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ARCTIC CHANGES

The Arctic is warming faster than lower latitudes. This high north region is important for the UK's future environmental security (climate), energy security and strategic interests. This POSTnote summarises the environmental change already occurring in the Arctic and its potential impact on the global climate, future commercial activities and Arctic governance.

Background

The Arctic can be defined as the area north of the Arctic Circle (66°34'N), a latitude which is only ~600km from the Shetland Islands. This area covers approximately 6% of the Earth's surface, and is inhabited by around 4 million humans including indigenous people who have been inhabitants of the Arctic for over 10,000 years. At the centre is the Arctic Ocean, a semi-enclosed sea surrounded by five coastal states: Canada, Greenland (Denmark), Svalbard (Norway), Russia and the USA.

In the past 50 years, average annual temperatures in some Arctic regions have risen by up to 3°C[1]. It is predicted that, depending on the local region and future carbon emissions, average annual temperatures will rise this century by a further 2 - 9°C, which is greater than the 1.8 - 3.4°C rise expected globally[2]. Temperature rise is driving environmental change in the Arctic region, which will feed back into enhanced global warming primarily due to ice melt and permafrost (soil) thaw.

As the Arctic warms, increased political interest in the region is occurring, driven by the belief that it will become accessible to greater commercial activity. Obviously economics, not climate change, primarily will drive future commercial ventures in the Arctic. Warming will bring some new hazards and difficulties, and the Arctic's inaccessibility to extensive human activity will remain.

Arctic Governance

Unlike Antarctica, which is an uninhabited landmass administered by the Antarctic Treaty System, there is no single regulatory regime covering the entire Arctic region. The Arctic land masses are sovereign territories, while the Arctic Ocean is covered by national legal regimes as well as the 1982 UN Convention on the Law of the Sea (UNCLOS; Box 1) and other international instruments. There are currently calls for new governance and regulatory regimes to protect the Arctic environment and its natural resources, and to control and improve the safety of shipping, tourism and hydrocarbon development. For instance, in late 2008, the European Parliament proposed a resolution calling for an international Arctic treaty.

The five Arctic states do not, however, believe a new comprehensive international legal regime to govern the Arctic is required. In 2008, they issued the Ilulissat Declaration[3] stating their commitment to the existing legal framework and to their cooperation with each other and interested parties to protect the environment.

Box 1. UNCLOS and Continental Shelf Claims.

UNCLOS contains a number of important features relevant to the Arctic Ocean including: navigational rights, territorial sea limits and economic jurisdiction. It also includes provisions relevant to commercial activities such as the conservation and management of living marine resources, marine environmental protection and the legal status of resources on the seabed beyond the limits of national jurisdiction.

UNCLOS also allows for coastal states to extend the outer limits of their continental shelves where these reach beyond the 200 nautical mile (~370km) exclusive economic zone (EEZ). In the Arctic region Russia, Iceland and Norway have already made submissions to extend their continental shelf limits. Russia's claim was made in 2001, and included the seabed at the North Pole. The UN Commission on the Limits of the Continental Shelf deferred a final recommendation on the Russian submission pending the provision of further scientific data to support the claim, which Russia is still collecting.

Canada and Denmark are currently mapping their continental shelves to gather detailed scientific evidence for future submissions. It is possible that some areas of their claims in the central region of the Arctic Ocean will overlap with areas of the 2001 Russian claim[4]. The Commission does not make recommendations over disputed territory. It is up to the states involved to resolve any boundary disputes in accordance with international law, and then to make amended submissions.

The US has not yet ratified UNCLOS, which is a major weakness of the convention. However, the new US administration has indicated that it wishes to do so, after which it will probably also submit an extension claim, and has indeed been acquiring data for such a submission.

In the past two years each of the five Arctic coastal states has either issued or begun work on new Arctic or High North strategies. All are based on similar objectives including: sustainable resource development, increased scientific research, environmental protection, infrastructure development (such as deep water harbours) and exercise of sovereignty. As each state moves to reinforce its Arctic presence, enhanced scientific and military operations in this region are occurring.

The Arctic Council
The Arctic Council was established in 1996 by the five Arctic coastal states and Sweden, Iceland and Finland as a consensus-based, non-legally binding, intergovernmental forum to engage politically on regional issues of sustainable development and environmental protection. Six organisations representing indigenous peoples are "Permanent Participants" of the Arctic Council and are consulted as part of the Council's consensus decision-making. The UK is a "State Observer" to the Arctic Council. In 2008, the European Commission (EC) requested "Observer" status but it has not yet been granted.

European Union Arctic Policy
In November 2008, the EC released a communication concerning the European Union (EU) and the Arctic[5], which is viewed as a first step towards an EU Arctic Policy. This sets out EU interests and proposes action by EU Member States and institutions around three main policy objectives:
- "protecting and preserving the Arctic in unison with its population;
- promoting sustainable use of resources; and,
- contributing to enhanced Arctic multilateral governance."

Environmental Changes
Melting Sea Ice
Sea ice can be broadly separated into two types:
- thin first-year ice, up to 2m thick at the end of winter, which tends to melt in summer;
- multi-year ice that survives for one or more seasons and increases in thickness (averaging ~4.5m) with age.

The extent of Arctic Ocean sea ice varies seasonally, being greatest in March at the end of winter and lowest in September at the end of summer. Thirty years of satellite measurements have shown a continual decline in sea ice extent, beyond natural variations, averaging 11.7% a decade in summer and 2.7% in winter[6]. The September 2007 and 2008 sea-ice areas were the smallest since satellite measurements began in 1979. This decrease is occurring faster than models predict, and at the same time the ice is getting younger and thinner.

From 1981 to 2000, multiyear ice made up on average 30% of winter sea ice cover. In March 2009, at the start of the summer melt season, only 10% of Arctic sea ice was more than 2 years old[6] (Fig 1). Whether this large area of thin ice will now lead to a rapid loss of sea ice is not known, but the most recent estimate is that the Arctic Ocean will become sea-ice free for a few months each summer in 20 to 40 years[7]. Melting sea ice will not directly increase global sea levels because it is already floating on the ocean. However, ice loss has important implications for the global climate (Box 2).

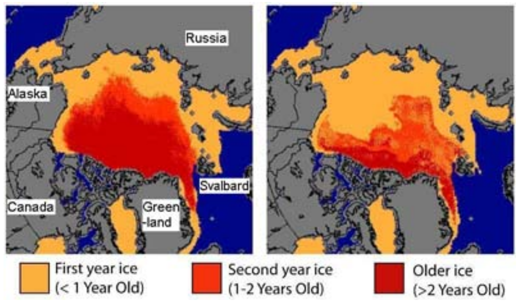

Fig 1. Comparison of sea ice age at the end of winter in February 2009 (right) with the 1981-2000 average (left)[8].

Box 2 Melting Snow and Ice: Global Implications.
Melting snow and ice cause further warming and global climate instability in a number of ways. Highly reflective white snow and ice in the Arctic are extremely important for the reflection of solar radiation (heat) back into space. As snow and ice melt, less solar radiation is reflected back into space, and the dark surfaces of the newly exposed land and open sea absorb a greater amount of heat, causing increased temperatures and yet further melt. This positive feedback mechanism will contribute to further, and possibly accelerated, Arctic and global temperature rise.

Both global and Arctic warming have the potential to drive further changes in Arctic oceanic and atmospheric circulation in ways that may further disrupt global climate stability:
- oceanic circulation: The Arctic Ocean is a major turning point for the water masses circulating the world's oceans. These transfer heat from equatorial to polar regions (the "Thermohaline Circulation"). Sinking cold and salty water drives this circulation in the Arctic, forcing it to move south into the North Atlantic and begin its global journey. It is possible that over the next 100 years, sufficient freshwater will enter the Arctic Ocean (from melting snow and ice on land; increased river inflow and changes to ocean circulation) to disturb this process, altering global climate patterns and affecting the UK's climate.
- atmospheric circulation: Sea ice influences global weather patterns, for example by restricting heat transfer from the ocean to the atmosphere. As sea ice decreases, warmth absorbed by the Arctic Ocean over summer will not be trapped under an insulating layer of ice in autumn and winter. Reduced sea ice has been linked to a warmer autumn atmosphere, which could cause altered storm patterns and lower winter rainfall in parts of the northern hemisphere, including the UK[6].

Melting Land Ice
Land ice (such as ice sheets and glaciers) will increase sea levels as it melts, enters the ocean and is not replaced. The island of Greenland is mostly covered by an ice sheet with an average thickness of 1.6km. It is predicted that should the Greenland ice-cap melt completely, it would raise global sea levels by up to 7m. Studies of the ice sheet show an inland thickening due to winter snow accumulation, but faster thinning near the coast has resulted in overall shrinkage. This has contributed 0.5mm to an overall rate of global sea level rise of 3.2mm a year since 2000. Models suggest, however, that due to alterations in the Earth's gravity field caused by melting land ice, Arctic ice sheets will have a smaller long term impact on UK local sea level rise compared with that on land masses further south[9].

Permafrost Thaw
Permafrost is perennially frozen earth, typically 350 to 650m thick, which may be overlain by a surface "active layer" that freezes and thaws seasonally. Since the 1980s, the temperature of the upper permafrost layer in some

Arctic regions has increased by up to 3°C, causing thawing[2]. As a result, the permafrost region is shrinking, shifting northwards and thinning, while the active layer is thickening. These changes have serious implications for atmospheric methane emissions (Box 3).

Permafrost is used as a solid foundation for buildings, roads, pipelines and other infrastructure. Thawing permafrost causes ground surface subsidence and damage to infrastructure and houses. Previously frozen Arctic permafrost coastlines are vulnerable to erosion from storm and wave action, which is made worse by the loss of wave-dampening sea ice. In some areas, mean erosion rates are up to 3m a year, and some communities have been forced to relocate already.

Box 3 Methane Release: Global Implications.

A warming Arctic may cause the release of large amounts of carbon dioxide (CO_2) and methane (CH_4, a greenhouse gas about 25 times more potent than CO_2), which have the potential to cause further global warming and "then the consequences for humanity could be very severe"[10].

Organic Matter Decay: CO_2 and CH_4 naturally enter the atmosphere from decaying organic plant and animal material. It is estimated that Arctic permafrost contains, locked up in frozen organic materials, an amount of carbon equivalent to, or more than, that currently in the atmosphere in the form of CO_2.[11] If permafrost thaws, creating waterlogged soil and wetland areas, the decomposition of these organic materials will release carbon into the atmosphere as CH_4. Arctic wetlands are already one of the largest natural sources of atmospheric CH_4, and it is estimated that CH_4 emissions resulting from permafrost thaw could double this century[11].

Methane Hydrates: Large volumes of solid CH_4 frozen in ice, called methane hydrates, are trapped by temperature and pressure conditions at shallow depths beneath the Arctic Ocean seabed. Estimates of the total amount of methane hydrate stored here vary from 30 to 230 billion tonnes of carbon[12], and in seabeds globally could reach 4500 thousand million tonnes[13]. Increasing ocean temperatures could cause the hydrates to melt and release CH_4 into the atmosphere.

Should the CH_4 be absorbed by sea water before reaching the atmosphere, it could contribute to increased ocean acidification which will damage marine ecosystems. If sufficient CH_4 is released from the Arctic seabed to cause further global warming, increased permafrost thaw could result, triggering greater CH_4 release from the Arctic land mass.

Methane hydrates provide structure to the seabed where they occur. If they destabilise a seabed collapse may result. In the past, such destabilised underwater landslides from the Norwegian continental slope have produced tsunamis that have reached Scotland. Similar events today could interrupt the pipeline delivery of natural gas across the North Sea to the UK.

Arctic Ecosystems

The changing physical environment is in turn forcing change in Arctic ecosystems, which globally are among the first and most severely affected by climate change. Arctic ecosystems are fragile, support a low biodiversity and are highly vulnerable to environmental disruption. In the future stress caused by climate change may be compounded by increasing human activities (Box 4).

Marine Ecosystems.

The ecosystems of the Arctic Ocean and surrounding peripheral seas are changing as the water warms and sea ice retreats. As sea ice melts, the unique environment that it provides for ice-associated species, from ice algae to polar bears, is lost. As more open areas become exposed, however, more light is reaching the water which, together with a longer growing season, is fuelling an increase in open water plankton growth at the base of the food chain[14]. The biodiversity of Arctic marine ecosystems, and in turn those found to the south in the Atlantic and Pacific Oceans, is altering as species are forced to shift north or, if unable to relocate, to become extinct. For example, over the past 40 years north-east Atlantic warm water plankton species and cod spawning sites off the Norwegian coast have shifted steadily northwards[14].

Land Based Ecosystems – a 'Greening' Arctic

In response to increasing temperature, longer growing seasons, more vegetation and northwards tree line movement have already been documented[1]. Polar desert regions are being replaced by tundra shrubs, which are in turn replaced by forests. Rising temperatures also bring more pest infestations and increase the intensity and frequency of forest fires. Masking of snow cover by shrubs and trees leads to increased heat absorption and further warming (Box 2). The increase in plant growth due to rising temperatures may help to offset the additional greenhouse gases entering the atmosphere from enhanced organic matter degradation (Box 3), but the interaction between these processes is not fully understood.

Box 4. Arctic Species

Arctic species are typically highly specialised to survive in the harsh polar conditions, and are therefore particularly vulnerable to climate change because their slow growth and low reproduction rates mean they cannot adapt to change quickly. A complex interaction of factors affect Arctic species. These include human impacts and direct factors such as temperature, ocean salinity, rainfall, snow and ice cover, as well as, indirect factors such as habitat change, competing species from the south, new pests and diseases and altered food availability[1]. Some illustrative examples are:

- **ice algae:** Small invertebrates feed on algae found in sea ice, and are in turn a major food source for juvenile fish such as polar cod. As sea ice retreats sea ice communities are changing. Algae of poor food quality are becoming dominant, reducing the energy available to animals higher up the food chain, such as fish, birds and mammals. This may impact the Arctic fisheries that rely on this food source.
- **bowhead whales:** Sea ice reduction affects bowhead whale populations via altered food availability or, as protective ice cover decreases, via increased killer whale predation and disruptive storm conditions. Bowheads are sensitive to low frequency noise such as that arising from commercial shipping and oil drilling. Increased use of the Bering Strait between the Arctic and Pacific Oceans will interfere directly with migration routes.
- **white-fronted geese:** The Arctic is of major importance for millions of waterbirds, many of which overwinter in UK wetlands including knot, dunlin and white-fronted geese. The endangered white-fronted goose population is currently declining. This is thought to be due to two main reasons: constraints on nesting caused by heavier spring snowfall at Greenland breeding sites, and competition from larger Canadian geese which have spread north into Greenland as the climate has warmed.

Human Activities

During the last part of the 20th century, human activities in the Arctic expanded rapidly, including oil, gas and mineral exploration and extraction, fishing, shipping and tourism. This expansion has caused concern as traditional societies and economies based on renewable resources such as fish and wildlife, and already having to adapt to climate change, are affected by industrial development, contaminants and barriers to trade. Further industrial expansion, if not carefully managed, may seriously threaten wildlife, vegetation, ecosystem functioning and indigenous peoples' health and welfare.

Oil and Gas

Economics of production are the main driver of future oil and gas development in the Arctic, not climate change as it is commonly believed. Currently the Arctic produces about 10% of the world's oil and 25% of its gas, the majority of this coming from Russia[15]. It is estimated that, of the world's undiscovered hydrocarbon resources, 13% of oil, 30% of natural gas and 20% of natural gas liquids could lie in the Arctic[16]. 84% of these resources lie offshore, within the Arctic states' 200 nautical mile EEZs. Although rising temperatures may improve access to new reservoirs, thawing permafrost, increased wave and storm action and unpredictable sea ice will hinder infrastructure construction, extraction and transport to markets.

The largest environmental effect of Arctic oil and gas activities on land is physical disturbance. Infrastructure and the long roads or pipelines needed to transport oil and gas damage tundra vegetation and disrupt wide-ranging species such as wolves and bears and migratory animals such as caribou and reindeer. At sea, oil spills are the largest potential environmental threat. They are difficult to control, may go unnoticed under ice, can spread over 100s-1000s km and could be severely detrimental for Arctic species and ecosystems[15].

Fisheries

Fish stocks of high commercial importance occur in the peripheral seas of the Arctic Ocean, including cod, pollack, shrimp and capelin. Rather than climate change, sustainable fisheries management is likely to be the most important determinant of future fish stock levels. Fisheries management in the Arctic Ocean is provided for by UNCLOS via the Fish Stocks Agreement, which relies on implementation at a regional level by appropriate international organisations.

Arctic fisheries management is currently fragmented, being based on bilateral arrangements between Arctic states and Regional Fisheries Management Organisations (RFMOs), which include the North East Atlantic Fisheries Commission. Large parts of the Arctic Ocean, however, are not covered by RFMOs because they have not been needed to date. As Arctic marine ecosystems change, if fish stocks migrate out of their current geographical regions into high seas areas or territorial seas beyond current RFMO coverage, inadequate fish stock management and overfishing may result.

Commercial Shipping

As summer sea ice disappears three Arctic Ocean shipping routes may become increasingly commercially viable:

- the various waterways known as the Northwest Passage located along the Canadian Arctic coast;
- the Russian Northern Sea route (the Northeast Passage); and,
- over the North Pole

All of these routes offer large distance savings for Asia-Europe transportation compared with current routes via the Suez or Panama Canals.

Although in the future the Arctic may be ice free for a few months at the end of summer, ice cover during the rest of the year will still prevent ships from transiting this region safely without expensive ice breaker escorts and insurance premiums. There are likely to be increased amounts of navigationally hazardous sea ice and ice bergs in the Ocean, which are a threat to ships and offshore structures. This may lead to slower transit speeds along Arctic shipping routes than sometimes suggested, reducing any savings in fuel consumption and emissions arising due to the shorter travel distances.

Arctic shipping is a potential threat to the environment, including oil discharges, exhaust emissions, the introduction of alien species in ballast water and noise pollution. Due to the Arctic's remoteness, there is a lack of emergency response capability for mitigating pollution and saving lives in the event of an accident there[17].

Tourism

Arctic tourism is focused on destination cruises offering environmental holiday experiences. It is a fast growing commercial Arctic activity, expanding by 50% in the last 15 years[18]. In the short term, expansion is likely to continue, however, in the longer term, if the Arctic environment changes to the extent that the pristine ice landscapes and polar wildlife disappear, tourism may decrease. This may cause economic hardship for remote indigenous communities who have come to depend on tourist income.

Overview

- The Arctic region is a current focus for future energy security and politics.
- Climate change in the Arctic is occurring now, most importantly causing sea ice melt and the potential future release of vast quantities of CH_4.
- Temperature rise will cause the Arctic environment, ecosystem functioning and biodiversity to change in ways that cannot currently be predicted.
- Increased commercial activities in the Arctic mean that there may be a need to strengthen existing regulatory frameworks to protect the environment and promote sustainable exploitation of natural resources.

Endnotes

1 Arctic Climate Impact Assessment 2004 *Impacts of a Warming Arctic* Cambridge University Press
2 *Climate Change 2007*: Fourth Assessment Report of the IPCC Cambridge University Press
3 http://arctic-council.org/filearchive/Ilulissat-declaration.pdf
4 http://www.dur.ac.uk/resources/ibru/arctic.pdf
5 http://ec.europa.eu/maritimeaffairs/pdf/com08_763_en.pdf
6 National Snow and Ice Data Center, http://nsidc.org/arcticseaicenews/
7 Wang & Overland 2009, *Geophysical Research Letters*, **36**
8 NSIDC, courtesy Maslanik & Fowler, University of Colorado
9 J. Bamber, University of Bristol, *oral communication*
10 Nisbet & Chappellaz 2009, Shifting Gear, Quickly, *Science*, **324**
11 UNEP Yearbook 2008, *Methane from the Arctic*
12 Arctic Monitoring & Assessment Programme 2009, *Update on Selected Climate Issues of Concern*
13 Archer & Buffet 2005, *Geochemistry, Geophysics, Geosystems*, **6**
14 Arctic Ocean Sciences Board 2008, *The iAOOS in 2008*
15 Arctic Monitoring & Assessment Programme 2007, *Arctic Oil & Gas*
16 U.S. Geological Survey Fact Sheet 3049, 2008
17 Arctic Council 2009, *Arctic Marine Shipping Assessment*
18 P. Mason, University of Bedfordshire, *oral communication*

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