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The future of UK Antarctic science: strategic priorities, essential needs and opportunities for international leadership

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Headlines

- The Antarctic region has been experiencing rapid change in recent decades due to human-induced factors. Most notably, climate heating is causing ice sheet melting, leading to sea level rise and disruption in global ocean heat circulation, with far-reaching consequences.
- At the same time, this region holds unique research potential that can help address a range of critically important scientific priorities, including climate change impacts, ecosystem protection, the likelihood of extra-terrestrial life and monitoring of space debris.
- Due to its long and impressive record of Antarctic research and its scientific, engineering and logistical capabilities in the region, the United Kingdom (UK) is strategically well-positioned to lead or play a key role in the delivery of these research priorities.
- To achieve this potential, the UK must act collectively and in partnership with others, as the best and most urgent research benefits from collaboration, cooperation and cost sharing. Crucially, it must mobilise experts both from within the UK and internationally from a range of disciplines, including the social sciences. In the twenty-first century, Antarctic research must not exist within its own bubble.

Antarctica and the United Kingdom

Antarctica, its surrounding islands and vast Southern Ocean (hereafter 'the Antarctic'), are critical components of the Earth system and matter greatly to the UK. What happens there has global consequences through sea level rise, oceanographic and biological changes that affect global biogeochemical cycles and ocean-driven inter-hemispheric exchange of heat. The ice and sediments of the continent, islands and surrounding ocean hold valuable archives of past changes in atmospheric composition, temperature, oceanic conditions, biogeochemical and ecological processes, and glaciation that provide unique insight into how the planet's natural systems operate. The Antarctic also supports exclusive and diverse biological assemblages that provide a range of globally important resources (e.g. fisheries) and ecosystem services that benefit humanity (e.g. biogeochemical cycling).

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Grantham Briefings analyse climate change and environmental research linked to work at Imperial, setting it in the context of national and international policy and the future research agenda. This paper and other publications are available from **www.imperial.ac.uk/grantham/publications**

The Antarctic provides a vital and distinctive vantage point for observing and monitoring Earth's environment, often as part of contributions to global observation networks. It is clear that human-driven climate heating, as well as regional influences (e.g. fisheries, tourism, scientific activity, pollutants etc.), are affecting the Antarctic and its ecosystems severely. Marine life, while recovering from nineteenth and twentieth century whaling and sealing, is experiencing major impacts from ocean warming and acidification, and the ongoing challenge of sustainable fishing. On land, there is a growing threat from alien species, especially at the coast. Though life is sparse further inland, micro-organisms inhabit the surface and subsurface of Antarctica in novel ways. Therefore, while we undertake Antarctic research we must minimise our impacts to protect it in accordance with international agreements. The Antarctic is a place that is yet to be fully and systematically explored, and curiosity-driven exploration remains essential to both scientific discovery and directing further research.

The Antarctic is regulated by the Antarctic Treaty System, consisting of the 1959 Antarctic Treaty and related agreements, which designate the region as "a natural reserve, devoted to peace and science". As a founding signatory to the Antarctic Treaty, and its Protocol on Environmental Protection in 1991, as well as the Convention for the Conservation of Antarctic Marine Living Resources (CAMLR Convention) in 1982, the UK has strong and well-established international commitments to Antarctic research. The international quality and pivotal role of UK Antarctic science is widely recognised; it is the second largest producer of scientific papers relating to the Antarctic, and over 80% of these are the result of international collaboration. The UK is also a founding member of the Scientific Committee on Antarctic Research (SCAR), which provides objective and independent scientific advice to the Antarctic Treaty System so that recommendations are underpinned by scientific evidence. Her Majesty's Government's (HMG's) 2021 UK Integrated Security Review noted the importance of the UK continuing "to uphold and strengthen the Antarctic Treaty System and maintain our leadership", particularly in the study of the global implications of climate change.

The UK investment in Antarctic science includes training of world-class scientists, support for infrastructure and logistics, and funding for research carried out by the British Antarctic Survey (BAS) and dozens of UK universities and research institutes. BAS also offers an array of expertise, logistics and equipment that make Antarctic fieldwork possible, both within the area known as British Antarctic Territory and more widely across the Antarctic.

It is appropriate to periodically identify some of the priority areas of science where future investment is required to address globally important scientific questions. This discussion paper highlights science priorities identified by the UK Antarctic science community. It also outlines how the UK can best utilise new state-of-the-art Antarctic infrastructure such as the *RRS Sir David Attenborough* and modernised station facilities, contribute to SCAR's new multi-year Scientific Research Programmes and Action and Expert Groups, and further develop its future multi-disciplinary collaborative research ambition.

Antarctic research pillars

By virtue of its geographical focus at an extreme end of the planet, world-class Antarctic research is perhaps like no other area of science. Most work requires substantial facility and logistic support, and the best programmes are characterised by long-term planning to address internationally-agreed priorities, multi-institutional collaboration around shared ambitions, the development and deployment of technology, resource and knowledge exchange, and societal engagement. Investments in the 'mechanics' that make Antarctic research possible are as essential as the programmes themselves, and it is important to consider the logistical requirements of research ambition. Considering these factors holistically, it is possible for the UK to maintain and develop its position as a global leader in Antarctic research.

There are three broad pillars that support Antarctic research (Figure 1): (1) **Observations** (the measurements we make); (2) **Methods** (how we design and perform science); and (3) **Agency and Impact** (how we make the most of our resources and results to influence external agendas).

Under **Observations**, our awareness that the Antarctic is undergoing change, that this change is of global significance, and that further investigation is urgent, stem from key measurements collected over decades. Our challenge is to maintain and develop such data collection to understand the processes operating now and in the past, and to anticipate trends into the future.

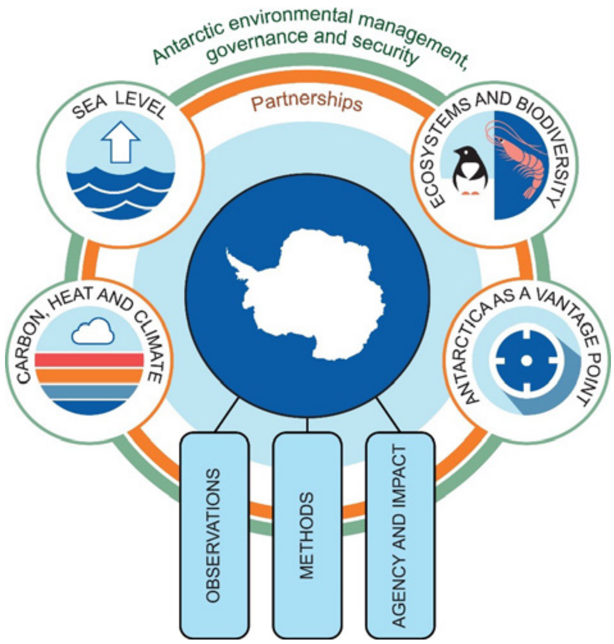

Figure 1: Antarctic research pillars and key research themes for UK Antarctic science

The **Methods** by which Antarctic research is undertaken relies strongly on fieldwork and sampling. This is increasingly enhanced with remote sensing and modelling to understand processes and make projections into the future. Samples collected in the Antarctic often require processing or laboratory analyses on site, at field stations, and back in the UK. Theoretical understanding of natural and social-political processes allows us to target measurements in critical regions of change, and to maximise the impact of our research efforts.

Agency and Impact is an essential element to consider at all stages of the Antarctic research process. As with all research, Antarctic science depends on highly-skilled people. Investment in training allows the pipeline of talented and diverse researchers to be enhanced. Collaboration between institutions and nations is often the best way to undertake complex field-based work, benefitting from cost sharing, combining and developing shared ideas, and building long-term scientific and diplomatic relations. The innovative development of equipment, often involving engineering talent from other areas of science, allows data to be collected from challenging locations. Antarctic research is impossible without the support of logistics and both fixed and mobile facilities, and maintenance and development of these assets is critical to future research needs and scientific leadership. Finally, because Antarctic science is of global significance, it is necessary that policy and translation opportunities are embedded in research planning and delivered as a priority, so that the impacts of scientific outcomes are maximised and heard across the planet in international policy and governance.

Many of the science questions we face require an understanding of different components of the Earth system, often operating over large geographic areas. Thanks to multi-disciplinary platforms like ships, stations and aircraft, Antarctic research benefits from the opportunity to take multiple samples and observations covering a range of scientific challenges simultaneously. This includes exploration of the links between physical, chemical, and biological processes, and the human drivers of change. Moreover, the UK's Antarctic logistics and facilities allow research across all realms of the polar environment, from the central ice sheet to the deep ocean, notwithstanding that some remain challenging to access.

The UK has a rare and widely acknowledged combination of expertise in each of these three pillars, offering opportunities to lead, undertake and disseminate complex research on problems critical to both the region and the world.

1 Alongside the UK Antarctic Science Conference in March 2021, the UK National Committee on Antarctic Research (UKNCAR) and the UK Antarctic and Arctic Partnerships Committee (UKAAP) ran an open online workshop on future UK Antarctic science priorities. This was attended by over 100 scientists of all career stages from 25 UK universities and research institutes. Over 40 presentations were given on future ideas and several others were submitted subsequently. A sub-group with leadership from UKNCAR, UKAAP, BAS, and several UK universities subsequently distilled the priorities and drew out the consistent themes.

Key science questions and future work

Consultation with the UK Antarctic science community[1] yielded a broad range of ideas for future science priorities within four 'grand challenge' areas:

1 – Sea level
2 – Carbon, heat and climate
3 – Ecosystems and biodiversity
4 – The Antarctic as a vantage point

In each area, scientists from multiple disciplines identified research questions that are important scientifically and timely (in many cases pressing). The UK is able to answer these questions through long-term scientific leadership, planning and collaboration among its institutions and with other nations.

Using scientific evidence to better manage and preserve the continent requires dedicated thinking and support within a fifth theme:

5 – Antarctic environmental management, governance and security

There is a close relationship between UK scientists, social scientists and diplomats/civil servants that enables the UK to be an influential voice in international forums such as the Antarctic Treaty Consultative Meetings (ATCM), the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and SCAR, as well as in regulating tourism through, for example, the International Association of Antarctica Tour Operators (IAATO).

Sea level

The challenge: Sea level rise is one of the most critical impacts of climate heating. Around 680 million people – 10% of the world's population – live in low-lying coastal regions that are susceptible to flooding from sea level rise.

Key research question: Will sea level rise be contained below one metre over the coming century and beyond, or will it be much higher?

The greatest uncertainty in how much global sea level will rise this century and beyond relates to how the massive polar ice sheets will react to global climate heating. The ongoing contribution of the ice sheets already exceeds that of the world's glaciers, and in combination with glaciers they now exceed sea level rise from thermal expansion of the ocean. The Intergovernmental Panel on Climate Change (IPCC) gives a range of projections of the consequences of future heating, and ice loss from the polar ice sheets is tracking closer to their worst-case projection than any other.

Why is it timely?

Satellite measurements show that some margins of the Antarctic ice sheet, where the ice rests on a bed below sea level that deepens toward the ice sheet centre, are thinning and losing mass rapidly. Data also reveal that the rate of West Antarctic ice mass loss has increased six-fold in the last 30 years. The time lag between temperature rises and the melting of ice means we are already 'locked in' to a certain amount of future sea level rise. If emissions are reduced quickly and global temperature rise stays below 2°C, sea level will still increase by at least half a metre in the next eighty years. We know from geological data that the ice sheets can, and have, shown more rapid changes in the past. Whether future rise exceeds one metre will depend on greenhouse emissions and how the polar ice sheets, especially in the Antarctic, react to the consequential global heating.

Innovative approaches to address the challenge

To reduce uncertainty in sea level predictions, advances are needed in five main areas:

- Geophysical surveys of subglacial topography and ice-covered bathymetry, some using autonomous systems equipped with instruments that can provide insight into ice sheet processes that cannot be accurately represented in current models;
- Collection of ocean data at ice sheet margins, often in the most inaccessible locations, using ocean gliders and autonomous vehicles deployed from ships or through ice shelf holes;
- Laboratory, field and modelling investigations of ice fracturing, flow and melting;
- Improved coupling between models of the ice, its bed, ocean and atmosphere, and improved remote sensing and field data on ice sheet change so that the interaction of complex processes can be captured and understood; and
- Resolving past changes to ascertain mechanisms and rates of key glaciological driving processes, because knowledge of past ice sheet change can be a vital guide to our future.

Carbon, heat and climate

The challenge: The Antarctic has a key role in regulating global climate via the cycling of heat and carbon, but the system is undergoing rapid change, with far-reaching consequences. The records stored within the ice, sediment and rocks inform us of how the Earth system has worked over the recent and deep-time history of our planet.

Key research question: Will the Antarctic continue to act as a planetary cooling system, or will it switch to becoming an amplifier of heating, and what would this mean for the UK and humanity more broadly?

Why is it timely?

The Antarctic is showing signs of rapid change in many key climatic elements, about which critical information is currently lacking. Sea ice is a key feature of the Antarctic which exerts strong controls on climate and oceanography. It has shown recent rapid changes and is vulnerable to future heating, but we have a poor understanding of the drivers of this change, its future evolution, and its impacts on physical, chemical and biological processes (and their feedbacks). Deglaciation of the Antarctic ice sheet is accelerating in key regions, and showing propensity for change in others, leading to the possibility of tipping points in the climate system as heating progresses and freshwater and trace elements are injected into the ocean. Processes of release and uptake of carbon, and other globally important nutrients, are changing but are not well understood despite their importance in biogeochemical cycles. Clouds are key drivers of change, controlling the surface energy budget and precipitation, and hence sea ice melt/formation, ice sheet surface mass balance and ocean-atmosphere heat exchanges, but they are poorly represented in numerical climate models. There is an urgent need to address these shortcomings to improve climate projections, which will inform and update climate policy and determine the ongoing effectiveness of climate change mitigation actions around the globe.

Persistent sub-zero temperatures and millennia of snow accumulation enable ice-core scientists to reconstruct uninterrupted records of climate change and to study the composition of the past atmosphere. Such records have been instrumental in proving the case for anthropogenic climate heating as they reveal that levels of greenhouse gas emissions since 1850 are unprecedented in at least the last 800,000 years. Additionally, records in rocks and sediments collected from the deep sea can go back millions of years, allowing Antarctica's climate evolution to be deciphered. Deep coring of ice and sediment will remain essential to climate studies (e.g. taking the ice-core record further back), but greater use of sample collection from blue ice zones, where very old ice is exposed at (or close to) the glacier surface, may allow samples from key periods to be collected in bulk. Ease of access reduces costs and larger samples enable innovative measurements of greenhouse gases. Such work may uncover past climate tipping points, which can show how likely it is that such changes will occur in future.

Innovative approaches to address the challenge

Future work in this area is likely to rely heavily on autonomous and cyber-infrastructure systems (alongside ship and land-based platforms), which can extend spatial and temporal measurements of key physical, biogeochemical and biological variables beyond currently available methods. These would be especially appropriate within ice-covered regions, marginal ice zones, the full depth of the ocean and during winter. Integration of observational data and models into oceanic 'digital twins' will allow for strategic optimised sampling thereby improving model predictions of future change. Multidisciplinary investigations that combine these emerging observational and modelling technologies will address key gaps and uncertainties in understanding, with the aim to:

- Reveal the ongoing and future impacts of sea ice on ocean circulation, biogeochemical cycling, biological processes and ocean/air fluxes of heat and climate-active gases across a range of spatio-temporal scales, including winter and early spring;
- Fully trace and quantify the various and changing sources and sinks of carbon in the Southern Ocean, including the drawdown of atmospheric carbon dioxide, carbon sequestration and export, and carbon release from the seabed and its biological communities;
- Determine the impacts of present and future deglaciation of the Antarctic on ocean circulation, delivery of trace elements into the ocean, and the export of heat and nutrients to lower latitudes;
- Improve cloud representation in models to constrain key climatic processes including radiative fluxes and precipitation; and
- Refine the historical context of greenhouse gas driven climate heating, and form evidence of past tipping points, through targeted ice and sediment coring, and with novel sample acquisition and data analyses from blue ice areas.

Ecosystems and biodiversity

The challenge: Life in the Antarctic exists in abundance in the ocean, and on land at the extremities of survival. Both are wildernesses, but changes in biodiversity have been substantial at sea due to marine exploitation and human-induced climate heating. Changes on land are now also becoming clear.

Key research question: How is life in the Antarctic being affected by humans, how will this continue in coming decades, and how can effective and long-lasting protection of Antarctic ecosystems and biodiversity be assured?

Why is it timely?

Ecosystems represent the sum of biological diversity, providing functions and services that underpin all life on Earth. Global climate is close to – if not at – a fundamental tipping point that will impact all ecosystems, with the polar regions under particular threat. Major shifts in Antarctic ecosystems are expected in the coming decades due to multiple stressors, including those from outside the Antarctic (climate-driven change) as well as direct human impacts of fisheries, tourism, pollution and scientific activity.

Ellsworth Mountains, West Antarctica, taken on a Twin Otter flight in December 2012.
Image credit: Pete Bucktrout, British Antarctic Survey.

Future step-changes in ecosystem structure and function will have major consequences on both regional and global scales, placing further pressure on Antarctic governance, including environmental protection and resource conservation. Truly integrated studies of ecosystems are required to make robust projections over coming decades to inform governance measures. These include understanding the responses of different biological systems to multiple drivers using a combination of laboratory, field and modelling approaches across a range of spatial, temporal and organisational scales.

Innovative approaches to address the challenge

Understanding Antarctic ecosystems and change will require innovative approaches and effective governance mechanisms to protect and maintain the continent's unique biodiversity. These include:

- The application of cutting-edge molecular and analytical techniques to decipher the evolutionary history of the Antarctic (which also supports predictions of future reactions to climate perturbations);
- The synergy of Antarctic biological and glaciological research communities, working together to better understand connections between Antarctic ice and biota;
- The role of benthic ecosystems in carbon cycle, sequestration and drawdown;
- Understanding multiple drivers of, and linkages between, different systems such as the role of primary productivity in forcing both circumpolar and global processes;
- Conservation tools, continually assessed and reconfigured to ensure they remain fit for purpose;
- The transfer of samples, data and knowledge from curiosity-driven investigations to applied research in biotechnological, pharmacological and medical applications, often referred to as 'bioprospecting'.

The Antarctic as a unique vantage point

The challenge: The Antarctic offers opportunities for cutting-edge research on life in extreme environments and space research, unavailable elsewhere.

Key research question: What can measurements from the Antarctic tell us about the likelihood of life in extra-terrestrial settings, how will space weather impact the planet, and how serious is the growing problem of debris in space?

Why is it timely?

In recent years there have been dramatic observations of life adapted to extreme conditions in the Antarctic, with microbes found within very cold (colder than -50°C) ice or isolated for many millennia beneath the ice sheets. The search for extra-terrestrial life, especially in icy settings such as Europa and Enceladus (moons of Jupiter and Saturn, respectively) can be informed by Antarctic research, enabling perfection of sampling and detection techniques and honing research strategies.

The number of satellites in low Earth orbit is growing exponentially, and the UK aims to double its share of the global space market by 2030. HMG's 2021 Integrated Review shows ambitious plans for UK Space Command and recognises that space is a more competitive and congested environment. The security of UK space assets and services is threatened by the increasing risk of satellite collisions with space debris. Mitigating this hazard is a focus of the United Nations (UN) Committee on the Peaceful Uses of Outer Space.

Space weather is the greatest source of uncertainty in pinpointing space object positions and planning costly collision avoidance manoeuvres. There is a critical gap in space weather observation capability and understanding over the Antarctic, which could be addressed through collaboration between UK industry, the global space object tracking network and UK research institutions.

Innovative approaches to address the challenge

While this challenge covers a range of scientific problems, they will all require particular innovation in specialised equipment deployed in remote locations, especially:

- Searching for life in ever more extreme environments, including those isolated beneath the ice surface for extended periods, will require the blended use of technological advances in deep-drilling, measurements and sampling;
- Monitoring and managing the transit of satellites, and measurements of space weather, rely on the polar gap being closed, requiring significant improvements in both ground-based and satellite observations and reliable data transmission.

Antarctic environmental management, governance and security

The challenge: As a founding signatory of the Antarctic Treaty, and as a nation committed to the highest standards in research, it is an imperative that we conduct Antarctic research in a manner that protects the environment. Such work requires careful planning and management, and bespoke designs in research techniques.

Key research question: How can the Antarctic be preserved as a natural wilderness while collecting scientific evidence that is crucial to societal and planetary well-being?

In addition to global pressures, the Antarctic is increasingly under local stresses from fishing, tourism, science and science support activities, and pollution. Collectively, these impacts on the Antarctic environment continue to increase, challenging both scientific approaches to mitigation and their input to (and the consensual operation of) the Antarctic Treaty's governance systems. Better understanding of ecosystems and their biodiversity is crucial to maintenance of ecosystem functioning, marine spatial planning, conservation, fisheries, infrastructural activity and the wilderness values that the Protocol on Environmental Protection and CAMLR Convention pledge to respect and protect. Policymakers within the Antarctic Treaty System have called out for the 'best available science' to inform decision-making on environmental protection and are mindful that the conservation challenges facing the Antarctic will require intense political bargaining and diplomatic exchange, some of which has been disrupted by the COVID-19 pandemic. This dependence on robust science is reflected in the FCDO British Antarctic Territory Strategy (2021).

A growing priority is to support research on the governance of the Antarctic. The continent has unique governance arrangements, and there is an urgent need to understand the pressures around environmental and heritage management – including delivery of UK obligations – alongside competing demands for utilisation of Antarctic resources and the challenges of working together politically in a contested world. The Antarctic is rightly being scrutinised as both resource and climate change-related pressures make themselves felt, and conservation will have to contend with the reality of a changing strategic geopolitical environment (as noted in HMG's 2021 Integrated Review).

It is also worth adding that global assessments on governance and environmental conservation are often lacking in Antarctic representation. It is vital that research not only contributes to the Antarctic Treaty System but also to global efforts in order to promote the planetary significance of the Antarctic.

Leadership and partnership

UK scientists from research institutes and universities, working in partnership with the UK armed forces and overseas collaborators, have been at the forefront of Antarctic research for many decades. They have made major contributions to SCAR programmes, CCAMLR's policy-related science on fisheries, and the IPCC's assessments of global climate heating. The UK has a globally-acknowledged reputation for excellence across each of the research areas identified in this paper and is well-positioned to lead or play a key role in their development. This standing is enhanced by recent investments in cutting-edge infrastructure, including a new state-of-the-art research vessel (the *RRS Sir David Attenborough*), modernised research station facilities, autonomous systems and advanced modelling capabilities, which collectively provide a superb capability for UK polar research. The UK is ideally placed to push further, to deliver scientific priorities identified by the national and international communities. Crucially, the British Antarctic Territory, where the UK mostly operates, is a region key to understanding Antarctic processes and links to the Earth system since it is where the greatest heating and changes in the Antarctic ecosystem have been observed.

Mock up showing how the *RRS Sir David Attenborough* will look once working in the Polar Regions.
Image credit: Pete Bucktrout, British Antarctic Survey.

UK science in the Antarctic benefits strongly from our position as a gateway nation, with Overseas Territories and research stations on and around the continent that serve as access points, sites of long-term data collection and places from which wide-ranging campaigns can be mobilised. In Antarctica, the UK has a leading role in maintaining the Antarctic Treaty System and is responsible for the management of nearly 20% of Antarctic Specially Protected Areas.

UK Antarctic science has an excellent track record, but the best and most impactful science is most often delivered in cooperation with key international partners and programmes. Bringing different expertise both from within the UK and internationally enables outstanding research that would otherwise not be possible. Additionally, addressing the science challenges outlined above will increasingly require more scientists from multiple disciplines working together.

Partnership and collaboration also bring value-added two-way benefits in terms of cost-sharing of expensive logistics and infrastructure, enabling access to technology, facilitating information-sharing and science diplomacy, and expediting access of UK researchers to regions not in the UK's traditional logistics footprint, as well as minimising greenhouse gas emissions and environmental impact.

Looking ahead

This paper provides a clear set of challenges and research priorities for UK Antarctic science and highlights the key pillars of Observations, Methods, and Agency and Impact that are crucial if we are to rise to these challenges. The priorities noted under five key questions are suitable targets for funding of UK or international research programmes in the coming years and, indeed, several will rely on significant new investment in long-term and repeated measurements. Much of this work will be necessary to fulfil UK commitments to wider global initiatives such as the UN Convention on Biological Diversity, the UN Framework Convention on Climate Change, the UN Decade of Ocean Science and the UN Sustainable Development Goals.

The UK is making very significant investment in its infrastructure to enable and deliver UK science in the Antarctic well into the twenty-first century, most notably through the *RRS Sir David Attenborough* and modernised station facilities, funded by United Kingdom Research and Innovation (UKRI). There is a clear need to ensure continued accessibility to these facilities in ways that maximise their effective use by the entire relevant research community, and engagement of that community is essential to successful research outcomes. Instrumentation and autonomous technology are vital to many future programmes and having simple mechanisms to access the technology alongside, and integrated with, use of ships, stations and aircraft will be critical.

Investment is also needed in people, in which continued support for training is targeted to ensure the research community is fully representative of the UK's society, so that the best talent can find a career in supporting, planning, and conducting twenty-first century polar work. UK polar science has begun to address the latter issue through the Diversity in Polar Science Initiative, but we must ensure we continue to focus on developing a more diverse research community.

The UK also needs to seek and harness expertise and interests within the social science community, as so much research has relevance and importance to diplomacy, governance, policy and decision-making. Enhancing the bridge between science and policy, and ensuring that policy needs are integrated into research design, also requires investment in training and carefully managed networks. The breadth of challenges facing us in analysing big datasets, along with the growing demand for autonomous systems and engineering for extreme environments, mean that the UK should also seek to broaden the community of researchers, industrial partners and funders to include those who might not immediately regard themselves as polar scientists. Twenty-first century Antarctic research must not exist within its own bubble.

By following the recommendations and guidance given here, the UK can position itself at the forefront of Antarctic science for many decades, working across disciplines and with international partners to deliver excellent, transformative science of global significance and public value.

Glossary of Terms

Biogeochemical cycles: the movement of chemical substances through organisms and their environment.

Bathymetry: the study of the beds or floors of water bodies.

Benthic ecosystem: an ecosystem at the bottom of the sea or lake.

Geophysical surveys: collection of data from rock, ice or water through methods such as radar, gravity, seismic or magnetic instruments, often done from ships or aircraft.

Ocean acidification: the lowering of seawater pH as it absorbs more carbon dioxide, with particular consequences for shell-building marine organisms.

Space weather: changes in the radiation and particles emitted by the sun which can interact with Earth and its atmosphere to produce a range of impacts, including on human technologies.

Subglacial topography: the configuration of land surfaces beneath glaciers.

Trace elements: chemical elements which are often necessary for biological processes but occur in low concentrations in the ocean.

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Ellsworth Mountains, West Antarctica, taken on a Twin Otter flight in December 2012.
Image credit: Pete Bucktrout, British Antarctic Survey.

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About the Grantham Institute and Imperial College London

In 2007, the Grantham Foundation for the Protection of the Environment made the visionary decision to support an Institute at Imperial College London to provide a vital global centre of excellence for research and education on climate change. Ten years on, the Grantham Institute is established as an authority on climate and environmental science.

The Grantham Institute is Imperial's hub for climate change and the environment, and one of six Global Institutes established to promote inter-disciplinary working and to meet some of the greatest challenges faced by society. We drive forward discovery, convert innovations into applications, train future leaders and communicate academic knowledge to businesses, industry and policymakers to help shape their decisions.

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About the UK National Committee on Antarctic Research

The UK National Committee for Antarctic Research (UKNCAR) promotes and co-ordinates the UK's interest in the activities of the Scientific Committee on Antarctic Research (SCAR). It is a committee under the auspices of the Royal Society, the national body representing the UK's interests to the International Science Council (ISC).

https://legacy.bas.ac.uk/UKNCAR/

About the UK Antarctic and Arctic Partnerships Committee

The UK Antarctic and Arctic Partnerships Committee (UKAAP) is a community-led initiative to bring together researchers across disciplines who are interested in advancing interdisciplinary work in the polar regions. It oversees the biannual Arctic/Antarctic symposium and acts as a bridge between polar scientists and key stakeholders.

https://ukaapartnership.org/