Is urban spread affecting the mean temperature at Armagh Observatory?

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1. Introduction

Meteorological observations have been made at Armagh Observatory (*Butler and Johnston, 1996*) since 1795. The records include one of the longest single-site instrumental temperature series in the UK and, indeed, Europe.

The Observatory is situated in 20 acres of land on a drumlin to the North East of Armagh town centre (Fig.1). The grounds surrounding the Observatory and its climate station have remained relatively unchanged over the past 200 years. However, in that time, the town of Armagh has spread in several directions, including to the north and east, past the Observatory site. Much of the development around the site has been in the form of housing built over the past 20-30 years and this development still continues.

It is a well documented fact that urban areas can cause localised climatic modification (*eg. Oke 1987; Ripley et al.1996*). One of the most obvious ways in which the local climate may be altered is in higher night-time air temperatures in the built up area as compared to the surrounding countryside. This "heat island" may result in minimum urban temperatures 5-6^{o}C greater than those of the surrounding rural area, in the early hours of calm, clear, nights in large cities (*Barry & Chorley 1992*).

With a population of around 14,000, Armagh, in UK terms, would be classed as a small town. Nevertheless, due to the fact that the built up area has extended beyond the Observatory site in the time during which instrumental meteorological observations have been made, the question of a possible non-climatic influence upon observed temperatures has to be considered.

2. Observations

In order to quantify the influence that urbanization may exert over air temperatures at the Observatory climate station, a comparative trial was initiated in February 1996.

Using equipment loaned to the Observatory by the Met. Office, three weather stations, A,B and C (Fig.1), were installed in rural locations, each approximately 1-2km from the urban boundary. The sites for these stations were carefully chosen to be as similar as possible to that of the Observatory climate station, O (Fig.1), to minimize any differences due to variations in shelter, topography, exposure, etc.

This required that each site be around 60m O.D., on a south facing slope with a grassy surface. In addition, it had to be reasonably accessible by road.

Following selection according to these criteria, Stevenson screens and rain gauges were installed on three suitable sites under the supervision of the Met. Office, on 22nd February 1996. To eliminate artificial temperature variations caused by the proximity of animals, a wire fence encircling each station, was constructed.

Observations commenced the following morning and, throughout the trial period, were timed, as far as possible, to coincide with the observations at the Observatory, bearing in mind that the total distance between stations was around 20km. Even so, the first readings were taken no more than 20 minutes before and the final readings no more than 20

minutes after the Observatory readings each day. Thus any bias which the slight differences between observing times may have introduced was kept to a minimum. A record of maximum and minimum air temperatures, wet and dry bulb temperatures and rainfall was made each morning at each station. However, when the daily maximum or minimum temperature occurred close to the time of observation, the readings for these days were excluded from subsequent analysis.

Within a few weeks of the commencement of the experiment, it became apparent that at one of the selected sites there were irregularities in the pattern of temperatures observed. The night-time minima at site B (fig.1) were generally 1-2^{o}C lower and the day-time maxima 1-2^{o}C higher than the other rural stations. In view of this, the thermometers at all three rural stations were tested by the Met.Office and were subsequently found to be accurate to within 0.1^{o}C.

It was found that site B was over-sheltered by nearby dense hedges and thus there was little air turbulence, even on breezy days. At night, cold air was 'ponded' by the hedges and this produced the abnormally low minima at site B compared to the other stations. The site was also located about 100m from, although approximately 10m above, an extensive area of flat marshy land. This factor may have further contributed to the anomalous temperatures.

Following our appreciation of these difficulties, another site, D (Fig.1), to the southwest of Armagh Observatory was selected close the ancient earthworks known as The Navan Fort. Again, the physical characteristics of the site were similar to those of the Observatory station. The equipment from site B was installed at site D, again under Met.Office supervision. Readings obtained at this site, subsequently were found to be more consistent with those from the other two rural sites.

3. Results

In Figure 2 we show the differences in daily maximum and minimum temperatures, between the Observatory and the mean of the three outlying rural stations (A,C,D). We note that, apart from an overall zero point difference, there is little evidence for a trend in the differences with temperature. In Table 1, the mean differences are listed. The observations made at site B and those which were made close to the time the maximum or minimum temperature occurred have been excluded from these results.

Table 1.

Mean temperature differences between Observatory (O) and the mean of the three rural (R) stations (A,C & D), February to October 1996

Means	O	R	O-R
		deg.C	
tmax	14.63	14.52	0.11
tmin	6.9	6.53	0.41

The mean difference in daily maxima between the Observatory and the mean of the three rural stations is found to be 0.11^{o}C, whilst the difference in minima is 0.41^{o}C, with the Observatory station warmer than the mean of the rural stations in both instances.

4. Discussion

Taken at face value, the above results indicate that a temperature differential exists between the site of the Observatory weather station and similar sites in a rural location. However, at the outset, it was stated that the aim of this work was to assess any influence the urban development of Armagh City around the Observatory site might exert on meteorological observations made at the Observatory. Therefore, in addition to spatial temperature variation, the temporal aspect must also be considered. Many of the residential areas surrounding Armagh have developed since the 1960s and growth is continuing at the present time.

Recent research into correspondence relating to the Observatory weather station has brought to light earlier studies

which have proved useful in assessing whether or not urban development has had an impact on observed temperatures.

A comparison was made between the Observatory and Loughgall (approx. 7 km to the NNE of the Observatory) over the period November 1957 to October 1963. Monthly means of maximum and minimum temperatures were determined for both sites and from these the mean monthly differences in temperature for each site were calculated for the six-year period. The comparison was repeated for the period January 1989 to December 1994. The year 1994 was chosen as the end of the recent period because the Loughgall weather station was re-sited in 1995. The station had previously remained on the same site since 1957.

Similar comparisons were made between Armagh and Annaghmore as well as between Armagh and Tandragee (approx. 19km to the N and 15km to the E respectively). Since the Annaghmore station was installed in 1980 and the Tandragee station in 1970, these comparisons could not be made over the same time span as that of Loughgall.

The results of the three comparisons are presented in table 2.

Table 2.

Mean temperature differences between Observatory and neighbouring met.stations.

		Observatory-N. Stn (deg. C)	
Station	Period	Maxima	Minima
Loughgall	1957-1963	0.26	0.61
	1989-1994	0.06	0.56
Annaghmore	1981-1983	-0.22	0.60
	1992-1994	-0.08	0.44
Tandragee	1970-1975	-0.50	0.13
	1989-1994	-0.35	0.58

Taking each of the outlying stations in turn, it is apparent that the mean difference in both maxima and minima between Loughgall and Armagh has decreased slightly (by 0.20 and 0.05°C respectively) over the past 30 years. This is opposite to what would be expected as much of the urban growth around the Observatory site has occurred over the last 20-30 years. A similar temperature change pattern can be seen in the Annaghmore-Armagh comparison, albeit on a shorter time scale since no data is available from Annaghmore prior to 1980.

The Tandragee-Armagh comparison shows the reverse trend with the mean differences in minima increasing (by 0.45°C) over the given time interval. Further investigation reveals that the Tandragee weather station is located within a few metres of a large electricity substation, covering an area of several acres. It is arguable that the large volume of metal in and around the substation acts as a reservoir for solar radiation and also that the equipment itself produces a significant amount of heat. These factors make the results of any comparison with data from Tandragee highly questionable, especially bearing in mind the relatively small temperature differences observed.

The location of the Observatory relative to the urbanised area of Armagh raises a further interesting point. Farmland and playing fields extend country-ward to the northeast from the boundary of the Observatory grounds. In other words, the Observatory is not completely enclosed within the built-up area; a `corridor' of open countryside extends into the grounds. The shape of an urban heat island corresponds closely with the geometry of the built up area with which it is associated (see Oke 1987) and, because the Observatory grounds lie country-ward of the urban boundary, it is possible that the urban heat island, in spite of its proximity, does not actually encroach into the Observatory grounds. The above comparison using historical data from neighbouring weather stations would support this case.

5. Conclusions

The data derived from the experimental work carried out in 1996 exhibits a mean difference in daily maximum temperatures of 0.11°C and 0.41°C in daily minimum temperatures between the site of the Observatory weather station and three similarly sited rural weather stations. However, recent research into the historical temperature records and comparisons with present day data from rural weather stations indicate that any temperature differences

which existed between the Observatory site and the countryside 20-30 years ago have not increased over the intervening years. This is contrary to the situation which would be expected if urban development were to influence air temperatures at the Observatory, since much of the growth of Armagh has taken place since the 1960s and still continues.

In addition, the fact that there has been no urban encroachment into the Observatory grounds and that the grounds have not been separated from the adjacent farmland by any development suggests that the Observatory weather station lies outside the urban climatic boundary.

It is concluded that temperature observations made at Armagh Observatory have been unaffected by rapid urbanisation over the past three decades.

6. Acknowledgements

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Figures

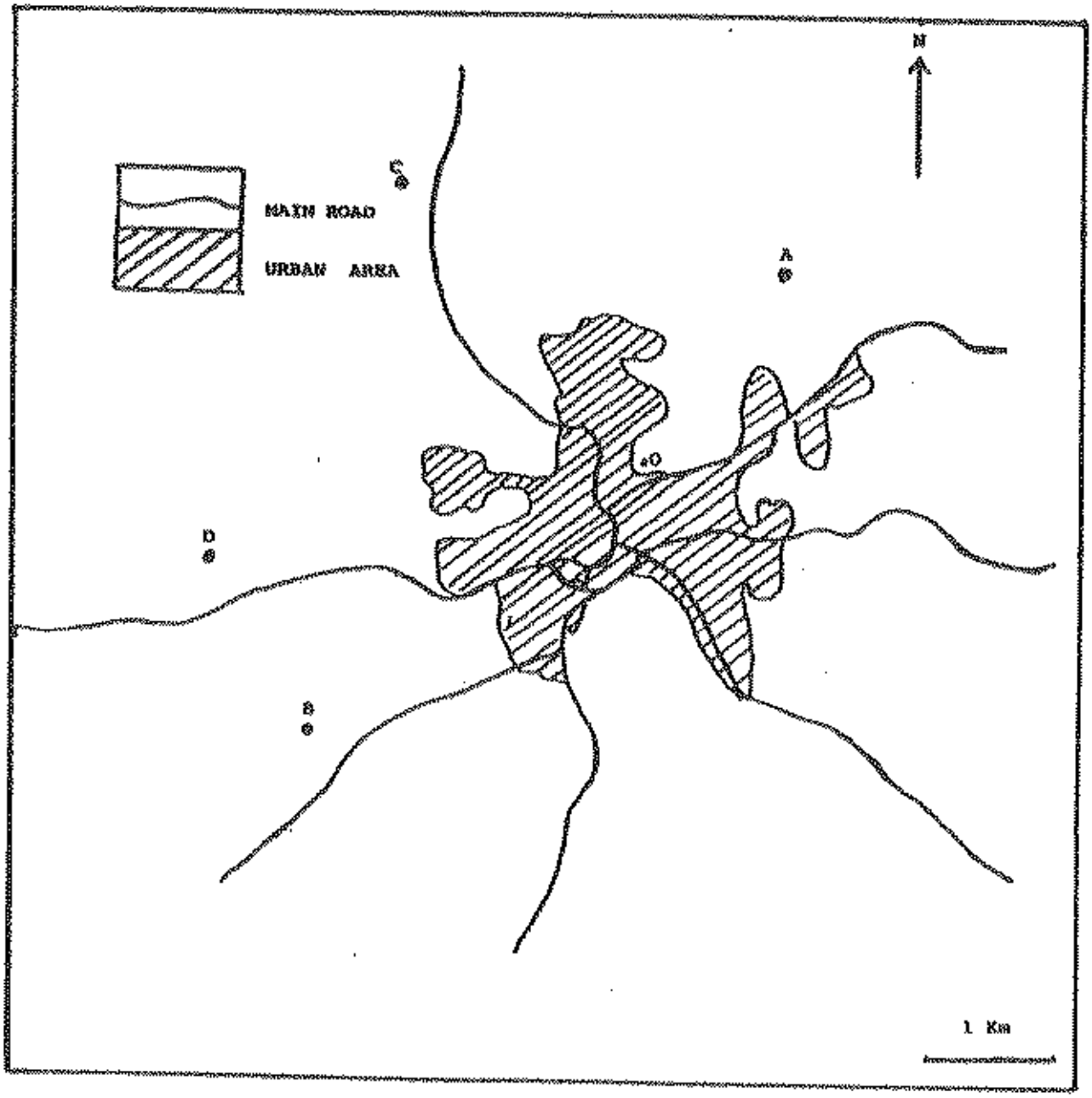

Figure 1. The location of the four outlying, rural stations and the Observatory at Armagh.

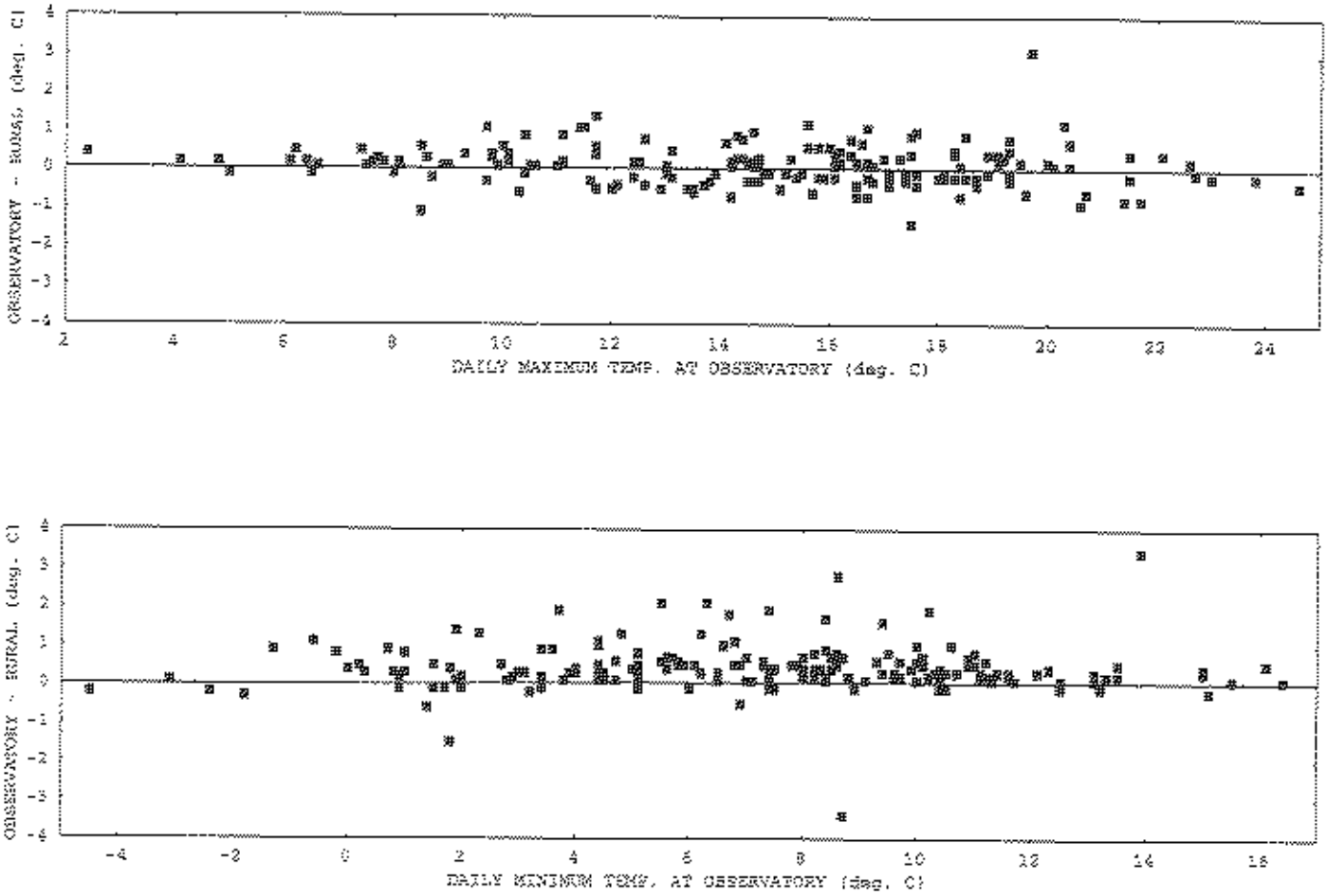

Figure 2. Differences between the mean of the three rural stations (A,C and D) and the Observatory (O) against the temperature recorded at the Observatory. Upper panel - maximum, lower panel - minimum. Note that, apart from a zero point difference, there appears to be no trend with temperature.