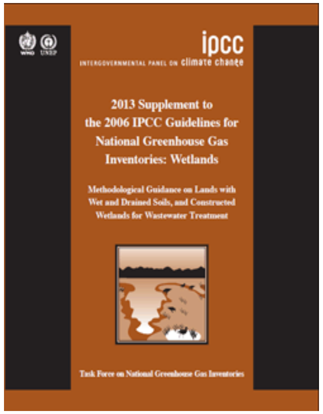
Also see Morris et al, AGU Earths Future (2016)

"Blue" Carbon Monitoring System

Leveraging field and remotely sensed data to reduce uncertainty in national inventories of coastal wetland carbon fluxes

L. Windham-Myers[1], Brian Bergamaschi[1], Judith Drexler[1], Kristin Byrd[1], Kevin Kroeger[1], Meagan Gonneea[1], Isa Woo[1], Matthew Ferner[2], Patrick Megonigal[3], Donald Weller[3], Lisa Schile[3], James Holmquist[3], Ariana Sutton-Grier[2], James Morris[5], John Callaway[6], Marc Simard[4], John Takekawa[7], Rusty Feagin[8], Stephen Crooks[9], Tiffany Troxler[10]

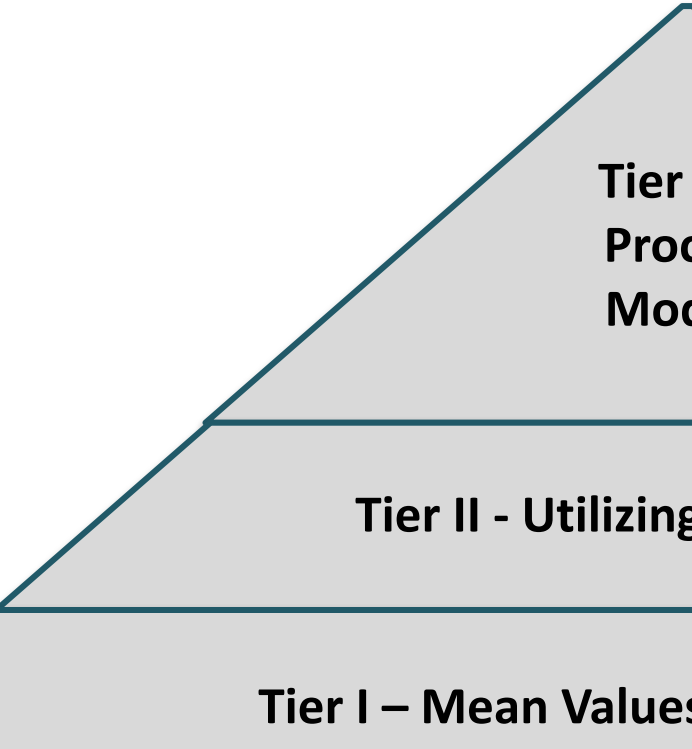
[1]USGS, [2]NOAA, [3]Smithonian, [4]NASA-JPL, [5]U. South Carolina, [6]U. San Francisco, [7]Audubon, [8]Texas A&M U, [9]Silvestrum, [10] Florida Intl U.


ipcc
INTERGOVERNMENTAL PANEL ON climate change

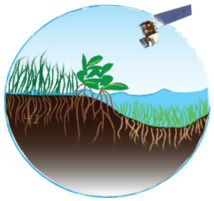
2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands

Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment

Task Force on National Greenhouse Gas Inventories

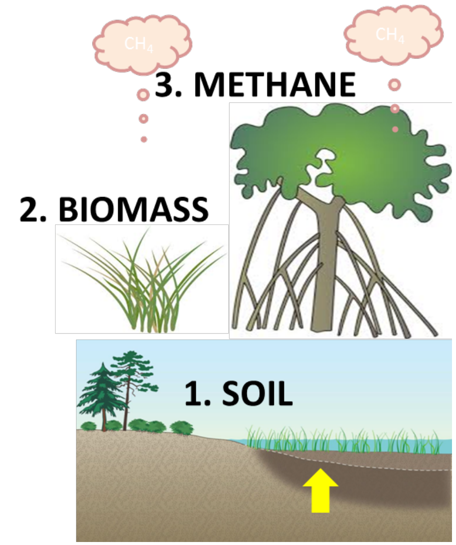


http://water.usgs.gov/nrp/blue-carbon/nasa-blue-cms/



"Blue" Carbon Monitoring System

Can we get beyond Tier 1 using national datasets?

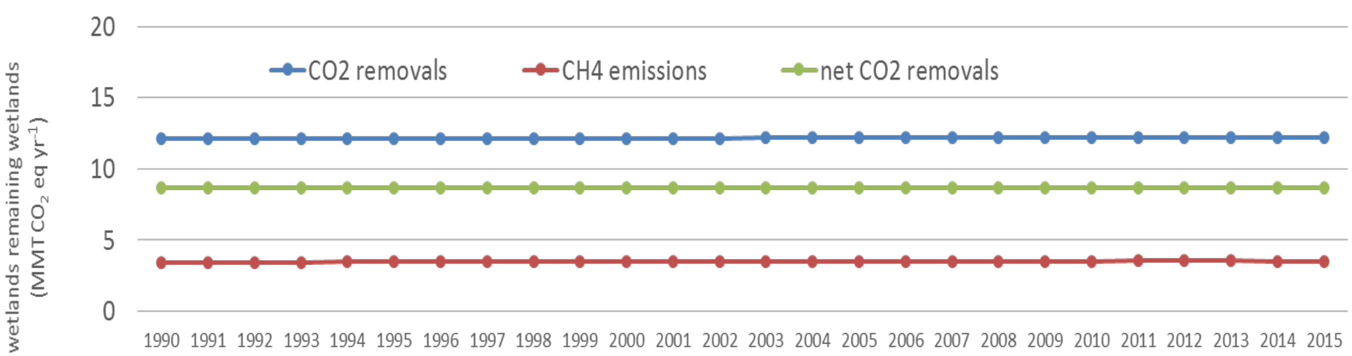


NOAA

EPA United States Environmental Protection Agency

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

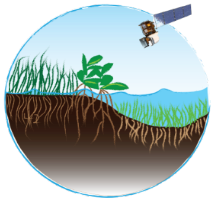
Annual estimated CO_2eq emissions and removals for wetlands remaining wetlands (98%)



3 Tg C burial per year

0.2 Tg CH_4 per year

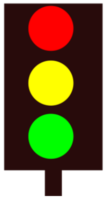
*Biomass C assumed = 0



Goal:

Reduce Uncertainty

How uncertain are these national layers?

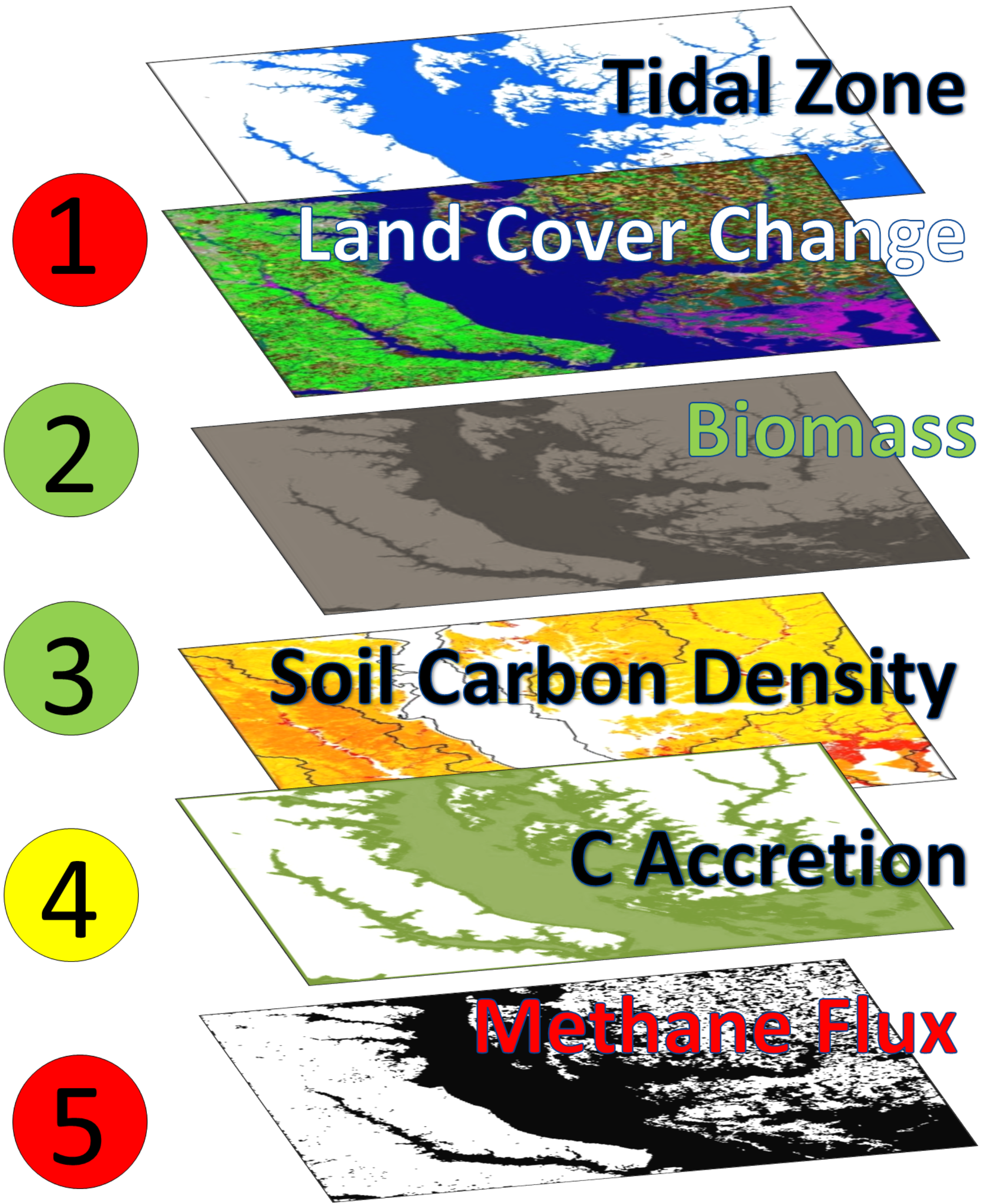


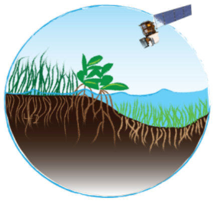
High
Medium
Low

How much better do they need to be to improve GHG accounting?

Where are the biggest data gaps?

Is the uncertainty with <u>monitoring</u> (quality, coverage) or <u>modeling</u> (process-based understanding)?



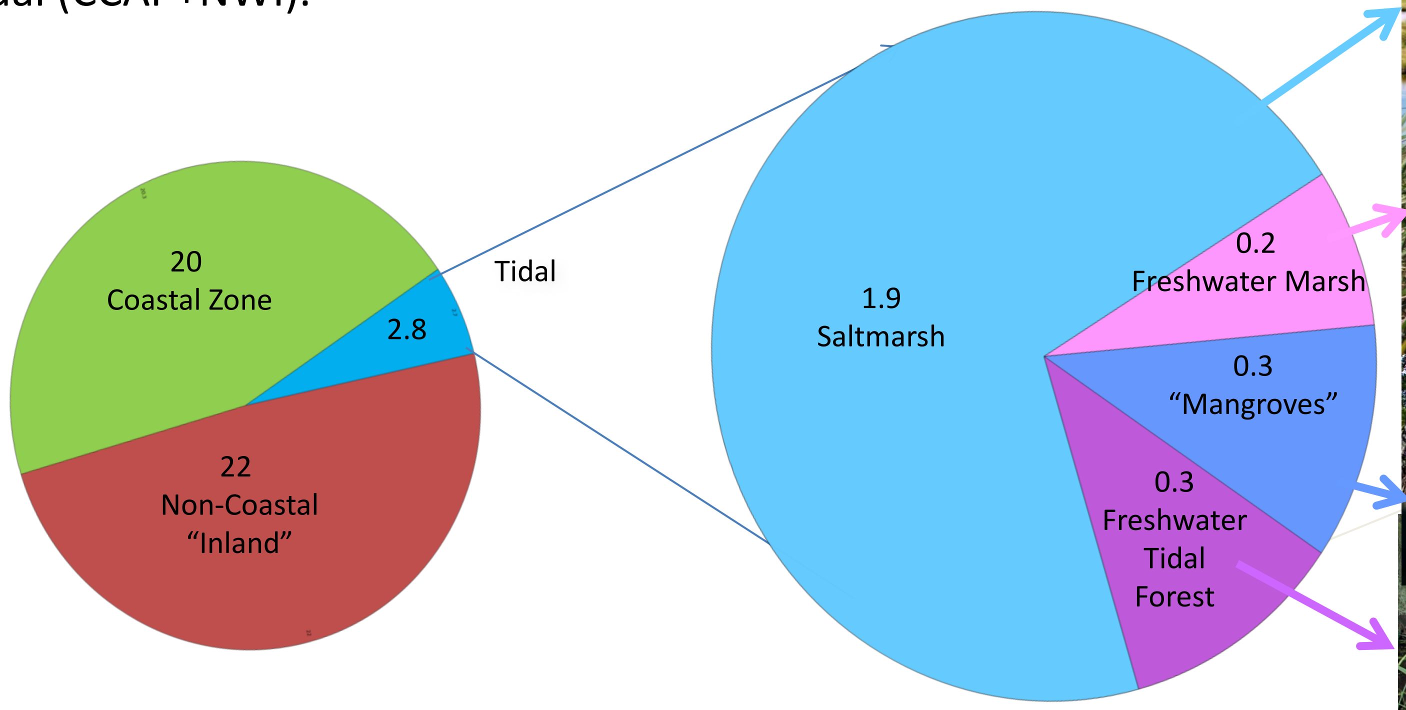


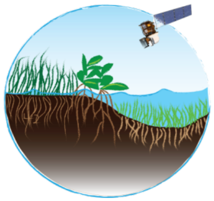
Land Cover: 2.8M ha mapped tidal wetlands

- NOAA's Coastal Change Analysis Program (CCAP)
- USFWS National Wetland Inventory (NWI)

Of the 45 Mha of U.S. wetlands (lower 48), 50% are coastal (CCAP) & 6% are tidal (CCAP+NWI).

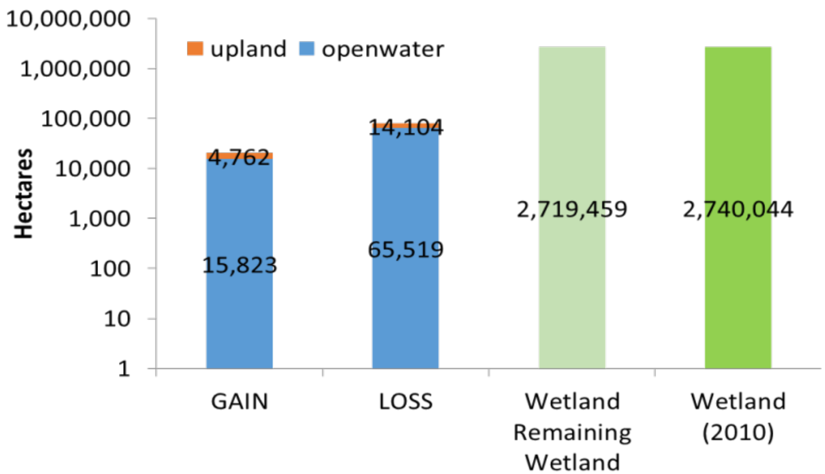
Of tidal wetlands, 80% are saline and 20% are freshwater.

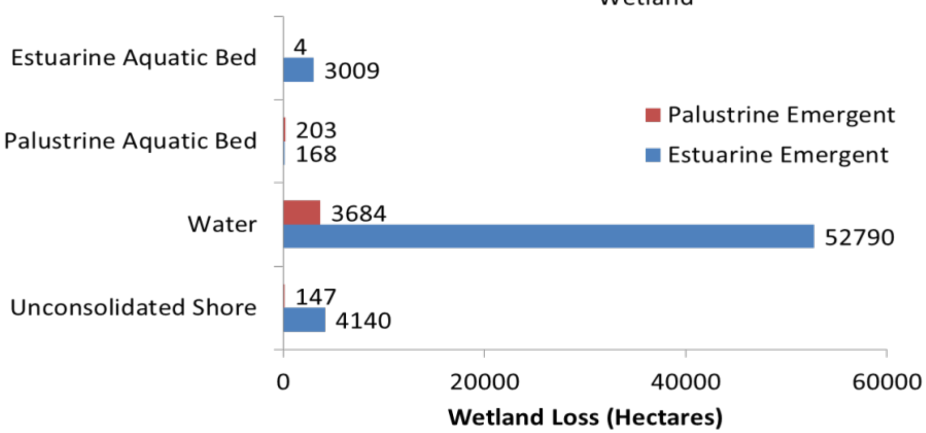




Land Cover Change: very little wetland loss 1996-2010

Conversions are dominantly Emergent Marsh to Open Water



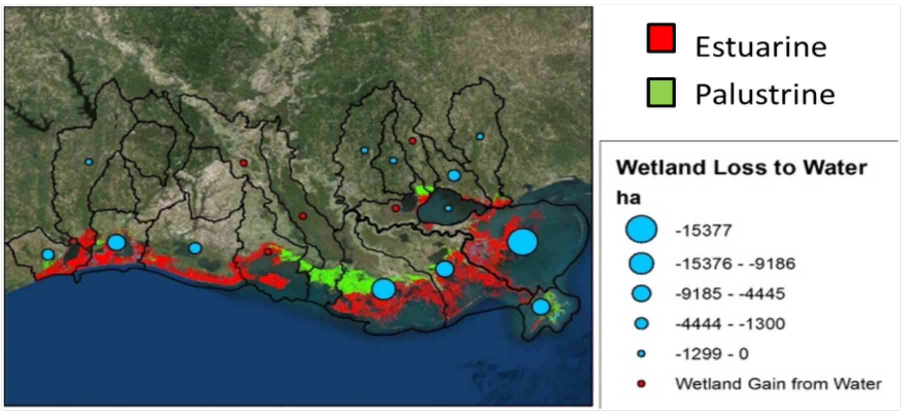


Conversions are 94% in Louisiana

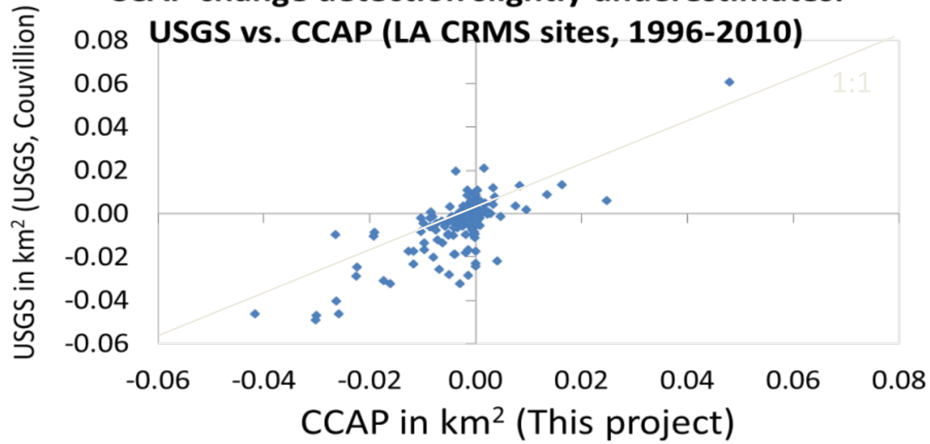
Summary of Conversions (CCAP 1996-2010):

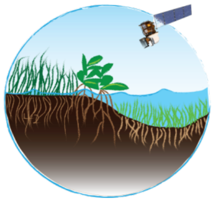
80% of loss (0.08Mha) = saltmarsh to open-water

75% of gain (0.02Mha) = open-water to saltmarsh



CCAP change detection slightly underestimates.



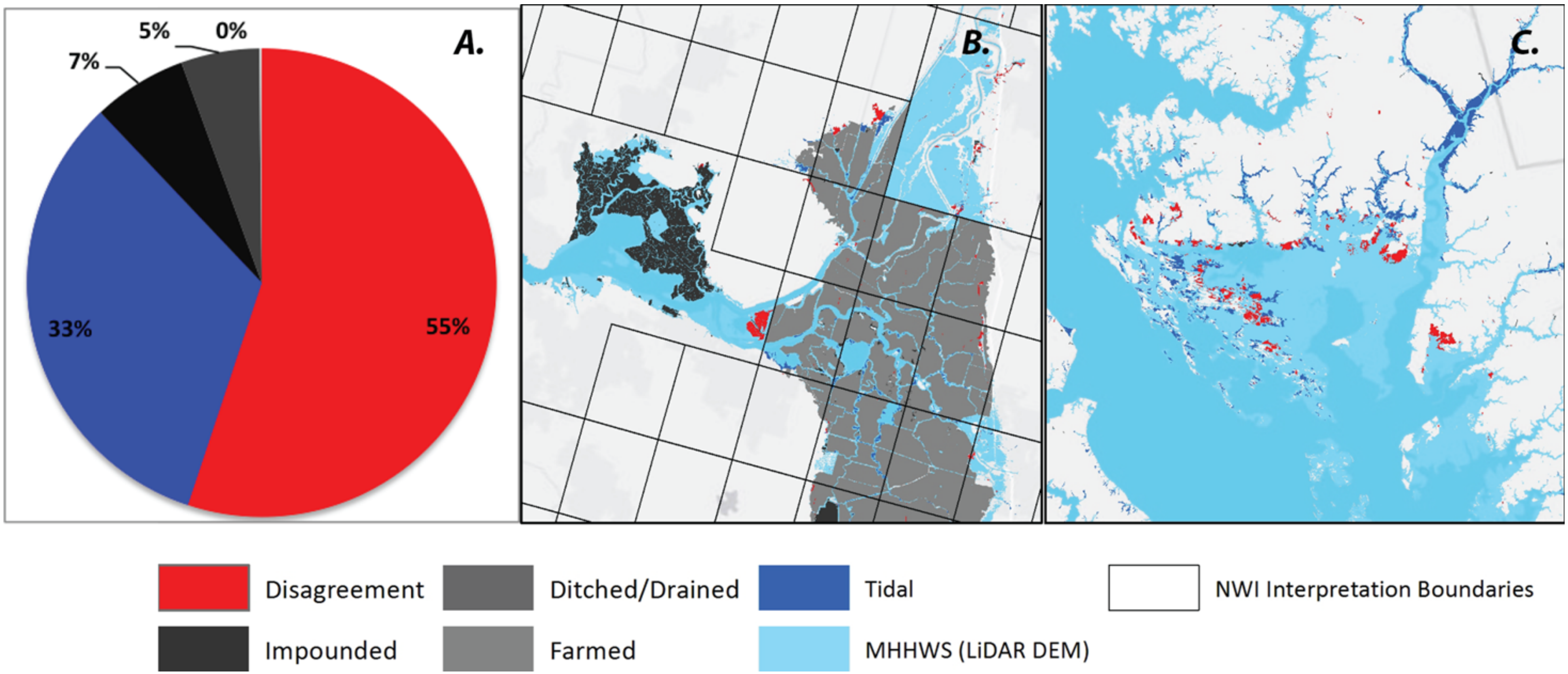


Better maps needed:

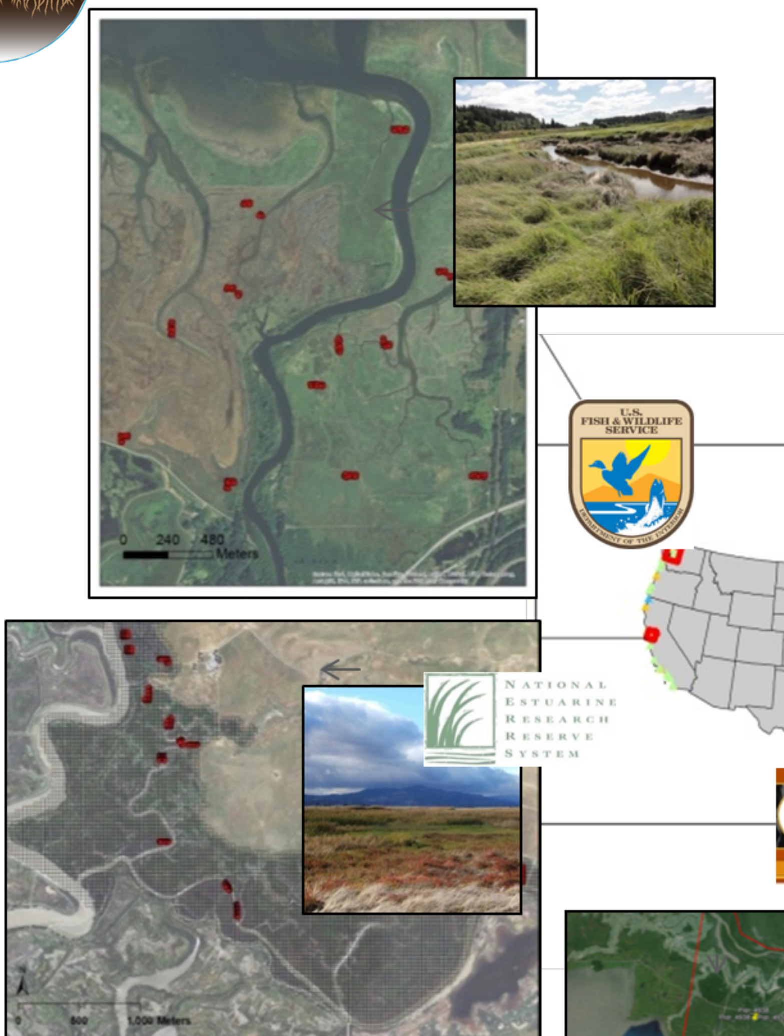
- **Tidal zone/connectivity**
- Salinity (fresh, mixed, saline)
- Elevation

e.g. NWI hydrology modifiers are not consistent with LiDAR or field observations

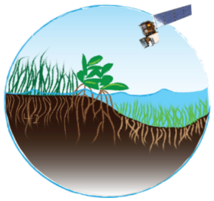
CONUS: +1M ha likely tidal | California Delta: errors | Chesapeake Bay: errors



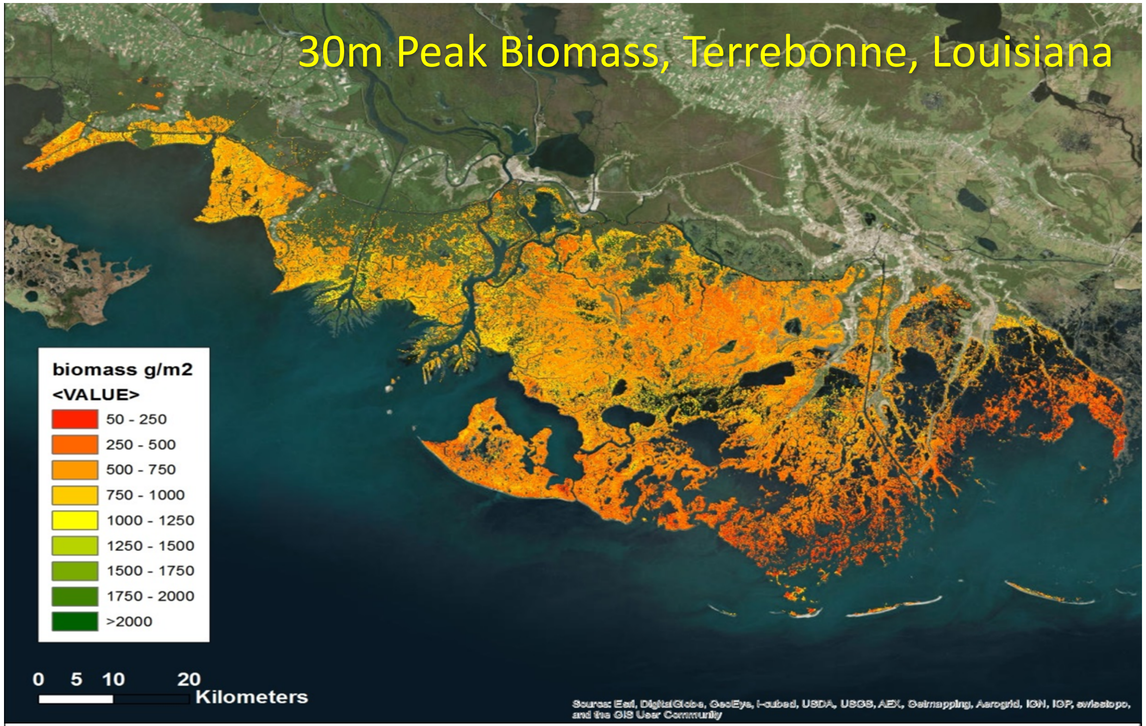
N=6 sentinel sites



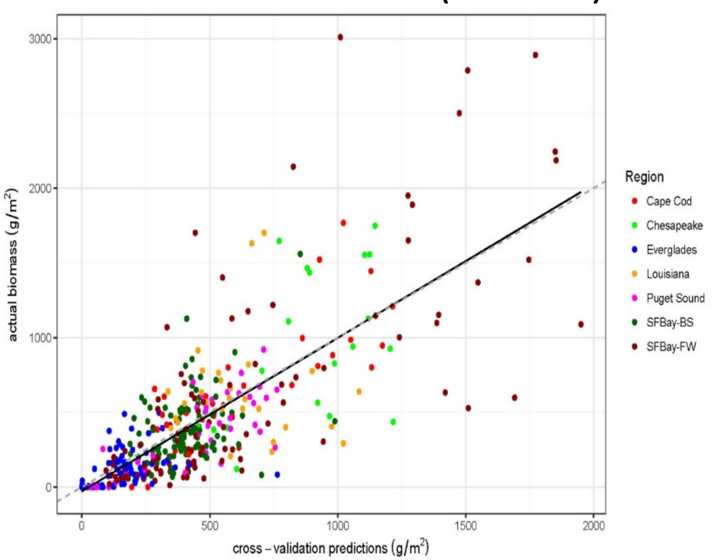
Biomass plots (>2600)

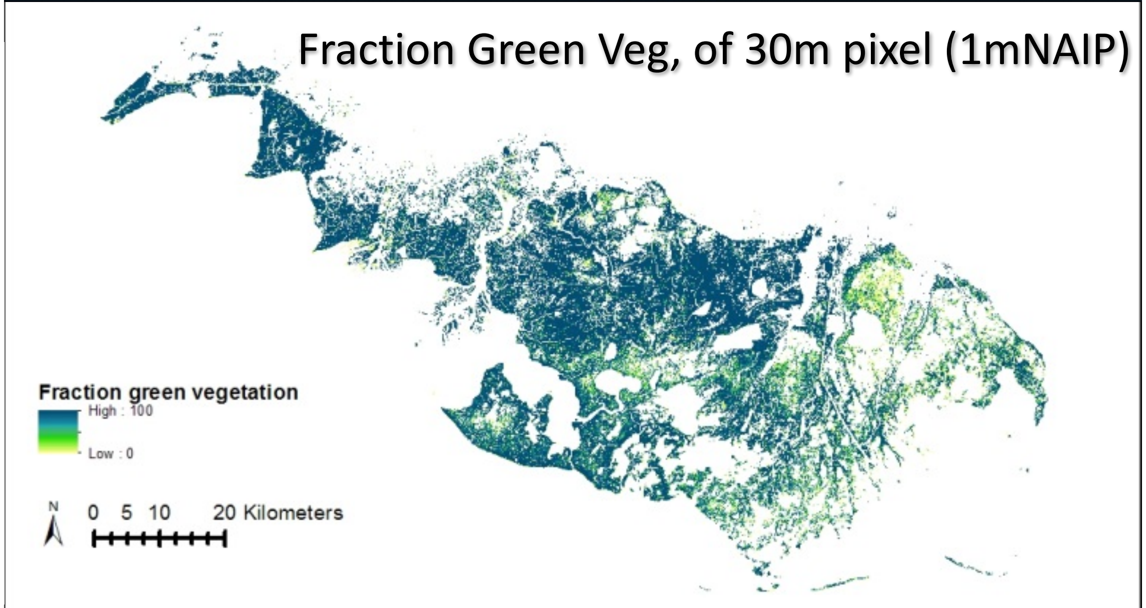


Biomass: Tidal Marsh



Modeled:Observed (no bias)



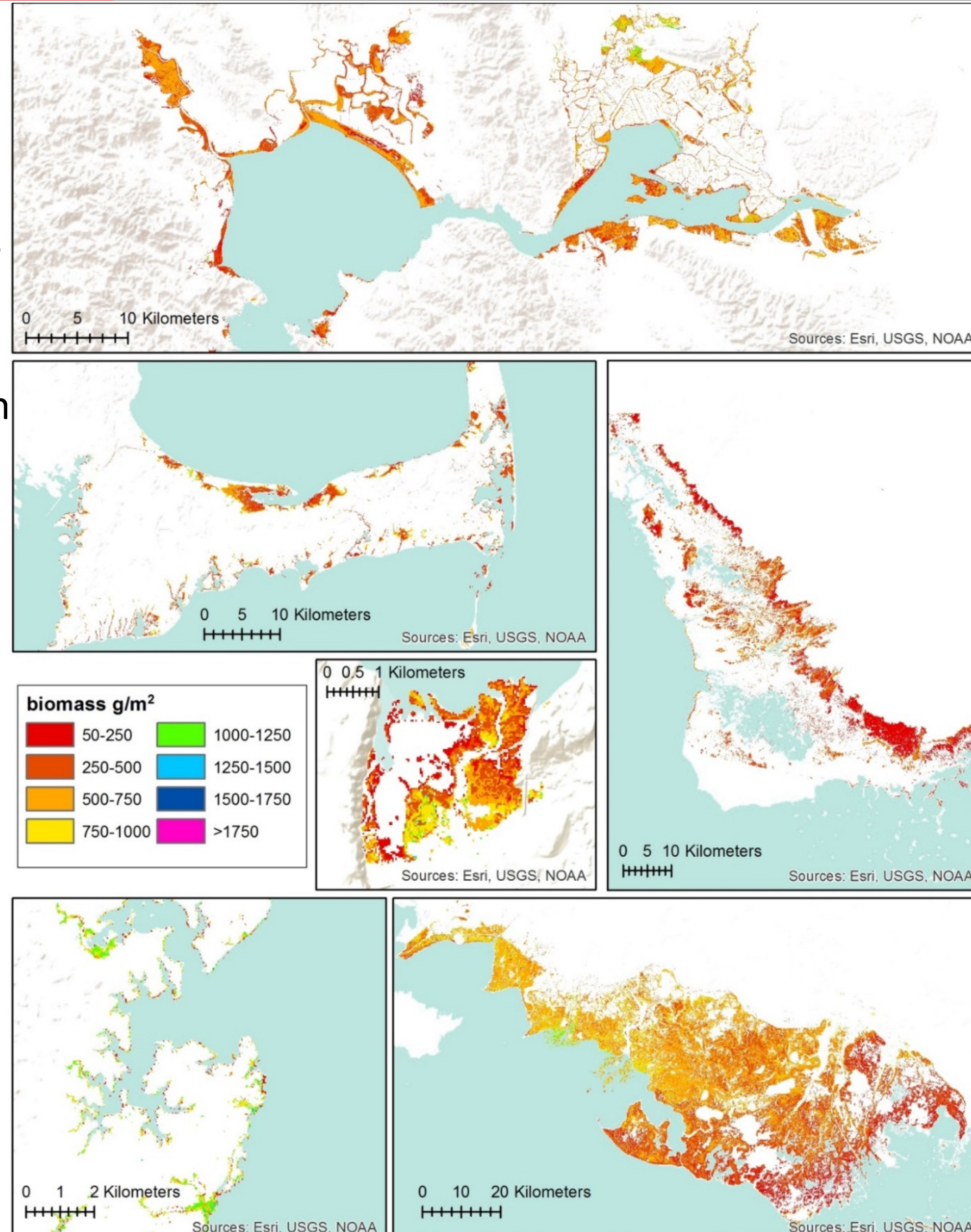


Biomass:

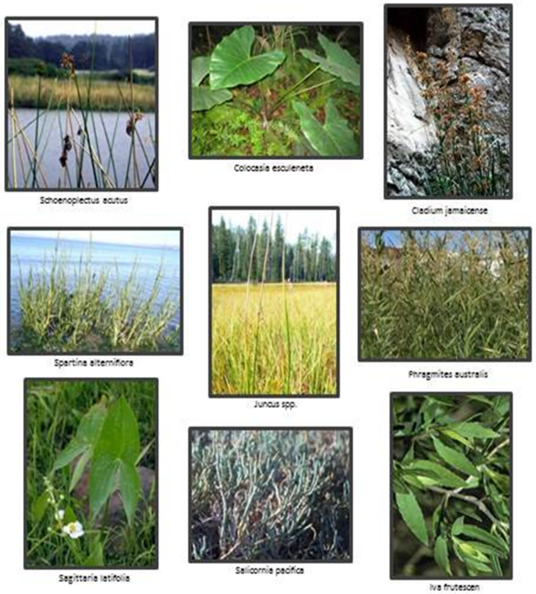
Byrd et al (in review)

Universal model for annually reproducible maps at 30m resolution for tidal marsh peak biomass based on LandSat and automated 1m NAIP water/soil/vegetation classifciation (RMSE = 311, R^2 = 0.58)

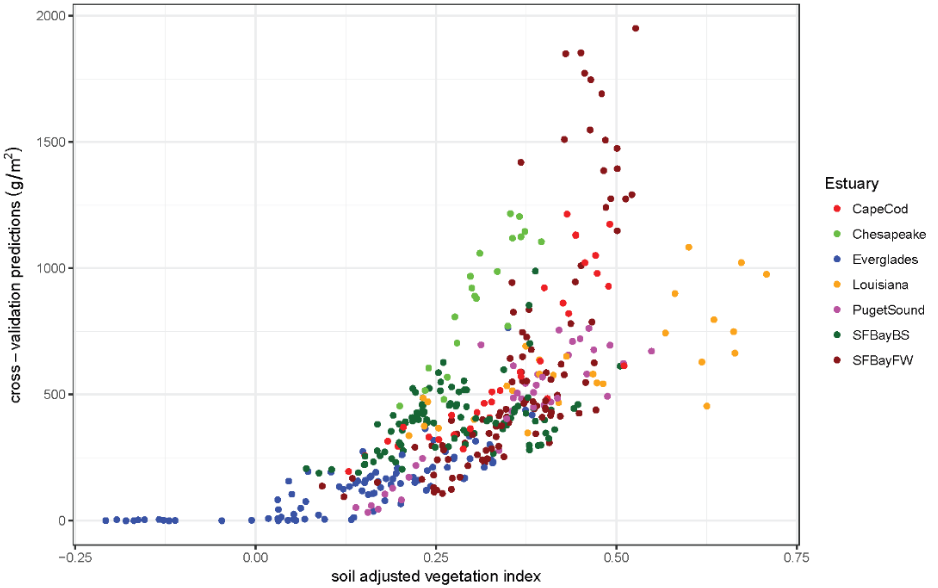
Random Forest Ranger Variable	Relative Importance
Soil-adjusted Veg Index	100
Norm.Diff.Red.Green	69
Wide Dynamic Range Veg Index	55
Norm.Diff.Green.Blue	36
Norm.Diff.SWIR2.Red	31
Norm.Diff.SWIR2.NearIR	21
Site.Chesapeake	17
Site.Everglades	7
Site.SanFrancisco Freshwater	6
Site.San Francisco Bay	4
Site.Louisiana	7
Site.Puget Sound	0
Site.CapeCod	0

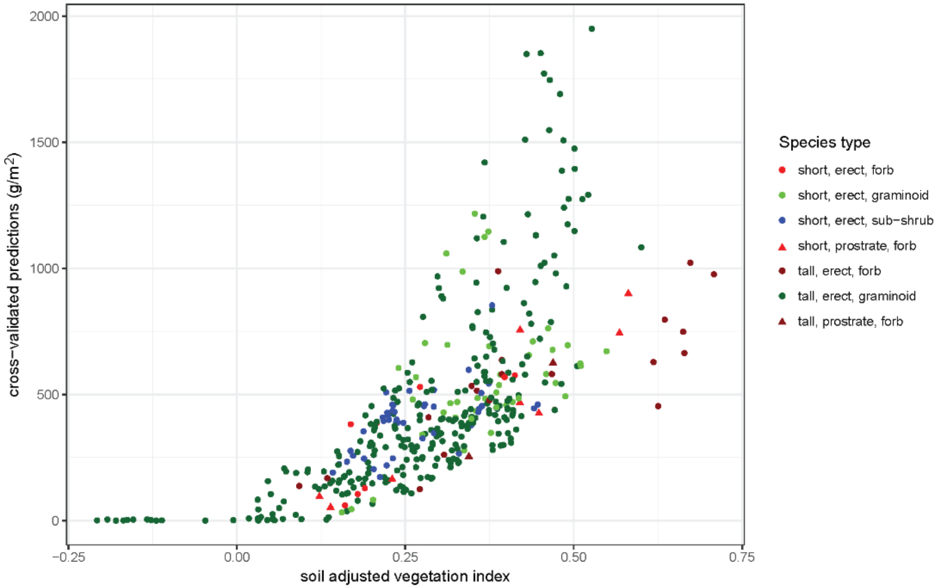


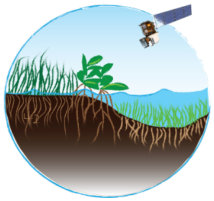
Tidal Marsh Biomass Model:



- Works across all 6 sites
- Works across all plant forms

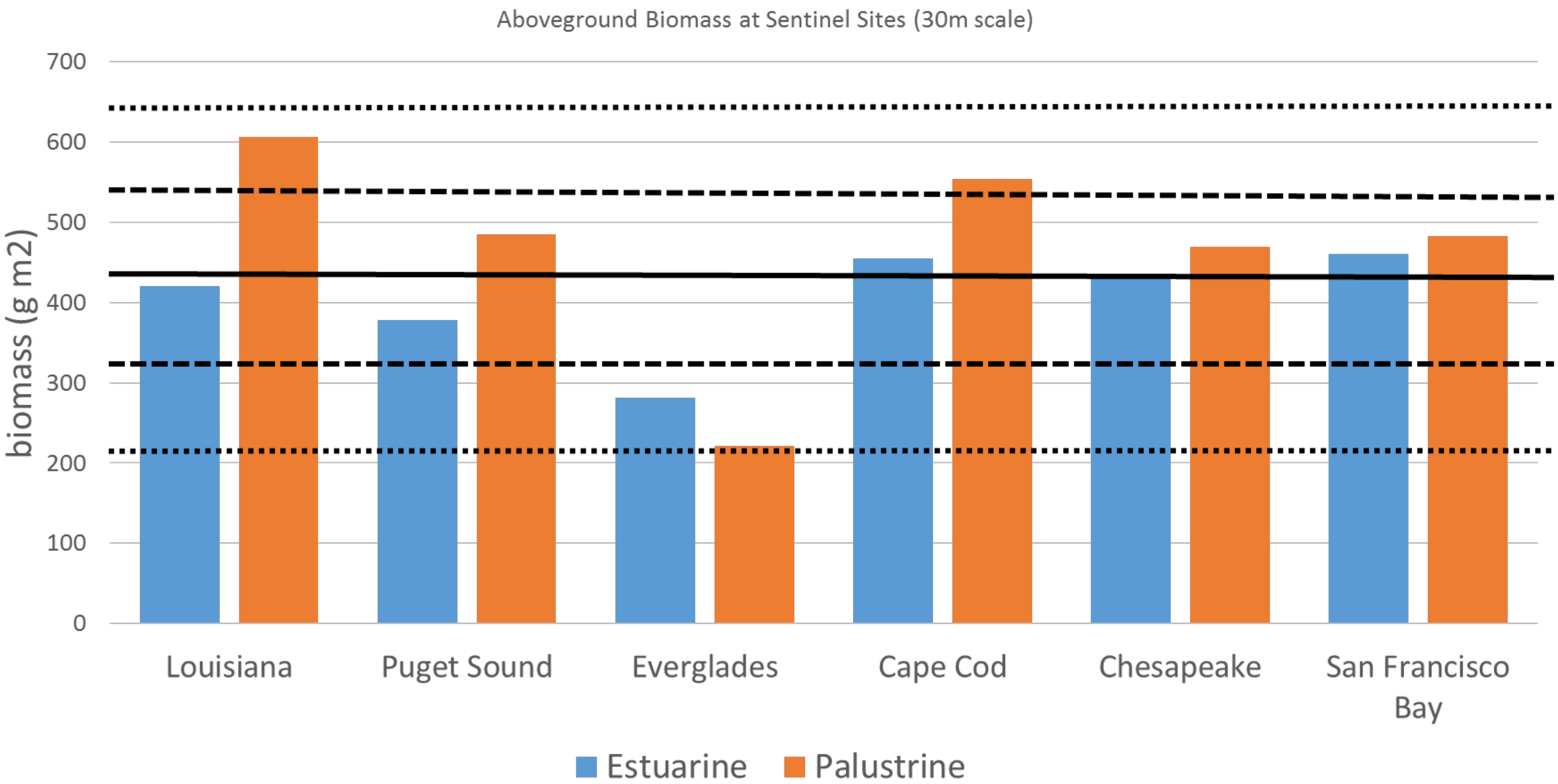




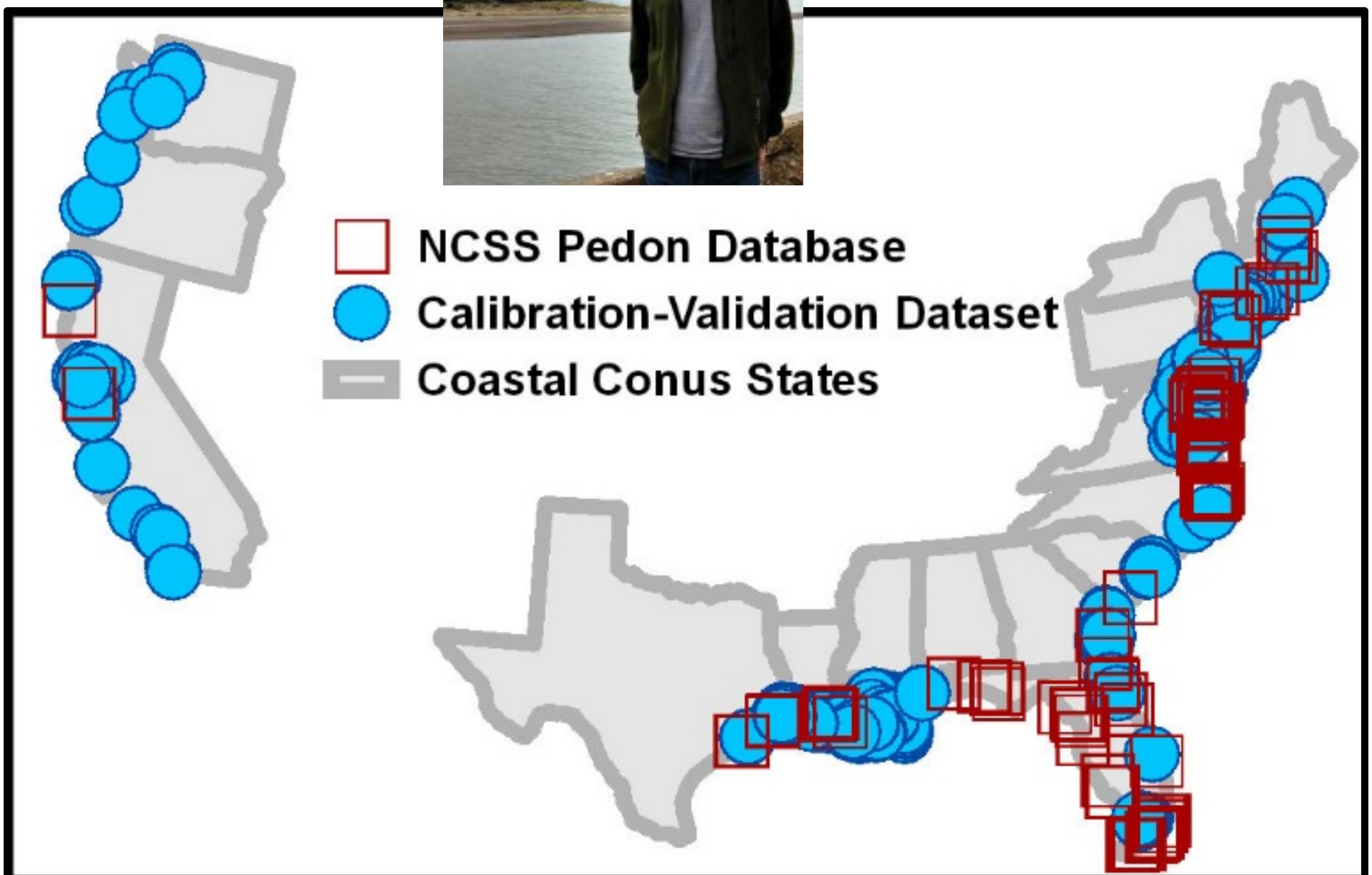


Biomass - Mean C Mg/Ha: EEM = 1.8, PEM = 2.0

- Similar stocks across all sites and salinities
- Similar %C tissue conversion (mean 44.1%, n=1384)



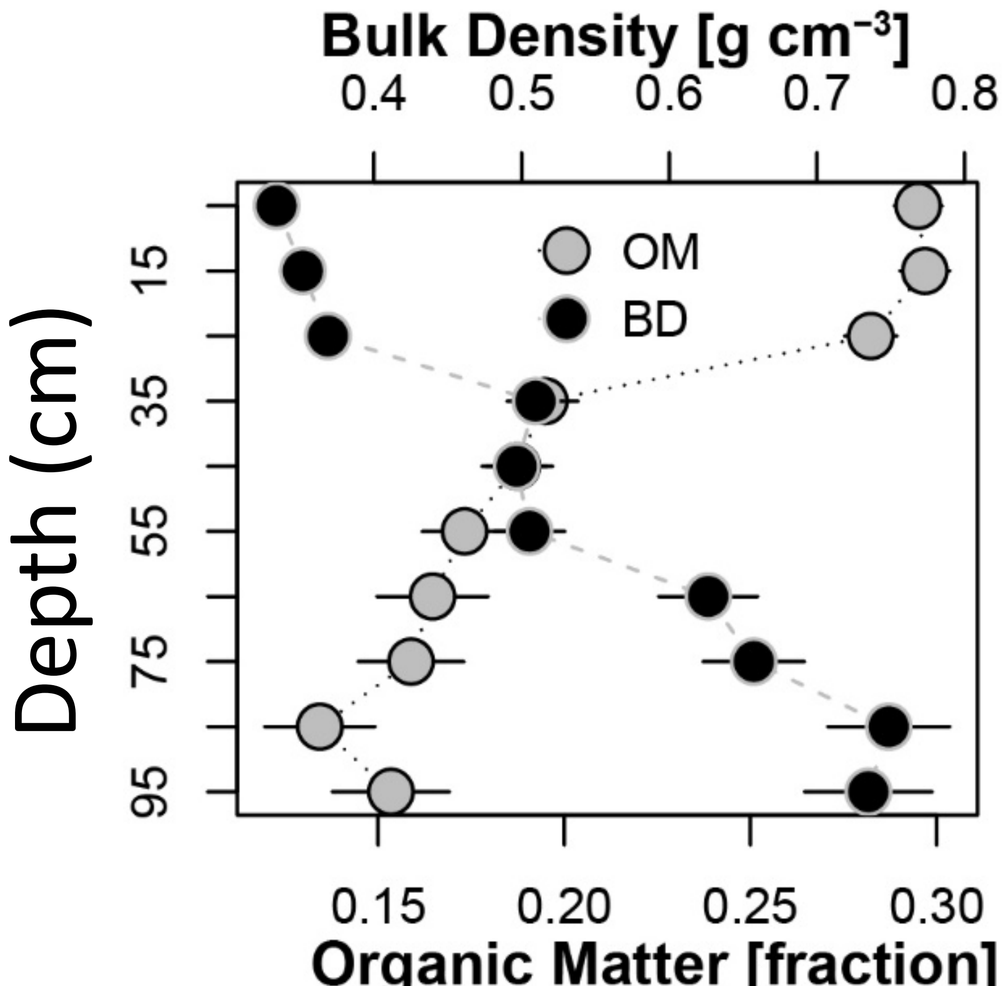
Soil C Stock: Community Effort

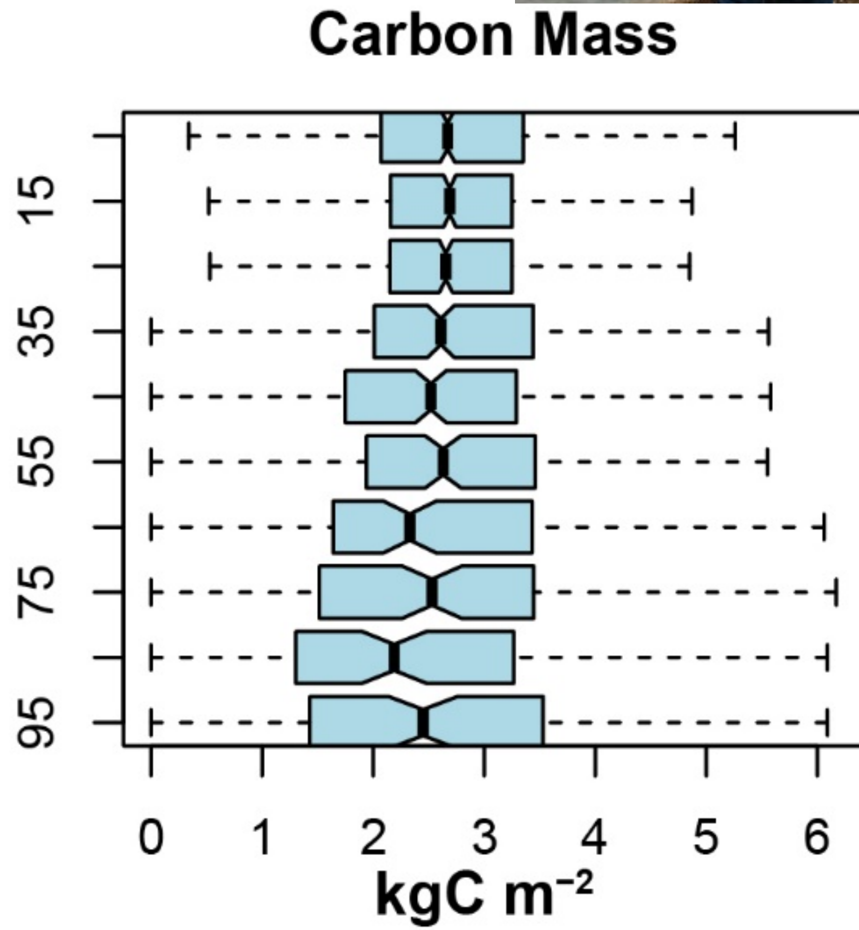


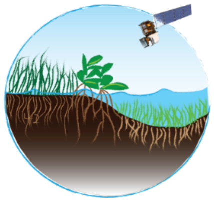
Shimon Anisfeld
Don Barber
Leah Beckett
Thomas Bianchi
Brandon Boyd
Andrew Breithaupt
Lauren Brown
Grace Brush
Kevin Buffington
John Callaway
Kirk Cochran
Chris Craft
Ron DeLaune
Katherine Drake
Judy Drexler
Troy Hill
David Johnson
Michael Kearny
Andrew Kemp
Conrad Kirby
Leper
Glen MacDonald
Helaine Markewich
Nathan McTigue
Patrick Megonigal
Scott Neubauer
Greg Noe
Andy Nyman
Rich Orson
Thomas Quirk
Sarai Piazza
Katrina Poppe
Willy Reay
John Rybsyck
Donny Smoak
Karen Thorne
Tiffany Troxler
USGS -NWRC CRMS
David Walters
Lisa Windham-Myers

Soil C stock is 26.44 g C m^{-3}(SE=1,SD=14)

- similar spatially and downcore

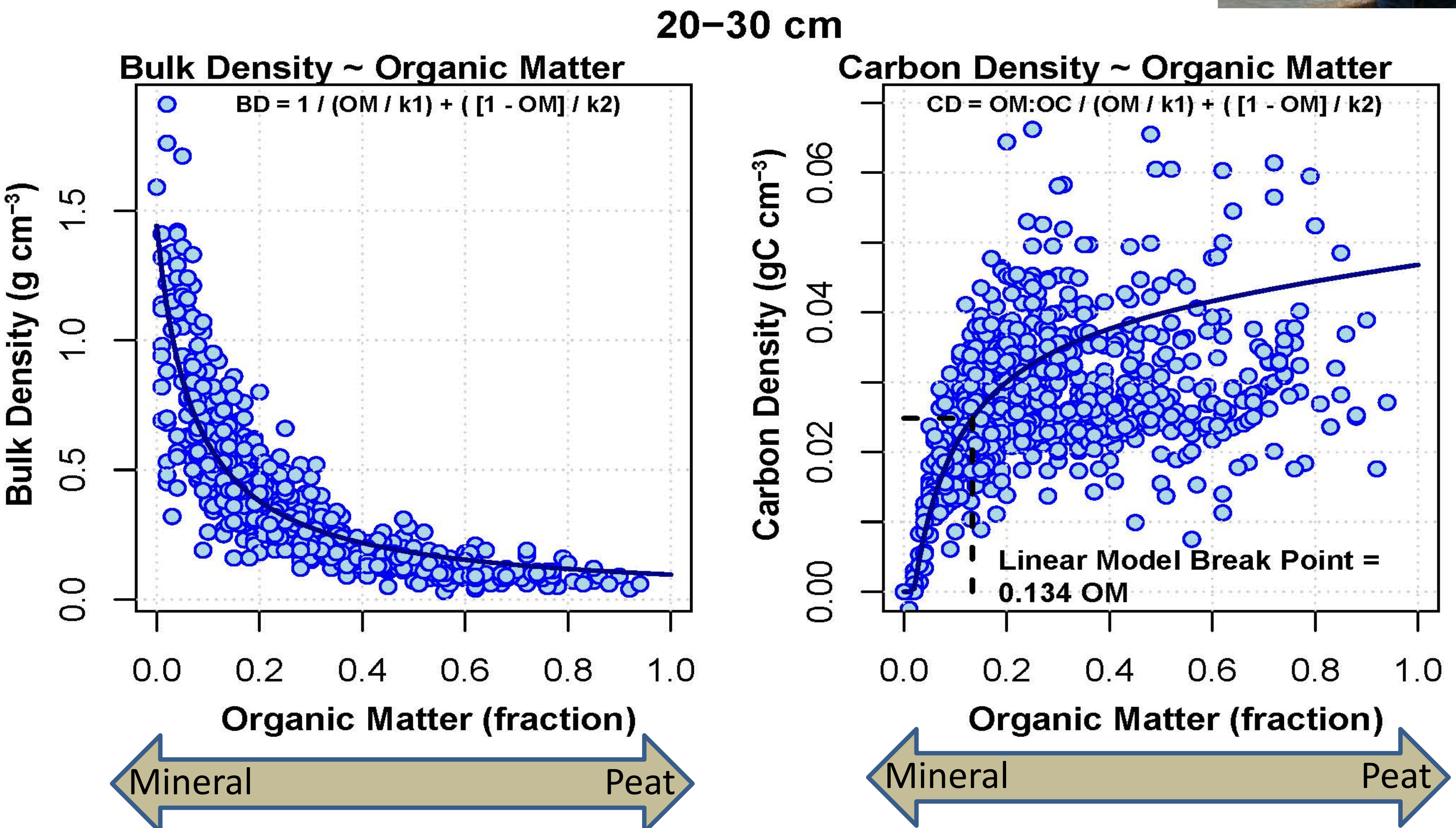






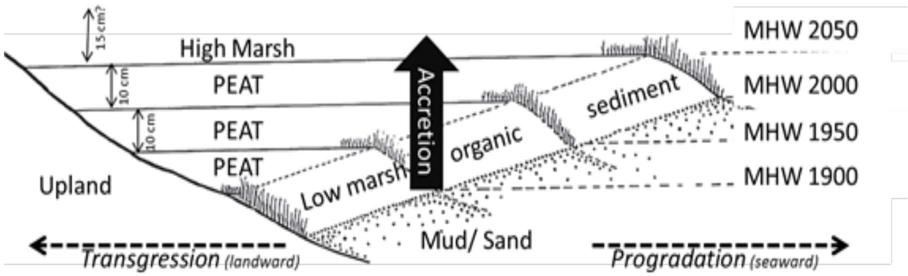
Soil C density saturates above 0.03

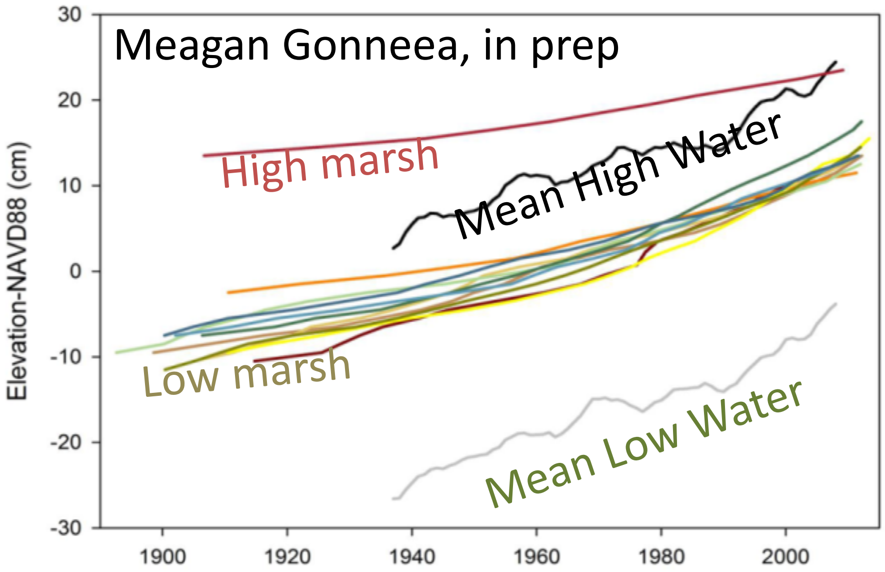
- Similar to EPA NWCA (0.028 g C cm^{-3})
- Mineral soil < 13.4% Organic matter



C Accretion= f (RSLR)

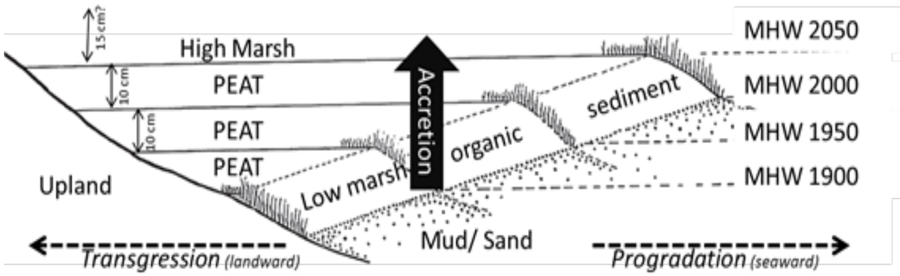
Redfield, 1965

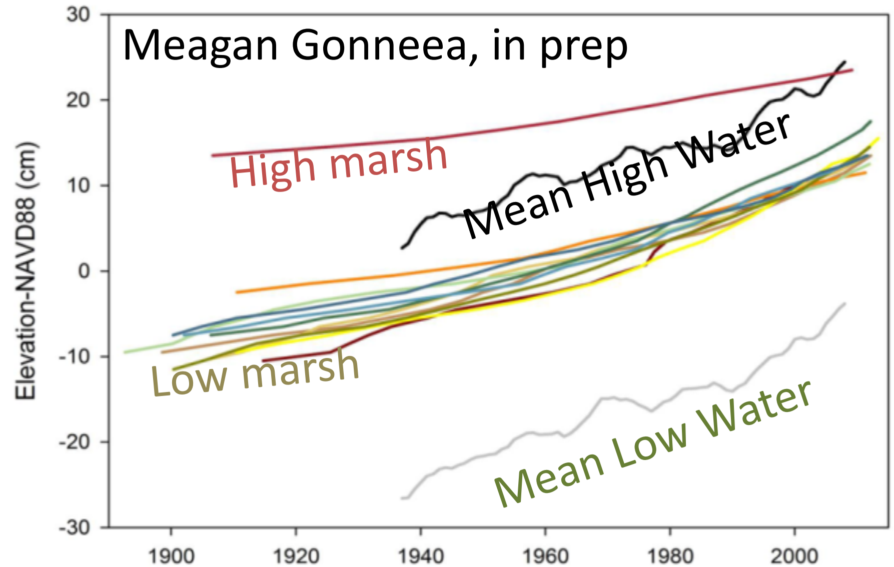


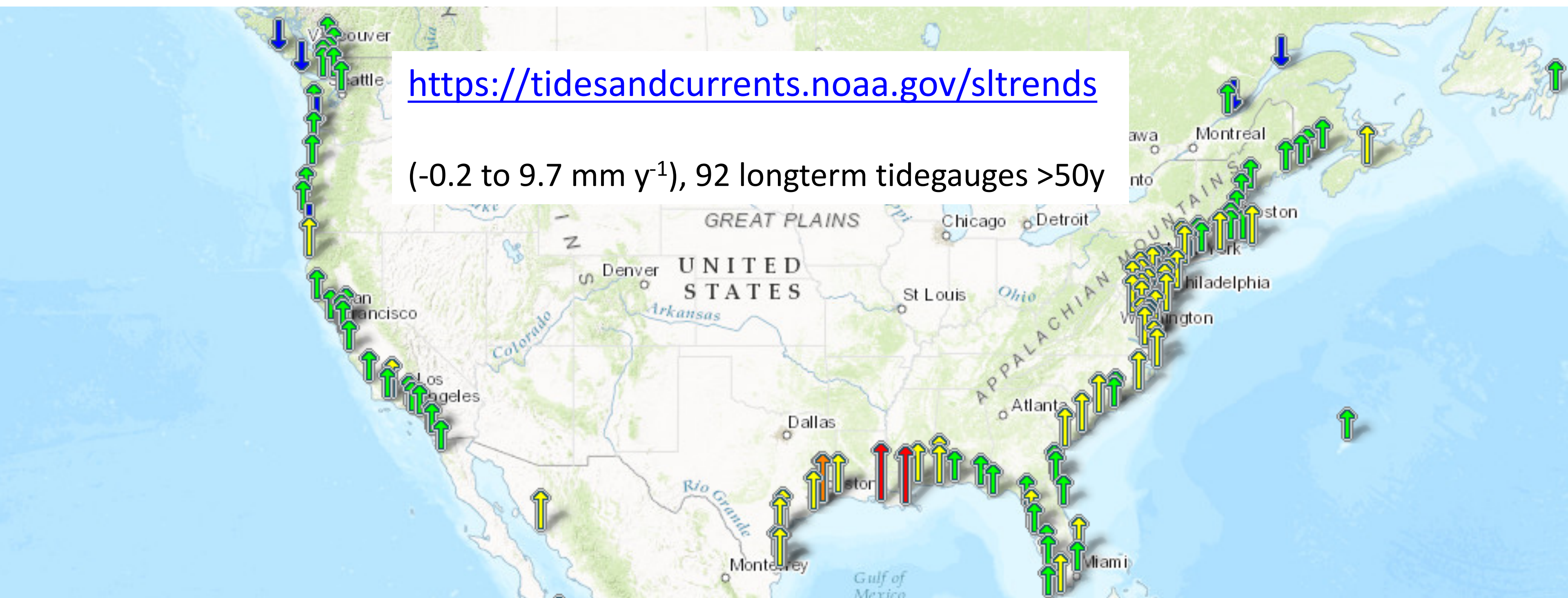


C Accretion= f (RSLR) but, is it mappable?

Redfield, 1965







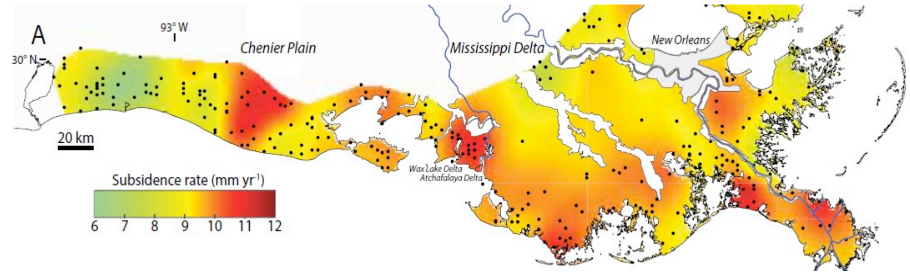
https://tidesandcurrents.noaa.gov/sltrends

(-0.2 to 9.7 mm y^{-1}), 92 longterm tidegauges >50y

C Accretion= f (RSLR) but, is it mappable?

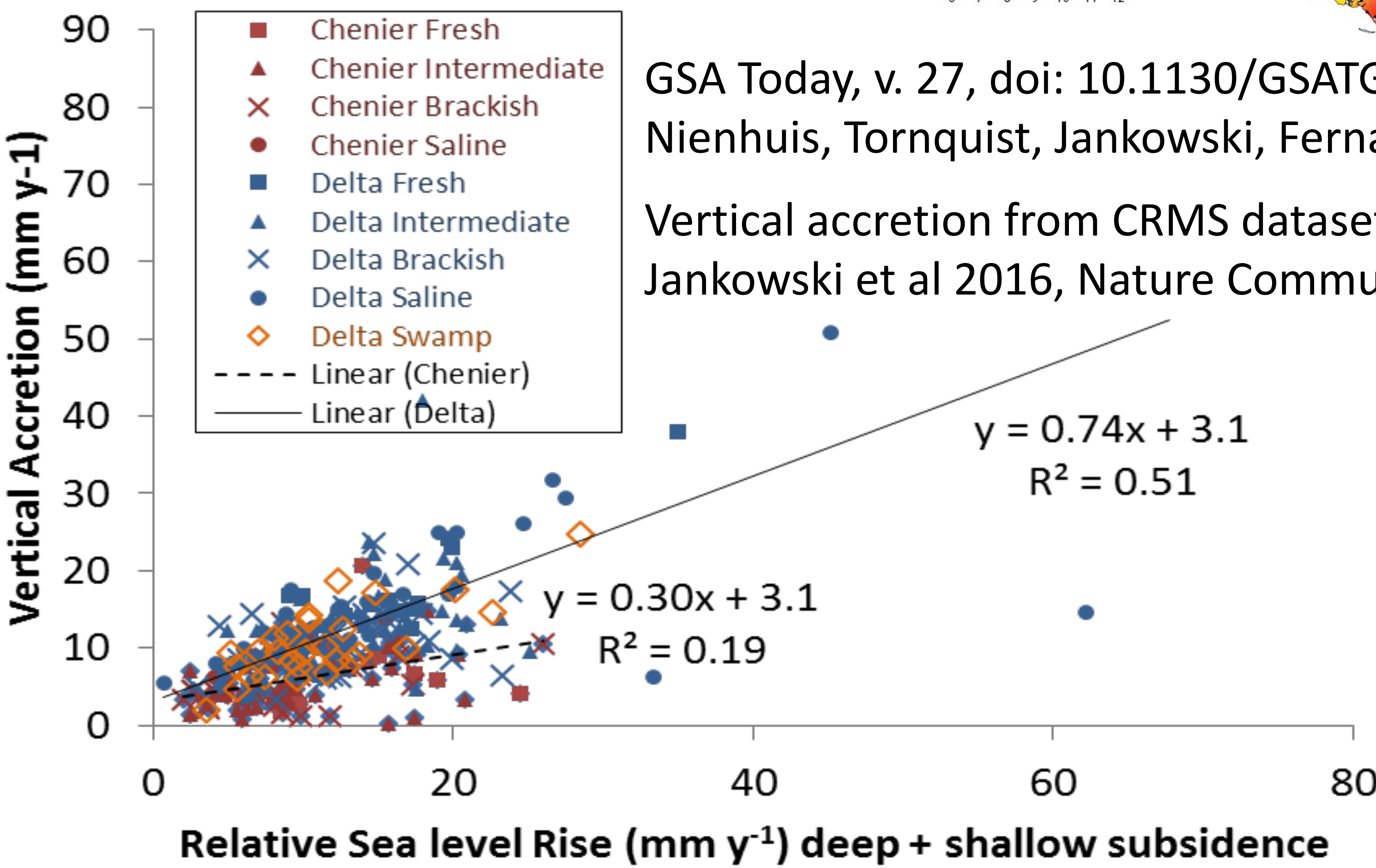
Not by 2 tidegauges in LA

"A New Subsidence Map for Louisiana"

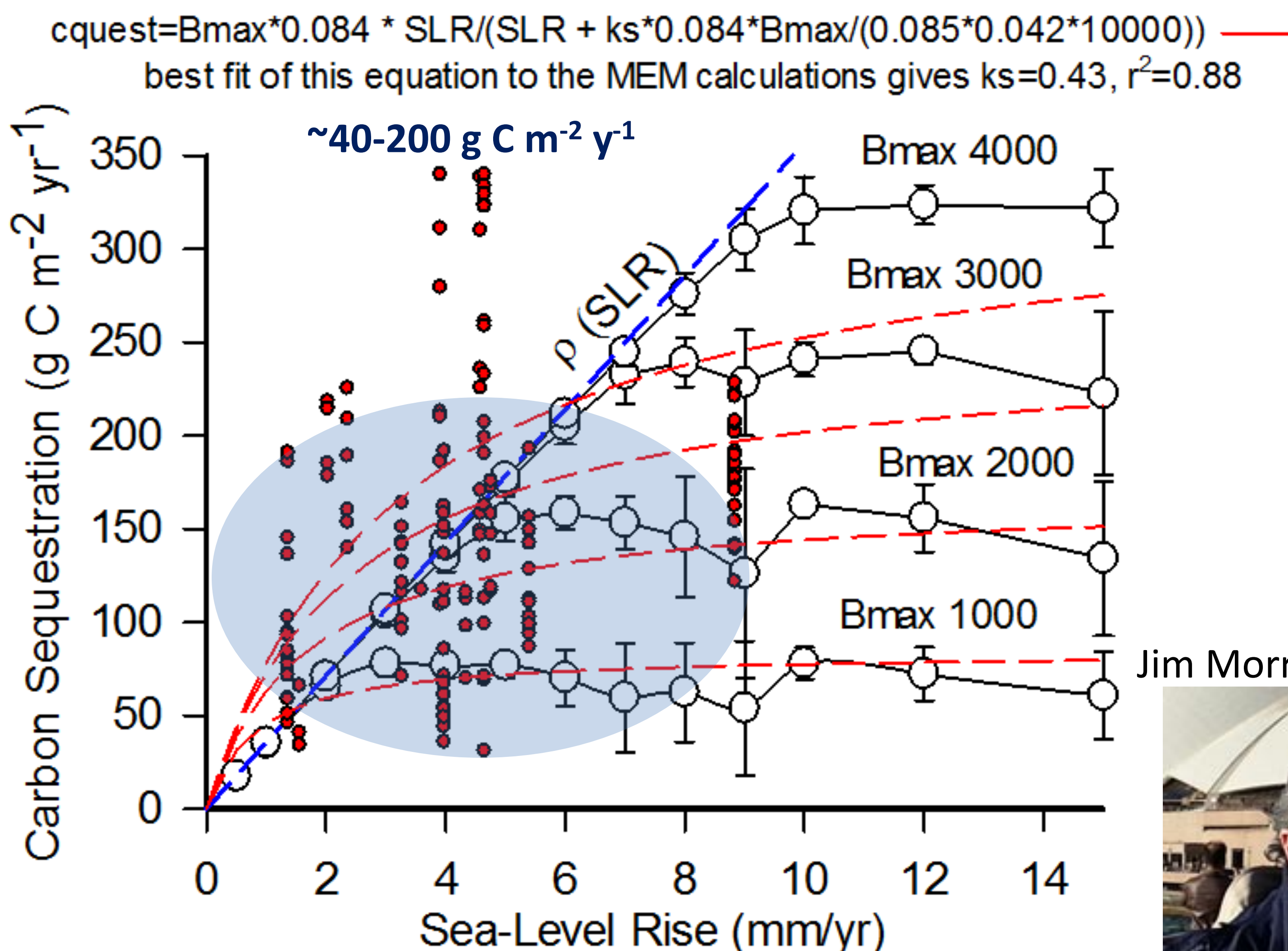


GSA Today, v. 27, doi: 10.1130/GSATG337GW.1, 2017
Nienhuis, Tornquist, Jankowski, Fernandez, and Keough

Vertical accretion from CRMS dataset
Jankowski et al 2016, Nature Communications

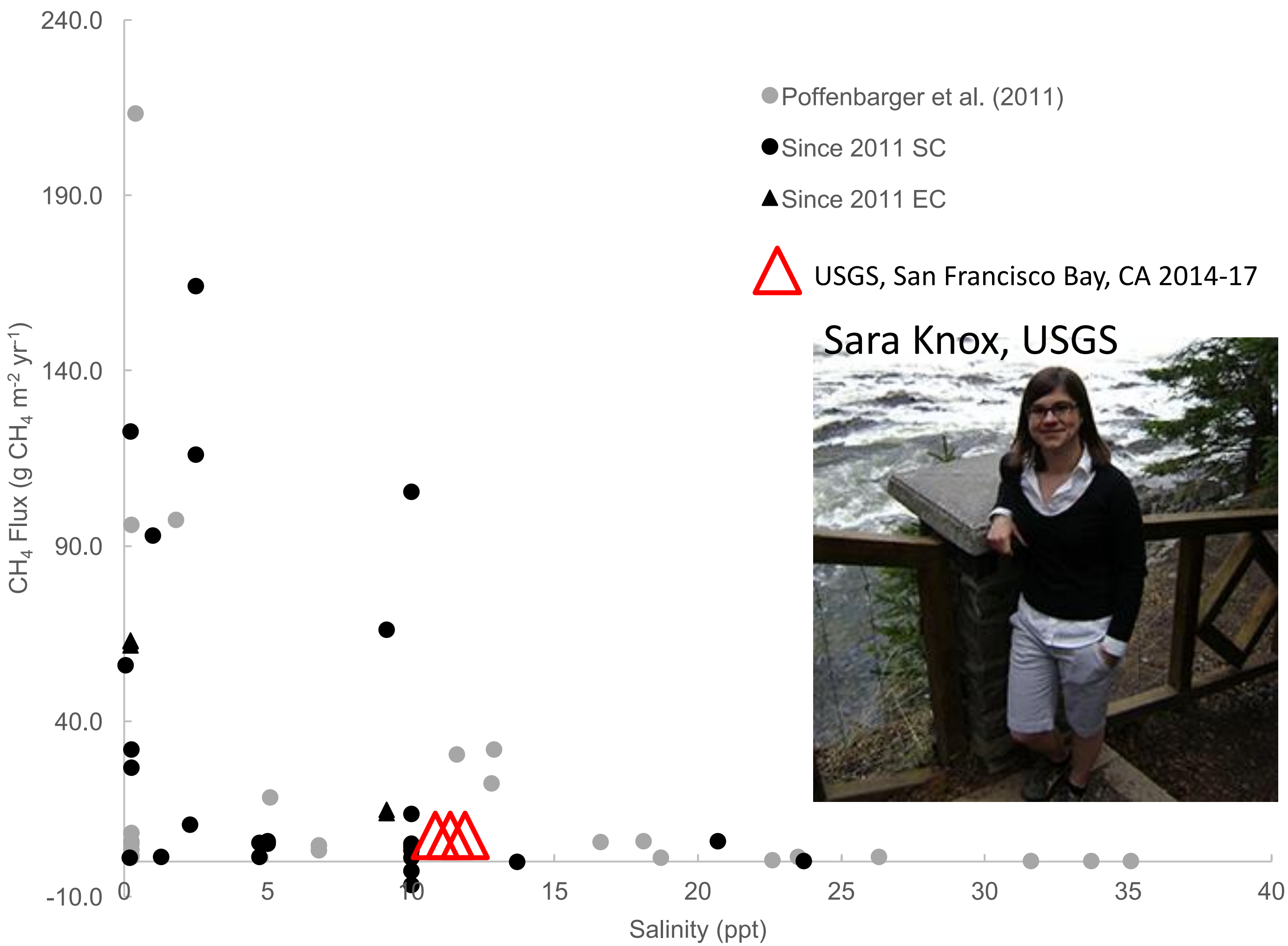


C Accretion = includes allochtonous and labile
C Sequestration = direct and longterm C sink



Jim Morris, U S Carolina

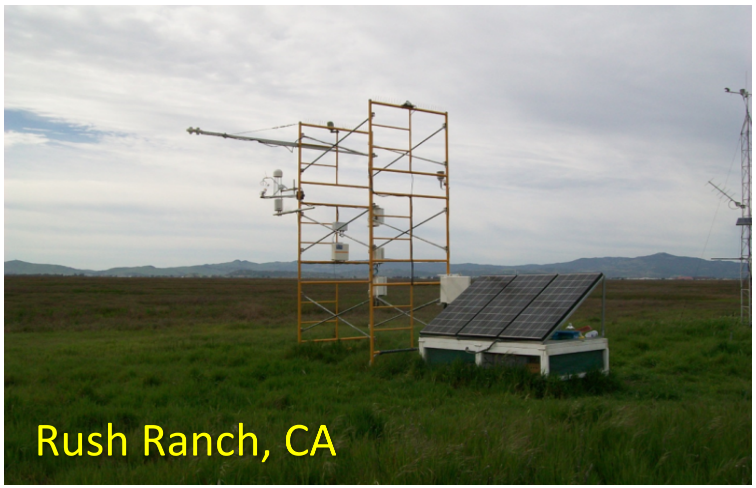
Methane Flux: > 18 ppt is negligible

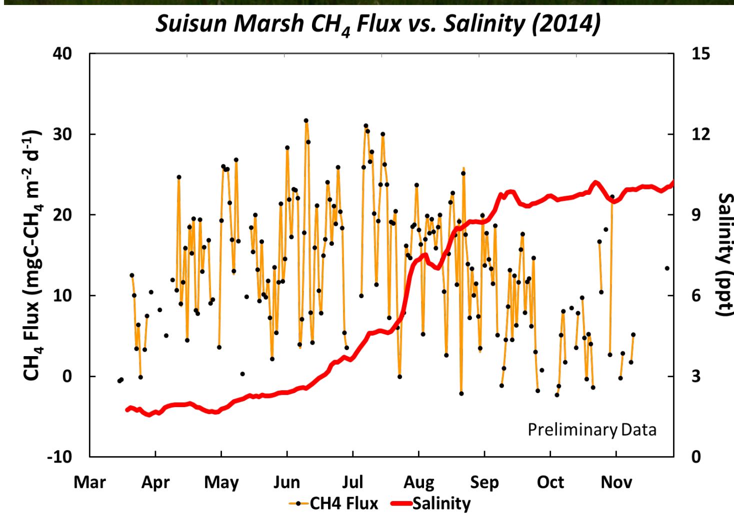


Methane Flux – Eddy Covariance Approach

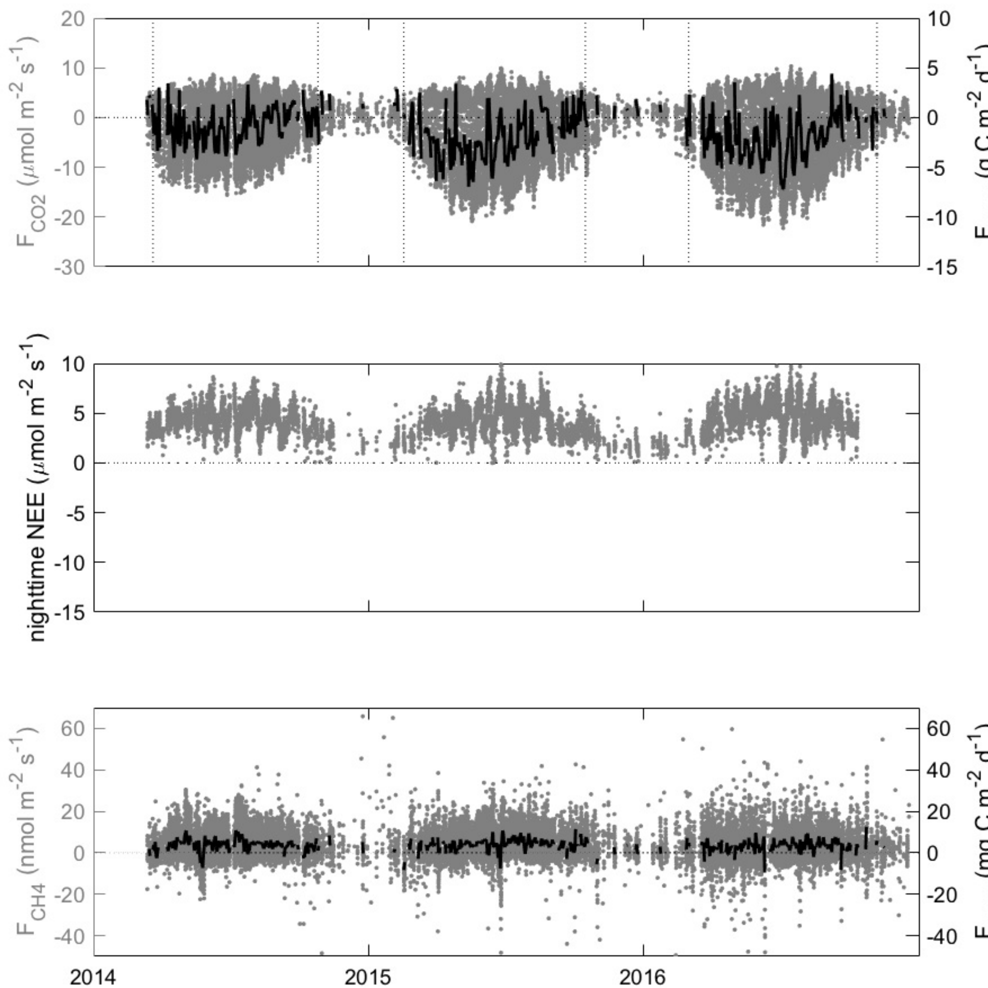
USGS science for a changing world *draft data (Anderson, Knox)*

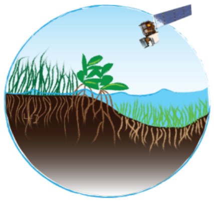
Low Emissions (~ 1.2 g CH_4 m^{-2} y^{-1})



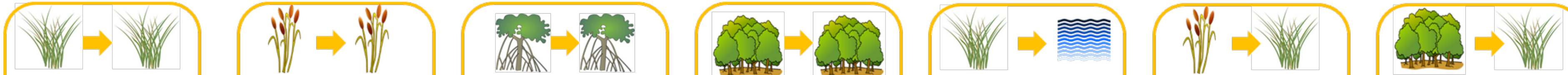


No clear f(salinity) or f(NEE)





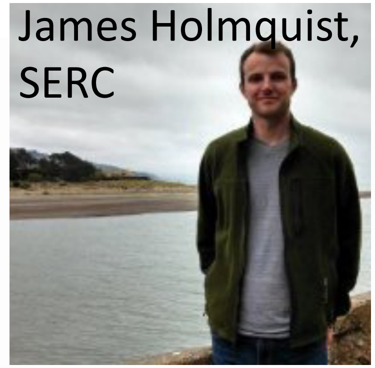
Future – what does this mean **C Accounting** in tidal wetlands?



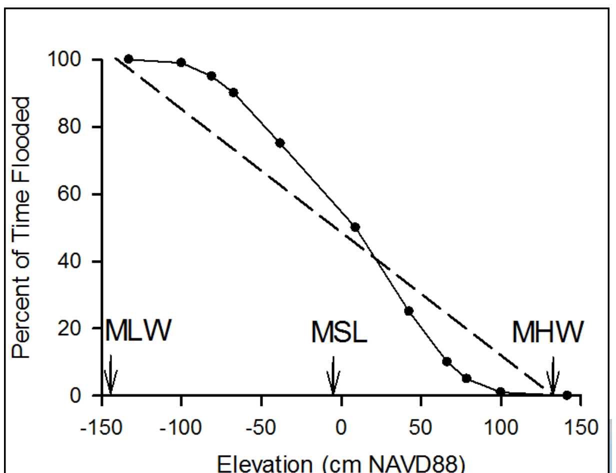
70% EEM-EEM	8% PEM-PEM	10% EFO-EFO	10% PFO-PFO	2% EEM-OW	1% PEM-EEM	1% PSS/FO-EEM
Mg CO_{2eq}/ha	Mg CO_{2eq}/ha	Mg CO_{2eq}/ha	Mg CO_{2eq}/ha	Mg CO_{2eq}/ha	Mg CO_{2eq}/ha	Mg CO_{2eq}/ha
-3.7	-3.7	-3.7	-3.7	+981	-3.7	-3.7
0	0	0	0	+7.4	0	+5
0	-3.9	0	-3.9	0	-3.9	-3.9

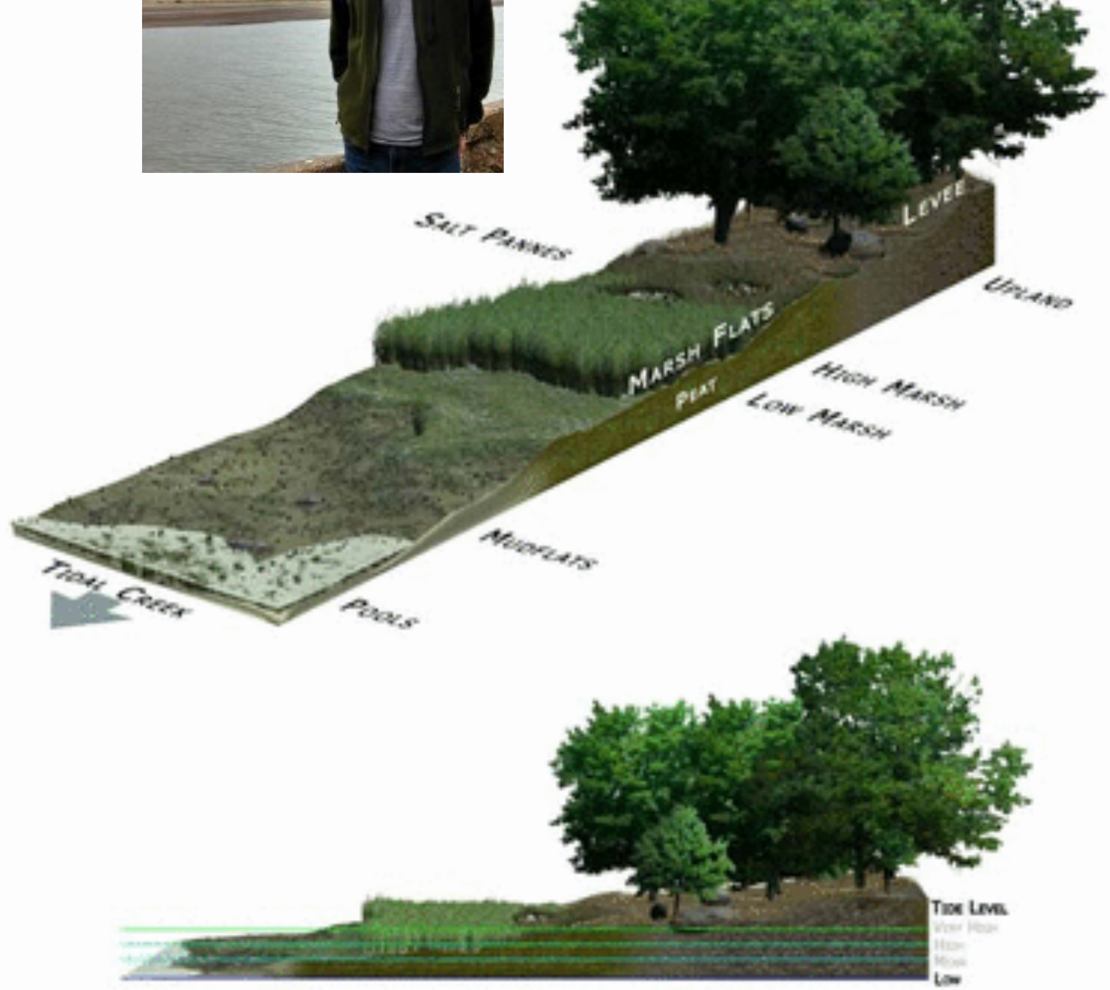
1. Biomass Stocks and Soil Stocks:
   Regional variation is minor
   Remaining variation is salinity and relative elevation (high/low marsh)
2. Accretion is difficult to model due to within-basin variability
3. Key uncertainties are tidal zone map and methane variability

Future – what does this mean **C Accounting** in tidal wetlands?

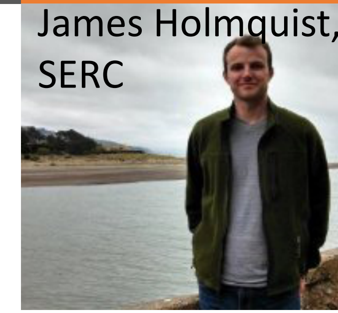


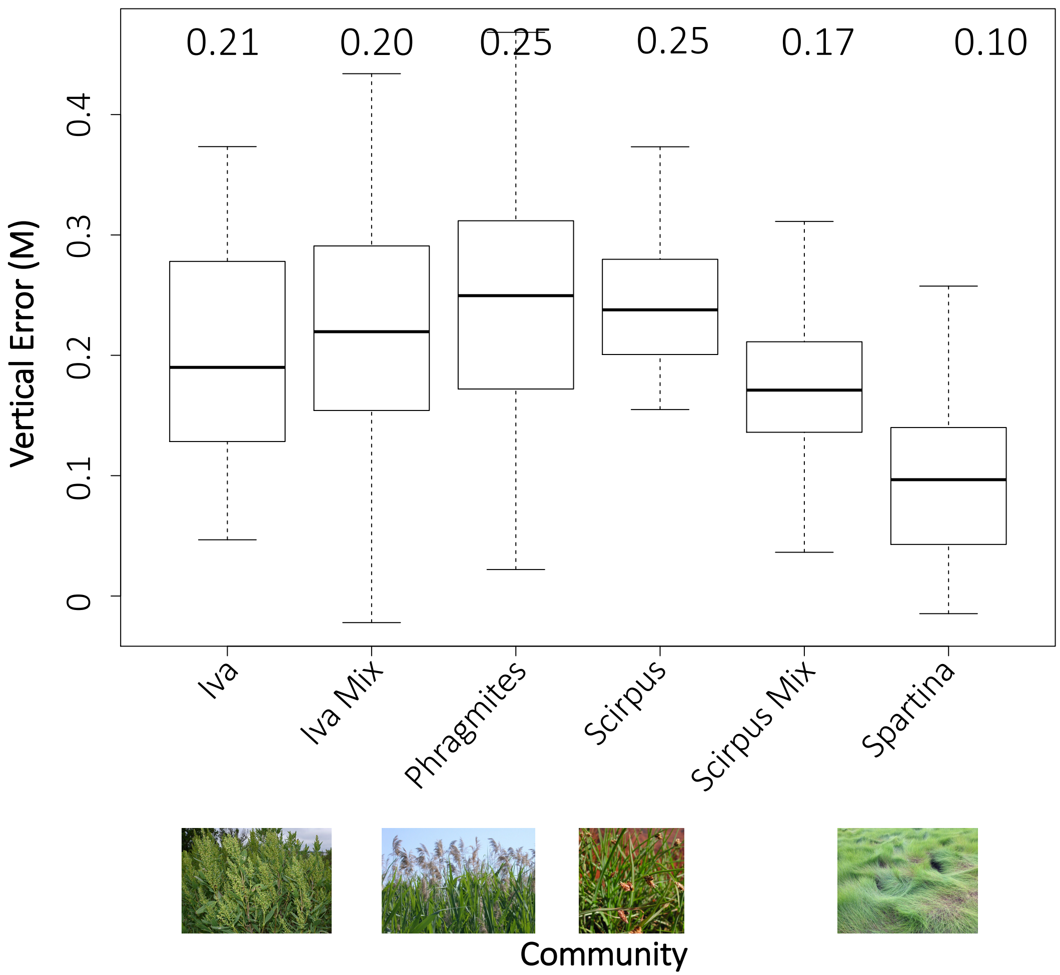
Relevant elevation (cm scale) by merging remotely sensed (LiDAR, spectral) and ground data is a critical modeling and monitoring need for C fluxes.





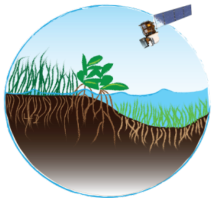
Vertical Errors Prior To Correction by Community (Training Points)



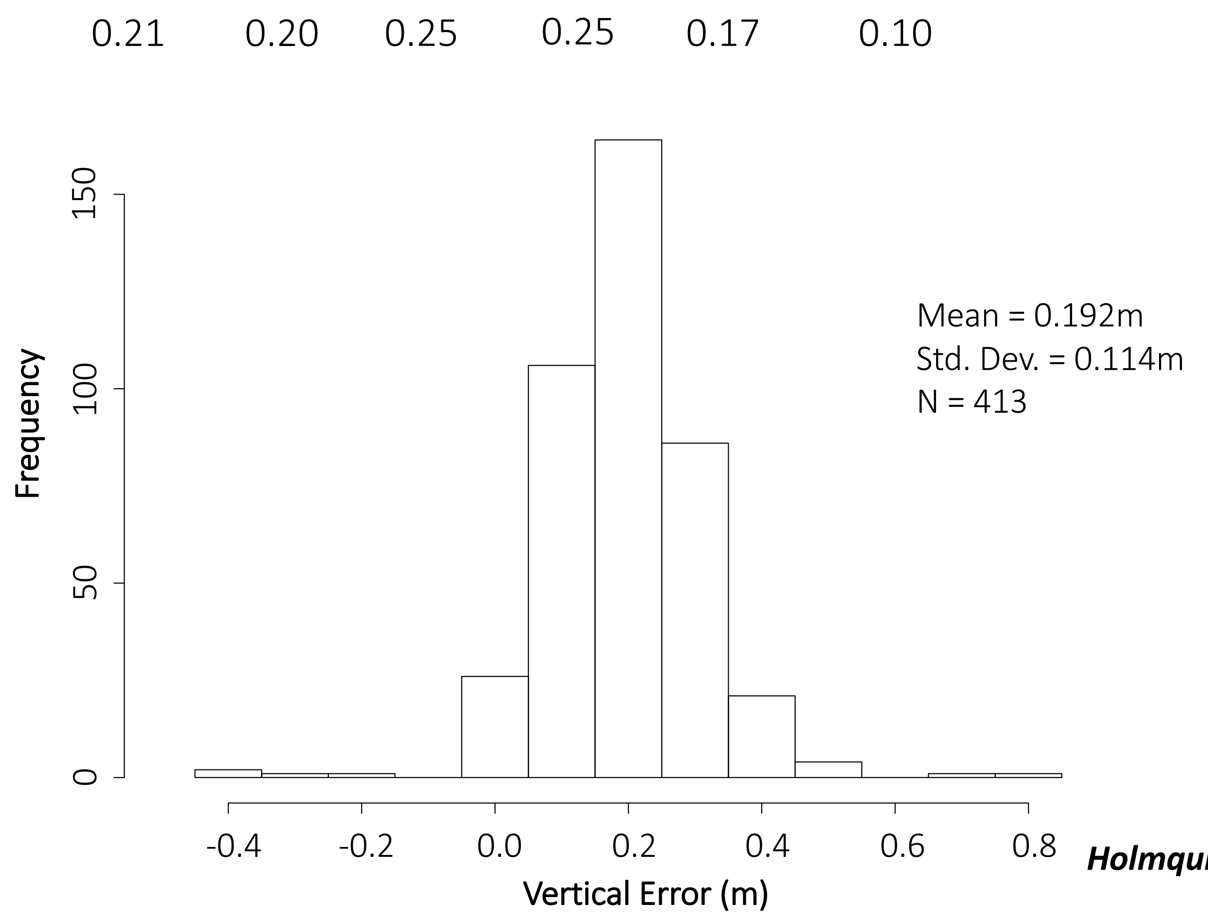


Correction Factors /
Mean Vertical Errors

Holmquist, Riera et al., In Prep.



Vertical Errors Distribution Prior To Correction (Training Points)

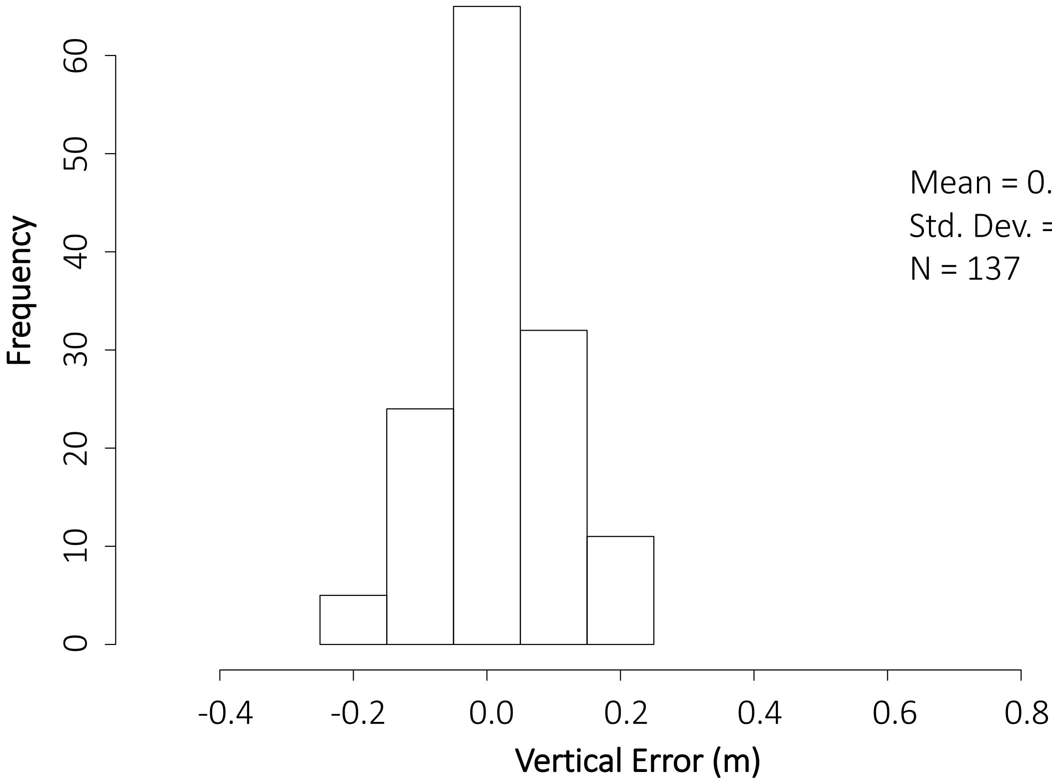


Holmquist, Riera et al., In Prep.

James Holmquist, SERC

Vertical Errors After Correction (Validation Points)

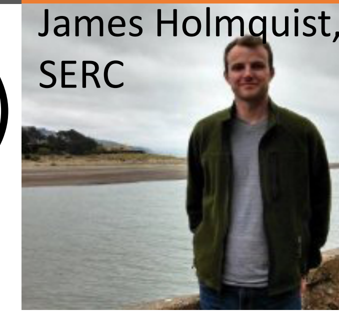
0.21 0.20 0.25 0.25 0.17 0.10

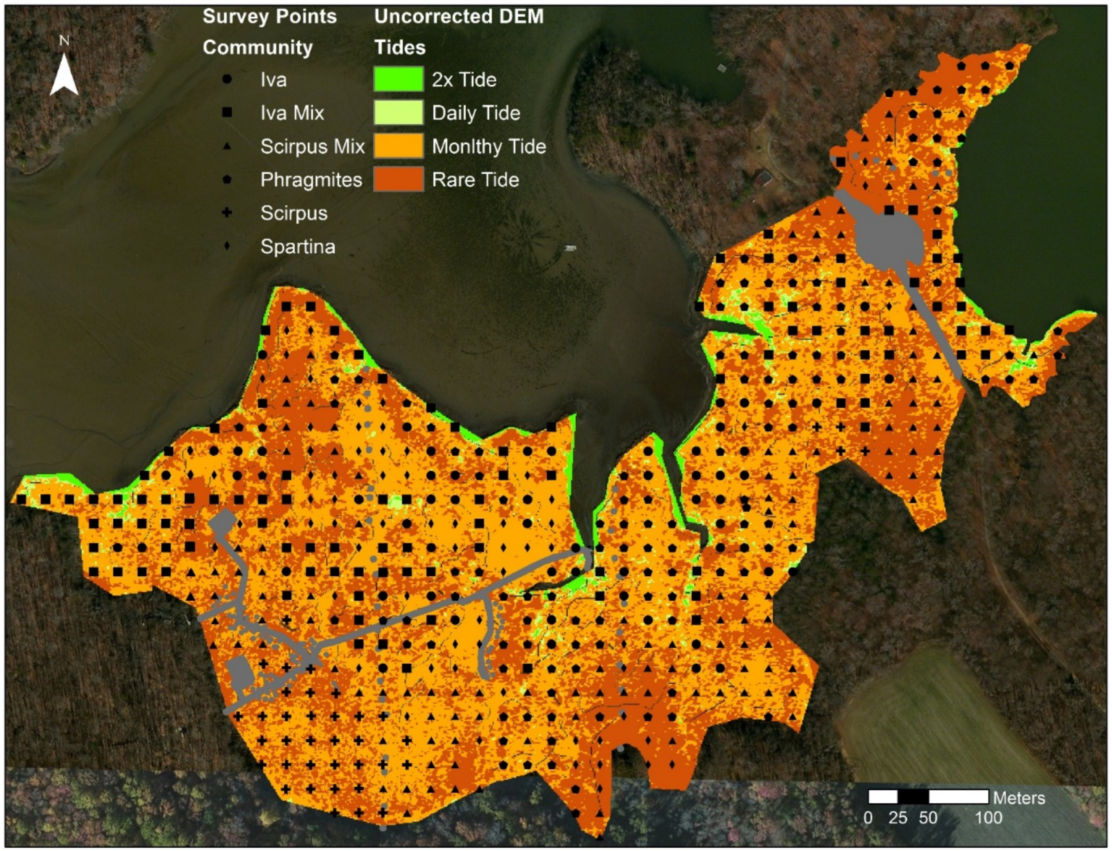


Holmquist, Riera et al., In Prep.

2011 Anne Arundel County DEM (MD)

James Holmquist, SERC

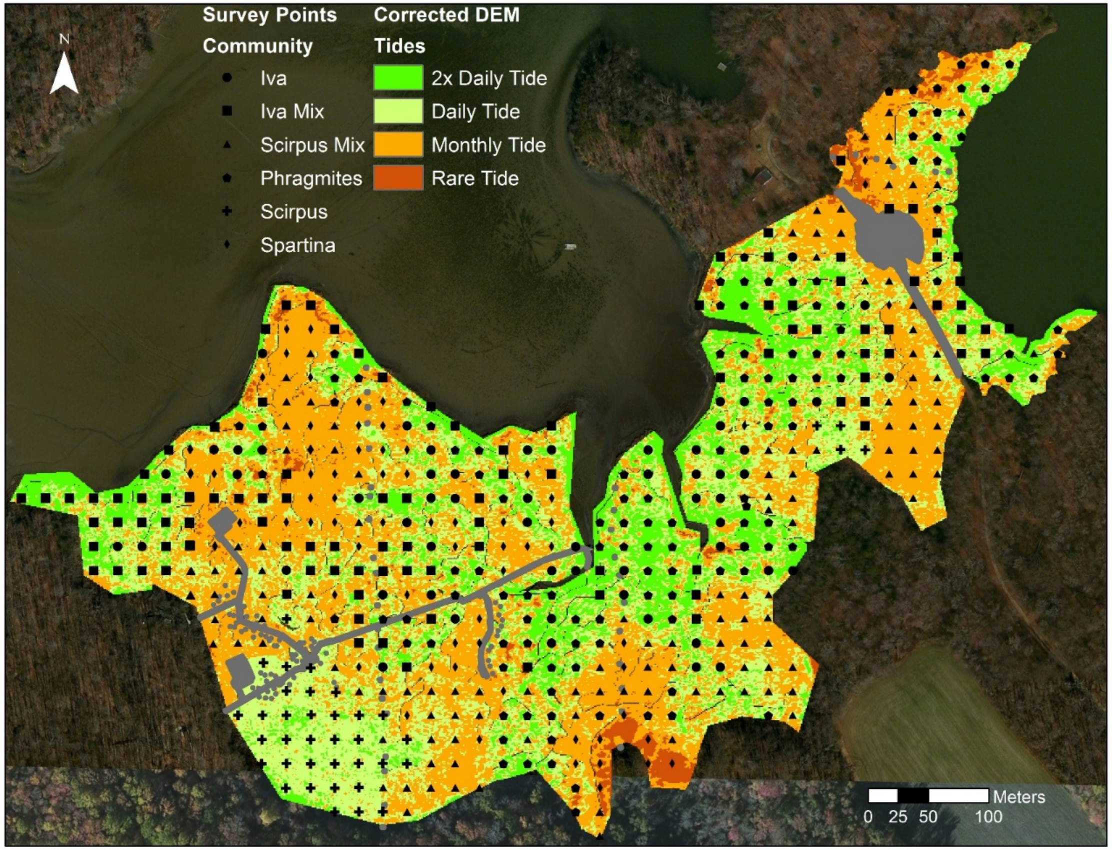




Holmquist, Riera et al., In Prep.

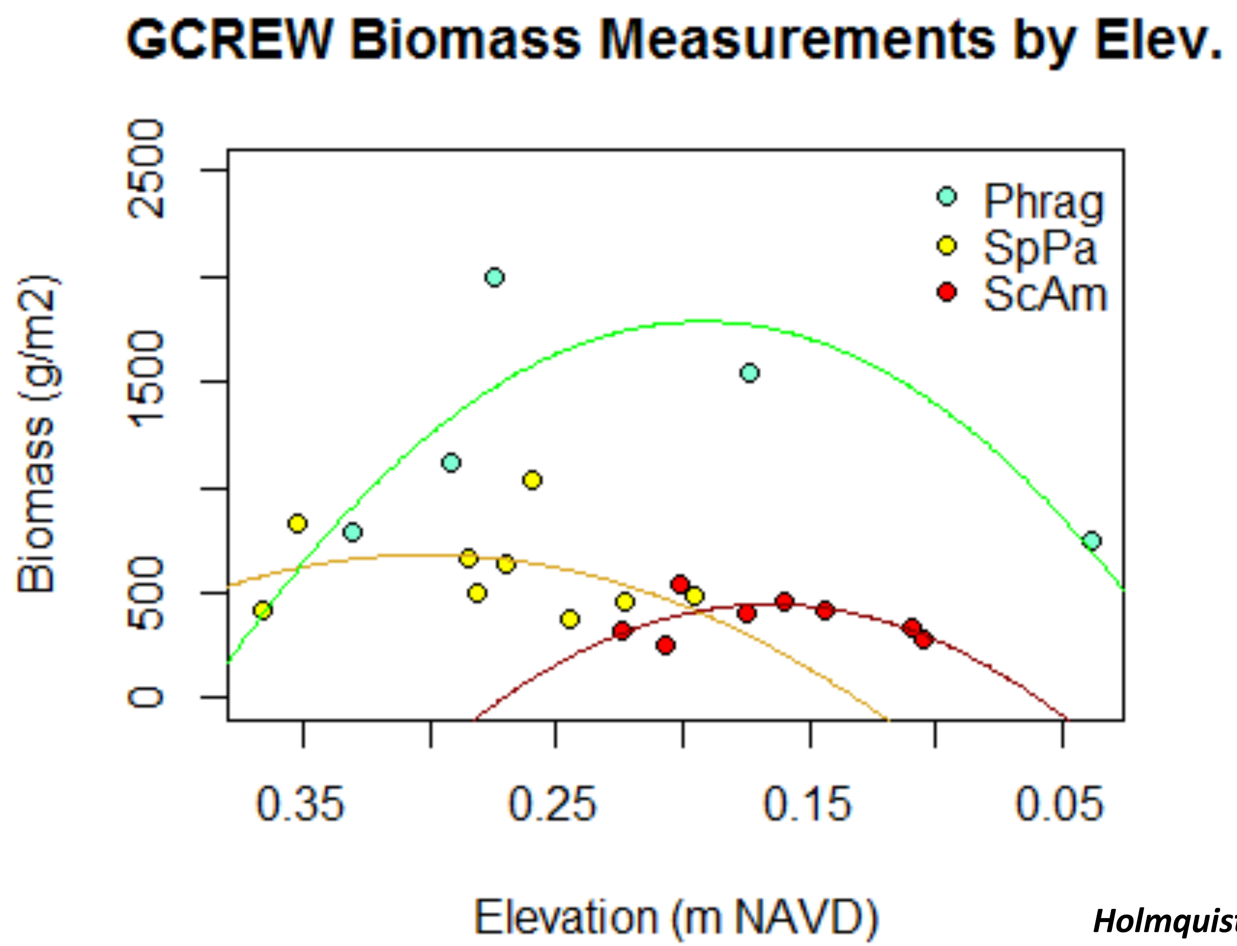
James Holmquist, SERC

Corrected 2011 Anne Arundel County DEM



Holmquist, Riera et al., In Prep.

Model Validation with Biomass



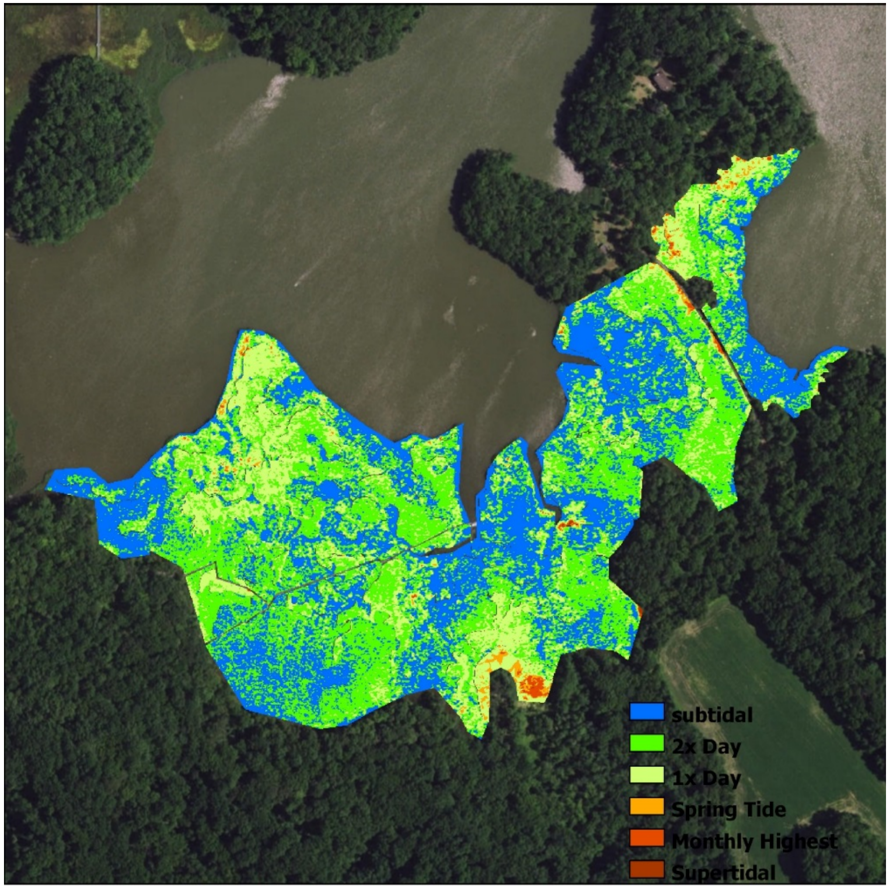
Holmquist, Byrd, Megonigal, In Prep.

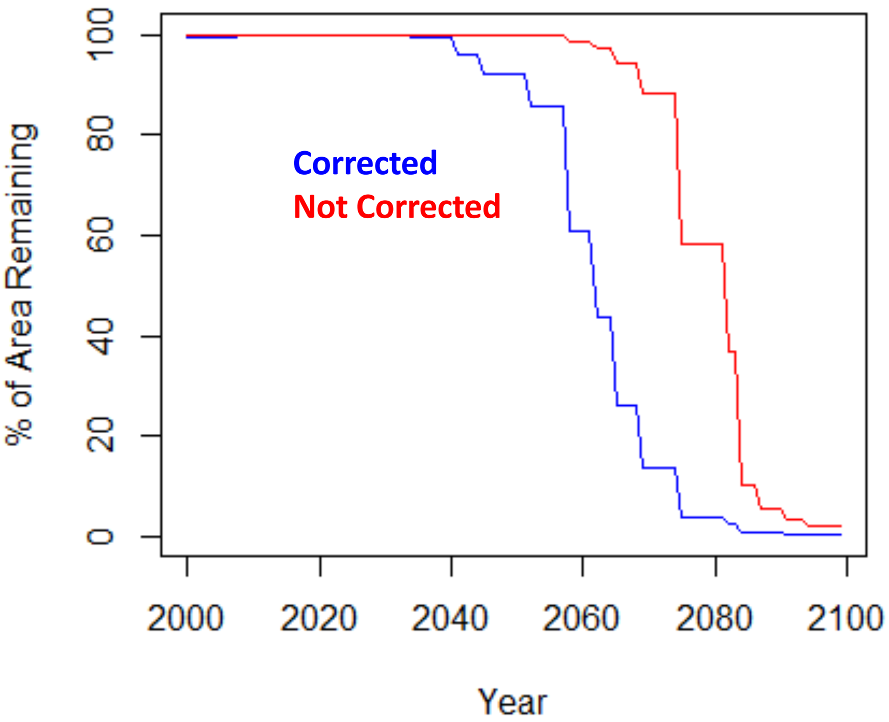
MEM projections (draft) – to illustrate elevation sensitivity

James Holmquist, SERC

Corrected

Not Corrected



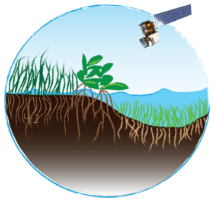


Holmquist, Riera et al., In Prep.

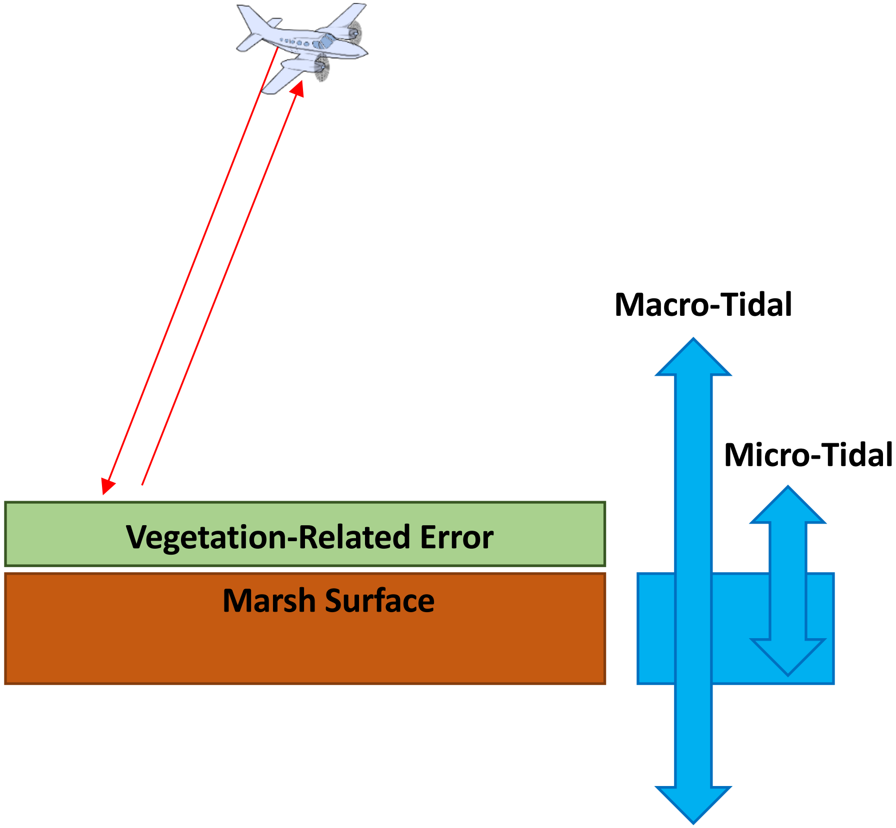
G-CREW Bias is typical.
Lit. review average bias is +22 cm.

Site	Cit	n	RMSE	ME
GCREW - before	Holmquist, Reiera, et al., In Prep	413		0.192
Grays Harbor	Buffington et al., 2016	1166	0.466	0.419
Willapa	Buffington et al., 2016	420	0.392	0.382
Siletz	Buffington et al., 2016	1113	0.304	0.269
Bull Island	Buffington et al., 2016	1166	0.145	0.078
Bandon	Buffington et al., 2016	1495	0.118	0.016
Petaluma	Buffington et al., 2016	623	0.289	0.282
Black John	Buffington et al., 2016	203	0.278	0.264
San Pablo	Buffington et al., 2016	374	0.265	0.253
Fagan	Buffington et al., 2016	578	0.256	0.242
Coon Island	Buffington et al., 2016	728	0.273	0.26
China Camp	Buffington et al., 2016	697	0.233	0.228
Corte Madera	Buffington et al., 2016	399	0.182	0.228
Morro	Buffington et al., 2016	2247	0.109	0.082
Mugu	Buffington et al., 2016	1465	0.155	0.154
Seal Beach	Buffington et al., 2016	3208	0.168	0.147
Newport	Buffington et al., 2016	962	0.183	0.14
Tijuana	Buffington et al., 2016	896	0.113	0.084
Sapelo Island - Total	Hladik and Alber, 2012	1380	0.18	0.1
lower Apalachicola River Marsh	Mederios et al., 2015	229	0.65	0.61
	SUM	19762	Avg:	0.2215

Bias Overwhelmingly Positive: Marsh DEMs are too high.

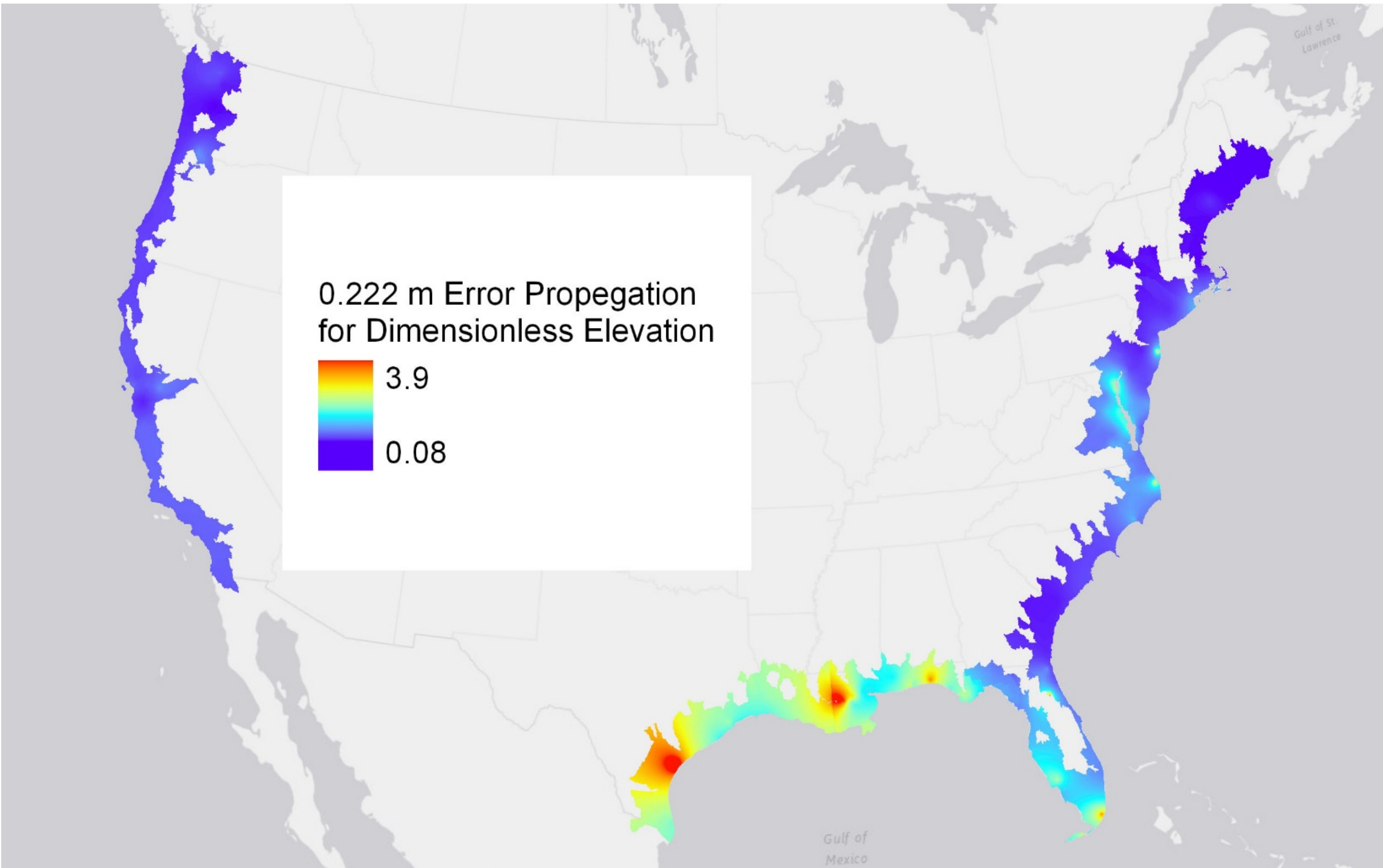


Error Propagation Varies Geographically Based on Tidal Range



- Tidal Range = High Tide (MHW) - Mean Sea-Level (MSL)
- Tidal Range varies across U.S.:
  - Small for Gulf Coast, FL, and Chesapeake Bay,
  - Large for PNW and New England.
- Bias propagates with different levels of seriousness depending on tidal range.

Error Propagation: Microtidal Gulf Coast is most susceptible to overestimated resilience

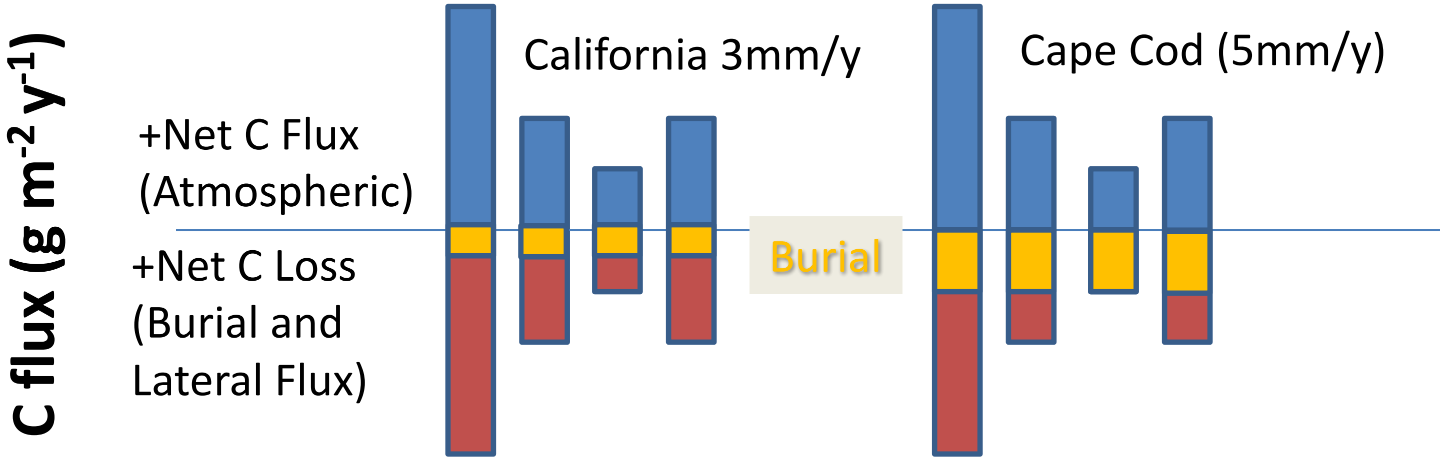


Future: What does this mean for **C Science in tidal wetlands?**

BIG QUESTIONS COMING OUT:
Why do soils saturate with carbon?
Why do compaction and decomposition rates appear to be connected?

PROPOSAL:

burial = constant (may be variable with annual SLR or not; suggest decadal scale)
lateral C flux IS proportional to NEE



Lateral flux = NEE – Burial : Burial = NEE-Lateral : NEE = Burial + Lateral

Future – What does this mean for **C scientists?**

We've got a lot of exciting work to do and datagaps to fill.