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Antarctic firn thickness variations from multi-mission satellite altimetry and firn modelling

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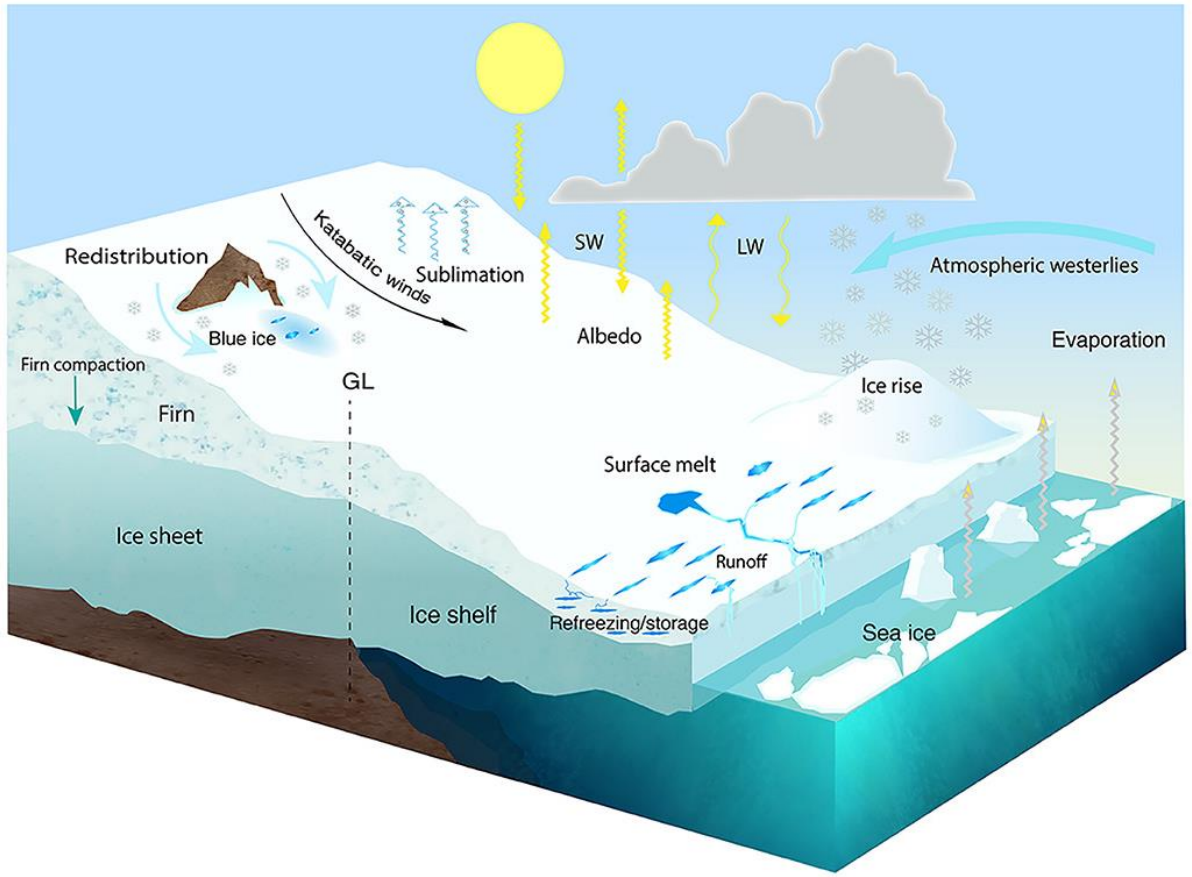
Firn thickness changes of the Antarctic Ice Sheet (AIS)

- occur due to surface mass balance (SMB) and firn processes
- vary strongly across various spatial and temporal scales

<u>Methods to study continent-wide firn thickness / elevation changes</u>

- firn modelling
- satellite altimetry



(Lenaerts et al., 2019)

Purpose of the study

Spatio-temporal characterisation and quantification of …

- **interannual signals:** firn thickness variations
  ⇒ required to isolate long-term trends in SMB and firn processes
  ⇒ by combining satellite altimetry and firn modelling
- **errors** in satellite altimetry and firn modelling

… at monthly and **grid-scale** (10 km x 10 km) resolution
⇒ spatial patterns required to identify the underlying processes (basin means not sufficient)

Data

Firn model: **IMAU**: Veldhuijsen et al. (2023)

Multi-mission satellite altimetry: **TUD**: Schröder et al. (2019) and **JPL**: Nilsson et al. (2022)
over the period 05-1992 to 12-2017

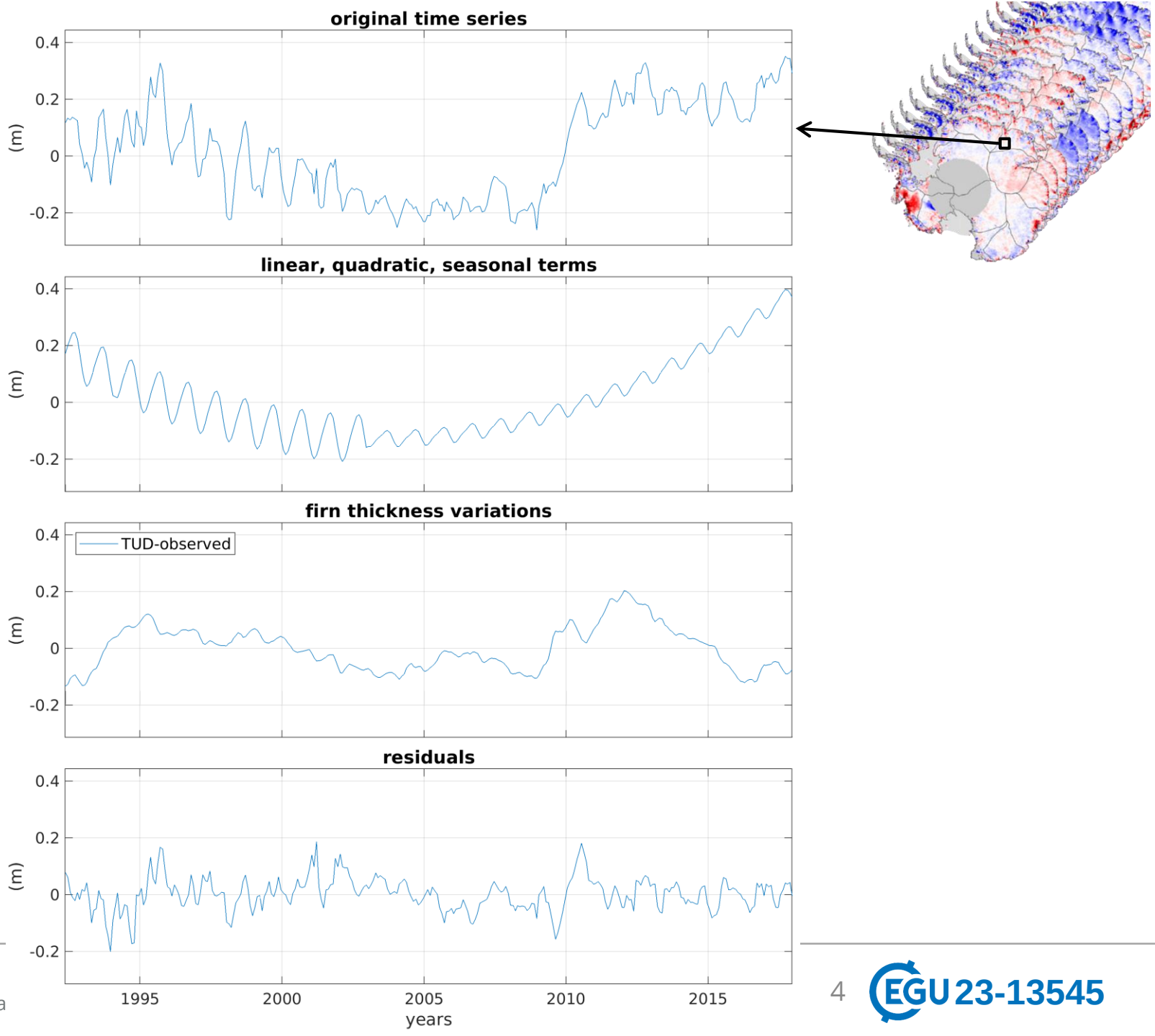
Method: regression approach

For each grid cell,

we fit to the time series of monthly elevation changes from altimetry,

- linear, quadratic and seasonal terms
- dominant temporal patterns in firn thickness variations derived from the IMAU firn model

  ⇒ sum of scaled temporal pattern: "**observed** firn thickness variations"



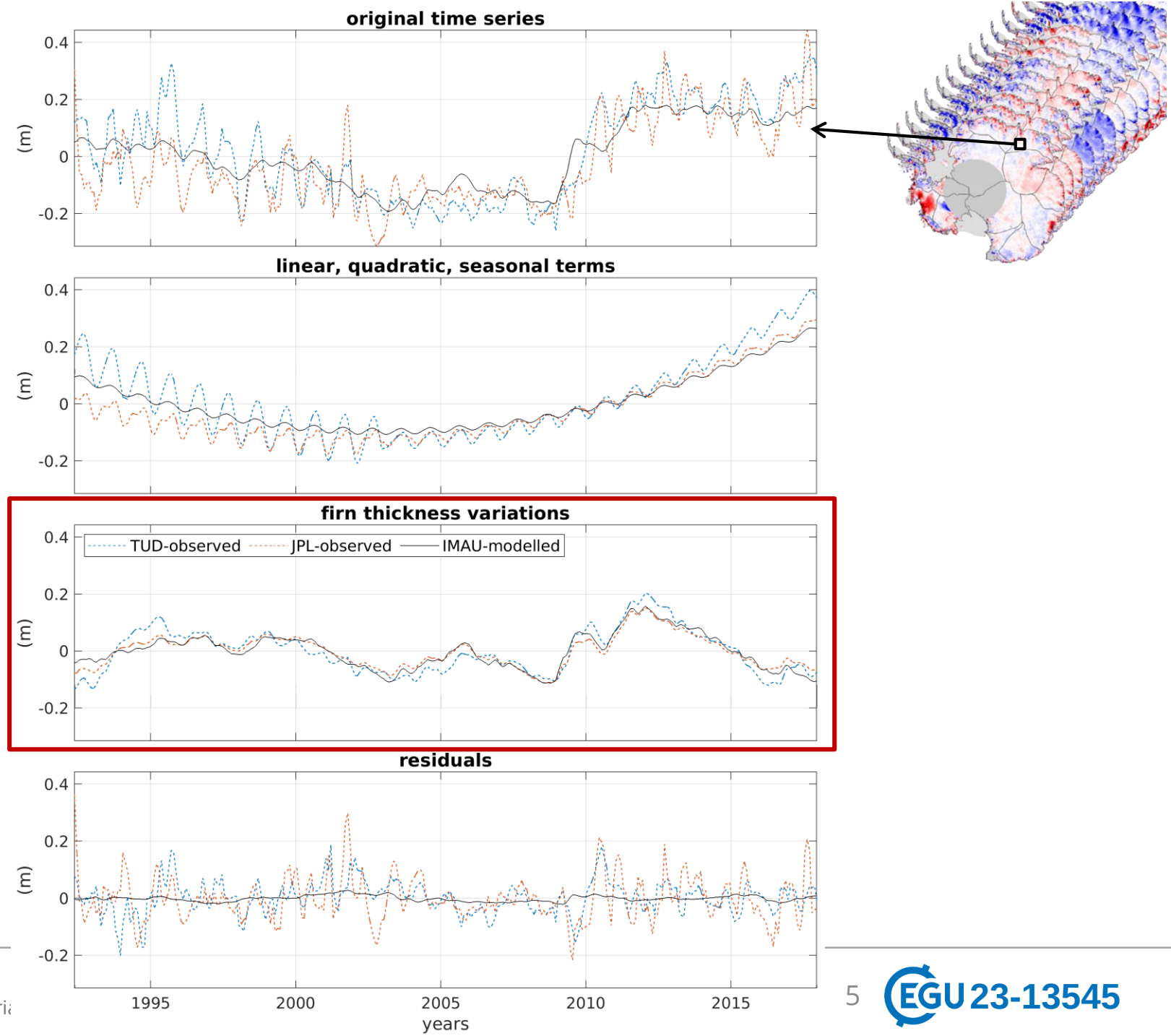
Method: regression approach

For each grid cell,

we fit to the time series of monthly elevation changes from altimetry,

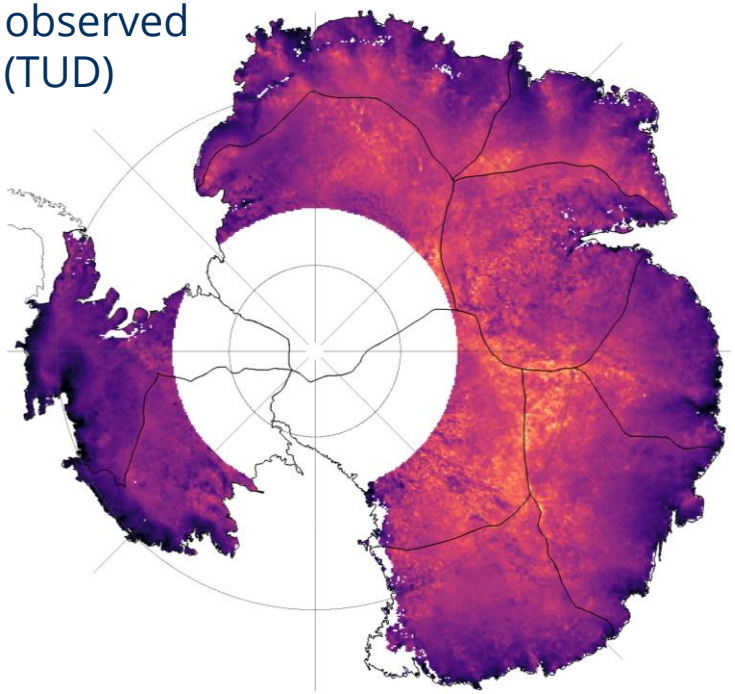
- linear, quadratic and seasonal terms
- dominant temporal patterns in firn thickness variations derived from the IMAU firn model

  ⇒ sum of scaled temporal pattern:
  "**observed** firn thickness variations"
  compared to
  "**modelled** firn thickness variations"

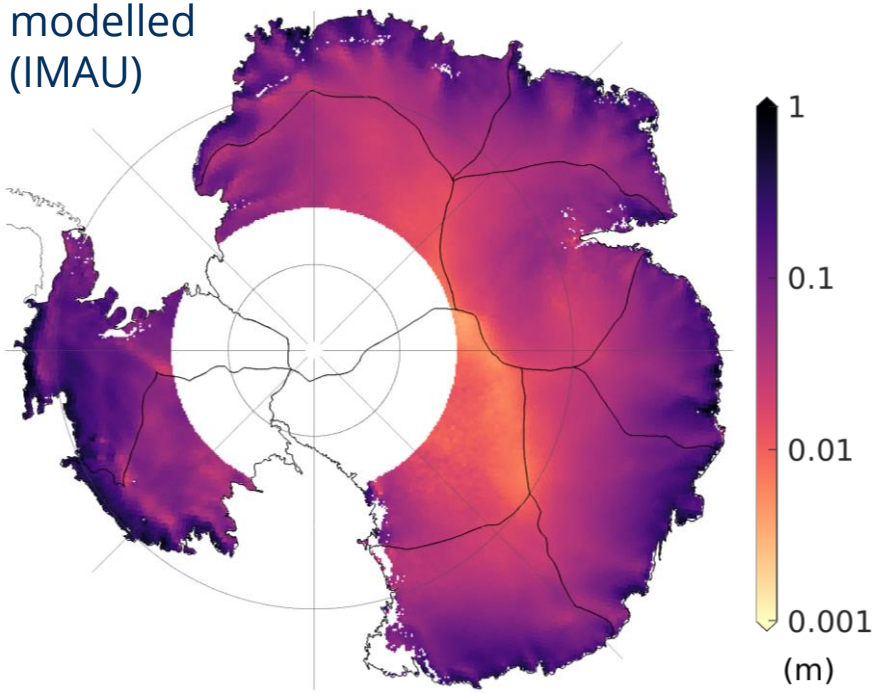


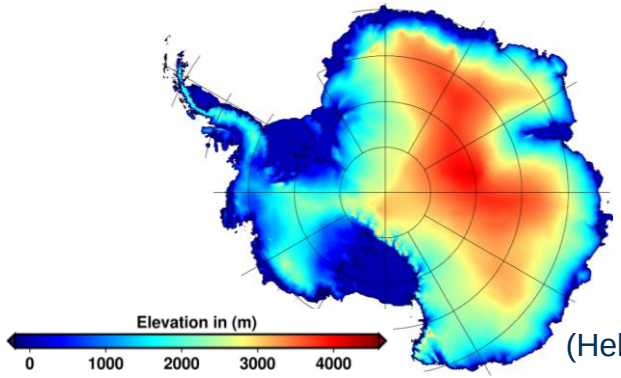
Results: root mean square (rms) of **firn thickness variations**

observed (TUD)



modelled (IMAU)

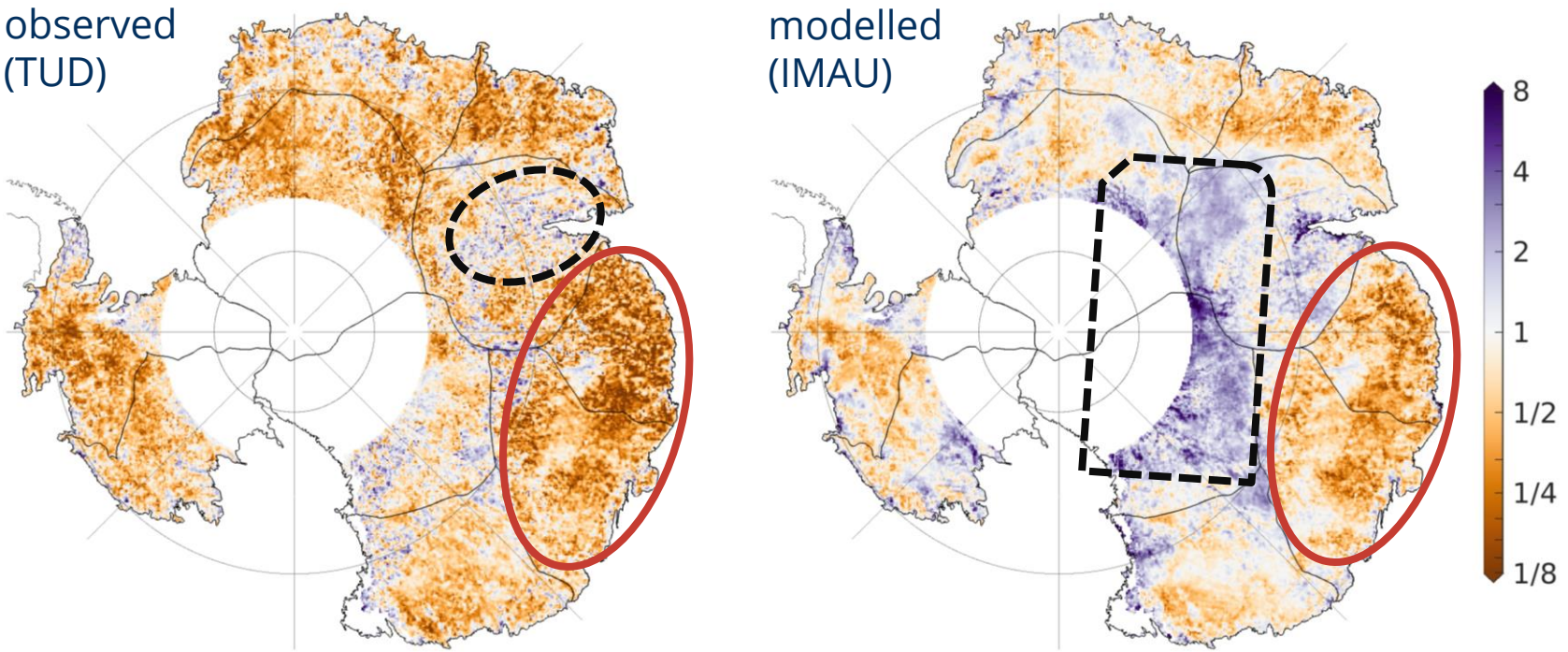




(Helm et al., 2014)

- largest magnitude at low elevations (mean rms values in the range of decimeters)
- smallest magnitude at high elevations (mean rms values in the range of centimeters)

Results: relative **uncertainties** of firn thickness variations



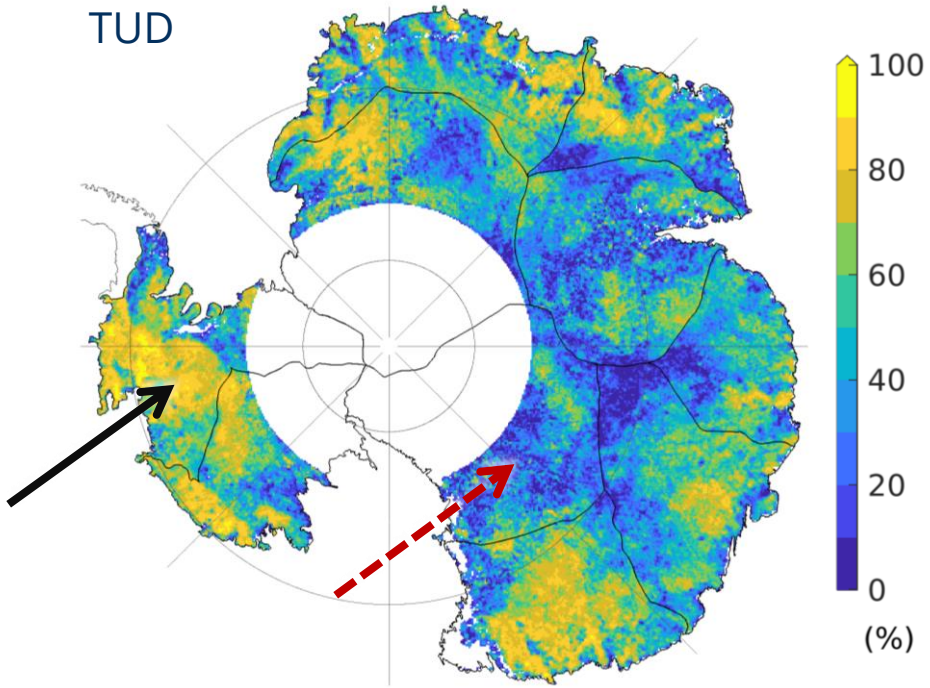
- particularly low relative uncertainties for Queen Mary Land and Wilkes Land
- difficulties e.g. at Amery Ice Shelf
- difficulties across the interior of the East AIS

Results: explained variance

*calculated over the period 2003–2017

mean over the AIS:
47%

range of basin means:
32% – 62%



- calculated for each grid cell individually
- averaged over selected areas afterwards

⇒ grid cells are considered equally

⇒ part of the altimetry variance is not yet explained

⇒ altimetry residuals are further investigated in the spatio-temporal and spectral domain

Summary

- new approach for **combining satellite altimetry and firn modelling** estimates at a **high temporal and spatial resolution**

- **observed firn thickness variations** explain only a part (about **47 %**) of the TUD altimetry data variance (*grid cells equally weighted)

- TUD **altimetry residuals** still contain real SMB and firn signals and altimetry errors

- **paper** in preparation