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The Institute for Catastrophic Loss Reduction (ICLR) was established in 1998 with the mission to reduce the loss of life and property caused by severe weather and earthquakes through the identification and support of sustained actions to improve society's capacity to adapt to, anticipate, mitigate, withstand and recover from natural disasters.

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Executive Summary

The world's urban population is growing, as is the importance of cities to the health of the nations they fuel. Unfortunately, many of the elements that define cities also contribute to their vulnerability. As our climate changes, natural hazards that surround our cities will also change, interacting with vulnerabilities to threaten the sustainability of the urban environment. These changing risk factors demand adaptation, including comprehensive efforts to reduce urban vulnerability and more proactive measures to minimize hazard impacts.

This paper discusses the implications of climate change for natural hazards that threaten Canada's cities, explores the expected impacts of this changing hazard variable and identifies strategies for adaptation that can be employed in response.

Introduction

Throughout the 20th century, the world's cities have grown in size and influence as centres of commerce, industry and communication. Globalization theorists posit that cities will become increasingly important in years to come, as state borders erode with advances in travel and communications. Today, it is estimated that about half of the world's population lives in urban areas, a figure that is expected to rise to 60 per cent by 2030¹.

In Canada, roughly 60 per cent of the population lives in urban areas of 100,000 people or more and about 80 per cent in urban areas of 10,000 or more². The Canadian economy is inextricably linked to the health of its cities; for example, the seven largest cities in Canada generate almost 45 per cent of the national GDP and large cities like Vancouver and Montreal account for over half of provincial GDP³.

Canada's cities play an important role as economic drivers, centres of concentrated industrial production and homes to a majority of the nation's citizens, making forward planning increasingly important to anticipate and prevent problems that may threaten urban sustainability. Natural hazards can pose a significant threat to urban areas, carrying the potential to disrupt economic and social activities, cause substantial damage to property and even kill people. Cities have become increasingly dependent on their lifelines, including transportation systems (e.g., air, water, road and rail) that move people and goods; water and electric power supply systems; and sewers and waste removal systems. All of these elements have become essential in the modern city, making them points of vulnerability. As such, it is important to recognize the impacts of hazards on cities and understand the role that climate change will play in the years to come.

What have we observed?

Every year, natural disasters threaten the sustainability of cities, disrupting and taxing their resources and threatening the lives of residents. Over the last decade, natural disasters have caused tremendous property losses around the world, averaging \$40 billion annually and reaching a staggering \$100 billion in 1999 (U.S. funds)⁴. Although earthquakes are important, about 80 per cent of the impacts are due to weather and weather-related hazards.

Canadians face a plethora of natural hazards. Some, such as earthquakes in British Columbia and the St. Lawrence Valley, are unaffected by a changing climate, but most are part of our weather and weather-related systems and will change as the climate changes. Weather hazards include tornadoes, hailstorms, winter storms and heat waves, while weather-related hazards include drought, storm surges, floods and moving ice. Weather and weather-related hazards vary in their likelihood across Canada: for example, tornadoes⁵ and hailstorms⁶ are most common on the Prairies and in southern Ontario, storm surges are common on the East coast⁷, and winter storms can occur across the country.

While the number of geophysical hazards has remained approximately constant [see Figure 1], the number of weather-related hazards has increased from 2-4 per year in past decades to about 12 per year in the last decade (with considerable year to year variability)⁸. Recent experience illustrates that natural hazards pose a significant threat in Canada and carry the potential for catastrophic loss [see Table 1]. Of particular note are hail and tornadoes, which can strike quickly and cause great loss of life (e.g., 29 people in Edmonton in 1987 and 12 in Barrie two years earlier). Another 12 people were killed, with 100 hospitalized, in the Pine Lake, Alberta tornado in the year 2000. Individual hailstorms hit Calgary twice in the 1990s, with damages over \$100 million.

In 1996, abnormally heavy rainfall led to major flooding in the Saguenay Region of Québec, which required the evacuation of 15,000 people and caused losses of over \$1.5 billion. Then in 1997, heavy snowfall and an unusually fast spring thaw contributed to a major flood in Manitoba's Red River Basin, which forced over 25,000 people to leave their homes and caused nearly \$1 billion in damages⁹. Floods usually occur more slowly and actions to prevent loss of life are usually possible (in Canada, at least, less so in developing countries) but the economic stress on cities impacted by floods is very large.

The health and sustainability of Canada's cities depends largely on the continuity of critical infrastructure lifelines, such as sewer and water, transportation and electrical power systems. Past experience in Canada has demonstrated that this urban machinery is highly susceptible to disaster damage. For example, the 1998 ice storm which struck Ontario, Québec and New Brunswick crippled power grids, caused structural damage to buildings and brought transportation to a halt, becoming Canada's most expensive natural disaster, exceeding \$5 billion in losses¹⁰ and causing at least 28 deaths. Similarly, the British Columbia blizzard of 1996 shut down the cities of Vancouver and Victoria for days, with a major economic impact.

While these dramatic and horrific events gain most of the media attention, the reality is that Canadians are affected by weather every day. Our changing climate means that the relationship between weather and our human activities now needs to be viewed differently. The complexities and interdependencies of our modern society and our cities have made us more vulnerable. In our pursuit of economic efficiency, we have eliminated redundancies, optimized processes, and automated our systems, while, unintentionally increasing our vulnerability. We have built homes, factories and transportation systems in more exposed locations. In doing so, we have increased the probability that weather events will interfere with us and our activities. In addition, while many of us have become more prosperous, there are also more homeless and other disadvantaged people who are at increased risk, most of whom are city dwellers.

What can we expect?

Over the past century, we have come to understand that disasters are “the disruptive and/or deadly and destructive outcome of triggering agents when they interact with, and are exacerbated by, various forms of vulnerability”¹¹. Our attitude toward disasters has evolved from a fatalistic fear of “Acts of God” to a broader understanding of the role human decisions play in determining our vulnerability and capacity to cope with the consequences of extreme events. From this perspective, two interacting variables can determine whether or not an emergency becomes a disaster, the *hazard* (triggering agent) that threatens a community and the *vulnerability* of the affected population.

Changing vulnerability

By their nature, cities are particularly vulnerable to natural hazards. High population density in urban areas means more people and property at risk. Large concrete expanses used in urban construction absorb summer sun and exasperate heat waves, which kill about 11 people per year in Canada and contribute to heart attacks and other heat-related ailments for many others¹². The use of sealed asphalt and concrete for city streets prevents ground absorption during an extreme rainfall event, contributing to a risk of flooding when drainage systems become overwhelmed¹³.

The way in which cities are planned and built also contributes to urban vulnerability. Because resistance to natural hazards is rarely built into new construction and redundancy schemes are rarely incorporated into infrastructure, failure of a particular building or system in the event of a disaster can mean tremendous losses. Nearsighted land-use planning (e.g., permitting residential development in a floodplain) puts people in harm’s way, while a lack of commitment to mitigation leaves inhabitants to bear the full impact of disaster losses.

Urban vulnerability is further augmented by Canada’s aging and deteriorating infrastructure; in many cases, the minimum standards that were used to design capacity in urban infrastructure are no longer appropriate for our changing climate. A 1995 survey by the Federation of Canadian Municipalities and McGill University indicates that Canadian municipal infrastructure is dangerously outdated and requires upgrades that could cost up to \$44 billion¹⁴.

Transportation is a particularly important component of urban infrastructure, as the flow of goods into and out of urban areas expands. As more Canadian businesses have adopted the doctrine of “just-in-time delivery”, the demand for daily shipping via rail and truck has increased substantially; in 2000, about 45 percent of domestic goods were shipped by rail, followed closely by trucking at 43 percent¹⁵. Both modes of transportation are vulnerable to natural hazards. For example, two major 1999 snowstorms in southern Ontario dumped 118 centimetres of snow within two weeks on the City of Toronto, virtually prohibiting transportation (including air traffic) in and around the city¹⁶. Near Sackville, New Brunswick, the only rail line connecting Halifax with the rest of Canada is located within two metres of the normal spring high tide line, where it is vulnerable to severance in the event of a storm surge¹⁷.

Changing hazards

In order to plan for urban sustainability, we must better understand the nature of hazards. Moreover, it is important to explore the impact that a changing climate will have on natural hazards that our cities face. A central question for this report is – are disaster-generating events, those trigger events, likely to increase in number and intensity as a result of climate change?

Over the past 150 years, the atmospheric carbon dioxide concentration has risen 31 per cent, a value unprecedented in the last 420,000 years¹⁸. While the atmospheric concentration of greenhouse gases has risen, there is also an expanding body of evidence indicating that there has been a real and substantial change in global mean temperatures. The change in the 20th century is unusual in comparison with changes in global temperature data for the past 600-1000 years that have been inferred from proxy indicators. Over the 20th century, the globally averaged surface air temperature has increased by $0.6\pm 0.2^{\circ}\text{C}$. In addition, there seems to be some evidence for a corresponding strengthening of the hydrological cycle, such that precipitation may be increasing at mid- and high-latitudes.

As was noted, there has been a significant increase in the number and costs of hazardous weather and weather-related events, but detecting changes in occurrences of extreme events is much more difficult than detecting changes in mean values. Since extreme events, by their nature, occur less frequently, there are difficulties in measuring and assessing their changes¹⁹. Studies have provided evidence that precipitation extremes may be becoming more intense²⁰, while analyses by Zhang et al.²¹ showed that for Canada, there is evidence of increasing precipitation related to an increasing frequency of precipitation events, and Stone et al.²² provided evidence for an increasing intensity of extreme precipitation. The Intergovernmental Panel on Climate Change (IPCC) applied a set of criteria to assign values to probabilistic statements, such as *likely*, meaning 66-90% confident that the result is true and concluded that,

*“It is likely that there has been widespread increase in heavy and extreme precipitation events in ...the mid- and high latitudes of the Northern Hemisphere.”*²³

The question of whether extreme weather events in general are changing has been controversial, but after an extensive review of the literature and with the input of several authors and international review, the IPCC²⁴ notes:

“Part of the observed upward trend in historical disaster losses is linked to socioeconomic factors such as population growth, increased wealth, and urbanization in vulnerable areas, and part is linked to climatic factors such as observed changes in precipitation, flooding, and drought events (e.g., see Section 8.22 and Chapter 10). Precise attribution is complex, and there are differences in the balance of these two causes by region and by type of event. Notably, the growth rate in the damage cost of non-weather related and anthropogenic losses was one-third that of weather-related events for the period 1960-1999 (Munich Re, 2000). Many of the observed upward trends in weather-related losses are consistent with what would be expected under human-induced climate change.”

As we look to the future, we need to recognize that there is again uncertainty, now in the predictions of climate change, but the statement of Dr. R. Watson, Chair, IPCC, speaking to the Sixth Conference of the Parties under the UN Framework Convention on Climate Change, best summarizes the consensus of most scientists:

“The overwhelming majority of scientific experts, whilst recognizing that scientific uncertainties exist, nonetheless believe that human-induced climate change is inevitable. Indeed, during the last few years, many parts of the world have suffered major heat waves, floods, droughts, fires and extreme weather events leading to significant economic losses and loss of life. While individual events cannot be directly linked to human-induced climate change, the frequency and magnitude of these types of events are predicted to increase in a warmer world.”

The research is summarized in Table 2 and we should assume that the frequency and intensity of such events will escalate. Specific effects of climate change include an increase in average precipitation and a greater frequency of intense precipitation events, more extreme seasonal temperatures, a higher risk of drought during summer months and an increased probability of hurricanes and tropical storms²⁵.

As climate change transforms the nature of hazards, cities will be faced with a number of direct impacts. Increased precipitation will challenge the design capacity of water collection systems and multiply the probability of flooding. Excess runoff from overwhelmed sewer systems could permit the infiltration of contaminants into local water supplies, as illustrated through the experience of Walkerton, Ontario in 2000²⁶, where heavy rainfall washed harmful bacteria from manure into a municipal well, causing seven deaths and serious illness for many others.

It is clear that natural hazards can have several impacts on human health²⁷. The health care system is becoming less resilient and more vulnerable due to the convergence of heavy workloads and external stressors, such as natural disasters. The “just in time” management of hospital services and the amalgamation of hospitals through regional boards are also increasing the vulnerability of health care services. Some essential hospital supplies and services are now delivered from a variety of locations within a region and may not be available on site during emergencies. Although there are many acute impacts of natural hazards on health, attention must also be given to the long-term health effects. Disaster-related health problems may require help from non-medical agencies, because people cannot cope unaided with the consequences of disasters.

Increasing snow precipitation and more frequent winter storms have implications for the annual cost of snow removal, necessary to preserve the integrity of transportation routes. Moreover, “it is estimated that approximately 7 percent of injury collisions and 12 percent of property damage collisions are directly attributable to inclement weather”, which “translates into a conservative estimate of \$1 billion per year” in health care and property damage costs²⁸. More frequent and intense winter storms could pose a greater threat to the road safety of drivers.

Higher average temperatures result in melting glaciers and thermal expansion in the oceans, contributing to an overall rise in sea level. As a result, coastal communities face a greater risk of flooding and a higher probability of storm surge²⁹, the effects of which have recently been felt in

Canada's Maritime provinces. In January 2000, for example, a severe six-day storm moved across the Maritimes, bringing high winds, snow and a storm surge in excess of 1.5 metres in the Northumberland Strait, which caused flooding and serious damage to wharves and buildings in many communities³⁰.

Urban residents also face challenges associated with more extreme temperatures. At present, bitter cold and severe winter storms cause more than 100 deaths in Canada every year, while serious heat waves exasperate the risk of heart attack or other ailments related to excessive heat exposure³¹. Electrical power generation will become increasingly strained as city-dwellers seek to cope with these extreme temperatures through heating and air conditioning.

In addition to direct threats, climate change is also predicted to contribute to worsening urban air pollution and more intense "heat islands" from higher overall temperatures³², which could exasperate allergic and respiratory disorders. Warmer, wetter weather creates the conditions under which insects and bacteria proliferate, contributing to the spread of infectious and vector-borne disease³³.

Canadian cities have already begun to experience the changing hazards associated with climate change. In British Columbia, for example, measured impacts of climate change include a 4 to 12 centimetre rise in coastal sea level over the last 100 years and a 2 to 4 per cent increase in average annual precipitation per decade since 1929³⁴. The implications of these changes are enormous for a community like the City of Richmond, which houses over 165,000 people in the floodplain of the Fraser River, on land with an average elevation of just one metre above sea level³⁵.

Climate change has had an opposite effect in the St. Lawrence River, where the water level has dropped 30 centimetres from 1991-98 and is expected to drop by over a metre in the future³⁶. Such significant reductions in the river flow pose a serious threat to cities like Montréal and Québec, which depend on the river for their water supply. Lowering of flow in the St. Lawrence River at Montréal has great impact on port capacity and thus the economy of the city.

What can we do?

As Canada's cities have grown, local governments have taken steps to adapt to natural hazards, employing emergency programs to plan for and respond to disasters. Experience with natural hazards has prompted substantial urban investments in efforts to contain or control hazards and increase community resistance to their impacts. Despite these efforts, disaster losses have continued to escalate over the past several decades, illustrating the need for more proactive efforts to prevent or reduce losses. Moreover, as the climate changes, city governments will have to tailor a program of adaptation that will reduce community vulnerability and mitigate the impact of increasingly volatile natural hazards.

Adaptation refers to measures taken in response to actual or expected changes in climate³⁷. These measures can take a number of forms, including *loss prevention* – actions to reduce vulnerability to climate change; *loss sharing* – spreading the risk of loss among a wider population (e.g., insurance); *behaviour modification* – eliminating the activity or behaviour that causes climate

change; and *relocation* – moving vulnerable populations or systems away from hazards induced by climate change³⁸.

From a structural perspective, adaptation can involve efforts to build resistance into construction and infrastructure to reduce the probability of failure during a hazard event, and resilience to bounce back quickly in the event that systems are overwhelmed. Resistance can be incorporated into new structures and systems through stricter standards, regulations and codes. Resilience can be enhanced through the employment of “break away” components, backup systems and regularly tested recovery procedures. In some communities, structural measures may be designed and built to withstand or divert specific hazards; for example, coastal communities will be particularly concerned with sea level rise and may be required to build protective barriers and dams against storm surges and coastal flooding³⁹. A prominent Canadian structural example is the Red River floodway in Winnipeg, Manitoba, which was built to divert waters around the city in the event of flooding and has prevented an estimated \$1 billion in property damages⁴⁰.

Adaptation also requires non-structural approaches, targeted at reducing community vulnerability to changing natural hazards. There are many services that can be employed by governments for this purpose, some of which include: hazard assessment and monitoring, planning and building codes, prediction and warning systems and public education and research.

Hazard assessment and monitoring

In order to create an appropriate adaptation strategy, a first step is to identify hazards that threaten the community and assess the risk to people and property. A comprehensive hazard assessment, particularly if it incorporates risk analysis, provides the information necessary for decision-makers to identify policy options and determine the appropriate strategy for mitigating natural hazards that threaten communities. Once vulnerabilities have been identified, actions can be taken to reduce risk⁴¹.

In recognition of the impacts of hazards on communities, several provincial governments have passed legislation requiring local governments to conduct a hazard assessment as a basis for emergency planning. Some examples include Québec’s Civil Protection Act, which requires citizens to be aware of the risks in their environment and obligates communities to incorporate a hazard assessment into an emergency plan⁴²; and Ontario’s Emergency Readiness Act, which requires each municipality to create an emergency management program, complete with hazard assessment, emergency plans, training and exercises⁴³.

Because individual communities may lack the resources or technical expertise to undertake a comprehensive hazard assessment, intergovernmental cooperation in this area can be very important. Encouraging examples of this can be found in British Columbia, where the Ministry of Energy and Mines has conducted detailed assessments of the earthquake and landslide hazards in the province, which have been incorporated into regional and local planning⁴⁴. In addition, local governments in British Columbia can take advantage of a comprehensive online Hazard, Risk and Vulnerability Analysis Toolkit produced by the Provincial Emergency Program as a part of its Disaster Resilient Communities initiative⁴⁵.

Several federal departments conduct vulnerability assessments and risk analyses concerning the hazards within their fields of responsibility, including the Meteorological Service of Canada (part of Environment Canada), the Geological Survey of Canada (part of Natural Resources Canada) and the Hydrographic and Ocean Science Division (part of the Department of Fisheries and Oceans Canada). Other organizations at both federal and provincial levels also have monitoring responsibilities; for example, the MSC cooperates with the provinces in water survey measures that provide the basis for flood hazard mapping and flood prediction.

The Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP) is the primary agency tasked with the coordination of government efforts for disaster mitigation. It serves as a resource point for information on natural and human-induced hazards and provides information on services available for disaster mitigation. One program of OCIPEP is the National Hazards Electronic Map and Assessment Tools Information System (NHEMATIS), a hazard database created through a public/private partnership which identifies and assesses facilities and individuals at risk from natural hazards in Canada. The information contained in the database also identifies potential future disasters, providing a basis for preparedness and mitigation activities⁴⁶. Another notable project is the Canadian Natural Hazards Assessment Project, a joint effort among the MSC, OCIPEP and the Institute for Catastrophic Loss Reduction (ICLR), which was undertaken to identify natural hazards in Canada and assess Canadian vulnerability as a basis for policy-making in the areas of preparedness and mitigation⁴⁷. The information from this project could be very helpful to local governments seeking to identify and assess the hazards they face.

Planning and building codes

A hazard assessment is an important first step in reducing vulnerability, but in order for communities to avoid future losses from natural hazards, this information must be incorporated into municipal planning. Local governments in Canada have the delegated authority to create an Official Plan, which is used to guide development in the community to ensure sustainability. If a hazard assessment were imbedded in the Official Plan, development proposals could be checked against known hazards and appropriate land uses could be assigned to minimize risk to people and property (e.g., avoiding residential construction in high-risk areas such as floodplains).

The planning process can incorporate adaptation and ensure that future community development is sustainable in light of expected changes in our climate. Building codes can also provide a tool for adaptation, to ensure that construction techniques contribute to the resistance and resilience of structures to natural hazards⁴⁸. To avoid flooding, for example, design criteria for public works infrastructure like sanitary and storm sewers can incorporate higher tolerances to account for unexpected events. Building codes can be used by governments to protect the interests of citizens; for example, by requiring a minimum standard for construction materials and techniques used in new home construction, governments are able to ensure a measure of safety for consumers who may not be fully informed of risk upon purchase.

While building codes offer the potential for disaster mitigation, they must be consistently enforced in order to be effective. Problems with enforcement have been strikingly illustrated in the United States; after Hurricane Andrew in 1992, insurance investigators estimated that

building code violations were to blame for approximately one quarter of the insured losses from the event⁴⁹.

Prediction and warning systems

Prediction involves collection and analysis of information on past and present occurrences of hazard events and use of a prediction model in order to estimate the likelihood of future events. Weather and weather-related predictions range from warnings of a tornado in the next ten minutes, to a winter storm in the next days through to climate change over the coming century (see Figure 2). New technologies have allowed better detection of weather and better prediction systems to improve the skill of short-term predictions and extend the range for longer-range predictions, but further investment in this area is needed to ensure greater resolution and precision⁵⁰. For example, though improvements in monitoring and forecasting technology over the last few decades have significantly improved the ability of scientists to predict the onset of El Niño (a phenomenon historically responsible for a number of extreme weather events that have resulted in natural disasters), the damage caused by extreme weather attributable to El Niño remains high, because current technology is only able to predict broad characteristics that will accompany the phenomenon, such as increased rainfall or higher temperatures in certain regions; more sophisticated modeling capabilities are required to predict specific effects of El Niño after it has begun⁵¹.

Once forecasts and predictions have been made, an effective warning system is required to disseminate the information to people who may be affected by them, so they can take appropriate actions to protect themselves from injury and loss. An effective warning system requires accurate sensing and observation equipment, processing and modeling facilities and an appropriate communications system for delivery⁵². Weather forecasts are routinely available through the media, generally provided by the Meteorological Service of Canada⁵³, which also provides a Weather Radio system to disseminate forecasts and warnings. The Government of Alberta has made great progress in this area; in the event of impending life-threatening events, local government officials have access to the Emergency Public Warning System (EPWS), which interrupts regular radio and television programming to broadcast a warning to citizens⁵⁴.

Public education and research

In many cases, mitigation strategies are not adopted because of a lack of public support. Though potentially devastating, disasters are relatively rare, while the costs and sacrifices associated with land-use regulation and building code enforcement can be seen every day. As a result, people are apt to resist mitigation strategies in the absence of a perceived threat⁵⁵. Public education can help people become aware of vulnerability, introduce them to alternative strategies for coping with hazards and stimulate public interest in disaster mitigation as a community priority. In order for people to make informed decisions and take mitigative actions at an individual level, they must have access to information not only about the hazards that they face, but also the potential damages that could result in the event of a disaster.

The need for public education has prompted several notable efforts in Canada, mainly targeted at children, who are particularly sensitive to the psychosocial effects of disasters. For example,

Sécurité Publique Québec provides an array of information for children and teachers on natural disasters and emergency preparedness⁵⁶. Similarly, teachers can integrate information on hazards and disasters into their curriculum using the *Expect the Unexpected* program of the Canadian Red Cross⁵⁷.

Research on climate change, particularly addressing the observed and expected impacts on Canada's cities, is an important tool to raise awareness among policy-makers and encourage adaptation strategies at all levels of government. The Canadian body of research in this area is growing, with notable efforts from research networks such as the Canadian Climate Impacts and Adaptation Research Network (C-CIARN),⁵⁸ the Canadian Foundation for Climate and Atmospheric Sciences⁵⁹ and the Meteorological Service of Canada. Further research on the relationship between climate change and natural hazards will help to facilitate comprehensive adaptation strategies to address changing risk to Canada's cities.

Concluding Remarks

Natural hazards pose a significant threat to cities in Canada, measured in physical disruption of infrastructure, human health effects and economic losses from damage and lost productivity. Climate change is expected to change the nature of hazards that surround Canadian cities, demanding adaptation to prevent catastrophic loss. Several strategies for adaptation have been introduced herein, each of which can contribute to a more resilient and sustainable urban environment.

Canadians face a wide range of temperatures and climatic conditions and we have adapted well to these variables. By anticipating the urban impacts of climate change and incorporating them into city planning, we can bolster our adaptive capacity in spite of the changing hazard environment we will experience in coming years. Active efforts to reduce vulnerability will protect the lives of Canadians and reduce losses from natural disasters.

Figure 1. Geophysical and weather related natural hazards in Canada (1900-2000)

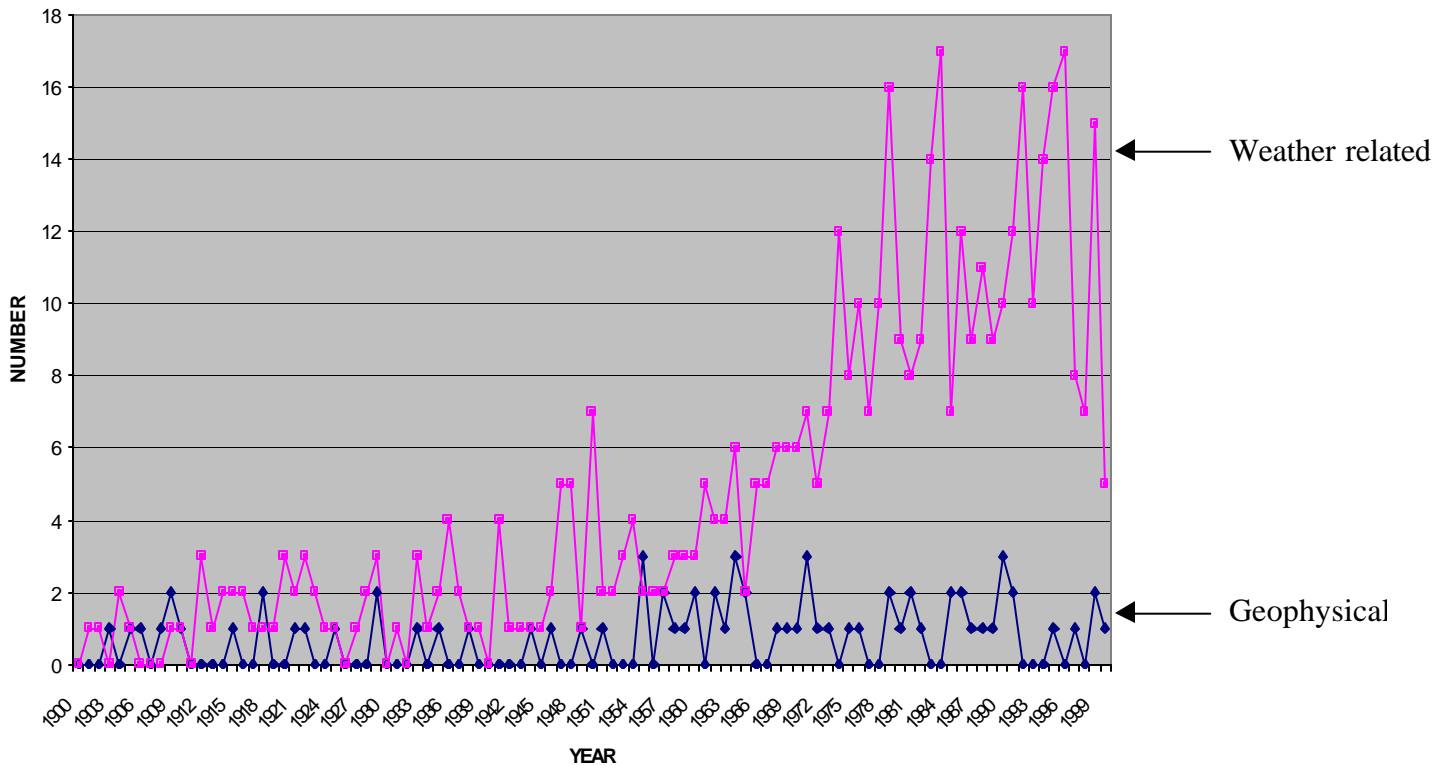
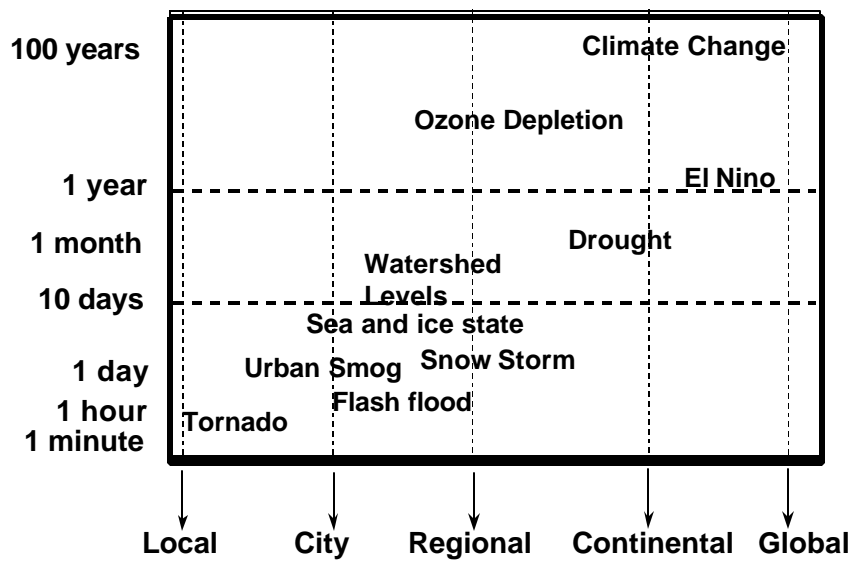


Figure 2. Continuum of weather and weather-related natural hazards, showing schematically the spatial and temporal scale of events.



Disaster	Number of deaths	Economic Cost (\$B Canadian)
Ice Storm (1998)	28	\$5.5
Edmonton tornado (1987)	27	\$0.15
Barrie tornado (1985)	12	\$0.2
Pine Lake tornado (2000)	12	\$0.02
Saguenay Flood (1996)	10	\$1.5
Manitoba flood (1997)	4	\$1
Calgary Hailstorm (1991)		\$0.36
B.C. Blizzard (1996)		\$0.2
Winnipeg Flood (1993)		\$0.16
Calgary Hailstorm (1996)		\$0.14

Table 1. Recent Canadian Natural Disasters

Changes in Phenomenon	Confidence in observed changes (latter half of the 20th century)	Confidence in projected changes (during the 21st century)
Higher maximum temperatures and more hot days over nearly all land areas	Likely	Very Likely
Higher minimum temperatures, fewer cold days and frost days over nearly all land areas	Very Likely	Very Likely
Reduced diurnal temperature range over most land areas	Very Likely	Very Likely
Increase of heat index (a measure of human discomfort) over land areas	Likely, over many areas	Very Likely, over most areas
More intense precipitation events	Likely, over many Northern hemisphere mid- to high latitude land areas	Very Likely, over many areas
Increased summer continental drying and associated risk of drought	Likely, in a few areas	Likely, over most midlatitude continental interiors (lack of consistent projections in other areas)
Increase in tropical cyclone peak wind intensities	Not observed in the few analyses available	Likely, over some areas
Increase in tropical cyclone mean and peak precipitation intensities	Insufficient data for assessment	Likely, over some areas

Table 2. Estimates of confidence in observed and projected changes in extreme weather and climate events

Virtually certain (>99% chance that a result is true); Very Likely (90-99% chance); Likely (66-90% chance); Medium Likelihood (33-66% chance); Unlikely (10-33% chance); Very Unlikely (1-10% chance); Exceptionally Unlikely (<1% chance). Source: McBean (2003), based on data from IPCC (2001a).

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