Urban Heat Island Effect

How much do calculations of global temperatures represent the real temperature of the Earth? The answer is there are serious problems with all the current measurements from surface stations to satellites but a major one is the contamination of the surface readings by changes in the physical conditions around the weather station. This article looks at one contentious issue and serious concern with the surface record known as the Urban Heat Island Effect (UHIE).

Why focus on that issue?

1. While satellite measures are available the Intergovernmental Panel on Climate Change (IPCC) does not use them for the official measure. They use the surface record and it is directly influenced by the Effect.
2. Because the UHIE was not identified in the early claims of global warming and allowed incorrect exaggerated claims.
3. Although official agencies take corrective measures for the UHIE there is considerable concern about how this is done and whether it is done correctly and adequately.
4. Few people know what it is or how it is important in the global warming debate.
5. The UHIE should be part of urban planning.

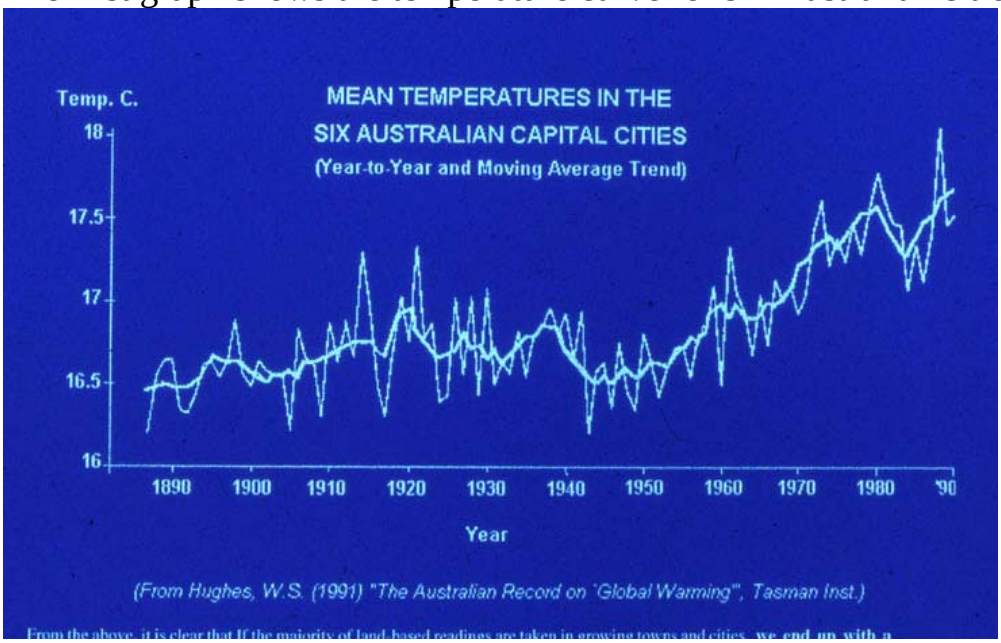
Official temperatures rarely represent the actual temperature of the city for which they are given because most weather stations are at the airport. In some instances they are outside the city and are not representative. In other places they are compromised by growth of the city. Airports were the natural location because pilots essentially were the only people using early weather services. In fact, Vilhelm Bjerknes developed much of the terminology we use in weather for use by aircrew in World War I. As one biography explained, "*He started research in the dynamic theory of atmospheric movement, systematic daily observation of the basic meteorological conditions, intensive calculation of predictions and graphic representation of meteorological change, and timely weather forecasts.*"

http://www.answers.com/topic/vilhelm-bjerknes

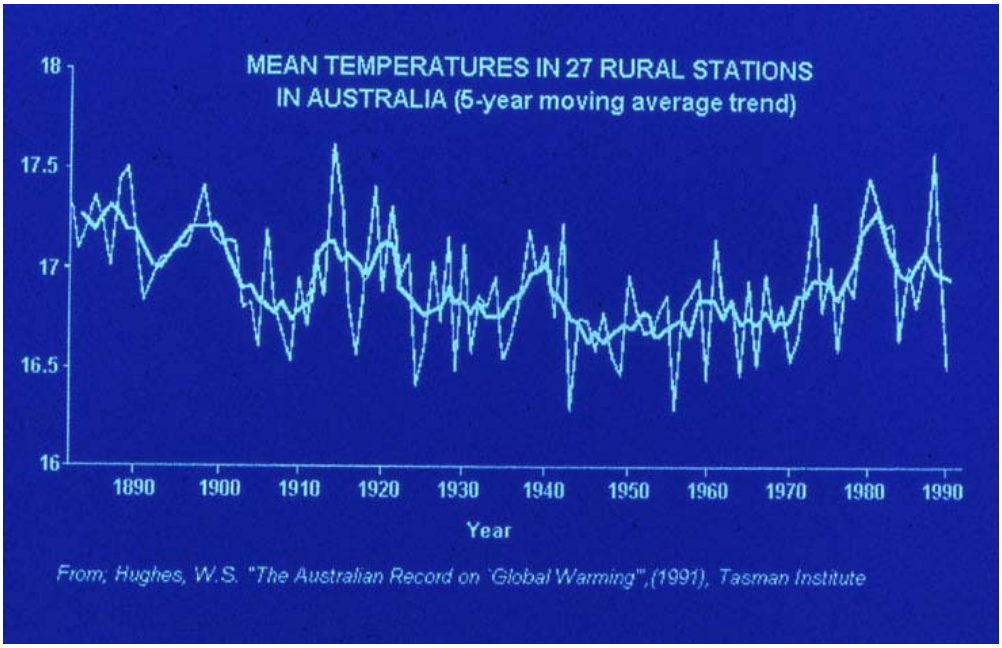
More stations in other areas were built since, but most are still at airports because it is important to keep a station in the same location as much as possible. In most cases, especially at airports, urban development has surrounded them to the detriment of the readings. It is this change in the surrounding region that affects the meteorological measures that is known as the UHIE. Ironically, a major factor causing urban expansion was the automobile. It allowed suburbs to develop from

which people could commute to work. Here are two graphs produced by Warwick Hughes of Australia to illustrate the connection.

The first graph shows the temperature curve for six Australian cities.



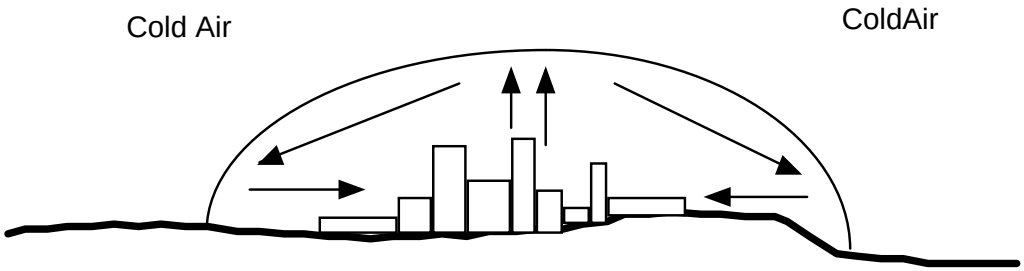
There are slight variations in temperature until a steady rise commencing in 1950. This was interpreted as evidence of global warming, but it was actually evidence of the UHIE. To illustrate the point Hughes plotted a temperature curve for 27 rural sites in Australia for the same time period.



These graphs were widely distributed and used to buttress arguments about what was wrong with the concept that CO2 is causing global warming. Despite knowledge in the discipline about the problem this was one of the first clear examples in the public arena. It was a culmination about research on the UHIE that began many years before.

The discovery that urban areas had different weather occurred unexpectedly, as is often the case in science. In the 1930s a German scientist A. Kratzer was studying the effects of pollution on trees in the Ruhr Valley. He discovered that temperatures were higher in built up areas than the surrounding countryside. His work lay dormant for some years, but the concept was revived shortly after the war when a man named T. J. Chandler did a study of the temperature of London, England. He attached a thermometer to the front of his car and traversed the city recording temperatures along specific routes. When he plotted these on a city map he discovered that they created a distinctive concentric pattern. It was warmer in the centre of the city and cooler as you moved out to the suburbs. Chandler had discovered and measured for the first time the UHIE. His work was published in 1952 in a book titled “The Climate of London.” A second important advance was the doctoral thesis of B.W.Atkinson who demonstrated how the precipitation patterns were also affected in the City of London.

Since then several other cities around the world have been studied. In Canada, measurements were carried out in Hamilton, Winnipeg, and Vancouver. Each city has different terrain and unique situations, but they all exhibited the distinctive weather patterns caused by altered surfaces. What emerges is a distinctive dome of warm air with a centre height of about 300 metres over the hottest part of the city.



Convective Dome of Warm Air with overriding Cold Air

A convection pattern is created inside the dome as the air in the middle rises. The air reaches the top of the dome and spreads out to the suburbs and is replaced

by air moving in from the suburbs. This means that any pockets of pollution get mixed and spread around the city.

The temperature contrast between the city and the countryside is most extreme in very cold climates. Drive towards most northern hemisphere cities on a cold calm January morning and you can see the dome outlined by the more polluted air trapped within the warmer bubble. During the day, the entire dome is like a hot air balloon rises and the dome dissipates. If the overall regional wind is strong enough it will displace the dome downwind away from the city. This can create different weather conditions for areas downwind.

Extra heat in the city is a little surprising because less sunlight is received at the ground. Particles of dust, water vapour and other material stirred from a variety of sources reduce the sunlight, especially when the sun angle is low in the winter. Yearly solar energy is reduced by 15% to 30% in larger cities, but in a strange twist, ultraviolet radiation (UV) is reduced the most. This appears to be a good situation, because skin cancer risks are reduced, however, the body needs UV. It produces the vitamin D that is essential to prevent rickets, a bone disease, and some forms of tuberculosis like scrofula.

So, if the amount of solar energy is reduced why is the downtown warmer than the countryside? A major clue was provided when the studies found that parks as small as a city block showed warmer temperatures in the winter and cooler in the summer. It is a major argument for the preservation of old parks and the creation of new ones in urban areas. The major cause is the change in the surface material. Secondary factors are heat loss from buildings and heat generated by cars and people.

Colour and structure of surface materials determine their ability to absorb and release heat. Concrete, asphalt, bricks and wood absorb heat very quickly during the day while water grass and trees absorb more slowly. At night the non-vegetative surfaces lose their heat quickly and the vegetative surfaces slowly, thus raising the temperature of the air in the city at night while parks and countryside remain cool.

The greatest surface changes are in the centre of the city where few trees exist, an area called the Central Business District (CBD), which has almost 100% solid surface which is impervious to water. As a result, extensive drainage systems are designed to carry water away quickly. In the country this water lies around and evaporates slowly or is used by plants and transpired by them. Both processes create cooling. When water evaporates it takes heat energy from the surrounding air thus creating cooling.

Impervious surfaces also exist in the suburbs were the average lot is usually 50 percent covered. The roof of the house, garage, driveway, and sidewalks all absorb heat in the day and radiate it back to the atmosphere at night. They also

prevent water penetrating the surface and remove it very quickly to the storm sewers.

Based on all the cities studied the following patterns emerge. If you live in a city or in the country consider where the airport is and maybe even measure the temperature difference.

Wind Speed: Buildings create drag, especially in the canyons of the CBD and as a result winds are 20% to 30% less. Since wind is important in evaporation this also reduces the rate of evaporative cooling.

Calms: Obviously, if wind speed is reduced there will be more calm conditions, from 5% to 20% more.

Sunshine: Dust and other particles reduce sunlight 5% to 15%

Annual Mean Temperature: 0.5° to 1.0°C higher

Ultraviolet radiation: Summer: 5% less, winter: 30% less. The low sun angle in winter causes the sunlight to pass through more dust.

Cloud cover: 5% to 10% more. Water vapour given off by human activities and more dust creates more cloud cover. In addition, the warmer air rising causes clouds to form. In addition, as Atkinson showed air is lifted as it passes over the dome, which creates more cloud.

Rainfall: 5% to 10% more.

Snowfall: 5% less because the temperatures are higher, especially in winter.

Fog: Winter: 100% more. Less wind, more water vapour and heat loss at night all cause this increase. Summer: 30% more.

Pollutants: Solid particles are 10 times more. Much of this is dust raised by automobiles. Traffic also grinds concrete to create very fine dust particles.

In some places the terrain can accentuate the conditions of the urban heat island. On the coast sea breezes develop during the day even if the overall wind pattern isn't from the west. In other locations cold air drains down off the mountains counteracting the onshore airflow, which results in the cold air trapping and holding the urban heat island air. If this condition persists for too long the

materials, including pollutants trapped in the dome build up and became problematic. This was the situation that made Los Angeles one of the most polluted cities.

Researchers have tried a variety of methods to obtain accurate measurements of the heat island. Thermometers for every block of the city would be ideal and provide a detailed view of the surface, but is too expensive. Few have attempted to measure the vertical component using tethered balloons and even helicopters. Unfortunately the down draft from the blades and heat from the engines made the helicopter a poor platform.

The standard method developed by Chandler in London was to attach shielded thermometers, usually thermocouples with instant response, on the front of a car. Traverses along major routes provide longitudinal profiles of the temperature variation across the city. At 12:30 am on September 15, 1973, Oke and Hay, researchers at the University of British Columbia, did a traverse of 26 km across Vancouver. Results showed many interesting changes.

- Temperatures ranged from about 7°C in the countryside to 15°C in the heart of the city (CBD).
- The most dramatic drop from 14°C to 8°C occurs in about 3 km from the suburbs to the countryside.
- Green spaces, even small ones, were distinctly cooler.
- Stanley Park with its tall trees was the coolest.
- The highest temperature is at Georgia and Burrard despite the proximity of the water in the harbour.
- The parks, although cooler, were still warmer than the countryside.

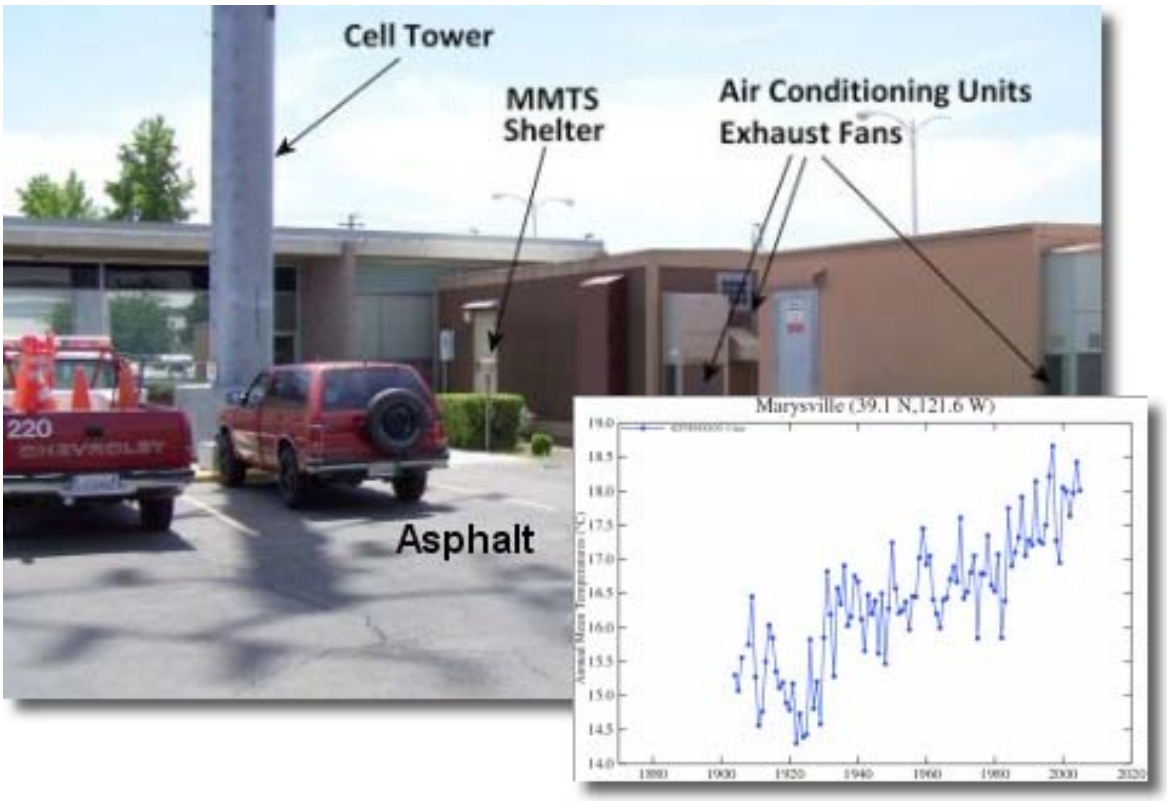
The dome of warmer air over the urban heat island is usually fully developed at night. If there is no wind it will remain in place, but gradually dissipate as the warm air rises and cooler air moves in from the suburbs in daytime. If the wind is blowing the dome will move away from the CBD toward the suburbs and countryside, unfortunately carrying the higher levels of dust and poor quality air.

Over the years the city has filled in around the airport so the urban heat island has increased its influence beyond the wind effects. When you separate urban weather stations from rural ones anywhere in the world a different trend of temperatures appears. Urban stations show a distinctive warming while there is very little change in rural stations.

The size of the city is important because it determines the amount of extra heat generated by industry, automobile and people. But studies at airports show that jet aircraft taxiing nearby or even heat from the darker surface runway can cause different readings. In other words even small, modified surfaces can create

change. The World Meteorological Organization (WMO) is very concerned about the location of instruments and changes in the surrounding area. Unless a station has remained in a completely unchanged environment it's likely the readings have changed over time. Little research exists to determine how large an area must remain unchanged, but one suspects it is quite large to be beyond the heat transported by wind.

Recently a new twist was added to the problem of the accuracy of the temperature measurements because of degradation and inappropriateness of the sites. Some questions were raised, but it wasn't until Anthony Watts decided to visit and record the conditions of sites within the US that the extent of the problem was seen. Here is just one example of the problems found at an official site. The source of the photograph is given below and anyone who wants to see the extent of the problem will find how many of the official sites are seriously compromised. The photograph is accompanied by a plot of the temperature curve for the site showing the increasing temperature most probably attributable to the artificial heat sources in the immediate vicinity.



http://www.surfacestations.org/

There are more detailed questions about the techniques used by those agencies such as the Goddard Institute for Space Studies (GISS) to adjust for the UHIE. The crux of the problem is examined here;

http://www.climateaudit.org/?p=2826

To the public a debate about tenths of a degree in temperature may seem specious and academic. Others have raised the issue that the original data is only recorded to one half a degree so reducing it tenths through statistics becomes redundant. Precision is important because a 0.6°C increase in the temperature record over 130 years was presented as not natural and therefore clear evidence of global warming due to human addition of CO2 in the atmosphere. Accuracy of the global average temperature is very questionable, especially as the basis for 'proving' humans are causing global warming.

We have become more conscious of the quality of life in our urban areas, but most of this is directed to visual and aesthetic considerations. The role and importance of vegetation in the city especially treed areas, needs much more attention. I had the privilege of speaking at the first Canadian conference on urban forests some years ago, but the concept needs momentum.

There is no doubt all towns and cities have modified their climate. The amount varies, but generally the larger the community the greater the change. Society has concerned itself with the forests outside the city limits, but they are probably even more important inside. Vegetation not only modifies the climate and creates areas of cool; it also absorbs pollution and particles. The more plants of any size we can incorporate into the built up areas the better. Every community should create a department of flora and fauna and establish development strategies that use knowledge about urban climates.

Dr. Tim Ball September 2008