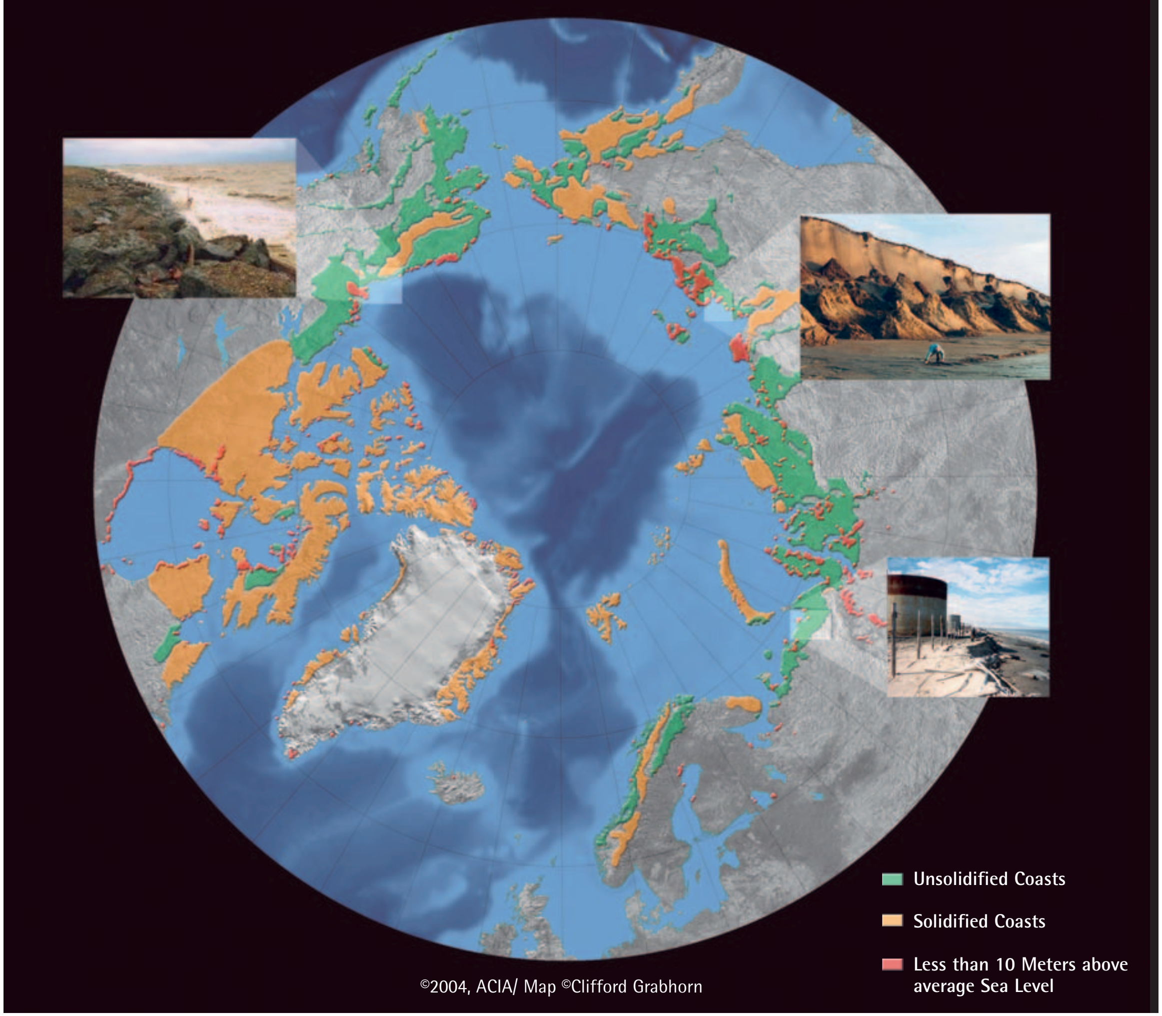
5 Many coastal communities and facilities face increasing exposure to storms.

Arctic Coastal Areas Susceptible to Erosion



The vulnerability of a coastline to erosion depends on sea level, the properties of the coastal materials, and environmental factors such as tectonic forces and wave action. Unsolidified arctic coasts (in green) containing variable amounts of ground ice, are more susceptible to erosion than solidified coasts (in orange). Unstable coastal environments are shown in the inset photographs from the Pechora, Laptev, and Beaufort Sea coasts. Tectonic forces create uplift in some places, including the Canadian Archipelago, Greenland, and Norway, and subsidence in others, such as along the Beaufort Sea and Siberian coasts. Areas (in red) in which elevation is less than 10 meters above average sea level are particularly vulnerable.

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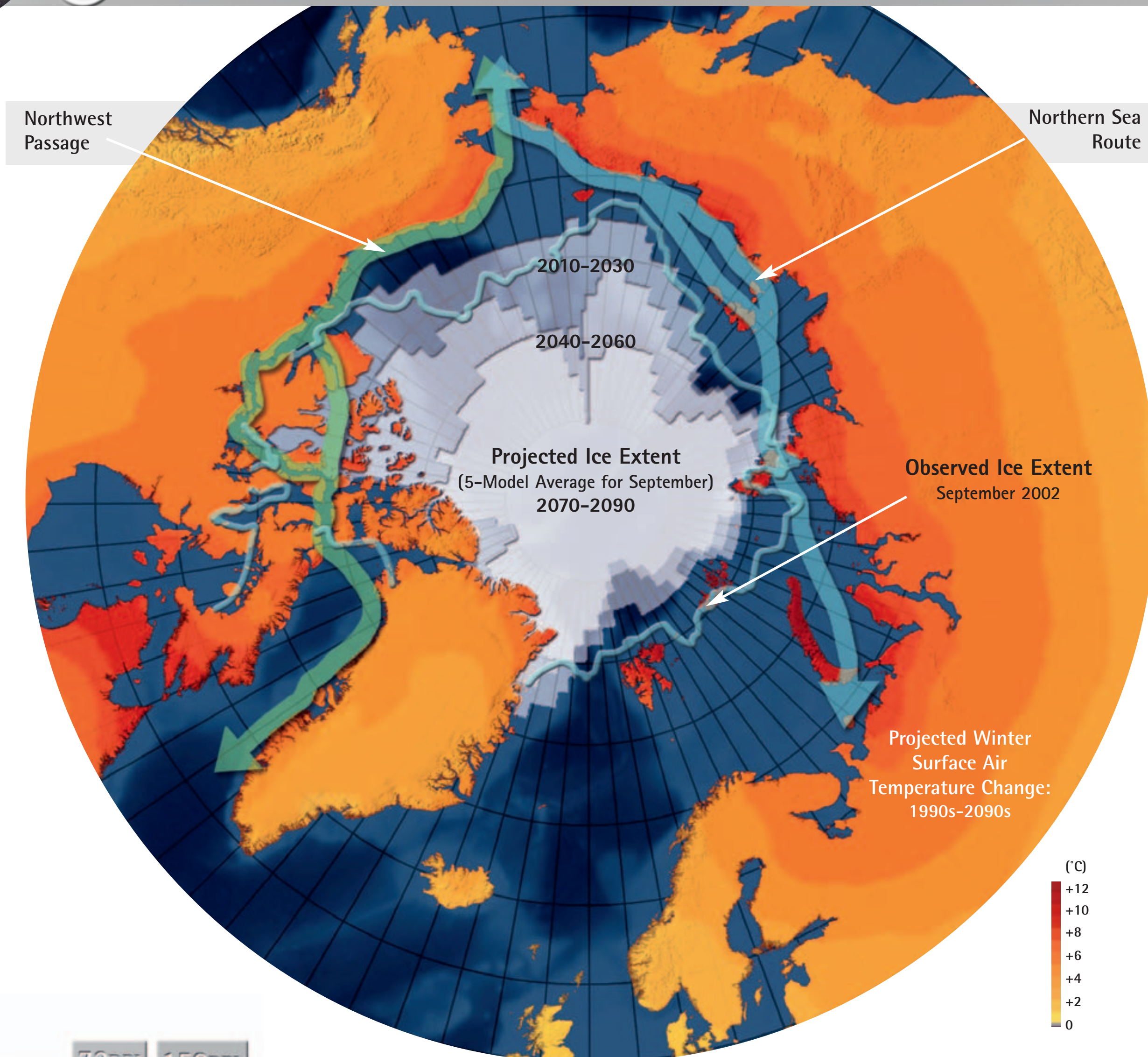
IMPACTS OF A WARMING ARCTIC

6 Reduced sea ice is very likely to increase marine transport and access to resources.



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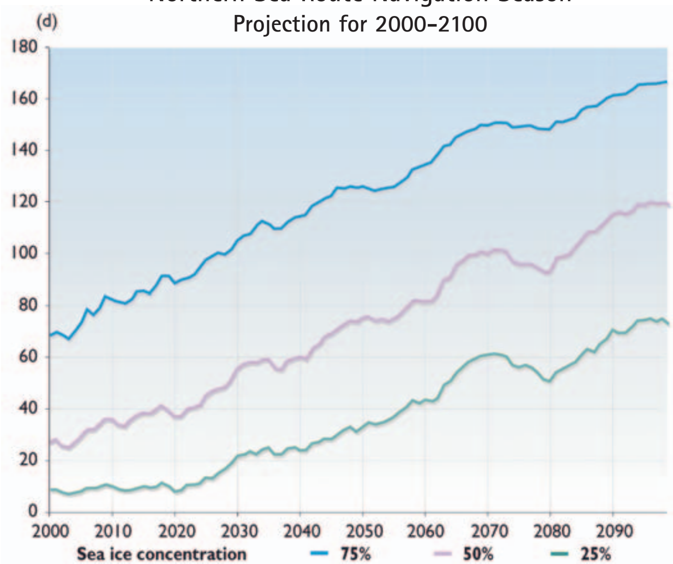
IMPACTS OF A WARMING ARCTIC

6 Reduced sea ice is very likely to increase marine transport and access to resources.

Northern Sea Route Navigation Season
Projection for 2000-2100



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The graph shows the projected increase in days of the navigation season through the Northern Sea Route as an average of five ACIA model projections.

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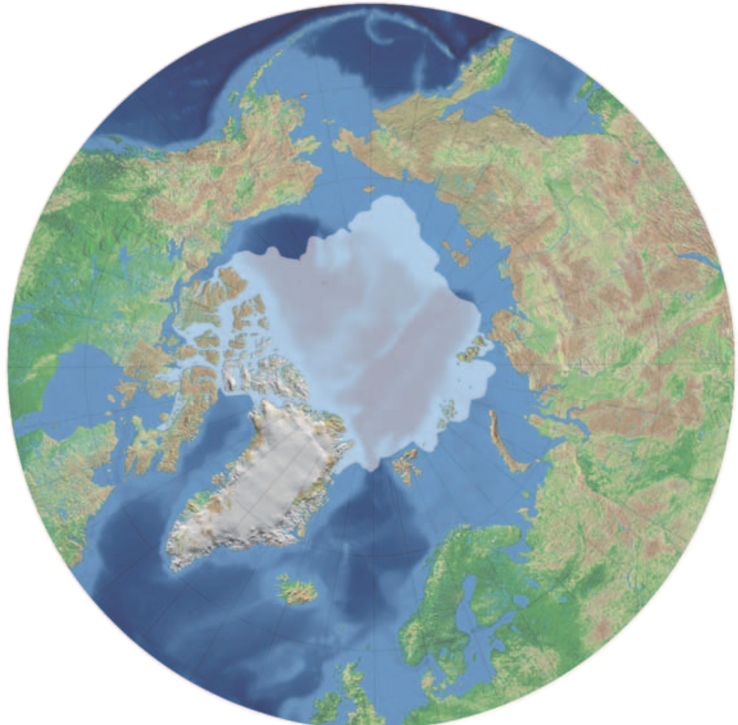
Observed Sea Ice Cover
September 16, 2002



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The satellite image of sea-ice extent for September 16, 2002 provides a good illustration of marine access around the Arctic Basin. Such low summer minimum ice extents create large areas of open water along much of the length of the NSR. The further north the ice edge retreats, the further north ships can sail in open water on trans-Arctic voyages, thereby avoiding the shallow shelf waters and narrow straits of the Russian Arctic.

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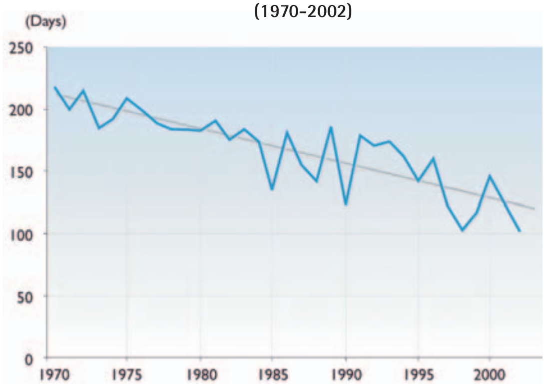
7 Thawing ground will disrupt transportation, buildings, and other infrastructure.

Alaska Winter Tundra Travel Days

(1970-2002)



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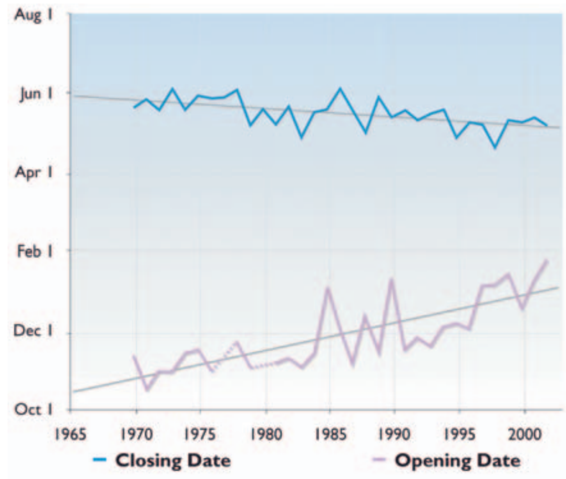
The number of days in which oil exploration activities on the tundra are allowed under Alaska Department of Natural Resources standards has been halved over the past 30 years due to climate warming. The standards are based on tundra hardness and snow conditions and are designed to protect the tundra from damage.

Opening and Closing Dates for Tundra Travel on Alaska's North Slope



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The number of travel days for oil exploration on the Alaskan tundra has been decreasing over recent decades as the opening dates come later and the closing dates come earlier.

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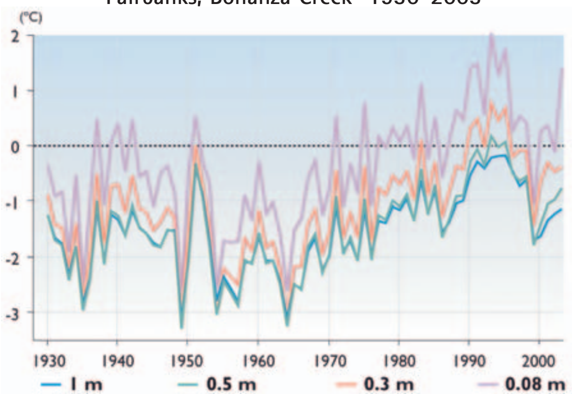
7 Thawing ground will disrupt transportation, buildings, and other infrastructure.

Average Annual Ground Temperature
Fairbanks, Bonanza Creek 1930–2003



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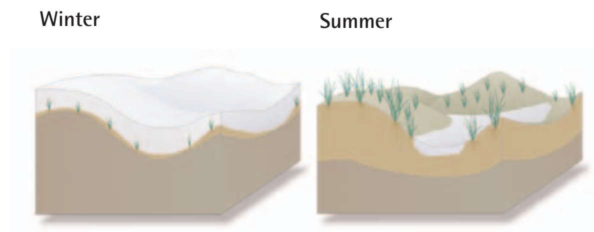
Seasonal Changes in Permafrost



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Active layer refers to the top layer of permafrost that thaws each year during the warm season and freezes again in winter.

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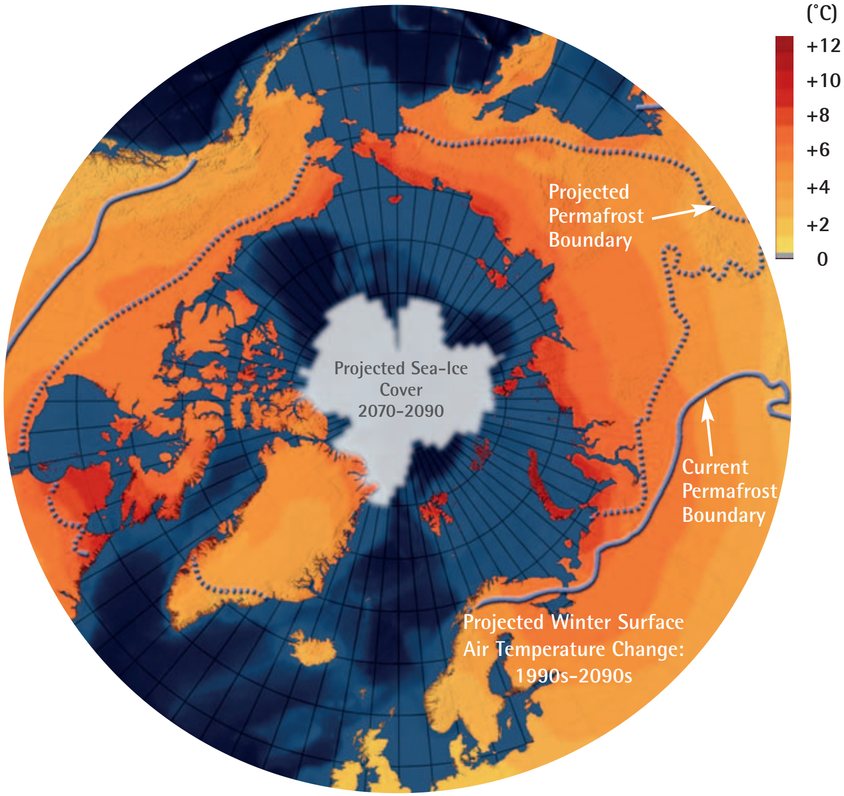
Permafrost temperatures over most of the sub-arctic land areas have increased by several tenths of a ˚C up to 2˚C during the past few decades, and the depth of the active layer is increasing in many areas. Over the next 100 years, these changes are projected to continue and their rate to increase, with permafrost degradation projected to occur over 10-20% of the present permafrost area, and the southern limit of permafrost projected to shift northward by several hundred kilometers.

Projected Change in Permafrost Boundary



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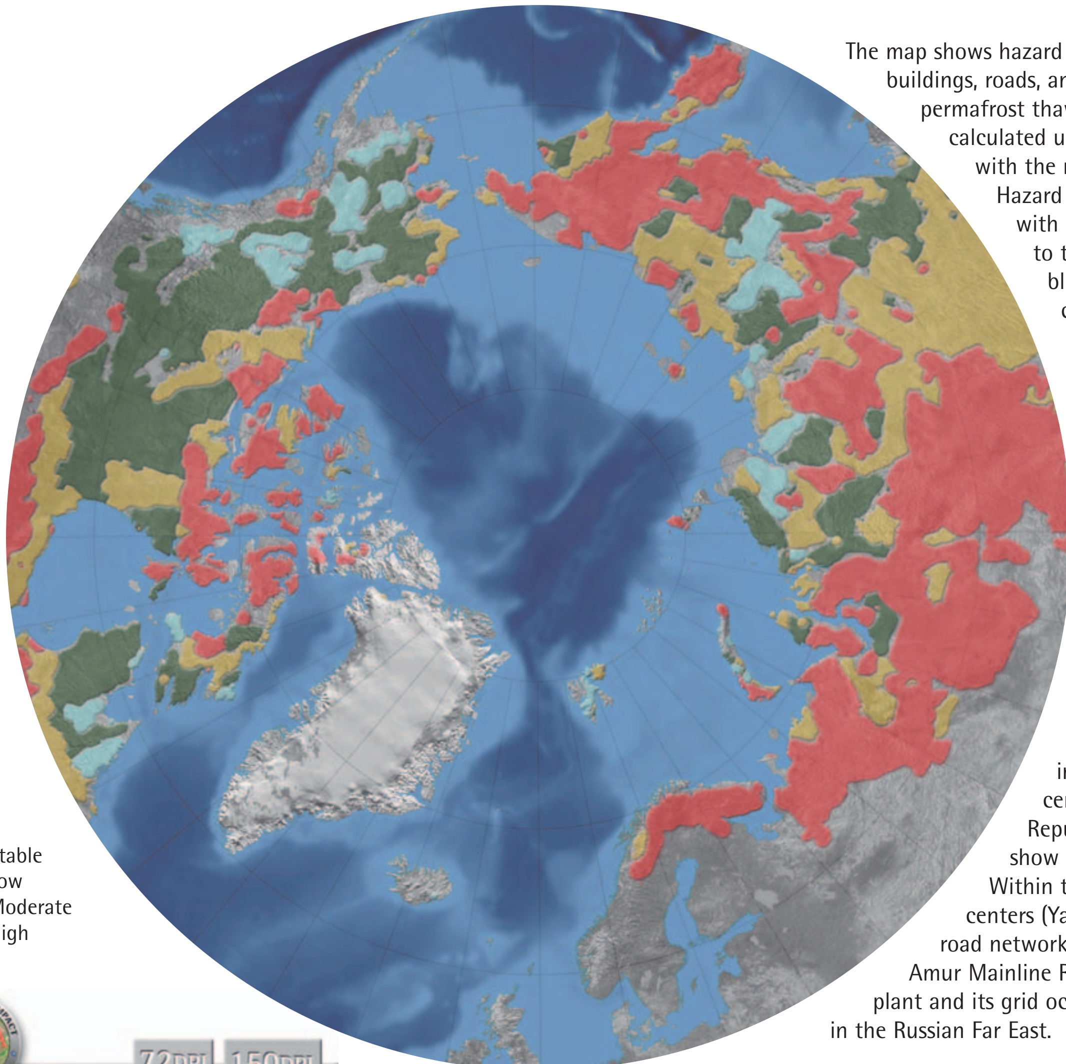
IMPACTS OF A WARMING ARCTIC

7 Thawing ground will disrupt transportation, buildings, and other infrastructure.

Infrastructure at Risk by 2050 Due to Permafrost Thaw



The map shows hazard potential by risk level for buildings, roads, and other infrastructure due to permafrost thaw by the middle of this century, calculated using the Hadley climate model with the moderate B2 emissions scenario. Hazard potential is partitioned into areas with high, moderate, and low susceptibility to thaw-induced settlement. Areas of stable permafrost, which are not likely to change, are also shown. A zone in the high and moderate risk category extends discontinuously around the Arctic Ocean, indicating high potential for coastal erosion. Also within these bands are population centers (Barrow, Inuvik) and river terminals on the Arctic coast of Russia (Salekhard, Igarka, Dudinka, Tiksi). Transportation and pipeline corridors traverse areas of high hazard potential in northwestern North America. The area containing the Nadym-Pur-Taz natural gas production complex and associated infrastructure in northwest Siberia also falls in the high-risk category. Large parts of central Siberia, particularly the Sakha Republic (Yakutia), and the Russian Far East show moderate or high hazard potential. Within these areas are several large population centers (Yakutsk, Noril'sk, Vorkuta), an extensive road network, and the Trans-Siberian and Baikal-Amur Mainline Railroads. The Bilibino nuclear power plant and its grid occupy an area of high hazard potential in the Russian Far East.

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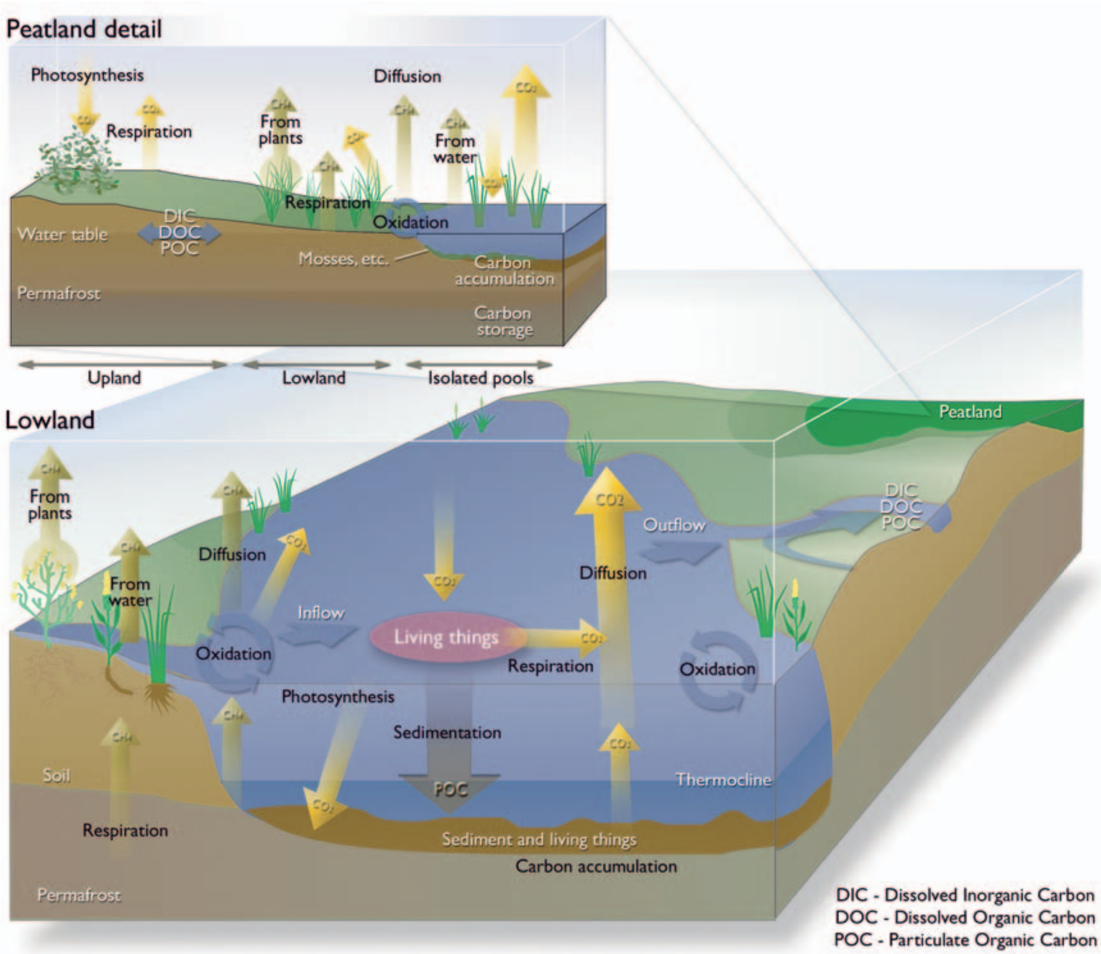
Carbon Cycling in Aquatic Ecosystems



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Simplified schematic of the cycling of carbon in high-latitude aquatic ecosystems. Arctic wetlands typically emit carbon to the atmosphere during spring melt and as plants die in autumn. They then absorb carbon from the atmosphere as plants grow during the warm season. Future changes in the release and uptake of carbon will therefore depend on changes in vegetation, temperature, and soil conditions. Similarly, carbon cycling in lakes, ponds, and rivers will also be sensitive to direct and indirect effects of climate change.

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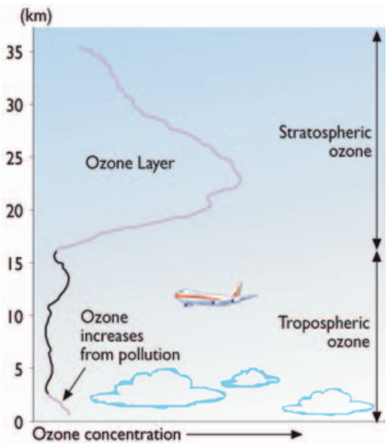
9 Elevated ultraviolet radiation levels will affect people, plants, and animals.

Ozone in the Atmosphere



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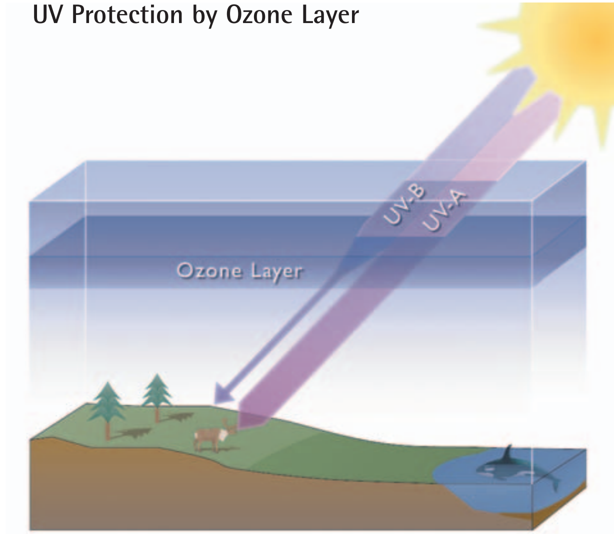
Most ozone resides in the stratosphere, relatively high above the earth's surface, where it protects life on earth from excess UV radiation. Increases in ozone levels occur near earth's surface as a result of pollution. This ground-level ozone, also known as smog, causes respiratory problems in humans and other negative impacts. The discussion in this report concerns stratospheric ozone, not ground-level ozone.

UV Protection by Ozone Layer



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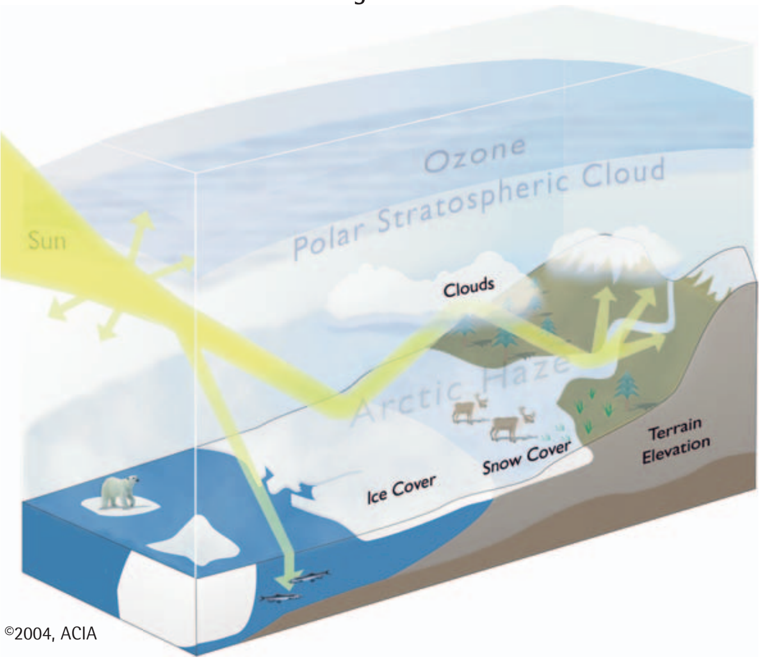
The stratospheric ozone layer absorbs some of the ultraviolet radiation from the sun. UV-B radiation is most strongly absorbed by ozone, greatly reducing the amount that reaches the earth. UV-A and other types of solar radiation are not strongly absorbed by ozone. Human exposure to UV increases the risk of skin cancer, cataracts, and a suppressed immune system. UV exposure can also damage plant and animal life on land, in the oceans, and in rivers and lakes.

IMPACTS OF A WARMING ARCTIC

9 Elevated ultraviolet radiation levels will affect people, plants, and animals.

Factors Affecting UV at the Surface



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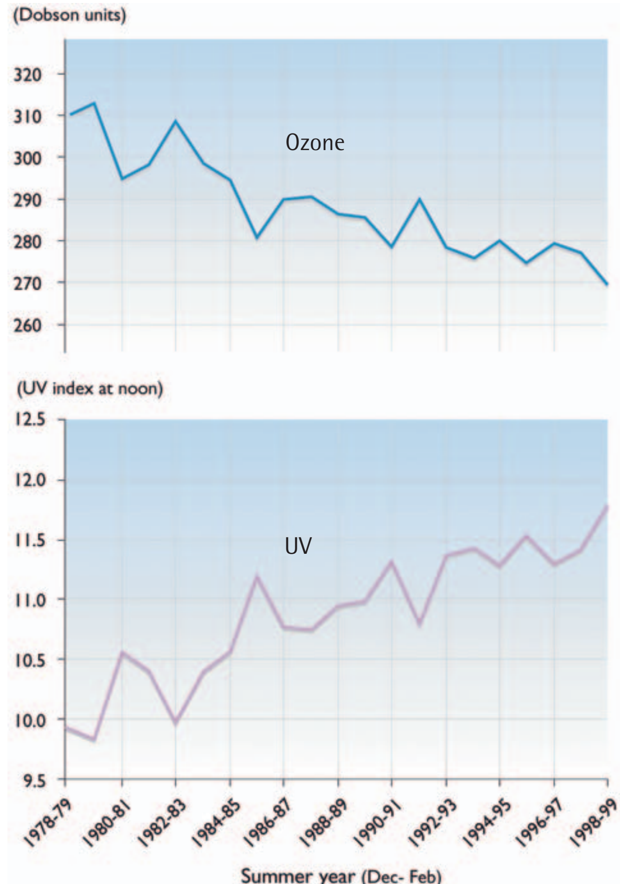
Ozone levels, clouds, the angle of the sun's rays, altitude, tiny particles in the atmosphere (which scientists refer to as aerosols), and the reflectivity of the surface (determined largely by the extent of snow cover, which is highly reflective), all influence the amount of UV reaching the surface.

This graph (right) demonstrates the well-established fact that all other factors being equal, less stratospheric ozone results in more UV radiation at the surface. Other factor salso affect UV levels, including clouds, snow, and ice, and any of these can alter this simple relationship.

As Ozone Declines, UV Rises



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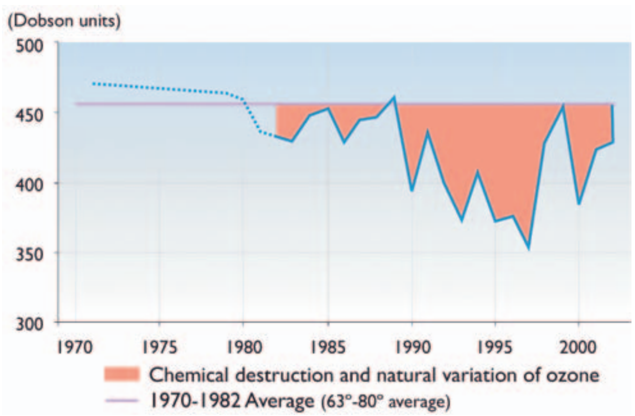
Arctic Ozone in March



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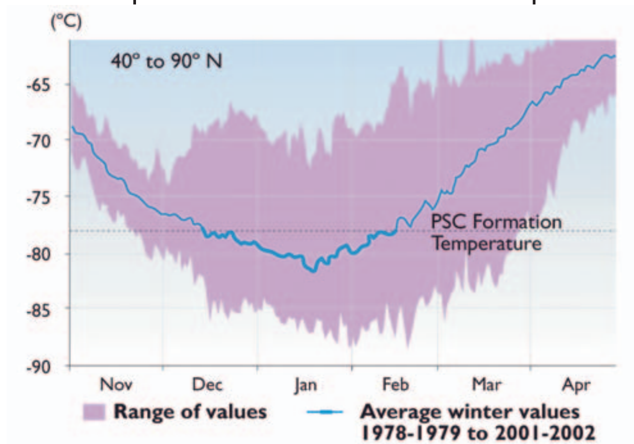
Ozone levels vary significantly from year to year. There is also a strong downward trend in ozone that is especially pronounced at the poles. This graph shows a pre-depletion average (solid red line) compared to ozone levels in more recent years. Natural variations in meteorological conditions influence the year-to-year changes, especially in the Arctic where depletion is highly sensitive to temperature. The blue line represents a monthly average in March in the Arctic. After 1982, significant depletion is found in most years.

Temperatures in the Polar Lower Stratosphere



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Over the Arctic, minimum air temperatures in the lower stratosphere are near -80˚C in January and February. Polar stratospheric clouds (PSCs) form when temperatures fall below -78˚C. The icy particles of these clouds are sites upon which ozone-destroying chemical reactions take place. Increasing concentrations of greenhouse gases, while warming the air near the earth's surface, act to cool the stratosphere, causing these clouds to form for a longer period of time, worsening ozone depletion.

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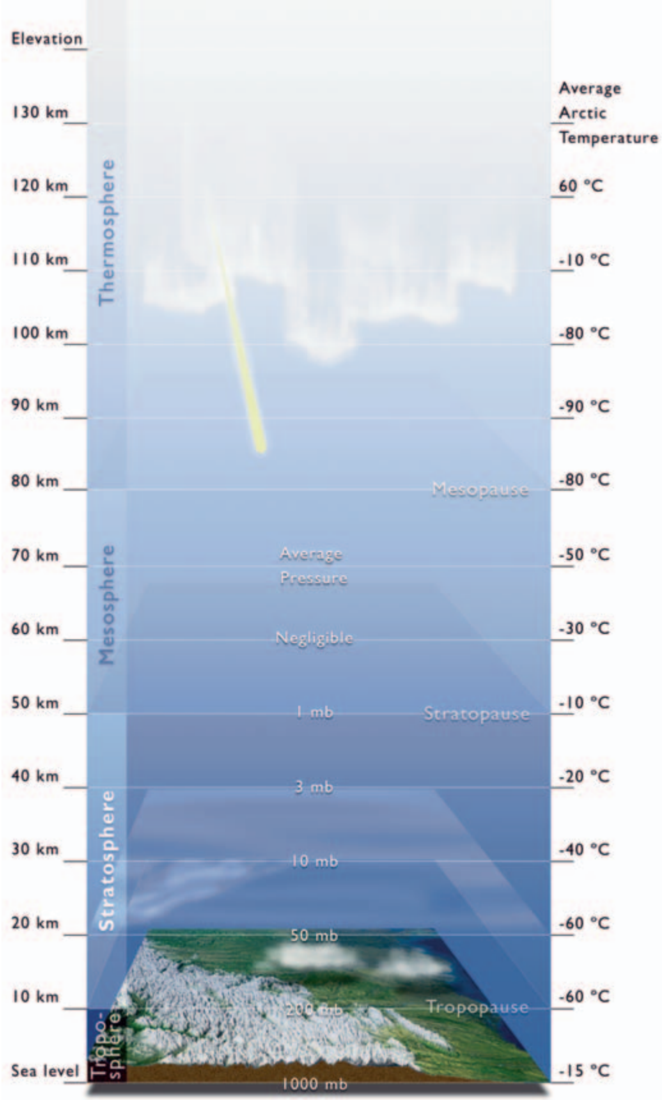
9 Elevated ultraviolet radiation levels will affect people, plants, and animals.

Layers of the Atmosphere



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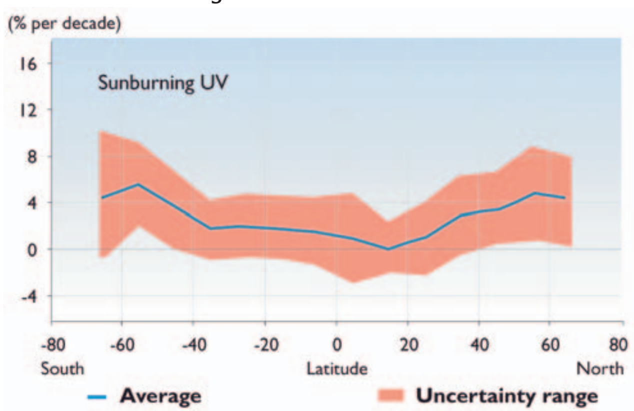
IMPACTS OF A WARMING ARCTIC

9 Elevated ultraviolet radiation levels will affect people, plants, and animals.

Changes in Surface UV Radiation



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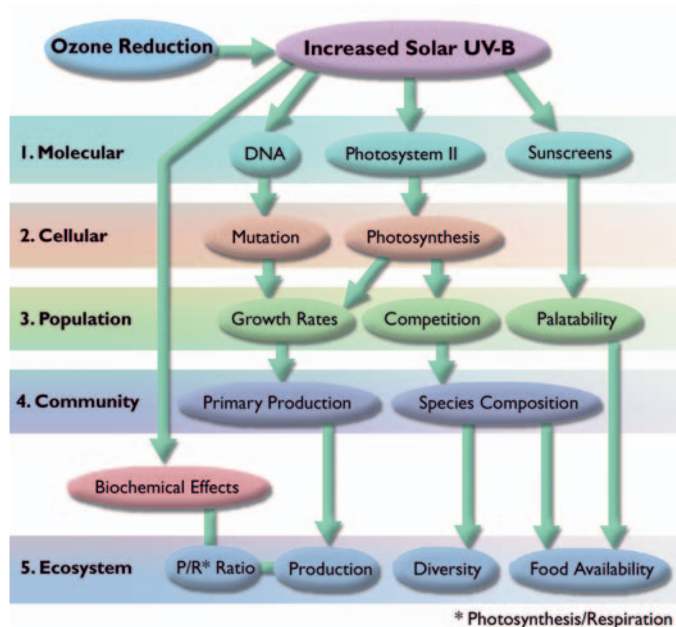
Sunburning UV has increased worldwide since 1980. The graph shows this UV at the surface, estimated from observed decreases in ozone and the relationship between ozone and UV established at various locations. The UV increases are largest near the poles because the reduction in ozone has been largest there.

Effects of Increased UV In Freshwater Ecosystems



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UV is the most reactive waveband in the solar spectrum and has a wide range of effects, from the molecular level to the level of the whole ecosystem.

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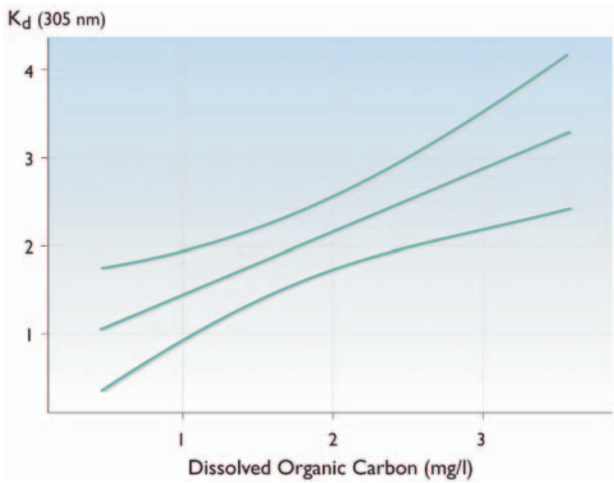
Atlantic Cod Embryos and UV



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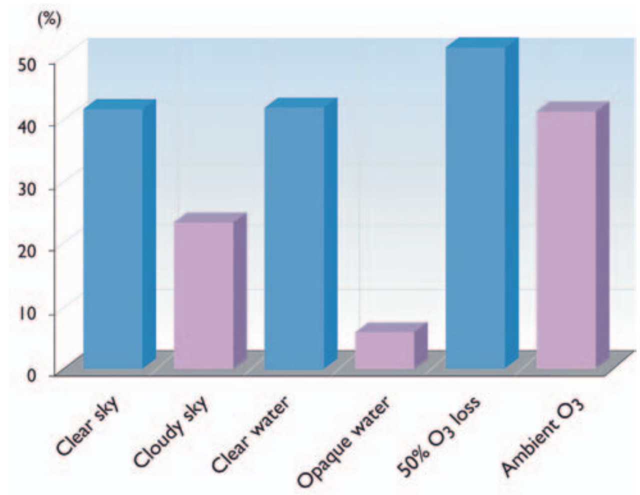
Atlantic cod embryos are sensitive to UV radiation. If protected from UV exposure, whether by stratospheric ozone, clouds, or dissolved organic carbon, their survival improves sharply. This graphic illustrates the level of protection provided by the organic matter content of the water column, with survival improving with increasing levels of dissolved organic matter. Climate change could affect levels of dissolved matter in water.

Zooplankton Embryos and UV



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Model simulations of the relative effects of selected variables on UV-induced death in *Calanus finmarchicus*. The graph illustrates that clouds, water opacity, and ozone all reduce embryo deaths due to UV, but that the opacity of the water column has the strongest protective effect of the three variables. Zooplankton are an essential part of the marine food chain.

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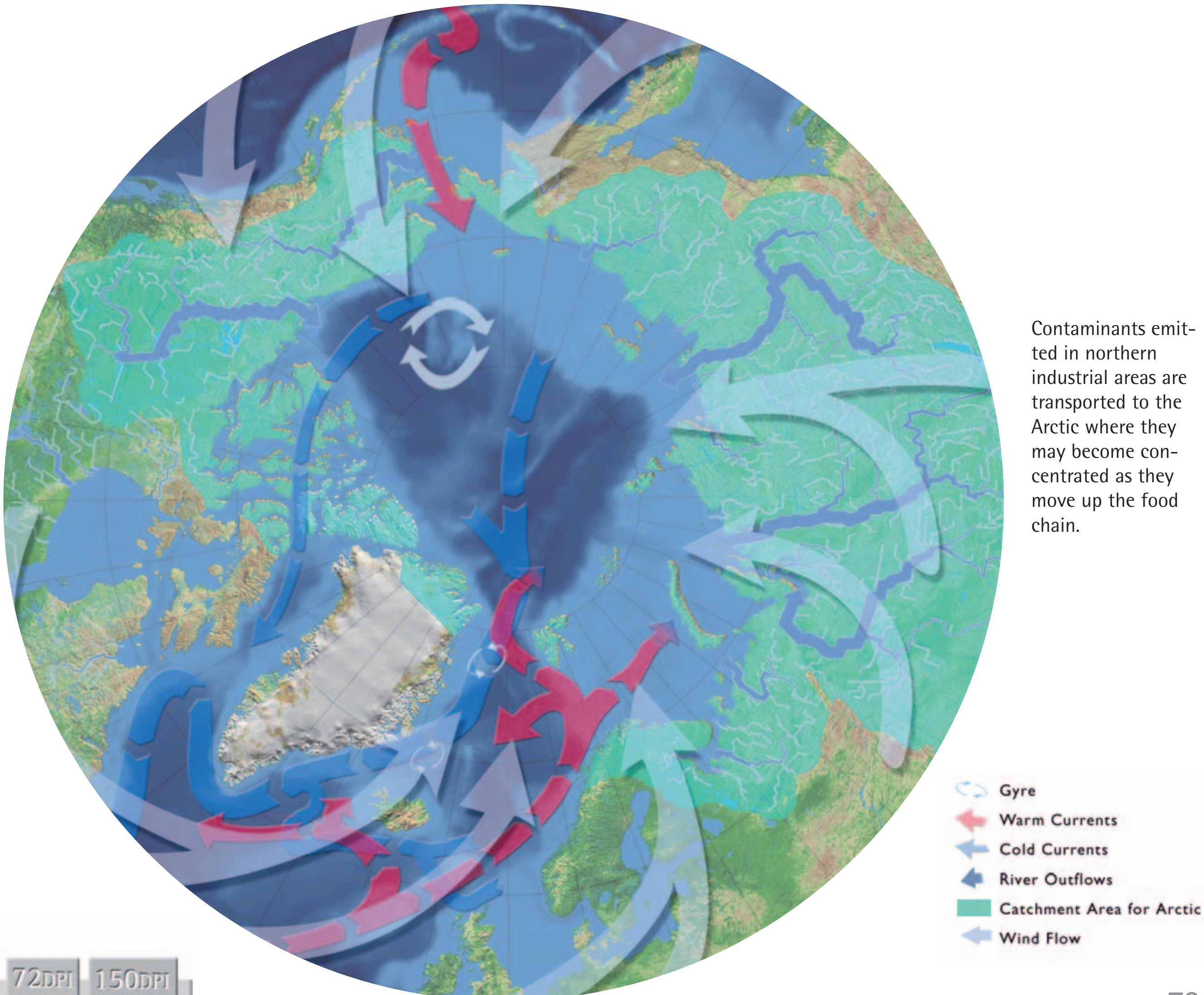
IMPACTS OF A WARMING ARCTIC

10 Multiple influences interact to cause impacts to people and ecosystems.

Wind, Rivers, and Ocean Currents Bring Contaminants into the Arctic



Contaminants emitted in northern industrial areas are transported to the Arctic where they may become concentrated as they move up the food chain.

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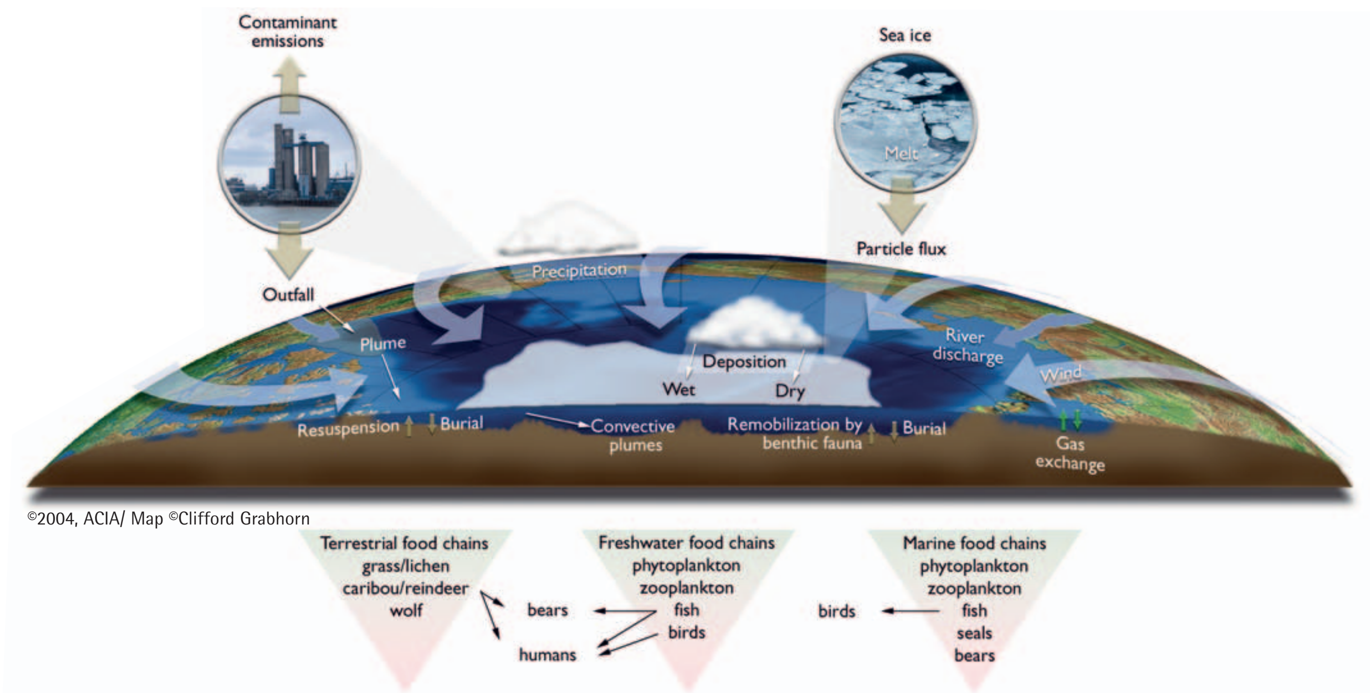
10 Multiple influences interact to cause impacts to people and ecosystems.

Contaminant Pathways



Contaminants including persistent organic pollutants and heavy metals transported to the Arctic from other regions are among the major environmental stresses that interact with climate change.

West Nile Virus Change in Canada

2001 | 2002 | 2003

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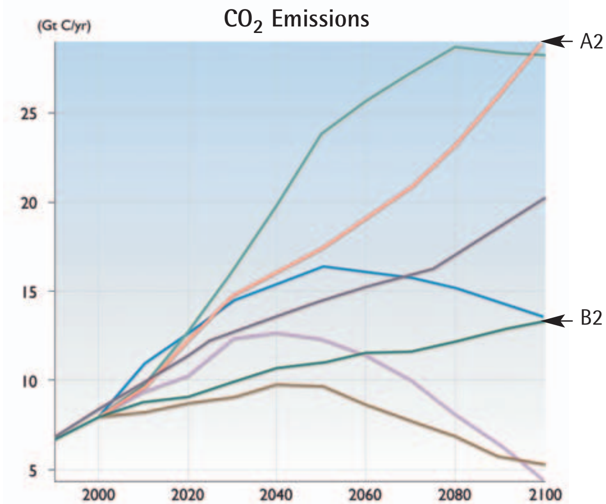
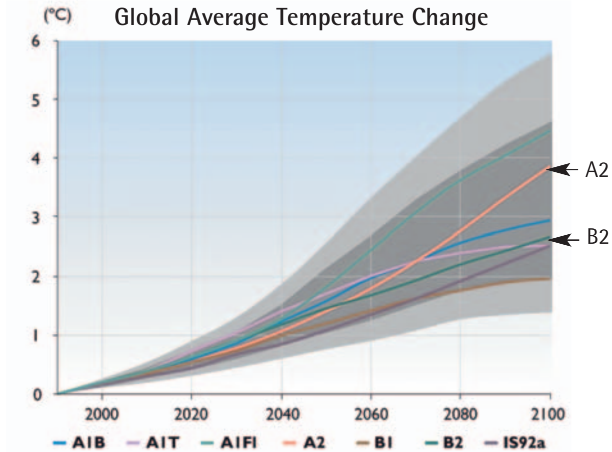
Dead Birds Submitted for Testing

Tested Positive for West Nile Virus

The West Nile encephalitis virus is a recent example of how far and fast a disease can spread once it becomes established in a new region. The West Nile virus can infect many bird and mammal species (including humans) and is transmitted by mosquitoes. It was first identified on the East Coast of North America in 1999 and spread to 43 states and six Canadian provinces by 2002. Migratory birds are responsible for its spread to other regions. Mosquitoes spread the virus to other birds (as well as to other animals and humans) within a region. Although the virus originated in tropical Africa, it has adapted to many North American mosquitoes, and so far, to over 110 species of North American bird, some of which migrate to the Arctic. Mosquito species known to transmit the virus are also found in the Arctic. Climate has historically limited the range of some insect-borne diseases, but climate change and adaptive disease agents such as the West Nile virus tend to favor continued northerly expansion. Some arctic regions, such as the State of Alaska, have initiated West Nile virus surveillance programs.

Projections for Six Illustrative Emissions Scenarios





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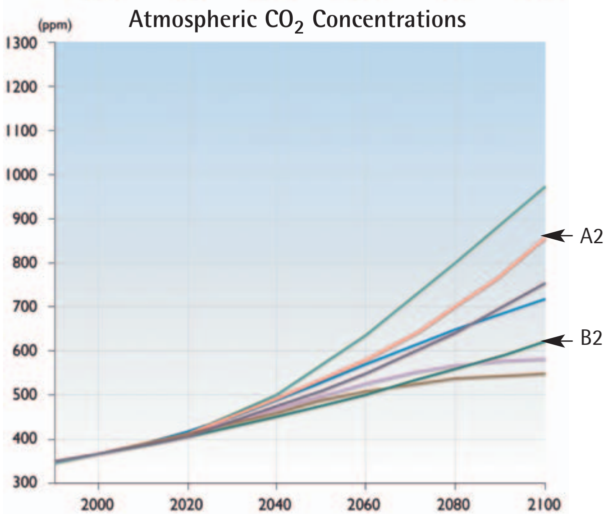

The first graph (upper left) shows projected CO_2 emissions for the six illustrative IPCC SRES scenarios. The second graph (lower left) shows the atmospheric CO_2 concentrations that would result from these emissions. The third graph (above) shows the projected temperature trends that would result from these concentrations.

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