Significant ice loss from Torngat Mountain Glaciers since the Little Ice Age

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Using a combination of lichenometry, remote sensing and in situ field data, this study reconstructs and dates former Little Ice Age margins, quantifies change up to present and analyzes factors influencing glacier change across the Torngat Mountain glacier range.

### Research Highlights
- Local lichen growth rates are used to estimate the Little Ice Age in the Torngats from the 17th to early 19th century.
- At least half of all glacier ice in the Torngats has been lost since the LIA, consistent with other alpine regions but inconsistent with other Arctic glaciers.
- Low-altitude glaciers show greater change — no significant spatial/topo-relationships.
- Evidence of significant glacier downwasting followed stagnation of remnant ice masses and;
- Torngat Mountain Glaciers are very climatically sensitive and may be susceptible to significant change in the future.

### Introduction

Torngat Mountain Glaciers (TMGs) exist in the only Arctic glacier range without previous change assessment. In 2008, the Torngat Mountain glacier project was launched with the purpose of collecting baseline information and increasing our understanding of TMGs. A major goal of this project is to investigate the climatic sensitivity of TMGs. This study reconstructs, dates and assesses TMG glacier changes from the Little Ice Age (LIA) to present.

### Torngat Mountain Glaciers

The glaciers of the Torngat Mountains are the southernmost in the eastern Canadian Arctic and the easternmost in continental North America. In total, 125+ active glaciers have been mapped covering an area of only 22 km\(^2\) (2005) - individual glaciers rarely reaching 0.5 km\(^2\) and never above 2 km\(^2\). The vast majority of TMGs are cirque glaciers occupying deep cirque basins with high back-walls and topographic shadowing, however small plateau ice caps and traditional alpine glaciers do exist in some locations (Figure 1a,b,c).

### Methods

#### Dating the Little Ice Age

LIA glacier margins in the Torngats were dated using lichenometry. This technique utilizes lichen growth rates and measured lichen sizes on moraines to estimate surface ages. In 1978 and 1983 eight lichen growth stations were established in Nachvak Fiord. These stations were re-visited in 2007 and 2011 providing 30+ year long growth records for lichens in the area. Combining the growth data with recent (2011) in situ measurements of lichens colonizing LIA moraines allows us to date the LIA in the Torngats.

#### Mapping the Little Ice Age

Little ice age glacier margins were mapped from 1:40,000 scale aerial photographs (2005) and followed established glaciological protocols. LIA glacier margins were deemed to be of two particular sub-types (Figure 2a,b).\(^1\) Large ice-cored moraines directly down-valley of current ice margins and;\(^2\) debris fields superimposing downwasting glacier ice delimiting former margins.

### Discussion

#### Lichenometry and Little Ice Age Timing

Lichen growth rates produced in this study are lower than those observed in Iceland and Whales, but resemble rates hypothesized by Bradwell and Armstrong (2007) for West Greenland. Lichenometric results show disagreement with previous work done in the region during the 1980s due to advances in procedures. The timing of the LIA (1610-1751 AD) for the Torngats is significantly earlier than for other North Atlantic glaciers but agrees well with regional reconstructions for Labrador (Figure 5).

#### Glacier Change Results

Quantified change from the LIA to present (~50%) is similar in magnitude to changes observed on other small mountain glaciers in the Austrian/Swiss/New Zealand Alps. The closest analogues to TMGs for both geography and climate are those in Baffin Island, Western Greenland and Bylot Island. These regions show significantly lower change since the LIA (~7% to ~20%) indicating a unique climatic/topographic response of TMGs.

#### Factors Influencing Change

Spatial relationships with glacier change are not evident in the data (Figure 3). For local setting the most significant factor influencing TMG change is altitude (Figure 6) where mean glacier elevation is weakly correlated with glacier change. Results suggest that higher altitude glaciers show less change than lower glaciers. We also find an upwards migration of glacier viability of 100 m. The results indicate that aspect, curvature, latitude, length, size and slope are not strongly influencing glacier change.

#### Glacier Downwasting

This study observes many examples of glacier stagnation followed by significant to total downwasting of once active glaciers (Figure 7). These formerly active LIA glaciers have often melted away leaving only inactive remnant ice/perennial snow patches or ice-cored debris field devoid of glacier flow.

### Conclusion

In summary:
- Regional lichen rates from data collected in Nachvak Fiord have been used to date LIA moraines across the Torngats giving 17th to early 18th century LIA dates for the Torngats;
- at least half of all glacier ice in the Torngats has been lost since the LIA, consistent with change rates observed in other alpine regions but inconsistent with other North Atlantic glaciers;
- ice losses show regional synchronicity while glaciers at lower elevation show more change than high-altitude glaciers;
- evidence is presented of glacier downwasting followed by thinning and stagnation for small LIA glaciers which have since melted away leaving only remnant ice masses and;
- these results suggest that TMGs are climatically sensitive and may be susceptible to significant change in temperature and/or precipitation in the future.

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