San Francisco Bay, Sacramento-San Joaquin Delta and California Coastal Inundation Depth Layer Mosaics

Version 6
May 26, 2016

URL: **http://keystone.gisc.berkeley.edu/cec_gas_study_layers**

The purpose of the study (Radke, *et.al.*, 2016) is to simulate the depth of future inundations resulting from sea level rise and likely future storm events, and to assess their impact on California's natural gas transmission pipeline infrastructure. Our inundation modeling focuses on three regions: the San Francisco Bay (the Bay), the Sacramento-San Joaquin River Delta Region (the Delta), and California's Coast (the Coast). To simulate the location and depth of inundation due to sea level rise (SLR) and storm surge in these regions, we integrate GIS based data with a 3 dimensional hydrodynamic model, 3Di (Stelling, 2012).

Source data:

For the Bay and Delta, we produced a $1m^2$ (horizontal resolution) earth surface model by fusing very high-resolution Light Detection and Ranging (LiDAR) data (see Table 1) with bathymetry and other elevation data. This surface is the base dataset to which we added the ocean tidal cycle, including wave motion and storm surge during near-100 year storm events. We based our simulations for the Bay and Delta regions on a storm event that occurred during February 5-7, 1998 where the peak water levels nearly reached estimated 100-year extremes. In the Bay and Delta regions we performed high-resolution ($3\text{-}12m^2$) modeling of inundation based on the 1998 event coupled with 0.0, 0.5, 1.0, and 1.41 meters of SLR, respectively.

Table 1: Input surface elevation data for our analyses (Bay, Delta, Coast).

Study Area	Name	Datum & Projection		Accuracy	
		Vertical	Horizontal	Fundamental Vertical	Horizontal
North Bay	NOAA California Coastal LiDAR Project	NAVD88	NAD83, UTM Zone 10N	0.05 meters at 95% confidence level	2.0 meters at 95% confidence level
South Bay	NOAA California Coastal LiDAR Project	NAVD88	NAD83, UTM Zone 10N	0.12 meters at 95% confidence level	2.0 meters at 95% confidence level
Sacramento-San Joaquin Delta	DWR California Department of Water Resources LiDAR survey	NAVD88	NAD83, UTM Zone 10N	0.18 meters at 95% confidence level	0.3 meters at 95% confidence level
California Coast	NOAA California Coastal LiDAR Project	NAVD88	NAD83, UTM Zones 10N & 11N	0.094 meters at 95% confidence level	0.5 meters at 95% confidence level

For the California coast our simulations are based on three separate but near100-year storm events (see Table 2). We simulate inundation along California's coast at a coarser resolution ($50m^2$) owing to its large spatial extent. We use three separate near 100-year storm events (see Table 2) coupled with the same four increments of SLR for our coastal simulations. The potential SLR increments are based on those used in previous California climate change impact studies that project regional SLR based on forecasts of relevant weather and climate parameters.

Table 2, Data sources used for the California coastal inundation studies: coastal regions, gauging stations and storm events

Coastal Region Storm Zone	NOAA Tidal Gauging Station	NOAA Station ID	Storm Start Date	Storm End Date	Tiles
South	La Jolla	9410230	1/9/2005	1/11/2005	1, 12
South	Los Angeles	9410660	1/9/2005	1/11/2005	2, 3, 4
South	Pt. San Luis	9412110	1/9/2005	1/11/2005	5, 6, 7, 8, mid 1a, mid1b
South	Monterey	9413450	1/9/2005	1/11/2005	mid2, mid3, 2a, 2c,2d,2e
Central	Pt. Reyes	9415020	2/5/1998	2/8/1998	2b, 3a, 3b, 4a, 4b, 4c
Central	Arena Cove	9416841	2/5/1998	2/8/1998	5a, 5b, 5c, 6a
North	North Spit	9418767	12/30/2005	1/1/2006	7a, 8a, 8b
North	Crescent City	9419750	12/30/2005	1/1/2006	8c, 9a

Constructing the inundation depth raster layers:

Three separate modeling steps are needed to prepare these surfaces. First, an accurate surface model combining bathymetry, land surface elevations and significant surface feature elevations which influence water flows, such as building footprints, levees, roadways, etc., are combined. Second, historic tidal and river water surface elevation data are acquired and combined with the surface model to provide inputs for the hydrodynamic model (3Di, described in our report). Third, simulations in 3Di are undertaken to predict hourly water surface elevations, over a 72 hour period, during the 100 year storm events, using projected future SLR (increments of 0, 0.5, 1.0, 1.41m). For inundated areas, subtracting the land surface elevation values from the water surface elevation values yields the depth of inundation values. The maximum of these inundation values observed over a 72 hour period comprises the inundation depth for each pixel or raster cell value displayed in each layer. Our research report (Radke, *et.al.*, 2016) provides an extensive discussion of the modeling considerations, data selection, analytical methods, and processing procedures:

Radke, J. D., G. S. Biging, M. Schmidt-Poolman, H. Foster, E. Roe, Y. Ju, O. Hoes, T. Beach, A. Alruheil, L. Meier, W. Hsu, R. Neuhausler, W. Fourt (University of California, Berkeley). 2016. *An Assessment of the Climate Change Vulnerability of the Natural Gas Transmission Infrastructure for the San Francisco Bay Area,*

Sacramento—San Joaquin Delta, and Coastal California. California Energy Commission.

Stelling, G. S. (2012). Quadtree flood simulations with sub-grid digital elevation models. Proceedings of the ICE - Water Management, 165(10), 567–580. http://doi.org/10.1680/wama.12.00018

Processing notes:

Due to the vast amount of data in the base model (over 8 billion data points) and limitations in computing power, the study areas are divided and modeled as a collection of tiles. Individual tiles for the Bay and the Delta have resolutions that range between $3m^2$ and $12m^2$, while tiles for the Coast are $50m^2$ resolution. The Bay tiles are delineated to maintain watershed geomorphological integrity while meeting the modeling objective of the highest resolution cell size possible. In the Delta region, once an island levee is over topped, the entire island would be compromised and inundated. Therefore, Delta tiles are delineated to maintain whole island integrity while achieving the highest resolution model cell size, which results in many overlapping tiles. Figure 1 illustrates the Bay-Delta tile system; Figure 2 illustrates the Coast tiles system where watershed geomorphological integrity is also maintained.

Figure 1, San Francisco Bay and Sacramento-San Joaquin Delta tile system.

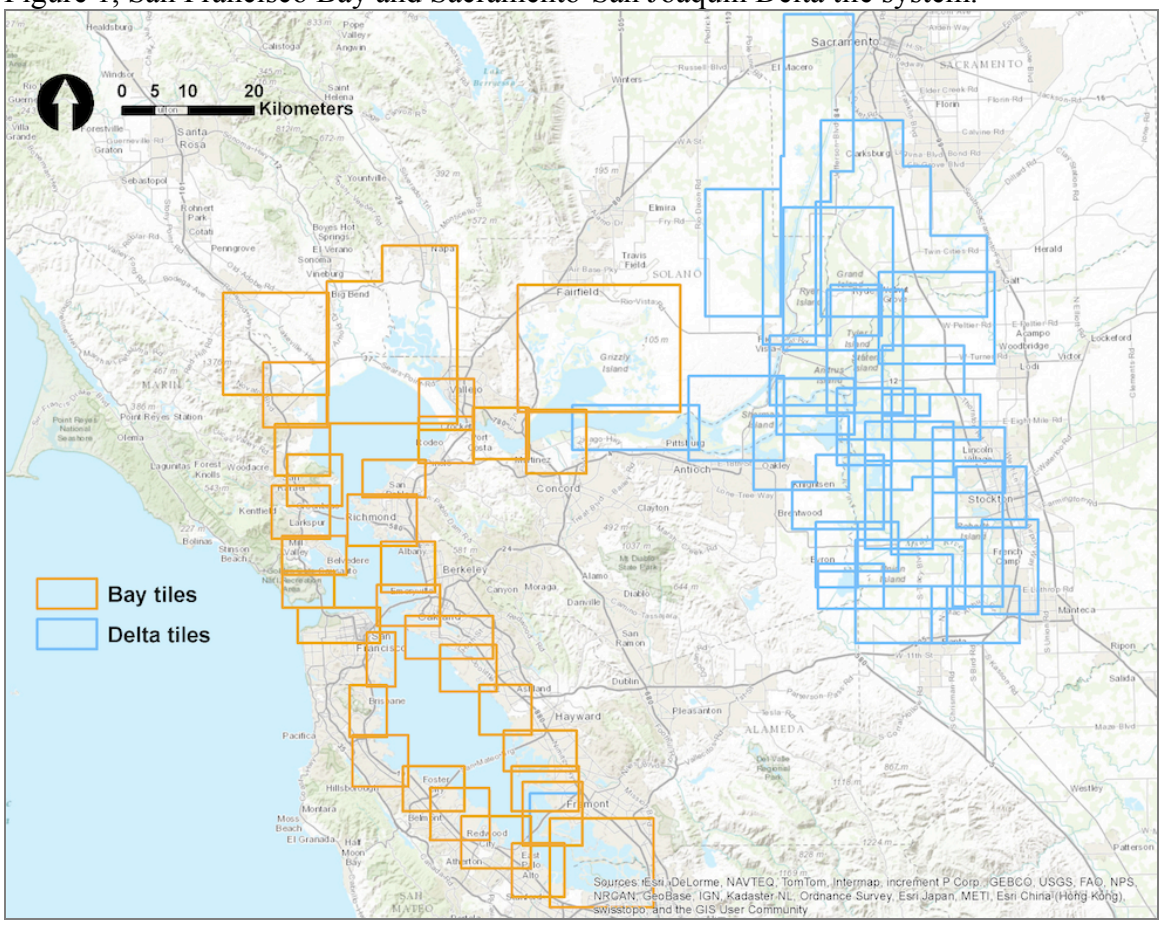
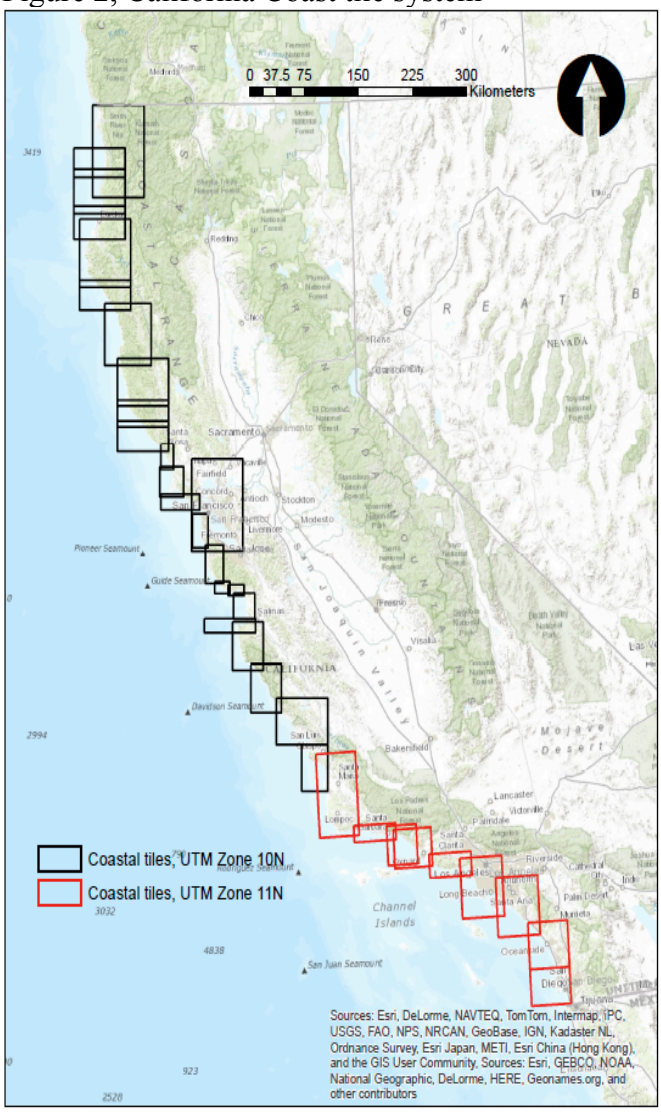


Figure 2, California Coast tile system



To produce the final inundation depth mosaics for the Bay and the Delta, the inundation depth layer for each tile is first re-sampled to a $3m^2$ layer using ArcGIS's BILINEAR re-sampling method. Second, depth values (in meters) in a layer are rounded to 3 decimal places. Finally, mosaics are assembled as the maximum of the source layers. To produce the final inundation depth mosaics for the Coast, the inundation depth layers are kept at $50m^2$ resolution, and are assembled as the maximum of those depth layers. All inundation raster layers represent the maximum inundation depths in meters during the storm event.

Mosaics are produced and delivered to the Cal-Adapt data site for ease of use for general mapping purposes (see Table 3 and Table 4). For those interested in including these data in very high spatial resolution research, we recommend downloading our original modeled individual tiles, linked to the Cal-Adapt data site.

Data delivered:

Table 3, San Francisco Bay and Sacramento-San Joaquin Delta inundation depth raster datasets supplied to the California Energy Commission

Directory	Dataset Name	Size (bytes)	Format	Datum & Projection	Raster values
SFBay	Bay_0mslr_max_blinear_snap_float.zip	268,940,381	Esri geotiff suite	Vertical: NAVD88 Horiz: NAD 1983 Proj: UTM10N	Horiz: 3x3 meters Vertical: meters
	Bay_05mslr_max_blinear_snap_float.zip	319,901,006			
	Bay_10mslr_max_blinear_snap_float.zip	367,504,710			
	Bay_141mslr_max_blinear_snap_float.zip	395,415,538			
Delta	Delta_0mslr_max_blinear_snap_float.zip	102,046,339			
	Delta_05mslr_max_blinear_snap_float.zip	100,135,700			
	Delta_10mslr_max_blinear_snap_float.zip	228,271,322			
	Delta_141mslr_max_blinear_snap_float.zip	292,080,856			

Table 4, North, Central and South Coast datasets supplied to the California Energy Commission.

Note: due to original coarse bathymetric data, these mosaic data contain periodic processing artifacts in deep water areas and should not be used for accurate bathymetry predictions in these areas.

Directory	Dataset Name	Size (bytes)	Format	Datum & Projection	Raster values
North_Coast	north_coast_0.0mSLR.zip	5,230,470	Esri geotiff suite	Vertical: NAVD88 Horiz: NAD 1983 Proj: "California" Teale-Albers (ESPG 6414)	Horiz: 50x50 meters Vertical: meters
	north_coast_0.5mSLR.zip	5,270,926			
	north_coast_1.0mSLR.zip	3,671,980			
	north_coast_1.41mSLR.zip	3,714,310			
Central_Coast	central_coast_0.0mSLR.zip	7,057,250			
	central_coast_0.5mSLR.zip	7,698,525			
	central_coast_1.0mSLR.zip	7,957,875			
	central_coast_1.41mSLR.zip	8,306,219			
South_Coast	south_coast_0.0mSLR.zip	12,380,788			
	south_coast_0.5mSLR.zip	12,456,187			
	south_coast_1.0mSLR.zip	12,600,942			
	south_coast_1.41mSLR.zip	12,841,431			

Contact: John Radke <ratt@berkeley.edu>
Subject: SFBay-Delta-Coastal Flood Inundation Models (May_2016_delivery)