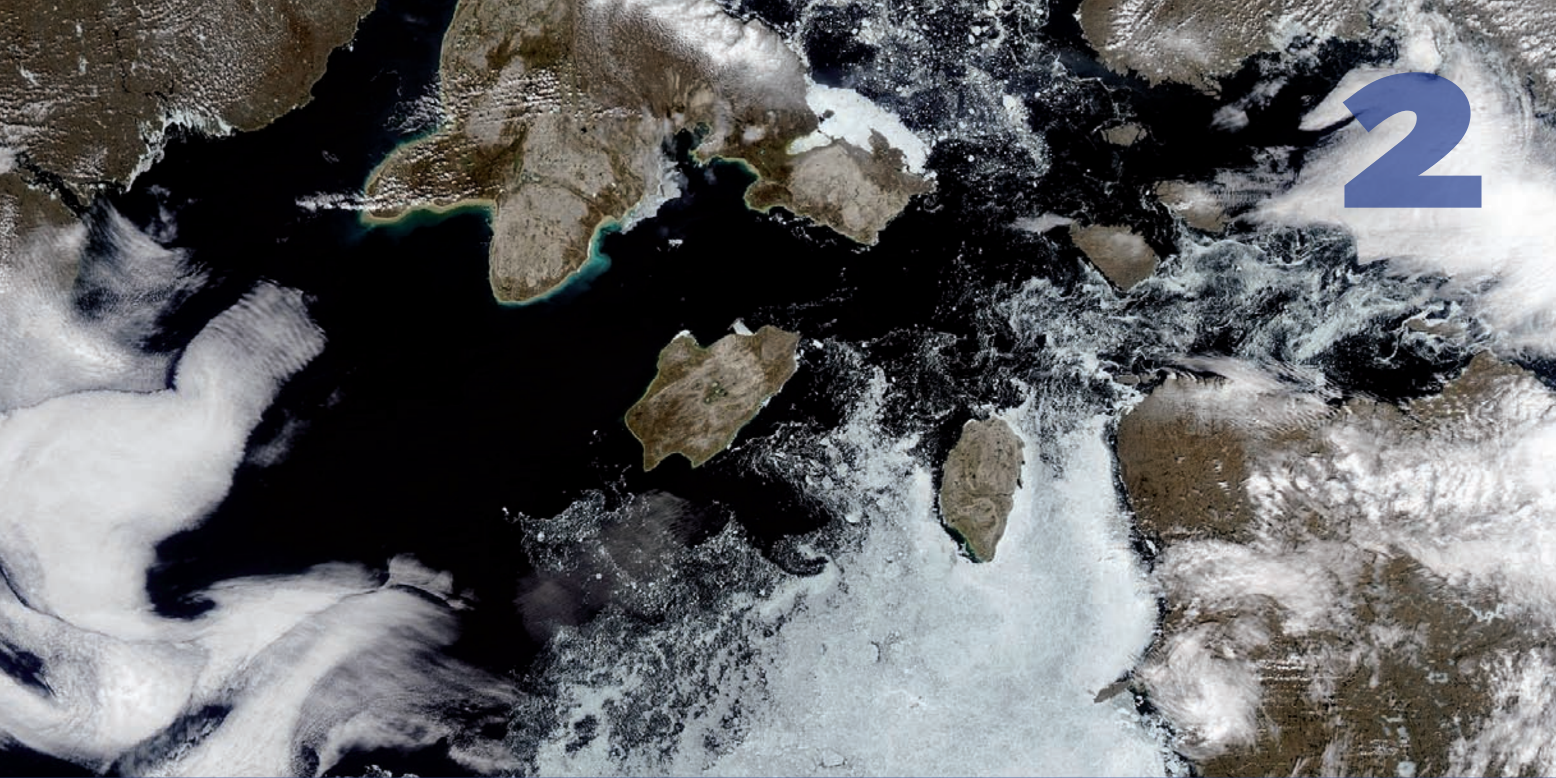

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Why are Ice and Snow Important to Us?

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Why are Ice and Snow Important to Us?

This report demonstrates how we are affected by ice and snow, whether we live in the northern regions or tropical climates or in between. Ice and snow are important components of the Earth's climate system and are particularly vulnerable to global warming. Ice and snow are important parts of northerners' identity and culture, especially for indigenous people, whose cultures have adapted to a world in which ice and snow are not only integral parts of the ecosystem but also support a sustainable way of life. Reduction of ice and snow damages the ecosystems that support these cultures and livelihoods.

"As our hunting culture is based on the cold, being frozen with lots of snow and ice, we thrive on it," says Sheila Watt-Cloutier, former Chair of the Inuit Circumpolar Council. *"We are in essence fighting for our right to be cold."*[1]

Ice and snow are also important in temperate and tropical areas. Hundreds of millions of people are affected by the ice and snow that accumulate in mountain regions. The slow melt from glaciers provides water to rivers supporting agriculture, domestic water supplies, hydroelectric power stations, and industry. If the glaciers disappear, people distant from these mountains, in the lowlands and big cities of Asia and South America, will suffer from the loss of this dry-season water flow.

The global significance of ice and snow is profound. Less ice, snow and permafrost may amplify global warming in various ways. Melting glaciers and ice sheets in Greenland and Antarctica will raise the mean sea level. The retreating sea ice, in combination with increased supply of fresh water from melting glaciers and warmer ocean temperatures, could affect the strength of major ocean currents.

Over the last few decades, the amount of ice and snow, especially in the Northern Hemisphere, has decreased substantially[2,3]. The primary reason for this decrease is the ongoing global warming that the WMO/UNEP Intergovernmental Panel on Climate Change[3] (see Chapter 9) attributes mainly to human activities. This trend will accelerate if the global warming continues.

This book looks at the forces driving this unprecedented change (Chapter 3), and at the current state and outlook for the components of the cryosphere (see Box 1): snow (Chapter 4), ice in the sea (Chapter 5), ice on the land (Chapter 6), frozen ground (Chapter 7) and river and lake ice (Chapter 8). The societal and ecological impacts of changes in the different components of ice and snow are discussed in each chapter. The final chapter (Chapter 9) returns to a holistic view, presenting some regional perspectives and looking at implications of current and projected changes, and at policy responses. The report is based on scientific knowledge and each chapter is written by experts in their field.

Changes in the polar regions are important to the rest of the world

In addition to receiving less sun radiation than temperate and tropical regions, the polar regions are cold because ice and snow reflect most of the solar radiation back to space, while open sea and bare ground absorb most of the solar radiation as heat. When the ice and snow cover begin to shrink because the climate is getting warmer, more solar radiation tends to be absorbed, which in turn accelerates the melting. This process develops slowly, but as more and more bare ground and open sea are exposed, the warming will increase and the snow melting will accelerate. Less ice and snow cover also means that less heat will be used for melting, which will contribute to the warming trend. In these ways, reduced ice and snow cover warms up polar regions and accelerates global warming. This is an example of what scientists call positive feedback, a self-reinforcing effect, in the climate system.

Climate scientists call the changes in the external natural and human-made factors that can explain the global warming over the last 150 years "climate forcings" (see also Chapter 3). Forcing is measured in watts per square metre of the Earth's surface – in other words, the rate of adding (warming) or subtracting (cooling) energy or heat from the Earth's heat balance. If all ice and snow were to disappear, and the effect of this were to be evened out across the globe, the Earth would receive 3 to 4 watts more heating per square metre than it does now[4]. For comparison, scientists believe that the climate forcing from all the additions and subtraction resulting from greenhouse gases, particulate matter, aerosols, solar radiation changes, and volcanic eruptions over the last hundred years equal about 1.6 watts per square metre[3]. This illustrates that the ice and snow covered surfaces in high latitude and high altitude regions contribute an important and essential cooling function for the whole planet.

Some of the feedbacks and interactions that result from warming in the polar regions are complex and very hard to predict. In the Arctic there is another positive climate feedback that may amplify global warming significantly. The uppermost part of the frozen tundra contains between 200 and 400 billion tonnes of carbon stored in organic material produced by the tundra vegetation[2] (Chapter 7). This organic material breaks down slowly and if the permafrost starts to thaw, decomposition will speed up and release the greenhouse gases methane and carbon dioxide. In addition, there are probably some thousand billion tonnes of methane frozen deep

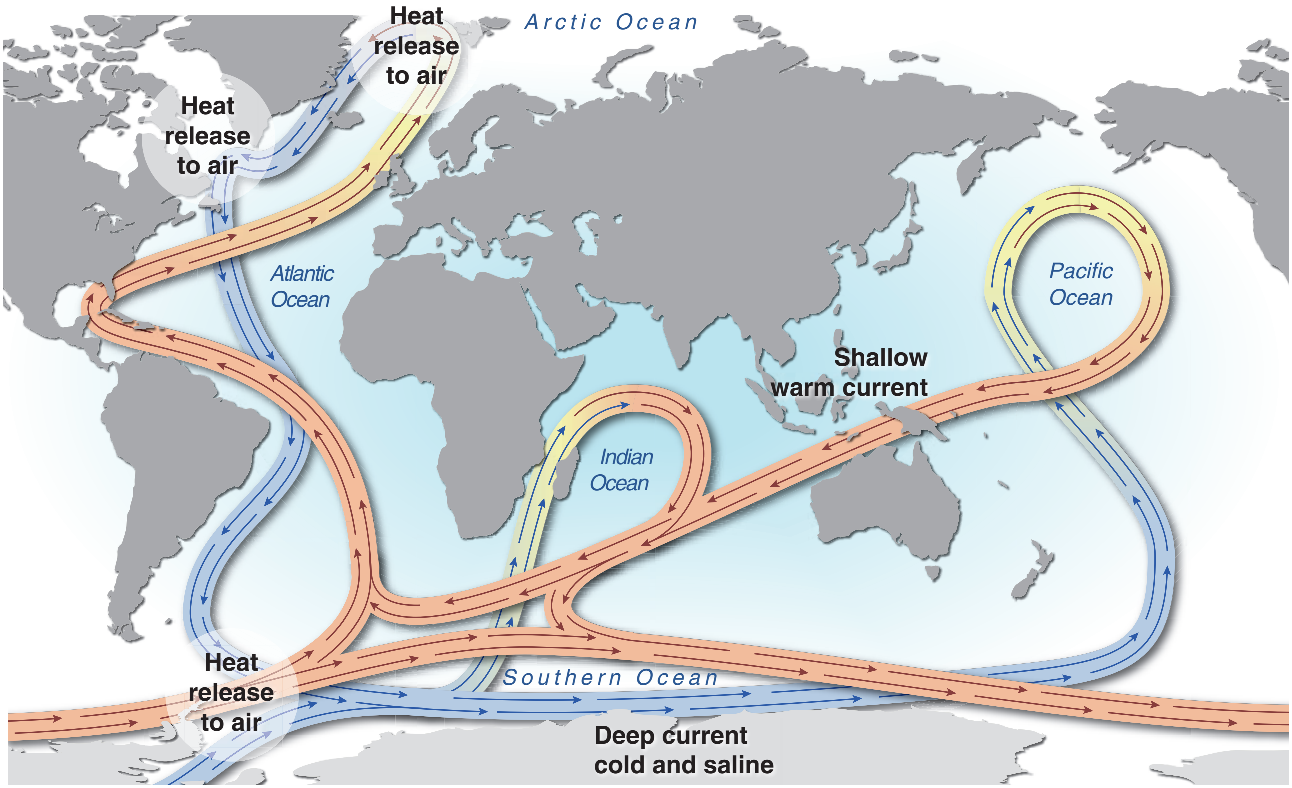

Figure 2.1: Thermohaline circulation, showing areas of major ocean–air heat transfer.

inside or below the permafrost (methane hydrates). We thus risk a situation where global warming melts the permafrost, which in turn adds extra greenhouse gases to the atmosphere, in all likelihood amplifying the warming. On the other hand, a considerable melting of the deep permafrost is necessary before the store of frozen methane could be affected, and that will take many years. During that time, the warming may cause the boreal forest to expand across the tundra, which will remove carbon from the atmosphere. But tree crowns absorb more heat from solar radiation than the flat, white tundra, which can again increase warming[2]. Thus, what the net effect will be on the global climate from these processes is unknown.

Another factor that may affect the global distribution of heat is a change in the major ocean currents caused by melting of ice, excess warming of ocean waters and their freshening. One of the main factors driving the ocean circulation is the formation of deep, dense water in the Greenland Sea, the sea near Baffin Island in eastern Canada, and in the Weddell Sea in Antarctica[3]. Water becomes heavier as it gets saltier and colder. The cold and saline water in these areas sinks and flows along the bottom of the world's oceans while the warmer water flows closer to the surface of the ocean to these colder areas, where it releases its warmth, and becomes colder and more saline. This thermohaline circulation (Figure 2.1) forms a major system of ocean currents, which is also called the Great Ocean Conveyor Belt. The North Atlantic Current is a part of this system. Thermohaline circulation may be affected by melting and freezing processes, such as reductions in the extent and thickness of sea ice (Chapter 5) and input of lighter fresh water from melting glaciers (Chapter 6). The IPCC[3] projects a 25 per cent reduction in this century of the North Atlantic Current because of a weakening of the deep water formation.

Changes from melting ice and snow affect people's homes and livelihoods worldwide

Sea-level rise is one of the most obvious consequences of melting ice on land (Chapter 6). The global sea level is currently rising by about 3 mm per year mostly because seawater expands as it gets warmer and because melting glaciers and ice sheets add fresh water to the oceans[3] (Chapter 6). The IPCC[3] projects that the sea level may rise by as much as half a metre in this century, mainly caused by the thermal expansion of seawater. There is,

Malekula Islands, Vanuatu.
Photo: Topham Picturepoint TopFoto.co.uk

Rhone glacier in Switzerland.
Photo: Konrad Steffen

Polar bear mother and cub on the sea ice – Baffin Bay.
Photo: Peter Van Wagner/iStock

of course, also the potential for the sea level to continue to rise a great deal more. If all the ice masses on land melted the sea level could eventually rise by around 65 metres[3]. This is virtually unthinkable, since the average temperature on Antarctica, where most of this ice is located, is now about –30 °C to –40 °C. But even a minor melting of these ice masses would have significant consequences. For example, if the ice melts by 20 per cent in Greenland and 5 per cent in Antarctica at the same time, the sea level will rise by 4 to 5 metres. This will have not only major consequences for the small islands in the Pacific, Caribbean, and the Indian Ocean, but also for countries like the Netherlands and Bangladesh; and cities and coastal infrastructure in many other countries will be affected negatively.

With few exceptions, all the alpine glaciers of the world are losing mass and it is predicted that this trend will continue as global warming progresses[5]. Glaciers in alpine areas act as buffers. During the rainy season, water is stored in the glaciers and the melt water helps maintain river systems during dry periods. An estimated 1.5 to 2 billion people in Asia (Himalayan region) and in Europe (The Alps) and the Americas (Andes and Rocky Mountains) depend on river systems with glaciers inside their catchment areas. In areas where the glaciers are melting, river runoff will increase for a period before a sharp decline in runoff. Without the water from mountain glaciers, serious problems are inevitable and the UN's Millennium Development Goals for fighting poverty and improving access to clean water will be jeopardized.

The ecosystems and biological diversity in polar and mountain regions will change significantly in a warming world. The zone along the edge of the sea ice is bursting with life despite what at first glance appears to us to be one of the most hostile environments on the Earth. Both the underside and the top surface of pack ice, as well as openings in the ice, are home to myriad marine plants and animals – from long strands of algae under the ice and innumerable small crustaceans, to seals, marine birds, and polar bears (Chapter 5). The ice-edge zone is a biological oasis in the spring and summer when the sun shines around the clock[2]. Many species are specifically adapted to the ice and they will have major problems surviving if the ice should disappear. The same goes for the tundra, where many species are completely dependent on an environment of snow and permafrost. If large parts of the tundra are replaced by trees and shrubs, an expected result of global warming, many of the species that live on the tundra will lose much of their current ranges[2]. Paradoxically, we can expect a greater biological diversity because different species will migrate north from the south.

People who depend on the living resources in the northern regions will have to adapt to major changes. Agriculture and the fishing industry may profit from a moderate warming, while those who live in a traditional way from the land – such as Saami, Arctic Athabaskan, Inuit and other Peoples – will face great challenges. This has already become evident.

Access to energy and mineral resources in the polar regions will increase as ice melts. The sea ice is the main barrier to maritime transport and access to the major continental shelves that surround the Arctic Ocean, where projections place a large part of the world's remaining petroleum resources. The increased interest in petroleum resources in the North is undoubtedly also linked to the decline of the sea ice. For example, it has been calculated that the length of navigation season through the Northern Sea Route along the Siberian coast will increase from 30 days to 120 days in this century, if

Snowfall in China.
Photo: UNEP/Still Pictures

Looking out on sea ice covering Hudson Bay, Canada.
Photo: John Main

Snowshoeing in Massachusetts, USA.
Photo: Nicholas Craig Zwinggi/iStock

the projections of the scientists come true[2]. Ironically, the feasibility of recovering petroleum resources from polar regions has increased because of global warming and the consequent thaw.

Because ice and snow are crucial components of the climate system, extensive research is conducted on them both in the polar and alpine areas of the world. In addition to extensive national research programmes, a global project entitled Climate and Cryosphere (CliC) is developed by the World Climate Research Programme (WCRP) of the World Meteorological Organization (WMO), the International Council for Science (ICSU) and the Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization. The International Geosphere-Biosphere Programme (IGBP) of ICSU is also important. The International Polar Year 2007-2008 (IPY) is jointly conducted by WMO and ICSU and represents one of the most ambitious coordinated science programmes ever attempted. It includes research and observation in both the Arctic and the Antarctic and explores the strong links these regions have with the rest of the globe. IPY is a truly international endeavour with over 60 countries participating in more than 200 projects covering a wide range of research disciplines, from geophysics to ecology to social science and economics.

The Cryosphere

Ice and snow in the seas, on the surface of the earth, and in the ground are collectively known as the cryosphere (see ‘The Cryosphere’, inside front cover). Snow, ice sheets and sea ice cover about 15 per cent of the Earth’s surface during the peak period in March to April, and about 6 per cent in August to September. Permanently-frozen ground, or permafrost, is found in both polar and alpine areas and covers about 20 per cent of Earth’s land areas. Ice and snow store more than 80 per cent of the fresh water on Earth, mainly in the big ice sheets in Greenland and Antarctica with a combined volume of about 30 million cubic kilometres.

The various components of the cryosphere play strong but different roles within the climate system.

- Due to their large volumes and areas, the two continental ice sheets of Antarctica and Greenland **actively influence the global climate** over time scales of millennia to millions of years.
- Snow and sea ice cover large areas too, but have relatively small volumes. They vary in size over the seasons. Snow and sea ice are connected to **key interactions and feedbacks** at global scales (albedo, ocean circulation). Permafrost is another important feedback component in the climate system through the methane cycle. Together with seasonal snow, permafrost influences soil water content and vegetation over continental-scale northern areas.
- Glaciers and ice caps, as well as seasonal ice on lakes, with their smaller areas and volumes, react relatively quickly to climate effects, influencing ecosystems and human activities on a local scale. They are good **indicators of change**, reflecting trends in a range of conditions and seasons, from winter lowlands (lake ice) to summer alpine areas (mountain glaciers). Despite the total volume of glaciers being several orders of magnitude smaller than that of the two major ice sheets, they currently contribute more to sea-level rise.

Seasonal variation in the extent of ice and snow cover is greatest in the Northern Hemisphere. Imagine the Earth with white caps on the top and bottom (2.2). The top cap increases by a factor of six from summer to winter, while the bottom cap only doubles from summer to winter. This difference is due to snow cover: in the Northern Hemisphere snow cover on land varies from less than 2 million km^2 in the summer to 40 to 50 million km^2 in the winter[3]. There is little snow cover in the Southern Hemisphere. In Antarctica, land ice covers about 14 million km^2 year-round, with little change from summer to winter. Sea ice cover in the Arctic varies between approximately 7 and 15 million km^2 seasonally, while sea ice cover in the Antarctic, though about the same extent at its peak, varies much more – from around 3 million km^2 during summer to 18 million km^2 in winter. This means that there is less multi-year sea ice in the Antarctic than in the Arctic, where much of the sea ice is older than one year.

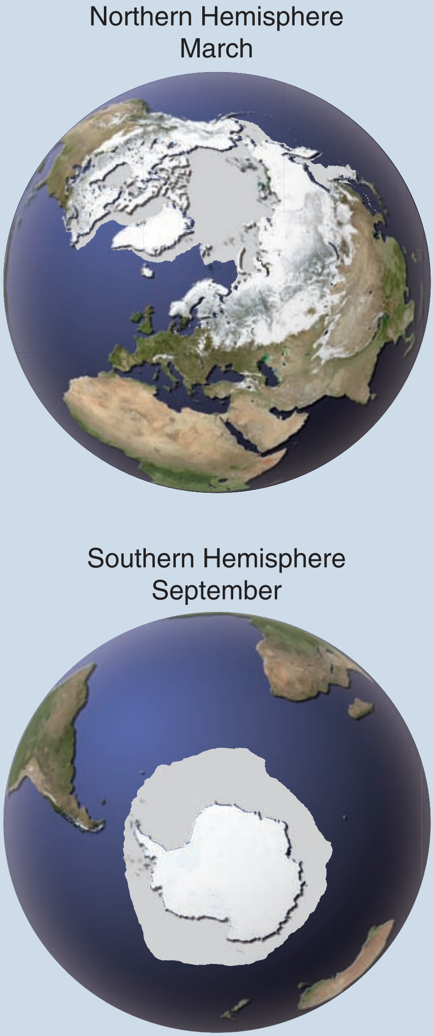

Figure 2.2: Ice and snow cover at peak periods in the annual cycles, Northern and Southern Hemispheres.

Source: Based on NASA Blue Marble NG, with data from the National Snow and Ice Data Centre

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