CLIMATE OBSERVATIONS IN THE NORTHWEST TERRITORIES (1957-2012)
Inuvik * Norman Wells * Yellowknife * Fort Smith

INTRODUCTION

The Arctic is experiencing a rapid and intense warming trend, which is apparent when temperature increases in Northwest Territories (NWT), Yukon, and Nunavut are compared against temperature trends throughout the rest of North America. The Mackenzie Valley is considered a global hotspot in terms of climate change and warming temperatures. The 2005 Arctic Climate Impact Assessment (ACIA) describes annual temperature increases of 2-3^{o}C in the Mackenzie Valley area and as much as 4^{o}C in the winter during the past fifty years. Along with the rise in temperature, precipitation patterns are also expected to change as a result of climate change.

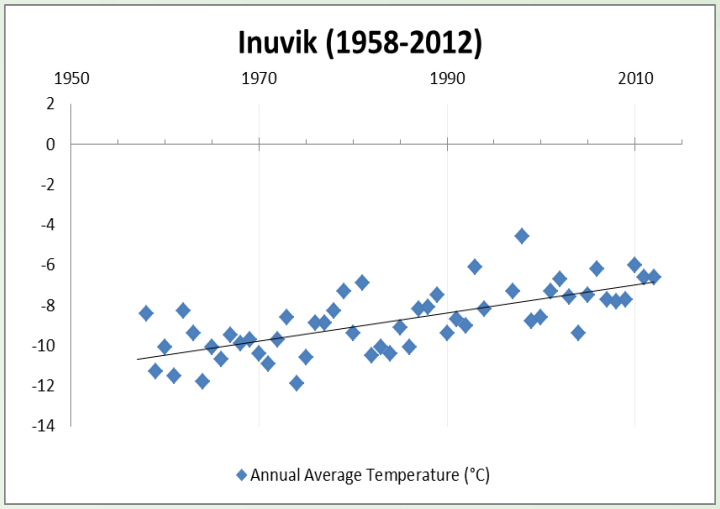
This paper looks at the trend more closely using Environment Canada weather stations data from four communities in the NWT. The airport weather stations in Inuvik, Norman Wells, Yellowknife and Fort Smith date back to the 1940's and are the longest standing and most consistent climate stations in the NWT. These four communities sit on a rough north to south transect and are well spaced to provide a good overview of the trends in the Mackenzie River watershed.

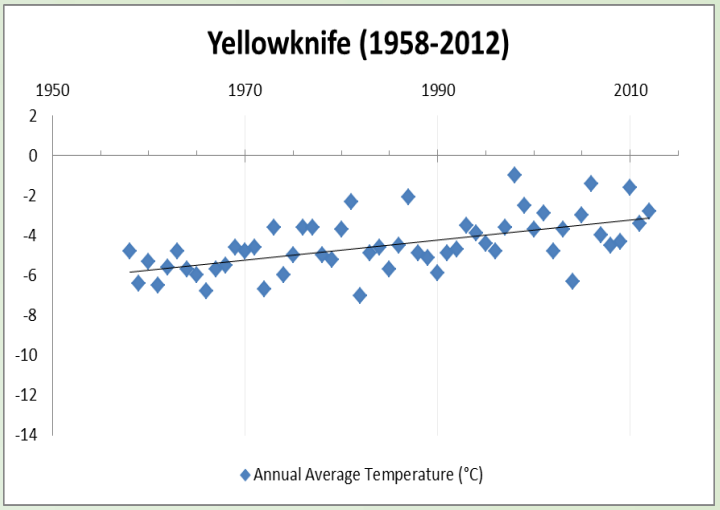
The series of graphs in this report show temperature and precipitation trends over more than a 50-year period, from 1958 to 2012.There are five series of graphs for temperature and six for precipitation. Temperature graphs show the annual mean and the means of the four seasons for each community. The precipitation graphs are similar, with the annual average graph showing both snowfall and precipitation and the spring precipitation graph showing the linear trend of snowfall. An additional precipitation graph shows the average winter rain in the four communities. A line of best linear fit is drawn through the data points to illustrate the trends**.** Unfortunately, Environment Canada's Adjusted and Homogenized Canadian Climate (AHCC) Data for Inuvik precipitation becomes increasingly sporadic from 1996 onwards. Therefore, Environment Canada's '*Inuvik Climate*' site was used, rather than the AHCC Data. Furthermore, winter-rain events are not graphed for the community due to lack of availability.

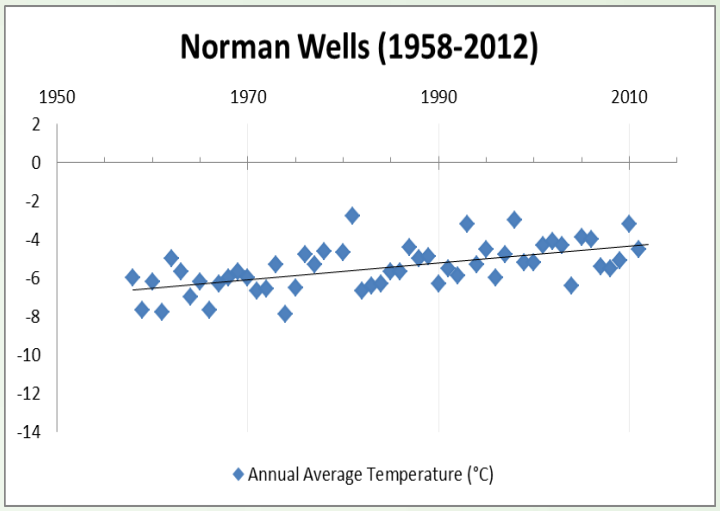
The data used in this document is adjusted and homogenized, using a number of adjustments applied to reflect shifts due to changes in instruments or observing procedures. All data used in this document is courtesy of Environment Canada and is available on their website at http://ec.gc.ca/dccha-ahccd/.

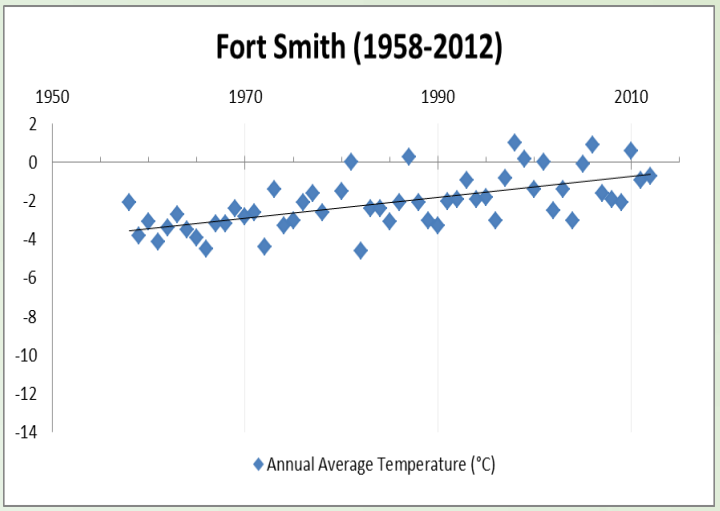
TEMPERATURE
Annual Mean Temperatures and Observations

The temperature graphs below show an increase in average temperature throughout the four chosen communities. This data shows an average temperature increase of 2.4°C for the NWT (from the average of all four communities). Large increases are noted across all four sites, with increases of 3.0°C in Inuvik, 2.5°C in Fort Smith, and 2.0°C in both Yellowknife and Norman Wells.



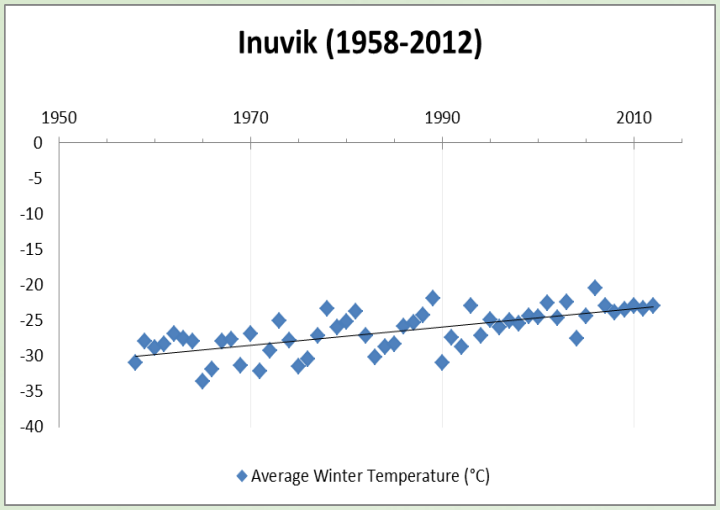


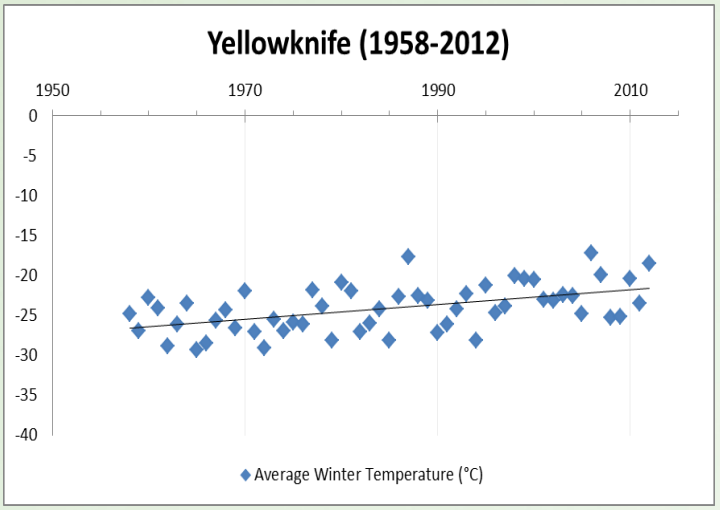


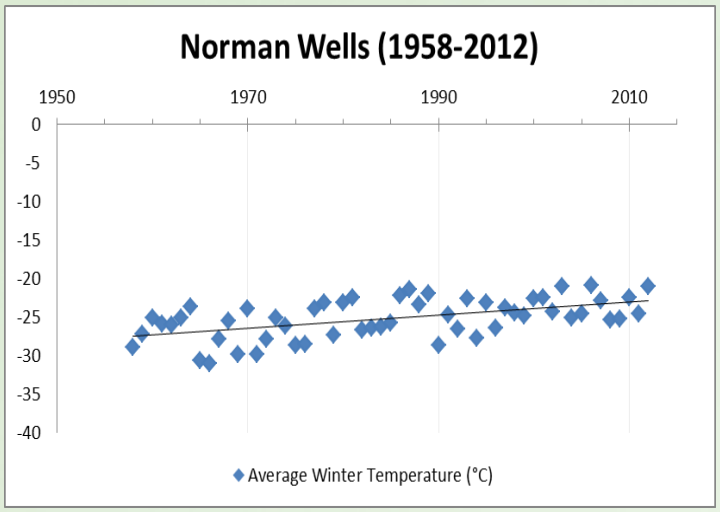


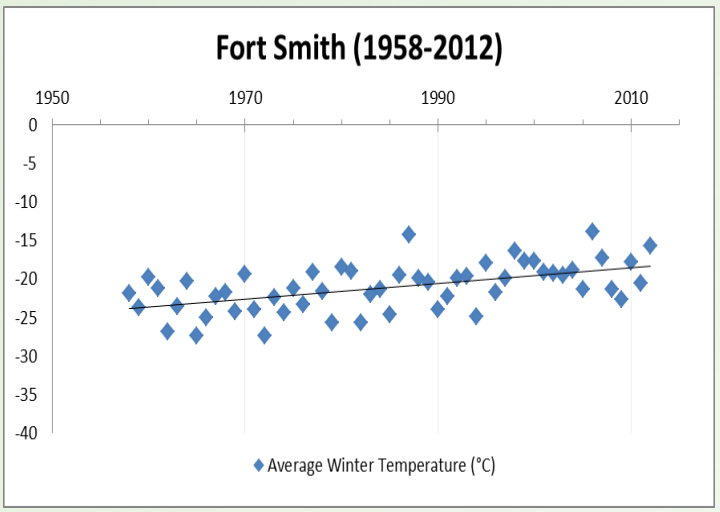
Winter Mean Temperatures and Observations (Dec-Feb)

Winters throughout the NWT show a large variation in temperature. It appears variation in winter temperatures has decreased in the past twenty years with considerably warmer winters in general, and fewer cold winters. Inuvik experienced the most significant winter warming with a 5.2°C increase since 1958. The average winter temperature in Norman Wells and Yellowknife increased by 2.9°C since 1958 while Fort Smith increased by 3.0°C. The warmest winter on record across all four communities was experienced in 2006.



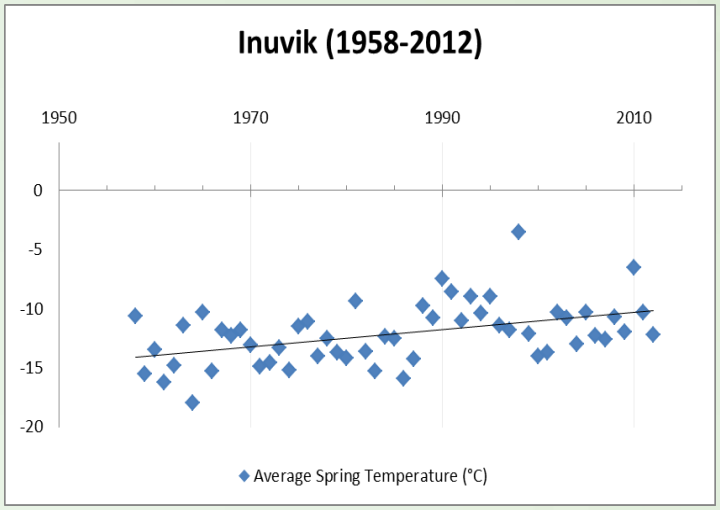


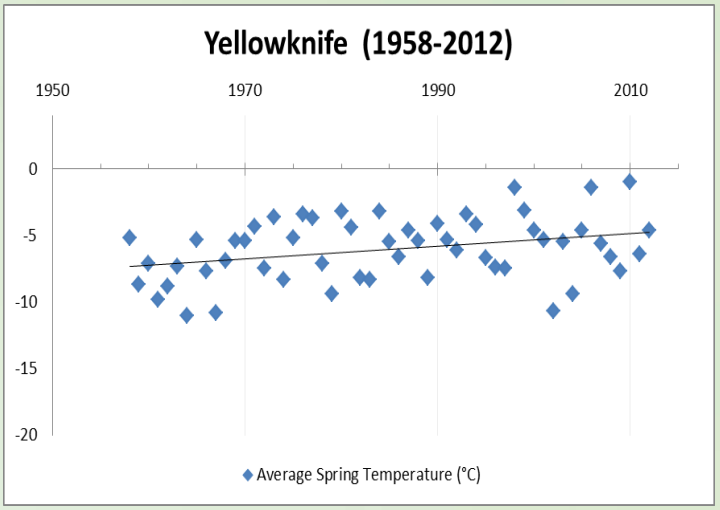


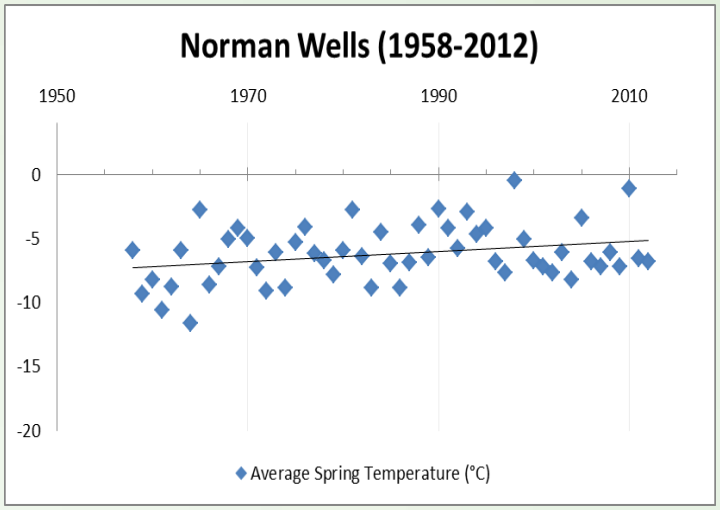


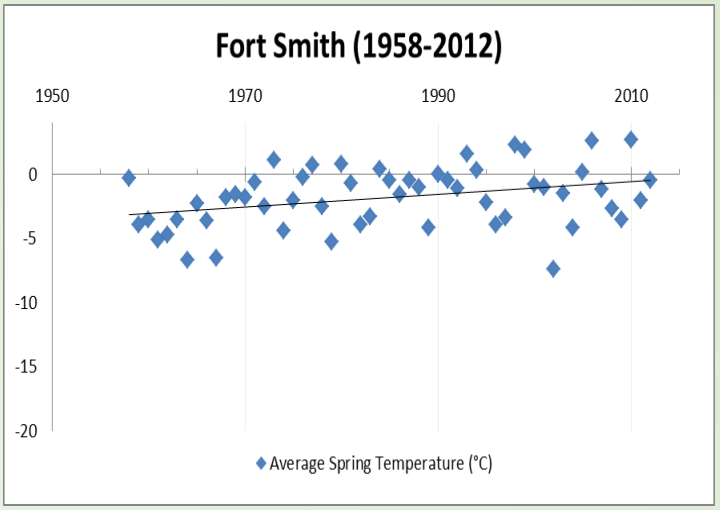
Spring Mean Temperatures (Mar – May)

Although not as dramatic as the winter temperature increase, there has been significant warming in the spring season as well. There is more temperature variation between years during spring than during winter but the trend is strongly towards warmer spring periods. Again, the greatest warming occurred in Inuvik with an increase of 3.8°C since 1958. Mean spring temperatures rose 3.0°C in Norman Wells, 2.7°C in Yellowknife and 2.3°C in Fort Smith.



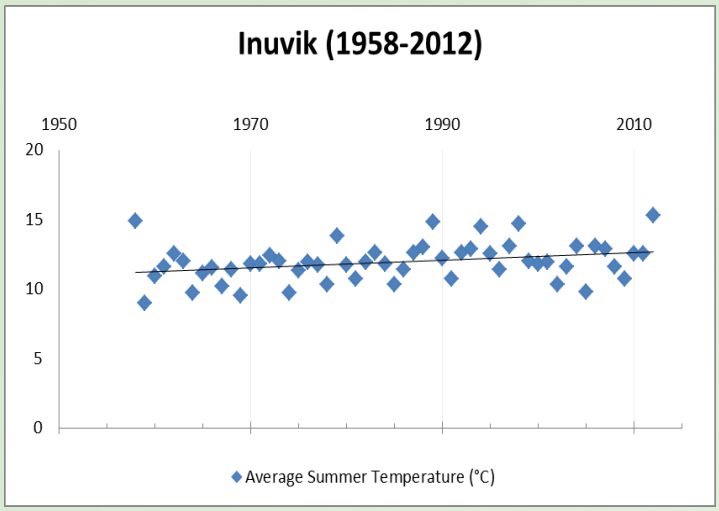


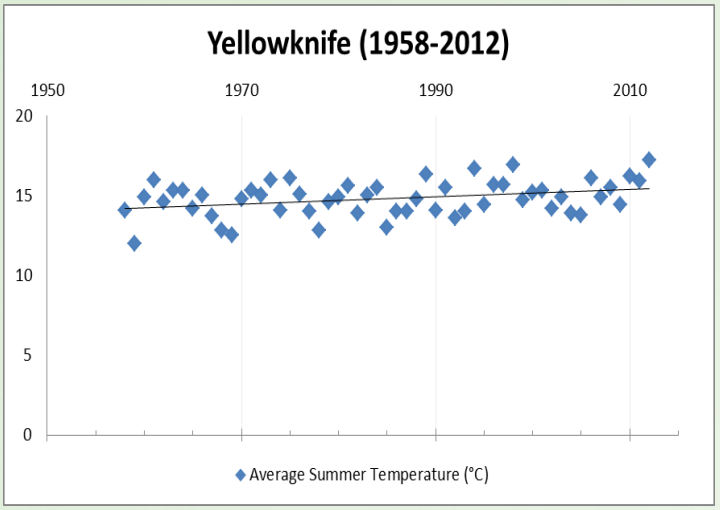


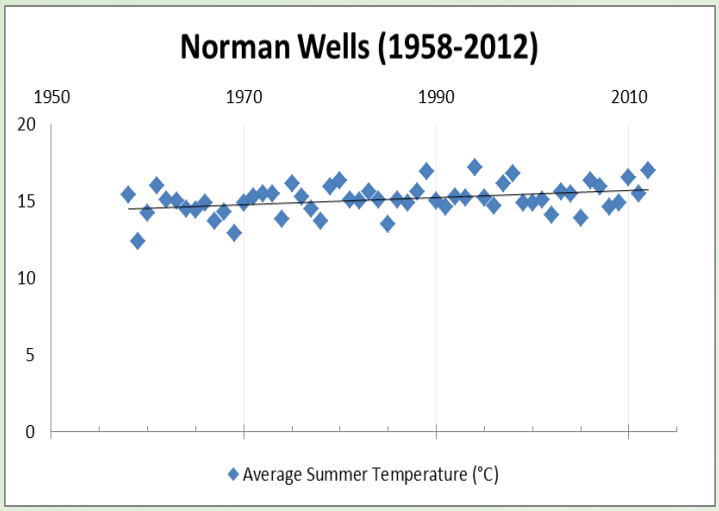


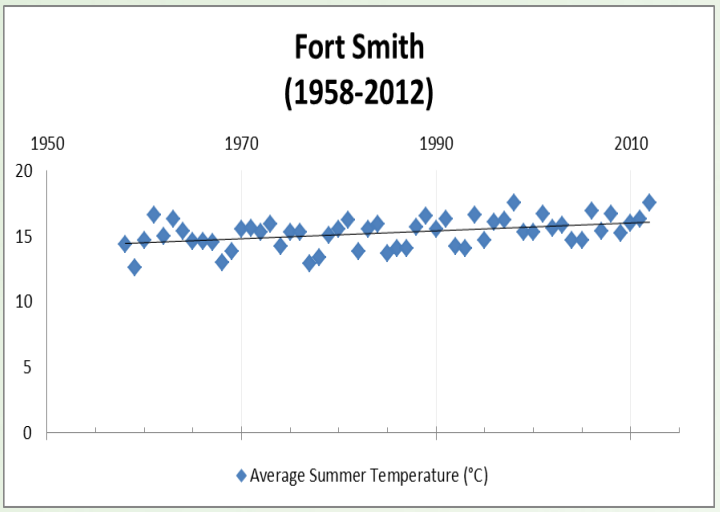
Summer Mean Temperatures and Observations (June - Aug)

Summer mean temperature trends are smaller in magnitude but all show a slow, steady warming trend. The warming trend in summers was least obvious in Inuvik, which warmed 0.7°C during the 56 years of observation. Summers in Norman Wells are, on average, 1.1°C warmer, 1.5°C warmer in Yellowknife and 1.7°C warmer in Fort Smith.



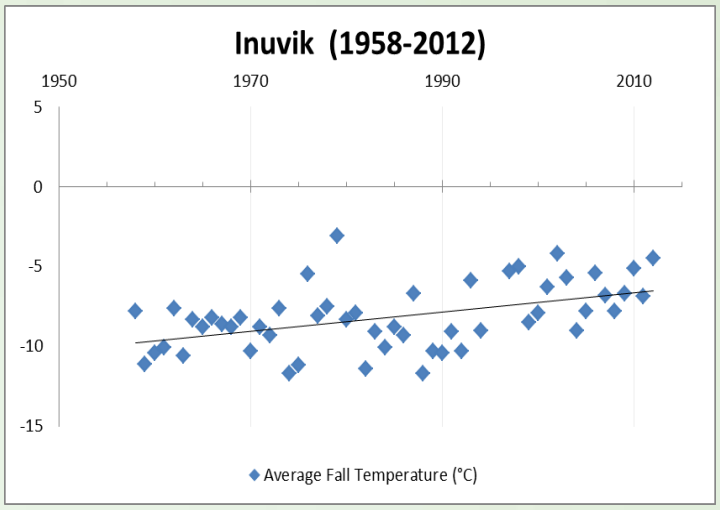


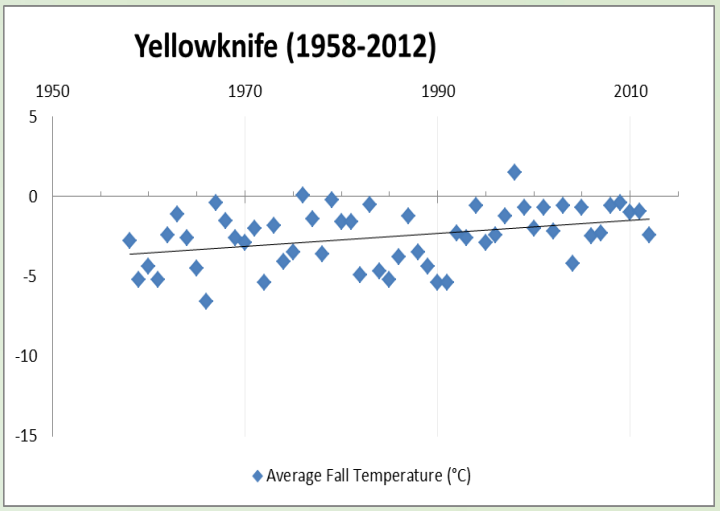


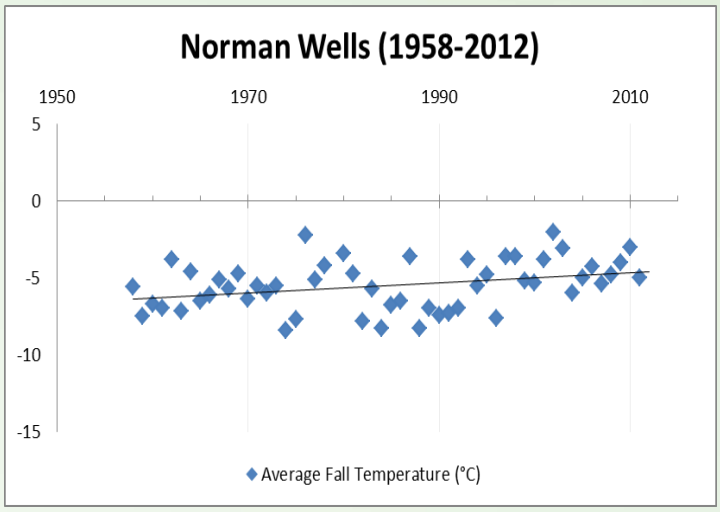


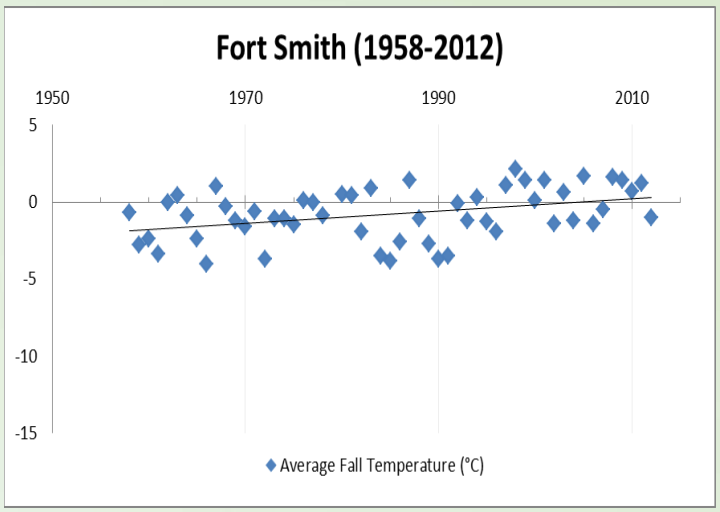
Fall Mean Temperatures and Observations (Sep - Nov)

All communities experienced an increase in fall mean temperatures. Inuvik and Yellowknife were both heavily impacted by warming trends, with approximately 3°C warming in both communities (3.2°C in Inuvik and 2.9°C in Yellowknife). Fort Smith experienced 2.6°C warming and Norman Wells was least impacted, with a 1.9°C increase in average autumn temperatures.





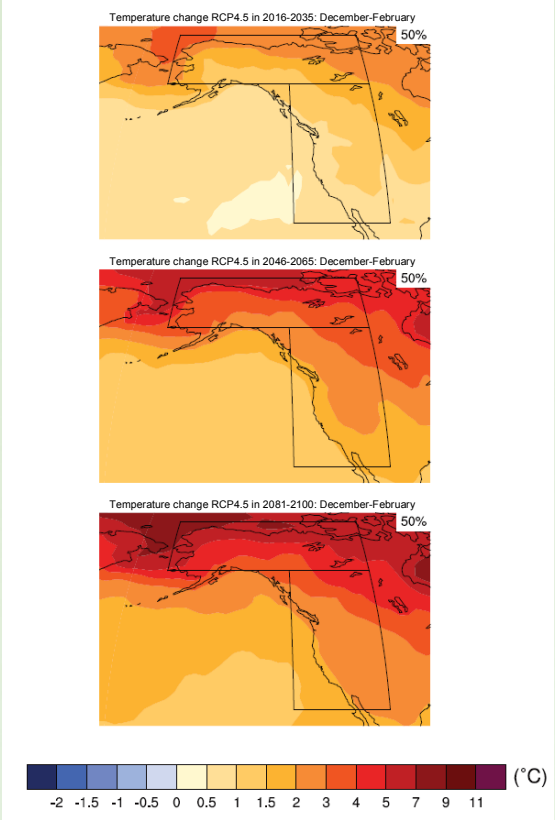




TEMPERATURE - DISCUSSION

Overall, temperatures during all four seasons have been rising with less significant changes seen during the summer season. Annual means show Inuvik is experiencing the greatest warming while Fort Smith, Norman Wells and Yellowknife have notable increases during the same span of time.

Winter and spring temperatures have increased more than summer and fall temperatures. Complex climate and geographic factors influence these seasonal variations. Some of the factors leading to less warming in the summer and fall include: the moderating effects of water bodies as heat sinks in the summer and fall; reduced snow and ice cover in the winter and spring, resulting in decreased albedo (light reflected off the ground) and therefore warmer temperatures; changes in cloud cover; and, alterations in larger scale atmospheric and oceanic circulation patterns.



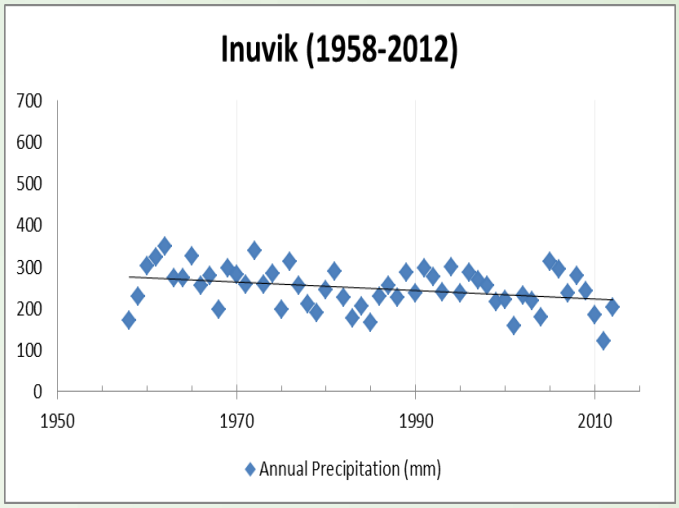
Map of Northwestern North America showing the changes in surface temperature predicted by the Intergovernmental Panel on Climate Change if carbon dioxide levels stabilize at 650ppm (CO2 levels are currently at ~400ppm). This is one of four possible emission pathways from the IPCC's (intergovernmental Panel on Climate Change) most recent report (AR5).

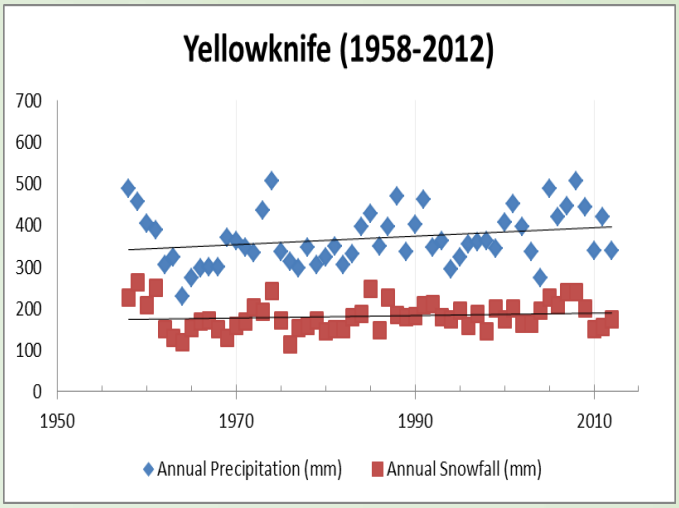
This warming trend which is observed during the past 54 years is extremely likely to continue into the foreseeable future as atmospheric greenhouse gas concentrations continue to increase due to human activities. The physical repercussions of a warming Arctic, such as reduced sea ice coverage, permafrost thaw and changes to plant and animal habitats, will worsen as this trend continues.

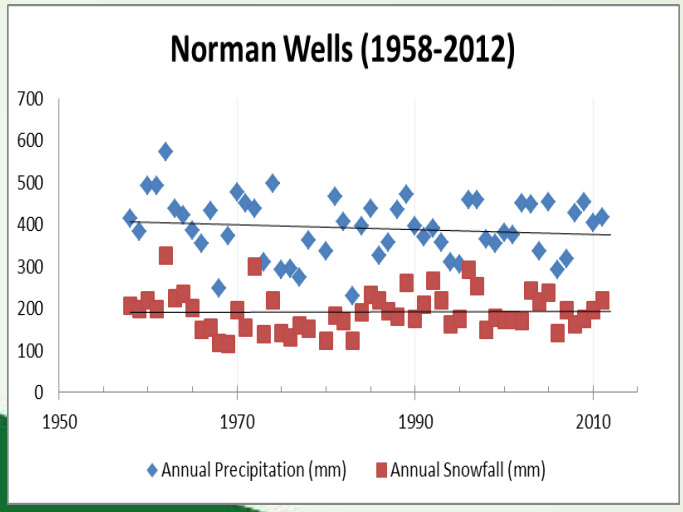
PRECIPITATION

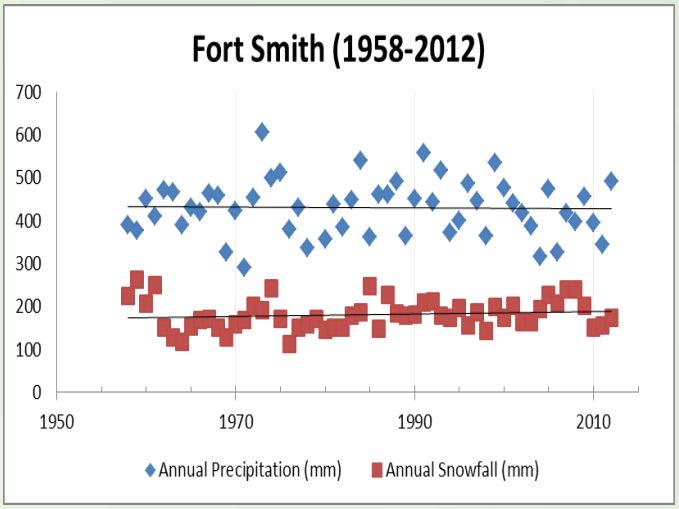
Average Annual Precipitation and Snowfall Observations

There are some interesting long-term changes occurring in precipitation and snowfall throughout the NWT. Though it is difficult to compare these parameters due to complex long-term weather patterns, some trends emerge from the graphs below. Yellowknife showed a generally increasing trend of both precipitation and snowfall while both Fort Smith and Norman Wells had decreasing annual precipitation coupled with increasing snowloads throughout the winter. Inuvik showed a decrease in precipitation but the change in snowfall is not shown due to missing observation data. Precipitation observations from Environment Canada's Inuvik Climate site were used for Inuvik's precipitation data rather than the Adjusted and Homogenized Canadian Climate Data for Inuvik, as the Climate site has more complete data.



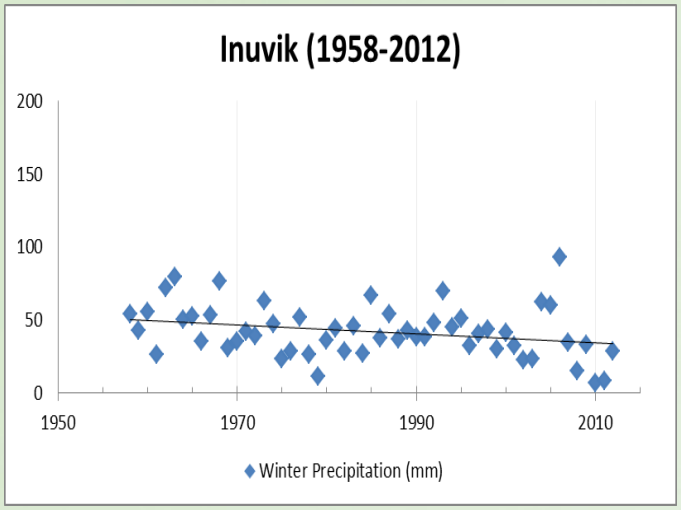


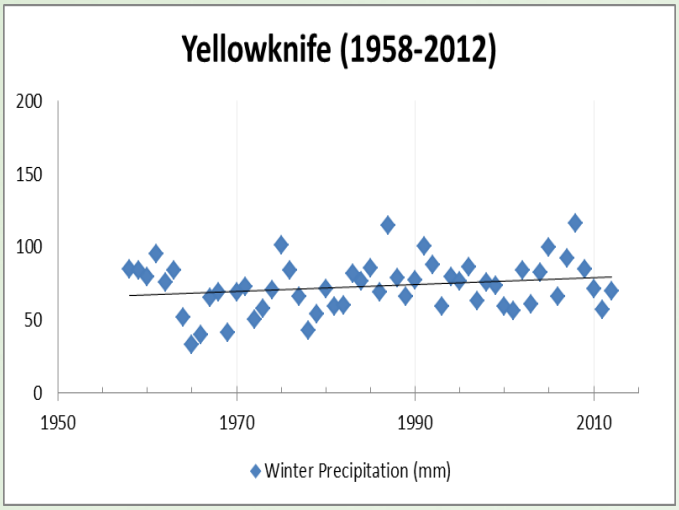


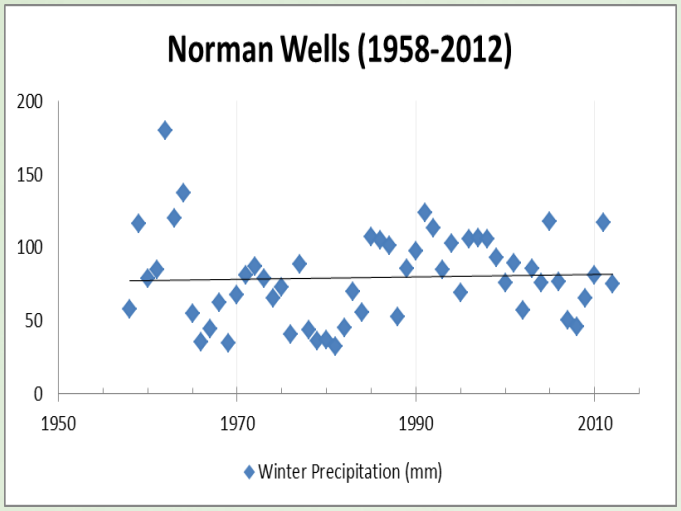


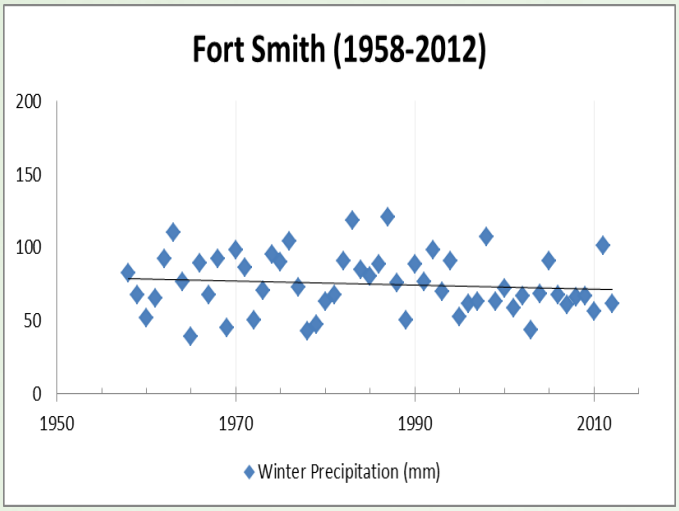
Winter Average Precipitation and Observations (Dec-Feb)

Winter average precipitation is based on snowfall equivalent values or water available when snowfall is melted. A standard 10:1 ratio for snow to melt equivalent is used. As such, when a decrease of precipitation occurs (mm), then a decrease in snowfall (cm) is represented in the data. Precipitation increases during the winter months were observed in Yellowknife and Norman Wells, though the increase in Norman Wells was very slight. Fort Smith and Inuvik experienced a decrease in winter precipitation with Inuvik's change being the most significant (increase or decrease) among the four communities.





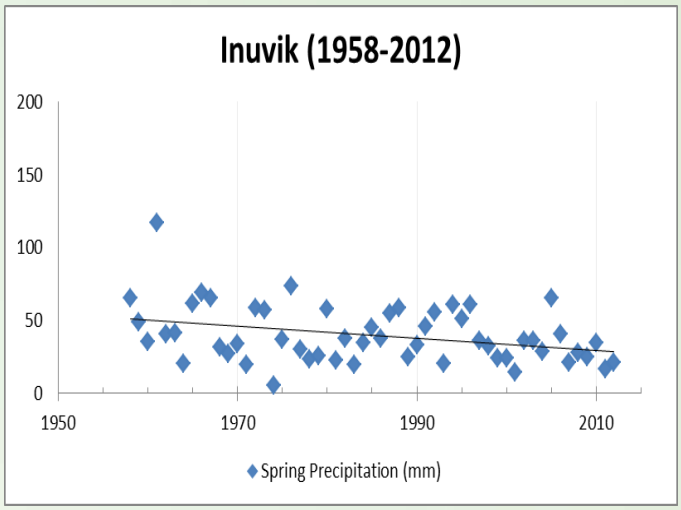


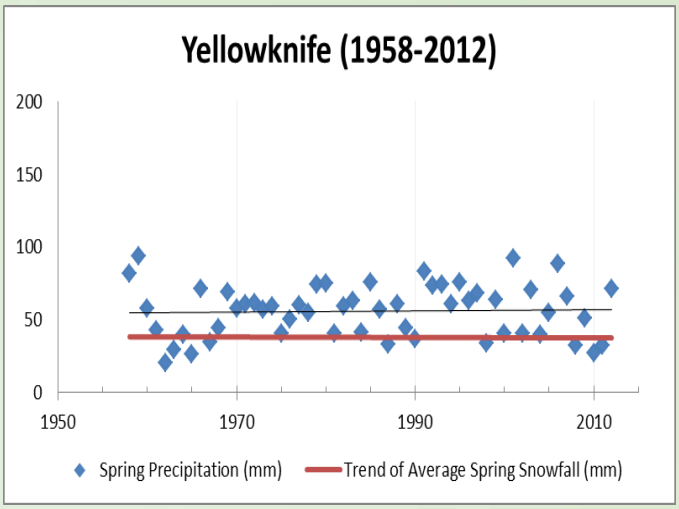


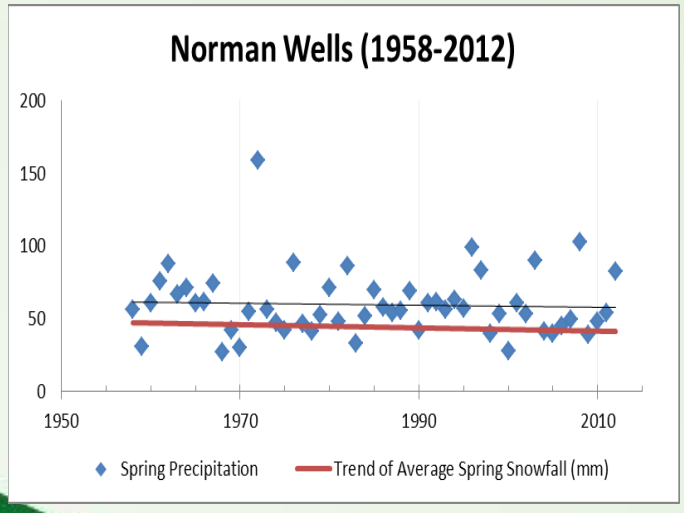
Spring Average Precipitation and Snowfall (Mar - May)

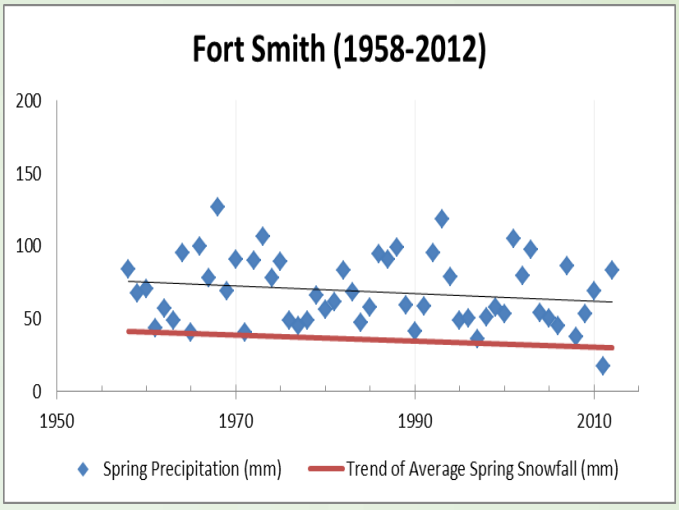
In all communities but Yellowknife, spring precipitation decreased during the observation period. Inuvik and Fort Smith showed the largest declines throughout the years while Norman Wells' decline in precipitation was only slight. Yellowknife's trend is slightly upwards, comparable to Norman Wells' downward trend.

Inuvik's spring snowfall is not shown due to incomplete data. All three remaining communities showed a decline in spring snowfall with Fort Smith decline being more pronounced than Norman Wells and Yellowknife. Declining snowfall when compared to increasing overall precipitation, as seen in the case of Yellowknife's spring, is indicative of warmer spring temperatures preventing snow from forming.



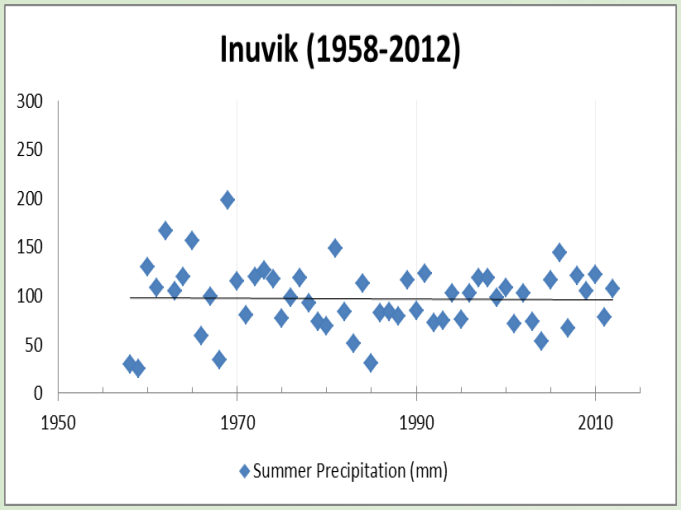


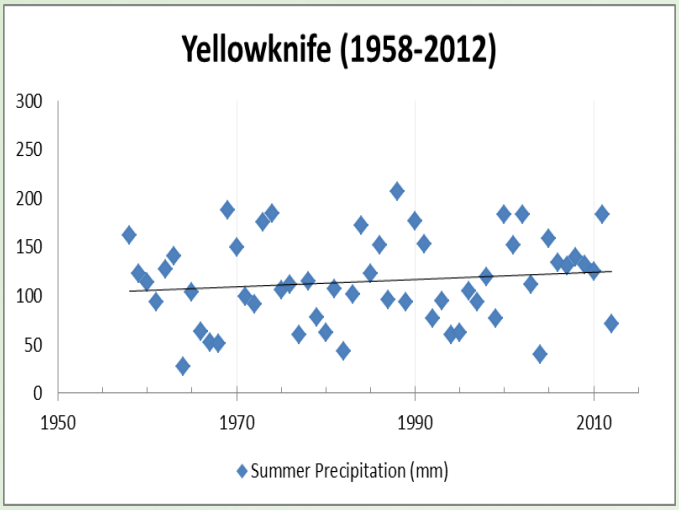


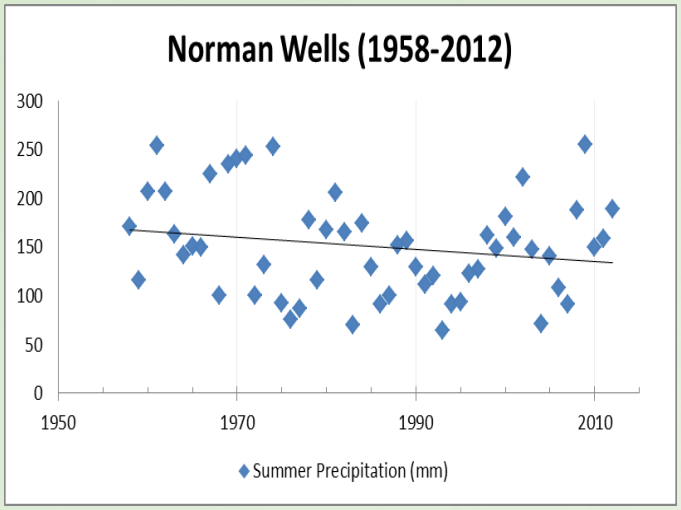


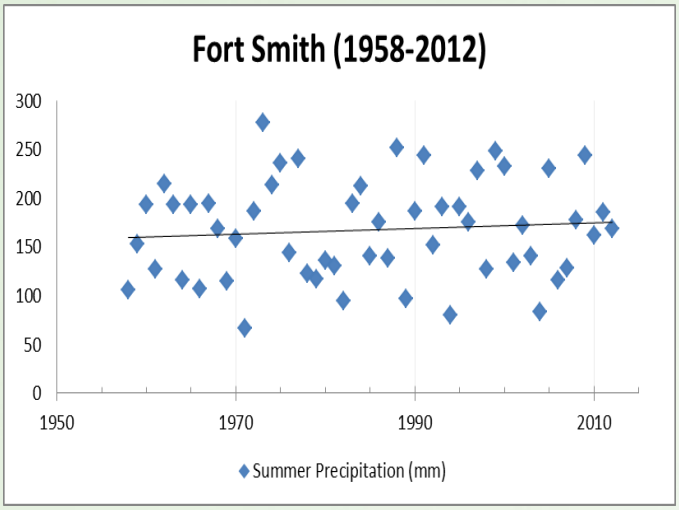
Summer Average Precipitation (June - Aug)

The summer precipitation trends are equally divided between increasing and decreasing. Yellowknife and Fort Smith showed increases throughout the 54 years of observation, while Inuvik and Norman Wells showed decreases in precipitation, though the decrease observed in Inuvik is slight.



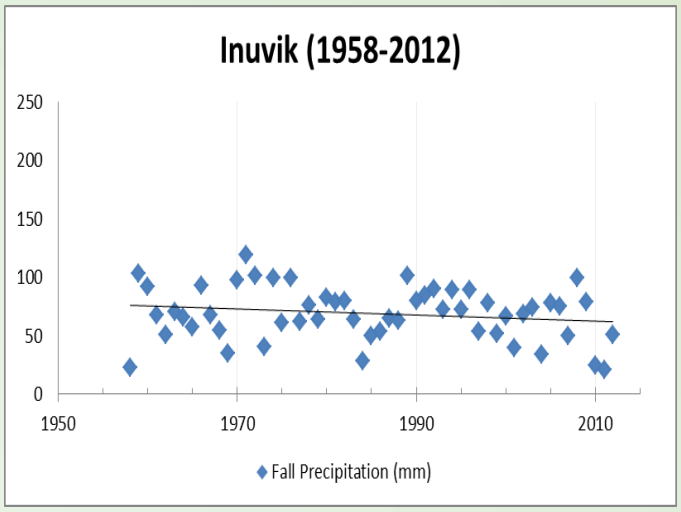


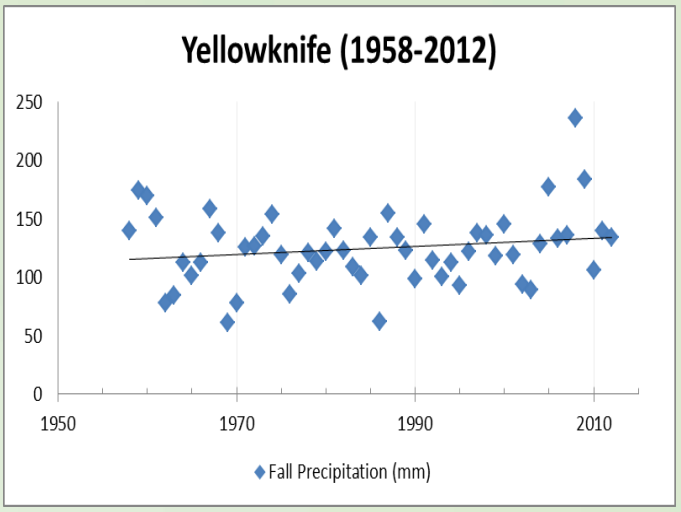


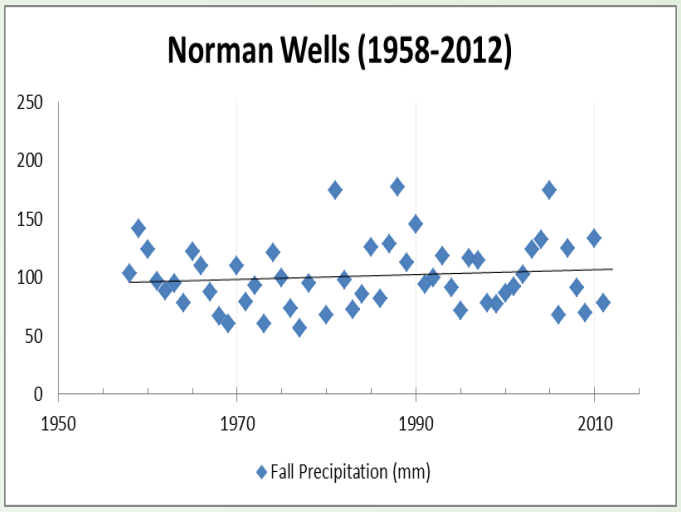


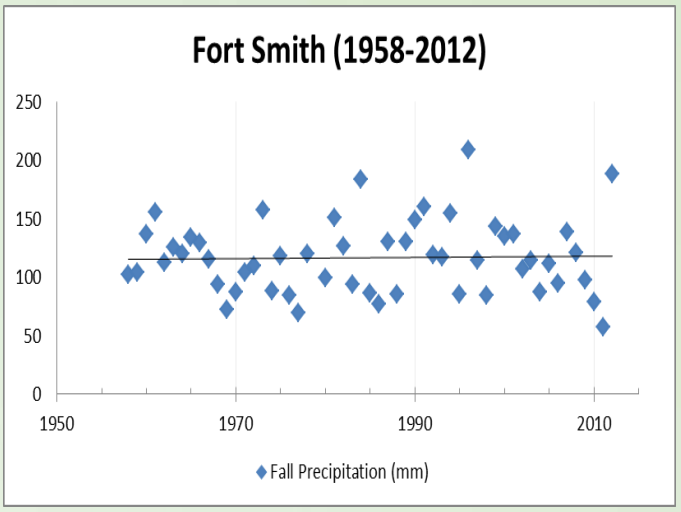
Fall Average Precipitation and Observations (Sep-Nov)

Yellowknife, Norman Wells and Fort Smith show an increase in precipitation over 54 years during the fall season. The trend in Fort Smith is very slight. Inuvik has experienced a slight downward trend.



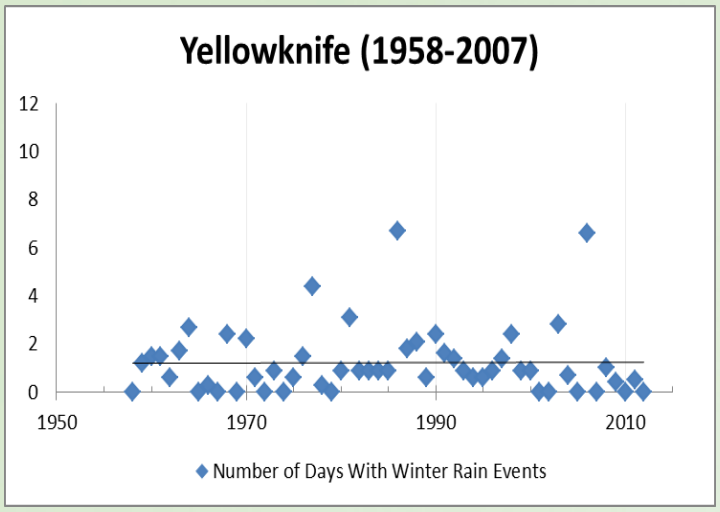


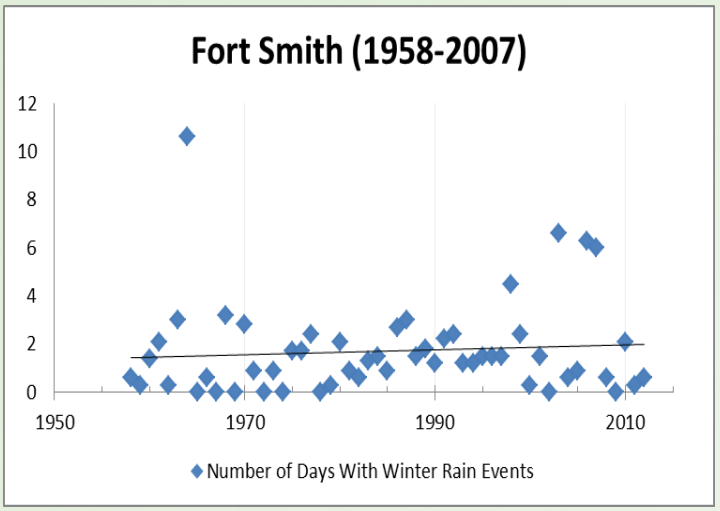


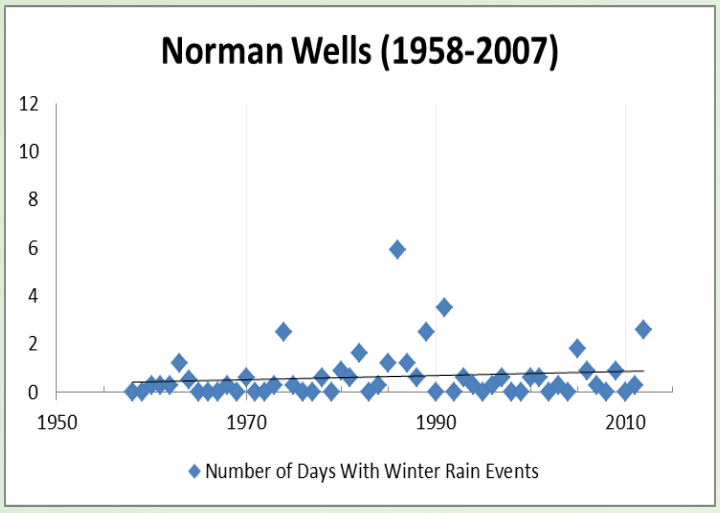


Winter Rain Events and Observations (Dec-Feb)

Winter rain is not a common occurrence in the NWT. However, as the climate warms, rain during our coldest months can be expected to increase. The graphs below outline trends in rain events between December and February. Observations in Norman Wells and Fort Smith show a slight increase in winter rain events throughout the years of observation. Yellowknife showed no increase or decrease. Inuvik is not shown due to incomplete data from the weather station from 1997 onward.





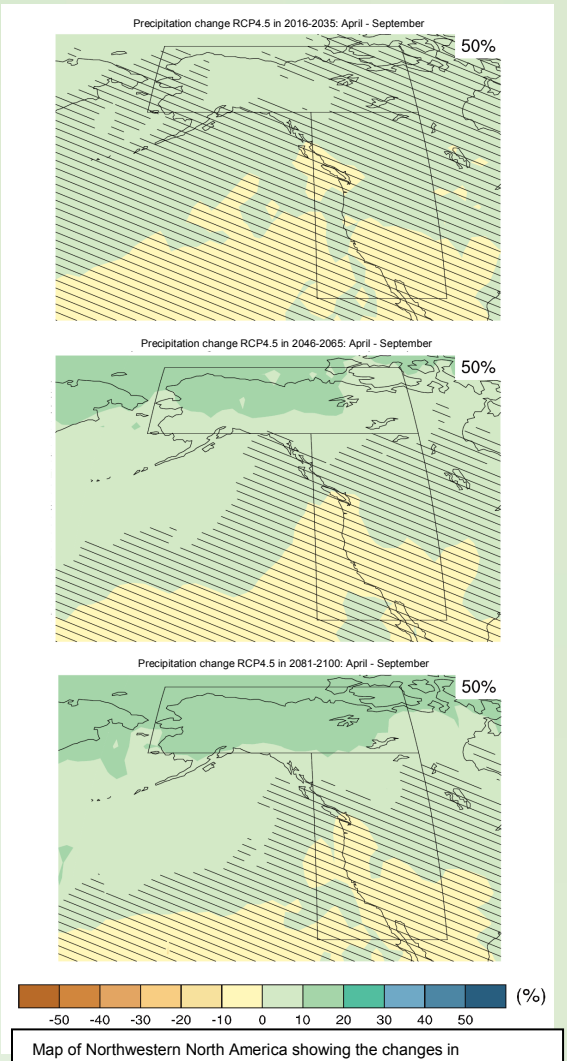


PRECIPITATION – DISCUSSION

Precipitation trends throughout the NWT are variable and difficult to confirm with no general trends visible throughout communities of the NWT. In some areas, annual precipitation increased and decreased in others. Inuvik has experienced the most change in precipitation during the years of observation with decreases in precipitation throughout all seasons, especially during winter and spring seasons.

There was also no agreement in the seasonal data. Some communities experience both increases in precipitation during some times of year and decreases in others. In general, the trends in summer and fall precipitation were the least pronounced, whether they were positive or negative. This may be linked to the similar trend observed in temperature trends, attributed to the moderating effects of water bodies as heat sinks in the summer and fall.

Winter precipitation was most affected by changes in temperature with Yellowknife and Inuvik both experiencing the largest shifts in precipitation regimes. These trends, increasing for Yellowknife and decreasing for Inuvik, show the complexity of the temperature and precipitation patterns. While both communities, close to large water bodies, have experienced substantial warming in the last half century, the precipitation patterns react differently. This helps demonstrate the difficulty in planning for climate change adaptation and the necessity for long-term monitoring of climate trends to properly identify changes and necessary adaptation actions.



Map of Northwestern North America showing the changes in precipitation predicted by the Intergovernmental Panel on Climate Change if carbon dioxide levels stabilize at 650ppm (CO_2 levels are currently at ~400ppm). This is one of four possible emission pathways from the IPCC's most recent report (AR5). Blacklines indicate areas where no significant change is expected.

Trends of winter rain events do show more agreement than other annual and seasonal trends. Two of the three communities with reliable precipitation data showed increases in these rain events. Yellowknife showed no increase or decrease.

DISCUSSION

Analysis of available data collected at weather stations supports the assertion Arctic temperatures are increasing faster than the global average as a result of climate change. This document shows substantial changes in the temperature and, to a lesser extent, precipitation levels in the NWT during the past 54 years. These changes are expected to accelerate with the continued impacts of global, human-made climate change and to influence ecosystems, plants, animals and people of the NWT.

The four communities are located long distances from each other in very different geographical areas. It is not possible to discuss all the variables affecting temperature and precipitation in this discussion. The communities of Norman Wells and Inuvik are similar geographically. Both are located in the Mackenzie Valley and are further north than the other two communities. They are affected by the mountains to the west as well as the climate altering effects of the Mackenzie Valley and the Beaufort Sea to the north. Yellowknife and Fort Smith are further south with a more continental climate and no nearby mountain ranges. In Yellowknife, Great Slave Lake moderates temperatures.

Despite these geographical differences, all four communities have experienced large increases in annual temperature. The largest increases, of 3.0^{o}C and 2.5^{o}C, were noted in Inuvik and Fort Smith respectively. Large increases were also apparent in Norman Wells (2.0^{o}C) and Yellowknife (2.0^{o}C). Though annual precipitation was less dramatically changed in the past 54 years, there are worrying downward trends and predictions for many of the communities. Fort Smith and Norman Wells have seen slight decreases in precipitation while Inuvik experienced a dramatic decrease. Yellowknife was the only community to experience a small increase overall. These decreases are contrary to the long term expectations resulting from climate change, as seen in the map of projected precipitation change from the IPCC's AR5.

CONCLUSION

Projections of Canada's climate change by the year 2050 indicate the most northerly regions will experience dramatic temperature change. The increases in observed temperatures in these four communities ranged from 2-3 degrees Celsius during 54 years of observation. It is projected current trends will continue and intensify regardless of global actions to reduce greenhouse gas emissions and will result in further changes to the NWT's temperature, precipitation, terrain and ecosystems. Adaptation and mitigation measures will be important as these trends continue with increasing greenhouse gas accumulation.

Observations show global trends in climate are not uniform. As global temperatures change, larger atmospheric circulation patterns also change and result in influences on regional climates that may produce unpredictable changes. While the overall temperature of the planet is rising, some regions are warming more rapidly than others and others may even be showing a cooling trend.

Further Reading

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