Changes in the Shape of Múlajökull Outlet Glacier Proglacial Lakes Between 1987 and 2021

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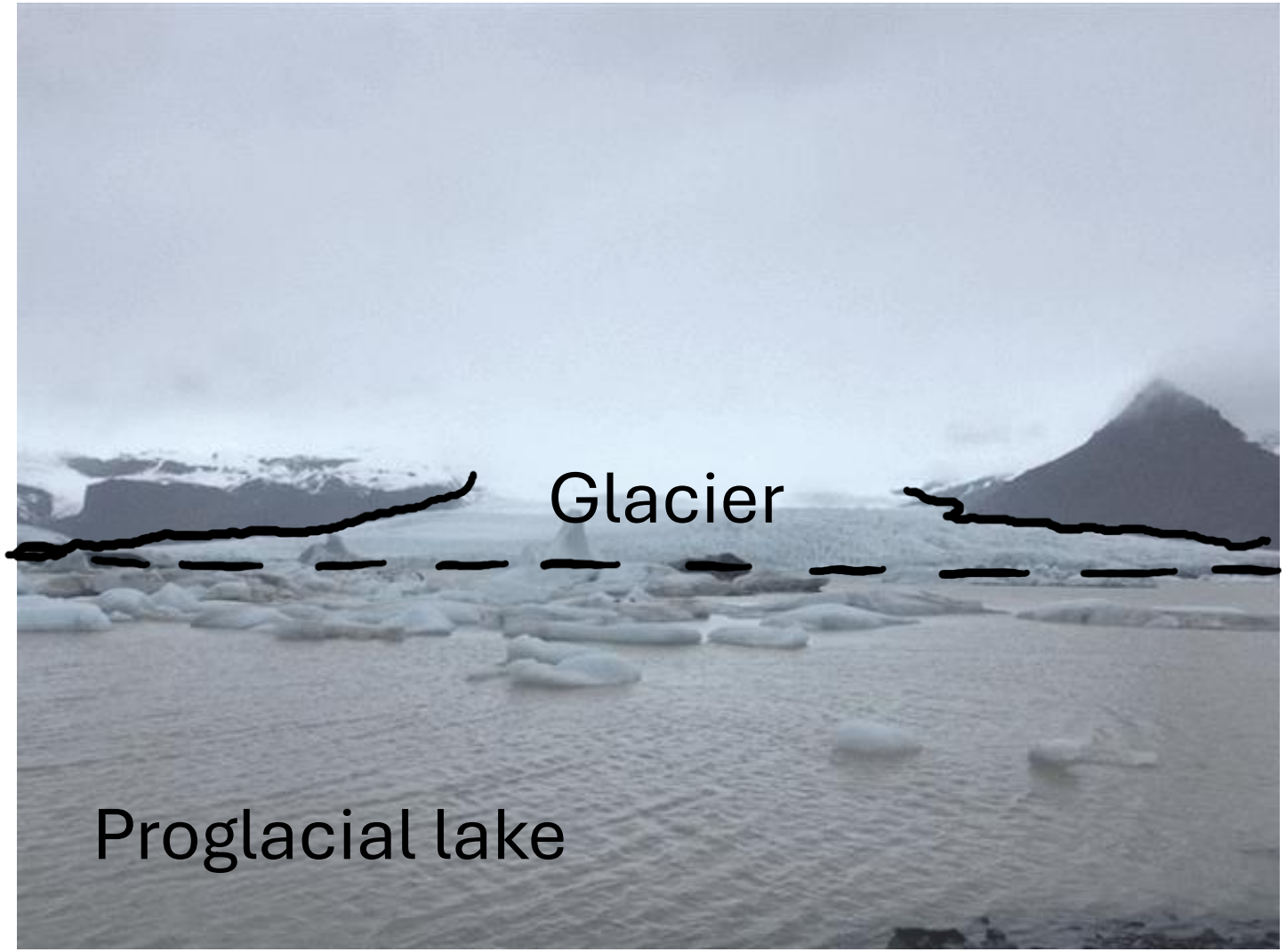

Proglacial lakes form in front of glaciers.

Water is often trapped due to the underlying topography or by the presence of another glacier.

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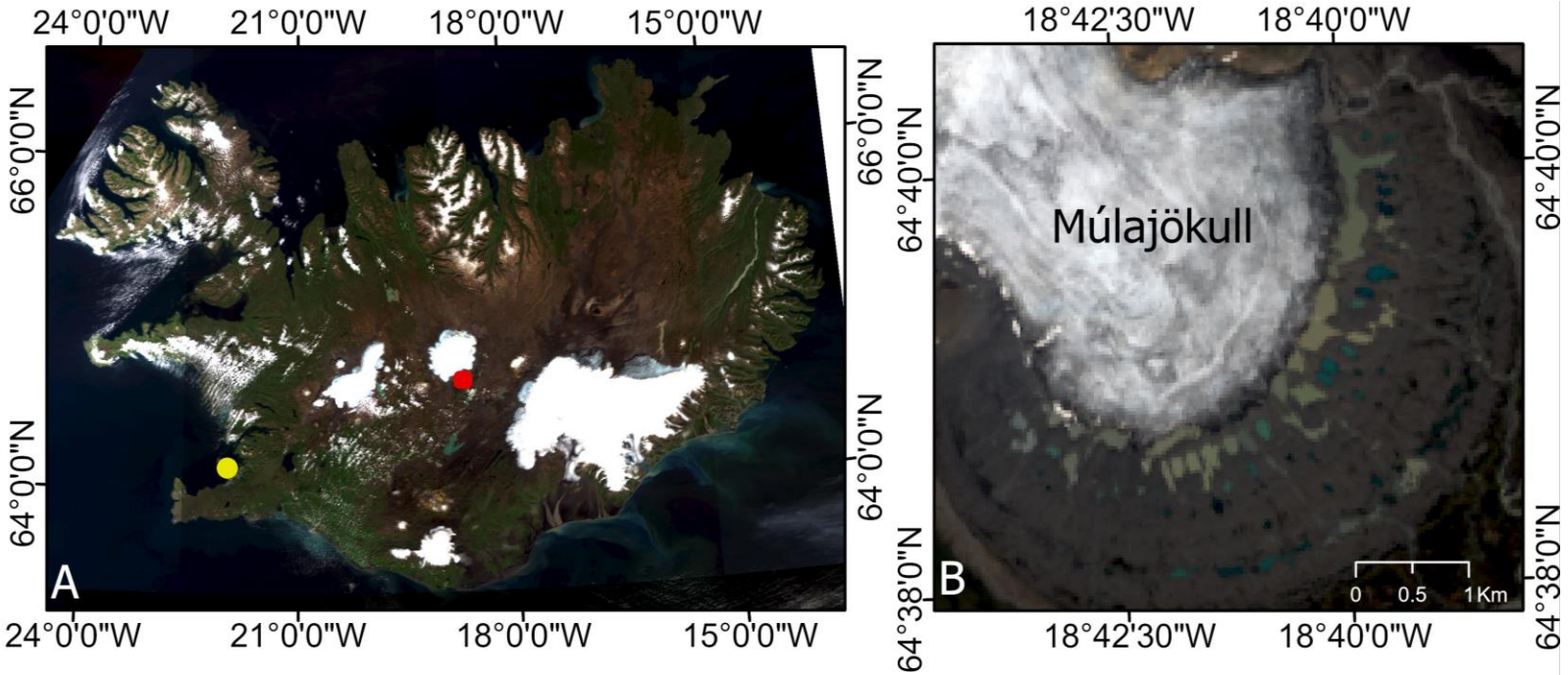
- As Icelandic glaciers retreat, the area of proglacial lakes has increased[1].
- The interactions between the proglacial lake and glacier will affect glacier dynamics[2,3].
- Iceland is experiencing the second highest rate of increase in glacial lake volume in the world[4].

[1]Dell, R. et al. (2019), *Journal of Glaciology*, 65(250).
[2]Geirsdóttir, Á. et al. (2008), *Geophysical Research Letters*, 35(17), .
[3]Tweed, F.S. & Carrivick, J.L. (2015), *Geology Today*, 31(3), pp. 96–102.
[4]Shugar, D.H. et al. (2020), *Nature Climate Change*, 10(10), pp. 939–945.

Múlajökull



Hofsjökull is the third largest ice cap in Iceland[5].

Múlajökull is surrounded by the only known area of active drumlins[6].

[5]Minchew, B. et al. (2016), *Journal of Glaciology*, 62(231).
[6]Benediktsson, Í.Ö. et al. (2016) , *Boreas*, 45(4), pp. 567–583.

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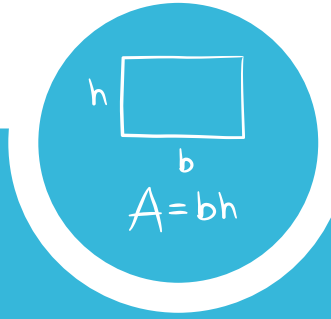
1
Glacier mapping

2
Identify proglacial lakes



3
Area calculation

4
Estimate water level using IceSat-2

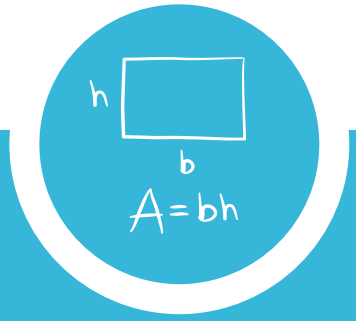
1
Glacier mapping

Glacier terminus positions were manually delineated from Landsat optical imagery at five time periods.

2 Identify proglacial lakes

55 scenes from Landsat 5, 7 and 8.

The Normalised Difference Water Index (NDWI) was calculated using Green and near infrared bands of each satellite image.



3 Area calculation

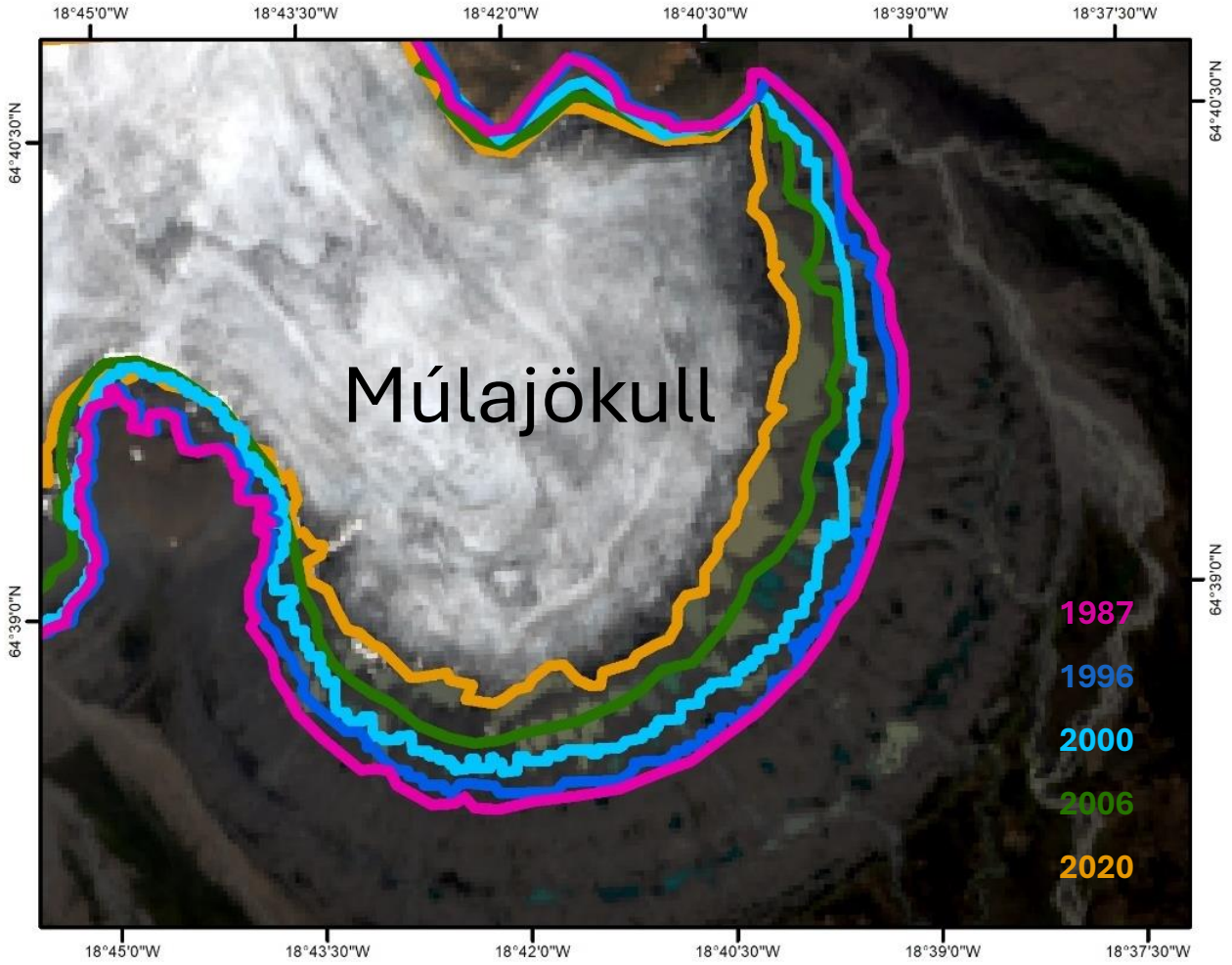
Area is calculated in the Google Earth Engine Script based on the number of pixels identified as water and the resolution of the image.

4
Estimate water level using IceSat-2

ATL06 product.

Long track segments of surface elevation between 2019 -2021.

Two beam pairs at two locations over the region of interest.

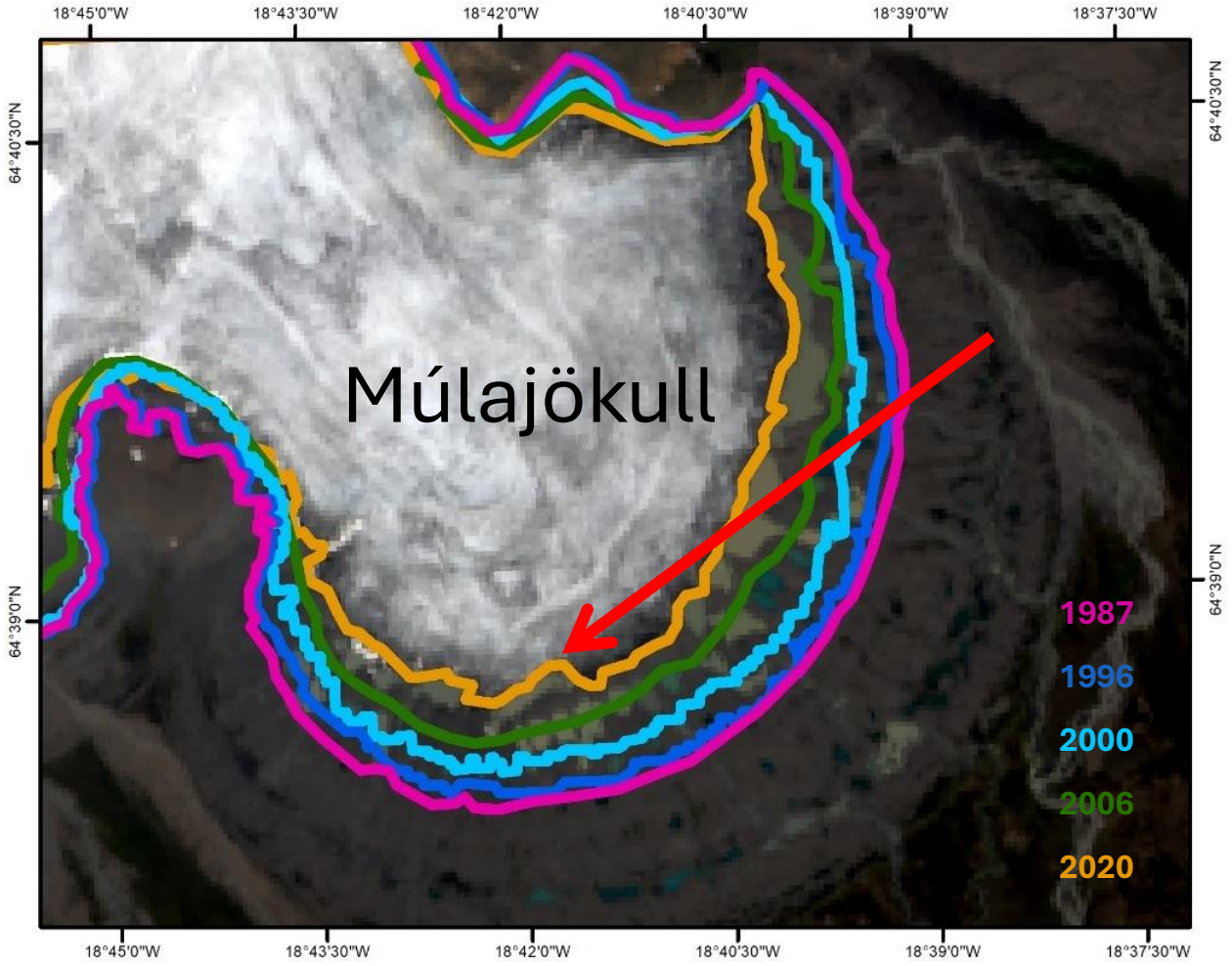


Landsat 8 image (02/07/2020) of Múlajökull outlet glacier with manually delineated glacier terminus positions.

Múlajökull terminus retreat

Between 1987 and 2020 the terminus of Múlajökull retreated approximately 600 m exposing an area of 4.62 km^2.

Approximately 400 m of this retreat occurred after 2000.



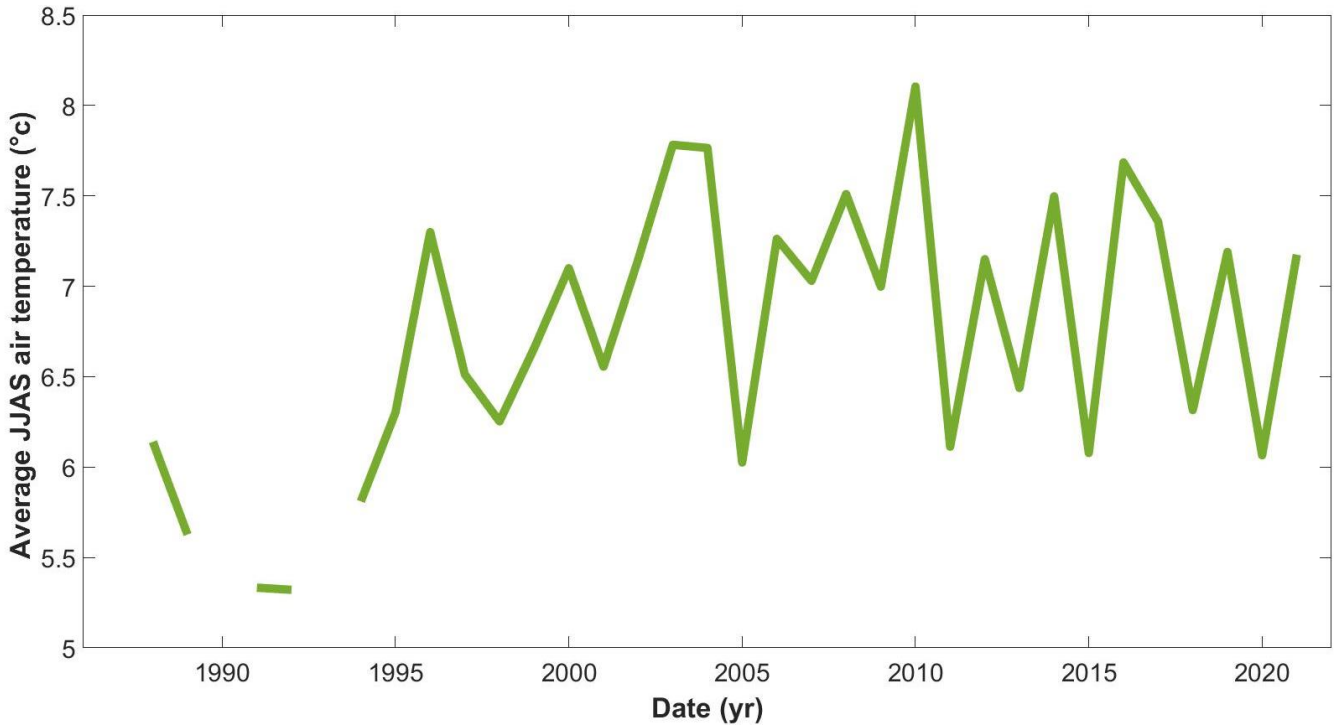
Landsat 8 image (02/07/2020) of Múlajökull outlet glacier with manually delineated glacier terminus positions.

Múlajökull terminus retreat

Terminus retreat is controlled by the underlying topography.

Greatest terminus retreat observed where direct contact with proglacial lake.

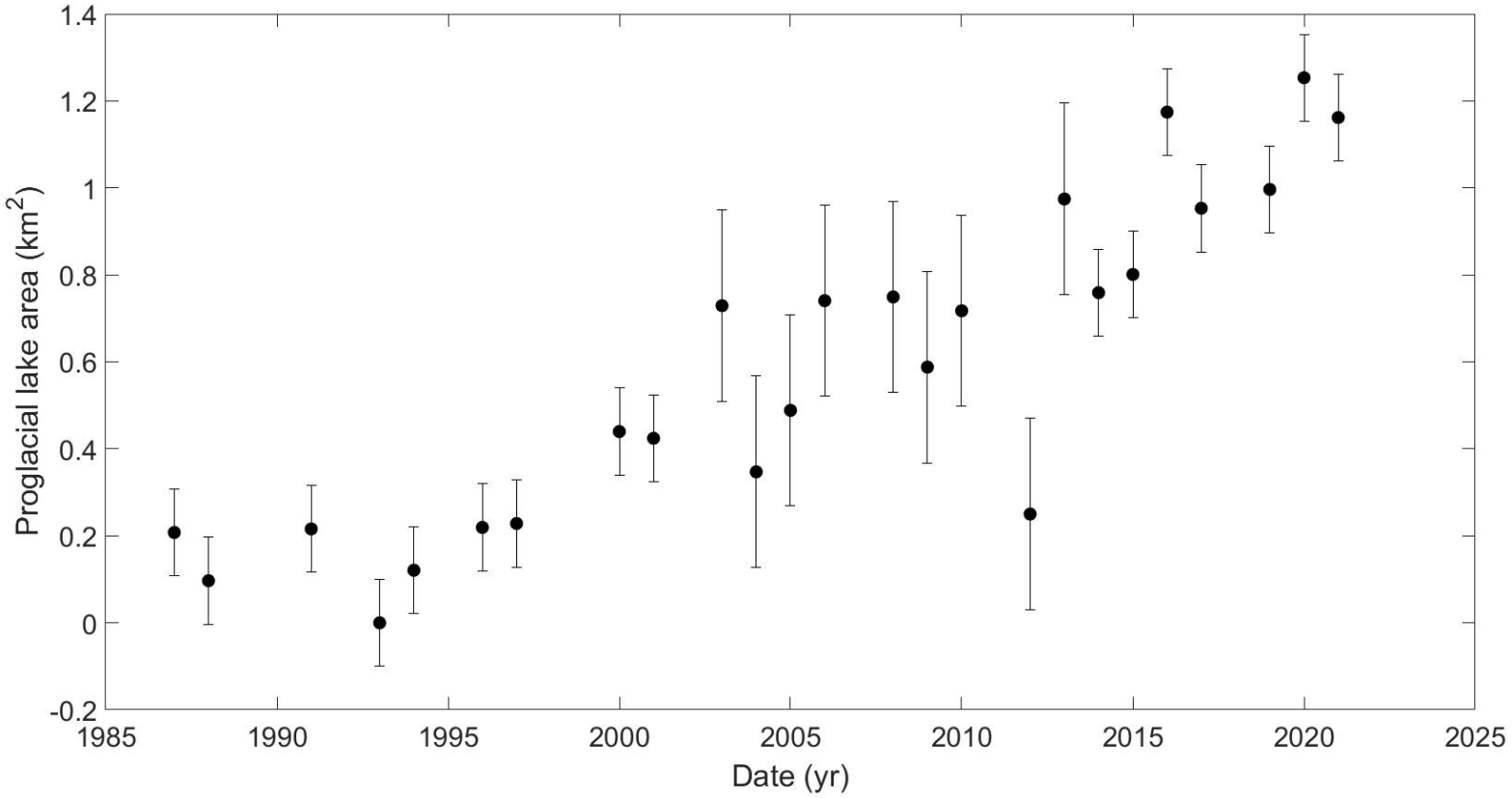
Air temperature change



Observed terminus retreat driven by increase in air temperature.

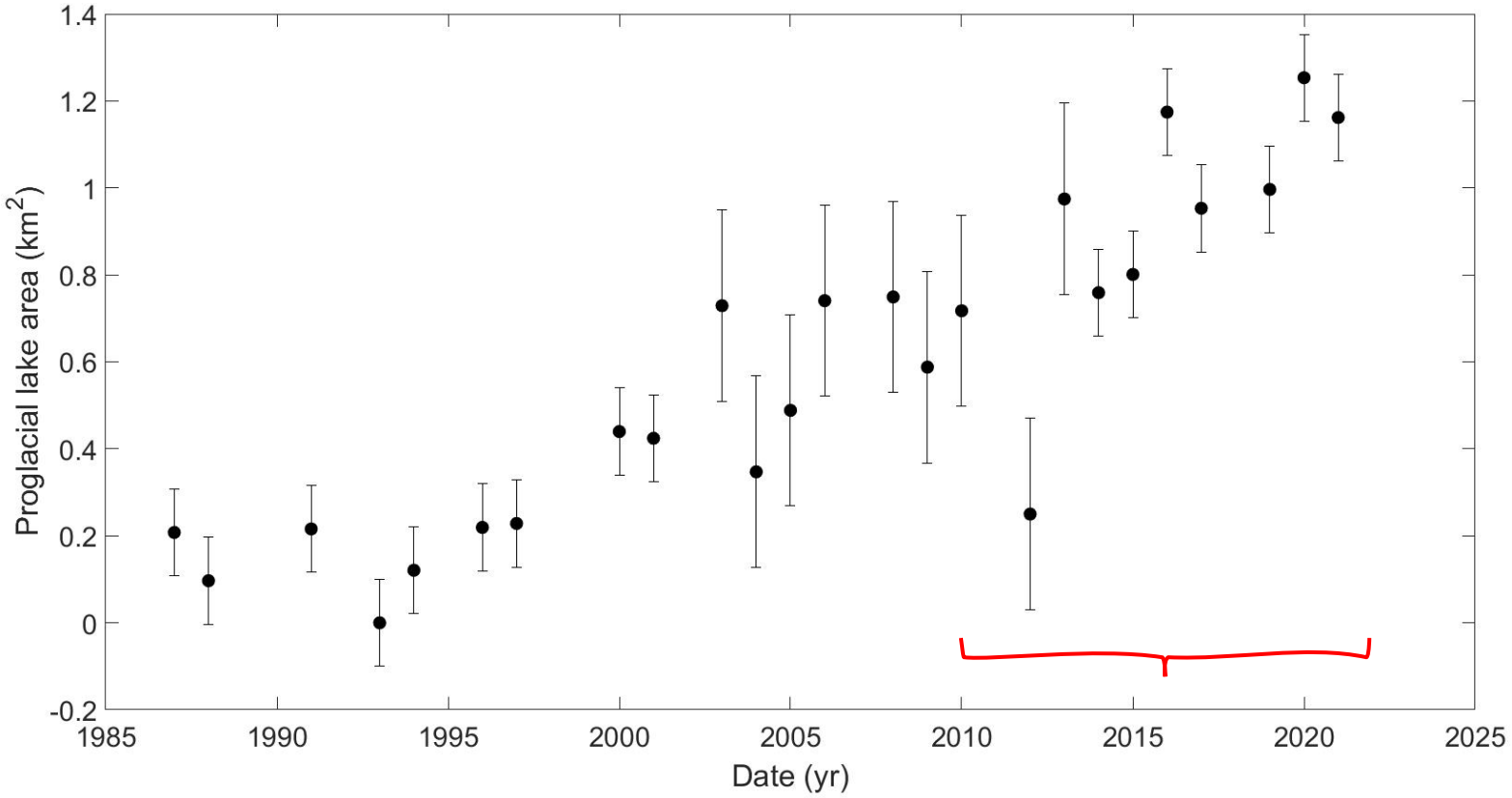
Average JJAS air temperature at Þúfuver weather station increased by 1°c.

Total area change

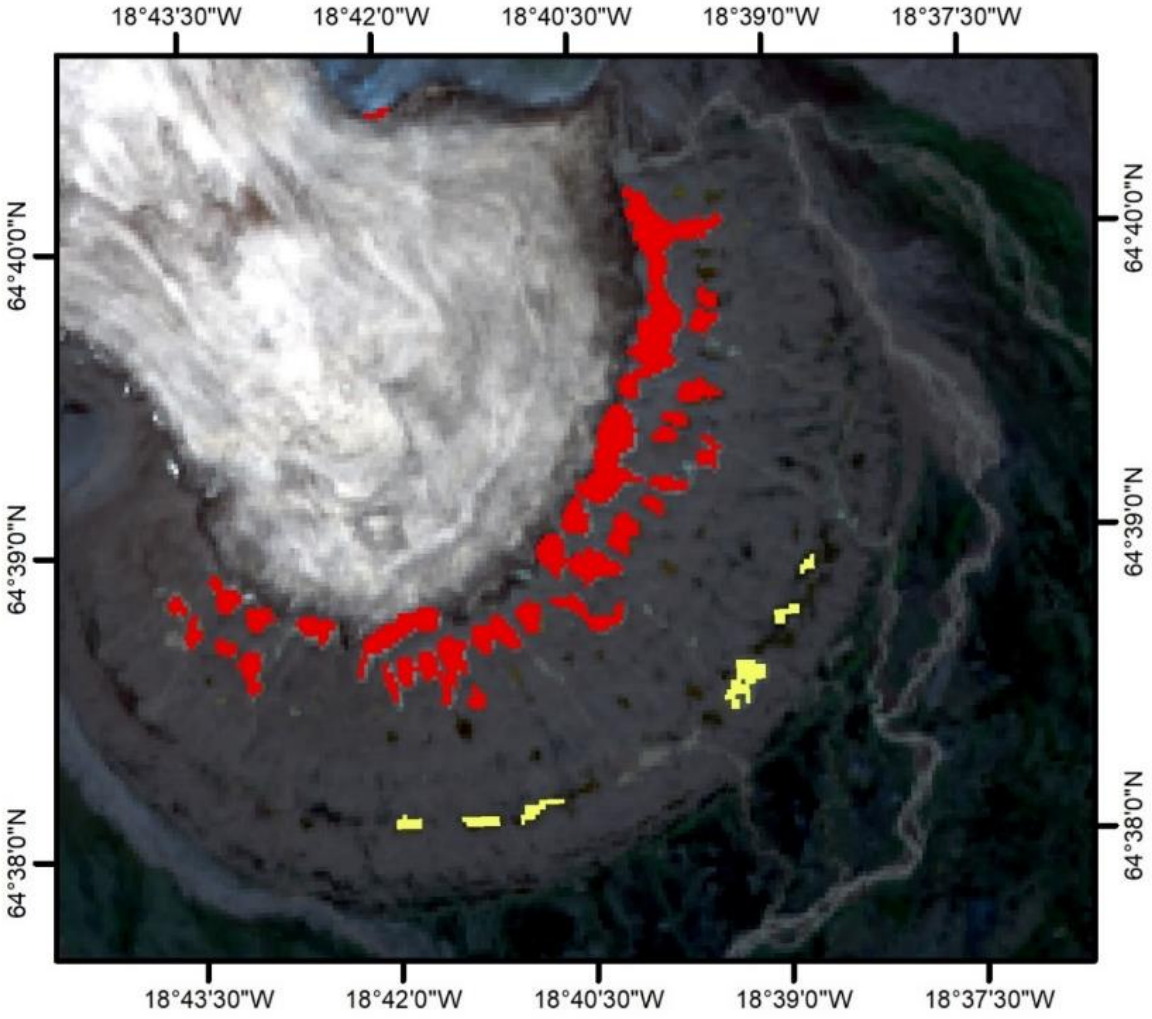


Proglacial lake area increased from 0.21 km^2 to 1.16 km^2 between 1987 and 2021.

Total area change



The greatest period of increase was between 2010 and 2021 where proglacial lake area increased from 0.72 km^2 to 1.16 km^2.



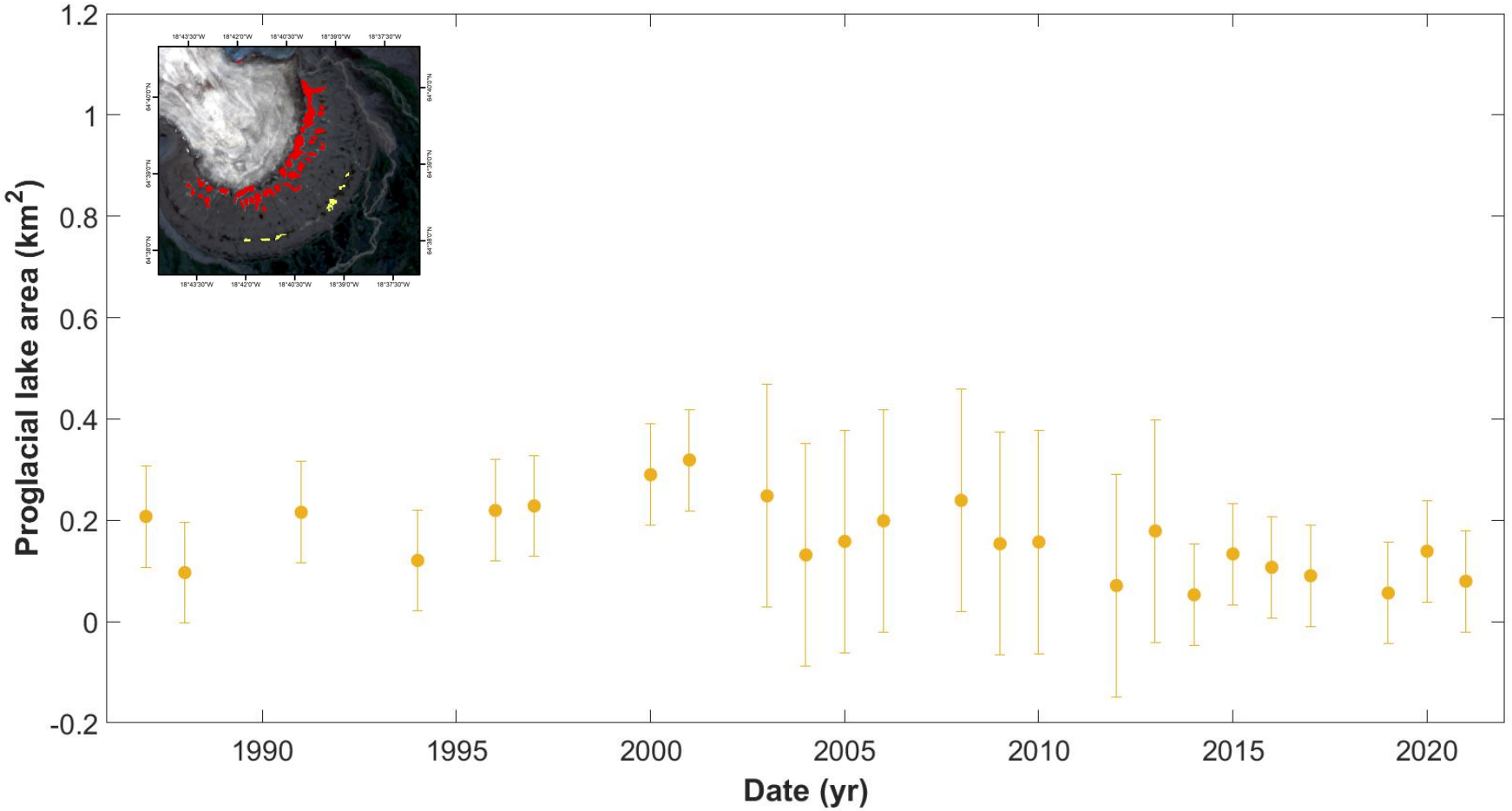
Landsat 8 image (02/07/2020) of Múlajökull outlet glacier with identified proglacial lakes.

Cause of lake area change

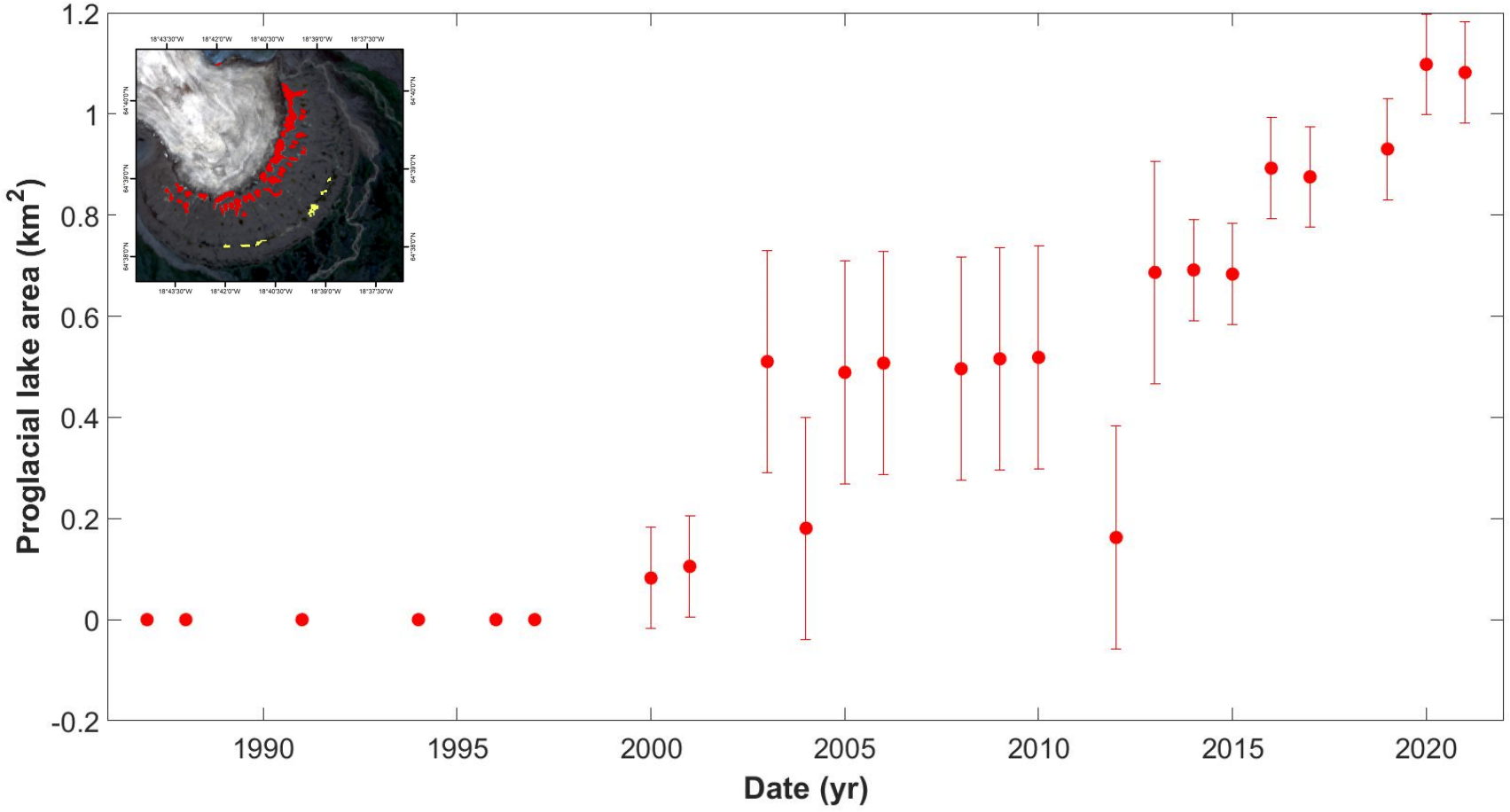
To analyse the relationship between terminus retreat and proglacial lakes the area is split into three.

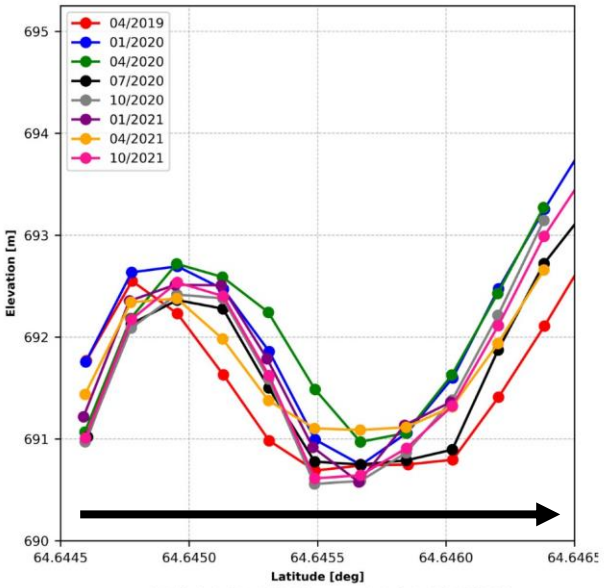
- Commonly exposed area (first identified in 1987)
- Newly exposed area (expose post 2000)
- Total (both areas)

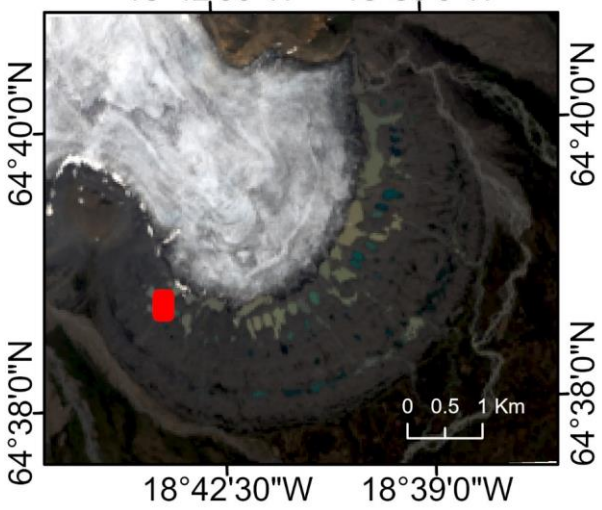
Commonly exposed area change

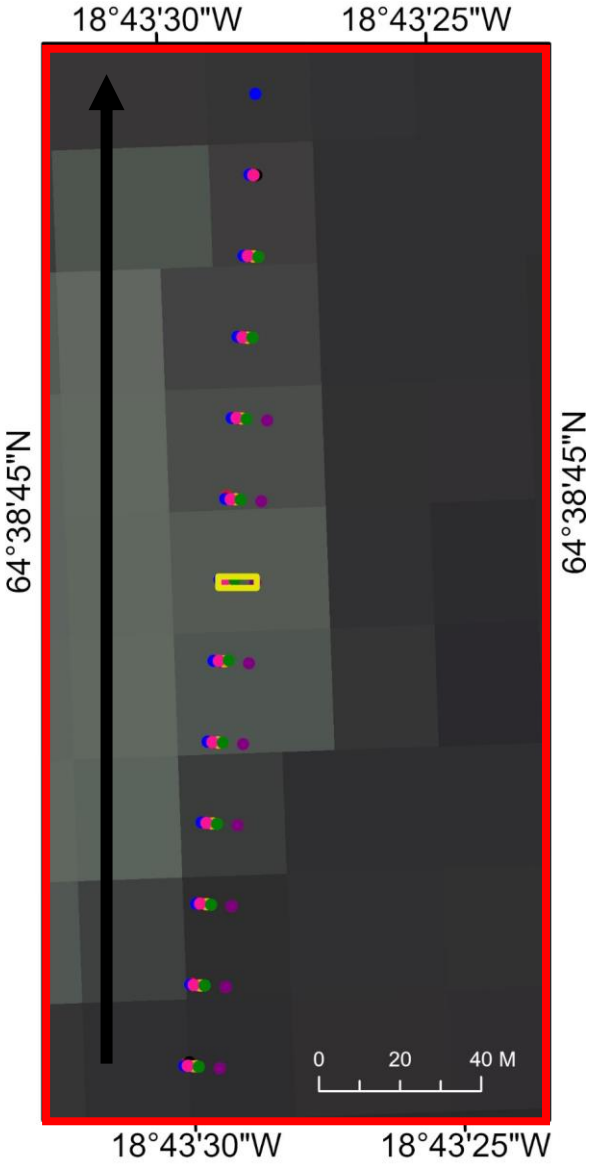


Newly exposed area change



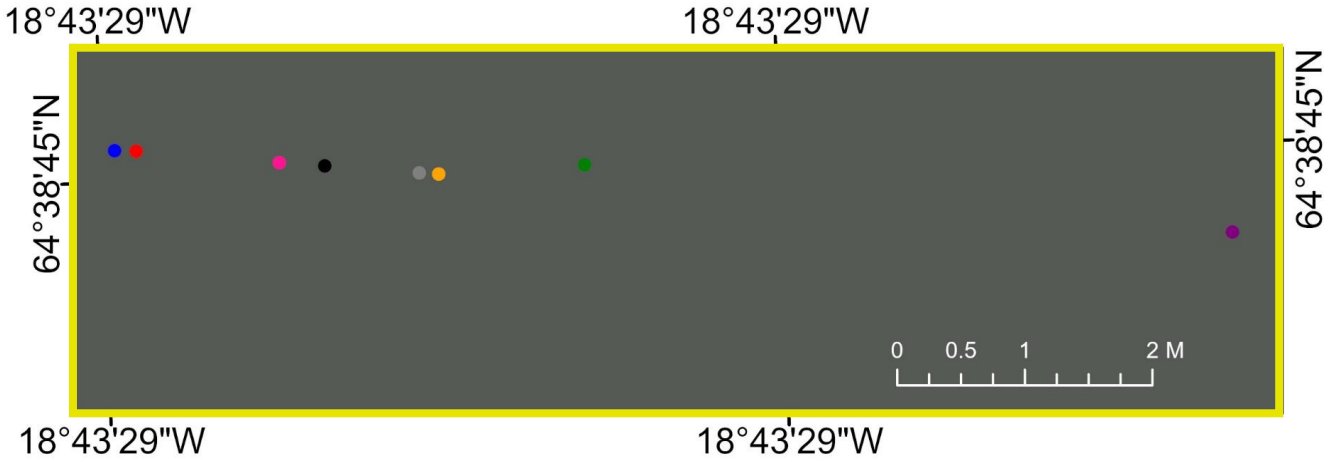


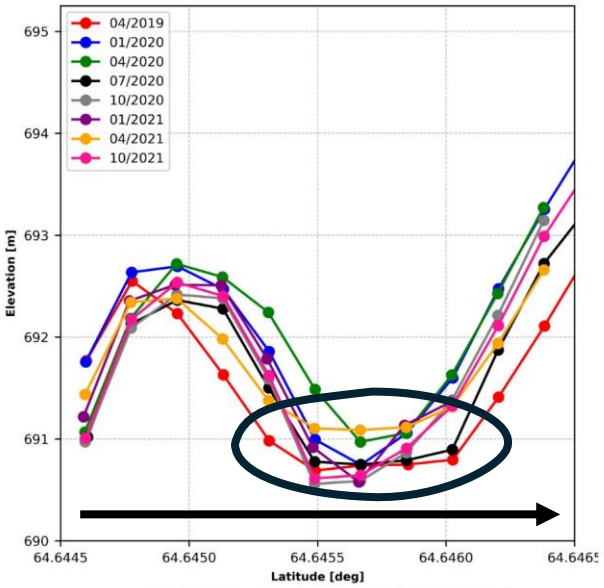


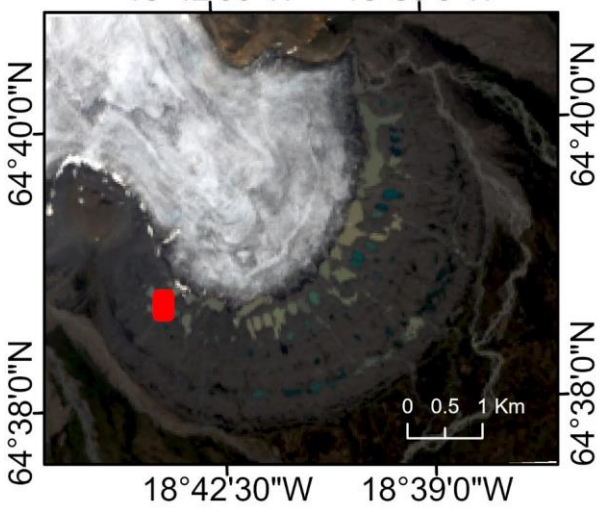


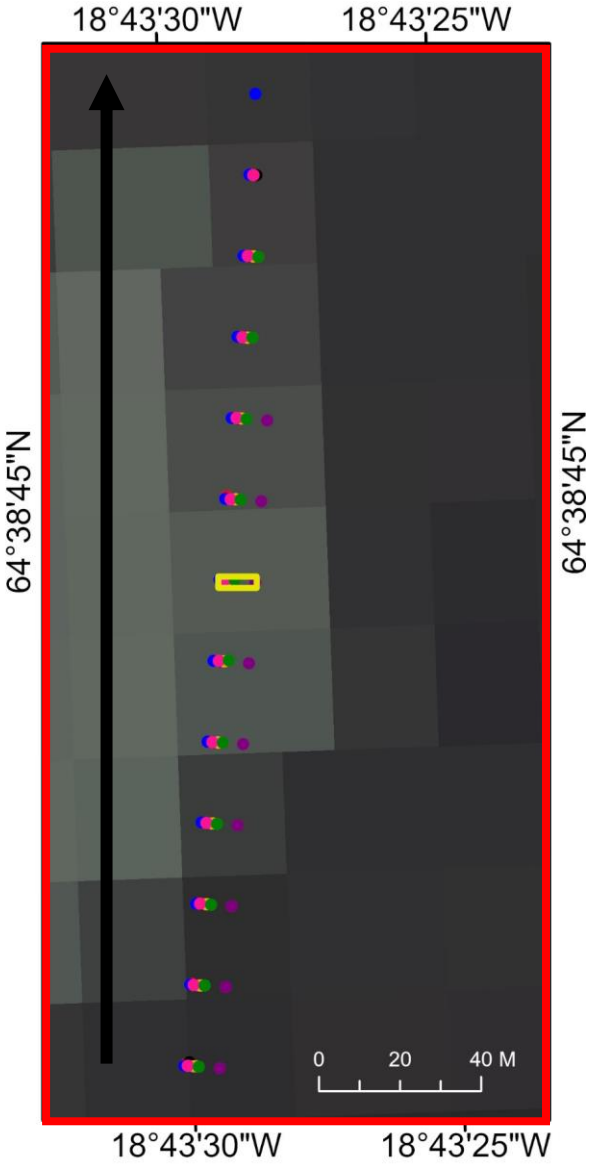
Surface profile

- Change observed.
- Repeat tracks have some geolocation error and therefore don't exactly overlay.









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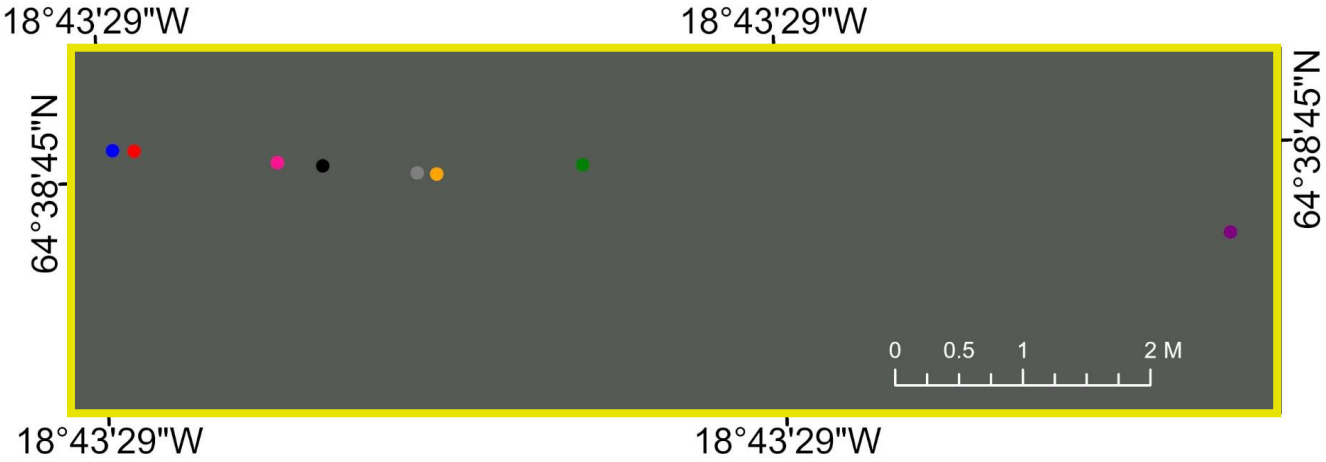

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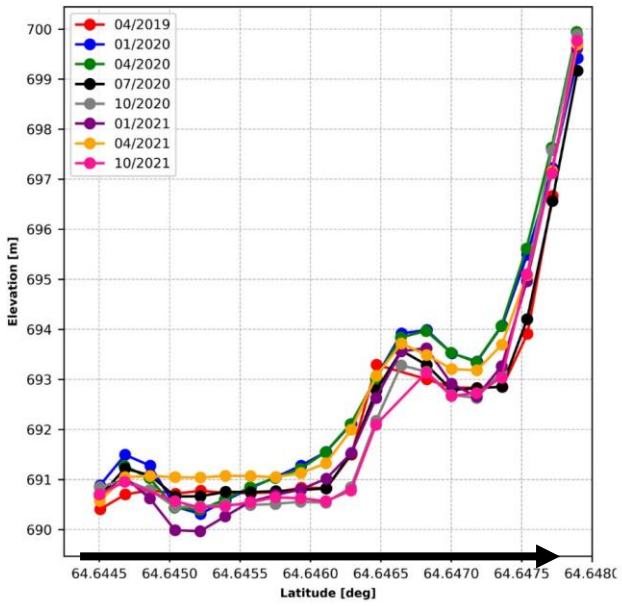
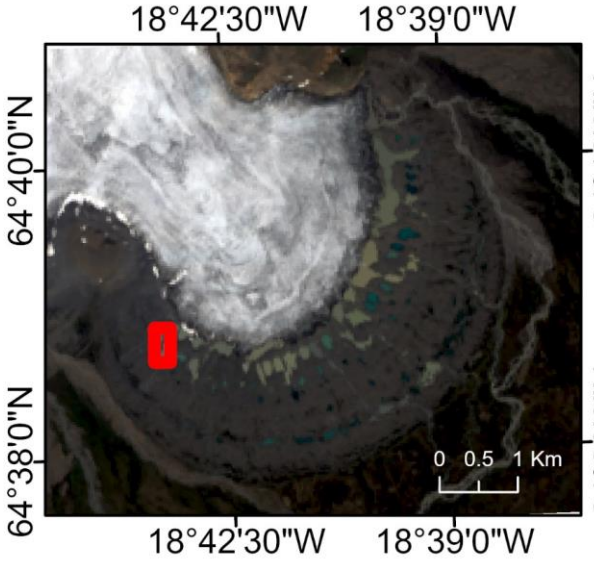
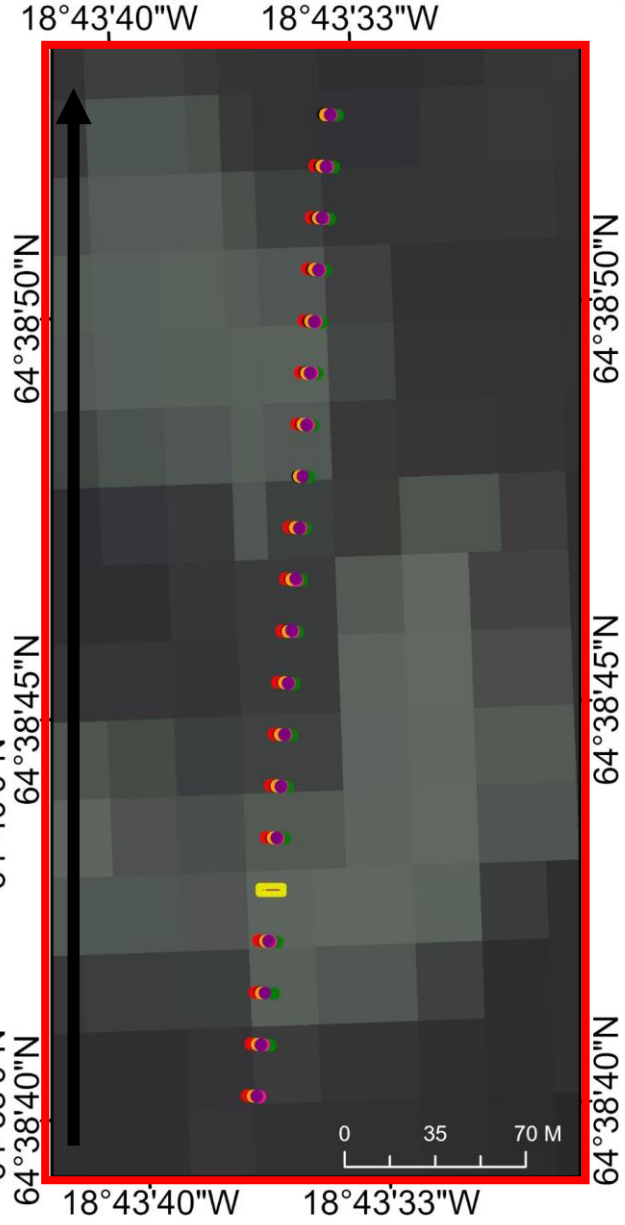
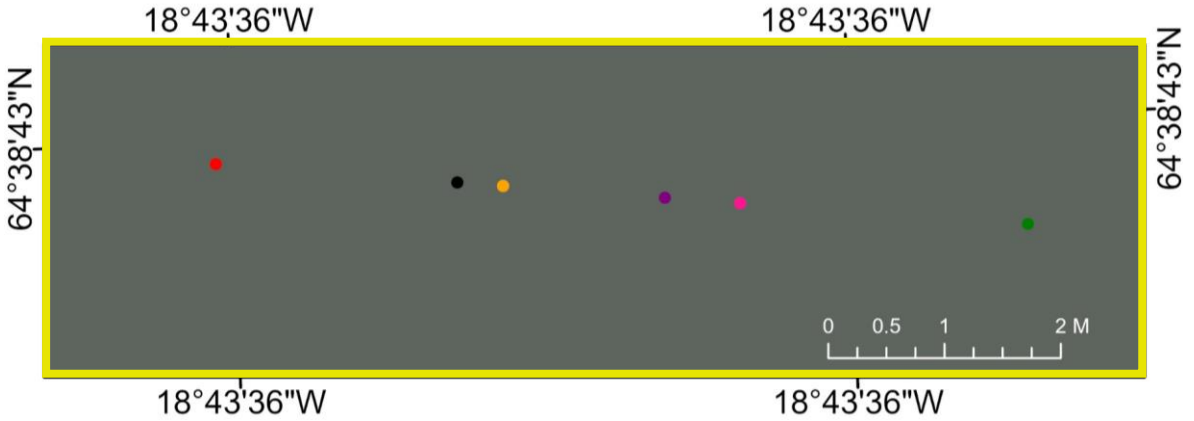






Surface profile

- Evidence of proglacial lake and surrounding topography
- Identification of features such as snow slumping and lake freeze.



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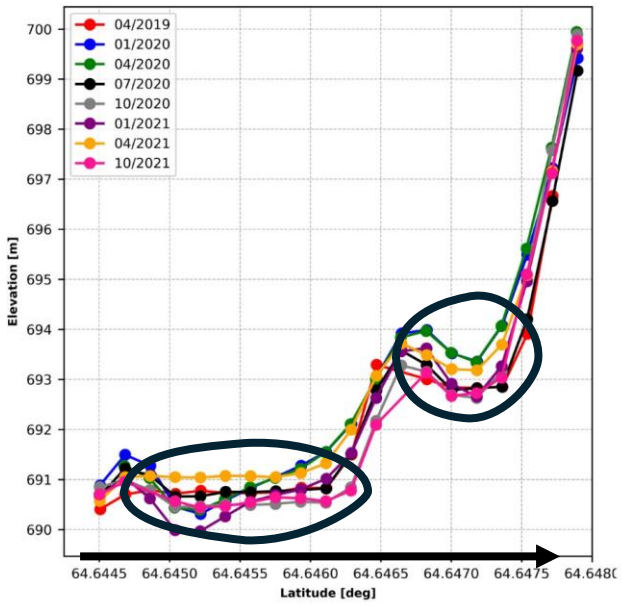

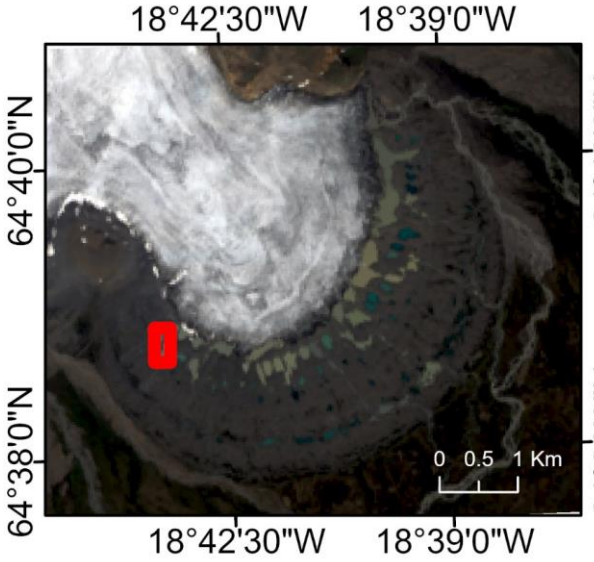

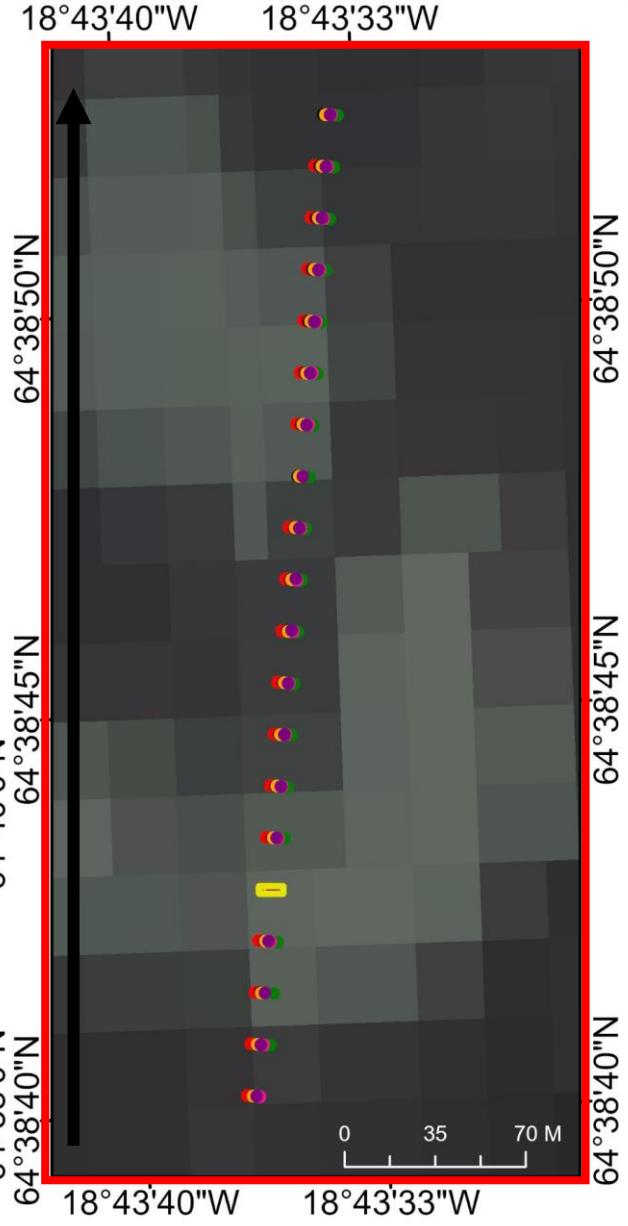

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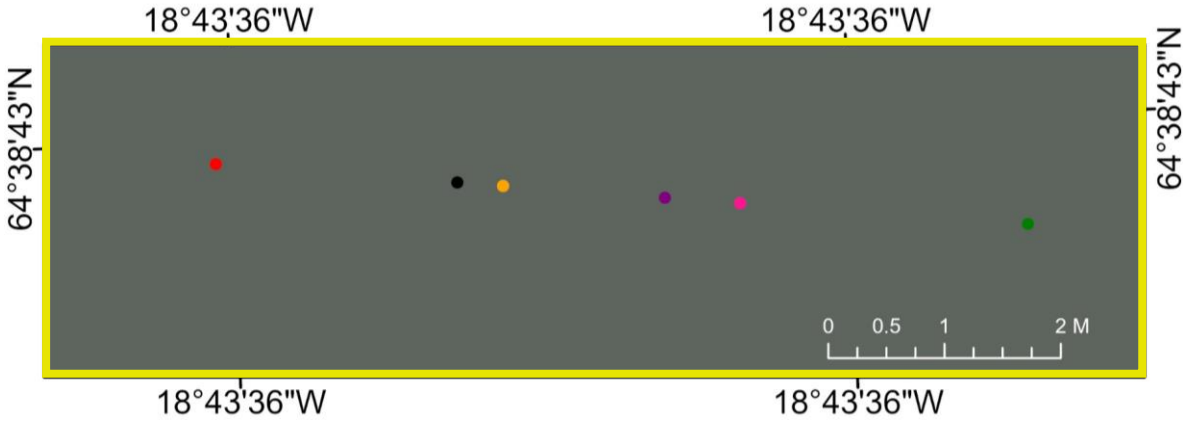
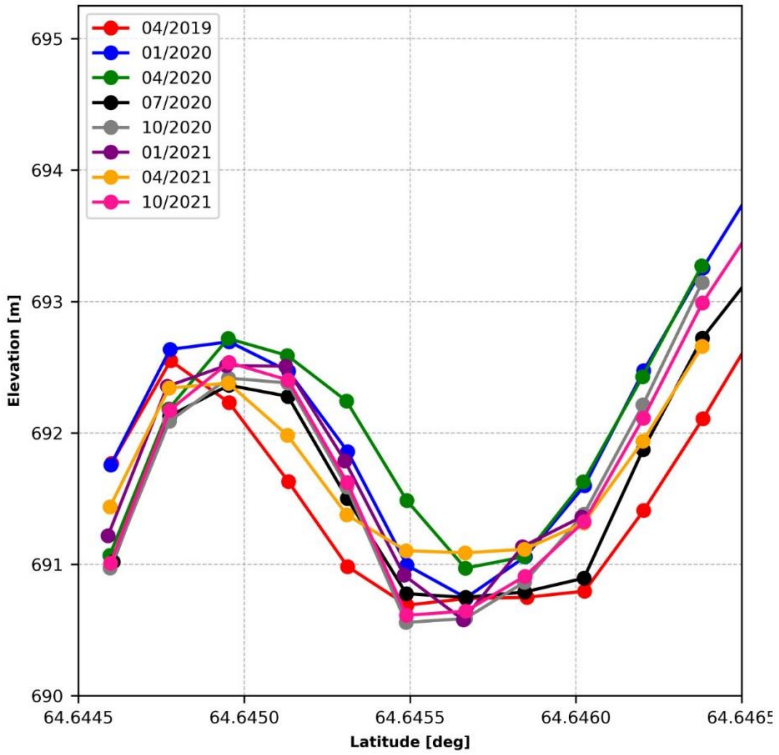


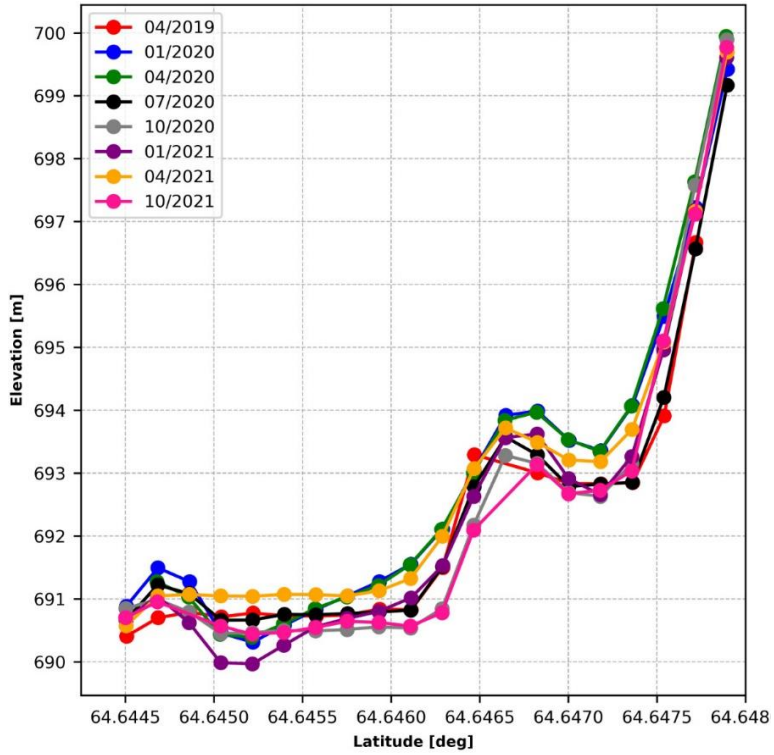
~ 0.5 m change in elevation.

12,500 m^3 volume?

Left beam



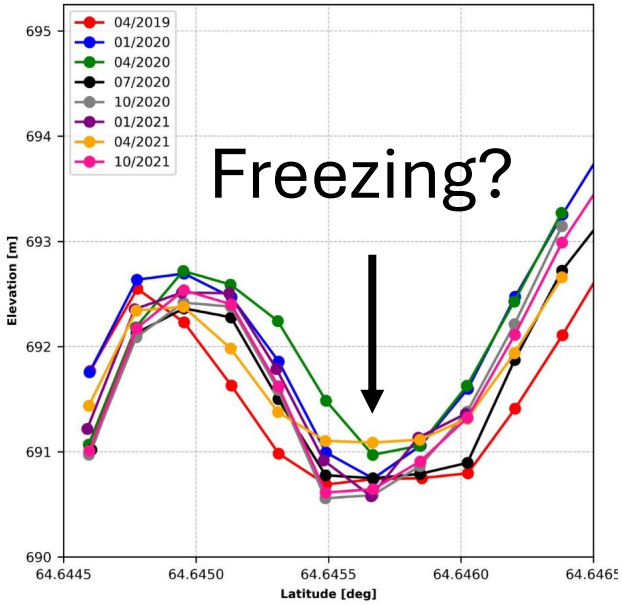
Right beam

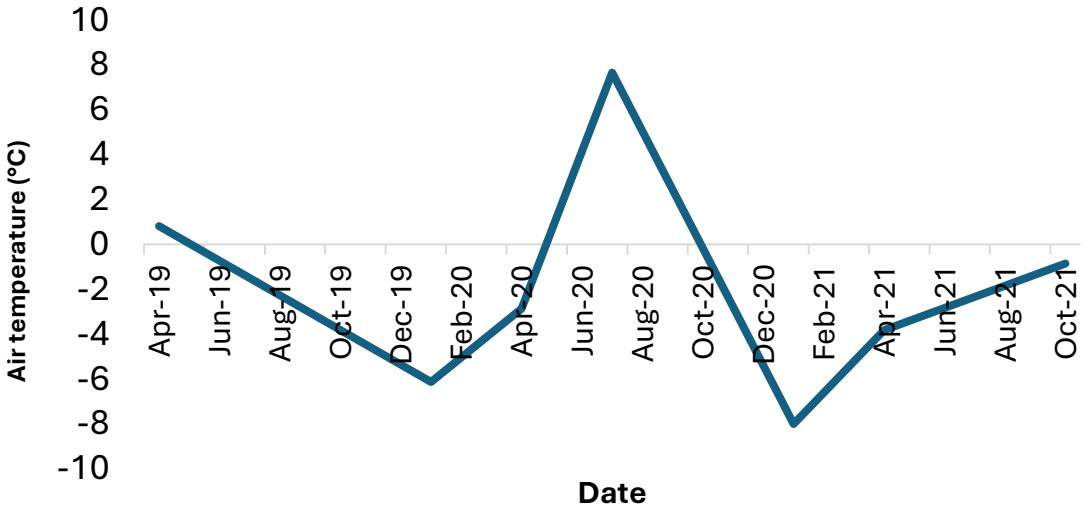


~1 m change in elevation.

44,000 m^3 volume?

Left beam





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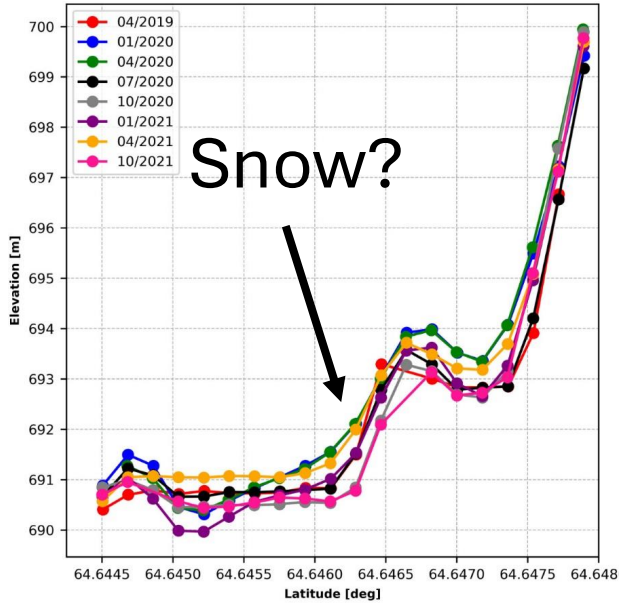
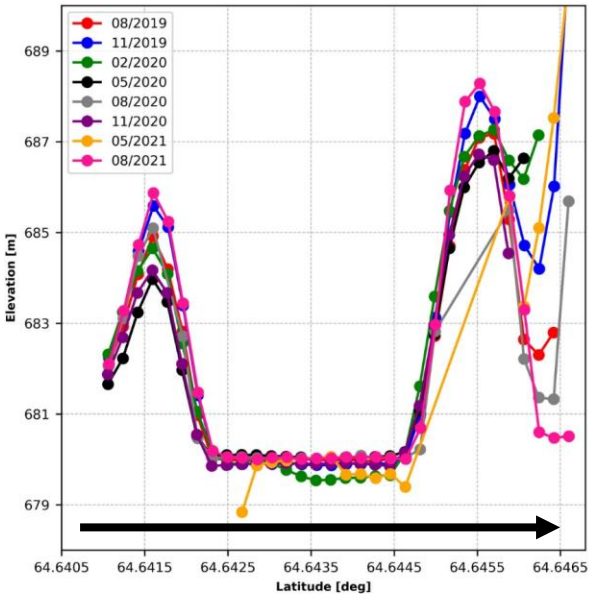
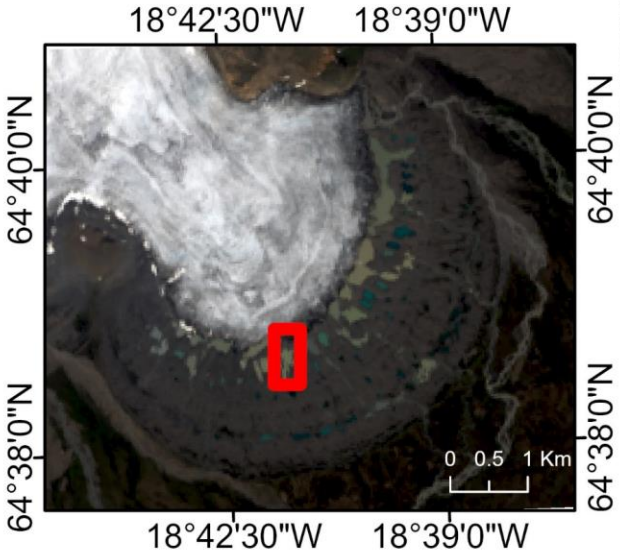
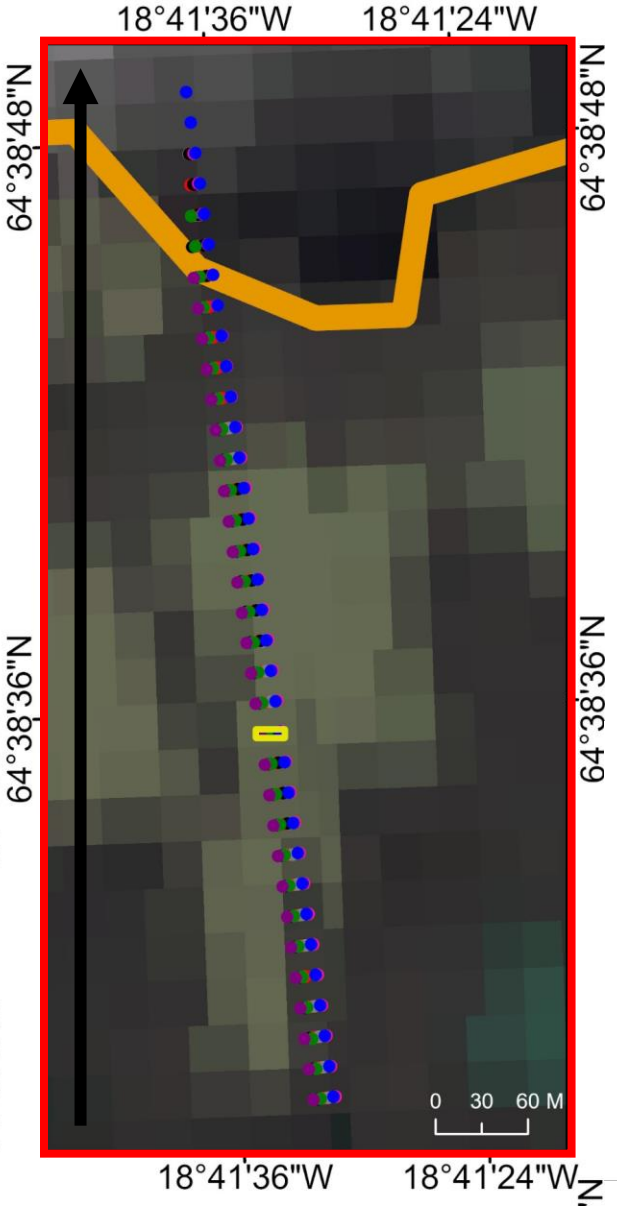


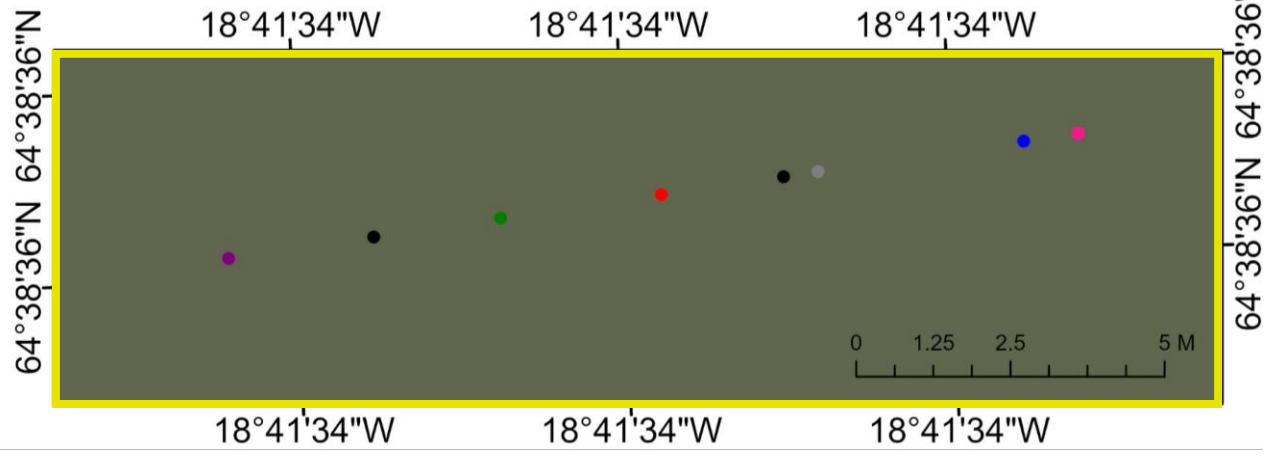


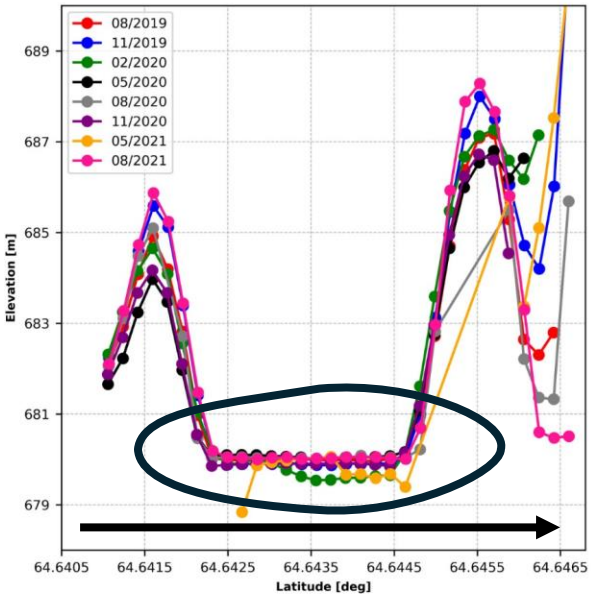


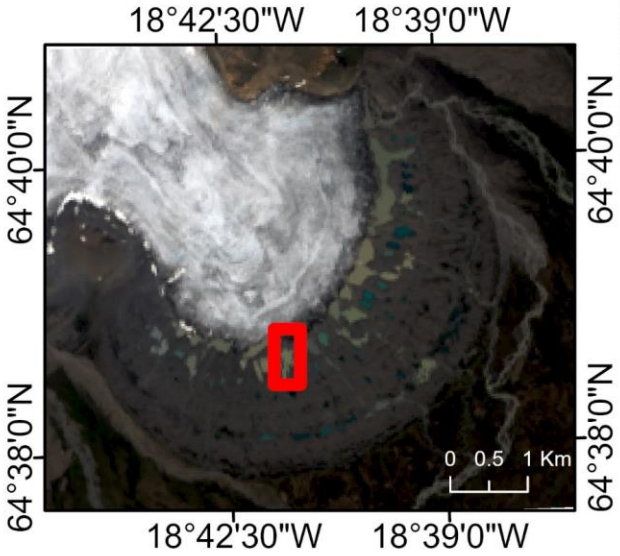


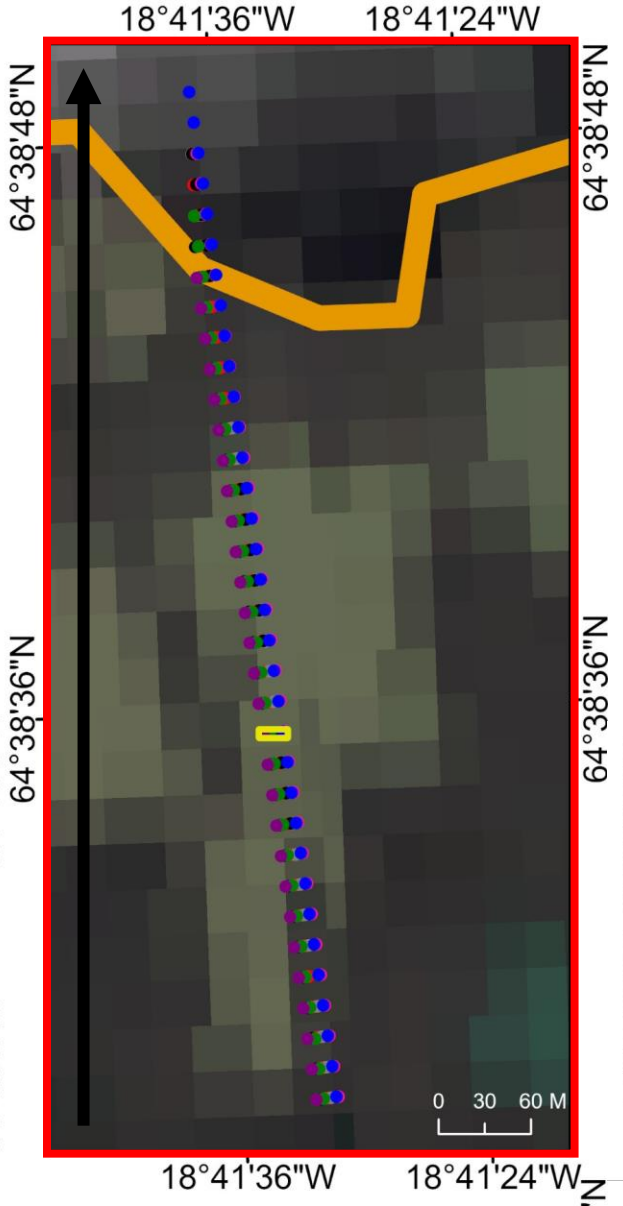
Surface profile

- Lake surface identified as flat surface in between surrounding geomorphology.
- Issues with missing points.









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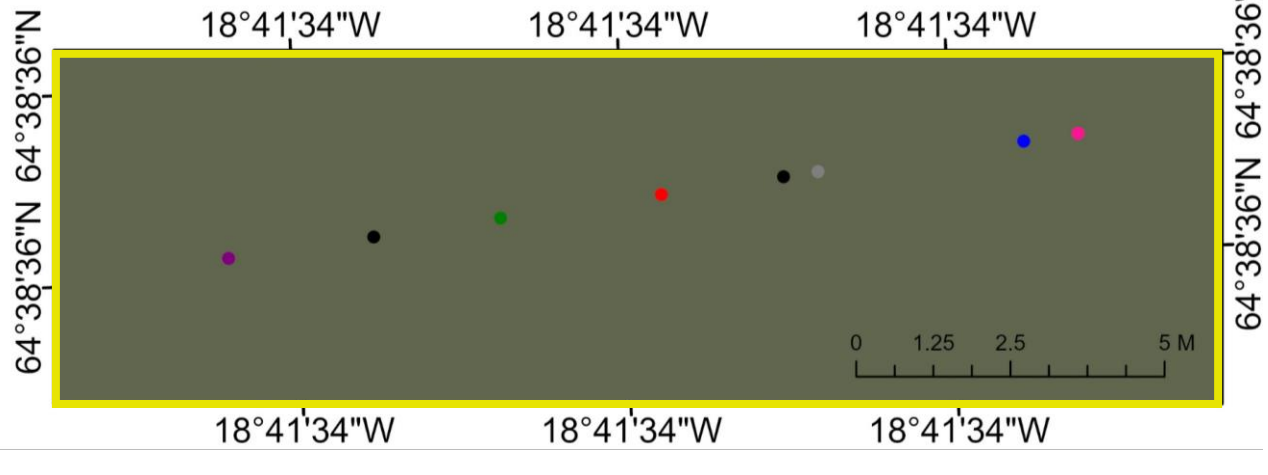

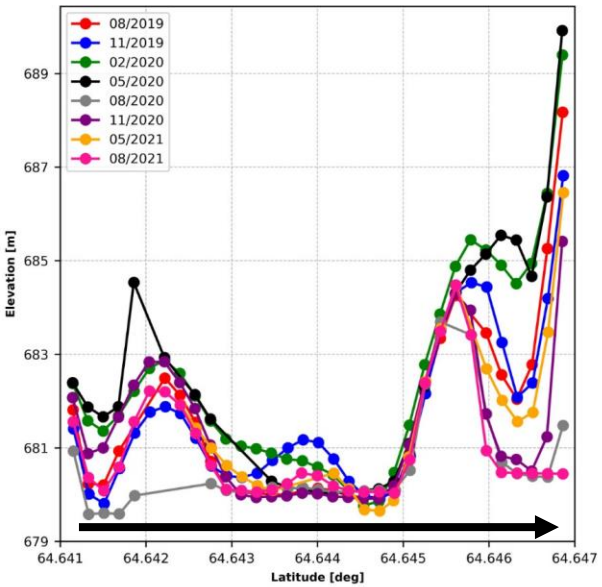

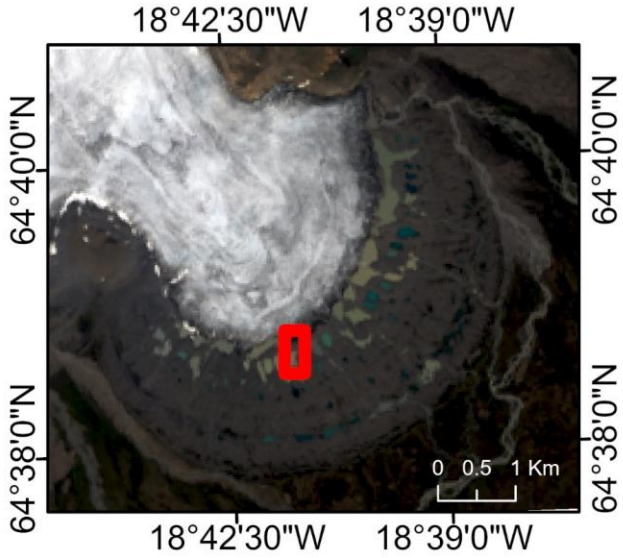

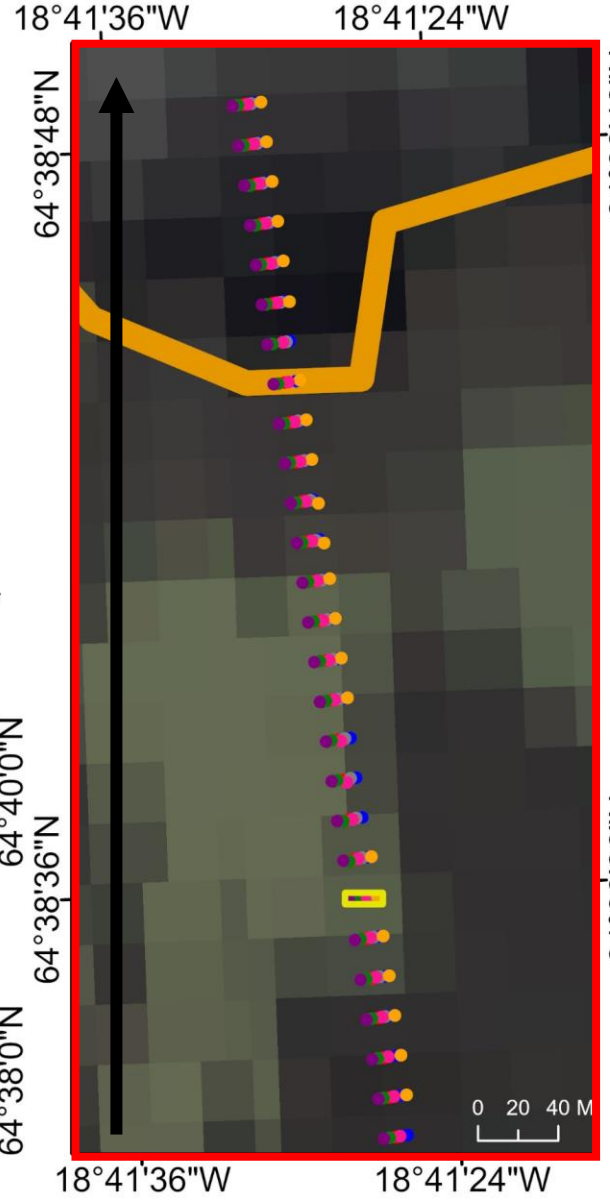

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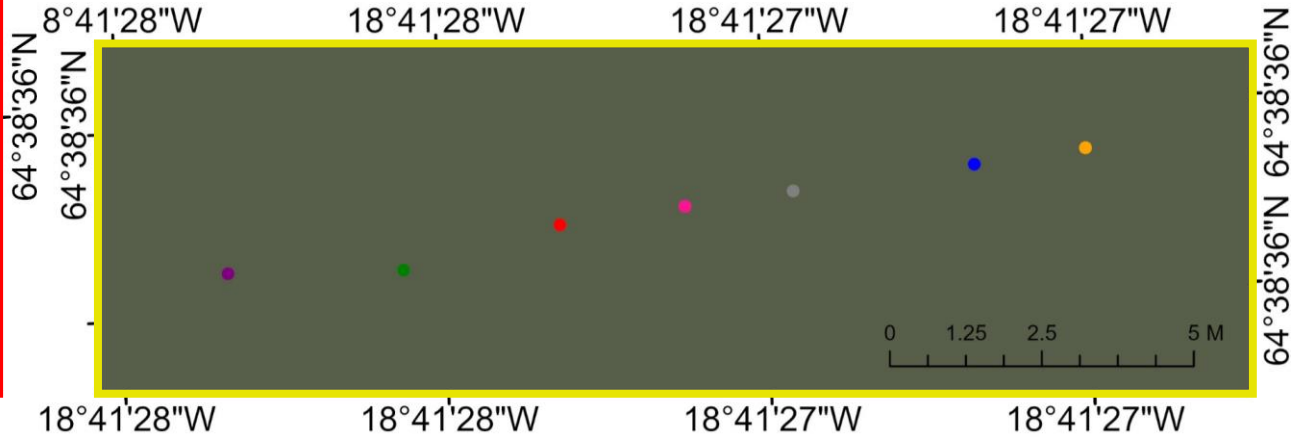
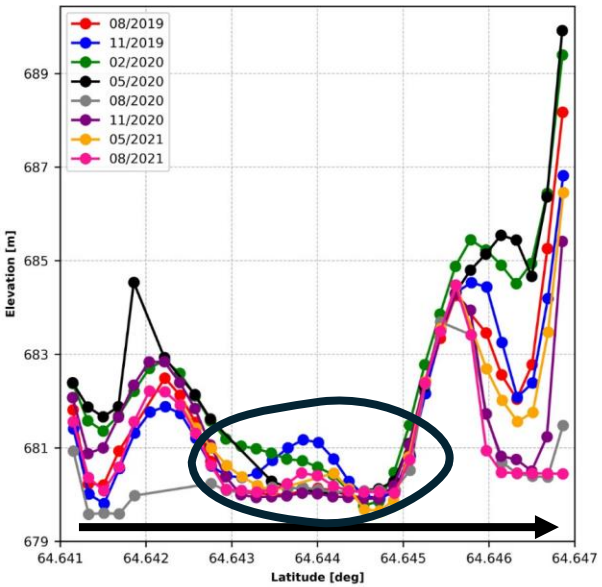
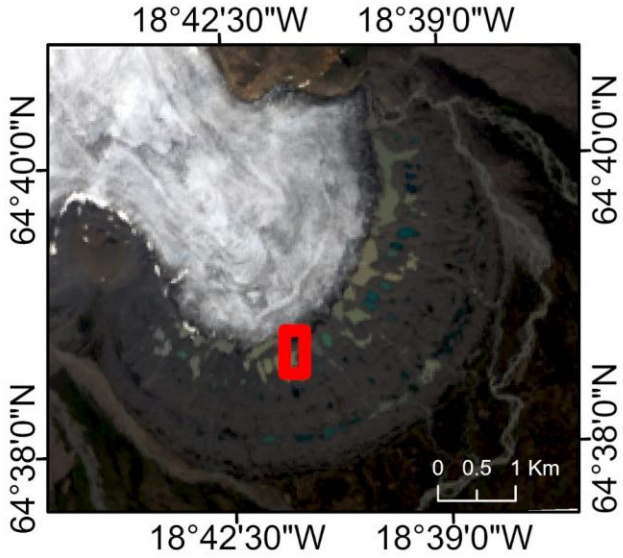
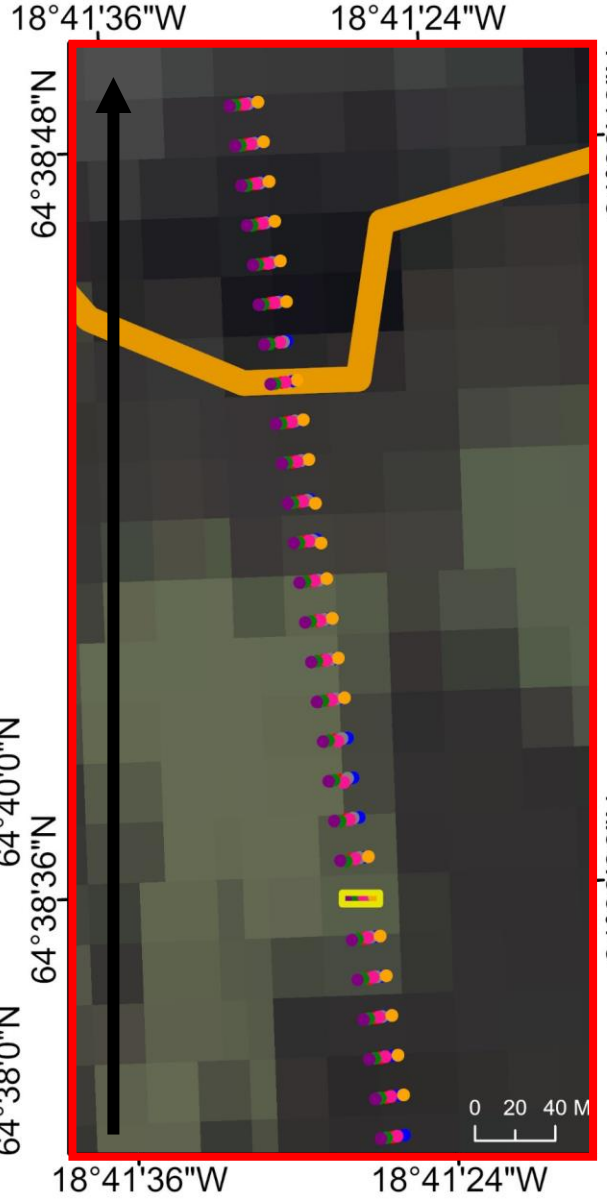
- Change in terminus observed.
- Issues with missing points and outliers.
- Issue with November 2019.









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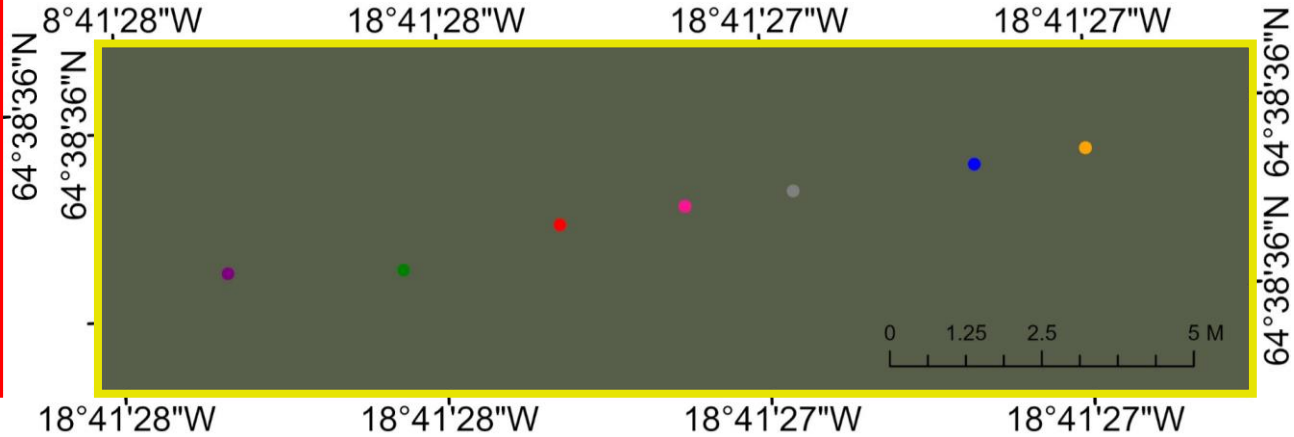
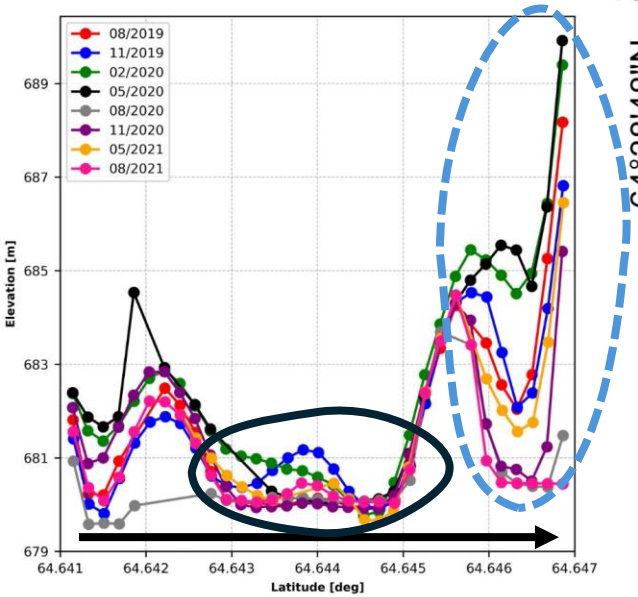
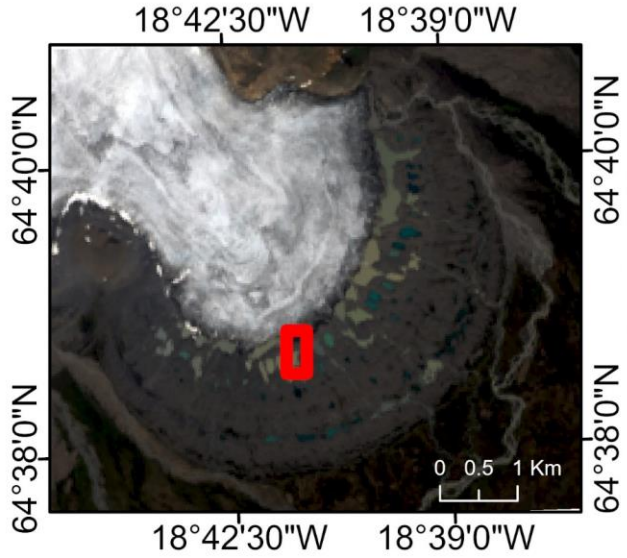
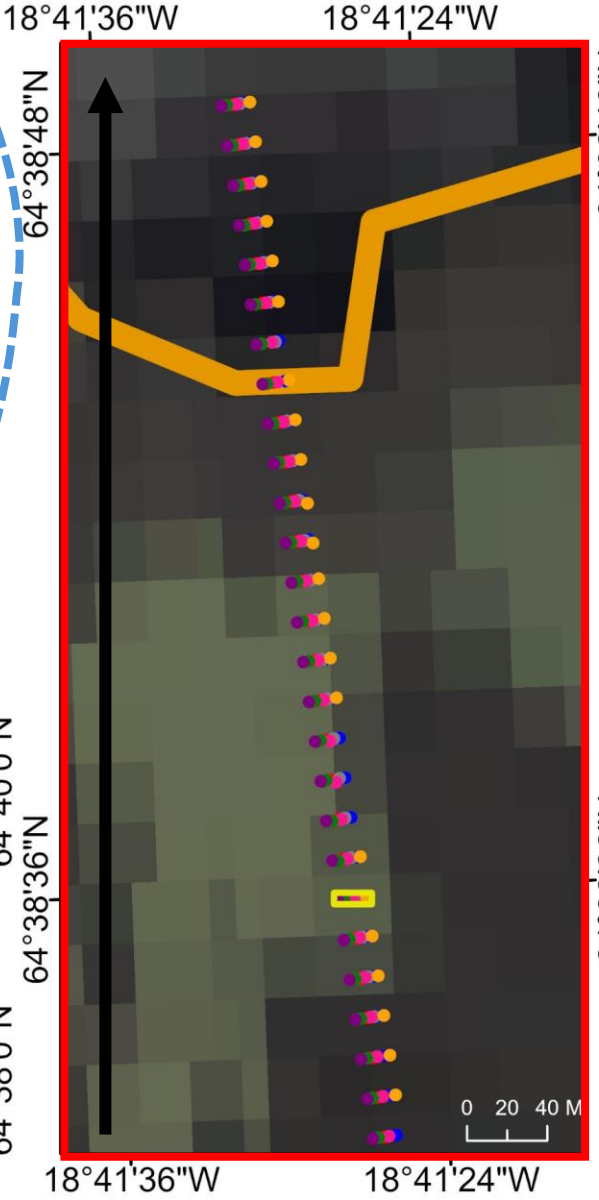


Cryo2ice Symposium 2024

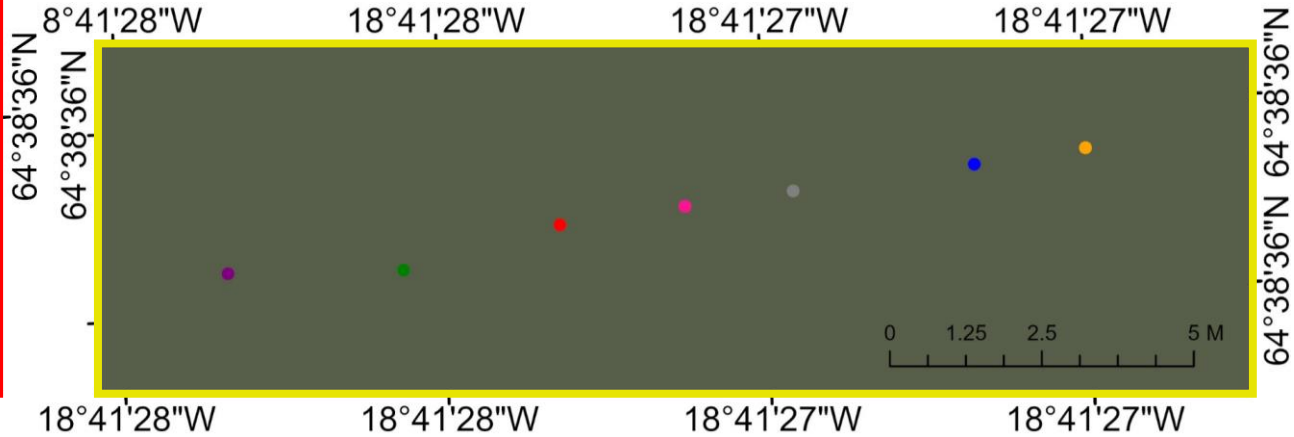






Surface profile

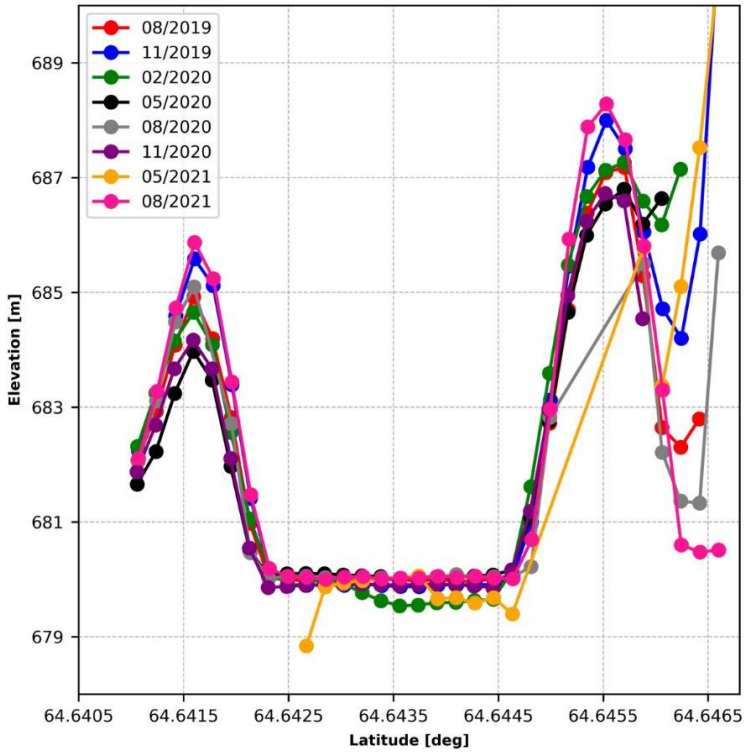
- Change in terminus observed.
- Issues with missing points and outliers.
- Issue with November 2019.



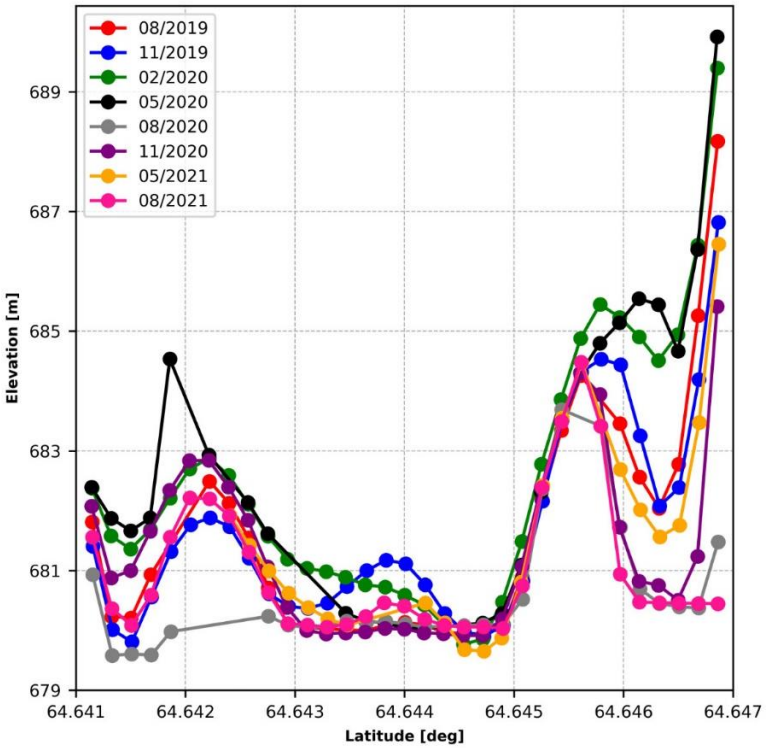
~ 0.65 m change in elevation.

33,970 m^3 volume?

Left beam



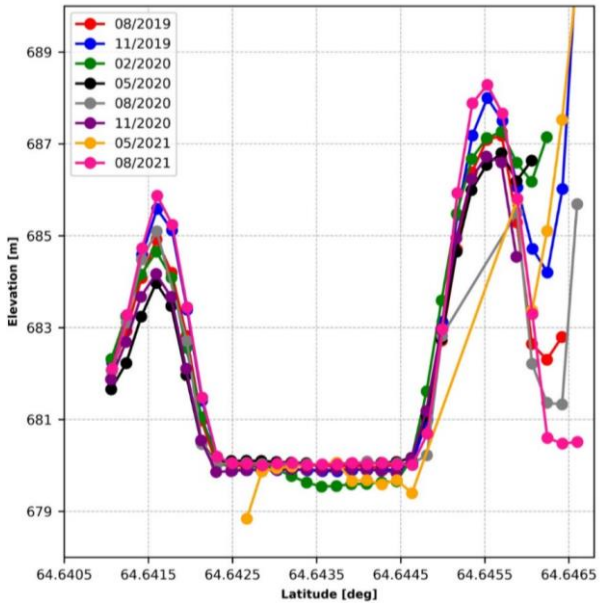
Right beam

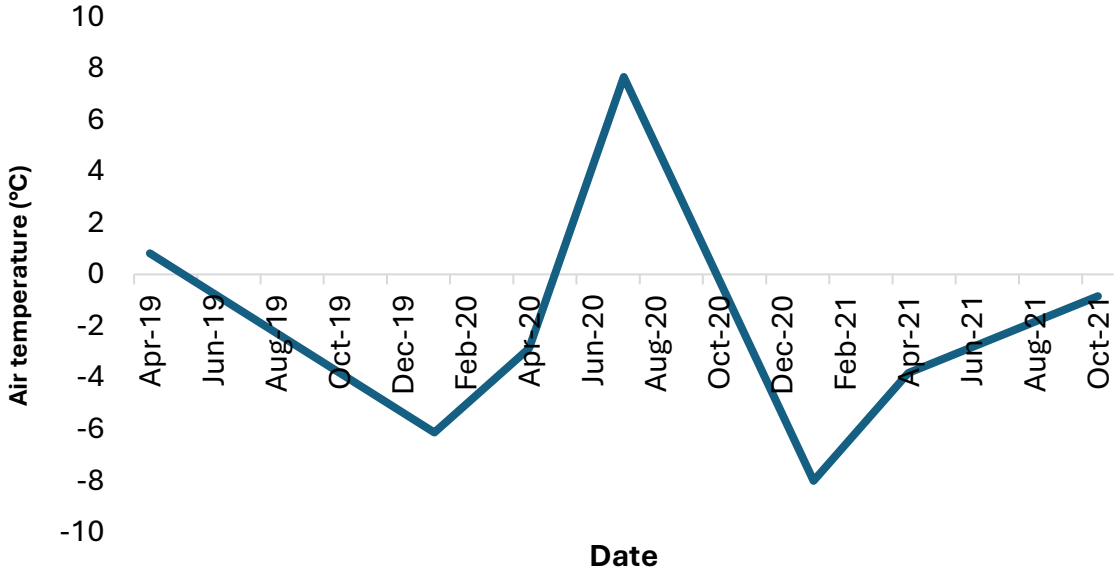


1.35 m change in elevation.

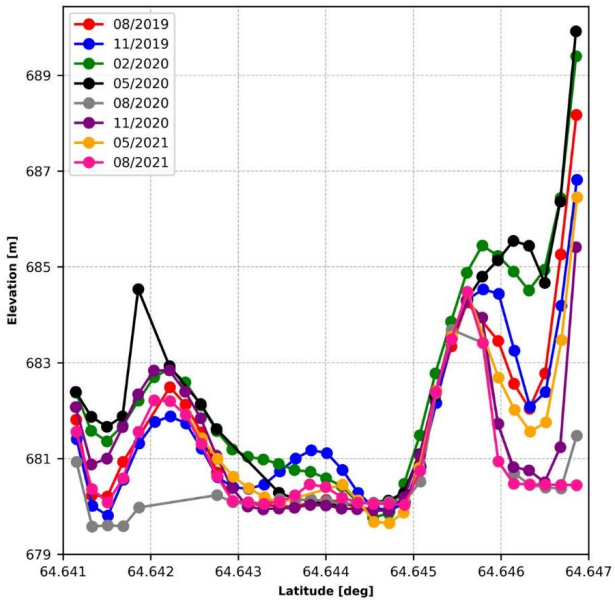
70,553 m^3 volume?

Left beam





Right beam



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Key points

Retreat of Múlajökull coincided with a **growth in proglacial lake area**.

Most of the increase in proglacial lake area has happened **after 2000**.

A quick look at Icesat-2 tracks over proglacial lakes shows **elevation change signal** however, developing this should be the focus of future work. Co-registration of data and removal of outliers is required

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