REMOTELY SENSED EVIDENCE OF ENHANCED EROSION DURING THE TWENTIETH CENTURY ON HERSCHEL ISLAND, YUKON TERRITORY

H. Lantuit and W. Pollard

Dpt of Geography and Centre for Climate and Global Change Research (C^2GCR), McGill University, 805 Sherbrooke West, Montréal, QC, H3A 2K6

Introduction

Herschel Island, also known as Qikiqtaruk, is located in the northern part of the Yukon Territory, Canada. The island is situated at 69°36'N and at 139°04'W. It lies approximately 60 km east of the boundary between Yukon and Alaska and 3 km north from the continental coast (Fig. 1). The island is located in the Southern Beaufort Sea, in the physiographic region of the Yukon Coastal Plain. The island is a moraine resulting from the late fluctuations of the pleistocene ice sheets and is mainly composed of marine, non-marine and mixed origin sediments (Bouchard 1974). Sediments are clays, clayey silts, silts and sands.

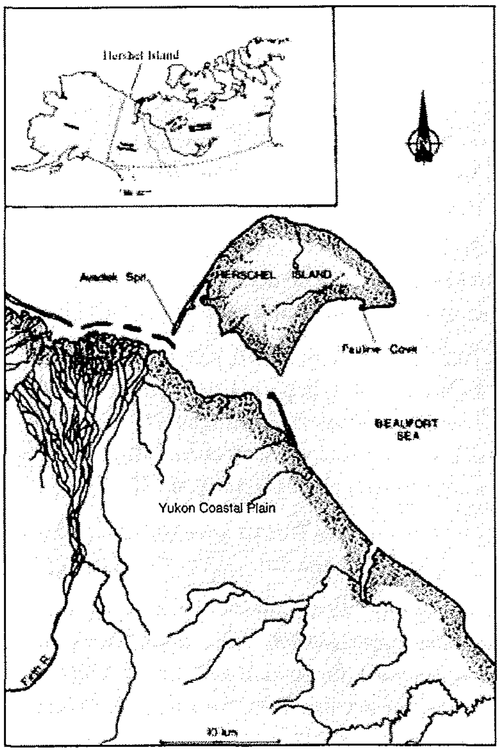

Figure 1. Herschel Island Location.

Recent attention has been given to the tremendous coastal retreat occurring in the area, which is assumed to be the most ice-rich area of the Canadian Arctic (Pollard and French 1980). Harper (1991) documented an average coastal retreat rate of 1.0 myr^{-1}, with some peak locations at 18myr^{-1} for the 1944-1970 period. Solomon (2002), in this issue documents average coastal retreat rates of –1 to –5myr^{-1} for the 1970-2000 period using the locations referenced by Harper (1991) in his study.

Global warming is believed to dramatically increase certain processes responsible for enhanced coastal erosion in the Arctic. McGillivray et al. (1993) showed that a longer open-water season, warmer sea temperatures and a reduced sea-ice extent would lead to greater storminess frequency, and hence, to enhanced erosional processes.

Few studies have documented the shoreline evolution on a large scale basis for the 1970-2000 period on Herschel Island. The purpose of this study was, then, to propose and update linear costal retreat rates in Herschel Island for the most recent period using the locations referenced by McDonald and Lewis (1973) in their study of the 1944-1970 shoreline evolution.

Methods

McDonald and Lewis (1973) used three airphoto series to document coastal retreat rates on Herschel Island, for 1944, 1954 and 1970. They established 60 study locations along Herschel island's shore and documented coastal retreat rates for these locations (Fig.2). We took for reference these points and calculated absolute coastal retreat distances and coastal retreat rates for the 1970-2000 period. The measurements were operated on the 1970 airphoto series and a 2000 ikonos image (1 meter resolution in panchromatic operating mode) approximately from the same period of the year (i.e late August).Fixed inland features (mainly tundra polygons edges) were identified and used to measure coastal evolution between the 1970 and 2000 shoreline. No rectification of optical distortion or terrain displacement was undertaken on the 1970 airphoto series. The 2000 ikonos image was displayed in geographic coordinates. As a result, the uncertainty of the measurements was roughly estimated at ±10%.

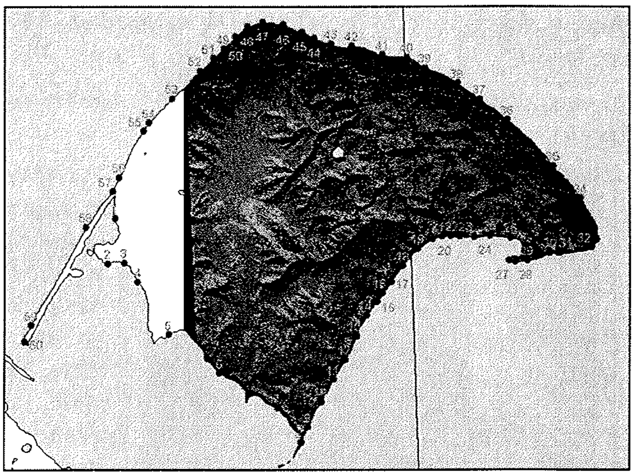

Figure 2. Study spots location. (Spots 1 to 7 are considered unexposed to ocean dynamics). The IKONOS image is displayed to show the matching area with McDonald and Lewis dataset (1973).

Results

Absolute retreat distances and coastal retreat rates were computed for the locations displayed on both the airphoto series and the satellite image. An average coastal retreat rate was calculated for locations exposed to ocean dynamics for the 1970-2000 period and was compared to McDonald and Lewis (1973) calculations for the 1954-2000 period. Results are displayed in Fig. 3.

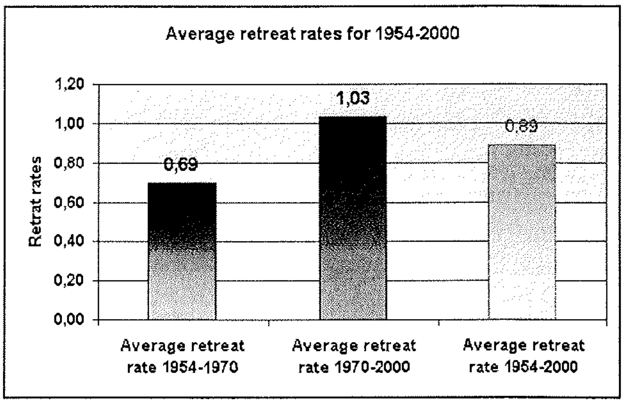

Figure 3. Average coastal retreat rates computed for the 1954-1970 period (red), 1970-2000 period (blue) and 1954-2000 period (yellow).

The average retreat rate for the 1970-2000 period was found to reach 1.03 myr^{-1}, as opposed to an average retreat rate of 0.69 myr^{-1} for the 1954-2000 period. It represents a 50% increase of coastal retreat over 28 years. Shoreline change along the exposed coastal areas for the 1970-2000 period varied from –64m to +108m (negative changes are erosional).

Results were computed and displayed in a GIS in order to detect the spatial patterns of erosion (Fig.4).

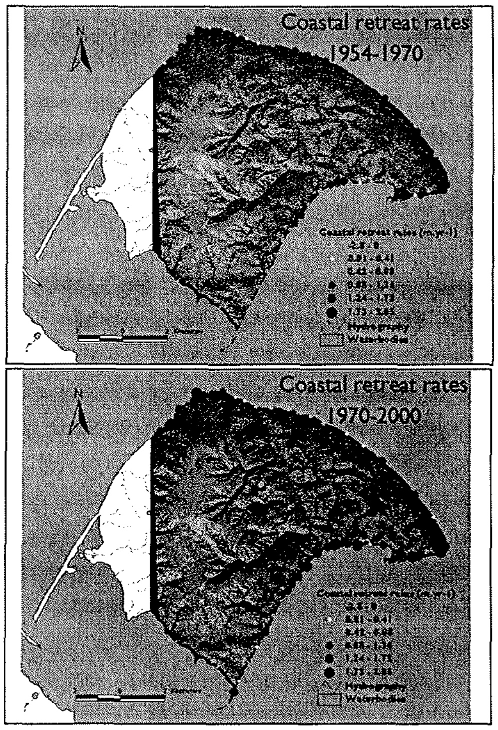

Figure 4. Mean annual coastal retreat rates computed for the 1954-1970 and 1970-2000 periods.

The distribution of the strongest eroding shorelines is clearly heterogeneous. The important eroding locations on the island are reported for the northern tip of the island, for Collinson Head on the eastern tip, and in Thetis Bay on the south-west shore. Storms have been shown to be the most important eroding agent for the shorelines of the southern Canadian Beaufort Sea (Solomon et Covill 1995) and to typically originate from the North-West. However, on Herschel Island, the North-western shore is not particularly more sensitive to the erosion processes. The coastal retreat rates are comparable for shores oriented differently: For the 1954-2000 period, we interpolated a coastal retreat rate of $1.09myr^{-1}$ for the south-west-facing shore, a rate of $1.04myr^{-1}$ for the east-facing shore, 0.70myr-1 for the north-east-facing shore and 1.05 myr^{-1} for the north-west-facing shore. The wind regime on Herschel Island is characterized by an unusual strong south-west component, which is a potential explanation for the erosional pattern on the island. However, this phenomenon can't solely explain the homogeneity of the erosional pattern on the island. We'll see below that this pattern is closely linked to the location of the major retrogressive thaw slumps.

The dramatic increase shown by our results strongly differ from the evolution described by Solomon (2002), who demonstrates that the rest of the southern Canadian Beaufort Sea has undergone a relative increase of the erosional processes and that the "highest rates of retreat are associated with spits or low tundra bluffs which are directly exposed to waves and storm surges caused by the northwesterly wind storms." Herschel Island is mainly characterized by high bluffs fronted by very narrow beaches and coastal retreat rates have been proven to increase in an important way in such configuration. Neither the wind configuration, nor the geomorphology of the island coasts can, then, solely explain such dramatic increase.

Solomon (2002), in this issue, also noted that the shoreline retreat rates could be quite high in areas were high ground ice content have been identified. Pollard and French (1980) have used geomorphic proxies such as polygonal soils, palsas, pingos or retrogressive thaw slumps to detect and identify the type of ground ice. Bouchard (1974) has shown that ice content rates on Herschel Island are believed to be somewhat 20% higher than ice content rates on the rest of the Yukon Coastal Plain. We identified all the major retrogressive thaw slumps on Herschel Island, as well, as surfaces characterized by polygonal soils, compared our results with Pollard (1990)'s study of ground ice on Herschel Island and linked these surfaces to the erosion al pattern displayed on the maps (Fig.4).

Ninety percents of the greatest rates computed for the 1970-2000 period appear to be associated with retrogressive thaw slumps (see Fig.5). Most of the greatest eroding locations were already undergoing strong erosion during 1954-1970 period. Certain locations, though, were weakly affected by the erosion during the 1954-1970 period and displayed values amongst the most important for the 1970-2000 period. A simple comparative analysis of the two datasets has taught us that these spectacular increase corresponded always to the activation or the reactivation of a large retrogressive thaw slump. The map of coastal retreat rates evolution between the two periods (Fig.5) clearly establishes the link between retrogressive thaw slumps, and then, high ice content, and enhanced coastal retreat rates. Ninety percents of the greatest increase between the two periods are associated with retrogressive thaw slumps. Ground ice appears, then, to be a prime order factor in the evolution of coastal retreat, as noted earlier by Hequette and Barnes (1990) for the southern Beaufort Sea.

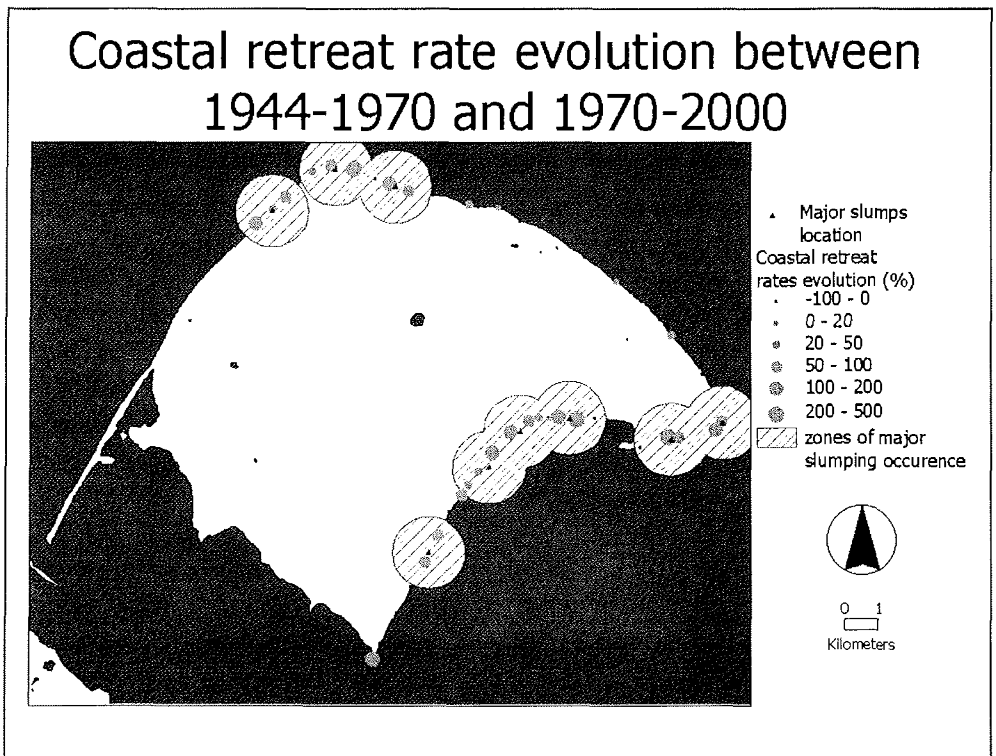

Figure 5. Coastal retreat rate evolution on Herschel Island between the 1944-1970 period and the 1970-2000 period. Note that the western tip of the island has not been included in the study.

One must note that a large part of the greatest increase between the two periods are not located exactly where the major slumps are, but in their close vicinity. A close examination of the airphotos and of the IKONOS image has led us to the conclusion that these cases correspond to the activation or reactivation of retrogressive thaw slumps. Some of these slumps have been proven to be dormant for more than a hundred years (De Krom 1990). It is critical, then to understand that this recent increase in the frequency of retrogressive thaw slumps occurrence can only be explained in terms of an important environmental change, which would include a change in the ocean dynamics and a change in the incoming radiation balance, as discussed by Lewkowicz (1991).

Conclusions

Shoreline erosion has been increasing dramatically over the 1954-2000 period on Herschel Island, Yukon Territory. Coastal retreat rate has been shown to change from $0.89myr^{-1}$ over the 1954-1970 period to $1.03myr^{-1}$ over the 1970-2000 period on the shorelines exposed to ocean dynamics. These changes are not compatible with the relative changes reported for the rest of the Beaufort Sea. The tremendous quantities of ground ice in Herschel Island which are associated with the huge retrogressive thaw slumps detected next to the major eroding areas are believed to be the driving factor for the outstanding erosion on the island. Further investigations are needed to map precisely the occurrence of ground ice on the island, to assess its precise role in the erosional processes and to interpolate a future evolution correlated to climate change.

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