

Climate Change and California Coastal Marshes

Coastal Ecosystem Response
to Climate Change (CERCC) Team

Glen MacDonald UCLA Presenting

Southwest
Climate
Science
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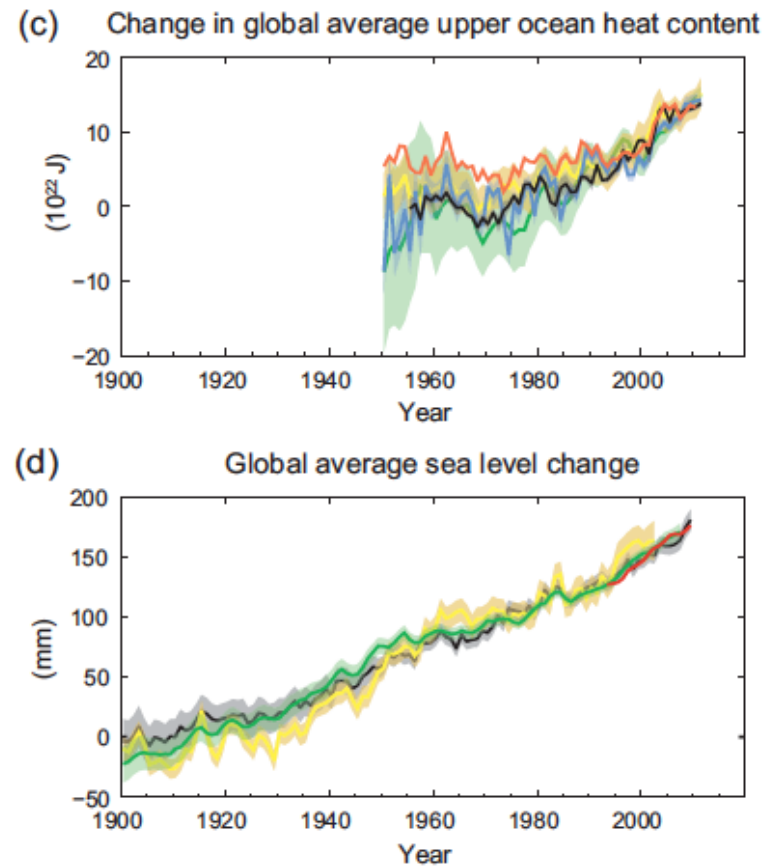
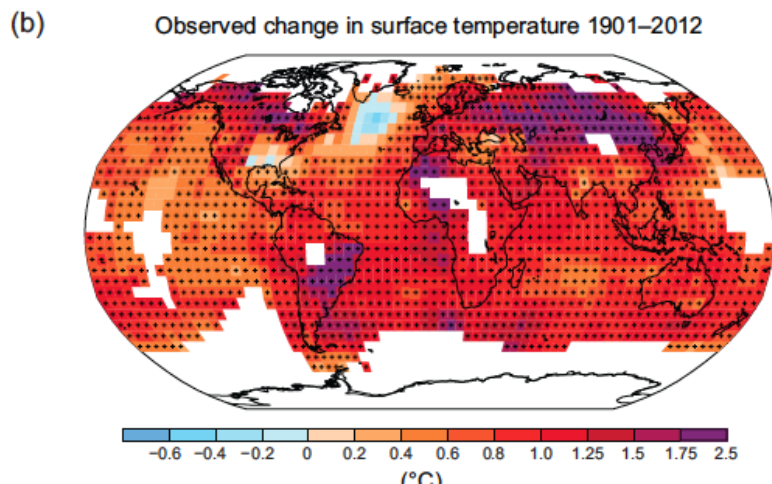
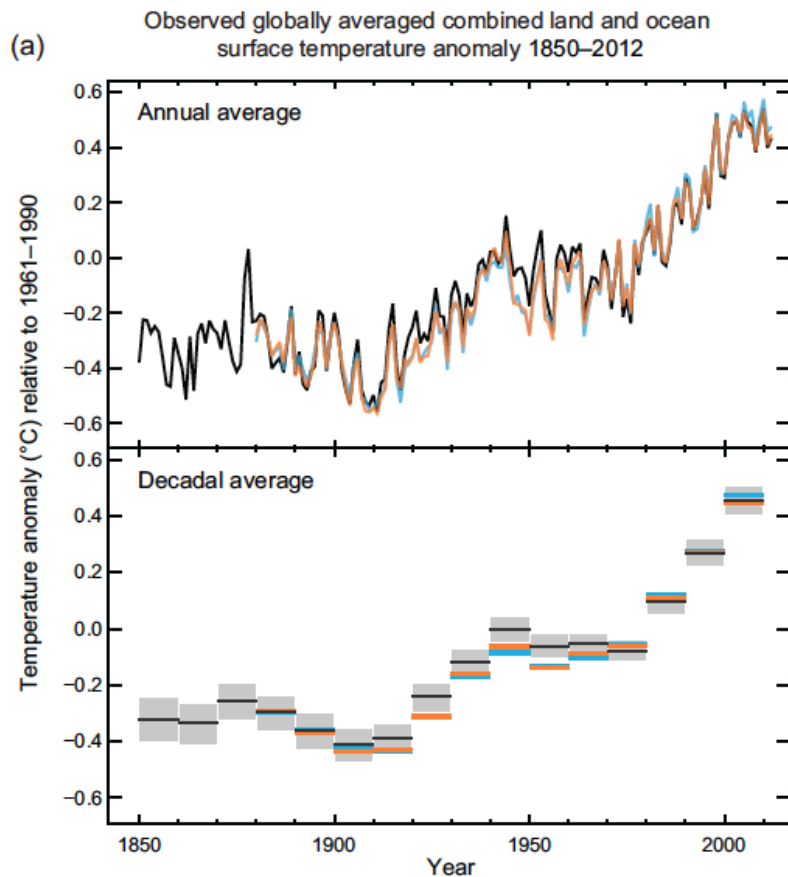
Rich Ambrose

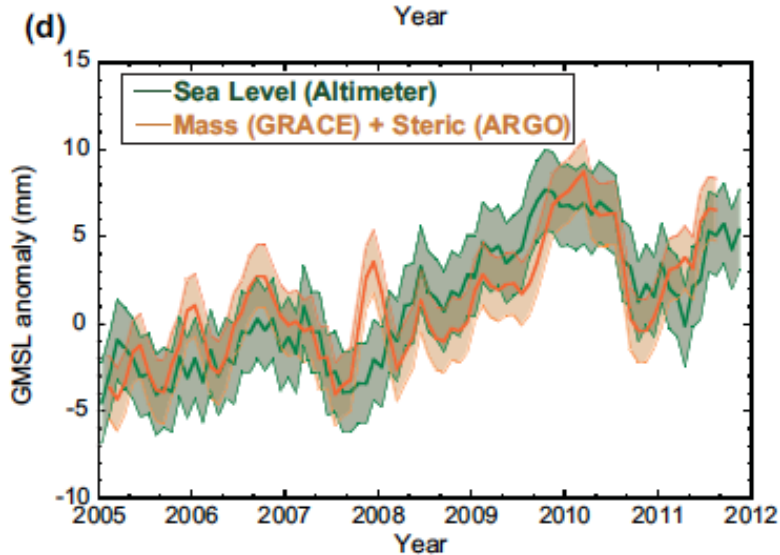
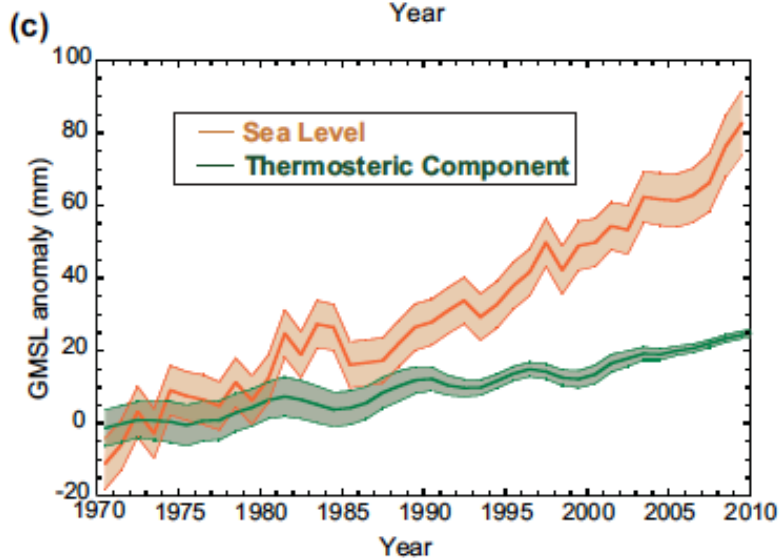
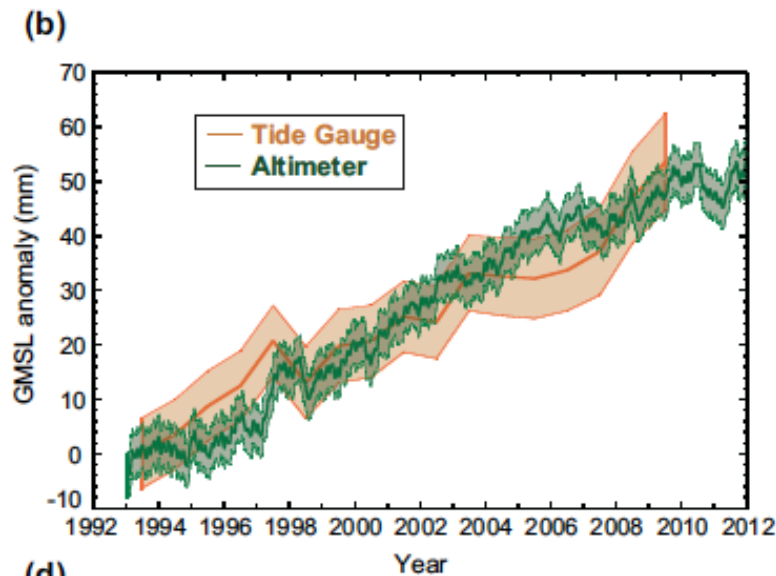
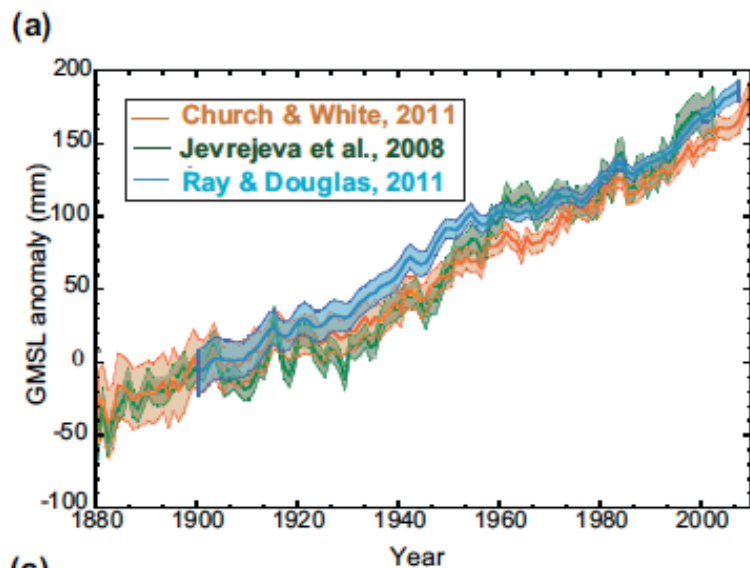
Lauren Brown

James Holmquist

Jordan Rosencranz

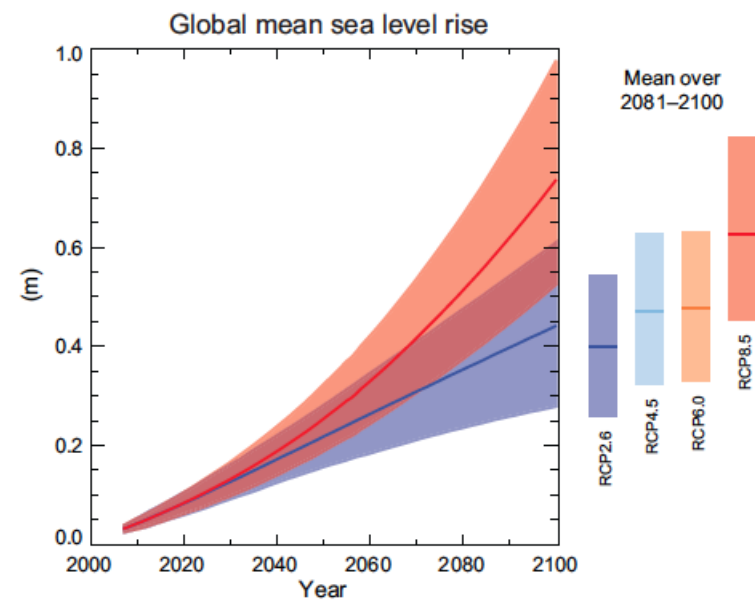
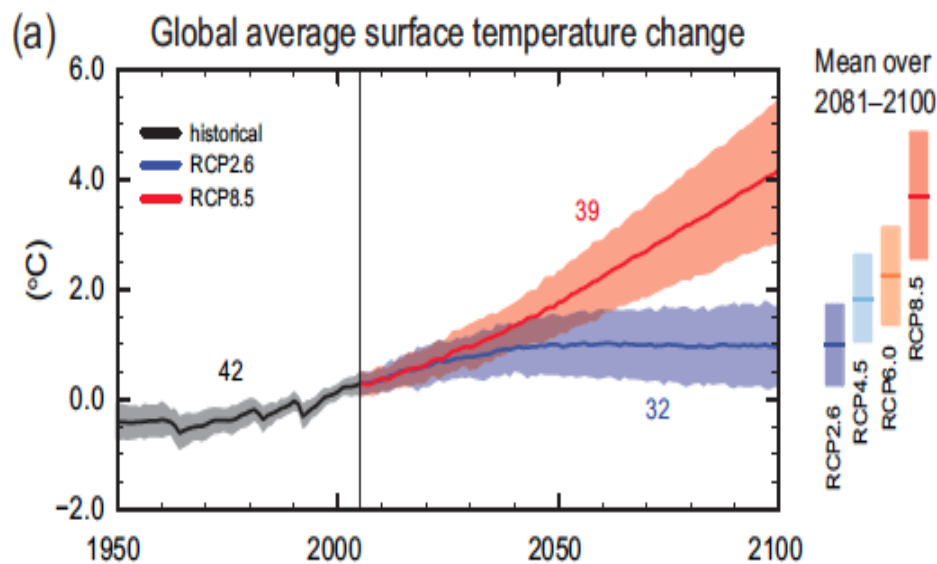






The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*). Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m (see Figure SPM.3). {3.7, 5.6, 13.2}

- Proxy and instrumental sea level data indicate a transition in the late 19th to the early 20th century from relatively low mean rates of rise over the previous two millennia to higher rates of rise (*high confidence*). It is *likely* that the rate of global mean sea level rise has continued to increase since the early 20th century. {3.7, 5.6, 13.2}
- It is *very likely* that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm yr⁻¹ between 1901 and 2010, 2.0 [1.7 to 2.3] mm yr⁻¹ between 1971 and 2010, and 3.2 [2.8 to 3.6] mm yr⁻¹ between 1993 and 2010. Tide-gauge and satellite altimeter data are consistent regarding the higher rate of the latter period. It is *likely* that similarly high rates occurred between 1920 and 1950. {3.7}
- Since the early 1970s, glacier mass loss and ocean thermal expansion from warming together explain about 75% of the observed global mean sea level rise (*high confidence*). Over the period 1993 to 2010, global mean sea level rise is, with *high confidence*, consistent with the sum of the observed contributions from ocean thermal expansion due to warming (1.1 [0.8 to 1.4] mm yr⁻¹), from changes in glaciers (0.76 [0.39 to 1.13] mm yr⁻¹), Greenland ice sheet (0.33 [0.25 to 0.41] mm yr⁻¹), Antarctic ice sheet (0.27 [0.16 to 0.38] mm yr⁻¹), and land water storage (0.38 [0.26 to 0.49] mm yr⁻¹). The sum of these contributions is 2.8 [2.3 to 3.4] mm yr⁻¹. {13.3}
- There is *very high confidence* that maximum global mean sea level during the last interglacial period (129,000 to 116,000 years ago) was, for several thousand years, at least 5 m higher than present, and *high confidence* that it did not exceed 10 m above present. During the last interglacial period, the Greenland ice sheet *very likely* contributed between 1.4 and 4.3 m to the higher global mean sea level, implying with *medium confidence* an additional contribution from the Antarctic ice sheet. This change in sea level occurred in the context of different orbital forcing and with high-latitude surface temperature, averaged over several thousand years, at least 2°C warmer than present (*high confidence*). {5.3, 5.6}

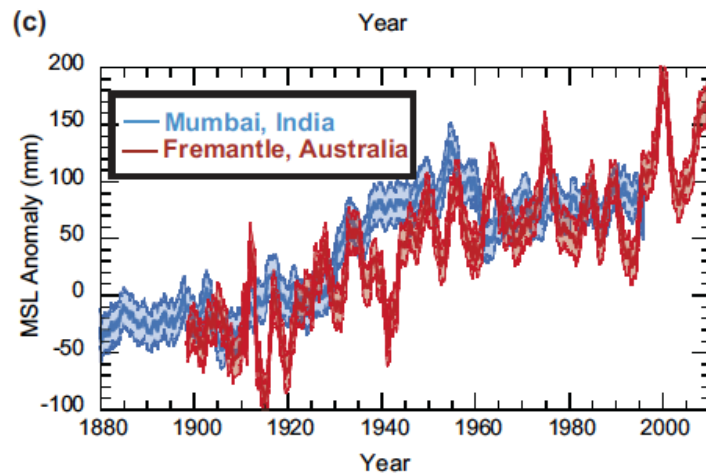
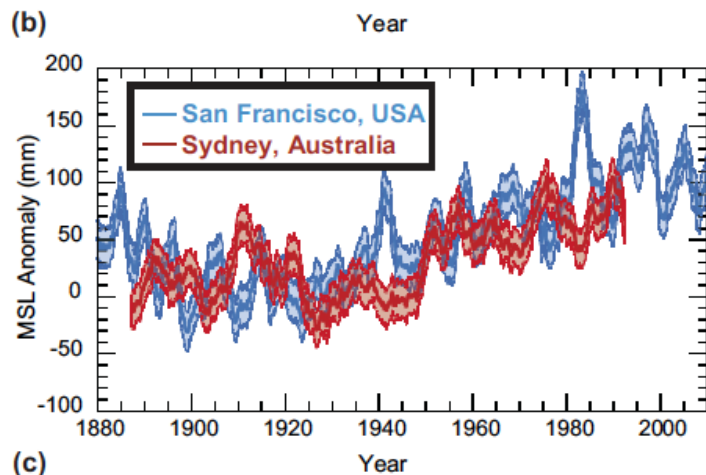
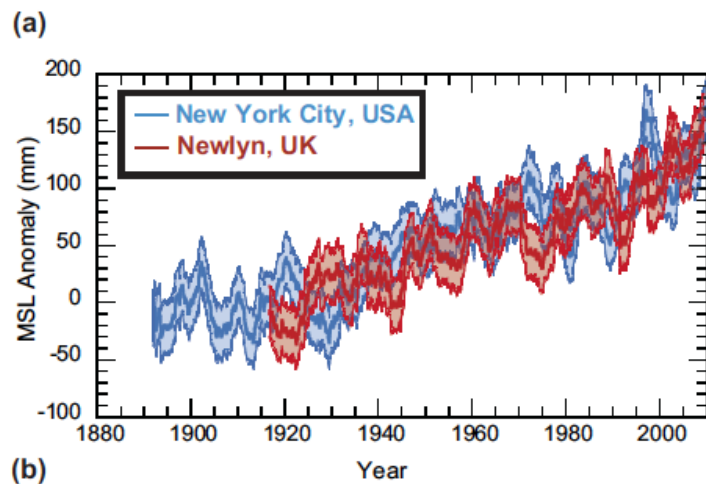


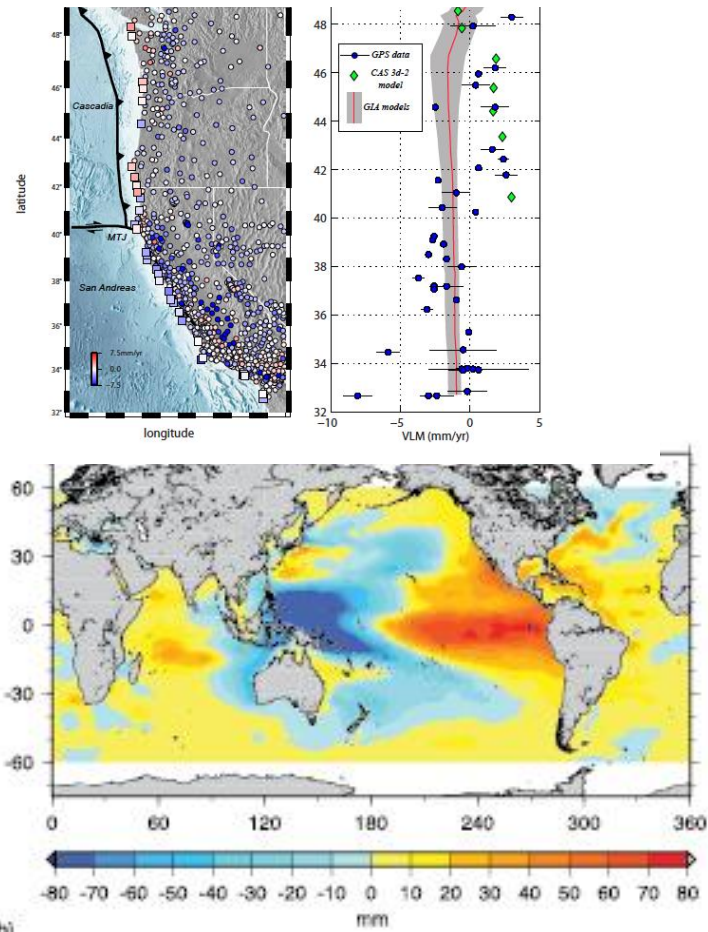
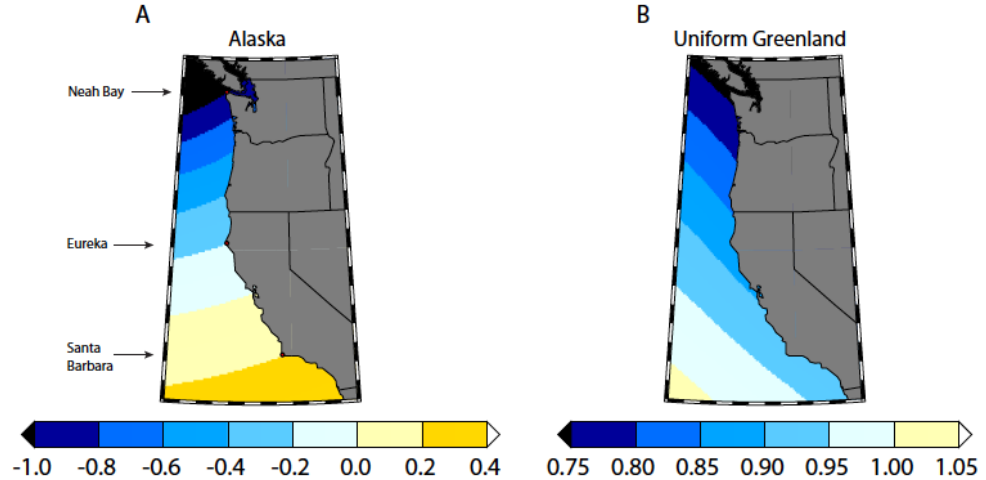
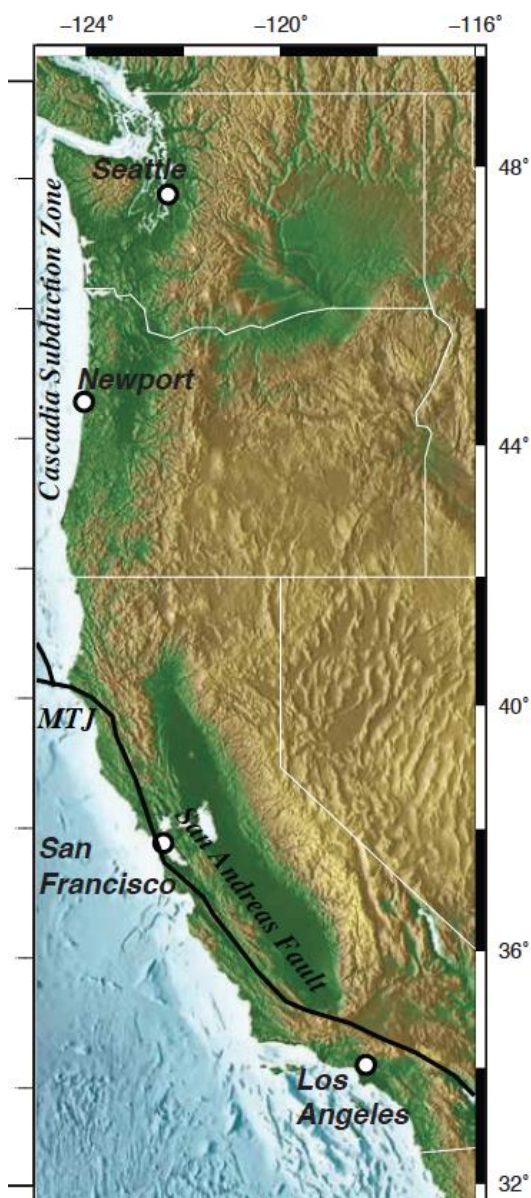
		2046–2065		2081–2100	
	Scenario	Mean	Likely range ^c	Mean	Likely range ^c
Global Mean Surface Temperature Change (°C) ^a	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	Likely range ^d	Mean	Likely range ^d
Global Mean Sea Level Rise (m) ^b	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

E.6 Sea Level

Global mean sea level will continue to rise during the 21st century (see Figure SPM.9). Under all RCP scenarios, the rate of sea level rise will *very likely* exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets. {13.3–13.5}

- Confidence in projections of global mean sea level rise has increased since the AR4 because of the improved physical understanding of the components of sea level, the improved agreement of process-based models with observations, and the inclusion of ice-sheet dynamical changes. {13.3–13.5}
- Global mean sea level rise for 2081–2100 relative to 1986–2005 will *likely* be in the ranges of 0.26 to 0.55 m for RCP2.6, 0.32 to 0.63 m for RCP4.5, 0.33 to 0.63 m for RCP6.0, and 0.45 to 0.82 m for RCP8.5 (*medium confidence*). For RCP8.5, the rise by the year 2100 is 0.52 to 0.98 m, with a rate during 2081 to 2100 of 8 to 16 mm yr⁻¹ (*medium confidence*). These ranges are derived from CMIP5 climate projections in combination with process-based models and literature assessment of glacier and ice sheet contributions (see Figure SPM.9, Table SPM.2). {13.5}
- In the RCP projections, thermal expansion accounts for 30 to 55% of 21st century global mean sea level rise, and glaciers for 15 to 35%. The increase in surface melting of the Greenland ice sheet will exceed the increase in snowfall, leading to a positive contribution from changes in surface mass balance to future sea level (*high confidence*). While surface melting will remain small, an increase in snowfall on the Antarctic ice sheet is expected (*medium confidence*), resulting in a negative contribution to future sea level from changes in surface mass balance. Changes in outflow from both ice sheets combined will *likely* make a contribution in the range of 0.03 to 0.20 m by 2081–2100 (*medium confidence*). {13.3–13.5}
- Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the *likely* range during the 21st century. However, there is *medium confidence* that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century. {13.4, 13.5}





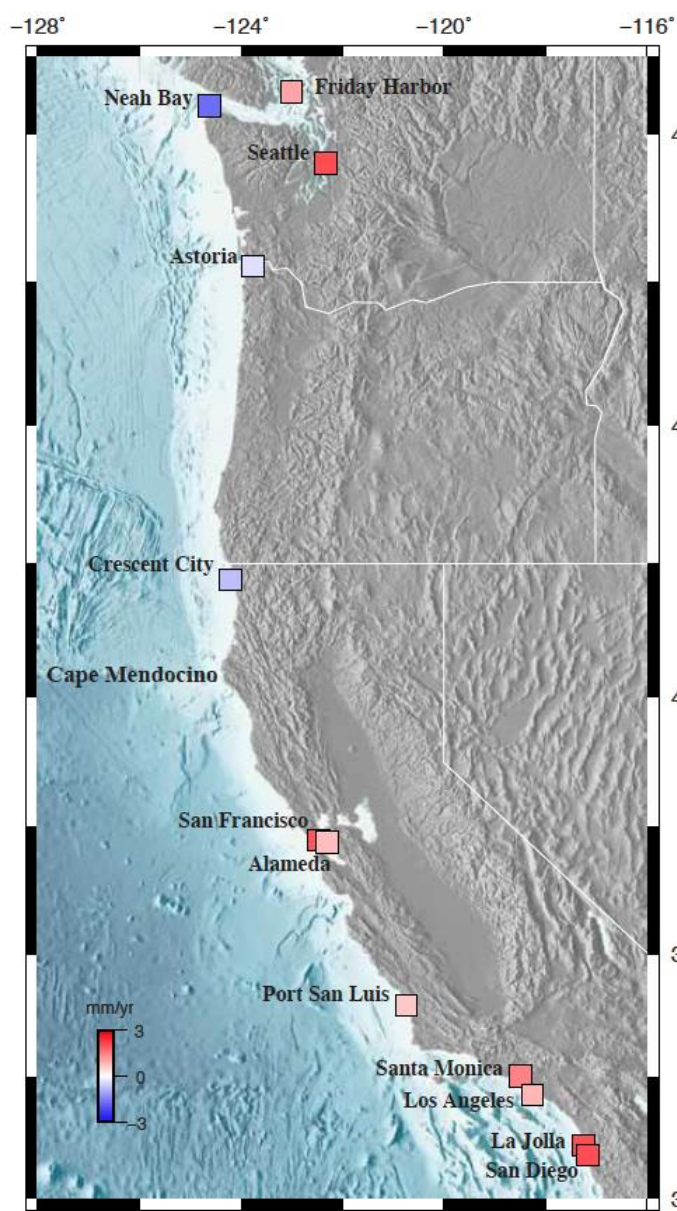
National Research Council. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Washington, DC: The National Academies Press, 2012.

Gravitational Changes Related to Ice Loss

Isostatic Rebound

Tectonics

“The total vertical land motion from all of these geological processes and human activities can be estimated from Global Positioning System (GPS) measurements, which show that much of the coast is rising about 1.5–3.0 mm per year north of Cape Mendocino. The coast south of Cape Mendocino is sinking at an average rate of about 1 mm per year, although GPS measured rates vary widely (-3.7–0.6 mm per year).” NRC 2012



Rates of relative sea-level change estimated from long tide gage records (63–108 years) analysis.

Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future 2012
http://www.nap.edu/catalog.php?record_id=13389

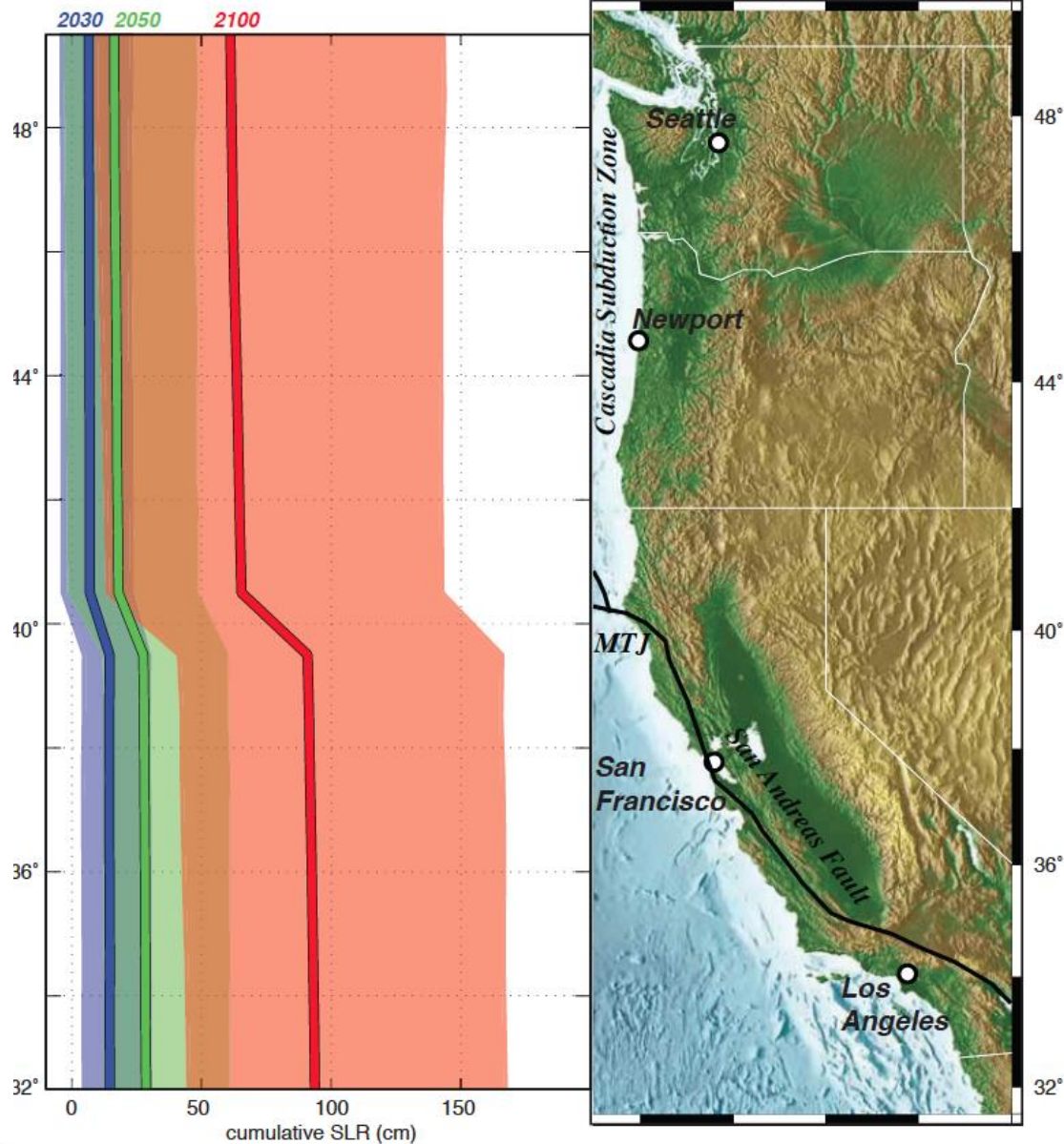
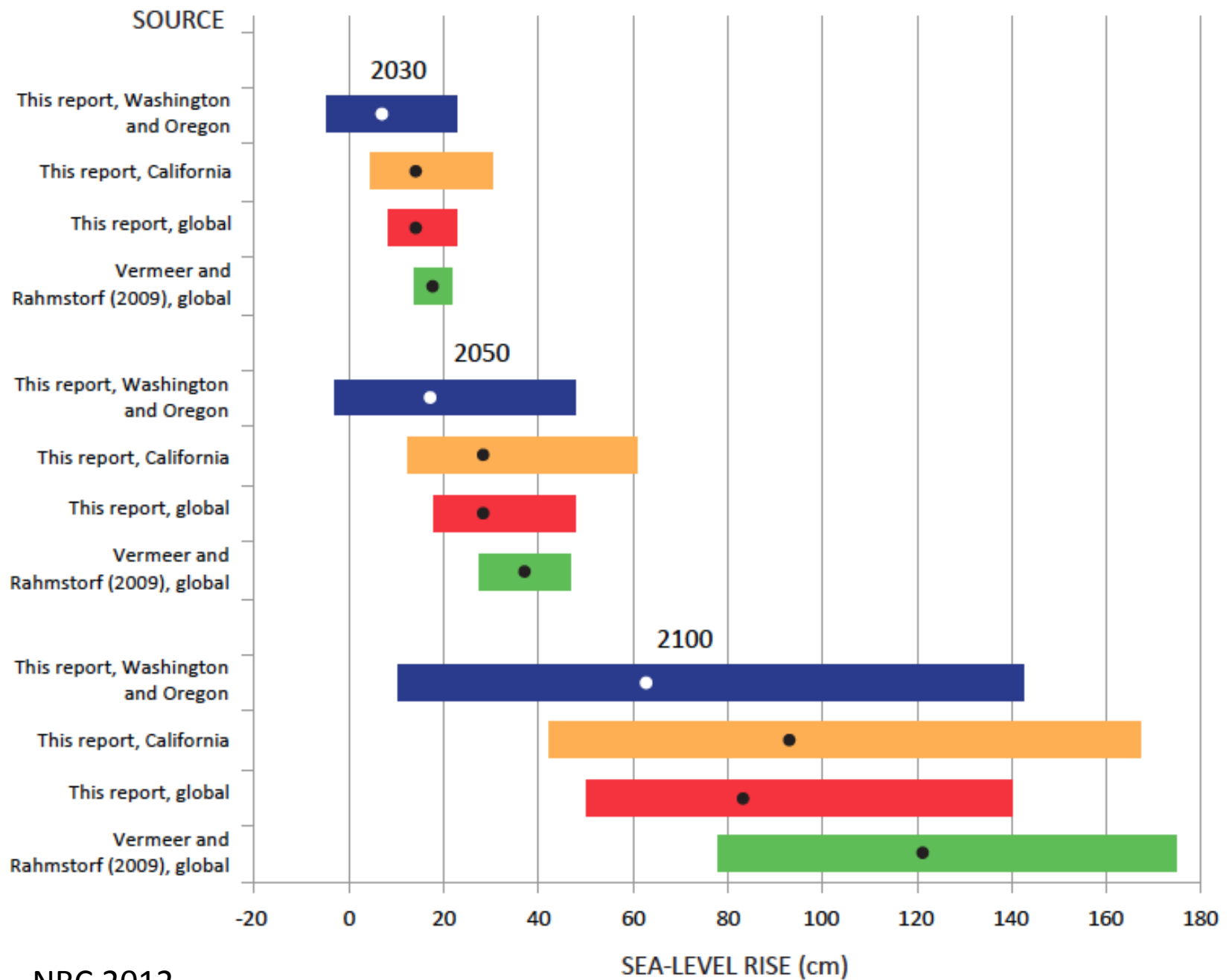


FIGURE S.1 Projected sea-level rise off California, Oregon, and Washington for 2030 (blue), 2050 (green), and 2100 (pink), relative to 2000, as a function of latitude. Solid lines are the projections, and shaded areas are the ranges. Ranges overlap, as indicated by the brown shading (low end of 2100 range and high end of 2050 range) and blue-green shading (low end of 2050 range and high end of 2030 range). MTJ = Mendocino Triple Junction, where the San Andreas Fault meets the Cascadia Subduction Zone.



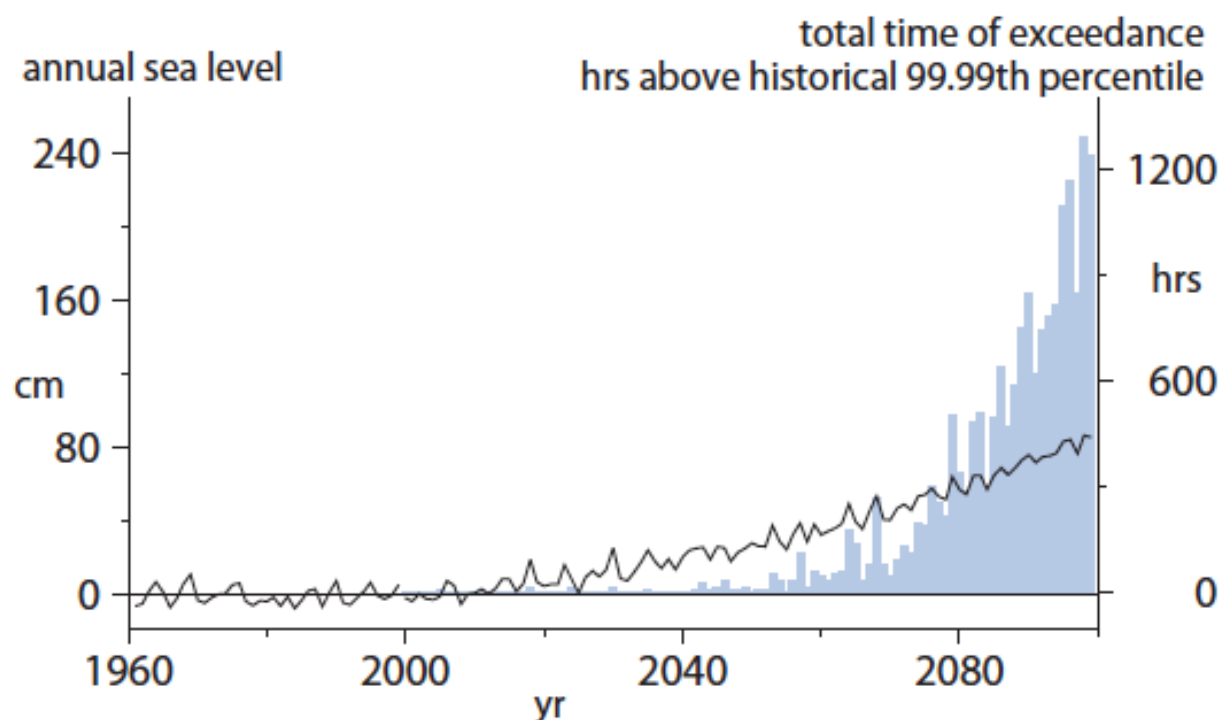
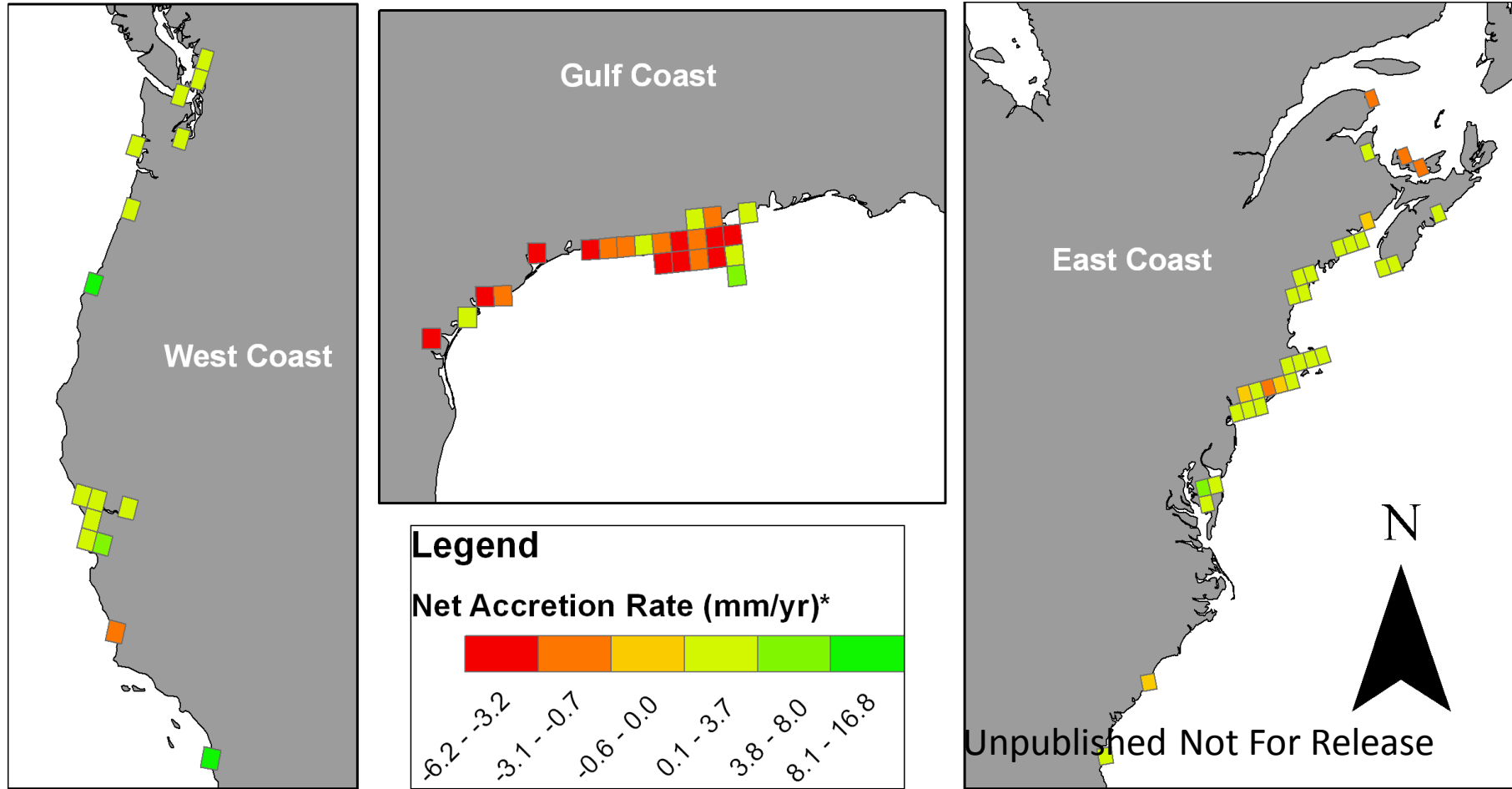


FIGURE 5.12 Projected number of hours (blue bars) of extremely high sea level off San Francisco under an assumed sea-level rise and climate change scenario. In this exercise, a sea-level event registers as an exceedance when San Francisco's projected sea level exceeds its recent (1970–2000) 99.99th percentile level, 1.4 m above historical mean sea level. In the recent historical period, sea level has exceeded this threshold about one time (1 hour) every 14 months. Sea-level rise (black line) during 1960–1999 was arbitrarily set to zero, then increased to the committee's projected level for the San Francisco area over the 21st century (92 cm). SOURCE: Adapted from Cloern et al. (2011).

The Broad Context – Synthesis of Existing Accretion Data



*Net Accretion Rate = (Accretion Rate - (Sea Level Rise + Subsidence))

Global mean sea level rise for 2081–2100 relative to 1986–2005 will *likely* be in the ranges of 0.26 to 0.55 m for RCP2.6, 0.32 to 0.63 m for RCP4.5, 0.33 to 0.63 m for RCP6.0, and 0.45 to 0.82 m for RCP8.5 (*medium confidence*). For RCP8.5, the rise by the year 2100 is 0.52 to 0.98 m, with a rate during 2081 to 2100 of 8 to 16 mm yr⁻¹ (*medium confidence*).

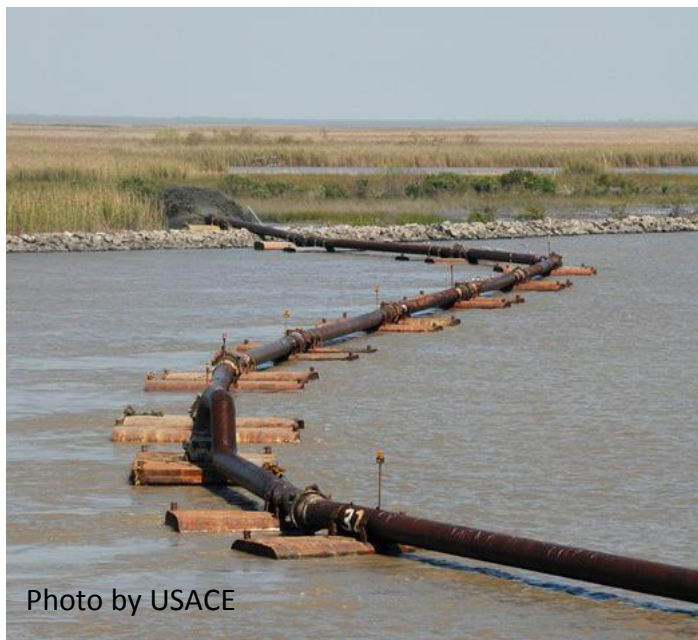
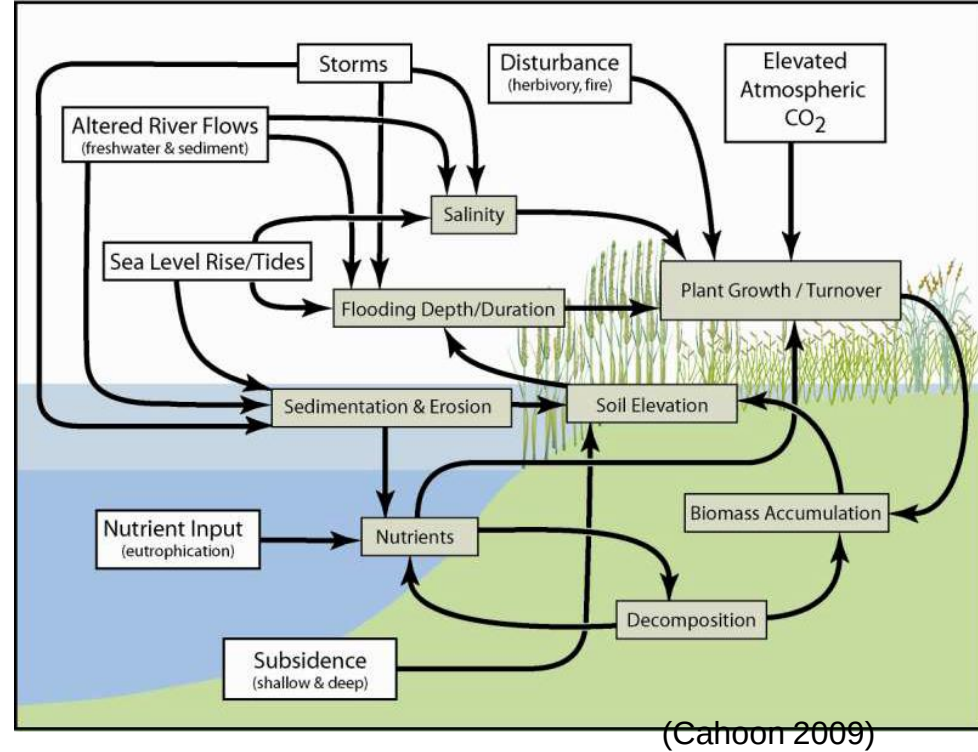
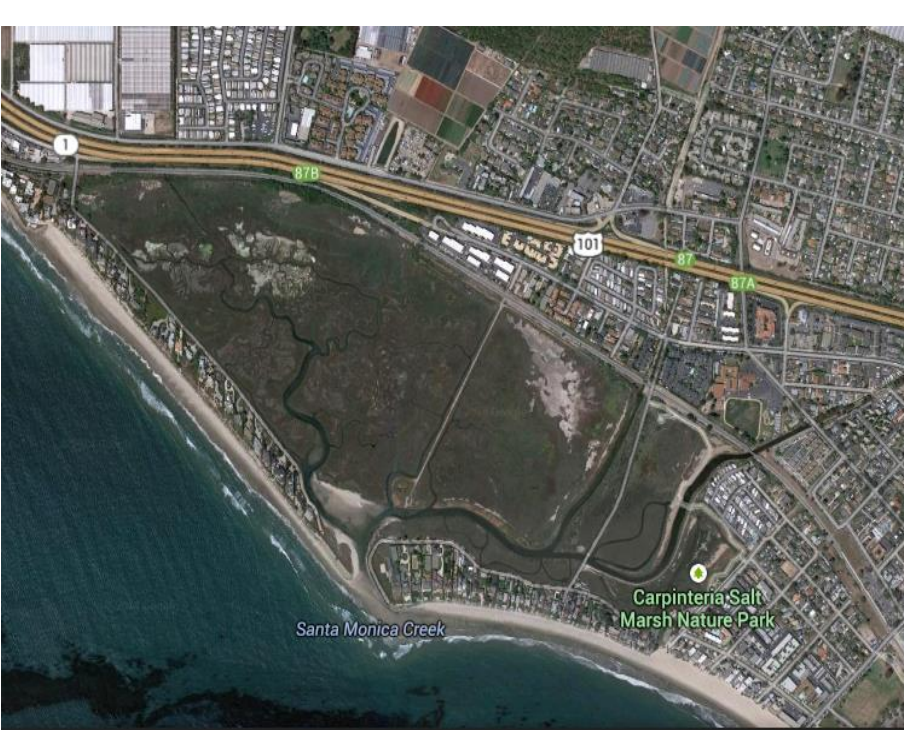


Photo by USACE



[Photo by Louisiana Governor's Office of Homeland Security and Emergency Preparedness]

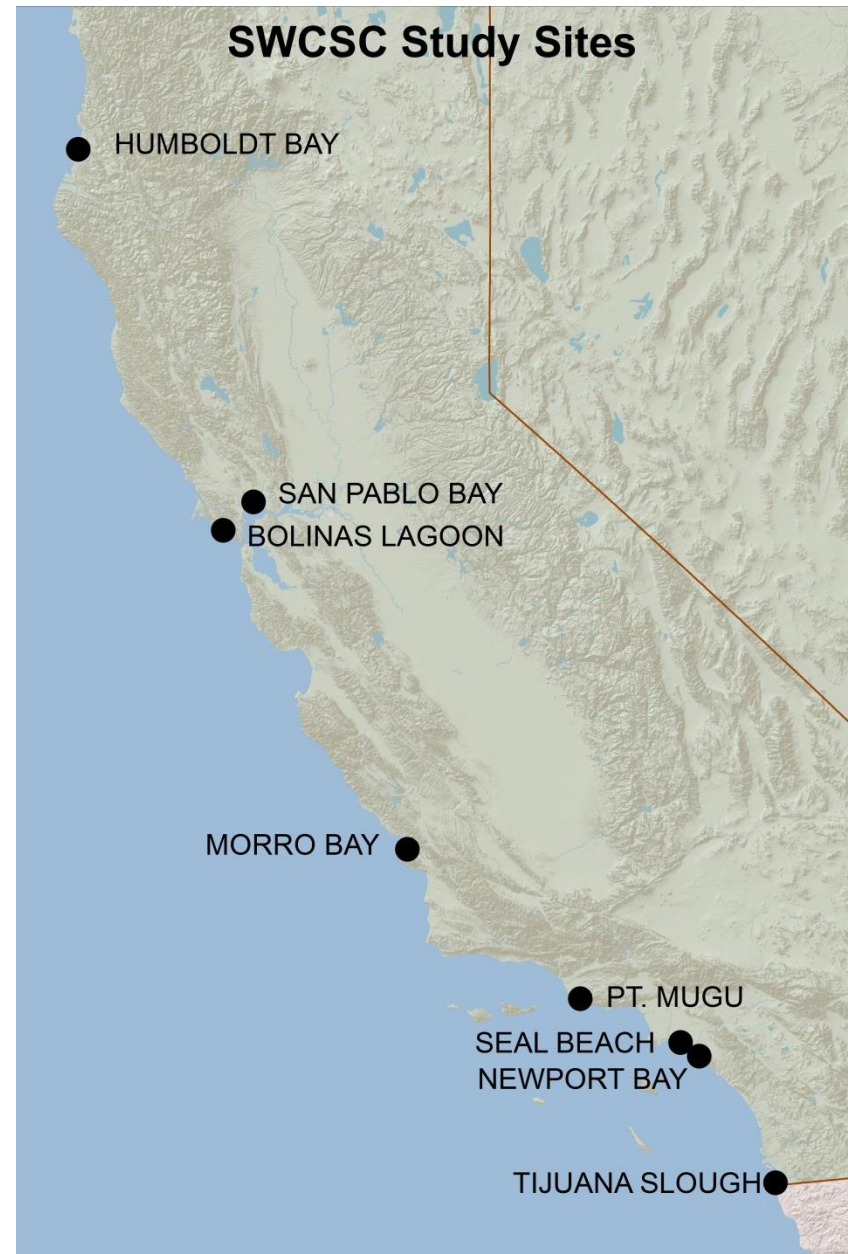
Coastal Ecosystem Response to Climate Change (CERCC)

Goal:

Model and Predict in Spatially and Temporally Explicit Manner Fates of California Coastal Marshes Over the 21st Century

Data Collection:

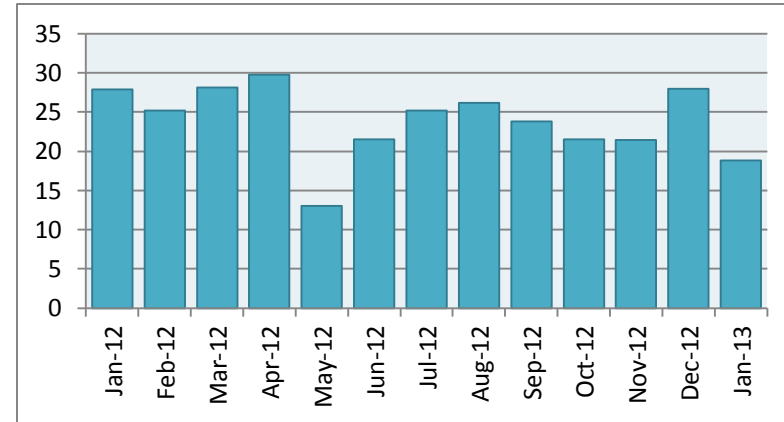
- Elevation
- Bathymetry
- Hydrology
- Vegetation
- Water Monitoring
- Sediment Sampling and Coring



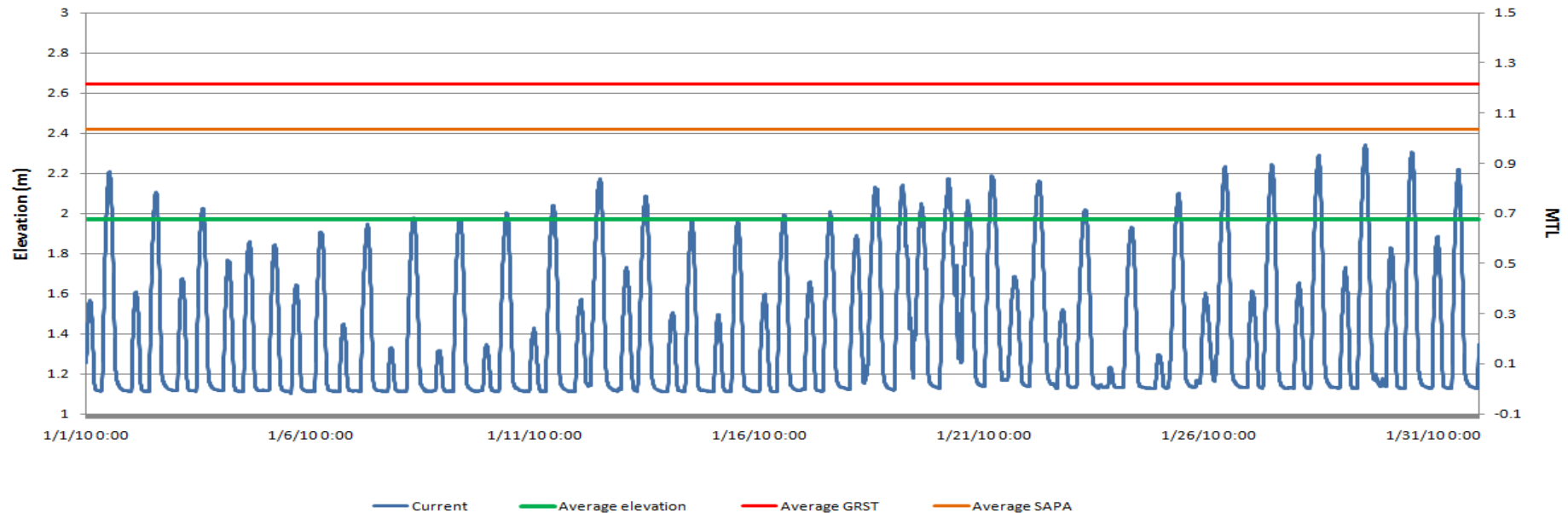
Water Monitoring

- We deployed water level data loggers (Model 3001, 0.01% FS resolution, Solinst Canada Ltd., Georgetown, Ontario) at all sites for continuous monitoring
- Loggers were placed at the mouth and upper reaches of second-order channels (tidal creeks) to capture the local tidal cycle, inundation patterns and salinity.

Percent Time Inundated for San Pablo Bay marsh

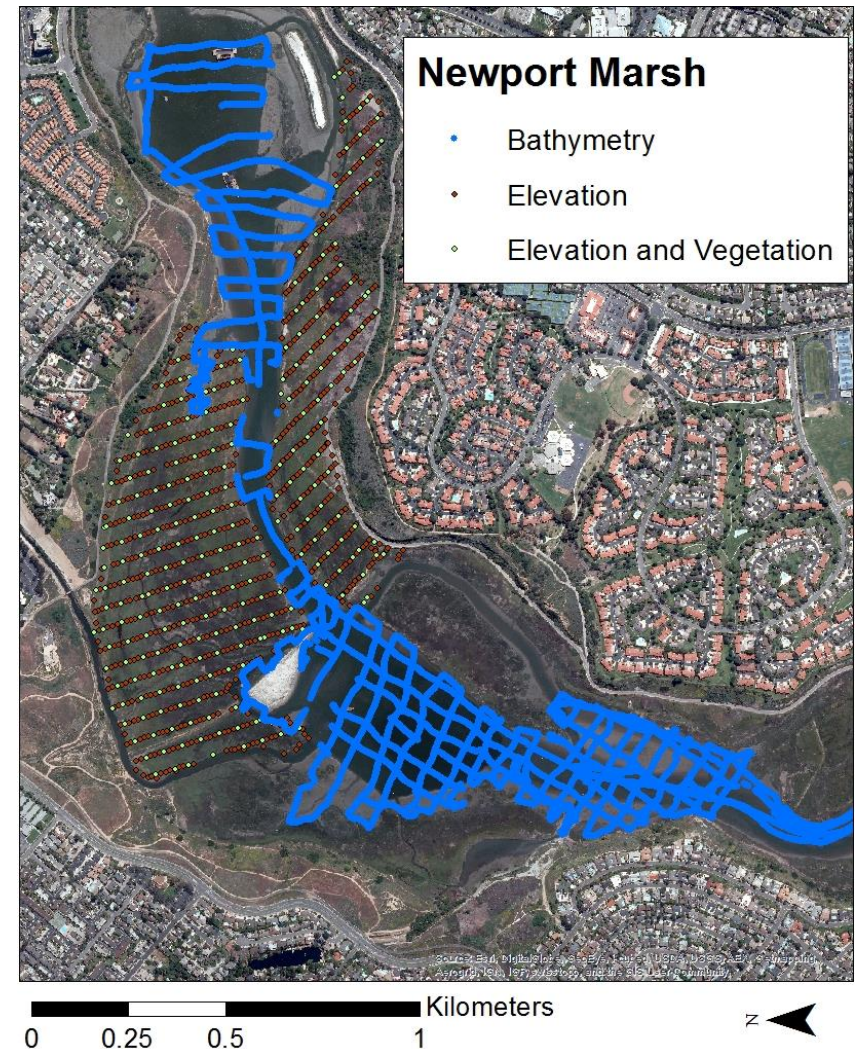


Local Tidal Data for San Pablo Bay marsh



Bathymetry

- Our bathymetric data was collected using a shallow-water echo-sounding system comprised of an acoustic profiler and a Leica RX1200 Real Time Kinematic (RTK) Global Positioning System (GPS) rover unit
- Bathymetry was conducted at all sites totaling 572 hectares of adjacent mudflats and channels



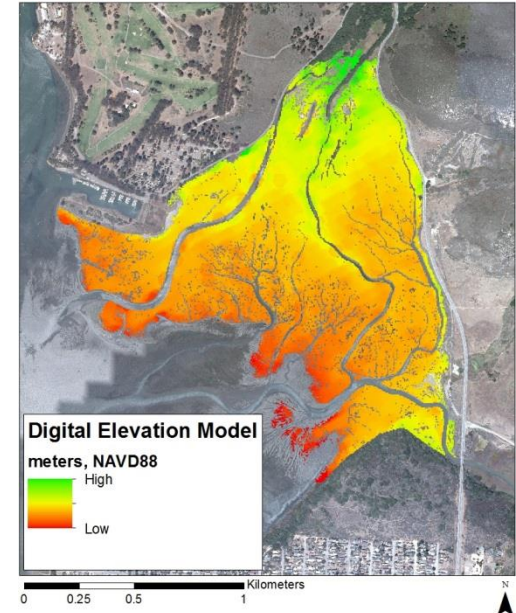
Elevation

- We conducted surveys with a Leica Real Time Kinematic GPS (± 2 cm x, y, z, accuracy)
- Surveyed along transects every 12.5m; transects separated by 50 m
- Created Digital Elevation Models

Morro Bay (188.1 Ha marsh)



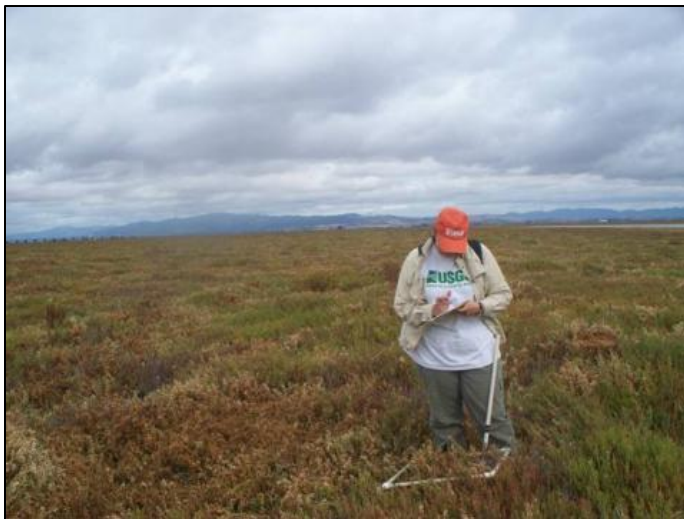
Morro Bay (188.1 Ha marsh)



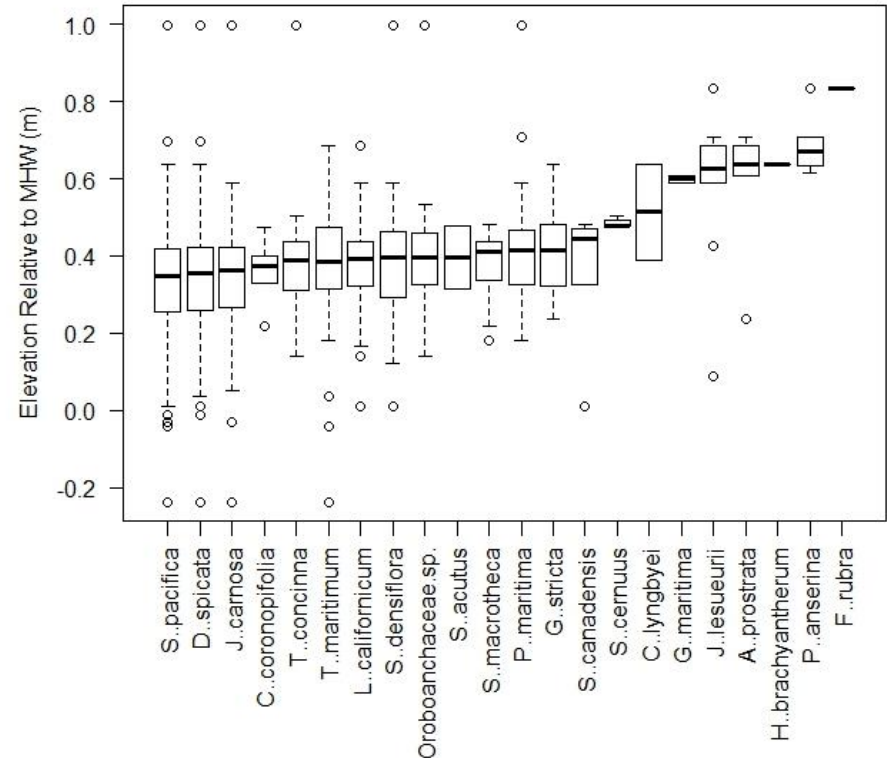
Site	Hectares	Elevation Measurements (n)	Mean Elevation	Maximum Elevation	Minimum Elevation	Elevation Range	Mean relative to MHW
Humboldt	169	3020	1.77	2.82	0.58	2.24	0.32
Bolinas	87	1832	1.58	3.42	1.12	2.3	0.03
San Pablo Bay	1410	1725	1.95	4.99	-0.17	5.16	0.11
Morro Bay	188	3115	1.63	3.05	0.5	2.55	0.25
Pt. Mugu	112	1924	1.73	2.76	1.04	1.72	0.35
Seal Beach	266	4757	1.34	3.56	0.31	3.25	0.01
Newport	61	1234	1.53	1.53	0.68	0.85	0.17
Tijuana Slough	374	5832	2.22	5.32	0.99	4.33	0.21

Vegetation

- Quantify plant species abundance and distribution relative to elevation and tidal ranges
- recorded vegetation data within a 0.25 m² quadrat at every fourth (25%) elevation point. We measured height (mean and maximum, measured within 0.05 m) and visually estimated percent cover for each species within each quadrat.



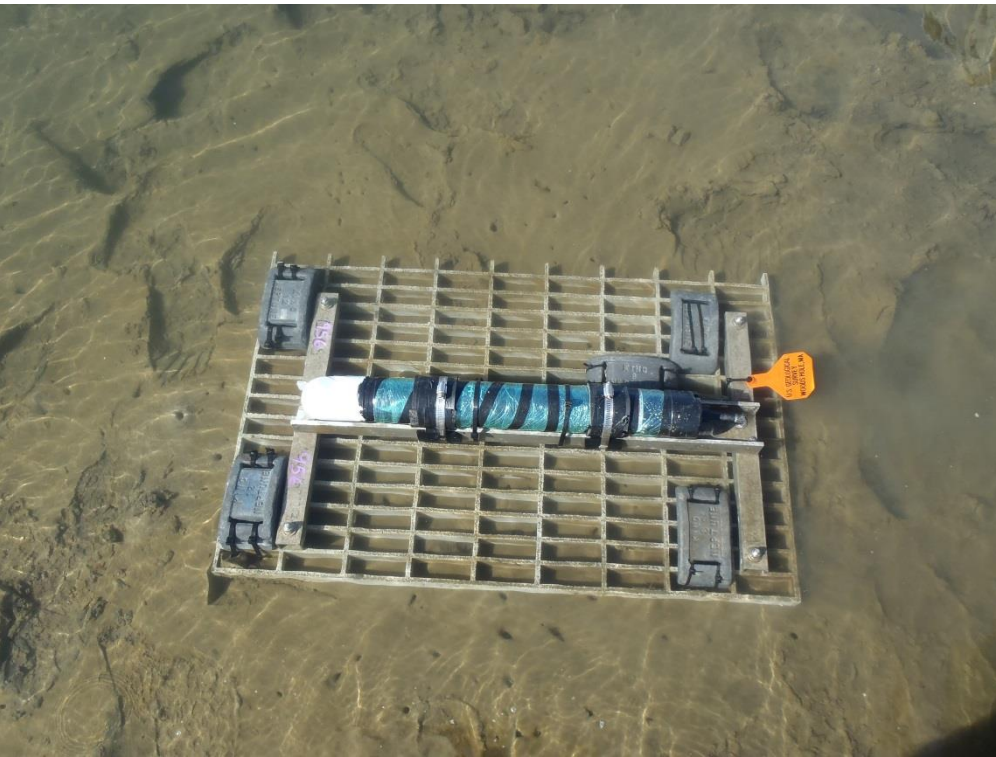
Elevation of Plant species relative to MHW in Humboldt Bay



Sediment

- SETs are used to determine changes in marsh surface elevation, contributions of surface and subsurface processes, and subsidence. Vertical accretion is measured from cores of marker horizons.
- Estimate sediment flux measurements to determine spatial patterns of suspended sediment concentrations in a spatially-explicit, 3-D accretion model.

Suspended Sediment Measurement

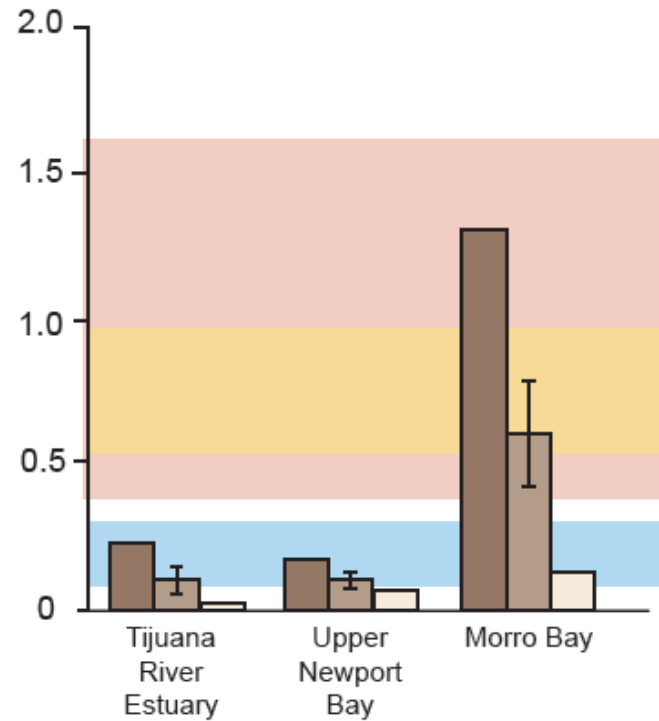


Surface Elevation Tables (SETs)

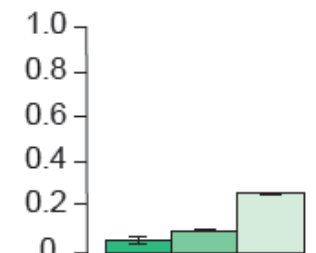




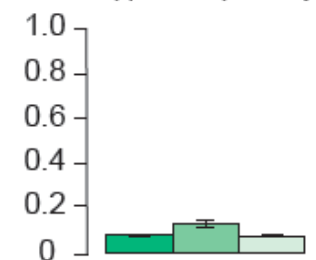
Past Accretion Compared to Past and Projected SLR



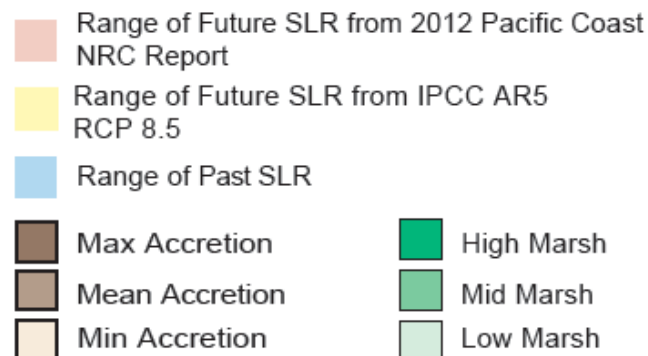
Tijuana River Estuary



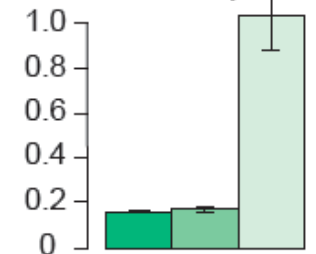
Upper Newport Bay



Key



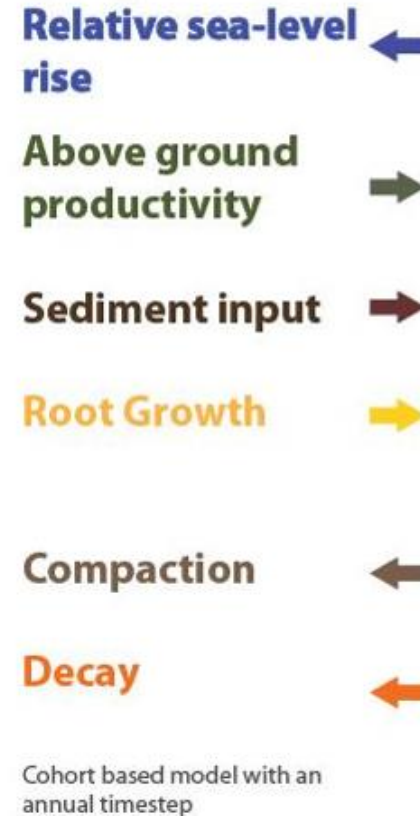
Morro Bay



Wetland Accretion Rate Model for Ecosystem Resilience (WARMER)

- Predict salt marsh elevation response to sea-level rise by explicitly modeling the primary above and belowground processes
- Use elevation, vegetation, Water, sediment sampling and core data for model parameterization and calibration

Conceptual Model

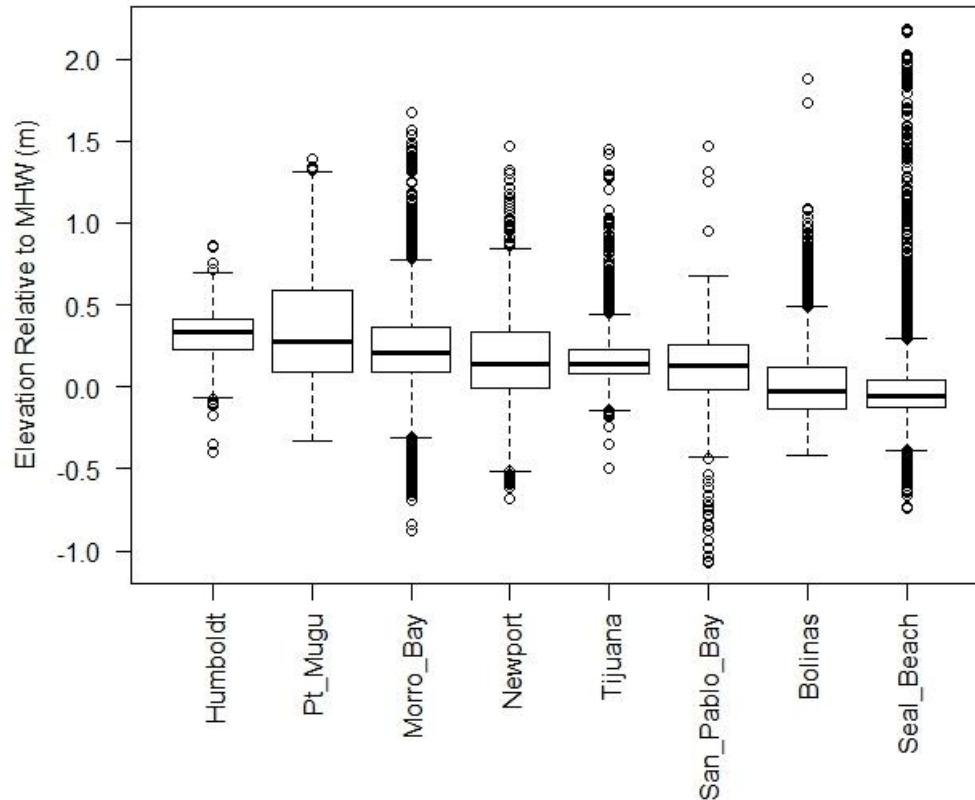




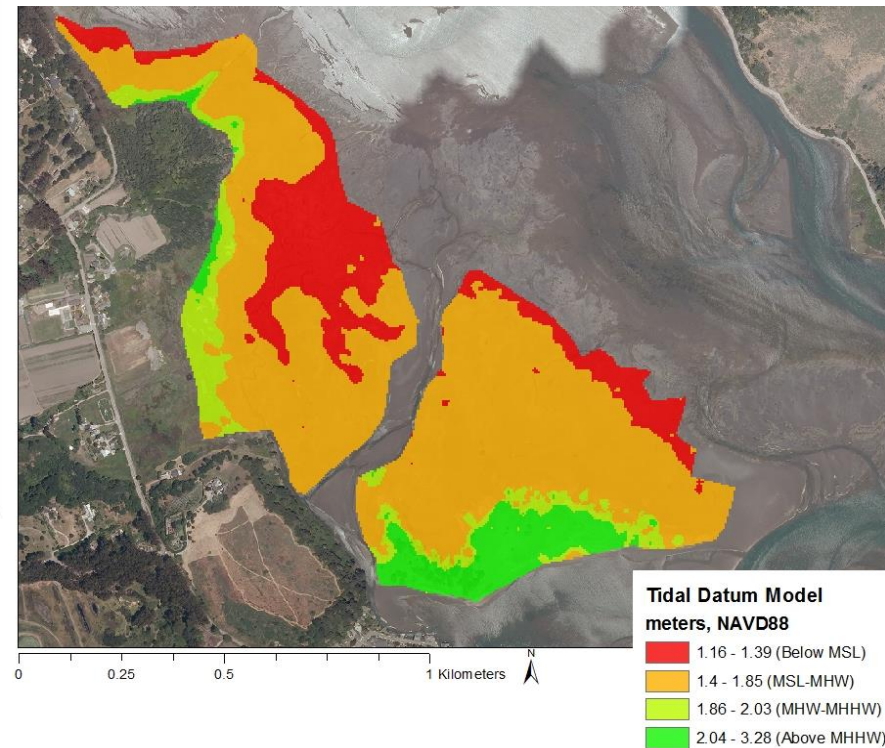
THANKS!

Water Monitoring

- Build Tidal Datum Models
- Compare Sites to assess vulnerability

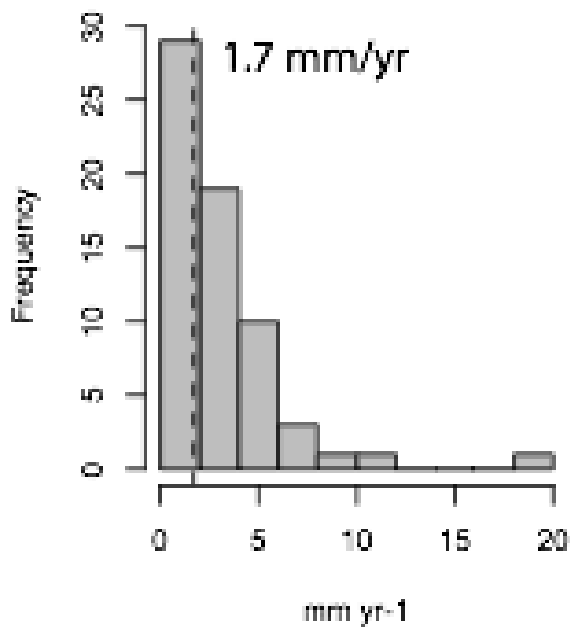


Bolinas Lagoon

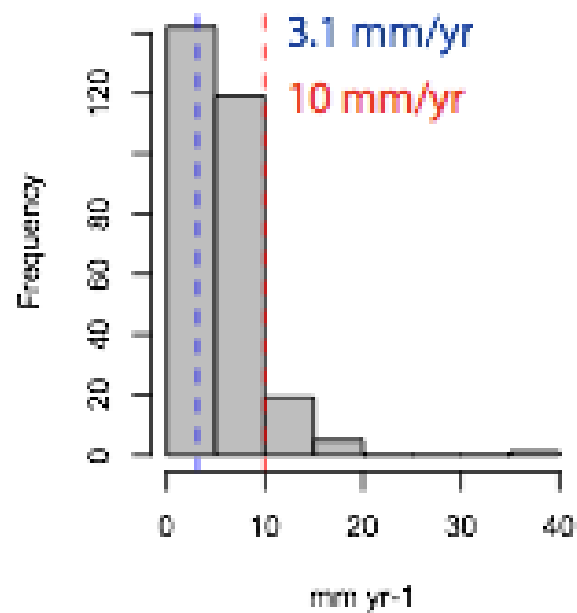




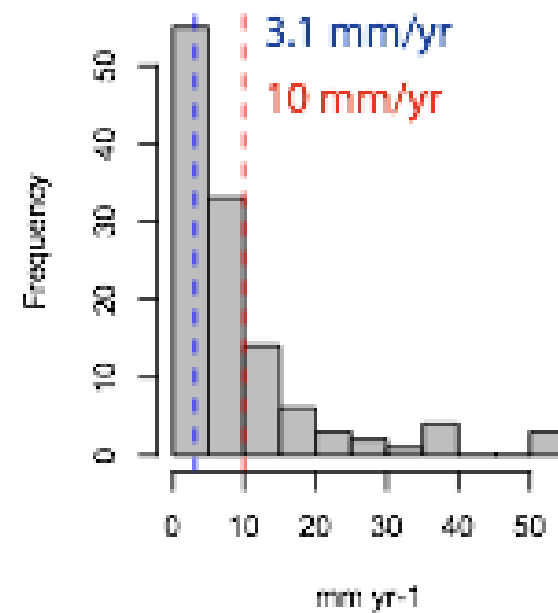
Holocene Accretion



Decadal Accretion



Recent Accretion



Unpublished Not For Release