Using the Coastal Storm Modeling System (CoSMoS) to assess climate-driven coastal hazards across California

Patrick L. Barnard[1*], Kees Nederhoff[2], Li H. Erikson[1], Amy C. Foxgrover[1], Juliette Finzi Hart[1], Patrick Limber[1], Andrea C. O'Neill[1], Maarten van Ormondt[7], Sean Vitousek[1], Nathan Wood[3], Maya Hayden[4], Jeanne M. Jones[5] and Kevin Befus[6]

[1]United States Geological Survey, Pacific Coastal and Marine Science Center, Santa Cruz, CA, 95060, USA
[2]Deltares USA. Silver Spring, MD 20910
[3]United States Geological Survey, Western Geographic Science Center, Portland, OR, 97201, USA
[4]Point Blue Conservation Science, Petaluma, CA, 94954, USA
[5]United States Geological Survey, Western Geographic Science Center, Menlo Park, CA, 94025, USA
[6]University of Arkansas
[7]Deltares. Delft, Netherlands

USGS science for a changing world

CoSMoS Coastal Storm Modeling System USGS

1871

Point Blue Conservation science for a healthy planet

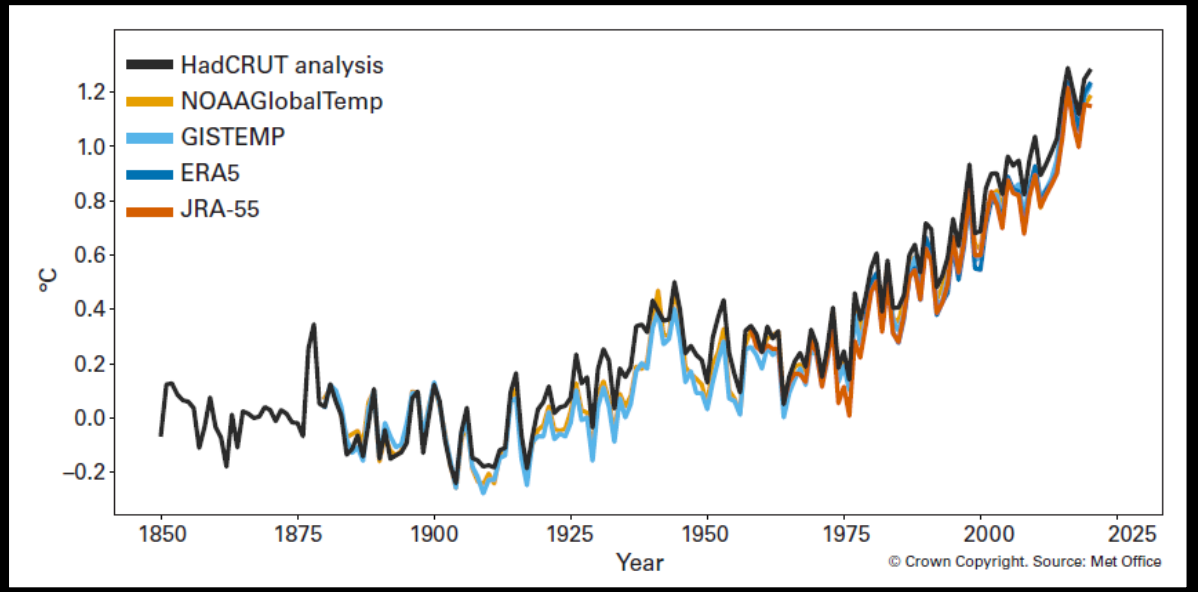
OCOF OUR COAST OUR FUTURE

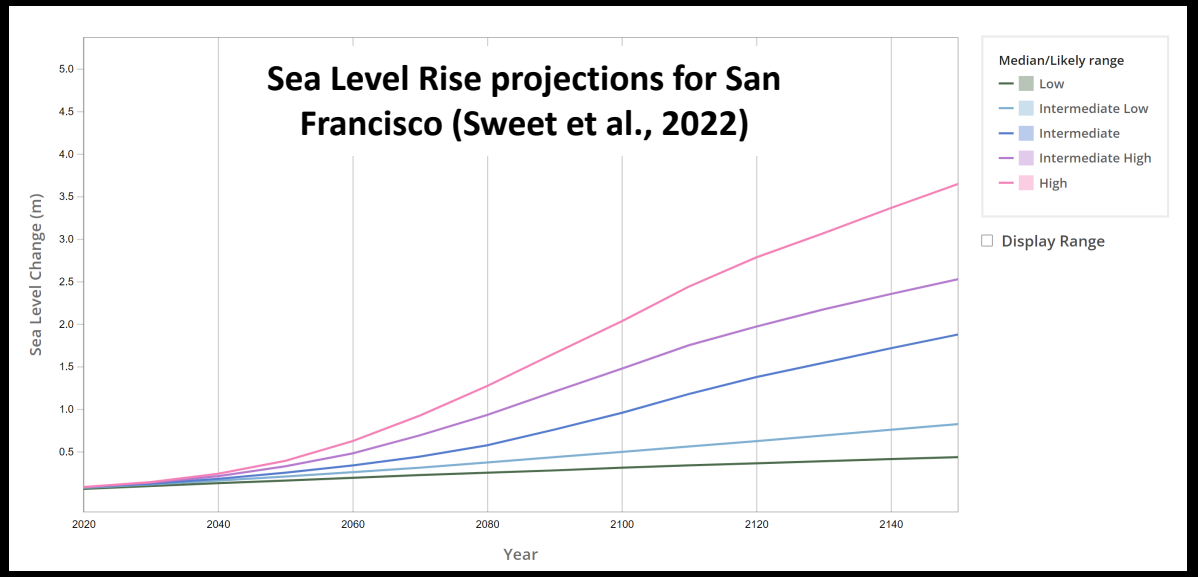
Deltares

Deltares USA

The Latest Science

- The past six years have been the six warmest years on record (WMO)
- “Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years” (AR6)
- The rate of sea level rise has ~tripled since 1971, currently 3.7 mm/yr (AR6)
- Sea level rise in the U.S. will be, on average, 25-30 cm (10-12 in) higher in the next 30 years, equivalent to SLR over the last century (Sweet et al., 2022)
- High tide flooding will increase by 3-12 times by 2050 (Sweet et al., 2022)





Sources: *World Meteorological Organization (2021):, State of the Global Climate 2020.*

IPCC (2021): Summary for Policymakers.

Sweet et al. (2022): Global and regional sea level rise scenarios for the United States: updated mean projections and extreme water level probabilities along U.S. coastlines.

USGS

The Relevance of Sea Level Rise

- Over 1 billion people are expected to live in the coastal zone by 2050
- SLR will likely cause ‘once-in-a-lifetime’ coastal flooding events to occur annually by 2050, and every day by 2100
- When considering storms and coastal change, ~3 times more people would be at risk
- In California
  - ~Half of beaches could be lost in addition to extensive ecological and cultural resources
  - Over 600,000 people and $200 billion in property at risk by 2100 (6% of GDP)
  - These potential impacts are ~ 10 times greater than the worst wildfires and earthquakes California history

Malé, Maldives

Sunset Beach, Sean Hiller

USGS

Imperial Beach, CA, November 25, 2015 (Chris Helmer)

San Francisco, CA (http://california.kingtides.net/)

Wiyot village site, Tuluwat Island, Humboldt Bay, CA (Aldaron Laird)

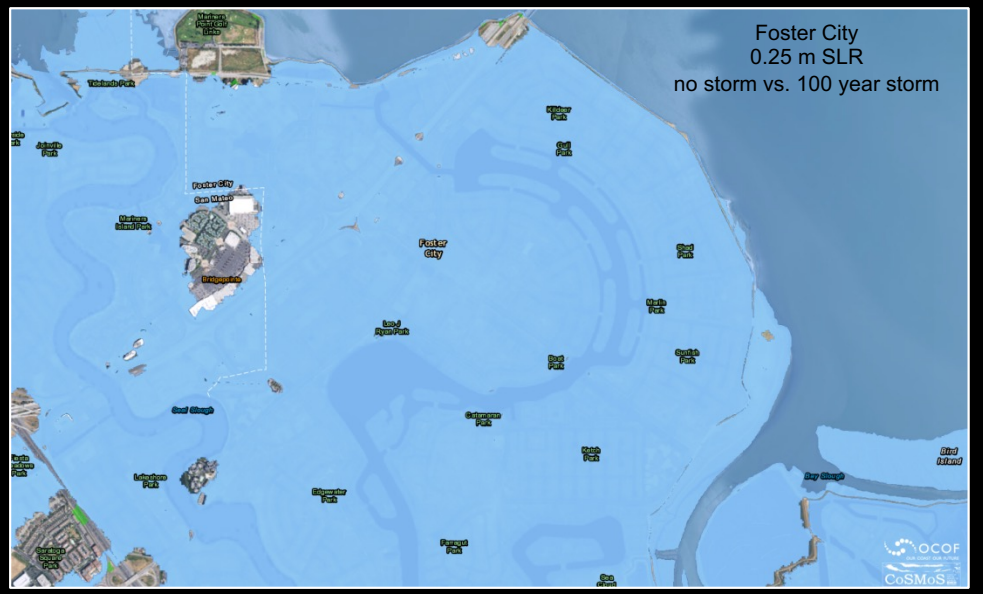
Newport Beach, CA, Winter 1983

Santa Cruz, CA, January 2017 (Nick Moless)

Coastal Vulnerability Approaches

Static

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



"Bathtub" models under predict flooding hazards

USGS

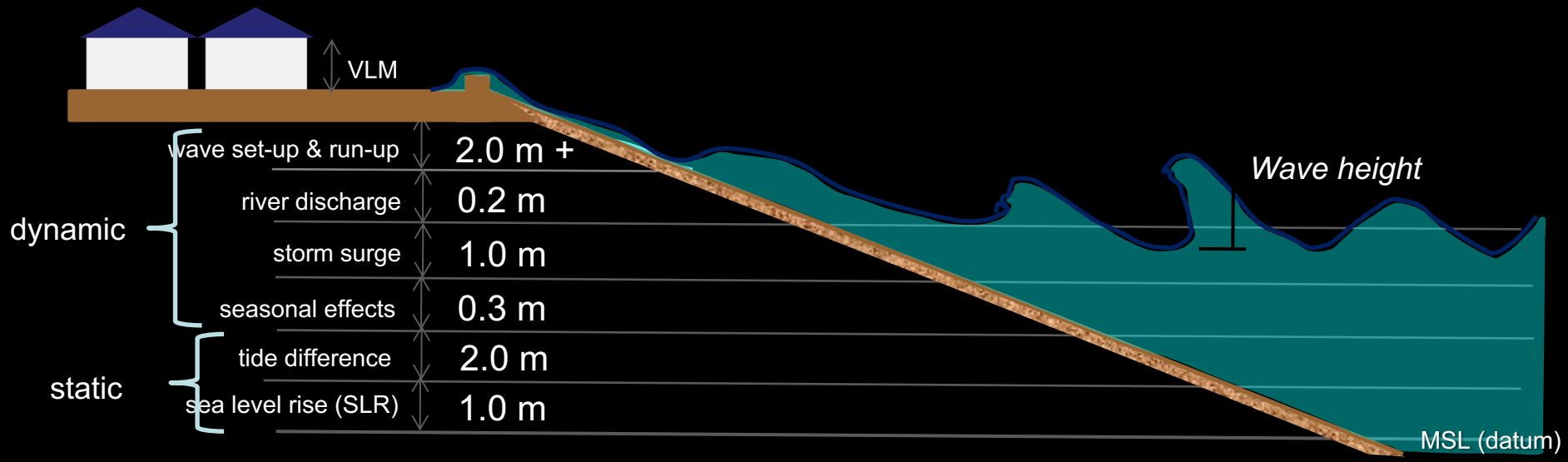
Coastal Vulnerability Approaches

Static

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

Dynamic: USGS-CoSMoS

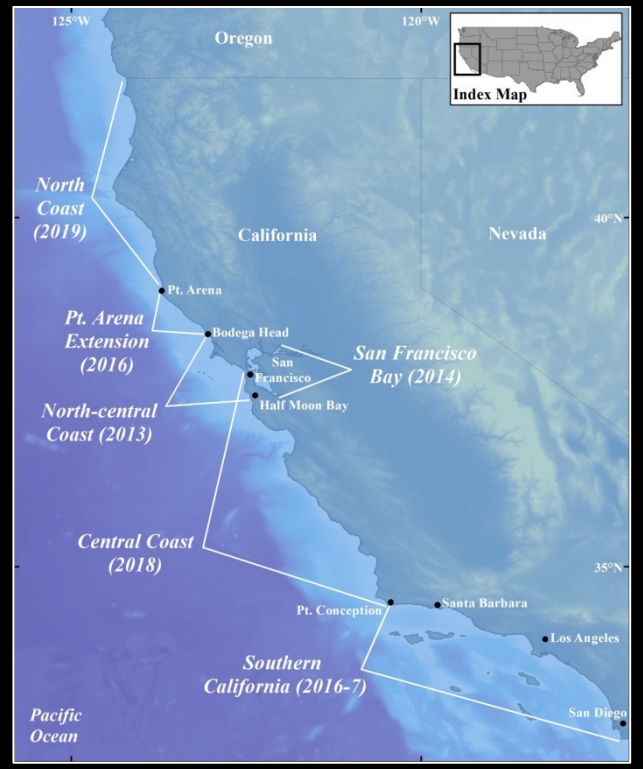
- All physics modeled
- Forced by Global Climate Models
- Includes wind, waves, atmospheric pressure, shoreline change
- Range of SLR and storm scenarios



USGS

Coastal Storm Modeling System (CoSMoS)

- Physics-based numerical modeling system for assessing coastal hazards due to climate change
- Predicts coastal hazards for the full range of sea level rise (0-5 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 (~150 different agencies) to meet their planning and adaptation needs

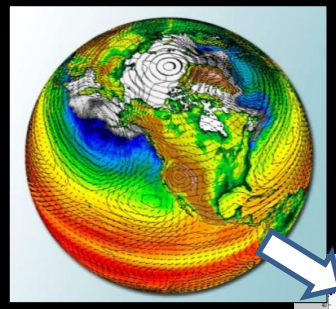


USGS

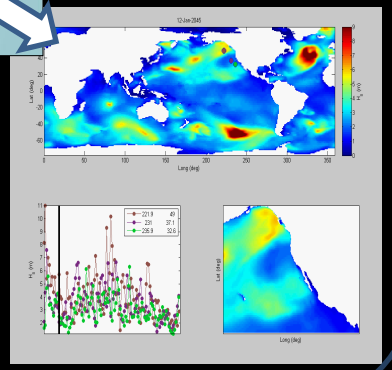
Coastal Storm Modeling System (CoSMoS)

Global

Global climate models (GCMs)



GCM winds

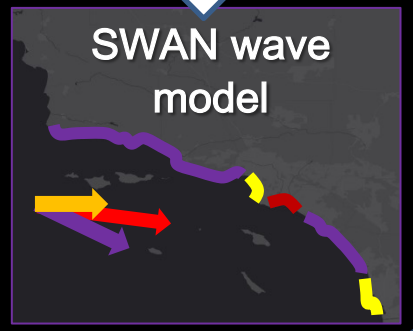


WW3 wave model

Downscaled winds and SLPs

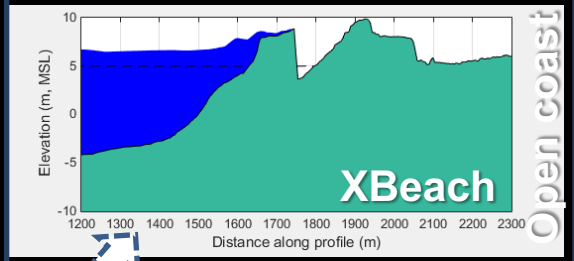
Regional

Tides, water levels, and regional forcing



Local

High resolution hydrodynamics, waves, & fluvial discharge



Long-term cliff recession and shoreline change

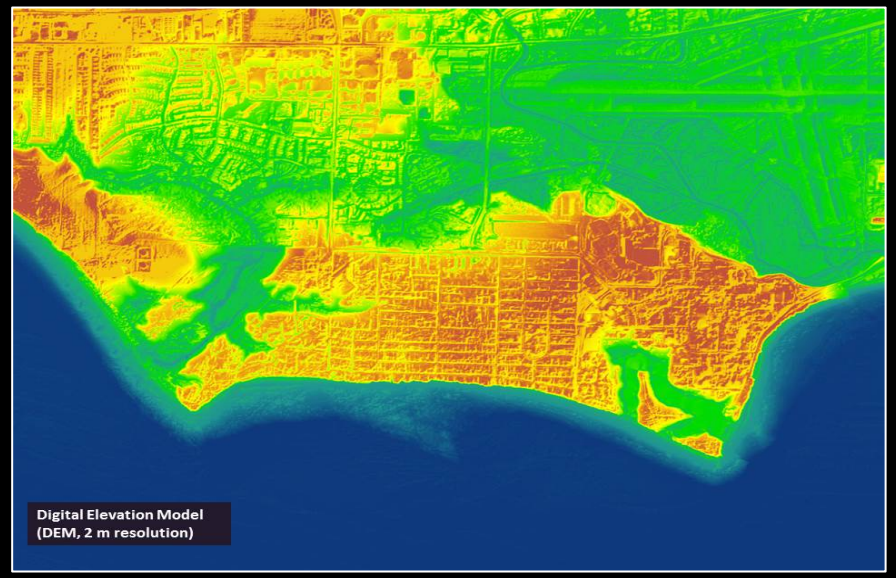
results projected onto hi-res DEM

Barnard et al., 2019. Dynamic flood modeling essential to assess the coastal impacts of climate change. *Scientific Reports,* Volume 9, Article #4309, 13 pp., http://dx.doi.org/10.1038/s41598-019-40742-z

USGS

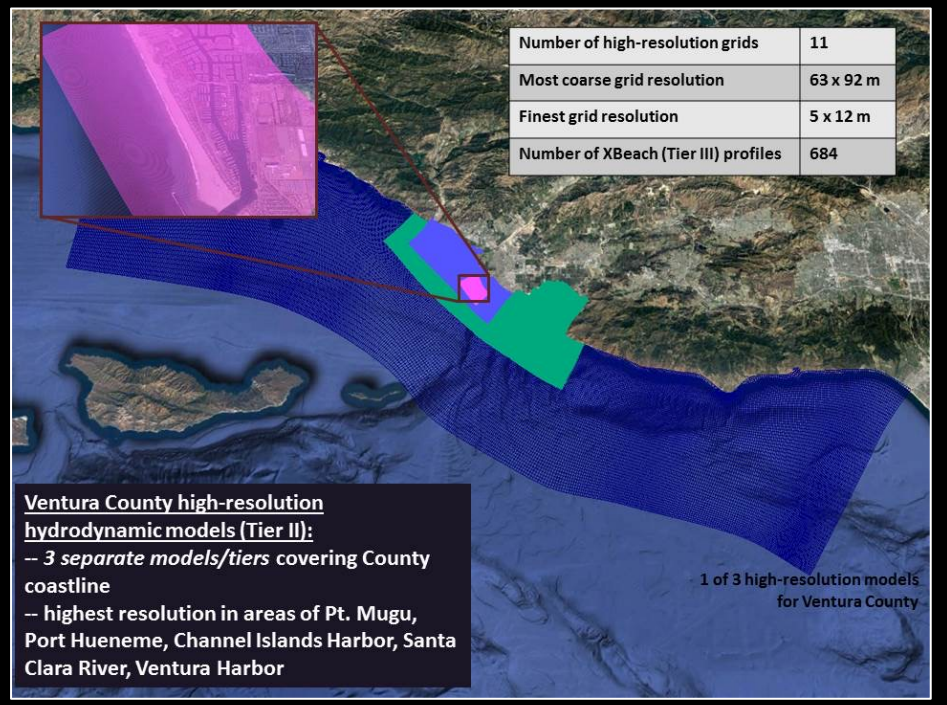
CoSMoS Coastal Storm Modeling System USGS

DEM and Computational Grids

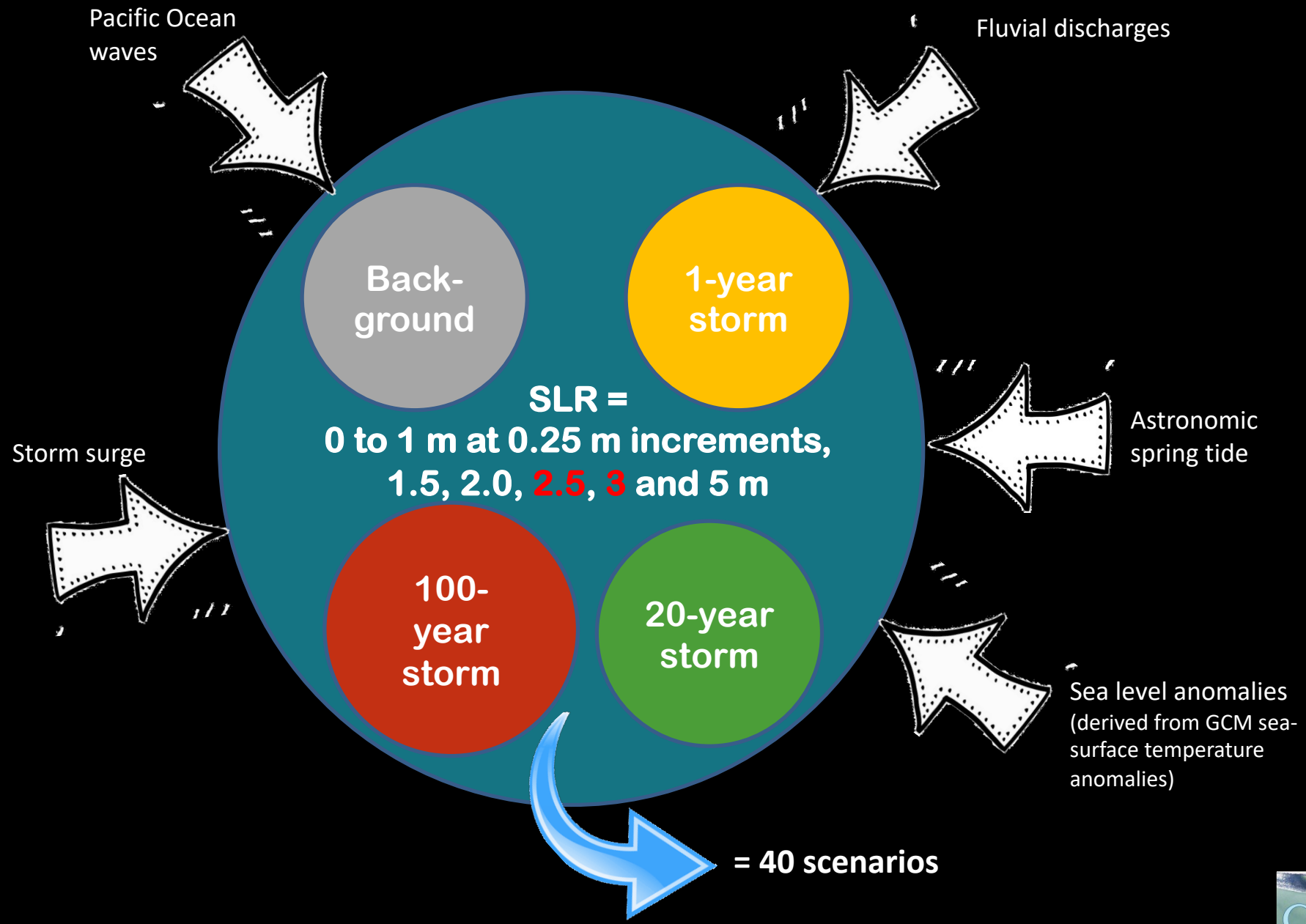


DEM: 2 m horizontal resolution

Hydrodynamic grids: fine to 5 m



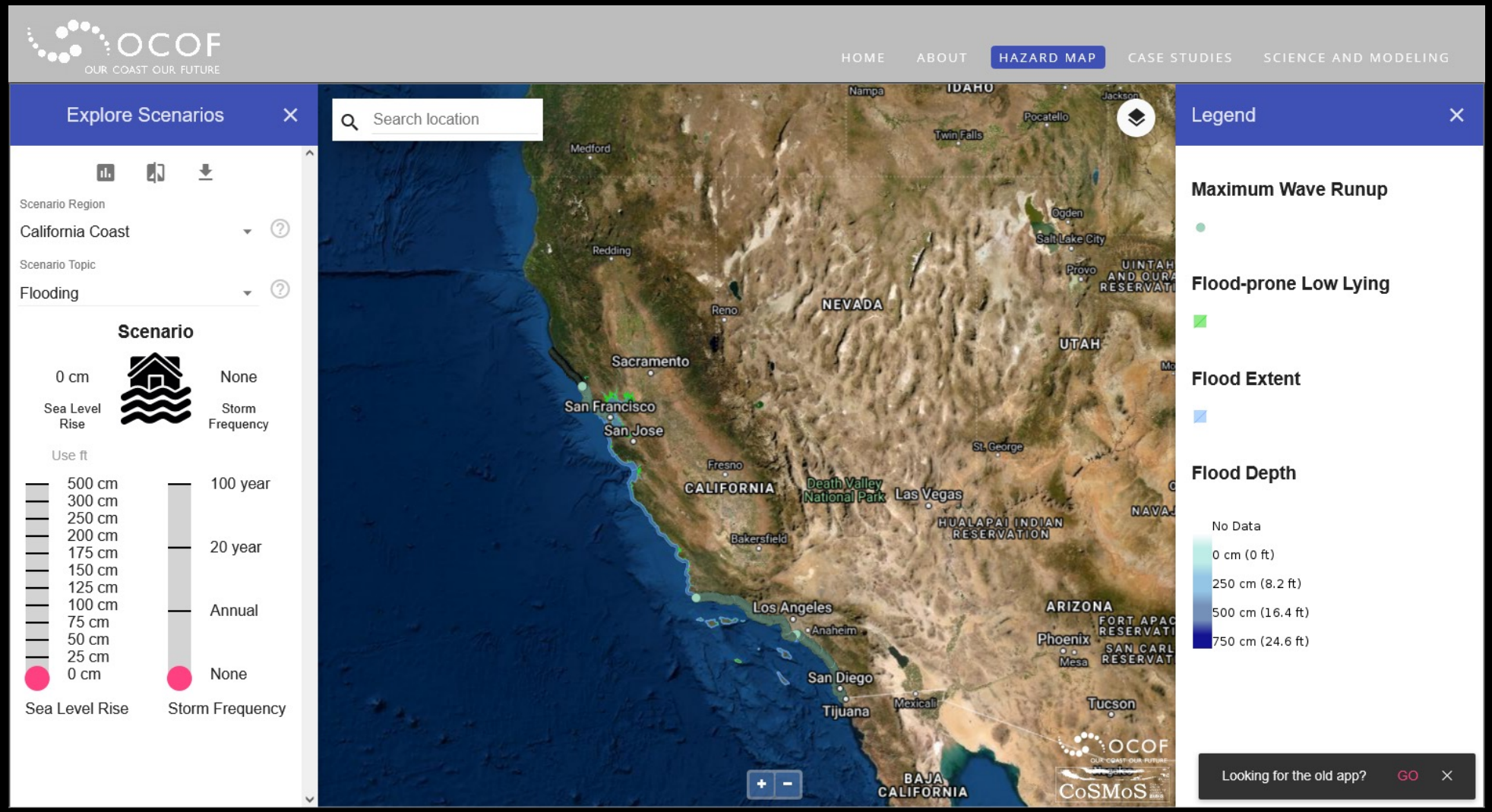
CoSMoS Coastal Storm Modeling System USGS



USGS

CoSMoS Coastal Storm Modeling System USGS

Viewing Coastal Hazards

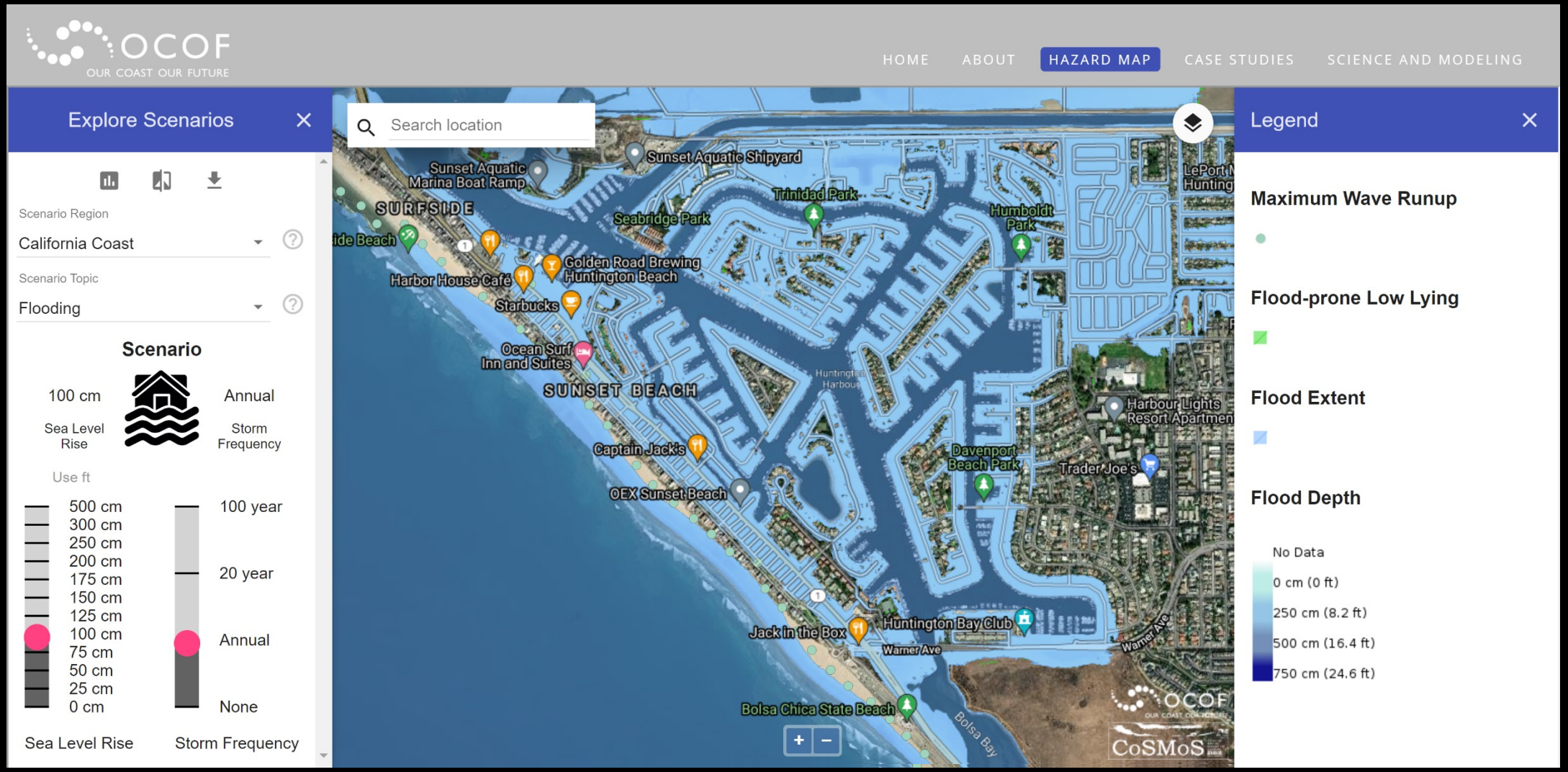


Our Coast, Our Future tool: *www.ourcoastourfuture.org*

USGS

Point Blue
Conservation science for a healthy planet

Viewing Coastal Hazards

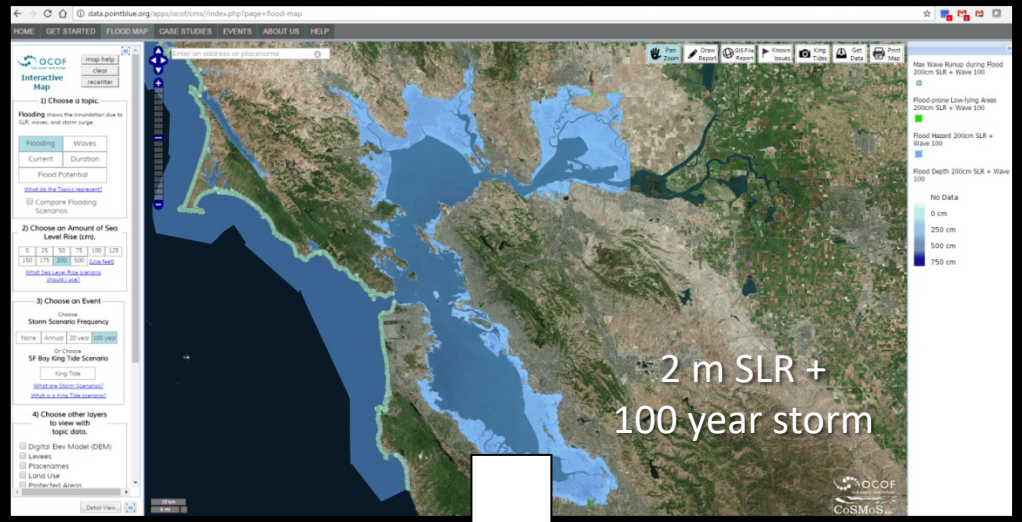


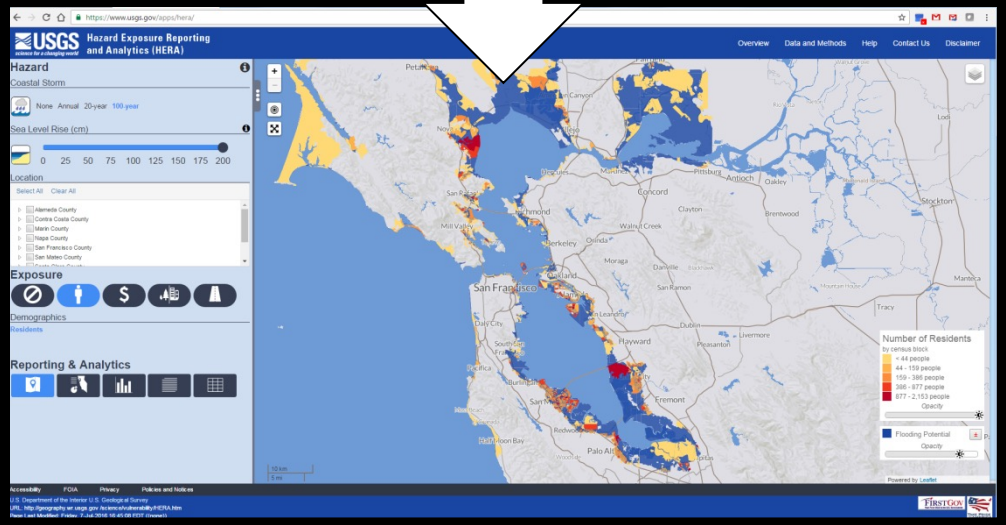
Our Coast, Our Future tool: *www.ourcoastourfuture.org*

USGS

Point Blue
Conservation science for a healthy planet

Societal Implications





=

California

- 600,000+ residents
- $200 billion in property
- 4,700 km of roads
- 350 critical facilities (e.g., schools, police stations, hospitals)

USGS

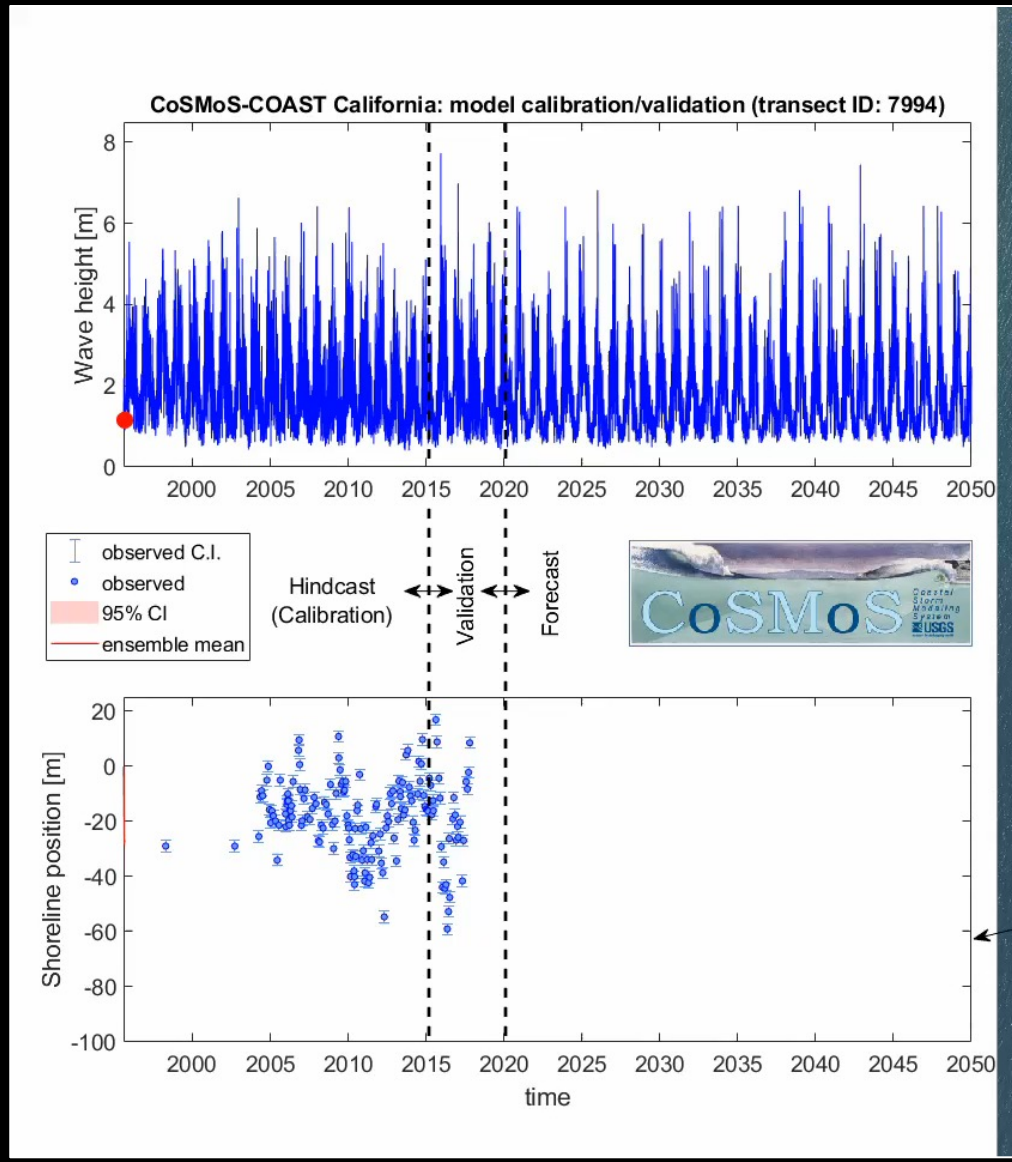
Hazards Exposure Reporting and Analytics (HERA)
www.usgs.gov/apps/hera

CoSMoS Coastal Storm Modeling System USGS

Shoreline Change

Approach Highlights

- Predicts future coastal change based on the SLR scenarios and total water level projections (CoSMoS-COAST).
- Auto-tunes model parameters along 50-m spaced transects to best fit historical data (LiDAR and satellite imagery)
- Projects coastal erosion hazards incorporating SLR, cross-shore and longshore transport, and sediment supply
- Erosion hazard maps for daily and storm conditions



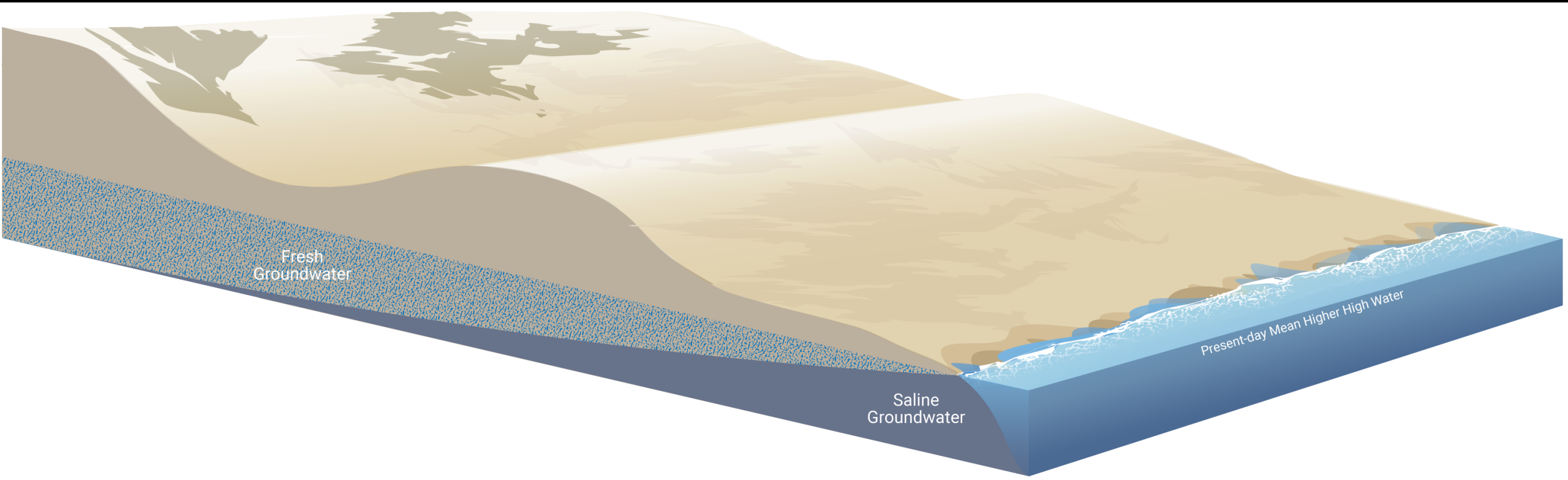
Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface*, Volume 122, p. 782-806, http://dx.doi.org/10.1002/2016JF004065

USGS science for a changing world

CoSMoS Coastal Storm Modeling System USGS

Miami, FL

How Sea Level Rise Affects the Groundwater Table

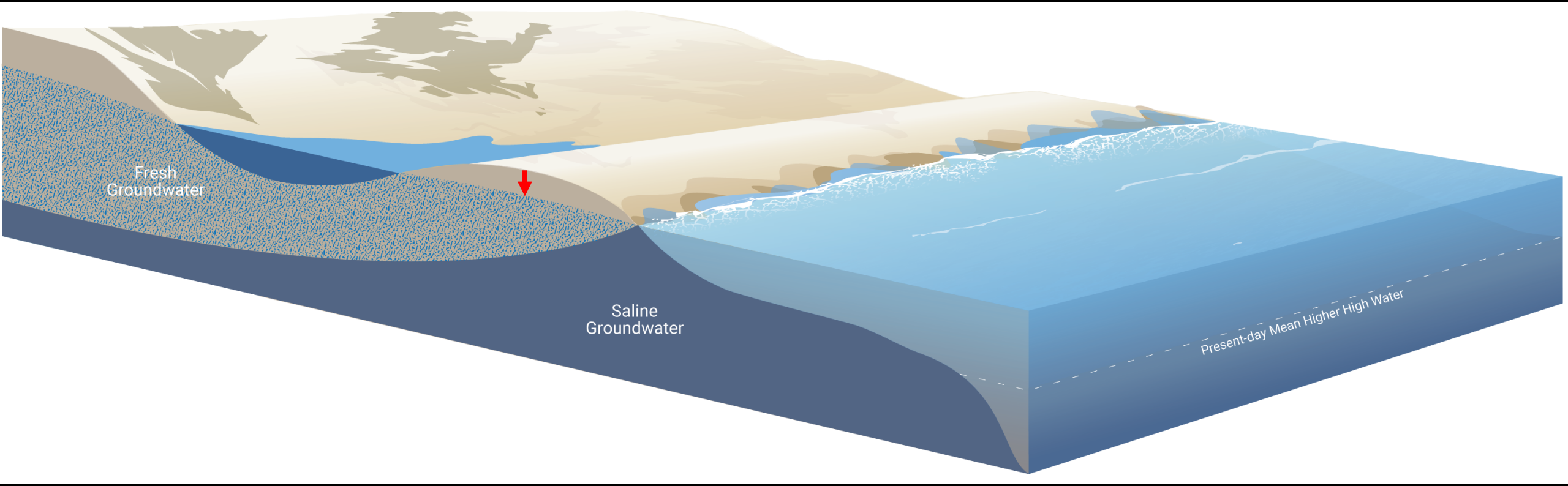


USGS

Point Blue
Conservation science
for a healthy planet

1871

How Sea Level Rise Affects the Groundwater Table

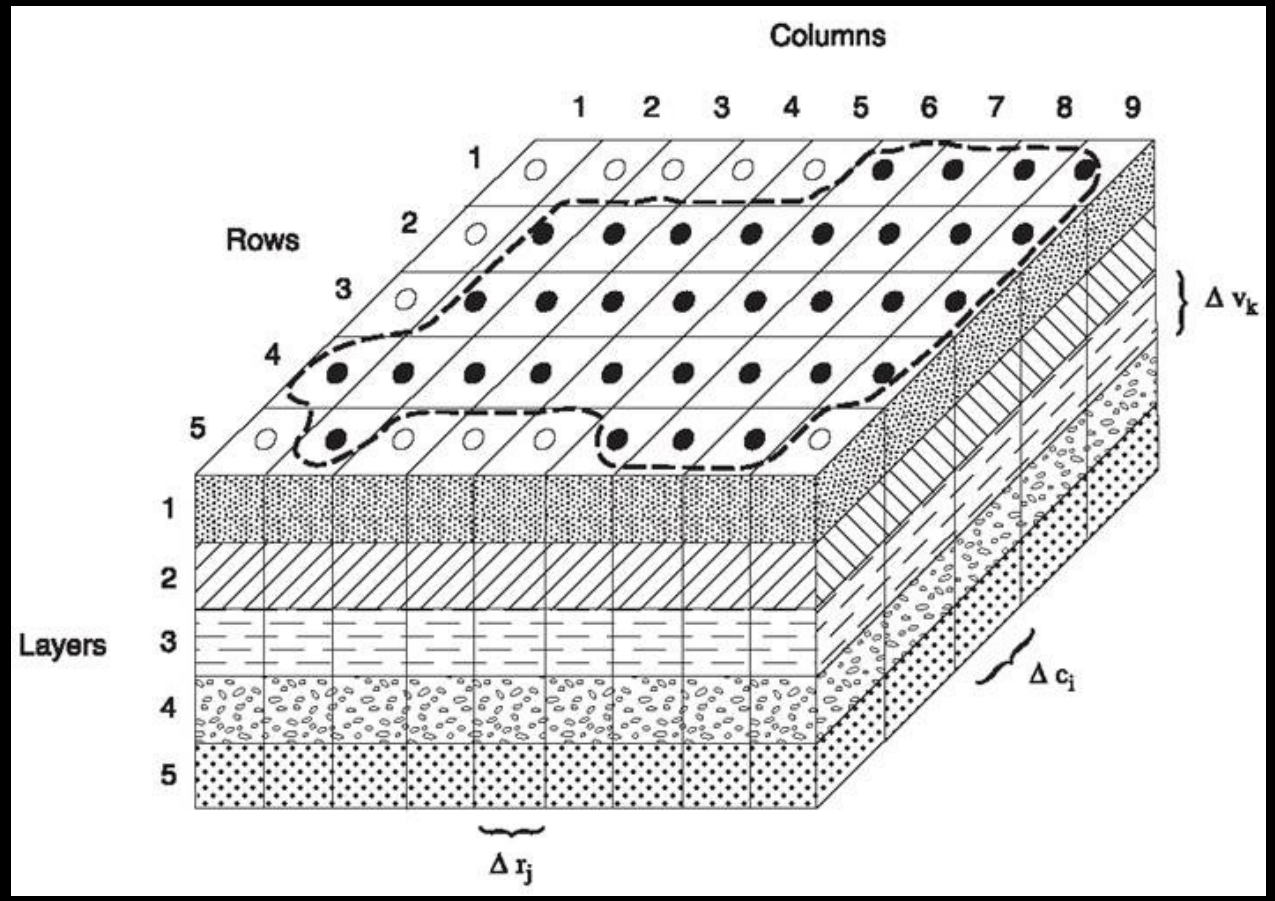


USGS

Point Blue
Conservation science
for a healthy planet

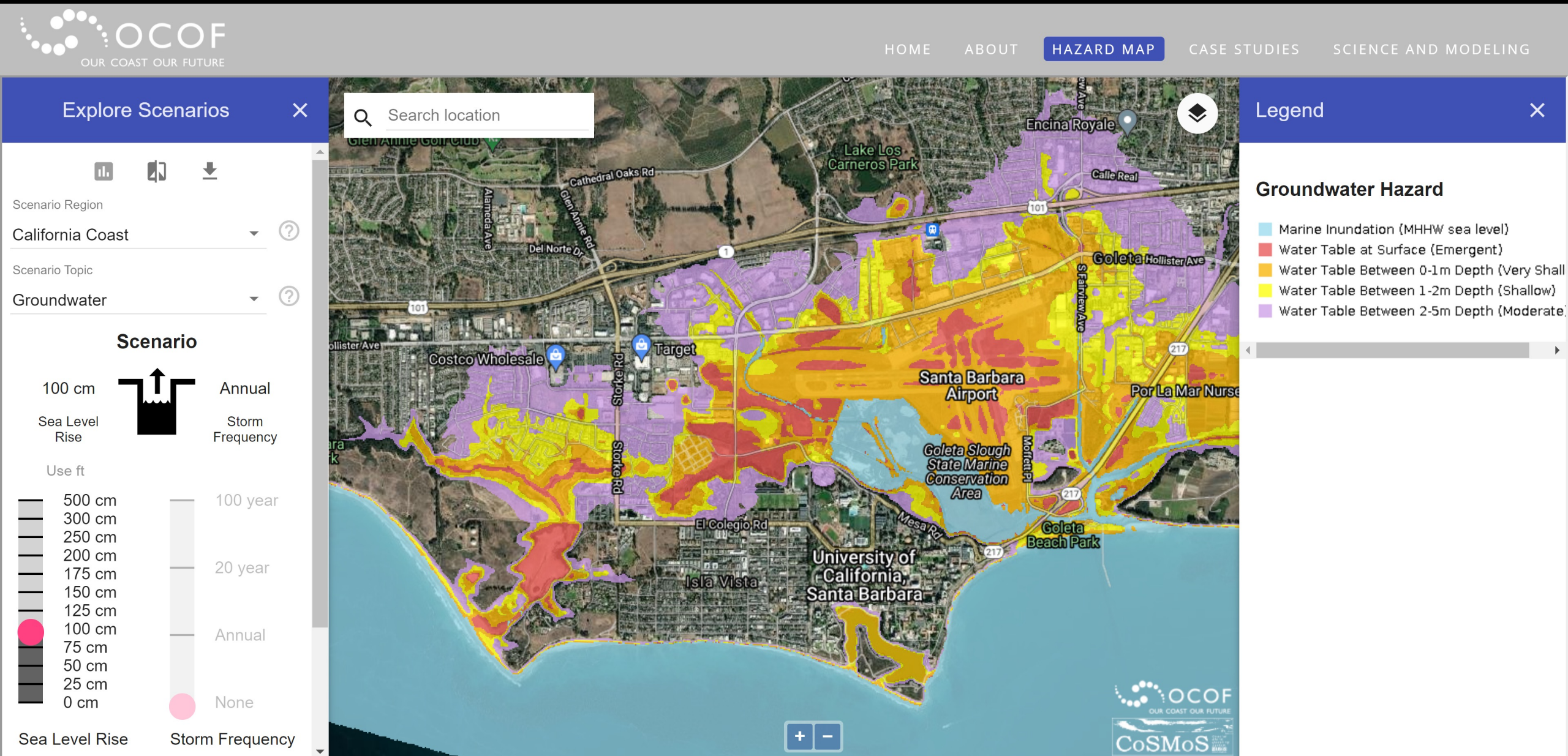
1871

Groundwater Modeling

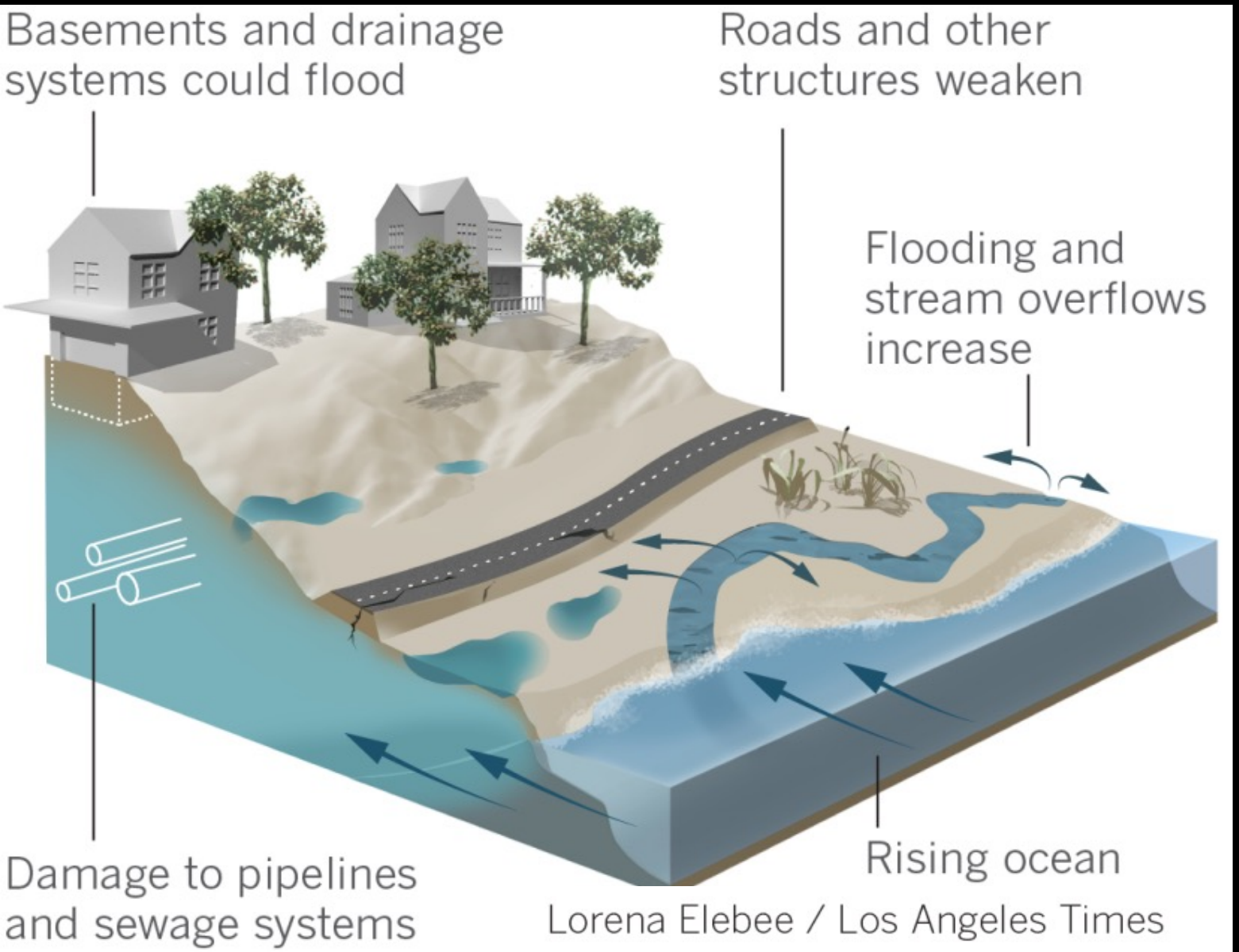


Befus, K.M., Barnard, P.L., Hoover, D.J., Finzi Hart, J.A. and Voss, C.I., 2020. Increasing threat of coastal groundwater hazards from sea-level rise in California. *Nature Climate Change*, Volume 10, p. 946-952, https://doi.org/10.1038/s41558-020-0874-1

Viewing Coastal Hazards



Groundwater Impacts?



California exposure

(2 m of SLR)

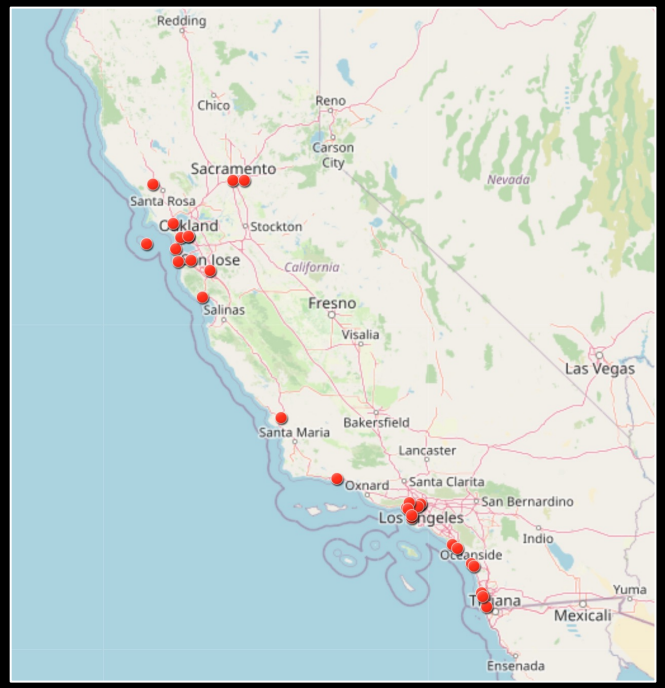
- **4 million residents**
- **$1.1 trillion in property**
- **1.1 million acres of ecological-rich coastal land (e.g., grasslands, forest, wetlands)**
- **33,000 km of roads**
- **3,000 critical facilities (e.g., schools, police stations, hospitals)**

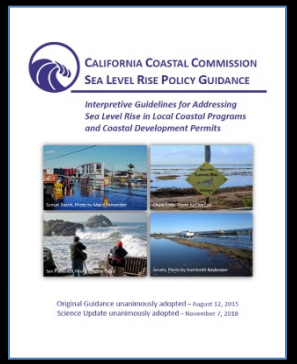
***6-9 times greater exposure then overland flooding**

Source:
Hazards Exposure Reporting and Analytics (HERA)
www.usgs.gov/apps/hera

How has CoSMoS been used?

- Dozens of cities and counties for updating their Local Coastal Programs (LCPs) for hazard mitigation and climate adaptation
- Caltrans to assess the vulnerability of transportation infrastructure across the state
- California Coastal Commission to evaluate coastal construction permits
- Integrated into state climate change guidance
- California State Legislature used CoSMoS/HERA results as justification for passing a $3.7 billion climate resilience spending package
- Current applications include operational flood forecasting in SF Bay, and expansion in Pacific Northwest, Alaska, Pacific Islands and Southeast U.S.





Sea Grant
University of Southern California

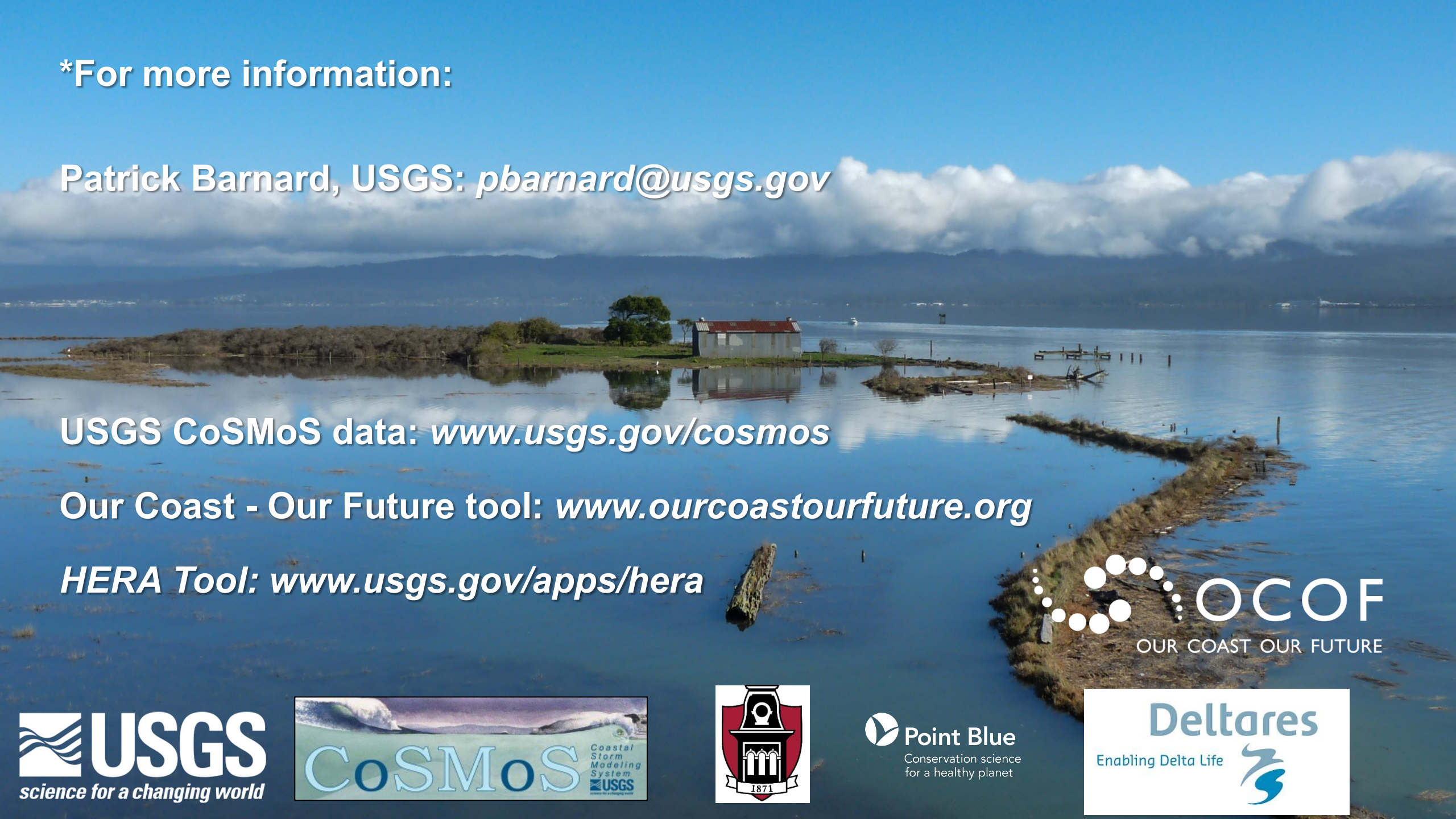
Caltrans

ADAPTLA

Tijuana River
National Estuarine Research Reserve

SEA CHANGE
SAN MATEO COUNTY

CoSMoS
Coastal Storm Modeling System
USGS



*For more information:

Patrick Barnard, USGS: *pbarnard@usgs.gov*

USGS CoSMoS data: *www.usgs.gov/cosmos*

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

HERA Tool: www.usgs.gov/apps/hera

OCOF
OUR COAST OUR FUTURE

USGS
science for a changing world

CoSMoS Coastal Storm Modeling System USGS

1871

Point Blue
Conservation science for a healthy planet

Deltares
Enabling Delta Life