Projected Climate Impacts along the Central California Coast

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Collaborators and funders:
Despite recent snowstorms, Colorado’s drought conditions continue in “anomalous” direction

There were only seven other weeks in the past 20 years that have been as intensely dry as the state’s current status.

California's Ancient Redwoods Face New Challenge From Wildfires And Warming Climate

Another day of record-breaking heat in Phoenix as heatwave persists
So how does this affect our coast....

- Warming temperatures reduce ice sheets and glaciers
  → increase ocean volume
  → affect vertical motion of land
- Shifts in atmospheric circulation
  → change storm tracks, winds, and waves
- Increasing ocean temperature and changes in global wind patterns
  → affect changes in sea surface

→ many global changes contribute to how sea level affects us locally
So how does this affect our coast....
So how big is the problem?

- Over 1 billion people are expected to live in the coastal zone by the middle of the 21st century
- 27 million presently live in CA coastal counties
- Over 600,000 people in CA at risk of flooding by the end of the century, in addition to over ~$150 billion in property, ~6% of CA GDP
- Initial estimates of 30,000 residents and $5.5 billion in property at risk in Santa Cruz and Monterey Counties by 2100
21st Century projections in California

State SLR Guidance for 2100
-Likely range of 30-110 cm
-3.05 m upper bound

Waves
-No significant changes in wave height
-More southerly wave directions

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

***Net effect***
-Today’s 100-year coastal water level event is projected to occur every 1-5 years by 2050 for much of California AND every daily high tide by 2100
-Greatest impacts on low-lying coastal areas
Coastal Vulnerability Approaches

Static

• Passive model, hydrological connectivity
• Tides only
• ‘1st order screening tool’

“Bathtub” models under predict flooding hazards

- tide difference 2.0 m
- sea level rise (SLR) 1.0 m

MSL (datum)
Coastal Vulnerability Approaches

**Static**
- Passive model, hydrological connectivity
- Tides only
- ‘1st order screening tool’

**Dynamic: USGS-CoSMoS**
- All physics modeled
- Forced by Global Climate Models
- Includes wind, waves, atmospheric pressure, shoreline change
- Range of SLR and storm scenarios

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**Graphical Representation**
- **VLM**
- **Wave set-up & run-up**: 2.0 m +
- **River discharge**: 0.2 m
- **Storm surge**: 1.0 m
- **Seasonal effects**: 0.3 m
- **Tide difference**: 2.0 m
- **Sea level rise (SLR)**: 1.0 m
- **Wave height**
- **MSL (datum)**

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**USGS**
Coastal Storm Modeling System (CoSMoS)

- 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
Carmel and Monterey
High-resolution Delft-3D grid development and elevation data
SLR = 0 to 2 m at 0.25 m increments, and 5 m

Background

1-year storm

100-year storm

20-year storm

Sea level anomalies (derived from GCM sea-surface temperature anomalies)

Pacific Ocean waves

Fluvial discharges

Astronomic spring tide

Storm surge

= 40 scenarios
Shoreline change: CoSMoS-COAST

- A (hybrid) numerical model to simulate long-term shoreline evolution
- Modeled processes include:
  - Longshore and Cross-shore transport
  - Effects of sea-level rise
  - Sediment supply by natural & anthropogenic sources

CoSMoS-COAST:
Coastal
One-line
Assimilated
Simulation
Tool

Cliff retreat

Ensemble of 5 different models to relate
- Wave impacts
- SLR
- Historical cliff behavior

Carmel
CoSMoS flood projection for 0 m SLR, 100-year storm
Carmel
CoSMoS flood projection for 1.0 m SLR, no storm

Preliminary Information - Subject to Revision. Not for Citation or Distribution.
Carmel

CoSMoS flood projection for 1.0 m SLR, 100-year storm
Carmel
CoSMoS flood projection for
2.0 m SLR, no storm
Carmel

CoSMoS flood projection for 2.0 m SLR, 100-year storm
Carmel
CoSMoS flood projection for
0 m SLR, 100-year storm
Carmel
CoSMoS flood projection for 1.0 m SLR, no storm
Carmel

CoSMoS flood projection for 1.0 m SLR, 100-year storm

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Carmel
CoSMoS flood projection for **2.0 m SLR, no storm**
Carmel
CoSMoS flood projection for **2.0 m SLR, 100-year storm**
Web tool - Flooding

Our Coast, Our Future tool: www.ourcoastourfuture.org
Web tool – Flood potential

Our Coast, Our Future tool: www.ourcoastourfuture.org
Cliff: 2 coastal management scenarios
  - No erosion beyond existing structures (‘hold the line’), or not

Shoreline: 4 coastal management scenarios
  - No erosion beyond urban infrastructure (‘hold the line’), or not
  - Incorporate historical rates of change in future projections (e.g. nourishment), or not
Coastal Climate Impacts by 2100

- 600,000+ residents
- $150 billion in property
- 4,700 km of roads
- 350 critical facilities (e.g., schools, police stations, hospitals)

California

Hazards Exposure Reporting and Analytics (HERA)
www.usgs.gov/apps/hera
Common SLR mitigation strategies:

- Retreat!
- Elevate
- Block
- Restore+

What about groundwater?
Coastal Groundwater response to SLR

- Major issues
  - Emergence/Inundation
  - Shallower coastal groundwater
  - Saltwater intrusion, major hazard for agriculture

- Inundation may exceed overland flooding and happen much sooner
- May impact infrastructure with no warning
- Low-lying areas most vulnerable

Groundwater - Carmel

Groundwater Depth (m)
- SLR: 1m
- Inundated (marine)
- Emergent
- Very Shallow (0 - 1m)
- Shallow (1 - 2m)
- 2 - 5m
- >5m

Sea level relative to MHHW, K 1.0

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC. © OpenStreetMap contributors, and the GIS User Community
Groundwater - Carmel

Sea level relative to MHHW, K 1.0
What makes CoSMoS unique?

- Explicit, high-resolution, dynamic modeling of waves, currents, storm surge, flooding, and beach change
- Considers the future evolution of storm patterns based on the latest Global Climate Models
- Uses state-of-the-art projections of (dynamically-downscaled) winds and waves to calculate surge and seas
- Extensively tested, calibrated, and validated with local, historic data on waves, water levels and coastal change
- Flood projections are based on dynamic wave set-up, i.e., any area that is wet for at least 2 minutes during a storm scenario
- Flooding is determined by the dynamic interaction of the evolving profile and ocean conditions during the storm event, including dune erosion and overtopping, and also the preceding long-term evolution of the coast
- Coastal change projections are based on a series of strenuously tested, peer-reviewed models, and calibrated by the local behavior of the coast
- Predicts the horizontal and vertical evolution of the entire beach profile through time
Central Coast CoSMoS

- Coastal change and flooding projections complete (Monterey online soon)
- Flooding projections available with Our Coast, Our Future and HERA web tools
- Groundwater projections for all coastal CA available online


Our Coast, Our Future tool: www.ourcoastourfuture.org

HERA Tool: www.usgs.gov/apps/hera

*For more information on CoSMoS, contact Patrick Barnard: pbarnard@usgs.gov

or contact Dan Hoover for groundwater projections: dhoover@usgs.gov