Meteorological Data recorded at Armagh Observatory from 1795 to 2001: Volume I - Daily, Monthly and Annual Rainfall 1838-2001

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1 Introduction

Armagh Observatory has the longest series of meteorological records from a single site in the UK or Ireland. In order to make these records generally available, the Armagh Observatory has received funding from the *UK Heritage Lottery Fund* and *The Irish Soldiers and Sailors Land Trust*. The project will provide access to over 7,000 pages of raw, daily, meteorological data stretching back to the year 1796, as well as calibrated and standardised meteorological series for scientific and educational use. This standardised data archive will include daily observations of rainfall, sunshine, temperature, pressure, cloud, humidity and wind. We present here the first of these series, the rainfall recorded from 1 January 1838 to 31 December 2001.

2 Rainfall measurements

Regular daily rainfall measurements from January 1836 for Armagh Observatory are recorded in 14 manuscript volumes deposited in the Observatory Archives (M117.2 in Butler and Hoskin, 1987). During 1836 and 1837 rainfall readings were recorded sporadically using a *Crossley* raingauge. This raingauge was found to be unreliable. Regular readings with the square gauge $S1$ commenced on 1 January 1838. Subsequent to this a variety of rainguages have been in operation, often with more than one gauge operating at any one time. A map showing the location of the gauges in the Observatory grounds, in as far as this is known, is given in Figure 1 (reproduced from Butler et al 1998).

One of the uncertainties that has to be be resolved is whether or not the daily entries were thrown back; that is, that the rainfall measured in the morning was entered in the final record book for the previous day.

We are reasonably certain that the rainfall readings were thrown back, since 1851, at least. This can be surmised from the readings for Armagh summarised by Lloyd

(1853). We note also, from the publication *British Rainfall* in 1865 (G.J Symmons), that the British Meteorological Society and the Royal Observatory recommended that rainfall be thrown back to the previous day. We do not know when this procedure become standard but Meteorological Office publications such as the *Quarterly Weather Report*, and *Hourly Readings and Meteorological Observations at Stations of the Second Order* for 1881, 1886, 1887 and 1888, remind the observers to throw back rainfall to the previous day. For example, in 1888 in *Meteorological Observations at Stations of the Second Order* we note the following:

> *"Rainfall is measured at 9 am each morning, and the amount registered entered to the previous day"*

Thomas Romney Robinson, the third director of the Observatory, was appointed in November 1823 and died in service on 28 February 1882 at the age of 88 years. He was interested in meteorology and is best known in that discipline for his *Cup-Anemometer*. We believe that he would have been aware of the widespread practice to throw rainfall data back one day and have therefore assumed that at Armagh this was done from the beginning of the series.

3 Metadata

Two previous accounts have been published which give details of the monthly and annual precipitation recorded at Armagh (see Grew, 1951 and Butler et al. 1998). These papers give details of the instruments used, their calibration and the long term variation and periodicity of rainfall at Armagh. Here, we give for the first time, the daily readings. As there have been some small changes here, from previous studies, we give in Table 1 the periods during which the various gauges were in operation and from which gauges the daily data has been taken in the present compilation.

Together with the publications and the record books, we have used various other sources of information in order to clarify the status of instruments at different times. These include comments in the record books, letters, inspector's reports, invoices of purchases, photographs and maps. A catalogue of these items has been prepared and is available to interested users via the World-Wide Web from the Observatory's Meteorological Data Bank *(http://climate.arm.ac.uk/archives/)*.

4 Data verification and correction

After entering the data onto computer, the complete daily rainfall series from 1836 to the present was verified taking into account the metadata. We have used the following codes to identify suspect data: -666 snow; -777 frozen raingauge; *** data that could not be read or identified; and -888 when data are not available. In order

to fill in the columns and rows, -999 was used to indicate dates that did not exist (e.g. 29,30,31 February in non-leap years).

When a reading was not recorded for the instrument selected for use at that time, the reading from another instrument was substituted. Details are given in the footnotes to Table 1. Occasionally, we do not have a valid substitution and we indicate this with the code -888. The days without any recorded rainfall data are: 31 March 1852, 24-28 May 1862, 29-30 September 1883, 23-25 April 1843 and 19-28 January 1944 .

The rainfall was measured in inches until 31^{st} December 1967, except for the month of March 1929 and, from 1^{st} June 1915 until 31^{st} December 1918 were they were entered in the book as millimetres. After the 1^{st} of January 1968 the rainfall has been consistently recorded in millimetres.

5 Standardization procedure.

Before standard equipment and procedures for meteorological observations were introduced in the late nineteenth century the design of rainguages varied considerably. It is important, therefore, when attempting to define long meteorological series, that careful attention is paid to the standardisation of early measurements. Whilst one might expect that sensitivity conversion factors could be computed from the geometry of the gauges and their measuring cylinders, where they are known, other factors such as the exposure of the gauges are equally important. Thus it is preferable to employ the overlapping periods of use of the various gauges to compute empirical conversion factors for each gauge in a particular location. The standard gauge to which all others are referred by this process is the eight-inch round gauge (I) in use from 18 January 1885 until 15 January 1964. The conversion of all data to the eight-inch standard has been undertaken because of the long period in which the gauge was in operation and its inherent accuracy. As there was no overlap between the eight-inch gauge (which does not survive) and the five-inch Meteorological Office standard that replaced it, we had to assume that there was no systematic difference in sensitivity between them. This assumption is justified by comparison with the rainfall data from the neighbouring site at Loughall Agricultural Research Station, details of which are given by Butler et al. (1998).

The conversion factors used were determined from the ratios of total precipitation for the overlapping periods during which two or more gauges were in operation. For the earlier gauges several steps are required involving intermediate overlapping gauges; for instance the ratio of S_2 to I involves the intermediary K, and the ratio of S_1 to I involves two intermediaries S_2 and K. The conversion factors used are essentially the same as those derived by Grew (1952). The standardized daily rainfall data are given in Table 2.

6 Monthly and annual totals and mean daily precipitation

- Totals: Monthly and annual totals are given in Table 3. Some differences between the new calibrated daily, monthly and annual totals and those published by the Meteorological Office are evident. We believe our new results to be more reliable than the earlier data. The total precipitation per season is given in Table 5.

- Means: The mean daily precipitation per month, per season and annually is given in Table 4 and 6.

Table 1: Rain gauges, their period of use and correction factors

Name	Period of use	Location	Cor. Factor	Data used for Table 2
Square(S1)	1 Jan 1838 - 9 March 1861	Roof	1.31	1 Jan 1838 - 31 Dec 1853 [a]
Round (R)	8 Sep 1839 - 31 Apr 1874	Roof	0.85	-
Square(S2)	5 Nov 1853 - 31 Dec 1884	N Lawn	1.00	1 Jan 1854 - 31 Dec 1884 [b]
Kew Auto(K)	1 May 1874 - 10 May 1885	N Lawn	0.96	-
	1 May 1885 - 31 Dec 1958	S Lawn A	0.96	-
8-inch (I)	1 Jan 1885 - 31 Apr 1885	N Lawn	1.00	1 Jan 1885 - 31 Apr 1885
	1 May 1885 - 31 Jan 1964	S Lawn A	1.00	1 May 1885 - 31 Jan 1964 [c]
5-inch (J)	1 Feb 1964 - 31 Sept 1987	S Lawn B	1.00	1 Feb 1964 - 31 Sept 1987
	1 Oct 1987 - present	S Lawn C	1.00	1 Oct 1987 - 31 Sept 1999
	1 Oct 1998 - present	S Lawn C	1.00	1 Oct 1999 - present
Dines TSR (D)	1 Oct 1946 - 31 Jan 1964	S Lawn A	-	-
	1 Feb 1864 - 31 Jan 1988	S Lawn B	-	-
	1 Feb 1988 - present	S Lawn C	-	-

[a] Except for: 6 Apr 1847, 14 May 1849, 25 Mar 1850, 1 Nov - 31 Dec 1851, 1 Mar - 30 Apr, 12 May, 4 Aug 1852 when the Round Gauge (R) was used.

[b] Except for: 3 Apr 1859, 1-31 Jul 1861, 22, 9 Jul 1862, 8 Jan, 6 Apr, 22 Dec 1863, 24, 28 Jun 1864, 30 May, 29 Oct 1865, 30 Jul, 11 Sep, 20 Oct 1866, 29 Apr, 13 Sep, 9 Oct 1867, 24 Jan, 12 Aug 1868, 20-21 Apr, 27 May 1869, 4 Jul, 1-31 Dec 1870 and 1-30 Apr 1874 when the R gauge was used; 1-31 May 1874, 5 Dec 1876, 21 Dec 1877, 22 Nov 1880, 20 Jul 1881 and 16 Oct 1882 when the Kew gauge (K) was used; and 1-17 May 1856 when the mean of R and S2 was used.

[c] Except for: 7,9 May 1947 when the Kew gauge (K) was used.

Other corrections, noted in the record book are: *"For the month of August 1845, we added 0.21 inches to the total" and "on 2 May 1864 we added 0.2 inches to the total", because the "cock" was left open those days.*

7 Acknowledgements

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8 References.

Butler, C.J., Coughlin, A.D.S. and Fee, D.T., 1998. Precipitation at Armagh Observatory, 1838-1997. Proc. R. Irish Acad., Biology and Environment, 96B, 123-140.

Butler, C. J. and Hoskin, M. A. 1987, The archives of Armagh Observatory, J. Hist. Astron. 18, 295-307.

Grew, S. 1951. Meteorology at Armagh Observatory: general note and study of rainfall, Irish Astron. J. Vol.1, 230-237.

Lloyd, H. 1854, Note on the meteorology of Ireland deduced from the observations made in the year 1851 under the direction of the Royal Irish Academy, Trans. R. Irish Acad. Part I - Science 22, 411-498.

Scott, R. H., 1870-1883. Hourly readings from the self recording instruments at the seven observatories, in connection with the Meteorological Office, H. M. Stationery Office, London.

Scott, R. H.,1881-1910. Meteorological Observations At Stations of the Second Order, H. M. Stationery Office, London.

Symmons, G. P.,1865. British Rainfall, 4-7.

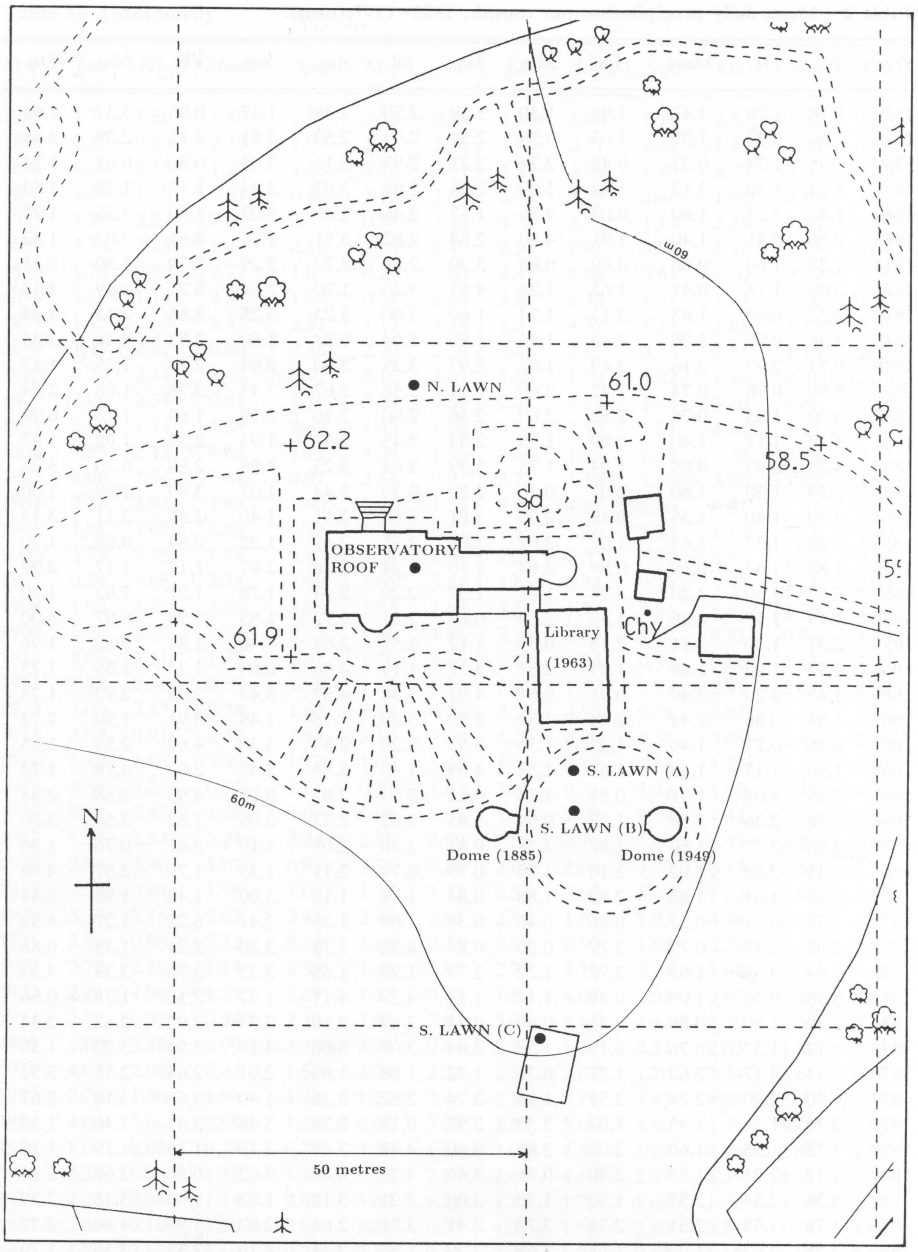

Fig. 1—The position of the various raingauges in use over the past 160 years at Armagh Observatory, from which data have been employed in this compilation, on a map showing the present layout of grounds and buildings. The automatic weather station erected by the Board of Trade in 1868, which was demolished in the early 1960s, lay close to the north end of the current library building. The position of the 60m contour is approximate (Based upon Ordnance Survey ace map, 1:1250 (1998), with the permission of the Controller of Her Majesty's Stationery Office (permit no. 1204), © Crown Copyright.)

Meteorological observations have been made at Armagh Observatory (Butler and Johnston, 1996) since 1795. The records include one of the longest single-site instrumental temperature series in the UK and, indeed, Europe. The Observatory is situated in 20 acres of land on a drumlin to the North East of Armagh town centre (Fig.1). The grounds surrounding the Observatory and its climate station have remained relatively unchanged over the past 200 years. However, in that time, the town of Armagh has spread in several directions, including to the north and east, past the Observatory site.Â The above comparison using historical data from neighbouring weather stations would support this case. 5. Conclusions.