Constraining Subglacial Melt Production using Subglacial Lake Activity

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THE UNIVERSITY of EDINBURGH School of GeoSciences

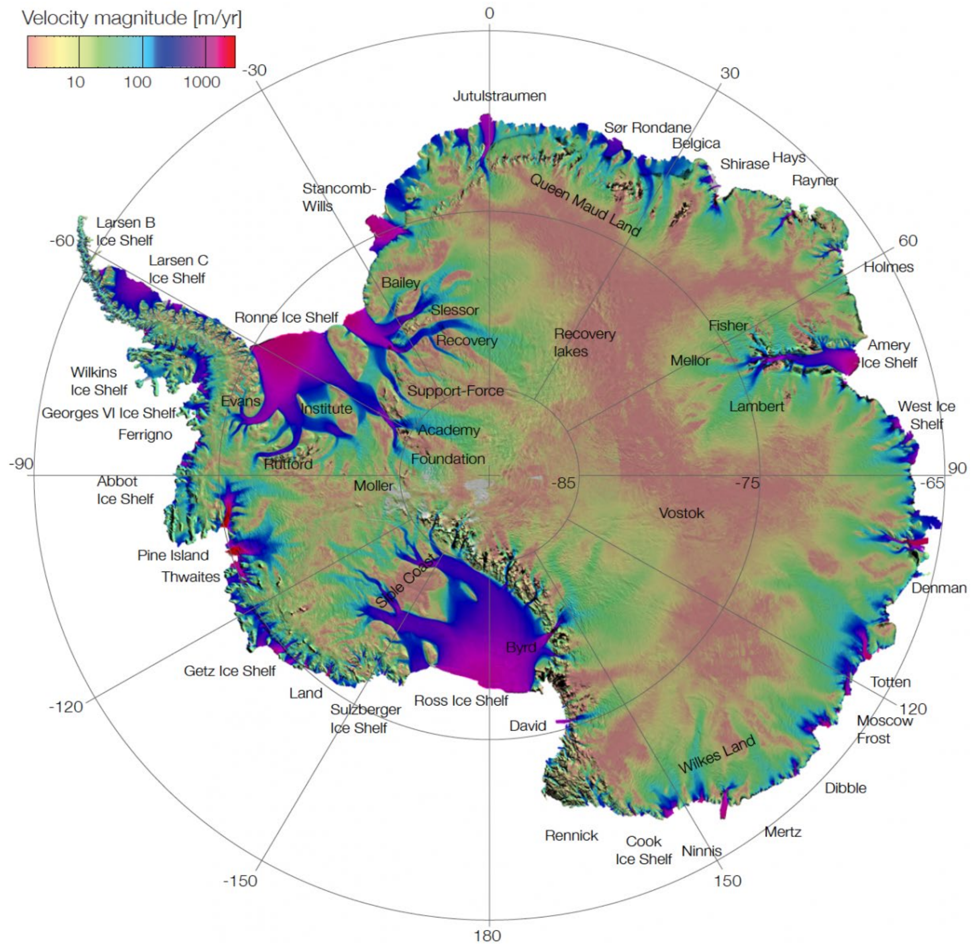
E3 DTP Edinburgh, Earth and Environment Doctoral Training Partnership

NERC SCIENCE OF THE ENVIRONMENT

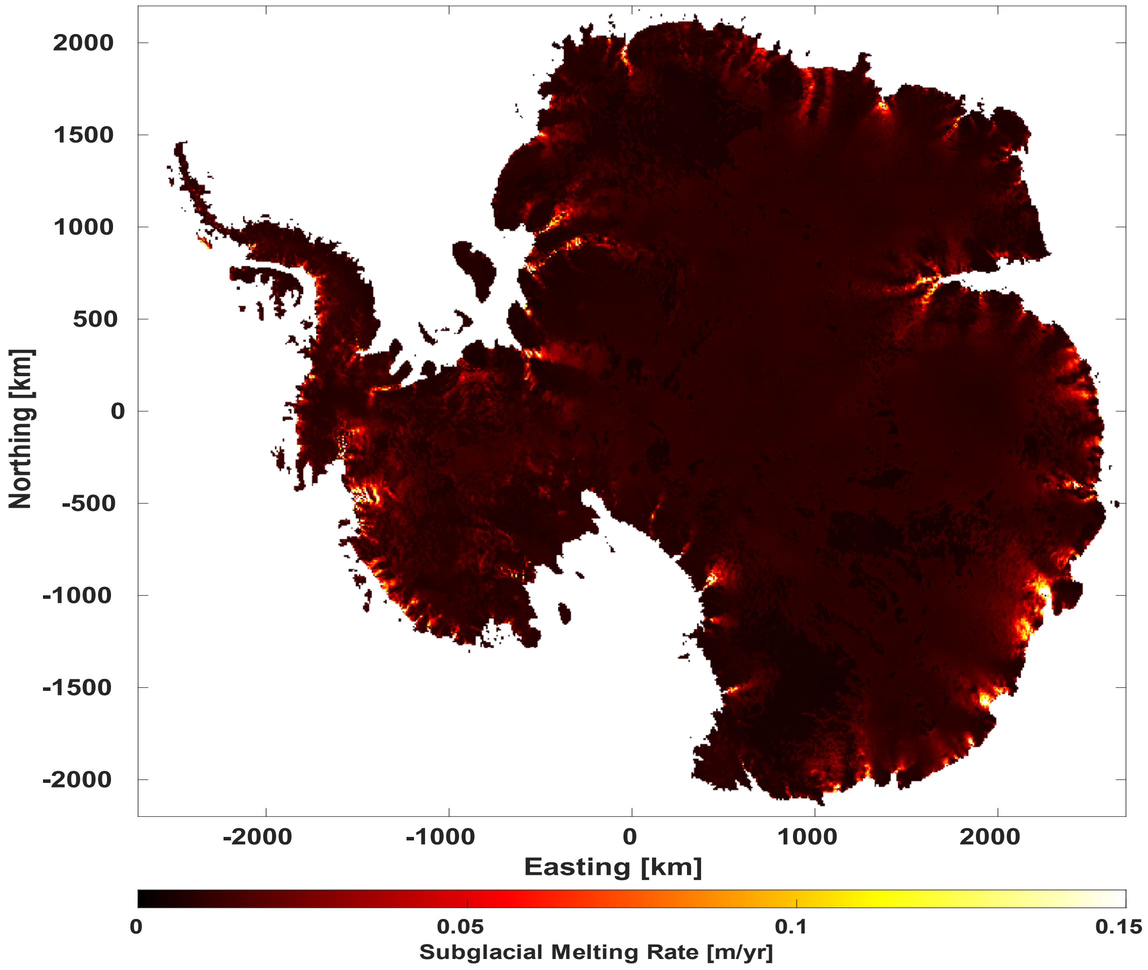
esa

4D Antarctica

Subglacial Melt Production



(NSIDC, 2018)



Importance of Subglacial Water

LETTERS

Increased flow speed on a large East Antarctic outlet glacier caused by subglacial floods

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Evidence from ice shelves for channelized meltwater flow beneath the Antarctic Ice Sheet

Anne M. Le Brocq, Neil Ross, Jennifer A. Griggs, Robert G. Bingham, Hugh F. J. Corr, Fausto Ferraccioli, Adrian Jenkins, Tom A. Jordan, Antony J. Payne, David M. Rippin & Martin J. Siegert

Nature Geoscience **6**, 945–948 (2013) | Cite this article

- Movement of water linked to **transient glacier flow acceleration**
- Discharges of subglacial water linked to **enhanced melting** at the grounding line
- Subglacial water discharge linked to **nutrient mixing** under ice shelves
- The presence, location, and movement of subglacial water are **first order controls of Antarctic mass balance**

Validating Subglacial Melting Rates

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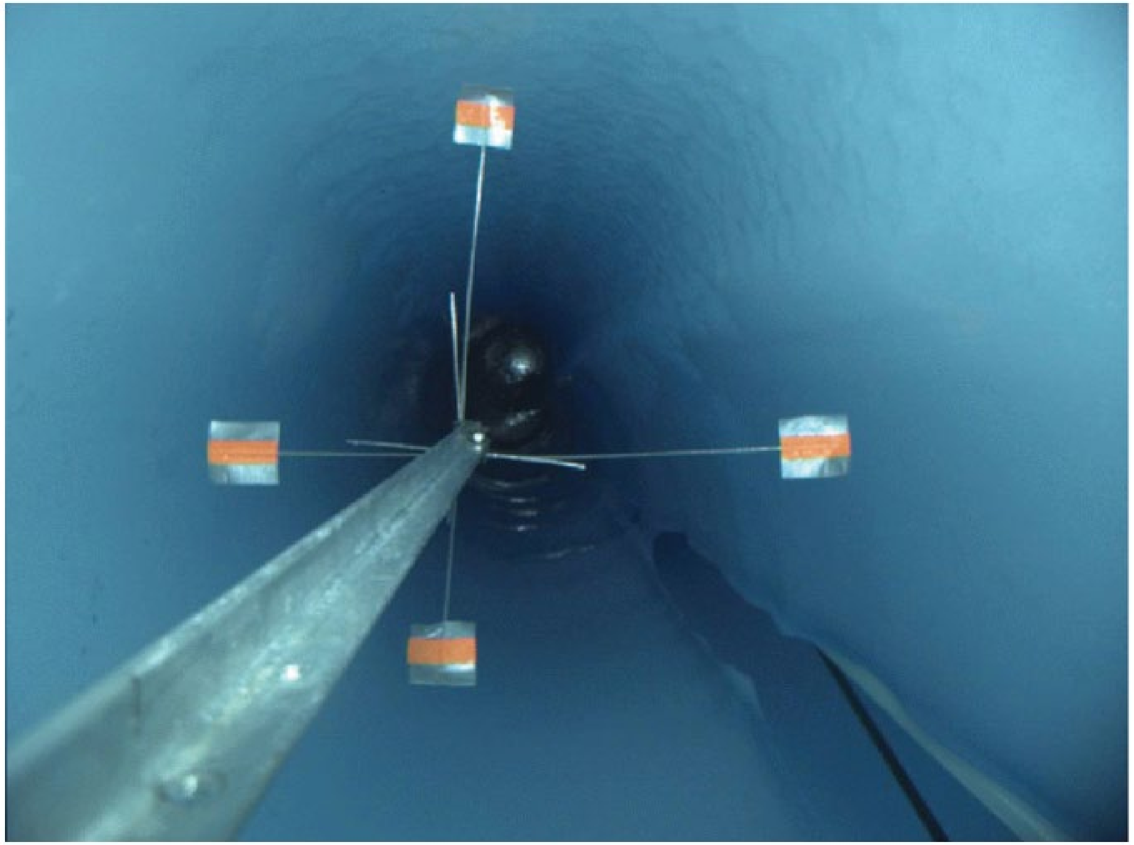
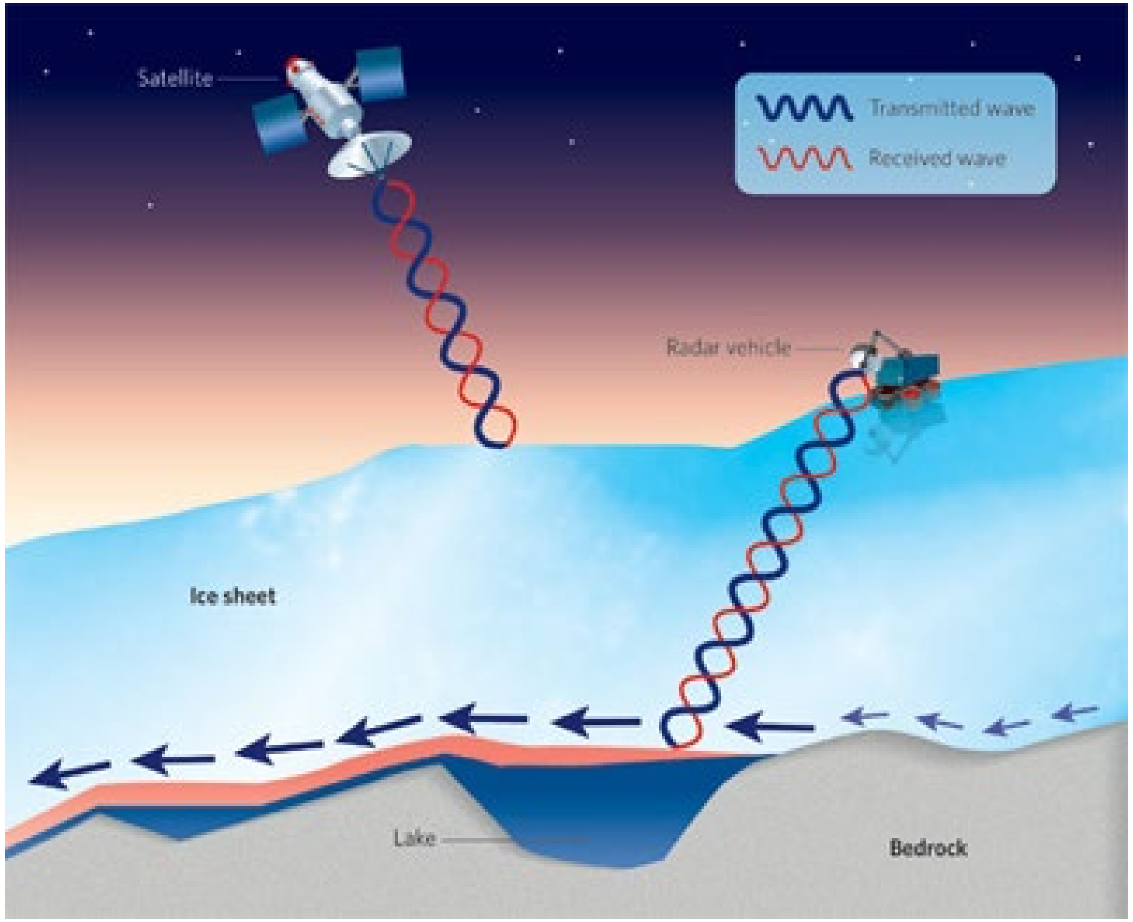
- Direct observations of subglacial system difficult due to thickness of ice
- Only direct observations are from deep drilling operations
- Subglacial melt is predominantly **constrained by models**
- Currently, there is **no method** of validating subglacial melt production

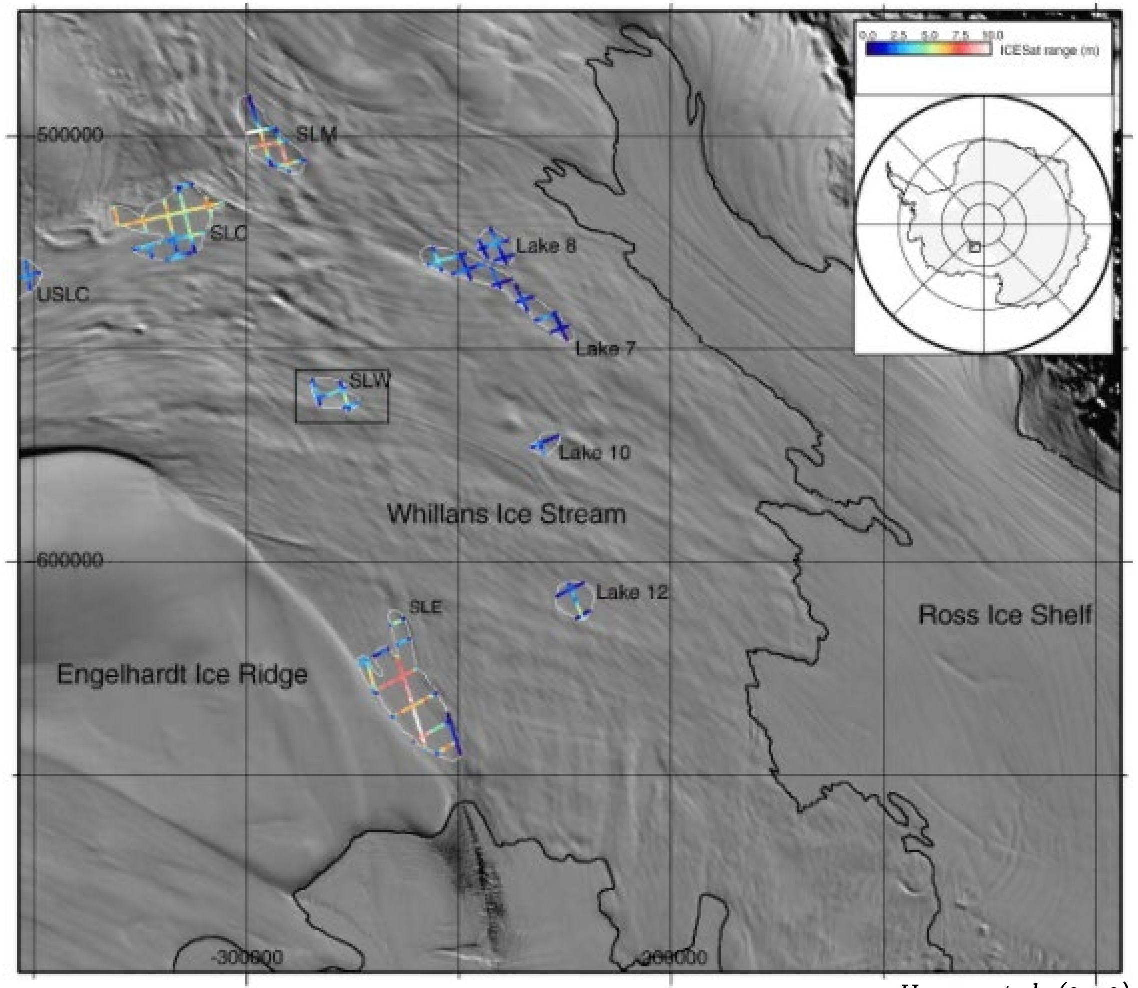


(Priscu et al., 2021)

Subglacial Lakes

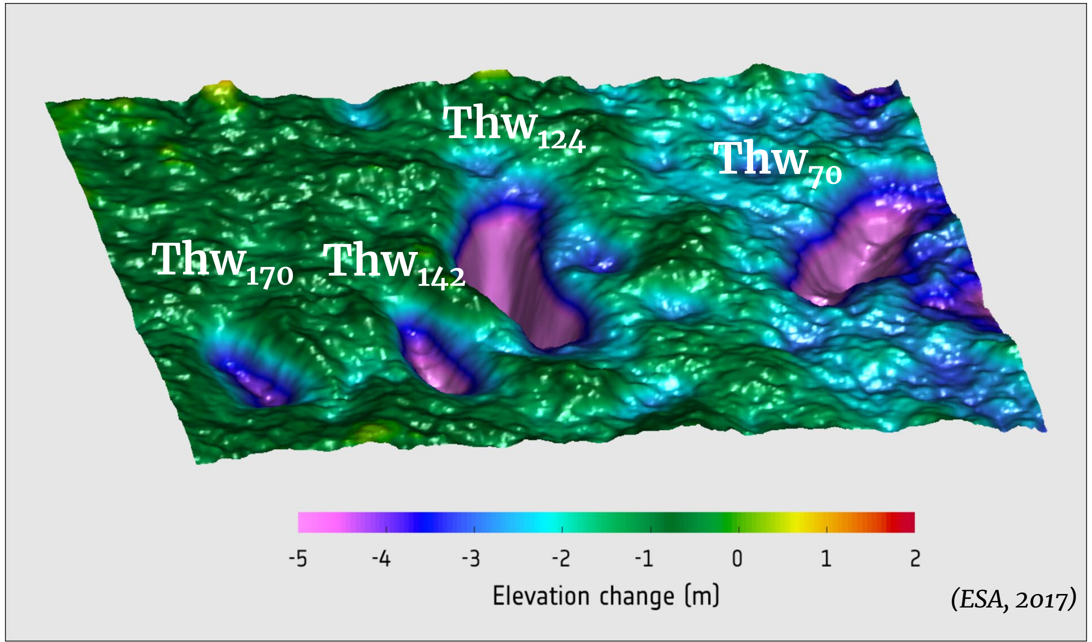


Kohler (2007)

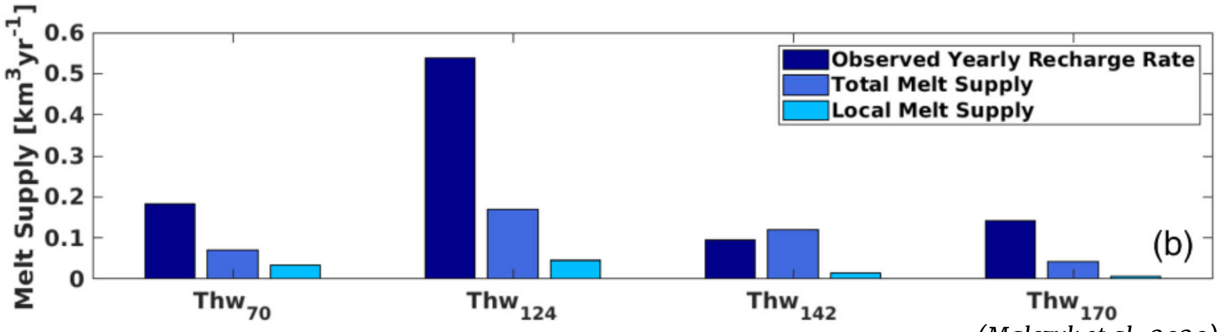


Horgan et al., (2012)

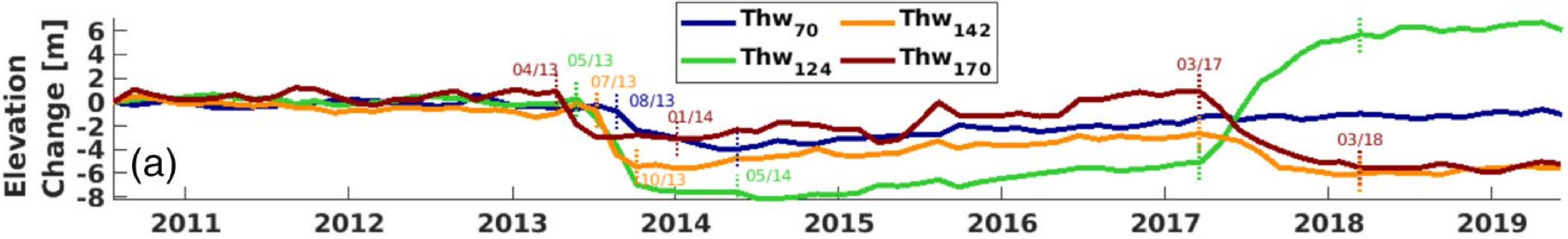
Thwaites Lake System



(ESA, 2017)



(Malczyk et al., 2020)



(Malczyk et al., 2020)

Objectives & Aims

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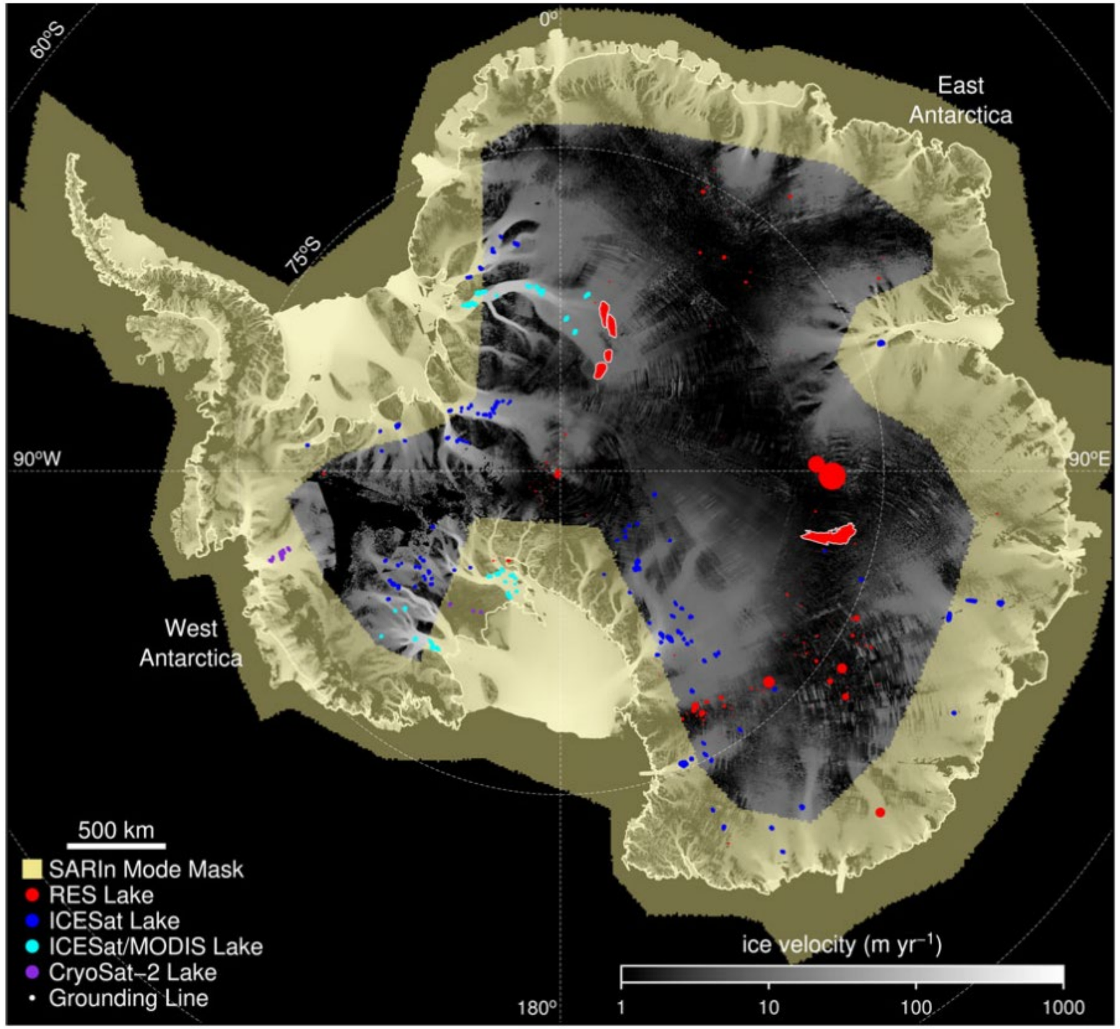
Can observing the recharge period of active subglacial lakes be used as a proxy for subglacial melt production?

1. Observe all active lakes across Antarctica. → 2. Model inwards flux for each lake → 3. Compare and contrast recharge rates

Method: Observing Subglacial Lakes



Siegfried & Fricker (2018)

- Swath processed CryoSat-2 elevations were collected for all known lakes existing within the SARin mask.
- A **timeseries of elevation change** was created for all lakes.
- If a lake displayed a **clear period of recharge** *(i.e elevation gain following a drainage event)*, recharge rates were **extracted using a linear fit**.
- **Masks were updated** by running a rate of change *(dhdt)* algorithm

Method: Subglacial Melting Rates

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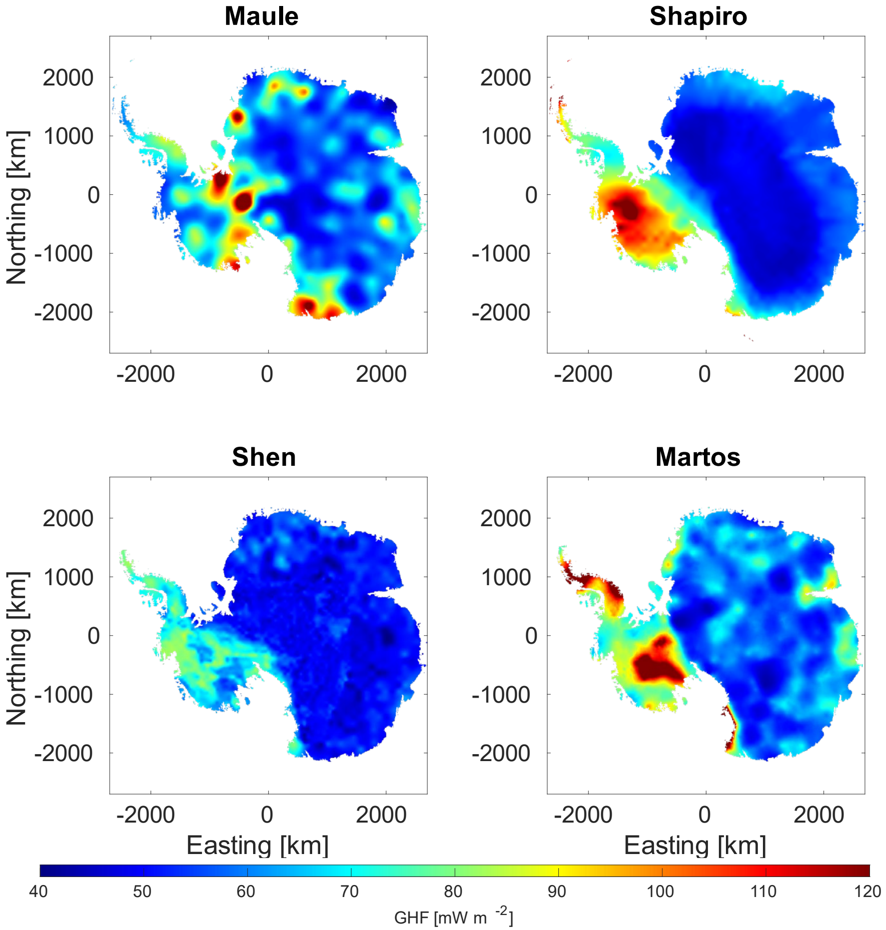
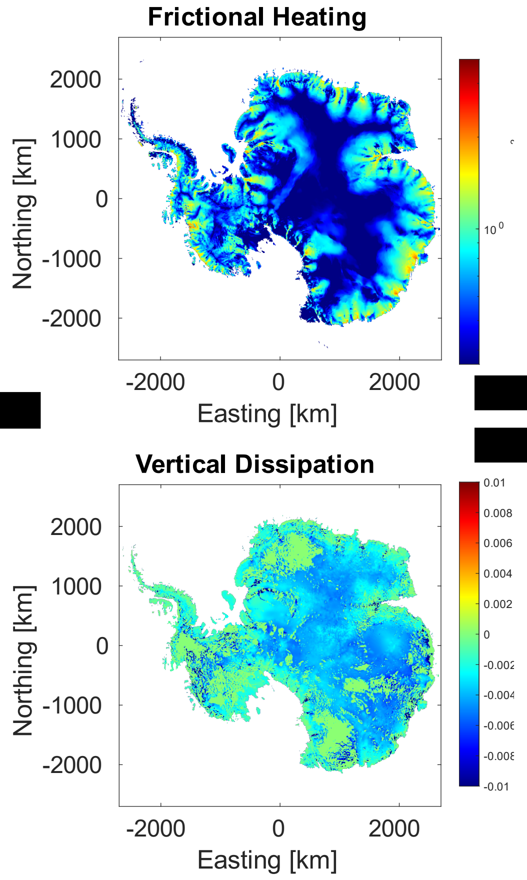
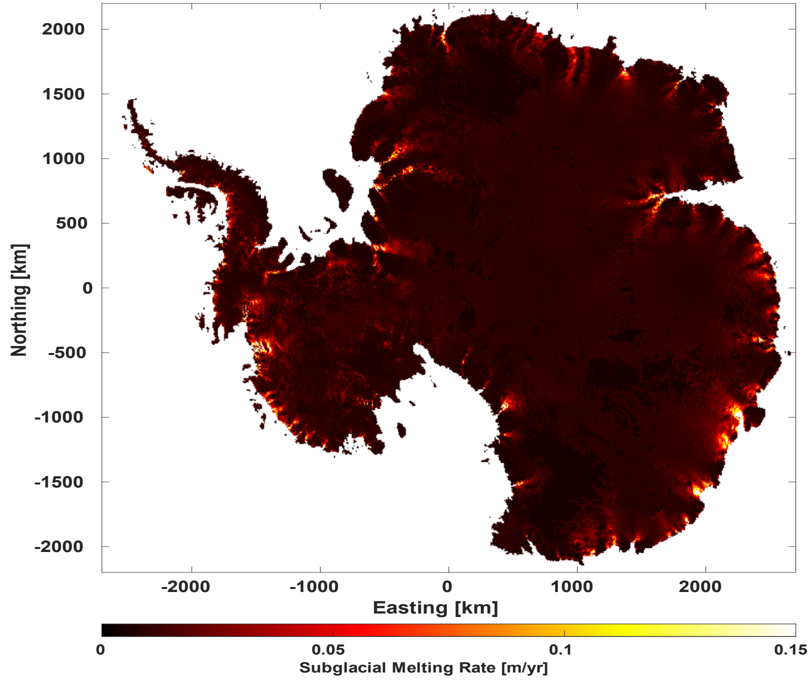
- **Melting rates across Antarctica** were calculated, with four geothermal heat flux realizations, *(Shen, Shapiro, Maule, Martos)*, frictional heating, and vertical dissipation.



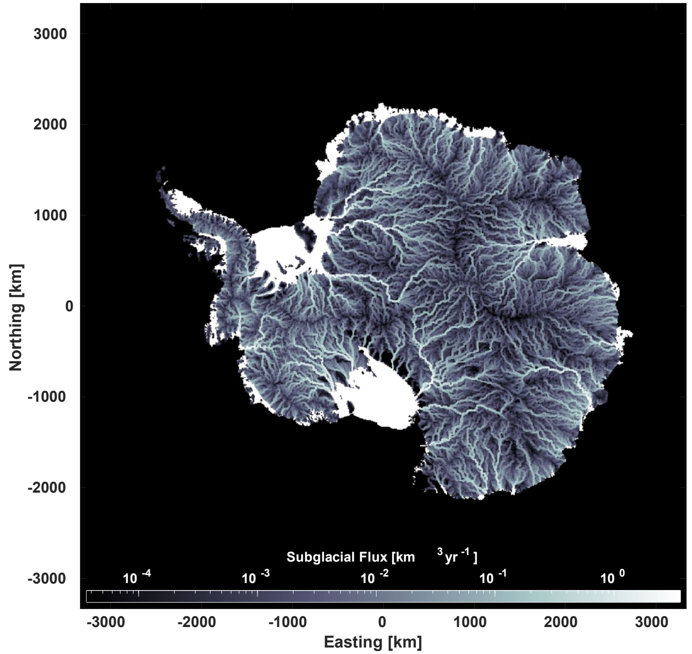


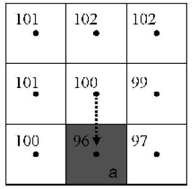
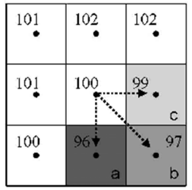
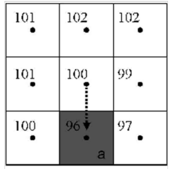


Method: Modelling Recharge Rates

- **Routing maps across Antarctica** created with three methods, forced over our four melting maps:
  - *TopoToolBox*
  - *Le Brocq*
  - *4D Antarctica Flow Model*

- 12 **estimates of recharge rates** for each lake collected. Allows to compare **impact of heat flux and routing**



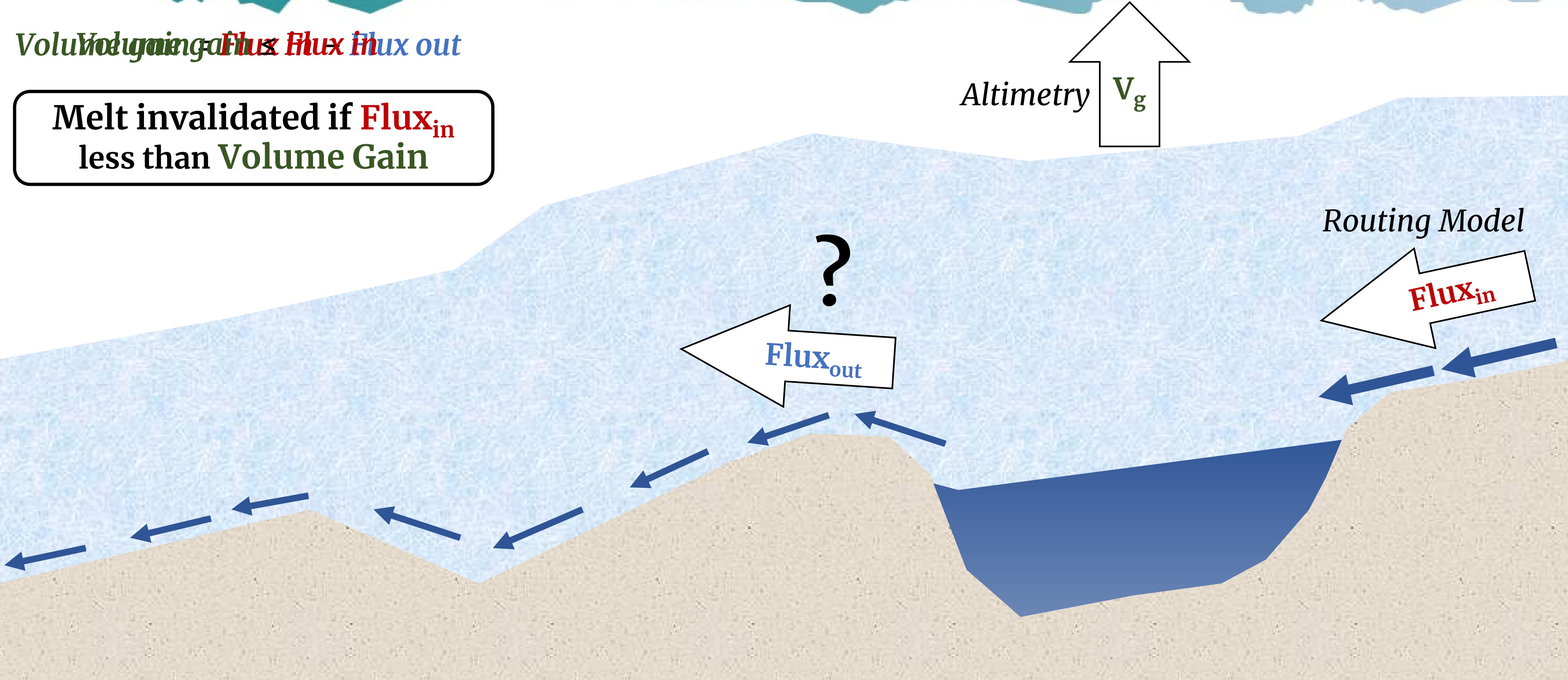
TopoToolBox *(D8)*	Le Brocq Flow model *(FD8)*	4D Antarctica Flow model *(Stochastic D8)*
 (a) D8 Scheme a = 100 %	 (b) FD8 Scheme a = 65.6 %, b = 23.0%, c = 15.4%	$\frac{1}{n}\sum$ 

Method: Constraining Melt Production

Volume gain = Flux in - Flux out

Volume gain ≤ Flux in

Melt invalidated if Flux_{in} less than Volume Gain



Method: Constraining Melt production over Multiple Lakes

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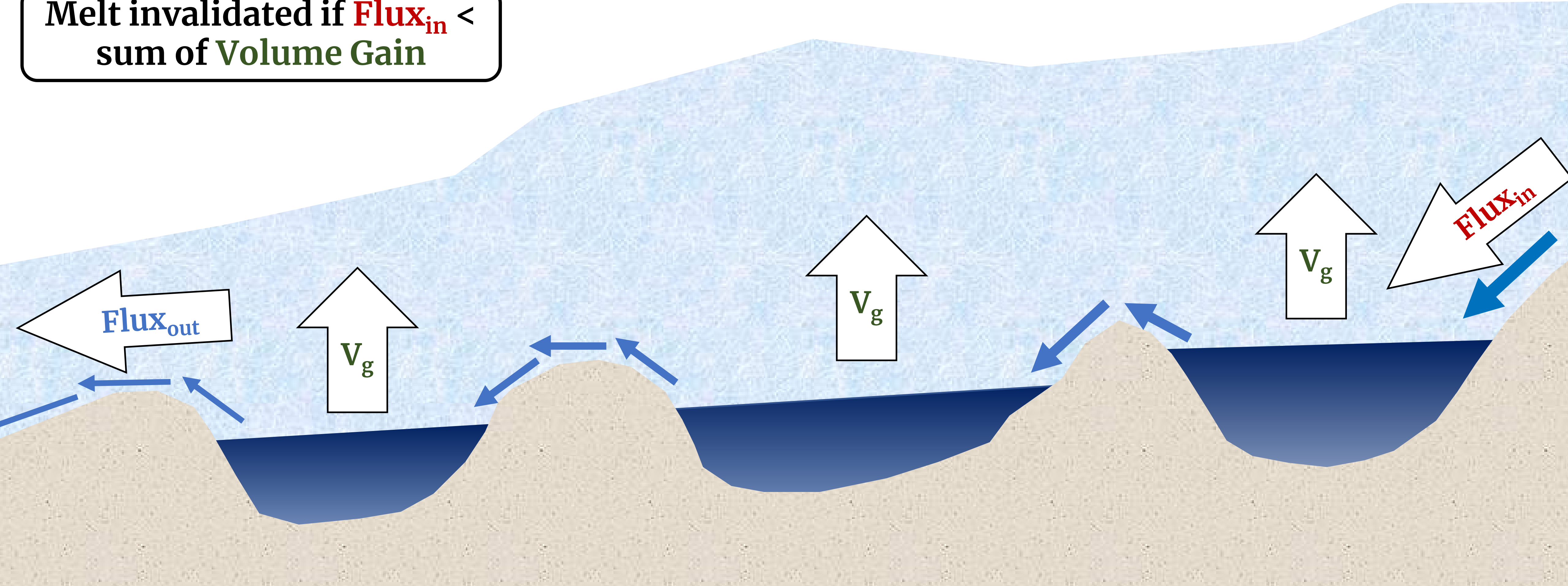
Sum of Volume gain = Flux in − Flux out

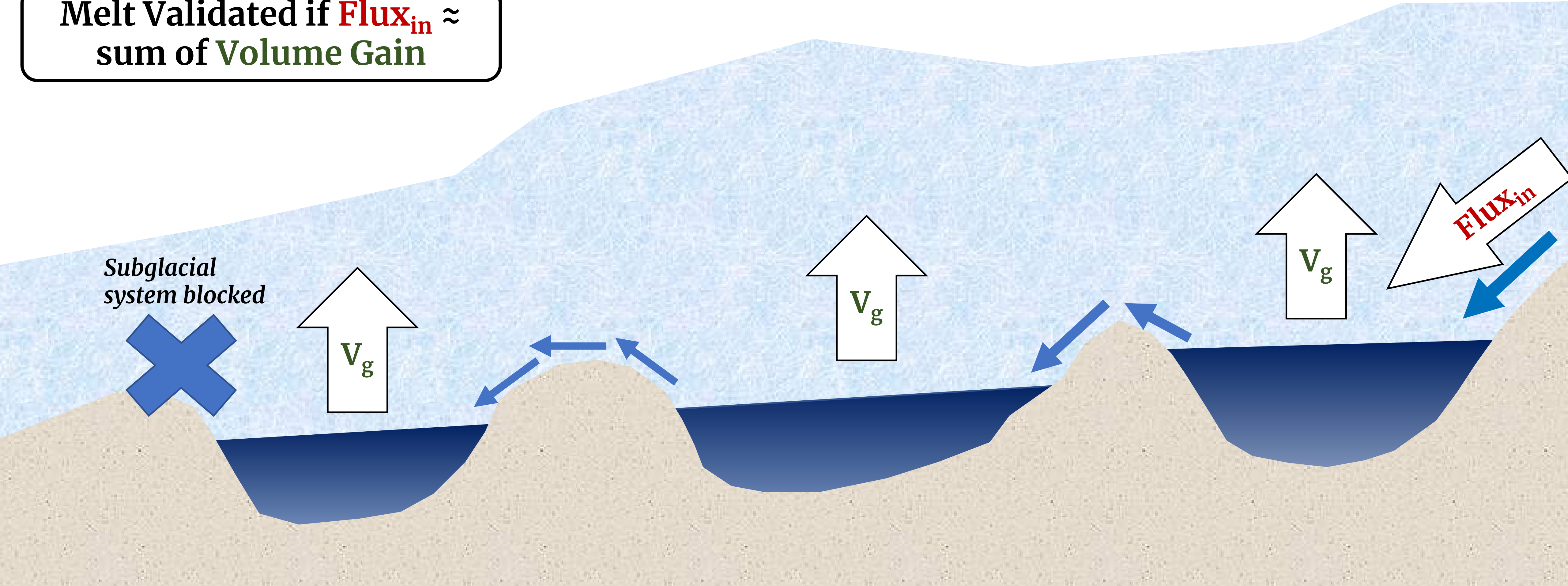
Melt invalidated if $Flux_{in}$ < sum of Volume Gain



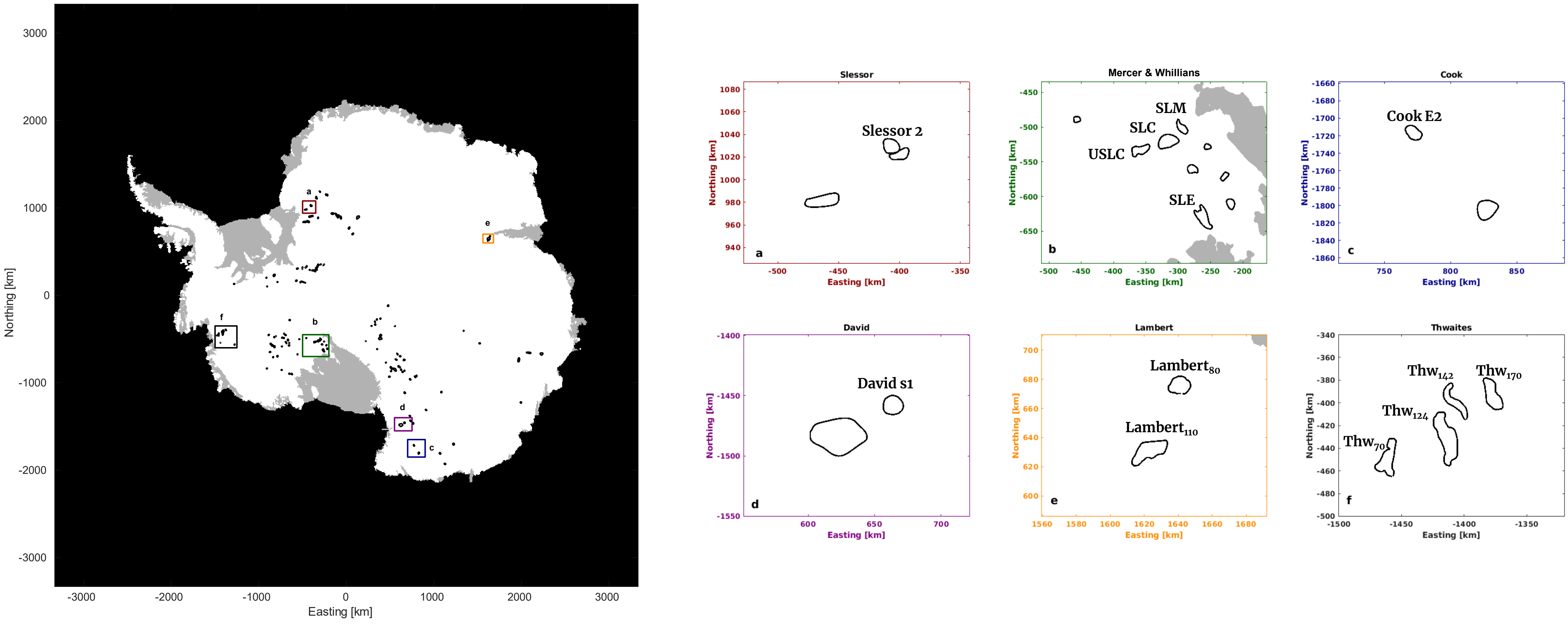
Method: Constraining Melt production (special case)

Sum of Volume gain ≈ Flux in

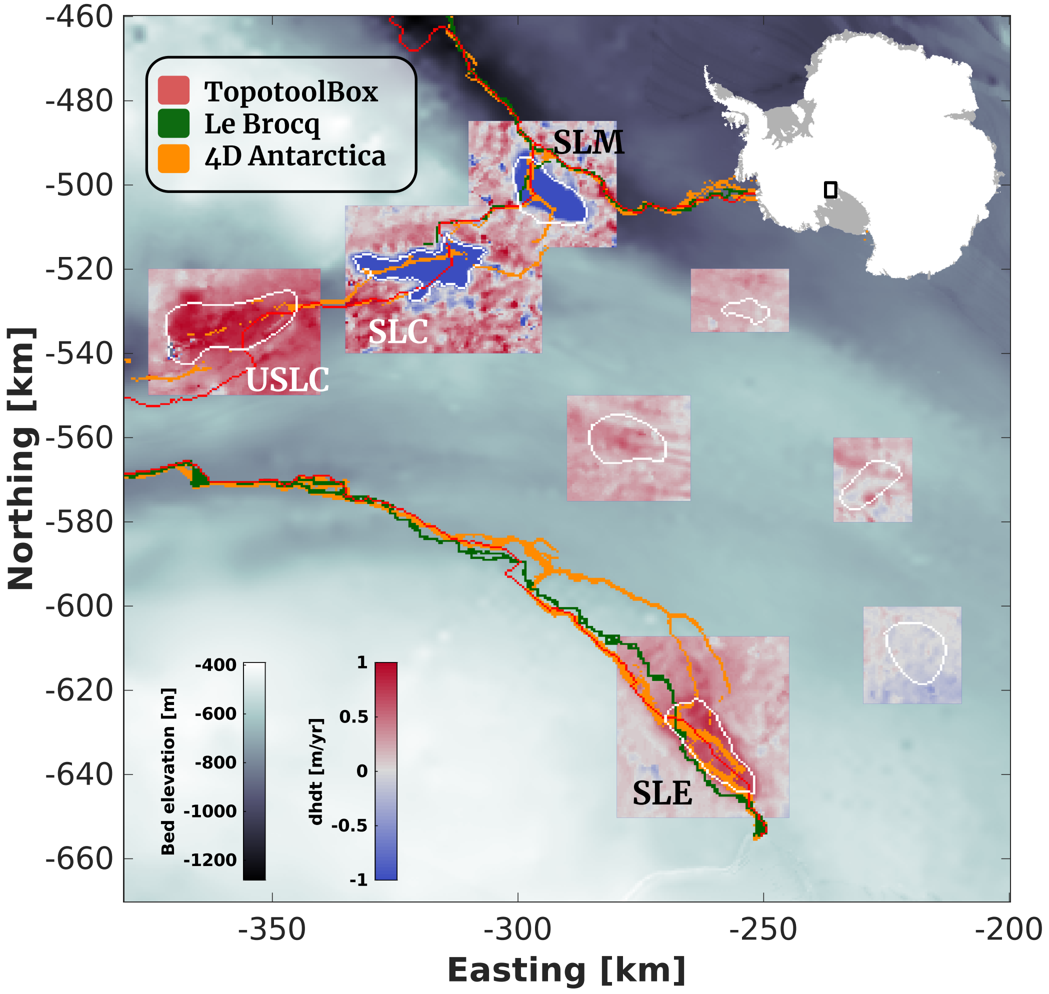
Melt Validated if $Flux_{in}$ ≈ sum of Volume Gain

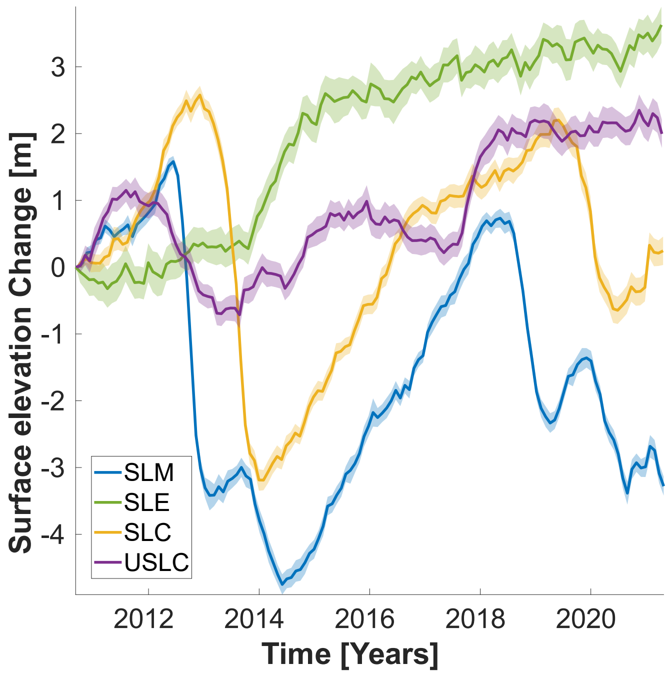


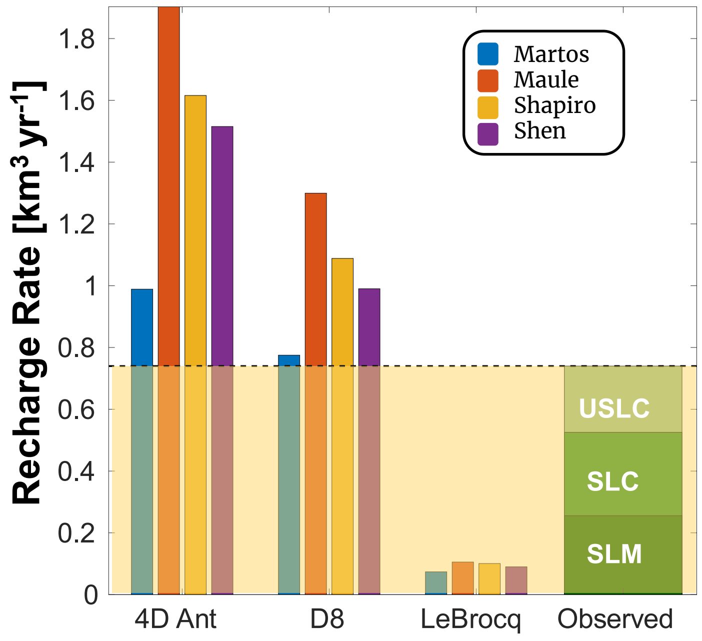
Results: Recharging Lakes



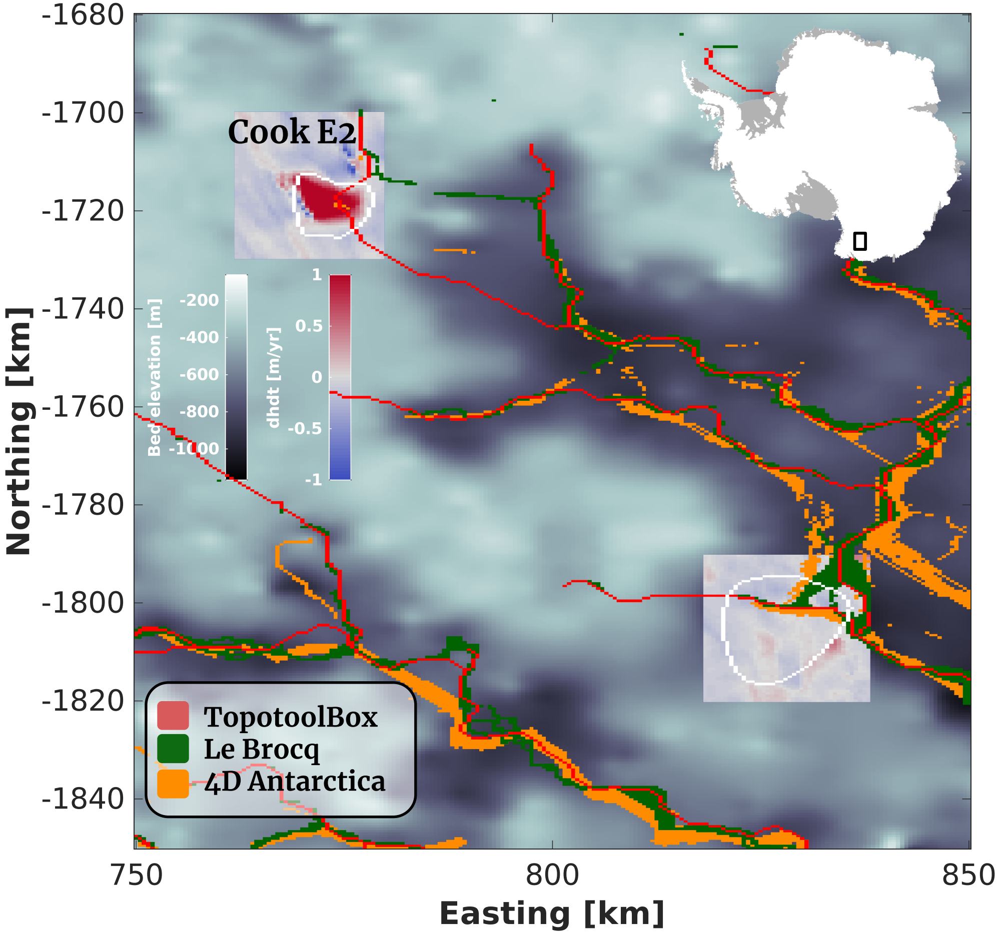
Case Study 1: Mercer & Whillians

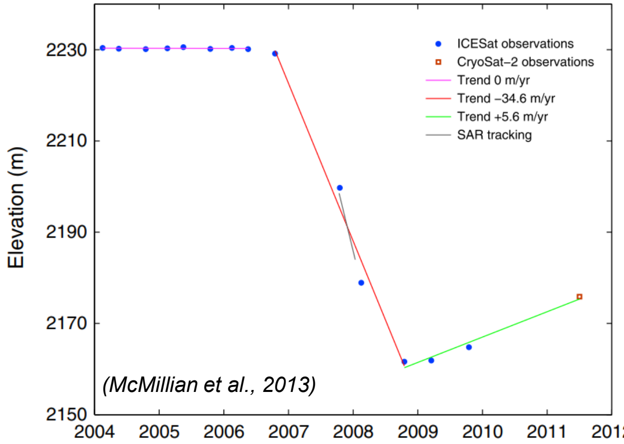


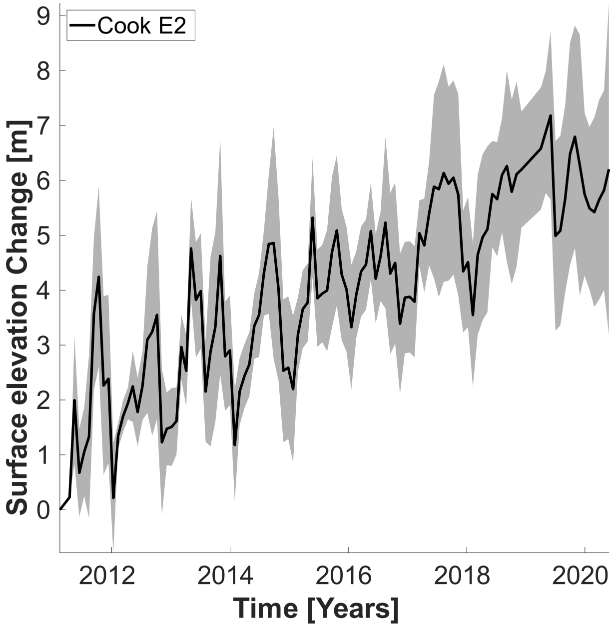


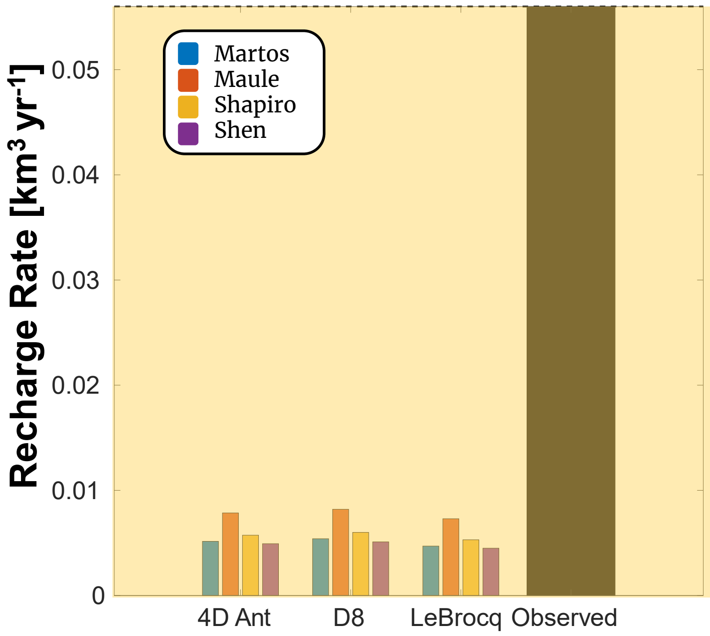


Case Study 2: Cook E2

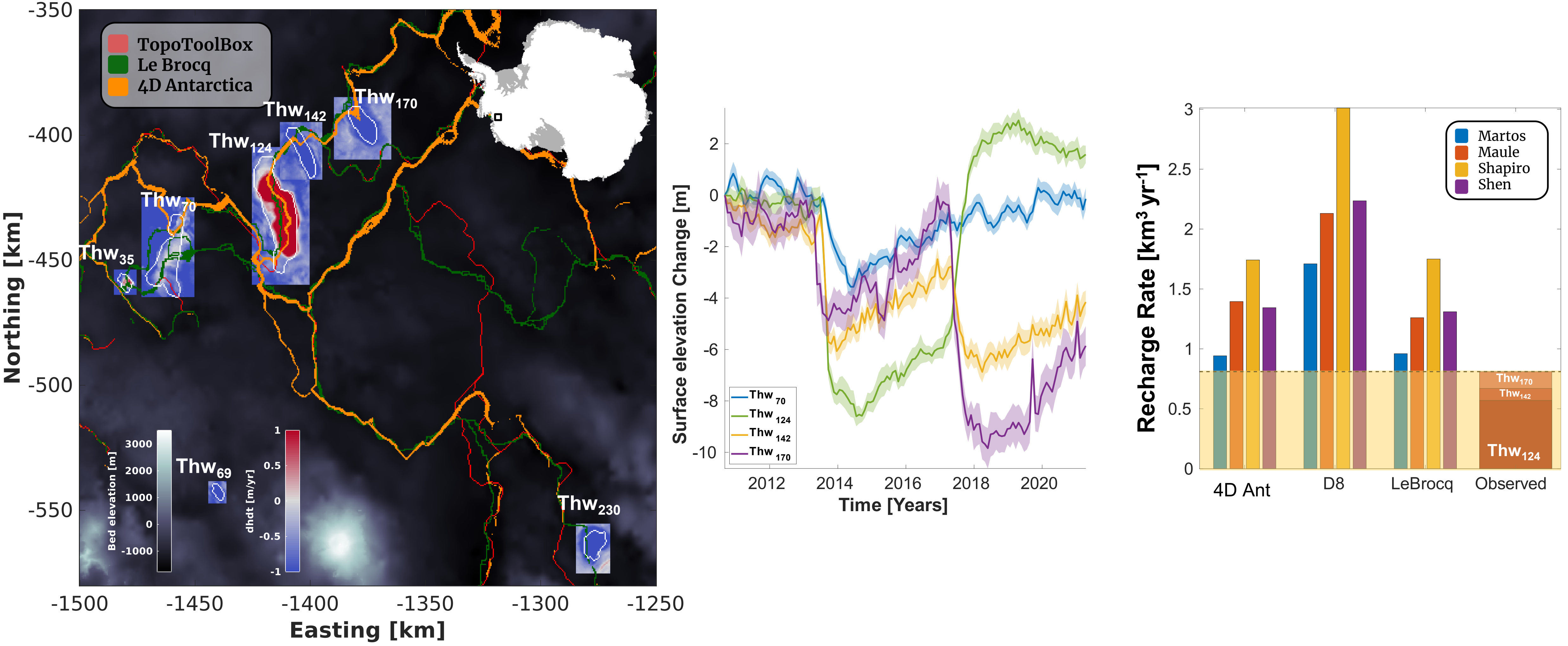




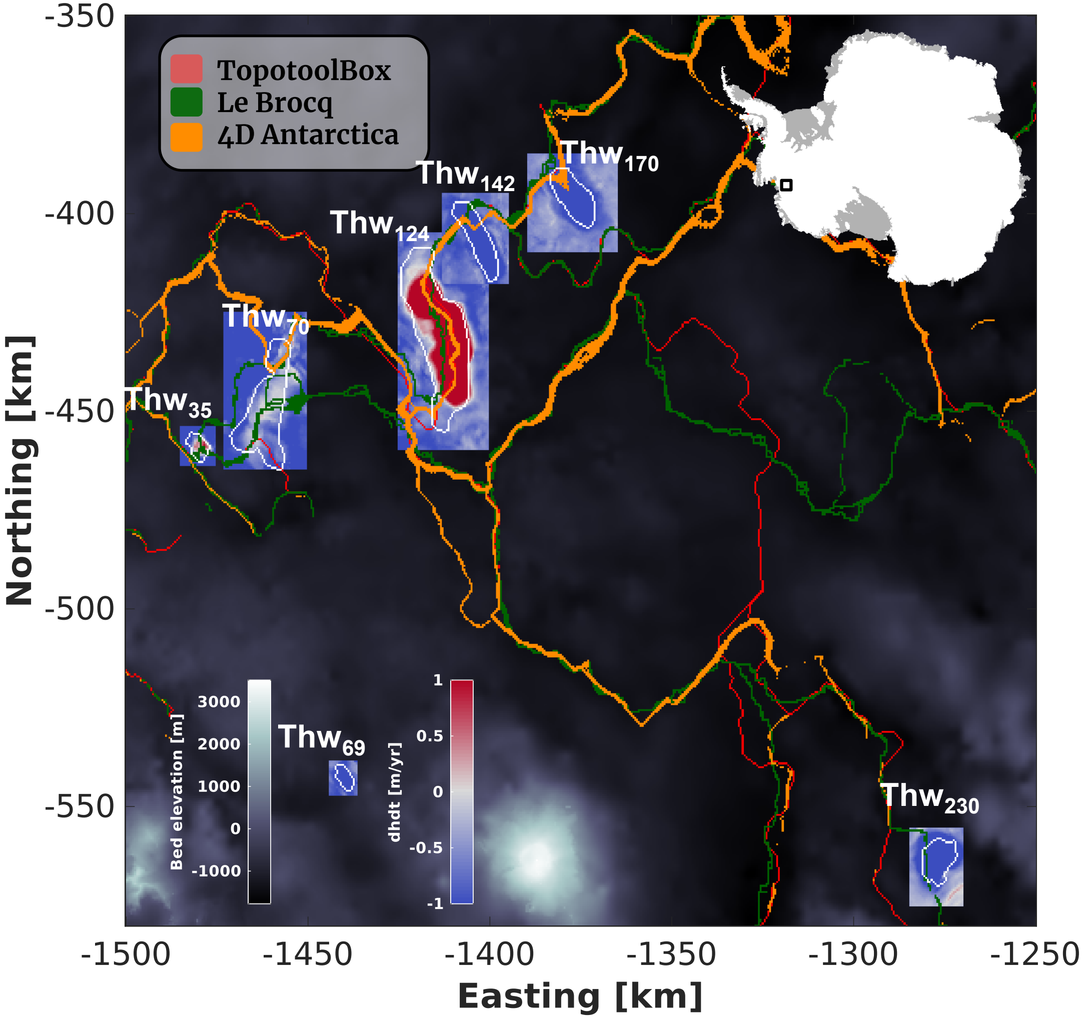


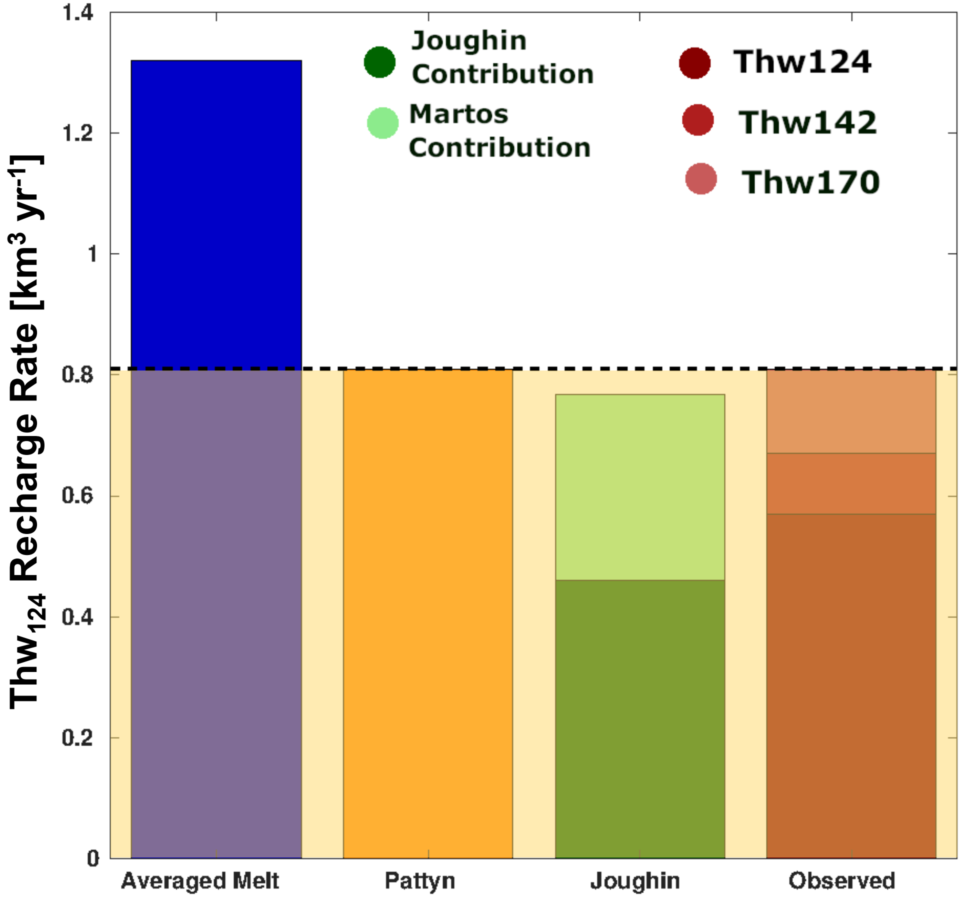


Case Study 3: Thwaites

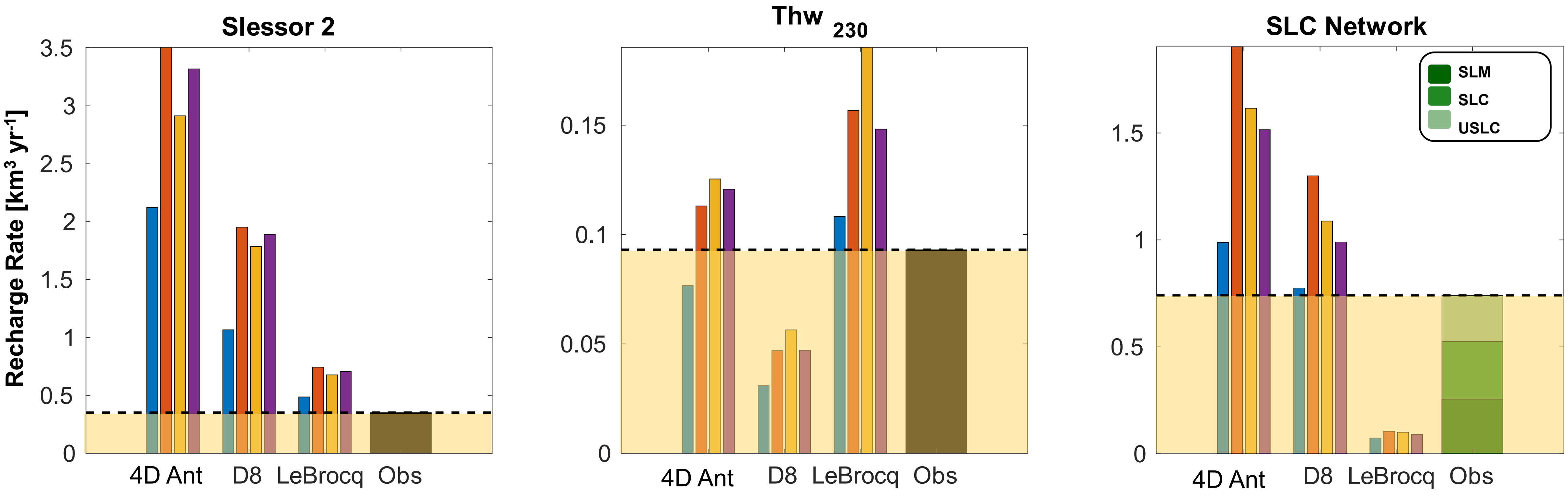


Results: Other melting products





Results: Global Recharge Rates



Conclusions

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- Developed a new **novel technique** for observing the behaviour of subglacial melting rates using remote sensing

- Modelled rates of recharge are able to account for those derived via altimetry, **effectively validating** all four of our melting estimates.

- **4D Antarctica Flow Model** appears to be the most robust routing approach.

- The only expectation is at **Cook E2**, where unknown processes are likely feeding the lakes uplift