IMPACTS OF CLIMATE CHANGE AND VARIABILITY ON TOURISM IN WESTERN NEWFOUNDLAND

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Impacts of Climate Change and Variability on Tourism in Western Newfoundland

by

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A thesis submitted to the

School of Graduate Studies

in partial fulfillment of the

Requirements for the degree of

Master of Science

Department of Geography

Memorial University

May 2009

St. John's Newfoundland

Abstract

Gros Morne National Park and Marble Mountain are primary attractions for tourists who enjoy outdoor activities. Ideal weather conditions can be defined for outdoor recreational activities during the summer or winter seasons. Climate change and variation influence the length of recreational seasons. The connections between changes and variations in climate conditions and outdoor activities were investigated using meteorological records and the linear trends of these parameters as measures of climate change and variation. Four weather stations were analysed as representative for Western Newfoundland: Daniel's Harbour, Deer Lake, Corner Brook and Stephenville. The mean parameters analysed were mean temperature, mean maximum and minimum temperature, total precipitation, snowfall, wind direction and wind speed monthly values. Daily mean maximum temperature, total precipitation, speed of maximum wind gust, snow on the ground, and hourly visibilities affect the suitability of conditions for outdoor activities.

Overall, the regional pattern shows a general temperature increase since 1933, most evident in summer and spring. Seasonally, winters recorded the highest variability in the number of warm and cold years. Spring, summer, and autumn recorded periods of strong variability of mean temperature between the early 1950s and mid-1990s. Prior to 1998-2007, the mean maximum and

minimum temperature showed substantial variation. All temperature parameters showed general increases in the decade 1998-2007.

All four sites show increases in precipitation and snowfall in all seasons throughout the available data series since 1933. Although in general summer outdoor activities show an increase of suitability for hiking and boat touring, differences between locations are dictated by wind speed and the number of days without precipitation. The tendency of variability of snow cover has a negative impact on snowmobiling and cross-country and back-country skiing.
Although there is a general decline in snow cover duration, the data show substantial variability. For instance, the record at Daniel's Harbour in 1964 showed 141 days with snow cover, and in the following year there was a record 205 days with snow cover.

Landscape touring remains a viable alternative for tourism under warmer summers and winters. Although evidence of climate change can be assessed by tourism operators, for planning and adaptation, increasing climate variability has potentially negative consequences for tourism, making planning outdoor recreational activities more difficult for both visitors and operators.

Acknowledgements

This research was partially funded by the Institute for Sustainability and Biodiversity, Environment and Conservation, NL; by an NSERC Discovery Grant and by Memorial University of Newfoundland. I am grateful to Dr. Norm Catto for his assistance and advice. I would like also to thank Dan and Mariana Deacu who supported my research with a desktop computer, my boyfriend Neculai Otoman for his financial and moral support, and our Secretary Carole Anne Coffey for all information and kindness provided throughout my study.

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1. Introduction and Focus of Study

1.1 Tourism in western Newfoundland

Tourism is one of the most rapidly growing service industries in western Newfoundland. In many communities, ongoing restrictions on fishing since 1992 have forced economic reorientation, with increased emphasis on petroleum exploration, mining, and aquaculture (Bergman 1997). Tourism is also seen as a key component of economic revitalization (Scott and McBoyle 2001). Recent celebrations, including the 500th anniversary of John Cabot's voyage (1997) and the 1000th anniversary of Leif Eirikson's landing at L'Anse-aux-Meadows (2000) have accentuated the visibility of the province to potential visitors from outside, as well as illustrating the potential economic impact of increased tourism. The tourism sector has become an important component of the Newfoundland and Labrador (NL) economy (Department of Tourism, Culture and Recreation Annual Report 1998, 2001).

Since 1992, non-resident tourism has been growing. In 1992 the total number of non-resident tourists in the province was 264,210, contributing $126.6 million to the provincial economy (Tourism, Culture, and Recreation, Provincial Tourism Performance 2003). Steady increases marked the intervening years. By 2007, the total number of non-resident tourists in the province reached 490,100 and the related total expenditures rose to $354.4 million (Tourism, Culture, and Recreation, Provincial Tourism Performance 2007)

Two key tourist attractions in Newfoundland are Gros Morne National Park and the Marble Mountain Resort. Gros Morne National Park was established in 1973, and was enshrined as a UNESCO World Heritage site in 1987.

Gros Morne National Park meets two of ten possible criteria for inclusion on the World Heritage List. Criterion VII refers to an area containing superlative natural phenomena or an area of exceptional natural beauty and aesthetic importance, while Criterion VIII refers to an outstanding example representing a major stage of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features (http://whc.unesco.org/en/criteria/). Gros Morne has thus been designated on the basis of the physical landscape.

Gros Morne is the most visible site in tourism materials produced by the NL government, and is promoted worldwide through a variety of media. Recorded visitation to Gros Morne in 2007 totalled 159,138, which represents 28% of the total of 566,734 tourists (non-resident and resident) who visited the province in that year (Tourism, Culture, and Recreation, Provincial Tourism Performance 2007). As visitation statistics record only those individuals who registered at the Visitor Centre, this figure represents a minimum estimate.

The Marble Mountain Development Corporation was established in 1988 to develop the Marble Mountain ski facility in the Humber River valley, between Deer Lake and Corner Brook. In 2007, total visitation was 88,152, representing 16% of the total number of Newfoundland tourists (Tourism, Culture, and Recreation, Provincial Tourism Performance 2007). As access is controlled and users of the Marble Mountain facility must pay for admission, the visitation total can be assumed to be accurate.

The prominence of these two attractions is the result of several factors, including increased national and international awareness, effective promotion, the inherent beauty and significance of the landscapes, improved facilities for tourists, and the quality of recreational opportunities, including summer hiking, kayaking, boating, and landscape tourism, and winter skiing and snowmobiling. However, factors such as fuel and transportation costs, accessibility and convenience of ferry and airline travel, competition from other tourism-related areas, and overall socio-economic conditions outside the province provide counterweights which can restrict tourism.

Gros Morne and Marble Mountain are therefore high-profile destinations. The regional significance of these two attractions is underestimated by considering the total number of visitors to the province, as the latter figure includes many travellers who do not leave the northeast Avalon metropolitan area.

1.2 Objective

The objectives of this study are:

- to determine the extent and potential impacts of climate change and variability on tourism to Gros Morne, Marble Mountain, and western Newfoundland in general; and
- to test the relationships between climate change and variation and tourism activities.

Climate factors potentially affecting tourism in Gros Morne and Marble Mountain will be analyzed. The investigation will consider both climate factors, including changes in precipitation, temperature, and wind velocity; and the impacts that changes in climate conditions could have upon tourism. Climate data used was collected from stations at Daniel's Harbour, Deer Lake, Corner Brook, and Stephenville.

1.3 Climate, Weather, and Tourism

Weather and climate have a major influence on tourism, particularly when a tourist is seeking to practice an outdoor activity.

1.3.1. Weather and Climate: Definitions

Weather is defined as the state of the atmosphere at a given time and is what tourists actually experience at a destination, thereby affecting their activities. *Climate* is the long term weather pattern, usually assessed over a 30-year period (the technical standard established by the World Meteorological Organization, and used by Environment Canada), and which can be expected as the statistical average condition at a location for a certain time (Scott *et al.* 2006a, 2006b). *Climate change* is any long-term significant change in climate, as measured over a minimum 30-year cycle.

Climate variability is used to denote deviations of meteorological conditions over a given period of time from the long-term average, without necessarily implying either change or an overall trend. Climate variability is measured by deviations of values of a meteorological parameter (anomalies) in a given region from the normal (mean) value for the same period (NSIDC Arctic Climatology and Meteorology Primer http://nsidc.org/arcticmet/).

Climate variations are considered as temporary shifts in meteorological conditions over time periods of one to several years, separate from any longer-term changes in climate (measured at least over a 30 year period). Variations can be cyclic, oscillatory (e.g. the North Atlantic Oscillation {NAO}), or random. Climate variation does not include individual weather events. Regions can experience either variation, change, or both conditions simultaneously (Catto 2006).

Separation of climate variation from change is important when considering impacts over different time scales. An ongoing change (e.g., increasing summer temperatures over 50 years) can be temporarily masked by weather events (a single cool summer within the 50-year interval). A climate change can also be masked by variation over a period of several years (e.g., alternating 2-3 year periods of cooler or warmer summers associated with oscillations such as the NAO). Where climate records are relatively short, or where tourism has developed relatively recently, separation of variations on the scale of ca. 2-5 years from change on the scale of ca. 30-50 years is desirable for an accurate assessment of impacts and prediction of effects over longer terms.

1.3.2 Tourism: Definitions

Tourism is defined as the activities of persons traveling to and staying in places outside their usual places of work and residence, the activities undertaken during their stay in those destinations, and the facilities created for their needs (Matheson and Wall 1982). While tourism is the practice of travelling for recreation, *recreation* is an activity in which individuals voluntarily engage for personal satisfaction and pleasure.

Outdoor recreation activities have been defined (Shivers 2002) as those activities that:

1. are undertaken outside – in open air;
2. do not involve organised competition or formal rules;
3. may require large areas of land, water or air;

4. May require an outdoor area of predominantly unmodified natural landscape;
5. may or may not require the existence of facilities or infrastructure; and
6. may or may not involve knowledge or skills.

Many outdoor recreational activities may only be practiced during a part of the year, usually either during the peak of the winter or summer season. Ideal weather conditions can be defined for every outdoor recreational activity during the summer or winter season, but many activities share similar meteorological limits (De Freitas 2001)

In order to reflect the significance of weather to seasonally oriented outdoor activities, Crowe *et al.* (1973, 1977) and Masterton *et al.* (1976, 1981) have defined a *winter recreational season* and a *summer recreational season.* The winter recreational season begins on the median date that snow cover reaches 2.5 cm depth and terminates on the median date of the last snow cover of 2.5 cm depth. *Spring thaw* represents a two-week period following the termination of winter.

The *summer recreational season* is composed of the spring shoulder, autumn shoulder, and high summer. The *spring shoulder* begins with the termination of the spring thaw and ends with the start of high summer. *High summer* begins on the date that the mean daily maximum temperature rises above 18°C and terminates on the date that the mean maximum temperature falls below 18°C.

The *autumn shoulder* begins with the termination of high summer and ends with the onset of winter.

The number and magnitude of temperature and precipitation anomalies are measures of climate change and variation. In addition, any linear trends of these parameters measured over decades represent climate change. Climate changes or variations will impact the suitability for outdoor activities at Gros Morne, Marble Mountain, and western Newfoundland in general.

Although the weather and climate impact tourism in many ways, this paper will focus on the influence of climate and weather on the length of recreational seasons. This influence affects the specific time when outdoor activities can take place, and which specific type of activity is suitable for each recreational season. The relationships between climate and tourism will be identified and assessed to determine the connections between changes and variations in climate conditions, and outdoor activities practiced by tourists in western Newfoundland.

1.4 Study Region

In this study, western Newfoundland is considered as the region extending along the Gulf of St. Lawrence coastline on the west coast of the island of Newfoundland, from Daniel's Harbour in the north through Corner Brook to Stephenville in the south. The study region includes the interior areas eastward to the eastern boundary of Gros Morne National Park and Deer Lake (Figure 1.1). As defined here, western Newfoundland includes the major tourist attractions of Gros Morne National Park and Marble Mountain, as well as the Humber Valley.

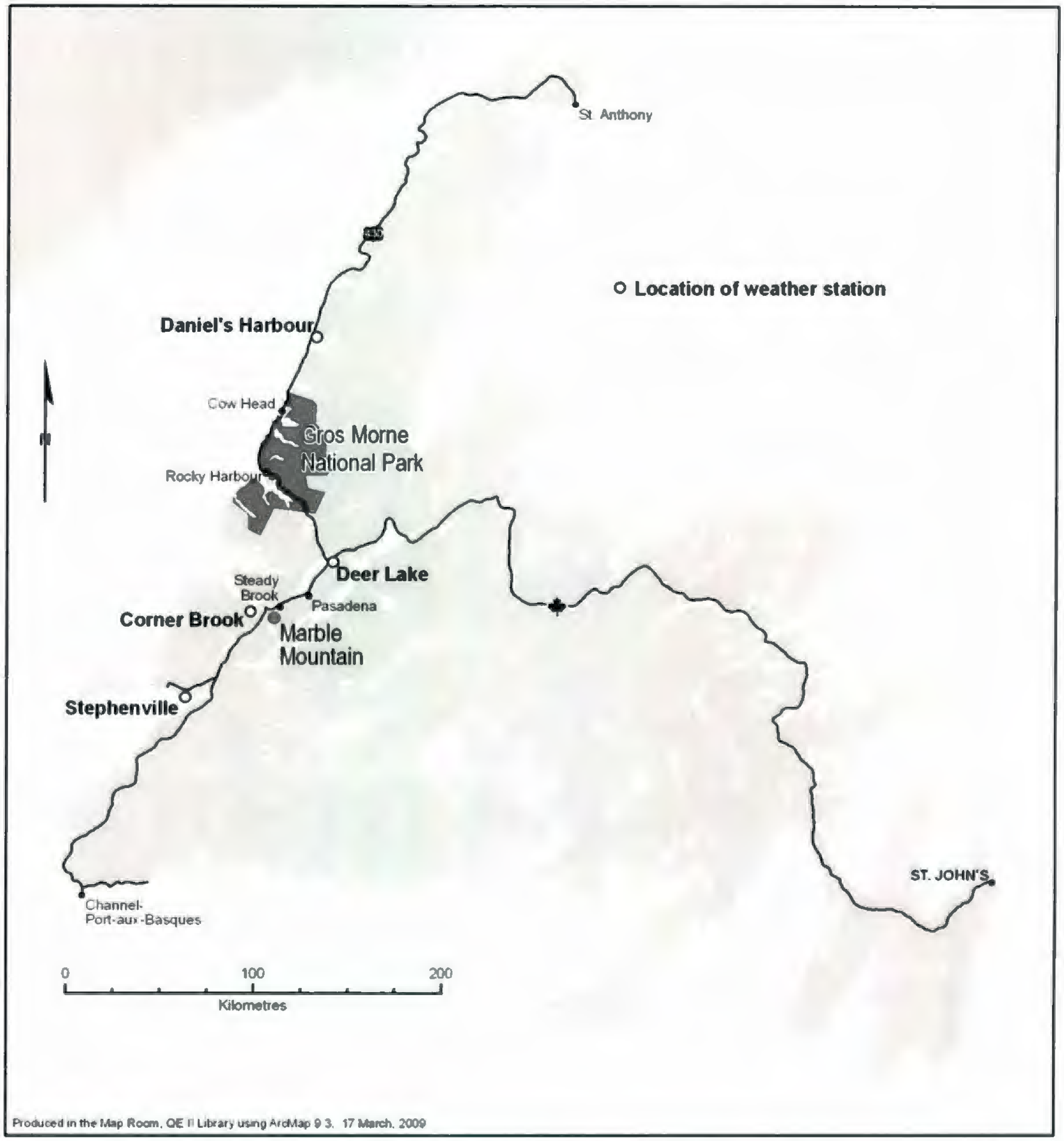


Figure 1.1 Study region, showing location of climate stations used in this study.

The Trans-Canada Highway, Viking Trail (NL Route 430), and other provincial highways connect the communities. Airports are located at Deer Lake and Stephenville. By automobile, Deer Lake is 20 minutes from Marble Mountain and 1 hour from Gros Morne. An automobile trip from Stephenville to Daniel's Harbour requires approximately 4 hours.

Surface transportation from North America depends upon Marine Atlantic's passenger ferries, departing daily from North Sydney, Nova Scotia. The sea journey ends at Channel--Port-aux-Basques, about a three hours drive on the Trans Canada Highway from Corner Brook and Marble Mountain Resort. The impact of climate and weather events on ferry operations and road traffic from Channel--Port-aux-Basques has been examined by Catto *et al.* (2006).

1.4.1 Gros Morne National Park

Gros Morne National Park (49°N, 58°W) encompasses 1805 km^2 (Berger *et al.* 1998; Figure 1.2). The park can be divided into two main physiographic entities: a narrow coastal plain, and the Long Range Mountains in the interior. Gros Morne National Park protects three eco-regions: the western Newfoundland forest, the Long Range Barrens, and the Northern Peninsula Forest. The coastal plain has a maximum width of 10 km in the northern part of the park, narrowing to the south. Numerous lakes and ponds are present in the coastal plain. The maximum elevation of the mountainous part is approximately 800 m.

Although domestic harvesting of wood by residents of enclave communities is permitted, 42% of the total area of Gros Morne National Park is covered with forest. The dominant tree species are balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), eastern larch (*Larix laricina*), and white birch (*Betula papyrifera*) (Roberts *et al.* 1998).

Parks Canada, the mandatory manager, recognizes Gros Morne National Park as a key tourism generator for the province. Interpretative and administrative facilities are concentrated at the Discovery Centre, near Woody Point. The mission of the Discovery Centre is to highlight interest in tourism and to link environmental protection with environmental education (http://www.pc.gc.ca/pn-np/nl/grosmorne/natcul/natcul12_e.asp).

Parks Canada recommends Gros Morne National Park as the ultimate destination for people who enjoy spending time in the outdoors and exploring. Within the Canada Park website the list under outdoor activities, which can be practiced in the park encompasses kayaking, boating and boat tours, hiking and wilderness hiking, cross-country skiing and snowmobiling, fishing, swimming, and picnicking. Within the Park boat ramps are located at Trout River Pond, Mill Brook, and Lomond. There are two boat tours offered within the park, the Tablelands Boat Tour that operates on Trout River Pond and the Western Brook Pond tour that operates on western Brook Pond. Other boat tours are offered in nearby communities and include tours of Bonne Bay and St. Paul's Inlet. There are more than 100 km of trails in the park and nine day-use areas facilities for picnics.

Figure 1.2 Gros Morne National Park Map

(http://www.pc.gc.ca/pn-np/nl/grosmorne/visit/visit7b_E.asp)

Enclave communities within Gros Morne National Park include Cow Head-Shallow Bay (population 495 in 2006; Statistics Canada 2006); St. Paul's (population 320); Rocky Harbour (population 1058), Norris Point (population 700), Bonne Bay (including Woody Point, population 435), and Trout River (population 630). The Cow Head-Shallow Bay area is a major tourist attraction because it has one of the best sandy beaches in Newfoundland. Cow Head hosts an annual Lobster Festival and Gros Morne Theatre Festival (http://www.cowhead.ca/).

The Rocky Harbour area contains the largest concentration of tourist-related facilities in the Gros Morne region. The town consists of six major areas spread along the coast: Lobster Cove, Woody Cove, Bear Cove, Bottom, Rocky Harbour Cove, and Rocky Harbour Pond (http://www.rockyharbour.ca).

1.4.2 Marble Mountain Area

Marble Mountain is located along the Humber Valley, southwest of Deer Lake and 10 km northeast of Corner Brook, directly south of the community of Steady Brook (Fig. 1.3). With an elevation of 546 m, Marble Mountain is part of the Long Range Mountains. The area occupies a series of steep ridges, forming part of the southern side of the Humber River valley.

Marble Mountain Resort offers 35 trails accessible by three quad chair lifts and a platter lift, and includes 70 hectares of skiing terrain (http://www.skimarble.com/). Marble Mountain's Governor's Express is the only high-speed detachable quad lift in Atlantic Canada. It is 1660 m in length (http://www.newfoundlandlabrador.com/Winter/Skiing.aspx) and has a ride time of approximately 8 minutes. Although the resort is open during the summer, downhill skiing is the primary reason for its establishment and continued financial viability.

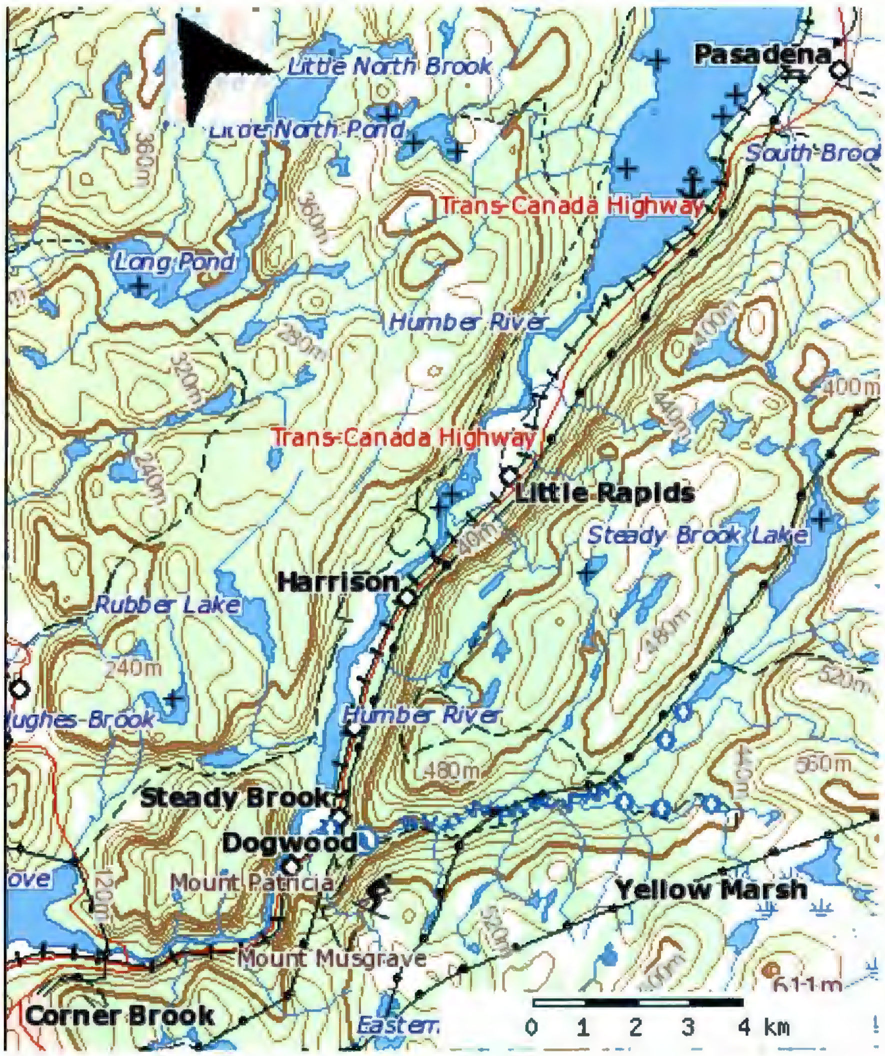


Figure 1.3 Marble Mountain Resort is located directly south of the community of Steady Brook. *http://atlas.nrcan.gc.ca/sites/english/maps/topo/map*

Steady Brook and Pasadena are the two nearest communities. Steady Brook had a population of 432 in 2006 (Statistics Canada 2006). Tourist attractions include the 'Heritage Tree', located at the entrance to Marble Mountain, and Steady Brook Falls, which tumble 30 m and are particularly spectacular after heavy rain or during snow melt in the spring. The local zipline is also a tourist attraction. The community also houses a museum of the fishery along the Humber River (Steady Brook town website).

Pasadena (2006 population 3,195; Statistics Canada, 2006) is located on the south shore of Deer Lake, 10 km northeast of Steady Brook. Beach Corp. Inc. operates a public beach open for family enjoyment throughout the summer. The Pasadena Ski Nature Park has over 19 km of groomed ski trails, 2 km of lighted trails for night skiing, 6 km of snowshoeing trails, and a ski chalet. Summer hiking and mountain biking are also promoted by the town (http://www.town.pasadena.nf.ca/).

1.5 Climate Stations

Environment Canada and its predecessors (including those outside Canada prior to 1949) have operated 10 climate stations throughout western Newfoundland. Of these, four climate stations were chosen to be representative: Daniel's Harbour, Deer Lake, Corner Brook, and Stephenville (Fig. 4). All are currently operated by the Meteorological Service of Canada, a branch of

Environment Canada. These stations were selected both by location and also because their records contain the longest available meteorological data series in western Newfoundland.

Station	**Location °N, °W**	**Elevation (m asl)**	**Years in Record**
Daniel's Harbour (DH)	50° 14.400' N, 57° 34.800' W	19.00 m	1946-2007*
Deer Lake	49° 10.200' N 57° 25.800' W	10.70 m	1933-2006*
Deer Lake Airport (DL)	49° 13.200' N 57° 24.000' W	21.90 m	1965-2007*
Corner Brook (CB)	48° 57.000' N 57° 57.000' W	4.6 m	1933-2006*
Corner Brook	48° 55.800' N 57° 55.200' W	151.80 m	1994-2007*
Stephenville Airport (ST)	48° 31.800' N 58° 33.000' W	24.40 m	1942-2007*

Table 1.1 Western Newfoundland Climate Station Locations

* Note that the data series are not continuous throughout the periods.

Source: *http://www.climate.weatheroffice.ec.gc.ca/advanceSearch*

The main climate parameters analysed were based on the following data recorded by Environment Canada:

1. Mean air temperature,

2. Mean maximum temperature,
3. Mean minimum temperature,
4. Total precipitation,
5. Snowfall,
6. Wind gust direction,
7. Wind gust speed.

Daily weather parameters obtained from the Environment Canada official website analyses included:

1. Snow cover ≥2.5 cm,
2. Maximum temperature ≥18°C.

Meteorological data quality for each station is presented in Appendix 1 for all meteorological parameters analysed for this study.

1.5.1 Daniel's Harbour

Daniel's Harbour (Figure 1.4) is located at 50° 14.400' N, 57° 34.800' W, 60 km north-northeast of the northern boundary of Gros Morne National Park, at 19 m elevation. Although the record contains many gaps, meteorological data recording began in 1946/1948 and was continued to 2007 for almost all parameters (Environment Canada, http://www.climate.weatheroffice.ec.gc.ca).

Daniel's Harbour remains a traditional Newfoundland fishing community. The community is encompassed by natural attractions, with interesting and beautiful beaches on the western side, and breathtaking scenery offered by the Long Range Mountains on the east. Total population is 290 (Statistics Canada 2006). The mean annual temperature is 3.2 °C, the mean total precipitation is 1054 mm, and the mean total annual snowfall is 364 cm (Table 1.2).

Figure 1.4 Topographic Map of Daniel's Harbour

http://atlas.nrcan.gc.ca/sites/english/maps/topo/map

Station	Mean Annual Temperature °C	Mean Annual Precipitation mm	Mean Annual Snowfall cm
ST	4.8	1238	374
CB	5	1186	411
DL	4.2	1034	285
DH	3.2	1054	364

Table 1.2 Mean Climate Parameters for all four Climate Stations

1.5.2 Deer Lake

Deer Lake (Figure 1.5) is the gateway to Gros Morne National Park. The town is situated around the northern end of Deer Lake, and on the banks of the Humber River. It is nestled in the foothills of the Long Range Mountains at the junction of the Trans-Canada Highway and the Viking Trail. Surrounded by lakes, rivers, forests, and mountains that offer the best of the Newfoundland outdoors, it promotes golfing, fishing, and sailing in summer, and skiing and snowmobiling in winter. The population in 2006 was 4,827 (Statistics Canada 2006). A particular attraction is the Newfoundland Insectarium.

The community was established to service the Newfoundland Railway and a hydroelectric power station. With the development of highway transportation after 1965, the centre of the community shifted along the Trans-Canada Highway. The decommissioning of the railway in 1989 left Deer Lake primarily economically dependent on servicing transportation and tourism.

At Deer Lake, meteorological data has been recorded at two stations. Between 1933 and 2006, meteorological measurements were determined from the station at 49° 10.200' N 57° 25.800', at 10.70 m asl. Since 1965, meteorological data has been collected from the station at the Deer Lake Airport at 21.9m asl. Data for snow cover, daily maximum temperature, and wind were recorded at the Deer Lake Airport station. The mean annual temperature is 4.2°C, the mean annual precipitation is 1034 mm, and the mean annual snowfall is 285 cm (Table 1.2).

Figure 1.5 Deer Lake Topographic Map

http://atlas.nrcan.gc.ca/sites/english/maps/topo/map

1.5.3 Corner Brook

Corner Brook (Figure 1.6) is the largest community in western Newfoundland, with 20,083 people (Statistics Canada 2006). The city was established to support the Newfoundland Railway, and is the site of the province's largest pulp-and-paper mill, a major contributor to the economy. Sir Wilfred Grenfell College (Memorial University) is also a significant employer. Maple Valley Industrial Park and numerous service industry businesses are also economically important (http://www.cornerbrook.com/).

Tourism is significant to Corner Brook. Tourist attractions include the Captain James Cook National Historic Site, the Railway Society of Newfoundland Historic Train Site, and the Corner Brook Museum and Archives. Outdoor-related attractions include the Corner Brook Stream Trail, boat touring and sailing on Humber Arm, hiking on Blow-Me-Down Mountain, and cross-country skiing on trails such as Blomidon Cat in adjacent Benoit's Cove. Hunting and fishing are also significant tourist attractions.

Two weather stations have been established at Corner Brook. The initial station was established in 1933. In 1994, another Corner Brook station was established at 48° 55.800' N, 57° 55.200' W at 151.80 m asl elevation, beside the old one. Both stations functioned simultaneously between 1994 and 2006, when the initial station was decommissioned. For this research, data from the first location was used because it provided almost continuous meteorological measurements from 1933 to 2006. Data missing between 2000 and 2007 for several months were completed from measurements provided by the new location at 151.80 m asl. The main climate parameters are listed in Table 1.2.

Figure 1.6. Corner Brook Topographic Map

http://atlas.nrcan.gc.ca/sites/english/maps/topo/map

1.5.4 Stephenville

Stephenville is 166 km northeast of the Marine Atlantic ferry terminal in Channel—Port-aux-Basques (Figure 1.7). The town of Stephenville was built on the shores of Bay St. George, with Table Mountain to the northwest and Indian Head Range to the east and northeast. The highest elevation on the island of Newfoundland island, 814 m above sea level, lies about 20 km north.

Banks, retail and wholesale businesses, restaurants, hotels, recreation facilities, government offices, schools, medical services, and a large variety of small businesses provide jobs for many people in Stephenville, and fuel the economy of the whole region. The population in 2006 was 8595 (Statistics Canada, 2006). Stephenville Airport, initially established in 1942, specializes in freight and commercial air service and is one of the air gateways for Corner Brook and Gros Morne.

Stephenville is adjacent to the ocean, lakes, rivers, forests, and mountains that exemplify the best of the Newfoundland outdoors. Harry's River, Fox Island River, Southwest Brook and Barachois Brook flow out of the mountains near Stephenville. All offer excellent kayaking, canoeing, and salmon fishing. Stephenville also offers opportunities for mountain bikers, hiking, snowmobiling and ATV enthusiasts.

The Stephenville climate station is located at the airport (48° 31.800' N, 58° 33.000' W) at 25.6 m asl elevation. This station has the most continuous record in western Newfoundland (almost 66 uninterrupted years), beginning in 1942 when the airport was constructed. The mean temperature at this location is 4.8 °C, mean total precipitation is 1238 mm and total snowfall is 374 cm.

Figure 1.7 Stephenville Topographic Map.

http://atlas.nrcan.gc.ca/sites/english/maps/topo/map

2. Previous Work

Research discussing the potential impacts of climate change on tourism has been conducted elsewhere in the world, although relatively little information is available for Atlantic Canada. This section initially considers previous research focused on climate and climate change in western Newfoundland, followed by a survey of research concerning the impacts of climate change on tourism.

2.1 Climate and Climate Change

Comprehensive summaries of the present climate of western Newfoundland are provided by Banfield (1981), Damman (1983), and Banfield and Jacobs (1998). The overall climate setting is influenced by the prevailing westerly winds and the proximity of the relatively cold waters of the Labrador Current system of the Atlantic Ocean (Hertzman 1997, Steyn *et al.* 1997). Mean February sea surface temperatures are less than 0°C (Markham 1980; Farmer 1981; Cote 1989). Local factors, including topography and local wind systems, create distinct regimes in many locations throughout western Newfoundland.

Deer Lake lies within the western Mountains and Central Uplands climate zone of Banfield (1981). The climate is classified as mid-boreal (modified Köppen-Geiger Dfb). Throughout the central part of the zone, the approximate daily mean temperature in January is -7°C, with a daily mean of 17°C in August (Banfield 1981; Environment Canada 2005). Temperatures are commonly 2°C to 4°C cooler at higher altitudes. Precipitation and the proportion of snow increase with altitude. At altitudes above 400 m asl in the Long Range Mountains, snow represents up to 70% of total precipitation, with amounts of more than 1000 cm (Martin 2004).

The West Coast climate zone (Banfield 1981) extends along the Gulf of St. Lawrence coastal plain, including the area from Stephenville northeast to Daniel's Harbour. Strong winds and periodic thaws limit the mean annual duration of snow cover to less than 70 days in many exposed coastal areas. The combination of substantial precipitation and low summer temperatures, however, result in limited evaporation during the summer months. The excess of precipitation over evaporation locally exceeds 100% during some summers, as well as throughout the winter months, creating a perhumid moisture regime and allowing wetlands to develop.

Banfield and Jacobs (1998) analysed the climate of Gros Morne National Park. The succession of weather stations adjacent to the park is discussed, and results compared to those from recently established auto-stations at the Visitor Centre, Big Level (Martin 2004) and Brassy Brook. Measurements from the Daniel's Harbour station, used in this thesis, were also used for calibration purposes. The trends identified by Banfield and Jacobs (1998) are consistent with the historical record at other eastern Canadian coastal locations (Morgan *et al.* 1993) and with those from Corner Brook (Hickman 2006). Banfield and Jacobs (1998) also consider the ratio of snowfall to rainfall as a measure of mild and cold winters. Mild winters are associated with low ratios of snowfall to rainfall (1979, 1981, 1983 and 1984), compared with cold winters marked by high snow-rain ratios (1990-1994).

Investigations concerning changes in meteorological data in western Newfoundland were conducted in conjunction with regional surveys by Morgan *et al.* (1993), Lewis (1997), Pocklington (1998), Lines and Pachura (2005), and Vasseur and Catto (2008). Morgan *et al.* (1993) analysed trends in the annual mean temperature record at coastal stations in eastern Canada since 1900. St. John's was chosen as representative for Newfoundland. St. John's recorded a similar pattern to those in the Maritimes, with a general rise during the first half of the century, a peak near 1950, followed by a general decline with periodic maxima (late 1960s, 1980). The linear trend during this century is positive with a warming of 0.4^{O}C. Spring, summer, and autumn for eastern Canada show lower amplitude variability than winter. Mean temperature differences between successive winters often exceed 4°C, and winter temperatures dominated the annual patterns.

Lewis (1997) looked at temperature and precipitation trends in Atlantic Canada compared with global and Canadian trends for both parameters. He noted a significant warming trend from 1895 with a peak in the mid 1950s, followed by a cooling trend into the 1990s. On a seasonal basis, the only warming trend of significance was for the summer season for the period 1895-1992, with a warming of 0.8°C. The complete seasonal picture of temperature trends for the period 1948-1995 included: winter temperature decrease -2.2^{O}C, no significant change in spring, summer temperature increase of 0.5^{O}C, and autumn decrease of -0.8^{O}C. During the period between 1895-1991 minimum temperatures increased by only 0.2°C and maximums increased by 0.4°C. Precipitation showed an increase since 1948 of ca. 10%. The results for the analyses of temperature and precipitation extremes for the period 1944-1990 for Atlantic Canada included: a decreasing trend in the number of days per year with a maximum temperature above 25^{O}C; an increasing trend in the number of days per year with minimum temperature below -15°C; an increasing trend in the number of daily precipitation events above 20 mm; and a very slightly increasing trend in the number of daily snowfall events above 15 cm. The available data suggested that variability between years and within seasons was more significant than overall change.

The data available until ca. 1995 and reported by these authors suggested that overall cooling, induced by both cooler winters and the dominant influence of the positive phases of the North Atlantic Oscillation (Hurrell 1995; Topliss 1997) could result in overall cooling for Atlantic Canada in general, and for Newfoundland in particular (Pocklington *et al.* 1994; Lewis 1997; Morgan and Pocklington 1997; Pocklington and Morgan 1997; Pocklington 1998). Tentative explanations proposed for these phenomena included the role of aerosols in reducing temperature and increasing precipitation, the accelerating influence of the NAO, and the role of onshore winds and changing ice cover. Subsequent data from 1995-2007, in combination with more recent research, have resulted in substantial modification of these initial conclusions.

Lines *et al.* (2003) and Lines and Pachura (2005) continued investigations into temperature and precipitation changes in Atlantic Canada. They noted a general increase in temperatures from the early-1990s, the end of the data series considered by Lewis (1997) and Pocklington (1998), through to 2005. Subsequent research (summarized in Vasseur and Catto, 2008) has substantiated these conclusions. The decade from 1998-2007 was marked by generally warmer and wetter conditions in Atlantic Canada, although with much variability. Warming trends were less evident in eastern Newfoundland than in western (Lines and Pachura 2005), but warming in western Newfoundland was less significant than in Maritime Canada. The available data suggest that trends identified in eastern Newfoundland (e.g. St. John's) were not necessarily replicated in western Newfoundland. Similar observations were made concerning the impact of wind regimes and the NAO on precipitation, temperature, and coastal storms and storm surges (Catto and Hickman 2004, 2006; Hickman 2006; Catto *et al.* 2006). The effect of the NAO, dominant in eastern Newfoundland (Catto *et al.* 2003), was relatively minimal or non-existent in southwestern Newfoundland (Karn 2004; Ingram 2005; Catto *et al.* 2006; Catto 2006, 2007). The new data and research efforts since 1997 have re-emphasized the significance of both local and regional factors in climate investigations, and have also highlighted the significance of variability in influencing the temperature and precipitation recorded at meteorological stations in western Newfoundland.

In Corner Brook, data from both the official Environment Canada weather station and from a privately-maintained record in Curling indicate an overall increase in mean annual precipitation over the period since 1950. This has resulted in increased potential for flooding in the city and around Humber Arm (Catto and Hickman 2004, 2006; Hickman 2006). Rain-on-snow flooding events, which cause significant socio-economic damage to Corner Brook and the Humber Arm communities, show increasing frequency related to a variety of causes (Hickman, 2006; Catto 2008).

The regional impact of climate change and variation in Atlantic Canada was investigated in a study commissioned by Natural Resources Canada, involving more than 100 collaborators, contributors, and informants (Vasseur and Catto 2008). Climate modelling data indicate increases in both mean annual temperature and precipitation for Atlantic Canada as a whole and western Newfoundland in particular. By 2050, there would be a 2 to 4 C° increase in summer temperature and a 1.5 to 6 C° increase during the winter. Coastal areas would record lesser changes than interior regions in term of temperatures. Precipitation will increase in the future, following the trend established since 1948. Variability, both seasonally and year by year, will be more evident.

Vasseur and Catto (2008) also conducted a sectoral analysis, including the anticipated impacts of climate change on tourism in Atlantic Canada. Where the natural environment is the most significant attraction, environment conditions are an important factor for tourists to visit a destination. The impacts of climate change on tourism in Atlantic Canada could be both positive and negative. Rising sea level, increased coastal erosion, storm activity, and vulnerable infrastructure due to erosion have negative impacts on tourism in coastal regions. A change of winter season duration and distribution of snow would negatively affect winter recreational activities such as skiing and snowmobiling. The study noted that further research in this area was required.

2.2 Impacts on Tourism

Some guidelines for study of climate change impacts on tourism in western Newfoundland are provided by previous research. The connections between climate change and tourism and recreation have been investigated for various sectors in North America (Scott *et al.* 2006a, 2006b, 2006c), South Africa (Preston-Whyte and Watson 2005), the Alps (Elsasser and Burki 2002), and Australia (Skinner and de Dear 2001). Scott *et al.* (2005) developed a comprehensive bibliography of implications of global climate change for tourism.

Skinner and de Dear (2001) developed a climatology based on thermal comfort in order to meet the need for information required by tourists from cooler climates about the potential problems of warmer climates. They divided Australia into three main regions based on summer severity. Climate-based conflict between tour operators and the government can occur, as when tour operators objected to the closing of a trail in the Uluru-Kata Tjutu National Park by the National Parks and Wildlife Service on hot days, for safety reasons. The Uluru-Kata Tjutu National Park is one of Australia's most significant tourist attractions, particularly with international visitors. Thermal injuries can range from mild heat exhaustion to serious heat stress, heatstroke and, in some cases, death. These clearly indicate a need for some risk management and safety strategies. In response, in 1988 the National Parks and Wildlife Service implemented a policy of park closures at 11:00 on days when the Australian Bureau of Meteorology forecasted maximum temperature at the nearby Yulara aerodrome to exceed 36^{O}C. The Australian research emphasizes the point that climate is a resource for the tourism industry, and like any resource, it requires prudent management.

Preston-Whyte and Watson (2005) noted that in South Africa, among the various kinds of tourism available there is continuing demand for landscape tourism, as well as viewing the diverse endemic flora and fauna. The purpose of their study was to assess the impact of warming and aridification on this kind of tourism. The anticipated disappearance of one-fifth of the temperate forest as a result of aridification by 2050 would negatively affect popular hiking trails. An example is the 67 km coastal trail through Knysna Park in Cape Province, the park's key attraction. Also, the trail is predicted to be affected by a 25 cm rise in mean sea level by 2050. Warming has reduced Kilimanjaro Mountain's ice-capped spatial extent by 82% since 1980 (Preston-Whyte and Watson, 2005), which also will reduce its attraction to visitors. Changes in distributional and compositional flora can affect the migration of ungulate herbivores, which are also an important tourist attraction.

Among several efforts that summarize the significance of climate for outdoor activities, many have a descriptive character. Climate change is considered within planning processes for tourism and recreation (e.g. Potter, 1965; Perry, 1972, 1973, 1997; Mieczkowski, 1985; De Feritas, 1990, 2001; George, 1993; Smith, 1993; and Wilton and Wirjanto, 1998).

Wilton and Wirjanto (1998) focused on the idea that inter-annual climate variability influences the length and quality of recreation seasons and the profitability of the tourism industry. The purpose of their study was to estimate the dimension of seasonal component in several Tourism Indicators for the period 1986-1997, and to discuss the importance of seasonality for different tourism indicators. Their results indicate that there is a sharp and pronounced seasonal pattern in Canadian tourism expenditures. Over the 1986 to 1997 period, third quarter (summer) tourism expenditures account for 43% of annual tourism expenditures, compared to only 17% in the first and fourth quarters. Tourism expenditures on accommodation, vehicle rentals, and recreation and entertainment have the most severe degree of seasonality, while tourism expenditures on passenger air transport have the least degree of seasonality. All tourism commodities have a seasonal peak in the third quarter, except for tourism expenditures on travel agency services, which peak in the first quarter. They suggest that a long term climate warming trend could increase domestic tourism in Canada.

De Feritas (2001) considered weather and climate together with geographical location, topography, landscape, flora and fauna as a natural resource for recreation and tourism. Climate can be treated as an economic asset for tourism. From this point of view, to assess climate for tourism purposes, a major problem is the selection of meteorological or climatological criteria. Only after solving this issue can the next step be addressed, which involves answering three main questions:

- When is the best time to visit?
- What clothing and equipment is needed?, and
- What are the weather hazards or climate extremes likely to be?

The type of climatic data and manner it is presented in tourism climate research depends on the way information can be used by tourist planners, operators, and the individual tourist. For instance, ski facility planners need information on the length of the snow season, and the individual skier wants seasonal distribution of probabilities that snow cover will be reliable for skiing at a particular location and time.

Another issue of climate data used for a tourism point of view is that standard meteorological or climate station data may not be representative of the recreational area - valleys, hills, coast, or beach. Climate station-data are intended to be representative of the bottom of the atmospheric column (usually adjacent to a major population centre) rather than a particular microclimate or location such as beach, park or ski slope. De Feritas' (2001) work is comprehensive and offers a multitude of applications to tourism climate research. It also includes discussion of previous work on climate and tourism with a view to identifying what concepts and theoretical frameworks are important for the present, and what future research should be conducted.

Impacts on specific activities have been investigated by several researchers in Canada. Earlier studies considered the recreational climates, without investigating the possibility of change. Masterton *et al.* (1976a) analysed the tourism and recreation climate of the Prairie Provinces. Tourism and outdoor seasons were defined and a two-season approach was taken. The percentage frequency of suitable activity days by ten-day period was mapped. The seasons' quality was determined by accumulation of days suitable for particular activities. Three classes for each outdoor activity were determined on the basis of a range of values. For example, Class I skiing conditions, where the season is longest, occur in central and northern Alberta and the adjacent Peace River area of British Columbia. Winter suitability patterns for snowmobiling were very similar to those for skiing. Summer activities were grouped into landscape touring, passive activities, vigorous activities, and beach activities. Restrictions were noted: e.g., Class I for vigorous activities was restricted by a combination of high temperature and high humidity in southern Alberta. Suitable days for beach activities ranged from zero (northern Manitoba) to over 50 days (southeast Alberta and southwest Saskatchewan).

Masterton *et al.* (1976b) analyzed recreational climatology of the National Capital Region (Ottawa), to describe the influence of climate on patterns of outdoor recreation, including the nature of activities. This research found that weather is a significant factor in determining the nature of outdoor recreation activities, and that personal comfort is enhanced when tourists are informed about weather conditions and their implications. Climate conditions limiting outdoor recreational activities included unduly hot, humid summer days and winter days without snow cover. Climate should be considered as a resource when planning recreational areas and facilities.

Crowe *et al.* (1977) considered the tourism recreation climate of Ontario. The data used included observations collected across Ontario for approximately 100 years at about 400 locations. For summer and winter, the elements of climate that significantly influence tourism and outdoor activities were defined. The effects of variations in these climatic elements upon recreation were expressed qualitatively and quantitatively in term of satisfaction indices. The relationships then were standardized to facilitate comparisons between activities and regions and used to develop a generalized index of suitability for winter and summer climate. The study used hourly station records of temperature, wind, humidity, visibility, cloudiness and precipitation to define the suitability of the weather at a specific time for a particular activity or group of activities. After the weather demands for a recreation pursuit have been determined, they then analyzed the weather records for each winter and summer day and decided whether or not the day could be considered satisfactory.

Scott *et al.* (2004, 2005, 2006a) assessed the influence of climate change on 15 Canadian Parks including Terra Nova National Park. Climate influences tourism directly by influencing:

- length and quality of tourism and recreation seasons;
- visitor participation/demand; and
- participants' satisfaction with the experience (e.g., hiking in warm, sunny conditions vs. cold rain or extreme heat).

Indirect influences include impacting the physical resources (e.g., snow cover, biodiversity, water levels) on which nature-based tourism depends.

Visitation to Canada's national parks is projected to increase, even under the most conservative climate change scenario. The assessment of park visitation also considered the potential impacts of demographic change through to the mid-2020s, and the possible synergistic impacts of climatic and demographic change. The synergistic effect of climate and demographic changes is projected to increase visitation, with the largest increase occurring in national parks located in eastern Canada. Visitor increases of 6% to 8% are projected for the 15 national parks analyzed for the 2020s with increases of 9% to 29% by the 2050s. Most of the increases are projected to occur outside of the traditional peak summer tourism season.

Winter activities, particularly skiing and snowmobiling, have been studied by several researchers. In the Swiss Alps, Elsasser and Burki (2002) underlined that the lack of snow at the end of the 1980s left a persistent imprint on the tourism industry. In a climate change environment, the modal elevation of snow-reliability will rise from 1200 m up to 1800 m over the next few decades. Only 44% of the ski resorts would then be snow-reliable.

Burki *et al.* (2005) showed that in a less snow-reliable skiing region, skiers will respond flexibly to changing snow conditions. During a period of snow-poor seasons, as expected more often under a changing climate, 49% of the skiers would change to a ski resort that is more snow-reliable, and 32% of the skiers would ski less often. They concluded that the most vulnerable ski resorts will be those in the lower regions of the Alps. Climate change will have a serious negative impact on the target group of tourists of these resorts: younger skiers, novice skiers, and day tourists.

Scott and Jones (2006b) used the baseline period 1961-90 to model natural snow cover in Ontario and Québec areas to simulate ski seasons. The ski operations model was then run with two climate change scenarios to project changes in the season length of alpine skiing in the 2020s, 2050s and 2080s. Their findings indicated that the winter recreation in Canada is at risk from climate change. The alpine skiing industry in Ontario and Québec is projected to be negatively impacted. Snowmaking will help minimize the negative impact of less natural snow in the decades to come, but the associated economic costs may become too high for some smaller ski operations. Warm-weather recreation in Canada is projected to benefit from changes in the climate. For example, it is projected that demand for campgrounds will increase, and a warmer climate could lead to the extension of current camping seasons in the decades to come.

McBoyle *et al.* (2007) indicate that in the Atlantic region, although sufficient winter precipitation is generally available, the maritime climate has frequent mid-winter thaws and rain events that adversely affect the snow pack for snowmobiling. This suggests that snowmobiling in this region could be particularly vulnerable under a changed climate. The results show that snowmobiling seasons in the Atlantic region (particularly the Maritimes) are among the shortest in North America, averaging no more than six weeks (41 days) in the 1961–90 baseline. In the 2020s, the average length of snowmobile seasons in this region were projected to be reduced between 35% and 62% (season reduced to between 12 and 16 days) and 39% and 50% (season reduced to between 11 and 20 days) under the least-change (NCARPCM B21) and warmest (CCSRNIES A11) climate change scenarios, respectively.

Climate change impacts on summer tourism in Canada have received less attention, with the primary focus on golf. Lamothe and Periard Consultants (1988) used the Crowe *et al.* (1977) criteria for defining a climatologically desirable golf day to assess the impact of climate change on the length of the golf season in Southern Québec. They estimated that for 2050, the golf season would be extended 6 weeks from its current 29-week average season.

Scott *et al.* (2006c), in order to assess the potential impact of climate change on golf participation, developed a multiple regression analysis that included three weather variables (maximum and minimum temperature, precipitation amount) and one temporal variable (day of the week). Their results indicated that golf participation would increase in the Greater Toronto Area even under the most conservative climate change scenario. The model projected increases in annual rounds played in the range of 5.5% to 13.5% in the 2020s and 7.7% to 23.7% in the 2050s even if golf courses did not adapt their operating seasons to new climatic conditions.

Thus, there are several studies which indicate the impact of climate change on tourism, particularly in terms of the lengths of recreational seasons and the suitability for specific activities such as skiing, snowmobiling, and golf. For western Newfoundland, the most important tourism attractions are Gros Morne National Park and Marble Mountain. It is thus opportune to assess the impact of climate change on the main outdoor activities for these attractions.

3. **Temperature Variations and Change**

3.1 Introduction

From the total of ten weather stations operated by the Environment Canada Meteorological Service, four were selected as representative: Daniel's Harbour, Deer Lake, Corner Brook, and Stephenville. The parameters analysed to assess climate variability and change were mean temperature, mean maximum and minimum temperature, precipitation, and wind direction and speed.

Although the historical weather observations within Gros Morne National Park at Rocky Harbour station and Grassy Brook auto-station are limited to the past 25 years, assessment of variability and climate change for this region is possible from the Daniel's Harbour records (Banfield and Jacobs 1998; Martin 2004). Analysis of West Newfoundland temperatures is limited to the 75 years since 1933, when data was first recorded. The time-series records from all the stations contain gaps due to missing data. Comparison between adjacent stations can alleviate some of the difficulties due to missing data. At Corner Brook, for example, partial data from the years 2001, 2002, 2003, 2006, and 2007 are provided by the record of the Corner Brook station at 151.80 m altitude, whereas all other data from Corner Brook were collected from the first station, at 4.60 m altitude. A summary of all available data is presented in Appendix 1.

Several methods to compensate for gaps in the time-series data were considered. The possibility of assuming values for missing data based on the means of the previous and subsequent three years was evaluated, but rejected due to the highly variable nature of the existing record. Averaging of temperature data to account for missing months was also rejected, as gaps in data series commonly encompassed entire or multiple seasons. Ultimately, these methods of accounting for missing data were rejected, and years with substantial amounts of missing data were not included in the analysis. In some instances, data from adjacent stations (e.g. at Corner Brook) were used to supplement incomplete records.

Annual averages for the years with missing data were not considered in the analyses, although complete data for individual seasons were included. For example, records from a station which included complete data for the summer season but lacked data from the autumn were included in analyses of summer conditions, but were excluded from autumn or yearly analyses. Data quality for each station and for each parameter discussed in this chapter is presented in Appendix 1.

Anomalies for the constituent three month seasons (spring, summer, autumn, winter) and annual analyses were determined for the four stations at Daniel's Harbour (DH), Deer Lake (DL), Corner Brook (CB), and Stephenville (ST). Spring includes March, April, and May; summer, June, July, and August; autumn, September, October, and November; and winter, December of one year followed by January and February of the next year.

The purpose of this chapter is to analyse the changes and variability at each station individually. Comparisons among the four stations are useful to assess regional trends, although individual stations may show deviations from the general pattern in western Newfoundland. Linear trends, if present, would indicate increasing or decreasing temperature, amounts of precipitation, and wind activity over long-term periods.

Environment Canada (e.g. Lines *et al.*, 2003) define the multi-annual average values for the period 1971-2000 as the Climate Normals for that period. Negative temperature anomalies indicate periods that were colder than the mutli-annual average for 1971-2000, and positive values indicate warmer than normal conditions. Values of anomalies between 1 and -1 C° are considered lie within the Normal temperature or multi-annual average. Values ≤ -1 C° are considered as cold years (colder than the multi-annual average) and those ≥ 1 C° are considered as warm years (warmer than the multi-annual average).

Each meteorological parameter is sequentially discussed for all four stations. Subsequently, analyses of overall patterns, differences between seasons, and differences between the time-series records are considered. Plotting and statistical analysis utilized Excel Microsoft Office (version 10) software. Illustrative graphs and charts are colour-coded, with yellow for values of anomalies close to normal (between +/-1°C), blue for values colder than normal (≥1 C°), and red for values warmer than normal (≥1 C°).

3.2 Annual Mean Temperature Variability and Change

Anomalies of mean temperature are calculated as departures from the normal average temperature for the corresponding range data of each location. Mean temperature anomalies for all four stations are shown in Figure 3.1.

Differences exist in the temperature records, both among stations and throughout the time of the records. In general, although differences among the stations are evident, the most significant temperature anomalies occur across western Newfoundland during distinct time periods. The first years for which complete data exist for each station are 1943 for Stephenville, 1934 for Corner Brook and Deer Lake (original stations), and 1947 for Daniel's Harbour. The last years for which data exist for each station are 2007 for Stephenville, Deer Lake (Airport), and Daniel's Harbour, and 2006 for Corner Brook (original station).

Regionally across western Newfoundland between 1934 and 2007, six periods marked by distinct temperature regimes can be recognized:

1. 1934-1950: close to normal

Although records from this period have numerous gaps, including during World War II, normal conditions generally dominated at all four stations. This period is interrupted by the cold years 1934 and 1939 for Corner Brook and Daniel's

Harbour, 1941 for Corner Brook, and 1948 for Daniel's Harbour. The colder locations are Corner Brook and Deer Lake.

2. 1951-1960: warmer

The early 1950s recorded a warmer period. Strong alternations of cold and warm years were recorded at the end of period. A cold year for Corner Brook and Daniel's Harbour was 1957, and for Deer Lake cold years were 1957 and 1959. Stephenville and Deer Lake recorded the highest number of years without any cold years.

3. 1961-1971: close to normal

This close to normal period was interrupted by 1966, a warm year for Daniel's Harbour, Deer Lake, and Corner Brook, and by 1969 for Daniel's Harbour. Stephenville recorded a cold year in 1964, different than the close to normal conditions recorded at the other locations.

4. **1972-1984: alternating cold, normal, warm**

The early 1970s were a cold period for all locations, and warmer conditions dominated the late 1970s and early 1980s. The warm period was interrupted by a cold 1982 year at Daniel's Harbour.

5. **1985-1995: colder**

This period was dominated by colder conditions from the beginning of the mid-1980s through the early 1990s. Corner Brook is characterised by the single cold year of 1992. The coldest locations were Deer Lake and Daniel's Harbour.

6. **1996- 2007: warmer**

The region was marked by a very warm period in the late 1990s and the early 2000s, followed by a period close to normal and a second warmer period after 2005. The warmest locations for this period were Deer Lake and Daniel's Harbour

The coldest and warmest departures from the mean are presented in Table 3.1. For the entire period of 75 years, the coldest years were 1941 for Deer Lake and 1972 for the other three locations.

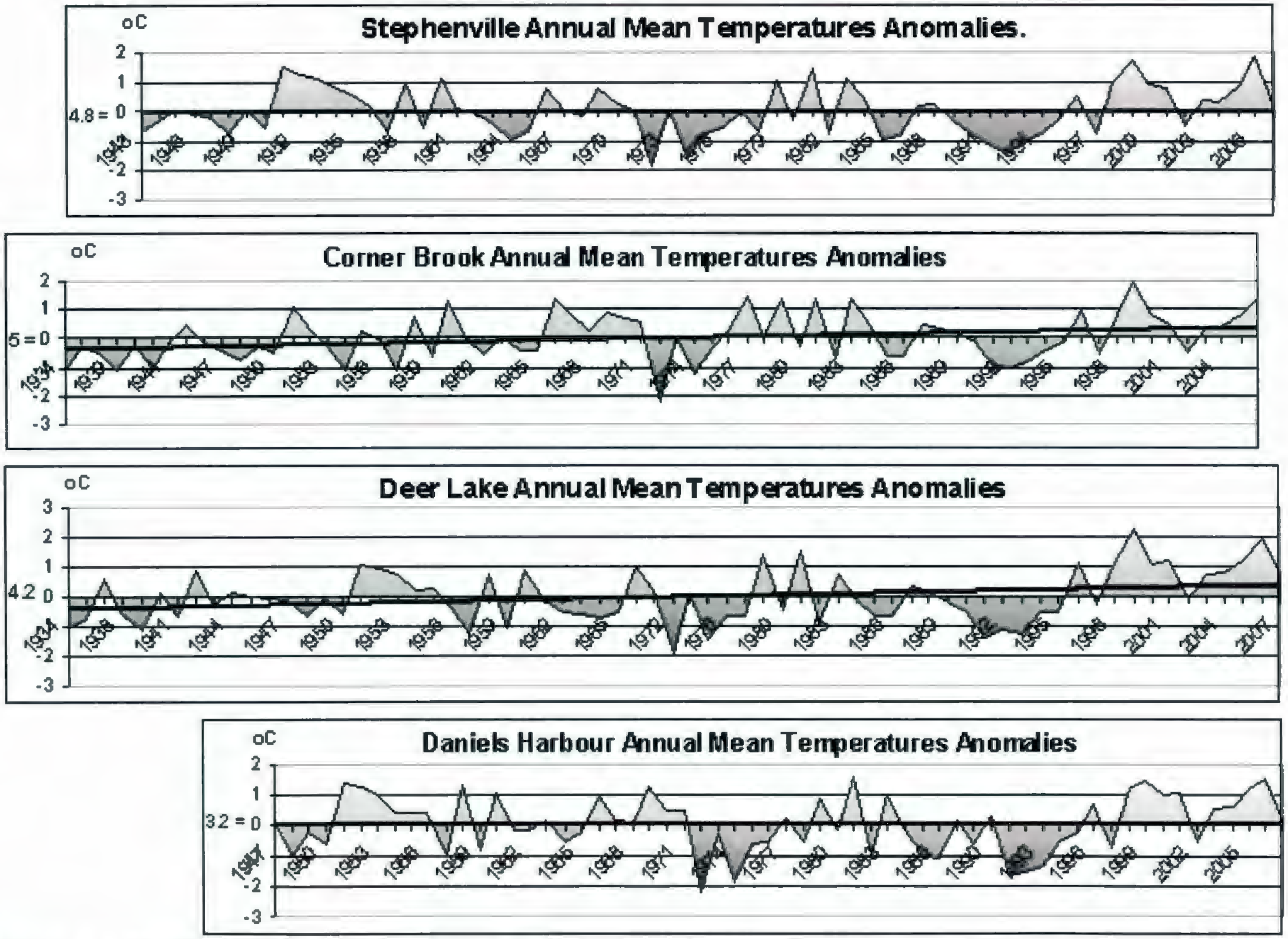


Figure 3.1 Mean Temperature Anomalies

The greatest negative departure exceeded 2°C for Deer Lake, Corner Brook and Daniel's Harbour. The warmest years were 2006 for Stephenville, 1999 for Corner Brook, 2003 for Deer Lake, and 1981 for Daniel's Harbour. The departure from the normal average exceeded 2°C for the warm year of 2003 at Deer Lake.

The linear trend for all stations is positive but very low, although Corner Brook and Deer Lake recorded a significant change of 0.8°C throughout the total time series. The normal annual temperatures (multi-annual average) range between 3.2°C at Daniel's Harbour and 5°C at Corner Brook.

Annual	Coldest	Year	Warmest	Year	Normal	Linear Trend	
ST	-1.9	1972	1.9	2006	4.8	0.1	flat+
CB	-2.3	1972	1.9	1999	5	0.8*	positive
DL	-2.3	1941	2.5	2003	4.2	0.8*	positive
DH	-2.2	1972	1.6	1981	3.2	0.1	flat+
*= significant							

Table 3.1 Normal, Coldest, and Warmest Years and Linear Trend

The distribution of cold and warm years compared to the multi-annual average for all four locations are presented in Figure 3.2. The Stephenville record shows 11 warm years and 7 cold years, representing 17% and 11%, respectively, of the total 65-year record. Corner Brook had 10 (14%) warm years and 8 (12%) cold within the total 69-year record. Deer Lake recorded 11 warm (16%) years and 9 cold (13%) in the total 67-year record, and Daniel's Harbour recorded 15 (25%) warm and 10 cold (17%) years.

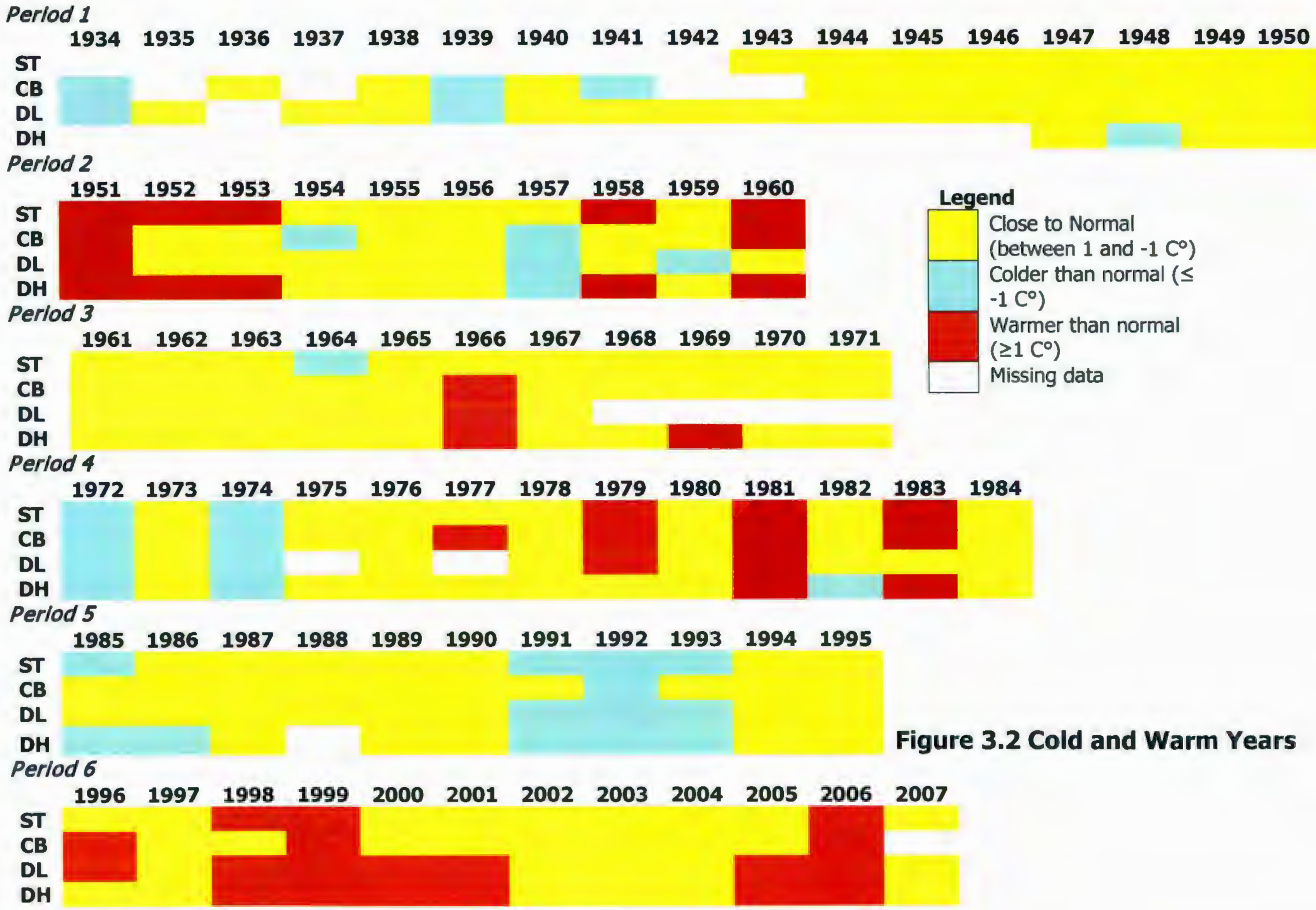


Figure 3.2 Cold and Warm Years

3.3. Temperatures: Seasonal Variability and Change of Seasons

For outdoor activities in western Newfoundland, the winter and summer seasons are more important. From a climate point of view, all four seasons must be examined for significant evidence of climatic changes.

3.3.1 Winter Mean Temperatures

Winter mean temperatures are calculated using values from three calendar months, beginning with December of the previous year and continuing with January and February. For convenience, the year cited refers to January, so 'Winter 1960' includes values from December 1959. Winter Mean temperature anomalies for all four stations are illustrated in Figures 3.3 and 3.4.

Both the temperature trends and the anomalous winter years show significant differences from the annual data discussed above. Although the first and last years for which data exist for each station are the same as for the Annual Mean Temperature, between 1933 and 2007 eight periods were distinguished in the winter mean temperature regime:

1. 1934-1950: alternating cold and close to normal

This period was dominated by cold conditions in more years than warm for the corresponding annual period. A warm year within this period is 1942, recorded at Daniel's Harbour. The other three locations had no recorded data for 1942.

2. 1951-1956: warm

For all locations, this was a warmer period than the corresponding annual period.

3. 1957-1961: alternating

Very strong alternating cold and warm years for all locations

4. 1962-1971: warm

The warmest part of the period is the late 1960s and 1970. The warmest location for this period is Corner Brook.

5. 1972-1977: cold

All locations had cold years during this period.

6. 1978-1988: close to normal

This period was interrupted by a warm 1982 year for all locations and by 1978 for Daniel's Harbour, and 1978 and 1983 for Corner Brook.

7. 1989 – 1995:

This was a cold period for all locations, with the exception of a warm 1990 for Daniel's Harbour.

8. 1996-2007: warm

This was a period dominated by warm years. Warm years marked the period 1998-2000 and 2004 for all locations. For Daniel's Harbour, 1997 was a colder winter than normal, as was 2003 for Corner Brook.

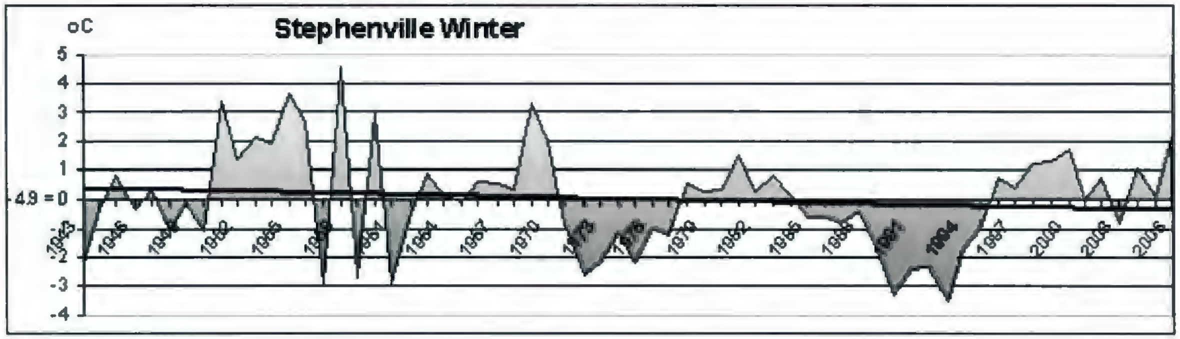
The coldest winters, with more than -3.5 °C departure for the entire range of data were 1933 for Stephenville, 1934 for Corner Brook and Deer Lake, and 1957 for Daniel's Harbour. The warmest winter year with a departure of more than 4°C was 1958 for all locations (Table 3.2)

Winter	Coldest	Year	Warmest	Year	Normal	Linear Trend	
ST	-3.5	1993	4.6	1958	-4.9	-0.8*	negative
CB	-5.8	1934	4.5	1958	-5.1	0.7*	positive
DL	-4.9	1934	4.3	1958	-6.4	1.0*	positive
DH	-4.3	1957	4.6	1958	-6.5	-0.5*	negative
*significant							

Table 3.2 Winter Normal, Coldest, Warmest Years, and Linear Trend

The linear trend for winter is significant for all locations. Stephenville and Daniel's Harbour recorded a decrease of winter mean temperature, more than -0.5°C, while Corner Brook and Deer Lake have recorded increases of approximately 1°C. The Normal temperatures for winter range between -4.9°C at Stephenville and - 6.5 °C at Daniel's Harbour.

Stephenville has experienced 17 warm (27%) and 19 cold (30%) winters (Figure 3.4). Corner Brook has seen equal numbers of warm and cold winters (20; 29%). Deer Lake has experienced 21 cold (26%) winters and 19 warm (29%) winters. Daniel's Harbour has also seen 19 warm (31%) winters and 16 cold (26%) winters.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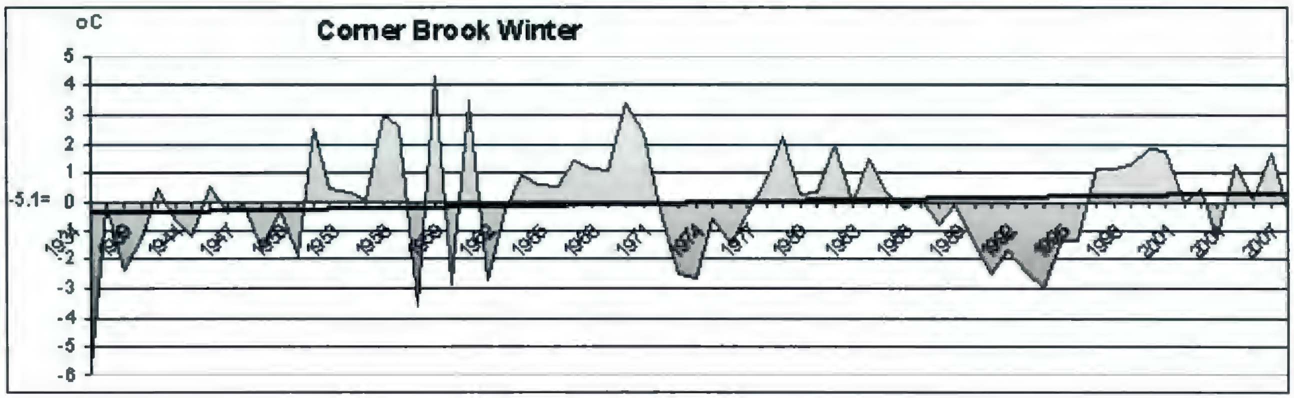
Stephenville Winter
-4.9 = 0


oC
Corner Brook Winter
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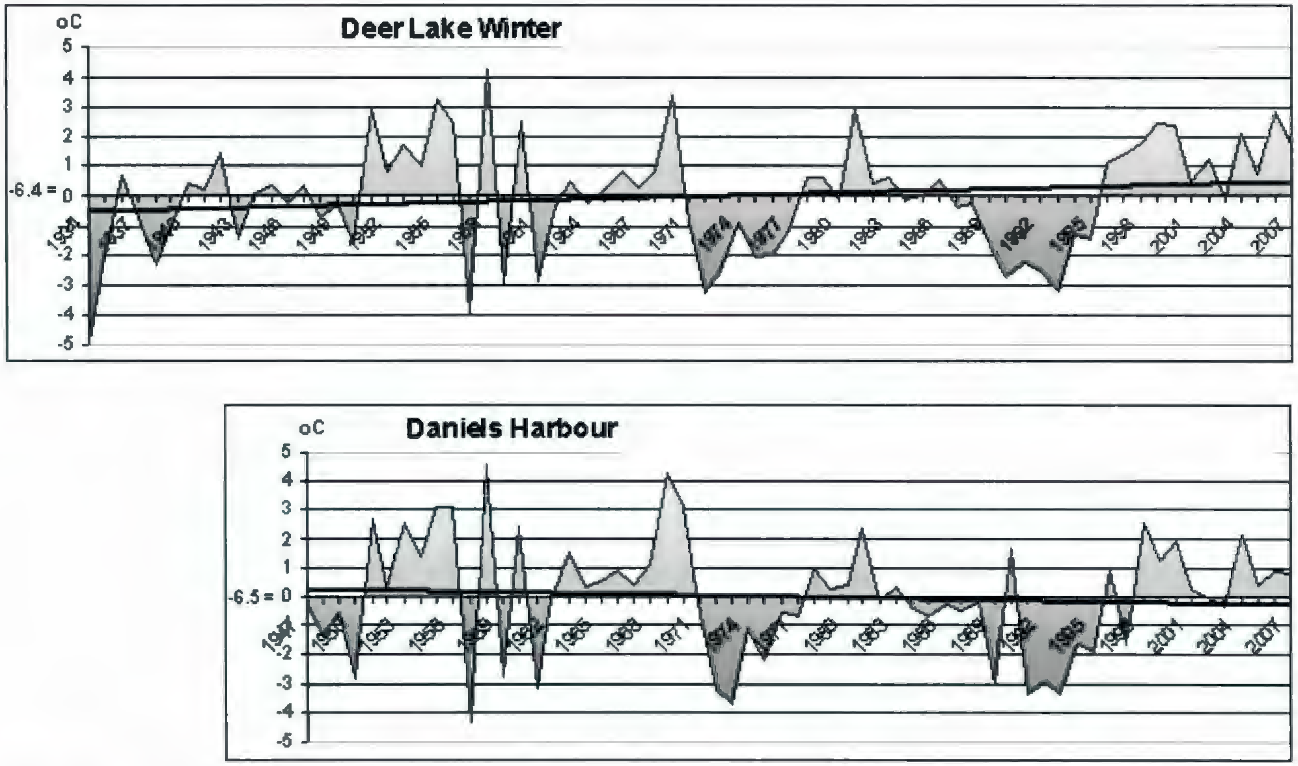


Figure 3.3 Winter Mean Temperature Anomalies

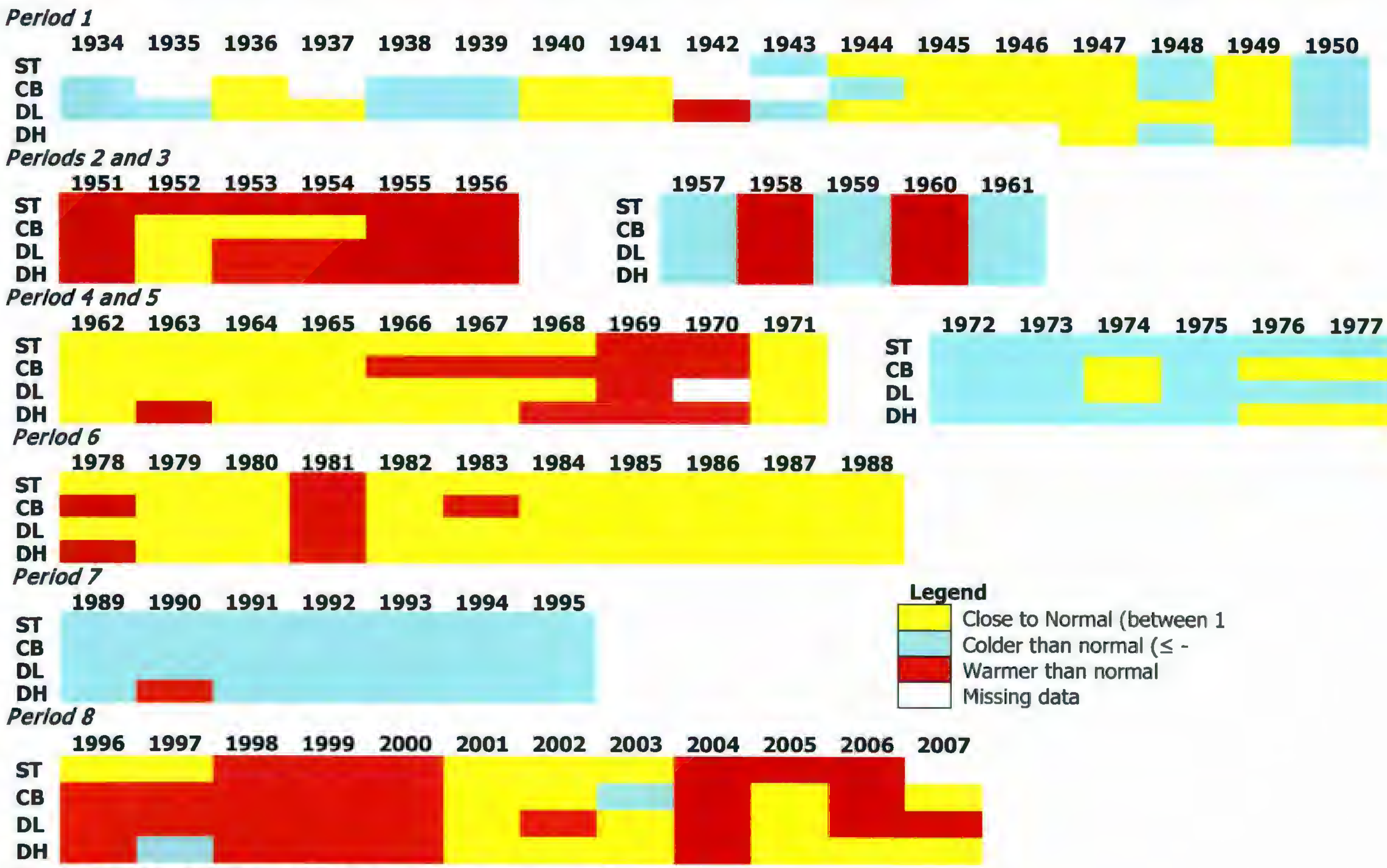


Figure 3.4 Variability of Cold and Warm Winter Years

3.3.2 Spring Mean Temperature

Spring mean temperature is calculated from the three average temperatures of March, April, and May. The first and last years for which data exist for each station are different than for winter and annual temperatures. For all four stations, the last year is 2007, and the first year is different for all four stations: 1942 for Stephenville, 1934 for Corner Brook, 1933 for Deer Lake, and 1947 for Daniel's Harbour. Spring mean temperature anomalies are shown in Figure 3.5.

Between 1933 and 2007, only four periods were designated (Figure 3.6):

1. 1933-1950: alternating

Cold spring years are more numerous than in the annual and winter records.

2. 1951-1953: warm

The warm period was shorter than the corresponding warm winter period in the early 1950s.

3. 1954-1997: strong variations.

This period can be subdivided into three intervals: 1954-1971; 1972-1989; and 1990-1997. Strong cold-warm variations occurred between 1957-1959 (1957 cold, 1958 warm, 1959 cold) and between 1977 and 1990 at all locations.

4. 1998-2007: warm

This period was interrupted by cold years in 2003 and 2007.

The coldest springs occurred in 1967 for Stephenville (-2.6°C departure from normal) and Deer Lake, 1939 for Corner Brook (-3°C departure) and 1972 for Daniel's Harbour (-3°C). The warmest spring occurred in 1979 for Corner Brook and Daniel's Harbour (more than 3°C), in 1983 for Stephenville (3°C) and in 1951 for Daniel's Harbour (2.9 °C). The linear trend (Table 3.3) is slightly positive for Stephenville and Daniel's Harbour, and significantly positive for Corner Brook and Deer Lake (more than 1°C). The coldest normal is at Daniel's Harbour, with 0.3°C, and the warmest at Corner Brook, with 2.2°C.

Spring	Coldest	Year	Warmest	year	Normal	Linear	Trend
ST	-2.6	1967	3	1983	2	0.4	positive
CB	-3	1939	3	1979	2.2	0.8*	positive
DL	-2.9	1967	3.5	1979	1.4	1.2*	positive
DH	-3	1972	2.9	1951	0.3	0.3	flat +
* Significant							

Table 3.3 Spring Normal, Coldest, Warmest Years, and Linear Trend

The numbers of warm and cold springs are different for each station and are illustrated in Table 3.3. The Stephenville record shows 15 warm (23%) and 18 cold (27%) springs from the 66-year time series. Corner Brook had 16 warm (23%) and 19 cold springs (27%), Deer Lake had 20 warm and cold springs (28% each) from the 71-year record, and Daniel's Harbour had 16 warm (26%) and 17 cold springs (28%).

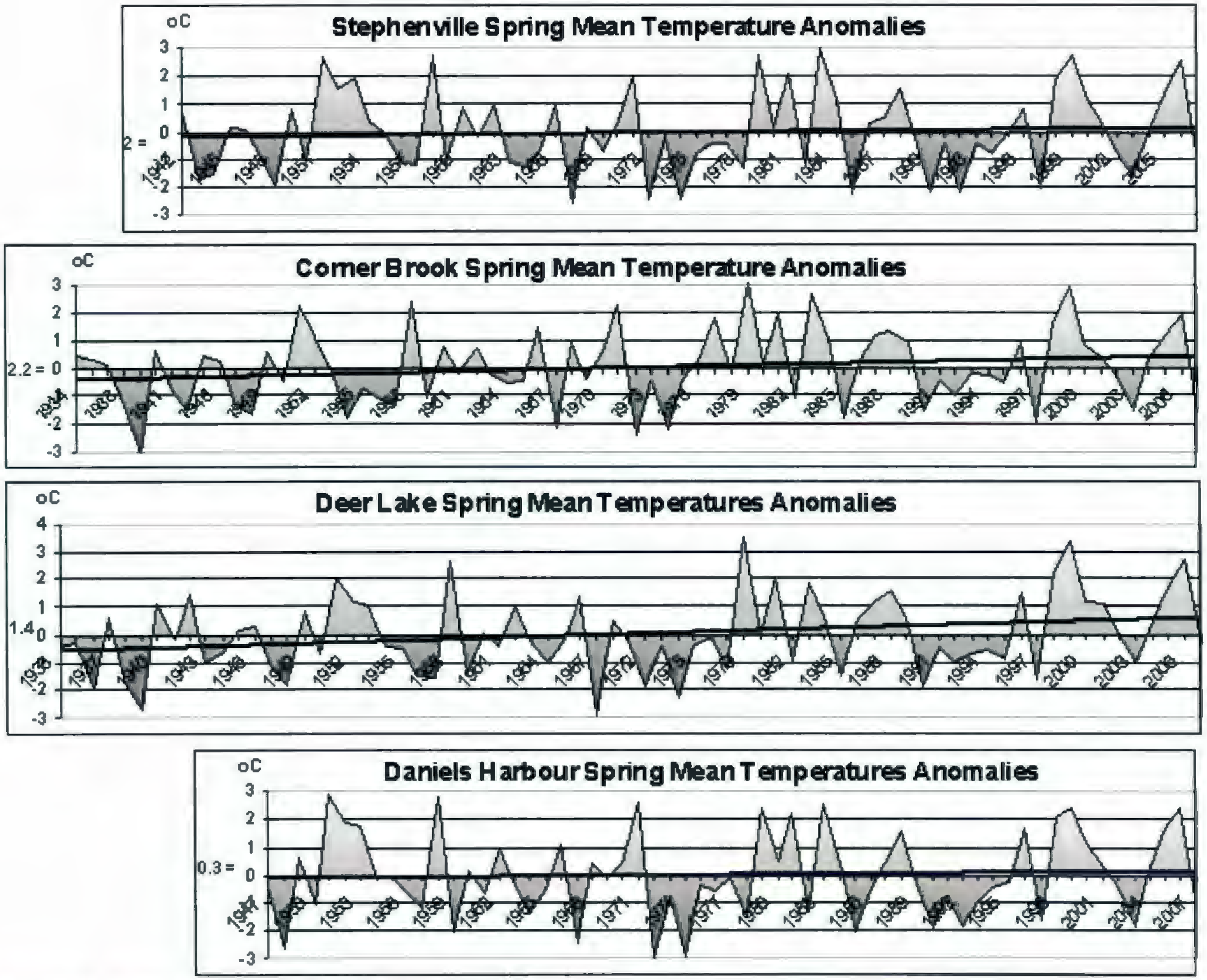


Figure 3.5 Spring Mean Temperature Anomalies

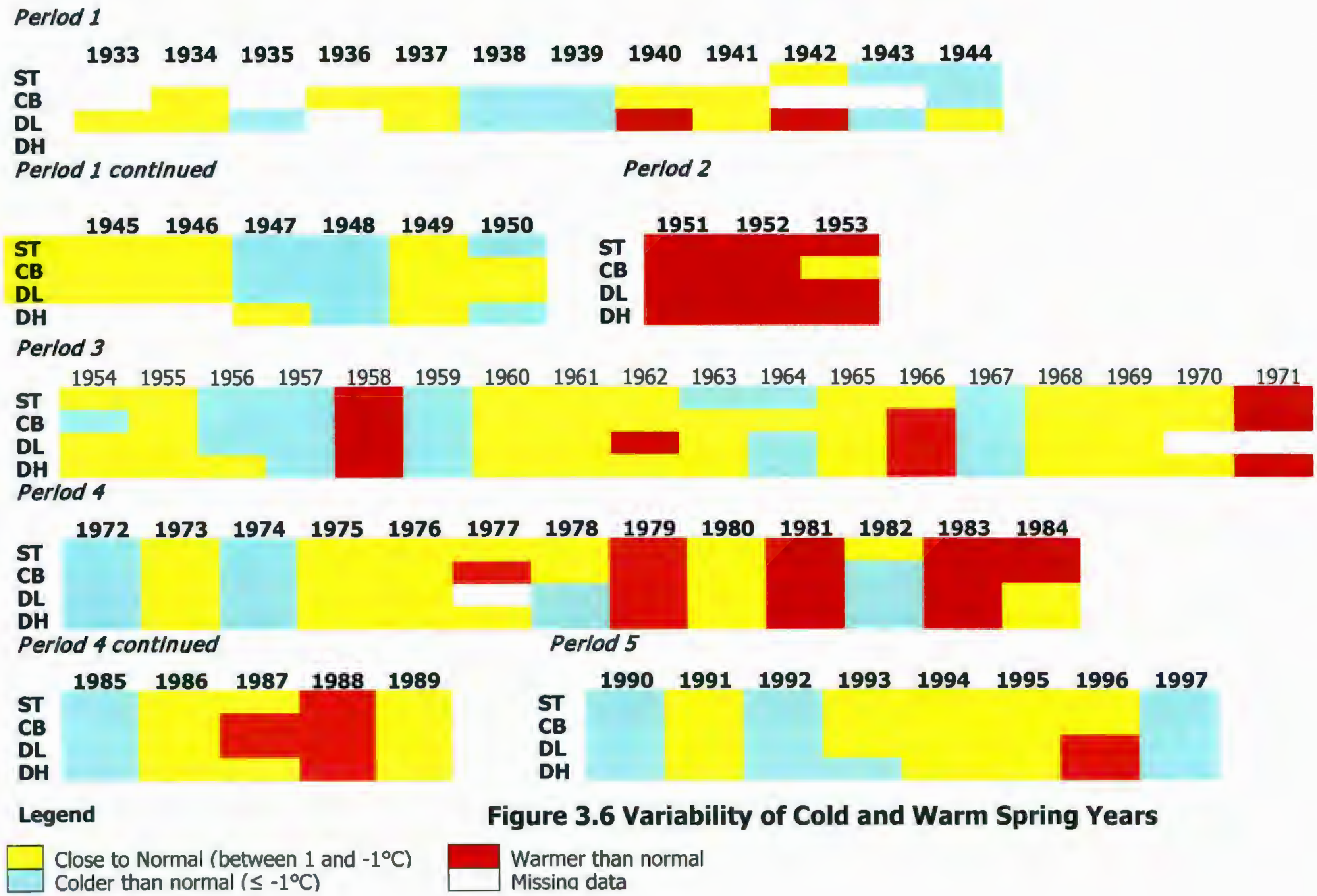


Figure 3.6 Variability of Cold and Warm Spring Years

3.3.3. Summer

The summer mean temperature includes three months average temperatures: June, July, and August. The summer mean temperature anomalies are presented in Figure 3.7. For all four stations, the last year for which data exist for each station is 2007. The first year is 1933 for Corner Brook and Deer Lake, 1942 for Stephenville, and 1947 for Daniel's Harbour.

Significant differences exist between the overall annual record of temperature and the temperatures recorded during summer. Between 1933 and 2007, as for spring, there are four periods in the summer temperature regime (Figure 3.8):

1. 1933-1943 alternating

This period is characterized by an extended warm period from 1936-1938.

2. 1944-1951: close to normal

An uninterrupted period of close to normal summer temperatures.

3. 1952-1998: alternating

This period is subdivided into three intervals: 1952-1969; 1970-1987; and 1988-1998. The intervals are interrupted by three cold periods; one in 1956-1958 at Deer Lake and Corner Brook, and another in 1962-1964 at almost all locations (except for 1962 at Stephenville and 1963 at Corner Brook and Daniel's Harbour). The last cold interval was 1991-1993 for all locations with the exception of 1993 at Stephenville.

4. 1999-2007: warm: This period is shorter than the corresponding periods for winter, spring, and annual temperatures.

The coldest summers occurred for Stephenville in 1968 (-1.9°C departure), for Corner Brook in 1954 (-2.2°C), for Deer lake in 1963 (-2°C) and for Daniel's Harbour in 1991 (-2°C). The warmest summer occurred in 1967 for Corner Brook (2.4 °C) and Deer Lake (2.2°C) and in 2006 for Stephenville (1.9°C) and Daniel's Harbour (1.8°C). The linear trends (Table 3.4) show significant increases for all four locations. An increase of 0.6°C occurred for Deer Lake and Daniel's Harbour, and close to 1°C for Corner Brook (0.9°C) and Stephenville (0.8°C). Normal summer temperatures range between 13°C for Daniel's Harbour and 15.5°C for Corner Brook.

Summer	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-1.9	1968	1.9	2006	14.7	0.8*	positive
CB	-2.2	1954	2.4	1967	15.5	0.9*	positive
DL	-2	1963	2.2	1967	15	0.6*	positive
DH	-2	1991	1.8	2006	13	0.6*	positive
*Significant							

Table 3.4 Summer Normal, Coldest, Warmest Years, and Linear Trend

Cold and warm summer years are illustrated in Figure 3.4. Stephenville has experienced 8 warm (12%) and 6 cold (9%) summers in 66 years. Corner Brook has seen 10 warm (18%) and 13 cold (24%) summers, Deer Lake 11 warm (15%) and 14 cold (19%) summers in 73 years, and Daniel's Harbour 7 warm (12%) and 9 cold (15%) summers in 60 years.

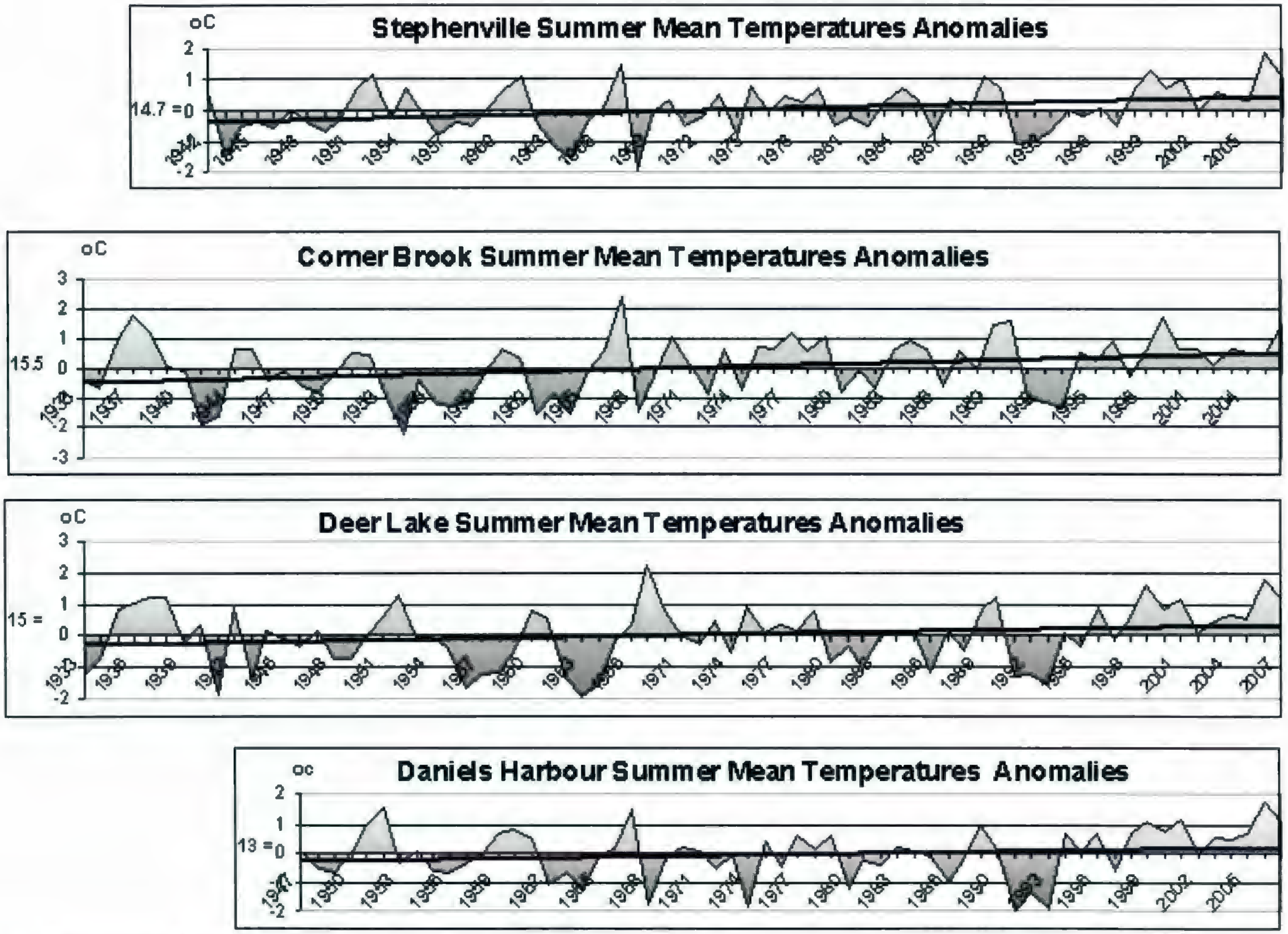


Figure 3.7. Summer Mean Temperature Anomalies

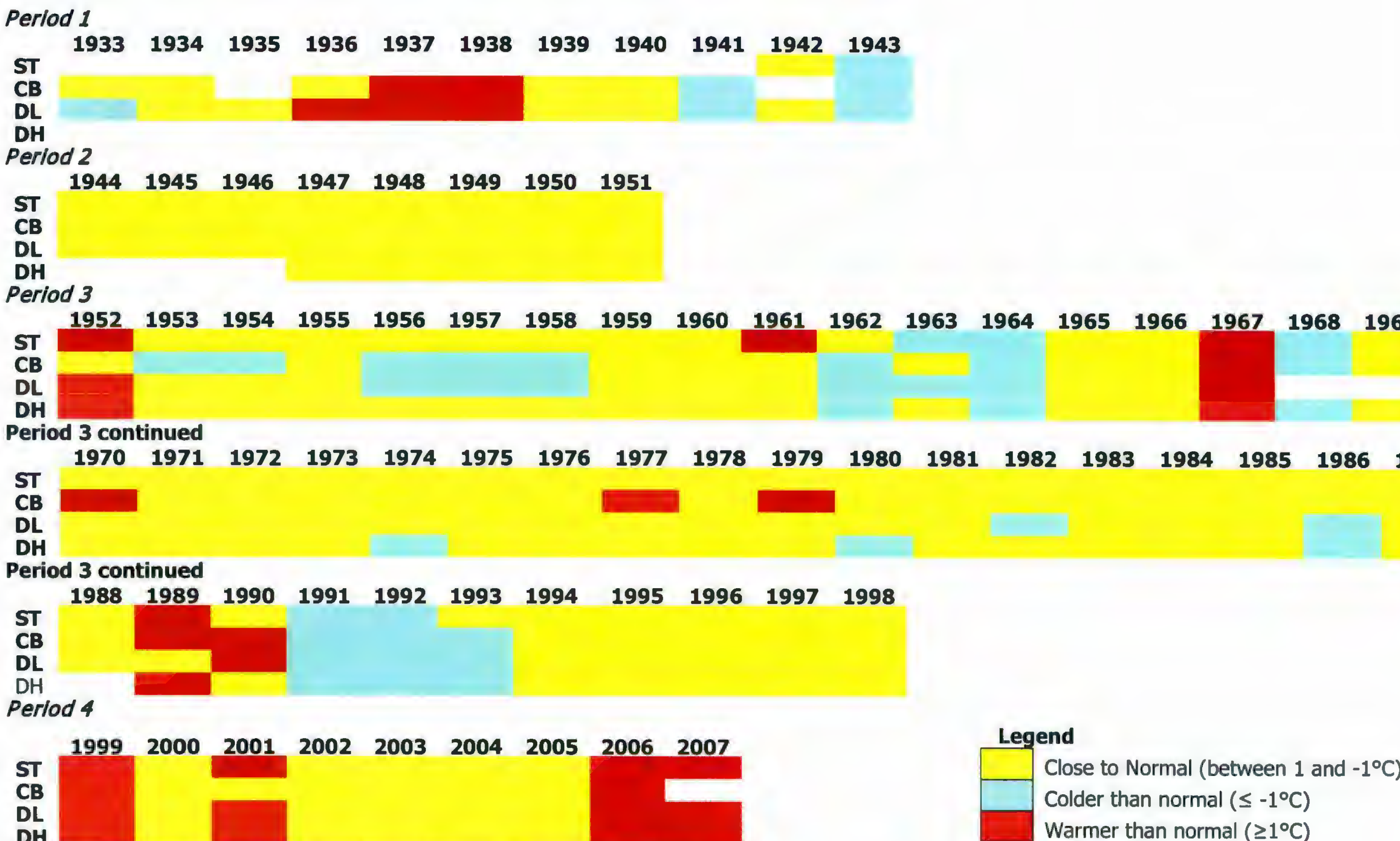


Figure 3.8 Variability of Cold and Warm Summer Years

3.3.4 Autumn

Autumn mean temperature includes the three months average of September, October, and November (Figure 3.9). The last year for which data exist for each station is 2007, with the exception of Corner Brook (2006). The first year is 1933 for Corner Brook and Deer Lake, 1942 for Stephenville, and 1947 for Daniel's Harbour.

The mean autumn temperature regimes are divided in five periods (see Figure 3.10):

1. 1933-1946: characterized by strong variations

The last years of this period are dominated by the warm years.

2. 1947-1960: close to normal.

Large periods of close to normal temperatures were interrupted by cold years for Deer Lake (1950, 1954 and 1956), and Corner Brook (1954).

3. 1961-1967: alternating warm and cold

The period was interrupted by some years with close to normal conditions. Warm autumns occurred in 1961 and 1967 for all locations.

4. 1968-1998: alternating

Close to normal and cold conditions, subdivided in two short periods: 1968-1984 and 1985-1998. Cold years included 1972 (for all stations except Deer Lake), 1974 (Stephenville), 1978 (all locations), 1980 (Deer Lake), 1982 and 1985 (Deer Lake and Stephenville), and 1986 (all locations). The period between 1987 and

1998 saw close to normal conditions, interrupted by a warm year in 1990 for Deer Lake.

5. 1999- 2007: warm and normal

2003 was warm for all locations.

The coldest autumn occurred in 1979 for Stephenville (-2°C), in 1967 for Corner Brook (-2.1°C), in 1941 for Deer Lake (-2.3°C) and 1986 for Daniel's Harbour (-2.8°C). The warmest autumn was 2003 for all locations (>2°C). Autumn multi-annual average temperatures range between 6.2°C at Daniel's Harbour and 11.5°C at Deer Lake (Table 3.5). The linear trends are significantly positive only for Corner Brook (increasing 0.8°C) and Deer Lake (0.7°C).

Autumn	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-2	1978	2.3	2003	7.5	0.3	flat+
CB	-2.1	1967	2.4	2003	7.4	0.8*	positive
DL	-2.3	1941	2.5	2003	11.5	0.7*	positive
DH	-2.8	1986	2.7	2003	6.2	0.3	flat+
*Significant							

Table 3.5 Autumn Normal, Coldest, Warmest Years, and Linear Trend

The distribution of numbers of warm and cold years is shown in Figure 3.5. Stephenville experienced 6 warm (9%) and 8 cold autumns (12%), Corner Brook has 8 warm (11%) and 10 cold (14%), Deer Lake 11 warm (15%) and 9 cold (13%), and Daniel's Harbour 6 warm and cold autumns (10%).

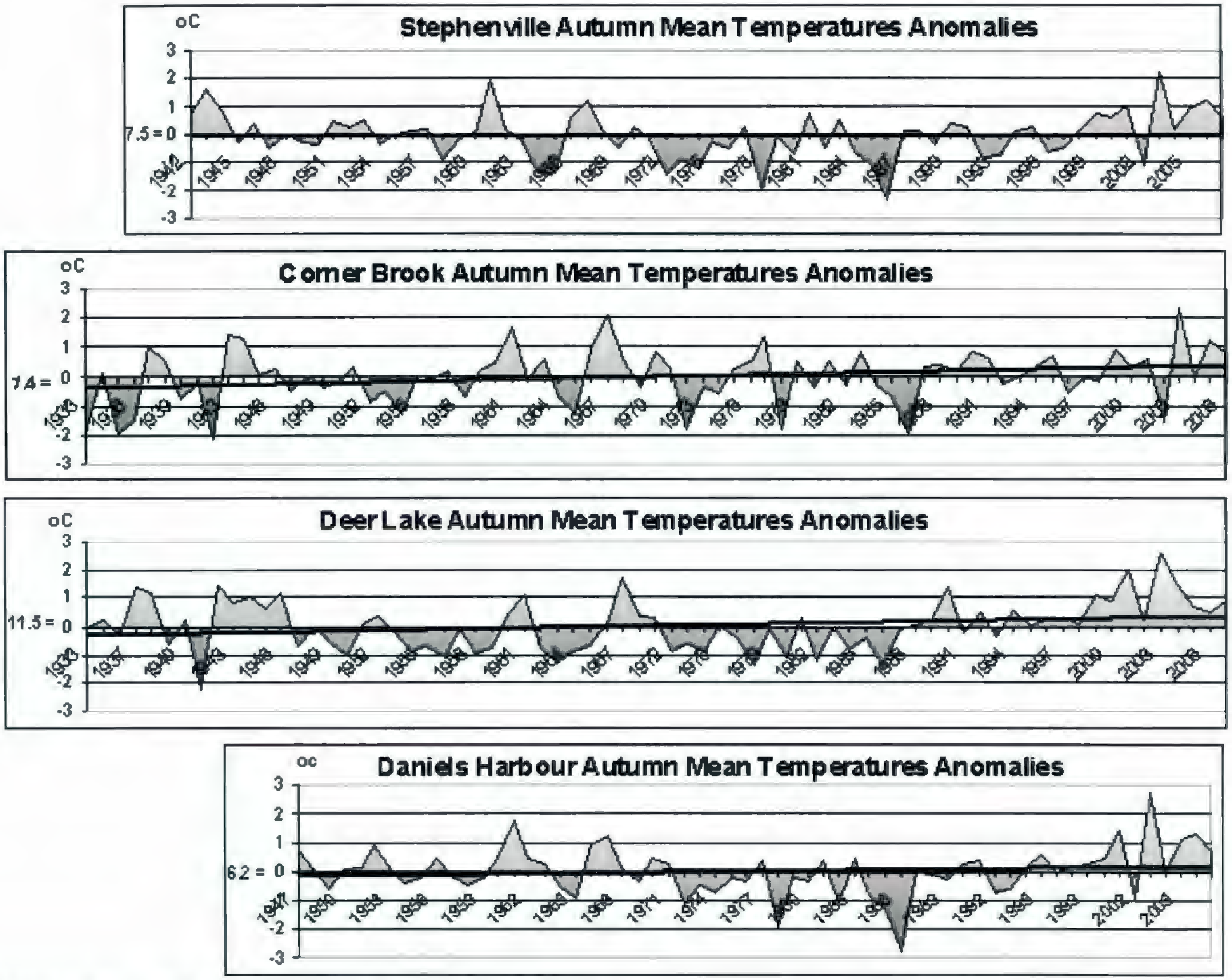


Figure 3.9 Autumn Mean Temperature Anomalies

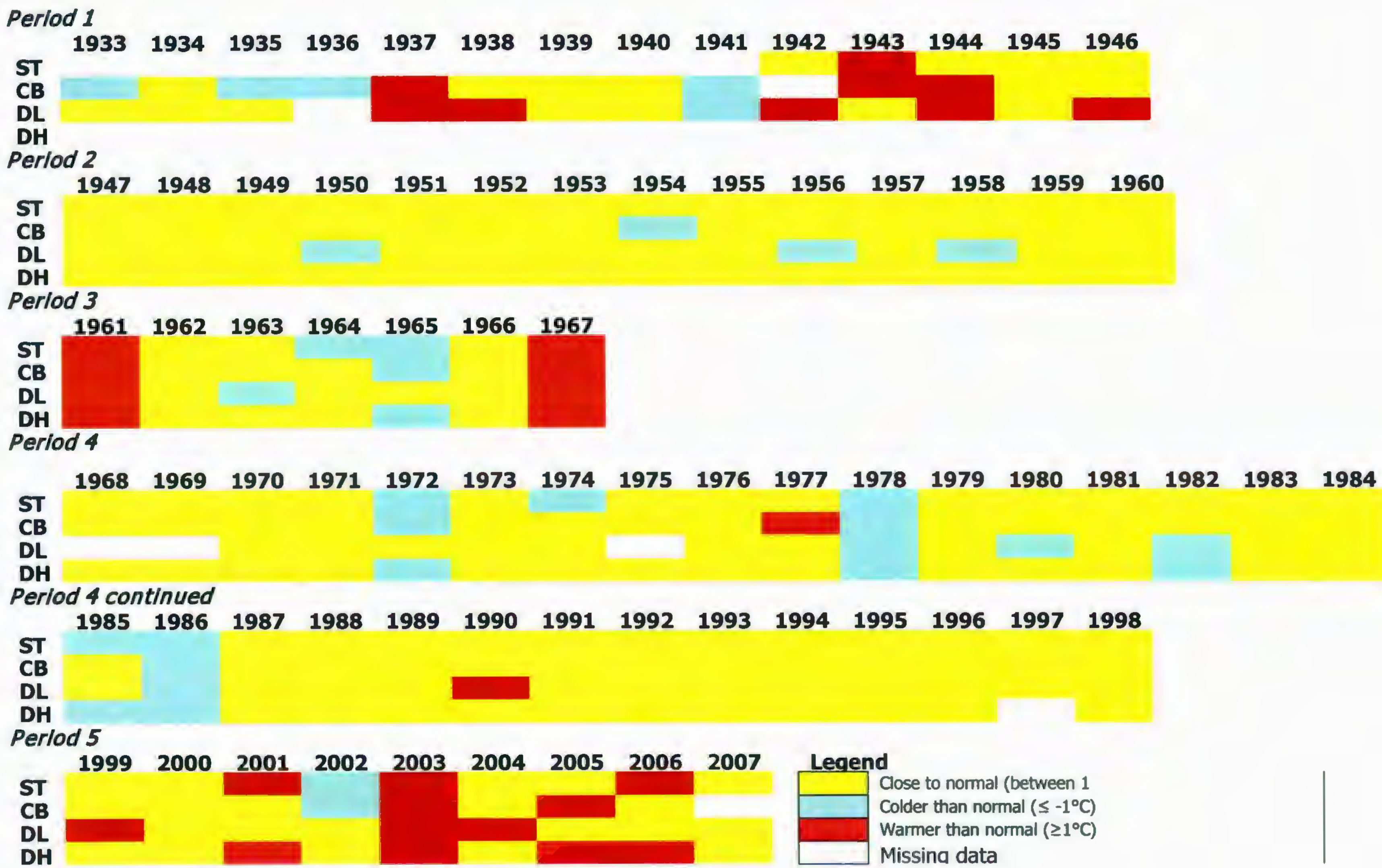


Figure 3.10 Variability of Cold and Warm Autumn Years

3.3.5 Summary

Mean annual temperatures for all stations between 1934 and 2007 show more warm years than cold for all stations. The linear trends show a significant increase in annual mean temperatures for Corner Brook and Deer Lake (Table 3.6). Lesser increases are shown by the data from Stephenville and Daniel's Harbour.

Station	Winter	Spring	Summer	Autumn	Annual
Stephenville	negative	positive	positive	flat+	flat+
Corner Brook	positive	positive	positive	positive	positive
Deer Lake	positive	positive	positive	positive	positive
Daniel's Harbour	negative	flat +	positive	flat+	flat+

Table 3.6. Summary of Trends of Changes in Mean Temperature

Winter mean temperatures are colder for Stephenville and Daniel's Harbour. At Deer Lake, the linear trend shows a significant increase of over 1°C in winter mean temperature. However, over the same period of 73 years, more colder-than-normal winter years than warmer-than-normal were recorded. A warming trend is recorded at Corner Brook.

Spring mean temperatures have generally increased, particularly at Corner Brook and Deer Lake. However, most stations have experienced more colder-than-normal than warmer-than-normal springs. The same pattern is evident for summer temperatures, with generally increasing summer temperature superimposed on a pattern with more colder-than-normal compared to warmer-than-normal years. Significant increases in autumn temperature are shown by the linear trends for Corner Brook and Deer Lake.

Overall, the regional pattern shows a general temperature increase, most evident in summer and spring. Declining temperatures were only measured for the winter seasons in Stephenville and Daniel's Harbour. The period 1998-2007 has seen generally warmer autumns (Period 5, Figure 3.10), summers (Period 4, Figure 3.8), springs (except for 2003 and 2007; Period 4, Figure 3.6), and winters (Period 8, Figure 3.4).

Seasonally, winters recorded the highest variability in the number of warm and cold years. Spring, summer, and autumn recorded periods of strong variability of mean temperature between the early 1950s and mid-1990s.

Corner Brook and Deer Lake appear to have similar patterns of mean temperature, which would be expected given their geographic proximity. However, the two stations most distant from each other, Stephenville and Daniel's Harbour, show similarities in their time-series data. Both sites are located in more exposed coastal settings than are Corner Brook and Deer Lake.

The data trends agree with the regional patterns recognized between 1951 and 1980 by Barry (1991) and Nicholas (1995). However, regional trends recognized in Maritime Canada by Morgan *et al.* (1993) and Pocklington *et al.* (1994) for 1950-1989 do not entirely coincide with those recognized here. In particular, the mid-1960s and 1985-1989 cool periods in Maritime Canada are not replicated in the data from western Newfoundland. Morgan *et al.* (1993) noted that spring, summer and autumn for the Maritime region show lower amplitude variability than does winter, in concordance with western Newfoundland data.

Lewis (1997) noted that temperature patterns in Atlantic Canada were at variance with those in other parts of Canada. The warming trend of the 1950s was followed by a cooling trend through the mid-1990s. An overall warming of 0.3 C° occurred in Atlantic Canada from 1948-2005 (Lewis, 1997; Lines *et al.*, 2003; Environment Canada, 2005). Summers showed the greatest increase in temperature (+0.8 C° mean), and warming characterized springs (+0.4°C) and autumns (+0.1 C°). Winters became colder (-1.0°C). Lewis (1997), Morgan and Pocklington (1997), Pocklington and Morgan (1998), and Jacobs and Banfield (2000) noted that temperatures in Atlantic Canada were generally not increasing at comparable rates to those elsewhere in North America, and suggested that regional factors were responsible. In particular, the role of the positive phase of the North Atlantic Oscillation in depressing winter temperatures was stressed (*also see* Hurrell 1995, Hurrell *et al.* 2003). The NAO has a major influence on winter conditions in eastern Newfoundland (Catto 2006).

The cold summer years of 1991 and 1992 are noteworthy, particularly for their potential impact on outdoor activities. This pattern is similar to that recorded in temperature data from eastern Newfoundland and elsewhere in Atlantic Canada. Cool summer temperatures impacted agriculture in the Burin

Peninsula during these years (Brake 2007), as well as outdoor activities in eastern Newfoundland. The cool temperatures were in part the result of the June 15, 1991 Mount Pinatubo eruption, which was the largest eruption of the 20th Century. Large volcanic eruptions can influence the global climate by reducing the amount of solar radiation reaching the Earth's surface, lowering temperatures in the troposphere, increasing temperatures in the tropical stratosphere and thereby changing atmospheric circulation patterns (Soden *et al.* 2002, McCormick *et al.* 1995).

In the period from 1996-2007, temperature changes in Atlantic Canada have more closely paralleled those elsewhere in eastern North America (Lines *et al.* 2003, Lines and Pancura 2005, Vasseur and Catto 2008). The period of warming evident elsewhere in Atlantic Canada is reflected in the data from western Newfoundland.

Variability is significant throughout the region, both annually and seasonally. The overall warming trends have occurred simultaneously with an increase in variability from colder-than-normal to warmer-than-normal years. The increased variation (or unpredictability) has potentially negative consequences for tourism, as both visitors and operators rely on consistent, predictable conditions.

3.4 Mean Maximum and Minimum Diurnal Temperatures

Tourist activities are governed by variations in diurnal temperatures. Daylight activities are more influenced by variations in daytime highs (or lows) than by night-time temperatures. Diurnal temperature variations have critical influences on snow cover. In order to study variations and changes in diurnal temperature patterns, Mean Maximum (daytime) and Mean Minimum (night-time) temperature data were analyzed for Stephenville, Corner Brook, Deer Lake and Daniel's Harbour over a minimum 60 year-range. The range of data varies by location; details are presented in Appendix 1. The approach follows that used for discussion of mean temperature (Section 3.3), including definition of 'close to normal', 'cold', and 'warm' years.

3.4.1 Annual Mean Maximum Temperatures

The main features of the Mean Maximum Temperature anomaly analysis are depicted in Table 3.7 and Figure 3.11. Between 1934 and 2007, six general periods can be recognized:

1. 1934-1950: close to normal, interrupted by a warm period 1936-1938

2. 1951-1971: close to normal

3. 1972-1974: cold

4. 1975-1983: dominantly warm

5. 1984-1998: close to normal, with cold years in 1991 and 1992

6. 1999-2007 dominantly warm.

For the 74-year record, the coldest year was recorded in 1972 at Corner Brook with a -2.3°C departure from the multi-annual average (Table 3.7). For Stephenville and Deer Lake, 1972 also was the coldest year. Daniel's Harbour recorded its coldest year in 1997. The warmest year was recorded at Deer Lake in 1999; 2006 for Stephenville and Daniel's Harbour; and 1936 for Corner Brook. For all locations, the linear trend of temperature change is very low to statistically insignificant, but positive, which denotes a very slight increase of less than 0.4°C. Overall, close to normal periods dominate the record, with a few short periods of alternating warm and cold conditions. The last regional cold period, 1991-1992, is in part due to the influence of the Pinatubo eruption.

Annual	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-1.5	1972	1.8	2006	8.5	0.4	positive
CB	-2.3	1972	1.8	1936	9	0.3	positive
DL	-1.7	1972	2.1	1999	8.8	0.3	positive
DH	-2.2	1997	1.9	2006	6.7	0.3	positive

Table 3.7 Annual Mean Maximum Temperatures and Linear Trend

Data from Stephenville and Daniel's Harbour are largely comparable, as are the data from Corner Brook and Deer Lake. Beginning in 1951, the number of warm years shows a south-to-north increase. Stephenville has the lowest number of cold years (7), and Corner Brook the highest (10). With the exception of 1997 at Daniel's Harbour, the period 1994-2007 has seen no years with annual mean maximum temperatures colder than normal.

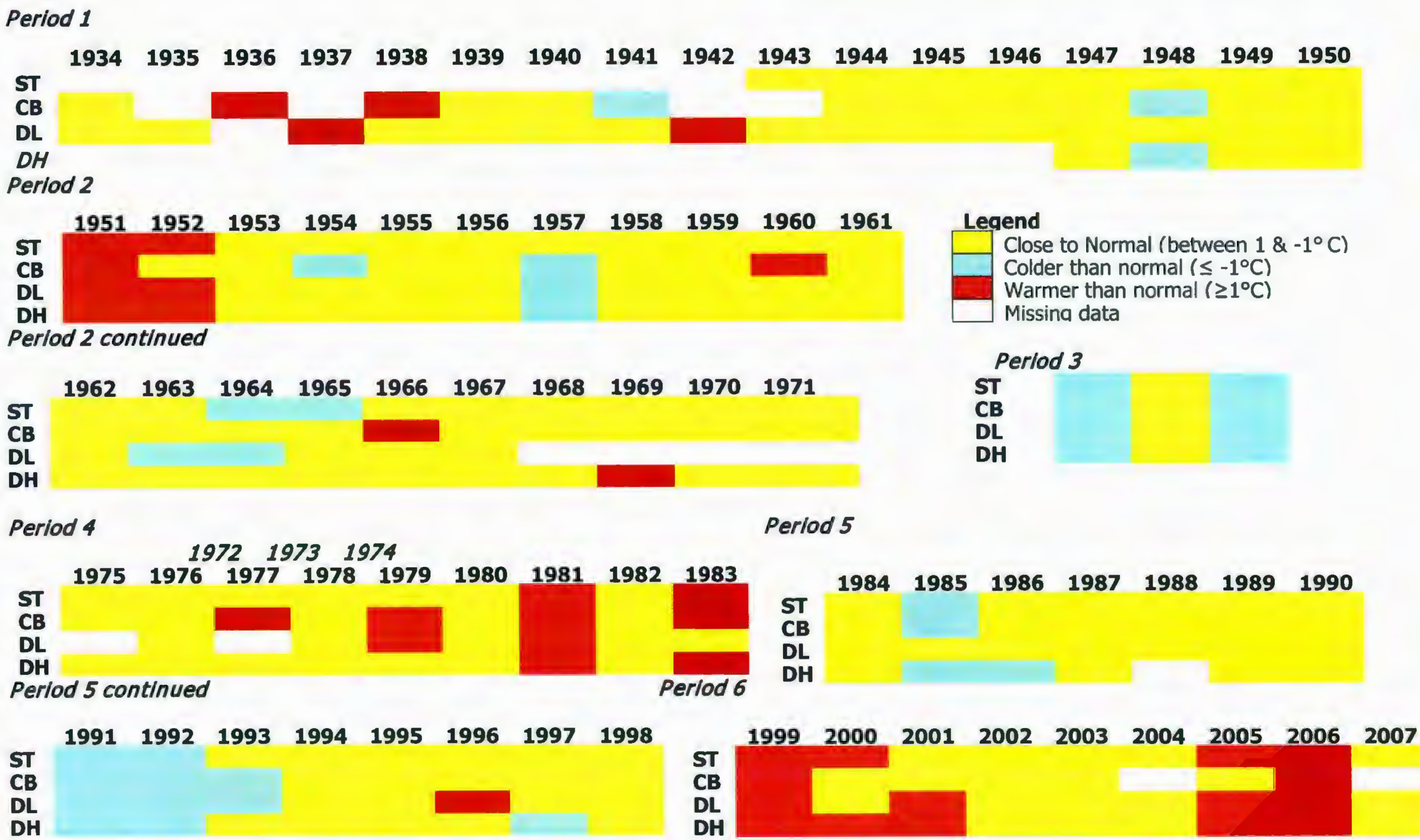


Figure 3.11 Annual Daytime Temperature Variability

3.4.2 Annual Mean Minimum Temperature

The principal features of the annual mean minimum temperature regime are presented in Appendix 2, Table 3.8, and Figure 3.12. The time between 1934 and 2007 is divided in nine distinct periods with specific night-time temperatures:

1. 1934-1941 cold

2. 1942-1950 close to normal

3. 1951-1960 warm

4. 1961-1971 close to normal

5. 1972-1976 dominantly cold

6. 1977-1983 dominantly warm

7. 1984- 1989 close to normal

8. 1990-1993 cold

9. 1994-2007 dominantly warm

Considering annual night-time temperature anomalies, 1972 was the coldest year recorded at Daniel's Harbour, Stephenville, and Deer Lake. For Corner Brook, the coldest year was 1936 with a departure of -2.5 C° from Normal (Table 3.8).

The warmest year for night-time anomalies recorded at Deer Lake and Corner Brook was 1999. Stephenville recorded its warmest year for night-time anomalies in 2006, and Daniel's Harbour in 1981. The linear trends show a high increase in night temperature for Corner Brook and Deer Lake, more than 1°C.

Stephenville has a flat, slightly negative trend. Daniel's Harbour recorded a negative trend of 0.5°C (Table 3.8).

Annual	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-2.2	1972	1.9	2006	1.1	-0.1	flat -
CB	-2.5	1936	2	1999	1.1	1.1*	positive
DL	-2.2	1972	2.3	1999	-0.5	1.3*	positive
DH	-2.8	1972	1.9	1981	-0.3	-0.5*	negative
*significant							

Table 3.8 Annual Mean Minimum Temperatures and Linear Trend

Approximately half of the record range is dominated by periods of close to normal conditions, but the record shows more extended periods of warming and cooling than do the daytime temperature data. The most recent period of generally cooler night-time temperatures terminated in 1993 for all stations, and the period 1994-2007 has been marked by normal to above-average night-time mean temperatures.

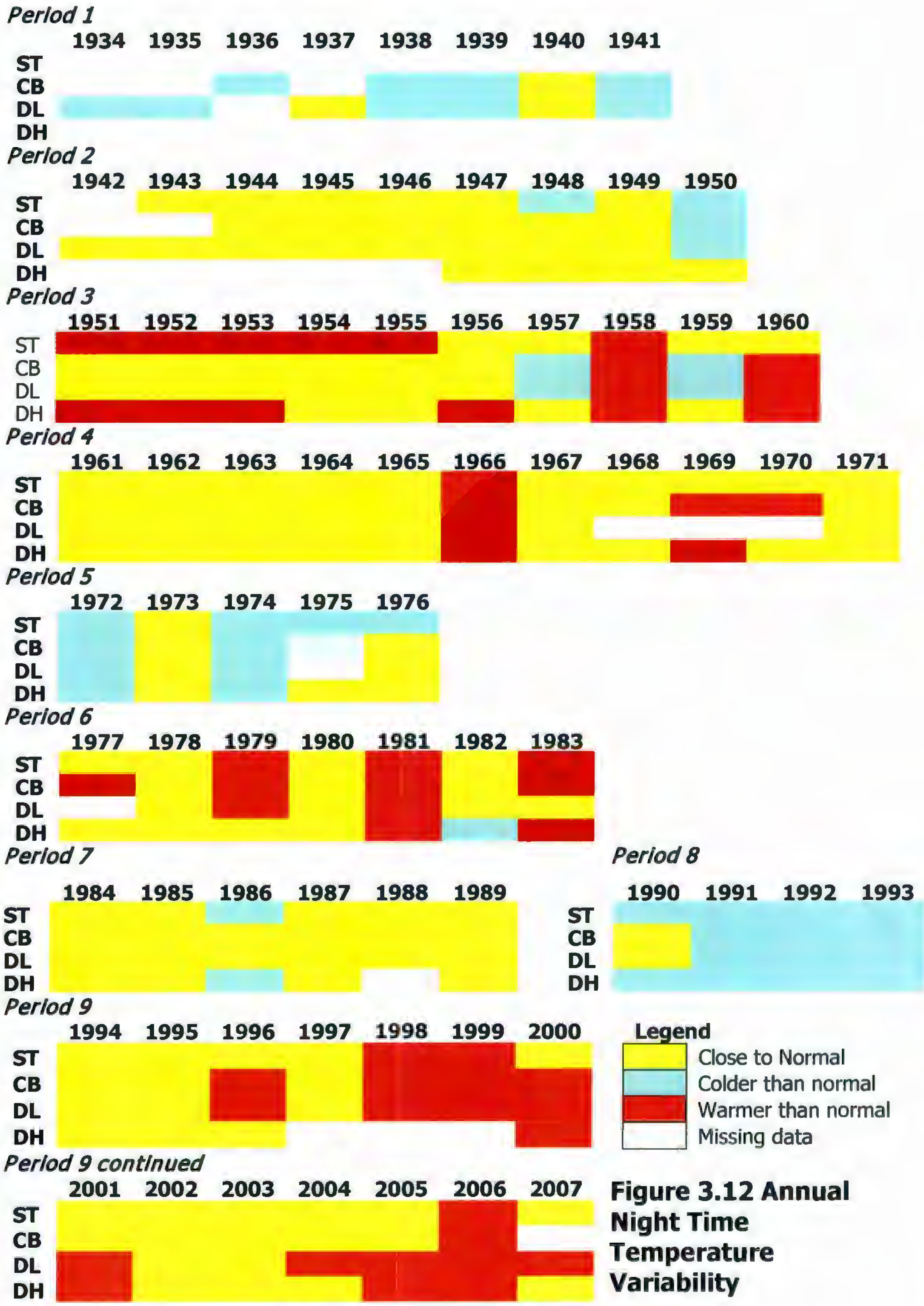


Figure 3.12 Annual Night Time Temperature Variability

3.4.3 Mean Maximum and Minimum Temperatures: Summary

Detailed analysis of seasonal changes in mean maximum (daytime) and mean minimum temperatures (night-time) were also conducted. A detailed discussion of this analysis is presented as Appendix 3. The results are summarized in Tables 3.9 and 3.10.

Station	**Winter**	**Spring**	**Summer**	**Autumn**	**Annual**
Stephenville	negative	positive	positive	positive	positive
Corner Brook	Flat+	positive	flat	negative	positive
Deer Lake	positive	positive	positive	negative	positive
Daniel's Harbour	negative	positive	positive	positive	positive

Table 3.9 Trends of Changes in Mean Maximum Temperatures

Station	**Winter**	**Spring**	**Summer**	**Autumn**	**Annual**
Stephenville	negative	flat-	positive	Flat-	flat -
Corner Brook	positive	positive	positive	positive	positive
Deer Lake	positive	positive	positive	positive	positive
Daniel's Harbour	negative	negative	flat +	Flat+	negative

Table 3.10 Trends of Changes in Mean Minimum Temperatures

All locations showed a net positive trend of increasing mean maximum temperatures. The seasonal trends include a general increase in spring maximums and summer maximums, with the qualified exception of Corner Brook. Winter and autumn trends show more variability, with individual stations recording opposing trends in consecutive seasons. Corner Brook shows a general decrease in the mean maximum temperatures over the autumn-winter period. Although winter maximum temperatures show decreases for Stephenville and Daniel's Harbour, the number of years with mean maximum temperatures above normal is greater than the number of years with lower winter maximums for all four stations.

Conversely, although all four stations show overall increases in spring maximums, the number of years with mean maximum temperatures below normal is greater than the number of years with higher spring maximums for Stephenville, Deer Lake, and Daniel's Harbour. A similar pattern is evident for summer maximum temperatures, with all sites except Stephenville showing more years with mean maximum temperatures below normal than years with higher summer maximums. For spring and summer, net increases in temperature are coupled with increased variability.

The largest increase in autumn mean maximum temperature was registered for Daniel's Harbour. Stephenville shows a smaller increase, whereas Corner Brook and Deer Lake show decreases. The numbers of anomalously cooler and warmer autumn years were similar to each other at all locations.

Annual mean minimum temperatures show significant positive changes for Corner Brook and Deer Lake (greater than 1°C), a slight decrease for Stephenville, and a negative trend for Daniel's Harbour. Anomalously warmer years (higher mean minimums) predominate over cooler years. Winter mean minimums decreased by approximately 1°C at Stephenville and Daniel's Harbour, but increased by a similar amount at Corner Brook and Deer Lake. Spring minimums also increased at Corner Brook and Deer Lake, while decreasing at Daniel's Harbour and Stephenville. All locations showed more anomalously warmer spring years (higher mean minimums) than anomalously colder spring years. Summer Mean Minimum Temperatures show significant increases, with the exception of Daniel's Harbour. Autumn Mean Minimum temperatures increased significantly at Corner Brook and Deer Lake.

Several main trends stand out from the data. The increases in mean annual temperature recorded at Corner Brook and Deer Lake (Table 3.5) are mirrored in increases in both mean maximum and mean minimum temperatures. The lesser, slightly positive trends in mean annual temperatures recorded for Stephenville and Daniel's Harbour are coupled with decreases in mean minimum temperatures, and particularly with decreased mean minimum and mean maximum values in the winter. The differences in the patterns of change in overall annual temperature among the sites are primarily due to the different patterns of changing winter temperatures. Spring and summer maxima and minima show less variation among the sites.

Corner Brook and Deer Lake show strongly similar responses in all the parameters. Although some differences exist between Stephenville and Daniel's Harbour, the changes in parameters from these sites generally resemble each other, and are distinct from those at Corner Brook and Deer Lake. Similarly to the variations in mean annual temperature (Table 3.5), the exposed coastal locations of Stephenville and Daniel's Harbour are marked by a distinctly different temperature regime than are the more interior locations of Corner Brook and Deer Lake.

Increased variability is evident in most of the parameter records. Net increases in mean maxima are coupled with increased numbers of anomalously cooler years. Corner Brook and Deer Lake show simultaneous declines in autumn mean maxima and increases in autumn mean minima. Daniel's Harbour and Stephenville show decreased spring minima coupled with increased maxima. Similarly, to the trends for mean annual temperature, the increased degree of variability poses challenges for tourism: if conditions cannot be easily predicted, planning outdoor recreational activities becomes more difficult.

Distinct periods of variation of mean maxima and mean minima were recorded for each of the four seasons (Appendix 3). Although the durations of seasonal periods vary, and patterns differ for each station, the general patterns of decadal changes are summarized in Table 3.11.

Prior to the most recent decade (1998-2007), the parameters showed substantial variation. Cooler conditions generally marked the years prior to 1942 at Corner Brook and Deer Lake, although summer and autumn mean maxima were higher.

Seasonal Parameter	***1933-1967****	***1968-1977***	***1978-1987***	***1988-1997***	***1998-2007***
Winter mean maximum	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally cool	Generally warm
Winter mean minimum	variable	variable	Generally warm	Generally cool	Generally warm
Spring mean maximum	Generally cool to normal	variable	variable	variable	Generally warm
Spring mean minimum	Generally cool	Generally cool	Generally warm	Generally cool	Generally warm
Summer mean maximum	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally warm
Summer mean minimum	Generally cool	Variable	Variable	Variable	Generally warm
Seasonal Parameter	***1933-1967****	***1968-1977***	***1978-1987***	***1988-1997***	***1998-2007***
Autumn mean maximum	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally warm
Autumn mean minimum	Generally normal to cool	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally warm

Table 3.11. Generalized Pattern of Seasonal Changes in Mean Maximum and Mean Minimum Temperatures. *(See Appendix 3 for detailed discussion.) *No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

The early 1950s were marked by higher winter and spring mean maxima and minima, but summer and autumn values did not generally show increases. Winter and spring mean minimum temperatures showed increases during the decade 1978-1987. All parameters showed general increases in the decade 1998-2007, although individual cooler years did occur (*see* Appendix 3). This decade, however, was the first in which all these parameters showed a common signal.

The data reported here can be compared with other studies of diurnal temperature changes. Karl *et al.* (1991) suggested that the Northern Hemisphere in general had seen large increases in daily minimum temperatures, with little corresponding increase in daily maxima. Skinner *et al.* (1993) analysed maximum and minimum temperatures across Canada for the period 1895-1989. They suggested night-time warming from the annual data. An overall warming of 0.3 C° occurred in Atlantic Canada from 1948-2005 (Lewis, 1997; Lines *et al.*, 2003; Environment Canada, 2005). Daily minimum temperatures showed a slight increase (0.3°C), but daily maximums decreased more (0.8°C). Over the period 1895-1991, Lewis (1997) noted a modal increase in minimum temperatures of 0.2°C in Atlantic Canada, in comparison to an increase of 0.4°C in maximum temperatures.

The variations in diurnal mean temperature averaged among the four stations showed general increases. Only the winter mean maximum value declined (by less than 0.1°C). The largest increases were registered by summer mean minimum (0.9°C), spring mean maximum (0.8°C), and autumn mean minimum (0.8°C) temperatures. Over the period 1933-2007, the mean increase in mean maximum temperature was 0.4°C (almost exclusively in spring and summer). The mean increase in mean minimum temperature was 0.6 C° (most markedly in summer and autumn).

In the period from 1998-2007, temperature changes in Atlantic Canada have more closely paralleled those elsewhere in eastern North America (Lines *et al.* 2003, Lines and Pancura 2005, Vasseur and Catto 2008). The general warming trend in the past decade is partially reflected in the increases in both diurnal maximum and minimum temperatures.

The period of warming evident elsewhere in Atlantic Canada generally is reflected in these data from the four western Newfoundland stations, but particularly in the Corner Brook and Deer Lake records. The declines in winter mean maximum, minimum, and overall temperatures at Stephenville and Daniel's Harbour, in particular prior to the period 1998-2007, contrast with the patterns registered at Corner Brook and Deer Lake, and with those in Atlantic Canada as a whole.

4. Precipitation Variations and Changes

Data collected from the Environment Canada website include total precipitation by month, and total rain and snow by month. These data are further supplemented by daily data, and data from adjacent but differing altitude stations (e.g. Corner Brook). Total precipitation data were used to calculate anomalies for multi-annual and seasonal (winter, spring, summer, and autumn) three month-duration seasons. Winter precipitation and snowfall totals include December of one year followed by January and February of the next year.

Precipitation anomalies for each year were calculated as percentage differences from the multi-annual corresponding average (based on 1971-2000 Climate Normals). Dry periods (pink on graphs below) are those with precipitation less than 90% of the multi-annual average. Extremely dry periods are those with precipitation less than 50% of the multi-annual average (red). Wet periods are those with more than 110% of the multi-annual percentage (blue); very wet had more than 150% (dark blue). Periods with values between 90 and 110% of the multi-annual average are considered as close-to- normal (yellow).

Differences exist in the precipitation records, both among stations and throughout the time of the records. In general, although differences among the stations are evident, the most significant precipitation anomalies occur across western Newfoundland during distinct time periods.

4.1 Annual Total Precipitation Variations and Changes

The multi-annual amounts of total precipitation were calculated for records of 62 years (Stephenville), 68 (Corner Brook), 66 (Deer Lake) and 49 years (Daniel's Harbour) duration. The Stephenville normal is 1238.0 mm, Corner Brook 1185.7 mm, Deer Lake 1034.1 mm, and Daniel's Harbour 1054.0 mm. These normals (Table 4.1) were used to calculate the percentage departure of annual precipitation totals.

Percentage changes in annual precipitation were calculated using the linear trends throughout the duration of the precipitation record for each site (Figure 4.1). All four sites show substantial increases in mean annual precipitation throughout the time series, with changes ranging from 11.3% (Daniel's Harbour) to 32.5% (Stephenville).

Station	*Mean Normal Pptn (mm)*	*Driest Year (% of Normal)*	*Wettest Year (% of Normal)*	*% change in Annual Pptn**	*Duration of Record***
ST	1238.0	1943 (68%)	1982 (134%)	32.5 %	1943-2007
CB	1185.7	1966 (74%)	2000 (126%)	14.2%	1934-2006
DL	1034.1	1947 (63%)	1995 (131%)	29.3%	1934-2007
DH	1054.0	1957 (62%)	1990 (139%)	11.3%	1948-2007

Table 4.1 Precipitation, Driest, Wettest Years, and Linear Trend

* calculated from linear trend over duration of record for each site

** years with missing data excluded

At Corner Brook since 1976, only 6 years have seen total precipitation below the 68-year mean value. Similarly, only 6 years since 1976 have seen precipitation below the mean annual total of 1238.0 mm at Stephenville.

Wet and dry anomalies for the four stations are summarized in Figure 4.2. For all locations, the available data prior to 1970 indicates a relatively dry period, with only isolated statistically wet years. The period 1970-2007 was generally wet. Drier intervals occurred in 1985-1987 and 2003-2005.

Proportions between wet and dry years vary between the four locations analysed. For all locations, the number of close to normal years (between 90-110%) exceeds dry and wet years. Stephenville recorded 21% dry and 21% wet years over the entire 62 year-range of data. However, no dry years have occurred since 1964, and all of the wet years have occurred since 1979. Corner Brook also recorded equal percentages (22%) of dry and wet years, although in the period 1976-2006 Corner Brook registered 3 anomalously dry and 13 anomalously wet years. Between 1976 and 2007, Deer Lake recorded 3 anomalously dry and 19 anomalously wet years, including 8 consecutive wet years between 1993 and 2000. Although the Daniel's Harbour record has significant gaps due to missing data, 14 of the 25 years between 1971 and 1995 were anomalously wet. Drier and normal conditions marked Daniel's Harbour in the period 2000-2007.

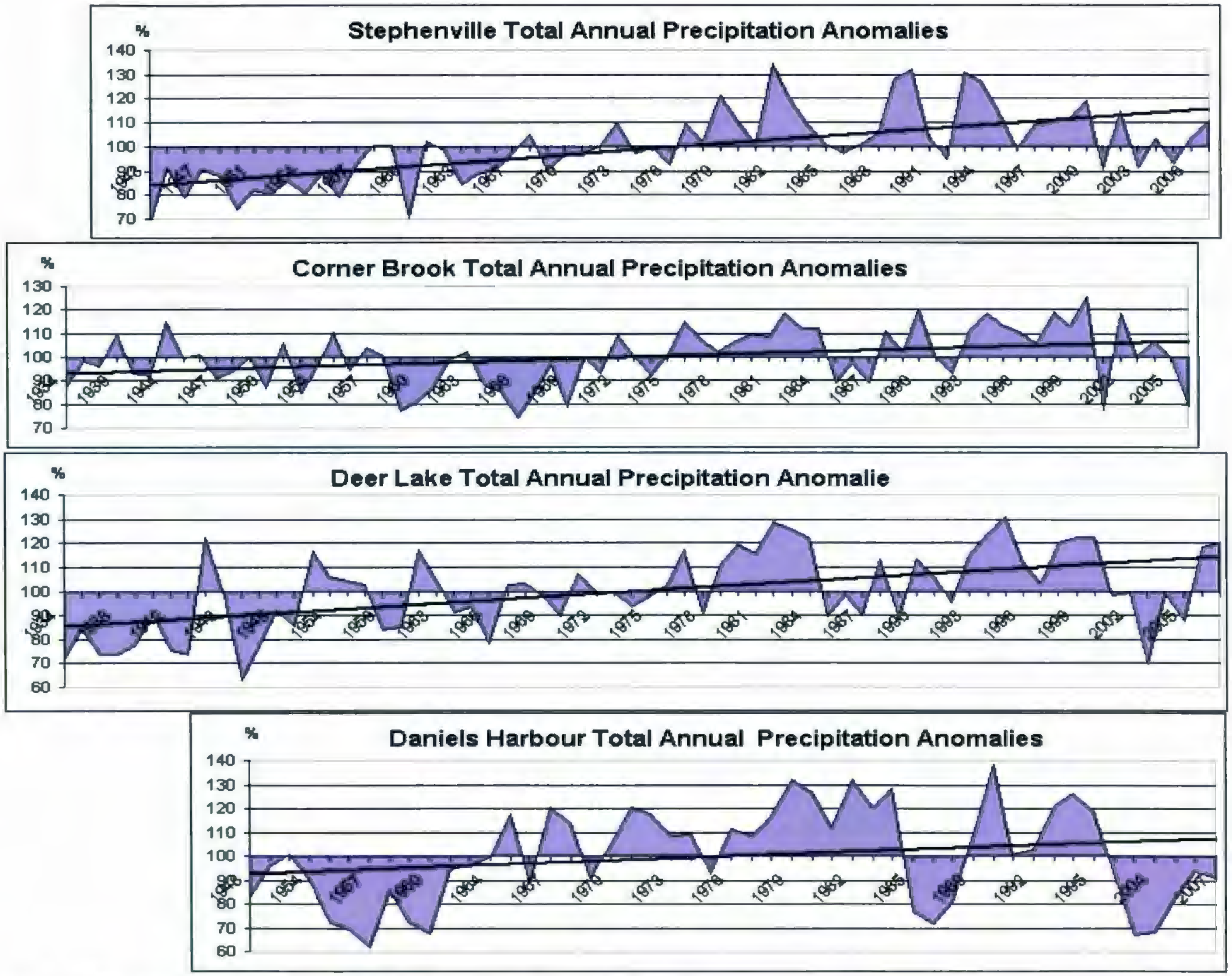


Figure 4.1 Percentage Changes in Annual Precipitation

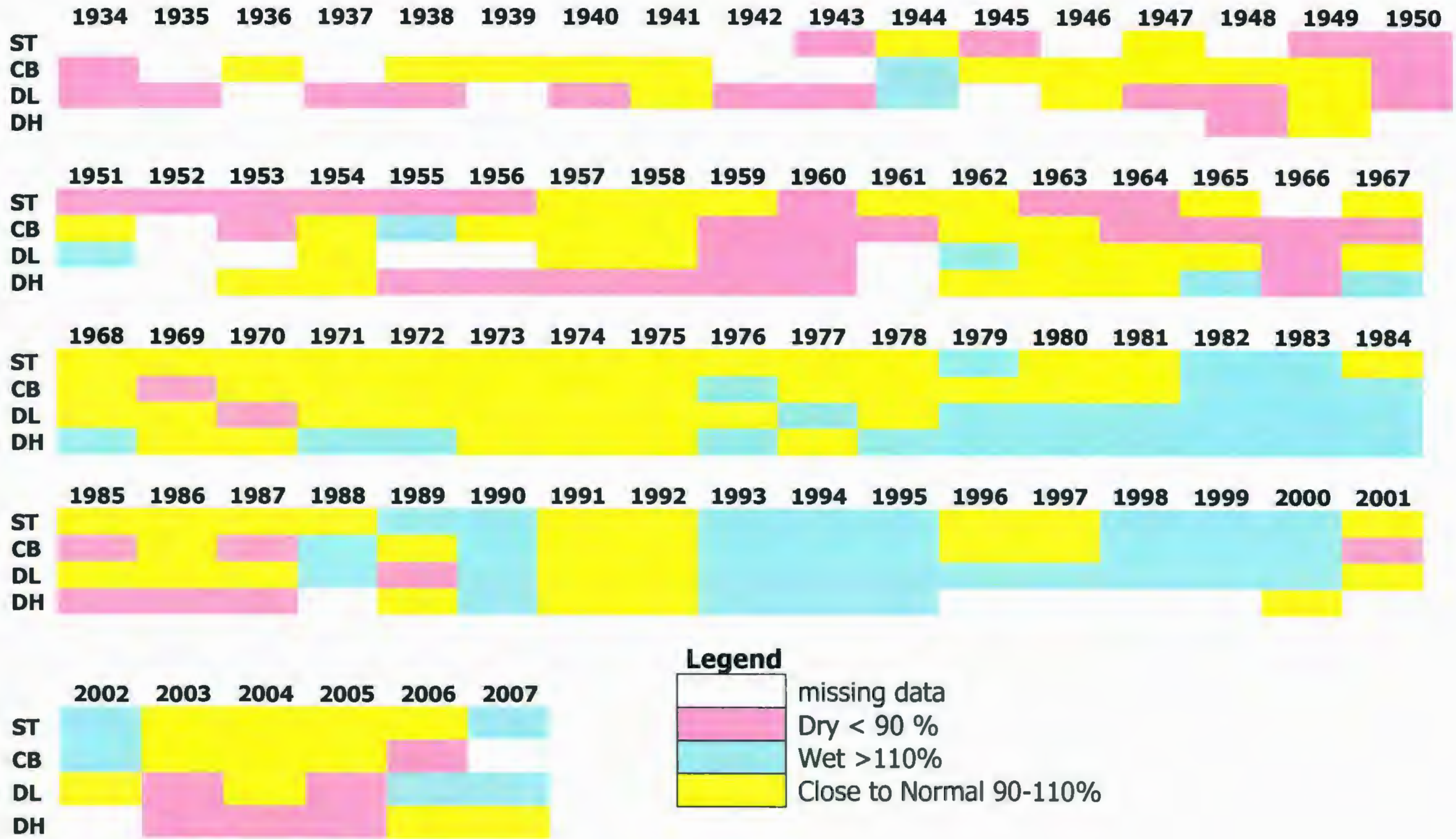


Figure 4.2 Annual Total Precipitation Variability

4.2 Total Precipitation by Seasons

Percentage differences from mean normal values were calculated for total precipitation for each of the three-month winter, spring, summer, and autumn seasons. In addition to the dry and wet anomalies designated above, seasons with total precipitation in excess of 150% of the normal for the time series are designated as very wet. Very dry seasons have less than 50% of the mean seasonal normal precipitation.

4.2.1 Winter Total Precipitation

Normal values were calculated for each of the four stations from the available record (Table 4.2). The patterns and linear trends for each station are illustrated in Figures 4.3 and 4.4, and Table 4.3. The general pattern is:

- decrease in precipitation between 1934 – 1945;
- strong variability with alternating dry, wet, and close to normal years between 1945-1975;
- increase in precipitation dominated by wet years after 1975, with a dry period for Daniel's Harbour between 1986-1989;
- relatively dry winter conditions from 2001, with the qualified exception of Deer Lake.

Station	*Mean Normal Pptn (mm)*	*Driest Year (% of Normal)*	*Wettest Year (% of Normal)*	*% change in Winter Pptn**	*Number of Years Included***
ST	333.9	1943 (39%)	1982 (177%)	22.8%	65
CB	365.9	2007 (50%)	1947 (152%)	13.1%	69
DL	249.3	1936 (32%)	1999 (161%)	58.1%	72
DH	258.6	1958 (38%)	1991 (163%)	11.6%	55

Table 4.2 Winter Normal Precipitation, Driest, Wettest Years, and Linear Trend

* calculated from linear trend over duration of record for each site
** years with missing data excluded

Station	**Number of Years**					
	Very Dry	**Dry**	**Normal**	**Wet**	**Very Wet**	**Total**
ST	2 (1943-4)	19	24	17	3 (1947, '82, '91)	65
CB	1 (2007)	21	27	19	1 (1947)	69
DL	7 (last in 1975)	20	14	28	3 (1963, '82, '99)	72
DH	1 (1958)	23	10	19	2 (1964, 1991)	55

Table 4.3 Winter Precipitation Regimes

Although there is a general increase in winter precipitation, the most significant characteristic of the winter precipitation data is the substantial variability, both temporal and spatial. In contrast to the temperature records, the winter precipitation records show more 'anomalous' than 'normal' years for all stations. Over the 30-year period 1978-2007, only 5 winters (1978, 1982, 1984, 1991, and 1994) were marked by wet conditions at all four stations. During the same interval, dry conditions were prevalent in 1981, 1998 (although complete data do not exist for Daniel's Harbour), and 2002. In some years (1988, 1992, 2000, 2003, 2005, 2006, 2007), wet winters at one or more stations coincide with dry winters at others. Substantial variation is a modal condition for winter precipitation in western Newfoundland.

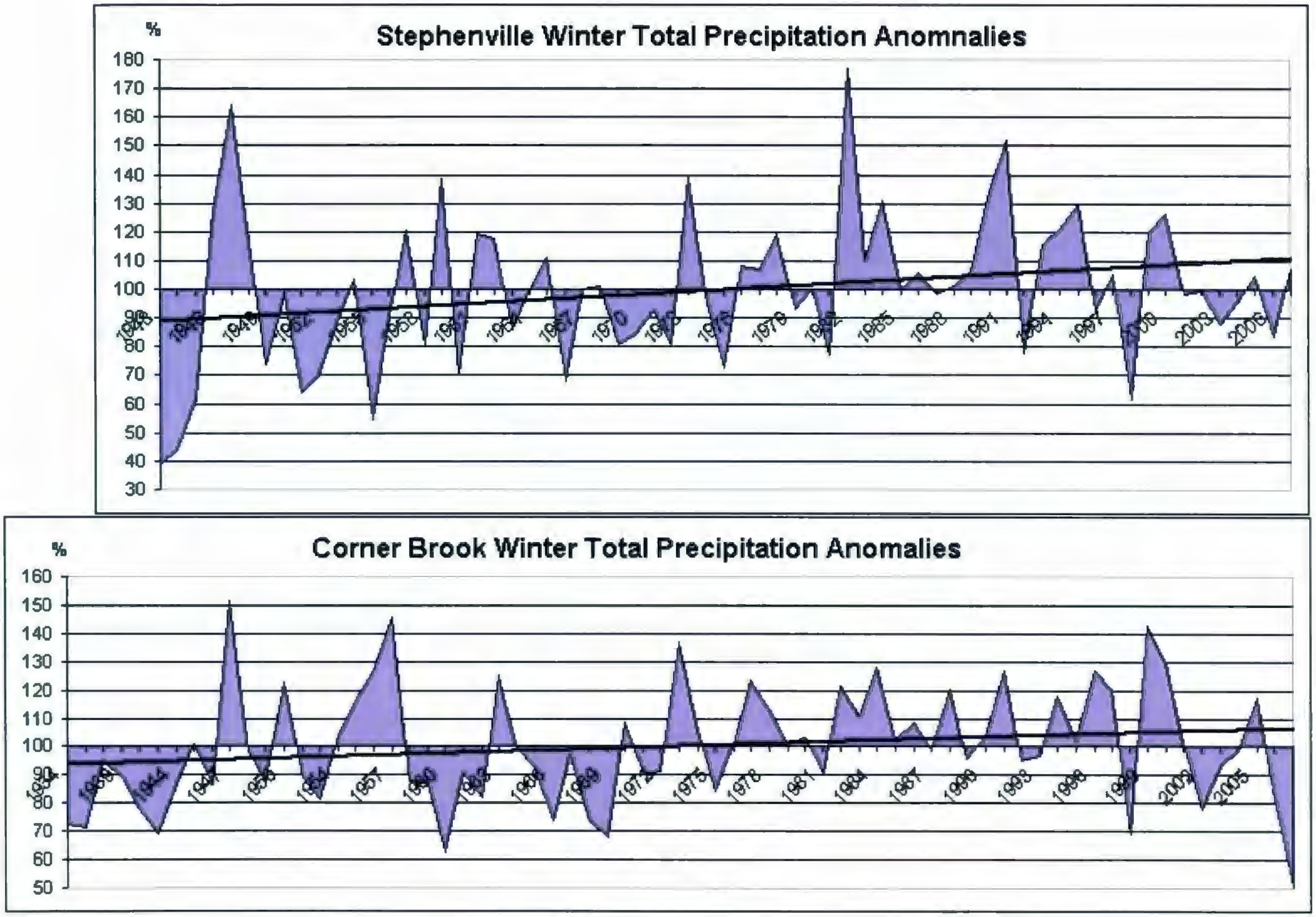
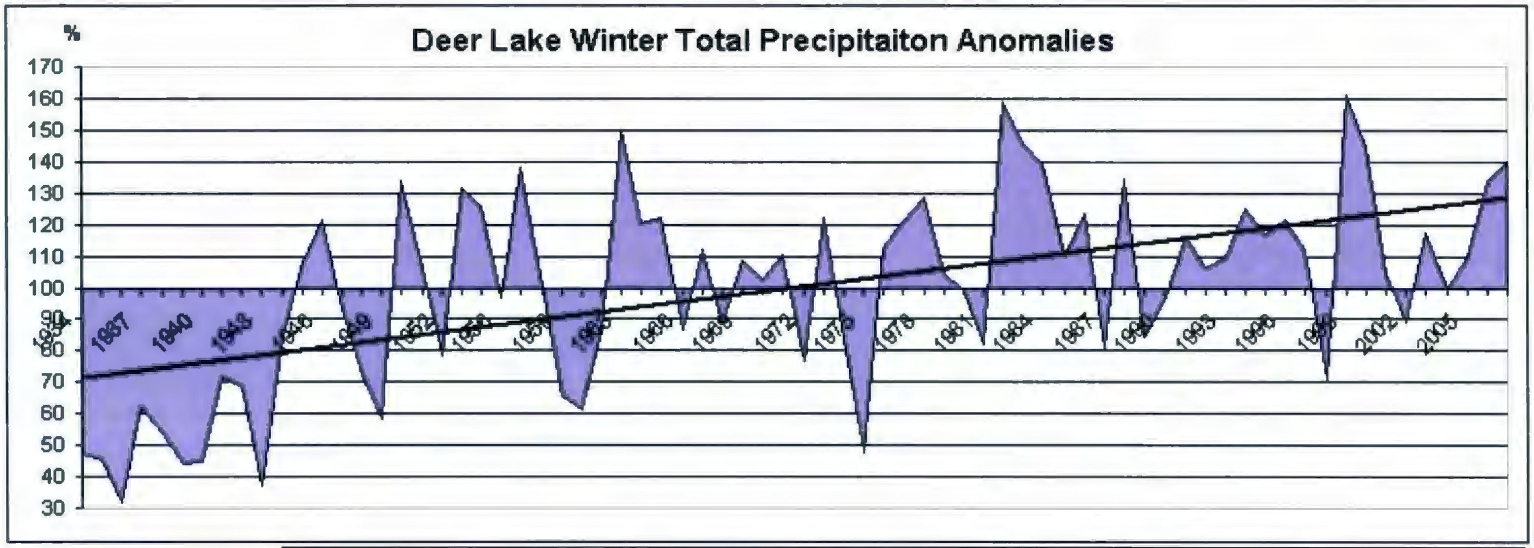
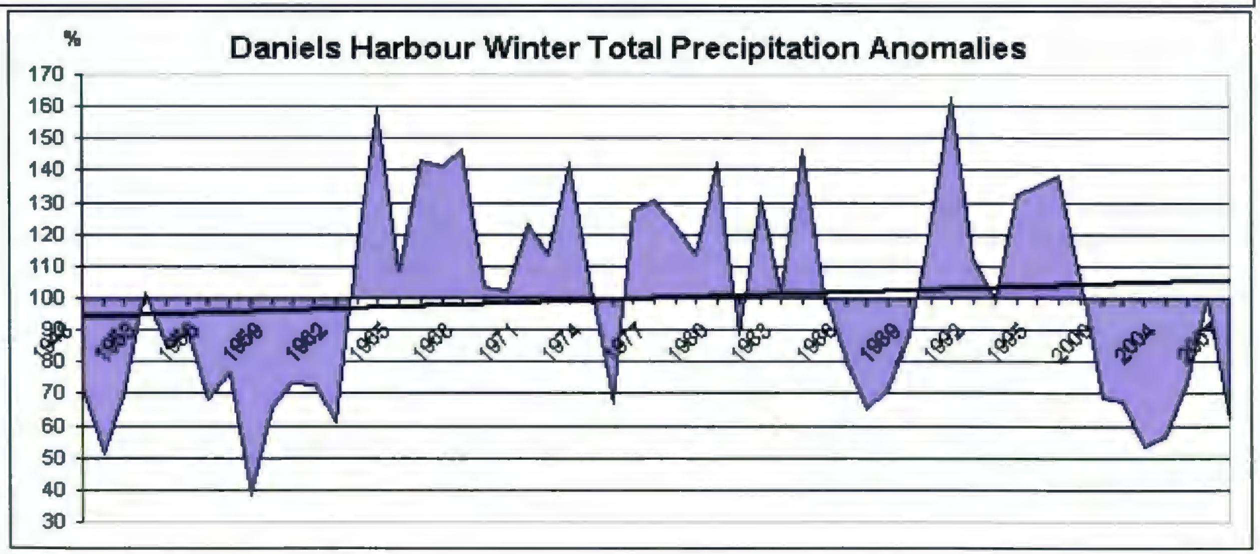


Figure 4.3 Percentage Changes in Winter Total Precipitation

Figure 4.3 continued





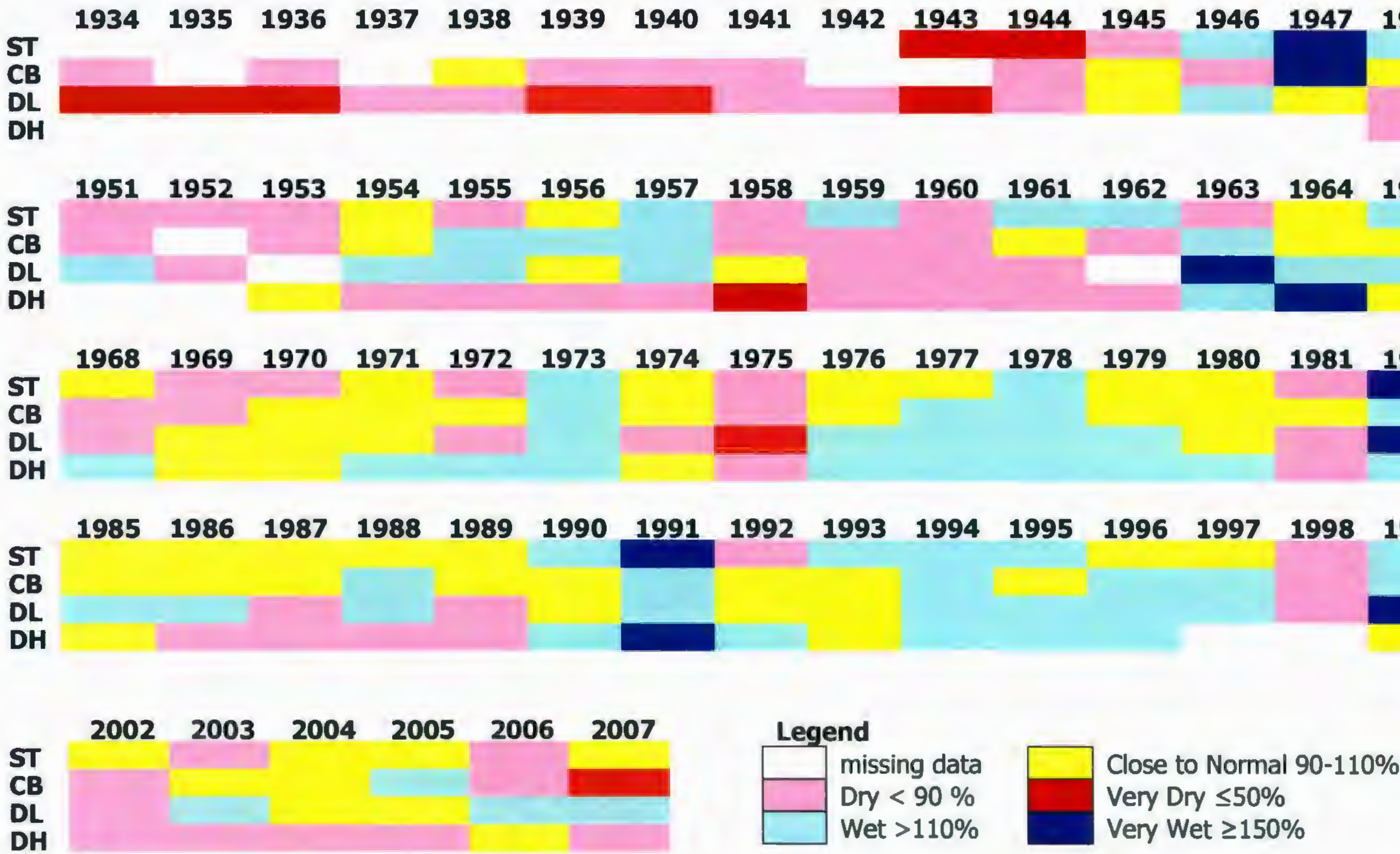


Figure 4.4 Winter Total Precipitation Variability

4.2.2 Spring Total Precipitation

Stephenville spring total precipitation was analyzed for 63 years, Corner Brook for 70 years, Deer Lake for 72 years and DH for 56 years. Normal values were calculated for spring seasons including March, April and May. Results are shown in Figure 4.5 and Tables 4.4 and 4.5. The wettest year is 1994 for all four locations. Dry and wet spring years are illustrated in Figure 4.5.

Station	*Mean Normal Pptn (mm)*	*Driest Year (% of Normal)*	*Wettest Year (% of Normal)*	*% change in Spring Pptn**	*Number of Years Included***
ST	237.4	1944 (44%)	1994 (200%)	45.9%	63
CB	226.5	2006 (44%)	1994 (181%)	13.2%	70
DL	204.8	2005 (50%)	1994 (173%)	25.4%	72
DH	203.2	1959 (44%)	1994 (169%)	12.3%	56

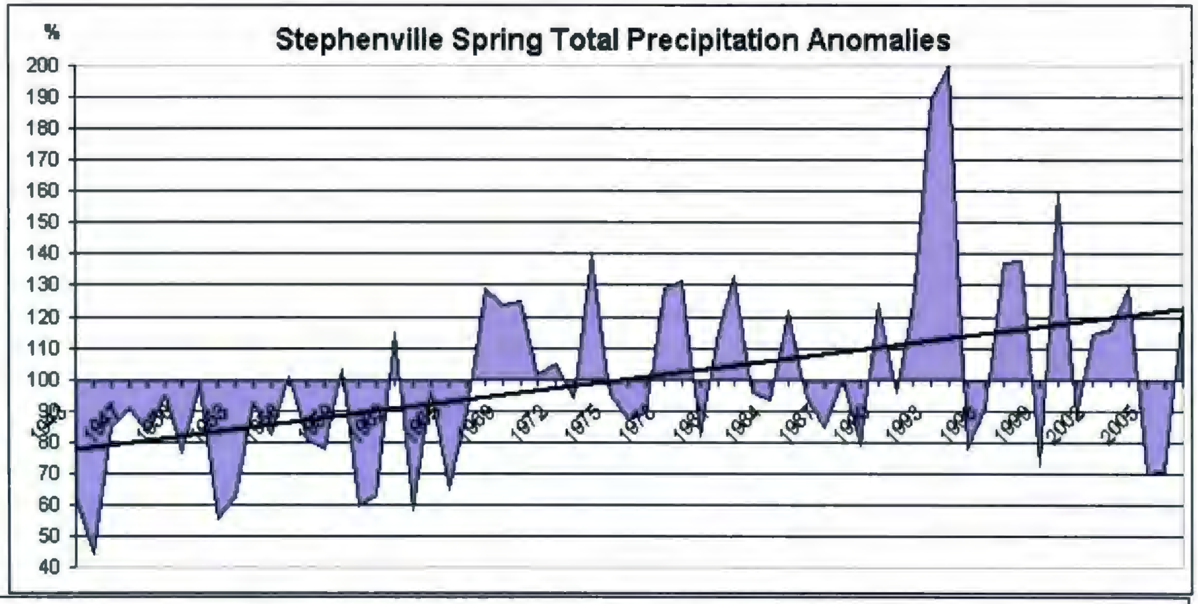
Table 4.4 Spring Precipitation, Driest, Wettest Years, and Linear Trend

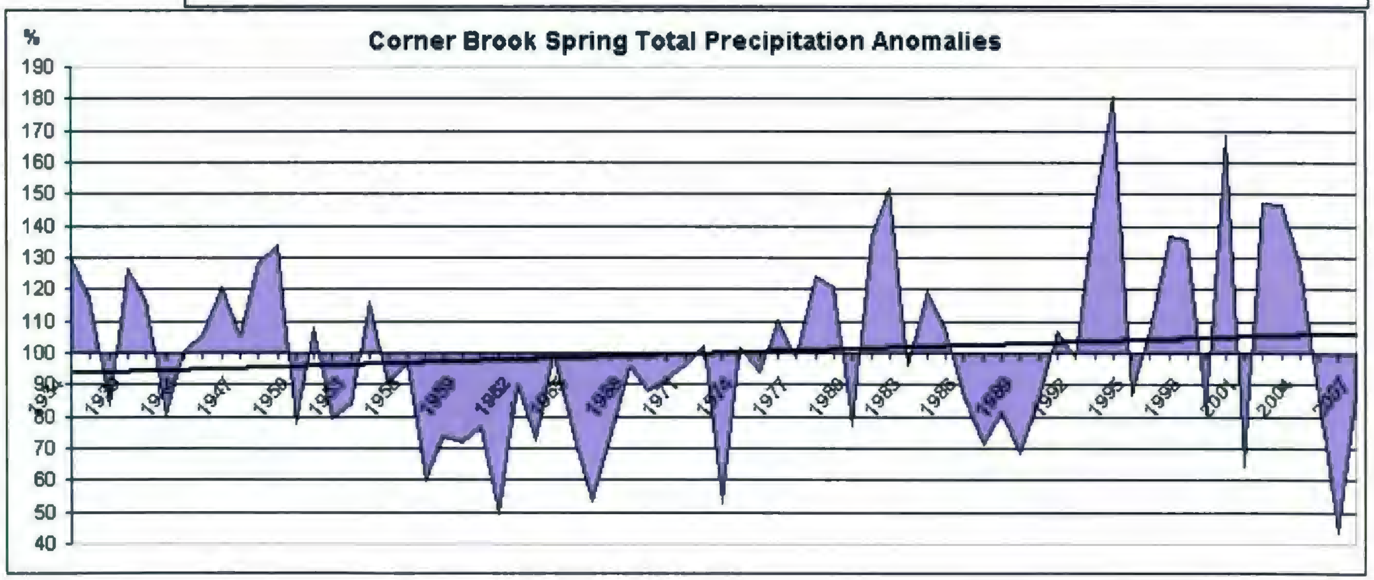
* calculated from linear trend over duration of record for each site
** years with missing data exclude

Station	Number of Years					
	Very Dry	**Dry**	**Normal**	**Wet**	**Very Wet**	**Total**
ST	1 (1944)	23	18	18	3 (1993, 1994, 2000)	63
CB	2 (1931, 2006)	27	20	18	3 (1982, 1994, 2000)	70
DL	1 (2005)	23	25	19	4 (1951, 1993, 1994, 1998)	72
DH	5 (1957, 1959, 1988, 1999, 2005)	15	15	17	4 (1972, 1982, 1983, 1994)	56

Table 4.5 Spring Precipitation Regimes

All localities show an increase in spring precipitation, most markedly at Stephenville and Deer Lake. For all four locations, more dry spring years occurred in the part of the record prior to 1964. Wetter springs characterized the period 1992-2004, with drier spring conditions marking the years 2005-2007.


%
Stephenville Spring Total Precipitation Anomalies
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40


%
Corner Brook Spring Total Precipitation Anomalies
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40

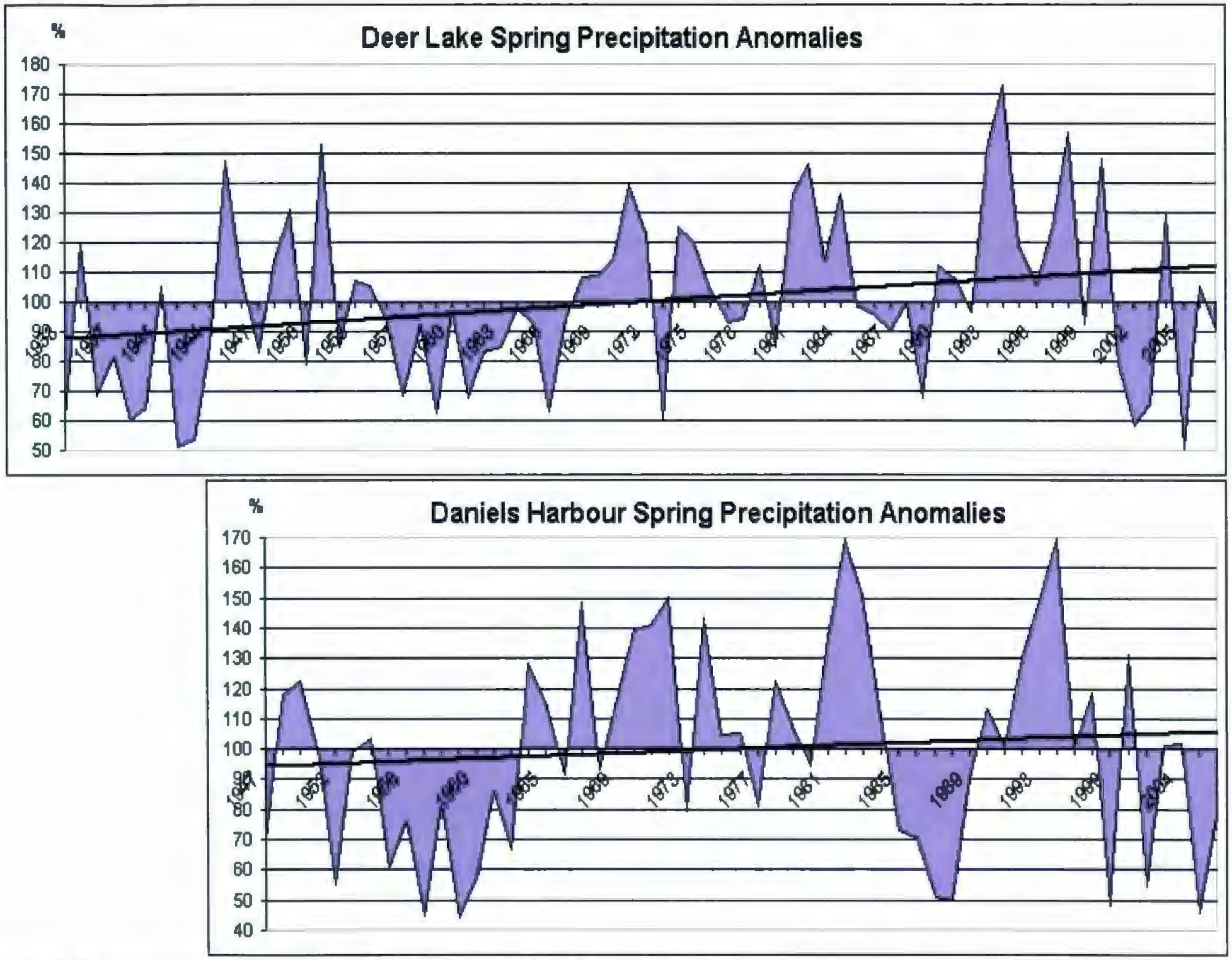


Figure 4.5 Percentage Changes in Spring Total Precipitation

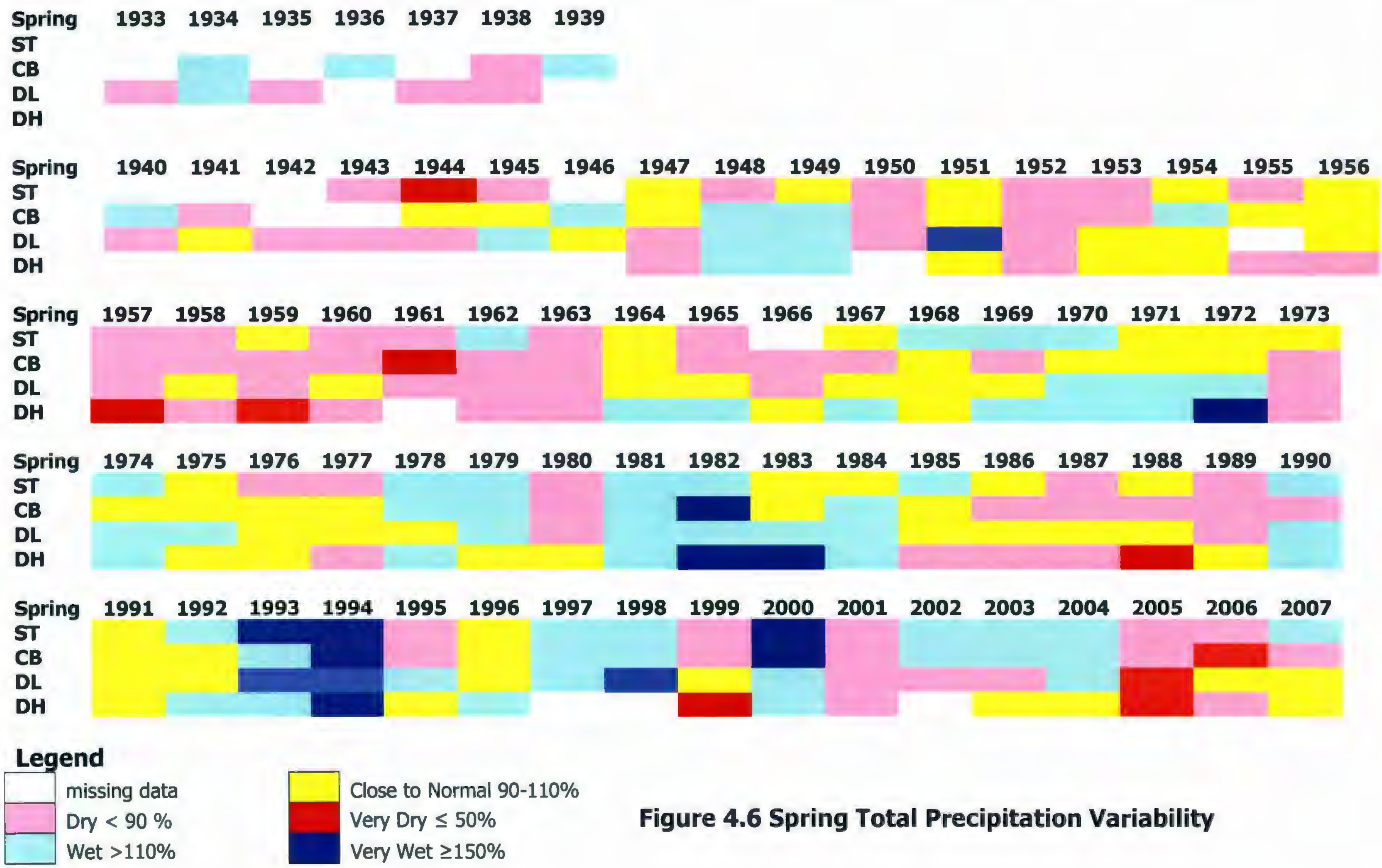


Figure 4.6 Spring Total Precipitation Variability

4.2.3 Summer Total Precipitation

Summer total precipitation includes June, July and August. The normal is calculated for the corresponding range of data for each location (Tables 4.6, 4.7). The Summer Normal are higher than Spring for all four locations. Stephenville and Corner Brook summer normals are less than the winter normals. Variability over time is shown in Figure 4.7 and 4.8. Generally, the period before 1975 was marked by summer precipitation below the normal. Most of the wettest years were after 1980, although the period 1999-2005 was generally drier.

Station	*Mean Normal Pptn (mm)*	*Driest Year (% of Normal)*	*Wettest Year (% of Normal)*	*% change In Summer Pptn**	*Number of Years Included***
ST	306.8	1945 (44%)	1983 (187%)	42.7%	65
CB	256.3	1974 (44%)	2006 (171%)	25.4%	72
DL	272.7	1947 (50%)	1995 (167%)	21.3%	72
DH	290.7	2003 (44%)	1984 (173%)	11.7%	56

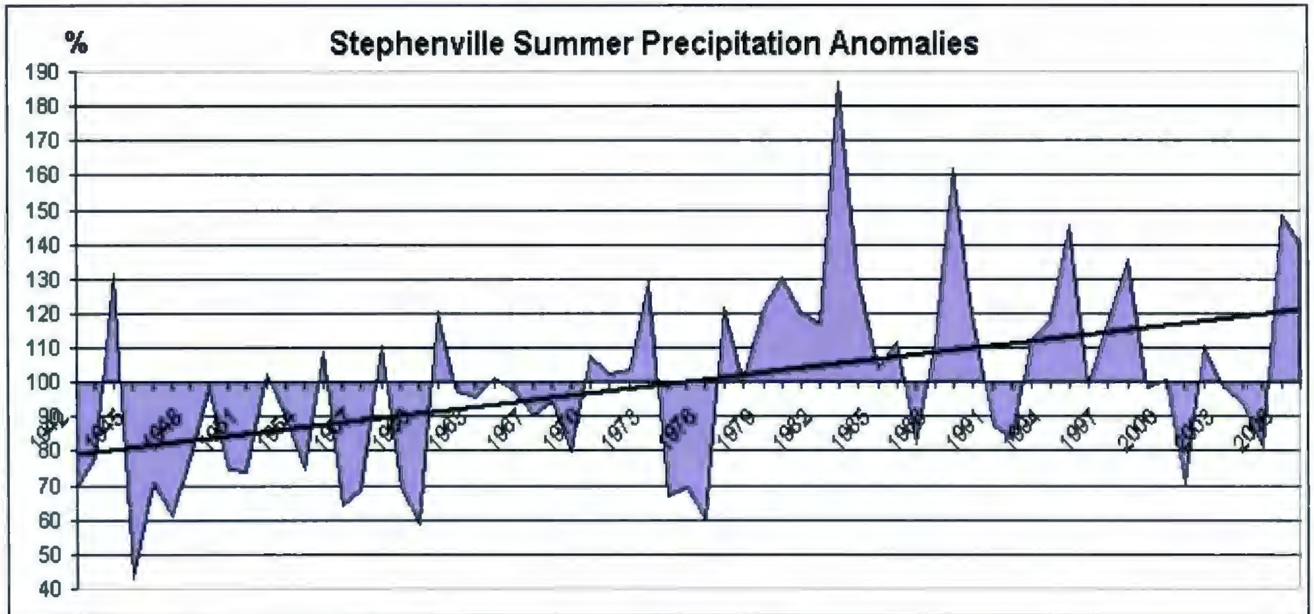
Table 4.6 Summer Normal Precipitation, Driest. Wettest Years and Linear Trend

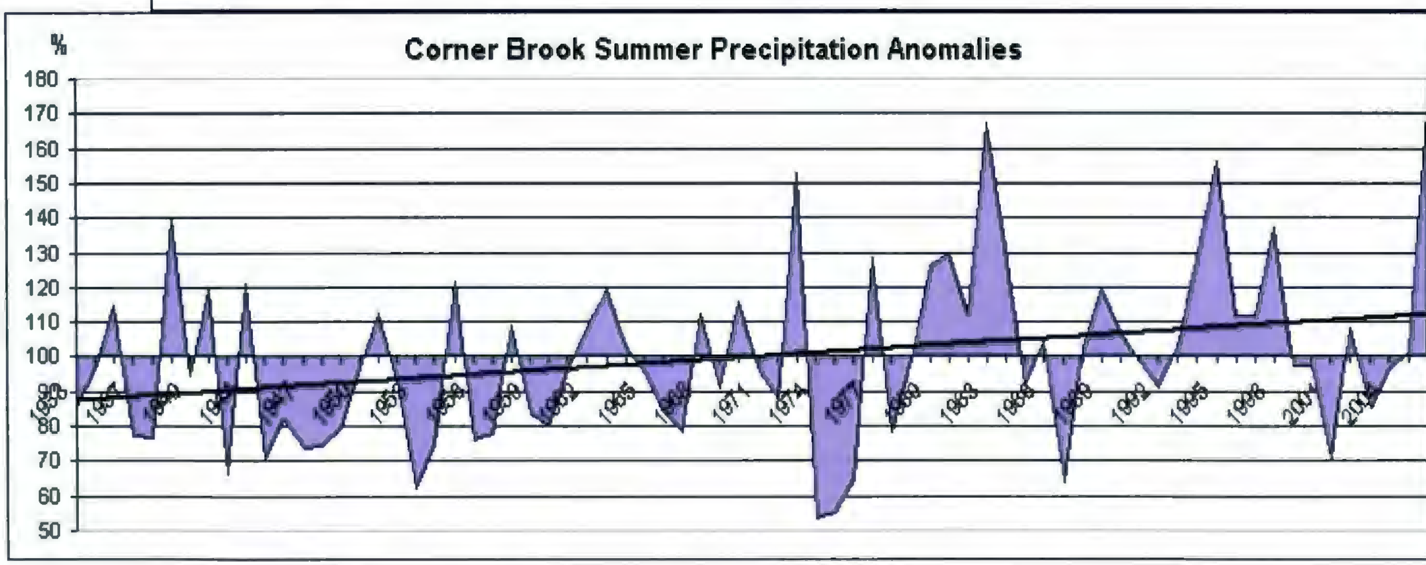
* calculated from linear trend over duration of record for each site
** years with missing data excluded

Station	Number of Years					
	Very Dry	**Dry**	**Normal**	**Wet**	**Very Wet**	**Total**
ST	1 (1945)	21	21	20	2 (1983, 1989)	65
CB	0	25	24	19	4 (1973, 1983, 1995, 2006)	72
DL	2 (1947, 1976)	21	28	18	3 (1983, 1995, 2007)	72
DH	1 (2003)	18	19	17	1 (1984)	56

Table 4.7 Summer Precipitation Regimes

All sites show significant variation from year to year. Throughout the periods analysed, Stephenville had only 21 'normal precipitation' summers, Corner Brook 24, Deer Lake 28, and Daniel's Harbour 19 (Table 4.7). Deer Lake and Corner Brook show strong variability throughout the time series. Variability increased for both Stephenville and Daniel's Harbour after 1985. Variable precipitation in consecutive summers complicates planning for tourism operators.


%
Stephenville Summer Precipitation Anomalies
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40


%
Corner Brook Summer Precipitation Anomalies
180
170
160
150
140
130
120
110
100
90
80
70
60
50

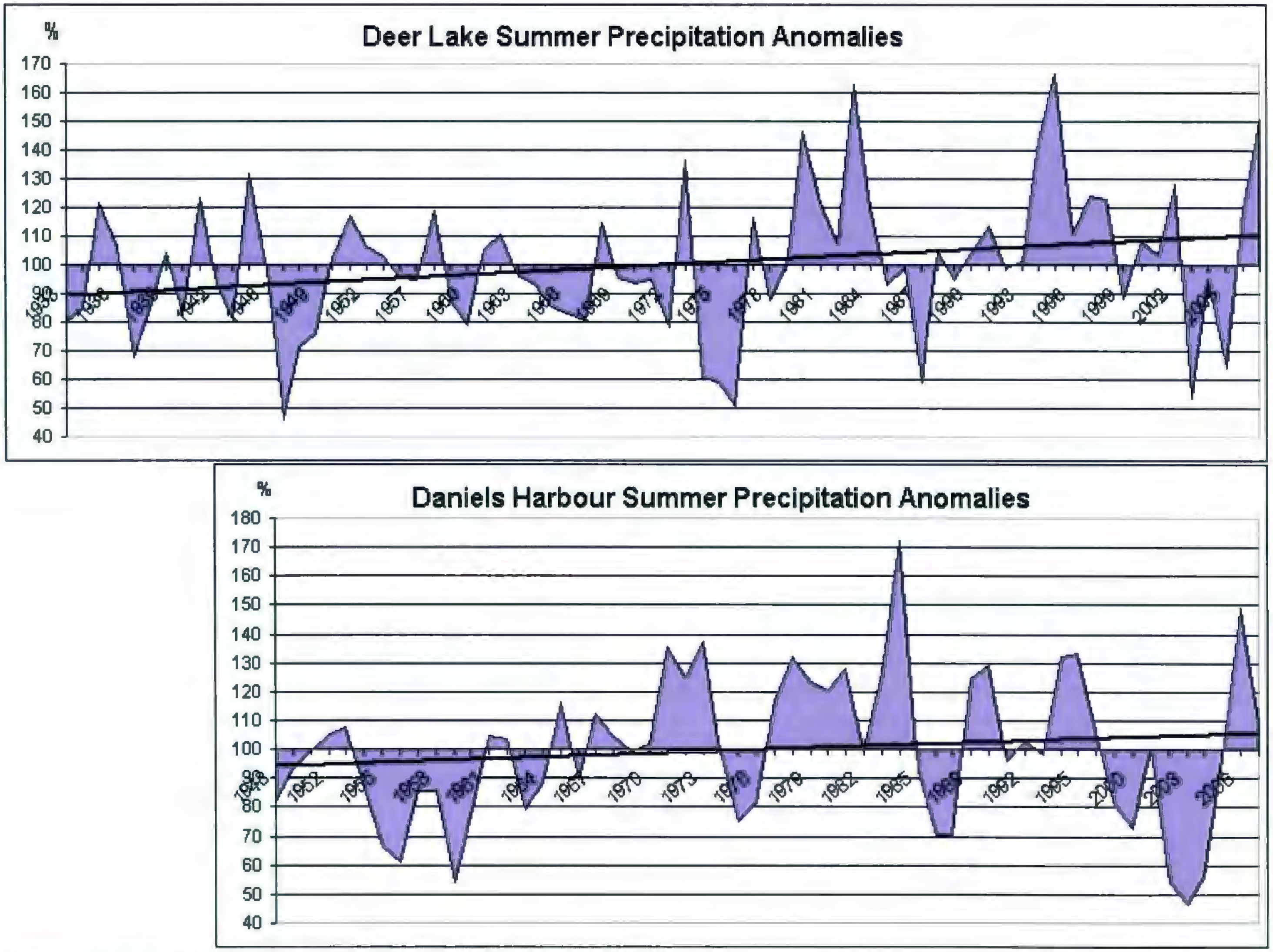


Figure 4.7 Percentage Changes in Summer Total Precipitation

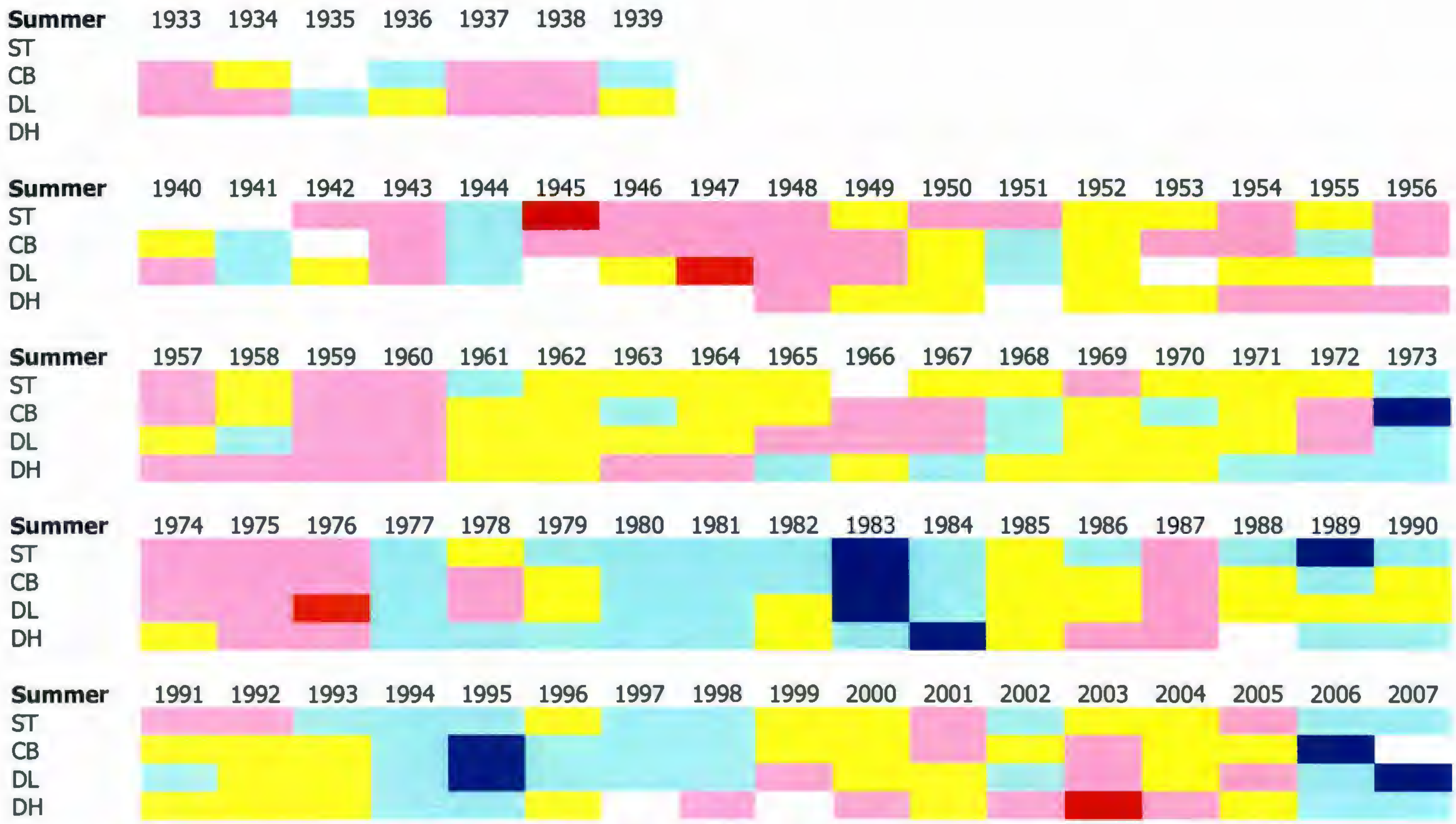


Figure 4.8 Summer Total Precipitation Variability

4.2.4 Autumn Total Precipitation

The driest autumn years occurred before 1960 for three locations. Corner Brook is the exception, with 2006 as the driest autumn (Table 4.8, 4.9, Figure 4.9, 4.10). The wettest years generally occurred after 1970.

The autumn normal precipitation is higher than winter, spring, and summer normal for Stephenville and Corner Brook. The Corner Brook autumn normal is higher than spring but less than winter, while autumn precipitation at Daniel's Harbour is higher than the winter and spring normal but less than summer.

Station	*Mean Normal Pptn (mm)*	*Driest Year (% of Normal)*	*Wettest Year (% of Normal)*	*% change in Autumn Pptn**	*Number of Years Included***
ST	354.6	1956 (61%)	2002 (146%)	25.9%	65
CB	331.4	2006 (53%)	1975 (156%)	4.5%	73
DL	299.7	1950 (55%)	1944 (160%)	16.7%	72
DH	283.3	1957 (47%)	1980 (184%)	9.5%	57

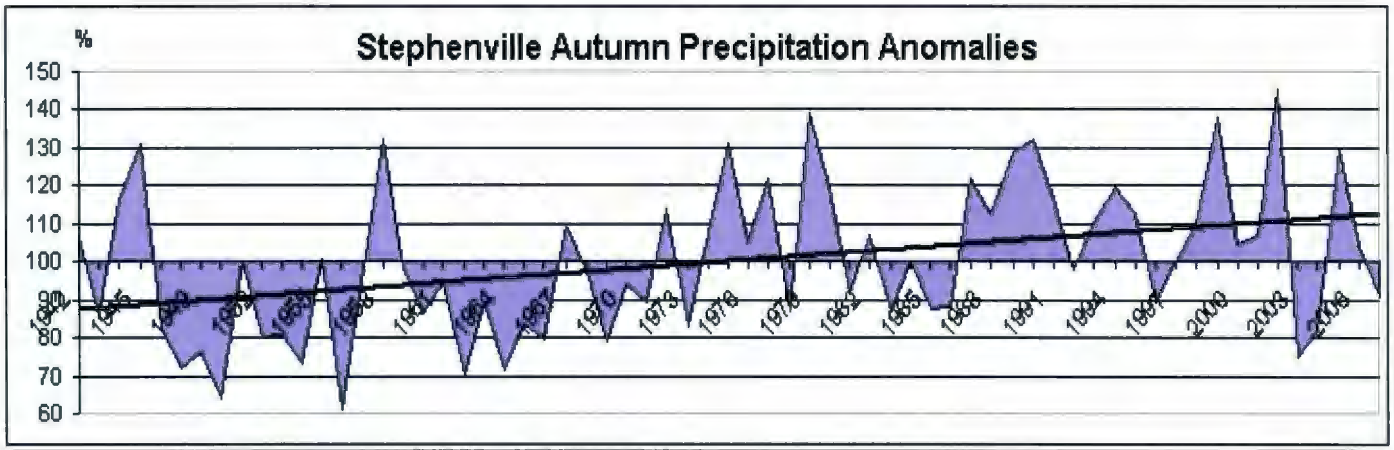
Table 4.8 Autumn Normal Precipitation, Driest, Wettest Years and Linear Trend

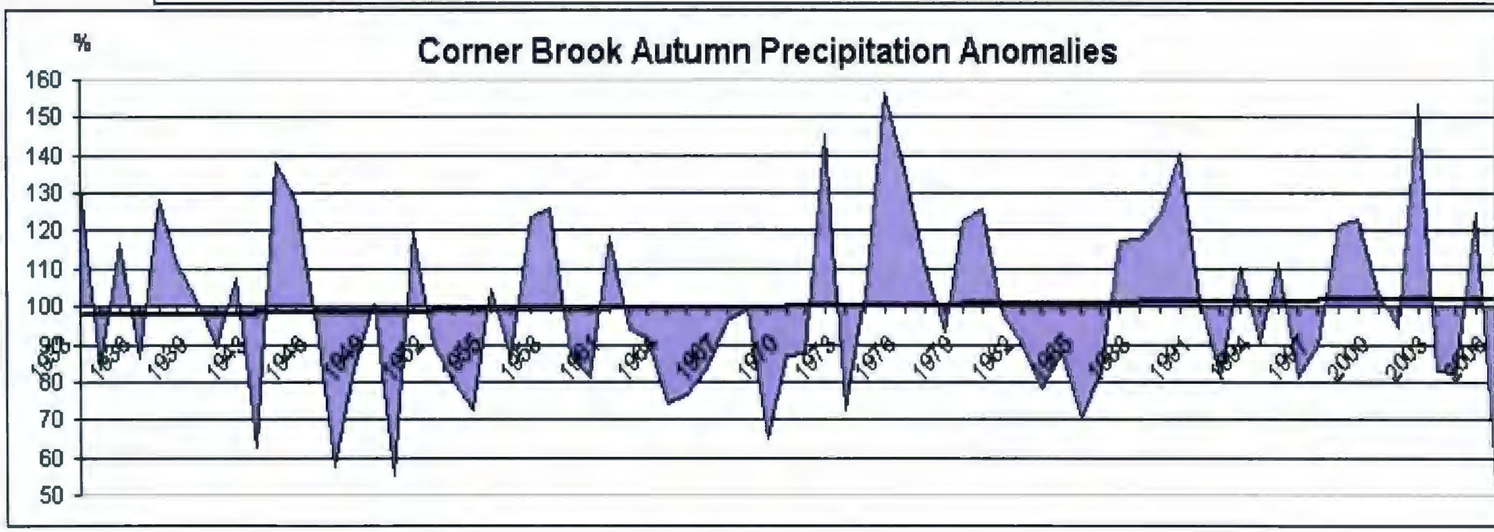
* calculated from linear trend over duration of record for each site
** years with missing data excluded

Station	Number of Years					
	Very Dry	**Dry**	**Normal**	**Wet**	**Very Wet**	**Total**
ST	0	25	22	18	0	65
CB	0	29	19	23	2 (1975, 2002)	73
DL	0	25	24	21	2 (1944, 1980)	72
DH	1 (1957)	22	17	14	3 (1979, 1980, 1990)	57

Table 4.9 Autumn Precipitation Regimes

Stephenville and Corner Brook autumn precipitation totals show strong variability year by year from the beginning of the record. Strong variability has characterized Daniel's Harbour and Deer Lake since 1970.


%
Stephenville Autumn Precipitation Anomalies
150
140
130
120
110
100
90
80
70
60
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006


%
Corner Brook Autumn Precipitation Anomalies
160
150
140
130
120
110
100
90
80
70
60
50
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006

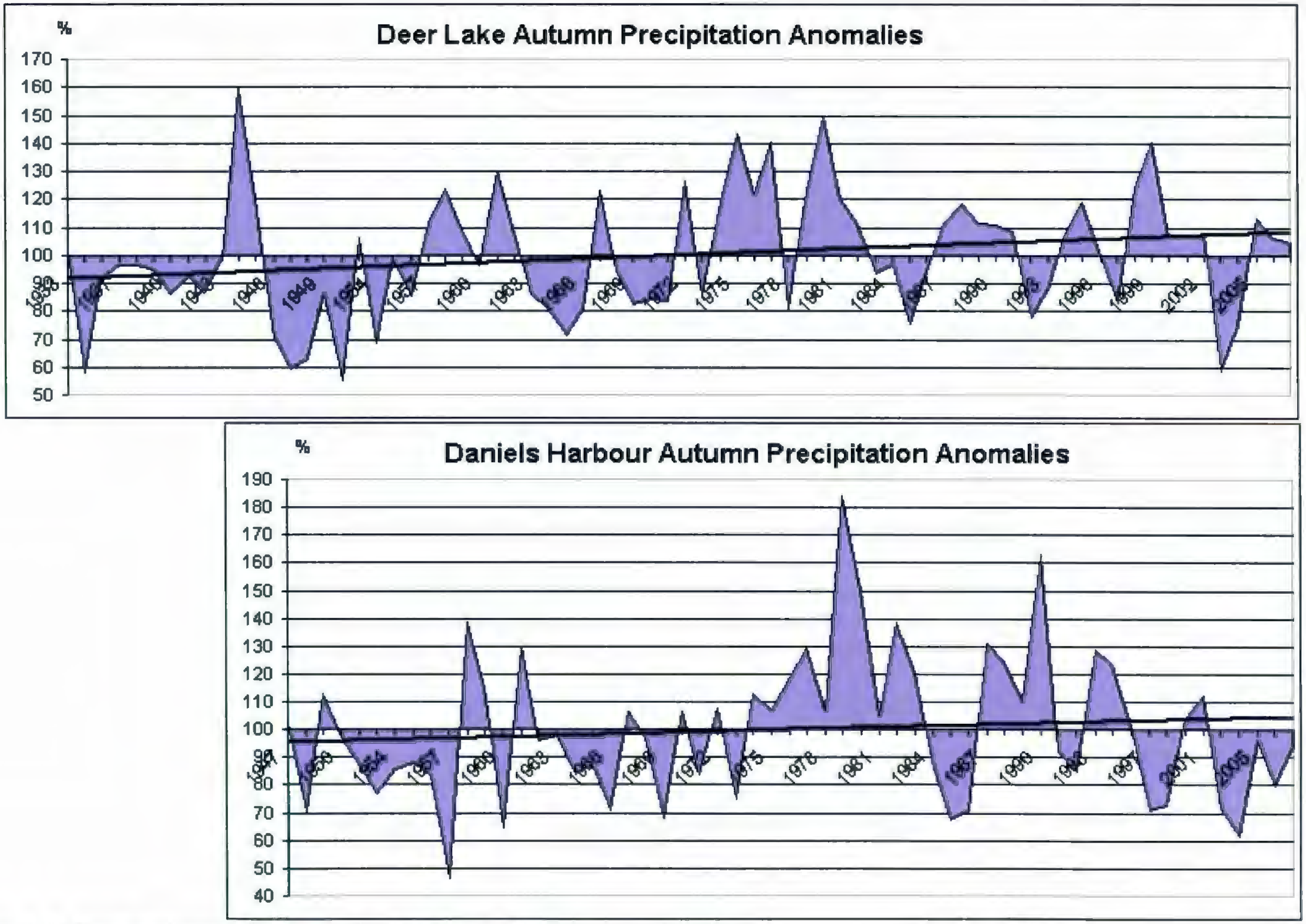


Figure 4.9 Percentage Changes in Autumn Total Precipitation

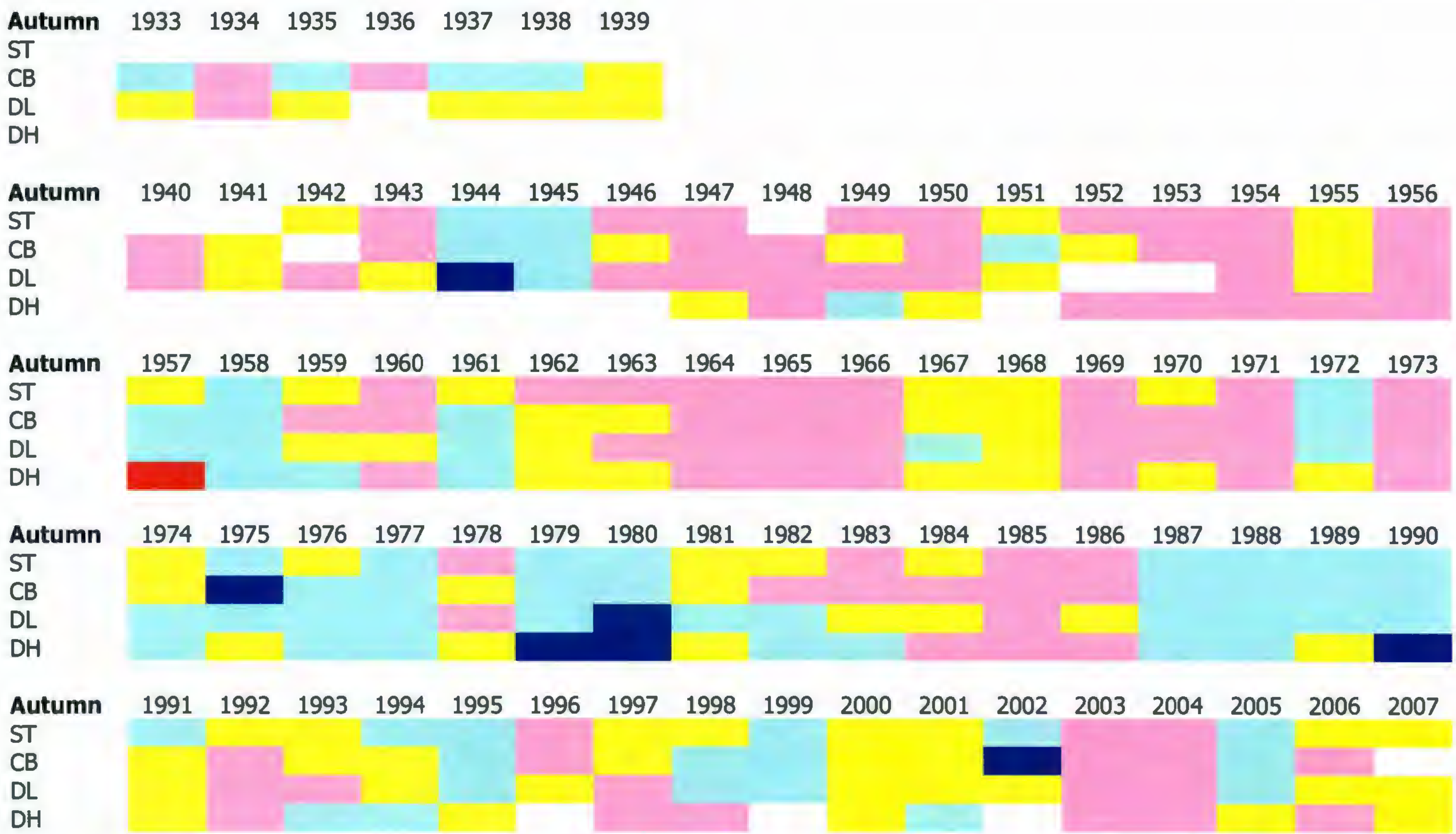


Figure 4.10 Autumn Total Precipitation Variability

4.2.5 Summary

Seasonal trends in precipitation for the four stations are summarized in Tables 4.10 and 4.11. All four sites show substantial increases in annual precipitation, and all four show increasing precipitation in each of the four seasons. The greatest percentage changes are evident in winter precipitation at Deer Lake, and spring and summer precipitation at Stephenville. Daniel's Harbour shows the least increase in precipitation in three of the four seasons.

Station	*% change in Winter Pptn**	*% change in Spring Pptn**	*% change in Summer Pptn**	*% change in Autumn Pptn**	*% change in Annual Pptn**
ST	22.8%	45.9%	42.7%	25.9%	32.5 %
CB	13.1%	13.2%	25.4%	4.5%	14.2%
DL	58.1%	25.4%	21.3%	16.7%	29.3%
DH	11.6%	12.3%	11.7%	9.5%	11.3%

Table 4.10 Seasonal Trends in Precipitation

* calculated from linear trend over duration of record for each site

Station	Number of Years									
	Winter		Spring		Summer		Autumn		Annual	
	Dry*	Wet**	Dry*	Wet**	Dry*	Wet**	Dry*	Wet**	Dry*	Wet**
ST	21	20	24	21	22	22	25	18	13	13
CB	22	20	29	21	25	23	29	25	15	15
DL	27	31	24	23	23	21	25	23	17	22
DH	24	21	20	21	19	18	23	17	14	17

*includes very dry
** includes very wet

Table 4.11 Seasonal Precipitation Regimes

4.3 Snowfall

4.3.1 Winter Snowfall

Environment Canada defines snowfall to represent the amount of frozen (solid) precipitation, measured in cm, observed during a 24-hour day. Winter snowfall is analysed for the winter months (December, January, and February). Extra-winter snowfall includes that in all autumn and spring months, as well as in June. Winter and annual total values for each year include snowfall totals from September through December of the previous year (e.g., the snowfall for '2001' includes all snow between September 2000 and June 2001). This procedure avoids splitting winter seasons between different years. Anomalies of winter, extra-winter, and total snowfalls are calculated as a percentage of departures from the normal of the entire data series.

Yearly variations in winter snowfall are shown in Tables 4.12 and 4.13, and Figures 4.11 and 4.12. The data show high percentage increases in snowfall throughout the available time series. However, with the exception of Corner Brook, winters prior to ca. 1962 were markedly less snowy than those of recent years. Over the period 1977-2007, only Deer Lake has seen a significant increase in snowfall.

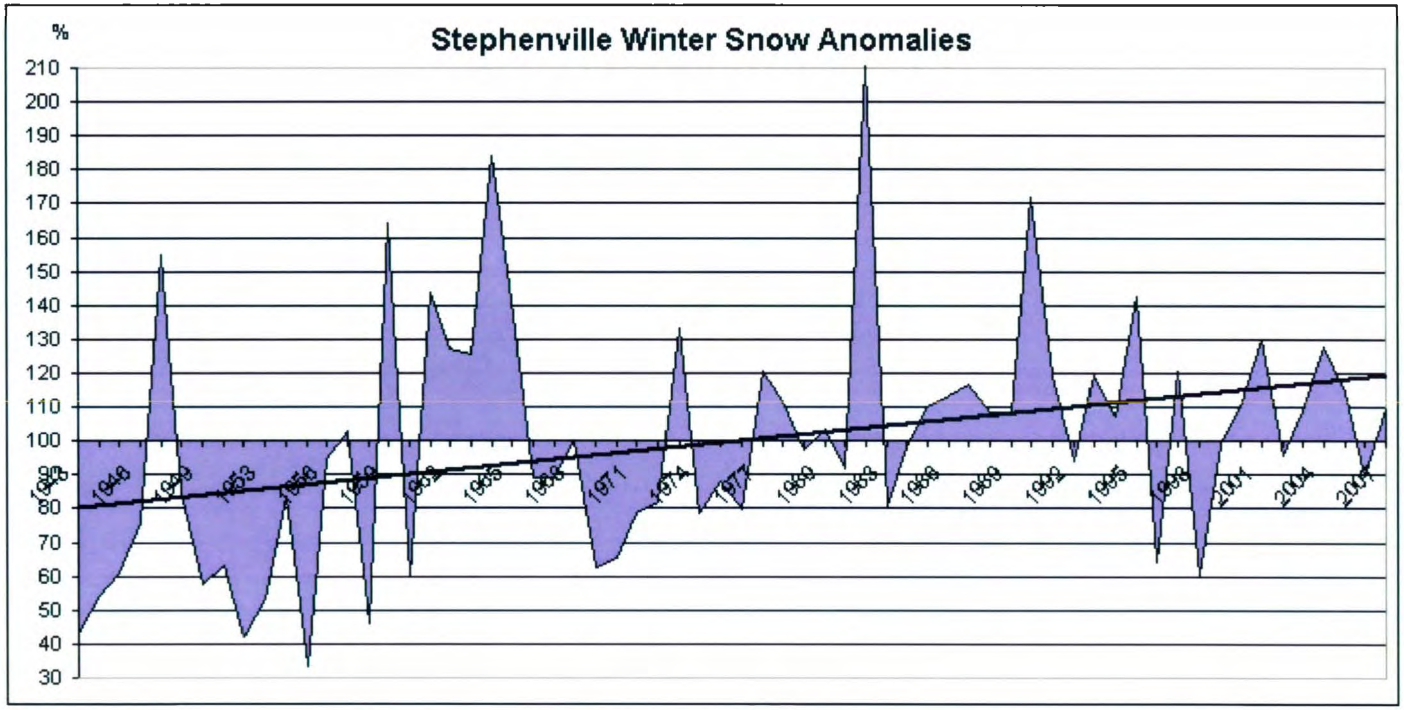
Station	*Mean Snowfall (cm)*	*Driest Year (% of Normal)*	*Wettest Year (% of Normal)*	*% change in Snowfall **	*Number of Years Included***	*% change 1977-2007**
ST	264.8	1955 (33%)	1982 (210%)	39.7%	64	-10.8
CB	278	1960 (39%)	1947 (164%)	5.0%	72	-3.9***
DL	184.4	1935 (29%)	1962 (170%)	74.8%	73	16.1
DH	235	1958 (20%)	1964 (155%)	68.5%	47	-34.4****

Table 4.12 Snowfall, Driest and Wettest Years, and Linear Trend

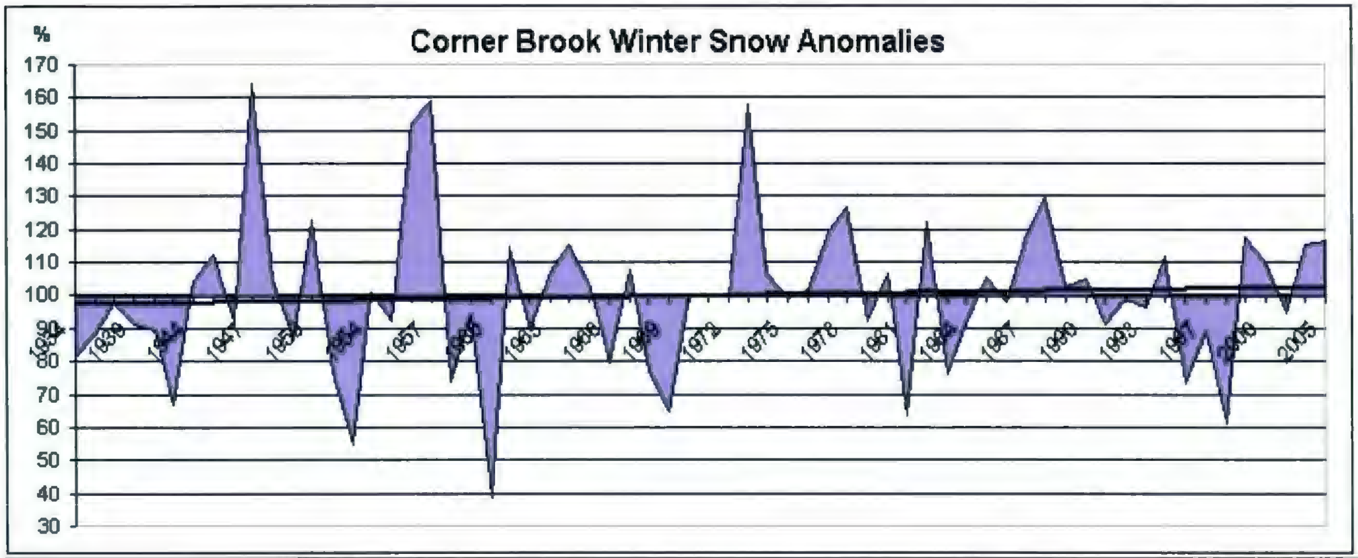
* calculated from linear trend over duration of record for each site
** years with missing data excluded
*** 1977-2005 ****1977-1996

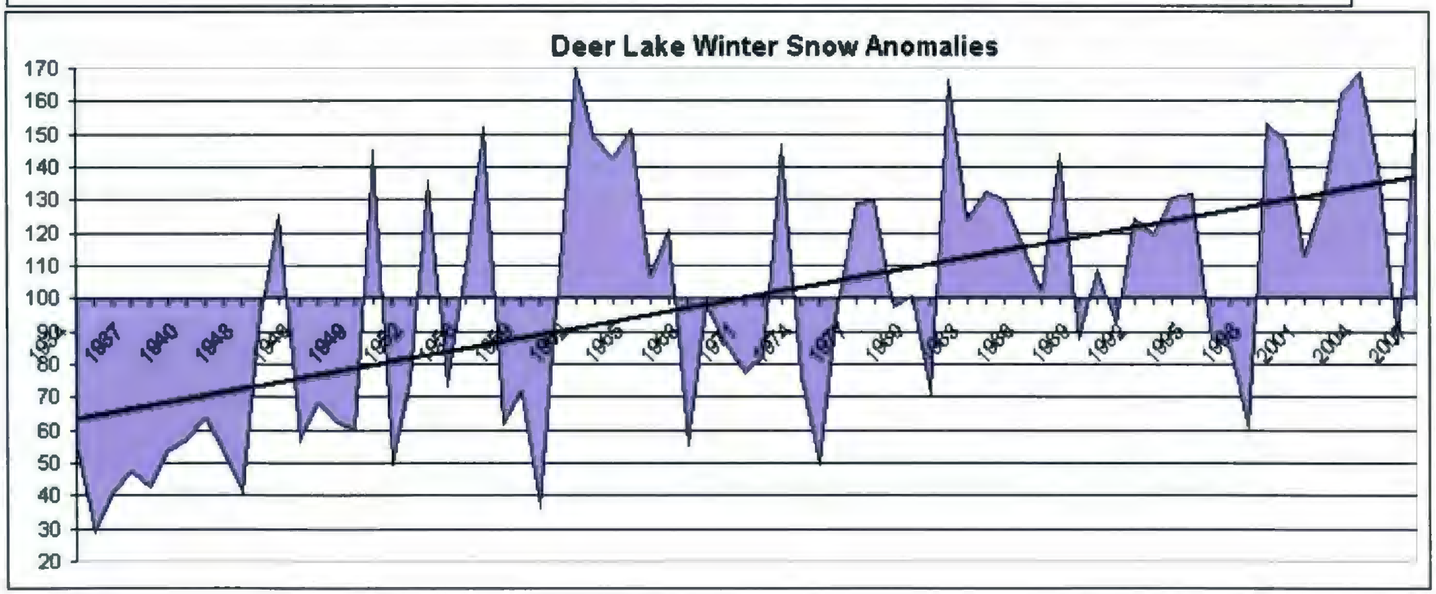
Station	Number of Years					
	Very Dry	Dry	Normal	Wet	Very Wet	Total
ST	4 (1943, 1952, 1955, 1958)	22	17	16	5 (1947, 1959, 1964, 1982, 1990)	64
CB	1 (1960)	16	30	13	4 (1947, 1956, 1957, 1973)	64
DL	8 (1935, 1936, 1937, 1938, 1943, 1951, 1960, 1975)	24	11	22	8 (1957, 1962, 1965, 1982, 1999, 2003, 2004, 2007)	73
DH	4 (1949, 1953, 1958, 1960)	13	10	17	3 (1964, 1977, 1982)	47

Table 4.13 Snowfall Regimes



Stephenville Winter Snow Anomalies
%
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30


Corner Brook Winter Snow Anomalies
%
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30


Deer Lake Winter Snow Anomalies
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20

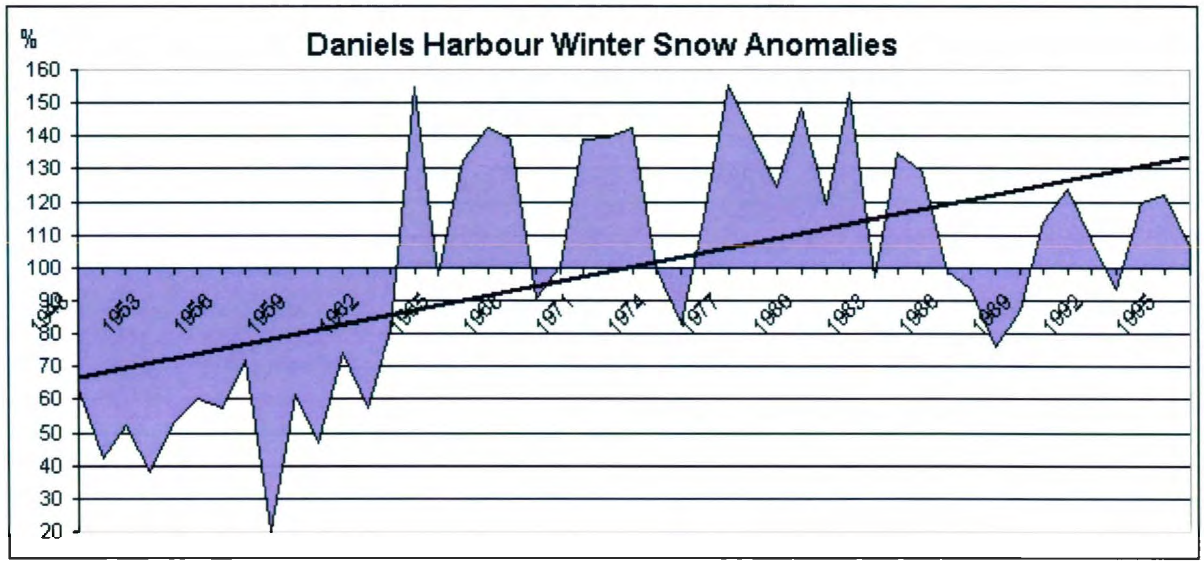


Figure 4.11 Percentage Changes in Winter Snowfall

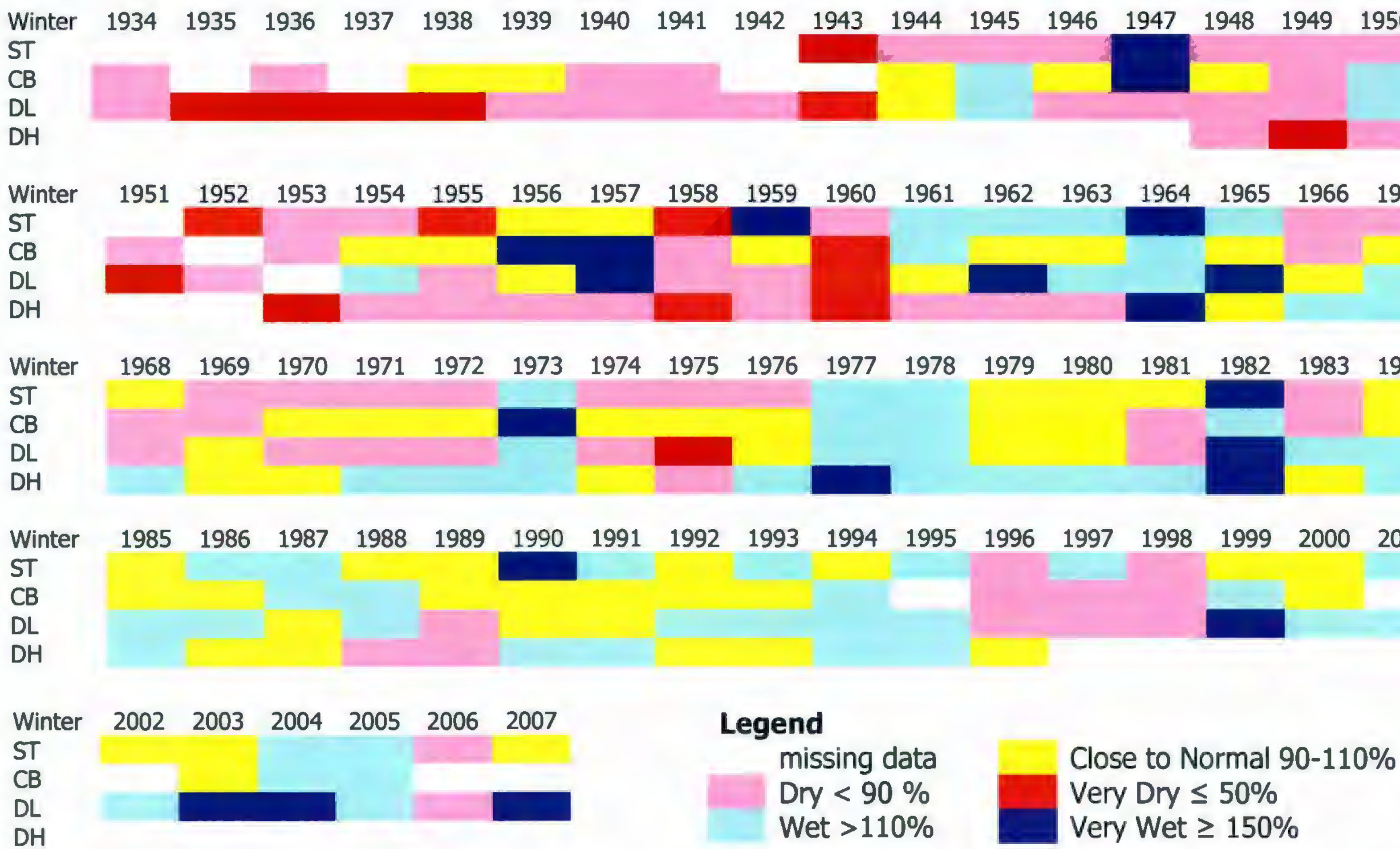


Figure 4.12 Winter Snowfall Variability

4.3.2 Extra-winter snow

Extra-winter snowfall (autumn and spring) does not benefit tourism, as it falls outside the skiing and snowmobiling season. Usually, the winter snowfall exceeds the extra-winter amount. In western Newfoundland, however, a substantial proportion of snowfall occurs in the autumn and spring. The changing percentages over time for each of the four stations are shown in Figures 4.13, 4.14, and 4.15.

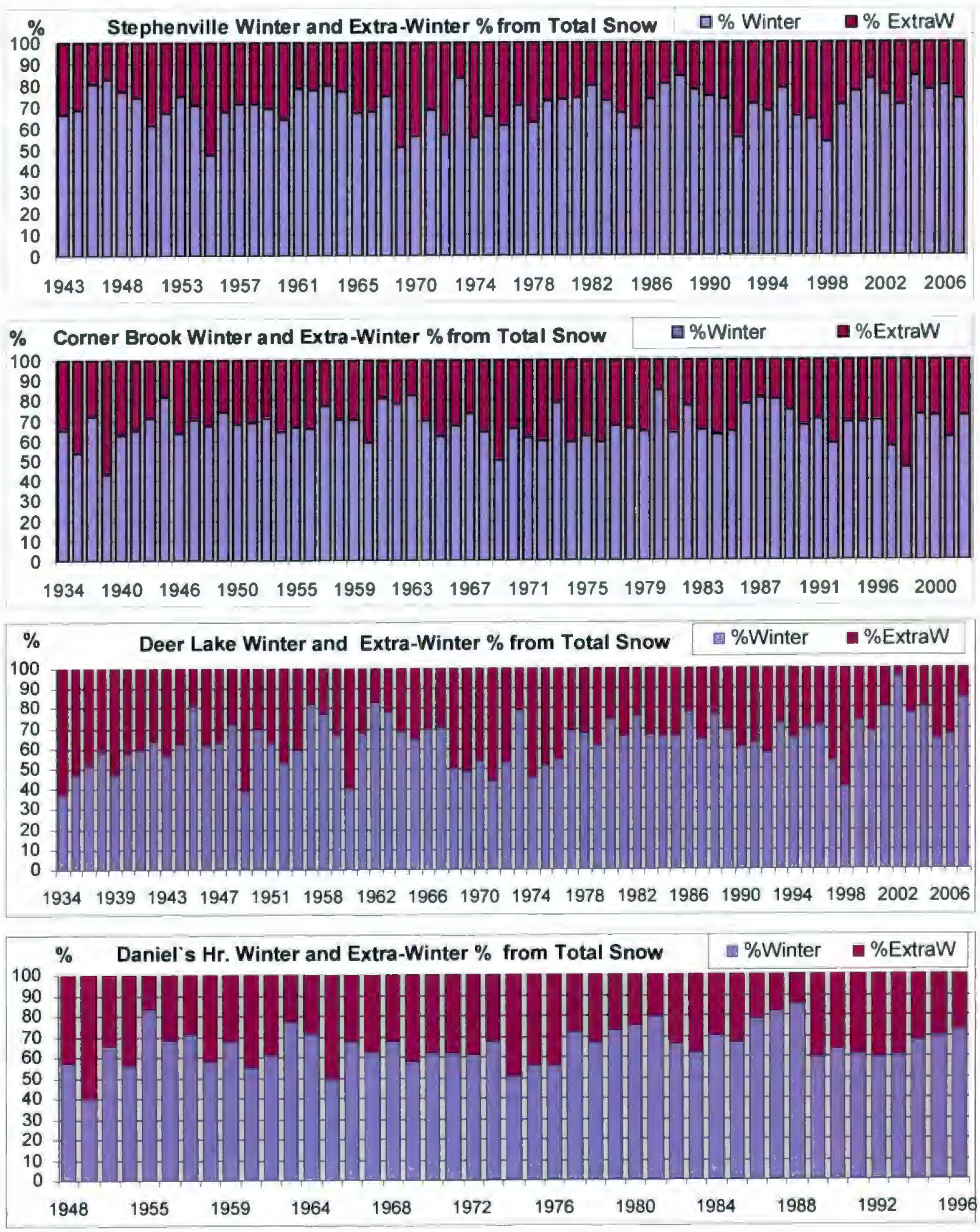
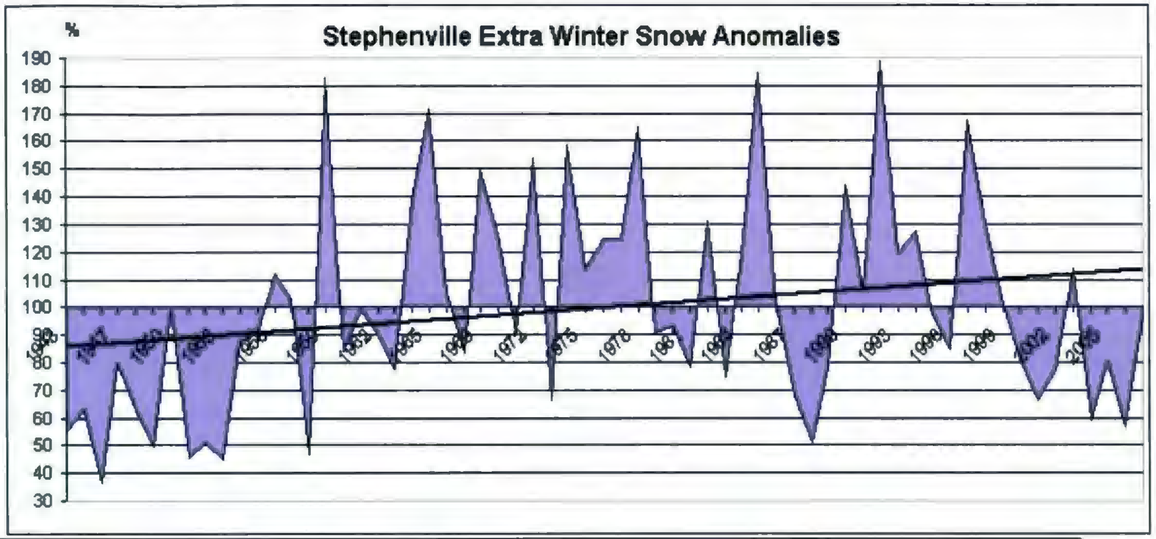
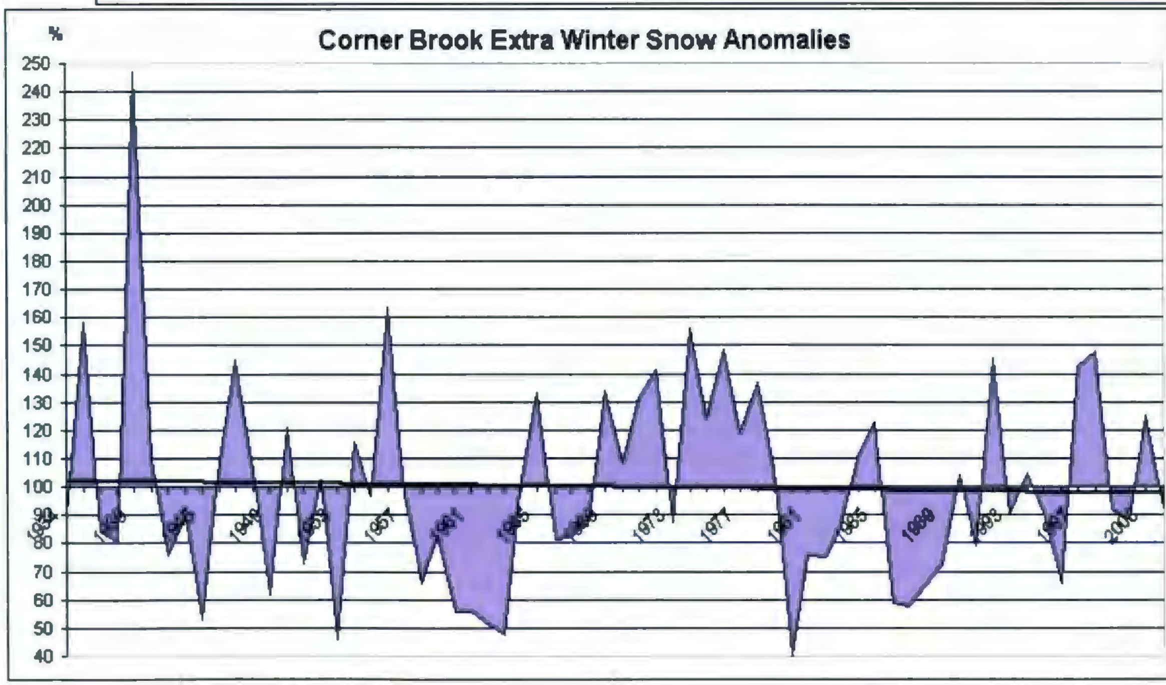


Figure 4.13 Percentages of Winter and Extra-Winter Snow of Total Snowfall



%
Stephenville Extra Winter Snow Anomalies



%
Corner Brook Extra Winter Snow Anomalies

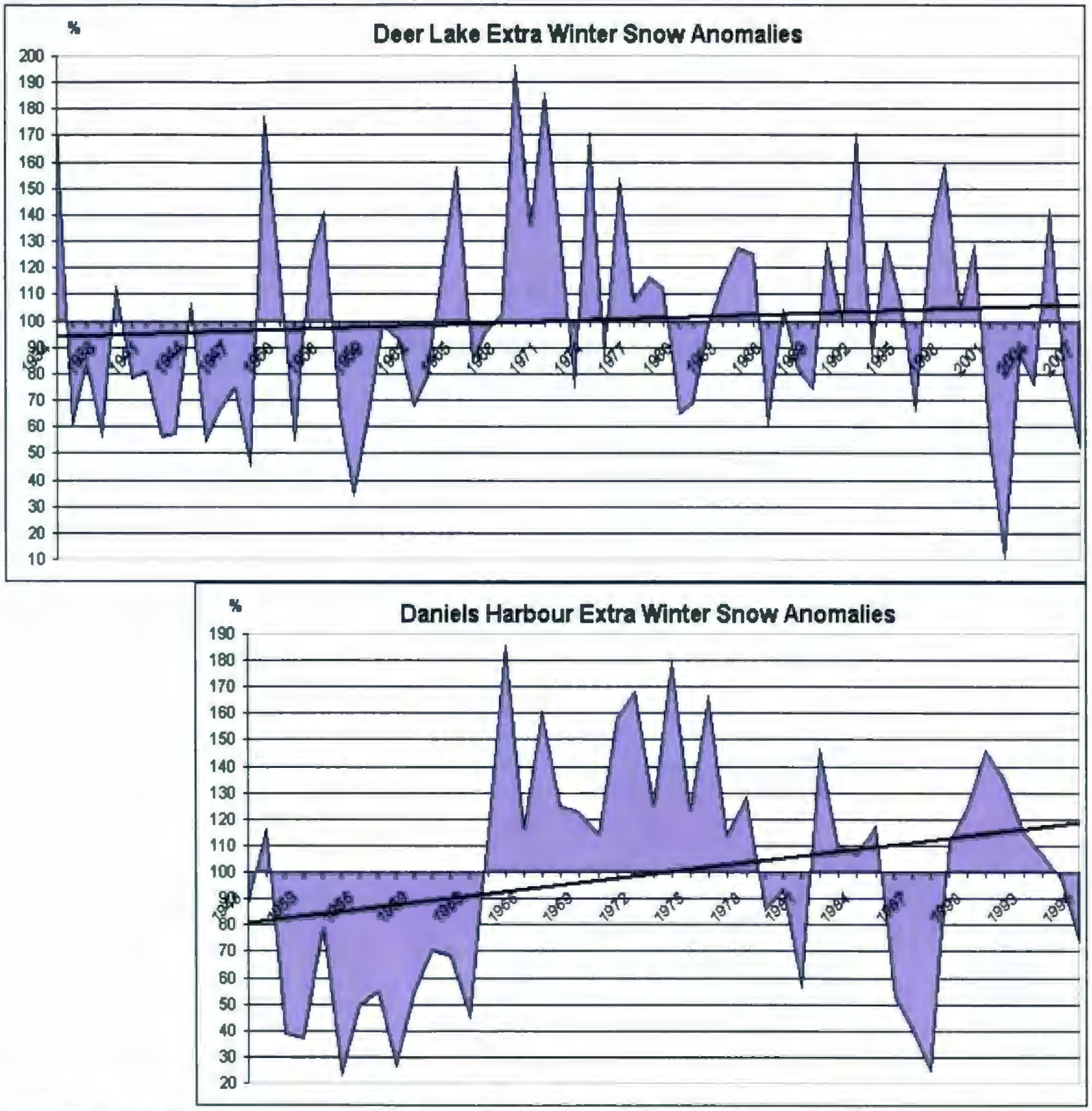


Figure 4.14 Percentage Changes in Extra-Winter Snowfall

	%	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
ST	Winter										66	68	80		83	77	74
	ExtraW										34	32	20		17	23	26
CB	Winter	65		54		72	44	63	65			71	82	64	70	68	74
	ExtraW	35		46		28	56	37	35			29	18	36	30	32	26
DL	Winter	37	47		51	58	47	58	59	64	57	62	81	61	63	72	38
	ExtraW	63	53		49	42	53	42	41	36	43	38	19	39	37	28	62
DH	Winter															57	40
	ExtraW															43	60

	%	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
ST	Winter	61		67	75	70	47	68	71	71	69	64	78	78	80	77	67
	ExtraW	39		33	25	30	53	32	29	29	31	36	22	22	20	23	33
CB	Winter	68	69		71	64	67	66	77	70	70	59	81	78	82	70	62
	ExtraW	32	31		29	36	33	34	23	30	30	41	19	22	18	30	38
DL	Winter	69	63	53				59	81	77	67	41	67	82	78	68	64
	ExtraW	31	37	47				41	19	23	33	59	33	18	22	32	36
DH	Winter				66	56	83	68	71	58	68	55		61	77	71	49
	ExtraW				34	44	17	32	29	42	32	45		39	23	29	51

	%	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
ST	Winter		68	75	51	56	68	57	83	55	66	61	71	63	73	73	74
	ExtraW		32	25	49	44	32	43	17	45	34	39	29	37	27	27	26
CB	Winter	67	73	65	50	66	61	60	79	59	62	59	68	66	64	85	64
	ExtraW	33	27	35	50	34	39	40	21	41	38	41	32	34	36	15	36
DL	Winter	70	70	50	48	54	44	53	79	45	51	54	69	67	62	74	66
	ExtraW	30	30	50	52	46	56	47	21	55	49	46	31	33	38	26	34
DH	Winter	68	62	67	58	62	62	60	68	51	55	56	72	67	73	75	80
	ExtraW	32	38	33	42	38	38	40	32	49	45	44	28	33	27	25	20

	%	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
ST	Winter	80	73	67	60	73	81	84	77	75	74	55	71	68	78	65	64
	ExtraW	20	27	33	40	27	19	16	23	25	26	45	29	32	22	35	36
CB	Winter	77	65	63	64	78	81	81	75	68	71	59	69	69		70	56
	ExtraW	23	35	37	36	22	19	19	25	32	29	41	31	31		30	44
DL	Winter	76	67	66	66	78	65	77	69	61	63	57	72	65	70	71	54
	ExtraW	24	33	34	34	22	35	23	31	39	37	43	28	35	30	29	46
DH	Winter	66	62	70	67	77	81	85	59	63	61	60	60	67	70	73	
	ExtraW	34	38	30	33	23	19	15	41	37	39	40	40	33	30	27	

	%	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ST	Winter	53	71	77	83	76	70	84	78	80	74
	ExtraW	47	29	23	17	24	30	16	22	20	26
CB	Winter	46	73	72			61	72			
	ExtraW	54	27	28			39	28			
DL	Winter	41	73	68	80	96	78	80	65	67	85
	ExtraW	59	27	32	20	4	22	20	35	33	15
DH	Winter										
	ExtraW										

Legend

72 Value in %
Extra-Winter ≥ 50%
Extra-Winter between 40-50%

Figure 4.15 Percentages of Winter and Extra-Winter Snowfall from Total Snowfall

4.4 Conclusion: Temperature and Precipitation Trends

All four sites show increases in precipitation in all seasons throughout the available data series. All sites also show increased snowfall, although the changes since 1977 are not as large as those throughout the entire time series. All sites also show increases in annual, seasonal, maximum, and minimum temperatures for the available time series, and particularly for the period 1998-2007 (Chapter 3, Table 3.11).

The available data indicate that Stephenville, Corner Brook, Deer Lake, and Daniel's Harbour are all experiencing a period of warmer and wetter climate.

5. Wind Variability and Change

Wind strength potentially has an impact on outdoor recreational activities. In addition, changes in the direction of prevailing winds can be related to changes in precipitation, both seasonally and annually.

Data indicating the direction of maximum wind gusts were collected from the monthly records of Environment Canada. Unfortunately, no data were recorded for the Corner Brook stations. At Daniel's Harbour, only 12 years of wind gust data exist, with data for numerous months missing. Consequently, the primary sources of data are the records from Stephenville and Deer Lake.

The available data is very weak. Numerous values reported are estimated, values are based on incomplete data, and in some instances more than one occurrence was recorded.

Trends of change in wind directions and wind speed are much more difficult to determine than are changes in temperature and precipitation. Wind parameters are strongly influenced by weather systems and topography.

The direction of the maximum gust (calibrated from geographic North, not magnetic) represents the direction from which the wind blows. This value is only reported if the maximum gust speed exceeds 29 km/h.

Currently, at both Deer Lake and Stephenville, prevailing winds vary from southerly to westerly, as is generally the case across Newfoundland (Banfield

1981). Figure 5.1 illustrates the orientation of peak wind gusts recorded annually at Stephenville, Deer Lake, and Daniel's Harbour since 1955. Peak wind gusts vary from southeast (135) to southwest (225) with no consistent pattern, and with no apparent relationship among the sites. The direction of the strongest winds has thus remained unchanged throughout the time series.

In spring, winds tend to be more south and southeast and in summer more south-west (Figure 5.2). South and southwest winds are influenced frequently by the movement of low pressure centres, and the local topography.

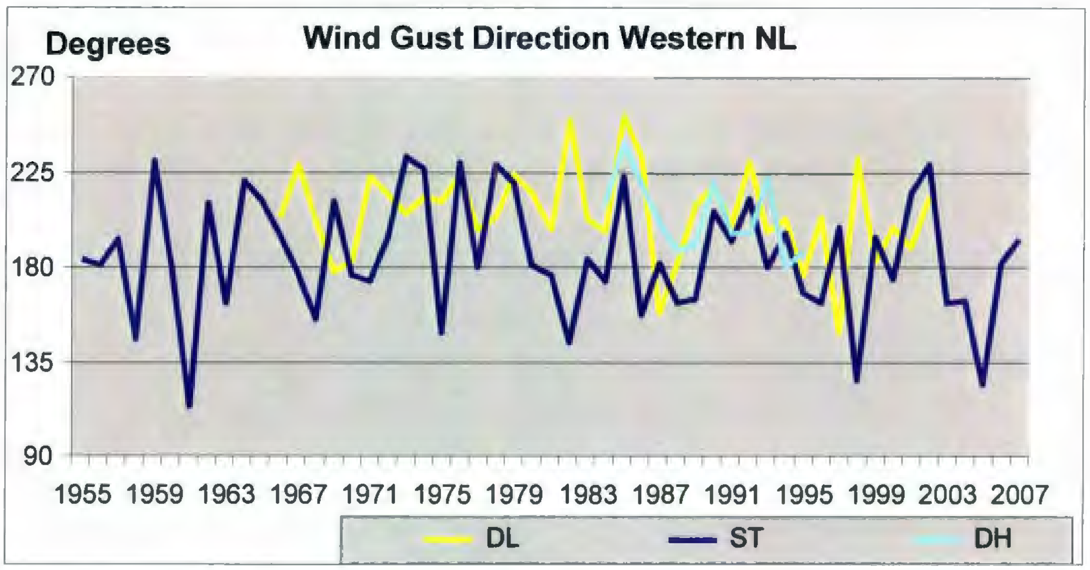


Figure 5.1 Wind Gust Direction Western NL

*Daniel's Harbour, partial records 1984-1995 (12 years)
**Stephenville, records 1955-2007 (53 years)
***Deer Lake, records 1966-2002 (37 years)

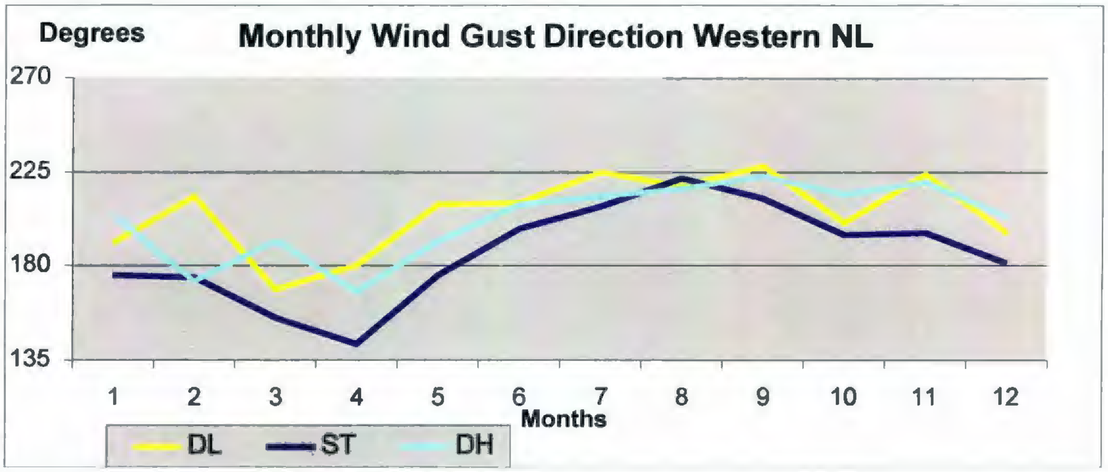


Figure 5.2 Monthly Variations in Wind Gust Direction

In eastern Newfoundland, variations between positive and negative states of the North Atlantic Oscillation (NAO) influence wind direction, velocity, and precipitation, particularly during winter (e.g. Topliss 1997, Catto *et al.* 2003, Vasseur and Catto 2008). Studies in southwestern Newfoundland, however, have indicated that the NAO does not have a major influence on wind directions and strengths in that region (Ingram 2005, Catto *et al.* 2006, Catto 2007).

To assess the influence of the NAO, an analysis comparing the direction of peak winds with NAO phases was conducted (Figure 5.3). The results indicate that southerly to southwesterly winds prevail during both positive and negative NAO phases, and hence there is no relationship between these parameters. This conclusion mirrors previous analysis of data from Channel-Port-aux-Basques, Burgeo, and the Wreckhouse areas of south-western Newfoundland (Catto *et al.* 2006).

There are two phases of the NAO: positive and negative. The positive phase of the NAO involves below-normal heights and pressure across the high latitudes of the North Atlantic along with above-normal heights and pressure over the central North Atlantic, the eastern United States, and western Europe. The negative phase of the NAO involves above-normal heights and pressure across the high latitudes of the North Atlantic along with below-normal heights and pressure over the central North Atlantic, the eastern United States, and western Europe. (Hurrell et al, 2003)

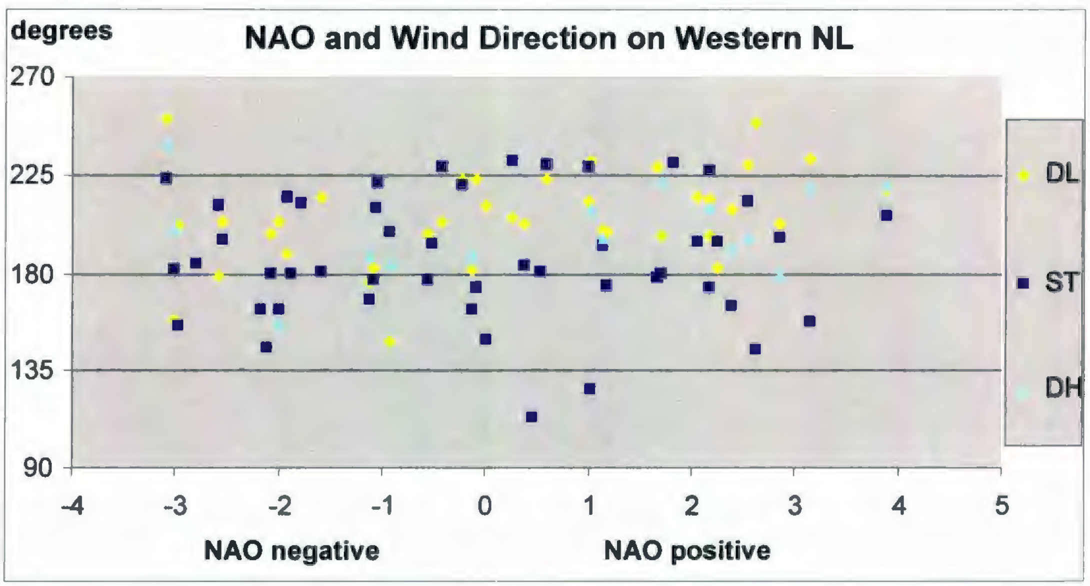


Figure 5.3 Wind Direction and NAO Phases

Increased wind velocity can have a deleterious impact on highway and marine transportation, as well as on outdoor recreational activities. Figure 5.4 illustrates the maximum speed of peak wind gusts for each year for Stephenville, Deer

Lake, and Daniel's Harbour. The time series for Daniel's Harbour is of insufficient length for reliable analysis.

The trend of wind speed is slightly negative for Deer Lake. In contrast, Stephenville recorded an overall positive wind speed trend, although most of the increase was noted between 1955 and 1980. In the period 1980-2007, peak wind speeds have varied, but no overall trend is evident. These results are in agreement with the other available records from south-western Newfoundland (Catto *et al.* 2006). For all three stations, peak wind speed is highest in the winter and lowest in the summer (Figure 5.5). The maximum speed of wind gusts annually showed no relationship to the NAO phases (Figure 5.6).

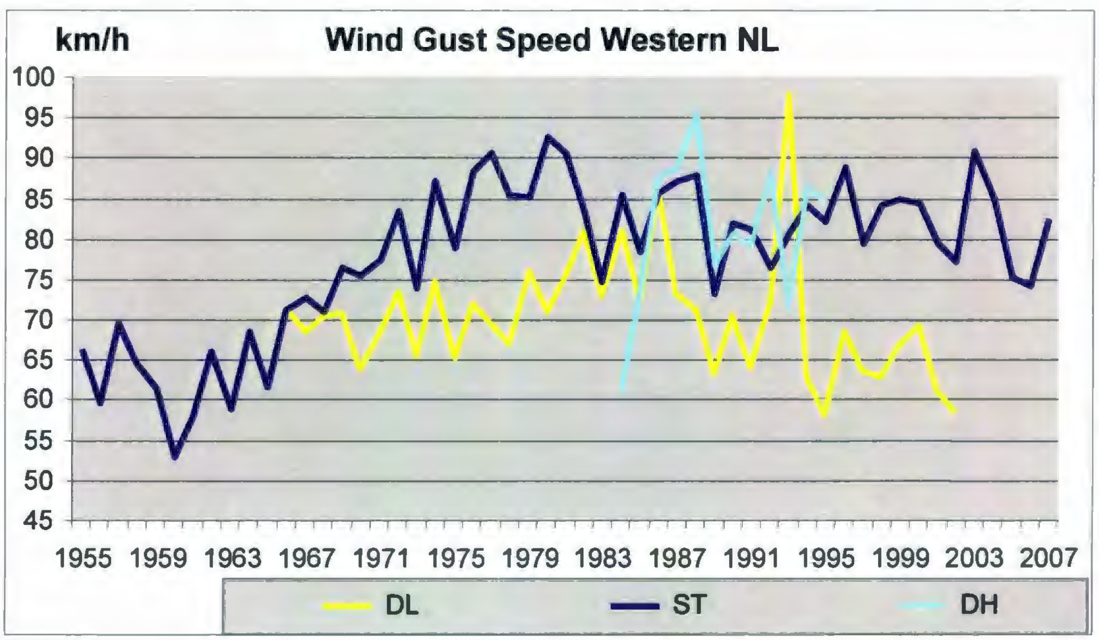


Figure 5.4 Maximum Speed of Wind Gusts Recorded Per Year

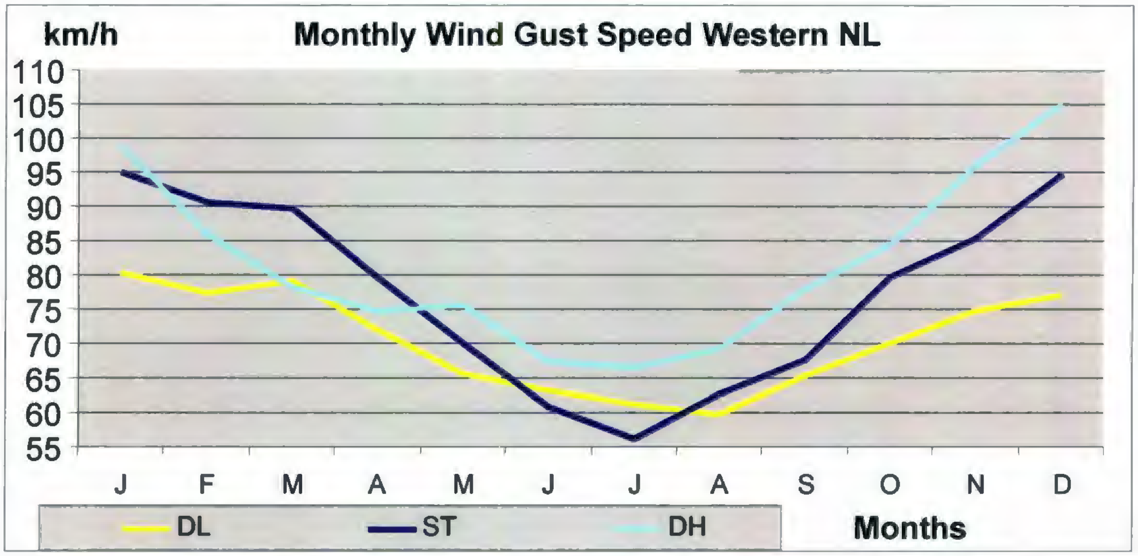


Figure 5.5 Monthly Distribution of Wind Speed

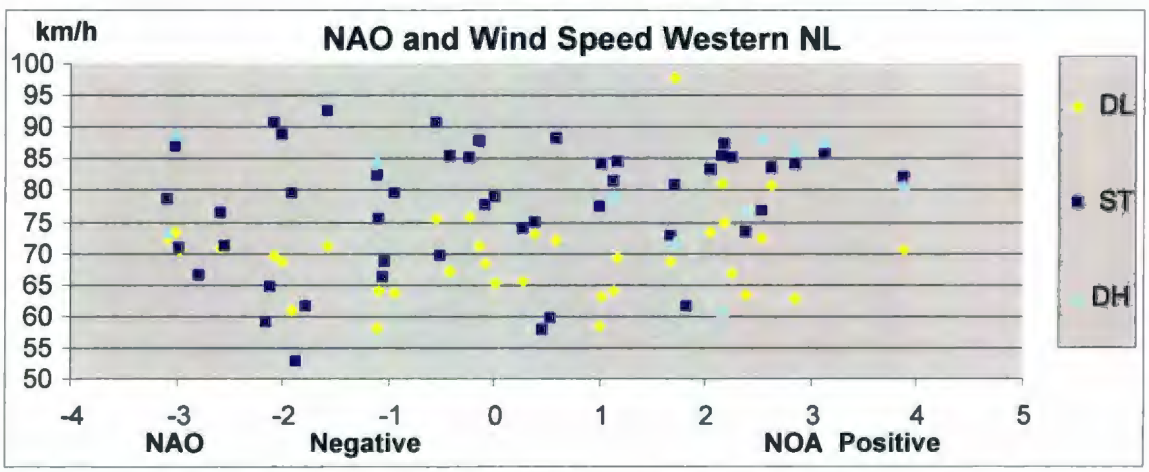


Figure 5.6 NAO Phases and Wind Speed

The available record of wind phenomena is very limited. However, no meaningful trends were observed. Wind direction and peak wind gust speed have not changed over the duration of the available time series, and there is no apparent linkage to the phases of the NAO. In western Newfoundland, although wind conditions will influence outdoor recreation activities, the parameters are undergoing irregular variations rather than systemic change.

6. Variation and Changes in Recreational Seasons

Outdoor recreation is extremely dependent on weather. Weather, and by extension climate, determines what kind of activities can take place and when. In order to understand how the climate influences patterns of outdoor recreation it is necessary to define suitable "seasons" for various types of activities and to specify the duration of these seasons. Crowe (1973), Masterton (1975, 1981), and Peach (1984) have outlined the components of tourist seasons in terms of different outdoor activities, and within the seasons the weather conditions necessary for specific outdoor activities. When the seasons are examined from a recreation point of view, they rarely conform to the astronomical definitions normally attributed to them. Many outdoor recreational activities may only be practiced during a portion of the year, usually the peak of either the winter or summer season.

The winter recreational season is defined on the basis of snow cover, and the summer season using temperature. Variability and change of these two recreational seasons over time can be inferred from temperature and snow cover data as recorded at meteorological stations, as discussed in previous chapters.

6.1 Variability of Winter Recreational Season

The number of days during which a minimum 2.5 cm snow cover is present can be considerably different than the total number of winter season days. The duration of the winter recreational season can be assessed by calculating the number of days during winter when a minimum of 2.5 cm snow cover was present on the ground.

Table 6.1 shows the year-by-year duration of the dates of the first and last occurrence of 2.5 cm snow cover. This data was used to construct trends of the duration of snow cover for the four meteorological stations of Stephenville, Corner Brook, Deer Lake, and Daniel's Harbour (Figure 6.1). Data series encompass periods ranging from 29 years (Corner Brook) through 53 years (Stephenville).

All four locations typically have a minimum snow cover of 2.5 cm by November. Snow cover typically disappears in April, although exceptions occur. The winter seasons for all locations vary year by year, between a minimum of 105 (Corner Brook, 1981) and a maximum of 205 days (Daniel's Harbour, 1965; Deer Lake, 1977). At individual stations, the range of variation typically extends over two months, from minima of ca. 130 to maxima of ca. 190 days.

Trends at Stephenville, Deer Lake, and Daniel's Harbour indicate overall declines in the number of days with snow cover, from ca. 170 days in the 1970s to ca. 150 days in the period 1995-2007. The patterns at all four stations show general similarities, suggesting that the conditions at Corner Brook can be estimated by comparison with the other records. In particular, trends at Deer Lake and Corner Brook are similar, although Corner Brook has a lesser duration of snow cover, due to its lower altitude and coastal situation.

Although there is a general decline in snow cover duration at Stephenville and Deer Lake, the sites with the longest records, the data show substantial variability. For instance, the record at Daniel's Harbour in 1964 showed 141 days with snow cover, and in the following year there was a record 205 days with snow cover. Two of the periods with the lowest amounts of snow cover, the early 1980s and 1997, correspond to strong El Niño events.

Comparing the linear trend of winter recreation seasons (table 6.2) with winter snowfall for all four locations (Chapter 5), snowfall increased at Deer Lake and Daniel's Harbour, while the duration of the winter recreational season decreased. These differences result in part from the different durations used to define the winter precipitation season (3 months), compared with the total duration of snow cover. However, the differences also indicate that total snowfall may not be an entirely accurate measure of the suitability of conditions for winter recreation, such as skiing and snowmobiling.

	ST			CB			DL			DH		
	Winter Season			**Winter Season**			**Winter Season**			**Winter Season**		
	First Day	**Last Day**	**Days**	**First Day**	**Last Day**	**Days**	**First Day**	**Last Day**	**Days**	**First Day**	**Last Day**	**Days**
1955	11/14/1954	4/17/1955	155									
1956	11/18/1955	4/10/1956	145							11/19/1955	5/9/1956	173
1957	11/11/1956	4/19/1957	143							11/19/1956	5/5/1957	168
1958	11/26/1957	3/5/1958	134							11/29/1957	4/20/1958	143
1959	11/18/1958	4/12/1959	146							11/18/1958	4/9/1959	143
1960	10/21/1959	4/26/1960	189							11/23/1959	4/12/1960	142
1961	11/21/1960	4/24/1961	155							11/11/1960	4/12/1961	153
1962	12/12/1961	4/29/1962	139							11/12/1961	5/10/1962	180
1963	11/27/1962	5/11/1963	166							12/13/1962	4/26/1963	135
1964	11/26/1963	4/15/1964	166							12/4/1963	4/22/1964	141
1965	11/4/1964	4/18/1965	166							11/2/1964	5/25/1965	205
1966	11/6/1965	4/30/1966	176				10/28/1965	4/10/1966	165	10/28/1965	4/28/1966	183
1967	12/13/1966	5/1/1967	140				11/20/1966	5/4/1967	166	11/16/1966	5/4/1967	170
1968	11/30/1967	4/5/1968	128				11/9/1967	4/12/1968	156	11/9/1967	4/15/1968	159
1969	11/11/1968	4/11/1969	152				11/12/1968	5/3/1969	173	11/8/1968	5/4/1969	178
1970	10/23/1969	4/21/1970	181				10/22/1969	4/24/1970	185	10/23/1969	4/30/1970	190
1971	12/6/1970	4/10/1971	146				11/15/1970	4/29/1971	166	10/27/1970	4/30/1971	186
1972	11/29/1971	4/22/1972	146				11/15/1971	5/13/1972	181	11/3/1971	5/15/1972	195
1973	10/20/1972	4/26/1973	189				10/14/1972	5/1/1973	200	10/14/1972	4/28/1973	197
1974	11/7/1973	5/4/1974	179				11/7/1973	5/29/1974	204	11/19/1973	5/14/1974	177
1975	11/22/1974	4/26/1975	156				10/28/1974	4/28/1975	183	10/28/1974	5/9/1975	194
1976	11/1/1975	4/16/1976	168				10/31/1975	4/26/1976	179	10/31/1975	5/1/1976	184
1977	11/9/1976	5/4/1977	177				10/19/1976	5/11/1977	205	10/19/1976	5/4/1977	198
1978	11/24/1977	4/25/1978	153				11/25/1977	5/3/1978	168	12/3/1977	4/29/1978	148
1979	11/21/1978	4/4/1979	137	11/11/1978	3/19/1979	129	11/12/1978	4/10/1979	150	11/12/1978	4/14/1979	154
1980	11/19/1979	4/3/1980	137	11/18/1979	3/31/1980	135	11/18/1979	4/15/1980	150	11/19/1979	5/24/1980	188
1981	11/19/1980	4/17/1981	150	12/11/1980	3/25/1981	105	11/17/1980	4/2/1981	114	12/12/1980	4/24/1981	134
	ST			**CB**			**DL**			**DH**		

	Winter Season			Winter Season			Winter Season			Winter Season		
	First Day	Last Day	Length	First Day	Last Day	Length	First Day	Last Day	Days	First Day	Last Day	Length
			Days			Days						Days
1982	11/30/1981	4/30/1982	152	11/13/1981	4/26/1982	165	11/14/1981	4/26/1982	164	11/24/1981	4/29/1982	157
1983	11/26/1982	3/29/1983	124	11/16/1982	4/6/1983	142	11/17/1982	4/12/1983	147	11/17/1982	4/11/1983	146
1984	11/30/1983	4/10/1984	133	12/1/1983	4/11/1984	133	11/12/1983	4/17/1984	158	11/30/1983	4/15/1984	138
1985	11/17/1984	5/5/1985	170	11/17/1984	4/30/1985	162	12/2/1984	5/7/1985	157	11/16/1984	5/14/1985	180
1986	11/15/1985	4/11/1986	148	11/11/1985	4/2/1986	143	11/13/1985	4/5/1986	144	12/2/1985	4/5/1986	125
1987	11/16/1986	4/2/1987	138	11/15/1986	4/14/1987	151	11/14/1986	4/14/1987	152	11/13/1986	4/13/1987	152
1988	11/8/1987	3/29/1988	144	11/8/1987	4/9/1988	154	11/8/1987	4/28/1988	173	11/14/1987	4/4/1988	143
1989	11/22/1988	4/14/1989	150	11/22/1988	4/23/1989	153	11/22/1988	4/23/1989	153	11/24/1988	4/29/1989	157
1990	11/21/1989	4/20/1990	151	11/21/1989	5/8/1990	168	11/20/1989	5/8/1990	170	11/24/1989	5/8/1990	166
1991	11/7/1990	4/11/1991	156	11/1/1990	4/19/1991	170	10/27/1990	4/26/1991	182	11/1/1990	4/20/1991	171
1992	11/12/1991	4/27/1992	168	11/12/1991	5/7/1992	178	10/28/1991	5/4/1992	190	11/12/1991	4/28/1992	169
1993	11/17/1992	4/12/1993	147	11/17/1992	4/24/1993	159	11/17/1992	4/23/1993	155	11/28/1992	4/20/1993	144
1994	11/25/1993	4/10/1994	137	11/24/1993	4/16/1994	144	10/25/1993	4/18/1994	176	10/25/1993	4/24/1994	182
1995	11/24/1994	4/20/1995	148	11/9/1994	4/23/1995	166	11/24/1994	5/6/1995	164	11/27/1994	4/30/1995	155
1996	12/2/1995	4/4/1996	125	12/2/1995	3/29/1996	119				12/1/1995	4/5/1996	127
1997	11/14/1996	5/2/1997	170	12/6/1996	4/30/1997	146		5/27/1997	147			
1998	11/18/1997	3/27/1998	130	11/13/1997	4/5/1998	144	10/29/1997	4/21/1998	175			
1999	11/15/1998	4/12/1999	149	11/15/1998	4/11/1999	148	11/14/1998	4/12/1999	150			
2000	11/9/1999	4/15/2000	159	10/19/1999	4/15/2000	175	10/19/1999	3/31/2000	165			
2001	11/22/2000	4/18/2001	148	10/29/2000	4/18/2001	172	11/22/2000	4/23/2001	153			
2002	11/14/2001	4/22/2002	160		4/28/2002		11/12/2001	4/10/2002	150			
2003	11/4/2002	4/18/2003	166	11/4/2002	4/23/2003	171	10/28/2002	4/22/2003	177			
2004	11/9/2003	4/6/2004	150	11/9/2003	5/9/2004	183	10/21/2003	4/21/2004	184			
2005	12/4/2004	4/14/2005	132	11/17/2004	4/20/2005	155	11/17/2004	4/29/2005	164			
2006	12/5/2005	3/26/2006	112	11/19/2005			12/6/2005	4/1/2006	117			
2007	12/2/2006	4/12/2007	132				11/30/2006	4/8/2007	130			

Table 6.1 Winter Recreational Season Length, Western NL

Missing data

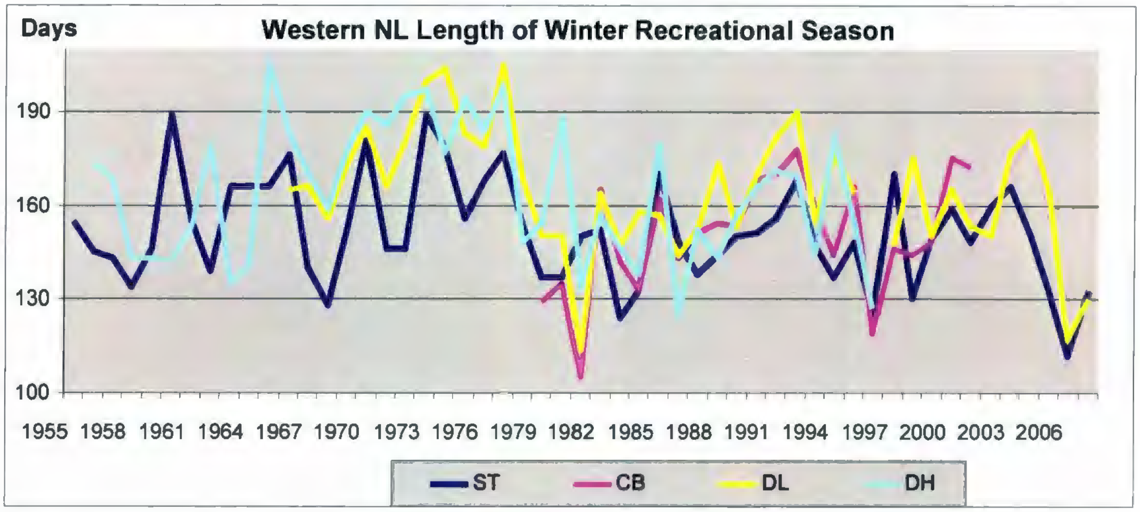


Figure 6.1 Winter Recreational Days, 1955-2007

Station	*Mean Normal days*	*Change In # of days*	*Geometry of Linear Trend*	*Number of Years*
ST	150.9	- 15.2	negative	53 (1955-2007)
CB	152.6	+31.3	positive	26 (1979-2005)
DL	160.5	-22.2	negative	41 (1966-2007)
DH	164.1	-12.6	negative	41(1956-1996)

Table 6.2 Winter Recreation Season

Potter (1965) suggested that snow cover was required on at least 80% of winter days to have reliable conditions for skiing. However, suitable weather conditions for skiing involve not just a specific amount of snow cover but also require temperature greater than -14°C, wind less than 24km/h, and light snow or flurries.

For all locations, this percentage was calculated from the number of days with snow depth of greater than 2.5 cm within the recreational winter season for each year. Table 6.3 shows the results of this analysis, indicating the percentages of days during the winter season with suitable snow cover for each station. Years with at least 80% of days with 2.5 cm snow cover are considered as reliable skiing years, whereas years with 60% or fewer are considered as very unreliable (c.f. Potter 1965).

Substantial yearly variability is evident in the region. However, conditions have generally been favourable at all sites in the past 25 years since 1982. Prolonged periods with multiple years of less reliable or very unreliable conditions have not occurred since ca. 1970. In contrast to the situation in eastern Newfoundland (Catto *et al.* 2003), NAO positive phase years are not necessarily marked by more reliable conditions. El Niño years, although marked by generally reduced snow cover, are not necessarily unreliable for skiing: 1997, the most recent strong El Niño year, was marked by reliable conditions at Stephenville and Corner Brook, and only slightly less reliable conditions at Deer Lake.

For tourist-dependent operations such as Marble Mountain Resort, the long-term reliability of snow conditions is vital. The number of reliable (>80%) years at Corner Brook and Deer Lake both exceed 60% for the available time series. The lowest percentage of days at both sites was 65%, indicating that for two-thirds of winter days, skiing conditions would be suitable. As Marble Mountain is located at a higher elevation than the weather stations at Corner Brook and Deer Lake, skiing conditions would be generally more suitable at the resort.

Stephenville (53% of years) and Daniel's Harbour (56%) have generally less reliable conditions for skiing. Skiing is less important as a tourist attraction and economic contributor at these communities than in the Humber Valley. However, cross-country skiing and snowmobiling are potential sources of income. Suitable conditions for snowmobiling differ from those required for skiing only in terms of temperature. Therefore, the level of snow cover required for snowmobiling and skiing is identical, thus the percentage of reliability is the same for both activities.

%	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
ST	50	83	100	33	93	48	80	72	67	70	72	52	99	73	76	64	86	97
CB																		
DL												82	87	78	87	71	87	86
DH		68	94	36	91	72	61	49	75	91	68	77	87	86	73	68	77	85

%	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
ST	82	80	90	79	88	97	77	86	53	88	69	80	83	92	91	76	90	99
CB							86	89	78	75	68	91	94	76	88	88	88	90
DL	84	71	80	78	78	95	73	87	98	82	80	87	87	90	97	88	89	91
DH	81	80	86	82	85	96	63	73	55	94	74	94	88	90	95	82	92	90

%	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ST	77	82	65	76	99	78	85	80	65	68	93	70	86	79	89	86	94
CB	79	83	97	87	73	70	90	76	71	65			88	72	88		
DL	73	85	65	76	100		74	78	96	73	100	83	87	79	91	99	89
DH	79	83	95	72	97	68											

Table 6.3 Reliable Years for Skiing Based on Snow Depth

Legend

83 ≥ 80 % reliable for skiing
60-79% less reliable for skiing
< 60% very unreliable for skiing
Missing data

6.2 Variability of Summer Recreational Season

A complete recreational summer season is opened by a period of spring shoulder, which follows the spring transition when the excess moisture from snowmelt and runoff dissipates and the temperature rises. Under such conditions, vigorous outdoor activities will take place along with passive activities such as fishing and picnicking. These activities will become more intensive and varied, reaching their peak during the high summer period. The complete range of both active and passive outdoor activities reach their peak in the high summer period, when the temperature is 18°C or greater.

The ending of a complete recreation summer season is the period following high summer. At this time, temperature decrease is the most important climate parameter influencing the decline of outdoor recreational activities.

Table 6.4 shows the dates of the beginning and ending of the summer season, defined as days between the initiation of the spring shoulder and the last day of the autumn shoulder. First occurrences vary between April and May, and the season can terminate as late as November. Figure 6.2 shows the yearly variability of the length of the complete summer recreational season at the four stations.

Overall, the length of the summer season shows strong variability year by year. The minimum length varies between 141 days (Deer Lake, 1972) and 163

(Stephenville, 1974) and the maximum length varies between 225 days (Daniel's Harbour, 1973) and 247 days (Stephenville, 1958).

The linear trends (Table 6.5) show increasing summer length, greater for Deer Lake and Stephenville and almost not increasing for Daniel's Harbour. The limited amount of data for Corner Brook limits the reliability of a trend analysis. However, overall trends for the available data from Corner Brook mirror those for the other stations.

The majority of the summer recreational season falls within the high summer period for all four sites (Figure 6.3). However, temperature variations during the theoretical 'high summer' period frequently result in daily maximum temperatures below the 18°C threshold required for true high summer conditions. This results in cooler summers than would be considered optimal for many outdoor activities.

The percentage of summer days with high summer conditions (temperature in excess of 18°C for at least one hour) on a yearly basis for each station is shown in Figure 6.4. Reliable summer weather for recreational activities can be defined as including high summer temperatures, and with peak wind speeds less than 24 km/h. For all four locations, the number of days with temperatures at or in excess of 18°C is considerably less than the total number of days in the summer season, varying from ca. 60% (Deer Lake) to ca. 30% (Daniel's Harbour). Thus, there are significant limitations on all summer outdoor activities throughout the region, including both passive (landscape touring, boat touring) and vigorous activities.

Vigorous activities include hiking, among the main outdoor activities in Gros Morne, and more energetic sports such as bicycling, kayaking, and hunting. For these activities, visibility and air temperatures impose different limits. Passive activities include fishing, picnicking, and camping which demand little physical exertion, making them enjoyable in cool and warm weather conditions. The conditions required for these activities are similar to those required for landscape touring.

	ST			CB			DL			DH		
	Summer Season			Summer Season			Summer Season			Summer Season		
	First Day	Last Day	Length	First Day	Last Day	Length	First Day	Last Day	Length	First Day	Last Day	Length
			Days			days			days			days
1955	5/1/1955	11/18/1955	202									
1956	4/24/1956	11/11/1956	206							5/23/1956	11/19/1956	181
1957	5/3/1957	11/26/1957	208							5/19/1957	11/29/1957	195
1958	3/17/1958	11/18/1958	247							5/4/1958	11/18/1958	199
1959	4/26/1959	10/21/1959	210							4/23/1959	11/23/1959	217
1960	5/10/1960	11/21/1960	198							4/26/1960	11/11/1960	200
1961	5/8/1961	12/12/1961	189							4/26/1961	11/12/1961	201
1962	5/13/1962	11/27/1962	199							5/24/1962	12/13/1962	204
1963	5/25/1963	11/26/1963	192							5/10/1963	12/4/1963	209
1964	4/29/1964	11/4/1964	190							5/6/1964	11/2/1964	181
1965	5/1/1965	11/6/1965	190							6/8/1965	10/28/1965	143
1966	5/14/1966	12/13/1966	214				4/24/1966	11/20/1966	211	5/12/1966	11/16/1966	202
1967	5/15/1967	11/30/1967	200				5/18/1967	11/9/1967	176	5/18/1967	11/9/1967	176
1968	4/19/1968	11/11/1968	207				4/26/1968	11/12/1968	202	4/29/1968	11/8/1968	194
1969	4/25/1969	10/23/1969	182				5/17/1969	10/22/1969	176	5/18/1969	10/23/1969	182
1970	5/5/1970	12/6/1970	216				5/8/1970	11/15/1970	192	5/14/1970	10/27/1970	167
1971	4/24/1971	11/29/1971	220				5/13/1971	11/15/1971	189	5/14/1971	11/3/1971	205
1972	5/6/1972	10/20/1972	168				5/27/1972	10/14/1972	141	5/19/1972	10/14/1972	149
1973	5/10/1973	11/7/1973	182				5/15/1973	11/7/1973	182	5/12/1973	11/19/1973	225
1974	5/18/1974	11/22/1974	163				6/12/1974	10/28/1974	148	5/28/1974	10/28/1974	154
1975	5/10/1975	11/1/1975	176				5/12/1975	10/31/1975	174	5/23/1975	10/31/1975	176
1976	4/30/1976	11/9/1976	194				5/10/1976	10/19/1976	171	5/15/1976	10/19/1976	158
1977	5/18/1977	11/24/1977	191				5/25/1977	11/25/1977	187	5/18/1977	12/3/1977	200
1978	5/9/1978	11/21/1978	197				5/17/1978	11/12/1978	188	5/13/1978	11/12/1978	184
1979	4/18/1979	11/19/1979	216	4/2/1979	11/18/1979	240	4/24/1979	11/18/1979	240	4/28/1979	11/19/1979	206
1980	4/17/1980	11/19/1980	217	4/14/1980	12/11/1980	242	4/29/1980	11/17/1980	203	6/7/1980	12/12/1980	159
1981	5/1/1981	11/30/1981	214	4/8/1981	11/13/1981	220	4/16/1981	11/14/1981	213	5/8/1981	11/24/1981	201

	ST			CB			DL			DH		
	Summer Season		Summer Season		Summer Season		Summer Season			Summer Season		
	First Day	Last Day	Length	First Day	Last Day	Length	First Day	Last Day	Length	First Day	Last Day	Length
			Days			days			days			days
1982	5/14/1982	11/26/1982	208	5/10/1982	11/16/1982	205	5/10/1982	11/17/1982	206	5/13/1982	11/17/1982	193
1983	4/12/1983	11/30/1983	233	4/20/1983	12/1/1983	230	4/26/1983	11/12/1983	201	4/25/1983	11/30/1983	220
1984	4/24/1984	11/17/1984	208	4/25/1984	11/17/1984	207	5/1/1984	12/2/1984	217	4/29/1984	11/16/1984	202
1985	5/19/1985	11/15/1985	181	5/14/1985	11/11/1985	188	5/21/1985	11/13/1985	179	5/28/1985	12/2/1985	198
1986	4/25/1986	11/16/1986	209	4/16/1986	11/15/1986	214	4/19/1986	11/14/1986	210	4/19/1986	11/13/1986	209
1987	4/16/1987	11/8/1987	207	4/28/1987	11/8/1987	195	4/28/1987	11/8/1987	202	4/27/1987	11/14/1987	202
1988	4/12/1988	11/22/1988	225	4/23/1988	11/22/1988	214	5/12/1988	11/22/1988	201	4/18/1988	11/24/1988	
1989	4/28/1989	11/21/1989	208	5/7/1989	11/21/1989	200	5/7/1989	11/20/1989	199	5/13/1989	11/24/1989	201
1990	5/4/1990	11/7/1990	188	5/22/1990	11/1/1990	185	5/22/1990	10/27/1990	179	5/22/1990	11/1/1990	184
1991	4/25/1991	11/12/1991	202	5/3/1991	11/12/1991	195	5/10/1991	10/28/1991	172	5/4/1991	11/12/1991	193
1992	5/11/1992	11/17/1992	191	5/19/1992	11/17/1992	188	5/18/1992	11/17/1992	189	5/12/1992	11/28/1992	201
1993	4/26/1993	11/25/1993	214	5/8/1993	11/24/1993	216	5/7/1993	10/25/1993	172	5/4/1993	10/25/1993	175
1994	4/24/1994	11/24/1994	184	4/30/1994	11/9/1994	194	5/2/1994	11/24/1994	207	5/8/1994	11/27/1994	204
1995	5/4/1995	12/2/1995	213	5/7/1995	12/2/1995	210	5/20/1995		173	5/14/1995	12/1/1995	202
1996	4/18/1996	11/14/1996	211	4/12/1996	12/6/1996	239			159	4/19/1996		168
1997	5/19/1997	11/18/1997	184	5/14/1997	11/13/1997	184	6/10/1997	10/29/1997	145			
1998	4/11/1998	11/15/1998	219	4/19/1998	11/15/1998	215	5/5/1998	11/14/1998	199			
1999	4/26/1999	11/9/1999	229	4/25/1999	10/19/1999	205	4/26/1999	10/19/1999	177			
2000	4/29/2000	11/22/2000	208	4/29/2000	10/29/2000	184	4/14/2000	11/22/2000	223			
2001	5/2/2001	11/14/2001	197	5/2/2001			5/7/2001	11/12/2001	190			
2002	5/6/2002	11/4/2002	183	5/12/2002	11/4/2002	177	4/24/2002	10/28/2002	188			
2003	5/2/2003	11/9/2003	192	5/7/2003	11/9/2003	187	5/6/2003	10/21/2003	178			
2004	4/20/2004	12/4/2004	229	5/23/2004	11/17/2004		5/5/2004	11/17/2004	217			
2005	4/28/2005	12/5/2005	222	5/4/2005	11/19/2005	142	5/13/2005	12/6/2005	214			
2006	4/9/2006	12/2/2006	238				4/15/2006	11/30/2006	230			
2007	4/26/2007	12/1/2007	190				4/22/2007	11/11/2007	204			

Table 6.4 Missing data **Summer Recreational Season Length**

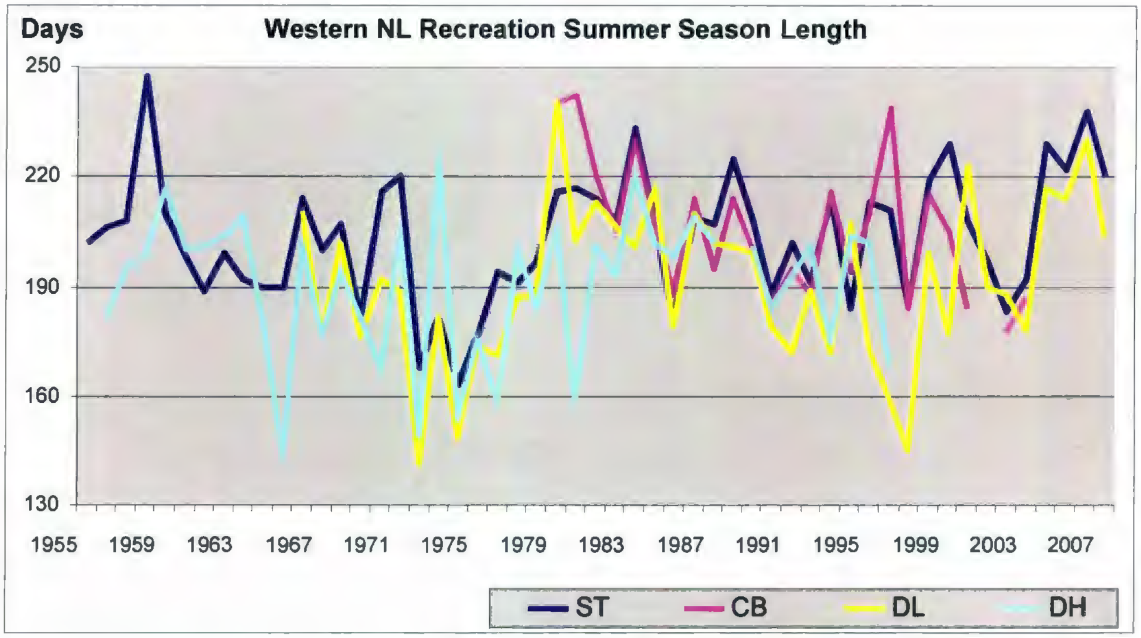


Figure 6.2 Summer Recreation Season Length

Station	*Mean Normal days*	*Change in # of days*	*Geometry of Linear Trend*	*Number of Years*
ST	203.6	+11.4	positive	53 (1955-2007)
CB	203	-46.1	negative	25 (1979-2005)
DL	191	13.8	positive	42 (1966-2007)
DH	190.5	2.3	positive	40(1956-1996)

Table 6.5 Linear Trends, Summer Recreational Season

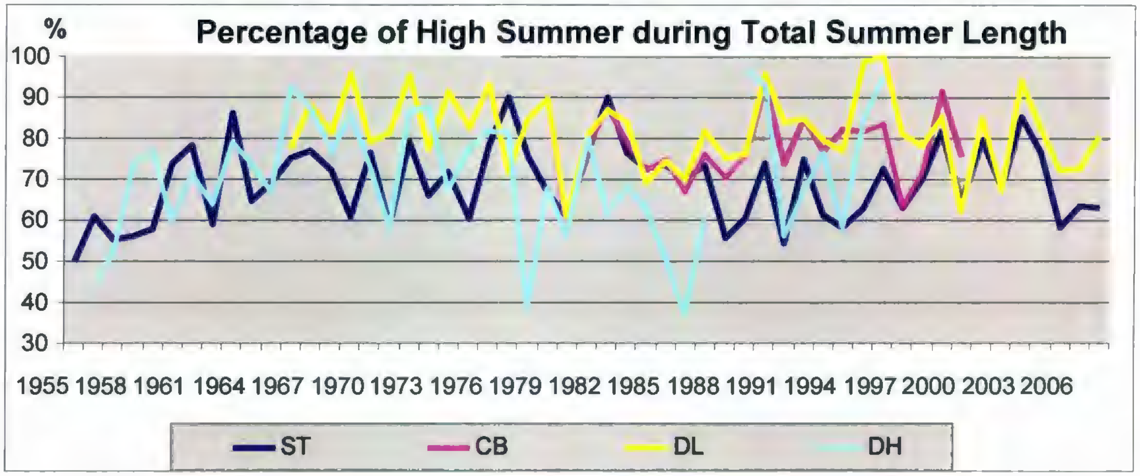


Figure 6.3 Percentage of High Summer Days

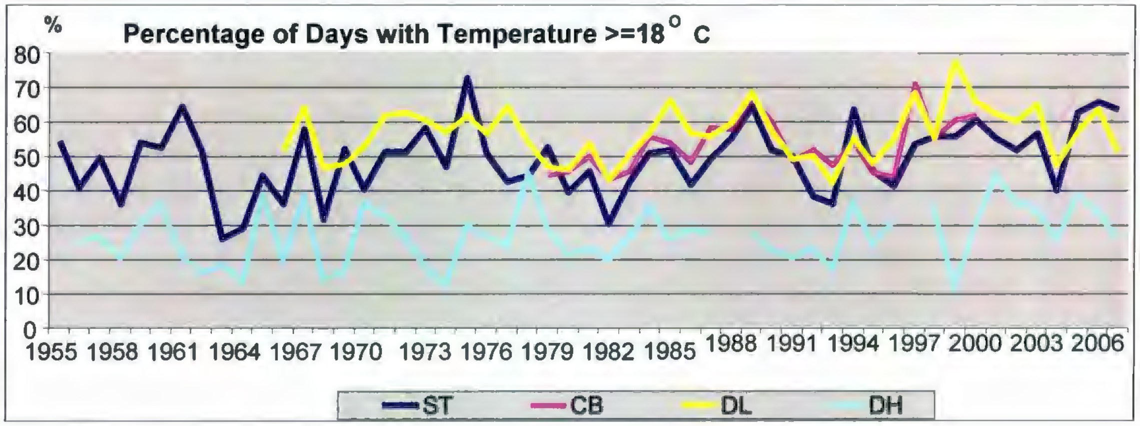


Figure 6.4 Percentages of Summer Temperature Days in High Summer

7. Weather Related Outdoor Activities

7.1 Introduction

Weather-sensitive tourism (Smith 1993) includes travel leading to appreciation of landscape and scenery, the practice of outdoor activities, and visits to historic and heritage sites. Many activities practiced by tourists in western Newfoundland are weather-sensitive.

Outdoor recreation activities are extremely dependent on both the natural resource base and the weather. The resource base determines what kind of activities can take place. For example, without water people cannot swim or take boat tours. However, the weather determines when the activities will take place (De Freitas 2001).

In some parts of the world, it is the climate itself which is the main feature promoting tourism. Abundant sunshine, warm, and dry conditions are the ideal holiday weather for many tourists from northern countries (Smith, 1985). Many tourism organizations highlight such perceived favourable climates, while not mentioning negative aspects such as heat waves and water shortages (Perry, 1997; Perry 2001, World Travel Guide News 2007, International Herald Tribune 2007). In Malaysia and Indonesia, travel brochures show photographs with beaches under a clear blue sky but do not emphasize that rainfall is generally heavy all year round (Smith, 1985). Accuracy of weather and climate-related information could be a key for a successful tourist experience. Some preliminary evidence suggests that the relatively cool summers of western Newfoundland could act to attract visitors from warmer summer climates (see Catto, 2006; Vasseur and Catto, 2008), but this question requires further investigation. The role of climate in determining the suitability of a region for tourism and the impact of climate on tourism is little known.

For Gros Morne in particular, and western Newfoundland in general, tourist promotion has focused on the beauty of scenery, and it is an important part of the tourism resource base. The Parks Canada website (*http://www.pc.gc.ca/pn-np/nl/grosmorne/index_E.asp)* states that Gros Morne "is an area of great natural beauty with a rich variety of scenery, wildlife, and recreational activities". Opportunities for visitors to hike, camp, or boat tour are emphasized. On the website's visitor information page, other suggested activities include fishing, kayaking, swimming, picnicking, cross-country skiing, and snowmobiling.

In both Parks Canada and NL Tourism publicity for Gros Morne, summer recreational activities are emphasized much more than are those confined to winter. Promotion of winter activities is very limited, with the exception of those associated with the Marble Mountain ski resort, where snow is the vital factor.

The basic tourist and outdoor activities that characterize the Canadian scene have been studied by Crowe *et al.* (1973). Some categories of activity emphasized by Crowe *et al.* (1973), notably swimming and sunbathing, are not generally considered as major tourist attractions in western Newfoundland. Although swimming facilities exist along Deer Lake, and beaches within Gros Morne are maintained by Parks Canada at Cow Head and Shallow Bay (Figure 7.1), no designated marine swimming beaches are present in the Stephenville or Daniel's Harbour areas. Beach activities are not extensively promoted, and facility development is limited.

Figure 7.1 Shallow Bay

Summer water temperatures (particularly in the Gulf of St. Lawrence) are perceived as too cold by many, both visitors and those interested in tourist promotion. The requisite water and air temperatures cited by Crowe *et al.* (1973) are 18°C or above. Study of any potential impacts of changing water temperatures on swimming in western Newfoundland is beyond the scope of this thesis.

Peach (1975) calculated the percentage frequency of time during which weather conditions were suitable for outdoor activities for 18 years of the weather record. Although in his study calculations were carried out for each ten-day period in the year and the number of suitable days in each ten-days period was expressed as a percentage, a comparison for each outdoor activity with his results is found in the sections discussing Summer and Winter Outdoor Activities.

In this chapter, outdoor activities are grouped in order of climate parameters required and the corresponding season:

I Summer Season: Hiking; Boat Touring and Kayaking

II Winter Season: Skiing; Snowmobiling

III Year round: Landscape Touring

Suitable weather for a given recreation pursuit can occur at any time during the primary season for that pursuit. For this reason, the outdoor recreational activities characterizing western Newfoundland can be reduced to two main groups:

- Summer season outdoor activities, including the spring thaw and autumn shoulder period; and

- Winter season outdoor activities.

Typical summer season outdoor activities include hiking, boat touring, kayaking, and landscape touring. Typical winter season activities include skiing, snowmobiling, and landscape touring.

The climatic parameters considered by Crowe et al (1973) for designating a suitable day for outdoor activities are: humidex, temperature, visibility, cloud cover, wind, snow cover, and precipitation. Humidex readings and cloud cover data were not available for western Newfoundland. High humidex values would discourage vigorous tourist activities in the summer months. Generally in western Newfoundland, relative humidity is high, but cooler summer temperatures reduce the humidex effect. Cloud cover is ubiquitous in coastal areas in western Newfoundland.

The meteorological parameters considered to designate suitable days for each outdoor activity in this study are: air temperature, visibility, wind speed, precipitation, and snow cover. Analysis was concentrated on the period from 1990-2007, when tourism promotion was accentuated in western Newfoundland. Due to the lack of available hourly temperature, precipitation, wind and snow cover data for the weather stations at Daniel's Harbour, Deer Lake, and Stephenville, daily data were used. Daily maximum temperatures were used because they reflect daytime conditions when almost all outdoor activities occur.

Exceptions are night-time skiing and snowmobiling. Data from Corner Brook were not sufficient to permit analysis.

Hourly data were available for visibility. A suitable day was defined as one with visibility of at least 3 km between 10:30 am and 6:30 pm. These hours do not coincide with those designated by Crowe et al (1973, 1975) between 10 am and 6 pm, but were used here because the visibility measurements were made by Environment Canada at 10:30 am and 6:30 pm.

A suitable day for any particular outdoor activity is one where all relevant climate parameters are met. Suitable days for specific outdoor activities were calculated for the season when those activities occur. Suitable days for hiking, boat touring, landscape touring, and kayaking were calculated for the entire summer season, including spring thaw and autumn shoulder (as defined in Section 1.3.2). Suitable skiing, snowmobiling, and landscape touring days were calculated for the winter recreational season.

7.2 Summer Outdoor Activities

7.2.1 Hiking

Hiking is the most practiced vigorous activity in the summer recreational season within Gros Morne National Park, due both to the available facilities and tourist preferences. Hiking is also a summer activity in Marble Mountain, with trails from the Marble Mountain lodge to the top of Marble Mountain and to Steady Brook Falls.

This outdoor activity is more enjoyable in a relatively light wind (less than 32 km/h) and in sunshine (cloud cover less than eight-tenths). Other criteria for designation of a suitable day for hiking are air temperatures between 12 and 24°C, humidex between 12 and 32°C, visibility greater than 3km, and no precipitation (Crowe *et al.,* 1973).

The length of the complete summer including spring and autumn shoulder vary with location. For Stephenville, the complete summer season extends from mid- to late April to late November. The corresponding periods for Deer Lake are early May-early November, and mid-May to late October for Daniel's Harbour.

For the entire length of each summer season (see Table 6.4), the number of days when temperature, visibility and wind speed were suitable for hiking were calculated for the three weather stations at Stephenville, Deer Lake and Daniel's Harbour where data were available from 1990 to 2007. When all of these parameters were met, that day was counted as suitable for hiking. Results are given in Table 7.1. Where data for the length of summer season were missing, the months representing the beginning and finish of summer were considered, and suitable days were estimated using those months. Calculations were excluded for years where data was lacking for any one of the meteorological parameters.

	ST Hiking Days			DL Hiking days			DH Hiking Days		
	Total days	% from mean days	% total summer season	Total days	% from mean days	% total summer season	Total days	% from mean days	% total summer season
1990	28	85	15	29	91	16	17	113	9
1991	28	85	14	30	94	17	11	73	6
1992	28	85	15	41	128	22	15	100	7
1993	31	94	14	39	122	23			
1994	34	103	18	34	106	16	9	60	4
1995	27	82	13	39	122	23	17	113	8
1996	35	106	17	44	138	28			
1997	22	67	12	30	94	21			
1998	40	121	18	39	122	20			
1999	34	103	15	30	94	17			
2000	23	70	11	31	97	14	20	133	
2001	26	79	13	32	100	17	13	87	
2002	31	94	17	23	72	12	8	53	
2003	42	127	22	37	116	21	24	160	
2004	37	112	16				19	127	
2005	64	194	29				10	67	
2006	39	118	16						
2007	22	67	12						
Av.	33		16	32		19	15		7

Table 7.1 Total Suitable Hiking Days

Legend

missing data

Both the maximum and minimum number of suitable days for hiking activity increase from north to south. Daniel's Harbour has a maximum of 24 days (2003) and a minimum of 8 days (2002), although the available data are very limited. Stephenville has a maximum of 64 days (2005) and a minimum of 22 days (1997). Figure 7.2 illustrates the variability in the number of suitable hiking days over the period 1990-2007.

Of the stations studied by Peach (1975), Deer Lake had the highest percentage of suitable days for vigorous activities, with 57% in late July and early August. Stephenville had over 40% suitable days throughout July and August. The concentration of suitable days for vigorous activities in July and August is primarily temperature-dependent. Deer Lake is the only station with more than 20% of suitable days for hiking in the entire summer recreational season (Table 7.1). Due to limited data, Daniel's Harbour and Corner Brook can not be included in the analysis.

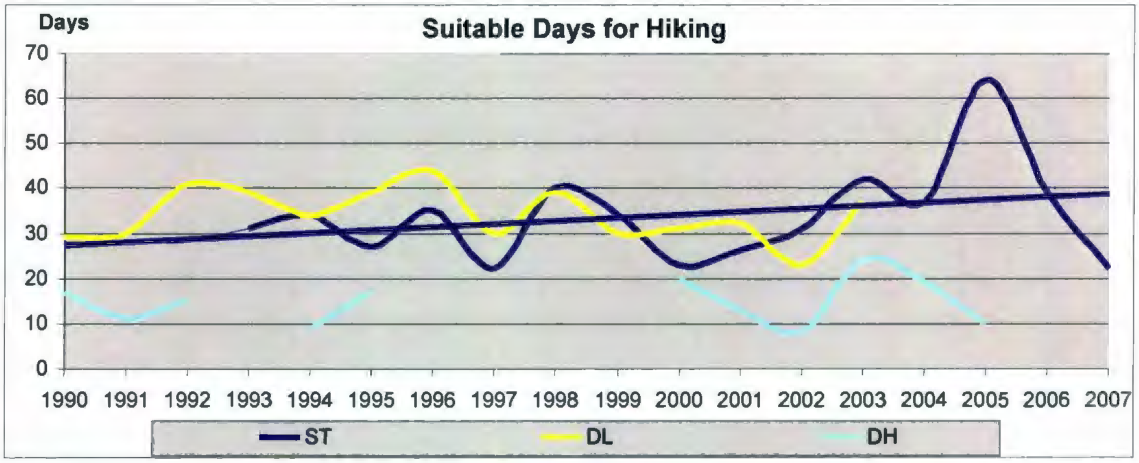


Figure 7.2 Variability of Suitable Days for Hiking

Stephenville has the longest data series, and the trend indicates an increase in the number of suitable hiking days (increase of 12 days, 1990-2007). Deer Lake has a shorter range of data, and the trend is slightly negative. However, the similarity of the Stephenville and Deer Lake data sets prior to 2003, coupled with the generally suitable conditions at Stephenville in the period

2004-2007, suggest that the negative trend recorded at Deer Lake may not be significant.

Differences between the total numbers of recreational summer days (see Chapter 6) and the number of days suitable for hiking reflects the importance of precipitation and wind gust speed. Overall, the summer recreational season is increasing at Stephenville and Deer Lake, while little change is recorded at Daniel's Harbour. The number of summer days without precipitation, however, is increasing at all three locations (Figure 7.3, 7.4). Days without precipitation constitute more than 40% of the total summer days at all locations. Although drier summers encourage hiking, comparison of Figures 7.2, 7.3, and 7.4 indicate that, for all locations, precipitation is not the dominant factor explaining the variation in the number of hiking suitable days.

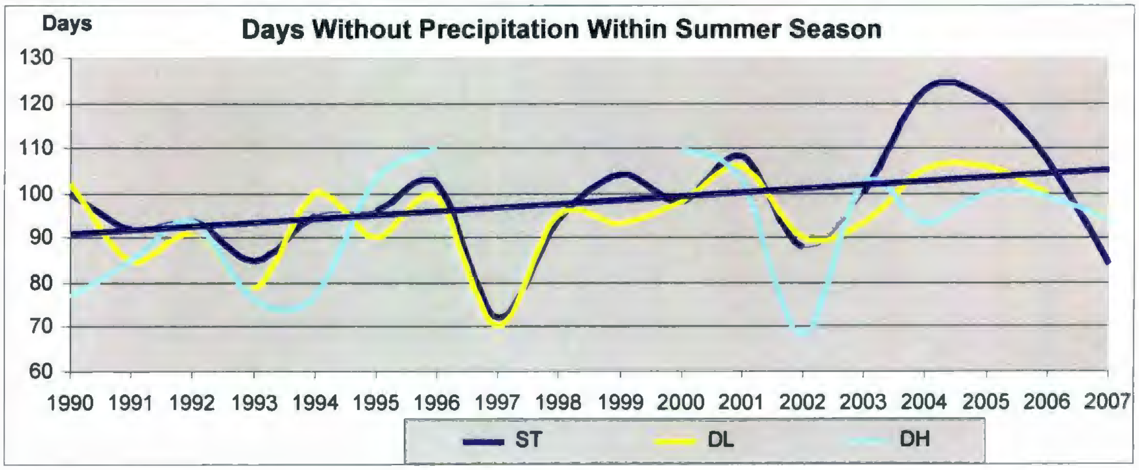


Figure 7.3 Days Without Precipitation, Summer Recreational Season

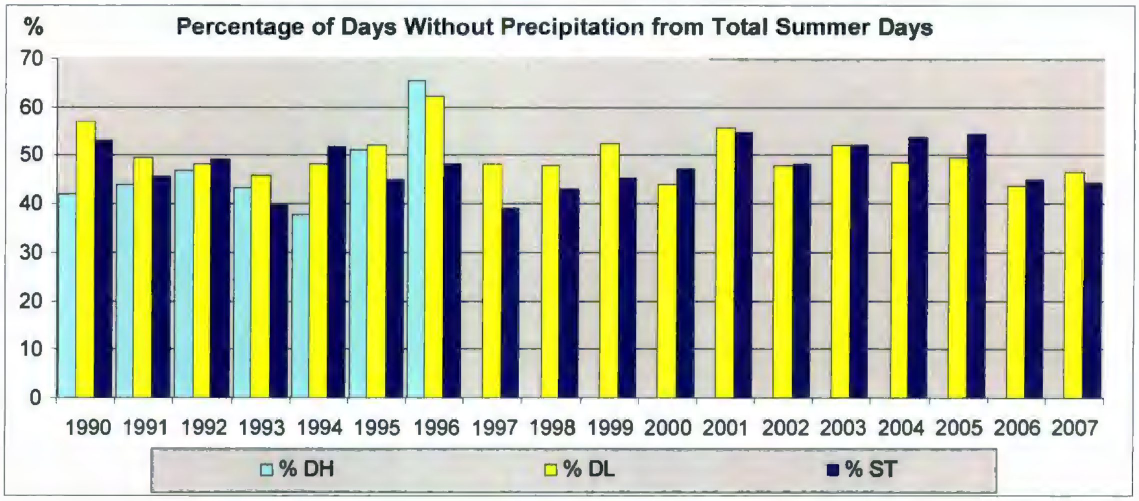


Figure 7.4 Variation of Percentage of Dry Days in Total Summer Days

Wind gust speed is the remaining parameter. Fig 7.5 shows the number of days with wind gusts less than 32 km/h within the complete summer season. Deer Lake recorded the highest number of windy days. The linear trend of number of days with wind speed less than 32 km/h is marginally decreasing for Deer Lake (no data after 2003) and Daniel's Harbour (with very limited data), and is positive for Stephenville. At Stephenville in 2005, more than 100 days with strong winds were recorded. The absence of data for Deer Lake since 2003, and in particular for 2005, may influence the obtained trend value.

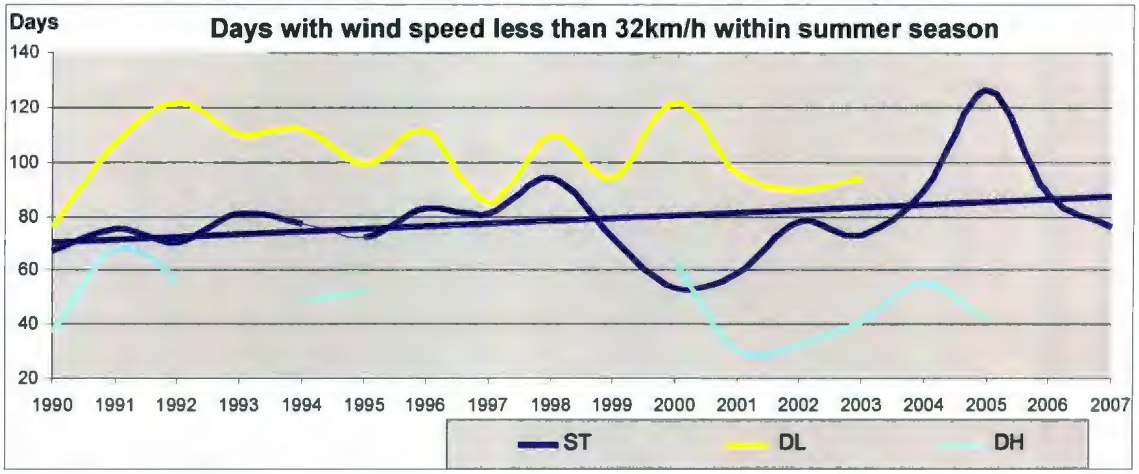


Figure 7.5 Variation of Summer Days With Wind Less Than 32 km/h

Fig 7.6 shows the impact of wind on suitable hiking days. The percentages of days with wind speed less than the 32km/h minimum required for hiking range around 40% for Stephenville. At Deer Lake, favourable wind conditions for hiking represent more than 50% of the complete summer season.

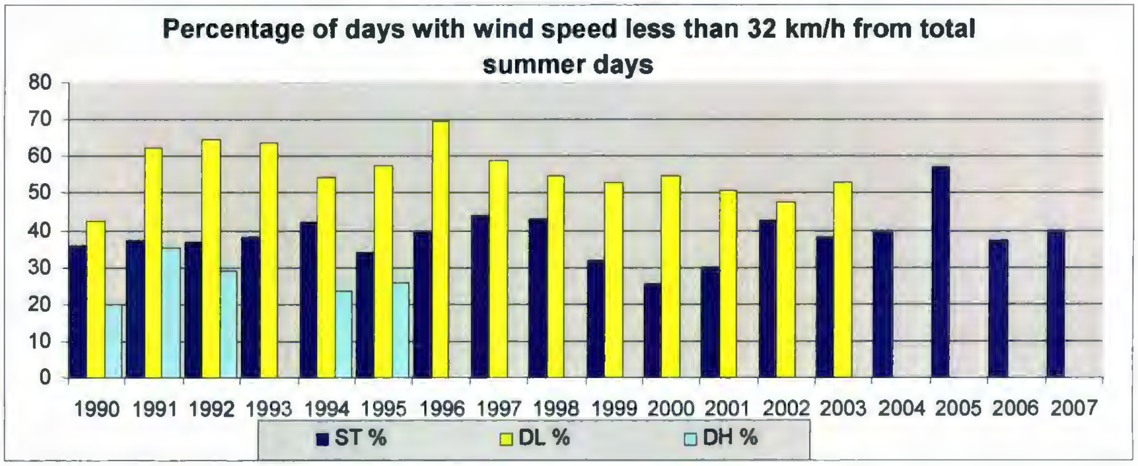


Figure 7.6 Wind Speed Less Than 32 km/h Expressed in Percentage From Total Summer Days

7.2.2 Boat touring

There are two boat tours in Gros Morne National Park. The Tablelands Boat Tour operates on Trout River Pond and the western Brook Pond tour operates on western Brook Pond. Other boat tours are offered in nearby communities, and include tours of Bonne Bay and St. Paul's Inlet. Boat touring is an outdoor activity which strongly depends on weather, particularly visibility and wind conditions.

Although Crowe et al (1973, 1975) did not consider boat touring and kayaking, Peach (1975) included these activities in the Newfoundland analyses. Weather requirements for boat touring are close to those desirable for landscape touring describe by Crowe et al 1975. For kayaking and boat touring, the maximum wind limit estimated by Peach (1975) is 32-40 km/h. Visibility must be 10 km or greater, temperature above -24 but below 24°C, and there must be a maximum of 2.5 mm precipitation. When winds are blowing from the land, wind speed on the sea tends to increase. This difference will limit yachting and boat touring activities.

Fig 7.7 shows the variation of suitable days for boat touring and kayaking. Significant variability is evident in the 1990-2007 data series. The differences between these three locations are dictated by wind speed.

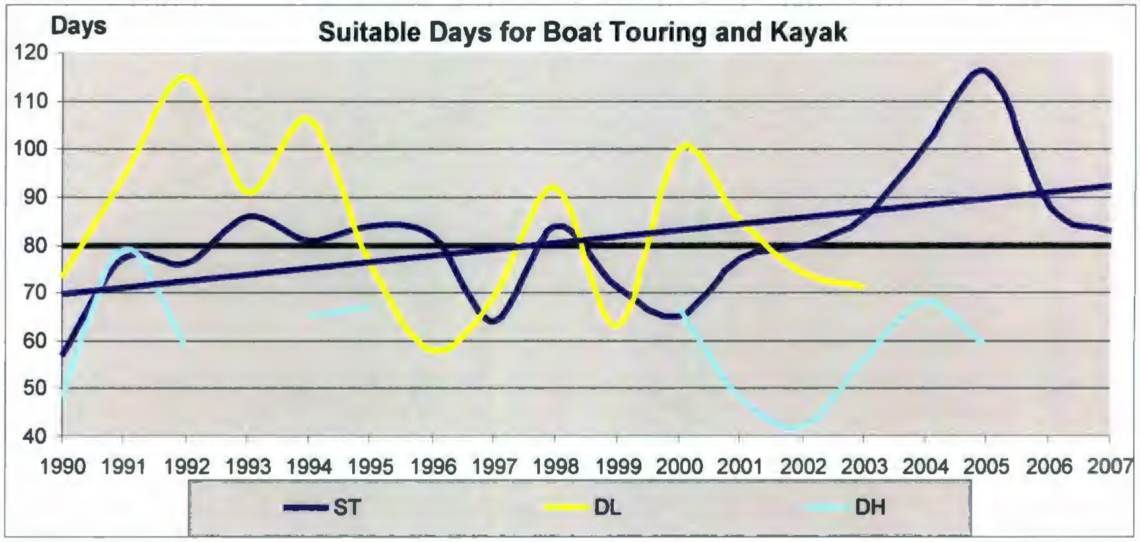


Figure 7.7 Variation of Boat Touring and Kayaking

This outdoor activity takes place also within the complete summer season. As the number of days with no precipitation is increasing (Figure 7.4), this factor would favour boat touring and kayaking. The general trend of boating and kayaking shows an increase of suitable days for Stephenville (Table 7.2), and decreased numbers of suitable days at Deer Lake and Daniel's Harbour, due primarily to increased wind speeds.

Peach (1975) suggested that the percentage of suitable days for yachting could be estimated by lowering the values for landscape touring by 10%. Using this method for the study area, 60-70% of the days from May to October could be considered suitable. Deer Lake recorded the highest percentage in the entire summer recreational season, with more than 11 years with values over 40%

(Table 7.2). Although fog could reduce this percentage for Stephenville (Peach, 1975), the mean percentage is 39% for 18 years.

	ST Boat/Kayak Days			DL Boat/Kayak Days			DH Boat/Kayak Days		
	Total days	% from mean days	% total summer season	Total days	% from mean days	% total summer season	Total days	% from mean days	% total summer season
1990	57	70	30	73	88	41	48	80	26
1991	77	95	38	94	113	55	79	132	41
1992	76	94	40	115	139	61	59	98	29
1993	86	106	40	91	110	53			
1994	81	100	44	106	128	51	65	108	32
1995	84	104	39	76	92	44	67	112	33
1996	82	101	39	58	70	36			
1997	64	79	35	69	83	48			
1998	84	104	38	92	111	46			
1999	71	88	31	63	76	36			
2000	65	80	31	100	120	45	67	112	
2001	77	95	39	85	102	45	48	80	
2002	80	99	44	74	89	39	42	70	
2003	86	106	45	71	86	40	56	93	
2004	101	125	44				68	113	
2005	116	143	52				59	98	
2006	88	109	37						
2007	83	102	44						
Mean	81		39	83		46	60		27

Table 7.2 Total Number of Suitable Boat Touring and Kayaking Days

Legend

(yellow)	missing data

7.3 Winter Season: Skiing and Snowmobiling

Crowe et al (1973) defined a day suitable for skiing or snowmobiling as one where the snow depth must average at least 2.5 cm, the wind must be less than 24 km/h and visibility greater than 1 km. The only difference between conditions suitable for these two winter outdoor activities is the temperature. For skiing, the temperature may be as low as -14°C. For snowmobiling, -21°C was considered the lower limit. Peach (1975) used a level of snow depth of 5 cm as more reliable for calculation of suitable days. The number of suitable days for skiing can thus be calculated by combining the methodologies of Crowe *et al.* (1975) and Peach (1975), using weather criteria from the meteorological data. All days are eliminated which have less than 5 cm snow cover, or have winds in excess of 24 km/h, or have temperatures below -14°C: any single criterion would be sufficient to eliminate a day as suitable. The total number of suitable days remaining can be compared with the total number of winter season days, and the percentage of suitable days for skiing and snowmobiling calculated for each station. This analysis is summarized in Table 7.3. Missing data (particularly for wind speeds) imposes some limitations on the analysis.

Skiing encompasses cross-country, back-country, and downhill skiing. These three groups of activities are practiced in the study area. Marble Mountain offers downhill and cross-country skiing, while Gros Morne National Park offers five cross-country skiing trails and backcountry skiing. All snowmobile operators must have a permit to snowmobile in Gros Morne.

Shortly after the median date of the first 2.5 cm of snow cover that marks the beginning of the recreational winter season, the frequency of suitable days for skiing and snowmobiling rises above 20%, with the highest values occurring in January and February. Peach (1975) considered that Stephenville had the highest number of suitable days for skiing and snowmobiling, with over 50% for three consecutive months.

Figure 7.8 shows the variation of suitable days for skiing during the winter season over the period 1990-2007. The lowest number of skiing days was recorded in Stephenville, with less than 30 per season. Deer Lake had more than 50 per season. The linear trends show an increase of skiing days for Deer Lake (albeit from very limited data) and a slight decrease for Stephenville. Figure 7.9 shows that variation of suitable days for snowmobiling does not differ markedly from skiing.

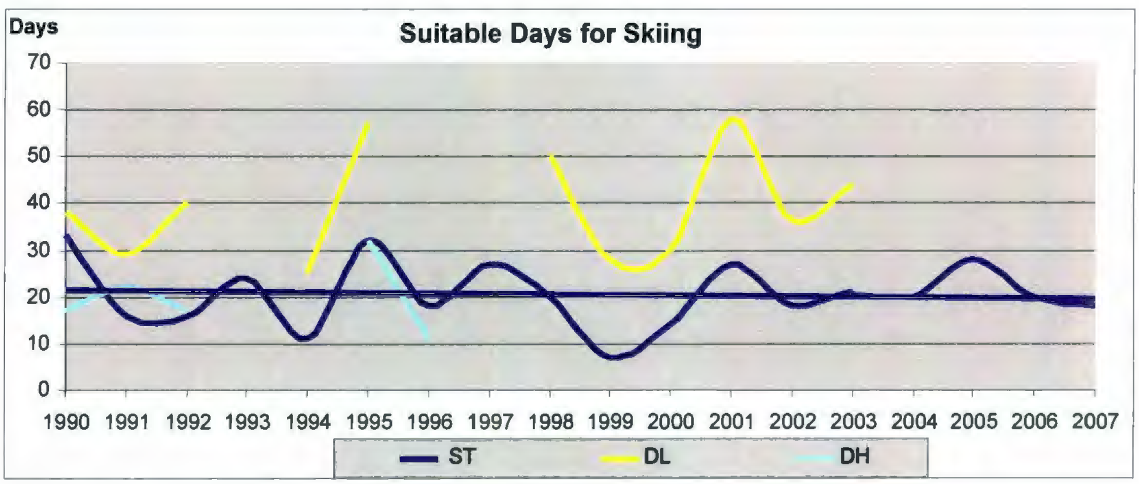


Figure 7.8 Variability of Suitable Days for Skiing

Peach (1975) included only Daniel's Harbour and Stephenville in his analysis of suitable days for skiing and snowmobiling. Stephenville recorded higher values (over 60% in January and February) of mean percentage frequency of suitable days for skiing and snowmobiling than Daniel's Harbour (over 40% in January and February). Table 7.3 and Figures 7.8 and 7.9 show that Stephenville recorded lower numbers of suitable days for skiing and snowmobiling than did Deer Lake, a result at variance with Peach (1975).

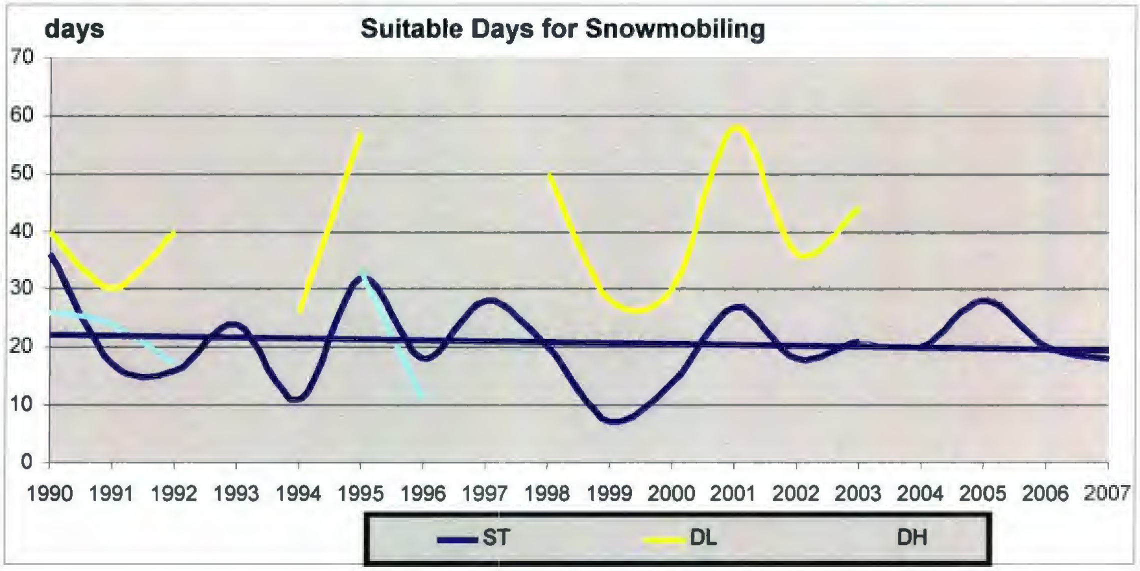


Figure 7.9 Variability of Suitable Days for Snowmobiling

Suitable conditions for snowmobiling differ from those required for skiing only in terms of temperature. Snowmobiling can be considered more as a passive outdoor activity which requires lesser physical exertion. In addition, snowmobile operators wear protective clothing to reduce wind chill. Consequently, the limiting temperature for snowmobiling is considered as -21°C (Masterton *et al.* 1981). As relatively few days at any of the four meteorological station sites have winter temperatures between -21°C and -14°C, the number of suitable days for skiing and snowmobiling can be considered similar.

	ST Skiing Days			DL Skiing Days			DH Skiing Days		
Year	Total days	% from mean days	% total winter season	Total days	% from mean days	% total winter	Total days	% from mean days	% total winter season
1990	33	157	22	38	95	22	17	85	10
1991	16	76	10	29	73	16	22	110	13
1992	16	76	10	40	100	21	17	85	10
1993	24	114	16						
1994	11	52	8	25	63	14			
1995	32	152	22	57	143	35	32	160	21
1996	18	86	14				11	55	9
1997	27	129	16						
1998	20	95	15	50	125	29			
1999	7	33	5	28	70	19			
2000	14	67	9	30	75	18			
2001	27	129	18	58	145	38			
2002	18	86	11	36	90	24			
2003	21	100	13	44	110	25			
2004	20	95	13						
2005	28	133	21						
2006	20	95	18						
2007	18	86	14						
Mean	21		14	40		24	20		13

	ST Snowmobiling Suitable Days			DL Snowmobiling Suitable Days			DH Snowmobiling Suitable Days		
Year	Total days	% from mean days	% total winter season	Total days	% from mean days	% total winter season	Total days	% from mean days	% total winter season
1990	36	171	24	40	100	24	26	118	16
1991	17	81	11	30	75	16	24	109	14
1992	16	76	10	40	100	21	17	77	10
1993	24	114	16						
1994	11	52	8	26	65	15			
1995	32	152	22	57	142.5	35	33	150	21
1996	18	86	14				11	50	9
1997	28	133	16						
1998	20	95	15	50	125	29			
1999	7	33	5	28	70	19			
2000	14	67	9	30	75	18			
2001	27	129	18	58	145	38			
2002	18	86	11	36	90	24			
2003	21	100	13	44	110	25			
2004	20	95	13						
2005	28	133	21						
2006	20	95	18						
2007	18	86	14						
Mean	21		14	40		24	22		14

Table 7.3 Percentage of Suitable Days of Skiing and Snowmobiling From Mean Average and from Total Winter Recreational Season Days

Legend

[yellow box] missing data

The climate parameter which controls the variation of suitable days for skiing and snowmobiling is the requirement for a minimum of 5 cm snow cover. Figure 7.9 shows the variation of numbers of days with snow cover of more than 5 cm during the winter recreational season. The numbers of days with snow cover more than 5 cm are in decline for all three locations.

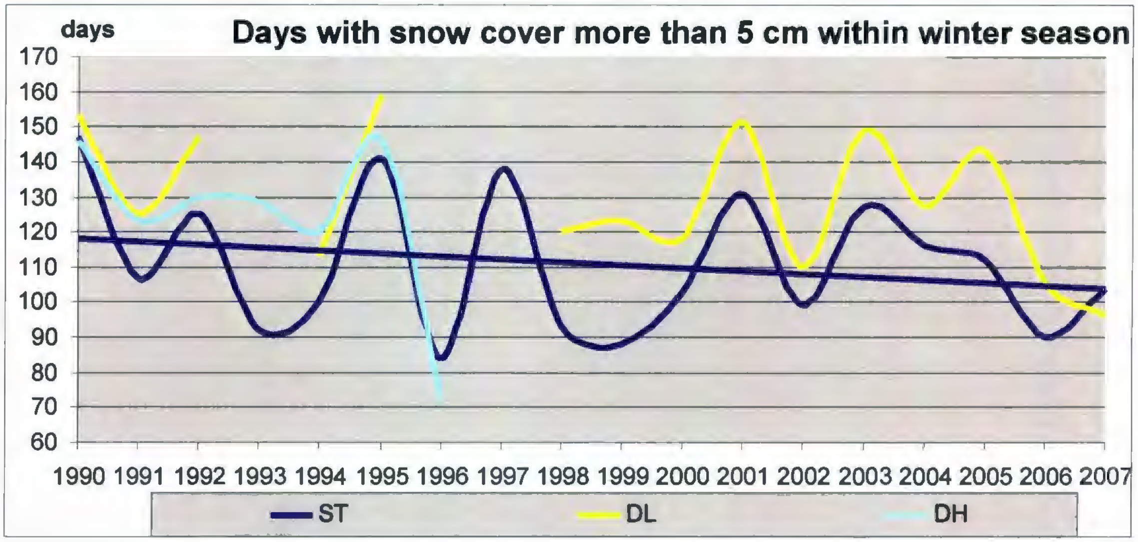


Figure 7.10 Variability of Snow Cover Using the Peach (1975) Criterion for Suitability

This tendency has a negative impact on snowmobiling and cross-country and back-country skiing. Downhill skiing is less impacted because the resort operator can manufacture artificial snow.

7.4 Year Round: Landscape Touring

Landscape touring involves driving for pleasure mainly during the warm season, but may also be carried out year-round. Variations in temperature are tolerated on a motor trip between -24 and 24°C (Crowe *et al.*, 1973). Visibility (greater than 3 km) is of prime importance in the enjoyment of landscape viewing. Other requirements are wind less than 40 km and nil precipitation. Although the greatest number of suitable days for landscape touring occurs during warm months, Table 7.3 shows that many suitable days occur during the winter season. Linear trends indicate an apparent increase of suitable days for landscape touring for Stephenville and a decrease for Deer Lake (Figure 7.11). However, the data is limited, and the high total in 2005 (123 days) for Stephenville may have excessively influenced the overall linear trend. The low summer values for Daniel's Harbour are due to the strong wind speed along the coastal plain and to the occurrence of fog, limiting visibility.

ST Landscape Suitable Days							
Year	Total Summer	Total Winter	Total Year	Total Summer from Total Year	Total Winter from Total Year	% from mean days	% total year from 365 days
	days	days	days	%	%		
1990	48	30	78	62	38	95	21
1991	50	25	75	67	33	91	21
1992	61	25	86	71	29	105	24
1993	57	31	88	65	35	107	24
1994	58	15	73	79	21	89	20
1995	59	27	86	69	31	105	24
1996	56	20	76	74	26	93	21
1997	42	25	67	63	37	82	18
1998	53	19	72	74	26	88	20
1999	56	10	66	85	15	80	18
2000	49	18	67	73	27	82	18
2001	63	22	85	74	26	104	23
2002	58	22	80	73	28	98	22
2003	67	24	91	74	26	111	25
2004	81	31	112	72	28	137	31
2005	96	27	123	78	22	150	34
2006	65	18	83	78	22	101	23
2007	51	12	63	81	19	77	17
Mean			82				

DL Landscape Suitable Days **Table 7.4 continue**

Year	Total Summer	Total Winter	Total Year	Total Summer from Total Year	Total Winter from Total Year	% from mean days	% total year from 365 days
	days	days	days	%	%	%	%
1990	56	48	104	54	46	101	28
1991	53	48	101	52	48	98	28
1992	73	60	133	55	45	129	36
1993	61						
1994	73	33	106	69	31	103	29
1995	60	59	119	50	50	116	33
1996	58						
1997	52						
1998	64	51	115	56	44	112	32
1999	43	27	70	61	39	68	19
2000	63	36	99	64	36	96	27
2001	60	47	107	56	44	104	29
2002	49	36	85	58	42	83	23
2003	48	47	95	51	49	92	26
Mean			103				

DH Landscape Suitable Days

Year	Total Summer	Total Winter	Total Year	Total Summer from Total Year	Total Winter from Tota Year	% from mean days	% total year from 365 days
	days	days	days	%	%	%	%
1990	38	37	75	51	49	99	21
1991	47	39	86	55	45	113	24
1992	41	32	73	56	44	96	20
1993							
1994	38						
1995	47	38	85	55	45	112	23
1996		31					
1997							
1998							
1999		20					
2000	54	20	74	73	27	97	20
2001	39	41	80	49	51	105	22
2002	24	29	53	45	55	70	15
2003	47	25	72	65	35	95	20
2004	51	35	86	59	41	113	24
2005	42	31	73	58	42	96	20
Mean			76				

Legend

(yellow) missing data

Table 7.4 Landscape Touring Suitable Days

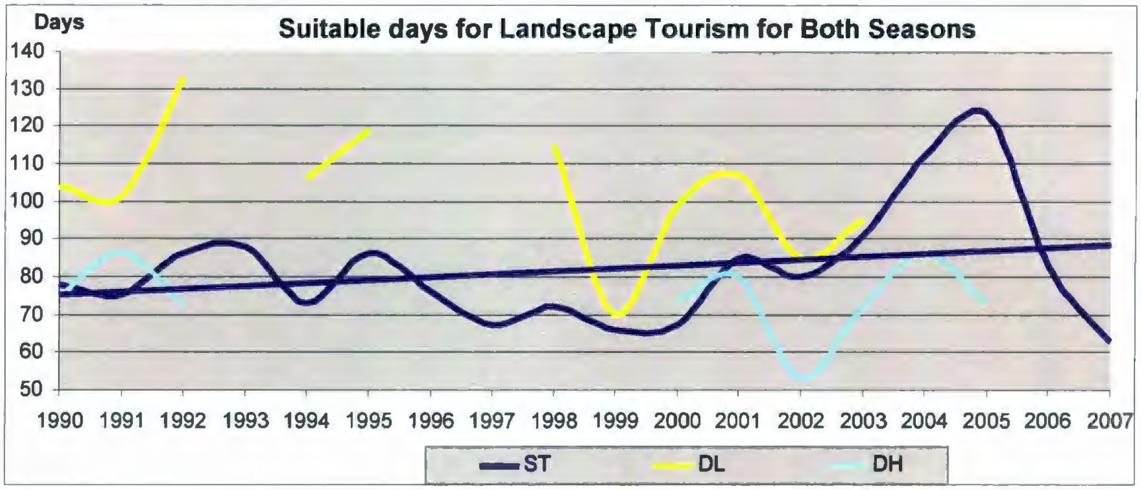


Figure 7.11 Suitable Landscape Touring Days, Year-Round

7.5 Summary

Stephenville is the only location with complete data available after 1990. Daniel's Harbour does not have sufficient data to make a pertinent analysis of impacts on outdoor activities.

Stephenville records an increase in suitability for summer outdoor activities (hiking, boat touring, kayaking, landscape touring). These activities are strongly impacted by precipitation and wind. The number of dry days during the summer season is increasing, positively impacting those activities. Decreased wind gust speed also positively impacts boat touring.

Suitability for winter activities, including skiing and snowmobiling, shows a slight decrease. This decrease is in relationship with the decreased number of days with snow cover more than 5 cm, the minimum required for winter activities.

Deer Lake shows an increase of suitable days for hiking and a slight decrease for boat touring and kayaking. The decrease of number of suitable days for boat touring and kayaking is related to the decreased number of days with low wind speed. The number of days without precipitation during the summer records is increasing as for Stephenville. Deer Lake has recorded a decrease in the number of days with snow cover more than 5 cm, potentially adversely impacting winter activities (skiing and snowmobiling). The decrease of winter outdoor activities for both locations is related to the decrease of winter season length, as discussed in Chapter 6.

Scott *et al.* (2004, 2005, 2006a) assessed the influence of climate change on 15 Canadian Parks including Terra Nova National Park. Their findings indicated that visitation to Canada's national parks is projected to increase, with the largest increase occurring in national parks located in eastern Canada. Visitor increases of 6% to 8% are projected for the 15 national parks analyzed for the 2020s with increases of 9% to 29% by the 2050s. Most of the increases are projected to occur outside of the traditional peak summer tourism season, as a result of changes in length of the summer and winter seasons. At Stephenville and Deer Lake, longer summer seasons and shortening of winter seasons by approximately 2 weeks will extend the occurrence of summer activities outside of the traditional summer season of May to September.

Stephenville and Deer Lake show a slight decreasing of winter outdoor season, as do Ontario and Québec (Scott and Jones 2006b). In those provinces, the alpine skiing industry is projected to be negatively impacted by climate change. Warm-weather recreation in Canada is projected to benefit from changes in the climate. Scott and Jones projected also that demand for campgrounds will increase and a warmer climate could lead to the extension of current camping seasons in the decades to come. For Stephenville and Deer Lake, it is evident that the increasing length of the summer season and the number of days suitable days for summer outdoor activities are responsive to climate change. At Gros Morne National Park, campgrounds open in May and close in October. However, the summer season began earlier than May in 27 years (Chapter 6). The summer season ended in October only in 2 years, for other years, warm (18°C daytime high) conditions occur in November or even in early December. This has led to a prolongation of the summer season and suitable conditions for summer activities.

Snowmobiling in the Atlantic region could be particularly vulnerable under a changed climate (McBoyle *et al.* 2007). Their results show that the snowmobiling seasons in the Atlantic region are among the shortest in North America, averaging no more than six weeks (41 days) in the 1961–90 baseline.

In the 2020s, the average length of snowmobile seasons in this region were projected to be reduced between 35% and 62%, and by 39% and 50% under the least-change and warmest climate change scenarios, respectively. Although western Newfoundland recorded a decreased length of winter season (see chapter 6), the reliability of a minimum snow cover of 2.5 cm shows a great picture for winter outdoor activities such skiing and snowmobiling, in contrast to the generalized picture for Atlantic Canada.

8. Conclusion: Implications of Climate Change for Tourism

In this chapter, the main evidence of climate change and variation, and the implications for outdoor activities and tourism are presented. Appendices contain summaries of climate analyses, length of recreational seasons, and analyses of outdoor activities. The significant changes and variations in climate and implications for tourism activities, in term of changes in recreational season and change in suitable days for each outdoor activity, are considered for each of the four sites.

8.1 Daniel's Harbour

Temperature is an important parameter in terms of outdoor activities. Temperatures higher than 18^{O}C during summer, and less than -14^{O}C in winter, inhibit outdoor activities. At Daniel's Harbour, the annual and winter night time-temperature, and the winter annual mean temperature recorded a significant decrease (>0.5 C°). For all seasons, except winter (decrease of 0.4 C°), daytime temperature recorded an increase of >0.5 C°. Although all seasons recorded increasing precipitation, the numbers of days with snow cover more than 5 cm (sufficient for all winter activities) decreased, albeit over only a short (7 year) data set.

Over a longer term (between 56 and 61 years), the ratio of warm and cold years and wet and dry years for each parameter recorded different distributions. Winters have become cooler, and summers warmer. Summers, springs, and autumns are drier and winters wetter.

Springs and autumns are colder but drier, which does not help to elongate the winter recreational season. A drier spring and autumn can lengthen the summer recreational season, but because temperature is the parameter which controls the length, there are no significant changes in the length of this season (2 days increase over 40 years).

Winter is marked by a decrease of daytime temperature (-0.4 C°) and increasing snowfall (161 cm), which could enhance winter outdoor activities. Summer climatic patterns show an increase of daytime temperature (1 C°) and an increase of summer precipitation of 58 mm. These summer climate characteristics increase the number of suitable days for summer activities such as hiking, boat touring, kayaking and landscape touring.

A detailed analysis of each type of outdoor activity for Daniel's Harbour is not possible because of short-term range data with many gaps. For summer outdoor activities, the data series includes 11 years, and for winter activities just 5 years. For this limited data, suitable days for boat touring, kayaking, landscape touring and snowmobiling recorded a slight decrease. Hiking and skiing suitable days recorded very slight increases.

8.2 Deer Lake Region

Mean annual temperatures increased in all seasons at Deer Lake. Night-time temperatures also increased during all seasons, particularly in winter. Night-time temperatures indirectly affect winter outdoor activities through melting of snow cover and transformation of snowfall to liquid precipitation.

Although precipitation for all seasons recorded increases, the winter season increases in total precipitation (145 mm) and for snowfall (105 cm) are high. Net precipitation increased by 29.3% between 1934 and 2007.

The winter recreational season length has decreased by 22 days between 1966 and 2007, and the summer recreational season increased by 14 days between 1966 and 2007. This is an effect of increasing spring daytime temperature, which elongates the summer season and diminishes the winter season. A warmer autumn diminishes the winter recreational season even the total precipitation is increasing. Although spring and autumn precipitation are increasing, snowfall in those seasons is reduced due to higher temperatures.

Although the winter recreational season is shorter, suitable conditions for winter season outdoor activities (skiing and snowmobiling) show a slight increase. This results from the increase in winter snowfall. Snowfall is thus increasing in the winter, as it simultaneously decreases in spring and autumn.

All summer outdoor activities recorded a decrease in the number of suitable days. The main climate parameter which negatively affects these activities is the very high increase of precipitation.

8.3 Corner Brook

Significant changes (>0.5 C°) have occurred in annual, winter, summer, spring, and autumn mean temperature and daytime spring temperature. Changes of more than 1 C° occurred in nighttime temperature for all seasons. Precipitation has increased by 14.2% over the period 1934-2006.

The winter recreational season pattern shows an increase of 31 days between 1979 and 2005. The summer recreational season has decreased by 46 days between 1979 and 2005. Changes in summer and winter outdoor activities were not analysed due to insufficient data.

8.4 Stephenville

All temperature parameters are significantly decreased for winter, and increased for summer. Between 1942 and 2007, there were increases in warm years, cold winters, and warm summers.

Although there were more dry years then wet over the period 1942-2007, the linear trends show high increases for annual total precipitation (402 mm, 32.5%), and for winter snowfall (105 cm) and summer rain (131 mm).

Transitional seasons, spring and autumn, also recorded increasing precipitation.

Wind gust speed is increasing, which can inhibit outdoor activities in both recreational seasons. The number of days with snow cover is decreasing, translating into a diminished winter recreational season by more than 2 weeks since 1955. The numbers of days with temperature more than 18°C has increased by 22, and the summer recreational season has been elongated by 2 weeks since 1955

Analysis of outdoor activities over 1990-2007 shows a concordance between the number of suitable days for outdoor activities and the trend of length of recreational seasons. Summer outdoor activities recorded a significant increase, while all winter outdoor activities recorded a slight decrease of 2 or 3 days. Suitable conditions for landscape tourism showed an increasing trend of about 2 weeks.

Overall, for all locations the annual mean temperature is increasing, especially since 1998. Winter temperatures tendencies are colder at Stephenville and Daniel's Harbour, while Corner Brook and Deer Lake have experienced increasing winter temperatures. Summer, spring, and autumn temperatures are warmer for all locations. Precipitation has increased at all localities between 14.2% at Corner Brook (1934-2006) and 32.5% at Stephenville (1943-2007).

8.5 Conclusion

Although tourism numbers depend on many factors, temperature and precipitation remain the main factors. Increasing temperature, winter snowfall and low precipitation in summer time are the most attractive conditions to spend leisure time.

Temperature increase is important not just in term of degrees but also in term of time of occurrence. An increase of temperature during the night or day will make a difference in terms of outdoor activities. For instance, increasing temperature during the day will be more enjoyable for most summer outdoor activities, but increase in night-time during the winter will contribute to an increase in snow-melting. Although the Deer Lake record shows increasing snowfall, the record of night-time temperature shows a very high increase of 1.7°C. Corner Brook, without showing an increase in winter snowfall, recorded a increase of temperature during the night of 1.4°C. These conditions are very important for Marble Mountain skiing area in terms of rapid melting of snowfall and great variability of snow cover.

Throughout seasons, the importance of change in temperature is evident. Increased summer temperature will also increase participation in outdoor activities. Precipitation, especially rain, poses problems for outdoor recreation. Summer and shoulder season rainfall record great variability, which poses difficulties for long term planning of outdoor activities. Extra-winter season snowfall could impact tourism demand in shoulder months.

The most interesting area is Marble Mountain for winter outdoor activities, but Corner Brook and Deer Lake do not show a significant increasing of shoulder-season snowfall. Stephenville and Daniel's Harbour record increases in snowfall in shoulder months, which can translate into better conditions for skiing and snowmobiling. Any increasing of extra-winter snowfall would be diminished by increased spring and autumn temperatures, particularly night-time increases.

Landscape touring remains a viable alternative for tourism in warmer summers and warmer winters for Deer Lake and Corner Brook. Landscape touring can be practiced all year around, and sites such as Arches Provincial Scenic Attraction (Figure 8.1) could be promoted effectively.

Figure 8.1 The Arches Provincial Scenic Attraction

For Daniel's Harbour, Deer Lake, and Stephenville, skiing and snowmobiling remain reliable winter activities. However, the tendency for warmer springs could cause the winter season to diminish in length.

In an environment marked by wetter and warmer winters, snowfall can easily transform to rain or freezing rain, affecting the quality and quantity of snow cover, a key parameter for winter outdoor activities. The numbers of days with snow cover more than 5 cm are decreasing for all locations.

Although the increasing summer temperatures make summer outdoor activities more enjoyable, the increasing precipitation could inhibit these activities, even though the summer recreational season can be lengthened by the warmer springs and autumns.

Climate change and variability influence tourism directly in terms of changes in lengths of summer and winter recreational seasons. Warm springs and autumns will elongate summer seasons and diminish winter seasons. Longer summer recreational seasons and warmer summer temperatures will potentially enhance summer activities already existing.

Changes in temperature and amount of precipitation directly affect tourists involved in outdoor activities. However, wet winters and cold temperatures for Stephenville and Daniel's Harbour will encourage winter outdoor activities (skiing and snowmobiling), while wet winters and warmer temperatures at Corner Brook and Deer Lake would adversely affect these activities.

Variability is significant throughout the region in most of the parameter records, both annually and seasonally. The overall warming trends have occurred simultaneously with an increase in variability from colder-than-normal to warmer-than-normal years. Although there is a general increase in winter precipitation, the most significant characteristic of the winter precipitation data is the substantial variability. The increasing unpredictability of temperature or amount of precipitation has potentially negative consequences for tourism, making it more difficult to plan outdoor recreational activities, for both visitors and operators.

In an environment wetter and warmer, tourism activities need more support in term of tourism marketing, new facilities, direct connection flights with more populous locations and a reassessment of new opportunities and resources.

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Appendix 1

Station	Data Range	Missing Years				
		Annual	Winter	Spring	Summer	Autumn
ST	1942-2007	1942	2007	--	--	--
CB	1933-2007 *	1933, 1935, 1937, 1942, 1943,	1933, 1935, 1937, 1942, 1943	1933, 1935, 1942, 1943	1935, 1942	1942, 2007
DL	1933-2007**	1933, 1936, 1968, 1969, 1970, 1971, 1975, 1977	1933, 1970	1936, 1944, 1970, 1971, 1977	1968, 1969	1936, 1939, 1955
DH	1947-2007***	1988	--	--	1988	1997

Table A1.1 Mean Annual Temperature

*Partial data from the years 2001, 2002, 2003 2006 and 2007 are provided by the record of the Corner Brook station at 151.80m altitude.

**Daily data used for 2004, 2005, 2006, and 2007.

*** Hourly data used to complete records from 1988, 1990, 1997, and 1999.

Station	Data Range	Missing Years				
		Annual	Winter	Spring	Summer	Autumn
ST	1942-2007	1942	1942	--	--	--
CB	1933-2007	1933, 1935, 1937, 1942, 1943, 2004	1933, 1935, 1937, 1942, 1943,	1933, 1935, 1942, 1943	1935, 1942, 2007	1942, 2004, 2007
DL	1933-2007	1933, 1936, 1967, 1968, 1969, 1970, 1971, 1975, 1977,	1933, 1970	1933, 1970, 1971, 1977	1968, 1969	1936, 1968, 1969, 1975
DH	1947-2007	1988	1947,	1997, 1998	1988, 1997	1996

A1.2 Mean Maximum Temperature

Station	Data Range	Missing Years				
		Annual	Winter	Spring	Summer	Autumn
ST	1942-2007	1942	1942	---	--	--
CB	1933-2007	1933,1934,1935, 1937, 1972, 1943	1933, 1935, 1937, 1942, 1943	1933, 1935, 1942, 1943	1935, 1942, 2007	1934, 1942, 2007
DL	1933-2007	1933, 1936, 1968, 1969, 1970, 1975, 1977	1933, 1970	1936, 1970, 1971, 1977	1968, 1969	1936, 1968, 1969, 1975
DH	1947-2007	1988, 1997, 1998, 1999	--	1997, 1998	1997, 1998, 1999	1997, 1999

A1.3 Mean Minimum Temperature

Station	Data Range	Missing Years				
		Annual	Winter	Spring	Summer	Autumn
ST	1942-2007	1942, 1946, 1948, 1966	1942	1942, 1946, 1966	1966	1948
CB	1933-2007	1933, 1935, 1937, 1942, 1943, 1952, 2007	1933, 1935, 1937, 1942, 1943, 1953	1933, 1935, 1937, 1942, 1943	1935, 1942, 2007	1942, 2007
DL	1933-2007	1933, 1936, 1939, 1945, 1955, 1956, 1961	1933, 1953, 1962	1936, 1939, 1955	1945, 1953, 1956	1936, 1952, 1953
DH	1947-2007	1947, 1950, 1951, 1952 1961, 1988, 1996, 1997, 1998, 1999, 2001, 2002	1947, 1951, 1952, 1997, 1998, 2001	1950, 1961, 1997, 1998, 2002	1947, 1951, 1988, 1997, 1999	1951, 1996, 1999, 2002

A1.4 Annual Total Precipitation

Station	Data Range	Missing Years		
		Winter	**Extra Winter**	**All Year Around**
ST	1943-2007	1951	1946, 1966	1946, 1951, 1966
CB	1934-2005	1935, 1937, 1942, 1943, 1952, 1995, 2001, 2002	1935, 1942, 1943,. 2001, 2002,2005	1935, 1937, 1942, 1943, 1952, 1995, 2001, 2002, 2005
DL	1934-2007	1953	1935, 1942, 1943, 2001, 2002, 2005, 2006, 2007	1936, 1953, 1954, 1955
DH	1948-1996	1951, 1952, 1997, 1998	1950, 1952, 1961	1950, 1952, 1961

A1.5 Winter Snowfall Precipitation

Station	Data Range	Missing Years		
		Winter	**Summer**	**Summer Temp ≥ 18°**
ST	1955-2007	---	---	--
CB	1979-2005	2002	2001, 2004	2001, 2002
DL	1966-2007	1996	--	--
DH	1956-1996	--	1988	
DH	1956-2007			1988, 1997, 1998

A1.6 Recreational Seasons

Station	Data Range	Missing Years		
		Precipitation	Wind Speed < 32 km/h	Snow Cover ≥ 5 cm
ST	1990-2007	---	---	---
DL	1990-2007	---	---	1993, 1996, 1997
DH	1990-2007	1997, 1998, 1999	1993, 1996, 19997, 1998, 1999, 2006, 2007	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007

A1.7 Climatic Parameter Required for Outdoor Activities

Station	Data Range	Missing Years				
		Hiking	Bout Touring	Landscape Touring	Skiing	Snowmobiling
ST	1990-2007	---	---	---	---	---
DL	1990-2003	---	---	---	1993, 1996, 1997	1993, 1996, 1997
DH	1990-2005	1993, 1996, 1997, 1998, 1999	1993, 1996, 1997, 1998, 1999	1993, 1996, 1997, 1998, 1999	1993, 1994, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005	1993, 1994, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005

A1.8 Outdoor Activities

Appendix 2

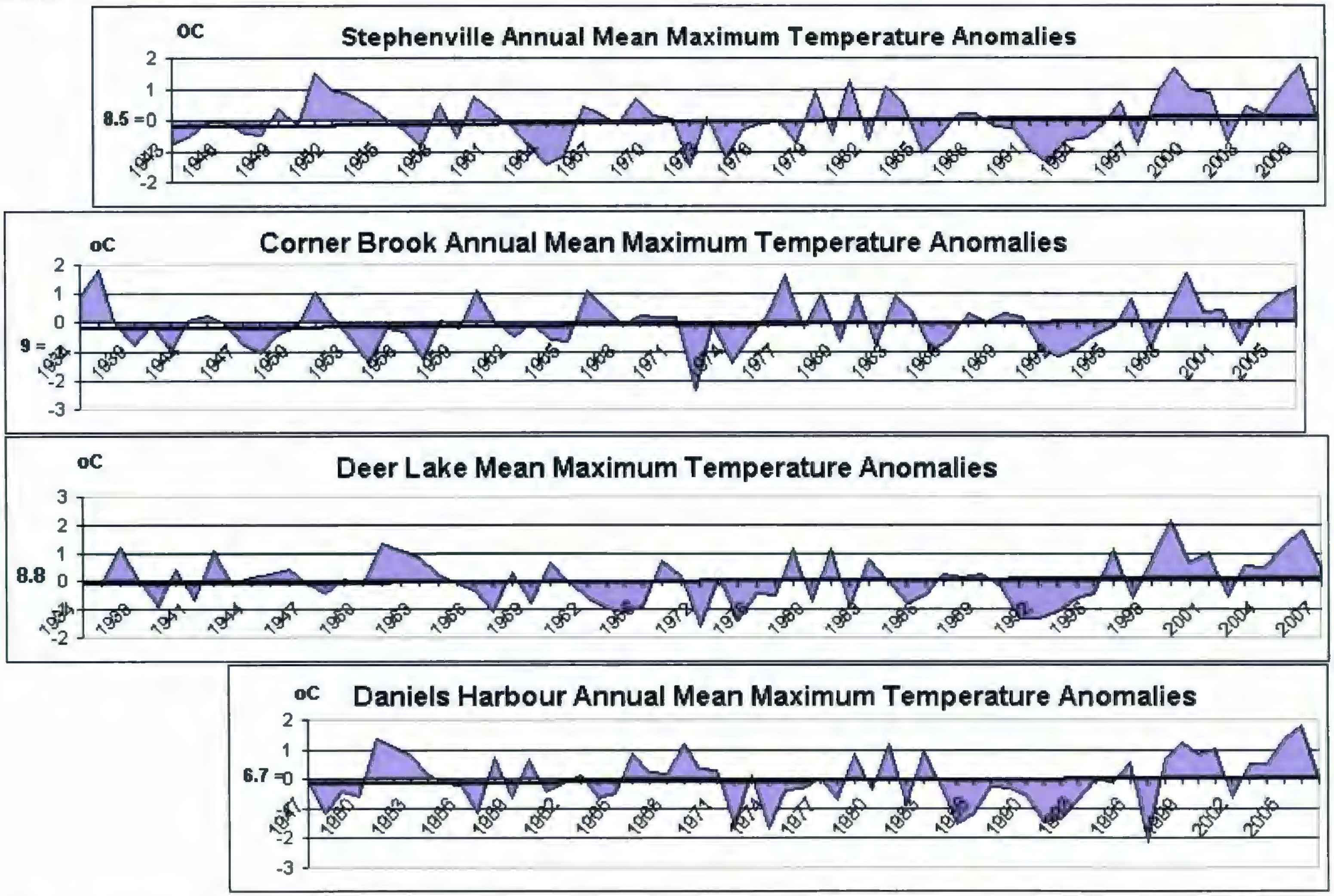
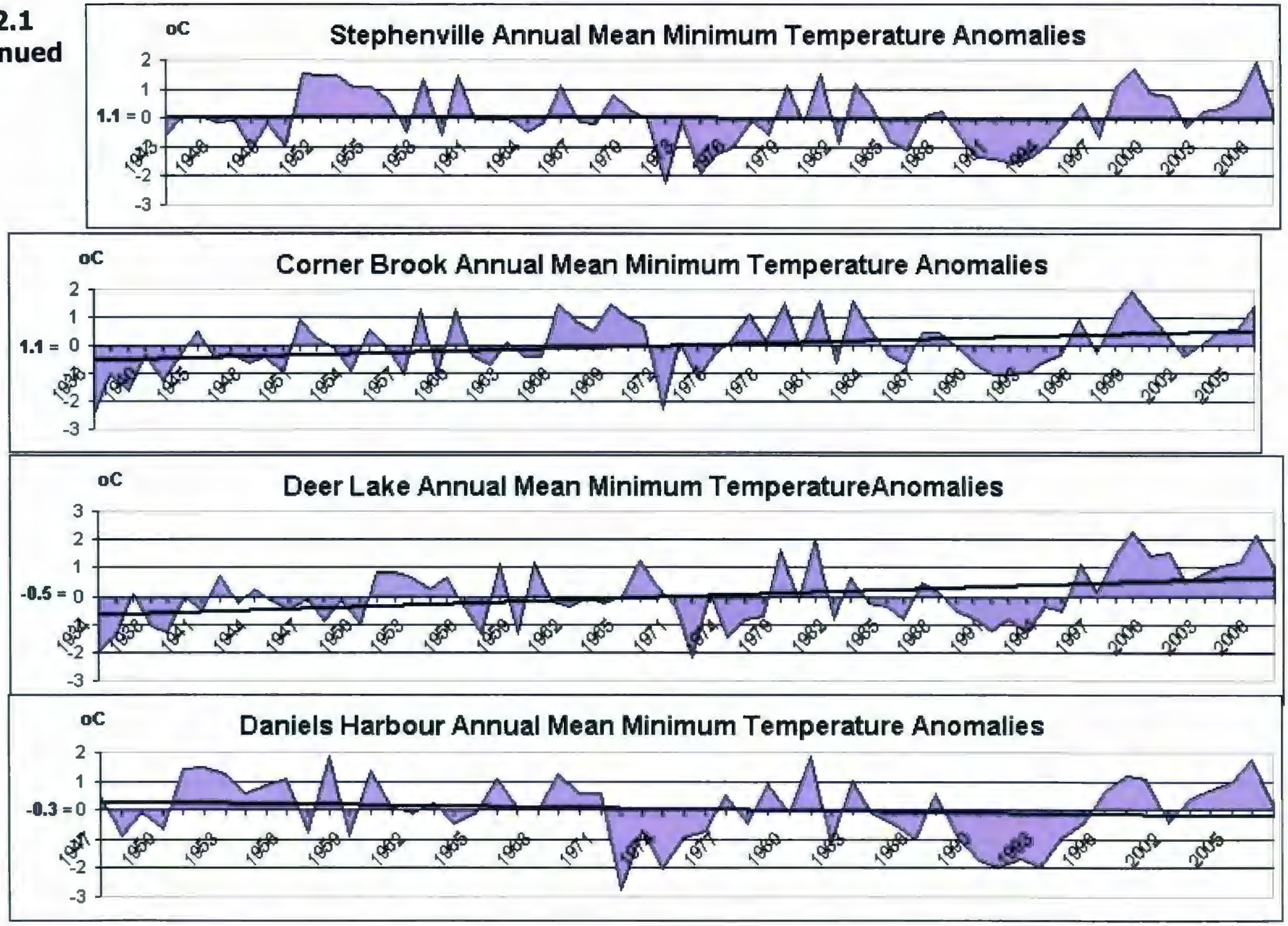


Figure A2.1 Annual Mean Maximum Minimum Temperature

Fig A2.1 Continued



Appendix 3: Seasonal Variability of Mean Maximum and Minimum Temperatures

A3.1 Winter Season

A3.1.1 Winter Mean Maximum Temperatures between 1934 and 2007 are summarized in Figure A3.1. Eight periods can be distinguished:

1. 1934 – 1950 alternations of cold and warm years interrupted by normal periods

2. 1951-1956 warm

3. 1957-1967 alternations of cold and warm periods. More variations from the n mid-1950s to the early 1960s

4. 1968-1970 warm

5. 1971-1975 cold

6. 1976-1987 close to normal with 1981 warm for all locations; 1977, 1978 and 1983 warm for Corner Brook and 1983 warm for Deer Lake.

7. 1988-1995 cold

8. 1996-2007 warm; with 1997 cold for Daniel's Harbour and some close to Normal periods.

For the period 1934-2007 winter daily temperatures recorded two periods of warming (1951-1956 and 1996-2000), and a period of cooling (1989-1995). Overall, more variability of cold and warm years is evident, interrupted by a short period of close to normal temperature (Table A3.1).

Seasonal Parameter	*1933-1967**	*1968-1977*	*1978-1987*	*1988-1997*	*1998-2007*
Winter mean maximum	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally cool	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

Winter	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-2.9	1957	3.9	1958	-1.4	-0.5*	negative
CB	-4.7	1934	3.7	1958	-1.7	0.1	Flat+
DL	-3.4	1957	3.5	1951	-2.3	0.3	positive
DH	-3.8	1957	4.1	1958	-2.7	-0.4	negative

*significant

Table A3.1 Mean Maximum Winter Temperature

The coldest departure from normal was recorded at Corner Brook in 1934 (-4.7°C). For the other three stations, 1957 is the coldest year. The warmest departure occurred at Daniel's Harbour in 1958 (4.1°C). 1958 was also the warmest year for Stephenville (3.9°C) and Corner Brook (3.7°C). For Deer Lake (3.5°C), the warmest year was 1951.

There is no evidence of substantial changes in winter maximum temperature for the western Newfoundland weather stations analysed. The trends show decreases of approximately 0.5°C for Stephenville and Daniel's Harbour and insignificant increases for Corner Brook and Deer Lake.

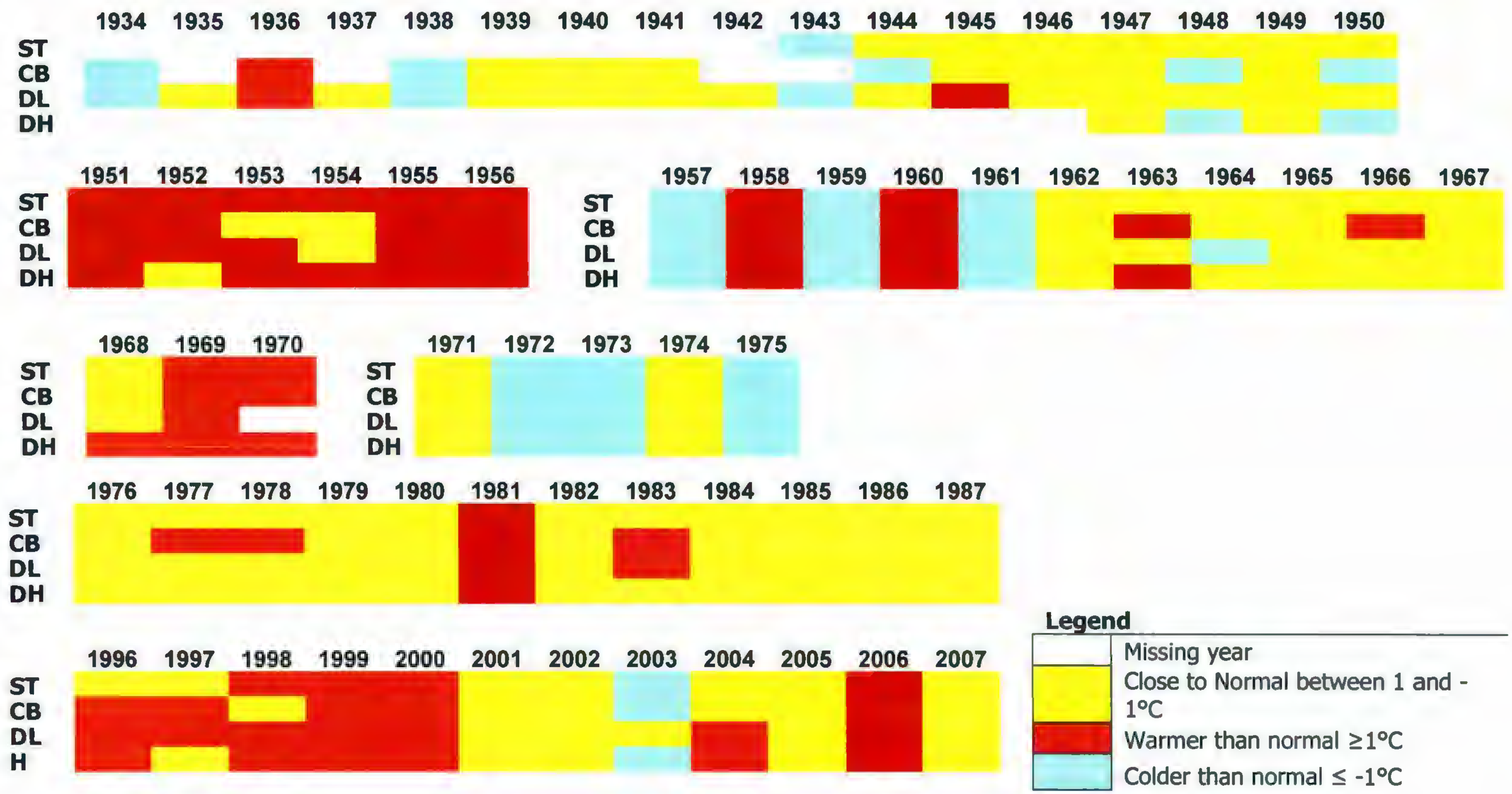


Figure A3.1 Winter Daytime Maximum Temperature Variability

A3.1.2. Winter Mean Minimum temperature between 1934 and 2007 are summarized in Figure A3.2 and Table A3.2. Nine periods can be distinguished:

1. 1934-1943 period dominated by **cold** with some warm years in the early 1940s

2. 1944-1950 close to normal with cold at the end of the 1940s

3. 1951-1956 warm

4. 1957-1962 alternating warm and cold

5. 1963-1970 warm

6. 1971-1977 cold

7. 1978-1988 warm with close to normal between 1984 and 1988

8. 1989 – 1995 cold

9. 1996 -2007 dominated by warm

Two cold periods, 1934-1939 and 1971-1977, are not matched by colder periods of winter daytime highs. The 1989-1995 cold period does correspond to a daytime winter cold period.

The warm periods 1951-1956 and 1998-2000 have corresponding warm periods for daytime winter maxima. The periods 1966-1970 and 2004-2007 do not correspond to warmer daytime maxima.

Seasonal Parameter	*1933-1967**	*1968-1977*	*1978-1987*	*1988-1997*	*1998-2007*
Winter mean minimum	variable	variable	Generally warm	Generally cool	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*
*** Stephenville and* Daniel's *Harbour Negative; Corner Brook and Deer Lake positive*

Winter	Coldest	year	Warmest	year	Normal	Linear	Trend
ST	-4.4	1993	5.4	1958	-8.3	-1*	negative
CB	-6.7	1934	5	1958	-8.6	1.4*	positive
DL	-6.4	1934	5.2	1958	-10.5	1.7*	positive
DH	-5.2	1990	5.1	1958	-10.3	-0.9*	negative
*Significant							

Table A3.2 Mean Minimum Winter Temperature

Winter night time trends record significant decreases for Stephenville and Daniel's Harbour and increases of over 1°C for Corner Brook and Deer Lake. All four locations recorded more than 20 warm years since 1950.

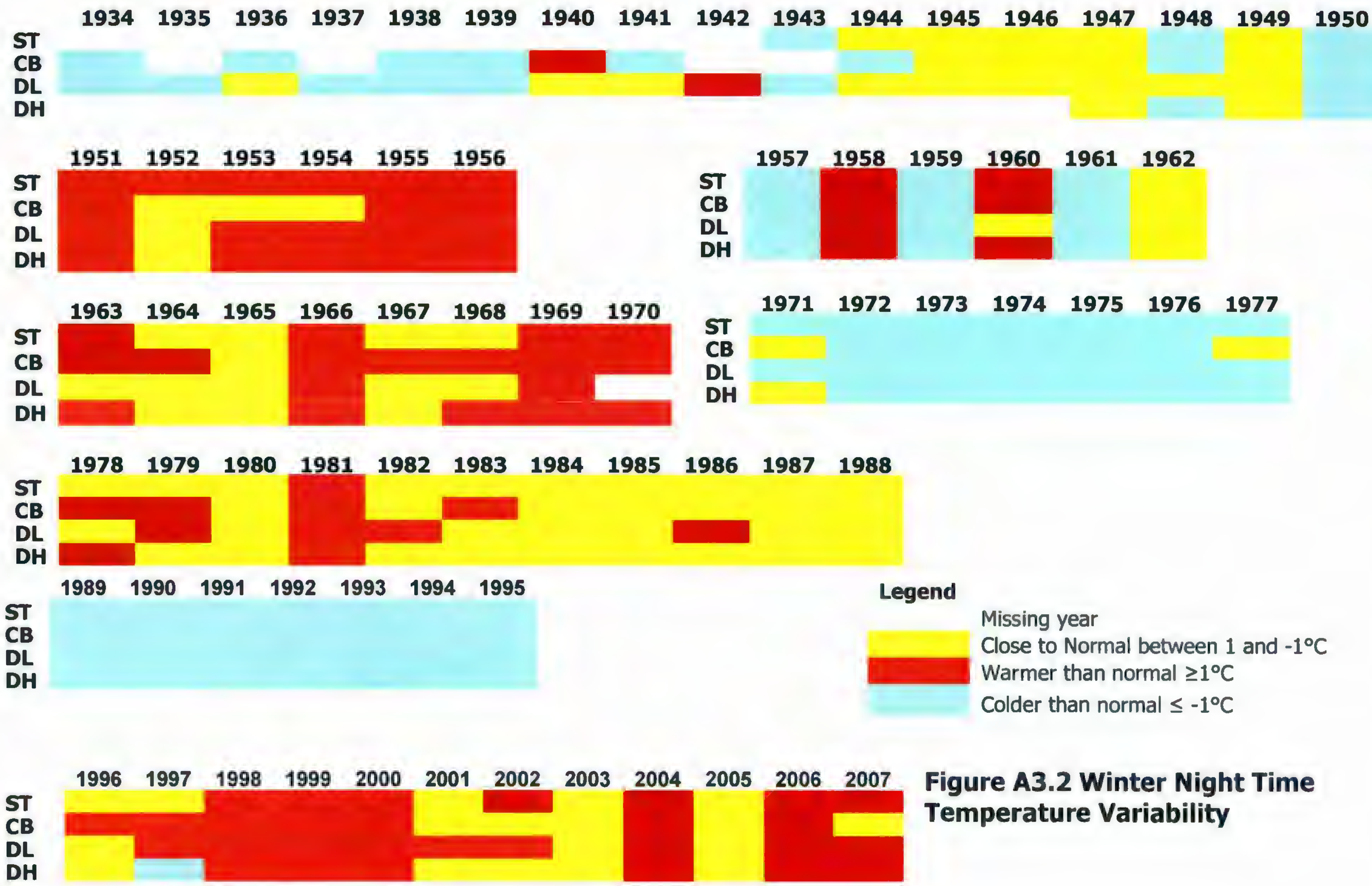


Figure A3.2 Winter Night Time Temperature Variability

A3.2 Spring Season

A3.2.1. Spring Mean Maximum Temperatures between 1934 and 2007 are summarized in Figure A3.3 and Table A3.3. Five periods can be distinguished:

1. 1933-1950 varying cold, warm and normal years, interrupted by years with missing data.

2. 1951-1953 warm for all locations

3. 1954-1965 cold, except 1958 warm for all locations

4. 1966 – 1995 varying warm, cold and close to normal, except 1990 and 1992 as cold years for all locations and a warm period 1986-1989.

5. 1996 -2007 varying

Seasonal Parameter	***1933-1967****	***1968-1977***	***1978-1987***	***1988-1997***	***1998-2007***
Spring mean maximum	Generally cool to normal	variable	variable	variable	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

Spring	**Coldest**	**Year**	**Warmest**	**Year**	**Normal**	**Linear**	**Trend**
ST	-2.3	1974	3.1	1983	5.9	0.9*	positive
CB	-2.6	1974	3.1	1979	6.3	0.7*	positive
DL	-2.9	1974	3.5	1999	6.3	1*	positive
DH	-2.5	2006	2.9	1951	3.9	0.8*	positive
*Significant							

Table A3.3 Mean Maximum Spring Temperature

The trends of change for daytime temperature are significantly positive for all locations. Spring mean maximum temperature variations are frequent and sharp. There are few consistent periods of warm or cold.

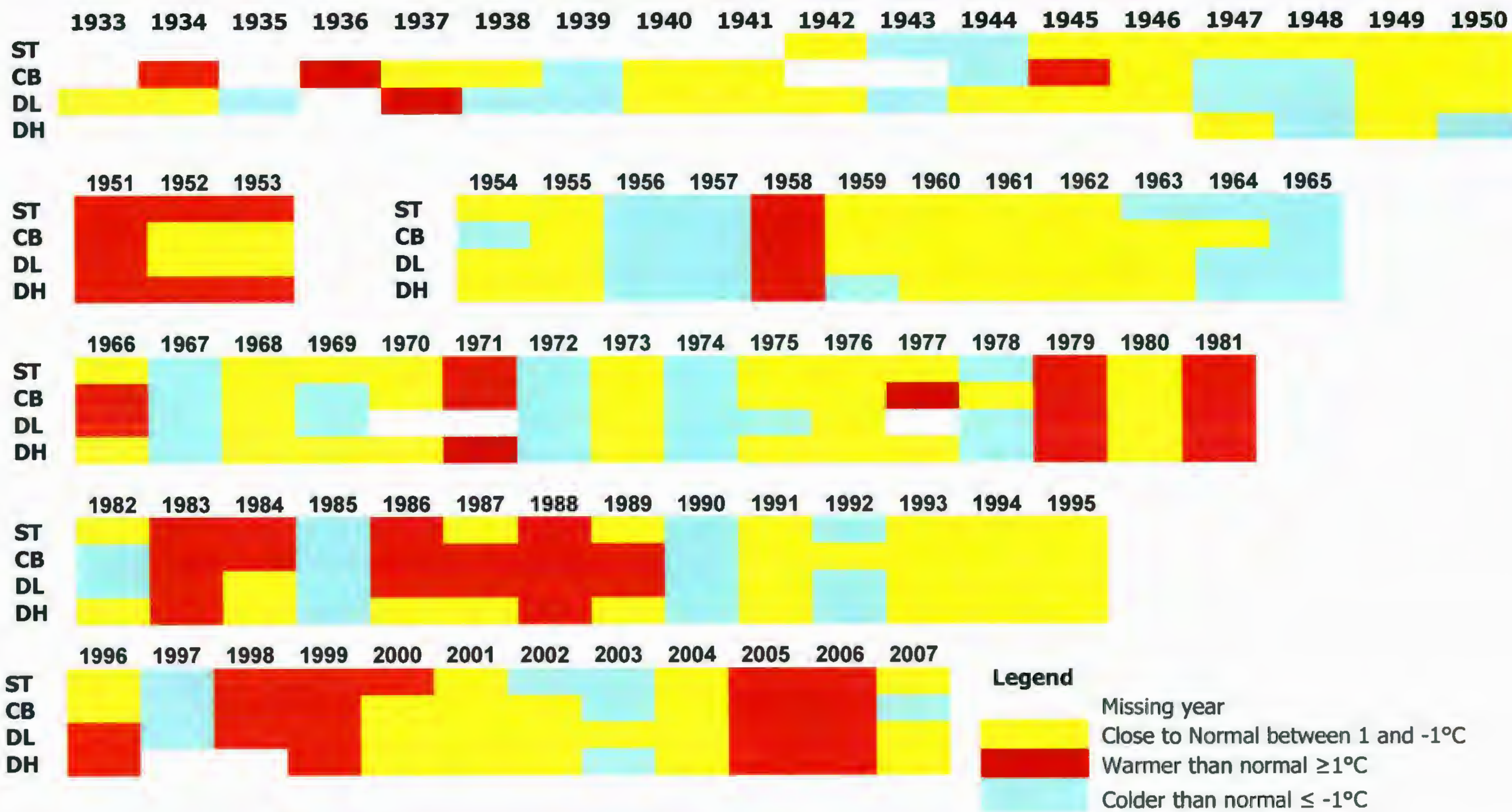


Figure A3.3 Spring Daytime Temperature Variability

A3.2.2. Spring Mean Minimum Temperatures between 1934 and 2007 are summarized in Figure A3.4 and Table A3.4. Seven periods can be distinguished:

1. 1933-1947 cold

2. 1948-1953 warm dominated

3. 1954-1971 varying cold and warm

4. 1972-1978 cold dominated, except warm 1977 for Deer Lake.

5. 1979-1988 warm dominated, except cold 1982 and 1985 for all locations

6. 1989-1995 cold dominated period

7. 1996-2007 warm with three cold years for all locations: 1997, 2003 and 2007

Seasonal Parameter	*1933-1967**	*1968-1977*	*1978-1987*	*1988-1997*	*1998-2007*
Spring mean minimum	Generally cool	Generally cool	Generally warm	Generally cool	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

Spring	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-2.9	1967	3	1999	-2	-0.1	flat-
CB	-3.5	1939	3	1999	-1.9	1*	positive
DL	-3.2	1967	3.5	1979	-3.5	1.3*	positive
DH	-3.8	1972	3.1	1971	-3.3	-0.4	negative
*Significant							

Table A3.4 Mean Minimum Spring Temperature

There is very little change in spring night-time temperature at Stephenville and Daniels Harbour. Corner Brook and Deer Lake record increases of more than 1°C.

Night-time spring temperatures are more variable than day-time spring temperature.

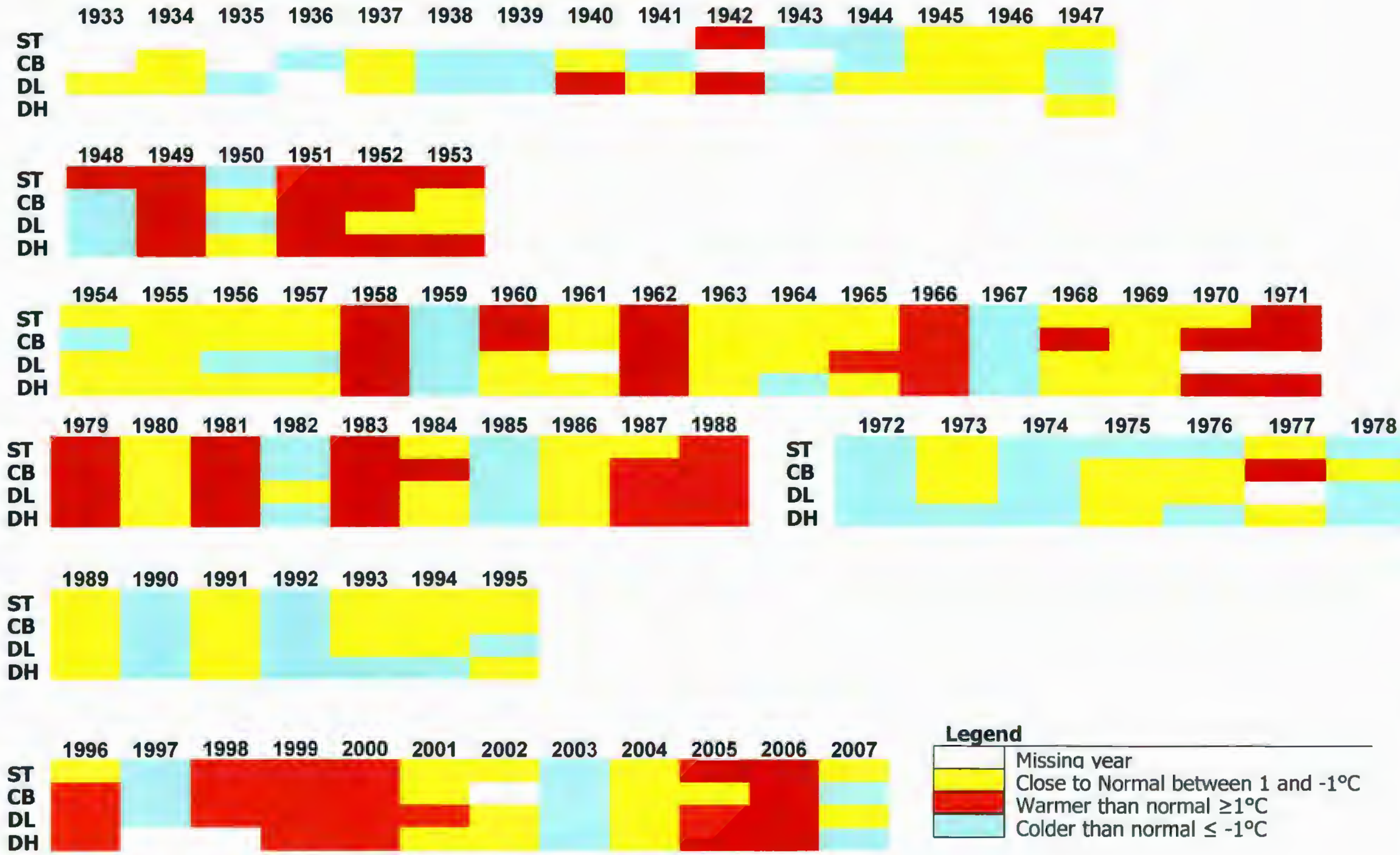


Figure A3.4 Spring Night Time Temperature Variability

A3.3 Summer Season

A3.3.1. Summer Mean Maximum Temperatures between 1934 and 2007 are summarized in Figure A3.5 and Table A3.5. Five periods can be distinguished:

1. 1933 – 1940 warm dominated

2. 1941-1955 close to Normal, with some variation and a warm year 1952 for all locations

3. 1956-1966 cold dominated

4. 1967-1998 close to normal, with variations.

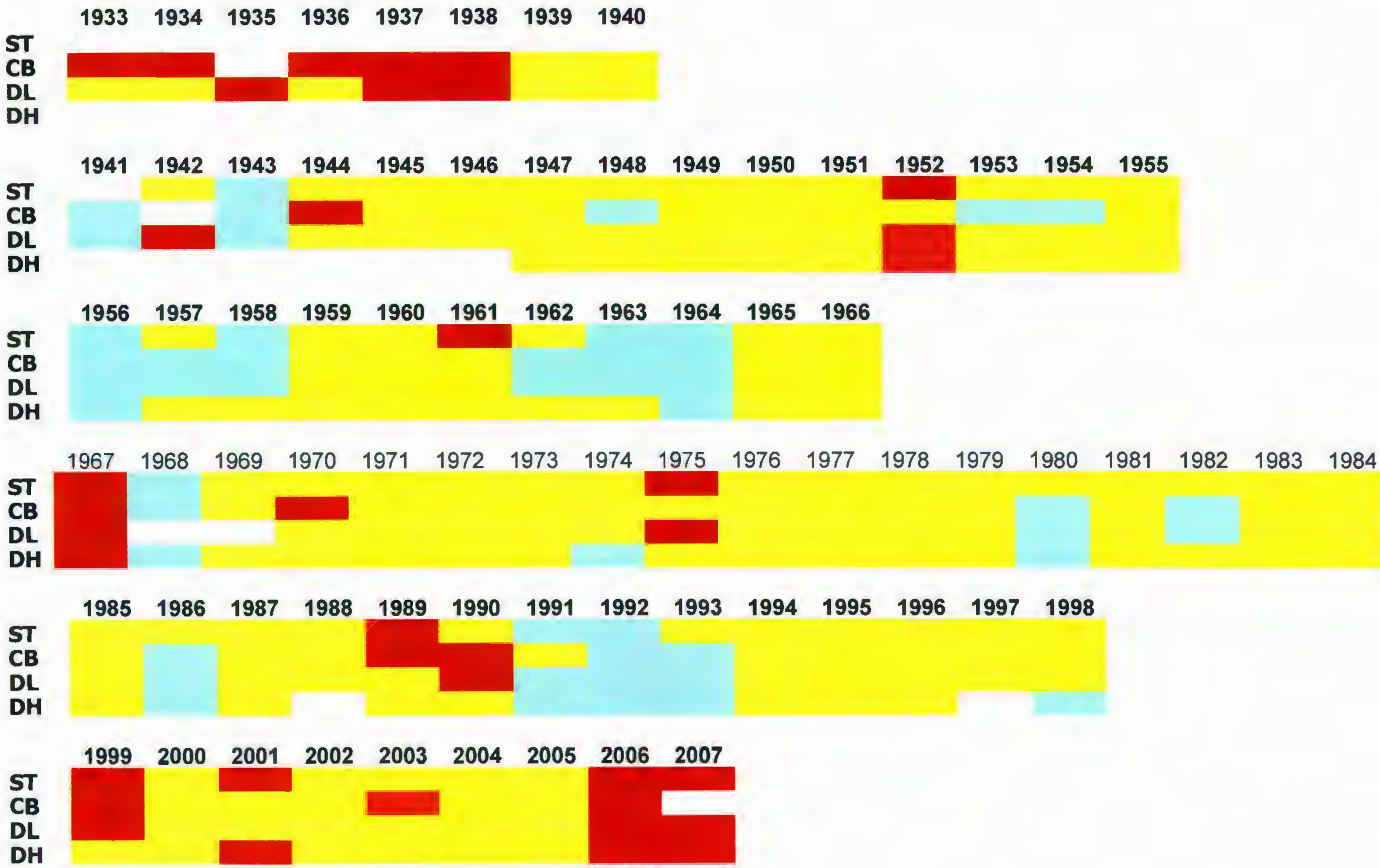
5. 1999-2007 generally warm

Seasonal Parameter	***1933-1967****	***1968-1977***	***1978-1987***	***1988-1997***	***1998-2007***
Summer mean maximum	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

Summer	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-2.1	1964	1.7	2006	18.7	1 *	positive
CB	-2.7	1954	4.5	1936	20.5	0.1	flat
DL	-2.8	1963	1.9	1937	20.6	0.1	positive
DH	-1.8	1991	2	2006	16.3	1*	positive
*significant							

Table A3.5 Mean Maximum Summer Temperature


1933 1934 1935 1936 1937 1938 1939 1940
ST
CB
DL
DH
1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955
ST
CB
DL
DH
1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966
ST
CB
DL
DH
1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984
ST
CB
DL
DH
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
ST
CB
DL
DH
1999 2000 2001 2002 2003 2004 2005 2006 2007
ST
CB
DL
DH

Legend

	Missing year
(yellow)	Close to Normal between 1 and -1°C
(red)	Warmer than normal ≥1°C
(light blue)	Colder than normal ≤ -1°C

Figure A3.5 Summer Daytime Temperature Variability

The linear trends of changes show no significant change for Deer Lake and Corner Brook and significant increases for Stephenville and Daniel's Harbour.

A3.3.2. Summer Mean Maximum Temperatures between 1934 and 2007 are summarized in Figure A3.6 and Table A3.6. Five periods can be distinguished:

1. 1933-1943 cold period with 9 years missing data for Stephenville and 11 years missing data for Daniel's Harbour

2. 1944-1950 close to normal period

3. 1951-1954 warm dominated period

4. 1955 1998 alternations of short warm, cold periods, and longer close to normal period, subdivided into shorter periods: 1955- 1972; 1973-1985; 1986-1998. This period includes cold years 1956-1957, 1962-1964, 1974 and 1991-1993 and warm years 1967, 1983-1984 and 1989.

5. 1999 -2007 warm

Seasonal Parameter	*1933-1967**	*1968-1977*	*1978-1987*	*1988-1997*	*1998-2007*
Summer mean minimum	Generally cool	Variable	Variable	Variable	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

Summer	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-2.1	1968	2.1	2006	10.7	0.6	positive
CB	-3.7	1934	2.3	1967	10.8	1.8*	positive
DL	-2.2	1956	2.5	1967	9.4	1.1*	positive
DH	-2.4	1993	1.8	1967	9.6	0.1	flat +
*Significant							

Table A3.6 Mean Minimum Summer Temperature

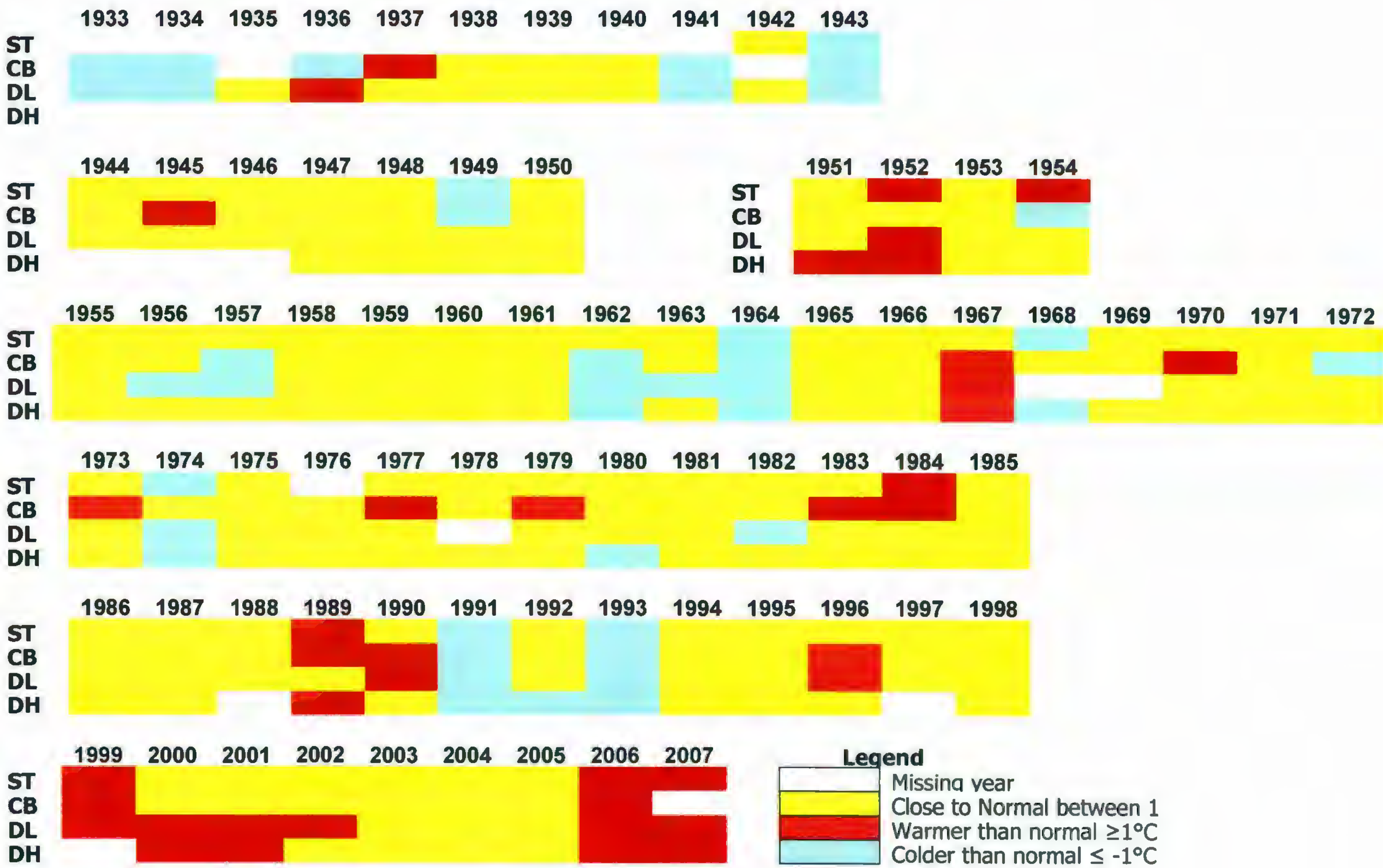


Figure A3.6 Summer Night Time Temperature Variability

There is clear evidence of change in term of increasing night time summer temperature for Corner Brook with high 1.8^{O}C and Deer Lake (approximately 1 ^{o}C) and a smaller increase for Stephenville.

A3.4 Autumn season

A3.4.1. Autumn Mean Maximum Temperatures between 1934 and 2007 are summarized in Figure A3.7 and Table A3.7. Five periods can be distinguished:

1. 1933 – 1946 warm

2. 1947-1960 close to Normal

3. 1961-1967 variations

4. 1968-2000 close to Normal (1968-1986; 1987-2000) interrupted by cold years: 1972, 1978, 1980 (Stephenville and Corner Brook), 1984 (Deer lake, Daniel's Harbour) and 1985 and 1986

5. 2001 – 2007 warm

The linear trend of daytime temperature (Table A3.7) shows insignificant changes for Corner Brook, Stephenville, and Deer Lake and a significant increase for Daniel's Harbour of 0.5°C.

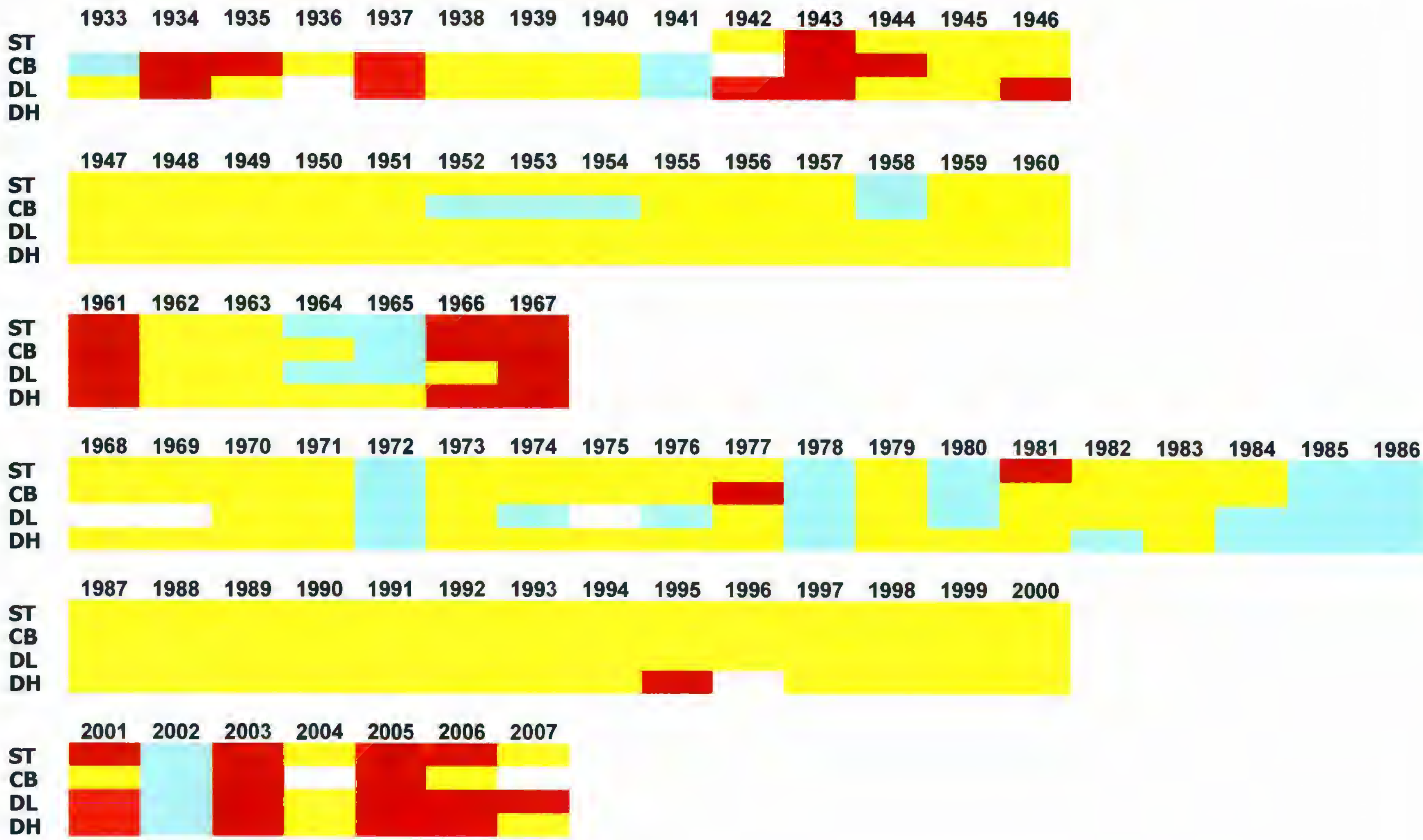
Seasonal Parameter	*1933-1967**	*1968-1977*	*1978-1987*	*1988-1997*	*1998-2007*
Autumn mean maximum	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

** Stephenville and Daniel's Harbour positive and Corner Brook and Deer Lake negative

Autumn	Coldest	year	Warmest	year	Normal	Linear trend	
ST	-2.2	1986	2.7	2003	10.8	0.1	positive
CB	-2.5	1972	3	1934	11	-0.2	negative
DL	-2.3	1986	2.6	2003	10.8	-0.3	negative
DH	-2.7	1986	2.9	2003	9.3	0.5*	positive
*Significant							

Table A3.7 Mean Maximum Autumn Temperature


1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946
ST
CB
DL
DH
1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960
ST
CB
DL
DH
1961 1962 1963 1964 1965 1966 1967
ST
CB
DL
DH
1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
ST
CB
DL
DH
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
ST
CB
DL
DH
2001 2002 2003 2004 2005 2006 2007
ST
CB
DL
DH

Legend

Missing year

Close to Normal between 1 and -1°C

Warmer than normal ≥1°C

Colder than normal ≤ -1°C

Figure A3.7 Autumn Daytime Temperature Variability

A3.4.2. Autumn Mean Minimum Temperatures between 1934 and 2007 are summarized in Figure A3.8 and Table A3.8. Five periods can be distinguished:

1. 1933-1942 cold

2. 1943-1971 close to Normal with warm years 1943, 1944, 1961, 1967 and cold 1965

3.1972-1986 close to Normal with cold years 1972, 1973 and 1974 (ST), 1978, 1986, 1982 (DL and DH)

4. 1987- 1999 close to Normal

5. 2000 -2007 warm

Seasonal Parameter	*1933-1967**	*1968-1977*	*1978-1987*	*1988-1997*	*1998-2007*
Autumn mean minimum	Generally normal to cool	Generally normal conditions	Generally normal conditions	Generally normal conditions	Generally warm

**No data for Stephenville prior to 1942; no data for Daniel's Harbour prior to 1947.*

Location	Coldest	Year	Warmest	Year	Normal	Linear	Trend
ST	-2.3	1959	2	1961	4.1	-0.0	Flat-
CB	-5	1935	2.2	1967	3.8	1.6*	positive
DL	-2.3	1978	2.6	2003	2.6	1.3*	positive
DH	-2.9	1986	2.5	2003	3.1	0.1	Flat+

Table A3.8 Mean Minimum Autumn Temperature


1933 1934 1935 1936 1937 1938 1939 1940 1941 1942
1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956
1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
2000 2001 2002 2003 2004 2005 2006 2007
ST
CB
DL
DH

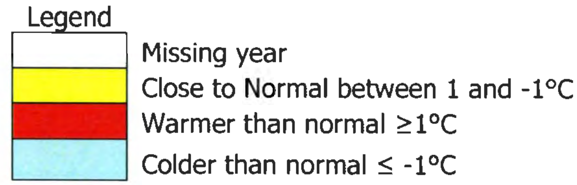


Figure A3.8 Autumn Night-Time Temperature Variability of Cold and Warm Years

The changes are positive at Corner Brook and Deer Lake, which recorded an increase of approximately 1.5°C over the entire records. For Stephenville and Daniel's Harbour, the corresponding records do not show any change in mean minimum autumn temperature.