



Science and Implementation
Plan for a proposed SCAR
Scientific Research
Programme



International
Science Council

Submitted May 2020

1. Name of the proposed SRP

Near-term Variability and Prediction of the Antarctic Climate System (AntClimNow)

2. Name(s) of the lead proponent(s) (including affiliations and contact information)

Tom Bracegirdle, British Antarctic Survey, Cambridge, UK. Email tjbra@bas.ac.uk.
Ilana Wainer, Instituto Oceanográfico, Universidade de São Paulo, São Paulo, Brazil.
Email wainer@usp.br.

3. Sponsoring SSG(s)

SCAR Physical Sciences Group (PSG)

4. Summary of the duration and budget request (in US\$ per year)

Duration of 8 years with a budget request of 29,250 US\$ per year. See Supporting Information for details.

5. Abstract

Many of the critical Antarctic and Southern Ocean climate science questions are related to understanding present-day climatic trends and estimating future changes in the near term (between 1 and 30 years). This topic is a key gap in the scope of the current SCAR SRPs due to its importance to Antarctic stakeholders both from a global and regional perspective. It is timely to fill this gap with the recent advances and current developments in relevant areas of climate and earth-system modelling, observations, climate proxy reconstructions and data science.

In terms of the SCAR Strategic Plan, the proposed SRP would address a number of scientific questions and priorities identified as part of the SCAR Horizon Scan. It would widen relevance to a broader spectrum of Antarctic scientists, connect communities and enhance progress across this spectrum. The proposed approach involves three main scientific objectives: (1) Quantify linkages between Antarctic climate variability and the rest of the planet; (2) Explain the contemporary annual-to-decadal time-scale trends in the Antarctic climate system and (3) Determine the near-term predictability of the Antarctic climate system. A further two objectives are to (4) enhance collaborations across the science disciplines, and (5) develop effective communication of the latest science by highlighting key results for impact assessments and to bodies concerned with how a changing climate may impact the governance and management of the Antarctic.

The core membership comprises 44 world-leading scientists from a diverse range of backgrounds in terms of expertise, career stage and geographical distribution.

a. Introduction

This SRP will improve near-term (1-30 years) Antarctic¹ climate prediction capacity, by combining advances in coupled modelling, improved observing technology and datasets, and developments in data science. More generally, it concerns the currently-evolving state of the climate system and the impacts of these changes both regionally and globally. These time scales are highly relevant across multiple disciplines and to a range of key stakeholders, whilst aligning strongly with scientific priorities identified as part of the SCAR Horizon Scan. The focus on the near term fills a gap in the current SRPs. In particular, near term climate prediction presents a clearly distinct scientific and policy challenge from the longer-term end-of-century focus of soon-to-conclude SCAR Programme Antarctic Climate Change in the 21st Century (AntClim21). The proposed AntClimNow programme is divided into the following themes:

- Theme 1. Antarctic climate variability and the global climate system
- Theme 2. Understanding present-day climate trends in Antarctica
- Theme 3. Predictability of the Antarctic climate system
- Theme 4. Global and regional cross-disciplinary impacts
- Theme 5. Communication of results to stakeholders

As shown in Figure 1, the overarching goal is to improve predictions of the Antarctic climate system in the near term. This will be achieved by utilising new observational and modelling datasets and analysing them by drawing both on new theoretical ideas and also on methods from the rapidly expanding field of data science. Communication of the latest science results to stakeholders is integral to the proposed programme.

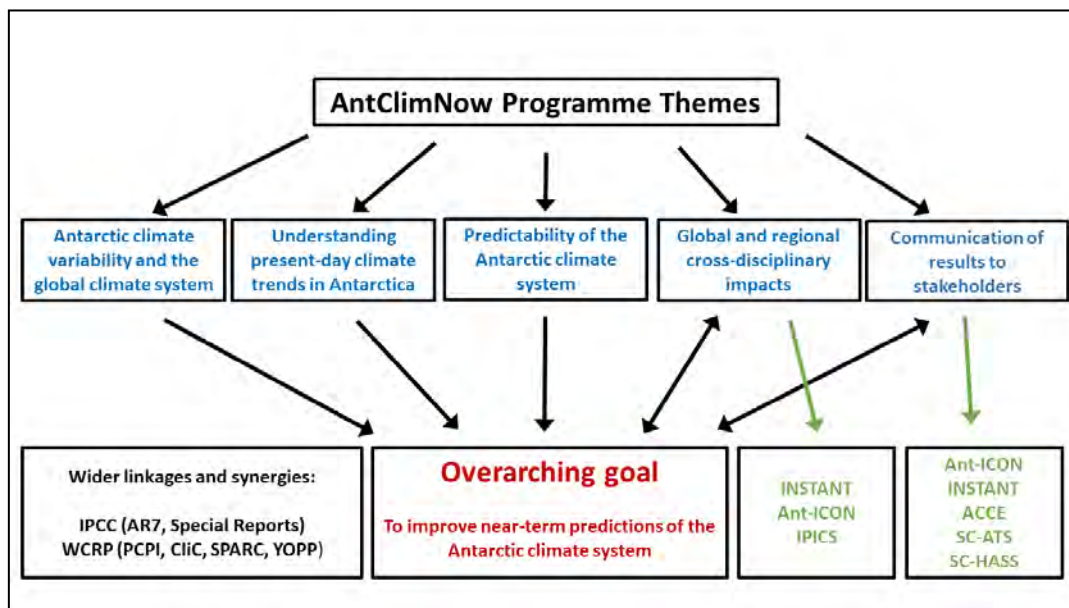


Figure 1. Schematic overview of the science and implementation plan of AntClimNow. Green arrows and text indicate linkages within SCAR. At the end of Section b more detail is provided on these and broader synergies.

The objectives of the proposed programme, listed below, reflect the above five themes. Their links to the SCAR Strategic Plan come through relevance to a range of Horizon

¹ SCAR's area of interest includes Antarctica, its offshore islands, and the surrounding Southern Ocean including the Antarctic Circumpolar Current, the northern boundary of which is the Subantarctic Front. Subantarctic islands that lie north of the Subantarctic Front and yet fall into SCAR's area of interest include Ile Amsterdam, Ile St Paul, Macquarie Island and Gough Island.

Scan questions (Kennicutt et al., 2014) (Objectives 1-4), through fostering interdisciplinary research activities (Objectives 4-5), and through strengthening collaborations with organisations and committees with interests in Antarctica (Objective 5).

- Objective 1: Quantify and understand atmospheric and oceanic linkages between Antarctic climate variability and the rest of the planet, with a focus on links with the tropics. These include tropical teleconnection impacts on Antarctica, and Antarctica's role in modulating global climate, weather and their extremes. Relevant to Horizon Scan (HS) questions 1, 2, 4, 6, 12, 13.
- Objective 2: Explain the contemporary annual-to-decadal time-scale trends in the Antarctic climate system, including the role of extreme events in these trends. Relevant to HS questions 11, 12, 13, 19, 20.
- Objective 3: Determine the predictability of the Antarctic climate system on a range of spatial and temporal scales, with a focus on quantifying uncertainties. Relevant to HS questions 7, 11, 15, 19.
- Objective 4: Identify cross-disciplinary connections and feedbacks to link scientific results from Objectives 1-3 to research programmes on impacts, for example, ecosystems or ice sheet dynamics and potential feedbacks to the climate system.
- Objective 5. Develop a dialogue with key Antarctic stakeholders (e.g. bodies such as the Committee for Environmental Protection (CEP) and Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) concerned with how a changing climate may impact the governance and management of the Antarctic) with an emphasis on the effective communication of science advances and remaining challenges.

b. Scientific background

Estimating how the Antarctic environment may change in the near term (years-to-multiple decades) is a scientifically complex task that involves significant contributions from both externally forced (e.g. anthropogenic) background climate change¹ and internally-generated climate variability² on annual to multi-decadal timescales (Kirtman et al., 2013) (see *Key definitions* text box below). In addition to primary meteorological and oceanic

Key definitions

¹**Externally forced climate change** is the steady ongoing background change due to factors such as increasing greenhouse gases. It can be thought of as a 'signal' that emerges over multiple decades.

²**Internal climate variability** is the 'noise' about this signal that results in some months, years, or decades, being unusually warm or cold (or rainy or dry). A well-known source of climate variability is the transition between El Niño and La Niña in the tropical Pacific that occurs every few years (referred to as ENSO) and alters conditions across the globe, including Antarctica. Although internal variability makes it difficult to know in advance whether a specific year will be warmer or colder than usual, there is intensive research into using predictability of phenomena such as ENSO to help improve estimates of atmosphere and ocean conditions over the next 1-10 years.

parameters, such as temperature, wind and sea ice, understanding the wider environment (e.g. surface mass balance, snow cover, ice shelves, ice sheets) and associated feedbacks is key in terms of quantifying ongoing and future impacts (e.g. Bronselaer et al., 2018; Cavanagh et al., 2017; Golledge et al., 2019).

The near-term response of the Antarctic environment to anthropogenic forcing is understood to depend largely on the relative strength of opposing impacts of stratospheric ozone recovery

and greenhouse gas increases (Arblaster et al., 2011; Barnes et al., 2014). Recent trends provide evidence to support this, in particular the well-documented summer impacts of stratospheric ozone depletion (the Antarctic ozone hole) on the westerly winds over the Southern Ocean (Gillett and Fyfe, 2013; Thompson and Solomon, 2002) and resulting influences on ocean circulation and warming of the eastern Antarctic Peninsula (Figure 2) (Marshall et al., 2006).

In addition to external forcings, Antarctic climate trends have some of the largest contributions from internal variability in comparison to the rest of the globe (see Figure 3, which is from Hawkins et al., 2016). As a consequence of this large internal variability, Hawkins et al. (2016) found that even in a scenario of rapid global warming there is a high chance of observing a local multi-decadal Antarctic cooling trend generated purely by internal climate variability. Reconstructions of past temperature (Figure 2) are broadly consistent with the variability generated in climate models, but the accuracy in near-term model predictions depend strongly on whether they can reliably reproduce the causes and responses of real-world variability and trends.

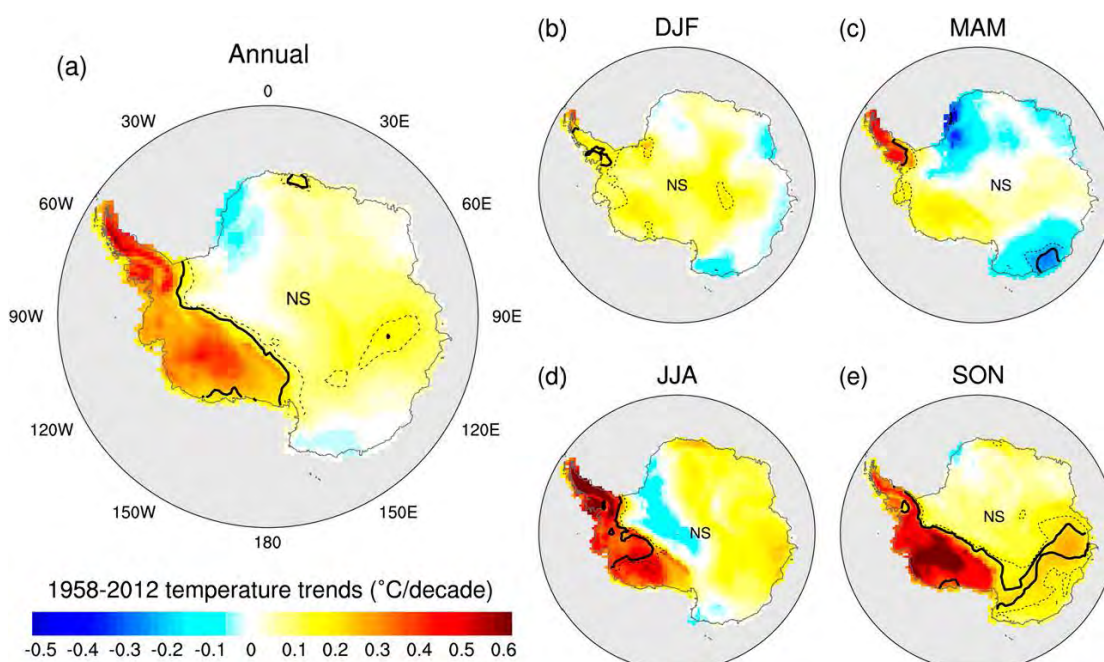


Figure 2. Reconstructed linear trends of 2-m air temperature over Antarctica from station observations from 1958-2012 (from Figure 4 of Nicolas and Bromwich, 2014). Notice the strong warming over West Antarctica, and little or no change over East Antarctica.

On timescales of less than ~10 years there is predictability in modes of internal climate variability such as ENSO. However, different types of ENSO events have been found to have contrasting impacts on Antarctica and more research is needed to improve our understanding of this link (e.g. Wilson et al., 2016). Moreover, this motivates the importance of maintaining a close link to the research community studying forcings of recent and ongoing changes to ENSO itself and potential implications for Antarctica (e.g. Cai et al., 2018; Hu and Fedorov, 2018; Zheng and Yu, 2017). In terms of sources of internal variability local to Antarctica, there is increasing evidence for strong variability generated by deep ocean convection within the Southern Ocean (Zhang et al., 2019). This is relevant to predicting near-term changes both within the Southern Ocean and over the Antarctic continent, which is strongly influenced by the surrounding Southern Ocean (Bracegirdle et al., 2015; Holloway et al., 2016; Krinner et al., 2014). It is also relevant globally since the Southern Ocean is responsible for $75\% \pm 22\%$ of the global ocean's heat uptake, and $43 \pm$

3% of ocean anthropogenic carbon uptake. Most of this occurs as a result of Mode and Intermediate water formation, which is closely tied to polar processes (Abernathey et al., 2016; Evans et al., 2018; Pellichero et al., 2018). The Southern Ocean is changing rapidly which could mean that in the near future its role in the regulation of climate could weaken or reverse given that the system is warming and freshening (Zhang et al., 2017).

To develop a more detailed picture of causes and impacts of near-term variability and trends, recent research has highlighted the importance of extreme events. For example regional accumulation totals over terrestrial Antarctica are dominated by rare extreme precipitation events on annual and longer timescales (e.g. Turner et al., 2019). In terms of impacts, there is modelling evidence that changes in variability and associated extreme events at lower (extra-polar) latitudes can be driven by changes in Antarctica (England et al., 2020; Lim et al., 2018).

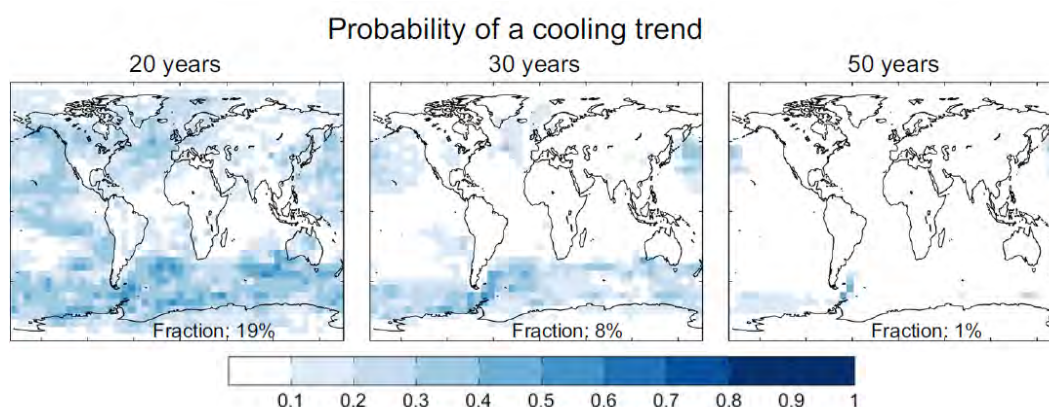


Figure 3. Climate model estimates of the probability of the occurrence of a cooling trend in a warming world under a quadrupling of CO₂ over 140 years for linear trends of 20, 30 and 50 years. From Figure 5 of Hawkins et al. (2016). The probability maps shown are based on a simplified climate modelling framework which can provide a highly valuable picture of the relative importance of greenhouse gas-forced climate change and the impact of internal climate variability (or unforced noise).

Why now?

- There is an urgent need to provide policy-makers and stakeholders with estimates on how Antarctic climate may change in the near-term, especially given its global connectivity through sea level rise, the deep ocean circulation and extreme events.
- One of the Grand Challenges of the World Climate Research Programme (WCRP) is Near-term Climate Prediction.
- A wide range of recent observational and modelling studies and associated advances in technical capability have set the stage for rapid advances in understanding and predicting annual to multi-decadal climate variability in Antarctica.
- The latest version of WCRP Coupled Model Inter-comparison Project (CMIP6) is producing results including new decadal prediction simulations and simulations targeted at understanding the causes and consequences of polar climate change.
- New syntheses providing reconstructions of past Antarctic climate and its variability are being produced that are potentially highly valuable in evaluating climate model skill in representing internal variability and thus indicating the reliability of model-derived envelopes of possible near-term conditions over Antarctica.
- Improved availability, coordination and dissemination of ocean observations from projects such as the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project and the Southern Ocean Observing System (SOOS) are currently

providing a wealth of new information that is highly important for improving process understanding and for climate model evaluation.

Synergies with other SCAR programmes and products

- The proposed SRP on Integrated Science to Support Antarctic and Southern Ocean Conservation (Ant-ICON). The topic of near-term climate prediction is highly relevant to this PPG. There is clear potential for collaboration. A key aim is for AntClimNow to liaise with Ant-ICON to provide relevant climate products to support their aim of providing policy-ready information to stakeholders.
- The proposed SRP on INStabilities and Thresholds in ANTArctica (INSTANT). Collaborate on areas of science that are related, such as tropical linkages and estimates of future conditions to 2050.
- The Standing Committee on Humanities and Social Sciences (SC-HASS) will be invited to discuss potential collaborative projects linking near-term climate predictions and the humanities.
- The current Action Group Tropical Antarctic Teleconnections (TATE) is focussed on examining climate processes linking the tropics to Antarctica and outcomes from this will be highly relevant to Theme 1 and will also feed into other themes.
- Antarctic Climate Change and the Environment (ACCE) will be an important route for communication of science results to policymakers and the wider community.
- It will be important to develop links with SOOS in relation to ocean observations.
- International Partnership in Ice Core Sciences (IPICS). Work with the international ice core community to promote the targeted collection and synthesis of proxy data suitable for model comparison.
- The Antarctic Sea-ice Processes and Climate (ASPeCt) Expert Group, which will be a key link in terms of sea ice processes, modelling and observations.
- Antarctic Clouds and Aerosols (ACA) Action Group, since the representation of clouds is one the major challenges in weather and climate models.

Synergies with other highly relevant international programmes

- Year of Polar Prediction (YOPP), which will include a number of legacy observational and modelling products and advances of high relevance to AntClimNow. A key related activity is sea ice prediction inter-comparisons and evaluations coordinated by the Sea Ice Prediction Network (SIPN) – South.
- The International Association for Meteorology and Atmospheric Sciences (IAMAS) International Commission on Polar Meteorology (ICPM), which holds regular meetings to facilitate and coordinate meteorological research in the polar regions.
- Develop links with the planned Antarctic Regional Climate Centre-Network, an initiative of the World Meteorological Organisation (WMO).
- PAGES2k, in particular through CLIVASH2K and future PAGES working groups. This will connect AntClimNow to researchers working on quantifying Antarctic climate variability from longer-term climate proxy datasets.
- The WCRP's Polar Climate Predictability Initiative (PCPI), which is co-sponsored by the highly relevant projects Climate and the Cryosphere (CliC) and Stratosphere-troposphere Processes And their Role in Climate Project (SPARC).

c. Methodology

To address the science objectives, key questions have been identified where there are clear opportunities for progress. These opportunities come from a combination of new modelling capabilities, new observational capabilities and datasets, and new analysis techniques in the rapidly-developing field of data science. Comprehensively addressing

all the key questions would require additional funding or support. Therefore, AntClimNow will aim to coordinate efforts to gain support for research contributing to achieving the proposed objectives.

Major datasets and analysis tools that will be fundamental to answering the key questions are as follows:

- The WCRP Coupled Model Inter-comparison Project Phase 6 (CMIP6), within which the key sub-projects are:
 - The Decadal Climate Prediction Project (DCPP).
 - The Antarctic component of the Coordinated Regional Downscaling Experiment (CORDEX).
- Decadal prediction systems (e.g. the UK Met Office DePreSys).
- Climate reconstructions based on in situ observations and climate proxies.
- Data science and machine learning.
- Reanalysis and other atmospheric reconstruction products
- Ground-based, balloon-borne and airborne observational datasets.

Key question 1: How large is real-world annual-to multi-decadal variability of the Antarctic climate system, and how well represented is it in the current generation of climate / earth-system models? Can we make better use of existing data, such as satellite remote sensing data and ocean sub-surface float data (Argo), and work to prepare better for new datasets? This relates to Objectives 1, 2 and 3.

Methodology: Utilise current advances in proxy reconstructions of Antarctic climate and surface mass balance variability in recent centuries and develop cross-disciplinary collaborations to help make the best use of such information in the evaluation of climate models. Identify priorities for new observations and use these and existing data to the improvement representation of important and/or missing processes in models.

Key question 2: What are the main drivers of annual-to-multi-decadal variability of Antarctica, the Southern Ocean and its ice-atmosphere interactions? This question relates both to Objectives 1 and 2.

Methodology: Key approaches to addressing this question are: (i) Use data science techniques (i.e. a range of statistical methods including recent advances in machine learning) to identify potential internal and extra-polar drivers of variability from observational and climate model datasets. (ii) Examine causality inferred from statistical results by conducting model-based sensitivity studies. (iii) Test the realism of climate model depictions through targeted investigations of new and existing in-situ, satellite and proxy observational datasets. (iv) Evaluate, and promote the development of, coupled high-resolution models of the Southern Ocean and Antarctica which for example are important for simulating internal modes of variability in the Southern Ocean.

Key question 3: How predictable is the Antarctic climate system on annual-to-decadal timescales? This relates to Objective 3 and 4.

Methodology: Planned ways of addressing this question are: (i) Assess output from the latest decadal prediction systems from leading weather and climate modelling centres. (ii) Complement dynamical modelling with statistical / machine learning approaches. (iii) Improve estimates of future change at high spatial resolution over key parts of Antarctica using both dynamical downscaling, for example in collaboration with Antarctic-CORDEX, and statistical downscaling.

Key Question 4: How best can predictions be downscaled and/or process studies be upscaled to enable improved parametrisation and better connections with ice sheet and ecosystem studies. This relates to Objective 3.

Methodology: Utilise idealised and high resolution numerical model studies, statistical and data science methods, available process studies and physical and biological observational data.

Key question 5: What are the key drivers of extreme events in Antarctica and what are the impacts of Antarctic variability and trends on extreme events in key regions of Antarctica, as well as globally? This relates to Objectives 1 and 2.

Methodology: A range of atmospheric datasets will be used to assess the drivers of extreme events over Antarctica and build on recent progress in, for example, the roles of atmospheric rivers and extreme storms in precipitation extremes (e.g. Wille et al., 2019). In terms of extra-polar impacts of Antarctica change, a key approach will be to use the CMIP6 experiment on polar amplification (PAMIP) (Smith et al., 2019) to evaluate potential impacts of Antarctic sea ice retreat on the rest of the globe.

Key question 6: How can the uncertainties inherent in prediction for the near term be best communicated to policy decision-makers and what information can be provided that would improve decision making? This relates to Objective 5.

Methodology: This will entail engagement with relevant decision-makers through, for example, joint workshops. Collaboration with Ant-ICON will be key in developing strong links to policymakers and researchers with a focus on Antarctic and Southern Ocean ecosystems.

d. Management and reporting

AntClimNow will be managed by a Scientific Steering Committee (SSC). Two co-Chief Officers will provide overall coordination of the SSC. To help ensure the sharing of effort across the themes, each SSC member is linked to a specific theme and will have responsibility for:

1. Delivery of the key aims of that theme; and
2. Organising and overseeing agreed theme-specific activities (e.g. workshops).

Scientific Steering Committee members

Co-Chief Officers: Tom Bracegirdle and Ilana Wainer

SSC members by theme:

Theme 1: Erik Behrens, Sheeba Chenoli, Ryan Fogt, Seong-Joong Kim

Theme 2: Matt England, Jan Lenaerts, Waliur Rahaman

Theme 3: Tom Bracegirdle, John Fyfe, Zhaomin Wang

Theme 4: Alia Khan, Shelley MacDonell, Craig Stevens, Ilana Wainer

Theme 5: Rachel Cavanagh, Liz Thomas

In the first year an early career researcher (ECR) representative will be selected in collaboration with the Association of Polar Early Career Scientists (APECS). They will work towards providing opportunities for ECRs to participate in AntClimNow activities and more generally contribute towards encouraging and providing support and opportunities for young researchers to develop the networks and experience that are important for making the transition to a successful mid-career polar scientist.

e. Milestones, outcomes, and benefits

Milestone and outcomes

1. AntClimNow will bring together scientists from a range of backgrounds to develop a community focussed on near-term Antarctic climate prediction. The extensive and diverse PPG membership as a starting point in this. Success in this regard will be measured in terms of the numbers, diversity and level of participation of the membership of AntClimNow.
2. This community will be used to facilitate scientific advances in near-term climate

predictions for Antarctica. Key metrics for success will be:

- Publications in the peer review science literature that are either fully written as part of AntClimNow activities, or include a significant identifiable contribution.
- A series of workshops are planned to focus on making progress on specific key questions or themes. Specific outcomes and measures of success from each workshop will depend on the detailed plans to be developed. However they will likely include: community synthesis datasets, grant funding applications, community coordination of observational data analysis or retrieval, and community coordination of climate modelling effort such as improving process parameterisations and designing model inter-comparison activities. Planned workshops for the first four years are as follows:

- Year 1

- Theme 3. Near term predictions: current status and future priorities for observations and modelling. Key focal points could include high resolution modelling, and defining the 'ideal' observation system.
- Cross-SRP mini-workshop on linkages on both the science and policy side (Themes 4 and 5) (video-conference).

- Year 2 (Potential to combine with SCAR 2022)

- Theme 1. Tropics to Antarctica workshop.
- Cross-SRP: (Theme 4) on atmospheric and oceanic influences on Antarctic ice sheet mass balance, including surface and basal mass balance and feedbacks. Joint with INSTANT.

- Year 3

- Theme 2. Improving models, modern observations and longer-term proxy datasets for better understanding of present-day climate trends.

- Year 4 (Potential to combine with SCAR 2024)

- Cross-SRP (Theme 5). Advances, opportunities and limitations of near-term predictions in providing information to Antarctic policymakers and stakeholders. Link to Ant-ICON.

- Years 5-8. Specific planning for the second four-year phase will be done during the first four years. A similar pattern of activities is anticipated. Key final outcomes will include a synthesis report and other finalisation products and activities to showcase the achievements of AntClimNow.

3. Convene science sessions SCAR Open Science Conferences and other major international conferences such as the AGU Fall Meeting. Success of these sessions will be judged both on the quality of the science presented as well as the diversity of attendees, with travel grants planned for ECRs and researchers from emerging Antarctic nations.

4. Develop clear coherent messages from within the climate science community to the wider community and stakeholders on the latest science on near-term climate prediction. Following the cross-SRP workshop in year 4, a summary document will be produced to bring together key messages from the work of the first four years.

5. Improved communication between scientists and stakeholders (e.g. environmental management groups, logistics managers, tourism and fisheries). To help ensure efficient and effective communication of science results, AntClimNow will coordinate with Ant-ICON and INSTANT to utilise their strong links to policymakers. Metrics for success will be: (i) Holding regular video-conference meetings between relevant members of Ant-ICON and AntClimNow (and other relevant attendees) and (ii) include a representative from Ant-ICON and AntClimNow on each other's SSCs.

6. At the end of the Programme produce a synthesis report bringing together the main findings.

Benefits

AntClimNow will provide a wide range of benefits. Principal among these are improvements in:

- near-term predictions of the Antarctic climate system;
- scientific understanding of the mechanisms for variability and trends in over Antarctic climate;
- knowledge on impacts of Antarctica on lower latitudes;
- quantification of uncertainty in such predictions; and
- communication to non-experts of the both the robust, high confidence, results and importantly the uncertainty and limitations in predictive skill.

The formation of an active and diverse community of world experts working together in the interests of improving scientific knowledge of the Antarctic is a major overall benefit. There are several untapped resources of scientific knowledge, technical capability and funding that could be utilised for Antarctic research, and this proposed SRP would help to bring these together as well as accelerate progress in the future.

f. Data management plan

SCADM will be consulted in developing plans for data collection and management. For paleoclimate data we will follow standards proposed by the PAGES community. Many of the planned activities of AntClimNow will involve use of existing data sources. Those of particular relevance include:

- The CMIP6 dataset. In particular (but not restricted to) the sub-projects:
 - DCPD - Decadal Climate Prediction Project (DCPD);
 - Historical and future (ScenarioMIP) climate forcing simulations;
 - FAFMIP - Flux-Anomaly-Forced Model Intercomparison Project;
 - CORDEX - Coordinated Regional Climate Downscaling Experiment; and
 - PMIP - Palaeoclimate Modelling Intercomparison Project.
- Atmosphere and ocean reanalyses and other reconstruction products.
- Satellite remote sensing products of the ocean/atmosphere/ice system. We will utilise existing datasets and prepare for future satellites such as EarthCARE.

g. Capacity building, education and training plan

AntClimNow will use a multi-pronged approach to help build capacity in the SCAR community. We will appoint one or more early ECRs to join the Scientific Steering Committee who will help to facilitate opportunities and support for ECRs. We will also work with the Association of Polar Early Career Scientists (APECS) and Young Earth System Scientists (YESS), ensuring participation of ECRs at all events and encouraging more senior members to act as APECS and YESS mentors.

We will facilitate opportunities for, and encourage the participation of, researchers from emerging Antarctic nations in AntClimNow events and activities. This will be done through: providing travel grants to workshops; raising awareness of the possibilities offered by the SCAR Fellowships Programme; and teaming up with APECS and YESS to utilise their global networks.

We will undertake a range of outreach and capacity building activities (listed below) in collaboration with other SRP's to communicate our results to the science community, policymakers and the general public. Specific planned activities are as follows, but with the aspiration to add further activities in response to opportunities that become available (such as schools talks or participation in science festivals):

- Year 1: Establish website content and social media accounts (e.g. Twitter and Facebook).
- Year 2: Attend an APECS and/or YESS meeting (in person or remotely) to present key current priorities and Antarctic climate science and help inform future Antarctic scientists of the work of SCAR.
- Year 3: Webinar on a key current issue/topic in Antarctic climate science, which will be aimed at a broad non-specialist audience.
- Year 4: Hold an event or activity at SCAR 2024 to help communicate the latest science on near-term climate prediction to the wider non-science Antarctic community and stakeholders, utilising, for example, the attendance of COMNAP delegates.
- Years 5-8: As outlined in the deliverables section above, specific planning for the second four-year phase will be done during the first four years, although a similar pattern of activities is anticipated.

An important resource to help ensure success in this regard will be active engagement with the SCAR Capacity Building, Education and Training (CBET) Advisory Group. We will also provide information and announcements through a range of channels (email mailing list, SCAR-hosted website, Twitter and Facebook).

h. References

- Abernathy, R. P., I. Cerovecki, P. R. Holland, E. Newsom, M. Mazlo, and L. D. Talley, 2016: Water-mass transformation by sea ice in the upper branch of the Southern Ocean overturning. *Nat. Geosci.*, **9**, 596-601.
- Bracegirdle, T. J., D. B. Stephenson, J. Turner, and T. Phillips, 2015: The importance of sea ice area biases in 21st century multimodel projections of Antarctic temperature and precipitation. *Geophysical Research Letters*, **42**.
- Bronselaer, B., and Coauthors, 2018: Change in future climate due to Antarctic meltwater. *Nature*, **564**, 53-58.
- Cai, W. J., and Coauthors, 2018: Increased variability of eastern Pacific El Niño under greenhouse warming. *Nature*, **564**, 201-206.
- Cavanagh, R. D., and Coauthors, 2017: A Synergistic Approach for Evaluating Climate Model Output for Ecological Applications. *Frontiers in Marine Science*, **4**.
- England, M. R., L. M. Polvani, L. T. Sun, and C. Deser, 2020: Tropical climate responses to projected Arctic and Antarctic sea-ice loss. *Nat. Geosci.*
- Evans, D. G., J. D. Zika, A. C. Naveira Garabato, and A. J. G. Nurser, 2018: The Cold Transit of Southern Ocean Upwelling. *Geophysical Research Letters*, **45**, 13386-13395.
- Gillett, N. P., and J. C. Fyfe, 2013: Annular mode changes in the CMIP5 simulations. *Geophysical Research Letters*, **40**, 1189-1193.
- Golledge, N. R., E. D. Keller, N. Gomez, K. A. Naughten, J. Bernales, L. D. Trusel, and T. L. Edwards, 2019: Global environmental consequences of twenty-first-century ice-sheet melt. *Nature*, **566**, 65-72.
- Hawkins, E., R. S. Smith, J. M. Gregory, and D. A. Stainforth, 2016: Irreducible uncertainty in near-term climate projections. *Climate Dynamics*, **46**, 3807-3819.
- Holloway, M. D., L. C. Sime, J. S. Singarayer, J. C. Tindall, P. Bunch, and P. J. Valdes, 2016: Antarctic last interglacial isotope peak in response to sea ice retreat not ice-sheet collapse. *Nature Communications*, **7**.
- Hu, S. N., and A. V. Fedorov, 2018: Cross-equatorial winds control El Niño diversity and change. *Nature Climate Change*, **8**, 798-802.
- Kennicutt, M. C., II, and Coauthors, 2014: Polar Research: Six priorities for Antarctic science. *Nature*, **512**, 23-25.
- Kirtman, B., and Coauthors, 2013: Near-term Climate Change: Projections and Predictability. *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 University Press.
- Krinner, G., C. Langeron, M. Menegoz, C. Agosta, and C. Brutel-Vuilmet, 2014: Oceanic Forcing of Antarctic Climate Change: A Study Using a Stretched-Grid Atmospheric General Circulation Model. *Journal of Climate*, **27**, 5786-5800.
- Lim, E. P., H. H. Hendon, and D. W. J. Thompson, 2018: Seasonal Evolution of Stratosphere-Troposphere Coupling in the Southern Hemisphere and Implications for the Predictability of Surface Climate. *Journal of Geophysical Research-Atmospheres*, **123**, 12002-12016.
- Marshall, G. J., A. Orr, N. P. M. van Lipzig, and J. C. King, 2006: The impact of a changing Southern Hemisphere Annular Mode on Antarctic Peninsula summer temperatures. *Journal of Climate*, **19**, 5388-5404.
- Nicolas, J. P., and D. H. Bromwich, 2014: New Reconstruction of Antarctic Near-Surface Temperatures: Multidecadal Trends and Reliability of Global Reanalyses. *Journal of Climate*, **27**, 8070-8093.
- Pellichero, V., J. B. Sallee, C. C. Chapman, and S. M. Downes, 2018: The southern ocean meridional overturning in the sea-ice sector is driven by freshwater fluxes. *Nature Communications*, **9**.
- Smith, D. M., and Coauthors, 2019: The Polar Amplification Model Intercomparison Project (PAMIP) contribution to CMIP6: investigating the causes and consequences of polar amplification. *Geoscientific Model Development*, **12**, 1139-1164.
- Thompson, D. W. J., and S. Solomon, 2002: Interpretation of recent Southern Hemisphere climate change. *Science*, 895-899.
- Turner, J., and Coauthors, 2019: The Dominant Role of Extreme Precipitation Events in Antarctic Snowfall Variability. *Geophysical Research Letters*, **46**, 3502-3511.
- Wille, J. D., V. Favier, A. Dufour, I. V. Gorodetskaya, J. Turner, C. Agosta, and F. Codron, 2019: West Antarctic surface melt triggered by atmospheric rivers. *Nat. Geosci.*, **12**, 911-916.
- Wilson, A. B., D. H. Bromwich, and K. M. Hines, 2016: Simulating the Mutual Forcing of Anomalous High Southern Latitude Atmospheric Circulation by El Niño Flavors and the Southern Annular Mode. *Journal of Climate*, **29**, 2291-2309.
- Zhang, L. P., T. L. Delworth, W. Cooke, and X. S. Yang, 2019: Natural variability of Southern Ocean convection as a driver of observed climate trends. *Nature Climate Change*, **9**, 59-65.
- Zhang, L. P., T. L. Delworth, X. S. Yang, R. G. Gudgel, L. W. Jia, G. A. Vecchi, and F. R. Zeng, 2017: Estimating Decadal Predictability for the Southern Ocean Using the GFDL CM2.1 Model. *Journal of Climate*, **30**, 5187-5203.
- Zheng, F., and J. Y. Yu, 2017: Contrasting the Skills and Biases of Deterministic Predictions for the Two Types of El Niño. *Adv. Atmos. Sci.*, **34**, 1395-1403.