Yukon Weather Centre Ret'd

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Climate Change in the Yukon, More Observations

by

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ABSTRACT
Surface observations from the Beaver Creek, Faro and Old Crow, Yukon are examined for evidence of climate change.

Table of Contents

Introduction

This report is an addition to Internal Report 109: Climate Change in the Yukon: Some Observations. Surface data from Beaver Creek, Faro and Old Crow for the years 1980 – 2010 are examined.

Data Sources

The monthly, daily and hourly climate archives for Yukon stations have been examined using the climate manager program (Purves and Trojan, 1995). Data were provided by Environment Canada and the Yukon Forest Service. The data were extracted using the Yukon Weather Centre's Climate Manager programs, and were ingested into Microsoft Excel where they were graphed and simple linear equations were calculated.

All the stations in the Yukon were examined for the length and continuity of their record. From over 150 stations with daily climate records in the Yukon, three more were chosen: Beaver Creek, Faro and Old Crow. These are the only remaining stations of the 150 to have enough data to make any reasonable analysis. However, even the records from these stations are not continuous. Surface observations from Faro and Old Crow were supplemented with observations from nearby automatic weather stations when possible. Although Beaver Creek has only one station ID throughout its forty-two year history, it had a small shift in position in August 1980 and again in October 1983. Faro A had a shift in position in September 1997. Finally, the station Old Crow A shows a slight shift in position in October 1997. Data taken before 1980 were ignored, so shifts in station position before that year are not mentioned here, but are listed in Environment Canada's Station Data catalogue at the end of this paper.

In some cases, the effect of using data from a neighbouring station could be estimated, but in other cases, it could not be.

None of these stations has any upper air records.

Method

The precipitation and temperature data were obtained from the daily records; the monthly records were found to be too unreliable. Summer was defined as being May 1 to August 31; Winter was defined as being November 1 to the last day in February. The year of the winter considered was taken to be that for November. Changes in temperature are given in degrees Celsius per decade (deg/d). Changes in precipitation are given in percent per decade or in millimetres per decade (mm/d). The change in percent is calculated using the regression coefficients calculated by Excel. Given the regression equation:

$$Pcp\ Amt = A + B*Years$$

the change per decade is simply:

$$B*10$$

And the percentage change for the period of record, R, is:

B/A*R*100%

Several common problems occurred when processing the data. These involved missing data, changes in instrumentation and changes in station locations.

If one day was missing, its absence was often ignored, or the twenty-year seasonal average for that day was computed and used. If several days were missing, up to ten, then the twenty-year average for these days was computed, centered on the missing day, and these averages were used in place of the missing data. Rarely, an entire month was missing. In this case, the twenty-year average for the month was used. For this report, hourly temperature data were also used, if possible, to fill in holes in the daily record. The mean daily maximum and minimum temperatures from the hourly records were compared to the corresponding daily records in order to calculate mean differences between the two. Normally these are on the order of 5 degrees C, with the daily minimum being lower than the lowest hourly value and the daily maximum being higher than the highest hourly value. Table 4. Number of Missing Observations shows the number of missing daily observations for each year for the five stations: three manned, and two automatic.

The issue of changes in station location was ignored. The changes in location were very small, and there were no data taken simultaneously at both the old and new locations so no comparisons could be made.

Discussion on Data Used

The data used in the analysis of temperature and precipitation will be grouped together and discussed by station. In the case of a few missing observations, the twenty year average was calculated for the month in question, centered on the year of the missing observations. If the missing year was too close to the beginning or end of the record, then either the first or last twenty-year averages were calculated. The calculated average was then used to replace the missing observations. In cases were observations from an automatic station were used to replace those from the manned station, averages for the season in question were calculated using days that were in the record of both stations. As many observations as were available were used. The observations from the automatic station were then adjusted to correspond to the average of the manned station. I.e., if the automatic station average temperatures were 0.5 C warmer than those of the manned station, then the observations from the automatic station were reduced by 0.5 C and used for the missing values of the manned station. Precipitation amounts from automatic stations were not used. Personal experience has shown they are often very unreliable.

<u>Beaver Creek Temperature and Precipitation.</u>

There are data for Beaver Creek from only one station: Beaver Creek A, 2100160. Extracts from the Canadian Climate Centre’s Station Catalogue are given in Table 1 and illustrate changes in the history of the station.

Sufficient temperature data are available beginning in 1984, although most years see some missing data. When possible, missing data were replaced with their twenty-year average or, in the case of temperatures, with hourly observations. June 2002 and both June and September 2003 were not available, and data for these months were replaced with the twenty-year averages for those months. Data for the years 2006-2010 were calculated using hourly temperature readings.

Precipitation data for Beaver Creek are available from 1981, although with missing values in a few years. January 1981 was missing and it was replaced with its twenty-year average. June 2002 and both June and September 2003 were missing and data for these months were replaced with their twenty-year averages. There are no useable daily records of precipitation for Beaver Creek beyond April 2005.

Faro Temperature and Precipitation.

Data for Faro were obtained from two stations: Faro A, 2100517, and Faro Auto, 2100518. Extracts from the Canadian Climate Centre's Station Catalogue are given in Table 2 and illustrate changes in the history of this station.

For temperatures, most years had some missing data. Sometimes it was a period of a few consecutive days, sometimes a few random days, other times whole months. Missing days were usually replaced with their twenty-year average. If there were data from the automatic station, data from that station were used, adjusted for the difference in the average values between those of the manned and the automatic stations. There were no useful data from either station for the year 2002. Data for the years 2007-2010 were taken entirely from the automatic station.

Faro is missing precipitation records for December 2000 and for many records for the years 2002 onward, except for 2006. Records from the automatic station did not appear to be very reliable, so the analysis of Faro's precipitation ended at 2001.

Old Crow Temperature and Precipitation.

Data for Old Crow were obtained from two stations: Old Crow A, 2100800 and Old Crow (AUT), 2100805. There were useable temperature records from 1985-2010. As with Faro matching observations were used to compute the differences between the manned and automatic stations so that adjustments could be made.

For temperatures, data from the automatic station were used from 2002-2010, except for the year 2004. The years 1981-1984 were missing two or three month's data each and they were not included in the study. Many years had a few observations missing, and the twenty-year averages were used to replace the missing values.

The annual precipitation was calculated for the years 1981 to 2010. Half of 2006 was missing; it was not included. September and November 2002, May 2003 and October 2005 were missing. The twenty-year averages were used in their places. Similarly for ten missing days in 1981 and nine days in 1983.

Snow on Ground

Snow on the Ground measured on 28 February is available at our three stations for some of the years between 1980 and 2007. Each station, however, is missing some data for at least one year. The availability of the data is listed here:

- **Beaver Creek**. Data were available from 1983 to 2006, with five missing years: 1985, 88, and 91-93. Furthermore, data for Feb 25 was used for 1987, Feb 26 for 1994, Mar. 1 for 1989 and 1995, and Mar. 4 for 1990.
- **Faro**. Data were available from 1981 to 2007 with data missing from2003.
- **Old Crow**. Data are available from 1987 to 2007 with two missing years: 1989 and 2006, and using the observation from March 2 for the year 1987.

Frost Free Days

Frost Free Days were calculated at our four stations for the period of record. Each station, however, is missing some data for at least one year. Data from the automatic stations at Faro and Old Crow were used to supplement data from the manned stations, while hourly data, if available, from Beaver Creek were similarly used to supplement missing daily observations.

- **Beaver Creek**. Data from 2100160 were used from 1981 to 2006. Hourly observations were used to provide data for the months of June in 2002 and 2003. The minimum hourly temperatures for the days in June from 1981 to 2006 were compared to the minimum daily temperatures for the matching days. The differences between the minimum hourly and daily temperatures were computed, and the probability of having a difference of 10C or more was only 11%. For each day in June 2002 and 2003 with a minimum hourly temperature less than 10, the hourly records for that day and the previous day were assessed to see how likely frost would be. None of the days examined were likely to have had frost because of high winds, high dewpoints, rain and/or cloud. For the years 1981 to 1983, observations were taken only on weekdays. Observations from these years were examined also to estimate if the weekends were likely to have frost.
- **Faro**. Data are available from 1981 to 2001, 2004 and 2006 from the manned station and from 2002 to 2010 for the auto station. Matching observations from the two stations were used to estimate what frost temperature should be used for the auto station; it was determined that 0.3 gave the best fit.
- **Old Crow**. Data from 1981 to 2007 were available from the manned station 2100800 and from 1996 to 2010 from the auto station. Several years had a few observations missing from one station or the other. Matching observations from the two stations were compared and the best match for frost-free days was made if a temperature of 0.5 was used for the auto station. There were no observations available for the manned station in September 2002 nor in May or June in 2006. For these years, and for the years 2008 to 2010 data from the Auto station were used.

Mean Hourly Wind Speeds

Hourly observations for all 24 hours per day are available only from the two auto stations, and their periods of record are not long enough to be useful. Faro Auto, 2100518, has the longest record with 18 years, Old Crow Auto, 2100805, has 15 years and there is no auto station at Beaver Creek.

Results

The results are presented by the dataset analyzed.

Mean Daily Minimum in Winter.

- **Beaver Creek**. (See Figure 1.) The data analyzed covers winters from 1983 to 2009 inclusive. Daily observations were used for winters up to 2005; hourly temperatures were used for winters 2006 to 2009. Minimum hourly temperatures for each day from 1990 to 2001 were compared to the minimum daily values for the corresponding days. It was found that the average minimum hourly temperature was 5.6 degrees higher than the average daily minimum. Over the period of record, Beaver Creek shows an overall increase of 0.2 deg/decade.
- **Faro**. (See Figure 2.) The data cover the winters from 1980 to 2009 inclusive. Observations from the manned station were used up to and including 2001, and for the years 2005 and 2006. Data from the auto station were used for the years 2002 to 2004 and for 2007 to 2009. Temperatures from the auto station were found to be about 0.2 degrees lower than those from the manned station. There were no observations for December 2000 so the twenty-year average for December was used in their place. Faro shows warming at a rate of 0.5 deg/decade.
- **Old Crow**. (See Figure 3.) Records from the manned station cover the winters 1980 to 2007, and observations from the auto station are available from 1995 to 2009. Both records have gaps of a few days or, on occasion, a few months. Observations from the auto station were used for the years 2002 and from 2006 to 2009. Observations from February 2005 were not available from either station: in this case, the observations from the manned station were used supplemented by the average February temperature. Missing observations from the first nine winters were replaced with their twenty-year average values. Old Crow shows significant warming over the past thirty years equal to a rate of 1.2 deg./decade.

Mean Daily Maximum Temperatures in Summer.

- **Beaver Creek**. (See Figure 4.) The data from 1984 to 2010 inclusive were used. Hourly data were used for the years 2006 to 2010 and for the months of June in 2002 and 2003. The hourly maximum temperature for each day in the summer was found to be 2.1 degrees lower than the corresponding daily maximum, so hourly values were adjusted accordingly. Over the years 1984 to 2010, the rate of warming of the mean summer daily maximum temperature is 0.5 deg/decade.
- **Faro**. (See Figure 5.) Observations from both the manned and auto station were used to give a dataset from 1981 to 2010. Observations from the auto station were used for the years 2002, 2003, 2005 and 2007 to 2010. The average summer maximum temperatures for the auto station are 0.4 degrees lower than for the manned station. The period of warming for the last thirty years is measured at 0.3 deg/decade.
- **Old Crow**. (See Figure 6.) Old Crow data from the summers of 1981 to 2010 were used. Observations from the auto station were used for the summers of 2003, 2006 and from 2008 to 2010. Daily maximum temperatures are 0.7 degrees warmer than the corresponding temperatures recorded at the manned station, and the auto temperatures were adjusted accordingly. Several observations were missing from the first four summers; these were

replaced with their twenty-year averages. Over the thirty-year period, Old Crow shows warming at a rate of, about 0.2 deg./decade.

Mean Annual Temperature.

- **Beaver Creek**. (See Figure 7.) The data record used covers the years from 1984 to 2010 inclusive. June data were missing for 2002 and June and September data were missing for 2003. 13 day's worth of data were missing in 1989. All these missing data were replaced with their twenty-year averages. Hourly data were used to estimate temperatures for 2006-2010. The annual curve shows a slight increase of the period equal to 0.1 degrees per decade.
- **Faro**. (See Figure 8.) There were enough data to construct analyze the years from 1981 to 2010 inclusive. Nearly all years were missing some observations, and these were replaced with their twenty-year averages. There were not enough data to process the year 2002. Some of the data from 2003 on were derived from the auto station 2100518. Over the thirty-year period the warming is measured at 0.3 degrees per decade.
- **Old Crow**. (See Figure 9.) Old Crow has useable data to cover the years 1985-2010. Many years were missing a few days, and these were replaced with their twenty-year averages. Data from the auto station, 2100805, were used from 2000 on to fill in holes in the dataset from the manned station. Data from the auto station were entirely from 2008 on. Old Crow, over the past 25 years, shows warming at a rate of 0.3 degrees per decade.

Total Winter Precipitation.

- **Beaver Creek**. (See Figure 10.) The data record covers every winter day from 1981 to 2005 except for November 10, 1982. Over this twenty-five-year span, winters have become steadily drier, dropping about 11.3 mm per decade, or about 38% over the period.
- **Faro**. (See Figure 11.) The period of record for this evaluation is from the winter of 1980 to 2007. Data from three winters were missing: 2002, 2003 and 2004. Data for the months of December 2000 and February 2008 were also missing. Data for these months were supplied by their twenty-year averages. Faro, too, shows a decline in winter precipitation, decreasing at a rate of 7.5 mm per decade. This represents a decrease of 29% over the period of 28 years.
- **Old Crow**. (See Figure 12.) Old Crow has useful data for winter precipitation that covers 1980 to 2006, with a few days missing in 1980 and 1983 and the months November 2002 and 2006, and February 2006. Old Crow shows a trend towards snowier winters, increasing at a rate of 2.7 mm per decade. Over the period of 27 years, this represents a increase of about 12%.

Total Summer Precipitation.

- **Beaver Creek**. (See Figure 13.) The period of record used is from 1981 to 2005. Data for the month of June were missing from the years 2002 and 2003; otherwise only three days were missing from the record. Data for the missing months of June were replaced with their twenty-year averages. Beaver Creek shows increasing summer precipitation, up about 20.3 mm per decade. Over the 25 year period, precipitation is up 22%.
- **Faro**. (See Figure 14.) Faro records of summer precipitation were used from 1981 to 2006, except for the years 2002 and 2003. Data were also missing from June 2005; again the twenty-year average June precipitation was used to fill the gap. There appears to be a slight decrease in

summer precipitation of about 3.8 mm per decade, which represents a decrease of about 6% over the period of 26 years.

- **Old Crow**. (See Figure 15.) Old Crow summer precipitation was analyzed for the years 1981 to 2008. Data for five complete months were missing: May 2003; May and June 2006; and, July and August 2008. Twenty-year averages were used to fill these missing months. The record shows year-to-year fluctuations in the amount of summer precipitation, but overall there is virtually no change, with a decrease of about 1 mm per decade.

Total Annual Precipitation.

- **Beaver Creek**. (See Figure 16.) The period of record used is from 1981 to 2005. Data for the months January 1981, June 2002, and June and September 2003 were missing. 15 days were missing in 1983 and a couple each in 1985 and 1998. The data show wide fluctuations from year to year, but an increase of 18 mm per decade is observed. Over the 25 years of record, precipitation has increased by 12%.
- **Faro**. (See Figure 17.) The period of record for Faro is from 1981 to 2007. The years 2002 and 2003 are absent. Seven additional months are missing: Dec 2000; January and December 2004; January and June 2005; and, May and August 2007. The twenty-year averages for these months were used in their place. Over the 27 years analyzed, there was virtually no trend, although there were large year-to-year variations.
- **Old Crow**. (See Figure 18.) The period of record used for Old Crow is also for the years 1981 to 2007. The year 2006 was missing 180 days, and was ignored. The missing months were: September and November 2002; May 2003; October 2005; and, November and December 2007. A few days were missing in other years as well. Again twenty-year averages were used to fill gaps of more than a couple of days. Over the 27 years, Old Crow shows a steady increase in annual precipitation of 13.4 mm per decade. Over the period, precipitation has increased by 14%.

Snow on Ground for February 28

- **Beaver Creek**. (See Figure 19.) Data for snow on ground are available for the years 1983 to 2006 with five years missing: 1985; 1988; and 1991-1993. In addition, data for five other years were taken from the nearest day closest to February 28. These days were: February 25, 1987; March 1, 1989; March 4, 1990; February 26, 1984 and March 1, 1995. In spite of the missing data, the curve shows a strong decrease in snow depth over the 24 years, amounting to 5.3 cm per decade or a reduction of 28%.
- **Faro**. (See Figure 20.) Faro Snow on Ground data for 28 Feb. from 1981 to 2007 were used. Only one year, 2003, was missing. This record also shows a strong decrease, amounting to 6.4 cm per decade or down 46% over the 27 year period.
- **Old Crow**. (See Figure 21.) Old Crow had data from 1987 to 2007 with two years missing: 1989 and 2006. The reading taken on March 2, 1987, was used for that year. Unlike the other stations, Old Crow shows an increase in snow depth over the period, up at a rate of 4.8 cm per decade or 28%.

Days Below –40 C.

- **Beaver Creek**. (See Figure 22.) Beaver Creek has data for the years 1984 to 2005. In this period of record were some missing days, and days nearby were checked to see if it was likely that any very cold days would have occurred, and adjustments were made, if it were deemed to be necessary. The average number of days with temperatures below –40 is 10.8 and there is a very slight increase in this number of time, amounting to 0.5 days per decade.
- **Faro**. (See Figure 23.) Faro had records from 1981 to 2010, although the years 2000 and 2002 were missing enough data to exclude them. Data from 2003 to 2010, except 2007, were taken from readings from the auto station, 2100518. Faro shows a decrease in the number of very cold days at a rate of 1.4 days per decade. Over the thirty-year period, the number of very cold days is down 38%. If this trend were to continue, there would be no days below –40 by 2060.
- **Old Crow**. (See Figure 24.) Old Crow also had records from 1981 to 2010, missing the year 2006. Data from the auto station, 2100805, were used for the years 2003, 2004 and 2008-2010. As with the other two stations, observations around missing days were examined to see if any adjustments would have to be made. Old Crow also show an overall trend towards fewer very cold days, about 2.5 days per decade. If this trend were to continue, there would be no days below –40 by 2095.

Frost-Free Days.

- **Beaver Creek**. (See Figure 25.) The data for Beaver Creek, from 1981 to 2005, show an increase of 6.4 days per decade, up 26% over the 25 years. For the first three years of the record, there were no observations taken on the weekend, and there are no records for June in 2002 or 2003. In the latter case, hourly temperatures were examined to determine if frost was likely. The minimum hourly temperature for each day in June from 1981 to 2005 – observations were taken just from 8:00 a.m. – 2:00 p.m. – were compared to the minimum daily temperature for the corresponding days. It was found that if the minimum hourly temperatures were 10 C, the chance of a daily minimum less than 0C was only 11%. If the minimum hourly temperature was 5C, the chance of frost was 55%. For the two missing months of June, the hourly observations for each day were examined to see how likely frost would be. If the minimum hourly temperature was greater than 12C, we considered the day to be frost-free. For minimum hourly temperatures less than that, we considered other factors such as wind, cloud, rain, high dewpoints etc. to rule out the likelihood of frost. For the missing weekend observations in the first three years, we had to make educated guesses as to whether frost might have occurred or not.
- **Faro**. (See Figure 26.) Faro also has wide year-to-year variations in the number of frost-free days, but over the period 1981-2010 the number of frost-free days has increased at a rate of 7.5 days per decade, up 30% in the thirty years. Data from the manned station were used from 1981 to 2001, and for the years 2004 and 2006. Data from the auto station, 2100518, were used for the remainder of the years. Comparisons were made between the daily minimum temperatures between the manned and auto stations for the months June to August from 1993-2007 and it was determined that the auto station minimum temperatures were 0.3C warmer than those from the manned station.
- **Old Crow**. (See Figure 27.) Data from 1981 to 2010 were used for Old Crow and, as with the other stations, there is a marked increase in the number of frost-free days: up at a rate of 7.3 days per decade for an increase of 38% over the thirty years. As with Faro, daily observations from the auto station were adjusted and used for several years. For Old Crow these years were:

2003, 2006, and 2008-2010. The auto station minimum temperatures run 0.5C higher than the temperatures from the manned station. When there were days missing from the records, the observations from the previous and following days were examined to see whether frost might have been likely.

Fine Fuel Moisture Codes

Finally, changes in the average June values for four of the Canadian Forest Service's Fire Weather Indices were examined for the years available up to 2010 for the three stations. Data were available beginning in 1981 for Beaver Creek, from 1985 for Old Crow and from 1986 in the case of Faro. Fortunately for us, these records are complete. The meteorologist working for, or on behalf of, the forest service ensures that the datasets are complete, and will fill in any missing data with a best-guess value considering the synoptic situation at the time.

The Canadian Forest Fire Danger Rating System provides for the assessment of relative fire potential solely on the basis of weather observations. The FWI System's six components individually and collectively account for the effects of fuel moisture and wind on ignition potential and probable fire behavior in the form of relative numeric ratings. (Canadian Forest Service, 1996.)

The Fine Fuel Moisture Code (FFMC) is a numeric rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and the flammability of fine fuel. (See Figures 28 to 30.)

For the three stations considered, Beaver Creek increased at a rate of 1.5 units per decade (6.5% in thirty years), Faro showed a decrease of 1.3 units per decade (4% in 25 years) while Old Crow showed a small increase over the 26 year period, rising at a rate of 0.9 units per decade (3%).

Initial Spread Index

The Initial Spread Index (ISI) is a numeric rating of the expected rate of fire spread. It combines the effects of wind and the FFMC on rate of spread without the influence of variable quantities of fuel. (See Figures 31 to 33.)

Beaver Creek showed a strong increase, up at a rate of 0.4 units per decade (52% over 30 years), Faro showed a slight decrease, down at a rate of 0.2 units per decade (2% over 25 years), while Old Crow remained essentially unchanged over its 26 years of record.

Drought Code

The Drought Code (DC) is a numeric rating of the average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smoldering in deep duff layers and large logs. This code is a measure of wet and dry spells. (See Figures 34 to 36.)

Each of the stations showed changes in Drought Codes over their periods of record. Beaver Creek up 18 points per decade (35% over thirty years), Faro up 57 points per decade (64% over 25 years), but Old Crow down 11.5 points per decade (13% over 26 years).

Fire Weather Index

The Fire Weather Index (FWI) component itself combines the ISI and Build Up Index (BUI) to indicate the potential intensity of a fire on level terrain in a stand of mature pine. (See Figures 110 to 117.)

Beaver Creek shows a strong increase in the Fire Weather Index, up at a rate of 1.2 points per decade (76% in thirty years); Faro shows essentially no change, whereas Old Crow shows a slight increase at a rate of 0.2 points per decade (6% over 26 years).

Conclusion

There is strong evidence of climate change in the Yukon in the set of weather data available for these and other stations in the territory. . (Purves, 2006 and Purves, 2010.) Overall, winters and summers are warmer, with winters showing the greatest change. Over the past thirty years, Beaver Creek, Faro and Old Crow had winters warming by 0.2 – 1.2 degrees per decade with the strongest warming seen in Old Crow.

Summer mean maximum temperatures show increases in the ranges of 0.2 to 0.5 degrees warming per decade. Beaver Creek had the strongest rate of warming of the three stations.

Over the past thirty years, winters, for the most part, are drier, although Old Crow has a very slight increase. Summers are wetter in Beaver Creek, with slightly drier summers for the other two stations.

Over the past thirty years, there has been a decrease in snow depth for the 28 February at Beaver Creek and Faro and an increase at Old Crow.

Forest Fire indices were also examined. Faro had a decrease in the Fine Fuel Moisture Codes, while Beaver Creek and Old Crow's trends were up. The Initial Spread Index was up in Beaver Creek, down in Faro, and essentially unchanged in Old Crow. Beaver Creek and Faro showed increasing Drought Codes, with the Old Crow's June 1 drought code decreasing. Finally, the Fire Weather Index was slightly higher in Beaver Creek but little changed in Faro and Old Crow.

This study has shown problems with the climate record datasets. Many stations have only very spotty records, and some stations have moved frequently. If there are no overlapping observations with those stations in their old and new locations, it is very difficult to estimate the effect of the move on the data. Environment Canada has not processed daily observations since around 2007, making it necessary to use data from nearby automatic stations, and/or trying to relate hourly observations to daily. Furthermore, it has been my experience that precipitation measured by automatic stations is highly suspect and none of these observations were used for this study.

Furthermore, there are considerable year-to-year variations in the data, and these variations can cause different results to be calculated depending on whether or not they are included in the sample.

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List of Figures

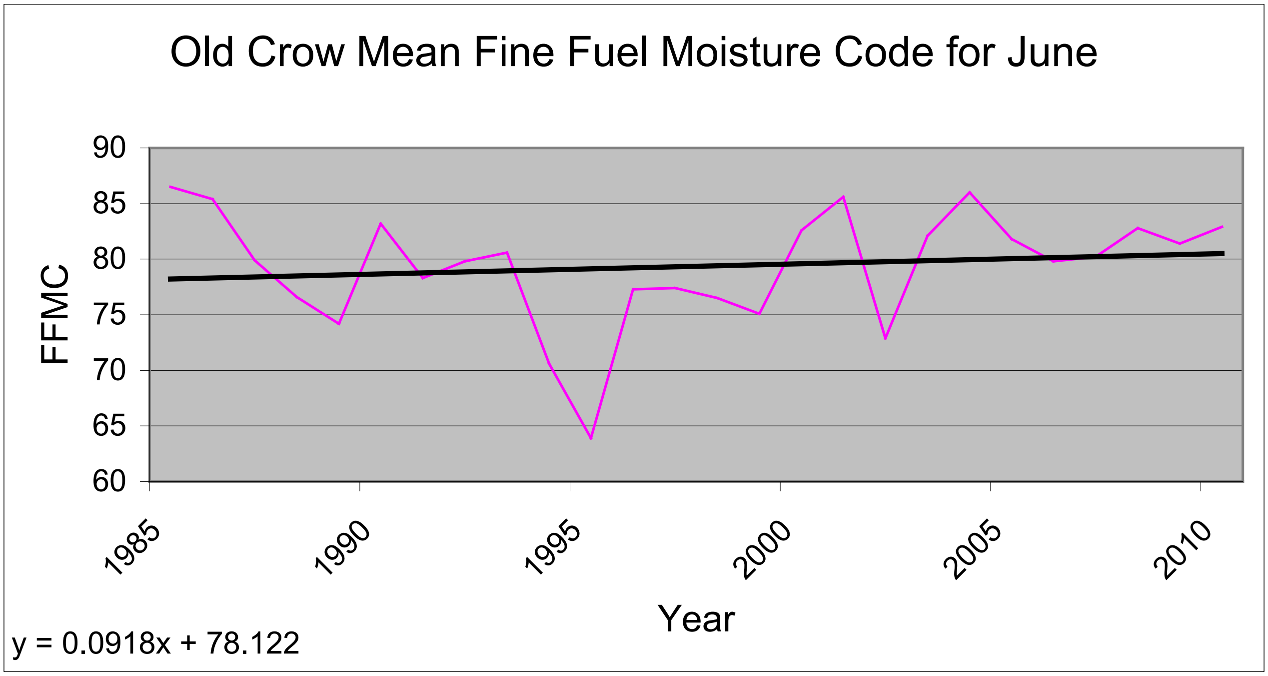

Figure 1. Beaver Creek Mean Daily Minimum in Winter.

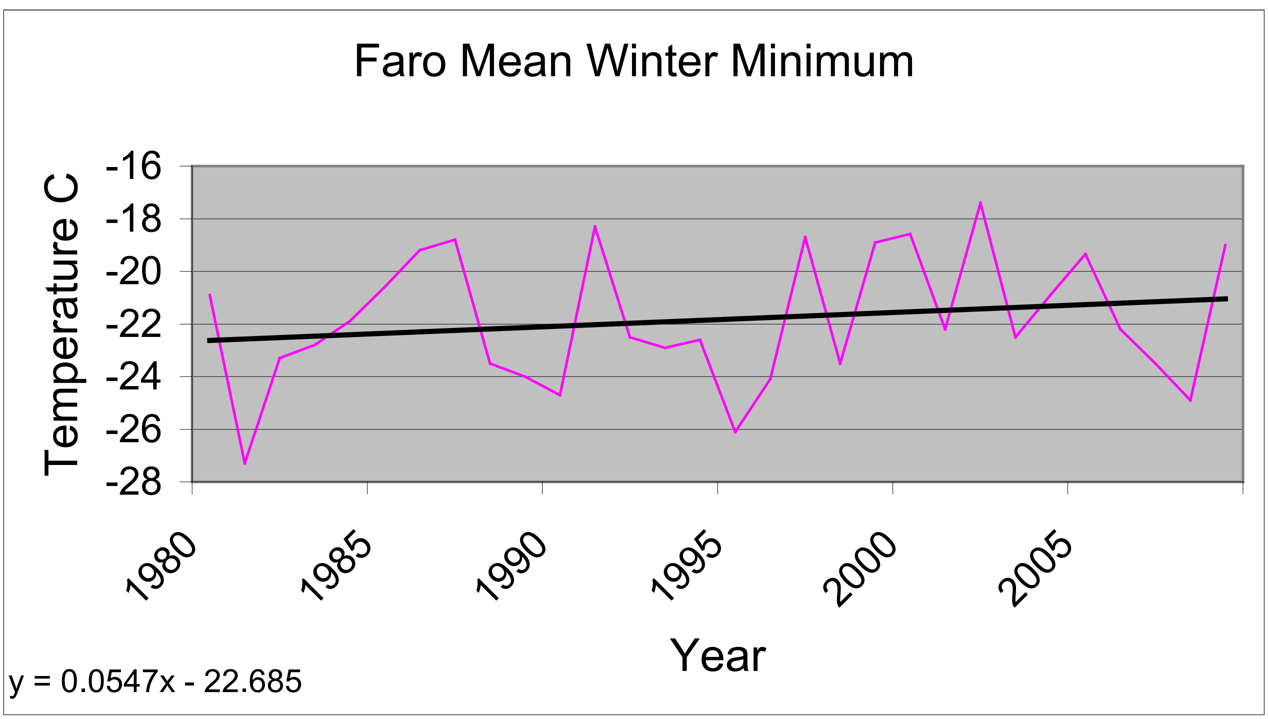

Figure 2. Faro Mean Daily Minimum in Winter.

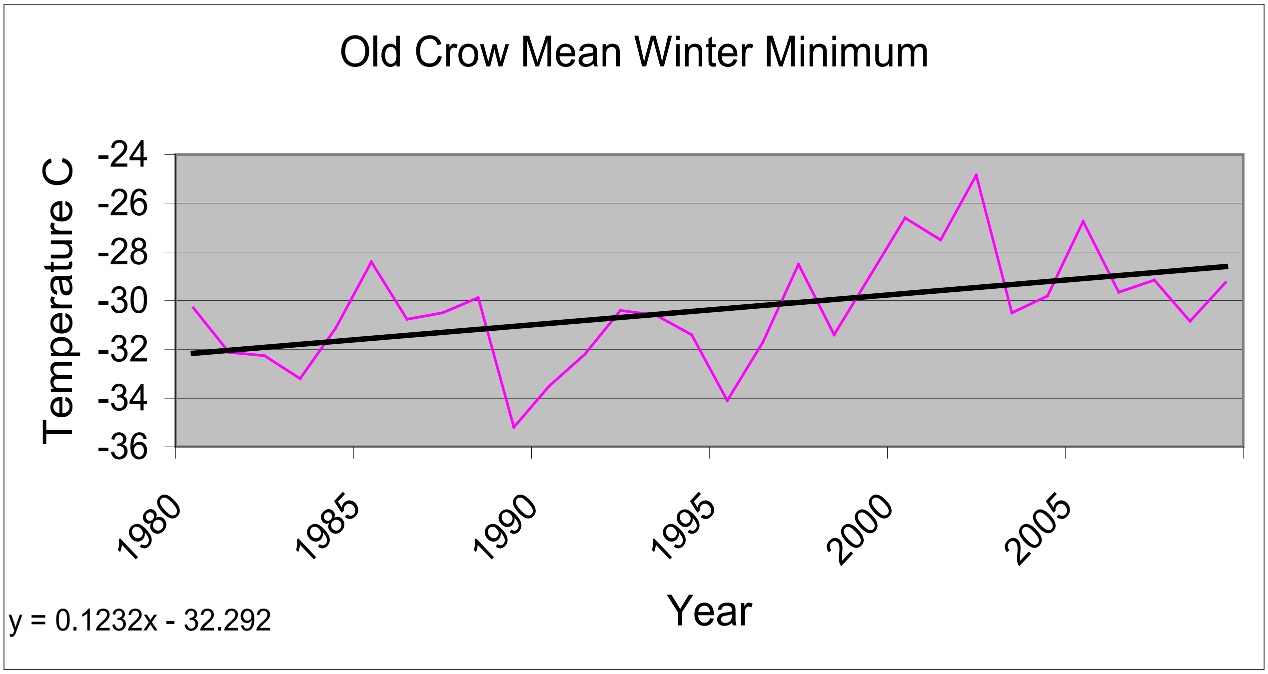

Figure 3. Old Crow Mean Daily Minimum in Winter.

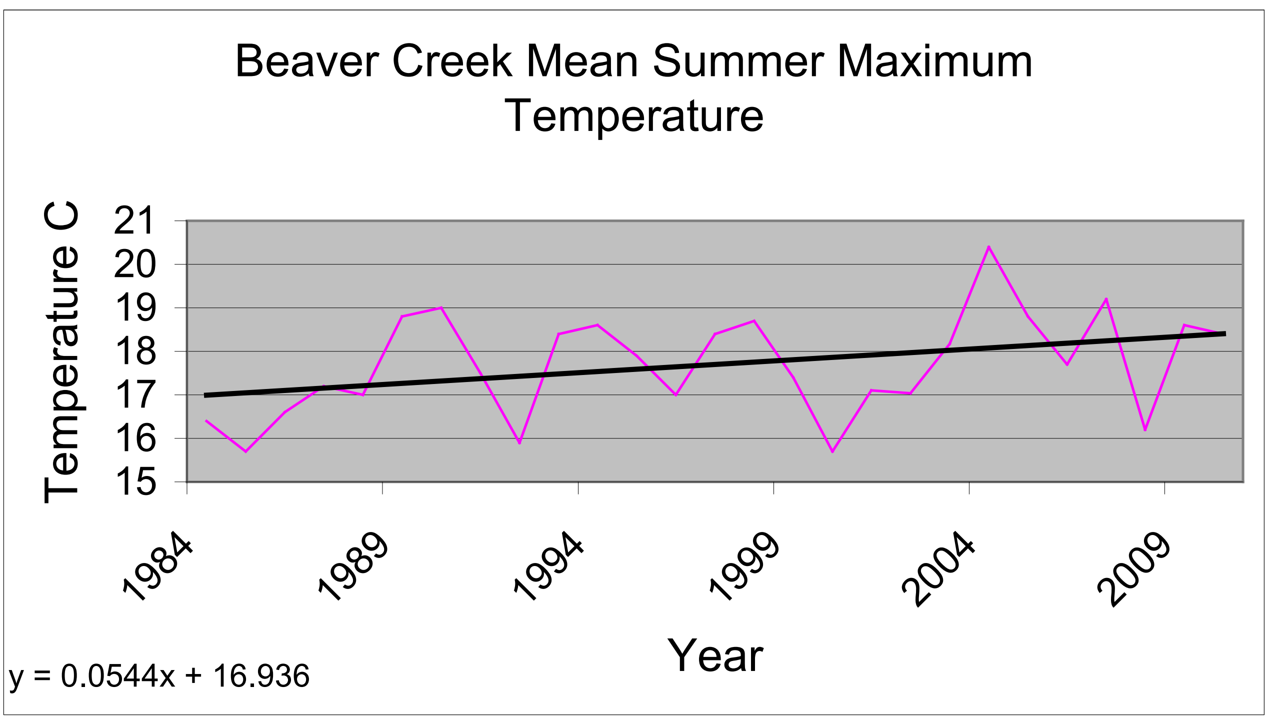

Figure 4. Beaver Creek Mean Summer Maximum Temperature.

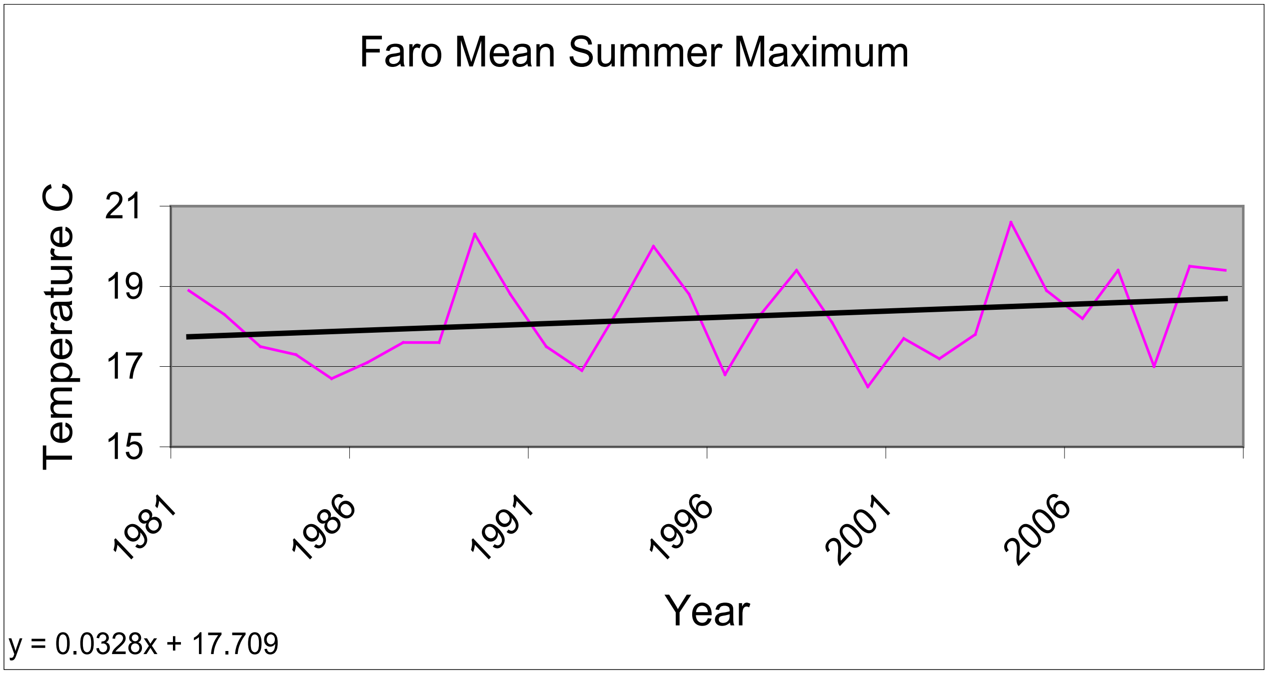

Figure 5. Faro Mean Daily Maximum in Summer.

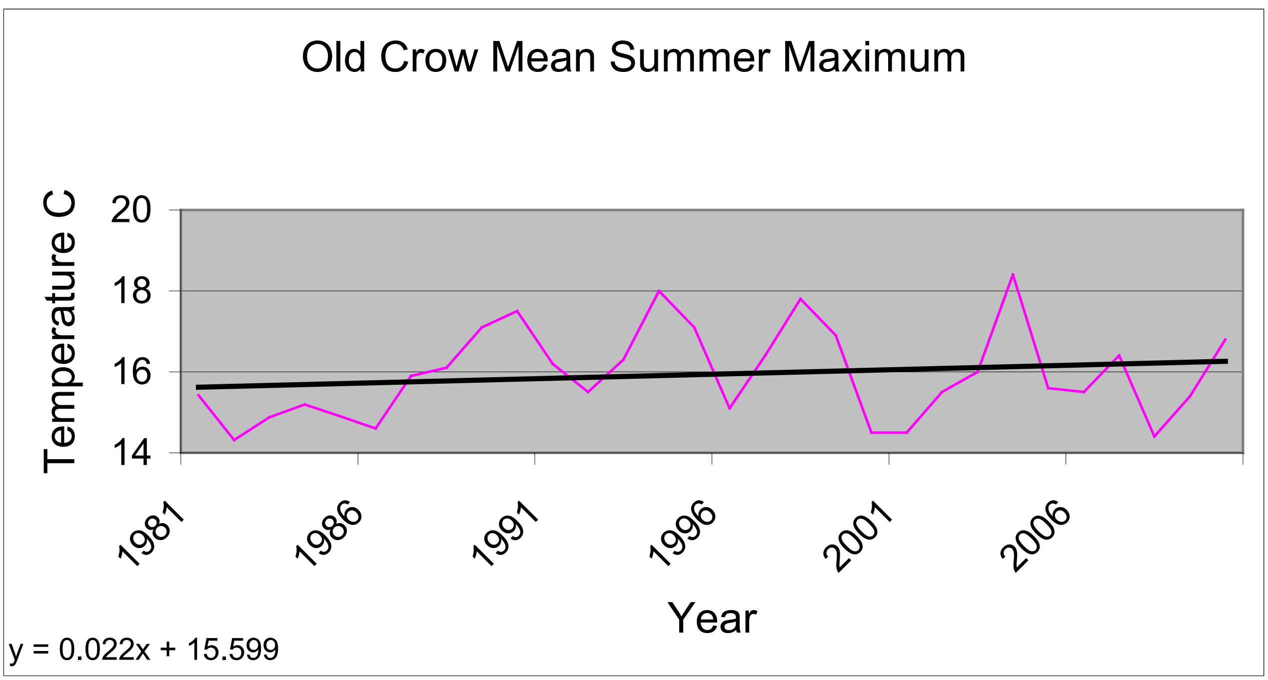

Figure 6. Old Crow Mean Daily Maximum in Summer.

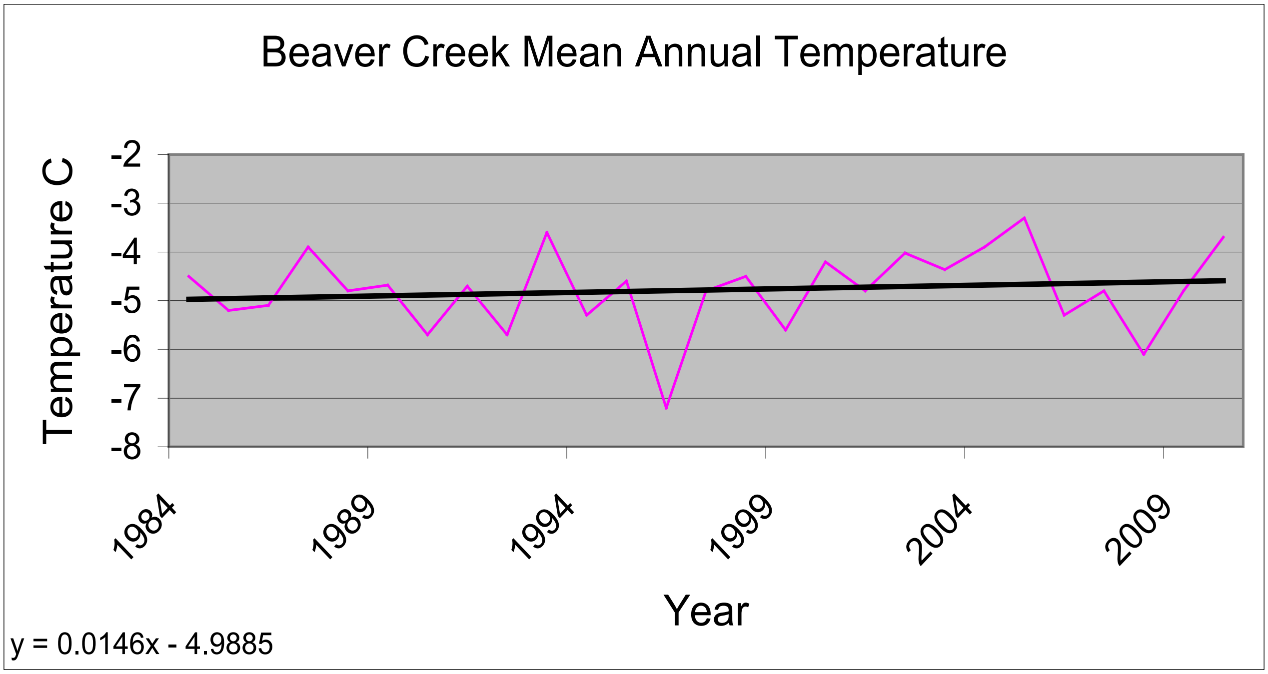

Figure 7. Beaver Creek Mean Annual Temperature.

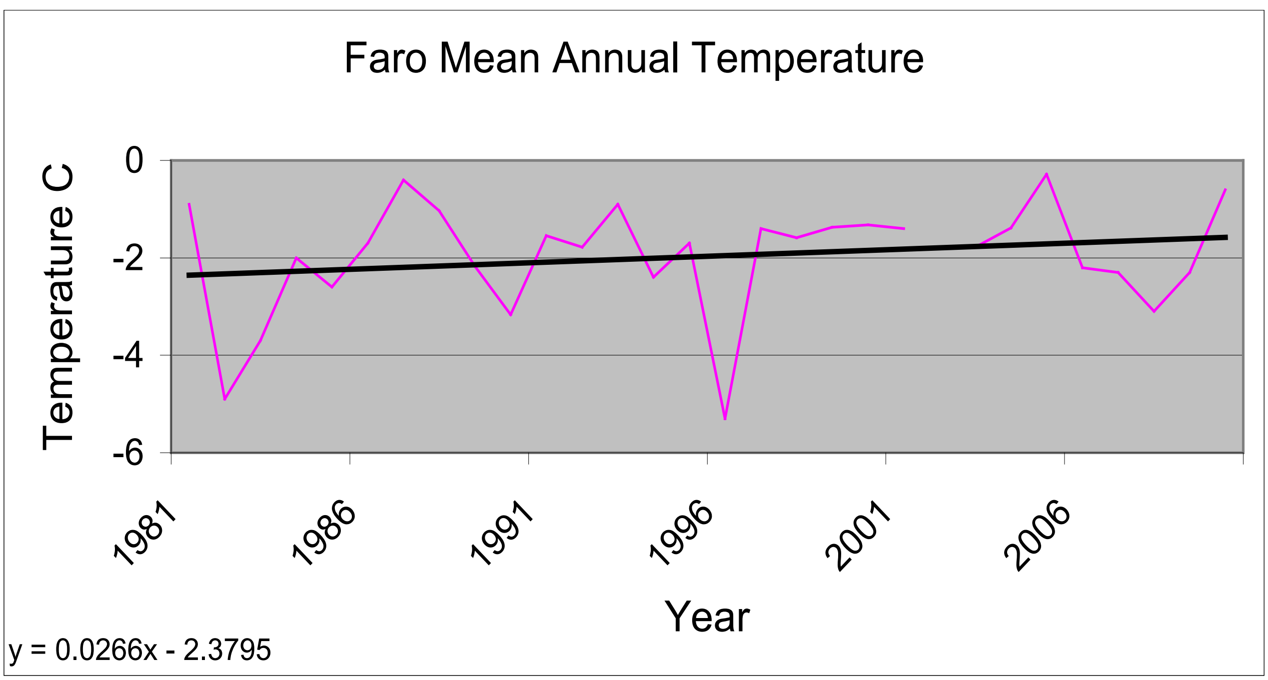

Figure 8. Faro Mean Annual Temperature.

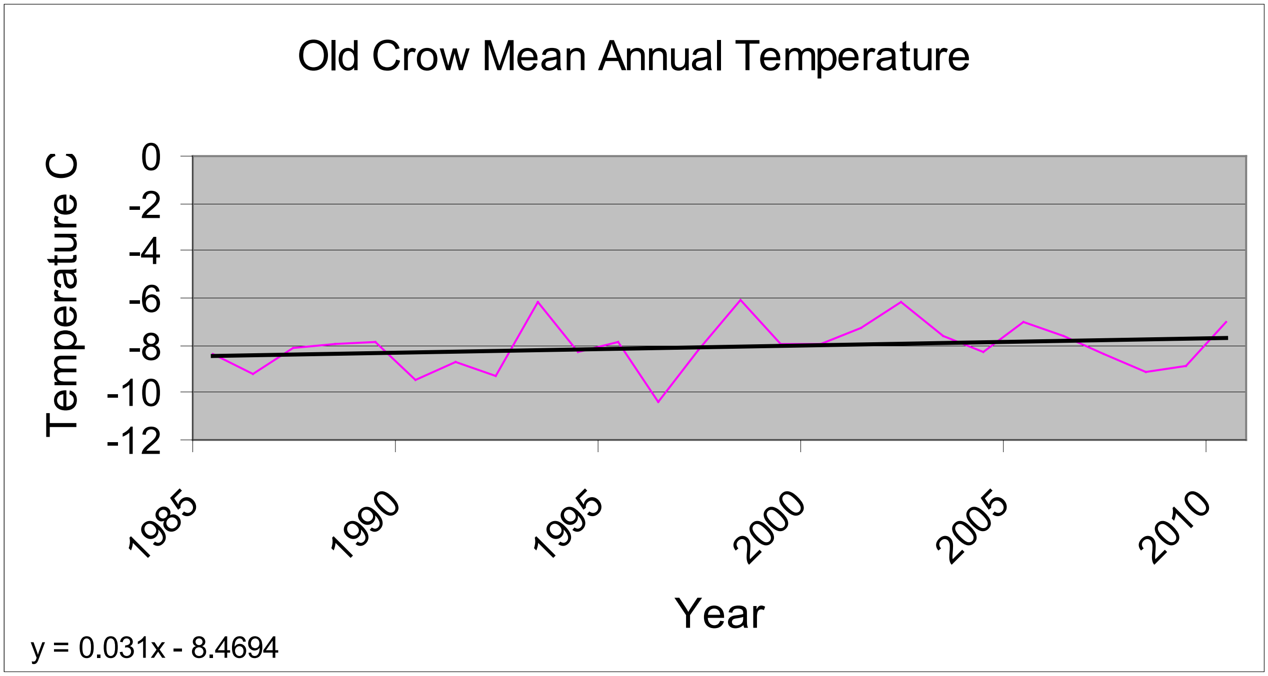

Figure 9. Old Crow Mean Annual Temperature.

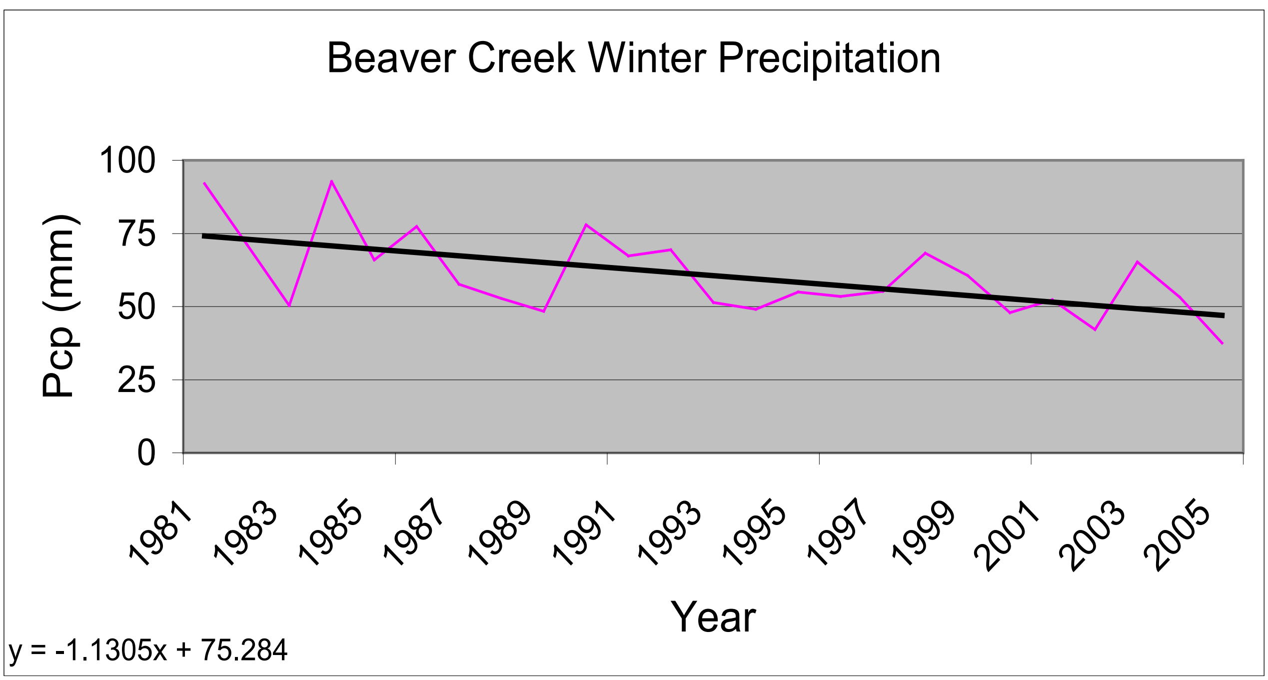

Figure 10. Beaver Creek Winter Precipitation.

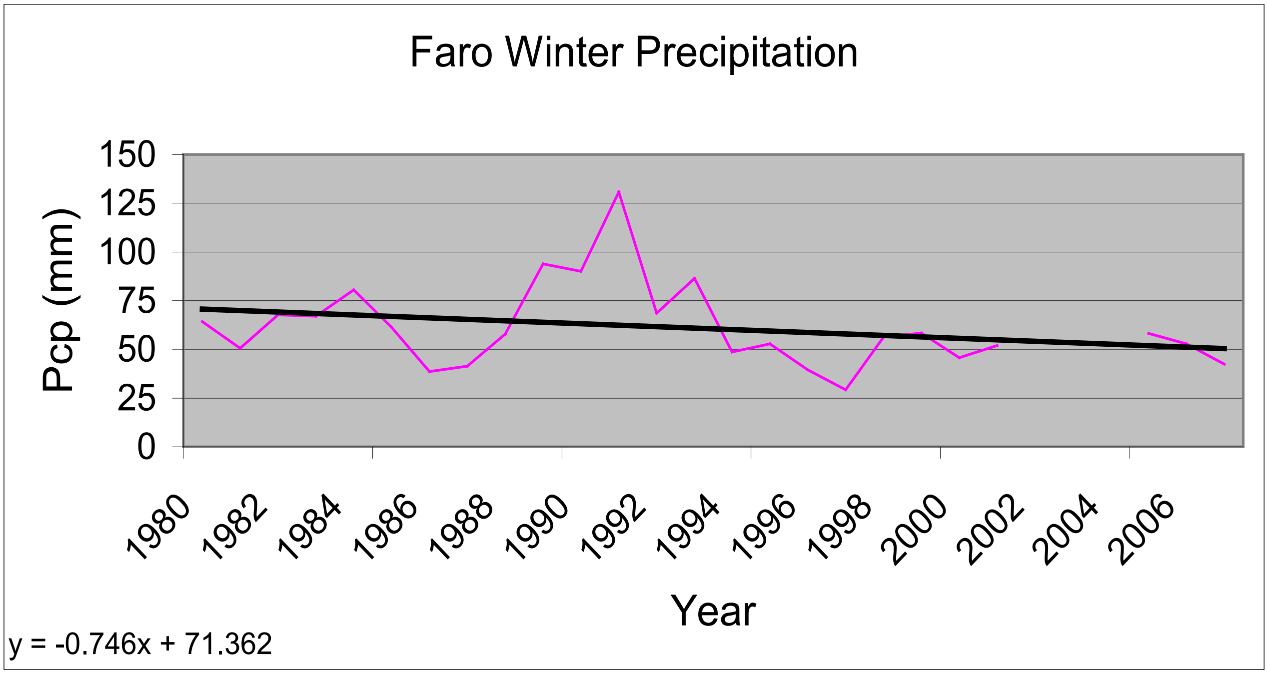

Figure 11. Faro Winter Precipitation.

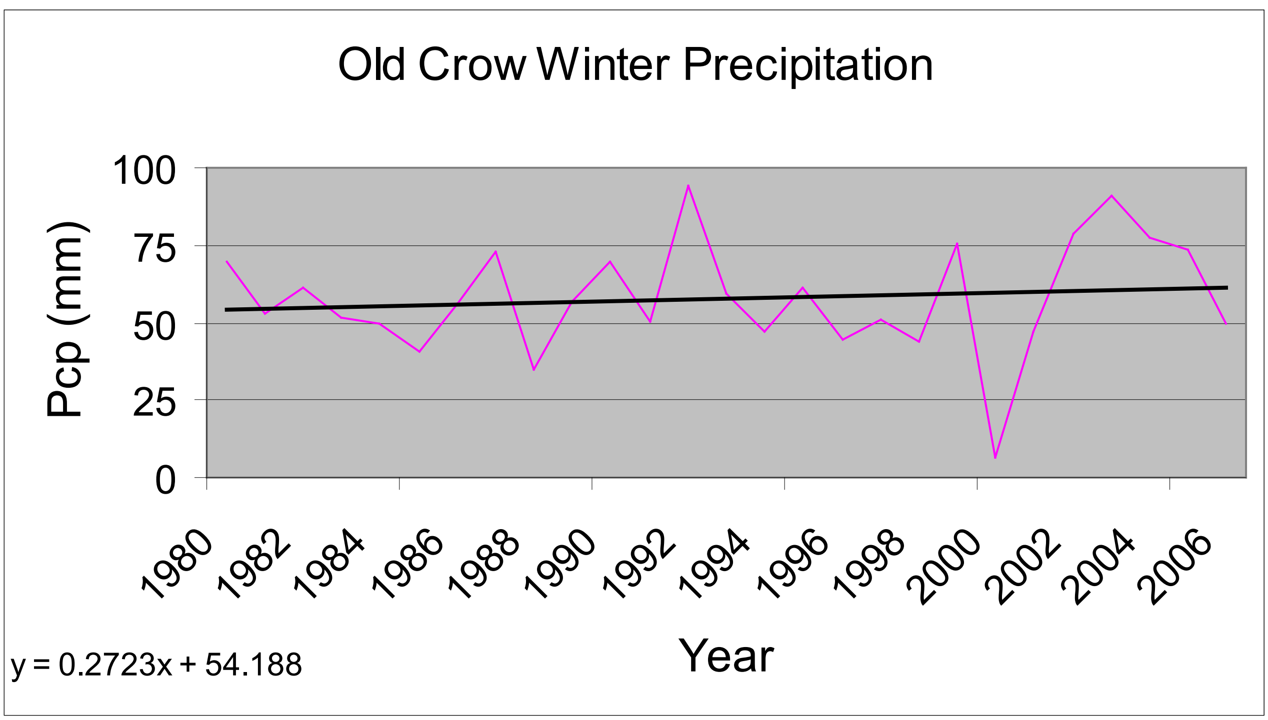

Figure 12. Old Crow Winter Precipitation.

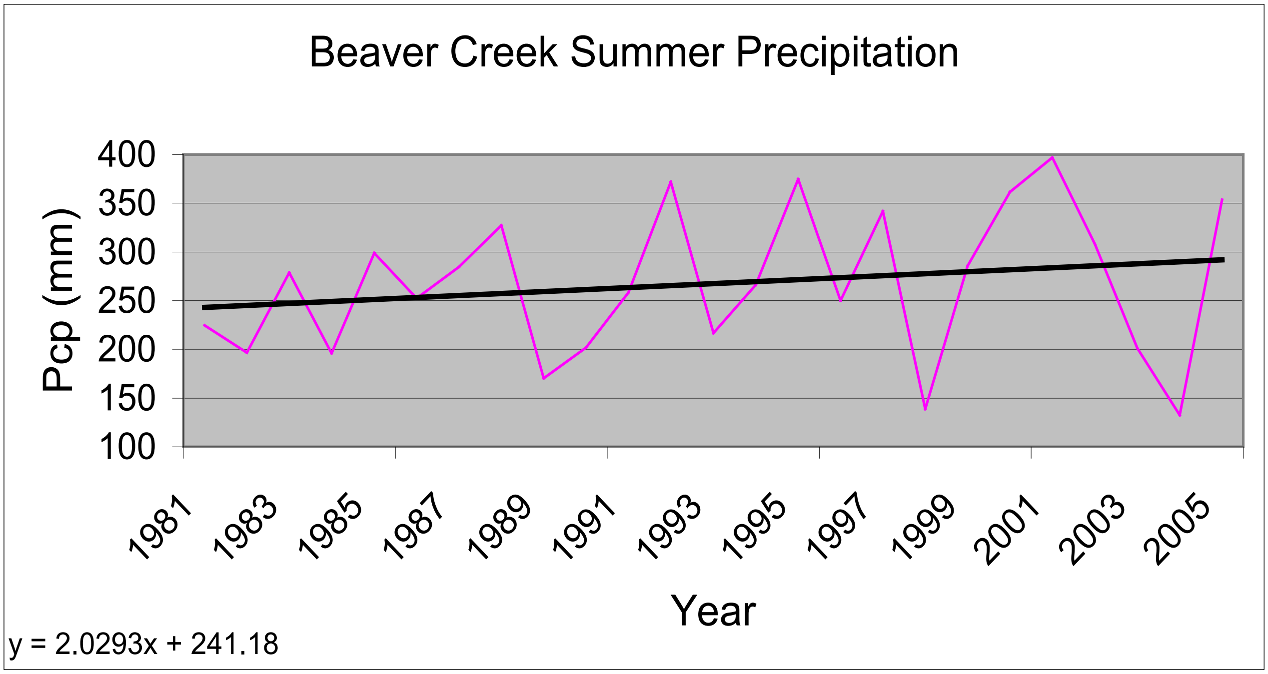

Figure 13. Beaver Creek Summer Precipitation.

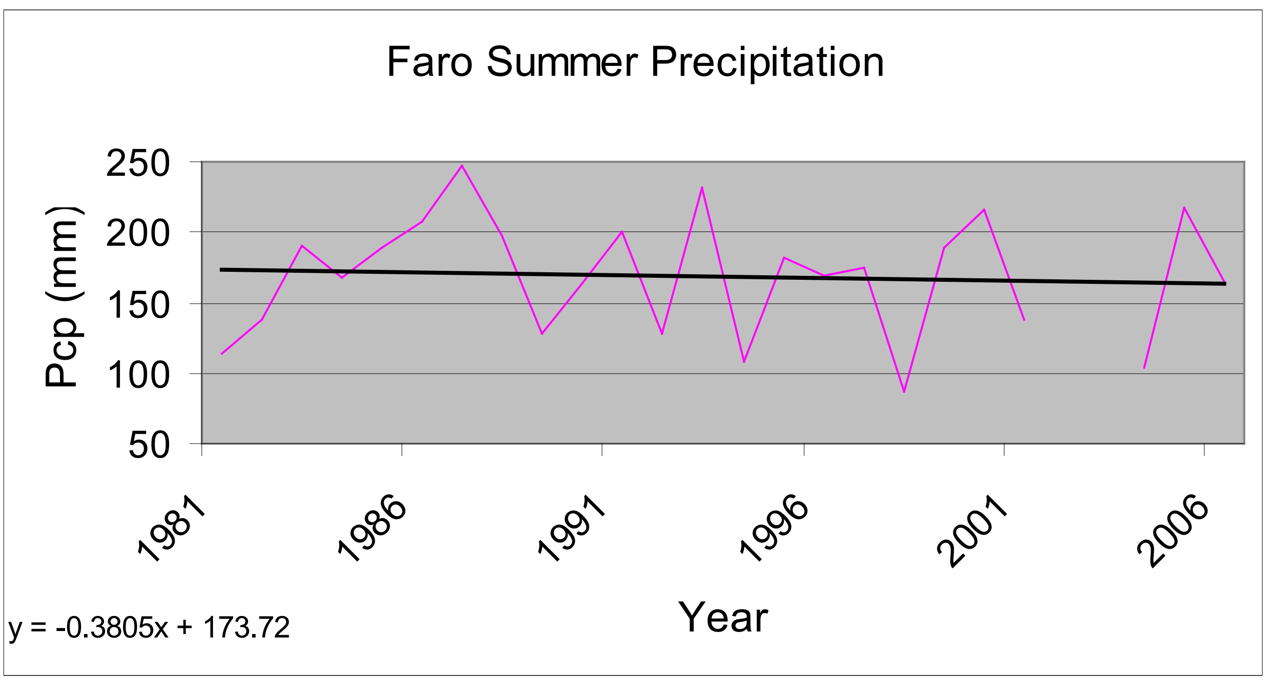

Figure 14. Faro Summer Precipitation.

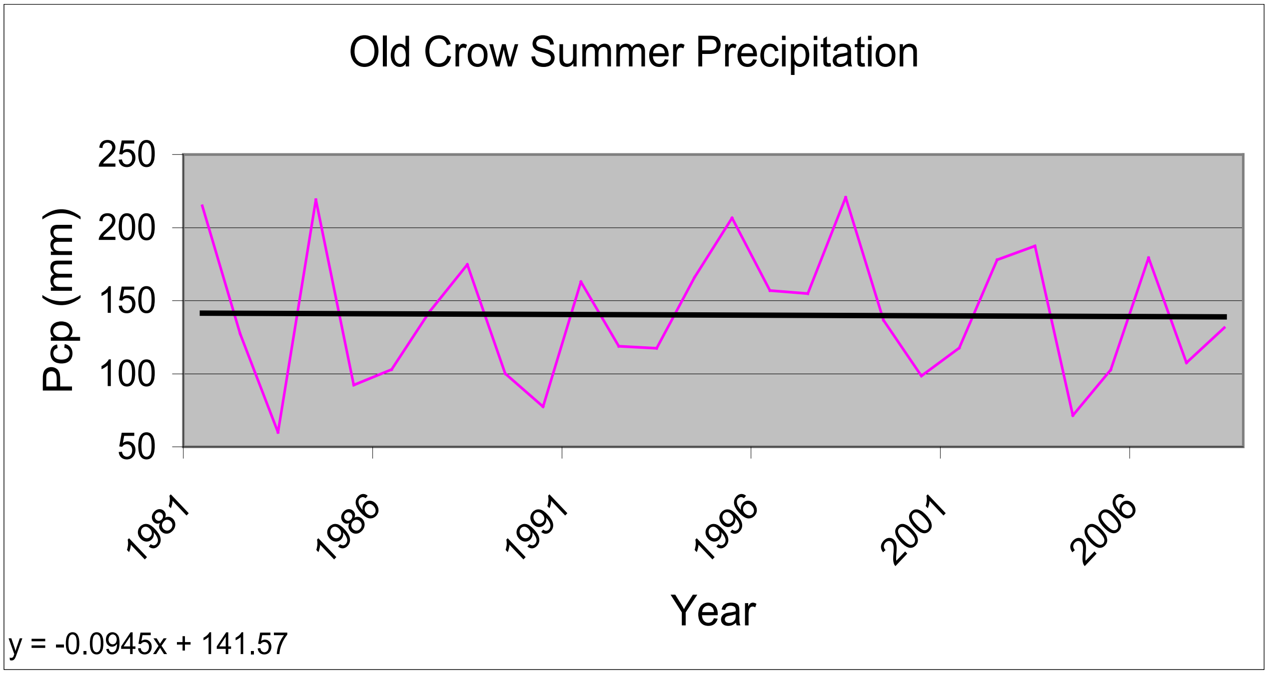

Figure 15. Old Crow Summer Precipitation.

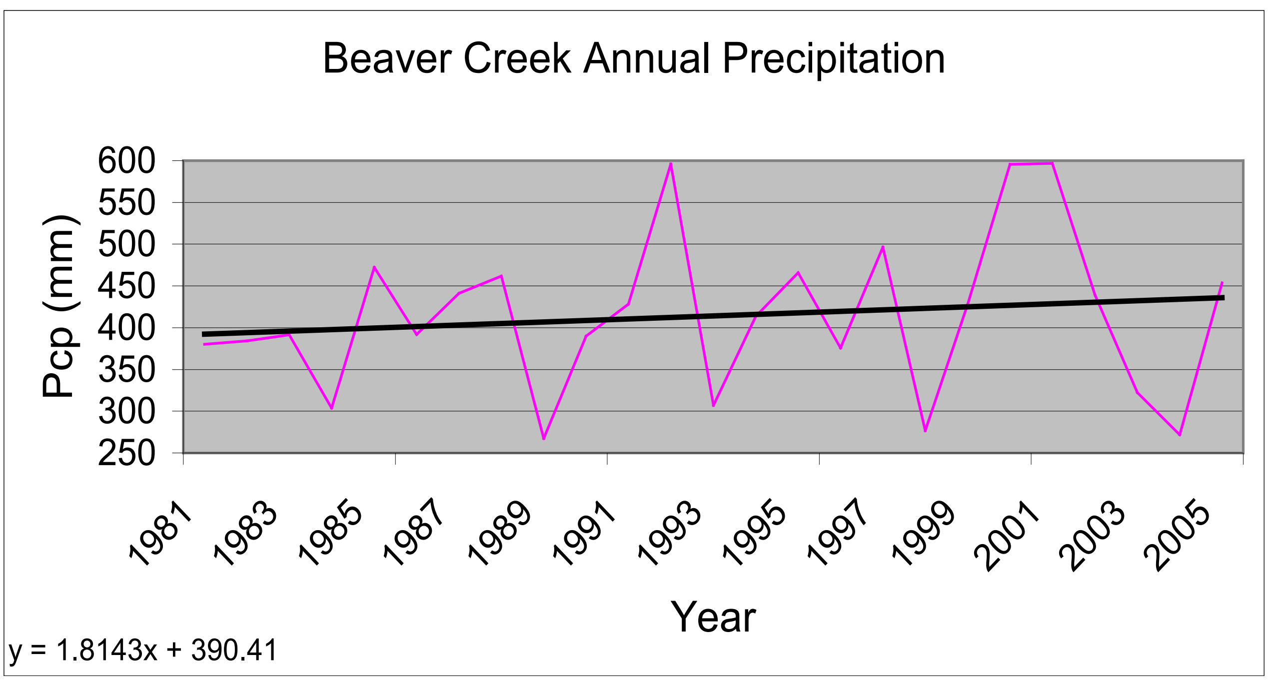

Figure 16. Beaver Creek Annual Precipitation.

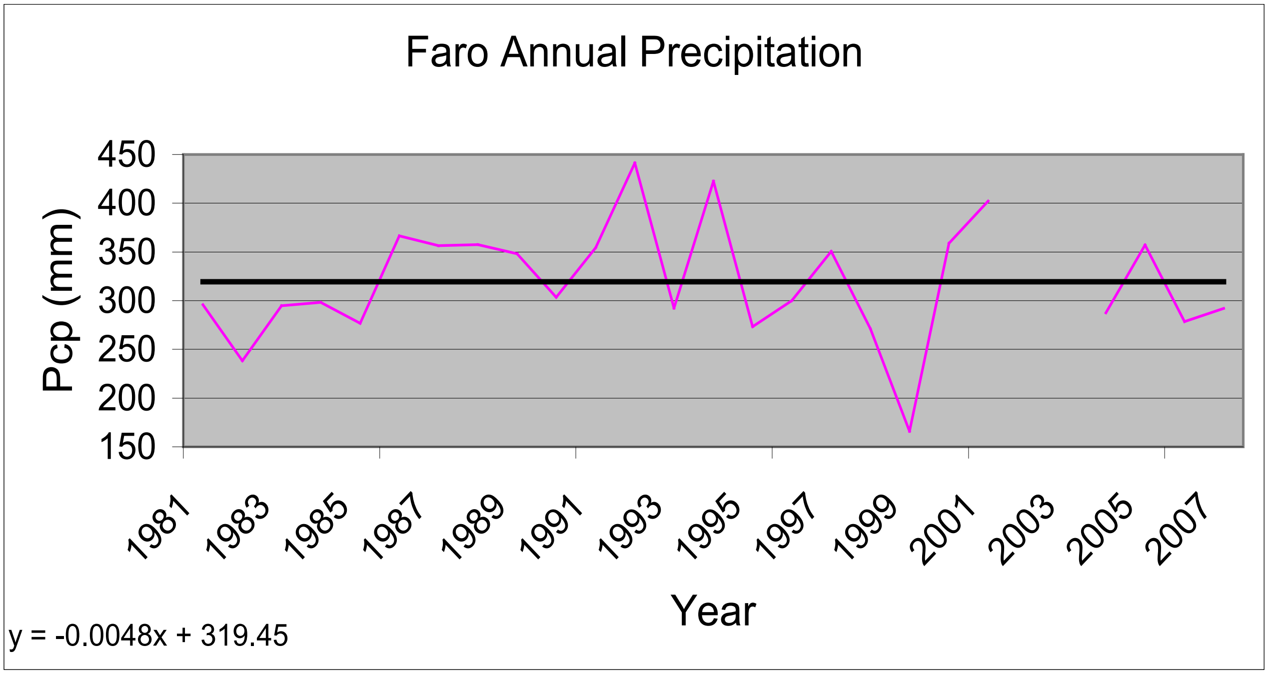

Figure 17. Faro Annual Precipitation.

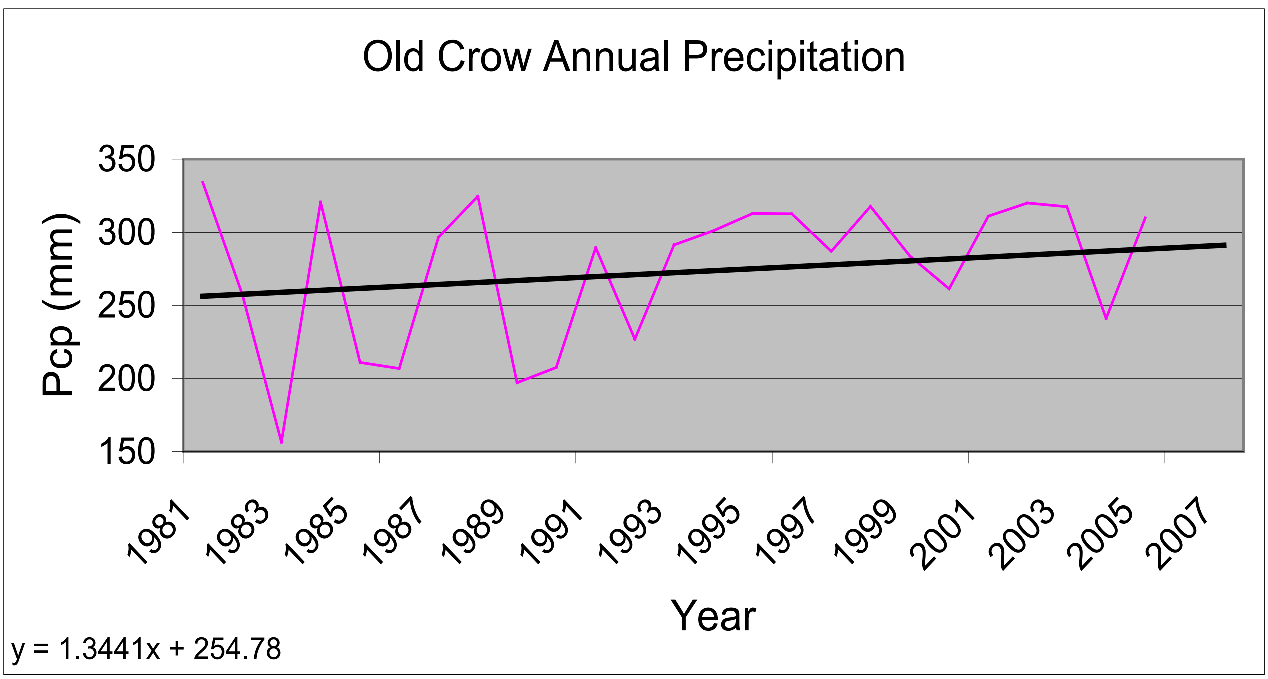

Figure 18. Old Crow Annual Precipitation.

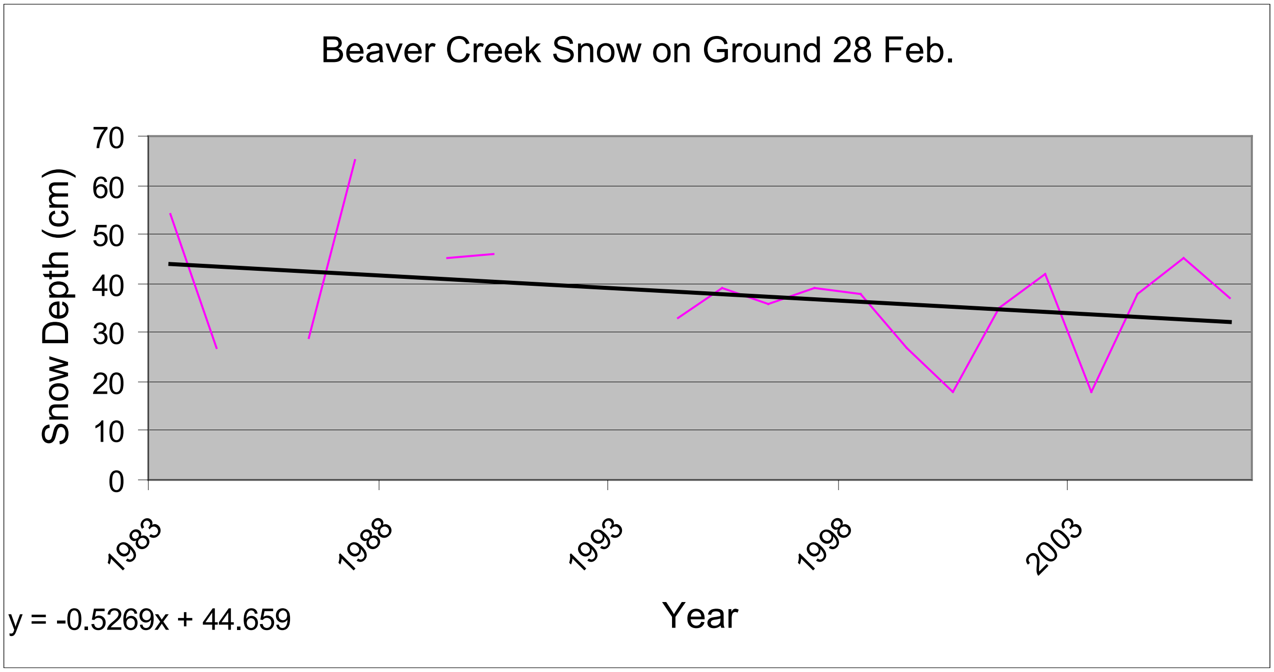

Figure 19. Beaver Creek Snow on Ground.

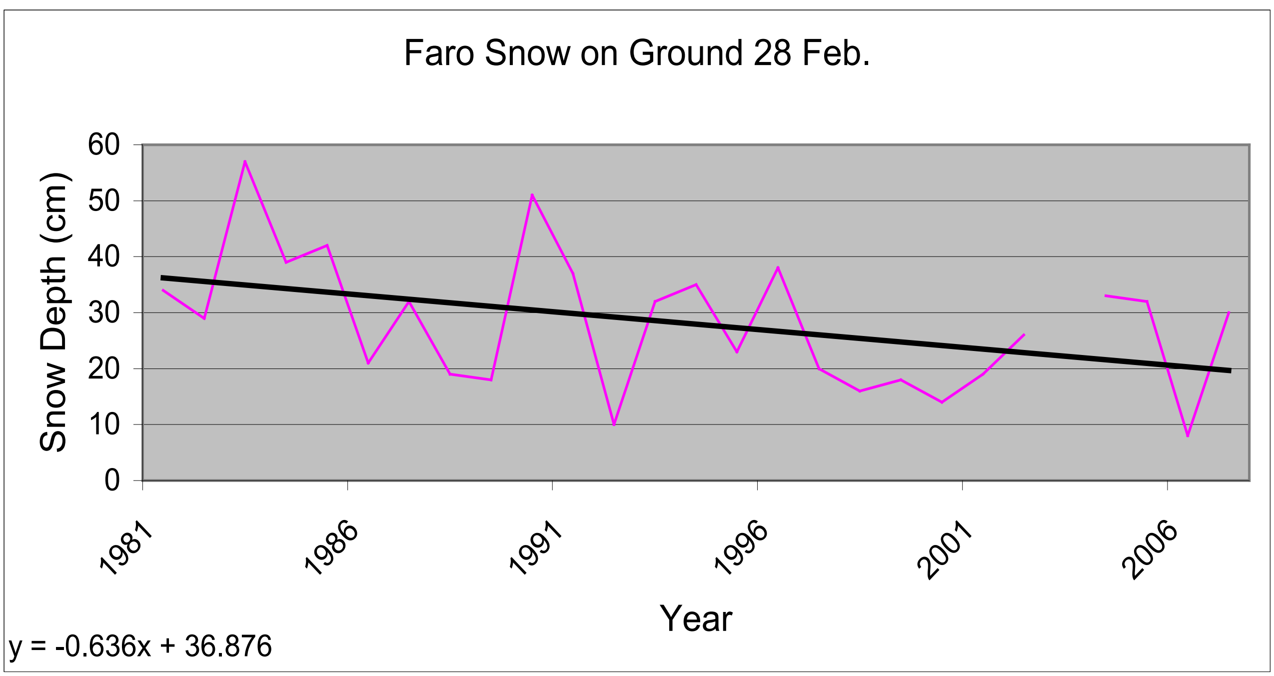

Figure 20. Faro Snow on Ground.

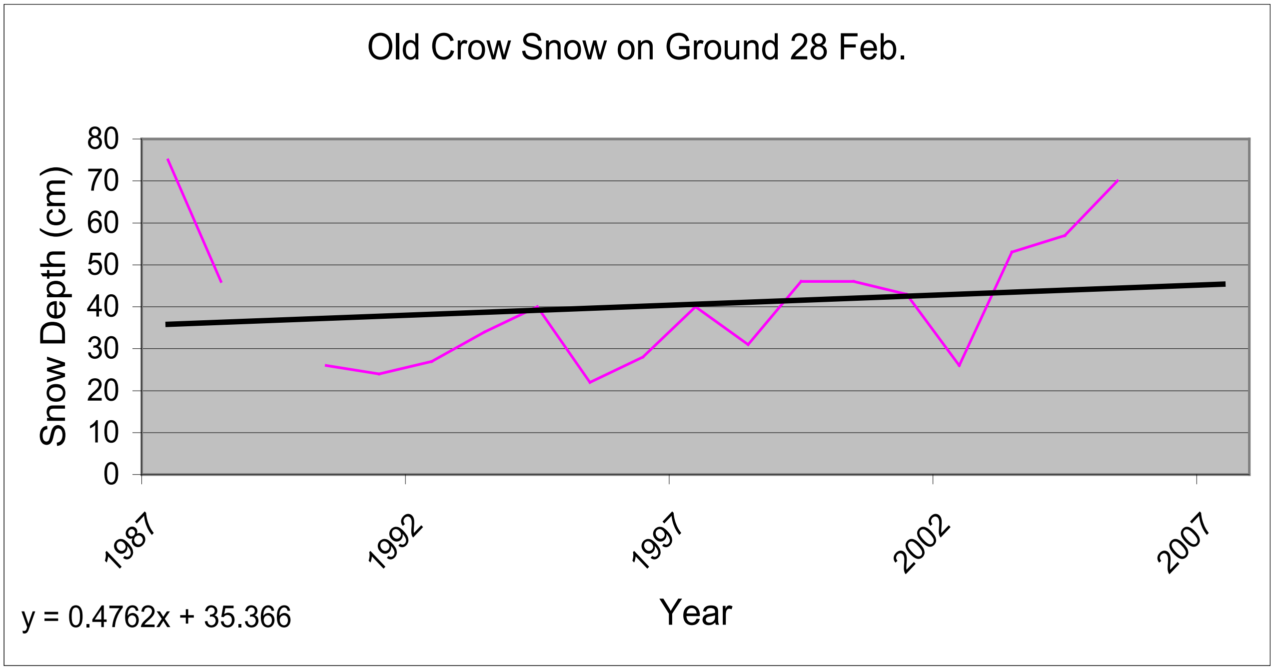

Figure 21. Old Crow Snow on Ground.

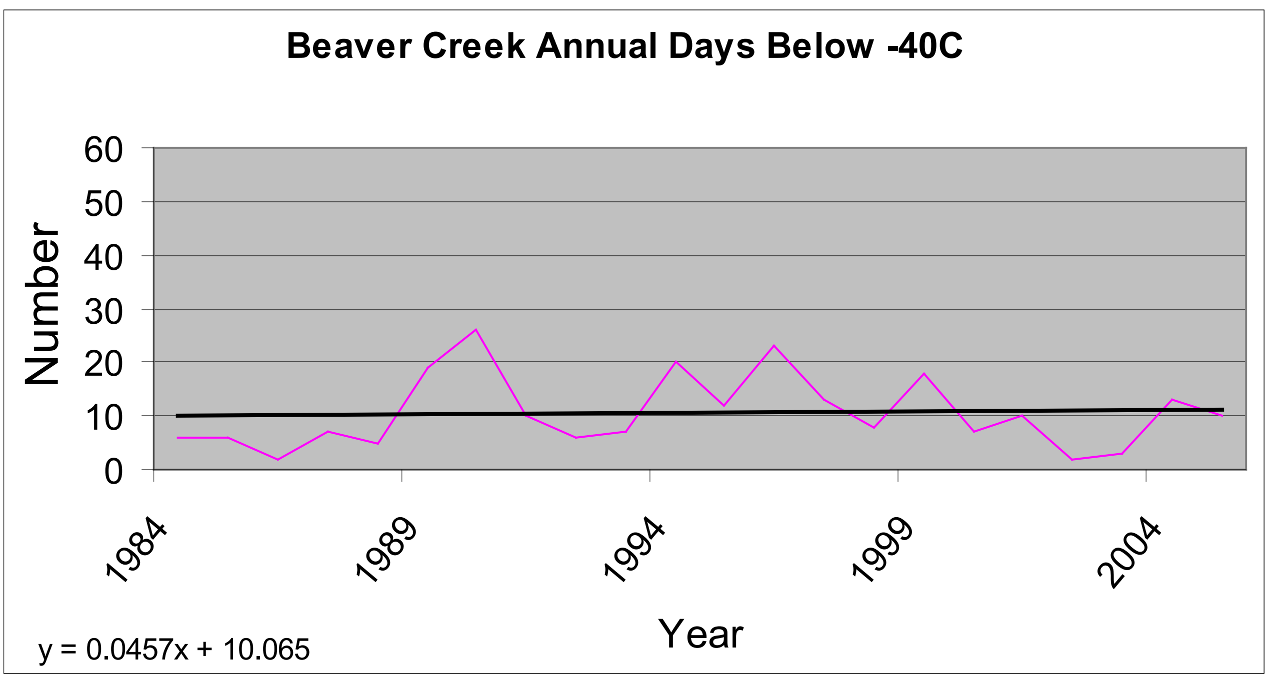

Figure 22. Beaver Creek Annual Days Below –40C.

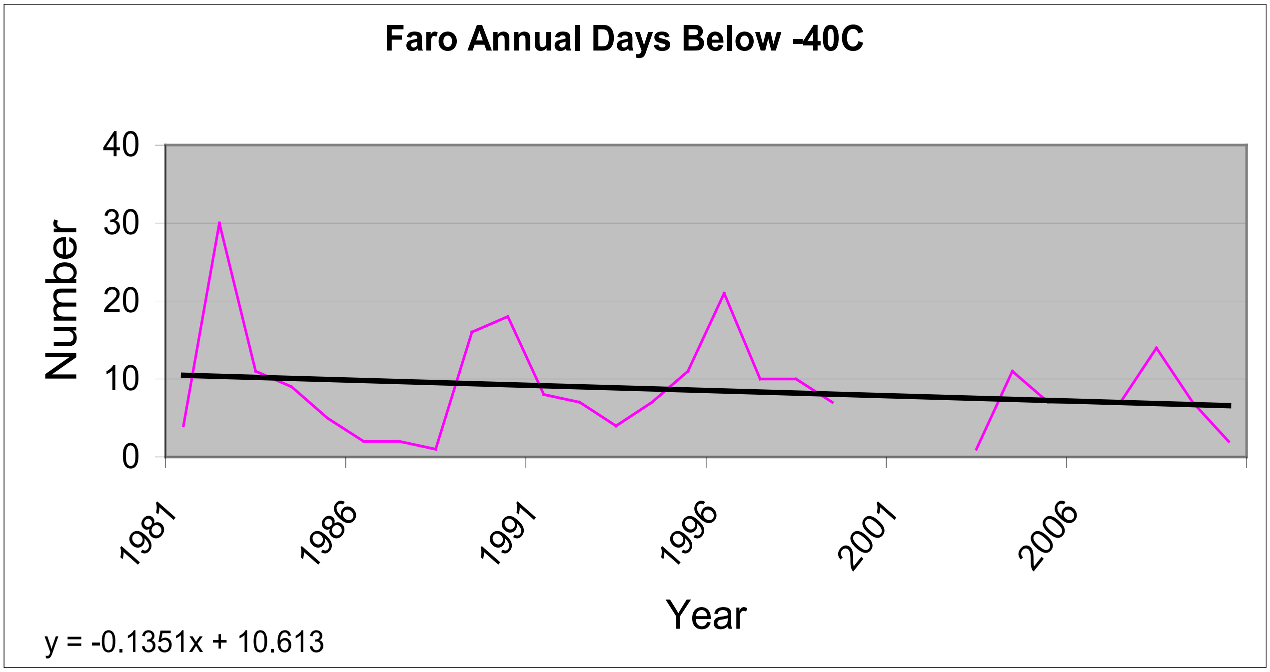

Figure 23. Faro Annual Days Below –40C.

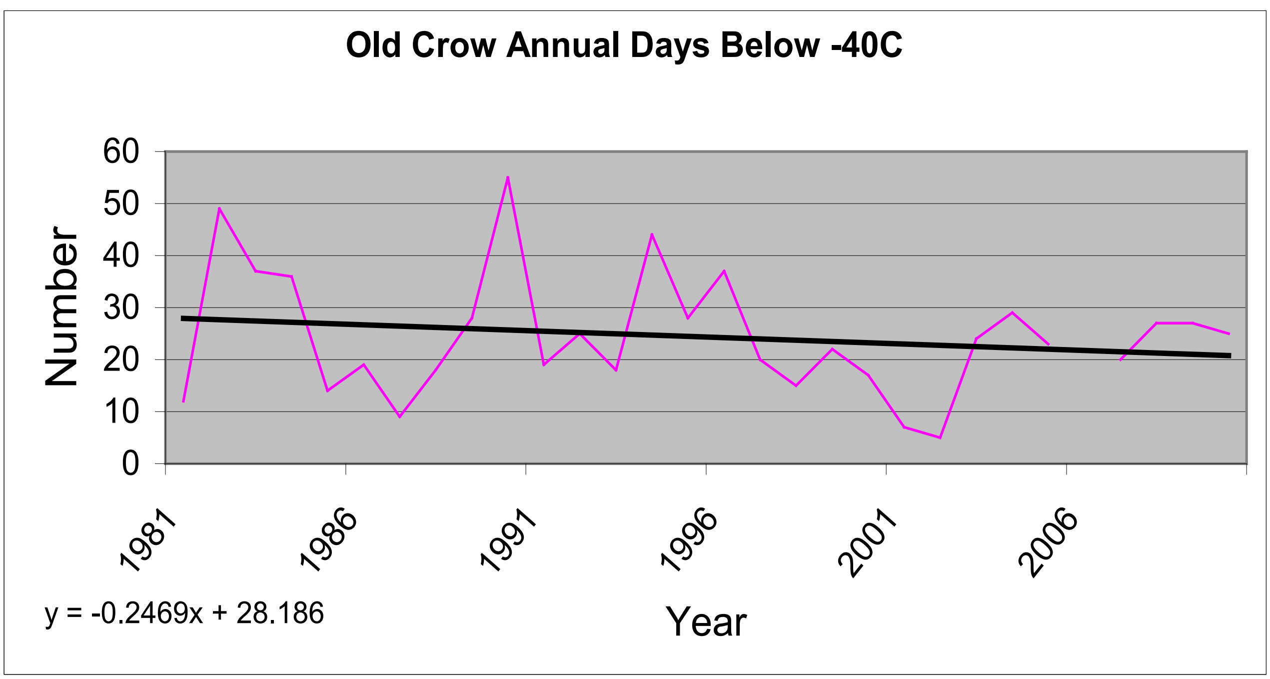

Figure 24. Old Crow Annual Days Below –40C.

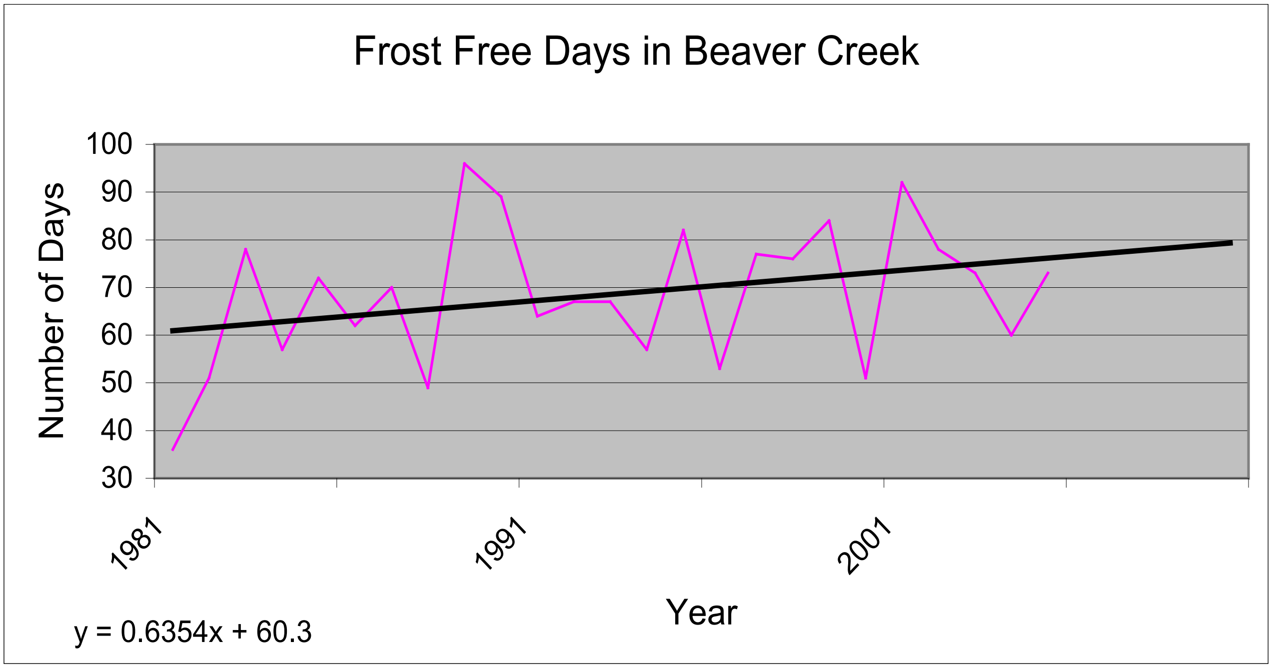

Figure 25. Beaver Creek Frost Free Days.

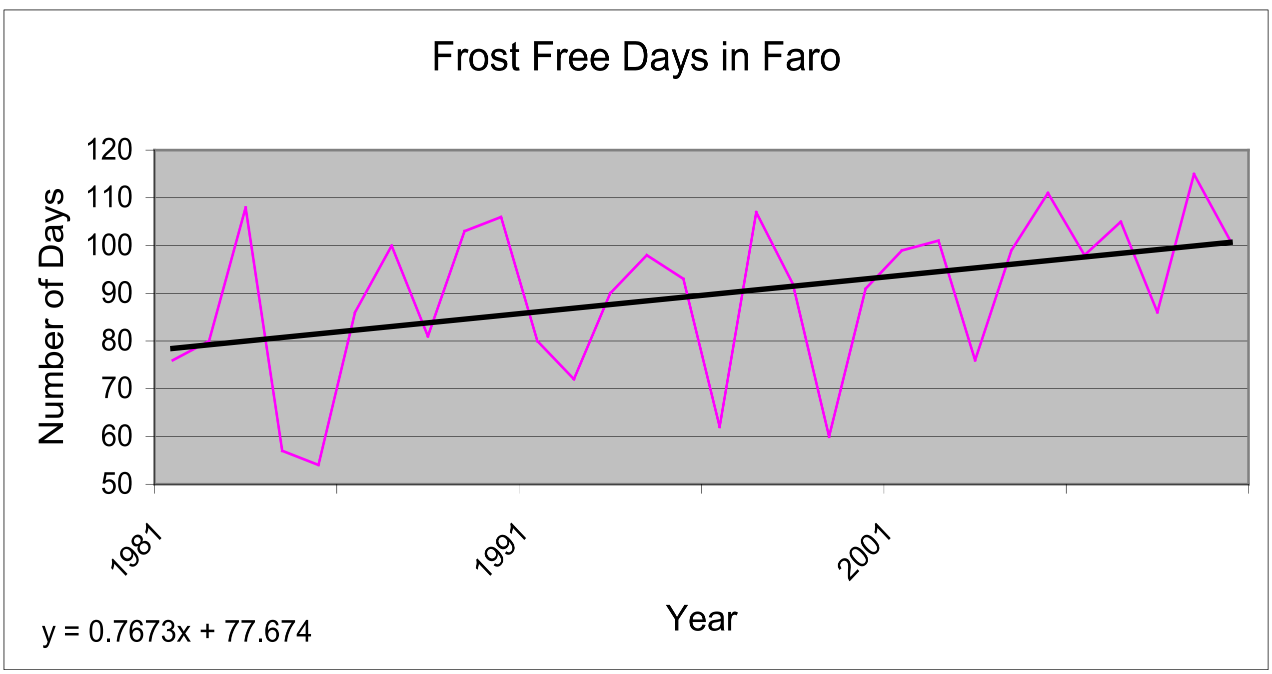

Figure 26. Faro Frost Free Days.

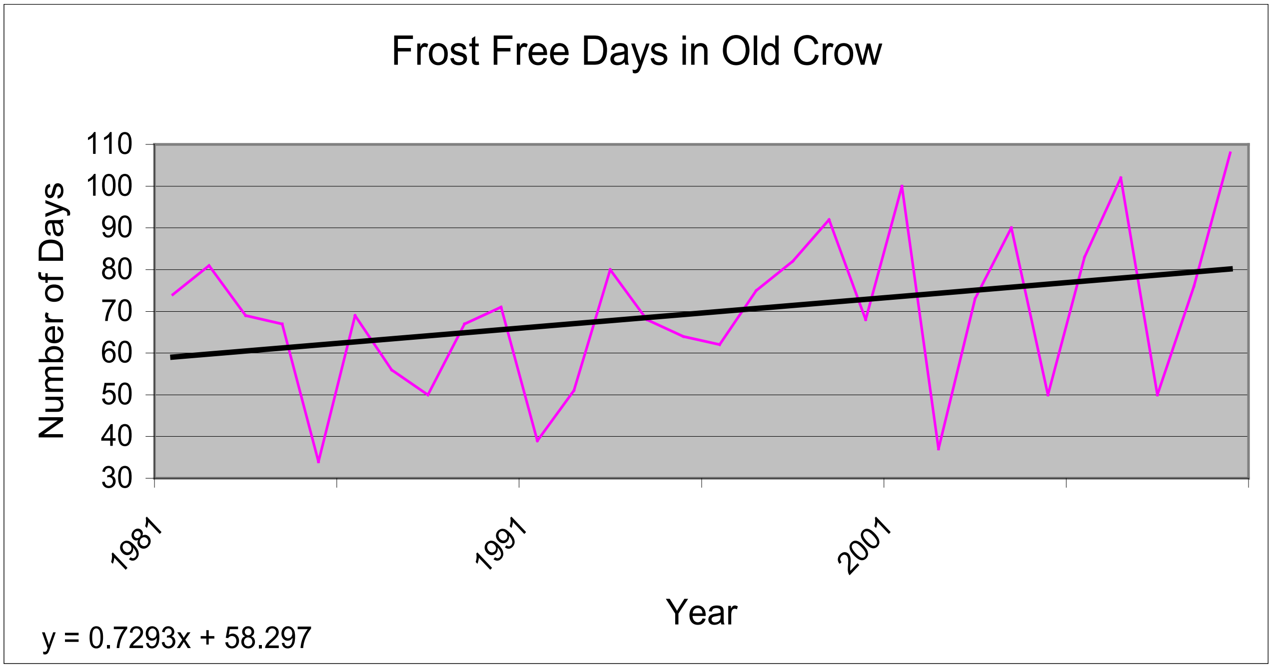

Figure 27. Old Crow Frost Free Days.

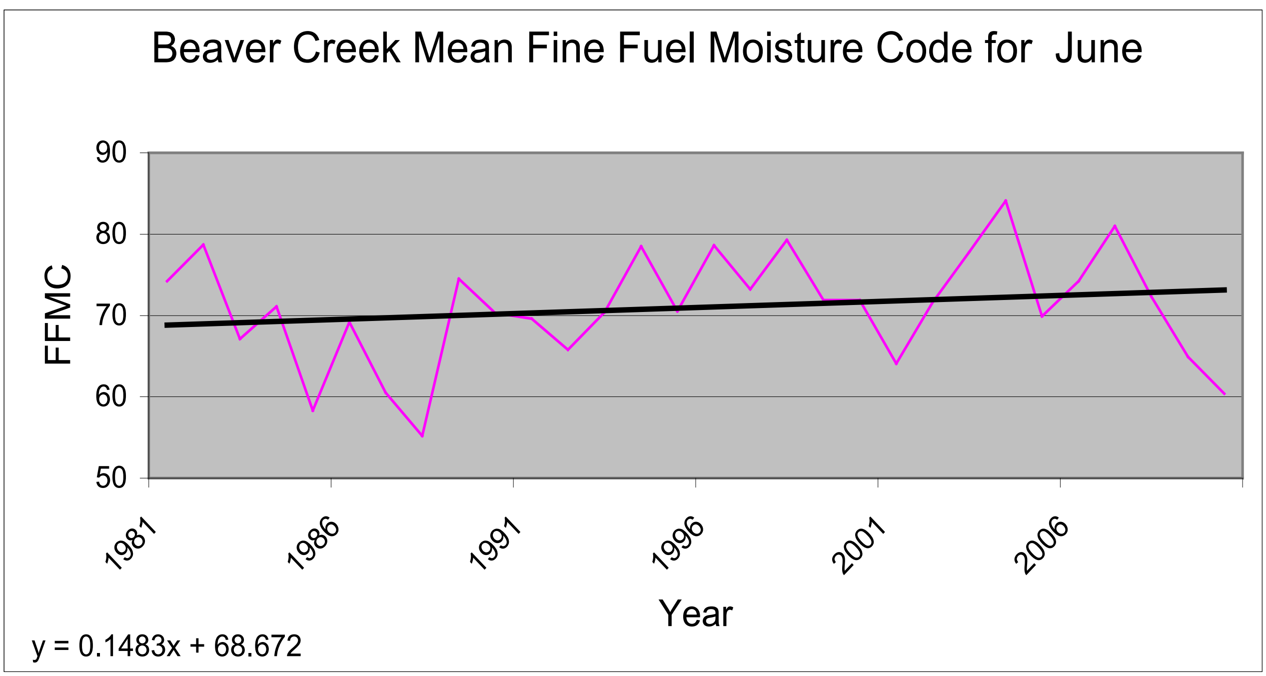

Figure 28. Beaver Creek Mean Fine Fuel Moisture Code for June.

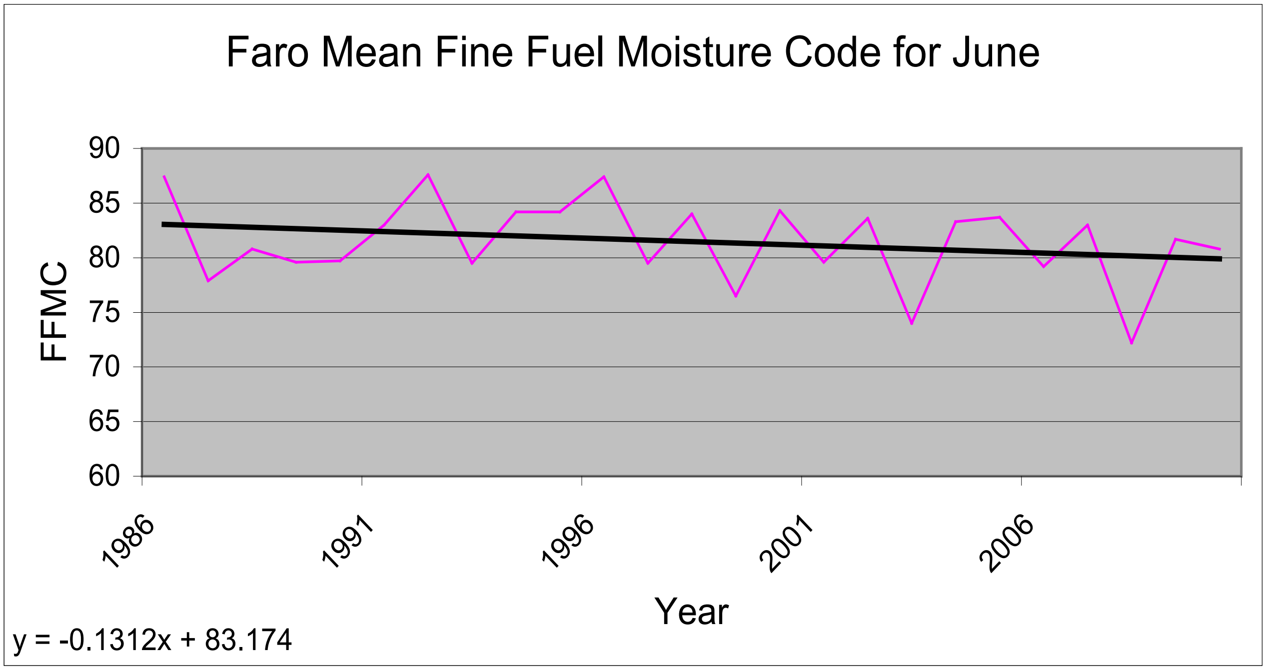

Figure 29. Faro Mean Fine Fuel Moisture Code for June.

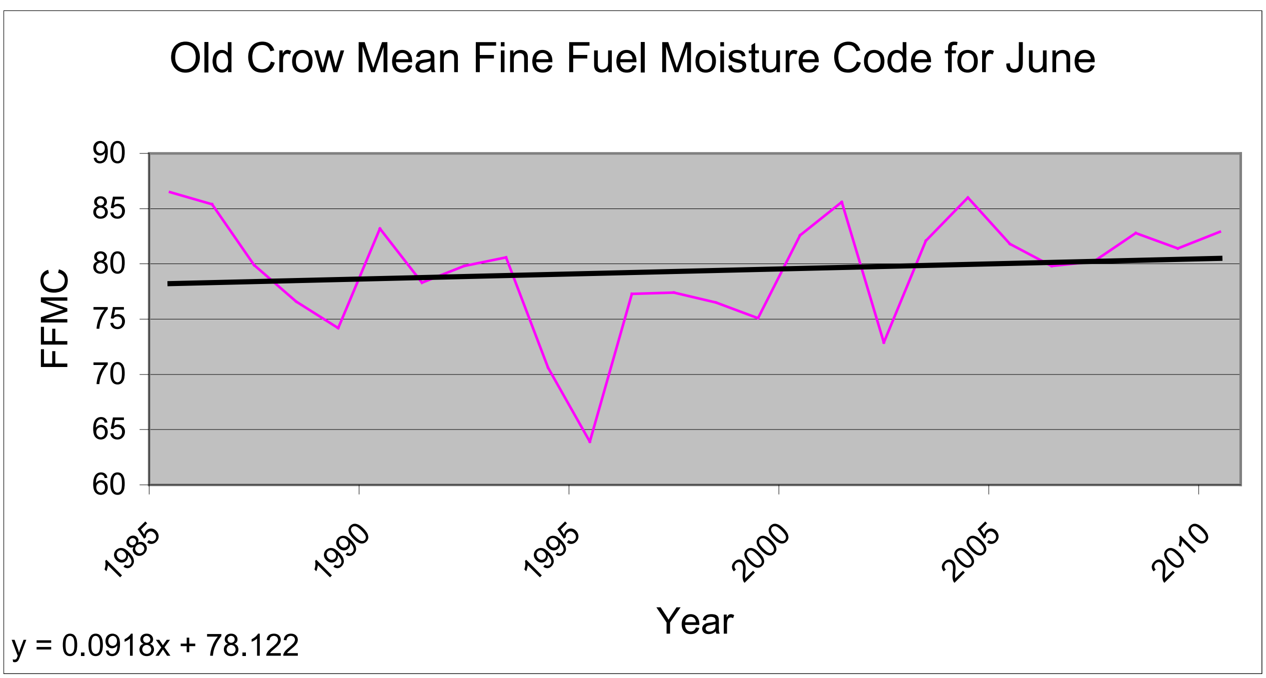

Figure 30. Old Crow Mean Fine Fuel Moisture Code for June.

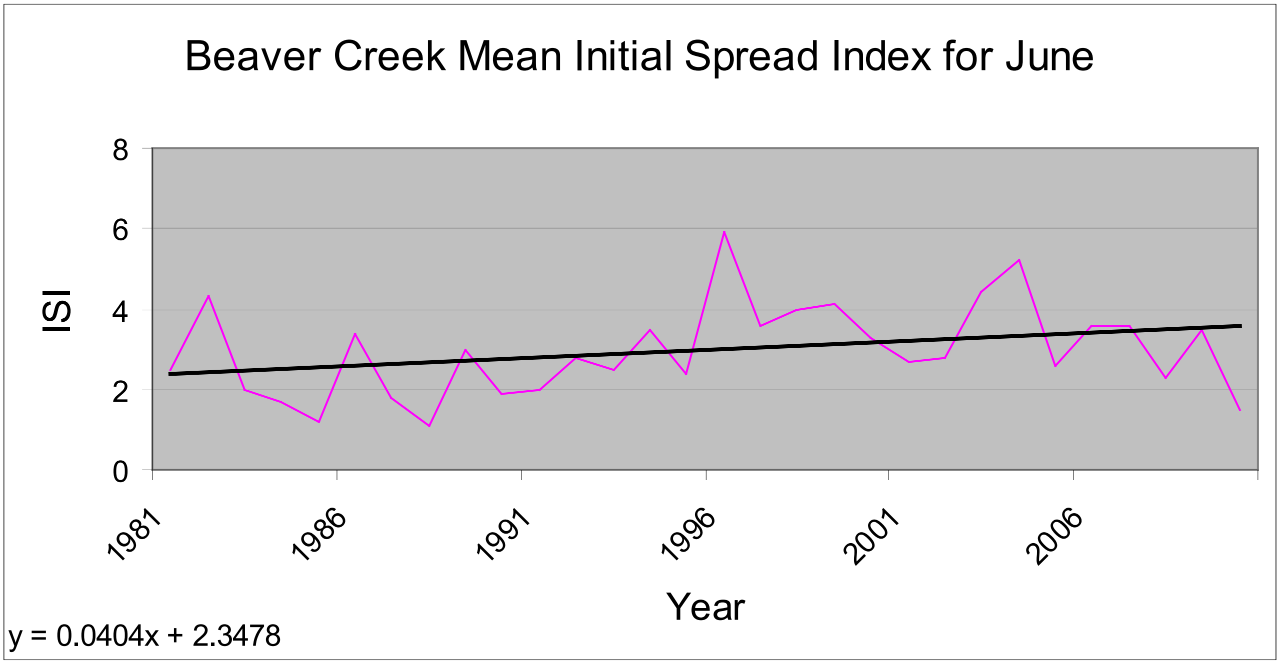

Figure 31. Beaver Creek Mean Initial Spread Index for June.

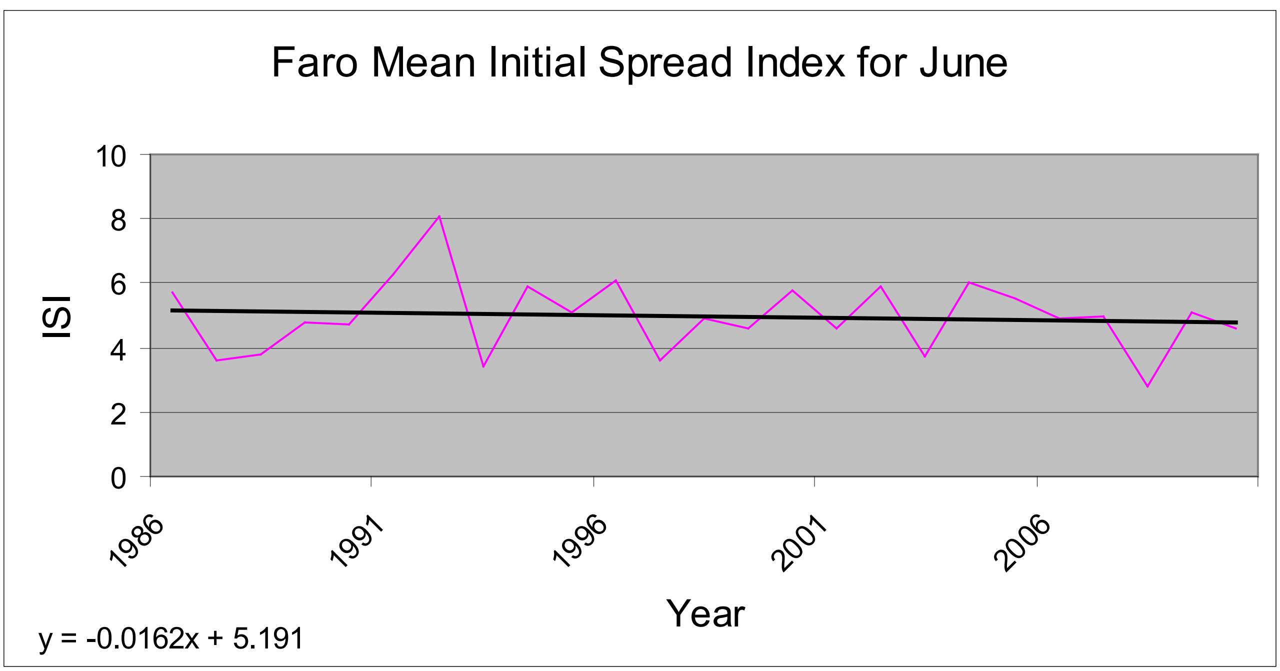

Figure 32. Faro Mean Initial Spread Index for June.

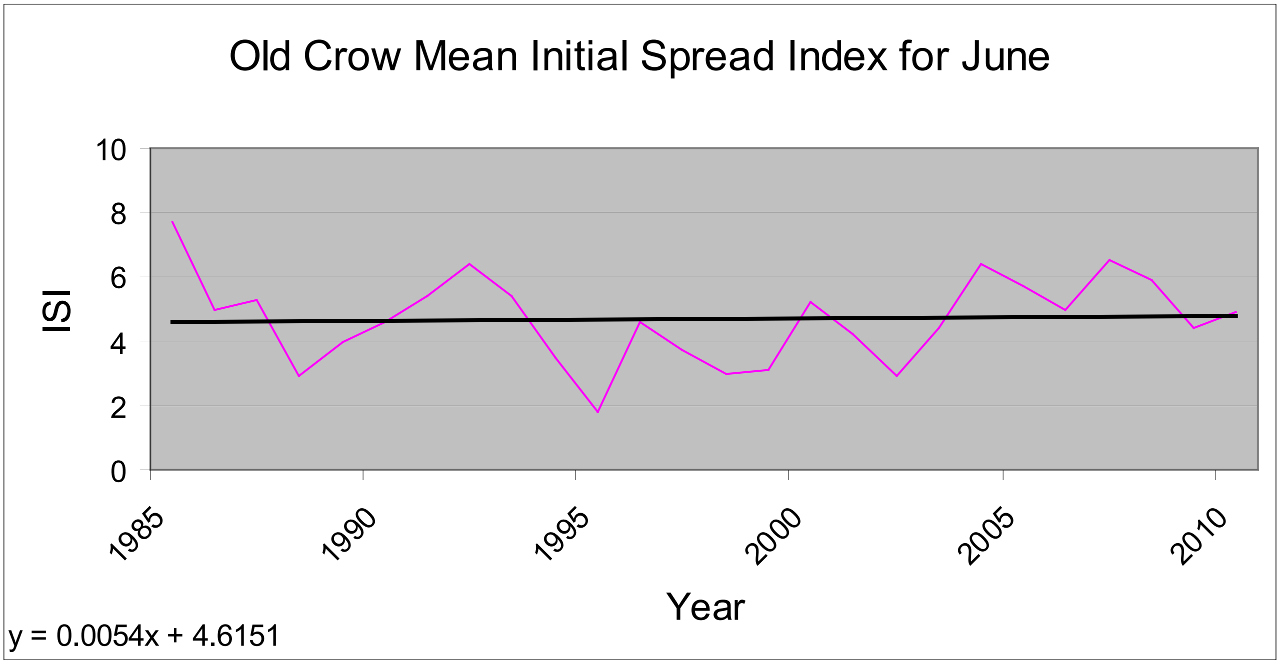

Figure 33. Old Crow Mean Initial Spread Index for June.

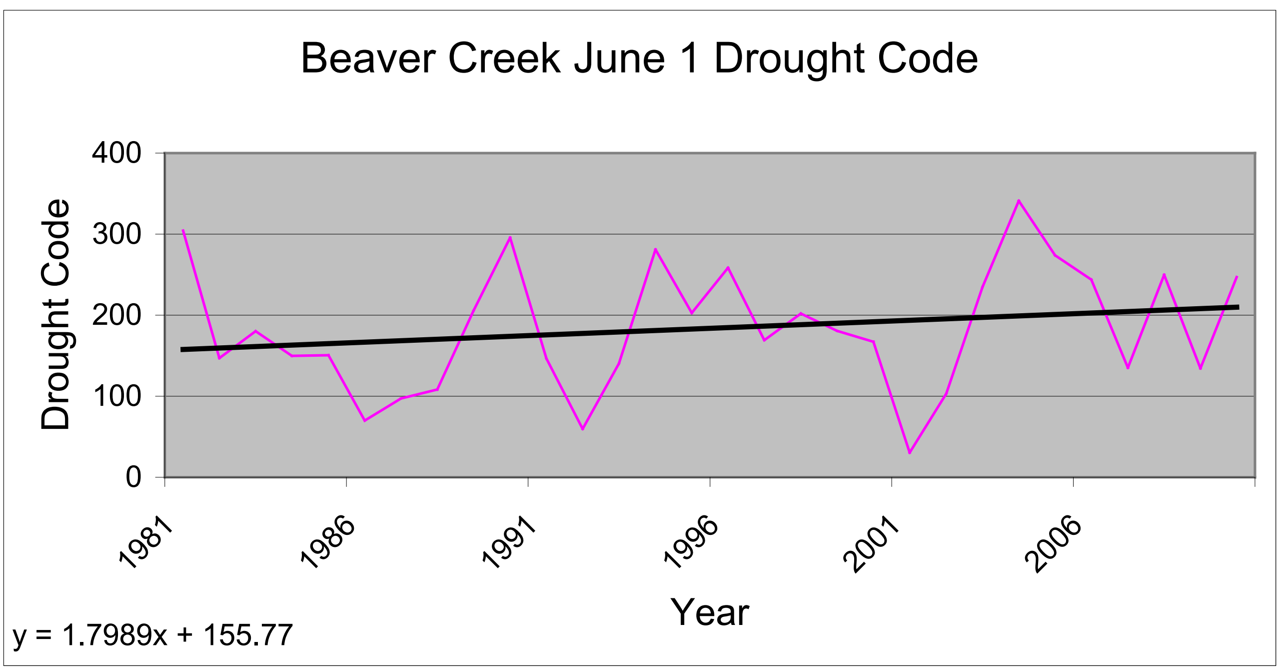

Figure 34. Beaver Creek Drought Code for June 1.

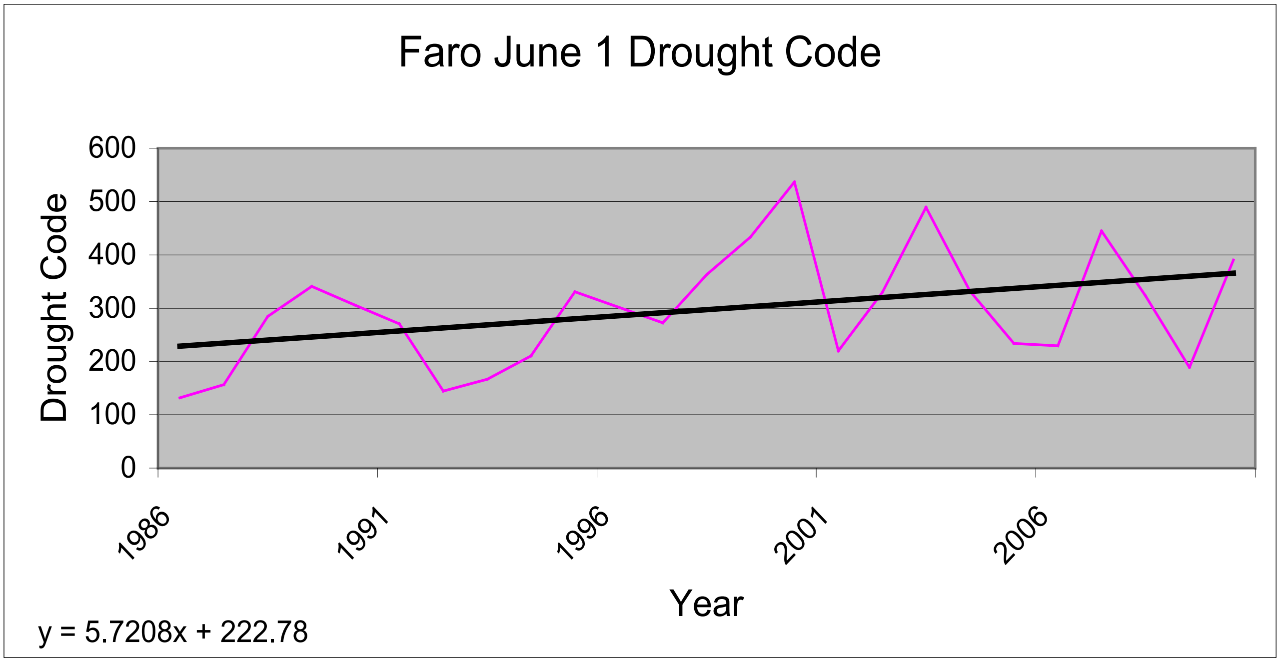

Figure 35. Faro Drought Code for June 1.

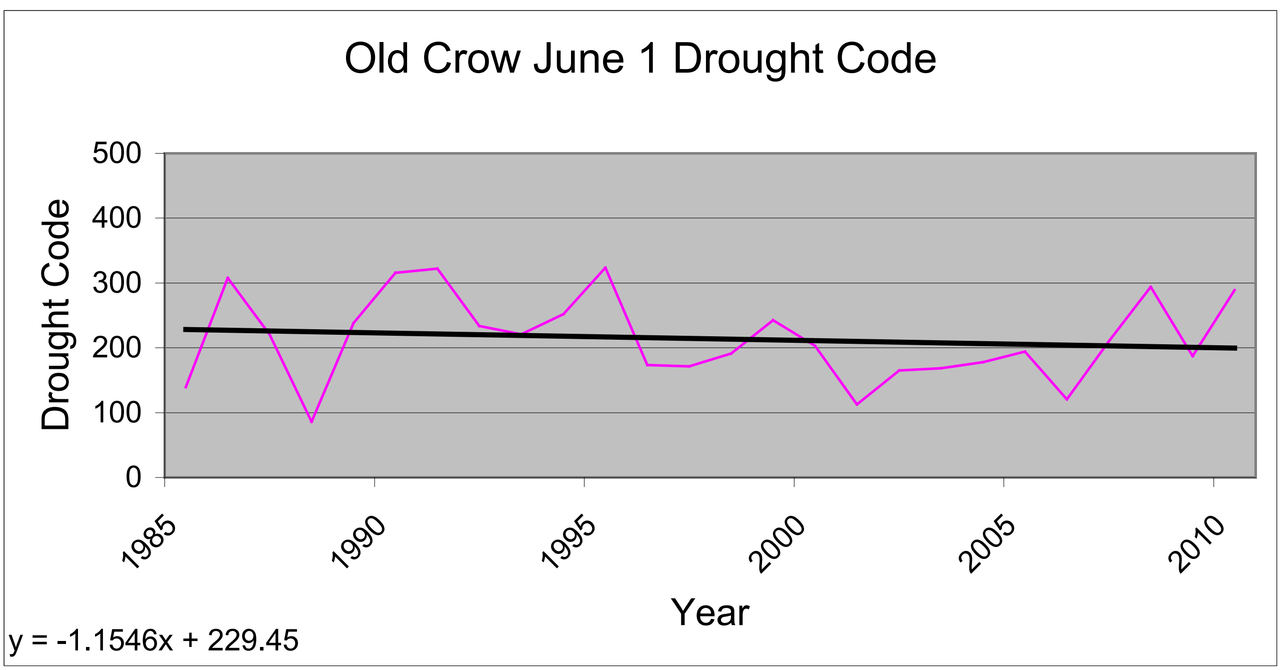

Figure 36. Old Crow Drought Code for June 1.

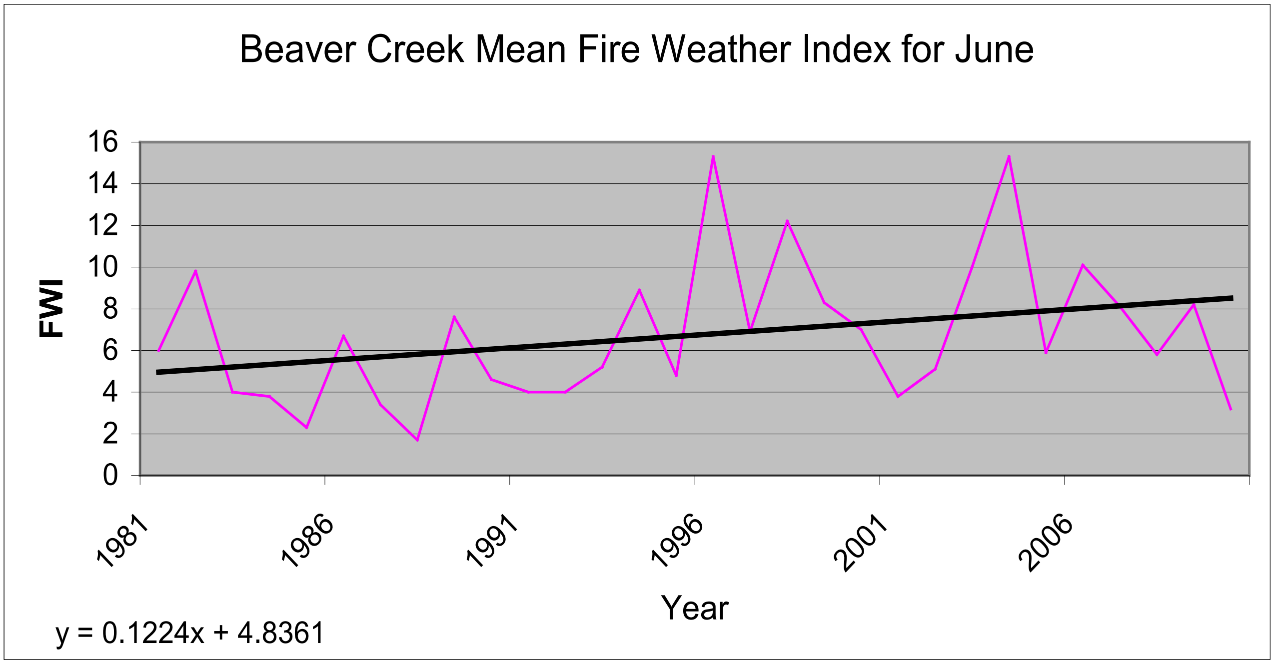

Figure 37. Beaver Creek Mean Fire Weather Index for June.

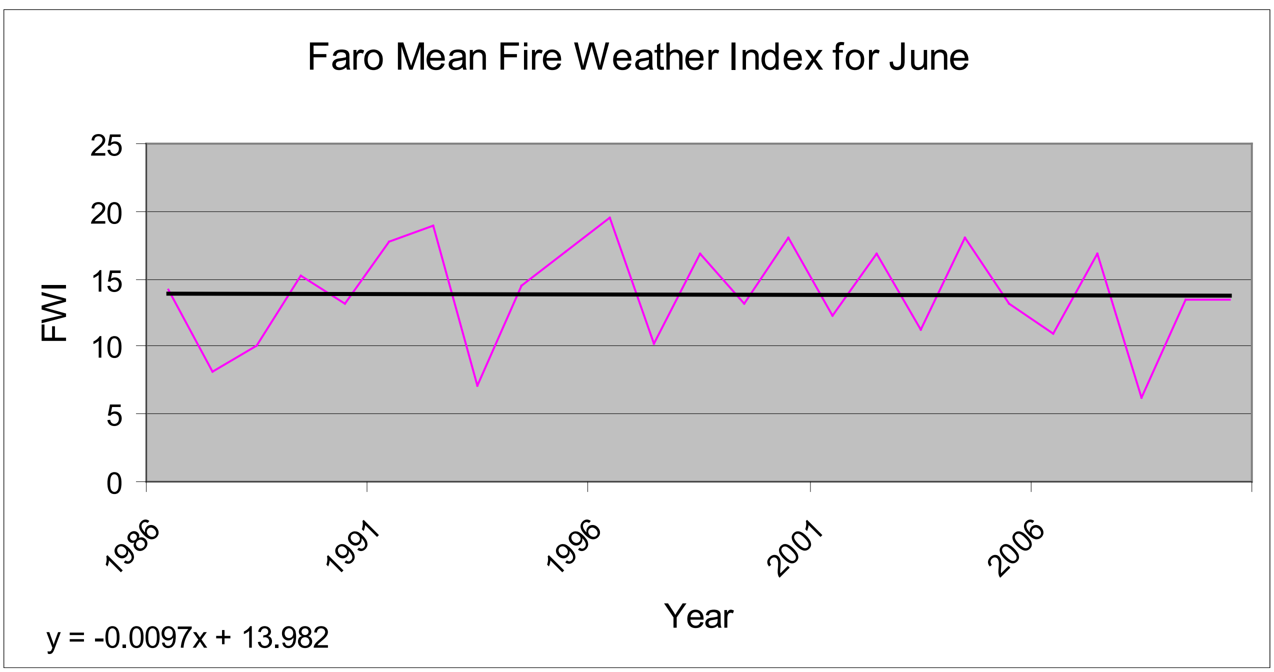

Figure 38. Faro Mean Fire Weather Index for June.

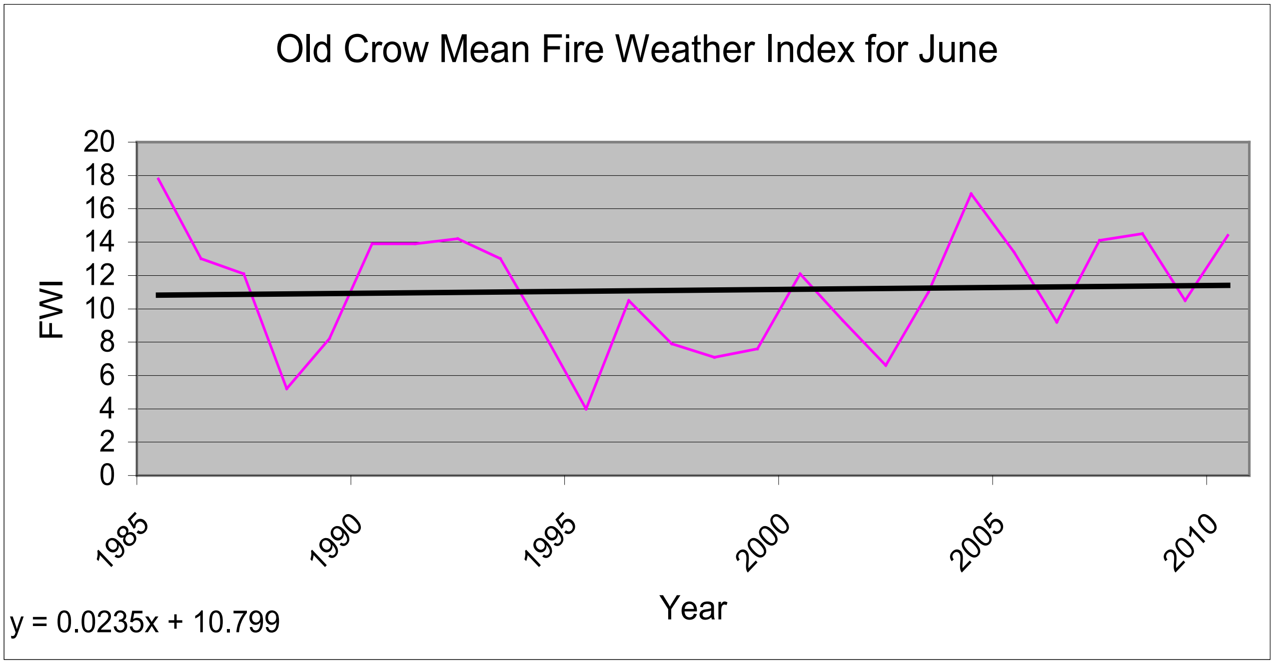

Figure 39. Old Crow Mean Fire Weather Index for June.

List of Tables

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|                                                                          SNOW SURVEY---------------------------->:  |A      |
|   +===================+                                              EVAPORATION---------------------->:         :  |I      |
|   | STATION CATALOGUE |                                          RATE OF PRECIPITATION---------->:| |S|:  |R  |U|:  |R      |
|   +===================+                                      PRECIPITATION-------------------->:|:| |O|:|S|A  |P|:  |       |
|                                                          TEMPERATURE------------------------>:|:|:| |I|:|U|D  |P|:  |Q      |
|                                                      HOURLY------------------------------->:|:|:|:| |L|:|N|I  |E|:  |U|N| R |
|                                                  SYNOPTIC------------------------------->:|:|:|:|:| | |:|S|A|O|R|:|T|A|I| E |
|                                                                | PERIOD WITH NO CHANGE  |:|:|:|:|:|W|T|:|H|T|Z| |:|O|L|P| G |
|                                                                |IN PROGRAM LOCATION OR  |:|:|:|:|:|I|E|:|I|I|O|A|:|W|I|H| I |
| CLIMATE STATION NAME              |PROV. | LAT.  | LONG. |ELEV.|NAME (S=SUMMER W=WINTER)|:|:|:|:|:|N|M|:|N|O|N|I|:|E|T|E| O |
|                                          |       |       |     |START YR-MO | END YR-MO |:|:|:|:|:|D|P|:|E|N|E|R|:|R|Y|R| N |
+=============================================================================================================================+

2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1897-07-01   1897-12-01| | |@|@| | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1898-11-01   1899-02-01| | |@|@| | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1900-10-01   1901-08-01| | |@|@| | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1901-08-01   1937-04-01|X|D|@|@| | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1937-04-01   1937-12-01|X|D|@|@| |B| | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1937-12-01   1953-08-01|X|D|@|@| | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1953-08-01   1953-09-01|X| |@|@| | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1953-09-01   1954-07-01|X|D|@|@| | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1954-07-01   1960-02-01|X|D|@|@| |B| | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1960-02-01   1960-03-01|X| |@|@| |B| | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1960-03-01   1965-09-01|X|X|@|@| |B| | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1965-09-01   1966-12-01|X|X|@|X| |B| | | | | | | | | |N| W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1966-12-01   1976-01-01|X|X|@|X| | | | | | | | | | | |N| W |
2100400 BEAVER CREEK                           YT  |  64 04 139 26 |      | 1976-01-01   1976-02-01| | |@| | | | | | | | | | | | | | W |
2100400 BEAVER CREEK                           YT  |  64 03 139 26 | 0320| 1976-02-01   1979-01-01| | |@|@| | | | | | | | | | | | | W |

2100402 BEAVER CREEK A                         YT  |               |      | 1956-10-10   1976-01-01| | | | | | | | | | | | | | | | |   |
2100402 BEAVER CREEK A                         YT  |  64 03 139 08 | 0369| 1976-01-01   1976-04-01|X|D|@|X| | | | | | | | | | | |N| W |
2100402 BEAVER CREEK A                         YT  |  64 03 139 08 | 0369| 1976-04-01   1986-04-01|X|D|@|X|X| | | | | | | | | | |N| W |
2100402 BEAVER CREEK A                         YT  |  64 03 139 08 | 0369| 1986-04-01 W 1988-11-17|X|D|X|X|X| | | | | | | | | | |N| W |
2100402 BEAVER CREEK A                         YT  |  64 03 139 08 | 0370| 1988-11-17 W 1994-06-03|X|D|X|X|X| | | | | | | | | | |N| P |
2100402 BEAVER CREEK A                         YT  |  64 03 139 08 | 0370| 1994-06-03   1997-09-11| |D|X|X|X| | | | | | | | | | |N| P |
2100402 BEAVER CREEK A                         YT  |  64 03 139 08 | 0370| 1997-09-11   1998-04-01| |D|X|X|X| | | | | | | | | | |N| P |
2100402 BEAVER CREEK A                         YT  |  64 03 139 08 | 0370| 1998-04-01 S           | |D|X|X|X| | | | | | | | | | |N| P |

2100LRP BEAVER CREEK                           YT  |  64 03 139 08 | 0370| 1988-01-13   1992-04-13| |H| | | | | | | | | | | | | | | W |
2100LRP BEAVER CREEK                           YT  |  64 03 139 08 | 0370| 1992-04-13   1995-09-29|H|H| | | | | | | | | | | | | | | P |
2100LRP BEAVER CREEK                           YT  |  64 03 139 08 | 0370| 1995-09-29             |H|H| | | | | | | | | | | | | | | P |
```

Table 1. Beaver Creek Station History.

```
+==============================================================================================================================+
|                                                                                   SNOW SURVEY---------------------------->:  |A       |
|   +====================+                                                      EVAPORATION----------------------->:         :  |I       |
|   | STATION CATALOGUE |                                                   RATE OF PRECIPITATION---------->:|  |S|:  |R  |U|:  |R       |
|   +====================+                                                PRECIPITATION------------------->:|:|  |O|:|S|A  |P|:  |        |
|                                                                      TEMPERATURE----------------------->:|:|:|  |I|:|U|D  |P|:  |Q       |
|                                                                  HOURLY------------------------------>:|:|:|:|  |L|:|N|I  |E|:  |U|N| R |
|                                                              SYNOPTIC------------------------------>:|:|:|:|:|  | |:|S|A|O|R|:|T|A|I| E |
|                                                                          | PERIOD WITH NO CHANGE  |:|:|:|:|:|W|T|:|H|T|Z| |:|O|L|P| G |
|                                                                          |IN PROGRAM LOCATION OR  |:|:|:|:|:|I|E|:|I|I|O|A|:|W|I|H| I |
| CLIMATE STATION NAME                      |PROV. | LAT.  | LONG.  |ELEV.|NAME (S=SUMMER W=WINTER)|:|:|:|:|:|N|M|:|N|O|N|I|:|E|T|E| O |
|                                                  |       |        |     |START YR-MO | END YR-MO |:|:|:|:|:|D|P|:|E|N|E|R|:|R|Y|R| N |
+==============================================================================================================================+

2100700+FARO LANDING                  YT  |  63 36 135 53 |     | 1924-10-01   1937-04-01|X|D|@|@| | | | | | | | | | | | W |
2100700+FARO LANDING                  YT  |  63 36 135 53 |     | 1937-04-01   1937-10-01|X|D|@|@| |B| | | | | | | | | | W |
2100700+FARO LANDING                  YT  |  63 36 135 53 |     | 1937-10-01   1953-09-01|X|D|@|@| | | | | | | | | | | | W |
2100700+FARO LANDING                  YT  |  63 36 135 53 |     | 1953-09-01   1953-10-01|X| |@|@| | | | | | | | | | | | W |
2100700+FARO LANDING                  YT  |  63 36 135 53 |     | 1953-10-01   1966-10-01|X|D|@|@| |B| | | | | | | | | | W |
2100700+FARO LANDING                  YT  |  63 36 135 53 |     | 1966-10-01   1967-09-01|X|D|@|X| |B| | | | | | | | |N| W |
2100700+FARO LANDING                  YT  |  63 36 135 53 |     | 1967-09-01   1967-10-01|X| |@|X| |B| | | | | | | | |N| W |
2100700+FARO                          YT  |  63 36 135 53 |     | 1967-10-01   1967-12-01|X|D|@|X| |B| | | | | | | | |N| W |
2100700+FARO                          YT  |  63 36 135 53 |     | 1967-12-01   1968-10-01|X|D|@|X| |B| | | | | |@| | |N| W |
2100700+FARO                          YT  |  63 36 135 53 |     | 1968-10-01   1968-11-01|X| |@|X| |B| | | | | |@| | |N| W |
2100700+FARO                          YT  |  63 36 135 53 |     | 1968-11-01   1969-02-01|X|D|@|X| |B| | | | | |@| | |N| W |

2100700+FARO A                        YT  |  63 37 135 52 |     | 1969-02-01   1971-04-01|X|D|@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1971-04-01   1971-05-01|X| |@|X| | | | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1971-05-01   1971-09-01|X|D|@|X| | | | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1971-09-01   1971-10-01|X| |@|X| | | | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1971-10-01   1972-04-01|X|D|@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1972-04-01   1972-05-01|X| |@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1972-05-01   1972-09-01|X|D|@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1972-09-01   1972-10-01|X| |@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1972-10-01   1973-04-01|X|D|@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1973-04-01   1973-05-01|X| |@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1973-05-01   1973-09-01|X|D|@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1973-09-01   1973-10-01|X| |@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1973-10-01   1974-07-01|X|D|@|X| |B| | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 |     | 1974-07-01   1975-06-01|X|D|@|X| | | | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 | 0504| 1975-06-01   1985-05-01|X|D|@|X|X| | | | | | |@| | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 | 0504| 1985-05-01   1985-06-14|X|D|@|X|X| | | | | | | | | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 | 0504| 1985-06-14   1986-04-01|X|D|@|X|X| |A| | | | | | | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 | 0504| 1986-04-01   1987-09-30|X|D|X|X|X| |A| | | | | | | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 | 0504| 1987-09-30   1988-09-30|X|D|X|X|X| | | | | | | | | |N| W |
2100700+FARO A                        YT  |  63 37 135 52 | 0504| 1988-09-30   1988-10-01|X|D| | |X| | | | | | | | | | | W |
2100700+FARO A                        YT  |  63 37 135 52 | 0504| 1988-10-01             | |D|X|X|X| | | | | | | | | |N| P |
```

Table 2. Faro Station History.

```
+===============================================================================================================================+
|                                                                                         SNOW SURVEY----------------------------->:  |A       |
|   +====================+                                                            EVAPORATION---------------------->:         :  |I       |
|   | STATION CATALOGUE |                                                          RATE OF PRECIPITATION---------->:| |S|:  |R  |U|:  |R       |
|   +====================+                                                     PRECIPITATION------------------->:|:| |O|:|S|A  |P|:  |        |
|                                                                            TEMPERATURE------------------------>:|:|:| |I|:|U|D  |P|:  |Q       |
|                                                                       HOURLY------------------------------->:|:|:|:| |L|:|N|I  |E|:  |U|N| R |
|                                                                 SYNOPTIC------------------------------->:|:|:|:|:| | |:|S|A|O|R|:|T|A|I| E |
|                                                                 | PERIOD WITH NO CHANGE  |:|:|:|:|:|W|T|:|H|T|Z| |:|O|L|P| G |
|                                                                 |IN PROGRAM LOCATION OR  |:|:|:|:|:|I|E|:|I|I|O|A|:|W|I|H| I |
| CLIMATE STATION NAME                |PROV. | LAT.  | LONG. |ELEV.|NAME (S=SUMMER W=WINTER)|:|:|:|:|:|N|M|:|N|O|N|I|:|E|T|E| O |
|                                            |       |       |     |START YR-MO | END YR-MO |:|:|:|:|:|D|P|:|E|N|E|R|:|R|Y|R| N |
+===============================================================================================================================+

2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1938-10-01   1938-11-01|X|D|@|@| | | | | | | | | | | | | W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1938-11-01   1942-02-01|X|D|@|@| |B| | | | | | | | | | | W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1942-02-01   1942-04-01| | |@|@| | | | | | | | | | | | | W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1942-04-01   1960-11-01|X|D|@|@| |B| | | | | | | | | | | W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1960-11-01   1964-12-01|X|D|@|X| |B| | | | | | | | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1964-12-01   1966-12-01|X|D|@|X| |B| | | | | |@| | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1966-12-01   1969-06-01|X|D|@|X| | | | | | | |@| | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1969-06-01   1969-10-01|X|D|@|X| | | |S| | | |@| | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1969-10-01   1981-07-01|X|D|@|X|X| |D| |S| | | |@| | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1981-07-01   1986-04-01|X|D|@|X|X| |D|A|S| | | |@| | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1986-04-01   1988-03-31|X|D|X|X|X| |D|A|S| | | |@| | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1988-03-31   1990-09-30|X|D|X|X|X| | |A|S| | | | | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1990-09-30   1993-08-31|X|D|X|X|X| | | |S| | | | | |N| W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1993-08-31   1993-09-01|X|D| | |X| | | |S| | | | | | | | W |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1993-09-01   1993-10-15|X|D|X|X|X| | | |S| | | | | | | | P |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1993-10-15   1993-10-18|H|G|X|X|X| | | |S| | | | | | | | P |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1993-10-18   1997-08-21|H|G|X|X|X| | | | | | | | | | | | P |
2101200 OLD CROW A                  YT  |  60 07 128 49 | 0690| 1997-08-21             |H|G|X|X|X| | | | | | | | | | | | P |
2101200 OLD CROW (AUT)              YT  |  60 07 128 49 | 0690| 1938-10-01   1938-11-01|X|D|@|@| | | | | | | | | | | | | W |

2101222 OLD CROW (YTG)              YT  |  60 04 128 43 | 0701|   (From the Environment Canada Website)
2101204 OLD CROW (AUT)              YT  |  60 07 128 49 | 0690|   (From the Environment Canada Website)
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Table 3. Old Crow Station History.

Number of Missing Daily Observations for Temperatures and Precipitation by Year

	Beaver Creek A 2100160		Faro A 2100517		Faro Auto 2100518		Old Crow A 2100800		Old Crow Auto 2100805	
Year	Temp	Precip	Temp	Precip	Temp	Precip	Temp	Precip	Temp	Precip
1980	331	317	0	1			121	65		
1981	172	31	0	0			63	10		
1982	172	1	0	0			57	0		
1983	131	15	0	0			94	9		
1984	3	0	0	0			96	3		
1985	3	2	1	0			19	0		
1986	2	0	1	0			17	0		
1987	5	0	3	0			6	0		
1988	0	0	3	0			26	0		
1989	13	0	9	0			4	0		
1990	4	0	8	0			0	0		
1991	1	0	4	0			0	0		
1992	2	0	6	0	347	365	0	0		
1993	1	0	0	0	127	322	0	0		
1994	0	0	0	0	262	354	1	0		
1995	0	0	0	0	25	196	14	0	313	
1996	0	0	0	0	34	259	2	0	31	366
1997	0	0	1	0	186	317	0	0	365	365
1998	1	2	4	0	365	365	2	0	334	365
1999	2	0	3	0	365	365	7	0	158	365
2000	4	0	36	31	366	366	5	0	3	366
2001	2	0	3	0	240	365	1	0	0	365
2002	32	30	244	244	83	335	60	60	1	365
2003	62	60	365	365	20	365	33	31	0	365
2004	0	0	62	62	7	366	2	0	1	366
2005	1	0	61	61	10	365	32	31	63	365
2006	306	306	0	0	0	243	183	180	88	86
2007	335	335	62	62	1	39	68	64	0	5
2008			213	213	0	2	274	274	0	5
2009					0	127			0	5
2010					0	244			0	2

Table 4. Number of Missing Daily Observations