Current and future coastal erosion hazards

Patrick Limber
U.S. Geological Survey
Current & future coastal erosion hazards

Ocean Isle Beach, NC

Video by Duncan Sinfield
Sea level rise and coastal change

Figure: Venus Bay Observation Project

Figure: CA Coastal Records Project
How to predict coastal change?

“All models are wrong, but some are useful.”

A: Not enough detail/data

B: Optimal balance between model detail, efficiency, and clear explanation

C: Reduced computational efficiency, “complexity paradox”
How to predict coastal change?
CoSMoS-COAST: Coastal One-line Assimilated Simulation Tool  Vitousek et al., 2017

- A (“process-based”) numerical model to simulate long-term shoreline evolution
  - Coastline is represented by shore-perpendicular transects:

- Modeled processes include:
  - Longshore sediment transport
  - Cross-shore sediment transport
  - Sea-level rise
  - Sediment supply by natural & anthropogenic sources

- Synthesized from models in the literature (with several improvements):

- Uses data assimilation (Extended Kalman Filter) to improve model skill
Data Assimilation: CoSMoS-COAST Simulation

Vitousek et al. (2017)
Simulation Results:
31% to 67% of Southern California beaches may become completely eroded by 2100 under sea-level rise scenarios of 0.93 to 2.0 m.
Long-term Morphodynamic Change: Sea Cliffs

- Ensemble of up to 7 cliff models
  - Beach protects cliff
  - Includes water level variations
- Includes models in scientific literature
- Uses machine learning (Artificial Neural Networks)
Cliff retreat results: Southern CA

- 19 to 39 m of land loss
- Erode up to ~300 million m$^3$ of cliff material in Southern California
What can we do?

“The present is the key to the past”

“The past & present are the keys to the future”

“We need more data”

Armstrong et al., 2016
Acknowledgments

Andy O’Neill
Amy Foxgrover
Christie Hegermiller
Jeff Danielson
Monica Palaseanu-Lovejoy
Sean Vitousek
Li Erikson
Patrick Barnard

Thank you!
plimber@usgs.gov
Sea cliff retreat projections

Transect 313, $E_{\text{env}} = 0.27$

Cliff retreat distance (m)

Elapsed time (years)

Frequency (m)

Cliff retreat distance (m)

Ensemble variance (m$^2$)

Elapsed time (years)

Cliff retreat distance (m)

Elapsed time (years)
Motivation:

0.5 – 2.0+ m of sea-level rise expected by 2100 will represent an unprecedented civil engineering challenge.
Current and future coastal erosion hazards

Patrick Limber
U.S. Geological Survey

Thank you
plimber@usgs.gov
Modeling approaches:

Believability of the model:

very low
Modeling approaches:

- **Believability of the model:**
  - very low
  - low

### Forward Model Compared to Data

**1990 - 2015 - 2100**

- Shoreline position vs. time for simulation and data.
Modeling approaches:

1. **Data-assimilated hindcast period**
   - Shoreline position
   - *Simulation*
   - *Data*
   - **Forward model**
   - **Very low**

2. **Forward model compared to data**
   - Shoreline position
   - *Simulation* (red line)
   - *Data* (black dots)
   - **Forward model**
   - **Low**

3. **Forward model forecast period**
   - Shoreline position
   - *Simulation*
   - *Data*
   - **Forward model**
   - **Low - Medium**
Modeling approaches:

1. **Very low believability**:
   - Forecast period: Data assimilated hindcast period.
   - Forward model: Very low.

2. **Low believability**:
   - Forecast period: Forward model compared to data.
   - Forward model: Low.

3. **Low-medium believability**:
   - Forecast period: Forward model forecast period.
   - Data-assimilated hindcast period: Low-medium.

4. **Medium believability**:
   - Forecast period: Forward model forecast period.
   - Data-assimilated hindcast period: Medium.

Years:
- 1990
- 2015
- 2100
Modeling approaches:

\[ \text{forward model} \]

\[ \text{data-assimilated hindcast period} \]

\[ \text{forward model comparison to data} \]

\[ \text{data-assimilated hindcast period} \]

\[ \text{forward model forecast period} \]

\[ \text{data-assimilated hindcast period} \]

\[ \text{forward model validation period} \]

\[ \text{forward model forecast period} \]

\[ \text{data-assimilated hindcast period} \]

\[ \text{simulation ensemble avg.} \]

\[ \text{envelope} \]

Believability of the model:

- very low
- low
- low - medium
- medium
- getting higher
- ...
Shoreline Data:

- 5 shorelines from USGS National Assessment of Shoreline Change
- 20 shorelines extracted from LIDAR surveys (most are from SCRIPPS 2003 – 2009; most are south of Long Beach)
- 20 shorelines from USGS field surveys (only in Santa Barbara area 2005 - present)
- More data would likely improve the model’s predictive capability