GC13C-0796

Levee Vertical Land Motion Changes in the Sacramento-San Joaquin Delta

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Abstract

The Sacramento-San Joaquin Delta is home to numerous islands that provide economically and agriculturally important land. However, the island interiors are sinking and most sit below sea level, making the levee roads that surround the islands vital for their continued health and productivity. Airborne LiDAR (Light Detection and Ranging) data over the islands was collected in 2007 and 2015 and mobile LiDAR data was collected along the levee roads on Bacon, Bouldin, Jersey, and Brannan-Andrus Islands in 2015 and 2016. These datasets provide high resolution topographic models with ~8 year separation that can be used to examine topographic change along the levees. A cross-section of each dataset was output along the approximate centerline of the levee road, so that profiles of the 2007 and 2015/2016 LiDAR observations could be compared. Regions of levee road subsidence and of levee road construction and reinforcement on the order of 0-3 centimeters per year were evident in locations around the islands. There is a high degree of spatial variability of these rates even for individual islands. Additionally, the levee road heights and rates of change, in regions of road subsidence, were compared to sea level rise projections to evaluate the risk that rising sea level may pose to the islands in the future.

Dataset	Type	Point Cloud Resolution	Collected By:
2007 ALS	Airborne Laser Scanning	< 1 point/m^2	CA Dept. of Water Resources (1)
2015/2016 MLS	Mobile Laser Scanning	> 100 points/m^2	USGS
2015 ALS	Airborne Laser Scanning	2 – 5 points/m^2	NCALM and CRREL

Methods

Georeferencing: The 2007 ALS data was received with the horizontal datum in NAD83 and the vertical datum in NAVD88, realized using the Geoid12A model from NGS. The 2015 ALS and 2015/2016 MLS point clouds were processed using the same horizontal and vertical datum (including geoid model). Primary base station locations were determined in NAD83 using the NGS Online Positioning Users Service (OPUS). Ellipsoidal heights for all point clouds were then transformed to NAVD88 using the Geoid12A model from the NGS.

Noise Filtering: The ALS and MLS datasets required filtering to remove erroneous LiDAR returns and features, such as buildings, trees, and powerlines, that might lead to an incorrect determination of the levee road position. As series of automated elevation and isolated points filters were used to complete this step in addition to manual filtering for persistent, near-road features.

Surface Interpolation: Following data filtering, TIN's were created for each dataset at the maximum resolution supported by the data. The MLS and 2015 ALS point cloud densities were both high enough to set a maximum edge length of 1 m for the near road triangulation. The 2007 ALS point cloud density was lower (< 1 point per m^2) and the maximum edge length of the triangulation had to be set to 2 m.

Data Output: Where available, MLS trajectories were used to output data from the TIN's at a 1 m resolution for both the ALS and MLS data. Where MLS trajectories were not available, the topographic high created by the levee itself was used to define the levee position and artificial trajectories were drawn to output the data along at a resolution of 1 m.

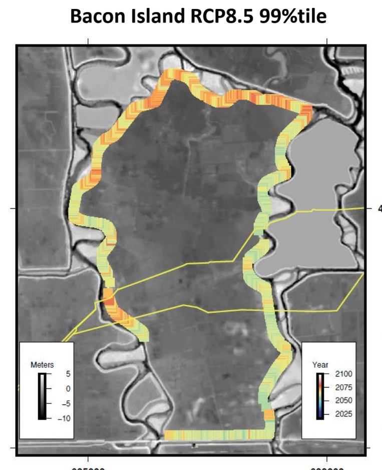
Determining levee subsidence rate: The 2007 ALS along road profile height was subtracted from the 2015 ALS along road profile height or, where available, the MLS along road profile height to determine the amount of levee subsidence during the study period. Combined with the length of the study period, the absolute subsidence was used to determine the average rate of subsidence over the ~ 8 year study.

Error Assessment: Error on all three datasets was evaluated and the cumulative error on both the ALS – ALS and the ALS – MLS comparisons was evaluated. The vertical RMSE for the 2007 ALS data is 9.4 cm (2). The vertical error on the 2015 NCALM ALS data is 5 cm and the vertical error on the 2015/2016 MLS data is 2 cm (3,4). The cumulative error for the ALS – ALS data (Grizzly and some of Sherman) and the ALS – MLS data is the square root of the sum of the squares of the two individual errors. The final error on the ALS – ALS data is 10.6 cm and the final error on the ALS – MLS data is 9.6 cm.

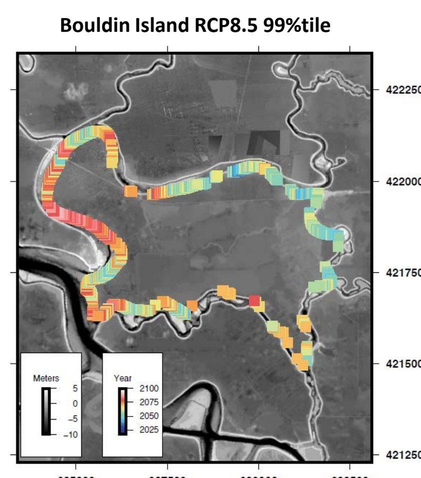
Sea Level Rise

We employ the recent projections developed for the 4th California Climate Assessment (5). These probabilistic projections follow preexisting methodology (6) modified by the recent results for the additional West Antarctic Ice Sheet contribution (7). The Kopp et al. (2014) (6) method creates a time-dependent probability distribution of the different components, assumed independent of one another, and samples them to calculate SLR probabilities. We refer the reader to Cayan et al. (2016) and Kopp et al. (2014) for thorough descriptions of the methodologies.

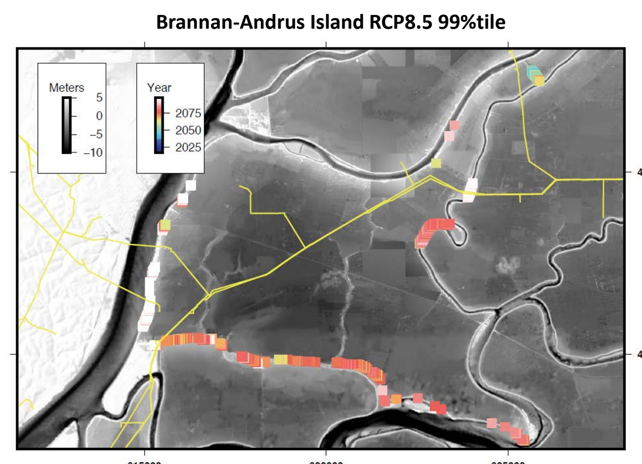
Bacon Island RCP8.5 99%tile



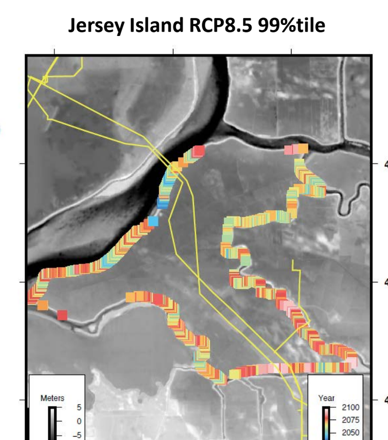
Bouldin Island RCP8.5 99%tile



Brannan-Andrus Island RCP8.5 99%tile



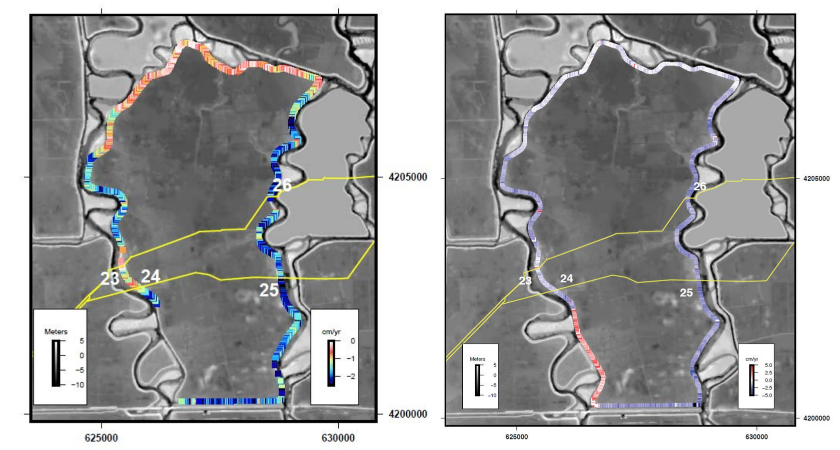
Jersey Island RCP8.5 99%tile



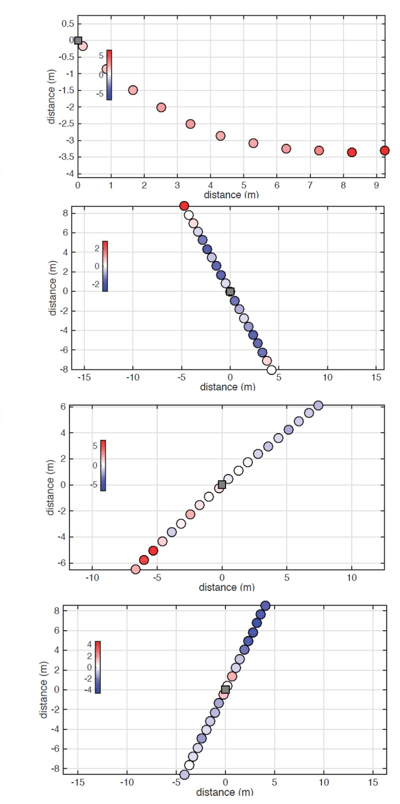
The four, island specific, scenarios shown here depict the year when the levees would fail based on the RCP8.5 (business as usual, without significant emissions caps) sea level rise projections.

Bacon Island

Vertical Levee Motion (VLM)



Levee Crossings

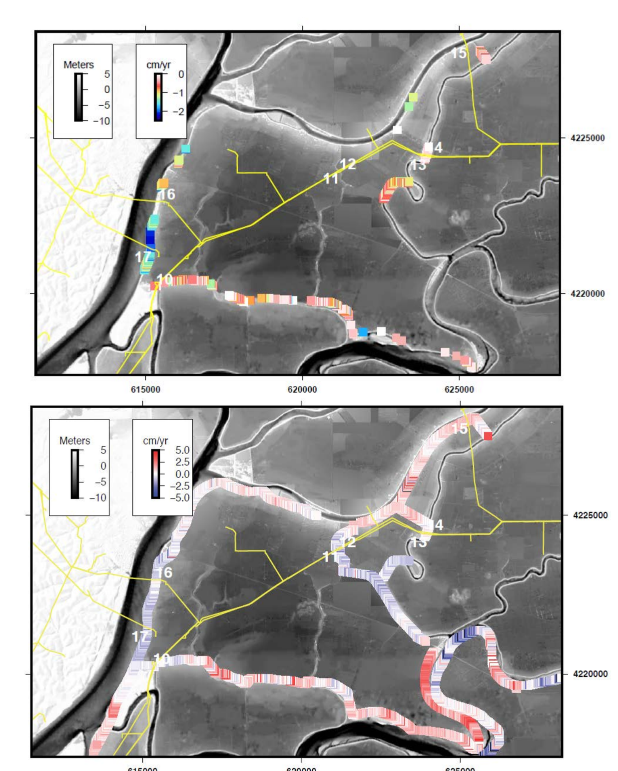


The left VLM plot shows only subsidence along the levee road while the right VLM plot shows both subsidence and positive change due to mitigation and construction activity. Yellow lines indicate where pipelines cross the levee roads and the plots on the right show the vertical motion near each crossing.

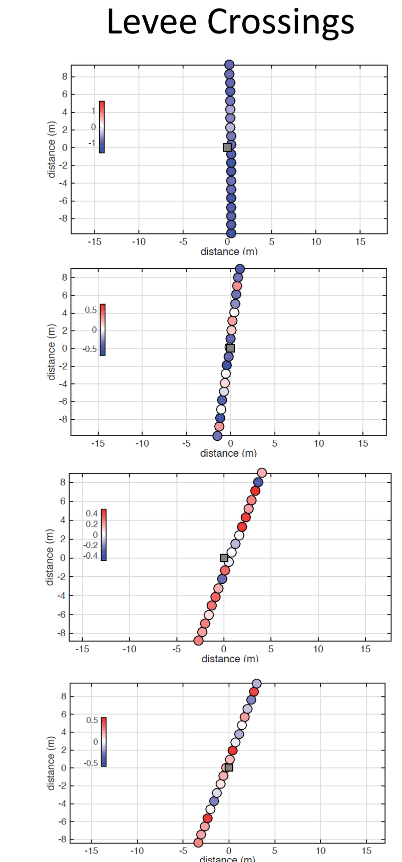
Bacon Island		CA Delta Stewardship Council (2)		
		Meets Standard	Minimally Below Standard	Below Standard
2007 - 2015 LiDAR Results	Increased Elevation	3	1	0
	No Significant Change	2	1	1
	Decreased Elevation	30	0	1

Brannan - Andrus Island

Vertical Levee Motion (VLM)



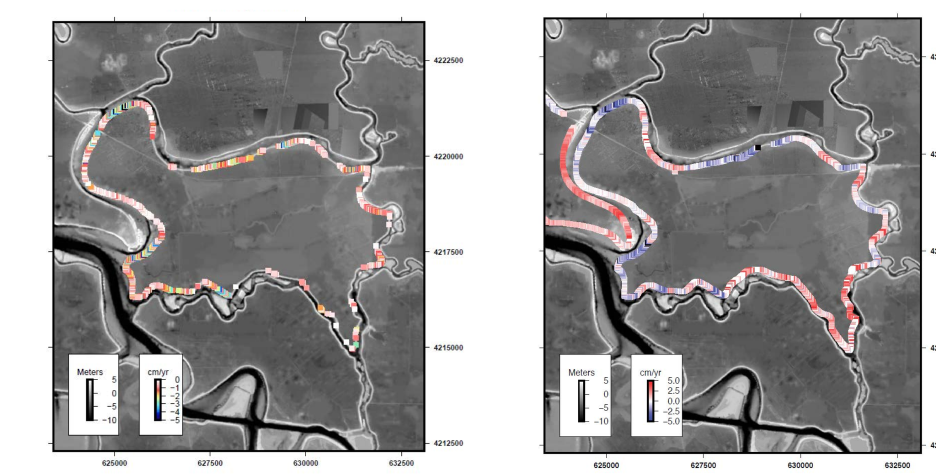
Levee Crossings



Brannan-Andrus Island		CA Delta Stewardship Council (2)		
		Meets Standard	Minimally Below Standard	Below Standard
2007 - 2015 LiDAR Results	Increased Elevation	4	0	0
	No Significant Change	7	0	0
	Decreased Elevation	1	0	0

Bouldin Island

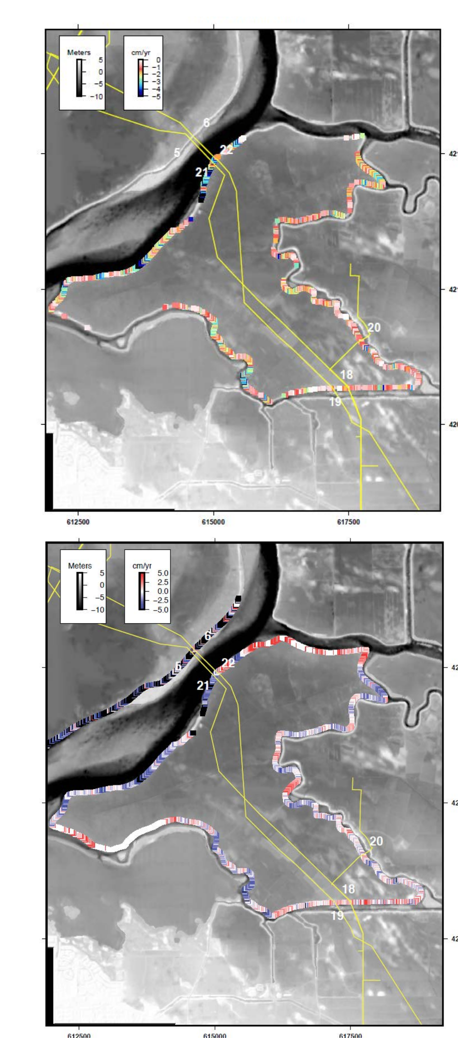
Vertical Levee Motion (VLM)



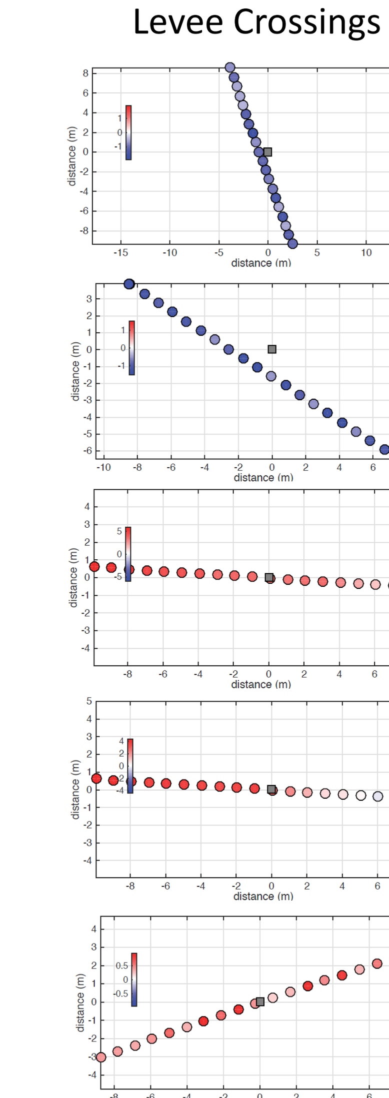
Bouldin Island		CA Delta Stewardship Council (2)		
		Meets Standard	Minimally Below Standard	Below Standard
2007 - 2015 LiDAR Results	Increased Elevation	9	0	5
	No Significant Change	19	3	1
	Decreased Elevation	7	0	1

Jersey Island

Vertical Levee Motion (VLM)



Levee Crossings



Jersey Island		CA Delta Stewardship Council (2)		
		Meets Standard	Minimally Below Standard	Below Standard
2007 - 2015 LiDAR Results	Increased Elevation	9	1	0
	No Significant Change	17	1	0
	Decreased Elevation	4	0	0

Conclusions

Using repeat aerial and mobile LiDAR surveys, we examined levee road health on Bacon, Bouldin, Brannan-Andrus, and Jersey Islands in the Sacramento – San Joaquin River Delta. Not only are the islands home to valuable farming land, there are also numerous pipelines crossing the Delta islands that could be adversely affected by changes in levee elevation. All of the islands surveyed show regions of both remediation and continued subsidence. Interestingly, remediation efforts have not been wholly focused on those areas registered as most at-risk for flooding events by the CA Delta Stewardship Council and subsidence continues in many of these at-risk areas. Levee road elevation was examined in detail near pipeline – road crossings to identify the pipelines currently experiencing the most stress from subsidence. Finally, sea level rise scenarios were paired with current levee elevations to map the segments of levee road that will be most at risk in the future. While most of the levees are predicted to withstand the earliest effects of sea level rise, Bouldin Island and parts of Jersey Island would be at-risk in the next few decades.

References

(1) Resources, C. D. of W. 2007 CDWR Lidar: San Joaquin River Delta (CA). *NOAA Data Access Viewer* (2007). Available at: https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=2523/details/2523. (Accessed: 20th July 2004)
(2) Council, C. D. S. Delta Levee Conditions Maps. *Delta Maps* Available at: http://deltacouncil.ca.gov/delta-maps.
(3) Glennie, C. Kinematic Terrestrial Light-Detection and Ranging Sytem for Scanning. *Transp. Res. Rec.* No. 2105, 135–141 (2009).
(4) Transportation Research Board. *Guidelines for the Use of Mobile LIDAR in Transportation Applications.* (2013).
(5) Cayan, D. R., J. Kalansky, S. Iacobellis and D. Pierce (2016). Creating Probabilistic Sea Level Rise Projections to support the 4th California Climate Assessment, California Energy Commission. Docket #: 16-IEPR-04.
(6) Kopp, R. E., R. M. Horton, C. M. Little, J. X. Mitrovica, M. Oppenheimer, D. Rasmussen, B. H. Strauss and C. Tebaldi (2014). "Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites." Earth's future 2(8): 383-406.
(7) DeConto, R. M. and D. Pollard (2016). "Contribution of Antarctica to past and future sea-level rise." Nature 531(7596): 591-597.