

Arctic Coastal Dynamics under Changing Relative Sea Level and Environmental Forcing, Canadian Arctic Archipelago

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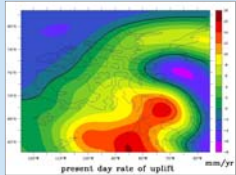
Abstract

Changes in climate variables and relative sea-level (RSL) are ongoing in the Canadian Arctic Archipelago (CAA). These regional changes threaten to modify the nature and timescale of arctic coastal processes. Further local variables such as bathymetry, sediment source and exposure to fetch alter the response

of coastal systems to changing climate and RSL. Increased sediment erosion, transport and deposition will create a more dynamic coastline. Arctic communities need an assessment of the sensitivity of their coastline for decision-making and adaptation planning.

Facts: changing environment

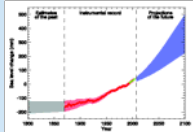
The CAA is currently subject to significant changes in relative sea-level, sea-ice extent, thickness and duration, storm frequency and intensity and air temperature. These changes are illustrated below.



RSL is rising in the western and eastern CAA and falling in the central Arctic.

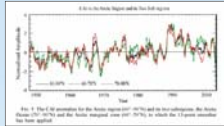
Tarasov, pers. comm. 2007

The rate and direction of RSL change results from the interaction between two components: the vertical motion of the earth crust (above) and global sea-level change (below).



Global sea-level is predicted to rise at a faster pace in the future.

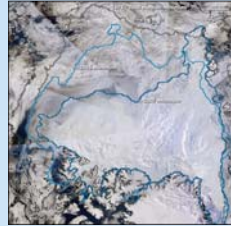
IPCC, 2007



The number, intensity and duration of cyclones in the Arctic have increased during the second half of the twentieth century (Zhang et al. 2004).

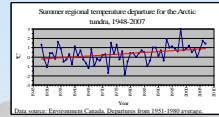
Zhang et al. 2004

<http://earthobservatory.nasa.gov>



Satellite data point towards alarming reduction in sea-ice extent, thickness (Rothrock & Zhang, 2005) and duration (NSDIC, 2007). The extent of sea-ice minima in 2007 is contoured in medium blue, the previous record low from 2005 in light blue and the long-term average in gray (above).

Air temperature is rising over the CAA.



Theory: coastal dynamics

Changing RSL

Even though RSL is in itself a passive control, the rate and direction of RSL change is of great significance to beach evolution since it constrains the reach of wave processes. RSL rate and direction of change is a determining factor in the access to sediment source and in the rate of sediment supply (Forbes et al., 1995). For example, a higher rate of RSL change results in higher rates of sediment supply.

Changing air temperature

Warmer air temperature contributes to the deepening of the active layer. Under the same wave conditions, an unfrozen gravel berm erodes up to 10 times faster than a frozen gravel berm (Cox & Monde, 1985).

Changing sea-ice conditions

Sea-ice protects the shoreline by reducing the potential for wave generation and propagation (Forbes & Taylor, 1994). Longer and more extensive open water season exposes the shoreline to more energy by increasing the intensity and the number of wave events.

Changing wave climate

Lower sea-level pressure and increased number, intensity and duration of cyclones result in more numerous and more extreme wave events, flooding and storm surges at the coast. Wave climate also dictates the ratio between overtopping and overwashing processes therefore controlling the rate of coastal retreat (Orford et al. 1995).

Reality: observed changes

The rate and direction of RSL change, the storm climate and the duration and extent of open water are useful regional parameters to gauge the sensitivity of a coastline to climate

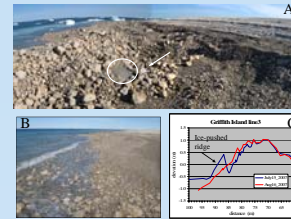
change. However, local factors such as bathymetry or sediment source often override the influence of regional parameters in coastal dynamics.

The following case studies illustrate the changing balance between regional and local factors and the morphological outcomes of such a dynamic balance.

1. From flying spits to fringing barriers in 50 years, Griffith Island.

Although arctic coasts are thought to be low energy, they sometimes evolve very rapidly. The SE coast of Griffith Island has experienced significant changes since 1958, evolving from a series of discontinuous flying spits to continuous fringing barriers.

This rapid evolution necessitates a supply in sediment which is not readily available from the modern coast. Recent field observations suggest that sea-ice plays a dominant role in the supply of sediment by pushing sediment from the nearshore to the foreshore. This sediment is subsequently reworked by waves.

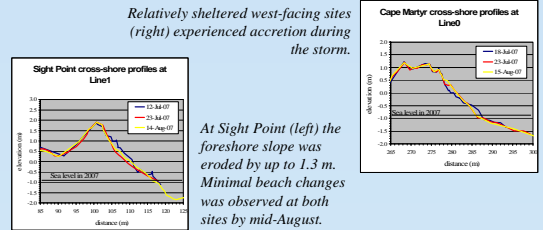
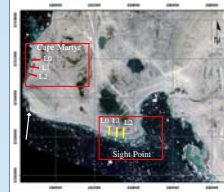


(A) Ice-pushed ridge with an ice core (circled) on the shoreface of G13 on 07/16/2007. Arrow shows field book for scale. (B) Same location on 08/17/2007 after significant wave activity. Boulders are left on the lower shoreface as a lag deposit while finer gravel was transported and sorted onshore by waves. (C) The shoreface prograded by up to 2.2m in 4 weeks.

2. The impacts of a storm on emerging gravel beaches, Cornwallis Island.

On July 20-22 2007, a deep cyclone produced strong easterly winds sustained over a 48 hour period. With negligible sea ice present in the region, maximum open-water fetch occurred and winds generated significant wave activity at the coast. Numerous cross-shore profiles were surveyed before, immediately after, and three weeks after the storm event.

Locations of the Cape Martyr and Sight Point study sites and profile lines. The location of a newly formed ridge is indicated by an arrow.



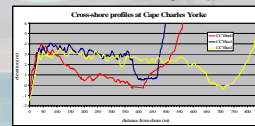
Relatively sheltered west-facing sites (right) experienced accretion during the storm.

At Sight Point (left) the foreshore slope was eroded by up to 1.3 m. Minimal beach changes was observed at both sites by mid-August.

Erosion of the south-facing beaches combined with a westward sediment transport likely provided material for the development of a new beach ridge (dashed line).

3. Rising RSL and prograded coastline, northern Baffin Island.

Cape Charles Yorke consists of a series of prograded gravel ridges deposited under rising RSL as indicated by the increasing crest elevation seaward (below). The morphology of the foreland suggests continuous progradation. In contrast, truncation of relict ridges by the modern shoreline suggests a regime shift to predominantly erosion. The reasons for this shift are currently being investigated.



The Cape Charles Yorke site illustrates how a coastal system may respond to changes in forcing. For instance, the system may be responding to changes in sediment supply or accommodation space (i.e. nearshore bathymetry).

Implications

The arctic coastline is a dynamic environment that is likely to become even more dynamic as sea-ice recedes, permafrost thaws and storm activity increases. Normal coastal processes such as sediment erosion, deposition and transport are likely to intensify in the future. The capacity for arctic communities to adapt to an increasingly dynamic coast relies on a thorough understanding of the coastal system at both regional and local scales.



References

- Cox, J.C. and M.C. Monde. 1985. Wave erosion of an unprotected frozen gravel berm. *Arctic Engineering Inc.*, 43 p.
- Forbes, D.L. and R.B. Taylor. 1994. Ice in the shore zone and the geomorphology of cold coasts. *Progress in Physical Geography* 18 (1), 59-89.
- Forbes, D.L., Orford, J.D., Carter, R.W.G., Shaw, J. and S.C. Jennings. 1995. Morphodynamic evolution, self-organization and instability of coarse-clastic barriers on paraglacial coasts. *Marine Geology* 126, 63-85.
- Orford, J.D., Carter, R.W.G., Jennings, S.C. and A.C. Hinton. 1995. Processes and timescales by which a gravel-dominated barrier responds geomorphologically to sea-level rise: Stony Head barrier, NS. *ESR* 20, p. 21-37.
- Rothrock, D.A. and J. Zhang. 2005. Arctic Ocean sea-ice volume: what explains its recent depletion? *J. Geov. Res.* 110.
- Zhang, X., Walsh, J.E., Zhang, J., Bhatt, U.S. and M. Reda. 2004. Climatology and interannual variability of Arctic cyclone activity: 1948-2002. *Journal of Climatology* 17, 2300-17.

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PDF | The arctic environment is changing: air temperatures, major river discharges and open water season length have increased, and storm intensities | Find, read and cite all the research you need on ResearchGate. Processes unique to arctic coastal dynamics. The unthawed arctic coast includes sections with predominantly fine-grained and ice-rich sediments. In the Canadian Arctic Archipelago, Hudson Bay, Labrador, Greenland and elsewhere. Ground ice. Primarily, understanding and responding to Arctic changes requires joint efforts by the global community. This means we must focus on international cooperation and dialogue. A safe, stable, sustainable and prosperous Arctic is important not just for the region itself, but for the European Union and for the world. Environmental, ecological and subsequent social changes are happening faster than ever before, affecting the way Arctic residents live. While it may seem remote, changes in the Arctic have global consequences. For instance, the melting of the Greenland ice sheet contributes to global sea-level rise and has the potential to change ocean circulation patterns that can impact the whole planet. Environmental Forcing of Coastal Dynamics The air thawing index, reflecting the sum of yearly positive temperatures that directly influence the intensity of permafrost thawing, i.e., thermodenudation, has increased since the last century in the whole Russian Arctic (Figure 3). In the western sector, the trends of this increase are more significant than in the east, while the fluctuations in the air thawing index are better expressed. DISCUSSION The increase of the air thawing index and ice-free period duration since the 1990s, and the coinciding general rise in erosion rates at the beginning of the XX century both in the western and eastern Russian Arctic give evidence of immediate response of coastal dynamics to the ongoing climate change. Keywords: Canada's Arctic strategy, Canadian and Russian relations cooperation and rivalry in the Far North. Canada, along with other "official" (coastal) Arctic states (Russia, the USA, Norway and Denmark), is a key "player" in the questions of the regional policy. And although by its material and human resources, it can not be compared to similar polar "heavyweights" like the USA and Russia, Canada still shows significant activity in the Arctic, as it has vital interests to her in the region. Arctic attracts Canada by its not cultivated bio resources. Arctic seas are habitat of the variety of unique species of fish and animals, including polar bears, arctic foxes, narwhal, whale, walrus, beluga. Canada's interests in the Arctic. The Canadian sector of the Arctic comes second by size (25%) after the Russian sector (40%). Canada is one of the five so-called "official" Arctic states (which, apart from Canada, include the U.S., Russia, Denmark and Norway). Along with the conventional oil and gas deposits, the coastal area of Canadian Arctic has huge reserves of methane hydrate. If its commercial production is launched, these reserves would last for several hundred years. Like Russia, Canada adheres to the sectoral concept of division of Arctic spaces, which is aimed at controlling the Arctic spaces up to the North Pole (i.e. a dividing line is conventionally drawn from the North Pole along the meridian to the extreme east and west points of the continental Arctic coast of Canada).