# Carbon Sequestration and Greenhouse Gas Budgets in Restored Tidal Wetlands

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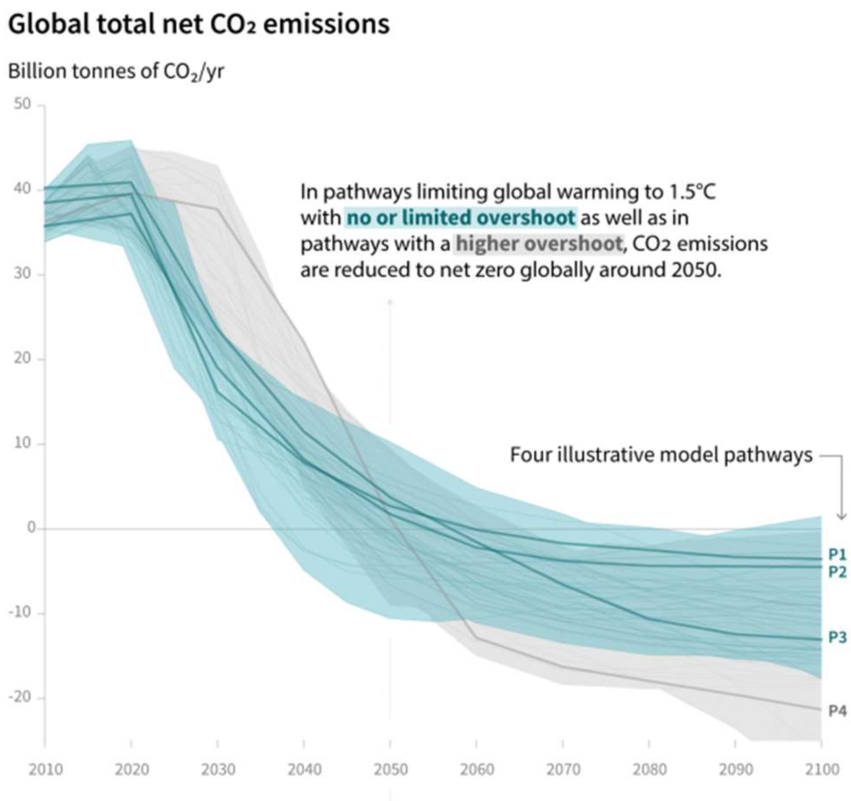
# Outline

I. Natural Climate Solutions and Carbon Markets
II. Carbon Cycling in Tidal Wetlands
III. 2 Local Case Studies: Eden Landing Ecological Reserve and Suisun Marsh

# Negative Emissions

- To avoid >1.5°C, some form of negative emission tech with carbon storage on land or sequestration in geological reservoirs is required



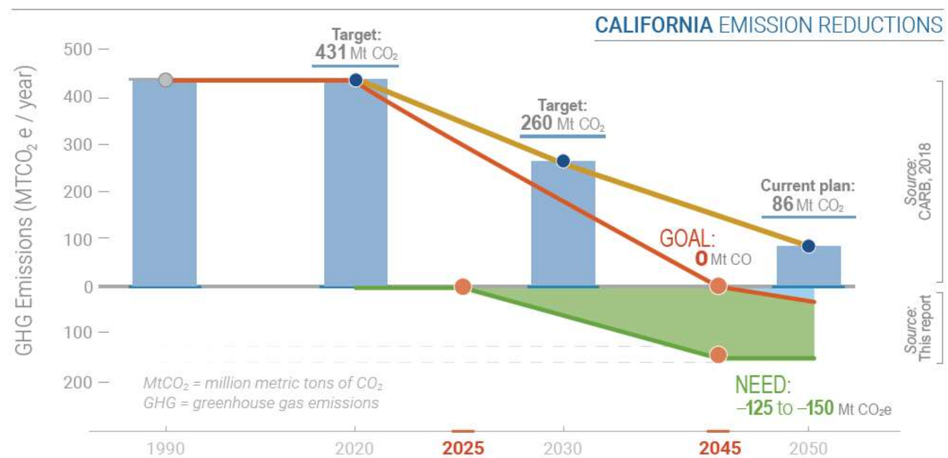
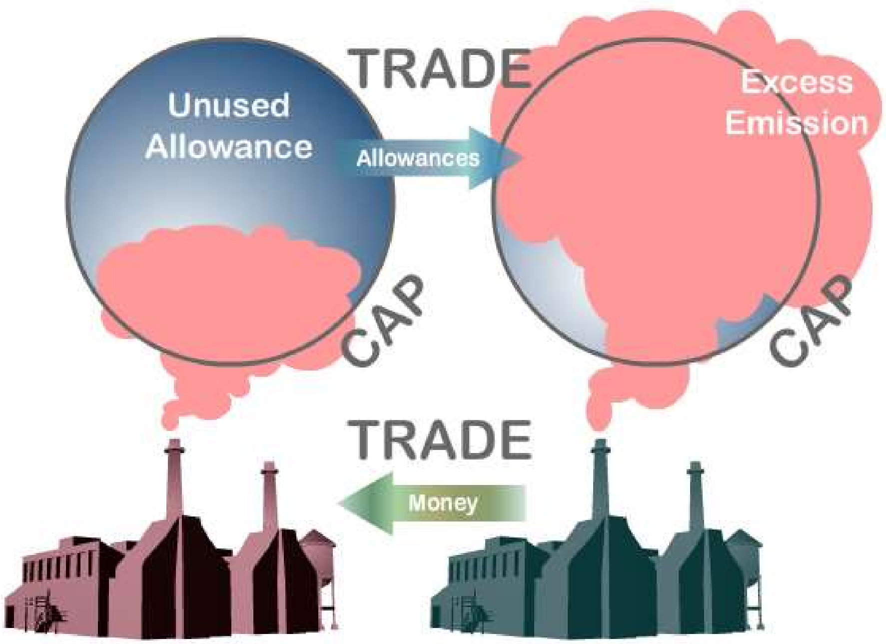




**Figure ES-1.** *Goals of California's emissions plan extrapolated to 2045 (CARB, 2017) with negative emissions estimates from this report.*

*Baker et al. Getting to Neutral, 2019*

*IPCC Special Report 2018*

# Carbon Market Systems




Solidarity.org

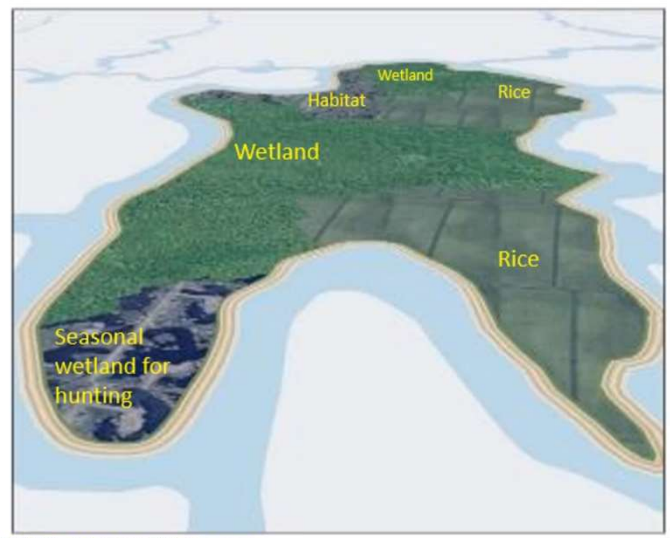
American Carbon Registry

*Arcadis*

*Texas Coastal Wetland restoration*

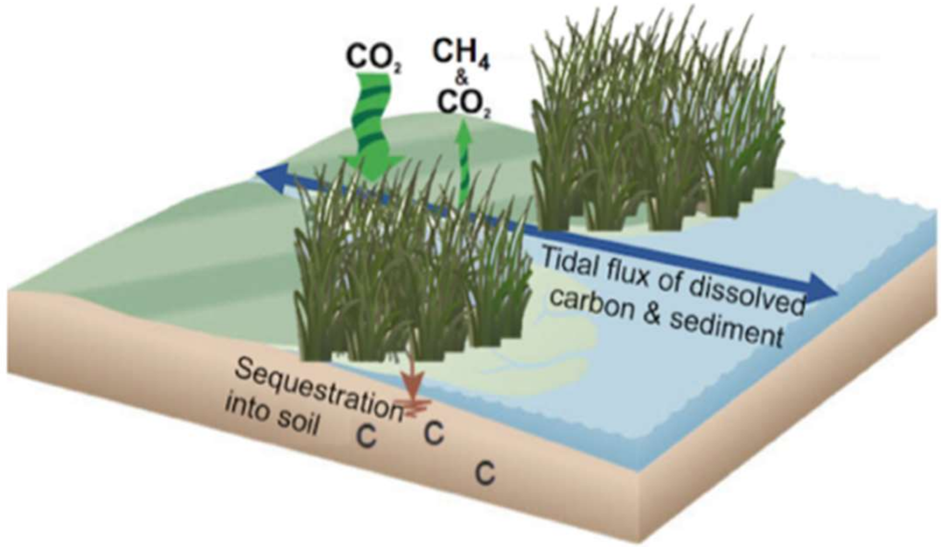
# California Carbon Offset Protocol

- Offset protocol approved by American Carbon Registry
  - CA Air Resources Board recommended protocol for adoption
- First issuance of voluntary credits Spring 2020
- CA Dept of Water Resources 1,700 acres wetland restoration project
  - Received $62/acre-- in compliance market likely $200-300/acre
- More projects in the pipeline


*Deverel, Hydrofocus*

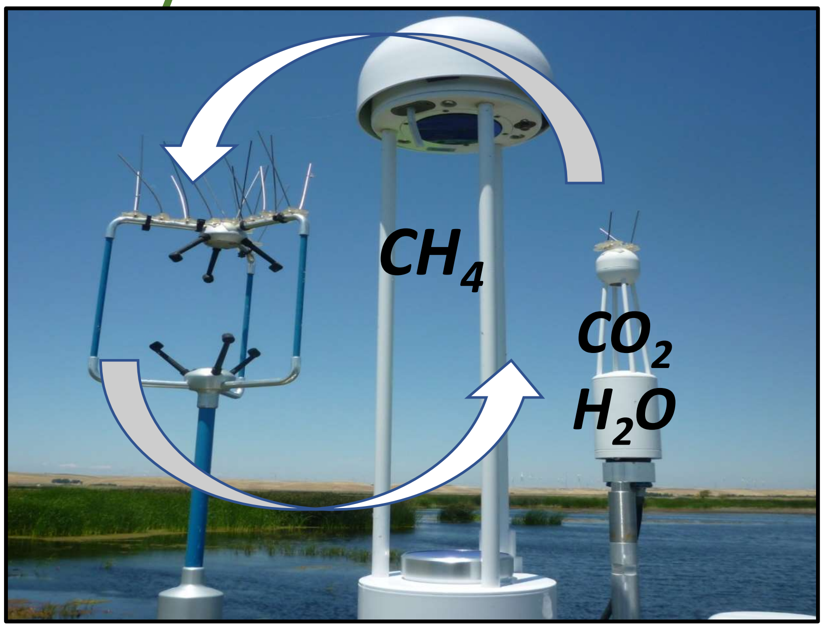
# Tidal Wetland Carbon Cycling

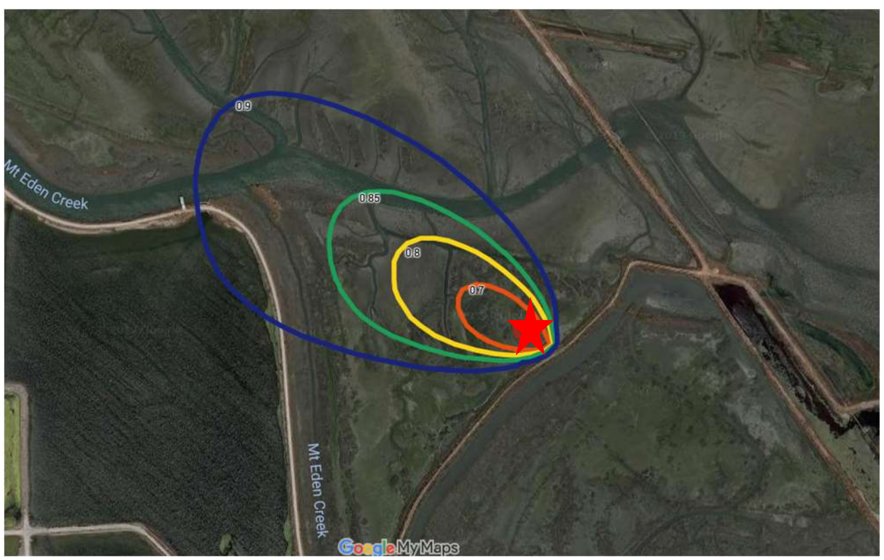



$$NECB = NEP - F_{CH4} - F_L$$

- Net ecosystem production (NEP, also known as –NEE; net ecosystem exchange of $CO_2$) is the net result of photosynthesis (GPP) and ecosystem plant and microbial respiration ($R_{eco}$)
- $F_{CH4}$ is methane ($CH_4$) flux
- $F_L$ is the net lateral (hydrologic) flux including fluxes of DIC (dissolved inorganic carbon), DOC (dissolved organic carbon), POC (particulate organic carbon) and methane

# Atmospheric Carbon Exchange: Eddy Covariance




Measure covariance of vertical wind velocity and concentrations of trace gases

$$F = \overline{w'c'}$$

*c* = mixing ratio of trace gas
*w* = vertical wind velocity

$$w' = w - \bar{w}$$

$$c' = c - \bar{c}$$

# Lateral Carbon Exchange

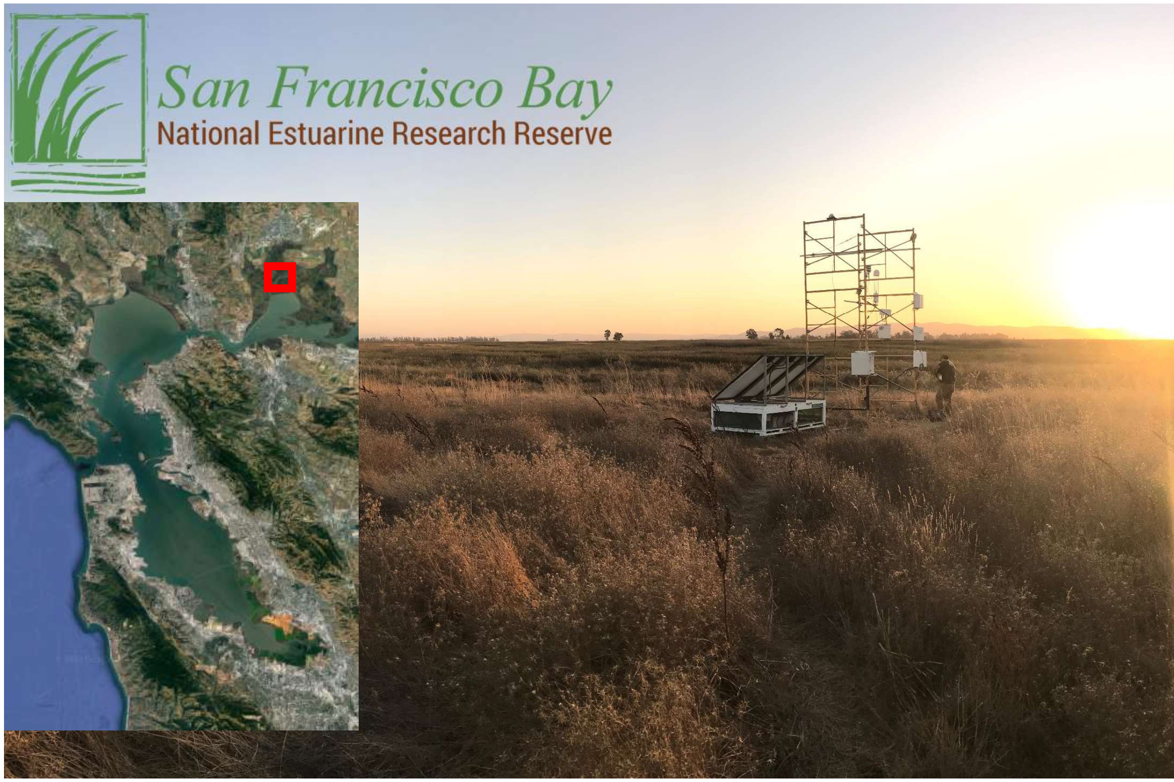
Field sensors deployed in tidal channel measuring:

1. Water velocity, depth
2. Turbidity (proxy for POC)
3. fDOM (proxy for DOC)
4. Dissolved $CO_2$ (proxy for DIC)

Calculate flux from mass volume of water exchange*concentration on Carbon

Kyle Nakatsuka, USGS

# Suisun Marsh (Rush Ranch)





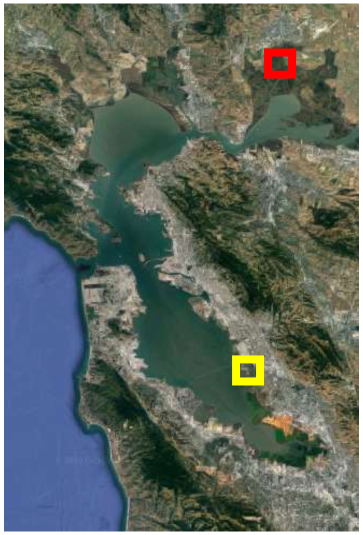
- Most extensive brackish marsh complex in California
- Mean tidal range: 1.72 m, Salinity range: 1 – 9 ppt (mesohaline)
- Water quality measurements recorded since 1995 (blue pin)
- $CO_2$ and $CH_4$ atmospheric exchange collected since 2014 (red pin)
- Lateral C flux (DIC, DOC, POC) since 2018

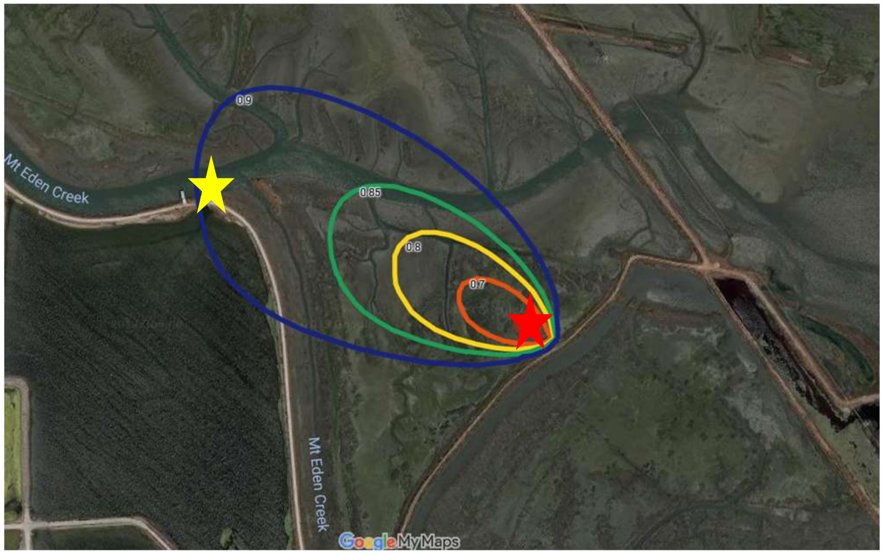
*Bogard et al. 2020 GBC, Knox et al. 2018, JGR Biogeosciences; Callaway et al. 2012, Estuaries and Coasts*

# Eden Landing Ecological Reserve

- Hayward, California
- Measuring atmospheric carbon fluxes since 2018
- Installed hydrologic flux station Aug 2020

- Mount Eden Creek Marsh
- Restored tidal marsh (2008)
- Salinity >30 ppt
- Mean elevation of 1.7m
- Tidal range of 2.4m
- Pickleweed (*Salicornia*) and Cordgrass (*Spartina*)

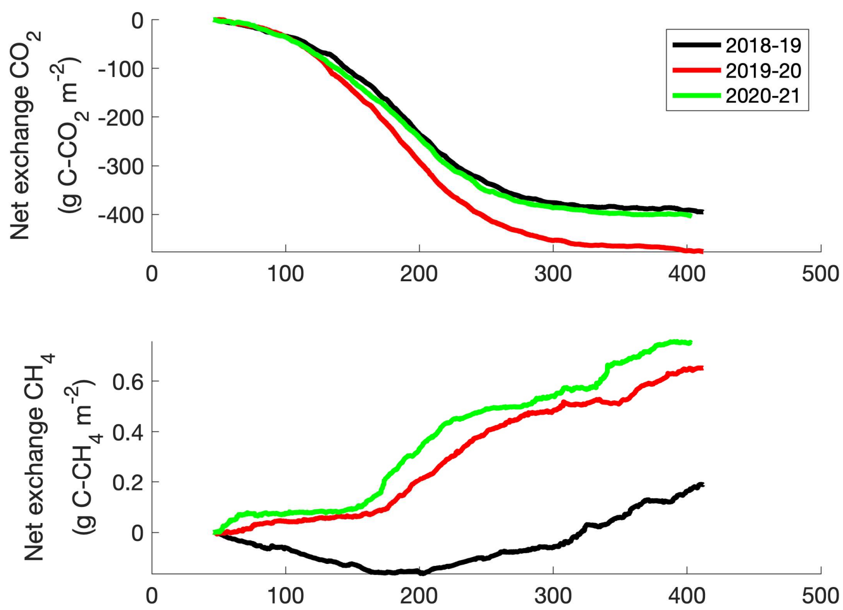





Kyle Nakatsuka, USGS

# Atmospheric Carbon Fluxes at Eden Landing and Rush Ranch

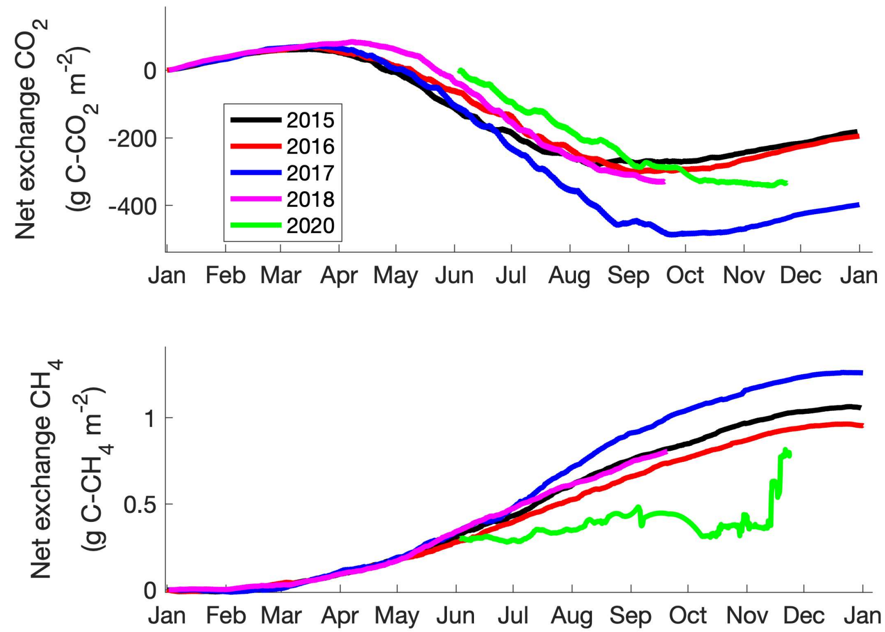
## Eden Landing




- Average Annual removal of $CO_2$= **424.8** g C-$CO_2$ $m^{-2}$ $yr^{-1}$ (SD= 44.9)

- Average Annual emission of $CH_4$ = **0.5** g C-$CH_4$ $m^{-2}$ $yr^{-1}$ (SD=0.3)

## Rush Ranch

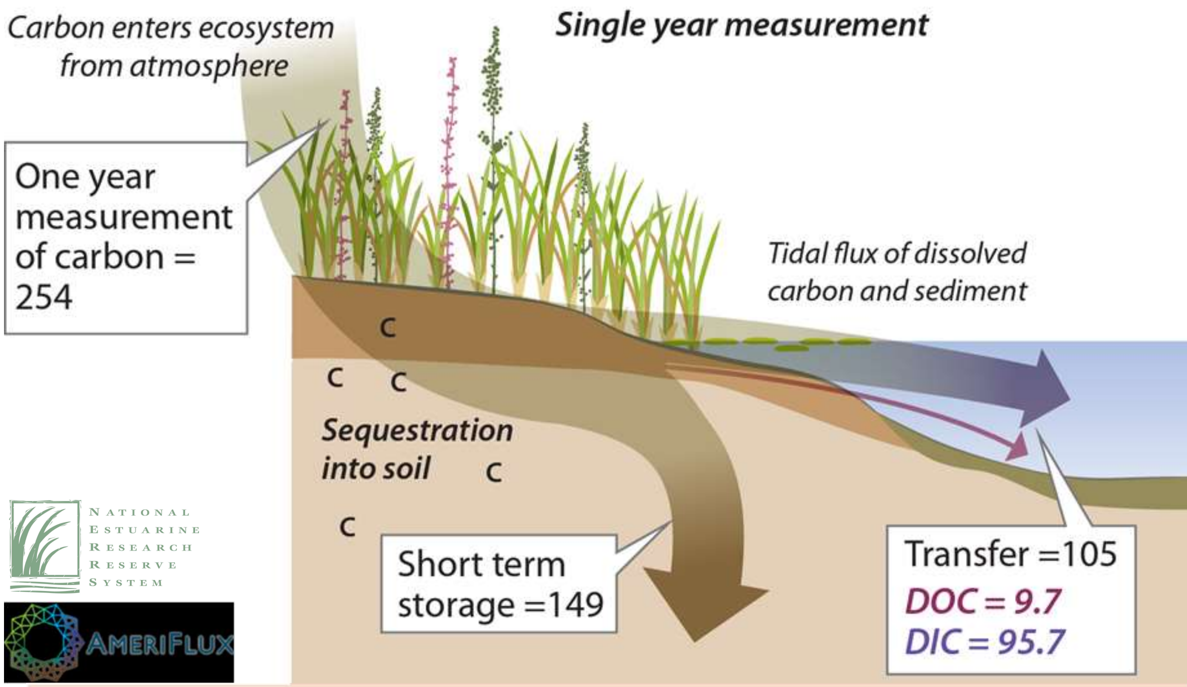



- Average Annual removal of $CO_2$= **287.3** g C-$CO_2$ $m^{-2}$ $yr^{-1}$ (SD= 94.5)

- Average Annual emission of $CH_4$ = **0.91** g C-$CH_4$ $m^{-2}$ $yr^{-1}$ (SD=0.3)

# Monitoring the Suisun Marsh: Carbon Budget

Instrumentation collecting high-frequency $CO_2$ and $CH_4$ exchange





Between 47 – 59 % of fixed carbon retained on site

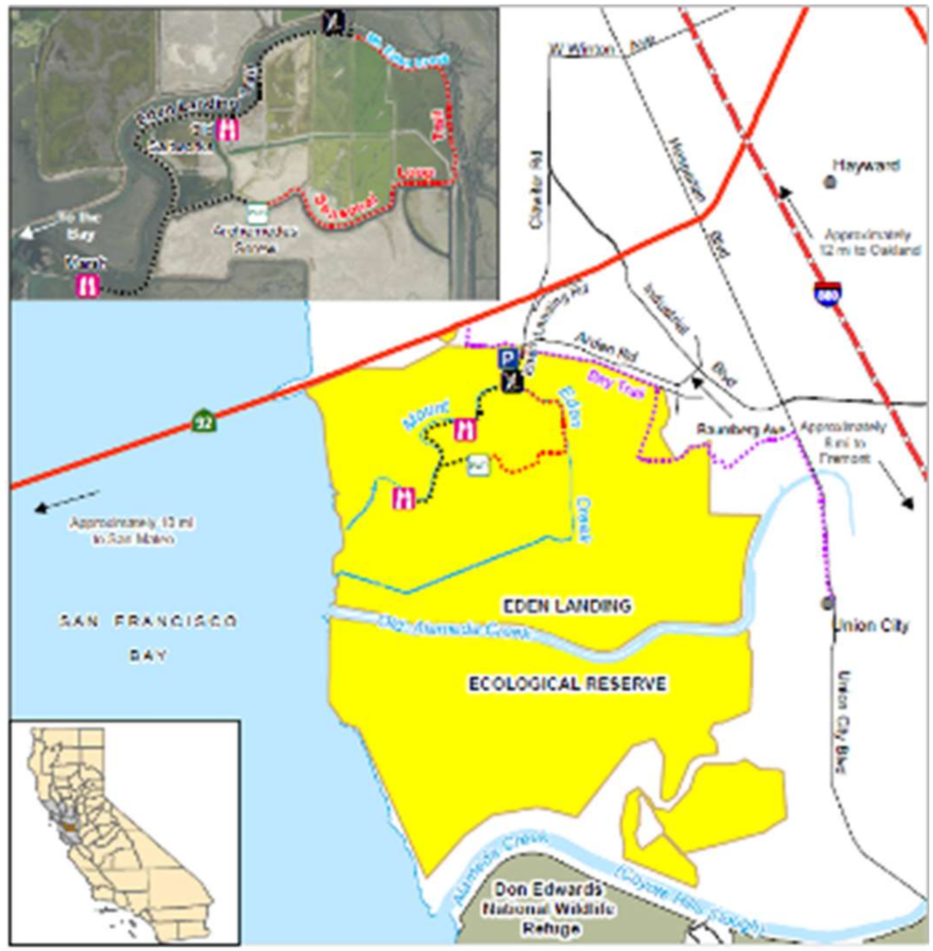
Next Steps:

- Expand analysis across multiple years
- Preliminary analysis show similar dynamics at EL

*Bogard et al. 2020 GBC*

# Back of Envelope Upscaling

- Assume 50% C remains in wetland
  - 200 g C $m^{-2}$ $yr^{-1}$
- Eden Landing Ecological Reserve =6400 acres
- 5184 MT C $yr^{-1}$
- Or 4000 cars off the road



# Future Work

- Constrain the DIC fluxes ($CO_2$, carbonate, bicarbonate)
- Calculating NECB for both sites for multiple years
- Integrate findings into a biogeochemical model
- Publish model online in accessible format

# Summary

- Tidal Wetlands in San Francisco Bay remove carbon from the atmosphere and store it in soils
- 2 case studies demonstrate high $CO_2$ removal with ~50% stored in the wetland
- tidal wetlands with salinity range of 9-35ppt show negligible $CH_4$ emissions
- A GHG protocol has been written to help finance wetland restoration in the Bay Delta and is recommended for adoption in the CA compliance market
- Tidal wetland restoration is a natural climate solution that can play a significant role in how we fight climate change

# Acknowledgements

COAST

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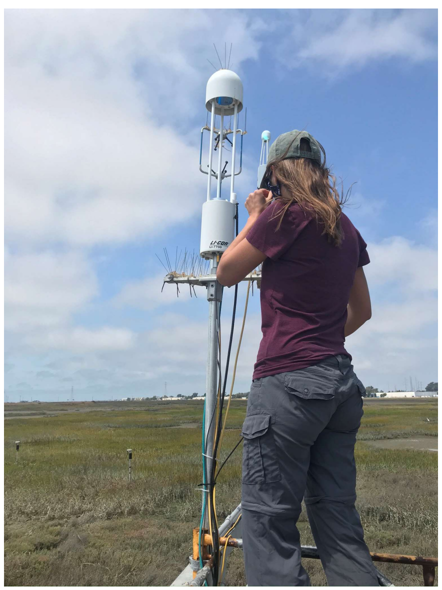

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