Challenges in catchment delineation under changing environmental conditions in the High Arctic – pros and cons of GIS tools in catchment analyses

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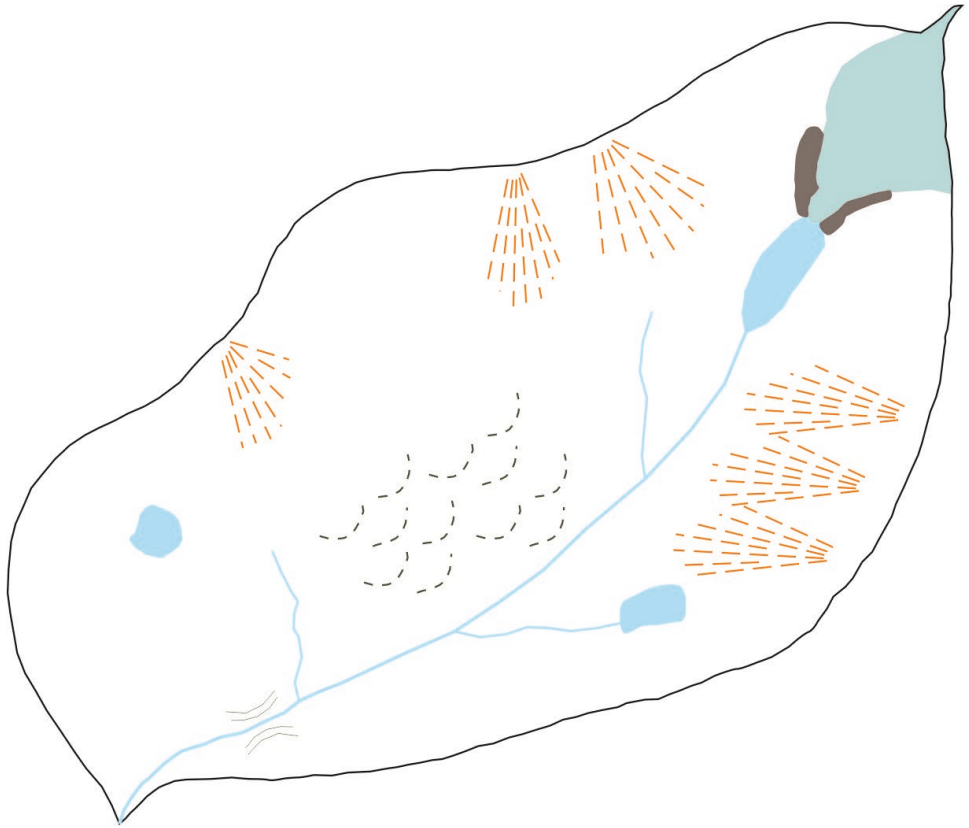
Presentation outline

1. Catchment as basic hydrological area
2. Small catchments and regional analysis
3. Standard methods
4. Proposed procedure
5. Delineation under changing climate
6. Summary

Catchment as a basic hydrological area

- Catchment - *the area of land from which water flows into a river, lake, or reservoir* (Cambridge dictionary)
  - Small catchment <10km^2
- Widely used in various fields of science



Small catchments and regional analysis…

potential catchments are clearly visible

Standard ArcMap methods

ArcGIS

Basin

DEM

↓

fill

↓

flow direction

↓

BASIN

Watershed

DEM

↓

fill

↓

flow direction

↓

flow accumulation

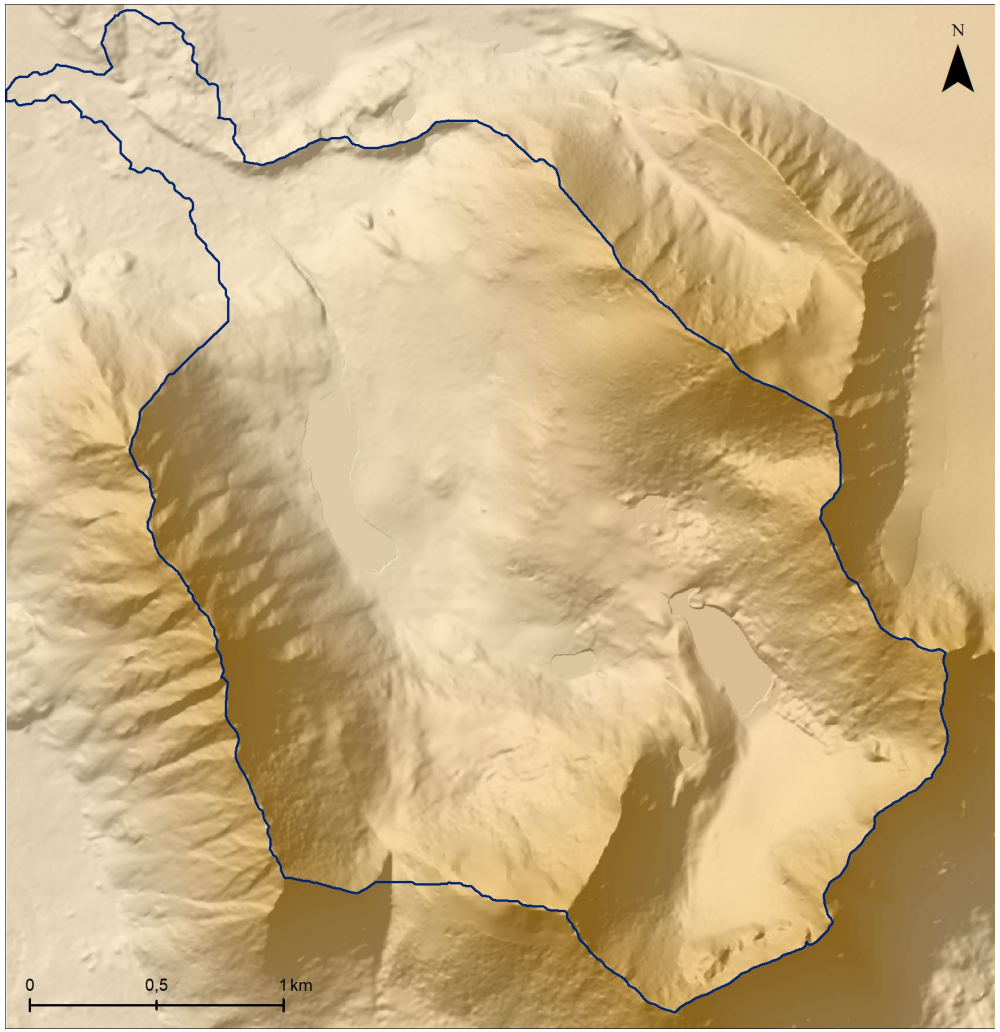
↓

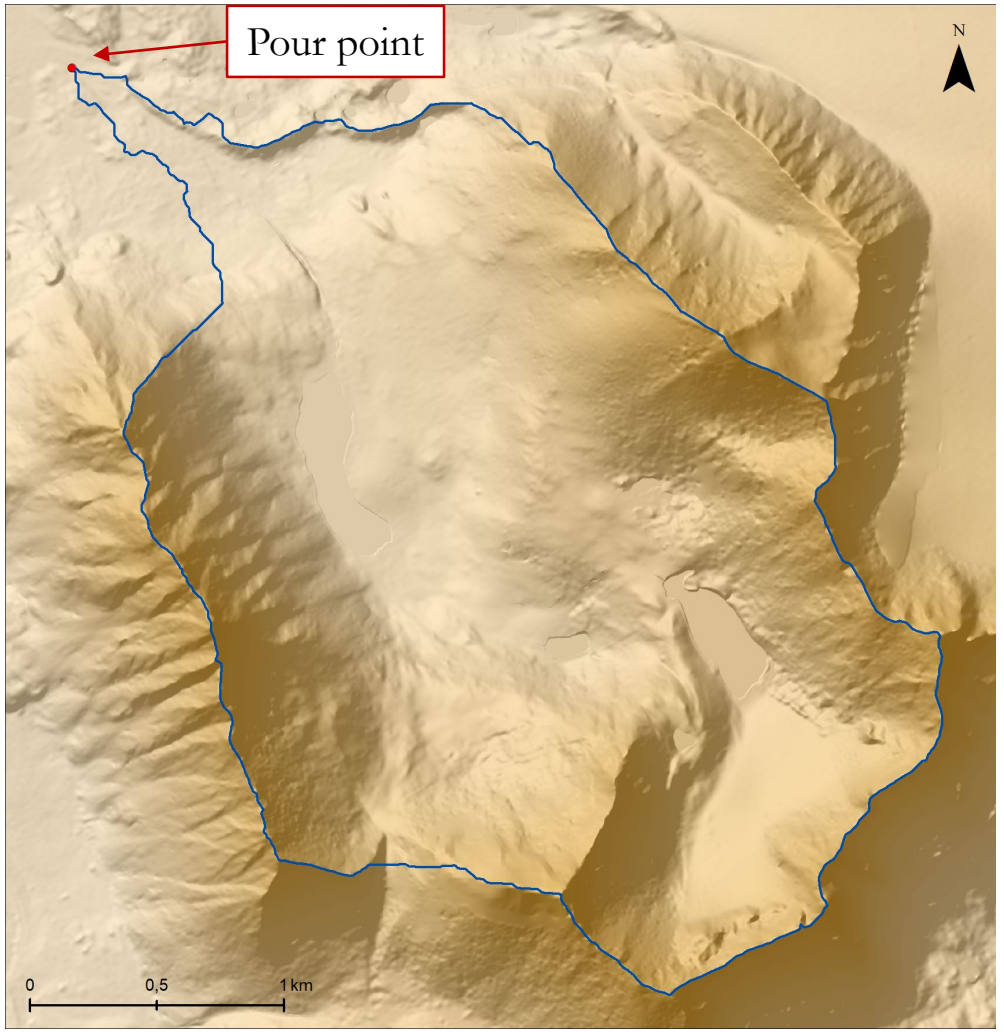
pour point

↓

WATERSHED

Effect of basin and watershed tools on 2m DEM





Works well for small areas, when manual verification is feasible…

But what happens if our research area is much bigger?

- Manual delineation of **pour points**…

…possible but time consuming 

- Feasible…

…but it is **not** what we want

- So how can we try to automatically designate pour points?

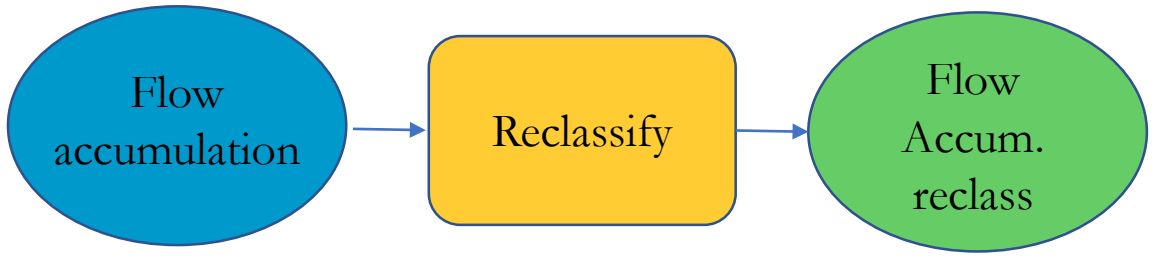
What we have:

- ❑ Digital Elevation Model (resolution 20 m)
- ❑ Hydrological object: drainage system (rivers, lakes) and glaciers
- ❑ Orthophotomap (resolution 40 cm)

Therefore we introduced the following procedure

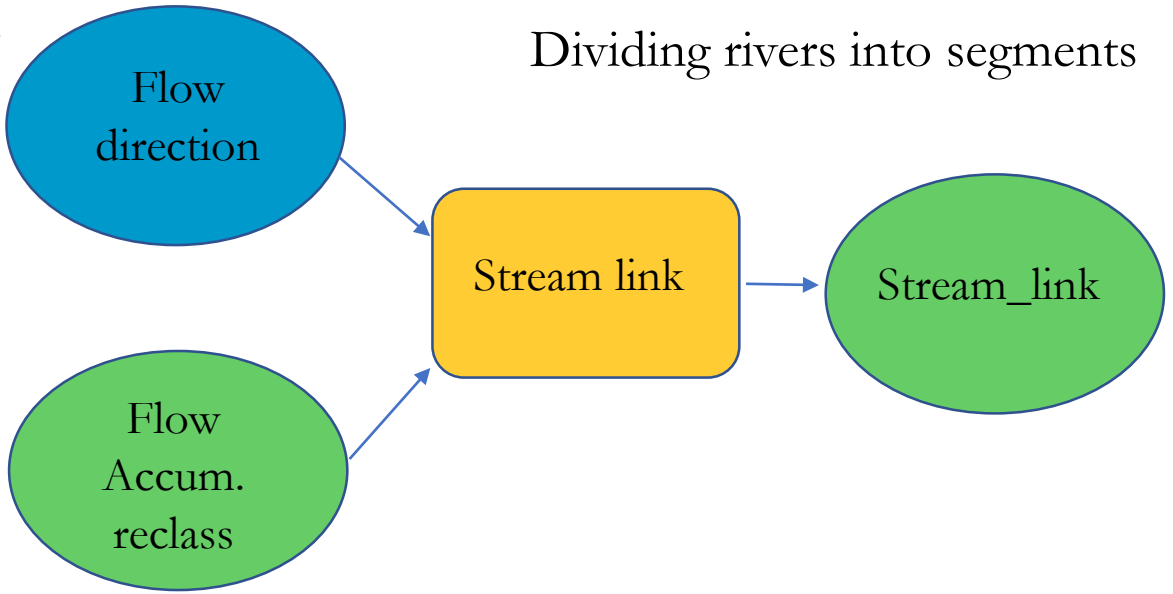
1

Limitation of the number of cells from which water flows to 1 unit



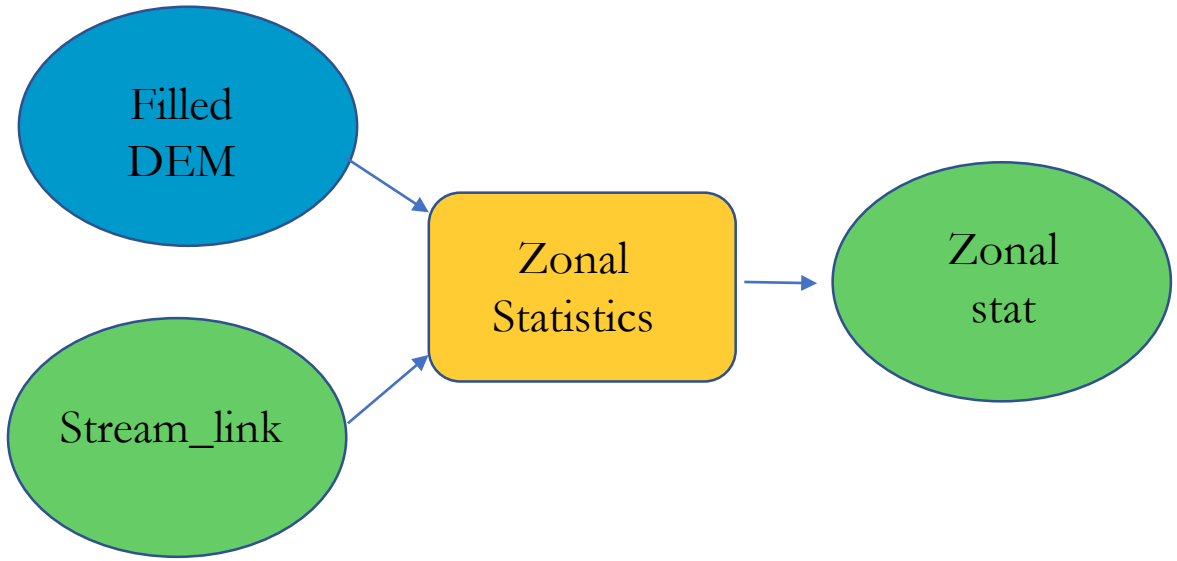
2

Dividing rivers into segments



3

Minimal value for each segment



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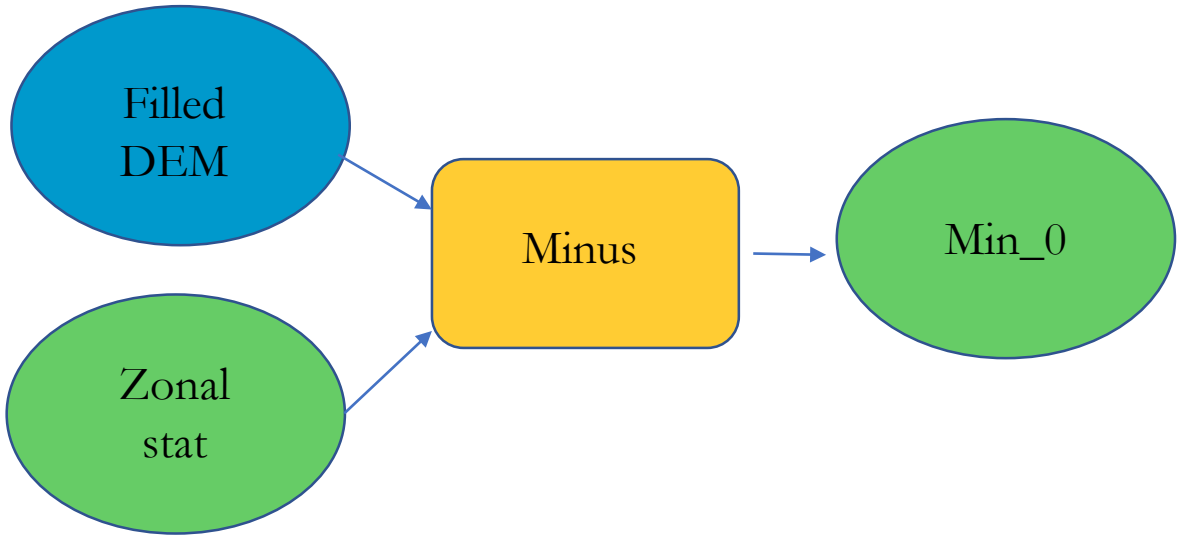
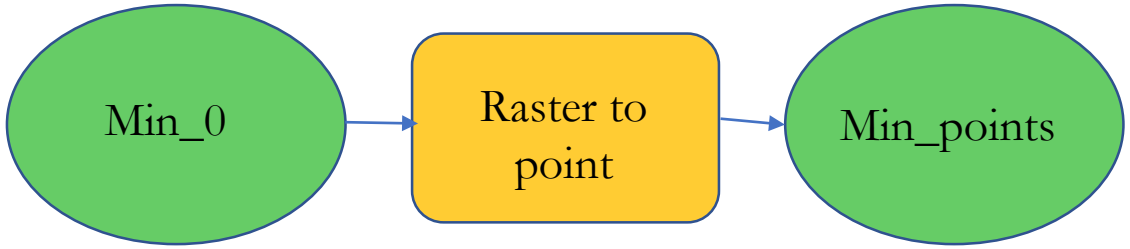


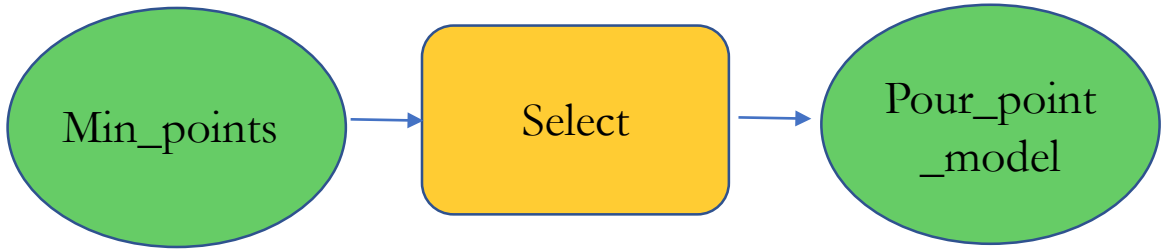
5

Conversion raster to point



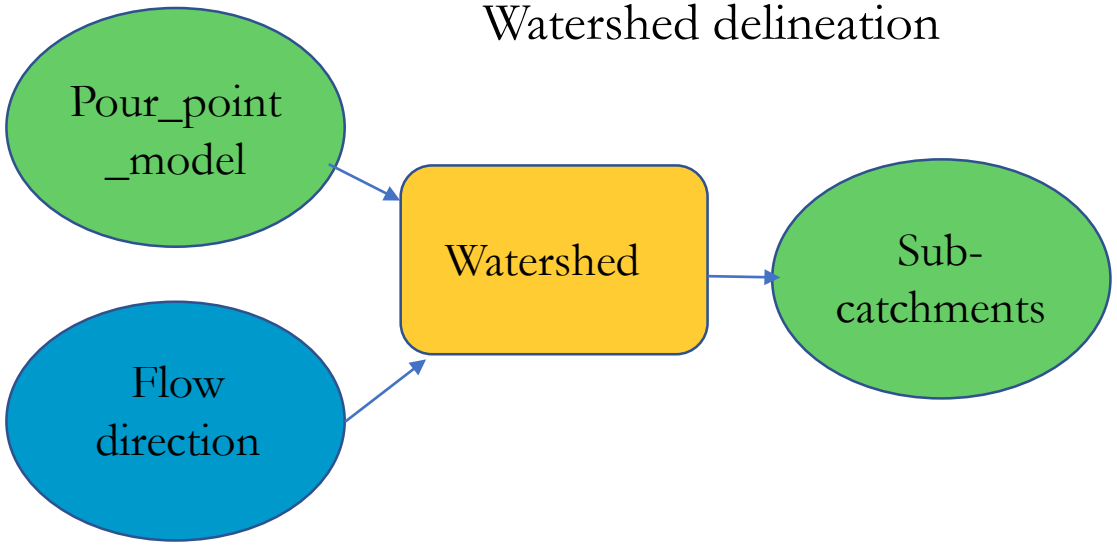
6

Selection of points to which the water flows



7

Watershed delineation



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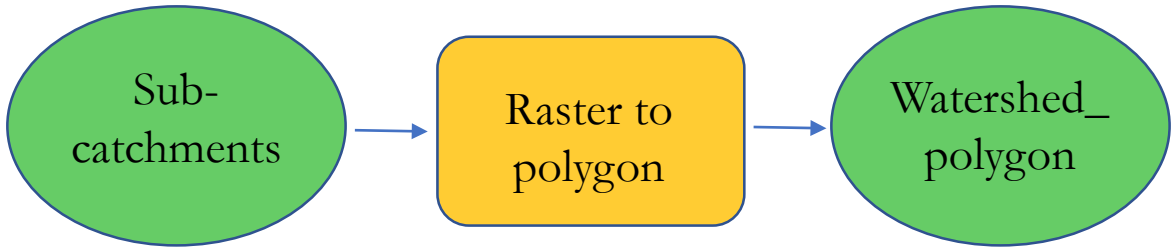
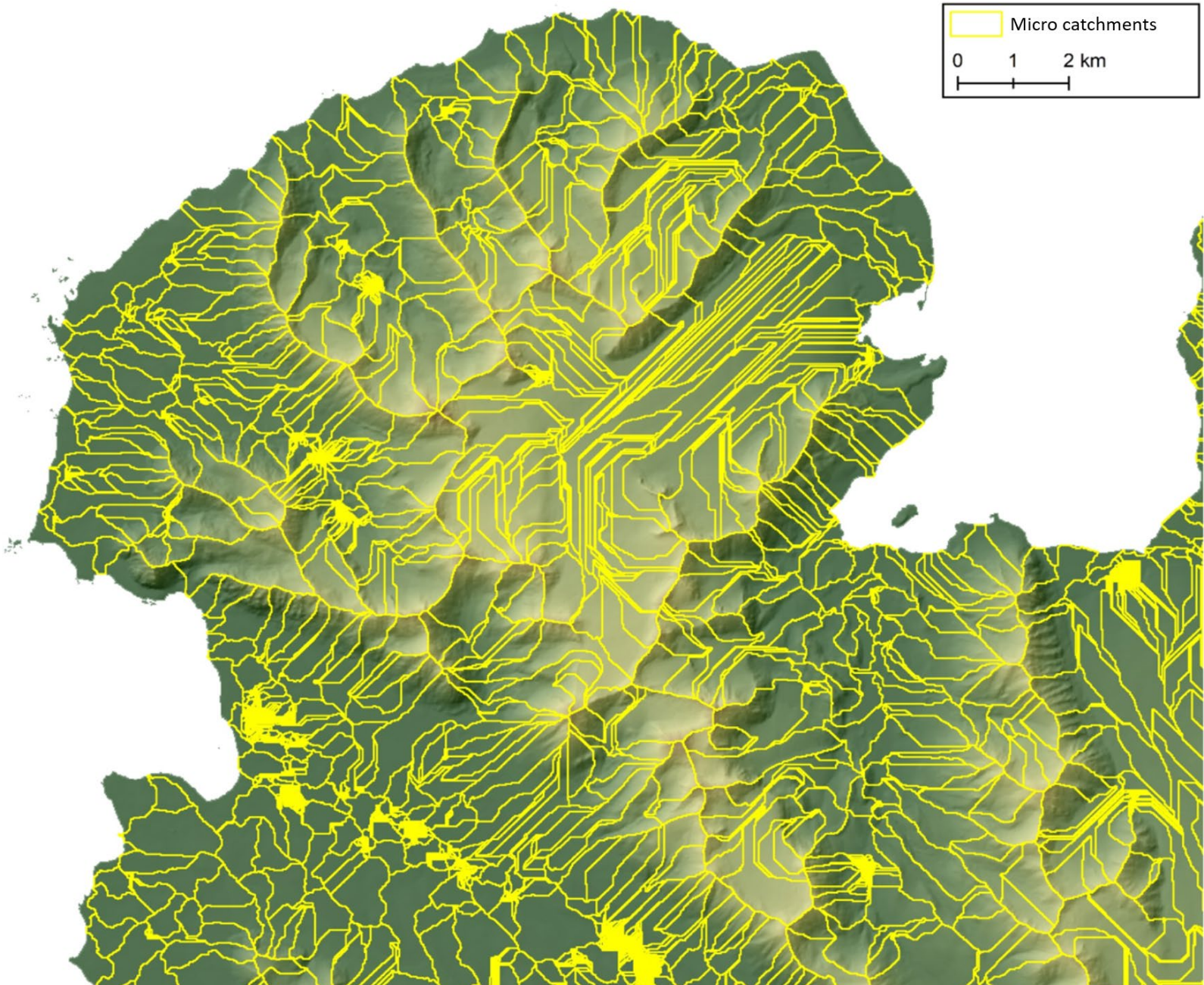
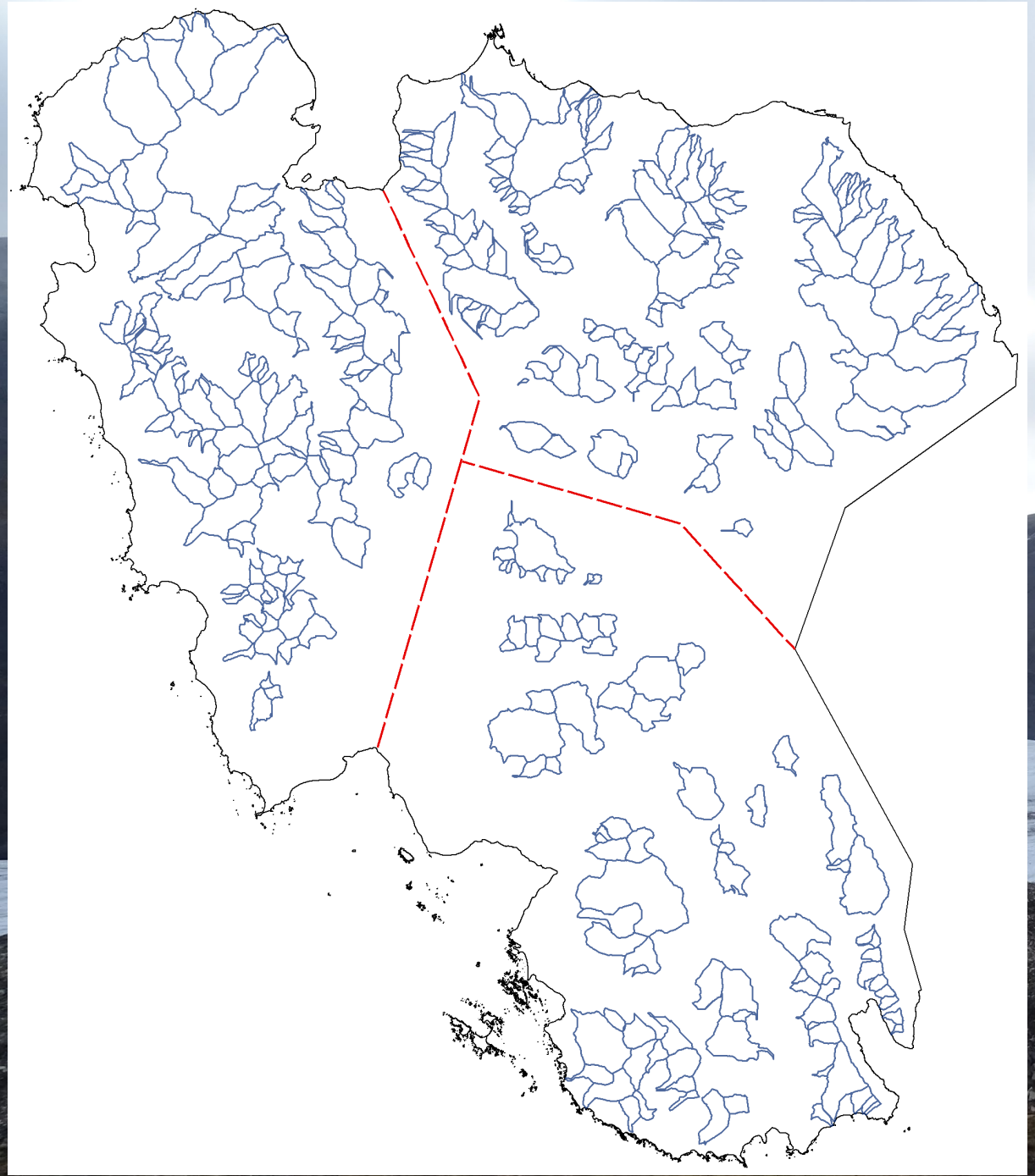


- Result product had around 30 000 micro catchments which ended in prevoiusly counted point „0”

- Water stagnation eg. lakes are densed pour points

  - The next step was **manual** classification and merging of desired catchments…





The final effect:

- 301 small catchments <10km^2
  +6 slightly over 10 km^2

Delineation under changing climate

Glacial retreat

Permafrost thawing

Less snow more rain

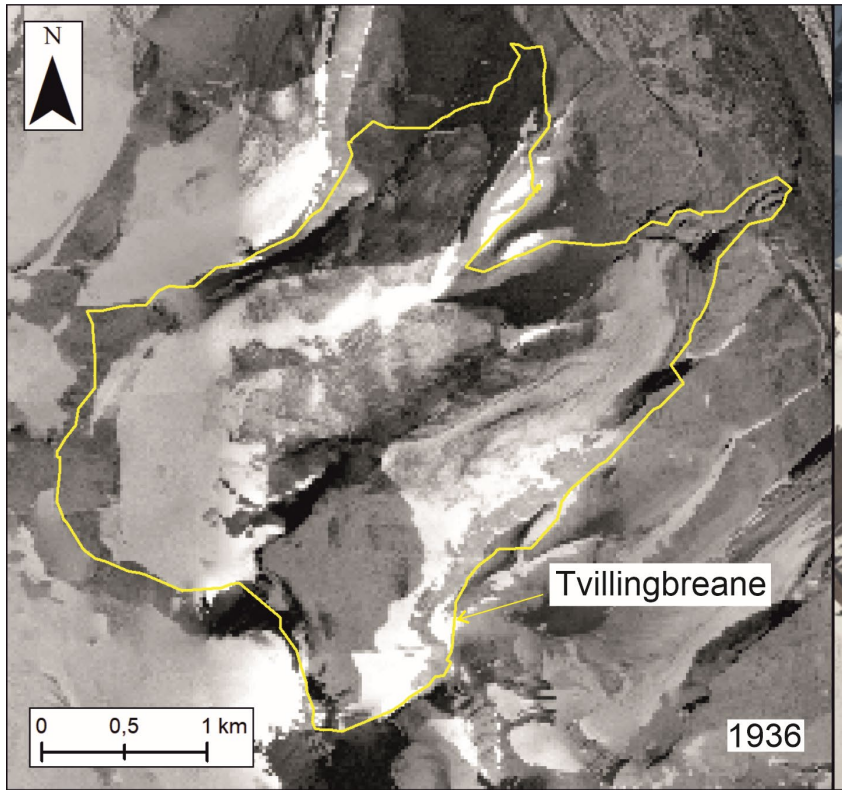
Ice-core melting

Lakes

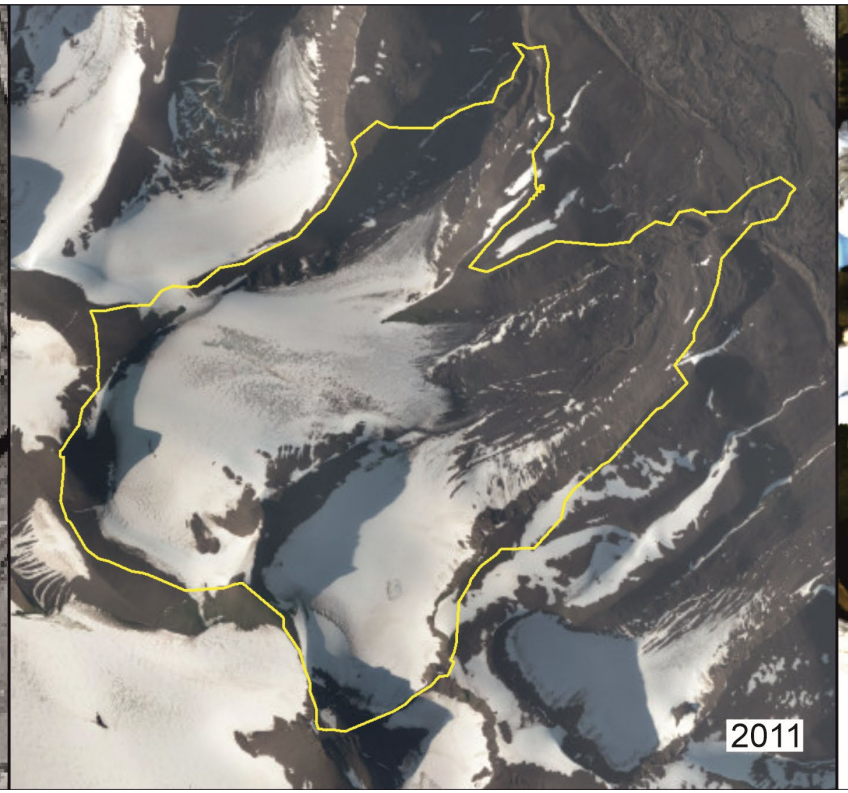
- Further ice mass loss until 2100
- Increases in temp. and active layer thickness
- Decrease in snow extent and duration
- Increase in rain precipitation

Due to climate change

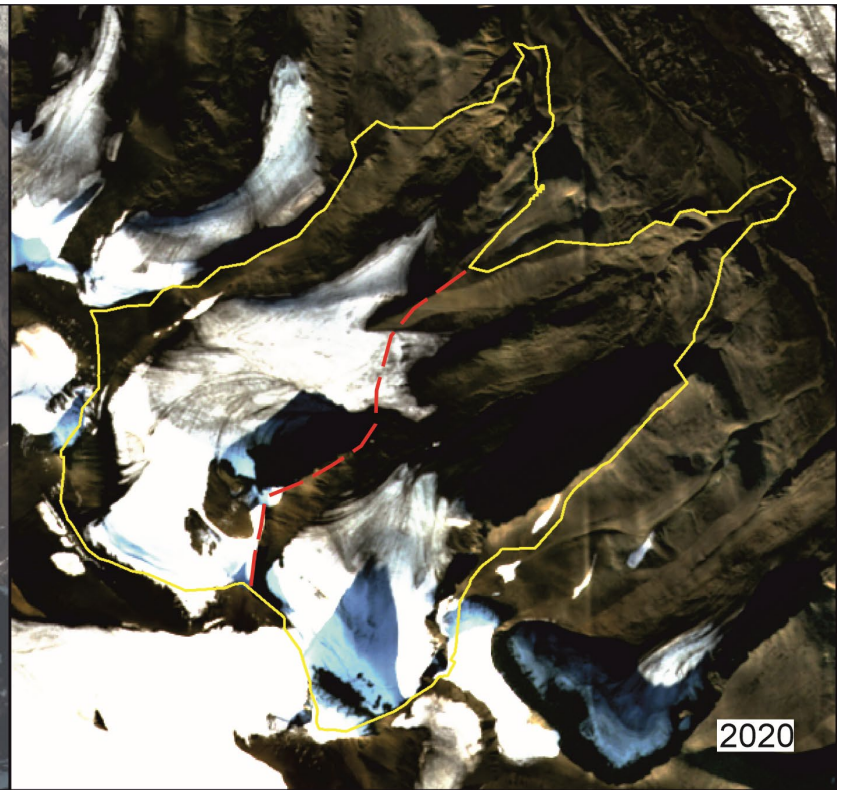
- Glaciers uncover mountain ridges -> facilitate watershed delineation
- But some catchments become divided



Source: Geymann et al. 2022



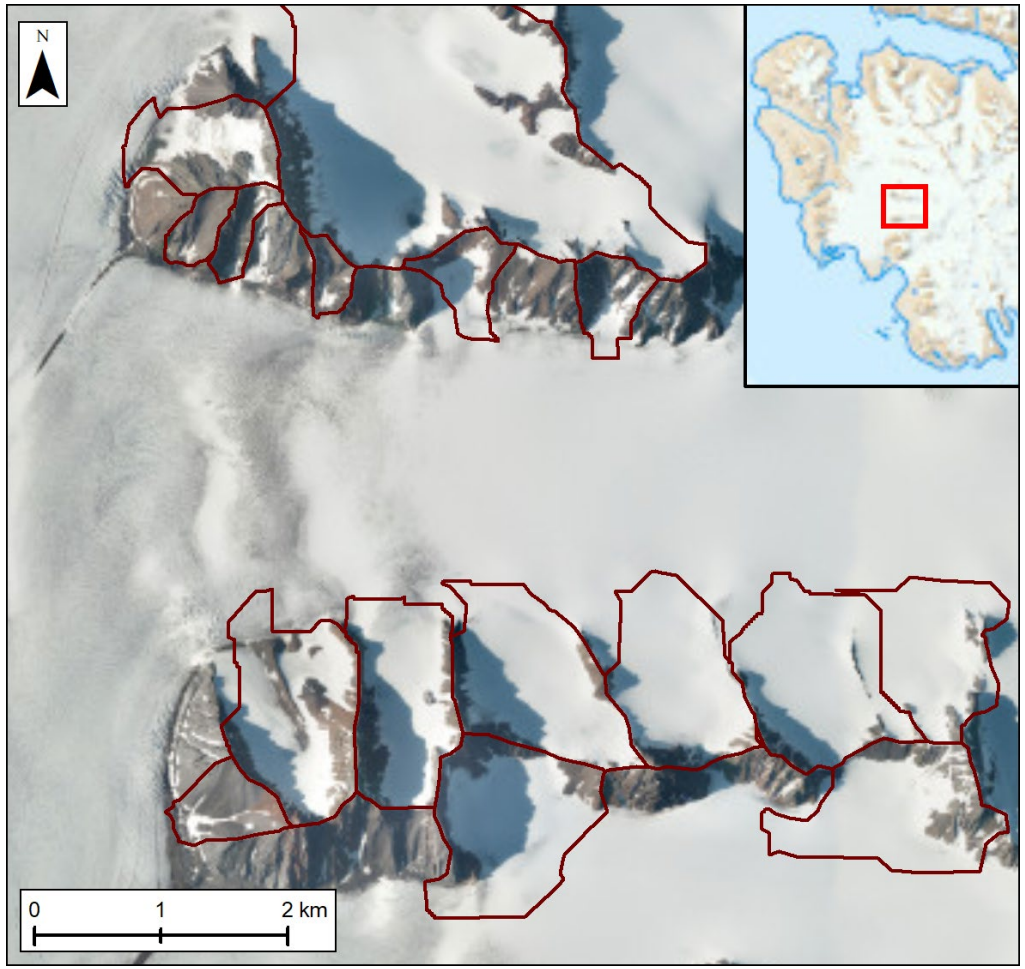
Source: Norwegian Polar Institute 2014



Source: SentinelHub

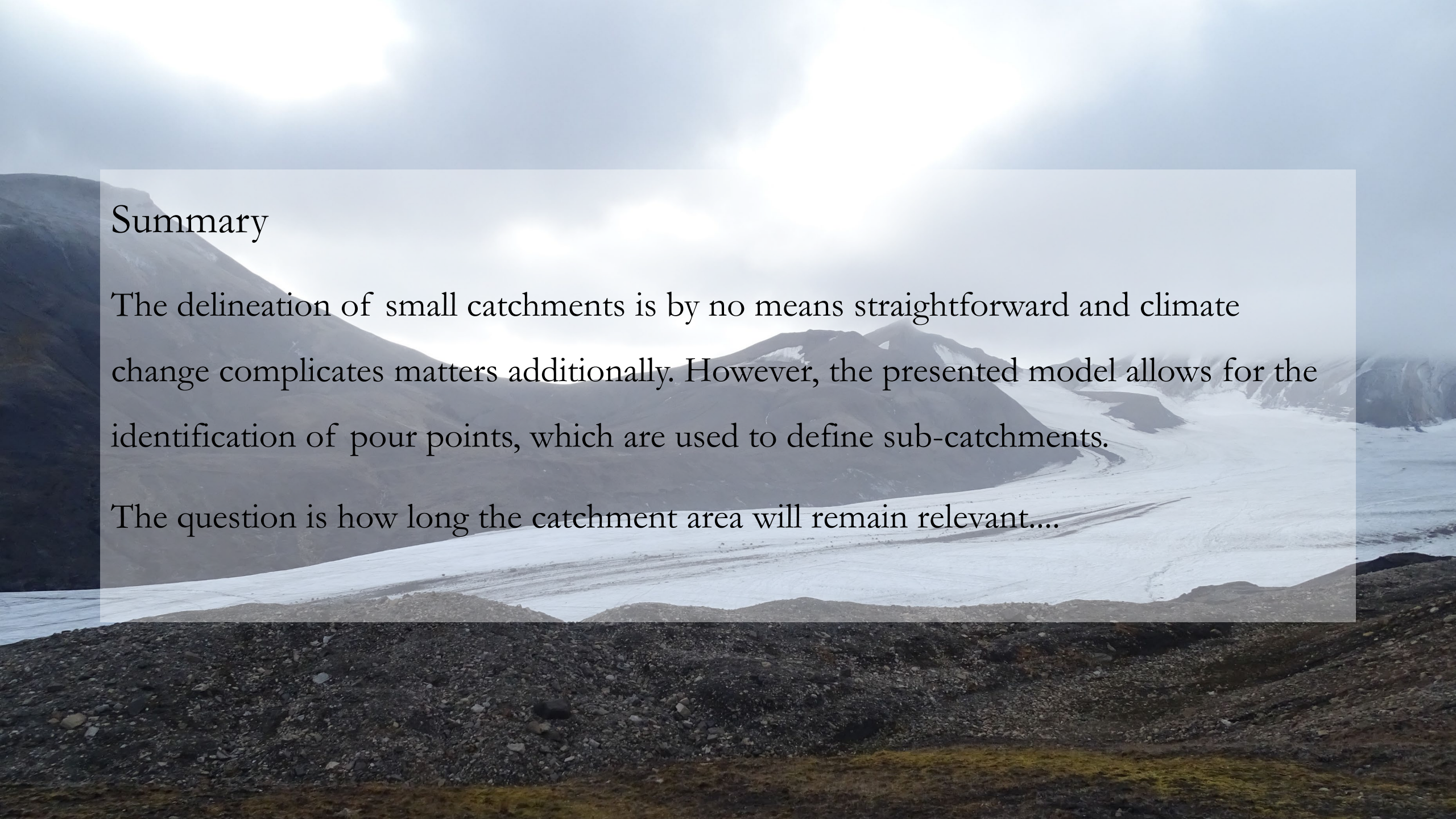
In terms of climate change

- Glaciers uncover mountain ridges -> facilitate watershed delineation
- But some catchments become divided
- Delineation of catchemnts on glaciated areas where lower part of the basin is located on a glacier makes it unstable



In terms of climate change

- Glaciers uncover mountain ridges -> facilitate watershed delineation
- But some catchments become divided
- Delineation of catchemnts on glaciated areas where lower part of the basin is located on a glacier makes it unstable
- Melting ice cores in moraines



Summary

The delineation of small catchments is by no means straightforward and climate change complicates matters additionally. However, the presented model allows for the identification of pour points, which are used to define sub-catchments.

The question is how long the catchment area will remain relevant....

Sources of datasets:

- Geyman E., van Pelt W., Maloof A., Aas H. F. and Kohler J. 2022. 1936/1938 DEM of Svalbard [Data set]. Norwegian Polar Institute. doi: 10.21334/npolar.2021.f6afca5c
- Norwegian Polar Institute. 2014. Kartdata Svalbard 1:1 000 000 (S1000 Kartdata) [Data set]. Norwegian Polar Institute. doi: 10.21334/npolar.2014.63730e2e
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- https://dictionary.cambridge.org/

„The very last moments” of Bratteggbreen, September 2018

Fot. M. Kasprzak

Thank you!