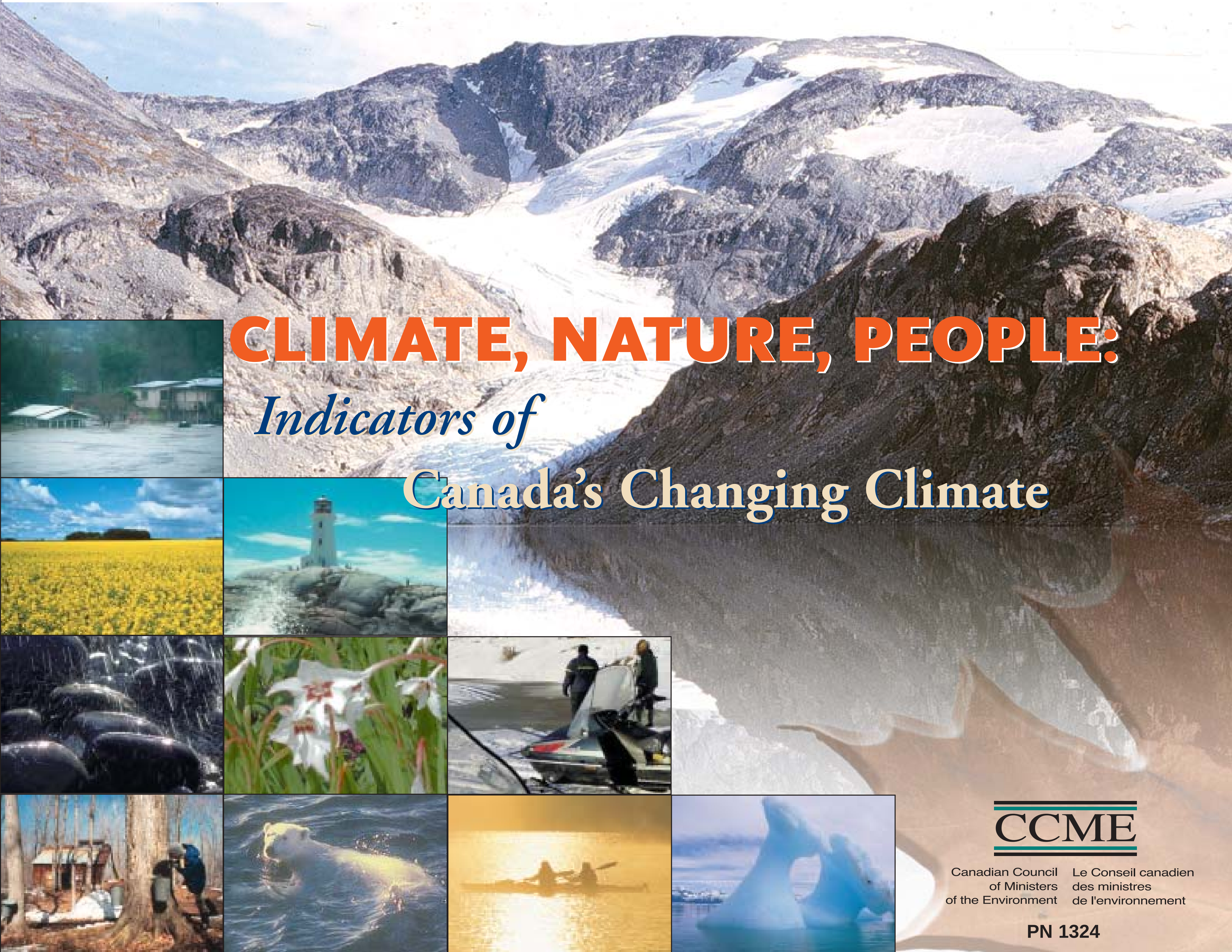
CLIMATE, NATURE, PEOPLE:

Indicators of Canada's Changing Climate



CCME

Canadian Council of Ministers of the Environment

Le Conseil canadien des ministres de l'environnement

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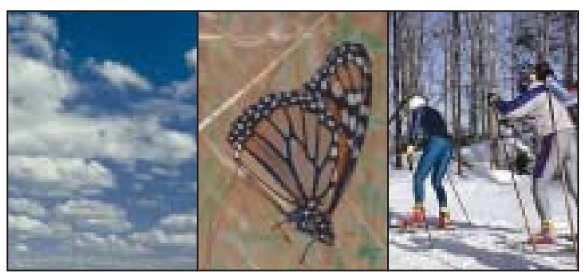

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HIGHLIGHTS

This set of indicators identifies changes in Canada's climate during the past 50 to 100 years and investigates selected impacts of these changes on Canadians and their environment. Key findings include:

CLIMATE

- Almost every part of southern Canada, from coast to coast, was warmer at the end of the twentieth century than it was at the beginning. Northwestern Canada has also seen strong warming over the past 50 years, but the Northeast has become cooler.
- Most of Canada has become wetter, with increases in precipitation ranging from 5% to 35%.
- Because of increased precipitation, Canada was generally snowier at the end of the twentieth century than at the beginning. Over the past 50 years, however, higher spring temperatures have reduced the proportion of precipitation falling as snow in some parts of southern Canada.
- Sea surface temperatures have risen substantially on Canada's west coast but appear to have changed little on the east coast.

NATURE

- Rising sea levels are making many areas along the Atlantic, Pacific, and Beaufort Sea coasts more vulnerable to flooding and erosion.
- Ice on rivers and lakes in most of Canada is breaking up earlier in the spring. During the past 30–50 years, however, there has been a tendency in much of the country towards earlier freezing dates in the fall.
- Most glaciers in Canada are shrinking.
- The area of the Canadian Arctic that is permanently covered by sea ice has decreased by about a quarter since the late 1960s. Hudson Bay is now ice free a week longer, on average, than it was 30 years ago.
- A shorter ice season has made survival more difficult for polar bears on the western side of Hudson Bay.

- Warmer temperatures may be contributing to recent increases in the population of the mountain pine beetle, an insect pest responsible for the destruction of valuable timber in B.C.
- Key stages in plant development, such as budding, leafing, and flowering, are occurring earlier, mainly because of earlier and warmer spring weather.

PEOPLE

- The traditional knowledge that aboriginal people relied on in the past to live off the land is becoming harder to apply as a result of more variable weather and changes in the timing of seasonal phenomena. A shorter, less reliable ice season has also made winter travel, hunting, and fishing in the North more difficult and dangerous.
- Although recent years have been marked by severe drought on the Prairies, long-term data do not show that droughts are occurring more often.
- Since 1900, data for the Great Lakes show periodic changes in water levels but no long-term trend towards lower water levels. Recent low water levels, however, have had important consequences for shipping, hydroelectric generation, and wildlife.
- The frost-free season has been getting longer in most parts of Canada because the last spring frosts have been happening earlier.
- Heating needs across most of Canada have decreased during the past century. Many parts of the country have also seen cooling needs rise.
- There is no strong evidence that extreme weather events have become more common in Canada, even though the 1990s witnessed some of the most damaging and costly weather disasters in Canadian history.

Because of the large size of Canada, the rate, extent, and impact of changes in climate vary from one part of the country to another. The indicators also show that the links between climate and specific impacts on nature and people are often complex.

Indicators will continue to be important tools for tracking the social, economic, and environmental effects of changes in our climate. Further work on the existing indicators and development of additional indicators is needed to expand our understanding of these impacts.

IS CANADA'S CLIMATE CHANGING? And does it really matter?

Climate affects just about every aspect of nature and human life. The kinds of plants and animals that inhabit a particular place are determined to a great extent by climate. So is the amount of water in a river or the height of a shoreline. Likewise, our health and safety, our comfort and mobility, our food supply, and our access to water all depend in one way or another on climate, as do many other things we need or value. When climate changes, all of these are affected too – sometimes slightly, sometimes considerably, sometimes for the better, and sometimes for the worse.

Canada's climate has begun to change in a number of ways, and some impacts of those changes are already noticeable. As citizens we need to be aware of those changes and their consequences for the world around us. That is why the Canadian Council of Ministers of the Environment (CCME) commissioned this report. Its objective is not to predict how climate change might unfold in the future but to give Canadians some idea of how a changing climate may already have affected their lives and the environment.

To do so, it uses what are known as indicators. Indicators are simple things that we can measure to learn about the condition of something more complex. In medicine, for example, blood pressure or body temperature are common indicators of the health of the human body. In economics, gross domestic product (GDP) indicates the wealth of a country by measuring the value of what it produces, usually in a year. Indicator measurements can also be tracked over a period of time to show whether or not there has been a change in condition. A change in GDP, for example, tells whether a country is getting richer or poorer, at least in money terms.

Climate change indicators do much the same thing. Some of them help us determine whether our climate is changing or not. These indicators are based on features of climate, like temperature and precipitation. Others indicate whether or not a changing climate is affecting the environment and people's lives. These indicators are aspects of nature (like glaciers or sea level) or people's activities (like growing garden plants or crops or heating our homes) that are considered sensitive to changes in climate. By tracking changes in the indicators over time, we can get a fairly good picture of how climate has been changing during the same period. We can also see how these changes are affecting our daily lives and how we might need to respond.

Nearly 100 possible indicators were examined for this report. The dozen that remain are the ones that best met the following criteria.

- The indicator had to measure changes that are important either for people or the environment.
- Data for the indicator had to be reliable and available for a long period of time, ideally 50 to 100 years or more. This is so that we can be more certain that the indicator is actually reflecting real, long-term changes in climate rather than natural short-term variations or cycles that change every few years or decades.
- The influence of climate on the indicator had to be clear and direct. This is sometimes a difficult requirement, because the environment and human activities are almost always subject to several forces of change at once.
- Data for the indicator had to be available in most parts of the country that the indicator is relevant to. This helps us see differences in the impacts of changes in climate across the country.

The 12 indicators have been grouped into two sections. The first includes those whose impacts are more directly on nature; the second, those whose impacts are more directly on people.

Because of the size and diversity of Canada, changes in climate are not occurring at the same rate or in the same way in every part of the country. That means that the indicators will also show different results in different parts of the country. To provide both the detail and the broader picture needed to understand these changes, the report presents each indicator through the following four elements:

- a brief introduction that explains the indicator's importance and sensitivity to climate
- a Focus section that looks at how the indicator has behaved over a period of time in a particular part of the country
- a context section, called The Bigger Picture, that summarizes how the indicator has behaved in other parts of the country or in the rest of the world and considers some of its implications
- a boxed story or list of facts that highlights additional information about the indicator and its significance.

Most of the indicators are based on data that have been collected and analyzed by government or university researchers. In selecting sources, care was taken to ensure that the reliability and statistical significance of the data could be adequately assessed. Because this publication is aimed at the general public, however, it does not provide extensive discussion of analytical methods, although the statistical significance of the data is noted where appropriate. Those interested in exploring such details further should refer to the original sources of information listed at the back of the publication.

Some indicators also use information derived from traditional and local knowledge. Traditional knowledge is the detailed environmental knowledge of aboriginal peoples who still survive to a large extent by harvesting the plants, animals, and other resources that the natural environment provides. It is expert knowledge that depends on close observation, and some of it has been accumulated over many generations.

CCME hopes that this brief report will give Canadians a better understanding of how climate change can affect their lives and a desire to learn more about it. The report ends, therefore, with references to sources of additional information about climate change impacts and actions that individuals might take to address their concerns about climate change in Canada.

Climate is often defined as average weather. More precisely, it is the long-term average for a particular time period and place. It is usually based on weather data that cover a span of at least 30 years, and it includes temperature, rain, snow, humidity, wind, sunshine, air pressure, and other weather characteristics.

Climate is naturally variable. It is never exactly the same from one period to another. Sometimes it can shift dramatically within a few hundred or thousand years, as it does when ice ages begin and end. Usually it varies within much narrower limits. For most of the past 1000 years, for example, the world's average temperature has remained within about half a degree of 14°C.

Over the past 100 or so years, however, the world's climate has changed noticeably. The world's average temperature was approximately 0.6°C warmer at the end of the twentieth century than it was at the beginning, and the 1990s were the hottest decade in 140 years of global climate records. Such changes may seem trifling, but the difference between global temperatures now and at the peak of the last ice age is a mere 5°C. Evidence of earlier climates suggests that global temperatures have warmed more during the twentieth century than in any other century during the past 1000 years.

Why are temperatures rising? Part of the reason may be an increase in energy from the sun. But atmospheric scientists attribute most of the warming over the past 50 years to increases in the quantity of greenhouse gases in the atmosphere. These are gases like carbon dioxide, methane, and nitrous oxide that absorb and retain heat from the Earth's surface. They are a small but extremely important part of the planet's natural atmosphere – so important, in fact, that without them, Earth would be some 33°C cooler than it is now and too cold to support life.

Since the early days of the industrial revolution some 200 years ago, huge increases in the burning of fossil fuels like coal and oil and the replacement of large areas of forest by farmland have greatly increased atmospheric concentrations of these gases. Concentrations of carbon dioxide and other greenhouse gases are still increasing, and as they do climate scientists expect that global temperatures will continue to get warmer.

Higher temperatures are not the whole story though. They in turn give rise to changes in other features of climate, such as rain and snowfall, winds, and the movement of weather systems. As a result, the world is not just becoming warmer. Weather patterns, like the amount of rain or snow in a given season or the occurrence of various weather extremes, are also changing. Some of these changes are already beginning to alter our environment – affecting the shape and character of the landscape, the makeup and behaviour of plant and animal communities, and the quality of people's lives.

Climate hasn't changed evenly around the world. Some parts of the globe have warmed more than the average. Others have warmed less. Some have even cooled. Because of the large size of Canada, it is no surprise then that the rate, extent, and impact of changes in climate vary from one part of the country to another.

Climate Records

When studying climate change, researchers use climate records that cover as long a period of time as possible. That makes it easier to distinguish between real, long-term change in the behaviour of the climate system and temporary changes, lasting only a few years or decades, that result from the system's natural variability.

In Canada, long records dating back 100 years or more are available for the southern half of the country. However, in the North – Yukon, the Northwest Territories, Nunavut, northern Quebec, and northern Labrador – records dating from before the 1950s are rare. To get the best possible understanding of climate change in Canada, then, we have to look at both a 100-year picture that covers only the southern half of the country and a 50-year picture that covers the whole country.

The two pictures are generally similar, but in some cases they disagree. That may be because changes that can dominate the shorter 50-year picture do not show up as strongly when looked at over a 100-year time span. Or it may be that the 50-year picture is showing new changes that were not evident earlier. It is difficult to determine, however, whether changes that show up only in the 50-year picture are temporary or represent a real and continuing pattern of change.

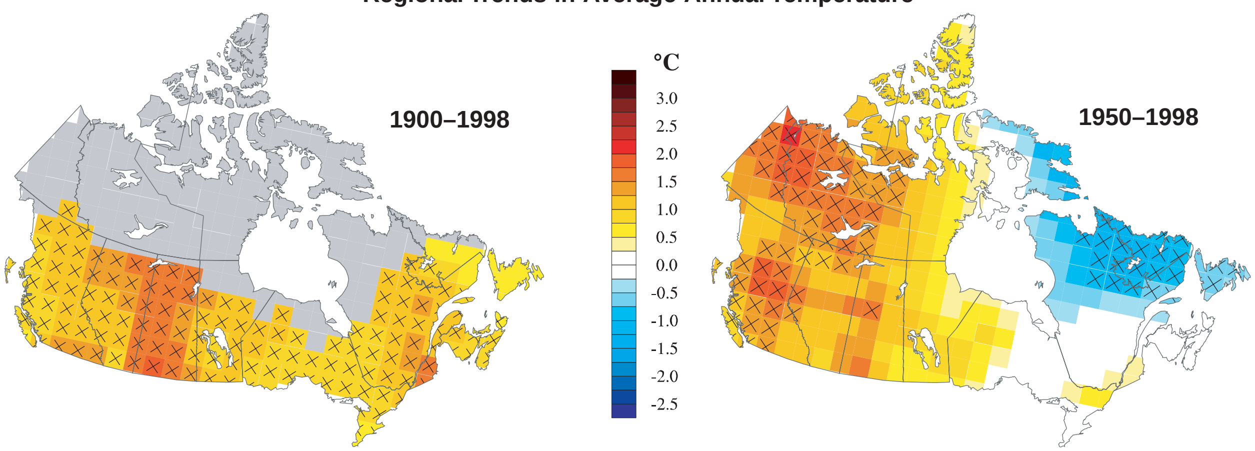
Temperature

Whether we look at the 50-year or the 100-year picture, it is clear that temperatures have been changing in just about every part of Canada. The 100-year picture shows that southern Canada as a whole warmed by 0.9°C between 1900 and 1998. During that time, the greatest warming – about 1.5°C – took place on the Prairies and the least – about 0.5°C – on the east and west coasts.

The 50-year picture, from 1950 to 1998, is more complicated. It still shows most of the country getting warmer, especially in the West and Northwest. However, it also shows that temperatures in parts of Ontario, Quebec, and the Maritimes changed little during this period, while the northeastern corner of the country – eastern Baffin Island, northern Quebec, and Newfoundland and Labrador, actually became cooler. The greatest warming occurred in the Mackenzie Basin, where the average annual temperature increased by 2°C over the 50 years. The greatest cooling – as much as 1.5°C – has been in parts of northern Quebec and Labrador. For all of Canada, the average temperature change during this period was 0.3°C.

In both the 50- and 100-year pictures, the greatest amount of warming has occurred in spring, and the next greatest in winter. Of all the seasons, fall has warmed the least.

Regional Trends in Average Annual Temperature

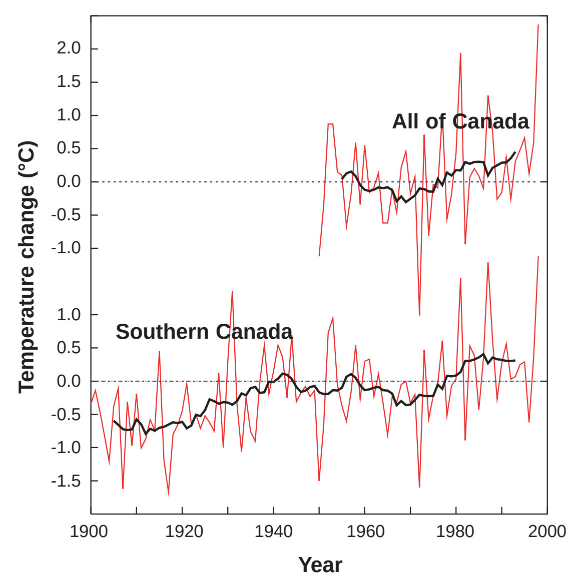


Source: *Adapted from Zhang et al., 2000*

Over the course of the twentieth century, all of southern Canada, from B.C. to Newfoundland and Labrador, warmed to some extent. In these maps, southern Canada is defined as the region lying south of the 60th parallel (the line that forms the northern border of B.C., Alberta, Saskatchewan, and Manitoba).

Since 1950, the greatest warming has occurred in the West and Northwest, while the Northeast has cooled. An x indicates results that are statistically significant. That means that scientists have a high degree of confidence that the changes are part of a real long-term trend and are not just due to chance.

National Annual Temperature Trends



Source: *Adapted from Zhang et al., 2000*

The graph shows the difference between each year's average temperature and the average for 1961 to 1990. The dark line running through each plot smooths out the year-to-year differences and makes it easier to see the general pattern of change over time. In southern Canada, temperatures rose rapidly between the early 1900s and the 1940s. They then fell slightly until the late 1960s but have continued to rise since then.

Highs and Lows

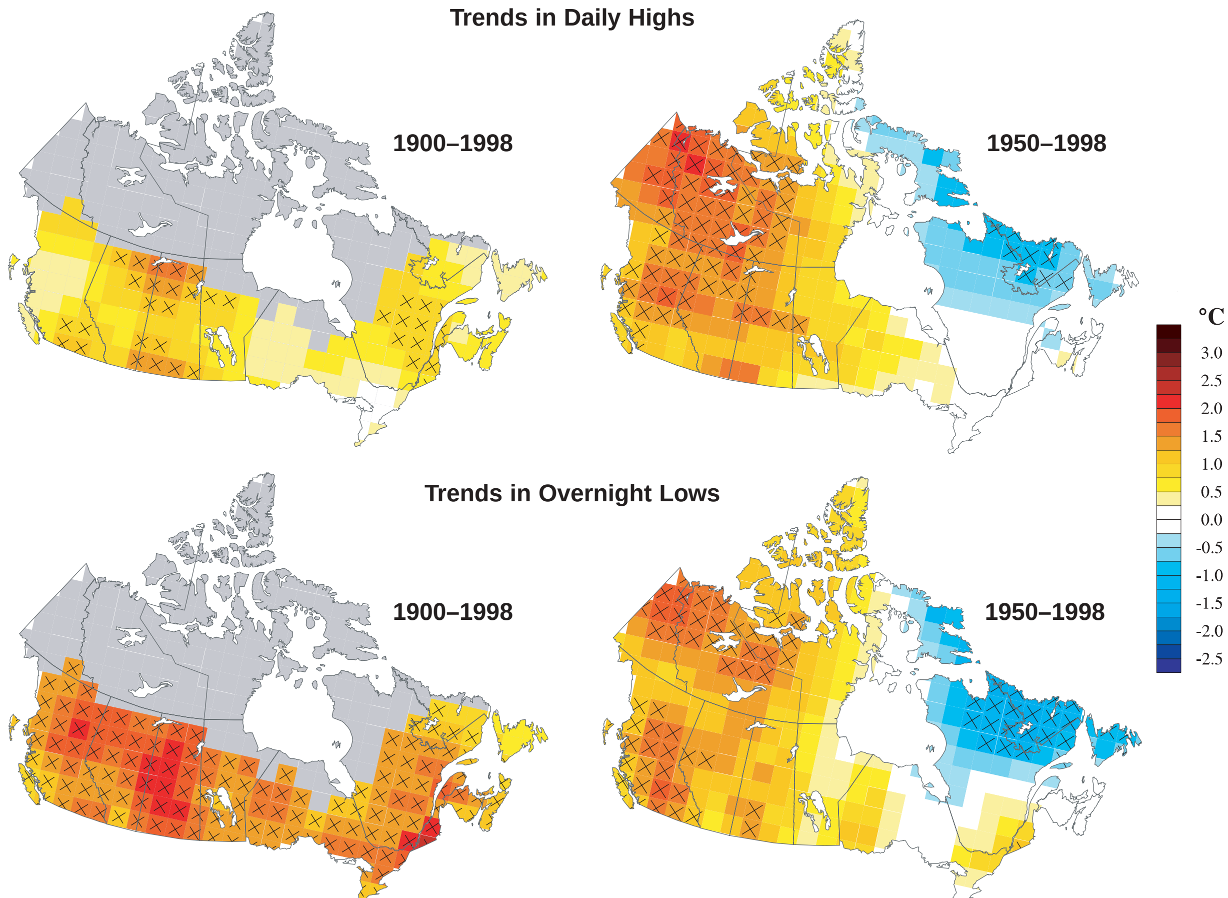
Climate change is usually discussed in terms of changes in average temperature, but averages don't tell the whole story. How warm it gets during the day and how cool it gets at night can also have important effects on people and the environment. Daily highs, for example, have a substantial influence on the growth of plants, while overnight lows determine when the first and last frosts occur and thus influence the length of the growing season.

For humans, higher daytime temperatures reduce heating requirements in the winter but increase the need for cooling in the summer. In the North, warmer nighttime temperatures affect transportation by shortening the number of weeks in which it is possible to travel on the ice and frozen ground. Changes in daily highs and overnight lows can have numerous other effects as well on everything from human health and safety to the survival of insect pests.

Over the past 100 years, daily high temperatures have risen in every province of Canada. Daily lows, however, have risen much more – in some cases twice as much, mainly because of strong nighttime warming in the earlier part of the last century. Both highs and lows have also increased more in winter than in summer.

In the shorter 50-year record, in contrast, significant differences between daytime and nightime warming do not show up in many parts of the country. However, some important seasonal differences are apparent. In Canada's Northwest, both winter and summer temperatures have increased, but the increase in winter temperatures has been much greater. In the Northeast, temperatures have cooled in winter but have become somewhat warmer in summer.

What all of this means is that – except for the northeastern corner of the country – more warming has gone on at the lower end of the temperature scale than at the higher end. The reduction in the number of cold winter nights has been more noticeable than the increase in hot summer days. So far, then, a warming climate has not made Canada appreciably hotter, but it has made it less cold.



Source: *Adapted from Zhang et al., 2000*

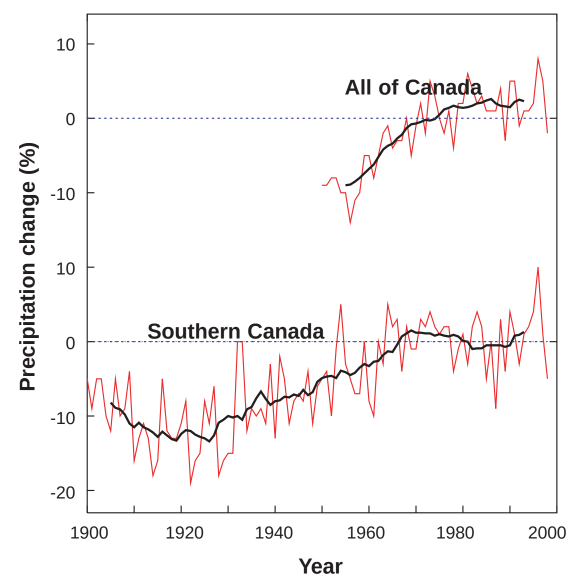
Over the past 100 years, overnight lows warmed more than daily highs across all of southern Canada. For the past 50 years, differences between daytime and nighttime temperatures have been far less striking. The x's in all maps indicate trends that are statistically significant.

Precipitation

As well as becoming warmer, most of Canada has become wetter. Almost all of southern Canada, except the southern Prairies, saw significant increases in precipitation between 1900 and 1998. Most of southern Canada now receives about 5–30% more precipitation than it did in 1900. Since 1950, the central Arctic has also seen significant increases, in some cases as much as 35%. The increases were evident in all seasons, although since 1950 they have been most widespread during the fall. Some parts of the country, however, experienced seasonal decreases in precipitation during this period. These occurred mostly in winter and spring.

The trend towards more precipitation is consistent with the way that our climate is expected to change in a warming world. That is because higher temperatures evaporate more water from the Earth's surface and a warmer atmosphere can hold more water vapour. That makes more moisture available in the air to fall as rain or snow, and in most regions that is likely to result in more precipitation during the year. Some areas may still get drier, however, as a result of changes in the circulation of the atmosphere.

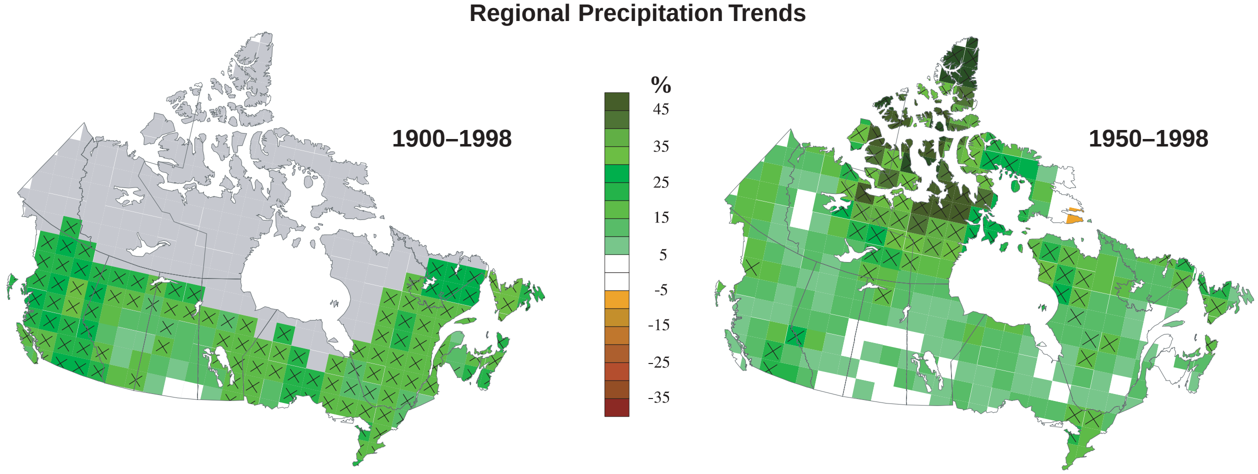
National Annual Precipitation Trends



Source: *Adapted from Zhang et al., 2000*

Canada has become wetter during the twentieth century. The graph shows the difference (in per cent) between each year's average precipitation and the average for 1961–1990. The dark line through the centre of each plot smooths out year-to-year differences so that longer-term changes are easier to see.

Regional Precipitation Trends



Source: *Adapted from Zhang et al., 2000*

The maps show average changes in annual precipitation (in per cent) for southern Canada between 1900 and 1998 and all of Canada between 1950 and 1998. Almost all of the country, except parts of the southern Prairies, has seen an increase. An x indicates changes that are statistically significant.

Snow and Rain

A warmer atmosphere may also affect the amount of precipitation that falls as rain and the amount that falls as snow. That is partly because the increases in precipitation that come with a warmer atmosphere may not be evenly distributed between the cold seasons (when precipitation is more likely to fall as snow) and the warm seasons (when it will fall as rain). It is also because a warmer climate is likely to have more fall, spring, and even winter days when temperatures are too high for precipitation to fall as snow. Over time, such changes can be expected to make Canada a rainier but less snowy place. What has actually happened so far, however, is more complicated. The trends depend very much on what part of the country you look at and when.

The 100-year precipitation picture actually shows the southern half of Canada becoming somewhat snowier. That's partly because of more precipitation in winter (which usually falls as snow) and partly because a larger proportion of fall precipitation fell as snow. Over the past 50 years, however, the proportion of precipitation falling as snow in the South has gone unchanged or decreased. These decreases are mainly a result of higher spring temperatures that have caused more precipitation to fall as rain. In some areas, though, they are the result of less winter and spring precipitation. But even though snow made up a smaller proportion of total precipitation in these years, the second half of the twentieth century was still snowier in southern Canada than the first – simply because the total amount of precipitation in the second half was greater

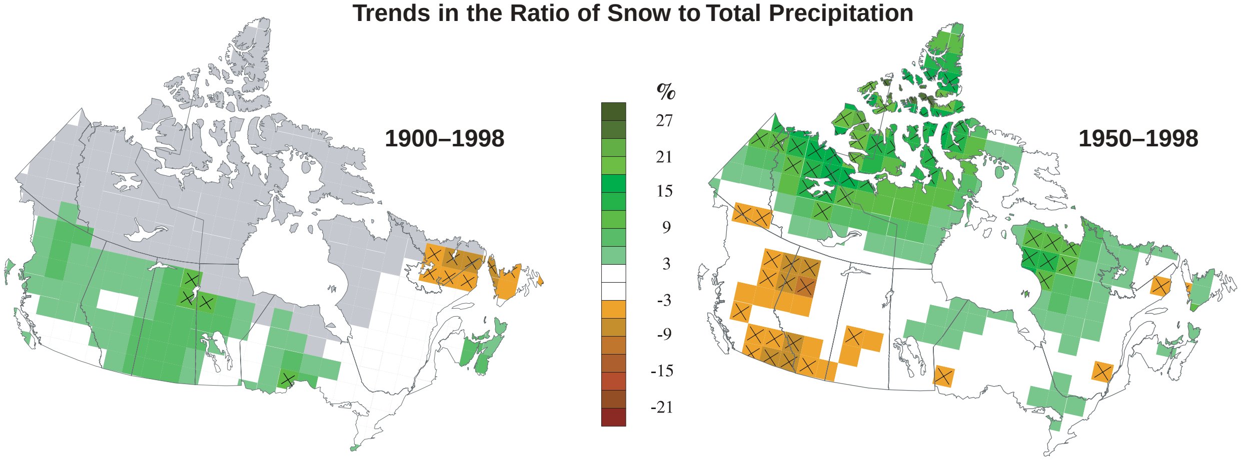
In the North, the past 50 years have seen an increase in the proportion of the year's precipitation that falls as snow. That reflects an increase in precipitation generally, especially during the cold seasons – fall, winter, and spring – when temperatures are still mostly cold enough to favour the formation of snow.

Whether precipitation falls as rain or snow is not a trivial matter. Less snow can result in lower snow-clearing costs, fewer transportation delays, less time lost at work, and fewer deaths and hospital admissions as a result of accidents, exposure, and injuries and heart attacks from snow shovelling. More rain in winter, however, could be a serious hazard if it occurs as freezing rain.

Snow is also a source of many ecological, economic, and social benefits. Snow stores moisture during the winter, and a lack of it can result in serious water shortages later in the year for hydroelectric systems, industries, farms, municipalities, inland waterways, and freshwater fisheries.

Finally, changes in snow cover can play an important role in climate change. Snow is highly reflective, and extensive snow cover retards the onset of warmer temperatures in spring by reflecting incoming sunlight away from the Earth's surface. When spring precipitation falls as rain rather than snow, the snow cover disappears faster and warmer weather arrives earlier.

Trends in the Ratio of Snow to Total Precipitation



Source: *Adapted from Zhang et al., 2000*

The maps show changes in the proportion of total precipitation that falls as snow. The green squares indicate that the amount of snow in the total precipitation mix has increased. Red indicates a decrease. An x indicates results that are statistically significant.

Sea Surface Temperature

The world's oceans are an important part of the climate system. They are a source of moisture for the atmosphere and a reservoir and transport system for heat. In fact, the top few metres of the world's oceans hold as much heat as the entire atmosphere. What happens to ocean temperatures is a crucial part of climate change.

The surface layer of the ocean is also important ecologically, because that is where sea life is most plentiful. Many factors affect the vitality of sea life, but water temperature is particularly significant. Fish, for example, are sensitive to water temperature and will have difficulty reproducing and surviving in water that is either too hot for them or too cold. Many species, in fact, will change their migration routes and feeding grounds to stay within their preferred temperature range. Water temperature also affects the ease with which winds and storms can replenish the nutrient supply of the surface layer by mixing it with the colder, nutrient-rich water below. Cold, salty water mixes best because it is very dense. Warmer water doesn't mix as easily because it is less dense and tends to float on the cooler water underneath it.

The oceans too have been warming, and like the atmosphere they have not warmed at the same rate everywhere. As with air temperatures, complete sets of measurements going back several decades are also needed to detect reliable trends in sea surface temperatures. Unfortunately, records of this kind for many Canadian locations are not available, and that makes it difficult to put together a 50- or 100-year picture of temperature changes in Canadian coastal waters.

The best data come from the Pacific coast, where lighthouse keepers have been measuring sea surface temperatures at several locations along the coast since the first half of the twentieth century. These records show temperature increases ranging from 0.9°C per century off the west coast of Vancouver Island to 1.8°C per century in the Georgia Basin.

Complete long-term records for the Atlantic coast are fewer and harder to assess. The best available set, for Cape Spear, Newfoundland, shows no long-term change in temperature. Generally, however, the results for the Atlantic and Pacific coasts agree with the general pattern of air temperature change in these areas.

As for other areas, such as the Gulf of St. Lawrence and the Arctic Ocean, records are either too short to give an accurate picture of climate change or need further analysis. It will be some time, therefore, before we have a good idea of how sea surface temperatures on all of Canada's coasts are changing.

Change in Sea Surface Temperature, 1914–2001

Source: *Environment Canada, with data from the British Columbia Ministry of Water, Land and Air Protection and Fisheries and Oceans Canada*

Sea surface temperatures have risen substantially on the west coast but appear to have changed little on the east. The rate of temperature change (in °C per century) is indicated in the blue circles. NC indicates no change.

Climate Change – What Next?

Canada's climate has changed, and in most regions of the country Canadians are now experiencing climates that are recognizably different from those that were familiar to their grandparents.

In looking at the indicators that follow, we should keep in mind that these changes are still continuing. In fact, the amount of climatic change seen over the past century is likely to be quite small compared to what most scientists expect to occur over the next 100 years and beyond. Changes that are now just becoming apparent are likely to become more obvious in the future, and other changes that have not yet been detected can be expected to emerge. That makes it important to continue tracking climate change and its many impacts. Indicators like the dozen that follow and others yet to be developed will be needed to help us understand those changes and their effects on us and our environment.

NATURE

NATURE

Weather and climate shape the physical environment. As a result, changes in climate should be clearly reflected in changes to our seas, lakes, rivers, and lands.

Changes in climate also affect plants and animals. However, the effects on Canada's forests, on freshwater fish habitat, or on the spread of natural pests, for example, are harder to interpret because living things vary in their ability to adapt to different climates. They may be affected by other stresses as well, such as habitat loss or pollution.

The six indicators selected for this section focus on physical features and living things that have shown a very clear sensitivity to changes in climate. They are:

- Sea Level Rise
- Sea Ice
- River and Lake Ice
- Glaciers
- Polar Bears
- Plant Development

Rising sea levels are making Canadian coasts more vulnerable to flooding and erosion.

Rising sea levels threaten familiar shoreline environments. Coastal wetlands, which are important ecosystems and barriers against shoreline erosion, gradually disappear. Bluffs and beaches are more exposed to erosion by waves, groundwater is more likely to become contaminated by salt water, and low-lying coastal areas may be permanently lost. In addition, wharves, buildings, roads, and other valuable seaside property face a greater risk of damage as a result of flooding from storms.

Although global sea levels have been rising since the last ice age, a changing climate is causing them to rise faster. That's mainly because a warmer climate causes sea water to expand as it warms, but water from melting glaciers and polar ice caps is also contributing to the rise. Over the past century, these factors have raised the average level of the world's oceans by between 10 and 20 cm.

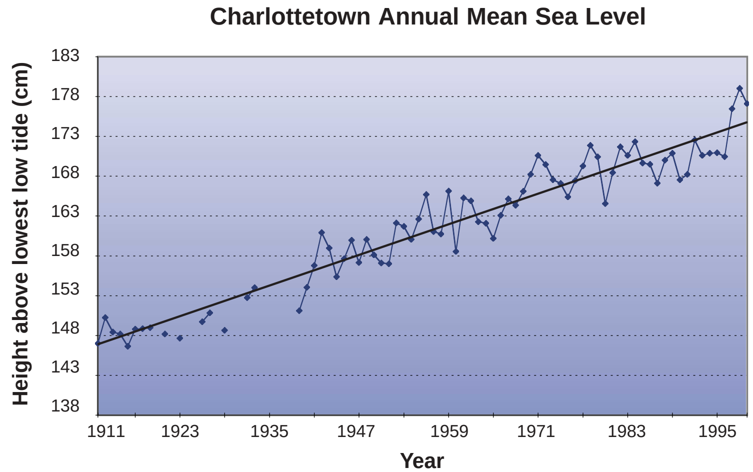
Local movements of the land as it adjusts to post–ice age changes can affect sea level too. Along coasts where the Earth's crust is rising, sea levels will increase more slowly or may even fall. Where the Earth's crust is sinking, sea level rise will be greater. As a result, changes in sea level can vary considerably from place to place.

FOCUS: Charlottetown, P.E.I.

Charlottetown is seriously threatened by rising sea levels. Much of its historic core lies just a few metres above the sea, and over the past century the city's average sea level has risen by nearly 30 cm. About 20 cm of that increase is probably the result of local sinking of the land after the last ice age. The rest can be linked to global sea level changes resulting from a warmer climate.

Charlottetown is not about to disappear permanently under the ocean, but higher sea levels are increasing its exposure to severe flooding from storm surges. Storm surges are caused by low air pressure and onshore winds and can temporarily raise the local water level a metre or more above normal. When a large storm surge occurs at the same time as very high tides, extensive flooding occurs.

Between 1911 and 2001, seven storm surge events were large enough to flood the Charlottetown waterfront. But as the sea continues to rise, increasingly smaller storm surges will cause flooding, and large storm surges will reach further inland if the land is not protected. If the sea had been at its present level throughout the twentieth century, storm surges would have flooded the city's waterfront on two more occasions.



Source: *Adapted from Parkes et al., 2002*

The annual sea level at Charlottetown between 1911 and 1998 is shown here in centimetres above the lowest expected low tide level. As well as contributing to long-term increases in sea level, climate also contributes to seasonal and year-to-year variations.

THE BIGGER PICTURE

With the longest coastline in the world, Canada is threatened on several fronts by rising sea levels. However, the possible impacts vary considerably from one place to another. In Atlantic Canada, coastal areas face the possibility of more frequent storm-induced flooding and greater rates of erosion. In Quebec, there is a growing risk that seaside roads along the North Shore of the Gulf of St. Lawrence, on the Gaspé Peninsula, and on the Îles-de-la-Madeleine will be damaged by coastal erosion and landslides.

Another highly vulnerable area is the Beaufort Sea coast – one of the few parts of the Arctic where sea levels appear to be rising. Coastal erosion there is made worse by the melting of sea and ground ice and is already causing the loss of town waterfront and structures in places such as Tuktoyaktuk.

In B.C. much of the coast is too steep and rocky to be seriously affected by sea level rise. Nevertheless, Prince Rupert, the highly urbanized Fraser Delta, and many low-lying areas of ecological and archaeological interest on Vancouver Island, the Queen Charlottes, and the Gulf Islands face a growing risk of flooding and erosion as a result of higher sea levels.

Source: *Natural Resources Canada*

Sea levels on both the Atlantic and Pacific coasts are rising but they are falling along much of the Arctic coast. The possible impacts of sea level rise depend not only on the rate of increase but on the coastline's sensitivity to higher sea levels. Sensitivity is determined by such factors as the height of the shoreline, its resistance to erosion, and the force of incoming waves.

THE GREAT STORM SURGE OF JANUARY 21, 2000

The storm rolled in from the Carolinas, walloping Atlantic Canada with up to 54 cm of snow and a 1.4-metre storm surge that reached parts of the Canadian coast just as unusually high tides were nearing their peak. The maximum water level exceeded the previous record by almost 40 cm in Charlottetown and even more along parts of the New Brunswick coast. As the storm passed through, massive chunks of ice piled up against the shore and the sea rushed in, flooding streets and buildings.

In Charlottetown, ice damaged wharves and knocked a lighthouse off its foundations. Much of the downtown core was flooded, power supplies were threatened, and city workers made makeshift dikes out of snow to hold back the incoming water. At the city's largest hotel, floodwaters came within metres of the underground parking garage.

Buildings were flooded and several people had to be evacuated from homes in seaside communities around P.E.I. and across the Northumberland Strait in New Brunswick and Nova Scotia. In Shediac, New Brunswick, boats and a backhoe were pressed into service to rescue stranded residents. At Malagash Point, Nova Scotia, two cottages were lifted off their foundations and carried several hundred metres down the beach. The storm also brought severe damage to the island of Newfoundland. High waves battered homes in Port aux Basques, while in Lamaline, on the Burin Peninsula, several houses were flooded and a breakwater was destroyed. Residents described it as the worst flooding to hit the village since the tidal wave of 1929. Miraculously, no lives were lost, but the storm left millions of dollars of damage in its wake.

"The sea ice, which is like land to us Inuit, has started to change..."

Sea ice is essential to the survival of many Arctic animals, and people in northern communities depend on it for hunting and fishing. It protects sensitive coastlines from wave erosion, and it influences local air and water temperatures and the changing of the seasons. It is also a danger to offshore oil rigs and an obstacle and hazard to shipping. Sea ice occurs along more than 90% of Canada's coastline. Only the Pacific coast is ice-free all year.

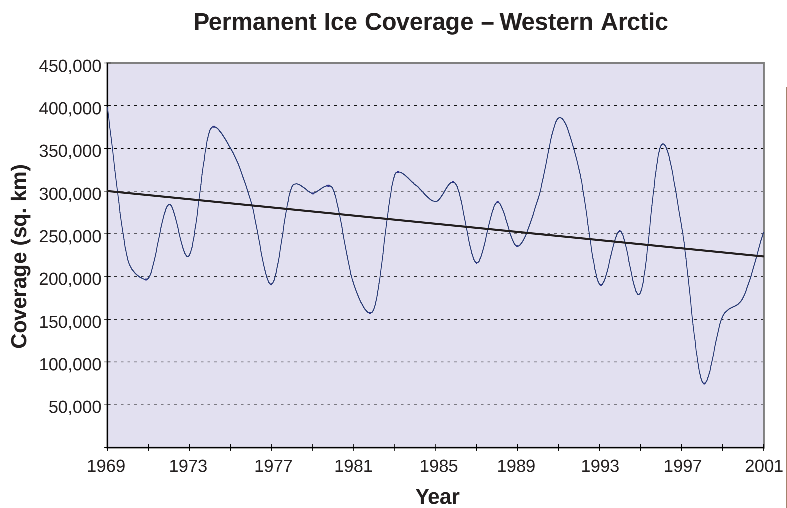
Canadian Arctic waters are almost completely ice covered in winter, but the ice normally begins to melt in July and doesn't refreeze until October. Some more southerly areas, like Hudson Bay and the Beaufort coast, become almost completely ice free in August and September. Other areas retain some or even quite a bit of ice cover throughout the year.

Sea ice is affected not only by air temperature but also by wind, snow cover, sunshine, the temperature and saltiness of the sea, and ocean currents. Changes in any of these factors can cause large year-to-year variations in the extent and thickness of sea ice and in the length of the ice season. Over the longer term, though, changes in air temperature are one of the most important influences on the amount of sea ice.

FOCUS: The Western Arctic

The western Arctic warmed considerably during the latter half of the twentieth century. It is therefore an area where we might expect to see a decrease in the amount of sea ice as a result of more melting in summer. That, in fact, appears to be happening. Over the past three decades, the area covered by sea ice throughout the year has shrunk by an average of about 80,000 square kilometres. That's an area slightly larger than New Brunswick and about a quarter of the area covered at the end of the 1960s.

The ice may also be getting thinner, but estimates of how much thinner are difficult to obtain. American scientists, using data collected by submarines, concluded that the average ice thickness in the Beaufort Sea at the end of September had decreased by about 45% between 1958–1976 and 1993–1997. Those results, however, were based on only a small number of submarine tracks. A more recent Canadian Ice Service study suggests that the ice may have thinned by only a quarter of that amount. Ongoing research suggests that the answer may lie somewhere between these estimates.



Source: *Environment Canada*

Permanent sea ice is ice that doesn't melt in the summer but remains throughout the year. In the western Arctic, the area covered by permanent sea ice has decreased by about 25% since 1969. Because these records cover only a few decades, however, we can't be completely sure whether this trend is the result of natural variations in the Arctic climate or longer-term climate change.

An ice road crosses the frozen Beaufort Sea.

THE BIGGER PICTURE

Sea ice coverage has decreased in the eastern Arctic as well and at about the same rate as in the west. In Hudson Bay, the ice-free season is now more than a week longer than it was 30 years ago. Along the Atlantic coast and in the Gulf of St. Lawrence, however, no clear trend has developed. In 2002, ice coverage in the Gulf hit its lowest level in more than 30 years, but ice accumulations in the area have varied considerably from one decade to another.

Changes in Arctic sea ice are now making it harder for some polar bear and seal populations to survive. For many Northerners, travel over the ice has also become more dangerous and less reliable, and hunting on the ice has become more difficult. In addition, sensitive coastal areas along the Beaufort coast and in the Gulf of St. Lawrence face a higher risk of erosion as longer ice-free periods increase the exposure of shorelines to high waves from storms.

In the Arctic, the season open to shipping is becoming longer, promising easier access to northern resources and renewing interest in trans-Arctic shipping routes. As other nations become more interested in these routes, however, Canada's sovereignty over its Arctic waters may be challenged.

Less sea ice can also mean more climate change. Ice, like snow, reflects much of the sun's energy back to space. When less ice covers the oceans, more of the sun's energy is able to warm the Earth's surface and temperatures rise higher and faster, particularly in polar regions in the spring.

Seal pups are born on the ice and must stay there until they can swim. In early 2002, many harp seal pups were lost in the Gulf of St. Lawrence when a mild winter resulted in a lack of sea ice.

SEA ICE AND THE INUIT

The Inuit, who rely on the ice for hunting and fishing, have an extensive knowledge of past and present ice conditions. The changes reported by the Inuit observers below not only provide further evidence of sea ice loss but also show how Inuit life is being affected.

"We used to go on the sea ice with dog sleds to hunt seals – now we have to use boats....We used to go a long way out – now we hunt close to shore."

Andy Carpenter (Sachs Harbour, Northwest Territories)
Sea Ice Variability and Climate Change Workshop, University of Winnipeg, 2002

"The sea ice, which is like land to us Inuit, has started to change its characteristics. The sea ice now shears off, and once it starts to melt there is no stopping it."

Larry Audlaluk (Grise Fiord, Nunavut)
Elders' Conference on Climate Change, Cambridge Bay, 2001

"Thin ice is now the norm in Frobisher Bay....Even in what we used to call early spring, the sea ice is now precarious and downright unnavigable by snowmobile in some areas."

Pauloosie Kilabuk (Iqaluit, Nunavut)
Elders' Conference on Climate Change, Cambridge Bay, 2001

"Now, even before the end of May, the sea ice has broken away. We have had a few cases where Inuit had to be rescued by boat, as a whole coastline had become ice-free. We may no longer be able to harvest seals or polar bears."

Zach Novalinga (Sanikiluaq, Nunavut)
Elders' Conference on Climate Change, Cambridge Bay, 2001

Freeze-up and breakup times are changing, and northern communities are worried about the consequences.

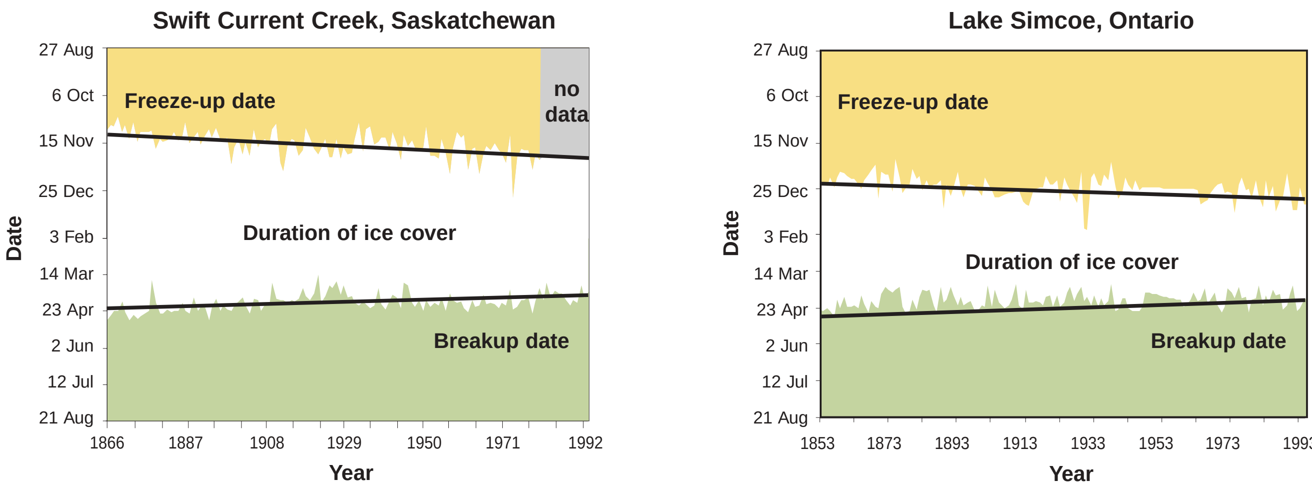
The formation and breakup of ice on rivers and lakes marks not only the changing of the seasons but also a change in the way that water can be used for travel, fishing, and recreation. It has important consequences for fish and other aquatic life too, because ice blocks the transfer of oxygen from the air to the water. In addition, changes in the duration of ice cover can affect the food supply for aquatic life, while changes in freeze-up and breakup times can cause birds to change their migration patterns. Spring breakup on rivers also brings a risk of floods caused by ice jams and damage to bridges and other structures from floating ice and debris.

The timing of freeze-up and breakup depends on a number of things, including precipitation, wind, sunshine, and various features of the water body itself, such as its size and the characteristics of its currents. Spring breakup times are more variable because they are also influenced by the amount of snow cover and the coldness of the preceding winter. Air temperature, however, is particularly important for both freeze-up and breakup, and changes in the timing of these events provide a good reflection of trends in fall and spring temperatures.

FOCUS: Saskatchewan and Ontario

Over the years, many people other than scientists have kept surprisingly good records of freeze-up and breakup dates. Where such records are available, freeze-up and breakup times can sometimes be traced back a century or more. In the case of the two locations shown here – Swift Current Creek in southwestern Saskatchewan and Lake Simcoe in south-central Ontario – the records date from the 1860s and 1850s respectively. They show that the average freeze-up date for Lake Simcoe is now about 13 days later than it was 140 years ago, and the average breakup date is about 4 days earlier. For Swift Current Creek, over a period of about 115 years, the change is more dramatic. Freeze-up is now about 24 days later and breakup about 14 days earlier.

These results are what might be expected from the temperature record of the past century, which shows more warming in southern Saskatchewan than in southern Ontario.



Source: *M. Futter/Ecological Monitoring and Assessment Network*

Over the past century and a half, Swift Current Creek and Lake Simcoe have been freezing later in the fall and breaking up earlier in the spring.

THE BIGGER PICTURE

An international team of scientists recently used various historical records to compile freeze-up and breakup dates for 39 rivers and lakes in Europe, Asia, and North America. They found that over the past 150 years, these lakes and rivers were freezing later in the fall and breaking up earlier in the spring. They concluded that across the Northern Hemisphere freeze-up is now occurring an average of 5.8 days later than it did a century ago, while breakup is happening 6.5 days earlier. In Canada the few rivers and lakes for which we have long historical records – like Swift Current Creek and Lake Simcoe – tend to fit the pattern of later freeze-up and earlier breakup.

Our most extensive and reliable source of scientific data for Canada, however, covers only the past 30 to 50 years and reveals a more complex pattern. It shows breakup starting earlier in the spring almost everywhere in the country except in the Atlantic region – but it also shows a widespread tendency towards earlier freeze-up dates in the fall. The net result is that there has been an increase during this period in the amount of time that most Canadian rivers and lakes remain ice-covered. The largest increase – more than a month – has been in Atlantic Canada.

These results match up well with the way that temperatures have changed in different seasons and different parts of the country over the past half century. Although they differ from the longer-term results, they don't contradict them. They merely reflect the fact that different patterns may show up when climate is viewed over shorter and longer periods.

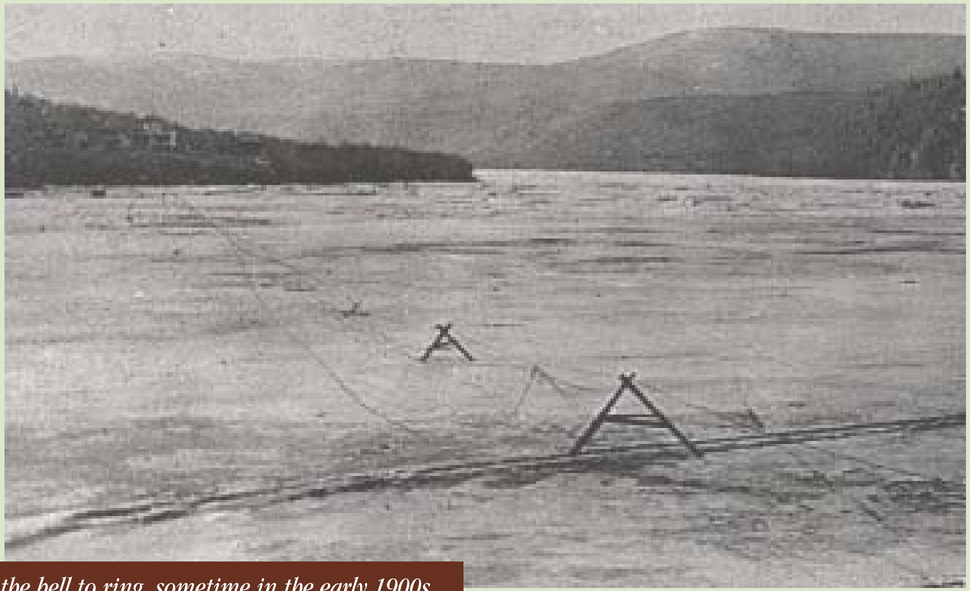
As a result of a recent string of warm years, there has been increasing concern about the difficulties that a shorter or more unpredictable ice season might bring to isolated northern settlements. Frozen lakes and rivers are essential to winter travel in the North. Hunters and trappers depend on them. So do whole communities whose supplies are trucked in from the south on winter roads that are built in part over frozen rivers, lakes, and bogs.

Manitoba, for example, builds about 2400 km of these roads every winter, and more than 25,000 people in 29 settlements rely on them. In 1997–1998, when the winter road season was unusually short, the provincial government had to supply these communities by air. The additional costs reached $14 million, or about three times the cost of building the winter road system. During the winter of 2001–2002 a number of the roads did not open until February, and one did not open at all.

BETS AND BELLS ON THE YUKON – SPRING BREAKUP AT DAWSON CITY

Thanks to the gambling instincts of a few prospectors, breakup records for the Yukon River at Dawson City go back to 1896. That spring, after betting on the exact minute when the breakup would start, the men set a series of wooden tripods across the middle of the river, ran a cord from them to a bell on the shore, and waited for it to signal the first shifting of the ice.

The bell has been set up every year since. It has rung as early as April 9 and as late as May 28. For most of the twentieth century, breakup was a May event, but since the mid-1980s April breakup dates have been more common. The average spring breakup date now arrives about 6 days earlier than it did a century ago.



Waiting for the bell to ring, sometime in the early 1900s.

Glacier shrinkage is changing the landscape and threatening water supplies.

Glaciers are powerful tourist attractions, but they are also a significant source of water for many rivers and streams. They therefore have a great influence on stream flow and the things that depend on it, such as power generation, irrigation, municipal water supplies, fish and other forms of aquatic life, and recreation.

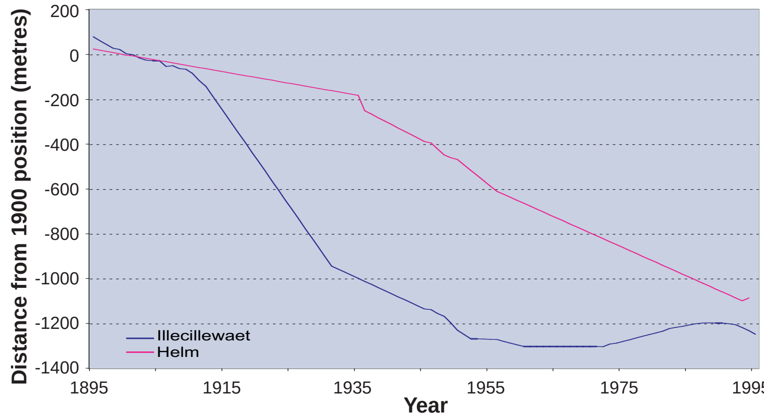
The total size of a glacier is closely linked to two climate-related phenomena: the amount of snow that falls on it in the winter and the amount of snow and ice lost to melting in the summer. Growth or shrinkage of the glacier eventually causes its front to advance or retreat, although the position of individual glacier fronts can change at different rates because of differences in the glaciers' elevation, length, speed of movement, and other factors.

Warmer temperatures increase the rate at which a glacier melts, and so does more rainfall. More snowfall, on the other hand, adds to a glacier's growth. In most areas, however, warmer temperatures are having a greater effect on glacier size than changes in either rain or snow.

FOCUS: British Columbia

Most of the glaciers and icefields in British Columbia have lost substantial amounts of ice over the twentieth century. The indicator presented here records what is happening to two mountain glaciers in different parts of southern B.C. – the Helm Glacier in Garibaldi Provincial Park north of Vancouver and the Illecillewaet Glacier in Glacier National Park near the Alberta border.

As the graph shows, both glaciers shrank by more than a kilometre between 1895 and 1995, although they have done so at different rates. The Helm Glacier has shrunk fairly steadily, but the Illecillewaet Glacier has changed more erratically, shrinking rapidly in the early part of the last century but then advancing in the 1970s and 1980s before staring to shrink again. The temporary growth was probably a result of a period of increased snowfall at higher elevations that offset the melting at lower levels.



Source: *Adapted from B.C. Ministry of Water, Land and Air Protection, 2002*

The graph plots the distance in metres between the positions of the glacier fronts in 1900 and their positions in other years. The minus values indicate that the glacier front has shrunk from its position in 1900.

Illecillewaet Glacier, 1999

THE BIGGER PICTURE

Since 1950, the greatest warming in Canada has occurred in the west and the northwest. Most glaciers in these regions are also shrinking rapidly. The 1300 or so glaciers on the eastern slopes of the Rockies, for example, are now about 25% to 75% smaller than they were in 1850. The area of warming also covers many of the High Arctic islands in Nunavut, where glaciers such as the Melville Island South Ice Cap have been shrinking gradually since at least the late 1950s. In eastern Nunavut, however, the situation is more complex: some glaciers are shrinking, while others are growing.

The melting of glaciers is a concern for Alberta, Saskatchewan, and Manitoba. Farmers depend on glacier-fed rivers like the Saskatchewan and the Bow for irrigation water, and cities like Edmonton, Calgary, and Saskatoon rely on them for municipal water supplies and recreation. At The Pas in Manitoba, reduced flows on the Saskatchewan could interfere with the native fishery and hydroelectric power generation.

Although the early stages of glacier shrinkage from melting are likely to increase the water supply to rivers, the flow of meltwater will eventually decrease as glaciers get smaller. The loss of water could be substantial. In a dry August, for example, about 25% of the water in the Bow is glacial. Recent evidence indicates that the amount of glacier water entering the Prairies' largest river, the Saskatchewan, has already begun to decrease.

What's happening in Canada is happening in other parts of the world. According to the World Resources Institute, the total size of the world's glaciers has decreased by about 12% during the twentieth century.

GLACIER FACTS

- Put them together in one place and Canada's 200,000 square kilometres of glaciers and icefields would cover an area about half the size of Newfoundland and Labrador. After Antarctica and Greenland, Canada has more glacier ice than any other part of the world.
- Meltwater from glaciers along the Alberta–B.C. border ends up in all three of Canada's oceans – the Pacific, the Arctic, and the Atlantic (through Hudson Bay).
- The Thompson glacier on Axel Heiberg Island in the Canadian High Arctic is growing while the neighbouring White glacier is shrinking. Both have been affected by earlier cooling and more recent warming, but the smaller White glacier has responded faster to the warming.
- Glaciers trap air, and all the chemicals in it, when they freeze. Air bubbles trapped in the ice are a valuable source of information about past climates and environments. More recently, glaciers have become a resting place for toxic chemicals deposited from the air. When the glaciers melt, these chemicals are released into rivers and lakes. Toxic chemicals that were once stored in the ice of Bow Glacier have now been detected in the waters of Bow Lake in Banff National Park.
- Alpine ice patches – mini-glaciers just a few hundred metres long or wide – are disappearing rapidly from Yukon mountain ridges. Their disappearance is producing a treasure trove of ancient human and animal artifacts. Because the ice is vanishing so rapidly, however, archaeologists are having trouble investigating all the new discoveries before the material decays or is disturbed.
- Wedgemount Glacier near the resort town of Whistler, B.C., has shrunk hundreds of metres in just the past two decades.

Wedgemount Glacier

Source: *Adapted from Canadian Geographic, 1998, and National Atlas of Canada*

Areas with glaciers and ice caps, shown here in blue, are found in B.C., Alberta, Yukon, the Northwest Territories, and Nunavut.

Polar bears are superbly adapted to the frozen Arctic environment. But can they survive in a warmer world?

Polar bears spend most of their lives on a frozen sea. This harsh environment is critical to their survival, because it is on the sea ice that they find the seals that are their main source of food.

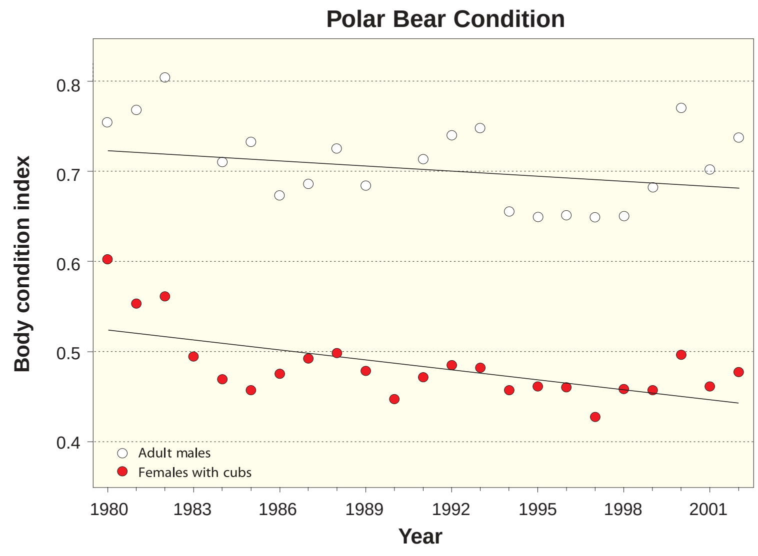
Climate change is expected to reduce the extent and thickness of sea ice in many parts of the Arctic and cause it to break up earlier. A shorter ice season would not only make it more difficult for polar bears to hunt but could also affect the abundance of their prey. These changes, if they continue, could eventually threaten the survival of polar bears in many, though not all, parts of Canada's North.

FOCUS: Western Hudson Bay

Polar bears in the northern Arctic can stay on the ice year-round, but on Hudson Bay the sea ice breaks up in the summer and is half gone by late June or mid-July. Although the bears stay on the ice as long as possible, they eventually come ashore, usually by late July or early August. While on land they eat very little, living mostly on fat reserves built up during their last few months on the ice. The later they leave the ice, the fatter they are, and the better their chances of survival. If the ice breaks up early, the bears must survive longer on less fat.

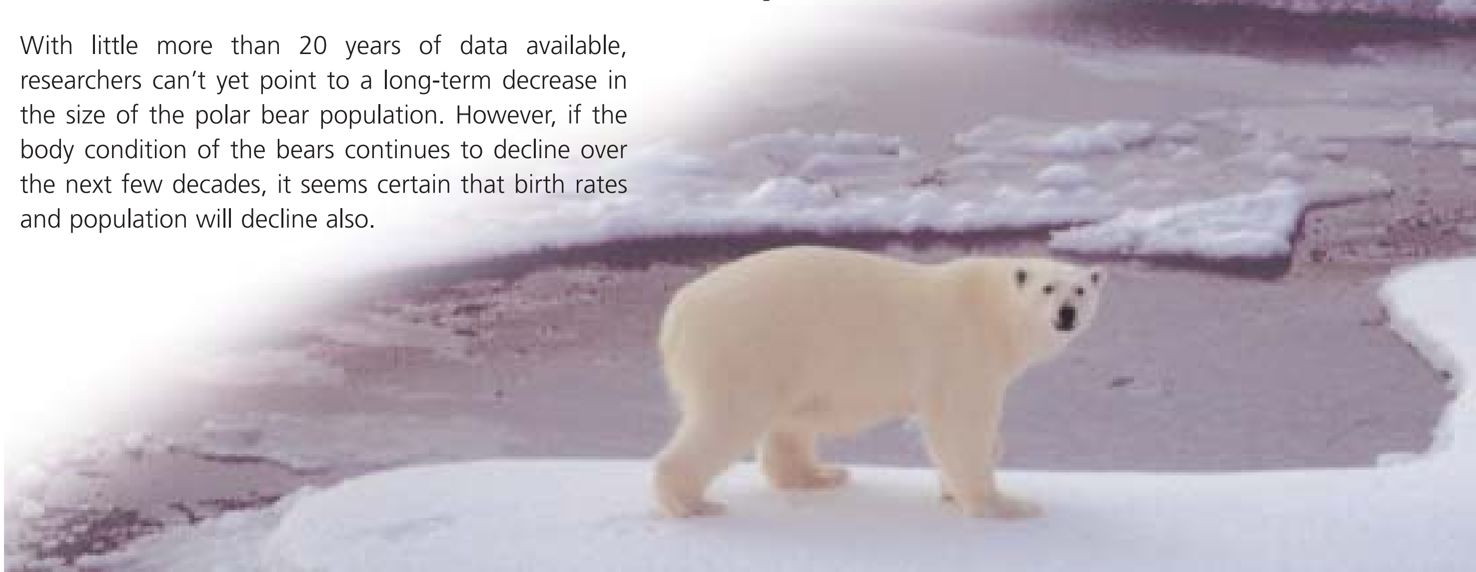
The timing of breakup varies considerably from one year to another, but by the late 1990s the ice on the western side of the bay was breaking up about two weeks earlier on average than it had in the late 1970s. According to scientists who have been studying polar bears in the region during those same years, the trend towards an earlier breakup has been matched by a decline in the physical condition of the bears. The animals have been getting thinner during their stay ashore and their birth rate has fallen. Although other factors can affect the health of polar bears, earlier breakup of the sea ice is the most likely cause of poorer health among the western Hudson Bay bears.

With little more than 20 years of data available, researchers can't yet point to a long-term decrease in the size of the polar bear population. However, if the body condition of the bears continues to decline over the next few decades, it seems certain that birth rates and population will decline also.



Source: *Adapted from N. Lunn and I. Stirling, Environment Canada*

The body condition index (which measures the relationship between weight and body length) provides good evidence of the general health of polar bears. The higher the index number, the healthier the bears. The decline in body condition since the early 1980s appears to be caused by a trend towards earlier breakup of the sea ice. That trend, in turn, is related to an increase in spring air temperature, which has risen at an average rate of 0.2–0.3°C per decade since 1950.



THE BIGGER PICTURE

There are as many as 25,000 polar bears in the world, and most of them, about 15,000, are in Canada. None, however, have been studied as long as those of western Hudson Bay. As a result, not much is known about how bears in other regions may have been affected by changes in climate. Nevertheless, the Hudson Bay evidence does raise concerns about the possible fate of other populations in the southern Arctic if the tendency towards shorter ice seasons continues.

Seals also depend on the sea ice, especially as a place to raise their young until they are old enough to swim and feed on their own. A study by scientists and Inuit hunters in the Beaufort Sea area has shown that seal pups born during short ice seasons are in poorer than average condition, perhaps because of later birth or earlier weaning. A trend towards shorter ice seasons could therefore result in a declining seal population. That, in turn, could create further survival problems for polar bears.

CHANGING ECOSYSTEMS

As climate changes, different plants and animals are affected in different ways. Some may benefit and expand their range and population. Others may migrate to areas where the environment is more favourable. If they don't, or can't, they face a more difficult existence or even extinction. As a result, changes in climate are altering and reshaping many of Canada's ecosystems. These changes are most evident in the North, but they are happening in other parts of the country too.

- New species are being seen in the western Arctic. Salmon have recently been reported in the Mackenzie River, while robins have been sighted on Banks Island. The bird is so rare in the area that there is no name for it in the local Inuvialuit dialect.
- Until recently, ring-necked ducks ranged no farther north than central B.C. In 1980 they were sighted in the northern Yukon and are now frequently seen in the area.
- The arctic fox can be found from Ellesmere Island to James Bay, but it is disappearing from the southern part of its range. Meanwhile, its southern cousin, the red fox, is advancing northwards.
- Until the 1980s, the Virginia opossum was unknown in southern Ontario. Milder winters now allow it to thrive as far north as Georgian Bay.
- Milder winters are also keeping long-tailed ducks in southern Ontario throughout the year. Because their feeding areas ice over less often, they now winter on the Lake Ontario shore instead of migrating further south.
- A comparison of fish surveys done in southern Ontario's Grand River watershed in 1983 and 1996 shows that many warm-water species are now colonizing the upper portions of the system, while many coldwater species have become less common.
- Since the mid-1990s, the explosion of the mountain pine beetle population in B.C. has resulted in the devastation of billions of dollars worth of timber. Warmer temperatures may be making it easier for the beetles to survive and multiply.
- In Manitoba, butterflies are appearing up to 12 days earlier in spring than they did 30 years ago.
- Red squirrels in southwestern Yukon now breed 18 days earlier on average than they did 10 years ago.

An arctic fox in its winter coat.

Major stages in the development of plants, such as budding, leafing, and flowering are triggered by seasonal changes in temperature, moisture, and the amount of light. In southern Canada, plants begin to develop rapidly when average daily temperatures reach and stay above certain critical levels.

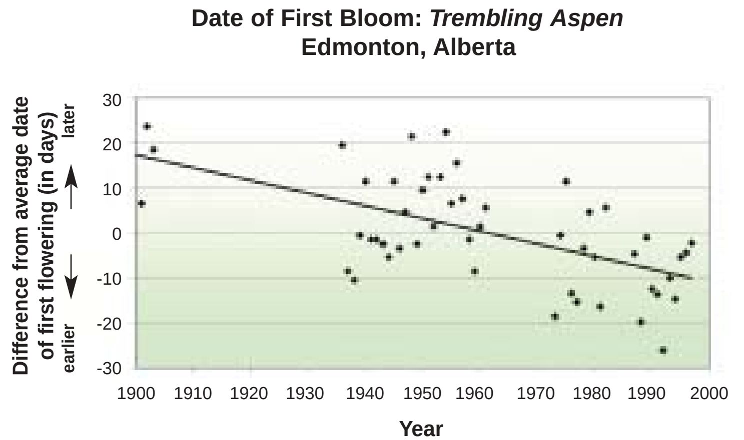
As a result, the timing of plant development varies from year to year with changes in weather conditions. The early arrival of warm weather results in plants developing sooner, while their development is slower if warm weather is delayed. Over the longer term, these changes in the timing of plant development make a good indicator of changes in climate. Farmers, ranchers, and gardeners are especially interested in these changes because of their effects on the way that crops, livestock, and garden plants have to be managed.

As our climate has changed, spring across much of the country has been getting warmer earlier. That should give most plants a head start on their development and result in the earlier arrival of noticeable events like budding and flowering.

FOCUS: Edmonton

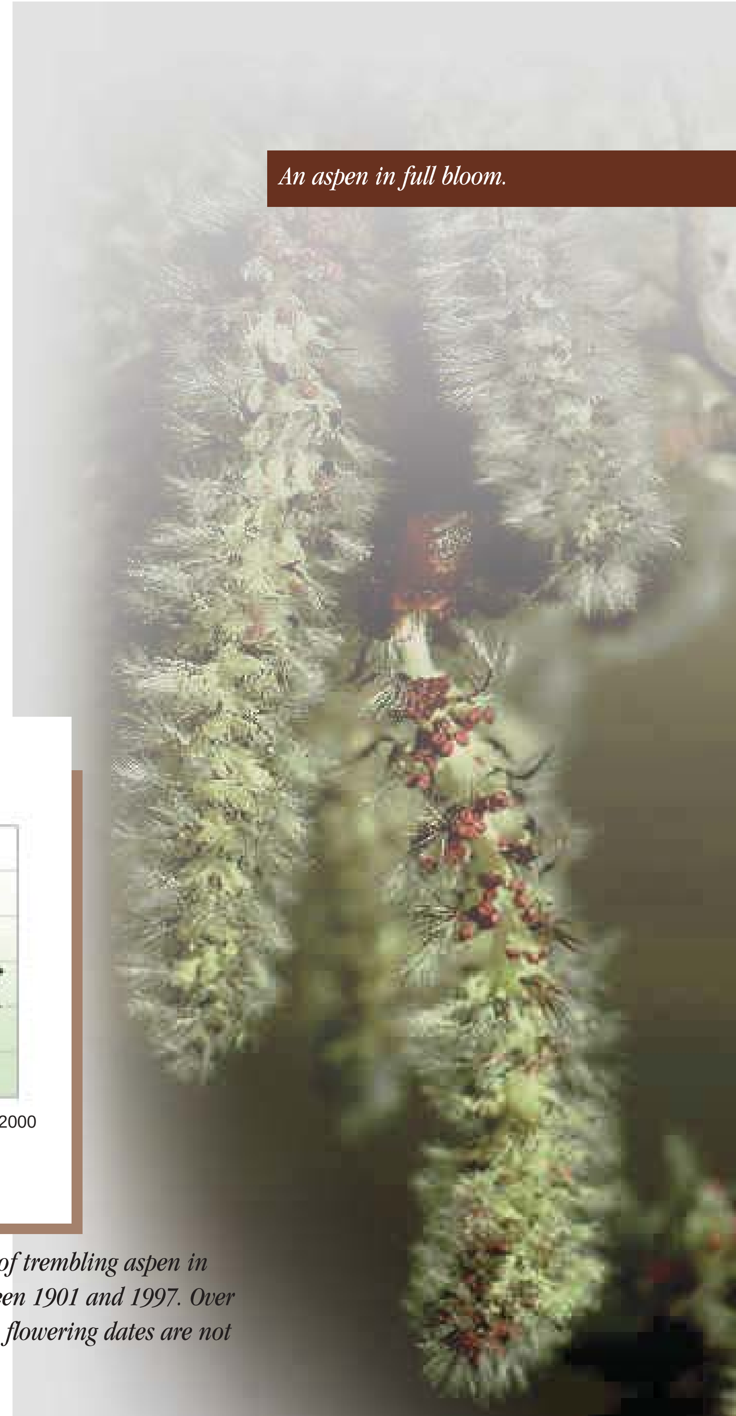
At various intervals over the past 100 years, observers in the Edmonton area have recorded the flowering date for a common North American tree, the trembling aspen. Researchers from the University of Alberta put four of these sets of observations together to see if there had been any noticeable change in the flowering dates during the twentieth century. They found that between 1901 and 1997 the average date of flowering had advanced by about 26 days – from early May at the beginning of the century to early April at the end.

The trend towards earlier flowering coincides with warmer springs on the Prairies. During the twentieth century, daily high temperatures in spring increased, on average, by more than 2°C, and overnight lows increased even more. The city of Edmonton has warmed more than nearby rural areas, mainly because it has less green space and more asphalt and buildings. This "urban effect" may have also influenced the earlier flowering of the trembling aspen in the area.



Source: *Adapted from Beaubien and Freeland, 2000*

The graph shows the difference between the average first-flowering date of trembling aspen in Edmonton (the zero line) and the flowering date for specific years between 1901 and 1997. Over the century, the first-flowering date advanced by about 26 days. Because flowering dates are not available for every year, this value is only approximate.



An aspen in full bloom.

THE BIGGER PICTURE

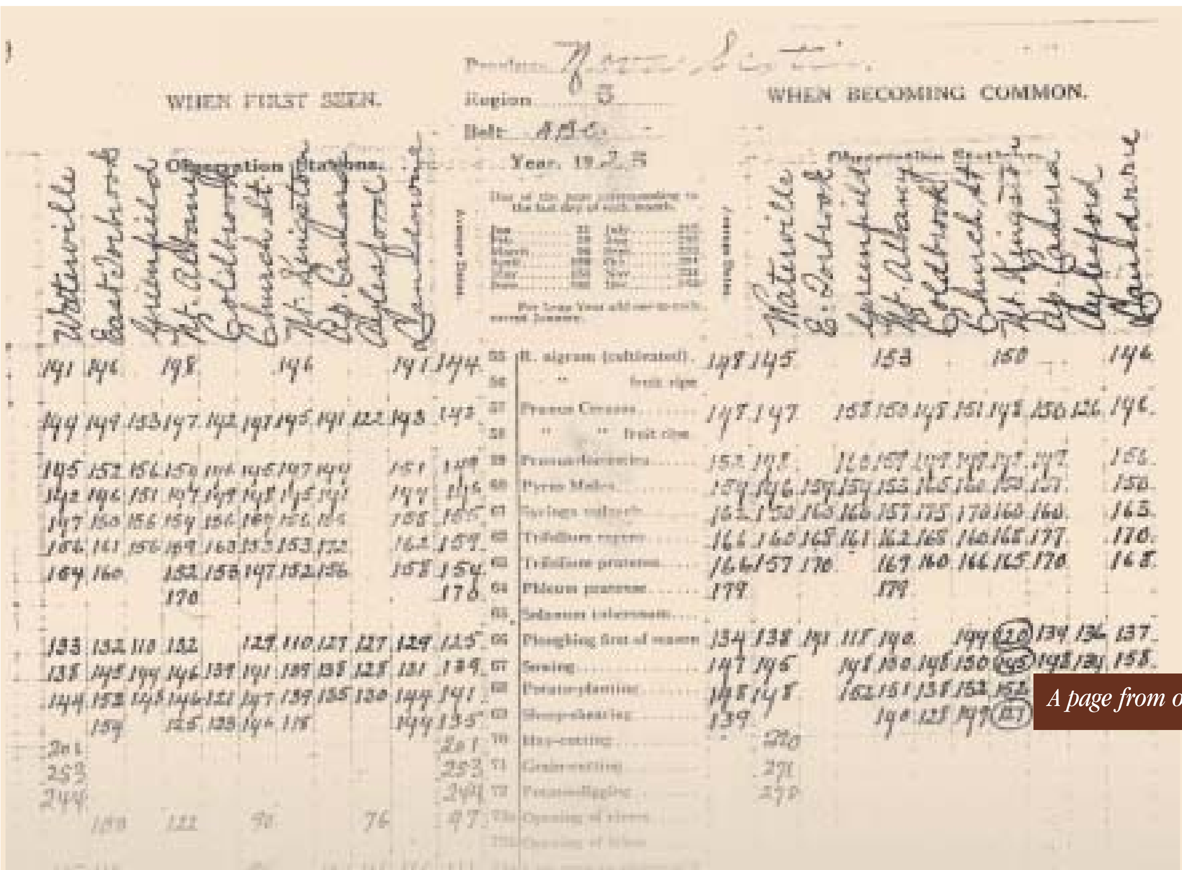
Most studies of plant development in Canada cover periods of about 20 years or less. Nevertheless, these and the few long-term studies that are available agree with what was seen in Edmonton – most plants are reaching major stages in their development earlier in the spring. Since 1937, for instance, the average date of full bloom for McIntosh apple trees in Summerland B.C. has advanced by about 5 days. Similarly, the average date when lilacs come into leaf in the United States and southern Canada advanced by 5–6 days between 1959 and 1993. In Europe, where more data covering longer periods are available, the trends are even stronger. Satellite observations also show an earlier greening of the Northern Hemisphere. Northern forests are now coming into leaf several days earlier and losing their leaves several days later than they did in the early 1980s.

These changes could have important consequences for ecosystems, agriculture, and human health. Earlier development means a longer growing season, which creates opportunities for growing new crops and improving farm yields. However, disease-carrying and crop-eating insects could become more of a problem since their breeding and growth are also affected by temperature. Hay fever sufferers could find their miseries starting earlier too. In addition, complex ecological relationships could be upset if interacting species, like plants and the insects that pollinate them or birds and the insects they eat, respond at different rates to climate change.

NOVA SCOTIA'S THOUSAND EYES

Between 1900 and 1923 hundreds of Nova Scotia students took part in a unique project that recorded more than 200 different seasonal natural events. It was the brainchild of Dr. Alexander MacKay, an innovative educator and naturalist and the province's superintendent of schools. The students recorded events as diverse as the flowering of plants, the emergence of butterflies, the return of migrating birds, and the occurrence of thunderstorms. Their observations were sent to Dr. MacKay and recorded in large, handwritten ledgers, which now provide an invaluable record of the seasonal behaviour of Nova Scotia wildlife in the early twentieth century.

A century later, Dr. MacKay's initiative has been revived as the Thousand Eyes Project. Once again, students are observing and recording natural phenomena, although this time other Nova Scotians can participate too. The project also uses the power of computers and an interactive web site to coordinate activities and to collate and report observations. As observations accumulate, it will be possible to compare today's results with those from 100 years ago. From these comparisons, scientists hope to get new insights into how Nova Scotia's climate is changing and how nature is responding.



A page from one of Dr. MacKay's ledgers, 1923.

PEOPLE

People and their activities are greatly influenced by climate. How we earn our living, how we build our homes and communities, and how we spend our leisure time all depend on the kind of weather we expect.

As with natural ecosystems, it is not often easy to separate the influence of climatic changes on human activities from other influences. And unlike other species, we humans have a greater ability to lessen the impacts of such changes by using technology and by modifying our behaviour.

To consider some of the ways in which a changing climate may be affecting the daily lives of Canadians, this section examines the following six indicators:

- Traditional Ways of Life
- Drought
- Great Lakes–St.Lawrence Water Levels
- Frost and the Frost-free Season
- Heating and Cooling
- Extreme Weather

As Canadians learn more about trends in climate, they may want to know more about potential economic impacts. For example, how might changes in climate affect shipping seasons, construction methods, insurance requirements, and tourism opportunities? They may also wish to consider climate changes in evaluating potential health and social impacts, such as the spread of insect-borne diseases, injuries due to cold and heat extremes, and weather-related traffic accidents.

The lives of many Canadians are closely tied to the land. This is especially true for aboriginal communities, who get much of their food from hunting and fishing and the harvesting of edible plants and berries. These traditional activities are also an important part of aboriginal culture, which contains a large amount of knowledge about climate and how it affects these activities and the environment that supports them.

The North's climate is changing, however, and it is changing faster than in most other parts of Canada. These changes are affecting many aspects of the northern environment, such as ice and terrain conditions and the supply of game, wild plants, and fresh water. As a result, native peoples are finding it harder to rely on the traditional knowledge and practices they have used for so long to survive in a region that is usually frozen for more than half the year.

FOCUS: Western Nunavut

Follow the line of the Alberta-Saskatchewan border north to the Arctic Ocean and you come to Coronation Gulf. The gulf and Bathurst Inlet to the east are the heart of a region known as West Kitikmeot. This region is home to the Bathurst caribou herd whose range extends across West Kitikmeot and south into the Northwest Territories.

In recent years, the Kitikmeot Inuit, who inhabit the region, have noticed dramatic changes in the local climate and environment. Winters and summers have become warmer, and sea and lake ice have been melting earlier in the spring. Fall freeze-up – an August or September event just a few decades ago – now happens mostly in October or November. The weather has also become more variable, and short-term temperature swings that cause repeated thawing and freezing have become more common. With a more variable climate, weather and ice conditions have become harder to predict, and that has made it more difficult and dangerous for hunters and others travelling on the land and ice.

The changing climate has affected plants and wildlife too. Summer vegetation is richer, and birds and animals rarely seen before are appearing more frequently. Because the Kitikmeot Inuit get much of their food from hunting, fishing, and sealing, they are affected by all of these changes.

They are particularly concerned, though, about the impacts on caribou. More plentiful vegetation can support a larger herd, but hotter summers put more stress on the animals, while the more rapid appearance of large expanses of open water in the spring forces them to alter their migration routes. More frequent thawing and freezing of the snow cover can result in starvation, because it leaves a thick layer of ice that the caribou can't dig through to reach the vegetation below. Thin ice is also a hazard. Two snowmobilers travelling in the Coronation Gulf area discovered stark evidence of this in 1996, when they suddenly encountered hundreds of antlers sticking through the ice – an "antler forest" that marked the site of a mass caribou drowning.

A caribou herd crosses an expanse of water.

THE BIGGER PICTURE

Climate change is a major concern throughout Canada's arctic and subarctic regions, and many communities have begun to record their observations of how it is affecting their environments and their lives. From the Yukon to central Nunavut most local observers agree that the climate is getting warmer. In eastern Nunavut, however, opinions are mixed as to whether it is warming or cooling, while in Nunavik (northern Quebec) residents have noticed warmer summers but more extreme cold in the winter. In northern Labrador, the perception is again one of general warming. In all regions, however, it is agreed that the weather has become more variable, stormier, and harder to predict.

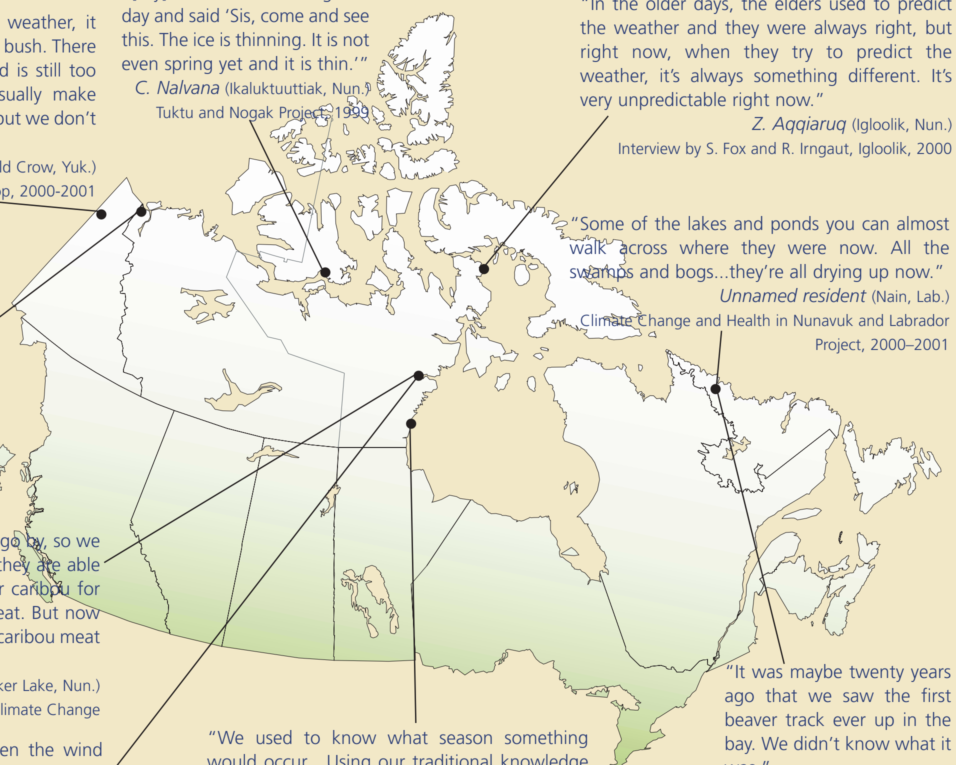
These observations generally agree with the scientifically measured trends, although the scientific record gives a stronger impression of cooling in the eastern Arctic than the reports of local observers do. This may be because local observers have given more emphasis to recent years, which have been unusually warm. The scientifically measured trends, on the other hand, cover a span of 50 years and include a greater number of cold years. But that could be changing. Parts of northern Quebec, at least, have been warming since the mid-1990s.

As a result of changes in climate, familiar environments are becoming less familiar. As in Kitikmeot, people in most parts of the North are noticing the arrival of birds, fish, and animals that have not been seen in their regions before. They are also noticing more unusual weather and more storms. Thunder and lightning, once very rare in the Arctic, are now being experienced more often, and in 2001 the Mackenzie Delta got its first tornado warning.

In coastal areas, people can no longer hunt, fish, or travel on the ice as often or as long as they used to, and thinning ice is making these activities more dangerous. Changing wind patterns are also making it more difficult to apply traditional navigational techniques like following the direction of snow drifts. Survival on the ice is more difficult as well, because stronger winds are often packing the snow harder and making it unsuitable for building igloos. Getting drinking water by melting sea ice is harder too, because old multiyear ice, which is mostly fresh water, is no longer as easy to find, and the more plentiful new ice is salty. In inland areas, problems such as melting permafrost and the drying of lakes and rivers are adding to the difficulties of tending traplines or travelling to hunting and fishing grounds in some areas.

Northerners are adapting to these changes in a number of ways – changing the timing of hunting and fishing activities, going to different locations, harvesting different types of fish and game, and being more cautious when travelling on the ice. Some changes also offer advantages. Extremely harsh winters are fewer and more time can be spent on the land in the summer. What is most endangered though is a way of life that has been based on a long relationship with the cold polar climate, a way of life that is very much a part of the identity of northern people.

CLIMATE CHANGE – THE NORTHERN EXPERIENCE



"Because of too much change in the weather, it makes it hard for people to go out in the bush. There is not much permafrost and the ground is still too soft under the snow. The grounds usually make cracking noises when it gets really cold, but we don't hear that anymore."
Shirley Kakfwi (Old Crow, Yuk.)
Arctic Borderlands Ecological Knowledge Co-op, 2000-2001

"[My] brother was sealing one day and said 'Sis, come and see this. The ice is thinning. It is not even spring yet and it is thin.'"
C. Nalvana (Ikaluktuuttiak, Nun.)
Tuktu and Nogak Project, 1999

"In the older days, the elders used to predict the weather and they were always right, but right now, when they try to predict the weather, it's always something different. It's very unpredictable right now."
Z. Aqqiaruq (Igloolik, Nun.)
Interview by S. Fox and R. Irngaut, Igloolik, 2000

"The snow melted in April. Usually the snow stays until June and waters the ground."
Unnamed resident
(Aklavik, N.W.T.)
Arctic Borderlands Ecological Knowledge Co-op, 1998–1999

"Some of the lakes and ponds you can almost walk across where they were now. All the swamps and bogs...they're all drying up now."
Unnamed resident (Nain, Lab.)
Climate Change and Health in Nunavuk and Labrador Project, 2000–2001

"Traditionally we didn't have calendars to go by, so we observed the nesting of the birds. When they are able to fly that is the time to start hunting for caribou for clothing skins and to start caching the meat. But now in the month of August you can't do your caribou meat caching. It's too warm."
Eugene Niviatsiak (Baker Lake, Nun.)
From Inuit Knowledge of Climate Change

"The wind blows a lot harder and when the wind blows that hard it packs the snow…so hard that it's almost like ice and it's not good now. You can't make igloo shelters with it."
M. Aqigaaq (Baker Lake, Nun.)
Interview by S. Fox and M. Kaluraq, Baker Lake, 2001

"We used to know what season something would occur....Using our traditional knowledge you would know what was going to happen when, but you can't predict anymore."
Donald Uluadluaq (Arviat, Nun.)
From Inuit Knowledge of Climate Change

"It was maybe twenty years ago that we saw the first beaver track ever up in the bay. We didn't know what it was."
Unnamed resident (Nain, Lab.)
Climate Change and Health in Nunavuk and Labrador Project, 2000–2001

Is drought becoming more frequent and severe? It's too soon to tell.

For farmers, drought means poor crops, more damage from insect pests, a greater risk of soil erosion by the wind, and possibly the need to sell off herds of cattle that can't be watered and fed. But drought can have many other impacts as well – water usage restrictions in cities, poorer water quality, higher food prices, lower power outputs from hydro dams, more forest fires, shrinking wetlands, and more stress on fish and waterfowl.

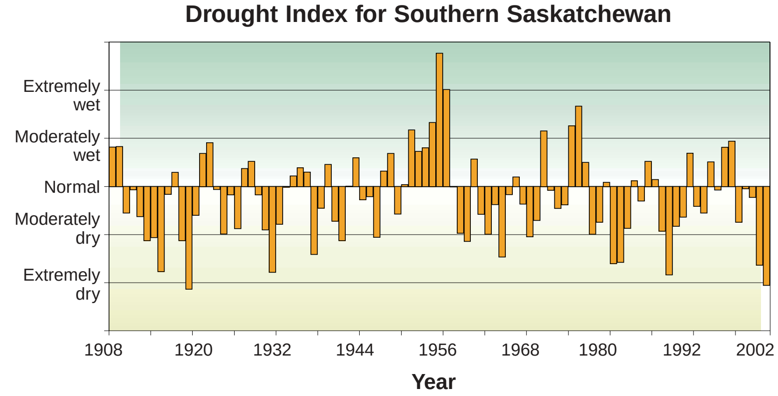
Although a warmer world is likely to be wetter overall, droughts could happen more often or be worse as a result of climate change. Why? In some areas it is because higher temperatures and a longer warm season could cause more moisture to be lost through evaporation than is gained from any increase in precipitation. Changes in weather patterns could also cause some places to get less rain than they used to while others get more. Or less rain might fall during the growing season (when it's needed) and more during the harvest season (when it's not).

FOCUS: The Prairies

The Prairies are one of Canada's most drought-prone regions. Their climate has also changed more over the past century than that of most other parts of the country, so it is here that we might expect an early indication of more frequent or more severe drought.

Climate records for the Prairies, however, do not show droughts happening more often than they did in the past. Nor is there any evidence yet that Prairie droughts are becoming more severe. Droughts that occurred 3–4 thousand years ago, for example, appear to have been worse than any in modern times.

Still, the most recent droughts on the Prairies have been quite severe. In fact, for some areas, 2001 and 2002 were drier than the driest years of the 1930s, when the region was devastated by the most destructive drought in Canadian history.



Source: *Adapted from R. Hopkinson, Environment Canada*

The index estimates the severity of drought on the basis of precipitation, the amount of moisture in the soil, evaporation, and other factors. It shows a number of droughts in the region over the past 100 years but no clear tendency towards either more severe or more frequent drought.

THE BIGGER PICTURE

Next to the Prairies, southern Ontario and the B.C. interior are the regions of Canada most affected by drought. Droughts also affect eastern Canada, but do not occur as often or last as long.

Although precipitation has generally increased in Canada during the twentieth century, there are some signs that severe dryness is occurring more often. The country as a whole, for example, has seen more extreme summer dryness – though not necessarily full-blown drought – in the second half of the century than in the first. Since the 1960s more of the country has also experienced unusually warm and dry spring weather. Two of the most severe and widespread droughts in Canadian history have occurred in the past 15 years. The drought of 1988 affected Ontario, Quebec, and the B.C. interior as well as the Prairies, while the drought of 2001 affected almost all of southern Canada and continued across the central and northern Prairies in 2002.

Could these recent events mark the beginning of a shift towards a more drought-prone climate? Perhaps. But more time will be needed to see if drought patterns in Canada are actually changing.

DROUGHT 2001

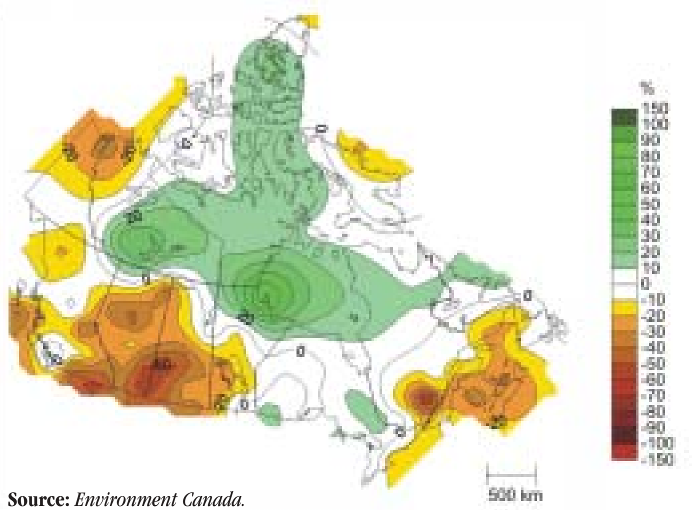
The drought of 2001 was one of the most intensive and widespread in Canadian history, affecting almost every farming region in the country. As so often before, it was worst on the Prairies, where wheat and canola yields fell by 43% from the previous year.

In the Great Lakes–St. Lawrence region, it was the driest summer in 54 years. Montreal's Dorval weather station recorded its driest April ever as well as a record 35-day rainless spell in the summer. Atlantic Canada had its fourth dry summer in five years, and both Charlottetown and Moncton reported their driest July and August ever. Most parts of B.C., in contrast, had a wetter than normal summer, but the preceding winter saw only about half the average levels of precipitation along the coast and in the southern interior.

While 2002 brought a return of normal conditions to the rest of the country, the drought lingered in many parts of central and northern Alberta and Saskatchewan. Failure of the hay crop forced many farmers to sell off their herds. Others more fortunate were able to keep going with surplus hay donated by eastern farmers. The soft wheat harvest was the smallest in 28 years, while barley yields hit a 34-year low. Canola fared poorly too, as output fell 35% below the already weak yields of the previous year.

Farmers felt the effects most directly, but the impacts rippled through every level of the economy – from small-town merchants serving cash-strapped farming communities to consumers across the country facing higher prices at the supermarket.

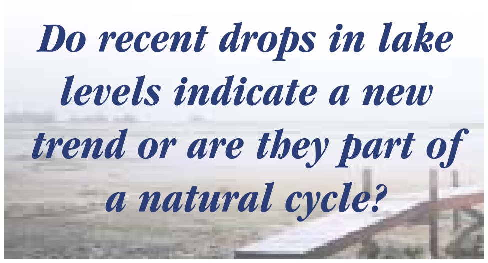
Differences from Normal Precipitation, 2001



Source: *Environment Canada.*

In 2001 rain and snowfall totals for the year were below normal for much of Canada. During the summer, dry conditions affected almost every farming region in the country.

The St. Mary reservoir channel near Spring Coulee, Alberta, after 66 days with no rainfall, summer 2001.



Do recent drops in lake levels indicate a new trend or are they part of a natural cycle?

Water levels in the Great Lakes are the result of a balance between water entering the system (through inflows from rivers, rain, snowfall, snowmelt and runoff) and water leaving it (through outflows to rivers, evaporation to the air, and withdrawals for various human uses). Natural seasonal and yearly variations in these factors can result in temporary changes in lake levels, but more permanent changes could come about as a result of climate change.

Changes in the climate of the Great Lakes–St. Lawrence region have brought more rainfall to replenish lake waters, but they have also brought higher temperatures, a longer warm season, and a shorter ice season, all of which increase evaporation and water loss. If the increases in rainfall and evaporation balance each other, climate change may have little effect on lake levels. There are concerns, however, that continued warming will increase evaporation rates more than precipitation and cause lake levels to fall.

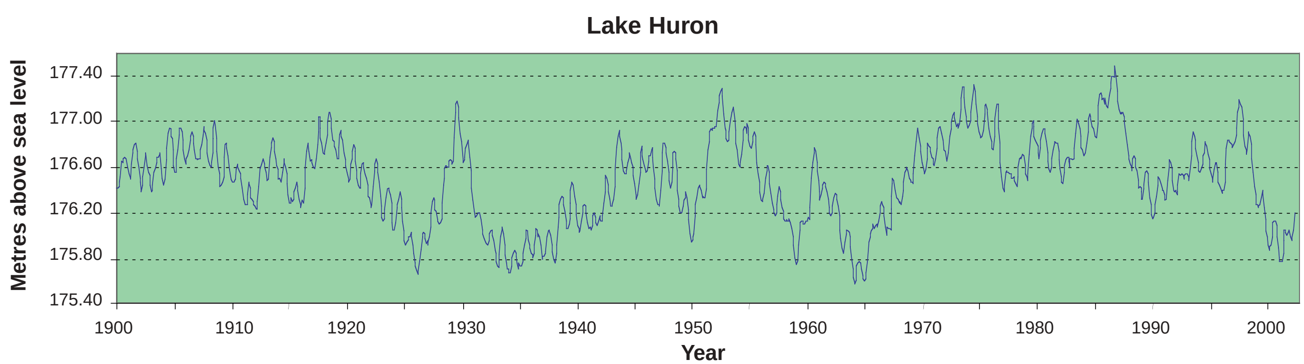
A significant lowering of lake levels could reduce the output of hydroelectric power, force ships to carry lighter loads, require cottagers to relocate docks, boathouses, and water intakes, and shrink or dry up wetlands that are important food sources and breeding grounds for fish and waterfowl. Extensive dredging would be needed to deepen channels and keep the connecting rivers between Lakes Huron and Erie navigable for commercial shipping. Similarly, the St. Lawrence River below Montreal might have to be totally transformed by the addition of dredged channels, locks, and dams to keep it open for large ships.

FOCUS: Lake Huron

Located in the middle of the Great Lakes system, Lake Huron is perhaps the most suitable of the lakes to use as an indicator of the effect of climate change on water levels. Lake Huron also reflects the influence of natural forces more directly than Lakes Superior and Ontario, where water levels are regulated to some extent by Canadian and U.S. authorities.

Over the past century, water levels in Lake Huron have not shown a consistent long-term trend. Instead, they have alternated irregularly every couple of decades between higher and lower phases. Extreme low water levels on the lake occurred in the mid-1960s, while the longest period of low-water levels was in the hot, dry years of the 1930s. Through the 1970s, 1980s, and most of the 1990s, lake levels were actually higher than the long-term average.

In the late 1990s, however, low water levels, similar to those of the 1960s, returned. It remains to be seen whether these signal the beginning of a longer trend or are just another phase in the lake's periodic swings between low and high water phases.



Source: *Environment Canada*

The graph shows changes in the average monthly lake level between 1900 and 2002. The level is given in metres above sea level. Although water levels in Lake Huron have varied considerably from decade to decade, no long-term change is yet apparent.

THE BIGGER PICTURE

Water levels in each of the Great Lakes and the St. Lawrence River are influenced to some extent by local climate and drainage conditions. Consequently, they do not always change in exactly the same way. Nevertheless, the long-term picture for Lake Huron is fairly representative of the system as a whole. Water levels in the Great Lakes have fluctuated within a range of about 1.8 metres over the past century, but no long-term trends have been apparent in any of the lakes or in the St. Lawrence River. Temperature changes in the region have been fairly small – about 0.5°C over 100 years – and that may be one reason why long-term changes in water levels have not yet appeared.

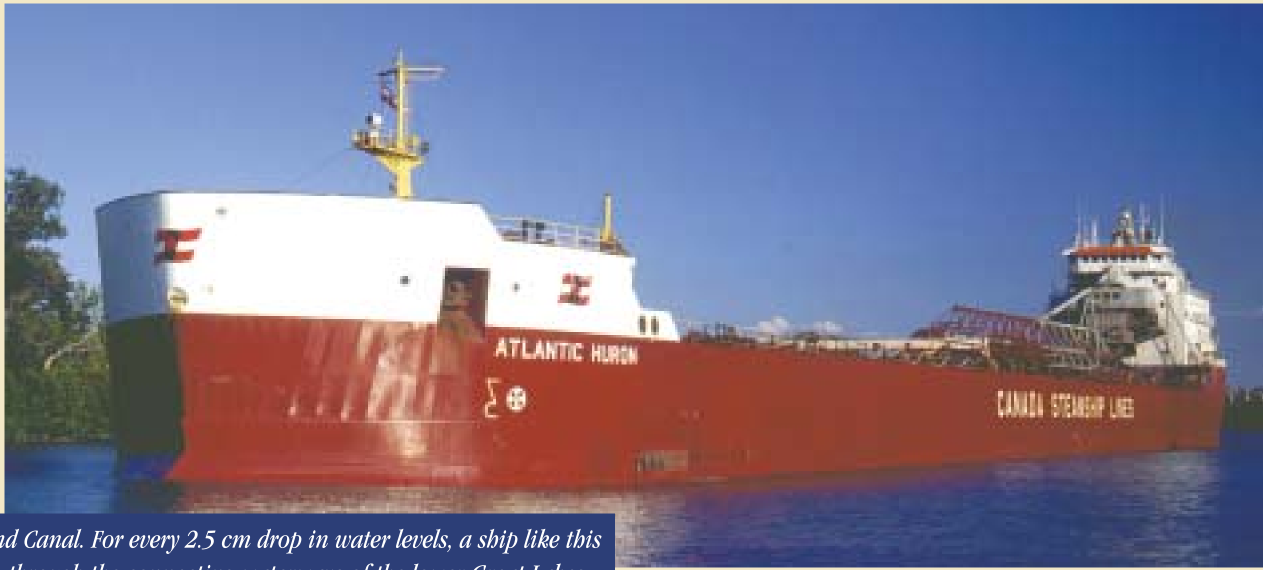
Still, concerns about low water levels remain, and one good reason is that the economic costs they impose are so high. Between 1988 and 1991, for example, when water levels at Montreal were 30 cm below average, the tonnage of goods passing through the port fell by 15%.

LOW WATER BLUES

After nearly three decades of high water levels, the rapid drop in lake levels in the late 1990s came as a sharp surprise to many. By 1999 the levels of all of the Great Lakes and the St. Lawrence River were below their long-term averages, and the system had lost almost as much water as flows over Niagara Falls in two and a half years.

In spite of above-average spring and early summer rains, water levels continued to drop in 2000. Cottagers found their docks on dry land and marina owners were forced to call in dredges to dig channels so they could keep their businesses open. Ships had to run lighter and higher in order to pass through canals and shallow channels, and hydroelectric power production was down substantially at both Niagara and Sault Ste. Marie.

The following year was not much better. In August, water levels in Montreal harbour were a record 95 cm below average. In late October, sustained high winds in Lake Erie pushed large volumes of water toward the lake's eastern end. This short-term effect caused already low water levels to fall a further 1.5 metres at the lake's western end and in the Detroit and St. Clair rivers. That was enough to make the link between Lakes Erie and Huron impassable for large vessels, and shipping traffic came to a halt until water levels rose two days later.



The Atlantic Huron transits the Welland Canal. For every 2.5 cm drop in water levels, a ship like this must travel 100 tonnes lighter to pass through the connecting waterways of the lower Great Lakes.

The frost-free season begins on the first day in spring when temperatures remain above freezing and ends on the first day in fall when freezing temperatures return. The earlier the frost-free season starts or the later it ends, the longer the growing season will be. A longer frost-free season is of interest to farmers and home gardeners alike because it gives them more choice in what they can grow and a better chance of seeing their annual crops and flowers survive to maturity.

The flip side of a longer frost-free season is a shorter frost season, and that is a benefit to governments that have to keep roads ice-free and for individuals and transportation companies that have to deal with ice hazards. It also means a longer season for construction. It is a disadvantage, however, to northern communities and to businesses like logging and oil and gas exploration that rely on frozen ground and waterways for moving goods and heavy equipment.

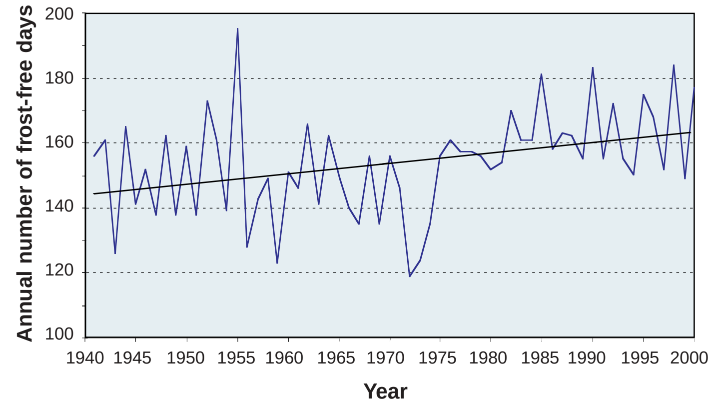
A number of factors can affect the persistence of frost. These include elevation, exposure to sunlight, vegetation, and proximity to water bodies or cities. As a result, even locations that are quite close to each other can have very different frost seasons. Air temperature, particularly the overnight low, is the dominant force, however, and regions that are becoming warmer can also expect to see shorter frost seasons.

FOCUS: Southwestern Ontario

Southwestern Ontario, with its mild climate and rich soils is prime farming country. Over the past century, it has warmed by about 0.5°C, somewhat less than the national average. Still, this has been enough to have a noticeable impact on the length of the frost-free period.

Temperature records for London airport, in the centre of the region, show that the average length of the frost-free season has increased by more than 18 days since the 1940s. The increase reflects a strong rise in winter and spring temperatures and especially in overnight lows.

Length of Frost-Free Period at London Airport, Ontario



Source: *J. Klaassen, Environment Canada*

A new soybean crop is off to a good start on this farm near London.

THE BIGGER PICTURE

The frost-free season has been getting longer in most other parts of Canada too. The biggest increases over the past 100 years have been seen in B.C. and on the Prairies. For most of Canada, spring has warmed more than any other season. Not surprisingly, then, the frost-free season has been getting longer largely because the last spring frosts are happening earlier.

While the frost-free season is getting longer on average, it can still vary considerably from one year to another, and unusually late spring or early fall frosts can still occur. While farmers thus face a smaller risk of losing a crop to frost, they still have to be cautious about planting too early or shifting production to varieties that require a longer growing season.

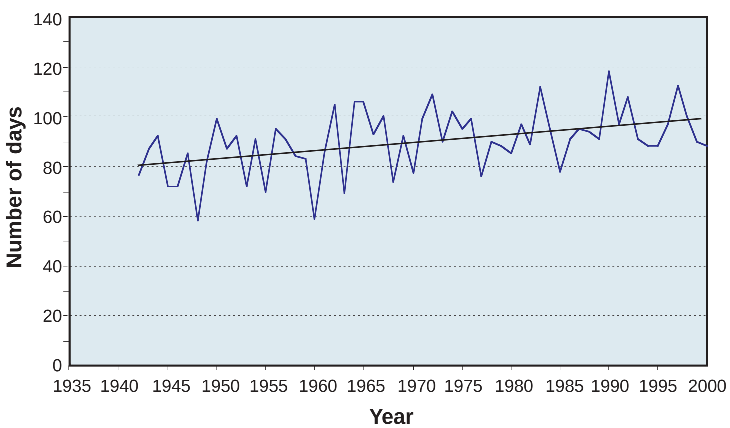
THE THAW-FREEZE-THAW-FREEZE SEASON

The transition from the frost to the frost-free season and back again is neither smooth nor sudden. As spring temperatures warm or fall temperatures cool, days with temperatures above freezing typically alternate with nights when temperatures are below the freezing point. Repeated cycles of thawing and freezing can be hard on trees and plants, especially in late winter or early spring. Large herbivores like deer and caribou suffer too, because refreezing puts a hard, icy crust on the snow that makes moving about and feeding difficult. When they occur in combination with rain and snow, thaw-freeze cycles also contribute to the weathering of building materials.

Preliminary studies indicate that in much of Canada thaw-freeze cycles are happening more often. Most of the stronger trends have been found in southern Ontario. The weakest have been in British Columbia. At Trenton, Ontario, thaw-freeze events have been increasing at the rate of 3.2 days per decade. At Swift Current, Saskatchewan, the rate is 3.9 days per decade. An interesting exception is the city of Toronto, where thaw-freeze cycles have been decreasing, possibly because of warming effects related to the city's growth.

Since the early 1980s, the construction industry has noticed that materials such as bricks and concrete are not lasting as long as expected in some parts of the country. Faster weathering as a result of more frequent thaw-freeze cycles is believed to be contributing to this problem, and because of it, building owners and taxpayers are facing added maintenance costs for buildings and other structures that use these materials.

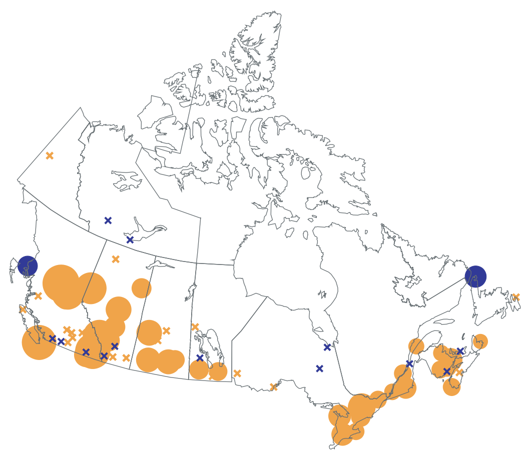
Number of Thaw-Freeze Days per Year at Trenton, Ontario



Source: *J. Klaassen, Environment Canada*

A day with a thaw-freeze cycle is one in which the daily high is above freezing and the overnight low is below freezing. In the 1940s Trenton averaged about 80 days with thaw-freeze cycles. By the 1980s and 1990s that number had climbed to about 95.

Trends in Length of Frost-free Period (days/100 years)



Source: *Environment Canada*

Orange dots indicate a longer frost-free season, blue dots a shorter. The larger the dots, the greater the change in the length of the season. The x's indicate changes that are not statistically significant. The largest increase (about 50 days per century) has occurred in central B.C. The largest decrease (about 30 days per century) has been in St. Anthony's, Newfoundland.

The amount of energy needed to heat a home for a year depends on how many cold days there are in the year and on how cold it gets on each of those days. When the weather is slightly cool, a little bit of heat might be needed for a few hours in the evening or early morning to stay comfortable. On a very cold day, a lot of heat will be needed all day and all night. A day's average temperature gives some idea of how much heat will be needed on that day.

Climatologists use a measurement known as heating degree-days (HDDs) to estimate heating needs more precisely. They assume that people will use at least some heat on any day that has an average outdoor temperature of less than 18°C. They then calculate the heating needs for each day by subtracting the day's average temperature from 18. The result is the number of heating degrees for that day or HDDs.

Cooling requirements, known as cooling degree-days or CDDs, can be measured in much the same way. The assumption this time is that there is some need for cooling on days when the average temperature is above 18°C. Subtracting 18 from the day's average temperature thus gives the number of cooling degrees for that day or CDDs.

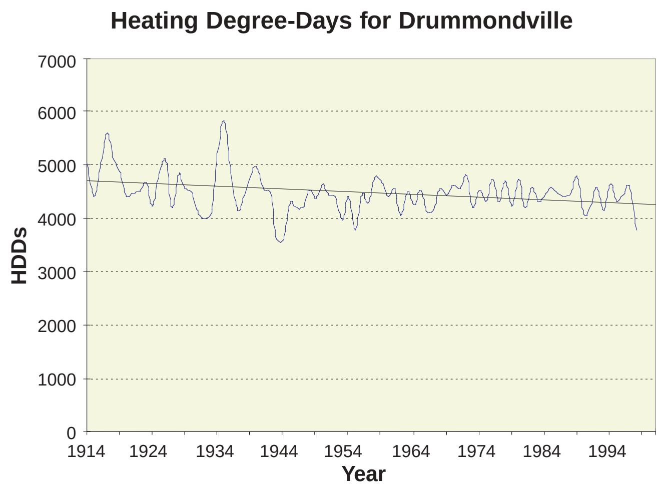
When the heating or cooling degrees for each day are added up for a season or year, the result is a very useful statistic that indicates how much demand there is for heating or cooling as a result of different climate conditions. The amount of energy actually needed to heat or cool a particular building will, of course, depend on many other factors, such as how well the building is insulated and the temperature that it is kept at.

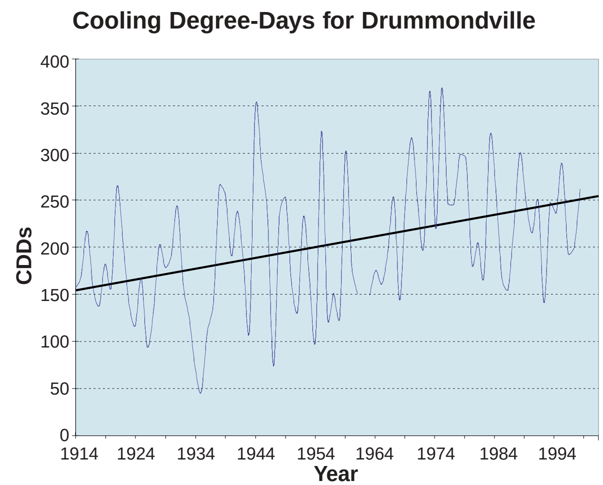
FOCUS: Drummondville, Quebec

In Canada, heating is always a bigger concern than cooling, and Drummondville is no exception. The city, 100 km northeast of Montreal, averages about 4500 HDDs a year, but with 250 CDDs a year (about the same as Montreal and Toronto) it still has plenty of hot summer days when air conditioning is welcome.

Over the past century, the average annual temperature in the Drummondville area has warmed by about 0.5°C – less than in some other parts of Canada but still enough to have had a noticeable impact on heating and cooling needs. At the beginning of the twenty-first century, Drummondville now averages 445 fewer heating degree-days per year than it did in the early twentieth century and has 100 more cooling degree-days. Those figures amount to a 9.5% decrease in HDDs and a 65.5% increase in CDDs.

Because the need for heating is much greater than the need for cooling, the energy savings from lower heating requirements are still more significant to the average person than any additional energy costs from higher cooling requirements. In fact, cooling becomes a significant cost only when people switch from electric fans to air conditioning to meet their cooling needs. As the cooling degree-day trend rises, however, more people may be inclined to make that change, and at that point cooling degree-days will begin to have an important impact on their budgets.





Source: *Environment Canada*

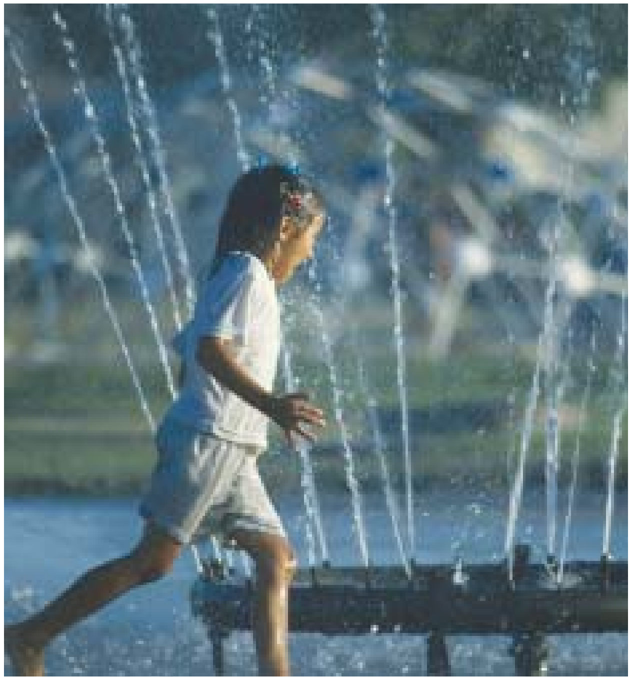
Because it is a large change in a small number, the increase in CDDs looks more important than the decrease in HDDs. However, the decrease in HDDs has had a greater impact on people's energy needs in Drummondville, simply because heating needs there are much greater than cooling needs.

THE BIGGER PICTURE

Heating degree-days in Canada vary from about 3,000 a year in balmy Victoria to about 13,000 in the Far North. Over the past century, HDDs have declined significantly in most of Canada.

Cooling degree-days range as high as 400 per year in the Windsor area of southwestern Ontario but average fewer than 100 in many parts of the country. Increases in cooling degree-days have been smaller and less widespread than the decreases in heating degree-days. Nevertheless, significant increases have occurred over the past century in southern B.C. and parts of the Prairies as well as in southern Quebec and the Maritimes. These trends are consistent with the way that our climate is changing – that is, both winters and summers have been getting warmer, but winters have warmed more.

In cities, these trends may also be affected by what is known as the heat island effect. City surfaces, like roads, buildings, and rooftops, absorb large amounts of heat from the sun during the day and then release it at night as they cool. Cars, furnaces, air conditioners, and other heat-producing equipment also add warmth to city air. As a result, temperatures within a city, especially a densely built downtown core, are often noticeably warmer than temperatures recorded on the city's outskirts. As a city grows, the heat island effect grows with it. Consequently, heating needs can decrease and cooling needs increase simply because a place is becoming more urbanized. It is a difficult task, however, to determine just how much of the warming in our cities is due to the heat island effect and how much is due to climate change.



HEATING AND COOLING DEGREE-DAYS ACROSS CANADA

The table gives heating and cooling needs for locations in each of the ten provinces and three territories. Heating needs in Vancouver are about half those in Winnipeg, although differences between other cities in southern Canada are less dramatic. Cooling needs, on the other hand, differ much more widely across the country.

Heating and Cooling Degree-Days for Selected Canadian Cities (Average Annual Totals, 1971–2000)

	HEATING DEGREE-DAYS	COOLING DEGREE-DAYS
St. John's, Newfoundland & Labrador	4,881	32
Charlottetown, Prince Edward Island	4,715	100
Halifax, Nova Scotia	4,367	104
Saint John, New Brunswick	4,754	37
Montreal, Quebec	4,575	235
Toronto, Ontario	4,066	252
Winnipeg, Manitoba	5,777	186
Regina, Saskatchewan	5,661	146
Edmonton, Alberta	5,708	28
Vancouver, British Columbia	2,926	44
Yellowknife, Northwest Territories	8,256	41
Whitehorse, Yukon	6,811	8
Resolute, Nunavut	12,526	0

Source: *Environment Canada*

Some of Canada's worst weather disasters occurred in the past decade. Do they signal a trend?

Extreme weather is weather that is unusual and often destructive. It includes events such as heat waves and cold spells, floods, droughts, severe thunderstorms, blizzards, ice storms, hurricanes, and tornadoes. For some kinds of events, however, what is considered extreme for one location may be quite normal for another. A 20 cm snowfall may be exceptional in Victoria, but not in Quebec City or St. John's.

Because different weather extremes have different causes, climate change could affect these extremes in a variety of ways. Although climate change could moderate some extremes, there are also concerns that it could lead to an increase in some of the most dangerous and destructive weather extremes. Some of these concerns are based on scientific arguments about how the processes that cause these extremes will be affected by a warmer climate. One such argument, for example, suggests that heavy rainstorms could become more common because a warmer atmosphere can hold more moisture to fuel these storms.

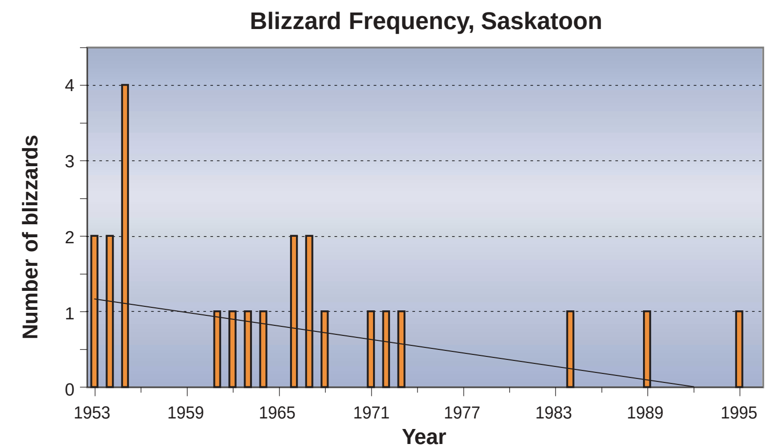
What is generally accepted, however, is that the warm season will get longer in most parts of Canada and that warm conditions will extend farther northwards. As a result, the risk of severe hot weather events such as heavy thunderstorms, hail, and tornadoes would extend over a longer period and affect a wider area. On the other hand, the time span in which severe winter weather may occur is likely to become shorter. Nevertheless, winter storms could still be quite intense.

Weather phenomena are very complicated, and unusually destructive events in particular are often the result of chance combinations of several factors. Consequently, there is still much to learn about how these events might be affected.

FOCUS: Prairie Blizzards

Blizzards combine bone-chilling temperatures, strong winds, and dense, blowing snow to pack one of winter's heaviest punches. They occur in almost every part of Canada, but Prairie blizzards are legendary for their ferocity. One that struck the Regina area in 1947 lasted 10 days and buried an entire train in a kilometre-long snowdrift.

Climate change could affect the intensity and frequency of these storms as well as the paths that they follow. As a result, blizzard patterns may be changing. In fact, a recent study shows that the number of blizzards has decreased significantly in southern Saskatchewan over the past half century. In Manitoba, however, there has been no change in blizzard frequency – possibly because the storm systems that affect Saskatchewan are not entirely the same as those that affect Manitoba.



Source: *Adapted from Lawson, 2003*

In Alberta, Saskatchewan, and Manitoba, a winter storm is a blizzard if it lasts at least 4 hours and has winds of 40 km/hour or more, a wind chill of –24.4°C or lower, and blowing snow with visibility less than 1 km. Over the past half century, the number of blizzards hitting Saskatoon has declined significantly. Regina has shown a similar trend, but Winnipeg has had no change in blizzard frequency.

THE BIGGER PICTURE

The 1990s witnessed a clustering of unusually severe weather events in both Canada and other parts of the world, including such disasters as the 1996 Saguenay flood in Quebec, the 1997 Red River flood in Manitoba, and the 1998 ice storm in Ontario, Quebec, and New Brunswick. The pattern continued in 2000, when the village of Vanguard, Saskatchewan, was flooded by 333 mm of rain in 10 hours – one and half times as much as it normally receives in a year.

Economic losses from weather events have also climbed sharply in recent years. However, the size of these losses also mirrors the growth of our society and economy: an extreme event today will affect more people and more property than it would have a few decades ago. That makes it harder to determine how much of the increase in losses is actually due to an increase in severe weather.

A similar problem also makes it difficult to judge whether tornadoes are occurring more frequently. Although the number of tornadoes reported over the past century has increased, climatologists note that the increase closely tracks the growth of the country's population. That makes it difficult to conclude whether more tornadoes are actually occurring or whether more are simply being reported.

We are on more solid ground in dealing with widely measured climate variables such as temperature and precipitation, and here, so far, there is little evidence of an increase in extremes. Canadian temperature records show that most of the country, except for the eastern Arctic, has seen a significant decrease in extremely cold weather over the past half century. At the same time, there has been no consistent increase in extremely hot weather.

There has also been no trend towards more frequent heavy rainfalls in Canada, even though precipitation has increased across the country during the past century. Since the 1940s most weather stations in southern Canada have recorded fewer heavy rainfalls, but the number of rainy days has increased. In some other parts of the world, however, such as the United States, Japan, and Australia, there has been a trend towards more intense precipitation.

It is hard to tell, therefore, whether many kinds of extreme weather events are becoming more common or not. Since extreme events are usually rare, it could take decades to detect a pattern of change.

THE GREAT ICE STORM OF 1998

Episodes of freezing rain are common in most of Canada, and occasionally they develop into major ice storms that are notable both for their sparkling beauty and the crushing weight of ice they leave on power lines and trees. But none had ever been as persistent or destructive as the storm that struck much of eastern Canada in January 1998.

Over a period of six days, freezing rain fell intermittently over an area extending from central Ontario to Prince Edward Island. Millions of trees, including valuable sugar maples, were toppled or damaged, and downed power lines left more than 4 million people without electricity. The Montreal area was affected the worst. Up to 100 mm of freezing rain fell south of the city, and some localities were without power for as long as five weeks. More than 600,000 people in Quebec and eastern Ontario sought refuge in emergency shelters, while 16,000 troops worked with utility crews from six provinces and eight American states to restore power and clean up the damage.

The storm was blamed directly for 28 deaths, and with damage estimated at over $5 billion, it was by far the costliest weather disaster in Canadian history. It is impossible to say that a single event such as this is the result of climate change. However, it does represent the kind of extreme event that some fear could become more common as climate change continues.

The climate in many parts of Canada appears to be changing. Although these changes are still in their early stages, the indicators make it clear that some impacts are already being felt by individuals, communities, businesses, and ecosystems. The severity and extent of these impacts varies quite a bit from one part of the country to another. Some are of relatively minor importance, some are quite serious. Some are harmful, while others are beneficial.

CLIMATE

The greatest changes have occurred in the western Arctic, the Mackenzie River Basin, and the Prairies, where rates of warming over the past century have equalled or exceeded 1.5°C – nearly triple the global average of about 0.6°C. The B.C. coast and the Great Lakes–St. Lawrence region have warmed at approximately the same rate as the planet as a whole, while northeastern Ontario, central Quebec, and the Atlantic Provinces have warmed the least, at about half the global rate. The eastern Arctic, northern Quebec, and Labrador, in contrast, have cooled, in some areas by as much as 1.5°C over the past 50 years.

Seasonally, most of Canada has experienced warmer and earlier springs, hotter summer nights (but little change in the number of hot summer days), and shorter, milder winters with less frequent cold spells. Falls, however, have shown a slight cooling trend, although most of the cooling has happened late in the season.

Canada has also become wetter almost everywhere and at every time of the year. Precipitation has increased by anywhere from 5% to 35% in most of the country since 1950. Only the southern Prairies have seen little or no increase. Over the same period, the proportion of yearly precipitation falling as snow has also been changing. The southern half of the country, for the most part, has become less snowy but rainier. The North, on the other hand, has become somewhat snowier.

Unfortunately, the picture for sea surface temperatures is less complete. Good data are available for the west coast and show surface temperatures increasing at rates between 0.9°C and 1.8°C per century. Information for eastern regions is more difficult to assess but tends to show little change, while data for the Arctic are either unavailable or need further analysis. The trends that have been detected are generally consistent with scientific expectations of climate change. They are also mirrored fairly closely by the indicators, which tend to show more change in the West and Northwest than in the East.

NATURE

As the indicators make clear, many aspects of Canada's physical environment are responding to changes in climate. Receding glaciers, thinner and less extensive sea ice, and earlier breakup dates for ice on rivers and lakes can all be connected to a warming atmosphere. Atmospheric warming is also a partial contributor to sea level rise along the Atlantic and Pacific coasts and in the Mackenzie Delta. As a result, these areas are becoming more vulnerable to shoreline erosion and flooding from heavy storms and high tides. In addition, the 1990s witnessed some of the most costly weather disasters in Canadian history. There was no strong evidence over the long term, however, that the extreme weather events that were examined were becoming more common.

The indicators also showed a number of impacts on living things. Populations of some species, such as the polar bears of western Hudson Bay, are finding survival more difficult as a result of changes in climate. For others, such as the mountain pine beetle, Canada has become a more hospitable place. Key stages in plant development, such as budding, leafing, and flowering, are also occurring earlier, due mainly to earlier and warmer spring weather. At the same time, plants and animals from warmer areas have advanced northwards and species adapted to colder conditions have retreated.

Most of these responses provide further evidence that climate is changing, but they also offer important insights into how these changes are altering and reshaping the natural world.

PEOPLE

For Canadians living in the southern half of the country, winters are becoming less hazardous as they become shorter and less extreme, and consumers are saving energy as a result of reduced heating needs. A longer frost-free season is also increasing the potential for growing new varieties of crops. On the negative side, cooling needs are increasing in much of the country, and more frequent thaw-freeze cycles are reducing the durability of some building materials.

For Canadians in the North, however, the impacts of a changing climate have been more pronounced. A shorter, less reliable ice season has made winter hunting and fishing more difficult and dangerous. The traditional knowledge that aboriginal people relied on in the past to live off the land is also becoming harder to apply as a result of more variable weather and changes in the timing of seasonal phenomena. In addition, winter roads that provide supply links to many northern communities are becoming less reliable and cannot be used for as long.

Some indicators, however, have not shown any significant trends. Although recent years have been marked by severe drought on the Prairies and low water levels on the Great Lakes, the corresponding indicators showed no significant change over the long term. There could be several reasons why trends did not appear. One is that these phenomena are not as responsive to climate change as thought. Another is that more time and further warming will be needed before the changes become significant. Only time – and continued tracking of the indicators – will tell.

TO FIND OUT MORE

A CLIMATE CHANGE LIBRARY

The climate change assessments published every five years by the Intergovernmental Panel on Climate Change (IPCC) are the most comprehensive and authoritative source of information available on the subject. These reports are highly technical, but plain language summaries are available on the IPCC web site, which is listed in the international section below. The latest volumes are:

IPCC, 2001. *Climate change 2001: The scientific basis.* Cambridge, Cambridge University Press.

IPCC, 2001. *Climate change, 2001: Impacts, adaptation, and vulnerability.* Cambridge, Cambridge University Press.

IPCC, 2001. *Climate change, 2001: Mitigation.* Cambridge, Cambridge University Press.

Other publications of interest to the general reader

Association professionnelle des météorologistes du Québec, 1999. *Changements climatiques et météo extrême.* L'Association. Province de Québec. (This publication can also be downloaded from www.sca.uqam.ca/apmq.)

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RESOURCES ON THE WEB

The sites listed below were active at the time this report was prepared. Since publication, however, the contents or addresses of some sites may have changed, and some sites may have been discontinued. If one of the links provided here no longer works, you may be able to find a replacement site by searching under the name of the organization responsible for the original site.

International

http://www.ipcc.ch. The Intergovernmental Panel on Climate Change is the most authoritative source of scientific information on the causes and impacts of climate change and responses to it.

http://www.unfccc.int. This United Nations site contains the texts and other information relating to the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

http://www.iisd.org/climatechange.htm. Based in Winnipeg, the International Institute of Sustainable Development promotes the development of regional, national, and international responses to climate change. It is a good source of information on climate change in the Arctic.

http://www.climatehotmap.org. This map-based web site documents observations of climate change and its impacts from around the world.

http://www.usgcrp.gov/usgcrp/nacc. A number of regional and sectoral reports on the consequences of climate change for the United States are available from this site. Many will be of interest to Canadians, especially those in regions near the U.S.

http://yosemite.epa.gov/OAR/globalwarming.nsf. The U.S. Environmental Protection Agency's climate change site contains material on how regions in the U.S. and other parts of the world may be affected by climate change.

National

http://www.climatechange.gc.ca. The Government of Canada's climate change web site has an abundance of information on the science of climate change, impacts on Canada, and Canadian responses. It also contains a large selection of links to other sites and resources for teachers and students.

http://www.ec.gc.ca/climate. Environment Canada's climate change site provides fact sheets on climate change science, impacts, and adaptation and control measures.

http://www.msc-smc.ec.gc.ca/ccrm/bulletin. Environment Canada's Climate Trends and Variations Bulletin relates the average temperature and total precipitation of the most recent season and year to longer-term regional and national changes.

http://www.ec.gc.ca/soer-ree. Canada's state of the environment InfoBase features *Environmental Signals: Canada's National Environmental Indicator Series,* a frequently updated series of indicators on climate change and other environmental issues.

http://adaptation.nrcan.gc.ca. From this site you can download *Climate Change Impacts and Adaptation: A Canadian Perspective,* for information on the implications of climate change for water resources, forestry, agriculture, and the coastal zone. The site also offers an excellent series of posters depicting the impacts of climate change on health and safety, communities, land resources, water, and coastal regions in different parts of Canada.

http://www.c-ciarn.ca. The Canadian Climate Impacts and Adaptation Research Network site is useful for people who already have some knowledge of climate change. The site's database has references to hundreds of papers on climate change impacts in Canada.

http://www.nccp.ca. The National Climate Change Policy Process site contains information on federal, provincial, and territorial climate change policy activities, as well as links to the sites of provincial and territorial governments, international agencies, and non-government agencies. Click on the link to the Climate Change Hub Gateway for access to the national climate change public education and outreach hub system, where you will find an extensive list of resources for the general public as well as for those working in public education.

Provincial and Territorial Government Sites

To find out more about how individual provinces and territories are responding to climate change, go to the following provincial and territorial web sites and follow the links to climate change.

http://www3.gov.ab.ca/env. Alberta Environment.

http://www.gov.bc.ca/wlap. British Columbia Ministry of Water, Land and Air Protection.

http://www.gov.mb.ca/est. Manitoba Energy, Science, and Technology.

http://www.gnb.ca/0085. New Brunswick Department of Natural Resources and Energy.

http://www.gov.nf.ca/env. Newfoundland and Labrador, Environment.

http://www.gov.nf.ca/mines&en. Newfoundland and Labrador, Mines and Energy.

http://www.gov.nt.ca/RWED/eps. Northwest Territories Resources, Wildlife, and Economic Development, Environmental Protection Service.

http://www.gov.nu.ca. Government of Nunavut.

http://www.ene.gov.on.ca. Ontario Ministry of the Environment.

http://www.gov.pe.ca/infopei/Environment_and_Land. Prince Edward Island, InfoPEI.

http://www.menv.gouv.qc.ca. Ministère de l'environnement du Québec.

http://www.mrn.gouv.qc.ca. Ministère des ressources naturelles du Québec.

http://www.se.gov.sk.ca. Saskatchewan Environment.

http://www.gov.ns.ca/energy. Nova Scotia Department of Energy.

http://www.environmentyukon.gov.yk.ca/epa. Yukon Department of Environment, Environmental Protection and Assessment.

Nature

http://adaptation.nrcan.gc.ca/posters. Natural Resources Canada's climate change posters cover every region of the country and explain how climate change is affecting sea level, sea ice, glaciers, water resources, and other aspects of the natural environment as well as human activities.

http://www.crysys.uwaterloo.ca/education/crysys_education.cfm. Go to this site for information from Canadian ice researchers on sea ice, glaciers and ice caps, river and lake ice, and snow.

http://ice-glaces.ec.gc.ca. The web site of the Canadian Ice Service provides information on current ice conditions along Canada's coasts and in the Great Lakes.

http://pbsg.npolar.no. The home page of the Polar Bear Specialist Group provides up-to-date information on the status of the world's polar bear populations as well as information on conservation issues, a polar bear FAQ, and links to other polar bear sites.

http://www.taiga.net/coop/indics. This site, maintained by the Arctic Borderlands Ecological Knowledge Cooperative, contains an extensive set of indicators that document changes in the physical environment and wildlife of northern Yukon.

http://www.thousandeyes.ca. Check the home page of Nova Scotia's Thousand Eyes project for background on the project and the latest update on results.

http://www.naturewatch.ca. NatureWatch gives amateur scientists a chance to contribute to the scientific monitoring of changes in the natural environment. Current programs include IceWatch, PlantWatch, FrogWatch, and WormWatch, and others are under development.

People

http://www.msc-smc.ec.gc.ca/media/top10. Go here for David Phillips's stories of headline-making weather events and impacts from the past year, the past decade, and the past century.

http://www.taiga.net/nce. The Northern Climate Exchange site is a good place to start for information on climate change in the North and its impacts on northern life.

http://www.agr.gc.ca/pfra/drought. The Prairie Farm Rehabilitation Agency posts regular updates on drought risks in western Canada, along with information on coping with drought.

http://www.on.ec.gc.ca/water/level-news. The latest information on Great Lakes water levels can be found at this site. For more information about Great Lakes water levels, go to the Canadian Hydrographic Service web site, **http://chswww.bur.dfo.ca/danp/tidal_e.html** and the web site of the Great Lakes Information Network, **http://www.great-lakes.net**.

http://www.msc-smc.ec.gc.ca/saib/climate/climat_e.cfm. Follow the links to the climate change pages of the Meteorological Service of Canada's Science Assessment and Integration Branch site and download fact sheets on extreme weather and reports and updates on recent climate events and advances in climate science.

Responding to Climate Change

http://www.climatechangesolutions.com. This site, run by the Pembina Institute in partnership with Environment Canada, Natural Resources Canada, and the Climate Change Action Fund, offers an extensive assortment of tools and resources to help families, municipalities, schools, farms, industries, and businesses reduce their greenhouse gas emissions.

http://energysolutionsalta.com. This Alberta-based site has energy-saving tips and case studies that all Canadians will find useful for reducing greenhouse gas emissions in the home, at work, in the community, and on the road.

www.climcalc.net. Use the climate change calculator to estimate your own contribution to climate change and determine the best way of reducing it.

http://oee.nrcan.gc.ca. Check this site to compare the energy efficiency of appliances, cars, and other products and to get official statistics and publications on energy use in Canada.

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