East Antarctica in a Changing Climate:

A Research Strategy for Continental Shelf Waters (2025–2039)

東南極と気候変動：

沿岸海洋・雪氷圏のための研究戦略（2025–2039）

AAPP Australian Antarctic Program Partnership

ACEAS Australian Centre for Excellence in Antarctic Science

Technical paper, November 2025

Vanderford Glacier, East Antarctica (photo: Pete Harmsen/AAD)

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Executive Summary

The East Antarctic continental shelf is the cornerstone of the Southern Ocean and Antarctic climate system yet remains one of the most poorly observed regions of the global ocean due to logistical challenges in sea ice cover, remoteness, and vastness. Changes on the East Antarctic shelf in response to a warming climate will have consequences for ice shelf-ocean-sea ice interaction, sea level rise, Antarctic Bottom Water formation, biological processes, and carbon cycling. Addressing these requires a dedicated, sustained and internationally coordinated observational effort (ship-based, autonomous, airborne, and satellite) tightly linked with modelling. Reliable projections of the future state of the Antarctic climate system depend heavily on new observations to constrain numerical models. As a follow-up to the recent Australia–Japan Workshop on Antarctic Science, this paper identifies research gaps in continental shelf waters and the coupled ice-ocean-atmosphere system of the East Antarctic sector, reviews current observation resources and ongoing research activities, and proposes a research strategy for the Fifth International Polar Year and beyond that aligns with international community initiatives. To achieve research capabilities agile enough to cover the rapidly changing system, further collaboration on our collective activities is highly welcome.

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統括的要約

東南極の沿岸海洋（大陸棚縁辺）は、南極の海洋-雪氷圏システムの要であるが、その海氷被覆・遠隔性・広大さに起因するアクセスの困難さにより、全球海洋の中でも依然として最も観測が乏しい海域となっている。温暖化する気候に対する東南極沿岸海洋の応答は、棚氷-海洋-海氷相互作用、全球海面上昇、南極底層水形成、海洋生態系、そして炭素循環に対して重大な影響を及ぼすものである。これらの課題に対処するためには、国際的に協調された専門的かつ継続的な観測プログラムを、船舶・自律型測器・航空機・衛星を活用して、モデリングと緊密に連携しながら実行することが不可欠である。南極の気候状態に関する将来予測の信頼性は、数値モデルを制約するための新たな観測データ取得に大きく依存する。先般の南極科学に関する日豪会合を踏まえ、本文書では、東南極の沿岸海洋および海洋-大気-雪氷圏結合系における未解決課題を特定し、現在の両国の観測リソースと進行中の研究活動を概観するとともに、国際研究コミュニティのイニシアチブと整合した第５回国際極年（IPY-5）およびそれ以降に向けた研究戦略を提案する。急速に変化するシステムを捉えるのに十分に機動的な観測研究能力を実現するため、これらの取り組みに対する更なる国際協力を大いに歓迎する。

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**The full list of participants can be found in Appendix A.*

1. Introduction

Processes and changes on the East Antarctic continental shelf have widespread consequences for the Earth's climate system. Here, any changes in the stability of the Antarctic Ice Sheet through ice mass loss; in the global ocean circulation through changes in heat, carbon and freshwater transport and storage; in the coverage and properties of sea ice; and in the Antarctic ecosystems through their role in the global carbon cycle are propagated to one another in ways we are only starting to fully comprehend.

The East Antarctic Ice Sheet (EAIS) holds a volume of ice grounded below sea level equivalent to 19 metres of global sea level rise, more than five times larger than the West Antarctic Ice Sheet (WAIS). This marine-grounded part of the EAIS is potentially vulnerable to changes in the surrounding ocean, which has enormous implications for coastal communities around the world. Dense water formed on the East Antarctic continental shelf ventilates the abyss and drives the deep cell of the overturning circulation, which dominates the transport and storage of heat, gas and nutrients in the global ocean. All marine life is ultimately supported by phytoplankton, so changes there will have consequences for Antarctic ecosystems and carbon cycling.

Despite its key role in the Earth's system, the East Antarctic continental shelf remains poorly observed and understood. Numerical models suffer from biases tied to poorly known boundary conditions (e.g., bathymetry) and inadequate representation of key physical processes. These gaps mean that we are unable to address urgent questions concerning the impacts of a warming climate on Antarctica and the consequences of changes on the continental shelf. These questions include:

- How much and how fast will East Antarctica contribute to global sea level rise?
- Will accelerating glacial melt and changing sea ice reduce the formation of Antarctic Bottom Water (AABW) and slow the deep overturning circulation, and what influence will this have on the global climate?
- How will Antarctic ecosystems and key biogeochemical processes respond to changing environmental conditions in this new icescape?

Internationally coordinated research efforts focusing on East Antarctica, tightly linked with modelling and across disciplines, are required to answer these questions.

This Research Strategy targets gaps in understanding of the East Antarctic continental shelf and slope waters that must be filled to address questions of critical importance to society. This strategy has been developed in meetings of Japanese and Australian scientists, aiming to strengthen their decades-long bilateral collaboration in East Antarctica. As such, its central focus is on their National Antarctic Programs.

However, the goal of this Research Strategy is to lay a foundation for a coordinated and comprehensive investigation of the East Antarctic continental shelf (20-170°E, following the Southern Ocean Observing System (SOOS) definition of the Southern Ocean Indian Sector (SOIS)), widely inviting nations with an interest in the region. We address the near term (the next five years or so) and the following decade, including the Fifth International Polar Year (IPY-5) in 2032/33.

2. State of Scientific Knowledge and Gaps

Here we present the current state of scientific knowledge on the key ice-ocean systems in East Antarctica, which are characterised by the distribution of ice shelves and coastal polynyas (Figure 1), followed by an assessment of the observational gaps. Table 1 summarises the regional observation coverage status on the East Antarctic continental shelf, where spatial data gaps are identified. Filling these gaps in observations and understanding requires an integrated research strategy as outlined here.

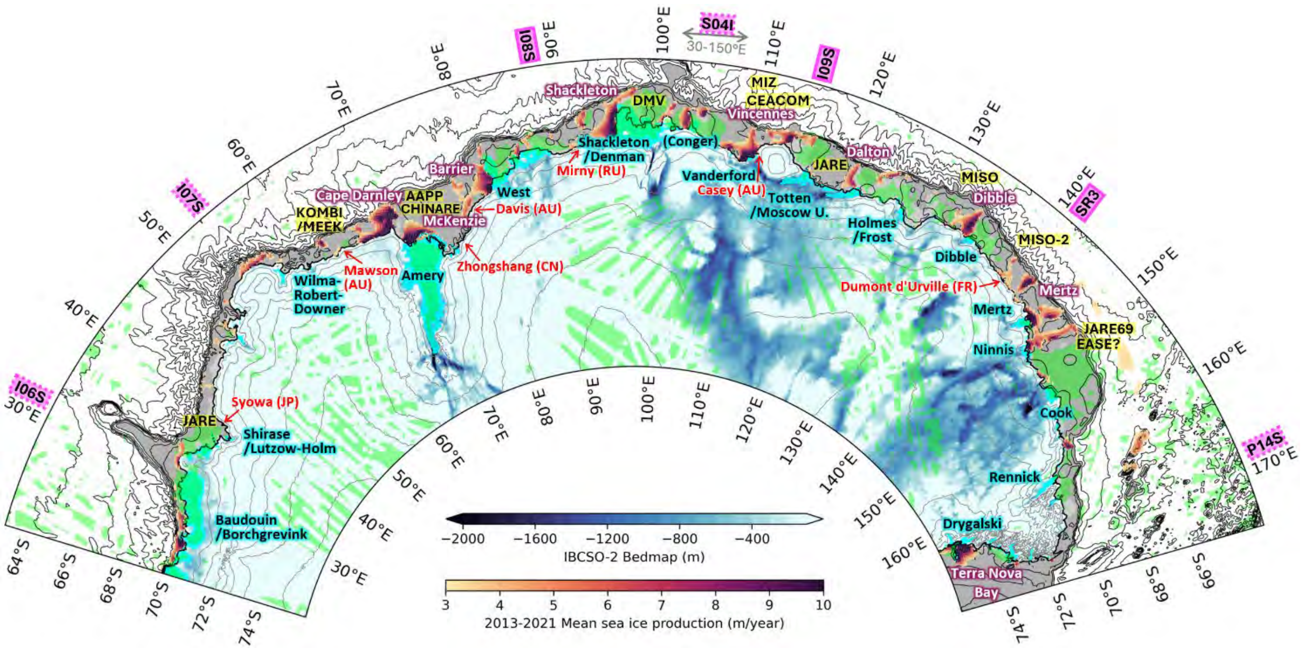

Figure 1. East Antarctic continental shelf and the key ice-ocean systems. Bathymetry is shown by black contours with 500 m intervals, where the grey area indicates the extent of continental shelf as shallower than 1,500 m. The IBCSO-2 subglacial topography and the 2013-2021 climatological annual mean sea ice production are shown by blue and red shading, respectively, where the key ice shelves and coastal polynyas are annotated. Green shaded areas indicate where the Bedmap-3 uncertainty exceeds 200 m, corresponding to the unmapped topography. Antarctic stations annually resupplied by icebreakers are annotated in red. Planned shelf campaigns before IPY-5 are highlighted in yellow (EASE is yet to be funded). GO-SHIP Core Lines are highlighted in pink, where lines yet to be supported by 2034 are indicated by dotted edge lines.

Table 1. Summary of regional observation coverage measures. The seven longitudinal sectors are based on the SOOS SOIS map and the key polynya-ice shelf systems. Primary Drivers are defined as the ice-ocean system components which make the location important. Bathymetric and hydrographic data status are assessed from **Poor** **Severe** to **Critical** based on both data coverage and climatic importance. The abbreviations for Primary Drivers are: mCDW (modified Circumpolar Deep Water), DSW (Dense Shelf Water). Known hazard for sea level rise (SLR) in each region is indicated under primary drivers).

Sector (Longitude)	Primary Drivers	Bathymetric Data Status	Oceanographic Data Status
1 (20°E–60°E): Roi Baudouin, Lüutzow-Holm Bay, Downer	mCDW Intrusion (Unknown for Baudouin)	Severe (mostly unmapped off Baudouin ice shelf)	Severe (near-total lack of winter data; access has been limited by fast ice)
2 (60°E–85°E): Cape Darnley, Amery, Prydz Bay	Polynyas, DSW Formation, Ice Shelf Meltwater, mCDW Intrusion	Poor (severe in Amery ice cavity)	Poor (severe lack of winter process data)
3 (85°E–100°E): West, Shackleton, Denman	Polynyas, mCDW Intrusion, Potential rapid and/or irreversible glacial retreat (**1.5 m of SLR**)	Severe (Denman shelf and ice cavity are largely unmapped; legacy data exist near West and Shackleton Ice Shelves)	Severe (a few research cruises in 2024/25)
4 (100°E–115°E): Conger, Vincennes Bay, Vanderford	mCDW Intrusion, Icescape Change, Potential rapid and/or irreversible glacial retreat	Poor (improving with gravity/seal data, but requires multi-beam survey)	Severe (sparse seal/ship data; limited time-series)
5 (115°E–130°E): Totten, Moscow University, Holmes	Deep mCDW Intrusion, Potential rapid and/or irreversible glacial retreat (**3.85 m of SLR**)	Poor (uncharted off Moscow University and Holmes Ice Shelves)	Severe (data poor and absent for Moscow University and Holmes Ice Shelves respectively)
6 (130°E–145°E): Dibble, Mertz	Polynyas, DSW Formation, Icescape Change	Poor (uncharted off Dibble Ice Shelf)	Poor (well-studied until the 2010s, but current observation is lacking)
7 (145°E–170°E): Ninnis, Cook, Rennick	Unknown (Potential rapid and/or irreversible glacial retreat; **3-4 m of SLR**)	Critical (almost entirely unmapped)	Critical (near-total absence of in-situ data)

2.1 System Knowledge Gaps

The following are critical unknowns in the ice-ocean system components (including processes modulated by the atmosphere), associated with the lack of observations to constrain models. Biogeochemical and ecological knowledge gaps are inserted into this structure so that they can be addressed concurrently.

- **Ice Shelf-Ocean-Sea Ice Interaction**: The vulnerability of the East Antarctic Ice Sheet to ocean heat is a primary unknown. The transport of heat across the continental shelf and into ice shelf cavities is poorly constrained because we do not know which of the physical gates—the slope and shelf topography or the ice shelf front—and the currents bounded to them is more important. The efficiency of ice shelf cavities in converting ocean heat into basal melting, governed by circulation and exchange dynamics, is poorly constrained for most ice shelves. Models are highly sensitive to the coastal bathymetry, which remains widely unmapped (Figure 1 and Table 1). Ice melt parameterisations used in nearly all ice sheet models are poorly constrained by the sparse direct measurements from under ice. Vulnerability of ice shelves to increased crevassing, hydro-fracture, calving, and large-scale ice disintegration, involving loss of protective sea ice (both pack and fast ice), needs to be addressed on a case-by-case basis—as does quantifying the role of coastal polynyas in modulating warm water intrusions into ice-shelf cavities. Deglaciation has important but yet unquantified implications for coastal ecological processes, through changes in underwater light, freshwater inputs, stratification, and iron supply.

- **AABW and Sea Ice Formation:** A lack of observations means that we cannot quantify the processes determining salinity on the continental shelf, which influences both AABW formation and basal melt. Potential risks for a critical feedback loop need to be addressed, where increased glacial meltwater freshens shelf waters to weaken AABW export and thin the abyssal layer, enabling more warm deep water to access the shelf and drive further melt. These factors have potentially important implications for biogeochemical cycles, e.g., through changes to the delivery of nutrients to support productivity and/or the perturbation of pelagic-benthic coupling, which transfers organic and inorganic carbon to depth. In winter, coastal polynyas inject vast volumes of dense brine and produce frazil ice, that can entrain ocean sediments and biogenic material into newly formed ice, but its initial nucleation, interaction with ambient seawater, and climatic and biological impacts are poorly understood. Ocean temperature and salinity dictate sea ice formation and its interaction with the ocean, but hydrographic data are severely limited in space and time (Table 1) and are summer-biased.

- **Shelf Circulation, Variability, and Connectivity:** The drivers of interannual variability in cross-shelf and along-shelf water exchange are poorly understood, making it difficult to interpret observations, initialise models and distinguish natural variability from forced trends. The dynamics of key features like the Antarctic Slope Current and coastal currents are not well-constrained due to the lack of velocity measurements as well as the uncharted topography. These currents can act as critical conduits or barriers for heat and freshwater transport, creating complex, non-local chain reactions downstream through discharging glacial meltwater, with implications for the ecosystem structure. Shelf circulation and mixing is mechanically driven by winds, surface cooling, meltwater inputs, tides, and ice collapse, but their relative roles and interactions (including those involving sea ice) are poorly understood. Fine-scale seawater property and velocity measurements to validate model parameters are also severely lacking.

- **Fast Ice-Iceberg-Pack Ice Interactions:** Icescape shaped by the distribution of fast ice, icebergs and pack ice is critical to the behaviour of recurrent coastal polynyas and thus to ice shelf-ocean dynamics. A key challenge is to better model these key icescape elements and interactions across the East Antarctic continental shelf (requiring high resolution) and to robustly predict likely changes and their regional and climatic impacts. Due to the uncertain bathymetry, which is critical to grounding of icebergs, and the lack of modelled ice shelf calving, models have not been able to simulate icescape dynamics realistically. Understanding drivers of the decline in multi-year fast ice and its impact on ice shelf dynamics is another key gap. While icebergs and coastal polynyas have been regarded as a source of nutrients, impacts of icescape dynamics on marine ecosystems are largely unknown.

2.2 Observational Gaps

Here we assess oceanography, bathymetry, ice shelf, and satellite measurements as a measure of observational gaps for continental shelf waters. The following gaps overarch the regional assessments provided in Table 1.

- **Shelf Oceanography:** Measurements of shelf water properties (temperature and salinity) and seawater velocities are very limited. Ship-based CTDs (including oxygen, nutrients and glacial meltwater) remain the 'gold standard' in oceanography, providing critical measurements for physical and biogeochemical analysis that no other platform can provide. Despite their importance, ship-based measurements (both CTDs and ADCPs) are heavily restricted to summer. Gliders significantly enhance the spatiotemporal coverage and resolution of ship-based measurements, but they are extremely scarce in East Antarctica. Autonomous ice-capable profiling floats operate year-round and provide CTD profiles, optionally with biogeochemical variables such as oxygen. However, to date their spatial coverage has been less systematic than ship-based CTDs. A similar situation exists with instrumented seals, which are more numerous, providing widespread shelf coverage but relatively lower-accuracy data. Continuous time-series of water properties and velocities can only be obtained from moorings, which have been deployed exclusively in key ice-ocean systems such as the Totten and Amery Ice Shelves. Ice-ocean and atmosphere-ocean fluxes in models and reanalysis products are poorly constrained by observation. Overall, there are severe observational gaps during winter, beneath the ice, and for most parameters other than temperature and salinity.

- **Shelf Bathymetry:** A majority of the East Antarctic continental shelf remains uncharted, with widespread bathymetric uncertainties exceeding 200 m (Figure 1). A critical lack of high-resolution, accurate multi-beam bathymetric measurements hinders our ability to model shelf circulation and ice-ocean interactions. There are ongoing efforts to estimate shelf bathymetry using seal dive depths and grounded Argo profiles and to extend coverage using satellite altimetry of icebergs. A substantial body of legacy geophysical data from the International Geophysical Year era remains undigitised, but it is expected that this data, particularly that collected by Soviet expeditions, will be integrated into forthcoming efforts. Some bathymetric gaps can be addressed using airborne measurements, which are less accurate but cover large areas efficiently. Gravity and expendable probe measurements have been conducted in some uncharted areas (e.g. through the ICECAP program), and these are expected to be utilised for future cruise plans.
- **Ice Shelf Measurements:** Direct measurements of ice shelf cavities (grounding lines, under-ice topography, water properties, circulation, and ice-ocean boundary layer) are notoriously difficult to obtain and therefore rare. Technologies such as autonomous underwater vehicles (AUVs), distributed optical fibre sensing and acoustically-geolocated floats and gliders need to be developed to measure the bathymetry, ice draft and ocean within ice-shelf cavities. On-ice instruments such as ApRES, sensors deployed through boreholes, and seismometer arrays are needed to address the vulnerability of ice shelves directly, but are not yet widely used. The East Antarctic grounding zones – the critical juncture between the ocean, grounded and floating land ice that controls the ice sheet response to ocean forcing – are among the most poorly surveyed in Antarctica. On average, only up to 50% of the grounding zone in the Aurora and Wilkes Subglacial Basins is within 5 km of existing survey data. Airborne gravity and radar surveys are essential for closing this gap.
- **Satellite Observations:** Satellites are essential for monitoring the East Antarctic continental shelf, particularly where in-situ measurements are limited. Passive microwave radiometers (e.g., AMSR2, SMOS, SMAP) provide daily fields of sea-ice concentration, drift, and sea-surface temperature through cloud cover and polar night. Radar altimetry missions such as Sentinel-6 and SWOT provide improved sea-surface height resolution, allowing better characterisation of mesoscale ocean circulation. However, key gaps persist. Sea-ice thickness products from SMOS and CryoSat-2 are subject to large and regionally variable uncertainties, especially where snow loading, surface roughness, and flooding complicate freeboard retrievals. Sea-surface salinity retrievals in cold waters have limited sensitivity, and persistent cloud and sea ice covers restrict the use of ocean-colour products for monitoring primary production. These gaps can be filled by targeted in-situ validation (e.g., ice type and thickness, snow depth, chlorophyll and particulate organic carbon), cross-sensor integration, and coupling with regional models.

3. Near-term (2025-2029) Plans and Strategy

Over the next 3-5 years, the level of resourcing in Australia and Japan is largely known. We first summarise current plans and then provide recommendations that would enhance the impact of planned work with little or no increase in resourcing.

3.1 Current Resources and Plans

Observations planned for the near-term period are shown in Figure 1.

Australia:

- **Vessels and Logistics:** RSV *Nuyina* (Polar Class 3+ icebreaker) and RV *Investigator*. Annual resupply to Mawson, Davis, and Casey Stations. Science time on RSV *Nuyina* presently alternates between 60 and 15 days per annum (i.e., 60 days every second year).
- **Planned Voyages:**
    - 2025/26: 4-week glider deployment off Casey (CSEACOM, RSV *Nuyina*).
    - 2026/27: repeat hydrography on GO-SHIP SR3 (140°E) and the continental slope featuring trace elements and isotopes, clouds and radiation, and biology (MISO-2, RV *Investigator*). To the east of the East Antarctic sector, GO-SHIP P15S (170°W) is revisited (P-TROPO, *RV Investigator*).
    - 2027/28 (or 2028/29): winter-spring Marginal Ice Zone (MIZ) voyage (RSV *Nuyina*) – to be confirmed.
    - 2029/30 or later: East Australian Sector Experiment (EASE) is a proposed voyage to the continental shelf near Cook Ice Shelf, not yet funded (RSV *Nuyina*) – to be confirmed.
    - **Notably, Australia has no ship-based oceanography voyages planned for the continental shelf in the next 5 years.**
- **Other observations:**
    - Up to 6 profiling floats per annum deployed on the shelf (supported by AAPP and IMOS).
    - Biological moorings off Mawson will provide bottom CTD and ADCP data over the continental slope, with plans to recover and redeploy each year (KOMBI/MEEK).
    - 3 physical/biogeochemical moorings off Denman-Shackleton Ice Shelves deployed in 2025, for recovery in 2026/27 (Denman Marine Voyage).
    - AAPP physical/biogeochemical mooring in Prydz Bay will provide hydrography, ADCP and organic carbon export (in collaboration with CHINARE).
    - 20 IMOS-funded seal tags (CTD loggers) per annum deployed from Kerguelen islands on sub-adult males targeting East Antarctic shelf forage areas (in collaboration with France).
    - Support for other instruments measuring ocean currents (e.g., Current Pressure Inverted Echo Sounders and EM-APEX floats) is being sought.

Japan (JARE):

- **Vessels and Logistics:** *Shirase* (Polar Class 2 icebreaker) resupplies Syowa Station every year. RV *Umitaka-maru* visits the East Antarctic continental margin every year but will be retired from JARE work post-2028. A next-generation *Shirase* is planned to launch in 2034.
- **Planned Voyages:**
    - During the 6-year JARE Phase X (2022-2027), *Shirase*'s annual CTD and mooring work at Totten will continue. Two marine science voyages are planned during JARE Phases X (2024/25 and 2025/26).

- RV *Umitaka-maru*'s last Antarctic occupation in 2028 is planned for the continental slope off the Cook/Ninnis region.
- JARE Phase XI (2028-2032) will feature the slope current, eddies, sea ice extremes, as well as ice-ocean interaction. The long-term Totten moorings will continue through Phase XI. Two marine science voyages are proposed during Phase XI (specific years of voyages to be confirmed).

3.2 Near-term Research Strategy

Collaboration is central to enhancing the scientific impact of the planned voyages described in 3.1. Collaboration will enhance the scientific outcomes with little additional resourcing, in part through improved coordination of activities described below with our international partners.

- **Sustain moorings** in the key ice-ocean systems (e.g., Totten, Denman, and Amery ice shelves) through international coordination and collaboration.
- **Sustain and enhance the array of profiling floats on the continental shelf**.
- **Operate underway instruments** (e.g., ADCPs and underway sampling of pCO_2) **in every cruise.**
- **Fill observational gaps of bathymetry with multi-beam echosounder in every cruise.**
- **Glider deployments** to resolve key ocean-ice-atmosphere-biosphere processes.
- **Glacial meltwater measurements** (e.g., stable oxygen isotope ratio, chlorophyll *a,* organic carbon, dissolved inorganic carbon) to link the ice-ocean system with biogeochemistry and to assess regional impact on marine productivity.
- **Airborne gravity and expendable probes** to address the critical bathymetry and hydrography gaps in areas that are hard to reach with ships alone. Airborne radar to survey grounded bed topography along the grounding zone and within regions where the grounding zone is likely to retreat over the coming decades.
- **Coordinate plans** with international partners, including through Antarctica InSync.

4. Future (2030-2039) Opportunities and Strategy

Here we present a vision for research strategy for IPY-5 and beyond (2030-2039). IPY-5 offers an opportunity to address the most urgent global challenges through substantial advances in polar research.

4.1 Need for Enhanced Observations

The continental shelf of East Antarctica is a 'blind spot' in the global ocean observing system. Notable advances have been made in recent years. Highlights include the sustained Japanese research effort near Totten Glacier, demonstration that profiling floats are an effective tool for sampling continental shelf waters by Australian scientists, broad-scale sampling of the shelf region by instrumented seals, deployment of radar instruments to measure basal melt, aircraft measurements of bathymetry near key ice shelves, and advances in numerical modelling of ice sheets and their interaction with the ocean and atmosphere. However, as the rate at which environmental changes are emerging is much faster than our current knowledge creation, transformative research efforts are essential. Without a substantial increase in support for observations and modelling of East Antarctica, the key Antarctic system knowledge gaps posed above will remain unanswered.

4.2 Vision for 2030 – 2039

Potential IPY-5 Flagship Projects on the East Antarctic continental shelf:

- **Upscaled shelf profiling float array:** A fully implemented array of profiling floats on the continental shelf is one of the most cost-efficient, agile and impactful investments that could be made for observing the continental shelf, as demonstrated by recent achievements made by Australia and other countries. The target is to maintain 50 profiling floats between 20-170°E (i.e., one float per three degrees of longitude, consistent with the Argo program design). This requires **deploying about 17 floats per annum** given a 3-year nominal float lifetime. For better understanding of shelf biogeochemistry and biology, a proportion of the floats should be equipped with oxygen sensors. Biogeochemical and bio-optical floats, substantially more expensive though expected to significantly enhance biogeochemistry data coverage, are envisioned as an ambitious program. The optimal array for shelf floats (including the number, deployment location and strategy, and sensor packages) is being considered by the Polar Argo Mission Team and will be guided by numerical simulations. This is a game-changing program that will enable the year-round state of the East Antarctica's continental shelf to be observed and monitored.

- **Integrated marine-terrestrial observations of the Wilkes Subglacial Basin**: The Wilkes Subglacial Basin, represented by the Cook and Ninnis Glacier systems, holds a volume of marine-grounded (hence potentially vulnerable) ice equivalent to 3-4 m of global sea level rise. The region has lost ice and contributed to sea level rise in past warm climates. In simulations of a warming climate, this region has significant accelerations in ice sheet mass loss between 2100 and 2200. However, the vulnerability of the region to future warming has been extremely difficult to assess due to the near-total absence of observations (Table 1). **We envision a multi-disciplinary, multi-national, multi-vessel effort to address this gap.** The experiment will involve multiple ships making oceanographic and multi-beam bathymetry observations on the continental shelf; radar, seismic and borehole measurements of the ice sheet and ice shelf, supported by aircraft or traverse; acoustically-tracked autonomous floats and gliders; airborne geophysics and deployment of oceanographic sensors; and a well-integrated hierarchy of modelling efforts. Given the scope and complexity of the proposed research, early commitments of ship time and resources are required to build the coalition of willing Antarctic research nations needed to realise this vision.
- **Winter cruises**: Dedicated multi-disciplinary winter-time cruises are essential to observe extremely under-sampled seasonal processes, such as polynya dynamics, frazil ice formation, warm water intrusions, air-sea fluxes, atmospheric, biogeochemical, and ecosystem processes. A good candidate is to revisit the Mertz Polynya during winter for the first time since Australia's last winter cruise in 1998. With a multi-vessel international effort like MOSAiC (i.e., overwintering with a ship tethered to sea ice) and RSV *Nuyina*'s significant research capabilities, winter cruises will bring groundbreaking science with proper preparation for extreme cold (e.g., measures to prevent sensors from freezing).

Elements Enabling Flagship Projects:

- **Ship time:** Additional ship time is required to fill gaps in observations of the East Antarctic continental shelf. Securing more dedicated marine science time from *Nuyina* is crucial to fully leverage its cutting-edge research capability. JAMSTEC's new PC4 research icebreaker *Mirai II*, currently assigned to the Arctic, will potentially be available for IPY-5 and beyond. Another possibility is University of Tokyo's RV *Hakuho-maru*, which has visited East Antarctica opportunistically.
- **Japan-Australia logistics collaboration**: We should continue to explore opportunities to collaborate on logistics related to marine research (e.g., assistance with deployment or recovery of instruments), to the benefit of both national programs. Further, it is desirable to expand cooperation to on-station resupply logistics to realise coordinated research programs.
- **Technologies for under-ice observations:** Technology for under-ice observations is developing rapidly. While requiring significant infrastructure investments, instruments such as AUVs, acoustically guided gliders and floats, moorings capable of telemetering data, ice-tethered profilers/systems and

distributed optical fibre sensing will play a role in future observations of the East Antarctic continental shelf.

Long-term Research Strategy:

- **Expanding ongoing research programs**: Australia and Japan have filled critical gaps in observations (both marine and terrestrial) and modelling in East Antarctica—notably in the Totten region, one of the largest contributors to future sea level rise (Table 1). However, we do not yet understand what regulates the ice shelf exposure to warm ocean waters capable of driving rapid basal melt. Building on Japan's ongoing and sustained commitments in the Totten region, we envision an expanded internationally collaborative effort, focused not only on logistics but also on research strategy, to address this gap. Enhancements could include additional floats and glider deployments in the area, moorings in key locations, radar and seismic measurements on ice shelves, and airborne geophysics and oceanographic measurements. These enhancements should be extended to other key systems, such as the Denman, Amery, and Vanderford ice shelves, where Australian-led programs are currently ongoing.
- **Observation-modelling coordination:** It is critical to coordinate observations and modelling, linking observation planning, data interpretation and model development into a comprehensive framework. A further coordination between modelling and observation (including satellites) is expected to be achieved via Consortium for Ocean-Sea Ice Modelling in Australia (COSIMA), the ACCESS-NRI with its model development and international initiatives such as RECOIL: a project led by the IAPSO/IACS Joint Commission on Ice-Ocean Interactions, which develops protocols to standardise the measurement of ocean-driven ice shelf melt and to reconcile melt estimates across observational platforms and with models capable of data assimilation. Ultimately, development and implementation of data assimilation of ice shelf, sea ice, and ocean observations into simulations, will provide the most accurate state estimates and forecasts as well as informing the design of optimal observing systems.
- **Alignment with community initiatives**: Observation and modelling efforts should align with national and international priorities. The SOOS Science and Implementation Plan emphasises significant data gaps remaining in observations of the ice-affected ocean, sea ice habitats, the ocean at depths >2000 m, the air-ocean-ice interface, biogeochemical and biological variables, and for seasons other than summer. The Australian Antarctic Decadal Strategy 2025–2035 and the Decadal Strategy of the Australian Academy of Sciences' National Committee for Earth System Science emphasise the importance of targeted observations in supporting the development and integration of process-based models into coupled ice sheet–climate models for robust projections of climate change and sea level rise due to Antarctic ice loss.

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Appendix A: List of Attendees

- **Organising Team:** Kaihe Yamazaki, Annie Foppert, Steve Rintoul, Nathan Bindoff
- **Domestic Invitees:** Abigail Smith, Adele Morrison, Alex Fraser, Amelie Meyer, Andrew Einhorn, Ariaan Purich, Beatriz Pena-Molino, Ben Galton-Fenzi, Benoit Legresy, David Gwyther, Edward Doddridge, Elizabeth Shadwick, Esmee Van Wijk, Felicity McCormack, Hannah Dawson, Helen Phillips, Jason Roberts, James Wyatt, Klaus Meiners, Laura Herraiz-Borreguero, Lenneke Jong, Maxim Nikurashin, Ole Rieke, Pat Wongpan, Paul Spence, Rob Massom, Sarah Thompson, Sophie Bestley, Sue Cook, Tobias Stål, Will Hobbs
- **International Invitees:** Kohei Mizobata, Daisuke Hirano, Shigeru Aoki, Toru Hirawake, Kay Ohshima, Sohey Nihashi, Svenja Halfter

Appendix B: Background and Scope

- 5th Australia–Japan Workshop on Antarctic Science in Tokyo, July 2025 (more info and Communiqué)
- UTAS Workshop on East Antarctic Shelf Waters in Hobart, October 2025