Climatological summaries of Thomas Hughes' meteorological data, for Stroud, UK (1775-1813)

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DATA PAPER

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Climatological summaries of Thomas Hughes' meteorological data, for Stroud, UK (1775–1813)

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Abstract

Thomas Hughes (1742–1813) kept a daily diary of weather and geoscience phenomena at Stroud in Gloucestershire, in the southern UK, between 1775 and 1813, following a short period of similar records made nearby from 1771. Data from the diary have previously been used in compiling the Central England Temperature series and to corroborate aurora sightings elsewhere in Europe. Recent historical research now confirms the suspected authorship of the diaries beyond doubt and strongly suggests that the pre-Stroud records were made in south Gloucestershire. Here, summary tables of monthly data between 1771 and 1813 are presented for thunderstorm days, snow days, rain days, rainfall, surface air pressure and auroral nights. Consistency checks, both between the different measurements contained and with other contemporary measurements, provide confidence in the reliability of the meteorological and geophysical data which spans part of the Dalton Minimum in solar activity.

KEYWORDS

climate, weather, Dalton minimum, thunderday

1 | INTRODUCTION

The weather diary of the Gloucestershire apothecary–surgeon Thomas Hughes (1742–1813) has provided an important resource for modern climatological and solar-terrestrial research, containing weather (temperature, barometric pressure, humidity and wind) and auroral information. Hughes' professional activities supported him in keeping a consistent daily diary of geophysical phenomena at a single location in Stroud, Gloucestershire, from 1775 to 1813. In particular, the thermometer measurements it contains contributed to the construction of the Central England Temperature series (Manley, 1953, 1974).

Although the temperature and aurora data have been extensively analysed and discussed (Manley, 1974; Harrison, 2005; Rowntree, 2012), the monthly climatological

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TABLE 1 Monthly total rainfall (units of mm)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1771	53	23	53	15	*25*	46	51	74	*48*	147	43	94	673
1772	69	86	84	74	53	51	71	69	*145*	*109*	198	43	1,052
1773	58	150	20	48	147	61	28	53	124	124	132	86	1,034
1774	124												
1775	69	89	56	20	13	61	137	157	84	84	66	38	874
1776	56	122	56	18	51	53	53	117	*74*	48	43	33	724
1777	*43*	*41*	64	86	89	71	97	61	20	127	53	30	782
1778	84	25	20	*23*	*76*	76	97	3	53	86	130	97	770
1779	18	20	18	*74*	66	69	76	48	*61*	94	69	127	739
1780	28	28	53	76	46	53	48	33	*117*	81	*61*	3	627
1781	69	*74*	3	69	36	79	46	38	*94*	*8*	107	86	706
1782	86	25	*86*	104	127	41	112	140	*112*	43	46	23	945
1783	119	104	61	10	51	48	56	46	66	38	43	13	655
1784	*20*	38	86	69	*53*	91	79	*53*	23	8	81	*43*	645
1785	41	51	*3*	10	18	33	33	*89*	109	84	46	81	597
1786	*140*	28	38	36	61	43	20	64	89	*104*	79	84	785
1787	15	74	104	*25*	43	48	114	38	79	81	*61*	69	752
1788	43	51	28	18	36	*23*	71	79	74	15	25	10	472
1789	*130*	64	71	46	112	109	102	*30*	*66*	*119*	48	71	968
1790	51	8	15	48	71	33	69	*43*	43	41	135	104	660
1791	117	58	25	*48*	20	18	99	*38*	23	91	165	*58*	762
1792	*79*	41	*94*	74	46	53	94	*122*	130	76	23	36	866
1793	*74*	38	89	89	25	25	36	*89*	91	36	79	53	724
1794	30	41	74	71	41	10	38	*61*	61	89	*104*	76	696
1795	30	89	107	81	10	*91*	33	53	13	201	84	61	853
1796	130	58	15	18	94	28	*104*	*28*	28	61	*46*	91	701
1797	61	13	33	51	109	137	*56*	89	*180*	51	76	130	986
1798	*66*	33	28	79	30	20	*155*	*25*	84	107	132	43	803
1799	*51*	104	51	97	66	18	*114*	157	183	89	124	18	1,072
1800	135	20	53	*104*	74	28	3	56	48	74	*170*	102	866
1801	*94*	51	117	15	99	43	89	43	61	86	*112*	91	902
1802	41	91	18	20	66	61	109	15	23	109	66	74	693
1803	66	41	15	38	48	74	15	33	*38*	18	109	160	655

(Continues)

TABLE 1 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1804	147	36	58	61	66	8	*84*	48	0	81	132	56	777
1805	69	43	20	79	61	43	48	71	53	51	25	56	620
1806	150	56	51	20	33	23	66	*76*	30	28	76	119	729
1807	*58*	38	10	10	124	51	89	41	66	*48*	*142*	61	739
1808	23	33	10	*112*	79	36	97	30	61	107	71	46	704
1809	*142*	102	*43*	112	71	51	*64*	122	107	5	43	*112*	973
1810	30	53	71	97	91	48	122	74	30	79	*175*	137	1,008
1811	66	89	74	76	147	71	91	64	76	122	89	46	1,011
1812	56	*114*	119	58	99	107	*66*	*51*	43	*152*	*84*	15	965
1813	53	145	25										
Count	43	42	42	41	41	41	41	41	41	41	41	41	41
Min	15	8	3	10	10	8	3	3	0	5	23	3	472
Median	66	51	52	58	61	48	71	53	66	81	79	61	762
Mean	71.7	59.2	50.5	55.6	65.2	52.0	73.9	63.9	71.0	78.1	87.7	67.7	794.3
Max	150	150	119	112	147	137	155	157	183	201	198	160	1,072

summaries have not been readily available. Transcriptions of these summaries are provided here for monthly rainfall (Table 1), monthly rain days (Table 2), monthly sea level pressure (Table 3), monthly snow days (Table 4), monthly thunderstorm days (Table 5) and monthly auroral nights (Table 6). Historical thunderstorm day information is of contemporary interest (Valdivideso *et al.*, 2019), as is meteorological data for the Dalton Minimum in solar activity, during which some of Hughes' observations were made.

2 | DESCRIPTION OF THE DATA SOURCE

2.1 | Survival and identification

Thomas Hughes (1742–1813) lived in Stroud, Gloucestershire, and is buried in the churchyard of St Laurence Church, Stroud. Following his death, his medical books and papers were bequeathed in his Will (Hughes, 1813; Anon, 1813a) to the Gloucester Infirmary, for storage in the cellars of the Infirmary building.[*] His weather diaries were later sent to the pioneer national rainfall data collector G.J. Symons, who ultimately presented them to the Royal Meteorological Society in January 1885 (Britton, 1927). Symons (1866) does not, however, mention Hughes' data in his summary of stations measuring rainfall prior to 1800.

In their current form, the diaries exist as three bound volumes, with an adhesive cover label dated 1927 and marked 'Royal Meteorological Society'. To this, the handwritten title—'Meteorological Register kept at Stroud, Gloucestershire 1775–1813'—summarised by C E Britton in a separate file' was added (Figure 1). Charles Britton was a Met Office employee,[†] and the value of his summaries is specially mentioned by Manley (1953). Initially, Britton did not know the author of the meteorological information. In the 'separate file' (Figure 2; Britton, 1927), he described his good fortune in meeting Major Charles J. Fisher of Stroud, whose grandfather Paul Hawkins Fisher had written 'Notes and Recollections of Stroud'. Major Fisher suggested Britton consulted P.H. Fisher's book. In this, Fisher (1891) reported that Hughes:

> *"kept a common place day book, in the form of loose sheets of paper, arranged alphabetically;*

[*]This building, in Southgate Street, was eventually demolished in the 1970s; materials stored in its cellars were irrecoverably water damaged.

[†]Charles Ernest Britton, BSc, (1894–1970) was a Technical Officer in the Met Office, commissioned into the RAF in 1939. In 1937, he published an analysis of weather and climate up to 1450, compiled from medieval chronicles. In 1943, Britton joined a team under Group Captain James Stagg, which ultimately provided the D-Day forecast for the invasion of France in June 1944.

TABLE 2 Monthly total of days with rain

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1771	9	11	8	6	13	9	14	15	17	23	17	20	162
1772	8	15	18	15	12	11	11	13	21	25	26	17	192
1773	20	15	4	14	19	18	12	10	20	24	26	22	204
1774													
1775	20	20	21	8	4	10	24	22	17	14	18	9	187
1776	5	26	12	9	12	18	21	20	14	11	14	10	172
1777	11		15	13	21	18	16	13	8	12	17	9	153
1778	18	12	11	*11*	16	15	16	3	10	16	24	16	168
1779	6	8	6	16	16	11	15	7	18	18	16	19	156
1780	7	11	15	21	15	13	11	10	18	19	*15*	5	160
1781	*14*	17	3	14	9	17	10	12	11	*4*	21	27	159
1782	18	10	16	19	20	10	18	22	17	19	15	8	192
1783	25	19	11	9	13	12	11	13	16	13	13	6	161
1784	6	*8*	11	19	7	20	10	12	8	5	18	6	130
1785	13	6	1	5	11	11	14	16	17	16	16	13	139
1786	17	11	8	7	13	9	7	15	17	7	16	15	142
1787	8	14	17	11	10	12	20	14	11	24	12	21	174
1788	11	15	13	8	7	9	*16*	14	16	2	5	3	119
1789	16	16	14	13	19	17	21	7		19	*14*	15	171
1790	12	4	5	12	18	12	15	12	10	12	14	16	142
1791	20	18	6	14	11	8	17		6	15	22	12	149
1792	16	11	16	13	17	11	16	15	23	20	8	13	179
1793	15	17	17	11	8	16	8	13	15	10	10	13	153
1794	5	15	13	13	14	4	9	12		18	20	14	137
1795	2	11	14	18	5	12	*10*	13	5	25	17	17	149
1796	21	11	8	4	17	9	21	5	9	14	12	*12*	143
1797	15	3	8	13	*18*	21	15	24	19	18	14	20	188
1798	15	*5*	9	12	*14*	*6*	22	*9*	*15*	16	18	11	152
1799	13	*8*	*9*	20	17	8	20	*17*	14	17	14	7	164
1800	16	6	9	20	*13*	10	4	11	16	15	18	16	154
1801	*14*	13	16	8	9	7	15	5	18	22	18	14	159
1802	8	16	10	13	9	*14*	20	10	7	17	14	11	149
1803	16	13	8	18	11	15	3	10	3	10	14	21	142

(Continues)

TABLE 2 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1804	23	12	14	15	17	5	15	10	0	20	17	11	159
1805	15	16	7	13	8	10	12	12	9	12	7	18	139
1806	25	15	13	9	9	*4*	20	12	*8*	7	18	26	166
1807	10	15	10	8	18	*9*	13	13	11	10	17	7	141
1808	10	11	4	13	14	8	15	8	16	22	15	10	146
1809	17	19	8		14	13	11	*19*		8	9	24	142
1810	6	15	15	13	11	6	19	14	7	11	21	19	157
1811	10	20	6	*11*	*20*	*10*	13	13	9	*20*	14	15	161
1812	11	20	17	10	16	*15*	15	10	8	22	14	6	164
1813	13	22	8										
Count	42	41	42	40	41	41	41	40	38	41	41	41	41
Min	2	3	1	4	4	4	3	3	0	2	5	3	119
Median	14	14	11	13	13	11	15	13	14	16	16	14	157
Mean	13.3	13.4	10.8	12.5	13.3	11.5	14.5	12.6	12.7	15.4	15.8	14.0	158.0
Max	25	26	21	21	21	21	24	24	23	25	26	27	204

> *in which he regularly entered notes of his doing, and made excerpts from the books he perused",*

Interpreting this with the medical references in the diaries, Britton (1927) concluded that the diarist was likely to be Thomas Hughes. In the 1891 second edition of Fisher's book consulted by Britton, the character of the diary entries is not discussed, beyond the implication that it was for his professional medical matters. However, in a recently discovered first edition[‡] of *Notes and Recollections of Stroud* (Fisher, 1871), Fisher's original text explicitly declared that Hughes:

> *"kept a register of the rain-water that fell in the year; for the gauging of which he contrived an apparatus at the top of his house".*

This additional material was not carried forward to the second edition of Fisher's memoir (Fisher, 1891). It is important, as it identifies Hughes as the weather diarist beyond doubt.

2.2 | Recording and site considerations

Britton (1927) concluded that the entries for 1771 and 1772 were from different sites, which he suspected were on the outskirts of Stroud. Closer inspection of Hughes' diaries, combined with new biographical information (summarised in the Appendix), indicates that entries in the first 2 years of the diary, 1771 and 1772, were made elsewhere; for the 21 August 1773, there is an entry 'at Stroud' and then in 1774 'removed to Stroud'. The specific location of the early observations is not known. The diaries state that Hughes moved to Stroud in 1774, only setting up his instruments to be ready for January 1775. The record for Stroud therefore begins in 1775, but some of the other information, such as the auroral data and to some extent rain, snow and thunder, is relatively independent of the exact site.

The original pages of the diary were arranged to form one month of records per page. At the end of a year, the sheets were folded down the centre. On the few occasions when Hughes was absent, the measurements were recorded in a different hand.[§] There is no previous indication of Hughes' interest in recording weather, but when the diary began on the 1 January 1771, it was sufficiently well constructed that it could be continued in a very similar format

[‡]This 1871 edition only emerged in April 2015, following an auction. It is kept by the Stroud Museum in the Park.

[§]Only one name is specifically mentioned in the whole diary, in Dec 1771: 'Jas Cooper who kept the records this week when I was indisposed'. A possible candidate for this temporary observer is Hughes' cousin, John, of Wotton-under Edge, who had the surname Cooper. An alternative is a James Cooper, son of Thomas and Frances Cooper, who was baptized in Wotton-under-Edge on 27 November 1749.

TABLE 3 Monthly mean surface pressure (units of hPa)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1771	1,009	1,018	1,014	1,020	1,016	1,022	1,021	1,017	1,020	1,016	1,025	1,005	1,016.9
1772	1,005	1,002		1,016	1,021	1,023	1,021	1,017	1,013	1,016	1,008	1,019	1,014.7
1773	1,014	1,014		1,014	1,014	1,017	1,023	1,021	1,013	1,012	1,007	1,008	1,014.3
1774													
1775	1,017	1,016	1,017	1,025	1,026	1,023	1,021	1,019	1,018	1,020	1,017	1,027	1,020.5
1776	1,014	1,003	1,022	1,027	1,018	1,020	1,021	1,020	1,021	1,020	1,021	1,022	1,019.1
1777	1,020		1,017	1,024	1,022	1,023		1,025	1,028	1,016	1,024	1,019	1,021.8
1778	1,015	1,019	1,017	1,020	1,021	1,027	1,023	1,031	1,026	1,013	1,014	1,019	1,020.5
1779	1,035	1,033	1,031	1,024	1,014	1,024	1,021	1,027	1,022	1,024	1,014	1,013	1,023.5
1780	1,019	1,024	1,017	1,008	1,019	1,018	1,019		1,018	1,008	1,015	1,028	1,017.6
1781	1,009	1,012	1,025	1,014	1,008	1,014	1,019	1,014	1,015		1,008	1,011	1,013.7
1782	1,012	1,016	1,010	1,007	1,017	1,020	1,017	1,008	1,016	1,016	1,017	1,021	1,014.6
1783	1,002	1,011	1,009	1,024	1,021	1,014	1,017	1,017	1,011	1,015	1,014	1,016	1,014.2
1784	1,013	1,008	1,007	1,009	1,020	1,025	1,016	1,020	1,018	1,021	1,014	1,010	1,015.0
1785	1,011	1,013	1,022	1,025	1,015	1,023	1,013	1,013	1,010	1,015	1,012	1,010	1,015.2
1786	1,006	1,017	1,009	1,014	1,016	1,017	1,019	1,015	1,013	1,017	1,010	1,006	1,013.3
1787	1,024	1,013	1,011	1,017	1,020	1,015	1,013	1,017	1,010	1,009	1,011	1,007	1,013.9
1788	1,019	1,005	1,008	1,021	1,013	1,018	1,014	1,015	1,012	1,023	1,022	1,017	1,015.5
1789	1,008	1,009	1,007	1,009	1,015	1,013	1,013	1,020		1,007	1,008	1,012	1,011.0
1790	1,019	1,025	1,026	1,014	1,019	1,020	1,013	1,017	1,019	1,015	1,012	1,015	1,017.8
1791	1,003	1,016	1,025	1,010	1,017	1,016	1,015		1,010	1,007	1,006	1,008	1,012.1
1792	1,007	1,017	1,010	1,015	1,021	1,017	1,014	1,015	1,011	1,010	1,018	1,014	1,014.2
1793	1,018	1,012	1,013	1,015	1,019	1,017	1,020	1,017	1,019	1,017	1,010	1,009	1,015.4
1794	1,020	1,013	1,018	1,015	1,025	1,021	1,019	1,017		1,012	1,009	1,017	1,016.7
1795	1,019	1,007	1,013	1,012	1,009	1,014	1,020	1,017	1,021	1,007	1,015	1,017	1,014.2
1796	1,009	1,011	1,020	1,020	1,014	1,017	1,012	1,021	1,018	1,018	1,013	1,013	1,015.6
1797	1,021	1,027	1,018	1,011	1,018	1,015	1,018	1,014	1,010	1,015	1,016	1,012	1,016.2
1798	1,016	1,021	1,018	1,017	1,013	1,023	1,009	1,022	1,014	1,015	1,006	1,015	1,015.7
1799	1,020	1,010	1,014	1,006	1,014	1,021	1,013	1,011	1,012	1,012	1,014	1,017	1,013.7
1800	1,003	1,014	1,015	1,008	1,014	1,028	1,026	1,022	1,012	1,016	1,009	1,008	1,014.6
1801		1,012	1,015	1,021	1,021	1,022	1,013	1,022	1,016	1,015	1,010	1,004	1,015.7
1802	1,020	1,013	1,024	1,022	1,018	1,014	1,015	1,021	1,022	1,014	1,008	1,012	1,016.9
1803	1,009	1,017	1,022	1,015	1,018	1,021	1,025	1,022	1,023	1,023	1,003	1,007	1,017.0

(Continues)

TABLE 3 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1804	1,005	1,023	1,007	1,011	1,016	1,024	1,014	1,018	1,025	1,010	1,015	1,014	1,015.2
1805	1,007	1,015	1,019	1,015	1,017	1,021	1,018	1,017	1,019	1,016	1,029	1,010	1,016.9
1806	1,005	1,014	1,012	1,021	1,014	1,025	1,018	1,015		1,017	1,012	1,006	1,014.4
1807	1,022	1,014	1,021	1,017	1,018	1,021	1,017	1,017	1,014	1,017	1,005	1,018	1,016.7
1808	1,015	1,024	1,024	1,015	1,017	1,020	1,019	1,016	1,015	1,013	1,016	1,014	1,017.3
1809	1,004	1,013	1,023	1,014	1,017	1,017	1,017	1,013	1,012	1,025	1,021	1,006	1,015.1
1810	1,024	1,016	1,009	1,010		1,023	1,013	1,016	1,024	1,018	1,002	1,010	1,015.2
1811	1,018	1,004	1,022	1,019	1,017			1,019	1,017	1,017	1,021	1,012	1,016.3
1812	1,016	1,008	1,012	1,017		1,019	1,019	1,020	1,023	1,005	1,015	1,019	1,015.8
1813	1,022	1,013	1,029										
Count	41	41	40	41	39	40	39	39	38	40	41	41	41
Min	1,002	1,002	1,007	1,006	1,008	1,013	1,009	1,008	1,010	1,005	1,002	1,004	1,011
Median	1,015	1,014	1,017	1,015	1,017	1,020	1,018	1,017	1,016	1,015	1,014	1,013	1,016
Mean	1,014.0	1,014.5	1,016.8	1,016.0	1,017.2	1,019.8	1,017.3	1,018.1	1,016.8	1,015.1	1,013.4	1,013.4	1,016.0
Max	1,035	1,033	1,031	1,027	1,026	1,028	1,026	1,031	1,028	1,025	1,029	1,028	1,024

for the following 40 years until just before his death in 1813, the only break being the full year of 1774 during which he moved to Stroud.

Hughes' 'observatory' was a chemist's shop[‖] on the north-facing side of the High Street in the centre of Stroud (51.43°N 2.26°W). Stroud lies at the confluence of five valleys, two of which lie in a generally northerly direction and two others lie more or less east–west. The town centre lies on the southern side of the east–west valley, and to the north, there is an arc of hills with the highest points being 271 m at 4.8 km to the north-west, 283 m at 7.2 km to the north, 272 m at 7.7 km to the north-east, and continuing at around 250 m or more to the east and closer to the town. None of the intervening land between these high points has an altitude below 170 m, and much of it is in fact higher. Thus, the view in the north-west to north-east arc from Thomas Hughes' vantage point at nominally 73.7 m was severely restricted to 2–3 km, because of the surrounding hills: there would have been no visibility down the southward valley from the site of Hughes' house.

An obvious consequence of Hughes' professional work was that his observations were restricted to times when he was at home, and consequently events may have been missed.

3 | CLIMATOLOGICAL ANALYSES

Britton summarized the diary information and climatological data in a short unpublished manuscript (Britton, 1927), kept with the diary (Figure 2). His summary was compiled from Hughes' daily[¶] records of the meteorological measurements together with comments about both weather and, where applicable, seasonal and medical comments. Britton considered extracting fog days but did not see value in providing a summary, as the definition applied to haze, mist and fog appeared quite variable. Further, Britton did provide a table of days of hail, but these are not extracted here as the use of thunder days, with which there is an overlap, is much more valuable. Britton's monthly data for rainfall amount and rain days, surface pressure, snow days, thunderstorm days and auroral nights are provided here as data tables, available in the University of Reading Research Data Archive at http://dx.doi.org/10.17864/1947.234. In these tables, values thought questionable by Britton are shown in italics, such as when there were fewer than 20 values from which to derive monthly mean values: the

[‖]Hughes' final home in Stroud, at 57 High Street, which he occupied after living in 56 High Street, has long remained a pharmacy and continues to house one.

[¶]Hughes' diary entries were occasionally made more frequently than daily. For example, in July 1793 he made multiple temperature measurements during the afternoons, no doubt to ascertain the maximum value.

TABLE 4 Monthly number of snow days

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1771	8	4	8	1	0	0	0	0	0	0	0	0	21
1772	10	7	4	2	0	0	0	0	0	0	0	0	23
1773	1	7	0	1	2	0	0	0	0	0	2	2	15
1774													
1775	3	0	4	0	0	0	0	0	0	0	1	0	8
1776	10	4	2	0	0	0	0	0	0	0	0	5	21
1777	7	3	3	0	0	0	0	0	0	0	0	2	15
1778	3	4	0	2	0	0	0	0	0	1	0	0	10
1779	2	0	0	0	1	0	0	0	0	0	4	3	10
1780	2	6	0	4	0	0	0	0	0	0	5	3	20
1781	2	1	1	0	0	0	0	0	0	0	0	1	5
1782	2	5	6	3	0	0	0	0	0	0	4	0	20
1783	5	1	5	0	1	0	0	0	0	0	1	4	17
1784	4	6	10	6	0	0	0	0	0	1	0	7	34
1785	6	8	6	1	0	0	0	0	0	2	1	2	26
1786	4	3	3	1	0	0	0	0	0	0	2	3	16
1787	1	0	0	2	0	0	0	0	0	0	0	2	5
1788	0	1	1	1	1	0	0	0	0	0	0	8	12
1789	6	1	13	1	0	0	0	0	0	0	0	2	23
1790	0	0	0	3	0	0	0	0	0	0	0	3	6
1791	1	3	0	0	0	0	0	0	0	0	0	6	10
1792	2	3	3	0	0	0	0	0	0	0	0	0	8
1793	1	1	4	4	0	0	0	0	0	0	0	0	10
1794	4	0	0	1	1	0	0	0	0	0	0	2	8
1795	9	9	4	1	0	0	0	0	0	0	1	0	24
1796	0	4	4	0	0	0	0	0	0	0	0	2	10
1797	3	1	1	1	1	0	0	0	0	0	0	0	7
1798	2	3	6	0	0	0	0	0	0	0	3	2	16
1799	2	5	7	2	0	0	0	0	0	0	0	3	19
1800	3	2	3	0	0	0	0	0	0	0	1	6	15
1801	2	4	2	2	0	0	0	0	0	0	2	2	14
1802	6	3	2	2	2	0	0	0	0	0	0	1	16
1803	6	4	2	0	0	0	0	0	0	0	1	1	14

(Continues)

TABLE 4 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1804	1	3	3	4	0	0	0	0	0	0	1	5	17
1805	7	1	2	2	0	0	0	0	0	0	0	4	16
1806	8	3	5	5	0	0	0	0	0	0	0	0	21
1807	4	5	1	3	0	0	0	0	0	0	7	1	21
1808	4	1	3	6	0	0	0	0	0	0	0	8	22
1809	7	1	2	6	0	0	0	0	0	0	1	0	17
1810	2	4	3	1	0	0	0	0	0	0	0	1	11
1811	4	0	1	2	0	0	0	0	0	0	0	1	8
1812	4	1	5	0	0	0	0	0	0	0	0	4	14
1813	3	0	1										
Count	42	42	42	41	41	41	41	41	41	41	41	41	41
Min	0	0	0	0	0	0	0	0	0	0	0	0	5
Median	3	3	3	1	0	0	0	0	0	0	0	2	15
Mean	3.8	2.9	3.1	1.7	0.2	0.0	0.0	0.0	0.0	0.1	0.9	2.3	15.2
Max	10	9	13	6	2	0	0	0	0	2	7	8	34

original use by Britton of both zeros and blanks in the tables has been retained, as it is not clear in some cases whether a blank should be interpreted as nothing was observed or nothing was recorded.

Summary statistics are given across all available data, although the first few years up to 1774 are for a different but probably nearby site in south Gloucestershire, perhaps at Hughes' former residences of Wotton-under-Edge (51.638°N 2.349°W) or Marshfield (51.462°N 2.317°W). In addition, some checks are applied to the data, presented in Figure 3. Because Hughes' data have had various use in other datasets, for example in filling in the Hornsby rainfall series for Oxford (Craddock and Craddock, 1977), care has been taken to avoid the possibility of circular comparison, and self-consistency checks devised.

3.1 | Rainfall amounts and rain days

Table 1 provides the monthly and annual rainfall amounts. The original data values provided by Britton were given in inches, and a conversion has been made to millimetres. The annual totals have been recalculated from the converted monthly values. The greatest annual rainfall was in 1799 and the least in 1788. Table 2 provides the distribution of rain days, defined as days on which at least 0.1 mm (0.005 inch) rain was recorded. September 1804 had no rain days, and December 1781 had the greatest number, 27. As a cross-check on the two sources of rain data, the monthly rainfall amounts have been plotted against the monthly rain days, and the two quantities are strongly correlated (Figure 3a). The frequency distribution of daily rainfall has also been found by combining the values from Tables 1 and 2 (Figure 3b). The median daily rainfall is 4.7mm, with an interquartile range of 2.6 mm.

3.2 | Surface barometric pressure

Table 3 provides the monthly surface pressure for months when there are 20 or more days' measurements available. Following Britton's analysis, the pressure values have been corrected for defective vacuum and reduced to mean sea level by adding 0.5 inches of mercury to the original measurements, before conversion to SI units using the factor of 33.8639 hPa/(inch Hg). Extreme daily values of sea level pressure identified by Britton (corrected and converted in the same way) were 1,050.1 hPa on 26 December 1778 and 961.1 hPa on 20 January 1791. These maximum and minimum values are corroborated by measurements of 1,047 hPa and 961 hPa, respectively, at London, on the same dates (Cornes *et al.*, 2012). Figure 3c plots the monthly mean pressure against the monthly mean rainfall. It is clear from this that there is negligible rainfall when the pressure is high and the greatest rainfall when the pressure is low, which provides a consistency check on the values tabulated.

TABLE 5 Monthly number of thunderstorm days

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1771	1	0	0	0	2	1	0	0	0	0	0	0	4
1772	0	0	0	0	0	1	2	0	2	0	0	0	5
1773	0	0	0	0	0	3	1	1	4	1	0	0	10
1774													
1775	0	0	0	0	0	5	3	2	4	1	0	1	16
1776	0	1	0	0	0	0	1	1	0	0	0	0	3
1777	0	0	0	0	0	0	1	3	0	0	0	0	4
1778	1	0	0	0	0	4	3	0	0	0	0	0	8
1779	0	0	0	2	0	2	3	1	3	0	0	0	11
1780	0	0	1	0	0	0	1	2	1	1	0	0	6
1781	0	1	0	0	1	4	0	2	1	0	1	0	10
1782	0	0	0	0	1	1	1	1	2	0	0	0	6
1783	1	0	0	0	0	2	4	3	2	0	0	0	12
1784	0	0	0	0	1	1	3	0	0	0	0	0	5
1785	1	0	0	0	0	1	3	0	0	0	0	0	5
1786	0	1	0	0	1	2	4	0	2	0	0	0	10
1787	0	0	0	0	0	4	0	3	1	2	0	0	10
1788	0	0	1	0	1	1	0	0	0	0	0	0	3
1789	0	0	0	1	1	5	3	1	0	0	0	0	11
1790	0	0	0	0	2	0	0	0	0	0	0	1	3
1791	1	0	0	0	0	1	1	2	0	0	1	1	7
1792	0	0	0	0	1	0	1	3	0	0	0	1	6
1793	0	0	0	0	1	0	2	2	0	1	0	0	6
1794	0	0	1	0	1	0	0	0	0	0	1	0	3
1795	0	0	0	1	0	2	1	1	0	0	0	0	5
1796	2	0	0	0	0	0	1	0	0	0	0	0	3
1797	0	0	0	0	3	2	1	4	0	0	0	0	10
1798	0	0	0	1	1	0	2	0	0	2	0	0	6
1799	0	1	0	1	1	0	3	0	0	0	0	0	6
1800	0	0	0	0	1	0	0	2	1	1	0	0	5
1801	0	0	0	0	2	1	3	1	0	0	0	0	7
1802	0	0	0	0	0	2	0	1	1	0	0	0	4
1803	0	0	0	2	0	0	2	1	0	0	1	0	6

(Continues)

TABLE 5 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1804	0	0	0	0	1	0	2	2	0	0	0	0	5
1805	0	0	0	0	0	1	2	0	0	0	0	0	3
1806	0	0	0	0	1	0	4	4	0	0	0	1	10
1807	0	0	0	0	0	1	1	1	0	0	0	0	3
1808	0	0	0	0	1	1	7	1	2	0	0	0	12
1809	0	0	1	0	4	0	2	3	1	0	0	0	11
1810	0	0	1	0	0	1	1	3	1	0	0	2	9
1811	0	0	0	0	5	2	1	1	2	1	0	0	12
1812	0	1	1	0	2	0	2	0	0	0	0	0	6
1813	0	1	0										
Count	42	42	42	41	41	41	41	41	41	41	41	41	41
Min	0	0	0	0	0	0	0	0	0	0	0	0	3
Median	0	0	0	0	1	1	1	1	0	0	0	0	6
Mean	0.2	0.1	0.1	0.2	0.9	1.2	1.8	1.3	0.7	0.2	0.1	0.2	7.0
Max	2	1	1	2	5	5	7	4	4	2	1	2	16

3.3 | Snow days

The monthly totals of days on which snow fell are provided in Table 4. Britton remarks that Hughes made a marginal note on the 11 June 1791 that 'Snow was said to fall upon hills', but this event was disregarded from the tabulation as only from a secondary source. The greatest number of snow days was 13 in March 1789. As a check on the snow day data, totals for each winter (December–January–February) were made and compared with the Central England Temperature (CET) for the same year, averaged across the same months. Figure 3d shows the values obtained. It is apparent that the winter total of snow days increases with decreasing CET; that is there are more snow days in colder winters. Dividing the data at the median values and constructing a contingency table, the Fisher exact test rejects the null hypothesis of a unit odds ratio with $p = 0.003$.

3.4 | Thunderstorm days

The monthly totals of days with thunder or lightning (as defined by Britton, so this potentially includes the possibility of distant lightning with inaudible thunder) are presented in Table 5. These values can be compared with the rain days and are generally smaller. As a test of the thunderstorm day data, the monthly thunderstorm days have been compared with the CET. Figure 3e shows this comparison for the June data. Again, by dividing the data at the median values and constructing a contingency table, the Fisher exact test marginally rejects the null hypothesis of a unit odds ratio at a confidence level of 95%.

3.5 | Auroral nights

Despite the limited view of the northern horizon, there are 69 Aurora Borealis sightings recorded in the diaries between 1771 and 1809 (identified by a marginal note of 'AB') which have been shown to agree with other international records of aurora sightings on the same dates (Harrison, 2005). Table 6 provides the auroral data as monthly totals. These are plotted against annual sunspot numbers in Figure 3f. Constructing a contingency table by splitting the data at the median, the Fisher exact test rejects a unit odds ratio with $p = 0.002$.

3.6 | Miscellaneous and phenological data

Hughes noted other astronomical phenomena. He recorded eight lunar eclipses in the period July 1776 to January 1804 and seven partial solar eclipses between June 1778 and June 1806. Meteorological phenomena recorded include a lunar halo on 22 occasions between February 1771 and November 1806, and two lunar rainbows in August 1781 and October

TABLE 6 Monthly number of auroral nights

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1771	0	1	2	0	2	4	0	0	0	1	1	0	11
1772	0	0	0	1	0	1	1	0	0	1	0	1	5
1773	1	0	2	0	0	0	0	0	1	1	0	0	5
1774	2												
1775	0	0	0	0	0	0	0	0	0	0	0	0	0
1776	2	2	0	0	0	0	0	0	0	0	0	0	4
1777	0	0	0	1	0	0	0	0	0	0	0	0	1
1778	0	0	1	0	0	0	0	0	3	1	0	0	5
1779	0	0	0	0	0	0	0	0	0	0	1	0	1
1780	0	1	1	0	0	0	1	0	0	0	0	0	3
1781	0	0	2	1	0	0	0	0	1	1	1	0	6
1782	0	0	0	0	0	0	0	0	1	0	1	0	2
1783	0	0	1	3	0	0	0	0	1	1	0	0	6
1784	0	0	0	0	0	0	0	0	0	0	0	0	0
1785	0	0	0	0	0	0	0	0	0	0	0	0	0
1786	0	0	0	0	0	0	0	0	0	2	0	0	2
1787	1	0	1	3	0	0	0	0	0	2	0	0	7
1788	0	1	0	0	1	0	0	0	0	1	0	0	3
1789	0	0	0	0	0	0	0	0	0	0	1	0	1
1790	0	0	0	0	0	0	0	0	0	0	0	0	0
1791	1	0	0	0	0	0	0	0	0	0	0	1	2
1792	0	0	0	0	0	0	0	0	0	1	0	0	1
1793	0	1	0	0	0	0	0	0	0	0	0	0	1
1794	0	0	0	0	0	0	0	0	0	0	0	0	0
1795	0	0	0	0	0	0	0	0	0	1	0	0	1
1796	0	0	0	0	0	0	0	0	0	0	0	0	0
1797	0	0	0	0	0	0	0	0	0	0	0	0	0
1798	0	0	0	0	0	0	0	0	0	0	0	0	0
1799	0	0	0	0	0	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0	0	0	0	0	0
1801	0	0	0	0	0	0	0	0	0	0	0	0	0
1802	0	0	0	0	0	0	0	0	0	0	0	0	0
1803	0	0	0	0	0	0	0	0	0	0	0	0	0

(Continues)

TABLE 6 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1804	0	0	0	0	0	0	0	0	0	1	0	0	1
1805	0	0	0	0	0	0	0	0	0	1	0	0	1
1806	0	0	0	0	0	0	0	0	0	0	0	0	0
1807	0	0	0	0	0	0	0	0	0	0	0	0	0
1808	0	0	0	0	0	0	0	0	0	0	0	0	0
1809	0	0	0	0	0	0	0	0	0	0	0	0	0
1810	0	0	0	0	0	0	0	0	0	0	0	0	0
1811	0	0	0	0	0	0	0	0	0	0	0	0	0
1812	0	0	0	0	0	0	0	0	0	0	0	0	0
1813	0	0	0										0
Count	43	42	42	41	41	41	41	41	41	41	41	41	42
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	7	6	10	9	3	5	2	0	7	15	5	2	69
Max	2	2	2	3	2	4	1	0	3	2	1	1	11

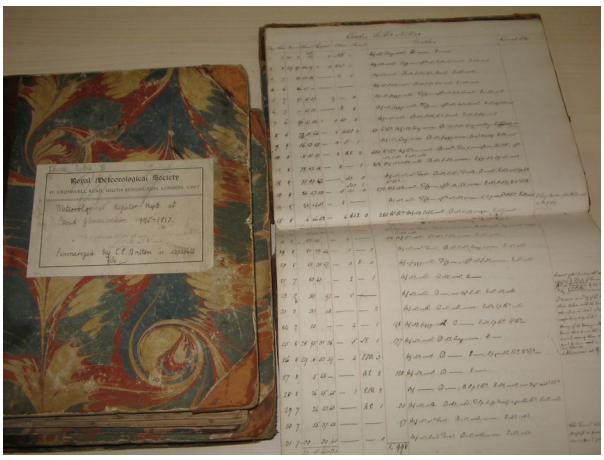

FIGURE 1 Physical form of the diary. *Left*: the binding used to protect the loose-leaf sheets *Right:* sample entries showing tabulated data

1797. He observed five solar halos and one solar parhelion (mock sun) between April 1771 and March 1804. He also recorded an earthquake on 8 September 1775, which is known from other records to have been centred on Swansea in South Wales, with magnitude 5.1 on the Richter scale (Harrison, 2005). Hughes mentioned on several occasions that the wind at higher levels was from a different direction than at lower levels ("8 *May 1791—Wind in higher regions NE—surface NW".*) This wind variation with height is an added detail rarely noted in other diaries of the time.

Thomas Hughes noted the dates when the cuckoo was first heard, and the foliation of beech trees for most years. The first cuckoo hearings ranged from 17th April (1785) to as late as 16th May (1778), and beech foliation ranged between 14th April

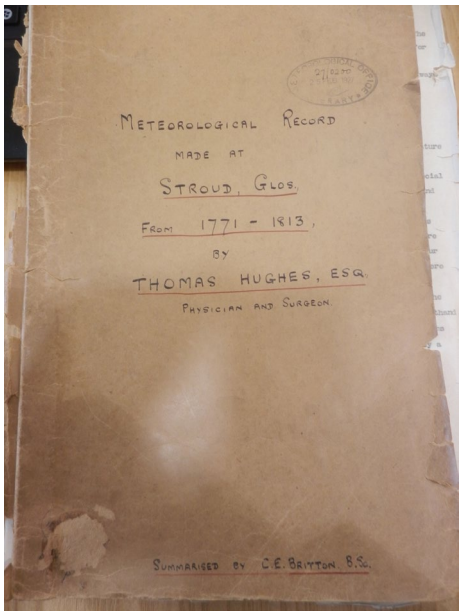

FIGURE 2 Loose-leaf cover for the notes on the diary made by C.E. Britton, received by the Meteorological Office Library on 25 February 1927

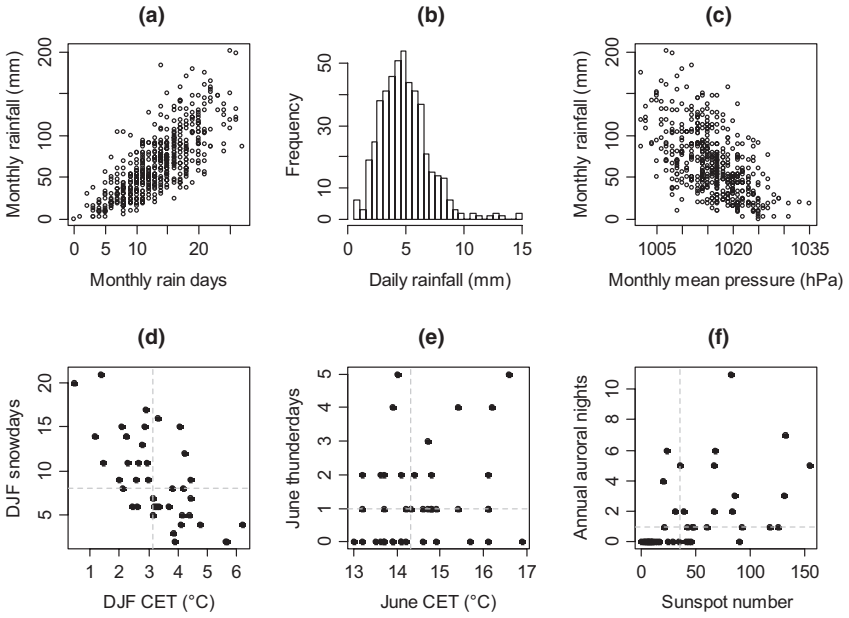

FIGURE 3 Tests of Hughes' data. (a) Monthly mean rainfall plotted against monthly rain days. (b) Histogram of daily rainfall, from dividing monthly rainfall by monthly rain days. (c) Monthly mean rainfall plotted against monthly mean pressure. (d) Total winter (December–January–February) snow days plotted against the DJF Central England Temperature (CET). (e) Thunderstorm days in June plotted against the June CET. (f) Annual auroral nights plotted against annual sunspot number. (In [d], [e] and [f], dashed grey lines mark the median values)

(1791) and 12th May (1771). Hughes included miscellaneous comments indirectly related to the local climate such as the success of the harvest. For example, he records in October 1783: 'No cyder made' and 26 May 1795: 'slight frost…kidney beans injured'. On 4 November 1806, he mentions that 'Had a good plate of kidney beans for dinner'.

4 | CONCLUSION

The long series of measurements for Stroud and south Gloucestershire has previously been recognised for its meteorological value, particularly concerning rainfall and temperature. However, the diary contains broader geophysical information which has largely been neglected until recently. Of these, the monthly thunderstorm days and auroral night summaries are probably the most useful, which are presented here together with previously unpublished monthly summaries of rain, snow and surface pressure. Investigations of the data suggest consistency between the different quantities, and with external contemporary records of the Central England Temperature and Sunspot number.

Recent historical research confirms the long-held assumption that anonymous weather diarist was indeed Thomas Hughes. It also provides some confidence that the earlier records (1771–1774) were obtained in south Gloucestershire, prior to the records beginning in Stroud in 1775. The consistent series of meteorological measurements and geophysical observations available is in part due to the combination of education and stable employment circumstances for an apothecary of the time. In addition, the medical network in which Hughes worked may well have provided additional necessary scientific training, formalism and structure. The consequence is a rare meteorological and geophysical dataset from the southern UK providing reliable information for part of the Dalton Minimum in solar activity.

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The second author, Barry Harrison, died suddenly during the preparation of this paper in 2019, aged eighty. He was a businessman and engineer with a lifelong interest in meteorology and a Stroud resident for almost sixty years. He actively researched Stroud's scientists, enthusiastically disseminating his discoveries through invited talks at local societies and organizations. Hughes' diaries themselves belong to the Royal Meteorological Society, kept in the National Meteorological Archive: material from the diary is reproduced with the permission of the Royal Meteorological Society. Help is also gratefully acknowledged in finding archive sources from Ian Mackintosh, Dr Jenner's House and Garden, Stroud Museum in the Park, the Royal College of Surgeons, the Royal College of Physicians, St Andrews' University Archives, Gloucestershire County Archives, the Gloucestershire Family History Society and the National Archive. Howard Beard helped with Figure A2. Tim Burt and a second anonymous reviewer are thanked for their comments which improved this manuscript.

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APPENDIX
Biographical notes on Thomas Hughes

Thomas Hughes (21 November 1742–25 May 1813) was born to a Gloucestershire family, to Thomas and Sarah, and baptized in Dursley in 1742. At fifteen, in September 1757, Hughes became an apprentice to John Cooper, an apothecary–surgeon in nearby Wotton-under-Edge who was also his cousin.* His apprenticeship's duration is not known, but its success is implied by the subsequent sale of Hughes' shop, in Marshfield, in 1767. This allowed Hughes to return to Wotton-under-Edge to begin a full partnership with John Cooper, as an apothecary–surgeon and man-midwife. Their medical partnership ended in the 1770s when Hughes was appointed as apothecary to a new Dispensary at Stroud, which provided medication for the sick, at no cost for the poor of the Parish. Figure A1 shows the relative position of the different sites. In 1774, Hughes moved to a house in the High Street, Stroud (Figure A2), and in 1776, he married the daughter of Stroud apothecary Joseph Colborne, Elizabeth. Following Elizabeth's death *c*1808, Thomas Hughes married again, to Mary Huntley in 1811 (Anon, 1811). There were no children from either marriage**.**

Thomas Hughes is described by the local diarist, Paul Hawkins Fisher, who recorded many aspects and individuals of eighteenth and nineteenth century Stroud in his book *Recollections of Stroud* (Fisher, 1891). Fisher remembered Hughes:

> *…as always appearing in the old medical costume, which was not laid aside until near the end of the last century; namely, a broad-brimmed hat, a wig with three rolls of curls, square-toed shoes with large buckles, and a gold-headed cane. Thus attired, and having an austere countenance and deliberate walk, he impressed my young mind with great awe.*

Fisher also mentions that, in 1803 when there was the possibility of a French invasion, Thomas Hughes enrolled in the local militia and served as the troop's surgeon and medical adviser for around 2 years.

'Mr Thomas Hughes' is listed as one of the two apothecaries in Stroudwater in 1783 (Anon, 1783). Thomas Hughes was a

*It is unlikely that Cooper was much older than Hughes, as Cooper was the second child of parents from Kidderminster, Worcestershire, who had married in 1738.

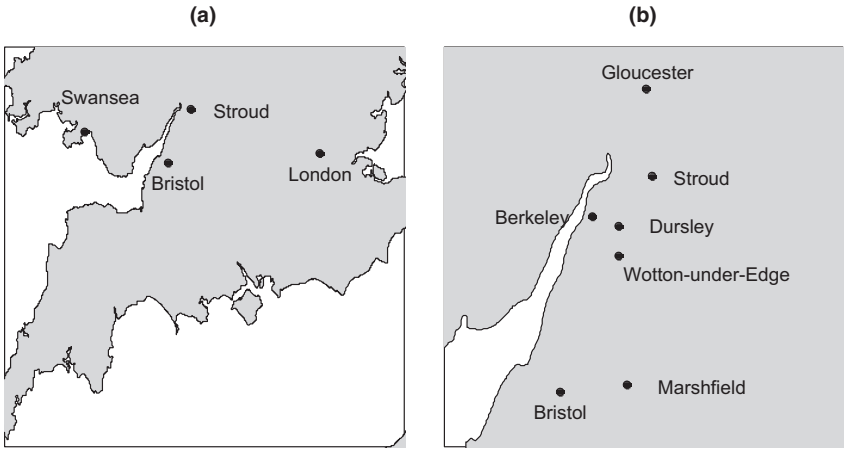

FIGURE A1 Locations relevant to Thomas Hughes' life. (a) Position of Stroud, also showing London and Bristol. (Swansea is marked as the epicentre of an earthquake Hughes noticed on 8 September 1775). (b) Relative positions of Hughes' birthplace, Dursley, his apprenticeship and practice at Wotton-under-Edge and his first shop at Marshfield are indicated, with the principal cities of Bristol and Gloucester also marked

FIGURE A2 Image of the pharmacist's shop where Hughes lived at 57 High Street, Stroud, taken around 1900. This was the site for the majority of his observations (from Burrow, 1902)

diligent and competent apothecary, surgeon and man-midwife.* He carefully recorded his medical activities and collected medical books, sufficiently so to be known as the 'Medical Dictionary'. Although almost all the original materials were lost through damage to the cellars of Gloucester Infirmary, several of his letters have survived and give detail of his actions and analysis. Hughes was a contemporary of the 'father of vaccination', Edward Jenner, who lived at Berkeley, less than 20 miles from Stroud.

Smallpox was a commonly encountered disease, but even so, Hughes' diary mentions a misdiagnosis of a smallpox case. There is no doubt that Hughes, and his medical partner William Darke, corresponded with Jenner about smallpox (e.g. Hughes, 1799). Hughes, Jenner and Darke investigated the effects of cowpox vaccination in 1798, 2 years after Jenner's first recorded successful vaccination. Darke reported his experiences to Jenner (Creighton, 1889), and Hughes wrote Jenner a long discourse (Hughes, 1799) detailing treatment and results. Whether these letters were ever answered or acknowledged is unclear: Jenner did refer to a report from Hughes' partner Dr Darke, but not to Hughes' report (Jenner, 1800). By the late 1780s, Jenner had founded two medical societies in Gloucestershire, one of which was open only to a few 'Old Friends, School-Fellows, and Fellow Students', his particular medical friends, who met for dinner and informal discussion† (Anon, 1896). In May 1789, a proposal was made for the membership of this society to be broadened: 'This Society is ready to receive communications in writing from any medical Gentlemen in Glocestershire...' but at the next meeting in July 'it is now considered this proposal does not meet with concurrence of the Society'. Hence, it seems unlikely that Thomas Hughes or his associates would have become members or presented papers.

Hughes employed two apprentice apothecary–surgeons during his tenure in Stroud, each trained for 3 years: one became a surgeon to Gloucester and later Cheltenham hospital who died aged 31, and the other is untraced. Hughes' medical activities were not restricted to the local Stroud area. He made frequent visits to Gloucester, Bristol and Bath hospitals, and London several times, in September 1781 and October 1782 attending a conference on influenza and again in October 1789. Even after his retirement, and as late as October 1812, he routinely visited Gloucester Infirmary.

St Laurence Church in Stroud, very close to Hughes' home, provided medical observations, such as an entry for 28 April 1787, 'Many cough at church', a phrase present on many other occasions. There are also references to children with scarlatina anginosa (scarlet fever), influenza, catarrh and

†It is fairer to refer to Hughes as an apothecary–surgeon rather than a doctor, as doctor would have required a university degree to practise medicine. The apothecary–surgeon dealt with every other aspect of health care, including the dispensing of drugs prescribed by the doctor.

‡These were somewhat ad hoc local societies. The Convivio-Medical Society met at Alveston, near Thornbury. The Gloucestershire Medical Society was formed in 1788 and met in the Fleece Inn, near Stroud. (It was also known as the Medico-Convivial Society or the Fleece Medical Society.) To limit the membership, the latter society's rules forbade those aged over forty from joining.

other ailments, including Hughes' own bouts of lumbago. He noted the incidence of 'cyder colic' in January 1789 as well as the lack of 'cyder' in 1783 and 1795.

Hughes' diary also reproduces notable events clearly obtained from other sources, especially the*Gentleman's Magazine*, a monthly publication of social, scientific and newsworthy reports circulated in Europe and America. He subscribed to this magazine, and both his death and his second wife's death were mentioned in it (Anon, 1813b; Anon, 1833).[†] His broader interest in meteorology is apparent from his inclusion in his diary of what now might be termed 'extreme weather' occurrences, originally reported in the magazine.

It can only be speculated as to why this diligent observer of the natural world kept the weather diaries, what had excited his initial interest, and what ideas he had as to how the conditions varied and the possibility of foretelling weather. However, there can be few men or women with a compelling hobby, not at all promoted in their own lifetime, whose activities somehow became more significant some 200 years later. It is therefore very fortunate that Thomas Hughes' diaries have survived.

[†]Thomas Hughes' widow became the second wife of his medical partner, Dr W.W. Darke.