

Santa Barbara and Ventura 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



*Ventura Pier, December 2015
(Ricky Staub)*

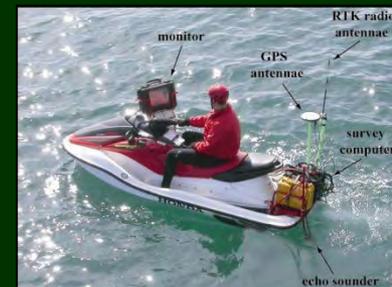
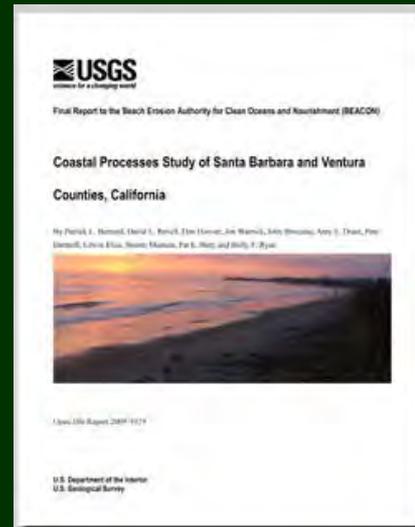
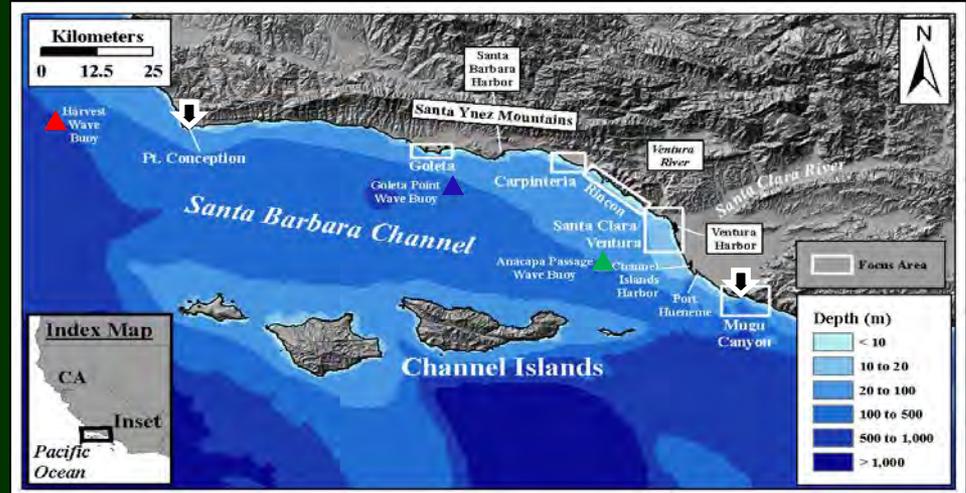
Santa Barbara Littoral Cell Coastal Processes Study (2005-present)

Scientific Objective: Gain a fundamental understanding of coastal change at a range of spatial and temporal scales, including climate change response

Data Collection:

- Beach and bathymetric change
- Regional survey (BEACON) lines
- Modeled sediment transport potential

Key Funding Partners: BEACON, CA Boating and Waterways, City of Carpinteria, and USACE



Support for CoSMoS SoCal

- State Coastal Conservancy



- City of Imperial Beach



- Tijuana River National Estuarine Research Reserve



- California Department of Fish & Wildlife



California Department of
Fish and Wildlife

- California's Fourth Climate Change Assessment (California Natural Resources Agency)



Projections for Southern California

SLR for Los Angeles (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)

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

El Niño for 21st Century (Cai et al., 2015, Barnard et al., 2015)

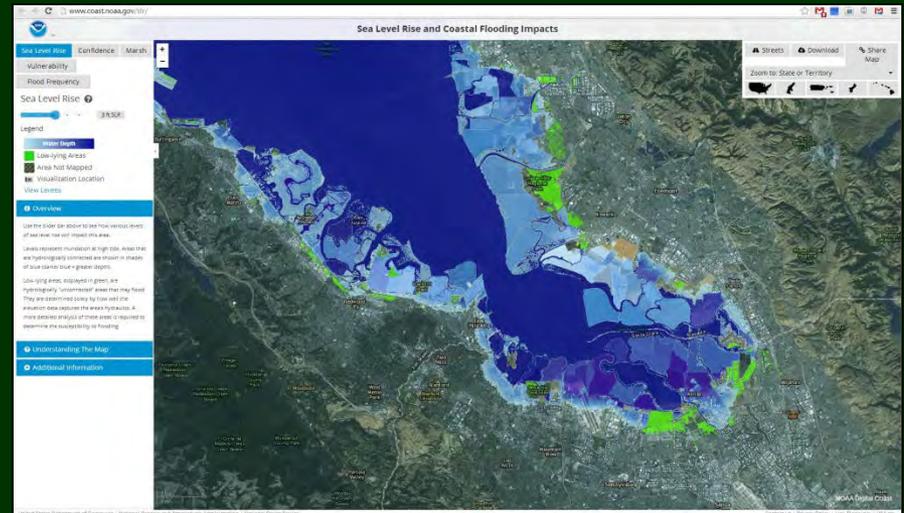
- More frequent extreme events
- Doubling of winter erosion
- Wave energy increase by 30%



Coastal Vulnerability Approaches

• STATIC: NOAA SLR Viewer

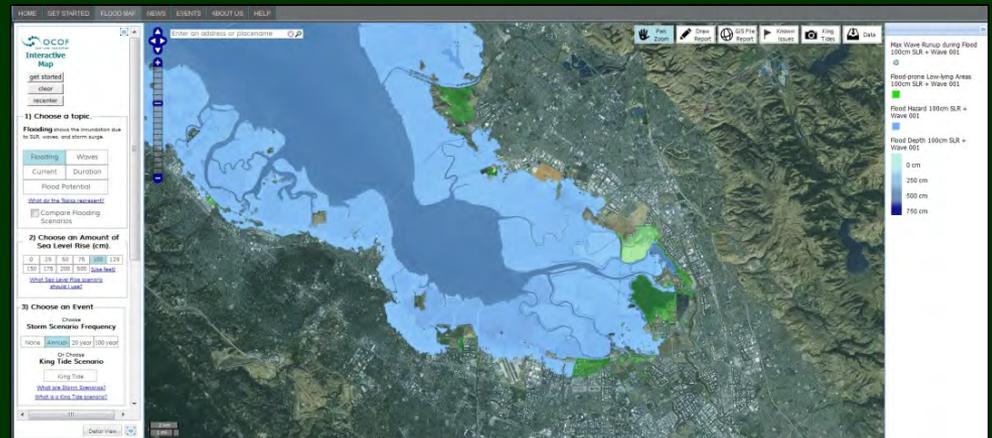
- Passive model, hydrological connectivity
- Tides only (MHHW)
- Excellent elevation data, datum control
- Wetland migration model, socioeconomic impacts
- ‘1st order screening tool’



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

• DYNAMIC: CoSMoS (also TNC, FEMA)

- 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

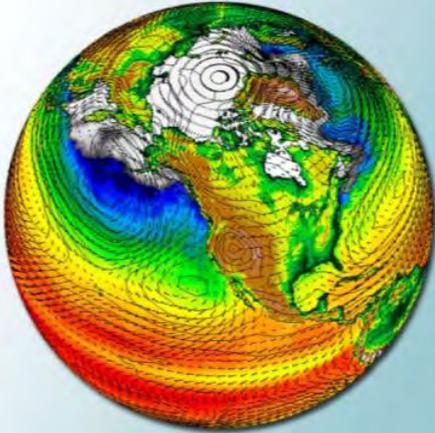
CoSMoS: A Tool for Coastal Resilience

- 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)

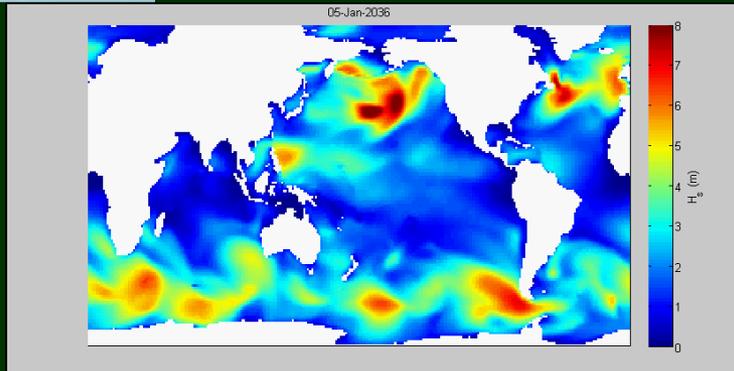


Identifying Future Risk with CoSMoS

1. Global forcing using the latest climate models



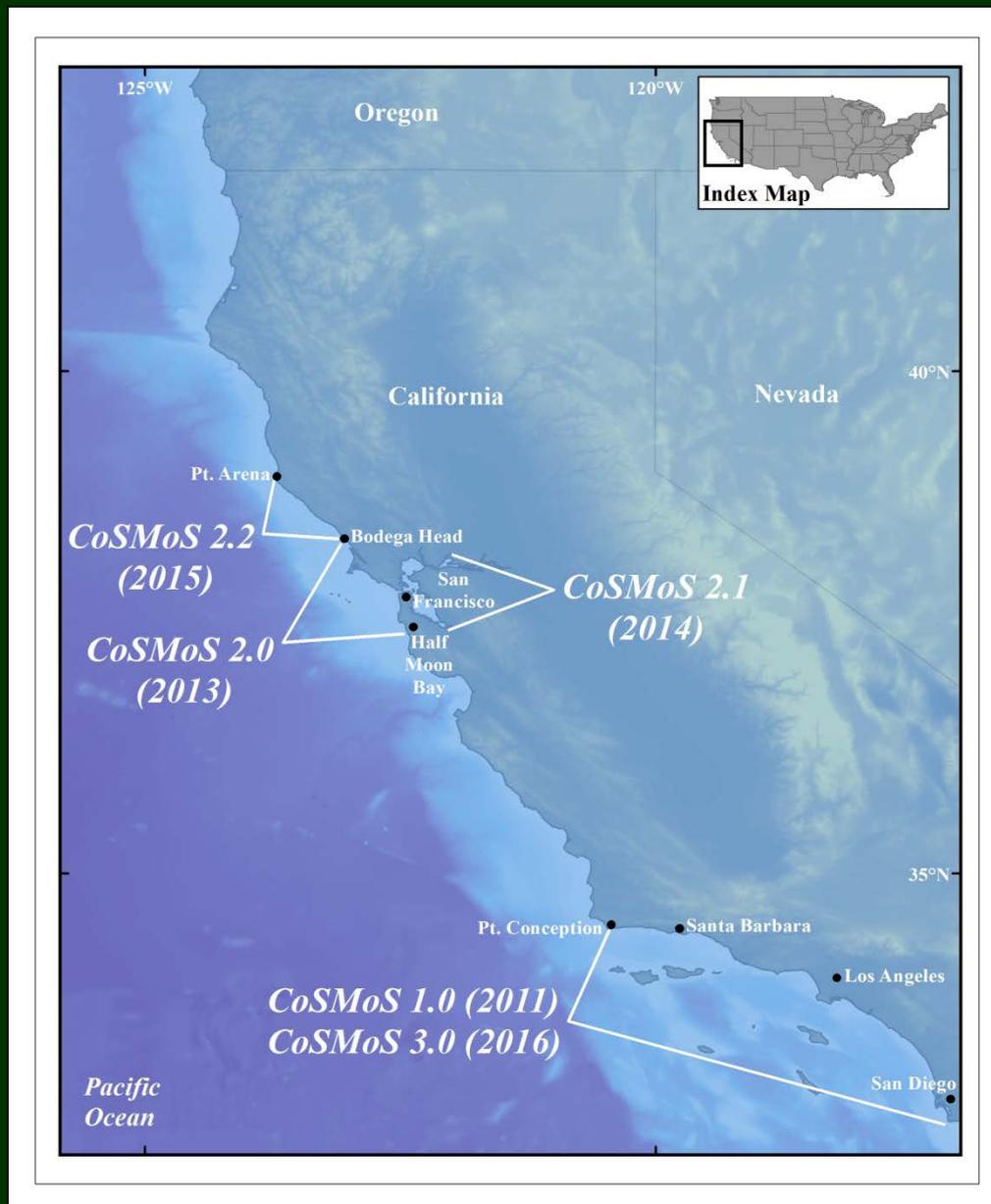
2. Drives global and regional wind/wave models



3. Scaled down to local hazards projections



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

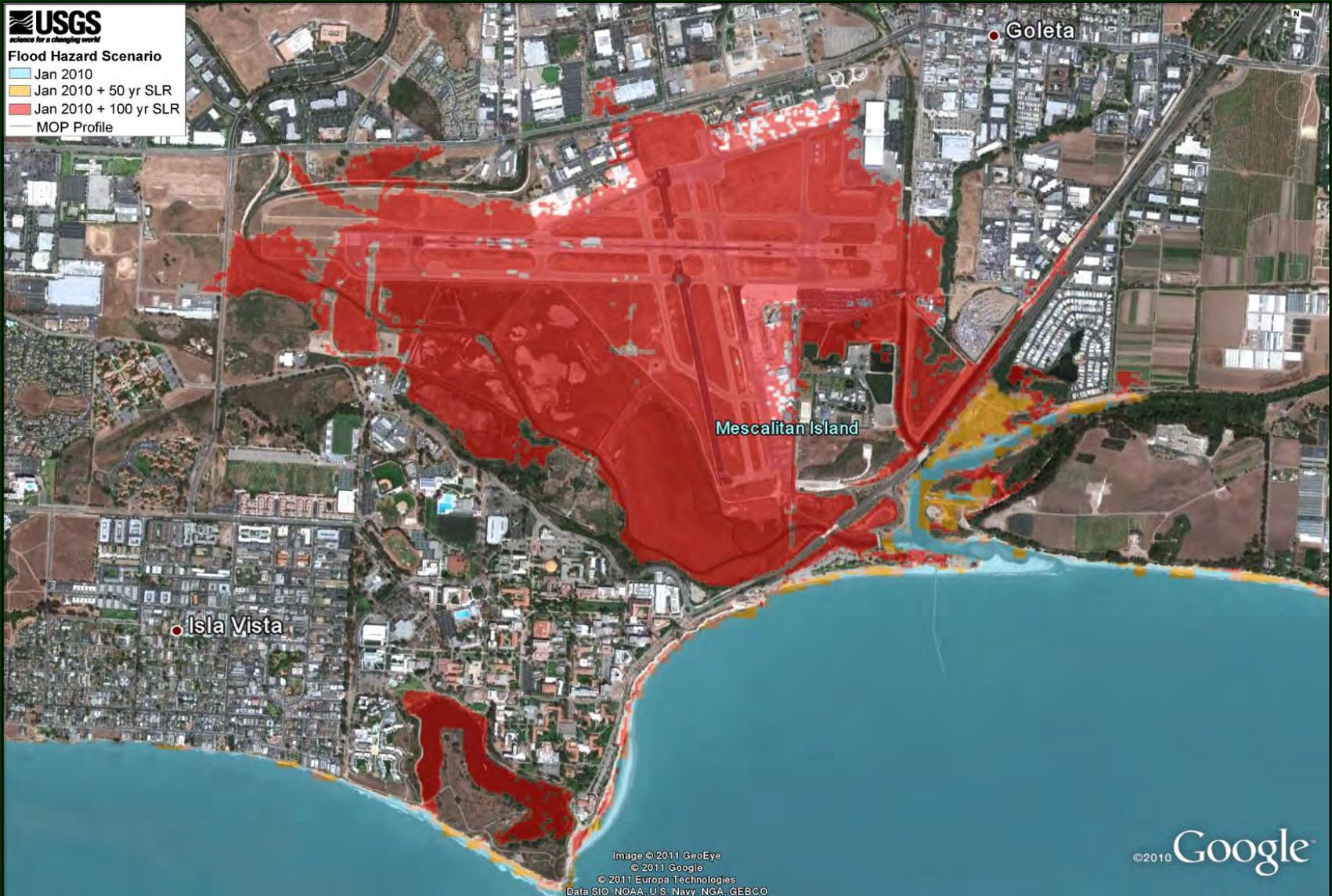
CoSMoS 2.0

- North-Central CA coast, 170 km, (Bodega Head to Half Moon Bay)
- 21st century winds & waves
- High resolution grids of lagoons and protected areas
- Daily, annual, 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

CoSMoS 1.0- Historical Storms and Climate Change



CoSMoS 2.0- CenCal/NorCal

HOME | OUR PROJECT | INTERACTIVE TOOLS | NEWS | EVENTS | ABOUT US | HELP

OCOF OUR COAST OUR FUTURE
Interactive Map

get started
clear
recenter

1) Choose a topic.
Flooding shows the extent of flooding due to SLR, waves, and storm surge.
Waves
Current
Uncertainty
[What do the Topics represent?](#)

2) Choose a Sea Level Rise (cm) level.
0 25 50 75 100 125
150 175 200 500
[What Sea Level Rise scenario should I use?](#)

3) Choose a storm scenario frequency
None Annual 20 year 100 year

4) Choose other layers to view with topic data.
 Placenames
 Land Use
 Protected Areas
 Rivers & Streams
 Cliff and Shoreline Retreat
 Shorebirds
 Coastal Armoring
 Roads and Transportation
 Trails
 Buildings
 Utilities & Services

Opacity

Detail View

Pan Zoom
Draw Report
GIS File Report
Data

Highlights of CoSMoS 3.0

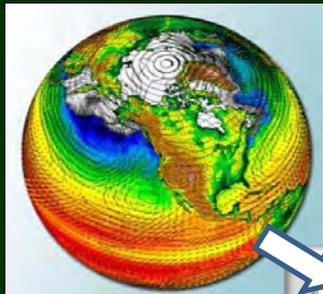
- Multi-agency collaboration featuring top coastal and climate scientists from Scripps, Oregon State University, private sector, and USGS
- Long-term coastal evolution modeled, including sandy beaches and cliffs
- Downscaled winds from GCMs to get locally-generated seas and surge
- Discharge from rivers for event response
- 100 yr storm events in combination with SLR 0 m to 1.5 m in 0.5 m increments delivered Fall 2015



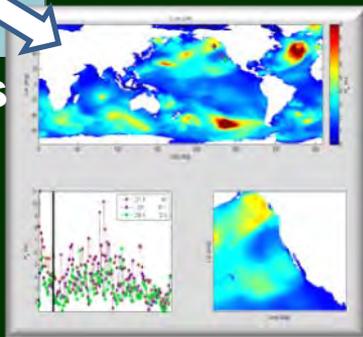
CoSMoS 3.0 Southern California

Global

Global conditions of future climate scenarios



GCM winds



WW3 wave model

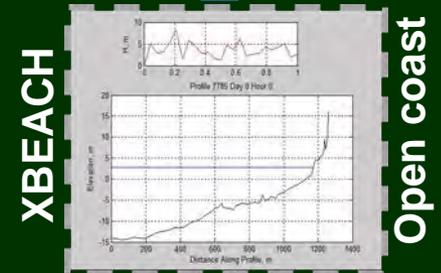
Regional

Tides, water levels, and regional forcing



Local

High resolution hydrodynamics and

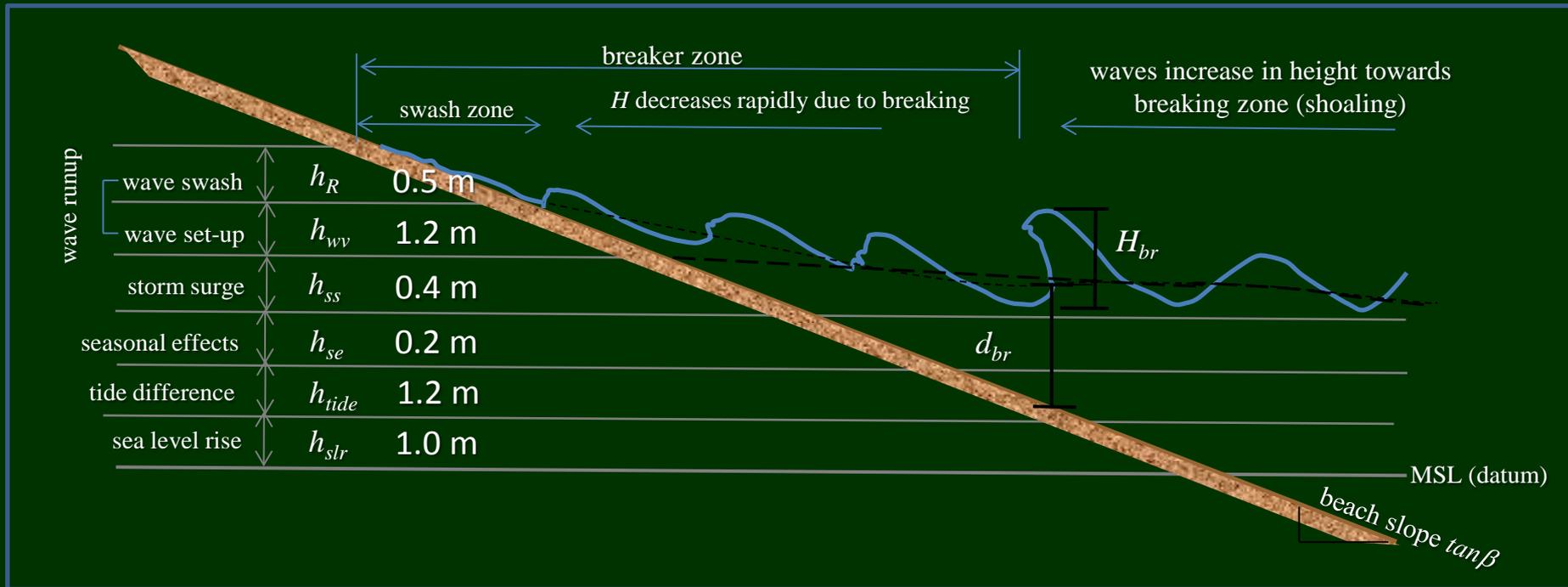


Open coast

Fluvial discharge
VLM
Coastal change

results
projected onto
hi-res DEM

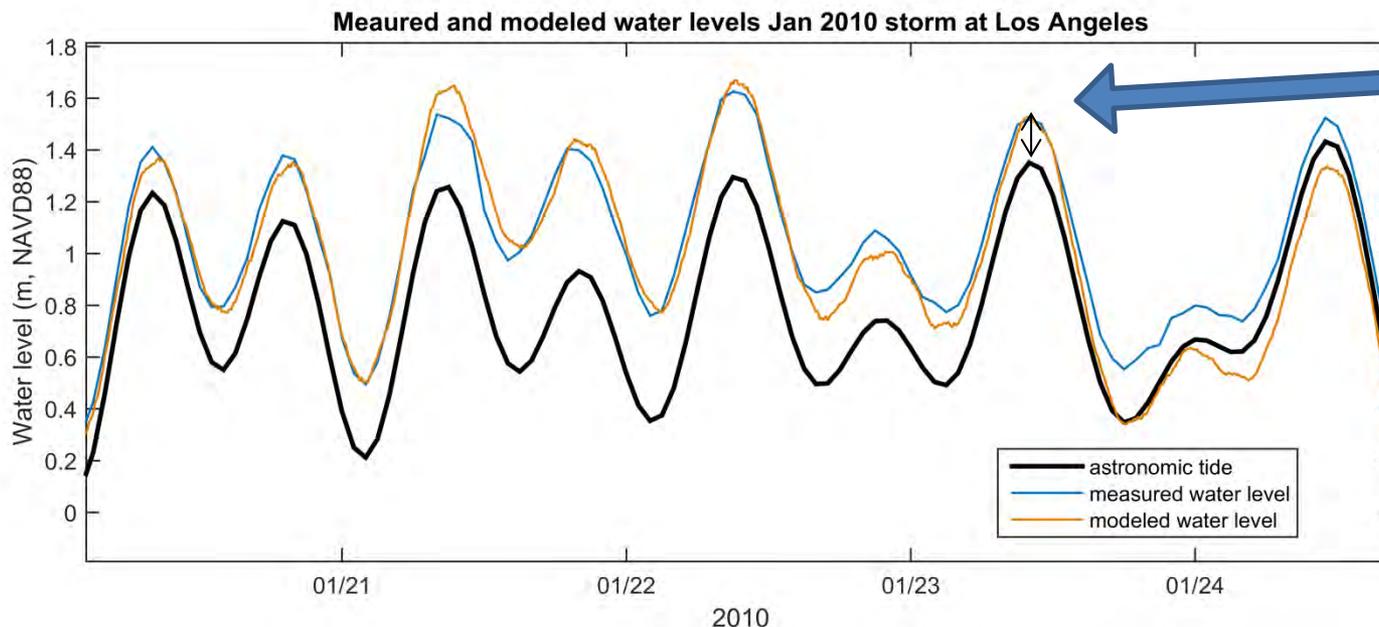
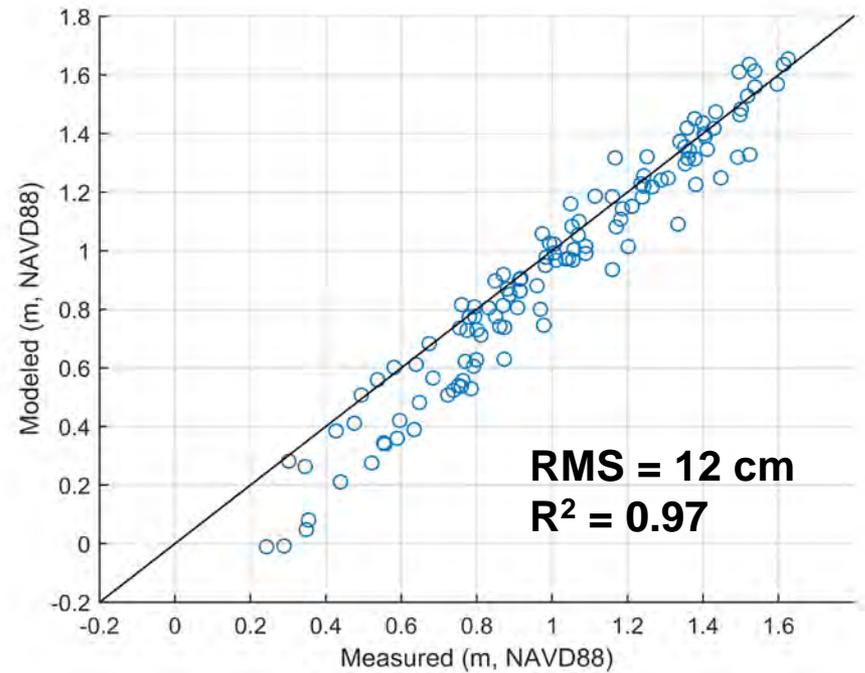
Overview of Processes Included in CoSMoS



*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

Los Angeles tide gauge

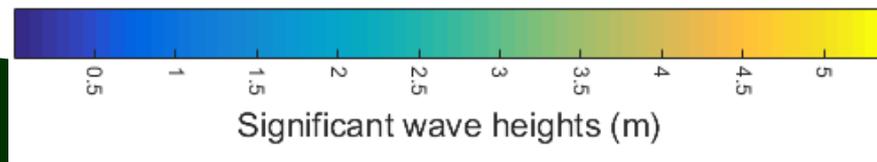
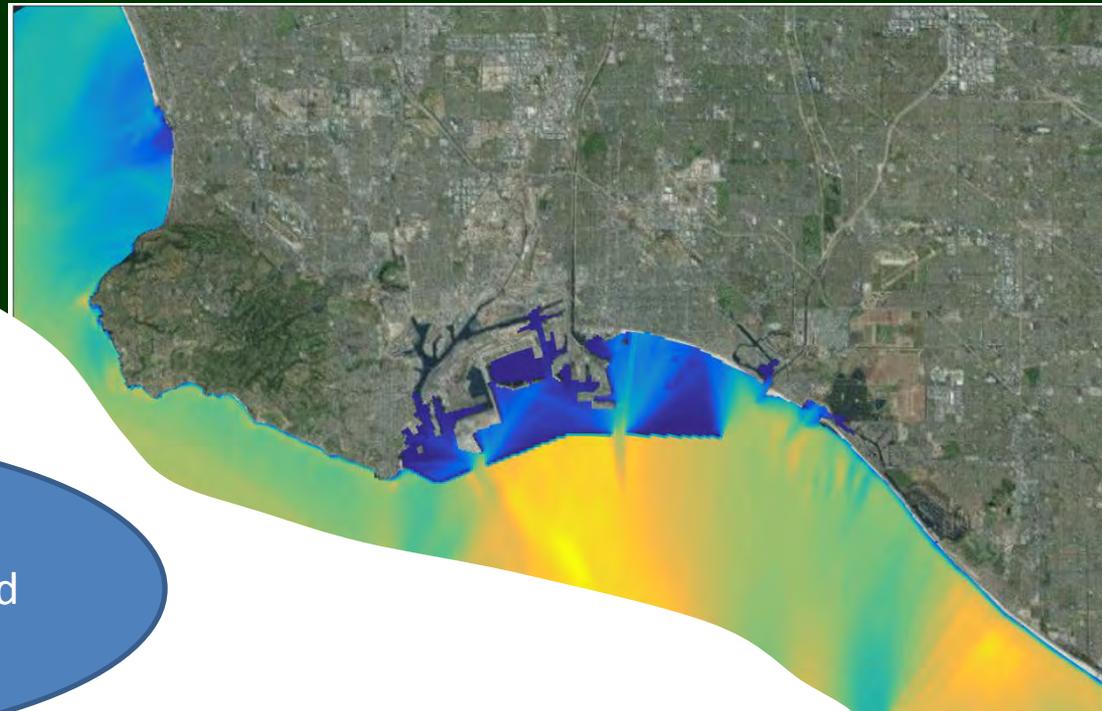


Predicted and
observed/modeled
water levels differ
by 6 to 52 cm

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



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

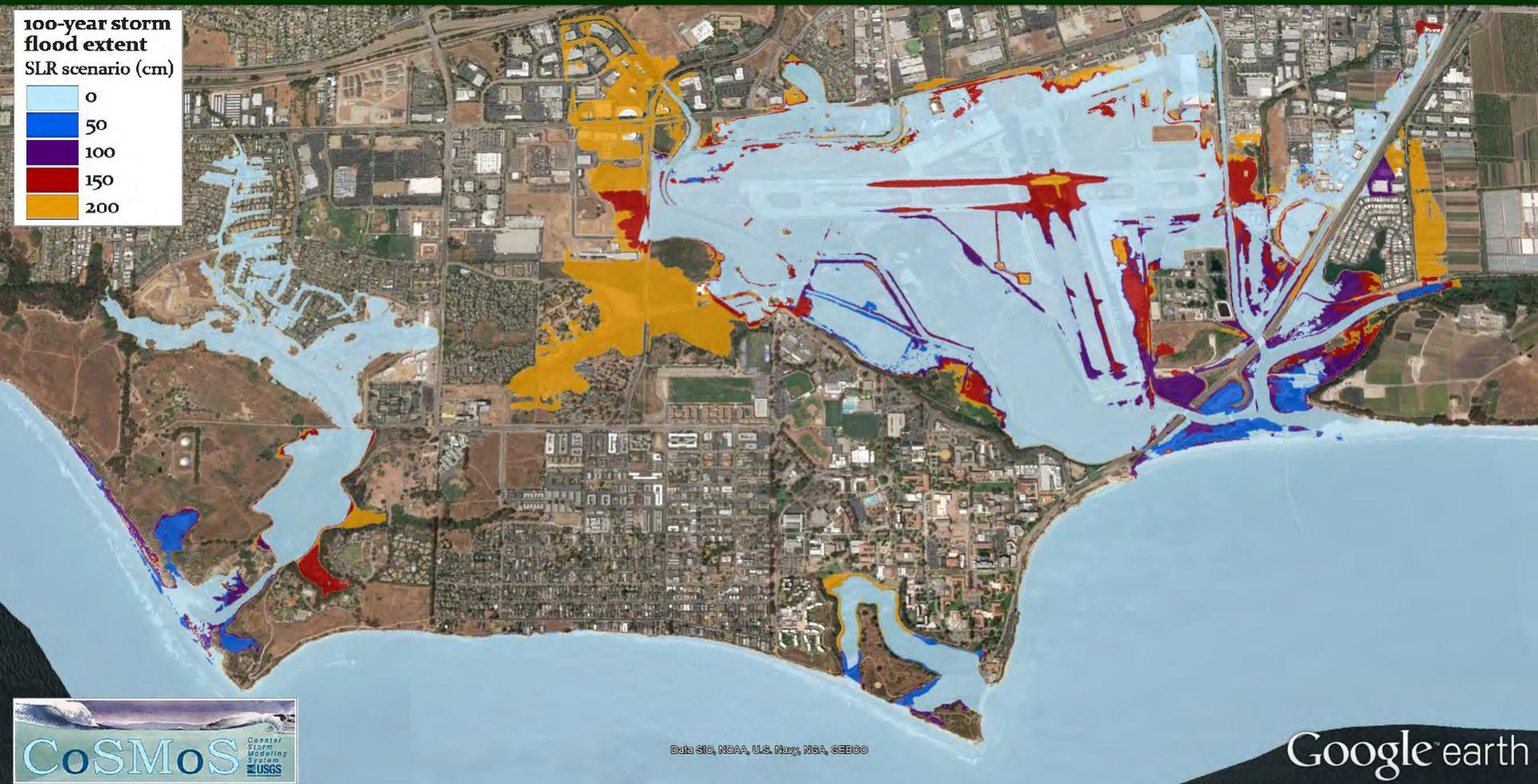
CoSMoS Winter 2015 Product Release

- 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, grids for flood depth, max. waves and currents
- 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

Flooding – Regional Overview



Flooding – Goleta



Flooding – Santa Barbara



Flooding – Carpinteria

100-year storm
flood extent
SLR scenario (cm)

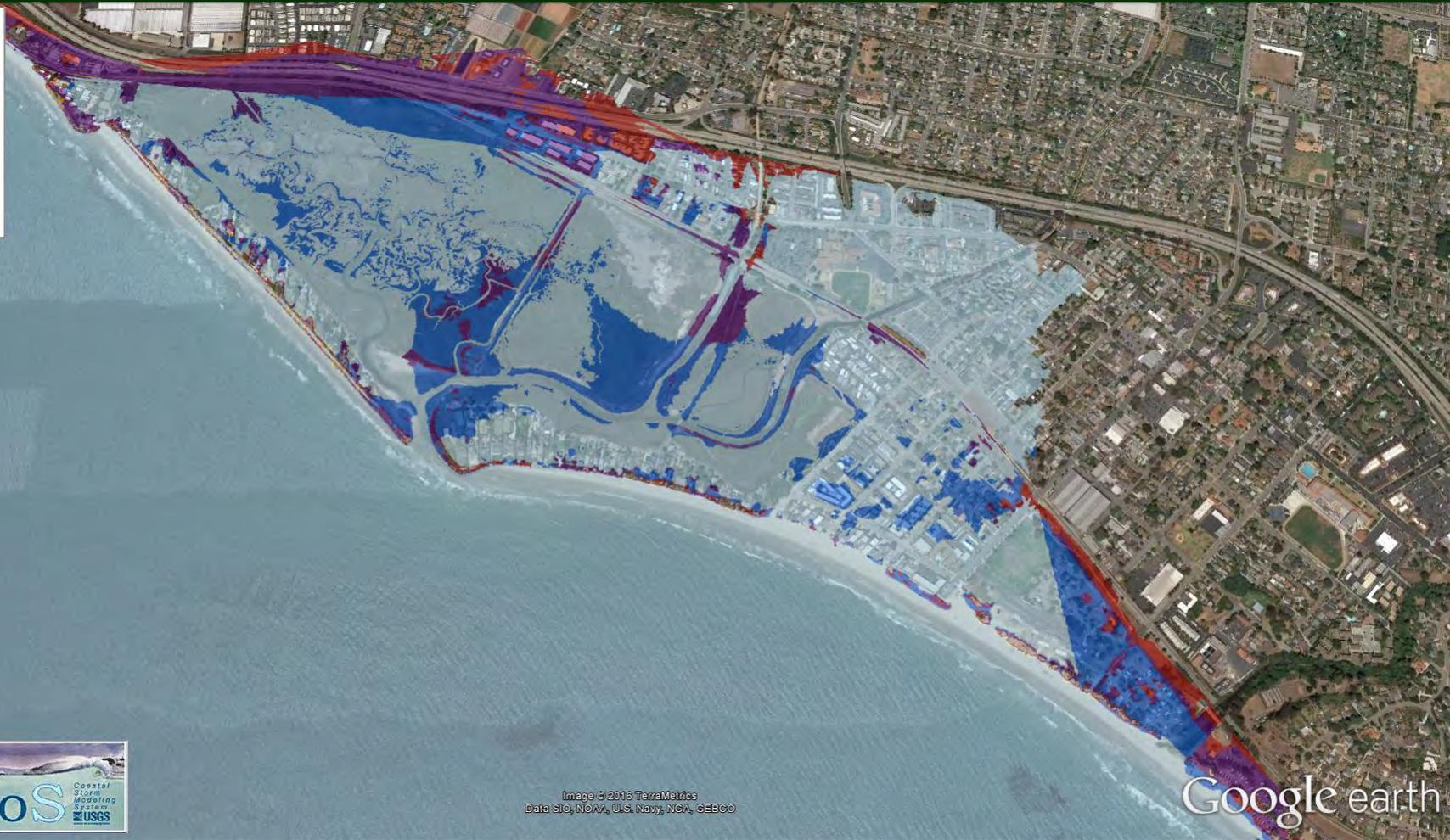
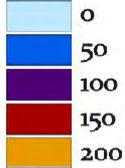


Image © 2016 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth

Flooding – Rincon

100-year storm
flood extent
SLR scenario (cm)



Google earth

Flooding – Ventura River Mouth

**100-year storm
flood extent**
SLR scenario (cm)

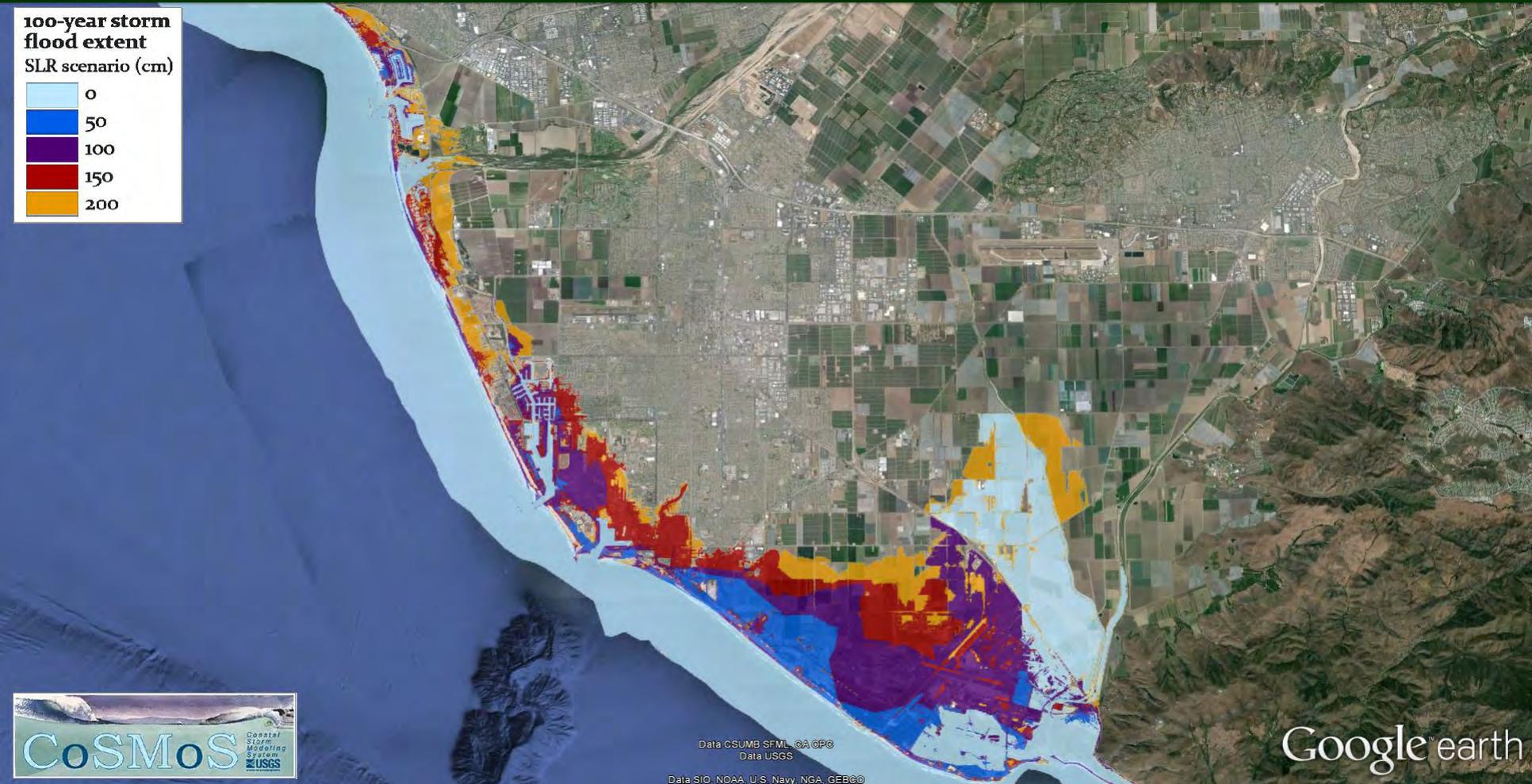
0
50
100
150
200



Google earth

Flooding – Santa Clara Alluvial Plain

100-year storm
flood extent
SLR scenario (cm)



Data CSUMB SFML, CA QPC
Data USGS

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth

Flooding – Pierpont/Ventura Harbor

100-year storm
flood extent
SLR scenario (cm)

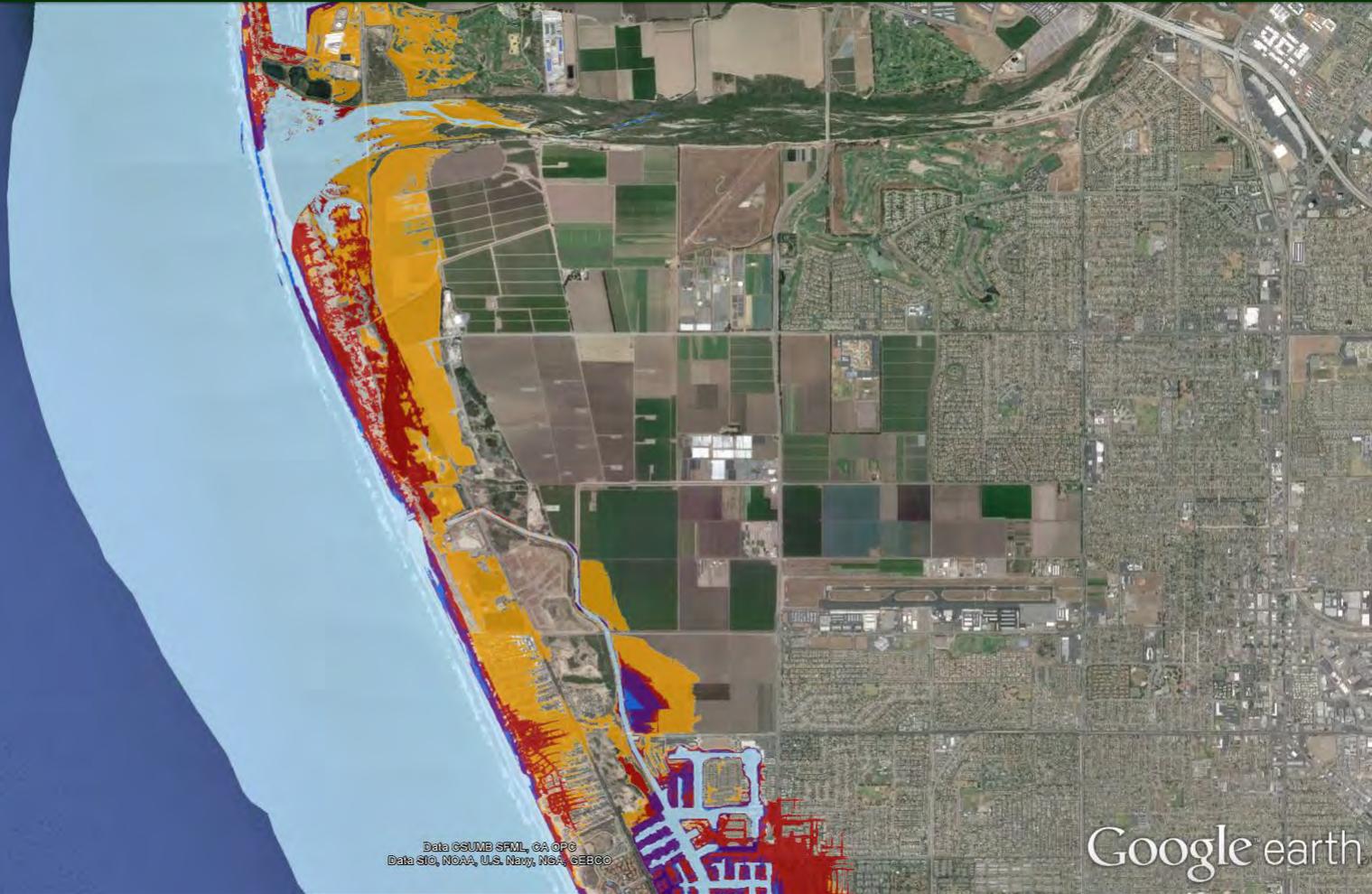


Data © SUMB SFML, CA OPC
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2016 TerraMetrics

Google earth

Flooding – Santa Clara River Mouth

100-year storm
flood extent
SLR scenario (cm)



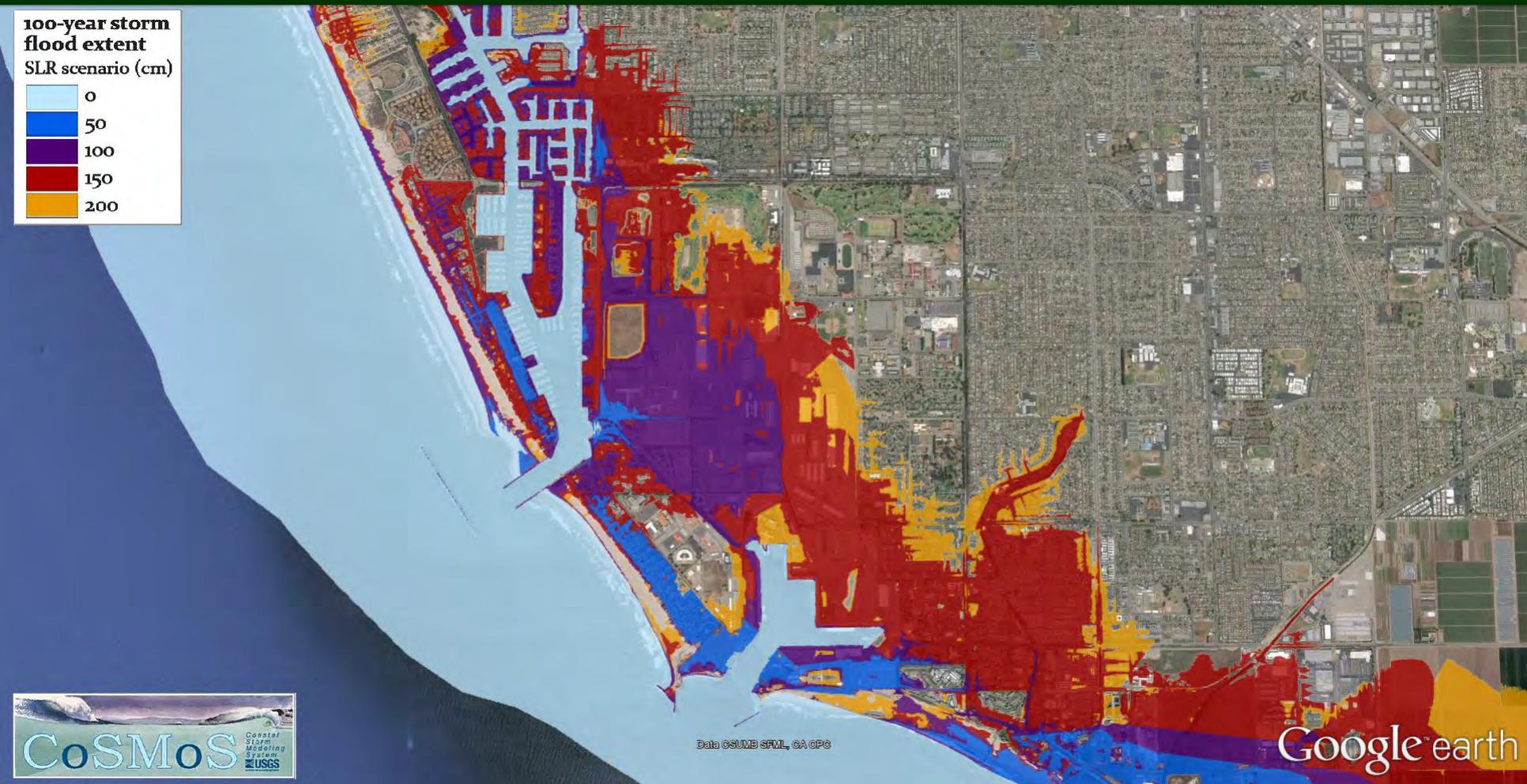
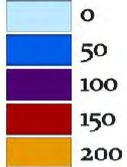
Data CSUMB SFML, CA OPG
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth



Flooding – Channel Islands Harbor

100-year storm
flood extent
SLR scenario (cm)

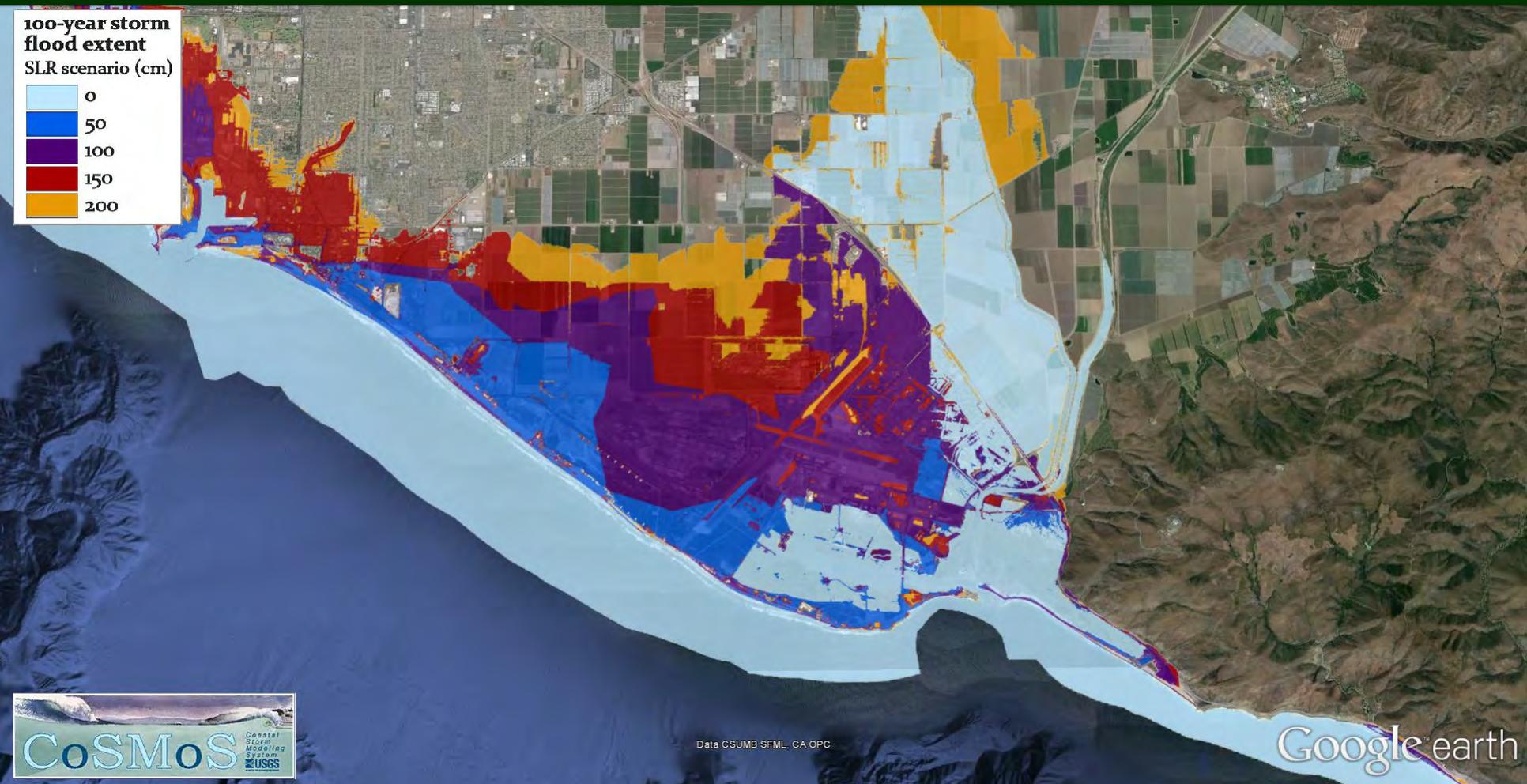


Data CSUMB SFML, CA OPC

Google earth

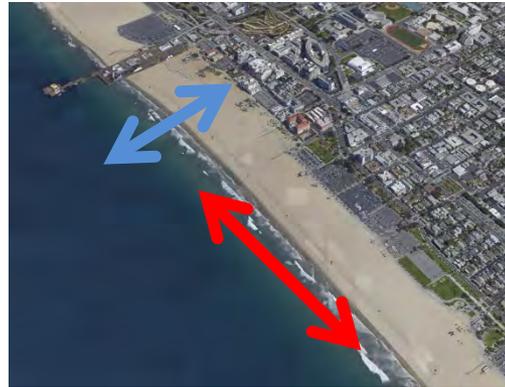
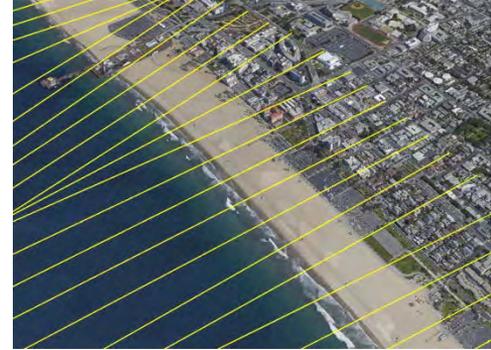


Flooding – Mugu



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**

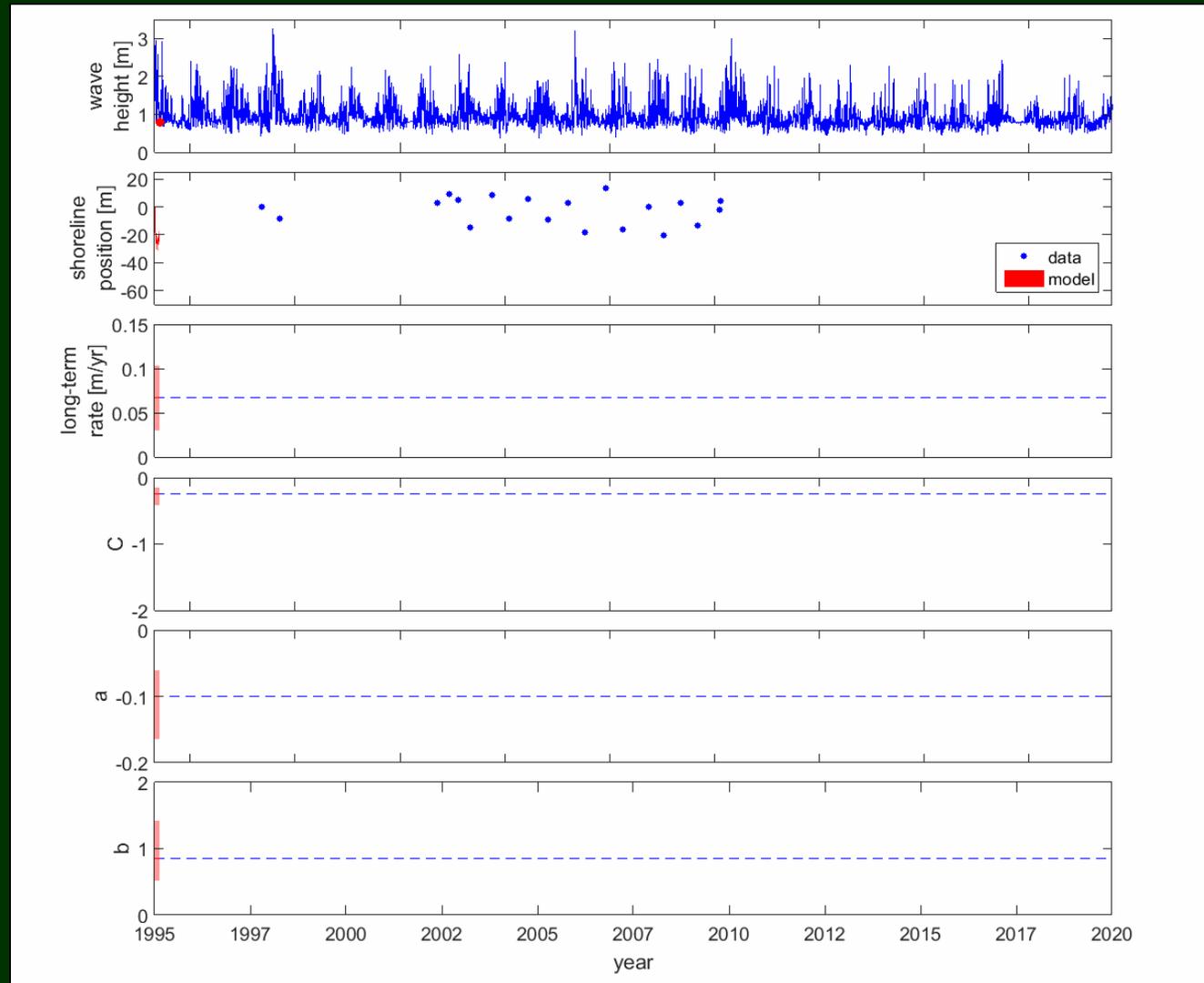


Data Assimilation

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.

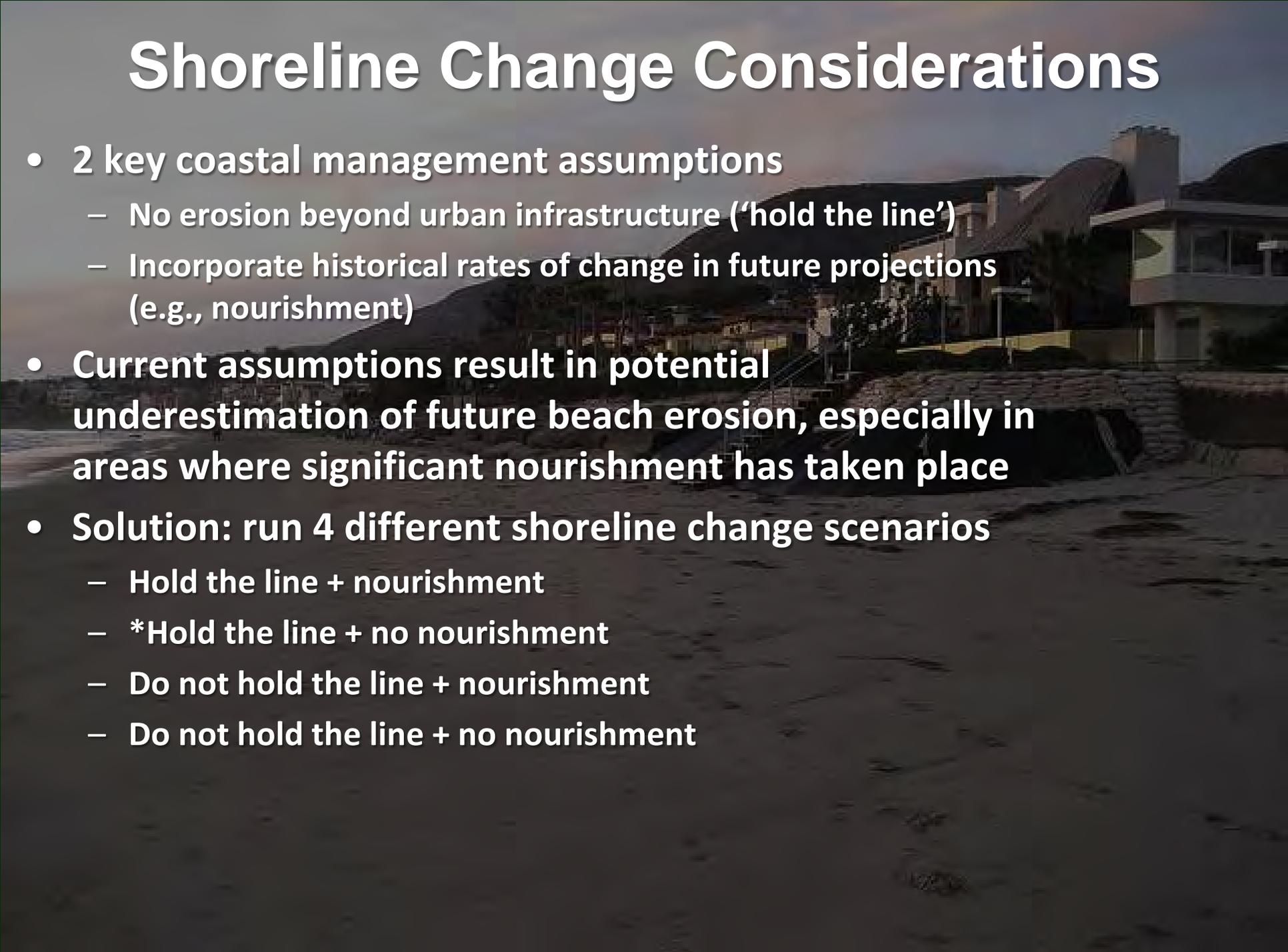
Simulation
output for a
single transect
at Del Mar
Beach:



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 – Gaviota

2100 shoreline position

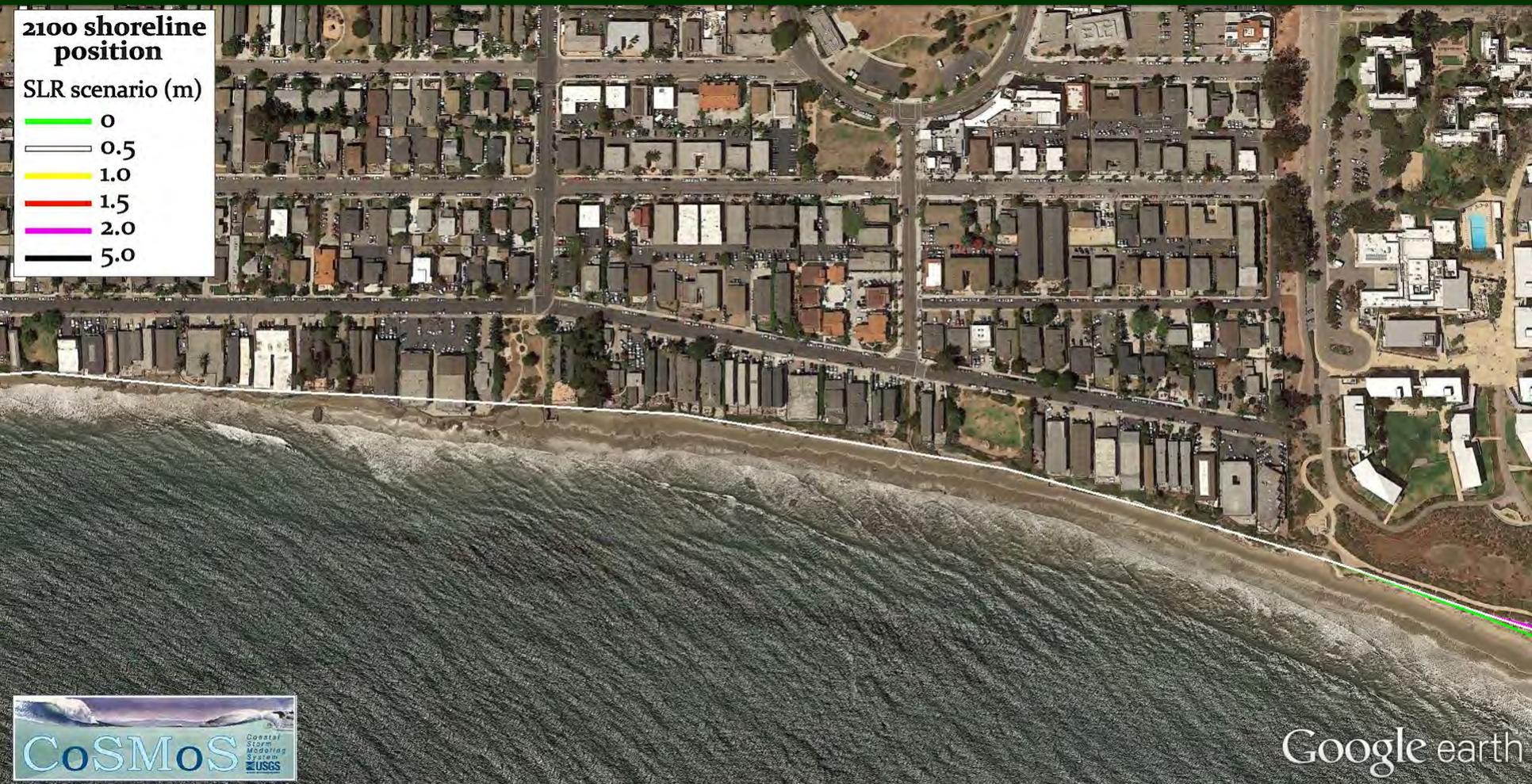
SLR scenario (m)

- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 5.0



Google earth

Shoreline Projections – Isla Vista



Shoreline Projections – Goleta



Shoreline Projections – East Beach



Shoreline Projections – Carpinteria



Shoreline Projections – Rincon

2100 shoreline position

SLR scenario (m)

- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 5.0



Google earth

Shoreline Projections – Ventura Pier

2100 shoreline position

SLR scenario (m)

- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 5.0



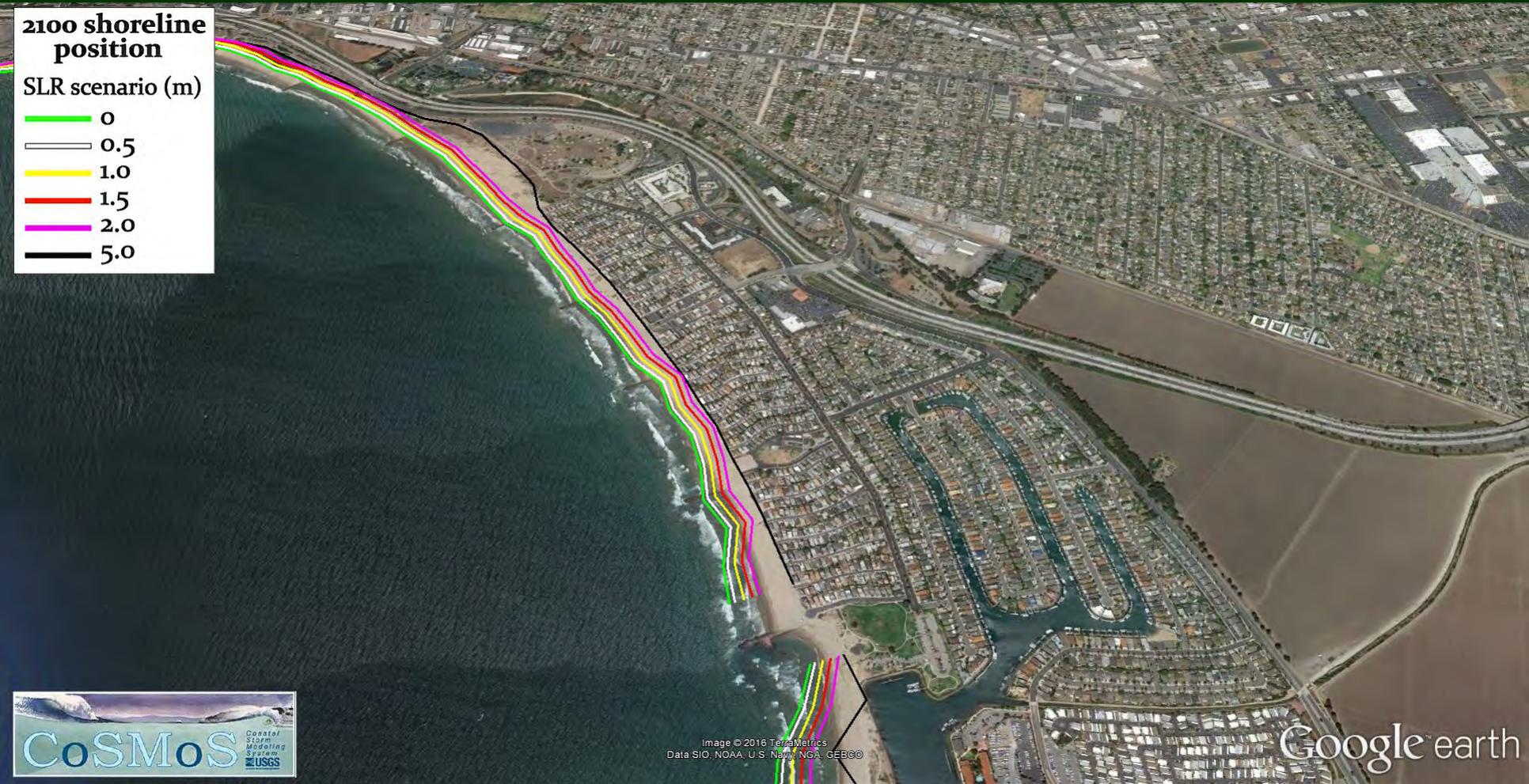
Google earth

Shoreline Projections – Pierpont

2100 shoreline position

SLR scenario (m)

- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 5.0



Google earth

Shoreline Projections – Santa Clara River

2100 shoreline position

SLR scenario (m)

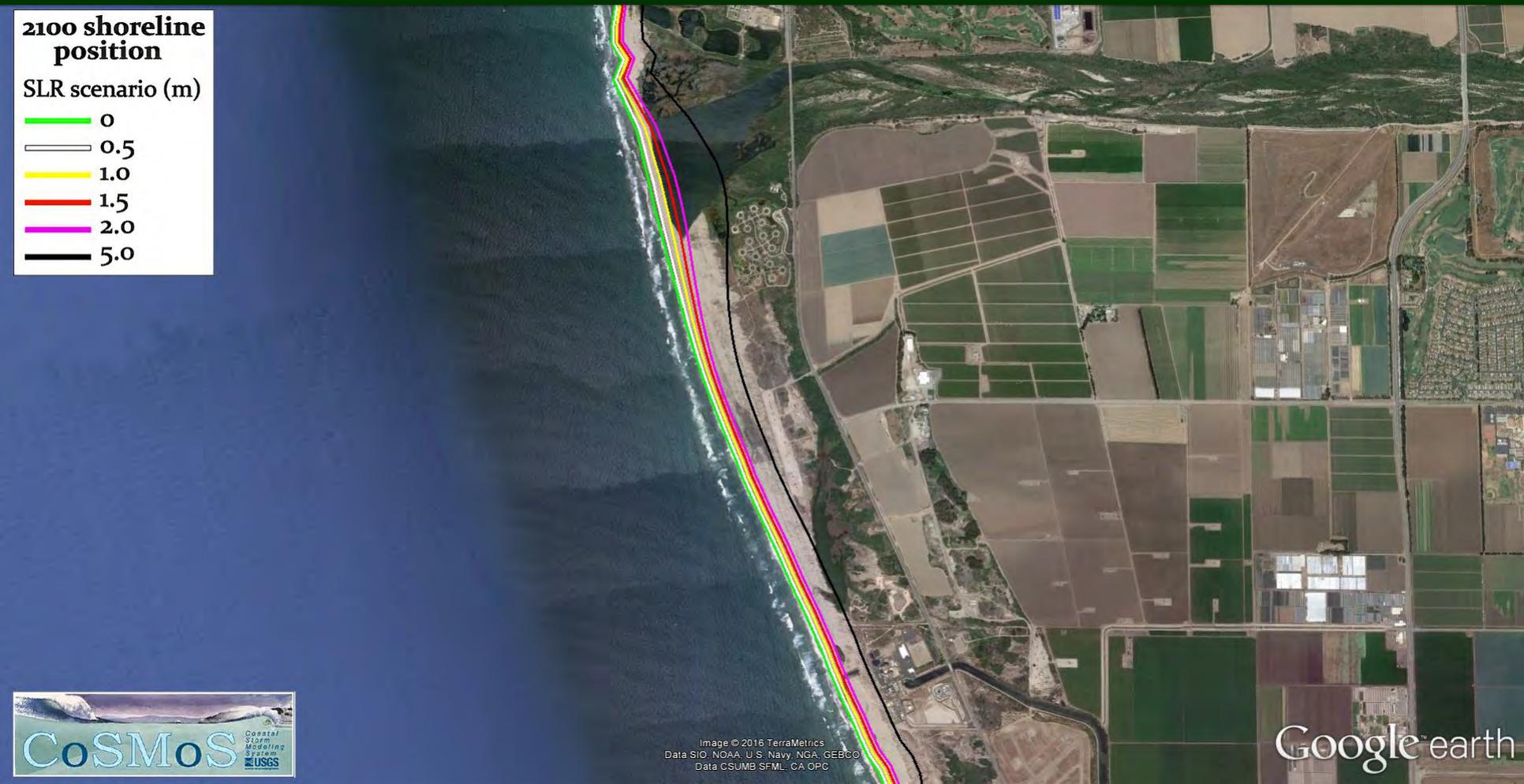
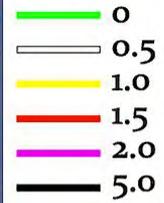


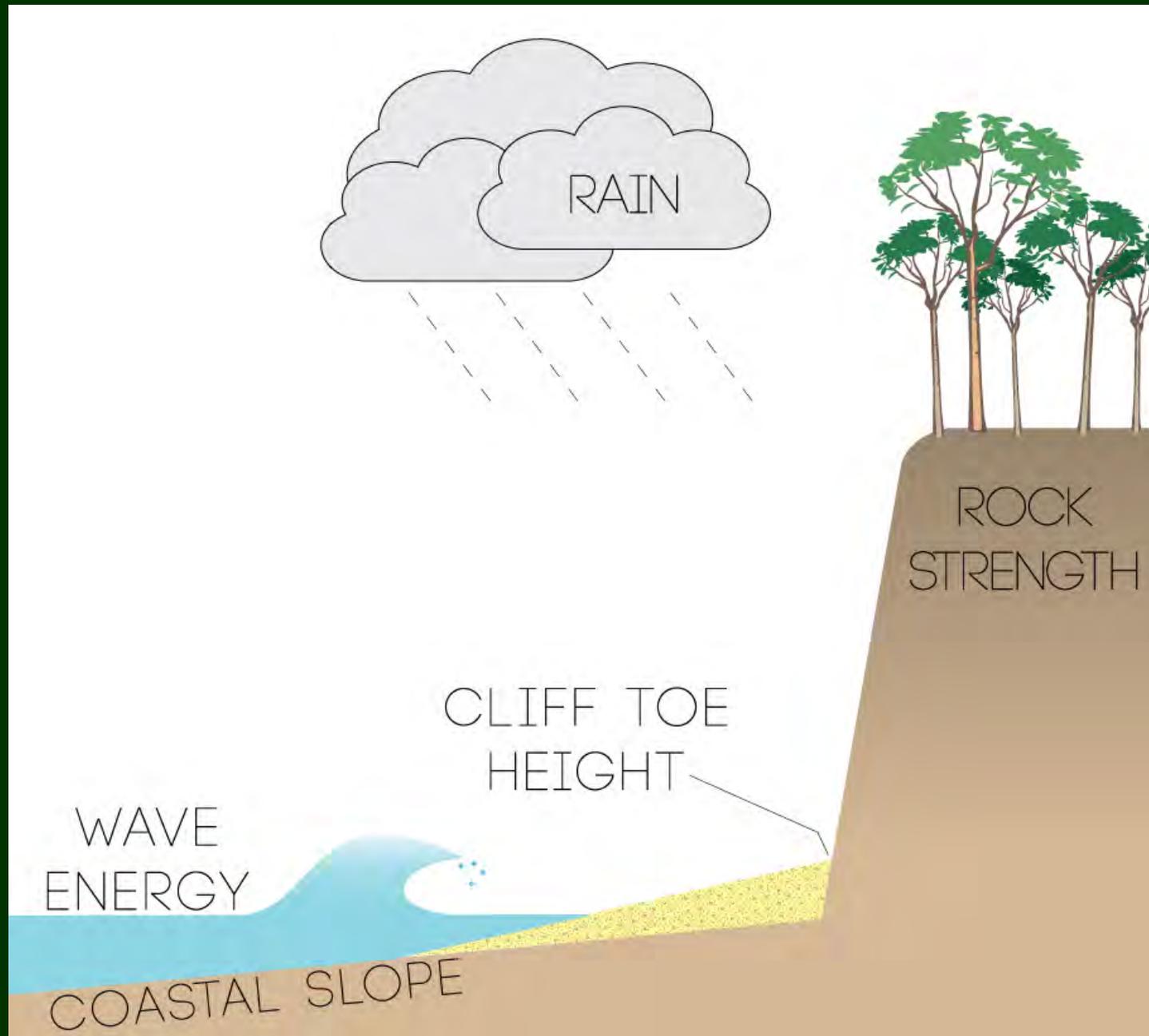
Image © 2016 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data CSUMB SFML, CA OPC

Google earth

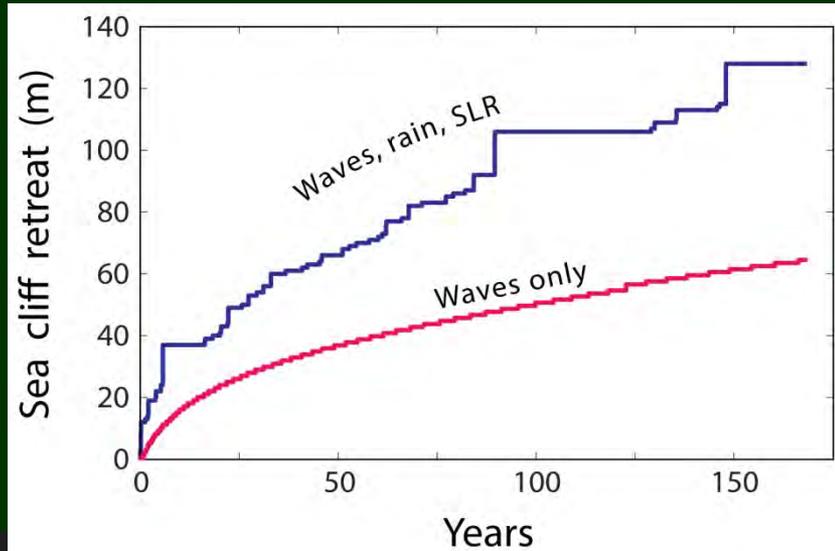
Shoreline Projections – Mugu



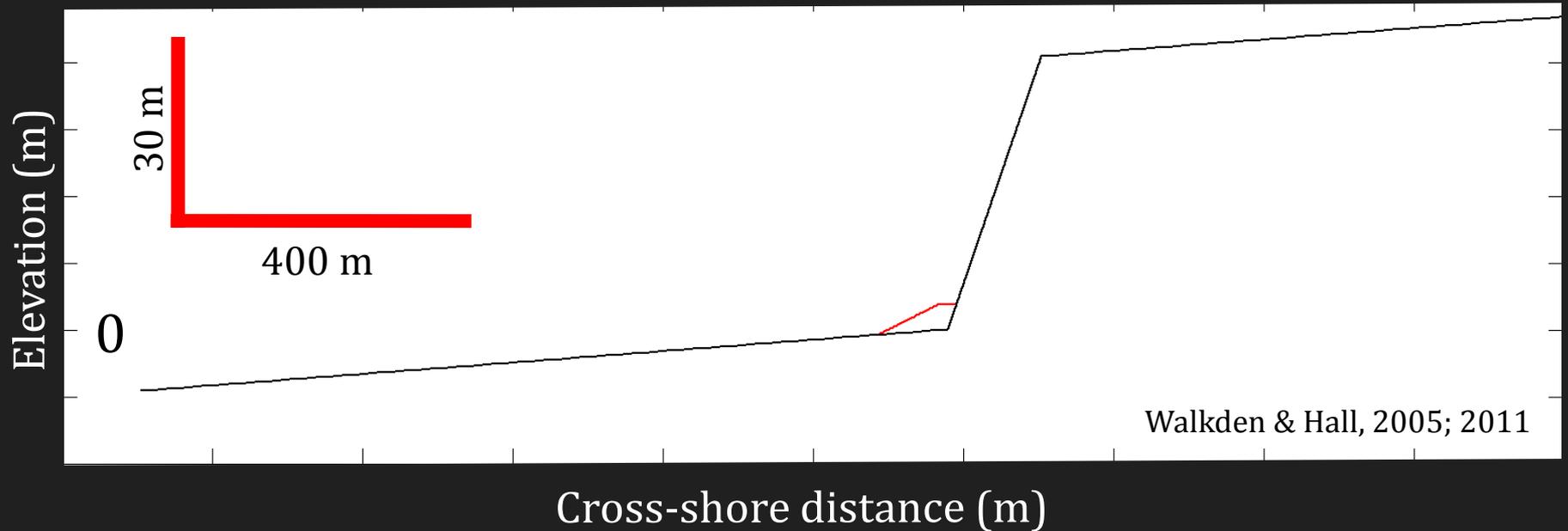
Factors Driving Sea Cliff Erosion & Retreat



Multi-decadal Models of Sea Cliff Erosion & Retreat

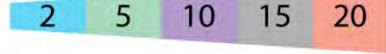


Rain, SLR cause more cliff retreat
(rain effects are in beta mode)

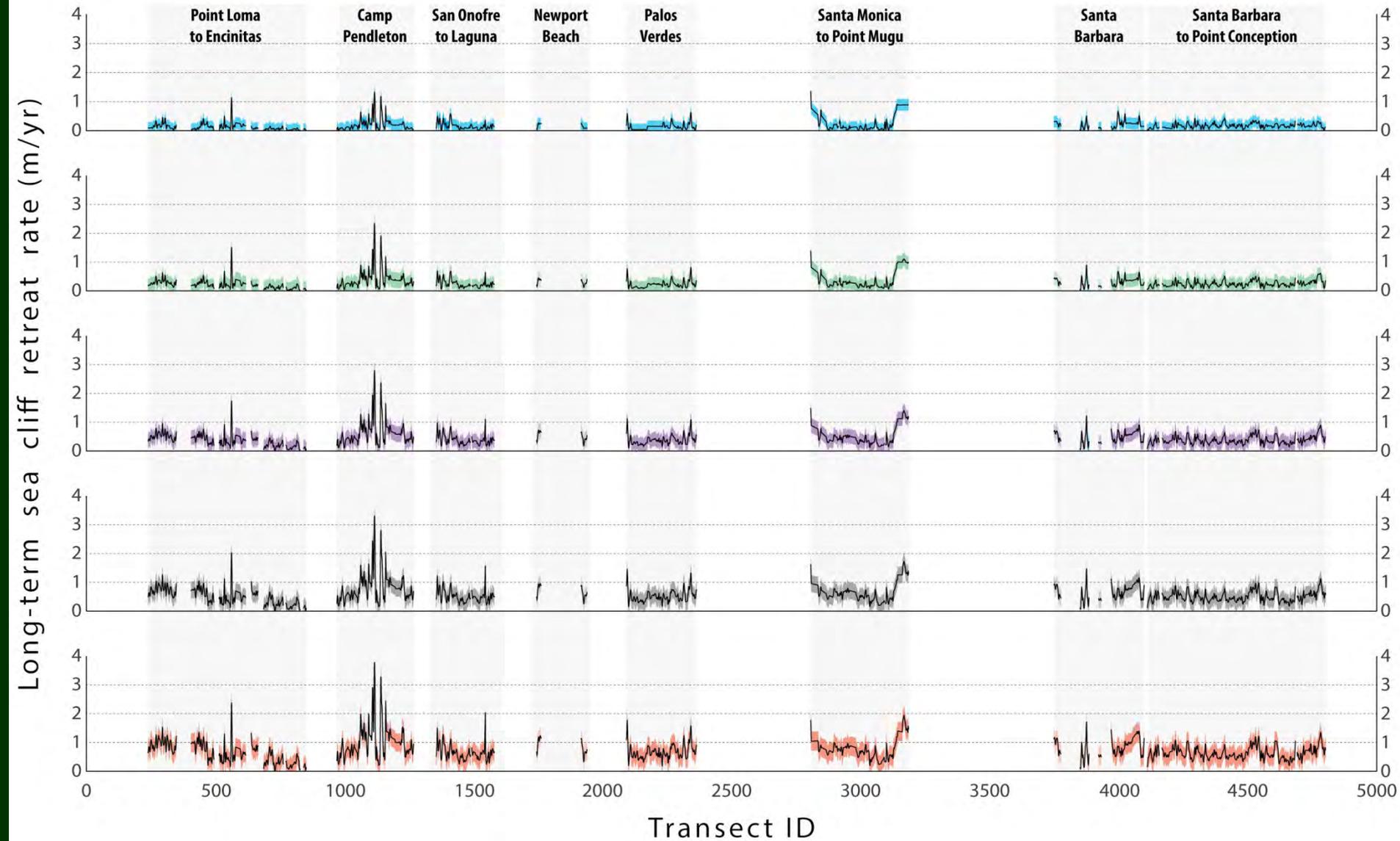


Results

sea level rise, mm/yr



uncertainty | projection



Cliff Retreat Projections – Gaviota

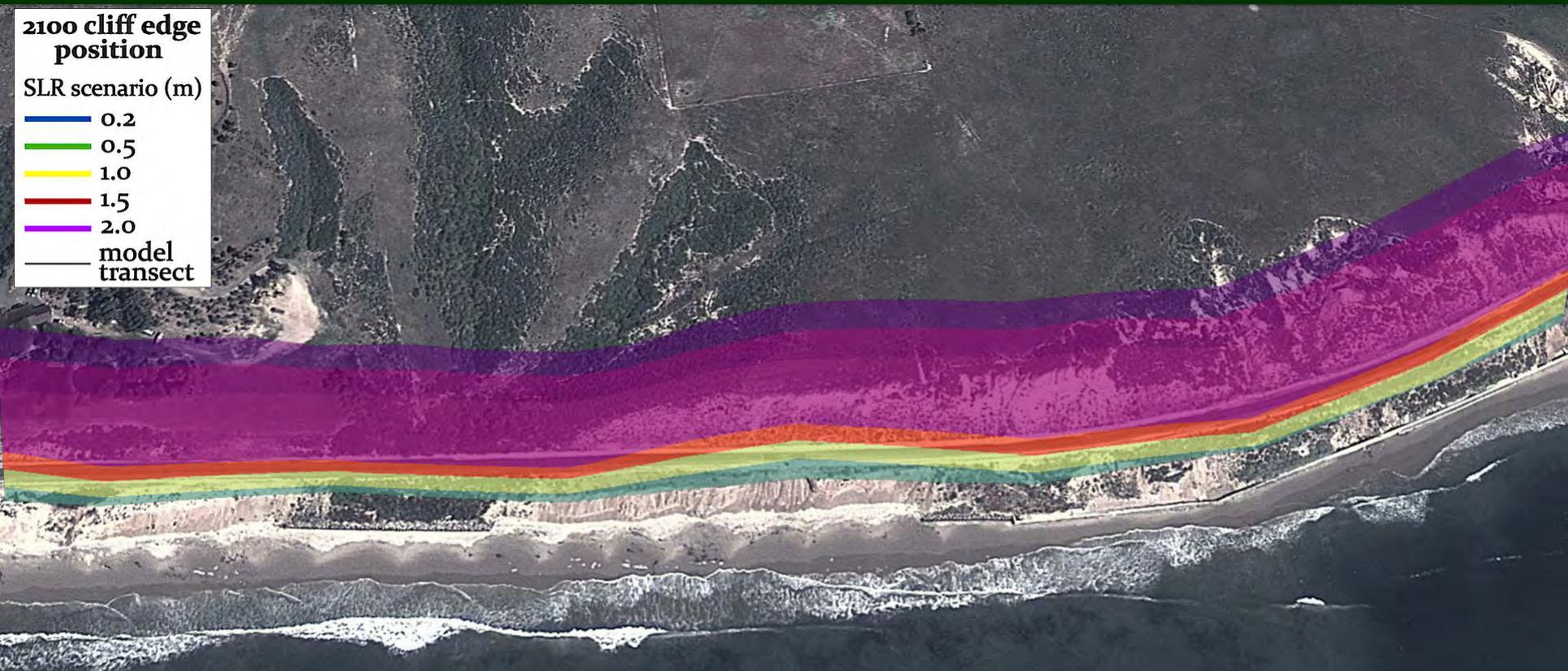


Image © 2016 DigitalGlobe

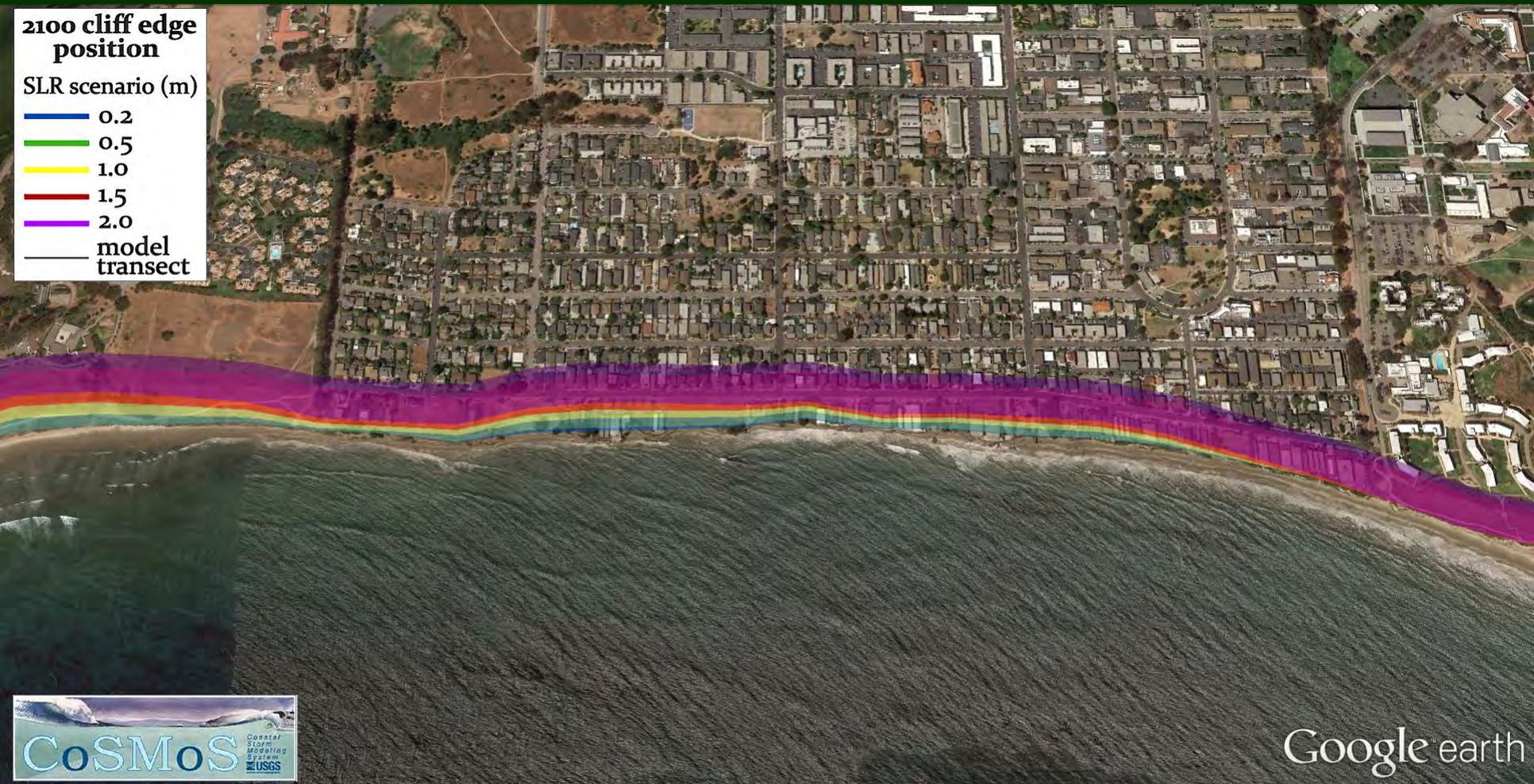
Google earth

Cliff Retreat Projections – El Cap



Google earth

Cliff Retreat Projections – Isla Vista



Cliff Retreat Projections – Hope Ranch



Cliff Retreat Projections – Mesa



Cliff Retreat Projections – Summerland



Cliff Retreat Projections – Carpinteria



Cliff Retreat Projections – South Ventura Co.

2100 cliff edge position
SLR scenario (m)

- 0.2
- 0.5
- 1.0
- 1.5
- 2.0
- model transect

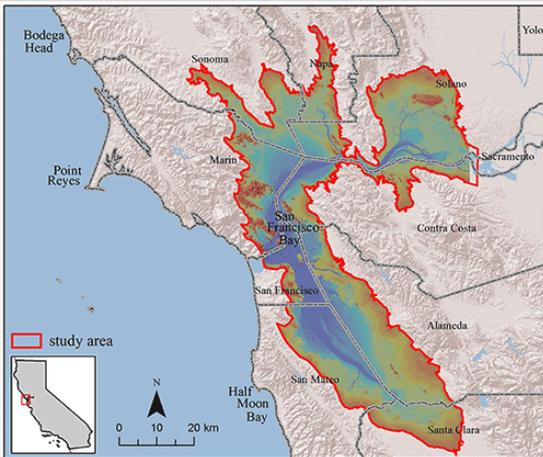
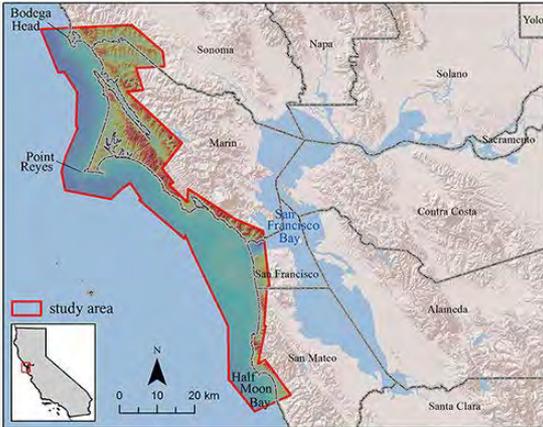


© 2016 Google

Google earth

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 (OCOOF) web tool
- Socioeconomic impacts and web tool
- Groundwater, hurricane impact pilots

*For more information, contact Patrick Barnard: pbarnard@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

