

Rivers on Ice: Evolution of Supraglacial Drainage Networks at Humboldt Glacier, NW Greenland

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Motivation

- Surface melt and runoff has become an increasingly dominant component of Greenland Ice Sheet (GrIS) mass loss ^[1]
- Supraglacial (SG) channels are an integral component of meltwater transport and are closely connected with supraglacial lakes
- To date, much of the hydrological interest has focussed on western regions of GrIS due to strong atmospheric warming, reduced albedo ('dark zone'), presence of hydrofracture events and limitations of fieldwork logistics ^[2]
- This work expands SG hydrological mapping to Humboldt Glacier (HG), NW GrIS: an area yet to be mapped
- HG is the largest marine terminating glacier in Greenland draining ~5% of the ice sheet ^[3] and enhanced meltwater availability has been linked to recent thinning and retreat ^[4]



Fig. 1- Example of a supraglacial channel. Red circle shows people for scale (image credit - Andrew Sole)

Method

Sentinel-2 and Landsat-era (5,7,8) optical imagery are used (<20% cloud cover) to respectively explore the seasonal and multi-annual evolution of SG drainage of HG*.

Following the method of Yang *et al.* (2015, 2017; see Fig.2):

- A normalised difference water index, or NDWI^[5] is created
- NDWI image is passed through an automatic river detection algorithm (Gabor filtering, path opening) helping to preserve river network continuity for effective delineation
- Two thresholds (t_{18} and t_5) are used to create binary river masks of both primary and secondary river channels
- A further threshold ($t_{0.4}$) applied to the original NDWI image is used to create binary lake masks
- Binary rivers channels and lakes are vectorised

Quantification includes river length, lake area, drainage density (D_d) and elevational and inland extent changes

*Hydrologically-connected saturated slush zones are retained due to their importance in meltwater production and movement. The crevasse zone in HG northern sector is removed prior to drainage quantification to avoid overestimation of river density^[6]. SG lakes >0.15km² are retained.

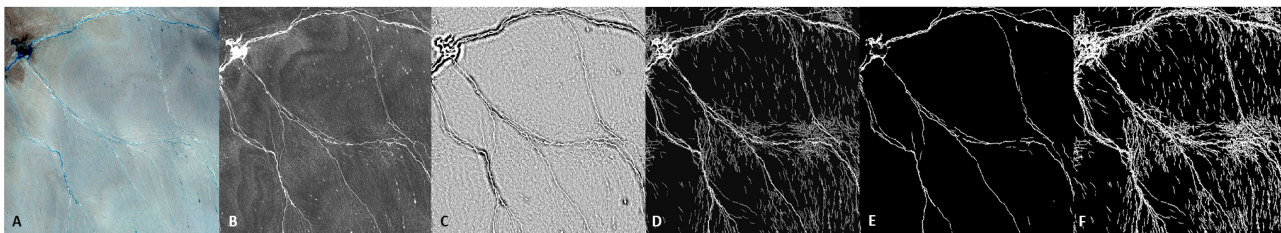


Fig. 2: Example of automatic river delineation using Yang *et al.* (2015) method on a Sentinel-2 image. [A] True colour image; [B] NDWI image; [C] bandpass filtered image; [D] Gabor filtered and path opened image; [E] thresholded (t_{18}) binary mask delineating primary rivers; [F] thresholded (t_5) binary mask delineating primary and secondary rivers ^[7,8]

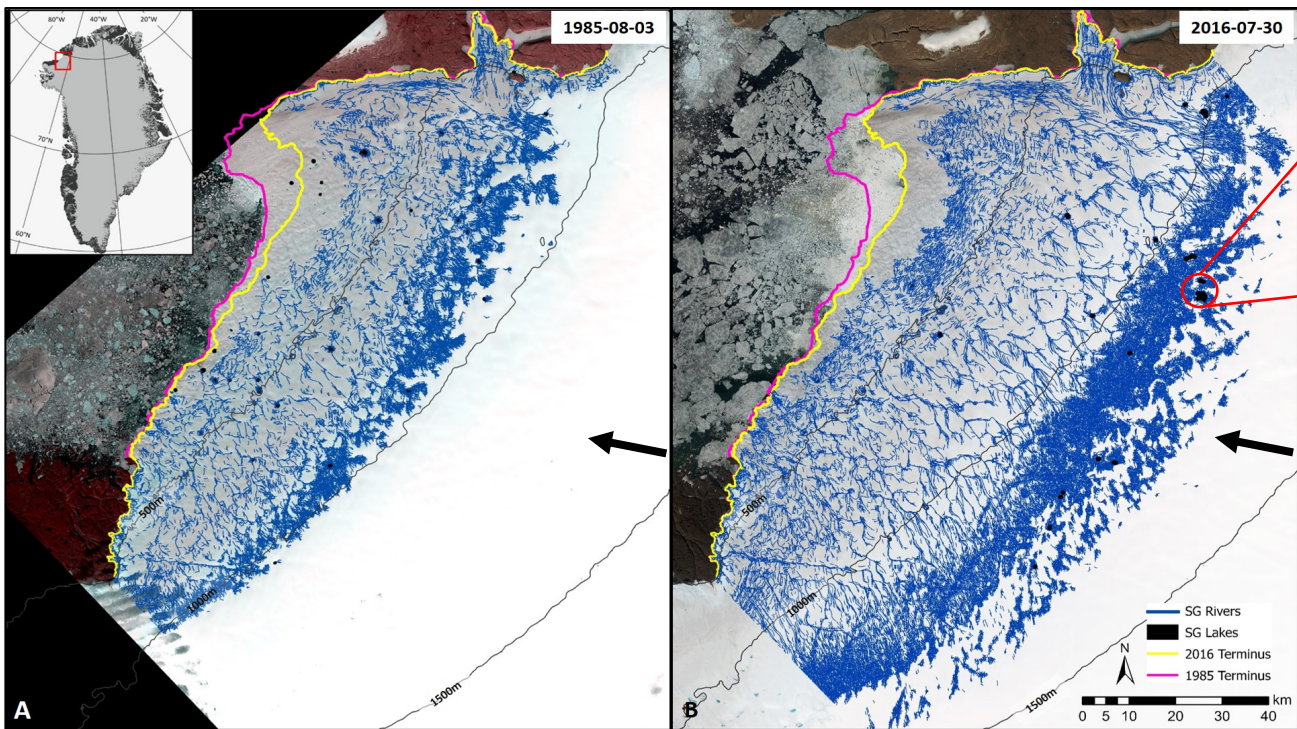


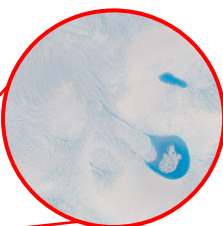
Fig. 3: Landsat-derived supraglacial (SG) river and lake locations at HG during respective melt seasons using t_5 . Northern crevasse region has been removed; [A] = drainage networks on 03-08-1985 extending maximum ~45km inland; [B] = drainage network on 30-07-2016 extending maximum ~83km inland. Elevation contours are created using the 10m mosaic ArcticDEM. Black arrows denote ice flow direction. (Inset: location of HG, north-western GrIS denoted by the red box)

Initial Findings

The total area mapped at HG is 18,572km² (with crevasse zone removed).

Comparing Landsat-derived (1985 and 2016) SG drainage networks (Fig.3):

- Total meltwater area = 755km² (1985) and 1764km² (2016)
- Drainage density has increased by 161% over the 30 year period
- Maximum inland melt extent has also increased by 88% over the same period, reaching a maximum elevation of ~1400m in 2016
- SG rivers have evolved to become less fragmented, longer, parallel channels (particularly in HG southern region)
- Mean SG lake size = 0.19km² (1985) and 0.27km² (2016)
- Time series animation (see QR code) of 2016 HG drainage evolution shows the progressive behaviour of the hydrological network as runoff intensifies, reaching maximum extent between 29th July and 7th August 2016.



QR CODE: Short time-series animation of the seasonal progression of Sentinel-2 mapped supraglacial drainage at HG during the 2016 melt season



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What's Next?

Continued work will:

- Further quantify processed Sentinel-2 dates spanning 2016-2020 melt seasons (May – September) *Paper in Progress*
- Further quantify SG drainage evolution from processed Landsat images over a 35-year study period (1985-2020)
- Estimate runoff values using MAR data and compare with satellite-mapped SG drainage
- Examine climatic influences on SG drainage
- Map moulins and explore impacts on localised ice dynamics at HG

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