The Cairngorm Climate, 1964-2006, and its impact on local tourism

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Jamie R.C. Munro

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‘I hereby declare that this dissertation has been composed by me and is based on my own work’

Signature: ________________________________

Abstract

Climate change is impacting the world in many different ways, particularly the winter tourism sector. The futures of ski centres, in Scotland and abroad, are becoming increasingly uncertain. This dissertation focuses on the climate of Scotland's largest ski centre – Cairngorm. An analysis of the Cairngorm climate is undertaken between the years of 1964-2006, with the mean temperature, snowfall, snow cover and snow depth constituting the main variables investigated at the seasonal, annual and decadal scales. Complementary data analysis is providing by wind speed/direction, North Atlantic Oscillation (NAO) winter values and ski run data. Textual exogenesis and interviews of key personnel provide further information on the history of skiing at Cairngorm Mountain and the impacts that the changing climate has had on business and tourism within the area. Results confirm that there has been a decrease in snow cover and depth with an increase in temperature in all seasons. However, snowfall has stayed relatively consistent and it is concluded that the higher temperatures have contributed to the decreased snow cover, thus decreasing skiing opportunities. The climate is seen as to act as a catalyst for change, both for businesses and tourism, and this has led to Cairngorm Mountain diversifying and the redevelopment of its nearest town, Aviemore.

Acknowledgements

Firstly, I would like to acknowledge Prof Charles Withers for his invaluable guidance during the undertaking of this dissertation. I would also like to thank the Edinburgh Meteorological Office for allowing me to work in their Saughton office in May 2007 and also for their guidance on my climatic queries. I wish to thank Cairngorm Mountain Ranger John McMorran for allowing me access to the Cairngorm Ranger Diaries. I also would like to thank the following for taking time out of their work schedule so that I could interview them:

Bob Kinnaird, Chief Executive of Cairngorm Mountain

Jonathan Gatenby, Chairman of Aviemore Business Association

Heather Galbraith, Sustainability Officer, Cairngorms National Park

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Introduction

Commercial skiing at Cairngorm first arrived in 1961 and since then Cairngorm has become the biggest ski centre in the UK. However, skiing in Scotland is frequently cited as the recreational activity which will suffer most from climate change. The snow season has shortened across the country since 1961, with the season starting later and finishing earlier in the year and this has been attributed to an increase in temperature (Barnett *et al*, 2006; Scherrer *et al*, 2004). In the future it is expected that warming will further reduce the number of days with snow lying and hence the viability of the skiing industry. Consequently, many ski resorts are now looking to diversify in order to remain financially sustainable, with Holden (2000) suggesting that the linking of the physical environment with suitable market attitudes could be vital to sustaining an environmental and economic future.

Tourism is an industry that is forecasted to grow by 50% over the next ten years (Yeoman & McMahon-Beattie, 2006), but with the growing influence of climate, tourism development needs to be assessed not only on social and environmental terms but also by their climate-compatibility angle (Elsasser & Bürki, 2002) . This is particularly true in areas where tourism is taking place in ecologically fragile environments, with the only artic-alpine environment in the UK being found on Cairngorm above 800m (Holden, 1998). Although the contribution from skiing to the UK economy is small, it has considerable significance and influence on the local economy of Aviemore. This is due to Cairngorm's close proximity to Aviemore and its situation within the heart of the Cairngorms National Park.

The aim of this dissertation is to understand the snow climate of Cairngorm Mountain and the impact of snow cover changes on skiing opportunities and tourism within the Cairngorm and Aviemore area. This dissertation uses both quantitative and qualitative data in order to achieve this aim. Quantitative climate data is used to determine various snow trends, along with subsidiary variables such as temperature and wind speed/direction over a forty-two year period. This provided the basis in which to test the common perception that there has been a decline in skiing opportunities on Cairngorm over the years. This is then supplemented with textual evidence in order to understand the skiing opportunities on Cairngorm over the years. The impact that the decline in skiing opportunities has had on tourism is then explored through interviews with key personal in the area. By exploring each form of evidence and examining the relationship between them, and understanding of the climate impact on businesses and tourism in the Cairngorm and Aviemore area can be achieved.

Few studies have been undertaken whereby the potential effects of climate change on mountain snow cover are investigated at the local scale (Trivedi *et al*, 2007). As Scotland exhibits regional climatic differences, it is important to investigate and understand the changes at a local scale; the results relevant for possible future planning of Cairngorm skiing and winter tourism in the area.

This dissertation refers to the 'snow climate', the term used by Laternser & Schneebeli (2006), which applies to snow depth, cover and fall. Other climatic variables such as temperature and wind speed/direction have been investigated but this is because they impact upon the snow climate, with Beniston (1997) acknowledging that snow is not solely dependant on temperature. Reference to

‘Cairngorm’ will be to the Cairngorm Ski Area and not the whole of the Cairngorm Mountains.

This dissertation will begin with a literature review, encompassing recent findings of the climatic influence on snow cover and the impact that this has had on ski destinations. The methods and research design is then discussed in the third chapter, along with the study location. The climatic data is investigated in the fourth chapter at the seasonal, annual and decadal scale in order to assess the trends at different time scales and account for a better understanding of any changes taking place. Chapter five includes the textual analysis and the results from the interviews, in which an understanding for the tourism and business changes taking place on Cairngorm and in Aviemore is approached. Chapter six provides the conclusion, in which the main findings, limitations and relevance of work are discussed. A summary of the main findings is provided at the end of each chapter.

2

Climate Change and Snow: A Summary of Recent Work

2.1 Climate Influences

The Earth's changing climate has always had an influence on the physical and social environment. Numerous investigations on the causes of climate change and the associated impacts have been undertaken, with the latest IPCC (Intergovernmental Panel on Climate Change) report providing the most recent climate forecasts. The causes of climate change have been attributed to both natural and anthropogenic influences. Natural influences arise from changes in the Earth's geography, cyclical variations in the Earth's orbit, solar variability and volcanic eruptions (Lamb, 1988; Lean *et al*, 1995; Crowley, 2000). The anthropogenic influences are largely attributed to the burning of fossil fuels and land use change. These have contributed to an increase in greenhouse gases (particularly carbon dioxide and methane) and the overall global warming since the mid nineteenth century (IPCC, 2007).

Within work on climate change are studies which assess the climate change impact on winter tourism and snow cover. The winter tourism sector, more specifically the skiing industry, relies heavily on a reliable snow cover and stands, therefore, to be greatly affected by climate change. In order to understand these issues as they relate to the Cairngorms, I here review other work on this issue.

2.2 Temperature effect on snow cover

The IPCC (2007) obtained satellite snow cover data for the northern hemisphere over the period of 1966-2005 from which it is concluded that there has been an annual snow cover reduction in every month except November and December. This has been related to an increase in temperature, with the mountains at lower elevations suffering more snow cover reduction from this temperature increase than those at higher elevations. The IPCC (2007) also identifies temperature as having a significant role in the variability and trends of the northern hemisphere snow cover area, as it determines the type of precipitation falling and the rate of snow melt. Temperature appears to be the key control on determining the snow cover and duration. Harrison *et al* (2001) found that for every 1°C increase in mean temperature there is a nine day reduction in the number of snow-lying days in Scotland. With the increasing temperature trends it appears that snow cover will continue to be reduced, particularly at lower elevation sites.

2.3 The Alpine Situation

Work undertaken in the Swiss Alps has assessed snow cover trends and the impacts of these trends on ski industries. Winter tourism is the most important source of income for Swiss alpine areas, with the industry providing regional economic growth for rural areas (Koening & Abegg, 1997). Snow trends analysis from 1931-1999 undertaken by Laternser & Schneobeli (2003) revealed a large spatial and temporal variability with a north/south divide apparent in conditions experienced. Such altitudinal variations in snow cover apparent in Switzerland are consistent with the IPCC (2007) findings, whereby at lower altitudes the snow deficiency since the 1980s become more notable. Beniston (1997) investigated the variations of snow depth and duration in the Swiss Alps over the last fifty years and concluded that large scale forcings, such as the North Atlantic Oscillation (NAO), have a long term dominant control on snow abundance in the Alps. He recognised that local factors, such as site characteristics, determined snow cover differences but that the overall timing and accumulation of the snow depth was governed by larger scale forcings. The current positive NAO winter index has resulted in warmer, wetter winters in western Europe and therefore created regional differences of snow cover and duration for different parts of Europe (Bednorz, 2004; Trivedi *et al*, 2007).

The Petkova *et al* (2004) study of snow cover variation in Bulgaria from 1931-2000 found that the widespread warming and reduction in winter precipitation resulted in decreased snow depth and duration at some sites but little change, and even increased snow depth and cover at others. They concluded that further understanding is required about the local and altitudinal response of snow cover to large scale climate change such as the NAO. Climate modelling of temperature against snow cover was undertaken for the Austrian Alps by Hantel *et al* (2000), with results suggesting that a rise in European temperature by 1K might reduce snow season by up to four weeks in winter and six weeks in spring.

2.4 Regional Differences

Such work highlights the problem the ski industries are facing, with a reduction in ski season and limited snow cover at the lower elevations resulting in financial and viability difficulties. Brown (2000) collected snow cover data from Canada, USA and the former Soviet Union for the period of 1915-1997 and found that the average winter snow depth over these northern hemisphere mid-latitude regions increased in accordance with increases in winter precipitation. This contrasts with work from Europe which suggests there to have been a decline in snow cover and depth. Such variation in view reflects the importance of regional climatic influences and the inherent danger in generalising climatic results to a larger scale. However, Brown (2000) also argues that North American spring snow cover has decreased rapidly since the 1980s. This result highlights the importance of investigating in different places and at different seasons to obtain more complete understanding of snow cover variations.

2.5 Scottish snow cover

Conditions in Scotland with regard to snow cover variability differ from those of continental Europe. Scotland experiences a predominant westerly airflow regime, with the advection of heat and moisture from the Atlantic Ocean exerting a strong influence on the climate experienced (Harrison, 1997). In comparing the milder, westerly influenced winter of 1988/89 with the continental easterly-type winter of 1985/86, Harrison (1997) found that a 65% decrease in snow-lying days in the 1988/89 winter in eastern Scotland. This study stressed the importance of airflow direction for the Scottish ski industries, with a shift towards a persistent westerly air regime for Scottish winters accounting for a general decrease in accumulation and persistence of snow cover (Harrison, 1993). A similar trend in reduction in snow-lying days and a higher snowline is apparent in Scotland given this shift to a warmer climate. For Harrison (1993), the sensitivity of Scottish snowfall and snow cover duration was attributed to the Scottish mid-latitude maritime climate, with annual fluctuations in snowfall a result of atmospheric conditions. Trivedi *et al* (2007) use of an empirical snow-climate model to investigate the data under various future climate scenarios concluded that snow cover will be lost at all elevations in the U.K, under all possible scenarios.

Snow cover in Scotland is not only important for the skiing industries but also with respect to its effect in hydrological systems. Soulsby *et al* (1997) identified the snow cover on the Cairngorm Mountains as being an important factor in water management, with melting snow contributing to major flood events and significantly influencing the chemical and ecological characteristics of streams. Interannual variation in snow cover is primarily controlled by temperature. Yet, Watson *et al* (2002) found that the total number of snow patches remaining throughout the year on the Cairngorm did not show the decline in number expected from a warmer Scottish climate at low altitudes. They found no evident increasing or decreasing trend. However, snow patches do not represent the more widespread cover with which other studies have worked. For snow patches, local conditions (exposure, relief, and aspect) are more of an influence for their survival than the general warming climate.

<u>2.6 Ski Industry Future</u>

A study by Harrison *et al* (1999) on the potential effects of climate change on the Scottish tourist industry concluded that low-lying areas will experience more frequent snow-free winter months due to the winter climate shift to a more westerly maritime character. Their work also concluded that changes in snow cover above 1000m would be small and relatively less significant due to the cooling effects of elevation in providing conditions for snowfall. The Cairngorm ski centre was developed when there was a trend towards colder winters and springs (Harrison *et al*, 1999), but it is now recognised that the future viability of skiing on the Cairngorms, particularly at lower elevations, is threatened by the shift to a warmer climate.

The fact that the climate is always changing is evident through interannual variability, with sporadic low-snow winters apparent throughout the centuries (Laternser & Schneobeli, 2003). What has changed, however, is that low-snow winters have never appeared in succession. The sequence of eleven low-snow winters in the Swiss Alps drew attention and awareness towards the impact that climate change is having on snow cover and winter tourism. These effects are now more relevant than in the past due to the fact that more investment and employment (capital intensity) is now attached, directly or indirectly, to the presence of sufficient snow cover. The consequence of the resultant increase in snowline elevation is the higher elevation resorts benefiting from the reduction in snow, and therefore snowsport opportunities, at lower elevation resorts (Elsasser & Messerli, 2001; Elsasser & Bürki, 2002; Abegg & Froesch, 1994).

2.7 Snow Cover Impact on Winter Tourism

Adaptive strategies are therefore essential in order to remain financially viable. Ski centres around the world can no longer rely on a good snow season every year and so diversification into other markets is required to adapt to the changing conditions. Harrison *et al* (2001) acknowledges the move towards diversification into other activities less reliant upon snow cover and based on wider mountain experiences, and this is mirrored by successful diversification into the cultural sector - theatre and music festivals – in the Swiss Alpine resorts of Arosa and Gstaad (Koenig & Abegg, 1997). In this sense, "climate change has to be viewed as a catalyst that will reinforce and accelerate the pace of structural change in the tourist industry and more clearly highlight the risks and opportunities inherent in tourist development" (Elsasser & Bürki, 2002, 255).

2.8 Chapter Summary

Extant work in assessing the future of snow cover and ski centres agrees that a warmer climate will reduce the reliability of snow cover, particularly at lower elevations. This in turn suggests that ski resorts at lower elevations will struggle to remain operational and that the higher altitude ski resorts will benefit from an increase in business due to customers preferring snow reliable resorts. Yet it is also evident that regional variations in conditions exist and such variation has been attributed to large-scale forcings, such as the North Atlantic Oscillation in Europe. Even though appropriate temperature and precipitation is required for snow to fall and remain on the surface, temperature becomes the controlling factor once the snow is present Beniston (1997). Precipitation further complicates the relationship between temperature and snow cover. As Brown (2000) notes, a small increase in precipitation levels could offset the warming of mid-latitude continental locations. However, skiing in Scotland has always been marginal and the projected rise in temperatures, 0.2°C/decade (IPCC, 2007), could signify the end of snowsport opportunities in Scotland and other low elevation resorts worldwide. Consequently, ski resorts are diversifying into new business sectors in order to remain viable.

Considering these findings, this dissertation aims to understand the snow climate of Cairngorm Mountain and the impact of snow cover changes on skiing opportunities and tourism within the Cairngorm and Aviemore area.

I will now turn to the methods used in undertaking this dissertation aim.

3

Methods and Research Design

3.1 Methods

In order to understand the climate of the Cairngorm Mountains and its impact on skiing and tourism in the area, both quantitative and qualitative data was gathered. Methods undertaken in researching the climate of the Cairngorms involve analysing data collected from the Meteorological Office, collecting Cairngorm ski run data in order to analyse skiing opportunity trends at different elevations, investigating textual accounts and using interviews to understand the impacts that the current climate trend has had on tourism at Cairngorm and in Aviemore. In doing so, the common perception that there has been an increase in temperatures and a consequential decrease in snow cover duration can be tested.

3.2 Data Sources & Rationale

3.2.1 Climate Data

Firstly, quantitative data was collected from the Meteorological Office in undertaking the analysis of the Cairngorm snow climate. The mean temperature, snow falling days, snow depth and snow lying days were recorded as these were deemed sufficient for understanding the snow climate of this area, with daily readings being available dating back to July 1963. The other possible source of archival climatic data was that from the Heriot Watt Automatic weather station, whereby data is recorded every half hour since 1990 (albeit with readings from 2003 missing). However, it was deemed insufficient due to a large number of obvious errors in data recorded. The majority of the 1970s data was unavailable but overall there was enough data available to distinguish any possible climatic trends.

3.2.1.1 Variable Scales

The seasonal, annual and decadal means were calculated for each variable, in order to assess the trends at different time scales and account for a better understanding of any changes taking place. It is also easier to evaluate and interpret grouped means in order to reduce the variation in the data. A range of figures - scatterplots, line graphs and bar charts - were constructed for interpreting trends and relationships between the aforementioned variables.

3.1.1.2 Trendlines

Three year moving averages were used to make the longer term trends clearer (this trendline period covering the most data and illustrating the trend most adequately) and coupled with a linear trendline to show the overall trend of each variable. This method was chosen as it is recognised that "snow-pack records averaged over monthly or yearly periods provide a useful insight into interannual or longer-timescale climatic fluctuations, since the day-to-day precipitation events and temperature fluctuations are smoothed out, allowing the longer-term fluctuations of snow amount to be analysed" (Benison, 1997, 282).

3.2.1.3 Snow - Lying Day

Snow cover duration depends on a number of factors: snowfall, elevation, relief, exposure and the temperature fluctuation at the start and the end of the snow season (Petkova *et al*, 2004). A snow-lying day indicates that snow was lying at some unspecified depth over more than 50% of the ground surface within the vicinity of the observer at 0900hours, and this can be rather subjective.

3.2.1.4 Wind Speed and Direction

Daily wind speed was retrieved from the Cairngorm ranger diaries due to insufficient wind speed data recorded by the Met Office station. Wind direction data was available from the Meteorological Office.

3.2.1.5 Statistical Analysis

It was felt that it would be beneficial for the climate data to be supported by statistics. The data was subjected to the Mann-Kendall test (a non-parametric test for the detection of trend in a time series). However, this computer programme would not work and therefore no statistical weighting is provided for any of these data trends. It was also recommended by Simon Tett, University of Edinburgh, that I use the LINEST excel function for the regression parameters but no meaningful results were obtained.

3.2.1.6 Overcoming Climate Data Problems

The total monthly snow depth was calculated for each month because there was a lot of data missing or incomplete to calculate the mean monthly snow depth. For example, for one month there may be only two readings of snow depth and for the next month there would be twenty readings. So instead of finding the mean of these depths, the total monthly depth (by taking the sum of all available recordings) was calculated, as it was not possible to tell whether there had been no depth or if there data was just incomplete. In doing so, the analysis of this variable is consistent and comparisons can be drawn. Ideally a whole data set for each variable would be required to get a true representation but this is one of the disadvantages on relying on secondary data. What is important to remember when analysing climatic variations over short time scales is that any analysis will be limited to the quality of data, the degree of fluctuation and that any trends in data using regression analysis is going to be affected by isolated extreme values (Harrison, 1997). A variation in climate station altitude, 762m from 1963-1970 and 1090m from 1970 onwards, offers an inconsistency in climate data retrieval. For the temperature data, this was overcome by subtracting the equivalent lapse rate difference of 2.132°C for the 328m station altitude difference [lapse rate 6.5°C/1000m (Ahrens, 2003)] from the pre-1970 data. This enabled a consistent data analysis from the 1090m altitude. However, it was not possible to correct the other variables to this altitudinal shift.

3.2.2 Ski Run Data

Ski run data was also collected from the Cairngorm Ranger Base station diary entries in order to assess the state of ski lift operation over the years. The data collected provides an extension for the data used in the Harrison *et al* (1999) paper in which they look at the number of days of operation of various different individual lifts operating at different altitudinal ranges; the lowest being the West Wall at 750m, the highest the Ptarmigan at 1060m. Data was collected for the same lift systems up to 2006/07 to understanding of the skiing situation at Cairngorm since the Harrison *et al* (1999) analysis. This data formed the basis of the investigation into the availability of skiing on Cairngorms over the years.

3.2.3 Textual Evidence

Written accounts have been shown to provide a useful type of evidence, with McEwan and Werritty (2007) making use of historical diary entries to reconstruct a catastrophic flood occurring on the River Findhorn in 1829. Therefore, to substantiate the climate statistics, the dissertation turned to other evidence in the form of the Scottish Ski Club Journals. These journals provided a brief written account of conditions experienced each season and an account of the skiing season compared with previous years. Therefore, a useful insight into the variation in ski season conditions can be recognised and used in conjunction with the other evidence to further understand the snow climate of the Cairngorms. The Scottish Mountaineering Club Journal was also consulted but there was insufficient relevant information.

3.2.4 Interviews

In addition to the quantitative and textual evidence, interviews were conducted with people whose lives are affected by the perceived changes. In doing so, an insight into the impact that the changing climate and reduction in skiing opportunities has had on businesses and tourism can be obtained.

3.3. Ethics

There are no ethical design implications involving anonymity or misquoting.

3.4 Study Location

The location of Aviemore and Cairngorm ski area (indicated as “Cairngorm Mountain”) is shown in figure 3.4 below.

Figure 3.4 Location Map of Cairngorm and Aviemore

Source: http://www.cairngormmountain.co.uk/essential-information/where-we-are/getting-here/

The dissertation aims will be achieved by exploring each form of evidence and examining the relationship between them, thereby assessing what role the snow climate has had on business and tourism in the Cairngorm and Aviemore area.

4

Analysis of Cairngorm Climate Data from 1964-2006

This chapter is comprised of climatic data at the seasonal, annual and decadal scales, with the relationships between variables also investigated. These trends, along with ski run data and skier numbers, provide an insight into the snow climate since 1964 and the impact that this has had on the skiing opportunities on Cairngorm.

4.1 Variable Relationships

Figures 4.1.1-4.1.3 relate the annual variation in mean temperature from the 1964-2006 average temperature to the other three variables under investigation; annual number of snow-lying days, annual number of snow/sleet falling days and annual total monthly snow depth. These show the relationship between variables quite clearly, with the exception of a few outliers which are investigated below. Figure 4.1.1 illustrates that the number of snow-lying days generally decreases when the annual temperature is above the 1964-2006 average, with the converse also illustrated. Figure 4.1.2 illustrates a similar relationship, this time with the total monthly depth being reduced when the annual temperature is above the 1964-2006 average. Figure 4.1.3 shows no real relationship: correlating snowfall to temperature is not a simple process. The air must be unsaturated (relative humidity <100%) and the wet bulb temperature (lowest temperature that can be attained by evaporating water into the air) must be at freezing or below for precipitation to fall as snow (Ahrens, 2003). Figure 4.1.4 illustrates the relationship between the number of days with snow falling and the number of days of snow lying: when there is above average snow falling days there is above average snow-lying days. This relationship is not straightforward, however, because conditions have to be right for snowfall to lie, ground temperature being a key control. This variable was not recorded however as there was little data available on ground temperatures. Figure 4.1.5 shows a strong, clear relationship between snow-lying days and total monthly depth – the more snow-lying days, the greater the total monthly depth. This intuitive relationship is here illustrated, a fact which generates confidence in the data set. Figure 4.1.6 illustrates that there is not a clear relationship with the number of snow falling days and the total monthly depth. This is because snowfall does not always manifest itself into snow depth as a result of ground temperatures, the wind (which drifts snow from hillsides into gullies), and rainfall.

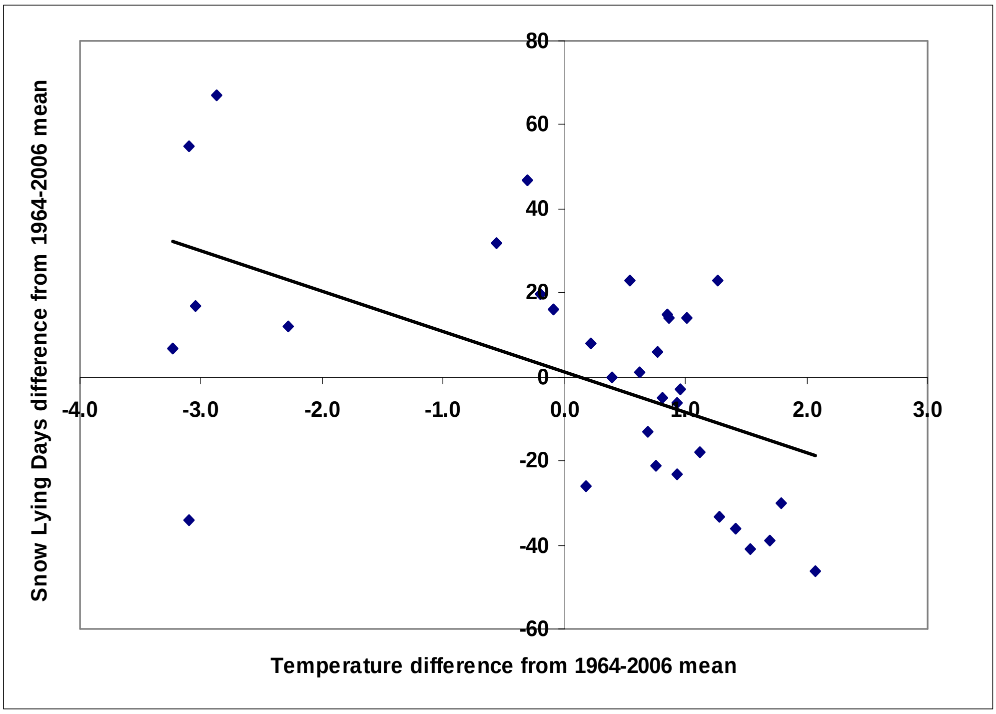

Figure 4.1.1 Relationship between the temperature and snow-lying days variance from the period means (4.7°C and 91.1 days respectively)

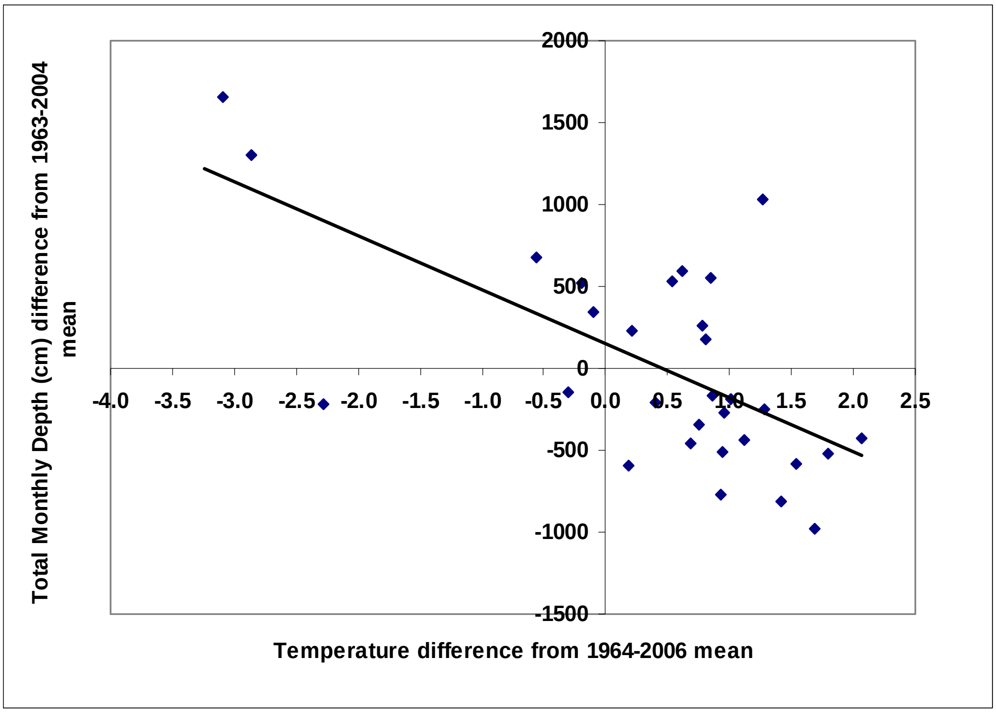

Figure 4.1.2 Relationship between the temperature and total monthly snow depth variance from the period means (4.7°C and 1305.4cm respectively)

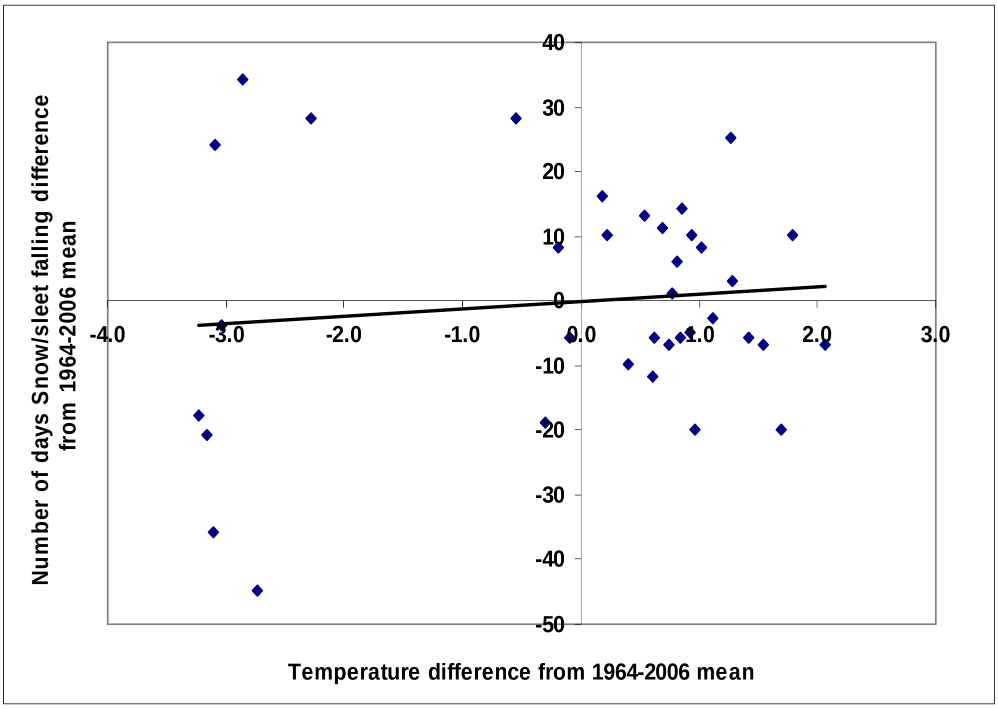

Figure 4.1.3 Relationship between the temperature and snow-falling days variance from the period means (4.7°C and 73.8 days)

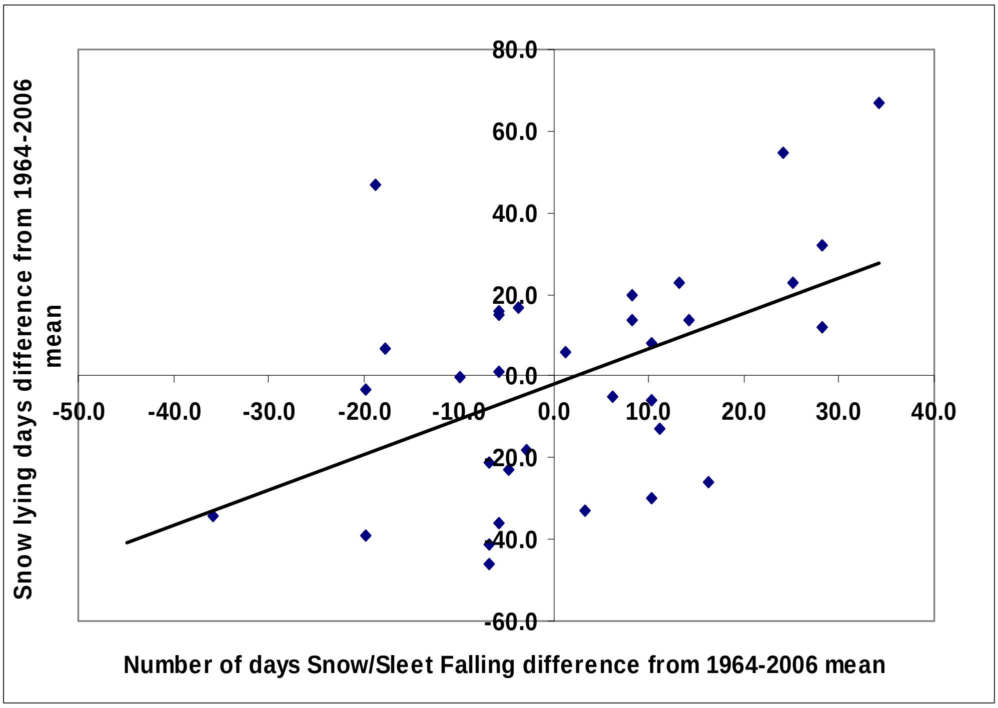

Figure 4.1.4 Relationship between the snow-falling days and snow-lying days from the period means (73.8 days and 91.1 days respectively)

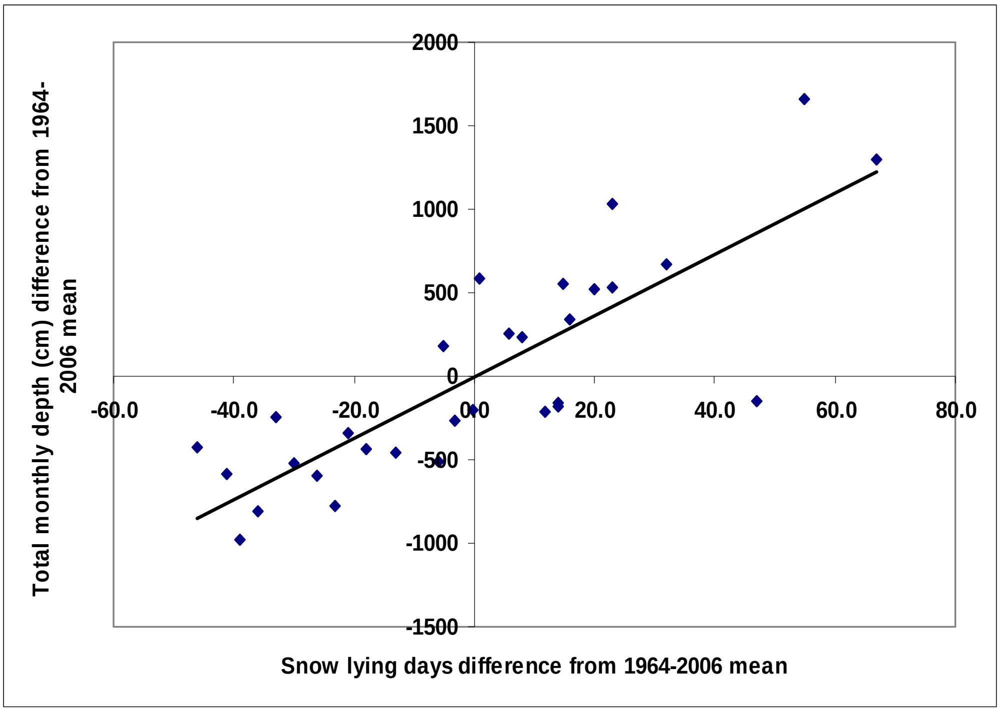

Figure 4.1.5 Relationship between the snow-lying days and the total monthly snow depth variance from the period means (91.1 days and 1305.4cm respectively)

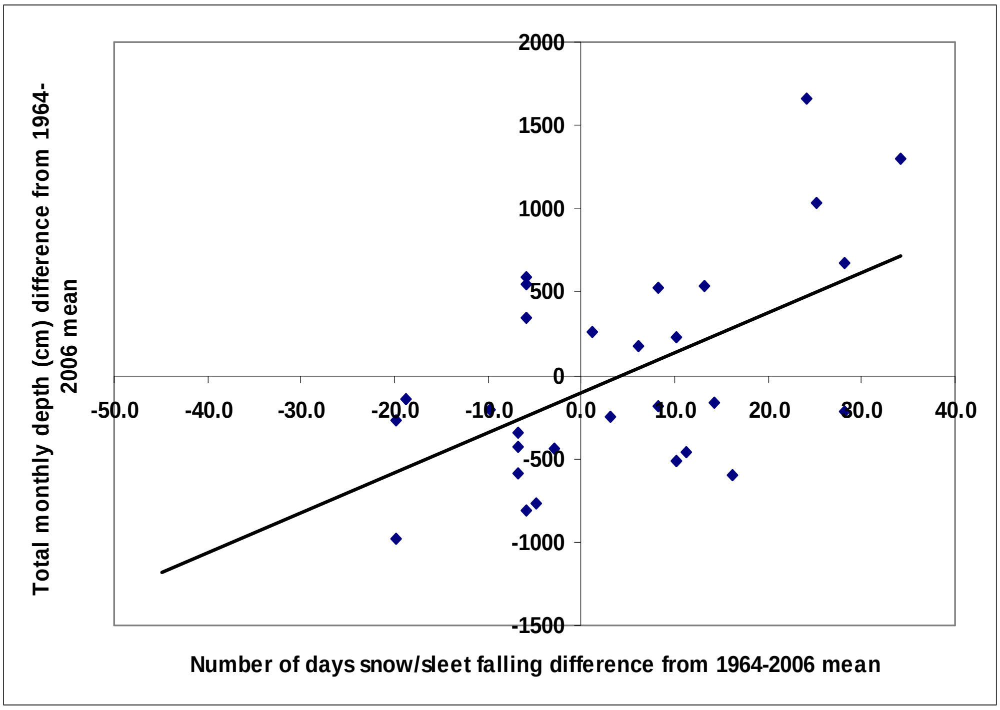

Figure 4.1.6 Relationship between the snow-falling days and total monthly snow depth variance from the period means (73.8 days and 1305.4cm respectively)

4.2 Seasonal Data

Grouping the monthly means seasonally allows for a clearer representation of trends and for seasonal comparison within variables. Seasonally grouping the monthly means provided the most adequate approach in which to assess the data in a meaningful manner. A large part of the data for the 1970s is missing. The 3-year moving average trendline has been interrupted in order for it not to be affected by missing data.

4.2.1 Winter Climate

Figures 4.2.1.1 - 4.2.1.4 show the winter (December – February) annual variance from the 1964-2006 mean of each variable. Figure 4.2.1.1 shows that there has been a very small increase in snow falling days but figures 4.2.1.2 and 4.2.1.3 show that snow-lying days and total monthly snow depths have decreased. This fact has been accompanied by an overall increase in mean temperatures (figure 4.2.1.4). The slight increase in the number of snow-falling days appears to be negated by the increase in winter temperatures and it is not surprising that winter snow lying days and depth trends have consequentially decreased. Rainfall may well also have had a fundamental influence on whether the snowfall becomes snow cover.

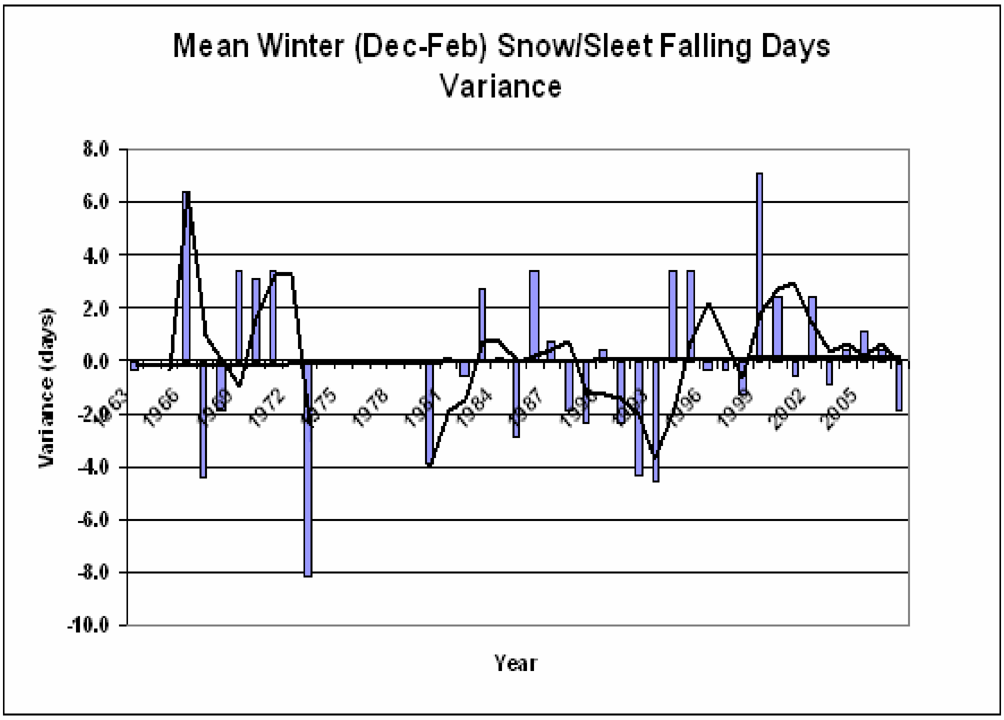

Figure 4.2.1.1 The mean winter (December-February) snow-falling days variance from the period mean (11.6 days)

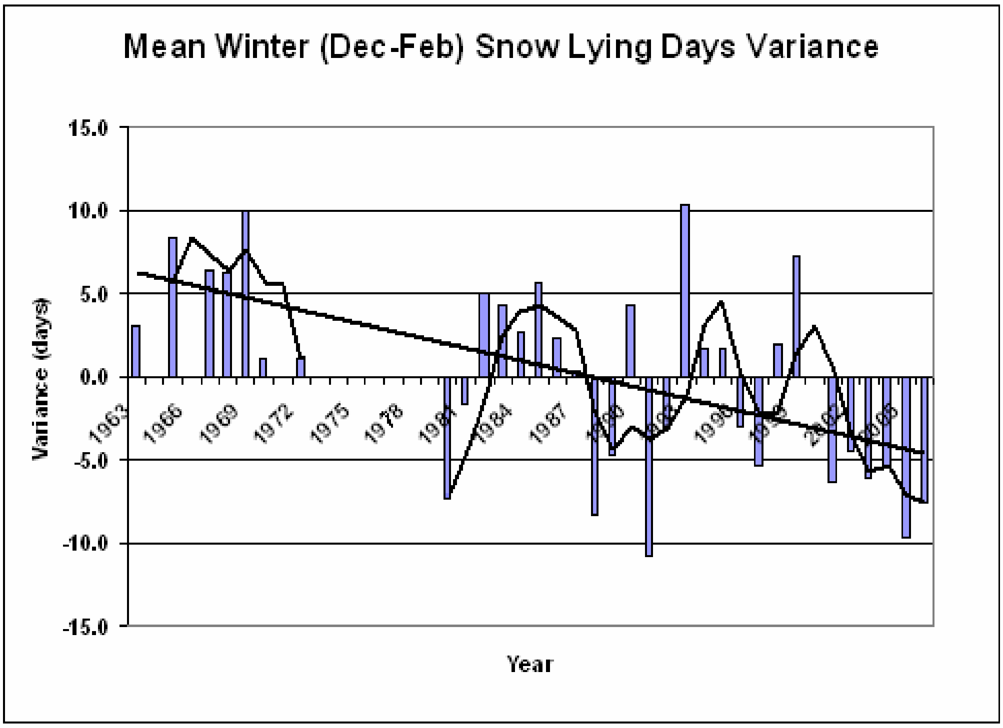

Figure 4.2.1.2 The mean winter (December-February) snow-lying days variance from the period mean (17 days)

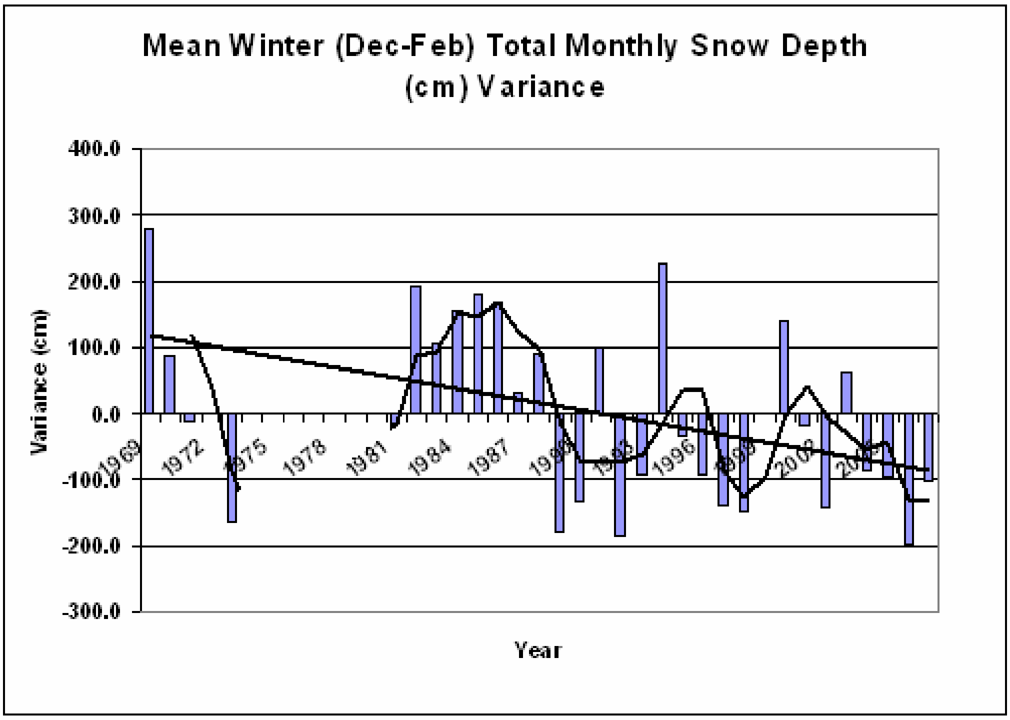

Figure 4.2.1.3 The mean winter (December-February) total monthly snow depth variance from the period mean (241.8 cm)

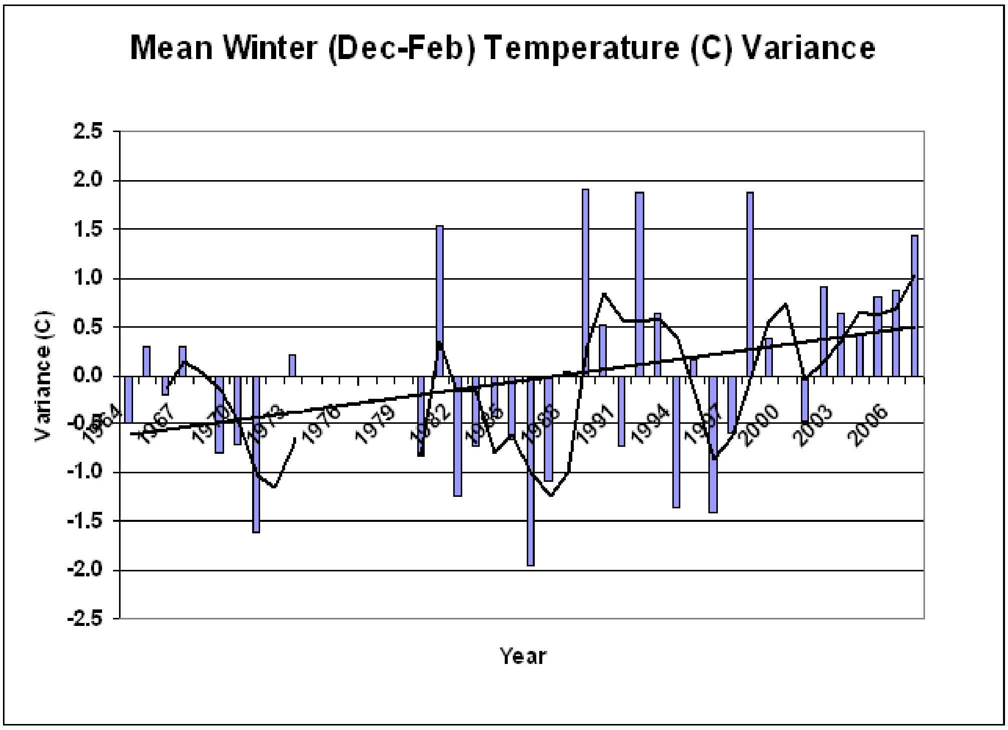

Figure 4.2.1.4. The mean winter (December-February) temperature variance from the period mean (0.9°C)

4.2.2 Spring Climate

Figures 4.2.2.1 - 4.2.2.4 show the spring, March - May, annual variance from the 1964-2006 mean of each variable. There is little difference in the number of snow-falling days over the forty-two year period (figure 4.2.2.1). The number of days with snow lying (figure 4.2.2.2) and the total monthly depth (figure 4.2.2.3) have both decreased, with a spell of less than average number of snow-lying days between 1987 and 1993 which may be attributed to the above average mean temperatures for those years (figure 4.2.2.4). The mean temperature for spring has risen overall but notably since the 1980s there has essentially been a continuation of above average mean temperatures, probably accounting for the decline in snow-lying days for this season.

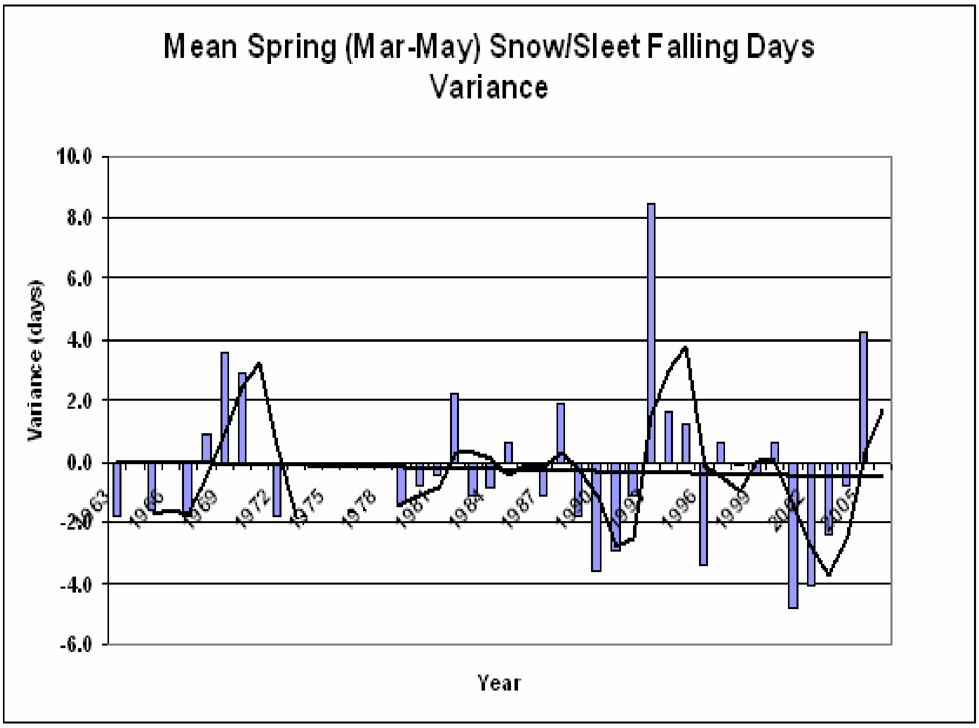

Figure 4.2.2.1 The mean spring (March-May) snow-falling days variance from the period mean (9.1 days)

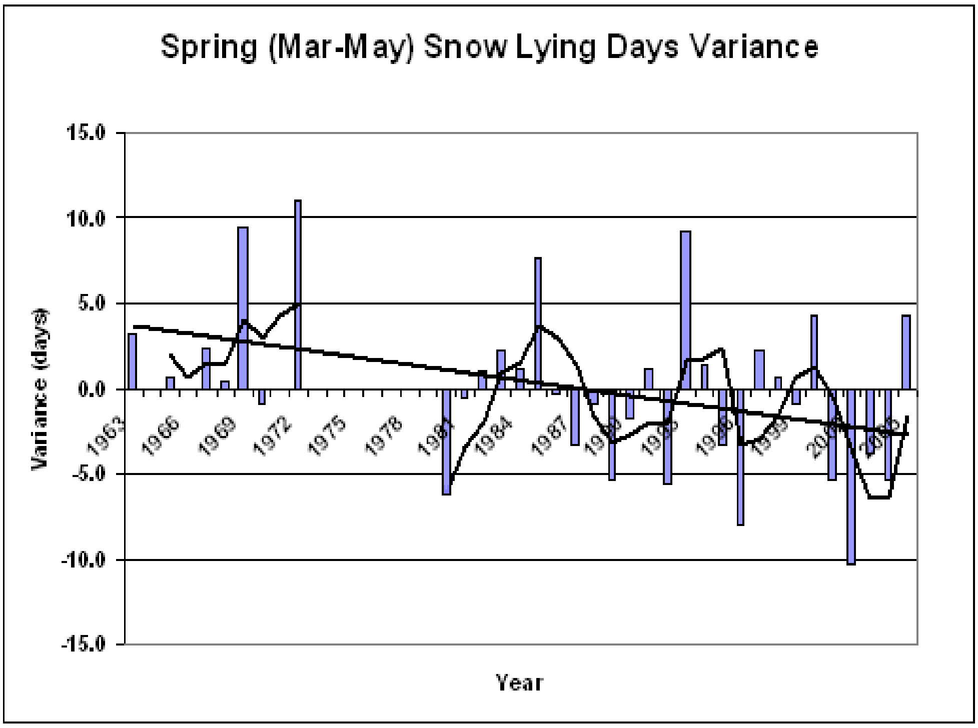

Figure.4.2.2.2 The mean spring (March-May) snow-lying days variance from the period mean (12.3 days)

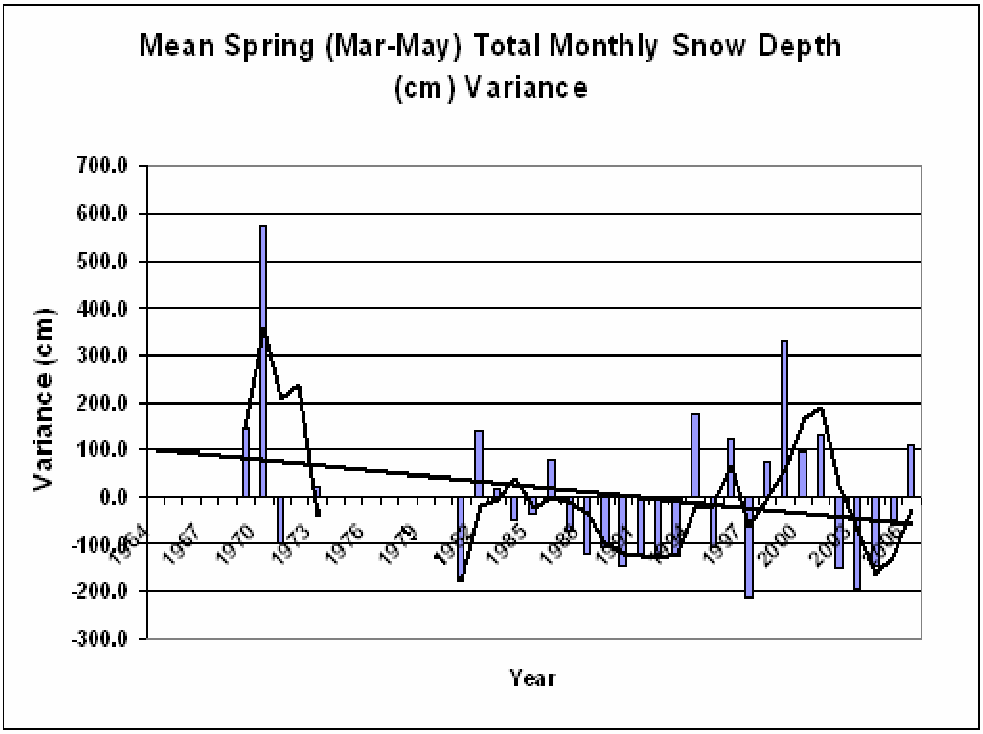

Figure 4.2.2.3 The mean spring (March-May) total monthly snow depth variance from the period mean (215.7 cm)

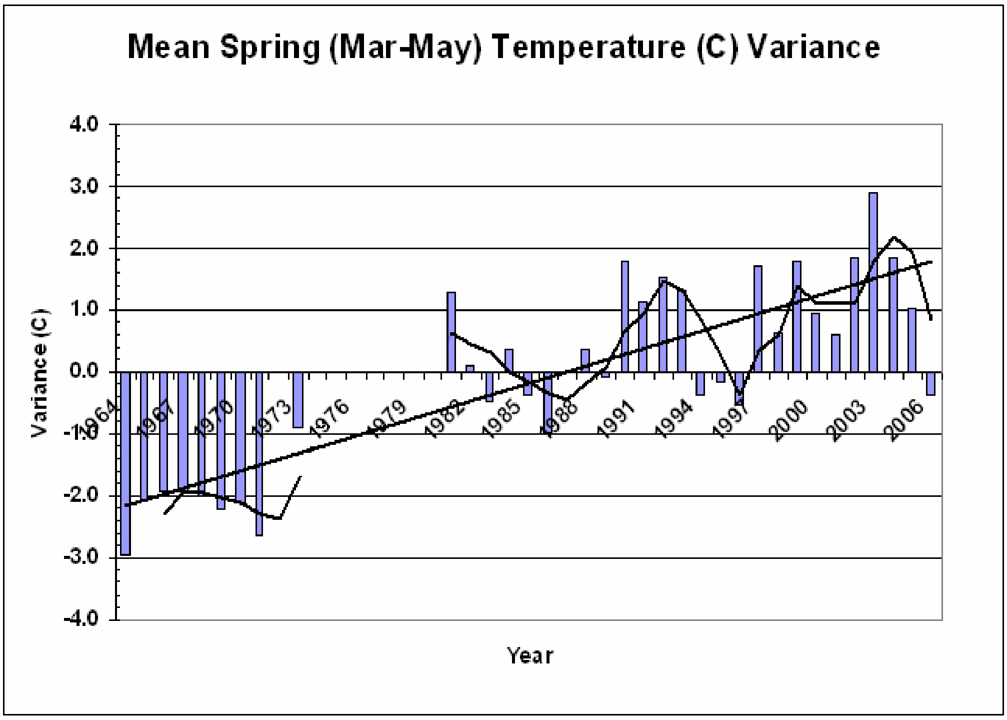

Figure 4.2.2.4 The mean spring (March-May) temperature variance from the period mean (3.5°C)

4.2.3 Summer Climate

Figure 4.2.3 depicts the mean summer (June-August) temperature variance from the period average. What is striking is that until the early 1970s, the mean temperatures were below the period average (9.2°C) but since then they have all been consistently above average. This accounts for the increasing trend. The trends for the summer snow variables were minimal to non existent and are therefore not shown.

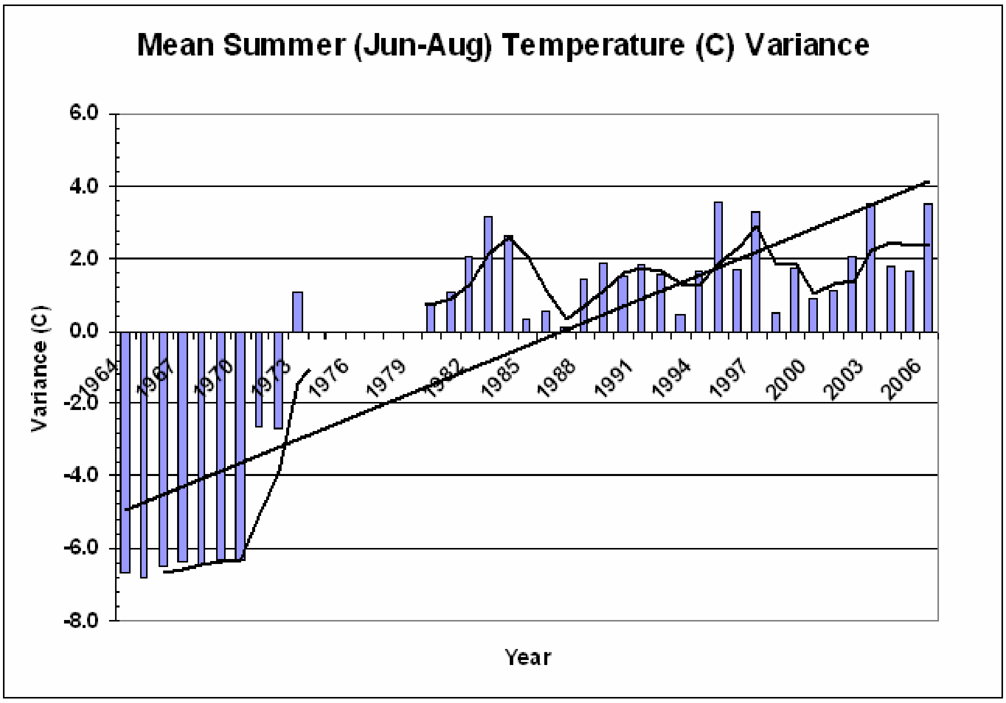

Figure 4.2.3 The mean summer (June-August) temperature variance from the period mean (9.2°C)

4.2.4 Autumn Climate

Figures 4.2.4.1 - 4.2.4.3 illustrate the trends for the autumn months, September - November, again with the annual means of the desired variable being compared to the variable mean for the 1964-2006 time period. Figure 4.2.4.1 shows that the number of snow falling days has stayed roughly consistent, the moving average depicting the variability between the years. Figure 4.2.4.2 shows that there is a slight decrease in autumnal snow-lying days over the forty-two years. However, this trend is affected by the anomalous 1991 season, the high snowfall (figure 4.2.4.1) responsible for this. Figure 4.2.4.3 is similar to figure 4.2.3, with a clear rise in mean temperatures for autumn, with above average mean temperatures beginning in the early 1980s. The autumnal total monthly depth mean is not portrayed as there was not enough data to analyse.

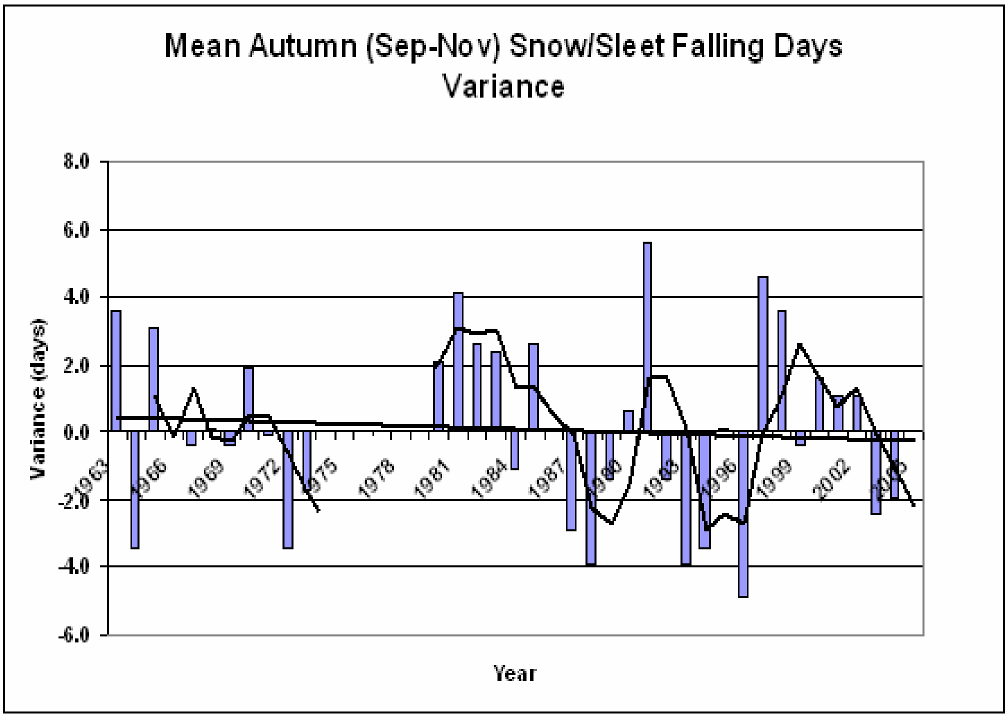

Figure 4.2.4.1 The mean autumn (September-November) snow-falling days variance from the period mean (7.4 days)

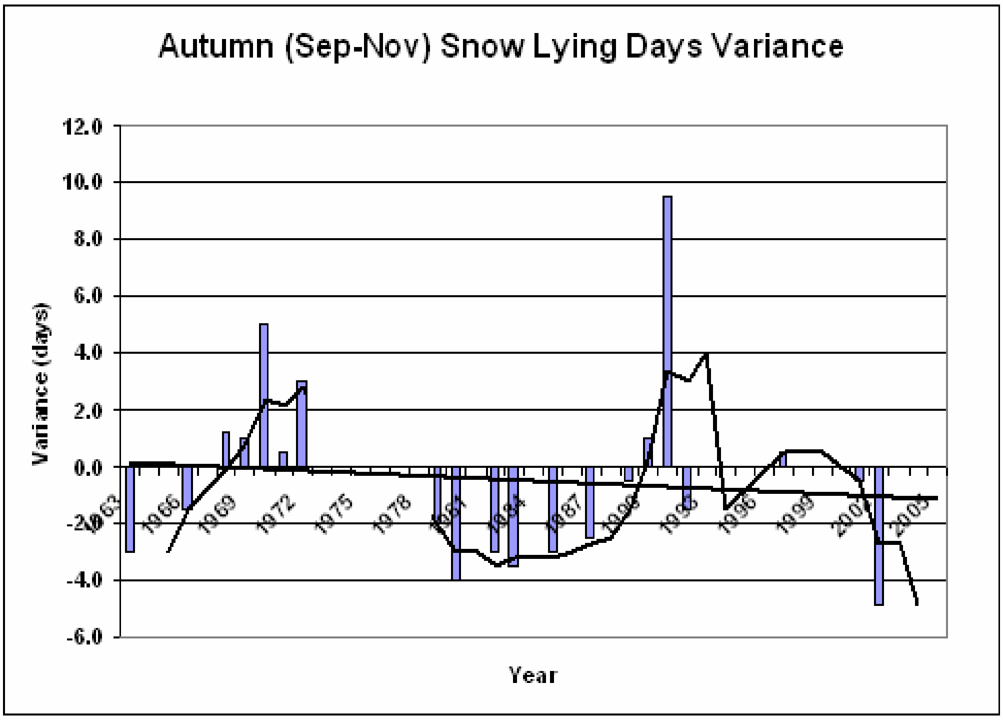

Figure 4.2.4.2 The mean autumn (September-November) snow-lying days variance from the period mean (7.1 days)

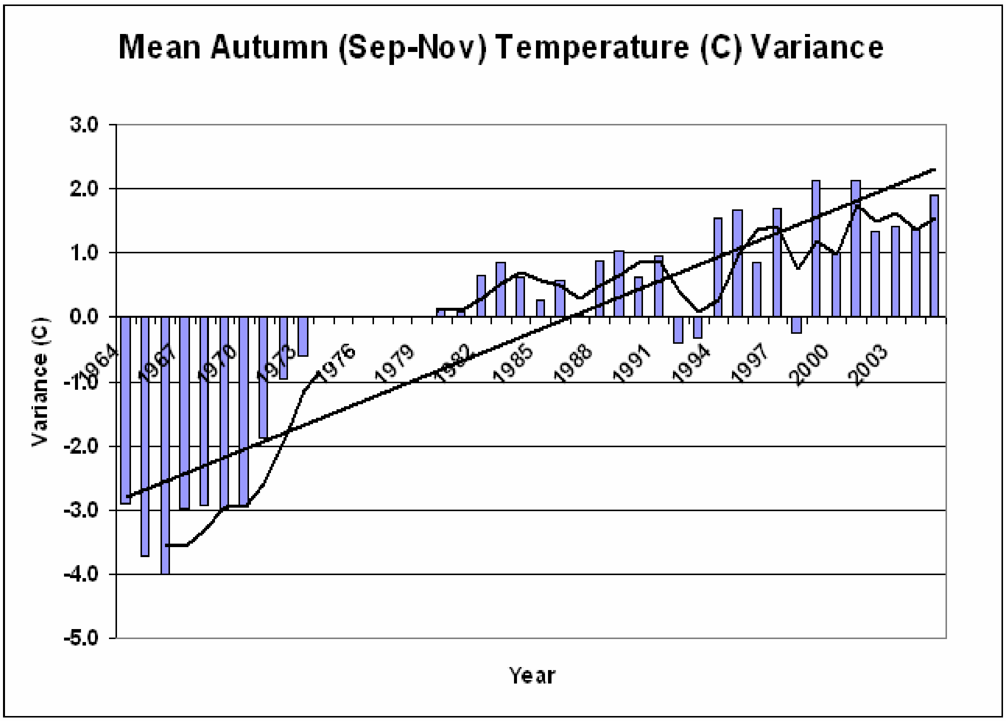

Figure 4.2.4.3 The mean autumn (September-November) temperature variance from the period mean (5°C)

<u>4.3 Annual Variable Variances</u>

Figures 4.3.1 – 4.3.4 depict the annual variance for each variable from the forty-two year mean under investigation. They provide a different timescale with which to view the trends, and in comparing the variables annually, it appears that temperature is the factor accounting for the decline in the number of snow-falling days (figure 4.3.2), the number of snow-lying days (figure 4.3.3) and the total monthly snow depth variance (figure 4.3.4). This is concluded as the annual mean temperature (figure 4.3.1) appears to have risen since the 1964 whereas the other three variables have decreased in value since then. It is also apparent that the annual mean temperature has stayed above the forty-two year average since the early 1980s compared to when it was previously consistently below the period average. The annual number of snow-falling days (figure 4.3.2) has not changed much over the investigated period, with high variances throughout the period with no particular time pattern. Figure 4.3.3 clearly

shows the annual variability of snow-lying days in addition to a decreasing trend. This is also true for the annual total monthly snow depth (figure 4.3.4), albeit with a lot of data unavailable at this scale before 1981. The fact that there are only four values between 1964 and 1981 available in figure 4.3.4 obviously affects the trendline gradients but it is felt that it is imperative to include all the data available for the analysis, and so even although the declining trend would be reduced had the pre-1981 values not been there, there would still be an overall declining trend and this is what is of interest.

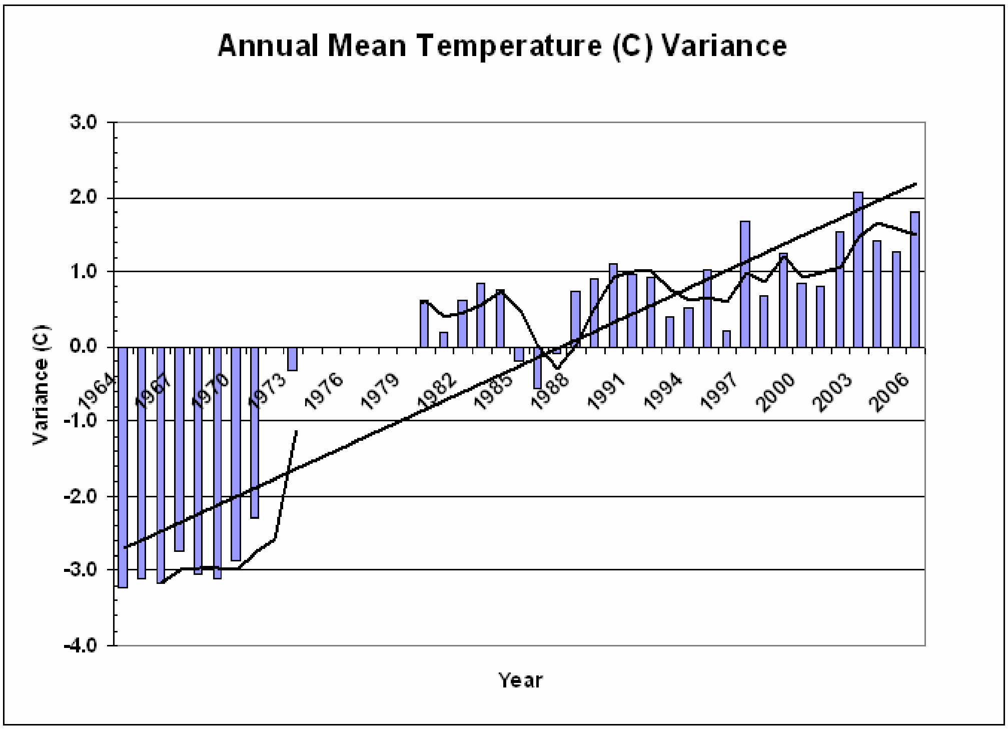

Figure 4.3.1 Annual mean temperature variance from the period mean (4.7°C)

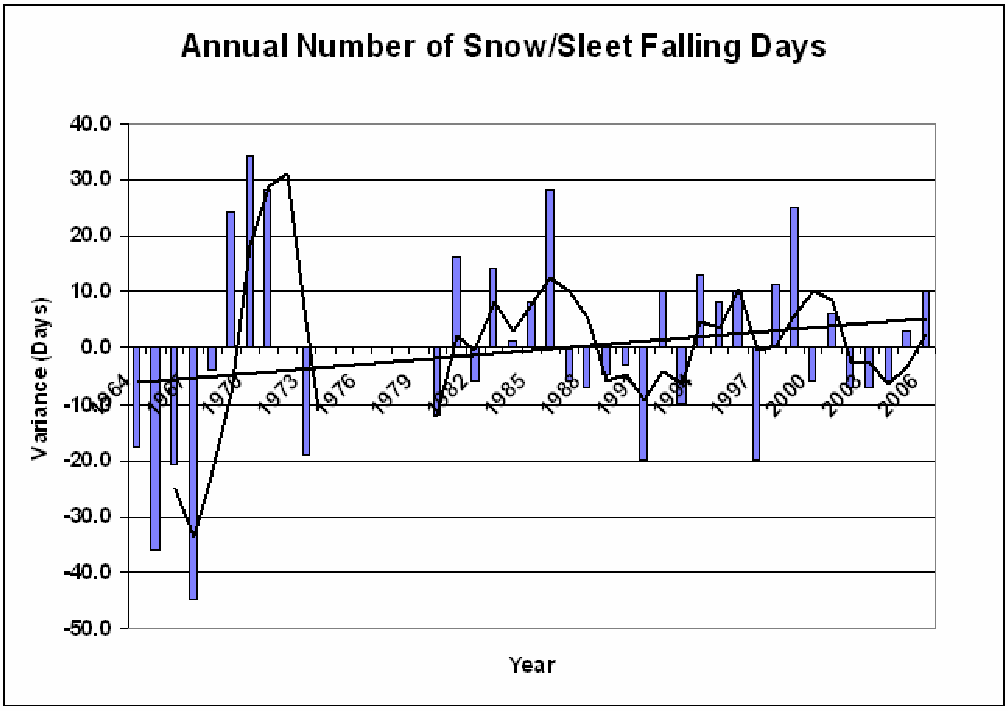

Figure 4.3.2 Annual number of snow-falling days variance from period mean (73.8 days)

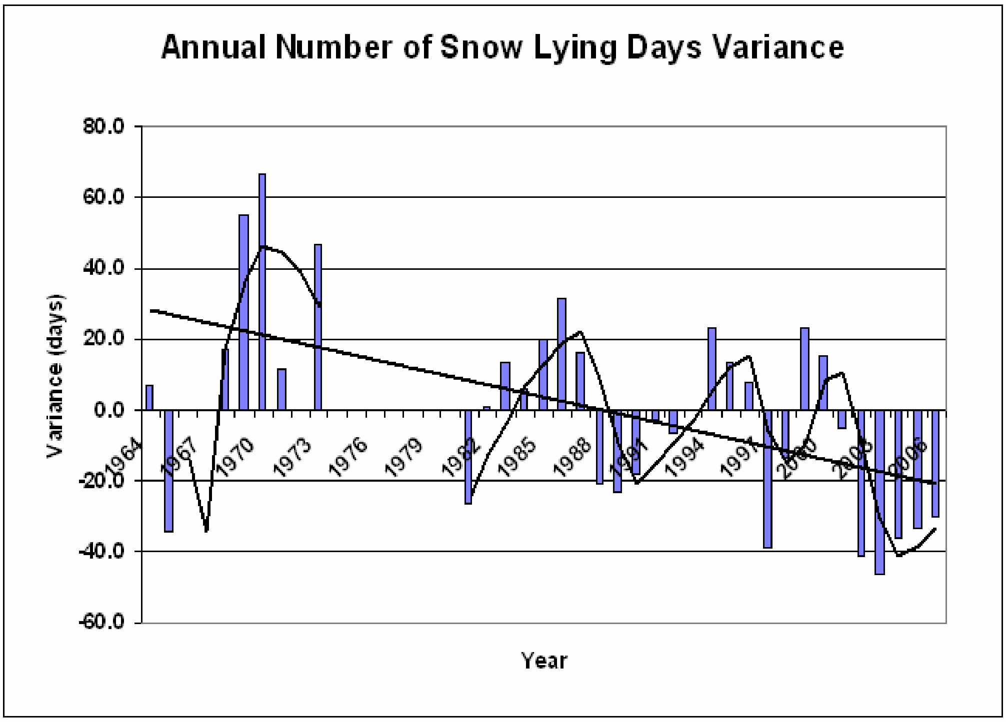

Figure 4.3.3 Annual number of snow-lying days variance from the period mean (91.1 days)

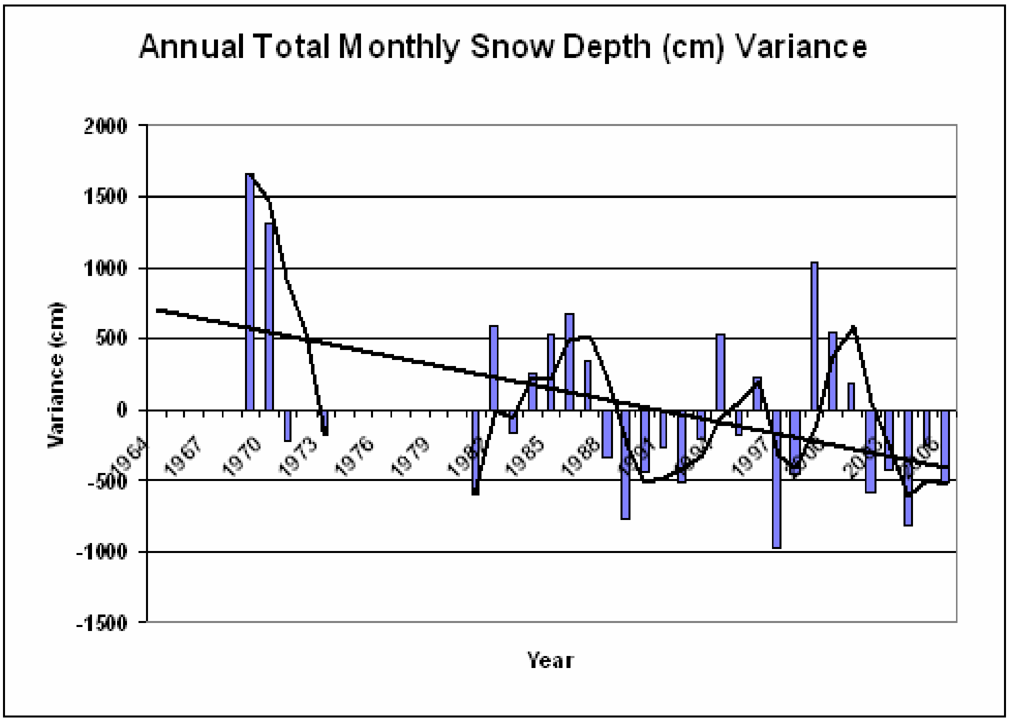

Figure 4.3.4 Annual total monthly snow depth variance from the period mean (1305.4cm)

4.4 Annual Variable Comparisons

Annual Comparisons were made between the four variables in order to further understand their relationships. Figures 4.4.1 – 4.4.6 illustrate the various annual comparisons. Figures 4.4.1 investigates the inverted relationship between the annual number of snow-lying days and the annual mean temperature. When the annual mean temperature rises, the annual number of snow-lying days fall. This is consistent throughout the forty-two year period under investigation. This is also true for the comparison between annual mean temperature and annual total monthly depth (figure 4.4.2). This is to be expected as snow melts as temperature rises. Figure 4.4.3 shows the annual number of snow-lying days complimenting the annual total monthly snow depth. Figure 4.4.4 somewhat shows an inverted relationship between annual snow falling days and annual mean temperature but as noted and shown (figure 4.1.3), the relationship between temperature and snowfall is not straightforward. This accounts for the fact that even although the mean annual temperature of, for example, 1997 is 1°C higher than 1991, the number of days of snowfall is practically equal. Figure 4.4.5 shows the annual number of snow-lying days against the annual number of snow-falling days: and there is a strong correlation. Where there does not seem to be a relationship, such as in comparing the similar number of annual snow lying days in 1997 and 2006 to their corresponding number of snow falling days, the fact that the mean annual temperature in 2006 is roughly equal to that for 1997 implies there must be other factors, other than air temperature, accounting for the difference in snow-lying days. Figure 4.4.6 links the annual total monthly depth to the annual number of snow-falling days and there appears to be a relationship, particularly in 1999 with the high snowfall producing a high total annual monthly depth.

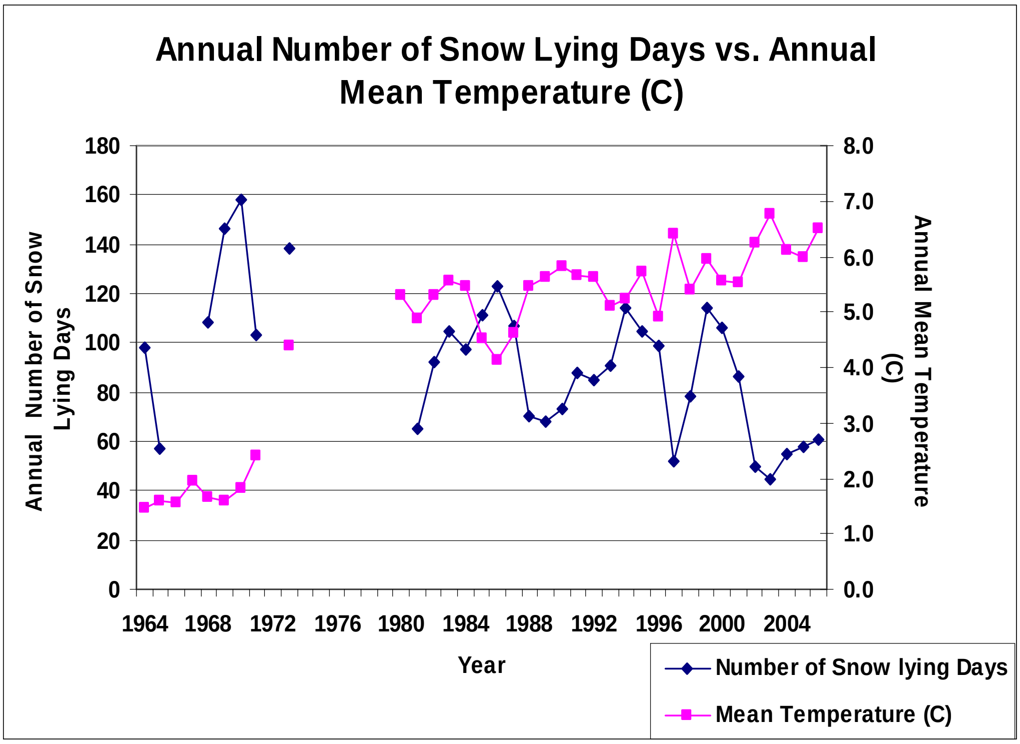

Figure 4.4.1 Annual number of snow-lying days comparison with annual mean temperature

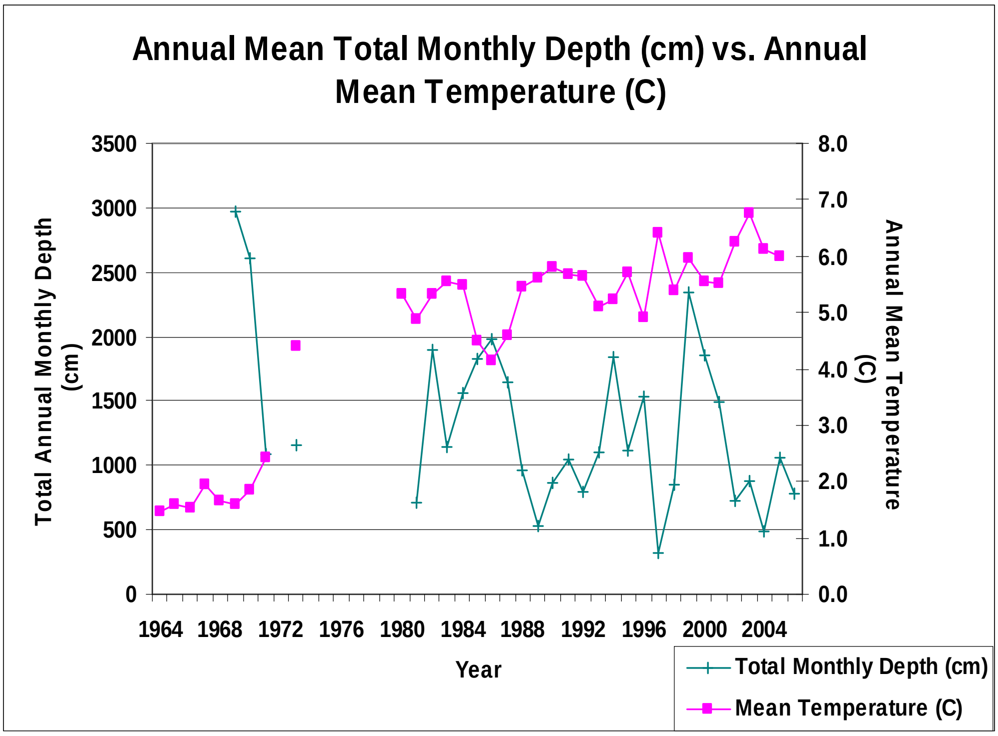

Figure 4.4.2 Annual total monthly snow depth comparison with annual mean temperature

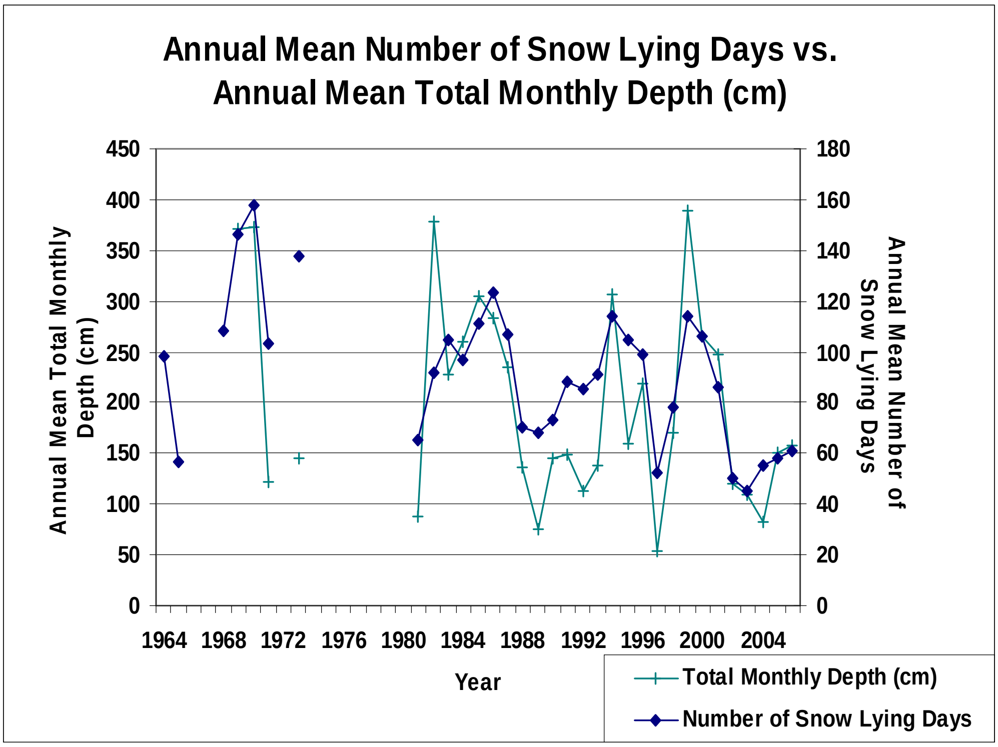

Figure 4.4.3 Annual snow-lying days comparison with annual snow-falling days

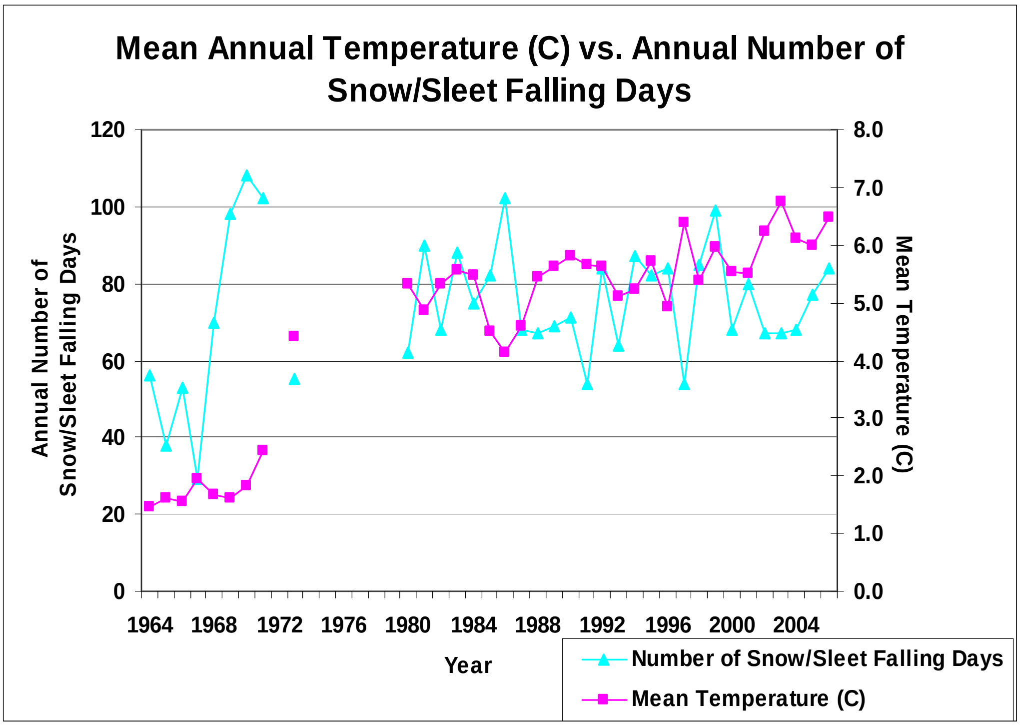

Figure 4.4.4 Annual mean temperature compared to annual snow-falling days

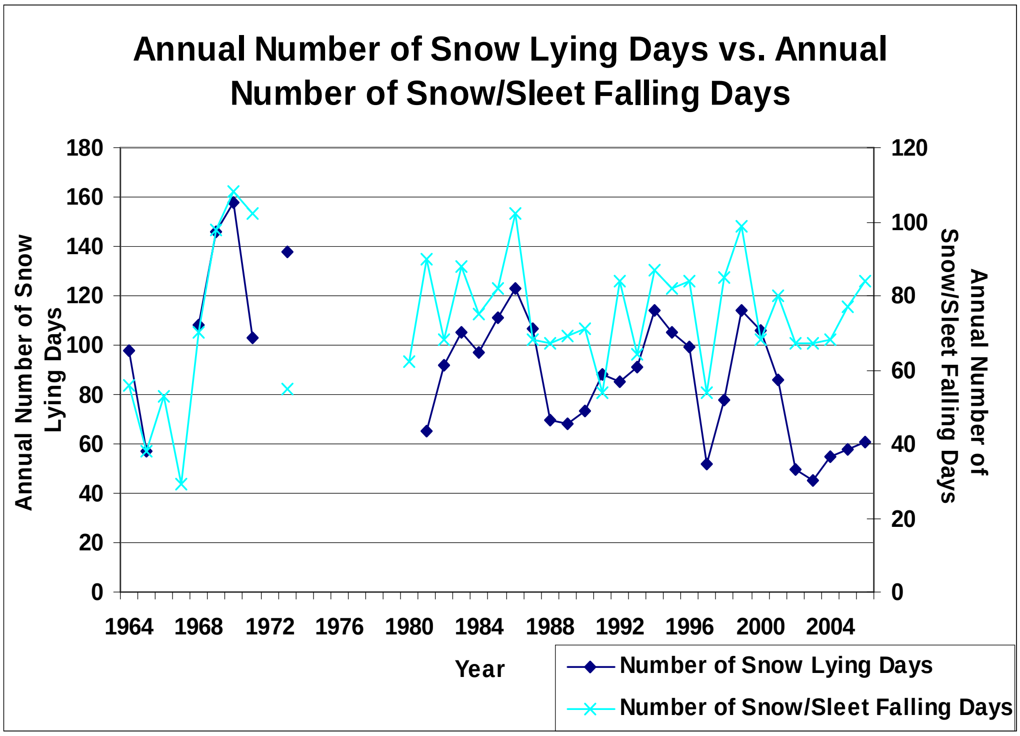

Figure 4.4.5 Annual snow-lying days compared to annual snow-falling days

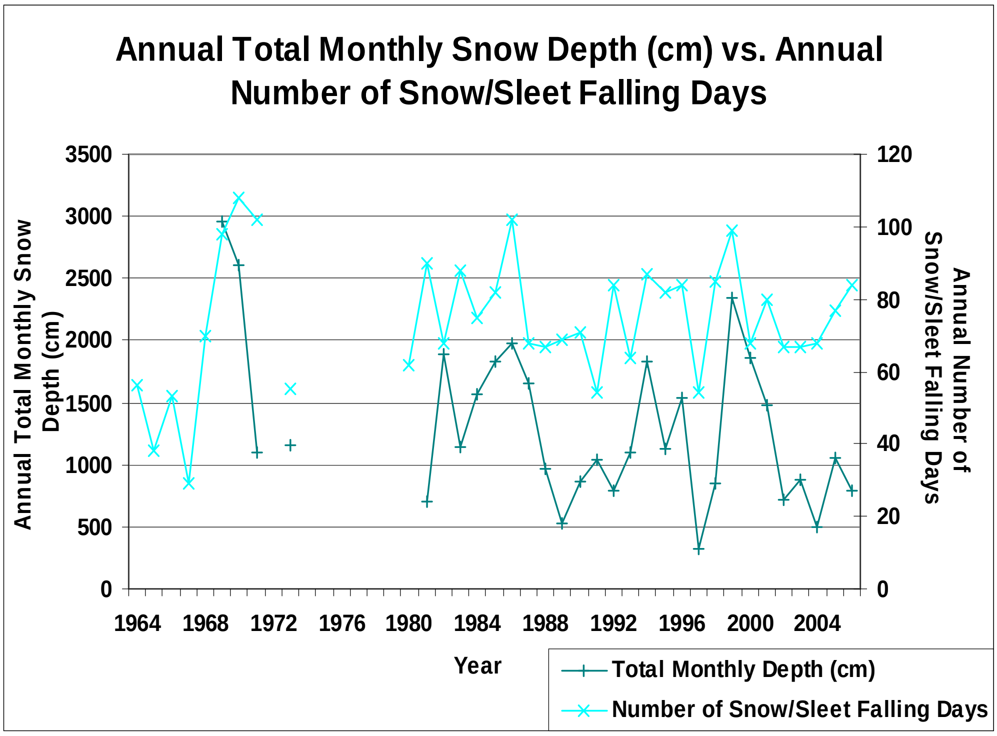

Figure 4.4.6 Annual total snow depth compared to annual snow-falling days

4.5 Decadal Scale Trends

The trends were then explored at the decadal scale and figures 4.5.1.1- 4.5.4.2 illustrate the findings. For figures 4.5.1.1, 4.5.2.1, 4.5.3.1 and 4.5.4.1, the decadal variance is calculated from the mean of each decade, and this is done for each of the four variables under study. In working out the decadal means, the mean of the annual mean was taken and, in the case of figures 4.5.1.2, 4.5.2.2, 4.5.3.2 and 4.5.4.2, the monthly annual means were averaged for the decade in question.. It must be stressed here that the decadal average for the 1960s and 2000s is calculated using only 7 years worth of data, a reflection of data availability. The 1970s decade is omitted due to the lack of data available.

4.5.1 Decadal Temperature

Figures 4.5.1.1 and 4.5.1.2 illustrate the decadal variance and the monthly decadal means respectively. Figure 4.5.1.1 clearly shows that on the decadal scale the mean temperatures have risen from being -3°C below the period average (4.6°C) in the 1960s to being 1.5°C above average for 2000s. Figure 4.5.1.2 shows clearly the winter temperature increase, as shown in figure 4.2.1.4, but also the large increase in summer temperatures, as shown in figure 4.2.3. This decadal scale is useful insomuch as it enables a comparison of monthly temperatures. What is apparent is the rate at which the monthly mean temperatures rise in each subsequent decade; this fast rate contributing to a rapid snow thaw and a decreased snow season (figure 4.3.3). It can be seen that the 1960s exhibited a low temperature range (~2°C), thereby enabling a greater number of days of snow cover (figure 4.5.3.2). Comparatively, the 2000s have exhibited a high temperature range (~11°C), thereby contributing to the reduction of snow-lying days and thus skiing opportunities.

4.5.2 Decadal Snow-Falling

The mean decadal variance of the number of snow-falling days (figure 4.5.2.1) shows a large increase from the 1960s to the 1980s but then a decrease in the number of above average snow-falling days to the 2000s; perhaps the continued increase in decadal temperature (figure 4.5.1.1) affecting the number of snow-falling days. Nevertheless, the overall increasing trend is in agreement with figure 4.3.2 whereby all the 1960s snowfall days are below the period mean whereas the majority of the variances thereafter are above the variable mean. Figure 4.5.2.2 showing that the number of snow-falling days for each decade follows a similar path to each other apart from the high values in February 1960s and April 1980s.

4.5.3 Decadal Snow-Lying

Figures 4.5.3.1 and 4.5.3.2 show clearly the reduction in the number of snow-lying days every decade, since the 1960s.

4.5.4 Decadal Total Monthly Snow Depth

Decline from the 1980s is also apparent for the decadal total monthly depth means (figures 4.5.4.1 and 4.5.4.2), with the 1960s decade omitted from this variable due to the lack of data.

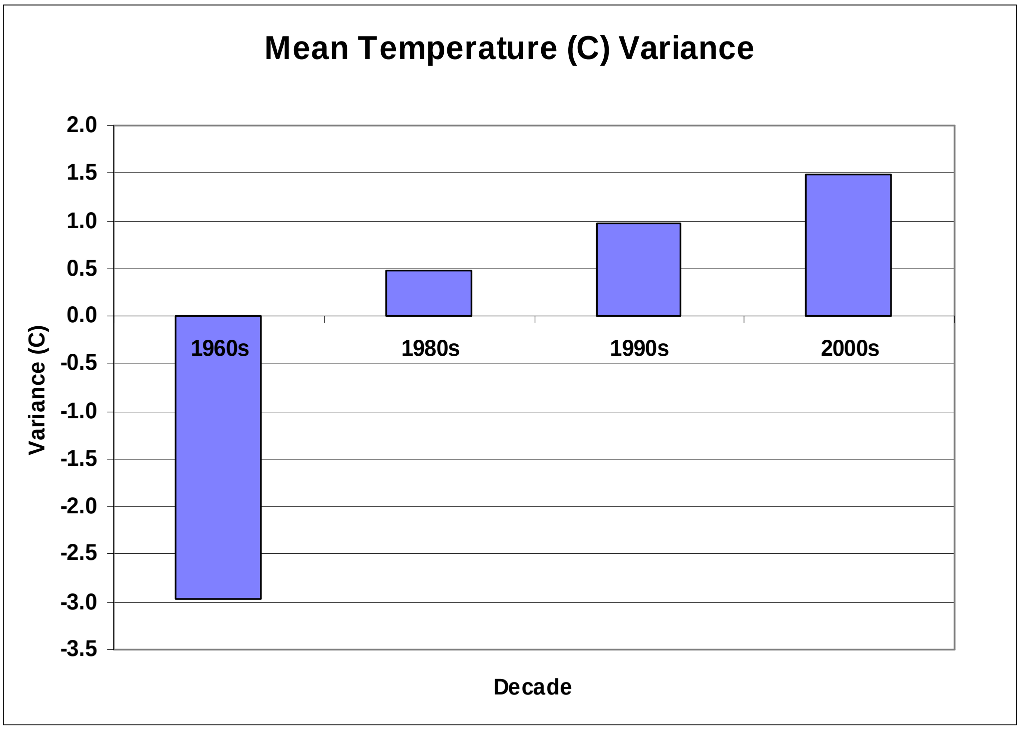

Figure 4.5.1.1 Decadal mean temperature variance from the period mean (4.6°C)

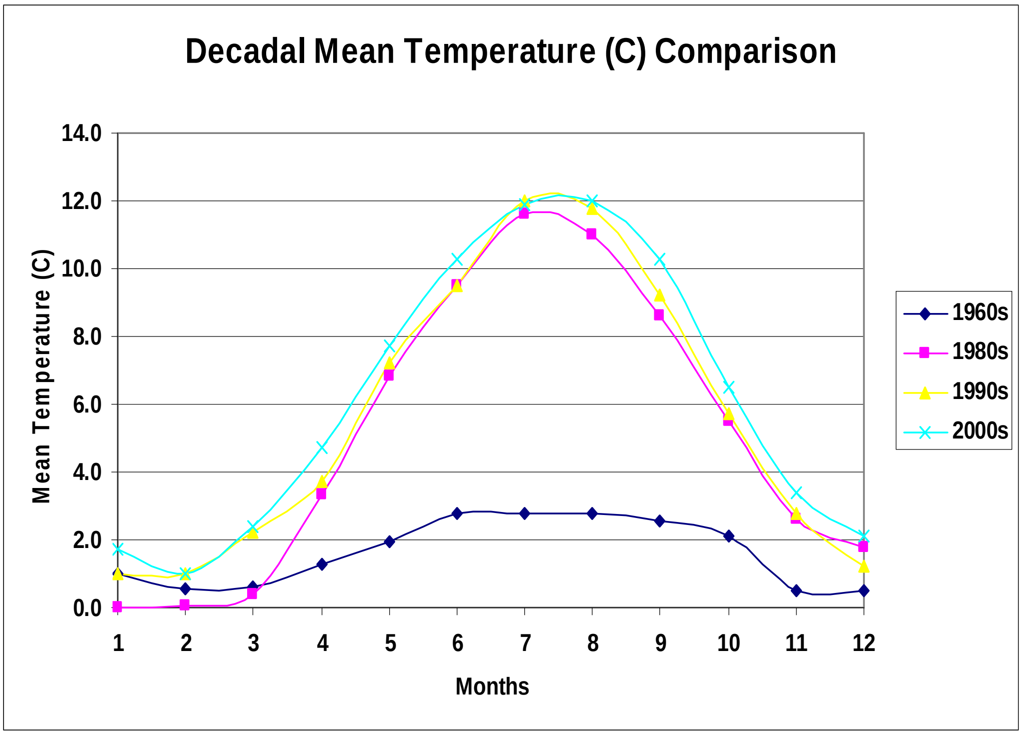

Figure 4.5.1.2 Decadal monthly mean temperature

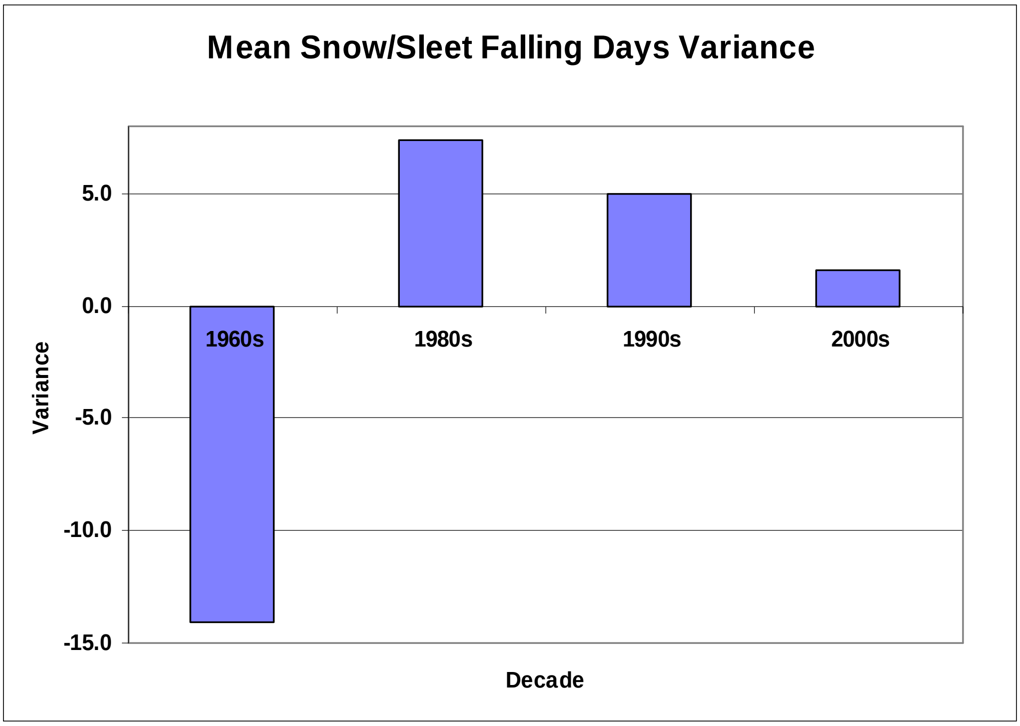

Figure 4.5.2.1 Decadal snow-falling days variance from the period mean (71.4 days)

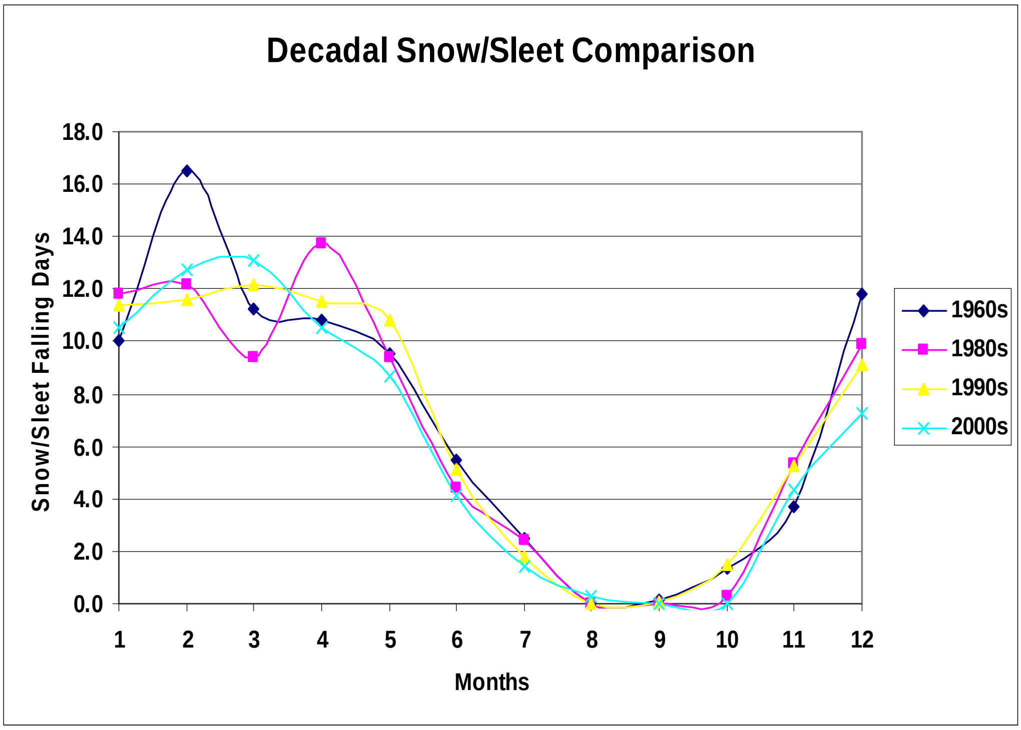

Figure 4.5.2.2 Decadal monthly number of snow-falling days

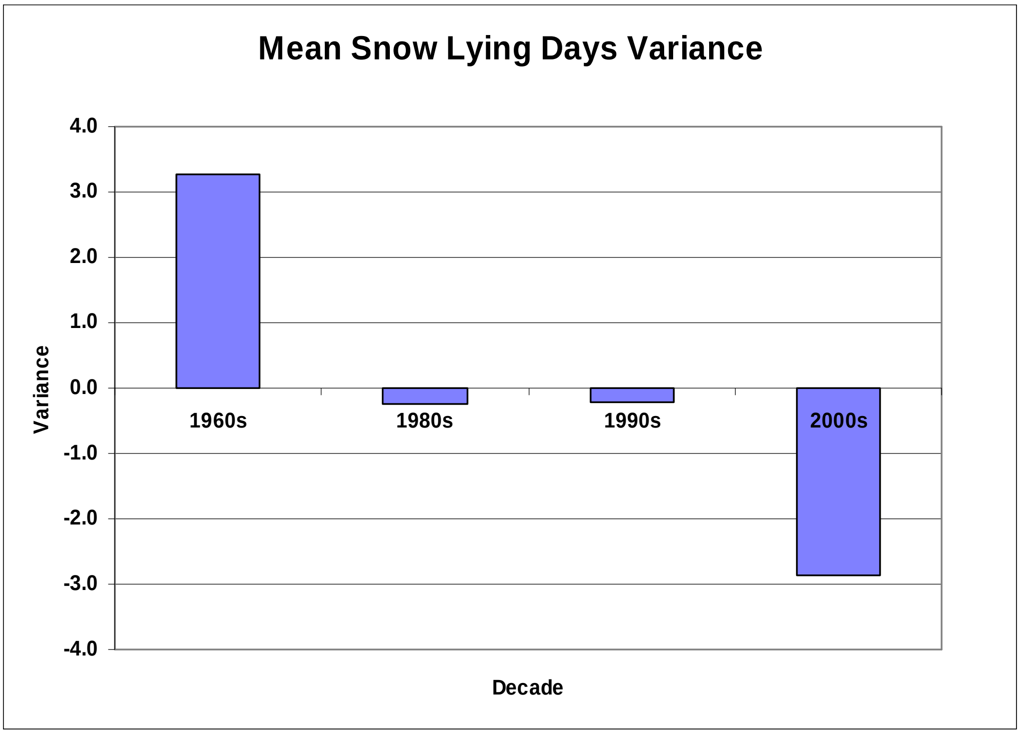

Figure 4.5.3.1 Decadal snow-lying days variance from the period mean (13.3 days)

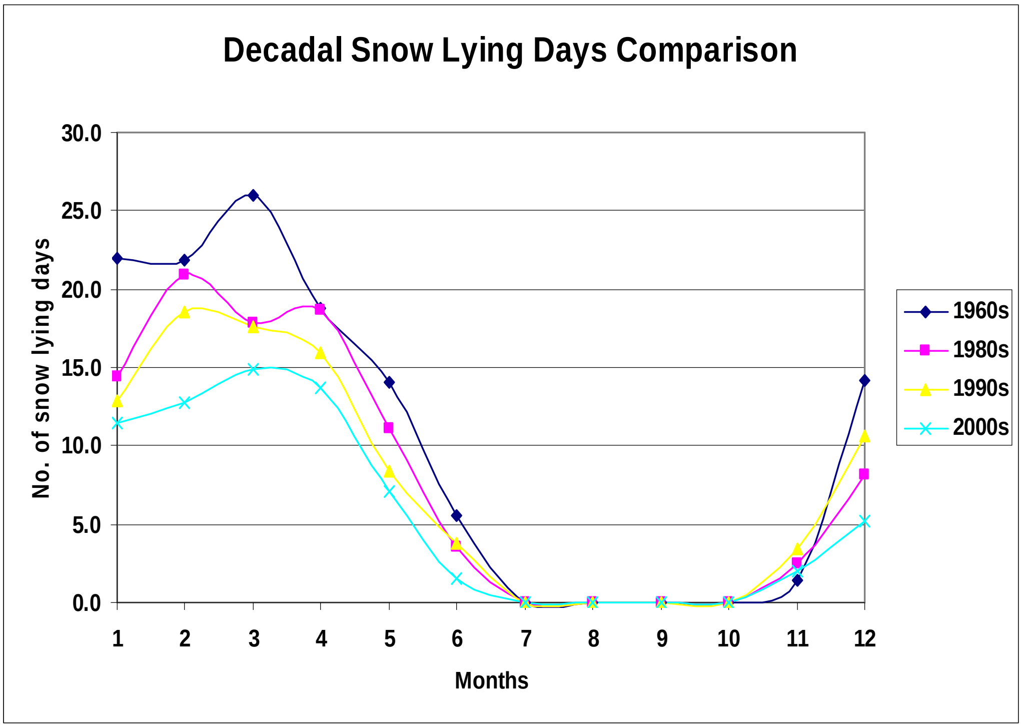

Figure 4.5.3.2 Decadal monthly number of snow-lying days

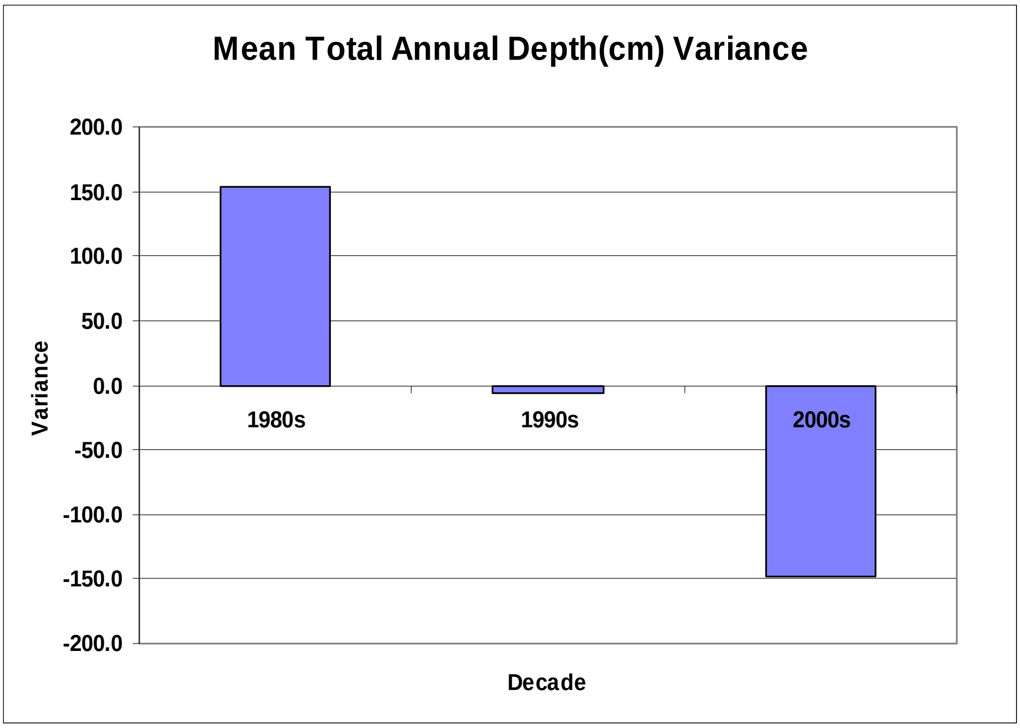

Figure 4.5.4.1 Decadal total annual depth variance from the period mean (1187.2 cm)

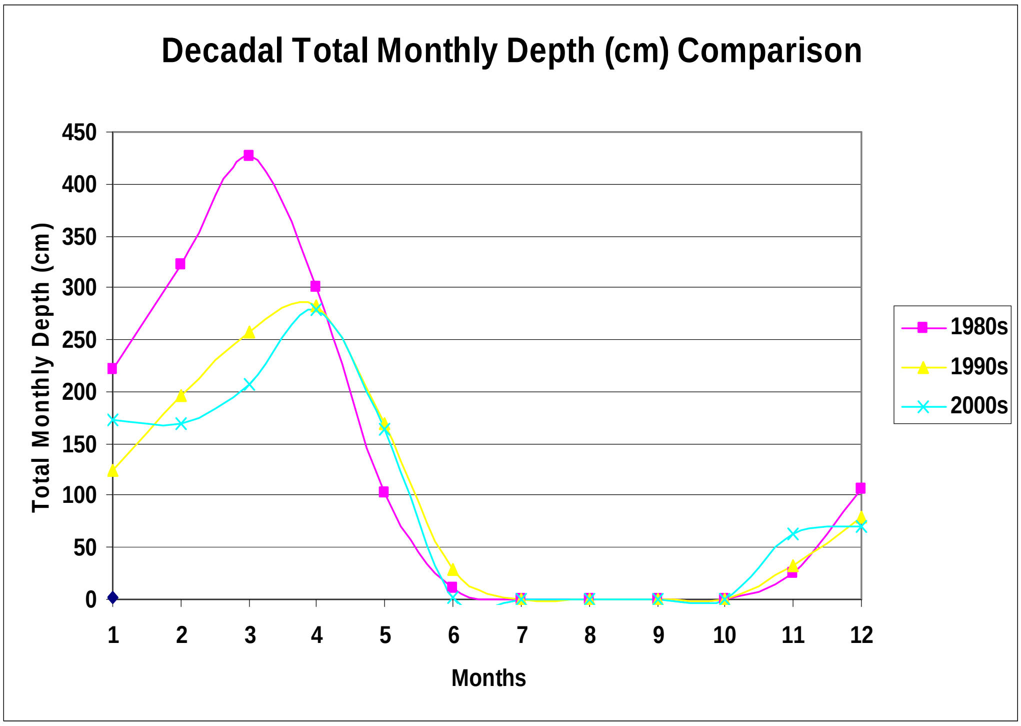

Figure 4.5.4.2 Decadal total monthly snow depth

4.6 Wind

Figures 4.6.1.1- 4.6.2.4 show the seasonal wind speed and wind direction. This was achieved by calculating a 3 month mean of the daily wind directions and wind speeds for each season each year.

4.6.1 Wind Speed

Wind speed is an important factor for snow accumulation in the gullies, with stronger winds combined with a cold spell necessary to allow the snowfall to form a base which will withstand days with milder temperatures. The seasonal wind speed for the summer (figure 4.6.1.2) and autumn (figure 4.6.1.3) has stayed relatively consistent at ~10m/s and ~15m/s respectively. However, the mean wind speed has decreased since 2000 in both winter (figure 4.6.1.4) and spring (figure 4.6.1.1), possibly lending to reduced full length ski runs (figures 4.7.1 – 4.7.6). Winter and spring wind speeds exhibit considerable interannual variability.

4.6.2 Wind Direction

The mean wind direction was also examined to see if there has been a shift in wind direction and if this has an effect on snow-lying days and temperature. Harrison (1993) recognises that there is a relationship between wind direction and snow cover, with a higher duration of cover attributed to cold easterly airstreams and a decrease in cover and accumulations associated with warmer, maritime westerly flow. It appears that all seasons exhibit a trend towards a more permanent westerly flow.

4.6.3 Interannual Wind Variability

What is also apparent, however, is the interannual variability which may account for some of the differences between the temperature, snow cover, snow depth and snowfall. Harrison (1993) highlights the winter of 1985/86 as one of the most severe in Scotland in recent years. The variables attributed to this winter are a south easterly wind (164°), 2°C below the 1964-2006 average winter mean temperature (0.9°C) and an above average number of snow-falling days, snow-lying days and total monthly snow depth. He then contrasts the winter of 1988/89 as being one of the mildest. This winter is attributed to a south westerly wind (244°), 1.9°C above period average (0.9°C) and below average snowfall, snow-lying days and total monthly snow depth. Therefore, it appears that the influence of the wind direction is attributable to the conditions experienced. The shift towards a more westerly, maritime airstream aiding the overall decrease in snow trends at the Cairngorms.

4.6.4 Wind Direction Interpretation

Caution is required in attributing these wind direction values to snow cover, depth and fall as these are three month means and therefore a month of easterly airflow accounting for increased snowfall, cover and depth could be unaccounted for by two months of westerly winds, thereby giving an overall wind direction mean towards the south west. An example of this is during the winter of 1985/86; whereby February had a mean wind direction of 98° but the winter mean wind direction was 164°. February 1986 was when most of the heavy snowfall occurred, with snow lying for the whole month at levels done to 200m (Harrison, 1993), and this highlights the caution involved in taking these winter means as absolute values and attributing them to the other variable trends.

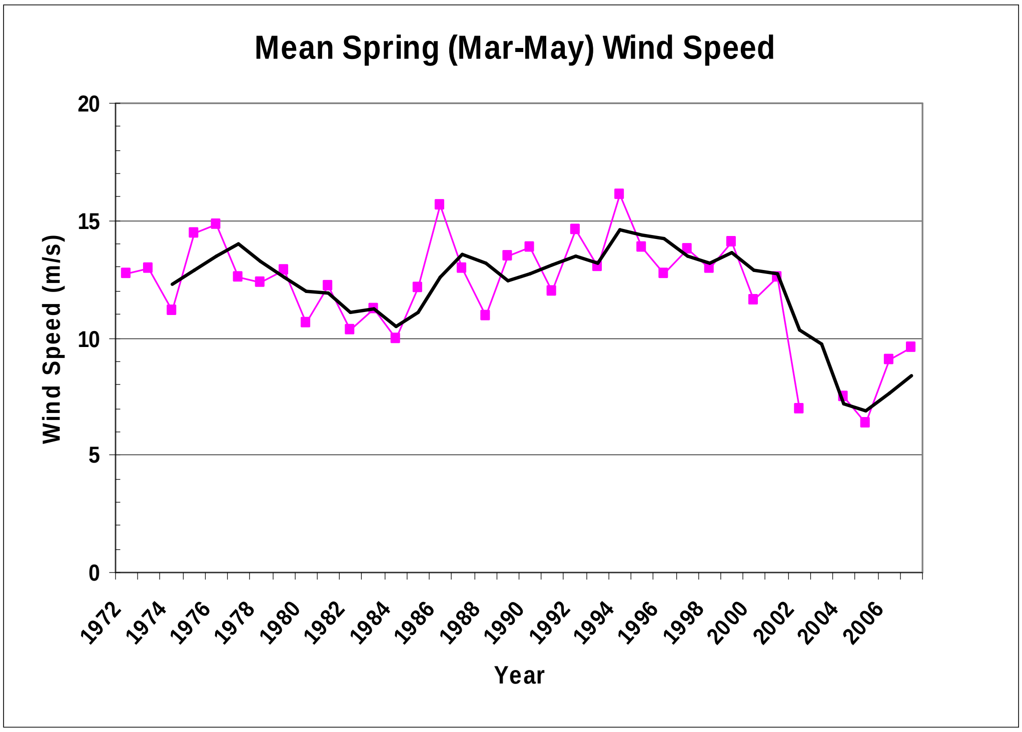

Figure 4.6.1.1 The mean spring (March-May) wind speed (m/s)

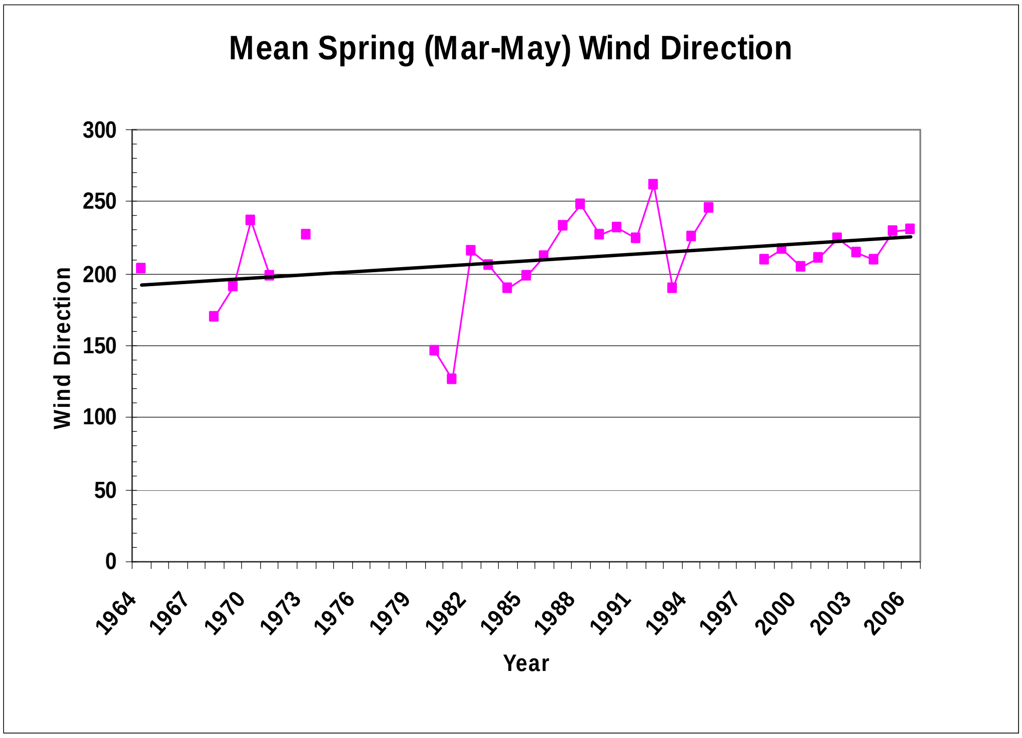

Figure 4.6.2.1 The mean spring (March-May) wind direction

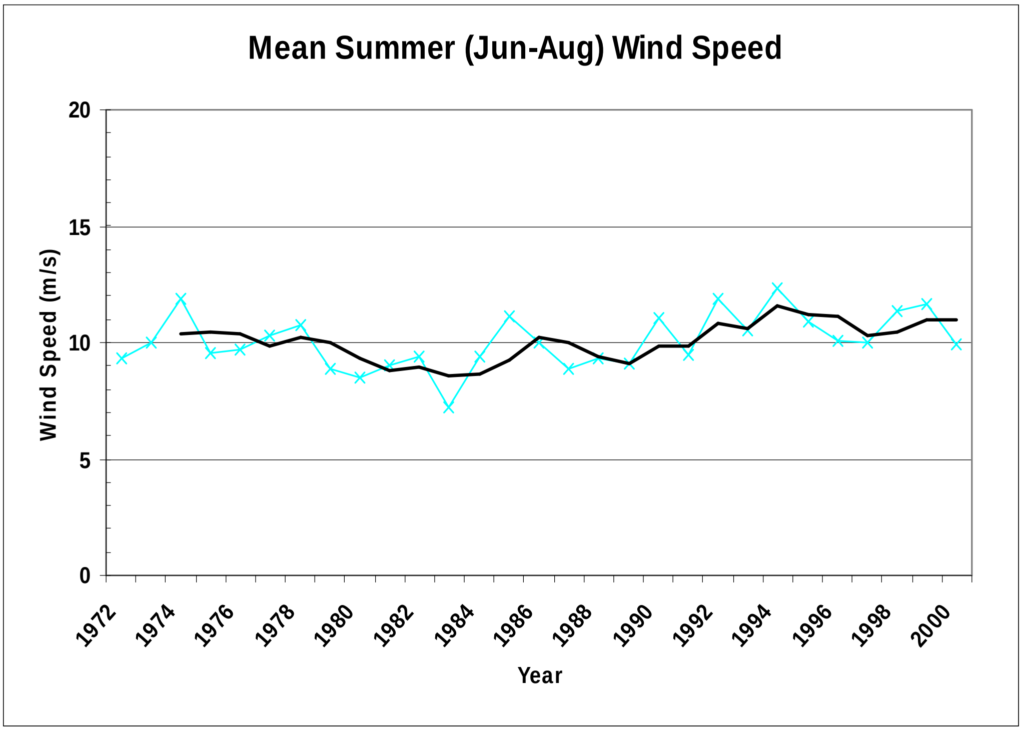

Figure 4.6.1.2 The mean summer (June-August) wind speed (m/s)

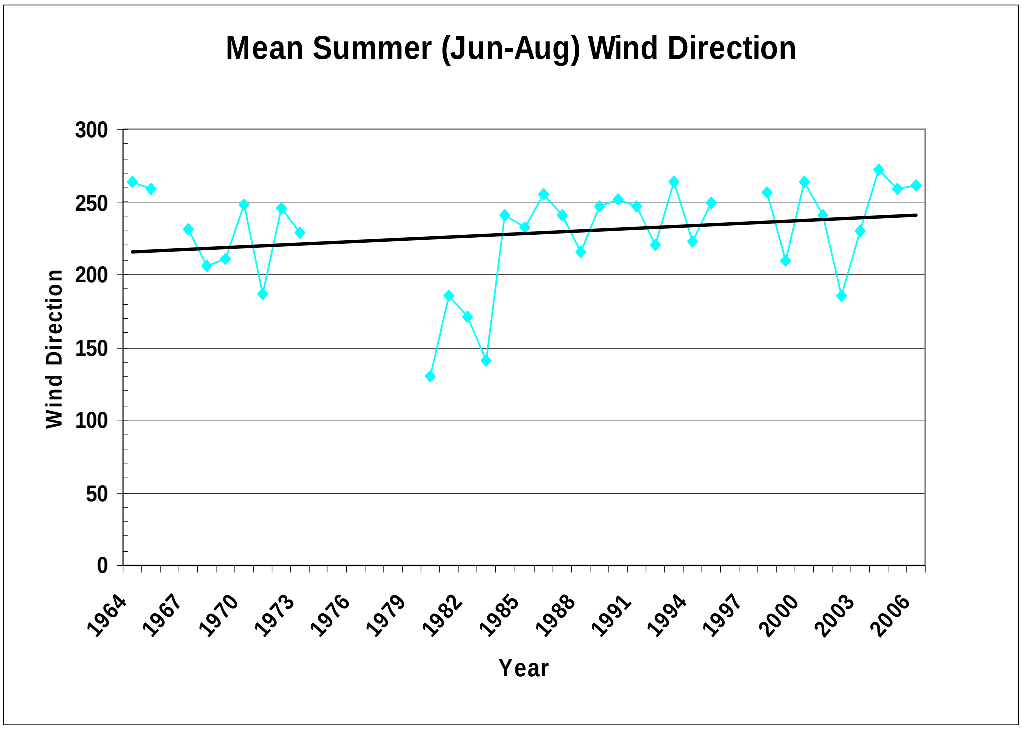

Figure 4.6.2.2 The mean summer (June-August) wind direction

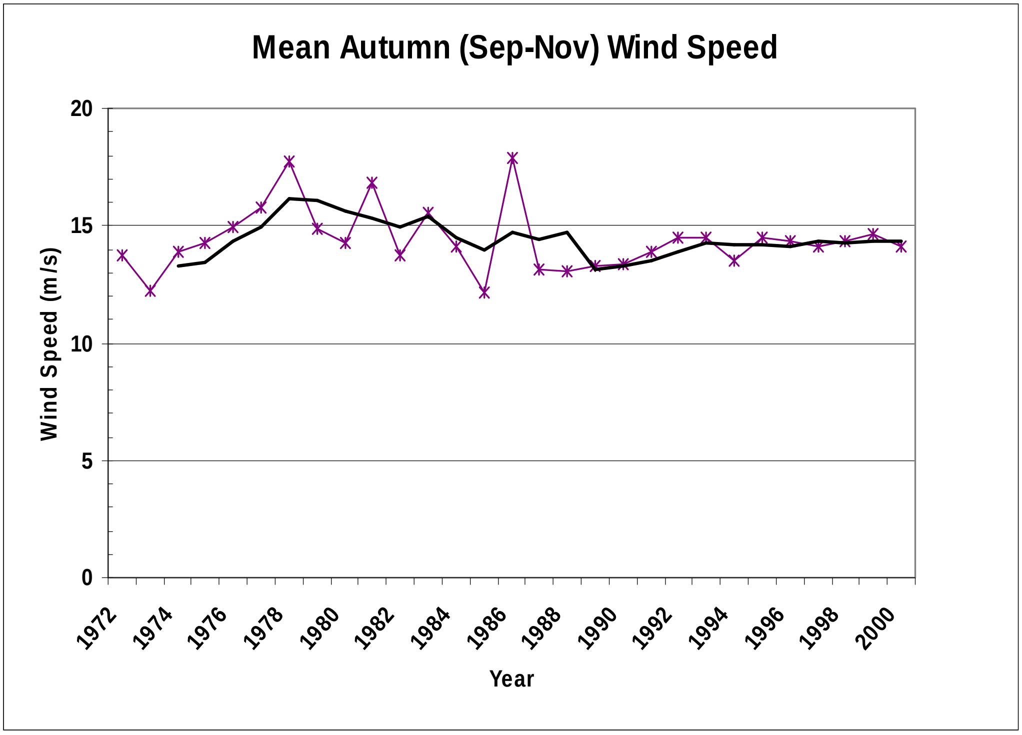

Figure 4.6.1.3 The mean autumn (September-November) wind speed (m/s)

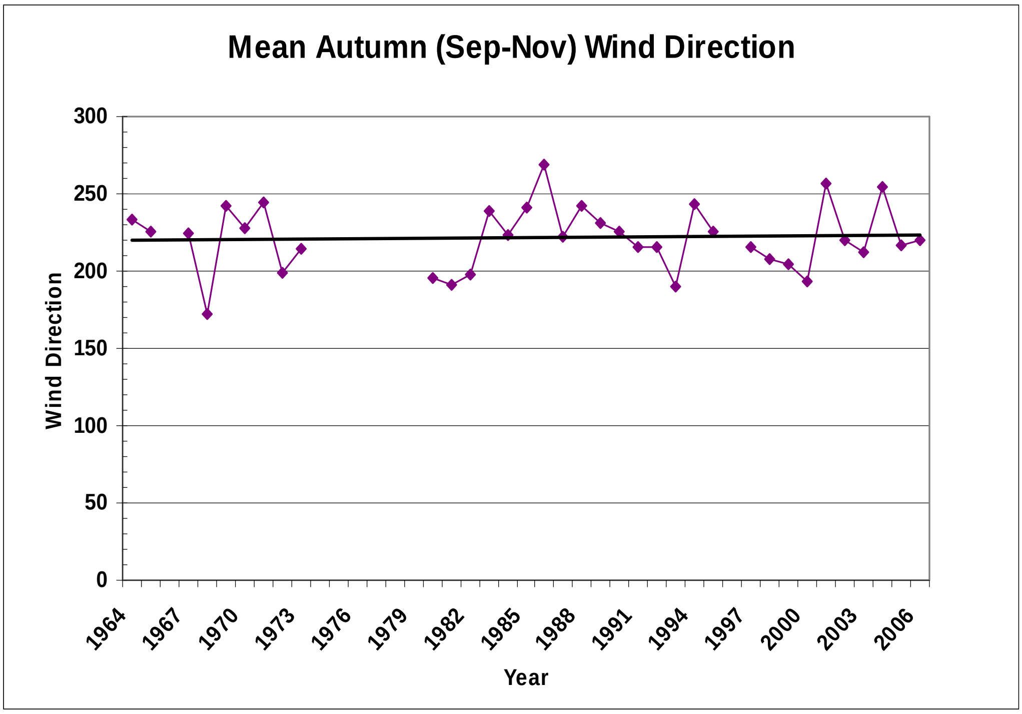

Figure 4.6.2.3 The mean autumn (September-November) wind direction

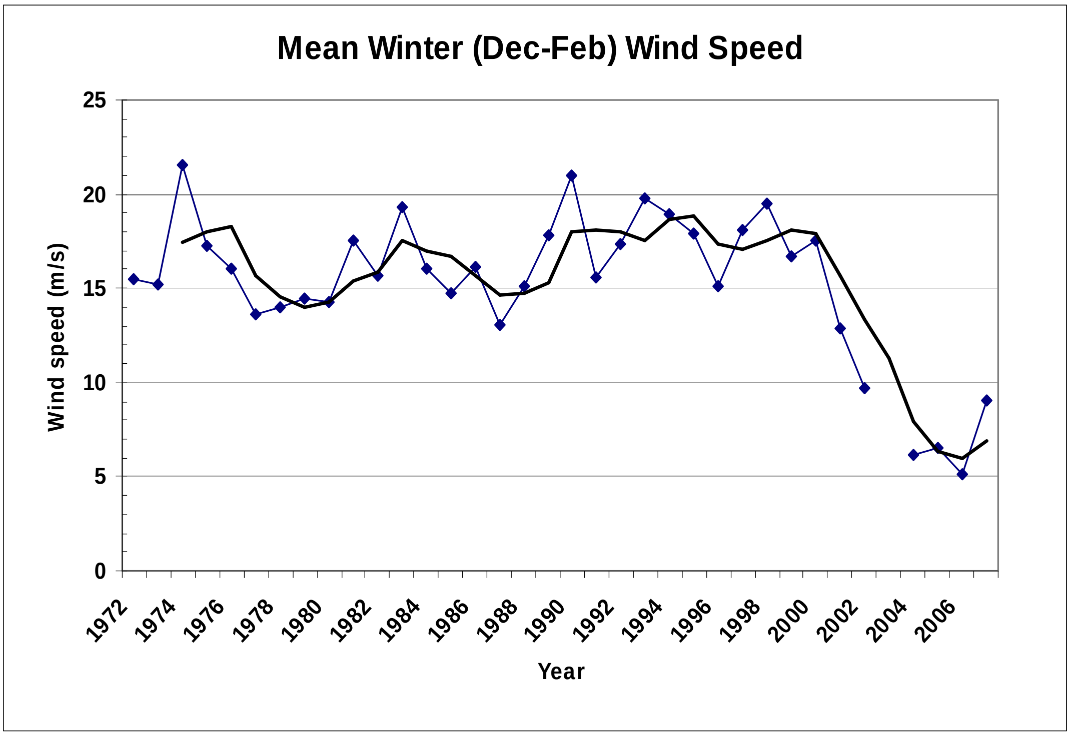

Figure 4.6.1.4 The mean winter (December-February) wind speed (m/s)

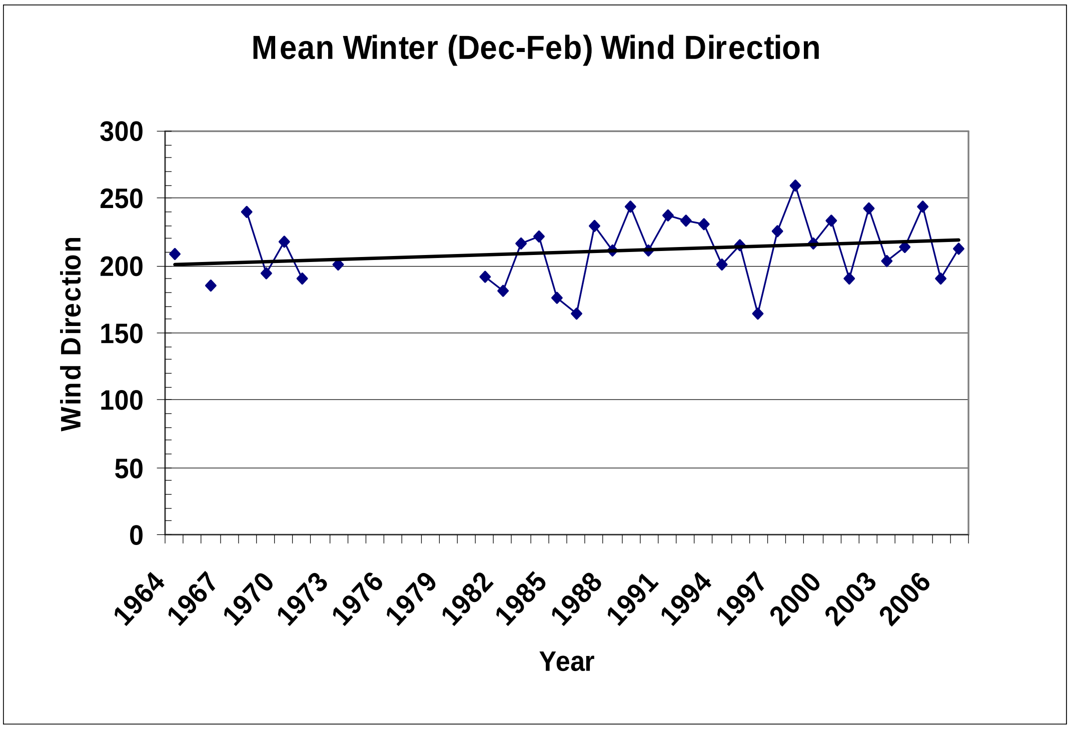

Figure 4.6.2.4 The mean winter (December-February) wind direction

4.7 Ski Run Data

Five of the six Cairngorm lifts investigated exhibit a decreasing trend, the highest lift, Ptarmigan (figure 4.7.6), showing a slight increase over the 1972-2006 period. As expected, the runs at higher levels fair better than the runs at lower levels and this is because snow has a greater longevity at higher, colder levels. It may also be due to the milder temperatures contributing to a greater amount of snowfall at these higher levels (Harrison *et al*, 2001). Also striking is the interannual variability in the number of days each lift is open. This is due to some lifts not running due to maintenance, high winds, poor visibility, and other lifts running which would service the same run that the lift under investigation would service (sometimes West Wall Poma closed when Coire n Ciste opens). Also if there is a lack of demand for lifts, they are closed for the day. All these reasons do not necessarily mean there is not a full a full length run - they are just logistical reasons, and so therefore caution must be advised into interpreting these trends and values as being absolute and indicative of snow cover.

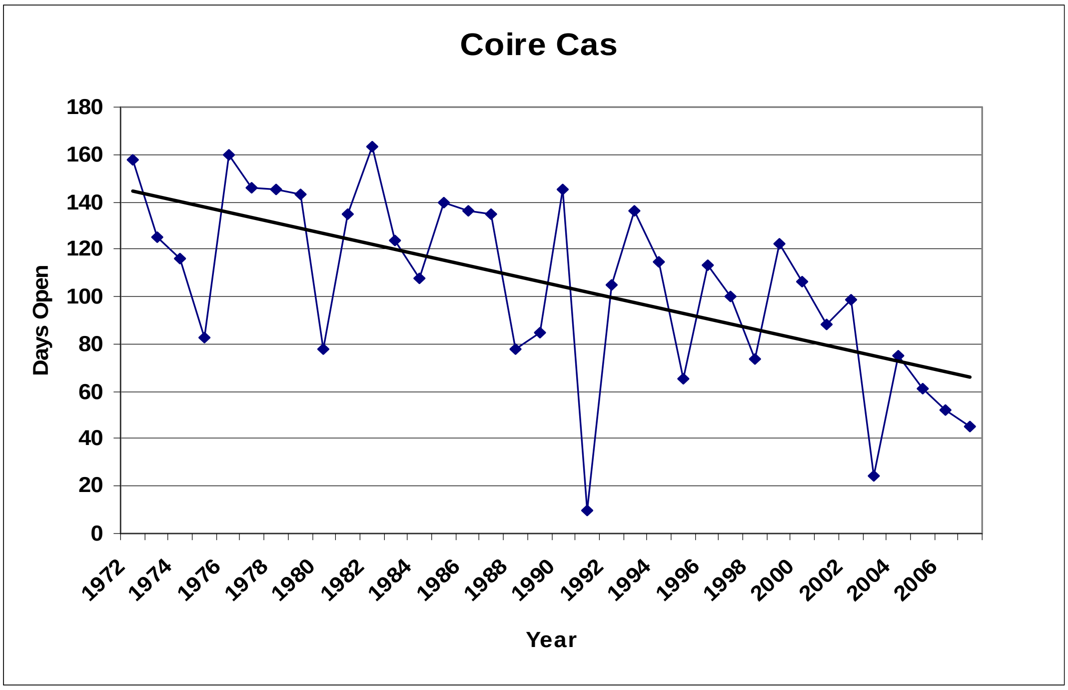

Figure 4.7.1 Number of days with a full length run available on Coire Cas, altitude: 760 –1000m. Data up to 1996 provided by Harrison *et al* (1999)

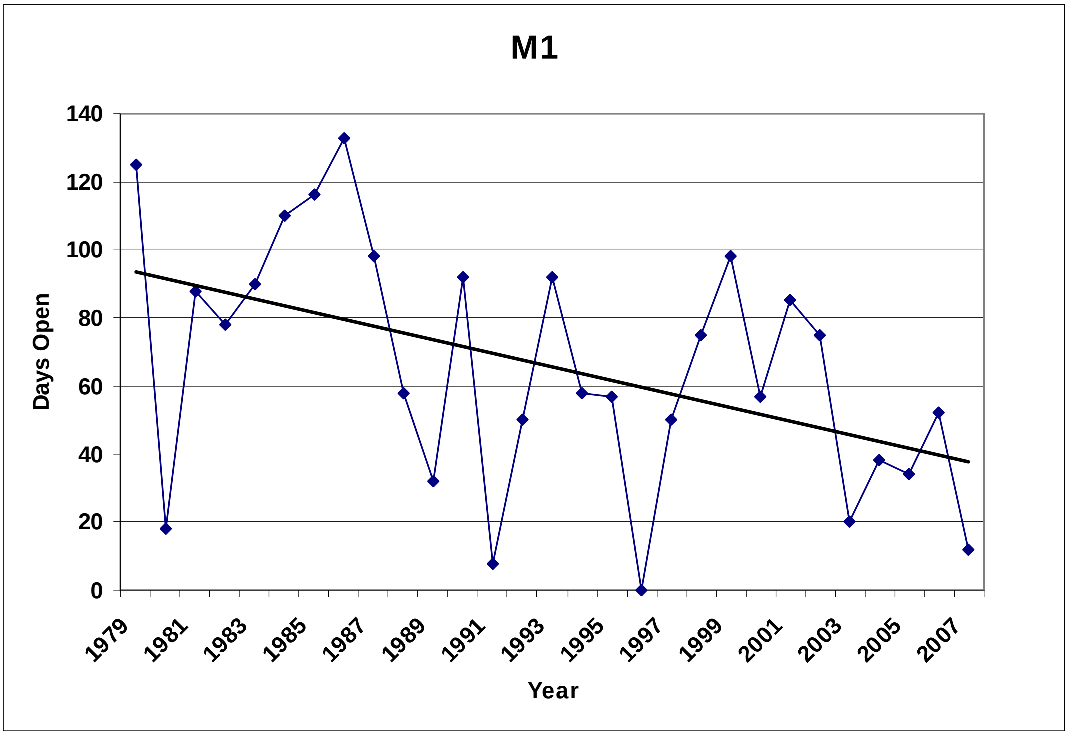

Figure 4.7.2 Number of days with a full run available on M1, altitude: 800-1050m. Data up to 1996 provided by Harrison *et al* (1999)

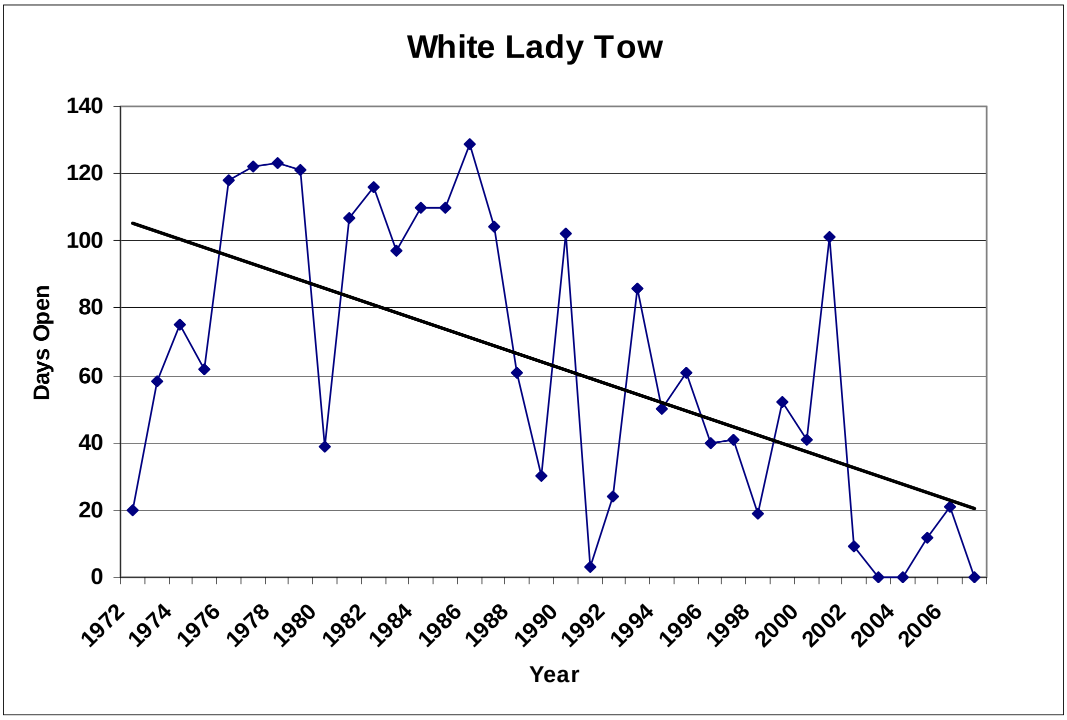

Figure 4.7.3 Number of days with a full length run available on White Lady Tow, altitude 750-1080m. Data up to1996 provided by Harrison *et al* (1999)

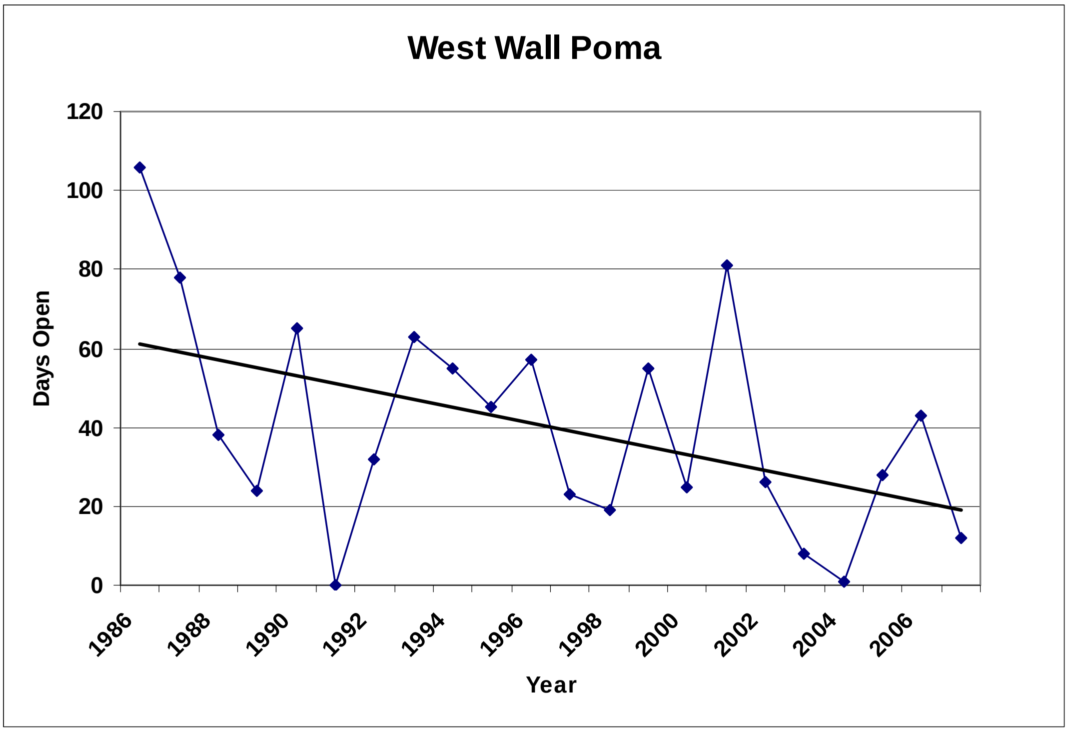

Figure 4.7.4 Number of days with a full length run available on West Wall Poma, altitude: 720-1060m. Data up to 1996 provided by Harrison *et al* (1999)

High Level Runs

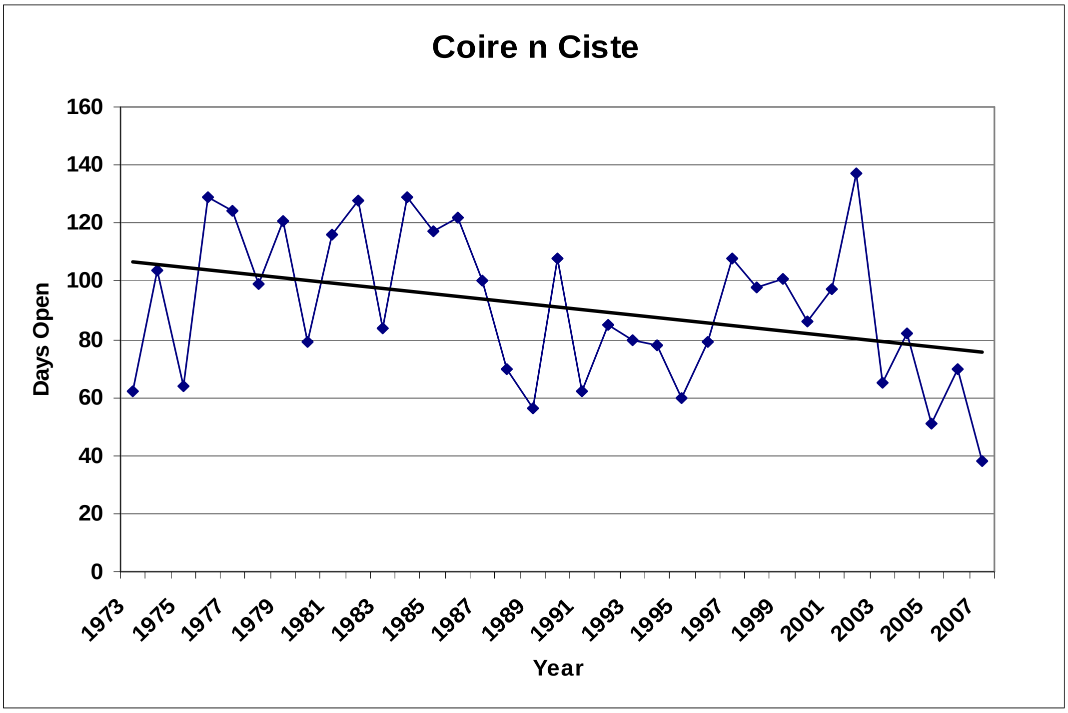

Figure 4.7.5 Number of days with a full length run available on Coire n Ciste, altitude: 980–1090m. Data up to 1996 provided by Harrison *et al* (1999)

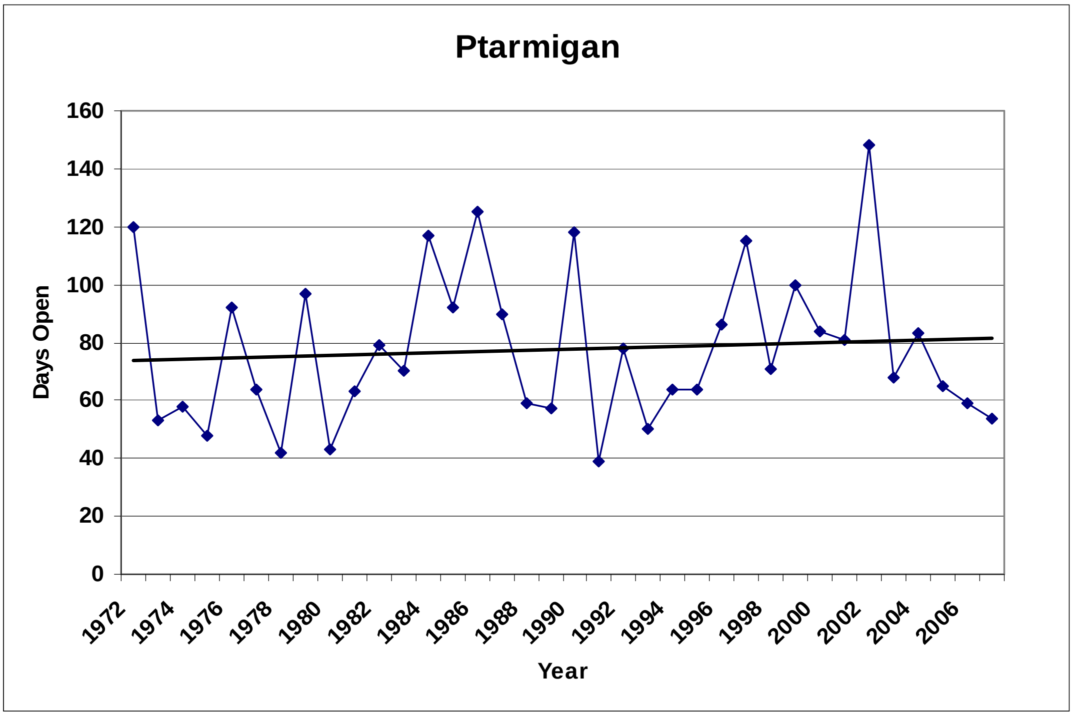

Figure 4.7.6 Number of days with a full length run available on Ptarmigan, altitude: 1060-1150m. Data up to 1996 provided by Harrison *et al* (1999)

4.8 North Atlantic Oscillation

Figure 4.8.1 shows the relationship between the North Atlantic Oscillation (NAO) winter index and the mean winter temperature values for the Cairngorms. In both variables, winter is defined as being December to March. What is apparent in the line graph is that there is a correlation between the mean winter temperature and the NAO winter index, with the below zero winter mean temperatures generally coinciding with the negative NAO index winters. This complicated relationship is also shown in figure 4.8.2. A similar relationship can be seen in figure 4.8.3, with a positive NAO winter index roughly correlating to higher snowfalls, and this has been found by Trivedi *et al* (2007) whereby precipitation levels appear to increase in high NAO index winters.

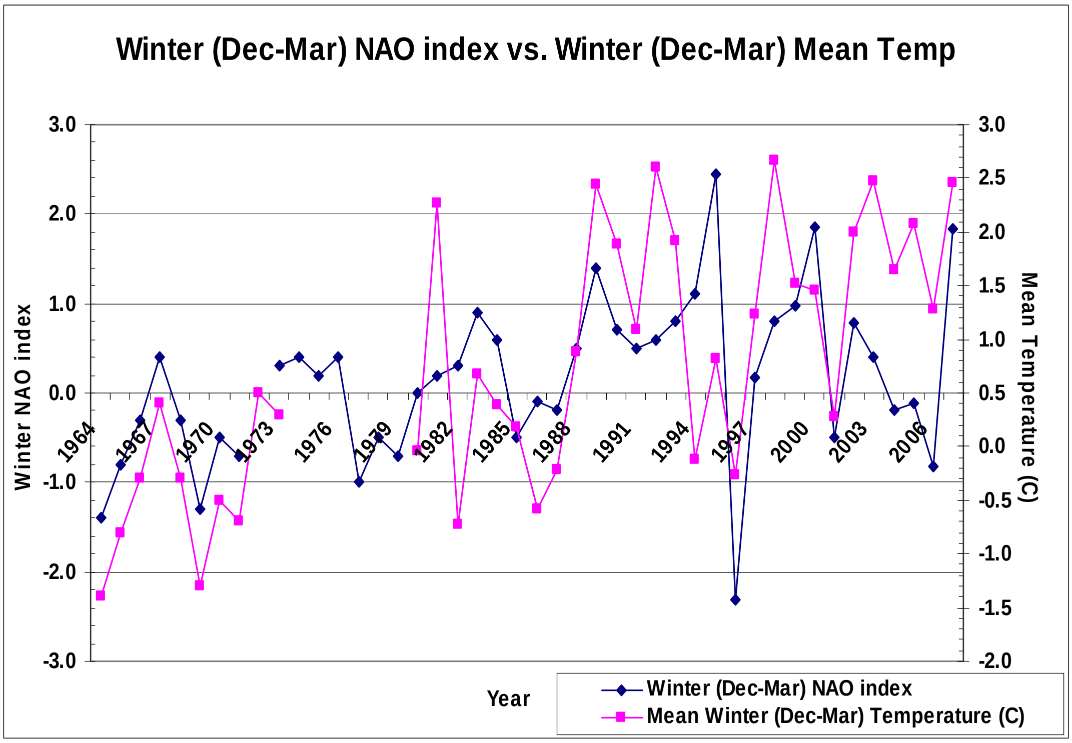

Figure 4.8.1 The winter (December-March) North Atlantic Oscillation (NAO) index relationship to the mean winter (December-March) temperature. NAO values from http://www.cru.uea.ac.uk/cru/data/nao.htm

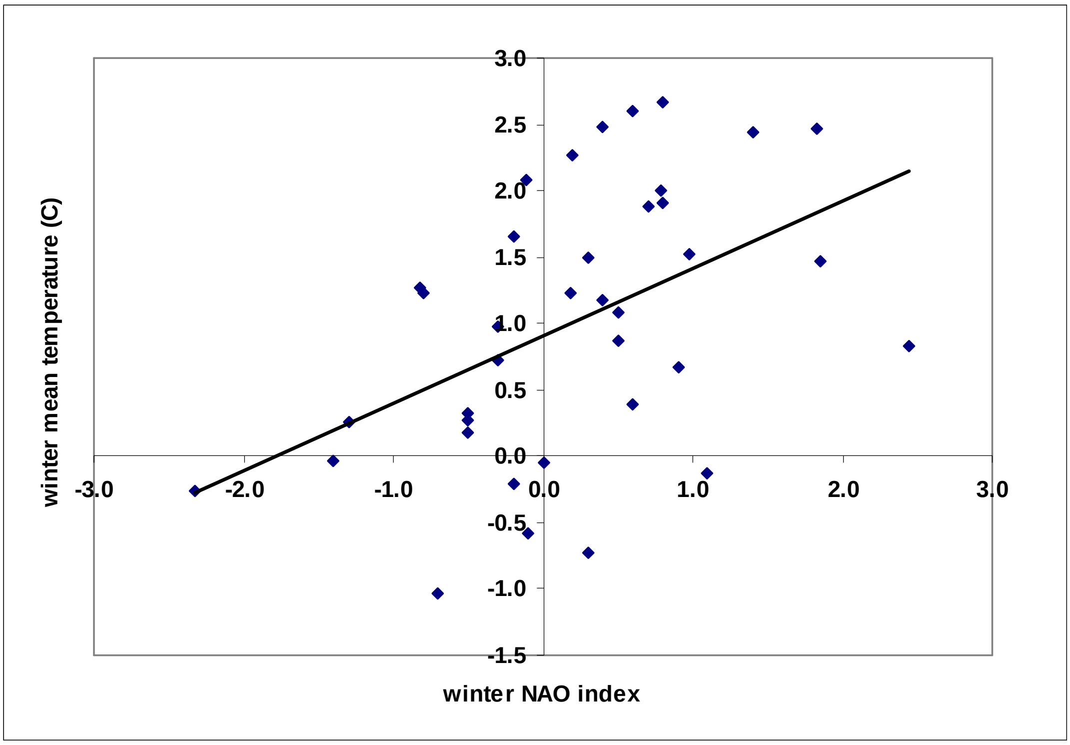

Figure 4.8.2 The winter (December-March) North Atlantic Oscillation (NAO) index relationship to the mean winter (December-March) temperature. Correlation R^2 value at 0.3466. NAO values fromhttp://www.cru.uea.ac.uk/cru/data/nao.htm

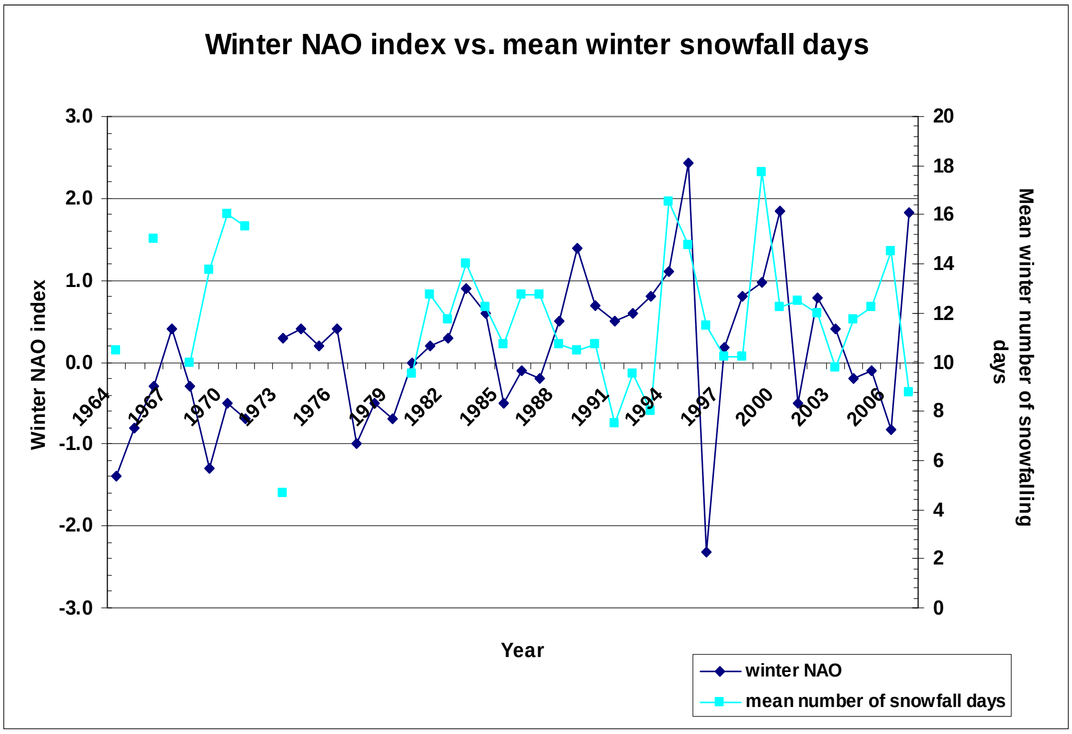

Figure 4.8.3 The winter (December-March) North Atlantic Oscillation (NAO) index relationship to the mean winter (December-March) snow-falling days. NAO values from http://www.cru.uea.ac.uk/cru/data/nao.htm

4.9 Temperature and Number of Skiers

In Figure 4.9, the annual number of Cairngorm skiers was contrasted to the winter mean annual temperature (December to February) and an inverted relationship is apparent. The higher mean temperature an analogy for lack of snow and skiing opportunities. The only anomalous point in this figure in 1995, where the rise in mean temperature did not coincide with a drop in skier numbers, may be explained by the above average annual number of snow-lying days (figure 4.3.3). There may also be other reasons for the decline in skier numbers and these shall be discussed in Chapter 5.

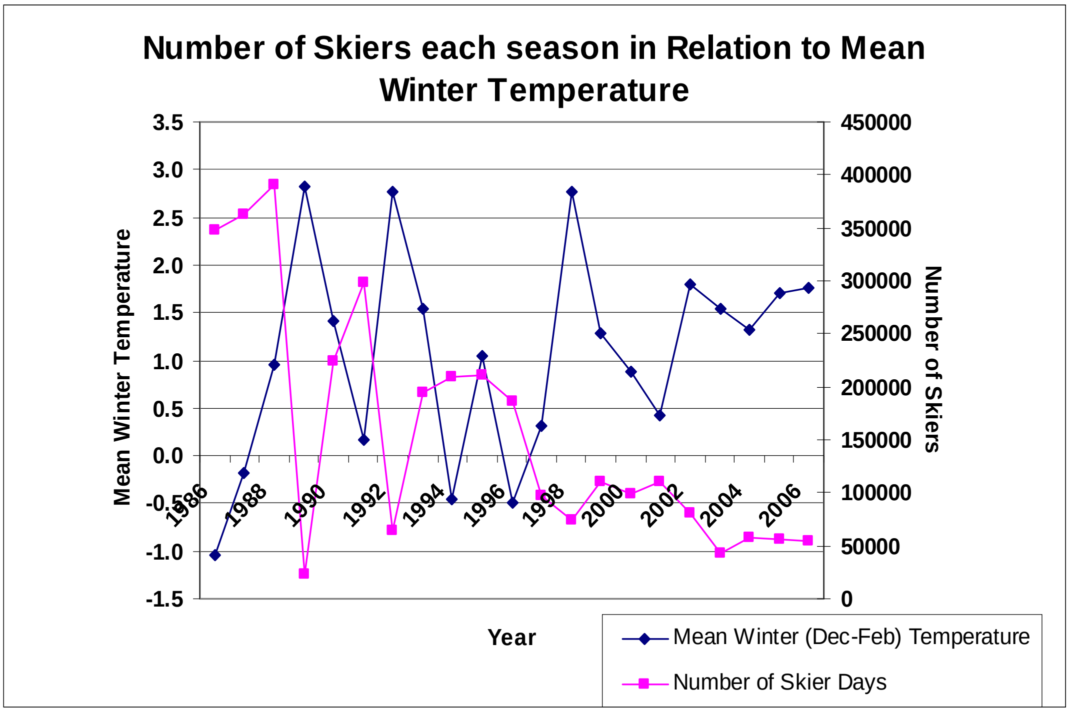

Figure 4.9 Skier numbers compared to mean winter (December-February) temperature

4.10 Trend in Skier Numbers in the Five Scottish Ski Resorts

It is not only Cairngorm that is being affected by changes in snow cover and skiing opportunities. Figure 4.10 depicts the five ski areas in Scotland, with each showing a downwards trend in skier numbers over the years. Interannual variability reflects the snow conditions at the time and even although Cairngorm is the largest ski centre in Scotland, there is little difference in visitor numbers between centres by the end of the 2004/05 season.

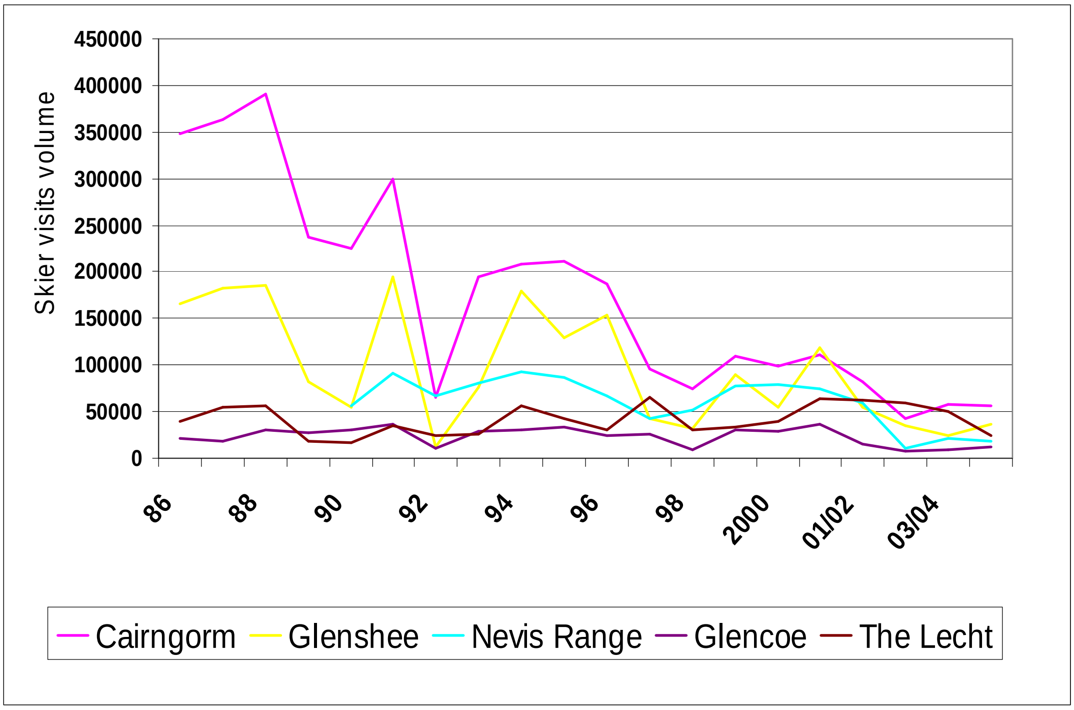

Figure 4.10 Skier visitor volume for the five Scottish ski centres

4.11 Chapter Summary

In summary, the main findings are:

- Temperature has increased since the 1960s and consequently the number of snow lying days has decreased, jeopardising the future of Cairngorm skiing.
- Temperature is the main variable determining snow cover duration and depth, this conclusion concordant with Beniston (1997).
- Summer temperatures have exhibited the greatest increase, with the annual range of temperatures increasing since the 1960s.
- The apparent rate of increase in temperatures between months at the decadal scale provides some explanation to the reduction in snow-lying days over the decades; the consequent faster thaw attributing to a reduced snow cover season
- The relationship between snowfall and temperature is not straightforward, as shown in figure 4.1.3.

- The annual number of snow-falling days has shown a slight increase but generally stayed consistent since the 1980s (±10 days), a trend which was not expected. However the amount of snow falling is unknown; it could be that although there are more snow-falling days, there is less snow falling each day.
- The winter and spring wind speeds have decreased considerably since 2000, culminating in a lack of wind blown snow in the gullies and contributing to the recent poor ski seasons.
- The seasonal wind direction has become more westerly but there is still interannual variability which contributes to snow cover.
- The overall increase in temperatures and reduced snow cover attributes to a decline in ski lift operation in Cairngorm, indicating a decline in skiing opportunities.
- The large scale forcing of the North Atlantic Oscillation (NAO) has some effect on mean winter temperatures and snowfall but the relationship is not strong due to other regional factors (aspect, elevation and relief, wind direction) impacting on temperature and snow.
- Cairngorm has experience a substantial decrease in skier numbers since 1986.

In light of this, I now turn to other sources of evidence in which to further understand the changes in snow and skiing conditions on Cairngorm Mountain.

5

<u>Ski community: textual accounts and contemporary perceptions/insights</u>

This chapter consists of other evidence to corroborate the quantitative, in which I have turned towards a textual account and towards those people affected by these climate changes.

The snow-lying days, snow-falling days and total monthly snow depth variables can be used to generate the snow climate variable trends over the last forty years. For an understanding of skiing conditions, however, textual sources such as the Scottish Ski Club Journal need to be explored. . Even although this journal provided a limited insight (no relevant accounts in the 1980s) about snow amounts and skiing quality, an understanding of skiing, climate and perception can be approached.

<u>5.1 Scottish Ski Club Journal Accounts</u>

In 1966, it is reported that the weather is not kind in the *normal* seasons of March and April, but it is wonderful in January and early February. This disagrees with Heller (1969), whereby he testifies that the winter season (December-February) in Scotland is not only doubtful for skiable snow but it is also unpleasant as far as weather is concerned. This contrast does not necessarily mean that one account is wrong - it merely shows that different regional conditions are apparent in Scotland and underlines the importance of investigating at the local scale. What is also interesting in the 1966 report is the fact that March and April are described as being the 'normal' season. From March onwards both snow and weather conditions are reported to improve, and the best Scottish conditions almost invariably prevail from early April to mid May. This indicates that the length of ski season was much longer in the 1960s compared to now, with figure 4.2.2.2 showing this decline in spring snow-lying days.

In 1971, the Scottish Ski Club recognised that Scottish skiing is struggling to establish itself as a commercial proposition and that the mild winter and reduced snow-lying days culminated in some ski tows in Cairngorm not being in operation for the first time. This affected skiing on Cairngorm, and it was described as “the worst since the creation of mechanised ski areas” (Scottish Ski Club Journal, 1971, 7). Cairngorm was also informed by the Glasgow Weather Centre that the general pattern is for the winters to be much colder. The actual winter temperature increase (figure 4.2.1.4) highlighting the uncertainty in making weather forecasts, particularly at the local scale.

In 1993, the high snowfall (figure 4.2.2.1) contributed to the dismissal of any theories about climate change affecting snowfall in Scotland (Scottish Ski Club Journal, 1993). The skiing continued until June 1st on Cairngorm and this was the first time this had happened in seventeen years.

The 1998/99 season gave renewed hope for the viability of Scottish skiing and this is evident in the last major positive winter snow-lying day variance peak (figure 4.2.1.2) and the spring total monthly snow depth (figure 4.2.2.3). However, it was also realised that the Scottish ski industry is declining and this is due to snow conditions, weather conditions and the ease of foreign travel. Bob Kinnaird, of Cairngorm Mountain, comments on this decline:

> “Times have changed: it is as easy to go skiing in North America as it is in the Alps and with the advent of cheap air carriers, the time share in the Highlands suddenly does not look such an attractive option. Admittedly the winters have not been as good recently, but even if they had I suspect the days of the Scottish purist were already numbered” (Scottish Ski Club Journal, 1999, 19)

Previous poor winters also create a skiing perception that skiing in Scotland is no longer viable or worthwhile. This is noted in the Scottish Ski Club Journal, with the previous poor conditions experienced having a direct effect on customer confidence. This is concurred by the Lecht Ski Company who complained of having no customers even although ‘alpine conditions’ were experienced in late February and early March; “it is almost as if, when there is no snow in the cities people think we (ski resorts) don’t have any either” (Scottish Ski Club Journal, 1999, 38). Perception of snow cover and skiing opportunities therefore is a factor in the ski industry success.

5.2 Scottish Ski Club Journal Summary

- Cairngorm is prone to stormy conditions which prevent skiing.
- The skiing season lasted much longer in the 1960s; starting earlier (~November) and finishing later (~May).
- Cairngorm was predicted to generally have colder winter temperatures, a trend which did not materialise (figure 4.2.1.4).
- High snowfall in 1993 dismissed snowfall reduction theories.
- By the late 1990s, Cairngorm realised that skiing opportunities were decreasing and this was due to snow conditions and ease of foreign travel.

- Customer confidence/perception is affected by poor winters and this affects skier numbers in subsequent ski seasons.
- Scotland has always been a marginal ski destination.

In light of these findings, I will now address some contemporary testimonies which provide further understanding of the impacts that the decline in skiing opportunities has had on the tourism of Cairngorm and Aviemore.

5.3 User Community Testimonies

In exploring the effect that the climate has had on tourism businesses in Cairngorm and Aviemore, I identified three key contacts; Cairngorm Mountain, Aviemore Business Association and the Cairngorms National Park. Through these interviews various key points were raised and this has provided a more complete appreciation of the business and tourism changes can be achieved.

5.3.1 Cairngorm Skiing & Perception

In interviewing Bob Kinnaird of Cairngorm Mountain, he was very adamant that skiing would continue to be the core winter product. He highlighted the unpredictability of the weather and the need to have a suitable business approach; "In business terms you make decisions in terms of six months - a year - five years, and you adapt and you change, and there is no reason to believe that we will not have snow to ski on this mountain over the next five-ten years. There is also no reason to believe that over that time we will not have a bumper winter". However, recognition was also given to the fact that Cairngorm (and Scotland) no longer receives the same snow cover duration, and the impact the warmer climate was having on the lower run sections, "Virtually every season now we can only ski the upper half of the Coire Cas - that would have been unheard of in the past" (Bob Kinnaird, Cairngorm Mountain). Therefore, it is evident that the snow climate has changed on Cairngorm. Cairngorm experiences markedly different winter climate patterns from continental Europe, due to its geographical location and the influence of the Gulf Stream; bringing warm waters from the south and subsequently impacting on the weather conditions. This causes our winters to be milder than similar latitudinal locations in Canada, for example, and consequently impacts on skiing in Cairngorm, which was acknowledged by Bob Kinnaird, "The Alpine climate life is a lot simpler plus it is a lot more consistent - when you start operating in the winter you know what you are getting the next day. Here it is a lot more complex. Our temperatures are right on the edge. We are a very marginal ski area." This contrast with the European climate introduces the next point.

5.3.2 Costs, Investment and Snow-making

With the warmer climate impacting on Cairngorm skiing, Cairngorm has been decided to reduce the skiing area, with lifts set up in the 1960/70s no longer serving the current market. The current snow climate experienced has forced Cairngorm to reconsider their ski plans;

> "What we would need is probably a string of about four good winters, where we made a reasonable return which allowed us to accrue the capital that is necessary to reinvest in the ski area. Then what would we do? We would actually still take out these lifts, including the white lady and some of these old lifts because they have been here for 40years! They have had their day and we would replace them with

these more strategic uplifts which would cater for the capacity and access most of the snow" (Bob Kinnaird, Cairngorm Mountain).

However, even with a smaller area to service, there is still the same investment of ~£750,000 on skiing before the season begins. However, the investment required, as mentioned by Bob Kinnaird, can be comparatively higher than in Europe, "The irony is that the cost of running a ski area in Scotland is proportionally higher than running an Alpine resort because of the age of the tows (they need a lot more repair), because of the weather (the tows get a lot more damaged – damp, humid atmosphere – things rust a lot quicker and there is wind damage." The state of the ski infrastructure and the decline in skier numbers (figure 4.7) has influenced the cost of skiing at Cairngorm (figure 5.3.2), with high prices compensating the market decline and initial investment costs. It should be noted that figure 5.3.2 only represents a sample of ski resorts around the world, but it provides a useful insight into understanding why more people are going abroad to ski.

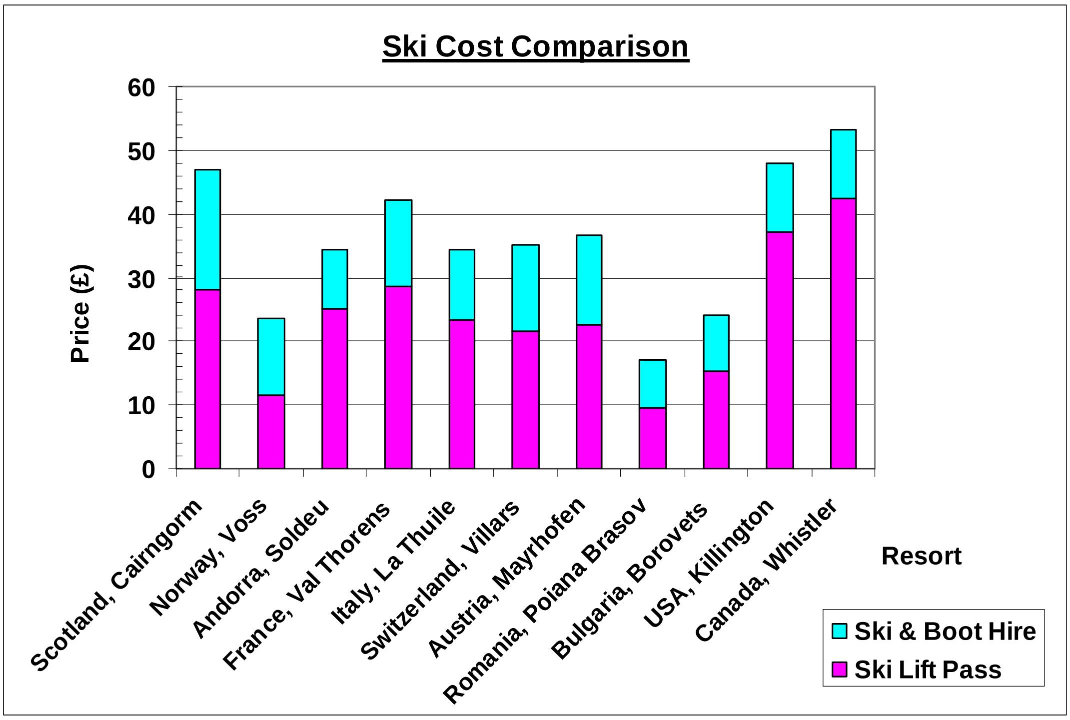

Fig 5.3.2 Comparing adult prices in Europe and North America based on 1 day lift pass with ski and boot hire. Prices based on 07/08 season and obtain from http://www.inghams.co.uk/ski/index.aspx Cairngorm prices obtained from http://www.cairngormmountain.org.uk/ski-essentials/snowsports-ticket-prices-2007-2008/

With the decline in snow cover and the competition from abroad, it would be reasonable to assume that Cairngorm would utilise snowmaking. However, with the inconsistent temperatures and the fact that Cairngorm represents a high sub arctic environment in the centre of a National Park, snowmaking becomes a feasibility issue;

"We have looked at making snow but again to make snow you need obviously capital in order to buy your snow making equipment, you need water, you need energy – there is a revenue cost to doing that. So there is an investment. Plus there is an environmental impact assessment about where you get that water from and whether you can use any chemicals in the making of the snow. This wouldn't be allowed here and then you have to look at the cost versus the benefit. And how much snow do you have to make to make a critical mass to offer skiing all the way through winter? A lot of investment is required and if you invest in that, with the way climate is going, will that benefit work?" (Bob Kinnaird, Cairngorm Mountain)

Investors' snow perception is also a factor, with the majority of investors no longer viewing Scotland as a ski destination in the current and forecasted climate. Cairngorm are looking into snowmaking, with technology continually advancing, but Cairngorm appear to be looking to the future, to "climate proof" their business and strive to be beneficial in terms of the environmental, social and economic community.

5.3.3 Climate Change and Funicular

This necessity for Cairngorm to "climate proof" their business forms the basis for their vision and the changes taking place on the mountain. One of the visions objectives is to "develop products and services for which climate is an opportunity, rather than a threat" (Cairngorm Mountain, 2006, 5). This argument has also been highlighted by the Cairngorms National Park, with Heather Galbraith, sustainability officer, commenting; "I think that climate change has been more of an opportunity overall rather than a threat, as it has shaken us up and accelerated the need to change and thus given a stronger, more year-round economy to the area." This has had implications for the tourism infrastructure in the area, the most notable being the Cairngorm funicular. The funicular plays a big part in the Cairngorm vision as it allows transportation to the top of the mountain in higher winds (<75m.p.h) than the previous chairlifts, but more importantly, it has increased numbers of non-skiers visiting the mountain, thereby increasing not only the winter trade but the year round trade;

> "Last year every ski area struggled but our market share changed from 34% of the Scottish market in 05/06 and last year (06/07) we were almost 50% of the Scottish market. This was because the funicular allows you to access the high level snow whereas other Scottish ski centres couldn't do this. It has also delivered environmentally, socially and economically to the area – with the numbers of non-skiing visitors increasing each year which is very important for the future" (Bob Kinnaird, Cairngorm Mountain).

The climate has accelerated Cairngorm's infrastructure changes but the transformation of the tourism market has also contributed to business change.

<u>5.3.4 Vision and Tourism Market Change</u>

It is important to investigate reasons why this vision, this strive to become more of a year-round destination, has occurred. There appears to be other factors than the climate which have contributed to the market change;

> "The skiing market is no longer as big – even if we had full cover of snow all winter, we would not get the skiing numbers that we had in the 1980s. Not just because of climate change but also because of the demographics, globalisation of winter sports tourism, and trends in what people do – people's behaviour and expectations have changed" (Bob Kinnaird, Cairngorm Mountain).

Therefore, there appears to be a social dimension contributing to the changes. The ease of foreign travel and the cheaper prices (figure 5.2.2) has obviously intensified competition. Further impact can largely be contributed to the media's influence on the public's perception of the snow cover changes, which in turn has contributed to the lack of investment in ski infrastructure. Expanding Bob Kinnaird's point about people's behaviour and expectations, the tourist market has developed through visual evidence of climatic changes coming from snow level and coverage changes in the Cairngorm area. Resultant holiday patterns have changed and this has aided other tourist pursuits, "Because the winter is not so severe, people are willing to come up and get muddy. Even in the 1990s you just wouldn't be able to go out and mountain bike because you are knee deep in snow, even at lower levels. The warmer temperatures and decline in snow duration has led to a lengthened summer season" (Jonathan Gatenby, Chairman of Aviemore Business Association). Consequently, it is this climate change awareness, accentuated by the poor skiing opportunities on Cairngorm, and tourist behaviour in light of this which has generated this shift to sustainable tourism.

5.3.5 Sustainable Tourism and Diversification

Through the media, people are more aware about 'green issues' and therefore the *need* for sustainable tourism. Sustainable tourism is "simply about asset management, where development and activity guarantees the integrity of the resource on which the industry is based (be it cultural, physical or otherwise) while maintaining economic viability (Godfrey, 1998, 214). Therefore, with Cairngorm's skiing viability under threat, there appears to be a heightened awareness of the climate impact and a need to diversify to continue to provide for the community in a sustainable fashion;

> "This business is measured on triple bottom line – social, environmental and economic. And it is the social and environmental that is crucial in the medium long

term so it's about looking after why people come here in the first place. We need look at the problem at where we fit into the bigger picture – in a fragile highland economy, within a Scottish National Park, within the looking of our communities. Therefore to continue to provide we needed to change our approach" (Bob Kinnaird, Cairngorm Mountain)

Diversification has therefore proved to be the next logical step and it has been driven by the climate impacting on the skiing opportunities but, equally, by the expansion of the "green economy". Cairngorm understands this and have therefore developed that market;

"There is a tipping point of awareness. Climate change is happening but along side that there is a much greater awareness of climate change. This year, over the last twelve months, there has been a massive tipping point of that awareness and we see i it every day in the press, in our social standards, what we do. And clearly that is a trend that will continue. For instance, ethical consumerism and ethical retailing is growing at something like 16% a year where normal retailing is not, so it makes total sense to get into that sector and it's a way to differentiate from competitors" (Bob Kinnaird, Cairngorm Mountain).

What is also emerging is a trend in innovative tourism; an experience and educational economy. What Cairngorm is attempting is to provide "a powerful mean to inspire people to want to live in more ecologically sustainable ways – through a connection with nature" (Cairngorm Mountain, 2006, 6). The reasons for this tourism shift and, particularly, in generating a sense of place through Cairngorm's Arts Initiative are outline below;

> "Because of climate change and because of skiing, we are right on the forefront of having to adapt our offering and I think that helps people to focus and understand the tangible implications of climate change. This is a good way of engaging people so I think it's a good opportunity and a good site and of course I think the climate is right concerning the trends and peoples behaviour. People are looking for an authentic experience; they are not looking for a shallow "disneyfication" of the mountain. They are looking for something they can live with and understand and hopefully also develop there own thinking. This is where the Arts project comes in. It broadens the offering and adds to authenticity; with artistic, mountain and cultural dimensions. This generates a sense of place which customers can find engaging and inspirational" (Bob Kinnaird, Cairngorm Mountain).

Thus, climate change has given Cairngorm an opportunity to identify other ways/opportunities on this mountain, with the resultant impact on Aviemore now discussed.

5.3.6 Aviemore

Aviemore became the first year-round purpose-built holiday resort in the 1960s when commercial skiing was introduced to Cairngorm. The Aviemore Centre suffered financial problems in the early 1980s and experienced a lack of investment and bad publicity. However, in recent years there has been a shift in attitudes, with businesses beginning to market Aviemore's assets;

> "The Aviemore Centre was still run down but businesses started to realise this wasn't the end of Aviemore. There were lots of independent traders who decided to stop looking 'inwards' to the aviemore centre, because in looking 'outwards' you realise we have some of the most stunning scenery in Britain, access to the outdoors with a variety of things to do which is nearly unprecedented and we have good road infrastructures" (Jonathan Gatenby, Chairman of Aviemore Business Association)

Cairngorm's activities and tourism trends have also impacted positively on Aviemore, and this can largely be attributed to the funicular, the creation of the Cairngorms National Park and now the redevelopment of the Aviemore Centre. This has combined to create a huge rise in business confidence.

<u>5.3.6.1 Destination Marketing</u>

This redevelopment in Aviemore owes a great deal to the formation of the Aviemore Business Association and the Aviemore Destination Management Organisation. These organisations formed in an attempt to convey a more accurate image of the area – which was once described as "a wart on the face of Scotland" (Kelbie, 2001). Jonathan Gatenby further explains this point;

> "The business association has the sole purpose of trying to spread a more accurate image of the area, using those attributes that we thought were most important to our businesses - the outdoors. I think that in the long term this will impact on the way this area is viewed because it is being marketed as a cohesive destination, as we needed to do something on a bigger scale which was unachievable through our individual efforts. If we are to challenge and compete on a reasonable level with

other international based holiday destinations, and not be sidelined as a has-been ski resort that no longer has skiing, we need to get involved in the additional services and infrastructure that will make it a better destination. You have to look at what the best in the world can offer, and if you are not constantly reassessing where you are a against what you perceive to be the best then you are never going to improve" (Jonathan Gatenby, Chairman of Aviemore Business Association).

Therefore the realisation that Aviemore has to re-invent itself and look to the future, in keeping with Cairngorm's plans, has helped Aviemore recovery and become one of the places to visit in Scottish tourism. The most recent proposal for Aviemore is to create a "world class" family adventure centre which would include a 300ft indoor ski slope, an Olympic size ice rink and an adrenaline course; the augmentation of the natural environment with this activity centre creating more reasons to come and stay in Aviemore (Macaulay, 2008). Thus, it appears that the decline in skiing opportunities has played a contributory role in the changes in Aviemore but there has also been a realisation that Aviemore has the desired assets to accommodate the current trend in sustainable, innovative tourism and in doing so, create a new sense of place.

5.4 User Community Testimonies Summary

In summary, the main findings are:

- Cairngorm still consider skiing as their main core winter product and believe skiing will continue to be possible (at least in near future)
- Cairngorm skiing is very marginal due to the maritime climate compared to Alpine Europe

- Current and future projected climate and changes in ski market size has led to Cairngorm reducing its ski infrastructure
- High cost of skiing on Cairngorm reflects the initial investment cost and the dwindling ski market, with UK skiers prefer foreign ski resorts as they have cheaper prices and more consistent, reliable weather.
- Snowmaking is a feasibility issue for Cairngorm, with the current climate jeopardising any resultant benefits
- Cairngorm has moved to "climate proof" their business, with the introduction of the funicular in 2001 a key step in this process
- The warmer climate and evident lack of skiing opportunities has acted as a catalyst for tourism changes on Cairngorm and in Aviemore
- The public's awareness of 'green issues' has resulted in this diversification into sustainable tourism; Cairngorm's Arts Initiative being an example
- Aviemore has redeveloped from a dilapidated holiday resort geared up for skiing to a vibrant, confident community cohesively marketing their assets
- The transformation of Aviemore has resulted from increased collaboration between operators to deliver a better visitor experience, the development of a Destination Management Organisation, aspirational branding and the realisation that it needs to become a year-round tourist destination

6

Conclusion

This dissertation set out to understand the snow climate of Cairngorm Mountain and the impact of snow cover changes on the skiing opportunities and tourism within the Cairngorm and Aviemore area. This aim was achieved by exploring the evidence in the form of quantitative climate data, textual exegesis and contemporary interviews. The quantitative data was able to provide an understanding of the snow climate on Cairngorm over a forty-two year period, spanning 1964-2006. In generating trends for the mean temperature, snow-lying days, snow-falling days and total monthly snow depth at the seasonal, annual and decadal scale, an understanding of the changes and the relationships between variables was achieved.

6.1 Main Findings

Temperatures have increased steadily since 1964 at the seasonal, annual and decadal scale and consequently the snow-lying days and total monthly snow depths have decreased. The apparent rate of increase in temperatures between months at the decadal scale (figure 4.5.1.2) provides some explanation to the reduction in snow-lying days; the consequential faster thaw attributing to a reduced snow cover season. The number of day with snow falling has stayed fairly consistent, if not exhibiting a slight increasing trend (figure 4.3.2). The winter and spring wind speeds have decreased considerably since 2000, culminating in a lack of wind blown snow in the gullies and contributing to the recent poor ski seasons. This has decreased the skiing opportunities on Cairngorm; with figures 4.7.1 to 4.7.5 illustrating a decrease in full length ski runs open and figure 4.10 showing the associated decrease in skier numbers since 1986. Textual analysis indicates that the skiing season used to begin in November and run until mid May but now the season rarely starts before January and is lucky to continue to mid April. Therefore, through climatic and textual analysis, the commonly held perception that Scottish (Cairngorm) skiing is in a state of decline has been demonstrated. Scotland has always been a marginal ski destination and there have always been times with poor conditions. However, in recent years, the frequency of poor conditions appears to have outweighed the good conditions which make business sustainability more difficult. Scottish skiing appears to have reached a tipping point whereby it will be unsustainable in the long time unless ski resorts diversify. Even although Cairngorm plans to continue skiing, there is a realisation that in order to remain sustainable the business must be 'climate proof'. The warmer climate and evident lack of skiing opportunities has acted as a catalyst for tourism changes on Cairngorm and in Aviemore. The introduction of the funicular in 2001 was a key step towards sustaining the future of the business, as it allowed access to higher level skiing which would otherwise not be possible in windy conditions. The funicular has also proved to be an attraction in itself in that "it offers all-season, mass-access to an environment that is culturally perceived to be 'wild' in a way that is unrivalled in the UK" (Cairngorm Mountain, 2006, 12). The public's awareness of 'green issues' and the need to live in a sustainable way has encouraged this diversification into sustainable tourism; with Cairngorm's ethical consumerism and Arts Initiative examples of such diversification. Aviemore has also been impacted by the decline in skiing opportunities on Cairngorm, with a redevelopment programme currently underway to transform Aviemore from a one-time ski resort to a cohesively marketed destination with a goal of generating a new image of a self-sustaining, year-round tourist destination. Together, Cairngorm and Aviemore want to become a mountain resort ranking with the best in the world, and the climatic impact on skiing opportunities appears to have been the catalyst in facilitating this vision.

6.2 Limitations and further work

There are a number of limitations in this dissertation. Firstly, there are a number of years of climate data missing in the 1970s. Having this data could alter the trends in each of the four variables investigated. Secondly, having a continuous dataset from the same altitude would have been ideal, as then there would not be such a degree of uncertainty attached to the 1960s data. Thirdly, the inability to attach any statistical significance to the quantitative data, in conjunction with being devoid of a longer time series, fails to establish the possibility that these trends have occurred by chance. Applying statistical analysis to a more complete data series would increase understanding of the future of snow and skiing on Cairngorm Mountain. Fourthly, rainfall was not collected in this dissertation as the records were largely unavailable. Constructing a rainfall analysis could prove beneficial in understanding the extent that rainfall is having on the snow cover lifetime. In addition, assessing the rainfall trend's impact on summer tourism at a local scale would be of interest; the assumption being that the Scottish summers are getting drier (Harrison *et al*, 1999). Access to relevant texts prevented a more rigorous exploration of textual records which could have further developed an understanding of historical snow cover changes. In showing the results of my climate data analysis to Bob Kinnaird, Cairngorm Mountain, his response indicated relevant further work, "We are aware we still get a lot of snow, the problem is that is does not stay, We appear to be experiencing rapid and frequent variations in weather patterns - particularly temperature and wind". Therefore, investigating the daily temperature fluctuations and frequency of thaws has been highlighted as being useful for Cairngorm. Making an allowance for these limitations, the conclusions of this work appear to support the key points in the literature review; that temperature seems to be the dominant control on snow cover and duration and that the snow/ski season is getting shorter. The findings also seem to support the Harrison *et al* (1999) claim that there may be some localised benefits from climate changes, with Cairngorm and Aviemore appearing to achieve a much more self-sustaining, all year round destination in light of climate pressures.

<u>6.3 Implications and Relevance</u>

It is evident from undertaking this dissertation that it would be have been ineffective to have solely relied on the quantitative climate data in order to understand the business and tourism changes undergoing at Cairngorm and in Aviemore. In combining the climate data with the textual and contemporary accounts, a fuller appreciation for the reasons for the decline in skiing on Cairngorm and the implication that this has had on Cairngorm's sustainability and Aviemore's tourism has been achieved.

Cairngorm were intrigued by my climate data results, particularly the fairly consistent number of snow-falling days (figure 4.3.2) and the post 2000 decrease in mean winter wind speed (figure 4.6.1.4). Bob Kinnaird had the following comments on his Cairngorm Blog;

"This may come as a surprise to some as there is no doubt that there is a perception that we get less snow than we used to. Of course this is only half the story; where we are seeing changes is in the length of time the snow stays around, particularly on the lower parts of the middle runs, which are the most popular at CairnGorm for intermediate/advanced skiing…..One of the other unexpected changes that Jamie's data is showing is an overall reduction in wind speed…. interesting. This may help to explain why the gullies have not tended to fill up as much as the old days"

As a result of my work being cited, I was also contacted by the Scotsman Newspaper. There appeared to be a significant interest in my work in light of my findings. This suggests that this dissertation has been relevant; in terms of Cairngorm Mountain attributing possible contributory factors to the decline in skiing opportunities and in terms of enlightening the public to the apparent misconceived perceptions regarding snowfall and increased temperatures. With this dissertation undertaken at a local scale, the results are directly relevant to people and businesses within the area. Had the dissertation adopted a larger, national scale, the degree of relevance would possibly have been reduced.

Therefore, in undertaking a snow climate analysis of Cairngorm and combining the quantitative results with textual and contemporary resources, an understanding of the impact that the decline in skiing opportunities has had on businesses and tourism within the Cairngorm and Aviemore area has been approached.

References

Abegg, B, Froesch, R, 1994, Climate change and winter tourism: Impact on transport companies in the Swiss canton Graubünden, 328-340, in Beniston, M (ed) *Mountain environments in changing climates*, Routledge, London

Ahrens, C.D, 2003, *Meteorology Today: An introduction to Weather, Climate, and the Environment*, 7th Edition, Thomson Learning, London

Barnett, C, Hossell, J, Perry, M, Procter, C & Hughes, G, 2006, Patterns of climate change across Scotland: Technical Report. *SNIFFER Project CC03, Scotland & Northern Ireland Forum for Environmental Research*, 102pp

Bednorz, E, 2004, Snow cover in eastern Europe in relation to temperature, precipitation and circulation, *International Journal of Climatology*, 24, 591-601

Beniston, M, 1997, Variations of snow depth and duration in the Swiss Alps over the last 50 years: Links to changes in large scale climatic forcings, *Climatic Change*, 36, 281-300

Brown, R.D, 2000, Northern Hemisphere snow cover variability and change, 1915-97, *American Meteorological Society, Climate Research Branch, Meteorological Service of Canada*

Cairngorm Mountain, 2006, A Vision For the Future

Crowley, T.J, 2000, Causes of climate change over the past 1000 years, *Science*, 289, 270-277

Elsasser, H & Messerli, P, 2001, The vulnerability of the snow industry in the Swiss Alps, *Mountain Research and Development*, 24, 4, 335-339

Elsasser, H & Bürki, R, 2002, Climate change as a threat to tourism in the Alps, *Climate Research*, 20, 253-257

Godfrey, K.B, 1998, Attitudes towards 'sustainable tourism' in the UK: a view from local government, *Tourism Management*, 19, 3, 213-224

Hantel, M, Ehrendorfen, M, Haslinger, A, 2000, Climate sensitivity of snow cover duration in Austria, *International Journal of Climatology*, 20, 615-640

Harrison, S.J, 1993, Differences in the duration of snow cover on Scottish Ski Slopes between mild and cold winters, *Scottish Geographical Magazine*, 109, 1, 37-44

Harrison, S.J, 1997, Changes in the Scottish Climate, *Botanical Journal of Scotland*, 49, 2, 287-300

Harrison, S.J, Winterbottom, S.J & Sheppard, C, 1999, The potential effects of climate change on the Scottish tourist industry, *Tourism Management*, 20, 203-211

Harrison, J, Winterbottom, S & Johnson, R, 2001, Climate Change and changing patterns of snowfall in Scotland, *Scottish Executive: Central Research Unit*

Heller, M, 1969, *Ski*, Faber & Faber Publishers, London

Holden, A, 1998, The use of visitor understanding in skiing management and development decisions at the Cairngorm Mountains, Scotland, *Tourism Management*, 19, 2, 145-152

Holden, A, 2000, Winter tourism and the environment in conflict: The case of Cairngorm, *International Journal of Tourism Research*, 2, 247-260

IPCC, 2007, www.ipcc.ch last accessed on 18/11/07

Kelbie, P, 2001, The Independent, London. Available from http://findarticles.com/p/articles/mi_qn4158/is_20011030/ai_n14437196 (last accessed 10/02/08)

Koenig, U & Abegg, B, 1997, Impacts of climate change on winter tourism in the Swiss Alps, *Journal of Sustainable Tourism*, 15, 1, 46-58

Lamb, H.H, 1988, *Weather, Climate and Human Affairs: A book of essays and other papers*, Routledge, New York

Laternser, L & Schneobeli, M, 2003, Long term snow climate trends of the Swiss Alps (1931-1999), *International Journal of Climatology*, 23, 733-750

Lean, J, Beer, J & Bradley, R, Reconstructions of solar irradiance since 1610: Implications for climate change, *Geophysical Research Letters*, 22, 23, 3195-3198

Macaulay, S, 2008, 'World-class" centre will be icing on cake for Aviemore, Press and Journal Newspaper, available from http://www.pressandjournal.co.uk/displayNode.jsp?nodeId=149235&command=displayContent&sourceNode=149218&contentPK=20096161&moduleName=InternalSearch&formname=sidebarsearch (last accessed 09/03/08)

Petkova, N, Koleva, E, Alexandrov, V, 2004, Snow cover variability and change in mountainous regions of Bulgaria, 1931-2000, *Meteorologische Zeitschrift*, 13, 1, 19-23

Scherrer, S.C & Appenzeller, C, Laternser, M, 2004, Trends in Swiss Alpine snow days: The role of local and large-scale climate variability, *Geophysical Research Letters*, 31, L13215

Scottish Ski Club Journals

Soulsby, C, Helliwell, R.C, Ferrier, R.C, Jenkins &A, Harriman, R, 1997, Seasonal snowpack influence on the hydrology of a sub arctic catchment in Scotland, *Journal of Hydrology*, 192, 17-32

Trivedi, M.R, Browne, M.K, Berry, P.M, Dawson, T.P, Morecroft, M.D, 2007, Projecting climate change impacts on mountain snow cover in central Scotland from historical patterns, *Arctic, Antarctic and Alpine Research*, 39, 3, 488-499

Watson, A, Davidson, R.W & Pottie, J, 2002, Snow patches lasting until winter in north-east Scotland in 1971-2000, *Arctic and Alpine Research*, 26, 2, 141-151
Yeoman, I & McMahon-Beattie, U, 2006, Understanding the impact of climate change on Scottish tourism, *Journal of Vacation Marketing*, 12, 4, 371-379

http://www.inghams.co.uk/ski/index.aspx (last accessed on 10/01/08)

http://www.cairngormmountain.org.uk/ski-essentials/snowsports-ticket-prices-2007-2008/ (last accessed 10/01/08)

http://www.cairngormmountain.co.uk/essential-information/where-we-are/getting-here/ (last accessed on 07/01/08)

http://www.cairngormmountain.org.uk/blog/ (last accessed 10/01/08)

http://www.cru.uea.ac.uk/cru/data/nao.htm (last accessed, 28/11/07)