

What can the surface of Thwaites Glacier tell us about bed conditions?



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Introduction

Ice-sheet models require better constraints on bed topography and slipperiness, but there are limited high resolution observations of these bed conditions from Thwaites Glacier in West Antarctica. However, surface elevation (REMA, Howat et al., 2019) and velocity (ITS_LIVE, Gardner et al., 2019) are available across the whole glacier at 8 m and 120 m resolution respectively.

A linear perturbation theory developed by Gudmundsson (2003, 2008) relates the Fourier transform of bed conditions to the Fourier transform of surface conditions. Here, we use this theory in combination with the REMA and ITS_LIVE data to explore what the surface of Thwaites Glacier can tell us about conditions at the bed.

Results

Inverted bed conditions

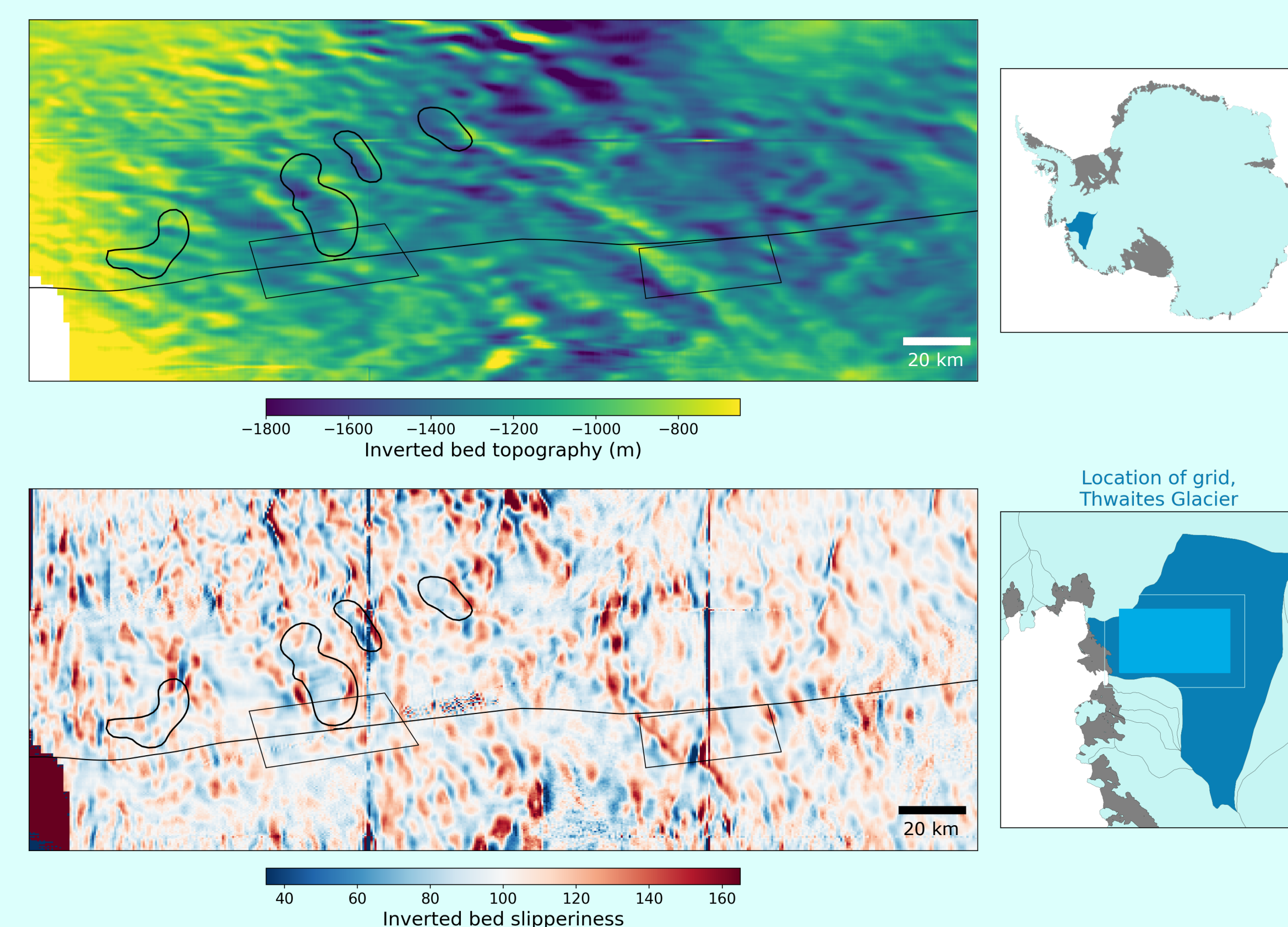


Figure 2: Inverted bed topography and slipperiness for a 160 by 280 km region of the main trunk of Thwaites Glacier. The black outlines are existing radar grids and subglacial lakes. The noisy lines along the slipperiness output are at 100 km spacing, and appear due to discontinuities in the REMA surface data where individual tiles join together. Bumps in the bed seem to display more variable bed slipperiness than smoother topographic lows, suggesting some geological control on slipperiness.

Comparison to radar data

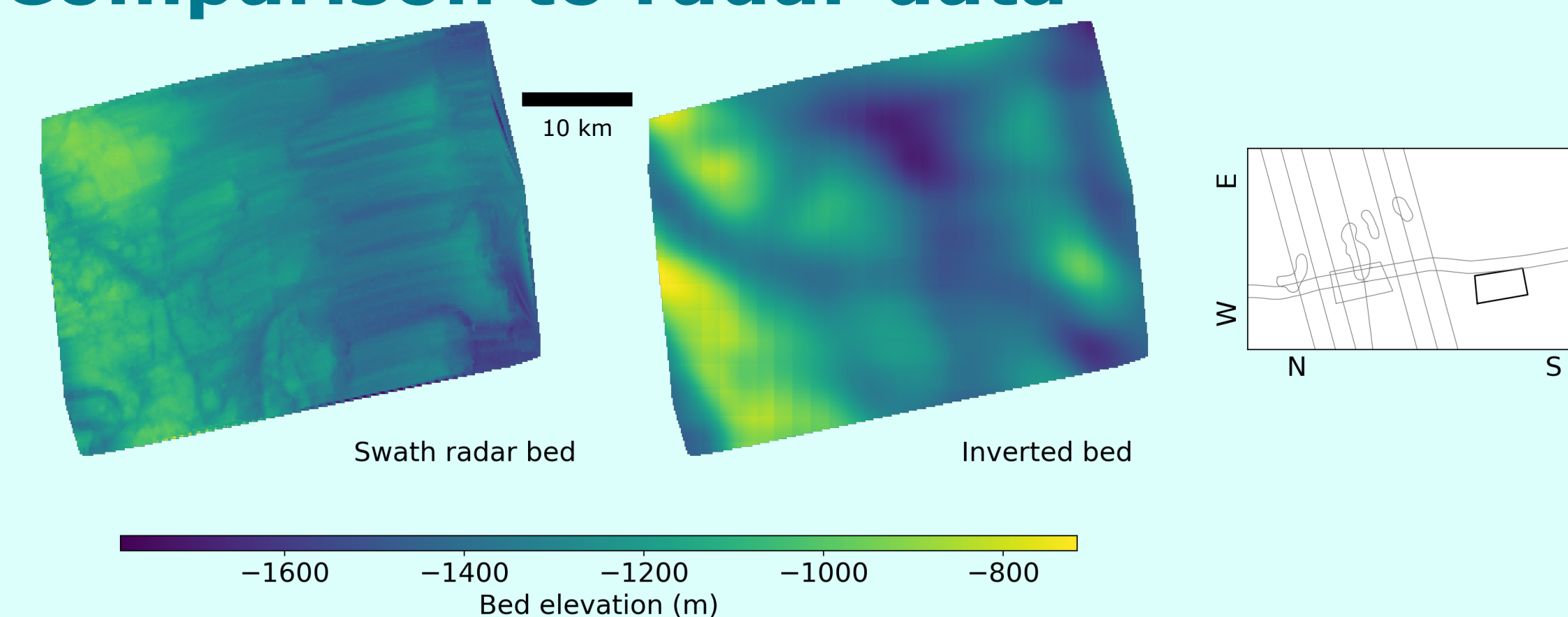


Figure 3: Comparison of the inverted bed with a swath radar surveyed bed (Holshuh et al., 2020) for the upper Thwaites region (20 by 40 km) suggests that the inversion is good at picking out the big shapes in the bed, but does not always get the amplitudes of landforms correct.

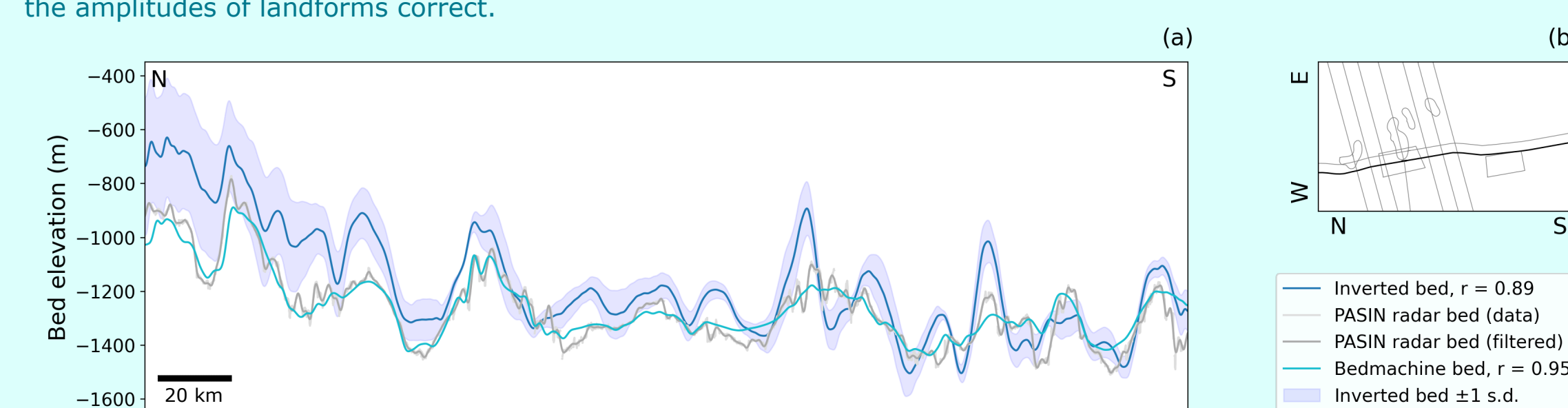


Figure 4: Comparison of the inverted bed with a PASIN radar flight line along the central flow line, and the bed profile from BedMachine Antarctica (Morlighem et al., 2019). Again this shows that the inversion is good at picking out the main features, but may exaggerate their amplitudes.

Future work

Extending to Full-Stokes transfer functions

The shallow-ice-stream transfer functions have poor resolution of small wavelength features. Gudmundsson (2003) gives a method for deriving a Stokes equivalent to these, and following this and then applying these Stokes transfer functions may allow better resolution of small wavelength features.

Including prior information from radar data in the inversion

Currently the inversion procedure does not involve any prior knowledge of the bed beneath the glacier, except a rough estimate of ice thickness. Including prior information about the bed from existing radar / seismic data would increase the reliability of the output, but this is complicated because point spatial information is difficult to represent in Fourier space.

Ice sheet modelling?

The impact of the bed topography and slipperiness presented here on the future of Thwaites Glacier could be explored in ice-sheet models, which may help to identify topographic features of importance as a focus for further work.

Methodology

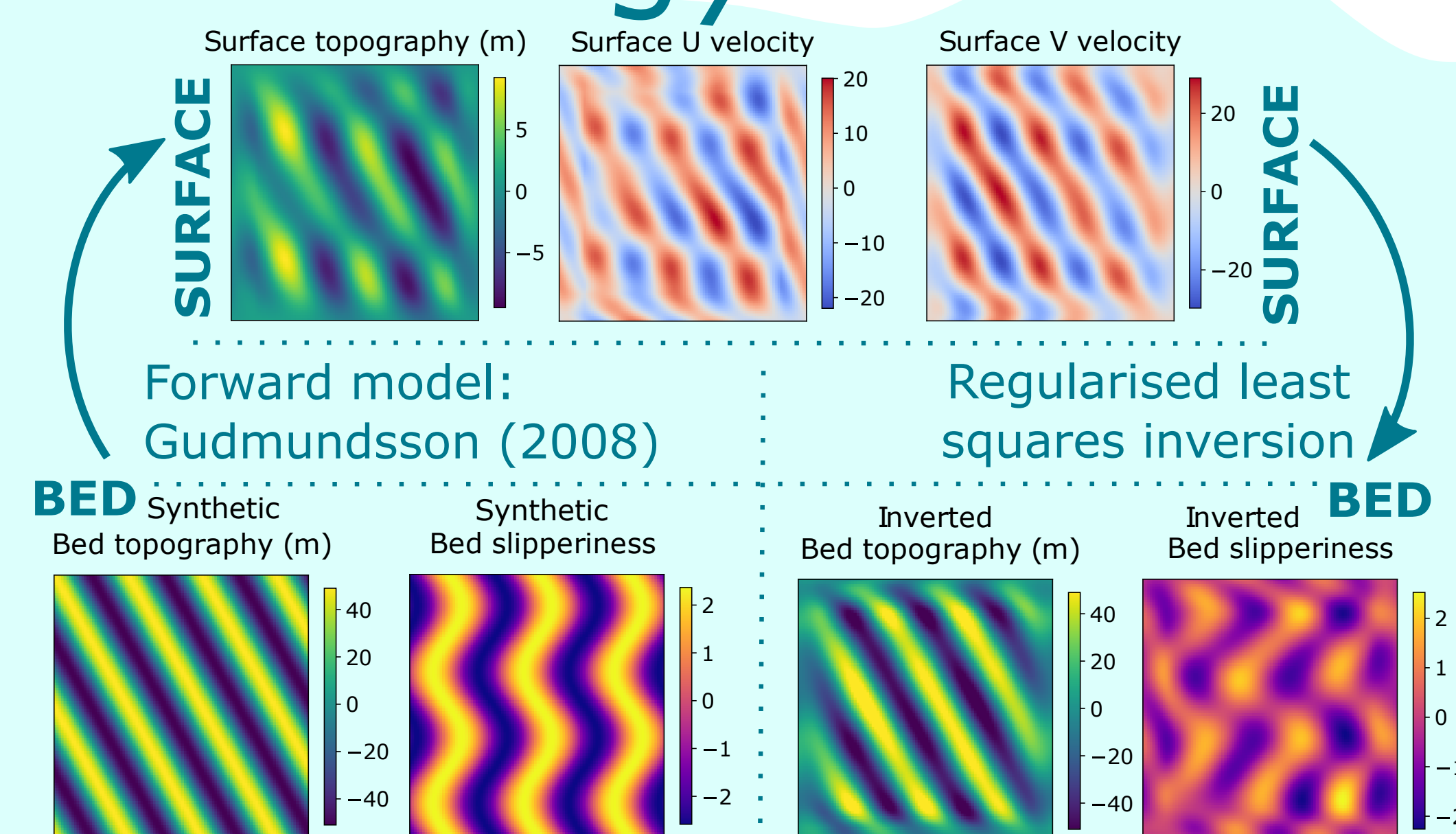


Figure 1: An example of an identical twin inversion, where bed topography and slipperiness are reconstructed using a regularised least squares inversion. Ice flow is from left to right. All values given are the difference from the mean for that variable (eg mean slipperiness).

Gudmundsson (2008) gives a set of transfer functions derived from the Shallow-Shelf Equations (MacAyeal, 1987) relating the Fourier spectrum of the bed conditions and surface conditions.

Synthetic tests (Fig. 1) for parameters thought to be applicable to Thwaites Glacier show that the inversion resolves landforms well if they are at an angle greater than 15° to the flow direction, a wavelength greater than 2000 m (the approximate ice thickness), or an amplitude of greater than 10 m (limited by the errors in the surface data).

References

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ITGC PASIN data acquired 2019/20, courtesy T. Jordan, British Antarctic Survey