Unearthing the forgotten record of glacier change in southeast Greenland

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Background

- Glaciers and ice sheets are key indicators of changing climate
  - documenting widespread retreat, and mass loss in recent decades;
  - yet, uncertainties remain regarding longer-term trends, rates of change, and response to variation in climate variables.

- The widespread, continuous monitoring of ice masses has been possible since the 'satellite era' (post-1972);
  - **prior to this, however, only more disparate records of glacial change exist** (as collated by the World Glacier Monitoring Service), and few of these records extend before the 1980s (coinciding with the launch of NASA's Landsat programme).

- Archived expedition, reconnaissance, and field photographs may hold the potential to 'back-extend' satellite records and improve understanding:
  - pertinent measures of glacial change (i.e. extent [frontal position], and surface elevation) depicted over multiple timesteps can be used to establish more long-term (> 50 year) trends.
  - **Computer vision techniques** (such as Structure from Motion [SfM], in this study) **can prove instrumental in extracting such glaciological metrics, and 3-D models, from these 2-D photographs.**

Study snapshot

- Aerial imagery from two time-steps (1931 & 1983) over a portion of southeastern Greenland was acquired*;
- Structure from Motion (SfM) was used to extract a 3D point cloud using repeat 2D scenes for this region:

  - allowing SfM algorithm to estimate the **focal length**, **altitude**, and **distance** between frames.

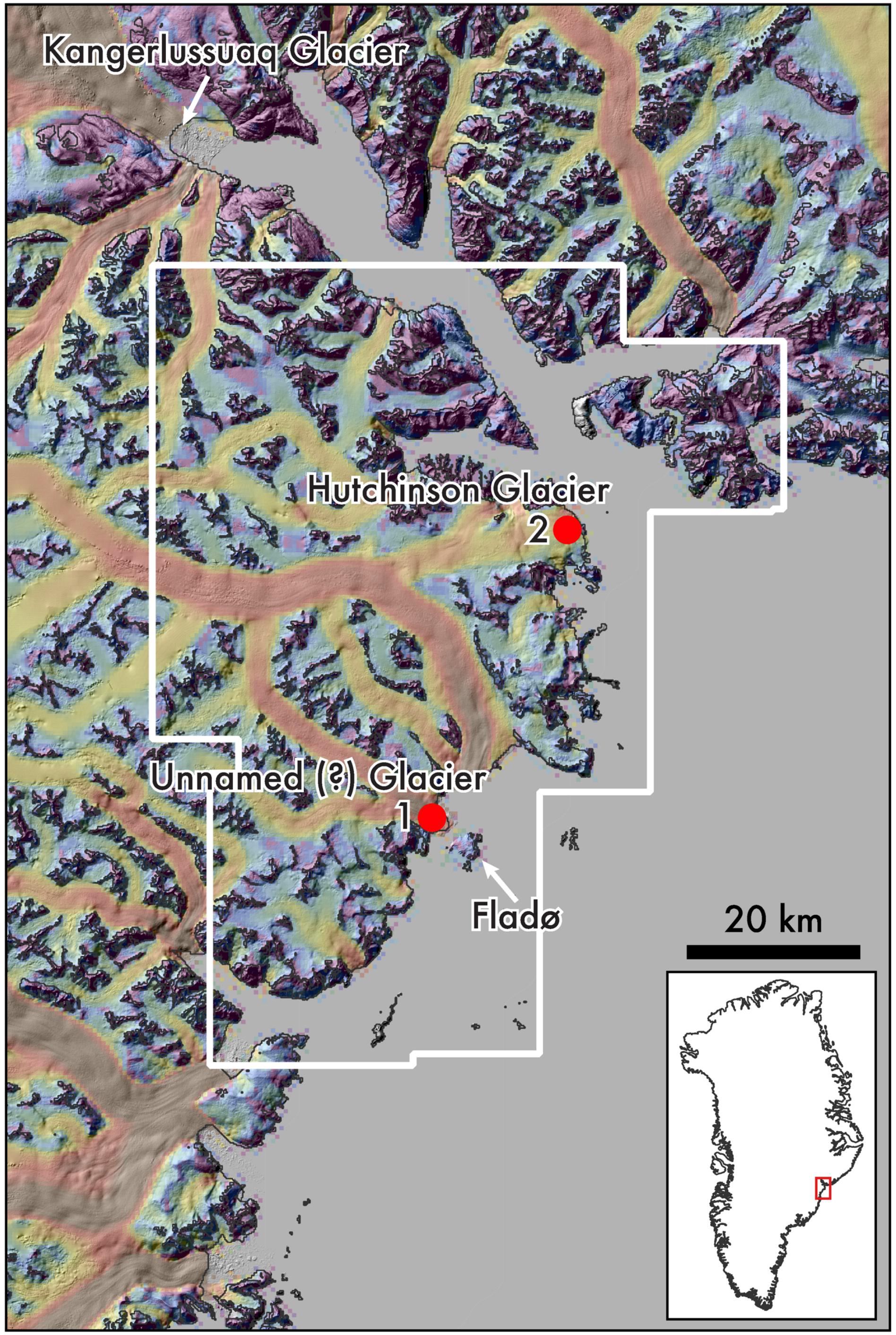
- Georectification was applied using stationary ground controls points (GCPs) from a baseline DEM

  - baseline: ArcticDEM (mosaic tiles at 2m resolution);

  - negligible weathering (or change) in stationary (bare rock) points was assumed.

- High resolution DEMs were produced at each timestep at a posting resolution of 10 m.

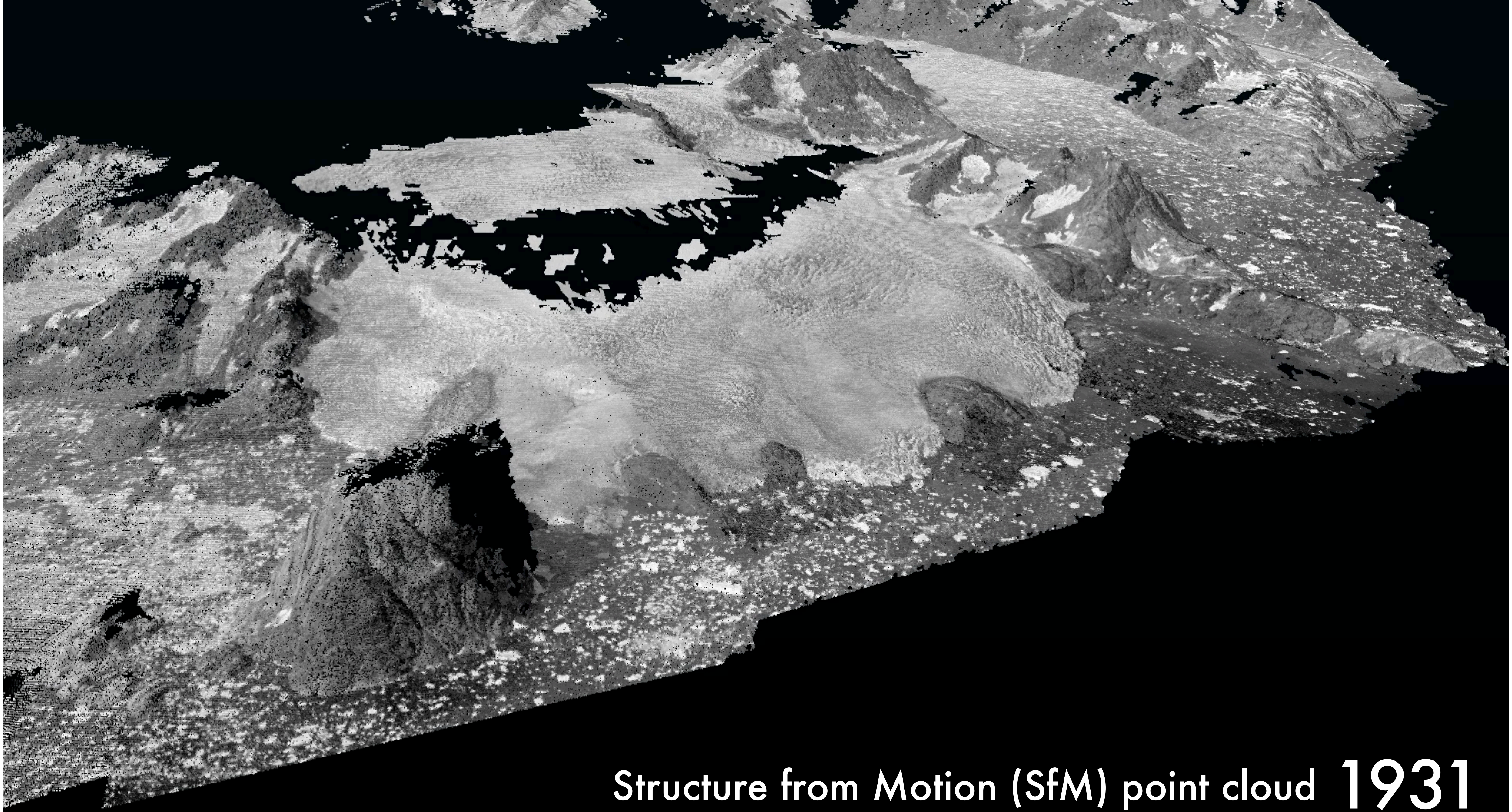
  - *For the purposes of ***#shareEGU*** this presentation will only focus on the creation and analysis of data covering the Hutchinson Glacier region (outlined & labelled, right).



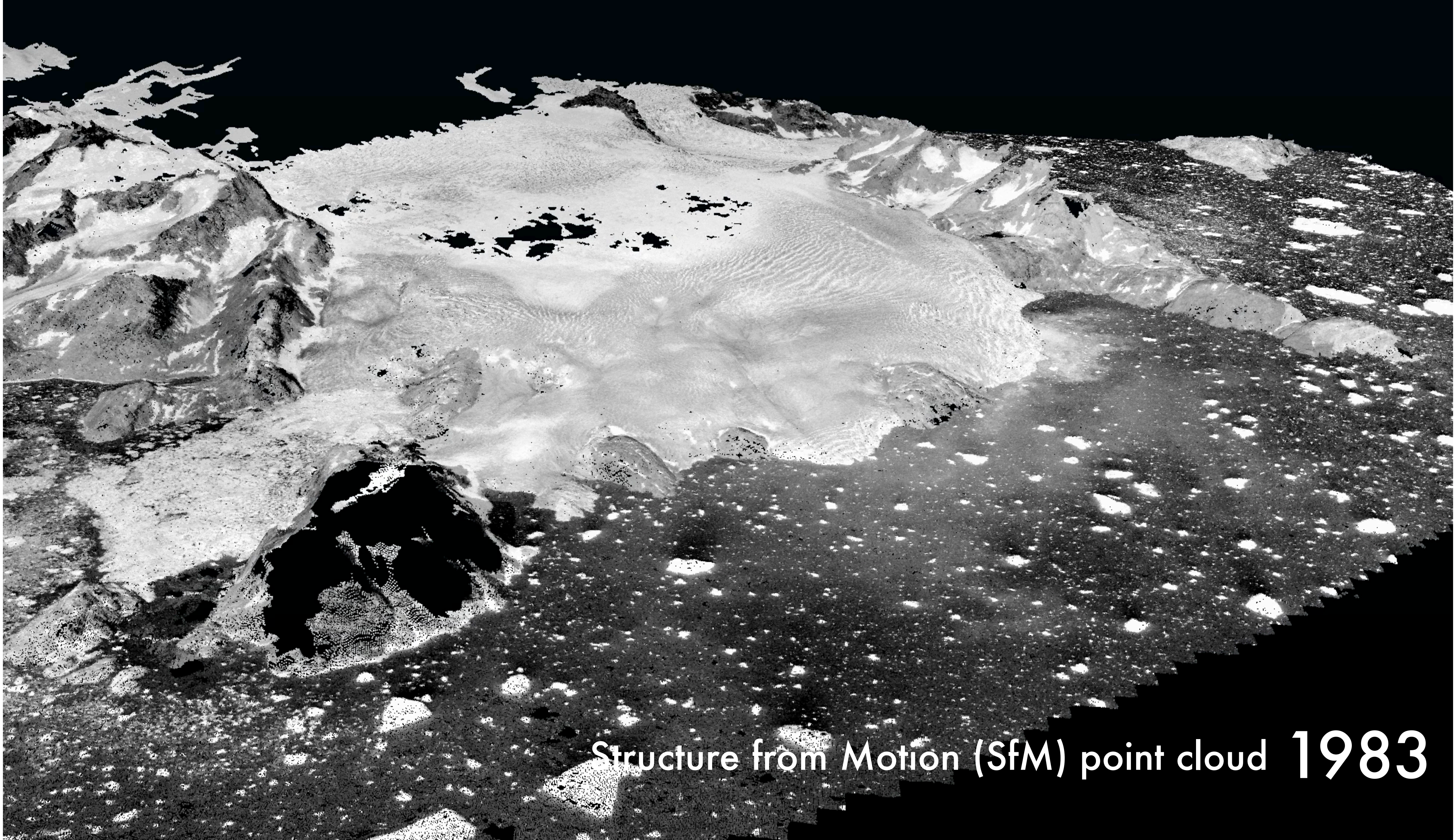
Examples of archival inputs

British Arctic Air Route Expedition (BAARE), 1930—31*

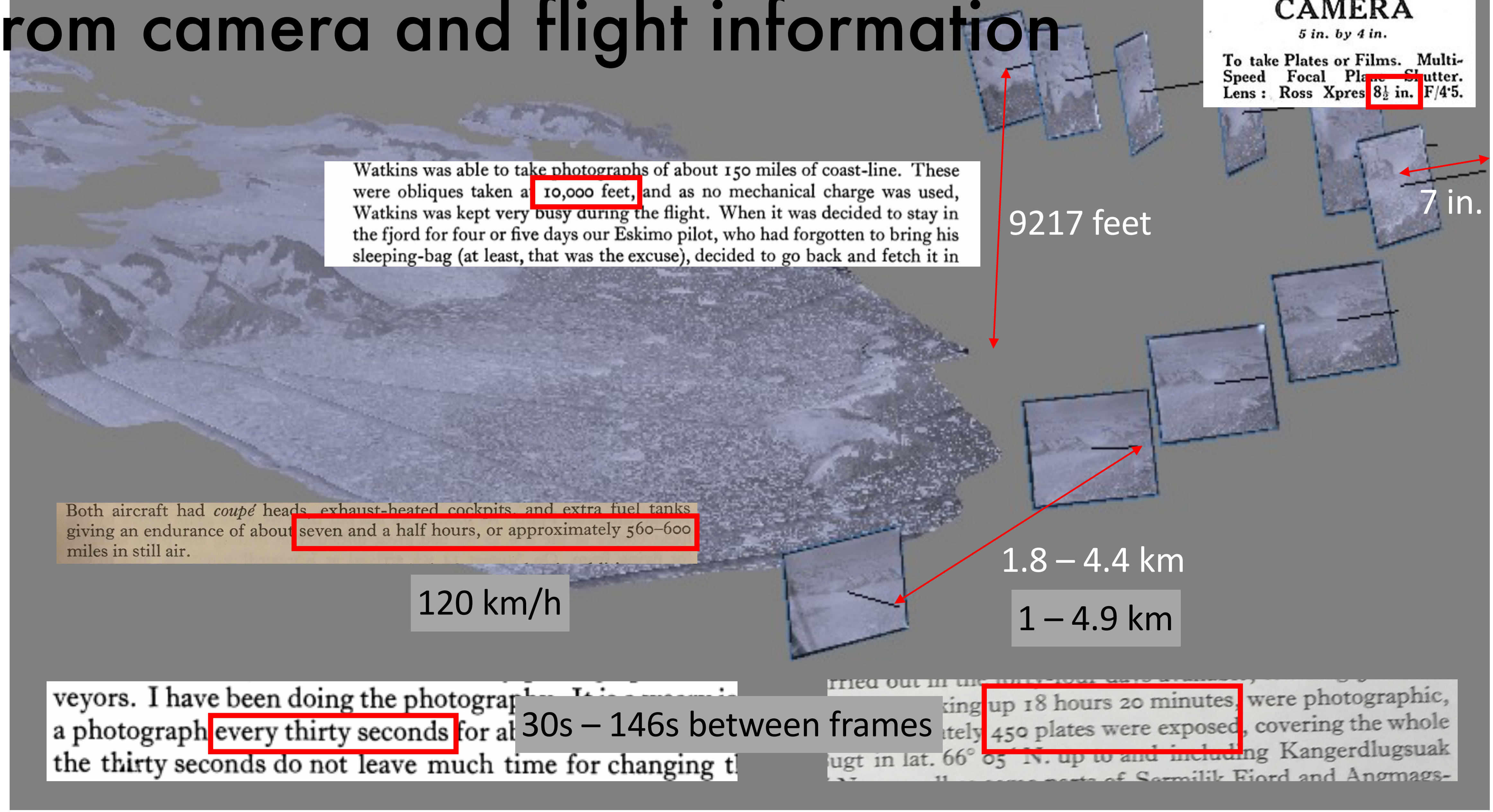
(Danish Geodata Agency [held by GEUS])



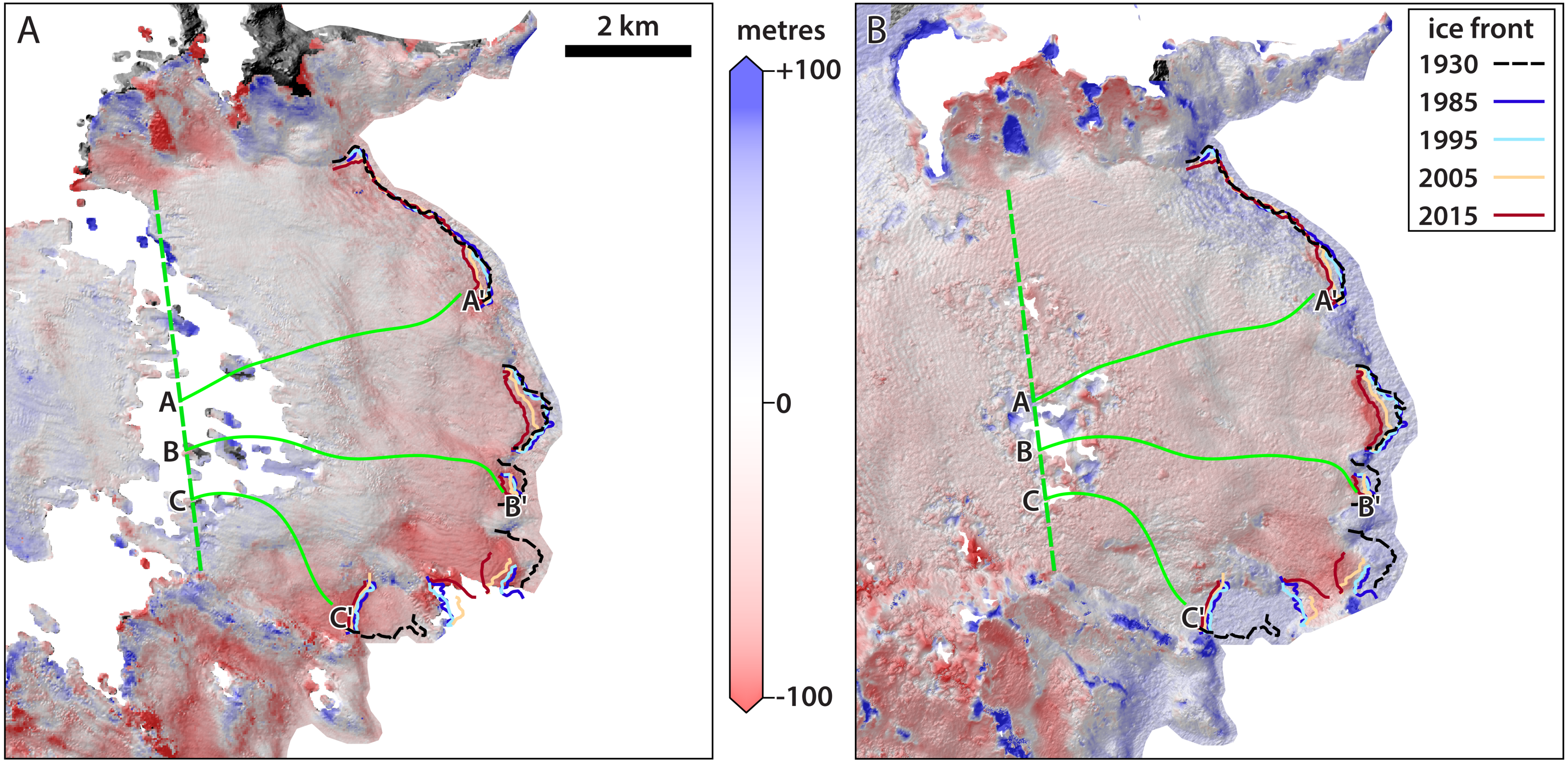
Structure from Motion (SfM) point cloud 1931


Structure from Motion (SfM) point cloud 1983

Validation of 1931 SfM PC production from camera and flight information



DEMs of Difference for Hutchinson Glacier



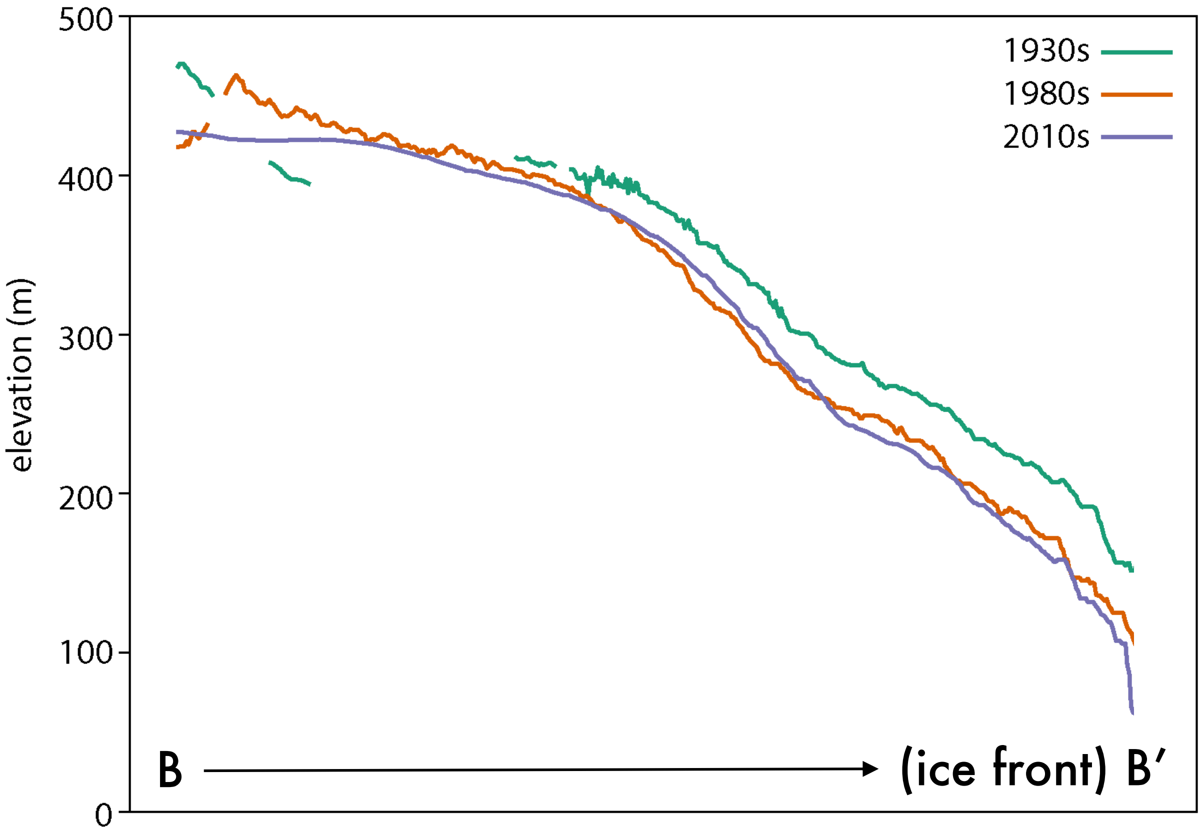
Elevation change 1930s–1980s

Elevation change 1980s–2010s

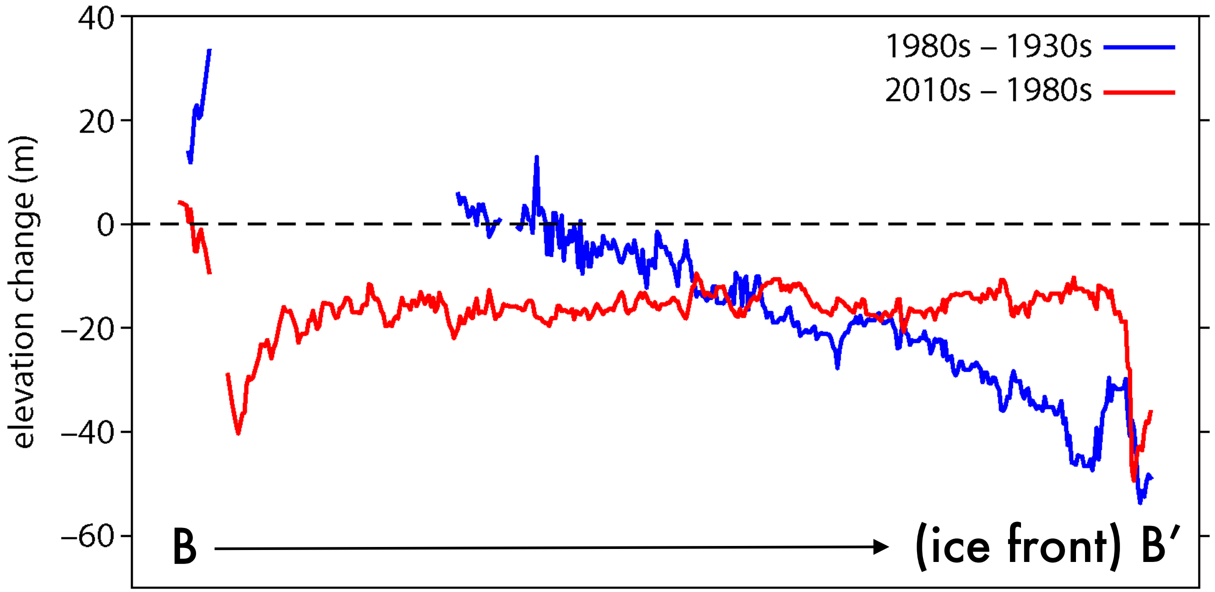
Lea (2018), GEEDiT tool

(profiles A, B, C are generated along contemporary flowlines)

Surface elevation change (profile B–B′)



a) Extracted surface elevations along profile B–B′ for generated DEMs for 1931, 1983 and the baseline ArcticDEM (average elevation 2010 to-date).



b) Elevation change (difference) between each time-step.

Early period shows marked lowering at glacier front, later period (between 1980s–2010s) shows more even distribution of throughout profile length.

Summary and future scope

- Using Structure from Motion, high resolution DEM snapshots can be extracted from archival photography to examine over 90 years of glacier change history in southeast Greenland;

- Whilst only one glacier has been presented here, we have covered a ca. 240,000 km length of coastline, extracting glaciological variables for ca. 20 outlet glaciers, providing insight into changing:
  - glacial extent (glacier front, and trimlines);
  - frontal characteristics (transition from marine- to land-terminating);
  - surface characteristics (hydrology, crevassing, etc.);
  - as well as, surface elevation – allowing the calculation of volumetric change since 1931.

- Available regional meteorological data (air temperature anomalies and sea surface temperature changes) will be incorporated to further assess trends between each timestep.

- Aside from repeat aerial photographs (with overlap) as used here, this project aims to make use of single shot photographs (with no overlap) for similar analysis using in-house computer vision techniques – this may extend to using Ponting's photographs from Scott's South Pole Expedition.