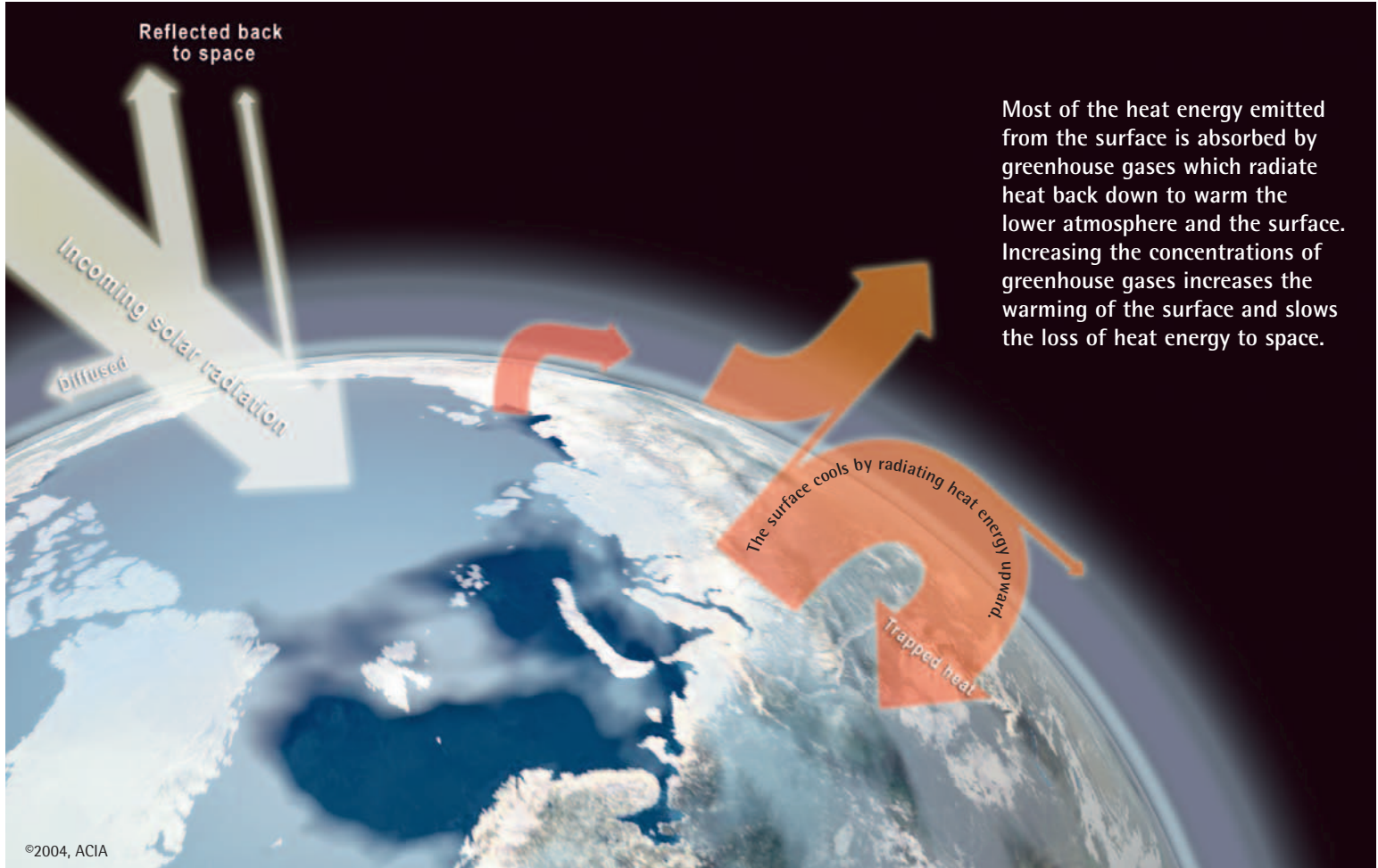




IMPACTS OF A WARMING ARCTIC

EXECUTIVE SUMMARY: Arctic Climate Change and Its Impacts

The Earth's Greenhouse Effect



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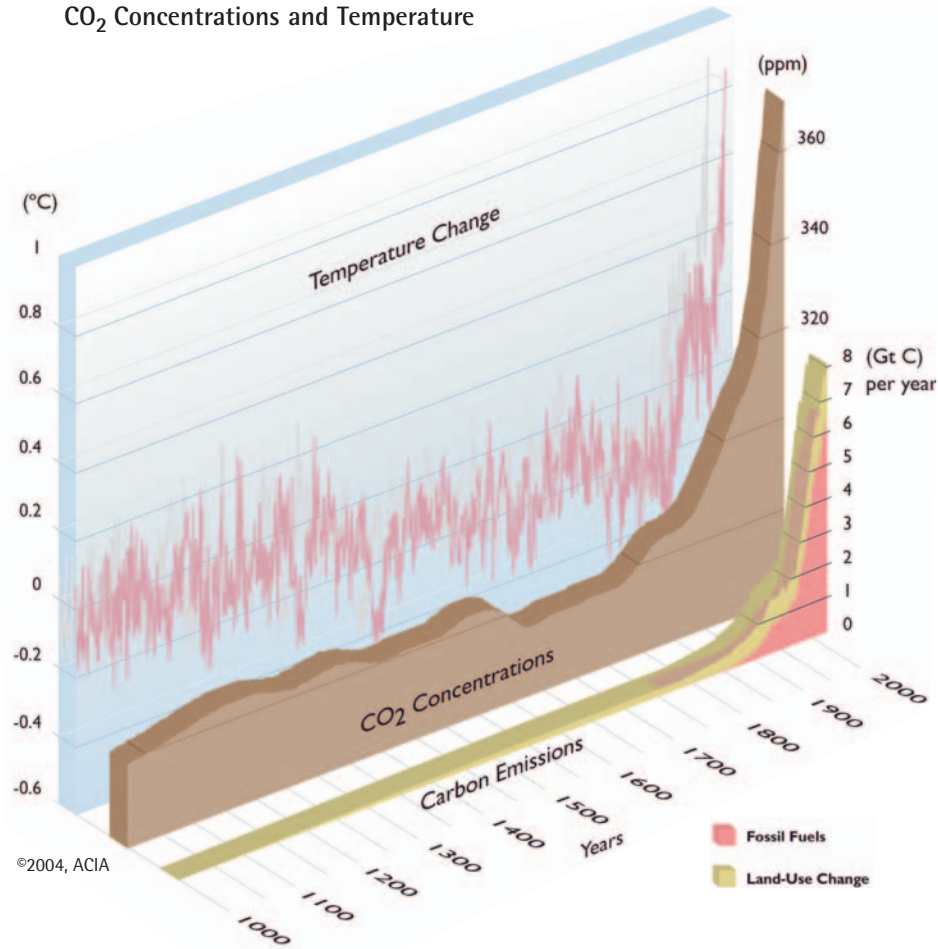
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IMPACTS OF A WARMING ARCTIC

EXECUTIVE SUMMARY: Arctic Climate Change and Its Impacts

1000 Years of Changes in Carbon Emissions,
CO₂ Concentrations and Temperature



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This 1000-year record tracks the rise in carbon emissions due to human activities (fossil fuel burning and land clearing) and the subsequent increase in atmospheric carbon dioxide concentrations, and air temperatures. The earlier parts of this Northern Hemisphere temperature reconstruction are derived from historical data, tree rings, and corals, while the later parts were directly measured. Measurements of carbon dioxide (CO₂) in air bubbles trapped in ice cores form the earlier part of the CO₂ record; direct atmospheric measurements of CO₂ concentration began in 1957.



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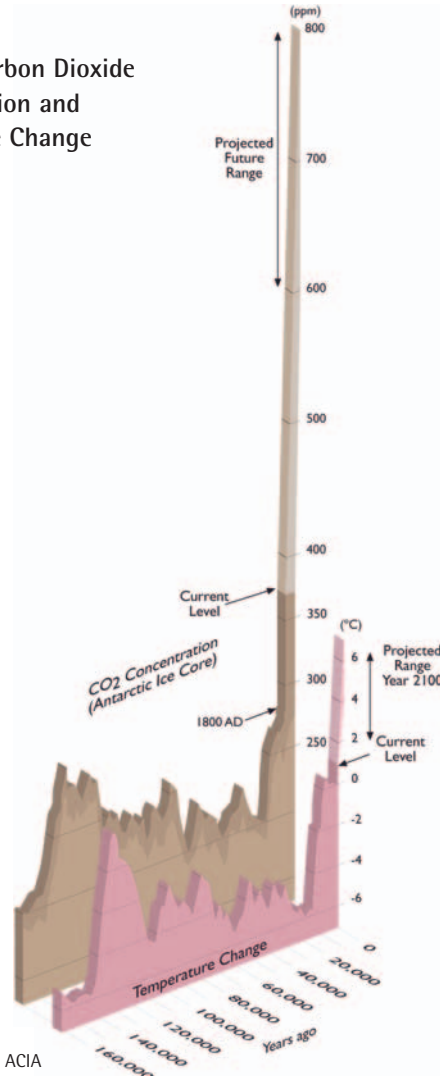
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IMPACTS OF A WARMING ARCTIC

EXECUTIVE SUMMARY: Arctic Climate Change and Its Impacts

Atmospheric Carbon Dioxide Concentration and Temperature Change



This record illustrates the relationship between temperature and atmospheric carbon dioxide concentrations over the past 160,000 years and the next 100 years. Historical data are derived from ice cores, recent data were directly measured, and model projections are used for the next 100 years.

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IMPACTS OF A WARMING ARCTIC

EXECUTIVE SUMMARY: Arctic Climate Change and Its Impacts



- Saami Council (SC)
- Russian Association of Indigenous Peoples of the North (RAIPON)
- Aleut International Association (AIA)
- Inuit Circumpolar Conference (ICC)
- Gwich'in Council International (GCI)
- Arctic Athabaskan Council (AAC)



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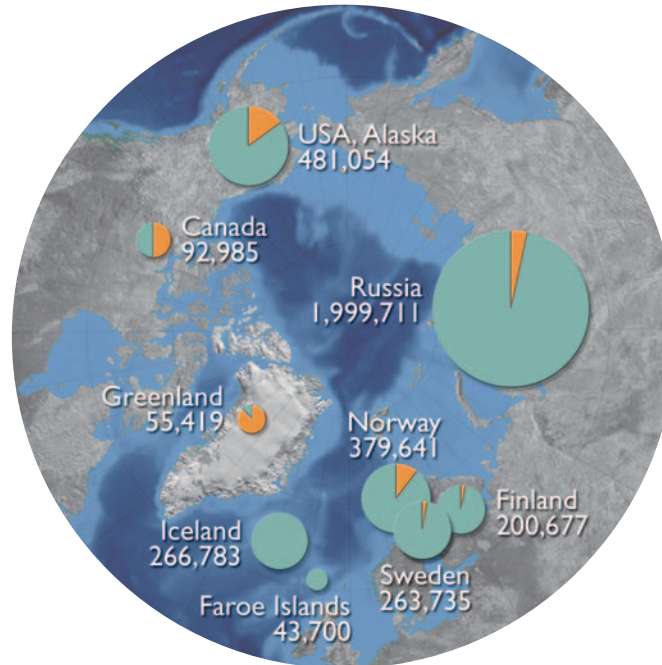
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EXECUTIVE SUMMARY: Arctic Climate Change and Its Impacts

Total and Indigenous Populations of the Arctic



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In the chart above, orange indicates the proportion of indigenous people within the populations of the arctic portions of the countries. The numbers are the total arctic populations of each country in the early 1990s. Indigenous people make up roughly 10% of the current population of the Arctic, though in the Canadian Arctic, they represent about half the population, and in Greenland, they are the majority.



IMPACTS OF A WARMING ARCTIC

EXECUTIVE SUMMARY: Arctic Climate Change and Its Impacts

Why Does the Arctic Warm Faster than Lower Latitudes?

1. As snow and ice melt, darker land and ocean surfaces absorb more solar energy.



2. More of the extra trapped energy goes directly into warming rather than into evaporation.



3. The atmospheric layer that has to warm in order to warm the surface is shallower in the Arctic.



4. As sea ice retreats, solar heat absorbed by the oceans is more easily transferred to the atmosphere.



5. Alterations in atmospheric and oceanic circulation can increase warming.



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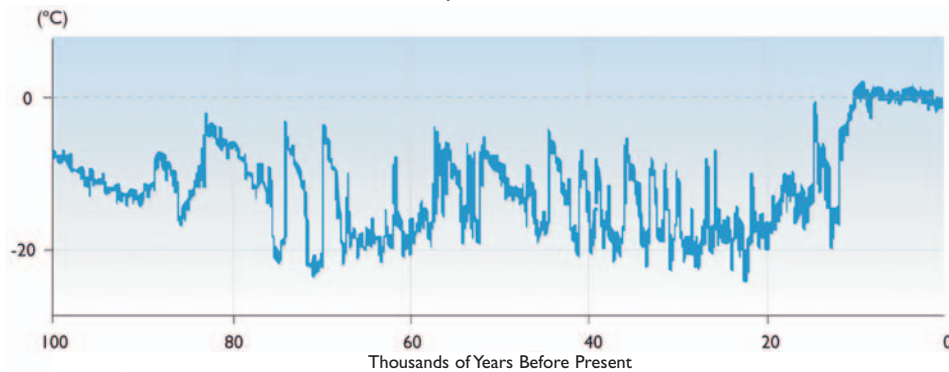
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IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

100000 Years of Temperature Variation in Greenland



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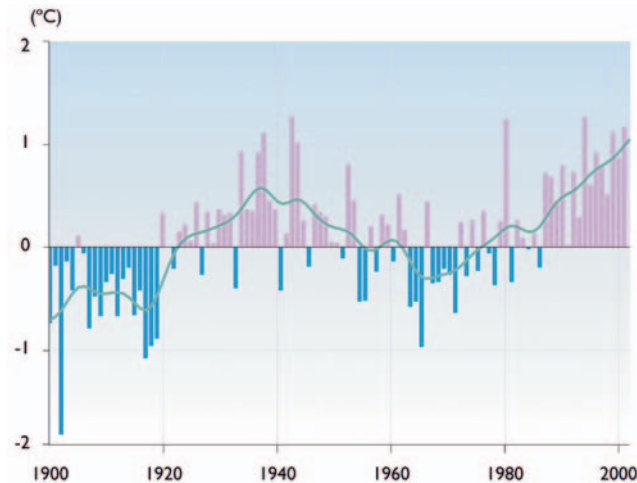
This record of temperature change (departures from present conditions) has been reconstructed from a Greenland ice core. The record demonstrates the high variability of the climate over the past 100 000 years. It also suggests that the climate of the past 10 000 years or so, which was the time during which human civilization developed, has been unusually stable. There is concern that the rapid warming caused by the increasing concentrations of greenhouse gases due to human activities could destabilize this state.



IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

Observed Arctic Temperature, 1900 to Present



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Annual average change in near surface air temperature from stations on land relative to the average for 1961-1990, for the region from 60 to 90°N.



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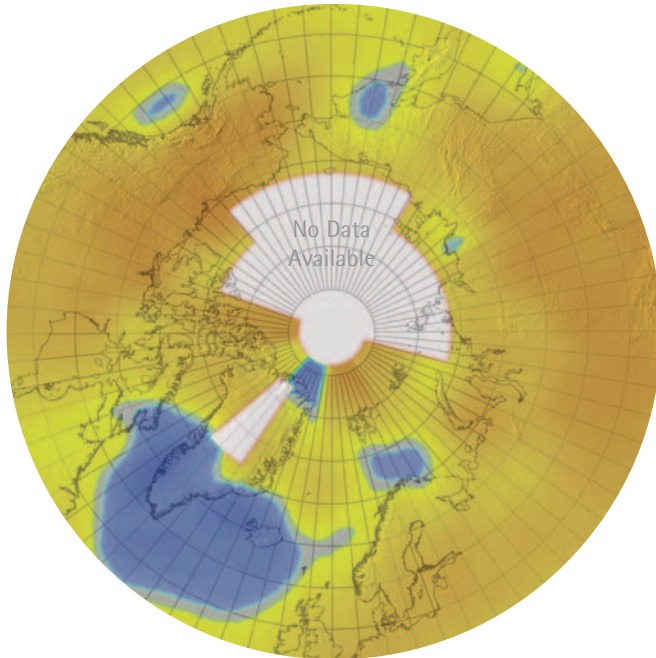
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IMPACTS OF A WARMING ARCTIC

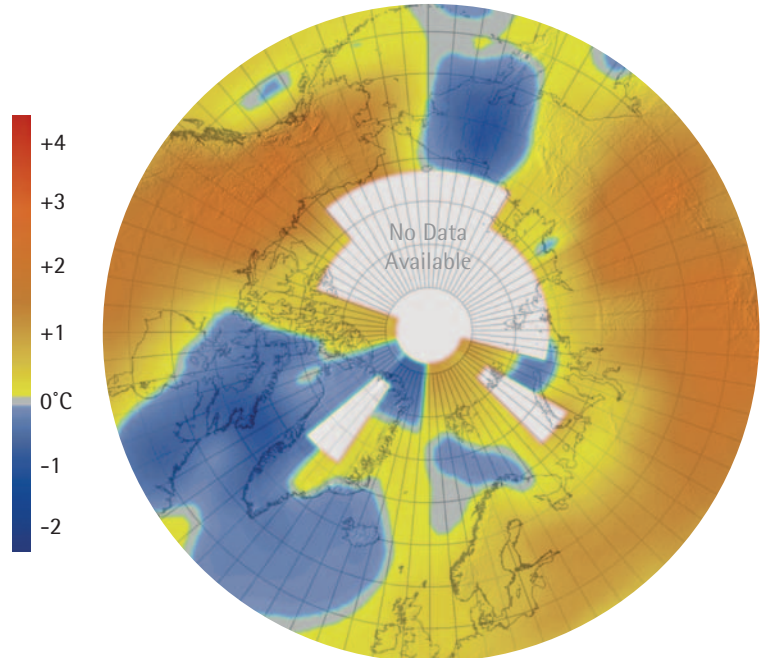
1 Arctic climate is now warming rapidly and much larger changes are projected.

Observed Surface Air Temperature Changes: 1954–2003
(ANNUAL, °C)



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Observed Surface Air Temperature Changes: 1954–2003
(WINTER: Dec-Feb in °C)



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The colors indicate the change in temperature from 1954 to 2003. The map indicates annual average temperature change, which ranges from a 2–3°C warming in Alaska and Siberia to a cooling of up to 1°C in southern Greenland.

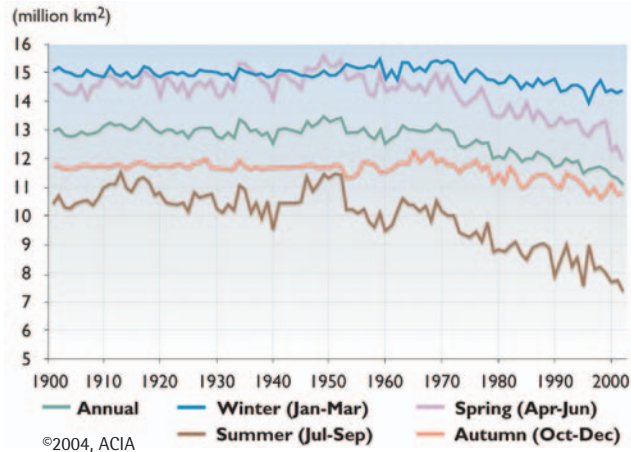
This map indicates the temperature change during the winter months, ranging from a warming of up to 4°C in Siberia and Northwest Canada to a cooling of 1°C over southern Greenland.



IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

Observed seasonal Arctic sea-ice extent (1900-2003)



Annual average extent of arctic sea ice from 1900 to 2003. A decline in sea-ice extent began about 50 years ago and this decline sharpened in recent decades, corresponding with the arctic warming trend. The decrease in sea-ice extent during summer is the most dramatic of the trends.



IMPACTS OF A WARMING ARCTIC

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Observed sea ice September 1979



Observed sea ice September 2003



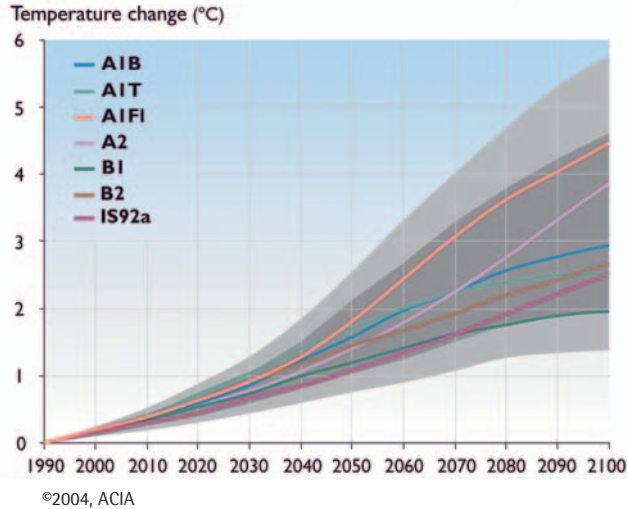
©NASA

The two images above, constructed from satellite data, compare arctic sea ice concentrations in September of 1979 and 2003. September is the month in which sea ice is at its yearly minimum and 1979 marks the first year that data of this kind became available in meaningful form. The lowest concentration of sea ice on record was in September 2002.

IMPACTS OF A WARMING ARCTIC

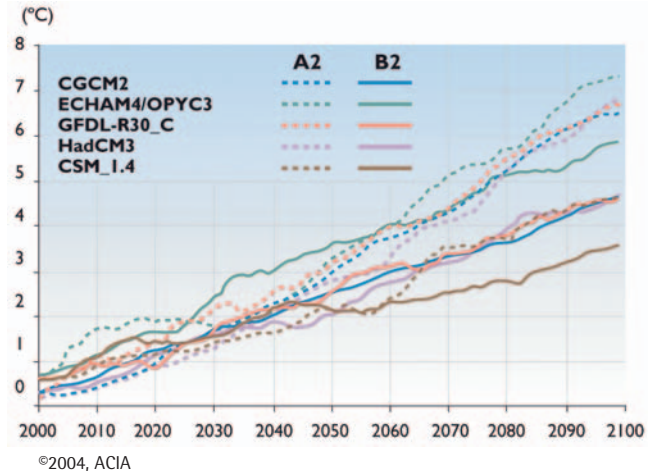
1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Global Temperature Rise



Projections of global temperature change (shown as departures from the 1990 temperature) from 1990 to 2100 for seven illustrative emissions scenarios. The brown line shows the projection of the B2 emissions scenario, the primary scenario used in this assessment, and the scenario on which the maps in this report showing projected climate changes are based. The pink line shows the A2 emissions scenario, used to a lesser degree in this assessment. The dark gray band shows the range of results for all the SRES emissions scenarios with one average model while the light gray band shows the full range of scenarios using various climate models.

Projected Arctic Surface Air Temperatures 2000–2100
60°N – Pole: Change from 1981–2000 average

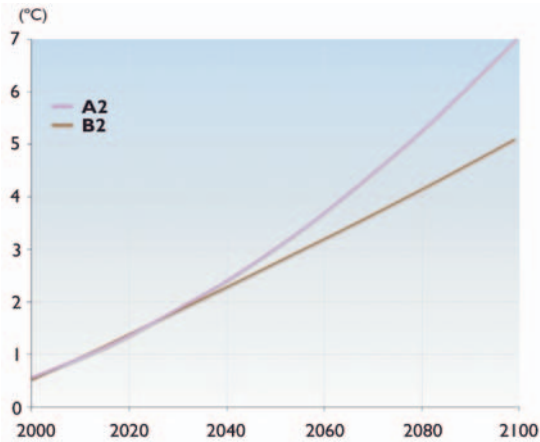


The ten lines show air temperatures for the region from 60°N to the pole as projected by each of the five ACIA global climate models using two different emissions scenarios. The projections remain similar through about 2040, showing about a 2°C temperature rise, but then diverge, showing increases from around 4° to over 7°C by 2100. The full range of models and scenarios reviewed by the IPCC cover a wider range of possible futures. Those used in this assessment fall roughly in the middle of this range, and thus represent neither best- nor worst-case scenarios.

IMPACTS OF A WARMING ARCTIC

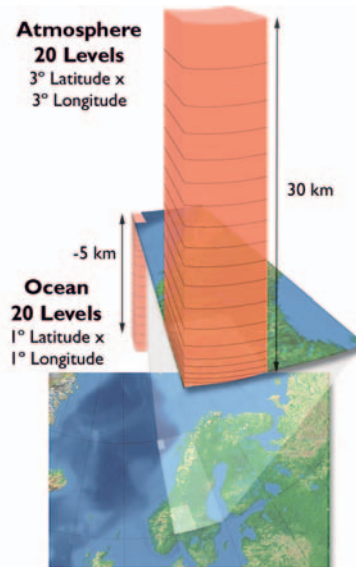
1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Arctic Temperature Rise



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Increases in arctic temperature (for 60°-90°N) projected by an average of ACIA models for the A2 and B2 emissions scenarios, relative to 1981-2000.



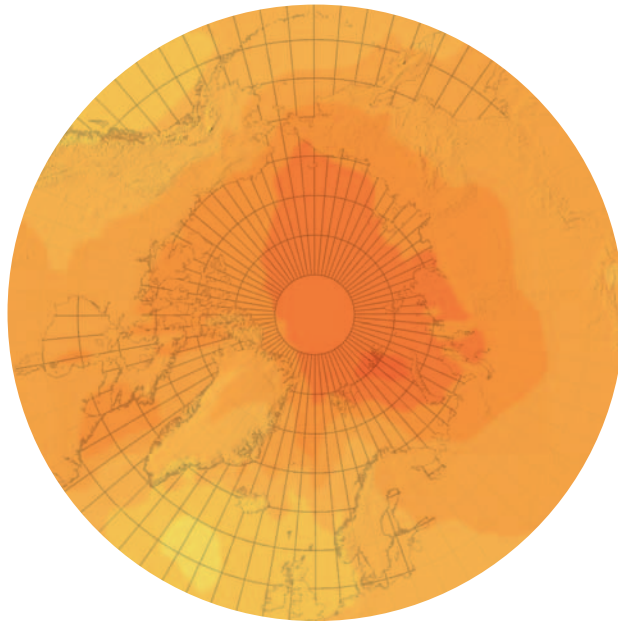
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Global climate models are computer simulations based on physical laws represented by mathematical equations that are solved using a three-dimensional grid over the globe. The models include the major components of the climate system including the atmosphere, oceans, land surface, snow and ice, living things, and the processes that go on within and between them. As illustrated in the figure, the resolution (grid size) of the global models is fairly coarse, meaning that there is generally higher confidence in larger scale projections and greater uncertainty at increasingly small scales.

IMPACTS OF A WARMING ARCTIC

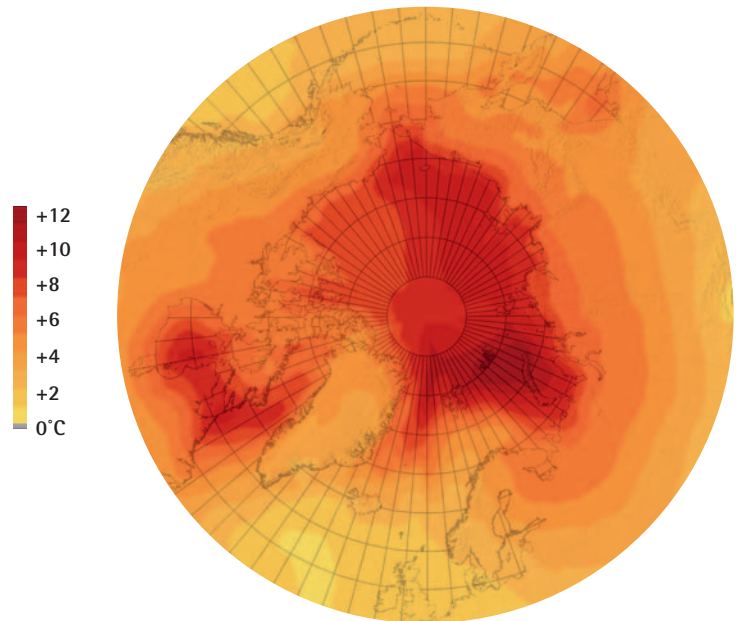
1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Surface Air Temperature Change
1990s-2090s in °C (Annual)



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Projected Surface Air Temperature Change
1990s-2090s in °C (Winter: Dec-Feb)



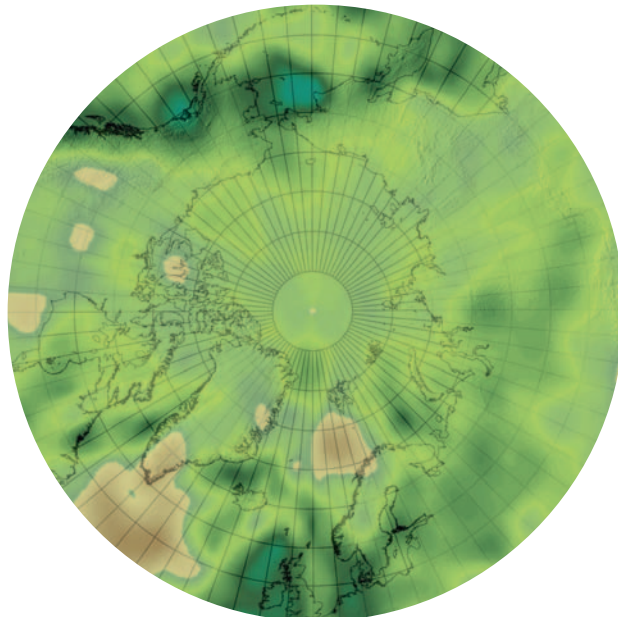
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These maps show the projected temperature change from the 1990s to the 2090s, based on the average change calculated by the five ACIA climate models using the lower of the two emissions scenarios (B2) considered in this assessment. On these maps, orange indicates that an area is projected to warm by about 6°C from the 1990s to the 2090s.

IMPACTS OF A WARMING ARCTIC

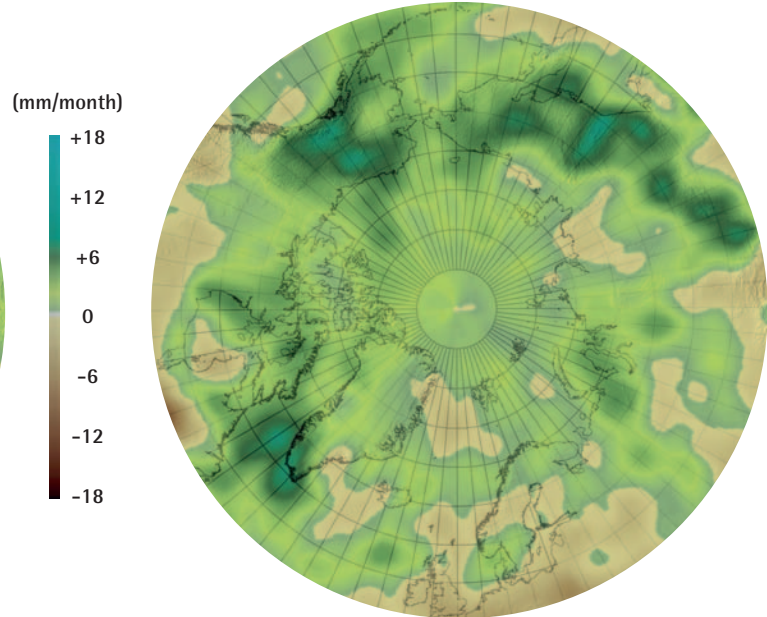
1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Precipitation Change
from 1980-1999 to 2070-2089 in mm/month (Feb)



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Projected Precipitation Change
from 1980-1999 to 2070-2089 in mm/month (Aug)



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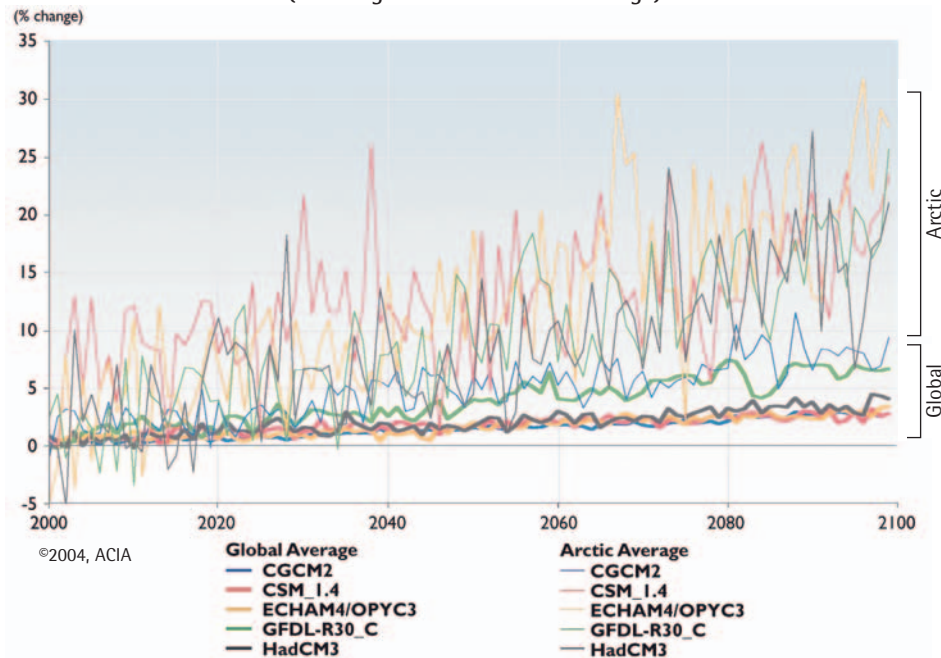
These maps show the projected precipitation change in mm per month, calculated by the ACIA climate models. On these maps, dark green indicates that precipitation is projected to increase by about six mm per month from the 1990s to the 2090s.



IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Precipitation Change
(% change from 1981-2000 average)



This graph shows percentage changes in average precipitation projected by the five ACIA climate models for the B2 emissions scenario. The heavy lines at the bottom are projected average global precipitation changes and the thinner lines above are projected arctic precipitation changes. As the results show, the precipitation increases are projected to be much greater in the Arctic than for the world as a whole. It is also apparent that the year-to-year variability is much greater in the Arctic.



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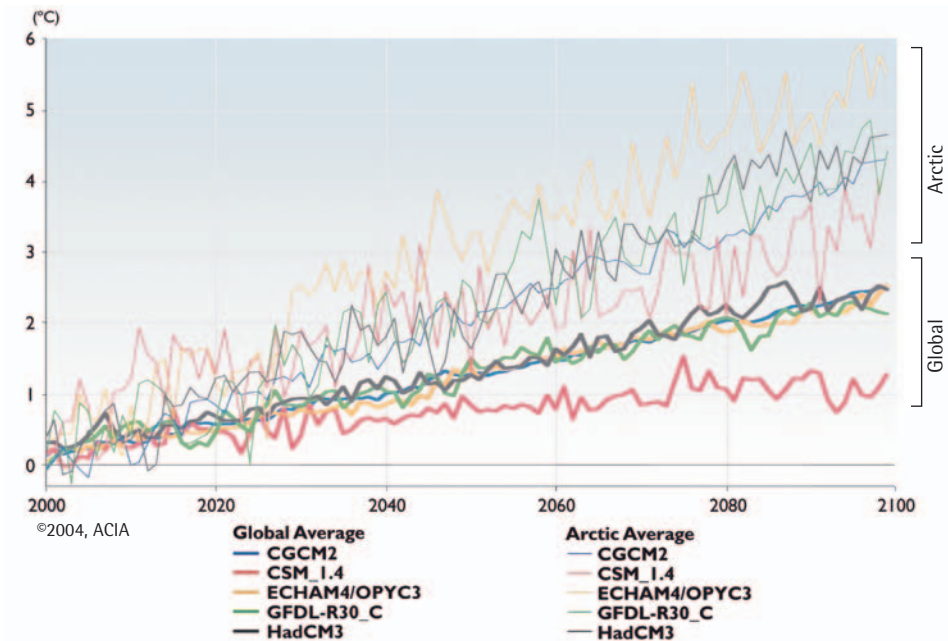
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IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Surface Air Temperature Change
(change from 1981-2000 Average)



This graph shows average temperatures projected by the five ACIA climate models for the B2 emissions scenario. The heavy lines at the bottom are projected average **global** temperature increases and the thinner lines above are the projected **arctic** temperature increase. As the results show, the temperature increases are projected to be much greater in the Arctic than for the world as a whole. It is also apparent that the year-to-year variability is greater in the Arctic.



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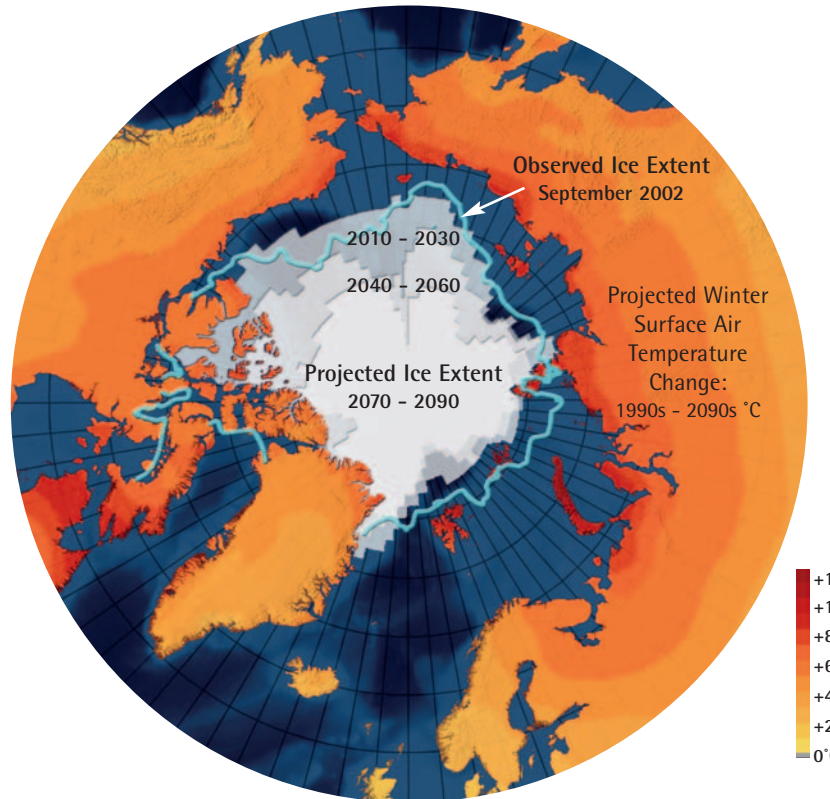
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IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Changes in Sea Ice



Sea ice has already declined considerably over the past half century. Additional declines of roughly 10-50% in annual average sea-ice extent are projected by 2100. Loss of sea ice during summer is projected to be considerably greater than the annual average decrease, with a 5-model average projecting more than a 50% decline by the end of this century, and some models showing near-complete disappearance of summer sea ice. The projected reductions in sea ice will increase regional and global warming by reducing the reflectivity of the ocean surface.

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IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

Projected Ice Extent (5-model average for September)

2010 - 2030



2040 - 2060



2070 - 2090



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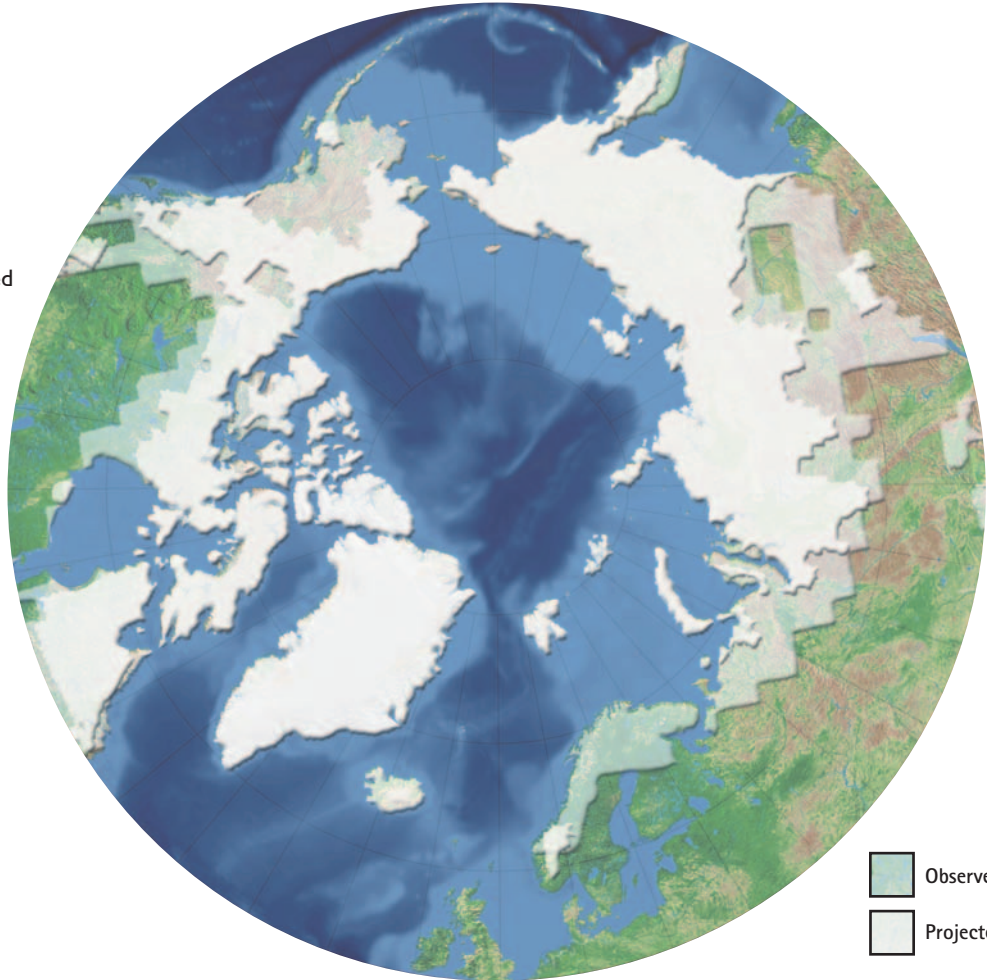
September sea-ice extent, already declining markedly, is projected to decline even more rapidly in the future. The three images above show the average of the projections from five climate models for three future time periods. As the century progresses, sea ice moves further and further from the coasts of arctic land masses, retreating to the central Arctic Ocean. Some models project the nearly complete loss of summer sea ice in this century.

IMPACTS OF A WARMING ARCTIC

1 Arctic climate is now warming rapidly and much larger changes are projected.

Snow Cover Observed and Projected (May)

May snow cover is projected to decrease substantially throughout the Arctic. The gray area in the figure shows the current extent of May snow cover. The white area is the projected area of May snow cover in the 2070 to 2090 time period based on ACIA model projections. The large-scale pattern of projected snow cover retreat in spring is apparent.

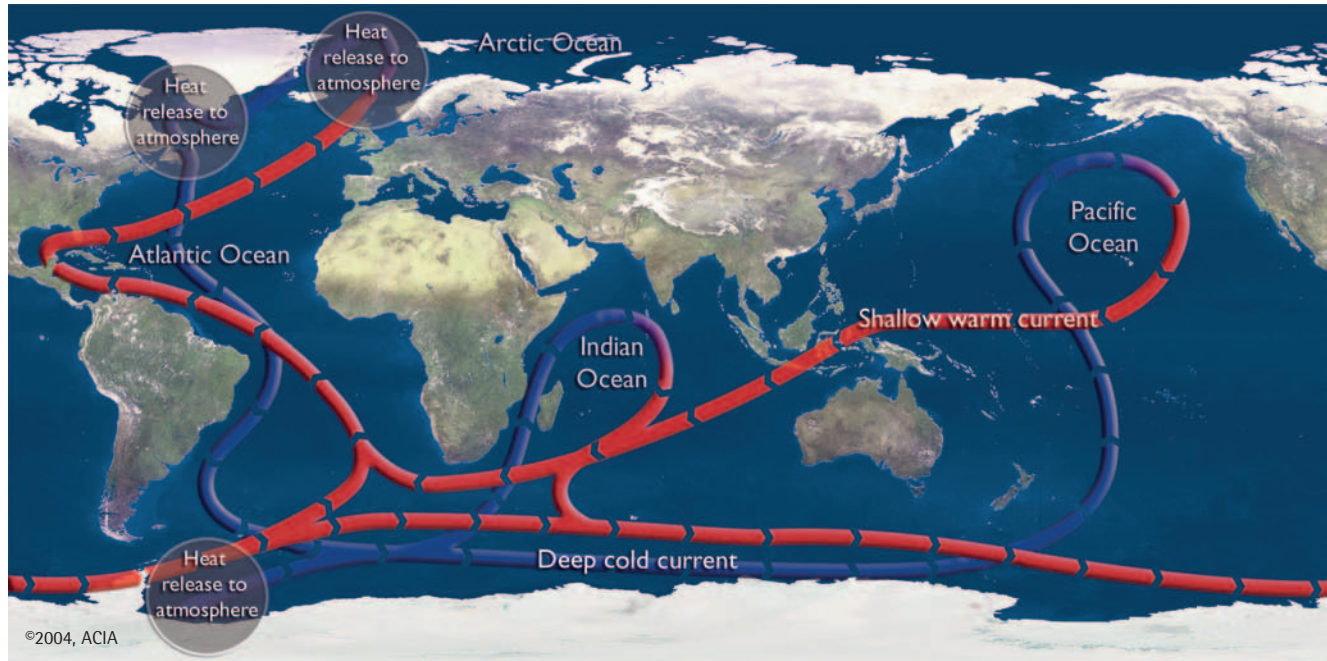


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IMPACTS OF A WARMING ARCTIC

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Global Ocean Circulation

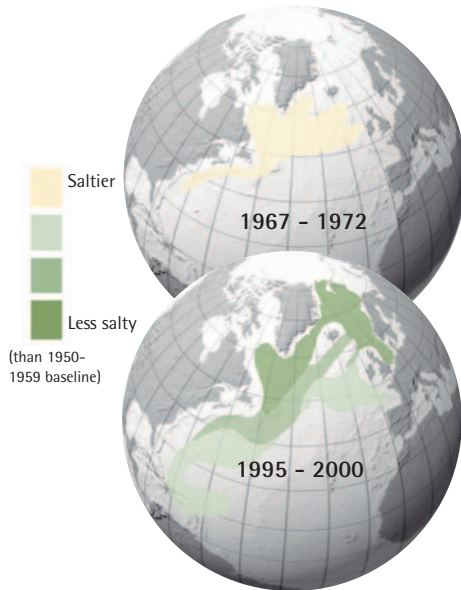


Changes in global ocean circulation can lead to abrupt climate change. Such change can be initiated by increases in arctic precipitation and river runoff, and the melting of arctic snow and ice, because these lead to reduced salinity of ocean waters in the North Atlantic.

IMPACTS OF A WARMING ARCTIC

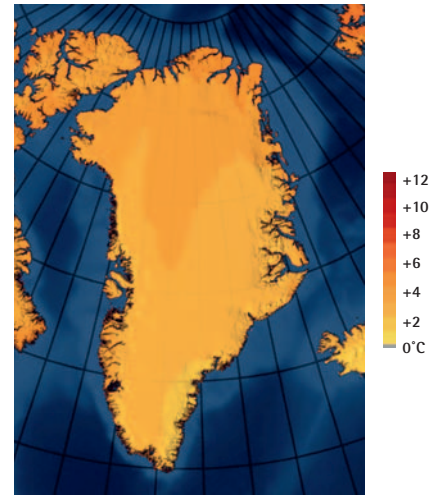
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Reduced Salinity of North Atlantic Waters



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Projected Annual Temperature Change 2070-2090



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