REGIONAL TEMPERATURE EFFECTS IN THE NORTHEASTERN U.S.

Average temperatures in the Northeastern US near the Atlantic seaboard have risen by 2–3°C in the past century (1900-2012), while they have risen by only 0.5–1 °C in the Midwest[1]. We postulate that this difference might be due at least in part to proximity to the ocean, and suggest that temperatures for locations near the ocean are correlated with sea-surface temperatures.

We use the temperature records in the Climate Time Series Browser from the University of Chicago[2], which in turn uses the GHCNM data set produced by NOAA's National Climate Data Center[3]. These data are supposed to have been adjusted to remove biases[4], in particular the urban heat-island effect. Since we will be comparing temperature for various locations in the Northeast US, including cities of various sizes, and the urban heat-island effect has been a point of contention with some commentators, we will first examine how well the correction works in the Midwest, far from any oceanic influences.

To make this test, we used Chicago/Midway as the city (naturally!), Aurora, IL as a nearby suburb, and Evansville, IL, a town in Southern Illinois with a population under 1000, as a rural base station. The temperature records for these locations were downloaded from the Climate Browser and inputted into Excel for plotting and data manipulation. The results are shown in Figure 1.

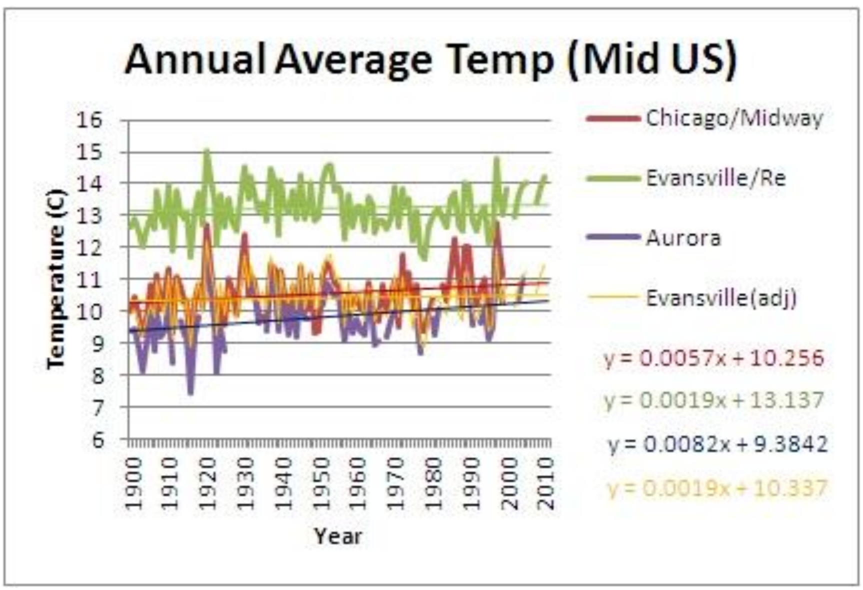

Figure 1. Temperature (°C) vs time for 3 locations in the US Midwest. Linear regressions (color-coded to match the graphs) are as computed by Excel, and are shown in the form y = Ax + B. The orange curve is the data for Evansville adjusted for latitude and elevation, as described in the text.

The data for Chicago and Aurora are already in close agreement, while the raw data (green curve) for Evansville differs by an offset that can be explained by its more southern latitude and its lower elevation. Relevant data are given in Table 1.

Table 1. Relevant Data for Three Locations in Illinois

Location	Altitude(m)	Latitude	Longitude
Chicago/Midway	190	41.8N	87.8W
Aurora	201	41.8N	88.3W
Evansville IL	118	38.1N	89.9W

To correct the Evansville data for latitude and altitude, we used a rate of change of -0.765 ^{o}C per degree of latitude[5], and the lapse rate of -6.5 ^{o}C/km altitude[6], amounting to a total downward shift of 2.8 ^{o}C. When this correction is applied, the Evansville data is in close agreement with the data for Chicago and Aurora, as seen from the orange curve in Figure 1, showing that the NCDC adjustment procedure correctly accounts for the urban heat-island effect, at least in this randomly-chosen case.

Turning now to the Northeast US, we chose Boston/Logan, Portland, ME, and Millinocket, ME as three locations on or near the Atlantic Ocean for study. The temperature data adjusted for both latitude and altitude as described above are shown in Figure 2.

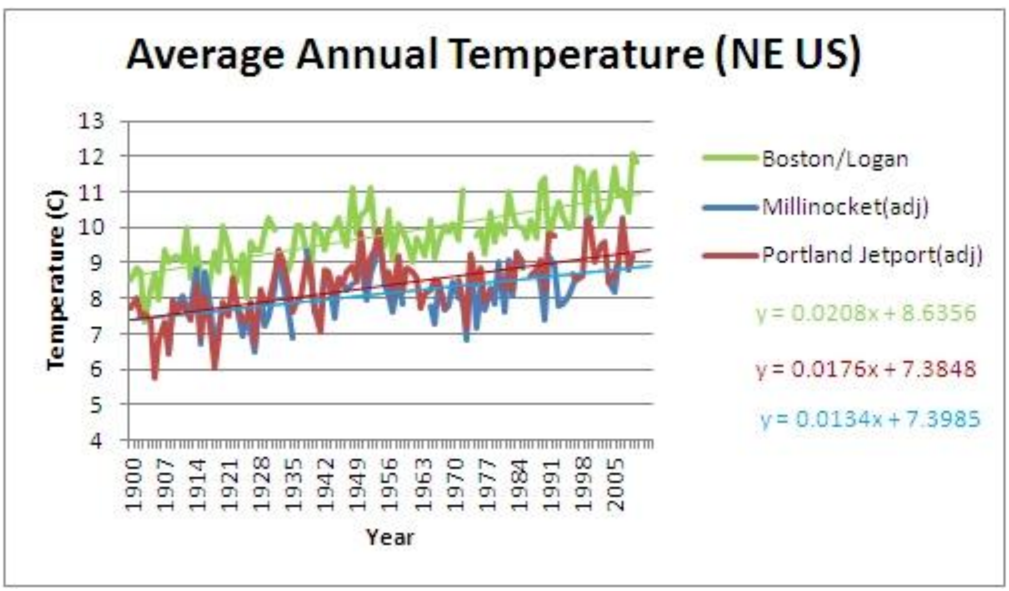

Figure 2. Temperature (^{o}C) vs time for 3 locations in the Northeast US. Linear regressions (color-coded to match the graphs) are as computed by Excel, and are shown in the form y = Ax + B. Data for Portland and Millinocket have been adjusted for latitude and elevation, as described in the text

The relevant data are given in Table 2.

Table 2. Relevant Data for Three Northeast US Locations

Location	Altitude(m)	Latitude	Longitude
Boston/Logan	9	42.4N	71W
Portland	13.7	43.6N	70.3W
Millinocket	109	45.7N	68.7W

Two features stand out in comparison to Figure 1: the slopes of the trend lines in Figure 1 are about 0.5 ^{o}C/century, while those in Figure 2 are about 1.5 ^{o}C/century, about 3 times larger; and the curve for Boston/Logan is shifted upwards from the curves for the other two Northeast locations by ~ 1.5 ^{o}C. Since we know the original data has been properly adjusted for the urban heat-island effect and other biases, these are both real effects which must have a physical explanation.

It is possible that these differences are due to proximity to the Atlantic Ocean. The larger heat capacity of the ocean tends to moderate temperature swings on the land nearby[7], an effect that is expected to fall off further inland. This suggests an influence of sea-surface temperatures on coastal air temperatures that decreases with distance from the ocean.

With regard to the 1.5 ^{o}C upward shift, it is known that sea-surface temperatures have been typically about 3 ^{o}C higher near Boston than near Portland[8]. A higher sea-surface temperature may cause a higher air temperature nearby, though a detailed mechanism is not clear, and it is not clear why the difference in air temperatures should be only half as large.

Sea-surface temperatures in both locations, as well as throughout the Gulf of Maine, have changed by about +1 ^{o}C since 1900[9]. We also might tentatively attribute the larger rates of temperature change in the Northeast data to the larger rate of change of ocean temperature in that area, as though the 'continental' temperature change of 0.5 ^{o}C is augmented by the 'oceanic' temperature change of 1 ^{o}C near the coast. One might then expect the trend-line slope of the temperature vs time graphs to decrease gradually from 1.5 ^{o}C to 0.5 ^{o}C as the distance from the Atlantic Ocean is increased. Some evidence on this idea can be gleaned from studying the slopes of the trend lines for several locations farther inland, as shown in Table 3, where the trend line slopes were obtained from fitting the annual temperature data for those locations. While it is broadly true that the slope decreases with distance from the ocean, it is not at all systematic; there are evidently other climatic effects involved, e.g., topography, such as moderate-height intervening mountain ranges.

Table 3. Trend-line slope (^oC/century) vs Distance from Atlantic Ocean

Location	Distance to Ocean (km)	Trend-line slope (^oC/century)
Boston MA	0	0.0208
Portland ME	0	0.0181
Bedford MA	27	0.0158
Lawrence MA	34	0.0206
Millinocket ME	135	0.0134
Albany NY	227	0.0112
Chelsea VT	240	0.0047
Syracuse NY	424	-0.0012
Chicago IL	1000	0.0057

The only fair conclusion to draw from these results is that the differences found between the Midwest and Northeast, and between locations in the Northeast, remain unexplained, though the influence of the ocean remains a possibility, and should be explored further.

REFERENCES

1. http://www.epa.gov/climatechange/science/indicators/weather-climate/temperature.html See figure 3, which is based on data from the National Climate Data Center.
2. http://climatemodels.uchicago.edu/
3. http://www.ncdc.noaa.gov
4. http://www.ncdc.noaa.gov/cmb-faq/temperature-monitoring.php:"We identified which GHCN stations were rural and which were urban. Then we created global temperature time series from the rural only stations and compared that to our full dataset. The result was that the two showed almost identical time series (actually the rural showed a little bit more warming) so there apparently was no lingering urban heat island bias in the adjusted GHCN dataset."
5. From http://commons.wikimedia.org/wiki/File:Annual_Average_Temperature_Map.jpg, temperature changes by -1 ^oC per 145km northward, and 1 degree of latitude is 111km.
6. http://en.wikipedia.org/wiki/Lapse_rate
7. "Atmosphere, Ocean, and Climate Dynamics", Marshall and Plumb, Elsevier, 2008 (ISBN 13:978-0-12-338691-7), Ch. 12).
8. http://www.nodc.noaa.gov/dsdt/cwtg/natl.html
9. Shearman and Lentz, J. Phys. Oceanography 40, 1004 (2010); http://www.whoi.edu/fileserver.do?id=79624&pt=10&p=52174