ACEAS

Australian Centre for Excellence in Antarctic Science

A Special Research Initative of the Australian Research Council

# REVISED PROPOSAL

## Background

This revision of the proposal was required to a take account of the amount awarded by the Australian Research Council (ARC). The budget in the application was based on $56 million of ARC cash plus $14 million of Universities cash contributions: a total of $70 million over seven years. The revised budget is based on a $20 million ARC cash grant plus $5 million of Universities' cash contributions: a total of $25 million scaled back to a term of four years commencing in early 2022.

There are presently significant additional uncertainties over the availability and timing of Antarctic and Southern Ocean logistical support for expeditions over the term of the grant. Plans and budgeted expenditure related to expeditions in this revised proposal have been made based on the best currently available information. Estimated funds for logistical and other expedition-related costs have been placed in a strategic reserve to facilitate future adjustments which are likely to be needed to account for any changes in the circumstances, in particular the provision, timing and costs of logistical support. Budget uncertainty exists also around expenditure items such as data and sample analysis following fieldwork and funds for such expenses have been included in the strategic reserve.

## The Centre

The overarching goal of the Centre is to prepare humanity for future climate-change risks from East Antarctica and the Southern Ocean by forging new knowledge of complex, interconnected processes and transforming predictive capability. The work will span modelling, and field and satellite observations, with a goal of reliably projecting the future of the coupled ocean-atmosphere-ice-ecosystem-solid Earth system and communicating this to stakeholders in industry and government. The Centre will develop a new generation of early career researchers trained in science, policy, governance, and law, and work toward achieving gender balance in Antarctic sciences.

The Centre is funded to operate, initially, over 4 years from early 2022.

## Participants

The Centre comprises the University of Tasmania (UTAS), in partnership with the Australian National University (ANU), the University of New South Wales (UNSW), University of Canberra (U Canberra), Curtin University (Curtin U), the University of South Australia (UniSA), The University of Melbourne (U Melb) and The University of Western Australia (UWA), and collaboration with 32 other leading national and international research institutions and Universities (See Appendix A).

## Programs

The Centre's program of research was revised to accommodate the funding awarded and a reduced duration, and to reflect possible changes to logistics and fieldwork plans. The Centre's major field work —

two marine science voyages, an on-shore field season, and seal tagging at Macquarie Island — are dependent on the support of the Australian Antarctic Division (AAD). Australia's new research icebreaker, RSV *Nuyina*, arrived in Hobart in October 2021. Given that it is a new and complex scientific platform there will be a substantial period of commissioning required by the AAD. This work, taken together with the normal uncertainties of Antarctic logistics around weather, ice conditions and other operational issues, may mean that the timing and scope of field work that is factored into AAD's logistics plans in coming seasons may need to be reviewed and adjusted.

**Program 1 (P1) – Circum Antarctic and East Antarctic**

*Program Leaders*: Anya Reading, Alex Sen Gupta, David Antoine

*Other Contributing CIs*: Alan Aitken, Leanne Armand, Nathan Bindoff, Julia Blanchard, Philip Boyd, John Church, Richard Coleman, Matt England, Jacqui Halpin, Laurie Menviel, Adele Morrison, Taryn Noble, Helen Phillips, Anya Reading, Eelco Rohling, Kate Selway, Paul Spence, Peter Strutton, Paul Tregoning, Christopher Watson, Jo Whittaker, Jan Zika

*Contributing PIs*: Shigeru Aoki, Wenju Cai, Hervé Claustre, Scott Doney, Tamsin Edwards, Helen Fricker, Sarah Gille, Karsten Gohl, Stephen Griffies, Bernd Kulessa, Amaelle Landais, Anders Levermann, Naomi Levine, Adrian Luckman, Mark Moore, Alberto Naveira Garabato, Terence O'Kane, Stephen Rintoul, James Risbey, Jason Roberts, Jean-Baptiste Sallée, Won Sang Lee, Lynne Talley, David Thompson, Andrew Thompson, John Toole, Michiel Van den Broeke, David Vaughan, Anna Wåhlin, Darren Waugh, Pippa Whitehouse, Eric Wolff, Yusuke Yokoyama, Xuebin Zhang

Overview

Antarctica and the Southern Ocean play a disproportionately important role in modulating global sea level and Earth's carbon cycle. Program 1 will focus on the large-scale drivers and small-scale processes that affect ocean and atmosphere circulation which modulate transport of heat and moisture to the Antarctic margin and East Antarctic ice sheet, as well as Southern Ocean productivity and biogeochemical (BCG) cycles. Incorporating outputs from the other programs, Program 1 will improve predictions of how sea level and the carbon cycle will be affected in the future by changes in Antarctica and the Southern Ocean. This will require the integration of historical and new observations for the detection and attribution (D&A) of change, constraints from palaeoclimate data on how and why circulation, mass balance and melt rates can change, process studies to understand the interaction between ocean, atmosphere, ice, solid earth and ecosystems, and a hierarchy of model experiments to understand past change and provide future projections. The program will make connections between modelling and analysis frameworks, and generate data-driven knowledge that informs the risks to the effective prediction of how ice sheets, oceans and climate respond to conditions and changes at, and across, system boundaries. Computer-based data analytics provided in Program 1 will help guide optimal field sampling, enable analysis of under-observed systems in other programs and provide new insight into the complex coupled system.

Program 1 will focus on the following overarching question:

> ***How can shifts in carbon, heat and moisture transport in the Antarctic and Southern Ocean system be better understood to improve projections of future climate and sea level changes?***

Specifically, Program 1 will

1. **Carbon**: Quantify the biological carbon pump (productivity) in the Southern Ocean (SO) and assess drivers of its recent (~20 years) variability and how productivity may change in the coming decades in response to changes in the physical environment (natural and climate change driven):

a. Use historical satellite records (ocean colour, temperature, altimetry, wind), BGC-Argo and other field observations to identify temporal signals in the phytoplankton ecosystems and their physical drivers from seasons to decadal timescales.
b. Assess the forcing role of the physical environment on the carbon pump from the meso-scale (eddies) to the basin-scale, and from seasonal to decadal time scales.
c. Combine the above with the 3D SO-scale modelling to improve projections of the efficiency of the biological carbon pump. Contribute to improving the modelling of the biological pump in that frame.
d. Use observations, both optical and biogeochemical (BGC), from past and upcoming field efforts to understand why the Southern Ocean still poses an issue to satellite ocean colour with a view to improving algorithms.

2. **Heat and circulation**: Quantify the changes to and the understand drivers of ocean and atmospheric circulation across a range of timescales affecting the flow of heat and moisture to the eastern Antarctic system:
    a. Understand changes to the atmospheric circulation (including heat and moisture fluxes) across timescales associated with anthropogenic forcing, regional and remote variability.
    b. Determine how circulation changes/climate modes and other local processes affect ocean circulation at the Antarctic margin.
    c. Quantify oceanic heat and other tracer fluxes to the Antarctic margin.
    d. Understand how increased melt rates will feed back to the large-scale circulation.

3. **Sea level**: Determine how East Antarctica affects sea level across a range of past and future timescales:
    a. Use geophysical data (heat flux, sub-ice meltwater, basal sediments, vertical land motion) to constrain where the solid Earth may affect ice sheet stability in parts of East Antarctica, and improve solid Earth models (Glacial Isostatic Adjustment [GIA]/viscosity) to provide a better constraint on future sea level rise projections
    b. Improve the quantification of ocean warming driven ice shelf/sheet loss from coastal East Antarctica through improved incorporation of high-resolution processes at the ice sheet margin into Earth system models.
    c. Improve the spatial and temporal understanding of past surface accumulation variability and trends across the surface of parts of the East Antarctic ice sheet and the potential role of surface accumulation in offsetting ice loss at the ice sheet margin.
    d. Combine improved regionals projections for East Antarctic ice mass change into global sea level projections.
    e. Assess risks to the effective prediction of changes to ice mass, ocean and climate, that arise from interactions and feedbacks between systems, across boundary domains, variability, and instability/threshold changes

4. **Detection and attribution (D&A)**: Improve the detection of variability and trends in the Southern Ocean and Antarctic climate, and their attribution to natural and/or anthropogenic climate processes:
    a. Assess regional characteristics and temporal trends and variability in satellite altimeter and tide gauge datasets.
    b. Improve the resolution and accuracy of satellite-derived estimates of surface mass balance over East Antarctica, including improving models of firn compaction and assessment of satellite datasets alongside ice-core derived histories of snow accumulation.

c. Improve the measurement of meltwater input from coastal East Antarctica
d. Assess reconstructions, observations and model simulations for East Antarctic and Southern Ocean change within the Climate Model Intercomparison Project (CMIP) D&A framework.

**Program 2 (P2) - Regional East Antarctic and its Provinces**

*Program Leaders*: Philip Boyd, Laurie Menviel, Vanessa Lucieer
*Other Contributing CIs*: Nathan Bindoff, Julia Blanchard, Michael Ellwood, Matt England, Nicole Hill, Mark Hindell, Delphine Lannuzel, Mary-Anne Lea, Andrew McMinn, Adele Morrison, Paul Spence
*Contributing PIs*: Hervé Claustre, Xavier Crosta, Scott Doney, Pierre Dutrieux, Naomi Levine, Rob Massom, Richard Matear, Clive McMahon, Klaus Meiners, Mark Moore, Alberto Naveira Garabato, James Risbey, Ted Scambos, Chris Stokes

Overview

The imprint of anthropogenic climate change on Antarctica and the Southern Ocean has so far revealed a pronounced asymmetry between West and East Antarctica, with distinct differences in air and sea-surface temperature as well as sea-ice changes, and ice shelf meltwater rates. P2 will focus on exploration of the causal linkages between atmosphere, ocean, cryosphere in both the present day and geological past to better inform future projections of how East Antarctica will be altered in the coming decades. This program will also investigate the consequent effects of a changing East Antarctica on open water and under ice biogeochemistry and ecology, using a combination of palaeo, contemporary and future model projections. Addressing these issues needs a multi-faceted archive derived from a combination of observations (regional remote-sensing, core records), improved mechanistic understanding from process studies (transdisciplinary voyages, links to P3) and advances in modelling (links with large scale climate/carbon cycle modelling in P1). P2 will forge linkages with allied activities (international ACEAS PIs and P1) taking place in West Antarctica to improve our understanding of the drivers of these conspicuous trends between the sub-continents.

Program 2 will focus on the following overarching question:

***What are the causal linkages between atmosphere, ocean, cryosphere, and their consequent effects on open water and under ice biogeochemistry and ecology in the East Antarctic under past, present and future conditions?***

Specifically, Program 2 will

1. Assess how Southern Ocean wind changes affect the regional oceanic circulation and sea ice (e.g. sea ice transport, creation of polynyas) on timescales ranging from decadal (e.g. over the last few centuries to millennia) to centennial (e.g. past abrupt climate change), to multi-millennial (e.g. glacial-interglacial timescales) using ocean/sea-ice models.
2. Assess how the above regional changes in wind, oceanic circulation and sea-ice impact ocean temperature, salinity, biogeochemical properties (e.g. $O_2$, DIC, $PO_4$, chlorophyll), and atmospheric $CO_2$ combining ocean/sea-ice/carbon cycle models and palaeo-proxy records.
3. Use palaeo-proxy records to identify past Antarctic meltwater events in East Antarctica, and assess their influence on oceanic circulation and sea-ice using proxy records and coupled modelling.
4. Evaluate the consequent effects on open water and under ice biogeochemistry and ecology for both contemporary and past climate.
5. Use palaeo-proxy records to assess past changes in ecosystem structure and function and export production near the Marginal Ice Zone (MIZ), and their potential link to changes in iron supply from the cryosphere and atmosphere.

6. Assess the impact of changes in oceanic circulation, sea-ice and iron inputs on ecosystems and the carbon cycle in the MIZ using Earth system models.
7. Perform contemporary measurements in the MIZ on under ice and open water food webs, coupled biogeochemistry, downward carbon export, water column and sea ice chemistry, and isotopes of oxygen, carbon and neodymium to calibrate palaeo proxy records.

**Program 3 (P3) – Sub-regional and Regional Antarctic Margin**

*Program Leaders*: Ben Galton-Fenzi, Zanna Chase, Adele Morrison

*Other Contributing CIs*: Nerilie Abram, Alan Aitken, Leanne Armand, Nathan Bindoff, Zanna Chase, Richard Coleman, Michael Ellwood, Matt England, Bishakh Gayen, Ian Goodwin, Jacqui Halpin, Nicole Hill, Matt King, Delphine Lannuzel, Vanessa Lucieer, Elisa Mantelli, Adele Morrison, Max Nikurashin, Taryn Noble, Helen Phillips, Eelco Rohling, Peter Strutton, Paul Tregoning, Duanne White, Jo Whittaker

*Contributing PIs*: Michael Bentley, Pierre Dutrieux, Stewart Jamieson, Bernd Kulessa, Adrian Luckman, Richard Matear, Terry O'Kane, Alix Post, Steven Rintoul, Jason Roberts, Won Sang Lee, Ted Scambos, Chris Stokes, Andrew Thompson, Anna Wåhlin, Pippa Whitehouse

Overview

Program 3 will focus on understanding the response of the icesheet/climate system to climate change, for areas understood to be vulnerable to rapid deglaciation of the ice sheet. The Program will focus on the integration of studies that cover the spatial domains from ice sheet accumulation basins through to the continental shelf break over a range of timescales. Existing datasets and modelling will be used to examine processes within these time and space scales and build towards a field program with a specific focus on the Denman/Shackleton region. The Program will focus on answering the following overarching question:

Program 3 will focus on the following overarching question:

***What is the risk of ice mass loss from key subglacial basins over the next decades to centuries, and what are the consequences for the local oceans and ecosystems?***

Specifically, Program 3 will

1. Quantify recent historical drivers and rates of retreat for key subglacial basins, with a key focus on the Denman Glacier region:
    a. Quantify mass inputs: Recent accumulation history and processes at the basin scale with reanalysis products.
    b. Quantify mass outputs: Basal melt coupled with measurements and modelling of ocean circulation pathways and variability within the cavity and upstream on the continental shelf.
    c. Examine retreat processes and feedbacks: bedrock uplift rates, glacier sliding and linkages with subglacial hydrology, geothermal heat flow and sedimentation for grounding line wedge stabilization, local atmospheric and oceanic forcing.
2. Quantify the stability of susceptible basins/glaciers and the risk of passing tipping points:
    a. Use a coupled model to explore ice retreat processes in the region and examine the sensitivity to climate.
    b. Obtain high-resolution geometry of continental shelf, subglacial basins, sub ice shelf ocean cavities and grounding zone conditions to constrain the models using a range of activities including geological mapping, and airborne and ship-based geophysics.
    c. Separate the signal caused by a warming climate from decadal variability in the historic record.

    d. Use coupled models to determine when/if ice retreat is likely to cross a tipping point, and how this region compares to East Antarctica generally.
3. Use palaeo reconstructions to provide an integrated view of possible futures for susceptible basins:
    a. Use marine sediment cores recovered from the slope to reconstruct ice sheet state for past climates warmer than present. This approach uses the analysis of new and legacy detrital sediment records coupled to knowledge of subglacial geology and sediment transport modes.
    b. Determine historical ice sheet volumes and retreat rates through bathymetric mapping, offshore geophysical data and land-based approaches (e.g. $^{10}$Be exposure dating).
    c. Compare modelled estimates of the timing, sequencing and magnitude of past basin-scale ice sheet retreat with observational constraints and thereby select the best model.
    d. Use an ice sheet model to understanding source to sink sediment pathways – useful for both understanding the hidden under ice geology, and also planning future fieldwork effort.
4. Identify how past and projected ice melt for key basins can impact local ecosystems in the adjacent ocean and seafloor through altered ocean state, iron fertilisation and sea ice (cross-program outputs):
    a. Quantify the iron supply associated with the retreating ice sheet including melt water and subglacial hydrology. This will involve sampling the ice sheet and melt water. Quantify meltwater input and its iron content. May include measurements of iron speciation, and measurements of ice sheet tracers other than salinity (e.g. d$^{18}$O, uranium isotopes, noble gasses through collaborations).
    b. Collect remote and in-situ observations to evaluate the influence of interannual variability in ice shelf melting and subglacial discharge events on primary productivity and seafloor biodiversity.
    c. Apply a regional model including BGC with glacial iron supply to predict regional ecosystem impacts. Can link to broader scale models to explore impacts on MIZ ecosystems of ice sheet iron.
    d. Use palaeoceanographic records to reconstruct ocean productivity and iron supply during past episodes of ice sheet retreat, as a way of assessing the integrated response and to evaluate models.

## Research Positions

**P1**

UTAS — Glacial Geophysicist: Will design and lead geophysical field campaigns, analyse new data and use mathematical modelling to investigate and validate active (sub-)glacial processes, with an emphasis on the response of major outlet glaciers to change.

UTAS — Marine Ecosystems Remote Sensing: Will conduct multi-variate analysis of bio-optical, chemical and physical data from biological profiling floats, and link them with satellite observations of biological and physical oceanographic properties/processes, including mesoscale and sub-mesoscale.

UTAS – Modes of Ocean Variability: Will focus on the interplay between modes of variability in the ocean, atmosphere and cryosphere using a combination of modelling approaches, data simulation and reanalysis products.

UTAS – Ocean Modelling: Will study ocean warming at the Antarctic continental margin, including examining mechanisms for rapid warming of Antarctic continental shelf waters via both large-scale drivers and fine-scale processes, including mesoscale eddies, tide-topography interactions, and bottom boundary flows to improve quantification of future glacier melt rates.

UTAS – Physical Oceanography - Ocean Transports: Will assess the drivers of momentum and energy balance of ocean currents that control the magnitude of the Southern Ocean overturning circulation using a combination of voyages, remote-sensing and modelling simulations.

UTAS – Sea Level Scientist: Will analyse regional satellite (e.g., Sentinel, SWOT) and tide gauge datasets, including observing and modelling solid-Earth deformation due to past and present glacier loading changes. Will work closely with P3 on glacial isostatic adjustment modelling.

UTAS — Tectonics and Ice Sheets: Will develop new models of under-ice crustal structure, geodynamics, past/present ice sheet erosion, past ocean state, past bedrock topography, and map bedrock heat flux.

UTAS — Computational Geophysics: Will develop multivariate and machine learning approaches, including investigations across system boundaries, e.g. solid Earth to ice, solid Earth to sea floor/ocean, and potentially other systems boundaries.

ANU — Mass Balance (remote sensing and modelling): Will focus on the present-day mass balance changes occurring in East Antarctica through a combination of satellite data (space gravity and altimetry).

ANU — Ocean Modelling: Will focus on present-day and projected ocean feedbacks on the melt rate of ice shelves, through high resolution ocean-sea ice modelling, including changes in polynya dynamics, ice shelf cavity circulations and cross-slope heat exchange.

ANU — Palaeoclimate Ice: Will develop isotope records from networks of ice drilling samples to reconstruct the spatial and temporal history of climate and accumulation variability in East Antarctica during the last millennium.

UNSW — Coupled Ocean-Atmosphere-Ice Feedbacks at the Antarctic Margin: Will examine the nature of sea-ice albedo, meltwater, and ocean circulation feedbacks onto the ice- atmosphere system using high-resolution coupled climate models, including research into abrupt, non-linear, and surprising changes that can occur at the Antarctic margin due to coupled ocean-atmosphere-ice feedbacks.

UNSW — Palaeo Ocean Modelling: Will study the Southern Ocean circulation and biogeochemistry response to past climate change using a state-of-the-art Earth System Model. The impact of large-scale changes in ocean circulation and/or meridional temperature gradients on Southern Ocean properties, including biogeochemistry, will be investigated.

UNSW — Southern Ocean Atmospheric Interactions: Will examine past and future changes in atmospheric circulation over the Southern Ocean and its relation to greenhouse gases, ozone, remote teleconnections and mesoscale ocean-atmosphere interactions using a hierarchy of sophisticated atmosphere, coupled and idealised process-based models.

UNSW — Southern Ocean Processes: Will examine open Southern Ocean processes today and near-future, spanning the upper and lower cells of the meridional overturning circulation, lateral circulation of water masses and interactions with topography, and the evolving heat and freshwater balance over the open ocean. This will combine model simulations, reanalysis products and diverse data sets (e.g., Argo, historical CTD, seals, reanalysis, sea ice drift/divergence).

UNSW — Thermodynamic Constraints on Changes in the Antarctic: Will apply a novel thermodynamic framework to both develop predictive theory and interpret state-of-the-art climate system models with a view to understanding which processes constrain future atmosphere, ice and ocean changes in the Antarctic region.

UNSW — Detection and Attribution of Climate Change in the Southern Ocean and Regional Sea Level Projections: Will focus on detecting and attributing change in the Southern Ocean using CMIP and high-resolution models and combining the Centre's ocean and ice sheet projections with other information to produce regional sea level projections.

Curtin U — Satellite Remote Sensing: Will analyse full records of satellite observations in search of decadal signals and their connection with physical processes. Improving interpretation and use of satellite ocean colour observations in the Southern Ocean using field observations (ships and BGC-Argo), as well as exploration of new capabilities from the NASA PACE mission and satellite-borne Lidars.

UniSA — Antarctic Solid Earth Geophysics: Will use geophysical data, particularly magnetotellurics and seismics, to investigate the structure of the crust and upper mantle beneath Antarctica and to develop constraints for glacial isostatic adjustment and surface heat flow models.

**P2**

UTAS — Under-ice Mapping: Will integrate existing physical, biogeochemical and ecological sensors onto ROV for multidisciplinary mapping supporting field research.

UTAS — Sea-ice and Open Water Biogeochemistry: Will focus on detecting and understanding how changes in open water and sea ice dynamics will alter water column biogeochemical properties and consequently ocean and sea-ice productivity.

UTAS — Sea Ice Microbial Ecology: Will focus on better understanding the environmental drivers of sea-ice microbial productivity and biogeochemistry using multi-faceted sensor arrays for under-ice missions on autonomous vehicles.

UTAS — Marine Ecosystem — Remote Sensing/Biological Floats: Will characterise Southern Ocean particle size spectra and zooplankton community structure using image analysis software on data streams from biological profiling floats.

UTAS — Marine Ecosystems — Foraging Strategies: Will focus on detection and analysis of the movements and foraging strategies of apex predators in relation to their prey fields and the underlying regional environmental properties.

UTAS — Marine Ecology (particle size spectrum modelling): Will develop numerical simulations of open water and under ice food webs using a nested suite of models, including functional size spectra modelling to explore trophodynamics from microbes to apex predators.

UTAS — Benthic Biodiversity: Will develop spatial predictions on the distribution of benthic biodiversity for the continental shelf under future climate scenarios using the fine-resolution coupled/oceanographic models being developed in the Centre.

ANU — Marine Biogeochemistry: Will utilise state-of-the-art stable metal isotope techniques, in combination with field and laboratory observations and experiments, to understand ecosystem functioning within the present-day Southern Ocean.

**P3**

UTAS — Palaeo Ice Sheet Modelling: Will develop, run and interrogate thin-film type ice sheet models suited for millennial timescale simulations to investigate the state and sensitivity of the palaeo-East Antarctic ice sheet. The position will sit in Program 3 and provides the link between many P3 initiatives. It also links strongly with P1 as this will be a whole of ice sheet model, so relevant to the circum-Antarctic scale.

UTAS — Ice Sheet/Shelf Modeller: Will develop basin-scale and whole-of-ice sheet/ocean models informed by new field data. Will perform projections to 2100 and beyond, interacting with the UNSW Dynamic Ice Sheet Modeller appointment.

UTAS — Antarctic Palaeoceanography: Will work on palaeo-proxy development and data synthesis and prepare and participate in a coring voyage in the final year.

ANU — Technical Officer: Will support analysis of new and existing samples and new sample collection.

ANU — Meltwater Pulses and Water-Column Stratification: Will reconstruct the timings and magnitudes of Antarctic meltwater pulses, and their impact on water-mass stratification, using palaeomagnetic, geochemical, ice-rafted debris, and stable isotopes paired with Mg/Ca temperature analyses.

ANU — Marine Palaeo Proxy (temperature and sea ice): Will focus on the development of new geochemical techniques and analyses from seafloor sediments to provide proxies of past sea-ice cover, sea-surface temperature, ecosystem structure and biostratigraphy.

UNSW — Palaeoclimate and Palaeoglaciology: Will develop a reconstruction of past millennial Antarctic surface katabatic and coastal winds. Model palaeo-ice accumulation rates, coastal ice sheet dynamics, coastal ocean currents and palaeo-ice shelf dynamics.

UNSW — Dynamic Ice Sheet Modeller: Will work with CSIRO, AAD, and the UTAS ice sheet modeller to examine variability versus trends in the response of East Antarctica's ice sheets and ice shelves to

anthropogenic change. This work will utilise CSIRO ENKF system and include the ROMS-Elmer coupled ocean-ice-atmosphere- land-ice sheet/shelf modelling platform, with forcing from the CAFE ensembles over the historic period and future climate trajectories.

U Melb — Basal Melting of Antarctic Ice Shelves: Will investigate the roles of meltwater buoyancy, horizontal currents, internal wave breaking and water exchanges between the continental shelf and sub-ice cavities using unique turbulence (and boundary layer) resolving computational and laboratory experiments.

U Canberra — Palaeo Ice Sheets: Will use surface exposure data and geomorphological analysis to constrain past ice sheet retreat with emphasis on past deglaciations.

UWA — Antarctic Crustal Geophysics and Bed Evolution: Will develop geophysical knowledge of Antarctica's crust and ice sheet bed, developing models of basal boundary conditions, now and through time, linked to palaeo-proxy studies.

**ACEAS Postdoctoral Positions — Summary List**

| Research Program | Lead CI | Uni | Postdoctoral Position | Start-Finish Years | Term Years Approx |
|---|---|---|---|---|---|
| P1, P2 | Peter Strutton | UTAS | UTAS Postdoctoral Research Associate - Marine Ecosystems Remote Sensing | 1-3 | 3 |
| P1 | Paul Spence | UTAS | UTAS Postdoctoral Research Associate – Ocean Modelling | 1-3 | 3 |
| P1 | Nathan Bindoff | UTAS | UTAS Postdoctoral Research Associate – Modes of Ocean Variability | 1-3 | 3 |
| P1, P2, P3 | Helen Phillips | UTAS | UTAS Postdoctoral Research Associate – Physical Oceanography | 2-4 | 3 |
| P1, P3 | Jo Whittaker | UTAS | UTAS Postdoctoral Research Associate - Tectonics and Ice Sheets | 1-3 | 3 |
| P1, P3 | Christopher Watson | UTAS | UTAS Postdoctoral Research Associate – Sea Level | 2-4 | 2 |
| P2 | Vanessa Lucieer | UTAS | UTAS Postdoctoral Research Associate - Under Ice Mapping | 2-3 | 2 |
| P2 | Mary-Anne Lea | UTAS | UTAS Postdoctoral Research Associate - Marine Ecosystems: Foraging Strategies | 1-3 | 3 |
| P2 | Philip Boyd | UTAS | UTAS Postdoctoral Research Associate - Marine Ecosystems: Remote Sensing/Biological Floats | 1-3 | 3 |
| P2 | Delphine Lannuzel | UTAS | UTAS Postdoctoral Research Associate – Sea Ice and Open Water Biogeochemistry | 2-4 | 3 |
| P2 | Andrew McMinn | UTAS | UTAS Postdoctoral Research Associate - Sea Ice Microbial Ecology | 2-4 | 3 |
| P1, P2 | Julia Blanchard | UTAS | UTAS Postdoctoral Research Associate - Marine Ecology | 1-3 | 3 |
| P2 | Nicole Hill | UTAS | UTAS Postdoctoral Research Associate - Benthic Biodiversity | 2 | 1 |
| P1, P3 | Elisa Mantelli | UTAS | UTAS Postdoctoral Research Associate - Ice Sheet/Shelf Modeller | 1-3 | 3 |
| P1, P3 | Richard Coleman | UTAS | UTAS Postdoctoral Research Associate - Glacial Geophysicist | 2-4 | 3 |
| P3 | Zanna Chase | UTAS | UTAS Postdoctoral Research Associate - Antarctic Palaeoceanography | 2-4 | 3 |
| P3 | Zanna Chase | UTAS | UTAS Postdoctoral Research Associate - Palaeo Ice Sheet Modelling | 2-4 | 3 |
| P1 | Anya Reading | UTAS | UTAS Postdoctoral Research Associate - Computational Geophysics | 1-3 | 3 |
| P1, P3 | Adele Morrison | ANU | ANU Postdoctoral Research Associate - Ocean Modelling | 1-3 | 3 |
| P1, P3 | Nerilie Abram | ANU | ANU Postdoctoral Research Associate - Palaeoclimate Ice | 3-4 | 2 |
| P1, P3 | Paul Tregoning | ANU | ANU Postdoctoral Research Associate - Mass Balance (remote sensing, modelling) | 1-3 | 3 |
| P2, P3 | Michael Ellwood | ANU | ANU Postdoctoral Research Associate - Marine Biogeochemistry | 2-3 | 2 |
| P3 | Eelco Rohling | ANU | ANU Postdoctoral Research Associate - Meltwater Pulses and Water Column Stratification | 2-3 | 2 |
| P3 | Leanne Armand | ANU | ANU Postdoctoral Research Associate - Marine Palaeo Proxy (temperature, sea ice) | 2-4 | 3 |
| P3 | Nerilie Abram | ANU | ANU Technical Officer | 2-4 | 6 |
| P1 | Jan Zika | UNSW | UNSW Postdoctoral Research Associate - Thermodynamic Constraints on Changes in the Antarctic | 1-3 | 3 |
| P1 | Matt England | UNSW | UNSW Postdoctoral Research Associate - Coupled Ocean-Atmosphere-Ice Feedbacks at the Antarctic | 1-3 | 3 |
| P1 | Alex Sen Gupta | UNSW | UNSW Postdoctoral Research Associate - Southern Ocean Atmospheric Interactions | 1-3 | 3 |
| P1 | Matt England | UNSW | UNSW Postdoctoral Research Associate - Southern Ocean Processes | 1-3 | 3 |
| P1 | Laurie Menviel | UNSW | UNSW Postdoctoral Research Associate - Palaeo Ocean Modelling | 1-3 | 3 |
| P1 | John Church | UNSW | UNSW Postdoctoral Research Associate - Detection and Attribution | 1-3 | 3 |
| P3 | Ian Goodwin | UNSW | UNSW Postdoctoral Research Associate - Palaeoclimate and Palaeoglaciology | 1-2 | 2 |
| P1, P3 | Matt England | UNSW | UNSW Postdoctoral Research Associate - Dynamic Ice Sheet Modeller | 1-3 | 3 |
| P3 | Duanne White | UC | Uni Canberra Postdoctoral Research Associate - Palaeo Ice Sheets | 3-4 | 2 |
| P1 | Kate Selway | Macq U | UniSA Postdoctoral Research Associate - Antarctic Solid Earth Geophysics | 3-4 | 2 |
| P1, P3 | Alan Aiken | UWA | UWA Postdoctoral Research Associate - Antarctic Crustal Geophysics and Bed Evolution | 2-3 | 2 |
| P1, P3 | Bishakh Gayen | UMelb | Uni Melb Postdoctoral Research Associate - Basal Melting of Antarctic Ice Shelves | 1-2 | 2 |
| P1 | David Antoine | Curtin U | Curtin Uni Postdoctoral Research Associate - Satellite Remote Sensing | 1-2 | 2 |

## Budget

The revised budget is based on the $20 million ARC cash grant plus $5 million of Universities' cash contributions, a total of $25 million, scaled back from a term of seven to four years. Year 1 (2022) has a ramp-up over the year of staff, students, and activity; Years 2 (2023) and 3 (2024) have virtually a full complement of staff with all students recruited by the end of Year 2; and Year 4 (2025) has a ramp-down of staff and activity over the year.

The disbursement of funds has been agreed between the Administering and Other Eligible Organisations. This justification covers the expenditure of the total $25m cash.

The overall breakdown of cash expenditure is: Personnel [68%]; Equipment [1%]; Maintenance/Operating [10%]; Travel [3%]; Logistics [14% (or 18% of ARC grant value)]; and Other [4%].

The Budget Summary Table is at Appendix B.

**Personnel: $17,112,246** (from ARC cash)
**Cash-funded staff:** 100 FTE*years over 4 years ($17,112,246 from ARC cash [incl $464,100 for PhD Scholarship top-ups])
**In-kind staff:** 46.0 FTE*years over 4 years from Eligible Organisations – UTAS 22.5, ANU 10.3, UNSW 9.2, U Canberra 0.8, UniSA 0.8, UWA 0.8, U Melbourne 0.8, and Curtin U 0.8 and a further 22.2 FTE*years over 4 years from other National and International Partners.

Personnel cost estimates are based on 2020 university salaries plus 30% on-costs without indexation.

*Research*
**Research Positions**
See description of roles, proposed start years and nominal terms of appointment for each position in the previous section.
*Management*
**Centre Project Manager** [HEO 9, 1.0 FTE for 4 years] Provide the Director with high-level governance, management, strategic planning and policy support in the operation of the Centre, and in the delivery of its research program. This senior appointment is in recognition of the complexity and strategic importance of effective operational leadership of a centre of this scale, and will be an individual with extensive research management experience.
**Centre Antarctic Graduate Training Coordinator** [Acad C, 0.6 FTE for 4 years] The Antarctic Graduate Training Coordinator will lead the development and implementation of graduate and early career training, and will focus on delivering a world-class 'value-added' learning and development experience for PhD students and postdoctoral researchers of the Centre.
**Centre Public Affairs and Stakeholder Engagement Officer** [HEO 7, 1.0 FTE for 4 years or two fractional appointments] Manage the Communications and Media program of the Centre to effectively communicate its research to the public. Manage the Centre's relationship with stakeholders, and develop, implement and manage the communications and stakeholder engagement strategy.
**Centre Data Manager** [HEO 7, 0.5 FTE for 3 years] Responsible for the day-to-day management of datasets and model outputs from the Centre, in compliance with its Data Management Policy and the Australian Code for Responsible Conduct of Research. Will include long term archival storage of data/metadata (particularly with the Australian Antarctic Data Centre), provision of datasets and creation and data serving. This appointment recognises data as a high-value asset.

**Centre Project Officer** [HEO 6, 1.0 FTE for 4 years] Responsible for the day-to-day running of the Centre, including co-ordinating administrative, human resource management and other services, and for providing general administrative assistance to the Chief Operating Officer and research staff based at UTAS. Undertake the processing of financial transactions including purchasing; claims for payment; travel arrangements; and liaise with UTAS Finance. Prepare reports and sub-project budgets, and undertake day-to-day financial monitoring against the budget, in conjunction with the Administration Manager.
**ANU Administration Officer** [HEO 4, 0.5 FTE] Liaise with the Project Officer as the Centre administrative contact at the node, and provide general administrative assistance to ANU researchers.
**UNSW Administration Officer** [HEO 4, 0.5 FTE] Liaise with the Project Officer as the Centre administrative contact at the node, and provide general administrative assistance to UNSW researchers.
**PhD Candidates** Twenty-five top-up scholarships will be available to PhD students from participating Universities affiliated with the Centre to be awarded on merit by the Management Committee based on the recommendations of the Graduate Training Coordinator.

**Equipment: $377,500** (from ARC and Universities cash)
*Computers:* **$152,500**
High-performance computers suitable for modelling, data manipulation, and field work for ARC-funded postdoctoral researchers, data manager and technicians including specialised software. Total 38 x $3.5k. **$132,500**; Computers for ARC-funded administrative staff and graduate training coordinator. Total 8 x $2.5k. **$20,000**; Universities will provide computers to PhD students affiliated with the Centre.
*Research Equipment:* **$225,000**
Glacier Surface Measurement Equipment (P1): Automatic phase sensitive radar (ApRES) to observe basal melt rates: 5 x $16k. **$80,000**
Power systems for geophysical equipment (P1): enabling year-round measurements with polar-rated gel-cell batteries, solar panels and polar housing. 10x$2.5k. **$25,000**
Animal-borne CTD/Fluorometry tags (P1): for measurement of CTD profiles under ice: These tags, proven operationally in Southern Ocean conditions, will be used to extend the coverage of animal-borne sensors in the Mertz Glacier region by deploying tags from a sub-Antarctic Island. **$120,000**

**Maintenance/Operating: $2,317,307**
*Management:* **$300,000** (from Universities cash)
Operating over three nodes including establishment expenses, consumables, meetings, communications, publications, dissemination of outputs, and outreach activities, including a web site.
*General Research Operating*: **$922,307** (from ARC cash)
PhD Project Operating - $4k per student per year x 3.5 years. **$350,000**; General Project Operating for project support of postdocs and technicians. **$411,757**; Iridium Data Transfer for Geophysical Data – **$48,000;** Integration of ROV (AAD) with Specim HI system (IMAS) – **$94,550**; High Resolution Satellite Imagery for Ground-truthing Fieldwork – **$18,000**.
*Expedition Research Operating:* **$368,000** (from Universities cash)
Denman Voyage – **$136,500**; Bunger Hills Expedition – **$101,500**; MIZ Voyage – **$124,000**; Sub Antarctic Island – Animal Mounted CTD Tagging – **$6,000**
*Other Research Operating:* **$727,000** (from ARC and Universities cash)
Field and Laboratory supplies and analysis services.

**Travel: $631,8140** (from ARC cash)
Expenses for Centre Management travel, and for Postdoctoral Research Associates and affiliated PhD students to attend international scientific conferences and to foster and strengthen collaboration between

researchers in Australia and overseas. Travel costs as per each University's policy - economy class and actual travelling expenses within limits. Estimate based on an average contribution for travel directly relevant to the project of $3k pa per Postdoctoral Research Associate and $2k pa per student. These funds can be used to leverage travel grants from University and other sources.

**Logistics: $3,525,000** (from Universities cash)
Fieldwork provided by AAD remains at the heart of the Centre's scientific activities and is required to make advances in our understanding of the coupled ice-ocean-atmosphere-ecosystem-solid Earth system. The revised scientific scope has provided a reduced geographical footprint for required fieldwork to reduce the expenditure on logistics but also to reflect the availability of logistics within the timeframe of the Centre.

The scope of the logistics has been reduced to focus on:

- One Marginal Ice Zone (MIZ) Voyage.
- One ice-front Voyage to Denman Glacier region (with alternatives of Vanderford and/or Totten Glaciers).
- One season of aircraft-supported on-ice and on-land fieldwork in the Denman Glacier region, with a base in the Bunger Hills.
- Seal tagging at Macquarie Island (or another sub-Antarctic island).

For work in the Denman Glacier/Bunger Hills region, it was originally proposed to use RSV *Nuyina* as a floating base with helicopters on-board in order to support onshore activities. It has been agreed with AAD that the air-supported and the ship-supported fieldwork need to be separated geographically and in time. Air-supported activities earlier than the ship-based activities will allow contemporaneous measurement on ice and under ice.

There have been extensive and positive discussions with AAD to clarify the availability of logistics. It is understood that early planning of this kind is subject to substantial uncertainty in addition to the regular uncertainties of year-to-year Antarctic fieldwork. The uncertainties of both COVID-19 and the delivery of RSV *Nuyina* mean that, at this time, logistics arrangements in a particular season cannot be confirmed.

Currently marine science voyages on RSV *Nuyina* are currently planned for:

- Marginal Ice Zone (MIZ) Q3–Q4 2023
- Denman Glacier Q1–Q2 2025

The Bunger Hills Expedition will be air-supported out of Casey Station, and is currently scheduled for Q4 2023 – Q1 2024.

The seal tagging on Macquarie Island is scheduled for Q4 2022 – Q1 2023

The budget estimates for logistics are based on information provided by the AAD at the application stage. The logistics and expedition operating expenses budgets will need to be reviewed and updated once the details of the expedition arrangements become available closer to the actual time.

- Marginal Ice Zone (MIZ) Voyage – 30 day, 30 people – **$765,000**
- Denman Glacier Voyage – 50 day, 30 people – **$930,000**
- Denman – Bunger Hills Expedition with 2 Helicopters - 42 day, 15 people – **$1,745,850**
- Sub Antarctic Island Seal Tagging – 21 day, 4 people – **$84,150**

**Other: $1,036,134**

*Recruitment Expenses:* Up to $8k per recruitment where relocation is required – **$181,124** (from Universities cash)

*Visiting Fellowships*: For hosting approximately 120 world-leading researchers over 4 years for short term visits generally involving multiple collaborators across the participating universities and partners, based on a Centre contribution of an average of approximately $1.5k per visiting scholar. These funds can be used to leverage additional visitor funds from Universities and other sources. – **$190,000** (from ARC and Universities cash)

*Research Workshops and Conferences*: For costs of Centre conferences and to provide seed funding to leverage other state, national and international support to host prestigious international conferences. – **$220,010** (from ARC cash)

*Stakeholder Engagement*: For building and maintaining the network of stakeholders and users of the Centre's research, and for writing, publishing and promoting the latest Antarctic and Southern Ocean scientific information in a form accessible to policy makers, government, industry and the general public. – **$295,000** (from ARC cash)

*Governance Expenses*: To fund the appointment of an independent Chair, and for meeting arrangements. – **$150,000** (from ARC cash)

## Governance and Organisation

To ensure effective operations and oversight, the Centre will have a two-level management and governance structure.

The Director will work with an independent Advisory Board which will meet at least twice a year, with additional meetings as required, to consider the Centre's governance, strategy, risk and opportunities. Prof Mary O'Kane (former New South Wales Chief Scientist and Engineer) has agreed to Chair the Board. The Director and Deputy-Directors will be advised by a Scientific Advisory Panel consisting of leading national and international Antarctic and Southern Ocean scientists. This Panel will meet at least once a year.

Day-to-day operations will be overseen by a Management Committee consisting of the Director and Deputy-Directors, Research Program Leaders and the Antarctic Graduate Training Coordinator, with the support of the Project Manager and other senior professional staff. Financial and management systems and reporting approaches will be based on the existing and well-tested framework within the ARC SRI for Antarctic Gateway Partnership.

The Centre aims to work with the Australian Antarctic Program Partnership (AAPP) and the other Antarctic SRI (Securing Antarctica's Environmental Future – SAEF), to provide consistent policy advice and maximise impact and influence. For instance, joint position papers are expected to be produced on topics of public interest. Strategic and translational plans will be developed within the first year of the Centre's operations.

**Memberships**

***Advisory Board*** *(8-10 persons)*

The Board will comprise:

- An independent Chairperson appointed by the Administering Organisation (University of Tasmania) in consultation with the other Australian University Participants (Prof Mary O'Kane)
- The Director of the Australian Antarctic Division or nominee (Dr Tas Van Ommen)
- The Director of CSIRO Oceans and Atmosphere or nominee (Dr Jaci Brown)

- The Deputy Vice-Chancellor (Research) of the Administering Organisation (University of Tasmania) or nominee (Prof Anthony Koutoulis)
- The Centre Director (Prof Matt King)
- Helen Bennett, Head of Climate Change Division, Department of Industry, Science, Energy and Resources
- Mark Leplastrier, Executive Manager, Natural Perils Reinsurance, Insurance Australia Group (IAG)
- Prof John Piggott, Director, ARC Centre of Excellence in Population Ageing Research
- Up to two additional external members with relevant expertise identified by the Board who may include senior international researchers, industry, government and end-user representatives, and representatives of community groups.
- The Project Manager as secretary and adviser to the Committee.

***Scientific Advisory Panel*** *(6-8 persons)*

Consisting of leading national and international Antarctic and Southern Ocean scientists including:

Dr Phil O'Brien (Chair) (former Chair of SCAR Geoscience Standing Science Group, Australia)
Prof Amy Leventer (Colgate University, USA)
Dr Catherine Ritz (SCAR VP for Science, France)
Prof Martin Siegert (Grantham Institute, UK)
Prof Eileen Hofmann (Old Dominion University, USA)
Prof Nathan Bindoff (AAPP Program Leader)
Others by invitation

***Management Committee*** *(10 persons)*

Director — Prof Matt King
Deputy Director (UTAS) — A/Prof Delphine Lannuzel
Deputy Director (ANU) — Prof Nerilie Abram
Deputy Director (UNSW) — Prof Matt England
Antarctic Graduate Training Coordinator
Project Manager
Leader Program 1 — Circum Antarctic and East Antarctica: Prof Anya Reading
Leader Program 2 — Regional: A/Prof Laurie Menviel
Leader Program 3 — Sub-regional: Dr Ben Galton-Fenzi

***Directorate*** *(7 persons)*

Director — Prof Matt King
Deputy Director (UTAS) — A/Prof Delphine Lannuzel
Deputy Director (ANU) — Prof Nerilie Abram
Deputy Director (UNSW) — Prof Matt England
Project Manager
Antarctic Graduate Training Coordinator
Public Affairs and Stakeholder Engagement Manager

***Administration*** *(4 persons)*

Project Officer
Administrative Officer (ANU)
Administrative Officer (UNSW)
Data Manager

**ARC Australian Centre for Excellence in Antarctic Science — Participants and Collaborators**

| Australian Universities | Chief Investigators |
|---|---|
| University of Tasmania (UTAS) | Matt King |
| | Delphine Lannuzel |
| | Nathan Bindoff |
| | Julia Blanchard |
| | Philip Boyd |
| | Zanna Chase |
| | Richard Coleman |
| | Jacqui Halpin |
| | Nicole Hill |
| | Mark Hindell |
| | Mary-Anne Lea |
| | Vanessa Lucieer |
| | Elisa Mantelli |
| | Andrew McMinn |
| | Max Nikurashin |
| | Taryn Noble |
| | Helen Phillips |
| | Anya Reading |
| | Paul Spence |
| | Pete Strutton |
| | Chris Watson |
| | Jo Whittaker |
| Australian National University (ANU) | Nerilie Abram |
| | Leanne Armand |
| | Michael Elwood |
| | Adele Morrison |
| | Eelco Rohling |
| | Paul Tregoning |
| University of New South Wales (UNSW) | Matt England |
| | John Church |
| | Ian Goodwin |
| | Laurie Menviel |
| | Alex Sen Gupta |
| | Jan Zika |
| University of Canberra (U Canberra) | Duanne White |
| Curtin University (Curtin U) | David Antoine |
| University of South Australia (UniSA) | Kate Selway |
| University of Melbourne (U Melb) | Bishakhdatta Gayen |
| University of Western Australia (UWA) | Alan Aitken |

| Other Participating Organisations | Partner Investigators |
|---|---|
| Alfred Wegener Institute (AWI), Germany | Karsten Gohl |
| Australian Antarctic Division (AAD) | Ben Galton-Fenzi |
| | Rob Massom |
| | Klaus Meiners |
| | Jason Roberts |
| British Antarctic Survey (BAS), UK | Pierre Dutrieux |
| | David Vaughan |
| California Institute of Technology (Caltech), USA | Andrew Thompson |
| CNRS - Institute of Geosciences and Environmental Research (IGE), Grenoble, France | Gael Durand |
| CNRS - Laboratories Environment and Paleoenvironment Oceanic and Continental (EPOC), University of Bordeaux, France | Xavier Crosta |
| CNRS - Laboratory for the Sciences of Climate and the Environment (LSCE), France | Amaelle Landais |
| CNRS - Laboratory of Oceanography and Climatology (LOCEAN), Sorbonne University, France | Jean-Baptiste Sallée |
| CNRS - Oceanography Laboratory Villefranche-sur-mer (LOV), Sorbonne University, France | Hervé Claustre |
| Colorado State University, USA | David Thompson |
| CSIRO | Wenju Cai |
| | Richard Matear |
| | Terence O'Kane |
| | Stephen Rintoul |
| | James Risbey |
| | Xuebin Zhang |
| Durham University, UK | Michael Bentley |
| | Stewart Jamieson |
| | Chris Stokes |
| | Pippa Whitehouse |
| Geoscience Australia (GA) | Alexandra Post |
| Hokkaido University, Japan | Shigeru Aoki |
| Johns Hopkins University, USA | Darren Waugh |
| King's College London, UK | Tamsin Edwards |
| Korea Polar Research Institute (KOPRI), South Korea | Won Sang Lee |
| National Oceanic and Atmospheric Administration (NOAA), USA | Stephen Griffies |
| Scripps Institution of Oceanography, University of California San Diego, USA | Helen Fricker |
| | Sarah Gille |
| | Lynne Talley |
| Swansea University, UK | Bernd Kulessa |
| | Adrian Luckman |
| Sydney Institute of Marine Science (SIMS) | Clive McMahon |
| University of Cambridge, UK | Eric Wolff |
| University of Colorado Boulder, USA | Ted Scambos |
| University of Gothenburg, Sweden | Anna Wåhlin |
| University of Southern California, USA | Naomi Levine |
| University of Tokyo, Japan | Yusuke Yokoyama |
| University of Virginia, USA | Scott Doney |
| Utrecht University, The Netherlands | Michiel Van Den Broeke |
| Woods Hole Oceanographic Institution (WHOI), USA | John Toole |

| Other Collaborating Organisations | Collaborators |
|---|---|
| Potsdam Institute for Climate Impact Research (PIK), Germany | Anders Levermann |
| University of Lapland, Finland | Rupert Gladstone |
| University of Southampton, UK | Mark Moore |
| | Alberto Naveira Garabato |