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The new face of the Arctic

Every summer the Arctic Ocean loses more ice — and it could all be gone within decades. **Quirin Schiermeier** looks at how the vanishing summer ice affects those living in the north.

It was on Christmas day that Duane Smith first noticed that something weird was happening. When he and his family went to church, they did so in the rain.

That was in 1983. "We'd never ever seen anything like it," remembers Smith — then a little boy in Inuvik, a town of 3,500 people just north of the Arctic Circle, and now president for the Inuit Circumpolar Council (Canada), an indigenous people's organization. "Around Christmas it was supposed to be some 30 degrees below zero. None of our elders had any memory of such mild weather in winter."

It could just have been weird weather. In fact, it was a harbinger of things to come. Nowhere else on the planet is the current warming trend more pronounced than in the Arctic, and nowhere else does it seem to leave a deeper mark. The Arctic was a favoured site for early-warning systems during the cold war. Today, it is the early-warming system for climate change.

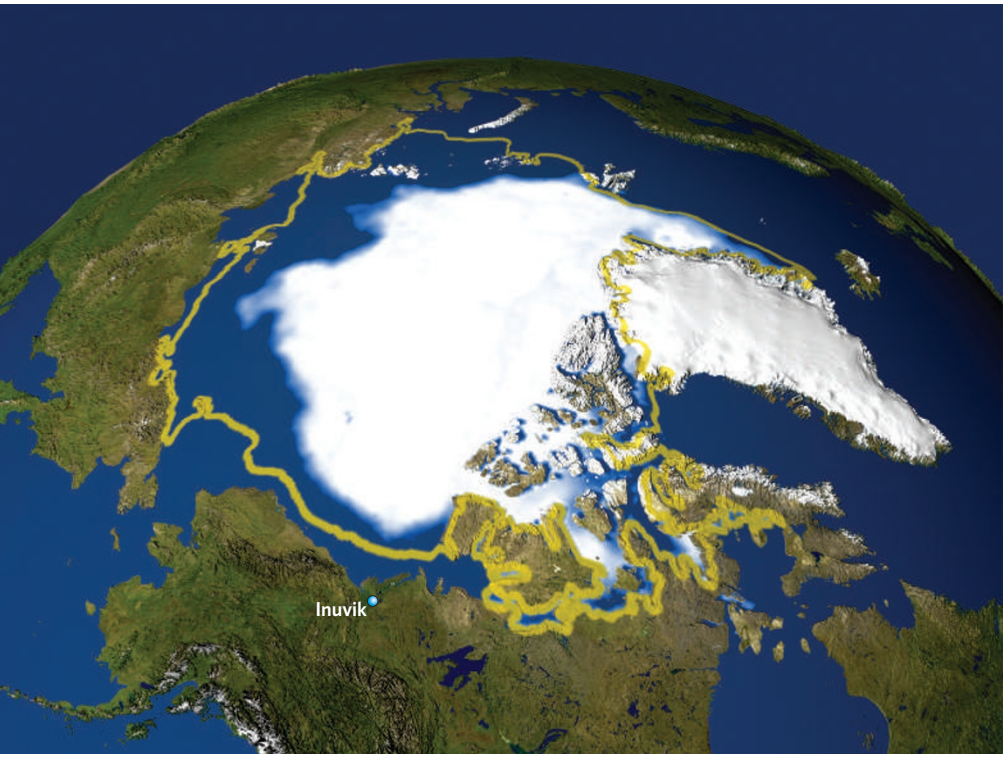
In recent years, researchers have started to pin down the details of what might happen to the Arctic as the planet warms. Although many of the specifics remain speculative (see 'How the Arctic might change', overleaf), everyone is certain that change is coming — and fast. "The Arctic is changing extremely abruptly on a geological time scale," says David Barber, a climatologist and sea-ice specialist at the University of Manitoba in Winnipeg, Canada. "There is no good historical analogue that could tell us what might happen."

Blame it on the sea ice. Unlike Antarctica — a continent surrounded by oceans — the Arctic is for the most part an ice-covered ocean, making it particularly vulnerable to climate change. Within several decades, the entire Arctic Ocean, including Hudson Bay and the countless channels between Canada's Arctic islands, could be free of ice during the summer months[1]. Palaeoclimatic evidence suggests that this has not been the case for at least the past 1 million years.

Less ice during the Arctic summer might not necessarily be all bad. New shipping channels and oil and gas regions could open up, for instance, and local hunters could get around by boat more easily (see 'Life in a warming world', overleaf). But the rate and magnitude of the changes are unprecedented, and the consequences are difficult to predict[2].

The amount of sea ice in the Arctic usually reaches its maximum — more than 14 million square kilometres in recent years — around the end of March. The slowly moving pack ice is separated from the immobile ice attached to the coastlines by the perennial 'circumpolar flaw lead' — a narrow corridor of open water that is rich in biological productivity and crucial for the heat exchange between the ocean and the atmosphere. This lead will be the focus of a multinational expedition led by Canada during this International Polar Year.

During the summer, ice melts and thins, reaching its minimum in September. The minimum extent of sea ice in the Arctic has decreased from a long-term average of more than 7 million square kilometres since 1979, to less than 6 million square kilometres in 2002 (ref. 3). Every year since, it has continued to drop or stay at near-record low levels. In



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By 2005, summer ice coverage was only about three-quarters of the Artic's long-term average (outline).

September 2005, the Arctic was covered by just 5.32 million square kilometres of ice — the lowest yet.

As more and more ice disappears, a vicious cycle sets in. Ice reflects away a large fraction of incoming sunlight, whereas the darker open ocean absorbs more radiation. This 'albedo' effect is the main reason why the influence of warming is significantly more pronounced at high northern latitudes than in temperate or tropical regions. A reduced albedo in the Arctic affects the entire planet's energy balance, causing yet more energy to be absorbed in the darker waters.

A sizeable problem

The ice is not only shrinking in its area, but also in its depth, as recorded by submarines[4] and radar images from satellites. And it seems to be declining even in the winter[5]. If the ice continues to disappear at its current rate of nearly 9% per decade, the Arctic Ocean will be ice-free in September by 2060. But if, as some scientists suspect, the shrinking were to accelerate, this date will come forward by 20 years to 2040.

This dire scenario is just one of seven computer simulations published in December by a team led by Marika Holland of the National Center for Atmospheric Research in Boulder, Colorado[1]. That particular simulation suggests that the summer Arctic sea ice will decrease from 6 million square kilometres to 2 million square kilometres in the course of a decade. The ice that remains would be tucked along the coasts of Canada and Greenland, leaving the central Arctic basically free of ice by the end of the melting season, although the region would refreeze during the winter.

The receding ice cover could also affect large-scale patterns of ocean circulation. Ice, for instance, seems to be moving at an increasing rate out of the Arctic Ocean through the Fram Strait to the east of Greenland and through the Canadian Arctic archipelago to Greenland's west. On average, the amount of ice moving out is around 10%, but during the winter of 2005 to 2006, a strong counterclockwise rotation pattern in the Arctic Ocean pushed about 40% of the pack ice into the warmer Atlantic waters. The events over the past two years, says Barber, are the first sign that the rates of ice export can change dramatically. If more storms start to enter the Arctic, as expected with the rising temperatures around the world, the pack ice will be broken up and potentially carried away more often.

Flow-on effects

Reduced sea-ice cover might also increase the influx of warm Pacific waters through the Bering Strait between Russia and Alaska. Koji Shimada, a physical oceanographer at the Institute of Observational Research for Global Change in Yokosuka, Japan, has suggested that because sea ice is starting to form later each year, the warmer Pacific waters will be able to flow into the Arctic[6]. Such ocean changes could dramatically affect the lives of Arctic organisms, from algae to fishes to mammals. "All indigenous animals are somehow tied to ice," says Jacqueline Grebmeier, a biological oceanographer at the University of Tennessee in Knoxville. "So the early-season retreat of ice will no doubt trigger cascading effects."

For instance, the thinning and retreat of sea ice allows more sunlight to penetrate the ocean earlier in the season, making surface waters richer and more biologically productive. Already, scientists have seen the dominant zooplankton in the Arctic — the small

HOW THE ARCTIC MIGHT CHANGE

5 years from now	10 years from now	20 years from now
The polar bear is listed as a threatened species.	The amount of multi-year pack ice decreases catastrophically.	The Arctic Ocean remains ice-free in September.
The UN Convention on the Law of the Sea adopts a protocol for the new polar ocean.	A new UN environmental regime for the Arctic comes into effect.	All known Russian offshore hydrocarbon deposits (oil, gas and gas condensate) are exploited commercially.
Development of hydrocarbon deposits starts in the eastern Kara Sea off Siberia.	Russia auctions offshore exploration licences for up to 20 billion tonnes of natural gas and petroleum.	Offshore oil and gas resources, unknown today, are being extensively developed.
The Galileo satellite system is used to combat illegal fisheries in Arctic waters.	Vector-borne diseases become more widespread among the Inuit as mosquitoes migrate to the Arctic.	Oil tankers and container ships sail the Northeast passage.
Norwegian oil companies commit themselves to being carbon neutral.	The Arctic cod is displaced by temperate fishes.	The United States and Russia undertake military manoeuvres in the polar sea.
All-season Canadian icebreakers patrol the eastern and western Arctic.	Canada installs high-frequency radar at the entrance to the Northwest passage to bolster its sovereignty.	

L. DICK/AP

Subsistence farmers in Alaska adapt their practices to cope with the ever-changing climate.

Life in a warming world

Some 100,000 Inuit live in regions north of the Arctic Circle on land that their ancestors have hunted and fished for generations. They know, both from their own observations and from what scientists tell them, that their environment is a hot spot for global warming.

"We don't get much cold any more, spring is coming earlier, and ice conditions are getting unpredictable to the point of people falling through the ice and drowning," says Duane Smith, an Inuit leader from Inuvik, Canada. Yet many reject the notion that climate change is all bad.

"I feel that governments are panicking a bit," says Frank Pokiak, a native of Tuktoyaktuk, Alaska, who chairs the Inuvialuit Game Council. "People need to understand that we've been living with changes all our lives. Climate change is just another thing we need to adapt to. We may need to harvest other species, perhaps grizzly bear, perhaps caribou, but we won't quit existing."

A warming Arctic has some advantages. The early breaking up of ice, for example, gives hunters a longer time to harvest beluga whales. Less ice would also facilitate hunting and travelling by boat.

On the other hand, regional hubs such as Inuvik depend on roads across the ice for food and other supplies. Hunting, transport and road safety will all be affected if the tundra turns into bogs earlier and freezes later. Increased dependence on helicopters has already notably increased the Inuits' cost of living, says Smith.

Many Inuit are working with scientists to help investigate the changes in the Arctic. Hunters and trappers, for instance, are being taught how to handle meteorological instruments. The Inuit have plenty to teach the scientists as well; at one point, researchers were about to conclude that Arctic cod (*Arctogadus glacialis*) had all gone because stocks were nowhere to be found, but Inuit fishermen showed them where on Canada's Mackenzie shelf the fish had hidden.

But some things are more difficult for indigenous people to understand. Explaining to Inuit that they and their food could be contaminated with chemicals produced far in the south is challenging, says Louis Fortier from University Laval in Quebec. Their native language knows nothing of 'molecules' or 'chemistry'.

So, working with Inuit elders, linguists from ArcticNet, an interdisciplinary network of Canadian researchers, have produced a bilingual glossary for terms that relate to climate change. In it, for instance, the word for 'carbon' — a key term in the future of the Inuit — is illustrated as 'the soot of fire'. **Q.S.**

copepods *Calanus hyperboreus* and *C. glacialis* — replaced by their warmer-water, Atlantic cousins *C. finmarchicus*. Their move is thought to be related to the fact that the surface waters in the Arctic are now warmer and so more algal food can be found there.

Mix and match

This 'Atlantification' of the Arctic comes at the expense of species composition and biodiversity, says Louis Fortier, a biological oceanographer at the University Laval in Quebec. As warmer water enters the Arctic basin, generalist species from temperature latitudes may move in and out-compete the Arctic specialists. In Canada's Hudson Bay, for instance, black guillemots (*Cepphus grylle*) used to feed exclusively on Arctic cod (*Arctogadus glacialis*). In recent years, scientists have found that up to half of the birds' stomach contents consisted of small capelin fish (*Mallotus villosus*), which are common around Iceland. Meanwhile, Arctic cod are increasingly being replaced by the larger Atlantic cod (*Gadus morhua*) as the dominant species in some parts of the Arctic Ocean.

Seals, whales and polar bears all feed on the smaller, easier-to-catch Arctic cod. The shrinking of the sea-ice habitat and the shifting ecosystem have already affected the behaviour of the most emblematic Arctic species — polar bears, walruses and ringed seals. The Pacific walrus (*Odobensus rosmanus divergens*), for instance, is being forced to feed in deeper waters as the sea ice retreats off the coasts of continents, and mother walruses seem to be separated from their calves more often as sea ice continues to fragment[7]. And polar bears are being considered for listing in the United States as a threatened species because of their disappearing sea-ice habitat.

Humans, too, are preparing for the change. Subsistence hunters are learning to follow mammal and fish populations into new areas as the ecosystem shifts[8]. And Inuit leaders such as Smith are realizing how they will have to adapt — and are even looking forward to it. "Our people have understood ice conditions for ages," he says. "Now we're keen to learn how global warming will change our world." ■

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