Taking Melbourne's Temperature

T W Quirk
twquirk@labyrinth.net.au

Abstract

The raw Melbourne temperature records of the Bureau of Meteorology are compared to the ACORN-Sat values. The ACORN-Sat adjustments are evaluated. This analysis shows evidence for a strong urban heat island effect.

The Melbourne temperature record is one of the "long time" instrumental records of Australian temperature. It starts in 1855 and continues to the present day. Originally measurements were made in the Flagstaff Gardens. Then when the Melbourne observatory was established in 1863 near the Botanical Gardens, the measurements were taken at that location until 1907 when there was a move to the present location on the corner of Victoria and Latrobe Streets in central Melbourne.

The raw annual average measurements[1] are shown in Figure 1. The Melbourne location statement (July 2014) records no thermometer changes between 1907 and 2000 for the minimum-temperature thermometer and between 1907 and 2001 for the maximum-temperature thermometer

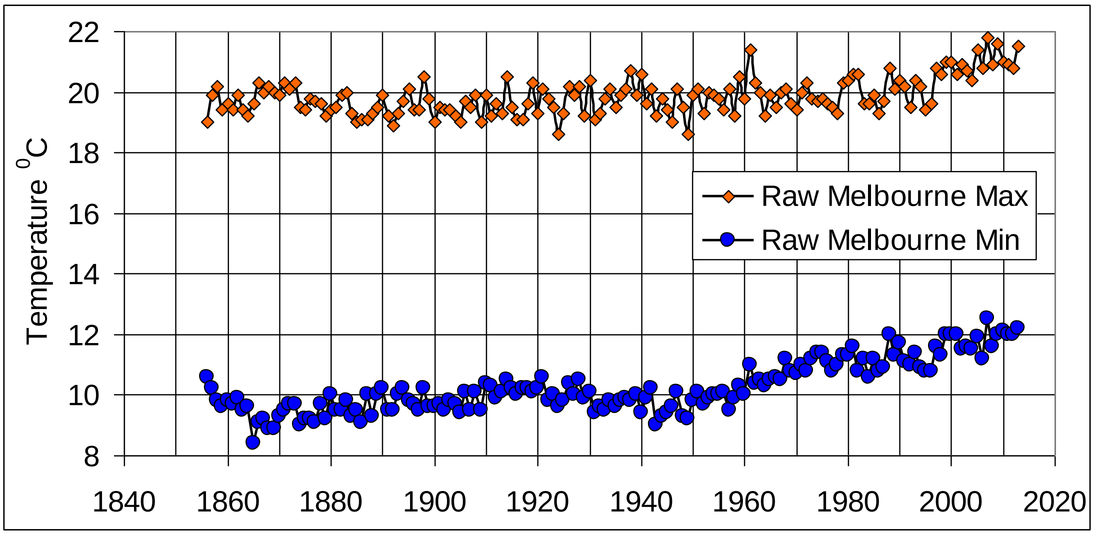

Figure 1: *Melbourne Regional Office annual average minimum and maximum temperatures, first measured in the Flagstaff Gardens, then at the Observatory, and then from 1907 at the present site, the corner of Victoria and Latrobe Streets.*

The Bureau of Meteorology (BOM) considers only the measurements after 1910 as being reliable but note that the raw record itself does not suggest anything wrong with the earlier data.

The maximum temperature, which generally occurs in the middle of the afternoon, shows almost no trend at all until about 1995. However the minimum temperature, which generally occurs in the early morning before sunrise, shows an upward trend starting at about 1945. With no sunlight on the ground, the night air cools but the heat emitted by buildings and human activities, the "urban heat island" effect, lessens the cooling. The upward trend of minimum temperature since 1945 perhaps reflects the change in the number and size of the buildings in the area surrounding the location of the thermometers.

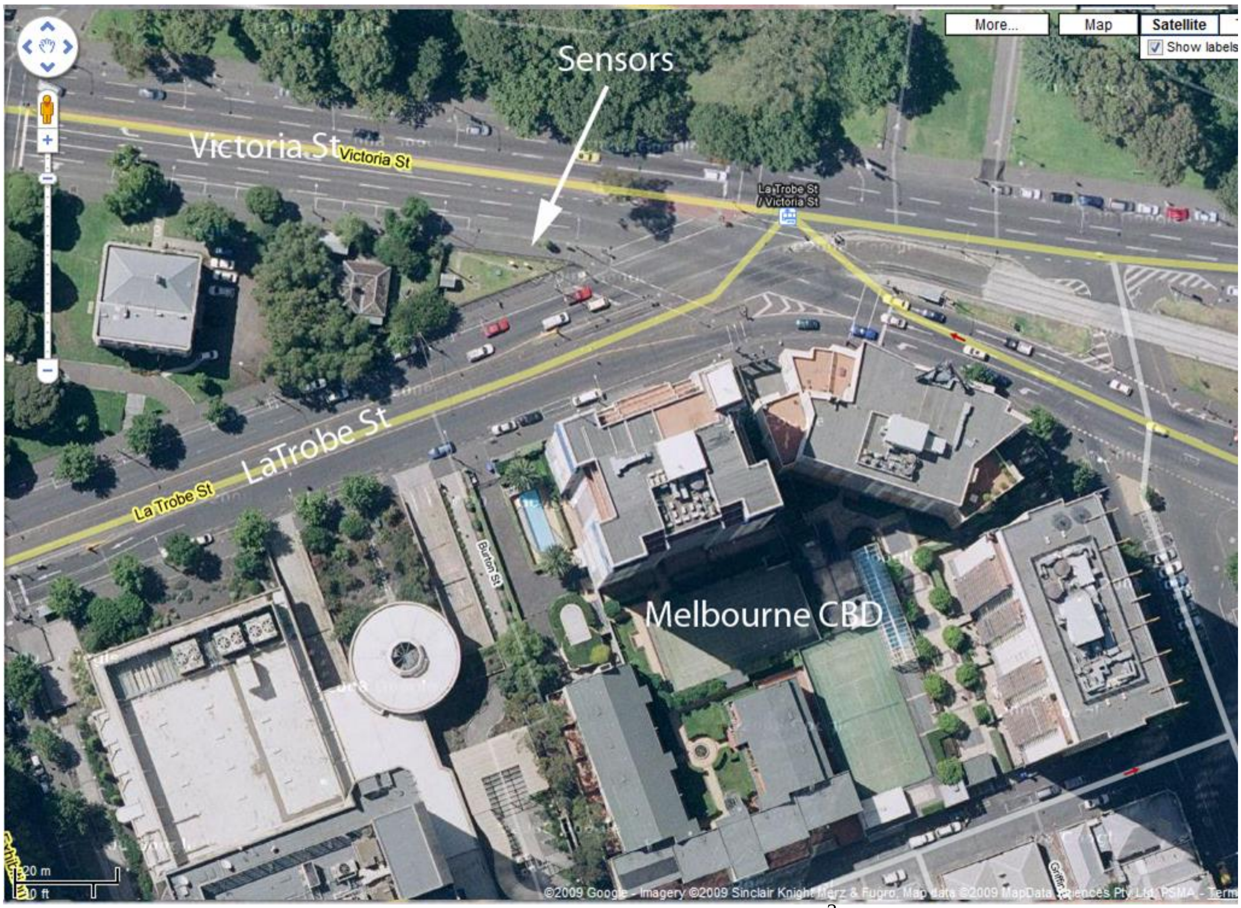

Figure 2: *Site of the BOM Regional Office measurement station*[2]

We can compare the Melbourne measurements with those starting in 1944 at Laverton, some 20 km from the Melbourne Regional Office location. See Figures 3 and 4. The Laverton instruments were moved some 1.2 km from the original site in 1997. One year of overlap measurements at Laverton show no significant change at that time in maximum-temperature readings, but do show a 0.2 degree decrease in the minimum-temperature readings.

Figure 3 shows an increase in the minimum temperatures, using the raw data, at the Melbourne location compared to that at Laverton from 1944 to the present. The comparison, roughly an increase of about 2 degrees compared with an increase of about 1 degree, is almost certainly an indication of the much larger urban heat island effect in Melbourne. Figure 4 shows both the maximum temperatures and the trends of maximum temperature in Melbourne to be much the same as in Laverton.

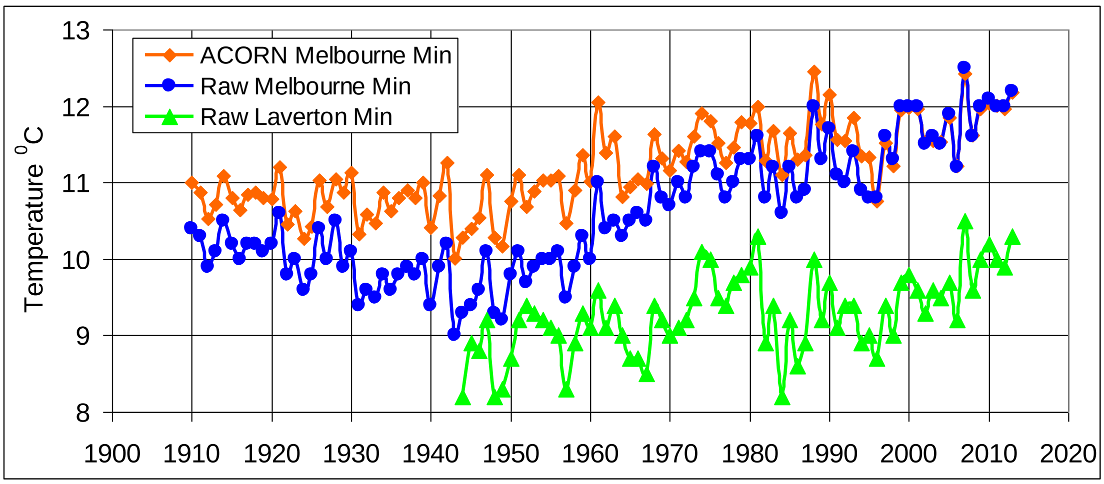

Figure 3: *Annual average minimum temperatures for the ACORN-SAT homogenized Melbourne Regional Office measurements, raw minimum temperatures for the Melbourne Regional Office and Laverton.*

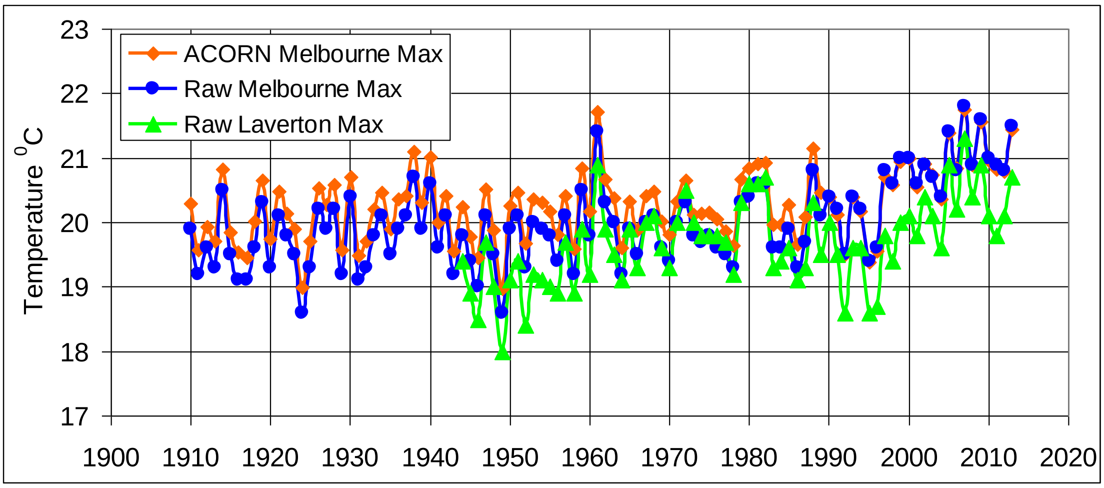

Figure 4: *Annual average maximum temperatures for the ACORN-SAT homogenized Melbourne Regional Office measurements, raw maximum temperatures for the Melbourne Regional Office and Laverton*

The third temperature series in each of Figures 2 and 3 is of the average annual temperatures recorded in the ACORN-SAT data[3] which has been "homogenized" by the Bureau of Meteorology. A comparison of the measured and adjusted temperature increases from 1944 to 2013 is shown in Table 1.

Table 1 Temperature increases from 1944 to 2013

Locations	Minimum temperature increase ^{0}C per decade	Maximum temperature increase ^{0}C per decade
ACORN-SAT Melbourne	0.18 ± 0.02	0.13 ± 0.03
Raw Melbourne	0.35 ± 0.02	0.21 ± 0.03
Raw Laverton	0.14 ± 0.03	0.16 ± 0.03
Raw Melbourne – Raw Laverton	0.21 ± 0.03	0.05 ± 0.05

Two conclusions can be drawn from this analysis:

- There is a clear heat island effect in central Melbourne that is detectable in the minimum temperature measurements. It may be as much as 0.2 degrees per decade (or 1 degree over 50 years!).
- The adjustments made to obtain the homogenised ACORN-SAT Melbourne data reduce the apparent long-term temperature increases. So these adjustments compensate somewhat for the urban warming but by increasing the temperatures of the earlier years!

The result of the ACORN-SAT adjustments made to the raw data for Melbourne is illustrated in Figure 5. There are sharp breaks rather than gradual changes that would be expected from the slow growth of the urban surroundings. The breaks do no appear to coincide with instrument changes. The Bureau explains the adjustments for the maximum and minimum temperatures as being "statistical".

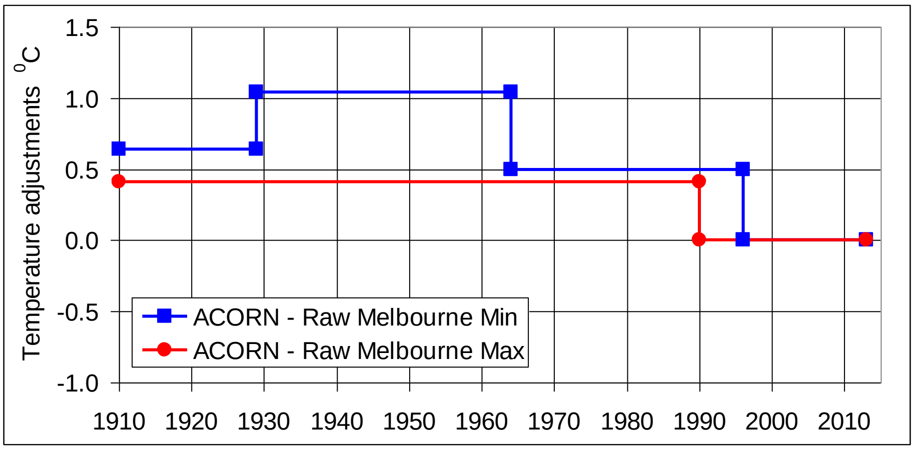

Figure 5: *ACORN-SAT adjustments to the raw Melbourne temperature measurements shown in Figures 2 and 3.*

In more detail, the ACORN-SAT Melbourne minimum temperatures before 1990 are shifted up relative to the raw data. The stepped adjustments would suggest instrument changes but the BOM records show thus is not the case. Further, there is no sign of the step changes in the direct Melbourne temperature records. An upward correction is also applied to the maximum temperatures, but is applied only to the past, before 1990, and not the present.

A step adjustment does not compensate for a gradual rise due to an urban heat island effect.
Would a time of observation change need a step adjustment? The explanation for the step change in 1964 is a change in the reading time of the thermometers from midnight before 1964 and at 9.00 am after 1964. This seems a remarkable adjustment. If the thermometers were read at midnight then the minimum and maximum would be for that day while a shift to a 9.00 am reading would give the minimum temperature for the day of the reading but the maximum for the previous day. How could this give rise to an adjustment? Even if the temperature were recorded for the wrong day only one day in a year would be wrong and then only by a small amount.

The Melbourne mean annual minimum and maximum temperature readings are shown in Figure 6. There is an unusual feature in the maximum record occurring in 1996. It is a break with a difference of 0.7 +/- 0.2 ^{0}C. The two straight lines are a best fit to the measurements and the difference is calculated from the line values in 1996. There is no statistically significant break in the minimum record. The fits are made between 1960 and 2014 as the minimum temperatures start increasing in the 1940s.

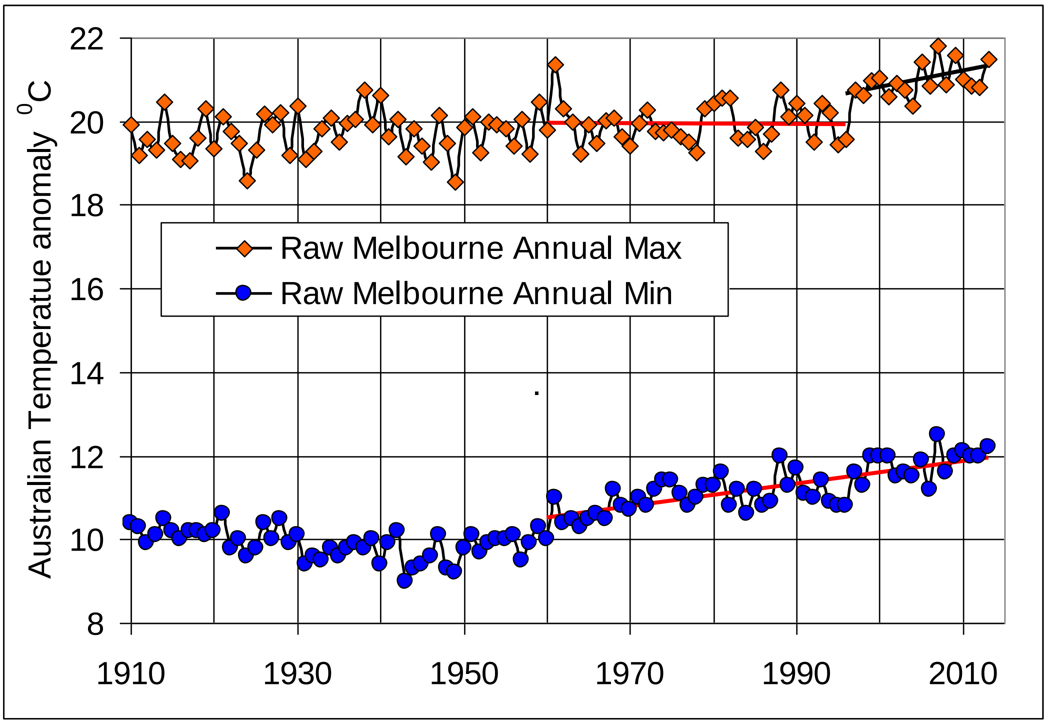

Figure 6: *Annual average raw minimum and maximum temperatures for the Melbourne Regional Office. The straight lines represent the best fit for two lines for the maximum record and one straight line for the minimum that shows no statistically significant break.*

The ACORN-SAT adjustment record (Figure 5) shows only an increase of 0.41 ^{0}C to the maximum temperature record starting at 1 Jan 1990. This adjustment is explained as "*statistical*". Interestingly the adjustment record shows a break in 1996 for the minimum temperature record and this change is ascribed to a new large apartment building "across the street to the south of the site".

It would appear that this step in 1996 is not a thermometer change as none is detailed in the raw data site record. However in the ACORN-Sat record a change to an Automatic Weather Station (AWS) is noted for 1996! An instrument change being the cause is ruled out by the above analysis. However the maximum temperature break does indeed come from the screening of the site from summer southerly winds[4] by the building of "City Gate" at 33 La Trobe Street (Figure 7). This is a 15 story 50 m high apartment tower completed in 1997 and to its east a further apartment building completed in 1998. These building are visible in Figure 2 on the south side of La Trobe Street and to the south east of the thermometer positions.

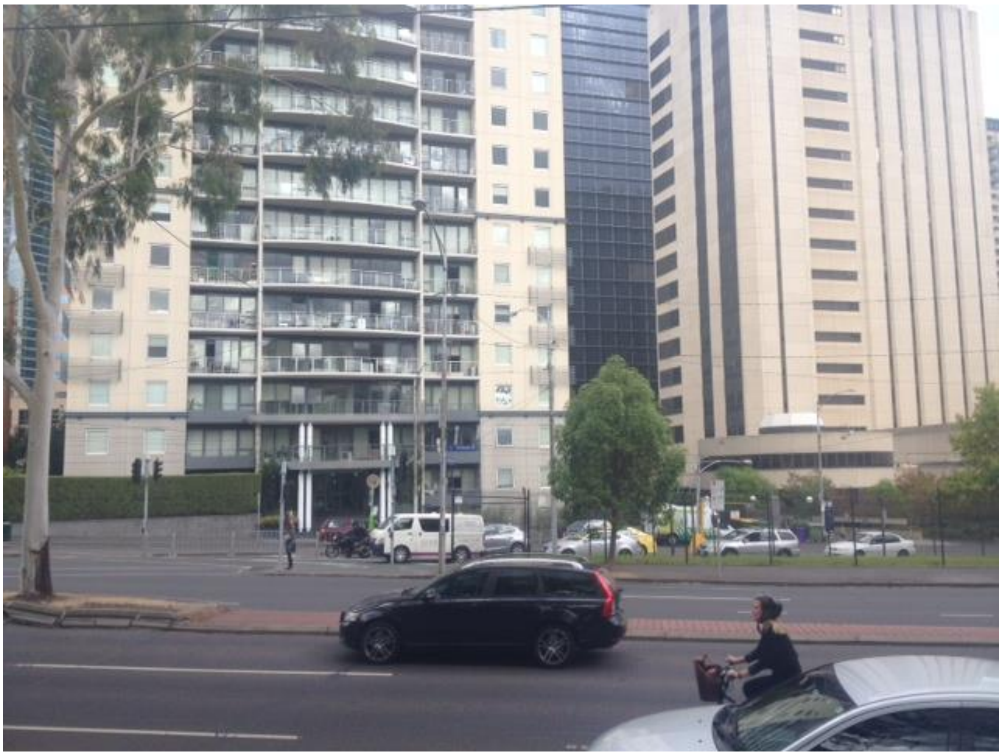

Figure 7: *CityGate tower directly to the south east of the BOM thermometer site in 2015 after the site was closed (see Figure 2)*

The explanations of the ACORN-SAT data adjustments do not provide much support for their validity. Only one of the many adjustments seems to be specifically linked to a change in procedure, and the term "statistical" conveys no physical or procedural change as justification.

The Importance of the Urban Heat Island Effect

The changes in temperature can be further explored by looking at summer and winter time series. Summer is the months of December, January and February while winter is June, July and August. The annual maximum temperatures for summer and winter are shown in Figure 8 and minimum temperatures in Figure 9.

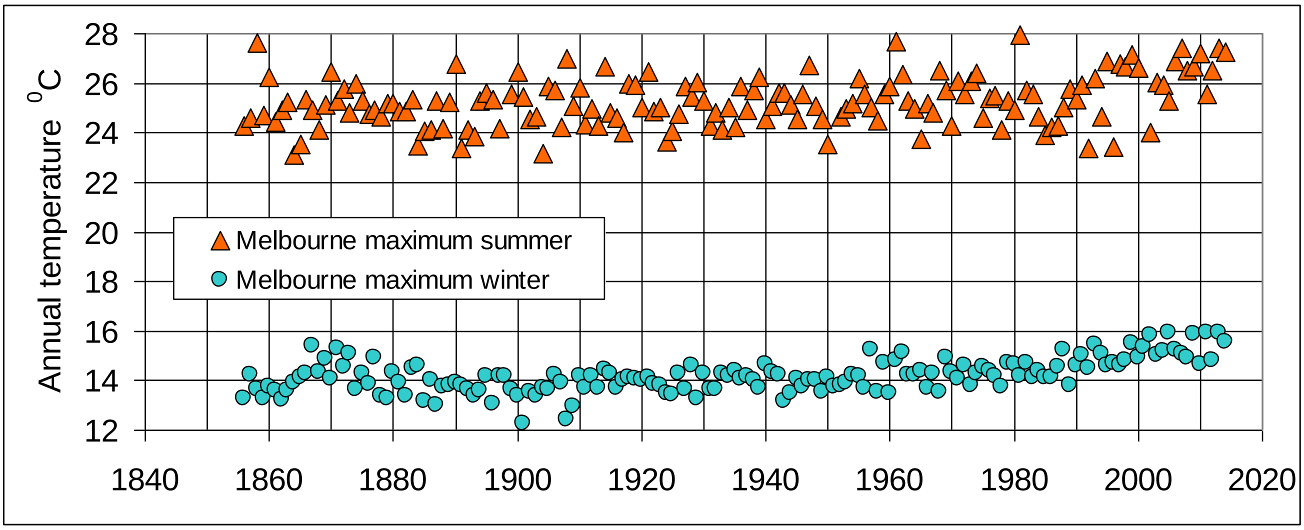

Figure 8: *Melbourne Regional Office annual summer and winter maximum temperatures*

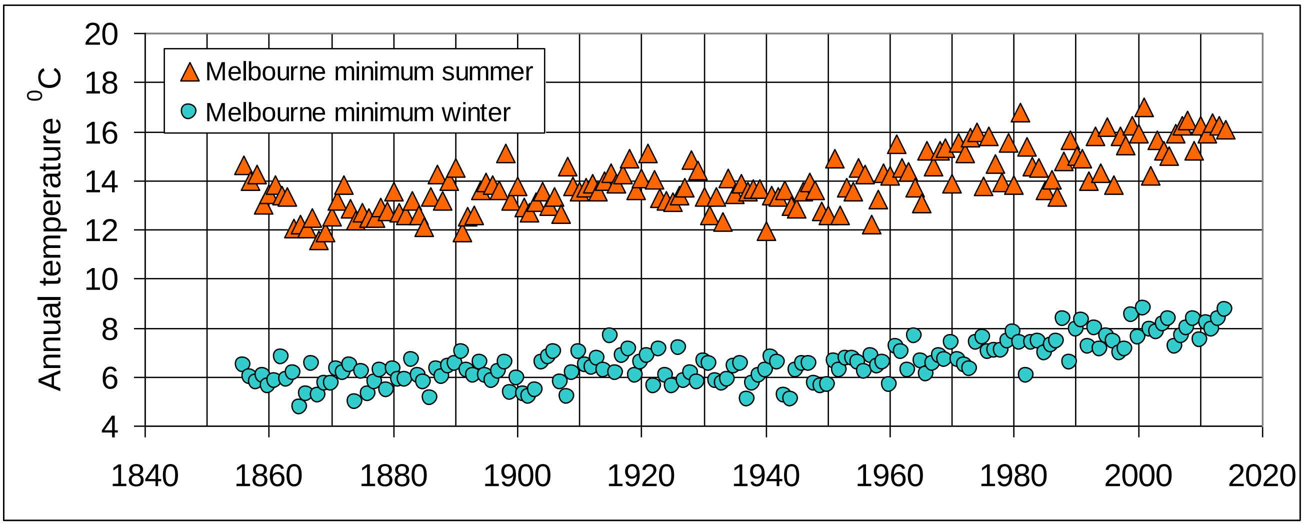

Figure 9: *Melbourne Regional Office annual summer and winter minimum temperatures*

There are two significant features for these time series:

1. The maximum summer temperature shows no increase in temperature from 1863 to 1996 when the site was effected by high rise buildings nearby. In fact the change from 1863 to 1996 is 0.03 +/- 0.02 ^{0}C per decade. This a rise of 0.45 +/- 0.29 ^{0}C in 133 years
2. The summer minimum and the summer and winter minima all show an increasing temperature after the mid 1940s. The increases are summarised in Table 2.

Table 2 Minimum and maximum temperature changes

1950-2014		**Temperature increase ^{0}C per decade**
Summer	Max*	-0.12+/- 0.12
	Min	0.23+/- 0.03
Winter	Max	0.36+/- 0.06
	Min	0.30+/- 0.03
Annual	Min	0.33+/- 0.02

* 1950-1996

It is apparent that the urban heat island effect is present in both minimum and maximum temperature records.

This effect is well illustrated by comparing the La Trobe Street - Victoria Street measurements with the new BOM site in Olympic Park, some 2.5 km distance to the south. There is some overlap of the sites and Figure 10 shows 19 months of overlap.

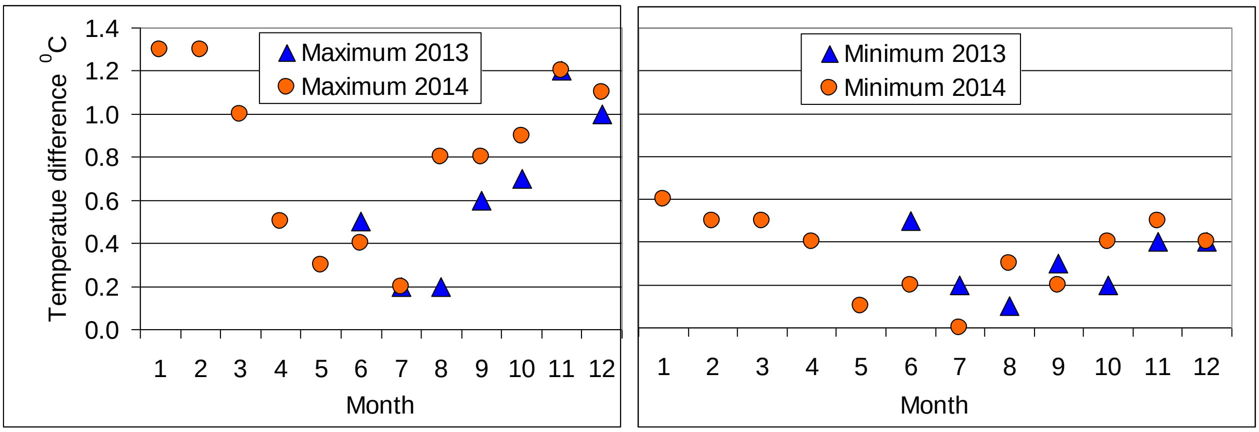

Figure 10: *Differences for BOM Melbourne Regional Office less Olympic Park monthly mean temperatures.*

The differences are greatest in the summer for both minimum and maximum temperatures. This indicates a strong urban heat island effect over a short distance of 4 km. This raises the question of how well sites can be used to determine adjustments if their monthly temperature variations are different.

Conclusions

There are two conclusions that arise from this analysis:

- It appears that not sufficient attention has been paid to examining the site surroundings and
- "Statistical" evidence is only useful if it can be used as a guide to finding instrumental or environmental changes.

The Melbourne measurements may not be used to derive the continent-wide Australian temperatures. Even so if the treatment of the Melbourne temperature measurements is an indication of the quality of the other homogenized measurements then there is a need to refine the analysis.

Finally the purpose for assembling the extensive temperature record is not clear as the "temperature" is what is measured and the ACORN-Sat adjustments give rise to a construct. If this is used to estimate mean temperatures then the problems of averaging minimum and maximum temperatures to give a mean raises a further series of problems that have not been addressed.

References:

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[1] Raw data: http://www.bom.gov.au/climate/data/index.shtml

[2] Image supplied from Joanne Nova- see http://joannenova.com.au/2014/09/the-hotter-nights-in-melbourne-and-some-mysterious-adjustments/print/

[3] ACORN-SAT information and data: http://www.bom.gov.au/climate/change/acorn-sat/

[4] http://www.emelbourne.net.au/biogs/EM00360b.htm

The wind varies from day to night and from season to season. Wind speed is usually lowest during the night and early hours of the morning before sunrise. It increases during the day as heating of the earth's surface induces turbulence in the wind stream. Wind also varies, with very localised effects of some weather phenomena such as showers and thunderstorms. Examples of the diurnal variation are the sea breeze, which brings relief on many hot days, and the valley or katabatic breeze, which brings cold air from inland Victoria down valleys during the night and early morning towards Melbourne. These breezes are responsible for winds being more often from the north during winter, particularly during the morning. They are also responsible for **winds being more often from the south during summer, particularly during the afternoon**. This is in spite of the predominant wind stream being westerly in origin. There is a marked tendency for the very windy days to occur during the late winter and early spring months. Melbourne's strongest wind gust on record is 120 km/hr on 3 September 1982