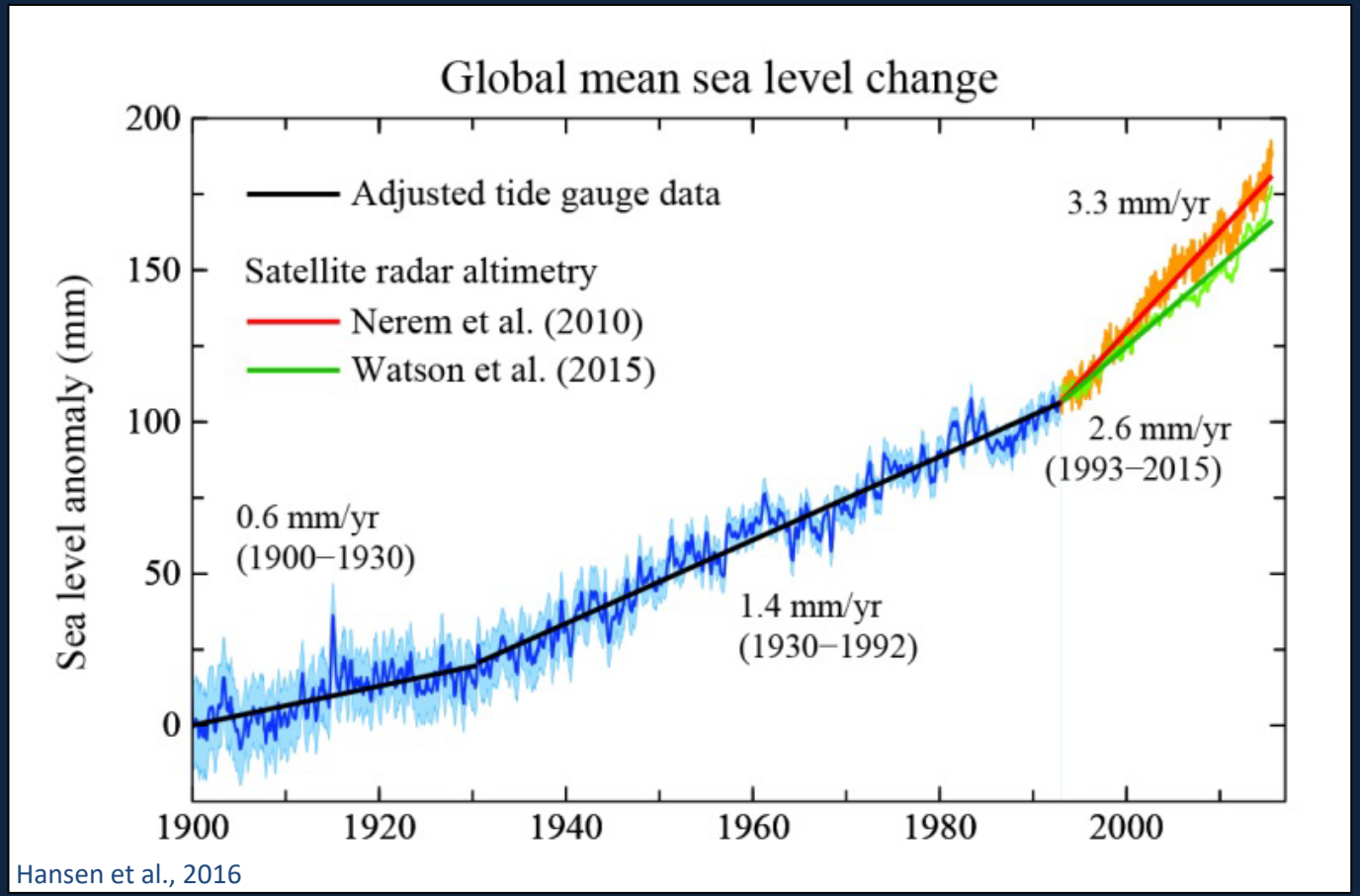
Sea Level Rise: From Global to Local

Juliette Hart, Ph.D. | Director of Outreach, USGS

Malibu City Council Presentation | Sep. 11, 2017

USGS

Global sea level rise (SLR) is accelerating



Hansen et al., 2016

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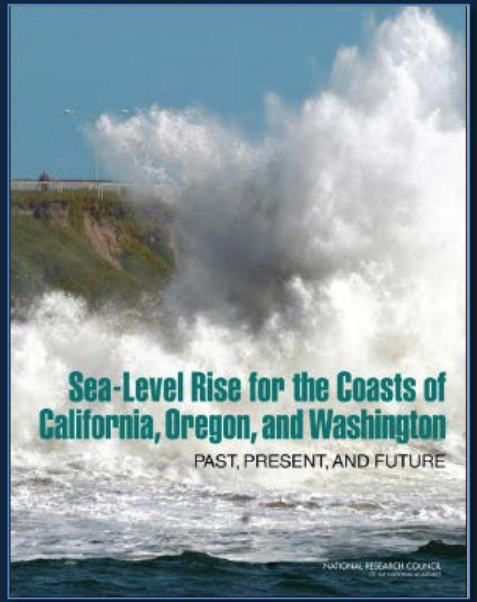
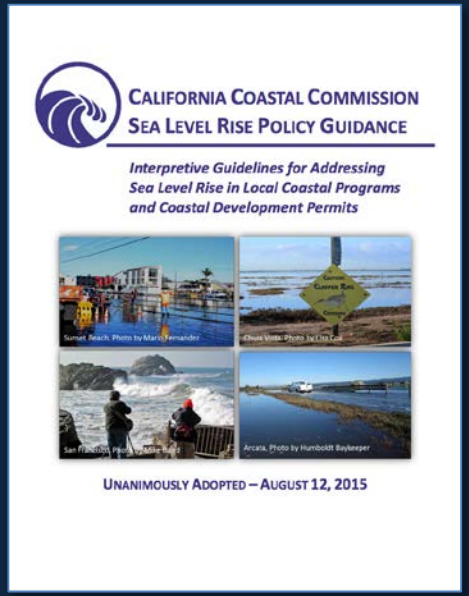
SLR in California

Time Period	Low	Mid	High
2000 - 2030	2 in	6 in	12 in
2000 – 2050	5 in	11 in	24 in
2000 – 2100	17 in	37 in	66 in





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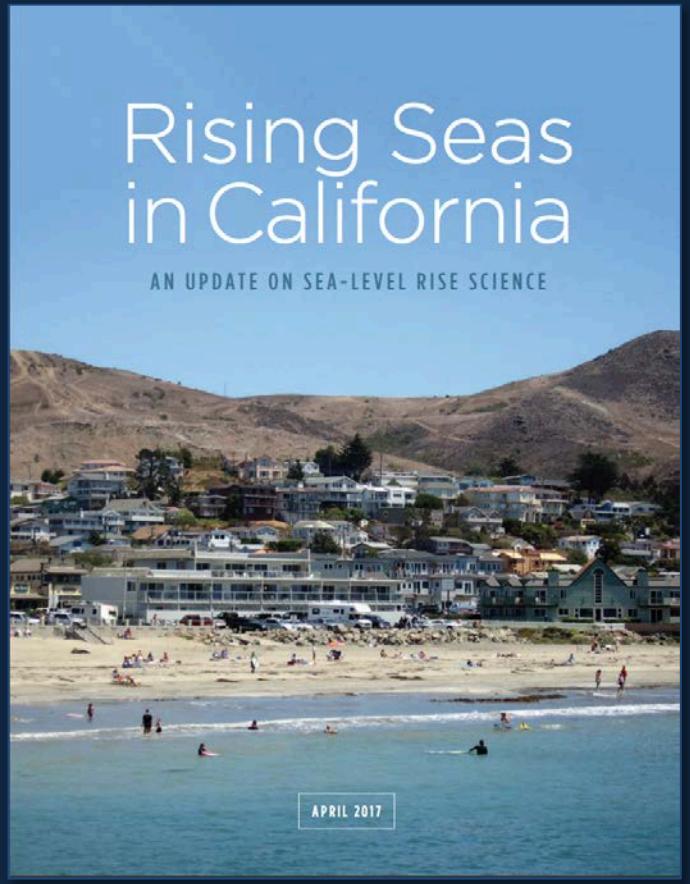
SLR in California



- Assigned probabilities for high and low GHG emission scenarios

- H^{++} = 10 ft (120 in)

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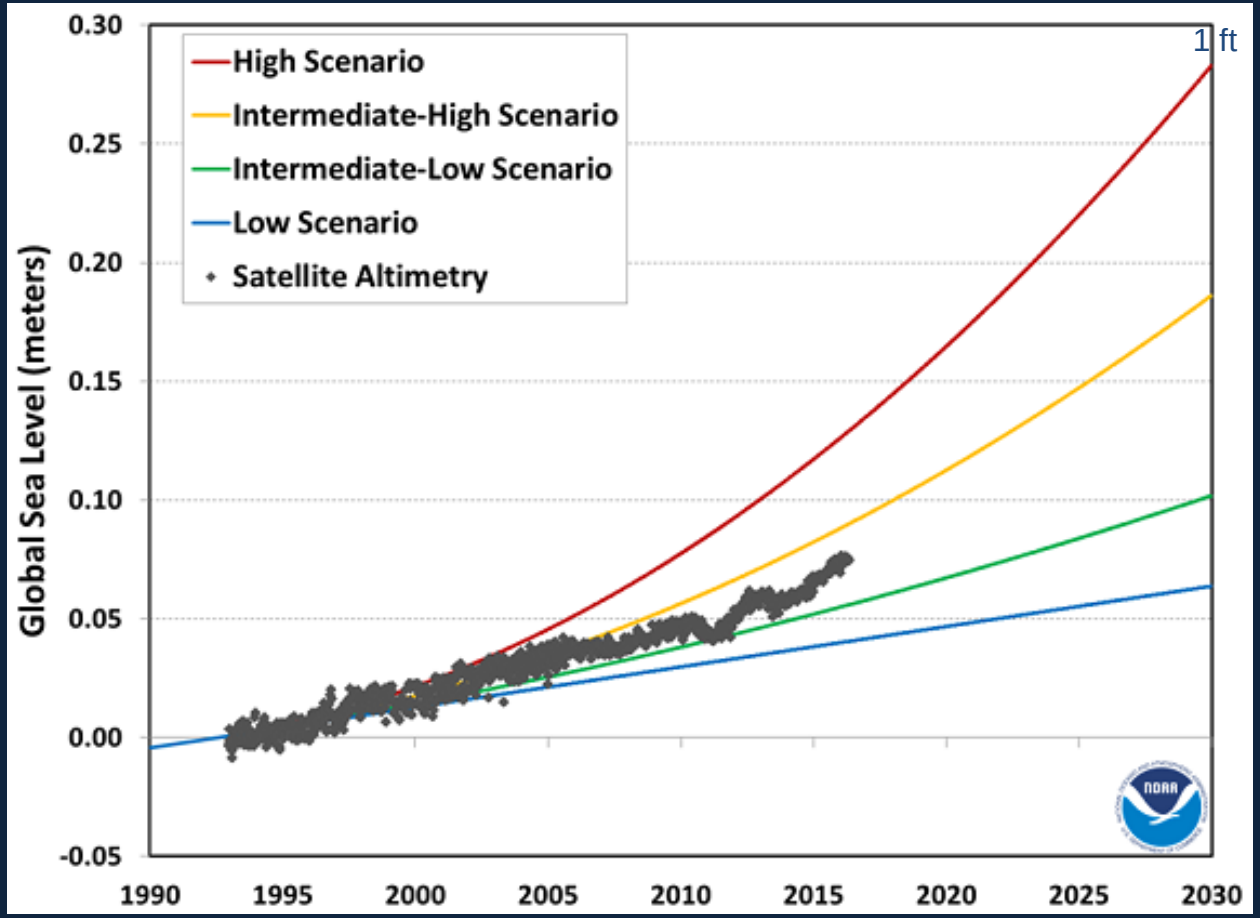
How are we tracking?



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Impacts from SLR

- Accelerated beach erosion rates
- Greater incidence of cliff failures
- Landwards translation of coastal flooding & inundation
- Beach/shore safety compromised
- Saltwater intrusion into coastal aquifers
- Impacts to navigation conditions

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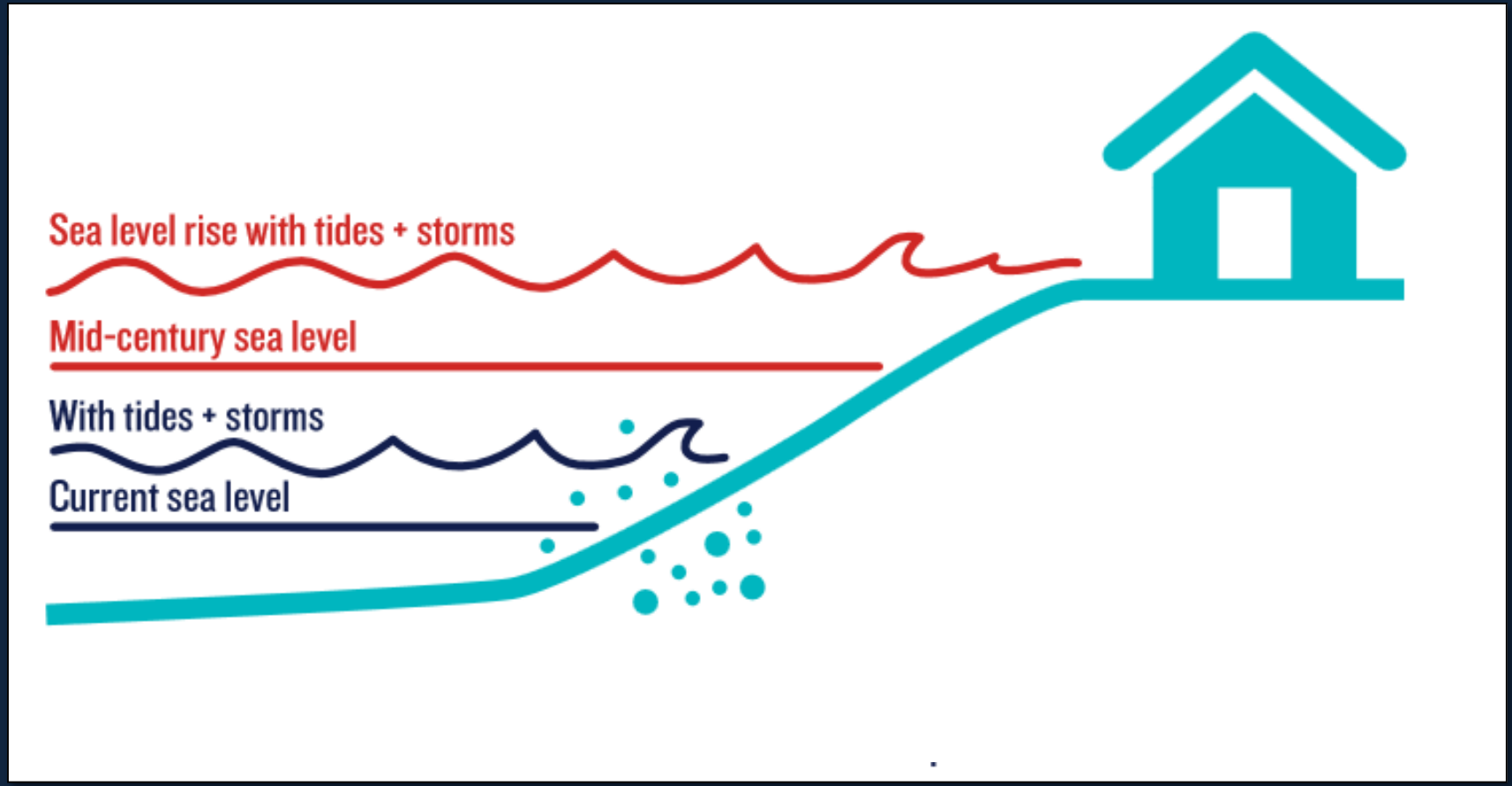
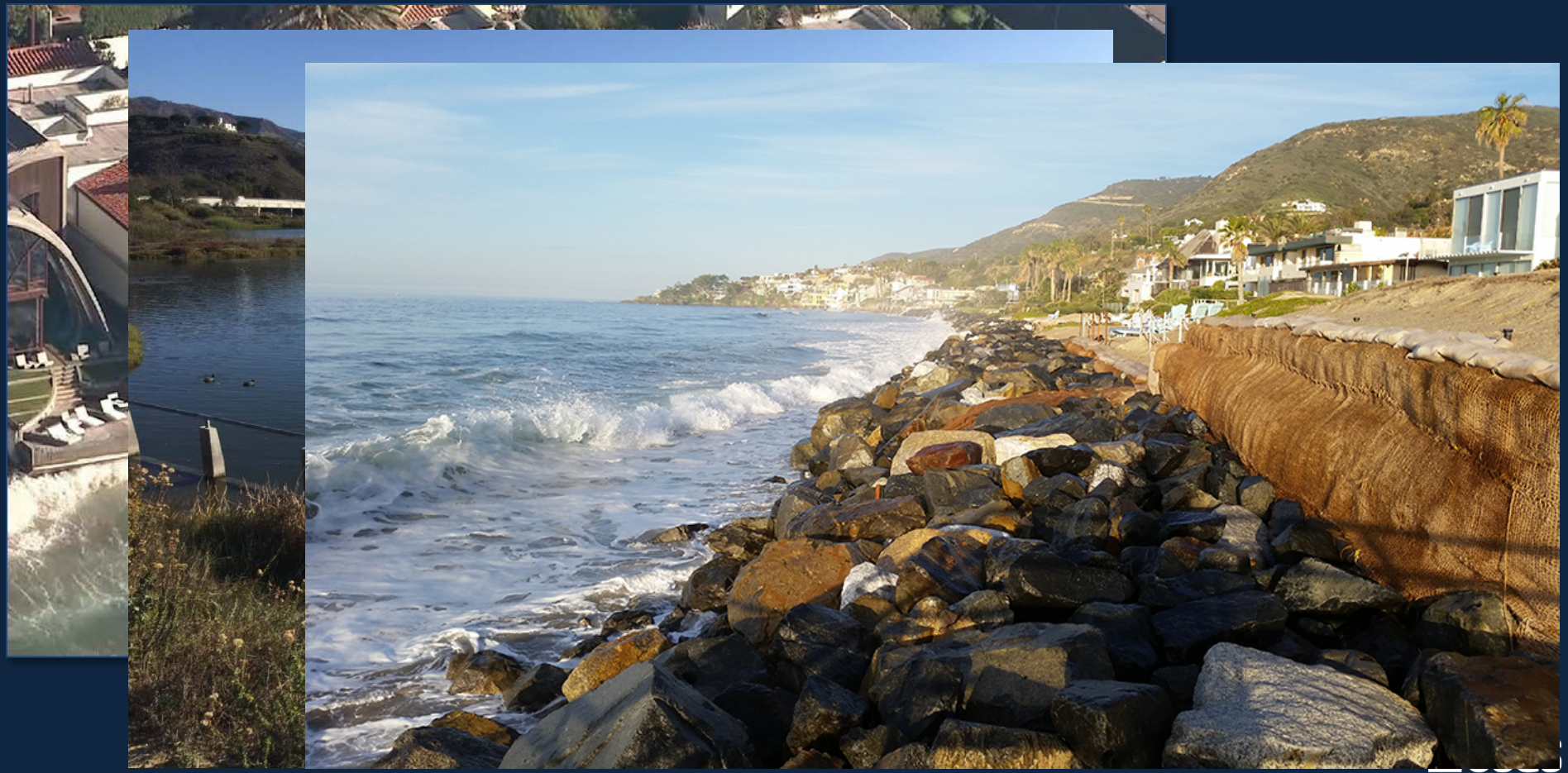
Beyond SLR…storms & tides



Coastal Flooding graphic courtesy of Climate Education Partners

USGS

Beyond SLR…storms & tides



2015-16 El Niño

http://wkbn.com/2016/01/05/record-tying-el-ninos-storms-hitting-parched-california/

- Top 3 El Niño events since at least 1870 (1982-83 and 1997-98)
- Wave energy > 50% above the average winter, highest since 1997
- Winter erosion in So Cal – 71% greater than normal

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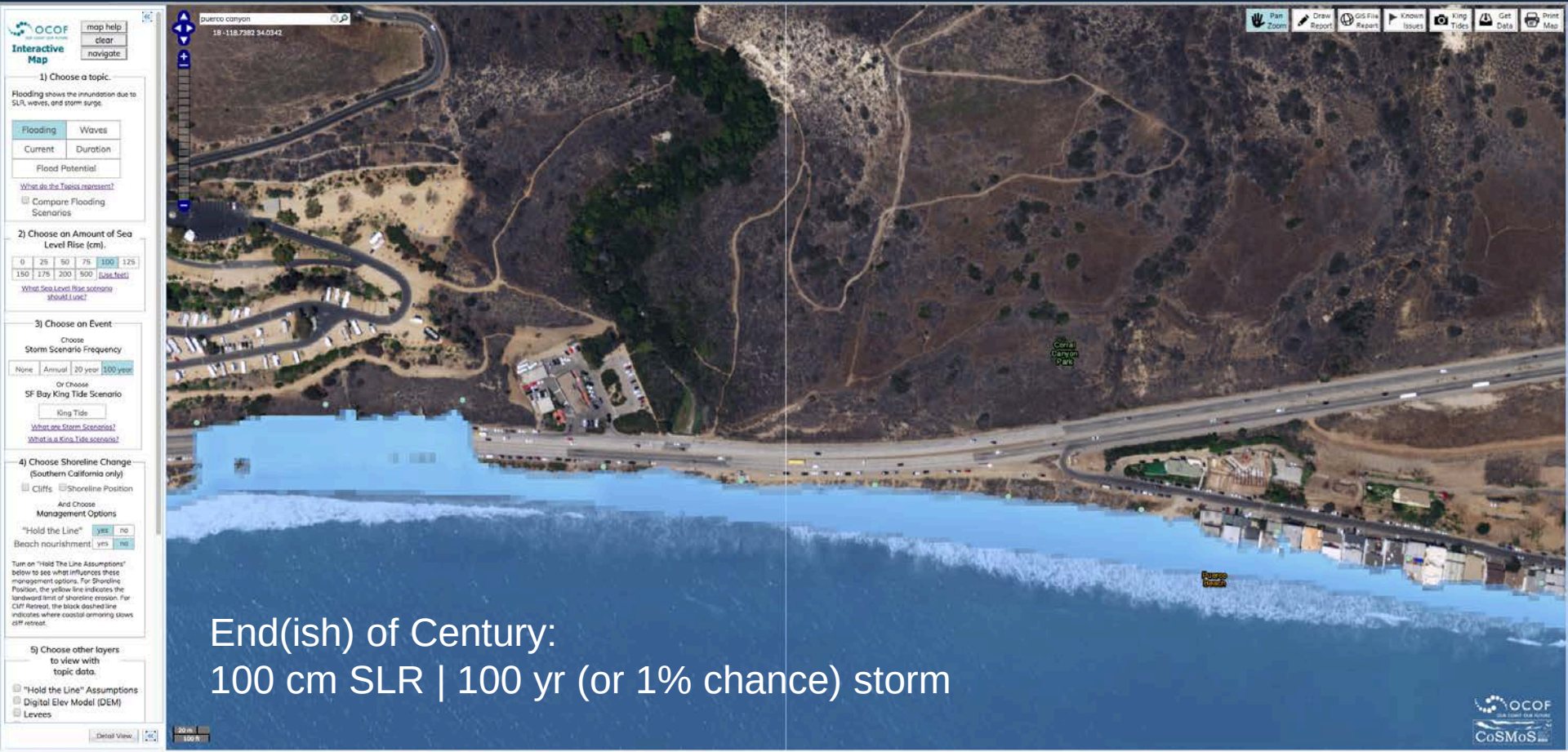
Coastal Flooding



Beach Change Projections (Broad Beach)

- Many beaches will erode … a lot (avg. = ~150 ft)
- 31 to 67% of beaches completely eroded by 2100

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Cliff Retreat Projections (Pt. Dume)

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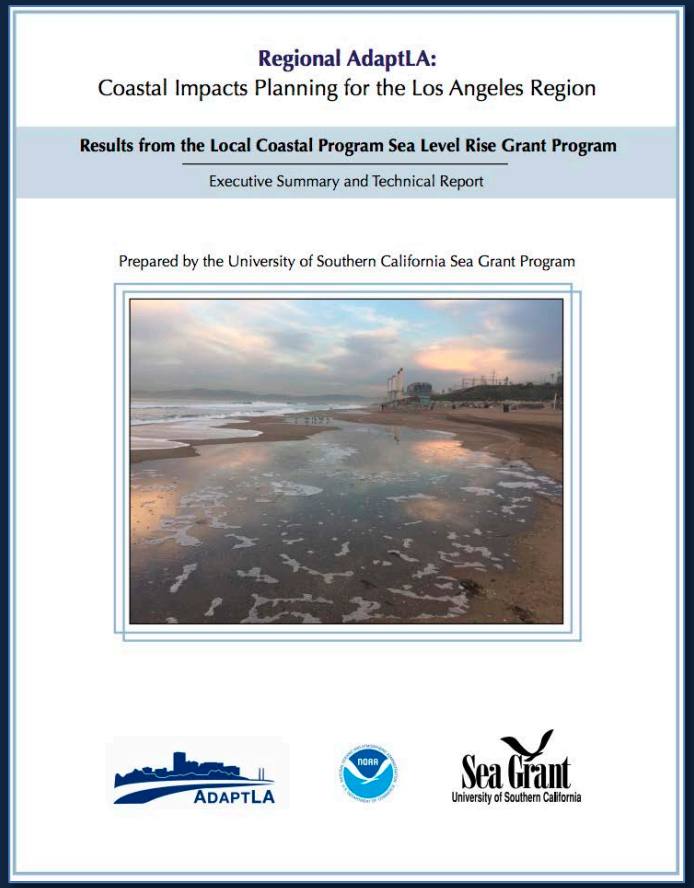
AdaptLA: Coastal Impacts Planning



- Grant awarded to City of Santa Monica by CA Ocean Protection Council
- Project convened and led by USC Sea Grant
- Scientific information:
  - Offshore/nearshore waves from USGS
  - Coastal Hazards Analysis– Environmental Science Associates (ESA)
  - Beach position change – TerraCosta Consulting
  - Exposure Analysis by ESA

USGS

AdaptLA: Exposure Analysis – Malibu

With 3 ft SLR (by 2100)

- 13.6 miles of roadway / bikeway impacted

With 3 ft SLR + 100 yr storm (by 2100)

- 25.7 miles of roadway / bikeway impacted
- 1695 bldgs impacted (mainly residential)

With 5.5 ft SLR + 100 yr storm (by 2100)

- 29.6 miles of roadway / bikeway impacted
- 1916 bldgs impacted (mainly residential)

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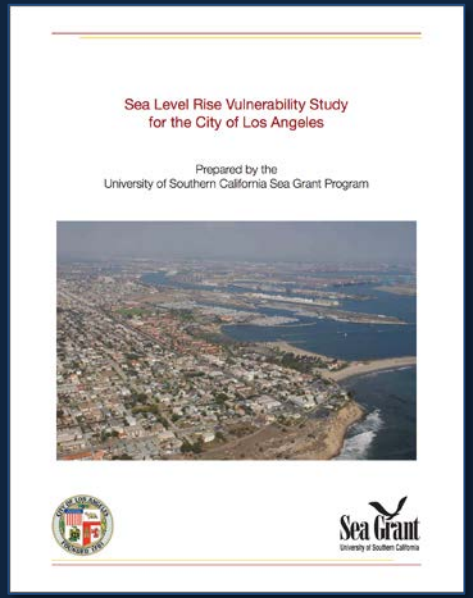
SLR Planning in L.A.

- SLR Vulnerability Assessments
  - City of LA, Santa Monica, Hermosa Beach, Port of LA, Port of LB, Long Beach

- Local Coastal Plans Updates
  - City of L.A. (Venice), Santa Monica, Hermosa Beach

- Hazard Mitigation Plan Updates
  - City of L.A., Hermosa Beach
  - Malibu…



Options for Adapting to SLR

Accommodate

- Elevate
- Setbacks

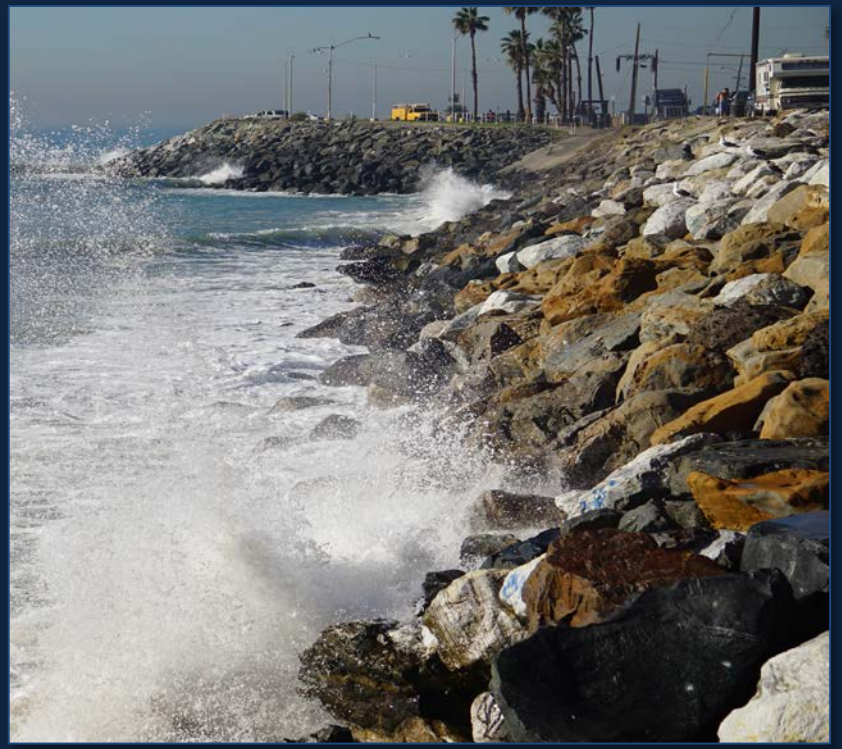
Options for Adapting to SLR

Accommodate

- Elevate
- Setbacks

Protect

- Sediment Management
- Beach Nourishment
- Cobble Nourishment
- Seawalls and Revetments
- Breakwaters
- Jetties
- Artificial Reefs
- Perched Beaches



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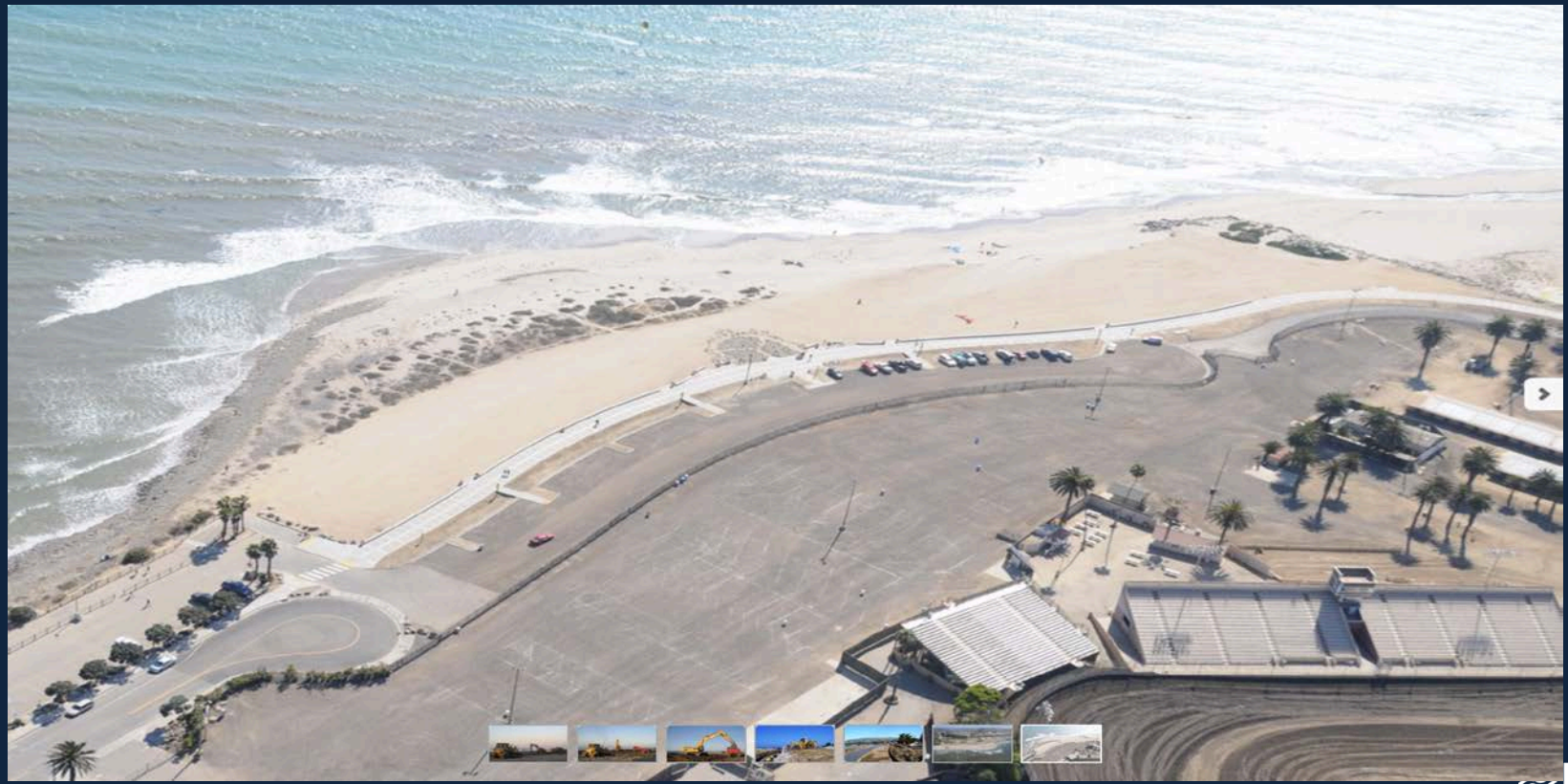
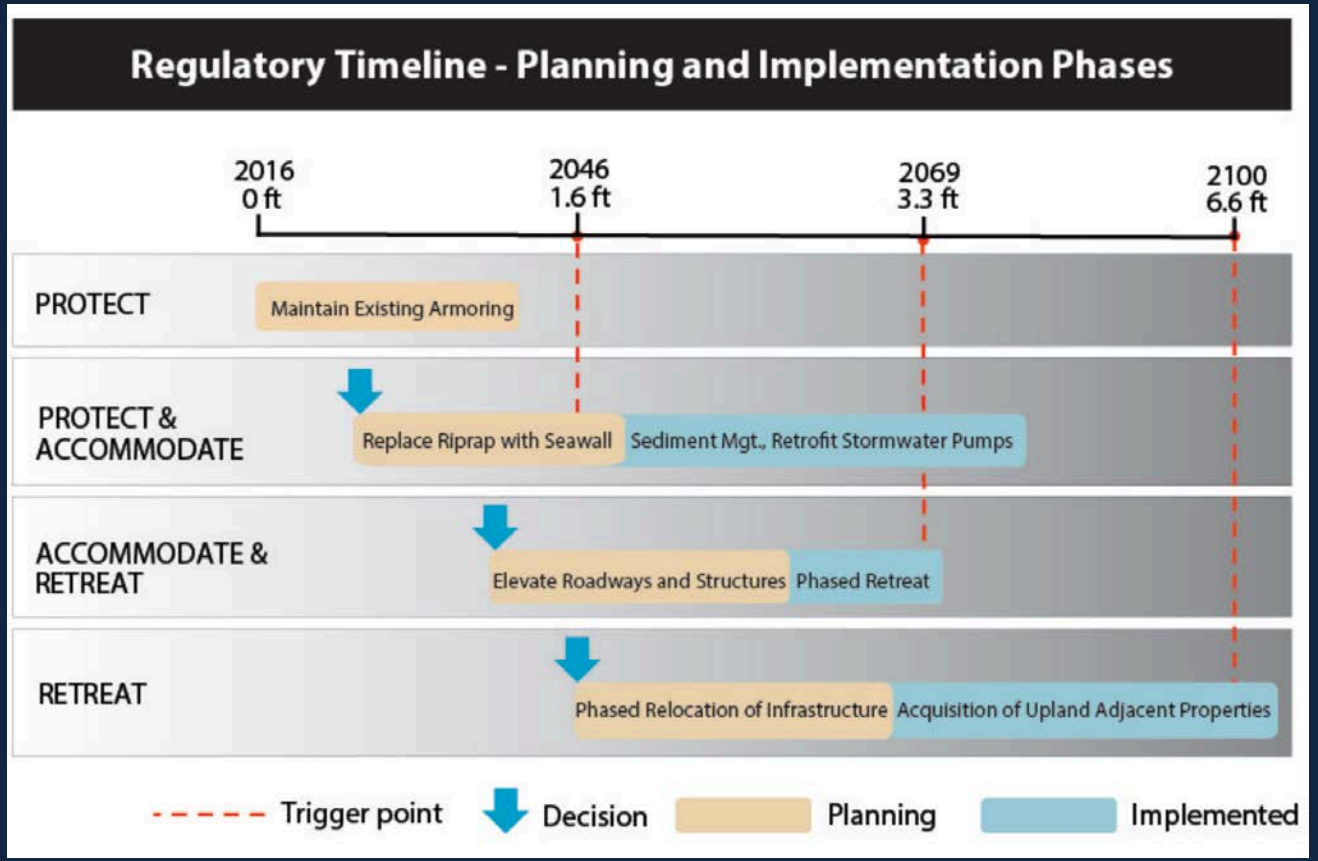
Options for Adapting to SLR

Retreat…Surfer's Point, Ventura



Tipping Points & Triggers



Imperial Beach SLR Vulnerability Assessment

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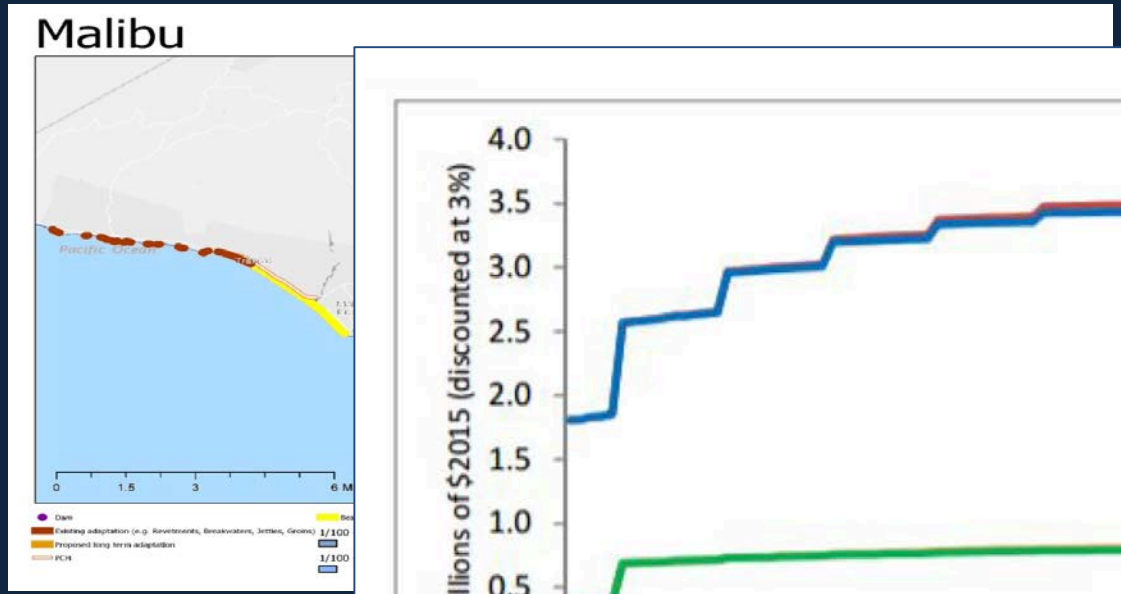
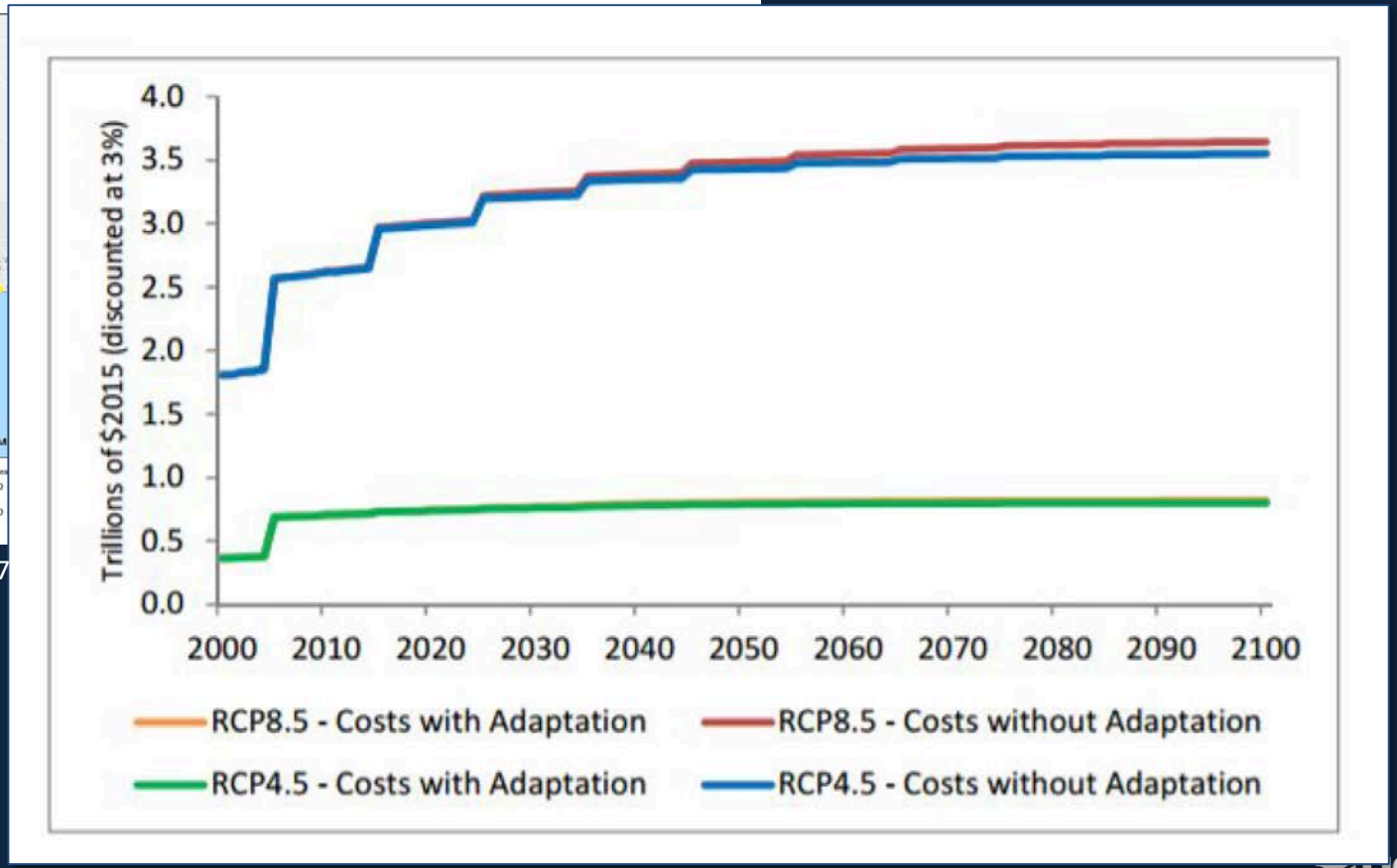
LA County Adaptation Cost Benefit Analysis



Aerts, de Ruig, Botzen 2017



US EPA 2017

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Juliette Hart | jfinzihart@usgs.gov
Patrick Barnard | pbarnard@usgs.gov
Nick Sadrpour | sadrpour@usc.edu

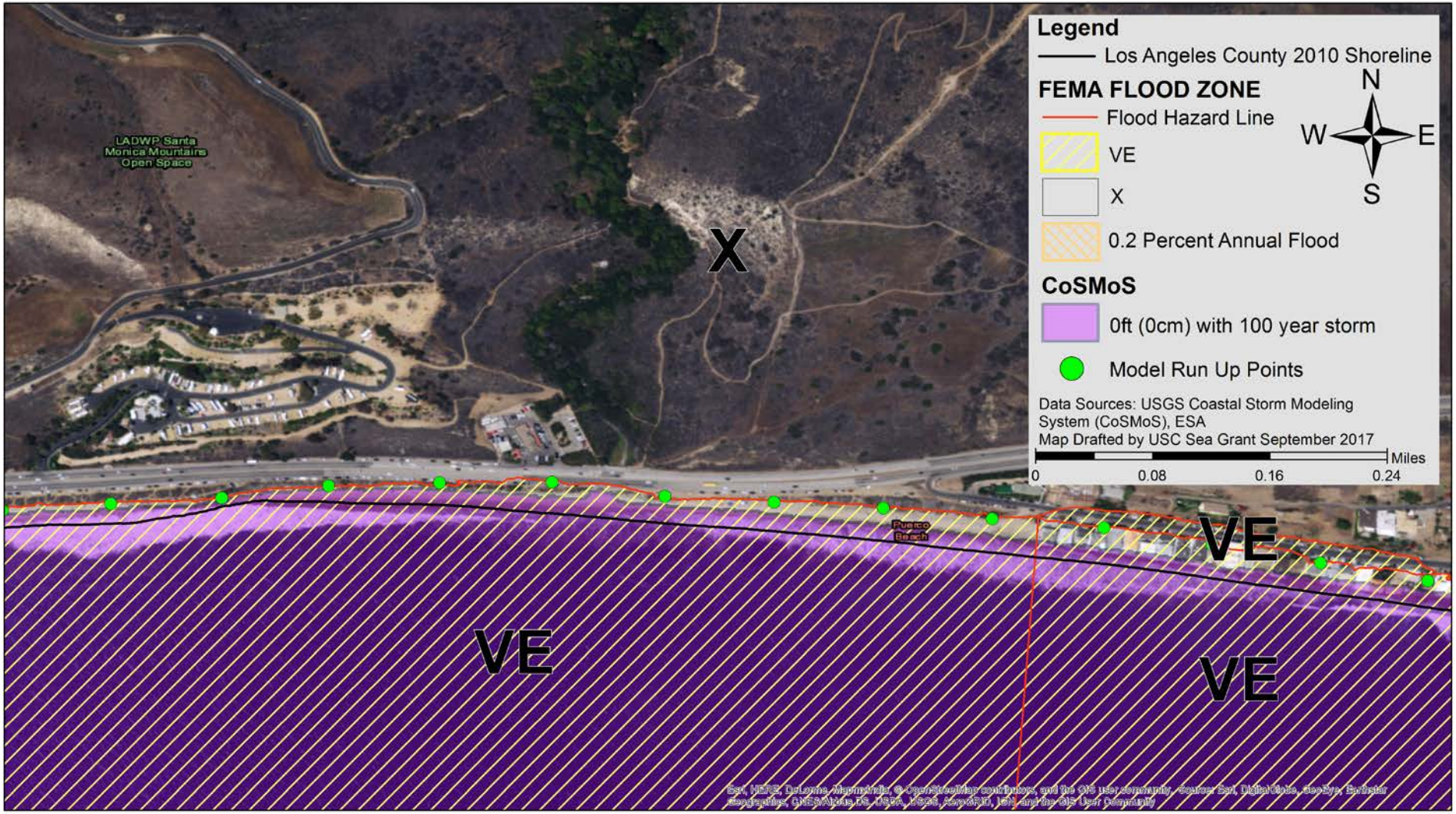
walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/

ourcoastourfuture.org

dornsife.usc.edu/uscseagrant/adaptla/

Sea Grant University of Southern California | Point Blue | NOAA | OSU Oregon State University | Coastal Conservancy | California Coastal Commission | California's Fourth Climate Change Assessment | California natural resources agency | California Department of Fish and Wildlife | USGS

EXTRA SLIDES


LADWP Santa Monica Mountains Open Space
X
Puerco Beach
VE
VE
VE
Legend
Los Angeles County 2010 Shoreline
FEMA FLOOD ZONE
Flood Hazard Line
VE
X
0.2 Percent Annual Flood
CoSMoS
0ft (0cm) with 100 year storm
Model Run Up Points
Data Sources: USGS Coastal Storm Modeling System (CoSMoS), ESA
Map Drafted by USC Sea Grant September 2017
Miles
0
0.08
0.16
0.24
N
W
E
S
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FEMA vs. CoSMoS

	FEMA	CoSMoS
Treatment of armoring	Assume most armor fails	Assume “hold the line”*
Storm scenarios	50 year historic time series	GCM-modeled storm for 21st Century
Flood extents	Wave run-up (ankles get wet)	Dynamic wave set-up (stays wet for ~2 min)
Flood modeling	“Empirical” model	Hydrodynamic modeling

USGS

CoSMoS in action…

County
- Sonoma County
- Marin County
- Santa Mateo County
- Santa Clara County
- Santa Barbara County
- Los Angeles County
  - Office of Emergency Management
  - Department of Beaches and Harbors
- San Diego County

State
- California Coastal Commission
- California Coastal Conservancy
- California Department of Emergency Services (CalOES)
- California Department of Fish & Wildlife
- California Department of Transportation (CalTrans)
- California Energy Commission
- California Natural Resources Agency
- California Ocean Protection Council

Federal
- National Park Service
- NOAA Gulf of Farallones National Marine Sanctuary
- NOAA Office for Coastal Management
- National Estuarine Research Reserve (NOAA)

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CoSMoS in action…

City

- City of San Francisco
- City of Pacifica
- City of San Jose
- City of Santa Barbara
- City of Los Angeles
- City of Santa Monica
- City of Hermosa Beach
- City of Long Beach
- City of Huntington Beach
- City of Imperial Beach
- City of Oceanside
- City of Encinitas
- City of Carlsbad
- City of San Diego
- City of Imperial Beach

Regional Scale

- AdaptLA: Coastal Impacts Planning for the LA Region
- California Climate Science Alliance
- Coastal Ecosystem Vulnerability Assessment (CEVA, Santa Barbara)
- LA Regional Collaborative on Climate Action and Sustainability (LARC)
- Regional Water Quality Control Board for LA and Ventura Counties
- San Diego Regional Climate Collaborative
- Southern California Coastal Water Research Project (SCCWRP)
- Wetlands Recovery Projects (San Diego - Orange County region & LA - Ventura - Santa Barbara region)

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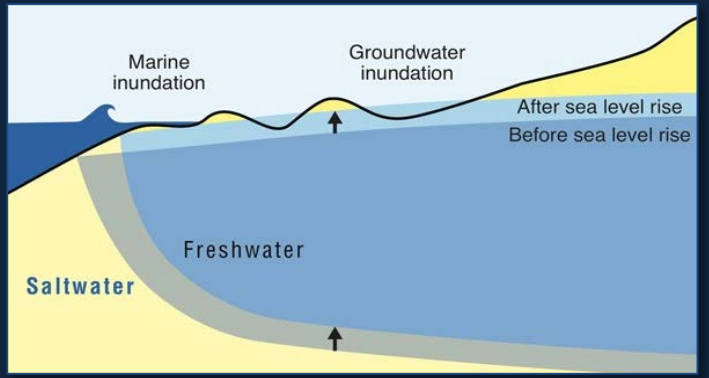
Groundwater Impacts

- Major issues
  - Inundation
  - Shallower coastal groundwater
  - Saltwater intrusion



- Groundwater inundation
  - May exceed overland flooding and happen much sooner
  - Low-lying areas most vulnerable

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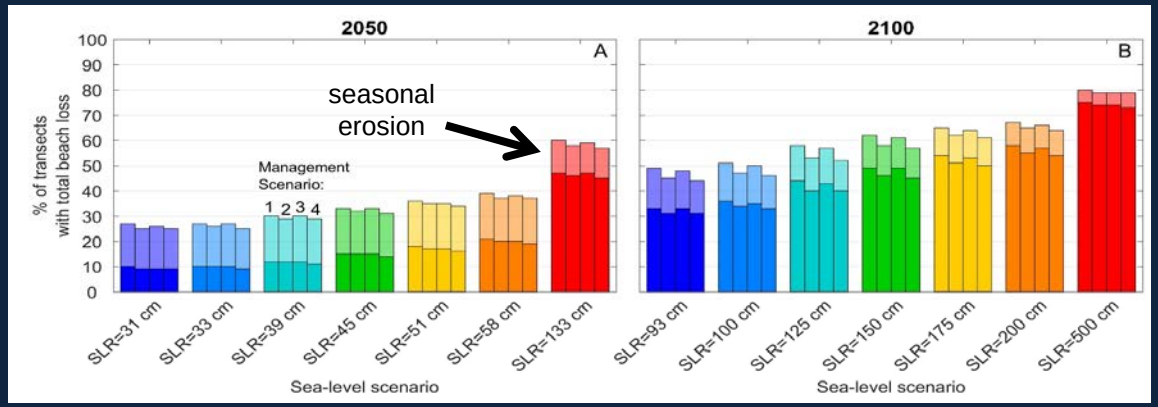
Projected Beach Change- SoCal

- Many beaches will erode considerably (avg. = ~50 m)



- 31 to 67% of beaches completely eroded*

*Highlighted in *Los Angeles Times*, *Orange County Register*, *Scientific American*, *Hans India*, etc.

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Rising Seas in California (2017)

Feet above 1991-2009 mean	MEDIAN	LIKELY RANGE	1-IN-20 CHANCE	1-IN-200 CHANCE
Year / Percentile	*50% probability SLR meets or exceeds...*	*67% probability SLR is between...*	*5% probability SLR meets or exceeds...*	*0.5% probability SLR meets or exceeds...*
2030	0.4	0.3 — 0.5	0.6	0.8
2050	0.9	0.6 — 1.1	1.4	1.9
2100 (RCP 2.6)	1.6	1.0 — 2.4	3.2	5.7
2100 (RCP 4.5)	1.9	1.2 — 2.7	3.5	5.9
2100 (RCP 8.5)	2.5	1.6 — 3.4	4.4	6.9
2100 (H++)	10			
2150 (RCP 2.6)	2.4	1.3 — 3.8	5.5	11.0
2150 (RCP 4.5)	3.0	1.7 — 4.6	6.4	11.7
2150 (RCP 8.5)	4.1	2.8 — 5.8	7.7	13.0
2150 (H++)	22			

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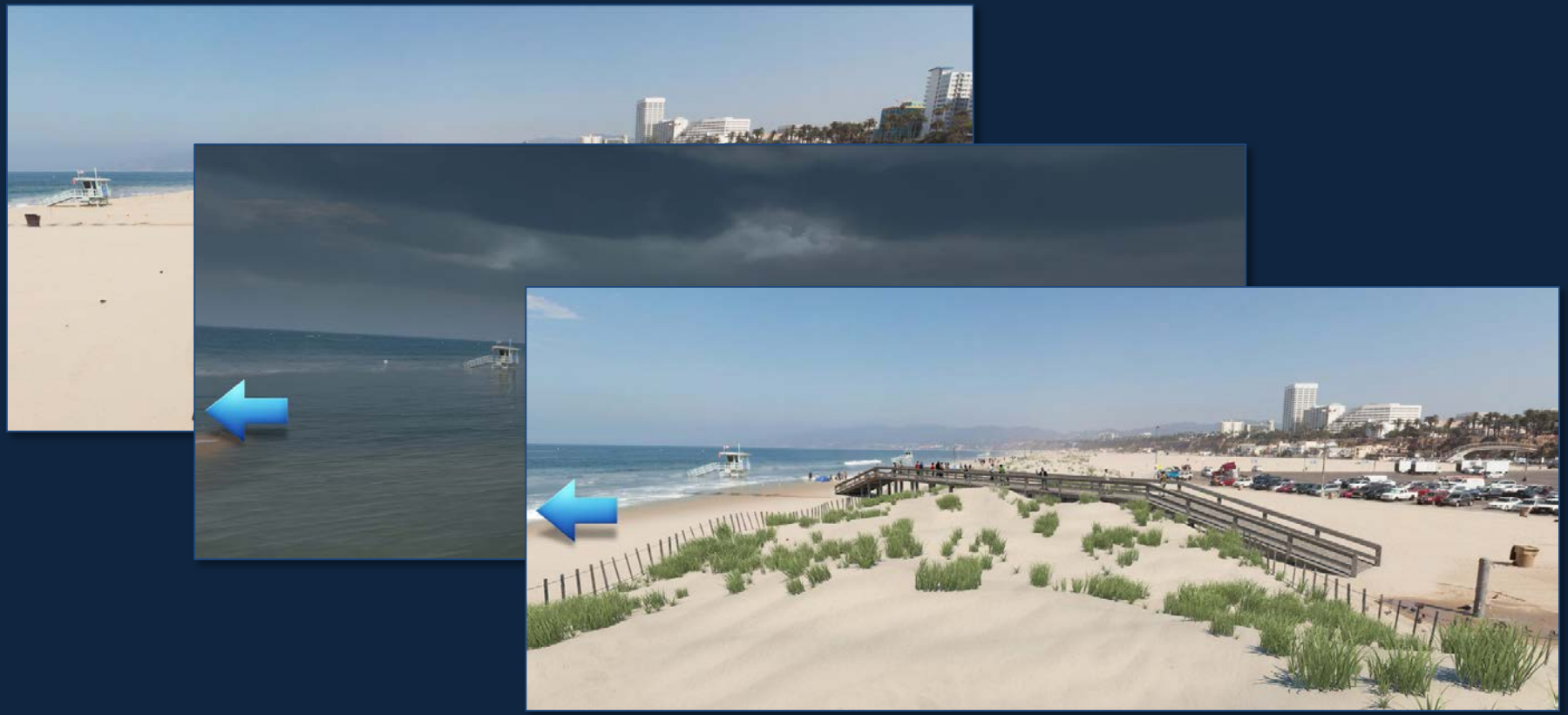
Santa Monica Owl

Mobile Owl: http://mobileowl.co/samo/

USGS

Santa Monica Owl

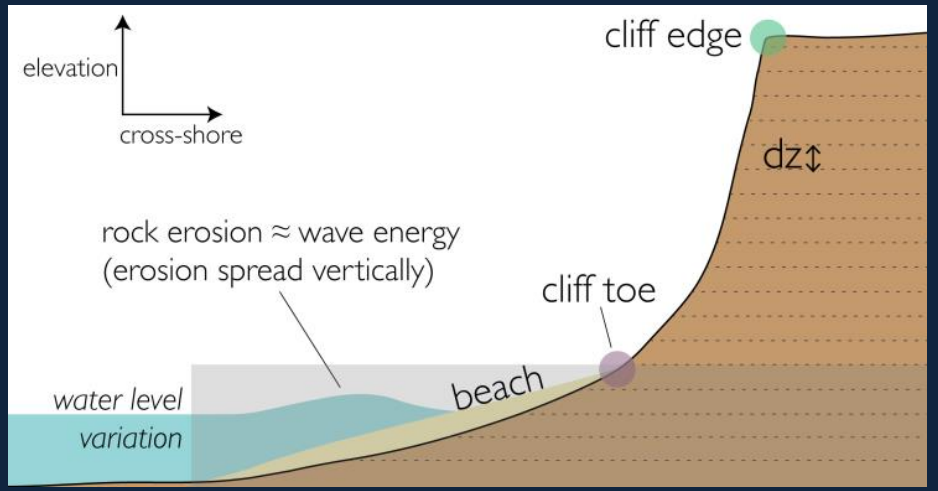


Mobile Owl: http://mobileowl.co/samo/

USGS

Long-term Cliff Retreat

- Uses an ensemble of up to 6 cliff models per transect
  - Beach protects cliff from waves
  - Includes water level variations (tides, run-up, set-up, surge, etc.)
- Synthesized from models in scientific literature (with several improvements)
- Uses machine learning (Artificial Neural Networks) to estimate model coefficients and extrapolate model behavior over study area



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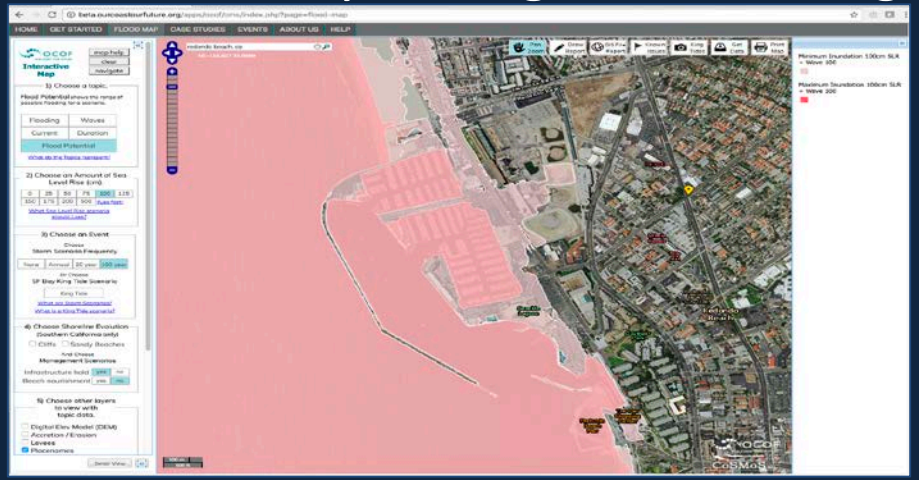
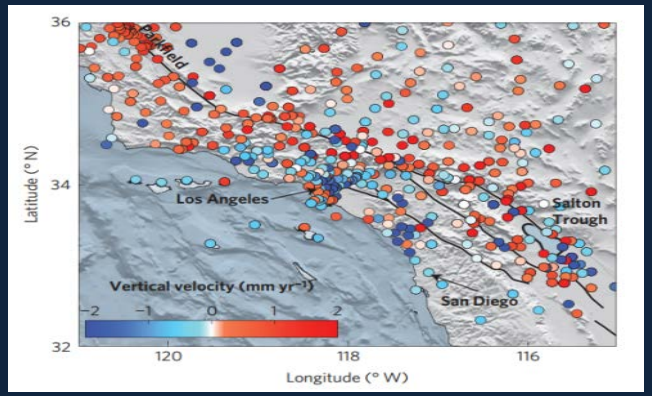
Flood Map Uncertainty (“potential”)

Generated by raising and lowering flood elevation data by





Model uncertainty

(*rms* = 0.12 m, at tide stations)

Area and number of storms validated against are small compared to the geographic extent of the study area and thus model

Vertical accuracy of DEM

(*rms* = 0.18 m in open terrain) (Dewberry 2012)

Vertical land motion

Spatially variable based on GPS data and statistical and physical tectonic models (Howell et al., 2016)

USGS

Future Conditions

Coastal Storms for California

-No significant changes in wave height

-Extreme events approach from ~10-15 degrees further south

El Niño for 21st Century

-More frequent extreme events

-Doubling of winter erosion

-Wave energy increase by 30%

Net effect

-Today's 100-year coastal water level event is projected to occur every 1-5 years by 2050 for much of California

-Greatest impacts on low-lying coastal areas

USGS