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The Vulnerability of Ports and Harbors to Climate Change

Patrick Barnard, Li Erikson, Juliette Finzi Hart, Amy Foxgrover, Liv Herdman, Patrick Limber, Andy O'Neill, and Sean Vitousek

Pacific Coastal and Marine Science Center, Santa Cruz, CA

U.S. Department of the Interior
U.S. Geological Survey

L.A. City Lifeguards

Collaborators and funders:

NOAA · OSU Oregon State University · Sea Grant · Resources Agency California Department Fish & Game · City of Imperial Beach, Most Southwesterly City, Incorporated July 18, 1956 · Coastal Conservancy · Tijuana River National Estuarine Research Reserve · California natural resources agency · Scripps Institution of Oceanography UCSD · Point Blue

How Big is the Problem?

- Over 1 billion people are expected to live in the coastal zone by the end of the 21st century
- 27 million presently live in CA coastal counties
- Over 2 million people in CA at risk of flooding by the end of the century, in addition to over $150 billion in property
  - 500,000 employees
  - 4,400 km of roads
  - 145 schools
  - 70 fire and police stations
  - 125 medical facilities (incl. hospitals)
- Impact by 2100 is over ~$1 trillion dollars, ~5% of CA GDP

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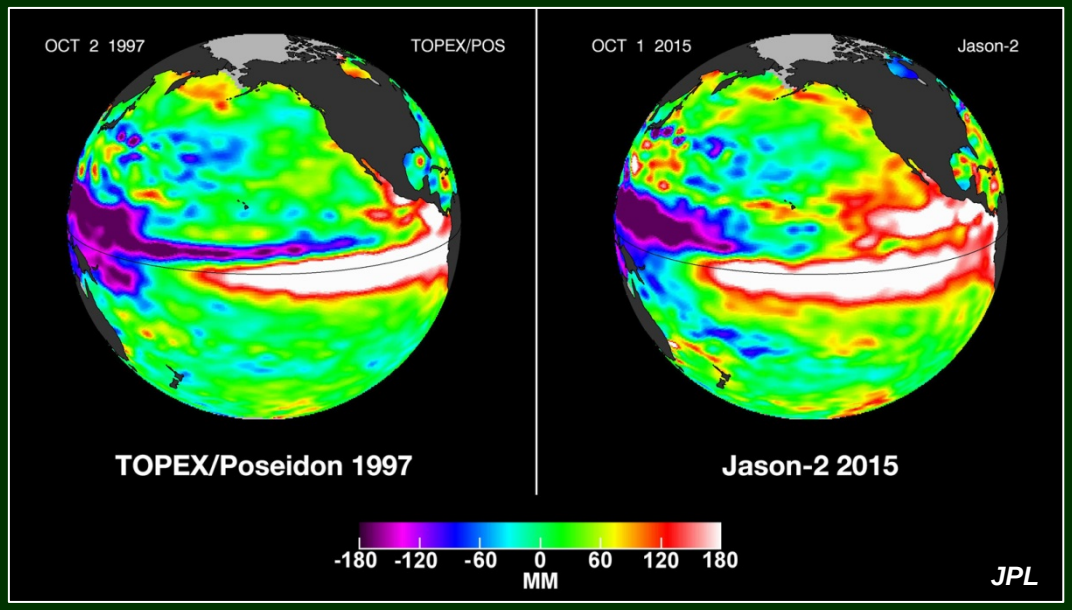
El Niño

- El Niño-Southern Oscillation (ENSO) is the dominant mode of climate variability across the Pacific Ocean basin
- The end-members of this cycle, El Niño and La Niña, are linked to elevated coastal hazards risk across the region
- In California El Niño = elevated seasonal water levels (30 cm), wave energy (50%), coastal erosion (70%), flooding and damages ($ billions)



January 27, 1983
Paul Silhavy

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21st Century Projections California

Pending State SLR Guidance for 2100

-Likely range of 30-110 cm
-3.05 m upper bound

Waves

-No significant changes in wave height
-More southerly wave directions

El Niño

-More frequent extreme events

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 (e.g., estuaries and harbors)

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Coastal Vulnerability Considerations

- Global factors:
  - Eustatic sea level
- Regional factors:
  - Ocean circulation patterns
  - Glacial fingerprinting
  - Tectonics (large-scale)
  - Isostasy
- Local factors:
  - Subsidence
  - Local tectonic deformation
  - Fluvial discharge AND sediment supply changes
  - Development and restoration
- Seasonal and storm impacts:
  - Steric effects
  - Waves and storm surge
  - River discharge

Sunset Beach, Sean Hiller


Nick Moless

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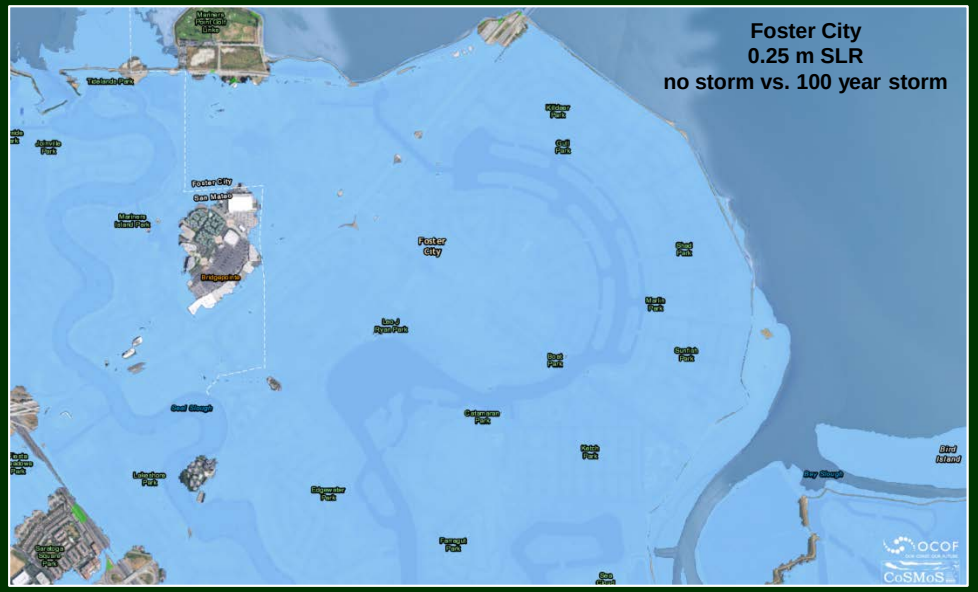
Coastal Vulnerability Approaches

Static: NOAA SLR Viewer

- Passive model, hydrological connectivity
- Tides only
- '1st order screening tool'



"Bathtub" models under predict flooding hazards

Coastal Vulnerability Approaches

Static: NOAA SLR Viewer

- Passive model, hydrological connectivity
- Tides only
- '1st order screening tool'

Dynamic: USGS-CoSMoS

- All physics modeled
- Forced by Global Climate Models
- Includes wind, waves, atmospheric pressure, shoreline change
- Range of SLR and storm scenarios

CoSMoS: A Tool for Coastal Resilience

- Physics-based numerical modeling system for assessing coastal hazards due to climate change
- Predicts coastal hazards for the full range of sea level rise (0-2, 5 m) and storm possibilities (up to 100 yr storm) using sophisticated global climate and ocean modeling tools
- Developing coastal vulnerability tools in collaboration with federal, state, and city governments to meet their planning and adaptation needs
- Emphasis on directly supporting federal and state-supported climate change guidance (e.g., Coastal Commission) and vulnerability assessments (e.g., LCP updates, OPC/Coastal Conservancy grants)

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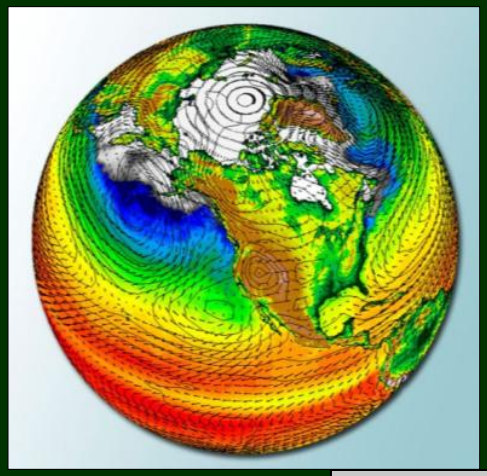
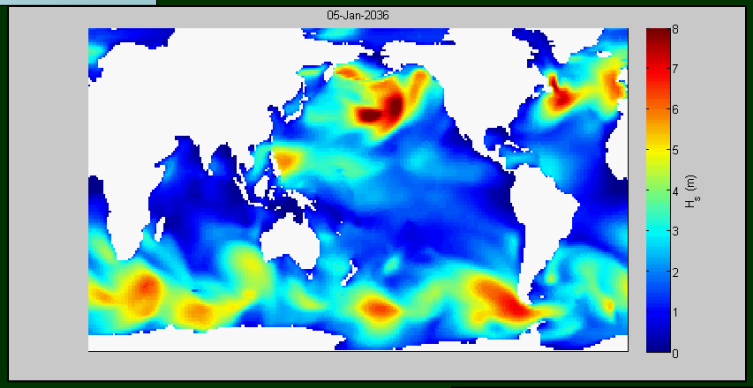
Identifying Future Risk with CoSMoS



1. Global forcing using the latest climate models



2. Drives global and regional wind/wave models

3. Scaled down to local hazards projections

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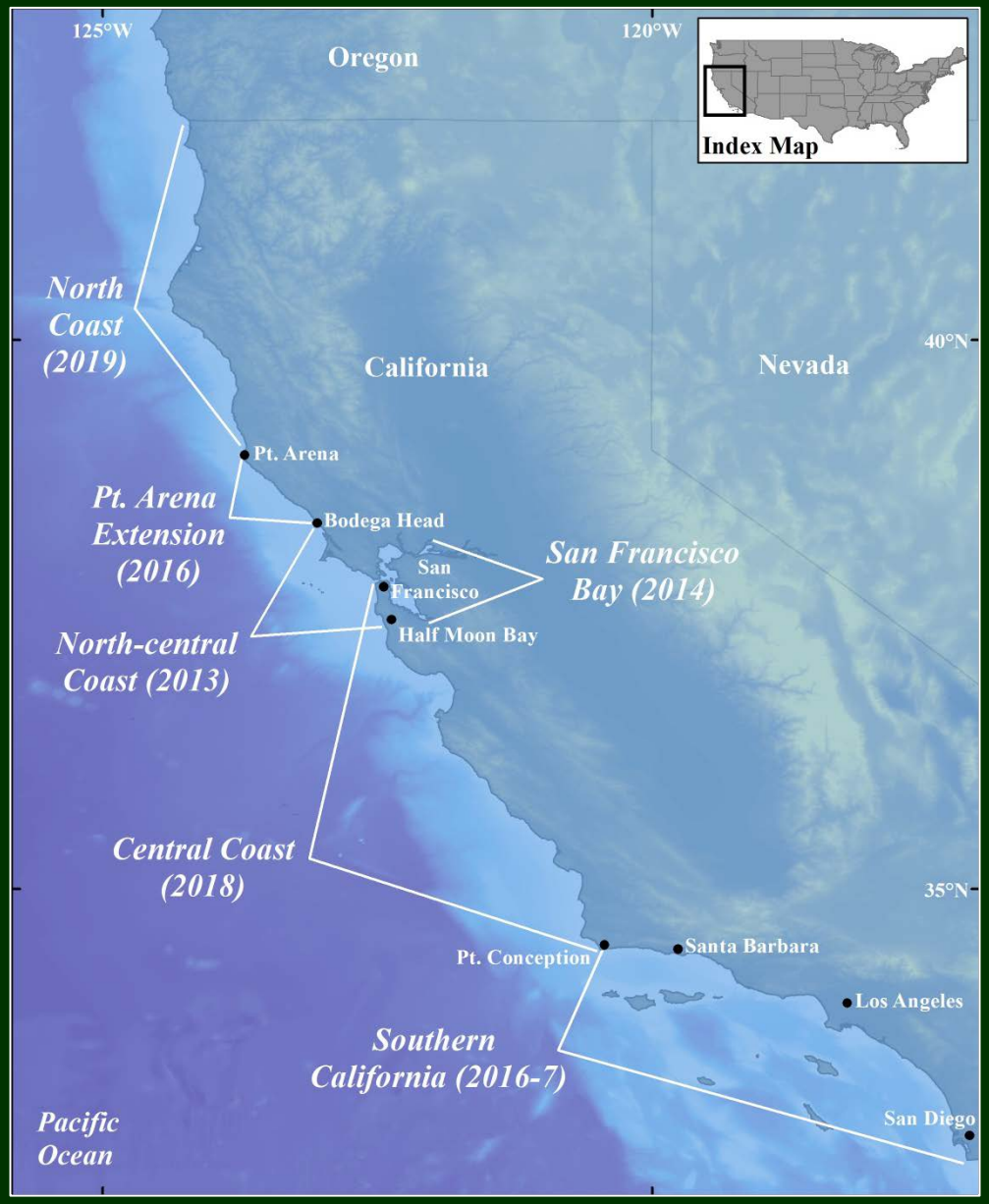
CoSMoS Coverage



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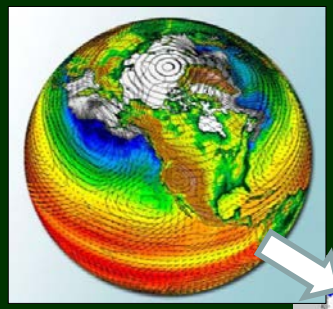
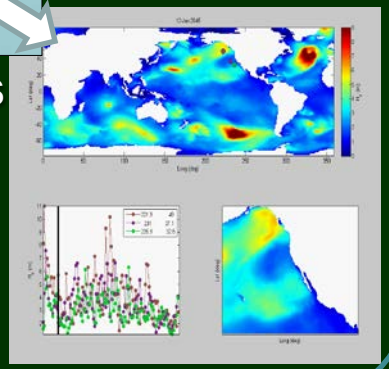
CoSMoS 3.0 Southern California

Global

Global climate models (GCMs)



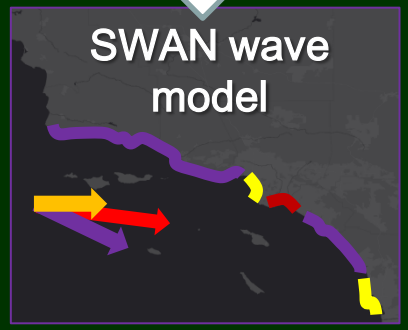
GCM winds



WW3 wave model

Regional

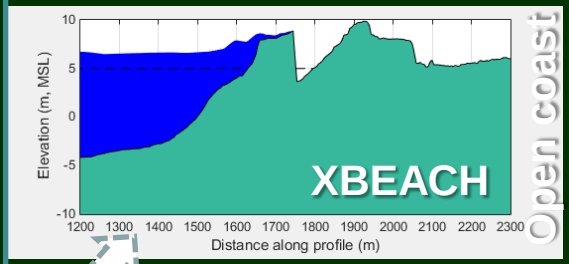
Tides, water levels, and regional forcing



SIO downscaled winds and SLPs

Local

High resolution hydrodynamics, waves, & fluvial discharge



Long-term cliff recession and shoreline change

results projected onto hi-res DEM

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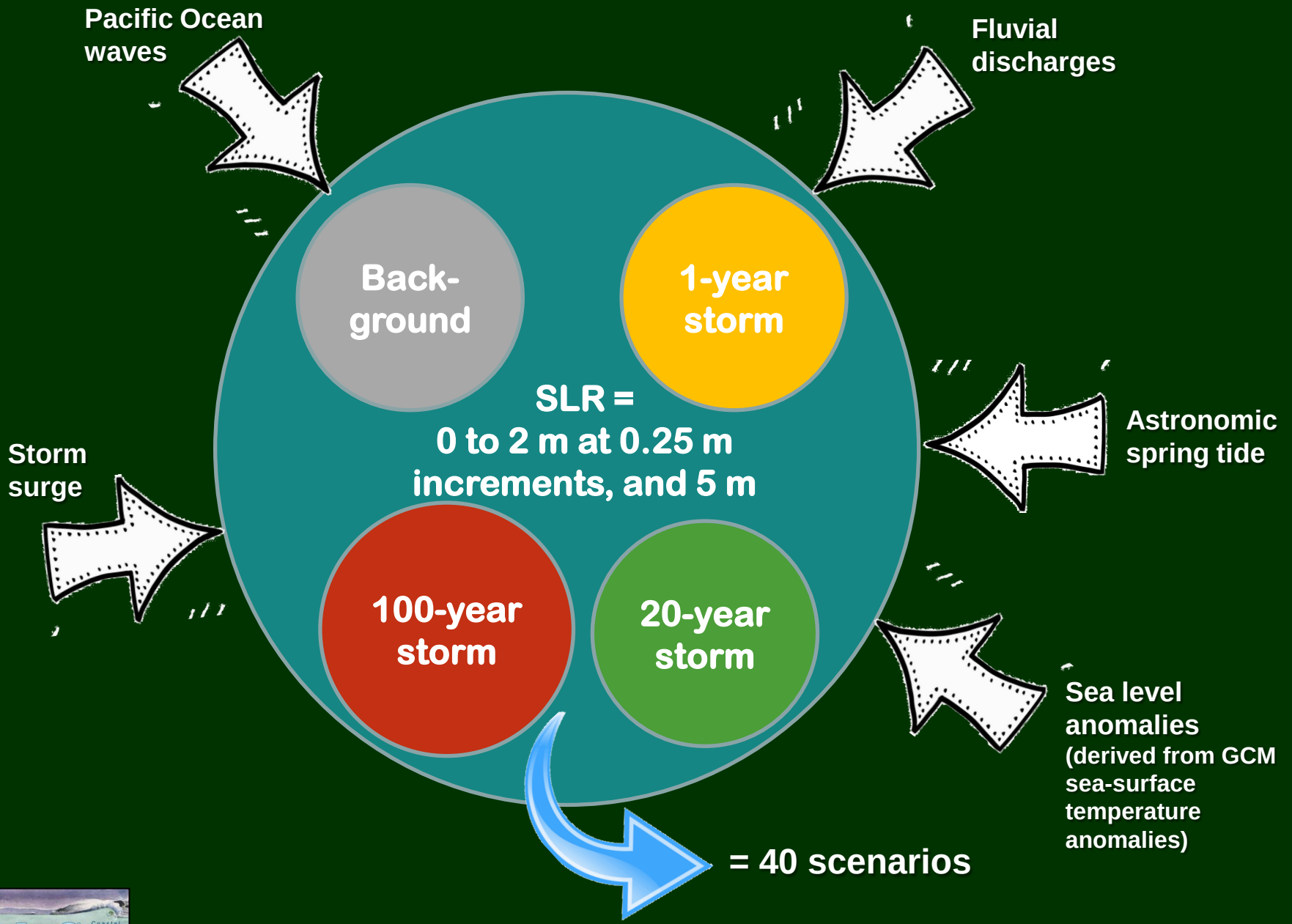
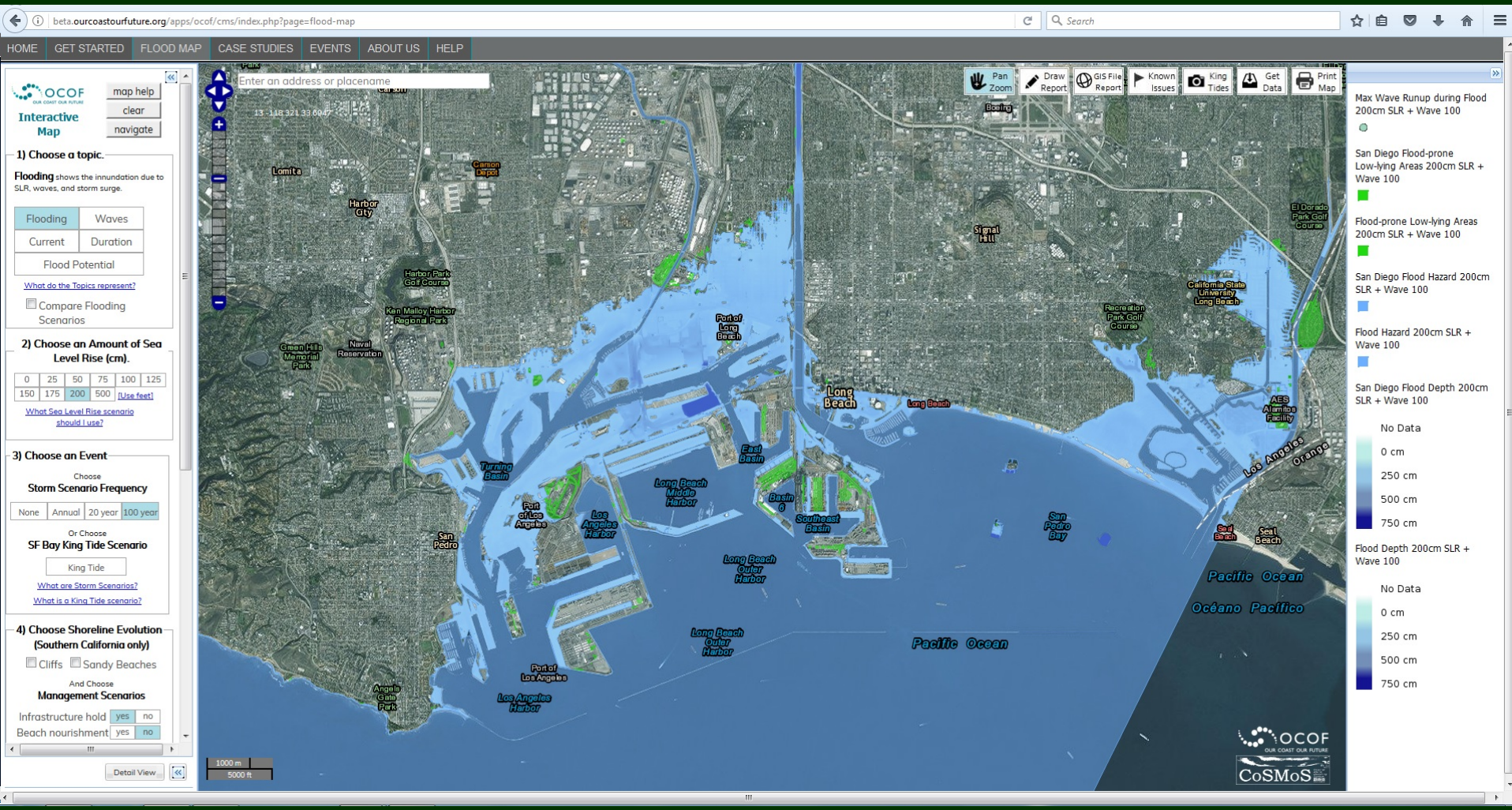

Pacific Ocean waves
Fluvial discharges
Back-ground
1-year storm
SLR =
0 to 2 m at 0.25 m increments, and 5 m
Storm surge
Astronomic spring tide
100-year storm
20-year storm
Sea level anomalies
(derived from GCM sea-surface temperature anomalies)
= 40 scenarios

Web Tool - Flooding



Our Coast, Our Future tool: *www.ourcoastourfuture.org*

Tipping Points

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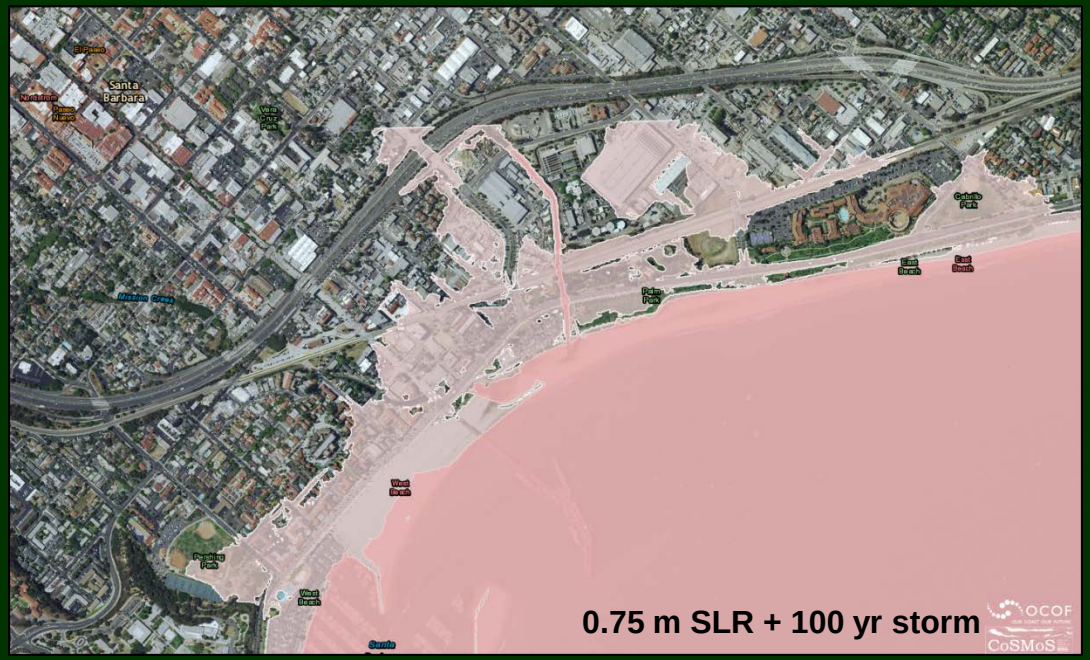
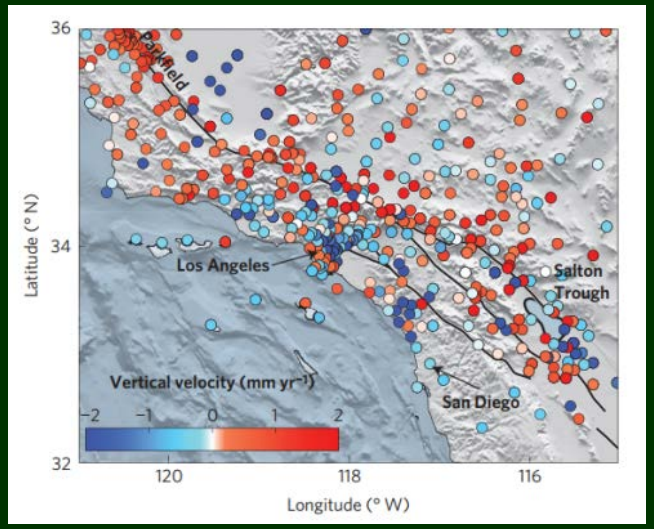
Flooding- Pillar Point

Flooding- Ventura Harbor

Flood Potential – Mapped Uncertainty





$$\varepsilon = \pm 0.50\ m \quad \pm 0.18\ m + \quad (0.4\ mm/yr | -0.6\ mm/yr)$$

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 uncertainty is increased

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)

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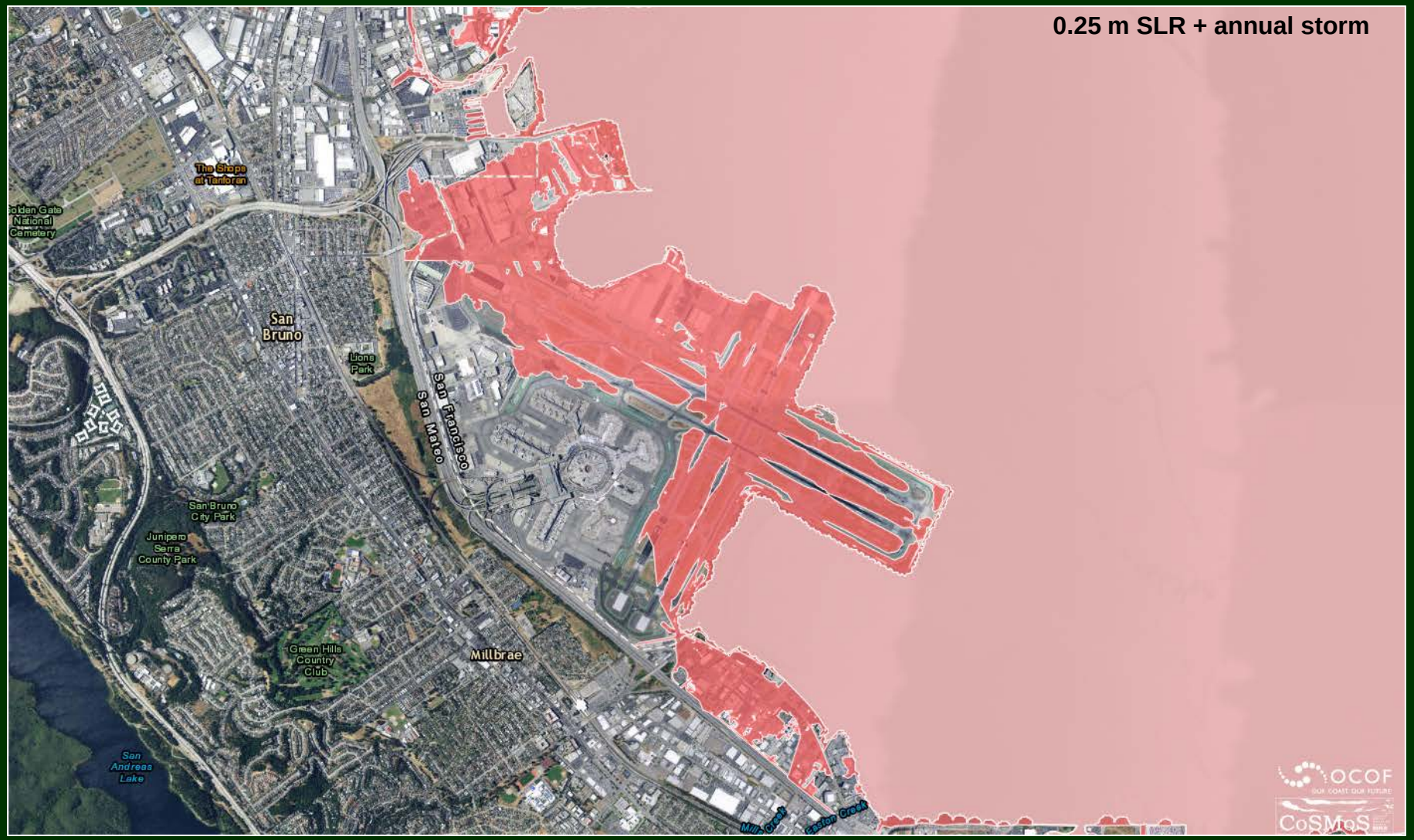
Flood Potential – Mapped Uncertainty



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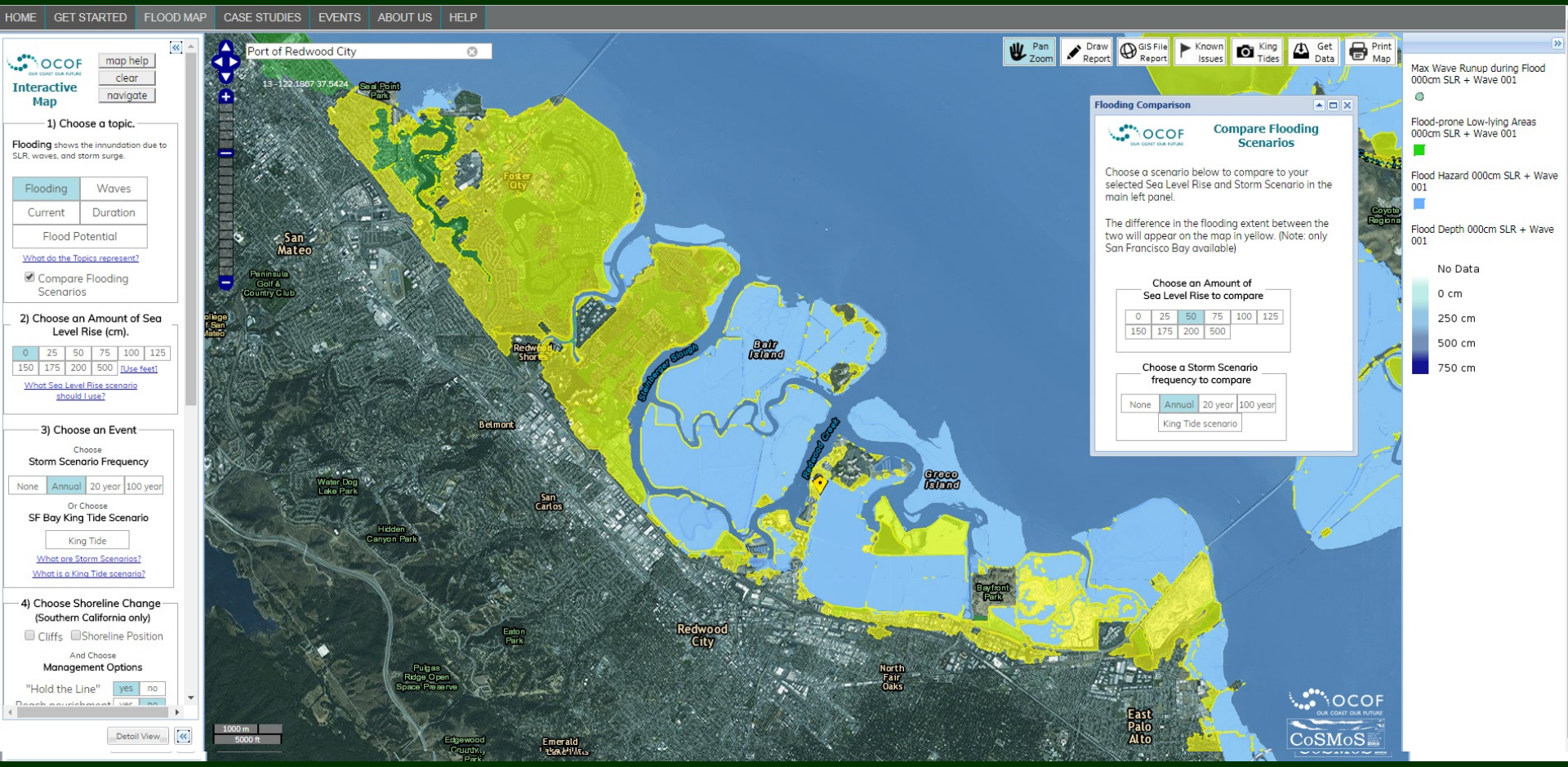
Comparing Scenarios



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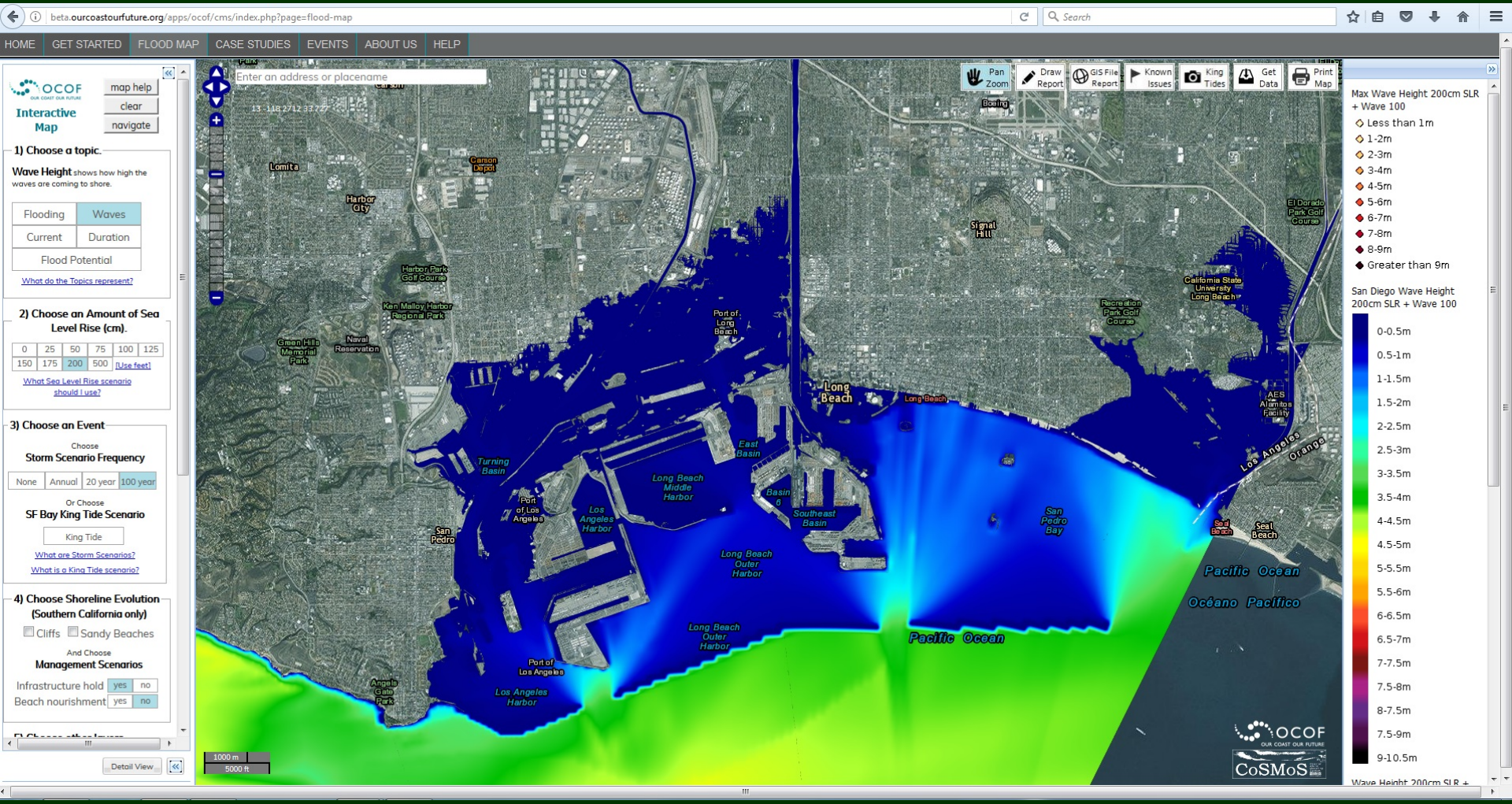
Web Tool - Waves and Currents



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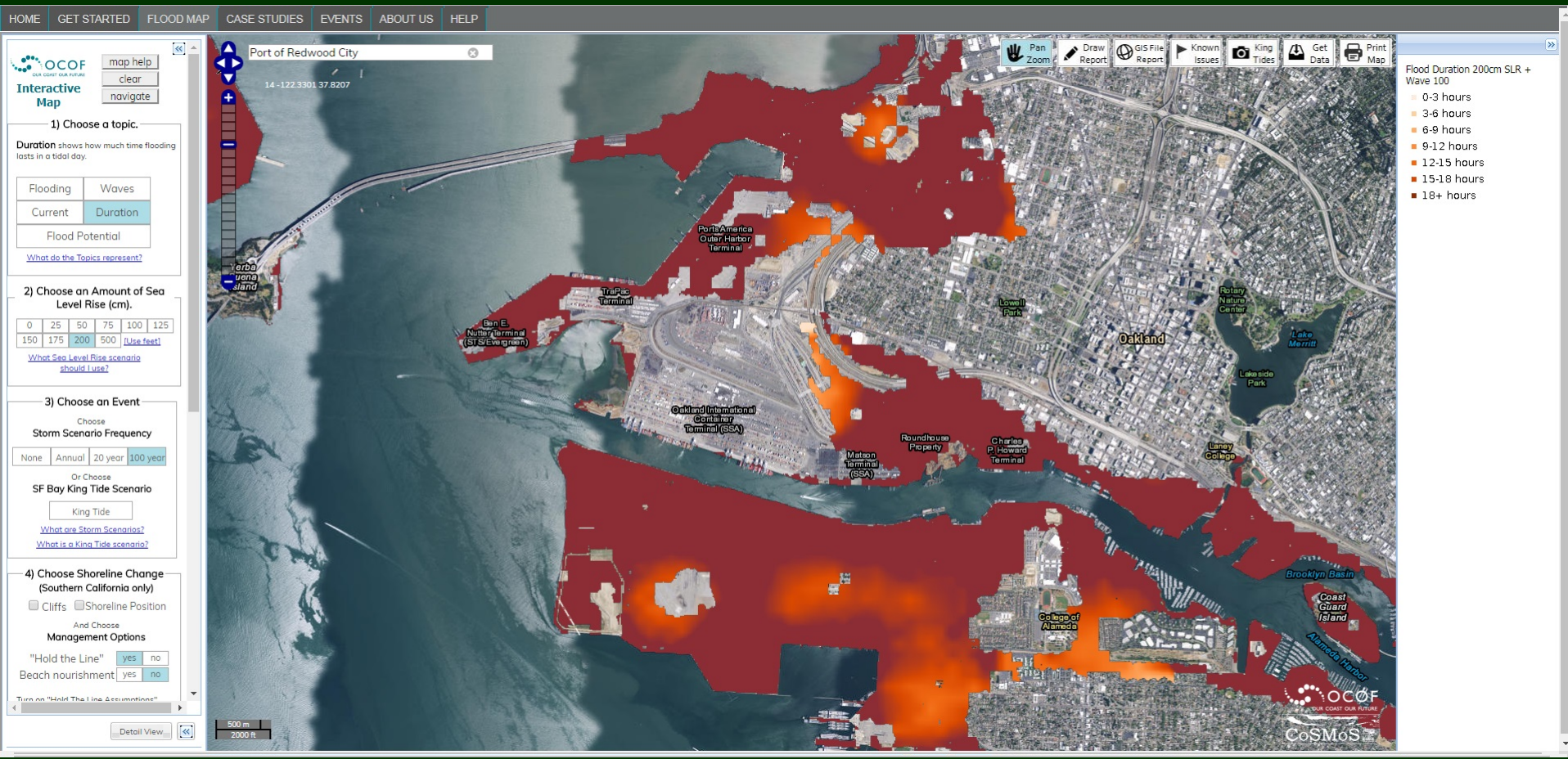
Flooding Duration



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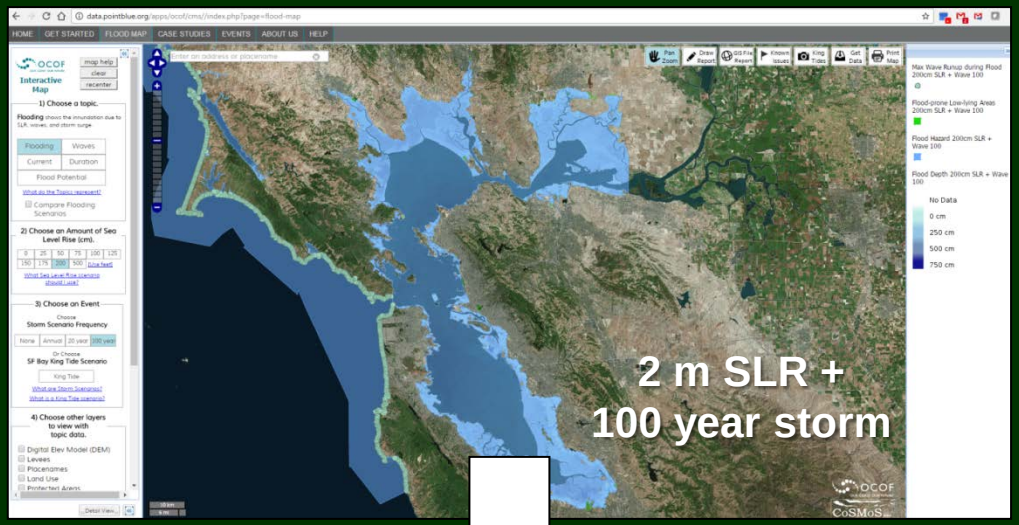
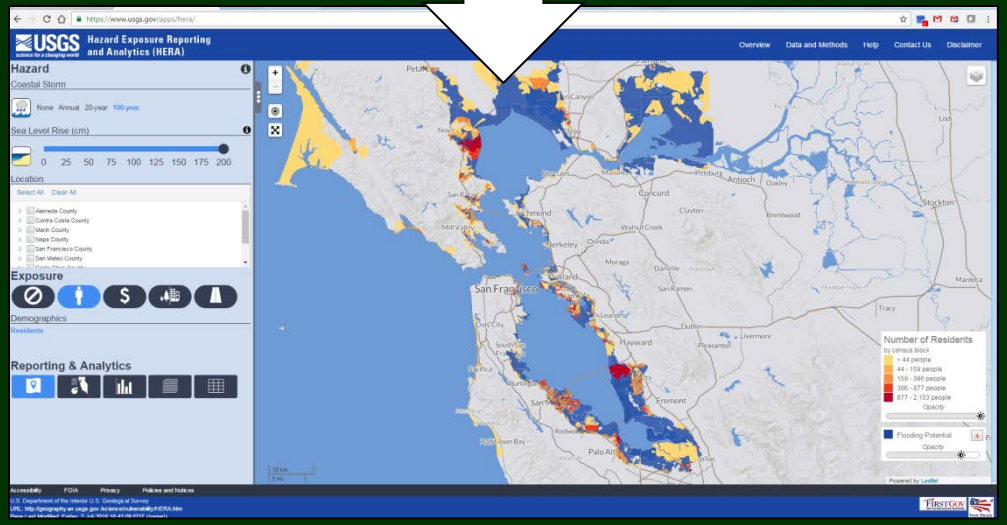
Socioeconomic Impacts



- Hazard Exposure Reporting and Analytics (HERA)
- 27 million residents in CA coastal counties
- 95% assessed



- 500,000+ residents
- $150 billion in property
- 4,700 km of roads
- 350 critical facilities

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www.usgs.gov/apps/hera

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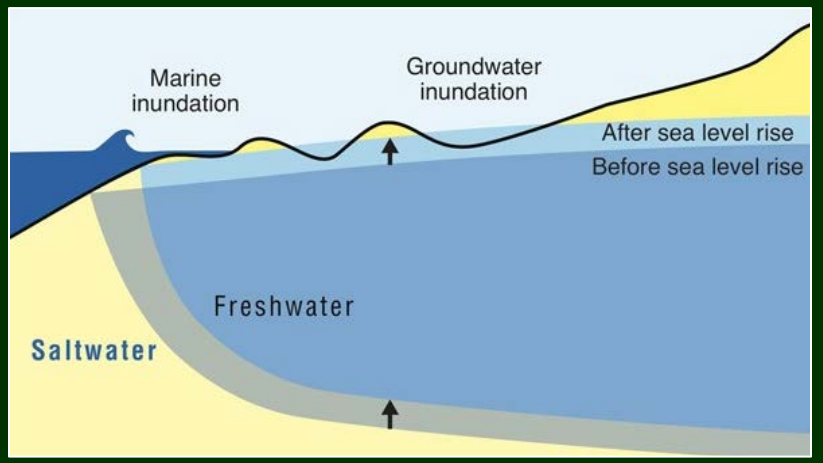
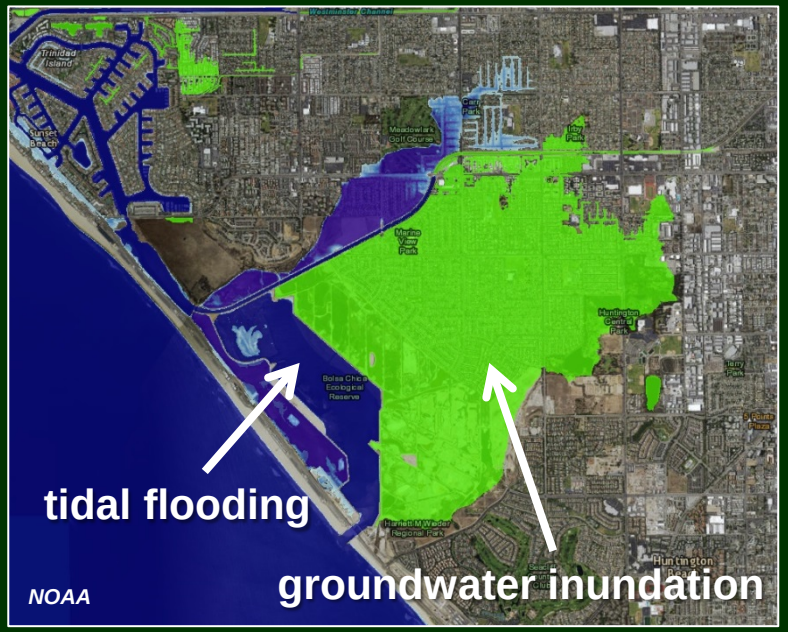
Groundwater Impacts

- **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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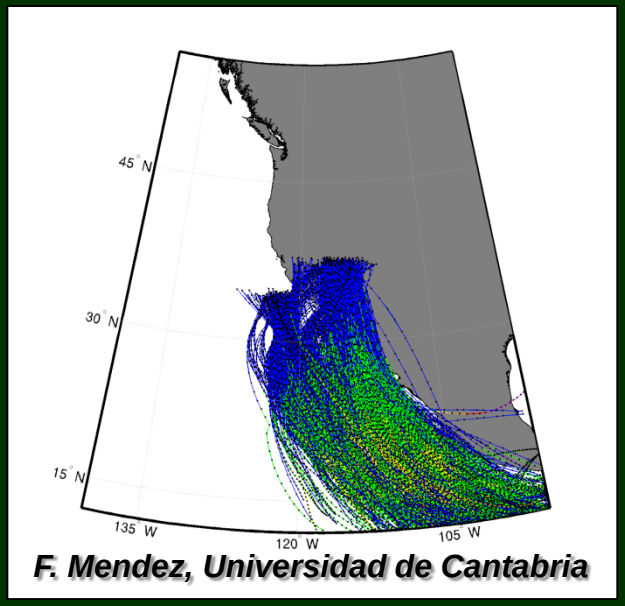
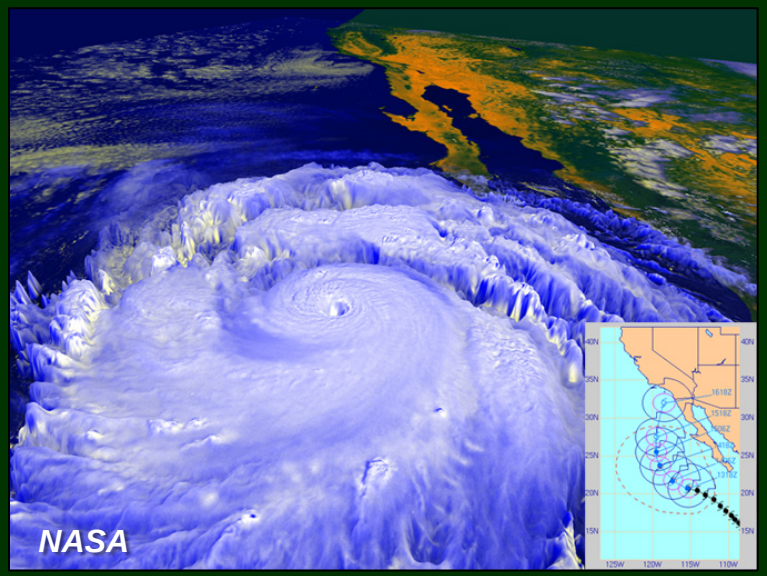
Hurricane Potential

- Hurricanes/tropical storms have the potential to significantly impact Southern California
  - San Diego Hurricane, October 2, 1858, produced hurricane/gale force winds from San Diego to LA
  - Un-named, September 25, 1939 (Long Beach), resulted in 90 deaths
- Peak potential during El Niño, but overall probability of landfall is very low
  - Record 13 hurricanes in 2015
  - Strongest winds ever recorded during Hurricane Patricia (345 km/hr = 214 mi/hr)
- Research ongoing
  - Will hurricane potential increase with climate change in the 21st century?
  - What is the probability of a hurricane making landfall?
  - What are the coastal hazards (e.g., coastal flooding, erosion) associated with such an event?



F. Mendez, Universidad de Cantabria



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Summary

- Beaches and harbors are highly vulnerable to climate change across California, esp. during El Niño winters
- CoSMoS coverage moving across the state, completion by 2019
- Web tools available to assess present and future impacts
- Further exploration of groundwater, hurricane impacts

*For more information, contact Patrick Barnard: *pbarnard@usgs.gov*

USGS CoSMoS website: *http://walrus.wr.usgs.gov/coastal_processes/cosmos/*

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