Santa Barbara and Ventura County CoSMoS Results

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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’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
- ‘1\textsuperscript{st} order screening tool’

**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

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

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 2.2 (2015)
- CoSMoS 2.0 (2013)
- CoSMoS 1.0 (2011)
- CoSMoS 3.0 (2016)
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

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 1.5 m in 0.5 m increments delivered Fall 2015
CoSMoS 3.0 Southern California

Global

Global conditions of future climate scenarios

Global conditions of future climate scenarios

Regional

Tides, water levels, and regional forcing

Regionalized storm response

20-year storm return

Local

High resolution hydrodynamics and waves

Fluvial discharge

VLM

Coastal change

results projected onto hi-res DEM

GCM winds

WW3 wave model

Delft FLOW-WAVE

XBEACH

Open coast
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

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

Los Angeles tide gauge

RMS = 12 cm
$R^2 = 0.97$
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
- Overlaid and differenced from the 2 m resolution DEM

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

Flooding – Ventura River Mouth
Flooding – Santa Clara Alluvial Plain

Flooding – Pierpont/Ventura Harbor

Flooding – Santa Clara River Mouth

Flooding – Channel Islands Harbor

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):

- 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

Model type:
- longshore + cross-shore + rate
- cross-shore + rate
- historical rate only
- no prediction (sea-wall, harbor, etc.)
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
Shoreline Projections – Isla Vista
Shoreline Projections – Goleta
Shoreline Projections – East Beach
Shoreline Projections – Carpinteria

2100 shoreline position
SLR scenario (m)
- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 5.0

Google earth
Shoreline Projections – Pierpont
Shoreline Projections – Santa Clara River
Shoreline Projections – Mugu
Factors Driving Sea Cliff Erosion & Retreat:

- Rain
- Wave energy
- Cliff toe height
- Coastal slope
- Rock strength
Multi-decadal Models of Sea Cliff Erosion & Retreat

Rain, SLR cause more cliff retreat

(rain effects are in beta mode)

Walkden & Hall, 2005; 2011
Results

Sea level rise, mm/yr

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
Cliff Retreat Projections – Gaviota
Cliff Retreat Projections – El Cap
Cliff Retreat Projections – Isla Vista
Cliff Retreat Projections – Hope Ranch

2100 cliff edge position

SLR scenario (m)
- 0.2
- 0.5
- 1.0
- 1.5
- 2.0

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model transect

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Google earth
Cliff Retreat Projections – Mesa
Cliff Retreat Projections – Carpinteria
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

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

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