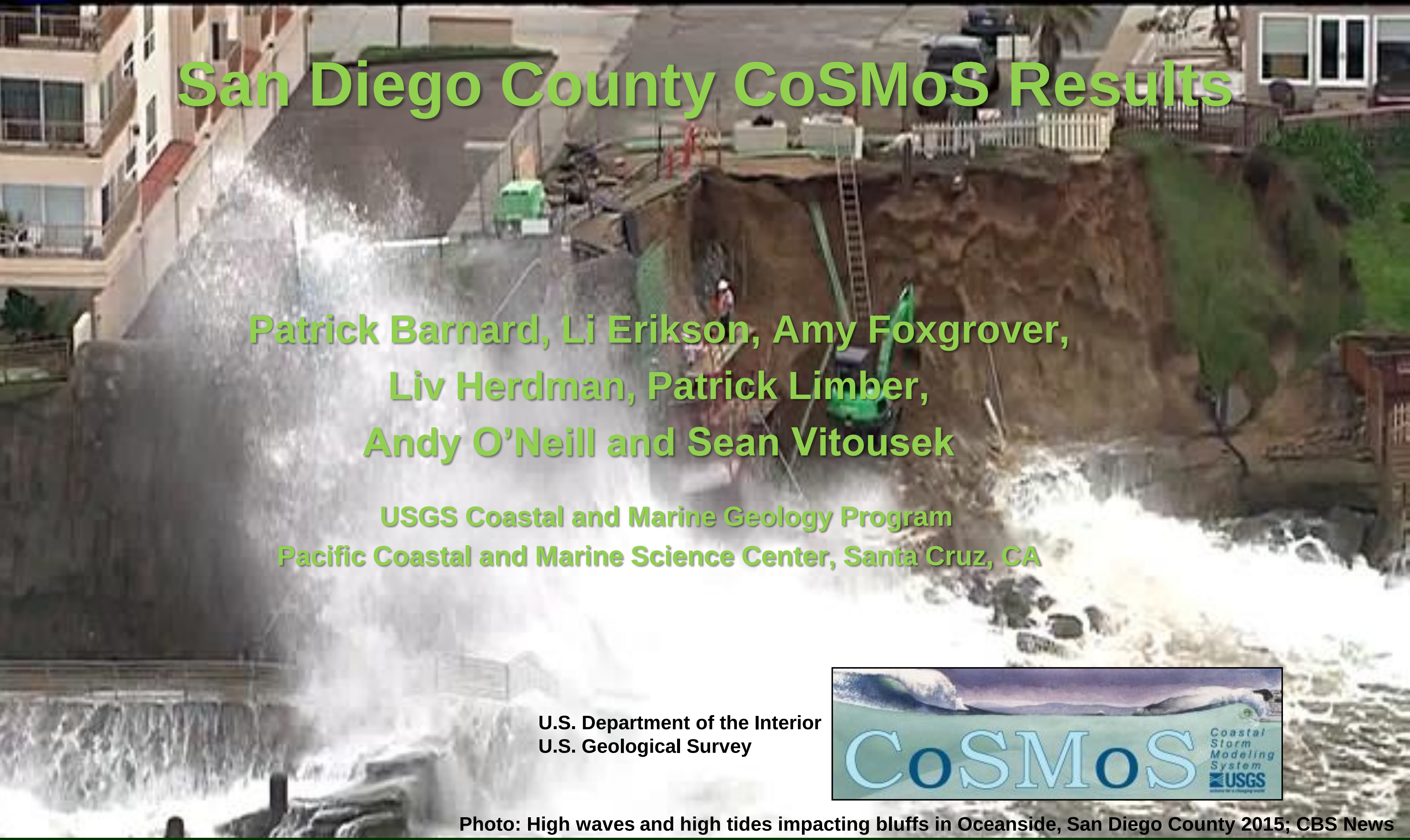


San Diego County CoSMoS Results

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

USGS Coastal and Marine Geology Program
Pacific Coastal and Marine Science Center, Santa Cruz, CA

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

Photo: High waves and high tides impacting bluffs in Oceanside, San Diego County 2015; CBS News

Support for CoSMoS SoCal

- State Coastal Conservancy
- City of Imperial Beach
- Tijuana River National Estuarine Research Reserve
- California Department of Fish & Wildlife
- California's Fourth Climate Change Assessment (California Natural Resources Agency)

USGS

Projections for Southern California

SLR for San Diego (NRC, 2012)
- 28 cm of sea level rise by 2050 (range 13-61 cm)
- 93 cm of sea level rise by 2100 (range 44-167 cm)
- includes global and regional effects (e.g., wind and circulation patterns, sea level fingerprint, glacial isostatic adjustment, tectonics)

Sunset Beach, Sean Hiller

Storms for Southern California (Bromirski et al., 2012; Erikson et al., 2015)
- No significant changes in wave height
- Extreme events approach from ~10-15 degrees further south


The Wedge

El Niño for 21st Century (Cai et al., 2015, Barnard et al., 2015)
- More frequent extreme events
- Doubling of winter erosion
- Wave energy increase by 30%

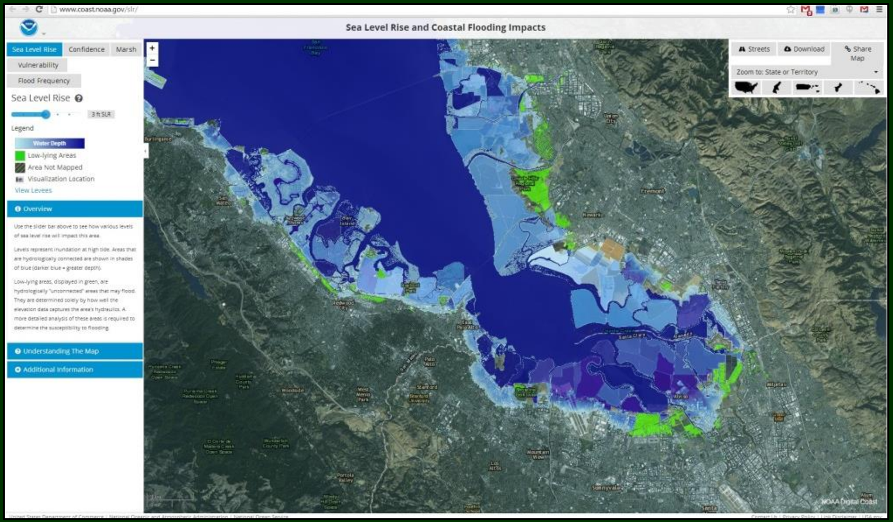
San Diego County 21st Century Vulnerability (Pacific Institute, 2009)
- 93,000 people at risk
- $2 billion in property


Imperial Beach, photo by Chris Helmer

USGS

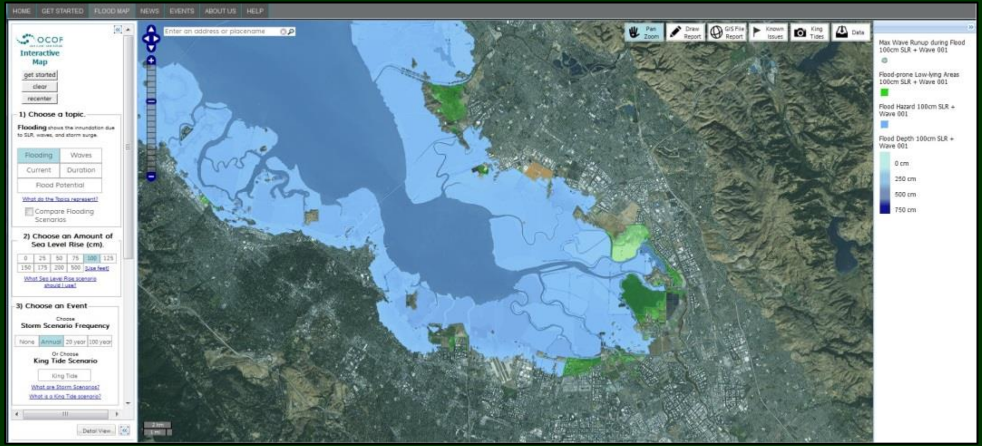
Coastal Vulnerability Approaches

- **STATIC**: NOAA SLR Viewer
  - –Passive model, hydrological connectivity
  - –Tides only (MHHW)
  - –Excellent elevation data, datum control
  - –Wetland migration model, socioeconomic impacts
  - –‘1st order screening tool’



http://www.coast.noaa.gov/slr/

- **DYNAMIC**: CoSMoS
  - –GCM ensemble forcing
  - –Includes wind, waves, sediment transport, fluvial discharge, and vertical land movement rates
  - –Range of SLR and storm scenarios
  - –Flooding extent explicitly modeled, hydrological connectivity



Our Coast Our Future: *www.prbo.org/ocof*

USGS

CoSMoS: A Tool for Coastal Resilience

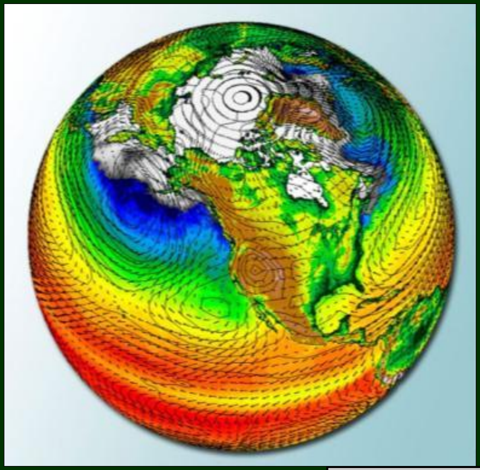
- Physics-based numerical modeling system for assessing coastal hazards due to climate change
- Predicts coastal hazards for the full range of sea level rise (0-2, 5 m) and storm possibilities (up to 100 yr storm) using sophisticated global climate and ocean modeling tools
- Developing coastal vulnerability 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)

Sunset Beach, Allan J. Schaben

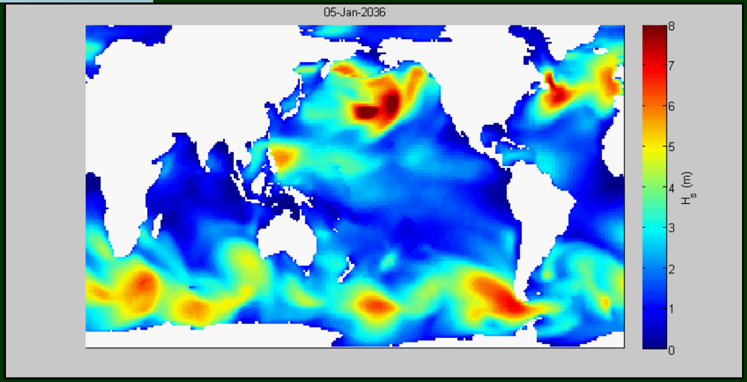

Sunset Beach, Mark Rightmire

USGS

Identifying Future Risk with CoSMoS



1. Global forcing using the latest climate models

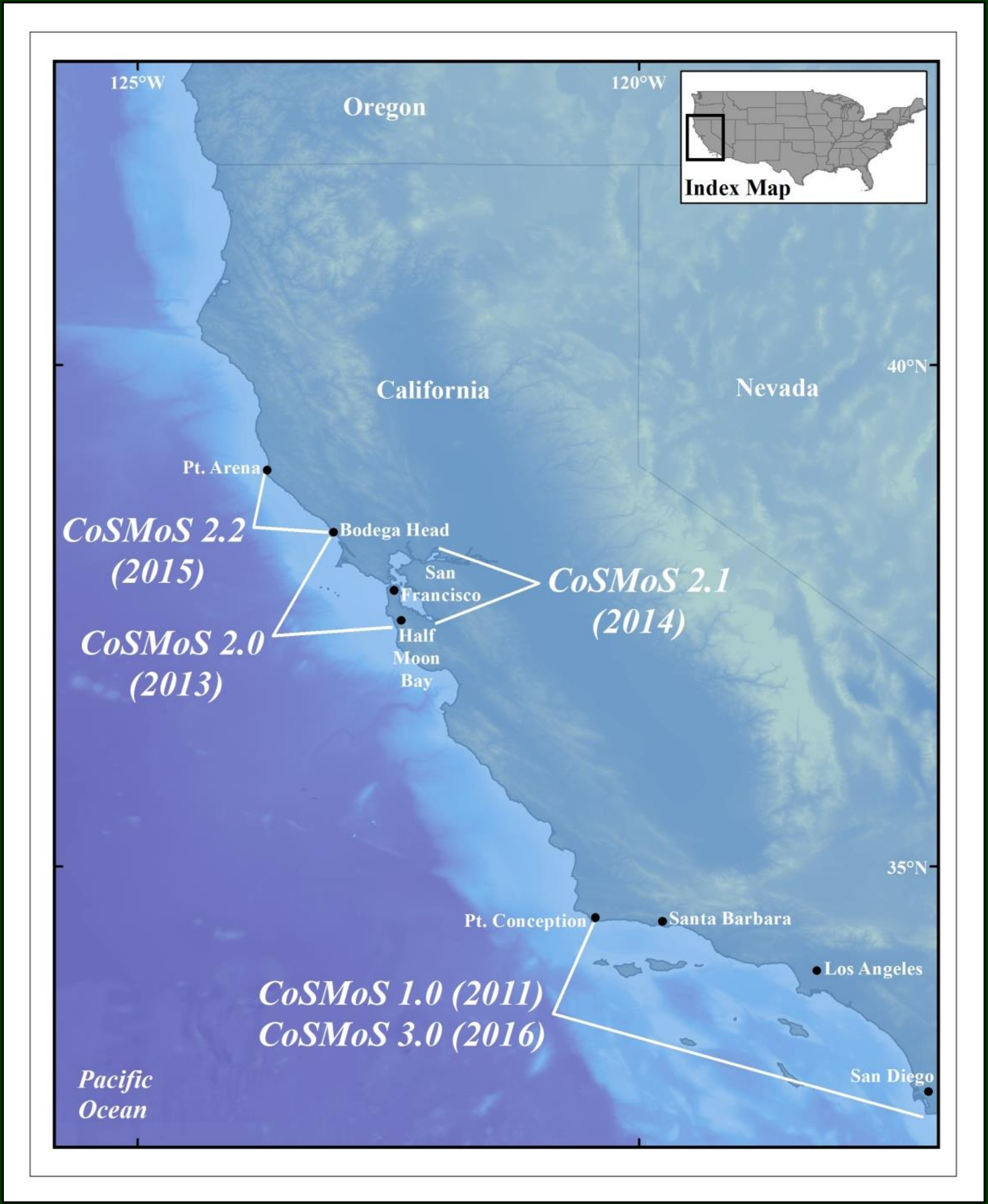


2. Drives global and regional wind/wave models

3. Scaled down to local hazards projections

USGS

CoSMoS Version Summary



CoSMoS Version Summary

CoSMoS 1.0

- So Cal, 470 km coastline (Pt. Conception -> Mexico border)
- Historical storms, 2 SLRs
- Global & regional parts continue to run operationally

CoSMoS 2.0

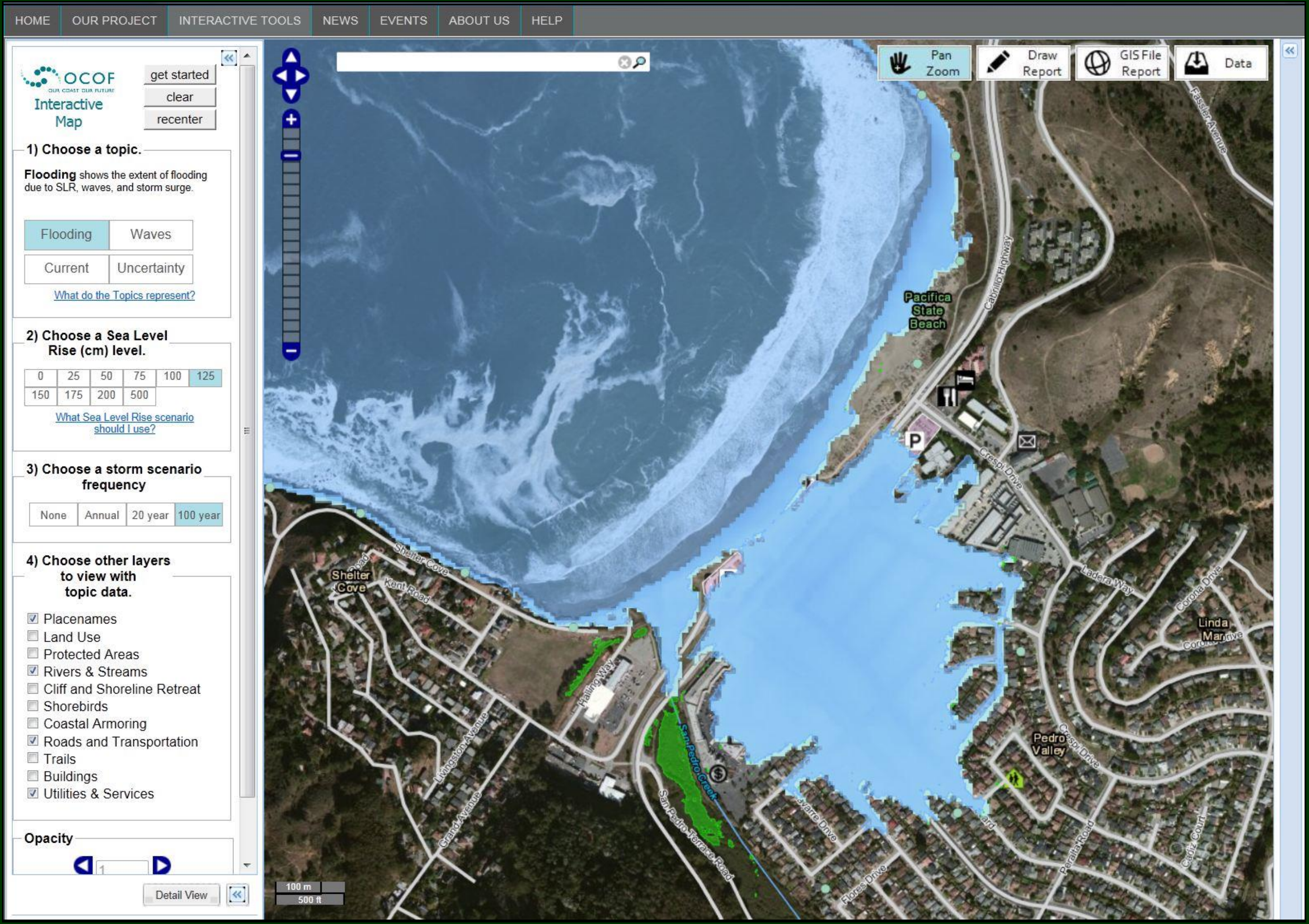
- North-Central CA coast, 170 km, (Bodega Head to Half Moon Bay)
- 21st century winds & waves
- High resolution grids of lagoons and protected areas
- Annual, 1 yr, 20 yr, 100 yr storm events in combination with SLR 0 m to 5 m at 0.25 m increments +5 m
- Web-based tool

CoSMoS 2.1

- San Francisco Bay
- Spatial- & time-downscaled climate scenario winds
- Fluvial discharges
- Vertical land motion
- Marsh accretion

USGS

CoSMoS 2.0- CenCal/NorCal



USGS

www.prbo.org/ocof (Our Coast - Our Future)

Highlights of CoSMoS 3.0

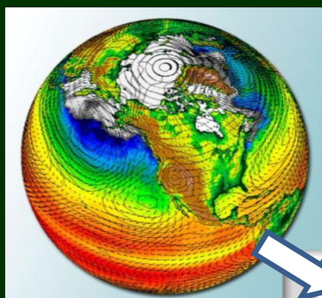
- Multi-agency collaboration featuring top coastal and climate scientists from Scripps, Oregon State University, private sector, and USGS
- Long-term coastal evolution modeled, including sandy beaches and cliffs
- Downscaled winds from GCMs to get locally-generated seas and surge
- Discharge from rivers for event response
- 100 yr storm events in combination with SLR 0 m to 2.0 m in 0.5 m increments

USGS

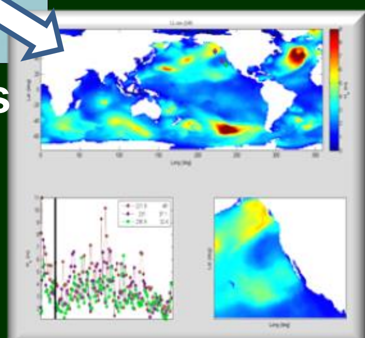
CoSMoS 3.0 Southern California

Global

Global conditions of future climate scenarios



GCM winds



WW3 wave model

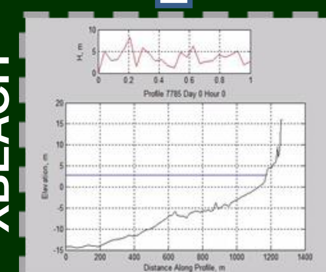
Regional

Tides, water levels, and regional forcing

Local

High resolution hydrodynamics and waves

XBEACH



Open coast

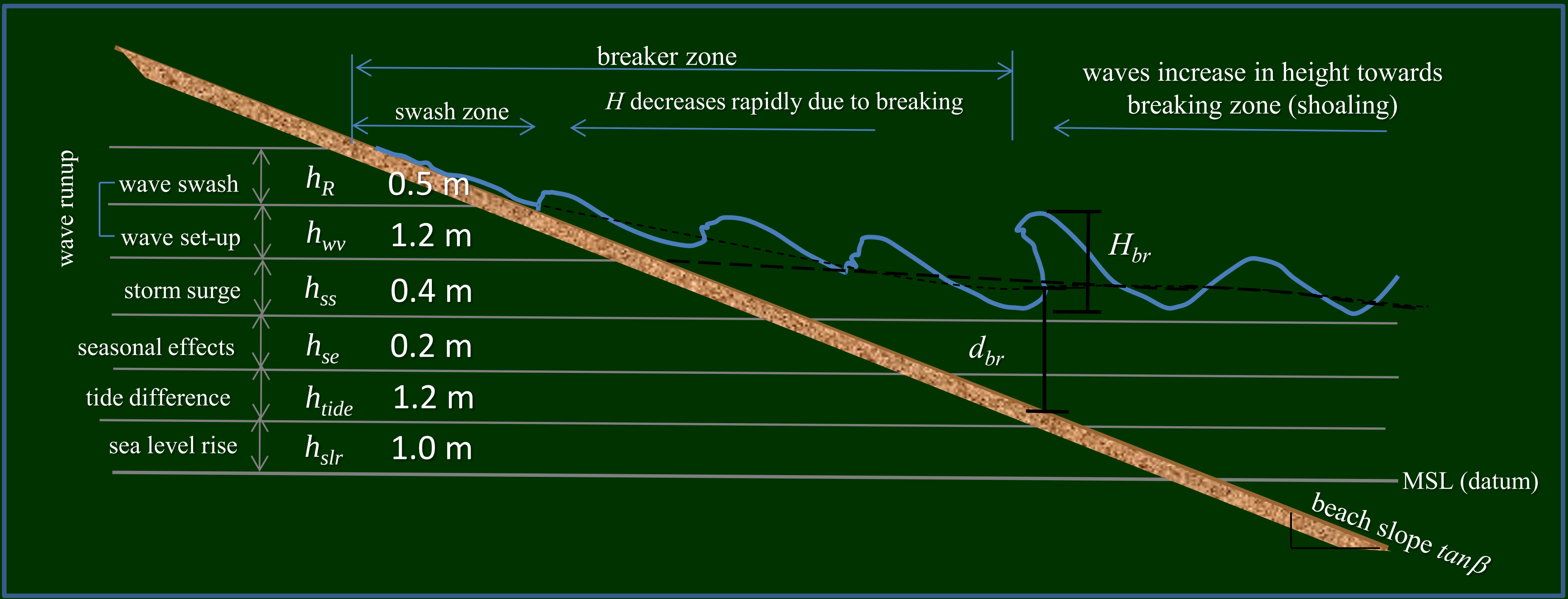
Fluvial discharge
VLM
Coastal change

results projected onto high-res DEM

USGS
science for a changing world

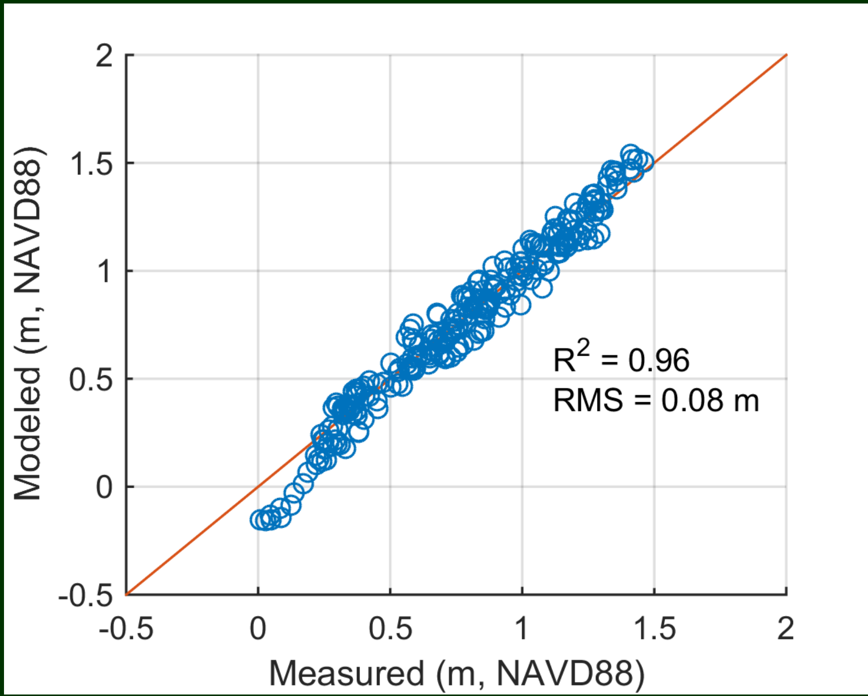
CoSMoS Coastal Storm Modeling System

Overview of Processes Included in CoSMoS

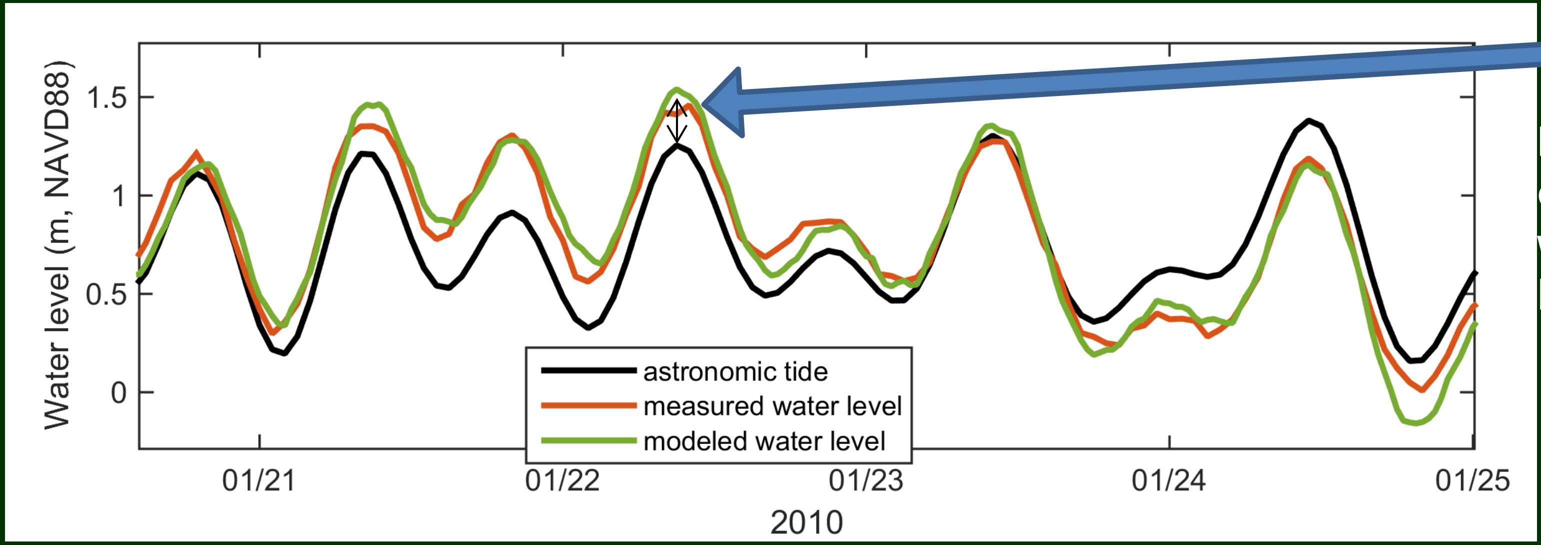


$$flood\ level\ is\ the\ combination\ of$$
$$rSLR + tides + seasonal\ effects + storm\ surge + wave\ setup + wave\ runup$$
$$+ fluvial\ discharge\ backflow$$

CoSMoS validated with January 2010 Storm



La Jolla tide gauge

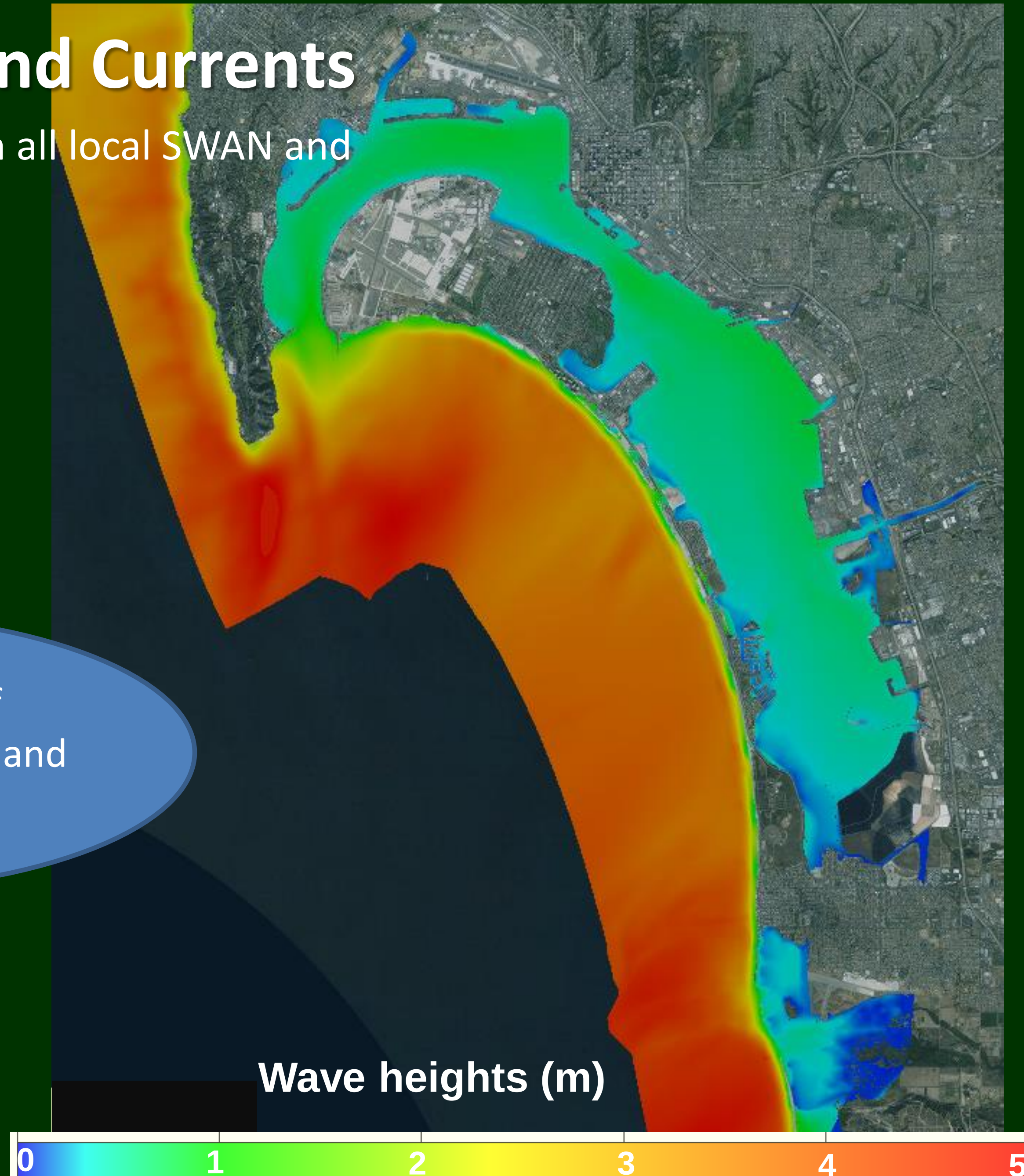


Predicted and observed/modeled water levels differ by ~2 to 37 cm

Products- Wave and Currents

- Delft3D model results from all local SWAN and FLOW runs are used to…

To generate maps of maximum wave heights and maximum currents

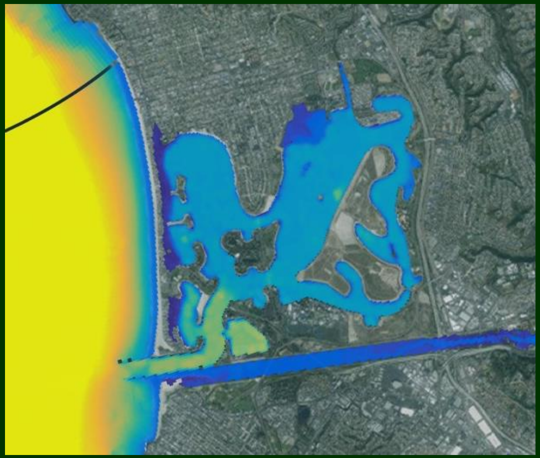


USGS

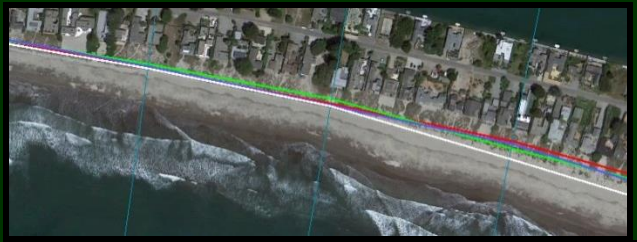
Products- Flood Maps

- Delft3D model results from high resolution grids (inlets, harbors, etc.)
- Combined with open coast XBeach results
- Overlain and differenced from the 2 m resolution DEM

High resolution model results



\+ XBeach results along open coast



= Flood map

To generate maps of flood extents, duration, and depth

USGS

CoSMoS Fall 2015 Product Release

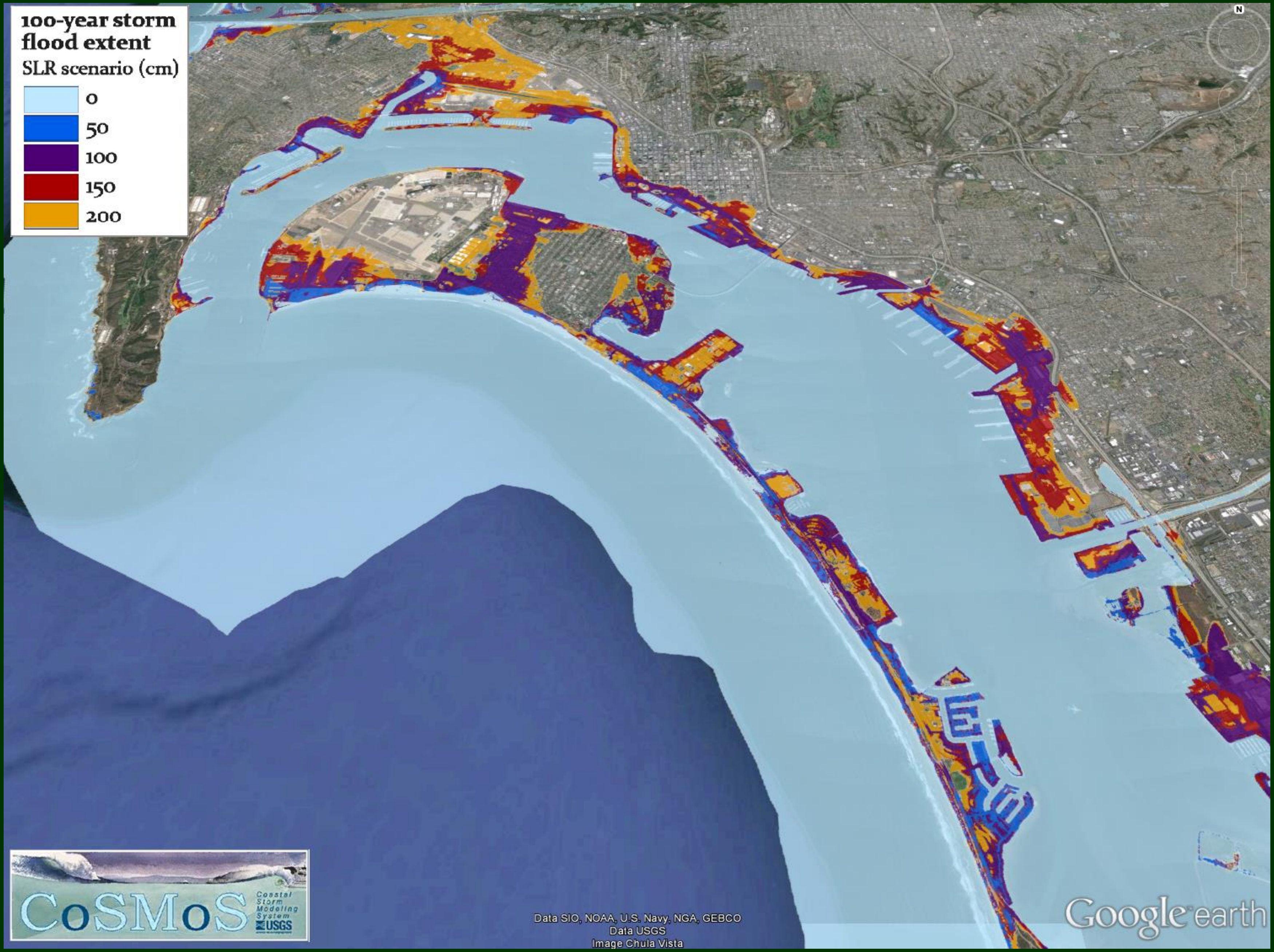
- **5 scenarios, 100 year storm + 0, 0.5, 1.0, 1.5 and 2.0 m SLR**
- **Available now: KMZs and shapefiles of flood extent, shoreline projections and cliff retreat**
- **Next summer: all 40 scenarios, integrated coastal change with coastal flooding**
  - **Coastal hazards data served up in Our Coast Our Future web tool**
  - **Socioeconomic data served up in USGS web tool**

http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

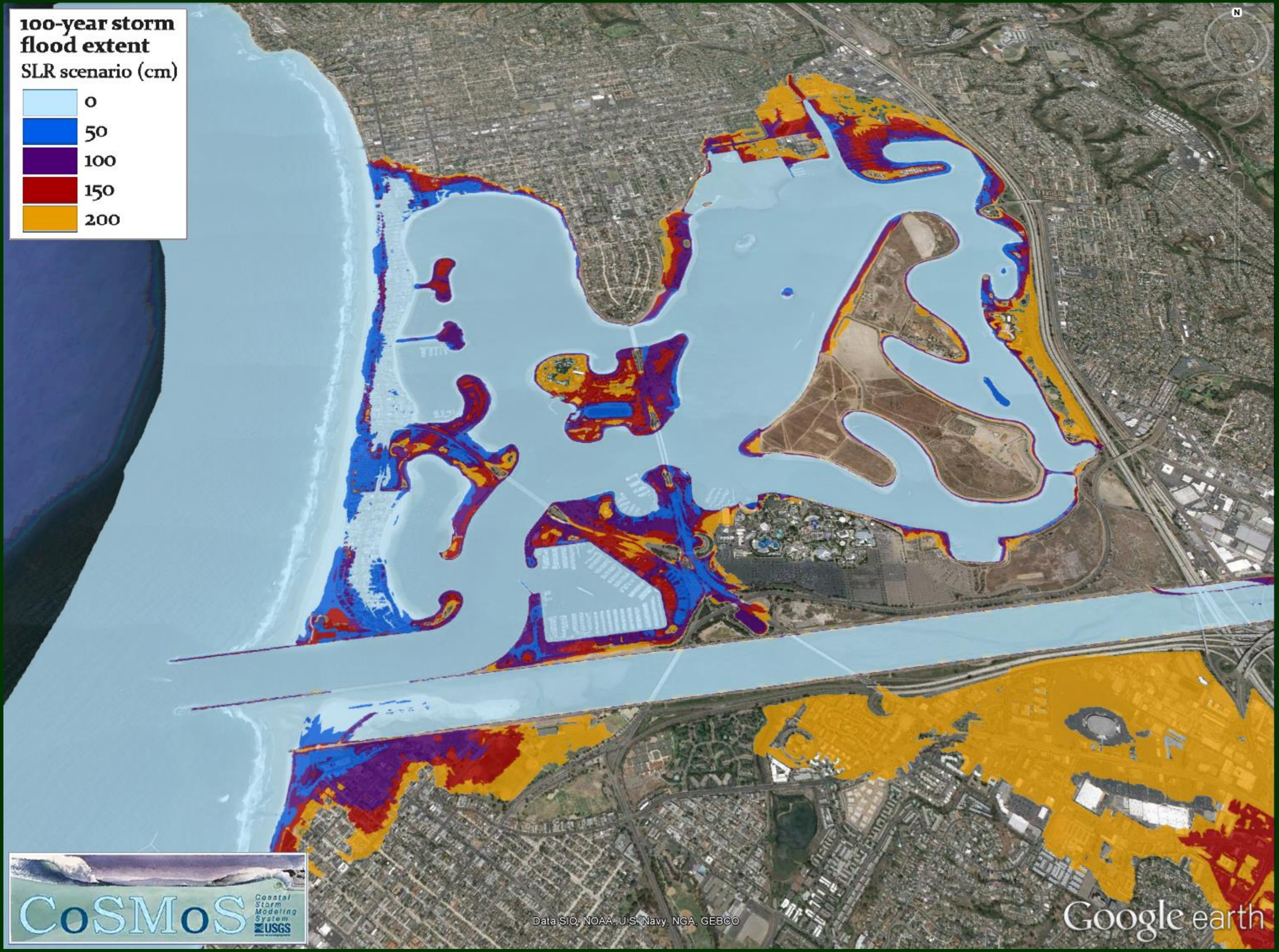
Flooding – San Diego County Overview

http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

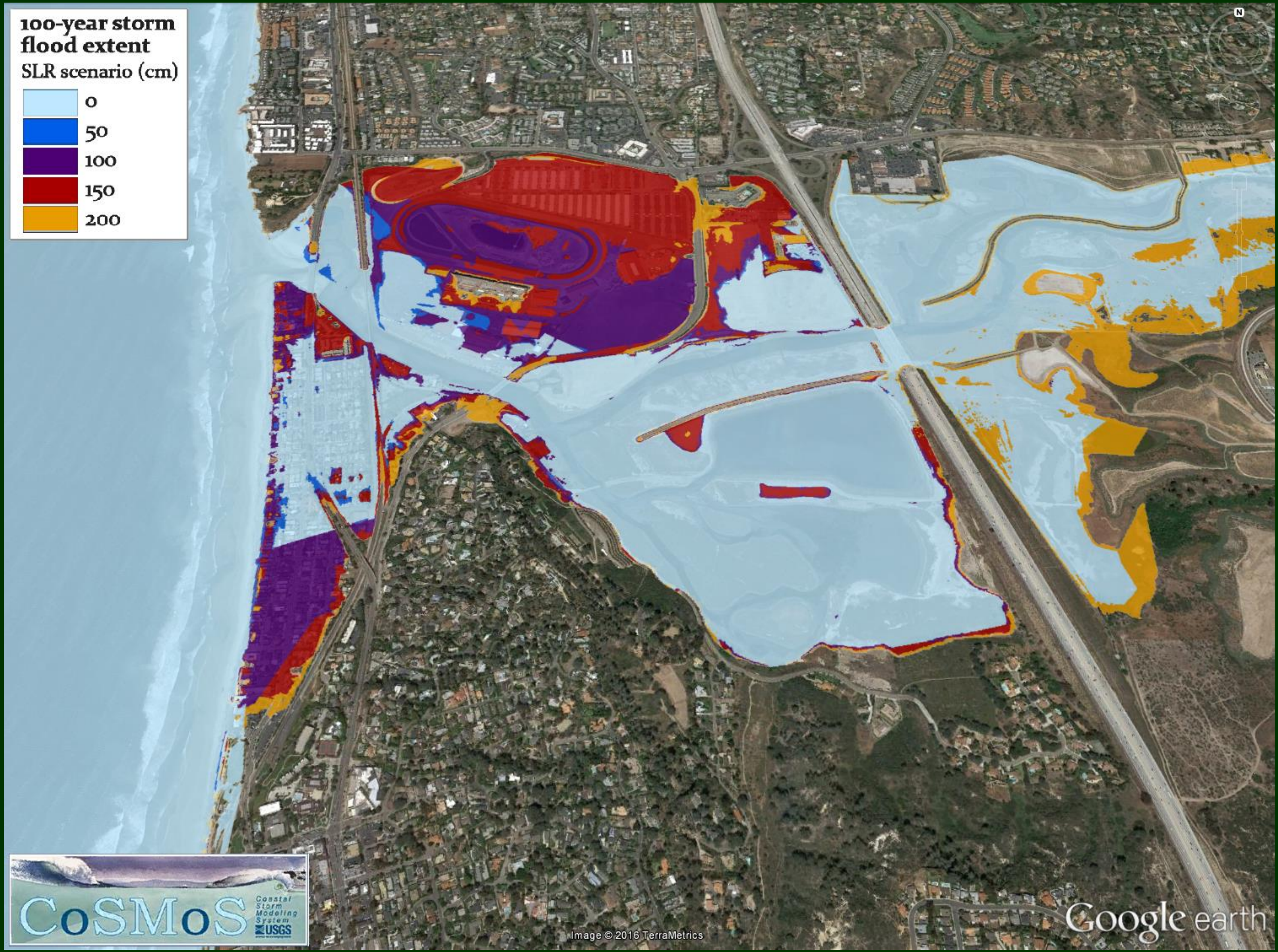
Flooding – San Diego Bay



Flooding – Mission Beach



Flooding – Del Mar

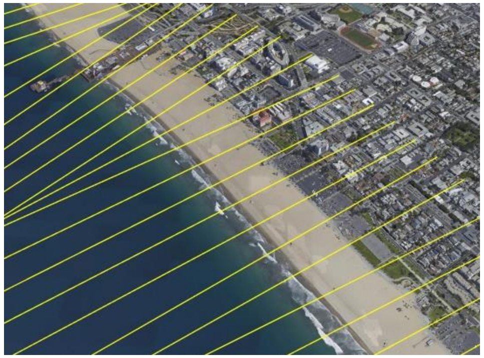


Flooding – Agua Hedionda (Carlsbad)

Flooding – Camp Pendleton South

CoSMoS-COAST: Coastal One-line Assimilated Simulation Tool

- **A (hybrid) numerical model to simulate long-term shoreline evolution**
  - coastline is represented by shore-perpendicular transects:



- **Two current assumptions: hold the line at urban interface and projection of historical rates**

- **Modeled processes include:**
  - Longshore sediment transport
  - Cross-shore sediment transport
  - Effects of sea-level rise
  - Sediment supply by natural & anthropogenic sources

- **Synthesized from models in scientific literature (with several improvements):**
  - Longshore transport: Pelnard-Considere 1956, Larson et al. 1997, Vitousek & Barnard 2015
  - Equilibrium shoreline change models: Miller & Dean 2004, Yates et al. 2009, Long & Plant 2012
  - Cross-shore transport due to sea-level rise: Bruun 1954, Davidson-Arnot 2005, Anderson et al. 2015

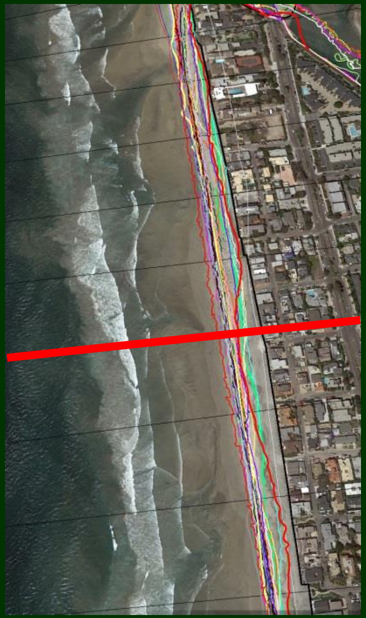
- **Uses data assimilation (Extended Kalman Filter) to improve model skill**

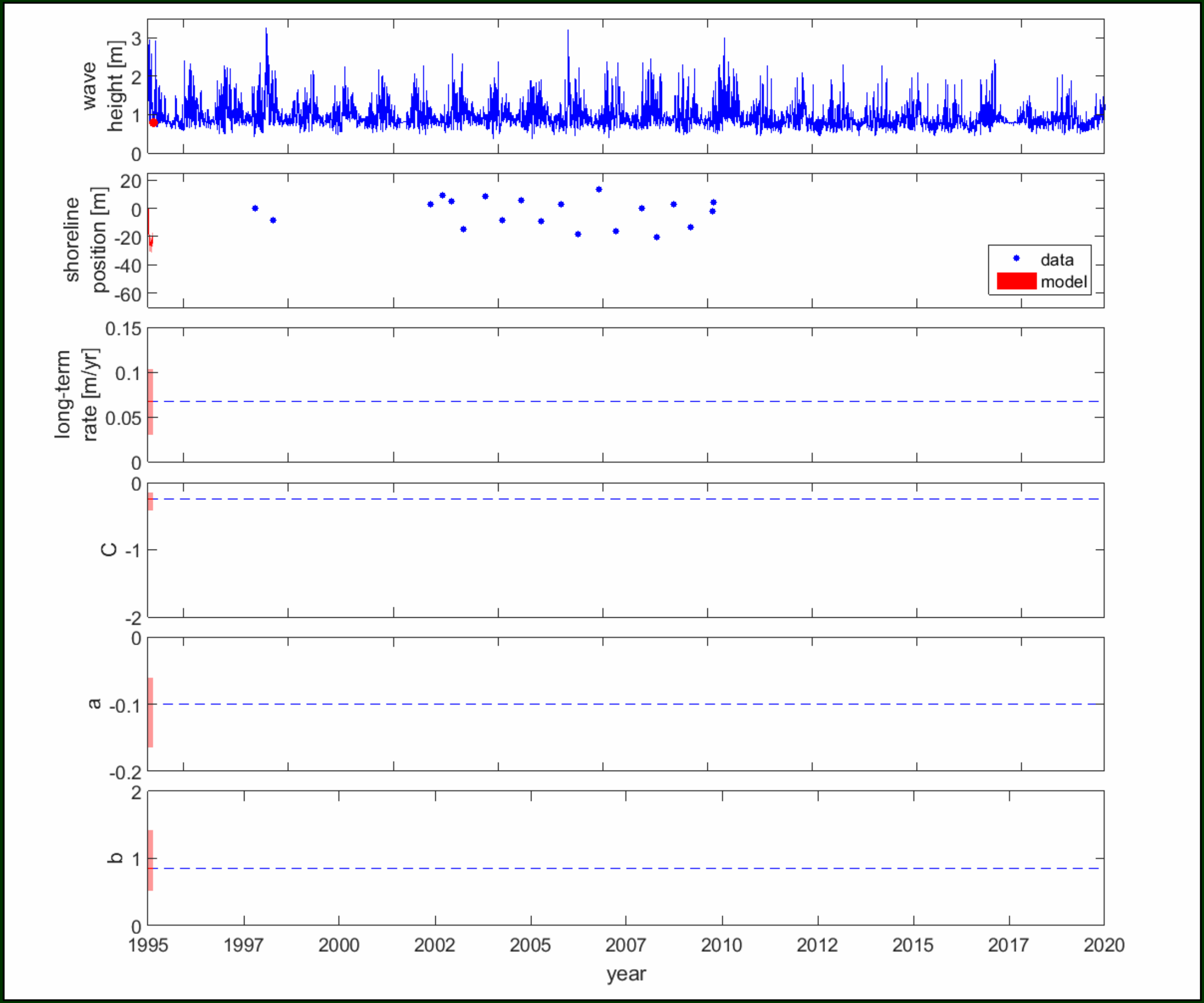
Data Assimilation

We use the *extended Kalman filter method* of Long & Plant 2012

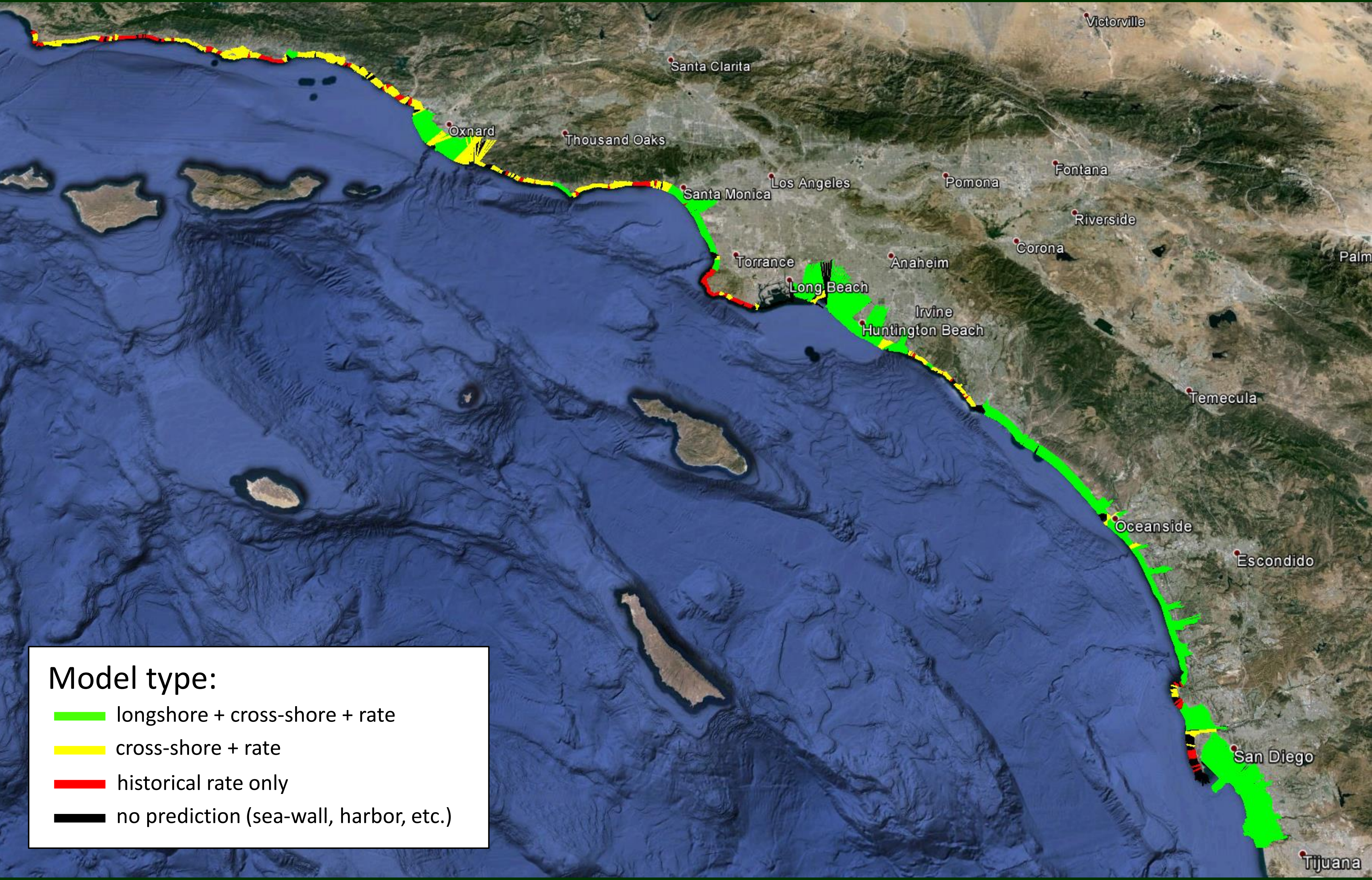
- Auto-tunes model parameters for each transect to best fit the historical shoreline data
- We improved the method to handle sparse shoreline data and ensure that parameters are positive or negative.

Simulation output for a single transect at Del Mar Beach:





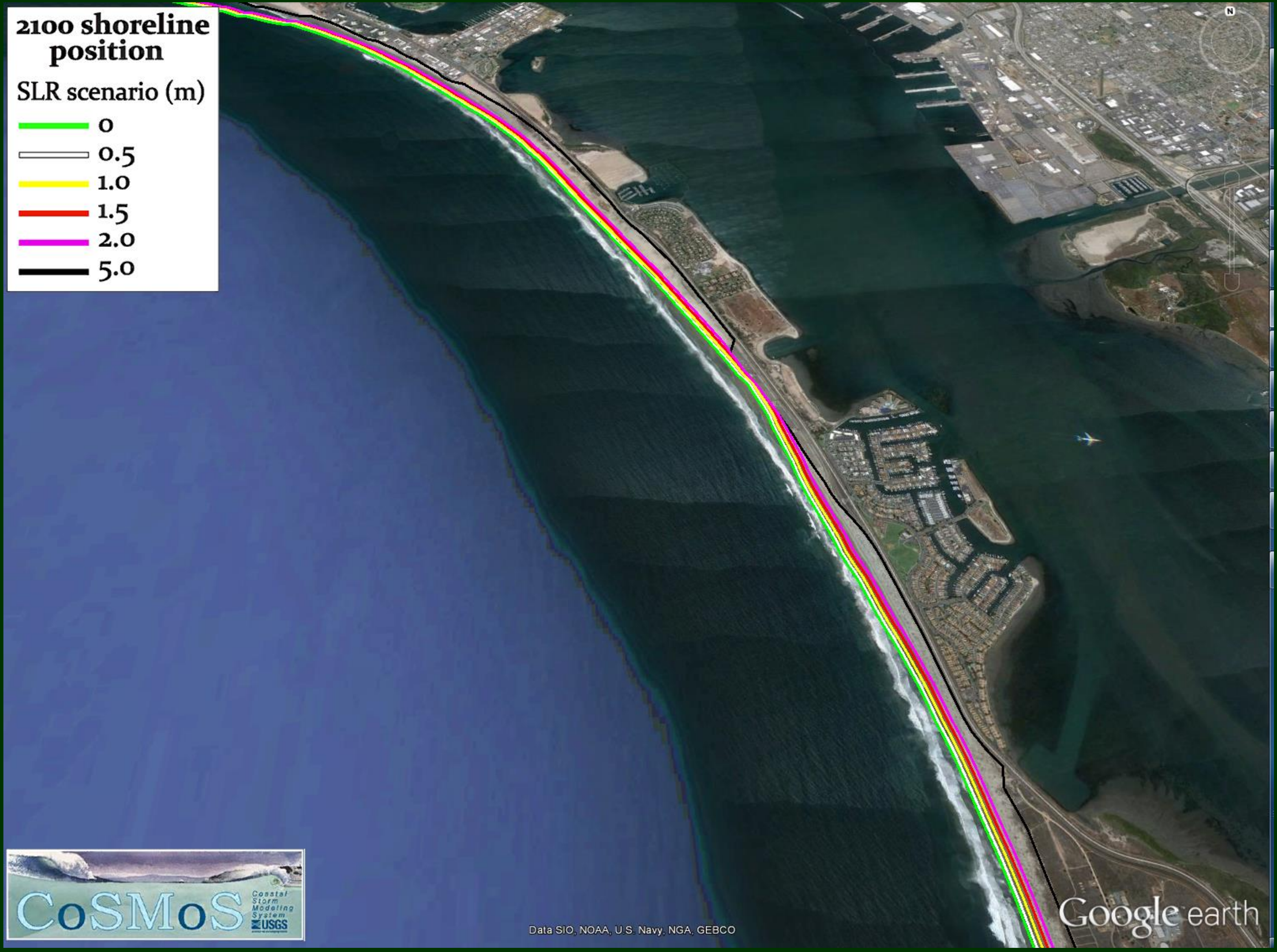
Model has ~4800 transects with ~100 m grid spacing



Shoreline Change Considerations

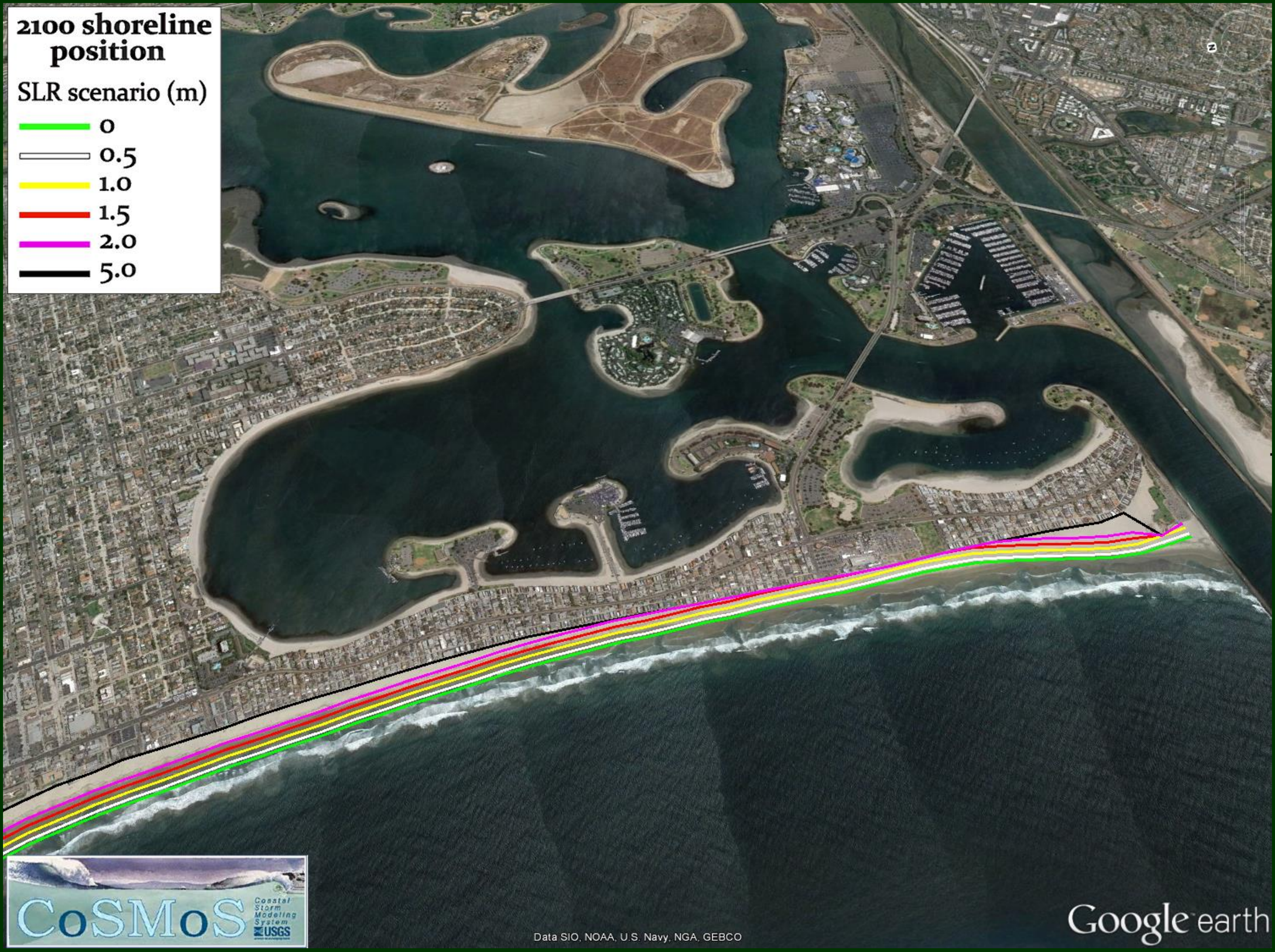
- 2 key coastal management assumptions
  - No erosion beyond urban infrastructure (‘hold the line’)
  - Incorporate historical rates of change in future projections (e.g., nourishment)
- Current assumptions result in potential underestimation of future beach erosion, especially in areas where significant nourishment has taken place
- Solution: run 4 different shoreline change scenarios
  - Hold the line + nourishment
  - Hold the line + no nourishment
  - Do not hold the line + nourishment
  - *Do not hold the line + no nourishment

Shoreline Projections – outer San Diego Bay



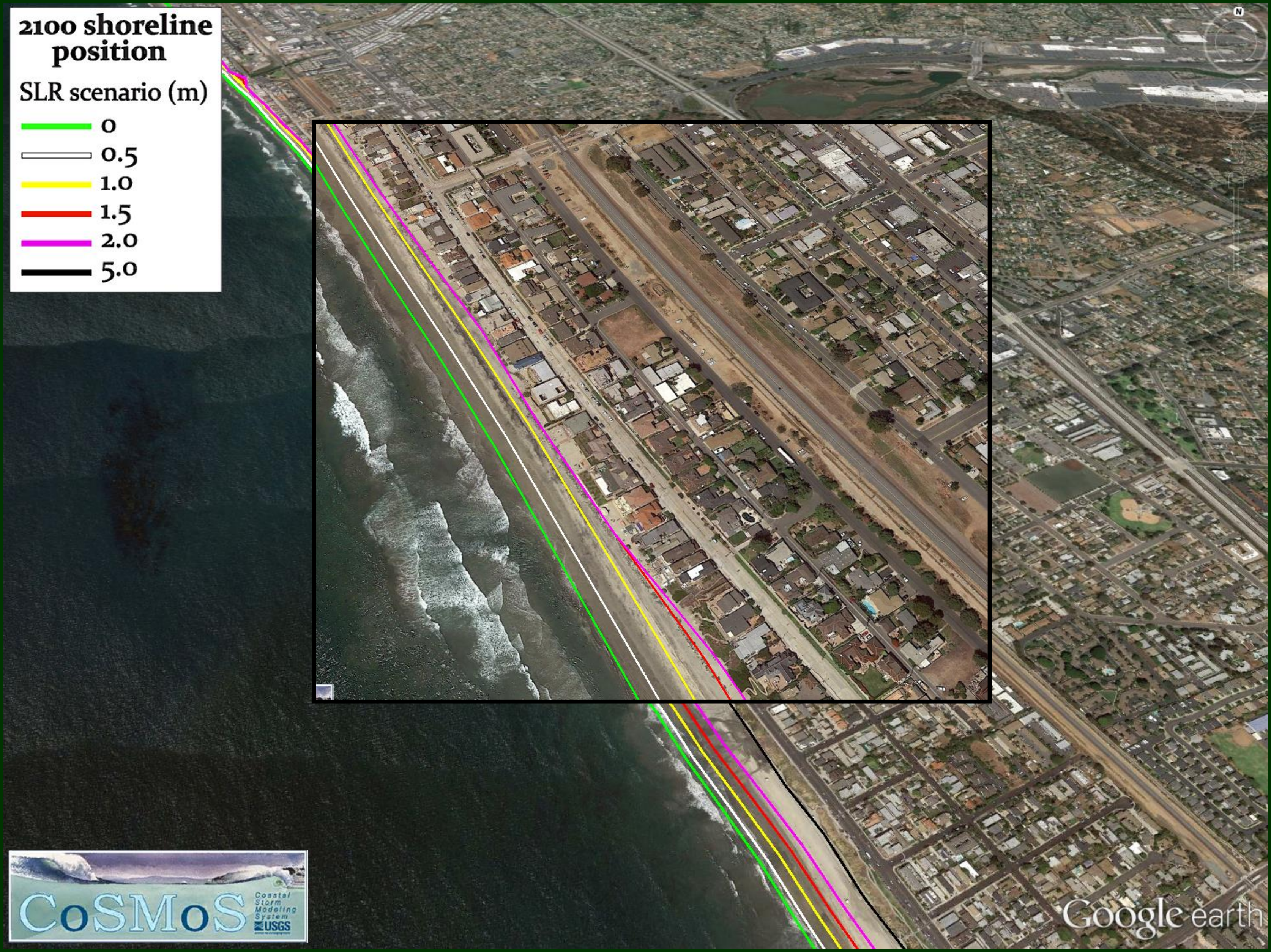
Shoreline Projections – Sunset Beach

Shoreline Projections – Mission Beach



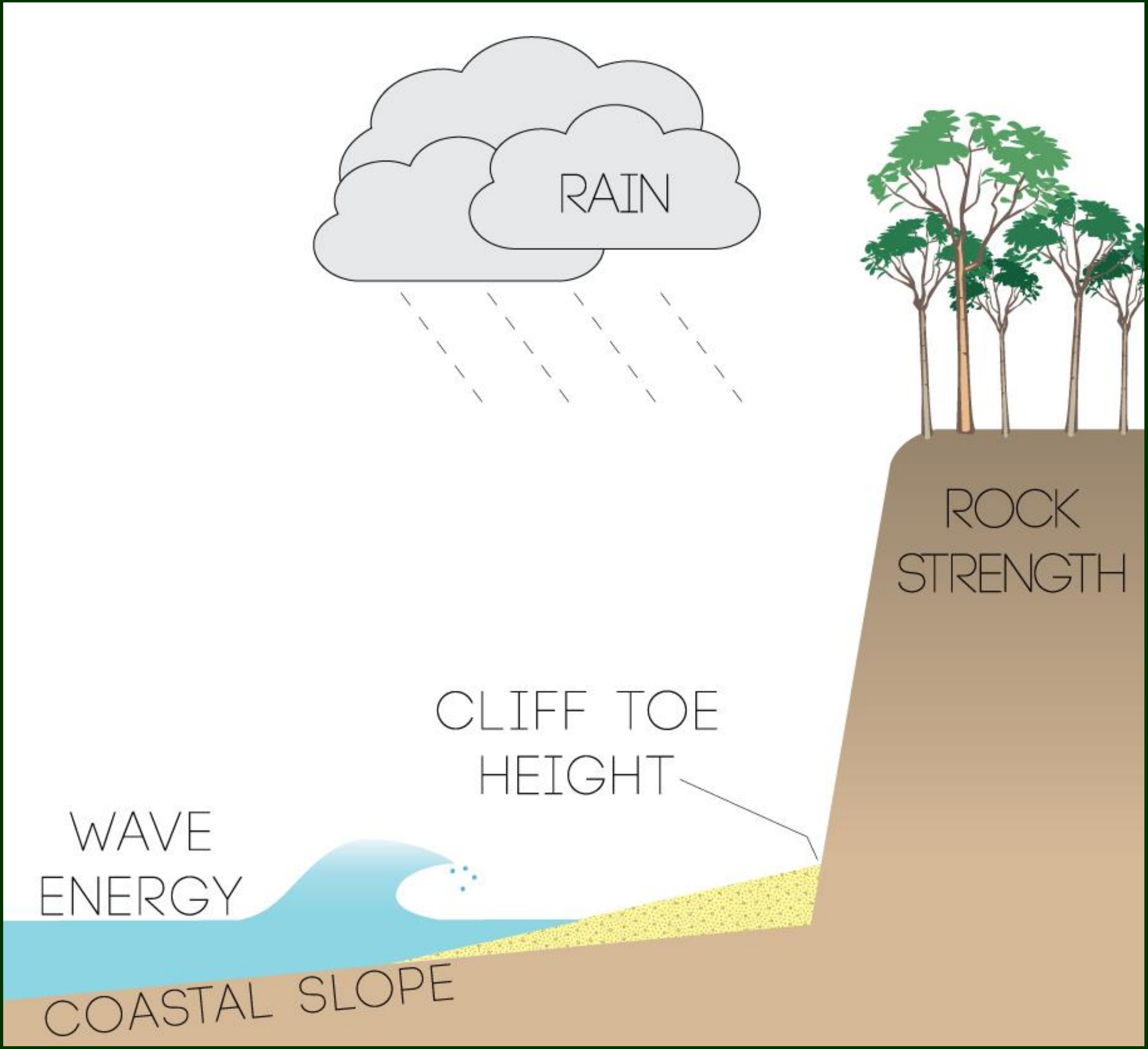
Shoreline Projections – Del Mar

Shoreline Projections – Carlsbad

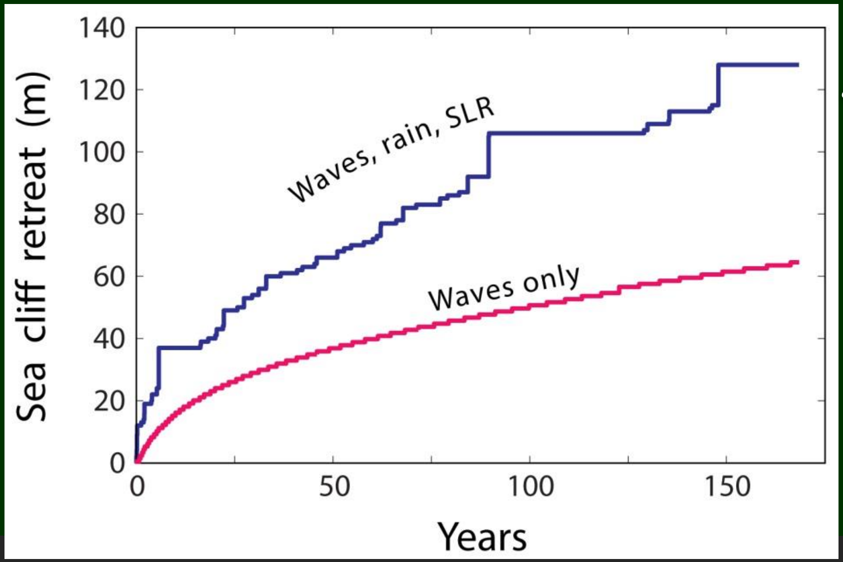


Shoreline Projections – Camp Pendleton South

Factors Driving Sea Cliff Erosion & Retreat

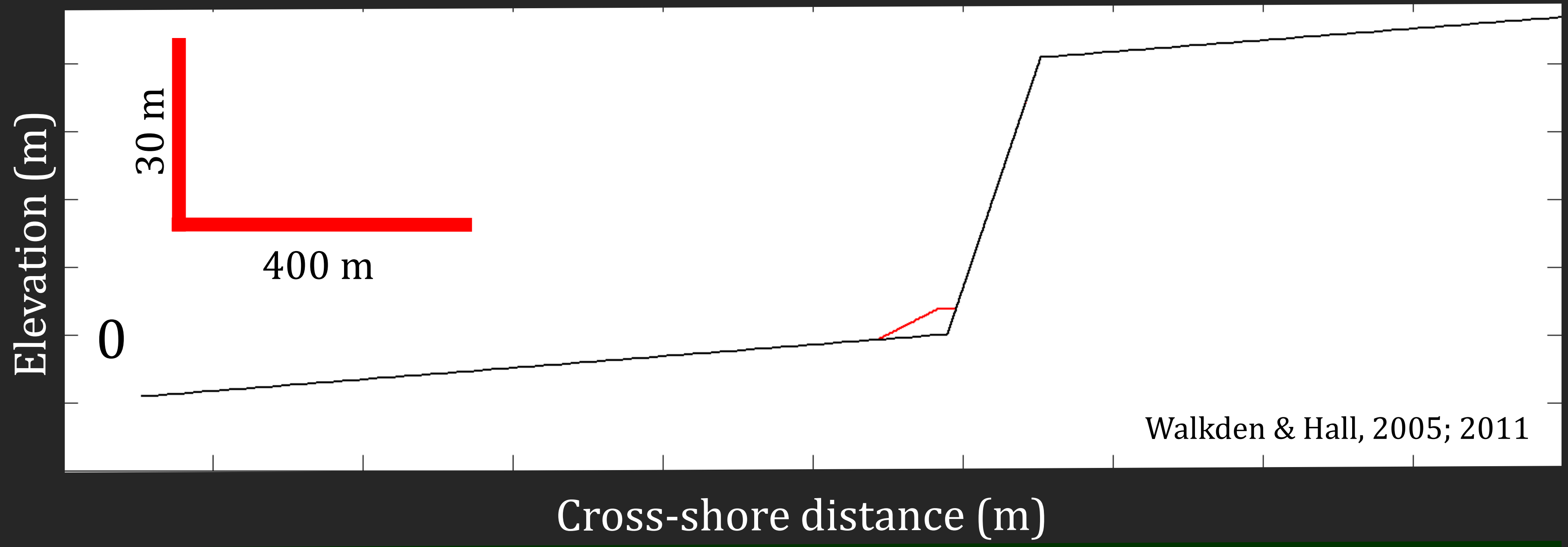


Multi-decadal Models of Sea Cliff Erosion & Retreat

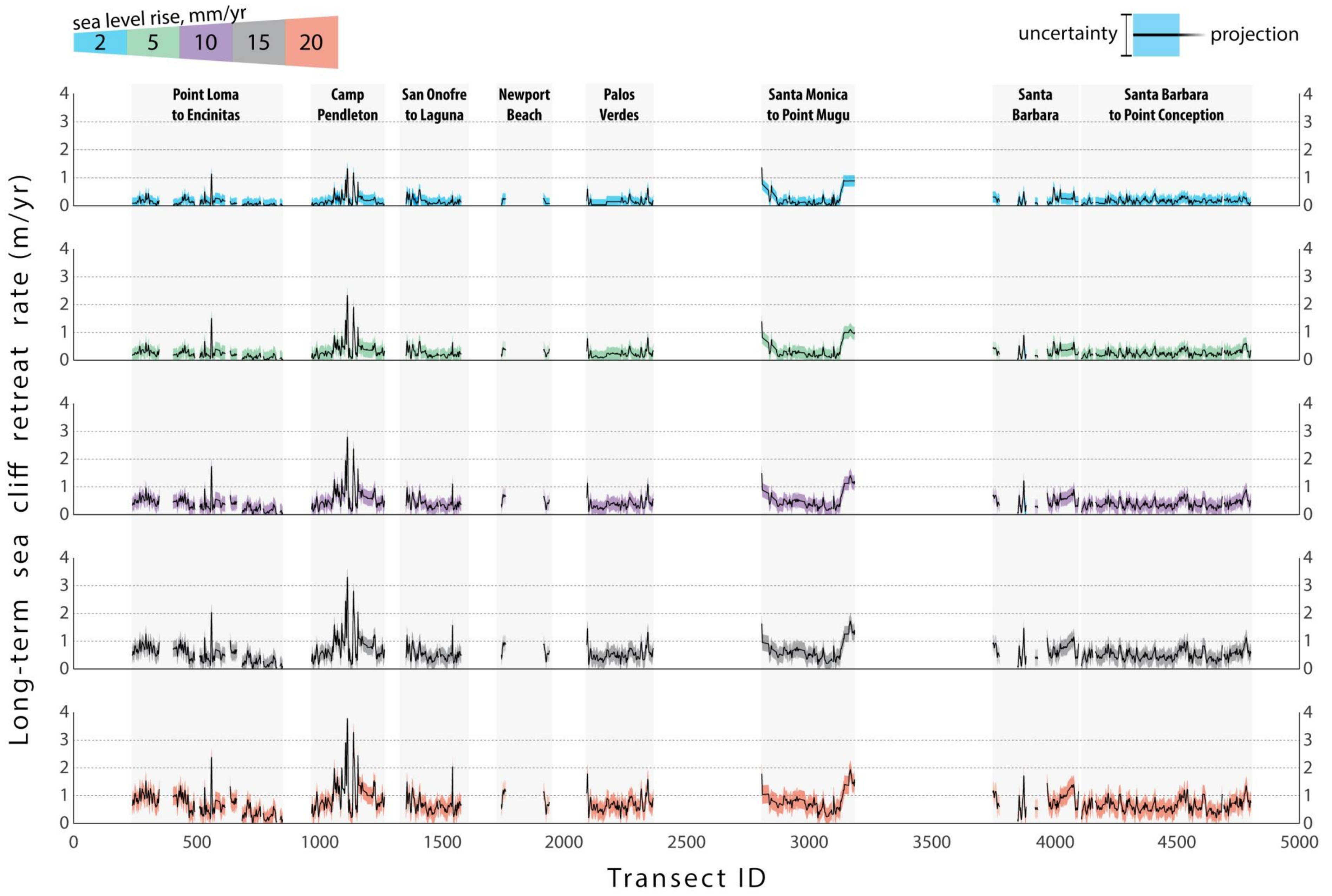


Rain, SLR cause more cliff retreat

(rain effects are in beta mode)



Results



sea level rise, mm/yr
2
5
10
15
20
uncertainty
projection
Point Loma to Encinitas
Camp Pendleton
San Onofre to Laguna
Newport Beach
Palos Verdes
Santa Monica to Point Mugu
Santa Barbara
Santa Barbara to Point Conception
Long-term sea cliff retreat rate (m/yr)
Transect ID
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

Cliff Retreat Projections – Point Loma

Cliff Retreat Projections – La Jolla

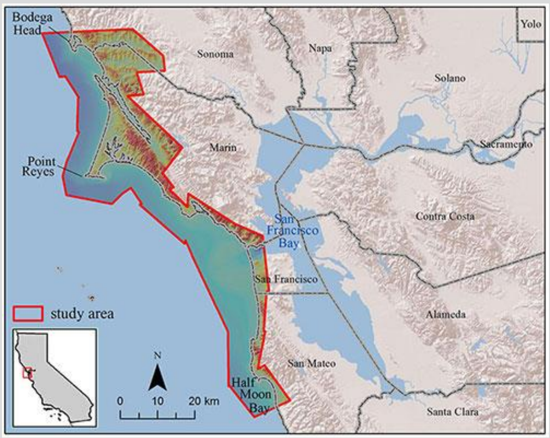
Cliff Retreat Projections – Del Mar

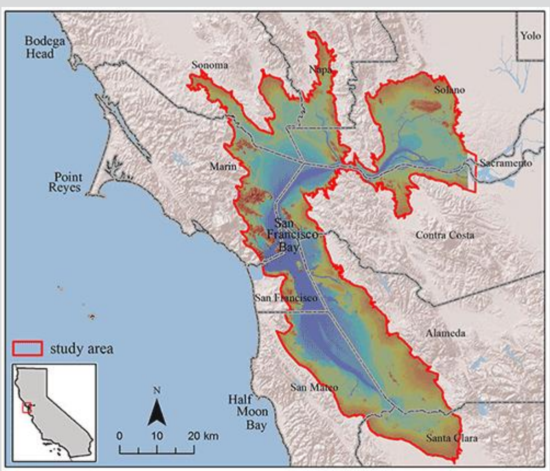
Cliff Retreat Projections – Solana Beach

Cliff Retreat Projections – Camp Pendleton

GIS-Based Exposure to Hazards

JURISDICTIONS





9 COUNTIES
56 INCORPORATED CITIES

ASSETS

RESIDENTS
(w/ demographics)

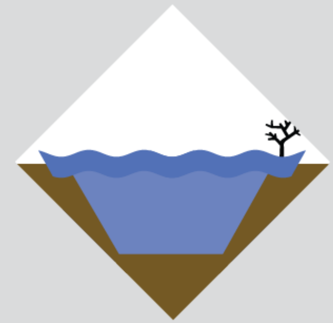
EMPLOYEES
(by sector)

BUSINESS SECTORS
PARCEL VALUES
BUILDING REPLACEMENT VALUE

ROADS AND RAILWAYS

LANDCOVER

HAZARD



FLOODING EXTENT
based on:

STORM FREQUENCY
None
Annual
20-year
100-year

SEA LEVEL RISE SCENARIOS

0 cm	100 cm
25 cm	125 cm
50 cm	150 cm
75 cm	175 cm
	200 cm

What's Coming Summer 2016

- **40 scenarios of SLR + storms**
- **Long-term coastal evolution integrated into flood mapping**
- **Our Coast Our Future (OCOF) web tool**
- **Socioeconomic impacts and web tool**
- **Groundwater, hurricane impact pilots**

***For more information, contact Patrick Barnard: pbarnard@usgs.gov or Li Erikson: lerikson@usgs.gov**

USGS CoSMoS data: ***http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html***

Our Coast- Our Future tool: ***www.prbo.org/ocof***

USGS

CoSMoS USGS science for a changing world