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Arctic Climate Change

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Climate change in general

Global climate change has been an important theme during the past twenty years, sparking intense debate among scientists, policymakers, industry leaders and the general public.

The climate debate centres around three main issues:

- *Is the climate changing? In what ways?*
- *What are the reasons for these changes?*
- *How will the climate change in the future?*

To help answer these questions, the United Nations established the Intergovernmental Panel on Climate Change (IPCC) in 1988. Its role is to objectively assess the scientific, technical and socio-economic information relevant to understanding the risk of human-induced climate change, its potential effects and options for adaptation and mitigation.

The first question has been the simplest and least controversial. There is a large, international consensus that the Earth is now in a period of climate change, and that the rate of change has accelerated during the last 50 to 100 years.

There is greater debate concerning the reasons for these changes. Several theories have been offered to explain observed changes, including natural climate cycles, fluctuations in ocean–atmosphere interactions, and changes in solar activity.

Nevertheless, there is strong agreement among the world's leading climate experts that the changes we are observing are caused by the release of so-called greenhouse gases from human activities. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFC). Scientists have observed a clear relationship between the increased amount of these gases in the atmosphere and an increase in temperature.

Uncertainty and debate are greatest regarding the future of climate change. Among other things, it is difficult to predict how large the emission of man-made climate gases will be in the future.

It is also difficult to predict how the environment will react to climate change, as there are so many complex and interwoven processes that affect each other. The IPCC has concentrated much of its effort on these questions, and has developed several scenarios that predict the temperature given different emissions rates.

Climate changes in the Arctic

How will climate change manifest itself in the Arctic? The Arctic Council commissioned the Arctic Climate Impact Assessment (ACIA) in 2000 to determine what changes are taking place in the Arctic, as well as the likely consequences of these changes over the course of the next century. Hundreds of researchers participated in the four-year study, which took a moderate emissions scenario from the IPCC (scenario B2) as its starting point.

The conclusions of the ACIA were published in November 2004 in the report, *Impacts of a Warming Arctic*. According to the report, four major manifestations of climate change are occurring in the Arctic today:

- *The Arctic climate is warmer and wetter.*
- *Snow, ice and permafrost are melting.*
- *Ocean levels are rising, and seawater is becoming less saline and more acidic.*
- *The ozone layer is thinning, and ultraviolet (UV) radiation is increasing.*

Table 1 summarizes the main trends, observed indications, and expected future developments of climate change contained in the ACIA report.

Consequences for the Arctic environment

The climate-related trends and changes that researchers believe may occur this century could have significant consequences on nature and on human activities.

Shrinking sea ice changes the basis of existence for animals and hunting culture

A variety of marine mammals are dependent on the sea ice, such as polar bears, walrus and seals, as well as several bird species. When the sea ice disappears, the basis of existence for these animals also disappears. As a variety of traditional cultures in the Arctic are dependent on these animals, an important foundation for their cultures will crumble after the ice vanishes.

Alteration of flora and fauna

Vegetation zones will move northwards as forest replaces tundra, and tundra replaces polar desert. Plant and animal species not currently found in the Arctic will move northwards into the region. Wetlands will dry up in some areas, while the thawing permafrost will create new wetlands in other areas.

Because the Arctic ecosystem has generally fewer species and relatively simple food webs,

Table 1 – Summary of findings from the Arctic Climate Impact Assessment (ACIA)

Main trends	Observed indications	Expected future developments
The Arctic climate is warmer and wetter.	The average annual temperature in the Arctic has increased about twice as much as in the rest of the world during the last decades.	The temperature will rise by 3–7°C in Arctic land areas and 7–10°C in ocean areas in the course of the next century.
	Precipitation in the Arctic has increased on average by 8 percent during the past century, especially in the form of rain.	Higher temperature leads to greater evaporation, which in turn leads to more precipitation. Precipitation will increase by 20 percent across the Arctic.
	Water discharge by Arctic rivers increased during recent decades, and the spring flood is greater and comes earlier. Rivers and lakes freeze later and thaw earlier.	The annual discharge of Arctic rivers will increase 10–25 percent during the next century.
Snow, ice and permafrost are melting.	Snow cover in the Arctic shrank by about 10 percent during the past 30 years.	Snow cover will shrink a further 10–20 percent over the next century.
	Glaciers are melting and retreating. The Greenland ice cap is melting at a significantly accelerated rate.	Melting of Arctic glaciers will accelerate and cause global sea levels to rise by 4 to 6 cm during the next century.
	The temperature in the permafrost has risen by up to 2°C in recent decades. Permafrost coverage and depth have steadily decreased.	The temperature will continue to rise in permafrost soils. The permafrost zone will retreat northwards by several hundred kilometres during the course of the next century.
	Summer sea-ice coverage has shrunk 15–20 percent during the last 30 years. The ice is thinner and less concentrated, and the ice edge has retreated northwards.	From half to all of the summer sea ice could disappear by 2100, with an average 10–50 percent reduction in the year-round ice coverage.
Ocean levels are rising, and seawater is becoming less salty and more acidic.	Ocean levels in the Arctic and the rest of the world have risen 10–20 cm during the last century.	Sea levels will rise 10–90 cm globally during the next century and that the rate of increase will accelerate with time. The greatest increase will occur in the Arctic.
	The salinity and density of seawater in the Arctic and North Atlantic have decreased due to the influx of fresh water.	Seawater salinity will continue to fall as continually more freshwater flows into the sea.
	The sea is more acidic, a phenomenon researchers believe is caused by increased absorption of carbon dioxide.	The ocean will become more acidic as CO_2 concentrations in the atmosphere continue to increase.
The ozone layer is thinning, and ultraviolet radiation is increasing.	The ozone layer over the Arctic has thinned by about 7 percent each year since 1979. A spring-time reduction of 25 percent has occurred during seven of the last nine years.	The ozone layer will continue to thin significantly in the decades to come. UV radiation will be 90 percent higher in 2010–2020 than it was in 1972–1992.

changes for some species in the food web can cause adverse consequences for the entire ecosystem. For example, mosses and lichens, which are especially sensitive to warming, constitute the foundation of several food webs, such as for reindeer.

A downward spiral of less snow and ice cover and increased warming

Snow and ice reflect much of the solar energy the Earth receives in the Arctic. When they melt, the landmass becomes darker and the sea is exposed. These absorb much more of the incoming solar energy, leading to a further rise in temperature.

The sun's warmth that is absorbed by the sea in the summer is easily transferred to the atmosphere in the winter. This heat transfer is more prominent in the Arctic than in other parts of the world because the Arctic atmosphere is thinner.

Increased absorption and release of greenhouse gases

Increased temperature in the Arctic sets in motion processes that both take up and release greenhouse gases. On the one hand, a warming can contribute to carbon-dioxide absorption by expanding the extent of Arctic forests. Forests absorb and store more CO_2 than tundra or the polar desert. It is also expected that a reduction in sea ice will enable the Arctic Ocean to absorb much more CO_2 than it does today.

On the other hand, large quantities of carbon and methane are bound up in the permafrost, and its thawing will release these gases. Large quantities are also stored in so-called methane hydrate deposits found in cold sea-bed sediments. A temperature increase may cause these deposits to decompose, causing a large release of methane to the atmosphere.

The net effect remains largely uncertain, though new studies suggest the warming effect will be the greatest.

Effects on fish and marine ecosystems

A complex interplay between several mechanisms effects fish stocks and their behaviour. Temperature, food access and individual spawning areas are three central factors, and a change in climate could affect all of them. However, there is great uncertainty regarding how the fish will react.

The leading expectation among researchers is that we will see both expansions and localizations of different fish species in the Arctic over the next 50 to 70 years.

Capelin, herring and cod stocks are expected to draw to the north and east in comparison to their locations today, and the stocks could increase. Species such as mackerel and blue whiting may move northwards into the Barents Sea, where they will compete with other fish species for food. The consequences of this remain unclear.

Should the Northeast Passage become ice-free for a large proportion of the year, new fish species may invade the European Arctic from the Bering Sea, such as pollack.

A warmer atmosphere retards development of the ozone layer and increases ultraviolet radiation

A warmer atmosphere reduces the ozone layer, which is our protection against UV radiation. The ozone hole is a phenomenon which occurs in the polar regions, exposing plants, animals and humans to more radiation there than in other parts of the world. Furthermore, warming melts snow cover, which provides an important additional protection layer for Arctic plants and animals.

Snow cover provides an important protection layer for Arctic plants and animals in their early growth stages. Warmer temperatures will reduce the snow cover, exposing them to more damaging ultraviolet radiation. Humans will also receive steadily more UV radiation. The next generation in the Arctic will be exposed to at least 30 percent more UV radiation than previous generations.

The sea is becoming more acidic

The oceans have absorbed half of all the carbon dioxide stemming from human activities during the last 200 years. In the sea, CO_2 is transformed into a weak carbonic acid, and now the oceans are in danger of become too acidic.

Increased acidity weakens and threatens a variety of small organisms, such as zooplankton and small shellfish, which form the foundation for the entire marine food chain. This is of particular concern for the Barents Sea fisheries, whose abundance is dependent upon the plankton.

Changes in seawater salinity and density can lead to a change in ocean currents

Warm tropical water is conveyed northwards by the North Atlantic Drift—the European branch of the Gulf Stream—to the coast of Norway. In the Arctic, the surface water becomes cold and more saline as the sea ice forms. This water is denser than the warm, tropical water, and sinks down to the bottom. The formation of this bottom-water draws the warm water further northwards.

Warming in the Arctic leads to more rain, greater

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melting of snow and ice, and greater discharge of freshwater from rivers to the sea. This could reduce the salinity and density of Arctic surface water, which could disrupt the formation of the deep bottom-waters. This in turn could weaken the North Atlantic Drift, or in the worst case cause it to stop altogether. If this were to occur, the average temperature in Norway and other European countries could drop dramatically.

Consequences for commercial activities

Better conditions for agriculture and forestry, new species and more insects

Agriculture in the Arctic is relatively modest. Longer and warmer growth seasons, along with more precipitation, would improve crop production, making commercial agriculture more economically viable. Forests are also likely to expand and establish themselves in new areas, leading to new opportunities in the commercial forestry sector. However, one must also expect that undesirable plant, animal and insect species will establish themselves in the Arctic, posing new challenges for agriculture and forestry.

Thawing permafrost can damage infrastructure

Roads, pipelines, buildings, utility lines and other infrastructure in the Arctic can be destabilized as the permafrost thaws. Extensive improvements and reconstruction of existing infrastructure may be necessary, and different techniques may be required for the building of new infrastructure.

Less sea ice will increase marine transport and access to resources

Sea ice currently limits the commercial usefulness of the Northeast Passage (across Russia) and the Northwest Passage (through the Canadian Arctic archipelago) as regular, year-round marine transport routes. As the sea ice continues to reduce in its extent and thickness, the likelihood of profitable, year-round transit use increases, especially for Russia's Northern Sea Route. It may even make possible routine voyages across the Central Arctic Ocean.

A reduction in ice cover will also open large areas to resource exploration and development—for both living and mineral resources. This may increase interest in jurisdiction over marine resources in the Arctic, even though much of the Arctic Ocean already lies within the coastal jurisdictions of Canada, Denmark (Greenland), Norway, Russia and the United States.

Changes in fisheries and aquaculture

Changes in the location, distribution and migration of fish stocks could have significant effects on the commercial fisheries. Stocks may move from the coastal jurisdiction of one state to that of another, potentially changing rights of access to a particular fishery. Other stocks may move outside the jurisdiction of any state, which could complicate prudent fisheries management and lead to uncontrolled fishing.

For the aquaculture industry, a small increase in temperature could increase growth rates for some fish, such as salmon. However, fish can only accept a small increase before the temperature exceeds their tolerance level, making it necessary for fish farms to relocate to cooler waters.

Storms, precipitation and ocean level changes will have effects on society

Coastal infrastructure and human habitation may be in need of additional strengthening and improvements to cope with more frequent storms, greater precipitation and rising ocean levels. The fishing fleet will encounter more extreme weather, affecting in particular the small vessels operating in the Barents and Kara Seas.

Concluding remarks

The climate-change scenarios outlined here assume the consequences will increase gradually over time. However, some researchers believe climate changes will rather occur as large, abrupt upheavals, with wide-ranging consequences.

The consequences of climate change cannot be understood in isolation from the world in which they occur. They affect—and are themselves affected by—a diverse range of other environmental and societal factors.

Summarized from "Climate Change in the Arctic?" (9/2005), available (in Norwegian) at ocean-futures.com

Maps with full colour version are available at www.dnak.org

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About FOCUS NORTH

This series of short fact sheets will cover current issues on developments in The High North. The first 10 issues are written by experts from Ocean Futures, www.ocean-futures.com The series can also be downloaded from the web, www.dnak.org

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