1. **Name of SRP**

INStabilities & Thresholds in ANTarctica (INSTANT)
– *The Antarctic Contribution to Sea-Level Change*

2. **Names of Lead Proponents**

Tim Naish, Antarctic Research Centre, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand, timothy.naish@vuw.ac.nz

Florence Colleoni, Istituto Nazionale di Oceanografia Sperimentale, Sgonico, 34010, Italy, fcolleoni@inogs.it

3. **Sponsoring Scientific Groups**

SCAR Geosciences Group
SCAR Physical Sciences Group
SCAR Life Sciences Group

4. **Summary of duration and budgetary requests**

Duration of 8 years. Budget under discussion (see supporting information)

5. **Abstract**

INSTANT is a new SCAR strategic research programme (SRP) that addresses one of the highest priority issues facing climate change science - *the question of Antarctica's uncertain contribution to sea-level change*. It utilises a multidisciplinary Earth systems approach combining geoscience, physical sciences, biological and social sciences to improve understanding of the interactions between the ocean, atmosphere, solid Earth and the Antarctic Ice Sheet (AIS) and aims at ensuring effective communication on this topic with stakeholders. INSTANT will draw upon, realign and refocus much of the high-impact research capacity that has existed within the ANTCLIM^{21}, PAIS, SERCE and ANTECO SRPs[1], in order to facilitate a step-change in our knowledge of AIS dynamics. To achieve this, INSTANT and its partners (e.g. WCRP) will focus on the poorly understood processes and feedbacks that influenced ice-sheets in the past, are influencing observed ice sheet changes, and will influence Antarctica's contribution to future global sea-level change. The key outcomes will be reconstructions of past and projections of future ice mass changes, with reduced uncertainties due to an improved knowledge of rate-determining instabilities and irreversible thresholds, which will be shared with various stakeholder groups. The ice sheet projections will be integrated into probabilistic sea-level projection frameworks for Intergovernmental Panel on Climate Change (IPCC) representative concentration pathways (RCPs) and shared socioeconomic pathways (SSPs)

---

[1] ANTCLIM^{21} = Antarctic Climate Change in the 21st Century (https://www.scar.org/antclim21/), PAIS = Past Antarctic Ice Sheet Dynamics (https://www.scar.org/science/pais/pais/), SERCE = Solid Earth response & influence on Cryospheric Evolution (https://www.scar.org/science/serce/serce/), ANTECO = State of the Antarctic Ecosystem (https://www.scar.org/science/anteco/home/).

The programme is structured into 4 Themes (Fig. 1):

1. **Atmosphere-Ice Interactions:** Improved understanding of atmospheric forcing processes on ice sheet dynamics.
2. **Ocean-Ice Interactions:** Improved understanding of ocean forcing processes of marine-based ice sheet dynamics.
3. **Earth-Ice Interactions:** Improved understanding of solid Earth processes and feedbacks on ice sheet dynamics and regional to global non uniform sea-level variations.
4. **Science-Stakeholder Interactions - Antarctica's contribution to sea-level change - *with improved knowledge of instabilities, thresholds and impacts*.** Here the aim is to integrate the science outputs of Themes 1-3 and improve our ability to reconstruct and predict the Antarctic ice sheet contribution to sea-level change and reduce uncertainties. We will provide greater understanding to policy-makers, practitioners/operators, and publics of the importance of improved projections of the Antarctic contribution to global sea-level change, as well as their impacts and implications.

INSTANT will implement the research in each Theme using a proven integrated data-model approach that involves:

1. Recent observations and paleo-reconstructions of the ice-atmosphere-ocean-Earth system, identifying forcings, feedbacks, and rates of change.
2. Process understanding at all time scales.
3. Modelling at all time scales (reconstructions and projections).
4. Engagement with representative stakeholders throughout the SRP.

Key contributions of INSTANT are at the interface of science and policy, and will involve engagement between earth system scientists, social scientists, practitioners, decision-makers, planners and publics. Stakeholder engagement and science communication will play an important role in this SRP. INSTANT will provide scientific evidence to assess the effectiveness of, and risks associated with, climate change mitigation pathways (e.g. UNFCC[2] Paris Agreement). This evidence will also guide adaptation approaches required to avoid the worst impacts, such as coastal flooding and erosion, groundwater inundation and salination, habitat loss and large-scale human migration. The impacts of sea-level and ice sheet change around Antarctica are also of critical interest to CCAMLR[3], COMNAP[4] and Antarctic Treaty System parties, as they will have profound implications for key Antarctic stakeholder groups including national programme operations, tourism and fisheries.

[2] UNFCCC = United Nations Framework Convention on Climate Change
[3] CCAMLR = Commission for the Conservation of Antarctic Marine Living Resource
[4] COMNAP = Council of Managers of National Antarctic Programs

A. Introduction

This is a Science and Implementation Plan (SIP) for a new Scientific Research Programme (SRP), entitled "INStabilities & Thresholds in ANTarctica (INSTANT) – *The Antarctic Contribution to Sea-Level Change".* INSTANT addresses one of the highest priority issues facing climate change science - *the question of Antarctica's uncertain contribution to sea-level change*. It utilises an integrated multidisciplinary Earth systems approach combining geoscience, physical sciences, biological sciences and social sciences to improve our understanding of the interactions between the ocean, atmosphere, solid Earth and cryosphere. INSTANT will be a SCAR umbrella programme that will work with its partners (WCRP, PALSEA, PMIP)[5] and other SCAR Groups to facilitate a step-change in our knowledge on processes and feedbacks that influenced ice-sheets in the past, are influencing observed ice sheet changes, and will influence Antarctica's contribution to future global sea-level change. The goal of INSTANT is to…

"Quantify the Antarctic ice sheet contribution to <u>past</u> and <u>future</u> global & regional sea-level change, from improved understanding of atmosphere, ocean and solid Earth interactions and feedbacks with the ice sheet, so that key stakeholders can better anticipate and assess the risk in order to manage and adapt to sea-level change and evaluate mitigation pathways".

The programme is structured into 4 Themes (Fig. 1):

1. **Atmosphere-Ice Interactions:** Improved understanding of atmospheric forcing processes on ice sheet dynamics, and vice-versa.
2. **Ocean-Ice Interactions:** Improved understanding of ocean forcing processes of marine-based ice sheet dynamics, and vice-versa.
3. **Earth-Ice Interactions:** Improved understanding of solid Earth processes and feedbacks on ice sheet dynamics and regional to global non-uniform sea-level variations.
4. **Science-Stakeholder Interactions - Antarctica's contribution to sea-level change - *with improved knowledge of instabilities, thresholds and impacts*.** Here the aim is to integrate the science outputs of Themes 1-3 and improve our ability to reconstruct and predict the Antarctic ice sheet contribution to sea-level change and reduce uncertainties. We will provide greater understanding to policy-makers, practitioners/operators, and publics of the importance of improved projections of the Antarctic contribution to global sea-level change, as well as their impacts and implications.

A lack of understanding concerning Antarctica's contribution to sea-level change is identified as a critical knowledge gap in the Intergovernmental Panel on Climate Change's (IPCC's) recently published Special Report on the Oceans & Cryosphere in a Changing Climate (SROCC), and Special Report on Global Warming of 1.5°C (SR1.5), as well as SCAR's

[5] WCRP = World Climate Research Programme (https://www.wcrp-climate.org/core-projects), PALSEA = Paleo Constraints on Sea-Level Rise (https://palseagroup.weebly.com/about-us.html), PMIP = Paleoclimate Modelling Intercomparison Project (https://pmip.lsce.ipsl.fr/), CMIP = Coupled Model Intercomparison Project (https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6)

Horizon Scan, and the SCAR and WCRP strategic plans[6]. International climate and Antarctic research bodies, such as SCAR and the WCRP, are developing research strategies that more directly address the role Antarctica plays in the rapid pace of environmental change, the risks facing humanity and the growing global sustainability problems it brings. SCAR also recognises the importance of the global adoption of the UN Sustainable Development Goals (SDGs)[7], and initiatives to give effect to them, such as Future Earth[8] and the Global Framework for Climate Services (GFCS)[9].

The new SRP will draw upon, realign, refocus and further develop much of the high-impact research capacity that already exists within the ANTCLIM[21], PAIS, SERCE and ANTECO SRPs[10]. This capability will map into Themes 1-3 to more effectively quantify the past and future response of the Antarctic ice sheet to climate change as well as ice sheet meltwater impacts on regional to global climate (Fig. 1). Themes 1-3 will feed into an Integrated Theme 4 focussed, throughout the programme's lifetime, on applied science and services, and including social scientists to help understand the science-policy interface and to integrate revised ice mass loss and sea-level projections within risk assessment, practitioner and policy contexts. The outcomes of the SRP will include improved ice mass loss projections for scenario-based (e.g. IPCC), probabilistic sea-level projections in forms that are of direct benefit to stakeholder groups.

This will be of interest to a broad range of end-users concerned with anticipating and managing the impacts of sea-level change including, decision-makers, regulators, planners, civil society, indigenous communities, business and industry, including agricultural, maritime, infrastructure, finance and insurance sectors. Stakeholder engagement and science communication will play an important role in this SRP because the outcomes of INSTANT will provide evidence to assess the effectiveness of, and risks associated with, climate change mitigation pathways (e.g. UNFCC[11] Paris Agreement). These outcomes will also guide adaptation approaches required to avoid the worse impacts, such as coastal flooding and erosion, groundwater inundation and salination, habitat loss and widespread human migration. The impacts of sea-level and ice sheet change around Antarctica are also of critical interest to CCAMLR[12], COMNAP[13] and Antarctic Treaty Parties, as they will have profound implications for key Antarctic stakeholder groups, including National Antarctic Programmes, tourism operators and fisheries.

INSTANT research will complement and work with existing SCAR Groups, such as AntArchitecture[14], BEDMAP-3, PRAMSO, ACCE, ASPeCT, FRISP, ISMASS, IPICS[15], as well as

---

[6] SROCC (https://www.ipcc.ch/srocc/), SR1.5 (https://www.ipcc.ch/sr15/), SCAR Horizon Scan (https://www.scar.org/about-us/horizon-scan/overview/), SCAR Strategic Plan (https://www.scar.org/about-us/futureplans/strategic-plan/), WCRP Strategic Plan (https://www.wcrp-climate.org/wcrp-sp), WCRP-Climate & Cryosphere (CLIC) action plan (http://www.climate-cryosphere.org/about).
[7] https://www.un.org/sustainabledevelopment/sustainable-development-goals/
[8] https://futureearth.org/
[9] https://gfcs.wmo.int/node/219
[10] ANTCLIM[21] = Antarctic Climate Change in the 21st Century (https://www.scar.org/antclim21/), PAIS = Past Antarctic Ice Sheet Dynamics (https://www.scar.org/science/pais/pais/), SERCE = Solid Earth response & Influence on Cryopsheric Evolution (https://www.scar.org/science/serce/serce/), ANTECO = State of the Antarctic Ecosystem (https://www.scar.org/science/anteco/home/).
[11] UNFCCC = United Nations Framework Convention on Climate Change
[12] CCAMLR = Commission for the Conservation of Antarctic Marine Living Resource
[13] COMNAP = Council of Managers of National Antarctic Programs
[14] https://www.scar.org/science/antarchitecture/home/
[15] https://www.scar.org/science/psg/home/

new initiatives as they develop, including the new SRPs (Fig. 1). This complementarity will be achieved through cross-membership on Steering Committees, the joint development of key objectives and action plans, and the identification of potential synergies and collaborative research. Each Theme will have key research questions, which will encompass SCAR Horizon Scan questions and other emerging issues that are priority research areas by key end users, policy makers, the SCAR scientific community or other relevant stakeholders.

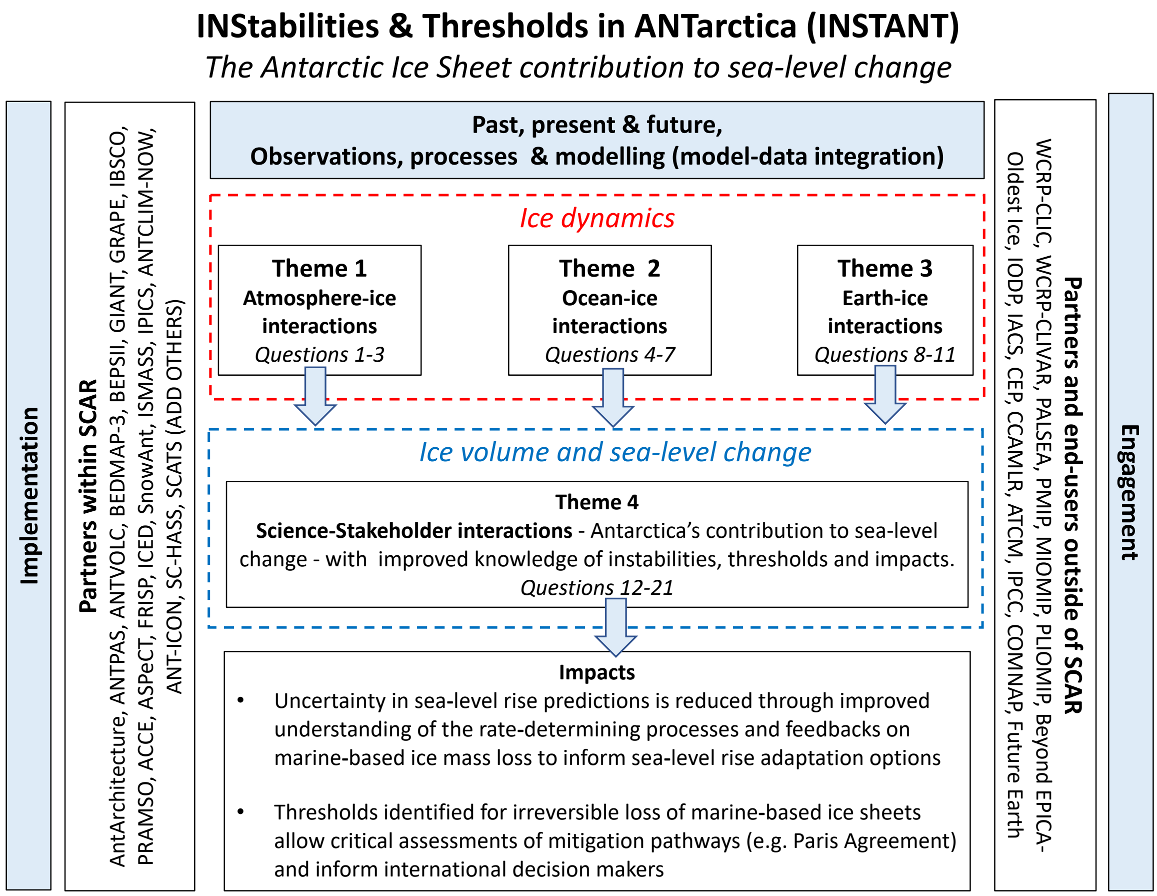


Figure 1: Proposed structure, approach and impacts of the INSTANT Strategic Research Programme

B. Scientific Approach and Rationale

Over the past eight years, four of SCAR's SRPs - PAIS, ANTCLIM[21], SERCE & parts of ANTECO together with the ISMASS[16] expert group (joint with IACS[17] & WCRP) have seen a convergence of activity on understanding the role of Antarctica and the Southern Ocean in the dynamics of the Earth System, especially global sea-level change and ocean carbon uptake. Among the many outcomes thereof, there is now widespread agreement that a future research programme is needed that should take a more integrated approach involving interactions between the atmosphere, ocean, cryosphere and solid Earth, and their influence on ice-sheet mass balance, but also involving the impact of ice sheet

[16] ISMASS = Ice Sheet Mass Balance and Sea-level project (http://www.climate-cryosphere.org/activities/ismass)
[17] IACS = International Association of Cryospheric Sciences (https://cryosphericsciences.org/)

meltwater on the regional to global climate. In addition to a wide range of more traditional approaches to the interdisciplinary work, novel areas of endeavour to inform past and future behaviour of the ice sheets will be utilised. For example:

(i) The use of genomics to constrain past ice-sheet configurations (*Strugnell et al. 2018*).
(ii) A constantly evolving suite of geochemical proxies and molecular biomarker tools for reconstructing past environmental conditions (e.g. *Wilson et al., 2018; Duncan et al., 2019; Klages et al., 2020, Jimenez-Espejo et al., 2020*).
(iii) Subglacial drilling access for understanding changes in past ice extent and basal hydrology (e.g. *Christner et al*., 2014; *Kingslake et al.,* 2018).
(iv) Integration with far-field sea-level reconstructions to constrain ice sheet sensitivity (e.g. *Dutton et al., 2015; Grant et al., 2019*),
(v) Higher resolution spatial mapping of sub-ice topography (*Morlighem et al., 2019*), sub-ice shelf bathymetry (*Tinto et al., 2019)* and paleogeographies *(e.g. Paxman et al., 2019),*
(vi) Longer observational records with better spatial coverage of ice, ocean and atmosphere (e.g. *Rintoul, 2018; Rignot et al., 2019; Bindoff et al., 2019*). Earth observation satellite data integrated with in-situ observations and modelling for the polar regions is a high-priority (e.g. EO4POLAR[18]).
(vii) Increasingly more sophisticated numerical realisations of ice sheet dynamics (e.g. *Pattyn et al.*, *2018*).
(viii) Statistical emulators to assess uncertainty (e.g. *Edwards et al*., 2019).
(ix) A processes-based understanding of feedbacks in the coupled Earth system (e.g. *Golledge et al., 2019*), especially ocean-ice (e.g. *Colleoni et al., 2018*; *Pattyn & Morlighem*, 2020) and solid Earth-ice (e.g. *Whitehouse et al*., 2019, *Smith et al., 2019*) interactions.

Global mean sea level (GMSL) has increased by ~22 cm since 1880, is the clearest global response to anthropogenic global warming, and will continue to rise well beyond the 21st century. Into the future, quantifying the pace of rise and our long-term commitment to higher seas is essential. At the current rate of CO_2 emissions, global mean temperatures will be 1.5°C and 2°C above pre-industrial levels in approximately 10 and 20 years, respectively (*IPCC, 2018*). Stabilisation at 1.5°C now requires direct carbon removal from the atmosphere. The global community depends on Antarctic scientists to generate new knowledge into ice sheet response to this projected warming and to integrate this knowledge with colleagues working on other components of the Earth system.

Improved understanding of Antarctic ice sheet contribution to future GMSL rise was one of the most urgent research priorities to emerge from the IPCC 5th Assessment Report (*IPCC, 2013*) which predicted between 52 and 98 cm of sea-level rise (SLR) by 2100, for its range of future emission scenarios known as the representative concentration pathways (RCPs). The AR5 estimates were limited by a lack of scientific knowledge of Antarctic ice sheet dynamics, so it provided the following caveat, “based on current understanding, only the collapse of marine-based sectors of the Antarctic Ice Sheet, if initiated, could cause global mean sea-level to rise substantially above the *likely* range during the 21st century”(*Church et al*., *2013*).

[18] EO for Polar Science Workshop, http://eo4polar.esa.int/

The problem is that since 2013, continental-scale estimates of future Antarctic ice loss, under a range of greenhouse gas (GHG) emissions scenarios, imply significantly higher plausible GMSL rise for RCP 8.5 - upper bound of the IPCC AR5 range (*Levermann et al*., 2014; *Golledge et al*., 2015; *Ritz et al*., 2015; *DeConto & Pollard*, 2016; *Bulthuis et al*., 2019; *Golledge et al*., 2019; *Edwards et al*. 2019). The models used for sea-level projections show that acceleration in mass loss observed by satellites over the last 10 years will continue (e.g. *Shepherd et al., 2012; IMBIE, 2018*), resulting in the polar ice sheets becoming the dominant contributor to global mean sea-level by mid-century. All the models provide probabilistic information, but vary considerably, both in their physical approaches and their resulting projections of Antarctica's future contribution to global mean sea-level.

To date, the various ice sheet model formulations, including the choice of grounding line parameterisations and basal sliding schemes, can strongly affect model response to a given forcing (*Brondex et al*., 2017; *Pattyn*, 2017), although sophisticated statistical methodologies have been increasingly used since AR5 to quantitatively gauge model uncertainty (*Bulthuis et al*., 2019; *Edwards et al*., 2019). Geomorphological studies (e.g. *Simkins et al., 2017*) show the complexity of subglacial morphology and hydrology that must be taken into consideration when modelling ice sheet behaviour. Although progress has been made (e.g. *Morlighem et al., 2019*), these data are still too sparse and INSTANT will promote more collection of novel data sets to better constrain ice-bed processes for use in models of ice sheet dynamics. Accurate atmospheric forcing of surface mass balance and sub-ice shelf melt are required to resolve the time-evolving dynamics of the system, with sub-ice melt rates being particularly important (*Schlegel et al*., 2018). An important ongoing deficiency, that INSTANT will contribute to, is the lack of ice-ocean coupling in most continental-scale models, which has been too computationally expensive to simulate the ocean at the spatial and temporal scales necessary to capture circulation in ice shelf cavities and time-evolving ice-ocean interactions (*Donat-Magnin et al*., 2017; *Hellmer et al.,* 2017).

Currently, most ocean-driven ice mass loss changes are observed in West Antarctica, which is predominantly marine-based and thus highly vulnerable to ocean warming. Dynamic ice loss driven by ocean changes has also been observed on the East Antarctic margin (*Li et al*., 2016; *Shen et al*., 2018). This is an important development, because East Antarctica contains much more ice than West Antarctica, so even minor changes there could make major contributions to sea-level rise in the future. Paleoclimate archives and reconstructions support the potential for East Antarctica ice loss in response to small increases in global GHGs and temperature (*Cook et al., 2013, Patterson et al., 2014, DeConto & Pollard, 2016; Levy et al., 2016; Gasson et al., 2016; Wilson et al., 2018, Aitken et al., 2016*).

In SROCC the likely (13-87 percentile) range for Antarctic Ice Sheet loss is equivalent to 2-28 cm of sea-level rise by 2100 under RCP8.5 (*IPCC*, *2019*). This range reflects our ongoing limited understanding of the physics and interactions/feedbacks, and the fact that individual studies only reflect part of the total uncertainty. The 5-95 percentile range has a significantly higher upper bound of up to 40 cm SLR by 2100, due to Antarctic ice loss. The skew to higher values is consistent with an expert elicitation study (*Bamber et al., 2019*), but the latter suggests considerably higher values for Antarctic contribution to sea-level rise than SROCC, for all representative concentration pathways (e.g. 95 percentile of 57cm).

Therefore, the response of Antarctica to projected warming still remains the single greatest uncertainty in SLR projections for the coming decades to centuries. Central to this uncertainty are poorly observed rate-determining processes affecting the dynamic response of ice sheets (*Pattyn et al., 2018*). Processes warranting attention control grounding zone migration rates, changes in the buttressing of grounded ice by ice shelves, marine ice sheet stability, calving dynamics and ice-cliff stability. SCAR scientists are at the forefront of research designed to reduce this uncertainty.

Sea-level change from land-based ice melting does not cause globally uniform sea-level rise (SLR). The delivery of ice to the ocean changes Earth's gravitational field and rotational state. This, together with the accompanying viscoelastic response of the solid Earth to ice loss (a process known as glacial isostatic adjustment; GIA), means that locations near a melting ice sheet experience less SLR than more distant locations, with deviations reaching 30% of the global mean. Crucially, these processes also feedback into ice sheet dynamics (*Gomez et al. 2010; Kingslake et al., 2018; Whitehouse et al., 2019*), and unlike most feedbacks which are positive, GIA might help stabilize a retreating ice margin by creating subglacial pining points (Fig. 2). Understanding the role of GIA and mantle dynamics within the ice sheet system is a critical area of enquiry.

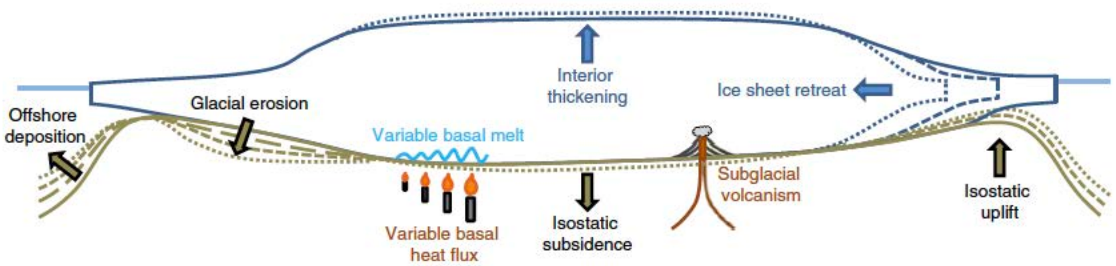


Figure 2. Summary of interactions between the solid Earth and the Antarctic Ice Sheet (Whitehouse et al., 2019)

The skill and performance of some ice sheet models (*Golledge et al., 2015; Ritz et al., 2015; DeConto & Pollard, 2016; Golledge et al., 2017*) have been developed and tested within the SCAR programmes (PAIS, ISMASS, SERCE) on past cold (*Golledge et al., 2014; Gomez et al*. 2015, *Konrad et al*. 2015, *Pollard et al*. 2017) and warm climate analogues (*Pollard et al., 2015; Levy et al., 2016; Gasson et al., 2016; Golledge et al., 2017*), constrained by geological data (*Naish et al., 2009; Smellie et al., 2011; Miller et al., 2012; McKay et al., 2012; Whitehouse et al., 2012; Briggs and Tarasov, 2013; Cook et al., 2013; Patterson et al., 2014; Levy et al., 2016; Grant et al., 2019*).

Some of these models also imply that a (de)stabilisation threshold may exist in the Antarctic ice sheet system. Although there is low confidence in the results, stabilising Earth's mean temperature below 2°C - the Paris Climate Agreement goal (RCP 2.6), could reduce long-term Antarctic ice loss to less than half a metre of SLR (*Golledge et al., 2015; DeConto & Pollard, 2016; Pattyn et al., 2018*). The threshold response is related to the buttressing role of ice shelves. But what processes lead to the destabilisation of Antarctic ice shelves and how do these relate to global mean surface temperature? Above 2°C global warming, enhanced melting, calving, and catastrophic collapse of ice shelves could occur, after which ongoing ocean warming will rapidly remove marine ice sheets grounded in deep sub-glacial basins. As climate change continues, the question becomes, when will we see amplified surface warming around Antarctica, and is there a temperature threshold for increased mass loss of the land-based ice sheet? Paleoclimate studies imply that there is a carbon-dioxide threshold (e.g. *Levy et al., 2016; 2019*).

Finally, and most significantly, because the magnitude of climate forcing projected for the next century has not been experienced by Earth for more than 3 million years, paleoclimate reconstructions of past Antarctic ice sheet response provide critical insights into its future behavior (*Naish et al., 2009; Patterson et al., 2014; Cook et al., 2015; Levy et al., 2016; McKay et al., 2016; Shakun et al., 2018*). The influence of both ocean dynamics and solid Earth deformation on ice sheet dynamics are yet to be assessed against these past policy-relevant warm climates.

Warm intervals are not all the same. There were "warmer-than-present" intervals in the past coinciding with higher atmospheric CO_2 concentrations, but also times when CO_2 concentration was at pre-industrial levels, and orbital forcing was more important, causing warming that reduced ice volume dramatically (*Dutton et al., 2015*). The response of the Antarctic ice sheet to climate change can be of the order of decades to millennia, therefore the ice sheet change that we observe today is the product of recent atmospheric and ocean warming, but also an ongoing solid Earth response to a climate perturbation that occurred thousands of years ago (e.g. GIA). Predictions that are limited to centennial time scale often do not consider processes related to the long time inertia of the Antarctic Ice sheet system, and therefore, miss an important aspect when trying to constrain sensitivity and commitment to future long-term changes.

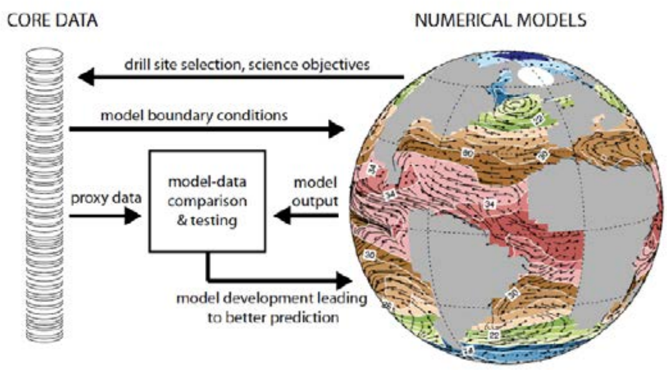
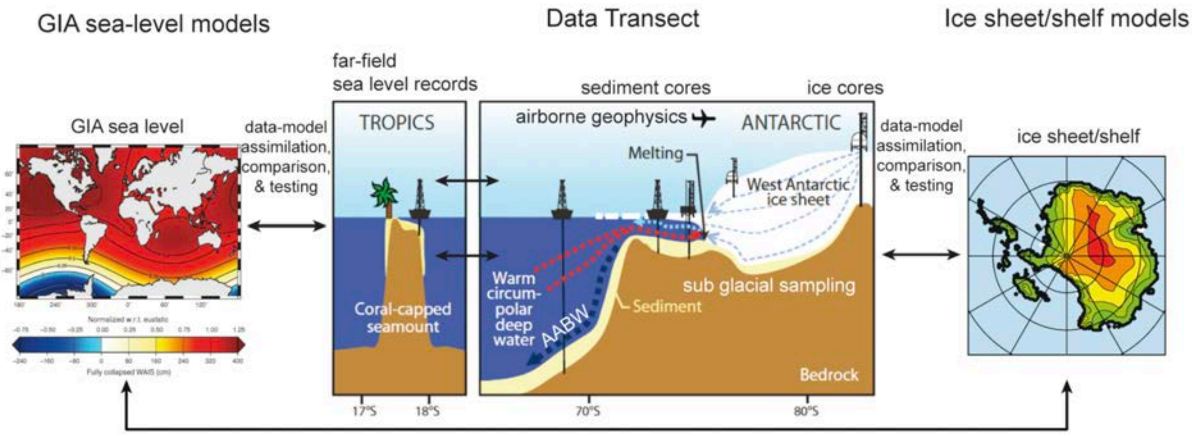


Figure. 3. INSTANT will continue to use highly successful model-data integration approaches developed in predecessor SCAR programme PAIS. A schematic representation of the "ice-to-sea" transect concept, extending from the ice sheet interior, along an ice flowline, and offshore to the tropics. The meridional transect links Antarctic ice sheet changes to both proximal and far field records of ice volume, ice sheet geometry, and sea level. The data-data and data-model concept links on-ice, proximal, and far-field records with the new generation of ice sheet models, including GIA models of time-evolving global sea level (modified from 2013-2023 IODP Science Plan and the PAIS SRP Science & Implementation Plan).



We will utilise sedimentary and ice core records of past ice sheet change, that provide key constraints on the long-term (multi-centennial to millennial) cryospheric response to climate and ocean conditions different from today. They capture the 'end-game' scenario that incorporates Earth system feedbacks across timescales (e.g. *Colleoni et al., 2018*), allowing a clearer picture of the full equilibrium shift (long-term commitments) that might occur under perturbed environmental conditions. Short-term projections of future ice sheet-derived sea-level rise (decades to centuries) are, by contrast, more accurately constrained by satellite-based measurements of ice flow speed or surface elevation changes, but can suffer from process-knowledge gaps, such as incompletely known ice dynamic responses, or ice-ocean-atmosphere interactions that play out over millennial timescales (such as isostatic rebound, dynamic topography, deep ocean circulation etc.).

A major focus of INSTANT will be to increase the amount and coverage of observations, especially in key areas such as the continental margin, Southern Ocean, ice shelf cavities, subglacial conditions, englacial properties, and ice surface, that will allow processes to be properly evaluated, boundary conditions to be constrained and model outputs to be validated. Such observations will involve geodetic, glaciological, geophysical, geological, oceanographic, and atmospheric communities, and will be dependent on the availability and development of continent-wide observing infrastructure including airborne and space-based remote sensing. INSTANT will support initiatives to leverage more of these observations. This will also include past (paleo) observations, which are reconstructed from ice and sediment cores, including proxies of environmental change, and provide key insights into the role of changing boundary conditions and processes allowing model-data validation for warmer climate worlds. INSTANT will help support researchers to access geomorphological and geological archives, make observations of modern and recent processes, and develop and use numerical models to reconstruct past changes and make projections. INSTANT will continue the highly successful model-data integration approach developed in predecessor SCAR programmes (e.g. Fig. 3).

Antarctic stakeholder engagement. Building on existing work by members of the SCAR *Standing Committee on the Humanities and Social Sciences (SC-HASS)* on the Antarctic science-policy interface (e.g. *Brysse et al., 2013; Hughes et al., 2016 & 2018*), science communication (*Salmon et al., 2017*), perceptions around Antarctic climate science (*O'Reilly 2015 & 2016*), and Antarctic governance in the Anthropocene (*Stephens, 2018; Dodds, Hemmings & Roberts, 2017*), INSTANT will work with a representative sample of the considerable stakeholder community (ATCM, COMNAP, policy-makers, key representatives of the business sector, including IAATO and tourism operators, finance and insurance companies, fisheries, etc.) to understand their needs and interests in this topic to enable them to become genuine partners in the research. Recent research (*Priestley et al., in prep.*) shows that publics in New Zealand have a poor understanding of sea-level rise, and it is currently not clear whether decision-makers have a better understanding of this topic. Consequently, as part of this SRP, we will undertake broader international public surveys to gauge stakeholder and public understanding of sea-level rise and then test the effect of different narrative framings of how we talk about SLR with different groups.

Sea-level & coastal hazards stakeholder engagement. Societal concerns about sea level rise originate from the potential impact of regional and coastal sea level change and associated changes in extremes on coastlines around the world, including potential shoreline recession, loss of coastal infrastructure, natural resources and biodiversity, and in the worst case, displacement of communities and migration of environmental refugees. By the end of the 21st century, it is very likely that a large fraction of the world's coasts will be affected by climate-induced sea level rise. A key uncertainty for coastal zone management, and sea-level rise projections on the 100-year time frame, is the contribution of the Antarctic ice sheet. End-users, can have widely varying tolerance for risk. In order to ensure end-users are connected with and understand the importance of the latest science and evolving uncertainties we will work with established initiatives, such as the WCRP "Sea Level Rise and Regional Impacts Grand Challenge"[19]. Their goal is to foster the development of sea-level projections that are of increasing benefit for coastal zone management. This involves close interaction with relevant coastal stakeholders to make sure that results of the proposed scientific research are most useful for coastal zone management, and impacts and adaptation efforts.

C. Experimental section and methodologies

INSTANT will support the implementation of projects that encompass all 3 ice dynamic themes (**Atmosphere-Ice Interactions, Ocean-Ice Interactions, Earth-Ice Interactions)**, so that we will be able to robustly assess both short-term, policy relevant, scenarios as well as the longer-term changes that will be 'locked-in' by current and projected emissions trajectories though science-stakeholder interactions. We will implement the research in each Theme (Fig.1) using a proven integrated data-model approach that involves:

1. Recent observations and paleo-reconstructions of the ice-atmosphere-ocean-Earth system, identifying forcings, feedbacks, and rates of change (Fig. 4).
2. Process understanding at all time scales (Fig. 5).
3. Modelling at all time scales (reconstructions and projections).
4. Involvement of a representation of stakeholders throughout the lifetime of the SRP

[19] https://www.wcrp-climate.org/gc-sea-level, http://www.clivar.org/research-foci/sea-level

Sedimentary archives integrated with climate and ice sheet model simulations will enable us to reconstruct the size and extent of past ice sheets during snap shots of key warm climate intervals. It will be then possible to evaluate ice sheet volume changes in response to past climate forcings that were similar to those projected for the coming decades and centuries. This approach also enables identification of tipping points and thresholds that have yet to be observed in the modern setting. Sedimentary records also provide details of ice-ocean-sediment interaction, and together with simulations of oceanic circulation coupled to dynamic ice sheet and Earth deformation models grounded in an observation-based understanding of modern processes, provide powerful insights into how the ice sheets responded in the past and will respond in the future. The acquisition of ice and geological archives will follow a strategy successfully implemented in PAIS, whereby critical elements of the integrated Antarctic ice sheet system are sampled along transects from the ice sheet to the ocean abyss (Fig. 3). The PRAMSO[20] sub-committee of PAIS is now a SCAR Action Group and will be critical in facilitating proposals to the IODP, ICDP and the ice core community for future drilling (e.g. Siple coast, Ekstrom Ice Shelf, Conrad Rise, Wilkes Land continental shelf, Totten Glacier & Sabrina Coast, Antarctic Peninsula sediment drifts, Beyond EPICA Oldest Ice[21])

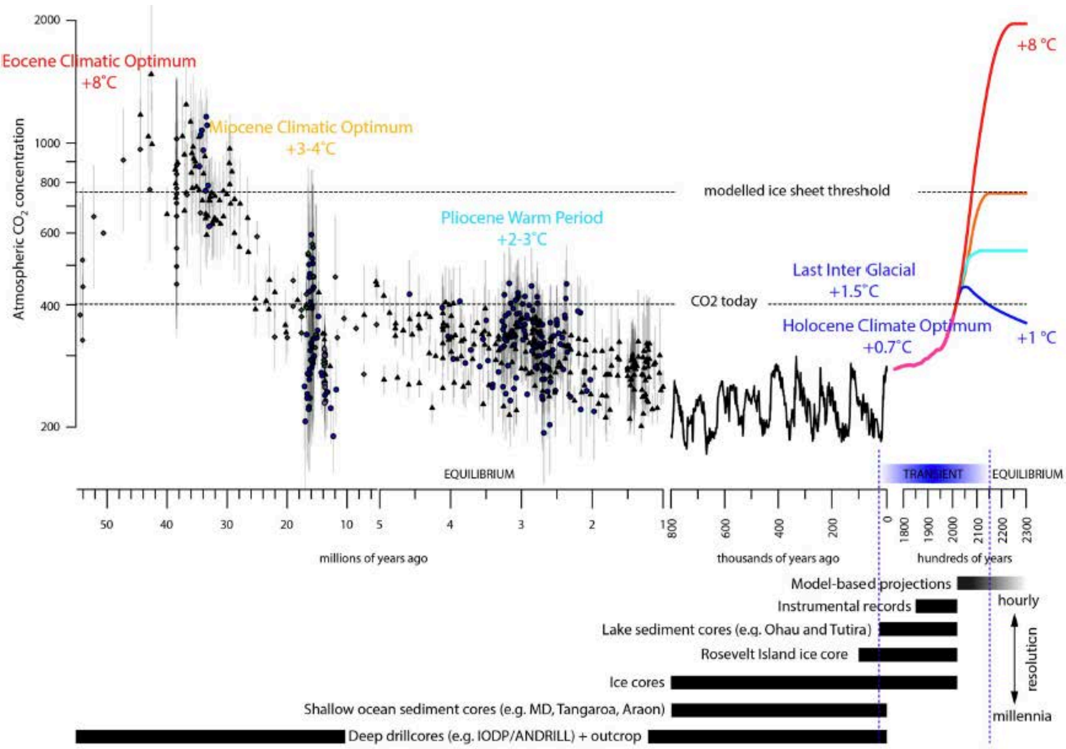


Figure 4. Representation of how paleoclimate archives and modern observations complement each other in observing and reconstructing Earth system responses to past and present atmospheric carbon dioxide concentrations providing context for projections (Fig. is based on NZ example).

To further improve ice sheet model skill, we will focus on generating new detailed knowledge of the current state and processes that control ice sheet dynamics. To this end we will obtain geological, geodetic and geophysical, remote and direct measurements from

[20] PRAMSO = Paleoclimate Records of Antarctic Margin and the Southern Ocean
[21] https://www.beyondepica.eu/en/

beneath ice shelves, across grounding zones, and from ice streams and outlet glaciers, ice shelf surface and off shore coast and ocean. These constraints will include sub ice-shelf bathymetry, ice stream basal conditions, englacial properties, ice shelf cavity, oceanic currents, temperature, and salinity and sea ice distribution. An aspect that INSTANT will address, is how to deconvolve local versus regional signals from ice and sedimentary archives in order to estimate time-evolving dynamics of the system (e.g. *Mezgec et al., 2017*). Both paleo and modern constraints will inform simulations using a range of numerical modelling approaches, including high-resolution catchment scale glacial models, regional atmosphere and ocean models, continental-scale ice sheet models coupled to both cavity-resolving regional ocean models, atmosphere or coupled climate models and Earth (GIA) models. Collaborations with the new SRP Antclim^{now} and with WCRP, ISMASS and PMIP groups will be critical for facilitating improvements in ice sheet, ocean and climate modelling.

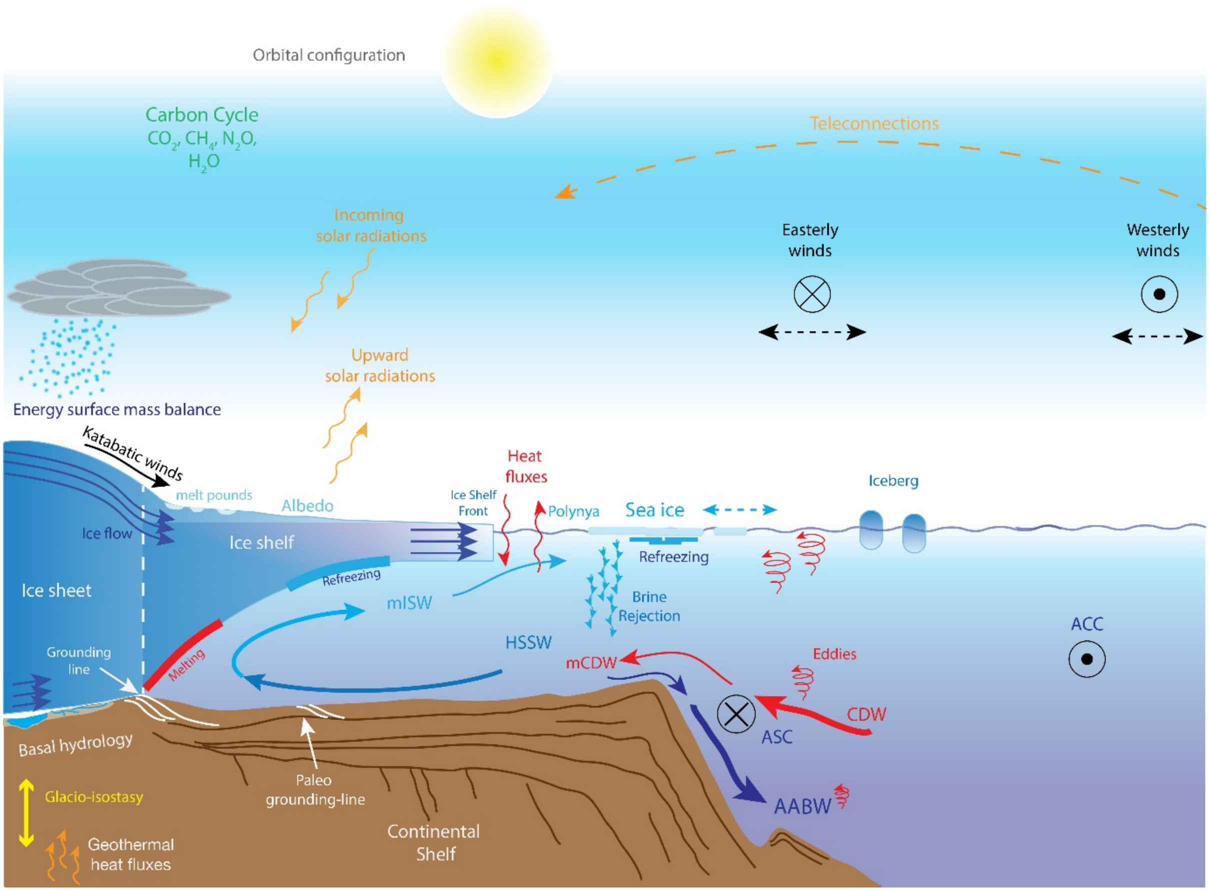


Figure 5. Conceptual and simplified view of the Antarctic polar system illustrating key feedbacks and processes (Colleoni et al., 2018).

Theme 1 - Atmosphere-ice interactions

This theme addresses a lack of knowledge of Antarctic climate and surface mass balance (SMB) changes, which was highlighted by the fifth IPCC assessment report (AR5) as one of the main uncertainties both for Antarctic climate (*Bindoff et al., 2013*), ice sheet and global sea-level projections (*Church et al., 2013*). The challenge of understanding the processes shaping SMB patterns at different time and spatial scales in polar regions requires both improved observations and modelling (*Frezzotti et al. 2013, Thomas et al., 2017*), which was a focus of the ANTCLIM[21] SRP, and requires collaboration with researchers studying other aspects of the AIS system, which will be facilitated by INSTANT. In addition, we intend to have strong linkages between this theme and new ANTCLIM^{Now} SRP, which aims to improve understanding of near-term decadal climate predictability. Consequences of mass balance changes in Antarctica are of global importance, as they directly affect global mean sea-level changes (*Shepherd et al. 2012*). Like the ice sheet dynamics, there is growing evidence that Antarctic climate and SMB appears to be strongly influenced by the evolution of the Southern Ocean and sea-ice field (*Zhang et al., 2019*). In areas where surface melt remains minor, the spatial and temporal variability in SMB can mainly be attributed to snowfall and snowdrift processes (e.g. *Eisen et al., 2008*). In the future, increasingly large parts of the coastal Antarctic will be characterized by higher accumulations rates, but also higher snow melt rates (*Trusel et al., 2015; Medley et al., 2018*), as was the case during warmer-than-present past periods. Associated complex processes like snowdrift (*Dadic et al., 2010)*, meltwater refreezing in the snowpack and meltwater storage and drainage (*Kingslake et al., 2017; Arthur et al., 2020*) need to be well-represented in climate models in order to correctly simulate the ice sheet SMB and meltwater discharge into oceans. Another important process is refreezing melt ponds for ice formation (*Hubbard et al., 2016*) that can lead to ice-shelf destabilisation by hydro-fracturing. Surface melting processes and feedbacks will become an increasingly important control on ice sheet mass balance as a zonally-amplified surface warming signal emerges.

Climate models still fail to accurately reproduce multi-decadal SMB trends at a regional scale, and progress has been limited by the challenge of correctly representing atmospheric circulation changes related to complex ocean/ice/sea-ice/atmosphere inter-actions. Finally, progress in reducing the uncertainties relative to projections of the future and past SMB of Antarctica largely depends on available ice and sediment core records, climate model skill in simulating teleconnections between low and mid-latitudes, and on the ability to correct for biases, considering the coupling between ocean, ice, and atmosphere in high southern latitudes (*Favier et al. 2017*).

Priority research questions.

1. *What processes control surface mass balance (SMB) on different spatial and temporal scales?*
    - *What is the impact of local (SAM, ASL) to tropical teleconnections (ENSO, IPO, PSA) on temperature and precipitation pathways in the past and in the future?*
    - *How does sea-ice extent influence temperature and precipitation along the low-elevation zones of Antarctica?*
2. *What processes control polar amplification on different spatial and temporal scales (collaborative with AntClim^{Now})?*
    - *How do the latitudinal temperature and precipitation gradients change through time, both in the past and in model projections, and what are the roles of teleconnections, sea ice extent, ice sheet extent, ozone, GHGs, Southern hemisphere Westerly Winds, ocean dynamics?*
    - *When will we see amplified surface warming around Antarctica?*
3. *How does supraglacial hydrology influence Antarctic ice sheet dynamics?*
    - *When does Antarctica become like Greenland?*

- *What is the distribution of melting and supraglacial water (and its relationship to atmospheric and ocean conditions?*
- *What are the mechanisms of meltwater drainage, ice sheet calving and ice shelf mass wasting?*

Theme 2 - Ocean-ice interactions

About a third of the Antarctic Ice Sheet (AIS) is a 'marine ice sheet', i.e. it rests on bedrock below sea level with most of the ice-sheet margin terminating directly in the ocean, and it is capable of non-linear and rapid melting and calving due to instabilities. (*Golledge et al., 2015; Joughin et al., 2014; Alley et al., 2015*; *DeConto & Pollard, 201*6; *Phipps et al., 2016*; *Colleoni et al., 2018*). In many places around the AIS margin, the seaward-flowing ice forms floating ice shelves. Ice shelves in contact with bathymetric features on the sea floor or confined within embayments provide back stress (buttressing) that impedes the seaward flow of the upstream ice and thereby stabilizes the ice sheet. The ice shelves are thus a key factor controlling AIS dynamics. Almost all Antarctic ice shelves provide substantial buttressing (*Fürst et al., 2016*), but some are currently thinning at an increasing rate (*Paolo et al., 2015; Khazendar et al., 2016*). Antarctic ice sheets lose roughly 50% of their mass through the basal melt of ice shelves, with the remaining mass lost by calving at the ice shelf front and a minimal contribution from surface melt (*Rignot et al., 2019; Smith et al. 2020*). A key aim of this theme is to understand the influence of global ocean circulation, via a modified thermohaline circulation (THC), the ACC, and atmospheric circulation, on the flux of heat across the continental shelf into grounding lines and ice shelf cavities, and the role of associated dense saline water and freshwater feedbacks, including sea-ice, ocean stratification and polynyas (e.g. *Bronselaer et al., 2018*; *Golledge et al., 2019*). Bathymetry also plays an important role on controlling ice shelf melt rates (*Goldberg et al., 2020*). Ice shelf thinning and loss of buttressing can initiate grounding line retreat. If the grounding line is located on bedrock sloping downwards toward the ice sheet interior, initial retreat can trigger a positive feedback, resulting in a self-sustaining process known as Marine Ice Sheet Instability (MISI). The disappearance of ice shelves may allow the formation of ice cliffs, which may be inherently unstable. This ice cliff failure may also lead to ice sheet retreat via a process called marine ice cliff instability (MICI), that has been hypothesized to cause partial collapse of the marine-based parts of the Antarctic ice sheet within a few centuries (*Pollard et al., 2015; DeConto and Pollard, 2016*). A critical step in addressing the questions (below) involves understanding the role of ocean dynamics using reconstructions, observations and by ultimately coupling dynamic ocean models to ice sheet models. The latter was a focus of the ANTCLIM[21] SRP, but needs to be further developed inside INSTANT by investigating oceanographic interactions with present and past sea bed models. Also, in theme 2 as for theme 1, we intend to have strong linkages with the new ANTCLIM^{Now} SRP.

<u>Priority research questions.</u>

i. What drives oceanic heat exchange across the continental shelves and how does this influence the stability of marine based ice sheets?
- *What is the role of regional-scale circulation (Ekman pumping, mCDW inflow, AABW outflow, eddies)?*
- *What is the role of bathymetry?*

- *What drives oceanic heat advection to the continental margins (shift of the westerlies, teleconnections, intensity of coastal easterlies, oceanic gateways, production of dense saline water)?*

ii. *What is the role of ocean dynamics within and at the margins of the ice shelf cavities?*
- *What is the role of cavity-scale circulation on basal melt rates?*
- *What is the role of cavity bathymetry?*

iii. *What is the role of sea ice, polynyas and meltwater on controlling the flux of heat, carbon and salt between the ocean-atmosphere and implications for ice sheet stability?*
- *How do freshwater feedbacks influence melt rates under ice shelves and at grounding lines?*
- *How do freshwater feedbacks influence the inflow of mCDW and outflow of dense shelf water?*
- *How do freshwater feedbacks influence regional to global climate?*

iv. *How do ice and marine sediment records, genomic signatures and seismic stratigraphy inform us about ocean and ice sheet-ice shelf variability?*
- *What was the rate and pattern of ice sheet retreat during past deglaciations?*
- *What was the sensitivity of the ice sheet to past warmer climates (higher CO_2 and/or stronger orbital forcing)?*

Theme 3 - Earth-ice interactions

The solid Earth provides basal boundary conditions for ice flow. Ice streams draining the interior of Antarctica are known to accelerate and decelerate over decadal to centennial timescales in response to changes at their boundaries (e.g. *Joughin et al., 2014*). These flow-speed changes are triggered by a range of factors, but a first-order control on the ice dynamic response is the geometry and geology of the bed (*Hulbe et al., 2020; Anandakrishnan et al., 1*998), with water, both within the substrate and at the bed, playing a significant role (*Fricker et al., 2007; Sternes et al., 2008*). An important control on the presence of water at the bed, as well as the rheological properties of the ice, is geothermal heat flow[22]. Subglacial processes are poorly understood, and modelling demonstrates that basal friction and ice rheology are primary controls on ice dynamics (*Lubes et al., 2006*).

The shape of the bed also exerts a direct control on ice dynamics. Reverse sloping beds and topographic pinning points directly influence the rate and thresholds for marine-based ice sheet stability (*Matsuoka et al., 2015; Kingslake et al., 2018; Bart & Tulaczyk, S., 2020)*, while continental margin bathymetry controls the delivery of warm CDW to the ice margin (*Colleoni et al., 2018*). Crucially, the ice sheet has the capacity to alter its bed: glacial isostatic adjustment (GIA), erosion by ice and water, and the deposition of sediment directly alter the shape of the bed and continental margins. The interpretation of glaciological and geological records of ice sheet change therefore relies on understanding the rate and spatial pattern of erosion and deposition *(Paxman et al., 2019)*, the isostatic response to changes in ice, ocean and sediment loading (*Whitehouse et al., 2019*), and the influence of dynamic topography (*Austermann et al., 2015).*

---

[22] White paper on Antarctic geothermal heat-flux research https://www.scar.org/scar-news/serce-news/scar-serce-ghf/

Basal topography, in combination with local sea level, also determines the position and dynamics of the grounding line. Future models of Antarctic ice dynamics should account for the counter-intuitive result that locations near a melting ice sheet experience sea-level fall due to changes to Earth's gravity field and viscoelastic deformation, and vice versa. This negative feedback has the potential to delay or reverse grounding line retreat (*Gomez et al. 2010; Kingslake et al., 2018; Larour et al., 2019*), particularly in regions hypothesized to be underlain by weak mantle rheology. Significant progress has been made in these different research fields by PAIS and SERCE and their predecessor SRPs. INSTANT will build on that legacy and further development of coupled ice sheet-erosion-GIA models, that incorporate spatial variations in Earth rheology properties and are grounded in an observation-based understanding of modern processes. This is necessary to advance our understanding of the controls on ice sheet behavior and the interpretation of global records of sea-level change.

Priority research questions.

8. *What are the sub-glacial properties and processes relevant for past and future ice sheet dynamics?*
    - *What are the properties of, and processes operating at, the ice sheet bed?*
    - *What is the spatial heterogeneity of geothermal heat flow and to what extent does it influence subglacial hydrology and ice rheology?*
9. *What is the strength of the feedbacks between processes associated with glacial isostatic adjustment and ice dynamics?*
    - *What is the spatial pattern of Earth rheology beneath Antarctica?*
    - *What is the sensitivity of grounding line dynamics to the spatial resolution at which GIA and bathymetry are represented within models?*
10. *What is the role of geological controls and erosion and sedimentation on ice sheet dynamics?*
    - *What is the coupled evolution of the ice sheet and its bed?*
    - *How quickly can grounding zone wedges form and to what degree can they stabilize the grounding line?*
11. *How do glaciological, geological and geophysical records inform us about ice sheet and landscape (inc. submarine and sub glacial) evolution?*
    - *What does surface exposure dating tell us about the rate and magnitude of change in ice volume and extent?*
    - *What can provenance studies tell us about long-term evolution of the Antarctic Ice Sheet and underlying topography?*
    - *How can seismic stratigraphy integrated with sediment records resolve basin architecture and inform about paleogeography?*
    - *What does ice sheet stratigraphy tell us about englacial and basal processes?*
    - *How can submarine glacial landforms inform about past ice sheet dynamics*

Theme 4 - Science-Stakeholder Interactions - Antarctica's contribution to sea-level change - *with improved knowledge of instabilities, thresholds and impacts*.

This Theme addresses Antarctica's contribution to sea-level change, *with improved knowledge of instabilities and thresholds,* to multiple stakeholder groups . To ensure a meaningful integration of the science in this SRP with impactful outcomes, this theme requires contributions by social scientists that involve:

- **Inclusion of current socio-economic and political realities.** This is essential to ensure thoughtful and evidence-based policy recommendations can grow out of the integrated science undertaken in this SRP, especially in a post-COVID world;
- **Futuring and scenario development**. This is critical for meaningful projections of the Antarctic contribution to global sea-level change that include the realities of highly complex and interconnected global socio-ecological systems. This will include using and communicating the RCP/SSP/SPA architecture outlined in the introduction of this proposal;
- **Research-informed communication**. Science communication research will enable the design, critique and testing of different framings arising from this SRP. It will provide advice on communication methods to researchers involved in this SRP and its stakeholders.

In particular, Theme 4 will integrate the understanding of Antarctic ice dynamics generated in Themes 1-3 to improve the ability to reconstruct and predict the Antarctic ice sheet contribution to sea-level change and reduce uncertainties. Theme 4 will address research questions that require an integrated understanding of the interactions between the atmosphere, ocean, solid Earth and the ice sheet; and with the multiple stakeholder needs. Theme 4 questions go to the heart of understanding ice sheet sensitivity, processes and feedbacks by which and where ice mass loss will occur, and how fast ice mass will be lost and contribute to future global and regional sea-level rise. Central to this theme will be improving our knowledge of instabilities within the integrated ice sheet system. For example, understanding the relative importance of sub-glacial vs supra-glacial processes on ice shelf stability will improve our ability to model ice shelf buttressing, and to better evaluate thresholds associated with irreversible processes such as MISI and MICI.

The research questions addressed in Theme 4 will be of interest to decision-makers and stakeholders concerned with anticipating and managing the risks of ongoing sea-level rise. Outcomes from Theme 4 will be integrated into probabilistic sea-level projection frameworks (e.g. *Kopp et al., 2017*) and applied to risk management strategies that seek to build resilience to sea-level rise. This work, at the interface of science and policy, is transdisciplinary, and will involve engagement between natural and social scientists, and key stakeholder groups. The transdisciplinary character of this work will require stakeholder involvement early on in this SRP and the understanding of stakeholder needs, both of which will be addressed in this theme.

12. *What controls the stability of ice shelves in general and are there thresholds?*
13. *What controls grounding line migration and are there thresholds?*
14. *How much do we decrease projection uncertainties of coupled modelling efforts with new validations?*
15. *What was the rate of mass change of the Antarctic ice sheet during past warmer-than-present interglacials, and what are the implications for ice sheet sensitivity and future projections?*

16. *What was the pattern, timing and rate of ice sheet retreat during past deglaciations and what are the implications for future projections?*
17. *What is the response of the AIS to future climate forcing scenarios and what is the impact of AIS melting on global climate?*
18. *How do the current socio-economic and political realities impact on the research outputs? Are there specific feedback loops that would enable a significant shift in outcomes?*
19. *What is public and stakeholders' current understanding of the amount, rate, timing and causal mechanism of sea level rise?*
20. *How would socio-environmental scenarios about the projected futures facilitate a better engagement with this research by stakeholder groups?*
21. *What are the key lessons arising from research into science communication that would be of most benefit in communication with stakeholder groups?*

D – Management and Reporting

Management

INSTANT will be overseen by a Scientific Steering Committee (SC), whose membership will comprise (20 members and up to 12 ex-offcio members):

- Chief Officers (2)
- Theme leaders (4)
- Deputy Theme Leaders, early-mid career researchers (EMCR) (4)
- Delegates from SCAR Scientific Groups (3)
- Delegates from SCAR Standing Groups (3)
- Ex-officio observers from other SCAR SRPs (2+)
- Ex-officio observers (1 from WCRP CliC, 1 from WCRP CLIVAR, 1 from PALSEA, 1 from ISMASS, 1 from PRAMSO, 1 from PMIP or PLIOMIP or MIOMIP, other SCAR Groups as appropriate.
- Data Co-ordinator (1)
- Communications Officer (EMCR) (1)
- Sea-Level Projections expert (Bob Kopp)(1)
- SC-HASS representatives (with expertise in science communication and futures) (2)

- SC members will have 4 year terms.
- The founding co-chairs will stand down in 2024, but will remain as ex-officio on the SC.
- The SC will meet at least once a year in coordination with major international symposia including SCAR-OSC AGU and EGU.
- In addition the SC will meet twice a year intercessionally by video teleconference

The Chief Officers will manage the day-to-day running of INSTANT, supported by the Deputy Chief Officers and Theme Leaders as required. Theme Leaders will develop action plans to address the high priority questions in consultation with ex-officio partner representatives and the Programme Planning Group (PPG) members. This will be done following a Programme Establishment Workshop (PEW). This SC will solicit and assess proposals for the use of INSTANT funds (e.g. for workshops, summer schools, travel) and make recommendations to the Chief Officers for their approval. Relevant expertise, gender balance, ECR representation and geographic coverage will be key considerations in the formation of this group.

At the PEW, Theme Leaders will develop Theme Action Committees (TACs) and plans and budgets. These should not be too big, but should be representative of expertise, gender, geography and age.

Given the interest in INSTANT already (e.g. 90 members of the PPG) and broad range of disciplines it covers, we expect Themes will be large, perhaps equivalent in size to previous SCAR SRPs. Therefore, they will need their own leadership, management and reporting structures, and appropriate budget. The role of the SC is to ensure cross-theme interactions and to avoid silo-ism. It is expected that individual researchers may participate in more than 1 theme.

The inclusion of ex-offcio members from partner organisations such as WCRP, PMIP, ISMASS and PALSEA and other SCAR groups will ensure effective co-ordination and avoid unnecessary duplication of effort between communities. The Sea-Level Projections expert is Professor Bob Kopp from Rutgers University, whose probabilistic sea-level projection methodology is being used by the IPCC in its 6th Assessment Report. Two-way communication and collaboration between the ice sheet and sea-level projections communities will ensure experiment design and research approach is appropriate for end-user's needs.

INSTANT will also participate in planning and workshops of other SRP's and SCAR groups as appropriate. The proposed research plan of ANTCLIM^{Now} is complementary and even contributes to the key questions of Themes 1 and 2, especially in terms of the near-term projections of the regional climate system and their influence on ice sheet dynamics. The outputs from both ANCLIM^{Now} and INSTANT will provided important context and projections for assessing the impact of climate change in ecological models being developed in ANT-ICON.

At this stage we have not identified sub-committees which could be useful in addressing specific issues within Themes or across Themes. These can be established with approval of the SC, but should not duplicate existing SCAR expert or action groups. An example of an existing SCAR expert group is PRAMSO which will be integral to the development and co-ordination of future geological drilling campaigns providing access to the ice shelf cavity and grounding line, bed of the ice sheet and the seafloor. Examples of future subcommittees could include (i) geothermal heat flow, (ii) bathymetry and topography, (iii) coupling of the Earths system with the ice sheet in models, and/or (iv) probabilities and uncertainties in projections.

Reporting

INSTANT will provide news, updates, information on themes, upcoming workshops, conferences, events, outputs and outcomes via its website. Researchers will also be able to identify their research outputs and outcomes as SCAR INSTANT contributions, increasing international visibility of their work and facilitating its translation into policy and decision-making tools and products. The latter may involve facilitating co-production with stakeholders and boundary organisations, uptake by IPCC, information papers to the Antarctic Treaty System, or even commissioned expert reports and assessments.

External reporting will take the form of annual reporting to the SCAR Executive Committee, and biennial reporting to the SCAR Delegates, detailing progress against milestones, deliverables (outputs and outcomes) and future plans. INSTANT will use social media, including Twitter, Facebook and Instagram. Oversight of the website and social media outlets will be facilitated by the INSTANT communications officers.

E – Milestones, outcomes, outputs and benefits

Milestones

The role of INSTANT is to help co-ordinate international research effort towards an improved understanding of Antarctic ice dynamics and meltwater contribution to future sea-level rise, by ensuring key knowledge gaps and questions are addressed as a high priority. Each theme will define a science action plan to ensure the key questions are addressed. This process will represent the first INSTANT step and will begin with the Programme Establishment Workshop (PEW). Theme Action Plans (TAPs) will identify Milestones linked to timelines and Outputs/Outcomes for each of the 1,2,3 themes. The second step of INSTANT will be definition of the Theme 4 TAP that will include the highest-level and integrated applied outcomes and impacts of themes 1,2 and 3. Theme action plans will identify and facilitate efforts and activities to put together projects, research consortia and funding bids in collaboration with INSTANT partners (e.g. WCRP, PMIP, ISMASS). Following the PEW, Themes may develop sub-committees and virtual or face-to-face meetings and workshops.

Outputs/Outcomes

INSTANT is an umbrella co-ordination initiative with limited funding, and therefore its role is facilitative, but with a strong emphasis on encouraging delivery of outputs and outcomes that benefit both the research community and broader society. To this end, and in no particular order, the key deliverables of INSTANT will be:

a. support for collaborative opportunities,
b. help with leveraging funding,
c. focus on key research areas and questions,
d. delivery of scientific journal articles and papers in the peer-reviewed literature,
e. facilitate the co-production of policy-relevant research updates and products as appropriate,
f. to encourage research focus relevant to WCRP Core Activities and Grand Challenges and IPCC Reports.
g. support capability development and training
h. undertake public outreach and engagement

i) Stakeholder engagement

Engagement and science communication play an important role in INSTANT. We will co-produce workshops, briefing documents, science updates with social scientists[23], our partners, and boundary workers for stakeholders. We will collaborate with science communicators[24] and provide public facing summaries (as brochures, talks and webinars). In addition, we will produce two guides to facilitate effective and impactful science communication about the Antarctic contribution to sea-level rise, one for the media when reporting on sea-level rise and one for researchers when talking to the media or other stakeholders about this topic.

ii) Publications in peer-reviewed journals

Publications in peer-reviewed journals will be a key deliverable of INSTANT, again with a focus on the overarching research questions and research themes detailed above. INSTANT will encourage and support collaborations across disciplines and groups to prepare and progress these papers, with members of the Steering Committee playing a key role in establishing and developing such collaborations.

iii) Submissions to the Antarctic Treaty system

INSTANT will co-ordinate and update the "Antarctic Climate Change and the Environment" Report every 5 years, beginning with a 10 year update in 2020, and also present a yearly update as an Information Paper to the Antarctic Treaty and Committee on Environmental Protection. This work strand will be undertaken in association with SC-ATS and other SRPs (ANTCLIM^{Now} and ANT-ICON) to ensure any relevant outputs are included in reporting

iv) Intergovernmental Panel on Climate Change

Like its predecessor SRPs - PAIS, SERCE and ANTCLIM[21], INSTANT has focussed its research questions on policy-facing knowledge required for IPCC assessment and special reports. Many INSTANT researchers have and continue to be involved in IPCC as authors, expert reviewers and through scoping meetings. While INSTANT will be constantly updating and improving knowledge of Antarctic ice sheet dynamics and sea-level projections inter-cessionally, IPCC will be the major vehicle by which INSTANT knowledge and projections are made available to end-users and practitioners. Our partnership with WCRP, whose science and implementation plan is directly geared to improve scientific delivery to IPCC, will ensure INSTANT is well connected with their initiatives such as the Grand Challenge on Melting Ice and Global Consequences (Led by Tim Naish) and Grand Challenge on Regional Sea Level (Natalya Gomez is on the steering committee) the ISMIP (Ice Sheet Model Intercomparison Project). ISMASS is a joint venture between SCAR and WCRP that INSTANT researchers are strongly involved in (Florence Colleoni is on the steering committee).

v) Other reports

Although publications in peer-reviewed journals and submissions to international bodies (as described above) will form the majority of INSTANT outputs, other reports and grey literature will be prepared as required. These could take the form of policy-ready summary documents or emerging issues syntheses for initiatives such as the Antarctic Environments Portal or reports to National Programs, government bodies, or institutions.

[23] https://www.scar.org/science/hass/humanities/
[24] https://www.wgtn.ac.nz/science/research/science-in-society

vi) Workshops and conferences

Initially a Programme Establishment Workshop (PEW) will enable TAPs to be developed. INSTANT will have deep engagement with its partners WCRP, ISMASS, PALSEA, PMIP and other SRPS and Groups within SCAR and will engage with their conference and workshop planning as appropriate (e.g. propose sessions). Likewise, partners will be involved in INSTANT conferences and workshops. Every 2 years INSTANT will hold a day symposium around the SCAR-OSC so that Themes can report and interact. There will be INSTANT meetings organised in association with major conferences (EGU, AGU) in between SCAR OSC years. INSTANT will run a major international conference with its partners including a policy-facing stakeholder session (300-500 people) every 3-4 years similar to the SCAR-PAIS Conference held in Trieste, Italy in 2017[25]. Additionally, stakeholder workshops will be co-produced with the sea-level projections community to engage end-users on the science behind the projections and their use.

vii) Brochures and other PR material

The SC, led by the Communications Co-ordinator, will develop a number of PR options and materials.

viii) Stakeholder engagement

Engagement and science communication will be a key focus of INSTANT. We will co-produce workshops, briefing documents, science updates with social scientists[26], our partners, and boundary workers for stakeholders and end-users. We will collaborate with science communicators[27] and provide public facing summaries (as brochures, talks and webinars).

Impacts

The outcomes of the INSTANT are improved ice mass loss projections (IPCC), probabilistic sea-level projections and a suite of related contextual and qualitative scenarios (see also, *Liggett et al., 2017*). This will be of interest to a broad range of stakeholders concerned with anticipating and managing the impacts of sea-level change including, decision-makers, regulators, planners, civil society, indigenous communities, business, industry, agricultural, maritime, infrastructure, finance and insurance sectors. It is anticipated that the outputs and outcomes, including the range of probabilistic sea-level projections and contextual scenarios, can be used to facilitate adaptation approaches required to avoid the worst impacts, such as coastal flooding and erosion, groundwater inundation and salination, habitat loss and widespread human migration. The impacts of sea-level and ice sheet change around Antarctica are also of critical interest to CCAMLR[28], COMNAP[29] and Antarctic Treaty System parties, as they will have profound implications for national programme operations, tourism and fisheries.

INSTANT will ensure its outcomes are useful, usable and used through effective engagement with stakeholders, and where appropriate, contribute to the co-production of products and services (Fig. 6). The latter requires a systems-level understanding of the science of sea-

[25] http://www.scar-pais.org/index.php/highlights/past-antarctic-ice-sheet-dynamics-pais-conference-2017-trieste-italy
[26] https://www.scar.org/science/hass/humanities/
[27] https://www.wgtn.ac.nz/science/research/science-in-society
[28] CCAMLR = Commission for the Conservation of Antarctic Marine Living Resource
[29] COMNAP = Council of Managers of National Antarctic Programs

level rise, coastal processes, hazards, human behaviour, and the natural and built environments, and of their dynamic interactions. This is where the use of scenarios to deal with complex social-ecological systems will be most useful (*Elsawah et al., 2020*). Contributing to that systems-level understanding, where scientific results are easily used by practitioners, will be the ultimate **impact** of the INSTANT Programme.

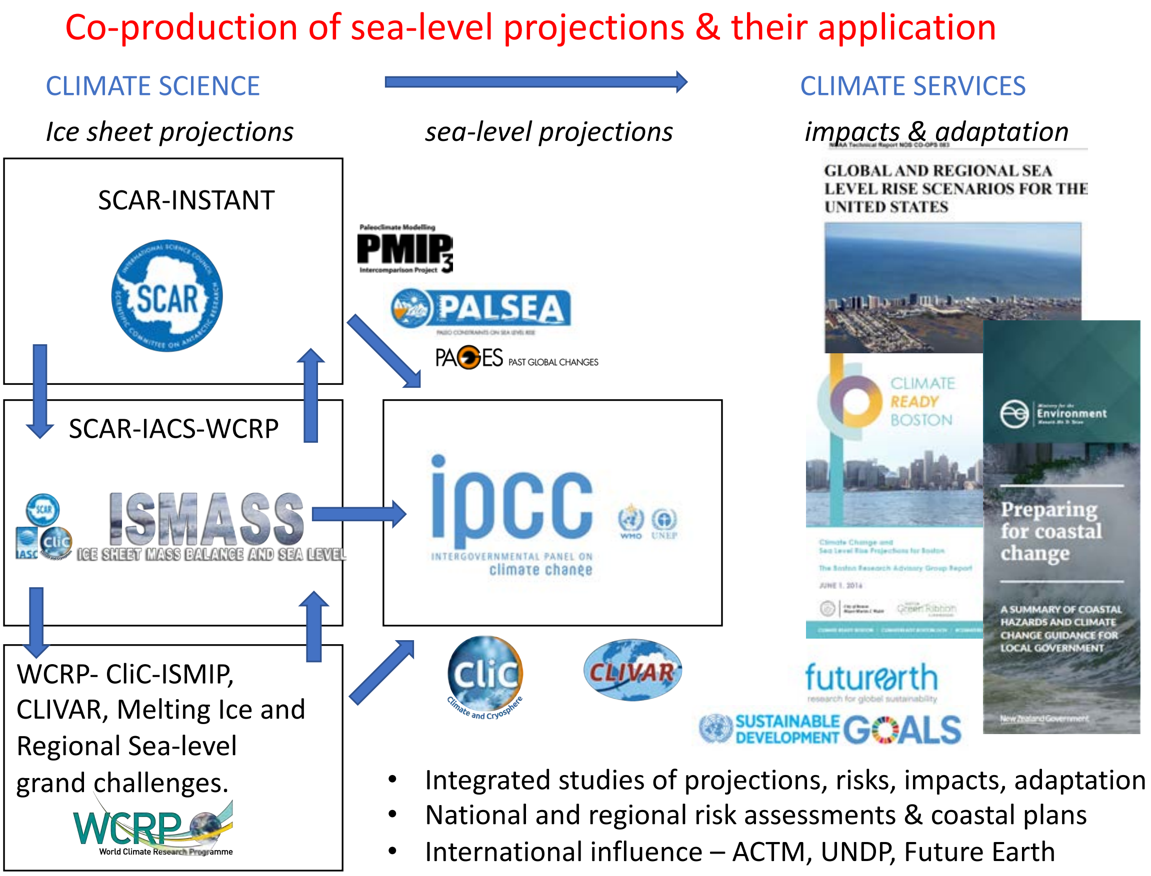


Figure 6. INSTANT science value chain & implementation pathway

G - Capacity building, education and training plan

INSTANT will liaise with the SCAR Capacity Building, Education and Training (CBET) Advisory Group[30], with the Polar Educators International association and with the Association of Polar Early Career Scientists (APECS)[31], to ensure effective communication and outreach.
The main activities will build on the successful approach built in the previous SRPs in organizing summer schools for training early career scientists and students such as:

- the PAIS-IODP school 2019: introduction to Antarctic paleoclimate research using sediment/rock cores[32]

---

[30] https://www.scar.org/capacity-building/cbet/
[31] Association of Polar Early Career Scientists (APECS)
[32] https://www.scar.org/scar-news/pais-news/pais-iodp-antarctic-school/

- the SERCE 2015 and 2019 GIA schools: history and theory of GIA, the geodetic, geological, and geophysical evidence used to constrain GIA-related processes, applications of GIA, and recent developments in the field[33]

These schools were attended by students from a range of nations, both with developed or no Antarctic Programs. Within INSTANT, we will strongly encourage the continuation of such strategy to stimulate the new generation of Antarctic scientists to develop multidisciplinary international networks on INSTANT themes, share knowledge, data, collaborate in joint actions and scientific proposals. INSTANT will promote applications to the SCAR early career and visiting fellowships. In addition INSTANT will financially support the participation to training schools organised by other bodies.

The outreach activities will include the organization of conferences, the production of videos and short reports published on the INSTANT website and on social media to inform the general public, journalists, and media publications. INSTANT will support and encourage young and early career scientists to be actively involved in leadership and management, and to take part in meetings and workshops by providing travel and expenses grants.

F – Data Management Plan

INSTANT will proactively encourage the development and application of good data curation and propagation practices. Authors of INSTANT-supported products will be encouraged to provide both metadata and new data/spatial layers into existing repositories. INSTANT will strictly adhere to data policy guidelines outlined in SCAR Report 39 (2011) by the Standing Committee on Antarctic Data Management (SCADM)[34]. INSTANT will ensure that metadata will be submitted, and datasets will be linked to the Antarctic Master Directory (AMD)[35].
For data management within INSTANT, a Data Coordinator will serve on the Steering Committee. The Data Coordinator, will 1) engage in cross-linkage activities and the facilitation of cross-SRP data sharing via web-based utilities, and 2) maintain ongoing communication with national programmes, currently expanding their emphasis on responsible and cost-effective data management, protection, archiving, and sharing.

While INSTANT will not directly support other data archiving infrastructure, it will maximize the effectiveness of its limited budget by encouraging responsible archiving of data and samples to established data centres and repositories. Among these databases the most relevant to the data to be generated by INSTANT will be QUANTARCTICA, CIMP6, SLDS, IODP, PANGEA, NOAA, UNAVCO, IRIS, and PMIP archives.

G – References

Aitken, A., Roberts, J., Ommen, T. *et al.* 2016. Repeated large-scale retreat and advance of Totten Glacier indicated by inland bed erosion. *Nature* 533**,** 385–389 (2016). https://doi.org/10.1038/nature17447

Alley, R., Anandakrishnan, S., Christianson, K., Horgan, H., Muto, A., Parizek, B., Pollard, D., Walker, R. 2015. *Annual Review of Earth and Planetary Sciences*.43:1, 207-231

[33] https://www.scar.org/scar-news/serce-news/gia-training-school/
[34] https://www.scar.org/data-products/scadm/overview/
[35] https://gcmd.nasa.gov/search/Titles.do?AutoDisplayTitles=true&subset=amd#titles

Anandakrishnan, S., Blankenship, D., Alley, R. et al. (1998). Influence of subglacial geology on the position of a West Antarctic ice stream from seismic observations. *Nature* 394, 62–65 (1998). https://doi.org/10.1038/27889.

Arthur et al., 2020 Recent understanding of Antarctic supraglacial lakes using satellite remote sensing. *Progress in Physical Geography: Earth and Environment*. https://doi.org/10.1177/0309133320916114

Austermann, J., D. Pollard, J.X. Mitrovica, R. Moucha, A.M. Forte, R.M. DeConto, D. Rowley, M.E. Raymo, 2015b. The impact of dynamic topography change on Antarctic Ice Sheet stability in the Pliocene. *Geology* 43, 927-930, doi:10.1130/G36988.1.

Bamber, J.L. et al., 2019. Ice sheet contributions to future sea level rise from structured expert judgment. *PNAS*, 116(23), 11195–11200.

Bindoff, N.L., W.W.L. Chemung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. Purca Cuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson, 2019. Changing Ocean, Marine Ecosystems, and Dependent Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)].

Bindoff NL, Stott PA, AchutaRao KM, Allen MR, Gillett N, Gutzler D, et al. Detection and attribution of climate change: from global to regional. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM, editors. *Climate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press; 2013.

Brysse, K., Oreskes, N., O'Reilly, J., & Oppenheimer, M. (2013). Climate change prediction: Erring on the side of least drama? *Global Environmental Change, 23*(1), 327–337. https://doi.org/10.1016/j.gloenvcha.2012.10.008.

Bronselaer, B., Winton, M., Griffies, S.M. *et al.* 2018. Change in future climate due to Antarctic meltwater. *Nature* 564, 53–58. https://doi.org/10.1038/s41586-018-0712-z

Brondex, J., O. Gagliardini, F. Gillet-Chaulet and G. Durand, 2017: Sensitivity of grounding line dynamics to the choice of the friction law. J. Glaciology , 63(241), 854–866, doi:10.1017/jog.2017.51.

Briggs, R., Tarasov, L., 2013, How to evaluate model-derived deglaciation chronologies: a case study using Antarctica, *Quaternary Science Reviews*, Volume 63, 2013, 109-127, ISSN 0277-3791, https://doi.org/10.1016/j.quascirev.2012.11.021.

Bulthuis, K., M. Arnst, S. Sun and F. Pattyn, 2019. Uncertainty quantification of the multi-centennial response of the Antarctic ice sheet to climate change. *The Cryosphere*, 13, 1349–1380.

Christner, B., Priscu, J., Achberger, A. et al. 2014. A microbial ecosystem beneath the West Antarctic ice sheet. *Nature* 512, 310–313https://doi.org/10.1038/nature13667

Colleoni, F., De Santis, L., Siddoway, C.S. et al. 2018. Spatio-temporal variability of processes across Antarctic ice-bed–ocean interfaces. *Nature Communications* 9, 2289 https://doi.org/10.1038/s41467-018-04583-0

Cook, C., van de Flierdt, T., Williams, T. et al. 2013. Dynamic behaviour of the East Antarctic ice sheet during Pliocene warmth. *Nature Geoscience* 6, 765–769. https://doi.org/10.1038/ngeo1889.

Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. *In: Climate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Dadic, R., Mott, R., Lehning, M., and Burlando, P. 2010, Wind influence on snow depth distribution and accumulation over glaciers, *Journal of Geophysical. Research.*, 115, F01012, doi:10.1029/2009JF001261.

DeConto, R.M. and D. Pollard, 2016. Contribution of Antarctica to past and future sea level rise. *Nature*, 531(7596), 591–597, doi:10.1038/ nature17145.

Dodds, K., Hemmings, A.D., and Roberts, P. (2017). *Handbook on the Politics of Antarctica*. Cheltenham: Edward Elgar.

Donat-Magnin, M. et al., 2017. Ice shelf Melt Response to Changing Winds and Glacier Dynamics in the Amundsen Sea Sector, Antarctica. *Journal of Geophysical. Research-Oceans*, 122(12), 10206–10224, doi:10.1002/2017JC013059.

Duncan, B., McKay, R., Bendle, J., Naish, T., Inglis, G.N., Moossen, H., Levy, R., Ventura, G.T., Lewis, A., Chamberlain, B., Walker, C. (2019). Lipid biomarker distributions in Oligocene and Miocene sediments from the Ross Sea region, Antarctica: Implications for use of biomarker proxies in glacially-influenced settings. *Palaeogeography, Palaeoclimatology, Palaeoecology 516*: 71-89. doi:10.1016/j.palaeo.2018.11.028

Dutton, A. et al. 2015. Sea-level rise due to polar ice-sheet mass loss during past warm periods. *Science*, 349, aaa4019.

Edwards, T.L., Brandon, M.A., Durand, G. et al. 2019. Revisiting Antarctic ice loss due to marine ice-cliff instability. *Nature* 566, 58–64. https://doi.org/10.1038/s41586-019-0901-4.

Eisen, O., et al., 2008. Ground-based measurements of spatial and temporal variability of snow accumulation in East Antarctica, *Reviews in Geophysics.*, 46, RG2001, doi:10.1029/2006RG000218.

Elsawah S., Hamilton S., Jakeman A., Rothman D., Schweizer V., Trutnevyte E., Carlsen H., Drakes C., Frame B., Fu B., Guivarch, C, Haasnoot, M., Kemp-Benedict E, Kok, K., Kosow, H,., Ryan, M., van Delden, H. (2020). Scenario processes for socio-environmental systems analysis of futures: A review of recent efforts and a salient research agenda for supporting decision making. *Science of the Total Environment*. Doi.org/10.1016/j.scitotenv.2020.138393

Favier, V., Krinner, G., Amory, C., Gallée, H., Beaumet, J., & Agosta, C. 2017.. Antarctica-regional climate and surface mass budget. *Current Climate Change Reports*, 3(4), 303-315.

Frezzotti M, Scarchilli C, Becagli S, Proposito M, Urbini S. 2013. A synthesis of the Antarctic surface mass balance during the last 800 yr. *Cryosphere*. 2013;7(1):303–19.

Fürst, J.J. et al., 2016. The safety band of Antarctic ice shelves. *Nature Climate Change*. 6, 479, doi:10.1038/nclimate2912.

Gasson, E., DeConto, R.M., Pollard, D., Levy, R.H. 2016. Dynamic Antarctic ice sheet during the early to mid-Miocene. *PNAS* 113: 3459-3464.

Goldberg, D., Smith, T., Narayanan, P., Morlighem, M. 2020. Bathymetric influences on Antarctic ice-shelf melt rates. *ESSOAr*, https://doi.org/10.1002/essoar.10503016.2

Golledge, N.R., Menviel, L., Carter, L., Fogwill, C.J., England, M.H., Cortese, G., Levy, R.H. 2014. Antarctic contribution to meltwater pulse 1A from reduced Southern Ocean overturning. *Nature*. Communications 5: 5107.

Golledge, N.R. et al., 2015. The multi-millennial Antarctic commitment to future sea level rise. *Nature*, 526(7573), 421–425.

Golledge, N.R., Levy, R.H., McKay, R.M., Naish, T.R. 2017. East Antarctic Ice Sheet most vulnerable to Weddell Sea warming. *Geophysical Research Letters* 44(5): 2343-2351.

Golledge, N.R., Keller, E.D., Gomez, N. et al. 2019. Global environmental consequences of twenty-first-century ice-sheet melt. *Nature* 566, 65–72. https://doi.org/10.1038/s41586-019-0889-9

Gomez, N., Mitrovica, J., Huybers, P. et al. 2010. Sea level as a stabilizing factor for marine-ice-sheet grounding lines. *Nature Geoscience* 3, 850–853.https://doi.org/10.1038/ngeo1012

Gomez, N., D. Pollard and D. Holland, 2015: Sea level feedback lowers projections of future Antarctic Ice sheet mass loss. *Nature Communications*., 6, 8798.

Grant, G.R., Naish, T.R., Dunbar, G.B. et al. 2019. The amplitude and origin of sea-level variability during the Pliocene epoch. *Nature*. 574, 237–241 https://doi.org/10.1038/s41586-019-1619-z

Hellmer, H.H., F. Kauker, R. Timmermann and T. Hattermann, 2017. The Fate of the Southern Weddell Sea Continental Shelf in a Warming Climate. *Journal of Climate*, 30(12), 4337–4350, doi:10.1175/jcli-d-16-0420.1.

Hubbard B, Luckman A, Ashmore DW, Bevan S, Kulessa B, Kuipers Munneke P, et al. 2016. Massive subsurface ice formed by refreezing of ice-shelf melt ponds. *Nature Communications*. 2016;7:11897.

Hulbe, C., 2017. Is ice sheet collapse in West Antarctica unstoppable. *Science* 356 (6341), 910-911. DOI: 10.1126/science.aam9728 S.

Hughes, K. A., Constable, A., Frenot, Y., López-Martínez, J., McIvor, E., Njåstad, B., Terauds, A., Liggett, D., Roldan, G., Wilmotte, A., & Xavier, J. C. (2018). Antarctic environmental protection: Strengthening the links between science and governance. *Environmental Science and Policy*, *83*, 86–95. https://doi.org/10.1016/j.envsci.2018.02.006

Hughes, K. A., Liggett, D., Roldan, G., Wilmotte, A., & Xavier, J. C. (2016). Narrowing the science/policy gap for environmental management. *Antarctic Science*, 1-1.

IMBIE, 2018, Shepherd, A., Ivins, E., Rignot, E. et al. 2018. Mass balance of the Antarctic Ice Sheet from 1992 to 2017. *Nature* 558, 219–222. https://doi.org/10.1038/s41586-018-0179-y

IPCC, 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC, 2018. *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate povert*y [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

IPCC, 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

Jimenez-Espejo F.J., Presti M., Kuhn G., Mckay R., Crosta X., Escutia C., Lucchi R.G., Tolotti R., Yoshimura T., Ortega Huertas M., Macrì P., Caburlotto A., De Santis L. 2020. Late Pleistocene oceanographic and depositional variations along the Wilkes Land margin (East Antarctica) reconstructed with geochemical proxies in deep-sea sediments. *Global and Planetary Change* 184 , 103045

Joughin, I., B.E. Smith and B. Medley, 2014. Marine ice sheet collapse potentially under way for the thwaites glacier basin, West Antarctica. *Science*, 344(6185), 735–738, doi:10.1126/science.1249055.

Khazendar, A. et al., 2016: Rapid submarine ice melting in the grounding zones of ice shelves in West Antarctica. *Nature. Communications*., 7, 13243.

Kingslake, J., Scherer, R.P., Albrecht, T. et al. 2018. Extensive retreat and re-advance of the West Antarctic Ice Sheet during the Holocene. *Nature* 558, 430–434. https://doi.org/10.1038/s41586-018-0208-x

Klages, J.P., Salzmann, U., Bickert, T. et al. 2020. Temperate rainforests near the South Pole during peak Cretaceous warmth. *Nature* 580, 81–86.https://doi.org/10.1038/s41586-020-2148-5

Konrad, H., I. Sasgen, D. Pollard and V. Klemann, 2015: Potential of the solid-Earth response for limiting long-term West Antarctic Ice Sheet retreat in a warming climate. *Earth Planetary Science Letters*, 432, 254–264.

Kopp, R.E., DeConto, R.M., Bader, D.A., Hay, C.C., Horton, R.M., Kulp, S., Oppenheimer, M., Pollard, D. and Strauss, B.H. 2017. Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections. *Earth's Future*, 5: 1217-1233. doi:10.1002/2017EF000663

Larour, E. et al., 2019. Slowdown in Antarctic mass loss from solid Earth and sea level feedbacks. *Science*, 364(6444), doi:10.1126/science.aav7908.

Levermann, A. et al., 2014. Projecting Antarctic ice discharge using response functions from SeaRISE ice sheet models. *Earth System Dynamics*., 5(2), 271.

Levy, R., et al., 2016. Antarctic ice sheet sensitivity to atmospheric CO2 variations during the Early-Middle Miocene. *PNAS*. 113: 3453-3458.

Levy, R.H., Meyers, S.R., Naish, T.R., Golledge, N.R., McKay, R.M., et al. 2019. Antarctic ice-sheet sensitivity to obliquity forcing enhanced through ocean connections. *Nature Geoscience* 12: 132-137.

Li, X., E. Rignot, J. Mouginot and B. Scheuchl, 2016. Ice flow dynamics and mass loss of Totten Glacier, East Antarctica, from 1989 to 2015*. Geophysical Research Letters*, 43(12), 6366–6373.

Liggett, D., Frame, B., Gilbert, N., & Morgan, F. (2017). Is it all going south? Four future scenarios for Antarctica. *Polar Record, 53*(5), 459-478.

Llubes, M., Lanseau, C. & Rémy, F. 2006. Relations between basal condition, subglacial hydrological networks and geothermal flux in Antarctica. *Earth and Planetary Science Letters* 241, 655–662 (2006).

McKay, R., Naish, T., Carter, L., Riesselman, C., Sjunneskog, C., Winter, D., Dunbar, R., Sangiorgi, F., Warren, C., Pagani, M., Schouten, S., Willmott, V., Levy, R., DeConto, R., Powell, R. 2012. Antarctic and Southern Ocean Influences on Late Pliocene cooling. *Proceedings Of The National Academies Of Sciences*, 109, 6423-642.

McKay, R.M., Golledge, N.R., Maas, S., Naish, T., Levy, R., Dunbar, G., Kuhn, G. (2016). Antarctic marine ice sheet retreat in the Ross Sea during the early Holocene. *Geology* 4: 7-10.

Medley, B., McConnell, J. R., Neumann, T. A., Reijmer, C. H., Chellman, N., Sigl, M., & Kipfstuhl, S. (2018). Temperature and snowfall in western Queen Maud Land increasing faster than climate model projections. *Geophysical Research Letters*, 45, 1472– 1480. https://doi.org/10.1002/2017GL075992

Mezgec et al., 2017, Holocene sea ice variability driven by wind and polynya efficiency in the Ross Sea. *Nature Communications*, 8: 133, DOI: 10.1038/s41467-017-01455-x.

Miller, K. G., J. D. Wright, J. V. Browning, A. Kulpecz, M. Kominz, T. R. Naish, B. S. Cramer, Y. Rosenthal, W. R. Peltier, and S. Sosdian. 2012. High tide of the warm Pliocene: Implications of global sea level for Antarctic deglaciation. *Geology* 40 (5): 407-10.

Morlighem, M., Rignot, E., Binder, T. et al. 2020 Deep glacial troughs and stabilizing ridges unveiled beneath the margins of the Antarctic ice sheet. *Nature Geoscience* 13**,** 132–137 (2020). https://doi.org/10.1038/s41561-019-0510-8

Naish, T. R. et al., 2009. Obliquity-paced Pliocene West Antarctic Ice Sheet Oscillations, *Nature*, 458, 322-328.

O'Reilly, J. (2015). Glacial dramas: Typos, projections, and peer review in the Intergovernmental Panel on Climate Change. In J. Barnes and M. Dove (Eds). *Climate cultures: anthropological Perspectives on Climate Change* (pp. 107-26). Yale University Press.

O'Reilly, J. (2016). Sensing the Ice: field science, models, and expert intimacy with knowledge. *Journal of the Royal Anthropological Institute 22*(1), 27-45.

Paolo, F.S., H.A. Fricker and L. Padman, 2015. Volume loss from Antarctic ice shelves is accelerating. *Science*, 348 (6232), 327–331.

Patterson, M., McKay, R., Naish, T. et al. 2014. Orbital forcing of the East Antarctic ice sheet during the Pliocene and Early Pleistocene. *Nature Geoscience* 7, 841–847 (2014). https://doi.org/10.1038/ngeo2273

Pattyn, F., Morlighem, M., 2020. The uncertain future of the Antarctic Ice Sheet. *Science*. 367, 1331-1335. DOI: 10.1126/science.aaz5487

Pattyn, F. et al., 2018: The Greenland and Antarctic ice sheets under 1.5ºC global warming. *Nature Climate Change*, 8(12), 1053–1061, doi:10.1038/ s41558-018-0305-8.

Pattyn, F., 2017. Sea level response to melting of Antarctic ice shelves on multi-centennial timescales with the fast Elementary Thermomechanical Ice Sheet model (f. ETISh v1. 0). *The Cryosphere*, 11(4), 1851–1878.

Phipps, S. J., Fogwill, C. J., and Turney, C. S. M.: Impacts of marine instability across the East Antarctic Ice Sheet on Southern Ocean dynamics, *The Cryosphere*, 10, 2317–2328, https://doi.org/10.5194/tc-10-2317-2016, 2016.

Pollard, D., R.M. DeConto and R.B. Alley, 2015. Potential Antarctic Ice Sheet retreat driven by hydrofracturing and ice cliff failure. *Earth Planetary Science Letters*, 412, 112–121.

Pollard, D., N. Gomez and R.M. DeConto, 2017. Variations of the Antarctic Ice Sheet in a Coupled Ice Sheet-Earth-Sea Level Model: Sensitivity to Viscoelastic Earth Properties. *Journal of Geophysical Research-Earth*, 122(11), 2124–2138.

Priestley, P., Heine, Z. and Milfont, T.L. (In preparation). Public understanding of climate change-related sea-level rise.

Rignot, E. et al., 2019. Four decades of Antarctic Ice Sheet mass balance from 1979–2017. *Proceeding of the National Academy of Sciences*, 116(4), 1095–1103, doi:10.1073/pnas.1812883116.

Rintoul, S.R., Chown, S.L., DeConto, R.M. et al. 2018. Choosing the future of Antarctica. *Nature* 558, 233–241 (2018). https://doi.org/10.1038/s41586-018-0173-4

Rintoul, S.R. 2018. The global influence of localized dynamics in the Southern Ocean. *Nature* 558, 209–218 (2018). https://doi.org/10.1038/s41586-018-0182-3

Ritz, C. et al., 2015. Potential sea level rise from Antarctic ice sheet instability constrained by observations. *Nature*, 528(7580), 115–118.

Salmon, R., Priestley, R., Fontana, M., & Milfont, T. L. (2017). Climate change communication in New Zealand. *Oxford Research Encyclopedia of Climate Science*. Retrieved 26 May. 2020, from https://oxfordre.com/climatescience/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-475.

Shakun, J.D., et al. 2018. Minimal East Antarctic Ice Sheet retreat onto land during the past eight million years. *Nature* 558: 284-287

Schlegel, N.J. et al., 2018: Exploration of Antarctic Ice Sheet 100-year contribution to sea level rise and associated model uncertainties using the ISSM framework. *The Cryosphere*, 12(11), 3511–3534, doi:10.5194/tc-12- 3511-2018.

Shen, Q. et al., 2018. Recent high-resolution Antarctic ice velocity maps reveal increased mass loss in Wilkes Land, East Antarctica. *Scientific Reports*, 8(1), 4477, doi:10.1038/s41598-018-22765-0..

Shepherd, A. et al., 2012. A reconciled estimate of ice sheet mass balance, *Science*. 338(6111):1183-9. doi: 10.1126/science.1228102.

Shepherd, A., Ivins, E., Rignot, E. et al. 2020. Mass balance of the Greenland Ice Sheet from 1992 to 2018. *Nature* 579, 233–239 (2020). https://doi.org/10.1038/s41586-019-1855-2.

Simkins L. M. et al., 2017. Anatomy of a meltwater drainage system beneath the ancestral East Antarctic ice sheet. *Nature Geoscience*. DOI: 10.1038/NGEO3012.

Smellie JL, Rocchi S, Gemelli M, Di Vincenzo G, Armienti P. 2011. A thin predominantly cold-based Late Miocene East Antarctic ice sheet inferred from glaciovolcanic sequences in northern Victoria Land, Antarctica. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 307: 129-149."

Smith, B., Fricker., H.A., et al. 2020. Pervasive ice sheet mass loss reflects competing ocean and atmospheric processes. *Science*. https://doi.org/10.1126/science.aaz5845

Smith J.A., Graham A.G.C., 2019. Post A.L., Hillenbrand C.D, Bart P.J. & Powell R.D. The marine geological imprint of Antarctic ice shelves *Nature Communications*. 10:5635 https://doi.org/10.1038/s41467-019-13496-5

Strugnell J., Pedro, J., Wilson, N., 2018. Dating Antarctic ice sheet collapse: Proposing a molecular genetic approach, *Quaternary Science Reviews*, 179, 153-157.

Stearns, L., Smith, B. & Hamilton, G. 2008. Increased flow speed on a large East Antarctic outlet glacier caused by subglacial floods. *Nature Geoscience* 1, 827–831https://doi.org/10.1038/ngeo356.

Stephens, T. (2018). The Antarctic Treaty System and the Anthropocene. *The Polar Journal, 8*(1), 29–43.

Paxman, G., Jamieson, S., Hochmuth, K., Gohl, K., Bentley, M., Leitchenkov, G., Ferraccioli, F., 2019. Reconstructions of Antarctic topography since the Eocene–Oligocene boundary, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 535 doi.org/10.1016/j.palaeo.2019.109346.

Tinto, K.J., Padman, L., Siddoway, C.S. *et al.* 2019. Ross Ice Shelf response to climate driven by the tectonic imprint on seafloor bathymetry. *Nature Geoscience.* 12**,** 441–449 (2019). https://doi.org/10.1038/s41561-019-0370-2

Thomas, E. R., Melchior Van Wessem, J., Roberts, J., Isaksson, E., Schlosser, E., Fudge, T. J., & Van Den Broeke, M. R. 2017. Regional Antarctic snow accumulation over the past 1000 years. *Climate of the Past*, 13(11), 1491-1513.

Trusel LD, Frey KE, Das SB, Karnauskas KB, Kuipers Munneke P, van Meijgaard E, et al. 2015. Divergent trajectories of Antarctic sur- face melt under two twenty-first-century climate scenarios. *Nature Geoscience*. 2015;8(12):927–32.

Whitehouse, P., Bentley, M., Milne, G., King, M., Thomas, I., 2012. A new glacial isostatic adjustment model for Antarctica: calibrated and tested using observations of relative sea-level change and present-day uplift rates, *Geophysical Journal International*, Volume 190, Issue 3, September 2012, Pages 1464–1482, https://doi.org/10.1111/j.1365-246X.2012.05557.x

Whitehouse, P.L., Gomez, N., King, M.A. et al. Solid Earth change and the evolution of the Antarctic Ice Sheet. *Nature Communications*. 10, 503 (2019). https://doi.org/10.1038/s41467-018-08068-y

Wilson, D.J., Bertram, R.A., Needham, E.F. et al. Ice loss from the East Antarctic Ice Sheet during late Pleistocene interglacials. *Nature* 561, 383–386 (2018). https://doi.org/10.1038/s41586-018-0501-8.

Supporting Information

i. Biosketch of proposed Chief-Officers (note that Scientific Steering Committee will be formed at the Programme Establishment Workshop)

Tim Naish

Tim Naish is a Professor in Earth Sciences at the Antarctic Research Centre, Victoria University of Wellington, where he was Director from 2008-2017, before taking up a Royal Society of New Zealand James Cook Fellowship. His research focuses on past, present and future climate change with specific emphasis on how the Antarctic ice sheets respond to climate change and influence global sea-level. He is the leader of the NZ Antarctic Science Platform's "Ice, Ocean and Atmosphere" Programme, and co-leads the "NZ SeaRise" Programme improving location-specific projections of sea-level rise. He has participated in 14 expeditions to Antarctica and helped found ANDRILL, a USD $30M international Antarctic Geological Drilling Program. Tim also holds leadership positions in the World Climate Research Program and the Scientific Committee on Antarctic Research. He has a strong commitment to communication of Antarctic and climate change science and its application to policy and society. He sits on Australian Government's National Advisory Committee on Climate Science. He was Lead Author on the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report. He has received the New Zealand Antarctic Medal, the Martha Muse Prize for Antarctic Science and Policy, his team won the NZ Prime Minister's Science Prize in 2019, and he is a Fellow of the Royal Society of New Zealand.

Florence Colleoni

Florence Colleoni is a Senior Scientist in paleoclimate and ice sheet modeling at the National Institute of Oceanography and Applied Geophysics in Trieste (Italy). Her research focuses on understanding the role of ice sheets in the climate system spanning all timescales from past to future. She has been investigating Northern Hemisphere glaciations and climate linkages from different points of view, using glacio-isostatic adjustment models, ice sheet models and climate models. She also explores the role of teleconnections between the tropics and high latitudes during past warm periods. She has been co-ordinating services to Scandinavian nuclear companies to develop extreme future scenarios of glaciation and deglaciation to explore the impact on coastal underground nuclear wastes repositories. Florence recently expanded her research to Antarctica and is highly active in the current SCAR PAIS program where she tries to strengthen the link between geologists, geophysics and climate and ice sheet modelers, promoting multi-disciplinary approach and bridging communities. Florence is also part of the ISMASS expert group since 2018 where she is representing PAIS and she has been reviewing different chapters of the last IPCC SROCC report about "The Ocean and the cryosphere in a Changing Climate". Florence has a strong commitment in Italy participating in national round tables about policy on climate change and sea level rise and represents the Italian polar sciences in Arctic Ministerial Conferences promoting science diplomacy. She also occasionally represents the Italian Antarctic Programme (PNRA) in international conferences.

ii. Justification of SCAR sponsorship.

The uncertain contribution of Antarctica's ice sheet to future sea-level rise is arguably one of the highest priority issues in climate science. It requires urgent attention and SCAR has the international standing, mandate (Strategic Plan, Horizon Scan) and multidisciplinary experts to address this. In fact the world requires SCAR to take up this challenge in partnership with the other invested organisations, such as World Climate Research Programme. SCAR's strategic science direction is increasingly driven by a moral obligation to better understand Antarctica's role in the global impacts of climate change, through improved communication and engagement with stakeholders. Importantly, INSTANT science will also strengthen evidence-based policy and decision-making for the ATS, its activities and other Antarctic stakeholders. Through collaboration, INSTANT will help provide co-ordination, strategic direction and raise the profile of more focussed science activities being undertaken by SCAR action and expert groups. In summary, INSTANT will help align, focus and support research activity both within and outside SCAR.

iii. International involvement and partnerships.

The INSTANT PPG (listed below) involves 90 members from 23 countries. (We have outlined in great detail strategic partnerships within this proposal and will not repeat it here)

Name	Nationality	SCAR role or affiliation	Expertise	Email
Abram, Nerilie	Australia	Antclim21, IPCC	climate dynamics/paleocli	nerilie.abram@anu.edu.au
Anderson, John	USA	PAIS	glacial sedimentology	johna@rice.edu
Austermann, Jacqueline	USA	PALSEA3, SERCE, PAIS, ECR	geodynamics	jackya@ldeo. Columbia.edu
Bentley, Mike	UK	PAIS	paleoclimatology	m.j.bentley@durham.ac.uk
Bertler, Nancy	NZ	ex Chief-officer Antclim21	ice cores	nancy.bertler@vuw.ac.nz
Bingham, Rob	UK	AntArchtecture	radar	r.bingham@ed.ac.uk
Bo, Sun	China	PAIS, SERCE	geology glaciology	sunbo@pric.org.cn
Burton-Johnston, Alex	UK	Geothermal Heat	solid earth	alerto@bas.ac.uk
Casado, Mathieu	Italy	PAIS, APECS, ECR	ice cores	mathieu.casado@awi.de
Chown, Steven	Australia	SCAR President	ecology	steven.chown@monash.edu
Colleoni, Florence	Italy	Co-Chief INSTANT, PAIS, ISMAS	climate ice sheet modelling	fcolleoni@inogs.it
Convey, Peter	UK	Ex Chief-officer ANT-ERA	terrestrial paleoecology	pcon@bas.ac.uk
DeConto, Rob	USA	PAIS, IPCC	ice sheet modeling	deconto@geo.umass.edu
DeSantis, Laura	Italy	Chief-officer PAIS	paleocenaography	ldesantis@inogs.it
Dunbar, Rob	USA	PAIS, Philanthropy	paleoclimatology	dunbar@stanford.edu
Dutton, Andrea	USA	PAIS, PALSEA3	paleo sea-level	adutton@ufl.edu
Eisen, Olaf	Germany	ANTCLIM21, PAIS, ISMASS	glaciology	Olaf.Eisen@awi.de
Escutia, Carlota	Spain	PAIS, PRAMSO, IODP	paleoclimatology	cescutia@ugr.es
Ferraccioli, Fausto	UK	ADMAP	airborne geophysics	ffe@bas.ac.uk
Forsberg, Rene	Denmark	DTU-Space, ESA	satellite observations	rf@space.dtu.dk
Goelzer, Heiko	Netherlands	ISMAS co-chair	ice sheet modelling	h.goelzer@uu.nl
Gohl, Karsten	Germany	PAIS, IODP	geology	Karsten.Gohl@awi.de
Golledge, Nick	NZ	PAIS, IPCC	ice sheet modelling	nicholas.golledge@vuw.ac.nz
Gomez, Natalya	Canada	PAIS SERCE	geodynamics	natalya.gomez@mcgill.ca
Goodwin, Ian	Australia	PAIS, Antclim21	paleoclimatology	ian.goodwin@mq.edu.au
Grant, Georgia	NZ	PAIS, PALSEA, ECR	paleoclimatology	g.grant@gns.cri.nz
Greenbaum, Jamin	USA	PAIS		jamin@utexas.edu
Halpin, Jacqui	USA	SERCE	geodyamics	jacqueline.halpin@utas.edu.au
Hansen, Samantha	USA	SERCE	geodyamics	shansen@geo.ua.edu
Hendry, Katherine	UK	SOOS, ECR	oceanography	k.hendry@bristol.ac.uk
Hogg, Ian	Canada	ANTERA	terrestrial paleoecology	ian.hogg@polar.gc.ca
Horgan, Huw	NZ	PAIS	glacial geophysics	huw.horgan@vuw.ac.nz
Ikehara, Minoru	Japan	PAIS	paleoceanography	ikehara@kochi-u.ac.jp
Jamieson, Stewart	UK	PAIS, SERCE	geology	stewart.jamieson@durham.ac.uk
Kageyama, Masa	France	WCRP JSC, PMIP, IPCC	climate modelling	masa.kageyama@lsce.ipsl.fr
King, Matt	Australia	Chief-officer SERCE	geodesy	matt.king@utas.edu.au
Kopp, Bob	USA	Sea-level projections	oceanography sea-level	robert.kopp@rutgers.edu
Kulhanek, Denise	USA	PAIS, IODP	paleontology	kulhanek@iodp.tamu.edu
Lee, Jae Il	Korea	PAIS	paleoclimatology	leeji@kopri.re.kr
Leitchenkov, German	Russia	PAIS	geology, tectonics	german_l@mail.ru
Lenaerts, Jan	USA	ISMASS	surface mass balance	Jan.Lenaerts@colorado.edu
Leppe, Marcelo	Chile	PAIS, ANTECO	paleobiology	mleppe@inach.cl
Levy, Richard	NZ	PAIS, PRAMSO, ICDP	paleoclimatology	r.levy@gns.cri.nz
Licht, Kathy	USA	PAIS	paleoclimatology	klicht@iupui.edu
Liggett, Daniela	NZ	Chair SC-HASS	social science	daniela.liggett@canterbury.ac.nz
Mackintosh, Andrew	Australia	PAIS, IACS	glaciology	andrew.mackintosh@monash.edu
Morlighem, Mathieu	USA	ISMIP6	ice sheet modelling	mathieu.morlighem@uci.edu
Naish, Tim	NZ	INSTANT co-Chief, PAIS co-Chie	paleoclimatology	tim.naish@vuw.ac.nz
Newman, Louise	Australia	SOOS	Ocean observations	newman@soos.aq
Nitsche, Frank	USA	SCADM	marine geophysics	fnitsche@ldeo.columbia.edu
Patterson, Molly	USA	PAIS	paleoclimatology	patterso@binghamton.edu
Frank, Pattyn	Belgium	ISMASS	Ice sheet modelling	fpattyn@ulb.ac.be
Ropert-Coudert, Yan	France	SCAR CO Life Sciences	terrestrial ecology	docyaounde@gmail.com
Pattyn, Frank	Belgium	ISMASS, ISMIP, ANCLIM21, IPC	ice sheet modelling	fpattyn@ulb.ac.be
Perez, Lara	UK	PAIS, ECR	marine geophysics	larafperez@gmail.com
Phipps, Steven	Australia	PAIS, Antclim21, ISMIP, PMIP	ice sheet modelling	Steven.Phipps@utas.edu.au
Priestley, Rebecca	NZ	Chair SCAR PEAS	science communications	Rebecca.Priestley@vuw.ac.nz
Quiquet, Aurelian	France	ANTCLIM21, PAIS, ISMASS	ice sheet modeling	Aurelien.Quiquet@lsce.ipsl.fr
Renwick, James	NZ	WCRP-CliC	sea-ice-climate	James.renwick@vuw.ac.nz
Riesselmann, Christina	NZ	PAIS	paleolcimatology	christina.riesselman@otago.ac.nz
Rintoul, Steven	AUS	Antclim21, IPCC	oceanography	Steve.Rintoul@csiro.au
Robinson, Sharon	Australia	ANTECO	terrestrial paleoecology	sharonr@uow.edu.au
Roberts, Jason	Australia	ICECAP	Geophysics	JasonL.Roberts@aad.gov.au
Roop, Heidi	USA	ECR eductaion	climate policy	hroop@uw.edu
Rovere, Alessio	Germany	PALSEA co-leader	paleo-sea level	arovere@marum.de
Russell, Joellen	USA	Antclim21, CMIP6	oceanography	jrussell@email.arizona.edu
Siegert, Martin	UK	PAIS subglacial lakes	glaciology	m.j.siegert@ed.ac.uk
Sime, Louise	UK	PAIS	ice cores	lsim@bas.ac.uk
Stefels, Jacqueline	Netherlands	BEPSII	biogeochemistry	j.stefels@rug.nl
Stenni, Barbara	Italy	PAIS, IPICS, EPICA	ice cores	barbara.stenni@unive.it
Stocchi, Paolo	Netherlands	PAIS	Geodynamics, sea-level	Paolo.Stocchi@nioz.nl
Strugnell, Jan	AUS	Chief-officer ANTECO	genetics	jan.strugnell@jcu.edu.au
Tinto, Kirsty	USA	SERCE, ROSETTA	airborne geophysics	tinto@ldeo.columbia.edu
van de Flierdt, Tina	UK	PAIS	geochemistry	tina.vandeflierdt@imperial.ac.uk
van den Broeke, Michiel	Netherlands	ISMASS	surface mass balance	m.r.vandenbroeke@uu.nl
Van ommen, Tas	Australia	AAD	glaciology	Tas.Van.Ommen@aad.gov.au
Wahlin, Anna	Sweden	SOOS	oceanography	anna.wahlin@marine.gu.se
Wellner, Julia	USA	PAIS	marine & glacial geology	jwellner@uh.edu
Wainer, Iliana	Brazil	ANTCLIM21	oceanography	ilanawainer@gmail.com
Whitehouse, Pippa	UK	Chief-officer SERCE	geodynamics	pippa.whitehouse@durham.ac.uk
Wiens, Doug	USA	PAIS, SERCE	geodyamics	DOUG@WUSTL.EDU
Williams, Trevor	USA	PAIS	paleoclimatology	williams@iodp.tamu.edu
Wilson, Nerida	Australia	ANTECO	genetics	Nerida.Wilson@museum.wa.gov.au
Wilson, Terry	USA	Ex Chief Officer SERCE, SCAR Vic	geology/tectonics	wilson.43osu@gmail.com