Meteorological Data recorded at Armagh Observatory: Volume 4 - Daily, Monthly and Annual Soil Temperatures 1904-2002

A. M. García-Suárez, C.J. Butler, B. Morrow

Armagh Observatory, College Hill, Armagh BT61 9DG, N. Ireland

1 Introduction

Armagh Observatory ($6^o39^{'}.8$ W, $54^o21^{'}.2$ N) has one of the longest series of meteorological records from a single site in the UK or Ireland. These records will be made available to the public on the Armagh Observatory Climate Web-site *http://climate.arm.ac.uk* where access is possible to over 7,000 pages of raw, daily, meteorological data stretching back to 1795, as well as calibrated and standardised meteorological series for scientific and educational use. This standardised data archive includes daily observations of rainfall, sunshine, temperature, pressure, cloud, humidity and wind.

The calibrated soil temperature data recorded at 1 foot/30 cm and 4 foot/100 cm depth from 21 April 1904 to 31 December 2002 are presented here together with details of the calibration procedure and corrections made for location and for changes from Imperial to Metric depths.

A paper outlining the long term seasonal and annual changes in soil temperature at Armagh and their comparison with other, similar, series from Birr, Co Offaly and Valentia, Co Kerry will appear in the International Journal for Climatology (García-Suárez and Butler, 2006).

2 Soil temperature

Soil temperatures in Ireland have significant daily and annual variations depending on the time of the year and on cloudiness, with greater variations on days with a clear sky. The top 20 cm of soil show the greatest daily temperature variation, with coldest temperatures occurring in the morning. The annual cycle of soil temperature has a peak in June and a minimum between December and January for well-drained soils. Temperatures are progressively smoothed with increasing depth and a lag develops that depends on heat conductivity (Collins and Cummins, 1996).

No temperature profiles with depth were previously available for Armagh Observatory. The nearest data of this type we have found is reported by Collins and Cummins T. (1996) for Kilkenny ($7^o15^{'}$ W and $52^o39^{'}$ N). They give the average monthly mean soil temperature at different depths throughout the year for 1958-1982. At this location, the 10 cm curve has the greatest fluctuation, warmest in June and coldest in January. Maximum temperatures of 15.2 ^{o}C and 14.8 ^{o}C for 30 cm

and 120 cm depth are reached in mid-July and the beginning of August respectively. To assist with our standardisation of the Armagh soil temperature data, we have determined the temperature profile with depth at Armagh Observatory from March 2002 to February 2003 (see below).

3 Soil temperature series and meta-data

Regular daily soil temperature measurements from April 1904 for Armagh Observatory are recorded in 9 manuscript volumes deposited in the Observatory Archives (M117.2 in Butler and Hoskin, 1987).

Various sources of information have been used 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 stored at Armagh Observatory. A catalogue of these items has been prepared and is available from the Observatory's Meteorological Web Site *(http://climate.arm.ac.uk/archives/* and García-Suárez *et al.* (2005b)). A list of the most relevant documents regarding soil temperatures is also included in section 9. Table 1 lists the soil thermometers used at Armagh Observatory from April 1904 to the present, their location and the date of the readings used for the Armagh series.

Table 1: Soil thermometers used at Armagh Observatory, 1904-2003.

Name	Period of use	Location[c]	Data used for Table
1 ft / 30 cm			
No.6794	21 Apr 1904 - 7 Jul 1946[b]	South(A)	21 Apr 1904 - 7 Jul 1946[b]
No.19551	1 Feb 1947 - 31 Dec 1957	South(A)	1 Feb 1947 - 31 Dec 1957
No. 21383/56 "old"	1 Jan 1958 - 31 Dec 1969	South(A)	1 Jan 1958 - 31 Jan 1968
No. 24350 "new"	1 Oct 1966 - 28 Feb 1972	South(B)	1 Feb 1968 - 31 Dec 1971
No. 25683/69	1 Jan 1972 - 31 Dec 1987	South(B)	1 Jan 1972 - 31 Dec 1987
No. 25941	1 Jan 1988 - present	South(C)	1 Jan 1988 - present
4 ft / 100 cm			
No.6793	21 Apr 1904 - 22 Jan 1938	South(A)	21 Apr 1904 - 22 Jan 1938
No.18563 "old"	23 Jan 1938 - 28 Feb 1972	South(A)	23 Jan 1938 - 31 Jan 1968
No.22561 "new"	1 Aug 1964 - 28 Feb 1972	South(B)	1 Feb 1968 - 28 Feb 1972
No.25888/69	1 Jan 1972 - 31 Dec 1993	South (B/C)	1 Jan 1972 - 31 Dec 1993
No.7955/89	1 Jan 1994 - present	South(C)	1994 - present

[a] On 7 July 1946 the 1 foot thermometer was broken and replaced on 1 Feb 1947.

[b] See García-Suárez *et al.* (2005b) and catalogued documents ARM/MET/000448-000452 and /000514.

[c] See map of Observatory in Figure 4.

4 Data verification and correction

4.1 Instrumental error

After entering the raw data onto computer, the complete daily soil temperature series from 1904 to the present was verified taking into account the meta-data. We have used the following codes to identify missing data: -888 when data are not available, and -999 for dates that did not exist (e.g. 29, 30, 31 February in non-leap years).

We have not made any correction for instrumental errors as none of the inspectors reports over the period 1904-2002 list systematic calibration corrections for the relevant thermometers in excess of 0.1°C, the nominal reading error of the thermometers.

4.2 Change in the Standard depths

Until 1970 the standard depth at which soil temperatures were measured at Armagh Observatory were 1 foot (304.8 mm) and 4 feet (1219.2 mm). From 1^{st} January 1971, following a proposal from the World Meteorological Organisation, the depths were redefined in metric units; namely at 30 and 100 cm, close to but not identical to the old Imperial depths (see García-Suárez *et al.* (2005b) and ARM/MET/000409, 412, 413 and 415). No overlap of readings at the 'old' and 'new' standard depths was made at Armagh. It is possible that these changes might have lead to a small systematic shift in readings, especially with the change from 4-ft to 1 metre. For this reason, we decided to measure temperature profiles versus depth at Armagh Observatory over a period of a year and determine the corrections empirically.

4.2.1 Measurement of soil temperature depth profiles

A soil tube was installed 5 m from the soil thermometers of the current met station (South Lawn C) in March 2002. Using an ordinary soil thermometer loaned to the Observatory by the Met Office, the temperature was measured at different depths (in cm): 20, 30, 30.5 (∼1 foot), 40, 50, 60, 80, 100 , 120, 122 (∼4 feet) and 140. Measurements were made every 50 min to 1 hour since the standard soil thermometer responds slowly to changes of temperature[1]. Subsequently, the readings for a complete profile required a full day of measurements. Sets of measurements were taken every 25 days approximately from March 2002 to February 2003.

Table 2: Soil temperature (°C) versus depth (cm) at Armagh Observatory, 2002-2003.

Date	T(20)	T(30)	T(30.5)	T(40)	T(50)	T(60)	T(80)	T(100)	T(120)	T(122)	T(140)	Grass Min	Mean air
14 Mar	4.0	5.6	5.3	5.9	6.1	6.5	7.0	7.5	7.5	7.5	7.7	-5.6	3.7
9 Apr	9.2	10.1	10.1	9.7	9.4	9.4	9.2	9.1	9.0	9.0	9.0	-1.4	8.5
6 May	-	-	11.5	-	-	-	-	10.3	10.3	10.3	-	1.5	11.0
14 May	11.9	12.1	12.1	12.0	12.0	11.8	11.5	**11.0**	10.9	**10.9**	10.8	6.4	11.8
7 Jun	15.0	15.0	15.0	14.7	14.7	-	13.6	**13.0**	12.6	**12.6**	12.6	13.3	14.3
4 Jul	15.3	15.1	15.1	15.2	15.0	14.8	14.5	**13.9**	13.8	**13.7**	13.6	9.6	12.7
1 Aug	16.7	16.6	16.6	16.6	16.5	16.3	16.0	**15.2**	15.0	**15.0**	14.9	15.7	18.5
30 Aug	16.5	16.8	16.8	16.8	16.8	16.7	16.5	**15.8**	15.6	**15.6**	15.4	11.4	15.6
25 Sep	14.3	14.3	14.3	14.6	14.8	14.9	14.9	**14.9**	14.8	**14.8**	14.7	3.5	11.6
23 Oct	8.7	9.5	9.5	9.8	10.6	10.8	11.9	**12.1**	12.3	**12.3**	12.5	1.2	5.4
25 Nov	9.1	8.7	8.7	9.0	9.2	9.2	9.8	10.2	10.2	10.2	10.3	4.1	9.3
18 Dec	3.9	4.4	4.4	4.7	5.1	5.5	7.5	8.4	8.4	8.4	8.7	-8.8	-1.3
16 Jan	6.0	5.7	5.7	6.1	6.2	6.4	7.0	7.0	7.0	7.0	7.3	2.3	8.2
13 Feb	3.9	4.4	4.4	5.1	5.6	5.9	6.3	6.9	6.9	6.9	7.3	-2.9	1.9

Table 2 lists the soil temperature depth profile data which shows that the temperatures for 30 cm and 30.5 cm (∼1ft) were identical for the period studied. On

[1]The bulb is encased in a thick layer of wax with an outer tube. This is required to prevent any change in the reading while the observation is being made.

the other hand, for temperatures at 100 cm and 122 cm (∼4ft); during spring and summer months, significant differences appear and, in some cases, those differences can be greater than 0.2°C. We have included the grass minimum and mean air temperatures at 9:00 am for comparison.

Figure 1 shows the temperature throughout the year and depth profiles at Armagh Observatory for dates listed in Table 2 from March 2002 to February 2003. The left panel of Figure 1 compares the temperatures at depths 30 cm/1ft and 100 cm/4ft. The middle panel shows additional profiles of the mean monthly temperature at 100cm/4-foot for the years 2002-2005 and the right panel shows the temperature depth-profiles at different dates approximately evenly spaced from March 2002 to February 2003. Both 30cm and 100cm soil temperatures series have their annual cycle maximum at the end of August (at around 17 and 15.5 °C respectively)whereas the minimum can occur from Dec to February with temperatures between 5 and 7 °C.

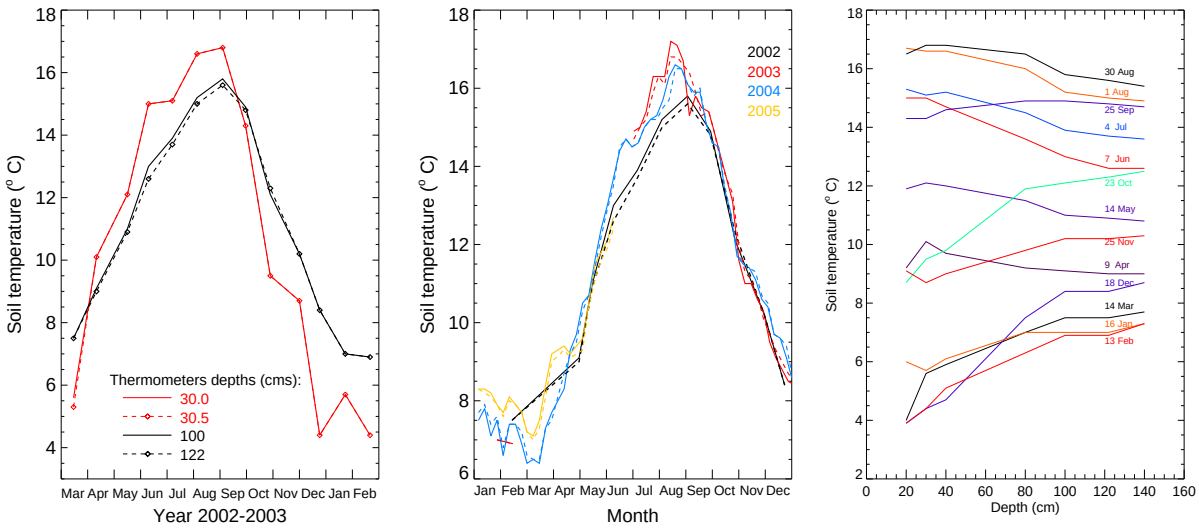

Figure 1: (left) Soil temperature at standard depths throughout the year at Armagh Observatory, 2002-2003; (middle) Soil temperature at 100 cm and 122 cm depth for 2002-2005 and (right) Soil temperature versus depth for various dates from 14 March 2002 to 13 February 2003.

4.2.2 Correction for change to metric depths

As mentioned before, temperatures at 30 cm and 30.5 cm (1ft) deep were found to be identical over the period studied. However, we did find a small but systematic difference in temperature between the 1 metre and 4 foot (122cm) readings which amounted to ∼0.1°C during summer and early autumn months of the trial period (see Figure 1, left panel). In Kilkenny, Collins and Cummins (1996) also found significant differences in soil temperatures at 100 cm and 120 cm. To standardise the entire series at 1 metre depth at Armagh Observatory, we have corrected the 4 ft temperatures by adding +0.1°C to the daily measurements from 15 May to 15 October in each year over the period when readings were made at 4 foot: 1904-1971.

This correction is the mean of the difference between the temperature recorded by the thermometers at 4ft and at 1 m depth from May to October 2002-2004. Although the correction has been determined from data for just three years, we do not expect significant changes. Nevertheless, we have decided to continue the overlapping temperature measurements at 122 cm and 100 cm for a further period. These 122 cm soil temperature measurements take place every Monday.

4.3 Thermometer location

The meteorological instruments have changed location three times since the soil temperature records started (see map of the Observatory in Figures 4 and 6 and the photograph in Figure 5). All the sites have been on the South Lawn of the Observatory, within less than 50 metres distance of each other, and in Brown Earth soils.

On the South Lawn of the Observatory there are two domes. The first, namely the Robinson Dome, was built in 1885 and the second in 1949. Between these domes are the sites S. Lawn(A) and S. Lawn(B). A gravel path which connected the Robinson Dome with the site of the meteorological instruments and the Main Building of the Observatory was built, we believe, in the 1930s but the exact date is unknown. In 1948 the path was resurfaced with tar macadam at a level three inches below the grass and an extension was laid to link the domes (see Figure 6). At that time, the soil thermometers were only 1 foot from the path at S. Lawn(A). In 1964 and 1966, a second 4 ft thermometer and a second 1 ft thermometer were installed at S. Lawn(B) and measurements overlapped with the existing thermometers for a number of months between 1964 to 1968 to study exposure effects caused mainly by the path. From 1968, soil thermometers were located in the S. Lawn(B), 6 ft from the path. From 1988 to the present, the soil thermometers have been at S. Lawn(C).

4.3.1 Effect of the path

- 4 foot thermometer. In 1963, the Met Office decided to install a second 4 foot thermometer and to overlap the readings for a year. The "old" 4 ft thermometer was situated 1 foot from the tarmac path whereas the "new" 4 ft thermometer was installed 6 feet from the path in 1964.

  In July 1966, S. D. Classey from the Met. Office submitted an internal report about Armagh Observatory and the earth temperatures (García-Suárez *et al.* (2005b) and in catalogue document ARM/MET/000514). In this report the situation of the thermometers and the path is described. We believe, as did Mr. Classey at the time, that the tarmac path may have affected the temperature readings. After this report, by which time the 4 ft overlap measurements had already been discontinued, it was decided to resume the overlap, at least for another year.

- 1 foot thermometer. The "old" 1 ft thermometer was also situated one foot from the edge of the the tarmac path. However, in 1963 it was decided that a new 1 ft tube was unnecessary. Nevertheless, the inspector later noted that, with six inches of heavy iron tube protruding above ground, a rise in

temperature due to conduction in the metal could have occurred when exposed to bright sunshine. For this reason, a further 1 ft tube was installed beside the "new" 4 ft thermometer in 1966.

Table 3: Differences (new-old) of 1-foot monthly mean temperature (°C), 1966-1968.

Year	1966	1967	1968
Month	diff(n-o)	diff(n-o)	diff(n-o)
Jan	-	0.67 ± 0.07	0.50 ± 0.06
Feb	-	0.58 ± 0.05	-
Mar	-	0.24 ± 0.05	-
Apr	-	0.03 ± 0.05	-
May	-	0.26 ± 0.05	-
Jun	-	-0.43± 0.06	-
Jul	-	0.04 ± 0.02	-
Aug	-	0.27 ± 0.05	-
Sep	-	0.41 ± 0.04	-
Oct	0.83± 0.07	0.66 ± 0.04	-
Nov	1.16± 0.07	0.72 ± 0.05	-
Dec	0.74± 0.06	0.66 ± 0.07	-

Table 4: Differences (new-old) of 4-foot monthly mean temperatures (°C), 1964-1968.

Year	1964	1965	1966	1967	1968
Month	diff(n-o)	diff(n-o)	diff(n-o)	diff(n-o)	diff(n-o)
Jan	-	0.22 ±0.02	-	0.36 ± 0.03	0.25 ± 0.03
Feb	-	0.07 ±0.03	-	0.16 ± 0.03	-
Mar	-	-0.03 ±0.03	-	-0.03 ± 0.02	-
Apr	-	-0.39 ±0.02	-	-0.32 ± 0.04	-
May	-	-0.64 ±0.04	-	-0.46 ± 0.02	-
Jun	-	-0.87 ±0.04	-	-1.00 ± 0.03	-
Jul	-	-0.77 ±0.02	-	-0.79 ± 0.01	-
Aug	-0.59 ± 0.19	-0.59 ±0.02	-	-0.55 ± 0.02	-
Sep	-0.41 ± 0.04	-0.29 ±0.08	-0.41± 0.02	-0.23 ± 0.02	-
Oct	-0.04 ± 0.03	-0.11 ±0.03	0.11 ± 0.04	0.06 ± 0.03	-
Nov	0.13 ± 0.03	0.27 ±0.04	0.58 ± 0.03	0.41 ± 0.02	-
Dec	0.32 ± 0.02	0.36 ±0.03	0.45 ± 0.03	0.30 ± 0.03	-

Tables 3 and 4 give the differences in monthly mean temperature at 1 foot between 1966-1968 and differences of monthly mean temperature at 4 feet between 1964-1968. The differences are new-old and tabulated errors are the standard errors of the mean. There are a total of 34 months of "new-old" overlap for the 4 ft thermometer and 16 months for the 1 ft thermometer. Note that, in both cases, the amount of data available in winter is higher than in summer.

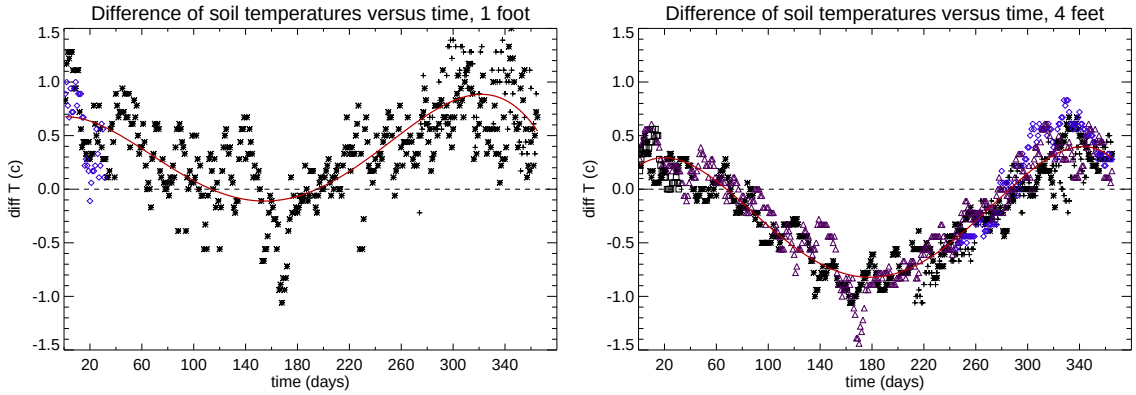

Figure 2: (left) Differences of 1-ft temperature (new - old), 1966-1968. Symbols: vertical crosses - 1966, asterisks - 1967, diamonds - 1968. (right) Differences of 4-ft temperature (new - old), 1964-1968. Symbols: vertical crosses - 1964, asterisks - 1965, diamonds - 1966, triangles - 1967 and squares - 1968.

To clarify the effect of the tarmac path on the temperature readings, we have plotted the daily differences of temperature (new - old) against day - number. Figure 2 shows that the proximity of the tarmac path had its biggest effect on the 4ft soil temperature in summer and on the 1 foot temperature in winter.

It is likely that the larger scatter in the one foot difference is due to a combination of soil moisture and sunshine variations (see García-Suárez *et al.*, 2005a). Because the path was deeper than the surrounding grass, greater daily variations in the 1 foot soil temperatures in winter measured by the "old" thermometer might be expected. Also, "old" thermometer readings could be up to 1 degree Celsius lower than those for the "new" thermometer. For the 4 ft soil temperatures, the greater heat absorption by the path in summer could explain why the soil temperatures for the "old" thermometer were up to 1 degree Celsius higher than those for the "new" thermometer.

But if the tarmac path affected the soil temperatures in this way, a sudden change should be observed in the recorded temperatures after the tarmac surface was first applied in 1948. Unfortunately, in years 1946 and 1947 there are gaps in both series of soil temperatures. Both thermometers were broken and they were not immediately replaced, possibly because the Met Office was short of supplies after the Second World War. The gap extends to seven months for the 1 ft soil temperature series and one month for the 4 ft series. For this reason, comparisons of temperatures before and after 1948 are difficult; nonetheless, no significant discontinuities in the series are evident at this time.

4.3.2 Correction for the effect of the path

Although the seasonal temperature means for both 1 ft and 4 ft deep soil temperature series against time did not show any significant discontinuities in the series due to the tarmac path as expected (see Figure 3), the difference of temperatures "new-old" was considered sufficiently well established (see Figure 2) that it was decided to apply a correction to the effect of the path to both series. The correction factors

were determined by the following procedure: (1) A curve (polynomial of order four) was fitted for 1 ft and 4 ft soil temperature to the data points listed in Tables 3 and 4 and shown in Figure 2. (2) Using these mean curves, the correction required for each day of the year was determined. (3) The corrections were applied to the "old" thermometer readings from 1949 to January 1968. Subsequently, as both series were recorded using the "new" thermometers, no correction was made.

4.4 Other possible sources of temperature discrepancies

The tarmac path may not had been the only source of problems for the soil thermometers. Other factors that may have had a temporary influence on soil temperatures are:

- Depth differences. In 1963 it was found that the old 4 ft soil thermometer tube had an accumulation of soil at the bottom of the tube, making the apparent depth 45 inches (not 48 inches; 4 feet). Subsequently another 4 ft soil tube was installed. In the following inspection, on 18th July 1966, the depth of the soil thermometer was only 43 inches.
- Old soil tubes. The old soil tubes (1 foot and 4 foot) had 6 inches of iron tubing protruding above ground level. This may have lead to an increase in heat conduction from the surface in bright sunshine conditions.

5 Comparison of the corrected 30 cm and 100 cm series

Figure 3 compares the corrected seasonal and annual means for the 30 cm and 100 cm soil temperature series. The corrected seasonal and annual mean soil temperature series for the 100 cm depth are shown in black whereas for the 30 cm depth the series are shown in: blue (winter), green (spring), red (summer), orange (autumn) and purple (annual). Note that for the 1949-1968 period, two corrections have been applied to the 100 cm soil temperature series: (i) for location with respect to the path and (ii) for the change in depth from four feet to one metre. In contrast, the 30 cm soil temperature series was corrected only for location.

The behaviour of the seasonal and annual mean curves is closely similar for both series with rises and falls in the 30 cm data mirrored at 100 cm. This close similarity in behaviour results in parallel temperature curves at the two depths in each season. In summer and spring, 30 cm temperatures are higher than at 1 m depth, whereas in autumn and winter, 100 cm temperatures are higher than at 30 cm. The most striking feature of Figure 3 is the gradual increase of summer, autumn and spring soil temperatures. Both 30 cm and 100 cm annual means were approximately 10 ^{o}C at the beginning of the 20^{th} century, whereas at present the annual means are around 10.5 ^{o}C. This enhancement is most significant for the summer mean in which temperatures have risen more than 1 ^{o}C. The winter means for both 30 cm and 100 cm series are much flatter with a marginally significant fall in the 1950s and 1960s.

In the long term, we note that whereas spring, autumn and winter temperatures rise in the 1990s compared to the 1970s and 1980s, in summer they appear to have fallen. This could either be due to the shift in the site in 1988 or to a true climatic change. Regrettably, it is no longer possible to reproduce measurements at sites South Lawn A and B due to earth works that have taken place in the Observatory grounds (see García-Suárez *et al.*, 2005a).

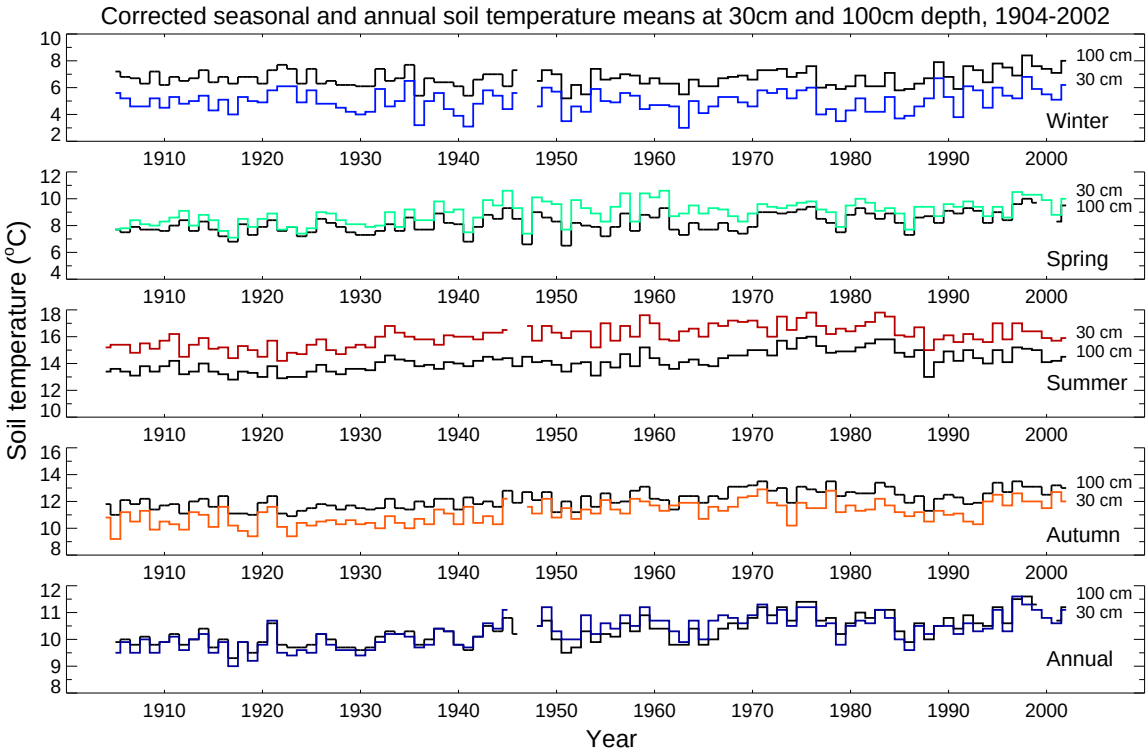

Figure 3: Comparisons between 100 cm and 30 cm seasonal and annual mean temperatures. Key: 100 cm series in black. 30 cm series for summer (red), autumn (orange), annual (black), spring (green) and winter (blue).

6 Daily, mean monthly, seasonal and annual soil temperatures

All daily, monthly, seasonal and annual soil temperature data are available from the Armagh Climate Web Site *http://climate.arm.ac.uk* and in the final version of this paper in Tables 6-11.

7 Acknowledgements

We wish to record our thanks to the Heritage Lottery Fund and the Irish Soldiers and Sailors Land Trust for their financial support for this project. Research at Armagh Observatory is grant-aided by the Department for Culture Arts and Leisure for Northern Ireland.

8 References.

Cruikshank, J. G., 1997. Soil and Environment: Northern Ireland, DANI

Collins J.F., Cummins T. 1996, Agroclimatic Atlas of Ireland, AGMET

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

García-Suárez, A.M., Butler, C. J., Morrow B., 2005a. Soil Temperatures at Armagh Observatory, N. Ireland from 1904-2003. Int. J. of Climatol. (in press)

García-Suárez, A.M., Hickey, K.R. and Butler, C.J., Park, E., 2005b. Vol 3 - Meteorological Data recorded at Armagh Observatory: Meta-data concerning Armagh Observatory Meteorological Records, 1796-2003. Preprint series Armagh Observatory (in preparation)

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

9 Additional information

We include here the map of the Observatory and the position of various soil thermometers in use over the last century. We also have included a photograph of the Observatory in the 1950s showing the sites South Lawn (A), South Lawn (B) and a path leading to the site South Lawn (C). Finally, we include a detailed map of South Lawn (A) and (B), showing the path circa 1986 and a list of the most relevant documents regarding soil temperatures.

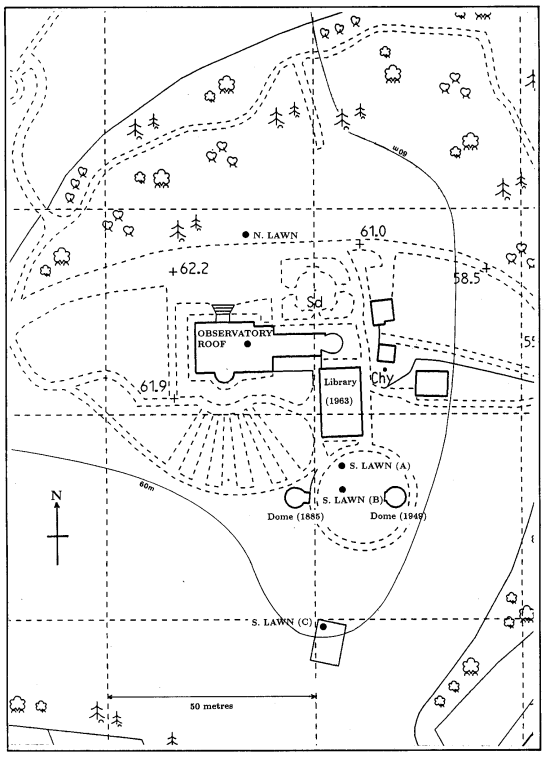

Figure 4: The position of various soil thermometers in use over the last century at Armagh Observatory, from which data have been employed in this compilation, on a map showing the recent (pre-2003) layout of grounds and buildings. The position of the 60m contour is approximate.

Figure 5: Observatory in 1950s

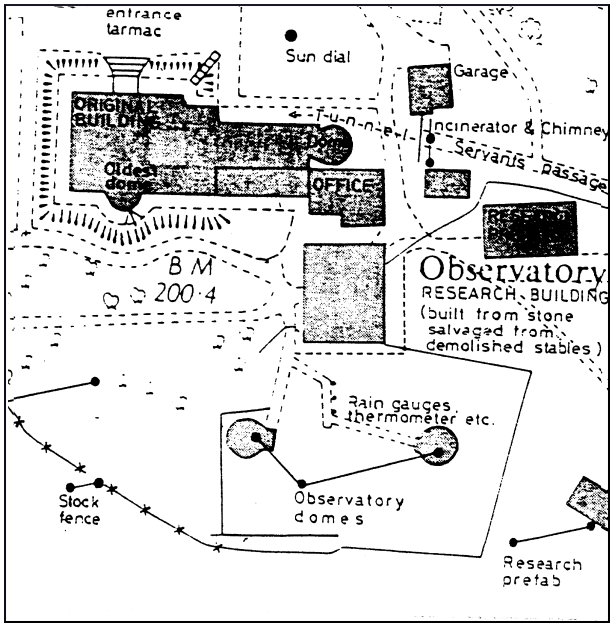

Figure 6: Detailed map of South Site (A) and (B) from 1986. Reference: García-Suárez *et al.* (2005b) ARM/MET/000447.

Table 5: List of the most relevant documents regarding soil temperature calibrations

Document no.[a]	Date	Description
ARM/MET/000260	1950/8	Description of Earth thermometers
ARM/MET/000280	1958	Maximum, minimum and soil temperatures before 1951
ARM/MET/000327	9/4/1965	Letter, earth thermometers
ARM/MET/000514	27/7/1966	Mr. Classey's report at MO. Earth Thermometers, overlap and preliminary study
ARM/MET/000373	12/9/1966	Overlap 1-ft and 4-ft earth temps.
ARM/MET/000374	1/10/1966	Armagh Earth Temperature data
ARM/MET/000397	3/1968	Installation instructions, Earth thermometers
ARM/MET/000409	30/6/1970	Adoption of metric depths for Earth temps. from Jan. 1971
ARM/MET/000412	3/9/1970	Adoption of metric depths for Earth therm. tubes
ARM/MET/000413	1970	Voucher (receipts) procedure, tube 100 cm, float TSR
ARM/MET/000415	15/10/1970	Installation of tubes (earth temps.)
ARM/MET/000447	1986	Map of Observatory and station site (copy). Survey 1986
ARM/MET/000513	18/11/1993	Summary on station history and site details, MO
ARM/MET/000480	1998	Alan Coughlin's Thesis Inspection, corrections and equipment
ARM/MET/000448	1998	Information collated about Earth Thermometer No. 19551
ARM/MET/000449	1998	Information collated about Earth Thermometer No. 6793
ARM/MET/000450	1998	Information collated about Earth Thermometer No. 6794
ARM/MET/000451	1998	Information collated about Earth Thermometer No. 18563
ARM/MET/000452	1998	Information collated about Earth Thermometer No. 21383/56
ARM/MET/000330	1998/10	E-mail J. Butler: preview of the met project
ARM/MET/000512	5/12/2001	Letter to MO, request info on thermometers
ARM/MET/000512	5/12/2001	Letter to MO, request info on thermometers Inspection, corrections and equipment
ARM/MET/000582	26/2/2002	Letter from Belfast Climate Office about soil temps. brown earth soils
ARM/MET/000600	6/2002	Monthly returns corrections : handwriting copies of corrections at Belfast Public Library Office. Miscellaneous
ARM/MET/000594	5/4/2002	Note on soil temperatures, instrument changes 1915-1953
ARM/MET/000599	5/2002	Notes taken from pocket registers by AMGS
ARM/MET/000588	2/2/2002	Letter to Mr. Lennon's Department of Agriculture N.Ireland (soil temperature)
ARM/MET/000616	19/2/2002	Email: mercury barometer (see ARM/MET/000618), soil temperatures, preparing visit to the Public Library Office
ARM/MET/000576	3/2002	Email: setting soil temperatures experiment (temp. versus depth)
ARM/MET/000600	6/2002	Monthly returns corrections : handwriting copies of corrections at Belfast Public Library Office. Miscellaneous
ARM/MET/000201	9/2003	Emails to Jack O'Sullivan in Cahirciveen regarding soil temperatures
ARM/MET/000630	11/2003	Emails to David Fitzgerald in Met Éireann regarding soil temperatures and 18th century temperatures for Dublin

[a] Catalogue number. For complete listing see *http://climate.arm.ac.uk/archives/*