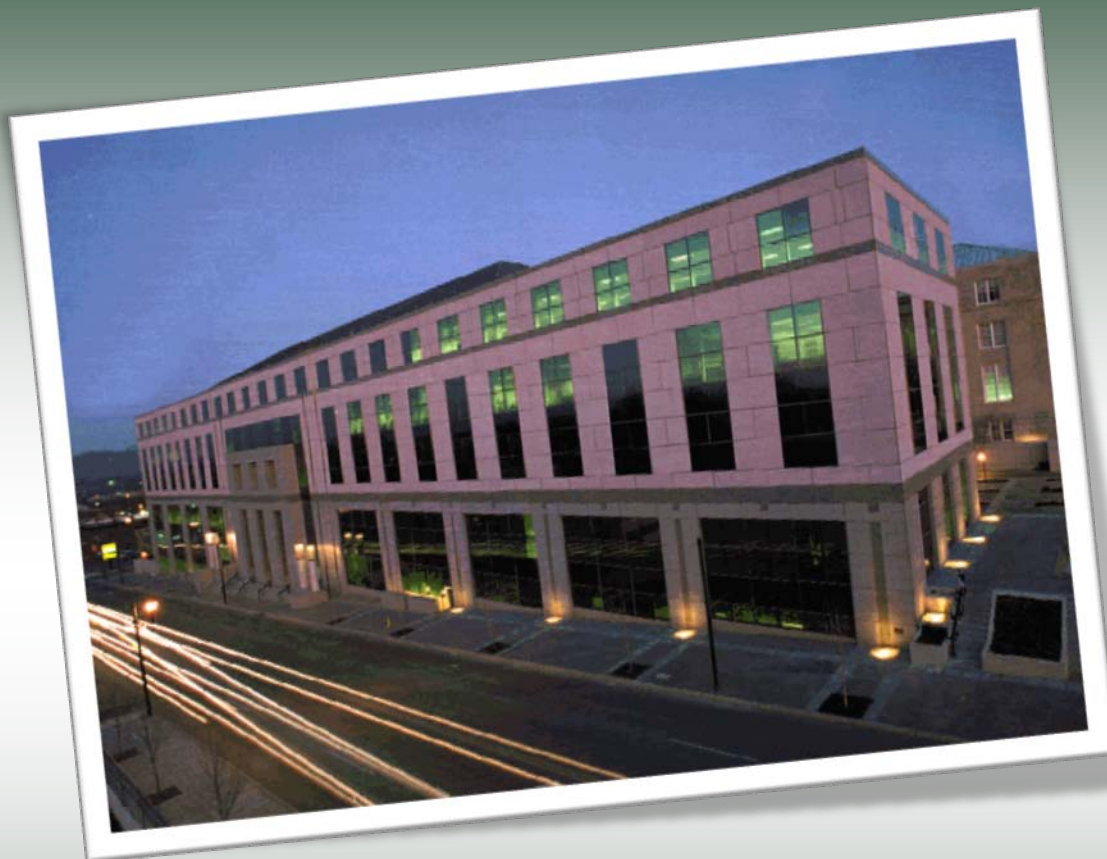


# CONTIGUOUS U. S. TEMPERATURE TRENDS USING NCDC RAW AND ADJUSTED DATA FOR ONE-PER-STATE RURAL AND URBAN STATION SETS

*by Edward R. Long, Ph.D.*



SPPI ORIGINAL PAPER



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# TABLE OF CONTENTS

<b>INTRODUCTION .....</b>	<b>3</b>
Table I – Rate of Temperature Change for the Contiguous 48.....	3
 <b>GRID LAYOUT OF THE UNITED STATES AND STATION SELECTION CRITERIA.....</b>	<b>3</b>
Figure 1 – NCDC contiguous 48 grid 5-deg x 5-deg division and station population for each grid box. ....	4
Figure 2 – NCDC contiguous 48 grid 2.5-deg x 3.5-deg division and station population for each grid box. ....	4
Figure 3 – A 5-deg grid overlay of Contiguous 48 map, including State boundaries. ....	5
Table II – Station Set 1, Rural Locations .....	6
Table III – Station Set 2, Urban Locations.....	7
 <b>RESULTS AND DISCUSSION .....</b>	<b>8</b>
<b>Raw NCDC Data .....</b>	<b>8</b>
Figure 4 – Annual and 11-year average temperature anomaly for rural raw data set for the contiguous 48 States. ....	8
Figure 5 – Annual and 11-year average temperature anomaly for urban raw data set for the contiguous 48 States.....	9
Figure 6 – Comparison of 11-averages of the raw rural and urban temperatures. ....	10
Figure 7 – Urban and rural U.S. populations.....	10
<b>Adjusted NCDC Data.....</b>	<b>11</b>
Figure 8 – Annual and 11-year average temperature anomaly for rural adjusted data set for the contiguous 48 States. ....	11
Figure 9 – Annual and 11-year average temperature anomaly for urban adjusted data set for the contiguous 48 States. ....	12
Figure 10 – Comparison of 11-averages of the adjusted rural and urban temperatures. ....	12
Figure 11 – Differences of rural raw and adjusted average data for raw values existed.....	13
 <b>SUMMARY.....</b>	<b>13</b>
 <b>REFERENCES.....</b>	<b>14</b>

# 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**

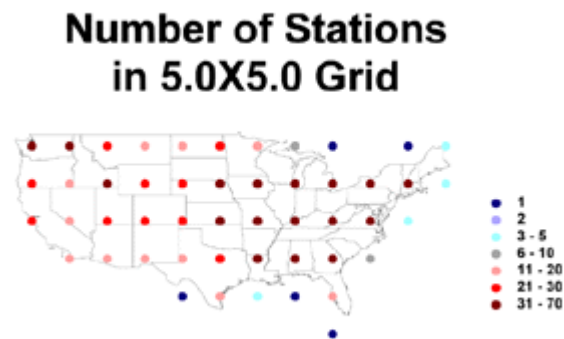
	Temperature Change/Century	
	°C	°F
<b>Contiguous 48, GISS (Ref 1)</b>	0.55	0.95
<b>Contiguous 48, NCDC (Ref 2)</b>	0.69	1.25

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.

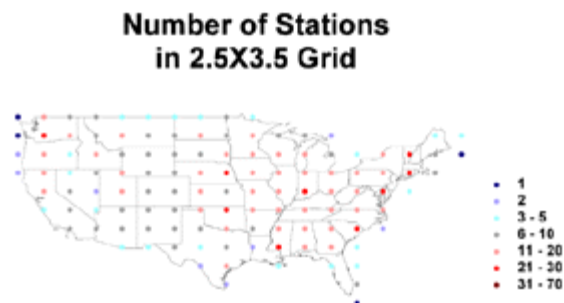
## GRID LAYOUT OF THE UNITED STATES AND STATION SELECTION CRITERIA

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-deg division and station population for each grid box.**

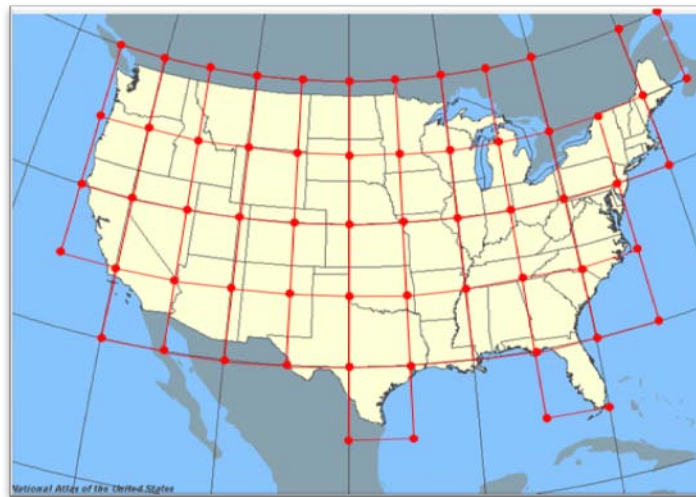


**Figure 2 – NCDC contiguous 48 grid 2.5-deg x 3.5-deg division and station population for each grid box.**

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 be 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**

<b>Station Number</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Elevation</b>	<b>State</b>	<b>Name</b>
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

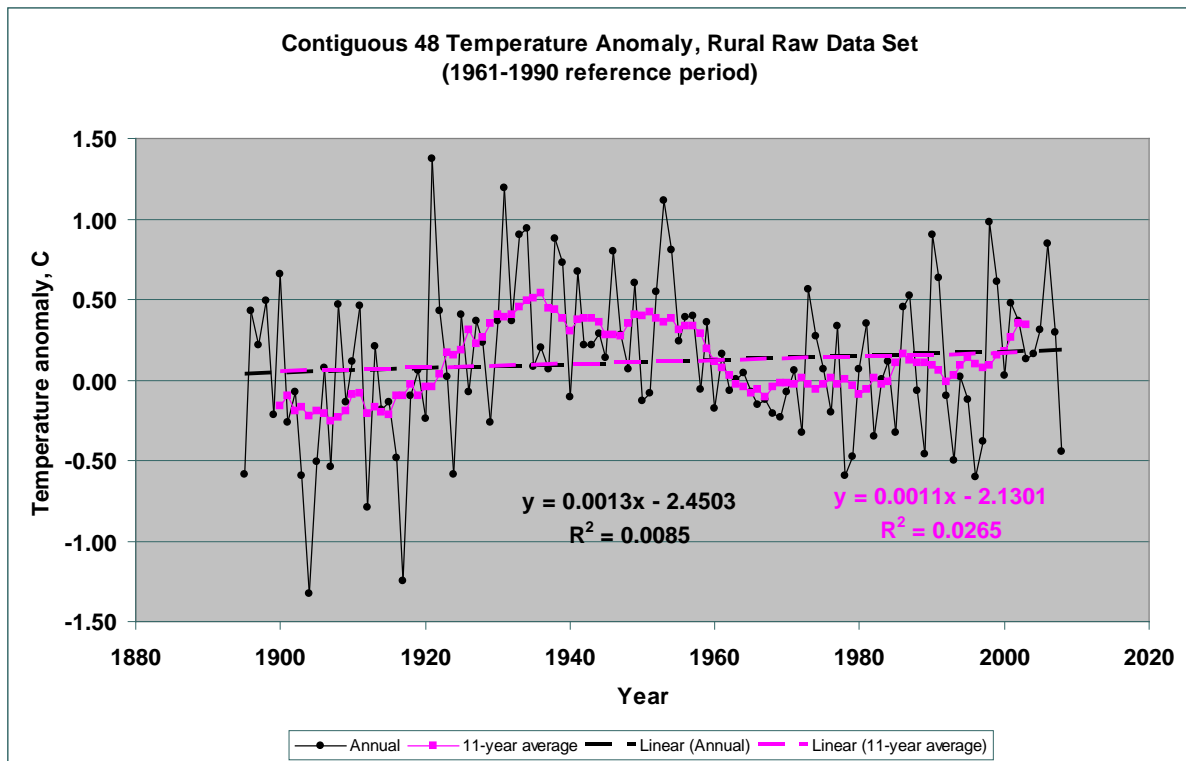


This is based on the assumption that within a certain latitude band stations along an East-West line experience the same climate and that within a grid unit the set of stations are somehow related in a manner that their temperature characteristics are interchangeable to an extent understood from averaging 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

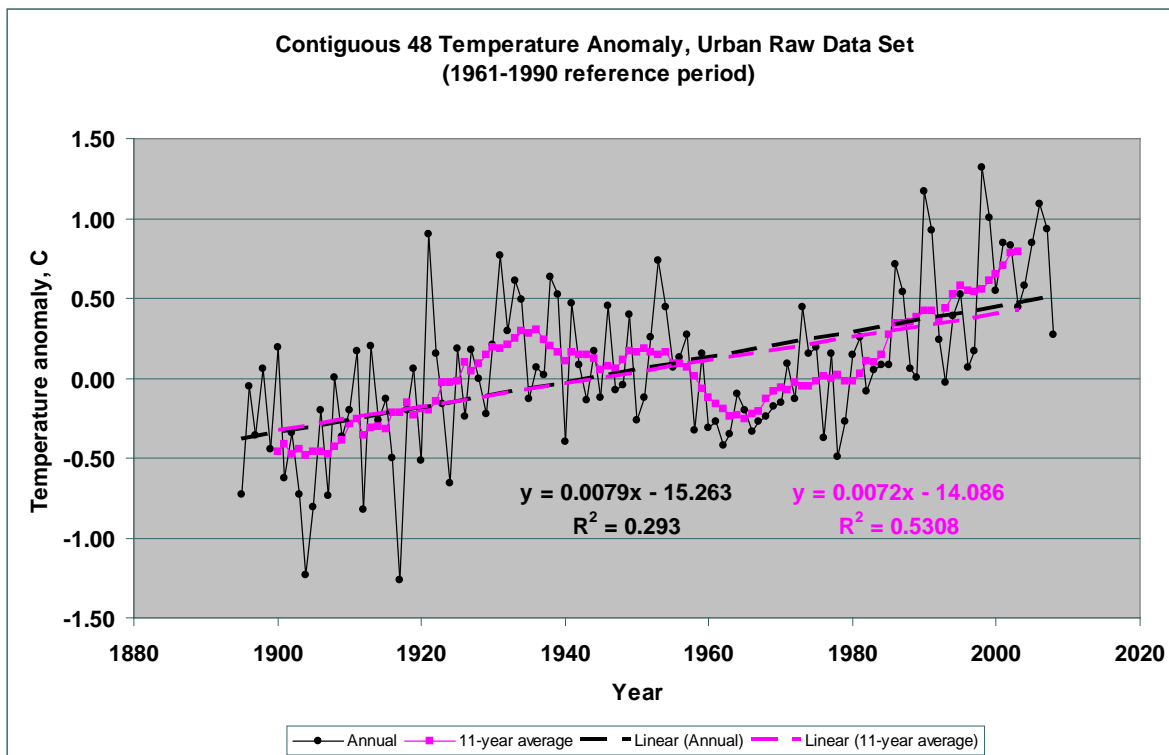
### Raw NCDC Data –

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 °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.**





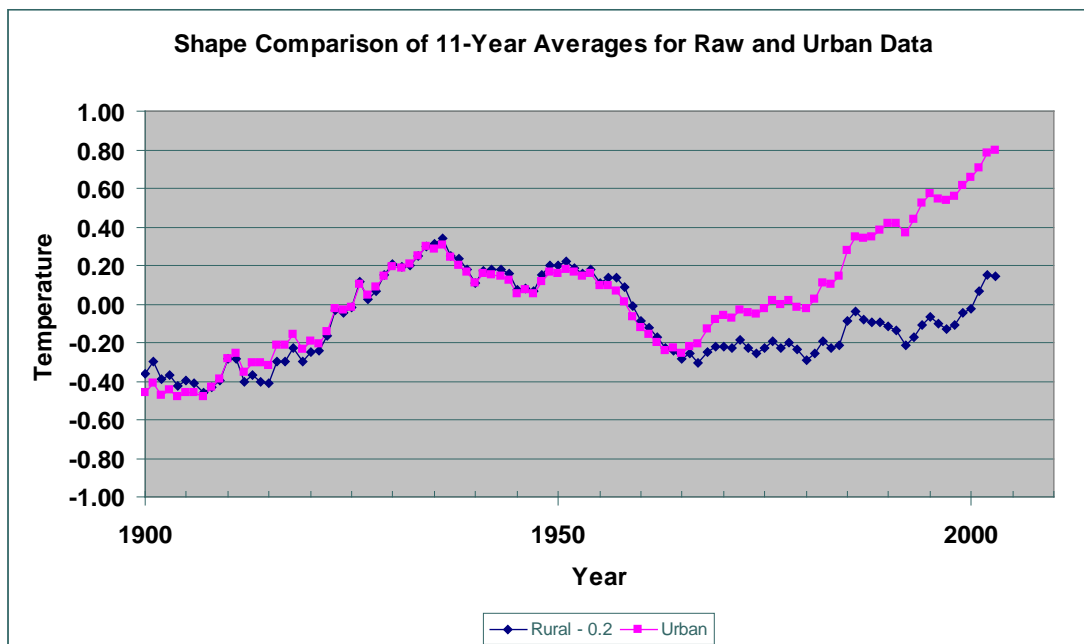
**Figure 5 – Annual and 11-year average temperature anomaly for urban raw data set for the contiguous 48 States.**

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:

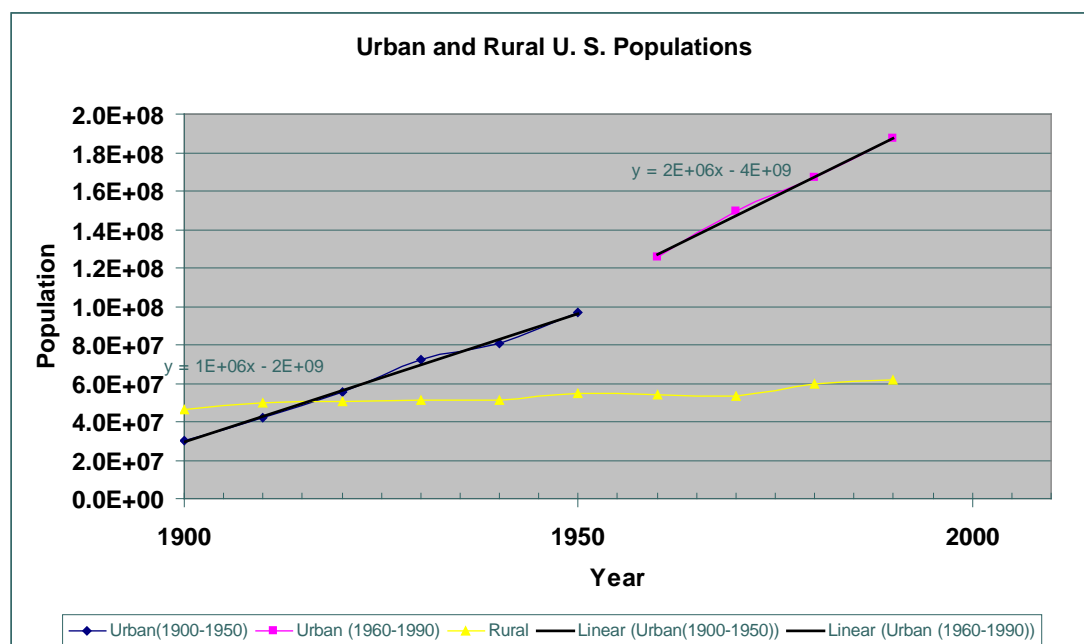
- The raw data is that measured at the time, so, simply stated, those were the temperatures.
- The two sets' year-to-year trends are strikingly similar with those for the rural being larger. This is what might be thought of an urban dampening effect on the rural excursions, a dome created by the urban 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.**

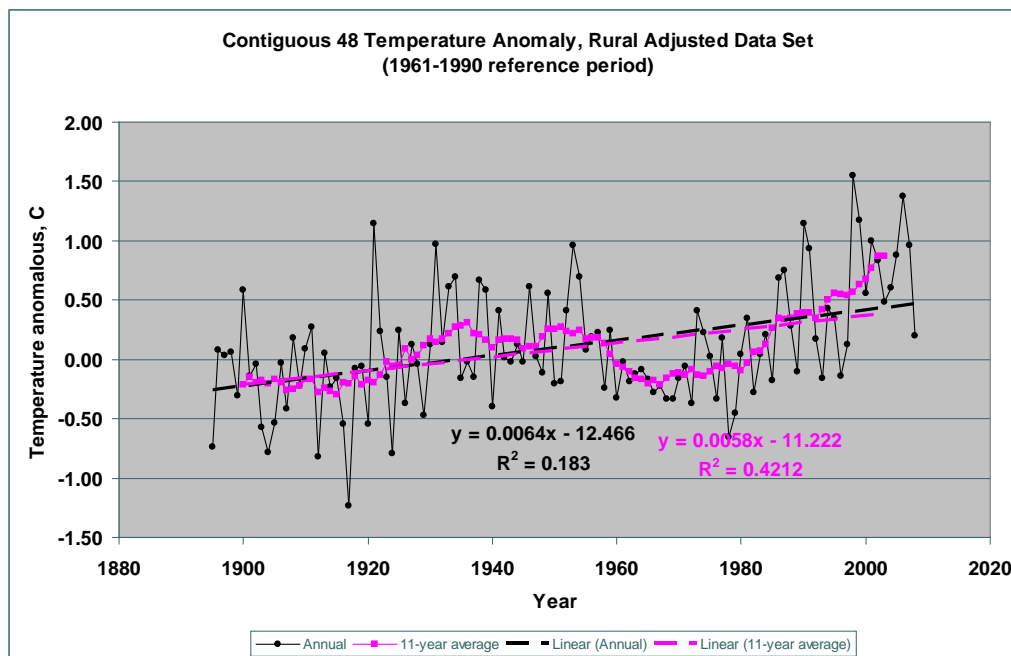


**Figure 7 – Urban and rural U.S. populations. The urban is divided into two groups in order to determine the first-order fits for the two periods.**

## Adjusted NCDC Data –

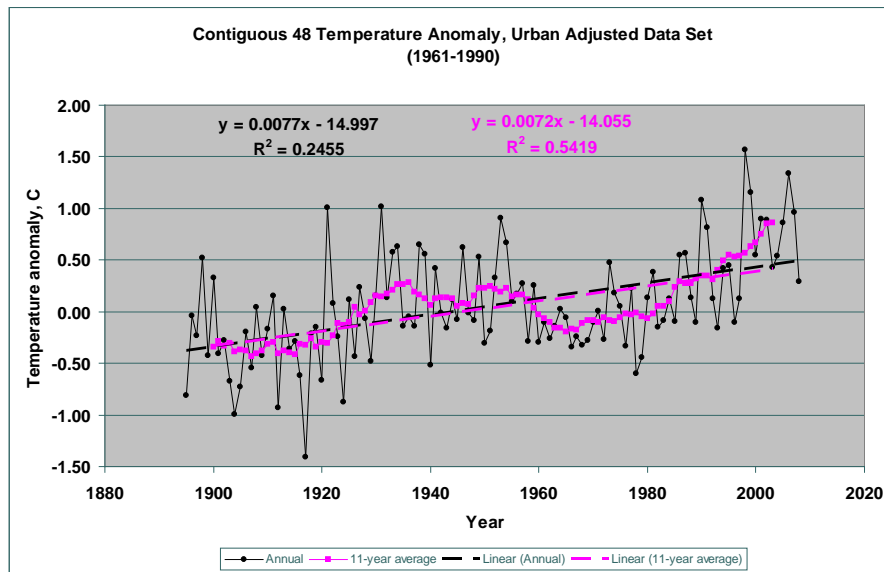
Figure 8 is a plot of the annual average and 11-year average temperature anomalies for the rural station set's adjusted data, for the Contiguous U. S. The reference period is inclusive for the interval 1961 - 1990, that used by the NCDC.

Figure 9 is a similar plot for the urban set's adjusted data. The linear regression fits are 0.64 and 0.77 °C/century for the respective sets.

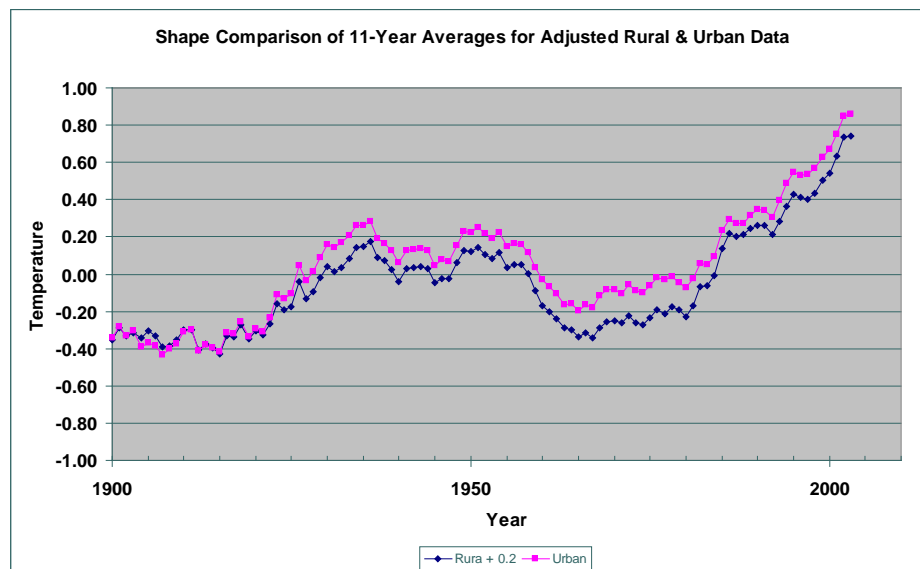


**Figure 8 – Annual and 11-year average temperature anomaly for rural adjusted data set for the contiguous 48 States.**

Thus, the adjustments to the data have increased the rural rate of increase by a factor of 5 and slightly decreased the urban rate, from that of the raw data. 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.



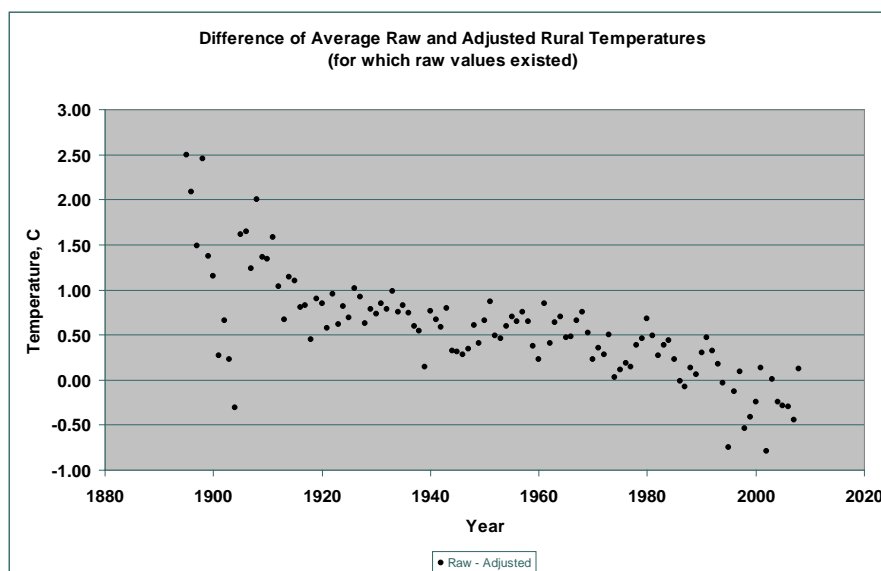
**Figure 9 – Annual and 11-year average temperature anomaly for urban adjusted data set for the contiguous 48 States.**



**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 °C/century temperature increase for the rural and urban environments. The adjusted data provides 0.64 and 0.77 °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 to that of the raw data shows a systematic treatment that causes the rural adjusted 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.

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**Edward R. Long** is a physicist who retired from NASA where he led NASA's Advanced Materials Program, was a team member for the development of several upper atmospheric research satellites, and was responsible for the non-manned portion of a study for the replacement of Shuttle. He currently provides consultant support to both government and the private sector concerning radiation in the space flight environment. He also provides technical consultant support to members of the Commonwealth of Virginia's legislative bodies.

Cover photo of the National Climatic Data Center (NCDC) from [noaa.gov](http://noaa.gov).

