Determining climate change-related impacts with the Coastal Storm Modeling System (CoSMoS)

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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.csc.noaa.gov/digitalcoast/tools/slrviewer

• 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://data.prbo.org/apps/ocof/
Components of Total Water Level Predictions

- **wave run-up** $h_R$ 2 m +
- **wave set-up** $h_{wv}$ 1.7 m
- **storm surge** $h_{ss}$ 1.0 m
- **seasonal effects** $h_{se}$ 0.3 m
- **tide difference** $h_{tide}$ 2 m
- **sea level rise** $h_{slr}$ 2 m

$H$ decreases rapidly due to breaking

waves increase in height towards breaking zone (shoaling)

Bolinas Lagoon

Bathtub model (SLR + MHHW)

Physics included (SLR + Extreme Event)

(adapted from Frisby and Goldberg, 1981)
State-of-Science Modeling System

- Acquire the most accurate topographic/bathymetric information
- Include all the physics: waves, tides, surge
- Use the latest sea level rise and storm scenarios from climate models developed for IPCC 2013 (CMIP5)
- Relevant products
CoSMoS: A Tool for Coastal Resilience

- Physics-based numerical modeling system for assessing coastal hazards on West Coast
- Predicts coastal hazards for the full range of sea level rise and storm possibilities using the most sophisticated global climate and ocean modeling tools
- Developing coastal vulnerability tools with guidance from federal (e.g., NOAA, NPS), state (e.g., California State Parks), and city governments (City of San Diego, L.A., and San Francisco) to meet their planning and adaptation needs
Model Inputs

• Elevation data (DEM)
• Waves (from GCMs)
• Wind and atmospheric pressure (from GCMs)
• Sea level rise (SLR) scenarios

Why use Global Climate Models?

• Future storm conditions are dependent on the complicated interaction between the Earth’s atmosphere and ocean systems
• The past several decades of wave measurements may not be indicative of the future wave climate
Model Outputs

- Flooding depth, extent and uncertainty
- Waves
- Currents
- Shoreline and profile change (event-based)
- Cliff failures
Model Assumptions

- GCMs provide the best representation of future wave climate
- DEM is adequate representation of future beach and nearshore elevation and slope (i.e., morphology)
- No management action
Model Applications

- Climate impacts assessments
- Coastal impacts for range of possible current AND future conditions (SLR and storms), ideal for Infrastructure and ecosystem vulnerability
- Web-based coastal planning user-interface
Model Uncertainties

- DEM: model processes and local-scale results limited to resolution and accuracy
- Modeling total water levels
- Projected forcing (i.e., storm conditions)
- Joint occurrence of SLR, storm and spring tide
Model Constraints (e.g., advantages/disadvantages)

- Ideal for planning for full range of potential current AND future coastal impacts
- Publicly available data and access to support
- Active scientific development
- Does not predict future beach morphology changes (but we are actively working on this)
Future Shoreline Change

- NOT incorporated in current version of CoSMoS
- Data-driven approaches show promise - current development within USGS (predicting long-term changes from extensive data analysis)
- Probabilistic and process-based approaches (GCMs and physics-based models)
- Ensemble projection with uncertainty is ideal approach
CoSMoS Version 1.0- SoCal

• Limited set of scenarios
  – January 2010 hindcast
  – January 2010 hindcast + 50 and 100 yr SLR per CA guidelines
Del Mar
CoSMoS Version 2.0- NorCal

- Collaboration with NOAA, PRBO Conservation Science and NPS- Our Coast-Our Future (OCOF)
- Focus on climate change impacts to outer coast and SF Bay (NERR)
- Sophisticated product tool with emphasis on ecological impacts
- Storm scenarios developed using latest IPCC (2013) radiative forcing scenarios and GCMs
- Flood flows and Bay hydrodynamics modeled, incl. depth of flow and uncertainty
- Fluvial discharge (2013)
- Wind forcing downscaled (2013)
- Relative land movement estimated (2013)

Subsidence in San Jose (1933-1969)
Identifying Future Risk with CoSMoS 2.0

1. Global forcing using the latest climate models

2. Drives global and regional wave models

3. Scaled down to local hazards projections
Scenario Summary

- January 2010 storm hindcast- testing and validation
- Global wave modeling: 2 emissions scenarios, 4 Global Climate Models
- Storm event and wave conditions = daily, annual, and 10, 20 and 100-year return interval events
- SLR scenarios = 0 to 2 m in 25 cm increments, and 5 m extreme scenario
- Total of 50 future scenarios of SLR and wave conditions
Future Storms and Wave Direction

- No significant change in wave height through 2100
- BUT extreme waves projected to come more from the south by 10-15°
- Change in wave direction will expose more south-facing beaches to hazardous conditions

<table>
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<th>scenario</th>
<th>$h_s$ (m)</th>
<th>$t_p$ (s)</th>
<th>$d_p$ (deg)</th>
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Online Tool- Flooding Extent

http://data.prbo.org/apps/ocof/
Online Tool - Flooding Uncertainty

http://data.prbo.org/apps/ocof/
CoSMoS - The Path Forward

- Pilot project for Southern California (Pt. Conception to Mexico) completed- kmz files are available showing flooding extent
- Supporting the AdaptLA climate change assessment
- North-central coast will be completed and tool available in early 2013
- New Southern California project proposed for 2013-2015
- Available as a real-time warning system for emergency managers, lifeline operators, and resource managers
- Internal project at USGS drives ongoing research and development of this modeling system

For more information, contact Patrick Barnard: pbarnard@usgs.gov
http://walrus.wr.usgs.gov/coastal_processes/socalhazards
http://data.prbo.org/apps/ocof/