A gentleman from Hampstead: statistical weather forecasting in 1750s London

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In August 1758, a subscriber to the relatively new London Chronicle (first published on 1 January 1757) may have opened the 3–5 August issue to the last page (or postscript) and been surprised to see a listing of daily meteorological data from July of that year, together with mediums (averages) for bimonthly (fortnight) sections of the data, for temperature, barometric pressure and wind direction (Figure 1). The bimonthly reports usually appeared on the last page of an issue in the midst of commercial and shipping news at Deal and other channel ports.

Daily weather data were not entirely absent from London publications: Gentleman’s Magazine published similar data in the daily stock market report from January 1747 onwards. However, averages of data rarely appeared in the popular press reports of daily weather, to the best of my knowledge, before 1800.

That reader may also have read the introductory column with some details supplied by the (anonymous) observer: a gentleman from Hampstead, who opines that the data such as he provides ‘are best made at some distance from any great city.’ He states that by ‘taking the medium of Heat in each fortnight for a course of years, we shall be able to fix the medium naturally to be expected.’ He asks that ‘is not the medium degree of temperature in every place a fixed degree? My observations over four years give reason to believe this is the case.’

Figure 1. Daily weather from the London Chronicle, July 1758; temperatures in °F, pressure in inches Hg. Taken from Hathitrust.org digital library.

The Hampstead gentleman made good on his promise in the next appearance of the weather report and began to answer his own question: ‘Is the medium degree of temperature in every place a fixed degree?’ To answer this question, he provided a forecasted ‘medium’ of temperature for the coming fortnight, which could be compared two weeks later with the ‘medium’ he computed from daily readings. There is every reason to believe that this is the first attempt to forecast a forthcoming temperature using a statistical method. I will show that his method was as expected: he averaged the ‘mediums’ of prior fortinights of previous years, adding data from each additional year for the next annual forecast.

The edition of 1–15 August (Figure 2) listed the weather data for the present fortnight and its forecast: 59.38°F (perhaps unfortunately overlooked in the July table by the typesetter) and also the mean for the following fortnight: 58.45 °F. The table itself provides the actual mean for that period: 61.93°F (the average of the posted whole-number temperatures). I deduce that the observer was an honest and meticulous man.

Who was the gentleman from Hampstead?

I do not know for sure, but circumstantial clues provide some pointers. He surely had a sound schooling in arithmetic, was of a methodical and persistent nature, and had a Gentleman’s status, or had worked himself to that status. The tables seem to display a slowly fracturing health. His introduction noted that such measurements ‘are best made at some distance from any great city.’ London was prone to toxic fogs: the ‘stinking fogs’ mentioned in both John Gadbury’s (1669–1689) and Boyle’s diaries (Gadbury, 1691; Cornes, 2019). Hampstead lay over two miles northwest of London in open country (Figure 3) and was ‘formerly famous for its medicinal waters’ (Brookes, 1827). A London gentleman might move there to improve his health and be within easy

Figure 2. Daily weather for 1–15 August 1758, with mean temperature prediction in °F for 16–31 August. Pressure in inches Hg. Taken from www.Hathitrust.org digital library.

1Hathitrust (www.Hathitrust.org) has some, but not all, of the relevant London Chronicles (1760, Jan-June, is missing), and some poor pages with blurred data. Searching for actual tables is tedious. Google has annual volumes of the Gentleman Magazines, London Magazine, Universal Magazine, and some London Chronicles, (half year volumes). www.newspaperarchive.com (subscription required) has the London Chronicle for 1760 January to June that is otherwise unavailable. Searching is very awkward. Spreadsheets of all relevant daily data are available from the author.
reach of the city. The average barometric pressure for Hampstead from his readings is 29.72 inches Hgg, suggesting an elevation of about 200 feet, perhaps the southern margins of the Heath from West End round to Stone Bridge.

One suspect can be dismissed right away: John Fothergill, a well-known London doctor who provided Gentleman’s Magazine with monthly climate statistics from about 1751 to mid-1755, together with a medical assessment of the illnesses active amongst his patients. Fothergill lived downtown on St James, Clerkenwell, 6 February 1697) but, despite extensive searching, no other trace of Francis Bateman.

When tables appeared late, they nevertheless turn up complete. My speculation is that Bateman left London for a more favourable environment, returned in December 1762 and managed until September 1763, when his health collapsed. He managed to complete the last fortnight in September, all of October and the first half of December.

It is unlikely he ever had, or anticipated getting, data for the following fortnights into 1762 for the reason I shall elucidate. As I shall demonstrate below in detail, the forecast of a forthcoming fortnight average was computed as the average of all previous corresponding fortnights. The forecast average for 1–15 January 1762, of 33.91°F, may be computed from data he published. That forecast value should be printed, as is the case with every forecast, in the tabulation for the previous fortnight (16–31 December 1761). In fact, the value printed was 37.63°F. Very oddly, that value was the ‘medium’ he had just calculated as the average temperature for 16–31 December.

I surmise he realised that he had no time to calculate the correct forecast and simply inserted the one he had to hand, knowing he was leaving for a period. The next published forecast was for the second fortnight of 1763, printed as usual in published data for the first fortnight in that year.

Whomsoever the observer was, he must satisfy the criteria of living in Hampstead from at least January 1754 till December 1763, with the exception of 1762.

The London Chronicle dataset

Bimonthly tables were printed by the London Chronicle, usually soon after they were received. The record extends from 1 July 1758 to 15 December 1763, with some gaps and sometimes substantial delays.

Table 1 summarises the coverage of the bimonthly tables. Most notably, there was a three fortnight gap in the spring of 1761 that eventually appeared in the 19 May issue. A reasonable supposition is that the observer had periodic bouts of illness because the London Chronicle nevertheless printed his observations after the 1762 absence. Other than the gaps, the data provide no particular problem in and of themselves. The computation of the ‘mediums’ of two datasets, in each table, computed to two decimal points, twice a month, was doubtless a thankless task but a necessary aspect of the observer’s decided methodology. I show later that these ‘mediums’ are usually very accurately computed. Bimonthly annual summaries were printed in the London Chronicle until 1761. Although the listing of daily data for 1758 were first published from 1 July onwards, bimonthly means are available for the first half of the year thanks to an annual summary that was also published at the end of the year.

The observer provides quite specific information on the instrumental set-up but no information on the actual instruments used. His thermometer was “… suspended so as to touch no wall, and be free from the heat of walls and chimneys, not in the Sun’s rays, nor where he has shone for some time before: and therefore it should be hung in a Northern position.” His own experiments, noted in the London Chronicle’s Introduction, had determined that ‘eight o’clock in the morning’ was the appropriate time for measurements and likely when he read his barometer. He remarks that such ‘observations were best made at some distance from any great

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1 Standard pressure at sea level in inches is 29.92 for practical purposes.
2 I am indebted to Prof. E. Lorraine de Montluzon for this information.
Table 1

**Availability of London Chronicle weather records by fortights containing daily data.**

|       | 1758 | 1759 | 1760 | 1761 | 1762 | 1763 | 1764 |
|-------|------|------|------|------|------|------|------|
| Jan   |      |      |      |      |      |      |      |
| Jan   |      |      |      |      |      |      |      |
| Feb   |      |      |      |      |      |      |      |
| Feb   |      |      |      |      |      |      |      |
| Mar   |      |      |      |      |      |      |      |
| Mar   |      |      |      |      |      |      |      |
| Apr   |      |      |      |      |      |      |      |
| Apr   |      |      |      |      |      |      |      |
| May   |      |      |      |      |      |      |      |
| May   |      |      |      |      |      |      |      |
| Jun   |      |      |      |      |      |      |      |
| Jun   |      |      |      |      |      |      |      |
| Jul   |      |      |      |      |      |      |      |
| Jul   |      |      |      |      |      |      |      |
| Aug   |      |      |      |      |      |      |      |
| Aug   |      |      |      |      |      |      |      |
| Sep   |      |      |      |      |      |      |      |
| Sep   |      |      |      |      |      |      |      |
| Oct   |      |      |      |      |      |      |      |
| Oct   |      |      |      |      |      |      |      |
| Nov   |      |      |      |      |      |      |      |
| Nov   |      |      |      |      |      |      |      |
| Dec   |      |      |      |      |      |      |      |
| Dec   |      |      |      |      |      |      |      |

*Pale green covers published fortights. Dark green indicates three fortights that were published very late (published simultaneously in May of that year). Years with partial records were 1758–1764. Complete records were available for the period 1 July 1758 to 31 December 1760.

\(^b\) As recorded in the Hampstead Gentleman’s Magazine, 23 September 1764.

Table 2

**Summary of calculation errors in London Chronicle weather tables.**

|               | Pressure error, mean ± SD (inches Hg) | Temp. error, mean ± SD (°F) | n  |
|---------------|--------------------------------------|-----------------------------|----|
| 1758          | 0.01 ± 0.05                          | 0.18 ± 0.44                 | 184|
| 1759          | −0.20 ± 0.06                         | −0.02 ± 0.46                | 365|
| 1760          | −0.01 ± 0.03                         | 0.01 ± 1.00                 | 366|
| 1761          | 0.00 ± 0.00                          | −0.06 ± 0.00                | 352|
| 1762          | Not published                        |                             |    |
| 1763          | 0.01 ± 0.07                          | −0.09 ± 0.27                | 304|
| Mean          | −0.04 ± 0.04                         | 0.00 ± 0.43                 |    |
| SD            | 0.09 ± 0.03                          | 0.11 ± 0.37                 |    |

city.’ His residence in Hampstead was at least 2.5 miles north-northwest of the city boundary.

Wind directions were recorded on a 16-point compass that I have reduced to an 8-point compass, by taking, for example, NbW to be NW. It is not stated at what time the wind was taken, although the default 0800h is most likely. No weather remarks are recorded, unlike most contemporary records.

**Data analysis**

The tables were transcribed into a spreadsheet to: (1) check on the average data provided by the London Chronicle records from the observer, (2) make quantitative comparisons with contemporary and comparable datasets from London sources and, as noted above, (3) check and reconstruct the statistical computations made in the records.

**Internal accuracy**

The internal numerical accuracy of the ‘medium’ calculations are summarised in Table 2. All observed source data for temperature are provided by the observer as whole numbers, degrees Fahrenheit and, for pressure, to two decimal places in units of inches Hg. I have used his whole-number reports of temperature to check his computations of ‘mediums’ and the predictions in his reports as printed to two decimal places. I have computed the mean error of pressure as −0.04 inHg and as 0.00 °F for temperature, with corresponding standard deviations of 0.04 inHg and 0.43 °F, respectively. The source tables show that the standard deviations arise because of a few erroneous calculations of the means by the observer, which are usually only a fraction of a degree Fahrenheit in error.

**Comparative sources**

Two other London sources published daily weather data each month contemporary with those in the London Chronicle record. Gentleman’s Magazine first published data from James Ayscough (Optician) on 1 July 1755 and continued until 23 August 1759; Ayscough was buried on 3 November 1759. An unattributed weather record was first published by the Gentleman’s Magazine in March 1755, with daily data backdated to 1 February and were stated to be obtained from Clerkenwell, 2 km north of Ludgate where the magazine’s office was located. The data format of the table is identical to that subsequently used by Ayscough. The Universal Magazine first published data from John Cuff on 28 July 1757 which continued to 24 December 1761. No daily data are available from any source in 1762 (except the last fortnight of December in the London Chronicle, discussed earlier), but daily data reappeared in Gentleman’s Magazine, without attribution, in January 1763. All these records are compared with the London Chronicle and with each other.

The intention here is to show that the Hampstead gentleman produced records...
of comparable accuracy to those of contemporary observers. With respect to instrument placement, Ayscough notes them at the end of both his July and August 1755 ‘Meteorological table’ in Gentleman’s Magazine (Figure 5). There is no indication where the thermometer was hung, but the times were given as 7am to 3pm and 8pm.

John Cuff describes his barometer and thermometer placement (Figure 6) but does not mention the time of observation, although early morning is the most probable time.

The 1763 daily record in Gentleman’s Magazine is unattributed. The magazine had been recording daily data since 1747, probably with Ayscough’s instruments and help. It faltered in the early 1750s but restarted in February 1755 with no attribution until Ayscough announced his record in July. The magazine’s office at Ludgate Hill may still have had a barometer and thermometer that were called into action.

Ayscough and the Hampstead gentleman both note their times of reading: Cuff does not, but both Cuff and Ayscough provide separate low- and high-temperature readings. Only the 1763 Gentleman’s Magazine record is silent on instrumentation and observation, and it published only a single temperature record. A reasonable method to check thermometer placement is to compare the minimum daily temperature for each year. Table 3 indicates that the records from all the sources were within a few degrees of each other. A daily record from Cumberland, published alongside Ayscough in Gentleman’s Magazine, would routinely record a temperature of about 40°F while reporting frost. This would correspond to the method of using a north-facing unheated room for the thermometer. Because the 1763 temperature record is comparable with the other low temperatures, it is assigned a low temperature status for comparison with the other sources.

Pressure and temperature comparisons

Because of the short period of record and its fractured nature, there is no year for which a complete daily record is available for every source (Table 4). Temperature correlations are provided but are of little statistical significance because of autocorrelation due to underlying seasonal trends. However, with barometric records, little was understood in the mid-eighteenth century about the relation of pressure to weather, except perhaps for the fact that a sudden shift to extreme low pressure, or vice-versa, often coincided with strong winds and rain.

William Hutchinson9 records a sudden drop in pressure one morning after leaving the Downs,[9] over an inch down to 28.5 inches Hg. He greatly reduced sail and rode out the storm opposite the Lizard.11 The next morning he encountered ‘a Dutch or Danish ship floating bottom-up.’ He was recording an episode from around 1750. Quoting personal experience, he doubted barometers ‘being of any great service to sea-faring people.’ In a later section (p. 190), he did, however, aver that ‘tho’ this instrument is found defective at times,12 yet it must be allowed the best guide we have for the purpose of showing signs of good or bad weather,’ and noted that ‘a quick rise as well as a quick fall of the quicksilver shows a changeable and uncertain weather.’

At the time, barometric records were effectively blind, that is, one did not know without a comparative record if the instrument was reading correctly. A comparison with contemporary records provides a useful check and demonstrates a probable instrumental failure in John Cuff’s data in December 1758 (Figure 7). Table 4 summarises the available set of correlations. The pressure correlations are all above 0.80, with coefficients of variation between 66% and 76%. Those between Hampstead and Cuff are very consistent. The temperature coefficients are high, over 0.90, that is, with covariance over 80%. A mutual correlation of all available daily temperature records yields a mean correlation of 0.76 and

1At the end of the monthly stock market page; both were based in Ludgate street.

The GM thermometer is described in Gentleman’s Magazine October 1748, p. 453 and was made by Mann and Ayscough, Mann was Ayscough’s Master.

9Privateer, and then Harbour Master at Liverpool for about 25 years; William Hutchinson (1799), pp. 4–6.

10East Kent safe harbourage shipping used to await a fair wind for the intended destination.

11Off the south Cornwall coast.

9A Tampion (sic) Hutchinson op. cit. p. 5, the maker was in fact Thomas Tompion, horologist (1639–1713).

12"Tampion (sic) Hutchinson op. cit., p. 5, the maker was in fact Thomas Tompion, horologist (1639–1713)."

Table 3

| Year | Hampstead | Cuff | Ayscough | GM |
|------|-----------|------|----------|----|
| 1758 | 23        | 25   | 20       | –  |
| 1759 | 24        | 24   | 27       | –  |
| 1760 | 23        | 23   | –        | –  |
| 1761 | 24        | 22   | –        | –  |
| 1762 | –         | –    | –        | –  |
| 1763 | 22        | –    | –        | 26 |

-- no record.

Figure 5. Header and footer to James Ayscough’s July 1755 table of daily weather in Gentleman’s Magazine.

Figure 6. John Cuff’s statement about his daily weather records for Universal Magazine.
Table 4

Correlation coefficients between annual temperature and pressure records for all available years, compared to the Hampstead Gentleman’s Magazine.

| Year | GM pressure | UM pressure | Low GM temp. | Low UM temp. | Notes |
|------|-------------|-------------|--------------|--------------|-------|
|      | Ayscough    | Cuff        | Ayscough     | Cuff         |       |
| 1758 | 0.83        | 0.81        | 0.92         | 0.96         | Second half of the year only |
| 1759 | 0.82        | 0.86        | 0.91         | 0.92         | Year to 24 August for Ayscough |
| 1760 | –           | 0.81        | –            | 0.95         |       |
| 1761 | –           | 0.84        | –            | 0.93         | Last year for Cuff |
| 1662 | No meteorological data published this year in London Chronicle | No observer named |

GM, Gentleman’s Magazine; UM, Universal Magazine.

Table 5

Predicted temperatures values (°F), calculated from observed data (bold).

| Month | Predicted value |
|-------|-----------------|
| July  | 61.13           |
| July  | 60.91           |
| August| 59.38           |

| Month | Predicted value |
|-------|-----------------|
| July  | 58.07 – 0.36    |
| July  | 57.81 – 3.1     |
| August| 61.93 2.55 59.89 |

Red entries are published predictions.

Bimonthly forecasting

The real novelty of the London Chronicle’s meteorological record was the provision of an average temperature forecast for the forthcoming fortnight. Quack forecasting was easily obtained from any street vendor: an almanac entry for February 1757 has only four mentions of weather (Sessions, 1757) (Figure 8). Hutchinson (op. cit. p.190) nevertheless noted, two decades later, ‘that these changes of the weather and the wind no way depend upon the situation or phases of the moon, or the sun at equinoxes, as they are too generally thought to do in this climate.’

With the hindsight of over two and a half centuries, it is easy to dismiss the attempt and method used to forecast as trivial, but it is a first step. The assumption must be that he used the average value from all corresponding prior fortnights as the forecast. Without that prior data, we have no way to check, but we can check his success.

From his own statement, he collected four years of data, now missing, to consolidate his hypothesis. We cannot check his results directly. However, his predicted value itself, and the current mean for the fortnight, allows a prediction for the same fortnight in the next year. For example, the prediction for the first fortnight of August 1758 is 59.38 °F (Table 5). If the method is correct, that value is the mean of four previous unknown values, with a total
How successful was the Hampstead gentleman?

Forecasting is usually a no-win situation! However, he took a common-sense and systematic approach, and a comparison with contemporary data demonstrates his competence (Tables 4, 6). I refrain from an exhaustive comparison of all the data he collected.

His method was bound to track close to existing data (Figure 9), and the deviations are not due to a fault in his method but to weather systems behaving erratically and whimsically.

Comparison of Hampstead and London records to Central England Temperature records

Hampstead in the 1750s, in open country well north of London, may be considered an approximate match to typical Central England Temperature (CET) terrain (Manley, 1974; Parker et al., 1992), although both

Table 6

| Year | Predicted | Actual | Difference |
|------|-----------|--------|------------|
| 1758 | 46.8      | 47.00  | 0.2        |
| 1759 | 48.55     | 51.98  | 3.4        |
| 1760 | 51.63     | 48.08  | −3.55      |
| 1761 | 48.96     | 47.71  | −1.25      |
| 1763 | 48.96     | 47.71  | −1.25      |

Mean ± SD 0.75 ± 2.7

Table 7

| Month | Predicted | Actual | Actual − Pred |
|-------|-----------|--------|---------------|
| Jan   | 0.4       | 2.4    | 2.0           |
| Feb   | 2.5       | 3.3    | 0.8           |
| Mar   | 3.7       | 4.1    | 0.4           |
| Apr   | 7.2       | 6.0    | −1.1          |
| May   | 10.2      | 13.1   | 2.9           |
| Jun   | 14.5      | 14.7   | 0.2           |
| Jul   | 16.1      | 14.4   | −1.7          |
| Aug   | 15.0      | 15.7   | 0.7           |
| Sep   | 12.8      | 11.3   | −1.5          |
| Oct   | 8.8       | 8.4    | −0.4          |
| Nov   | 4.6       | 5.7    | 1.1           |
| Dec   | 3.4       | 3.4    | 0.0           |

Mean 8.3 8.6 0.3

SD 5.5 5.0 1.4

SE 1.6 1.5 0.4

Positive residual values highlighted in red.

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of: 59.38 × 4 = 237.52. If we now add the actual mean value for the first fortnight of August 1758 to that total (61.93) and divide by 5, we should obtain the estimate for the same fortnight next year, which is ((237.52 + 61.93)/5) = 59.89, the prediction published. Grey cells in the spreadsheet sample are cells newly completed in this manner because the method is exactly as suspected and can be worked backwards to recover the missing predicted values for the first half of 1758. Take the second fortnight of July (second row, Table 5). We need the predicted value in the first column for 1758. The record is now 5 years and so will be structured as 4 years with unknown individual values plus the known value for 1758, 57.81. Following the earlier argument, and changing the sign, we have ((60.29 × 5) − 57.81)/4 = 60.91. The difference between the actual and the predicted value is = −3.10. Other missing predictions can be filled in, in the same manner.

Figure 9. 1758–1763 fortnightly mean temperatures (blue) from the London Chronicle, compared to predicted means for the same fortnights (red, °F, and no 1762 data).
are outside the CET area itself. The other three records are in central London, with tightly packed buildings that would likely affect temperature and impede air flow from wood and coal-burning heating used for domestic and commercial purposes. A brief comparison of the CET series is worthwhile to explore what extreme urban conditions for the period might demonstrate compared to nearby open country.

A caveat is that there is a short period covered, a focus on one person’s work outside the city, and discontinuity in data available. The year 1758 is the only year for which a full matching daily record is available between Ayscough, Cuff and Hampstead, and for that year, the Cuff record is 0.41 degC cooler than Ayscough.

### Hampstead and CET

As noted, the fortnight forecasts for 1758 at Hampstead are the average of the previous four years (1754–1757). Reduced to monthly

#### Table 9

|          | 1758 Hp | 1758 CET | Diff. | 1759 Hp | 1759 CET | Diff. | 1760 Hp | 1760 CET | Diff. | 1761 Hp | 1761 CET | Diff. | Average |
|----------|--------|---------|-------|--------|---------|-------|--------|---------|-------|--------|---------|-------|---------|
| Jan      | 2.4    | 2.6     | −0.2  | 2.6    | 5.9     | −3.3  | 1.4    | 1.9     | −0.5  | 4.2    | 5.4     | −1.2  | −1.3    |
| Feb      | 3.3    | 3.8     | −0.5  | 5.6    | 5.8     | −0.2  | 3.2    | 3.8     | −0.6  | 1.7    | 5.8     | −4.1  | −1.3    |
| Mar      | 4.1    | 5.2     | −1.1  | 5.2    | 6.1     | −0.9  | 4.3    | 6.6     | −2.3  | 5.9    | 6.8     | −0.9  | −1.3    |
| Apr      | 6.0    | 7.2     | −1.2  | 7.7    | 8.6     | −0.9  | 8.5    | 9.4     | −0.9  | 7.1    | 9.4     | −2.3  | −1.3    |
| May      | 13.1   | 13.8    | −0.7  | 11.4   | 12.1    | −0.7  | 10.6   | 11.7    | −1.1  | 11.2   | 11.9    | −0.7  | −0.8    |
| Jun      | 14.7   | 14.6    | 0.1   | 15.0   | 15.0    | 0.0   | 15.0   | 15.2    | −0.2  | 11.9   | 14.3    | −2.4  | −0.6    |
| Jul      | 14.4   | 14.2    | 0.2   | 18.0   | 18.2    | −0.2  | 16.3   | 16.9    | −0.6  | 16.0   | 15.8    | 0.2   | −0.1    |
| Aug      | 15.7   | 16.4    | −0.7  | 15.3   | 16.3    | −1.0  | 15.1   | 15.8    | −0.7  | 16.5   | 16.4    | 0.1   | −0.6    |
| Sep      | 11.3   | 11.9    | −0.6  | 12.7   | 13.5    | −0.8  | 14.6   | 15.7    | −1.1  | 13.6   | 14.2    | −0.6  | −0.8    |
| Oct      | 8.4    | 8.1     | 0.3   | 10.1   | 10.9    | −0.8  | 8.6    | 9.2     | −0.6  | 8.2    | 9.4     | −1.2  | −0.6    |
| Nov      | 5.7    | 5.7     | 0.0   | 3.8    | 5.1     | −1.3  | 6.0    | 5.7     | 0.3   | 5.4    | 6.2     | −0.8  | −0.5    |
| Dec      | 3.4    | 3.9     | −0.5  | 2.3    | 2.5     | −0.2  | 6.0    | 6.1     | −0.1  | 2.8    | 4.4     | −1.6  | −0.6    |
| Mean     | 8.6    | 9.0     | −0.4  | 9.1    | 10.0    | −0.9  | 9.1    | 9.8     | −0.7  | 8.7    | 10.0    | −1.3  | −0.8    |
| SD       | 5.0    | 4.9     | 0.5   | 5.4    | 5.1     | 0.3   | 5.1    | 5.2     | 0.6   | 5.0    | 4.4     | 1.2   |
| SE       | 1.2    | 1.2     | 0.4   | 1.3    | 1.2     | 0.5   | 1.2    | 1.2     | 0.4   | 1.2    | 1.1     | 0.6   |

Positive residual values highlighted in red, negative in blue.

#### Table 10

|          | 1755 Cet | Lon – CET | Diff. | 1756 Cet | Lon – CET | Diff. | 1757 Cet | Lon – CET | Diff. | 1658 Cet | Lon – CET | Diff. |
|----------|----------|-----------|-------|----------|-----------|-------|----------|-----------|-------|----------|-----------|-------|
| Jan      | 3.3      | 2.2       | 1.1   | 5.1      | 4.4       | 0.7   | 1.0      | 0.3       | 0.7   | 3.4      | 2.6       | 0.8   |
| Feb      | 2.9      | 1.2       | 1.7   | 4.5      | 4.6       | −0.1  | 5.3      | 4.4       | 1.3   | 4.6      | 3.8       | 0.8   |
| Mar      | 6.0      | 3.9       | 2.1   | 5.8      | 6.0       | −0.2  | 5.4      | 4.9       | 0.5   | 4.8      | 5.2       | −0.4  |
| Apr      | 12.2     | 10.0      | 2.2   | 6.3      | 6.7       | −0.4  | 7.5      | 8.1       | −0.6  | 6.5      | 7.2       | −0.7  |
| May      | 11.7     | 9.4       | 2.3   | 6.2      | 9.1       | −2.9  | 10.5     | 10.7      | −0.2  | 12.4     | 13.8      | −1.4  |
| Jun      | 18.4     | 15.7      | 2.7   | 13.8     | 13.8      | 0.0   | 13.0     | 14        | −1.0  | 14.4     | 14.6      | −0.2  |
| Jul      | 15.1     | 15.0      | 0.1   | 14.8     | 16.1      | −1.3  | 17.6     | 18.4      | −0.8  | 14.0     | 14.2      | −0.2  |
| Aug      | 14.3     | 14.6      | −0.3  | 14.3     | 14.7      | −0.4  | 15.3     | 15.2      | 0.1   | 16.5     | 16.4      | 0.1   |
| Sep      | 13.2     | 13.5      | −0.3  | 13.2     | 13.6      | −0.4  | 15.4     | 13.3      | 2.1   | 13.6     | 11.9      | 1.7   |
| Oct      | 9.5      | 8.4       | 1.1   | 10.7     | 9.4       | 1.3   | 10.6     | 8.2       | 2.4   | 10.1     | 8.1       | 2.0   |
| Nov      | 4.3      | 4.7       | −0.4  | 3.7      | 3.9       | −0.2  | 10.3     | 7.1       | 3.2   | 7.2      | 5.7       | 1.5   |
| Dec      | 4.7      | 3.9       | 0.8   | 3.8      | 2.9       | −0.9  | 5.7      | 3.2       | 2.5   | 5.4      | 3.9       | 1.5   |
| Mean     | 9.6      | 8.6       | 1.0   | 8.5      | 8.8       | −0.3  | 9.8      | 8.8       | 1.0   | 9.4      | 8.8       | 0.6   |
| SD       | 5.3      | 5.3       | 0.0   | 4.4      | 4.7       | −0.3  | 5.0      | 5.5       | −0.5  | 4.4      | 4.7       | 1.0   |
| SE       | 1.6      | 1.6       | 0.0   | 1.3      | 1.4       | −0.1  | 1.5      | 1.6       | −0.1  | 1.3      | 1.4       | 0.3   |

Positive residual values highlighted in red, negative in blue.
Overall, Hampstead for those four years can be regarded as a ‘cool’ match to CET estimates even though 1755 and 1756 are noted as wet summers (Brazell, 1968), as is 1758, which is nevertheless substantially warmer than expected based on the previous four years. The degree to which those wet summers are reflected in CET monthly estimates, based on data well to the northwest, is unknown. The monthly patterns suggest that the wetter summers, which also affect 1758 itself, might be primarily a London region phenomenon.

The Hampstead data reduced to months for the years 1758–1761 are complete and are compared to CET (Table 9). The results are essentially similar to the 1754–1757 period, with perhaps a weak tendency to occasionally surpass CET in the summer or autumn. Overall, the Hampstead period from 1754 to 1761 might also be regarded as a ‘cool’ match to CET estimates, 0.8 degC cooler over the period.

### Table 11

|          | 1759 | 1760 | 1761 |
|----------|------|------|------|
| Cuff     | CET  | Lon – CET Diff. | Cuff | CET | Lon – CET Diff. | Cuff | CET | Lon – CET Diff. |
| Jan      | 5.9  | 5.9 | 0.0 | 1.2 | 1.9 | −0.7 | 8.1 | 5.4 | 2.7 |
| Feb      | 6.1  | 5.8 | 0.3 | 2.6 | 3.8 | −1.2 | 3.9 | 5.8 | −1.9 |
| Mar      | 3.3  | 6.1 | −2.8 | 3.9 | 6.6 | −2.7 | 3.3 | 6.8 | −3.5 |
| Apr      | 8.9  | 8.6 | 0.3 | 8.9 | 9.4 | −0.5 | 7.2 | 9.4 | −2.2 |
| May      | 11.4 | 12.1 | −0.7 | 10.2 | 11.7 | −1.5 | 10.3 | 11.9 | −1.6 |
| Jun      | 15.6 | 15.0 | 0.6 | 15.0 | 15.2 | −0.2 | 13.0 | 14.3 | −1.3 |
| Jul      | 16.7 | 18.2 | −1.5 | 16.3 | 16.9 | −0.6 | 12.8 | 15.8 | −3.0 |
| Aug      | 15.7 | 16.3 | −0.6 | 15.1 | 15.8 | −0.7 | 15.6 | 16.4 | −0.8 |
| Sep      | 11.9 | 13.5 | −1.6 | 14.4 | 15.7 | −1.3 | 13.1 | 14.2 | −1.1 |
| Oct      | 9.0  | 10.9 | −1.9 | 7.8 | 9.2 | −1.4 | 6.9 | 9.4 | −2.5 |
| Nov      | 3.3  | 5.1 | −1.8 | 4.5 | 5.7 | −1.2 | 5.3 | 6.2 | 0.9 |
| Dec      | 6.0  | 2.5 | 3.5 | 4.7 | 6.1 | −1.4 | 9.7 | 4.4 | 5.3 |

Mean 9.5 8.8 0.7 8.7 9.8 −1.1 9.1 10.0 −0.9
SD 4.8 5.1 1.6 5.4 5.2 0.6 4.0 4.4 2.5
SE 4.6 4.9 1.7 1.6 1.6 0.2 1.2 1.3 0.8

Positive residual values highlighted in red, negative in purple.

### Table 12

| Month | 1763 CET | 1763 LC | 1763 Lon – CET | 1763 LC – CET |
|-------|----------|---------|---------------|--------------|
| Jan   | −0.80    | 0.14    | −1.6          | 0.9          | −0.8 |
| Feb   | 4.90     | 7.68    | 5.6           | 2.8          | −0.7 |
| Mar   | 5.40     | 6.54    | 3.7           | 1.1          | 1.7 |
| Apr   | 8.90     | 9.44    | 5.5           | 0.5          | 3.4 |
| May   | 10.20    | 11.28   | 8.4           | 1.1          | 1.8 |
| Jun   | 14.60    | 16.38   | 12.2          | 1.8          | 2.4 |
| Jul   | 15.30    | 17.74   | 16.2          | 2.4          | −0.9 |
| Aug   | 15.30    | 17.66   | 15.1          | 2.4          | 0.2 |
| Sep   | 13.10    | 14.57   | 1.5           | 1.5          | 1.5 |
| Oct   | 8.30     | 9.62    | 9.2           | 1.3          | −0.9 |
| Nov   | 5.80     | 7.46    | 1.7           | 1.7          | 1.7 |
| Dec   | 6.20     | 8.16    | 2.0           | 2.0          | 2.0 |

Average 8.9 9.9 8.2 1.0 0.7

Positive residual values highlighted in red, negative in purple.

LC, London Chronicle.

London and CET

Table 10 compares monthly values for the CET over the years 1755–1758 from Ayscough’s daily records reduced to months. Although monthly data are available for 1754 from Fothergill’s reports in Gentleman’s Magazine, they are nearly all indoor records, without computed averages, and therefore are not comparable.

The differences clearly imply warmer months from autumn to spring, most easily attributed to domestic and commercial heat production. Only 1756 seems slightly deviant, with both the CET and London notably cool from April through to June and London averages very close to the CET from February to September apart from March and July. Three of the four years show London warmer than the CET over the year. Table 11, using Cuff’s London data, may still display the ‘winter’ warming in 1759–1761, but far less emphatically so.

Table 12 compares monthly temperatures for 1763 from the London Chronicle, CET and Gentleman’s Magazine. Although it is not often mentioned, the Thames froze starting on 25 December 1762. Andrews (1887) cites Gentleman’s Magazine, (January 1763), but the London Magazine (January 1763) is explicit: ‘The Thames was frozen over, above the bridge, so that, in many places, passengers and carriages passed over the ice, and booths were erected and fairs held in other places.’ By 14 January ‘Coals were mounted up to a great price,’ and ‘Forty sail of laden colliers lie off Gravesend, but can proceed no higher.’ Intense frost and easterly winds continued until the end of January: Bateman reports mean temperatures of 27.40°F for 1–15 January and 30.69°F for the following fortnight. Table 12 shows London warmer than CET throughout the year, whereas Hampstead is cooler for half of the months for which Hampstead has data.

Overall, 7 years, drawn from two different observers for London, are about 0.15 degC warmer than the CET, and Hampstead is cooler than the CET about by 0.85 degC. Given Hampstead’s open country and slightly elevated situation, compared to London’s lower elevation and dense, congested urban nature, this seems to be a reasonably consistent result over the period.
Whether varying predominant regional wind directions, interacting with the alignment of London streets was a factor in dissipating fuel-generated warmth for some years and months, more than others, might be a topic worth exploring.

**Conclusion**

Years ago, looking for ancestors, I saw weather reports in the London Chronicle without spotting the forecast. Recently, I looked again for the 1762 data absent in Gentleman’s Magazine and the Universal Magazine. It turns out, very sadly, that that was Francis Bateman’s bad year too! What you see above then followed. In this light, I hope that I have unravelled what Francis Bateman was doing and that his observations are entirely comparable to the instrument makers who first began to produce a public record of London’s daily weather. Foremost, he was perhaps the first statistical weather forecaster.

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East Africa’s 2019 short rains (October–December [OND]) were one of the wettest in recent decades. Floods and landslides
occurred across the region, with initial estimates suggesting over 2.8 million people were adversely affected. Here we highlight some of the factors associated with this anomalously wet season and discuss the season in relation to the expected climate change signals over the region.

Figure 1 depicts the positive rainfall anomaly across East Africa; more than double the climatological rainfall was experienced at many locations. Rainfall started in early October 2019 (Figure 1b) and continued past the normal end of the short rains into January 2020, with flooding in Homa Bay, Kenya, at the end of January. Figure 1(c) shows that 2019 was one of the wettest short rains seasons since 1985, surpassed only by 1997, when large scale flooding was experienced across the region. The extremely high rainfall in 1997 was associated with the strong El Niño event (Black, 2005); there was no significant El Niño event during October–December 2019. Kenya Meteorological Department (KMD) report that all meteorological stations in Kenya recorded above 125% of their October–December long term means during OND 2019. At the coast, Mombasa recorded 942.1mm (over 300% of long-term mean) and in central Kenya, Meru recorded 1415.3mm (KMD, 2019).

October–December 2019 saw a strongly positive Indian Ocean Dipole (IOD, Box 1) event in the Indian Ocean (Saji et al., 1999; Webster et al., 1999), with anomalously warm SSTs in the western Indian Ocean, adjacent to East Africa, and anomalously cool SSTs in the eastern Indian Ocean.

Figure 2. Timeseries of Dipole Mode Index (a, b) and SST anomaly (c), air temperature anomaly (d), precipitation anomaly (e) and 850hPa wind anomaly (f) for OND 2019. In (f) the colours show the zonal wind anomaly, and vectors show the total wind anomaly. (g, h) show the mean climatological 850hPa wind in OND, and the mean 850hPa wind in OND 2019; vectors show the total wind and colours show the zonal wind. DMI taken from https://stateoftheocean.osmc.noaa.gov/sur/ind/dmi.php. All anomalies are relative to 1981–2010 and are taken from NCEP reanalysis (temperature and wind), NOAA Extended SST V4 (SST) and GPCP precipitation (precipitation); https://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl.
Figures 2(a–c) shows the SST anomalies in October–December 2019, and a time series of the IOD index; showing that this is one of the strongest events in the last 30 years. Positive IOD events tend to lead to enhanced rainfall over East Africa, with the positive IOD events in 1961 and 1997 leading to extremely wet conditions over East Africa (Saji et al., 1999); 1997 was also a strong El Niño year. Black et al. (2003) report that only IOD events where the Dipole Mode Index (DMI) is greater than 0.5°C for 3 contiguous months (when the zonal SST gradient is reversed for several months) lead to enhanced rainfall over East Africa. The positive IOD event in 2019 started in late summer, and persisted through to December (Figure 2b), thus falling within the ‘extreme events’ category as defined by Black et al. (2003) and influencing East African rainfall (Figures 1 and 2).

Climatologically, during OND westerly winds in the central equatorial Indian Ocean transport moisture away from East Africa (Figure 2g). During extreme positive IOD events strong low-level easterly wind anomalies (Figure 2f) are present in the north-central Indian Ocean, which weakens the westerly flow (Figures 2g,h) that normally transports moisture away from East Africa and leads to wetter conditions over East Africa and drier conditions in the central and eastern Indian Ocean basin (Black et al., 2003). Figure 2(e) shows that there were wetter conditions to the west and drier conditions over the central and eastern Indian Ocean in OND 2019. Figure 2(f) shows the 850hPa wind anomaly for OND 2019; this closely resembles the wind anomalies in extreme IOD events (figure 12 in Black et al., 2003), and Figure 2(h) shows that low-level winds over the central equatorial Indian Ocean (east of 70°E) were reversed in OND 2019, with strong easterly anomalies and easterly flow south of India (Figure 2f). This acts to reduce the advection of moisture away from, and enhances moisture transport towards, East Africa (Black et al., 2003).

Several other factors also contributed to the exceptionally wet season and the extremely heavy rainfall in October and December (Figure 1b). A sub-seasonal tropical atmospheric phenomenon within the atmosphere, which enhances convective activity, called the Madden-Julian Oscillation (MJO), was active over Africa and the Indian Ocean, especially during October. The presence of tropical cyclones in the western Indian Ocean also influenced rainfall over East Africa. In early December, there were four active tropical storms in the Indian Ocean Basin. While only one cyclone made landfall over East Africa (Cyclone Pawan made landfall over Somalia on 7th December), the presence of tropical cyclones influences wind patterns, and hence precipitation over the region. However, the interaction is complex; Cyclone Idai in March 2019 coincided with a delayed onset of the long rains season and lower rainfall over Kenya, while Cyclones Dumazile and Eliakim in March 2018 were associated with enhanced rainfall over Kenya. Finney et al. (2019) demonstrated that during the long rains (March–May [MAM]) the location of cyclones is key to determining their impact; cyclones to the east of Madagascar are associated with westerly winds around Lake Victoria, which tend to enhance rainfall (Figure 3). In early December 2019, Cyclones

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Figures 3(a) shows the impact of Indian Ocean cyclones on rainfall around Lake Victoria during MAM, with green/purple colours showing where cyclones are associated with increased/decreased chance of westerly winds over the Lake Victoria region (blue box) (based on analysis in Finney et al., 2019). (b) Figure showing the cyclone tracks (IBTrACS), mean precipitation and 700hPa wind anomalies (NCEP/NCAR reanalysis) on 7th December when Cyclones Ambali and Belna were active in the western Indian Ocean; the cross on the tracks shows the position at 1200 UTC on 7 December 2019.

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Figure 4. Forecasts for OND 2019 from IRI (a) and GHACOF (b) and Kenya Met Department (c). IRI forecast image credit: International Research Institute for Climate and Society, Columbia University. GHACOF forecast from the GHACOF 53 statement.
Belna and Ambali were both located east of Madagascar and coincided with enhanced rainfall over Kenya. This suggests the results of Finney et al. (2019) may be applicable in seasons other than the long rains. Figure 3 shows the 700hPa wind anomaly and precipitation for 7 December 2019; this shows westerly wind anomalies over Kenya and heavy rainfall, particularly over western and southern Kenya. The cyclones north of the equator may have also impacted the flow and precipitation over East Africa.

An above average wet season was correctly forecast in advance (Figure 4). The 53rd Greater Horn of Africa Climate Outlook Forum (GHACOF), held in Tanzania in late August 2019, reported a ‘higher chance of wetter conditions in most of the equatorial and southern sectors during October to December 2019’ (Figure 4b), with greater than 50% probability of above average rainfall over some regions. This was strongly influenced by the evolving positive IOD event that was forecast to continue during the short rains. The IRI (International Research Institute for Climate and Society) seasonal forecast issued in September 2019 also indicated above normal rainfall for OND 2019 over Eastern Africa (Figure 4a). Given the strong forcing from the IOD it is possible that the GHACOF forecast was overly cautious in predicting increased rainfall; this cannot be evaluated based from a single prediction, but Walker et al. (2019) have recently shown to be the case in such situations where there is strong forcing from the IOD.

The anomalously wet conditions continued after the normal end of the short rains in December into January 2020; Figure 5(b) shows the precipitation anomaly over East Africa in January 2020. Following the heavy rainfall in OND 2019, and the saturated soil conditions, this has led to further flooding and adverse consequences. This may be related to the persistence of the warm SST anomaly in the western Indian Ocean (Figure 6). While the IOD index was less than 0.5°C after early January 2020 (Figure 2b), this was due to a weakening of the cool anomaly in the eastern Indian Ocean; the warm SST anomaly in the western Indian Ocean persisted throughout January 2020. Figures 6(a) and (b) shows the interannual correlation between January SSTs and January rainfall over East Africa (region shown on map); this shows that years with warm SSTs in the western Indian Ocean in January are associated with higher rainfall over East Africa in January. Above average January rainfall was also found in 1998 (following the strong IOD event in 1997: Figures 2a, 5a). Figure 6(c) shows that SSTs were also above average in the western Indian Ocean in January 1998. Thus, this persistence of the warm SSTs in the western Indian Ocean may be linked to above average January rainfall over East Africa; further analysis is required to determine the precise mechanisms.

Figure 5. Precipitation (TAMSATv3, relative to 1985–2020) anomalies in January 1998 and January 2020.

Figure 6. Correlation of January rainfall over Eastern Africa (region in black, TAMSATv3) against HadISST SST over 1985–2019; stippling indicates where the correlation is significant at the 90% level (a), (b) shows the scatter plot of mean January rainfall over East Africa (black region, TAMSATv3) against mean January SST (HadISST) over the purple box shown in (a) for 1985–2019. (c, d) show the SST anomaly in January 1998 and January 2020. For (c and d) SST anomalies are relative to 1981–2010 and are taken from NOAA Extended SST V4 (SST); https://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl.
Box 1. Indian Ocean Dipole

The Indian Ocean Dipole (IOD) describes the difference in sea surface temperatures (SSTs) between the east and west Indian Ocean. On average in October–December the eastern Indian Ocean is warmer than the western Indian Ocean. During positive IOD events warm SST anomalies in the west and cool SST anomalies in the east lead to a reversal of the zonal SST gradient, which impacts the weather, particularly rainfall, over the Indian Ocean and surrounding continents. Over East Africa, positive IOD events are associated with enhanced rainfall, whereas over the Maritime Continent and Indonesia positive IOD events are associated with suppressed rainfall.

Often positive IOD events occur during El Niño events, for example 1982 and 1997. But in other years such as 1961 and 2019 strong IOD events can occur during neutral ENSO conditions.

January 2020 has also seen a potentially unprecedented locust outbreak across East Africa, damaging crops and raising concerns around food security. This is related to the extreme weather; wet conditions and above average temperatures (Figures 2d,e and 7b), which have led to favourable climate and vegetation characteristics for the locusts. Again, the same conditions were found in January 1998; although in that case the locust outbreak was restricted to Ethiopia, and did not affect Kenya, perhaps because it experienced a negative temperature anomaly in January 1998 (Figure 7a).

Future projections from climate models indicate increasing rainfall during the short rains under future climate change (Rowell et al., 2015; Dunning et al., 2018), suggesting that events such as the increased rainfall during the 2019 short rains could become more frequent under climate change. IPCC projections also show an increase in December–January rainfall over the Horn of Africa, with at least 90% of models agreeing on the sign of change (Collins et al., 2013). Furthermore, recent work has shown that climate change can also increase the intensity of rain in storms over Africa because global warming increases the saturation vapour pressure and so potentially the total column water and storm intensities (Kendon et al., 2019; Finney et al., 2020). Therefore, for any given strength of positive IOD events, more intense rainfall events are expected in the future.

Cai et al. (2018) explored the relationship between strongly positive IOD events and climate change; they concluded that under a global average warming of 1.5 degC (above pre-industrial levels) strongly positive IOD events may occur twice as often. Furthermore, the rate of recent warming of the western Indian Ocean is one of the fastest of any tropical ocean over the last century (Roxy et al., 2014), and climate models project that continuation of these higher rates of warming should be expected under climate change (Zheng et al., 2013; Chu et al., 2014). There is strong agreement across climate models regarding these changes in Indian Ocean SSTs, therefore increasing our confidence in increased occurrence of very wet short rains and January rainfall over East Africa under future climate change.

The season had many adverse impacts on society, including severe flooding that led to the destruction of property, loss of lives (both human and livestock) and crops, and displacement of people. In cereal growing regions, farmers were unable to harvest their crops; landslides and mud slides destroyed homes in West Pokot and led to loss of life, and roads and bridges were washed away in some areas, disrupting transport systems (Kenya Meteorological Department, 2019). Furthermore, the season made a major contribution to a rapid rise in Lake Victoria’s water level, and combined with above average rainfall during the 2020 long rains led to record breaking water levels there (Marsham, 2020). With future projections suggesting that such seasons could become more frequent under climate change, societies should prepare and adapt for more events similar to the short rains of 2019 and January rainfall of 2020. It will be increasingly important to use forecasts in risk management to help adapt to such events, especially for the short rains, where seasonal forecasts have been shown to have higher skill (Walker et al., 2019).

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TAMSATv3 data is available from http://www.tamsat.org.uk/. CHIRPS data is available from https://data.chc.ucsb.edu/products/CHIRPS-2.0/. DMI Index from https://stateoftheocean.osm.noaa.gov/sur/ind/dmi.php. IBTrACS data from https://www.metoffice.gov.uk/hadobs/hadisst/. Forecast data was obtained from https://www.esrl.noaa.gov/iri, ICPAC and KMD. All other fields were obtained from https://www.ncdc.noaa.gov/ibtracs/. HadISST data from https://data.chc.ucsb.edu/products/HadISST/. ENSO strength data from https://www.tamsat.org.uk/. CHIRPS data is available from http://chirps.vicuna.nsst.cgs.nrcan.gc.ca/CHIRPS-2.0/. DMI Index from https://data.chc.ucsb.edu/products/DMIv3/.

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