A Farewell to Ice

Arctic climate feedbacks and their worldwide effects

Peter Wadhams

The changing Arctic

An enormous change has occurred in the appearance of our planet during the last two decades. The Arctic Ocean, which has an area of 14 million sq km (five times that of the Mediterranean), used to be full of formidably thick and rugged sea ice, winter and summer. Today the ice is thin and weak, and in summer it shrinks back to an area of only 3-4 million sq km, less than half of its summer area as recently as the 1980s. The media report extensively on the disappearance of the summer ice, but most people do not realize that even in winter the ice now has a character which is quite different from the recent past.

I first went to the Arctic in summer 1970, aboard the Canadian icebreaker "Hudson", which was carrying out the first circumnavigation of the Americas. After sailing around South America and up through Bering Strait we were to attempt a feat accomplished by only nine ships before us, a transit of the Northwest Passage. All along the north coasts of Alaska and the Northwest Territories, the Arctic Ocean sea ice lay close in to the land, leaving us a slot only a few miles wide to navigate and carry out our surveys. Sometimes the ice pushed right up to the coast and we had to break our way through, and eventually, when we were in the middle of the Northwest Passage, we had to be rescued by a heavier Government icebreaker, the "John A. Macdonald". In those days, a battle with sea ice in the Canadian Arctic was normal, even in high summer. In 1903-6 it took Amundsen three years for the first transit of the Northwest Passage, while the second ship, the Royal Canadian Mounted Police schooner "St. Roch", still needed two seasons, in 1942-4.

Today the situation is transformed. In September (the month of greatest ice retreat) a vast area of blue ocean surrounds the Pole. The 3-4 million square km of remaining ice is only half of the area in the 1970s-1980s and the average thickness has also halved, so the summer ice volume is only a quarter of what it was then. Warming of the Arctic is proceeding 3-4 times as fast as the rest of the world, and this is causing the accelerated loss of ice which within a very few years will yield a completely ice-free summer Arctic.

The ice also looks different. In the past most Arctic ice was multi-year ice, several years old. It had a rugged and magnificent topography, with huge pressure ridges which blocked the paths of explorers and ships and which had keels reaching down 50 metres or more into the ocean. Today most of the ice is first-year; it grows during a single winter, reaches a maximum thickness of only 1-1.5 metres, and has only a few shallow ridges to break up the very flat ice surface. Ice which grows during a single winter can easily melt away during a single summer, causing what the US climatologist Mark Serreze calls the "Arctic death spiral". And the death of the summer ice is close.

Global impacts of Arctic change

The ice retreat is not just a curiosity of the Arctic. The global consequences are dramatic. Once ice melts, the **albedo** of the ocean– the fraction of solar radiation reflected back into space – drops from 0.6 (dirty summer ice) to 0.1 (open water only), which will accelerate warming of the whole planet. It has been estimated that the rate of loss of ice is causing a global albedo decrease which is adding a quarter to the direct effect of man-made global warming. Even this is an underestimate because the albedo effect is not confined to ice. We also see faster spring snow melt in Arctic coastal lands as sea ice recedes, due to warmer air masses moving over the coasts from the newly ice-free sea; in 2012 we saw a 6 million square kilometre negative area anomaly in June compared with 1980. Since the albedo of snow-free land is similar to that of open water (0.1), an anomaly of this size is equivalent in albedo to a sea ice retreat of similar magnitude. So if we put these two effects together the overall ice/snow-albedo feedback adds 50% to the direct global heating effect, showing how the Arctic has become a driver of, rather than just a responder to, global change. For every two molecules of greenhouse gas that we put into the atmosphere, the snow-ice feedback adds the equivalent of one more molecule for heating the planet.

A second, truly global, consequence of ice retreat is its impact on **sea level rise**. The rate of melt of the Greenland ice sheet has greatly increased in recent years, due to warmer air moving over Greenland in summer from the open Arctic Ocean. Until the 1980s global sea level rise was due partly to ocean warming – which makes the water less dense so that the level stands higher – and partly to the retreat of mountain glaciers in places like the Alps and the Rockies. Then after the 1980s pools of melt water began to appear on the Greenland ice sheet, with much of the water disappearing down holes called moulins which bring it down to deeper levels or to bedrock. Here is lubricates outlet glaciers which began to accelerate until some of them are now moving twice as fast as before, depositing much more ice into the ocean as icebergs. In the record year of 2012 there was a time in July when 97% of the Greenland ice sheet surface was covered with melt water, and a gravity satellite called GRACE, which measures the mass of the ice sheet, is finding that 300 cubic kilometers of ice are now being lost per year. Greenland is now the biggest generator of global sea level rise and a similar melt is starting in Antarctica. The impact is very serious: official predictions by the Intergovernmental Panel on Climate Change (IPCC) are for a 60-90 cm rise this century, but most glaciologists are estimating 1 metre or more, maybe much more. This will have a disastrous effect on coastal cities like Miami, New York, Shanghai and Venice, as well as increasing the flood frequency on low-lying crowded coastlines like Bangla Desh. It is irreversible.

A third effect, and possibly the greatest immediate threat, is **seabed methane** feedback. This was mentioned by the Pope in his encyclical "Laudato Si". Removal of the ice cover takes away a vital air conditioning system for the Arctic. So long as some ice is present in summer, however thin, the sea surface temperature cannot rise above 0ºC, since if the water warmed further it would lose its heat in melting some of the overlying ice. With the ice gone completely, the surface water now warms up by several degrees (up to 7ºC) by absorbing solar radiation, and over the shallow continental shelves this heat extends down to the seabed. This melts the offshore permafrost, frozen sediments which have lain there undisturbed since the last Ice Age. The thawing of offshore permafrost is like releasing the lid of a pressure cooker; it triggers the release of huge plumes of methane gas from the disintegration of methane hydrates (a compound of methane and ice) trapped within the underlying sediment. Methane has a greenhouse warming effect 23 times greater than carbon dioxide per molecule. An annual Russian-US expedition to the East Siberian Sea is already observing methane plumes welling up from the seabed, and this observation has been duplicated by Swedish and Norwegian work in the Laptev and Kara Seas.

Since offshore methane release causes general atmospheric levels of the gas to rise, it will give an immediate boost to global warming. One third of the Arctic Ocean is composed of shelves only 50-100 metres deep, so the area involved is huge. Russian scientists estimate that 50 gigatons (1 gigaton = 10^{12} tons) of methane could be emitted from the East Siberian Shelf during the next few years. I and two colleagues estimated that this emission, occurring over 10 years, would give an extra warming of 0.6°C worldwide by 2040, while an economic analysis by my co-authors, using a model employed by the British Government, estimated a vast cost to the world of 60 trillion dollars over a century. This adds 15% to the overall cost of man-induced global warming, while the immediate temperature rise is likely to prove disastrous to our attempts to limit the rate of warming of our planet. This dire threat has caught most scientists unprepared, because significant summer retreat of ice in the shelf seas started only in about 2005, so this is a new phenomenon which has probably never occurred since before the last Ice Age.

A further huge threat to our planetary wellbeing is the likelihood that Arctic warming and sea ice retreat have been the cause of **extreme weather patterns** which have occurred over the past seven years, typically involving very cold or stormy weather in winter in certain parts of Europe and North America and very warm weather in others. The jet stream, the fast-moving boundary flow which separates Arctic from lower-latitude air masses, has slowed, because of the smaller temperature difference between low latitudes and the fast-warming Arctic. As the flow gets weaker the jet stream follows a wavier path, bringing cold air masses down to lower latitudes in the southward lobes and warm air to unusually high latitudes in the northward lobes.

The slow movement of these lobes enables prolonged persistence of a local weather system in one mode, e.g. drought, flooding, cold weather or heatwaves. The biggest effects occur in mid-northern latitudes which is exactly the location of the planet's most productive croplands. If the effects persist, this could be a serious threat to global food production, with both direct consequences in the form of famine, and indirect in the form of social unrest in poor countries due to rises in food prices. With a rapidly increasing population, the world cannot sustain a check to its capability to produce food. Very serious famine is inevitable.

The final major feedback is one that may offer some benefit, but only to nations in northwest Europe. The **thermohaline circulation**, or "global conveyor belt", is a very slow circulation of the world ocean, not driven by winds but by the distribution of heat and precipitation over the oceans. It has been called a conveyor belt because there are surface and deep components, with areas of upwelling or sinking to connect them, like the cogwheels in a conveyor belt. In the Atlantic the surface current is part of the Gulf Stream, taking water from the tropics northeastward to bathe the coastline of Europe and then head further north still. Up in the Greenland Sea some of it sinks in a very small region at 75°N 0°W, and this is one of the main cogwheels of the conveyor. But it is a cogwheel that is failing: the sinking had been driven by ice formation in winter, with the surface water gaining extra density


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from the salt that is left in the water when ice forms. In this special region the extra salt was just enough to drive deep cylinders of sinking water called "chimneys".

But since 1998 no sea ice has formed in this region, and chimneys no longer form; the conveyor belt is failing. Because of this weakening, the European Environment Agency estimates that by the end of the century Britain, Ireland, Iceland and the French and Norwegian coastlines (and the NW tip of Spain) will experience "only" 2°C of warming, compared to a ruinous 4°C for most of continental Europe. This is good news for NW Europe, but not for tropical America, since the loss of this current will increase the temperature of tropical Atlantic waters, and hence increase the intensity of hurricanes.

The need for action

The global feedbacks created by Arctic ice retreat are of enormous importance for two reasons:-

They show the invalidity of arguments which point to the economic advantages of sea ice retreat in terms of easier marine transport and oil exploration. Each of these two benefits has been estimated to be worth billions of dollars – but the cost to the planet of the warming which makes them possible is measured in trillions of dollars.

They show that future climate warming cannot be modelled in a linear way based on the quantity of CO_2 emissions. The reality is that new feedbacks come into play at certain critical stages, which accelerate warming and may end up dominating the future pattern of global change. It is not quite a runaway warming such as that which removed the water from Venus, but we have pointed to two emerging feedbacks which pose big dangers – albedo feedback and methane feedback. So it may be that even if we reduce CO_2 emissions radically, the system may not respond – it is developing a momentum of its own.

A serious problem is that these effects were downplayed in the past by the very body, IPCC, which was established to warn the world of dangerous climatic change. Now, with the Paris Agreement of 2015, the legal onus is on every country of the world to reduce its carbon emissions such that global temperatures do not rise by more than 2°C – and if possible 1.5°C. My own conclusion, based on the way in which Arctic feedbacks enhance the warming rate, is that even a rapid reduction in CO_2 emissions will not work in time (a problem made infinitely worse by the insane global vandalism of Trump) so we must urgently consider emergency methods which could slow down the rate of warming and give us time to change to a new way of living on this planet. This means applying geoengineering techniques, repugnant as these are to many people including scientists.

Geoengineering can be thought of as a sticking plaster solution to our global problem. It consists of reducing the radiation absorbed by the planet, typically by spreading finely divided powder in the stratosphere, or more benignly by injecting fine water droplets into the lower parts of marine stratus clouds to make them brighter, that is to increase their albedo. It is not a permanent solution. It does nothing to halt the growth of CO_2 in the atmosphere, so as soon as the treatment is stopped the disease (rapid warming) breaks out with greater virulence. It also does nothing to halt the acidification of the ocean, another product of increased CO_2 levels, which will wipe out coral reefs and seriously impact marine life.

The only actual *solution* to catastrophic global warming, apart from an impossible appeal to mankind's better nature, is to find a way to *take CO2 out of the atmosphere*. This is the ultimate technofix, and those wise souls who advocate that we live in closer harmony with nature find the concept appalling, because it would allow us to continue with all our bad habits such as continued fossil fuel use. But it is unavoidable. Various methods have been proposed, such as massive worldwide tree-planting; carbon capture and storage from coal-fired power plant exhausts; or even the exposure to the atmosphere of billions of tons of crushed olivine rock, which very slowly undergoes a chemical reaction in air involving absorption of CO_2. None of these can be scaled up in time. It is clear that a straightforward cost-effective and energy-effective method to take CO_2 out of the air has to be developed, and here is a true challenge to mankind. Can we persuade our politicians and scientists to have a new Manhattan Project, a focus for a massive worldwide research effort, to design an effective method of removing CO_2 from the normal atmosphere and turning it into a benign substance which can be stored or used? To my mind this is the most important challenge in science and technology today, since our very existence is at stake. We have created global warming and we ought to be able to stop it.

I have spent my entire scientific life from the age of 21 working on the science of sea ice and the polar oceans. What do these changes mean to me as I say a personal farewell to this magic landscape? Overwhelmingly I feel that this is a spiritual impoverishment of the Earth as well as a practical catastrophe for mankind. Our own greed and stupidity have taken away the beautiful world of Arctic sea ice which once protected us from the impacts of climatic extremes. Now urgent action is needed if we are to save ourselves from the consequences.

My personal testament on these changes is a book called "A Farewell to Ice" (UK: Allen Lane, US: Oxford University Press), in which I describe the decline of sea ice, its frightening worldwide consequences, and the measures which I believe we must take to save ourselves from the rapid climate change which is resulting.

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