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The Arctic and the UK: climate, research and engagement

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Headlines

- The Arctic has warmed by around 2°C since 1850, approximately double the global average. Even if the Paris Agreement successfully limits global warming to a further 0.5°C, the Arctic is expected to warm by at least another 1°C.
- The United Kingdom's (UK) weather is linked to conditions in the European Arctic. For example, high atmospheric pressure in the Nordic Seas divert damaging storms across the UK and mainland Europe, with the potential to cause societal disruption from flooding.
- It is possible, although presently unconfirmed, that alterations in Arctic conditions provoked the 'Beast from the East' winter storm in 2018.
- Scientists need to take observations and improve their understanding of climatic processes in the Nordic Seas and the Arctic Ocean to fill gaps in knowledge about the links between the Arctic climate and the UK's weather; a risk identified by the Intergovernmental Panel on Climate Change (IPCC).
- The UK has significant research expertise and experience to understand how global warming will change the Arctic's environment and affect the UK.
- This strength, allied with the capabilities of the UK's new polar research ship the RRS *Sir David Attenborough*, warrants an integrated programme of research, including advanced numerical modelling, to improve predictions of future extreme weather events.
- Such a programme must acknowledge that the Arctic is politically an increasingly congested and contested space. It should be designed in collaboration with key Arctic and near-Arctic nations to increase the UK's influence and ability to prepare, respond and plan for future extreme weather events.

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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**

Introduction

The United Kingdom (UK) has a long-standing and continuing relationship with the Arctic. This relationship has three dimensions: societal, political and environmental.

For centuries, the UK has actively participated in scientific discovery in the Arctic, applying its experience, expertise and logistics to a variety of high-latitude scientific frontiers on land and ice, at sea and in the atmosphere[1]. Although located outside the Arctic circle, the UK actively participates in the International Arctic Science Committee, has a small permanent research base on the Norwegian Arctic archipelago Svalbard, and collaborates extensively with Arctic nations and others in Arctic research (Figure 1). The UK is the fourth largest producer of Arctic research (behind the United States, Canada and Norway), the bulk of which involves international collaboration[2].

The UK's interests in the Arctic are founded on strategic priorities as well as scientific ambition. The UK is a long-standing Observer to the Arctic Council, which oversees diplomatic exchange across the region, and the government has developed a policy framework for its activity in the Arctic[3,4] and a strategy for defence is anticipated[5]. The City of London has a commercial interest in the Arctic region, as an acknowledged global centre for shipping and insurance[6,7].

There is also increasing evidence that the UK's climate is affected by the Arctic. In the last few years the British Isles have been subject to extreme weather conditions potentially linked to changes in the Arctic. Examples include the severe winter of 2018 and heavy storms in 2015 and 2020. As the climate changes, it is vital that scientists understand this relationship fully, to help policymakers prepare for the future appropriately. The UK's scientific community is well-placed to address these knowledge gaps.

The UK must also acknowledge that despite strategic reasons for acquiring knowledge of Arctic process and change, it has no sovereignty rights in the Arctic region and must work both diplomatically and in partnership with Arctic states and other nations[8,9].

The UK is in the final stages of building its new £200 million ice-strengthened research ship, the *RRS Sir David Attenborough*[10], which will increase its capability and capacity for Polar marine research in the coming decades, allowing access to the most challenging locations and expanding the UK's ability to take critical measurements across the Arctic Ocean and Nordic Seas. As of June 2020, however, the UK had no formal plan for the use of the ship in Arctic research.

This paper presents evidence for the UK to take a strategic multi-disciplinary approach to its Arctic programme. It first explores scientists' current understanding of the Arctic environment, then describes how this relates to the UK's climate and identifies gaps in the scientific knowledge.

Figure 1: Map of the Arctic, with sea ice extent in September 2019 (pink line) and mean September sea ice extent 1981-2010 (blue line).

The paper finishes by identifying some of the political priorities that might inform a UK Arctic Science strategy.

A changing climate

The Arctic atmosphere is undergoing drastic change, driven by processes that are intertwined with those occurring at the mid-latitudes via physical and chemical processes that scientists cannot yet fully explain[11,12].

The melting of Arctic sea ice in recent decades (Figure 1) has become like a canary in the coal mine for climate change. Substantial declines have been seen in its age, thickness, extent and concentration over the satellite era (since 1979). These declines, unprecedented in so far as measurements and records permit, have led to the Arctic warming at twice the rate of the rest of the planet[13] (2°C since 1850 compared with 1°C globally), leading to widespread habitat loss for Arctic marine species such as seals and polar bears[14].

As the Arctic sea ice decreases, scientists expect to see more algae in the surface water – this group of simple organisms at the bottom of the food chain includes giant kelp and seaweeds as well as other smaller organisms that require light to grow. More algae will affect the number of plankton organisms that feed on them, with knock-on consequences along the food chain from fish to seals to polar bears. Importantly, this may also affect viability of northern fisheries[15,16,17].

The Arctic seas are also becoming more acidic, due to increased absorption of CO_2 in the water, forming carbonic acid[18]. This affects how and whether organisms can live in the water and is likely to remain a problem even under greenhouse gas reductions compliant with the 2015 Paris Agreement[19], and will be severe if emissions exceed this.

Snow cover on land increases reflection of the sun's energy and, as with melting sea ice, a marked reduction in the snow season length leads to enhanced local warming. Equally important is the condition of permafrost, where water is stored as ice within the ground[20]. Arctic land surfaces are warming faster than anywhere else on the planet, and the permafrost is melting. As it does so, the ground becomes weaker, threatening any infrastructure built on it (e.g. a Russian oil tank collapsed in the Arctic in May 2020). Thawing permafrost also leads to increased sediment transport to rivers and eventually the ocean, changing nutrient conditions with as-yet-unknown effects on the marine ecosystem and fisheries. Along coasts dominated by soft sediments, melting sea ice leads to more energetic waves that erode cliffs, accelerating the loss of land and increasing sediment transfer to the ocean. The thawing of sediments, both on land and at the coast, releases greenhouse gases (carbon dioxide (CO_2) and methane (CH_4)) to the atmosphere and creates a feedback loop that magnifies global warming.

The Arctic's influence on the UK's weather

In the last few years, the British Isles have been subject to extreme weather conditions potentially linked to changes in the Arctic (Figure 2); for example during the 'Beast from the East' in winter 2018, when Arctic air blasted the country, temperatures fell to well below 0°C for several days and over half a metre of snow fell in some areas. The storm caused over a billion pounds of damage, the direct loss of 10 lives[21] from accidents associated with the weather, and scores of deaths associated with colder homes, predominantly among the elderly. Winter storms in 2015 and 2020 led to flooding and disruption for the people of the UK. The cost of this severe weather to the UK is immense; for example storms Ciara and Dennis in 2020 are estimated collectively to have cost the insurance industry around £425 million[22].

Dominant UK weather systems

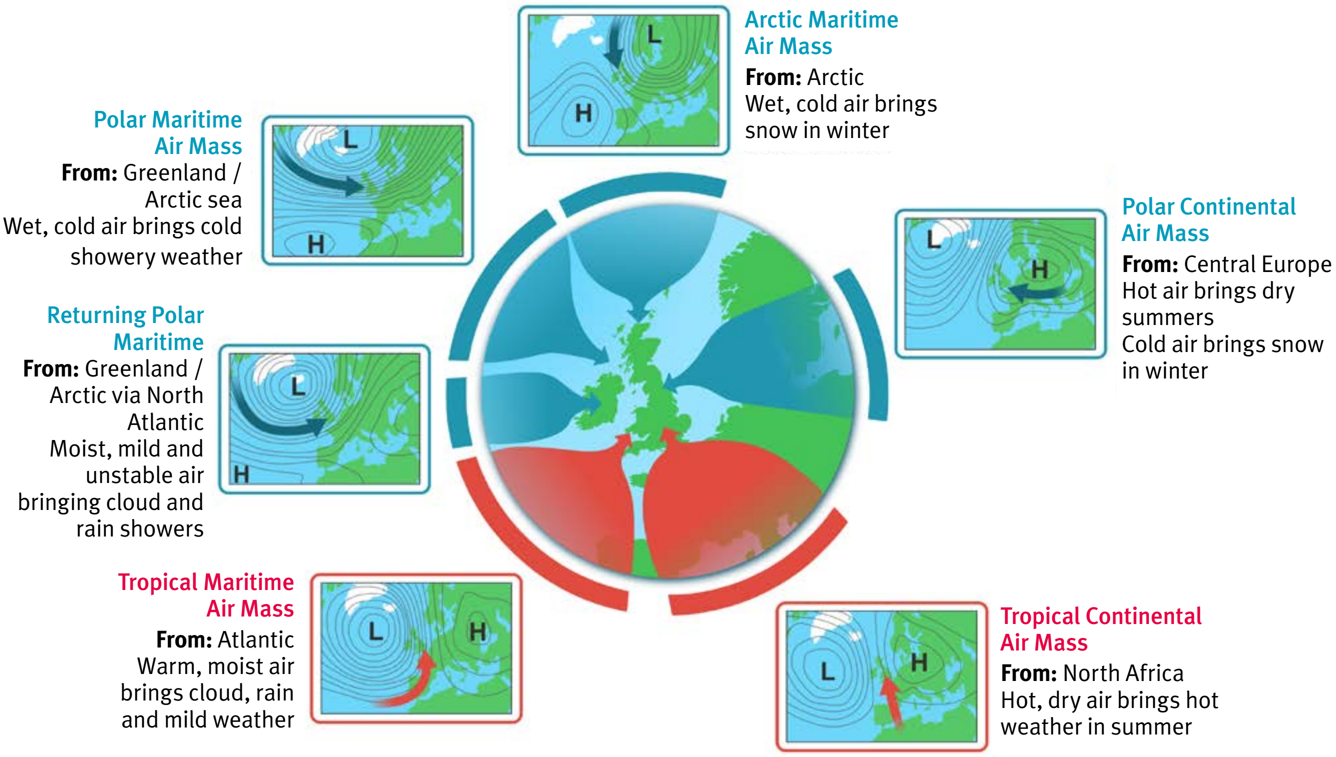

Figure 2: The UK's weather is controlled by surrounding atmospheric conditions of low and high pressure, many of which are either in, or related to, the Arctic. Under climate warming, which is acute in the Arctic, the UK's weather systems may experience change as these conditions are altered. This figure depicts classic weather systems that affect the UK, showing regions of high and low pressure. Arrows (red being warm, blue being cold) denote the origins of the air arriving at the UK under different weather patterns. This infographic was inspired by a 'UK weather systems' diagram from the Met Office.

How does the Arctic climate affect the UK?

The UK is vulnerable to the immediate and direct consequences of a changing Arctic (see Figure 2). For example, cold-air outbreaks and polar continental air masses, influenced by regions of high and low pressure, strongly affect the weather conditions in the UK.

These linkages are driven by physical processes that scientists cannot yet fully explain; from small-scale interactions between the atmosphere and ocean, turbulence where different air flows meet, to changes in the polar vortex (a low pressure counter-clockwise air flow 10km above and centred on the North Pole). The ability of weather forecasting models to track the development of these phenomena is limited by the sparsity of direct observations from ships and buoys in the Arctic, and a better understanding of Arctic processes is required to fully exploit information from existing satellite sensors. Uncertainties in each of these research areas reduces scientists' ability to predict short-term UK weather and long-term changes in Arctic and European climates.

Fundamentally scientists' understanding of how ongoing changes to the Arctic impact the UK over a range of timescales from seasons to centuries is imprecise[23,24]. This has led the Intergovernmental Panel on Climate Change (IPCC) to report only low-to-medium confidence in our knowledge of the current nature of Arctic and mid-latitude weather linkages, medium confidence in our understanding of the impact of the physical changes on ocean biodiversity, and medium confidence in our knowledge of ice loss from Greenland[25,26].

The changing Arctic Ocean and the UK

There are two major concerns on how future changes to the Arctic Ocean will affect the UK.

The first stems from the fact that the Arctic Ocean is a major store of – and conduit for – freshwater. The freshwater arrives in the Arctic Ocean primarily from the runoff from the great Siberian rivers, which discharge 10% of the total global river freshwater, and which is stored in the Arctic Ocean as diluted seawater (sea ice is only about 10% of stored freshwater). If this freshwater were to escape from the Arctic Ocean it would be channelled through the Davis and Fram Straits and on into Baffin Bay and the Nordic Seas, then on into the northern North Atlantic – the region that drives the global ocean circulation[27]. Adding more freshwater to the North Atlantic could curtail the ocean circulation known colloquially as the 'global conveyor belt', the mechanism that brings ocean heat north and is responsible for the UK's mild winters. For the UK, this curtailment could affect its weather, possibly reducing temperatures substantially.

The second concern is that several hundred meters beneath the surface of the Arctic Ocean lies warm water – the northernmost tail of the global conveyor belt. Currently, the ocean is layered, which makes it nearly impossible for the sub-surface ocean heat to reach the surface. If it did, however, there is enough heat in this existing warm water layer to melt all Arctic sea ice ten times over. As the sea ice melts and reduces in its extent (see Figure 1), winds can stir up the ocean currents, leading to far more mixing beneath the ocean surface than there is today. It is possible for such mixing to bring Arctic Ocean sub-surface heat to the surface, leading to even faster sea ice melting, maybe all year-round, and this would accelerate Arctic warming significantly.

The importance of future research

Whilst scientists are certain that the UK's weather is influenced by Arctic conditions to some degree, it is yet to be determined how large this influence is and, therefore, how future Arctic change (directly from warming) will impact the UK in terms of societal disruption, economic cost and physical change. According to the Polar Regions section of the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate[28], there is a major gap in the understanding of the Arctic influence on lower-latitude weather, such as for the UK (see Box 1). The problem is compounded by a lack of measurements and models that do not represent the Arctic well. While scientists can speculate about the nature of the Arctic's response to future warming, they and therefore policy-makers do not know enough to sensibly respond to it[29]. Taking observations and understanding processes within the Nordic Seas and the Arctic Ocean is critical to filling this knowledge gap, alongside developing atmospheric and ocean models that better reflect the genuine nature of Arctic processes.

The politics of a changing Arctic

The international waters of the Central Arctic Ocean are likely to attract ever greater interest in the future[35]. As Arctic sea ice reduces further, the Arctic Ocean will be opened to shipping using the 'Northern Sea Route' between the Pacific and Atlantic[36]. More trade routes and more developed infrastructure will increase extraction, fishing and tourism[37,38].

HM Government's 2018 Arctic Policy Framework states explicitly that the "UK's primary foreign policy objective" (in the Arctic) is "maintaining the Arctic as a peaceful and stable region"[39]. The Ministry of Defence, meanwhile, is producing an Arctic Defence Strategy that "will put the Arctic and the High North central to the security of the United Kingdom"[40]. These goals will be pursued against a background of profound environmental change in the Arctic even if global warming is limited to 1.5°C, as Arctic resource extraction and maritime activity are expected to increase. The UK will need to be responsive to the challenges and opportunities that emerge as a result, especially if is it to play a significant role in maintaining the Arctic as a peaceful and stable region, in a way that remains conducive to the security of the UK as foreign and defence policy priorities evolve.

Box 1: Understanding Arctic processes

Whilst it is contentious that changing sea ice and snow conditions are significantly influencing the UK's weather[30], a lack of consensus among scientists on the strength of linkages reveals a challenging knowledge gap[31,32]. Current weather forecast models do not do a good job in capturing Arctic conditions and this has implications for forecasting sea ice, which is especially important commercially and politically as the volume of Arctic shipping grows[33,34]. A recent example was observed by the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) programme in which a ship was frozen into the sea ice to drift across the Arctic. The researchers experienced a storm that, while predicted several days in advance, possessed an unusual structure not captured in models of Arctic weather systems. Broader than this, Arctic clouds and surface-atmosphere interactions are poorly represented in weather forecast models, because they are different in form to those in lower latitudes. These problems lead to a lack of consensus in Arctic models in predicting future changes.

German ice breaker 'Polarstern' locked within sea ice in the Arctic Ocean. Photo: Marcel Nicolaus, 25 October 2019.

There are already signs of growing strategic competition in the Arctic[41]. Although peaceful presently, this could change. The interests of major actors including the US, China, Russia, India, NATO and the European Union in the Arctic are evolving rapidly[42]. Relations between the West and Russia remain tense as military activity in the Arctic increases. Commercial opportunities for the UK are extensive across trade, financial and legal services, mineral resource extraction, tourism and fisheries. However, they are complicated by inter-state competition, unpredictable domestic regulatory frameworks, the devolution of authority (and, potentially, sovereignty) to regional and Indigenous decision makers. Furthermore, there is conflict between those that would keep the Arctic free of industrial activity and those that depend on development to raise living standards in the region. More positively, there has been good progress recently on international scientific collaboration and the management of prospective fisheries in the Central Arctic Ocean, in which the UK has been involved as part of the EU, and intends to commit to after it leaves the EU.

Yet, there is still much that is unknown about how geopolitical and security trends are likely to unfold, how they will intersect with other drivers of change (including environmental, technological, socioeconomic and ideological), and what opportunities they might produce for trade and other forms of wealth creation that could benefit the UK. The potential for the UK after leaving the EU to expand its partnerships through commercial, defence and science diplomacy with non-EU Arctic states such as Canada, Iceland, Norway and the US, as well as others from beyond the region such as China, India, South Korea, Germany and Japan, also needs further investigation.

The UK's Arctic political and social science community has a strong record for producing policy-relevant and impactful research[43]. A forward-looking strategic and coordinated Arctic research programme would help the UK Government understand, anticipate and respond to the changing Arctic in ways that further its principle policy objectives and expand Britain's post-Brexit presence on the world stage.

Conclusions

The UK's weather and, particularly, extreme weather events are linked to conditions in the Arctic and surrounding regions, through physical interconnections and feedbacks between the ice, ocean, biosphere and atmosphere. The Arctic is warming at double the global rate and scientists can hypothesise, based on available evidence, that changing Arctic conditions will lead to an increase in the intensity and frequency of extreme UK weather. However, understanding whether this is the case, and to what level future UK weather will be determined by the Arctic, requires far better knowledge of the processes operating across this vast and isolated region, acknowledging also the political sensitivities that exist between sovereign Arctic nations and those that wish to work there in collaboration.

With the launch of the polar research ship, the RRS *Sir David Attenborough*, the UK has an excellent scientific and logistics platform with which to plan and conduct high-latitude research in the oceans, ice and atmosphere to a level not previously possible. The next decade could, therefore, see better knowledge and predictions of UK extreme weather, provided UK researchers and policymakers take the opportunity to instigate and run multi-disciplinary and well-designed research activities in the Arctic in partnership with international agencies and researchers, and trace through the implications and opportunities for UK business, diplomacy and wider society.

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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.

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