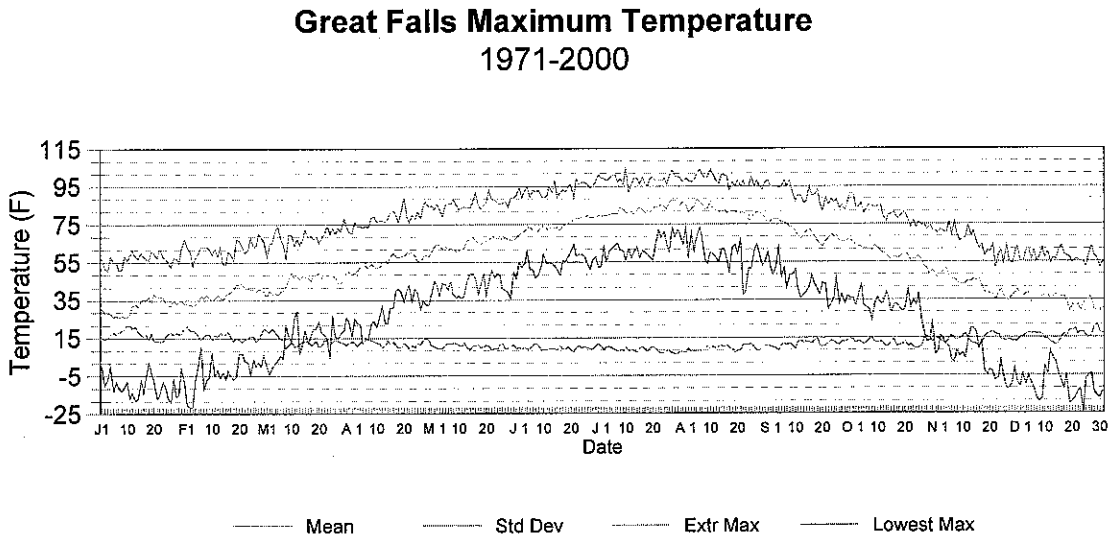
What is "Normal" Temperature?

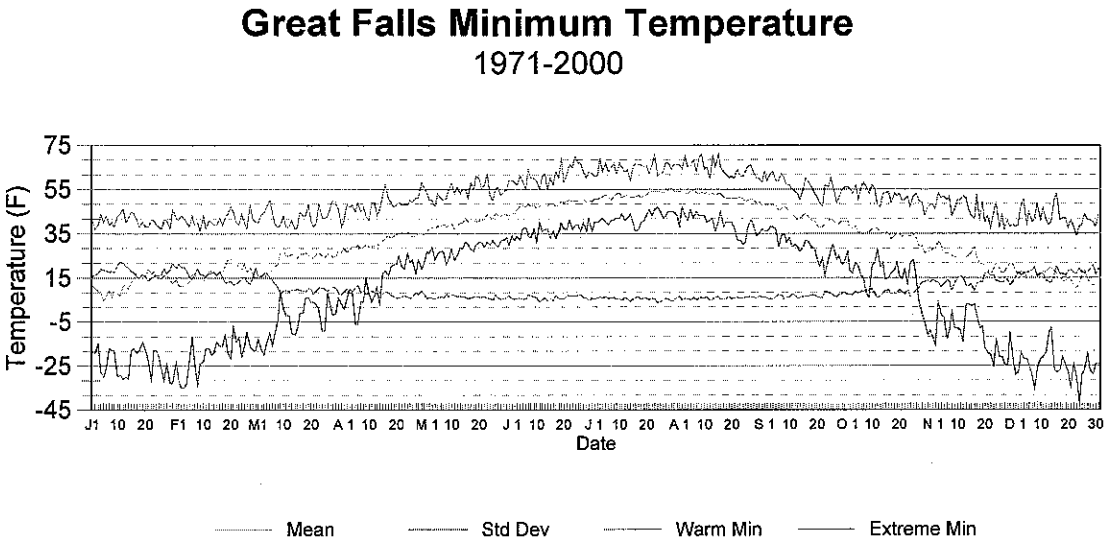
"Normal" air temperature can have differing meanings. The World Meteorological Organization attempted to formalize normal temperatures in order to have a standardized international period. This helps in determining climatological trends. At the International Meteorological Conference in Warsaw, Poland in 1935, the years 1901-1930 were selected as the international standard period for normals. In the U.S., NOAA's (National Oceanic and Atmospheric Administration) National Weather Service (previously the Weather Bureau) adopted this 30-year standard and now, recalculates "normals" at the end of each decade, using the preceding 30 years' data as input. This practice accounts for slow changes in climate and adds data from more recently established stations to the network. When computing "normals" for a 30-year period, as with an annual temperature trace, trends from warmer to cooler, and warmer again are seen. However, this line is not a smooth line, as shown in the following figures (Figs. 1 and 2). A statistical technique is used to smooth out the line to eliminate daily "jumping" of values. The information presented here does not employ the smoothing technique. Additionally, this paper argues that in extreme climates, such as Montana, the term "average temperature" should be used, rather than "normal temperature."

Figure 1. Maximum Temperature at Great Falls (1971-2000):
Period Extreme Maximum, Mean temperature, Lowest Maximum and one Standard Deviation.



The largest variation occurs during the winter, with a standard deviation of 22 on January 10, 11 and December 29. The lowest standard deviation occurs in the summer, with the lowest of 6°F on July 28.

Figure 2. Minimum Temperature at Great Falls (1971-2000):
Period Extreme Minimum, Mean temperature, Lowest Minimum and one Standard Deviation.



The largest variation again occurs during the winter, with a standard deviation of 22 on January 11. The lowest standard deviation occurs in the summer, with the lowest of 4°F on July 28.

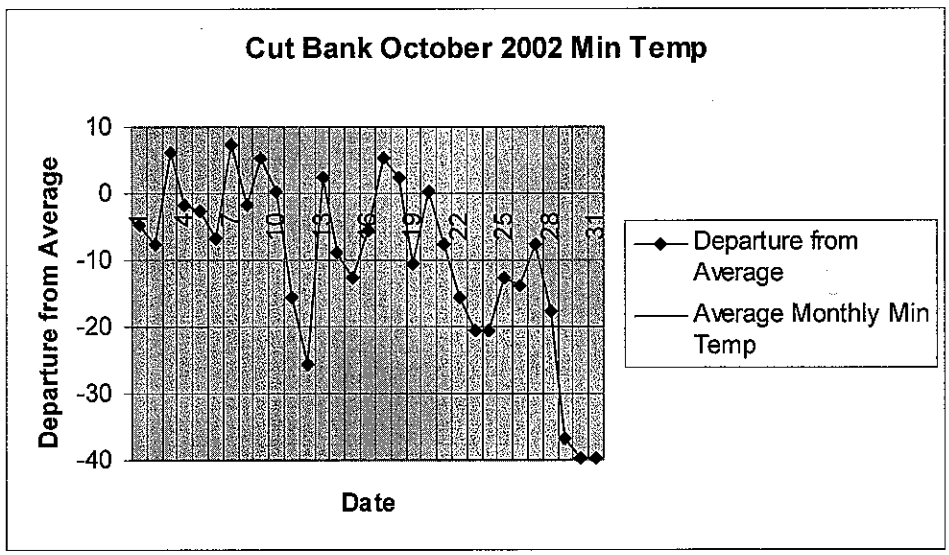
Normals, standard deviations, ranges and probability

In computing a "normal" or average temperature, daily values for the preceding 30 years are used. Because of daily temperature fluctuations, this "normal" value likely includes several values not even close to the "normal." To express the spread, or variance, in the computations, we can employ other statistical functions by looking at a normal distribution of the data and finding values such as a *standard deviation.* In a normal distribution, 68% of the 30 values (20 of the 30) will fall within one standard deviation of the computed average temperature. Simply put, the standard deviation is an expression of the scattering, of the observations. If one standard deviation is small (4°F), the "normal" or average temperature is a good representation of the input values. So, at Great Falls in July, an average minimum temperature of 56°F would be a good representation of all 30 values. If the standard deviation is large (15-25°F), the "normal" value has much more scatter associated with it, so more likely implies that it is just an average of the values, rather than a "normal" value. As shown in Figures 1 and 2, the largest variation in maximum temperature is in January. Looking at January 11, the range in maximum values is 59°F to -17°F! The range in minimum values is 44°F to -29°F. These ranges underscore the wide fluctuation in values used in computing the "normal." In July, on the 28th, the lowest standard deviation occurred. On this date, the range in high temperatures was 100°F to 72°F. The range in minimum values was 64° to 45°F, or much smaller than the range in temperatures in January.

This variation becomes important in Montana when "normal" temperatures are discussed in the cool season. In the summer months, the standard deviation of the temperature (both maximum and minimum) is generally less than 10°F. In the cool months, the standard deviation reaches more than 20°F. While NOAA's National Weather Service releases climatological information relating to the computed "normal," in reality, if the standard deviation is 20°F with a "normal" of 30°F, there is as much of a chance that the temperature could be 15°F, 30°F, or even 45°F! A daily probability chart could show this. On a daily basis, this may be noteworthy, but it is only over a longer period of time, over a week or more, where the significance of above (or below) average values bears out.

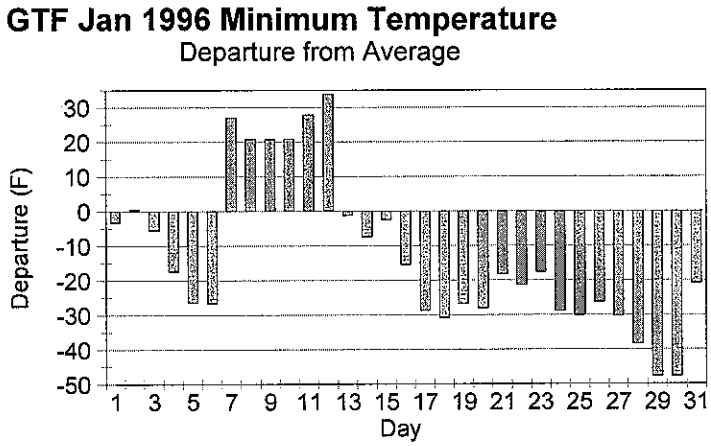
In Montana, especially in areas affected by chinook winds, this is played out by experiencing periods in the winter where temperature may remain above freezing for a period, but later, the high temperature may be near zero. Following (Figure 3) is an example from Cut Bank, in October 2002. The monthly minimum temperature averaged 10°F below the 30-year "normal" value. The average monthly temperature was 21.8°F, but by reviewing Figure 3, only eight of the values were within three degrees of the computed mean. Values as much as 40 degrees below "normal" were included in the computation. At this time of the year, one standard deviation in low temperatures is around 15°F. With the daily computed "normal" of 27°F and a standard deviation of 15°F, an observation of 2°F on October 31 is not too "abnormal." The low temperature was -8°F, which makes it a bit more significant, however, a low temperature of 14°F on October 28, though 13 degrees below "normal" is within one standard deviation. However, a probability forecast would have a minimum between 33-35°F. Actually, there is a 16 percent chance that the low temperature would have been less than 15°F.

Figure 3. Cut Bank October 2002 Minimum Temperatures Departures from Average.



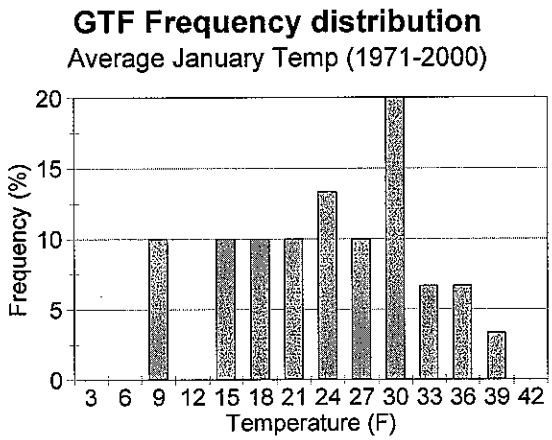
There are other ways to look at the importance of an average, rather than "normal." In another example, at Great Falls in January 1996 (Fig. 4), the month's average temperature was 11°F below "normal." The low temperatures averaged 13°F below "normal." On a daily basis, the variation was quite dramatic as shown in the following figure. There were only five days in which the minimum temperature was within five degrees of the daily "normal" temperature, and only three days within three degrees of the daily "normal." With standard deviations between 15-22°F during the month, fully one-half of the month's temperatures fell within one standard deviation of the computed "normal." A frequency distribution of ranges of average temperature at Great Falls (Fig. 5) further emphasizes these deviations. This shows, that even though the "normal" temperature is around 22°F, this only occurred about 10 percent of the time in the 30 year period.

Figure 4. Great Falls January 1996 Minimum Temperature Departures from Average



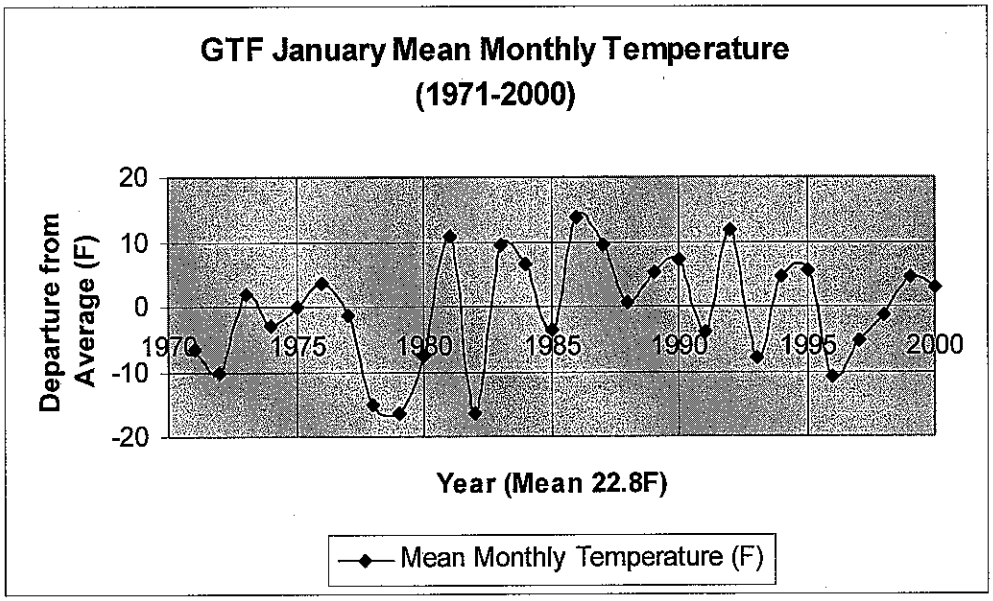
The greatest occurrence of values was actually between 30-32°F. These values occurred 20 percent of the time. This further emphasizes that the computed normals are not really normals, but averages, and should be so stated.

Figure 5. Great Falls Average January Temperature Frequency Distribution.



Another example uses mean January temperatures for Great Falls from 1971 through 2000. Figure 6 shows that even the monthly averages show wide variations. The standard deviation for this period is 8°F, meaning that the monthly mean temperature, or "normal" may be anywhere from 14.8°F to 30.8°F! Indeed, during this 30-year period, only seven or 23% of the values were within three degrees of the "normal value. Thirteen other years' values fell within the one standard deviation interval of 8°F.

Figure 6. Great Falls January Mean Monthly Temperature trace.



Conclusions

While NOAA's National Weather Service will likely continue to publish "normal" temperature values, one needs to keep in mind that the "normal" is simply an average of all the values. It is possible that not even one of the input values is equal to the computed "normal," and the most commonly occurring values may be significantly separated from the "normal". This further underscores that, although it is *interesting* to know the "normal" or average temperature; it is probably more important to understand the distribution of the values used in computing the "normal," which the ranges, standard deviation, variance and frequency distributions can relate.

References

Cooper, D. & Schindler, P. 2000. *Business Research Methods, 7th Ed.* McGraw Hill Irwin. Boston.

Crutchfield, H. 1983. *General Climatology, 4th Ed.* Prentice Hall, Englewood Cliffs, NJ.

Glossary of Meteorology, Huschke, R, ed. 1959. American Meteorological Society. Boston.

Levin, R. 1981. *Statistics for Management, 2nd Ed.* Prentice Hall, Englewood Cliffs, NJ.

Other climatological information can be found at the following:

http://www.ncdc.noaa.gov	The National Climatic Data Center.
http://www.wrh.noaa.gov/Greatfalls	National Weather Service Great Falls' home page. Look under the climate section.
http://www.wrcc.dri.edu	The Western Region Climate Center. Look under the historical station section to find daily standard deviation information for selected stations.