University of BRISTOL

Mapping science and policy priorities in a Changing Central Arctic Ocean: a review for scientists and policy makers

Katharine Hendry, with thanks to the UK Arctic and Antarctic Partnership

The Central Arctic Ocean current risks and concerns[1]

- Average CAO surface temperatures have increased, as have extreme Arctic 'heatwaves'
- Sea ice in the Arctic is shrinking in extent and thickness, to levels unprecedented for at least 1000 years, and is more vulnerable to increased storm activity
- Ice freeze-up is happening later in the year, delaying snow accumulation on the ice, reducing the snow thickness and insulation
- Sea ice loss rates from the CAO via the Transpolar Drift [Box 1] have increased
- Changes in Arctic sea ice and storms may be influencing UK weather patterns
- Strong acidification of the CAO is occurring, threatening the marine ecosystem of the region
- Arctic warming has led to profound changes in the marine ecosystem including an increase in production of algae in ice-free waters and changes in zooplankton, fish and mammal foraging behaviour
- Shipping around the margins of the Arctic Ocean has increased, bringing potential positive economic impacts but potential risks including increased amount and types of marine pollutants in the CAO

Report summary

The Arctic is in a state of rapid climatic change. The Central Arctic Ocean (CAO) plays a pivotal role in regional and global climate, but is experiencing unprecedented changes in temperature, sea ice extent, and biology, as well as acidification and pollution. The extent to which these changes, which are already underway, will continue, accelerate or potentially reverse depends on our actions.

Scientific understanding of the Arctic is critical to enable the correct decisions to be made. Now is the best time for the UK to take advantage of cutting-edge capabilities and technology – especially in the form of the new polar research vessel the RRS *Sir David Attenborough* – people, funding opportunities, and proven international networks, to solve some of the challenges that face the CAO.

Box 1: What is the CAO like?

The Arctic Ocean is the world's smallest ocean, with large areas of shallow continental shelves. Two large-scale ocean currents dominate the circulation system, the Beaufort Gyre and Transpolar Drift, influencing freshwater export, and regional and midlatitude weather patterns - including in the UK.

The CAO sea ice plays a role in global climate, through heat and freshwater fluxes and the Earth's radiation budget through albedo effects (reflection of solar radiation).

The unique physical characteristics of the Arctic Ocean result in its strong sensitivity to climatic change - with global implications – due to a number of feedbacks relating to sea ice, the hydrological cycle, ocean-atmospheric heat exchange, and transport of oceanic and atmospheric heat from lower latitudes.

1 Special Report on Oceans and Cryosphere in a Changing Climate, IPCC, 2019. Chapter 3. https://www.ipcc.ch/srocc/home/ *[Accessed October 2019]*

How is the CAO changing? What do we know, what don't we know?

What are the scientific priorities?

Impacts on vulnerable regions

Quantifying and understanding:

- the impacts of multiple stressors
- changes in biodiversity and ecologically important 'keystone' species
- resilience in food-web structures
- pollution, noise, marine plastics and acidification, and their impacts
- bottom-up processes in marine ecosystem

Providing baseline information on essential ocean variables for conservation strategies e.g. Marine Protected Areas (MPAs)

The role of oceans in climate

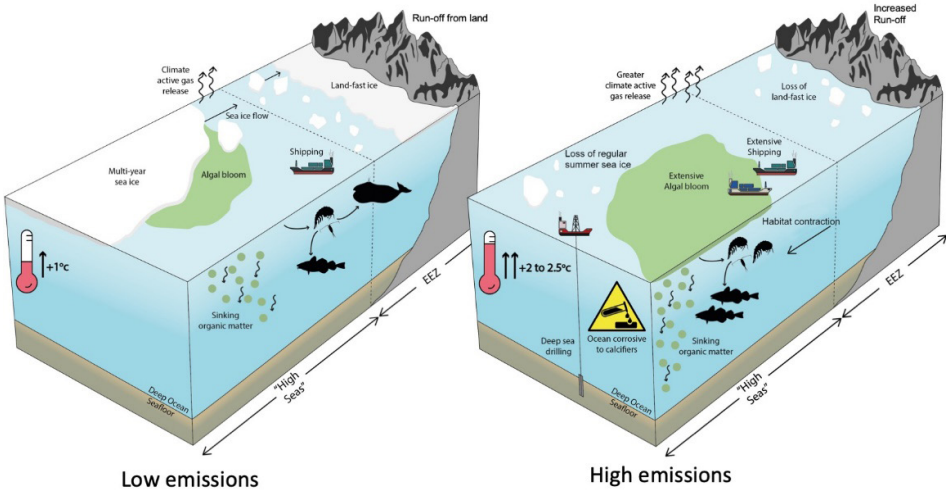
- Quantifying and understanding sea ice dynamics, including observations and predictions
- Understanding interactions between oceans and atmosphere e.g. release of climate-active gases and aerosols, and uptake of carbon dioxide
- Developing a mechanistic understanding of the connections between the CAO, mid- and low-latitude weather and global climate

International and cooperative solutions

- Understanding the value and limitations of governance strategies aimed at reducing risk and boosting resilience for CAO ecosystems, and impacts on human populations
- Broadening the systematic collection and open availability of seasonal and high-resolution data coverage e.g. Earth observation, remote sensing, autonomous technology
- Developing and sharing infrastructure and logistics
- Promoting open data and cyberinfrastructure
- Promoting education and diversity
- Building and maintaining synergies and collaborations
- Developing and implementing possible adaptation strategies

Solutions to Sustainable Development Goals[2]

- Developing the knowledge and technology required for sustainable development of Arctic regions



Contrasting predictions for the future of the CAO based on a low emissions scenario (left) and a high emissions scenario (right). Information drawn from[1], with approximate temperature increases based on predictions for Atlantic Layer warming (Vavrus et al., 2012; Koenigk & Brodeau, 2014) and changing air/sea/ice fluxes at the surface.

2 https://sustainabledevelopment.un.org

What are the geopolitics of the CAO?

Although a strong foundation for Arctic governance exists in the United Nations Convention on the Law of the Sea (UNCLOS), further regulatory innovations are required to maximise resilience to climate change as well as hazards associated with increased economic activity1.

The Arctic Council[3] has promoted cooperation in areas of environment and sustainable development, Arctic-related issues, empowerment and regional stability, since its beginning in 1996. The Arctic Council has passed three binding agreements, on cooperation on search and rescue, oil spill clean-up, and scientific research. The Arctic Council comprises the Eight Arctic states (Canada, the Kingdom of Denmark, Iceland, Finland, Norway, Sweden, the Russian Federation, and the USA), Permanent Participants and observers (including the UK).

The International Arctic Science Committee (IASC)[4] was established in 1990, with a remit covering cooperative research into natural and social sciences relating to Arctic land, oceans, atmosphere and space.

Most of the CAO are international waters or the "high seas" of the Arctic, or Areas Beyond National Jurisdiction (ABNJ) [Box 2]; they are outside of Exclusive Economic Zones (EEZs) and all nations have the right to access the waters and airspace in these regions, except for activities prohibited by international law.

Two major agreements were signed in 2017/8:

- The Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (2018; directed at the cautious prevention of unregulated fishing in the CAO)
- The IMO International Code for Ships Operating in Polar Waters (Polar Code) entered into force on 1 January 2017; major aspects of environmental and safety management north of 60°N)

A key role of the Arctic Council is environmental protection, including coordination of the Arctic Environmental Protection Strategy (AEPS) and Sustaining Arctic Observing Networks (SAON).

(Over the page) Seabed claims in the Central Arctic Ocean, produced by the Cartography Unit, University of Durham.

Box 2: Arctic Governance and UNCLOS

The UN Convention on the Law of the Sea (UNCLOS 1982) declares states have defined rights to the seafloor and superjacent waters within 200 nautical miles of coastal baselines - the Exclusive Economic Zone (EEZ). Under certain conditions, when the continental shelf extends beyond 200 miles, a claim can be lodged with the UN Secretary-General to extend rights to seabed resources out to 350 miles or, in some cases, further. The relevance of UNCLOS as providing the fundamental framework for Arctic Ocean governance was fully accepted by the five Central Arctic Ocean coastal states in the Ilulissat Declaration in 2008. Outer continental shelf claims in the Central Arctic Ocean have now been made by Russia, Norway, Denmark, and Canada. USA have not ratified the UNCLOS so are not able to make a claim, although it has recognised most aspects of UNCLOS as consistent with customary international law.

The seafloor region outside of the EEZ and state claim is termed "The Area", and is presided over by the International Seabed Authority (ISA).

3 https://arctic-council.org *[Accessed October 2019]*
4 https://iasc.info/ *[Accessed October 2019]*

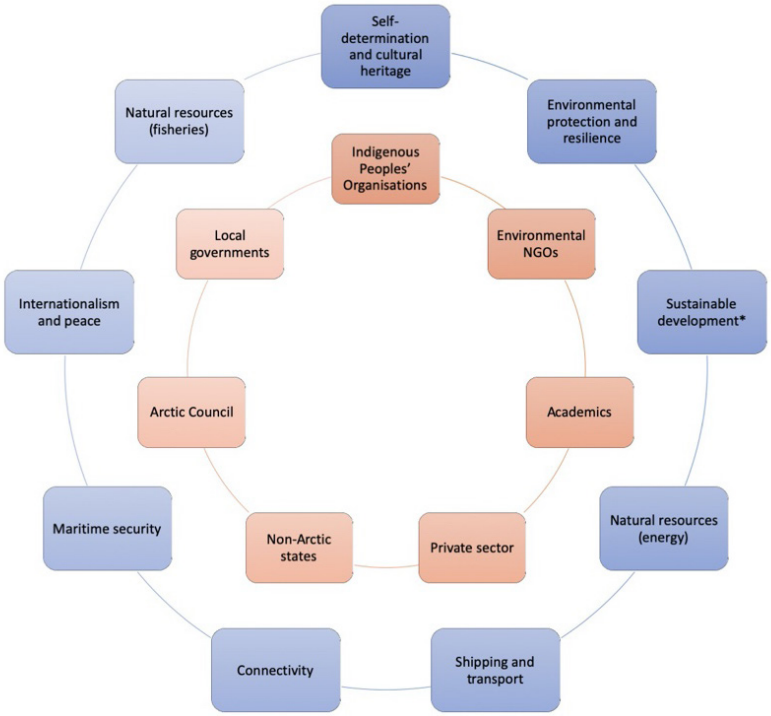
IBRU

Durham University
Department of Geography

Seabed Claims in the Central Arctic Ocean

- Internal waters
- Waters outside the Central Arctic Ocean (CAO)
- Unclaimable or unclaimed continental shelf
- Norway CAO continental shelf beyond 200 M (approved by CLCS)
- Russia CAO claimed continental shelf beyond 200 M (under review by CLCS)
- Canada CAO claimed continental shelf beyond 200 M (under review by CLCS)
- Potential USA CAO continental shelf beyond 200 M
- Denmark CAO claimed continental shelf beyond 200 M (under review by CLCS)

What are the international socioeconomic and policy priorities in the Central Arctic Ocean and how can they be addressed by scientists?



Schematic of priorities and major stakeholders in the CAO region.
*Focusing on UN Sustainable Development Goals (SDGs) [5]

Box 3: Indigenous Peoples' Organisations

Indigenous People of the Arctic are rights and knowledge holders in all governance structures and organisations under the UN Declaration on the Rights of Indigenous Peoples.

There are a number of Indigenous Peoples' Organisations (IPOs), active within Arctic governance, including as Permanent Participants (PPs) in the Arctic Council, with a potential interest in activities in the CAO including the seabed.

Box 4: Emergent Climate Technologies

Geoengineering is the "deliberate large-scale intervention in the Earth's natural systems to counteract climate change"[1]. Multiple climate altering technologies are developing relatively rapidly (e.g. geological carbon capture, sea ice restoration and enhanced reflectivity[2]). Legislation is not currently in place for the management of the sector priorities, despite long-term and global (trans-boundary) implications. These emerging technologies are not covered sufficiently by the existing governance structures in place for the high seas via the London Protocol (2006) - a matter of considerable concern. This is particularly important in the CAO, given that it could be considered that there is a joint responsibility in the high seas for safe, effective, and responsible exploration of climate altering technologies.

1 http://www.geoengineering.ox.ac.uk *[Accessed October 2019]*
2 https://www.carbfix.com/ *[Accessed October 2019]*, https://www.ice911.org/ *[Accessed October 2019]*

5 https://www.un.org/sustainabledevelopment/sustainable-development-goals/ *[Accessed October 2019]*

Challenges for the UK policy makers and scientists

Scientific challenges

- The CAO is a complex region – can we unpick the multiple stressors involved?
- The Arctic as a whole is changing rapidly - can observations keep up?
- Effective scientific advances are going to require cross-discipline, multi-disciplinary approaches and genuine co-production with Indigenous Knowledge – are the necessary networks available?

Logistics and governance challenges

- Arctic governance structures are fragmented – is the existing Arctic Observing network (SAON) sufficiently robust or does it need an overarching and internationally supported Arctic observing network?
- Does the CAO, as a largely enclosed and relatively inaccessible sea, present unique opportunities for collective governance?
- The CAO is inaccessible throughout the year in some regions, or during winter – how can we collect the high-resolution data needed? do new technologies offer new opportunities?

Impact challenges

- The CAO is changing rapidly, but those changes are being sustained, so governance responses also need to be rapid but sustainable – can we align decision-making, and research programs, with the pace of Arctic change? What is the UK's role in convening or encouraging this?
- Communication between scientists/local knowledge holders and researchers and governments, the private sector, and other international organisations (e.g. NGOs) is essential – can we agree on an integrated action plan?
- Different stakeholders have different priorities [Box 4], even between the UK Government Departments, that are governed by different legislation – can we align priorities?

Box 5: Stakeholder views

A recent survey by the University of California Irvine School of Law[1] revealed some of the views of different stakeholders across 21 countries including governments, non-government, academics, and Arctic policy works. On average 80% of respondents were in favour of the CAO fisheries treaty, and this was fairly uniform across stakeholders, ranging from 71-94% between sectors. This was also the case for approval for regionally-targeted environmental impact assessments (77% on average, 71-85% depending on sector). However, there were more variable views on an environmental protection treaty: on average 76% were in favour but this ranged from 50% for government workers to 80% for academics.

1 J. DiMento (2019). Arctic Environmental Governance Expert Views: A Summary of Results of the 2019 UCI Arctic Environmental Governance Survey (unpublished results). Note: results are not statistically significant, due to the methodology employed in the survey.

Existing UK strengths and opportunities

- Excellence in relevant natural science fields and historical Arctic research record
- Strengths in engineering sciences, especially in autonomous underwater robotics and drones
- Strong record of cross-discipline collaboration, e.g. UK Arctic and Antarctic Partnership and NERC Changing Arctic Ocean[6]
- Diverse history of leadership in oceanographic research throughout the UK
- World-leading universities and institutes, and strengths in training and supporting the next generation of scientists
- Existing pool of cutting-edge oceanographic equipment and data management
- Cutting-edge infrastructure and capabilities [Box 6]
- Engagement in international flagship programs such as the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC[7])
- Existing science-into-policy organisations with priorities linked to the CAO e.g. Marine Science Coordination Committee (MSCC)[8], Marine Climate Change Impacts Partnership (MCCIP)[9]
- Opportunities to come from co-production of research with local communities, Indigenous Peoples and PPs
- Increasing interest in research and development coordinated between academic institutions, private sector industry, NGOs and governments
- Involvement in funding cooperation on an international scale, including bilateral agreements with Arctic states (e.g. upcoming UK government cross-department 'International Ocean Strategy'[10]) – international links are going to be as important as ever as the UK exits the European Union

Box 6: UK Arctic Science Infrastructure

- The new ice-strengthened polar research vessel, RRS Sir David Attenborough, was named in 2019 and is due to enter sea trials in 2020 (with an estimated lifetime of 20-30 years)
- Two "blue-water" ships, the RRS James Cook and RRS Discovery
- Ny-Ålesund Research Station, Svalbard, is largely used for terrestrial and coastal research, but could act as a staging post for CAO research, for testing and engineering of new innovations, and generally building international collaborations
- The NERC fleet of airplanes, which can be fitted with remote sensing equipment
- NERC fleet of autonomous vehicles (National Oceanography Centre Southampton, Marine Scotland Science and SAMS) managed by the National Marine Facilities

An artist's impression of the RRS Sir David Attenborough, the new UK polar vessel – image credit Rolls Royce

6 https://www.changing-arctic-ocean.ac.uk/ *[Accessed October 2019]*
7 https://www.mosaic-expedition.org/ *[Accessed October 2019]*
8 https://www.gov.uk/government/publications/uk-marine-science-strategy-2010-to-2025 *[Accessed November 2019]*
9 http://www.mccip.org.uk/ *[Accessed November 2019]*
10 https://www.gov.uk/government/news/foreign-secretary-announces-uk-strategy-to-protect-worlds-oceans *[Accessed November 2019]*

Mapping science and policy priorities

Policy-makers' questions	Science drivers
What technology and knowledge do we need to deliver on sustainable development within the Arctic?	Improving sustainable technologies and engineering solutions
How are people and wildlife impacted by multiple stressors?	Improving our understanding of ecosystem services and sensitivity, from surface waters to the seafloor
How is the CAO and broader Arctic region impacted by different marine pollutants?	Improving our understanding of marine pollution (including noise), especially in the light of increased shipping
What information do we need for establishing a safe and secure CAO?	Improving spatial and temporal information on important environmental parameters
What information do we need for establishing Marine Protected Areas (MPAs) or other protection schemes?	Improving our understanding of bottom-up processes and their links with ecosystems and climate
How are the changes in the CAO going to impact the rest of the world?	Improving our understanding of teleconnection
How can internationalism, knowledge exchange, co-production and sharing of data and facilities promote science diplomacy? **How can education be improved within the Arctic and globally, using opportunities arising from working in the CAO?**	**Approaches:** Place an emphasis on co-benefits Invest in infrastructure Engage with upcoming international activities Promote outreach and education Use science and data for diplomacy

Recommendations for policy makers and scientists

Policy-makers	Scientists
Position the UK as a focal point for global agenda setting and international collaborations **Work with international partners to build a coherent CAO integrated observing system** **Place an emphasis on co-benefits and give due consideration to the dual priorities of sustainable development and environmental protection;** utilise UK Research and Innovation funding streams to solve the broad, cross-discipline questions surrounding the future of the CAO **Invest in infrastructure required for CAO research,** to complement the activities of the RRS Sir David Attenborough, and promote sustainable research **Engage with upcoming international activities** Build on momentum from the UN Framework Convention on Climate Change (UNFCCC), Our Ocean (Oslo), and Conference of the Parties (COP26) in Glasgow 2020 **Promote outreach and education** Secure funds and support for schemes to build the careers of the next generation of scientists, from school students to Early Career Researchers (ECRs) **Use science and data for diplomacy** Science in diplomacy, informing foreign policy objectives with scientific advice *Science for diplomacy, using science cooperation to improve international relations between countries* Diplomacy for science, facilitating international science cooperation	**Envisage where the gaps are in understating the CAO, especially between the disciplines** Use existing data and marine science platforms for discussion and dissemination *Build objectives around high-level environmental and societal drivers, and specify scientific goals relating to these drivers and operational limitations* Plan observations around a clear framework structure, using the concept of key Arctic Essential Variables, based on the concepts of urgency and technological "readiness" **Engage from the outset and at every level with Indigenous Peoples, to develop co-produced research that is synergistic with Indigenous Knowledge (IK) exchange** Collaborate with PPs and other Indigenous groups to publish more co-produced work *Engage with informal actors* Build an environment of trust with partners and other stakeholders *Think creatively about co-benefits* Keep up strong communication links throughout the duration of the project **Liaise with British Antarctic Survey and the National Marine Facilities** [Box 6] **Engage with key activities under the UN Decade of Ocean Science for Sustainable Development** **Liaise with Arctic organisations** on a national level (UK Arctic Office, UKAAP), a European level (European Polar Board, EU-PolarNet) and international level (IASC, Partnership for Observation of the Global Ocean POGO) **Understand what research and knowledge actors across the region want.** What projects and policies are the Arctic Council, IMO and other international bodies pursuing. **Promote and nurture the early career researchers within the community** via UK Polar Network and Association of Polar Early Career Scientists (UKPN/APECS) **Promote open access publishing and open data**

Further information

UK Arctic Office arctic.ac.uk

UKAAP ukaapartnership.org

UKPN/APECS apecs.is

IASC iasc.info

POGO ocean-partners.org

European Polar Board europeanpolarboard.org

Foreign Commonwealth Office Arctic Policy Report: Beyond the Ice www.gov.uk/government/publications/beyond-the-ice-uk-policy-towards-the-arctic

Arctic Connections: Scotland's Arctic Policy Framework www.gov.scot/publications/arctic-connections-scotlands-arctic-policy-framework/

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Vavrus, S. J., et al. (2012). Journal of Climate, 25(8), 2696-2710.