USGS Shoreline Change Studies
Along Alaska's Arctic Coast

USGS – Coastal and Marine Geology Program
Pacific Coastal and Marine Science Center
Santa Cruz California

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Today’s talk

• CMGP/PCMSC – who are we & what do we do
• Northern Alaska historical shoreline change study
• Barter Island – a natural laboratory
• Assessing future risk; future work
Who we are:
• Geologists, Oceanographers, Physical Scientists, Ecologists, Microbiologists, Geochemists, Engineers

What we do:
• Investigate processes that result in changes to coastal and marine environments that have societal implications related to natural hazards, resource sustainability, and environmental change.
• Our research focuses on geologic processes on the seafloor and at the water/land interface, and examines how these processes drive changes that impact ecosystems and humans.
• Non-regulatory. The majority of our partners are management and regulatory agencies that rely on our science to inform their decision-making.
USGS Coastal and Marine Geology Program
Research Themes

• Understanding coastal change
  – Historical shoreline change
  – Geologic structure and history of coastal regions
  – Coastal impacts of sea-level rise
  – Extreme storms

• Geologic hazards and catastrophic events
  – Submarine earthquakes, landslides, tsunami
  – Coastal inundation
  – Oil and gas spills
  – Forecasting of coastal hazard probability and occurrence

• Ocean resources and America’s needs
  – Gas hydrates
  – Law of the sea
  – Marine aggregates and minerals
  – Living resources

• Ecosystem science
  – Estuaries and wetlands
  – Coral reefs
  – River restoration
  – Seafloor habitat
CMG- Pacific Coastal and Marine Science Center
Projects with an Alaska Coastal Component

1. National Assessment of Coastal Change Hazards (NACCH) – Historical Shoreline Change
2. Coastal Climate Impacts (CoCI) to the U.S. Pacific and Arctic Coasts
3. Coastal National Elevation Database Science Applications Project (CoNED)
4. Tsunami Hazards, Modeling, and the Sedimentary Record
5. Earthquake Hazards, gas hydrates (offshore)
Motivation and Objectives

• Large Federal land and resource holdings
• DOD installations (DEW and active radar stations)
• Oil and gas resource development and infrastructure
• Wildlife habitat, Federal trust species
• Threatened communities and cultures

• Document the historical record of shoreline positions.
• Develop a better understanding of the forces driving coastal change.
• Provide scientific information that can be used for a better understanding of coastal change to improve ecosystem management strategies.

• Results provide scientists, land managers, and people in industry and coastal communities information on how the coasts are changing.
  – Understand natural change and human impacts on the coast
  – Evaluate potential coastal hazards and improve planning for the future
  – Measure, evaluate, and project effects of climate change on the coast
Physical process /ecosystem response questions:

How will projected changes in ocean temperature, sea-ice extent, sea-level rise, storminess, open-water duration, permafrost, land subsidence/emergence, and river discharge impact:

• Coastal bluffs and low-lying coastal tundra?
• Barrier island and lagoon systems?
• Arctic river deltas and mud flats?
• Benthic and pelagic marine zones

Tapped thermokarst lake (Arp et al. 2010, Polar Biology)
Previous USGS coastal change studies

Erk Reimnitz and Peter Barnes, CMG/PCMSC; 1980s

Mars and Houseknecht, 2005

Jones, 2008
• Document and assess the historical record of shoreline positions for the Nation using a consistent methodology.
• Understand and forecast the impact of storms.
• Understand coastal vulnerabilities to sea-level rise.
• Model and project SLR, storm, and climate change impacts.

http://marine.usgs.gov/coastalchangehazards/

Erikson and others, in review
Objectives

- Develop a national record of shoreline positions and assessment tools.
- Apply standard and uniform methods of shoreline change analysis.
- Establish procedures for future comparisons of shoreline position.
- Contribute to forecast of future coastal conditions.

http://coastal.er.usgs.gov/shoreline-change/
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Coastal image and elevation data sets (2004-2016)

2009-2012 Airborne lidar elevation
~ 1.5 km coastal swath
~ 1 m point spacing/30 cm vertical
Some estuary/delta gaps,

Available online:
USGS Earth Explorer
https://earthexplorer.usgs.gov/
DGGS Elevation Data Portal
http://elevation.alaska.gov/

2009-2012 aerial photography and DEM
Derived using SfM photogrammetry
~ 1.5 km coastal swath
~ 30 cm horizontal/30 cm vertical
Coming soon, DGGS and Earth Explorer

*ShoreZone
Regional, temporally consistent shorelines

- **1940-1950s**: NOAA topographic survey maps (T-sheets)*
- **1970-1980s**: Alaska High Altitude Photographs (AHAP), T-sheets
- **2000s**: Aerial and satellite images (USGS, FWS, BP-Alaska, ConocoPhillips)
- **2010s**: Lidar DEMs, aerial photography and SfM DEMs**
- * Oldest shorelines in other NASC studies are early-mid 1800s
- ** The modern AK shoreline is not elevation based b/c of tidal datum and geoid issues
Datasets georeferenced and shorelines digitized

Coastal change rates calculated for long-term (~60 yr) and shorter-term (~30 yr) using DSAS

50 m intervals along the coast; no bays or deltas

For Icy Cape to U.S. Canadian border > 25,000 measurements (1,650 km; 1,000 miles)

Phase 1: U.S. Canadian Border to Icy Cape
Complete, 2015 and 2017 update

Phase 2: Icy Cape to Cape Wales
In progress; 2018 release

Phase 3: Cape Wales to Platinum
With DGGS, FEMA funding, in progress
Results: Icy Cape to U.S. Canadian Border (1947-2012)

- The coast is dominantly erosional over all analysis periods.
- Change rates are considerably higher on the Beaufort Sea coast compared to the Chukchi Sea coast (6x higher over the long-term and 20x higher over the short-term).
- Rates are highly variable (-25 to +20 m/yr over the short-term).
- Extreme rates associated with migration of barrier islands and limited sections of mainland coast.
- Exposed mainland coasts showed highest average retreat rates; sheltered coasts the lowest.
- Along the Beaufort Sea coast, the percentage of transects retreating greater than 1 m/yr is substantially higher between Cape Halkett and Barrow compared to the rest of the coast.

Rates are reported for 10 sub-regions and 5 shoreline types (Sheltered, Exposed, Mainland, Exposed mainland, Exposed barrier) for long-term (1940s-2010s) and short-term (1980s-2010s).

Gibbs and Richmond, 2017
Results: Icy Cape to U.S. Canadian Border (1947-2012)

-1.4 m/yr

-0.3 m/yr

-1.8 m/yr

Gibbs and Richmond, 2017
## Comparison with other National Shoreline Change Rates

<table>
<thead>
<tr>
<th>Location</th>
<th>Transects</th>
<th>Ave Rate m/yr</th>
<th>Max Rate m/yr</th>
<th>% Retreating</th>
<th>% Accreting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louisiana</td>
<td>2,490</td>
<td>-7.1</td>
<td>-36.8; 7.2</td>
<td>91</td>
<td>9</td>
</tr>
<tr>
<td>Mississippi</td>
<td>724</td>
<td>-2.3</td>
<td>-13.5; 3.0</td>
<td>80</td>
<td>20</td>
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<tr>
<td>N Alaska</td>
<td>25,626</td>
<td>-1.4</td>
<td>-25.1; 20.6</td>
<td>84</td>
<td>16</td>
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<tr>
<td>Texas</td>
<td>10,626</td>
<td>-0.7</td>
<td>-9.2; 14.9</td>
<td>64</td>
<td>36</td>
</tr>
<tr>
<td>N Carolina</td>
<td>8,849</td>
<td>-0.7</td>
<td>-7.6; 10.7</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>NEMA*</td>
<td>19,784</td>
<td>-0.5</td>
<td>-18.5; 21.5</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>S Carolina</td>
<td>4,921</td>
<td>-0.5</td>
<td>-13.0; 16.9</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>Alabama</td>
<td>1,294</td>
<td>-0.4</td>
<td>-2.8; 2.2</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>Florida (Gulf)</td>
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<td>-0.1</td>
<td>-7.7; 7.6</td>
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<td>42</td>
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<tr>
<td>Hawaii</td>
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<td>-2.2; 2.8</td>
<td>70</td>
<td>30</td>
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<tr>
<td>Oregon</td>
<td>7,113</td>
<td>0.03</td>
<td>-4.4; 26.5</td>
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<td>46</td>
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<tr>
<td>Florida (Atl)</td>
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<td>0.2</td>
<td>-5.5; 14.3</td>
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<td>61</td>
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<tr>
<td>Georgia</td>
<td>2,566</td>
<td>1.0</td>
<td>-9.4; 13.9</td>
<td>35</td>
<td>65</td>
</tr>
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<td>Washington</td>
<td>1,974</td>
<td>3.8</td>
<td>-56.5; 43.1</td>
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<td>91</td>
</tr>
</tbody>
</table>

*NEMA = New England & Mid Atlantic States

Published reports and data for each location available at: https://marine.usgs.gov/coastalchangehazardsportal/
Is erosion accelerating?

Limited data sets and high uncertainties makes it difficult to confidently assess any change in regional trends.

- Erosion and accretion rates increase from the long-term to the short-term.
- The percent of transects accreting increased (eroding decreased) from the long- to short-term.
- These results suggest
  1) coasts are eroding more rapidly (in many places resulting in permanent loss of permafrost bluff and tundra landscape).
  2) eroded material is being redistributed and deposited as more ephemeral and dynamic beach, barrier spit, barrier island land forms.
- We need more shorelines to improve the confidence in observed change in trends.
Results – Icy Cape to U.S. Canadian Border

• v. 1 (2015) 2 shorelines (1940s, 2000s); full report and detailed assessment, GIS

• v. 2 (2017) 4 shorelines (1940s, 1980s, 2000s 2010s); reports updated methods and
  uncertainty/error analysis, GIS
  GIS data: Gibbs and others, 2017. https://doi.org/10.5066/F72Z13N1

Also:
https://marine.usgs.gov/coastalchangehazardsportal/
http://maps.dggs.alaska.gov/shoreline
**Proposed new work:**
**Arctic Barrier Island Evolution Research**

**Goal:** Advance models of barrier evolution in the cryospheric environment.
- Arctic BI = 22% of the global total
- Geomorphologically distinct as a result of cryospheric processes
- Sediment transport and budgets are influenced by sea ice, permafrost, processes of thermal-mechanical erosion, seasonal fluvial input, and sea-ice entrained sediment.

**Methods:**
- **Geology** - coring and geophysical techniques
- **History** - shoreline position and volume change
- **Modeling** - existing and new approaches
Assessing Future Risk

(Li Erikson)

1. Use outputs from the latest atmosphere-ocean coupled GCMs to force global and regional wave and inundation models.

2. Drive global and regional wave and inundation models.

3. Scaled down to local hazard forecasts.
Alaska waves and storm surges – past and future

Generated time-series and quantified changes in deep-water wave conditions surrounding the Alaska coast in response to climate change

Products and interesting findings:
- Downloadable wave and wind time-series for 4 global climate models and 2 climate change scenarios
- Significant increases in wave heights and periods are projected for some seasons; greatest increases are noted in the Arctic
- Incident wave directions are projected to shift poleward

Erikson, et al., 2016. http://dx.doi.org/10.5066/F7D798GR
Alaska waves and storm surges – past and future

Generated time-series and quantified changes in deep-water wave conditions surrounding the Alaska coast in response to climate change.

Generated time-series and analysis of extreme wave runup, storm surge and astronomic tides in coastal communities of the Bering Sea.

Interesting finding:
Storm surges at Unalakleet (3m) >> Gambell. Wave runup is the primary contributor to overland flow and coastal flooding at Gambell.

Alaska waves and storm surges – past and future

Generated time-series and quantified changes in deep-water wave conditions surrounding the Alaska coast in response to climate change.

Generated time-series and analysis of hindcast extreme wave runup, storm surge, and astronomic tides in coastal communities of the Bering Sea.

Quantified changes in the extent and frequency of marsh flooding and resilience of an Arctic barrier island in response to climate change.

Erikson, et al., 2017 (USGS OFR; publication pending)
Current directions

1. Historical bluff change rates
2. Thermo-mechanical-sloughing permafrost (TMSPF) bluff recession model
3. Flood hazard maps

Future water levels, waves, and air & sea temperatures

Future bluff recession rates
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**Project website:** [http://walrus.wr.usgs.gov/climate-change/hiLat.html](http://walrus.wr.usgs.gov/climate-change/hiLat.html)
This site is periodically updated and contains links to downloadable reports and oblique photography of the North Slope.

*Barter Island, Sept. 2016*