What is New in the Arctic Coastal Zone?

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Sea Ice Decline

Monthly Sea Ice Extent 1979-2015

Rate of Change in Open Water Days 1979-2012

Over last 30 years, length of open water expanded 1.5-3 times (Barnhart et al., 2014)

From: NSIDC, November 2015
Regional Coastal Retreat

Progradation of the shoreline and, particularly in case of barrier island and spits, also may represent the migration alongshore of a landscape feature. The average rate of shoreline change for the entire study area was -1.4 meters per year (m/yr) (range -18.6 to +10.9 m/yr) with an individual transect uncertainty of ±0.3 m/yr. Maximum erosion rates (18.6 m/yr) are some of the highest in the world, but are restricted to small sections of the north coast of Alaska.

Average shoreline change rates along Beaufort Sea coast are nearly six times higher (-1.7 m/yr) than along the Chukchi Sea coast (-0.3 m/yr). The highest rates of both erosion and accretion in the study area were measured within Region 6 (Cape Halkett to Drew Point), with rates of erosion greater than 18 m/yr between Cape Halkett and Pogik Bay, and rates of accretion greater than +10.5 m/yr on the western side of Pogik Bay. The highest average rates of shoreline change (-5.8 m/yr) were measured within Region 6, and the lowest (-0.3 m/yr) along the Chukchi coast in Regions 9 and 10 (Barrow to Icy Cape).

Sheltered mainland-lagoon shorelines comprise 42 percent of all transects in the study area and are 88 percent erosional. Open-ocean exposed shorelines comprise 58 percent of all transects and are 81 percent erosional. Average shoreline change rates along exposed shorelines are twice as high (-1.8 m/yr) compared to sheltered shorelines (-0.9 m/yr). Barrier shoreline transects (includes barrier islands, spits, and beaches) comprise 29 percent of the total transects and 50 percent of all exposed shoreline transects. Average shoreline change rates on barrier shorelines are not significantly different than exposed mainland shorelines (-1.7 and -1.8 m/yr, respectively); however, the barrier transects have the lowest percent of erosional transects (75 percent) and highest accretional (25 percent) of all shoreline types. Considerable migration and translation in the position of the barrier islands and spits during the analysis period resulted in substantial erosion and accretion; however, because of the lack of overlapping shoreline positions, some of these changes could not be measured using the Digital Shoreline Analysis System method of analysis, particularly in Regions 3, 4, and 8. An analysis of changes in the surface area of those barrier islands in those regions, however, indicates a net gain in barrier island surface area of nearly 1.7 million square meters, or about 10 percent, during the study period. A volumetric change analysis could not be completed because of the lack of elevation values for the historical datasets.

In contrast to the majority of the Nation's shorelines, for all but 3 months of the year (July–September), the north coast of Alaska is protected by landfast sea ice from processes such as waves, winds, and currents that typically drive coastal change on beaches in more temperate regions of the world. Projected and observed increases in periods of sea-ice free conditions, as sea-ice melts earlier and forms later in the year, particularly in the autumn, when large storms are more common in the Arctic, suggest that Arctic coasts will be more vulnerable to storm surge and wave energy, potentially resulting in accelerated shoreline erosion and terrestrial habitat loss in the future.

(From Gibbs and Richmond, 2015; USGS Open File Report 1048)
Bluffs are 4-5 m high

Deep notches

Ice Content 64%

5.6 m
Why is Coastal Erosion Important?

Shismaref, Alaska
565 people need to relocate

*Photo: Shismaref Erosion and Relocation Committee*

Oil and gas infrastructure
Mitigation of several wells

*Photos: Gary Clow, USGS & S. Flora, BLM*
Arctic-wide warming and decline in sea ice extent occur concurrently with increase in erosion; this suggests a causal relationship.

- Can we quantify the erosion processes?
- Are there any non-linear feedbacks?

Aim to model the erosion process to ultimately make predictions into next 50 years.
Field Observations 2007-2011

Sea Surface Temperature and Water Level

Bathymetry and Waves

Wind, Air T, Radiation

Permafrost Temperature
Sea Ice needs to be gone before sea water temperature starts increasing, and waves start bathing icy bluffs.

Sea Ice Season versus Open Water Season = limiting factor
Quantify erosion ($E_w$) with iceberg melt model

$$E_w = 0.000146 \lambda \left( \frac{R}{\tau} \right)^{0.2} \left( \frac{H}{\tau} \right)^{0.8} (T_w - \delta_w)$$

(White et al., 1980; Kubat et al., 2007; Wobus et al., 2010; Barnhart et al., 2014.)

High sea water temperature forces rapid erosion
Time-lapse camera August 13th-August 21st, 2010
Wind, Sea-Ice and Fetch Model

Sea Ice Concentration Year # 2007, Day # 1: January 01

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Open Water Sea Ice Concentration 100% Sea Ice
Good match between observed and predicted set up and wave heights
Cumulative wave height increases 2.5 times over last 30 years (Overeem et al., 2011)
Hypothesis: erosion from fall storms is less efficient due to lower SST. (Overeem et al., 2011).
Model: large erosion events over last 30 years have not occurred beyond ~Sept 15. Coastal flooding can still occur.
By 2050, the entire Arctic coastline will experience an additional 60 days of open water each year, assuming rise of greenhouse emissions continues. (Barnhart et al., Nature Climate Change, 2015)
Mean number of open water (no sea ice) days per year in the NCAR CESM Large Ensemble (across 30 ensemble members)

Year: 1920

Conclusions

- Erosion is widespread, 84% of Chukchi and Beaufort Coast sees erosion. Erosion is controlled by expanding open water season.

- Wave exposure and storm surges increased. Erosion of the icy bluffs is largely a thermal process, sea water temperatures dominate rates.

- Postulated dampening mechanism is corroborated by modeling; erosion is less efficient in Fall season.
New Challenges

- Understanding of sea ice and coastal dynamics near major rivers, i.e. the Yukon and Mackenzie Rivers. Dire need of observations of heat, chemical, physical interactions during river spring flood and summer ice break-up conditions.

- Understanding of coastal system for extreme events, i.e. during Arctic Cyclones. Focus on storm surges and barrier island and spit dynamics.

- Assessing the land-ocean exchange of carbon and nutrient fluxes to nearshore system associated with coastal erosion, river dynamics. Need for nearshore observations during transition times, observations on biochemistry. (ARCTIC_COLORS).