The Science of Climate Change

Climate change is a shift in the “average weather” that a given region experiences. This is measured by changes in all the features we associate with weather, such as temperature, wind patterns, precipitation, and storms. Global climate change means change in the climate of the Earth as a whole. Global climate change does occur naturally the ice age is an example. The Earth's natural climate has always been, and still is, constantly changing. The climate change we are seeing today differs from previous climate change in both its rate and its magnitude.

The temperature on Earth is regulated by a system known as the “greenhouse effect”. Greenhouse gases primarily water vapour, carbon dioxide, methane, and nitrous oxide trap the heat of the sun, preventing radiation from dissipating into space. Without the effect of these naturally occurring gases, the average temperature on the Earth would be -18° C, instead of the current average of 15°. Life as we know it would be impossible.

Over the past 200 years, emissions of these gases due to human activities have accumulated in the atmosphere, where, because of their long life, they stay for anywhere from decades to centuries. As a result, since the Industrial Revolution, concentrations of carbon dioxide have increased by 30 per cent, methane by 145 per cent, and nitrous oxide by 15 per cent.

The cause of these increases has been human activities related to our increasingly sophisticated and mechanized lifestyle, in particular the burning of fossil fuels such as coal, oil, and natural gas to generate electricity and in factories and cars. As well, we have cleared more land for human use in the past 100 years than in all of prior human history. This has resulted in the loss of forests and wetlands, which absorb and store greenhouse gases and naturally regulate the atmosphere.

In effect, by increasing the amount of these heat-trapping gases, we have “enhanced” the natural greenhouse effect to the point that it has the potential to warm the planet at a rate that has never been experienced in human history. Already, the average global temperature has increased by about 0.5° C in the past 100 years, and temperature increases over the next 100 years are expected to significantly surpass any such change of the past 10,000 years.

Trends in CO_2 Concentrations (Past 1000 Years)

Raising the global temperature may trigger a series of changes within the overall global climate system. For instance, global sea levels have risen 10-25 cm over the past 100 years, and are expected to continue to rise due to increases in temperature. We are also seeing increases in severe weather events. Such impacts of climate change could have far-reaching and/or unpredictable environmental, social, and economic consequences. Indeed, the climate change problem and the related changes it may bring about are among the most serious of the environmental issues that we face today.

Future Projections

Scientists have been able to make some projections about how greenhouse gas concentrations may change over the next hundred years, based on a range of scenarios.

The most extreme scenario is based on an assumption that high economic growth will continue, and that humans will continue to use coal, oil, and gas globally for their energy needs. This scenario suggests that concentrations of carbon dioxide could reach more than three times pre-industrial levels by 2100. Even the most hopeful scenario based on low growth in global population and intensive conversion to renewable energies suggests that carbon dioxide concentrations would be about 75 per cent higher than pre-industrial levels by 2100, and would continue to rise thereafter. Stabilizing global emissions at 1990 levels now would have the same effect, because of the long life of these gases in the atmosphere.

Canadian scientists have developed one of the most advanced climate models in the international research community to determine what these projected increased in greenhouse gas concentration could mean. Their research suggests that average global surface temperatures could increase on average by almost a half degree each decade during the next century.

Projected Temperature Change between 1910 and 2040 AD

Combined Effect of Projected Greenhouse Gas and Sulphate Aerosol Increases. Canadian Model

To provide an idea of what that means, global warming over the next century could be as great as the change in temperature between the peak of the last ice age, some 25,000 years ago, and today.

Stabilizing greenhouse gases is only a part of the solution, though. Scientific projections also indicate that, even if the concentrations of greenhouse gases were stabilized by 2100, air temperature could continue to increase. As well, sea levels, which are expected to rise anywhere from 15 to 95 cm by 2100, could continue to rise at a similar rate in future centuries. This would be the case even after concentrations of greenhouse gases had been stabilized, and even after global mean temperatures had stabilized. This is because of the long time it takes oceans to heat up before they fully respond to increased air temperatures.

Potential Impacts of Climate Change

There is little doubt about the significance of these projections. In general, all available models agree that warming will be greater in Arctic regions than in equatorial regions, and that continents will warm more than oceans. Beyond this, however, scientists are not able to predict the exact consequences of continued increases in greenhouse gas concentrations or its impact on specific regions.

As a northern country, Canada will likely warm more than many other countries. These warmer temperatures could provide some benefits longer growing seasons in the summer, less demand for heating in the winter. But these benefits will come at a cost and, without strategies in place to adapt to the changes, we may miss out on the benefits entirely.

As well, Canadians may be better equipped to deal with the impacts of climate change than many parts of the developing world, where existing environmental and ecological problems could be worsened. This could have costly implications for geopolitical security and foreign aid.

Around the world, climate change is projected to:

- threaten the world's boreal forests with an increased fire risk because of the drying climate;
- cause water needs to outstrip supply;
- cause severe water loss due to changes in evaporation and precipitation patterns;
- cause flood damage to low-lying countries and island states, including loss of coastal land to rising sea levels;
- encourage the movement of tropical diseases such as malaria northward, where populations have little or no immunity; and
- affect international trade patterns.

The consequences for Canada arising from these impacts on the international community, particularly our trading partners and competitors, will be substantial.

In Canada

We are likely to see changes in our ability to grow food and potential costly changes to the methods we use to do it. Warmer temperatures could create conditions for more severe weather events, including thunderstorms and an increased frequency of tornadoes, with attendant risk to life and property. Drier conditions and warmer temperatures could also cause more frequent forest fires. More frequent heat waves could affect the health of Canadians, especially in cities.

Higher air temperatures and removal of the insulating vegetative cover could lead to a melting of permafrost in the Arctic. This could cause more landslides in some areas, and problems for the construction and maintenance of pipelines, roads, and bridges. Glaciers could retreat more quickly because of higher air temperatures, resulting in less late season runoff, and placing fish habitats and water supplies in dependent communities at risk.

Canadian scientists have examined the potential impact of climate change on human health and our environment, including our water resources, fisheries, forests, wildlife, and ecosystems. They have projected what climate change could hold for each of these aspects of our environment, recognizing that the rate of change, as well as the number and severity of extreme weather events, will affect the magnitude of the impacts and our ability to cope with them. Their projections for different aspects of our environment are provided below.

Potential Impacts of Climate Change on Water Resources

Because water plays a central role in many economic and societal functions, the implications of climate change for water resources are key to defining overall impacts. Climate change is expected to directly affect both the quantity of water available and its quality, creating competing demands for this resource from multiple sectors.

Potential Key Effects

Water levels in the Great Lakes and St. Lawrence River are expected to decline. Major impacts include: a decrease in both groundwater and surface water; concerns regarding integrity and quality of the shoreline and associated facilities; and a decrease in shipping capacity. In 1964, low water levels caused a $35 million loss for Great Lakes shipping and hydropower, and one-third of municipalities along the lakes had water supply problems.

Projected sea-level rise will generally contribute to deeper drafts in marine harbours and channels, but could lead to significant damage to coastal support infrastructure. The potential of increased storm activity has raised concerns regarding the necessity of increased navigational aid support.

In the Prairies, the projections of increased temperature, decreased snow pack with an earlier melt season, and a more vigorous hydrological cycle are of particular concern in terms of their implications for water availability and soil moisture, as well as the frequency and intensity of floods and droughts. The 1988 drought on the Prairies resulted in a 31 per cent reduction in grain production and export losses of $4 billion.

Projections of water availability and flows suggest differentiated impacts on hydroelectric generation potential, with possible increases in Labrador and northern Quebec, and possible decreases in Ontario, the Prairies, and southeastern British Columbia.

Impacts of Climate Change on Fisheries

Climate change can be expected to have a significant impact on fisheries in Canada affecting both the productivity of fish populations and how they are distributed throughout lakes, streams, and oceans. Changes to water temperature, currents, water quality, food supply, and predators could all have effects on fish populations.

Potential Key Effects

The freshwater fishery is mostly a subsistence and recreational fishery. Change to the distribution of highly prized species would have an effect on the recreation fishery industry, with possible losses occurring in some areas. In general, as lake and stream temperatures warm, species at the warmer southern limit will either die or migrate northward to more favourable habitats. Cool and cold-water freshwater fish populations, including species such as trout, whitefish, and grayling, could be reduced in many lakes and streams on the Canadian Shield due to declining water levels and flow and reductions in nutrient loading and recycling.

Freshwater fish species that currently live at the northern limit, or cold-water limit, of their preferred habitats in larger lakes will likely benefit from warmer water temperatures, experiencing increased survival and growth.
Growth rates, age of sexual maturity, and distribution of some marine fish species are sensitive to water temperatures. Cooler temperatures could typically result in delayed spawning and a shift in distribution southward, while warmer temperatures could result in earlier spawning and a shift in distribution to the north.

In the Pacific, the abundance of the southern salmon populations are expected to decline, as are those of Pacific cod. Higher, more consistent sustainable harvests are anticipated from northern salmon populations, with Sockeye salmon most affected.

Impacts of Climate Change on Forestry

A general trend towards warmer conditions combined with increasing levels of carbon dioxide could increase forest distribution and growth in Canada. It could take decades, or even centuries, however, before forests adjust to new climatic conditions. During this period of adjustment, the boreal forest in particular could be more vulnerable to insects and diseases, forest fires, and competition from unwanted species, and the forestry industry will have to adapt to new climatic conditions. The rate of change, as well as the number and severity of extreme events, will dramatically affect the magnitude of impacts and our ability to cope with

them.

Potential Key Effects

If carbon dioxide levels were to double, the Taiga and Boreal forest belts could shift northward by about 500 km. However, it would not be the Taiga or Boreal forest as we know it that would move northward, but rather the more fast-moving flexible species such as those with wider seed dispersal, faster growth, and early maturation.

The boreal forest itself is expected to undergo an extensive reduction in size, as grasslands and temperate deciduous species may invade from the south, and northern expansion is limited by poor soils and insufficient sunshine amounts. Forest fires and pest infestations are expected to increase in frequency, area, and intensity due to warmer and drier conditions. Increased fire incidence will lead to loss of habitat for species that inhabit mature forests. This may be eased by changes in fire management policy in order to facilitate species migration and forest adaptation, but this would require significant investment. In 1994, Canada lost four million hectares of forest to fires. Since 1980, Canada has lost an average of 2.4 million hectares of forest to fires each year, a 140 per cent increase over the previous 30 years.

Within the Temperate Conifer zone of British Columbia, forests could shift upward in elevation and, under the worst scenario, disappear entirely from some zones due to a lack of winter cooling for forest regeneration, drought, stress, and increased sensitivity to spring frosts.

Changes in Forest and Grasslands Boundaries

Changes in Forest and Grasslands Boundaries

Impacts of Climate Change on Health

Climate change could affect the health of Canadians due to higher temperatures, more frequent storms, and increases in air pollution episodes. Changes in the transmission of insect- or water-borne diseases could also have an impact on Canadians' health. As well as affecting the health of individual Canadians, these projected changes would place additional stresses on the health-infrastructure and social-support systems.

Potential Key Effects

The World Health Organization has warned that heat stress and climate-induced respiratory problems as a result of reduced air quality could occur in large urban areas, and could lead to increased death rates.

Warmer temperatures and shorter cold seasons could allow disease-carrying hosts to survive at locations further north than at present. Two commonly mentioned diseases are Rocky Mountain Spotted Fever (in the U.S.) and Lyme disease. Mosquito-borne diseases such as malaria and encephalitis could expand into Canada, presenting a challenge for our health care system.

Changes in ecosystems may also affect the supply of foods available to those who depend on hunting and gathering, such as the aboriginal people of northern Canada. Changes in ecosystems may allow different species of plants to flourish, possibly causing problems for asthma and allergy sufferers.

Impacts of Climate Change on Infrastructure

The threats posed by climate change to Canadian infrastructure are many and varied, with significant environmental, social, and economic implications. Some anticipatory measures, such as greater flood control and larger water reservoirs, can be undertaken, but these have social and economic costs of their own. One important measure would be to base new construction on engineering standards revised to take account of changing climate.

Potential Key Effects

In Canada's North, melting permafrost will likely affect infrastructure and transportation, including the integrity of foundations (pipelines, bridges and buildings), water control structures, ice-roads and, the melting of the assumed impermeable permafrost beds of mine-tailing ponds and landfill sites.

Higher sea levels could increase coastal erosion and damage from storm surges, and present problems for coastal infrastructure such as harbours, water supplies, and sewage disposal systems. Most of the coast of Prince Edward Island is highly sensitive to the impact of sea-level rise due to its low relief and bedrock. The current sea level rise of 3.5 mm per year is already causing erosion problems in some areas. The coasts of southwestern BC and the Beaufort Sea are also sensitive to sea level rise.

Projected changes in rainfall intensity and snowmelt runoff could increase the potential for flooding in water basins, with over-tipping of dams, culverts, and flood control structures. Projected increases in rainfall intensity could change the patterns of flooding in Canada, requiring adaptation of flood-prevention infrastructure. In addition, the occurrence of spills from urban sewage systems is likely to increase.

Human settlements and infrastructure are especially vulnerable to extreme weather events. In 1996, floods and hailstorms cost an estimated $1.5 billion in damages to homes, business, and infrastructure.

Impacts of Climate Change on Tourism and Outdoor Recreation

Changed weather patterns could mean differences in how Canadians enjoy our outdoors. But climate change's projected impact on the tourism and recreation sector can be offset by measures such as relocation of facilities, application and improvement of technology, and the development of multi-season recreational centres. These are all occurring to varying degrees at present.

Potential Key Effects

Hunting of game and waterfowl is likely to feel the impact of climate change as wildlife may be displaced due to habitat loss, altering community structures, or increased competition. Wetland habitat in particular could be significantly altered both in quantity and quality.

Recreational fishing may be locally disrupted by lower water levels in lakes, declining flow rates in streams, warmer temperatures, and reductions in nutrient loading.

The season for outdoor activities in winter will likely be shorter, especially in more southerly latitudes. Existing ski resorts may have to rely increasingly on artificial snowmaking to maintain the season.

Impacts of Climate Change on Wilderness

Climate change poses significant threats to unmanaged ecosystems in Canada, including wetlands, permafrost areas, and the Southern Arctic Ecozone. Some preventive measures can be taken to offset these threats, but overall, human intervention will be necessary to minimize or adapt to the anticipated effects of climate change. One vital need, for example, is for increased intervention to reduce the risks posed by landslides and debris torrents in mountainous areas.

Potential Key Effects

Altered precipitation and temperature regimes could affect the seasonal pattern and variability of water levels of wetlands, thereby affecting their functioning including flood protection, water cleansing and waterfowl/wildlife habitat.
Projected losses in prairie pothole wetlands will have a negative impact on domestic and migratory wildfowl and aquatic populations. These wetlands currently yield 50 to 75 per cent of all waterfowl produced annually in North America. Trends in duck abundance already reflect the interactions between changing wetness regimes and landscape alteration; additional stress (e.g., from climate change impacts) would be of considerable concern.

Affected peat lands in the north that currently are sinks where atmospheric carbons accumulate, are predicted to become sources of atmospheric carbon, and are projected to disappear from south of 60 in the Mackenzie Basin, though their number may increase further north. Patchy Arctic wetlands, currently supported by surface flow, may not persist. Lakes and ponds, which have permafrost hydrologic divides, are more likely to drain laterally on to the groundwater system, dramatically altering hydrology and dependent ecosystems.

Loss of breeding and forage habitats for migratory wildfowl and mammals may occur within the Southern Arctic Ecozone, which is projected to all but disappear from mainland areas. This ecozone, which contains the Queen Maud Gulf Lowlands and is currently the home of a significant proportion of the Inuit population, is the major breeding and nesting ground for a variety of migratory birds. As well, it is the major summer range and calving grounds for Canada's largest caribou herd, and provides habitat for bear, wolf, moose, arctic ground squirrels and lemmings.

New scientific findings released by the Intergovernmental Panel on Climate Change (IPCC)

provide new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities. You can consult the following reports: *Climate Change 2001 - Mitigation; Impacts, Adaptation and Vulnerability; The Scientific Basis*.

Find out more about the science of climate change and the possible impacts on our weather, ecosystems, health and way of life.