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A community vision for next-generation bed mapping in Antarctica

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Antarctic bed mapping underpins our understanding of ice-sheet stability, grounding-line retreat and future sea-level rise. Detailed geomorphological and geophysical knowledge, integrated with geological characteristics, reveals long-term processes such as erosion, sediment transport to the ocean and contributions to global geochemical cycles. Despite major advances in radar surveys, large regions of the Antarctic Ice Sheet remain poorly constrained. A side meeting held on 8 May 2025, immediately after the Royal Society's Theo Murphy Meeting on Next Generation Ice-sheet Bed Measurements, gathered international experts to identify priorities for advancing coordinated surveys, data integration and open infrastructure. These discussions, timely as the community prepares for the fifth International Polar Year (IPY5; 2032–2033), emphasized harmonized survey design, closer integration with modelling and remote-sensing communities, improved data standards and archiving, and implementation of emerging technologies such as swath radar, drone and artificial intelligence-assisted data interpretations. Together, they highlight both the urgency and the opportunity to build an internationally coherent framework for next-generation Antarctic bed measurements.

This article is part of the Theo Murphy meeting issue 'Next generation ice-sheet bed measurements'.

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1. Introduction

Mapping the Antarctic bed is foundational to multi-disciplinary science. The shape, roughness and hydrological properties of the bed govern ice dynamics and grounding-line stability. At the same time, bed mapping provides a geological and geophysical framework for understanding landscape evolution beneath the ice. It reveals patterns of past erosion, sediment pathways to the ocean and the redistribution of materials that influence global geochemical cycles. Integrating these insights with gravity, magnetic and seismic data helps connect present-day ice behaviour to the continent's long-term tectonic and sedimentary history, providing knowledge essential for improving predictions of future sea-level change.

The Royal Society's Theo Murphy Meeting Next Generation Ice-sheet Bed Measurements (Edinburgh, 6–7 May 2025) brought together leaders from radar, geophysical, modelling and remote-sensing communities to develop a shared perspective of the new frontiers of this field [1]. To follow up, the Antarctic RINGS Action Group of SCAR (Scientific Committee on Antarctic Research) co-organized a one-day side meeting (8 May 2025) with the Theo Murphy Meeting Organising Committee and the University of Edinburgh's School of GeoSciences.

This meeting focused on practical, logistical and conceptual pathways for future collaboration in Antarctic bed mapping. Discussions considered immediate actions needed to build foundations for the next Bedmap generation [2], to prepare for the upcoming fifth International Polar Year (IPY5, 2032–2033) and to sustain attention on longer-term goals.

The RINGS initiative emphasizes circum-Antarctic observations to fill data gaps near the current grounding line (primary ring), within tens of kilometres inland where future retreat may occur (landward ring), and over ice shelves, ice rises and sea ice where ships cannot easily survey seabed topography (seaward ring) [3]. However, the meeting also considered bed mapping elsewhere in Antarctica, including the ice-sheet interior. Integrating seabed mapping with land ice bed mapping is crucial, but it was beyond the scope of this meeting.

Meeting participants represented a wide range of expertise, career stages, genders and nationalities. This opinion piece provides a set of community priorities developed during breakout and plenary discussions to offer a snapshot of an evolving integrated perspective on how the community can sustain collective efforts in designing and executing surveys, and in compiling and sharing survey data to maximize the scientific value of the next-generation Antarctic bed mapping.

2. Community priorities emerging from the meeting discussions

(a) Survey design: defining priorities and strategies

Participants agreed that uneven data coverage remains a major scientific and logistical challenge [3]. Despite impressive progress over the six decades, major gaps persist in key dynamic regions such as Marie Byrd Land, Wilkes Subglacial Basin and Aurora Subglacial Basin ([4], in this volume). Inconsistent data density and quality constrain models of the ice sheet, subglacial hydrology and ice–ocean interaction, resulting in large uncertainties in sea-level projections.

To address this, three main survey contexts were identified: (i) no-data regions requiring initial reconnaissance mapping, (ii) regions with sparse or inconsistent data suitable for targeted infill or cross-validation, and (iii) regions for repeat surveys to detect temporal evolution of subglacial environments in the vicinity of grounding zones or satellite-detected active subglacial lakes. The vicinity of the grounding line has the highest scientific priority because once the land ice retreats, it is not possible to measure details of the bed topography using radar (as radio waves do not penetrate through seawater) and gravity inversions often used for bathymetry cannot deliver such levels of detail. It is an urgent need to map 'near-future seabed' before the grounding-line retreats.

Selecting among these three survey contexts requires balancing scientific importance, logistical feasibility and opportunities for multi-national coordination. Participants noted that prioritization should focus not only on where data are missing but also on where missing data most strongly limit predictive capability, such as the grounding line within each drainage basin and regions with higher vulnerability to change. The RINGS Action Group examined ISMIP6 projections of the 2100 grounding-line positions for this purpose [5] and mapped them together with the bed topography data used for generating the bed topography used for the ISMIP6 experiments (§4.6.2 in [3]). This analysis illustrates regions where large retreat is projected consistently by many models, where large discrepancies are present between models and where bed topography data are limited. The latter two infer lower confidence in the model results. It is crucial to carry out a similar analysis with ISMIP7 projections to 2300.

(b) Integrating topography data into modelling and satellite observations

Individual ice thickness (or bed elevation) observations are compiled as bed topography maps, which are used to constrain ice-flow modelling or to derive satellite-based products such as ice discharge from the Antarctic Ice Sheet. Bed topography compilation can be performed in many different ways and must be optimized for different purposes. Similarly, bed roughness depends on transect orientation (e.g. [6]) and thus survey design. Survey resolution and transect arrangement also affect the bed map products. This poses a challenge for modelling because individual surveys are usually designed for their own scientific questions and therefore may not be optimized to efficiently constrain the topographic properties that most strongly influence predictive uncertainty.

Actions proposed include (i) mapping spatial sensitivity of model parameters to guide field priorities and requirements (e.g. [7]), (ii) developing end-to-end uncertainty estimate frameworks from radar signal to model input (e.g. [8], described in §4.7 of [3]), (iii) using satellite time series (e.g. ICESat-2, InSAR) to identify dynamic regions requiring repeated radar surveys, (iv) inferring broad patterns of bed topography using ice-surface mapping (e.g. [9,10]), and (v) leveraging satellite missions to pinpoint 'bullseyes' for focused airborne campaigns (e.g. [11]).

Enhanced communication between modellers, satellite specialists and data producers would ensure that new bed datasets are directly relevant for predictive ice-sheet modelling and for satellite data use.

(c) Survey hardware, software and data processing

Participants identified fragmentation in radar systems, processing pipelines and metadata standards as a major barrier to interoperability. Calibration, filtering and reflector picking practices vary widely, complicating data integration. Many of these issues have been outlined, albeit with a focus on picking internal reflectors, in the recent review of the SCAR AntArchitecture Action Group [12].

Efforts such as Open Polar Radar (OPR)—an international initiative led by the University of Kansas's Centre for Remote Sensing and Integrated Systems—aim to consolidate polar radar software ecosystems and promote standardized, searchable datasets [13]. In parallel, the Bedmap Database offers a complementary approach to unify data pipelines from bed picks to integrated bed products [14].

The meeting discussed expressing radar signal-to-noise ratios as an uncertainty metric, standardizing metadata following FAIR (Findable, Accessible, Interoperable and Reusable) principles and transparent documenting via Bedmap3 metadata models [14]. Together, these measures would improve reproducibility from radar data to bed topography and cross-platform comparison.

Emerging technologies, including swath radar, Unmanned Aircraft Vehicles (UAVs) and artificial intelligence (AI)-assisted interpretation, promise transformative improvements, and their success depends on shared standards and interoperability.

(d) International logistics and operations

Surveying Antarctica remains constrained by logistics and cost. Participants discussed strategies to expand capacity, including (i) shared flight operations across national programmes, (ii) use of chartered or commercial platforms to fill gaps, (iii) development of long-range autonomous systems (UAVs, drones), and (iv) alternative funding models involving public–private partnerships.

While private logistics may offer flexibility, participants cautioned that public leadership is vital for sustained field capability. Coordination through SCAR and COMNAP (Council Of Managers of National Antarctic Programmes) could help match national assets to shared goals and promote efficiency in flight coordination including fuel allocation, remote camp operations, and emergency and contingency planning.

(e) Scientific co-benefits beyond bed topography

The community emphasized that bed surveys yield numerous co-benefits. For example, SCAR's AntArchitecture Action Group has compiled radar stratigraphy datasets in Antarctica, which can be used to delineate past and present ice dynamics, to infer bed topography where the bed is not well detected and to identify possible anomalous features of geothermal heat flow [12]. The operation of portable gravimeters and magnetometers has recently become a more routine part of aerogeophysical surveying. Also, non-geophysical instruments such as air samplers and high-resolution cameras can be operated while radar surveys are carried out.

A multi-purpose survey design can thus maximize scientific returns from expensive field campaigns. Examples include coherent, coordinated deployment of airborne surveys and *in situ* seismic surveys to characterize ice-shelf cavities, and subglacial sediments and water. Another example is an airborne radar survey that intersects ice core site(s), where radar reflectors are dated and used to derive long-term surface mass balance (e.g. [15]).

(f) Data flow, traceability and open archiving

Effective and transparent data flow from acquisition to public release is essential to fully understand the data product. Key recommendations were as follows: (i) preservation of full metadata for acquisition and processing, (ii) supporting open-source processing codes for reproducibility, (iii) use of absolute geospatial reference frames (bed elevation rather than thickness), (iv) implementing versioning for gridded products ('Bedmap 3.x' before 'Bedmap 4'), and (v) incentivizing data sharing via co-authorship and citation credit.

Participants envisioned a SCAR-hosted data portal providing mirrored archives and programmatic access. Automation of integration workflows ('auto-Bedmap' or Bedmachine products [16]) could enable continuous updates as new data arrive. A major obstacle to such automated workflows is consistency between the datasets. The Bedmap3 gridded product was made through iterative screening of data to avoid obvious artefacts [2]. This process should be revisited to develop a rigorous integrated dataset so that this screening process can be reproduced and tuned to provide various standard datasets for different purposes. Data science, including AI, is an emerging tool to fill geographical data gaps of relevant datasets, to quantify uncertainties in the bed products and to optimize survey planning.

3. Building an open, sustainable and global bed mapping framework

The meeting concluded with optimism and urgency to establish a decade-scale international programme, coordinated by SCAR, leading to the next IPY5 (2032–2033). This could serve as a unifying milestone to sustain community efforts to release future versions of Bedmap through more automated and transparent data pipelines like 'Bedmap-X'. Multi-disciplinary collaborations including geophysicists, modellers and satellite remote-sensing specialists are crucial to designing the most efficient survey plans. International coordination such as RINGS or 'RINGS Follow-on' is crucial to pool various resources for the best possible coordinated surveys.

Achieving this vision requires both technical and cultural advances. Key enablers include: (i) formalized coordination via SCAR and COMNAP, (ii) training and capacity building, particularly for early-career researchers, (iii) cross-sector partnerships linking public institutions, logistics providers and philanthropic actors, (iv) integration across radar, gravimetry, satellite and modelling communities, and (v) open, cloud-based data infrastructure to ensure accessibility and transparency.

4. Summary

The discussions underscored growing momentum towards a more coordinated, inclusive and open approach to Antarctic bed mapping. From technical collaboration to global governance, the community recognizes that no single national Antarctic programme can, or should, meet the challenge alone.

The next decade offers a unique opportunity to build a sustainable framework linking technology, logistics and collaboration. By working together, this worldwide community can deliver the data foundation required to understand and predict the Antarctic Ice Sheet's role in our changing planet. Ongoing survey efforts under RINGS provide a highly useful mechanism for this purpose. Lessons learnt through RINGS and other community efforts such as Bedmap and OPR should be best utilized through an international open network of various specialists. By embracing shared ownership of both data and vision, the Antarctic community can collectively chart the bed of Antarctica in ways that truly serve future generations.

Data accessibility. This article has no additional data.

Declaration of AI use. The authors used AI-assisted software to help draft and polish the manuscript based on meeting notes.

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