Climate Change, Sea-Level Rise, and Coastal Erosion in California

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Collaborators and funders:
Objectives

• Improve understanding of factors controlling shoreline evolution
  – Waves, tides, currents, sediment supply
  – Extreme/intermittent events (waves, floods, cliff failure)
  – Human factors (armoring/nourishment, climate change)

• Develop models to predict future change

• Test and refine models using measured coastal response from a variety of settings, and under various forcing scenarios (changes in sea level, wave energy/direction, and rain/runoff)

• Communicate model predictions to coastal planners/decision makers
Projections for San Francisco Area and State overall

SLR for San Francisco (NRC 2012)
- 28 cm SLR by 2050 (range 12-61 cm)
- 92 cm SLR by 2100 (range 42-166 cm)

SLR for CA (OST 2017)
- 18 cm to 34 cm (67% probability) of SLR by 2050
- 30 cm to 104 cm (305 cm upper limit!) SLR by 2100

Storms for California
- No significant changes in wave height
- Extreme events from ~10-15 degrees further south

El Niño for 21st Century
- 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
- Greatest impacts on low-lying coastal areas (e.g., Stinson Beach, San Francisco Bay)
USGS Shoreline Research and Monitoring

- Beach, bluff, and nearshore bathymetry surveys: Seasonal, interannual and longer (e.g., El Niño) timescale changes in shoreline position and coastal morphology
  - Ocean Beach (OB)
  - Northern Monterey Bay (NMB)
  - Central CA coastline
  - Santa Barbara Littoral Cell (SBLC)
- Statewide CA beach and cliff erosion rate update (using 2014-16 Lidar)
- CoSMoS modeling
  - Predictions of coastal hazards due to storms and sea level rise (SLR)
  - Web tools to visualize and quantify impacts, outreach coordinator (J. Finzi Hart) to facilitate use by communities and planners
- CoSMoS-COAST modeling
  - Predictions of shoreline evolution (mostly retreat) due to storms and SLR
- Cliff erosion/retreat modeling
  - Predictions of cliff retreat due to storms and SLR
Monitoring Sites

1. **Ocean Beach**: April 2004 – present
   - 188 beach topography surveys (~monthly)
   - 42 bathymetric surveys (2-4/yr)
   - 42 SfM surveys (~monthly since 12/2014)

2. **Northern Monterey Bay**: Oct 2014 – present
   - 8 beach topo surveys (Spring & Fall, 2+/yr)
   - 8 bathy surveys (S&F, 2+/yr, ~200 lines each)
   - 4/8 additional topo surveys at Santa Cruz/Capitola beaches (erosion and flood events)

3. **Central CA Coast**: Dec 2015 - present
   - 18+ SfM flights (intervals weeks - months)

4. **Santa Barbara Littoral Cell**: Oct 2005 – present
   - 6 focus sites: Goleta, Carpinteria, Rincon, N and S Ventura, Mugu Canyon.
   - Montecito added Spring 2018
   - 99 beach topo surveys (Spring and Fall)
   - 89 bathy surveys (mostly Fall, some Spring)
   - 5 SfM flights (Fall 2016 - Spring 2018)

Regular monitoring only covers ~5% of California coast (~60 of 1,340 km)* - coastal dynamics not well constrained!

*including Scripps So Cal monitoring
Monitoring Methods

• GPS surveys
  – Beaches (SUV, ATV, walking)
  – Nearshore bathymetry (PWCs with single-beam echosounders)

• Structure from Motion (SfM) digital surface models from photographs
  – Handheld (bluffs)
  – Small plane (beaches/bluffs)
  – Drone (beaches/bluffs)
Regional CA Coastal Dynamics

2015/16
- Extreme EN erosion – good summer recovery at OB, NMB, less in SBLC
- Below average rainfall

2016/17
- ~Average erosion – good summer recovery at OB, NMB, less in SBLC
- Lots of AR rain in N/C CA, less in So CA
  - OB: increased bluff failures
  - NMB: San Lorenzo River and Soquel Creek flooding (major)
  - SBLC: Ventura and Santa Clara river flooding (minor)

2017/18
- Below average erosion (net accretion in SB!)
- Record fires and AR rain - Montecito mudflows, regional sediment inputs

**Southern CA shoreline position data from Scripps monitoring programs

PROVISIONAL DATA SUBJECT TO REVISION
CoSMoS Modeling and Products

Products complete for:
- North-Central coast (2013)
- San Francisco Bay (2014)
- Pt Arena (2016)
- Southern California (2016-17)

In work for:
- Central Coast (2018)
- North Coast (2019)

Hazard Exposure Reporting and Analytics (HERA)
- 600,000+ residents
- $150 billion in property
- 4,700 km of roads
- 350 critical facilities
CoSMoS-COAST: Coastal One-line Assimilated Simulation Tool

• A (hybrid) numerical model predicting long-term shoreline evolution
  - Coastline represented by shore-perpendicular transects
  - Built from existing models (with improvements)

• Management scenarios
  - 1. hold the line at urban interface, no nourishment
  - 2. hold the line, continue existing nourishment
  - 3. let urban interface erode, no nourishment
  - 4. let interface erode, continue nourishment

• Modeled processes include
  - Longshore sediment transport
  - Cross-shore sediment transport
  - Effects of sea-level rise
  - Sediment supply by natural & anthropogenic sources

• So CA 2100, SLR 0.93 – 2.0m
  - Average ~50m erosion
  - 31-67% of beaches completely eroded

Vitousek et al., 2017. JGR-ES
Cliff Retreat Modeling

- Ensemble approach - up to 7 cliff models per transect
  - Beach protects cliff from waves
  - Includes water level variations (tides, run-up, set-up, surge, etc.)

- Synthesized from existing models (with improvements)

- Artificial Neural Networks to estimate model coefficients and extrapolate model behavior over study area

Limber et al., in prep
Future Coastal Change

- Today’s 100-year coastal water level event projected to occur every 1-5 years by 2050
- Up to 2/3 of beaches completely eroded by 2100 (SLR and urbanized coast effects)
- Cliffs will erode up to 3 times faster than present
- More frequent/intense El Niño erosion?
- More extreme droughts/wildfires/intense rainfall – less frequent but more intense sediment inputs?