Memorandum submitted by Dr. D.R. Keiller (CRU 23)

Background Information and Introduction

By way of introduction, my name is Dr. Don Keiller, I studied Natural Sciences at Cambridge University, graduating with a 2.1 in 1977. After graduation I continued my studies at Cambridge University and was awarded a PhD in 1981. Since then I have held a variety of teaching and research positions at, Leicester, Sheffield, and Staffordshire Universities and for the last 18 years worked in the Department of Life Sciences at Anglia Ruskin University, where I am Deputy Head of Department. I have published 20 peer-reviewed publications, the most recent four been about the effects of enhanced ultraviolet radiation on plant growth and development. Since concerns were first raised about the environmental effects of the "Ozone Hole", I have taken an active interest in the science of Climate Change and was one of the individuals who used the F.O.I. Act to request data from CRU.

Summary of Main Points.

- National Oceanic and Atmospheric Administration (NOAA)'s National Climatic Data Center (NCDC), NASA's Goddard Institute for Space Studies (GISS) and CRU databases are not independent as they all rely on the same basic ground-station data.
- Instrumental temperature data for the pre-satellite era (1850-1980) have been so widely, systematically and unidirectionally altered that it cannot be credibly asserted what level of "global warming" has occurred in the 20th century.
- All terrestrial surface-temperature databases exhibit very serious problems that render them unfit for determining accurate long-term temperature trends.
- All of the problems have skewed the data to overstate observed warming both regionally and globally.
- Global terrestrial temperature data are compromised because more than three-quarters of the 6,000 stations that once existed are no longer reporting.
- There has been a bias towards removing higher-altitude, higher-latitude and rural stations, leading to a further overstatement of warming.
- Contamination by urbanization, changes in land use, improper siting, and inadequately-calibrated instrument upgrades, further overstates warming.
- Numerous peer-reviewed papers in recent years have shown the overstatement of observed longer term warming is between 30-50% from urban heat-island contamination alone.
- Inappropriate selection of observing sites, combined with interpolation to adjacent stations and vacant data grids, may make heat-island bias greater than 50% of 20th-century warming.
- Satellite temperature monitoring has provided an alternative to terrestrial stations in compiling the global lower-troposphere temperature record. Their findings are increasingly diverging from the ground station-based temperature records in a manner consistent with evidence of a warm bias in the surface temperature record.
- Global terrestrial climate databases are seriously flawed and can no longer be used to assess climate trends, or validate climate model forecasts.

Detailed Submission

(1) It is my understanding that The Science and Technology Committee will be undertaking an inquiry into the unauthorised publication of data, emails and documents relating to the work of the Climatic Research Unit (CRU) at the University of East Anglia (UEA). The Committee has agreed to examine and invite written submissions on three questions:

- What are the implications of the disclosures for the integrity of scientific research?
- Are the terms of reference and scope of the Independent Review announced on 3 December 2009 by UEA adequate?
- How independent are the other two international data sets?

As these questions will require considerable in-depth study to address correctly, I am unconvinced that any single 3000 word submission will prove adequate. Accordingly I refer the readers of this submission to selected papers from the peer-reviewed literature and webpages, where additional backgound information and confirmatory detail can be obtained. There are also a number of figures (Appendix 1, page 7) which help illustrate points made in the text, however the text itself is freestanding.

(2) With regards to the implications of the CRU disclosures for the integrity of scientific research, a detailed timeline and (subjective) commentary of the emails can be found here; http://scienceandpublicpolicy.org/reprint/climategate_analysis.html. What is absolutely clear from these emails is the Professor Jones and colleagues at CRU conspired to obstruct reasonable and legitimate requests for access to scientific data. This charge has been upheld by The Information Commissioner. What these emails reveal is a detailed and systematic conspiracy to prevent other scientists gaining access to CRU datasets. Such obstruction strikes at the very heart of the scientific method, that is the scrutiny and verification of data and results by one's peers. Until all data, adjustment procedures and computer code relating to CRU's temperature records are released to the scientific community, for proper scrutiny and verification, all peer-reviewed publications whose conclusions rely on CRU's temperature records must be withdrawn as "unproven". Similarly all policy decisions based on this data and conclusions drawn from it are also unsafe, until proven otherwise.

(3) Secondly there is the issue of the independence, scientific credibility and integrity of CRU's and other official temperature records. Multiple lines of evidence suggest that the various official temperature records are neither independent, nor credible. Here I draw the reader's attention to the report "Surface Temperature Records: Policy Driven Deception?" by Joseph D'Aleo and Anthony Watts, (2010). Full details are at; http://scienceandpublicpolicy.org/originals/policy_driven_deception.html

Main submission follows:

(4) Divergence between Satellite and Ground-based Temperature Records.

Five organizations publish Global temperature data. Two – Remote Sensing Systems (RSS) and the University of Alabama at Huntsville (UAH) – are satellite measured datasets. The three terrestrial institutions – National Oceanic and Atmospheric Administration (NOAA)'s National Climatic Data Center (NCDC), NASA's Goddard Institute for Space Studies (GISS), and the University of East Anglia's Climatic Research Unit (CRU) – all depend on data supplied by ground stations *via* NOAA. ***Hence the three international terrestrial data sets are not independent.*** When the satellites were first launched, their temperature readings were in good agreement with the surface station data. However over the 30 years of measurement, there has been increasing divergence of satellite data from ground-based stations, which now, on average, measure some 0.2°C warmer than the satellites (Fig. 1, Appendix 1). Such a difference amounts to 0.6°C per century, a figure comparable in magnitude with the total measured warming over the past 100 years. Moreover this divergence does not arise from satellite errors. (Klotzbach, P.J., R.A. Pielke Sr., R.A. Pielke Jr., J.R. Christy, and R.T. McNider, 2009: An alternative explanation for differential temperature trends at the surface and in the lower troposphere. *J. Geophys. Res.*, 114), rather a multitude of technical issues with the ground-based stations, described below.

(5) Vanishing Stations.

Perhaps one of the biggest issues with the global data is the disappearance of temperature monitoring stations from the Global networks after 1990. Whilst more than 6000 stations were active in the mid-1970s, only 1500, or less, are in use today.

Of greater concern is the observation that the stations that were dropped from the monitoring network were mainly rural and/or at higher latitudes and altitudes. This positioning tended to make them "cooler" stations, hence their removal introduced a warming bias, thus making any accurate assessment of overall warming impossible. This is demonstrated in Fig. 2. which shows that the temperature average of all global stations does not fluctuate significantly until 1990, after which the average temperature jumps up at precisely the time as large-scale station drop-out. A study by Willmott et al (Willmott, Robeson and Feddema, 1991 "Influence of Spatially Variable Instrument Networks on Climatic Averages, *Geophysical Research Letters* vol. 18 No. 12, pp2249-2251) calculated a +0.2°C bias in the global average owing to pre-1990 station closures.

(6) Data Adjustments

The leaking of emails from CRU has initiated examinations of the global datasets not only at CRU, NASA, and NOAA, but in various countries throughout the World. Though the Hadley Centre implied their data was in agreement with other datasets and was thus trustworthy, the truth is that until all data is released for verification, this can not be determined. That the datasets are in agreement is not surprising given that they are not trully independent (paragraph 4). Furthermore it is clear that adjustment and manipulation of raw station temperature data is the norm, rather than the exception. Temperature adjustments are often made that are hard to explain but, with one exception (paragraph. 7), invariably increase the apparent warming. Typically a warming trend is artificially introduced to rural stations by adjusting earlier periods to make them appear cooler. Unfortunately without full access to the primary temperature data and all adjustment procedures, the accuracy of these these adjustments is impossible to quantify. An example of such a station dataset adjustment is shown in Fig 3. According to NOAA, adjustments are made for the following reasons:

- Time of Observation (TOBS): The temperature data are adjusted for the time-of-observation bias (Karl, T.R., C.N. Williams, Jr., P.J. Young, and W.M. Wendland, 1986: A model to estimate the time of observation bias associated with monthly mean maximum, minimum, and mean temperature for the United States, *J. Climate Appl. Meteor*., 25, 145-160.), which occurs when observing times are changed from midnight to some time earlier in the day. The ending time of the 24-h climatological day varies from station to station and/or over a period of years at a given station. The time of observation (TOB) can introduce a non-climatic bias into the monthly means.
- Equipment Change: Temperature data at stations that have the Maximum/Minimum Temperature System (MMTS) are adjusted for the bias introduced when the liquid-in-glass thermometers were replaced with the MMTS (Quayle, R.G., D.R. Easterling, T.R. Karl, and P.Y. Hughes, 1991: Effects of recent thermometer changes in the cooperative station network, *Bull. Am. Meteorol. Soc*., 72, 1718-1724.). The MMTS adjustment program is supposed to debias the data obtained from stations with MMTS sensors.
- Station History Adjustment (SHAP): Here the homogeneity adjustment scheme described in Karl et al (Karl, T.R., and C.W. Williams, Jr., 1987: An approach to adjusting climatological time series for discontinuous inhomogeneities, *J. Climate Appl. Meteor., 26, 1744-1763*) is performed using the station history metadata file to account for time series discontinuities due to random station moves and other station changes. The debiased data from the MMTS adjustment are then entered into the Station History Adjustment Program or SHAP.
- Fill Missing Data (FILNET): Estimates for missing data are provided using a procedure similar to that used in SHAP. This adjustment uses the debiased data from the SHAP and fills in missing original data when needed (i.e. calculates estimated data) based on a "network" of the best correlated nearby stations. Unfortunately this algorithm can produce unusual adjustments. Witness the effect of adjustments (Fig 4) made at a high quality (Climate Reference Network, CRN=1 http://www1.ncdc.noaa.gov/pub/data/uscrn/documentation/program/X030FullDocumentD0.pdf) ground station (see paragraph. 8).
- Urban Warming Adjustment (see paragraph. 7): The final adjustment is for a positive urban warming bias which uses the regression approach outlined in Karl et al. (Karl, T.R., H.F. Diaz, and G. Kukla, 1988: Urbanization: its detection and effect in the United States climate record, *J. Climate*, 1, 1099-1123.). The result of this adjustment provides the "final" version of the data.

Interestingly, Tom Karl, author of many of these adjustment procedures, is involved with Professor Jones in many of the CRU email exchanges. The cumulative effect of all these adjustments is approximately a one-half degree Fahrenheit warming (0.28°C) in the annual time series over a 50-year period from the 1940's until the last decade of the century. This is of a similar order of magnitude to the total amount of warming observed (Fig 5). Whether all these adjustments work as they should remains debatable. One, correction for Urban Warming Adjustment, does not, as described below.

(7) Urban Heat Island (UHI) Effect

Weather data from cities as collected by meteorological stations are indisputably contaminated by UHI bias and land-use changes. This contamination has to be removed or adjusted for in order to accurately identify true background climatic changes or trends. In cities, vertical walls, steel and concrete absorb the sun's heat and are slow to cool at night. Oke (Oke, T.R. 1973. City size and the urban heat island. *Atmospheric Environment* 7: 769-779.) found that the urban heat-island (in °C) increases according to the formula –

Urban heat-island warming = 0.317 ln P, where P = population.

Thus a village with a population of 10 has a warm bias of 0.73°C. A village with 100 has a warm bias of 1.46°C and a town with a population of 1000 people has a warm bias of 2.2°C. A large city with a million people has a warm bias of 4.4°C.

This effect has been well-documented by other studies e.g. Goodridge (1996), Fig 6.

However the IPCC continues to rely on a single paper by Professor Jones (CRU) (Jones PD, Groisman PYa, Coughlan M, Plummer N, Wangl WC, Karl TR (1990) Assessment of urbanization effects in time series of surface air temperatures over land. *Nature* 347:169-172) that concludes that UHI only contributes 0.05°C over the period 1900 to 1990 and this is the UHI correction that is applied to the various terrestrial temperature datasets. However more recent work (Hinkel, K.M., Nelson, F.E., Klene, A.E. and Bell, J.H. 2003. The urban heat island in winter at Barrow, Alaska. *International Journal of Climatology* 23: 1889-1905) shows an average 2.2°C UHI in Barrow, Alaska which has a population of 4600. Remarkably a more recent paper by Jones (Jones, Lister, and Li, 2008. Urbanization effects in large-scale temperature records, with an emphasis on China, *J. Geophys. Res*., 113,) finds that UHI-related warming over China is about 0.1°C degree per decade, or 1°C degree per century, some 20 times greater than he previously acknowledged. Finally GISS sites are defined to be "rural" if the town has a population under 10,000, however, as stated above, such a classification is likely to produce a significant non-climatic warming bias in ground-station data. Furthermore, the GISS population database is out of date and stations at cities with populations greatly exceeding 10,000 are incorrectly classified as rural. For example, in Peru there are 13 stations classified as rural. Of these, one station is located at a city with a population of 400,000. Five are at cities with populations from 50,000- 135,000. Clearly current corrections for UHI in the terrestrial temperature databases need urgent review.

(8) Instrument Siting

According to the The World Meteorological Organization's (WMO) own criteria, which is followed by the NOAA's National Weather Service (NWS), temperature sensors should be located on an instrument tower at 1.5 meters (5 feet) above the surface of the ground. The tower should be on flat, horizontal ground surrounded by a clear surface, over grass, or low vegetation, kept less than 4 inches high. The tower should be at least 100 meters (110 yards) from tall trees, artificial heating, or reflecting surfaces, such as buildings, concrete surfaces, and parking lots. Pielke et al (Pielke Sr., R.A., C. Davey, D. Niyogi, S. Fall, J. Steinweg-Woods, K. Hubbard, X. Lin, M. Cai, Y.-K. Lim, H. Li, J. Nielsen-Gammon, K. Gallo, R. Hale, R. Mahmood, S. Foster, R.T. McNider, and P. Blanken, 2007. Unresolved issues with the assessment of multi-decadal global land surface temperature trends *J. Geophys. Res*., 112.) found that the majority of U.S. stations surveyed did not meet WMO requirements for proper siting. The average warm bias for these inappropriately-sited stations exceeded 1° C, using the NWS's own criteria.. A separate, independent survey of climate stations carried out by the meteorologist, Anthony Watts, came to a

similar conclusion (Fig. 7). There is no reason to believe that stations outside of the U.S. are any better; in fact there is evidence (paragraph 7) that they may be worse in terms of siting and maintainance. Again current methods of correction for poorly-sited stations are inadequate.

(9) Instrument Changes

The modernization of weather stations in the United States and around the World, replaced many human observers with instruments (HO-83 Hygro-thermometer) that initially had major errors and "warm biases". Work by Gall (Gall, R., Young, K., Schotland, R, Schmitz, J.: 1992. The Recent Maximum temperature Anomalies In Tucson. Are they real or an Instrument Problem? *J. of Climate*, 5, 657-664.) identified that the new HO-83 thermometer had a significant warm bias, whilst Karl (Karl, T.R., 1995: Critical issues for long-term climate monitoring. *Climate Change*, 31, 185.) reported a sudden jump in temperature of about 0.5ºC at stations when the new thermometer was introduced. This discontinuity (Fig.,8), caused by the introduction of the HO-83, was not adjusted for in the USHCN database for the period from the 1980s to the late 1990s, after which the instruments were again replaced.

(10) Homogenisation

It has been stated (Menne, Matthew J., Claude N. Williams, Jr. and Russell S. Vose, 2009: The United States Historical Climatology Network Monthly Temperature Data – Version 2. *Bulletin of the American Meteorological Society*, in press) that "station siting errors do not matter". However their method of analysis is flawed because when they compare, for example, urban and rural stations, they do so using "post-homogenisation" data. What this homogenisation process does is to weigh the data from one station against that of its nearest neighbours. Whilst this is, ostensibly, to fill in data gaps and eliminate discontinuities, the effect is to average out individual station data. What may have well started out as a CRN=1 station (Fig 7) is subsumed by data from poorer quality stations (see Figs 9 and 10 for explanation). One effect is to introduce an artificial warming to rural station data from adjacent urban sites, hence any post- homogenisation comparison of station data quality is meaningless.

(11) Summary of Conclusions

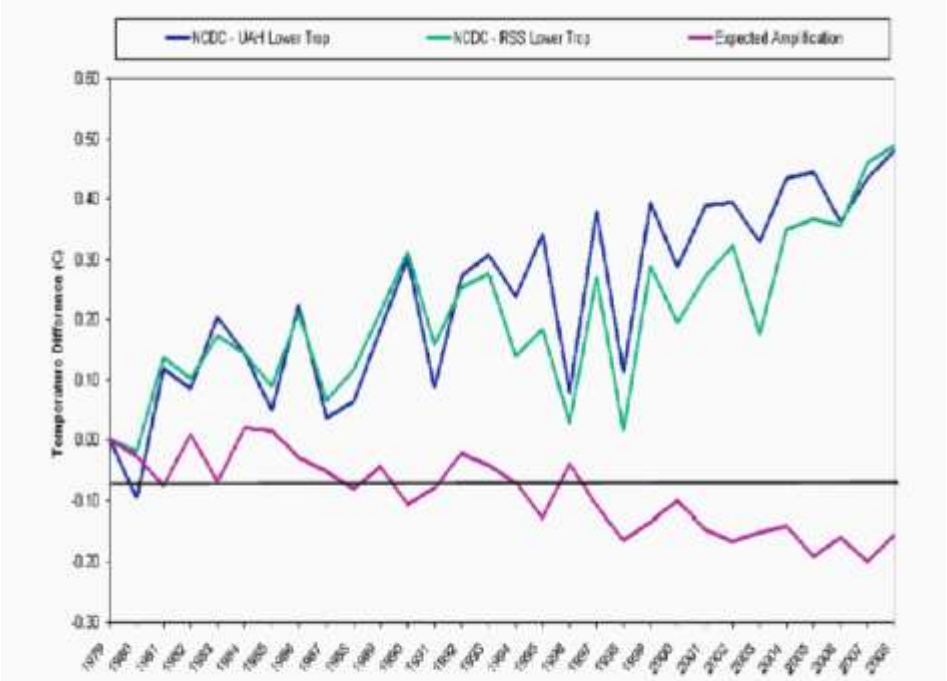
- National Oceanic and Atmospheric Administration (NOAA)'s National Climatic Data Center (NCDC), NASA's Goddard Institute for Space Studies (GISS) and CRU databases are not independent as they all rely on the same basic ground-station data.
- Instrumental temperature data for the pre-satellite era (1850-1980) have been so widely, systematically, and unidirectionally altered that it cannot be credibly asserted what level of "global warming" has occurred in the 20th. Century.
- All terrestrial surface-temperature databases exhibit very serious problems that render them unfit for determining accurate long-term temperature trends.
- All of the problems have skewed the data to overstate observed warming both regionally and globally.
- Global terrestrial temperature data are compromised because more than three-quarters of the 6,000 stations that once existed are no longer reporting.
- There has been a bias towards removing higher-altitude, higher-latitude, and rural stations, leading to a further overstatement of warming.

- Contamination by urbanization, changes in land use, improper siting, and inadequately-calibrated instrument upgrades further overstates warming.
- Numerous peer-reviewed papers have shown the overstatement of observed longer term warming is 30-50% from UHI contamination alone.
- Inappropriate selection of observing sites, combined with interpolation to adjacent stations and vacant data grids, may make heat-island bias greater than 50% of 20th-century warming.
- Satellite temperature monitoring has provided an alternative to terrestrial stations in compiling the global lower-troposphere temperature record. Their findings are increasingly diverging from the ground station-based constructions in a manner consistent with evidence of a warm bias in the surface temperature record.
- Global terrestrial climate databases are seriously flawed and can no longer be used to assess climate trends or validate climate model forecasts.

Dr. D.R. Keiller
February 2010

Appendix (1) Figures to support the text.

Fig. 1 A comparison between satellite and ground-based temperature trends. Note the increasingly divergent warm bias of ground-station measurements.



*NCDC (terrestrial) minus **UAH (satellite: blue)** and minus **RSS (satellite: green)** lower-troposphere annual land temperature differences, 1979-2008. The **expected difference (purple)** given the model amplification lapse-rate factor of 1.2 is also shown. All differences are zeroed to 1979.*

Fig 2. Relationship between station numbers and Global temperature. Note the step change in average temperatures that occurs as station numbers fall.

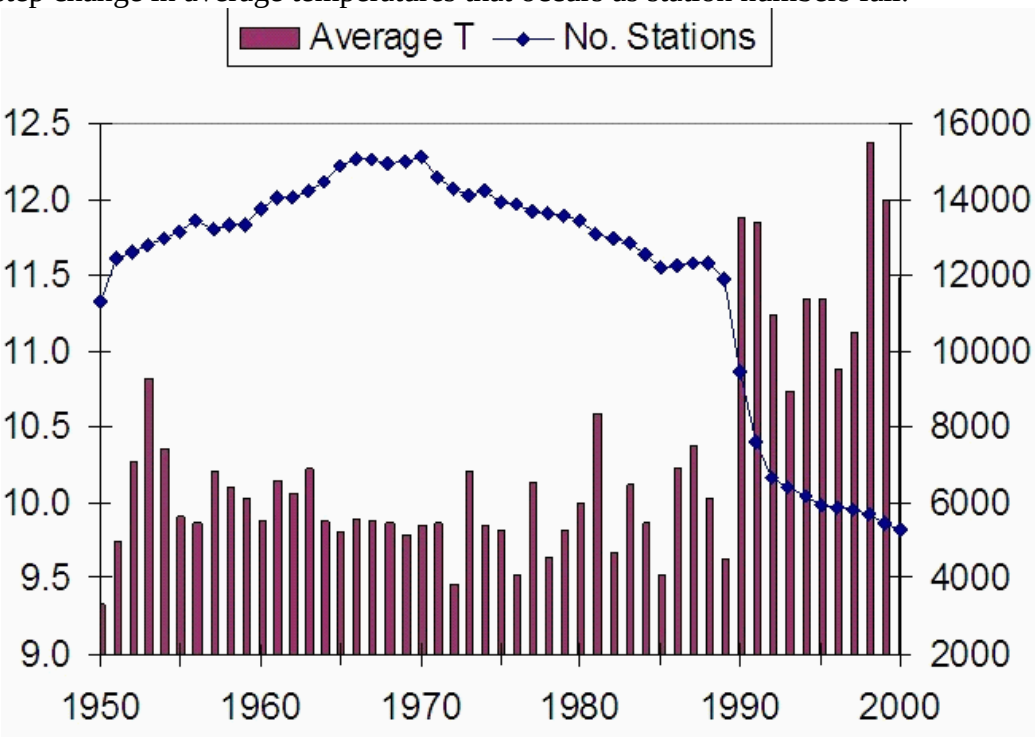


Fig. 3 Two versions of a dataset USHCN v1 (prior to adjustment) and USHCN v2 (post adjustment). Note the marked cooling of past temperatures after adjustment.

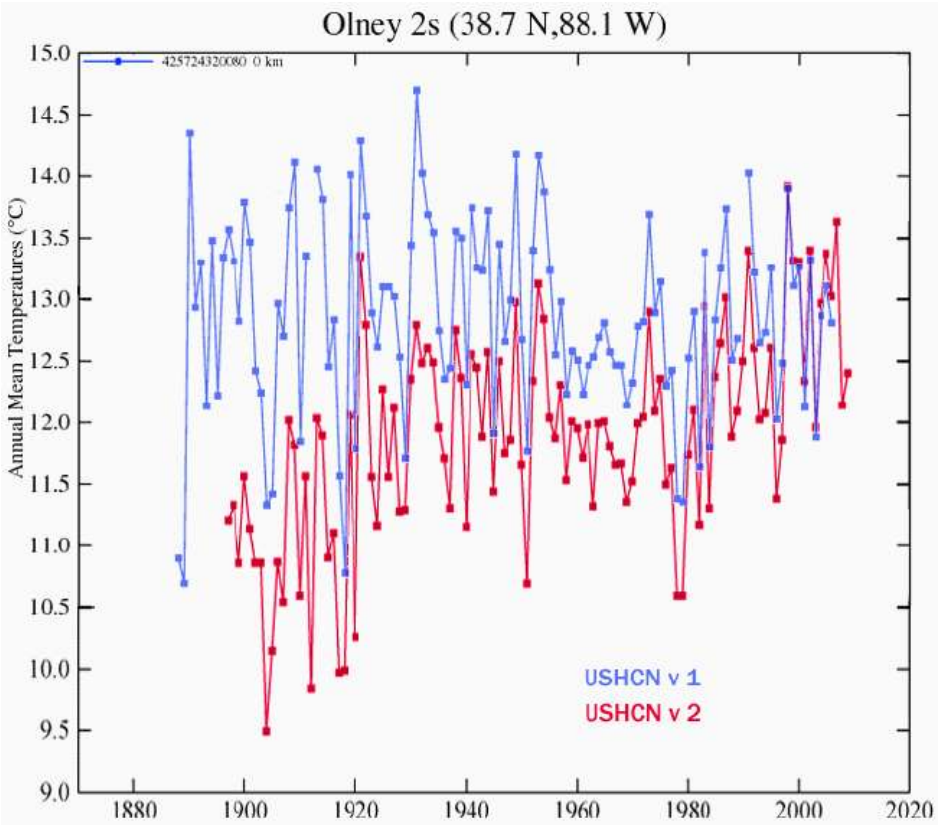


Fig. 4 Adjustments to temperature record (USCHN v2) made by "Filnet" compared with original data (USHCN v1). Again note the "cooling" of past temperature data.

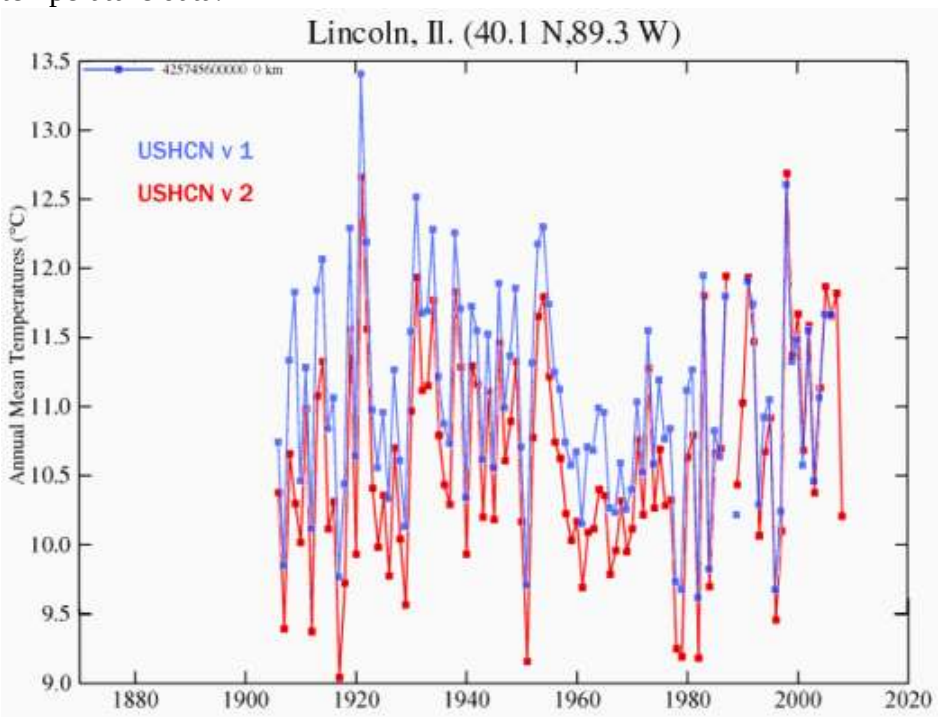


Fig. 5 Culmulative effect of all adjustments. Note the overall warming effect of these adjustments.

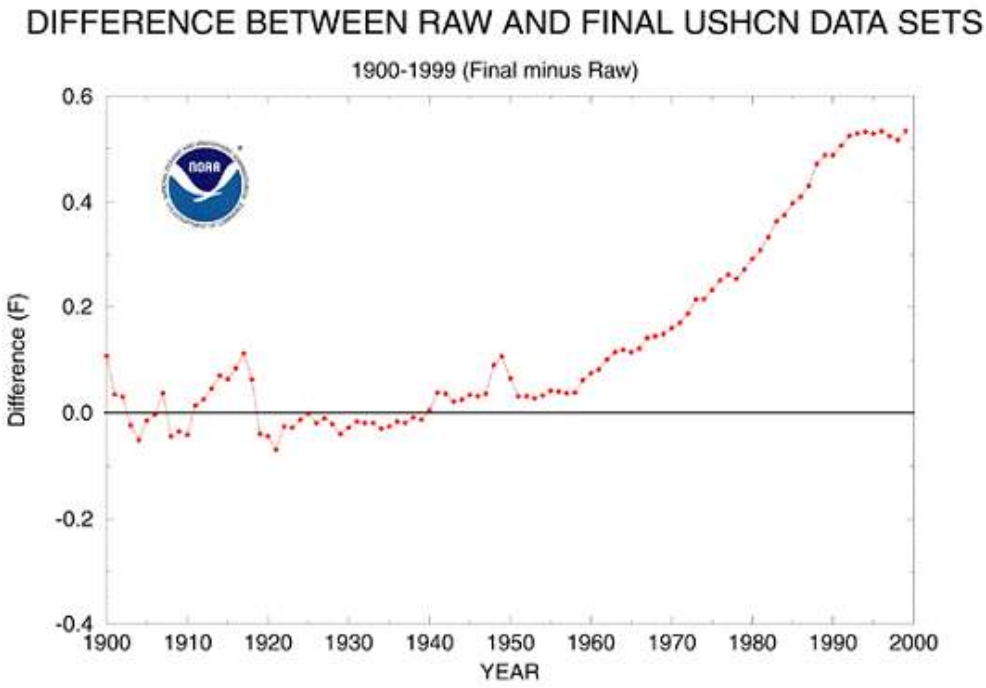


Fig. 6 The Urban Heat Island Effect in California (CA) (Goodridge, J.D. (1996) Comments on "Regional Simulations of Greenhouse Warming including Natural Variability". *Bull, Amer. Meteorological Society* 77:1588-1599). Note increased warming in more densely populated areas.

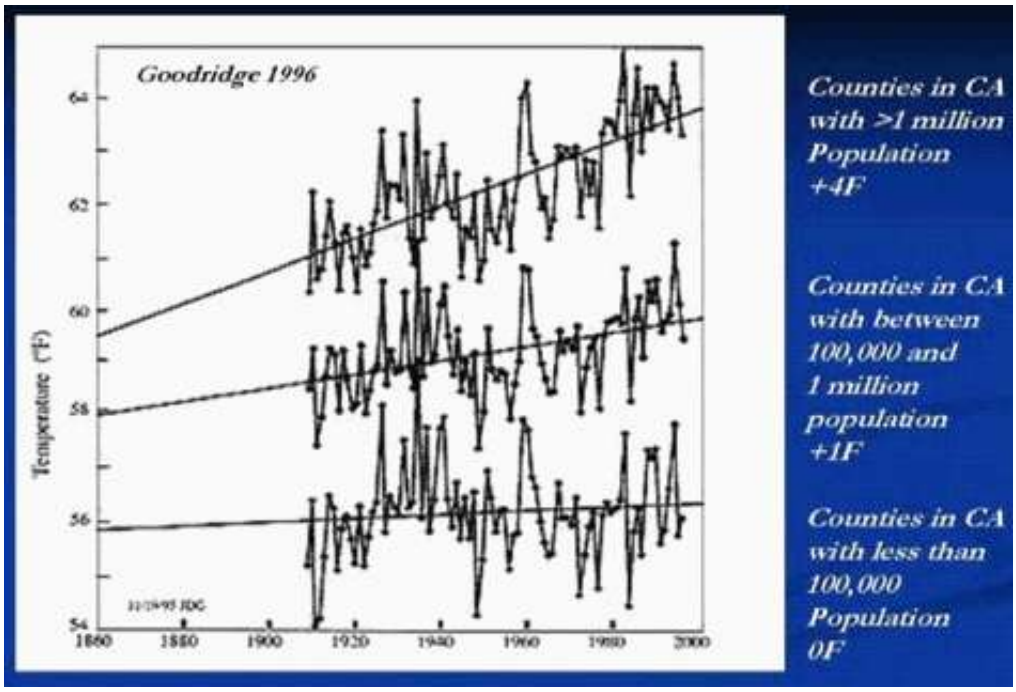


Fig. 7 Quality assessment of United States Historical Climate Network.

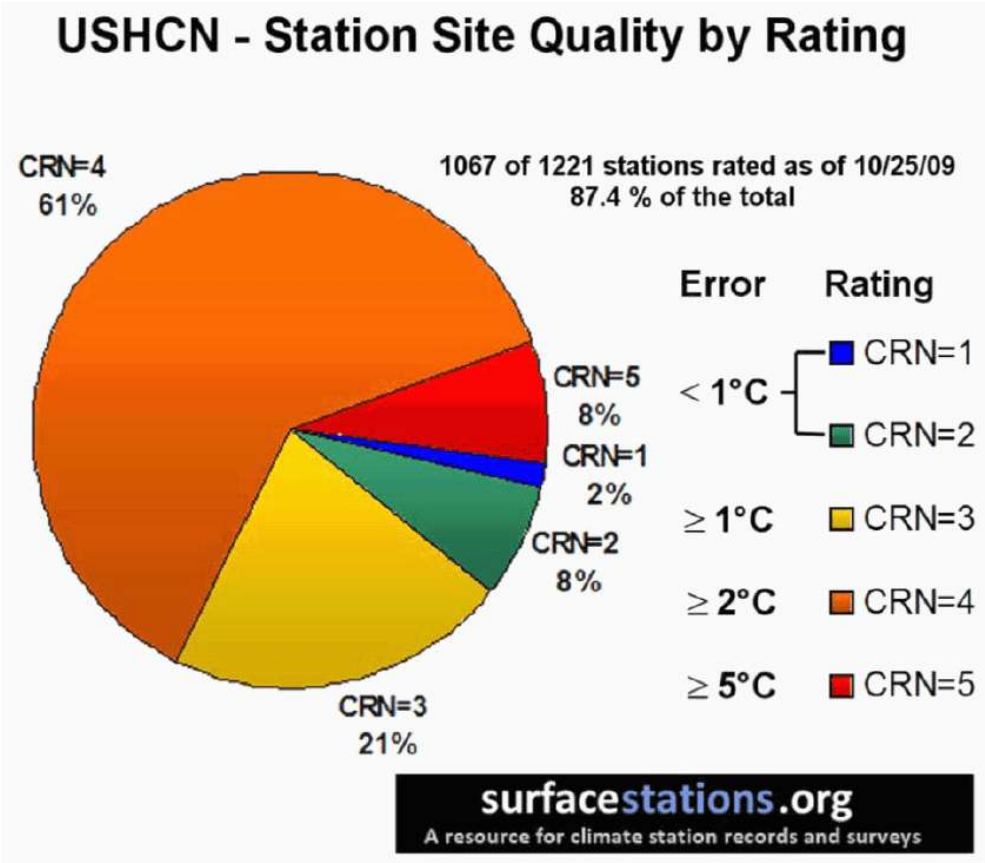


Fig. 8 Effects of Instrument changes. Note the uncorrected discontinuity at the time of instrument change

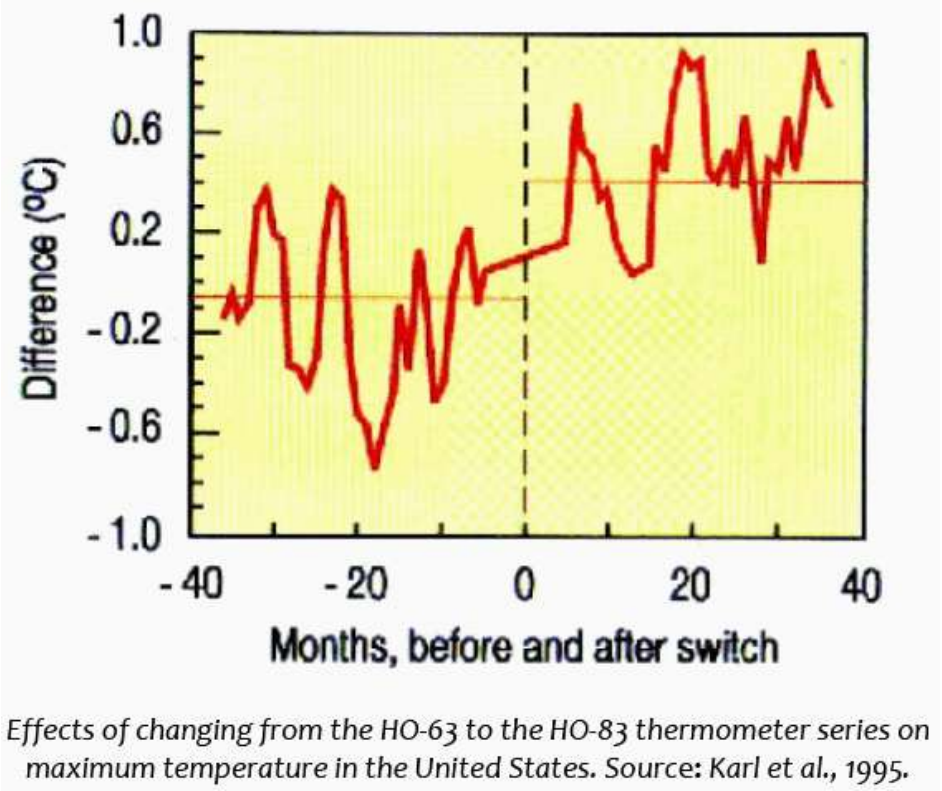


Fig. 9 Visual table of CRN station quality ratings and what they might look like as water pollution turbidity levels, rated as 1 to 5 from best to worst turbidity:

Fig. 10 The Homogenisation Process. In the map below, applying a homogenisation smoothing, that is weighting stations by comparison with neighbours (often distant) results in each station producing data that would be closer to an average value based on the neighbouring stations.