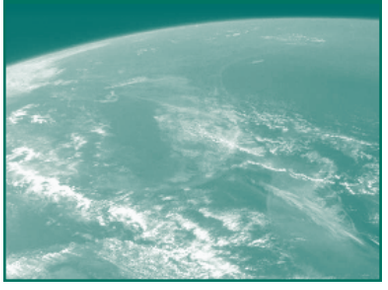
THE CANADA COUNTRY STUDY

Climate Impacts and Adaptation



VOLUME VIII
NATIONAL CROSS-CUTTING ISSUES VOLUME

EXECUTIVE SUMMARY

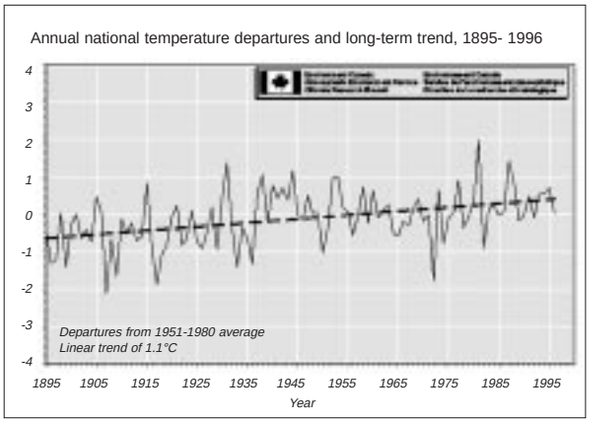
A. INTRODUCTION

The scientific and technical results of the assessment phase of the Canada Country Study (CCS) are published in eight volumes - six regional volumes (Arctic, Atlantic, Ontario, Pacific and Yukon, Prairies, and Québec), a national sectoral volume consisting of twelve papers and a cross-cutting issues volume consisting of eight papers. The current document - the Executive Summary of the cross-cutting issues volume - provides a digest of the material in the eight cross-cutting papers (costs of adaptations and residual impacts of climate change, extreme events, integrated air issues, extra-territorial issues, domestic trade and commerce, changing landscapes, sustainable development and northern subsistence and land-based economies).

The issue of climate change

The Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report concludes that the balance of evidence suggests a discernible human influence on global climate. Human activities are increasing the atmospheric concentrations of greenhouse gases and these changes are projected to lead to regional and global changes in climate and climate-related parameters such as temperature, precipitation, soil moisture and sea level.

In order to understand how the world's climate may respond, sophisticated computer models called general circulation models (GCMs) are used to simulate the type of climate that might exist when global concentrations of greenhouse gases are doubled from pre-industrial levels. As an initial focus has been on providing a state-of-the-art assessment based on existing scientific and technical literature, the results of the CCS are not based on a single climate scenario. Instead, it includes the range of scenarios used as a basis for the various papers and reports appearing in the literature. In general, the main model scenarios used come from one of five GCMs which have been deve-loped in Canada, the United States or the United Kingdom: CCC92 – Canadian Centre for Climate Modelling and Analysis 2nd generation model; GFDL91 – Geophysical Fluid Dynamics Laboratory model (US); GISS85 – Goddard Institute for Space Studies model (US); NCAR93 – National Center for Atmospheric Research model (US) and; UKMO95 – UK Meteorological Office model.

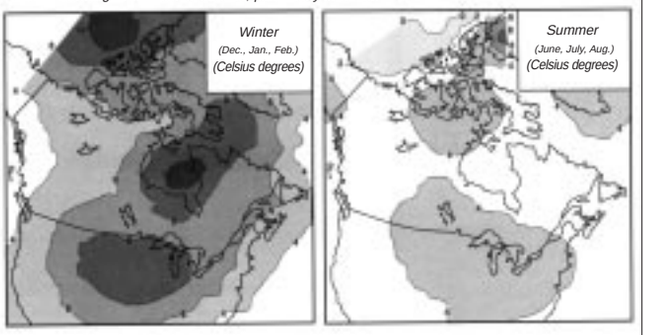


Environment Canada Environnement Canada

Canada

CCC GCM2 2xCO_2 temperature projections for Canada for winter and summer seasons

Climate changes wil not be distributed uniformly. For a doubling of carbon dioxide concentrations, GCM2 projects an increase of 3.5C in the earth's average annual temperature but shows more substantial warming over much of Canada, particularly in winter.



Model	Winter	Summer
GFDL 91 - Geophysical Fluid Dynamics Laboratory GCM	2-6°C	2-3°C
GISS 85 - Goddard Institute for Space Studies GCM	2-14°C	1-2°C

When interpreting the results presented here, based on these scenarios, the reader should be aware that confidence is higher in the hemispheric-to-continental projections of climate change than in the regional projections, where confidence remains low. It is also worth noting that the majority of the identified changes in climate and, therefore, the identified impacts, are projected to occur over the next century, and that the average rate of warming would probably be greater than any seen in the last 10,000 years. Furthermore, although future, unexpected, large and rapid climate system changes (as have occurred in the past) are difficult to predict, future changes may also involve "surprises".

B. CROSS-CUTTING ISSUES LINK TO CLIMATE CHANGE

Introduction

The studies comprising the Canada Country Study indicate the possibility of significant implications for Canada as a consequence of projected changes in climate. Our climate is variable and Canadians and the economy react to it on different temporal and spatial scales. In addition to regional and sectoral impacts, there are a number of concerns related to climate change that are multidisciplinary in nature and broad in scope. These are called cross-cutting issues and highlights of the key findings are identified in this executive summary.

Costing the adaptations and residual impacts of climate change

The issue of identifying the costs of impacts and adaptations to climate change was highlighted as an important aspect of the CCS. Very few studies exist which definitively quantify the costs of adaptation to, and residual impacts from, the projected climate change for Canada. There are methodological issues regarding attempts to assess the various impacts of climate change and account for them in monetary terms. Values cited by the IPCC of some percentage of GDP (i.e. 1-2% of GDP assuming a doubling of atmospheric carbon dioxide by 2050 and a mean global warming of 2.5oC) reflect predominately estimates for the U.S. and extrapolations thereof. There are other methodological issues regarding aggregation of costs across individuals, sectors and regions, as well as across time, and the disregard for the cost of adapting to a changing climate and for the social value of most non-market goods and services. Finally, there are many uncertainties in the timing and magnitude of climate change that affect the results.

Extreme weather events

Small changes in the mean climate or climate variability can produce relatively large changes in the frequency of extreme events with a small change in variability having a stronger effect than a similar change in the mean. At this time, there remains considerable uncertainty regarding projections of changes in flooding and other extreme events, the implications, should these changes occur, warrants consideration of the possible impacts.

Storms: It is not clear at this time whether extra-tropical storms will become stronger or weaker under climate change. Intuitively, however, one would expect more frequent and more intense convective activity in a warmer world. In addition, climate models suggest an increase in the probability of intense precipitation with increased greenhouse gas concentrations. Changes in the number or geographic distribution of convective storms (severe thunderstorms producing hail, lightning, tornadoes, heavy rain and strong winds), however, remain a difficult issue for GCMs due to their small scale.

Extreme temperature events: In a warmer climate, it is expected that heat waves would become more frequent, while cold spells would become rarer. Premature structural failure due to deterioration over months and years could be accelerated where increased occurrences of such things as hours of sunshine, temperature extremes, and frequency of combined wind and rain are anticipated.

Floods and droughts: New results reinforce the view that variability associated with the enhanced hydrological cycle translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places. In those areas where the length of dry spells and the severity of droughts are projected to increase, concerns are heightened regarding potential impacts on water availability and vegetative growth. Conversely, where precipitation intensity increases or other climate factors increase the potential for flooding, the flooding of low-lying homes, docks and port facilities as well as stresses on water distribution and sewage systems caused by projected increases in sea level, extreme precipitation, and spring ice jams on rivers is a major concern.

Integrated air issues

Ecosystems, agriculture, human health and other sectors and regions will not be impacted by climate change acting in isolation, but also by other atmospheric conditions such as stratospheric ozone depletion, acidic deposition, smog (mainly ground-level ozone), suspended particulate matter and hazardous air pollutants. However, atmospheric scientists and decision makers in Canada have largely addressed these issues individually resulting in single-issue policies such as the Montreal Protocol to ban stratospheric ozone-depleting substances.

It is now recognized that climate change has the potential to exacerbate the other air issues. Excess greenhouse gases and projected higher temperatures can be expected to alter atmospheric chemistry, especially through interactions between the key greenhouse gases (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and ozone (O_3), as well as the most important oxidants (hydroxyl radical (OH) and hydrogen peroxide (H_2O_2)), and other trace gases/particles that are involved in one or more of the other five air issues.

Examples of effects of climate change on the other air issues:

Stratospheric ozone: Carbon dioxide contributes to modification of the temperature structure of the atmosphere, including a projected cooling of the higher atmosphere (i.e. the stratosphere). Normally, less ozone is destroyed if the stratosphere is cooler, so the effect of increased atmospheric CO_2 is to decrease ozone depletion. However, increasing atmospheric CO_2 concentrations are expected to cause further cooling of the lower stratosphere and this could enhance the formation of polar stratospheric clouds (PSCs) in some regions, convert potential ozone-depleting species to their active forms and, thereby, potentially intensifying ozone depletion.

Acidic deposition: Climate warming would increase the physical and chemical transformation rates of primary and secondary acidifying materials. The general circulation of the atmosphere and precipitation patterns are expected to change, and the overall tropospheric reactions and instability would change affecting the acid rain issue. These changes are expected to alter the transport trajectories of acidifying gases and the subsequent deposition patterns and regional concentrations. Summertime emissions of sulphur and nitrogen compounds from power plants could increase because of increased demand for air conditioning of buildings and automobiles. Hydrogen peroxide (H_2O_2) is also produced, which is a strong oxidant and catalyst in the production of sulphuric acid, thereby increasing the acidic deposition.

Smog: Natural and anthropogenic emissions of several pollutants (e.g. NOx and VOCs) and particulate matter are sensitive to weather conditions. For example, VOCs released from fuel tanks, solvent use and chemical plants are more volatile at high temperatures. Also, nitrogen compounds emitted by soil microbes and VOCs from vegetation are temperature dependent. Climate change is also expected to increase the potential for smog episodes as a result of increased frequency of hot summer days.

Conversely, other air issues also have effects on climate change:

Stratospheric ozone: Decreased ozone in the stratosphere results in reduced flux of ozone to the upper troposphere where it acts as a greenhouse gas. A thinner ozone layer allows more UV-B radiation to penetrate into the lower atmosphere, where it increases the production of OH radical (a primary sink for methane, a greenhouse gas about 20 times more powerful than CO_2). Thus, destruction of stratospheric ozone could lead to a decrease in the rate of climate warming.

Acidic deposition: Precursors of acidic precipitation (SO_2 and NOx) oxidize in the atmosphere and form sulphate and nitrate aerosols. These particles reflect some solar radiation back to space, causing negative radiative forcing (climate cooling).

Suspended particulate matter: Some aerosols such as soot are efficient light absorbers and cause slight warming, the net (direct and indirect) global mean radiative forcing of anthropogenic aerosols is negative and the magnitude is significant. Some studies suggest that, on a global average, anthropogenic sulphate particles mask about 25% of the warming caused by CO_2 and other GHGs.

Extra-territorial influences

Most of the studies highlighted earlier and in the other volumes focused on the potential climate change impacts in

Canada. Canada, however, is a member of a family of nations and Canadians have interests and connections to people and places across the globe. Therefore, the effects of climate change beyond Canada's borders also needs to be considered. Issues of international trade, security (both food security and military security) and international migrations are highlighted.

International trade: The effects of climate change on international prices and supply and demand could have as much effect on Canada as the first and second order impacts of climate change in Canada itself. Although climate change will affect all sectors of the economy, almost all of the research on climate and international trade has focused on the agricultural trade. A number of models predict that Canada's position on the world market as a leading agricultural exporter will be improved. This is both because climate changes are projected to improve overall yields in Canada and because Canadian producers will fare better than their competitors in places such as the American Great Plains. All of these model outcomes, however, are sensitive to assumptions about levels of adaptation, costs for which are not generally accounted for in these projections, and assumptions about the effect of CO_2 fertilization.

The possible effects of climate change on other sectors of international trade such as forestry, fisheries and energy are poorly known. However, since Canada relies heavily on exports from these production sectors, Canada's trade balance is vulnerable to the projected changes in climate.

International relations: Future climate change is projected to affect Canada's foreign relations in a number of ways. If, as most people project, it is the developing nation's that are most severely affected by anthropogenic climate change, there will likely be an increase in tensions between developed and developing countries.

Climate change could also create new sources of tension within the international community. Warmer temperatures are projected to exacerbate problems of international air pollution. Transboundary water management will also be affected. For example, in the event of long-term drought in the central American states, a scenario predicted by many GCMs, Canada can expect to face increasing pressure from the US for southern diversions of water. The melting of sea ice in the Northwest Passage may makes this waterway navigable. Although Canada has long claimed the Northwest Passage as an internal waterway, this has never been recognized by all members of the international community.

The management of international common property resources is also climate sensitive and thus potentially affected by climate change. For instance, the productivity of Pacific salmon is strongly tied to the pattern of climate and ocean circulation in the North Pacific. In the past, changes in this climatic regime have produced both dramatic declines and increases in catches. When pressures have been placed on the resource, there have been conflicts among fisheries stakeholders, complicating international efforts to manage this resource sustainably.

Food and military security: Canada's geopolitical position buffers it from most military offenses, and its abundant agricultural sector and peaceful border with the United States insulates it from the vagaries of climate change-induced variations in food production. Although there is considerable uncertainty as to the nature of changes in extreme events as a result of climate changes, projected changes in the frequency or severity of these events could lead to an increase in the demand for domestic security forces to assist civilian authorities in the face of natural disasters.

Also chronic, intra-national and ethnic conflicts such as in Bosnia and Rwanda affect Canada and Canadians a number of ways: by making the world a more dangerous place; by spilling over the boundaries through acts of international terrorism; by escalating into wider conflicts; by increasing demands for Canadian participation in peace-keeping and diplomatic missions; and by contributing to internal and international refugee problems.

Environmental migrations: The effect of climate change on environmental migrants coming to Canada is unknown. Estimates of the number of refugees generated by projected changes in climate range as high as 150 million, though only the most mobile of those could be expected to make their way to Canada. This enhancement of the number of international refugees would put an unprecedented strain on Canada's refugee assimilation mechanisms, though the exact cost would be impossible to quantify at this time.

Domestic trade and commerce

Research of the impacts of Canadian domestic trade under climate change is quite meager and statistics about interprovincial trade are generally of poor quality. As a result, potential impacts in this area are quite speculative in nature.

Domestic trade and commerce is likely to intensify with northern regions of Canada possibly becoming the new frontier. Large population centres in the south (i.e. markets and service centers) are not likely to change location as manufacturing activities are less dependent on natural resource location than on manpower cost and availability of services. Projected impacts on natural resources could result in shifts or movements of centres of activity (e.g., agricultural opportunities, and harvesting and processing centres in the forestry and fish-

eries industries). These changes could lead to shifts in people and commerce within and across regions as opportunities arise and production potentials change. Concerns are being raised regarding the sustainability of vulnerable communities and industries due to projected changes in the availability of water as a result of projected changes in climate.

Changing landscapes

Broad landscape-scale effects of climate change should be anticipated for Canada. These impacts are expected to be driven by the resulting forces of: altered and more variable hydrology, melting of permafrost; rising sea levels, and the shifting and altering of ecozones. Such broad-scale landscape alterations have serious implications for hydrology, wildlife, biodiversity, infrastructure and transportation, economic activities, cultural values and lifestyles, and the well-being of Canadians.

Sustainable development and climate change

At first glance it might seem odd to suggest that climate change and sustainable development represent very different ways to think about global environmental problems. This has led to difficulties in establishing strong working linkages between the research and policy communities, both here in Canada and at the international level. Within the climate change and sustainable development research communities, different visions of future development are being generated. This has led to problems in several key areas such as: differences in scenarios of emissions, economic patterns, etc.; unequal treatment of mitigation (abatement) and adaptation (vulnerability) aspects of climate change; ethical concerns raised by developing countries, and; questions about the relevance of science to policy making on climate change and sustainable development. These visions have very different dimensions, and as long as they remain separate, there is a risk of significant errors in the assessments of costs and benefits of responding to climate change.

Northern subsistence and land-based economies

Northern indigenous peoples, already one of the more vulnerable segments of Canadian society, would be affected by ecosystem shifts caused by climate change. Very little is known about the possible impacts climate change might have on the northern economy which is comprised of three sectors: the wage sector, transfer payments, and subsistence harvesting. The types of changes anticipated to accompany climate change as described, however, are likely to challenge severely the capacity to adapt of many subsistence societies. The effects are likely to be wide-spread, with regional variations, and attempts to modify or prevent events/effects for vast northern regions are not likely to be viable once the impacts begin to be felt.

Climate change may affect the distribution of animals and other resources on which subsistence and land-based economies are based. Under conditions of projected climate warming, multi-year ice and large areas of discontinuous permafrost are expected to disappear, precipitation is expected to increase on average by 20 to 30% and the length of the annual frost-free period would increase. Terrestrial, aquatic and marine mammals in the Arctic and subarctic live in a marginally supportive physical environment and small changes in conditions could have major impacts on their health and survival. The transition in the north to settlement life over the last forty years has reduced, though not eliminated, northern peoples' options for traveling to new areas in response to animal migrations. Loss of waterfowl and fish populations would have serious implications for the subsistence economy because these resources are not likely be replaced by other wild food sources.

Thermal expansion of the ocean coupled with melting glaciers and ice sheets are projected to raise mean sea levels about 50 cm from the present to the end of the 21st century. Such changes in sea level are expected to have effects on the Arctic's coastal settlements, and costly measures may be needed to protect them from flood damage, if indeed they can even be protected.

Climate change may affect the validity of traditional knowledge and local adaptations. For example, hunters, fishers and trappers depend on detailed local knowledge of animal distributions and behaviour, snowfall patterns, and timing of freeze-up and break-up. Climate change can play havoc with the use of such knowledge by making locational knowledge unreliable.

Climate change may interfere with wildlife harvests, thus resulting in diet-related problems and medical costs through elevated levels of cardiovascular disorders, diabetes and vitamin-deficiency disorders. As the consumption of fresh meat in the diet has declined, the nutrients formerly provided by this diet are not been replaced by the new food choices. This is thought to be the major mechanism behind the virtual epidemic of obesity, cardiovascular disorders, and diabetes mellitus among northern populations. The pursuit of subsistence harvesting demands a high level of physical fitness. As members of subsistence societies fall prey to modern diseases they are less able to hunt for wildlife and so contribute to their family's welfare.

A warmer climate would result in melting permafrost, the thawing of wastes and greatly increasing the possibility of contaminating water resources. The increase of ultraviolet-B radi-

ation caused by thinning of the ozone layer in the Arctic stratosphere is a real threat to human and animal health as well as to productivity of terrestrial and marine vegetation.

C. SCIENCE GAPS AND RECOMMENDATIONS FOR FURTHER RESEARCH

On a national basis, we need to fill science gaps. We need to predict with higher confidence the impacts of climate change on Canada's landscapes, on physical and biological processes, and on our socio-economic sectors so that we can develop adaptation strategies to deal where possible with such impacts. To put this into a societal context, we must turn such physical and biological changes into socio-economic values (costs and benefits).

Costing research: Develop a true benchmark estimate of the costs over time of adaptation to, and residual impacts from, climate change for Canada (e.g., estimating a time profile of marginal costs of CO_2 emissions).

Extreme weather events: Develop and maintain databases related to the costs of and adaptations to natural hazards; develop climate change scenarios based upon real case studies of extreme events, as well for assumed reductions in the return periods of these events; assess how Canadians perceive their risks related to natural hazards and climate change in order to better understand how adaptive decisions are made.

Climate change and other air issues: Conduct an integrated assessment of the climatic effects of all gaseous and particulate emissions, the physical and chemical processes involved, the effects on socioeconomic systems and ecosystems, and the various control strategies on all of the air issues; assess the most cost effective and socially acceptable control measures for each air issue; assess the possible effects of other air issues on the frequencies and intensities of extreme weather events;

Climate change and other non-climatic factors: Use an integrated approach to study the impacts of multiple stresses on human health, socio-economic sectors, and ecosystems. Studies should consider climate change as one of many factors which determine the overall response. For example, projected population changes and associated changing land-use and air and water quality will continue to influence the health and existence of natural and human systems. Impacts and adaptation studies should include consideration of competing interests, current policies and boundary demands.

Indirect, extraterritorial effects: Assess the indirect links between climate change and international trade regimes and policies on specific economic sectors in Canada such as agriculture, forestry, fisheries and energy; conduct further work on the effects on Canada of environmental refugees displaced by climate change.

Domestic trade and commerce: Assess how patterns of human settlement in Canada would be affected by changes in domestic flows of trade and commerce under climate change; improve input-output analysis capabilities with availability of better quality provincial economic statistics.

Changing landscapes: Develop and maintain databases on critical variables to improve prediction of climate change impacts on regional ecosystems. Variables required include seasonal averages and the degree of between-year variability in: temperature, precipitation, wind and radiation; the intensity and probability of extreme events including drought, storms and floods; snow cover distribution, depth, extent and duration; precipitation at varying elevations; the probability of short-term anomalies such as late spring/summer frosts, mid-winter temperature or rain events, and intense spring storms; surface heat fluxes and UV-B irradiation; sea-level pressures.

Sustainable development and climate change: Ensure that climate change and sustainable development is explicitly included in their respective research agendas; conduct integrated assessments of climate change that incorporate alternative methodologies that complement global scale integrated assessment models.

Northern subsistence and land based economies: Conduct research to link available biological/ecological information on the impacts of climate change to local resource use and the northern economy; determine the effects of non-linear, sudden changes in climate on northern regions; differentiate between the potential effects of climate change in the north from the cumulative impacts of large-scale development projects; determine the limits to adaptability in northern subsistence economies; conduct research to develop adaptive management strategies with emphasis on the resilience of social and ecological systems, and on flexibility to respond to uncertainty and largely unpredictable climate change; conduct research to study the issue of the health of northern populations relative to the implications climate change has for the long-term availability of country foods; improve knowledge on the epidemiology of climate change for the north; develop methodologies to estimate costs of increasing dependence on financial government support, and the costs of facilitating adaptation options to encourage self-reliance.