Polar Science – Perspectives from the Royal Society Global Environmental Research Committee

This paper has been produced following a science meeting of the Royal Society Global Environment Research Committee (see 'context' on page 3), and provides an overview of that discussion. It does not seek to represent the views of the Royal Society or to produce a comprehensive overview of the science, but instead to highlight some specific areas of potential interest to researchers, funders and government.

Polar Science: executive summary

GERC identified five key areas for Polar Science where further study or significant investment is important, and a further five thematic challenges that cut across a range of science questions.

Key priorities for study are: the polar ice sheets and their contribution to sea-level change; sea ice change; the widespread impacts of melting permafrost including on regional hydrology and the carbon cycle; marine ecosystem change and opportunities for cross-research council and industrial partnership; and improved representation of processes in climate models.

Cross-disciplinary themes identified include: the need for definition of baselines, including from palaeo data; better temporal and spatial sampling distribution, and use of technologies; the vital nature of international co-operation in Polar Science; and the need for multi-disciplinary approaches to understanding multiple and complex stresses in the polar environment.

Introduction

The Polar Regions play a critical role in global processes:

- they are an important part of the climate system;
- the ice sheets at the poles will be the dominant influence on sea level rise in the coming centuries;
- changes in sea ice can fundamentally affect air-sea interactions and regional climate, including that of Europe;
- the Southern Ocean plays a disproportionate role in global biogeochemical cycles including taking up a significant fraction of CO_2 released by humans;
- the Southern Ocean marine ecosystems provides a unique set of environmental adaptations and has undergone significant overfishing and climate-related stress;
- the Arctic is home to native peoples and reduced sea ice opens it up for greatly increased shipping transit and for resource exploitation, including oil and gas.

The UK has great strength in Polar Science, both in NERC Research Centres and in Universities. The UK occupies a prominent leadership role in and has recently invested in major international programmes (eg NERC-NSF Thwaites Glacier programme) and in future capability, especially a new Polar ship, the *RRS Sir David Attenborough*, and research station development in Antarctica.

Science issues

GERC discussion identified five of the most important areas of polar research:

1. ***Sea level rise***: The West Antarctic and the Greenland ice sheets and near-polar glaciers will increasingly dominate the projection of cryospheric contribution to sea level change. Approaches to understand the contribution of both, the two polar ice sheets and the near polar glaciers, to sea level rise are distinctly different:
    - The ice sheets require process models, underpinned by field observations to parametrise processes in the ice sheet and its forcing mechanisms.
    - In contrast, the understanding of small near-polar glaciers' contribution may be more fruitful if viewed as a big data problem using statistical approaches.

    Elements of both approaches are necessary to understand the evolution at the ice-ocean boundary; increasing co-operation between glaciological and oceanographic communities is required here. A

particular concern is that the Greenland and West Antarctic Ice Sheets may reach a point where rapid or irreversible change occurs, exceeding planning estimates of sea level change (the Thwaites programme addresses this). There is need for verifiable sea level projections up to (and ultimately beyond) 2100.

2. ***Impacts of melting permafrost***: The Arctic permafrost is changing rapidly and with a range of impacts. The temporal and spatial patterns of this change are not well understood due to significant temporal and spatial under-sampling of a large region. Changes to permafrost will have severe impacts on Arctic hydrology (including precipitation patterns) in addition to those on the carbon cycle. The potential knock-on effects on ecosystems and human activity are not yet established.

3. ***Representation of processes in climate models***: The representation of the Polar Regions in global climate models is still an area for development. Ongoing challenges include capturing seawater properties in ocean models, modelling processes of heat transport onto the continental shelf, the representation of sea ice, teleconnections to mid-latitudes, and modelling the atmospheric boundary layer and clouds. Some of these are being directly addressed through the Year of Polar Prediction and through the international MOSAIC programme. There is also an opportunity to better link the climatic and glaciological communities in the Arctic, particularly around study of the Greenland Ice Sheet.

4. ***Polar marine ecosystems*** are highly adapted to their environment and are particularly vulnerable to climate change. These ecosystems are key players in marine geochemical cycles, recycling carbon and other nutrients, and projecting the likely change is a challenge. There is an opportunity in UKRI for cross-research council approaches to understanding and exploiting the specialist adaptations, including potential biotech industrial involvement. Linkages between nearshore ecosystems within 5km-10km of the coast and the offshore systems, both behaving very differently, is poorly understood. Better data and modelling on how they interact are needed.

5. ***The key role of sea ice***: a wide range of studies are identifying sea ice as a key constituent of our understanding of the polar environment. Changes in sea ice extent and thickness are having direct impacts on oceanography, atmospheric climate, terrestrial systems, ecosystems, as well as humans and their built infrastructure. The many implications of rapid Arctic change require urgent assessment while the representation of Antarctic sea ice in models remains poor, hampering projections of future change.

The discussion also raised five key linking themes that apply to several areas of Polar Science:

1. ***Baselines***: There is an urgent need to define baselines for a range of environments (marine, terrestrial, ice) and across a wide spatial scale. A full understanding of change and rates of change will be undermined if we do not establish these baselines, as a record of the start of the Anthropocene. In most parts of the polar regions significant environmental change is underway and so although contemporary snapshots are still important there is a recognition of an important role for palaeo-science to provide baselines from the recent (centuries to few millennia) geological past.

2. ***Temporal and spatial improvements in sampling, and use of technology:*** Understanding ongoing change and its impacts requires a commitment to monitor change at regular intervals. Our understanding of the Polar Regions is biased towards the summer months and is often spatially restricted around particular facilities. There is an opportunity for more intensive use of technologies, such as autonomous devices, remote sensing and a pressing need for better sampling during winter. Advanced engineering developments have been important in driving forward the science in key areas but the committee also noted the potential for lower cost, lower-tech approaches, particularly where these can allow widely distributed ('swarm') or repeated measurements. The tagging of seals for collecting oceanographic data is a notable example. The need for transformative technology to address environmental science challenges in the Polar Regions is a major opportunity for cross-disciplinary work and GERC noted such funding sources as the Industrial Strategy Challenge Fund.

3. ***International co-operation***: The UK is a world leader in Polar Science, exemplified by the many leading roles that UK scientists play in working groups of SCAR (Scientific Committee on Antarctic Research), but the widespread nature of change and its environmental impacts, along with the costs of providing infrastructure and deploying scientists and technologies to the Polar Regions means that international collaboration is necessary. Two key priorities emerge, namely the need to be able to respond nimbly to

international opportunities, and enhanced access to international facilities, especially in the Arctic where the UK currently only has one station.

4. ***Beyond disciplinary science:*** the committee noted that an increasing amount of work on the Polar Regions is being carried out by those who might not identify as 'polar scientists', and welcome this expansion of the community tackling Polar Science challenges. Moreover, increased co-operation between science and social sciences is likely to be required to fully understand impacts of environmental change, particularly in the Arctic.

5. ***The role of multiple stressors***: The requirement for multi-disciplinary approaches was also noted in understanding multiple stressors on environmental systems: we have only limited understanding of the role of multiple stressors in the marine and terrestrial environments but there is growing recognition that there are likely to be important compounding effects.

The context for Global Environmental Research Committee reports

The Royal Society's Global Environment Research Committee (GERC) is charged with advising the Royal Society, and interacting with research councils, the environmental science community and other bodies. To do this, it is undertaking a rolling series of reviews of areas of science within its remit. The areas it has identified are (in alphabetical order): Air quality, Biodiversity, Carbon and other biogeochemical cycles, Climate, Natural resources (including land use) and food, Oceans, Polar science, and Water. In each area, GERC uses its own expertise, and that of a number of invited experts to consider the questions:

1. What are the hot research topics in this area at present?

2. What is the status of UK science within this area?

3. What are the most pressing research needs in the next 5-10 years?

4. Are there specific areas where UK science should be focussed to meet these needs?

5. How should priority topics be incorporated into multidisciplinary (funded across research councils) issues that Future Earth and its UK committee should consider?

This paper results from the discussion about polar science, held in October 2018. In addition to contributions from its regular and co-opted members, the committee was advised in person by Prof Lloyd Peck (British Antarctic Survey), Prof Ian Renfrew (UEA), Dr Kate Hendry (University of Bristol), Prof Mary Edwards (University of Southampton, Prof Karen Heywood (UEA) and Prof David Vaughan (British Antarctic Survey). The resulting paper evidently represents only a snapshot of issues, and is not a comprehensive survey of the science area. Exclusion of a topic from this document does not negate its importance, and many areas that are already under intense research are not highlighted here. It does not represent the view of the Royal Society, but puts a spotlight on some trends that will inform future activity by the Royal Society, UKRI, and UK Future Earth.

Membership of GERC (including co-opted members) at the time this topic was discussed (Oct 2018) was: Prof Eric Wolff FRS (chair), Dr Kirsti Ashworth, Prof. Mike Bentley, Dr Maria Dornelas, Prof Pierre Friedlingstein, Prof Joanna Haigh FRS, Dr Kate Hamer (NERC), Prof Gideon Henderson FRS, Dr John Ingram, Prof Corinne Le Quéré FRS, Prof Yadvinder Mahli FRS, Prof Paul Monks, Prof Peter Smith FRS, Prof Martin Solan, Prof Chris Thomas FRS. Dr Holly Winton acted as Secretary. Incoming members Prof Harry Bryden FRS, Prof Sue Hartley and Prof Louise Heathwaite also attended the discussion.