Estimating the thickness of the Müller Ice Cap using an inversion of the shallow ice approximation

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Introduction

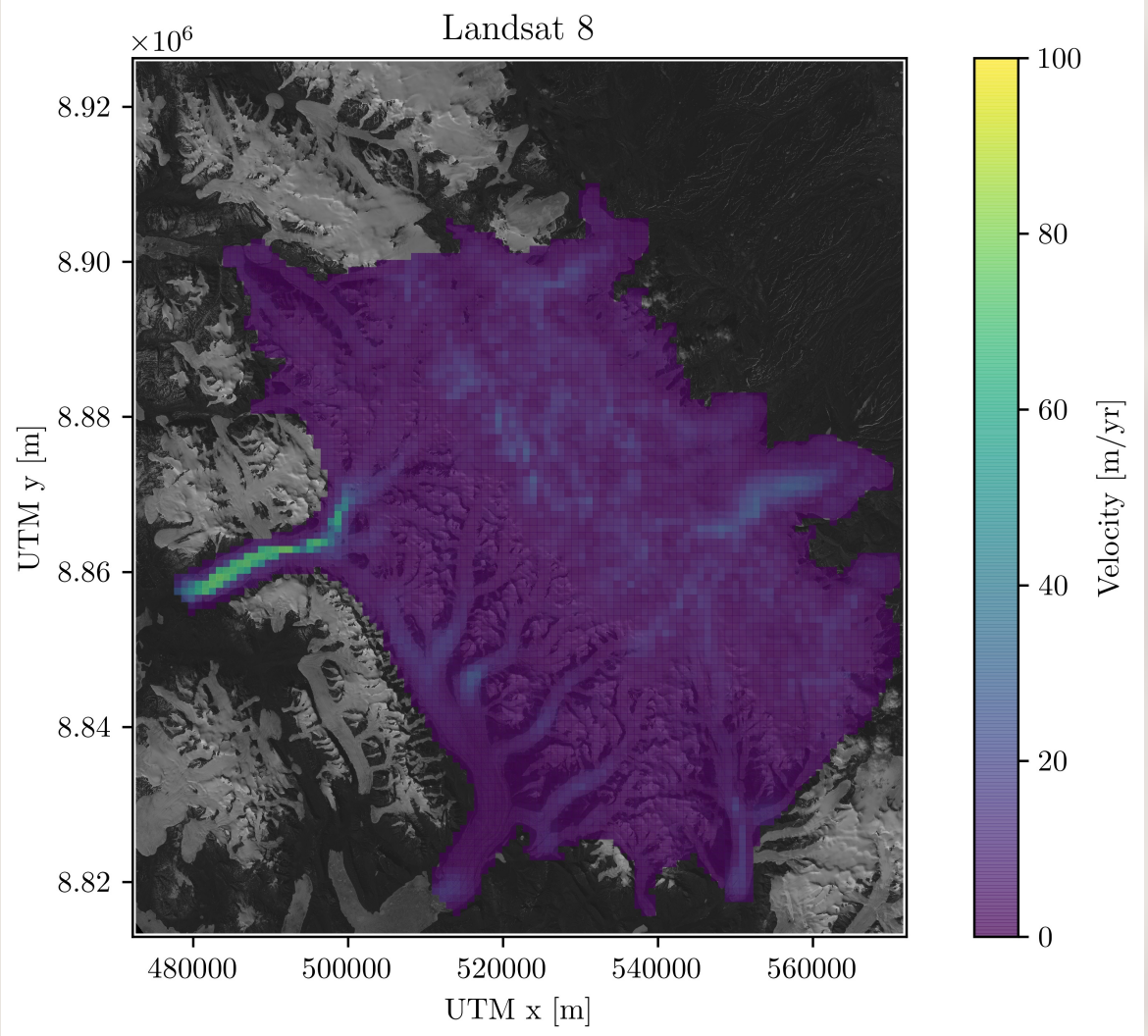
The Müller Ice Cap is located on Axel Heiberg Island in Arctic Canada. Only limited research has been conducted on the main ice cap. Therefore, researches from Canada and Denmark are planning to drill a full depth ice core. In order to gain as much information as possible from the ice core it is crucial to choose the right drill site location. The drill site should have a great ice thickness, little ice flow, and little melt, to ensure stratified countable layers reaching as far back in time as possible.



Surface velocities

A median surface velocity map over the Landsat 8 period (2014-2019) has been made using feature tracking of optical Landsat 8 panchromatic images.

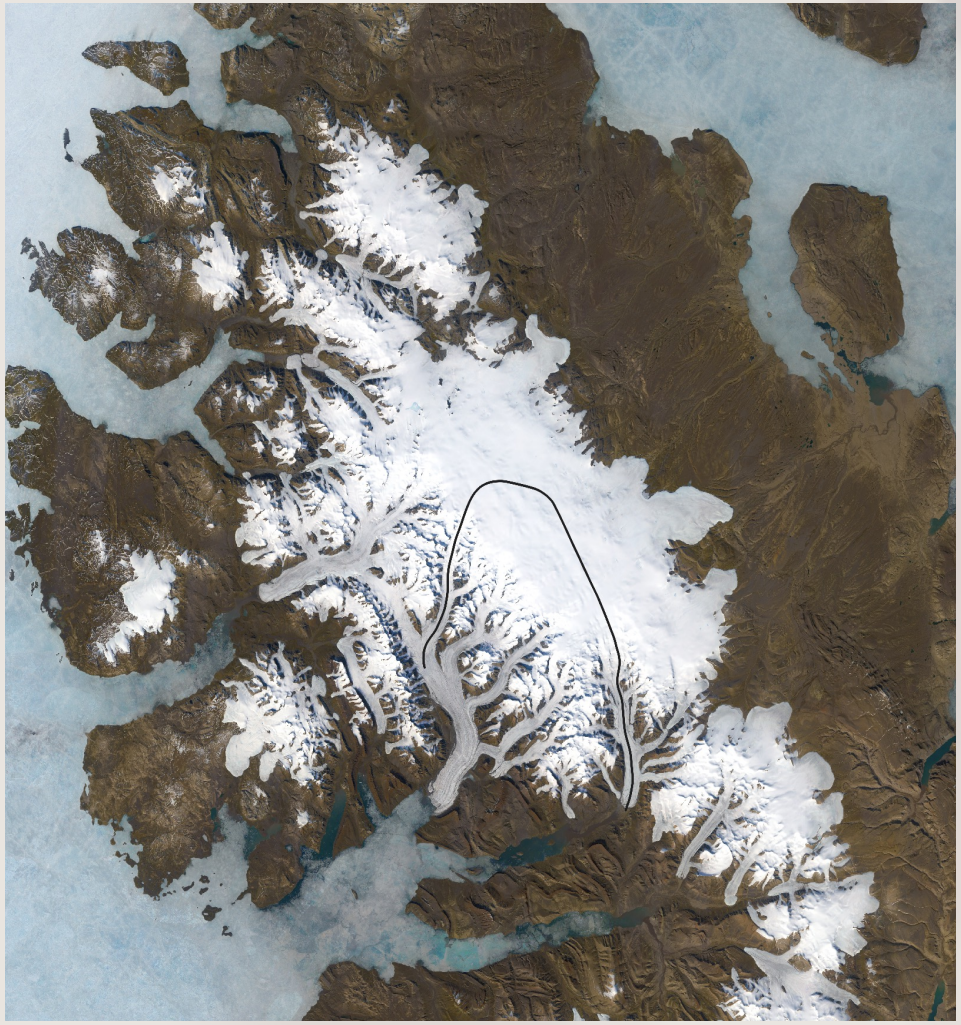
Data available at
https://doi.org/10.5281/zenodo.4290041



Shallow ice inversion

The idea behing the method is to be able to perform a fast first order approximation of the ice thickness distribtuion of an ice cap, when only sparse thickness measurements exists.

This is the case of the Müller Ice Cap, where only one Operation IceBridge flight line covers the ice cap.



Shallow ice inversion - theory

From the shallow ice approximation without sliding we know that

$$Q \propto \alpha^n H^{n+2}$$

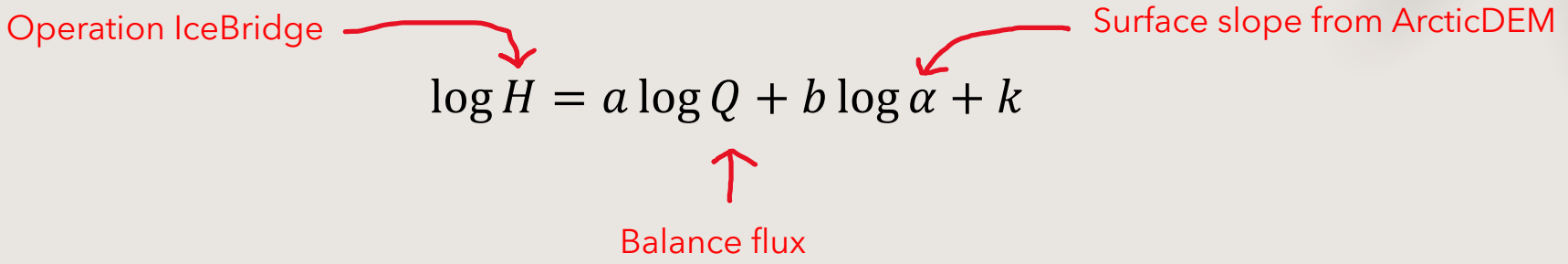
Linearity can thus be obtained

$$\log H = a \log Q + b \log \alpha + k$$

Where $a = \frac{1}{n+2}$, $b = -\frac{n}{n+2}$, and k is a tuning parameter in which density, gravity and the temperature dependent rate factor are all captured.

Shallow ice inversion - theory

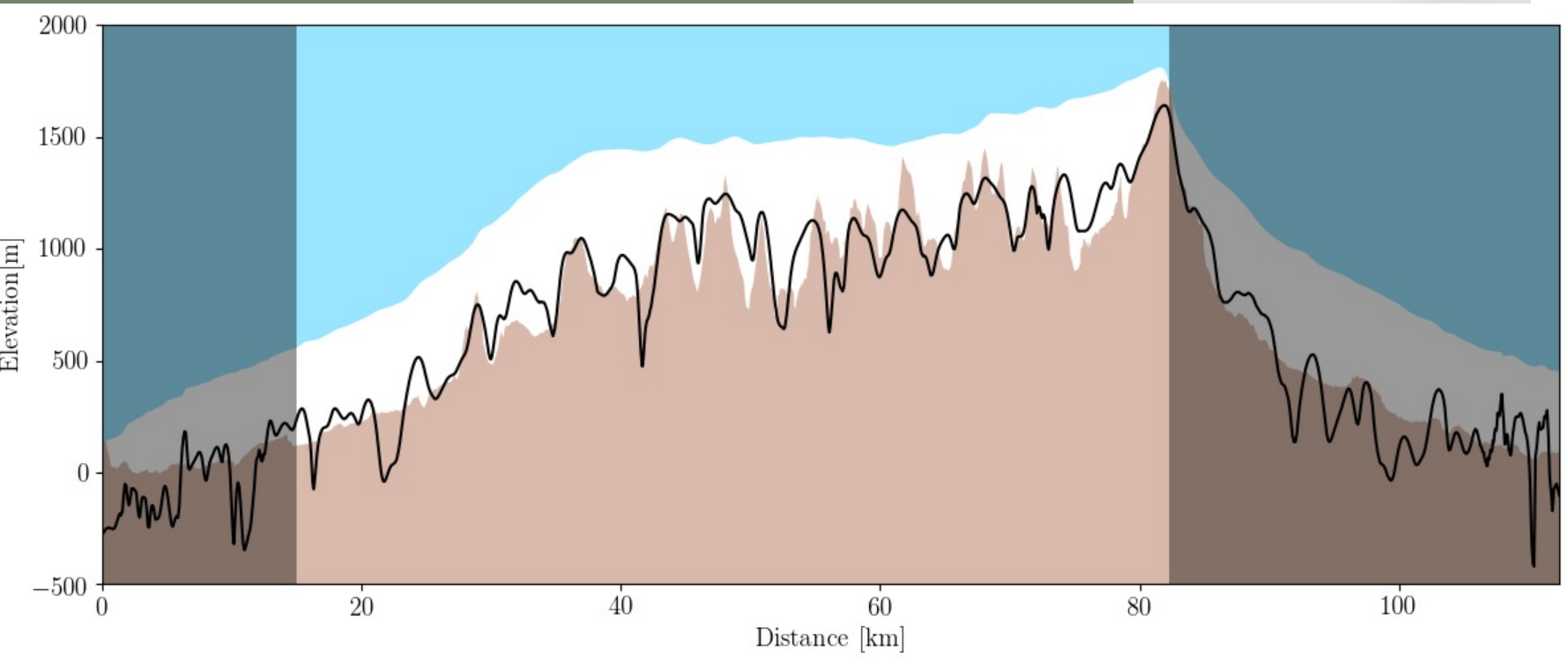
Instead of obtaining a, b and k from theory, they are obtained from a regression using thickness measurements from Operation IceBridge.

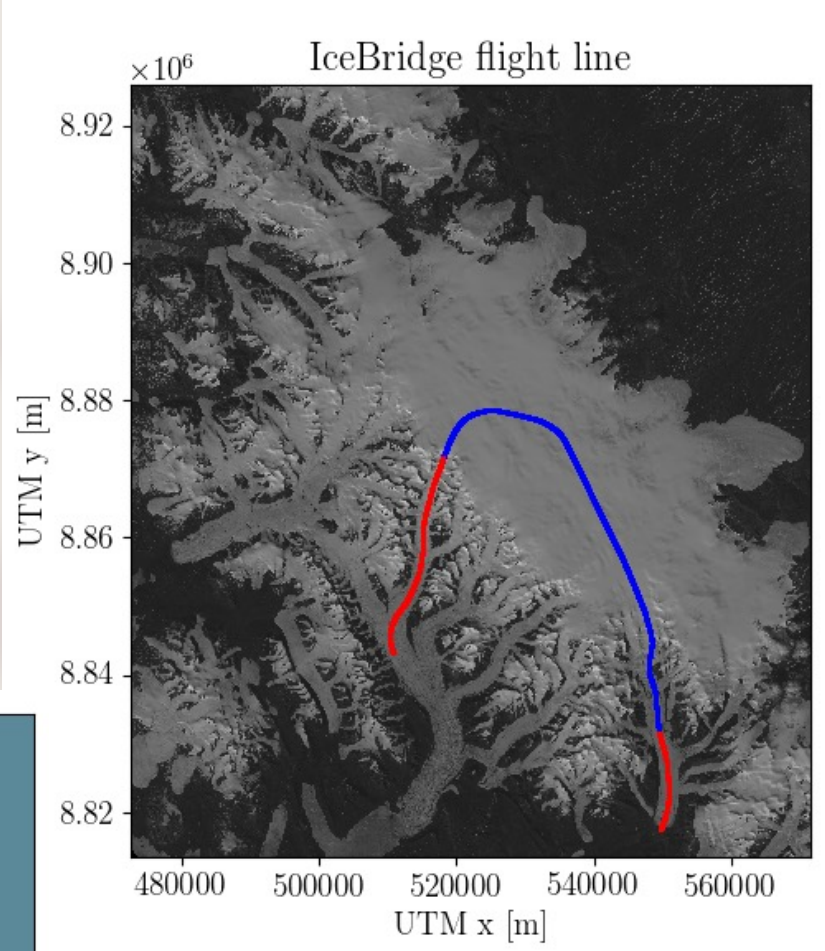


a, b, and k can thus be applied to the entire ice cap after performing the regression. Note that k can absorb any multiplicative errors in SMB and Q.

Thickness results

The non-shaded part of the cross section has been used to perform the regression, which is the part of the IceBridge flight line marked in blue.





Thickness comparison

The thickness has been modeled using several methods, and have all been compared to those of Farinotti et al. 2019.

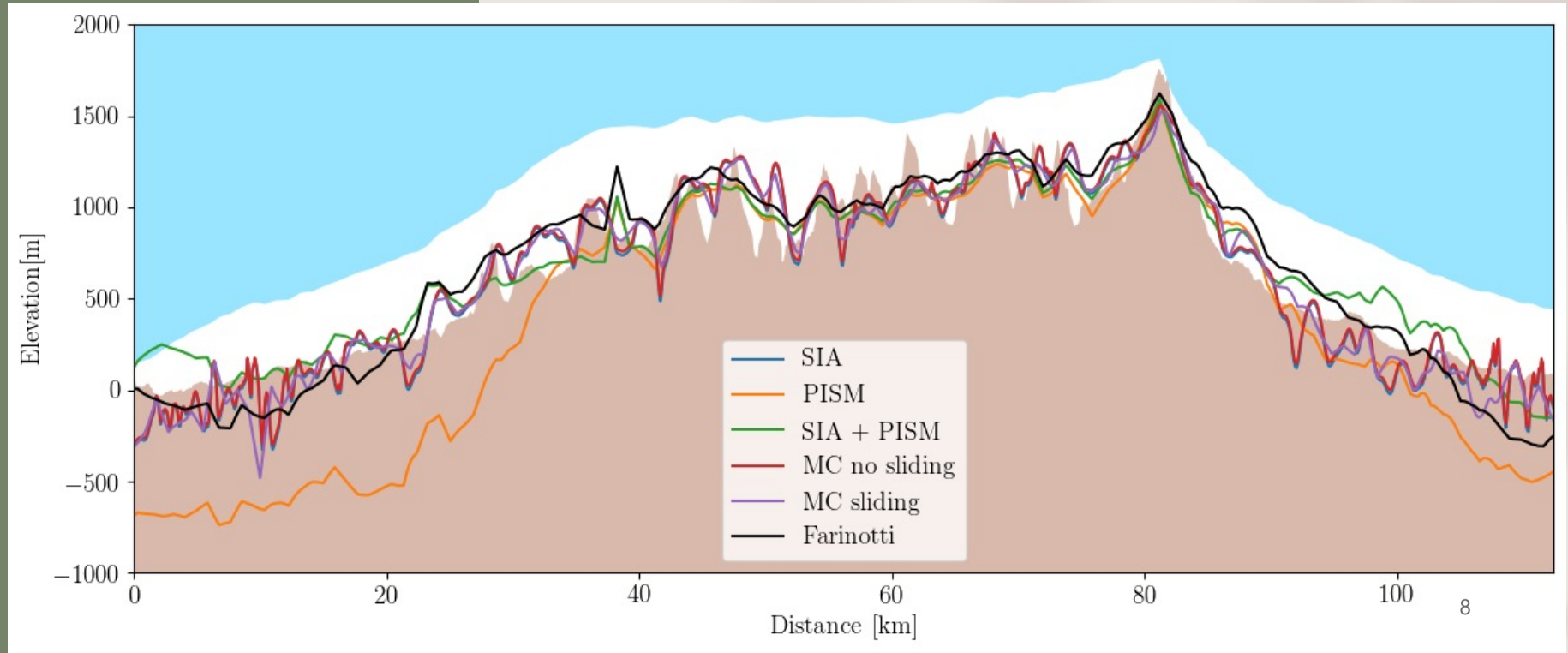
The figure shows the modeled bedrocks rather than thicknesses.

The shape of the ice in white is given by the surface elevation from ArcticDEM and the Operation IceBridge thickness.

The SIA inversion was the fastest of all methods, and showed better or equally good results.

Ice thickness data is available at https://doi.org/10.5281/zenodo.4290039

SIA (preferred): The method described in this presentation
PISM: Iterative inverse method using PISM as forward model, with the Farinotti et al. 2019 bedrock as initial guess.
SIA+PISM: Iterative inverse method using PISM as a forward model, with the SIA inversion bedrock as initial guess.
MC no sliding: Solving the SIA without sliding using a Monte Carlo sampling method.
MC sliding: Solving the SIA with sliding using a Monte Carlo sampling method.
Farinotti: Farinotti et al. 2019, A consensus estimate for the ice thickness distribution of all glaciers on Earth.



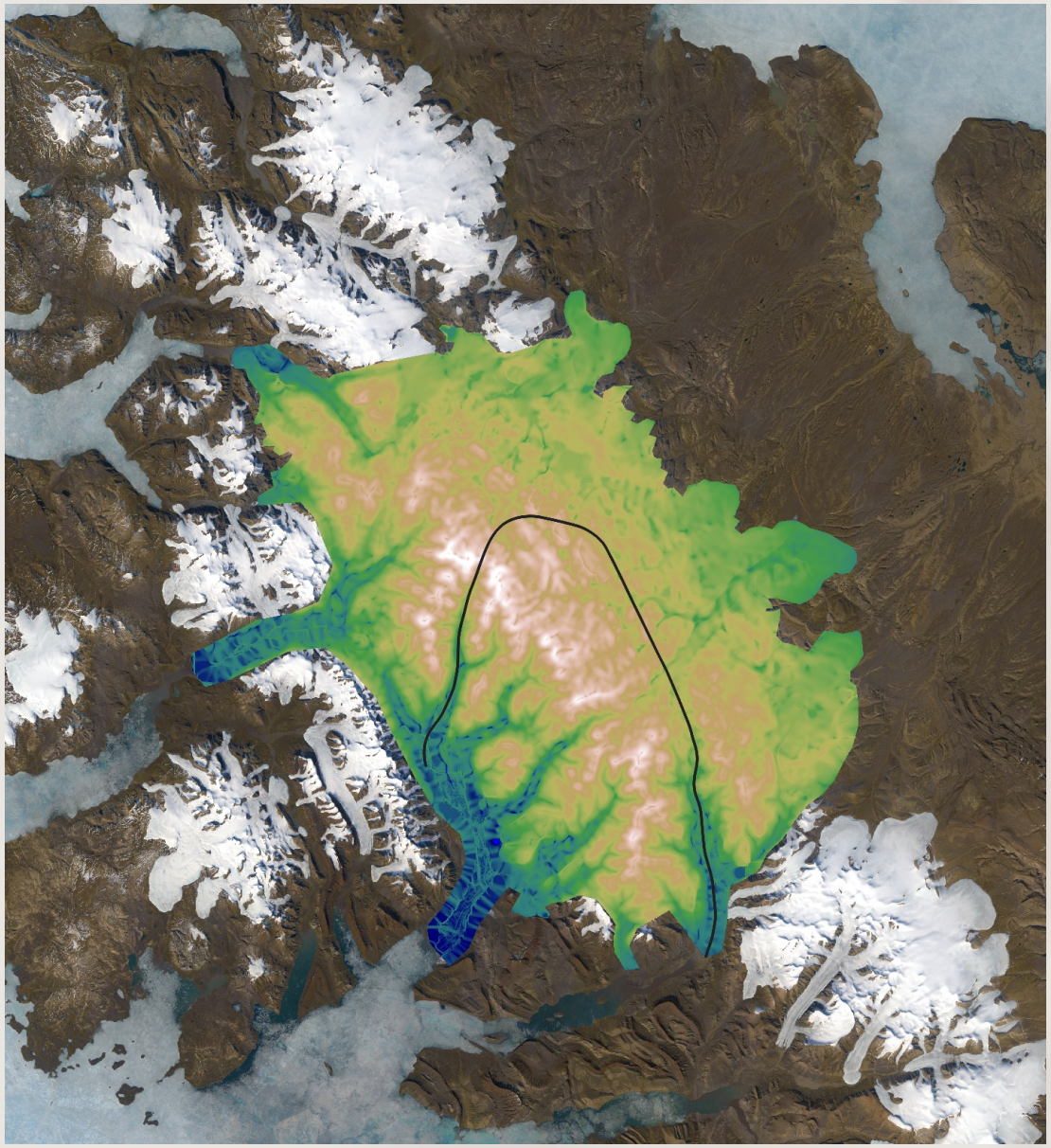
Results

2D inferred bedrock elevation under the entire ice cap.

Used in drill site selection.

More data will be collected with GPR for comparison with the model results.

No seams between drainage basins in contrast to traditional flowline approaches.



Conclusion

Semi-empirical method of ice thickness estimation.

- Insensetive to SMB
- 2.5-dimensional (works better on ice caps)
- Fast and efficient
- As good or better than models with more ice physics

If you are more interested in the different methods, have a look at my thesis (CLICK HERE) or stay tuned for a publication in the near future.

