CANADIAN ANTARCTIC RESEARCH WORKSHOP REPORT

October 2016

POLAR KNOWLEDGE CANADA

Polar Knowledge Canada
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EXECUTIVE SUMMARY

Antarctica is a significant region that regulates global climate and ocean systems and is important for Canada and the world. Antarctic research can improve understanding of a range of phenomena, including Earth and biological systems, space weather, and the universe. It provides excellent conditions for understanding adaptation of biota and humans to extreme environments and testing the performance of technologies. Antarctic research is also necessary to inform decisions regarding the governance and environmental protection of Antarctica.

Canadians doing Antarctic research are currently based at more than 15 Canadian universities and four federal government organizations, as well as some other institutions, and conduct Antarctic research by carrying out fieldwork and utilizing available observations through collaborations with other nations and leveraging Arctic observations. Canadian Antarctic researchers have expertise in a range of research areas, and their intellectual and technical contributions are extremely valued by the international community.

Polar Knowledge Canada (POLAR) convened a Canadian Antarctic Research Workshop on October 3rd-4th, 2016 at the Canadian Museum of Nature in Ottawa, Ontario to explore opportunities to strengthen Canadian Antarctic research activities, including through the development of a program. This report captures the outcomes of workshop discussions.

Importance of increased Antarctic engagement by Canada

Canada has been a non-consultative party to the Antarctic Treaty since 1988. As a non-consultative party, Canada is unable to participate in Antarctic governance decisions that will have implications for the environmental protection of this internationally significant region and the Canadian activities that take place there. For a successful request for consultative status, a prospective country needs to demonstrate interest and an ongoing commitment in the region by conducting substantial scientific research there. Consultative status would signal a strong interest in Antarctic governance decisions and assist in positioning Canada as a leader in polar and global issues.

Need for a Canadian Antarctic Research Program

The costs of both terrestrial and ocean-based Antarctic fieldwork are high due to logistical complexities resulting from the remoteness and extreme environmental conditions of Antarctica. As a result, similar to Arctic fieldwork, a large proportion of the total cost of a research project is often devoted to accessing study sites. In the absence of a Canadian Antarctic program, and given available domestic research funding sources, researchers presently rely significantly on the national Antarctic programs of other countries for logistics and research support. A Canadian program with dedicated resources for Antarctic research would enable researchers to propose and drive Antarctic research, and address priorities of importance to Canada.

Approach to developing and delivering a Canadian program

A Canadian Antarctic Research Program could be developed with an investment of seed funds that builds on existing Antarctic resources. Instead of building a Canadian Antarctic research station with logistics services, funds could be used to financially support Canadian researchers to work in collaboration and partnership with other nations. This would provide Canada with the flexibility to choose scientific targets and geographical regions while ensuring responsiveness to evolving research priorities by partnering with nations and researchers that focus on a specific scientific issue or are already operating in a specific region of Antarctica. It would also enable Canada to build on and leverage existing research relationships and initiatives between Canadian and international Antarctic researchers, while reducing environmental impacts and costs associated with the construction, operation and maintenance of new Antarctic infrastructure.

Where a strong Canadian contribution is desired, there may be a need for the development of partnership agreements with other nations to (a) define common scientific goals and geographical region(s) of interest; (b) clarify roles, responsibilities and contributions; and (c) provide for funding envelopes that can be accessed by Canadian and international researchers through a competitive process.

Key supporting elements for a Canadian program include funds that target both new and experienced Antarctic researchers to address Canadian priorities and to undertake fundamental science that can lead to important new discoveries, the appointment of a program director with an Antarctic science background, and an ongoing effort to ensure open and accessible data to support new research and policy. Strong coordination within the domestic and international Antarctic research community and Canadian representation at international Antarctic conferences and scientific planning meetings would be needed to facilitate collaboration. Greater communications and outreach within Canada is also needed to enhance awareness of the importance of Antarctica and the value of Antarctic research to Canada.

Implications of various funding scenarios

Six broad Antarctic research themes were defined for the purpose of focusing discussions during the workshop[1]. Workshop participants discussed benefits and limitations associated with three funding scenarios: $500,000; $1 million; and $2 million per year, per research theme. With a low funding scenario, the potential Canadian contribution would be incremental, with Canadian researchers generally serving as junior partners within existing international collaborations, and relying almost exclusively on the national Antarctic programs of other countries. This would limit opportunities to address Canadian priorities. In the longer term, if there are insufficient opportunities for researchers to increase and sustain involvement, there would also be a risk of Canada not fully benefiting from investments in early career researchers and training of highly qualified personnel. Despite these limitations, this low funding scenario would assist in increasing the current level of involvement of Canadians in Antarctic research.

At higher funding scenarios, Canadian researchers could enter into collaborations as equal or lead partners. This would be especially significant in disciplines that require field or ship-borne investigations to acquire new data. Canadian Antarctic researchers could also undertake a spectrum of scientific activities under each research theme. A sufficiently resourced Canadian Antarctic Research Program would enable Canadian researchers to exercise stronger research leadership and more robustly address Canadian research priorities.

Next steps

The findings of this workshop will be used by POLAR to inform future plans and activities under its mandate to promote the development and dissemination of knowledge of Antarctica. This will include promoting workshop findings among Canadian and international polar research stakeholders, and pursuing opportunities to develop a Canadian Antarctic Research Program.

[1]The six research themes are: geology, solid-Earth geophysics, and ice sheets; atmosphere, Southern Ocean and cryosphere; space and atmospheric physics, astronomy and astrophysics; permafrost, soils and landscapes; biota and ecosystems; and human activities in Antarctica.

Introduction

Polar Knowledge Canada (POLAR) is Canada's lead federal agency to strengthen Canadian leadership in polar science and technology, which includes a mandate to promote the development and dissemination of knowledge of the Antarctic. POLAR convened a Canadian Antarctic Research Workshop on October 3rd-4th, 2016 at the Canadian Museum of Nature in Ottawa, Ontario to explore opportunities to strengthen Canadian Antarctic research and inform next steps towards the development of a Canadian Antarctic Research Program. POLAR's Canadian Committee on Antarctic Research (CCAR)[2] provides advice and guidance on Antarctic matters, including the planning of this workshop. For more information about POLAR, including its mandate and activities, please see Annex B.

The workshop included over 60 participants, of which more than 35 are active Canadian polar researchers from universities and government. The remaining workshop participants were federal program managers and policy analysts, representatives from international Antarctic research programs, and other individuals with an interest in supporting or promoting Canadian Antarctic research.[3]

Workshop objectives

- Consider the strengths of the Canadian Antarctic research community;
- Build a shared understanding of the challenges and barriers Canadian researchers face when pursing Antarctic research;
- Consider how a Canadian Antarctic Research Program could build on existing domestic and international opportunities to address Canadian research and policy priorities; and,
- Foster a stronger sense of community.

Workshop structure

Workshop participants considered the following:

- International and domestic Antarctic research and policy context;
- Recent Canadian involvement in Antarctic research and additional non-Antarctic research strengths that could be applied;
- Future directions for Antarctic research, including those which are identified in the following documents:
  - Scientific Committee on Antarctic Research (SCAR) Antarctic and Southern Ocean Science Horizon Scan (2014)-80 pressing research questions for the next two decades, as identified by the international Antarctic research and policy community[4]; and,
  - Council of Managers of National Antarctic Programs (COMNAP) Antarctic Roadmap Challenges initiative (2016)-the supporting technologies, logistics and infrastructure needed to address the 80 pressing questions identified from the SCAR Science Horizon Scan[5].
- Challenges and opportunities associated with securing and utilizing funding and in-kind support, accessing Antarctic infrastructure and logistics, collaborating with domestic and international partners, and beginning and sustaining Antarctic research involvement; and,
- Three funding scenarios to explore associated benefits and limitations.

The workshop agenda is available in Annex A.

[2]For more information about POLAR's Canadian Committee on Antarctic Research (CCAR), please see: https://www.canada.ca/en/polar-knowledge/advancingpolarknowledge/canada-and-the-antarctic.html
[3]List of workshop participants available via info@polar.gc.ca
[4]Report available at: http://www.scar.org/horizonscan
[5]Report available at: https://www.comnap.aq/Projects/SitePages/ARC.aspx

CANADIAN COMMITTEE ON ANTARCTIC RESEARCH

The Canadian Committee on Antarctic Research (CCAR) provides advice and guidance to POLAR on Antarctic matters, and assisted with the planning and delivery of this workshop.

Thomas James-Research Scientist, Geological Survey of Canada, Natural Resources Canada and School of Earth and Ocean Sciences, University of Victoria (CCAR Chair)

Dermot Antoniades-Canada Research Chair in Aquatic Environments and Water Quality and Assistant Professor, Université Laval

Anita Dey Nuttall-Associate Director, UAlberta North, University of Alberta

Gustavo Ferreyra-Professor/Researcher, Phytoplankton Ecology, Institut des sciences de la mer de Rimouski, Université du Québec à Rimouski

Julie Friddell-Director, Canadian Cryospheric Information Network/Polar Data Catalogue, University of Waterloo

Nathan Gillett-Manager and Research Scientist, Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada

Denis Lacelle-Associate Professor, Department of Geography, Environment and Geomatics, University of Ottawa

Wayne Pollard-Professor, Department of Geography, McGill University

Peter Pulsifer-Research Associate, Geomatics and Cartographic Research Centre, Carleton University

Peter Suedfeld-Professor Emeritus, Department of Psychology, University of British Columbia

Jayachandran Thayyil-Professor, Department of Physics, University of New Brunswick

Diana E. Varela-Associate Professor, Department of Biology and School of Earth and Ocean Sciences, University of Victoria

Importance of Antarctica and Antarctic research

Antarctica is a globally significant region and Antarctic research encompasses a range of disciplines and topics that are important for Canada.

Changes in the Antarctic region have global implications. Antarctica and the Southern Ocean are a significant component of the global climate and ocean system, and contain approximately 85% of the world's freshwater resources. For example, processes that occur in the region influence weather patterns, heat transport, and oceanic uptake of anthropogenic carbon dioxide from the environment. Changes in Antarctic ice sheets and the solid-Earth response have implications for global sea level and coastal communities, and in turn, global and national security and infrastructure.

Antarctic research supports Antarctic governance decisions and environmental protection by providing a better understanding of both the positive and negative impacts of human activities in Antarctica, including from science and tourism, and related management policies. As a country with a developed economy that also undertakes significant research and economic activities in Antarctica (e.g. tourism), Canada has a social responsibility to support research and protection of this important region.

Antarctica is also an analogue for certain regions of Canada and other extreme environments, and provides an ideal platform to study certain phenomena and test technologies. Antarctica's cold, dry and stable atmosphere provides ideal conditions for observing space, and understanding the nature and origins of the universe. With the ionosphere in the Antarctic and Arctic linked by terrestrial magnetic field lines, observations from both regions are essential to understand complex interactions, and the implications for technologies and related infrastructure on Earth and in space. Antarctica's environment is also ideal for testing the performance of technologies in remote and extreme conditions.

Antarctic research can contribute to comparative studies with the Arctic to enhance understanding

of both polar regions, in research topics such as persistent organic pollutants, cruise ship tourism, and invasive species. Antarctica is an excellent analogue for space, given its hazardous and isolated environment, communications restrictions, and adaptation challenges for personnel. Antarctic research can contribute to further understanding of geological processes and conditions in certain regions of Canada and the preservation, adaptation and limits of life in extreme environments, with insights for origins of life on Earth and beyond. It can also provide insights and understanding regarding human life and adaptation in Antarctica and other extreme and isolated environments.

Canada's status within the Antarctic Treaty System

The Antarctic Treaty establishes Antarctica as a place for peaceful and scientific purposes. Canada acceded to the Antarctic Treaty as a non-consultative party on May 4, 1988[6]. Canada is a full party of the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol) since December 13, 2003, and enacted the *Antarctic Environmental Protection Act*, which is administered by Environment and Climate Change Canada (ECCC).

Canada has significant interests in Antarctica. In addition to the significance of Antarctica from a global climate and ocean systems and space weather perspective, Antarctic governance decisions have implications for Canadian activities in the region. Canadians are involved in scientific research and technology development, tourism, education and outreach activities, and the provision of operational support. For further information on Canadian activities in Antarctica, see Annex C.

Consultative status would provide a platform from which issues that have implications for Canada and Canadian activities can be managed. With non-consultative status, Canada can participate in discussions at Antarctic Treaty Consultative Meetings (ATCMs), but cannot vote on decisions regarding the governance of this globally significant region, despite having significant interests and activities there.

Although Canada is a full party to the Committee for Environmental Protection (CEP), CEP is an advisory body to the ATCM. As a result, Canada is bound under any changes made to the Protocol that result from decisions made at the ATCM. Consultative status would also enable Canada to increase compliance promotion and inspection capabilities under Canada's *Antarctic Environmental Protection Act*.

Consultative status can position Canada as a leader in polar and global issues. Science is the currency in Antarctica. As stated in Article IX of the Antarctic Treaty, to attain Consultative Status, a prospective country needs to demonstrate interest in Antarctica "by conducting substantial scientific research activity there". Attaining consultative status would signal that Canada recognizes the importance of the region and desires to have a voice at the table to collectively manage and govern the region. The intellectual and technical expertise of Canadian Antarctic researchers is extremely valued by the international research community. The attainment of Consultative Status would signal a commitment to assume a more active role within the international Antarctic research community, which can further understanding of changes occurring in the region, inform decision-making, and strengthen overall polar science capacity.

Most Arctic Council states and observers are Consultative Parties to the Antarctic Treaty. Increased engagement in Antarctic science and governance could assist Canada in developing and strengthening bilateral and multilateral relations with other countries that can be useful in addressing global issues that may arise in other regions of the world, including Canada's Arctic.

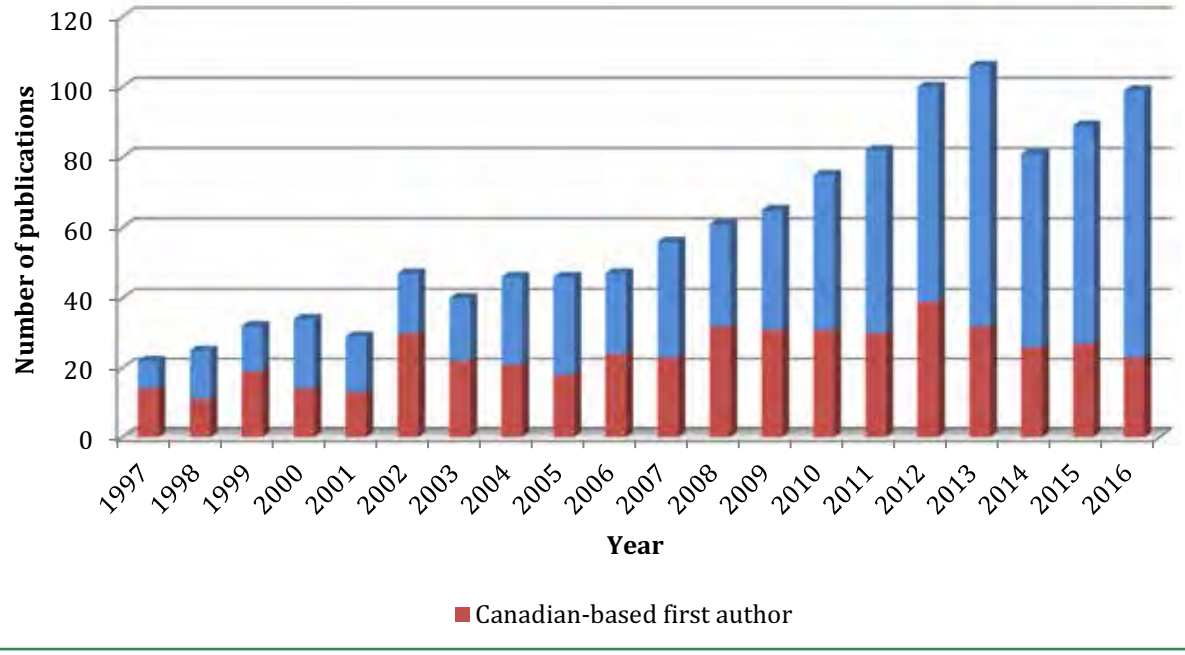
[6]See Annex D for a list of consultative and non-consultative parties to the Antarctic Treaty.

Highlights of recent Canadian Antarctic research involvement

Canadians have sustained involvement in Antarctic research over decades. Based on a list of Canadian Antarctic research publications (journal articles and review articles) generated using Web of Science[7], Figure 1 illustrates the total number of Canadian Antarctic research publications from 1997 to 2016 only, highlighting those with a Canadian-based first author as one indicator of research leadership. Results were reviewed to ensure inclusion of only relevant publications, defined as those covering research in or about Antarctica, sub-Antarctic islands, and the Southern Ocean, including comparative studies using data or observations from other geographic regions[8]. This was achieved primarily by reviewing the title or abstract of the publication, and in some cases, the full publication where further information was required.

Journal and review articles published by Canadian researchers from 1997-2016 cover physical, biological, human, social and geosciences research, as well as technology development, data management and geographic information. Although it may not provide a complete picture of the extent of Canadian research contributions given methodological limitations[9], it is evident that Canadians have made significant Antarctic research contributions over decades.

Figure 1: Canadian Antarctic research publications (1997-2016)



[7]Search parameters: All journal articles or review papers between 1997 and 2016 with one or more authors based at an institution in Canada, and one or more of the following keywords in either the title, abstract, author keyword or keywords plus field: 'Antarctic*', 'Southern Ocean', 'Ross Sea', 'Amundsen Sea', or 'Weddell Sea'.

[8]In order for a paper to be included, in cases where the focus was clearly not on Antarctica, a comparison to the Antarctic case or situation required an element of further analysis or extended discussion. Thus, a cursory one or two sentence comparison to Antarctica or the Southern Ocean case in the main text of the paper, and a brief mention in the abstract would not qualify the paper as "Antarctic research". In contrast, however, the results of laboratory analysis of samples from Antarctica or the Southern Ocean, even in a paper where the majority of samples were collected from elsewhere, would qualify the paper as "Antarctic research".

[9]Methodological limitations: The analysis does not include additional types of publications such as books and abstracts from some conferences, and keyword search was limited to title, abstract, or keyword fields only, which may not fully capture all potentially relevant Canadian Antarctic publications.

Six themes were identified in advance of the workshop for the purposes of highlighting recent Canadian involvement in Antarctic research during the workshop, and facilitating breakout discussions. They are as follows:

- Geology, solid-Earth geophysics, and ice sheets;
- Atmosphere, Southern Ocean and cryosphere;
- Space and atmospheric physics, astronomy and astrophysics;
- Permafrost, soils and landscapes;
- Biota and ecosystems; and
- Human activities in Antarctica.

The themes were designed to encompass the range of Canadian Antarctic research, while allowing for a roughly equal number of participants in each workshop breakout group. There is overlap in themes, and participants were encouraged to join the breakout group that most closely related to their research or policy interests.

The remainder of this section provides some highlights of recent Canadian involvement in Antarctic research. This is based on the following sources of information:

- Canadian Antarctic research bibliography by C. Simon L. Ommanney (2012)[10], plus additional publications since 2012;
- A list of Canadian Antarctic researchers and their expertise;
- Input from a 2015 Canadian Call for Input in relation to the 80 pressing questions identified in the SCAR Science Horizon Scan; and,
- Additional areas of Canadian Antarctic research expertise highlighted by theme leaders and workshop participants.

Geology, solid-Earth geophysics and ice sheets

East Antarctica is much like the cratonic Canadian Shield. In contrast, West Antarctica has undergone geologically recent rifting, has a thin lithosphere, and high crustal heat flow. East and West Antarctica are separated by the Transantarctic Mountains. Canadian tectonics and volcanism research in Antarctica has included study of mineral deposits in relation to tectonic evolution and reworking of the crust; estimations of the velocity of tectonic plates using space geodesy; and investigation of the plumbing system of the active Mount Erebus volcano and understanding how volcanism is related to regional tectonics.

The remote sensing Earth observation satellite RADARSAT has been an important Canadian contribution to Antarctic research and has contributed importantly to knowledge, and iconic images, of the surface velocity of the Antarctic ice sheet and its mass balance. Full and partial coverage of Antarctica were acquired in 1997, 2000, 2007, 2009-11 and 2014-16 from RADARSAT 1 and 2. RADARSAT 1 and 2 have contributed significantly to completing the first radar-generated map of surface ice velocities illustrating the speed and direction of ice flow in Antarctica. Canada is currently building RADARSAT Constellation Mission (RCM) satellites that will be launched in 2018 by the Canadian Space Agency and enable daily coverage of the polar regions.

Canadians have researched glacier processes, dynamics, and mass balance, including past evolution, and present and future drivers of change such as climate variability; use of glacial systems to archive past climates; subglacial processes and systems, including stability and drainage of subglacial water systems; and stability and tipping points and implications for changes in global climate. Instability of marine-based ice sheets is a key topic that has included Canadian Antarctic research involvement. With warm, inflowing circumpolar deep water melting the base of glaciers, this is causing thinning and receding. Under certain circumstances, retreat could accelerate under thinning scenarios, with recent publications putting the contribution to global sea level from Antarctic ice sheets at approximately one metre by the year 2100.

Glacial isostatic adjustment (GIA) - aka postglacial rebound - is the response of the solid Earth to ice-mass change. The behaviour of ice sheets and glaciers depend on bed conditions, including elevation relative to sea level and crustal heat flow. Canadian researchers have been involved in calibrating GIA to more

[10]Bibliography available at: https://era.library.ualberta.ca/files/nv9352930#.WCN_97wrLAw

accurately model changes and potential feedbacks. This has included the effect of GIA on ice mass balance estimates; and modeling and interpreting measurements of interactions between ice sheets, sea level and the solid Earth in response to past, present and future climate.

Space and atmospheric physics, astronomy and astrophysics

In the past five years, approximately 48 Canadian researchers, including graduate students, have conducted Antarctic related research pertaining to space and atmospheric physics, astronomy, and astrophysics. Canadian researchers have been authors on approximately 64 refereed publications in scientific journals over the past five years. Key sources of federal funding include Canada Foundation for Innovation (CFI), Canadian Space Agency, and the Natural Sciences and Engineering Research Council of Canada (NSERC).

In terms of space and atmospheric physics, Canadian researchers have examined similarities and differences between auroras, and have constructed meteor radars for middle atmospheric research for installation in Antarctica. Canadians are operating radars and other instrumentation in the northern hemisphere, which complement similar radars in the southern hemisphere. This includes the Super Dual Auroral Radar Network (SuperDARN); Geospace Observatory (GO) Canada, with a distributed array of magnetometers, all-sky imagers, photometers, riometers and radars; and the Canadian High Arctic Ionospheric Network (CHAIN), with 40 specialized GPS receivers and 6 high-frequency radars. This Arctic instrumentation is leveraged to increase access to similar Antarctic instrumentation to support scientific research.

Canadian astronomy and astrophysics research has included involvement in the following international initiatives to better understand the origin, nature and evolution of the universe:

- Balloon experiments:
  - Suborbital Polarimeter for Inflation, Dust and the Epoch of Reionization (SPIDER);
  - Balloon Observations of Millimetric Extragalactic Radiation and Geophysics (BOOMERanG); and,
  - Balloon-borne Large Aperture Sub-millimeter Telescope (BLAST).
- Research using ground-based telescopes and observatories:
  - South Pole Telescope (SPT);
  - Background Imaging of Cosmic Extragalactic Polarization (BICEP) 2 and 3 detectors and Keck Array telescopes;
  - Instrumentation, observation and data analysis related to the search for and characterization of transiting exoplanets; and,
  - Antarctic Muon and Neutrino Detector Array (AMANDA) and IceCube Neutrino Observatory.

Atmosphere, Southern Ocean and cryosphere

Antarctica and the Southern Ocean play a key role in the global climate and ocean system. The Southern Ocean is responsible for 50% of the ocean uptake of anthropogenic carbon, and has absorbed over 65% of the heat associated with global warming. Three quarters of the biological production in the global ocean north of 30 degrees S is fertilized by nutrients upwelled in the Southern Ocean, which is of major significance to fisheries. Antarctica is also home to the largest ice sheet on Earth, which is melting at an accelerating rate due in part to warming of the surrounding Southern Ocean. Antarctic sea ice has consistently defied expectations in a warming world, with many regions counter-intuitively experiencing sea ice gains. While the reasons for these gains are

not fully understood, one possible contributor is a freshening of surface waters due to ice shelf melt.

The climatic importance of the Southern Ocean is a consequence of its vigorous circulation. The Antarctic Circumpolar Current is the strongest ocean current in the world, and is the sole link among the three major ocean basins. The meridional overturning circulation drives the strong exchange of heat and carbon with the atmosphere. The Southern Ocean and Antarctica are heavily influenced by human-induced changes, which in turn have globally relevant impacts. For example, the Southern Ocean is warming at twice the rate of the global ocean, and this has been attributed to changes in the concentrations of atmospheric greenhouse gases. Human-induced ozone depletion is strongest in the Antarctic, and affects the winds, ocean circulation, and sea ice. Polar ozone depletion also has a very significant effect on subtropical precipitation, with direct human consequences.

Canadian Southern Hemisphere climate and Southern Ocean research has included examining circulation and processes; human and natural forcing; and biogeochemistry and carbon cycling. Specific areas of focus have included measuring and modeling ozone, and assessing the impacts of ozone depletion and recovery on regional and global climate. Simulations of Antarctic ozone depletion, recovery and climate effects made with the Canadian Middle Atmosphere Model have played prominent roles in successive World Meteorological Organization assessments of ozone depletion, helping to inform international policy in this area. Canadian scientists have also published on the impacts of anthropogenic greenhouse gases, and other human and natural forcing agents on the Southern Hemisphere climate. Canadian Antarctic researchers have been involved in research regarding sea ice trends, variability, processes and biogeochemistry using both modeling and observations. Canadians have also researched Antarctic glacier dynamics and change, carbon cycling and glacial sediments.

Biota and ecosystems

Canadians have conducted Antarctic biota and ecosystems research pertaining to a range of environments including marine, ice, terrestrial, and freshwater. They have studied a variety of Antarctic organisms including, but not limited to, plankton, fish, birds, marine mammals and benthos, and they have studied the effects of climate change on marine ecosystems. Key topics or research themes in which Canadian Antarctic research involvement has been strongest, based on numbers of publications, include plankton and impacts of global changes at the organism and ecosystem levels. Overall, there has been a general increase over time in the number of Antarctic biota and ecosystems related papers with Canadian authors over time, with some annual variation.

Research regarding contaminants, including local vs. global impacts, was noted as an opportunity for further Canadian involvement, given strong Canadian expertise. Canadian researchers have significant expertise in sea ice biota research that could be further applied to Antarctica. There is a significant gap in Antarctic research in understanding what happens to organisms during the polar night and during the transition from polar night to polar day, which could be addressed in part through remote sensing. The presence of invasive species arising from climate change and other factors is another topic where Canadian expertise could be applied. An opportunity exists for further research and monitoring at common ship and air landing points in Antarctica, especially with regard to informing environmental impact assessments.

Permafrost, soils and landscapes

Canadians have researched the distribution and origin of ground ice in the Antarctic and its role in shaping landscapes and have been instrumental in improving understanding of the distribution of permafrost in Antarctica. With strong permafrost research capacity in Canada, there may be an opportunity for increased Antarctic research in this area.

Canadians have been involved in soils and remediation research, including soil conditions and environmental factors that shape soil microbial communities; soil biochemistry and carbon and nitrogen dynamics; response of soil and microorganisms to pollutants and temperature increases; and the assessment of bioremediation potential and treatment strategies. Bioremediation was noted as a key area of strength of Canadian researchers, and a potential area for further research. Canadians have also researched microbial life in the McMurdo Dry Valleys, which serve as an analogue for Mars.

With respect to freshwater landscapes, Canadian Antarctic research has included characteristics, structure and functioning of perennially ice-covered lakes; use of lake sediments to reconstruct Quaternary environmental and climate change; and fluvial geomorphology and processes. Further research to compare perennially ice-covered lakes in the Antarctic and Arctic was noted as an opportunity. Canadian researchers have also studied the effects of human activities from research stations on nearby lakes and potable water sources, which has relevance to Canada and northern development.

Other landscape changes, including the effect of weathering in cold-dry regions in the absence of water, and glacial and Aeolian landscape processes have also been studied by Canadian Antarctic researchers.

Human activities in Antarctica

Humans are an important species in Antarctica, with human activities including research and related activities, tourism and exploration. It is important to understand and respond to both acute and chronic effects of human impacts, given that human activities in Antarctica reach far beyond that continent, and that the global impact of humans strongly affects Antarctica.

Canadian participation in exploration has been via expeditions organized by other countries, and Canadian researchers continue to be hosted in Antarctica by other countries. The absence of strong Canadian programmatic support for Canadian Antarctic research may encourage some Canadians to consider working for institutions in other nations where there are increased opportunities to pursue Antarctic research or to focus their research on other geographic regions.

The international Antarctic community is eager for Canada to assume a stronger role in both Antarctic research and governance. Canadians have significant expertise to contribute, including some transferable knowledge from the Arctic. Clarity regarding Canada's scientific, political and strategic Antarctic goals would guide appropriate action. Workshop participants noted four key areas of research related to human activities in Antarctica in which Canadian researchers have expertise:

- Tourism;
- Governance;
- Environmental impacts of human activities; and,
- Impacts of extreme environments on humans.

Canada is a full signatory to the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol), which is in force. The effects of a growing tourism industry need to be mitigated, and it is also necessary to mitigate and respond to accidents, such as ships running aground and releasing waste. Canadians have been involved in research to minimize the environmental impact of human activities in Antarctica in and around research stations, and in remote field locations. There may be opportunities to share knowledge regarding Antarctic and Arctic tourism and environmental protection research and policy. As well, Canadians have experience in cold climate building design and instrumentation that could be applied to Antarctica.

Canadian research has also examined impacts of isolation in the Antarctic. There can be a lack of follow up with personnel when they return from deployment in the Antarctic. An important research gap is the understanding of how human physical and mental health is affected by deployment to Antarctica, especially for lengthy or repeated deployments.

The Canadian Antarctic research context: Challenges and opportunities

Challenges and opportunities experienced by Canadian Antarctic researchers were discussed in breakout groups. The following summarizes the discussions.

Canadians doing Antarctic research are currently based at more than 15 Canadian universities and four federal government organizations, as well as some other institutions. They conduct Antarctic research by doing fieldwork in Antarctica and/or using available observations. The costs of doing research in Antarctica are very high, especially for fieldwork and the deployment of instruments, due to remote and extreme conditions. Other costs of Antarctic research can include, but are not limited to, completing health and safety training and tests in advance of fieldwork; travelling to an international Antarctic access/staging location (e.g. Punta Arenas, Chile; Ushuaia/Rio Gallegos, Argentina; Christchurch, New Zealand; Hobart, Australia; Cape Town, South Africa); securing computing resources; shipping equipment and samples, and covering costs of lab use, and research and support staff. In the absence of a Canadian Antarctic Research Program, Canadian Antarctic researchers rely significantly on the national Antarctic programs of other countries, and/or funding from Canadian sources that are not dedicated exclusively to Antarctic research.

Current domestic funding sources do not meet the needs of Canadian Antarctic researchers.

In the absence of dedicated funds for Canadian Antarctic research, Canadians must apply and compete for the same funds available to Canadians conducting research on other topics. It can also be challenging for Canadian government-based researchers to obtain programmatic support to do Antarctic research, because, with the exception of POLAR and ECCC, Antarctica generally does not fall within the mandated responsibilities of science-based departments.

Nevertheless, in cases where there is a global scope, such as climate modeling, or where there are impacts on Canada, such as the important Antarctic contribution to sea level change, some Antarctic research has taken place within the Canadian federal government. For academic researchers, examples of some domestic sources of funding that have been used to support Canadian Antarctic research include the Natural Sciences and Engineering Research Council (NSERC), Canada Foundation for Innovation (CFI), the Canadian Space Agency, and provincial funding agencies. Key challenges associated with domestic sources for research funding include:

- *Small funding envelopes* that do not adequately cover greater costs of doing Antarctic research. Funds are quickly applied to cover basic operational costs, with insufficient funds remaining to cover fieldwork and subsequent follow up work including data analysis.
- *Narrowly targeted funding opportunities* in terms of priorities, including strong emphasis on applied vs. fundamental research and/or strong orientation towards industry-driven needs, which makes it difficult to rationalize support for many larger-scale research initiatives such as environmental and earth systems research.
- *Time-limited opportunities*, which do not facilitate continuity or promote longer-term research activities.
- *Gap in collaborative funding.* Workshop participants indicated that from an Antarctic perspective, current funding opportunities are primarily individually focused and do not facilitate collaboration with international researchers. Therefore, they are not well aligned with the highly collaborative nature of Antarctic research and do not promote both international and domestic (government and

non-government) collaboration. While larger-scale Networks of Centres of Excellence (NCE) opportunities are available, workshop participants indicated that fundamental Antarctic research is not well aligned with recent and current calls for proposals.

- *Lack of coordination* between funding to support research infrastructure and funding to support related operational costs.

In addition to developing a Canadian Antarctic Research Program, additional opportunities suggested by workshop participants that would improve domestic support for Canadian Antarctic research included:

- A special Antarctic themed call for Networks of Centres of Excellence (NCE) initiative to facilitate a large-scale research network;
- Reinstatement of the former NSERC Special Research Opportunities (SRO) or a similar program, which participants indicated as useful in terms of facilitating participation in large-scale international collaborative projects that arise on relatively short notice; and,
- An Antarctic or polar research supplement program (similar to the existing NSERC Northern Research Supplements Program), to assist in covering the higher logistics costs of research in Antarctica.

A funded Canadian Antarctic program would better support Canadian researchers in driving Antarctic research and addressing Canadian priorities.

A sufficiently resourced Canadian Antarctic research program could better support Canadian researchers in addressing Canadian Antarctic research priorities. With past and present Canadian involvement in Antarctic research being largely reactive and reflecting the priorities of other nations, a Canadian program could also provide Canadian Antarctic researchers with a better opportunity to plan and define Antarctic research from the outset, and provide a better opportunity for Canadian researchers based at both government and non-government institutions to collaborate. Programmatic infrastructure can facilitate Canadian coordination both nationally and with other national Antarctic programs, and strengthen collaboration opportunities through partnership agreements. At present, Canadian Antarctic research priorities are not articulated, and development of these priorities would inform the development of a Canadian Antarctic research program.

Workshop participants also noted potential opportunities to supplement federal funds with funds from other sources such as:

- *The private sector*-For example, communications and navigation companies may be interested in supporting Antarctic research that assists in informing technology design and/or involves testing technological performance in remote and extreme conditions.
- *Private funders*-Private funders with an interest in Antarctica and in creating a legacy may be interested in supporting a program or specific research project.
- *Crowd-sourced fundraising*-Seeking pledges from the general public for specific scientific projects via an online platform in conjunction with social media promotion.

Private funding, while beneficial, cannot replace or eliminate the need for new and dedicated federal funds, which are important in terms of demonstrating sustained Canadian commitment to this internationally significant region.

Increased reciprocal exchange opportunities in Canada's Arctic can assist in better leveraging Canadian access to Antarctic infrastructure and logistics.

Canada has significant Arctic infrastructure and logistics that could be leveraged. With an Antarctic mandate and the Canadian High Arctic Research Station (CHARS) campus, POLAR is uniquely positioned to leverage interest in CHARS and

provide reciprocal in-kind exchange opportunities in the polar regions that could increase access for Canadian researchers to Antarctic infrastructure and logistics.

Workshop participants discussed additional ways in which Canada could consider using and building on existing Antarctic infrastructure and logistics. Given that the Antarctic field season takes place from October to March, there is potentially an opportunity for Canadian icebreakers to be used in both polar regions as a research platform, if they are not operationally required in Canada or scheduled for repairs or upgrades during the austral summer. However, the significant operational costs of operating a Canadian icebreaker in the Antarctic, in addition to the time required to transit to and from the Antarctic, were noted. As a result, use of a Canadian icebreaker in the Antarctic may require contributions from other countries. Alternatively, Canadian ship-based expeditions could be conducted using an icebreaker already in the southern hemisphere, or through an expedition in collaboration with partners from other countries.

Additional infrastructure and logistics options that Canada could consider include:

- Deployment of instruments, either by Canadian researchers or by international researchers/ programs on behalf of Canada;
- Payment for partial use of an existing Antarctic research facility, should there be Canadian plans to conduct science on a more independent basis, or conduct science that does not align with the program priorities of the country operating the station;
- Logistics sharing with the national Antarctic programs of other countries (e.g., shared use of contracted helicopters); and,
- Partnerships with tourism operators to transport researchers and/or equipment to Antarctica or deploy instrumentation to collect data while en route to or from Antarctica.

Greater awareness is needed among the Canadian research and policy community and the general public of the importance of Antarctica and the value of Antarctic research to Canada.

Within Canada, Antarctica is often considered in relation to, and sometimes in competition with, the Arctic. Antarctic research can further the understanding of polar linkages and implications for global climate and ocean systems, but Antarctic research is also important in its own right. Workshop participants noted a common misconception within Canada that Antarctic research is not useful for Canada. Participants also mentioned the common perception that increased attention to Antarctica or further support for Antarctic research would require diverting attention and resources from the Canadian Arctic and Arctic research. This perception does not acknowledge the benefits of better engaging a major community of polar researchers and the unique scientific issues to be addressed through Antarctic research.

Greater awareness of the value of Antarctic research is needed. Suggestions provided by workshop participants included communications and outreach initiatives such as newsletters to strengthen awareness of the importance of Antarctica and Antarctic research to Canada and Canadians. Workshop participants also noted the benefits of establishing a Canadian Antarctic policy that articulates Canada's Antarctic interests and objectives.

Greater coordination is needed within the Canadian Antarctic research community, and between the Canadian and international Antarctic research communities.

Participants noted the value of strengthening coordination within the existing Canadian Antarctic research community to:

- Facilitate increased collaboration among Canadian Antarctic researchers;

- Generate greater awareness of the community and its research contributions;
- Strengthen the voice of the Canadian Antarctic research community, including to better advocate for alternative funding models to support the needs of Antarctic researchers; and,
- Strengthen leveraging opportunities and attract further resources to support Antarctic research.

A notable example of how increased coordination can benefit a scientific community is the Canadian particle physics research community, which self-organized to create the Institute of Particle Physics (IPP) in order to better promote the community and its research priorities and strengthen the participation of Canadian university-based researchers in large international experimental programs in particle physics.

Connections between Canadian and international Antarctic researchers are important for beginning and sustaining Canadian involvement in Antarctic research, especially in the absence of a Canadian Antarctic research program and Canadian government owned and operated Antarctic infrastructure and logistics. Although there is strong grass-roots collaboration within the existing community, the need for an agency within Canada to better connect Antarctic researchers and infrastructure and logistics resources, both domestically and internationally, was raised to:

- Bring greater attention to who within Canada is doing Antarctic research to assist in identifying potential Canadian collaborative partners; and,
- Facilitate the development and implementation of research and infrastructure/logistics agreements to provide increased opportunities.

Increased participation of Canadian researchers in international Antarctic conferences, workshops and scientific planning meetings is important in strengthening connections and collaboration among researchers and raising the profile of Canadian Antarctic research. With the focus of SCAR on initiating, developing and coordinating international Antarctic research, increased Canadian participation in SCAR scientific committees, groups and programs[11] would be particularly beneficial. Dedicated funds would, however, be needed to ensure strong and sustained Canadian involvement.

Ongoing effort is needed to ensure open and accessible data.

Article III of the Antarctic Treaty requires that scientific observations and results from Antarctica be exchanged and made freely available. In addition to satisfying Treaty requirements, good data management is critical to ensure that valuable data is stewarded and discoverable to facilitate new and further research. Depending on the nature of the research project, approximately 15-30% of research budgets may need to be allocated for data management to ensure that data is properly stewarded from the outset, made discoverable to other researchers and interested individuals, and avoid higher expenses that would be required to recover data that has not been properly stewarded from the outset.

SCAR's Standing Committee on Antarctic Data Management (SCADM) facilitates international cooperation and coordination on Antarctic data management, including through the Antarctic Master Directory-the largest collection of Antarctic data to which all signatory countries to the Antarctic Treaty contribute via National Antarctic Data Centres (NADCs). The Polar Data Catalogue (PDC), as Canada's new NADC, will serve as the focal point for Antarctic data management in Canada and work with individual researchers to assist them in producing and maintaining metadata records. While the PDC can serve as a long-term home for data, it can also point to existing data repositories.

Funding scenarios: Benefits and limitations

Workshop participants discussed benefits and limitations associated with three different funding scenarios for Canadian Antarctic research. The nature of research activities, and in turn the associated costs,

[11]Further information regarding SCAR scientific committees, groups and programs is available here: http://scar.org/science

can differ significantly across research disciplines and topics, depending on whether the research requires collection of new data through either field or ship-based work in remote regions (e.g., geology, glaciology, oceanography, marine biology), station-based research only requiring deployment of instrumentation and field work in the immediate vicinity of a station, research based on available observations (e.g., modeling, data mining, analysis and interpretation of remote sensing), or some research in the social sciences requiring access to international archives and libraries.

When exploring funding scenarios, workshop participants expressed their desire for the ability to:

- Be in a position to assume a leadership role, including proposing and driving the research and addressing Canadian research priorities;
- Undertake research under multiple research themes or topics, including research to address pressing priorities, but also opportunities for fundamental research, given the strong potential for Antarctic research to lead to new scientific discoveries;
- Undertake a spectrum of scientific activities under each research theme or topic, including accessing more remote field sites; and,
- Access research funds for both new and experienced Antarctic researchers at various career stages.

During the discussions, there was a general understanding that existing infrastructure and logistical support of other nations would continue to provide access to Antarctica and the surrounding waters for Canadian researchers through partnerships and scientific collaboration. The possibility of developing Canadian infrastructure and logistical support was raised, but generally in the context of contributing to operating costs and augmenting logistical support at existing research stations and bases. The possibility of a Canadian vessel undertaking Antarctic research was also discussed. In recognition of the significant associated costs, partnering with another international research expedition to address mutual scientific priorities was noted as a cost-effective option.

There are several benefits for Canada in developing and delivering an Antarctic program that utilizes and builds on existing Antarctic research infrastructure and logistics, including:

- Ability to be flexible and nimble in choosing scientific targets and geographical regions to accommodate new or shifting priorities by partnering with nations and researchers focusing on a specific scientific issue or already operating in a region;
- Opportunity to build on and leverage existing research relationships and initiatives between Canadian and international Antarctic researchers; and,
- Limiting the environmental impacts and financial costs associated with constructing, operating and maintaining a new station or base in Antarctica.

Although this mode of operation differs from most consultative parties to the Antarctic Treaty, it is consistent with the conduct of much of Antarctic science, which tends to be highly collaborative, owing to its cost, remoteness, and logistical challenges.

A potential limitation for Canada, however, relates to taking and maintaining a leadership role in Antarctic science, especially in those disciplines requiring field or ship-borne investigations to acquire new data. This was seen as a particular concern for the low funding scenarios, where some workshop participants characterized potential Canadian contributions as incremental. However, it was acknowledged that this limitation could begin to be overcome at the highest funding scenario ($2M/year per research theme), given that it could enable Canadian researchers to enter into collaborations as equal or lead partners in larger projects with a significant and sustained field component.

The highest funding scenario would also enable greater leveraging capacity with respect to both domestic and international resources, such as the development of one or two research chairs in Antarctic research at Canadian universities. It could support teams of Canadian researchers in undertaking more integrated and collaborative research projects to address a myriad

of common and/or interrelated research questions. Examples of this could include, but are not limited to:

- Glaciological studies of ice-sheet history, including fundamental studies of inception of ice streaming, ice flow, delivery of ice to the oceans, and role of ice shelves, needed for understanding the future Antarctic ice sheet and its contribution to sea-level change;
- Observatories for biota and ecosystems to better understand trends, relationships, etc. and ecosystem functioning and adaptation;
- Geophysical studies, including seismological and geodetic measurements to better discern Earth structure and dynamics, interactions of the solid Earth with the Antarctic ice sheets, and improve the understanding of Antarctic ice-sheet mass balance; and,
- Research regarding life in extreme environments, encompassing both the physical environment and microbiology, with planetary exploration application.

Canada's Arctic was noted as a useful leveraging opportunity. For example, international researchers could be provided with in-kind use of infrastructure and logistics in Canada's Arctic in exchange for similar in-kind use of existing Antarctic infrastructure and logistics.

Benefits and limitations of the three funding scenarios are summarized in Table 1.

Table 1: Summary of benefits and limitations of three funding scenarios

Funding scenarios	Benefits	Limitations
A) $500k/year *per research theme*	► Provides support for a number of Canadian researchers in carrying out research activities in international research projects. Enables Canadian researchers to be junior partners in collaborations. Funds could be used for travel to international Antarctic staging locations; support for graduate students and training of highly qualified personnel; purchasing sensors or other instrumentation that could be deployed on behalf of Canadian researchers; laboratory costs; or attendance at conferences and training schools. ► Assists in developing or further strengthening research relationships, including through participation in Antarctic workshops and meetings convened by organizations such as SCAR. ► Could assist in strengthening connections between Arctic and Antarctic programs and researchers to promote and develop bipolar research	► Researchers would rely almost exclusively on the national programs of other countries to support fieldwork, limiting the ability to ensure that Canadian research priorities are met. ► Would enable a very limited number of Canadian researchers to secure a stronger position within an international Antarctic research project. ► May not sufficiently support multiple research priorities ► Facilitates activities that are incremental (rather than new) to existing international research initiatives ► Relies on national programs of other countries to support fieldwork, limiting the ability of Canadian researchers to address Canadian priorities, develop scientific plans, and choose and access field sites. ► If there are insufficient opportunities to increase and sustain involvement in Antarctic research in the longer term, leads to risk of not strongly benefitting from investments in graduate students and training of highly qualified personnel
B) $1M/year *per research theme*	Provides the benefits of the $500k/year scenario, plus: ► Enables a greater number of research projects, or more substantive scientific contributions to a smaller number of projects ► Enables Canadian researchers and highly qualified personnel to be more active players within the international Antarctic research community	► May be difficult to support projects requiring remote field work, and undertaking scientific activities during the austral winter

Funding scenarios	Benefits	Limitations
C) $2M/year ***per research theme***	Provides the benefits of the $1M/year scenario, plus enables: ► Canadian researchers to assume a stronger leadership role within the international Antarctic research community, and to address Canadian priorities; ► Greater leveraging capacity with respect to both domestic and international resources; and, ► Increased and sustained investments in early career researchers and the training of highly qualified personnel to strengthen the next generation of polar researchers.	► May be difficult to support multiple researcher teams in accessing more remote field sites and undertaking scientific activities during the austral winter

Discussion of workshop findings

The workshop discussions and participants confirmed that Canadian researchers have broad expertise and interest in Antarctica and Antarctic research. Antarctic research is seen as relevant and interesting, both in its own right, and as it relates to Canada and Canadian interests. The conversations revealed the numerous means by which Canadians have undertaken Antarctic research despite the lack of a formal Canadian Antarctic research program; however, this has been achieved with great personal and financial effort. Participants expressed a keen desire to lead in Antarctic science and also acknowledged the costs of carrying out Antarctic science, especially in disciplines such as geology, geophysics, glaciology, ecology, and oceanography, which may require field or ship-borne work, often in locations distant from research stations, in order to acquire new data. Current limitations for Canadian Antarctic researchers include funding sources that are not tailored to Antarctic requirements and the need to join projects and activities largely defined by researchers from other nations, owing to the lack of Canadian Antarctic infrastructure and logistical support. Nevertheless, many Canadian researchers do exhibit scientific leadership as evidenced, for example, by the number of Canadian researchers with first-authored Antarctic papers and by a number of Canadian researchers with strong Antarctic citation records.

Some consultative parties to the Antarctic Treaty have raised concerns regarding environmental impacts associated with the construction and subsequent operation of new Antarctic research stations or bases. Consultative parties have also noted opportunities to maximize use of existing facilities. As described above, there are several advantages to carrying out Antarctic research in close partnership with other nations without developing independent Canadian infrastructure or a logistical capability. The anticipated need to utilize existing infrastructure and logistical support implies that partnerships and collaborations will continue to be an integral part of nearly all Canadian Antarctic activities.

Looking forward, there are various options for a future Canadian Antarctic research program. Minimally, in a low funding scenario, funds could be made available through a competitive process to better enable Canadians to provide a contribution to international projects. This approach would not differ greatly from the present *ad hoc* approach, where partnerships and collaborations are developed at the working level, but the funding could be focused on priority areas and would provide much needed funds to support collaboration and participation at international meetings.

At higher levels of funding, where a strong Canadian contribution is desired, there may be a need for the development of partnership agreements with other nations to clarify roles and responsibilities and agree upon costs and in-kind contributions, either on a project-by-project basis, or at a program level. In practice, joint research initiatives with another nation (or nations) may need to be defined that specifies at a high level the scientific objectives and geographical region(s) under consideration and that provides funding envelopes under a competitive process. This would then enable Canadian researchers to propose international collaborations to carry out the work. Alternatively, a 'Letter of Interest' process could be developed where a proposed collaborative project is outlined and provided to Canada and the relevant national program of another country. If the proposed project were deemed to be of interest, the research team would then be invited to develop a full proposal for competitive review by the relevant national agencies.

Regardless of the size of the Canadian program, development of strategic objectives and priority setting would be required. Some Antarctic research may be of greater relevance and interest to Canada and Canadian researchers, suggesting the need for a focused approach to address issues of greatest importance, while keeping open the option of responding to emerging opportunities and undertaking fundamental research that can lead to important scientific discoveries.

Conclusion and next steps

Antarctica is a significant region for Canada and the world, from the perspectives of both scientific research and governance of a significant region that regulates global climate and ocean systems. There would be significant value in increased Canadian engagement in Antarctic governance and the establishment of a Canadian Antarctic Research Program. A sufficiently resourced program that builds on and leverages existing Antarctic research momentum, infrastructure and logistics through partnerships would enable Canadian researchers to exercise stronger research leadership and address research priorities important for Canada and the world.

The findings of this workshop will inform future plans and activities of POLAR under its mandate to promote the development and dissemination of knowledge of the Antarctic, with continued advice and guidance from its Canadian Committee on Antarctic Research (CCAR) and other polar research and program experts. This will include promoting workshop findings among Canadian and international polar research stakeholders, and pursuing opportunities to develop a Canadian Antarctic Research Program.

Annexes

Annex A-Workshop agenda

Canadian Antarctic Research Workshop
Participants Agenda
Monday, October 3-4 2016
Canadian Museum of Nature, Rotunda Room
240 McLeod Street, Ottawa, ON
Convened by Polar Knowledge Canada (POLAR)

Workshop Objectives: By gathering together Canadian Antarctic researchers and other interested individuals, we hope to:

- Consider the strengths of the existing Canadian Antarctic research community, including in relation to Antarctic research areas underserved by the international Antarctic research community which Canadian research expertise could augment;
- Build a shared understanding of the challenges and barriers Canadian researchers face when pursing Antarctic research;
- Consider how a Canadian Antarctic Research Program could build on existing domestic and international opportunities to increase Canadian Antarctic research to address key Antarctic research gaps and Canadian research and policy priorities; and,
- Foster a stronger sense of community among Canadian Antarctic researchers.

Day 1: October 3, 2016

Time	Agenda Item
8:30-9:00	**Light Breakfast, Registration and Networking**
9:00-10:00	**Introductory Remarks** ▸ *Richard Boudreault*, Chair, Board of Directors, POLAR ▸ *Mark Graham*, Vice-President, Research and Collections, Canadian Museum of Nature ▸ *David Grimes*, Assistant Deputy Minister, Meteorological Service of Canada and President, World Meteorological Organization **Roundtable Introductions** ▸ All workshop participants **Workshop Overview and Housekeeping** ▸ *Barb Sweazey* and *Jennifer Davis*, Stratos
10:00-10:30	**Setting the Stage** (*David J. Scott*, President, POLAR) ▸ POLAR's mandate and Antarctic activities ▸ Current domestic and international Antarctic research and policy context
10:30-10:45	Health Break
10:45-12:00	**State of Play in Canadian and International Antarctic Research** ▸ Introduction of topics (*Thomas James*, Research Scientist, Natural Resources Canada and Chair, Canadian Committee on Antarctic Research) ▸ Presentations ▹ **Geology, solid-Earth geophysics and ice sheets** (*Thomas James*, Research Scientist, Natural Resources Canada) ▹ **Atmosphere, Southern Ocean and cryosphere** (*Neil Swart*, Research Scientist, Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada) ▹ **Space and atmospheric physics, astronomy and astrophysics** (*Jayachandran Thayyil*, Professor, Physics, University of New Brunswick) ▸ Small group conversations
12:00-1:00	Lunch (provided)
1:00-2:15	**State of Play in Canadian and International Antarctic Research (continued)** ▸ Presentation ▹ **Biota and ecosystems** (*Gustavo Ferreyra*, Professor-Researcher, Institut des sciences de la mer de Rimouski, Université du Québec à Rimouski) ▹ **Permafrost, soils and landscapes** (*Denis Lacelle*, Associate Professor, Department of Geography, Environment and Geomatics, University of Ottawa) ▹ **Human activities in Antarctica** (*Peter Suedfeld*, Professor Emeritus, Department of Psychology, University of British Columbia) ▸ Small group conversations
2:15-2:30	Health Break
2:30-4:00	**Canadian Antarctic Research: Challenges and Opportunities (Small Groups and Reporting)**
4:00-4:15	**Closing Remarks and Reflections** ▸ *David J. Scott*, President, POLAR ▸ *Barb Sweazey*, Stratos

Day 2: October 4, 2016

Time	Agenda Item
8:30-9:00	**Light Breakfast and Networking**
9:00-9:15	**Opening Remarks** (*Barb Sweazey*, Stratos)
9:15-10:00	**State of Play in the International Antarctic Program Operating Context: Science, Infrastructure, Logistics and International Collaboration** ► **US Antarctic Program, National Science Foundation:** *Scott Borg*, Head, Antarctic Infrastructure and Logistics ► **British Antarctic Survey:** *Anna Jones*, Deputy Science Leader, Atmosphere, Ice and Climate Team
10:00-10:15	**Antarctic Data and Geographic Information** (*Peter Pulsifer*, Carleton University)
10:15-10:30	**The Value Proposition for a Program** ► *Barb Sweazey*, Stratos
10:30-10:45	**Health Break**
10:45-12:00	**Scenario 1: The Value Proposition for a Program (Small Groups)**
12:00-1:00	**Lunch (provided)**
1:00-1:45	**Scenario 1: The Value Proposition for a Program (Reporting Back)**
1:45-2:30	**Scenario 2: The Value Proposition for a Program (Small Groups and Reporting)**
2:30-2:45	**Health Break**
2:45-3:30	**Scenario 3: The Value Proposition for a Program (Small Groups and Reporting)**
3:30-4:00	**Overall Value-Add: Plenary Reflections**
4:00-4:15	**Closing Remarks** ► *Barb Sweazey*, Stratos ► *David J. Scott*, President, POLAR

Annex B-About Polar Knowledge Canada (POLAR)

Polar Knowledge Canada (POLAR) is Canada's lead federal agency to strengthen Canadian leadership in polar science and technology. POLAR consists of:

- A knowledge management and engagement function to support Arctic and Antarctic research;
- Pan-northern Science and Technology program; and,
- The world-class Canadian High Arctic Research Station (CHARS) campus that will be operational in 2017/18 in Cambridge Bay, Nunavut.

This includes a mandate to promote the development and dissemination of knowledge of the Antarctic. POLAR is working to strengthen Canadian Antarctic research activities, including through the development of a Canadian Antarctic Research Program. POLAR's Canadian Committee on Antarctic Research (CCAR) provides advice and guidance to POLAR on Antarctic matters, and assisted with the planning of this workshop.

POLAR is working to increase Canada's international profile as a circumpolar nation and advising the government on matters related to the polar regions. POLAR is also Canada's adhering body to the Scientific Committee on Antarctic Research (SCAR) and International Committee on Antarctic Research (IASC), and is an observer of the Council of Managers of National Antarctic Programs (COMNAP). POLAR serves as a point of contact for the international polar research community to explore opportunities to pursue research in Canada's Arctic and to collaborate with Canadians in the Antarctic.

POLAR's Canadian High Arctic Research Station (CHARS) campus and pan-northern science and technology program are attracting significant interest from the international polar research community. As a result, there is an unprecedented opportunity to leverage resources to better coordinate, increase and expand opportunities for Canadian Antarctic research. This includes in-kind use of infrastructure and logistics in Canada's Arctic for international polar researchers in exchange for the in-kind use of similar resources in the Antarctic by Canadian researchers.

The CHARS campus will consist of a Main Research Building, a Field and Maintenance Building and accommodation units for visiting researchers and scientists. The facilities will include maintenance and field-staging facilities, a modest inventory of the Polar Continental Shelf Program (Natural Resources Canada) field equipment for general use, advanced laboratories, a technology development centre and a Knowledge Sharing Centre. Up to 40 full-time scientists and support staff will be based in Cambridge Bay once the campus facilities are fully operational.

Annex C-Overview of Canadian activities in Antarctica

Canada is very much a polar nation. The more than 100 Canadian place names in Antarctica commemorate the important contributions Canadians have made to the region.

Scientific research and technology development
Primarily in partnership with the national Antarctic programs of other countries, Canadians conduct physical, biological, human, social and geosciences Antarctic research. Canadians have also been involved in technology development, to facilitate and support Antarctic science and operations, and data management and geographic information activities to support scientific research. For example, the Canadian RADARSAT missions significantly contributed to the development of continent-wide maps of Antarctic ice sheet and glacier flow. Currently, Canadians doing Antarctic research are based at more than 15 Canadian universities and four federal government organizations, as well as some other institutions.

Tourism and education and outreach activities
Several Canadian tourism companies operate regularly in Antarctica and carry approximately 10-15% of tourists visiting the Antarctic annually. In 2015/16, Canada was the sixth highest country in terms of tourists, with Canadians accounting for 4.8% of tourists. As just one example of education and outreach activities, Students On Ice organizes and leads educational expeditions to Antarctica for Canadian and international high school and university students.

Operational support
For more than 30 years, Kenn Borek Air has been the largest private charter aircraft operator in Antarctica, supporting research at stations and remote field sites, and planning and carrying out medical evacuations.

Canadian products
Many Canadian products are used in Antarctica, including Bombardier skidoos and snowcats and Canada Goose apparel.

Antarctic marine living resources
Canadian companies are involved in the import and re-export of Antarctic marine species including Antarctic krill and toothfish. Canadian companies also manufacture oil from Antarctic krill, which is used in nutritional supplements.

Annex D-Status of Countries within the Antarctic Treaty System

Countries with consultative status

- Argentina
- Australia
- Belgium
- Brazil
- Bulgaria
- Chile
- China
- Czech Republic
- Ecuador
- Finland
- France
- Germany
- India
- Italy
- Japan
- Korea (ROK)
- Netherlands
- New Zealand
- Norway
- Peru
- Poland
- Russian Federation
- South Africa
- Spain
- Sweden
- Ukraine
- United Kingdom
- United States
- Uruguay

Countries with non-consultative status

- Austria
- Belarus
- **Canada**
- Colombia
- Cuba
- Denmark
- Estonia
- Greece
- Guatemala
- Hungary
- Iceland
- Kazakhstan
- Korea (DPRK)
- Malaysia
- Monaco
- Mongolia
- Pakistan
- Papua New Guinea
- Portugal
- Romania
- Slovak Republic
- Switzerland
- Turkey
- Venezuela

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