3.3. Urban Heat Islands

How accurate are the surface temperature records cited by the IPCC as showing unprecedented millennial warmth over the past couple decades? The IPCC considers them very accurate and nearly free of any contaminating influence, yielding a 1905-2005 increase of 0.74°C ± 0.18°C (IPCC, 2007-I, p. 237). Warming in many growing cities, on the other hand, may have been a full order of magnitude greater. Since nearly all near-surface air temperature records of this period have been obtained from sensors located in population centers that have experienced significant growth, it is essential that urban heat island (UHI) effects be removed from all original temperature records when attempting to accurately assess what has truly happened in the natural non-urban environment.

The IPCC dismisses this concern, saying the UHI is "an order of magnitude smaller than decadal and longer time-scale trends" (p. 244) and "UHI effects are real but local, and have a negligible influence (less than 0.006° C per decade over land and zero over the oceans) on these [observed temperature] values" (p. 5). On this extremely important matter, the IPCC is simply wrong, as the rest of this section demonstrates.

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3.3.1. Global

Hegerl *et al*. (2001) describe UHI-induced temperature perversions as one of three types of systematic error in the surface air temperature record whose magnitude "cannot be assessed at present." Nevertheless, they go on to do just that, claiming "it has been estimated that temperature trends over rural stations only are very similar to trends using all station data, suggesting that the effect of urbanization on estimates of global-scale signals should be small." This statement is patently false.

De Laat and Maurellis (2004) used a global dataset developed by Van Aardenne *et al*. (2001), which reveals the spatial distribution of various levels of industrial activity over the planet as quantified by the intensity of anthropogenic CO_2 emissions to divide the surface of the earth into non-industrial and industrial sectors of various intensity levels, after which they plotted the 1979-2001 temperature trends (°C/decade) of the different sectors using data from both the surface and the lower and middle troposphere.

The two scientists report that "measurements of surface and lower tropospheric temperature change give a very different picture from climate model predictions and show strong observational evidence that the degree of industrialization is correlated with surface temperature increases as well as lower tropospheric temperature changes." Specifically, they find that the surface and lower tropospheric warming trends of all industrial regions are greater than the mean warming trend of the earth's non-industrial regions, and that the difference in warming rate between the two types of land use grows ever larger as the degree of industrialization increases.

In discussing the implications of their findings, De Laat and Maurellis say "areas with larger temperature trends (corresponding to higher CO_2 emissions) cover a considerable part of the globe," which implies that "the 'real' global mean surface temperature trend is very likely to be considerably smaller than the temperature trend in the CRU [Hadley Center/Climate Research Unit] data," since the temperature measurements that comprise that data base "are often conducted in the vicinity of human (industrial) activity." These observations, in their words, "suggest a hitherto-overlooked driver of local surface temperature increases, which is linked to the degree of industrialization" and "lends strong support to other indications that surface processes (possibly changes in land-use or the urban heat effect) are crucial players in observed surface temperature changes (Kalnay and Cai, 2003; Gallo *et al*., 1996, 1999)." They conclude that "the observed surface temperature changes might be a result of local surface heating processes and not related to radiative greenhouse gas forcing."

A similar study was conducted by McKitrick and Michaels (2004), who calculated 1979-2000 linear trends of monthly mean near-surface air temperature for 218 stations in 93 countries, based upon data they obtained from the Goddard Institute of Space Studies (GISS), after which they regressed the results against indicators of local economic activity—such as income, gross domestic product growth rates, and coal use—to see if there was any evidence of these socioeconomic factors affecting the supposedly "pristine as possible" temperature data. Then, they repeated the process using the gridded surface air temperature data of the IPCC.

The two scientists report that the spatial pattern of trends they derived from the GISS data was "significantly correlated with non-climatic factors, including economic activity and sociopolitical characteristics." Likewise, with respect to the IPCC data, they say "very similar correlations appear, despite previous attempts to remove non-climatic effects." These "socioeconomic effects," in the words of McKitrick and Michaels, "add up to a net warming bias," although they say "precise estimation of its magnitude will require further work."

We can get a good feel for the magnitude of the "socioeconomic effect" in some *past* work, such as that of Oke (1973), who measured the urban heat island strength of 10 settlements in the St. Lawrence Lowlands of Canada that had populations ranging from approximately 1,000 to 2,000,000 people, after which he compared his results with those obtained for a number of other cities in North America, as well as some in Europe. Over the population range studied, Oke found that the magnitude of the urban heat island was linearly correlated with the logarithm of population; this relationship indicated that at the lowest population value encountered, i.e., 1,000 inhabitants, there was an urban heat island effect of 2° to 2.5°C, which warming is more than twice as great as the increase in mean global air temperature believed to have occurred since the end of the Little Ice Age. It should be abundantly clear there is ample opportunity for large errors to occur in thermometer-derived surface air temperature histories of the twentieth century, and that error is probably best described as a large and growing warming bias.

That this urban heat island-induced error has indeed corrupted data bases that are claimed to be immune from it is suggested by the work of Hegerl and Wallace (2000), who attempted to determine if trends in recognizable atmospheric modes of variability could account for all or part of the observed trend in surface-troposphere temperature differential, i.e., lapse rate, which has been driven by the upward-inclined trend in surface-derived temperatures and the nearly level trend in satellite-derived tropospheric temperatures over the last two decades of the twentieth century. After doing everything they could conceive of doing, they had to conclude that "modes of variability that affect surface temperature cannot explain trends in the observed lapse rate," and that "no mechanism with clear spatial or time structure can be found that accounts for that trend." In addition, they had to acknowledge that "all attempts to explain all or a significant part of the observed lapse rate trend by modes of climate variability with structured patterns from observations have failed," and that "an approach applying model data to isolate such a pattern has also failed." Nor could they find any evidence "that interdecadal variations in radiative forcing, such as might be caused by volcanic eruptions, variations in solar output, or stratospheric ozone depletion alone, offer a compelling explanation." Hence, the two scientists ultimately concluded that "there remains a gap in our fundamental understanding of the processes that cause the lapse rate to vary on interdecadal timescales."

On the other hand, the reason why no meteorological or climatic explanation could be found for the ever-increasing difference between the surface- and satellite-derived temperature trends of the past 20-plus years may be that one of the temperature records is incorrect. Faced with this possibility, one would logically want to determine which of the records is likely to be erroneous and then assess the consequences of that determination. Although this task may seem daunting, it is really not that difficult. One reason why is the good correspondence Hegerl and Wallace found to exist between the satellite and radiosonde temperature trends, which leaves little reason for doubting the veracity of the satellite results, since this comparison essentially amounts to an *in situ* validation of the satellite record. A second important reason comes from the realization that it would be extremely easy for a spurious warming of 0.12°C per decade to be introduced into the surface air temperature trend as a consequence of the worldwide intensification of the urban heat island effect that was likely driven by the world population increase that occurred in most of the places where surface air temperature measurements were made over the last two decades of the twentieth century.

It appears almost certain that surface-based temperature histories of the globe contain a significant warming bias introduced by insufficient corrections for the *non*-greenhouse-gas-induced urban heat island effect. Furthermore, it may well be next to impossible to make proper corrections for this deficiency, as the urban heat island of even small towns *dwarfs* any concomitant augmented greenhouse effect that may be present.

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3.3.2. North America

In studying the urban heat island (UHI) of Houston, Texas, Streutker (2003) analyzed 82 sets of nighttime radiation data obtained from the split-window infrared channels of the Advanced Very High Resolution Radiometer on board the NOAA-9 satellite during March 1985 through February 1987 and from 125 sets of similar data obtained from the NOAA-14 satellite during July 1999 through June 2001. Between these two periods, it was found that the mean nighttime surface temperature of Houston rose by 0.82 ± 0.10 °C. In addition, Streutker notes that the growth of the Houston UHI, both in magnitude and spatial extent, "scales roughly with the increase in population," and that the mean rural temperature measured during the second interval was "virtually identical to the earlier interval."

This informative study demonstrates that the UHI phenomenon can sometimes be very powerful, for in just 12 years the UHI of Houston grew by more than the IPCC contends the mean surface air temperature of the planet rose over the entire past century, during which period earth's population rose by approximately 280 percent, or nearly an order of magnitude more than the 30 percent population growth experienced by Houston over the 12 years of Streutker's study.

A very different type of study was conducted by Maul and Davis (2001), who analyzed air and seawater temperature data obtained over the past century at the sites of several primary tide gauges maintained by the U.S. Coast and Geodetic Survey. Noting that each of these sites "experienced significant population growth in the last 100 years," and that "with the increase in maritime traffic and discharge of wastewater one would expect water temperatures to rise" (due to a maritime analogue of the urban heat island effect), they calculated trends for the 14 longest records and derived a mean century-long seawater warming of 0.74°C, with Boston registering a 100-year warming of 3.6°C. In addition, they report that air temperature trends at the tide gauge sites, which represent the standard urban heat island effect, were "much larger" than the seawater temperature trends.

In another different type of study, Dow and DeWalle (2000) analyzed trends in annual evaporation and Bowen ratio measurements on 51 eastern U.S. watersheds that had experienced various degrees of urbanization between 1920 and 1990. In doing so, they determined that as residential development progressively occurred on what originally were rural watersheds, watershed evaporation decreased and sensible heating of the atmosphere increased. And from relationships derived from the suite of watersheds investigated, they calculated that complete transformation from 100 percent rural to 100 percent urban characteristics resulted in a 31 percent decrease in watershed evaporation and a 13 W/m^2 increase in sensible heating of the atmosphere.

Climate modeling exercises suggest that a doubling of the air's CO_2 concentration will result in a nominal 4 W/m^2 increase in the radiative forcing of earth's surface-troposphere system, which has often been predicted to produce an approximate 4°C increase in the mean near-surface air temperature of the globe, indicative of an order-of-magnitude climate sensitivity of 1°C per W/m^2 change in radiative forcing. Thus, to a first approximation, the 13 W/m^2 increase in the sensible heating of the near-surface atmosphere produced by the total urbanization of a pristine rural watershed in the eastern United States could be expected to produce an increase of about 13°C in near-surface air temperature over the central portion of the watershed, which is consistent with maximum urban heat island effects observed in large and densely populated cities. Hence, a 10 percent rural-to-urban transformation could well produce a warming on the order of 1.3°C, and a mere 2 percent transformation could increase the near-surface air temperature by as much as a quarter of a degree Centigrade.

This powerful anthropogenic but non-greenhouse-gas-induced effect of urbanization on the energy balance of watersheds and the temperature of the boundary-layer air above them begins to express itself with the very first hint of urbanization and, hence, may be readily overlooked in studies seeking to identify a greenhouse-gas-induced global warming signal. In fact, the fledgling urban heat island effect may already be present in many temperature records that have routinely been considered "rural enough" to be devoid of all human influence.

A case in point is provided by the study of Changnon (1999), who used a series of measurements of soil temperatures obtained in a totally rural setting in central Illinois between 1889 and 1952 and a contemporary set of air temperature measurements made in an adjacent growing community (as well as similar data obtained from other nearby small towns), to evaluate the magnitude of unsuspected heat island effects that may be present in small towns and cities that are typically assumed to be free of urban-induced warming. This work revealed that soil temperature in the totally rural setting experienced an increase from the decade of 1901-1910 to the decade of 1941-1950 that amounted to 0.4°C.

This warming is 0.2°C *less* than the 0.6°C warming determined for the same time period from the entire dataset of the U.S. Historical Climatology Network, which is supposedly corrected for urban heating effects. It is also 0.2°C less than the 0.6°C warming determined for this time period by 11 benchmark stations in Illinois with the highest quality long-term temperature data, all of which are located in communities that had populations of less than 6,000 people as of 1990. And it is 0.17°C less than the 0.57°C warming derived from data obtained at the three benchmark stations closest to the site of the soil temperature measurements and with populations of less than 2,000 people.

Changnon says his findings suggest that "both sets of surface air temperature data for Illinois believed to have the best data quality with little or no urban effects may contain urban influences causing increases of 0.2°C from 1901 to 1950." He further notes—in a grand understatement—that "this could be significant because the IPCC (1995) indicated that the global mean temperature increased 0.3°C from 1890 to 1950."

DeGaetano and Allen (2002b) used data from the U.S. Historical Climatology Network to calculate trends in the occurrence of maximum and minimum temperatures greater than the 90th, 95th, and 99th percentile across the United States over the period 1960-1996. In the case of daily warm minimum temperatures, the slope of the regression line fit to the data of a plot of the annual number of 95th percentile exceedences vs. year was found to be 0.09 exceedences per year for rural stations, 0.16 for suburban stations, and 0.26 for urban stations, making the rate of increase in extreme warm minimum temperatures at urban stations nearly three times greater than the rate of increase at rural stations less affected by growing urban heat islands. Likewise, the rate of increase in the annual number of daily maximum temperature 95th percentile exceedences per year over the same time period was found to be 50 percent greater at urban stations than it was at rural stations.

Working on the Arctic Coastal Plain near the Chuckchi Sea at Barrow, Alaska—which is described by Hinkel *et al*. (2003) as "the northernmost settlement in the USA and the largest native community in the Arctic," the population of which "has grown from about 300 residents in 1900 to more than 4600 in 2000"—the four researchers installed 54 temperature-recording instruments in mid-June of 2001, half of them within the urban area and the other half distributed across approximately 150 km^2 of surrounding land, all of which provided air temperature data at hourly intervals approximately two meters above the surface of the ground. In this paper, they describe the results they obtained for the following winter. Based on urban-rural spatial averages for the entire winter period (December 2001-March 2002), they determined the urban area to be 2.2°C warmer than the rural area. During this period, the mean daily urban-rural temperature difference increased with decreasing temperature, "reaching a peak value of around 6°C in January-February." It was also determined that the daily urban-rural temperature difference increased with decreasing wind speed, such that under calm conditions (< 2 m s^{-1}) the daily urban-rural temperature difference was 3.2°C in the winter. Last of all, under simultaneous calm and cold conditions, the urban-rural temperature difference was observed to achieve hourly magnitudes exceeding 9°C.

Four years later, Hinkel and Nelson (2007) reported that for the period 1 December to 31 March of four consecutive winters, the spatially averaged temperature of the urban area of Barrow was about 2°C warmer than that of the rural area, and that it was not uncommon for the daily magnitude of the urban heat island to exceed 4°C. In fact, they say that on some days the magnitude of the urban heat island exceeded 6°C, and that values in excess of 8°C were sometimes recorded, while noting that the warmest individual site temperatures were "consistently observed in the urban core area."

These results indicate just how difficult it is to measure a background global temperature increase that is believed to have been less than 1°C over the past century (representing a warming of less than 0.1°C per decade), when the presence of a mere 4,500 people can create a winter heat island that may be two orders of magnitude greater than the signal being sought. Clearly, there is no way that temperature measurements made within the range of influence of even a small village can be adjusted to the degree of accuracy that is required to reveal the true magnitude of the pristine rural temperature change.

Moving south, we find Ziska *et al*. (2004) working within and around Baltimore, Maryland, where they characterized the gradual changes that occur in a number of environmental variables as one moves from a rural location (a farm approximately 50 km from the city center) to a suburban location (a park approximately 10 km from the city center) to an urban location (the Baltimore Science Center approximately 0.5 km from the city center). At each of these locations, four 2 x 2 m plots were excavated to a depth of about 1.1 m, after which they were filled with identical soils, the top layers of which contained seeds of naturally occurring plants of the area. These seeds sprouted in the spring of the year, and the plants they produced were allowed to grow until they senesced in the fall, after which all of them were cut at ground level, removed, dried and weighed.

Ziska *et al*. report that along the rural-to-suburban-to-urban transect, the only consistent differences in the environmental variables they measured were a rural-to-urban increase of 21 percent in average daytime atmospheric CO_2 concentration and increases of 1.6 and 3.3°C in maximum (daytime) and minimum (nighttime) daily temperatures, respectively, which changes, in their words, are "consistent with most short-term (~50 year) global change scenarios regarding CO_2 concentration and air temperature." In addition, they determined that "productivity, determined as final above-ground biomass, and maximum plant height were positively affected by daytime and soil temperatures as well as enhanced CO_2, increasing 60 and 115% for the suburban and urban sites, respectively, relative to the rural site."

The three researchers say their results suggest that "urban environments may act as a reasonable surrogate for investigating future climatic change in vegetative communities," and those results indicate that rising air temperatures and CO_2 concentrations tend to produce dramatic increases in the productivity of the natural ecosystems typical of the greater Baltimore area and, by inference, probably those of many other areas as well.

Three years later, George *et al*. (2007) reported on five years of work at the same three transect locations, stating that "atmospheric CO_2 was consistently and significantly increased on average by 66 ppm from the rural to the urban site over the five years of the study," and that "air temperature was also consistently and significantly higher at the urban site (14.8°C) compared to the suburban (13.6°C) and rural (12.7°C) sites." And they again noted that the increases in atmospheric CO_2 and air temperature they observed "are similar to changes predicted in the short term with global climate change, therefore providing an environment suitable for studying future effects of climate change on terrestrial ecosystems," specifically noting that "urban areas are currently experiencing elevated atmospheric CO_2 and temperature levels that can significantly affect plant growth compared to rural areas."

Working further south still, LaDochy *et al*. (2007) report that "when speculating on how global warming would impact the state [of California], climate change models and assessments often assume that the influence would be uniform (Hansen *et al*., 1998; Hayhoe *et al*., 2004; Leung *et al*., 2004)." Feeling a need to assess the validity of this assumption, they calculated temperature trends over the 50-year period 1950-2000 to explore the extent of warming in various sub-regions of the state, after which they attempted to evaluate the influence of human-induced changes to the landscape on the observed temperature trends and determine their significance compared to those caused by changes in atmospheric composition, such as the air's CO_2 concentration.

In pursuing this protocol, the three researchers found that "most regions showed a stronger increase in minimum temperatures than with mean and maximum temperatures," and that "areas of intensive urbanization showed the largest positive trends, while rural, non-agricultural regions showed the least warming." In fact, they report that the Northeast Interior Basins of the state actually experienced *cooling*. Large urban sites, on the other hand, exhibited rates of warming "over twice those for the state, for the mean maximum temperature, and over five times the state's mean rate for the minimum temperature." Consequently, they concluded that "if we assume that global warming affects all regions of the state, then the small increases seen in rural stations can be an estimate of this general warming pattern over land," which implies that "larger increases," such as those they observed in areas of intensive urbanization, "must then be due to local or regional surface changes."

Noting that "breezy cities on small tropical islands ... may not be exempt from the same local climate change effects and urban heat island effects seen in large continental cities," Gonzalez *et al*. (2005) describe the results of their research into this topic, which they conducted in and about San Juan, Puerto Rico. In this particular study, a NASA Learjet—carrying the Airborne Thermal and Land Applications Sensor (ATLAS) that operates in visual and infrared wavebands—flew several flight lines, both day and night, over the San Juan metropolitan area, the El Yunque National Forest east of San Juan, plus other nearby areas, obtaining surface temperatures, while strategically placed ground instruments recorded local air temperatures. This work revealed that surface temperature differences between urbanized areas and limited vegetated areas were higher than 3°C during daytime, creating an urban heat island with "the peak of the high temperature dome exactly over the commercial area of downtown," where noontime air temperatures were as much as 3°C greater than those of surrounding rural areas. In addition, the eleven researchers report that "a recent climatological analysis of the surface [air] temperature of the city has revealed that the local temperature has been increasing over the neighboring vegetated areas at a rate of 0.06°C per year for the past 30 years."

In discussing their findings, Gonzalez *et al*. state that "the urban heat island dominates the sea breeze effects in downtown areas," and they say that "trends similar to those reported in [their] article may be expected in the future as coastal cities become more populated." Indeed, it is probable that this phenomenon has long been operative in coastal cities around the world, helping to erroneously inflate the surface air temperature record of the planet and contributing to the infamous "hockey stick" representation of this parameter that has been so highly touted by the Intergovernmental Panel on Climate Change.

One year later, Velazquez-Lozada *et al*. (2006) evaluated the thermal impacts of historical land cover and land use (LCLU) changes in San Juan, Puerto Rico over the last four decades of the twentieth century via an analysis of air temperatures measured at a height of approximately two meters above ground level within four different LCLU types (urban-coastal, rural-inland, rural-coastal and urban-inland), after which they estimated what the strength of the urban heat island might be in the year 2050, based on anticipated LCLU changes and a model predicated upon their data of the past 40 years. In doing so, their work revealed "the existence of an urban heat island in the tropical coastal city of San Juan, Puerto Rico that has been increasing at a rate of 0.06°C per year for the last 40 years." In addition, they report that predicted LCLU changes between now and 2050 will lead to an urban heat island effect "as high as 8°C for the year 2050."

Noting that a mass population migration from rural Mexico into medium- and large-sized cities took place throughout the second half of the twentieth century, Jáuregui (2005) examined the effect of this rapid urbanization on city air temperatures, analyzing the 1950-1990 minimum air temperature series of seven large cities with populations in excess of a million people and seven medium-sized cities with populations ranging from 125,000 to 700,000 people. This work indicated that temperature trends were positive at all locations, ranging from 0.02°C per decade to 0.74°C per decade. Grouped by population, the average trend for the seven large cities was 0.57°C per decade, while the average trend for the seven mid-sized cities was 0.37°C per decade. In discussing these results, Jáuregui says they "suggest that the accelerated urbanization process in recent decades may have substantially contributed to the warming of the urban air observed in large cities in Mexico."

One additional question that may arise in relation to this topic is the direct heating of near-surface air in towns and cities by the urban CO_2 dome that occurs above them. Does it contribute significantly to the urban heat island?

In a study designed to answer this question, Balling *et al*. (2002) obtained vertical profiles of atmospheric CO_2 concentration, temperature, and humidity over Phoenix, Arizona from measurements made in association with once-daily aircraft flights conducted over a 14-day period in January 2000 that extended through, and far above, the top of the city's urban CO_2 dome during the times of its maximum manifestation. They then employed a one-dimensional infrared radiation simulation model to determine the thermal impact of the urban CO_2 dome on the near-surface temperature of the city. These exercises revealed that the CO_2 concentration of the air over Phoenix dropped off rapidly with altitude, returning from a central-city surface value on the order of 600 ppm to a normal non-urban background value of approximately 378 ppm at an air pressure of 800 hPa, creating a calculated surface warming of only 0.12°C at the time of maximum CO_2-induced warming potential, which is about an order of magnitude less than the urban heat island effect of cities the size of Phoenix. In fact, the authors concluded that the warming induced by the urban CO_2 dome of Phoenix is possibly two orders of magnitude smaller than that produced by other sources of the city's urban heat island. Although the doings of man are indeed responsible for high urban air temperatures (which can sometimes rise 10°C or more above those of surrounding rural areas), these high values are not the result of a local CO_2-enhanced greenhouse effect.

Meteorologist Anthony Watts (2009), in research too new to have appeared yet in a peer-reviewed journal, discovered compelling evidence that the temperature stations used to reconstruct the U.S. surface temperature are unreliable and systemically biased toward recording more warming over time. Watts recruited a team of more than 650 volunteers to visually inspect the temperature stations used by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) to measure changes in temperatures in the U.S. In the researcher's words, "using the same quality standards established by NOAA, they found that 89 percent of the stations – nearly 9 of every 10 – fail to meet NOAA's own siting requirements for stations with an expected reporting error of less than 1º C. Many of them fall *far* short of that standard [italics in the original]."

Watts goes on to report finding stations "located next to the exhaust fans of air conditioning units, causing them to report much- higher-than-actual temperatures. We found stations surrounded by asphalt parking lots and located near roads, sidewalks, and buildings that absorb and radiate heat. We found 68 stations located at wastewater treatment plants, where the process of waste digestion causes temperatures to be higher than in surrounding areas."

Watts also discovered that failure to adequately account for changes in the technology used by temperature stations over time—including moving from whitewash to latex paint and from mercury thermostats to digital technology—"have further contaminated the data, once again in the direction of falsely raising temperature readings." Watts is also extremely critical of adjustments to the raw data made by both NOAA and NASA, which "far from correcting the warming biases, actually compounded the measurement errors."

The results of these several North American studies demonstrate that the impact of population growth on the urban heat island effect is very real and can be very large, overshadowing the effects of natural temperature change. This insight is not new: more than three decades ago, Oke (1973) demonstrated that towns with as few as a thousand inhabitants typically create a warming of the air within them that is more than twice as great as the increase in mean global air temperature believed to have occurred since the end of the Little Ice Age, while the urban heat islands of the great metropolises of the world create warmings that rival those that occur between full-fledged ice ages and interglacials. Extensive research conducted since then by independent scientists has confirmed Oke's finding. Due to extensive corruption of land-based temperature data from urban heat islands, the North

American temperature record cannot be cited as providing reliable data in support of the greenhouse theory of global warming.

Additional information on this topic, including reviews of newer publications as they become available, can be found at http://www.co2science.org/subject/u/uhinorthamerica.php.

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3.3.3. Asia

Hasanean (2001) investigated surface air temperature trends with data obtained from meteorological stations located in eight Eastern Mediterranean cities: Malta, Athens, Tripoli, Alexandria, Amman, Beirut, Jerusalem, and Latakia. The period of analysis varied from station to station according to available data, with Malta having the longest temperature record (1853-1991) and Latakia the shortest (1952-1991). Four of the cities exhibited overall warming trends and four of them cooling trends. In addition, there was an important warming around 1910 that began nearly simultaneously at all of the longer-record stations, as well as a second warming in the 1970s; but Hasanean reports that the latter warming was "not uniform, continuous or of the same order" as the warming that began about 1910, nor was it evident at all of the stations. One interpretation of this non-uniformity of temperature behavior in the 1970s is that it may have been the result of temporal differences in city urbanization histories that were accentuated about that time, which could have resulted in significantly different urban heat island trajectories at the several sites over the latter portions of their records.

In a more direct study of the urban heat island effect that was conducted in South Korea, Choi *et al*. (2003) compared the mean station temperatures of three groupings of cities (one comprised of four large urban stations with a mean 1995 population of 4,830,000, one comprised of six smaller urban stations with a mean 1995 population of 548,000, and one comprised of six "rural" stations with a mean 1995 population of 214,000) over the period 1968-1999. This analysis revealed, in their words, that the "temperatures of large urban stations exhibit higher urban bias than those of smaller urban stations and that the magnitude of urban bias has increased since the late 1980s." Specifically, they note that "estimates of the annual mean magnitude of urban bias range from 0.35°C for smaller urban stations to 0.50°C for large urban stations." In addition, they indicate that "none of the rural stations used for this study can represent a true non-urbanized environment." Hence, they correctly conclude that their results are underestimates of the true urban effect, and that "urban growth biases are very serious in South Korea and must be taken into account when assessing the reliability of temperature trends."

In a second study conducted in South Korea, Chung *et al*. (2004a) report there was an "overlapping of the rapid urbanization-industrialization period with the global warming era," and that the background climatic trends from urbanized areas might therefore be contaminated by a growing urban heat island effect. To investigate this possibility, they say "monthly averages of daily minimum, maximum, and mean temperature at 14 synoptic stations were prepared for 1951-1980 (past normal) and 1971-2000 (current normal) periods," after which "regression equations were used to determine potential effects of urbanization and to extract the net contribution of regional climate change to the apparent temperature change." Twelve of these stations were growing urban sites of various size, while two (where populations actually *decreased*) were rural, one being located inland and one on a remote island.

In terms of change over the 20 years that separated the two normal periods, Chung *et al*. report that in Seoul, where population increase was greatest, annual mean daily minimum temperature increased by 0.7°C, while a mere 0.1°C increase was detected at one of the two rural sites and a 0.1°C decrease was detected at the other, for no net change in their aggregate mean value. In the case of annual mean daily maximum temperature, a 0.4°C increase was observed at Seoul and a 0.3°C increase was observed at the two rural sites. Hence, the change in the annual mean daily mean temperature was an increase of 0.15°C at the two rural sites (indicative of regional background warming of 0.075°C per decade), while the change of annual mean daily mean temperature at Seoul was an increase of 0.55°C, or 0.275°C per decade (indicative of an urban-induced warming of 0.2°C per decade in addition to the regional background warming of 0.075°C per decade). Also, corresponding results for urban areas of intermediate size defined a linear relationship that connected these two extreme results when plotted against the logarithm of population increase over the two-decade period.

In light of the significantly intensifying urban heat island effect detected in their study, Chung *et al*. say it is "necessary to subtract the computed urbanization effect from the observed data at urban stations in order to prepare an intended nationwide climatic atlas," noting that "rural climatological normals should be used instead of the conventional normals to simulate ecosystem responses to climatic change, because the urban area is still much smaller than natural and agricultural ecosystems in Korea."

A third study of South Korea conducted by Chung *et al*. (2004b) evaluated temperature changes at 10 urban and rural Korean stations over the period 1974-2002. They found "during the last 29 years, the increase in annual mean temperature was 1.5°C for Seoul and 0.6°C for the rural and seashore stations," while increases in mean January temperatures ranged from 0.8 to 2.4°C for the 10 stations. In addition, they state that "rapid industrialization of the Korean Peninsula occurred during the late 1970s and late 1980s," and that when plotted on a map, "the remarkable industrialization and expansion ... correlate with the distribution of increases in temperature." Consequently, as in the study of Chung *et al*. (2004a), Chung *et al*. (2004b) found that over the past several decades, much (and in many cases *most*) of the warming experienced in the urban areas of Korea was the result of local urban influences that were not indicative of regional background warming.

Shifting attention to China, Weng (2001) evaluated the effect of land cover changes on surface temperatures of the Zhujiang Delta (an area of slightly more than 17,000 km^2) via a series of analyses of remotely sensed Landsat Thematic Mapper data. They found that between 1989 and 1997, the area of land devoted to agriculture declined by nearly 50 percent, while urban land area increased by close to the same percentage. Then, upon normalizing the surface radiant temperature for the years 1989 and 1997, they used image differencing to produce a radiant temperature change image that they overlaid with images of urban expansion. The results indicated, in Weng's words, that "urban development between 1989 and 1997 has given rise to an average increase of 13.01°C in surface radiant temperature."

In Shanghai, Chen *et al*. (2003) evaluated several characteristics of that city's urban heat island, including its likely cause, based on analyses of monthly meteorological data from 1961 to 1997 at 16 stations in and around this hub of economic activity that is one of the most flourishing urban areas in all of China. Defining the urban heat island of Shanghai as the mean annual air temperature difference between urban Longhua and suburban Songjiang, Chen *et al.* found that its strength increased in essentially linear fashion from 1977 to 1997 by 1°C.

Commenting on this finding, Chen *et al*. say "the main factor causing the intensity of the heat island in Shanghai is associated with the increasing energy consumption due to economic development," noting that in 1995 the Environment Research Center of Peking University determined that the annual heating intensity due to energy consumption by human activities was approximately 25 Wm^{-2} in the urban area of Shanghai but only 0.5 Wm^{-2} in its suburbs. In addition, they point out that the 0.5°C/decade intensification of Shanghai's urban heat island is an order of magnitude greater than the 0.05°C/decade global warming of the earth over the past century, which is indicative of the fact that ongoing intensification of even strong urban heat islands cannot be discounted.

Simultaneously, Kalnay and Cai (2003) used differences between trends in directly observed surface air temperature and trends determined from the NCEP-NCAR 50-year Reanalysis (NNR) project (based on atmospheric vertical soundings derived from satellites and balloons) to estimate the impact of land-use changes on surface warming. Over undisturbed rural areas of the United States, they found that the surface- and reanalysis-derived air temperature data yielded essentially identical trends, implying that differences between the two approaches over urban areas would represent urban heat island effects. Consequently, Zhou *et al*. (2004) applied the same technique over southeast China, using an improved version of reanalysis that includes newer physics, observed soil moisture forcing, and a more accurate characterization of clouds.

For the period January 1979 to December 1998, the eight scientists involved in the work derived an "estimated warming of mean surface [air] temperature of 0.05°C per decade attributable to urbanization," which they say "is much larger than previous estimates for other periods and locations, including the estimate of 0.027°C for the continental U.S. (Kalnay and Cai, 2003)." They note, however, that because their analysis "is from the winter season over a period of rapid urbanization and for a country with a much higher population density, we expect our results to give higher values than those estimated in other locations and over longer periods."

In a similar study, Frauenfeld *et al*. (2005) used daily surface air temperature measurements from 161 stations located throughout the Tibetan Plateau (TP) to calculate the region's mean annual temperature for each year from 1958 through 2000, while in the second approach they used 2-meter temperatures from the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis (ERA-40), which temperatures, in their words, "are derived from rawinsonde profiles, satellite retrievals, aircraft reports, and other sources including some surface observations." This approach, according to them, results in "more temporally homogeneous fields" that provide "a better assessment of large-scale temperature variability across the plateau."

Frauenfeld *et al*. report that over the period 1958-2000, "time series based on aggregating all station data on the TP show a statistically significant positive trend of 0.16°C per decade," as has also been reported by Liu and Chen (2000). However, they say that "no trends are evident in the ERA-40 data for the plateau as a whole."

In discussing this discrepancy, the three scientists suggest that "a potential explanation for the difference between reanalysis and station trends is the extensive local and regional land use change that has occurred across the TP over the last 50 years." They note, for example, that "over the last 30 years, livestock numbers across the TP have increased more than 200% due to inappropriate land management practices and are now at levels that exceed the carrying capacity of the region (Du *et al*., 2004)." The resultant overgrazing, in their words, "has caused land degradation and desertification at an alarming rate (Zhu and Li, 2000; Zeng *et al*., 2003)," and they note that "in other parts of the world, land degradation due to overgrazing has been shown to cause significant local temperature increases (e.g., Balling *et al*., 1998)."

Another point they raise is that "urbanization, which can result in 8°-11°C higher temperatures than in surrounding rural areas (e.g., Brandsma *et al*., 2003), has also occurred extensively on the TP," noting that "construction of a gas pipeline in the 1970s and highway expansion projects in the early 1980s have resulted in a dramatic population influx from other parts of China, contributing to both urbanization and a changed landscape." In this regard, they say that "the original Tibetan section of Lhasa (i.e., the pre-1950 Lhasa) now only comprises 4% of the city, suggesting a 2400% increase in size over the last 50 years." And they add that "similar population increases have occurred at other locations across the TP," and that "even villages and small towns can exhibit a strong urban heat island effect."

In concluding their analysis of the situation, Frauenfeld *et al*. contend that "these local changes are reflected in station temperature records." We note that when the surface-generated anomalies are removed, as in the case of the ERA-40 reanalysis results they present, it is clear there has been no warming of the Tibetan Plateau since at least 1958. Likewise, we submit that the other results reported in this section imply much the same about other parts of China and greater Asia.

In conclusion, a large body of research conducted by scores of scientists working in countries around the world reveals that the twentieth century warming claimed by the IPCC, Mann *et al*. (1998, 1999), and Mann and Jones (2003) to represent mean global background conditions is likely significantly biased towards warming over the past 30 years and is therefore not a true representation of earth's recent thermal history.

Additional information on this topic, including reviews of newer publications as they become available, can be found at http://www.co2science.org/subject/u/uhiasia.php

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3.4. Fingerprints

Is there a method that can distinguish anthropogenic global warming from natural warming? The IPCC (IPCC-SAR, 1996, p. 411; IPCC, 2007-I, p. 668) and many scientists believe the "fingerprint" method is the only reliable one. It compares the observed pattern of warming with a pattern calculated from greenhouse models. While an agreement of such fingerprints cannot prove an anthropogenic origin for warming, it would be consistent with such a conclusion. A mismatch would argue strongly against any significant contribution from greenhouse gas (GHG) forcing and support the conclusion that the observed warming is mostly of natural origin.

Climate models all predict that, if GHG is driving climate change, there will be a unique fingerprint in the form of a warming trend increasing with altitude in the tropical troposphere, the region of the atmosphere up to about 15 kilometers. (See Figure 3.4.1.) Climate changes due to solar variability or other known natural factors will not yield this pattern; only sustained greenhouse warming will do so.

The fingerprint method was first attempted in the IPCC's Second Assessment Report (SAR) (IPCC-SAR, 1996, p. 411). Its Chapter 8, titled "Detection and Attribution," attributed observed temperature changes to anthropogenic factors—greenhouse gases and aerosols. The attempted match of warming trends with altitude turned out to be spurious, since it depended entirely on a particular choice of time interval for the comparison (Michaels and Knappenberger, 1996). Similarly, an attempt to correlate the observed and calculated geographic distribution of surface temperature trends (Santer *et al.* 1996) involved making changes on a published graph that could and did mislead readers (Singer, 1999, p. 9; Singer, 2000, pp. 15, 43-44). In spite of these shortcomings, IPCC-SAR concluded that "the balance of evidence" supported AGW.

With the availability of higher-quality temperature data, especially from balloons and satellites, and with improved GH models, it has become possible to apply the fingerprint method in a more realistic way. This was done in a report issued by the U.S. Climate Change Science Program (CCSP) in April 2006—making it readily available to the IPCC for its Fourth Assessment Report—and it permits the most realistic comparison of fingerprints (Karl *et al.*, 2006).

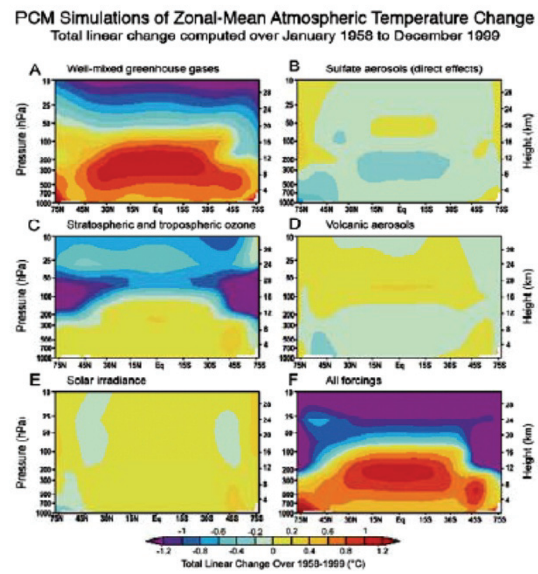

Figure 1.3. PCM simulations of the vertical profile of temperature change due to various forcings, and the effect due to all forcings taken together (after Santer et al., 2000).

Figure 3.4.1. Model-calculated zonal mean atmospheric temperature change from 1890 to 1999 (degrees C per century) as simulated by climate models from [A] well-mixed greenhouse gases, [B] sulfate aerosols (direct effects only), [C] stratospheric and tropospheric ozone, [D] volcanic aerosols, [E] solar irradiance, and [F] all forcings (U.S. Climate Change Science Program 2006, p. 22). Note the pronounced increase in warming trend with altitude in figures A and F, which the IPCC identified as the 'fingerprint' of greenhouse forcing.

The CCSP report is an outgrowth of an NAS report "Reconciling Observations of Global Temperature Change" issued in January 2000 (NAS, 2000). That NAS report compared surface and troposphere temperature trends and concluded they cannot be reconciled. Six years later, the CCSP report expanded considerably on the NAS study. It is