Analysis of temperature statistics for Minneapolis and Boston from 1950 through 2012

by Robert Damon

Many scientific papers over the last several decades have reported a trend toward increasing global temperatures, and have indicated that temperatures in recent decades have, for the northern hemisphere, risen above levels seen for at least the past 1300 years[1]. However, these changes are not uniformly geographically distributed globally. Past work by climate scientists indicates that during the period from approximately 1950 through 1978, temperature was relatively stable globally, with year-to-year variation, but no overall trend. However, following that period, temperature has trended up consistently (but with continued significant year-to-year variability)[2].

Temperature trends were evaluated for the cities of Minneapolis, Minnesota and Boston, Massachusetts as two representative North American cities, both urbanized for many decades (both of which I have lived in), with one close to the Atlantic Ocean, and the other approximately mid-continent. Figure 1 shows temperature trends for both cities, with the trend line from 1950—2013.

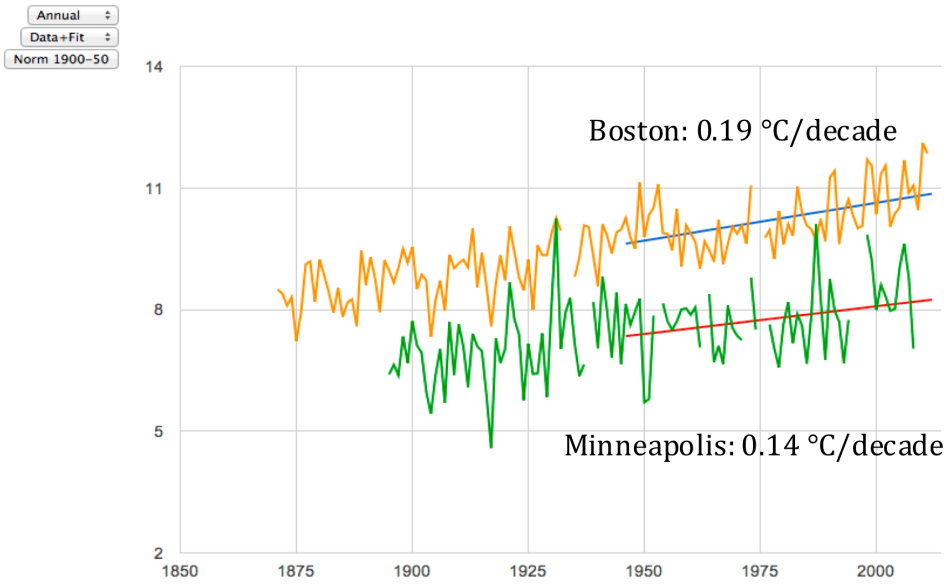

Figure 1. Temperature trends for Minneapolis and Boston.

Source: http://climatemodels.uchicago.edu/timeseries/#FqsBsl

Both cities show a trend toward higher temperatures, with the trend for Boston apparently higher than that for Minneapolis, although normalizing the trends for 1900-1950 shows the trends to be quite similar.

A more detailed analysis was done for both cities with goals of determining, month-by-month over the period 1950-2012, the trends in daily high and low temperatures, evaluating whether the global trends mentioned above were seen in these two cities, and to compare the trends in the two cities. The data was analyzed separately for the overall period, and for the periods 1950-1978 and 1978-2012.

Daily high and low temperature data were retrieved from the National Climatic Data Center[3] for both cities. Means, standard deviations, and standard errors of the monthly data for each year were calculated, and plots were made of monthly mean temperatures (separately for daily highs and lows) vs. year. In addition, plots of the monthly standard errors over the time periods were made. Linear regression analyses were done on both the temperature data and the standard errors to determine the monthly temperature trends and to determine if there was a trend in temperature variability over time[4].

Example plots are shown below for March in Minneapolis (left panel) and Boston (right panel), 1950-2012. Monthly high and low temperatures are shown as means ± S.E.

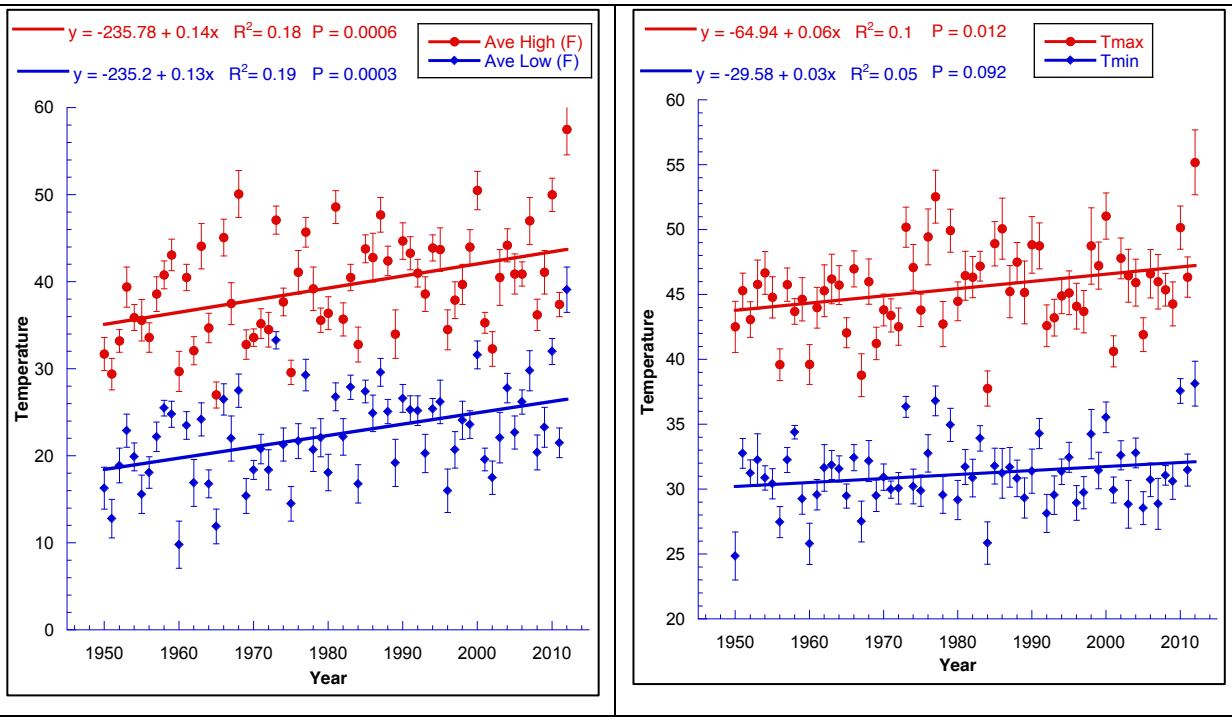

Figure 2. Monthly averages of daily high and low temperatures (± S.E.) for March in Minneapolis (left panel) and Boston (right panel) for the period 1950-2012.

Detailed results of the regression analyses are shown in the tables:

Table 1. Slopes of the linear regression of daily high and low temperature vs. year for 1950-2012, 1950-1978 and 1978-2012.

	Slope					
	High Temp 1950-2012	Low Temp 1950-2012	High Temp 1950-1978	LowTemp 1950-1978	High Temp 1978-2012	LowTemp 1978-2012
Jan	**0.08**	**0.14**	-0.14	-0.17	0.1	**0.22**
Feb	0.05	**0.1**	-0.08	-0.07	0.05	0.07
March	**0.14**	**0.13**	0.19	0.18	0.14	0.12
April	**0.08**	**0.07**	0.12	0.08	0.06	**0.1**
May	0.01	**0.04**	0.08	0.01	-0.06	0.04
June	0.01	**0.04**	0.01	-0.02	0.02	**0.13**
July	0.03	**0.07**	0.05	0.02	0.06	**0.12**
August	0	0.05	0.02	-0.05	0.04	**0.07**
September	0.04	**0.07**	0	-0.02	0.08	**0.09**
October	-0.04	0.01	-0.1	-0.1	0.06	**0.13**
November	0.05	**0.07**	0.02	0.03	**0.17**	**0.19**
December	0.03	0.06	-0.11	-0.1	0.09	0.17
Averages	0.040	0.071	0.005	-0.018	0.068	0.121

Values highlighted in a bold, red font were statistically significant (P<0.05); bold blue font: P≤0.1

Table 2. Boston. Slopes of the linear regression of daily high and low temperature vs. year for 1950-2012, 1950-1978 and 1978-2012.

	Slope					
	High Temp 1950-2012	Low Temp 1950-2012	High Temp 1950-1978	LowTemp 1950-1978	High Temp 1978-2012	LowTemp 1978-2012
Jan	0	0.01	-0.14	-0.12	0.05	0.03
Feb	0.03	0.03	-0.1	-0.07	0.07	0.07
March	**0.06**	**0.03**	0.1	0.07	0.05	0.06
April	0.01	0.02	0.04	-0.01	**0.08**	0.03
May	-0.01	**0.02**	0.01	0.05	-0.02	0
june	-0.02	0.01	-0.02	0.01	-0.04	0.03
July	0	0.02	-0.03	0	-0.01	0.03
August	0.01	**0.04**	0.04	0.06	0.03	0.04
September	0.02	**0.04**	-0.04	0	0.03	**0.09**
October	-0.02	0	-0.06	-0.04	0.04	**0.08**
November	0.01	0	-0.06	0.02	0.01	0.05
December	0.04	0.05	-0.02	-0.01	0.04	0.08
Averages	0.011	0.023	-0.023	-0.003	0.028	0.049

Values highlighted in a bold, red font were statistically significant (P<0.05); bold blue font: P≤0.1.

The overall conclusions are as follows:

Temperature trends during 1950-1978 were small and possibly slightly negative (but not statistically significant) for both cities.

Temperature trends during 1978-2012, and during the overall 1950-2012 period were positive for both cities.

During the overall period, and during the 1978-2012 period, the trend toward increasing temperatures was stronger for the daily low temperatures than for the daily high temperatures for both cities. This is consistent with expectations for temperature changes driven by an increasing greenhouse effect during these periods.

In this analysis, the trend toward increasing temperatures during the 1950-2012 and 1978-2012 periods appeared stronger for Minneapolis than for Boston. This might be anticipated due to the moderating effect of Boston's proximity to the ocean. An explanation for the apparently larger temperature trend for Boston seen in Figure 1 (prior to normalizing to 1900-1950) is not apparent, but may have to do with temperature averaging, and possibly missing data (broken lines in Fig. 1). Also, data used in this study was complete through the end of 2012, whereas Fig. 1 data was complete only to 2008 for Minneapolis and 2011 for Boston.

Slopes of the regression lines indicate that seasonal temperature trends are somewhat inconsistent. For the overall period 1950-2012, upward trends were strongest in winter and spring for both cities. None of the slopes were statistically significant during the 1950-1978 period. For the 1978-2012 period, Minneapolis trends were strongest in fall and winter. For Boston, trends for daily highs were strongest during winter and spring, whereas they were strongest during fall and winter for daily lows. Summer trends were weakest for both cities during the 1950-2012 and 1978-2012 periods.

No statistically significant increase was seen in the monthly standard errors, indicating no increase in monthly temperature variability over the period. Indeed, slopes of the regression of monthly standard error vs. year were either 0 or negative for most months (exceptions: March in Minneapolis, where the slope of the regression line of the high temperature standard errors was +0.01; P=0.05, and Boston, where the slopes were positive for March (0.0026) and July (0.0005) and were NS. The trend toward increasing temperatures therefore could not be attributed to a statistical artifact of increased temperature variability during the period.

References

1. Mann ME, et al., PNAS **105** (36), 13252-13257, 2008.

(http://www.pnas.org/content/105/36/13252.full.pdf+html?sid=d037bb09-4891-4827-bc12-4ba5e6ba65bf)

2. http://climate.nasa.gov/key_indicators

3. http://www.ncdc.noaa.gov

4. Linear regression and statistical analysis was done using Kaleidagraph (Synergy Software) and JMP (SAS Institute).