Lessons learnt from the former bed of Thwaites Glacier: a new bathymetric dataset

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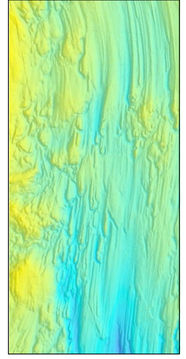


1. Summary

The bed of Thwaites Glacier (TG) provides a fundamental control on the stability of its marine-terminating margin. The sea-floor immediately offshore Thwaites Glacier (TG) represents the former bed of the glacier and can help us understand processes affecting ice flow over the bed, ice-shelf pinning after grounding line retreat, and, importantly, the topographic routing of warm water to the grounding zone.

Problem:
Surveying the extant bed of TG or the sub-ice shelf cavity is logistically difficult and expensive leading to low spatial coverage and/or coarse-resolution regional datasets of bed characteristics.

Goal:
Use newly acquired bathymetric data to characterise the morphology and composition of the former bed of TG to gain new insights into grounding-zone and ice-shelf processes that may contribute to the stability of the glacier.

Key findings (see Hogan et al. (2020) now online in The Cryosphere Discussions):
1. Immediately beyond the current ice shelf the sea-floor comprises a series of NE-SW trending sea-floor highs and a deep (>1200 m) trough; smaller troughs between the highs provide potential pathways to the grounding line.

2. Glacial landforms on sea-floor highs show that this area was a former grounding zone for TG and that they later acted as pinning points for Thwaites Ice Shelf. Some pinning points appear to be erodible material whereas others comprise "hard" bedrock.

3. Spectral analyses of sea-floor roughnesses, and calculations of basal drag, indicate that the area immediately offshore TG is comparable to the bed upstream of the present-day grounding zone.

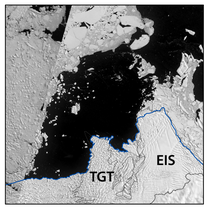
4. Comparisons with existing modelled/interpolated bathymetries show that the cross-sectional areas of sea-floor troughs have been underestimated by up to 40%. This has significant implications for the volume of warm-water accessing the grounding zone.

2. A new bathymetric dataset

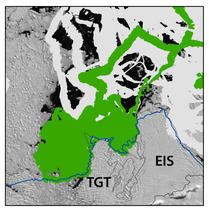
In 2019 - in exceptional ice-free conditions (A) - we acquired more than 2000 km² of new multi-beam bathymetric data (green in B) immediately offshore Thwaites Glacier.

All available data from the inner Amundsen Sea were compiled and gridded (C). These grids will be made available to the community as high-resolution (50 m) and medium-resolution (500 m) digital gridded products.

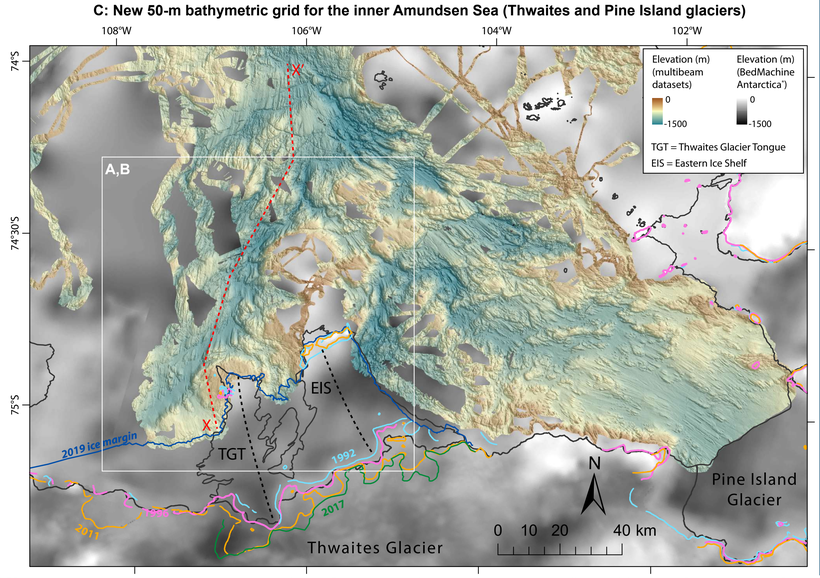
A: Landsat / MODIS imagery from 13 February 2019



B: Existing bathymetry data (grey) and 2019 data (green)



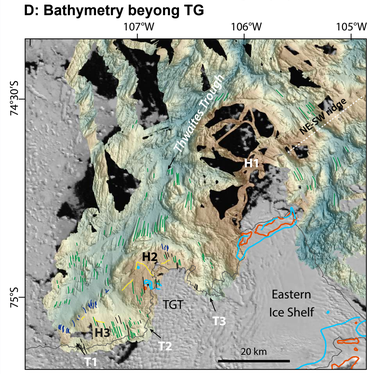
C: New 50-m bathymetric grid for the inner Amundsen Sea (Thwaites and Pine Island glaciers)



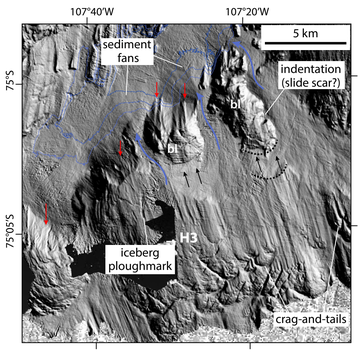
3. Sea-floor morphology and landform evidence

North of TG is a series of topographic highs (H1, H2, H3) trending NE-SW that are interrupted by troughs (T1, T2, T3). Beyond this is a deep (>1200 m), sinuous trough, here named *Thwaites Trough* (D).

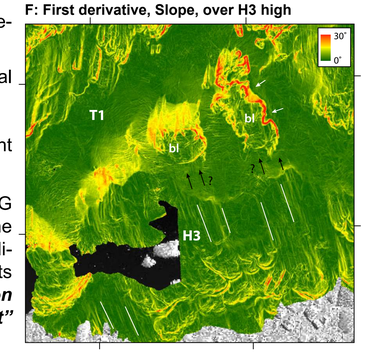
D: Bathymetry beyong TG



E: Sea-floor landforms over H3 high



F: First derivative, Slope, over H3 high



Sea-floor morphology and landforms (E, F) revealed in the bathymetric dataset include:

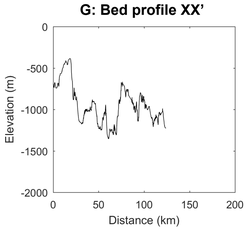
- Grounding-zone wedges and subglacial linear features on H2 and H3
- Remarkably flat-topped parts of highs
- Gullies on the front of highs and sediment fans down-slope

Interpretation: H2 and H3 - a former TG grounding zone - were later planed off by the action of an ice shelf. Unconsolidated sediments on, and in front of, the highs suggests they have been eroded. ***Does this erosion lead to premature ungrounding from "soft" pinning points?***

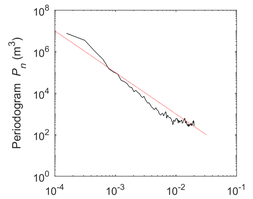
4. Bed roughnesses and basal drag

We use the power spectra of a range of bed profiles (e.g. G, J) together with the theoretical expression for "form drag" of Schoof (2002) to approximate the drag caused by bed undulations at different spatial frequencies:

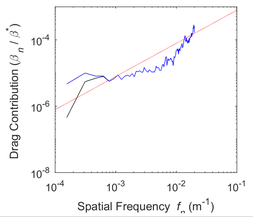
G: Bed profile XX'



H: Roughness power



I: Basal drag contribution

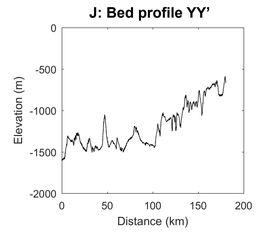


Results: The variance of roughness decreases with increasing spatial frequency (H, K), approximately following an inverse-power law (red line).

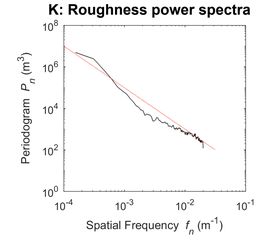
[For more information on derivations of basal drag see poster EGU-10035 in CR5.9.]

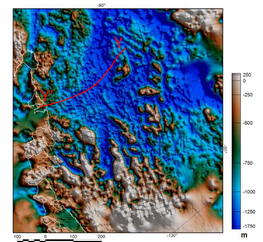
- The power-law approximation holds for bed profiles from the offshore area as well as for profiles from the extant bed of TG.
- Using the coefficient of the power law approximation (0.1 m) and a typical ice thickness of 1 km we find that undulations on scales smaller than λ = 150 m will result in significant vertical shear in the overlying ice.

J: Bed profile YY'

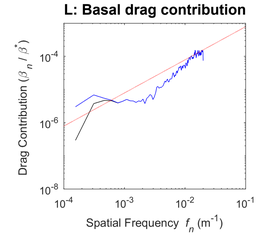


K: Roughness power spectra



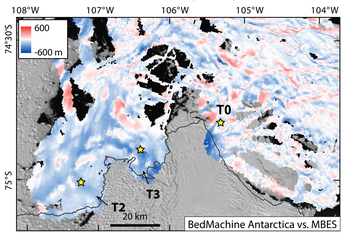


L: Basal drag contribution



5. Implications for warm water routing

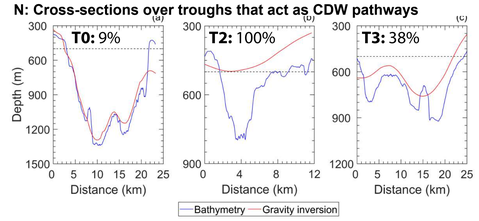
M: Difference map - BedMachine Antarcica minus bathymetry



Gravity-derived bathymetries underestimate the cross-sectional area of troughs below 500 m by up to 9-38%, where they are resolved (N).

High frequency (km to sub-km) bed undulations are not captured by modelled bathymetries but are important for accurately calculating warm water inflows via sea-floor troughs.

N: Cross-sections over troughs that act as CDW pathways



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