Climate Change

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BACKGROUND

The United Nations Intergovernmental Panel on Climate Change (IPCC) and the national science academies of eleven nations, including Canada and United States, have recognized that the Earth's atmosphere is warming and that human activities that release greenhouse gases are an important cause. Warming of the atmosphere affects the temperature of air, land, and water, which in turn affects patterns of precipitation, evaporation, and wind, as well as ocean temperature and currents. This paper presents indicators of climate change for British Columbia, with emphasis on the coastal region.

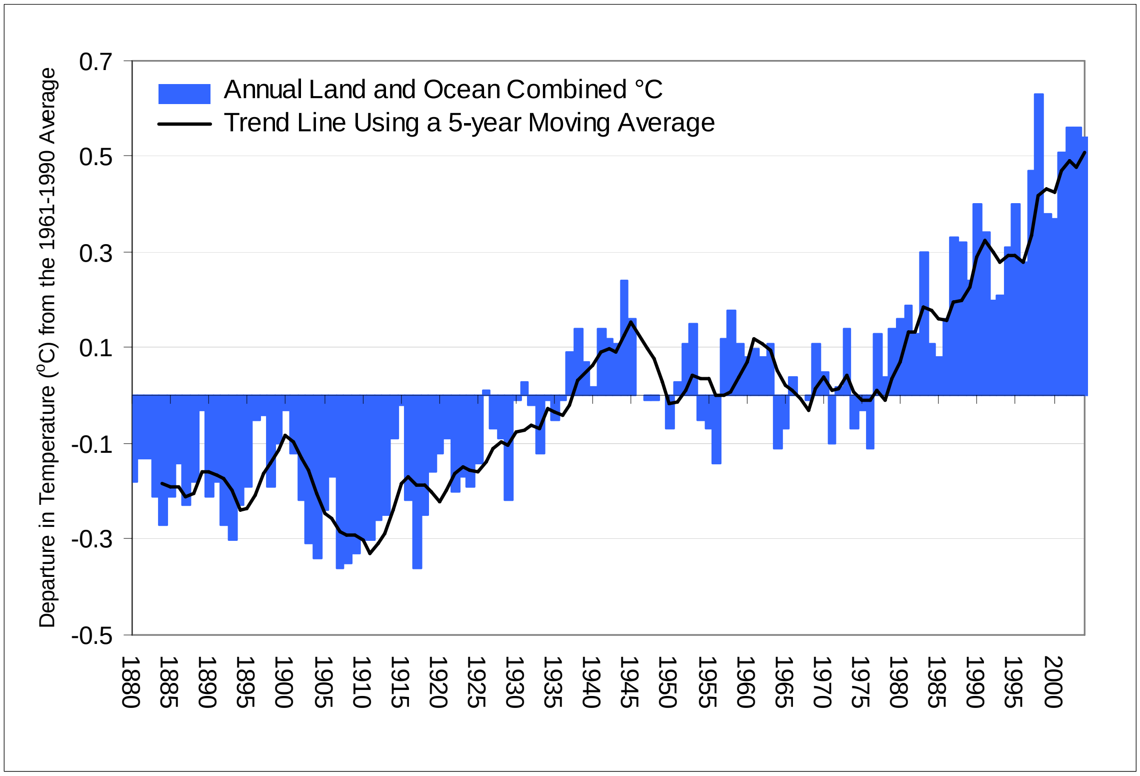
Greenhouse gases are atmospheric gases such as carbon dioxide, methane, and nitrous oxide. They trap solar energy, warming the atmosphere and the surface of the Earth, and play a critical role in maintaining the temperature of the Earth within a range suitable for life. However, as the levels of these gases build up in the atmosphere, they act like the transparent roof of a greenhouse, which allows in sunlight while trapping the heat energy.

GREENHOUSE GASES

Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), and other trace compounds. These gases are released into the atmosphere by many naturally occurring processes as well as by human activity such as fossil fuel combustion, deforestation, agriculture, and industrial activity. Human-created greenhouse gases include perfluorocarbons (PFCs), which are a byproduct of aluminum production; sulfurhexafluoride (SF_6), which is used minimally in electrical switches; and hydrofluorocarbons (HFCs), which now replace the ozone-depleting chlorinated fluorocarbons (CFCs) in many applications.

Records show that global temperatures, averaged world-wide over the land and sea, rose 0.6 ± 0.2ºC during the 20th century (see Figure 1). The year 1998 was the warmest year since instrument records began in 1861. The next four warmest years have all occurred since 2000. Although natural forces such as solar and volcanic activity may have contributed, the IPCC attributes most of the warming of the last 50 years to human activities that release greenhouse gases into the atmosphere (IPCC 2001b). Long-term records show that CO_2 in the atmosphere has risen from pre-industrial concentrations of about 280 parts per million (ppm) in 1750 to about 375 ppm today. The IPCC concluded that "emissions of CO_2 due to fossil fuel burning are virtually certain to be the dominant influence on the trends in atmospheric CO_2 concentrations during the 21st century" (IPCC 2001b).

Figure 1. Annual global land temperature and ocean temperature (ºC), relative to the average temperature for 1961–1990.



Source: National Oceanic and Atmosphere Administration (NOAA)
http://lwf.ncdc.noaa.gov/oa/climate/research/anomalies/anomalies.html#anomalies.

Natural Sources of Climate Variation

The time scales of natural variations in climate range from cycles of a few years to tens of thousands of years. For example, global temperatures were warmer in the 13th to 15th centuries than in the 16th to 19th centuries.

British Columbia is affected by two major sources of natural short-term variation in the regional climate:

- The Pacific Decadal Oscillation (PDO) is a little understood natural cycling of warm and cool phases in the sea surface temperatures of the Pacific Ocean. The PDO appears to affect the BC climate over a 50- to 60-year cycle (Moore et al. 2002), spending roughly 20 to 30 years in each phase. In British Columbia, the warm phase of the PDO is generally associated with above-average air and ocean surface temperatures and below-average springtime snow pack.
- The El Niño Southern Oscillation (ENSO) phenomenon is related to shifts in tropical air pressure that change temperature and precipitation patterns along the West Coast every few years. For British Columbia an El Niño event generally means a warmer

winter with below-average precipitation, while a La Niña event means a cooler winter with above-average precipitation.

The ENSO and PDO can reinforce or weaken each other's effects, making it difficult to discern short-term trends in the climate and to predict future impacts. The strength of ENSO events varied considerably during the last millennium and the ENSO appears to be sensitive to the background climate, but at this time it is not possible to predict how it will respond to global warming (Tudhope and Collins 2003).

Research shows that the Earth is not warming evenly. Some parts, particularly northern latitudes, have been warming more rapidly than equatorial regions. The impact of global climate change may be intensified or moderated regionally as different levels of the atmosphere, land, and oceans respond on different time scales. Worldwide sea surface temperature, for example, has been increasing about half as quickly as temperature over land, and the deeper water of the ocean has been warming even more slowly. Local conditions also modify the impact. Average overnight low temperatures have been increasing about twice as fast as daytime highs, but about half of this effect may be due to urban and other land-use changes, with the rest due to the effect of global temperature changes (Kalnay and Cai 2003).

These sources of natural climate variability confuse and add uncertainty to trends, therefore small changes will probably remain undetectable for many more years. Despite these caveats, where trends are presented in this review, there is a good level of confidence in the direction, if not the absolute size, of the trends. Note that previously reported indicators for the province (e.g., BCMWLAP 2002b) have been updated and in some cases presented differently to display the current understanding of climate trends and impacts.

Impacts of Climate Change

Because of the global scale involved and the complexity of interactions between climate variables, it is not certain how much the global climate will be affected. Global-scale computer climate simulations for the coming century have been developed by climate research centres in Canada, United States, United Kingdom, Germany, Japan, and Australia. Several greenhouse gas emission scenarios prescribed by the United Nations IPCC are modelled by each centre to produce a range of plausible outcomes. At the global scale, over the coming century, the models project that northern high latitudes will experience the greatest warming, particularly in the winter, with an increase in average annual precipitation (IPCC 2001a).

Given the global scale of predicted changes to the climate, it is reasonable to expect that this will significantly affect physical and biological systems, as well as have socio-economic impacts.

Physical Impacts

Projected—and in some cases already observed—changes to global physical processes as a result of atmospheric warming include:

- increasing frequency and severity of extreme weather, such as heat waves, drought, and high-intensity rainfall (Stott et al. 2004);
- changes in the timing of river flow and water volume (e.g., Whitfield et al. 2002);
- shrinking and loss of mountain glaciers and snow packs, which is of particular concern for communities, growers, and hydroelectricity generators that depend on snow melt for their water supply;
- rising sea level, which has increased about 15–20 cm world-wide during the 20th century (see Indicator 4);
- alteration of ocean temperature, salinity, and density, which may in turn affect ocean circulation and productivity. As has been observed in the past (e.g., Rahmstorf 2003), changes in ocean circulation may be triggered as oceans warm.

Biological Impacts

Climate is the major factor controlling the global pattern of ecosystems and distribution of plants and animals. Therefore a changing climate is expected to drive significant changes in ecosystems and biodiversity. For example, a shift in the pattern of river flow would affect any biological processes that are sensitive to the timing and quantity of freshwater input, such as fish migration and spawning. The most sensitive ecosystems, such as high-altitude and high-latitude ecosystems, already show signs of being affected (Gitay et al. 2001).

Impacts on ecosystems may include changes to:

- ecosystem structure, such as the predominant vegetation, species composition, and distribution of age classes;
- ecosystem function, including productivity, nutrient cycling, and water flows;
- distribution of ecosystems within and across the landscape;
- patterns of disturbance, such as fires, insect and disease infestations, and invasion by alien species.

Impacts on species include changes in:

- phenology, which is the timing of flowering, emergence, and migration;
- growth rate, development, and reproduction;
- interactions between species, such as predation, and competition (see text box).

Recent studies have shown that climate change has already begun to affect biodiversity globally. Changes have been observed in the timing of reproduction and migration, species distribution and population sizes, and the frequency and intensity of fires and pest infestations (e.g., Parmesan and Yohe 2003; Root et al. 2003). Although some species may be able to move to more favourable climates or adapt to the changes, it is likely that most will not. For some, their way may be blocked by unfavourable conditions nearby (e.g., mountains, dry lands), while for others the rate of change required will be too great. For example, in the past, it appears that plant species have dispersed about 20 to 200 km per century (Malcolm and Markham 2000), but within 100 years, Canada's boreal forest is expected to be displaced northward by 200 to 1200 km (Dokken et al. 2002).

HOW CLIMATE CHANGE CAN AFFECT OCEAN PRODUCTIVITY

Spring diatom blooms in the ocean signal the start of the seasonal cycle of production on the BC coast. The timing of the blooms is roughly the same every year because the diatoms respond to day length or light intensity. In contrast, the physiology of organisms as diverse as the copepods that feed on diatoms and the salmon that feed on copepods responds to temperature. As spring comes earlier, these organisms may shift their seasonal cycle of development and reproduction to earlier in the year. They are then out of synchrony with the peak production of the diatoms they depend on for food. Such inefficiency in energy transfer between trophic levels already may have altered some marine ecosystems enough to contribute to the decline of fish stocks (Edwards and Richardson 2004).

Socio-economic Impacts

An immediate economic effect of climate change is the cost of dealing with extreme weather events. Such events also have a social cost to people who are displaced or suffer physical injury and property loss. On the coast, the impact of rising sea level coupled with more extreme weather could increase the risk and costs associated with:

- floods in low-lying coastal areas;
- storm damage to waterfront homes, roads, and port facilities, and erosion of the shoreline;
- saltwater intrusion into groundwater aquifers and saline contamination of low-lying agricultural lands.

Communities and industries that depend on fresh water sources affected by climate change (such as snow pack), will need to invest in conservation measures, developing alternative supplies and building infrastructure. Any economic activities that depend on land-based natural resources, such as agriculture, forestry, salmon fisheries, and even tourism, will feel the effects of changing climate. Long-term changes in ocean conditions will affect the human communities and resource industries that depend on the sea.

Climate change also may affect human health and safety by increasing the range of certain diseases (such as malaria) and the risk of heat-related illnesses, such as heat stroke. Globally, societies that are currently experiencing social, economic, and climatic stresses are likely to be both worst affected and least able to adapt. This includes many in the developing world, low-lying islands and coastal regions, and the urban poor (Burchdal and Hare 2004).

INDICATORS

1. Key Indicator: Long-term trends in air temperature

This is a status indicator. It addresses the questions: Has the climate changed in British Columbia? What are the long-term trends in temperature?

Air temperature and precipitation (see Indicator 2) are the two most commonly measured and widely studied climate variables. Trends in annual temperature for 1950–2001 show the direction and rate of change for this period and also provide an indication of conditions likely in the future.

Methodology and Data

Data presented in this indicator were provided by the Climate Research Branch of Environment Canada; data was analyzed by the Aquatic and Atmospheric Division of the Pacific and Yukon Region of Environment Canada.

Temperature records from 58 climate stations in western Canada were analyzed; 36 stations were in British Columbia. These 36 stations cover all four climatic zones in the province (Table 1); the 22 stations outside British Columbia were used to complete temperature contouring along provincial boundaries. Temperature records were limited to the period 1950–2001 because of gaps and lack of data at many stations before 1950. Trends calculated between 1950 and 2001 were adjusted to a 50-year basis.

The daily quality-controlled temperature data in Environment Canada's archives were adjusted to correct for non-climate-related changes such as relocation of stations and instrument changes. The resulting datasets, taken from *www.cccma.bc.ec.gc.ca/hccd/*, are called Adjusted Historical Canadian Climate Data (Vincent and Gullet 1997; Mekis and Hogg 1999).

Annual and seasonal temperature trends were calculated, as were the number of frost-free days. Trends in frost-free days were calculated from daily minimum temperature data. Trends in the annually averaged daily maximum and minimum temperatures and the number of frost-free days are given in Table 2 for 12 BC climate stations.

Table 1. Location of British Columbia climate stations providing data for the air temperature indicator.

Station name	Climatic zone	Station name	Climatic zone
Abbotsford Airport	Pacific	Wistaria	South BC mountains
Aggasiz CDA	Pacific	Barkerville	South BC mountains
Victoria Gonzales Hts	Pacific	Burns Lake CS	South BC mountains
Comox Airport	Pacific	Fort St. James	South BC mountains
Port Hardy Airport	Pacific	Quesnel Airport	South BC mountains
Estevan Point	Pacific	Summerland CDA	South BC mountains
Prince Rupert Airport	Pacific	Cranbrook Airport	South BC mountains
Sandspit Airport	Pacific	Kamloops Airport	South BC mountains
Bella Coola	Pacific	Golden Airport	South BC mountains
Cape St. James	Pacific	Prince George Airport	South BC mountains
Stewart Airport	Pacific	Kaslo	South BC mountains
Quatsino	Pacific	Warfield	South BC mountains
Victoria Airport	Pacific	Vavenby	South BC mountains
Dease Lake	North BC mountains	Revelstoke	South BC mountains
Fort St. John	Northwestern forest	Princeton Airport	South BC mountains
Fort Nelson	Northwestern forest	Vernon CS	South BC mountains
Smithers Airport	South BC mountains	Castlegar Airport	South BC mountains
Tatlayoko Lake	South BC mountains	Creston	South BC mountains

Source: Climate Research Branch, Environment Canada.

Trends were calculated using the Microsoft Excel template MAKESENS developed by the Finnish Meteorological Institute (Salmi et al. 2002) (available at *www.fmi.fi/organization/contacts_25.html*). The MAKESENS software uses the nonparametric Sen's linear estimate for the slope of the trend line and the nonparametric Mann-Kendall test to evaluate whether that slope is statistically different from zero (no trend). Before trend calculations, the data were adjusted for autocorrelation using the prewhitening method of Wang and Swail (2001). This is a statistical correction method applied to data so that the subsequent analysis avoids overestimating the significance of a trend.

Temperature trends were mapped onto the provincial map with Surfer® (Golden Software) contouring and mapping software (Figure 2).

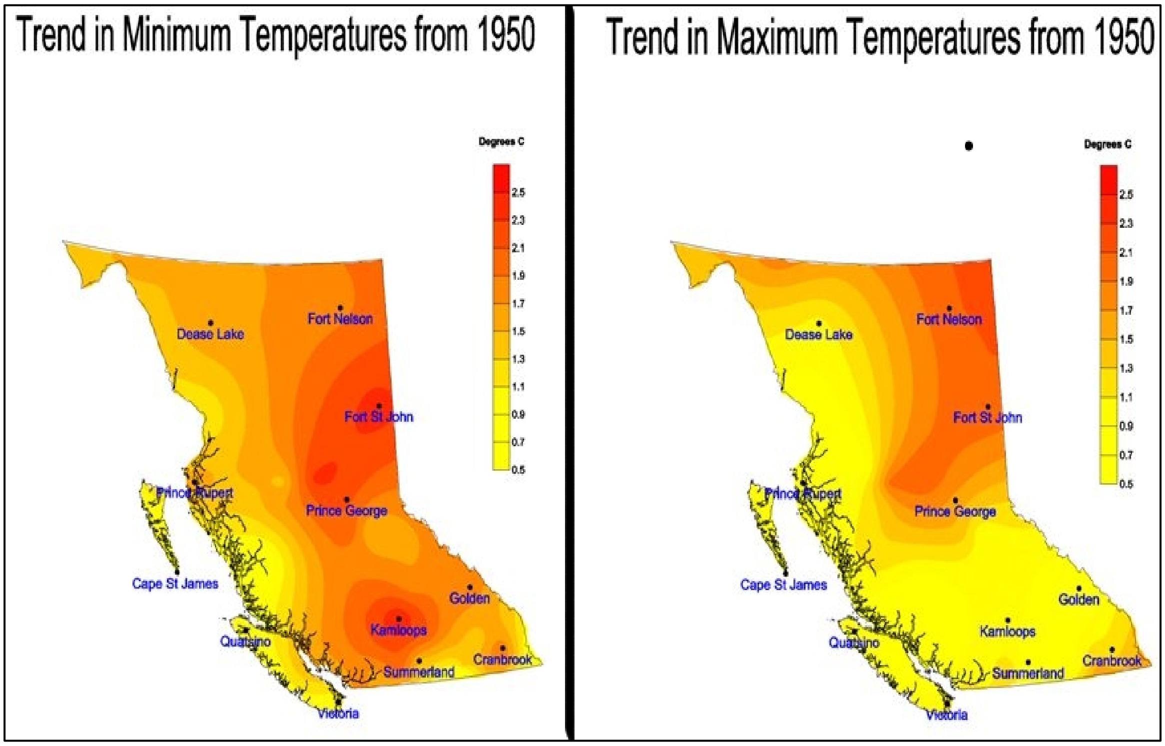
Table 2. Fifty-year trends in the annually averaged daily maximum (Tmax) and minimum (Tmin) temperatures and the increase in the number of frost-free days for 12 of the climate stations used in the analysis for Figure 2.

Station name	Element	Winter	Spring	Summer	Autumn	Annual
Victoria Airport	Tmin (°C)	1.0	1.8*	1.0*	0.5	0.9
	Tmax (°C)	1.0	1.3*	1.0*	0.8	1.0*
	Frost-free days (days)					21.8
Quatsino	Tmin (°C)	1.9	2.0*	0.7	0.8	1.0
	Tmax (°C)	0.7	5.4*	0.8	0.2	0.47
	Frost-free days (days)					21.3
Cape St James	Tmin (°C)	1.4	1.6*	0.5	0.5	0.9
	Tmax (°C)	0.6	0.8	0.8	0.6	0.8
	Frost-free days (days)					15.6
Prince Rupert Airport	Tmin (°C)	2.1	2.1*	1.2	1.0	1.6*
	Tmax (°C)	1.2	1.2*	0.4	0.1	0.7
	Frost-free days (days)					46.3*
Prince George Airport	Tmin (°C)	4.0	2.8*	2.0*	0.7	2.2*
	Tmax (°C)	1.6	2.2*	0.8	0.5	1.6*
	Frost-free days (days)					21.3*
Summerland	Tmin (°C)	1.7	1.7*	1.2*	0.9	1.4
	Tmax (°C)	0.9	1.3*	0.5	0.8	0.7
	Frost-free days (days)					16.1
Cranbrook Airport	Tmin (°C)	2.1	2.4*	1.2	1.1	1.9
	Tmax (°C)	0.8	2.3*	0.6	1.3	1.2
	Frost-free days (days)					15.6
Kamloops Airport	Tmin (°C)	3.0	2.5*	2.6*	1.0	2.5*
	Tmax (°C)	2.2	2.4*	0.2	0.1	1.0
	Frost-free days (days)					34.8*
Golden	Tmin (°C)	2.2	2.5*	1.5*	1.0	1.8*
	Tmax (°C)	1.6	1.1	0.7	1.2	0.7
	Frost-free days (days)					18.2*
Fort St John	Tmin (°C)	5.3*	3.4*	0.8	0.6	2.4*
	Tmax (°C)	4.5*	2.9*	0.2	0.1	2.1*
	Frost-free days (days)					18.2*
Dease Lake	Tmin (°C)	3.7	1.9*	0.7	0.3	1.7*
	Tmax (°C)	3.2	2.4*	0.3	–0.5	1.0
	Frost-free days (days)					10.4
Fort Nelson Airport	Tmin (°C)	3.9*	2.5*	0.6	0.4	1.8*
	Tmax (°C)	3.9*	3.5*	0.4	0.3	2.1*
	Frost-free days (days)					12.5*

Source: Environment Canada: *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm*.

Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

Figure 2. Fifty-year trends in daily minimum and daily maximum temperatures shown as change in degrees Celsius since 1950.



Source: Environment Canada *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm*.

Note: The graphic shows generalized temperature changes for the region but is not meant to represent accurate temperature changes for specific areas or locations.

Interpretation

Data from BC climate stations (Table 2) show rising temperatures and fewer days with frost over a 50-year period at many stations in the province. The pattern was generally similar at the other 24 BC monitoring stations not displayed in Table 2. Most of British Columbia appears to be experiencing a pattern of warming consistent with what has been observed globally. No station shows a decrease in temperature over the period 1950–2001, and analysis showed that, averaged over the whole year, air temperature has been rising throughout the province. Winter and spring temperatures in British Columbia appear to be rising more rapidly than summer temperatures, which is the same trend other researchers have found over a similar period, 1950–1998 (Zhang et al. 2000).

The overnight minimum air temperature has been increasing faster than the daytime maximum, with most of British Columbia showing higher annual minimum temperatures (Figure 2). This is creating a climate with a narrower daily temperature range, a longer growing season, and fewer days of frost each year. The temperature increases have been least pronounced on the coast and more pronounced in northeastern British Columbia and in the Okanagan region. This pattern is consistent with the output of climate models.

2. Secondary Indicator: Long-term trends in precipitation

This is a status indicator. It addresses the questions: Are precipitation patterns changing? Is climate change affecting precipitation patterns in British Columbia?

Precipitation (along with temperature) is one of the two most important variables affecting terrestrial and coastal ecosystems.

Methodology and Data

Daily precipitation data were obtained from the Climate Research Branch of Environment Canada.

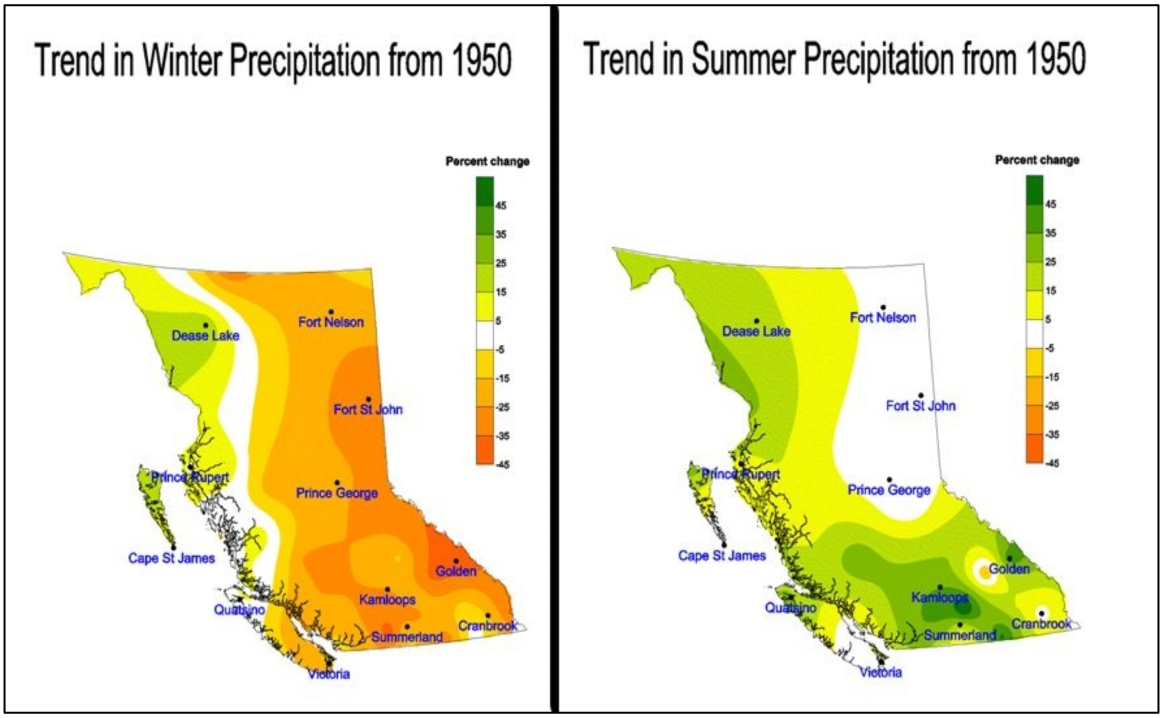
The analysis reported here used data from 40 climate monitoring stations in British Columbia (listed in Table 3). An additional seven stations in Alberta, Yukon, and Northwest Territories were used to aid contouring near the provincial borders. The trend analysis was limited to the period 1950–2001 because of gaps and a general lack of data at many stations before the 1950s. The quality-controlled precipitation data in Environment Canada's archives were adjusted to correct for non-climate-related changes, such as relocation of stations and instrument changes. The resulting datasets taken from *www.cccma.bc.ec.gc.ca/hccd/* are called Adjusted Historical Canadian Climate Data (AHCCD; Vincent and Gullet 1997; Mekis and Hogg 1999).

Table 3. Locations of the climate monitoring stations in British Columbia used in the precipitation analysis.

Agassiz	Grand Forks	Revelstoke Airport
Barkerville	Kamloops Airport	Sandspit Airport
Bella Coola	Kaslo	Smithers Airport
Blue River Airport	Kelowna Airport	Stewart Airport
Cape St. James	Langara	Summerland CDA
Comox Airport	McInnes Island	Tatlayoko Lake
Cranbrook Airport	Oliver STP	Terrace Airport
Creston	Port Hardy Airport	Vancouver Airport
Dease Lake	Prince George Airport	Vavenby
Estevan Point	Prince Rupert Airport	Vernon CS
Fort Nelson Airport	Princeton Airport	Victoria Airport
Fort St. James	Quatsino	Warfield
Fort St. John Airport	Quesnel Airport	Wistaria
Golden Airport		

Precipitation trends were mapped onto the provincial map with Surfer® (Golden Software) contouring and mapping software (Figure 3).

Figure 3. Fifty-year trends in summer and winter precipitation, shown as percentage change since 1950.



Source: Environment Canada *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm*.

Note: The graphic shows generalized precipitation changes for the region, but is not meant to represent accurate changes in amounts for specific areas or locations.

Interpretation

Total annual precipitation (1950–2001) has increased in several regions of British Columbia, with the Okanagan and North Coast regions showing the largest increases. Eastern British Columbia has been receiving less precipitation on an annual basis. The annual trends mask a more significant shift in seasonal patterns: with the exception of the North Coast, winter throughout most of the province has become drier (see Figure 3). Except for the Rocky Mountains, spring and summer have become wetter.

As shown in Table 4, most of British Columbia is experiencing drier winters, but wetter spring and summer conditions.

Table 4. Percentage change in precipitation over 50 years for 12 of the climate stations used in the analysis for Figure 3.

	Trend (%)				
Station name	Winter	Spring	Summer	Autumn	Annual
Victoria Int’l A	–16	13	–4	–3	–3
Quatsino	–1	22	31	14	13
Cape St. James	6	–4	–1	3	13
Prince Rupert A	3	2	11	31*	18*
Prince George A	–20	18	0	–3	–4
Summerland	–18	52*	21	4	19
Cranbrook A	–79*	20	0	–28	–28
Kamloops A	–25	46*	34	31	21*
Golden	–42*	32	42*	9	2
Fort St. John	–33	–12	–2	12	–8
Dease Lake	24	20	18	8	27*
Fort Nelson A	–21	–5	3	22	5

Source: Environment Canada *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm*.

Note: Asterisks indicate statistical significance. Probability, or chance, that there is no trend (α): <5%.

Overall patterns of temperature and precipitation have not changed in lockstep over most of the province. A few patterns that do appear for the province are:

- South Coast: spring has become warmer, but average precipitation has not changed significantly since 1950.
- North Coast: night-time temperatures are warmer in the spring and the region has become wetter over the annual cycle.
- Rocky Mountains and Northern Interior Plains: summers are warmer, with not much change in annual precipitation. Winters have become warmer and drier.
- Okanagan: springs are warmer and wetter.

3. Secondary Indicator: Coastal ocean temperature

This is a status indicator. It addresses the question: Is climate change affecting ocean temperature along the BC coast?

The temperature of the ocean affects coastal weather and climate. Ocean temperature is influenced by air temperature and, in turn, ocean temperature influences air temperature. Ocean temperature, with salinity, affects the survival, growth, and reproductive success of marine life and the productivity and composition of marine ecosystems.

Methodology and Data

The naturally large variability in ocean temperatures, due to cycles such as the PDO and ENSO, means that a very long series of observations is needed to detect underlying long-term trends. The longest water temperature series for the BC coast comes from daily surface observations taken at eight lighthouses and at the Pacific Biological Station in Departure Bay (Table 5).

Daily sampling at lighthouse stations is done at high tide only during the daytime. Because high tide occurs about 50 minutes later each day, temperatures are not taken at the same time each day. When the daytime high tide approaches 6 p.m., the sampling cycle starts again at 6 a.m. Because afternoon temperatures tend to be higher, this sampling protocol creates a 14-day signal as an artefact. The temperature of the water is measured with a thermometer, generally with an accuracy of about 0.2ºC.

Daily and monthly mean data were obtained from the Fisheries and Oceans Canada website (*www-sci.pac.dfo-mpo.gc.ca/osap/data*). The annual means reported here have been calculated from the monthly mean data for only those years where monthly mean values are available for all 12 months.

Table 5. Location of the stations providing data for the ocean temperature indicator.

Station	Latitude (°N)	Longitude (°W)	Year of first observation	Area
Langara Island	54°09’	133°02’	1936	North Coast
McInnes Island	52°10’	128°26’	1954	Central Coast
Pine Island	50°35	127°26	1937	Central Coast
Kains Island	50°16’	127°01’	1935	West Coast Vancouver Island
Nootka Point	49°14’	126°20’	1934	West Coast Vancouver Island
Amphitrite Point	48°33’	125°19’	1934	West Coast Vancouver Island
Departure Bay	49°08’	123°34’	1914	East Coast Vancouver Island
Entrance Island	49°08’	123°29’	1936	Strait of Georgia
Race Rocks	48°11’	123°19’	1921	Juan de Fuca Strait

The annual maximum and minimum sea-surface temperatures were determined from daily observations. Because there are gaps in the observations in some years, a maximum or minimum reading was included in this analysis only if observations were available for every day within seven days before or after the maximum or minimum and if the extreme reading occurred at a likely time of year. Extraordinary maximum and minimum records were used only when other observations around the same time indicated that the extreme values were probably real and not the result of an error. For extreme values likely to occur during the winter, the data are included in a given "year" beginning October 1 through to September 30 of the next year.

Trends were determined using the Microsoft Excel template MAKESENS. This template uses a nonparametric Mann-Kendall test to assess the probability that there is a trend statistically different from zero, and a nonparametric Sen's linear estimate for the slope of the trend line. Most series had significant autocorrelations at time lags of one and two sampling intervals, so the calculations were prewhitened using the procedure described in Wang and Swail (2001) until the trend and first-lag autocorrelation changed by less than 5% from one iteration to the next.

Note that other methods for computing trends yield slightly different results, both in terms of confidence intervals and the number of datasets showing significant positive trends. Regardless of the computational method, however, there is agreement in the overall finding that there are detectable and significant increases in sea-surface temperature.

Interpretation

Over the last 50 years, the ocean has become warmer all along the BC coast, as indicated by trends in the annual mean sea surface temperatures (Figure 4). Not all of the nine stations showed statistically significant trends, but for the five that do, all trends are positive. The annual mean temperatures for at least one station in each major coastal area had a positive trend that was significantly different from zero at the 95% confidence level. The largest and most significant increase was a warming of 0.9°C in 50 years for Langara Island, at the northwest tip of the Queen Charlotte Islands. The second largest change, 0.8°C in 50 years, was for Entrance Island, in the central Strait of Georgia.

More than half of the coastal stations show a significant increase in mean annual sea-surface temperature (Table 6). Fewer stations show significant trends in the annual maximum and minimum temperatures (Tables 7 and 8). The extreme values are more variable than the annual means, as shown by the greater standard deviations. The variations in annual mean sea-surface temperatures from year to year were only about 0.5ºC at any of the nine stations. This compares with an average annual range between minimum and maximum daily temperatures of 5 to16ºC.

Three of the nine stations show statistically significant increases in either the annual maximum or annual minimum temperature. The most statistically significant trend is an increase in annual maximum temperature at Entrance Island, 1.7°C in 50 years. The largest increase in the annual minimum is at Langara Island, 1.7°C in 50 years, but this is only weakly significant. These two stations also showed the largest trends in annual mean temperatures. It appears that the increase in the annual mean at Langara may reflect warmer winter waters, whereas the increase at Entrance Island reflects increased summer warming in the Strait of Georgia.

The water around Langara Island, at the extreme northwest point on the BC coast, is about 1.5°C colder than that around Amphitrite Point, on the southwest coast of Vancouver Island, for both annual mean and average annual extremes. At the present rate of increase, temperatures at Langara Island would resemble current conditions at Amphitrite Point in less than a hundred years.

Table 6. Mean annual sea-surface temperature at nine stations on the BC coast.

Station	First year	Latest year	Years used	Annual mean (°C)	Standard deviation (°C)	Trend (°C/50 years)
Langara Island	1941	2003	61	8.8	0.52	0.94*
McInnes Island	1955	2003	46	9.6	0.48	0.65
Pine Island	1937	2003	65	8.7	0.51	0.71*
Kains Island	1935	2003	68	10.2	0.55	0.43
Nootka Point	1935	2003	32	10.9	0.51	0.55
Amphitrite Point	1935	2003	68	10.4	0.52	0.50*
Departure Bay	1915	2003	68	11.1	0.50	0.29
Entrance Island	1937	2002	65	11.2	0.51	0.82*
Race Rocks	1922	2003	64	9.1	0.44	0.39*

Source: Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/data*.

Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

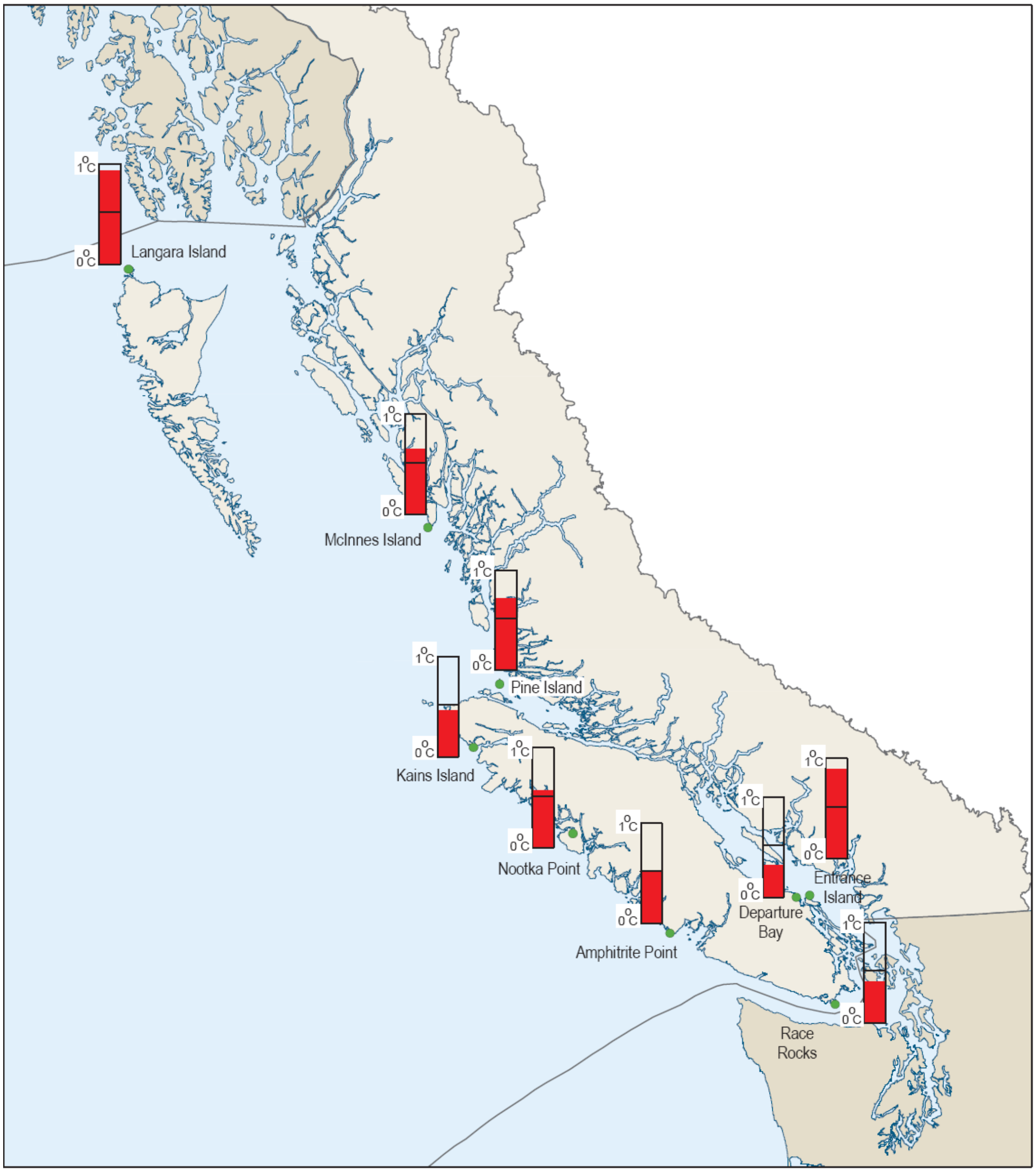
Table 7. Mean annual maximum sea-surface temperatures at nine stations on the BC coast.

Station	First year	Latest year	Years used	Mean annual maximum (°C)	Standard deviation (°C)	Trend (°C/50 years)
Langara Island	1940	2004	48	13.8	1.00	0.70
McInnes Island	1954	2004	43	15.2	0.79	0.81
Pine Island	1937	2003	65	11.6	0.82	0.34
Kains Island	1935	2003	64	15.5	0.86	–0.07
Nootka Point	1938	2004	32	18.4	0.97	1.13*
Amphitrite Point	1935	2002	58	15.2	1.06	0.60
Departure Bay	1915	2004	66	20.8	1.17	0.32
Entrance Island	1936	2004	68	20.6	1.30	1.69*
Race Rocks	1921	2004	79	12.5	0.91	0.30

Source: Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/data*.

Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

Figure 4. Rates of changes in sea-surface temperature (ºC/50 years) at nine lighthouse stations on the BC coast.



Source: Fisheries and Oceans Canada *www.pac.dfo-mpo.gc.ca/sci/osap/data*.

Note: Red bars indicate values that are statistically significant at <0.5%.

Table 8. Mean annual minimum sea-surface temperature at nine stations on the BC coast.

Station	First year	Latest year	Years used	Mean annual minimum (°C)	Standard deviation (°C)	Trend (°C/50 years)
Langara Island	1937	2004	47	4.8	1.22	1.72
McInnes Island	1955	2002	45	5.4	0.84	0.13
Pine Island	1939	2004	62	6.7	0.75	0.68*
Kains Island	1935	2004	64	6.2	1.09	0.57
Nootka Point	1937	2004	33	4.8	1.22	–0.06
Amphitrite Point	1936	2004	52	5.9	1.06	0.14
Departure Bay	1915	2003	65	4.0	1.73	0.80
Entrance Island	1937	2004	64	5.1	1.24	–0.26
Race Rocks	1922	2003	70	6.4	0.88	0.51

Source: Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/data*.

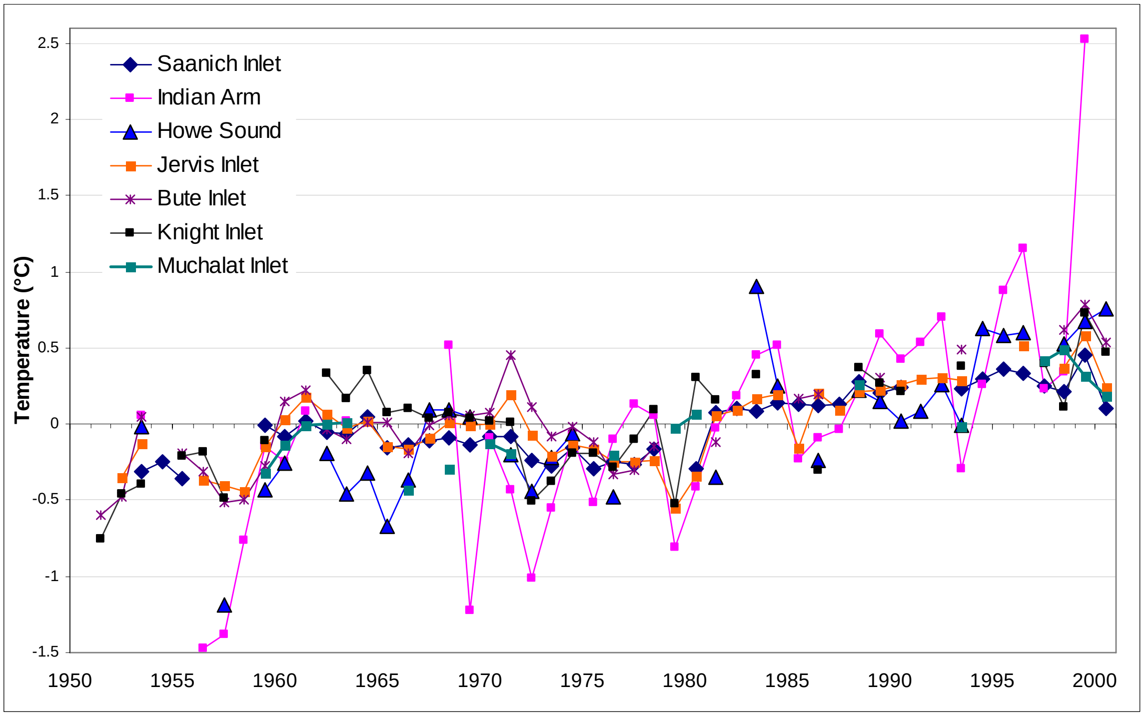
Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

Supplementary Information: Deep-Water Warming

A warming trend in the ocean along the southern BC coast also shows in the deeper waters of five inlets on the mainland coast and two on Vancouver Island (Figure 5). Consistent with the temperature trends shown in the sea-surface indicator, all seven inlets showed a warming of 0.5 to 1.0°C over the last 50 years.

Note that the graph displays temperature anomalies that depart from the average (set as 0°C) over the period for each time series. Bottom water temperatures in the inlets generally range from 6.5 to 8.5°C.

Figure 5. Deep-water temperature anomalies for inlets in southern British Columbia. Zero represents the average over the period for each time series.



Source: Ocean Science and Productivity Group, Institute of Ocean Sciences, Fisheries and Oceans Canada *www-sci.pac.dfo-mpo.gc.ca/osap/projects/bcinlets/intro_e.htm*.

Note: Observations were collected from at least 200 m below the surface, so they are not subject to the same daily and tidal temperature variation as surface waters. Sampling was less frequent than shore station observations, typically once per year, with frequent gaps of several years between sampling.

4. Secondary Indicator: Sea level on the British Columbia coast

This is a status indicator. It addresses the questions: Is sea level rising along the BC coast? How will climate change affect shore zones in British Columbia?

One widely publicized consequence of global warming is a projected rise in sea level. Rising sea levels are due partly to an increase in the volume of water as it warms and expands and partly to the increased flow of freshwater from land as melting ice adds to the total volume of water in the oceans (Miller and Douglas 2004). Combined with extreme weather, a rise in sea level may result in more frequent flooding and salt contamination of low lying areas, as well as storm damage to areas and structures previously above high water.

Methodology and Data

Water levels along the British Columbia coast are recorded by tide gauges at stations maintained by the Canadian Hydrographic Service and the Water Survey of Canada. Some recording stations have records going back to 1909, although there are gaps for some years. Water level observations consist of short averages of the position of a float in a vertical tube or stilling well. The stilling well is connected to the nearby ocean by a small hole or tube, removing most of the effect of short-period disturbances like wind-generated waves or vessel wakes. Early gauges recorded on paper charts were read manually to provide values hourly and at high and low water. More recent equipment electronically records a 1-minute average every minute. The vertical position of the gauge is referred to nearby geodetic benchmarks. Zero is set to correspond to nautical chart datum, which has traditionally been the level of lowest normal tides.

For this indicator, climate trends were examined using data from four tide gauge stations with long records that were considered broadly representative of three of the four coastal oceanic regions (Table 9). No data series was long enough to detect trends for the fourth oceanic region, the outer coast of the Queen Charlotte Islands.

Table 9. Annual change in mean sea level since first year of records at four locations on the BC coast.

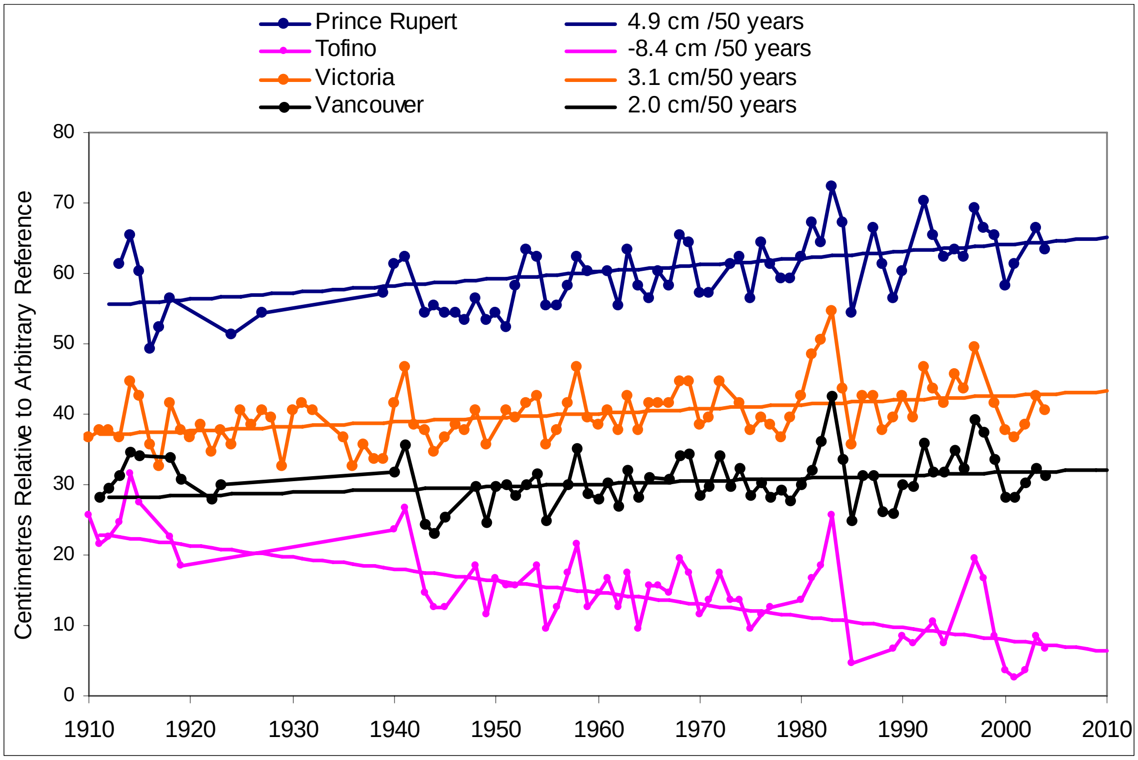
Station	First full year	Latest full year	Years used	Annual mean (cm)	Standard deviation (cm)	Trend (cm/50 years)	Chance of no trend
Prince Rupert	1913	2004	68	384.7	4.9	4.9	<0.05
Tofino	1910	2004	60	213.5	6.3	–8.4	<0.001
Vancouver	1911	2004	69	305.7	4.8	2.0	>0.1
Victoria	1910	2003	90	187.4	4.0	3.1	<0.01

Source: Marine Environmental Data Service, Fisheries and Oceans Canada.

Sea level data were obtained from the Marine Environmental Data Service (MEDS) of Fisheries and Oceans Canada. Trends were fitted to annual mean values to assess mean sea level rise. The means were based on all available data, including observations read manually from chart recordings not presently available in digital format. Except for Victoria, each station had some years missing. Even the most complete years were missing data for a few days. The data for Vancouver had not been adjusted for changes to the datum (the zero point of the scale) for the years between 1910 and 1957. The annual means were recalculated for Vancouver for those years, using the values corrected for the datum change, by adding 61 cm from 1910 through 1948 and 12 cm from 1949 through 1957.

Trends were determined using the Microsoft Excel template MAKESENS. This template uses Sen's linear estimate for the slope of the trend line and uses a non-parametric Mann-Kendall test to assess the probability that there is a trend statistically significant from zero. Most series had significant autocorrelations at time lags of one and two sampling intervals (years), so the calculations were iterated using the procedure described in Wang and Swail (2001) until the trend and first-lag autocorrelation changed by less than 5% from one iteration to the next. Removing the effects of autocorrelation provides a statistically reliable estimate of the trend. To display the trends on one graph, the data were rescaled by adding a unique elevation to all the data for each station. Results are shown in Figure 6.

Figure 6. Changes in annual mean sea level at four locations on the BC coast.



Source: Marine Environmental Data Service, Fisheries and Oceans Canada.

Note: Trend lines were fitted using MAKESENS.

Interpretation

The analysis of sea level records shows that relative sea levels have been rising at Prince Rupert, Vancouver, and Victoria, but falling at Tofino. Differences between stations are explained on the basis of geological processes, which cause vertical movements of the shoreline that partly or completely cancel the effects of an expanding ocean. The landmass of British Columbia is rebounding vertically after the massive ice sheet melted approximately 10,000 years ago—a process called isostatic rebound. The rate of rebound along the coast is estimated to be 0 to 4 mm per year. Also, the western edge of the North American continent is sliding over adjacent oceanic plates, resulting in crustal uplift estimated to be as high as 4 mm per year along the southwest coast of Vancouver Island near Tofino (Peltier 1996). The effect is that the measured water level drops as the coast (and the zero datum point) rises.

The level of water against the BC coast also varies cyclically. The largest effects (with typical range of variation in parentheses) recorded by tide gauges (J. Garrett, pers. comm.) are associated with:

- tides, at periods as long as 19 years and as short as 4 cycles per day (5 m);
- variation in the large-scale ocean circulation, such as ENSO (30 cm);
- variation in atmospheric pressure (30 cm);
- variation in winds or "storm surges" (less than 1 m in BC waters);
- seasonal variations in ocean temperature and salinity due to variations in freshwater discharge from coastal rivers (less than 10 cm).

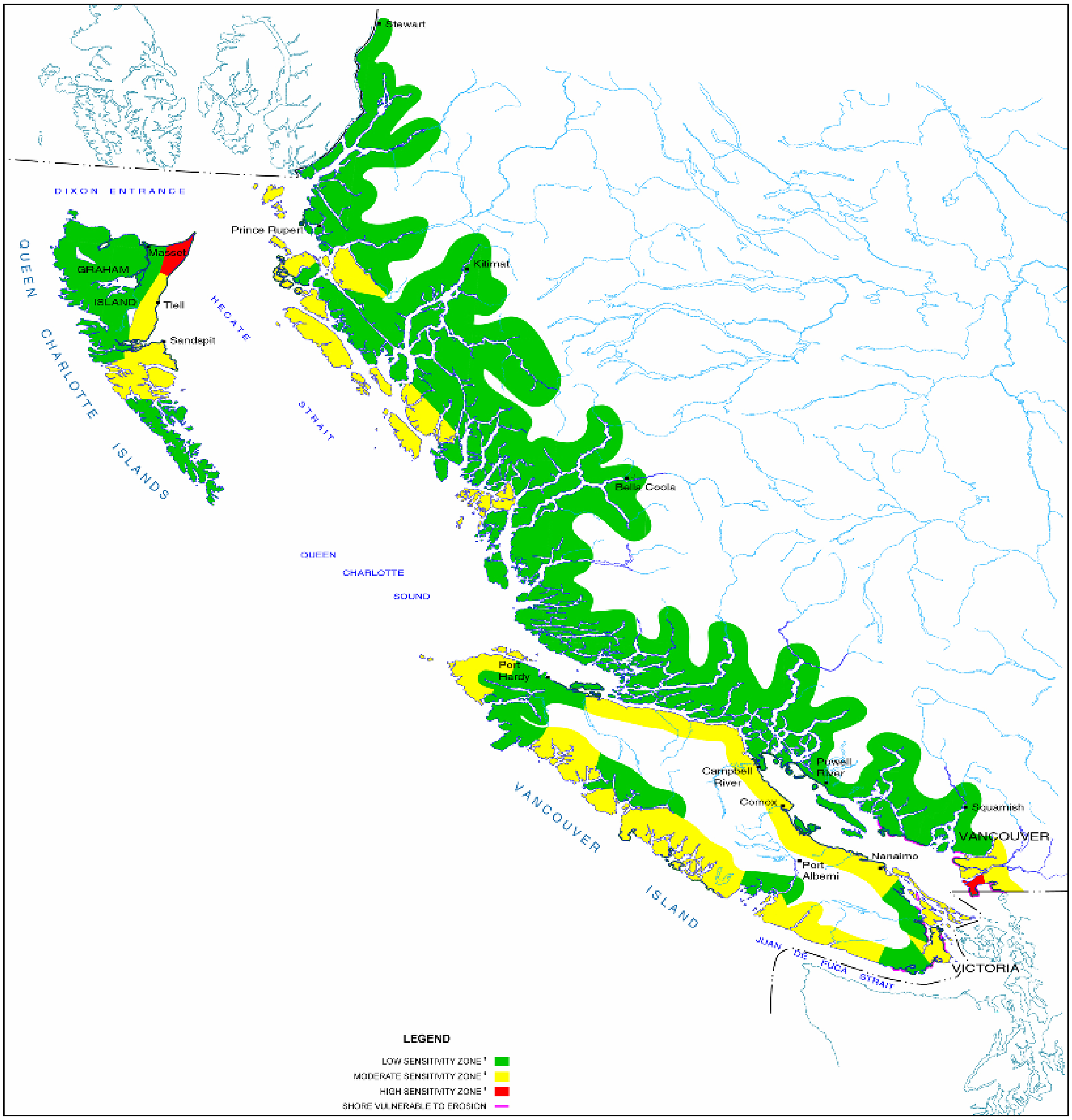
The magnitude of these effects means that interannual changes in mean sea level can be greater than the cumulative rise over the entire period. From 1980 to 1983, mean sea level rose by 12 cm in Victoria and Vancouver and by 10 cm in Prince Rupert. However, from 1983 to 1985 it declined by 19 cm in Victoria, 17 cm in Vancouver, and 18 cm in Prince Rupert. Both of these changes were associated with an ENSO event. Nevertheless, at all stations except Tofino, continuing the long-term trend in sea level would result in mean and extreme relative sea levels higher than have yet been observed. At Tofino, it is expected that relative sea level will continue to fall, exposing more of the shoreline until the next major subduction zone earthquake causes coastal land to drop.

In the long term, global mean sea level is projected to rise by 0.09–0.88 m between 1990 and 2100 (IPCC 2001b). The rate and magnitude of sea level rise are not uniform over the globe; they differ with ocean basin, reflecting variations in ocean heating and the way in which ocean currents redistribute the heat and water mass. One indication of what might be happening in the northeast Pacific Ocean is provided by measurements of the expansion of the upper 1000 m of the ocean water column due to warming and decreased salt content between 1956 and 1986. This suggests a contribution of 1.1 mm per year to the overall rate of sea level rise (Thomson and Tabata 1989).

Supplementary Information: Sensitivity of the BC Coast to Sea Level Rise

Rising sea level is a practical concern on the BC coast. Parts of the Lower Mainland coast are particularly vulnerable to erosion and flooding under extreme weather conditions (Figure 7), but areas with rocky, relatively steep-sided fiords are not considered sensitive to rising sea levels, flooding, or erosion from extreme wave action. Sections of British Columbia's coast that would be the most sensitive to rising sea levels include the Fraser Delta and the Naikoon area of the Queen Charlotte Islands, which is presently eroding. These areas are vulnerable to flooding and erosion from waves, which could reach into areas not normally washed by the sea. In these areas, changing weather patterns may give rise to more frequent occurrences of unusually high or low sea levels, resulting in flooding of low lying areas or exposure of normally submerged areas (Beckman et al. 1997).

Figure 7. Sensitivity of the BC coastline to sea level rise and erosion.



Source: Hay & Co. Consultants 2004.

WHAT IS HAPPENING IN THE ENVIRONMENT?

As shown by the trends in the indicators presented in this paper, the climate in British Columbia has changed in the last half-century. Average air temperature has become higher in many areas. Overnight lows have been increasing faster than daytime highs, resulting in fewer nights with frost. Air temperature on the coast has been less affected than in the interior and northeast of the province. Springtime temperatures are generally warmer over the whole province. With the exception of the north coast, winters have become dryer throughout most of the province. Although this coincides with a period in which the PDO shifted from its cool phase to a warm one in the late 1970s, the method of analysis for temperature and precipitation trends used in these indicators was designed to remove bias in the records due to such cyclic influences.

Sea surface temperature has risen over the entire coast, with the North Coast and the central Strait of Georgia showing the largest increases. Deep-water temperatures have also increased in five inlets on the South Coast. With the exception of areas of the coast being pushed up due to geological processes, relative sea level has risen along parts of the BC coast over the century.

The direction and spatial pattern of the climate changes reported for British Columbia are consistent with broader trends in North America and the type of changes predicted by climate models for the region. Table 10 presents the range of predictions from eight global modelling centres for the north and south coast of the province as well as the central and northeastern interior. The analysis shows that by 2050, there is significant likelihood of warming in both winter and summer for coastal and interior regions. There is less agreement among the model outcomes for changes in precipitation, with some predicting drier winters on the south coast and others wetter winters. Generally the model results show that for much of the province, winters will likely become wetter and summers drier.

Table 10. Range of predicted changes in winter and summer temperature and precipitation by 2050 for four regions in British Columbia.

BC location	Temperature change by 2050 (ºC)		Precipitation change by 2050 (%)	
	Winter	Summer	Winter	Summer
North Coast	0 to 3.5 warmer	1.5 to 3 warmer	0 to 25 wetter	–25 to +5
South Coast	0 to 3 warmer	1.5 to 5 warmer	–10 to + 25	–50 to 0 drier
Central Interior	0.5 to 4.5 warmer	1.5 to 3.5 warmer	0 to 30 wetter	–20 to 0 drier
Northeast Interior	0 to 6 warmer	1.5 to 3 warmer	5 to 30 wetter	–15 to +20

Source: From data in the Canadian Institute for Climate Studies, University of Victoria (*www.cics.uvic.ca*) study of model results from eight global climate modelling centres. A total of 25 model runs using the eight models were used to determine the range of values under different IPCC emission scenarios (Nakicenovic and Swart 2000).

Note: Values shown are net changes for 2050 relative to the base period, defined as average temperature and precipitation for summers and winters during the period 1961–1990.

Global climate models are considered low resolution because they employ grids that are generally 400 km across at Canadian latitudes, and thus are not well suited for detailed regional assessment. One method of increasing regional detail is to run higher resolution regional climate models over a smaller area, nested inside the global models. A team of researchers at Université du Québec à Montréal and Ouranos Inc. are developing and testing the Canadian Regional Climate Model (CRCM) that provides 45-km resolution. Some early results can be found at *www.cccma.bc.ec.gc.ca* and a description of the methodology is available at *www.mrcc.uqam.ca*. Other regional climate models are being developed and will be run over North America in the coming years (see *www.narccap.ucar.edu/*). When a suite of these models is available covering British Columbia, it will be possible to develop more detailed impact assessments.

WHY IS CLIMATE CHANGE HAPPENING?

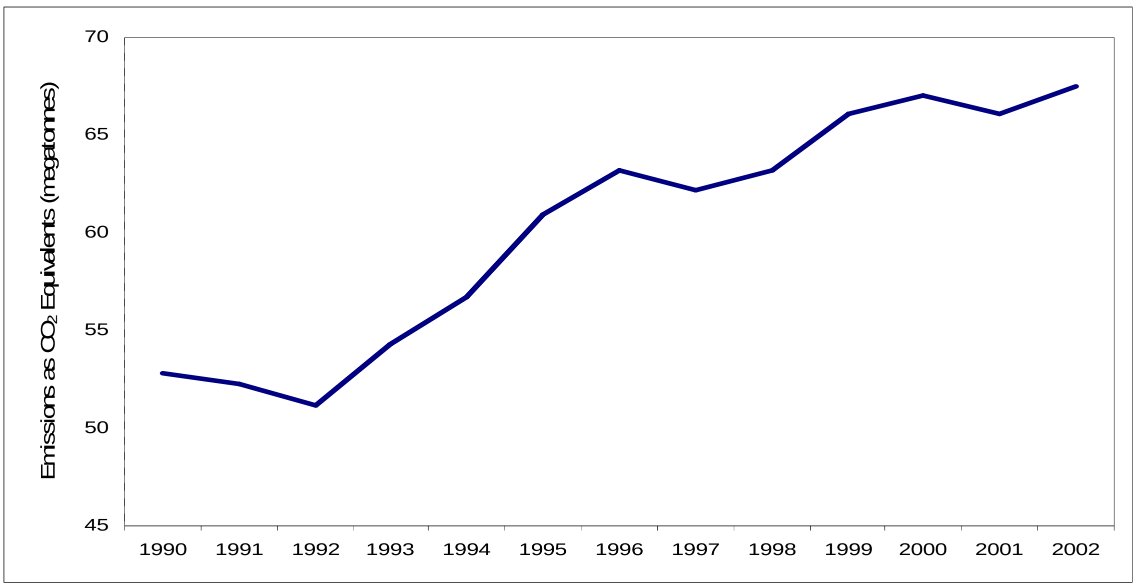
Carbon dioxide in the world's atmosphere has risen from its pre-industrial concentration of about 280 parts per million (ppm) to about 375 ppm today. Along with increasing concentrations of other greenhouse gases, this rise is causing the atmosphere to trap more heat. Although water vapour is a greenhouse gas, and there are natural sources of other greenhouse gases, most climate scientists agree that emissions of CO_2 due to fossil fuel burning are, and will continue to be, the dominant influence causing atmospheric CO_2 concentrations to rise during the 21st century (e.g., IPCC 2001b). This means that human activity is largely responsible for the increase in the gases causing rising air temperature. Climate models show that increasing concentrations of CO_2 could raise the global average surface temperature an additional 1.4–5.8ºC by 2100 (Houghton et al. 2001).

CO_2 EQUIVALENTS

Different greenhouse gases are more or less efficient at trapping solar energy. Therefore, to enable comparisons, greenhouse gases are described in terms of the amount of CO_2 (in metric tonnes) that would cause the same effect as an amount or mixture of other greenhouse gases. This measure is then used to compare the emissions of different greenhouse gases based on their global warming potential.

From 1990 to 2002, British Columbia's greenhouse gas emissions rose an average 2.1% per year. Emissions rose from 51.2 million tonnes of CO_2 equivalents in 1992 to 67.5 million tonnes in 2002 (Figure 8). This is better than the Canadian average (which rose an average of 2.8% annually). However, compared to other provinces, much of British Columbia's population lives in a relatively mild climate that does not require as much energy for winter heating. Another advantage is that the province obtains much of its electricity from hydroelectric generation rather than fossil fuel burning. Greenhouse gas emissions per capita in BC were 16.4 tonnes of CO_2 equivalent in 2002. This continues an upward trend that started in 1997, when emissions were 15.4 tonnes per person (e.g., BCMWLAP 2002a); however, British Columbia remains the province with the third lowest per capita emissions in Canada.

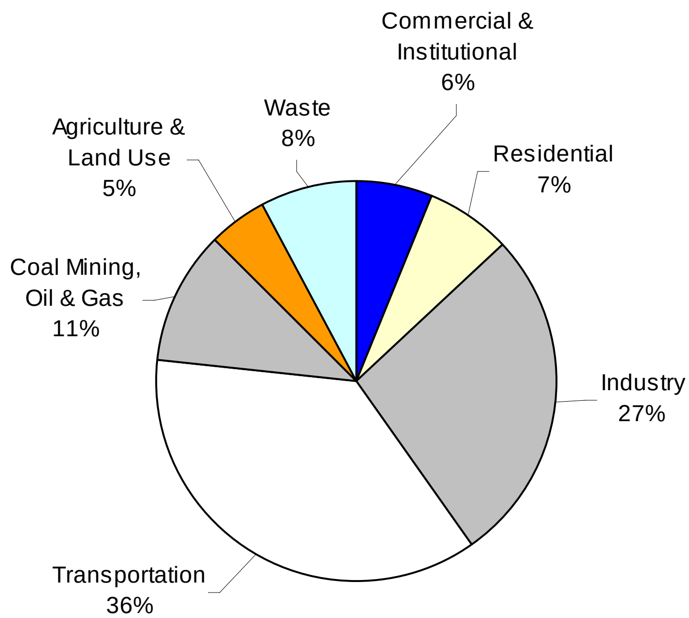
Figure 8. Total greenhouse gas emissions in British Columbia 1990 to 2002 in megatonnes of CO_2 equivalents.



Source: Environment Canada 2003, *www.ec.gc.ca/pdb/ghg/1990_02_report/ann10_e.cfm*.

More than 90% of the greenhouse gas emissions in Canada are associated with the consumption and production of energy. Figure 9 shows the sources of greenhouse gas emissions in the province. The largest source is the transportation sector, which includes commercial and private vehicles of all kinds. Of particular concern for coastal British Columbia is a recent report forecasting significant net increases in emissions from marine vessels in the Lower Fraser Valley region. This source is expected to increase the CO_2 equivalent emissions for that region by 52% over the next 20 years (GVRD 2003).

Figure 9. Sources of greenhouse gas emissions in British Columbia (2002).



Source: Environment Canada 2004.

WHY IS CLIMATE CHANGE IMPORTANT?

For British Columbia, the type of climate-related changes predicted for the 21st century include:

- a reduced snow pack in southern BC and at mid elevations;
- an earlier spring freshet on many snow-dominated river systems;
- reduced summer stream flows, particularly on snow-dominated river systems;
- glacial retreat and disappearance in southern BC;
- warmer temperatures in some lakes and rivers;
- reduced summer soil moisture in some regions;
- increased frequency and severity of natural disturbances such as fire, diseases, pest outbreaks;
- large-scale shifts in ecosystems and loss of ecosystems, including some wetland and alpine areas;
- an increase in growing-degree days.

Such changes will affect communities and the provincial economy. The type of socio-economic impacts that may occur were seen in 2003 when some parts of the coast and the Southern Interior experienced the most serious drought conditions in more than a hundred years. Utilities rationed water, cattle were culled, and salmon died from heat stress in waters that were too warm. Dry forest conditions contributed to some of the worst forest fires in provincial history. The total cost of the 2003 fires is estimated at $700 million (Filmon 2004). Although the extreme events of 2003 may be a weather anomaly, they are also consistent with global projections of an increased probability of extreme weather (Stott et al. 2004).

Another example of the link between climate change and large socio-economic impact is the spread of mountain pine beetle in British Columbia, which threatens most of the merchantable pine in the province and will cause major changes in local economies (see text box).

CLIMATE CHANGE OPPORTUNIST: MOUNTAIN PINE BEETLE

Warmer winters and longer growing seasons of recent years are associated with the current mountain pine beetle outbreak in British Columbia. The larvae of the beetles overwinter in pine trees. In the early stage, the larvae are vulnerable to cold winter temperatures, but late-stage larvae can withstand temperatures close to –40ºC. With a longer growing season, more larvae reach the cold-hardy stage before winter sets in, and with fewer cold winters, more survive through to the following year. It is anticipated that as the climate warms, the beetle will significantly expand its range in British Columbia (Carroll et al. 2002). Forestry researchers now believe that the beetle population is so large and widespread that it is predicted to kill more than 80% of mature pine trees in the province by 2020 (Eng et al. 2004).

WHAT IS BEING DONE ABOUT CLIMATE CHANGE?

Reducing greenhouse gas emissions on a global scale is expected to slow the rate—and possibly the magnitude—of climate change. However, IPCC scientists estimate that greenhouse gas emissions must be reduced by 50–60% just to stabilize global atmospheric concentrations of carbon dioxide at 500 ± 50 ppm (nearly double the pre-industrial concentration) by the middle of the next century (Pacala and Sokolow 2004).

The 1992 United Nations Framework Convention on Climate Change—supported by most nations including Canada and the United States—stated that global atmospheric concentrations of these gases must be stabilized at a level that would prevent dangerous interference with the climate system. The largest international agreement on climate change is the Kyoto Protocol, which came into force internationally in February 2005, after being ratified by 140 nations. It calls on the 35 most industrialized nations to reduce fossil fuel emissions of carbon dioxide and other greenhouse gases to an average 5.2% below 1990 levels. Canada ratified the Kyoto Protocol in 2002, committing to reduce total greenhouse gas emissions across the country to a level 6% below that of 1990. It commits Canada to reaching this target by 2012.

Improvements in energy efficiency in Canada reduced the growth in energy consumption by 13% from 1990 to 2002 (Behidj et al. 2004). Despite increased efficiencies, however, energy use continues to grow as the Canadian population and economy expand. For example, greenhouse gas emissions from the residential sector in Canada were 8% higher in 2002 than in 1990 (Behidj et al. 2004). Global emissions of most greenhouse gases have increased since 1992 (Houghten et al. 2001).

Even if countries succeed in reducing future greenhouse gas emissions, the excess greenhouse gases already in the atmosphere are expected to continue to drive climate change and its impacts for centuries. An effective response to climate change therefore also includes long-term planning to adapt to the impacts.

In 2005, the federal government released the report "Moving Forward on Climate Change: A Plan for Honouring our Kyoto Commitment" (see *www.climatechange.gc.ca*). With the change in government, the plan is currently under review.

In December 2004, the province released "Weather, Climate and the Future: BC's Plan." The plan outlines how the province will work with the federal government, industry, local government, and individuals to address climate change. It lists 40 actions aimed at reducing greenhouse gas emissions and adapting to climate change. The Plan establishes a provincial target to maintain or improve on BC's ranking as the third lowest emitter of greenhouse gases per capita among the provinces. In addition to this aggregate target, specific targets will be set for agriculture, buildings, government operations, and other sectors (see *www.env.gov.bc.ca/air/climate/index.html*).

Five main areas of the Plan emphasize:

- cost effective actions that both address greenhouse gas emissions and enhance competitiveness;
- efficient infrastructure and opportunities for innovation;
- management of forest and agricultural land to enhance carbon sinks and reduce impacts in BC forests;
- reduction of emissions from government operations, increased public outreach, and establishment of partnerships with other jurisdictions;
- research to improve understanding of impacts on water resources and to increase capacity to adapt to droughts and floods.

The industry and business sectors in the province are responding to the challenge of reducing greenhouse gas emissions. Here are just a few of many examples:

- Duke Energy has completed three acid gas reinjection projects at facilities in northeastern British Columbia that reduce their annual greenhouse gas emissions to the atmosphere by approximately 140 kilotonnes.
- Lafarge North America rebuilt its Richmond cement plant with new technology in 1999, reducing their greenhouse gas emissions from burning fuels by more than 25%.
- Telus's Vancouver head office saved an annual 520 tonnes of greenhouse gas emissions through a state-of-the-art renovation. By reusing steel and concrete during the renovation, Telus also avoided 15,300 tonnes of greenhouse gas emissions that would have been emitted had new materials been used.
- Green Buildings BC, a BC Buildings Corporation initiative, has supported and monitored four pilot building programs whose energy savings are 26–41% better than the Model National Energy Code for Buildings standard.
- VanCity Credit Union offers energy efficiency loans tailored to businesses, and is the first financial institution in Canada to introduce a low-interest Clean Air Car Loan for hybrid vehicles.

WHAT CAN YOU DO?

Individual Canadians are responsible for about one-quarter of all greenhouse gas emissions, mainly from energy used for driving and in the home.

A very important step consumers can take is to consider fuel economy when purchasing a vehicle. Road transportation is responsible for almost a quarter of all greenhouse gas emissions, amounting to 15.6 million tonnes in 2003 for British Columbia. Personal transport, made up of cars and light trucks together, accounts for about two-thirds of this figure and is the largest single emissions category in the province and across the country.

Despite advances in technology, the fuel economy of the average Canadian's personal vehicle has actually been getting worse since 1986, largely due to the popularity of light trucks, a class of vehicles that includes sport utility vehicles (SUVs) (Schingh et al. 2000). Although new vehicles are cleaner and more efficient than those produced 20 years ago, trends show increasing numbers of heavier and more powerful vehicles, travelling greater distances, which leads to higher total fuel consumption and increasing emissions of CO_2.

DID YOU KNOW THAT:

- When driven for 25,000 km, an average car saves about 2 tonnes of greenhouse gas emissions compared to an average light truck or SUV. It costs 42% more for fuel to drive the same distance in an average light truck than in an average car. There is an even greater saving in driving a small, fuel-efficient car.
- Idling for 10 minutes a day can produce about a quarter tonne of CO_2 emissions each year.
- About 70% of cars and light trucks have at least one tire that is over- or under-inflated. Maintaining the correct tire pressure could reduce vehicle greenhouse gases by at least one-eighth of a tonne each year.
- A compact fluorescent light bulb lasts up to ten times longer and uses a quarter of the electricity of a regular incandescent light bulb. Replacing all the bulbs in a home with compact fluorescent bulbs could reduce greenhouse gas emission by another eighth of a tonne annually.

Source: Canada's Guide to the One-Tonne Challenge, 2005.

Residential energy use is the second major area for reducing personal contributions to greenhouse gases. Households use energy mainly for space heating and cooling, hot water, lighting, and operating appliances. Even considering hydroelectric production of electricity in British Columbia, residential use is still a relatively large source of greenhouse gas emissions in the province (about 7.5% of the total).

Ways households can save energy and help reduce greenhouse gas emissions include:

- Obtain an energy audit for the home and follow recommendations to reduce consumption.
- Use automatic setback thermostats for night-time and periods of absence.
- Select lighting fixtures and bulbs that use less energy.
- Turn off lights and computer equipment at night.
- Select appliances with an Energy Star rating when purchasing new ones.

Much more information for individuals, communities, local government, and industry is available at these sources:

- The Greenhouse Gas Action Guide (*www.ghgactionguide.ca/*) describes initiatives in agriculture, transportation, and waste generation to help industry, business, and individuals reduce greenhouse gas emissions.
- The BC Climate Exchange (*www.bcclimateexchange.ca*) provides a clearinghouse for educational resources, ways to reduce emissions, and lists of events and funding opportunities.

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