James Bay Advisory Committee on the Environment
Comité consultatif pour l’environnement de la Baie James
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PORTRAIT AND KNOWN ENVIRONMENTAL IMPACTS OF CLIMATE CHANGE ON THE JAMES BAY TERRITORY

June 2007

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1. Introduction

Concern about global warming has become widespread since 1992, the year the Kyoto Protocol (Japan) was signed. The relationship between the planet's average temperature and carbon dioxide was first stated in 1894 by Svante Arrhenius (Nobel Prize in Chemistry in 1903). The hypothesis regarding the impact of human activity on the climate was advanced during the world's first climate conference in 1979. The scientific consensus on the issue is recent, however. Controversy over the reality and causes of global warming comes more from the media than the scientific community. Most opponents of the hypothesis that human activity affects the climate are connected to the major oil companies.

The role of the James Bay Advisory Committee on the Environment (JBACE) includes counselling governments (federal, provincial, regional and local) on the environmental and social protection regime (Section 22 of the James Bay and Northern Quebec Agreement). In this respect, the JBACE comments on proposed laws, regulations and policies affecting the regime. In addition, the Committee oversees application of the environmental and social impact assessment and review procedure; under this procedure, development projects are the subject of an evaluation and, occasionally, of an impact assessment, to "minimize the negative impact of development (…) upon the Native people and the wildlife resources…" (JBNQA; para. 22.2.2a).

To the extent that climate change has an impact on the Cree environment and social milieu, the JBACE would like to gain a better understanding of this phenomenon and, if need be, recommend a course of action to governments. This summary document, which describes the current understanding of climate change in general and of the James Bay Territory in particular, should help the JBACE fulfill its role.

This document comprises three sections. The first aims to describe the key scientific elements relating to global warming. These elements concern the global climate as well as the climate in Canada and in Quebec. This first section on the climate ends with some data pertaining to the James Bay Territory. The second section of the document deals with the consequences of global warming on water, forest and wildlife resources. An understanding of the impacts on these various resources involves a context that goes beyond the James Bay Territory. Finally, the last section of the document presents various avenues that can be explored to further define the impact of global warming on the populations in the James Bay Territory.

2. The science of climate change

The benchmark for an understanding of climate change is undoubtedly the Intergovernmental Panel on Climate Change (IPCC). This organization was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The IPCC's mission is to "assess the scientific, technical and socio-economic information" in order to gain a better understanding of the risks related to human-induced climate change. The IPCC does not conduct research but its publications are based on scientific and technical publications whose scientific value is widely recognized (IPCC 2007). The IPCC is comprised of hundreds of experts from universities, research centers, companies and environmental protection associations. Each IPCC member is accredited by his or her own government.

At regular intervals (every five to six years), the IPCC does an assessment of the state of knowledge relative to climate warming. The most recent reports were published in 2007. These reports contribute, among other things, to the "implementation of the UN Framework Convention on Climate Change (UNFCCC)".

In Quebec, the Ouranos Consortium, an organization that is international in scope, was established in 2002 to pool and develop expertise on global warming. This organization aims to "advance the understanding of the issues and the associated requirements for adaptation resulting from climate change on the scale of the North American continent". The Government of Quebec, the Meteorological Service of Canada, Hydro-Québec, research groups and centres as well as universities work in partnership with the Ouranos Consortium. The ArcticNet Group is also spearheading research into the Arctic climate.

Although temperature and precipitation are now being recorded precisely in many locations, that was not always the case. Data series from thermometers and pluviometers are relatively recent (the oldest series go back 300 years). Climate studies often require knowledge of the climate hundreds or even thousands of years ago. The data used are based on temperature estimates established from tree growth rings, air bubbles trapped in ice cores or marine fossil sediments.

2.1 Temperature

The Earth's surface temperature has increased by an average of 0.6°C from the end of the 19th century to the present day (Folland et al. 2001) (Figure 2-1a). Global warming has been the most rapid over the past 1,000 years (Figure 2-1b). The warming of the climate has not been constant over time. Since 1861 (the earliest date from which reliable trends can be established), two periods have been marked by global warming. These two periods are from 1910 to 1945 and from 1976 to the present. The 1990s is the warmest decade on record since 1861. The greatest surface temperature increase was observed north of the 60th parallel with a rise of 1.3°C since 1880. The degree of warming also varies according to the season. Winter warming exceeds summer warming (2.2°C and 0.6°C, respectively).

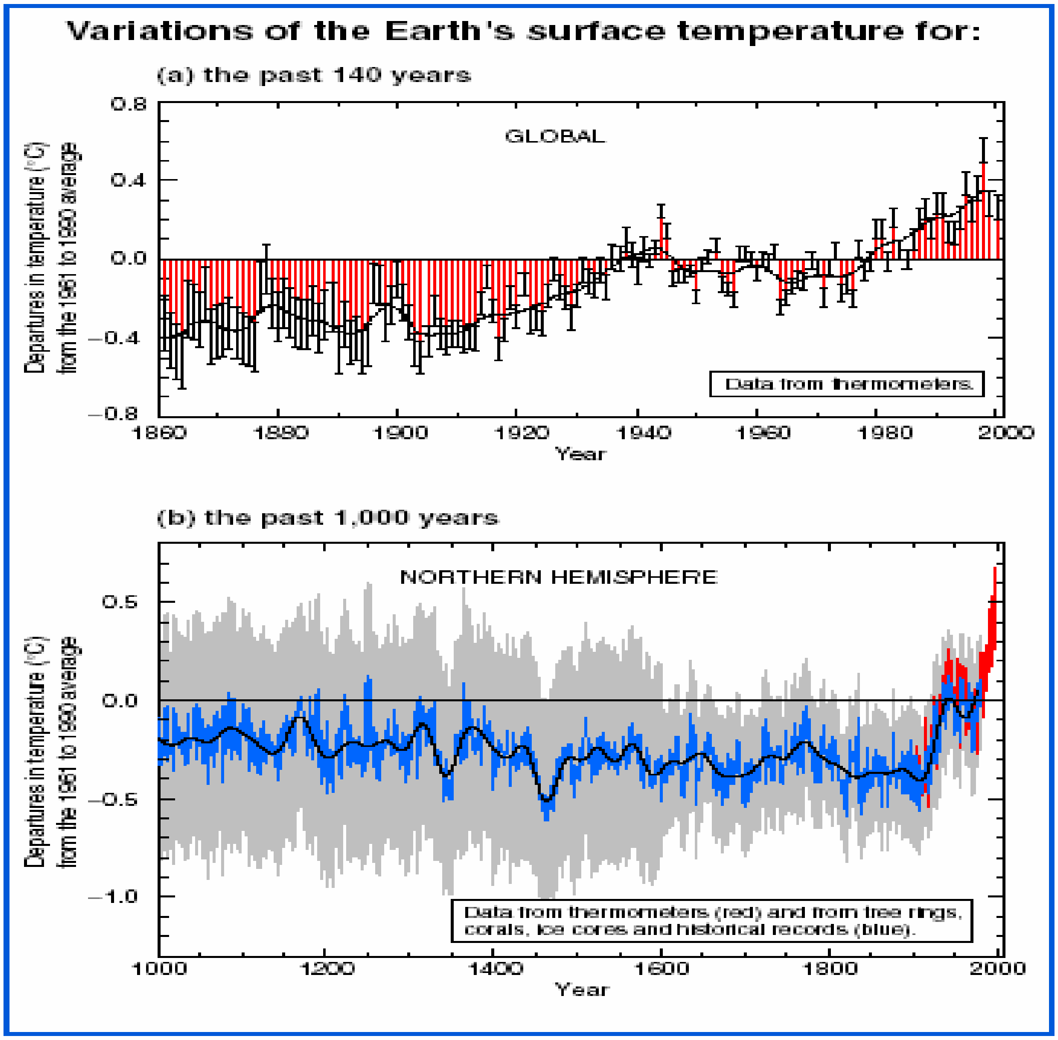


Figure 2-1: Variations in the Earth's surface temperature over the past 140 years and the past 1,000 years (from IPCC 2001): **a)** annual temperature data (grey bars), uncertainty of annual data (uncertainty bars in black), moving average with a window of 10 years (blue line); **b)** annual temperature variations (dark grey and black), data uncertainty (light grey), averages over 50 years (in blue).

For Canada, the average annual temperature increase has been 0.9°C in the past century (Bonsal et al. 2001), with most of this warming occurring during the winter and spring. In Southern Quebec, the studies conducted in connection with the Ouranos Consortium established climate trends relying on 60 weather stations. Between 1960 and 2003, the increases in temperature have been the greatest in winter and more variable during the summer. The warming is greater for minimum temperatures than for maximum temperatures. In Southern Quebec, winters are not as cold with an increase in frost/thaw episodes. The warm season is of the same duration but is becoming hotter. Finally, the results of the interpolation of these data lead one to believe that warming trends are even more pronounced in the north (Yagouti et al. 2006).

2.2 Precipitation

The main global trends point to an increase in nebulosity, rainfall intensity and total concentration of water vapour (IPCC 2001). A 5% to 10% increase in precipitation has been observed since 1900 in the middle and high latitudes of the Northern Hemisphere. A decrease in the snow cover and shortening of the frost period correspond to a warming of the Earth's surface in the Northern Hemisphere.

In Canada, an increase in total annual precipitation is observed for the period from 1960 to 2000 (Zhang et al. 2000). In Eastern Canada, precipitation has increased during the spring and in the north. Abundant snowfalls are more prevalent in the fall and winter. The increase in precipitation is estimated at 1.7% of the average per decade for Canada as a whole between 1948 and 1995. North of the 55th parallel, the increase in precipitation is noticeably greater with an increase of 2.3% over the average per decade (Mekis and Hogg 1999).

In Quebec, rainfall was abundant during the period 1869-1912, but less abundant than that observed in the more recent periods (Gosselin and Perrier 2001). It is not possible to conclude, however, that there has been an increase in extreme events, because the distribution of pluviometers has changed too much since that time.

2.3 Expected climate change

The scenarios derived from climate projections forecast an increase in sea levels of 21 cm to 70 cm by 2100 according to the models (IPCC 2001). The climate change expected for North America and Quebec can be seen on the website of the Canadian Climate Impacts Scenarios Project (CCIS 2006). The many scenarios available give the anomalies in temperature and precipitation between the 2050 horizon and the reference period from 1961 to 1990 (Figure 2-2 and Figure 2-3). With the ECHAM4 gg1 model, the climate change in Quebec consists of a 4°C increase compared with the period from 1961 to 1990 (Figure 2-2). The forecast changes in precipitation are less pronounced. In the southern part of the province, a slight increase in precipitation is forecast, and a larger increase, of up to 30% a day, is expected in the northern part of the province by 2050. The increase in precipitation is expected to be greater between 2050 and 2080 (Figure 2-3).

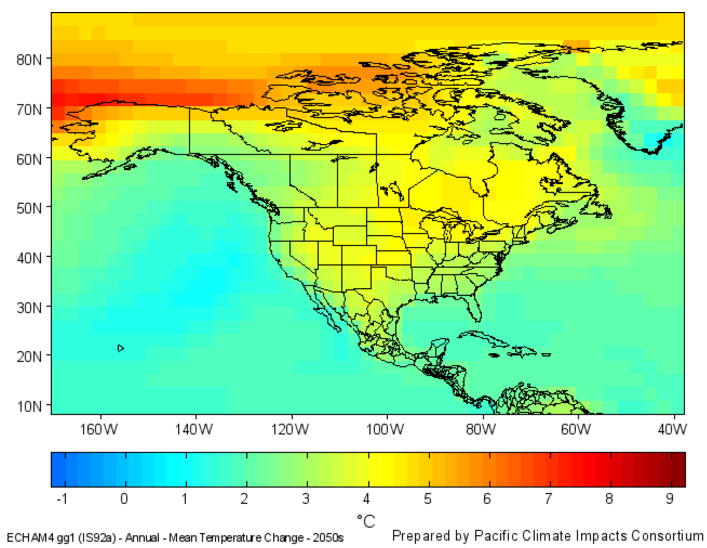


Figure 2-2: Temperature anomalies for 2050 in comparison with the period from 1961 to 1990 according to a ECHAM4 gg1 scenario (CCIS 2006)

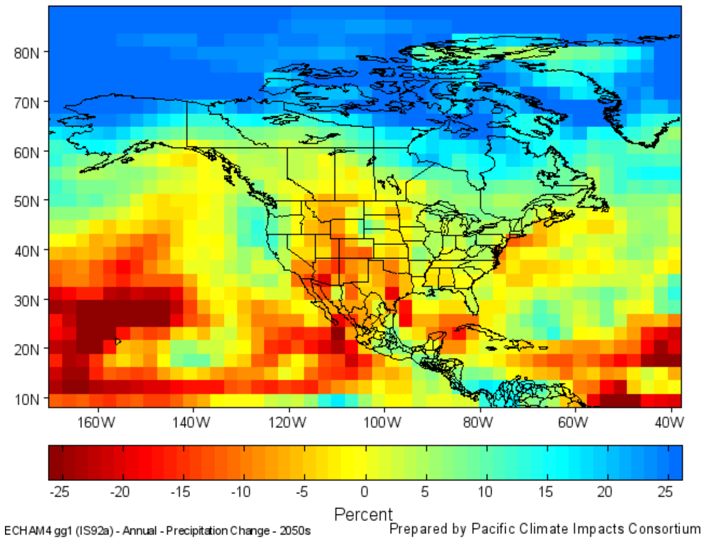


Figure 2-3: Precipitation anomalies for 2050 in comparison with the period from 1961 to 1990 according to a ECHAM4 gg1 scenario (CCIS 2006)

Global warming:

- The global climate has warmed by about 0.6°C since the end of the 19th century.
- The 1990s was the warmest decade of the past century.
- The models predict warming of 1.8°C to 4°C for the central values by the end of the 21st century. The extreme values range from 1.1°C to 6.4°C.

- Mountain glaciers are shrinking as are those of Greenland and the Antarctic, and sea levels are rising faster than before, by more than 3 mm a year.

In Canada and Quebec:

- The climate has warmed by about 1°C over the past century.
- Warming will continue to be more pronounced in the northern regions.
- The models predict a warmer and wetter climate for Northern Quebec.

(Ouranos 2007)

Table 2-1: Summary of forecast climate change compared with 1961-1990

		Northern Quebec		
		2020	**2050**	**2080**
Winter	**Temperature**	2.5 to 3.5°C	4 to 7°C	6 to 12.5°C
	Precipitation	1 to 18%	2 to 32%	5 to 53%
Summer	**Temperature**	1 to 2.5°C	1.5 to 4°C	2 to 6°C
	Precipitation	1 to 12%	3 to 19%	5 to 30%
		Southern Quebec		
		2020	**2050**	**2080**
Winter	**Temperature**	1 to 2.5°C	2 to 5°C	3.5 to 8°C
	Precipitation	-5 to 19%	0 to 32%	1 to 43%
Summer	**Temperature**	1 to 2°C	2.5 to 4°C	2.5 to 6°C
	Precipitation	-5 to 10%	-7 to 14%	-11 to 150%

Source: http://www.ouranos.ca/intro/IPCC2007_f.html

2.4 Acceleration and slowdown factors (carbon sources and carbon sinks)

The increase in greenhouse gases as a result of human activity is the main factor accelerating climate warming (IPCC 2007). Greenhouse gases trap heat on the Earth's surface. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), ozone (O_3), nitrous oxide (N_2O) and water vapour (gaseous H_2O). These gases are naturally present in the atmosphere and allow for an average Earth surface temperature of 15°C. Without these gases, it is estimated that the temperature would be -18°C (IPCC 2001). Industrialization, the use of fossil fuels and deforestation have, however, contributed to an increase in the concentration of greenhouse gases from 280 parts per million (ppm) in the mid-19th century to 380 ppm today (IPCC 2001). The increase in greenhouse gases has been exponential since industrialization began (IPCC 2001).

The main carbon dioxide sources and sinks are factors that, respectively, accelerate and slow climate change (Table 2-2).

Table 2-2: Average annual estimate of carbon dioxide sources, sinks and reservoirs derived from anthropogenic carbon dioxide emissions 1980–1989 (Environment Canada 2006a)

A. Sources	
	Estimate (range) (gigatonnes/year)
Emissions from the combustion of fossil fuels and cement production Net emissions from changes in the use of tropical lands	5.5 (5.0 – 6.0) 1.6 (0.6 – 2.6)
Total	7.1 (6.0 – 8.2)
B. Sinks	
	Estimate (range) (gigatonnes/year)
Storage in the atmosphere Absorption by oceans Absorption by second-growth forests in the Northern Hemisphere Additional terrestrial sinks (fertilization with carbon dioxide, fertilization with nitrogen, climate effects)	3.2 (3.0 – 3.4) 2.0 (1.2 – 2.8) 0.5 (0.0 – 1.0) 1.4 (0.0 – 2.9)
Total	**7.1**
*The upper and lower limits correspond to an estimated confidence interval of 90%. ** Fertilization with carbon dioxide and nitrogen constitutes additional sinks where increases in atmospheric concentrations of carbon dioxide and nitrogen oxides from anthropogenic emissions provide additional nutrients necessary for plants in the ecosystems concerned. Climate feedback occurs when changes in temperature, precipitation or other climate variables enhance the growth conditions of plants and, consequently, favour the accumulation of biomass. Source: IPCC, 1995	

In addition to greenhouse gases, aerosols (suspended particles in the atmosphere) have an impact on solar radiation. Aerosols include soot and sulphates. These particles reduce surface temperatures by absorbing the incident solar radiation (soot) in the lower atmosphere or by dispersing and reflecting the incident light (sulphate aerosols) and favouring the formation of clouds. The presence of aerosols reduces the effect of greenhouse gases but cannot offset them.

In Canada, greenhouse gas emissions totalled 740 megatonnes (Mt) of CO_2 equivalent in 2003. Quebec accounts for 12.3% of these emissions, or the equivalent of 91.0 MT of CO_2 (in 2003), which corresponds to an average of 12.1 tonnes per person. The transportation sector alone accounts for 34 Mt CO_2 eq., or 37.4% of emissions (Figure 2-4).

To calculate the emissions for a given territory, there are formulas that take into account the vehicle types and the number of kilometres travelled in the city or over longer distances. The average emissions for light vehicles are 2,400 kg of CO_2 for 10,000 km (Energuide 2006). Heavier vehicles consume more. In the James Bay Territory, more than 20,000 vehicles of all types are in use. A rough approximation (based on these numbers) yields 0.5 Mt of CO_2 emissions due to road transportation in the Territory. A more precise calculation of CO_2 emissions in the James Bay Territory would, however, take into account the types of vehicle and the distance travelled by these vehicles.

Comparison of average CO_2 emissions by type of transport:

- **Air transport**: 0.85 kg of CO_2 per kilometre and per passenger (if the plane is full);

- **Road transport**: 0.20 kg of CO_2 per kilometre and per passenger (for one occupant per vehicle); and

- **Bus transport**: 0.07 kg per kilometre and per passenger (if the bus is full).

(Environment Canada 2005)

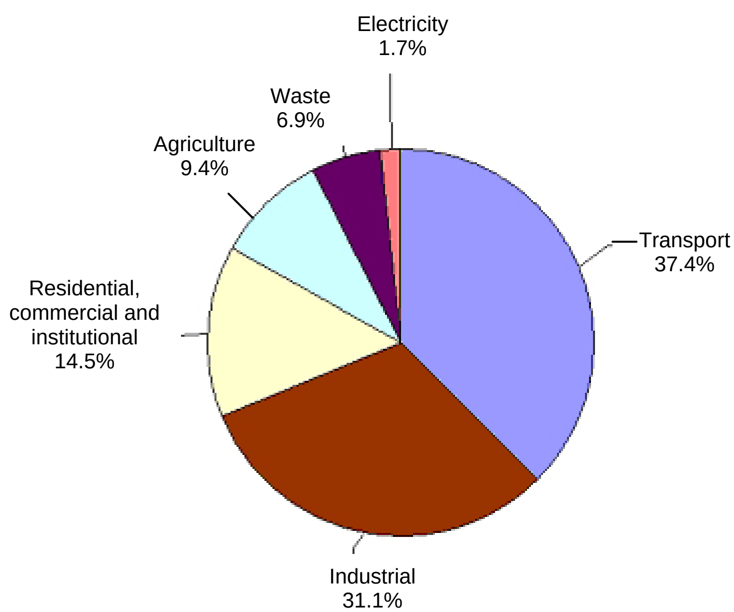


Figure 2-4: Breakdown of greenhouse gases in Quebec by sector of activity in 2003 (MDDEP 2003)

The main cause: greenhouse gases (GHG)

- "Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations" with a probability greater than 90%

- Carbon dioxide concentrations in the atmosphere "exceed by far" what has been observed for the past 650,000 years. The same is true of methane.

(IPCC 2007)

2.5 Impacts specific to northern environments

Climate scenarios suggest that global warming may be even more pronounced in northern regions. In the Canadian north, this phenomenon has already caused melting of the permafrost, a shorter snow cover and a shorter icy period. The impacts on infrastructures, such as residential buildings and airports, are being studied by teams from Environment Canada, Transport Canada, Transport Quebec, Ouranos and the Centre d'études nordiques at Université Laval. This warming also tends to reduce the duration and thickness of the ice cover on lakes and rivers. This phenomenon makes river crossing a high-risk activity during strategic periods of the year when wildlife is available for hunting and trapping. A study is being made in Nunavik under the stewardship of the Kativik Regional Government with the support of Environment Canada through the Northern Ecosystem Initiative, Ouranos and ArcticNet.

2.6 The James Bay Territory and its climate

The James Bay Territory is a vast area covering more than 350,000 km², or one-fifth of the Province of Quebec. This territory lies approximately between the 49th and 55th parallels. It is bounded on the west by James Bay and Hudson Bay and on the east by the watershed of the Otish Mountains toward the basins of the St. Lawrence and of James Bay. The James Bay Territory is in the boreal ecoclimate zone (MRN 2005). The territory has a population of about 30,000. It is home to nine Cree villages: Whapmagoostui, Chisasibi, Wemindji, Eastmain, Waskaganish, Nemaska, Waswanipi, Ouje-Bougoumou and Mistissini. The other villages are mainly in the southern portion of the territory

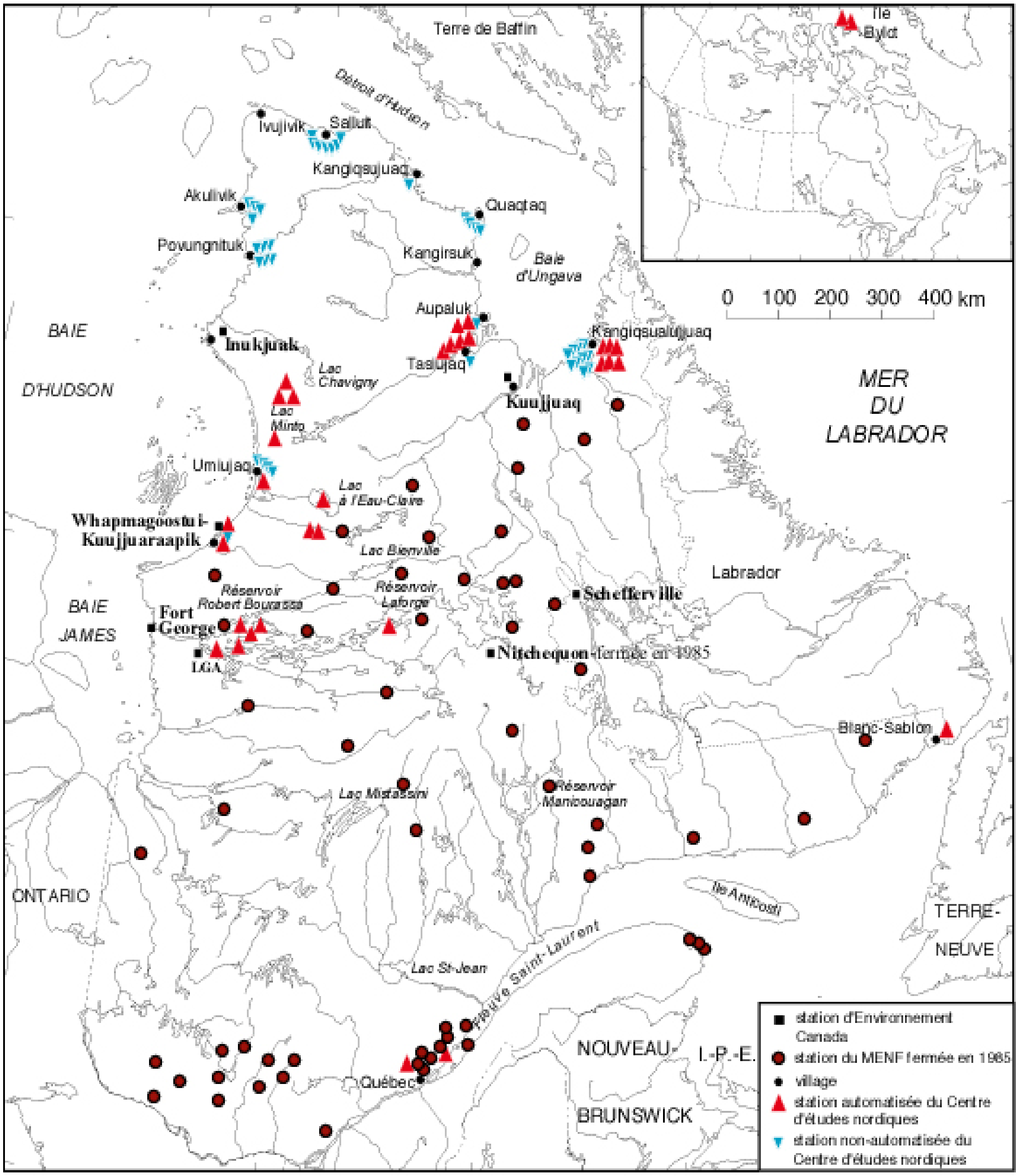
(Chibougamau, Chapais, Lebel-sur-Quévillon, Matagami, Radisson, Val Canton and Villebois). In the Nord-du-Québec administrative region, more than 50% of the population is less than 30 years old (2004 data).

2.6.1 Available climate data

Many weather stations are located in the James Bay Territory. The Centre d'études nordiques has had its own weather stations since 1995, Hydro-Québec since the 1980s, Quebec's Department of Sustainable Development, Environment and Parks (MDDEP) during various periods from 1970 to 1995 and Environment Canada since the 1920s. These stations have been mapped (Figure 2-5) with the exception of Hydro-Québec's stations.[1] Hydro-Québec had a network of weather stations in the James Bay Territory. These stations were active from 1995 to 2004 (Marie-Josée Doray, Hydro-Québec, personal communication). The quality of the historical weather observations of this network ranges from fair to unusable (Enviromet International Inc. 2003). Hydro-Québec therefore installed a new network in 2005 to meet the international standards of the World Meteorological Organization. The co-ordinates of the network active from 1990 to 2004 and the measured meteorological parameters are presented in the appendix in Tables 7-1 and 7-2. The co-ordinates of the new network's stations and the parameters measured are shown in Tables 7-3 to 7-6.

A list of data available by station in the James Bay Territory will be compiled by the Centre d'études nordiques. The map below does not show all the Environment Canada stations in the James Bay Territory but most are indicated elsewhere in this report (Table 2-3).

[1] See the appendix for a list of Hydro-Québec weather stations.



Legend:

■	Environment Canada station	●	MENF station closed in 1985
●	Village	▲	Automated station of the Centre d'études nordiques
▽	Non-automated station of the Centre d'études nordiques		

Figure 2-5: Map of the weather stations of the Centre d'études nordiques (triangles) and the MDDEP (then known as the Ministère de l'Environnement et de la Faune (MENF)) from 1970 to 1995 (circles)

Table 2-3: Environment Canada weather stations in the James Bay Territory

Name of station	Latitude	Longitude	Altitude
* BONNARD	50°44' N	71°03' O	506 m
* CHAPAIS 2	49°47' N	74°51' O	396 m
HEMON	49°04' N	72°36' O	183 m
JOUTEL	49°28' N	78°18' O	290 m
* KUUJJUARAPIK A	55°17' N	77°45' O	10 m
LA GRANDE RIVIERE A	53°38' N	77°42' O	195 m
MATAGAMI A	49°46' N	77°49' O	281 m

Note: An * indicates stations that meet World Meteorological Organization standards.

2.6.2 Spatial climate variations in the James Bay Territory

The main spatial climate differences in the James Bay Territory can be summarized as follows (Figure 2-6):

- The southern part of the Territory is warmer and wetter than the north;

- The southern and eastern regions of the Territory get more solid and liquid precipitation than do the west and north.

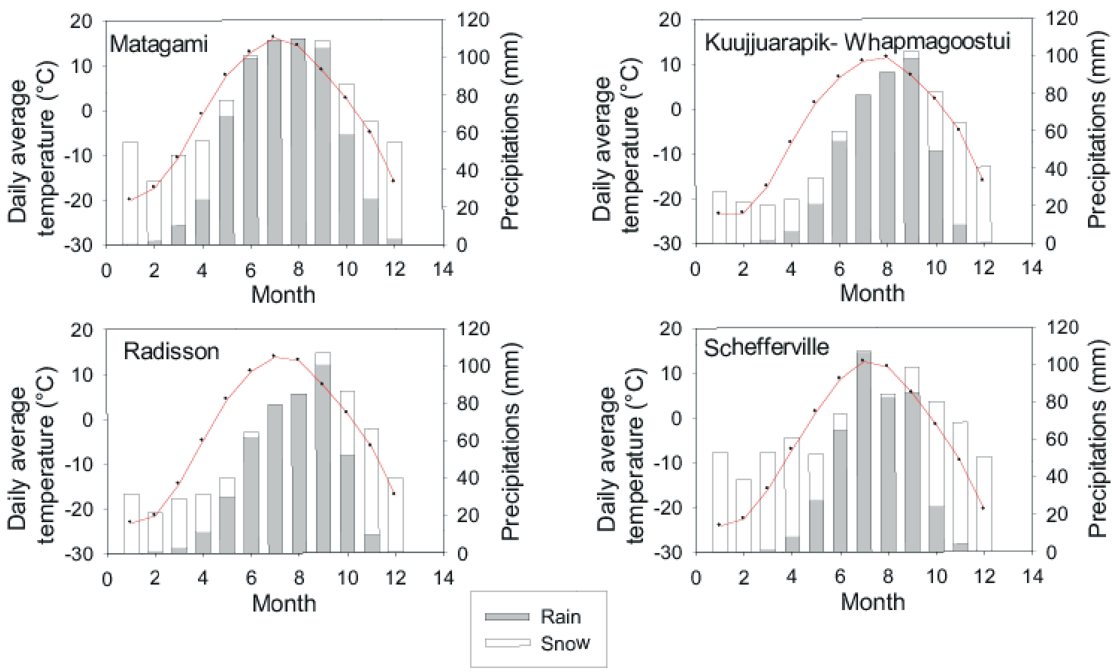


Figure 2-6: Climatograms for Matagami (southern portion of the Territory), Kuujjuarapik-Whapmagoostui (northern portion), Radisson (western portion) and Schefferville (to the east and outside the Territory). Source of data: Environment Canada stations

2.6.3 Main climate trends

The climate trends observed during the period from 1970 to 2002 show that the average annual temperature increased by 1 to 1.5°C. The thermal sum (degrees-days above 5°C) increased from 100 to 140 degrees-days during this period in the boreal forest zone (Meunier 2006). The warming has been especially pronounced since the mid-1990s.

The climate models suggest an increase in temperature of about 4°C for the James Bay Territory and an increase in precipitation of 2 to 32% a day by 2050 (CCIS 2006)

3. Consequences of climate change

3.1 Water resources

The expected climate change should affect the frequency of El Niño and La Niña events. El Niño events, which are responsible for dryer winter conditions in Canada, should be longer and more frequent. El Niño years should be punctuated by years of heavy rainfalls because of the effects of La Niña. Indeed, the frequency of El Niño and La Niña events increased during the 20th century, and it appears that their intensity rose in the 1980s and 1990s compared with the 1950s (Table 7-7 and Table 7-8) (Environment Canada 2007).

For instance, studies conducted in the Canada-U.S. Great Lakes region show the effects of global warming on river flow, groundwater, the water supply in the Great Plains region and the level of the Great Lakes. Many of the lake and river systems whose levels and rates of flow are expected to decrease, on average, are among the most heavily used in Canada and are also shared with the United States. It has already been observed that the minimum flow rates and low-water levels have decreased in the summer and early fall in south-central British Columbia since 1995 (Leith and Whitfield 1998) and on the southern Prairies since 1993 (Yulianti and Burn 1998). Consequently, it appears that water-conservation measures will be important, especially in cases of high consumption, such as for irrigation. There is also the risk of a reduction, over the long term, in the groundwater replenishment rate in southern Canada.

As for Quebec's northern rivers, which are generally covered with ice in the winter, ice breakup and the flooding it causes could occur in the wintertime rather than in the spring (Clair et al. 1997).

Climate change could increase river flows and groundwater levels in the James Bay Territory. The risk of ice jams could be greater in the winter.

3.2 Coastal areas

Sea-level rise caused by partial melting of glaciers and polar ice caps increases the sensitivity of coastlines. Coastal areas will be more prone to flooding, erosion, beach migration and coastal-dune destabilization (Natural Resources Canada 2006c). Two areas of Canada are particularly at risk: Atlantic Canada and parts of the Beaufort Sea coast. The James Bay and Hudson Bay coastlines present a low to average sensitivity (Environment Canada – Canada Atlas). They are gradually being spared these effects because of an even more rapid isostatic rebound in the region.

The James Bay **coastal areas** present a **low sensitivity to climate change,** in part because the isostatic rebound is still rapid in this region.

3.3 Forests

Forests absorb and release large quantities of CO_2. A growing forest is a carbon sink, whereas a mature forest is in equilibrium with the atmosphere in terms of carbon exchanges. Photosynthesis allows the absorption of CO_2. The climate factors that affect the rate of photosynthesis are light intensity, air temperature, water availability, atmospheric concentration of CO_2, atmospheric pollutants and soil conditions (Kozlowski and Pallardy 1997). In the next few paragraphs, we will examine the main elements modified by the expected climate warming.

3.3.1 Impacts of climate change on forest physiology

The increase in greenhouse gases, especially CO_2, over the past 150 years, warming and increased precipitation should affect the physiological processes of plants. The combined action of these various factors is difficult to predict, however (Forget et al. 2003).

3.3.1.1 CO_2 concentrations

Certain physiological processes appear to be favoured by an increased concentration of CO_2 (Table 3-1). Plants are expected to make more efficient use of light, water and nutrients. Photorespiration should be less efficient, however. Given that the growth of tree species is often limited by the availability of CO_2, an increase in greenhouse gas concentrations should have a positive effect (Kirshchbaum 2000). Still, the positive impact of CO_2 on growth is highly dependent on the availability of soil nutrients (Drake et al. 1997, Kirshchbaum 2000). The positive impact of CO_2 on growth will also depend on the species considered and the development stages. The species benefiting the most from an increase in CO_2 are annual and perennial herbaceous species. Those benefiting the least are conifers and late-succession tree species (maple, yellow birch, white spruce and white pine). Younger trees will benefit more from CO_2 fertilization than will older trees (Papadocol 2000).

It is important to note that the positive effects of CO_2 on tree growth could be cancelled out by the negative effects of certain gases, such as ozone (O_3) and sulphur dioxide (SO_2) (Isebrands et al. 2001). Studies of the quaking aspen show that the tree's productivity has already decreased because of the current levels of ozone in the air (Percy et al. 2002).

For the black spruce, the dominant species in Quebec's boreal forest, the consequences of a doubling of CO_2 are:

- A quicker budbreak in the spring;
- Greater tolerance to frost by young buds in early fall;
- Regulation of photosynthetic activity.

(Bertrand and Bigras 2006)

3.3.1.2 Temperature

Physiological processes are affected by an increase in temperature (Table 3-1). In general, temperature increases benefit both photosynthetic activity and respiration. The net carbon balance will, however, plateau and then diminish with a continued increase in temperature (Kirshchbaum 2000).

The effects of temperature on growth vary according to the species. Growth of the sugar maple (Courchesne et al. 2001) and the grey pine (Brooks et al. 1998) is favoured, but an increase in temperature can reduce the length of the terminal shoot of the Douglas fir (Olszyk et al. 1998).

- In general and for Quebec, an increase in temperature should favour tree growth.

- For black spruce and grey pine, the dominant species in the James Bay Territory, radial growth is positively correlated with an early start to the season (Hofgaard et al. 1999).

3.3.1.3 Precipitation

The impact of water stress depends on the physiological process considered. For instance, where photosynthetic activity is concerned, efficient use of light diminishes with drought, whereas photorespiration, respiration, efficient use of water and tree sensitivity to insects and disease increase under the same conditions of water stress.

- For the black spruce, a study of Western Quebec showed that an increase in precipitation in June appeared to have a beneficial effect on radial growth (Hofgaard et al. 1999).

- **In Northern Quebec (north of 50°N), an increase in precipitation could compensate for a potential increase in evaporation caused by higher temperatures** (Forget et al. 2003).

Table 3-1: Effect of an increase in the concentration of CO_2 and of the temperature on the various physiological processes (from Colombo 1998)

Physiological process	Increase in CO_2 concentration	Increase in temperature
Photosynthesis	Increase subject to feedback related to available resources	Increase subject to feedback related to available resources
Photorespiration	Decrease (in general)	Increase
Night respiration	Slight decrease	Increase
Stoma conductivity	Decrease	Increase up to temperatures of 30-35°C
Light-use efficiency	Increase	No change
Water-use efficiency	Increase	Decrease
Nutrition-use efficiency	Increase	No effect
Phenology	Shorter growing season because of later budbreak and/or earlier bud formation	• Earlier budbreak in the spring • Hardening of buds later in the season
Allocation of carbon / structure of tree	• Increase in growth rates • Reduction in stoma density • Increase in root growth	• Increase in growth rates • Earlier budbreak and flowering
Sensitivity to stress	Increase in tolerance to drought with closing of stomata	Increase in potential damage from winter and spring frosts

The effects of increases in CO_2 concentrations and temperatures on the physiological processes of plants can be positive or negative depending on the process considered. Generally speaking, the most recent IPCC reports consider that the boreal forest would be favoured by an increase of 2 to 3°C, but the boreal ecosystem would be greatly harmed by increases greater than 3°C.

3.3.2 Migration of species and relocation of ecosystems

Paleoecological studies have shown that the distribution of ecosystems was linked to the climate (Delcourt and Delcourt 1988). In line with the studies of climate and vegetation changes that occurred thousands of years ago, one can consider the impact of the present climate warming on the composition and distribution of the current ecosystems. In this sense, the studies of Rizzo and Wilken (1992) and Luckman and Kavanagh (2000) lead us to believe that the habitats of species move northward and to higher altitudes. Paleoecological studies have shown that it is not ecosystems that migrate but rather individual species. Still, the speed of the current climate warming is unprecedented, so it is difficult to establish projections respecting the migration of species. Statistical models describing landscapes seem to perform best in predicting changes. An example that is frequently quoted in government documents is presented below:

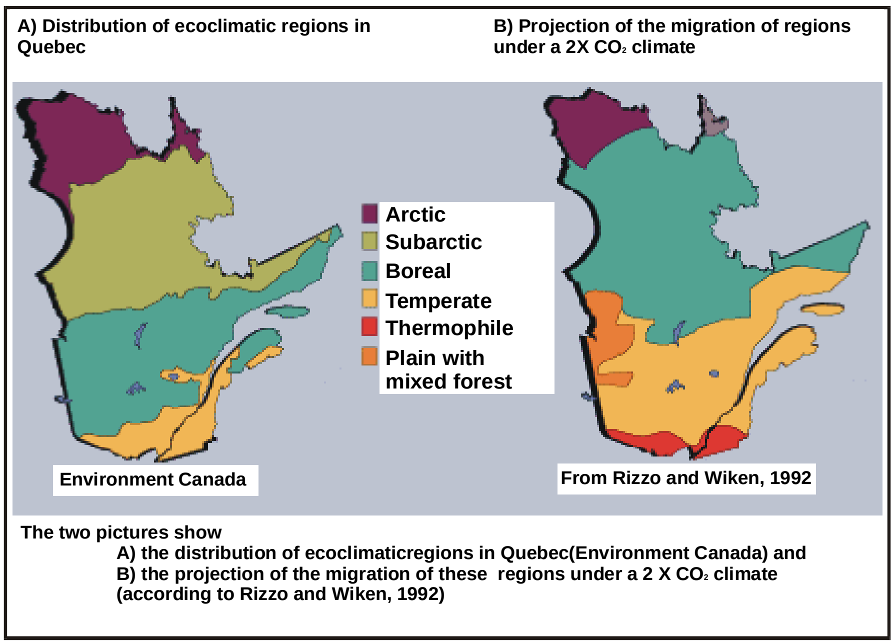


Figure 3-1: Breakdown of Quebec's ecoclimatic regions a) now and b) under a climate where CO_2 concentrations would be twice the level measured in the pre-industrial era (2 x 280 ppm)

Still, we can question the merits of a map that is based solely on climate projections. The dynamics of forest ecosystems are more complex and do not react only to temperature but also to precipitation and frequency of disturbances. One must also consider the various phases of the forest dynamics, namely seed production, the installation of seedlings and individual growth.

Consequences for forest ecosystems:

- Significant changes in habitat potential for tree species are expected and could lead to a new composition of vegetation communities in Quebec (Rizzo and Wilken 1992)

- The speed of climate change is unprecedented and could lead to local loss or extinction of species with a weak dispersion capacity or a limited dispersion area (Thompson et al. 1998)

- The ability of species to migrate in response to climate change will be strongly influenced by auto-ecological species constraints, such as seed dispersion, and by factors such as forest fragmentation, regeneration practices and disturbance regime (Flannigan et al. 2001)

From Forget et al. 2003

3.3.3 Natural disturbances

Natural disturbances, such as epidemics and forest fires, have considerable influence on the forest dynamics of boreal forests. An impact assessment of climate change on Quebec's boreal forest requires an understanding of how climate change can affect the frequency and intensity of natural disturbances.

3.3.3.1 Forest fires

The impact of higher temperatures on forest fires is difficult to forecast. In the early 1990s, it was recognized that an increase in temperatures could increase the occurrence of forest fires (Overpeck et al. 1990, Flannigan and Van Wagner 1991, Clark 1998). Still, opinions voiced by an expert in that area (Dr. Mike Flannigan), and reproduced on the website of Natural Resources Canada, show that it is difficult to draw such a conclusion: “My best guess is a 50 percent increase in Canadian forest fires by the year 2050, but that figure could be completely incorrect ” (Information Forestry 2001).

In Quebec, most of the studies done on the subject have been carried out in the Lake Duparquet area of the Abitibi region by the team of Dr. Yves Bergeron. These studies show that an increase in temperature could be more than offset by an increase in abundance and a better temporal distribution of precipitation (Bergeron 1998).

The work now being done by Dr. Bergeron’s team aims to assess the impact of climate change on forest yields to help forest stakeholders adapt more effectively to the possible consequences. The five key objectives are: (i) to quantify the relationship between climate and radial growth for two major commercial species, namely the quaking aspen and the black spruce, and to project their expected growth as a result of forecast climate change; (ii) to determine the relationship between climate and forest-fire frequency, and to make frequency projections, again based on forecast climate change; (iii) to evaluate how climate change will affect the growth and distribution of the two species in relation to a topographical drainage gradient and to use these results to factor climate into the growth equations of yield tables; (iv) to simulate various scenarios for a forest management unit, taking into account the effects of climate change on growth and forest fires; and (v) to assist stakeholders in order to maximize adaptation of silvicultural practices to climate change.

In a scenario where the CO_2 rate is doubled, studies forecast that Quebec's forest-fire season will be 27 days longer (Wotton and Flannigan 1993) and that it will start earlier (Stocks et al. 1998).

The global models that form the basis for climate simulations used to determine the risks of forest fire show an increased risk for the James Bay Territory. The map produced by Brian Stocks and his colleagues at the Canadian Forest Service (Natural Resources Canada 2006a) shows that the risk of forest fires will increase in the 21st century for the James Bay Territory. Thus the forest-fire risk index, which was 1 to 2 (on a scale of 0 to 6) for the period from 1980 to 1989, is now estimated at 2 to 4 for the period from 2090 to 2099, depending on the location in the James Bay Territory (Environment Canada – Canada Atlas).

It is very difficult to predict **the impact of climate change on the risk of forest fires**. The increase in precipitation could reduce the risk of forest fires but the models established by Natural Resources Canada indicate an increased risk for the James Bay Territory.

3.3.3.2 Epidemics

In the boreal forest, the most damaging epidemics for the forest cover are caused by the spruce budworm (Choristoneura fumiferana (Clem.). The forecast climate warming could have a positive effect on the reproduction of insects and their development (Lysyk 1989). Milder winters could also be beneficial to the survival of certain pest insects (Williams 1995). Given the more rapid migration of insects, one of the risks of climate warming is an invasion of exotic pest insects in the temperate and boreal forest distribution area (Dale et al. 2001). Still, it is difficult to forecast the incidence of epidemics on the forest landscape. Changes in the composition of the vegetation cover vary depending on whether the models consider the effects of pest insects (Niemela et al. 2001). Finally, fibre loss due to the herbivorous nature of pest insects results in a flow of carbon to the atmosphere, which could aggravate global warming (Volney and Fleming 2000).

Climate warming should favour insect epidemics and the invasion of ecosystems by exotic pest insects.

3.3.4 Socio-economic impacts

Phenologic changes in forest ecosystems as a result of climate change could have consequences for the social milieu as regards forest use (Table 3-2).

Table 3-2: A few examples of the socio-economic impacts of climate change (Environment Canada 2006b)

Physical impacts	Socio-economic impacts
Changes in forest productivity	Changes in the production of timber and rental value
Increase in greenhouse gases in the atmosphere	Introduction of mitigation policies and carbon credit-permits creating a carbon sequestration market
Increase in disturbances	Loss of forest products and non-commercial goods
Migration of ecozones northward	Changes in land values and land-use options
Climatic and ecosystemic changes	Economic restructuring leading to social and individual tensions and other social pathologies
Changes in ecosystems and specialized species	Changes in non-commercial values
Changes in ecosystems	Deterioration of parks and natural reserves, and increase in conflicts over land use

3.4 Peat bogs

Peat bogs are an essential feature of the Canadian landscape as they cover 14% of Canada's land mass (Natural Resources Canada 2006b). Peat bogs are areas where decomposing vegetation has accumulated on the surface to depths that may exceed 40 cm. Peat bogs have an important ecological role to play in the regulation of drainage networks. Water is stored in these wet environments and slowly replenishes aquifers. These processes help reduce river flows during flooding and maintain them during drought. Peat bogs are also a habitat for many wildlife species, in particular waterfowl. Finally, wet environments retain contaminants. With respect to climate change, peat bogs are now huge carbon sinks, but in a warmer climate the captured carbon could be freed and thus accentuate global warming (Natural Resources Canada 2006b).

At present, peat bogs constitute sites that reduce atmospheric CO_2 (**carbon sinks**) but they **could become sources** of greenhouse gases with the forecast warming.

Studies are now being made in the James Bay Territory to assess the impact of climate change on these complex ecosystems. Three 150-km^2 areas have been retained in the LG1, LG2 and LG3 regions, all of which include various types of peat bog. The findings will help identify the relationship, over the past four decades, between changes in the surface characteristics of peat bogs and the climate in this boreal region, where climate-prediction models forecast a more pronounced increase in temperatures. These studies are being made under the direction of Michelle Garneau (of the Université du Québec à Montréal) and Serge Payette (of Université Laval in Quebec City).

3.5 Wildlife

Most studies aiming to better understand the impact of climate change on wildlife are concerned with changes in the phenology of organisms (the timing of recurring life-cycle events, such as reproduction, and organisms’ response to their environment). The climate can have a direct impact on wildlife phenology or indirect effects through changes in wildlife habitats. Thus the survival of certain vertebrates may depend on a proper fit between the phenology of plant species and reproduction (Einum and Fleming 2000, Thomas et al. 2001).

3.5.1 Indirect effects of the climate

Experimental studies in controlled environments show that increased warming accelerates plant growth and hastens the beginning of the next phenological stage (Saxe et al. 2001, Badeck et al. 2004). One of the consequences of climate change could be desynchronization between the availability of plants and the wildlife that eats them. Herbivores usually raise their offspring during the peak availability of the plants that they consume (Perrins 1970, Nilsson 1994). Consequently, animals may have to reproduce earlier to stay in tune with the phenology of their food.

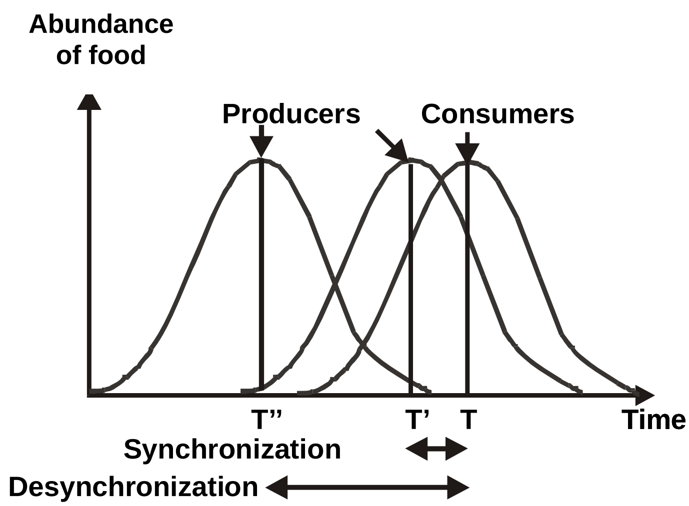


Figure 3-2: Phenological synchronization between the needs of consumers (vertebrates) and the abundance peak of producers (vegetation or related herbivores) during reproduction (adapted from Durant et al. 2005).

A study made in the Yukon shows the indirect effect of climate warming on red squirrels (*Tamasciurus hudsonicus*). Climate warming and an increase in the abundance of spruce cones are correlated with earlier reproduction dates for the red squirrel population studied (Réale et al. 2003, Berteaux et al. 2004).

The indirect effects of global warming on wildlife include thawing and reduction of the ice cover in Arctic regions. This has a major effect on polar bears, which must swim far more and have difficulty obtaining food (Envirozine 2005).

3.5.2 Direct effects

Many studies have shown a correlation between climate warming and the reproduction dates of certain vertebrates (Crick and Sparks 1999, Sanz 2002). In North America, the average egg-laying date occurred 10.1 days earlier in 1998 than in 1971. Meta-analysis of 675 species in many locations has shown an overall advance in spring phenologies (plants and animals) of 2.3 days per decade (Parmesan and Yohe 2003). Not all species react in the same fashion, however. In birds, for instance, 47% of the 168 species studied brought forward their reproduction date, whereas 8% delayed it and 45% did not change it (Parmesan and Yohe 2003, Visser et al. 2004).

3.5.3 Studies of the James Bay Territory

Research is taking place at the Université du Québec à Rimouski under the direction of Dominique Berteaux under the auspices of the Canada Research Chair in Northern Ecosystem Conservation (Berteaux et al. 2006). A research theme developed by Dominique Berteaux in partnership with ArcticNet focuses on the response of boreal forest mammals to climate change.

Moreover, one of ArcticNet's research themes is "food, water and resources in the shifting north-south geothermal gradient of the terrestrial Eastern Canadian Arctic" (ArcticNet 2006). This theme is an integrated regional impact assessment of climate warming and societal conditions along the north-south gradient of the Eastern Canadian Arctic and subarctic. Research will take place in the Northern RiSCC sector, an area that covers more than 30 degrees of latitude, from 53°N (James Bay) to 83°N (Quttinirpaaq National Park, Ellesmere Island, Nunavut) and has various ecoclimatic zones, such as boreal forest, shrubby tundra and High Arctic polar desert.

The Canadian Wildlife Service conducted research on the James Bay goose (Canadian Wildlife Service 2006). The species studied were the brant, the Canada goose and the lesser snow goose. These species have an economic importance because they are hunted by the Cree and Inuit populations of Northern Quebec. The purpose of the study was to obtain information on the ecological needs of geese in those periods when they gather and reproduce in the coastal wetlands of James Bay to assess, forecast and mitigate the impact of the region's activities. The study was made in partnership with Arctic Goose Joint Venture (AGJV), James Bay Energy Corporation (SEBJ), GENIVAR consulting group and Eeyou Corporation. The knowledge acquired during the study could allow for an evaluation of the indirect effects of climate change on the avian populations observed and, consequently, a better understanding of the impacts of climate change on this resource.

Studies to be monitored:

- The studies by Dominique Berteaux of the Université du Québec à Rimouski concerning the response of mammals living in the boreal forest to ongoing climate change.

- The studies conducted by ArcticNet on "food, water and resources in the shifting north-south geothermal gradient of the terrestrial Eastern Canadian Arctic."

- The Canadian Wildlife Service studies on avian wildlife, including waterfowl.

3.6 Energy and the James Bay Territory

The watershed of the La Grande Hydroelectric Complex covers 177,000 km², or 12% of Quebec's total area. The annual electrical output of the La Grande Hydroelectric Complex is about 83 terawatt hours (TWh) and represents more than 40% of the electricity consumed in Quebec (193 TWh in 2003). The construction of three new generating stations between 2003 and 2011 (Eastmain-1, Eastmain-1A and Sarcelle) and the diversion of the headwater of the Rupert River toward the La Grande power stations will raise the total output of the La Grande Hydroelectric Complex to about 94 TWh.

Studies conducted in the James Bay Territory have assessed the changes in runoff in three drainage basins that are important for hydroelectricity production. Singh (1988 in Bruce et al. 1999) foresees an increase in the runoff of the La Grande River (15.6% to 16.5%), the Caniapiscau River (13.0% to 15.7%) and the Opinaca-Eastmain River (6.7% to 20.2%). These increases do not, however, exceed the annual variations in the net capacity of the drainage basins (Bruce et al. 1999).

The expected increase in precipitation in the James Bay Territory should lead to an increase in the generation of electricity.

In relation to climate change, it should be noted that hydroelectricity generates the least amount of greenhouse gases (during the operations phase) and far less than generating stations that use oil, coal or natural gas (Tremblay 2005). The first years after the priming of reservoirs are marked by an increase in greenhouse gas emissions. These emissions are due to the decomposition of the labile fraction of flooded organic materials. The reservoirs' emissions return to rates equivalent to those of lakes and rivers after a 10-year period (SEBJ 2004). Indeed, the maximum flooded area of the Rupert reaches for the Eastmain-1-A project is equivalent to 346 km.² The maximum greenhouse gas emissions should be measured every two to four years after priming and reach 128,000 to 685,000 tonnes of CO_2 equivalent per year. Thereafter, emissions should drop to 32,000 to 71,000 tonnes of CO_2 equivalent per year whereas they are now –36,000 to 81,000 tonnes of CO_2 equivalent per year (SEBJ 2004).

4. Research to address knowledge gaps regarding the James Bay Territory

The research directly linked to climate change and carried out, at least in part, in the James Bay Territory is listed in the table below (Table 4-1). These research themes generally involve many projects and are the subject of ongoing work, which explains why they do not have a precise timetable associated with them.

Table 4-1: Themes of research conducted in the James Bay Territory

	Research theme and objectives	Resource persons or institutions
Climate	Regional modelling of the climate to forecast the scope of climate change and its impacts	Ouranos (Montreal) Environment Canada
	SILA network of experimental stations (monitoring of northern climate)	Yves Bégin (Université Laval)
Water resources	Variations in the levels of Quebec's subarctic great lakes	Yves Bégin (Université Laval) Ouranos
	Vulnerability and adaptation to climate change for the water sector	Meteorological Service of Canada
Forest	**Southern James Bay** Study on the dynamics of forest ecosystems and their interactions with the climate and disturbances	Yves Bergeron (UQAT)
	Northern James Bay - Long-term impacts of interactions between disturbances and climate change - Ecology of Upper Boreal fires - Forest dynamics at the boreal-subarctic interface - Reproduction ecology of boreal ecosystems (forecast the reproductive behaviour of boreal ecosystems under the impact of climate change)	Dominique Arseneault Luc Sirois
Peat bogs	James Bay peat bogs: historical monitoring and climate change This study aims to recreate the spatio-temporal dynamics of peat bogs to predict how they will be affected by climate change	Michelle Garneau (UQAM) Serge Payette (Université Laval)
Wildlife	Response to climate change of mammals living in the boreal forest	Dominique Berteaux (UQAR)
	Impact of climate change on avian wildlife	Joel Béty (UQAR) Jean-Luc DesGranges (Canadian Wildlife Service)
Energy	Quebec's energy strategies determine the province's energy needs and policies in line with greenhouse gas reduction objectives	Hydro-Québec Ministère des Ressources naturelles et de la Faune du Québec

5. Conclusion

Representatives of the scientific community present in Paris on February 1, 2007, published a summary of the work of several hundred researchers throughout the world. Their conclusions were clear. Climate change is indisputable. In the Northern Hemisphere, the past century was the warmest in 1,300 years (IPCC 2007). Eleven of the past 12 years have been the warmest since 1850. The average increase in terrestrial temperatures is expected to be 3°C by 2100. These scientists also assure us with a probability of 90% that human activities causing greenhouse gas emissions are responsible for this warming (IPCC 2007).

The impacts of climate change are sometimes difficult to forecast. The concentration of greenhouse gases, temperature and precipitation all act on ecosystems. The interactions between these factors are complex and hard to forecast.

Some key conclusions can be drawn, however, with respect to the James Bay Territory (Table 5-1). Average warming of 4°C is forecast by 2050. This warming should be more pronounced in the winter than in the summer. The models indicate that precipitation will increase by up to 30% a day by 2050. This climate change will have consequences for ecosystems. In the James Bay Territory, we can expect the same changes as those already observed globally, including migration of plant and animal species farther north. As in the past, these migrations will vary according to the characteristics of each species. The coastal areas of the James Bay Territory are not threatened by accelerated erosion, as is the case with the North Shore.

Table 5-1: Main impacts for the James Bay Territory

Sector	**Expected impacts**
Climate	Average warming of 4°C by 2050 compared with the 1961-1990 period Increase in precipitation of up to 30% a day by 2050 compared with the 1961-1990 period
Water resources	Increase in water resources Little or no risk for coastal areas
Forest	Positive and negative impacts on plant ecology depending on species and development stage. Generally speaking, more extensive growth of tree species. Trend to northward migration of forest ecosystems No consensus on a possible increase in forest fires More epidemics
Peat bogs	Now a carbon sink but could become a source of greenhouse gases with climate warming
Wildlife	Northward migration of certain species Earlier reproduction Risk of desynchronization with vegetation, which could be detrimental to animal health or lead to wildlife reproduction at earlier dates

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7. Appendices

This last section contains information tables on Hydro-Québec's stations of its old network active from 1995 to 2004 (Table 7-1 and Table 7-2) and of its new network installed since 2005 (Table 7-3, Table 7-4, Table 7-5 and Table 7-6). These data were provided by Hydro-Québec.

The data influenced by El Niño and La Niña events is compiled in Tables 7-7 and 7-8

Table 7-1: Co-ordinates of Hydro-Québec's weather stations active between 1990 and 2004 and the parameters measured (section 1)

Name of station	RMCQ indicative	Territory unit	Status	Latitude	Longitude	Measured meteorological parameters [2]						
						T	RH	P	IP	Vpcpn	Wind	Snow
Brisay - Barrage amont	CQBR	La Grande	Inactive	54°26'39"	70°30'43"	x		x			x	
Caniapiscau Nord-Est	CQCQ	La Grande	Inactive	54°31'06"	69°13'23"			x				
Caniapiscau Nord-Ouest	CQCN	La Grande	Inactive	54°25'38"	70°10'42"	x		x			x	
Caniapiscau Sud	CQCS	La Grande	Inactive	54°06'47"	69°55'32"	x		x	x			
Duncan - Barrage amont	CQDC	La Grande	Inactive	53°35'27"	77°30'16"	x		x			x	
Duplanter - Barrage amont	CQDP	La Grande	Inactive	54°50'47"	69°48'44"	x		x			x	
Eastmain - Météo	CQEA	La Grande	Inactive	52°12'35"	76°35'00"	x		x			x	
LA 2 KD-04	CQDK	La Grande	Inactive	54°40'04"	71°02'10"	x		x	x		x	
La Sarcelle - Météo	CQLS	La Grande	Inactive	52°40'01"	76°38'08"	x		x			x	
Lac Frégate	CQLF	La Grande	Inactive	53°12'14"	74°50'10"	x		x				
LG 2- Barrage amont	CQXP	La Grande	Inactive	53°47'25"	77°26'30"	x		x			x	
LG 2 Nord-Est	CQXN	La Grande	Inactive	54°08'35"	76°15'12"	x		x			x	
LG 3 - Barrage amont météo	CQXM	La Grande	Inactive	53°43'30"	75°59'00"	x		x			x	
LG 3 TA10	CQXI	La Grande	Inactive	53°55'54"	75°23'12"	x		x			x	
LG 3 TA12	CQXJ	La Grande	Inactive	53°55'40"	75°27'55"	x					x	
LG 3 TA32	CQXK	La Grande	Inactive	53°29'01"	76°00'35"	x		x			x	
LG 4 - Barrage amont	CQXA	La Grande	Inactive	53°53'11"	73°27'48"	x					x	
LG 4 Est	CQXE	La Grande	Inactive	53°57'33"	73°00'09"	x		x			x	
LG 4 Sud	CQXS	La Grande	Inactive	53°49'35"	73°06'49"			x				
Petit Opinaca	CQPO	La Grande	Inactive	52°22'21"	76°45'27"	x		x			x	
Vincelotte	CQVI	La Grande	Inactive	54°14'25"	72°27'42"	x		x				
Bourque - Barrage amont	CQBQ	La Grande	Inactive	47°36'49"	77°18'29"			x				
Dozois Est	CQDZ	La Grande	Inactive	47°27'08"	77°04'43"	x		x			x	x

[2] **T**: air temperature; **RH**: relative humidity; **P**: total precipitation on precipitation gauge; **IP**: rain on swivelling runnel pluviometer; **Vpcpn**: wind direction and speed on precipitation gauge; **Wind**: wind direction and speed at 10 metres; **Snow**: snow thickness.

Table 7-2: Co-ordinates of Hydro-Québec's weather stations active between 1990 and 2004 and the parameters measured (section 2)

Name of station	RMCQ indicative	Territory unit	Status	Latitude	Longitude	Measured meteorological parameters [3]						
						T	RH	P	IP	Vpcpn	Wind	Snow
Bersimis 1 Est	CQBM	Manicouagan	Inactive	49°36'21"	70°06'21"	x		x	x		x	
Bersimis 1 Ouest	CQBO	Manicouagan	Inactive	49°25'58"	70°55'41"	x		x	x			
Lac Ste-Anne	CQAE	Manicouagan	Inactive	50°08'33"	67°53'57"	x		x	x			
Manic 3 Nord	CQYN	Manicouagan	Inactive	50°12'49"	68°36'32"	x		x	x			
Manic 5 - Météo	CQYY	Manicouagan	Inactive	50°37'20"	68°43'20"	x		x	x			x
Manic 5 Est	CQYE	Manicouagan	Inactive	51°19'20"	68°09'53"	x		x	x		x	
Manic 5 Nord-Ouest	CQYO	Manicouagan	Inactive	51°39'13"	69°03'22"	x		x	x			
Manic 5 Sud	CQYS	Manicouagan	Inactive	51°06'14"	68°50'02"	x		x	x			
Mistigougèche - Barrage amont	CQMG	Manicouagan	Inactive	48°10'30"	68°01'30"	x		x				
Mitis - Barrage amont	CQMM	Manicouagan	Inactive	48°19'53"	67°54'54"	x		x				
Outardes 4 Nord	CQON	Manicouagan	Inactive	50°32'19"	69°12'12"	x		x	x			
Outardes 4 Sud	CQOS	Manicouagan	Inactive	50°06'13"	68°59'15"	x		x	x		x	
Pamouscachiou - Barrage aval		Manicouagan	Inactive	49°19'45"	70°58'52"	x						
Ste-Marguerite - Campement	CQSM	Manicouagan	Inactive	50°46'57"	66°54'57"	x	x	x	x		x	
Châteauvert C - Barrage amont	CQCV	Des Cascades	Inactive	47°45'29"	73°53'48"	x		x				
Châteauvert C - Bris barrage		Des Cascades	Inactive	47°45'34"	73°53'12"	x						
Gouin - Barrage aval	CQGV	Des Cascades	Inactive	48°20'59"	74°05'55"			x				
Gouin Sud-Ouest	CQGS	Des Cascades	Inactive	48°27'04"	75°19'48"	x		x			x	
Matawin - Barrage amont	CQMW	Des Cascades	Inactive	46°51'42"	73°39'32"	x		x				
Matawin - Bris barrage	CQMX	Des Cascades	Inactive	46°51'48"	73°39'30"	x					x	
Mékinac - Barrage amont	CQKM	Des Cascades	Inactive	46°58'32"	72°39'20"	x		x				
Barrière - Barrage amont	CQBA	Beauharnois-Gatineau	Inactive	47°29'55"	76°43'50"			x				
Cabonga - Barrage amont	CQCB	Beauharnois-Gatineau	Inactive	47°18'35"	76°28'14"			x				
Mercier - Barrage amont	CQME	Beauharnois-Gatineau	Inactive	46°43'06"	75°59'11"	x		x		x	x	x

[3] **T**: air temperature; **RH**: relative humidity; **P**: total precipitation on precipitation gauge; **IP**: rain on swivelling runnel pluviometer; **Vpcpn**: wind direction and speed on precipitation gauge; **Wind**: wind direction and speed at 10 metres; **Snow**: snow thickness.

Table 7-3: Co-ordinates of Hydro-Québec's weather stations installed since 2005 and the parameters measured (section 1)

Name of station	RMCQ Indicative	Prov/Territ.	Partners	Elevation (metres)	Latitude	Longitude	Measured meteorological parameters																		
							TAi000H (201)	TAm000H (203)	TAx000H (204)	TAn000H (205)	TDi000H (206)	HAi000H (301)	HAm000H (302)	VDm400H (402)	VVm400H (502)	VDm500H (403)	VVm500H (503)	VDxi500H (406)	VVxi500H (506)	VVxih500H (507)	VDm025B (405)	VVm025B (505)	PC030B (604)	PC040H (701)	NSi000H (801)
Barrage Robert-Bourassa	CMBU	Québec	Hydro-Québec	191.0	53°46'37"	77°28'25"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Barrage Vincelotte	CMVN	Québec	Hydro-Québec	446.0	54°20'12"	72°30'43"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Barrière - Barrage amont	CMBA	Québec	Hydro-Québec	363.2	47°29'56"	76°43'50"	x	x	x	x		x	x								x	x	x	x	x
Bersimis 1 Est	CMBM	Québec	Hydro-Québec	406.0	49°36'21"	70°06'40"	x	x	x	x		x	x								x	x	x	x	x
Caniapiscau Sud	CMCS	Québec	Hydro-Québec	540.6	54°06'46"	69°55'33"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
De Pontois	CMRP	Québec	Hydro-Québec	329.0	53°09'58"	74°28'16"	x	x	x	x		x	x								x	x	x	x	x
Fontanges	CMFE	Québec	Hydro-Québec	469.3	54°33'17"	71°10'47"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Gorge Prosper 2	CMGP	Québec	Hydro-Québec	337.0	52°10'07"	74°35'35"	x	x	x	x		x	x								x	x	x	x	x
Gouin Sud-Ouest	CMGS	Québec	Hydro-Québec	404.8	48°27'01"	75°19'31"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Hart Jaune	CMHJ	Québec	Hydro-Québec	483.1	51°47'05"	67°54'15"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kepimits	CAKE	Nfld and Labrador	Hydro-Québec	540.0	52°39'10"	64°50'18"	x	x	x	x		x	x								x	x	x	x	x
La Loutre	CMUT	Québec	Hydro-Québec	390.0	48°19'57"	74°01'51"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
La Sarcelle 2	CMAR	Québec	Hydro-Québec	220.0	52°40'08"	76°35'40"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Aunaukach	CMMP	Québec	Hydro-Québec	313.0	52°41'13"	75°26'18"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Bourinot	CMPN	Québec	Hydro-Québec	570.8	52°42'28"	70°57'22"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Chastrier	CMLC	Québec	Hydro-Québec	546.1	53°59'28"	69°04'39"	x	x	x	x		x	x								x	x	x	x	x
Lac Despinolles	CMSY	Québec	Hydro-Québec	707.0	52°29'34"	69°15'09"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Falaise	CMLD	Québec	Hydro-Québec	550.9	54°15'53"	68°14'35"	x	x	x	x		x	x								x	x	x	x	x
Lac Grandjean	CMKW	Québec	Hydro-Québec	360.0	54°27'22"	74°20'04"	x	x	x	x		x	x								x	x	x	x	x
Lac Madigan	CMMZ	Québec	Hydro-Québec	593.5	53°21'25"	69°49'21"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Pau	CMPX	Québec	Hydro-Québec	580.9	54°49'36"	69°54'22"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Plétipi	CMPI	Québec	Hydro-Québec	537.9	51°49'11"	70°03'59"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Puisseaux 2	CMPU	Québec	Hydro-Québec	488.4	53°36'01"	71°10'57"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 7-4: Co-ordinates of Hydro-Québec's weather stations installed since 2005 and the parameters measured (section 2)

Name of station	RMCQ Indicative	Prov/Territ.	Partners	Elevation (metres)	Latitude	Longitude	Measured meteorological parameters																		
							TAi000H (201)	TAm000H (203)	TAx000H (204)	TAn000H (205)	TDi000H (206)	HAi000H (301)	HAm000H (302)	VDm400H (402)	VVm400H (502)	VDm500H (403)	VVm500H (503)	VDxi500H (406)	VVxi500H (506)	VVxih500H (507)	VDm025B (405)	VVm025B (505)	PC030B (604)	PC040H (701)	NSi000H (801)
Lac Raimbault	CMRA	Québec	Hydro-Québec	625.0	53°11'44"	68°21'24"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Rossignol	CMRX	Québec	Hydro-Québec	405.0	52°41'04"	73°47'19"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lac Ste-Anne 2	CMAF	Québec	Hydro-Québec	300.0	50°06'12"	67°56'43"	x	x	x	x		x	x								x	x	x	x	x
LG 3 TA10	CMXI	Québec	Hydro-Québec	277.0	53°55'52"	75°23'13"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
LG 4 Est	CMXE	Québec	Hydro-Québec	378.0	53°57'35"	73°00'06"	x	x	x	x		x	x								x	x	x	x	x
LG-3 Taïga	CMXT	Québec	Hydro-Québec	254.0	53°33'55"	76°06'55"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Manic 5 Est	CMYE	Québec	Hydro-Québec	365.0	51°19'20"	68°09'53"																			
Matawin - Barrage amont	CMMW	Québec	Hydro-Québec	362.7	46°51'43"	73°39'33"	x	x	x	x		x	x								x	x	x	x	x
Metchin	CAMN	Nfld and Labrador	Hydro-Québec	335.0	53°26'22"	63°15'33"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Michikimats	CAMK	Nfld and Labrador	Hydro-Québec	520.0	54°33'49"	64°07'10"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Outardes 4 Sud	CMOS	Québec	Hydro-Québec	357.8	50°06'11"	68°59'15"	x	x	x	x		x	x								x	x	x	x	x
Petit Opinaca 2	CMOA	Québec	Hydro-Québec	220.0	52°22'10"	76°46'34"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Polaris	CMPW	Québec	Hydro-Québec	410.0	53°43'25"	72°51'39"																		x	
Rapide Sept	CMRS	Québec	Hydro-Québec	338.8	47°47'51"	78°17'46"	x	x	x	x		x	x								x	x	x	x	x
Réservoir Baskatong	CMKG	Québec	Hydro-Québec	220.0	46°43'05"	75°59'12"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Réservoir Dozois	CMDW	Québec	Hydro-Québec	360.3	47°26'51"	77°04'34"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Réservoir Pipmuacan	CMPP	Québec	Hydro-Québec	566.2	49°21'35"	70°54'55"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rivière Ashuanipi	CAAH	Nfld and Labrador	Hydro-Québec	520.0	53°13'25"	66°12'23"																		x	
Rivière aux Eaux Mortes - Météo	CMRE	Québec	Hydro-Québec	301.0	47°05'51"	72°29'45"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rivière Betsiamites	CMBS	Québec	Hydro-Québec	423.0	49°58'36"	69°54'48"																		x	
Rivière Eastmain	CMEN	Québec	Hydro-Québec	372.0	52°01'33"	73°21'22"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rivière Kanaaupscow	CMRK	Québec	Hydro-Québec	189.0	54°14'31"	76°09'23"	x	x	x	x		x	x								x	x	x	x	x

Table 7-5: Co-ordinates of Hydro-Québec's weather stations installed since 2005 and the parameters measured (section 3)

Name of station	RMCQ Indicative	Prov/Territ.	Partners	Elevation (metres)	Latitude	Longitude	Measured meteorological parameters																		
							TAi000H (201)	TAm000H (203)	TAx000H (204)	TAn000H (205)	TDi000H (206)	HAi000H (301)	HAm000H (302)	VDm400H (402)	VVm400H (502)	VDm500H (403)	VVm500H (503)	VDxi500H (406)	VVxi500H (506)	VVxih500H (507)	VDm025B (405)	VVm025B (505)	PC030B (604)	PC040H (701)	NSi000H (801)
Rivière Misask	CMHC	Québec	Hydro-Québec	424.0	52°33'57"	72°22'49"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rivière Mouchalagane	CMRM	Québec	Hydro-Québec	400.0	52°08'11"	69°30'29"																		x	
Rivière Opinaca	CMOP	Québec	Hydro-Québec	248.0	52°47'00"	75°44'35"																		x	
Rivière Rupert	CMRZ	Québec	Hydro-Québec	290.0	51°31'14"	75°26'26"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rivière Sakami	CMAK	Québec	Hydro-Québec	440.0	53°05'05"	72°45'56"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rivière Ste-Marguerite	CMSN	Québec	Hydro-Québec	480.0	51°53'48"	67°03'04"																		x	
Rivière Toulnoustouc	CMTO	Québec	Hydro-Québec	332.1	50°42'31"	67°44'09"	x	x	x	x		x	x								x	x	x	x	x
Rivière Windigo - Météo	CMRW	Québec	Hydro-Québec	310.2	47°54'57"	73°22'11"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Simms	CASI	Terre-Neuve-et-Labrador	Hydro-Québec	490.0	53°46'37"	65°48'59"	x	x	x	x		x	x								x	x	x	x	x
Ste-Marguerite - Campement	CMSM	Québec	Hydro-Québec	511.0	50°46'54"	66°54'51"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Valois	CMVO	Québec	Hydro-Québec	648.0	51°40'51"	68°59'00"	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 7-6: Explanation of parameters measured for the network of weather stations installed in 2005

SCADA	Parameter	Element	Height (metre)	Unit	Aggregation	Period (min)	Frequency	Type	Definition
TAi000H_201	Air temperature	Air temperature		°C	average	1	hourly	acquired	Average value of last minute before the hour
TAm000H_203	Air temperature	Air temperature		°C	average	60	hourly	acquired	Hourly maximum value
TAx000H_204	Air temperature	Air temperature		°C	maximum	60	hourly	acquired	Hourly maximum value
TAn000H_205	Air temperature	Air temperature		°C	minimum	60	hourly	acquired	Hourly maximum value
HAi000H_301	Air humidity	Relative humidity		%	average	1	hourly	acquired	Average value of last minute before the hour
HAm000H_302	Air humidity	Relative humidity		%	average	60	hourly	acquired	Hourly maximum value
VDm400H_402	Wind	Wind direction	10	degrees	average	10	hourly	acquired	Average value of last 10 minutes of hour
VVm400H_502	Wind	Wind speed	10	km/h	average	10	hourly	acquired	Average value of last 10 minutes of hour
VDm500H_403	Wind	Wind direction	10	degrees	average	60	hourly	acquired	Hourly maximum value
VVm500H_503	Wind	Wind speed	10	km/h	average	60	hourly	acquired	Hourly maximum value
VDm025B_405	Wind	Wind direction	2,5	degrees	average	15	15 minutes	acquired	Average value of last 15 minutes
VVm025B_505	Wind	Wind speed	2,5	km/h	average	15	15 minutes	acquired	Average value of last 15 minutes
VDxi500H_406	Wind	Wind direction	10	degrees	maximum	60	hourly	acquired	Instantaneous value of last hour wind peak
VVxi500H_506	Wind	Wind speed	10	km/h	maximum	60	hourly	acquired	Instantaneous value of last hour wind peak
VVxih500H_507	Wind	Time of peak wind	10	hh:mm	instantaneous	60	hourly	acquired	Hour/minute of last hour wind peak
PC030B_604	Total precipitation	Accumulated precipitation		mm	analysed	15	15 minutes	acquired	Instantaneous analysed value 15 minutes
PC040H_701	Liquid precipitation	Accumulated liquid precipitation (A/B)		mm	instantaneous	60	hourly	acquired	Instantaneous hourly value
NSi000H_801	Snow on ground	Height of snow on ground		cm	average	1	hourly	acquired	Average value of last minute before the hour

Table 7-7: El Niño and La Niña years, 1950-2004

Year	Classification	Year	Classification	Year	Classification
1950-51	La Niña moderate	1970-71	La Niña moderate	1990-91	El Niño weak
1951-52	Neutral	1971-72	Neutral	1991-92	El Niño strong
1952-53	El Niño weak	1972-73	El Niño moderate	1992-93	El Niño weak
1953-54	Neutral	1973-74	La Niña strong	1993-94	Neutral
1954-55	La Niña moderate	1974-75	La Niña weak	1994-95	El Niño weak
1955-56	La Niña moderate	1975-76	La Niña moderate	1995-96	La Niña weak
1956-57	Neutral	1976-77	El Niño weak	1996-97	Neutral
1957-58	El Niño strong	1977-78	El Niño weak	1997-98	El Niño strong
1958-59	El Niño weak	1978-79	Neutral	1998-99	La Niña moderate
1959-60	Neutral	1979-80	El Niño weak	1999-2000	La Niña strong
1960-61	Neutral	1980-81	Neutral	2000-01	Neutral
1961-62	Neutral	1981-82	Neutral	2001-02	Neutral
1962-63	Neutral	1982-83	El Niño strong	2002-03	El Niño moderate
1963-64	El Niño weak	1983-84	La Niña weak	2003-04	Neutral
1964-65	La Niña weak	1984-85	La Niña weak		
1965-66	El Niño moderate	1985-86	Neutral		
1966-67	Neutral	1986-87	El Niño moderate		
1967-68	Neutral	1987-88	El Niño weak		
1968-69	El Niño moderate	1988-89	La Niña strong		
1969-70	El Niño weak	1989-90	Neutral		

(Source: Environment Canada 2007)
http://www.msc.ec.gc.ca/education/elnino/comparing/index_f.cfm.

Table 7-8: El Niño and La Niña years, 1900-1950

Year	Classification	Year	Classification	Year	Classification
1900-01	Neutral	1920-21	**La Niña**	1940-41	**El Niño**
1901-02	Neutral	1921-22	Neutral	1941-42	**El Niño**
1902-03	Neutral	1922-23	Neutral	1942-43	**La Niña**
1903-04	**La Niña**	1923-24	Neutral	1943-44	Neutral
1904-05	**El Niño**	1924-25	**La Niña**	1944-45	Neutral
1905-06	**El Niño**	1925-26	**El Niño**	1945-46	Neutral
1906-07	Neutral	1926-27	Neutral	1946-47	Neutral
1907-08	Neutral	1927-28	Neutral	1947-48	Neutral
1908-09	Neutral	1928-29	**La Niña**	1948-49	Neutral
1909-10	**La Niña**	1929-30	**La Niña**	1949-50	**La Niña**
1910-11	Neutral	1930-31	Neutral		
1911-12	**El Niño**	1931-32	Neutral		
1912-13	Neutral	1932-33	Neutral		
1913-14	Neutral	1933-34	Neutral		
1914-15	**El Niño**	1934-35	Neutral		
1915-16	Neutral	1935-36	Neutral		
1916-17	**La Niña**	1936-37	Neutral		
1917-18	**La Niña**	1937-38	Neutral		
1918-19	**El Niño**	1938-39	**La Niña**		
1919-20	Neutral	1939-40	Neutral		

(Source: Environment Canada 2007)
http://www.msc.ec.gc.ca/education/elnino/comparing/index_f.cfm.