Orange County CoSMoS Results

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Huntington Beach Pier, January 1983
(H. Lorren Au Jr., Orange County Register)
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%

Orange County 21st Century Vulnerability (Pacific Institute, 2009)
-110,000 people at risk
-$17 billion in property
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 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
  - SWAN wave model
  - Regionalized storm response
  - 20-year storm return

**Local**
- High resolution hydrodynamics and waves
  - Delft FLOW-WAVE
  - XBEACH
  - Fluvial discharge
  - VLM
  - Coastal change
  - Results projected onto hi-res DEM

Open coast
Overview of Processes Included in CoSMoS

The 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

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 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 – Seal Beach/ Sunset Beach
Flooding – Bolsa Chica
Flooding – Newport Beach

100-year storm flood extent
SLR scenario (cm)
- 0
- 50
- 100
- 150
- 200

Data USGS
Data CSUMB SFML, CA OPC
Flooding – Corona del Mar

100-year storm flood extent
SLR scenario (cm)
- 0
- 50
- 100
- 150
- 200
Flooding – Laguna

100-year storm
flood extent

SLR scenario (cm)

0
50
100
150
200
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 – Newport Beach

2100 shoreline position

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

Data USGS
Shoreline Projections – Capistrano Beach
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

Sea level rise (mm/yr)

Transsects:
- Point Loma to Encinitas
- Camp Pendleton
- San Onofre to Laguna
- Newport Beach
- Palos Verdes
- Santa Monica to Point Mugu
- Santa Barbara

Long-term sea cliff retreat rate (m/yr)

Transect ID

Uncertainty and projection indicated.
Cliff Retreat Projections – Corona del Mar

2100 cliff edge position
SLR scenario (m)

- 0.2
- 0.5
- 1.0
- 1.5
- 2.0

model transect
Cliff Retreat Projections – Dana Point

2100 cliff edge position

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

model transect
Cliff Retreat Projections – N. San Clemente
GIS-Based Exposure to Hazards

JURISDICTIONS

- Study area
- 9 COUNTIES
- 56 INCORPORATED CITIES

ASSETS

- RESIDENTS (w/ demographics)
- EMPLOYEES (by sector)
- BUSINESS SECTORS
- PARCEL VALUES
- BUILDING REPLACEMENT VALUE

HAZARD

- FLOODING EXTENT
- based on:
  - STORM FREQUENCY
    - None
    - Annual
    - 20-year
    - 100-year

- SEA LEVEL RISE SCENARIOS
  - 0 cm
  - 25 cm
  - 50 cm
  - 75 cm
  - 100 cm
  - 125 cm
  - 150 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

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