The Canadian Centre for Climate Modelling and Analysis

CCCma

As Canada's climate changes, and weather patterns shift, Canadian climate models provide guidance in an uncertain future.

Environment Canada Environnement Canada

Canada

Canada's climate is changing

Temperatures are rising in Canada, particularly in the Arctic, where permafrost is thawing and the ocean's ice cover is shrinking. Further south, winter snow is melting earlier and western glaciers are retreating. Even greater climate changes are expected in the future, including a continued rise in temperatures, shifts in rainfall patterns, and increases in certain types of hazardous weather, such as heavy spring rains and heat waves. As a cold northern country, Canada will be one of the most greatly affected countries in the world.

Traditionally, climatologists looked to past weather records to provide guidance to the future. However, scientists expect that future climate change will be greater than anything experienced in the past 1,000 years . Although past events can still provide some guidance, scientists are now working to predict future climate through complex computer simulations made with global and regional climate models.

A Canadian centre of expertise

The Canadian Centre for Climate Modelling and Analysis (CCCma) was established in the early 1970s, within Environment Canada, a department of the federal government. The Centre focused on basic climate research, and quickly became a leader in the new science of climate modelling and the development of scientifically-based projections of future climate change.

Early climate models were based solely on the behaviour of the atmosphere. At Environment Canada's headquarters in Toronto, the Centre worked closely with other scientists who specialized in the study of the physical processes that determine weather and climate, and in the detailed measurement of temperature, precipitation and other weather elements.

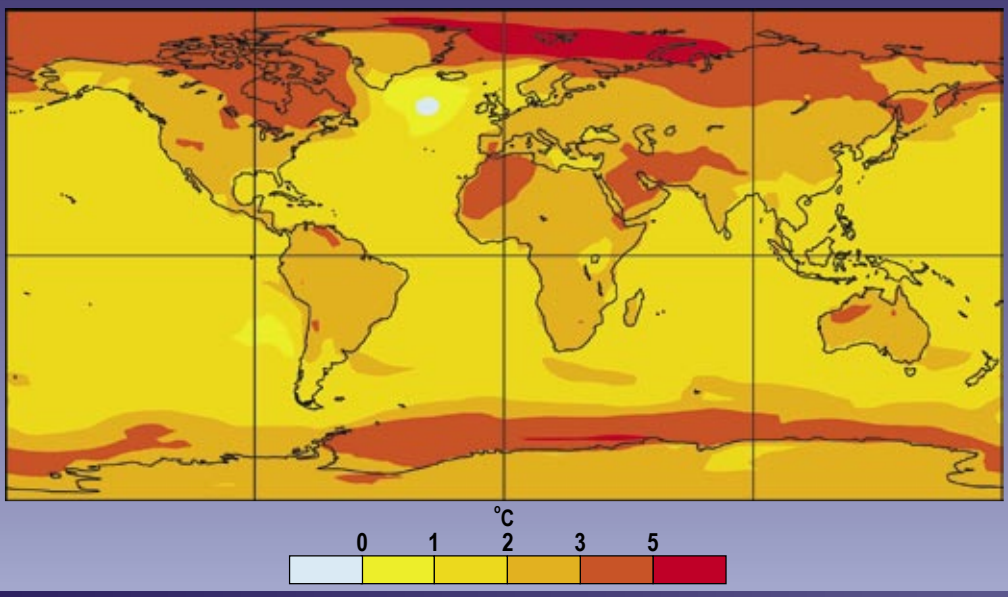
In 1993, the Centre moved to the University of Victoria, on Canada's west coast, to access additional areas of expertise required to develop more complete models of the climate system. Working with scientists at the university and the nearby federal Institute of Ocean Sciences, a more complex climate model was created that extends from the top of the atmosphere to the bottom of the ocean. Today, about 30 scientists, support staff and research associates work at the Centre, with access to one of the most powerful supercomputing facilities in Canada.

The development of a global climate model is a highly specialized activity that requires long-term investment in scientific expertise and computing infrastructure. The Canadian Centre is widely recognized as an international leader in this complex field, and is one of only a handful of such institutes in the world.

Results from the Canadian climate model have been used by researchers around the world, including scientific assessments by the Intergovernmental Panel on Climate Change, the international scientific authority on this issue. In Canada, the work of the Centre provides the basic research and quantitative projections necessary to support a wide range of studies on future climate and its potential impact on our country.

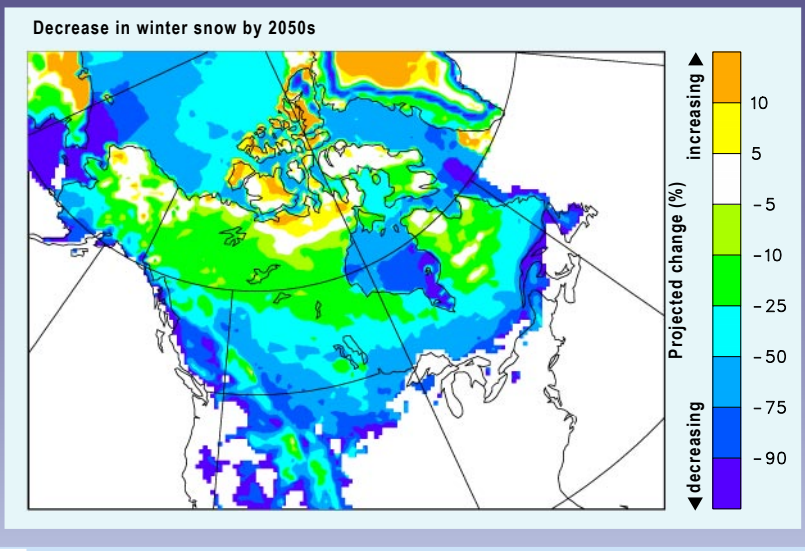
A warmer world

Canada's climate model produces science-based projections of future climate change. By the middle of this century, temperatures are expected to rise significantly, especially in the polar regions. ***(Average annual temperature change, 2041 to 2060 as compared to 1971 to 1990, from model CGCM3, SRES AIB).***



Helping Canadians prepare for climate change

The Canadian global climate model serves as the foundation for regional climate models, which can produce results in finer detail, providing better guidance for long-term planning in a wide variety of fields, including many of Canada's major industries. Here the Canadian Regional Climate Model, developed by Environment Canada and the University of Québec at Montréal shows the projected change, to the middle of this century, in snow cover. As the climate warms, winter snow could decrease by 50% in much of southern Canada and increase slightly in the high Arctic. *(Average winter snow accumulation, Dec. to Jan.,expressed in snow water equivalents, 2041 to 2060 , as compared to 1971 to 1990, from model CRCM3.6. Data provided by the OURANOS research consortium)*



Providing guidance for Canadians

The Centre provides science-based projections of climate change to guide Canadians in an uncertain future. These predictions are used by many of our major industries, including agriculture, forestry and construction. Governments and other decision-makers find this information useful for long-term planning and policy development. In addition, a wide variety of other specialists, including those working with health, the environment, natural ecosystems, and community planning, also use the results of the Canadian climate model.

What is a climate model?

A climate model is a complex computer program that uses mathematical equations to represent the physical laws governing the behaviour of the Earth's atmosphere, oceans, sea ice and land surface, and the intricate and interconnected physical processes that determine weather and climate.

The computer program simulates these processes on a grid that divides the atmosphere, oceans and upper soil layers into more than a million three-dimensional boxes. The processes that create weather are re-created within each of these boxes, and then integrated to produce a global picture. The result is a realistic presentation of weather patterns and how they develop and change, at intervals of about 15 minutes. Climate, the longer-term average of daily weather patterns, is recreated by running the model for very long periods of time, simulating the slow changes of past climate and then projecting it decades or even centuries into the future.

Climate modelling requires highly advanced supercomputers — to simulate a single year of weather involves over 100 trillion mathematical operations. A typical simulation, spanning over 100 years, takes several months to complete. Results from the model are then analyzed in detail and distilled into data for use in various applications.

New challenges for Canada's model

Over time, the Canadian climate model has improved significantly, as understanding of the global climate system has grown, and computer capacity has increased. The Centre is now using its third generation global climate model for a wide range of applications, while developing a fourth generation model.

The next Canadian model will be even more comprehensive and will provide more detailed and realistic results. For example, sulphur dioxide, a common air pollutant produced by the burning of fossil fuels, forms fine particles (known as aerosols) which cool the climate by reflecting sunlight back into space. This aerosol effect will be incorporated into the new model.

Work is also progressing on the global carbon cycle — the withdrawal of carbon dioxide from the atmosphere by plants; its storage in plants, soil and the deep ocean; and its eventual release back into the atmosphere. Modelling these processes will allow researchers to answer questions about the role of the oceans and forests in reducing the build-up of carbon dioxide in the atmosphere, and how human activities can upset the natural carbon balance.

What have we learned from the Canadian model?

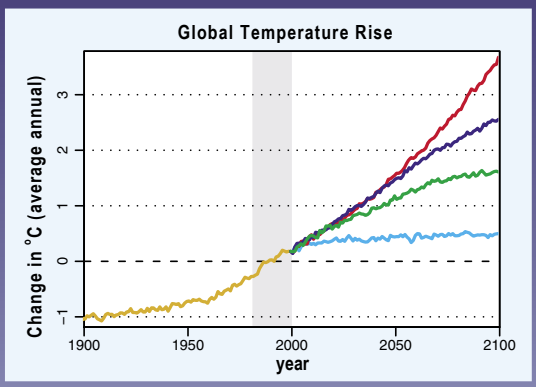
The Canadian global climate model can provide guidance on many questions of scientific and societal importance, including:

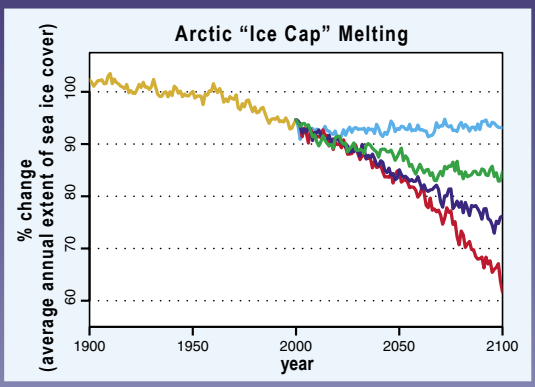
1. **Have human activities already caused the climate to change?**
   Climate models can be used to study the past as well as the future. The model can be started with the climate and atmospheric conditions that existed in the 19th century, and run forward to the present, to reproduce the climate over the past century. Such experiments allow scientists to change elements in the model, and compare the results with the real climate to identify causes of the observed changes. What is clear is that human emissions of greenhouse gases, such as carbon dioxide, have had a substantial effect on the Earth's climate — an effect well beyond what could be attributed to natural causes.

2. **What will the climate be like in the future?**
   Model projections of future climate are one of today's greatest scientific challenges — not only is knowledge of the physical climate system incomplete, but there is great uncertainty about future human activities and how those activities will affect future levels of greenhouse gases. Population growth, economic development and technological advances will all have major impacts on our future climate. To account for the "human factor", the international research community has developed various scenarios of potential human development. Future concentrations of greenhouse gases in the atmosphere can be calculated for each scenario, and a climate model can then be used to show how the climate system would respond. Different scenarios, and different climate models, all produce different renditions of the future climate, but all have certain key results in common. These include global warming that is well beyond what has been experienced in the last 1,000 years, shrinking sea ice, decreasing amounts of snow, and rising global sea level.

Understanding the consequences of our actions

Human activity will have a substantial effect on the Earth's future climate. The Canadian climate model can demonstrate the effect of different paths of human development. The results range from an additional warming of about 4° C if future population growth is rapid and technology is slow to change; to a warming of only 1.5° C if we move quickly to a global "green" economy, with low population growth and clean energy sources. We are committed to an additional half degree of warming caused by the greenhouse gases which we have already released *(Model: CGCM3)*.

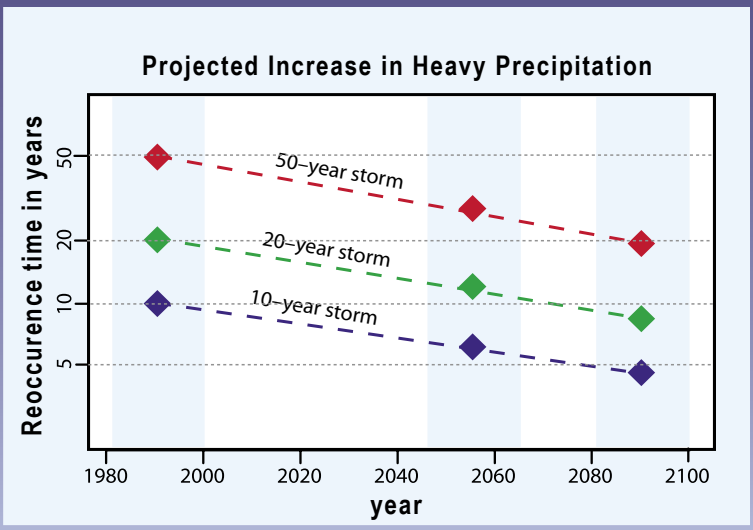




- Future rapid growth, slow technological change *(SRES A2)*
- Mixed future of "green" energy & fossil fuel use *(SRES A1B)*
- A future "green" world, with clean energy *(SRES B1)*
- Already committed future change
- Model reproduction of past change *(20C3M)*

Hazardous weather on the horizon

In Canada, certain types of hazardous weather, such as heavy rainfall and heat waves, are expected to increase. Sudden heavy rain storms, which can lead to major flooding, are a particular concern. According to projections by the Canadian climate model, a very heavy rain or snow storm which normally occurs only once every 20 years, could occur once every 14 years by the 2050s and once every 7 years by 2100. *(24-hour precipitation extremes for North America 25°N - 65°N latitude, from model CGCM3 SRES A1B)*



A glimpse of Canada's future

Over the next century, the Canadian climate model indicates that the most northerly regions of the earth will experience the greatest warming, with potentially serious impacts on Arctic communities and ecosystems. Major changes in climate are also expected in the Prairies, the east and west coasts and the Great Lakes basin. Many communities and climate-sensitive industries will be profoundly affected, including forestry, agriculture, marine transportation, fishing and oil and gas development. Just as every part of this country is affected in some way by the vagaries of today's weather, we will all be affected by our evolving climate.

The magnitude and rate of change projected for the 21st century will put enormous pressure on our environment, our infrastructure and our social fabric. Climate modelling can help us avoid aggravating the situation by providing a glimpse of the future. Ultimately, this comparatively new science, led by groups like the Canadian Centre for Climate Modelling and Analysis, should help us reach the point where decisions with the potential to affect our world are made by people who have looked at the model results and have "seen" the consequences.

For more information:

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