San Diego County CoSMoS Results

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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)
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)

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%

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

Sunset Beach, Sean Hiller
The Wedge
Imperial Beach, photo by Chris Helmer
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’

**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

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
- 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
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 2.0 m in 0.5 m increments
CoSMoS 3.0 Southern California

Global conditions of future climate scenarios

GCM winds

WW3 wave model

Regional

Tides, water levels, and regional forcing

SWAN wave model

Regionalized storm response

20-year storm return

Fluvial discharge
VLM
Coastal change

Local

High resolution hydrodynamics and waves

Delft FLOW-WAVE

Open coast

results projected onto high-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

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
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

To generate maps of flood extents, duration, and depth

High resolution model results

XBeach results along open coast

Flood map
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

Flooding – San Diego County Overview

Flooding – San Diego Bay
Flooding – Mission Beach
Flooding – Del Mar
Flooding – Camp Pendleton South

100-year storm flood extent
SLR scenario (cm)

- 0
- 50
- 100
- 150
- 200

CoSMoS
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 type:
- longshore + cross-shore + rate
- cross-shore + rate
- historical rate only
- no prediction (sea-wall, harbor, etc.)

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

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

race track
Shoreline Projections – Camp Pendleton South

2100 shoreline position
SLR scenario (m)
- Green: 0
- Yellow: 0.5
- Pink: 1.0
- Red: 1.5
- Purple: 2.0
- Black: 5.0

Oceanside

Image © 2016 TerraMetrics
Data SD: NOAA, U.S. Navy, NGA, DEBCO

CoSMoS

Google earth
Factors Driving Sea Cliff Erosion & Retreat

- Rain
- Rock strength
- Cliff toe height
- Wave energy
- Coastal slope
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

[Graph showing sea level rise projections across different transects and transect IDs.]
Cliff Retreat Projections – Point Loma
Cliff Retreat Projections – La Jolla

2100 cliff edge position
SLR scenario (m)
- 0.2
- 0.5
- 1.0
- 1.5
- 2.0
- model transect

CoSMoS
Cliff Retreat Projections – Del Mar
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

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