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Assessing the distribution and characteristics of supraglacial channels in an Alpine setting

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1. Background & Aims

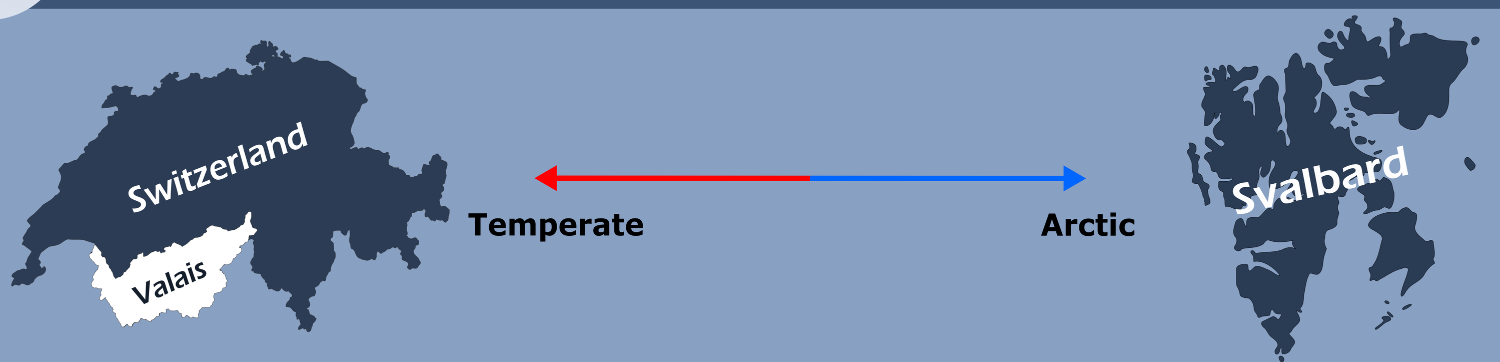
Supraglacial channels occur under active surface melting and rainfall and route meltwater to englacial, subglacial and peripheral positions. Crucially, in alpine regions, glaciers are a vital water resource, with the amount of run-off and meltwater transport pathways having an impact on hydropower generation, contaminant levels and freshwater supply. However, the mechanism of meltwater transport remains relatively understudied, particularly in a mountain glacier and ice cap setting where channels are often below the pixel resolution of most satellites.

Research Questions:

1. What is the distribution and characteristics of supraglacial channels?
2. What are the controls on channel occurence and characteristics?
3. How do channels evolve within a melt season?

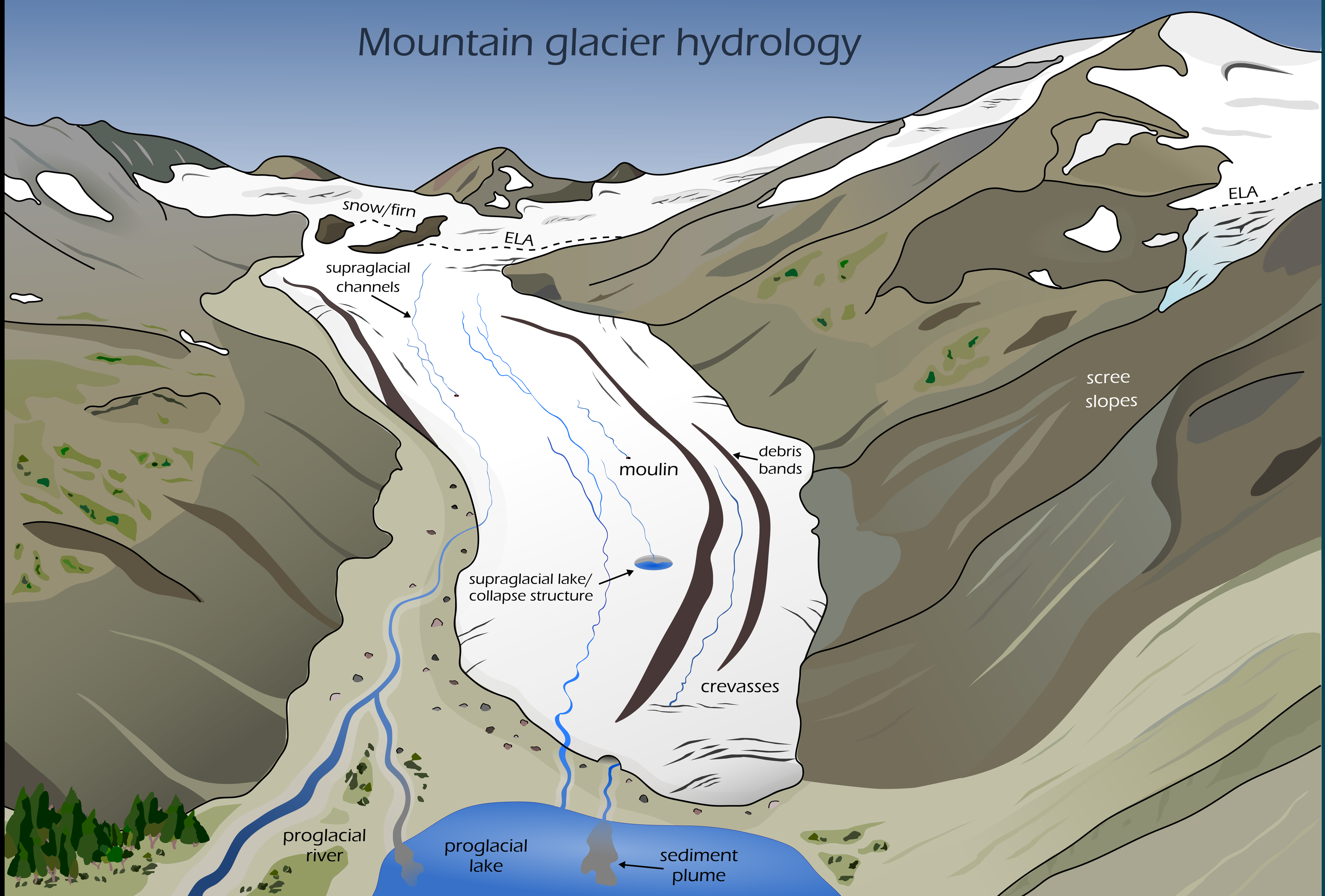
Given the lack of understanding of supraglacial channels and their importance for surface mass balance, heat and contaminant transfer and glacier dynamics, this project aims to improve the state of knowledge on supraglacial channels on mountain glaciers and ice caps, providing insight into their distribution, morphology, and evolution. This will be done by (1) large scale mapping of channels. (2) Extracting and analysing metrics. (3) Extensive fieldwork where channel properties will be measured (e.g., depth and discharge) and seasonal evolution will be documented using UAVs and time-lapse photography.

2. Study Location



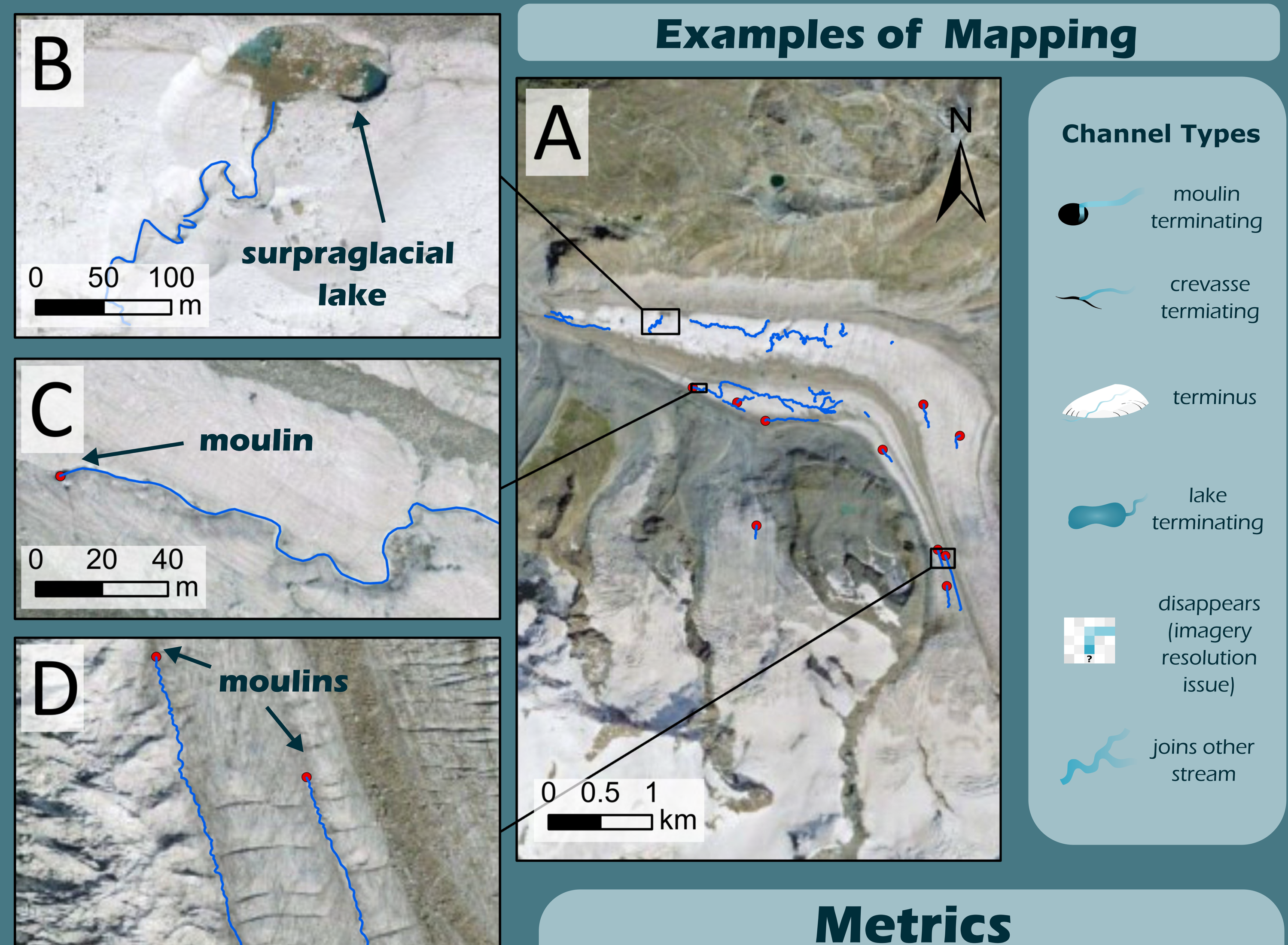
- Two contrasting study sites have been chosen, Switzerland and Svalbard. Switzerland has a longer melt season and higher ablation rates than Svalbard. This latitudinal comparison will enable us to evaluate the role of climatic forcing on channel distribution, morphology and evolution and test whether the controls on channel formation vary between climates.
- Mapping was conducted in Valais Canton in Southern Switzerland. Valais contained 207 suitably snow-free glaciers (> 0.1 km^2) in 2020 and has a similar glacier size distribution to the 667 glaciers in Switzerland and encompasses glaciers of varying characteristics (e.g., debris, size, aspect). We mapped 1890 channels across 85 glaciers where channels were detected. At present, only Switzerland has been analysed.

Mountain glacier hydrology



3. Methods

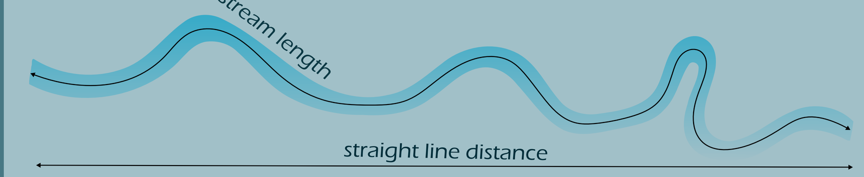
Examples of Mapping



Data availability

- Small streams on mountain glaciers can only be clearly manually delineated from high-resolution imagery.
- Orthophotos (~ 15 cm resolution) are available for Switzerland (2020) and Svalbard (2012).
- DEMS (0.5 m to 2 m) were used to extract stream properties (e.g., slope & fength).

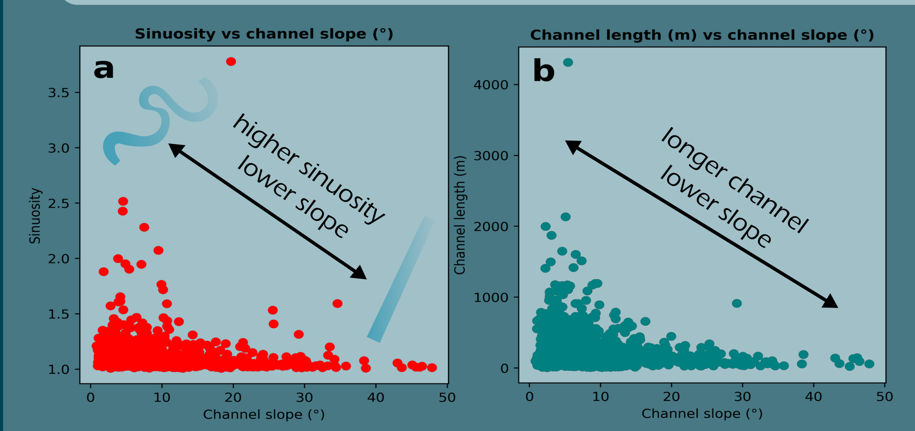
Metrics



Metric	Description	Metric	Description
Drainage density	Total stream length/ glacier area	Sinuosity	Stream length/straight line distance
Elevation	Min, max & mean extracted using a DEM	Slope	Use of a DEM and ArcGIS tools to auto calculate slope
Length	Stream length calculated using ArcGIS tools	Profile	Coefficient calculated for cancave/convex profile

4. Results - Switzerland

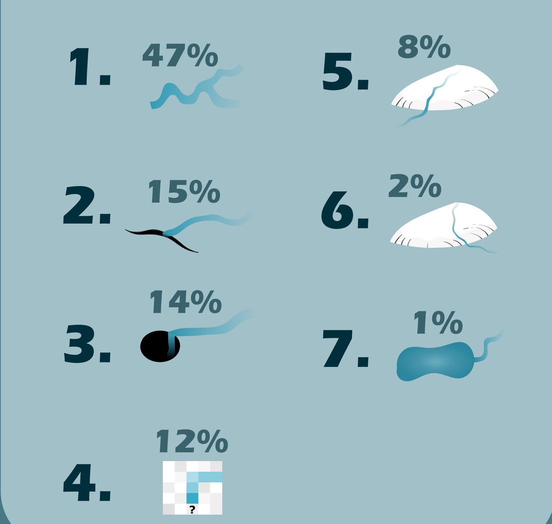
Channel characteristics



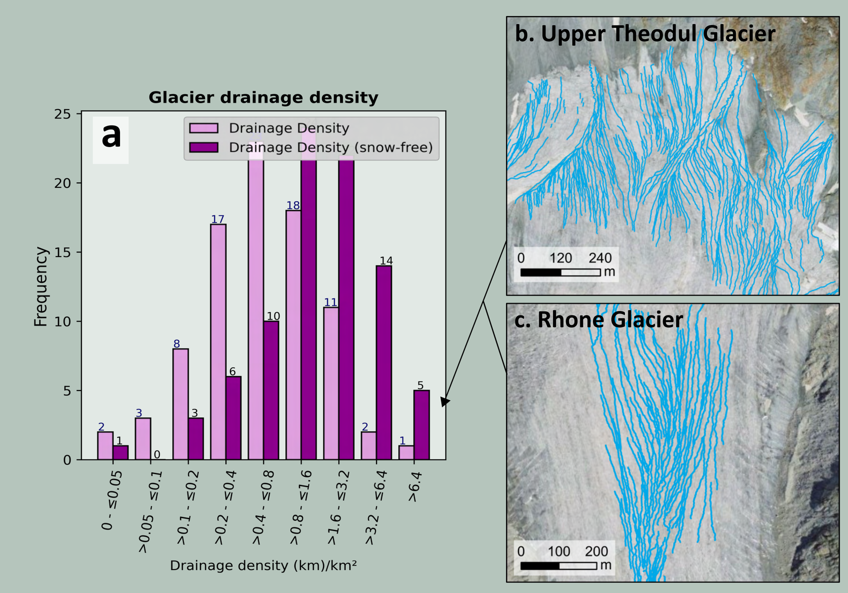
Controls on channel formation

- Channels have a mean slope of 8° with a mean sinuosity of 1.1.
- The most sinuous channels are more likely to occur on low slopes.
- Large channels often occur at the interace between debris-covered and clean ice, particularly next to medial moraines.
- Glacier structure affects channel morphology with trace and shallow crevasses exploited to produce long, straight channel segments.
- We find no difference in sinuosity between clean & debris-covered glaciers.

Where does the water go?



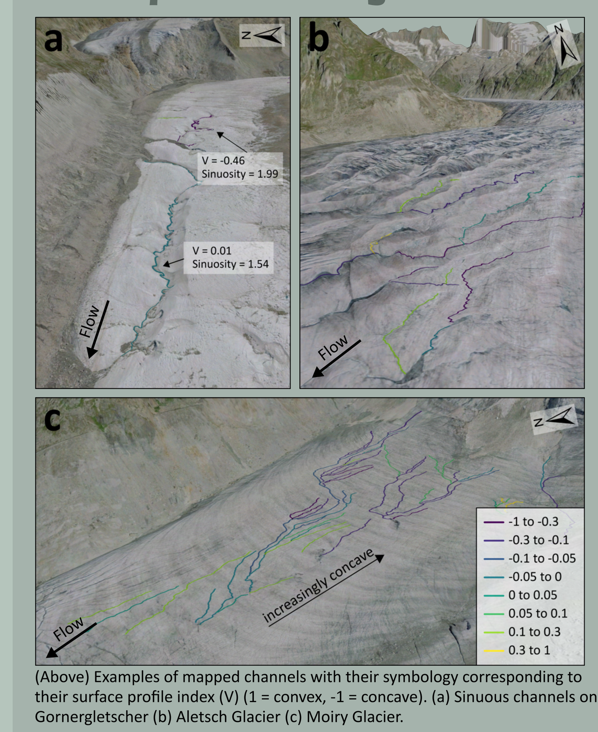
Controls on drainage density



Controls on drainage density

- Glaciers containing channels have a mean area of 5 km^2 compared to glaciers without channels (0.6 km^2).
- Glaciers with channels have a snow-free area slope of 21°, compared to 28° on glaciers without channels.
- Glaciers without channels are more likely to terminate at higher elevations (average minimum elevation: 2936 m) compared to glaciers with channels (average minimum elevation: 2797 m).

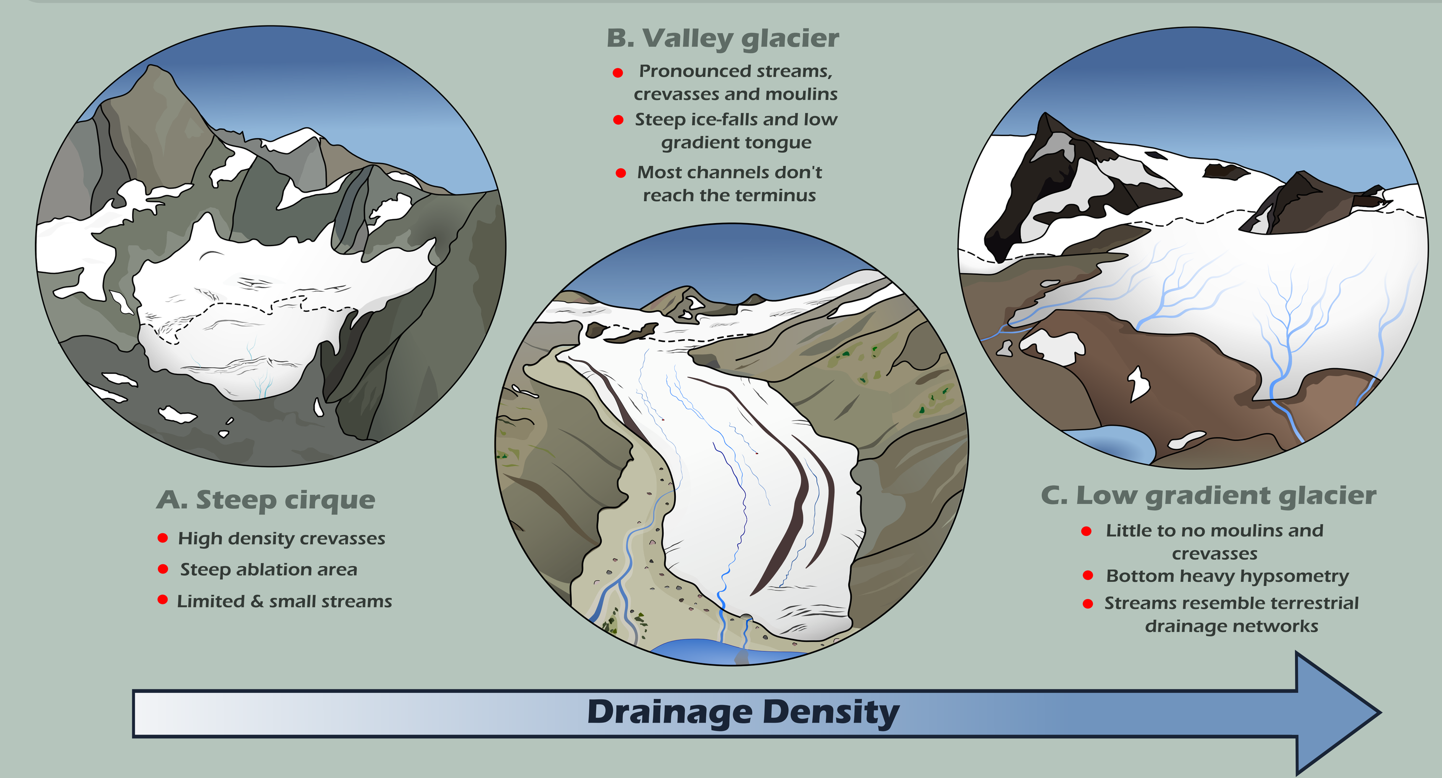
Examples of drainage networks



(Above) Examples of mapped channels with their symbology corresponding to their surface profile index (V) (1 = convex, -1 = concave). (a) Sinuous channels on Gornergletscher (b) Aletsch Glacier (c) Moiry Glacier.

- Glacier drainage networks often resemble terrestrial drainage networks, but are complicated by the presence of moulins and crevasses.

Drainage density by glacier configuration



5. Next Steps

1. Interpretation

- Finalise analysing the significance of relationships between variables in the dataset.
- Data collection is finalised for Switzerland and will now be written-up into a paper summarising the key controls on channel formation in the Swiss Alps.

2. Fieldwork

- Fieldwork will be conducted twice in Switzerland , early and late into the melt season to observe channel evolution.
- UAV surveys will produce high resolution DEMs and orthophotos to detect smaller channels at select field sites.
- Metrics that cannot be measured remotely (e.g., depth, discharge etc.) will be measured in the field.

3. Svalbard

- Once controls on stream formation are established for Switzerland, they will be tested at a polythermal glaciers on Svalbard. Mapping will be conducted from orthophotos for a smaller study area comprised of varying glacier types (e.g., debris vs clean glaciers).