AN ANALYSIS OF CLIMATE CHANGE IN THE UNITED STATES USING RECORD HIGH AND RECORD LOW TEMPERATURE DATA

Kirby R. Cundiff, PhD, CFA, CFP®
Associate Professor of Finance Rochester Institute of Technology

Abstract

To test climate change or global warming theories in the United States I analyzed record high and record low data for locations in all 50 of the United States for both January and July over the entire available record. While there was a general trend of increasing numbers of record highs and decreasing numbers of record lows, most of the regional results were not statistically significant and there were many counter trend examples. Of particular interest were the record highs during the extremely hot summers of the Great Depression in 1930s.

Keywords: Climate change, temperature records, global warming

Introduction:

To test climate change and or global warming theories in the United States I analyzed record high and record low data for locations in all 50 of the United States for both January and July over the available record. The data was obtained from the weather.com site for one city in each state. For examples data for Kirksville, MO may be obtained at: http://www.weather.com/outlook/health/fitness/wxclimatology/daily/63501. The cities were chosen based upon which locations had the longest available time series of record high and record low temperature data. In some states I was able to locate data going back to the 1870s. The shortest times series I used went back to the 1930s. Record high and low temperatures were grouped based on which decade they occurred in for each state and a time series regression analysis was completed to see if the number of record highs or lows was increasing or decreasing as a function of time.

While there was a general trend of increasing numbers of record highs and decreasing numbers of record lows, most of the regional results were not statistically significant and there were many counter examples. Of particular interest were the record highs during the extremely hot summers of the Great Depression in 1930s. A sample of graphs including graphs showing the 1930s are shown at the end of the paper. No effort was made to correct for the urban heat island effect (some of the thermometers that are now in the middle of cities were in the country side in the past) and this effect would tend to bias the data toward increasing the number of record highs and decreasing the number of record lows.

Literature Review:

Climate change has been studied over a variety of time periods and using a variety of approaches including satellite data, ice core data, and the analysis of a series of temperature reading from thermometers placed in various locations around the planet. Satellite data shows that over the past four decades the troposphere has warmed and the stratosphere has cooled, but satellite data only goes back to the 1970s (Satellite, 2013). The ice core data is useful for the longest time period going back several hundred thousand years and showing fluctuations in the earth's temperature of around 10 °C from ice ages to inter glacial warm periods like the present age (figure 1).

Both CO_2 and temperature data may be obtained from the ice core data, but in the case of temperature no direct measurement is possible. The temperature values are estimated from different isotopes of oxygen and hydrogen. The methodology is based on the assumption that different isotopes evaporate at different rates depending on the temperature. It is generally considered that the best estimate of temperature from ice cores is based on the use of both Oxygen-18 and Deuterium. A strong correlation between CO_2 levels and temperature is apparent in the ice core data (Ice Cores, 2013).

The popular model of climate change or global warming is that human created CO_2 is driving an increase in temperature around the Earth as stated by the Intergovernmental Panel on Climate Change. The 1990 executive summary of the Working Group I Summary for Policymakers report says they are certain that emissions resulting from human activities are substantially increasing the atmospheric concentrations of greenhouse gases, resulting on average in an additional warming of the Earth's surface.

The IPCC calculate with confidence that CO_2 has been responsible for over half the enhanced greenhouse effect. They predict that under a "business as usual" (BAU) scenario, global mean temperature will increase by about 0.3 °C per decade during the 21st century. They judge that global mean surface air temperature has increased by 0.3 to 0.6 °C over the last 100 years, broadly consistent with the prediction of climate models, but also of the same magnitude as natural climate variability. The IPCC believe that a definitive detection of the enhanced greenhouse effect is not likely for a decade or more.

Climate Change 1995, the IPCC's Second Assessment Report (SAR), was finished in 1996. The Summary for Policymakers of the Working Group I report contains headings:

1. Greenhouse gas concentrations have continued to increase
2. Anthropogenic aerosols tend to produce negative radiative forcings
3. Climate has changed over the past century (air temperature has increased by between 0.3 and 0.6 °C since the late 19th century; this estimate has not significantly changed since the 1990 report)
4. The balance of evidence suggests a discernible human influence on global climate (considerable progress since the 1990 report in distinguishing between natural and anthropogenic influences on climate, including aerosols; coupled models; pattern-based studies)
5. Climate is expected to continue to change in the future (increasing realism of simulations increases confidence; important uncertainties remain but are taken into account in the range of model projections)
6. There are still many uncertainties (estimates of future emissions and biogeochemical cycling; models; instrument data for model testing, assessment of variability, and detection studies)

(Intergovernmental Panel, 2013).

Other scientists have questioned if the correlation between CO_2 and temperature in the ice core data indicates that CO_2 is driving temperature increases or if temperature increases are driving CO_2 increases:

Indermühle et al. (2000) found that CO_2 lags behind the temperature by 1200±700 years, using Antarctic ice-cores between 60 and 20 kyr before present (figure 2).

Fischer et al. (1999) reported a time lag of 600±400 yr during early de-glacial changes in the last three glacial–interglacial transitions.

Siegenthaler et al. (2005) found a best lag of 1900 years in the Antarctic data.

Monnin et al. (2001) found that the start of the CO_2 increase in the beginning of the last interglacial period lagged the start of the temperature increase by 800 year (Shaviv, 2007).

Many scientists believe that the primary driver of climate change on planet earth is changes in solar activity. See for example Bond et al. (2001), Dansgaard (1984), and Friis-Christensen et al. (1999). A good summary of this research is Fred Singer's *Unstoppable Global Warming* (2007).

The third primary source of temperature data comes from a series of thermometers placed all over the planet. The IPCC assessment indicates that the global air temperature has increased by 0.3 to 0.6 °C over the last 100 years. Given the complications of averaging the temperature changes in the readings of a large number of thermometers from locations all over the planet to obtain a global mean temperature, it is questionable whether the errors bars in this analysis are less than 0.6 °C. Evans (2010) discusses some of the complications with this sort of analysis. This series of thermometers is the data set that is analyzed in this paper. Most of the regression results are found to be consistent with global warming, but the results are largely not statistically significant and there many interesting counter examples.

Hansen et al. (2010) of the National Aeronautics and Space Administration (NASA) have studied the modern thermometer record and believe that 2010 was the hottest year on record. Mann et al. (2004) have studied a combination of tree ring data and the modern thermometer record and believe that the twentieth century is the hottest century on record. The highest temperature ever recorded on earth was 56.7 °C (134 °F) on July 10, 1913 in Death Valley, CA (List).

Meehl et al. (2009) found a relative increase of record high maximum temperatures compared to record low minimum temperatures in the United States as a function of time since the 1950s. Their data set starts after the very hot period of the 1930s.

Methodology:

Simple regression analysis is used to attempt to fit the available data to the equation $y_i = mt_i + b$ by solving for the coefficient, m, and the y-intercept b. For time-series analysis, y_i is the number of record highs or record lows in a given decade and t_i is a given decade.

Regression analyses yields not only the best fit values for m_j and b, but also an indication of how good the data fit is which is reflected in the t-statistics, t, and the coefficients of determination, R^2. The t-statistic is equal to the slope, m, divided by the standard error of the slope and indicates how significant the t values are in predicting the y value. For large sample sizes, t-statistics greater than 2.6 are considered significant at the 1% confidence level, and t-statistics greater than 1.96 are considered significant at the 5% confidence level for large samples. The longest data sets we use run from 1870 to 2000 or for 14 decades. The t-stat for a 95% confidence level and 14 data points is 2.145. For a more detailed discussion of regression analyses see DeFusco et al. (2001).

Empirical Results:

As can be seen in table 1, most of the regressions do show that the number of record high temperatures in the US has been increasing and the number of record low temperatures in the US has been decreasing during the last century, but less than 20% of the regressions have statistically significant t-statistics. There are many interesting counter examples; graphs of which are shown at the end of this paper. The most significant of these counter examples is the 1930s in the Midwest which for many states have by far the largest number of record highs during the 20^{th} century.

The summers of 1930s in the Midwest United States:

The most interesting and most extensive counter trend examples are the summers of the 1930s during the Great Depression in the Midwest and several other US locations. Most of the Midwest record high July graphs show a huge spike during the 1930s making this the hottest decade on record at least for the U.S. Midwest. During this time period the farmers of the American Midwest experienced the well know dust bowl. A series of graphs demonstrating the record high dominance of the summers of the 1930s are shown at the end of this paper. For example large 1930s record high spikes are shown for Homer, AK, Champaign, IL, Kirksville, MO, Billings, MT, Lima, OH, Tulsa, OK, Roanoke, VA, and Green Bay, WI.

Conclusions and Discussion:

While the data does tend to show that the U.S. has grown warmer over the past 100 years the evidence is rather weak. There is a general trend of increasing numbers of record highs and decreasing numbers of record lows, but most of the regional results are not statistically significant and there are many counter trend examples. Of particular interest in the U.S. are the Midwest summers of the 1930s. Record high July temperatures were most likely to occur during this time period for many locations. Since no effect was made in this analysis to correct for the heat island effect (some of the thermometers that are now in the middle of cities were in the country side in the past) and this effect would tend to bias the data toward increases the number of record high temperatures and decreasing the number of record low temperatures, the support for a warming North America during the 20^{th} century is even weaker.

I would like to thank my Quantitative Analysis classes at Northeastern State University and my Data Analysis classes at the Rochester Institute of Technology for their assistance with this project.

References:

Bond, G. et al. Persistent Solar Influence on North Atlantic Climate during the Holocene. *Science*, *294*, 2130-136, 2001.

Dansgaard, W. et al. North Atlantic Climatic Oscillations Revealed by Deep Greenland Ice Cores. *Climate Processes and Climate Sensitivity, 29*, 288-98, 1984.

DeFusco, R. A., McLeavey, D. W., Pinto, J. E., Runkle, D. E., *Quantitative Methods for Investment Analysis*. Charlottesville, Virginia: Association for Investment Management and Research, 2001.

Evans, D. Is the Western Climate Establishment Corrupt?" *SPPI Collaborative Paper*. Retrieved November 8, 2010 from http://scienceandpublicpolicy.org/originals/western_climate_establishment_corrupt.html

Fischer et al. Ice Core Records of Atmospheric CO_2 Around the Last Three Glacial Terminations. *Science, 283*, 1712-1714, 1999.

Friis-Christensen, E. and Lassen, K. Length of the Solar Cycle: An Indicator of Solar Activity Closely Associated with Climate. *Science 254*, 698-700, 1999.

Hansen et al. Global Surface Temperature Change. Retrieved 2010 from http://thinkprogress.org/climate/2010/06/03/206131/nasa-giss-james-hansen-study-global-warming-record-hottest-year/?mobile=nc

Ice cores. *Climate Data Information*. Retrieved March 21, 2013, from http://www.climatedata.info/Proxy/Proxy/icecores.html

Indermühle et al. *Geophysical Research Letters 27*, 735, 2000.

Intergovernmental Panel on Climate Change. In *Wikipedia, The Free Encyclopedia*. Retrieved March 21, 2013, from http://en.wikipedia.org/w/index.php?title=Intergovernmental_Panel_on_Climate_Change&oldid=542195567

List of weather records. In *Wikipedia, The Free Encyclopedia*. Retrieved March 21, 2013, from http://en.wikipedia.org/w/index.php?title=List_of_weather_records&oldid=544328037

M.E. Mann et al. Global-Scale Temperature Patterns and Climate Forcing over the Past Six Centuries. *Nature 430*, 105, 2004

Meehl, et al. The relative increase of record high maximum temperatures compared to record low minimum temperatures in the U.S., *Geophysical Research Letters*. Retrieved 2009 from http://onlinelibrary.wiley.com/doi/10.1029/2009GL040736/abstract and http://www2.ucar.edu/news/1036/record-high-temperatures-far-outpace-record-lows-across-us

Monnin et al. Atmospheric CO2 Concentrations over the Last Glacial Termination. *Science 291*, 112-114. Retrieved 2001 from http://www.sciencemag.org/content/291/5501/112.abstract

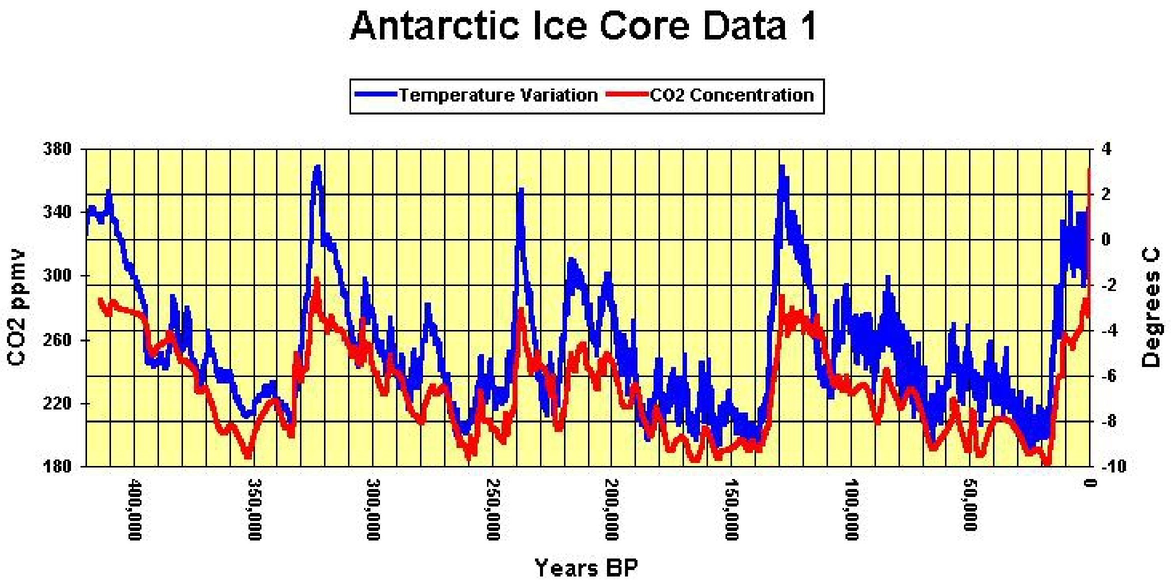
National Oceanic and Climate Administration, National Climate Data Center. Retrieved from http://www.ncdc.noaa.gov/cmb-faq/anomalies.php

Satellite temperature measurements. In *Wikipedia, The Free Encyclopedia*. Retrieved March 21, 2013, from http://en.wikipedia.org/w/index.php?title=Satellite_temperature_measurements&oldid=542601893

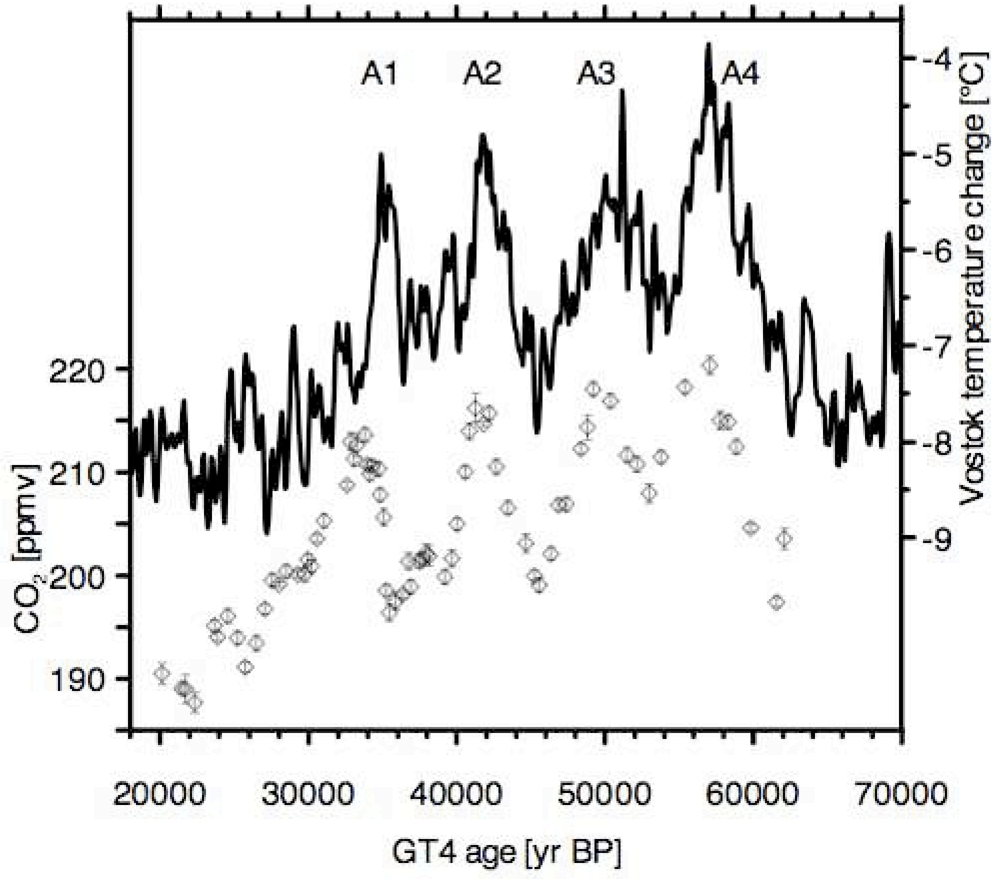
Shaviv, N. The Inconvenient Truth About the Ice core Carbon Dioxide Temperature Correlations. *Science Bits.* Retrieved March 22, 2007 from http://www.sciencebits.com/IceCoreTruth.

Siegenthaler et al. Stable Carbon Cycle-Climate Relationship During the Late Pleistocene, *Science*, *310* 313-1317. Retrieved 2005 from http://www.sciencemag.org/content/310/5752/1313.full.pdf

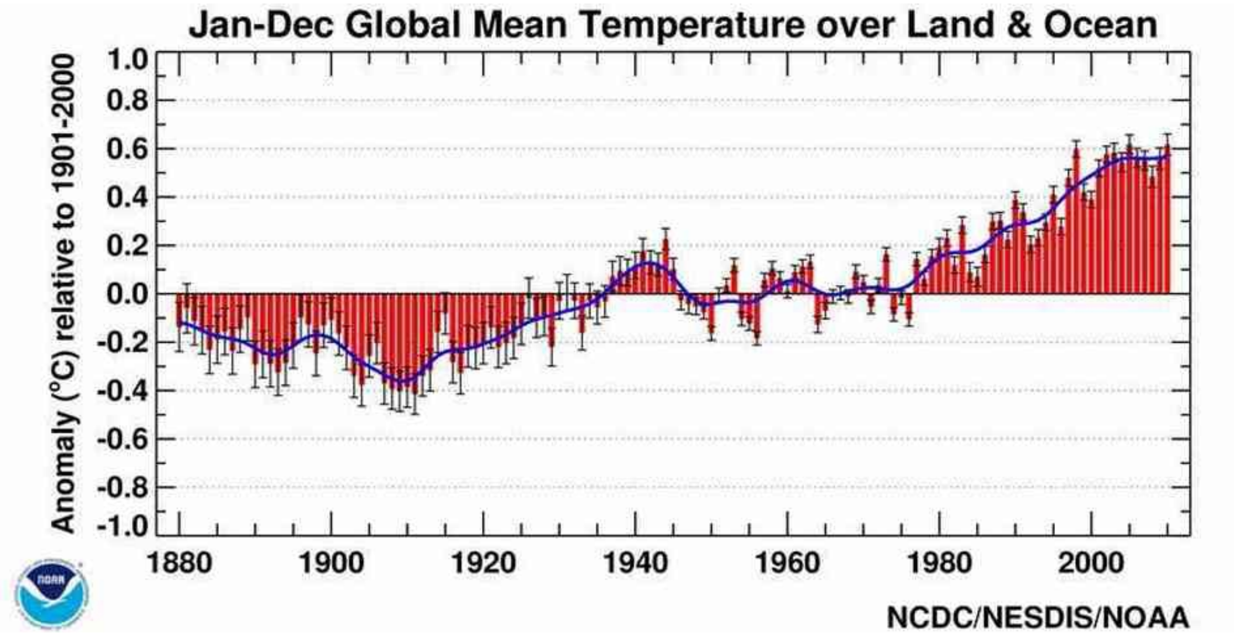
Singer, F. S. and Avery, D. T. *Unstoppable Global Warming*. New York, NY: Rowman & Littlefield Publishers, 2007.



(figure 1)

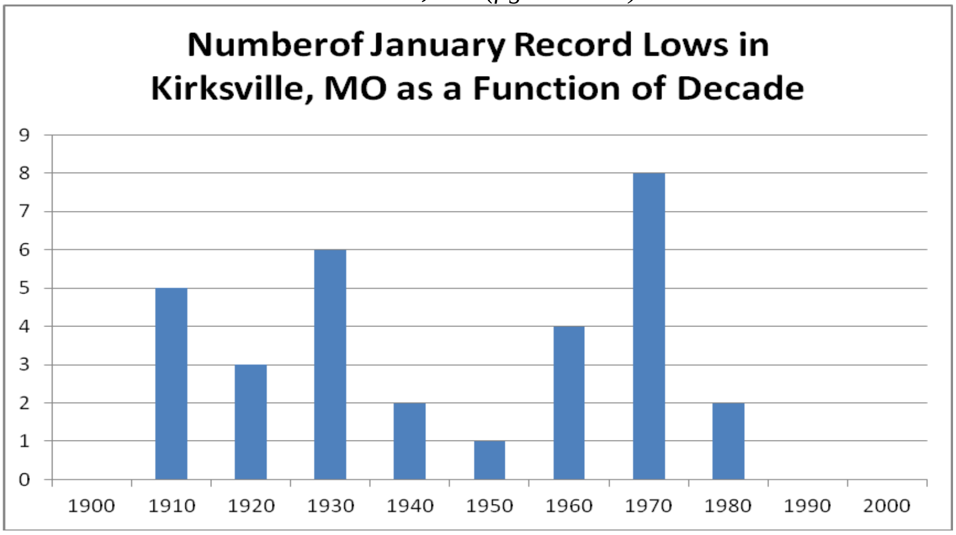


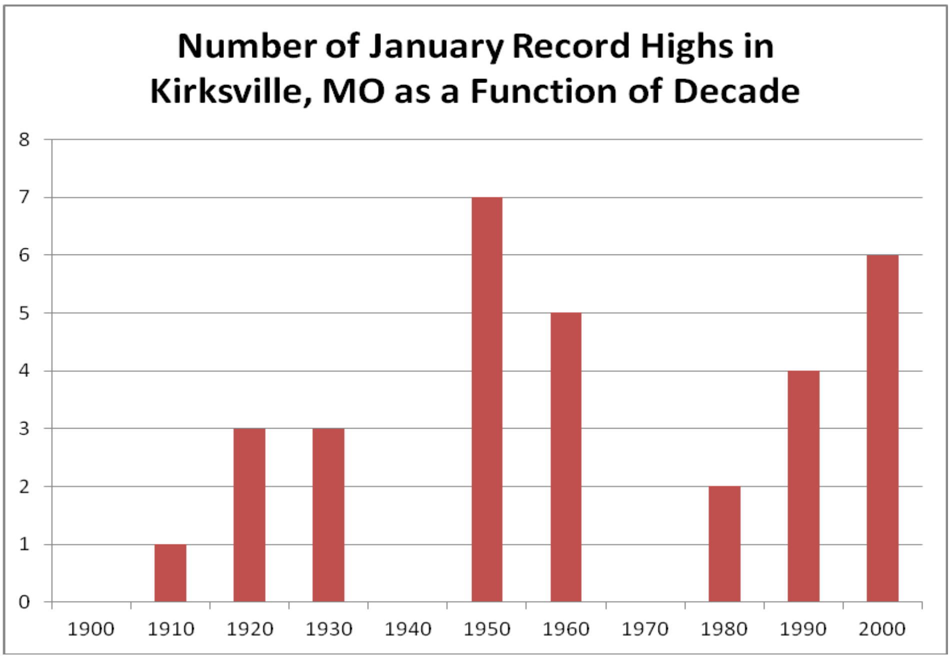
(figure 2)

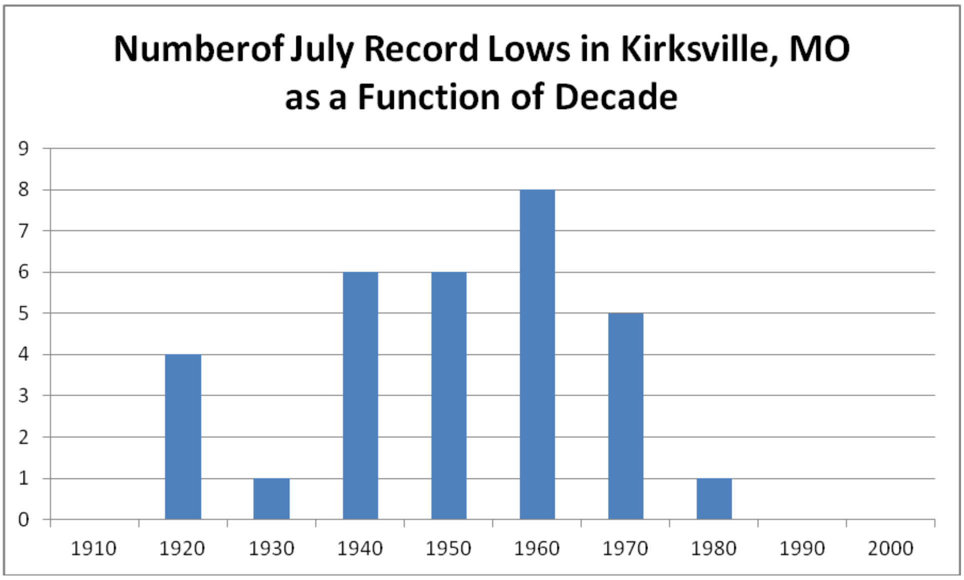


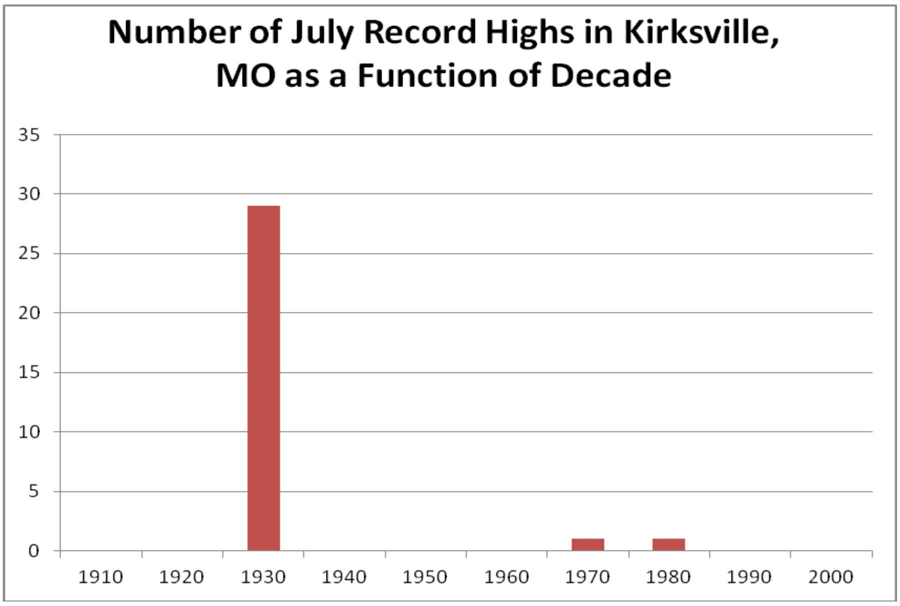
(figure 3)

***Kirksville, MO** (figures 4 – 7)*

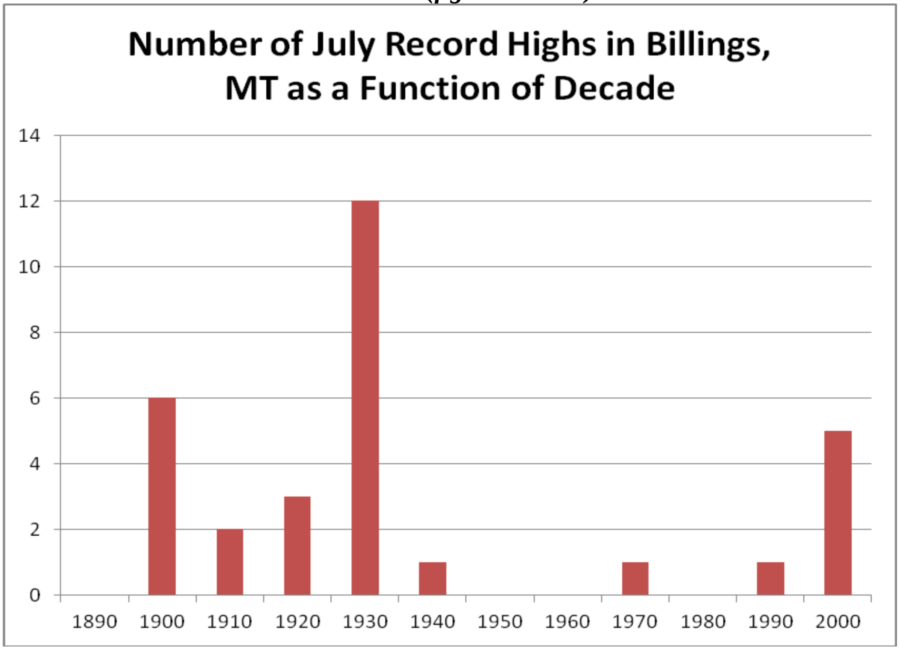


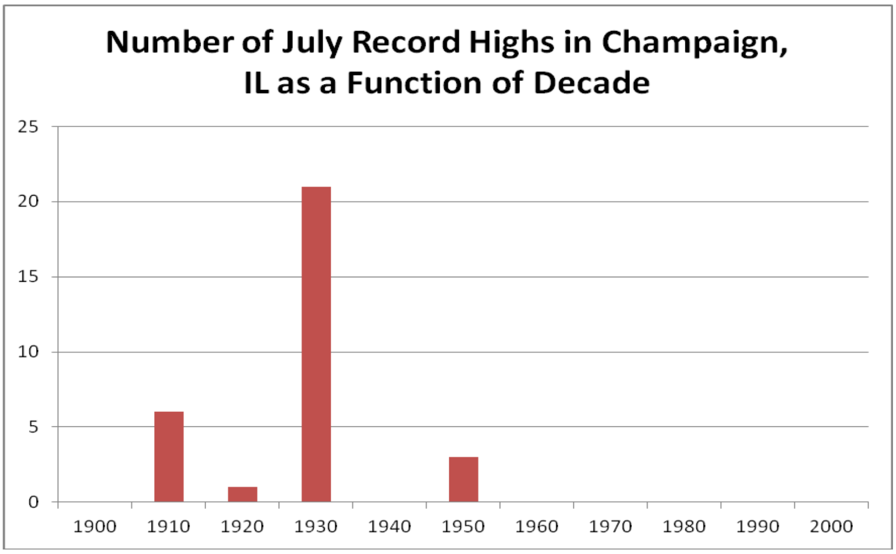


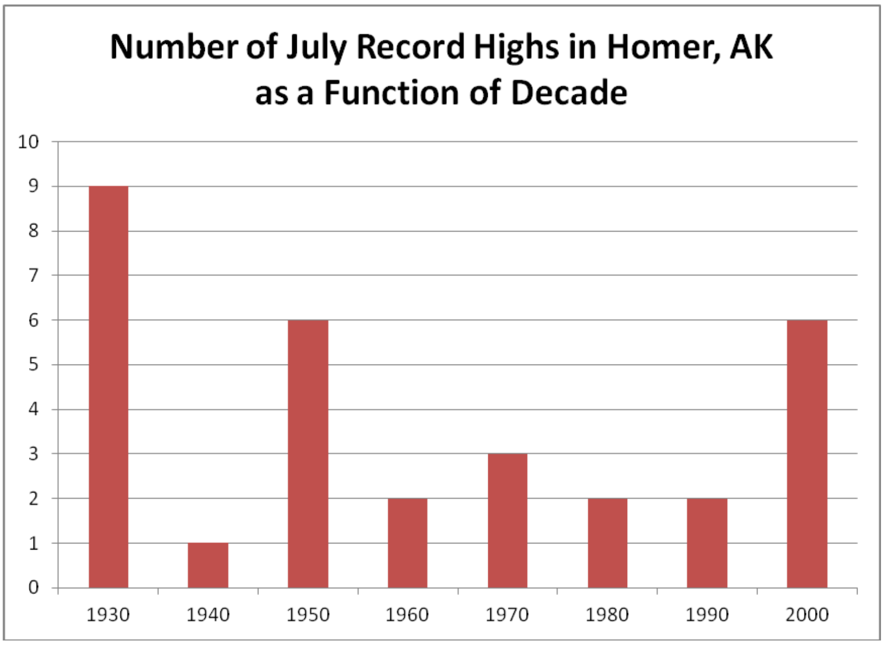


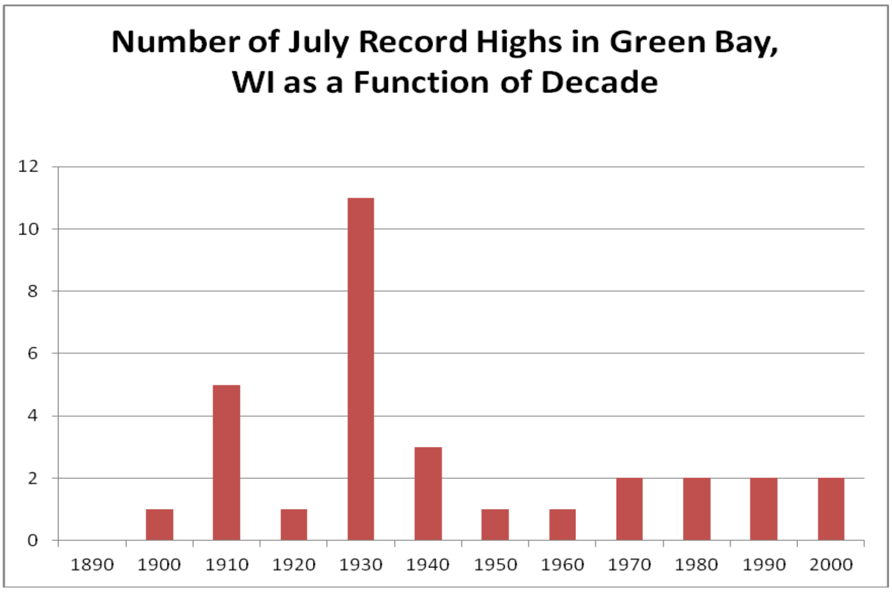


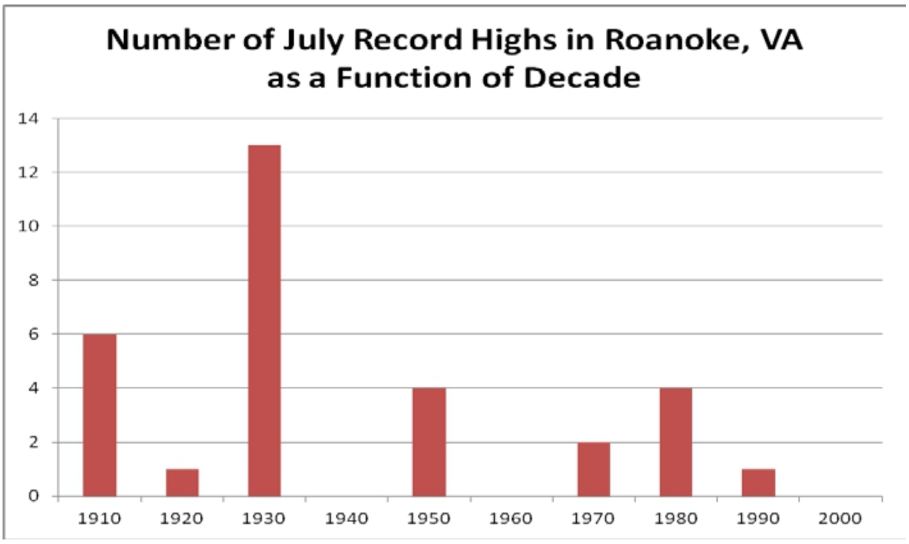
The 1930s (figures 8 – 14)

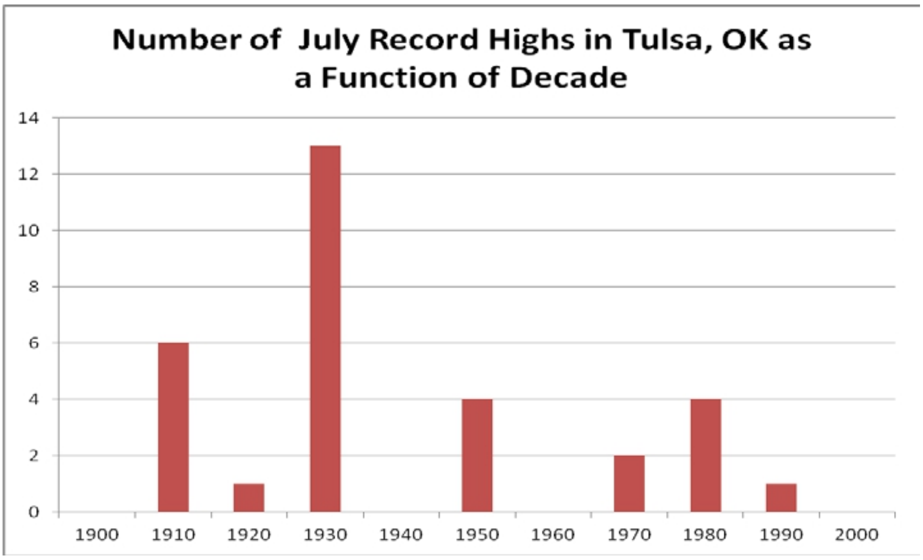


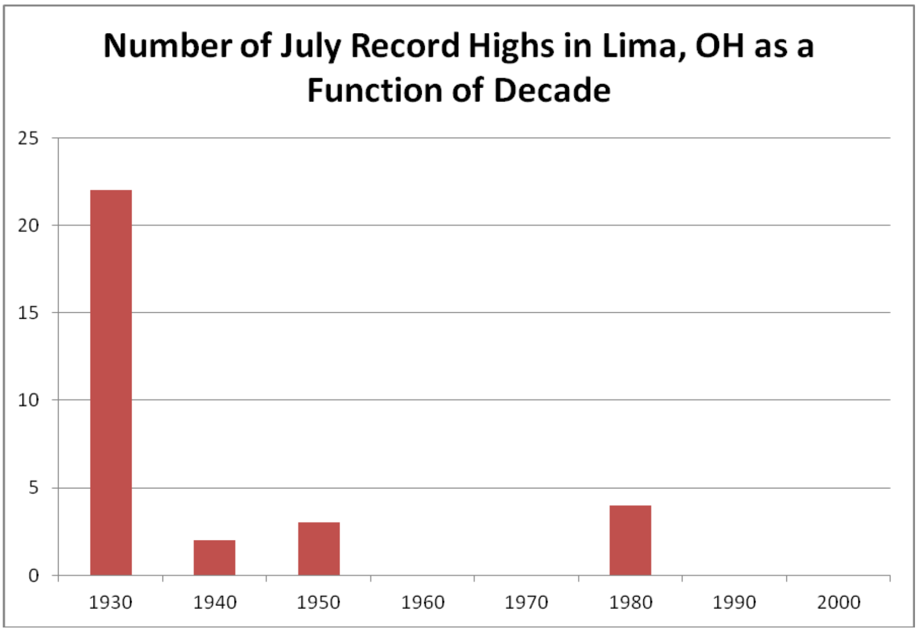



Number of July Record Highs in Homer, AK as a Function of Decade
10
9
8
7
6
5
4
3
2
1
0
1930
1940
1950
1960
1970
1980
1990
2000

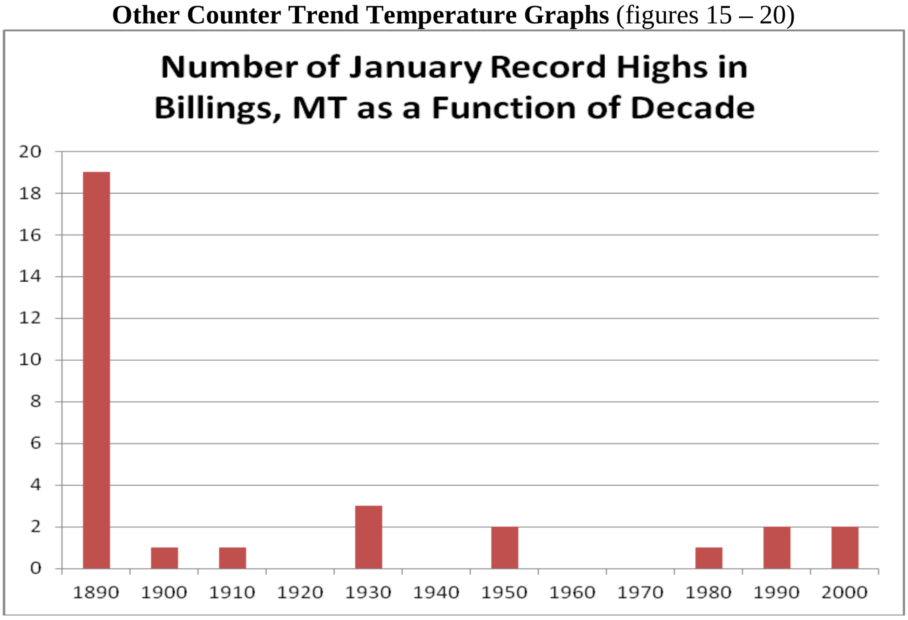

Number of July Record Highs in Green Bay, WI as a Function of Decade
12
10
8
6
4
2
0
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

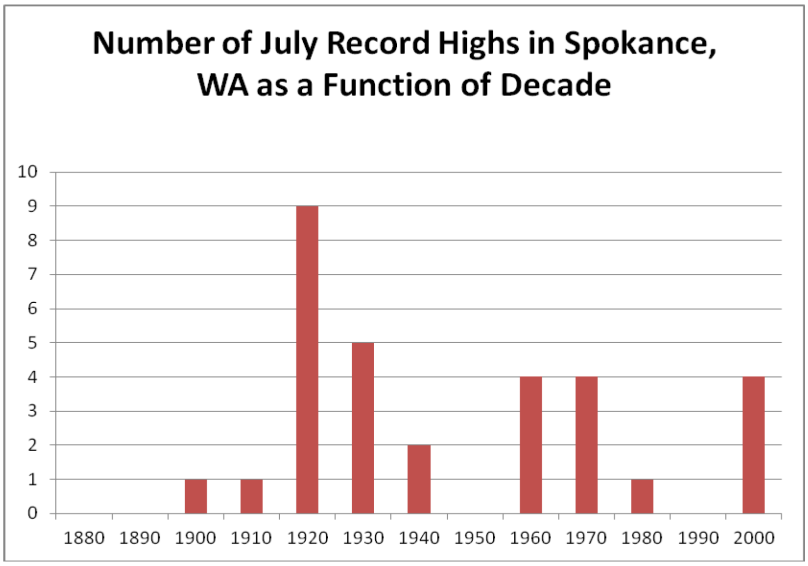

Number of July Record Highs in Roanoke, VA as a Function of Decade
14
12
10
8
6
4
2
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

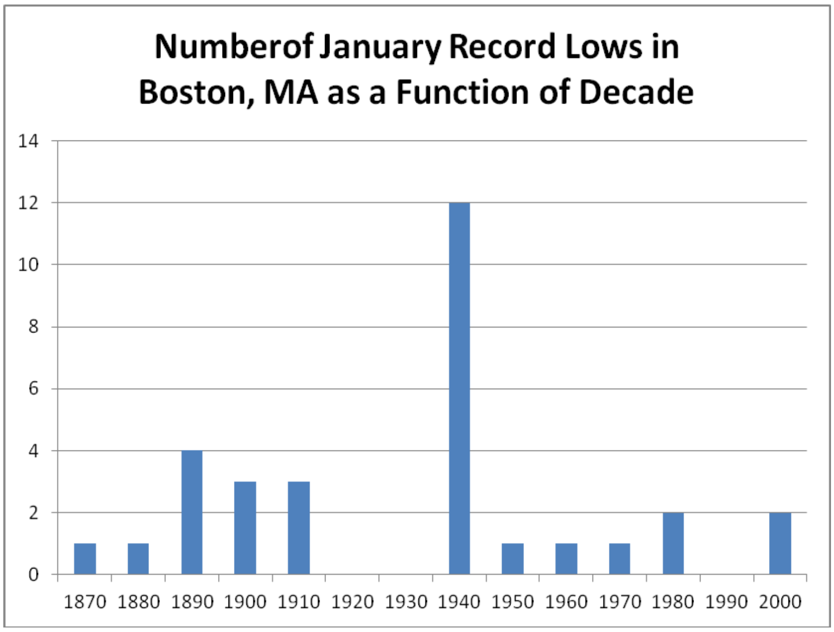


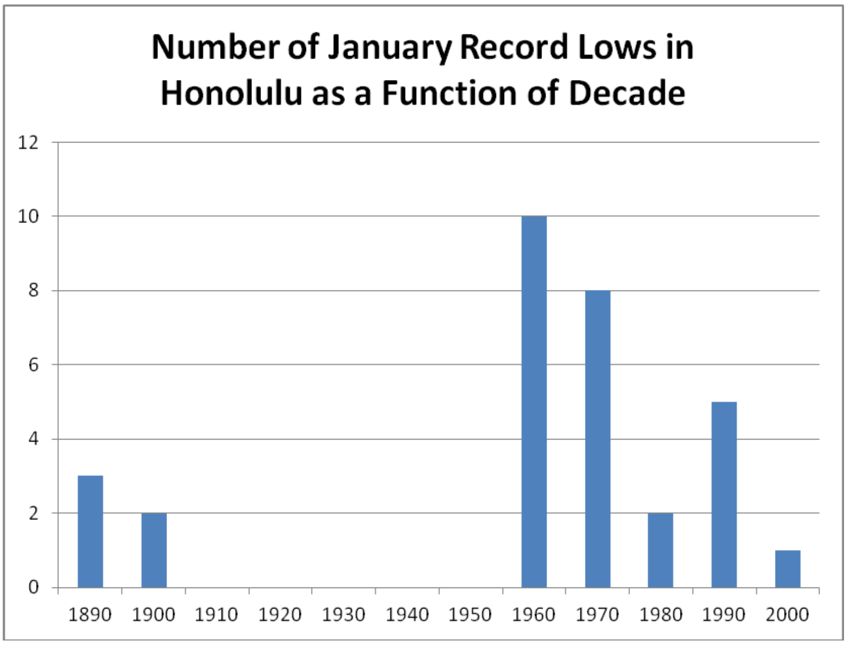


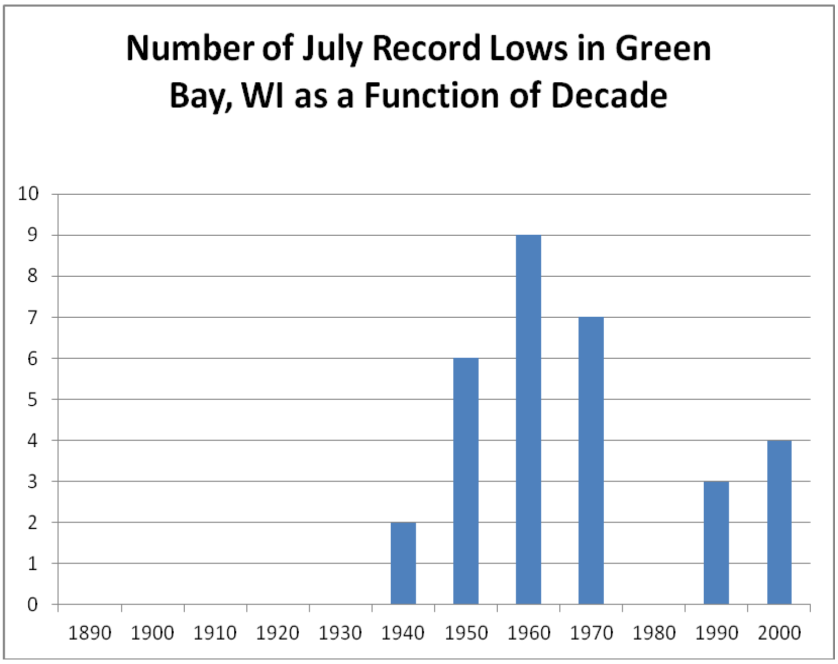
Other Counter Trend Temperature Graphs (figures 15 – 20)

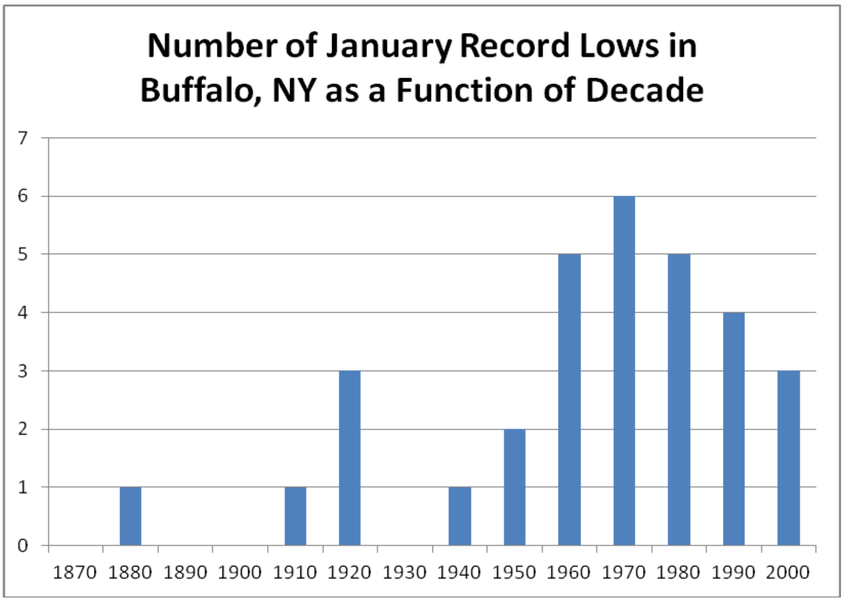



Number of July Record Highs in Spokance, WA as a Function of Decade
10
9
8
7
6
5
4
3
2
1
0
1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000


Numberof January Record Lows in Boston, MA as a Function of Decade
14
12
10
8
6
4
2
0
1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000


Number of January Record Lows in Honolulu as a Function of Decade
12
10
8
6
4
2
0
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000


Number of July Record Lows in Green Bay, WI as a Function of Decade
10
9
8
7
6
5
4
3
2
1
0
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000


Number of January Record Lows in Buffalo, NY as a Function of Decade
7
6
5
4
3
2
1
0
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

(table 1)

	High		**(t-stats)**	**Low**			
	January	**July**		**January**	**July**		**Start Date**
AL	-0.029	0.975		-0.103	0.036		1900
AK	0.000	0.844		-0.462	**-2.885**		1920
AZ	**2.332**	**2.331**		-1.104	-1.503		1870
AR	**2.919**	**2.682**		-1.340	1.801		1880
CA	1.672	**2.448**		-1.135	**-2.284**		1880
CO	1.442	**2.522**		-1.292	**-2.846**		1900
CT	0.040	-0.425		0.000	-0.676		1920
DE	0.838	-0.122		0.658	0.411		1890
DC	1.691	1.302		**-2.600**	-1.867		1870
FL	**2.135**	**2.437**		-0.396	-1.303		1890
GA	1.252	1.739		0.276	-0.766		1880
HI	2.564	0.783		1.107	-1.630		1890
ID	-0.119	0.906		**-4.185**	0.887		1930
IL	-1.346	-1.046		-1.060	**-4.004**		1900
IN	**-2.768**	-1.451		-0.798	**-2.151**		1900
IA	1.213	-0.919		0.175	-1.010		1890
KS	0.928	1.816		-1.728	-0.756		1890
KY	1.388	0.356		1.039	1.088		1870
LA	1.875	1.896		1.148	**2.297**		1870
ME	1.156	0.287		1.549	1.450		1870
MD	0.506	1.237		**-3.179**	**-3.727**		1890
MA	1.277	0.563		-0.260	**-2.953**		1870
MI	0.733	-0.624		0.857	-1.947		1890
MN	1.184	0.492		-1.727	0.211		1870
MO	1.025	-0.812		-1.430	-0.504		1910
MT	-1.562	-0.577		**-2.233**	**-3.105**		1890
NE	0.789	-1.953		-0.650	1.600		1930
NV	0.430	0.984		-1.806	-1.262		1880
NH	0.279	1.628		0.624	**-3.723**		1920
NJ	0.198	**-3.152**		-0.077	-1.096		1930
NM	1.361	**2.295**		-0.175	**-2.475**		1890
NY	1.311	2.108		**3.679**	1.018		1870
NC	-0.324	-0.382		0.028	0.030		1900
ND	1.036	0.357		-1.333	0.154		1880
OH	-0.225	-1.970		-0.366	-2.810		1930
OK	0.547	-0.782		-1.451	0.874		1900
OR	-0.094	1.197		-1.158	0.886		1910
PA	**2.263**	1.657		0.263	0.550		1890
RI	**2.037**	**2.344**		0.484	0.426		1900
SC	-0.256	1.897		0.083	-1.732		1930
SD	0.638	-0.015		-1.010	-1.322		1890
TN	1.990	1.064		-0.724	-0.275		1870
TX	1.363	1.922		-0.915	-0.767		1880
UT	0.900	2.103		-1.039	-1.704		1920
VT	0.463	-0.405		-0.797	-0.463		1930
VA	-0.241	-0.518		0.675	**-2.198**		1910
WA	0.294	0.479		-1.365	1.110		1920
WV	-1.105	-0.747		0.621	0.035		1900
WI	0.523	-0.231		0.299	1.999		1890
WY	1.526	1.873		**-2.997**	**-2.827**		1870
Average	0.731	0.608		-0.545	-0.818		
SD	1.104	1.371		1.320	1.631		