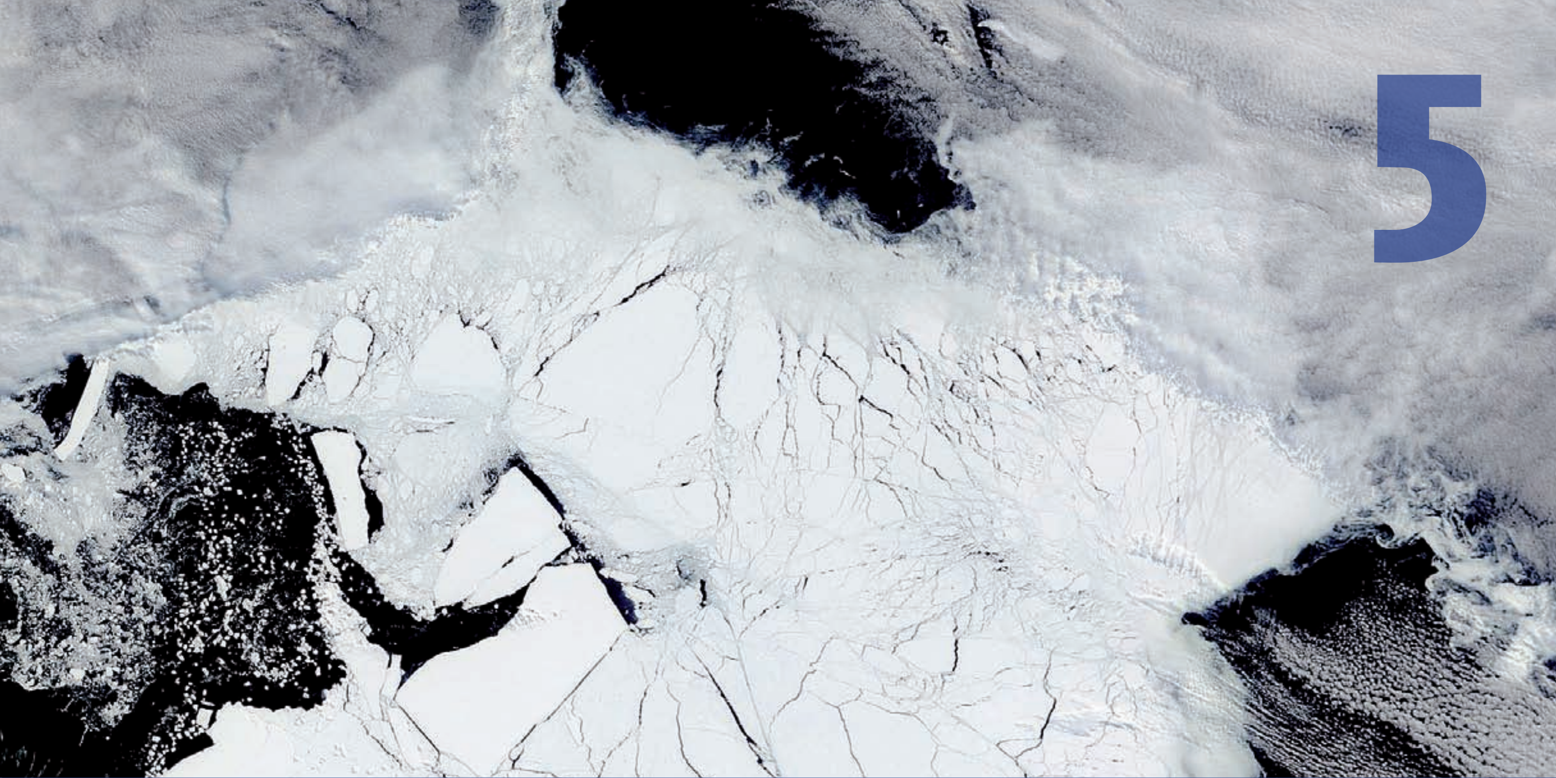

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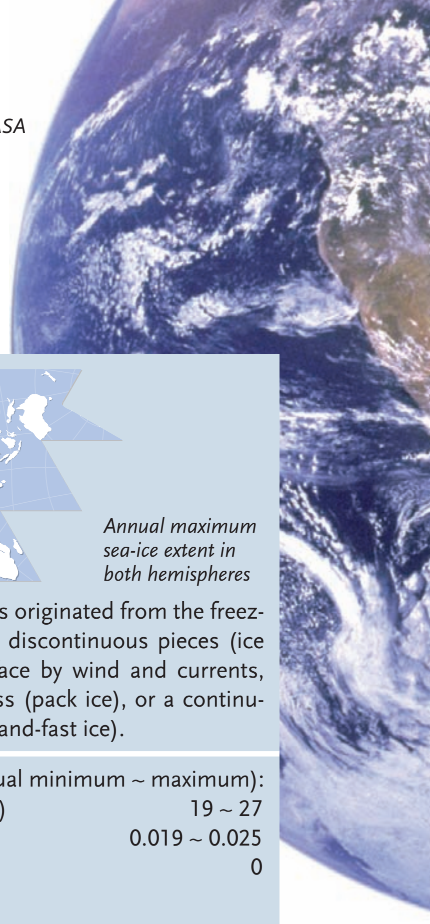
Ice in the Sea

Sebastian Gerland (lead author, Norwegian Polar Institute, Tromsø, Norway); **Jon Aars** (Norwegian Polar Institute, Tromsø, Norway); **Tom Bracegirdle** (British Antarctic Survey, Cambridge, UK); **Eddy Carmack** (Fisheries and Oceans, Canada, Institute of Ocean Sciences, Sidney, BC, Canada); **Haakon Hop** (Norwegian Polar Institute, Tromsø, Norway); **Grete K. Hovelsrud** (CICERO: Centre for International Climate and Environmental Research, Oslo, Norway); **Kit Kovacs** (Norwegian Polar Institute, Tromsø, Norway); **Christian Lydersen** (Norwegian Polar Institute, Tromsø, Norway); **Don K. Perovich** (U.S. Army ERDC – Cold Regions Research and Engineering Laboratory, Hanover, NH, USA); **Jackie Richter-Menge** (U.S. Army ERDC – Cold Regions Research and Engineering Laboratory, Hanover, NH, USA); **Stine Rybråten** (CICERO: Centre for International Climate and Environmental Research, Oslo, Norway); **Hallvard Strøm** (Norwegian Polar Institute, Tromsø, Norway); and **John Turner** (British Antarctic Survey, Cambridge, UK)

Ice in the Sea



Source: NASA

Summary

Sea ice plays a key role for climate and is important as habitat and for human activities and economies. Observations show and models indicate that climate and sea-ice regimes are changing. Sea-ice extent in the Arctic decreased substantially during the last 30 years; Antarctic sea ice is decreasing in some areas, but overall it has shown a slight increase during this period. Climate models project further decreases in sea-ice extent in the Arctic during this century and comparable decreases in Antarctic sea-ice extent. There are uncertainties attached to the rate at which these changes will occur, and there is a risk of tipping points being crossed and abrupt reductions in sea ice occurring. To reduce these uncertainties, more large-scale continuous observations are needed, especially of ice and snow thickness.

Changes to sea ice will have major impacts on both the physical and biological environment at all scales from global to regional. The reduction in albedo (reflection of solar radiation) resulting from less ice cover is a feedback mechanism that accelerates the rate that sea ice declines and also the rate at which Earth warms. Changes in sea ice contribute to altering the ocean thermohaline circulation, especially in the North Atlantic.

Sea ice is a complex environment with a diversity of habitats and seasonal variation to which life in the polar seas is closely adapted. Many species are now being affected by changes in sea ice in the Arctic, and, if the changes continue, there is a strong risk of species extinctions. There is a range of direct consequences of changes in sea ice for economies and human well-being – including threats to indigenous cultures and opening of new sea routes and economic opportunities.

Annual maximum sea-ice extent in both hemispheres

Sea ice: ice found at sea which has originated from the freezing of sea water. Sea ice may be discontinuous pieces (ice floes) moved on the ocean surface by wind and currents, driven together into a single mass (pack ice), or a continuous sheet attached to the coast (land-fast ice).

Sea ice, Arctic and Antarctic (annual minimum ~ maximum):	
Area Covered (million square km)	19 ~ 27
Ice Volume (million cubic km)	0.019 ~ 0.025
Potential Sea-level Rise (cm)	0

Source: IPCC 2007[1a]

Introduction to sea ice

Seen from space, the Earth is dominated by the colours blue, white, and grey-brown. Blue from the ice-free ocean surfaces, white from snow, ice and clouds, and grey-brown from snow-free and ice-free land surfaces. The brighter the colour, the more the sun's rays are reflected back into space, and the less the Earth warms up. An important part of the Earth's white surface area is sea ice.

In the Arctic, winter sea ice extends over an area of approximately 15 million km^2 at its peak in March and up to 7 million km^2 in September, at the end of the summer melt season. Corresponding numbers for the Southern Ocean

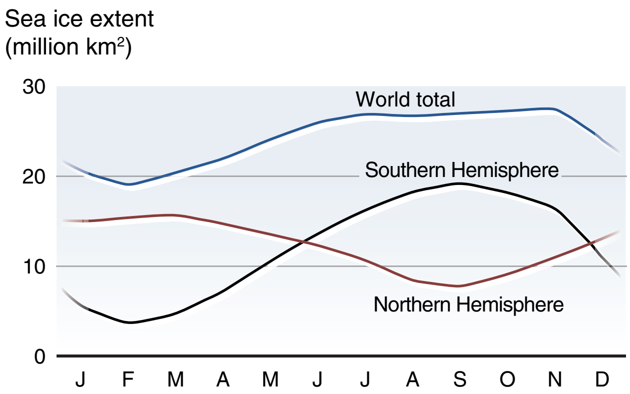


Figure 5.1: Monthly average variations in sea-ice extent in total and in both hemispheres.

Source: Based on Thomas 2004[1] *(amended from original by J. Comiso, NASA)*

around the Antarctic continent are approximately 3 million km^2 in February during the Antarctic summer and 18 million km^2 at the height of winter in September (Figure 5.1). In regions with seasonal sea ice, the ice cover achieves a thickness varying from less than 1 metre to more than 2 metres, depending on air and water temperatures and other conditions. In regions where ice survives the summer, thicker, multi-year ice is formed. But these conditions are changing. Sea ice has decreased in the Arctic and is projected to decline much more in both polar regions, with consequences to climate, ecosystems and human livelihoods.

Sea ice is extremely important to the climates of the polar regions because of the part it plays in insulating the atmosphere from the huge heat source in the ocean, its role in the formation of bottom water (the densest water found in the ocean, which is extremely important in the circulation of the ocean), and the part it plays in feedback and amplification processes. Snow-covered sea ice is highly reflective and returns a lot of sunlight back to space. In contrast, when sea ice is not present the dark ocean can absorb this heat from the Sun.

Sea ice is home to many ice-associated organisms, from tiny algae and crustaceans to penguins, polar bears and whales. Many organisms in Arctic and Antarctic marine food webs depend on the ice itself or on processes connected with sea ice. And sea ice is important to humans.

It affects transportation routes, navigation and access to resources such as fish and oil in polar waters and in seas with seasonal and periodic ice cover. It is crucial to the livelihoods and cultures of coastal Arctic indigenous people.

People have been studying sea ice for millennia, from Arctic indigenous people who continue to study and adapt to sea-ice conditions as part of their daily lives, through 16th century commercial whalers, to the early polar scientific researchers of the 19th century (Figure 5.2). During the 20th century scientific research on sea ice became more sophisticated, with ship expeditions and ice drifting stations (mostly Russian) in the Arctic and various expeditions to Antarctica. Modern polar research is supported by ships or land-based stations with advanced instrumentation, satellite observations and moorings as well as advanced modelling. During the International Polar Year (2007–2008) research activity is aimed at improving understanding of sea ice, its interaction with atmosphere and ocean, its role in marine ecosystems, and the consequences of changes in sea ice brought about by global warming.

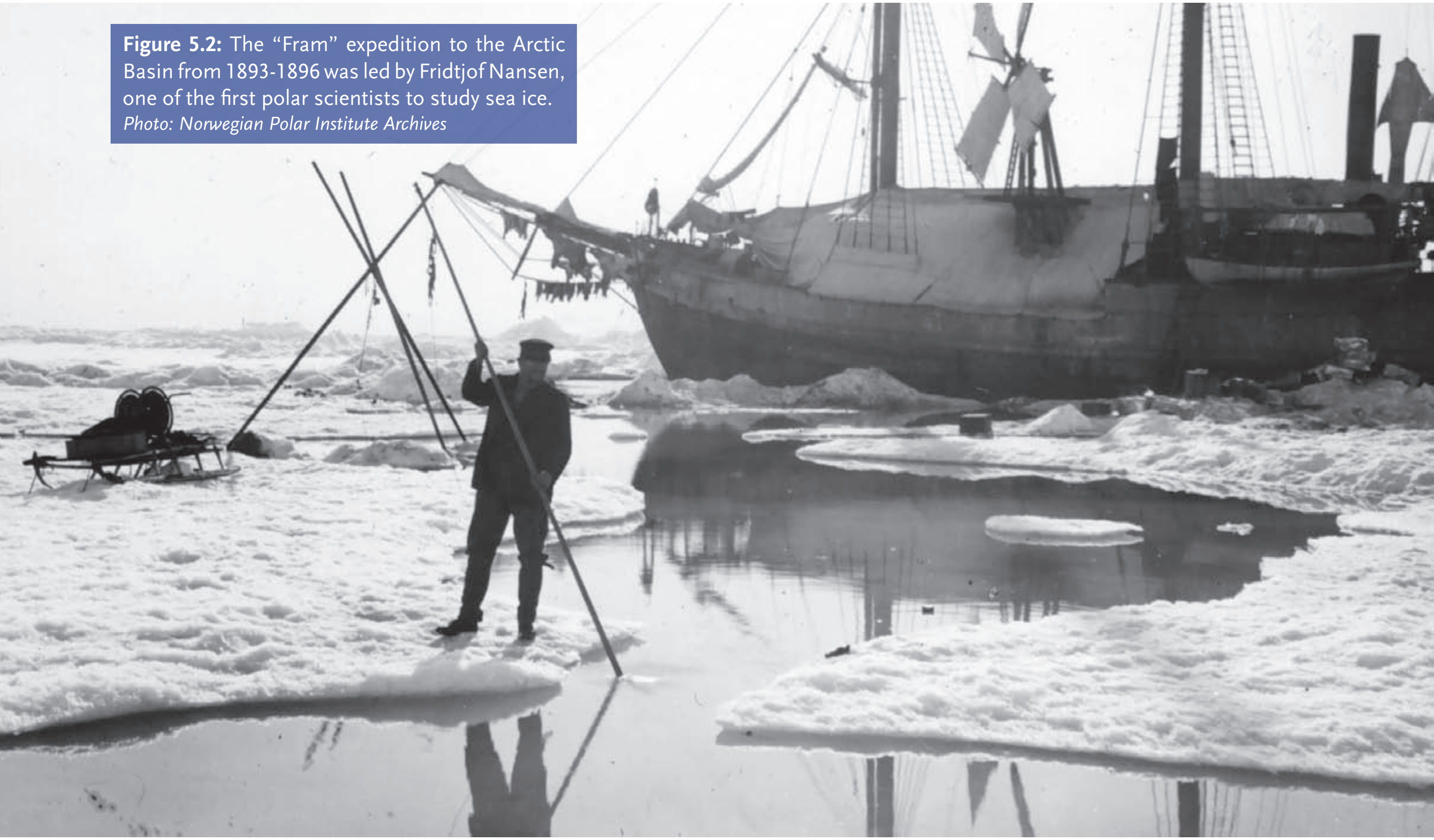


Figure 5.2: The “Fram” expedition to the Arctic Basin from 1893-1896 was led by Fridtjof Nansen, one of the first polar scientists to study sea ice.
Photo: Norwegian Polar Institute Archives

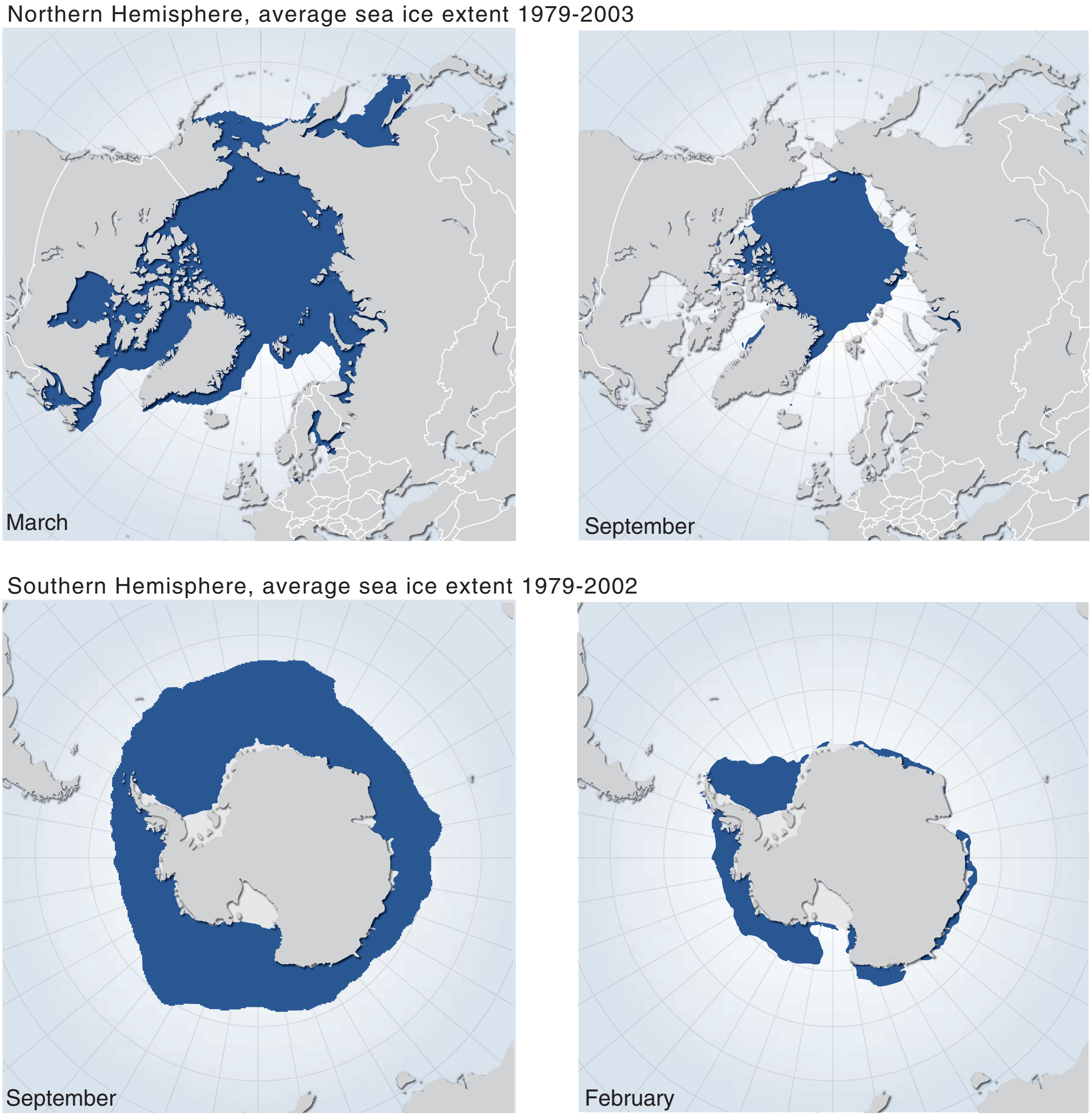


Figure 5.3: Maps of average sea-ice extent in the Arctic summer (September) and winter (March), and in the Antarctic summer (February) and winter (September). They represent average sea-ice extent from 1979 to 2002/2003, based on passive microwave satellite observations. The two polar regions are drawn to the same scale.

Source: Based on Stroeve and Meier 1999 updated 2005[3] (Antarctic); Armstrong and Brodzik 2005[4] (Arctic)

Trends in sea ice

Passive microwave sensors on satellites have monitored the extent of the sea-ice cover since 1978[2]. This technique is widely used to investigate fluctuations in ice extent over the seasons, variability between years, and long-term trends. The seasonal variation of ice extent is much greater in the Antarctic where there is about six times as much ice in winter as in summer. Currently, in the Arctic, ice approximately doubles from summer to winter. Figure 5.3 shows the average minimum and maximum extents of Arctic and Antarctic sea ice in recent decades.

Northern Hemisphere trends

Despite considerable year-to-year variability, significant negative trends are apparent in both maximum and minimum ice extents, with a rate of decrease of 2.5 per cent per decade for March and 8.9 per cent per decade for September[5–7] (Figure 5.4).

There are major regional differences (Figure 5.5), with the strongest decline in ice extent observed for the Greenland Sea (10.6 per cent per decade). The smallest decreases of annual mean sea-ice extent were found in the Arctic Ocean, the Canadian Archipelago and the Gulf of St. Lawrence. In the marginal Arctic seas off Siberia (the Kara, Laptev, East Siberian and Chukchi Seas) a slight negative, but not significant, trend in ice extent was observed between 1900 and 2000[8].

Figure 5.6 compares the Arctic sea-ice extent in September for the years 1982 (the record maximum since 1979) and 2005 (the record minimum). The ice extent was 7.5

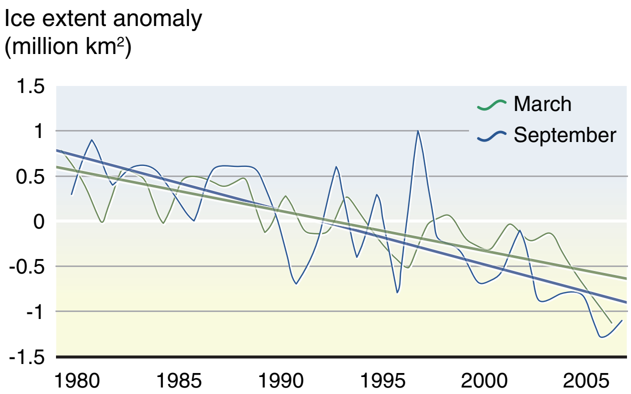


Figure 5.4: Time series of the difference in Arctic sea-ice extent in March (maximum) and September (minimum) from the mean values for the time period 1979–2006. Based on a linear least squares regression, the rate of decrease in March and September was 2.5% per decade and 8.9% per decade, respectively.

Source: Data courtesy of National Snow and Ice Data Center (NSIDC)

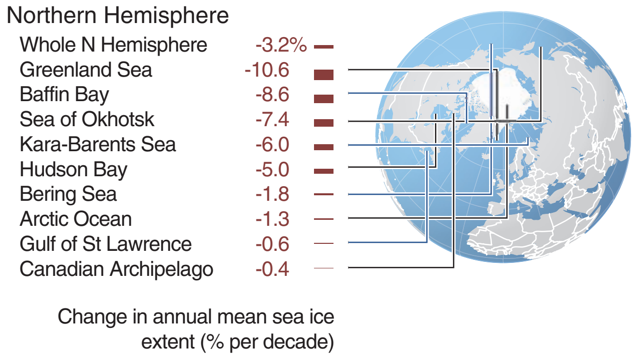


Figure 5.5: Regional changes in Arctic annual mean sea-ice extent (% per decade) for the period 1979–2004.

Source: Data courtesy of NASA 2007a[9] million km^2 in 1982 and only 5.6 million km^2 in 2005, a difference of 25 per cent. As has been observed in other recent years, the retreat of the ice cover was particularly pronounced along the Eurasian coast. Indeed, the retreat was so pronounced that at the end of the summer of 2005 the Northern Sea Route across the top of Eurasia was completely ice-free (see section below on shipping and tourism).

Ice extent is only part of the equation. To assess changes in ice cover it is also important to look at ice thickness – however ice thickness is difficult to monitor and measurements are much more limited. Satellite-based techniques have only recently been introduced and there is no comprehensive record of sea-ice thickness. There are many datasets of ice thickness from measurements taken opportunistically, including holes drilled through the ice, observations from ships, upward-looking sonars moored at the sea floor[10], and above-ice surveys using laser techniques and electromagnetic sensors[11].

The most comprehensive source of ice-thickness observations were the sonar profiles made from submarines cruising under the Arctic ice cover from the 1950s to the 1990s. These observations were made irregularly, but researchers were able to group them for comparison into seven regions and into two time periods. Rothrock and others[12] concluded from these records that a substantial thinning of the ice occurred in several regions between the period 1956–1978 and the 1990s, with an overall 40 per cent decrease in thickness from an average of 3.1 m to 1. 8 m. Other later publications dealing with analyses of submarine-based sonar data conclude that the thinning rates may have been less than this[13,14].

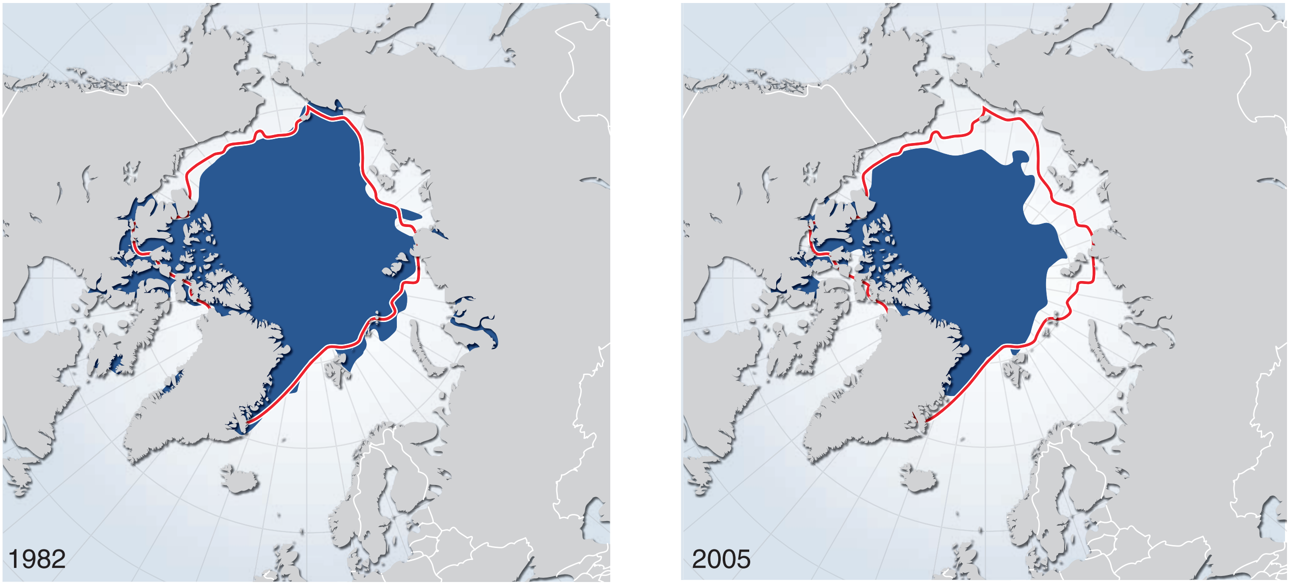
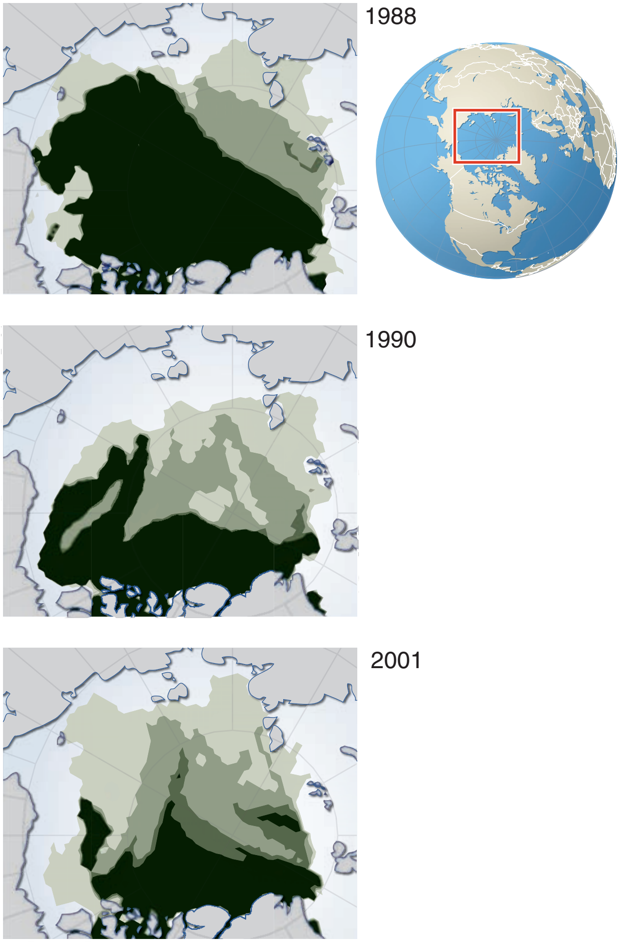


Figure 5.6: Arctic sea ice minimum extent in September 1982 and 2005. The red line indicates the median minimum extent of the ice cover for the period 1979–2000. The September 2005 extent marked a record minimum for the period 1979–2006.

Source: Data courtesy of National Snow and Ice Data Center (NSIDC)



Thickness of land-fast ice is monitored from coastal sites in Arctic Canada, Svalbard and Siberia[8,15,16]. Most sites show large variations among years and among decades. Data extending back to 1936 from sites off the coast of Siberia show, in general, no significant trends up to 2000[8]. Consistent observations at Svalbard do not go that far back in time, but monitoring during the last decade showed that during the warmer-than-normal winters of 2005/2006 and 2006/2007 the land-fast ice in most Svalbard fjords was less extensive, thinner and lasted for a shorter time than normal.

The age of sea ice in the Arctic is also changing. Studies show that in recent years there is a higher proportion of younger ice to older ice than was observed in the late 1980s[6] (Figure 5.7).

Southern Hemisphere trends

In contrast to the Arctic, there are signs of a slight increase in the extent of annual mean sea ice over the period 1979–2005 (+1.2 per cent per decade) based on the NASA Team retrieval algorithm[18]. The IPCC[20] concluded that this overall increase was not significant and that there are no consistent trends during the period of satellite observations. There are, however, indications that sea ice may be increasing more at the period of minimum coverage (March) than at the period of maximum sea-ice extent in September. There is also regional