Comparison of temperature variations observed during the August 11th 1999 Total Solar Eclipse at Amiens to data recorded by members of the public on a special web site hosted by the Science Museum (London).

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Abstract

Comparison of air temperature measurements made during the August 11th 1999 Total Solar Eclipse at Amiens to those made in the UK show that the rate of temperature change either side of totality had a magnitude of approximately 2.0×10^{-3} K s^{-1} and that there was a delay between totality and the lowest air temperature of approximately 200 s.

Introduction

The aim of this experiment was to investigate how air temperature varied during the August 11th 1999 total solar eclipse. The rate of temperature change (hereafter called "temperature gradient") before and after totality were compared to determine if ambient air temperatures responded in a similar manner in both periods.

Experimental Procedure

During the experiment temperatures were measured with a digital thermometer purchased from Boots the Chemists. This instrument displays temperatures using a 1°C interval scale. It was not possible to calibrate the thermometer before use but as the author was interested in rates of temperature change, rather than absolute temperature values, this was not seen to be serious enough to stop the experiment. Furthermore, subsequent testing of the device has shown it to work well with an accuracy of +/- 1°C.

Light levels were also measured using a Gossen Bisix 2 photographic light meter. The blind was moved across the cell window so that the device was measuring incident light levels. By comparing variations in temperature to those of the incident light level it was possible to determine what delay, if any, occurred between totality and the temperature minimum.

A sheltered spot was found in the park in Amiens with the aim of reducing, as far as possible, the effects of the wind and draughts from passers-by. Both the thermometer and light meter were placed on the ground, facing towards the Sun. Readings from the two instruments were recorded at approximately 5 minute intervals except during a 15 minute period centred on totality when they were recorded at 1 minute intervals. Care was taken to minimise movement of the instruments once the experiment started.

The Science Museum (London) invited members of the public to perform some observations of the effects of the eclipse. One experiment involved recording wet and dry bulb temperature changes at 15 minute intervals. This data set is fairly course when compared to the 5 minute intervals used at Amiens. Additionally no information was recorded on the steps taken to ensure the accuracy of the results presented and (to the best of the authors knowledge) none of the observations have been validated.

It is felt that meaningful comparisons can be drawn from the dry bulb results if we assume that an observer who completes most of the observations can be classified as 'conscientious' enough to record valid data. Results from the Science Museum web site were printed where an observer had recorded observations for most of the period between 1st Contact and 4th Contact and then grouped by drawing together data from geographically close postal codes. Times for totality were estimated using table 1 and figure 4 from "The RGO Guide to the 1999 Total Eclipse of the Sun".

Graphs were produced from the Amiens and Science Museum data and then compared to determine if temperature varied in a consistent way throughout the eclipse.

Results

The following tables (numbers 1 to 6) present the data used in this analysis. All temperatures are in °C and times are GMT.

Table 1 : Geographical details of Science Museum data used in comparison to Amiens observations.

Data Set	Area	Number of observers	Estimated time of Totality	Estimated % Totality
1	Devon & Cornwall	5	10.15	100
2	Leicester	4	10.19	93
3	Nottingham	3	10.19	92
4	London	8	10.19	96 to 99

Table 2 : Data set 1, Devon & Cornwall.

Time	TR19 6JB	TR13 8NR	TR13 5NR	PL23 1LX	Ave
8.00	16	17	17.1	16.5	16.7
8.15	15	17	16.6	17	16.4
8.30	16	16.5	17.1	16.5	16.5
8.45	16	17	17.1	17	16.8
9.00	16.5	17	16.6	17	16.8
9.15	16	17	16.6	18	16.9
9.30	17	17	16.6	17.5	17.0
9.45	16.5	17	16.5	17	16.8
10.00	16.5	16.5	16.6	15.5	16.3
10.15	15	16.5	16.1	14.5	15.5
10.30	16	16.5	16.5	15	16.0
10.45	16.5	16.5	16.6	17	16.7
11.00	#	17	16.6	20	17.9
11.15	19	17	17.3	20	18.3
11.30	18	18.5	18.5	19.5	18.6
11.45	18	18.5	18.3	19.5	18.6
12.00	18	18	18	19.5	18.4
12.15	17.5	18	18.3	19	18.2
12.30	#	18	18.1	18	18.0

Table 3 : Data set 2, Leicester

TQ9 7QJ	LE7 9HA	LE7 9UU	LE17	LE2 5UE	Ave
19	13	15	15	16	14.8
22.5	13	15	15	16	14.8
20.5	13.5	16	16	17	15.6
19	14	17	16	17.5	16.1
22	15	#	15	17.5	15.8
#	15	18	16	18	16.8
19.5	14.5	18	16	17	16.4
19.5	14	18	15	18	16.3
17.5	13.5	17	15	16.5	15.5
16	13	15	14	15.5	14.4
16	12	#	14	15	13.7
17	13	17	15	15.5	15.1
18	14	19	16	16	16.3
19	#	#	17	18	17.5
20	16	#	18	18	17.3
22	#	#	19	18	18.5
25	#	#	19	18	18.5
26.5	14	#	19	18.5	17.2
22.5	14	#	19	20	17.7

Table 4 : Data set 3, Nottingham

Time	NG12 4EA	NG4 3LL	DY13 8ET	Ave
8.00	15.9	13.5	13.5	14.3
8.15	16.2	14	#	15.1
8.30	18.2	14.5	14	15.6
8.45	20.1	15	#	17.6
9.00	18.1	15	15	16.0
9.15	16.7	15	#	15.9
9.30	16.9	15.5	16	16.1
9.45	17.5	15.5	#	16.5
10.00	16.2	15	15	15.4
10.15	15.2	14.5	#	14.9
10.30	14.4	14	15.5	14.6
10.45	14.7	14.5	#	14.6
11.00	15.1	15	16	15.4
11.15	15.7	16.5	#	16.1
11.30	16.3	17	18	17.1
11.45	17.7	19	#	18.4
12.00	17.5	19	17	17.8
12.15	24.9	19	#	22.0
12.30	23.4	20	18	20.5

Table 5 : Data set 4, London

AL8 7NN	CM5 9JJ	E7 0LU	EN1 3HP	OX11 9NW	RG8 7EX	RG41 1JU	TN5 6UJ	Ave
11.5	#	15.2	18	#	17	14.5	#	15.2
12.5	#	15.7	19	#	21	14.9	#	16.6
13	#	15.6	19	#	20	15.5	14.8	16.3
13	#	16.1	19	#	19	16.2	14.9	16.4
13	#	16.3	19.5	#	22	18.6	15.7	17.5
12	#	16.7	20	18	21	20.2	15.8	17.8
13.5	21	17.1	20	18.5	19	21.5	17.4	18.5
14	18	16.4	19.5	17	19	20.1	16	17.5
13	17	16	19	16.5	18	18	15.6	16.6
12	16	15	18	15.5	16	16.1	14.5	15.4
12	15	14.7	18	15	16	13.7	13.9	14.8
12.5	16	15.4	18	16	16	13.9	15.3	15.4
14	16.5	18.1	19	17	17	15.5	15.7	16.6
15	18	18.4	19.5	19	18	17.3	16.5	17.7
16	19	19	19	20.5	19	18.6	17.6	18.6
16.5	19.5	19.5	19.5	19.5	19	20	16.8	18.8
17	20	21.3	20	19	20	22.3	18.1	19.7
17	20	21.5	20	#	21	#	17.4	19.5
18	20.5	21.6	21	#	20	#	#	20.2

Table 6 : Temperature and Light Level observations from Amiens

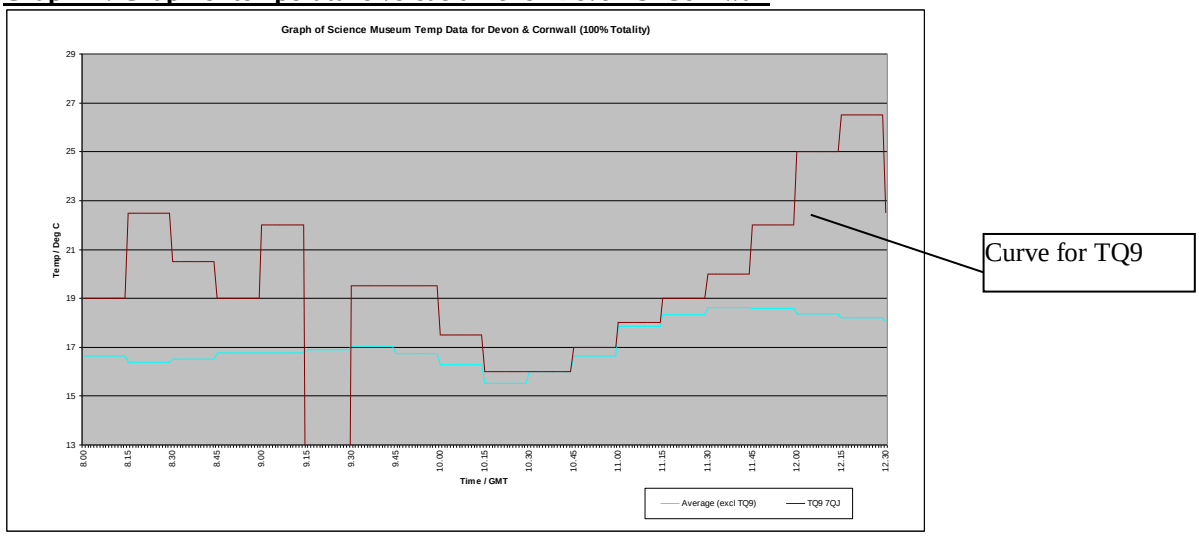
Time / GMT	Temp / °C	Light Level	Time / GMT	Temp / °C	Light Level
8.46	24	6.5	10.20	20	1.6
8.51	24	6.6	10.21	20	1.2
8.57	24	6.3	10.22	20	1.0
9.00	24	6.3	10.23 (Totality)	20	1.0
9.04	24	6.3	10.24	20	1.0
9.10	24	6.7	10.25	19	1.2
9.20	24	6.6	10.26	19	1.5
9.25	24	6.3	10.27	19	1.8
9.30	25	6.3	10.28	19	2.0
9.35	24	6.5	10.30	19	2.5
9.40	24	6.0	10.35	19	4.0
9.45	24	6.2	10.45	21	5.0
9.50	24	5.7	10.50	20	4.7
9.55	23	5.6	10.55	20	5.0
10.00	23	5.2	11.00	20	5.0
10.05	22	4.8	11.05	20	5.7
10.10	22	4.0	11.10	21	5.9
10.15	21	3.5	11.15	23	6.3
10.17	21	2.5	11.20	24	6.5
10.18	21	2.2	11.25	25	6.7
10.19	20	2.0	11.30	26	6.7

The conditions at Amiens were broadly similar to those affecting the UK, dense low level cloud with few breaks. The cloud cover was fairly constant throughout the entire observing time. Short breaks allowed views of the partial phases and a particularly fortunate one occurred at totality. There was little wind although a light breeze did pick up around 10.00 and persisted for about 45 minutes.

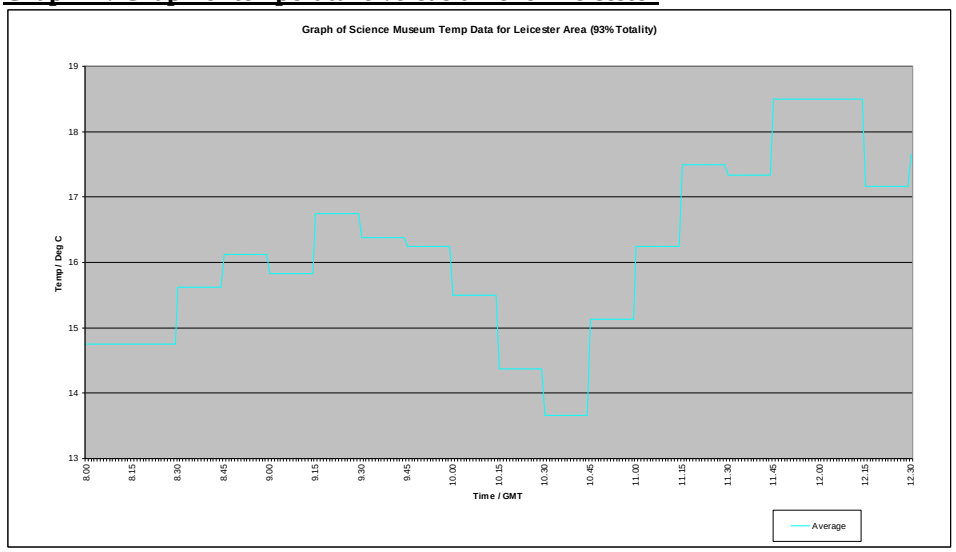
The psychological effects of the rapid change in light levels are worth mentioning. I observed the air to feel “cooler - noticeably” at 9.57 when the light levels had fallen by 14% and temperature by 1°C. At 10.07 I recorded that it felt a “bit cooler” when the light level had fallen a further 12% and temperature by 1°C. Around totality I simply record that it is cool but, interestingly, at 10.26 (only 3 minutes after totality) I note that it “feels warmer”. At 10.26 the light level had increased by 50% from its low point during totality but it was still only 20% of the initial level; what is even more relevant is that the temperature had actually fallen by a further 1°C.

The following graphs show the average value of each data point in data sets 1 to 4 (for Devon & Cornwall the results from postal code TQ9 7QJ were excluded because they were abnormally high compared to the other 4 observer’s results) and a similar plot for the results from Amiens. In all cases temperatures were assumed to remain constant between data points.

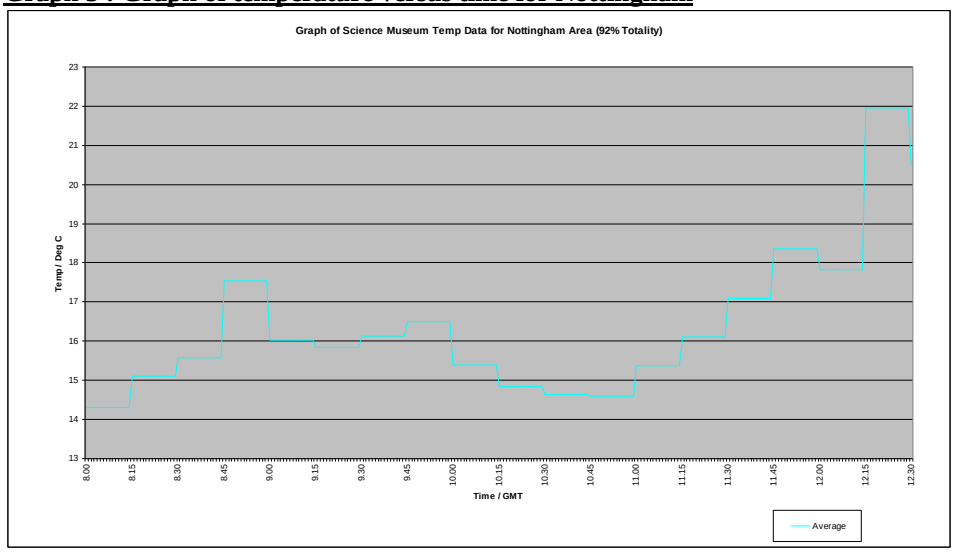
Graph 1 : Graph of temperature versus time for Devon & Cornwall



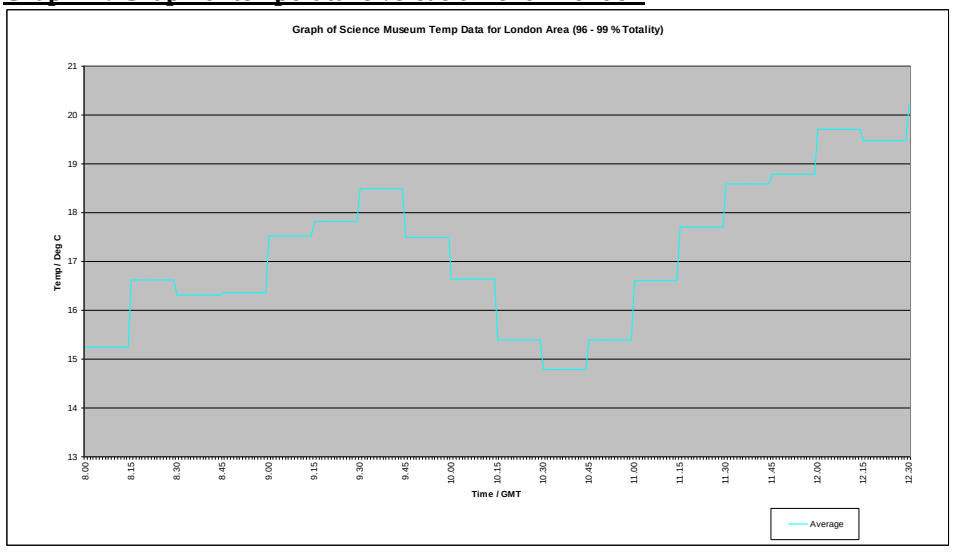
Graph 2 : Graph of temperature versus time for Leicester



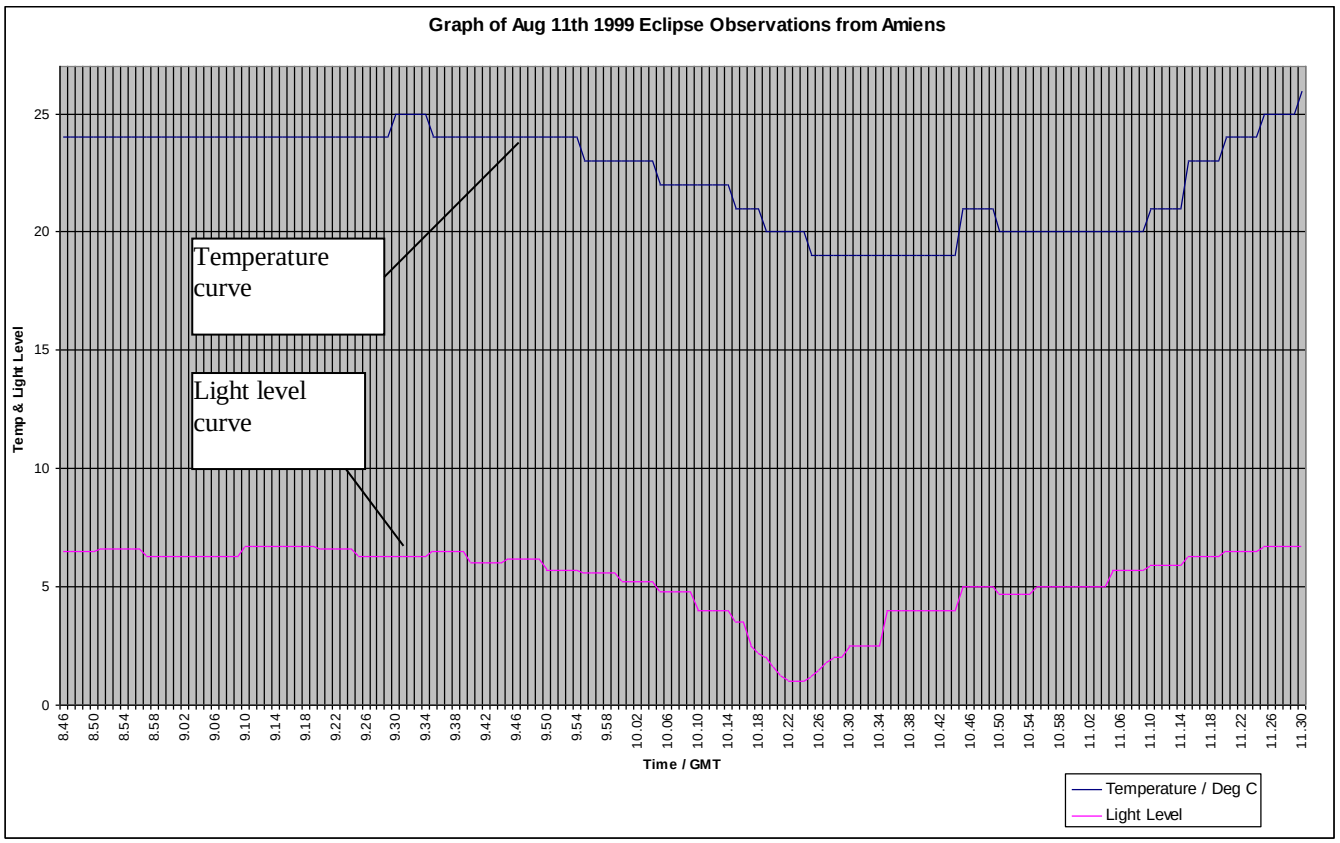
Graph 3 : Graph of temperature versus time for Nottingham



Graph 4 : Graph of temperature versus time for London



Graph 5 : Graph of temperature and light level versus time for Amiens



The following table presents a comparison of the key points that emerge from comparing the 5 graphs,

Table 7 : Analytical comparison of Graphs 1 to 5

Area	Temperature gradient 30 mins before totality / K s^{-1}	Time delay from totality to lowest temperature / s	Duration of lowest temperature / s	Temperature gradient after totality / K s-1
Devon & Cornwall	-8.3×10^{-4}	60	900	$+8.3 \times 10^{-4}$
Leicester	-1.7×10^{-3}	600	900	$+1.7 \times 10^{-3}$
Nottingham	-8.3×10^{-4}	600	1800	1.3×10^{-3}
London	-1.7×10^{-3}	600	900	$+1.7 \times 10^{-3}$
Amiens	-3.3×10^{-3}	180	1200 (1)	$+3.3 \times 10^{-3}$

Notes : (1) - At Amiens the temperature stayed at the minimum temperature for 20 minutes, it then rose by 1°C (ignoring a momentary increase by a further 1°C at 10.45 that lasted for a maximum of 5 minutes) and remained at that temperature for a further 30 minutes before steadily increasing at the $+3.3 \times 10^{-3}$ °C s^{-1} rate shown in table 7. Data sets 1 to 4 do not indicate that sites on the UK mainland exhibited the same behaviour, but this could be masked by the relative coarseness of that data.

The results shown in table 7 lie within an order of magnitude of each other, indicating broad similarities between the observed temperature changes.

I shall first consider the UK results and then contrast them to those observed at Amiens.

With the exception of the Nottingham results, both the magnitude of the temperature gradients either side of totality and the duration of the lowest temperature were the same. There is some variation in the delay between totality and the moment of lowest temperature; the result for Devon & Cornwall seems to be anomalously low and the best we can say is that the upper limit was 600 s.

In the Nottingham area the magnitude of the temperature gradient after totality was 57% greater than that observed before and the lowest temperature persisted for twice as long. The Nottingham data set is the weakest of the 4 extracted from the Science Museum web site; being composed of only 3 observers, one of whom only reported data at 30 minute intervals. Nottingham is quite close to Leicester and the differences highlighted above are, therefore, difficult to explain. It would appear that some localised factors acted in the Nottingham area to give a different profile to the 3 other areas considered. Because of that the Nottingham data is excluded from the rest of the analysis.

Contrasting the results from data sets 1, 2 and 4 to those from Amiens we see that the UK had lower temperature gradients either side of totality whilst Amiens had the second shortest delay between totality and the lowest temperature and also the longest duration at the lowest temperature.

The differences in the time delay to the lowest temperature need to be treated with caution because of the coarseness of the Science Museum data. To within an order of magnitude the delays were close. On average the delay was 360 s; however, on balance the Amiens data is believed to be more accurate and a baseline estimate of 200 s will be made.

That Amiens' temperature gradients were twice those observed in Leicester and four times that observed in the other areas is difficult to understand. All 4 areas (Devon & Cornwall, Leicester, London and Amiens) are fairly close to the coast and well populated. At this stage the author can only conjecture that topographical or consistent meteorological differences between continental Europe and the UK are factors affecting this result.

Conclusion

From the analysis above I conclude that the temperature gradients either side of totality had equal magnitudes of approximately 2.0×10^{-3} K s^{-1} ($^{+}$/- 1.2×10^{-3}). Furthermore, there was a delay between totality and the lowest air temperature of approximately 200 s (Lower limit of 60s, upper limit of 600s). There are indications of geographical variations in the response of air temperature to the eclipse. Further study of this would be required to reduce the uncertainties in the values found.

If the experiment were to be repeated a sensible enhancement would be to include air pressure measurements. This would allow investigation into how variations in air density affect the temperature gradients.

Bibliography

The RGO Guide to the 1999 Total Eclipse of the Sun, Steve Bell, ISBN 0-905087-03-8

Acknowledgement

The author would like to acknowledge the Science Museum (London) as the source of the data presented in tables 2 to 5; the web site address is http://eclipse.domino.com. The members of the public who contributed that data are :

TR19 6JB - Suzanne Gough, TR13 8NR - Sam Spicer, TR13 5NR - Frances Thomson, PL23 1LX - Gail Muin, TQ9 7QJ - James Baskett, LE7 9HA - Jonathan Hamilton, LE7 9UU - David Lomax, LE17 - Richard Elliott, LE2 5UE - Elizabeth Ewers, NG12 4EA - Luke Odell, NG4 3LL - Ron Wilton, DY13 8ET - Luke Roberts, AL8 7NN - Robert Midgeley, CM5 9JJ - James Silvester, E7 0LU - Maureen Gould, EN1 3HP - Andrew Whelan, OX11 9NW - Catherine Dunn, RG8 7EX - Sarah Butterworth, RG41 1JU - J J Trott, TN5 6UJ - Judith Maizel-Long.