Simple investigations of local microclimates using an affordable USB temperature logger

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Introduction

The exploration of microclimates has long been a popular and fruitful area of study, for example to show the urban heat island effect across a city (Chandler, 1965; Knight *et al.*, 2010), in school grounds as a GCSE fieldwork project (Royal Geographical Society, 2014) or for planning gardens (Royal Horticultural Society, 2011). Over the past couple of years, USB temperature loggers have become available that potentially could make such investigations easier. I have looked at the suitability of one such device, the Mindsets Mini USB Temperature Datalogger, which is small, cheap (about £17 + VAT)[1] and simple to use, and I report some of the results here. The device (henceforth referred to as a 'logger') looks like a memory stick, measuring about 70mm × 20mm × 10mm, but actually contains a temperature sensor, clock, data logger and battery (Figure 1). The battery lasts a year or so and can be easily replaced. The logger can record 8192 temperature/time pairs at a sampling rate controllable by the user, ranging from once a second to once an hour, giving a recording period from 2h to almost a year.

To download the data, the logger is simply plugged into a USB port of a PC, and the software (available free online) transfers it to an Excel spreadsheet, and also plots a self-scaling temperature versus time curve that can be saved as a pdf file. Inserting two or more (up to 10) loggers in succession allows the data from all devices to be saved on the same spreadsheet, and labelled and plotted on the same graph. The loggers can then be reset for their next use. They cover a temperature range of −20 to +60°C, enough to cope with all but the most extreme UK temperatures, with a resolution of 0.1 degC over most of the range. Of course, resolution is not the same thing as accuracy, and the latter is investigated below. The logger is housed in a plastic case with a single ventilation hole; the case can be easily removed to allow better exposure of the temperature sensor. This paper looks at some characteristics of the device, and demonstrates ways in which it can be used for simple investigations, using logging intervals in the range 1–10min. Note that some of the measurements shown were carried out with an earlier version of the logger that had a temperature resolution of 0.4 degC.

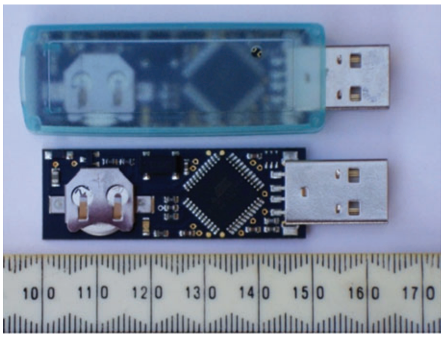

Figure 1. The temperature logger as supplied (top) showing the ventilation hole in the top right corner, and with casing removed (bottom): scale in mm.

Consistency and accuracy of measurements

If several loggers are to be used to compare temperatures at different places, then they obviously need to agree with one another (ideally, but not essentially, with good accuracy). Figure 2 shows the temperatures over a period of nearly 3 days from 3 loggers taped together and placed sequentially at a number of places in a house (starting with an airing cupboard) and garden.

As can be seen, the three devices track well; the average temperatures were in fact all within a range of 0.2 degC, and the standard deviations of the differences between one logger and the other two were both 0.11 degC. Figure 3 shows the minute-by-minute differences over the whole period; for the vast majority of the time the loggers agreed to within ±0.3 degC. The larger differences evident in Figure 3 occur at times when the logger was moved rapidly between locations with very different temperatures seen in Figure 2, for example when the logger was brought in from outdoors (1°C) to an inside room (15°C). This sort of difference may be due to somewhat different response times, the room having no air movement, and would not occur when outdoors. Of course, comparisons using only three devices are hardly exhaustive, but they do provide a promising indication that consistency between devices is good.

Accuracy of the three loggers was investigated by immersing them (in a plastic bag) in a bath of ice slush, which was stirred for about 20min. Once they had become stable, the logged temperatures recorded 0.2, 0.5

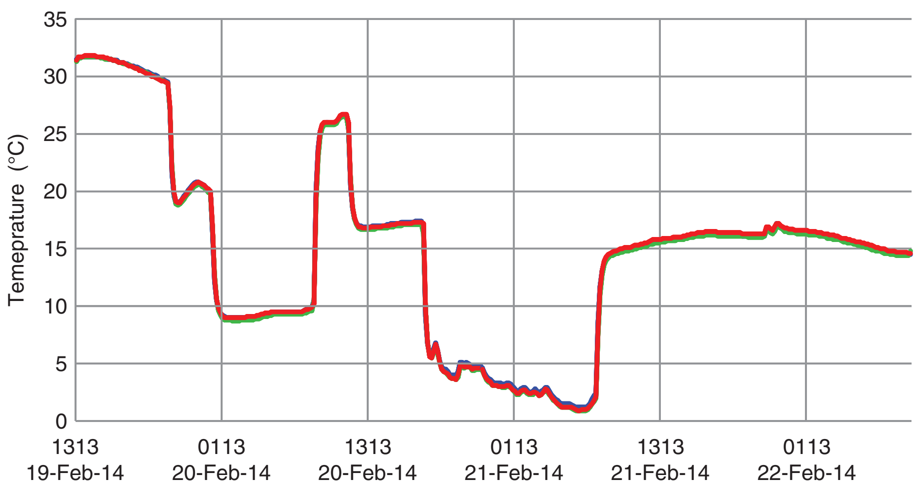

Figure 2. Temperature traces from three loggers over the period 19–22 February 2014, with times in UTC.

[1] http://mindsetsonline.co.uk/Site/dataloggers/

and 0.6°C respectively. To extend this accuracy test to a wider range of temperatures, one logger was taped underneath the radiation screen of a Davis Vantage Pro2 weather station; the latter's specification quotes a temperature accuracy of ±0.5 degC. Figure 4 shows the two temperature traces over a period of five nights, selecting only those times when solar radiation was zero, in order to avoid times when the exposed logger was heated by the sun. As can be seen, the logger tracks the weather station temperatures quite well, albeit over a restricted temperature range; the difference between the two has a mean of 0.2 degC and a standard deviation of ±0.1 degC.

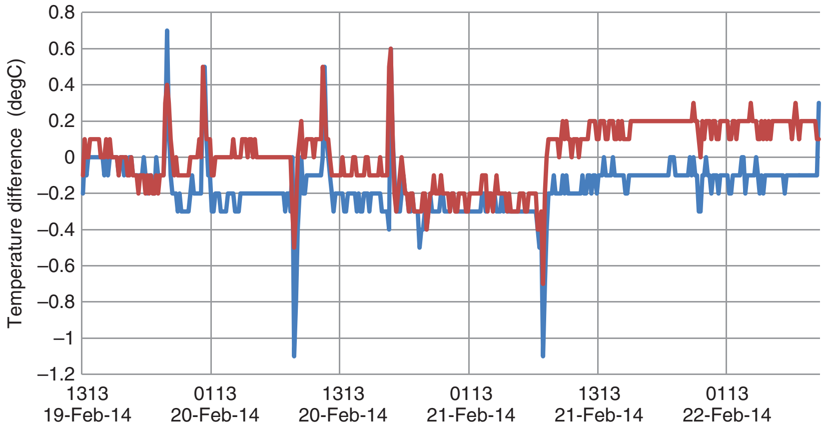

Figure 3. Temperature differences between one of the loggers (arbitrarily chosen as a reference) and the other two, during the same period as in Figure 2.

Some investigations

The sample investigations discussed below illustrate the flexibility of the logger, but two practical points need to be borne in mind. First, if exposed to direct sunlight, the logger will record the temperature to which it is itself being heated, rather than the air temperature it is trying to measure – this is of course true of all types of temperature sensor. To minimise this problem in general outdoor use the logger would need to be housed in a simple screen that shades it from sunlight yet allows adequate flow of ambient air (the screen would also prevent errors from infrared cooling at night); however, I have not investigated ways of doing this. Second, when outdoors, the devices must be protected from damage by rain or dew – a 70mL plastic yogurt pot with a snap-on lid fits the bill nicely. However, if the pot itself becomes wet then it will act as a wet bulb and indicate temperatures lower than the air temperature.

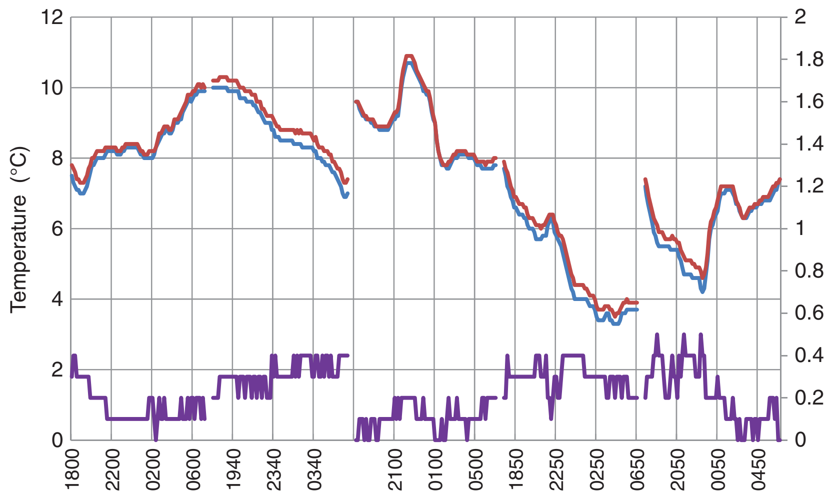

Figure 4. Temperature from the logger (blue) and Davis VP2 weather station (red) over the five nights 22–27 February 2014, and the difference (degC) between them (purple, right-hand scale): times in UTC.

Temperature at various locations in a domestic garden

The microclimate around a school or garden is a popular topic of investigation, and Figure 5 shows the variation in temperature over two nights and one day at five locations around the author's house and garden. On the second (clear) night the grass surface of a small (10m × 7m) back lawn fell to −3.5°C, even though surrounded by fences and walls. Just 2m away, the surface of a bare-soil flowerbed at the base of a garage wall was some 4 degC warmer. At a very sheltered location in the 3m wide passage separating two houses, the temperature was some 7 degC warmer than the lawn. Increasing cloud after about 0100 UTC raised temperatures, so that by 0800 UTC all sensors were in the range 4–5°C.

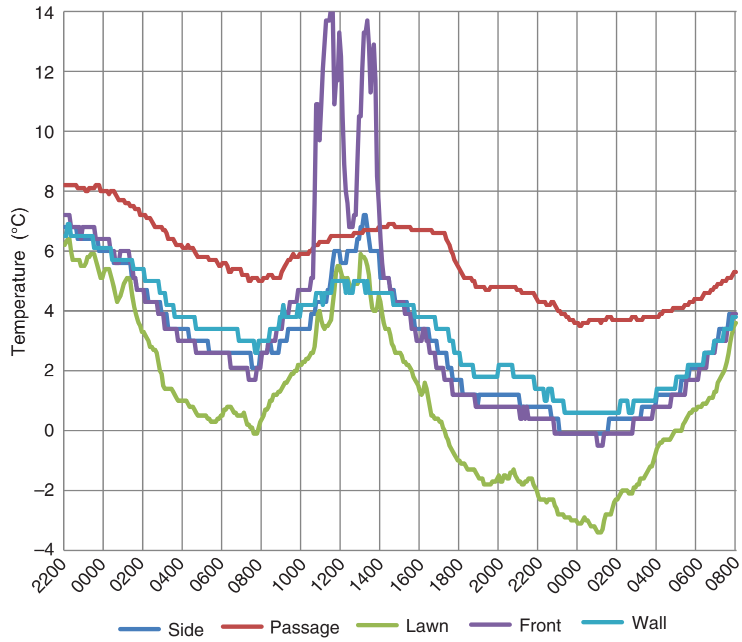

Figure 5. Temperature over the period 2200 UTC on 18 November to 0800 UTC on 20 November 2013 (times in UTC), at five locations around a house and garden. The spikes on the 'Front' (purple) trace are where direct solar radiation has heated up the container, and hence the air around the sensor, well above ambient air temperature.

Temperature above and below snow

Snow provides a blanket over the ground that can prevent the loss of heat. Figure 6

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shows traces from three loggers placed in the middle of a snow-covered lawn, one buried under 10cm of snow, one on top of the snow and one on a nearby cleared grass patch. At the snow surface, temperature drops away to −7°C during the clear night, whereas snow insulation prevents the buried sensor from falling below about −1°C, some 6 degC warmer than the air above. The grass surface stays a degree or two warmer than the snow surface. After about 0530 UTC, the surface temperatures start to rise, probably due to increasing cloud cover.

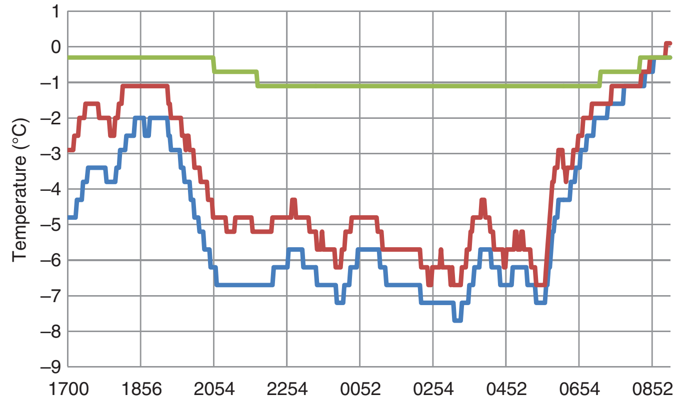

Figure 6. Temperature versus time of day (UTC) on grass under snow (green), on the surface of the snow (blue) and on a cleared area of grass (red), during the night of 20/21 January 2013.

Temperature variations above and below ground

Figure 7 shows the variation in air temperature and soil temperature at two depths (roughly 10 and 20cm) below a grass surface over 8 days in July 2013; the air temperature was measured by a Davis VP2 weather station and the soil temperature by two loggers. The reduced range of diurnal temperature variation at 10cm, and especially at 20cm, compared with air temperature, can be clearly seen. The graph also shows the way in which the daily peaks in 10 and 20cm soil temperatures lag behind that in air temperature.

This lag is more clearly shown in Figure 8, where the diurnal cycle over the 8 days has been averaged. The maximum surface air temperature occurs at about 1630 UTC, whereas the maxima at 10 and 20cm below ground occur at about 1900 and 2100 UTC respectively, that is, some 2.5 and 4.5h later than the air temperature.

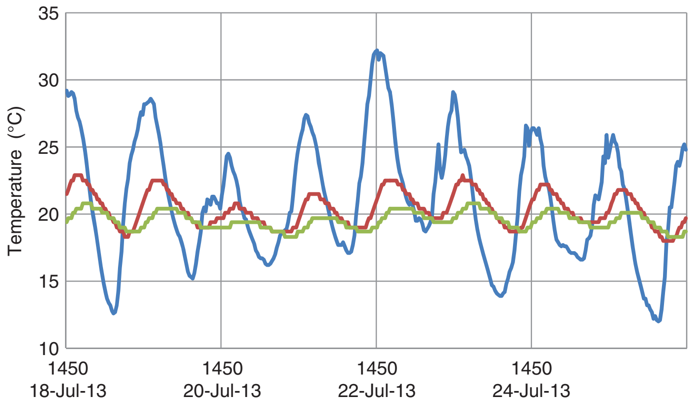

Figure 7. The air temperature at a height of 1.2m (blue) and soil temperatures at depths of 10cm (red) and 20cm (green) below a grass surface: times in UTC.

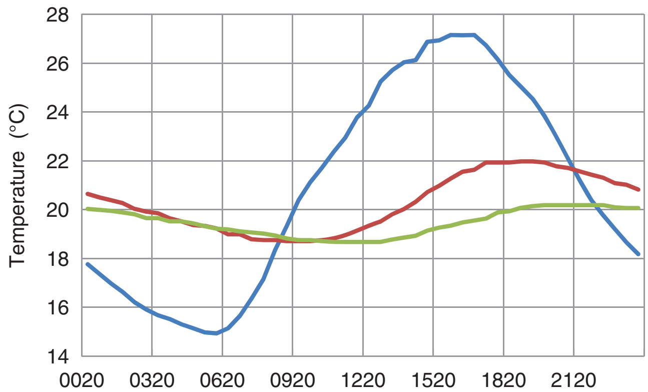

Figure 8. The air temperature at a height of 1.2m (blue) and soil temperatures at depths of 10cm (red) and 20cm (green) below a grass surface, averaged over the 8 day period shown in Figure 7: times in UTC.

Temperature under garden fleece

Garden fleece is claimed to be able to protect young plants from frost, but does it work? Figure 9 shows temperatures through a cold, clear, night measured by two loggers about 10cm apart on the surface of a lawn, with one covered by four layers of very thin garden fleece; the fleece kept the grass surface up to 4 degC warmer than the totally exposed lawn.

The heat island effect of a town

The way in which towns tend to stay warmer than the surrounding countryside on clear nights is known as the urban heat-island (UHI) effect, one of the main causes of which is the storage of daytime heat in buildings. To investigate this, a logger was placed in a plastic bag, taped to a car aerial, and driven from about 10 miles outside Reading, into the town centre and back out the same way, on a clear, calm, night. The temperature cross-section is shown in Figure 10, in which the centre of the town can be seen to be some 4 degC warmer than the

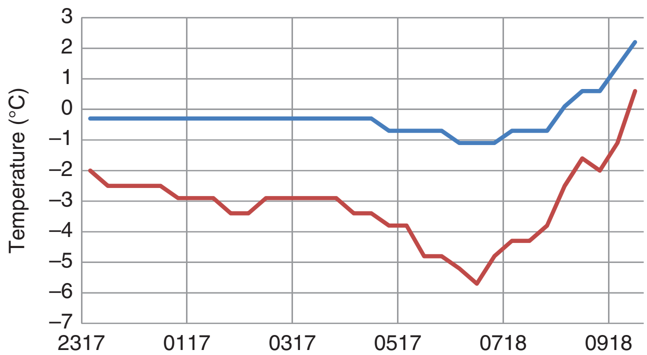

Figure 9. Temperatures during the night of 6/7 February 2013 (times in UTC) at the surface of a lawn open to the sky (red) and nearby but covered with a garden fleece (blue).

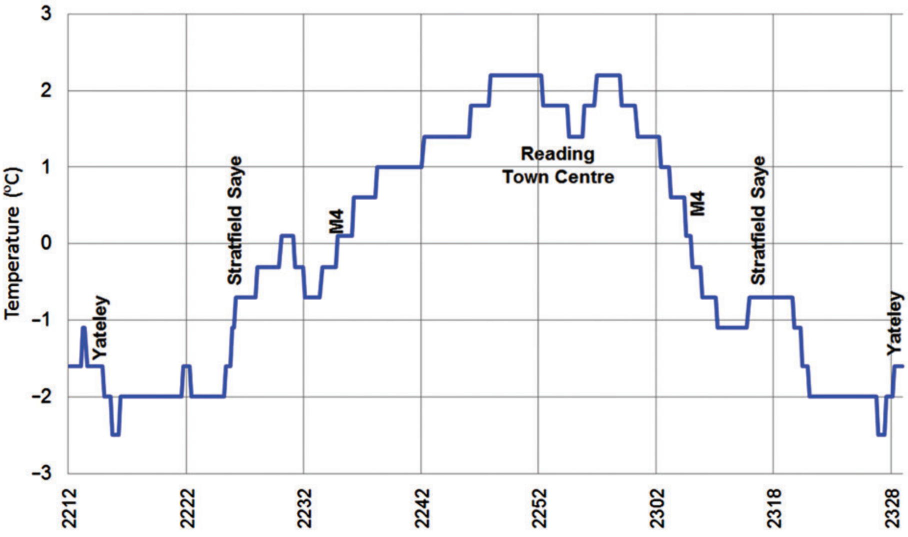

Figure 10. The heat island effect of Reading, 18 February 2013. A temperature cross-section going from the surrounding countryside into the town centre and back out again, with times in UTC.

surrounding countryside. The low cost of the logger would allow many of them to be deployed (suitably screened) for a month or so to explore the temporal and spatial characteristics of the UHI effect in very great detail.

Light logger

The same company also manufactures a similar sized USB logger that measures light level in lux. This, in a suitable housing, is being investigated as a possible sensor for solar radiation. Early results are promising, and a future paper is planned.

Conclusions

The Mindsets USB Temperature Datalogger is a cheap, small, versatile and acceptably accurate device. It is suitable for use in a wide range of easily undertaken and informative investigations of temperature microclimate in buildings, gardens and school grounds, as well as over a wide urban area. It may also be considered as a replacement for a thermograph in a thermometer screen.

Acknowledgements

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Obituary

Sir (Basil) John Mason 18 August 1923–6 January 2015

Sir John Mason, distinguished academic and former Director General of the Meteorological Office died on 6 January.

John Mason obtained a First Class degree in Physics from the University of London and was appointed lecturer in the Meteorology Department of Imperial College in 1948, following national service in the Radar Branch of the Royal Air Force. He was elected Fellow of the Royal Meteorological Society in the same year. Following a period as Research Professor in the University of California he was, in 1961, appointed as the first Professor of Cloud Physics in the Physics Department at Imperial College. His time at Imperial College led to significant developments in understanding of the physical processes operating within clouds. His classic textbook *The Physics of Clouds* was published in 1957.

I first met John Mason in 1963 while I was a second year undergraduate physics student at Bristol University looking for potential research opportunities. He had been invited to lecture to the student physical society and gave a stimulating presentation on an area of physics of which I had previously known nothing. His presentational skills were outstanding and he was a frequent panel member on such programmes as the Brains Trust where he tackled questions on a wide range of physics topics with similar enthusiasm. This enthusiasm helped him to build up a strong research group from which many students went on to become leaders of their own groups throughout the world. He would later boast that his past students and colleagues were to be found in all major cloud physics research groups. Laboratory studies formed a major part of the work at this time. The need for these was revealed by increasing numbers of field observations, which also provided a critical test of new theories. The development of