Modeling sea-level rise vulnerability of tidal wetlands across south San Francisco Bay

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September 10, 2024
South Bay Salt Pond Restoration Project
Brown Bag Science Speaker Series

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ACKNOWLEDGEMENTS

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Field and lab assistance: James Hada, Desmond Mackell, Mckenna Bristow

Project Funders & Partners

National Wildlife Refuge System

U.S. Fish & Wildlife Service

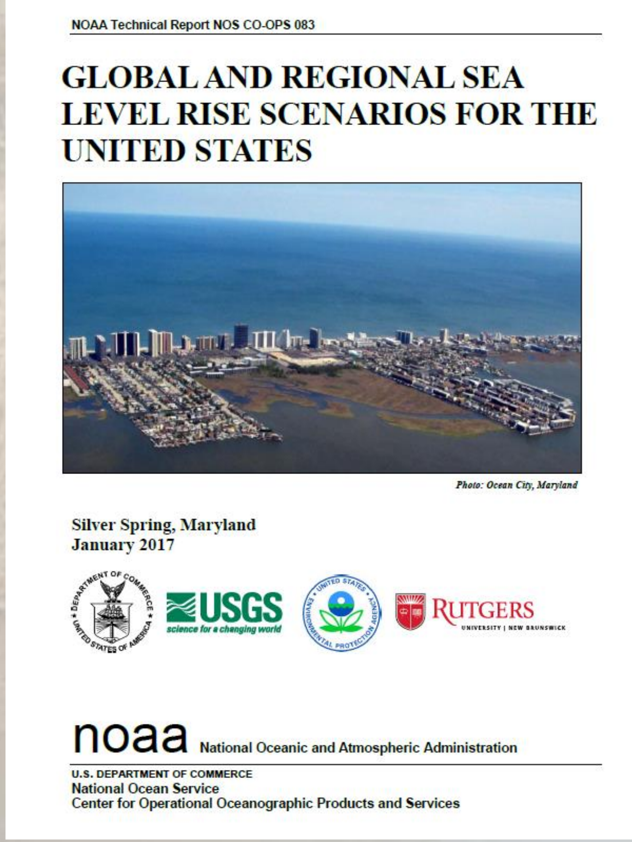
Coastal Conservancy

USGS science for a changing world

California Wildlife Foundation

Our 20th Year South Bay Salt Pond Restoration Project

We can no longer manage for a static environment


NOAA Technical Report NOS CO-OPS 083

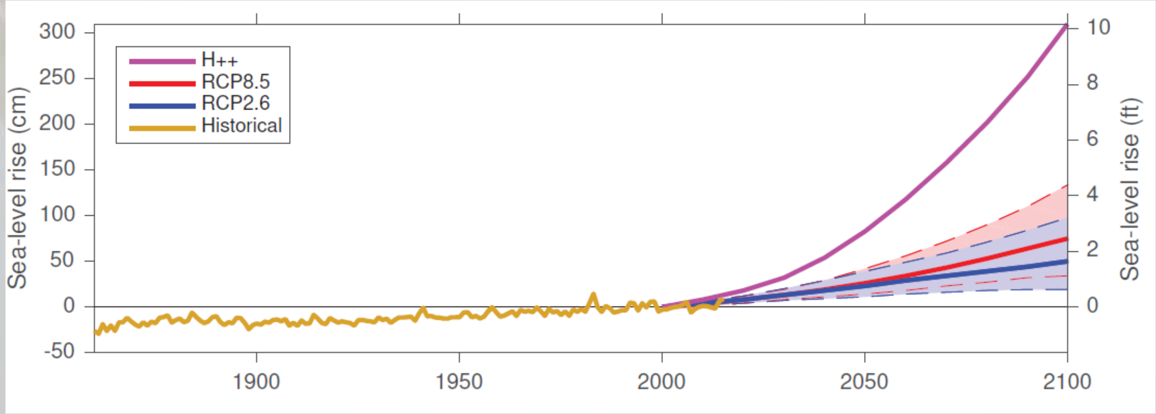
GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

Photo: Ocean City, Maryland

Silver Spring, Maryland
January 2017

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services



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Modeling can be a tool to inform management decisions

Baseline data

Hydrology

Elevation

Veg

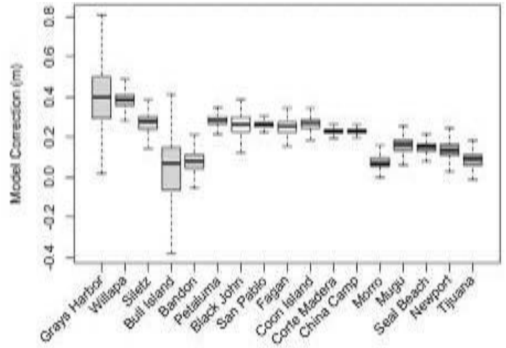
Accretion

Experiments

Greenhouse

Field

LEAN model



Modeling

2010

2030

2050

2110

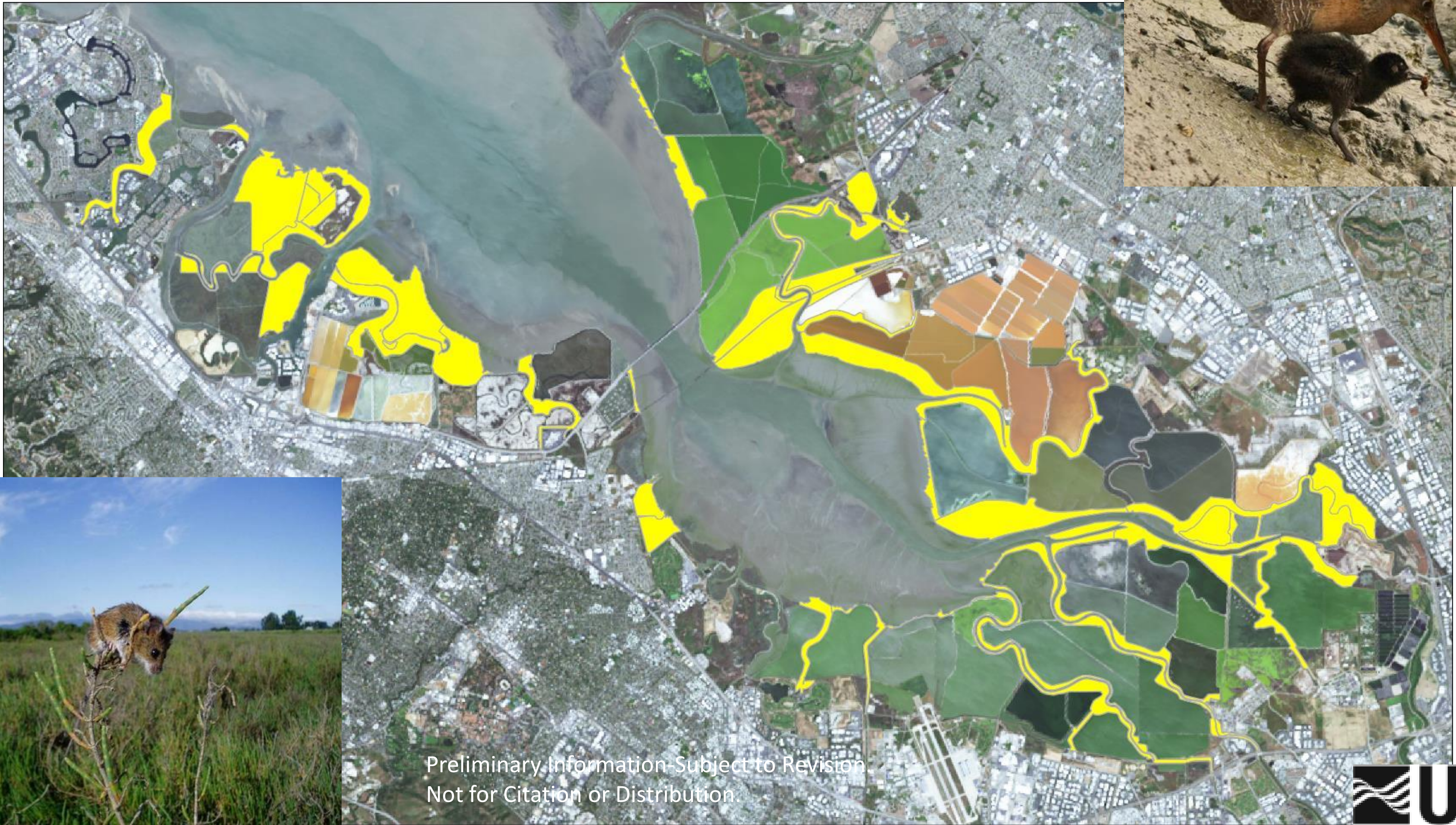
Sea-level rise

Morro Bay

USGS

Buffington et al. (2016); Janousek et al. (2016); Thorne et al. (2018); Janousek et al, in press; Buffington et al., 2021, 2024

Don Edwards National Wildlife Refuge
3086 ha tidal marsh



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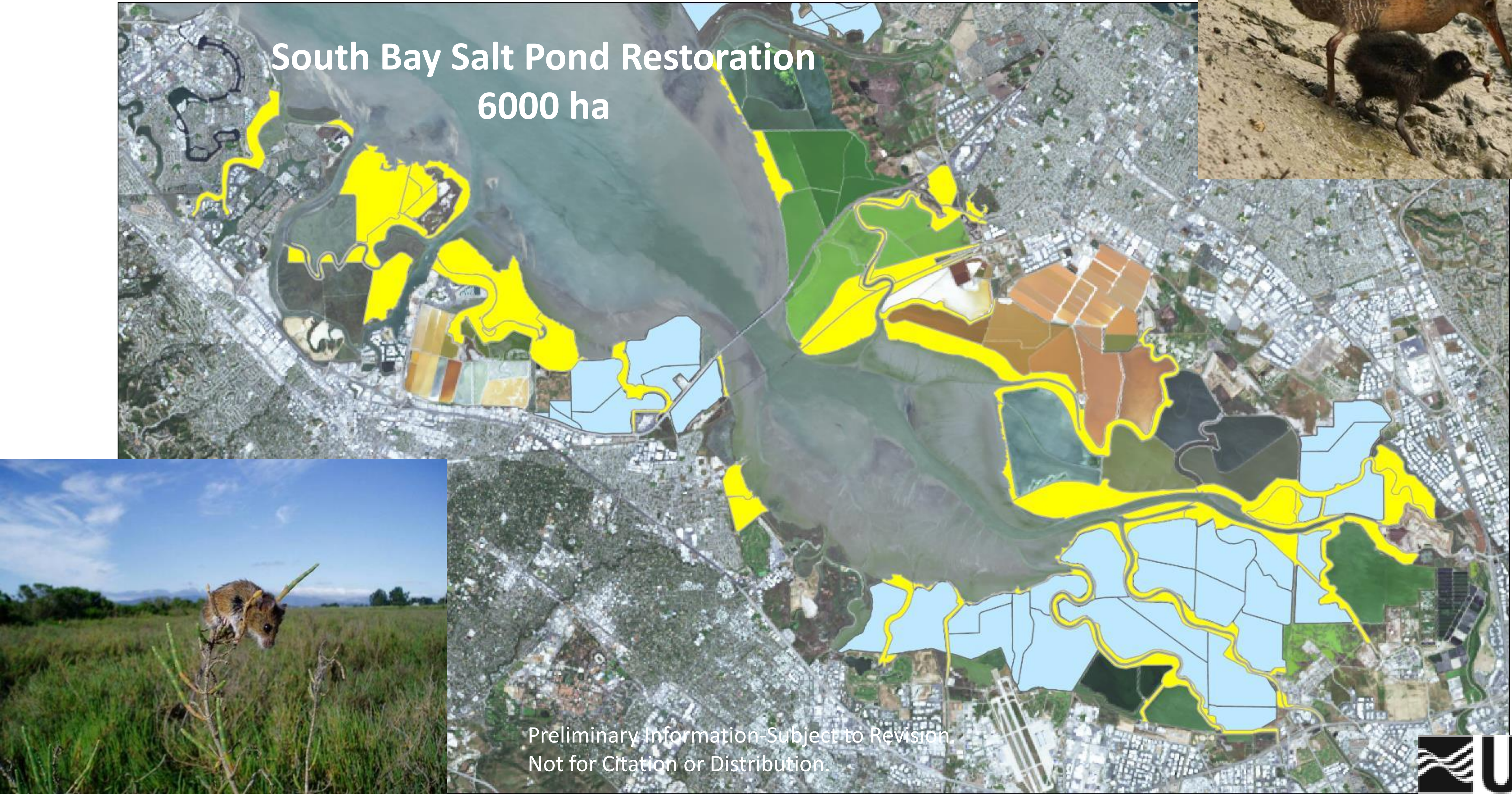

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Tidal marshes

- Tidal marshes can ‘keep pace’ with sea-level rise
- Biological and geophysical processes interact to determine wetland elevation
- Marsh elevation, in turn, drives biotic composition and function

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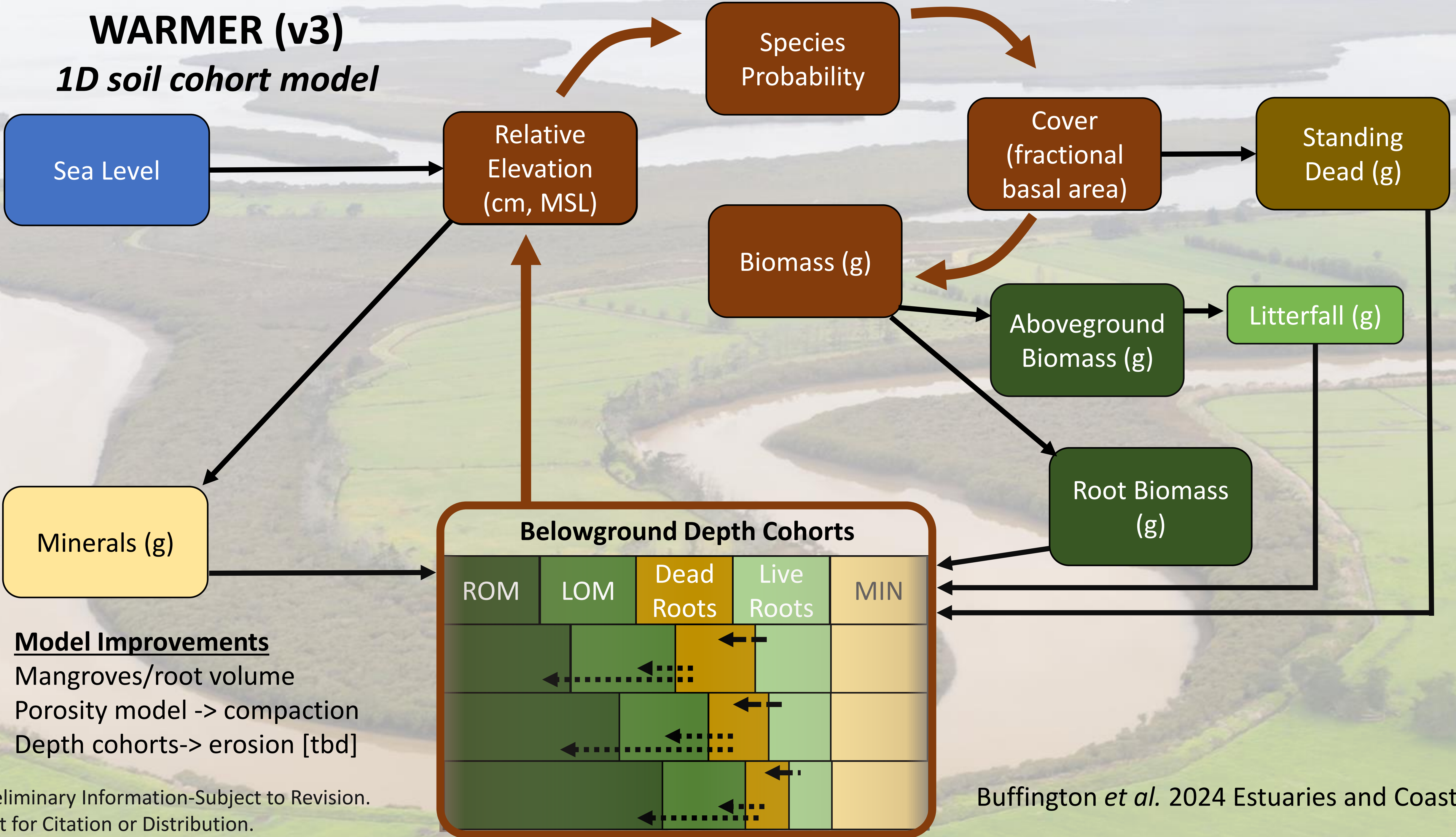
Objectives

1. Estimate marsh accretion rates
2. Calibrate WARMER model
3. Model marsh vulnerability to sea-level rise
4. Assess carbon stocks

WARMER (v3)

1D soil cohort model



Model Improvements

Mangroves/root volume

Porosity model -> compaction

Depth cohorts-> erosion [tbd]

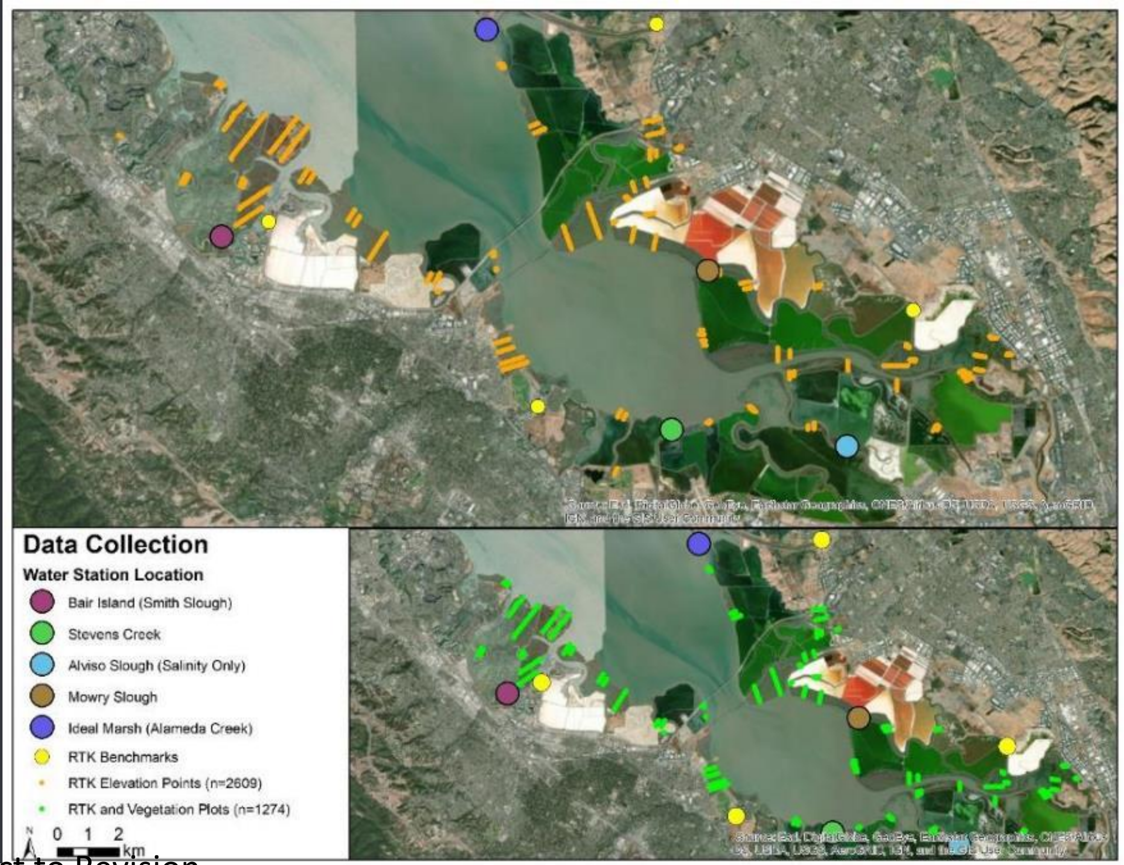
Buffington *et al.* 2024 Estuaries and Coasts

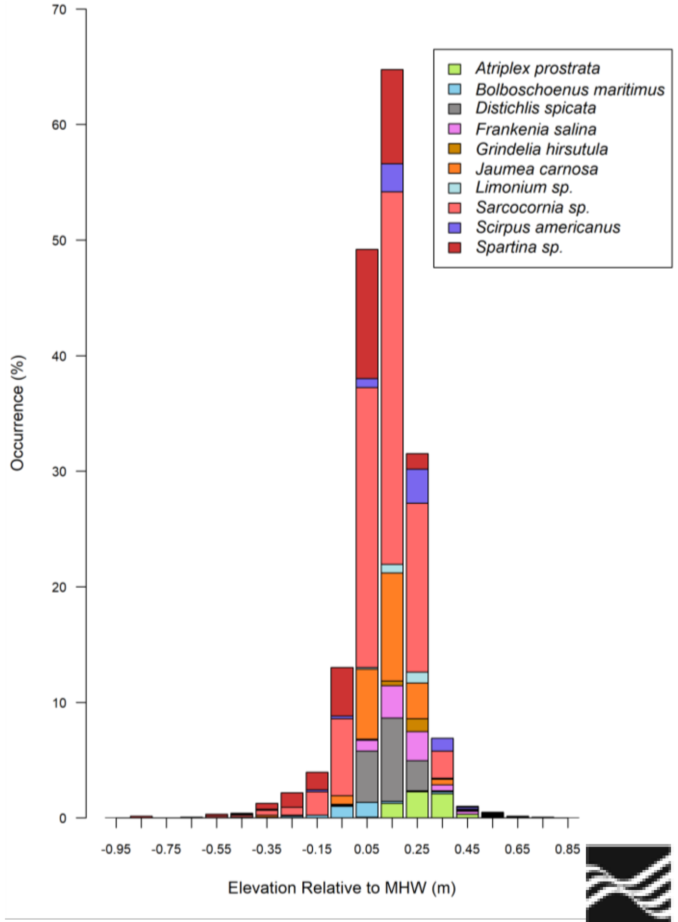
Key Assumptions of 1D WARMER

- Vertical processes solely responsible for long-term marsh evolution
  - No edge erosion simulated
  - Calibrated using soil cores sampled from the marsh plain, far (>10 m) from tidal channels/marsh edge.
- Net depositional
- Vegetation defined by elevation niche & competition for space
  - No salinity effects
  - No facilitation

Field data

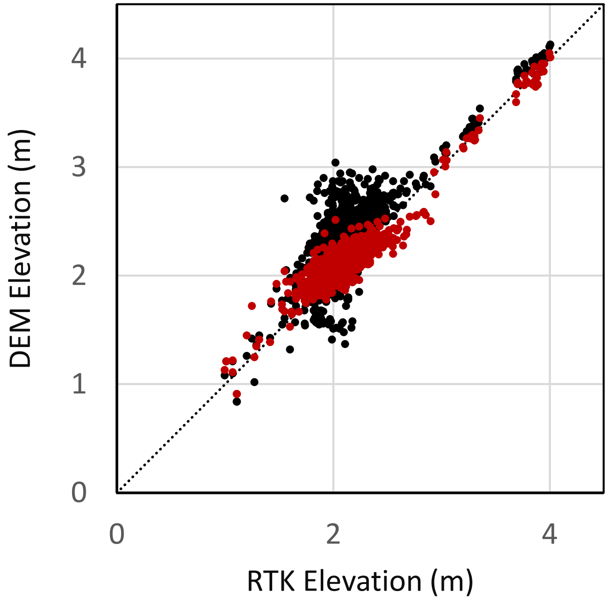
- 2809 RTK GPS points
- 1274 vegetation survey points
- 5 water level and salinity loggers





Error Assessment

2010 LiDAR: +0.18 m average bias

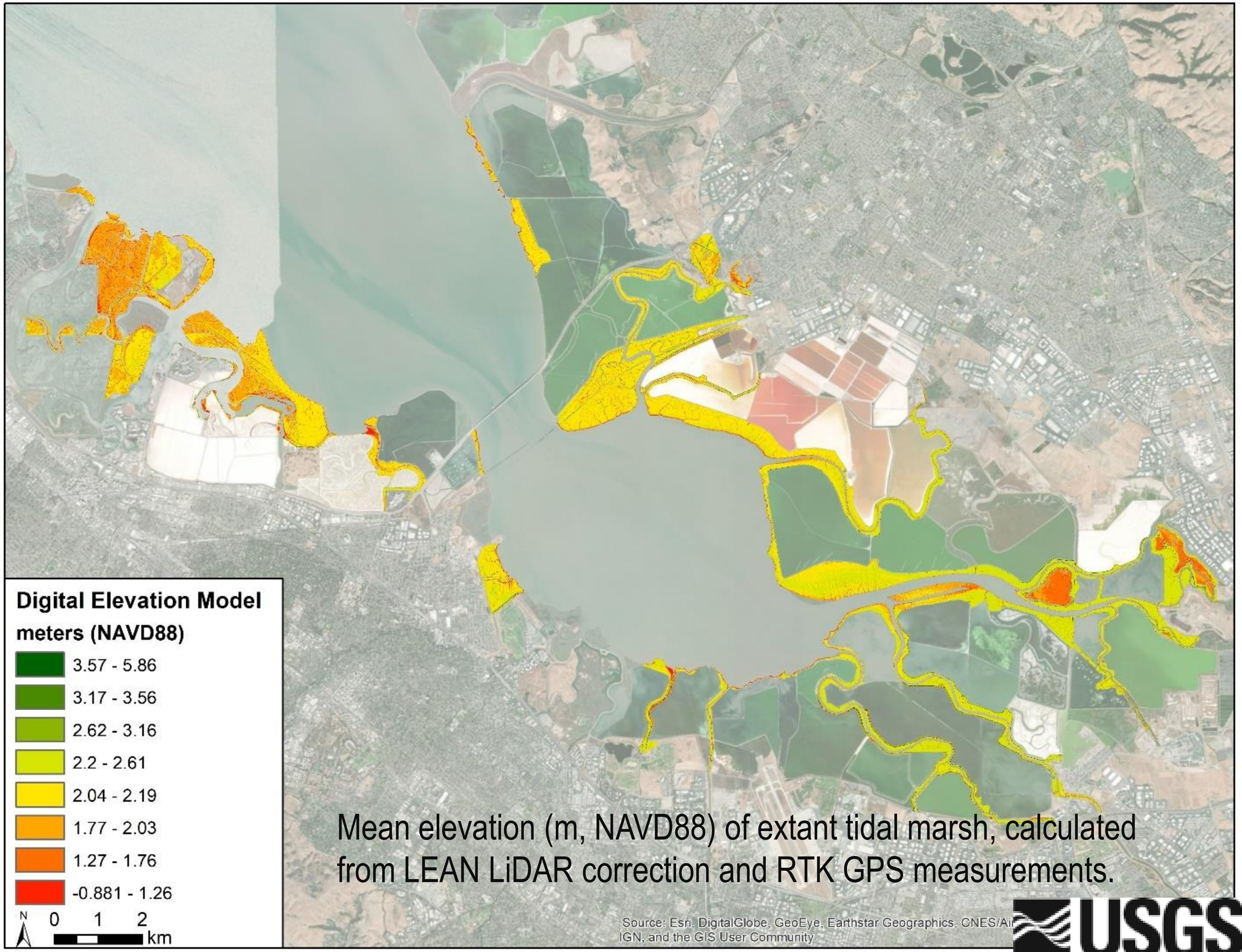


Root-mean-error-squared

- Initial: 0.241 m
- 10-fold CV: 0.108 m
- Final: 0.093 m

RTK & DEM Correlation (r^2)

- Initial: 0.836
- 10-fold CV: 0.889
- Final: 0.932



Mean elevation (m, NAVD88) of extant tidal marsh, calculated from LEAN LiDAR correction and RTK GPS measurements.

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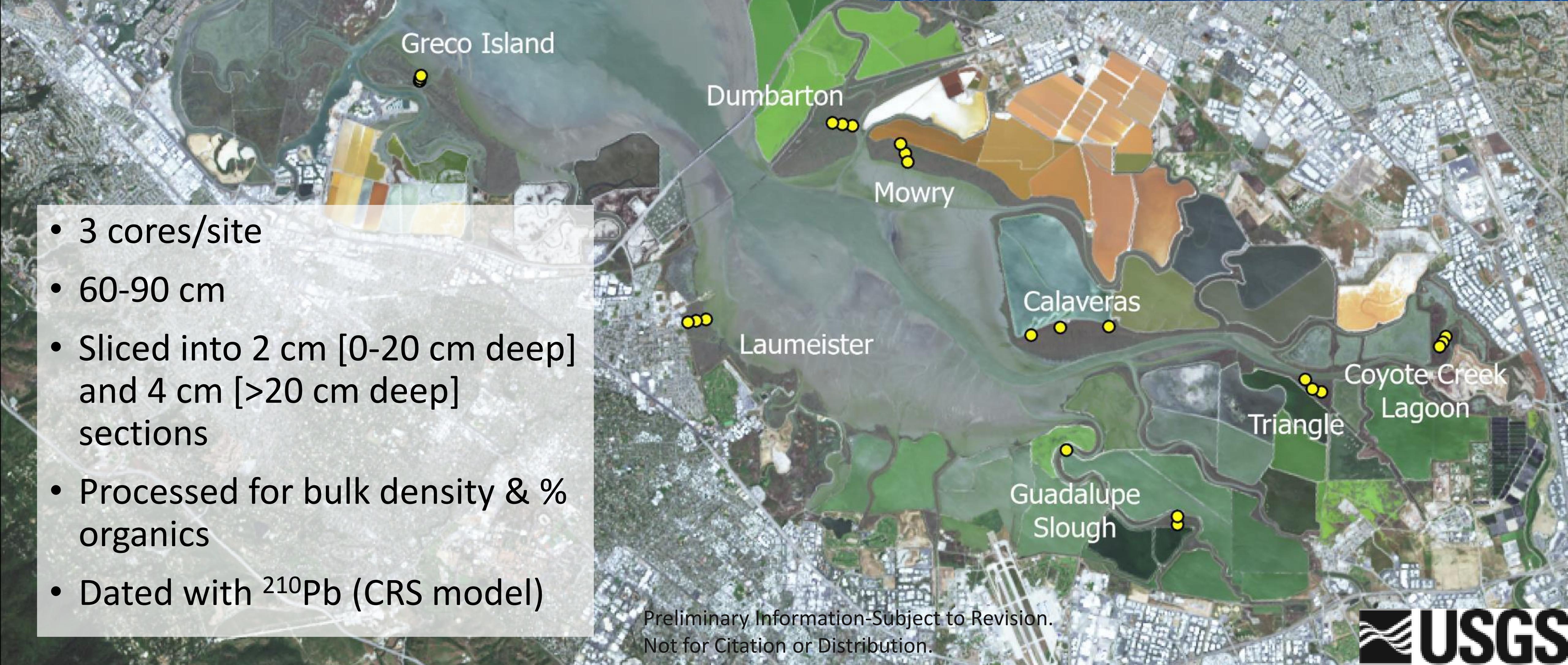
Soil cores



- 3 cores/site
- 60-90 cm
- Sliced into 2 cm [0-20 cm deep] and 4 cm [>20 cm deep] sections
- Processed for bulk density & % organics
- Dated with ^{210}Pb (CRS model)

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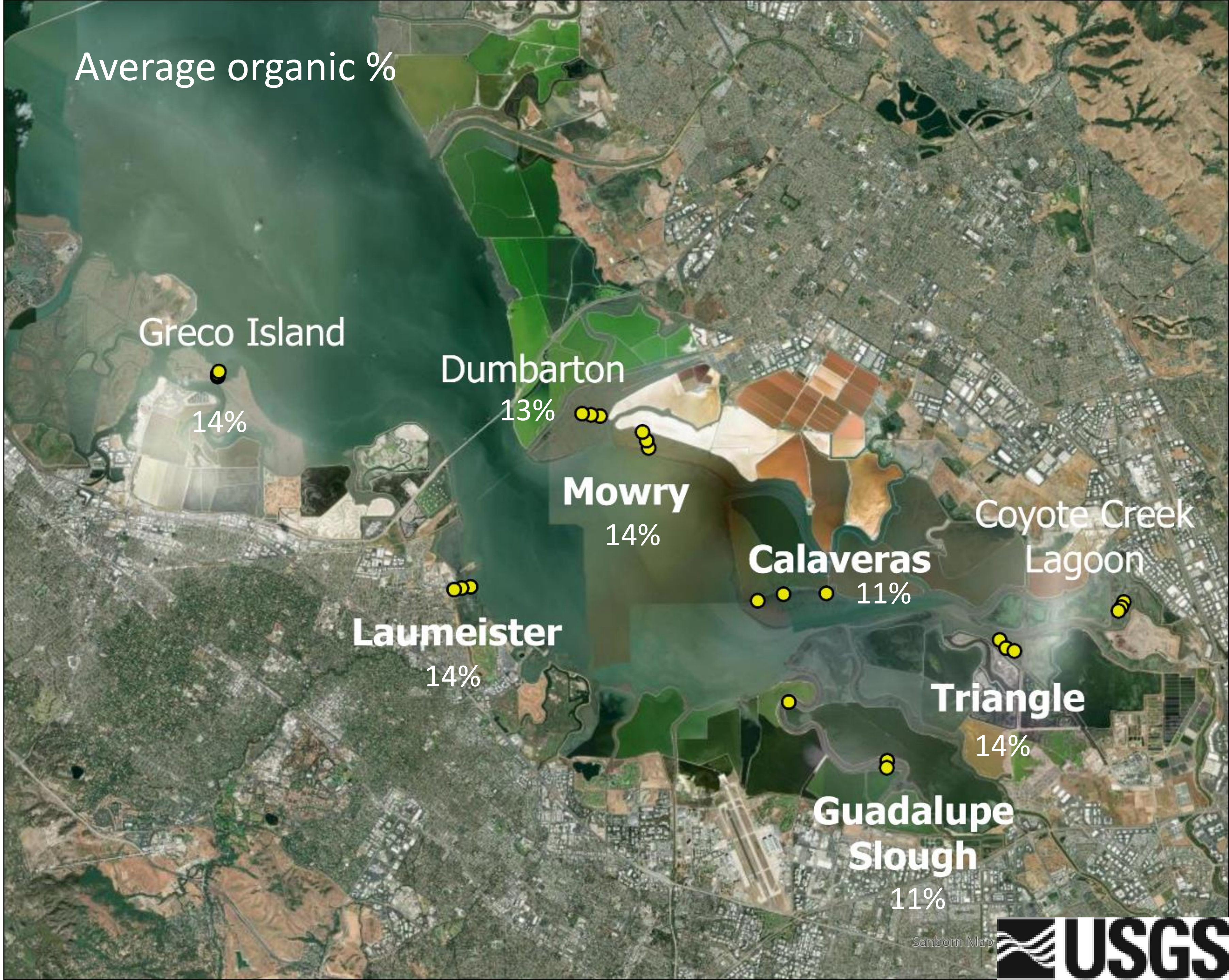
% Organics

- Relatively low organics (11-14%)
- Low variation



Preliminary Information-Subject to Revision.
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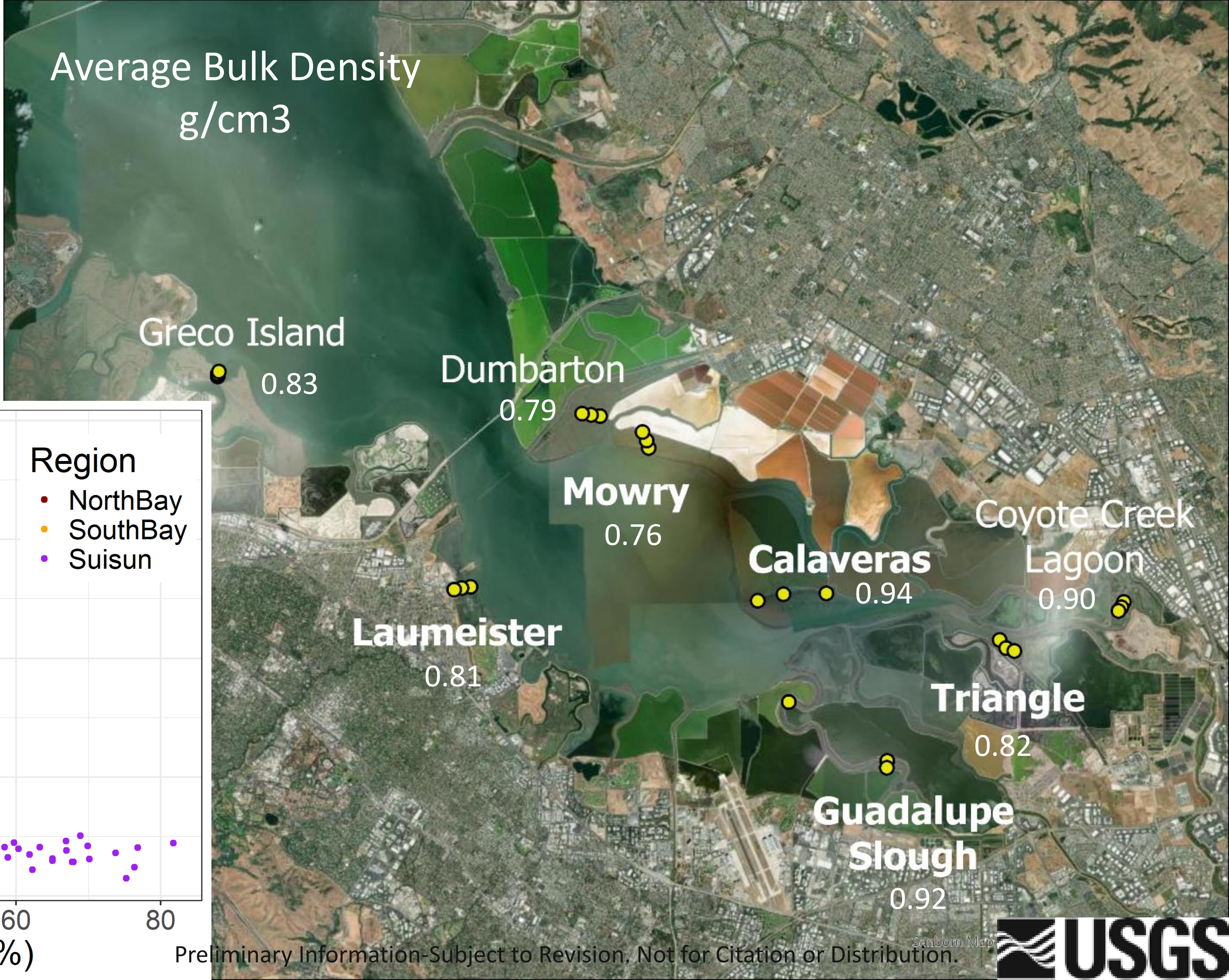
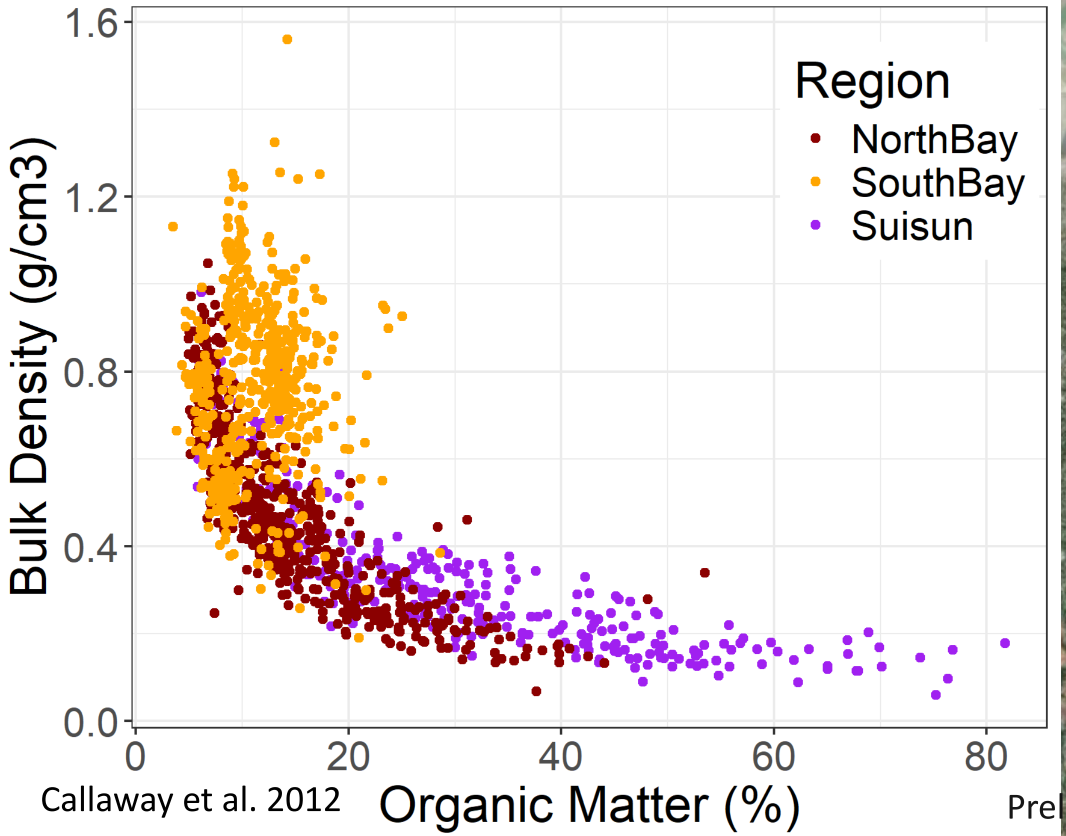
Bulk Density

Very dense soil (0.76-0.94 g/cm^3)





Callaway et al. 2012

Total carbon stocks (1m)

376 ± 73 Mg C/ha

231 Mg C/ha global meta- analysis *(Maxwell et al. 2023)*

Don Edwards in the 86th percentile for C stocks

Total Stocks: 1.16 ± 0.22 Tg C (1 m)

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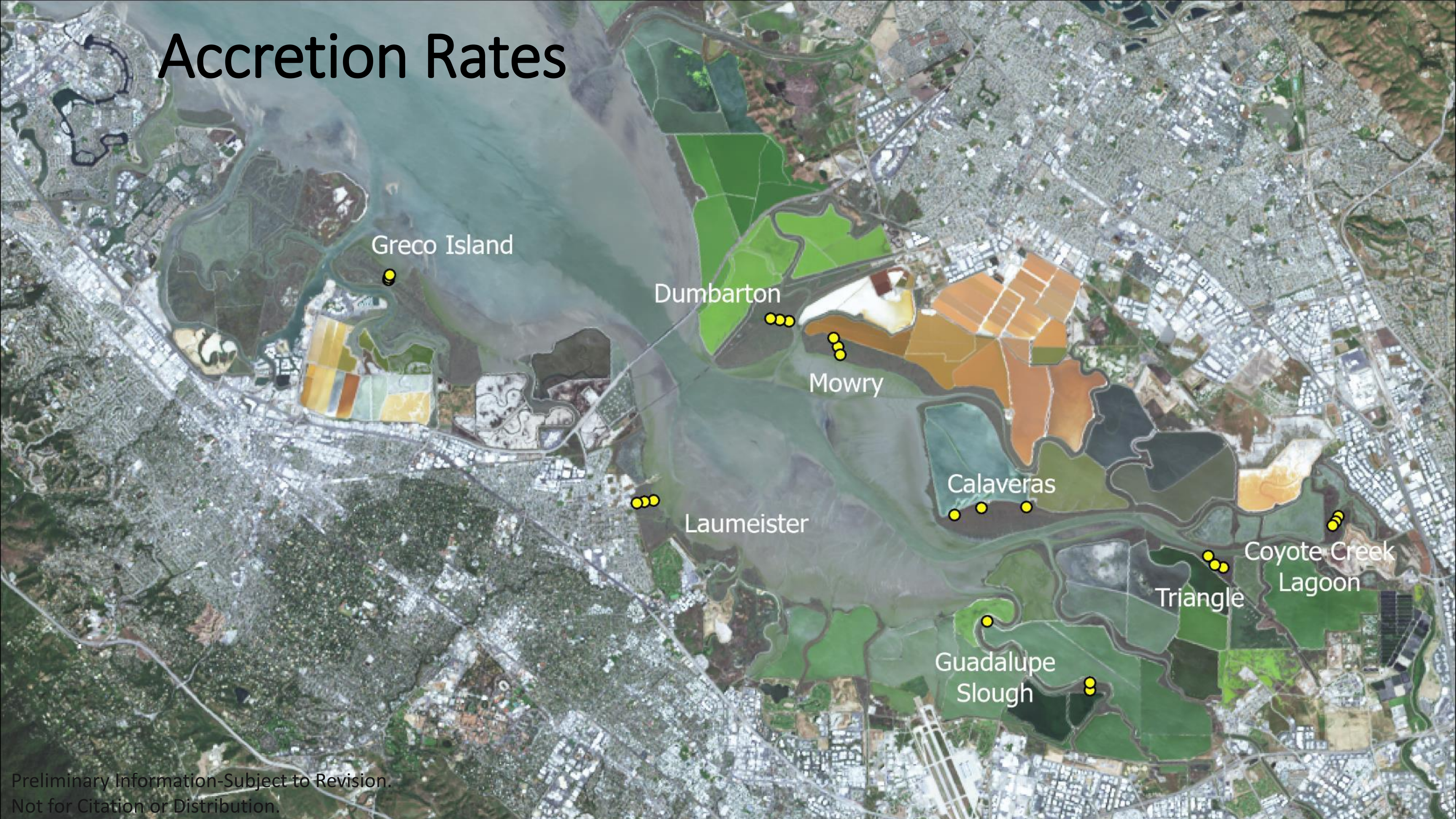
Accretion Rates



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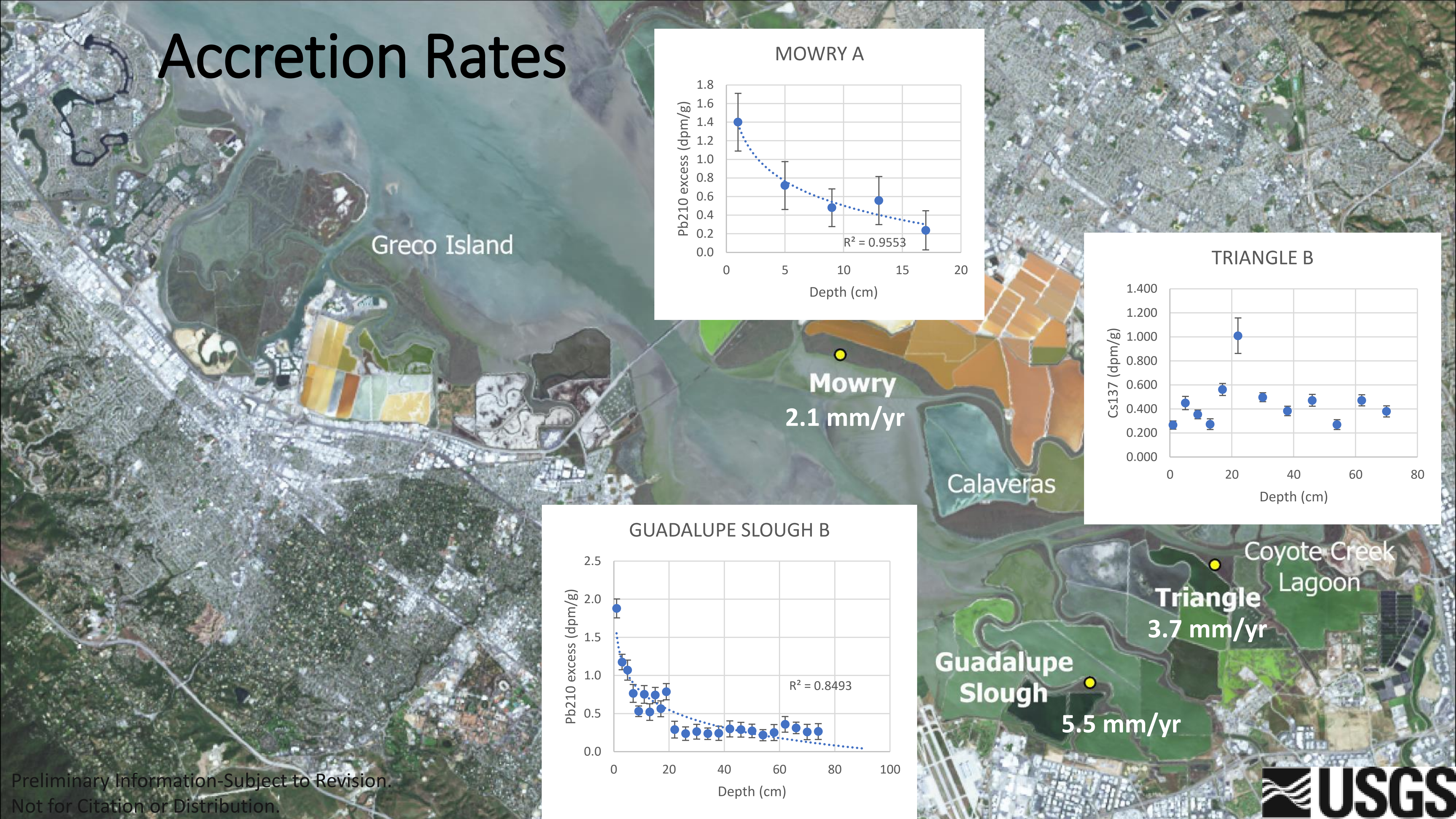
Accretion Rates



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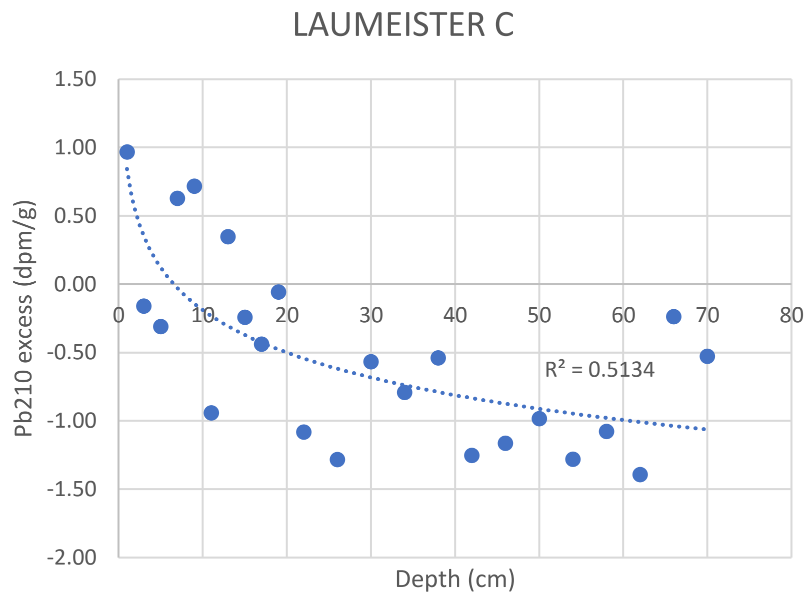
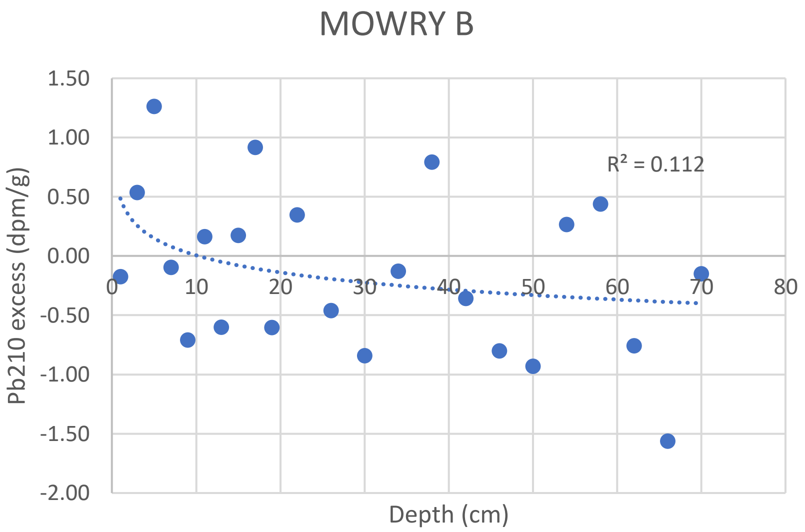
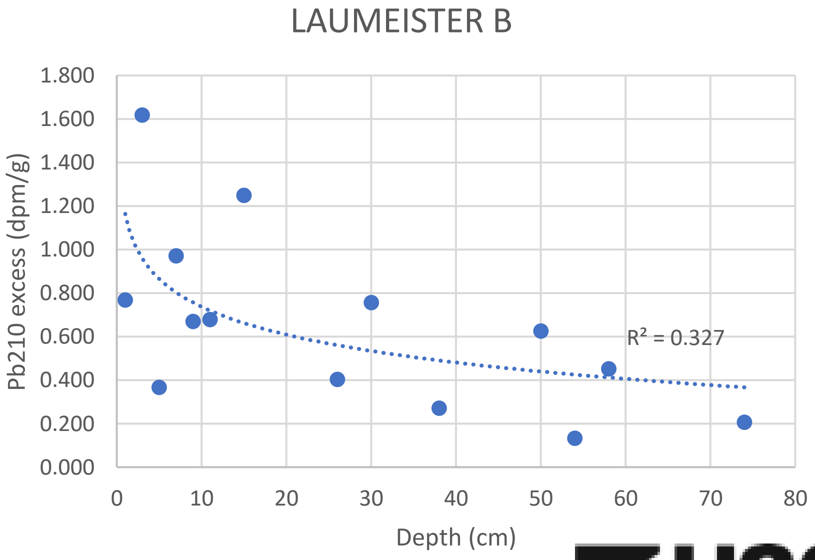
Soil Dating

- Many cores were not able to be dated due to low/noisy Pb210 signal
  - Low precipitation
  - Gamma spec. vs alpha
  - Sediment mixing
- Dating continues…







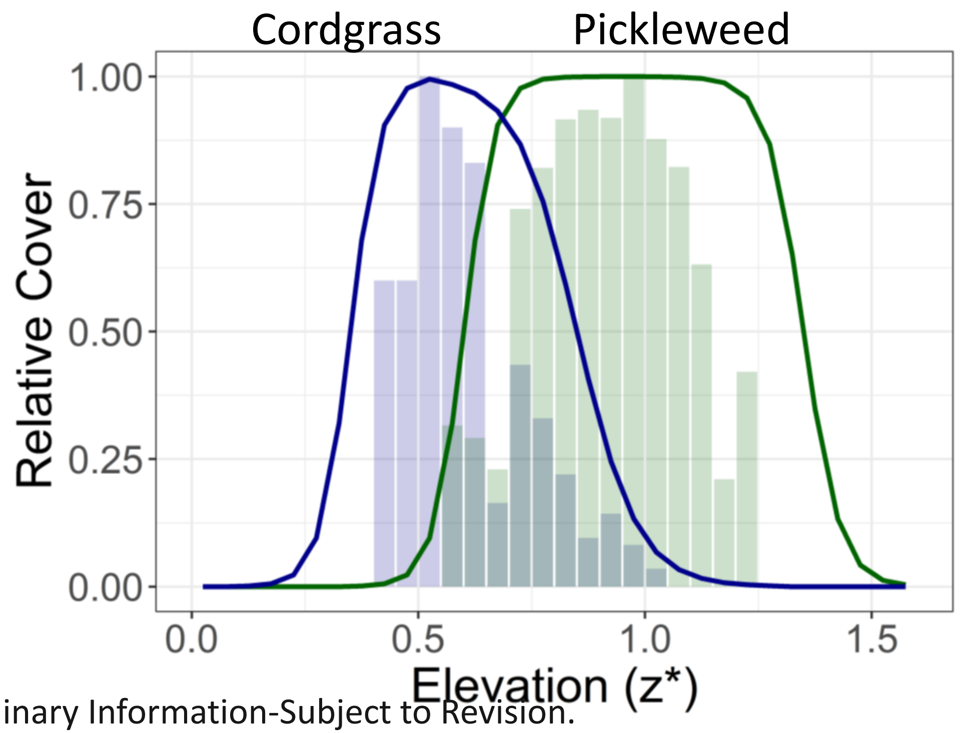
Surface elevation tables & marker horizon (SET-MH)

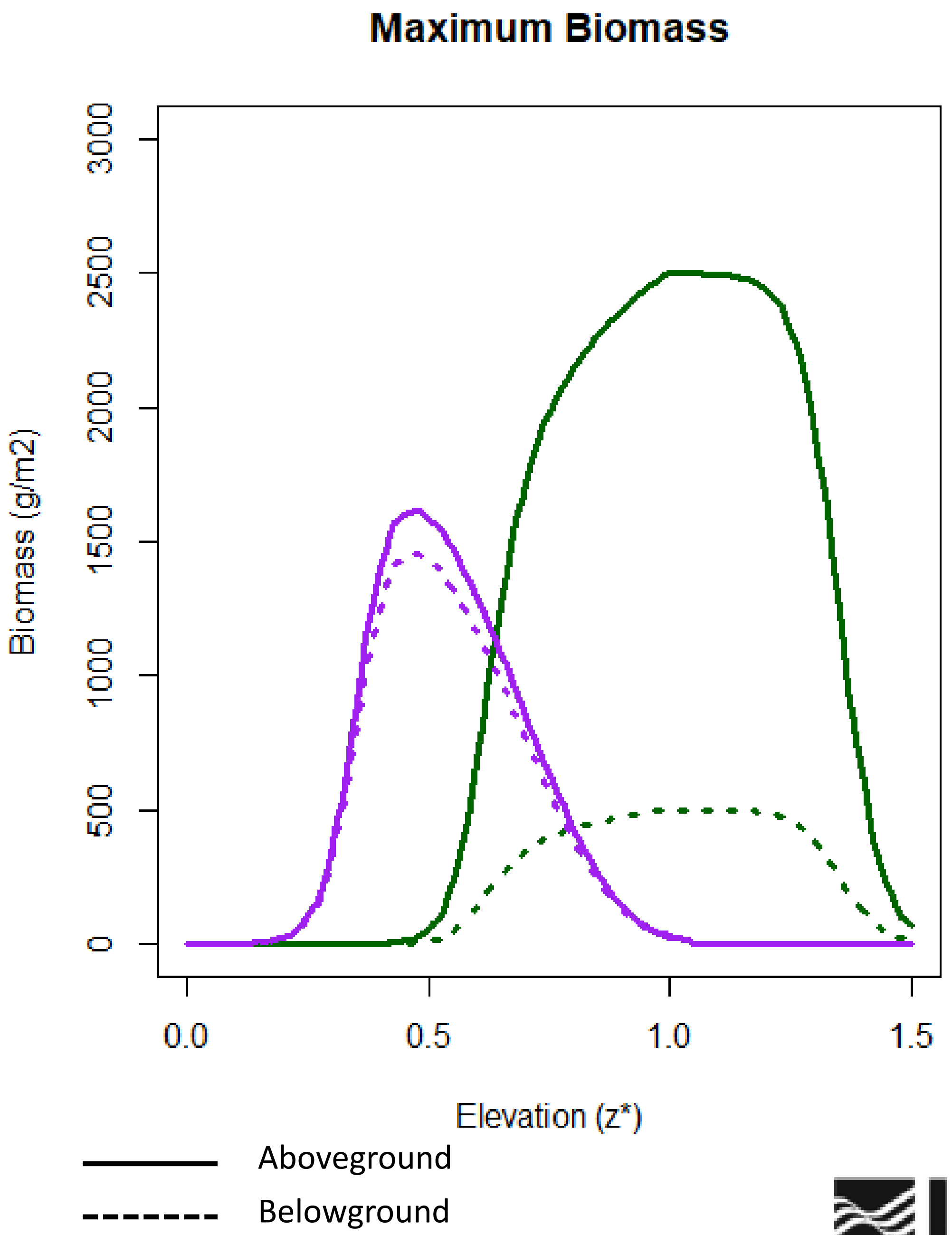
- Millimeter-scale changes in marsh elevation and sediment deposition
- 20 SET-MHs installed across 5 Don Edwards marshes in 2022
- Minimum 3 years data required for trend analysis

Model Setup

Plant surveys used to define species-specific elevation niche

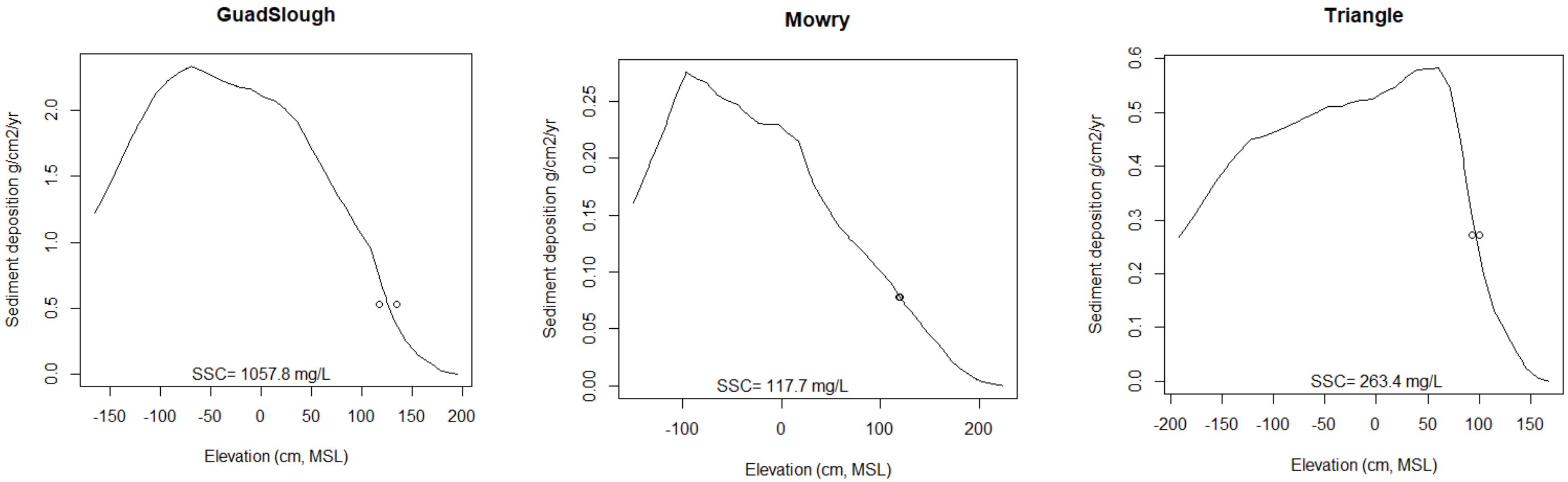
BG biomass accounts for niche, flooding~productivity, root:shoot





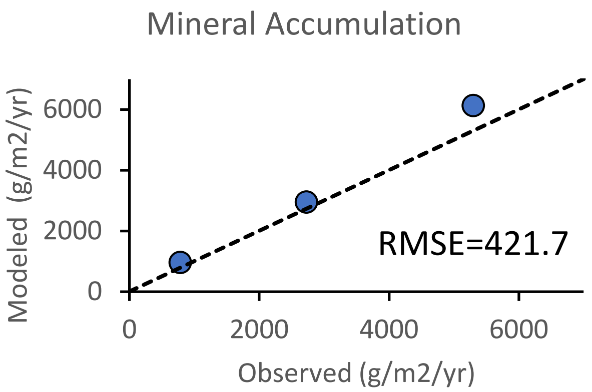
Model Calibration

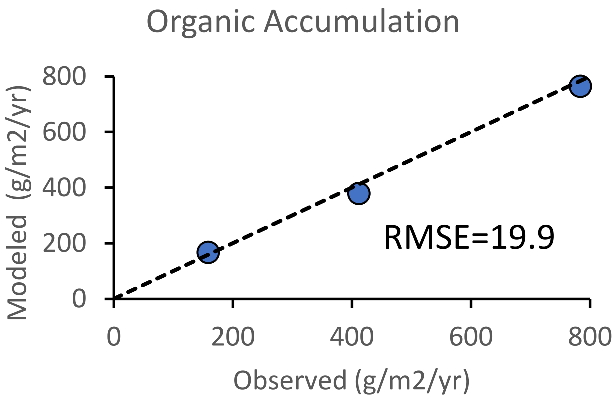
Site-specific tidal harmonics –> unique flooding patterns
Soil core sediment accumulation rate used to calibrate 1D deposition function

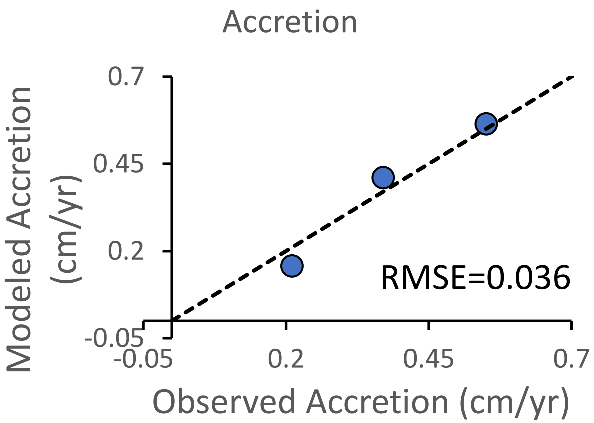


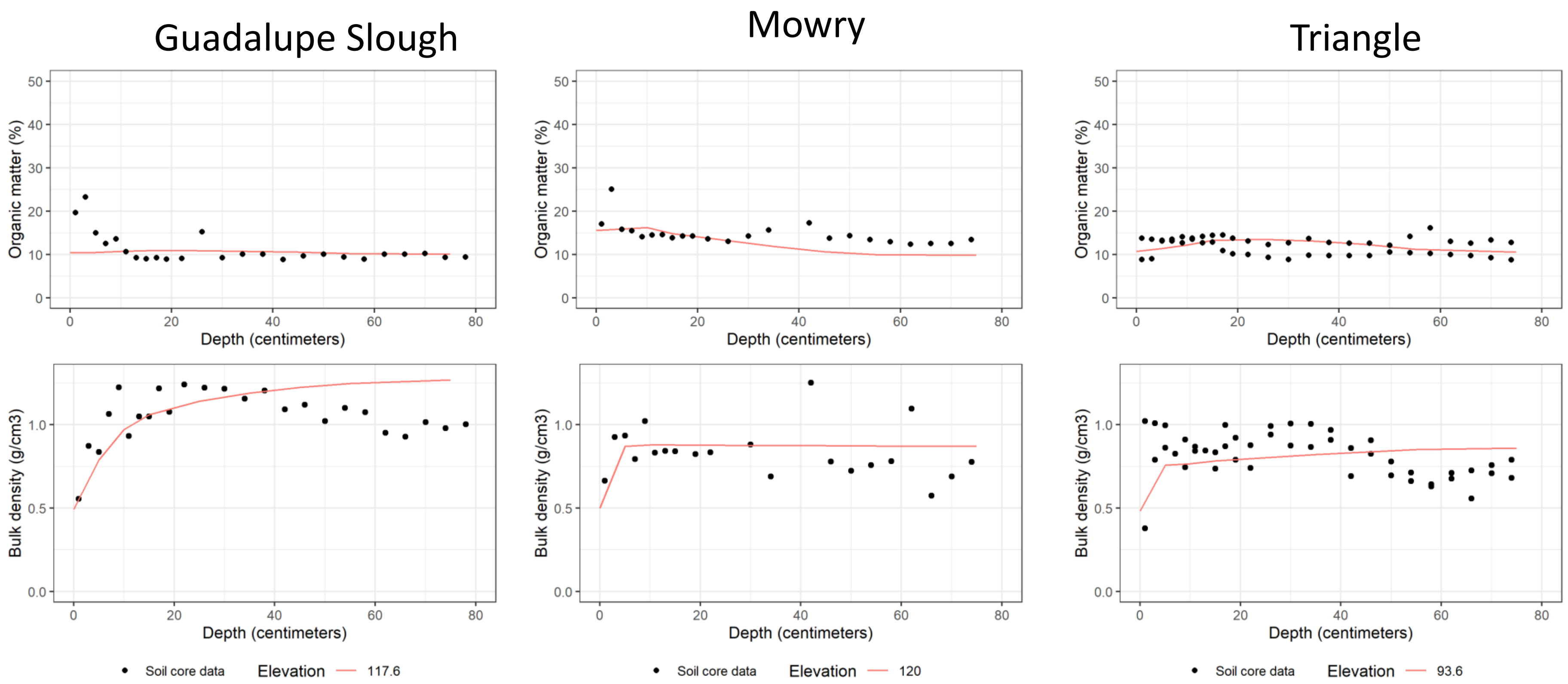
Calibration

50 year hindcast used to calibrate decomposition rate
[comparing observed & modeled organic accumulation]









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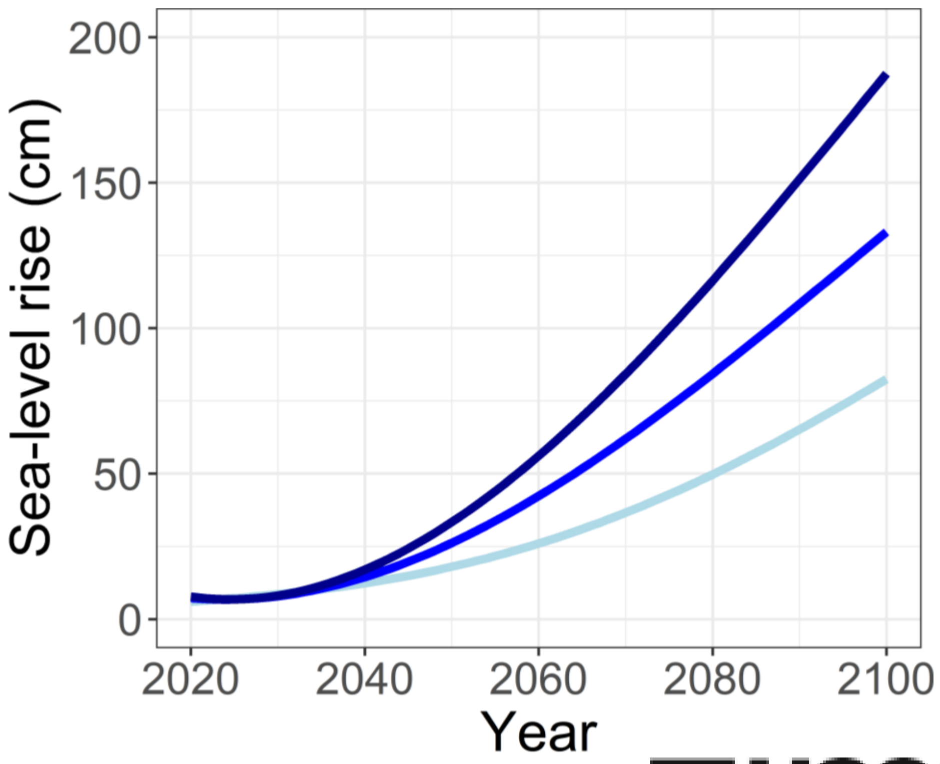
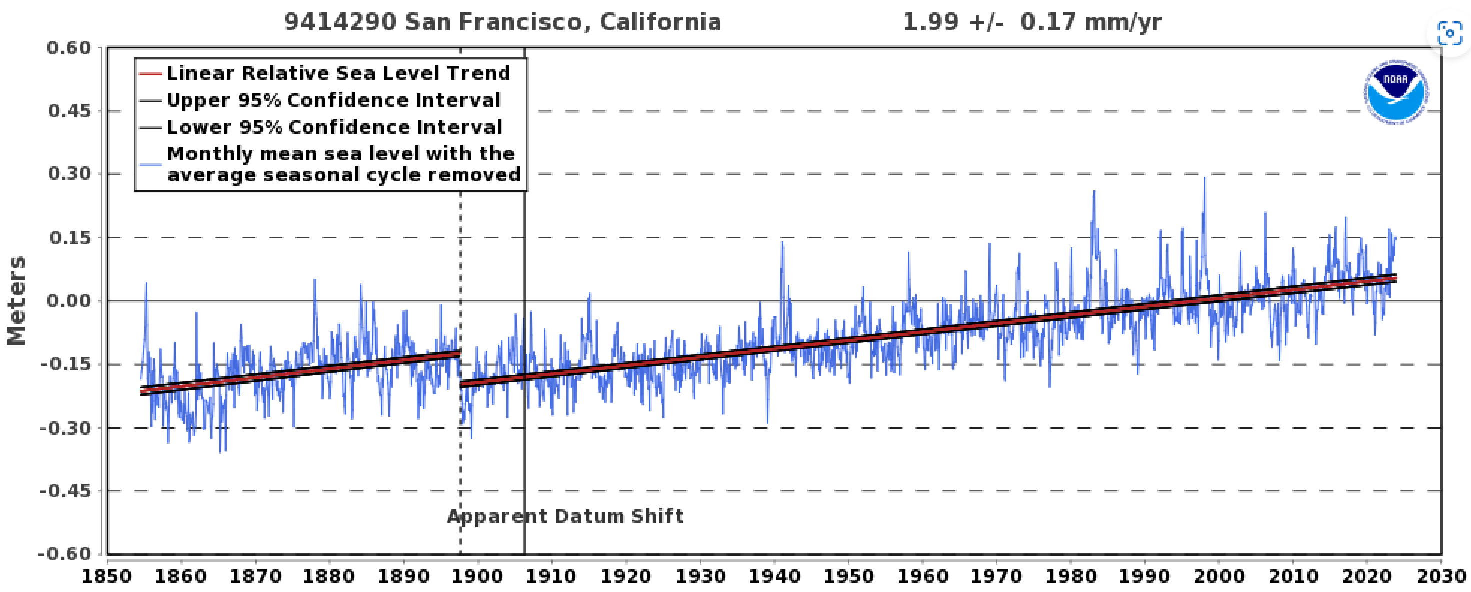
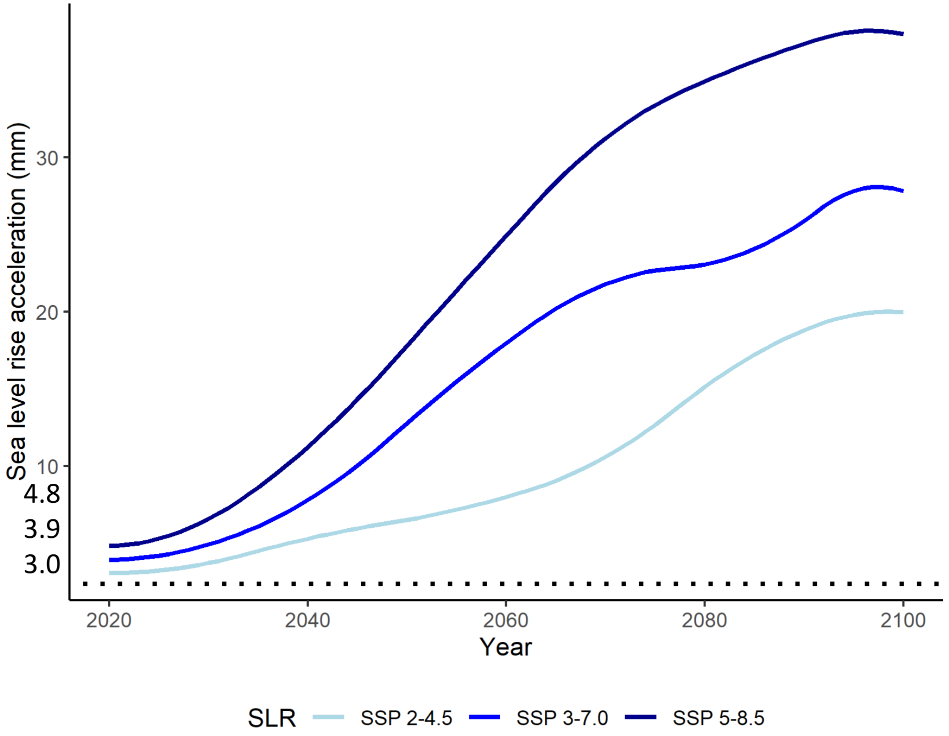
SLR Projections

- IPCC AR6 sea-level rise projections (Alameda)
  - SSP 2-4.5 (Intermediate): 84 cm by 2100
  - SSP 3-7.0: (Intermediate-high): 135 cm by 2100
  - SSP 5-8.5: (High): 188 cm by 2100
- Sediment scenarios
  - Historic
  - 30% less

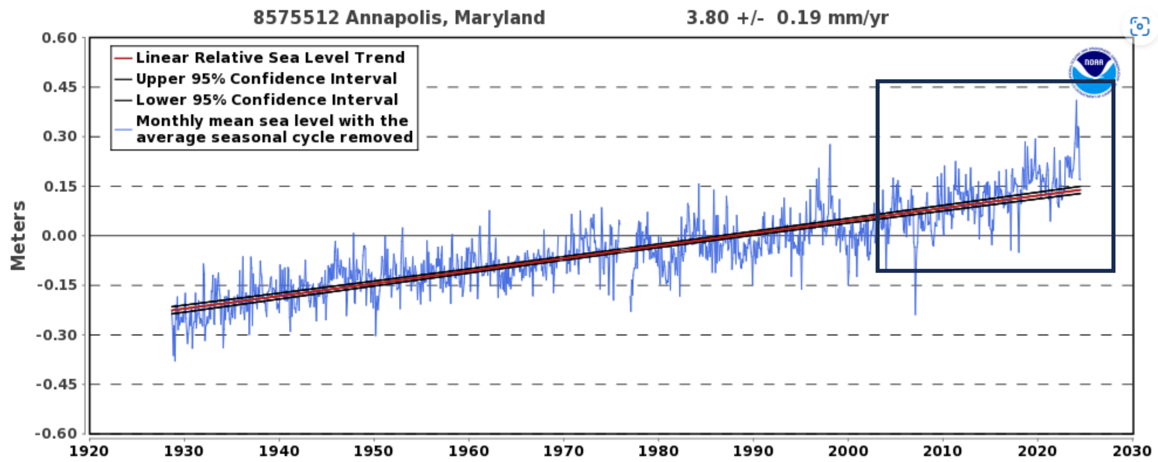




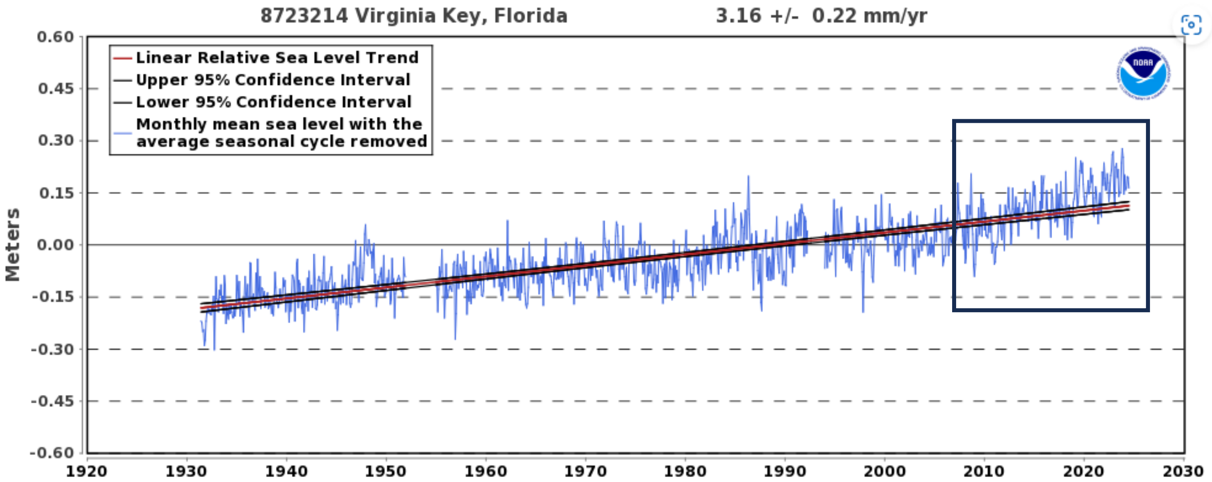
9414290 San Francisco, California
1.99 +/- 0.17 mm/yr
Linear Relative Sea Level Trend
Upper 95% Confidence Interval
Lower 95% Confidence Interval
Monthly mean sea level with the average seasonal cycle removed
Apparent Datum Shift
Meters



Sea level rise acceleration (mm)
Year
SLR
SSP 2-4.5
SSP 3-7.0
SSP 5-8.5

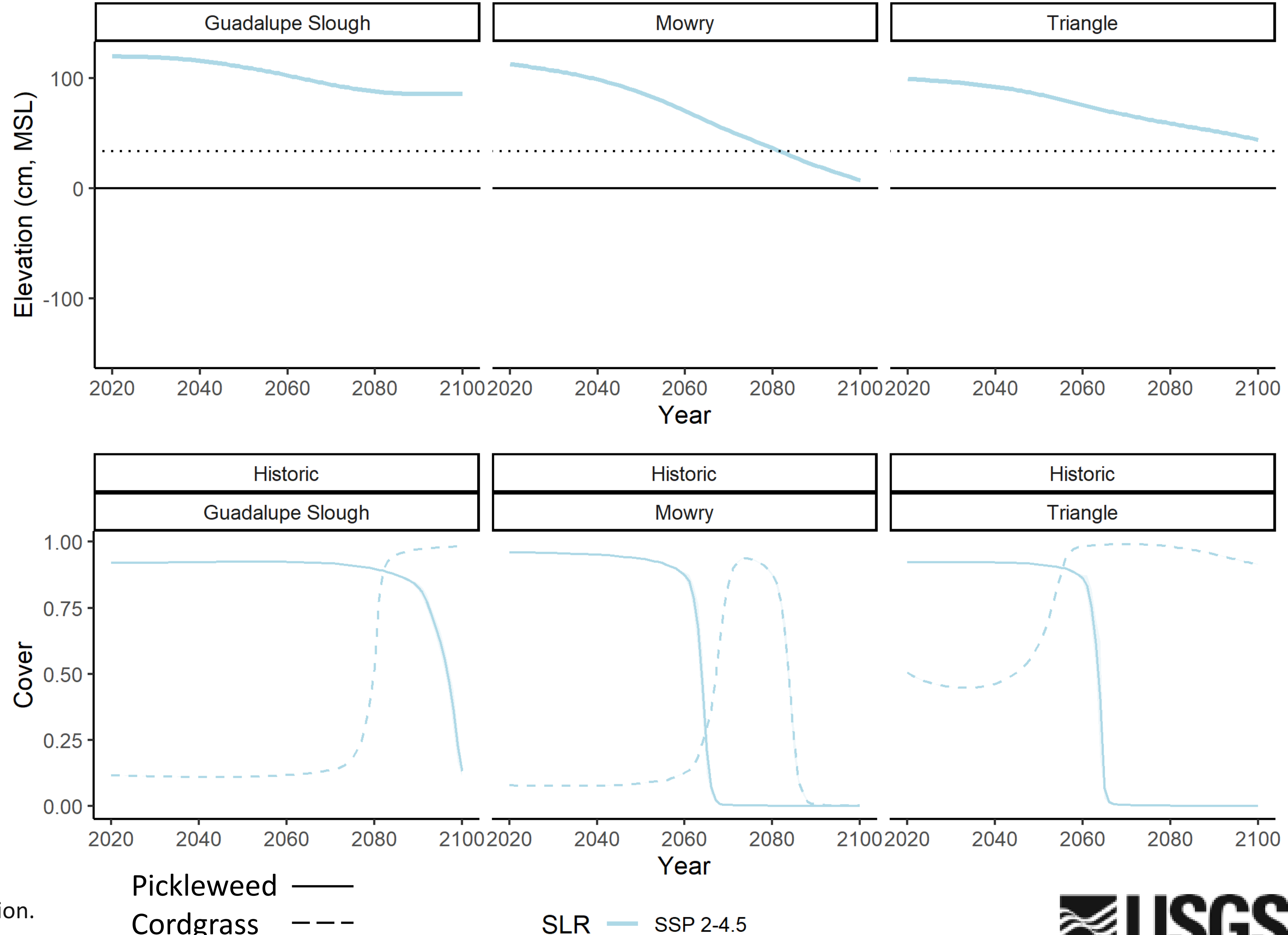


8575512 Annapolis, Maryland
3.80 +/- 0.19 mm/yr
Linear Relative Sea Level Trend
Upper 95% Confidence Interval
Lower 95% Confidence Interval
Monthly mean sea level with the average seasonal cycle removed
Meters



8723214 Virginia Key, Florida
3.16 +/- 0.22 mm/yr
Linear Relative Sea Level Trend
Upper 95% Confidence Interval
Lower 95% Confidence Interval
Monthly mean sea level with the average seasonal cycle removed
Meters

Historic sediment



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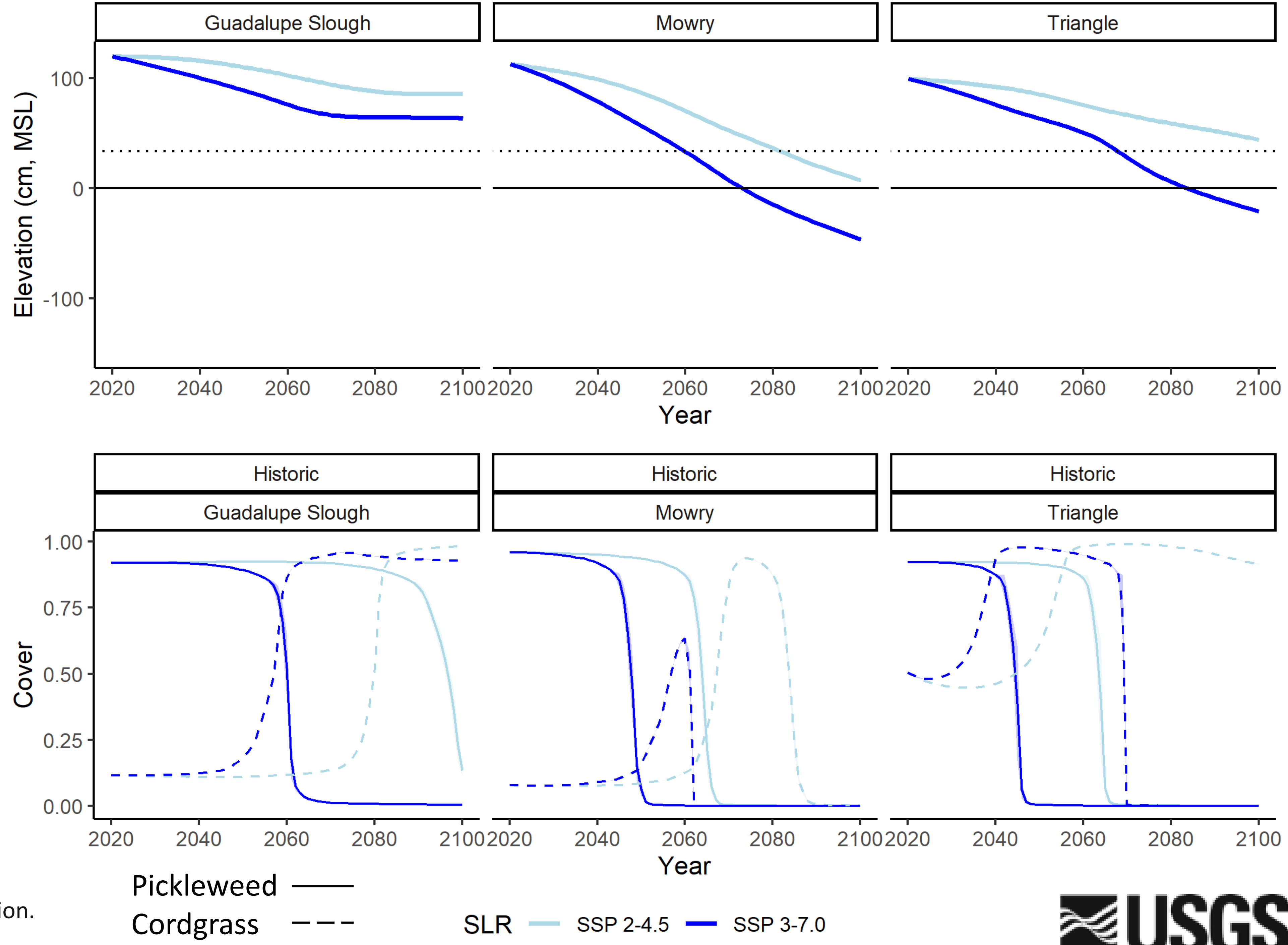
Historic sediment



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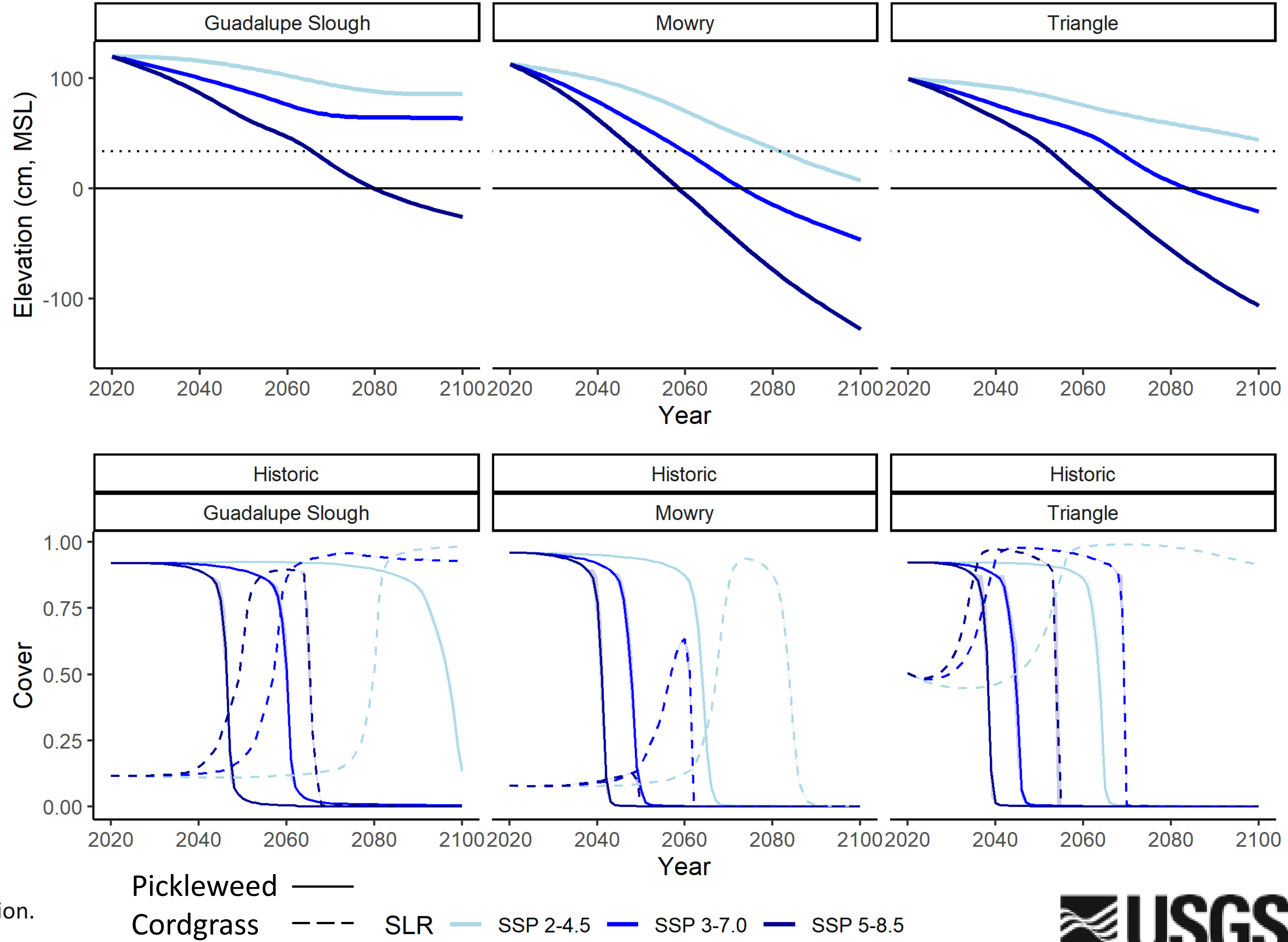
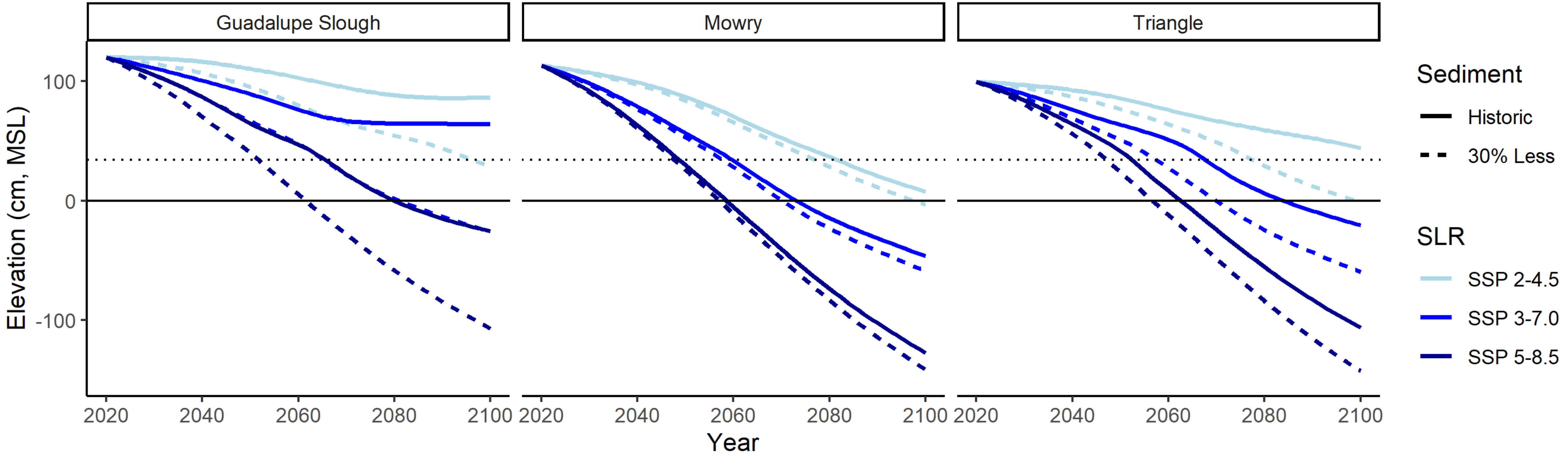
Historic sediment



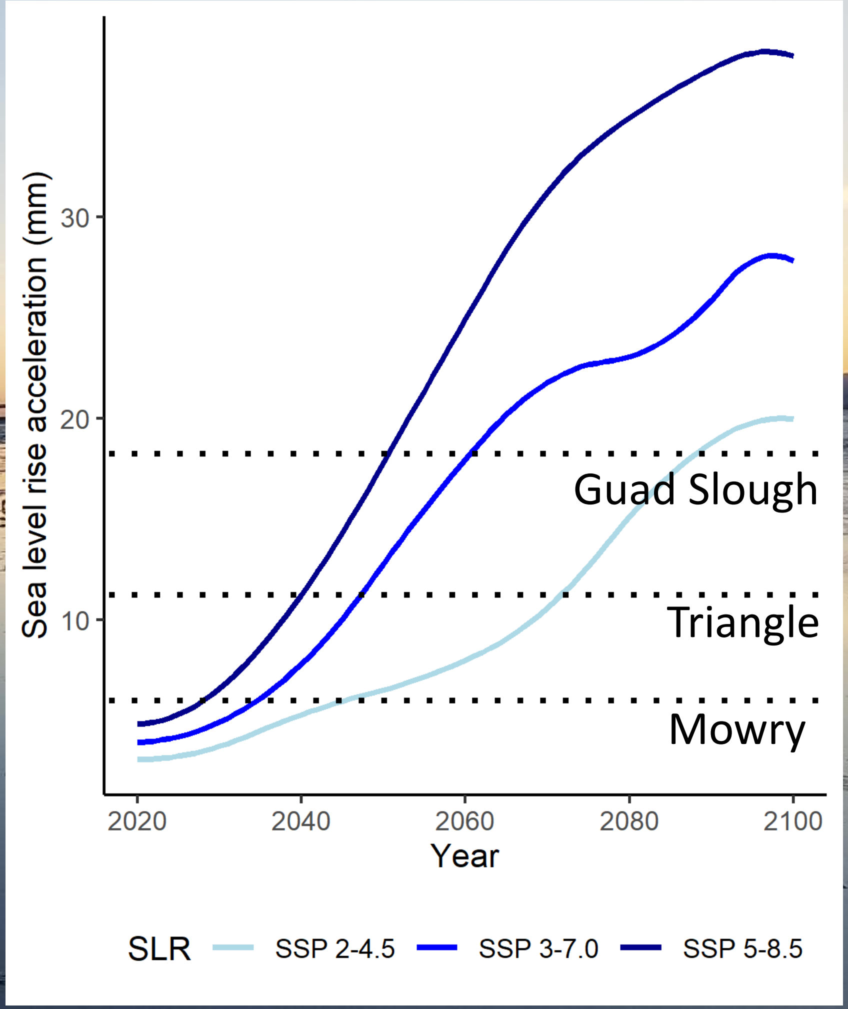
Sediment Scenarios



SLR Thresholds

- Model run at mean elevation
- Linear sea-level rise (2-20 mm/yr)
- >50% vegetation cover after 200 years = resilient
- Historic & 30% less sediment scenarios

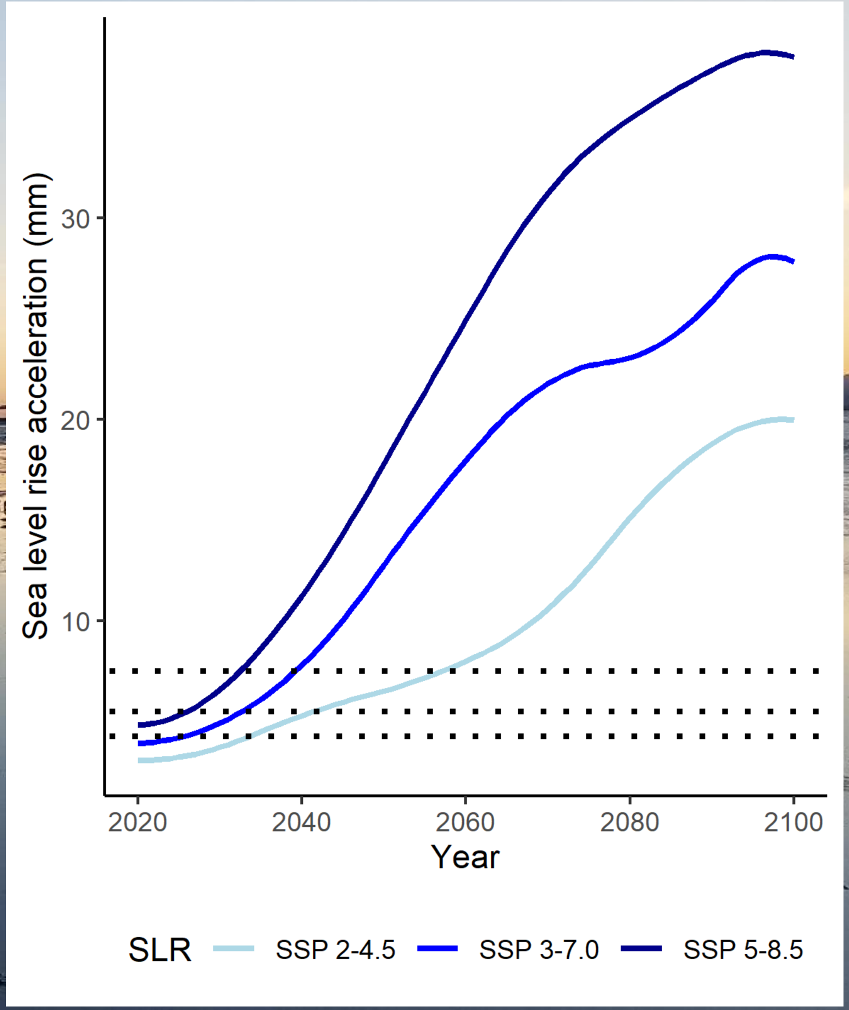
Site	**Historic Sediment**
Mowry	6.0
Triangle	11.25
Guadalupe Slough	18.25



SLR Thresholds

- Model run at mean elevation
- Linear sea-level rise (2-20 mm/yr)
- >50% vegetation cover after 200 years = resilient
- Historic & 30% less sediment scenarios

Site	Historic Sediment	30% Less Sediment
Mowry	6.0	4.5
Triangle	11.25	5.5
Guadalupe Slough	18.25	7.5



Conclusions

- South bay marsh soil is very dense! [0.76-0.94 g/cm^3]
  - SFEI Sediment Survival report used 0.51 g/cm^3 for estimating sediment needed for supporting restorations
  - Potentially underestimating sediment needed in south bay by 30-50%
- So much carbon! Because of their density, carbon storage of these marshes is among the highest in the world
- Issues with radiometric dating -> SETs are the way to go!

USGS

Conclusions

- Marshes are generally resilient to the moderate sea-level rise scenario
- Higher SLR & lower sediment availability leads to high vulnerability
- Habitat transitions possible starting ~2040
- Nowhere to migrate – accretion is key to survival

- What about lateral processes? Edge erosion/progradation & channel widening?

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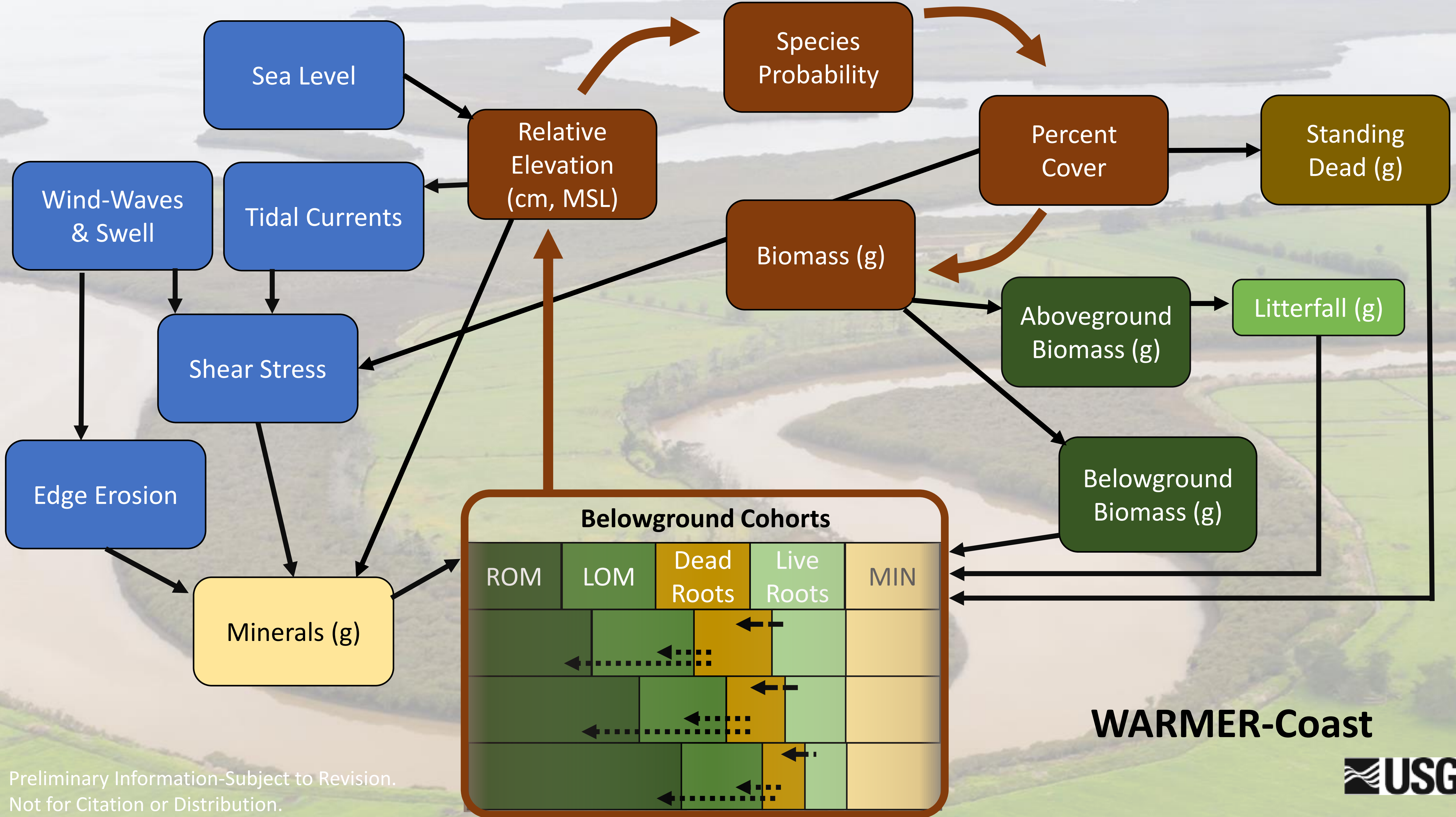

WARMER-Coast

Thanks!

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