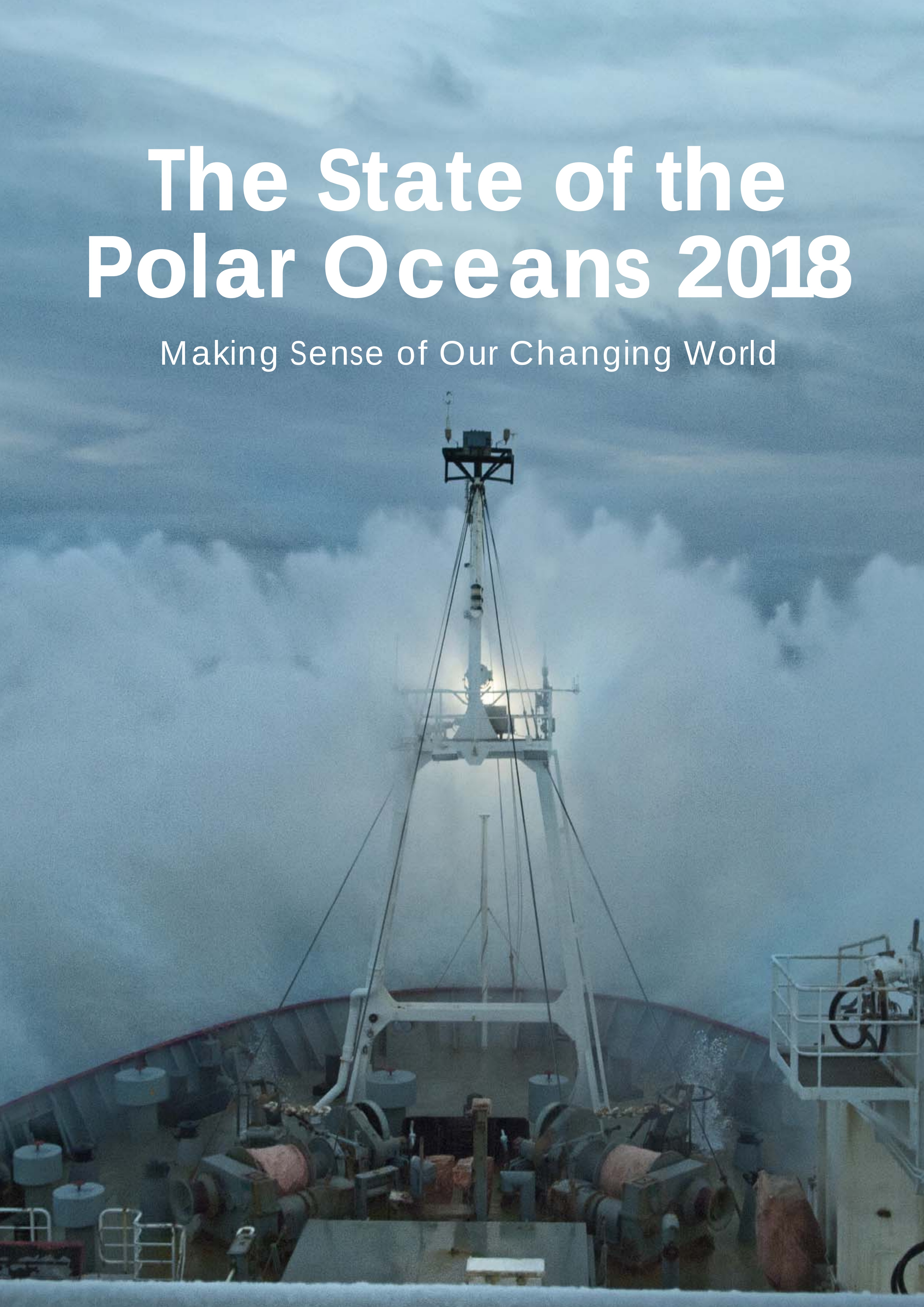
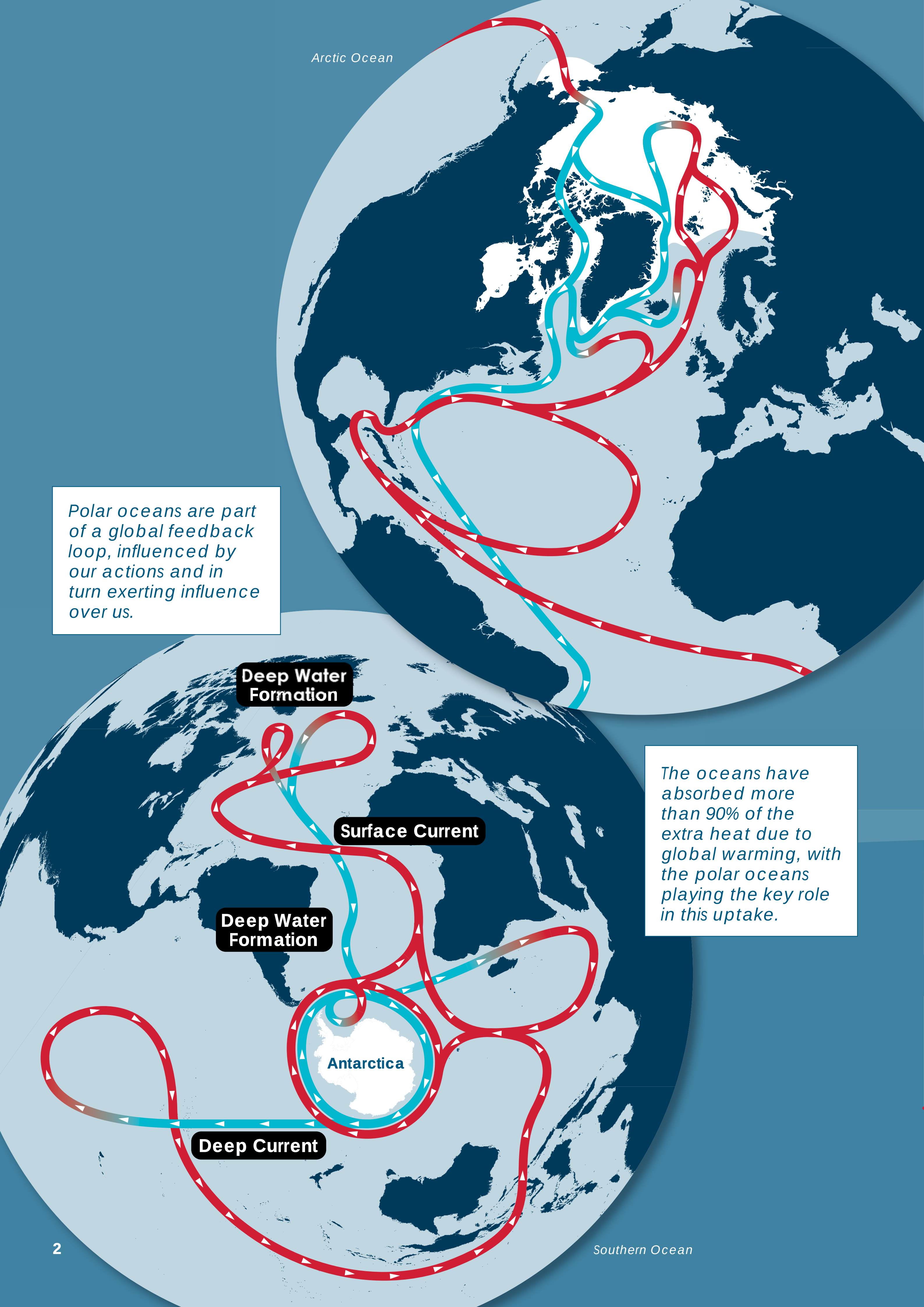
The State of the Polar Oceans 2018

Making Sense of Our Changing World





Polar oceans are part of a global feedback loop, influenced by our actions and in turn exerting influence over us.

The oceans have absorbed more than 90% of the extra heat due to global warming, with the polar oceans playing the key role in this uptake.

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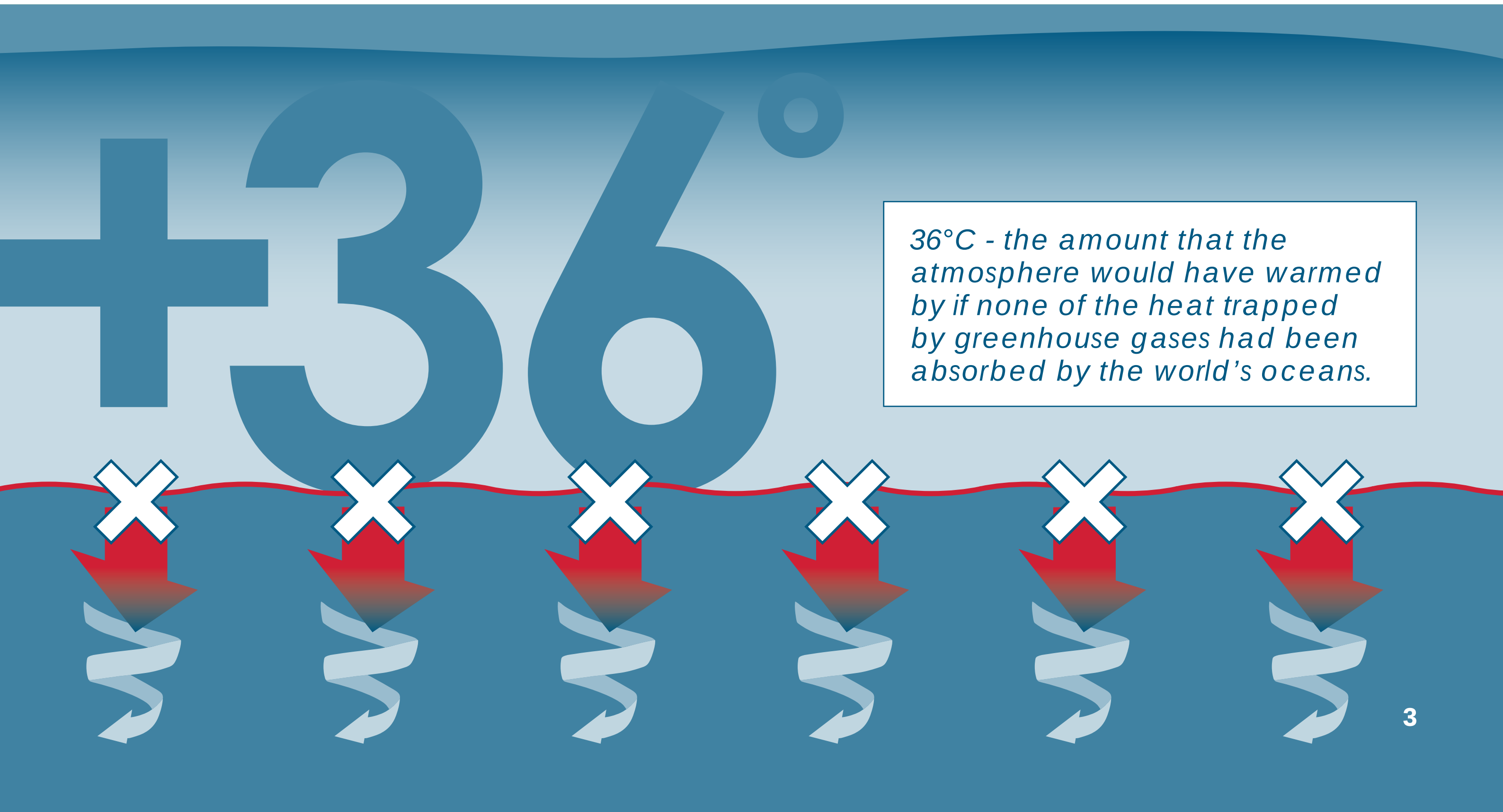


36°C - the amount that the atmosphere would have warmed by if none of the heat trapped by greenhouse gases had been absorbed by the world's oceans.

Foreword

The vast frozen worlds of the Polar Regions are a major component of the Earth's global climate system.

The polar oceans are amongst the least understood environments on our planet. They respond to global temperature change; absorb heat and carbon from the atmosphere, including that produced by humans; they sustain millions of seabirds, whales and fish; and provide food for a hungry world. These oceans keep our planet cool and supply other oceans with nutrients. But, because of their remoteness and inhospitable nature, data coverage is extremely sparse.

Understanding the polar oceans is absolutely key to understanding the big questions about our global environment. By working together scientists create observing systems to collect and interpret crucial scientific data that shapes policy, protects the environment and ultimately improves people's lives. Recent technological advances mean that scientists can now combine high-quality land and ship-based observations with high-quality satellite data from previously-inaccessible areas.

Over decades studies have shed new light on the consequences of the shrinking sea ice for ocean circulation, climate and the ecosystem. Surveys of the deep ocean have yielded vital discoveries about marine biodiversity and informed an international census of marine life. Long-term studies have helped understand the marine food chain, and have provided critical scientific information to underpin the sustainable management of fisheries.

The report demonstrates that we are advancing our understanding. There remains, however, an urgent need for further investigations if we are to be, as we absolutely must, able to provide the understanding needed to help people live with, and adapt to, environmental change.

Professor Dame Jane Francis
Director, British Antarctic Survey

Associate Professor Dr Ole Arve Misund
Director, Norwegian Polar Institute

Scientists conduct a wide range of multi-disciplinary polar science on board state-of-the-art ice-strengthened research ships (Image: British Antarctic Survey).

How the polar oceans shape our world

The polar oceans are inextricably linked to the rest of our planet in many diverse and multilayered ways.

The role they play in the global ecosystem is indispensable. They serve as the heart and lungs of our planet's complex circulatory system, provide food for millions of people and support a huge variety of marine life, both native and migratory.

The polar oceans control global temperatures. Despite accounting for around 20 per cent of the world's ocean surface these cold seas absorb more than 75 per cent of the total amount of heat absorbed by all of our oceans. The polar oceans are the biggest contributors to a global marine heatsink that has taken up more than 90 per cent of all the extra heat trapped in the Earth system since the industrial revolution began.

The polar oceans absorb much of the human-made carbon dioxide that our seas remove from our atmosphere: the Southern Ocean alone soaks up around 40 per cent of all the carbon our oceans extract from the air.

Temperature changes, both within the polar oceans and in the air above them, have a pronounced effect on global sea levels: modest warming can increase the amount of glacial ice that melts into our seas. The effect is compounded by thermal expansion, as warmer water takes up more space.

The polar oceans drive global ocean circulation, moving gases, dissolved minerals and organic matter around our planet and injecting new waters into our seas. Nutrients exported from the biologically rich Southern Ocean sustain as much as three-quarters of global ocean primary production outside the Southern Ocean, underpinning marine food chains worldwide.

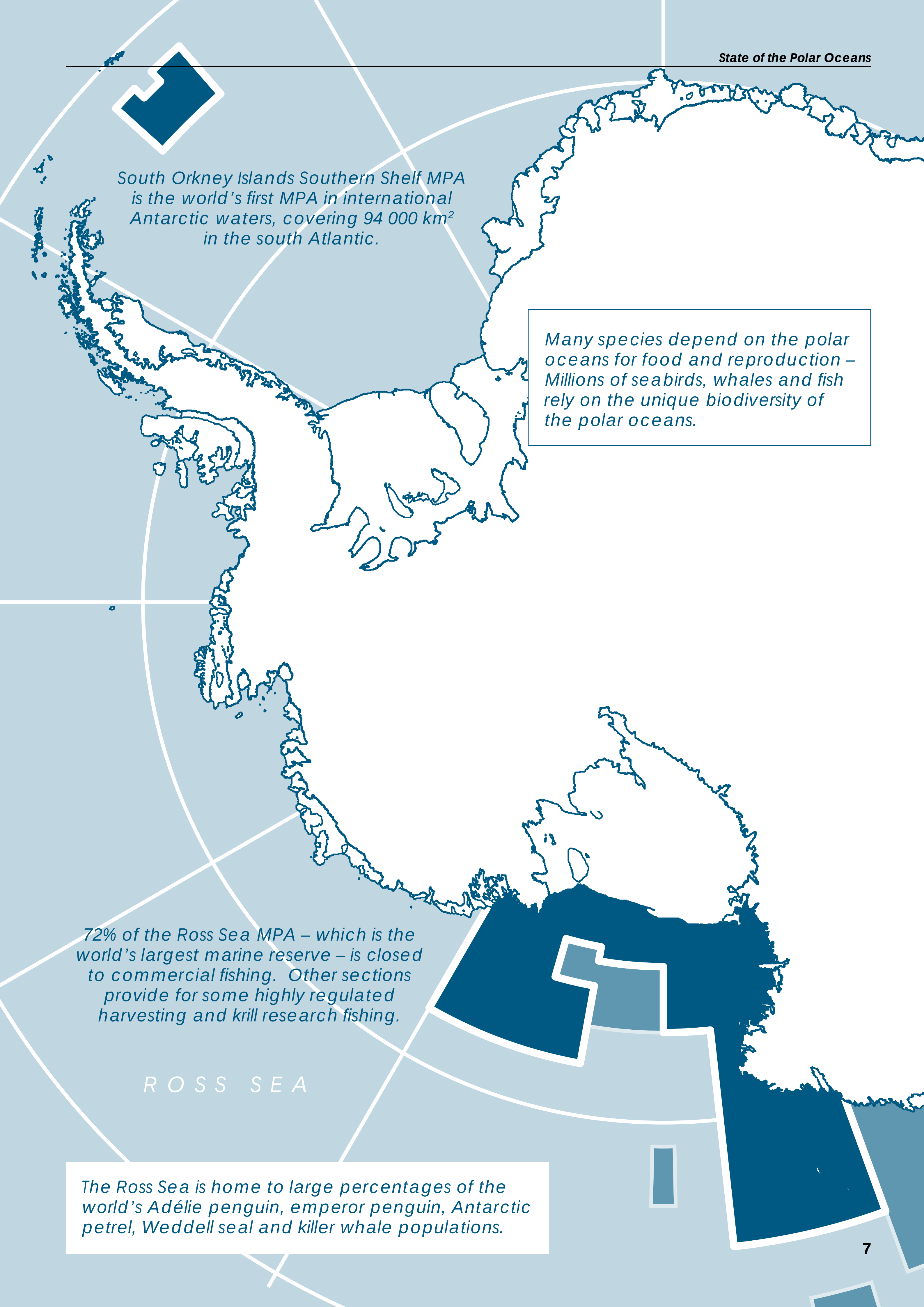
Many species depend on the polar oceans for food and reproduction. Millions of seabirds, whales and fish all rely on the unique biodiversity of the polar oceans for their survival. Humans, too, benefit from the polar-ocean ecosystems: more than seven million tonnes of fish is caught from Arctic waters annually, equivalent to ten per cent of the global fin fish catch. The Southern Ocean ecosystem is founded upon Antarctic krill which, with up to 400 trillion individuals, represents one of the largest biomasses of any individual species.

The polar oceans are already economically significant, and likely to become more so in the future. Reduced Arctic sea ice is opening up access to oil, gas and mineral reserves; the Arctic is thought to contain more than 20 per cent of the world's undiscovered, recoverable oil and gas. The Protocol on Environmental Protection to the Antarctic Treaty prohibits commercial mining activities in the southern continent, but fishing and tourism activities there are of growing economic significance.

The Arctic Ocean provides food and economic opportunities for indigenous communities who have been living in the Arctic's coastal regions for centuries. These communities possess intimate knowledge of the Arctic environment, and are profoundly aware of its changes.

With so many connections to global systems, the polar oceans cannot be considered in isolation. They are part of a multidisciplinary global system, influenced by our actions and in turn exerting influence over us.

It is this multifaceted integration that gives us the ability to use our observations from these regions to improve our predictions of changes elsewhere. As polar science continues to evolve its technologies and techniques, our understanding of the polar oceans' relationship with the rest of the planet – and accordingly the global consequences of change in these remote parts of the world – will continue to grow.



South Orkney Islands Southern Shelf MPA is the world's first MPA in international Antarctic waters, covering 94 000 km² in the south Atlantic.

Many species depend on the polar oceans for food and reproduction – Millions of seabirds, whales and fish rely on the unique biodiversity of the polar oceans.

72% of the Ross Sea MPA – which is the world's largest marine reserve – is closed to commercial fishing. Other sections provide for some highly regulated harvesting and krill research fishing.

The Ross Sea is home to large percentages of the world's Adélie penguin, emperor penguin, Antarctic petrel, Weddell seal and killer whale populations.

The polar oceans today, and tomorrow

International research has shown beyond doubt that the polar oceans are changing – and in many areas the rate of that change is accelerating.

Observations collected over decades in the Arctic and Antarctic have helped reveal the causes of these changes, and informed detailed scientific models enabling the prediction of future trends. Working in collaboration with international colleagues, UK and Norwegian scientists are studying every aspect of polar ocean change.

Data from shipborne research programmes reveal that the polar oceans are changing. (Image: UiT The Arctic University of Norway)

Upwelling, circulation and stratification

In the Arctic, there is evidence that properties of the ocean related to heat, freshwater and energy are changing quite rapidly and with increasing regional variability, and this has an impact on global circulation and distribution of nutrients and carbon dioxide.

The amount of freshwater and reduction in sea ice affect the marine life. Freshwater has been accumulating in the Canadian Basin and around Greenland, increasing stratification there. At the same time, warm and nutrient-rich Atlantic water entering the less sea-ice-covered Eurasian Basin appears to be in closer contact with the productive surface layer and the sea ice above it, than before.

Microscopic plant-like organisms known as phytoplankton, which underpin the ocean food chain and help oxygenate the sea, require both sunlight and nutrients, so they cannot grow without resupply of nutrients either from deeper waters or from elsewhere in the ocean via currents. While this mixing is inhibited in the stratified ocean, it is still provoked to some extent by storms and currents, and reduced surface ice is also creating more opportunities for upper-layer phytoplankton growth.

In the Southern Ocean, the Antarctic Circumpolar Current, driven by strong westerly winds, has not changed its flow significantly despite those winds becoming stronger and moving further south. This is attributed to an increase in the intensity of ocean eddies, which are expected to continue to grow in strength in future years.

These strong winds also bring nutrient-rich deep waters up to the sunlit surface, providing phytoplankton with the food for growth. These organisms in turn not only support marine life, but also absorb carbon dioxide, increasing the ocean's ability to act as a carbon sink for greenhouse-gas emissions.

Temperature changes and sea ice

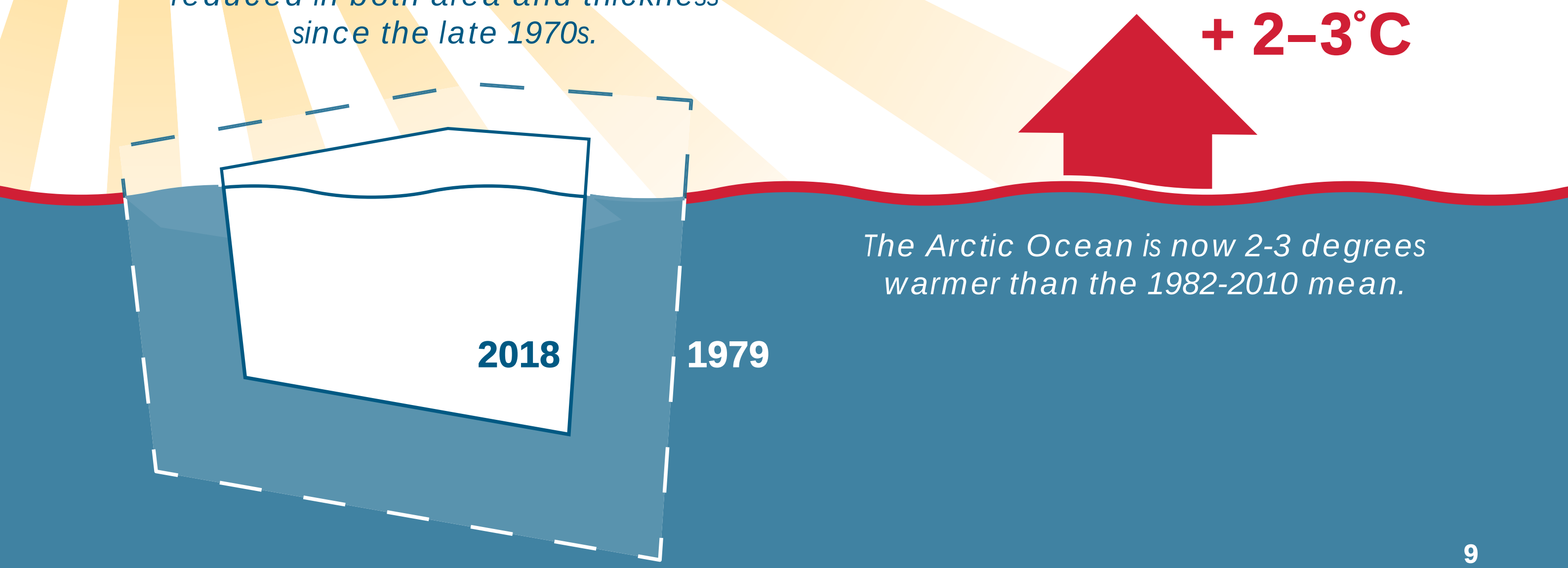
The polar oceans are warming up: summer surface temperatures in large parts of the Arctic Ocean are now 2–3°C warmer than the 1982–2010 mean. Unsurprisingly, the warming of the Arctic Ocean is having a dramatic effect on Arctic sea ice. Satellite records have revealed a significant decrease in sea ice extent in all months, especially in summer. There has been a reduction in summer sea ice extent from about 7 million square kilometres in the late 1970s to around 4 million square kilometres in 2017; a reduction of nearly 50%. Furthermore, time-series analysis of UK submarine records, and measurements covering the sea-ice export from the Arctic Ocean through Fram Strait, concluded that the mean thickness has declined by more than 40%. Taken together these changes have led to a fundamental shift in the sea ice regime in the Arctic; the region is no longer dominated by a thick multi-year ice. Instead it is controlled by thinner, more dynamic, first year ice.

In the Southern Ocean, which has accounted for the largest proportion of the total ocean uptake of extra heat since the start of the industrial era, the picture is more variable. The greatest increase in temperature has been recorded in the shallowest 2,000m of the sea, but this does not apply to the southernmost part of the ocean, where ongoing upwelling of colder, deeper waters is helping to maintain a more constant surface temperature.

Despite increasing temperatures, Southern Ocean sea-ice extent has actually increased overall during the last few decades – though there is significant regional variation. This is due to a complex interplay of factors including reduced ozone over Antarctica, strengthening winds creating areas of open water in which sea ice is more likely to form, and less ocean mixing due to increased freshwater input from the Antarctic Ice Sheet.

This counterintuitive development is a perfect illustration of the complexity of the polar ocean systems, where environmental changes are the result of interactions between a myriad of elements including solar radiation, the atmosphere, the ocean and ice. Such complexity makes predicting future change a formidable challenge, but by gathering more evidence, improving technology and evolving numerical models, polar scientists are increasing their ability to draw meaningful conclusions that provide a basis for policy and business decisions.

Summer sea ice in the Arctic has reduced in both area and thickness since the late 1970s.



The Arctic Ocean is now 2-3 degrees warmer than the 1982-2010 mean.

Krill fisheries and climate change

Oxygen levels in the world's oceans have decreased by an average of two per cent in the last 50 years, but nowhere is this trend more prevalent than in the Arctic Ocean. The change is a further consequence of stratification, which prevents deep, oxygen-depleted waters from reaching and absorbing oxygen from the surface. Because warm water is able to hold less oxygen than cold, rising temperatures are also restricting the ocean's ability to absorb oxygen.

Reduced oxygen in Arctic seawater will ultimately impact on fish stocks, causing fish to grow more slowly, to reach smaller sizes, and to produce fewer offspring. This will have ramifications all the way up the food chain, affecting both fisheries and the indigenous and local communities who source their food from the seas.

Increased acidity is changing the workings of the marine ecosystem, promoting growth of some plankton while hampering the ability of other species to form protective shells.

A keystone species in the Southern Ocean, Antarctic krill is found in its highest abundance in the Scotia Sea and the seas around the South Shetland Islands.

Penguins, seals, whales and fish feed on krill (Image: British Antarctic Survey).

Areas that have warmed over recent decades. Krill are sensitive to environmental conditions: They benefit from sea ice to protect their young and adults grow best in cool waters. Increased carbon dioxide levels also make their eggs less likely to hatch. These conditions will become less favourable for krill and other animals in some areas if climate change continues unabated into the future.

The current annual Antarctic krill catch equates to less than 0.1 per cent of their estimated biomass. Management of this fishery is part of a wider system of conservation of Southern Ocean marine living resources which includes a developing network of Marine Protected Areas (MPAs). Understanding how the krill stock and the fish, seals, seabirds and whales that depend on it will respond to climate change is critical for ensuring that the fishery is well managed into the future. Scientists monitor the krill stock and its predators using a variety of research methods. These include modelling and comparisons between areas that are open to human activities, including krill fishing, and those where very little human activity takes place.

MPAs enable these studies to contribute to international policy decisions aimed at protecting and preserving marine species, biodiversity, and food security.

International collaboration, including UK and Norwegian science projects, has advanced our understanding of polar marine ecosystems and the challenges they face. By addressing these major issues in polar ecology and conservation, scientists continue to deepen their understanding of the effects of climate change, fishing and pollution, and advise on policy measures to protect vulnerable species, preserve biodiversity, improve fishery management and maintain food security.

Plastics

Some three-quarters of all of the litter in our oceans is believed to be plastic, and every year the global population adds another five million tonnes to our seas. In the polar oceans, the British Antarctic Survey has been monitoring the presence of large plastic items for more than 30 years, but more recently scientists have become aware of the accumulation of much smaller plastic debris: microplastics.

The Southern Ocean absorbs billions of tonnes of carbon dioxide from the atmosphere every year. Processes within the Arctic Ocean bury and store carbon for thousands of years.

Microplastics are plastic particles smaller than 5mm in diameter. They enter the oceans from items such as toothpaste, shower gels and clothing, or form as larger plastic items break down. Tests have shown that a single polyester fleece jacket can release more than 1,900 microplastic fibres per wash.

A Norwegian study recently found up to 234 microplastic particles in a single litre of melted Arctic sea ice. Once these particles enter the seas they are ingested by sea creatures who mistake them for food. The long-term effects of this are uncertain, but scientists are initiating monitoring programmes of plastic levels in both polar oceans, and working to understand the effect this proliferation of plastic waste is having on polar ecosystems.

Plastic debris is found in both polar oceans (Image: Shutterstock).

How technology supports polar ocean research

The polar oceans are the least understood bodies of water on our planet.

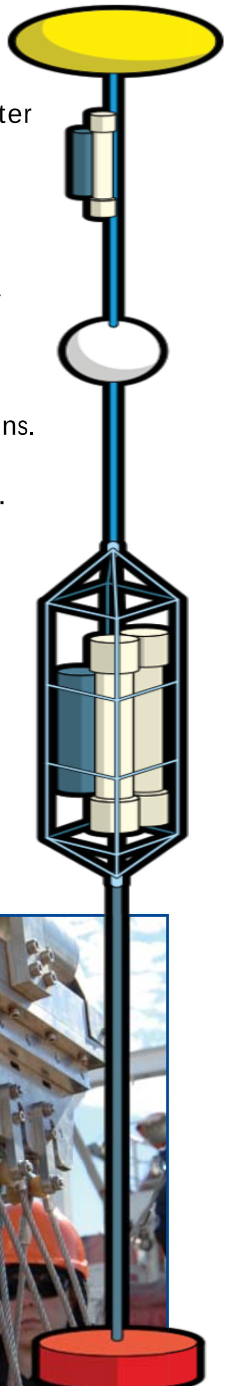
Their remoteness, vastness and inhospitable environment all present significant challenges when gathering data and conducting science. However, advances in technology are creating opportunities for data collection that go far beyond what was possible even a couple of decades ago.

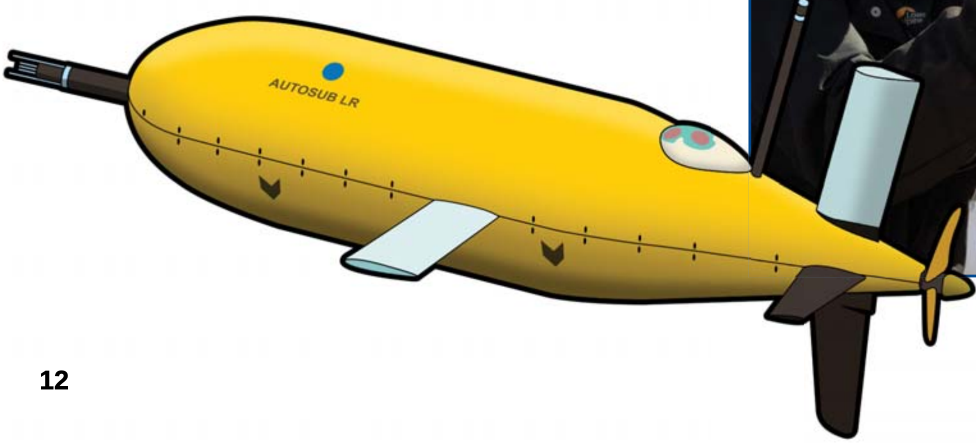
The international polar science community now has access to polar observing systems that are more stable, durable and capable than ever before. Robotic profiling floats alone have allowed scientists to gather almost ten times as much temperature data from the seas in the 2000s as they were able to in the 1980s, while UK and Norway researchers collaborating on numerous Arctic projects have exploited systems including time-series moorings, ice-tethered platforms and satellite tagging of seals.

Scientists are beginning to overcome the strong seasonal bias that has traditionally been present in polar research. In the Arctic Ocean, data is now collected consistently throughout the year through a combination of shipborne, autonomous and moored sensors. In the more remote and turbulent Southern Ocean, data collection still takes place predominantly during the austral summer, but this seasonality is becoming less pronounced.

Technological progress is bringing greater automation and huge improvements in connectivity now enable data to be collected remotely, in real time, from across a network of ocean-going sensors. This exponential growth in data in turn feeds into more advanced and accurate numerical models, which estimate change more precisely and reduce uncertainty in climate predictions. More immediately, the extra data also enables improved weather forecasting.

The drive for improved technologies creates opportunities for high-tech industry. Development of these systems requires highly-skilled workers, and climate scientists and software experts are needed to make best use of them. Systems capable of operating in the hostile polar oceans are also likely to have applications in other extreme environments.





Towed bongo nets on the back deck of RRS James Clark Ross in the Southern Ocean (Peter Enderlein, British Antarctic Survey)

Contributors

Michael Meredith[1], Arild Sundfjord[2], Stephanie Henson[3], Andrew Meijers[1], Eugene Murphy[1], Richard Bellerby[4], Malin Daase[5], Finlo Cottier[5/6], Mark Belchier[1], Melissa Chierici[7/10], Ingrid Ellingsen[8], Stig Falk-Petersen[9], Simeon Hill[1], Paul Holland[1], Geraint Tarling[1], Phil Trathan[1], John Turner[1], Jeremy Wilkinson[1], Layla Batchellier[1], Linda Capper[1], Jamie Oliver[1]

1 British Antarctic Survey NATURAL ENVIRONMENT RESEARCH COUNCIL

2 NORWEGIAN POLAR INSTITUTE

3 National Oceanography Centre NATURAL ENVIRONMENT RESEARCH COUNCIL

4 NIVA Norwegian Institute for Water Research

5 UNIVERSITY OF TROMSØ UiT / THE ARCTIC UNIVERSITY OF NORWAY

6 SAMS

7 INSTITUTE OF MARINE RESEARCH

8 SINTEF

9 Akvaplan niva

10 The University Centre in Svalbard

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Polar bear on sea ice north of Nordaustlandet, Svalbard (Image: Angelika Renner, British Antarctic Survey).

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