# Contiguous U. S. Temperature Trends Using NCDC Raw and Adjusted Data for One-Per-State Rural and Urban Station Sets

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## Introduction

The Goddard Institute for Space science (GISS), the National Climatic Data Center (NCDC), and centers processing satellite data, such as the University of Alabama at Huntsville (UAH), have published temperature and rate of temperature change for the Contiguous United States, or ‘Lower 48’. A summary of the rate of temperature change reported by GISS (Ref 1) and NCDC (Ref 2) are provided in Table I. UAH’s data began in 1979.

**Table I – Rate of temperature Change for the Contiguous 48**

| | Temperature Change/Century | |
|---|---|---|
| | °C | °F |
| **Contiguous 48, GISS (Ref 1)** | 0.55 | 0.95 |
| **Contiguous 48, NCDC (Ref 2)** | 0.69 | 1.25 |

Both GISS and NCDC have been criticized for their station selections and the protocols they use for adjusting raw data, (Ref 3 - 5). GISS, over a 10-year period has modified their data by progressively lowering temperature values for far-back dates and raising those in the more recent past (Ref 3). These changes have caused their 2000 reporting of a 0.35 °C/century in 2000 to increase to 0.44 °C/century in 2009, a 26-percent increase. NCDC’s protocols for adjusting raw data for missing dates, use of urban locations, relocations, etc. has led to an increase in the rate of temperature change for the Contiguous U. S., for the period from 1940 to 2007, from a 0.1 °C/century for the raw data to a 0.6 °C/century, for the adjusted data (Ref 4). Whether or not these changes are intentional, or the consequence of a questionable protocol, has been and continues to be, discussed. This paper does not intend to add to the speculation of which but rather to determine the rate of change for the Contiguous U.S. from the two NCDC data sets, raw and adjusted, from meteorological stations, based on a rural and an urban stations locations, and comment on the result.

## Grid LayOut of the United States and Station Selection Criteria

One criteria common to most station selections or sampling is to use a 5-deg latitudinal x 5-deg longitudinal grid. NCDC’s (NOAA) for the Contiguous U. S. is shown in Figure 1 (Ref 6), although NCDC concludes a 2.5-deg x 3.5-deg grid is preferable in terms of station density average and that all interior grid boxes have more than one station. The 2.5-deg by 3.5 deg grid box is shown in Figure 2.

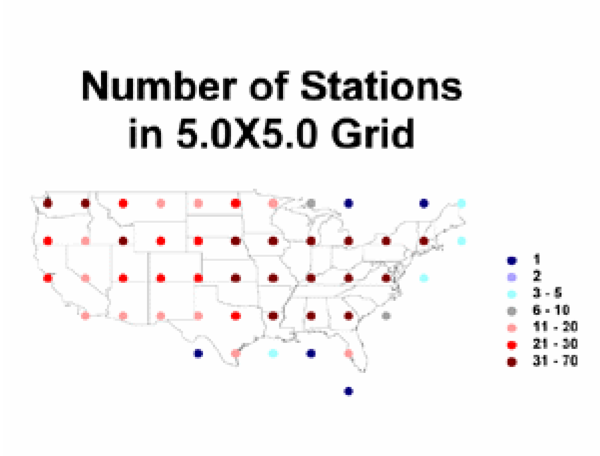


**Figure 1 – NCDC contiguous 48 grid 5-deg x 5-degdivision and station population for each grid box**

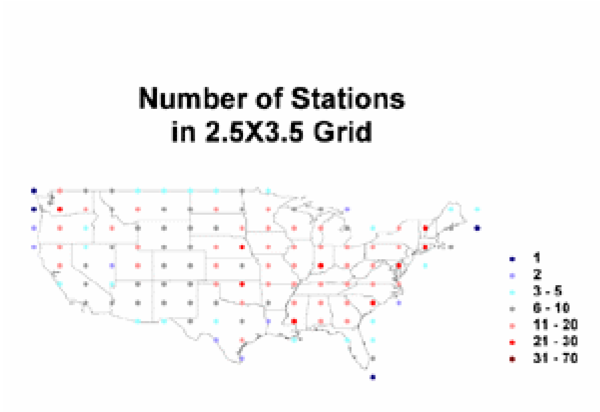


**Figure 2 – NCDC contiguous 48 grid 2.5-deg x 3.5-degdivision and station population for each grid box**

Ref 6 states the assumption '… stations in the same latitude bands tend to share a more similar climate." Another assumption is that "…averaging station anomalies within regions of similar size (grid boxes) and then calculating the average of all the grid box averages, a more representative region-wide anomaly can be calculated. This makes grid box averaging superior to simply taking the average of all stations in the domain." While these assumptions in themselves can be argued to be reasonable, the problem would seem to be the methodologies engendered in treatment for a mix of urban and rural locations. Ref 4 suggests that the 'adjustment' protocol appears to accent to a warming effect rather than eliminate it. This, if correct, leaves serious doubt for whether the rate of increase in temperature found from the adjusted data is due to natural warming trends or warming because of another reason, such as erroneous consideration of the effects of urban warming.

Figure 3 is an alternate view of a 5-deg by 5-deg grid division of the Contiguous U. S. The state boundaries are included and suggest, with the exception of the North Eastern portion, an alternate approach would be to select an equal number of stations per State.

To make such an approach simple we elected to select one station per State. Two sets of 48 stations have been chosen from a posted list of the stations employed by the NCDC, Ref 7. The first set consists of stations with 'rural' locations. In the context of this paper, 'rural' means a station whose location is with no more than one dwelling in its vicinity or at the outer boundary of a small community whose population does not exceed a small multiple of a thousand residents. The second set consists of stations with 'urban' locations. In the context of this paper, 'urban' means a station at the site of a sizeable airport, an industrial area within a city, or near the center of a well-populated city with industrial activity. The number 48 is about half in number of the 114 stations anticipated for NOAA-NCDC's U. S. Climate Reference Network (USCRN) (Ref 8) , which is a network apart from those now used by NCDC and GISS and whose installations began after 1999. Thus the statistics according to the number of sampled stations should similar. The two sets of stations, rural and urban, are provided in Tables II and III respectively.

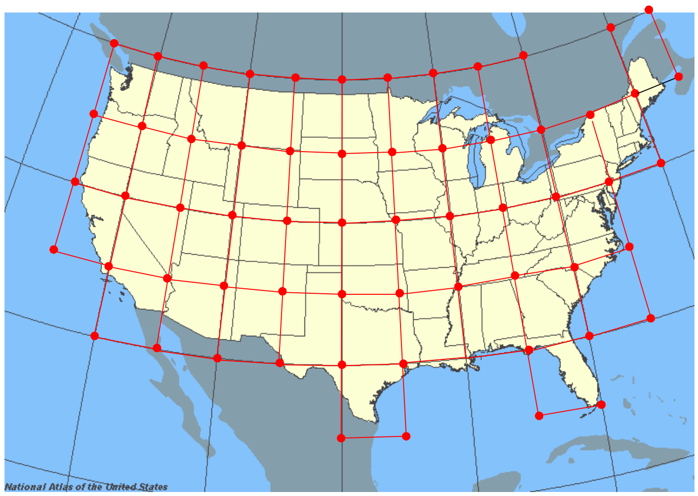


**Figure 3 – A 5-deg grid overlay of Contiguous 48 map, including State boundaries**

No knowledge is assumed regarding the conditions at the station sites, such as those made recently for classifying the actual conditions of existing stations, Ref 9. Also, no consideration was given for the duration of service. Even so, with few exceptions, the beginning dates were in the late 1890's and the stations are, for the most part, still in service.

For each set, rates of temperature increase were determined for both the raw and adjusted data. An argument can be made that since the raw data set has some missing years, for most of the stations, and since the missing years are not coupled from one station to another, nor did all of the stations begin in 1895 and continue through 2008, the period of this study, the set is not adequate. But an equally good argument can be made that adjusted set of data is no more valid. The adjusted set is based on 'filling-in-of-missing-values' of one station set using the data of another station that is at a near-by distance.

**Table II – Station set 1, rural locations**

| Station Number | Latitude | Longitude | Elevation | State | Name |
|---|---|---|---|---|---|
| 13816 | 31.87 | -86.2542 | 132 | AL | HIGHLAND HOME |
| 21248 | 36.1533 | -109.5394 | 1709.9 | AZ | CANYON DE CHELLY |
| 35512 | 35.5125 | -93.8683 | 253 | AR | OZARK 2 |
| 49855 | 37.75 | -119.5897 | 1224.7 | CA | YOSEMITE PARK HQ |
| 58204 | 37.9492 | -107.8733 | 2643.2 | CO | TELLURIDE 4WNW |
| 62658 | 41.95 | -73.3667 | 167.6 | CT | FALLS VILLAGE |
| 73595 | 38.8161 | -75.5761 | 13.7 | DE | GREENWOOD 2NE |
| 85275 | 30.4517 | -83.4119 | 36.6 | FL | MADISON |
| 90586 | 30.8228 | -84.6175 | 57.9 | GA | BAINBRIDGE INTL PAPER |
| 103143 | 46.0931 | -115.5356 | 475.5 | ID | FENN RS |
| 110187 | 37.4814 | -89.2344 | 195.1 | IL | ANNA 2 NNE |
| 120676 | 40.6683 | -84.9305 | 265.2 | IN | BERNE WWTP |
| 130112 | 41.0656 | -92.7867 | 268.2 | IA | ALBIA 3 NNE |
| 143527 | 38.8586 | -99.3358 | 612.6 | KS | HAYS 1 S |
| 150381 | 36.8825 | -83.8819 | 301.8 | KY | BARBOURVILLE |
| 160205 | 30.7094 | -90.525 | 51.8 | LA | AMITE |
| 170100 | 44.3739 | -68.2592 | 143.3 | ME | ACADIA NP |
| 182523 | 38.8833 | -75.8 | 14.9 | MD | DENTON 2 E |
| 190535 | 42.4833 | -71.2833 | 48.8 | MA | BEDFORD |
| 201439 | 46.5192 | -87.9858 | 487.4 | MI | CHAMPION VAN RIPER PK |
| 211630 | 46.7047 | -92.5253 | 385.6 | MN | CLOQUET |
| 221094 | 31.5447 | -90.4581 | 132.6 | MS | BROOKHAVEN CITY |
| 230856 | 39.3447 | -91.1711 | 270.4 | MO | BOWLING GREEN 1 E |
| 241552 | 47.2194 | -111.71 | 1024.1 | MT | CASCADE 5 S |
| 253715 | 42.5119 | -102.6944 | 1159.8 | NE | HAY SPRINGS 12 S |
| 264950 | 39.4136 | -114.7733 | 1911.1 | NV | MCGILL |
| 272999 | 45.0875 | -71.2872 | 506 | NH | FIRST CONNECTICUT LAKE |
| 281582 | 41.0347 | -74.4233 | 231.6 | NJ | CHARLOTTEBURG RSVR |
| 294369 | 35.7783 | -106.6872 | 1908.7 | NM | JEMEZ SPRINGS |
| 300183 | 42.3017 | -77.9889 | 440.4 | NY | ANGELICA |
| 314055 | 35.0536 | -83.1892 | 1170.4 | NC | HIGHLANDS |
| 323287 | 46.1581 | -98.4 | 437.4 | ND | FULLERTON 1 ESE |
| 331541 | 41.0517 | -81.9361 | 359.7 | OH | CHIPPEWA LAKE |
| 340179 | 34.5903 | -99.3344 | 420.6 | OK | ALTUS IRIG RSCH STN |
| 351897 | 43.7917 | -123.0275 | 181.4 | OR | COTTAGE GROVE 1 NNE |
| 362537 | 39.805 | -77.2292 | 164.6 | PA | EISENHOWER NHS |
| 374266 | 41.4906 | -71.5414 | 34.7 | RI | KINGSTON |
| 381588 | 34.7319 | -79.8833 | 42.7 | SC | CHERAW |
| 390043 | 43.4892 | -99.0631 | 512.1 | SD | ACADEMY 2NE |
| 405187 | 35.4139 | -86.8086 | 239.9 | TN | LEWISBURG EXP STN |
| 410639 | 28.4575 | -97.7061 | 77.7 | TX | BEEVILLE 5 NE |
| 420086 | 37.4403 | -112.4819 | 2145.8 | UT | ALTON |
| 431360 | 43.9833 | -72.45 | 243.8 | VT | CHELSEA |
| 449263 | 38.9036 | -78.485 | 205.7 | VA | WOODSTOCK 2 NE |
| 454764 | 46.7492 | -121.812 | 841.9 | WA | LONGMIRE RAINIER NPS |
| 468384 | 38.8008 | -81.3619 | 287.4 | WV | SPENCER |
| 475932 | 44.3589 | -88.7189 | 243.8 | WI | NEW LONDON |
| 487388 | 44.7764 | -108.7592 | 1332 | WY | POWELL FLD STN |

**Table III – Station set 2, urban locations**

| Station Number | Latitude | Longitude | Elevation | State | Name |
|---|---|---|---|---|---|
| 18024 | 33.4164 | -86.135 | 136.6 | AL | TALLADEGA |
| 28815 | 32.2292 | -110.9536 | 742.2 | AZ | TUCSON WFO |
| 35754 | 34.2256 | -92.0189 | 65.5 | AR | PINE BLUFF |
| 46719 | 34.1483 | -118.1447 | 263.3 | CA | PASADENA |
| 55722 | 38.4858 | -107.8792 | 1764.5 | CO | MONTROSE #2 |
| 63207 | 41.3506 | -72.0394 | 12.2 | CT | GROTON |
| 76410 | 39.6694 | -75.7514 | 27.4 | DE | NEWARK UNIV FARM |
| 86997 | 30.4781 | -87.1869 | 34.1 | FL | PENSACOLA RGNL AP |
| 97847 | 32.13 | -81.21 | 14 | GA | SAVANNAH INTL AP |
| 104670 | 42.7325 | -114.5192 | 1140 | ID | JEROME |
| 110338 | 41.7806 | -88.3092 | 201.2 | IL | AURORA |
| 126001 | 37.9286 | -87.8956 | 108.8 | IN | MT VERNON |
| 131402 | 43.0775 | -92.6714 | 309.1 | IA | CHARLES CITY |
| 144588 | 39.3256 | -94.9189 | 265.2 | KS | LEAVENWORTH |
| 150909 | 36.9647 | -86.4239 | 160.9 | KY | BOWLING GREEN RGNL AP |
| 160549 | 30.5372 | -91.1469 | 19.5 | LA | BATON ROUGE METRO AP |
| 172426 | 44.9067 | -66.9919 | 25.9 | ME | EASTPORT |
| 185718 | 39.2811 | -76.61 | 6.1 | MD | MD SCI CTR BALTIMORE |
| 195246 | 41.6333 | -70.9333 | 21.3 | MA | NEW BEDFORD |
| 205650 | 42.6083 | -82.8183 | 176.8 | MI | MT CLEMENS ANG BASE |
| 215435 | 44.8831 | -93.2289 | 265.8 | MN | MINNEAPOLIS/ST PAUL AP |
| 221865 | 31.2503 | -89.8361 | 45.7 | MS | COLUMBIA |
| 234271 | 38.585 | -92.1825 | 204.2 | MO | JEFFERSON CITY WTP |
| 247286 | 47.315 | -114.0983 | 883.9 | MT | SAINT IGNATIUS |
| 250622 | 40.2994 | -96.75 | 395.3 | NE | BEATRICE 1N |
| 266779 | 39.4839 | -119.7711 | 1344.2 | NV | RENO AP |
| 273850 | 43.7031 | -72.2847 | 183.8 | NH | HANOVER |
| 280325 | 39.3792 | -74.4242 | 3 | NJ | ATLANTIC CITY |
| 297610 | 33.3075 | -104.5083 | 1112.2 | NM | ROSWELL IND AP |
| 301012 | 42.9408 | -78.7358 | 214.9 | NY | BUFFALO NIAGARA INTL |
| 317615 | 35.6836 | -80.4822 | 213.4 | NC | SALISBURY |
| 323207 | 46.05 | -100.6667 | 510.5 | ND | FT YATES 4 SW |
| 338534 | 40.8333 | -83.2833 | 260.3 | OH | UPPER SANDUSKY |
| 344204 | 34.9894 | -99.0525 | 474.3 | OK | HOBART MUNI AP |
| 350328 | 46.1569 | -123.8825 | 2.7 | OR | ASTORIA AP PORT OF |
| 368449 | 40.7933 | -77.8672 | 356.6 | PA | STATE COLLEGE |
| 376698 | 41.7219 | -71.4325 | 15.5 | RI | PROVIDENCE WSO AP |
| 381944 | 33.9831 | -81.0167 | 73.8 | SC | COLUMBIA UNIV OF SC |
| 398932 | 44.9047 | -97.1494 | 532.8 | SD | WATERTOWN RGNL AP |
| 401790 | 36.5467 | -87.3567 | 116.4 | TN | CLARKSVILLE WWTP |
| 412015 | 27.7742 | -97.5122 | 13.4 | TX | CORPUS CHRISTI AP |
| 425826 | 41.0428 | -111.6722 | 1551.4 | UT | MORGAN POWER & LIGHT |
| 431081 | 44.4681 | -73.1503 | 100.6 | VT | BURLINGTON WSO AP |
| 446139 | 36.9033 | -76.1922 | 9.1 | VA | NORFOLK INTL AP |
| 457458 | 47.65 | -122.3 | 5.8 | WA | SEATTLE URBAN SITE |
| 465707 | 39.4019 | -77.9844 | 162.8 | WV | MARTINSBURG E WV RGNL |
| 475474 | 43.0719 | -88.0294 | 221.3 | WI | MILWAUKEE MT MARY COL |
| 487845 | 41.5942 | -109.0653 | 2055 | WY | ROCK SPRINGS AP |

This is based on the assumption that within a certain latitude band stations along an East-West line experience the same climate and that within a grid unit the set of stations are somehow related in a manner that their temperature characteristics are interchangeable to an extent understood from averaging and distribution within the grid and/or latitude. There are examples of stations within a small geographical distribution that refute this assumption. Thus the adjusted set is, on the whole no better than the raw set. Furthermore, as will be seen in the discussion of the data, the raw set has characteristics that argue it to be as valid, if not more so, than the adjusted set, especially in that it suffers no human bias.

## Results and Discussion

Raw NCDC Data –

Figure 4 is a plot of the annual average and 11-year average temperature anomalies for the rural station set's raw data. The reference period is inclusive for the interval 1961 - 1990, that used by the NCDC. Figure 5 is a like plot for the urban set. The slopes of the linear regression fits are 0.13 and 0.79 $^{o}$C/century for the respective sets

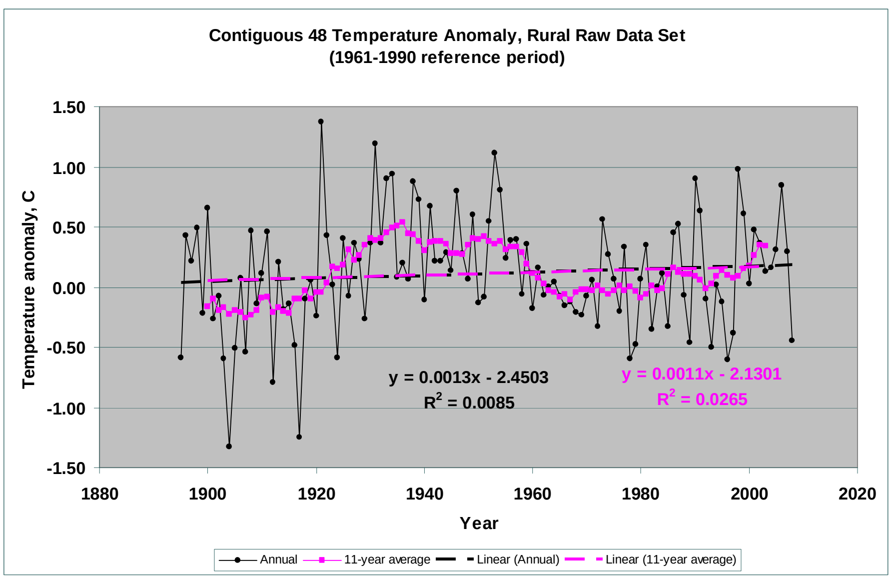


**Figure 4 – Annual and 11-year average temperature anomaly for rural raw data set for the contiguous 48 States**

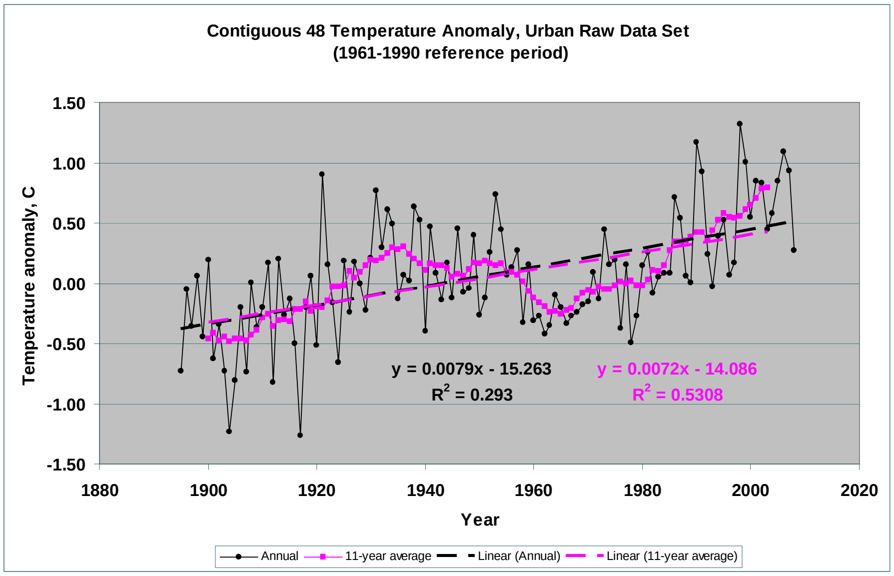


**Figure 5 – Annual and 11-year average temperature anomaly for urban raw data set for the contiguous 48 States**

A logical question presents itself from the onset: 'Are these two sets of raw data reasonable representations of the time span?' The answer is 'yes', based on several observations:

- The raw data is that measured at the time, so, simply stated, those were the temperatures.
- The two sets year-to-year trends are strikingly similar with those for the rural being larger. This is what might be thought of an urban dampening effect on the rural excursions, a dome created by the urban environment separating the urban environment from the surrounding countryside.
- The long-term trends are similar up to about 1965 (see Figure 6). The divergence of the two sets for later dates is the cause of the overall linear fit's slope being larger for the urban data.

While there may be more than one explanation for the departure of the rural and urban trends in Figure 6, one is the size and location of the Contiguous U. S. population. Figure 7 is the rural and urban populations for the time span. The size and the rate of growth of the urban portion of the population dramatically increased during the 1950-1960 period, and continued at a rate of growth twice that before the period, while the rural population has remained approximately constant, Ref 10. The urban growth was likely due to a combination of the 'baby boom' and the 'migration to the city'.

These considerations support a thesis that the raw data, even though having missing dates, provides an accurate assessment that nature itself warmed little for the period and the 'warming' is a consequence of urban heating.

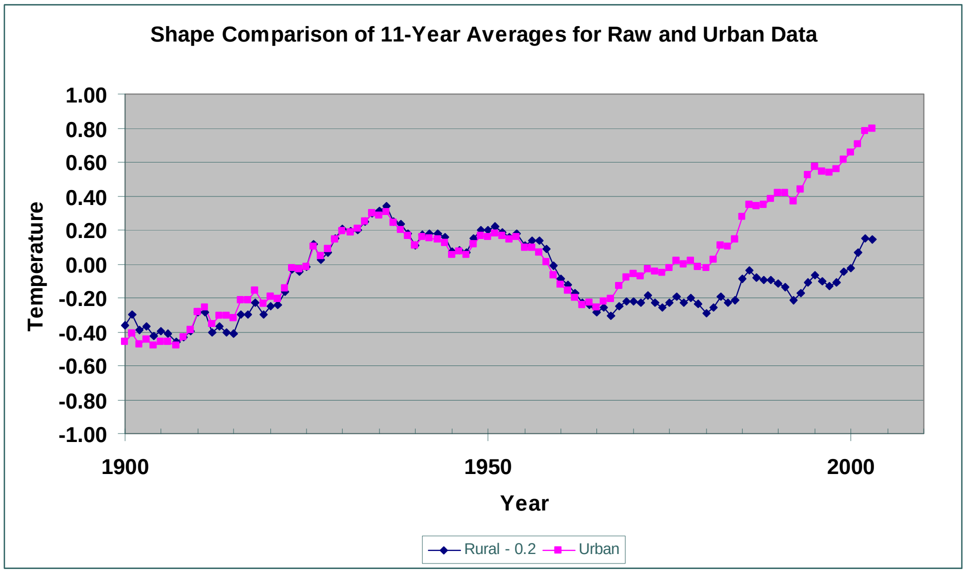


**Figure 6 – Comparison of 11-averages of the raw rural and urban temperatures. The rural data is offset by a factor of '-0.2', due to the smaller value of its average, compared to that for the urban, for the 1961-1990 period.**

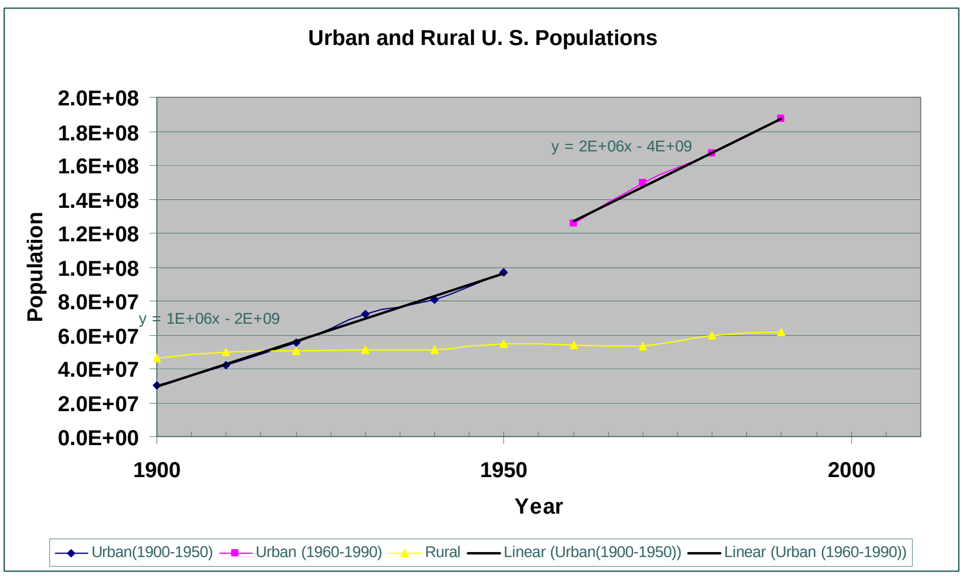


**Figure 7 – Urban and rural U.S. populations. The urban is divided into two groups in order to determine the first-order fits for the two periods.**

Adjusted NCDC Data –

Figure 8 is a plot of the annual average and 11-year average temperature anomalies for the rural station set's adjusted data, for the Contiguous U. S. The reference period is inclusive for the interval 1961 - 1990, that used by the NCDC. The linear regression fits are 0.64 and 0.77 $^{o}$C/century for the respective sets

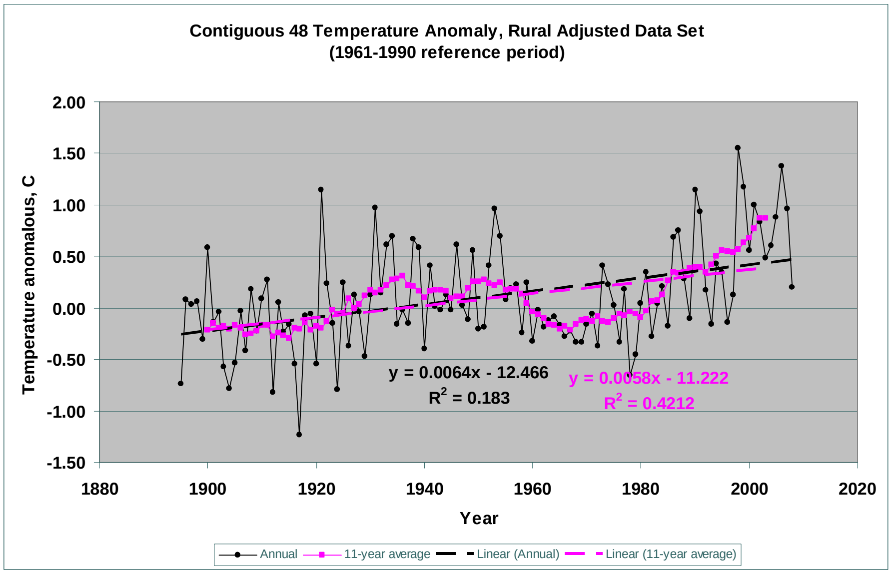


**Figure 8 – Annual and 11-year average temperature anomaly for rural adjusted data set for the contiguous 48 States**

Thus, the adjustments to the data have increased the rural rate of increase by a factor of 5 and slightly decreased the urban rate. NCDC provides a description of its protocols, Ref 11. The NCDC states, "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." No doubt this is the case as can be observed from Figures 8 and 9. But, this is after they 'adjusted' the raw data for rural and urban environments which, as would be expected, were different. So the 'adjustments' eradicated the difference and hid urban heating. The consequence is the five-fold increase in the rural temperature rate of increase and a slight decrease in the rate of increase of the urban temperature. Indeed as the NCDC stated, and is shown in Figure 10, there is little difference in the adjusted rural and urban trends. But, what is striking is the magnitude of the changes that had to be made to the raw rural data in order to arrive at its adjusted values. This is shown in Figure 11.

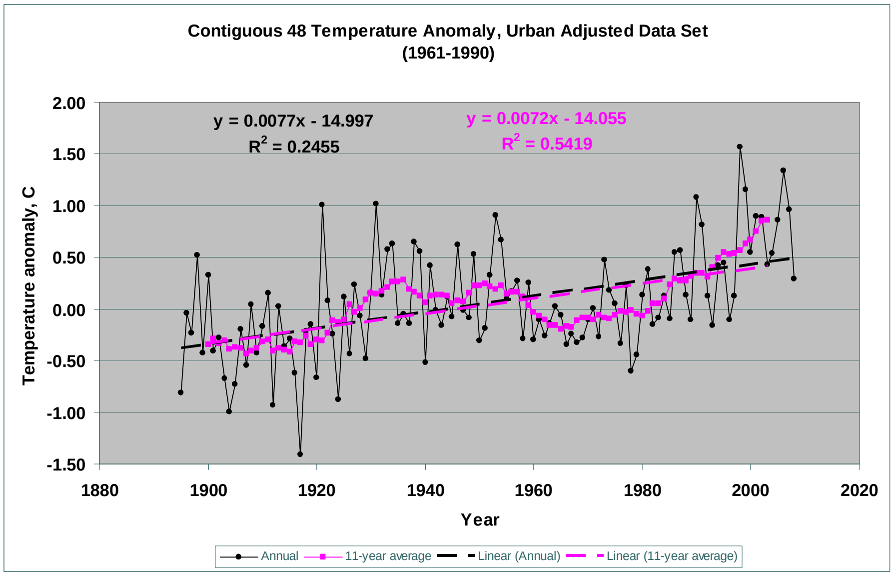


**Figure 9 - Annual and 11-year average temperature anomaly for urban adjusted data set for the contiguous 48 States**

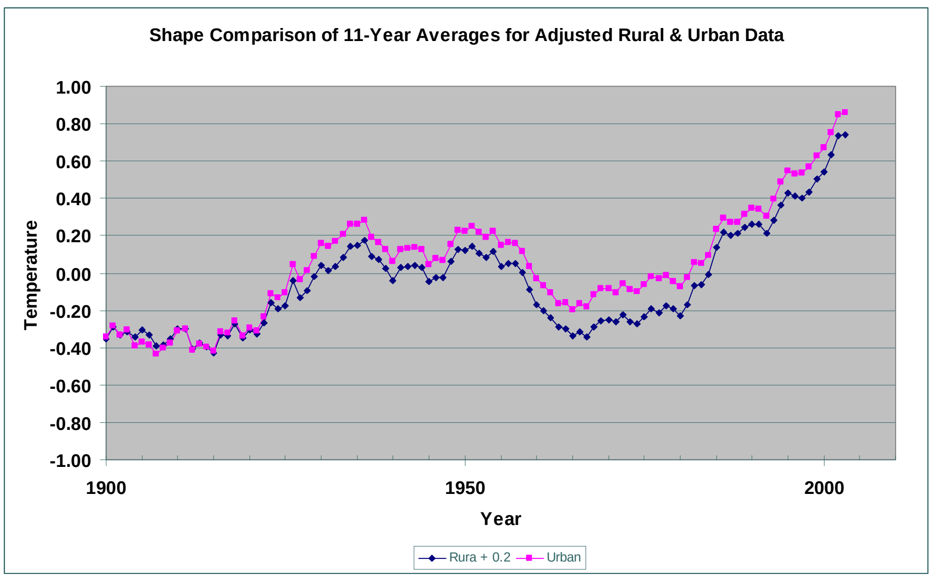


**Figure 10 – Comparison of 11-averages of the adjusted rural and urban temperatures. The rural data is offset by a factor of '+ 0.2', due to the larger value of its average, compared to that for the urban, for the 1961-1990 period.**

The content in Figure 11 was determined as follows: In the raw data station sets, rural and urban, most all of the individual stations have years, one or more, for which there were no data (blanks) – in this case we are concerned with the raw rural data. These same years were then also to blanks in the adjusted rural data set and this revised adjusted set was averaged for each year. The values in Figure 11 are the differences of these two rural data sets, the raw and the revised adjusted. In other words, these are the results of the NCDC's adjustments of the raw data for which there were values. To state differently, the NCDC has taken liberty to alter the actual rural measured values. Thus the adjusted rural values are a systematic increase from the raw values, more and more back into time and a decrease for the more current years. At the same time the urban temperatures were little, or not, adjusted from their raw values. The results is an implication of warming that has not occurred in nature, but indeed has occurred in urban surroundings as people gathered more into cities and cities grew in size and became more industrial nature. So, in recognizing this aspect, one has to say there has been warming due to man, but it is an urban warming. The temperatures due to nature itself, at least within the Contiguous U. S., have increased at a non-significant rate and do not appear to have any correspondence to the presence or lack of presence of carbon dioxide.

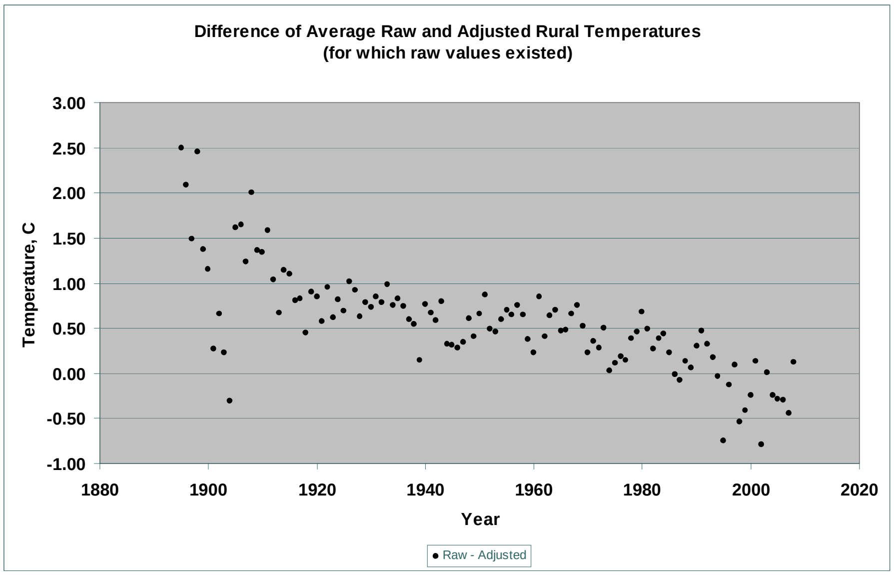


**Figure 11 – Differences of rural raw and adjusted average data for raw values existed.**

## Summary

Both raw and adjusted data from the NCDC has been examined for a selected Contiguous U. S. set of rural and urban stations, 48 each or one per State. The raw data provides 0.13 and 0.79 $^{o}$C/century temperature increase for the rural and urban environments. The adjusted data provides 0.64 and 0.77 $^{o}$C/century respectively. The rates for the raw data appear to correspond to the historical change of rural and urban U. S. populations and indicate warming is due to urban warming. Comparison of the adjusted data for the rural set shows a systematic treatment that causes the rural set's temperature rate of increase to be 5-fold more than that of the raw data. The adjusted urban data set's and raw urban data set's rates of temperature increase are the same. This suggests the consequence of the NCDC's protocol for adjusting the data is to cause historical data to take on the time-line characteristics of urban data. The consequence intended or not, is to report a false rate of temperature increase for the Contiguous U. S.

## References

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