The Changing Arctic Inquiry
Written evidence submitted by the National Oceanography Centre

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Introduction

The National Oceanography Centre (NOC) is a research centre that is part of the Natural Environment Research Council (NERC) and provides UK national capability in oceanographic sciences. The NOC mission entails:

- undertaking integrated ocean research and technology development from the coast to the deep ocean. The NOC is the UK's leading institution for deep ocean research, sea level science, coastal physical processes and technology development
- providing large research infrastructure (global class research ships, nationally pooled marine equipment, marine robotics facilities and management of national marine data assets and samples including ocean sediment cores).
- working with government and business to translate science and technology into independent scientific advice, data products and commercial products.

1. How is the Arctic changing?

1.1 What are the most significant environmental changes taking place in the Arctic?

The Arctic environment is facing rapid changes as surface temperatures there are rising twice as fast as the global average, a phenomenon known as 'Arctic amplification'. In response, sea ice is rapidly diminishing in extent and thickness, the ice-free season is lengthening, and trees and shrubs are spreading northward. These changes have wide-ranging effects via feedbacks on climate, as well as strong effects on biodiversity and local communities, and also on sea-level rise. There are consequent impacts on the future of societies and economies, locally, regionally and globally (1).

An unusual Arctic weather event was observed in February 2018. The Danish Meteorological Institute (DMI) reported that the average daily temperatures in the Arctic have been up to 20 ºC higher than average (Figure 1, ref. 2). Ruth Mottram of the DMI noted that, "*Spikes in temperature are part of the normal weather patterns – what has been unusual about this event is that it has persisted for so long and that it has been so warm […] Going back to the late 1950s at least we have never seen such high temperatures in the high Arctic*." (3)

Robert Rohde, Berkeley Earth, observed that, "*In 50 years of Arctic reconstructions, the current warming event is both the most intense and one of the longest-lived warming events ever observed during winter*" (3)

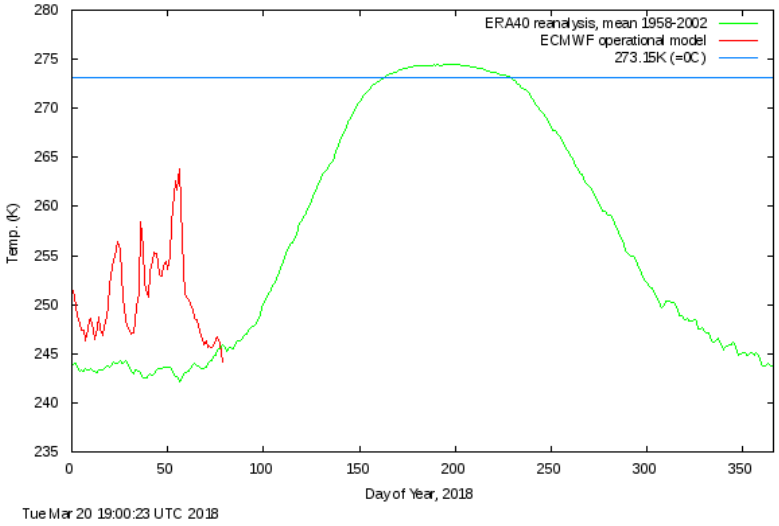

Figure 1. Daily mean temperature and climate north of the 80th northern parallel, as a function of the date of year – Danish Meteorological Institute (2). Record high temperatures observed during February 2018. The average temperature for the month was ~ 243 K (- 30 ºC).

This Arctic warm anomaly was part of an "exchange" that was allied to the so-called "Beast from the East", a spell of anomalously cold weather experienced at the same throughout the UK and Europe. The primary concern is that global warming is regionally enhanced by Arctic amplification, and is impacting northern hemisphere weather and climate, eroding the polar vortex, the powerful winds that once insulated the frozen north (3, 4).

Warming of the Arctic leads to increased sea ice melt, which in turn influences levels of stratification (due to freshening of surface waters) and thence the supply and replenishment of ocean nutrients from deeper waters.

Atmospheric concentrations of CO_2 are increasing globally, causing more CO_2 to dissolve, ultimately lowering the pH of surface waters (i.e. ocean acidification).

Satellite-derived estimates of pan-Arctic primary production suggest that it is increasing but the underlying mechanism remains unclear. These estimates also exclude primary production by ice algae and therefore their implications remain difficult to ascertain (could it be that increased pelagic primary production is a consequence of reduced under-ice primary production due to loss of sea ice?).

Blooms of ice-associated diatoms are expected to decrease as the ice melts. This has potential ramifications for the herbivorous animals (copepods: *Calanus* spp.) that consume the nutrient- and energy rich diatom biomass and use this to fuel their annual spawning.

Rapid warming and sea ice melt is causing the northward expansion of subarctic fish species and is driving regional changes in the phytoplankton community size structure and diversity at the base of the food web. These lower trophic levels sustain the fisheries and also support the top Arctic predators (seals, whales and

polar bears), which in turn are a food source for local subsidence hunting communities.

1.2 What might they mean for the UK, for example in terms of sea level rise or changes to climate?

- The UK may be affected by changes in weather and extremes, for example, longer spells of low temperatures in the winter and high temperatures in the summer.
- Fish populations will change in response to changing ocean temperatures and the timing and pathways of their migrations potentially disrupted.
- Reduced ice cover is opening up new shipping routes and exploitation opportunities (e.g. oil and gas, minerals).
- Arctic warming means that increased melting of the Greenland ice cap is impacting sea level rise.

1.3 How well prepared is the UK Government for these impacts?

HM Government's 2013 policy framework '*Adapting to Change – UK policy towards the Arctic*' recognised that the consequences of changes in the Arctic extend far beyond the Arctic region and cover a broad span of the UK's interests: societal, economic and environmental. The document also highlighted the need to devise responsible policy with full regard to the environment. UK-based Arctic science was identified as having a unique role in contributing to policy, reputation and influence. The Arctic Research Programme (ARP), funded by the Natural Environment Research Council (NERC) ran from 2011 to 2016, and made £15 million available for research into changes in the Arctic and their possible future consequences worldwide (1).

The second iteration of this framework, *Beyond the Ice: UK Policy towards the Arctic* (5) published in 2018 recognises the need to protect the Arctic environment and sets out the UK's commitment '*to remain a good neighbour to the Arctic, as a responsible steward of its interests*.'

2. How is the Arctic changing?

2.1 What is the extent of plastic and microplastic pollution in the Arctic?

Clear statements about the relative levels of plastic pollution between areas or between time periods are particularly difficult due to a lack of consistent sampling and analytical protocols. From a very limited observational basis, it is clear that the Arctic is exposed to plastic pollution as are all oceanic environments. Macroplastic material (>1mm in size) tends to predominate in the surface waters and on shorelines whereas the vast majority of microplastic particles (1-1000μm) are found in the sediments. With considerable uncertainty in its estimation, it would appear that the sediments in the Fram Strait have higher concentrations than the other deep sea sediments so far studied.

2.2 Where does this come from?

Macroplastic particles such as bottles, fishing nets, bags and packaging may well have marks indicating its place of manufacture but this does not provide conclusive information on its entry route to the marine system.

The majority of microplastics are generated as a result of breakdown of macroplastics although a small proportion come from microbeads (personal care and cleaning products). The two sources of microplastic in the Fram region are thought to be from sea ice as higher concentrations are found further north and directly transported from the North Atlantic. Many different types of polymers have been found (eg chlorinated polyethylene, polyamide and polypropylene) but these do not provide forensic proof of the source region.

2.3 What could the UK Government do to reduce it?

Although the UK contribution to plastic pollution in the Arctic is probably relatively small, practical developments are highly desirable. These include changes to commercial practice related to the manufacture and use of plastics and in the development of recycling methodology. Public education to reduce plastic waste should be enhanced still further. Environmental science must be supported to a much higher degree so that the temporal and spatial distribution of plastic pollution is better understood and the potential harms can be assessed in a way which is supported by evidence.

Sections 3 and 4

The NERC's Arctic Office will cover UK policy issues within sections 3 and 4 of their response.

3. UK policy

3.1 Has the UK's policy framework on the Arctic helped it achieve its vision of ensuring 'policies are developed on the basis of sound science with full regard to the environment, and where only responsible development takes place'?

3.2 Is the framework still fit for purpose in light of environmental and geopolitical changes?

4. UK policy

4.1 What role did the UK play in developing the integrated European Union policy for the Arctic and in encouraging the sustainable use of Arctic resources?

4.2 Will the UK's relationship to the Arctic change after leaving the European Union in respect of policy, trade or regulation?

5. UK-led scientific research

5.1 How active has Government been in supporting UK research in the Arctic?

Historically, UK Arctic research interests used to devolve onto the interests of individuals and was somewhat scattered. In the past ten or fifteen years or so, however, a more cohesive community has developed in response to NERC's provision of strategic funding through three substantial programmes, as follows.

- Changing Arctic Ocean: Implications for marine biology & biogeochemistry - £16M, five year programme, 2017 – 2022
  http://www.nerc.ac.uk/research/funded/programmes/arcticocean/

The over-arching goal of this programme is to understand how change in the physical environment (ice and ocean) will affect the large-scale ecosystem structure and biogeochemical functioning of the Arctic Ocean, the potential major impacts and provide projections for future ecosystem services.

- Arctic Research Programme - £15M, five year programme, 2010 – 2015)
  http://www.nerc.ac.uk/research/funded/programmes/arctic/

The overarching aim of this programme was to improve our capability to predict changes in the Arctic, particularly over timescales of months to decades, including regional impacts and the potential for feedbacks on the global Earth System.

- Arctic IPY – International Polar Year 2007 – 2008
  http://www.nerc.ac.uk/research/funded/programmes/arcticipy/

NERC's Arctic-IPY funding was focused and directed to IPY programmes in which the UK community could make a significant contribution and which would enhance the delivery of NERC strategic priorities.

A comprehensive overview of Arctic programmes funded by NERC is available on this web page, which is maintained by its Arctic Office:
https://www.arctic.ac.uk/research/uk-arctic-projects/

NERC funds the Arctic Office which is hosted by the British Antarctic Survey: https://www.arctic.ac.uk/ The Arctic Office is tasked with supporting and helping coordinate research and logistical activities in the Arctic region by the UK Arctic science community.

5.2 What impact has the Natural Environmental Research Council's (NERC's) recent 5-year research programme had so far?

Understanding and predicting climate change in the Arctic, both from a local and global perspective, was the focus of the NERC Arctic Research Programme (ARP), which ran from 2011 to 2016. Key topics included the degree to which current effects of climate change reinforce or mitigate future change, and the identification of critical processes contributing to such changes, now and in the future. Research spanned

atmosphere, ice, oceans, lakes, wetlands, tundra and forest, to improve our knowledge and understanding of present and likely future functioning of climate and ecosystems. The NERC Arctic Office sponsored last year (2017) the production of a policy report, "The Rapidly Changing Arctic Environment" (1), which summarised the ARP's impact (Prof. Bacon was a co-author).

Research identified processes that both reinforce climate change and have neutral effects but very few mitigating processes. This suggests that many changes are likely to increase in rate and severity. Permafrost thaw and increasing temperatures are highly likely to increase greenhouse gas emissions, and coastal areas are increasingly suffering from erosion and sea-level rise. Increased cloudiness traps warmth above sea ice and reinforces ice melt. Ocean warming and the melting of sea ice are being reinforced by increased ice-free surface area which absorbs more warmth. Arctic Ocean currents are accelerating and ocean mixing “hot-spots” can bring ocean heat up to the surface from below. There are logical, but speculative, consequences of these two findings: accelerated and seasonally-extended sea-ice decline, and increases in mid-latitude (including the UK) extreme weather events.

Increased freshwater flows into the Arctic and northern North Atlantic may weaken the current system (the “overturning circulation”, of which the Gulf Stream is part) that brings ocean heat to northern European latitudes. The impact of global warming may be regionally reduced, with uncertain consequences for UK weather and climate.

Increased commercial shipping activity due to diminishing sea ice will require improved short-term shipping and specialised forecasts that take into account changing ocean currents, waves, seasons, and weather patterns, in order to minimise risk (6). Similar considerations are required for expanding offshore commercial operations, including fishing, oil and gas and mineral exploration. Resource extraction and transportation environmental risks should be weighed against the industrial and societal benefits (Blue Actions, Yamal 2040 Scenarios Workshop, http://www.blue-action.eu/index.php?id=4146).

Risk of methane release from the ocean is not deemed high, as most methane becomes processed into CO2 before reaching the atmosphere. Methane hydrates, the form methane takes when trapped under water, are also unlikely to cause under-sea landslides. The largest source of greenhouse gases in the Arctic, and that most likely to increase in the future, comes from land, specifically wetlands, as well as from shelf regions due to submerged, thawing permafrost and coastal erosion due to higher waves (1,7).

5.3 Are there any gaps in the current research programme that the NERC should address in future programmes?

The announcement of NERC’s five year programme, *The Changing Arctic Ocean: Implications for marine biology & biogeochemistry* (http://www.nerc.ac.uk/research/funded/programmes/arcticocean/) was welcome and will doubtless improve the state of knowledge of the Arctic’s biology and ecosystem. However, it was a missed opportunity not to continue a degree of support for understanding Arctic climate change and remote impacts, a priority area for the UK.

UK Government, through the NERC, is investing significantly in development of marine robotics, including a recent £19M capital injection as part of the Industrial Strategy Challenge Fund that is being co-ordinated by NOC. http://noc.ac.uk/news/£19-million-government-investment-noc-technology-announced

This will deliver enhanced capability in exploring and monitoring challenging under-ice and ice-margin environments, using Autonomous Underwater Vehicles (AUVs) with extended endurance such as the new Autosub Long Range developed at NOC (which will be capable of long-endurance under-ice missions). New opportunities for polar environmental monitoring using marine robots are also being developed by NOC's industry partners, such as micro-AUVs that can be launched from unmanned surface or aerial vehicles to monitor oil spills, and acoustic devices that can be attached to marine robots to monitor ocean noise levels and presence of marine mammals.

In summer 2018, NOC is planning to co-ordinate a major marine robot demonstrator mission in Norwegian Arctic waters (MASSMO5), that will explore how fleets of marine robots can support environmental observation. And a new €5M EU Horizon 2020 research programme called EU Marine Robots will likely see NOC and its partners undertake further demonstrator missions in Arctic waters in 2019 and/or 2020. NERC could leverage these opportunities by investigating potential for targeted projects, co-delivered with UK industry partners, that specifically focus on minimising environmental impacts in Arctic waters, e.g. use of marine robots for rapid emergency response and/or environmental monitoring in hostile environments.

6. UK-led scientific research

6.1 What are the implications of leaving the EU for the UK's scientific research in the Arctic?

NERC's Arctic Office web site lists EU Arctic projects involving UK researchers: https://www.arctic.ac.uk/research/uk-arctic-projects/ so withdrawal from the EU is likely to impact future Arctic research.

The Horizon 2020 Arctic projects have created the EU Arctic Cluster, a network, which merges findings on Arctic change and its global implications. Its objective is to provide guidance and policy-relevant information and support the EU in advancing international cooperation, in responding to the impacts of climate change on the Arctic's fragile environment, and on promoting and contributing to sustainable development.

The Arctic Cluster includes the ARICE (Arctic Research Icebreaker Consortium), announced in 2018, which will involve research institutes from around the world, including BAS and aims to better coordinate the polar research fleet.

The EU Arctic Cluster: http://www.eu-polarnet.eu/eu-arctic-cluster/

From the NOC's perspective, however, we are not strongly tied into Framework Programmes as the bulk of our Arctic research has been delivered through the

Natural Environment Research Council. Historically our bilateral agreements with European partners and other international partners, and also the UK's subscription to the European Space Agency (ESA) have proved highly effective and are likely to continue. See also §6.3 below.

6.2 What have the impacts been to date?

Marine Scientific Research

A large part of the Arctic water column and a significant area of the Arctic seabed are under the jurisdiction of the five Arctic States with respect to the undertaking of UK Government funded Marine Scientific Research (MSR). It is under UNCLOS in general and Part XIII specifically that the Arctic States exercise the governance of MSR in waters under their jurisdiction. It is assessed that current and future access for UK scientists undertaking UK Government funded MSR in Arctic States maritime zones is not compromised by the UK leaving the EU. Under UNCLOS Part XIII the EU cannot make diplomatic requests to undertake MSR in Arctic States waters on behalf of member States, only individual EU member states can currently make application for diplomatic access. Currently, the Flag State that owns the research vessel is the state that makes the request for diplomatic access. For example, in the case of EU funded Arctic science using the RV *Polarstern,* this would be Germany.

The governance of MSR in Arctic waters was the subject of an international conference in Germany in 2011. The discussion and outcomes of this conference are captured in *Arctic Science, International Law and Climate Change – Legal Aspects of Marine Science in the Arctic Ocean* (8). Annex 2 of the book contains the summary conclusions of the conference. It is recommended that access to this annex might be useful for members of the current Arctic Inquiry to have a better understanding of the diplomatic landscape of State funded MSR in Arctic waters. However, note should be taken that some of the conclusions have since been overtaken by events, in particular those relating to MSR and extended continental shelf claims in the Arctic basin. For example, Norway and Russia have settled overlapping claims. The significant conclusion was that participating States in the conference agreed that UNCLOS and Part XIII is the best way for all parties involved to both promote and govern MSR in Arctic waters.

In his 2018 book, *Britain and the Arctic,* Duncan Depledge (9) states the pre-eminence of British Arctic science 2006 to 2015 funded by UK Government, which was ranked 4th in terms of output and 6th in terms of impact. This is the highest ranking achieved by a non-Arctic State. However, Depledge is critical of the lack of presence of UK scientists at key Arctic science meetings stating that China, Japan and Korea are enhancing their profile at such meetings. Depledge is concerned that the UK, by not maintaining a high profile in the appropriate Arctic scientific forums, may lose influence even if it funds more research.

6.3 How are agreements on international cooperation, joint research projects and access to funding streams like Horizon 2020 likely to be impacted?

Please see our response to 6.1. In the Arctic context, and from an NOC perspective, it is not clear whether withdrawal from the EU will be significantly detrimental. Examples (below) illustrate the strength and success of high-profile international engagements that have not depended on the Horizon 2020 (or related) programmes.

- The CryoSat-2 satellite is a UK-led ESA mission that was launched in 2010, and has enabled scientists to measure the sea ice volume as an indicator of the changes taking place in the Arctic: http://www.nerc.ac.uk/planetearth/stories/1366/ was funded by multiple partners including NERC, the European Space Agency, and the German Aerospace Center.
  Cryosat-2: https://www.esa.int/Our_Activities/Operations/CryoSat-2_operations

- In 2017 NERC announced the Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) initiative which was developed in partnership with the Department for Business, Energy & Industrial Strategy. The programme's coordinator is Germany's Alfred Wegener Institute. The focus of the programme will be the year round operation of RV *Polarstern*, drifting with the sea ice across the central Arctic during 2019 to 2020.
  MOSAic: http://www.mosaicobservatory.org/index.html

- The UK-Canada Arctic Partnership is an opportunity for UK-based researchers to apply for bursaries to support participation in funded Canadian-led Arctic research in Arctic Canada. The Department for Business, Energy and industrial Strategy, working with the British High Commission in Ottawa and the NERC Arctic Office, is funding a second year (2018) of the bursaries programme.

  UK-Canada Arctic Partnership https://www.arctic.ac.uk/wp-content/uploads/sites/8/sites/8/2017/11/UK-Canada-Arctic-Partnership-Bursaries-Second-Year.pdf

- In 2016 the British Embassy in Moscow announced the UK Bilateral Projects Programme which invited proposals for project initiatives in Russia which would contribute to objectives that included UK Russia collaborative projects on the Artic polar region.

  New round for UK Bilateral Projects Programme:
  https://www.gov.uk/government/news/new-round-for-uk-bilateral-projects-programme-2016-2017-to-accept-bids-in-russia

  In 2917 a UK-Russia bilateral project, 'Development of the UK-Russia Arctic Research and Collaboration Network' was launched. The project was funded by the Foreign and Commonwealth Office, the UK Embassy in Russia and implemented by the UArctic Research Office, NarFU.

Development of the UK-Russia Arctic Research and Collaboration Network https://www.uarctic.org/news/2017/9/the-uk-russia-bilateral-project-successfully-started-in-aberdeen/

These types of partnerships have been enabled through national subscription so, provided Government policy does not change, these agreements should continue.

7. UK-led scientific research

7.1 Have actual or proposed changes in policy or funding towards Arctic research by other major players, such as the United States, had an impact on UK research capacity in the Arctic?

We are aware that the United States is continuing to show interest in matters relating to the Arctic and that the US Coastguard is looking to grow its fleet to include three heavy and three medium icebreakers (8). US research does not impact UK research significantly.

7.2 How might the UK need to adapt its approach?

The UK invests a large sum in Antarctic research whilst the Antarctic is 12 000 km away. In contrast the Arctic starts north of the Shetlands, however, dedicated Arctic research funding is intermittent, whilst the impacts of changes in the Arctic may be felt directly in the UK. Please see our response at 8.1.

8. Promoting good governance and business standards

8.1 To what extent has the UK promoted business standards, best practice and responsible development in the Arctic and thereby reduced environmental impact of commercial activities (including fossil fuel extraction, mining, shipping and tourism)? How successful has it been? What more could it do?

The Lloyds *Arctic Opening* report (9) of 2012 is the reference for this section of our response. The foreword of this report was written by the then CEO of Lloyds, Richard Ward. In the foreword Mr Ward states that, "*there is a clear need for sustained investment in Arctic research",* because current data and information will help facilitate the effective risk management of the future environmental and economic uncertainties in the Arctic.

There is a wide range of potential scenarios for the UK's engagement in future Arctic opportunites, depending principally on local investment conditions and global commodity prices. Oil and gas, mining and the shipping industries will be the biggest drivers and beneficiaries of Arctic economic development. Industries supporting these activities, such as fisheries, aquaculture, tourism and scientific research, could also contribute to the longer-term economic sustainability of Arctic communities. Based on current trends, expected investment in the Arctic could reach $100 bn or more over the next decade. However, given the high risk/potentially high reward nature of Arctic investment, this figure could be significantly higher or lower. Specific

investment strategies will depend on the regional and global industrial foci, e.g., alternative energy sources, political climate, new technologies, land pipeline network development vs. marine transportation, etc. (e.g., Blue Action, Yamal 2040 Scenarios Workshop, http://www.blue-action.eu/index.php?id=4146).

Risks such as an oil spill are not necessarily more likely in the Arctic than other extreme environments, however, the potential environmental consequences and costs of a clean-up may be significant, with knock-on implications for governments, businesses and the insurance industry. Specifically the unknowns are related to the oceanic pathways of the contaminant and timescales for the pollutants to reach populated areas in the UK and Europe (12).

In managing the challenges of Arctic development, there is a need for a coordinated responses and common standards that ensure best practice to underpin sustainable development and to uphold the public interest.

For businesses operating in the Arctic, there must be robust risk management frameworks and processes in place that adopt best practice and contain worst case scenarios, crisis response plans and full-scale exercises. Some risk can be transferred to specialist insurers.

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In case of query

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