# *Understanding Coastline Evolution*

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science for a changing world

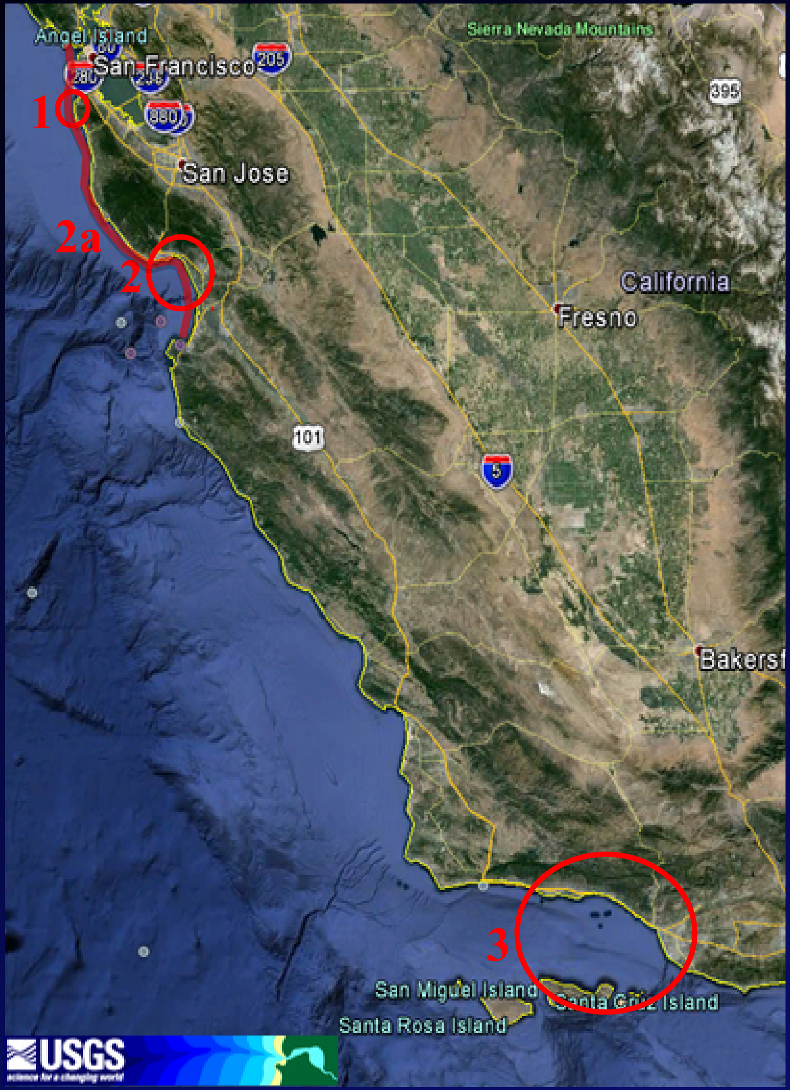
# Shorelines Change – Why?

- Natural variability:
  - ***Days - seasons***: dynamic balance between wind, waves, tides, currents and mobile substrate (sand) and cliffs/bluffs (intermittent failure)
  - ***Multi-year*** changes in waves/water levels and regional climate
    - Natural year-to-year variability
    - Natural multi-year cycles – e.g., El Niño
  - ***Even longer*** term changes in climate and sea level – e.g., glacial/interglacial cycling
- Human contributions:
  - ***Shoreline modifications*** affecting waves, currents, sand supply and transport
  - ***Climate change*** affecting sea level, waves, currents and regional climate

# U.S.G.S. P.C.M.S.C. Coastal Research

- *"Science for a Changing World"* - unbiased information to support decision making on both natural and human-impacted questions
  - Need to understand natural system behavior to accurately predict future change and human impacts
- Ongoing work in many areas:
  - Beach and nearshore monitoring, experiments and data collection to understand ***sand transport***
  - ***Bluff erosion*** monitoring and modeling
  - Numerical modeling of ***coastal flooding*** due to storms, waves, tides, sea level rise
  - Development of ***new technology*** to improve data acquisition, quality, reduce cost

# USGS beach and nearshore monitoring (CA)




**1. Ocean Beach**: April 2004 – present
- 165 beach topo surveys (~monthly)
- 38 nearshore bathy surveys (2-4/yr)

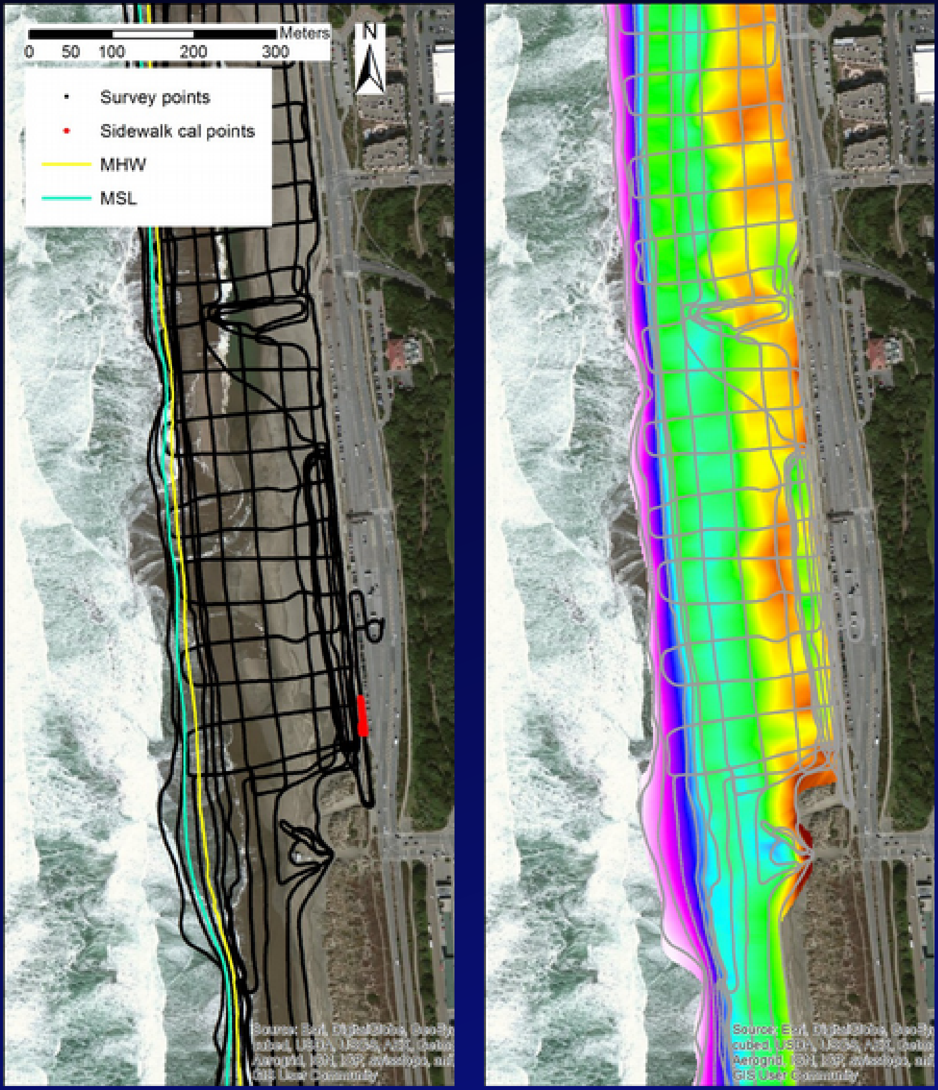
**2. Northern Monterey Bay** : Oct 2014 – present
- 4 beach topo (Spring and Fall)
- 4 bathy (Spring and Fall)

2a. **Monterey Bay & N**: 2015 – present
- ~monthly aerial bluff photo survey
- analysis of CA Coastal Records aerial photos from 2002 - 2013

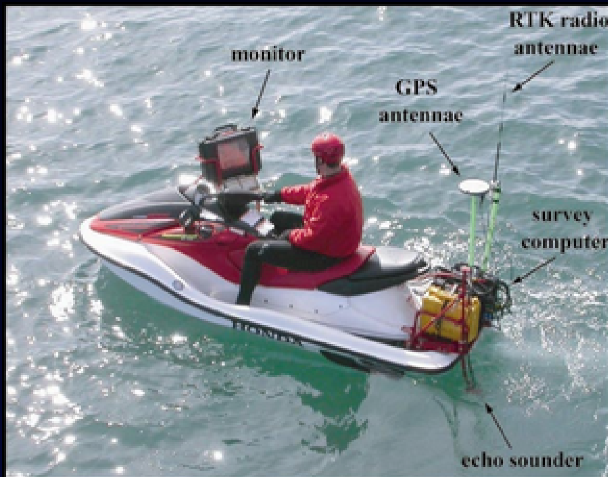
**3. Santa Barbara Littoral Cell**: Oct 2005 – present
- 6 focus sites: Goleta, Carpinteria, Rincon, N and S Ventura, Mugu Canyon
- 83 beach topo (Spring and Fall)
- 74 bathy (mostly Fall, some Spring)

# Beach topographic surveys

- Precise (few cm) GPS position and elevation data
- Medium temporal and spatial resolution (~monthly, ~10-50m line spacing)
- Focus on waterline, MSL – MHW elevations to capture shoreline change
- Robust, easy to operate system



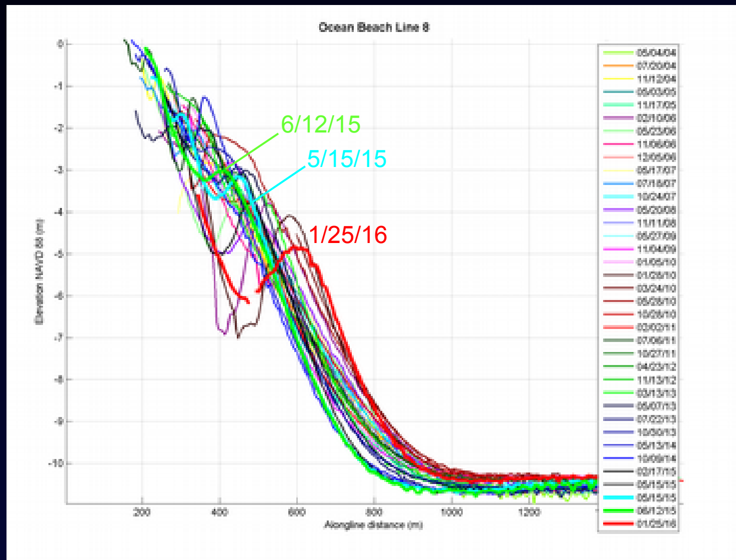
# Nearshore bathymetric surveys

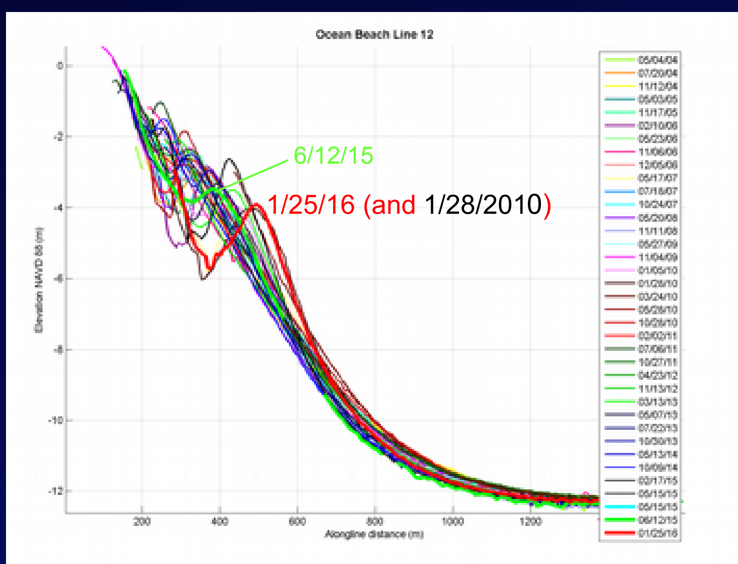





- Precise (few cm) GPS with single-beam echosounder
- Moderate temporal and spatial resolution (~2-4x/yr 50 - 500m line spacing)
- Focus on active bar zone
- Difficult environment – surf, wind, fog
- Calibration challenging

# Bathymetric change, 2004 - 2016

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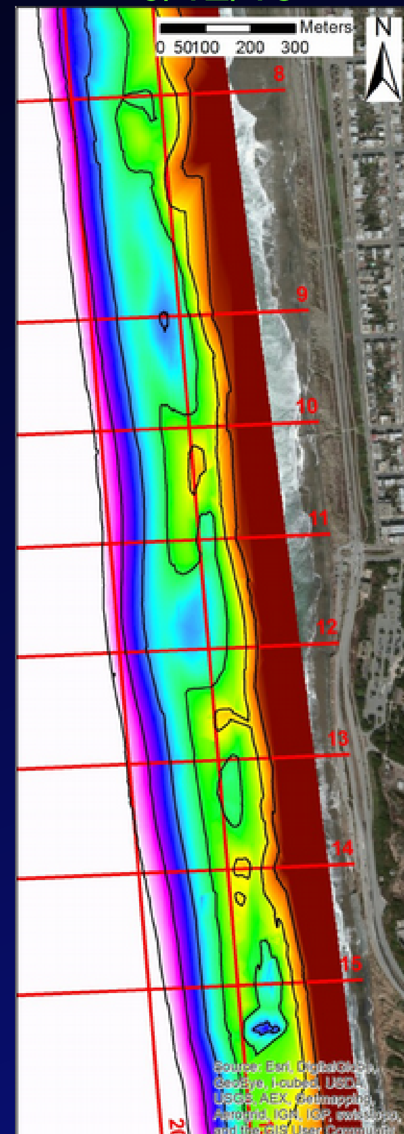


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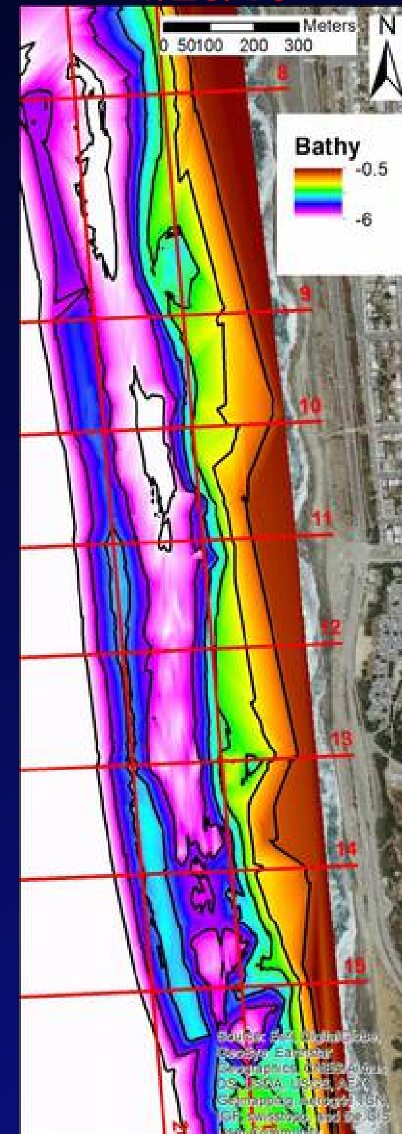
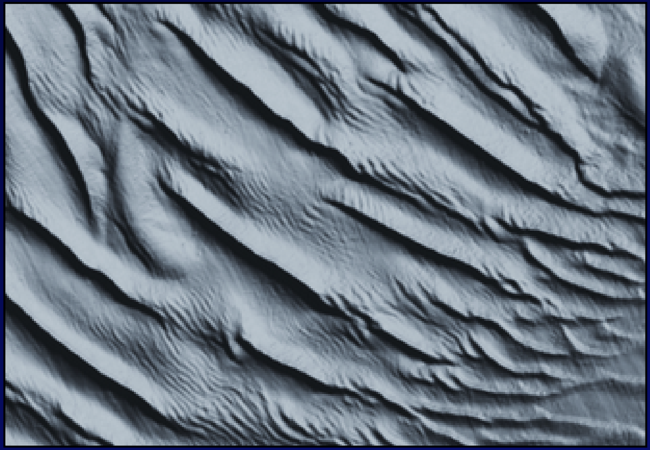


# Experiments and Data Collection

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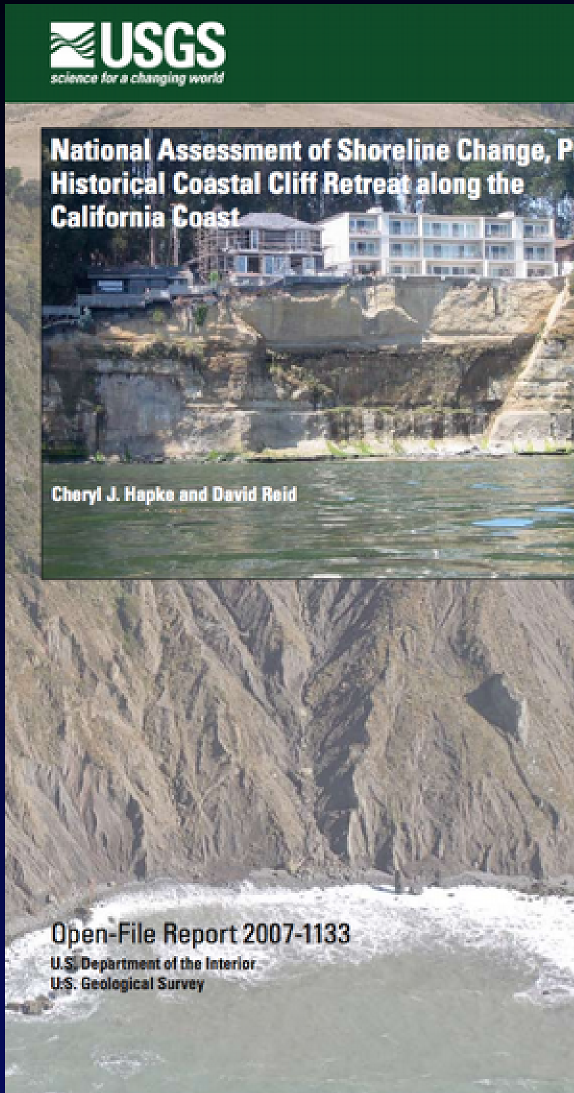
# Bluff erosion in the HMB area – 1929-1998



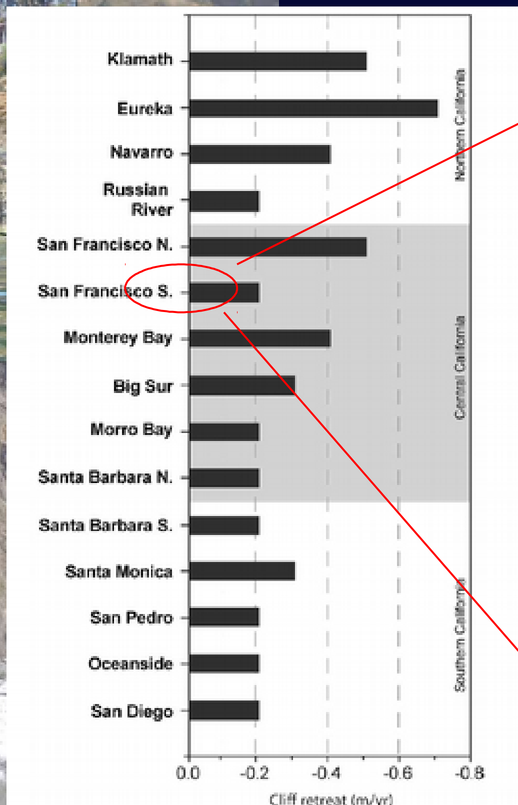




Figure 5. Average rates of coastal cliff retreat showing overall higher rates in Northern California and decreasing consistently to the south.

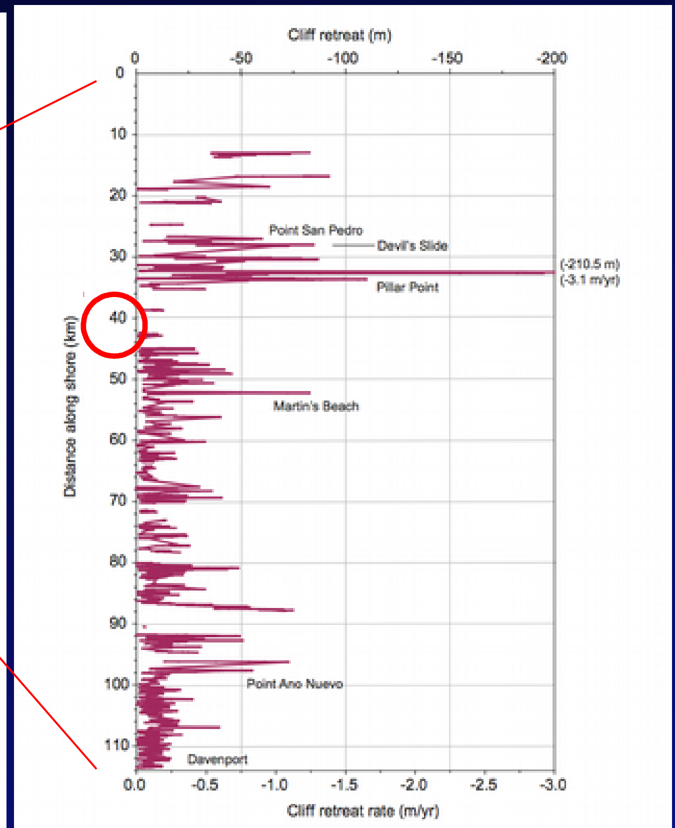
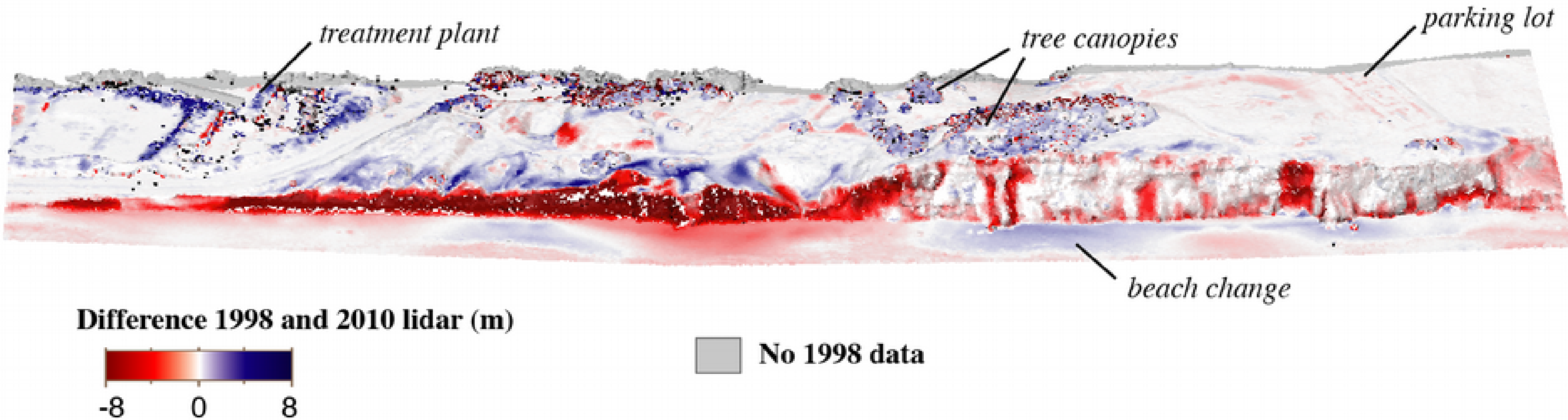



Figure 22. Cliff retreat rates and spatial distribution of rates for the San Francisco South region (see Figures 9 and 10B for reference).

# Recent bluff erosion - Lidar and historical photos

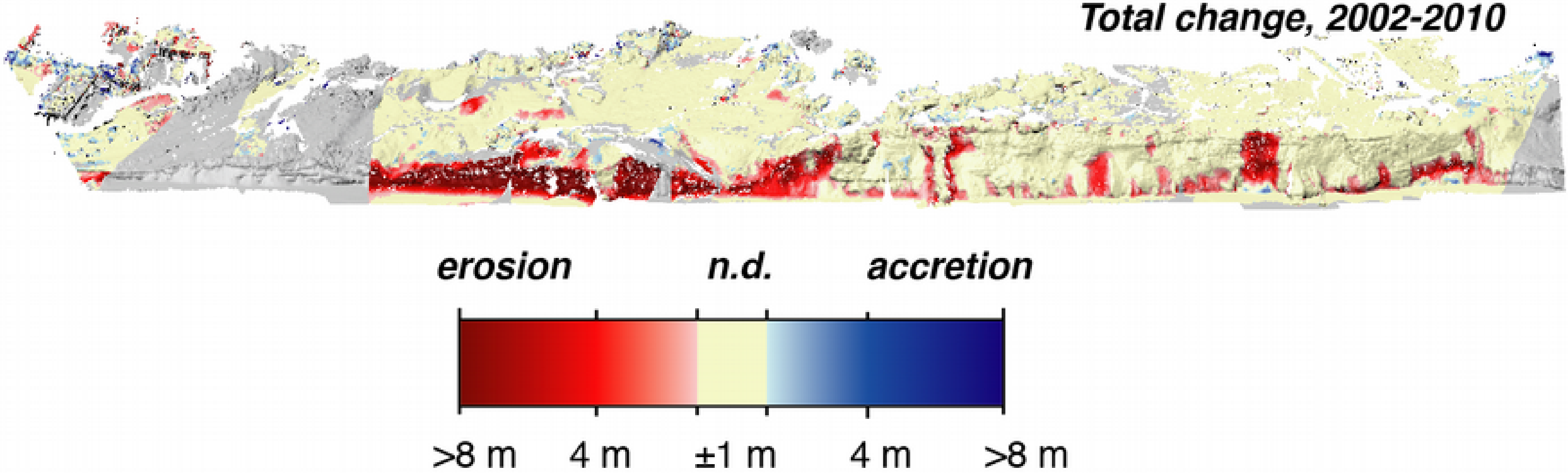
## Lidar

**Total change, 1998-2010**

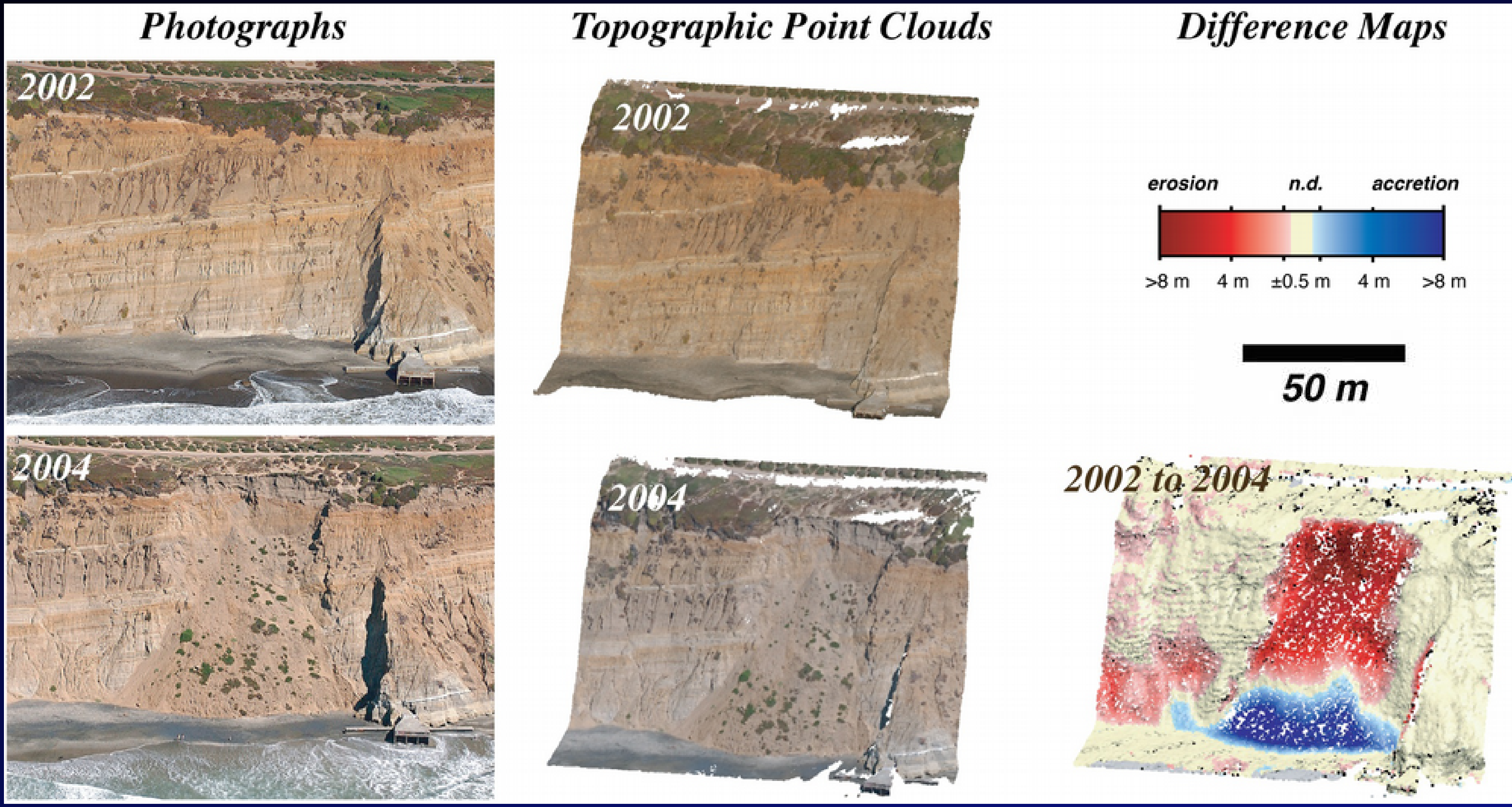



## Historical Photos (Structure from Motion (SfM))

**Total change, 2002-2010**

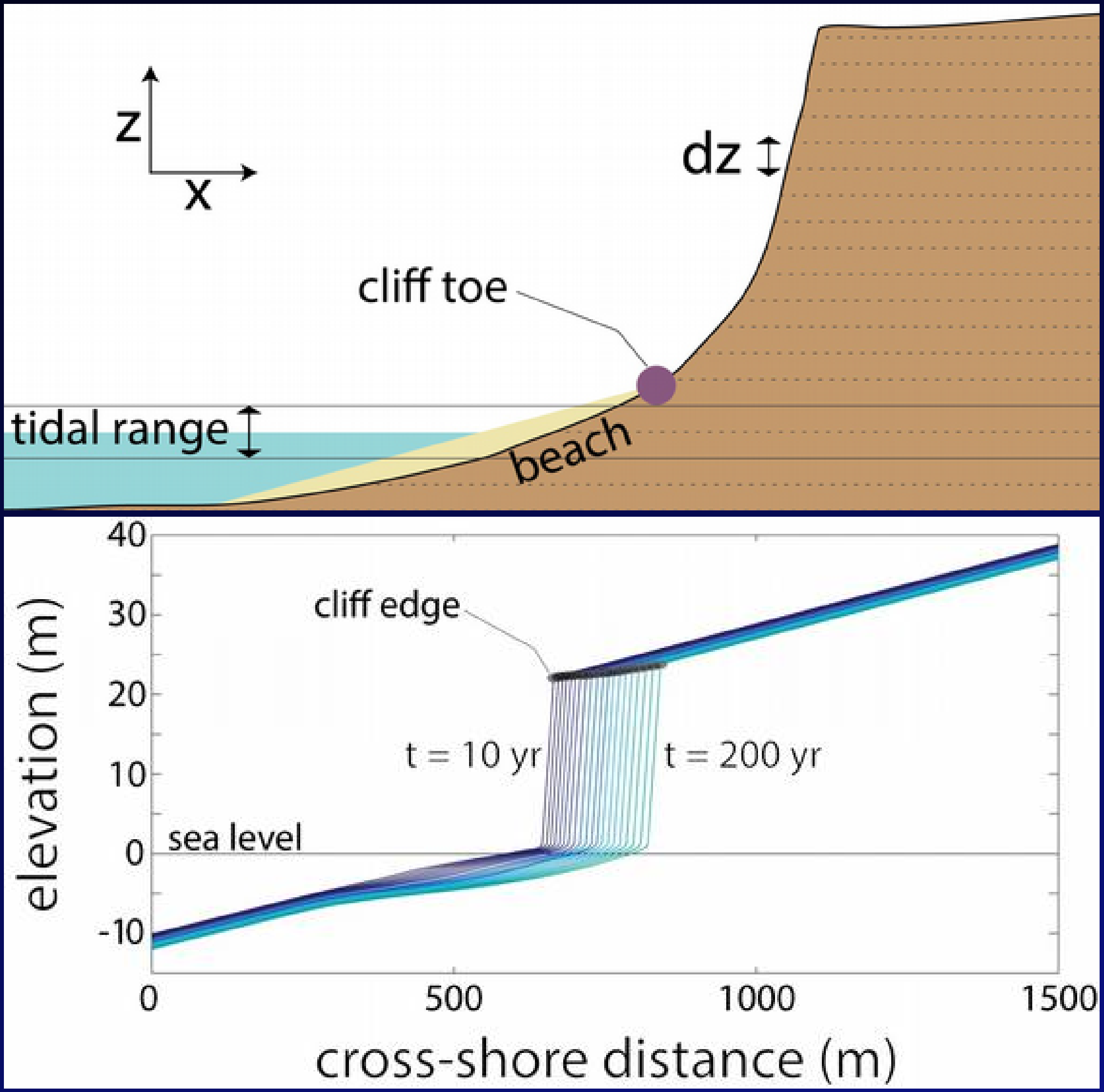


# Ft Funston Landslide Example, SfM Analysis

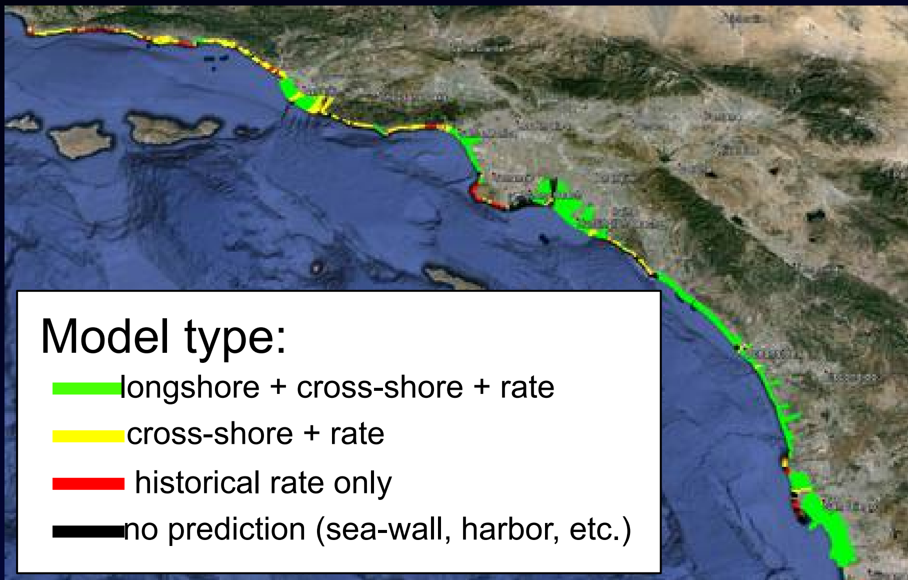


# Cliff Retreat Modeling

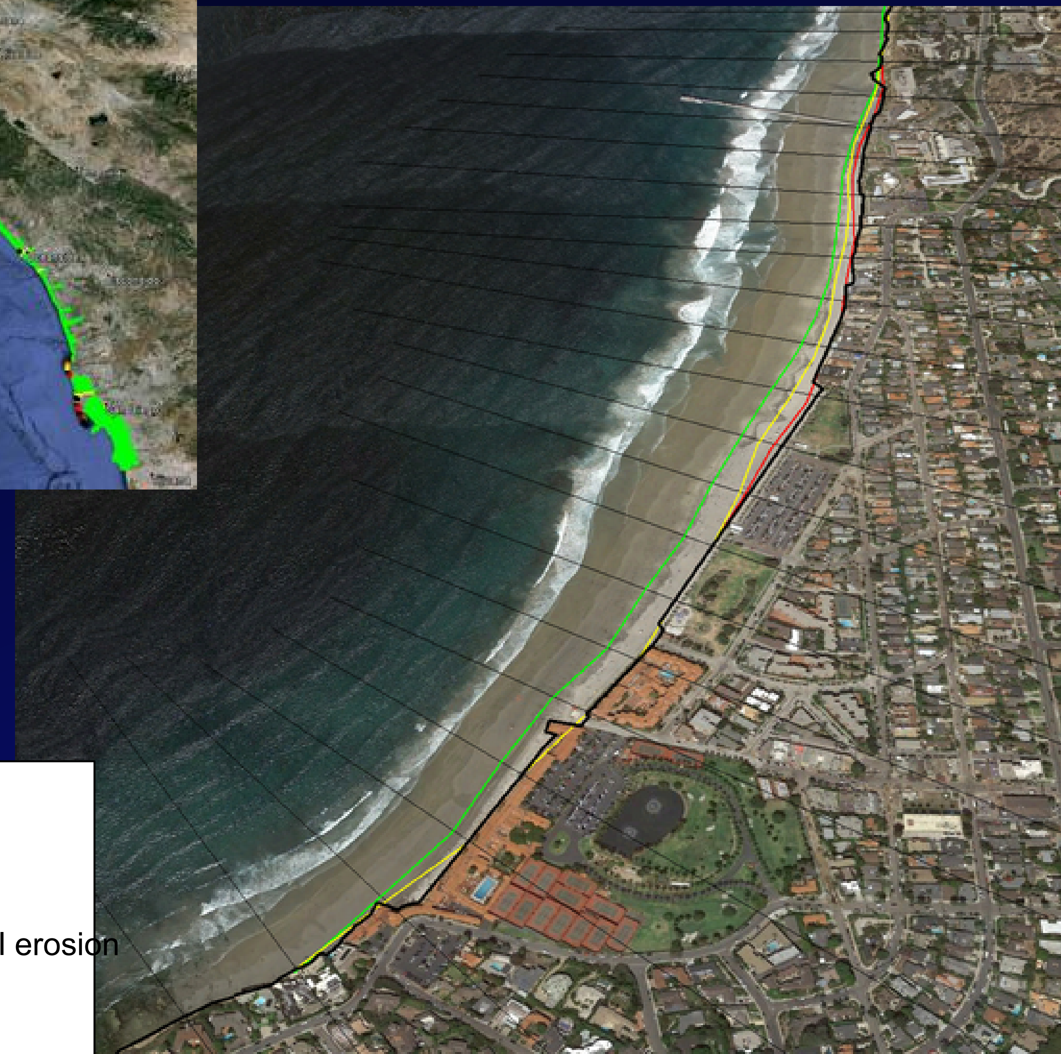
- Predict sea cliff response to sea level rise (SLR) and wave impacts during 21st century
- Include tides, waves, SLR, rock hardness, beach width, rainfall
- Calibrate using historical cliff retreat rates with historical waves
- Useful over decades to centuries, large spatial scales



# Shoreline Evolution Modeling in So. CA




**Results (preliminary):**
**Shoreline in 2100 w/ 1.0 m of SLR**



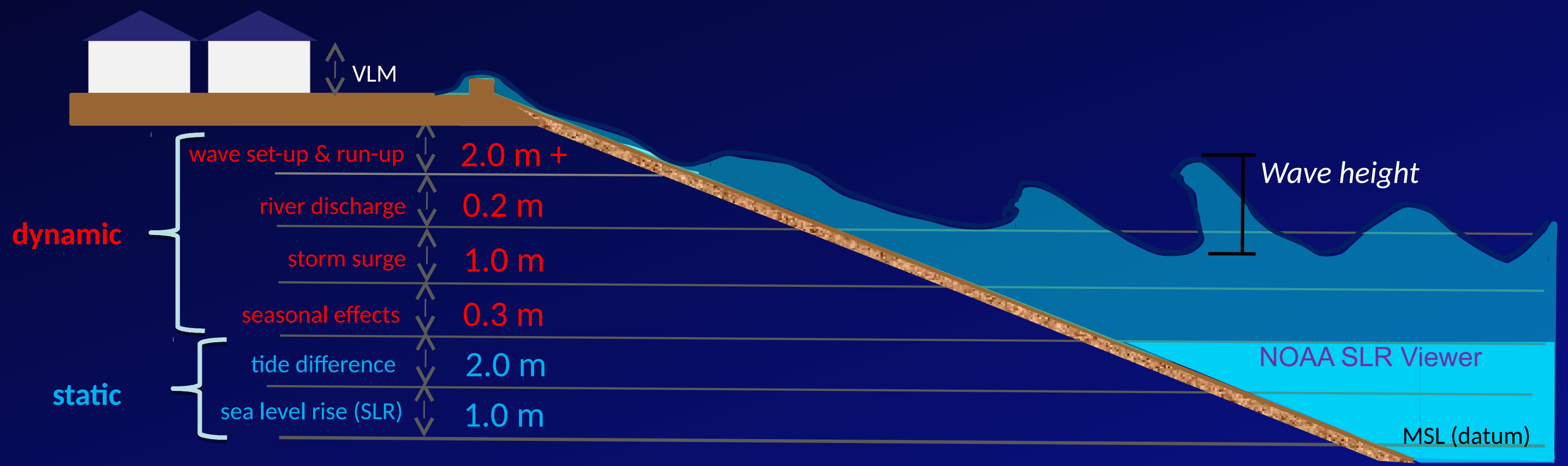
# Coastal Vulnerability Assessment

### Static: NOAA SLR Viewer

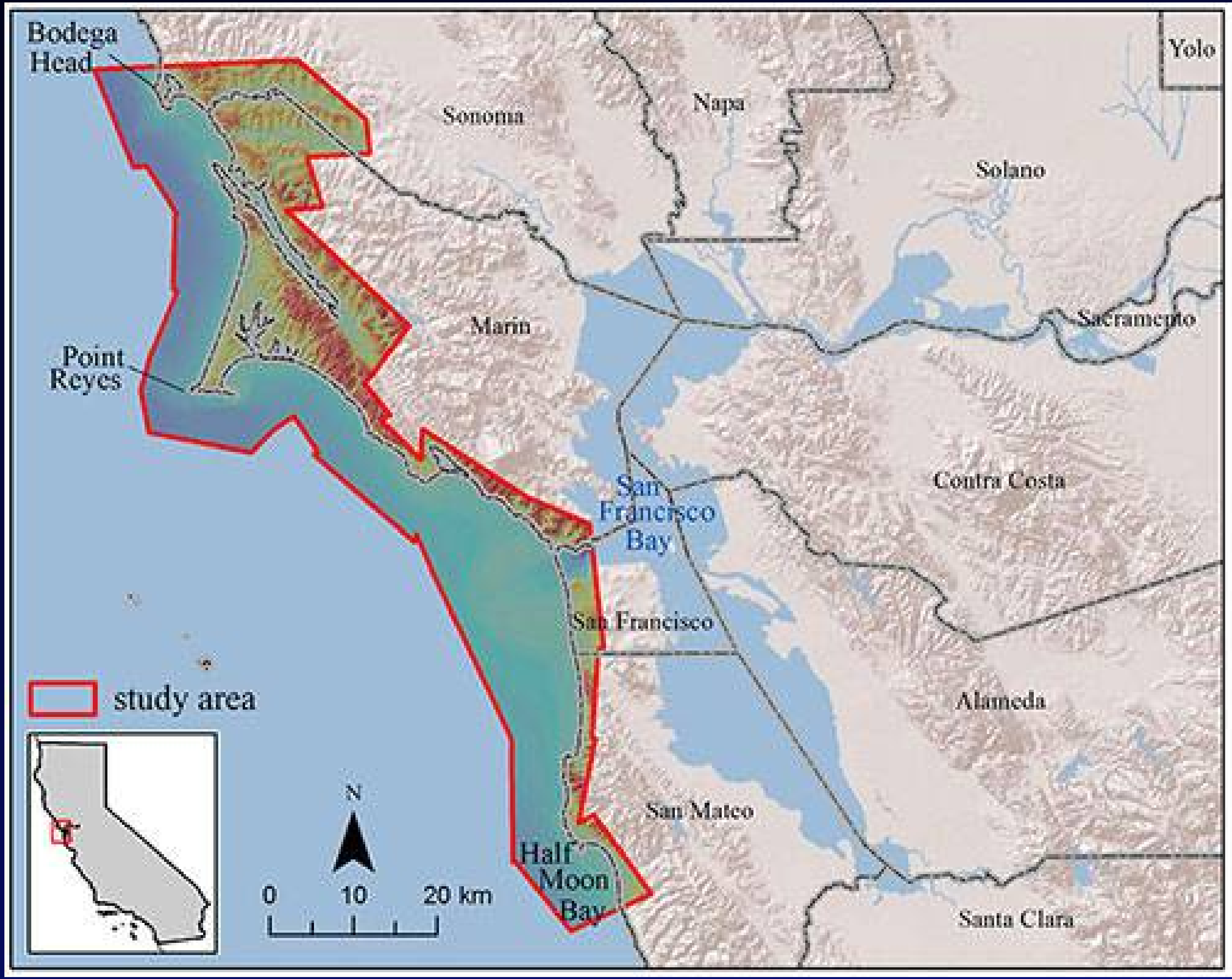
- Passive "bathtub" model
- Tides and SLR only
- 1st order screening tool
  -underpredicts actual coastal flooding hazard

### Dynamic: USGS-CoSMoS

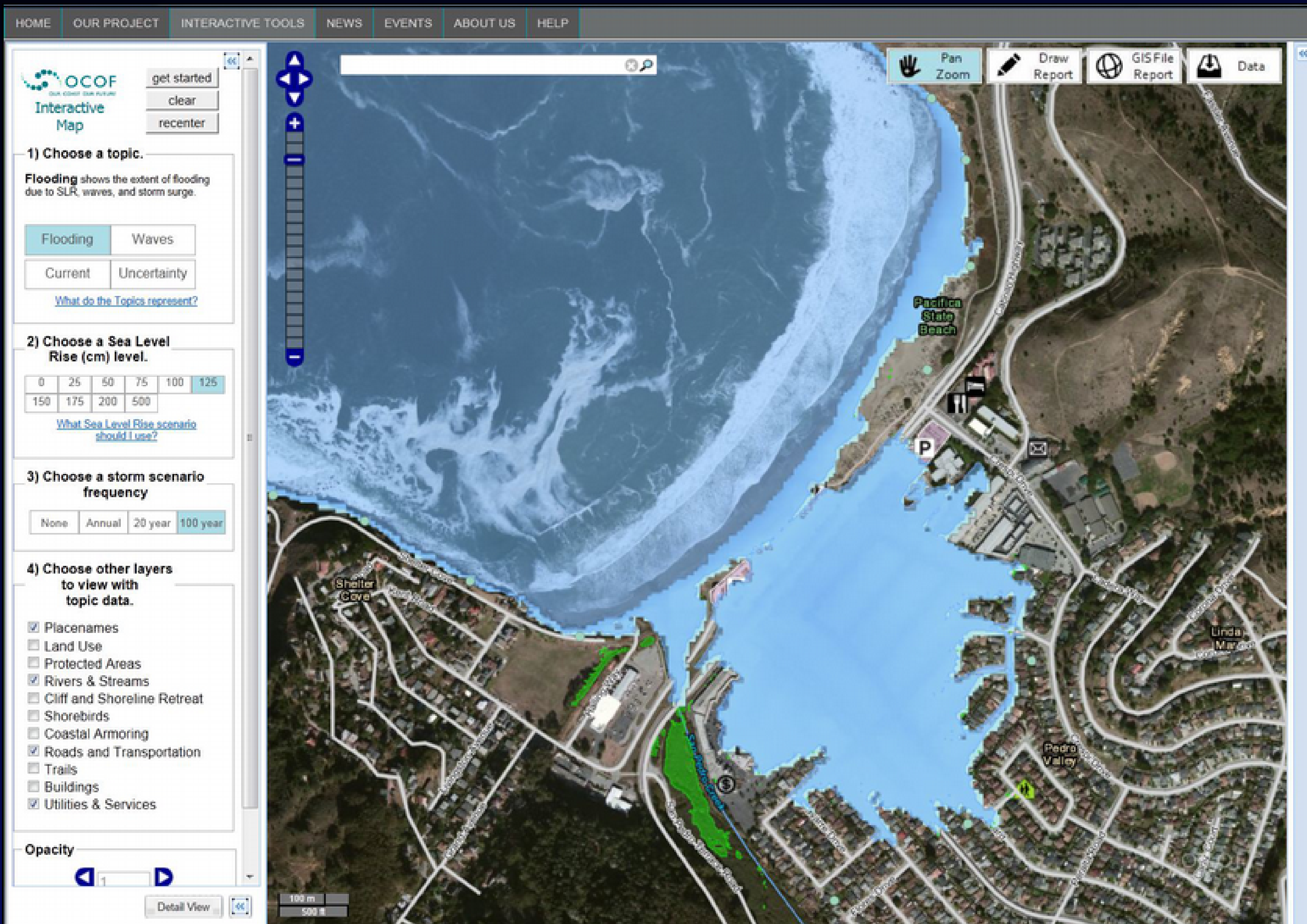
- All physics modeled
- Forced by Global Climate Models
- Includes wind, waves, atmospheric pressure, shoreline change
- Range of SLR and storm scenarios



# CoSMoS 2.0
# North-Central CA (Outer Coast)

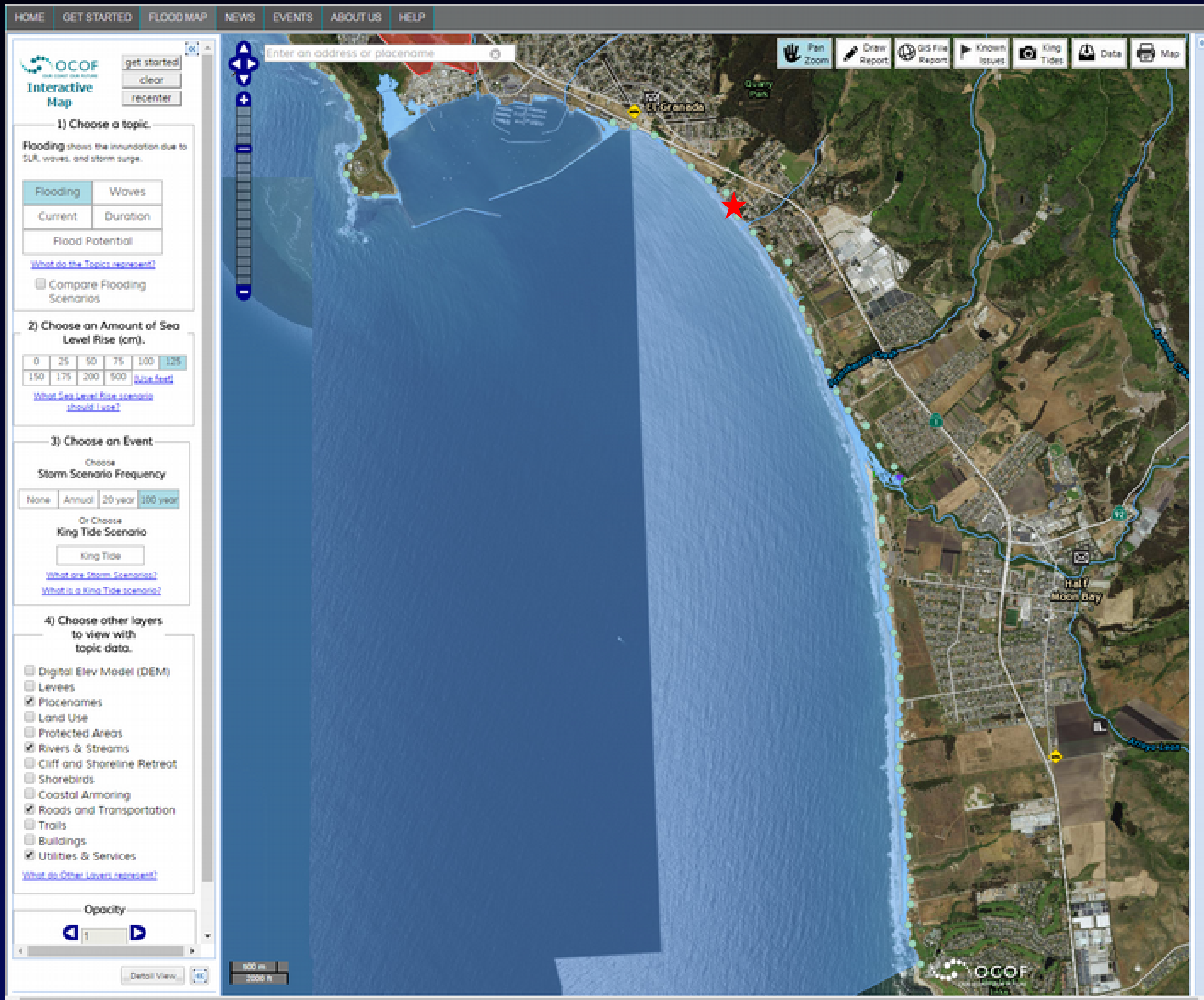


# 1.25m SLR + 100y Storms (Pacifica)



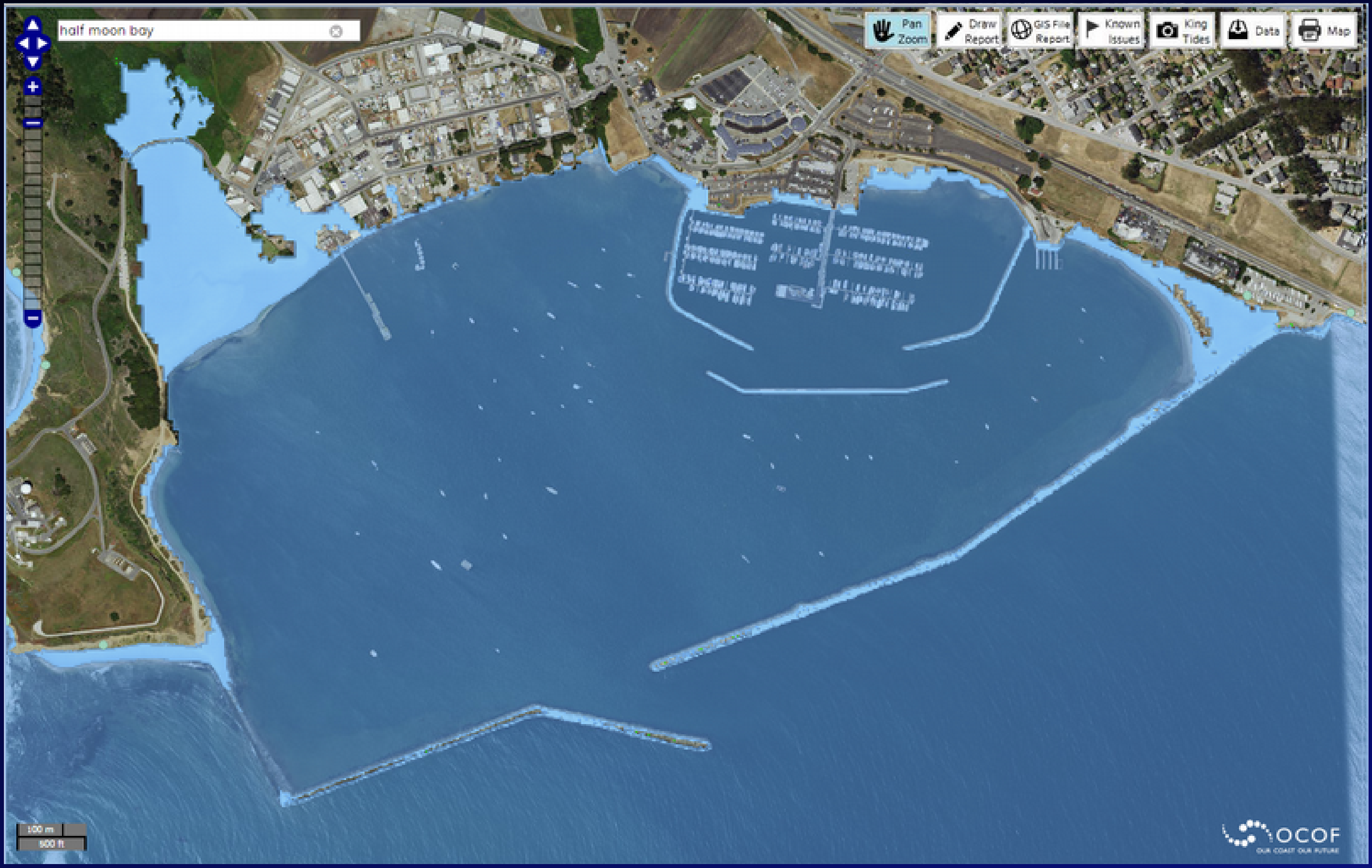

www.ourcoastourfuture.org (Our Coast, Our Future)

# 1.25m SLR + 100y Storms (Half Moon Bay)

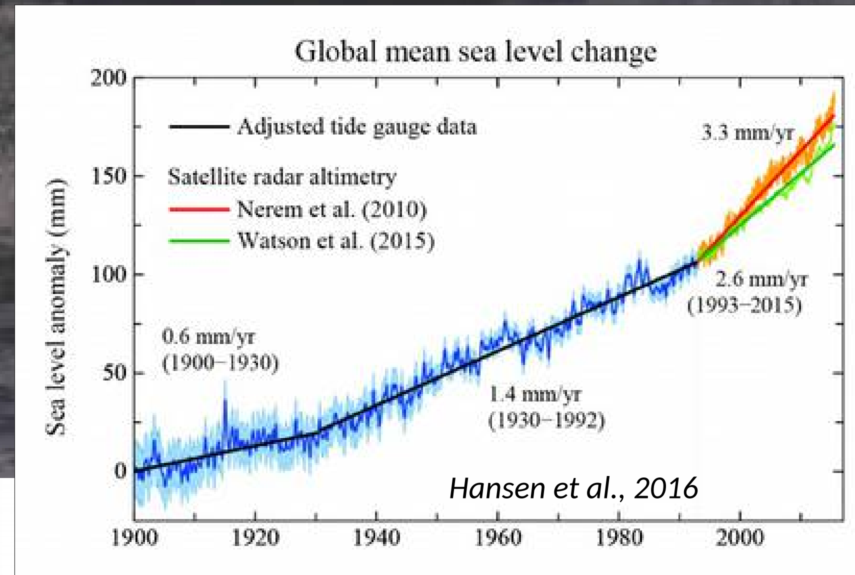



www.ourcoastourfuture.org (Our Coast, Our Future)

# 1.25m SLR + 100y Storms (Pillar Point Harbor)



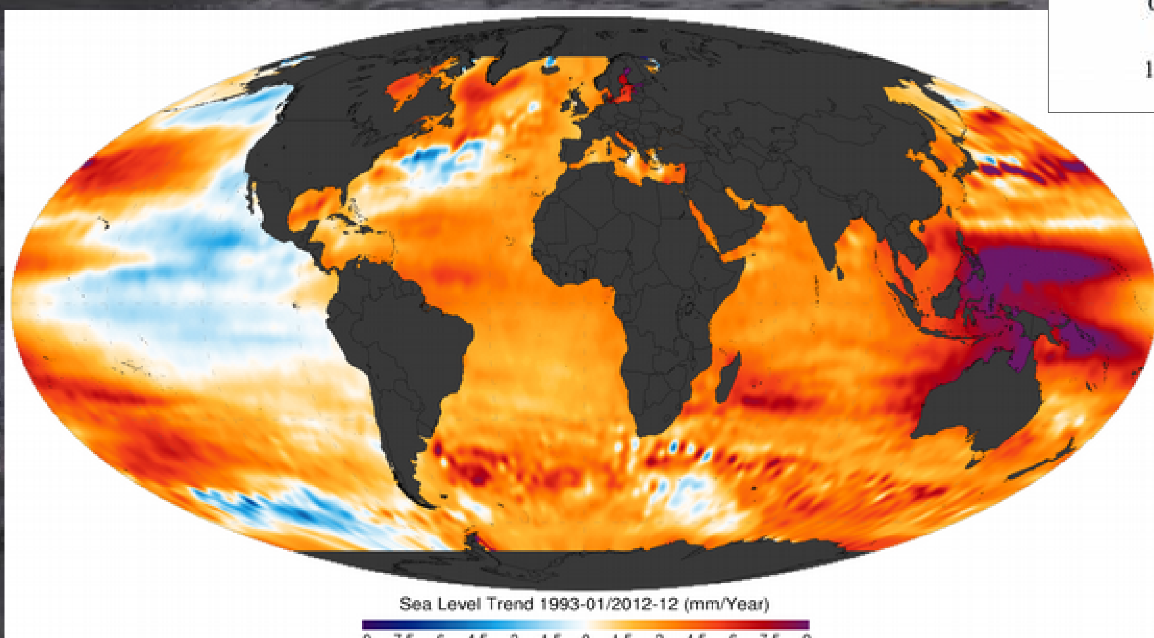
# Recent Sea Level Rise




*Hansen et al., 2016*

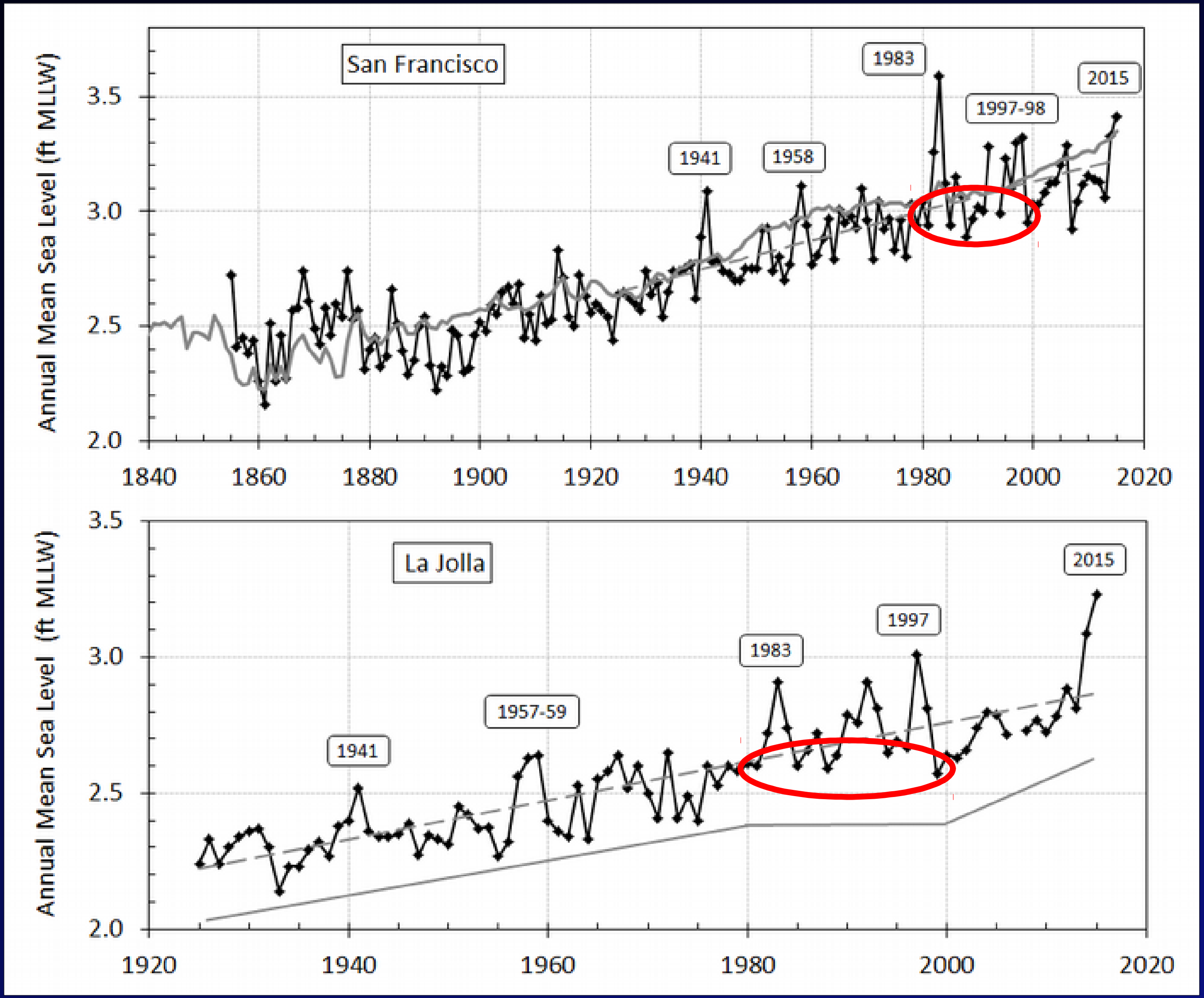
**SLR is not spatially uniform**

Global SLR is accelerating




*NOAA, 2012*

# Regional Sea Level Rise

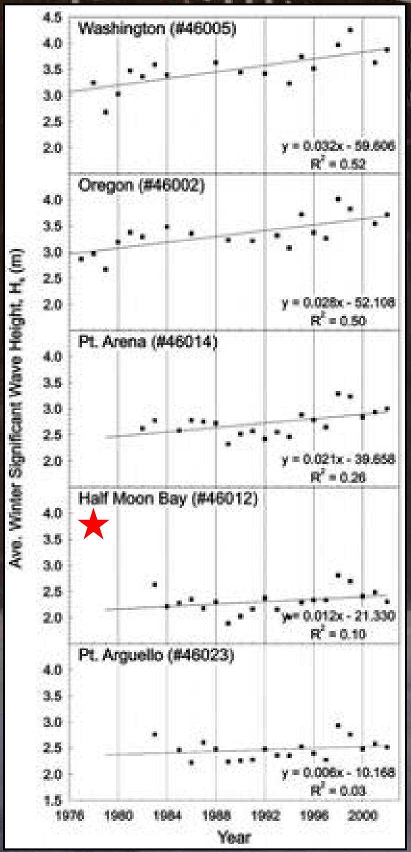



*Flick et al. (2016)*

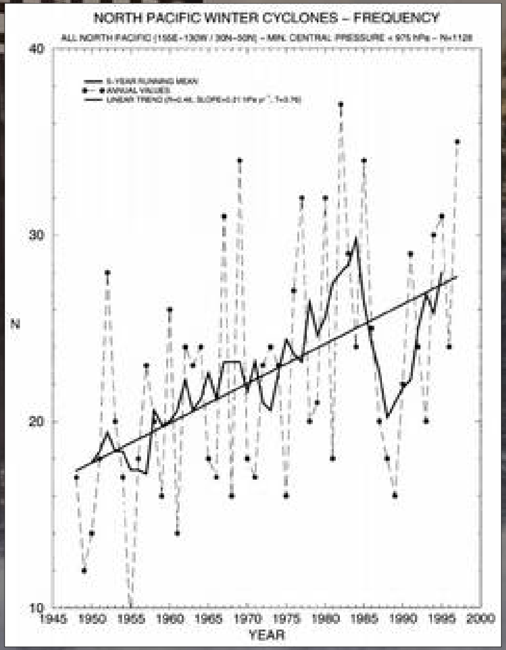
# Recent Findings- Storms

- Storms and average winter and extreme waves appear to be getting larger and more frequent as you go north along the U.S. West Coast

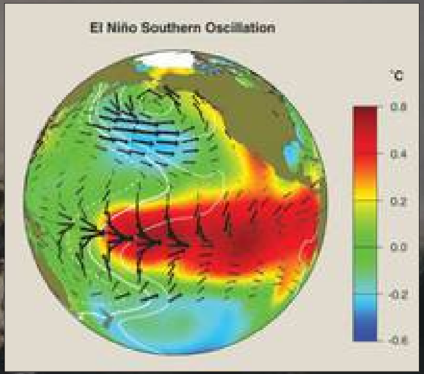
- No evidence for changes in the strength or frequency of El Niños over last ~150 years (Ray and Giese, 2012) but perhaps a shift in styles



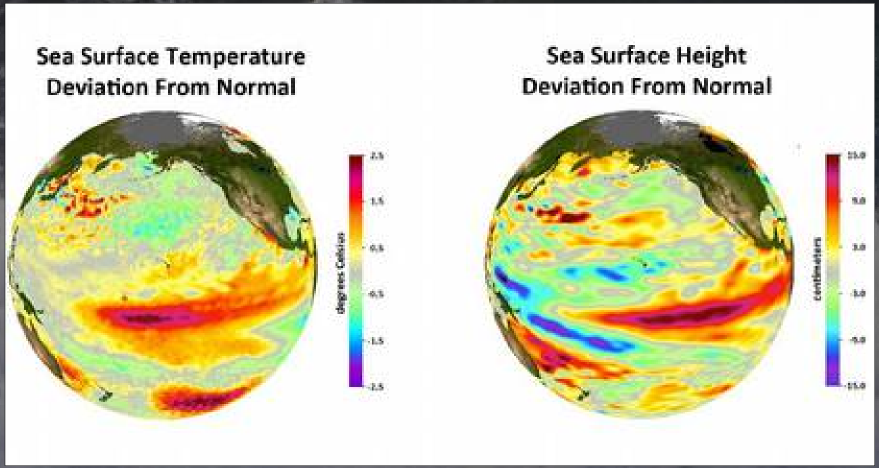

*Allan and Komar (2006)*




*Graham and Diaz (2001)*



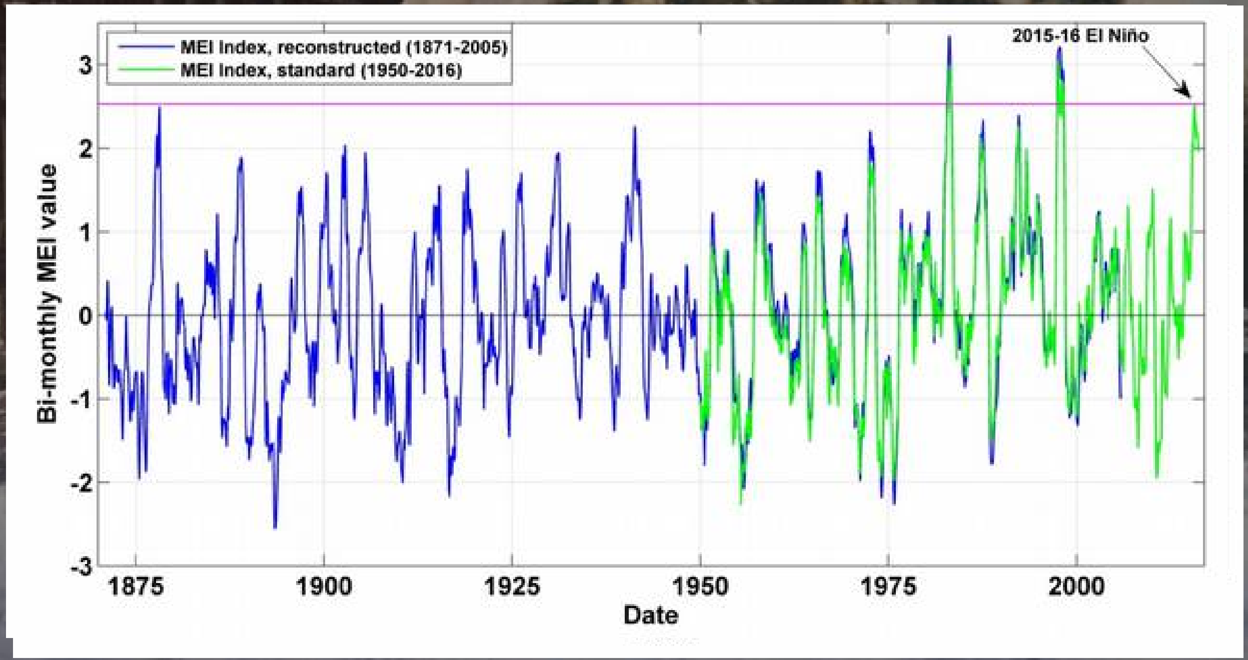

*McPhaden et al. (2006)*




*Lee and McPhaden (2010)*

# 2015-16 El Niño Impacts in California

- SST conditions at or above historical extreme El Niños
- Water level anomalies +15-20 cm across California
- Wave energy > 50% above the average winter
- Top 3 El Niño Events since at least 1870




*Ventura Pier, December 2015 (Ricky Staub)*

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# 2015-16 El Niño Impacts in California

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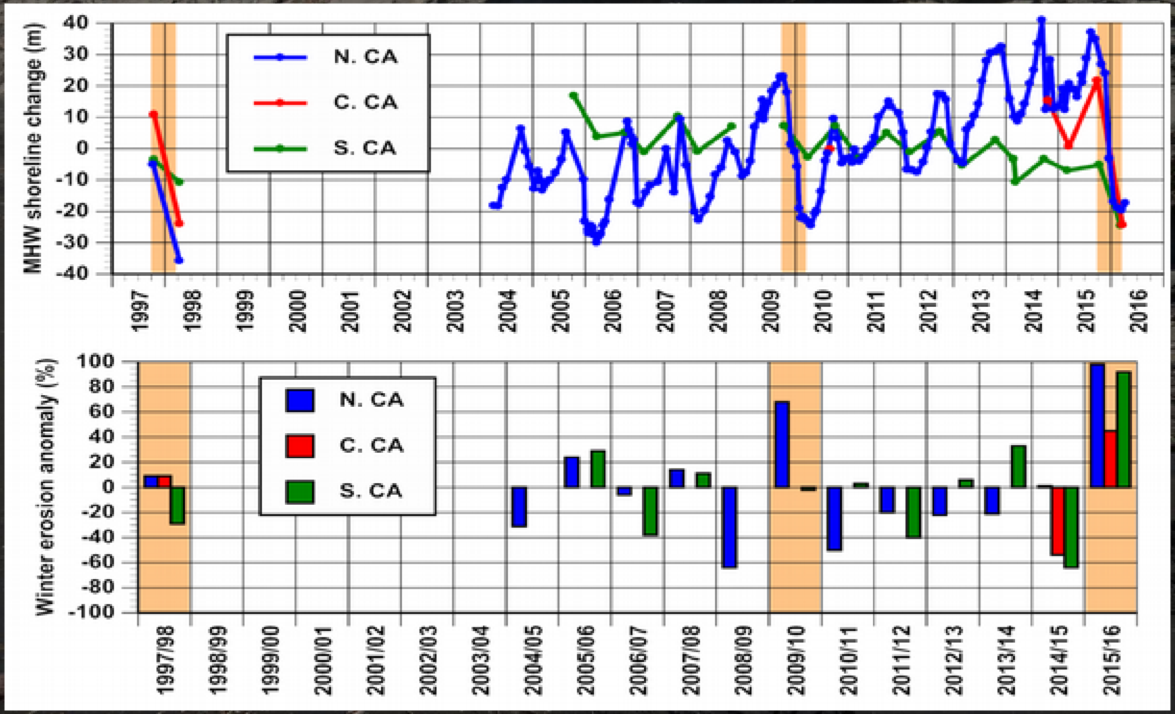
# 2015-16 El Niño Shoreline Change

- **Most significant winter beach erosion in the historical record across CA**
- **80% more erosion than the average winter**
- **Shoreline retreat** 2-5 **times the prior winter**

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# Projections for San Francisco Area

**<u>SLR for San Francisco (NRC, 2012)</u>**

-28 cm of sea level rise by 2050 (range 12-61 cm)
-92 cm of sea level rise by 2100 (range 42-166 cm)

**<u>Storms for California</u>**

-No significant changes in wave height
-Extreme events approach from ~10-15 degrees further south

**<u>El Niño for 21st Century</u>**

-More frequent extreme events
-Doubling of winter erosion
-Wave energy increase by 30%

**<u>***Net effect***</u>**

-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., Stinson Beach, San Francisco Bay)

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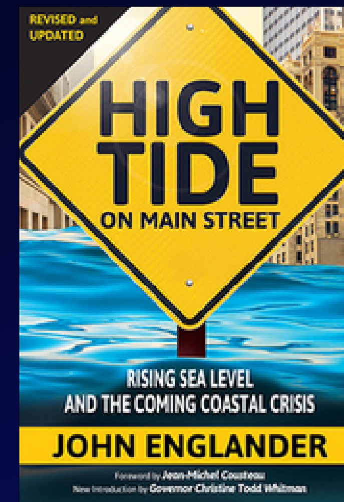
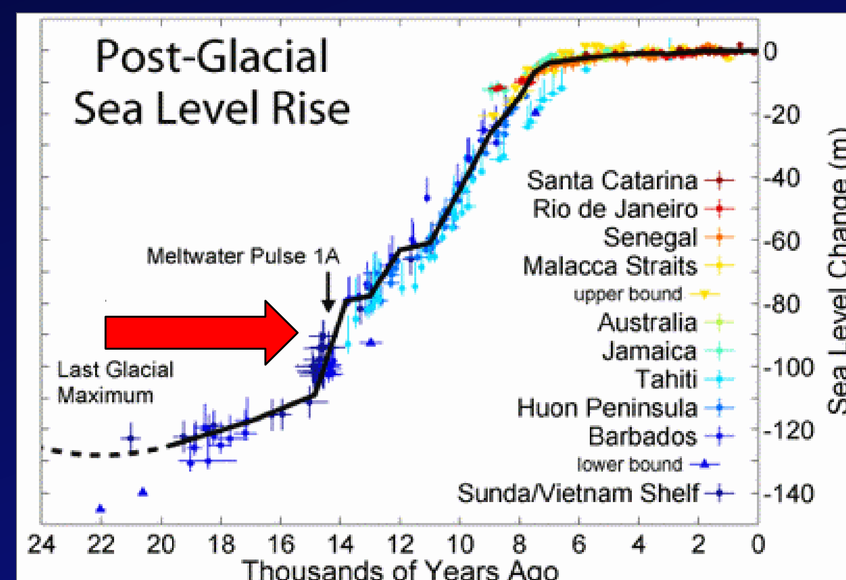
# Thank You!

**For more info, contact Dan Hoover: dhoover@usgs.gov**

# Climate Change Factoids

- Based on the cyclical pattern of earth's orbit around the sun we should actually be experiencing global cooling right now
- The rate of $C0_2$ increase in the atmosphere is 20,000 times faster than any time in the last 500 million years
- 15 million years ago global temperature was ~6° warmer ($CO_2$ was the same as today), but sea level was 30 m higher
- 125,000 years ago global temperature was ~2° warmer but sea level was 8 m higher
- 14,000 years ago sea level rose 20 m in 4 centuries (Meltwater Pulse 1A)




*Fleming et al. (1998), Fleming (2000), Milne et al. (2005)*

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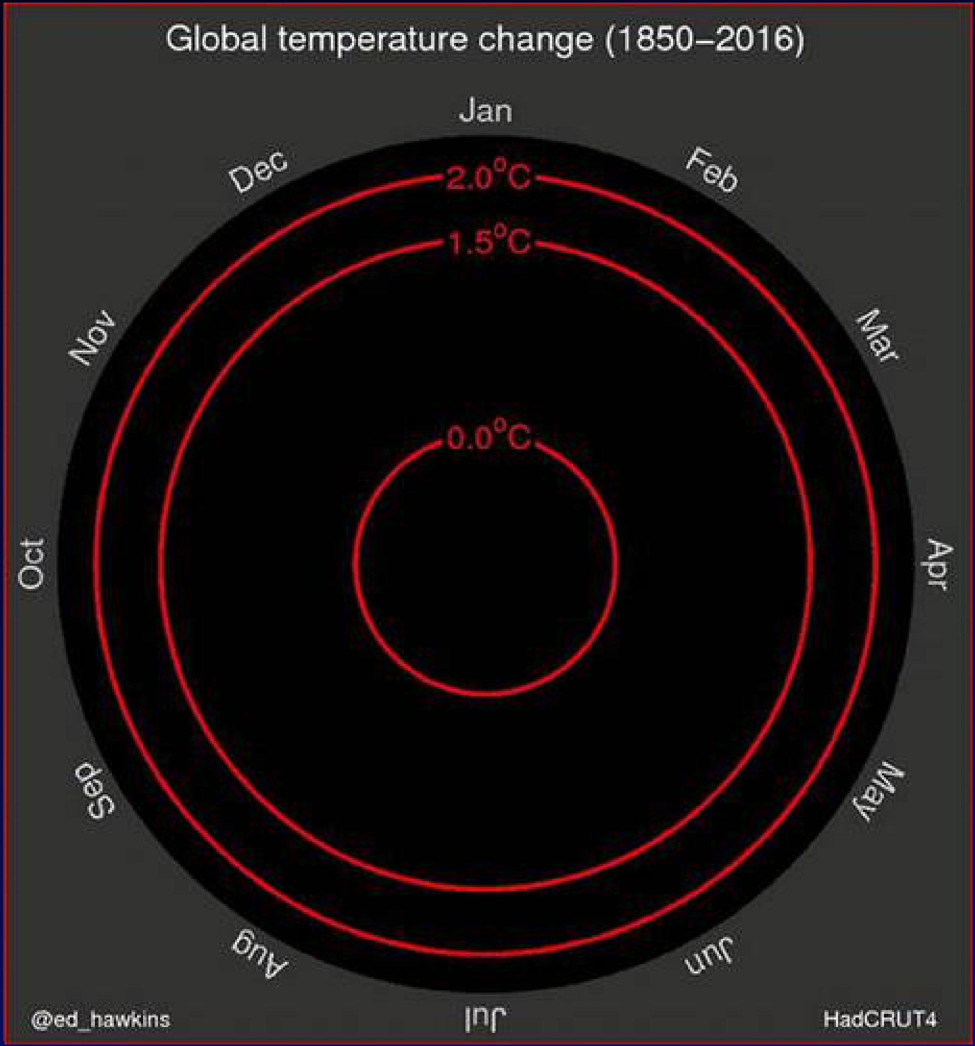
# Temperature Change




*Ed Hawkins, University of Reading*

*http://www.climate-lab-book.ac.uk/2016/spiralling-global-temperatures/#more-4330*