MAXIMUM AND MINIMUM TEMPERATURES AT ARMAGH OBSERVATORY, 1844-1992, AND THE LENGTH OF THE SUNSPOT CYCLE

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Abstract.

The question of whether or not the Earth's climate is influenced by solar activity has received considerable attention since the mid-nineteenth century. Most investigations have adopted the sunspot number as the parameter of solar activity. Recently, however, it has been shown by Friis-Christensen and Lassen (1991) that the mean northern hemisphere temperature, from 1861-1990, follows a strikingly similar trend to the *length* of the sunspot cycle, suggesting that the recent global warming could, at least in part, arise from changes in solar activity. In view of the importance of this result, we have examined a set of continuous meteorological records, maintained at Armagh Observatory since 1844, to assess, first, whether data from a single site can give meaningful information on global trends, and second, whether the data from this particular site for the period 1844-1866 can be used to extend the baseline of the comparison with solar activity. We find that both are indeed the case and that there is a strong correlation between the solar cycle length and the mean temperature at Armagh over the past 149 years.

1. Introduction

In studies of climatic variability, and in particular global warming, it has been common practice to use the combined data from many sites, spread geographically as widely as possible. Whilst this gives a valid global picture in the modern era, when accurate instruments and systematic methods are commonplace, it becomes more difficult to move backwards in time, particularly before 1880 when there were far fewer meteorological stations and records were not made in a standardized way. Changes in measurement techniques, in the siting of instruments and in the immediate environment of the meteorological station, can all be the source of small differences that could be confused with real climatic changes. An average of the results from a number of stations may be expected to reduce the impact of the deficiencies in any one of them and the loss of individual stations and their replacement by others becomes a less serious problem. However, in some cases, where data have been gathered over a long period by careful and assiduous observers, where there has been little change in the environment, due, say, to urban encroachment, the data from a single site may be of particular value in assessing long-term trends in the Earth's climate. Armagh Observatory (see Bennett, 1990) where meteorological observations have been carried out since 1795, is believed to be one such site.

The Armagh meteorological station is situated close to the centre of the Observatory grounds on the top of a drumlin at 61m above mean sea level.

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Throughout much of the nineteenth century, the third director at Armagh Observatory, Thomas Romney Robinson, who is principally remembered for his cup anemometer, maintained a keen interest in meteorology. It was he who established the current series of meteorological measurements with daily pressure and temperature from 1833, rainfall from 1836 and hourly anemometer readings from 1846. Maximum and minimum temperatures, which form the basis of this study, were started in 1843. Though a considerable amount of earlier data survives, it is unfortunately not continuous (see Butler and Hoskin, 1987).

TABLE I

Maximum and Minimum Thermometers in use at Armagh Observatory, 1843-1899

Type	Period	Thermometer	Correction
Maximum:	Dec. 1843 - May 1860	Newman	
	Dec. 1860 - Sep. 1882	Casella	-1.7°C (-3.0°F)
	Oct. 1882 - Oct. 1892	Negretti 3404	-0.3°C (-0.5°F)
	Nov. 1892 - Oct. 1899	ditto	-0.6°C (-1.0°F)
Minimum:	Dec. 1843 - Sep. 1882	Newman	-0.3°C (-0.6°F)
	Oct. 1882 - Nov. 1899	Casella 427	0.0°C

2. Corrections for Thermometers

One of the principal difficulties associated with this type of study is to ascertain the reliability of the thermometers which were used, their calibrations, and any changes in measuring techniques or exposure which might introduce systematic errors. After 1900, the thermometers in use at Armagh were generally accurate to within 0.06°C. In Table 1, we list the details of the maximum and minimum thermometers in use at Armagh Observatory, up until 1900. Only two minimum thermometers were employed in the period 1844-1899 and, because of the extended period of their use, they were more reliably calibrated. On the other hand, three maximum thermometers were used and for the earliest of these, the Newman thermometer, we have not found any calibration data. Therefore, for the maximum temperatures, 1844-1860, we have assumed a correction of zero. This thermometer was unfortunately broken in May 1860 and replaced later that year with a Casella thermometer which had an unusually large error of -1.7°C (-3.0°F). This correction was determined by reference to a standard thermometer from

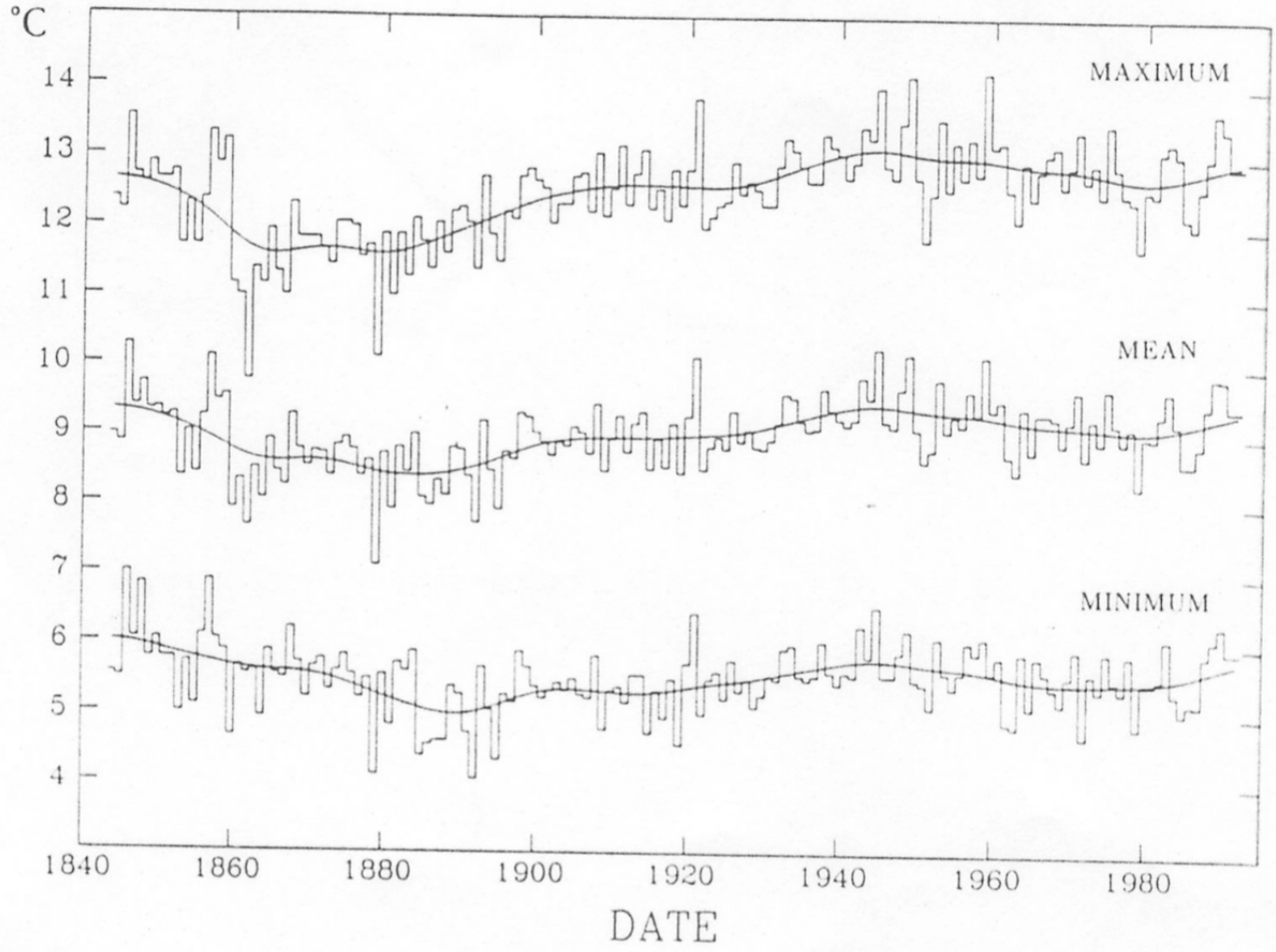

Fig. 1. The annual mean maximum, annual mean minimum and annual mean temperature at Armagh Observatory: 1844-1992

Kew on several occasions in the period 1870-1882 and found to be stable.

Initially, the maximum and minimum thermometers at Armagh were placed in a ventilated metal box suspended 3.5m above ground level on the north side of the east tower (still there in 1993). The adjacent building which housed the Mural Circle and Transit Instrument was not heated at this time. From January 1885 the thermometers were placed in a Stevenson Screen, 43m south of the earlier site. During the period 1868-1883, the British Board of Trade maintained an automatic weather station at Armagh Observatory, one of seven established in the British Isles, from which hourly measures of temperature, pressure, rainfall and wind-speed were published by Scott (1870-1883). The thermograph, which was set up in a north wall screen, 6.1m southeast of the original thermometer site, allowed Robinson, Dreyer and subsequently ourselves to confirm the calibrations of the maximum and minimum thermometers in use at that time. *

* Also it has revealed a discrepancy in published data for maximum and minimum temperatures by Scott (1884-1910) which were given without correction for thermometer error, contrary to statements in those publications.

3. Maximum, Minimum and Mean Temperature at Armagh Observatory

In Figure 1 we show the mean annual maximum and minimum temperature at Armagh Observatory for the years 1844-1992 with the data corrected for the thermometer errors listed in Table 1. Superimposed on the data is a running mean with a gaussian shaped filter which has a half-width of five years. With reference to Figure 1, we note the following: (1) The amplitude of the variation in minimum temperature is less than that in maximum temperature. (2) Years with higher or lower than average maximum tend to have higher or lower than average minimum - but this is not invariably the case, as for instance in 1862 which had the lowest mean maximum (2°C below normal) on record, but had a mean minimum close to average. This was also an exceptionally wet year with cloudy summer months. (3) There was an exceptionally warm period in the 1840s when both maximum and minimum temperatures were high; minima noticeably so, with higher values than at any other time during the 149 year coverage. The Great Famine in Ireland occurred at this time as a result of the devastation of the potato crop by fungal attack (blight). (4) The long-term variations in maximum and minimum temperatures have the same general behaviour, with a colder than average period in the second half of the 19th century, a significantly warmer period around 1950, a fall in temperature in the 1960s and 1970s and subsequent rise in the 1980s. This behaviour has been noted in many climatic studies, for example Lamb (1977). We should also note that, due to the lack of any calibration data for the first maximum thermometer, prior to 1860, the maximum curve could be less reliable than the minimum curve.

4. Relationship between Armagh and Northern Hemisphere Mean Temperature

Climatological data from single sites, though of interest, becomes substantially more important if they can be used to indicate global trends. In particular, if we can establish a clear relationship between them, then we can use the longer baseline data for a single site to predict the global trend at times in the early 19th and late 18th centuries, when the geographical distribution of meteorological stations was insufficient to determine the global picture. In Figure 2 we show the mean temperature at Armagh, for the years 1844-1992, together with the deviation from the northern hemisphere mean for 1880-1985 given by Hansen (1987). There is general agreement in the behaviour of the two curves, over the range in common, though the amplitude of the change is greater at Armagh than in the NH mean. It is noticeable in Figure 2 that the rise in the NH mean has already begun in the 1970s, whereas this does not occur in the Armagh data until the 1980s. It is now

well known, (see Lamb, 1977 and Hansen, 1987), that the long-term variations in temperature are more extreme at higher latitudes (>64°N) than at low latitudes (<44°N). Therefore, it is not surprising that the variation of the mean temperature at Armagh (latitude 54.3°) is greater than the average for the northern hemisphere. → Lamb '77

In Figure 3 we show the mean temperature at Armagh (from the smoothed curve in Figure 1) plotted against the mean NH temperature anomaly extended to include 1861-1880 and 1985-1990, as given by Friis-Christensen and Lassen (1991). We note a good correlation, though the two most recent points for 1982 and 1985 come below the general relation defined by the other points. This is presumably due to the effect, noted above, of the delay in the most recent rise in temperature at Armagh compared with the average for the northern hemisphere. We may also note that the three earliest points, for 1866, 1873 and 1878, which required a large instrumental correction for the maximum temperature (−1.7°C), lie well within the band defined by the remaining points. This confirms that the correction that has been applied to the maximum temperatures in the period 1860-1882 is reasonable.

5. The Relationship between Mean Temperature at Armagh and the Length of the Solar Cycle

It has recently been shown by Friis-Christensen and Lassen (1991) and Burroughs (1992) that the behaviour of the mean NH temperature anomaly, over the period 1865-1990, follows closely the variation of the sunspot cycle length. However, this conclusion is based on similarity in behaviour over two cool periods (circa 1890 and 1970) and one warm period (circa 1950) followed by a rise to current levels. The correlation would be strengthened if it could be shown that the same agreement continues back into the early 19th century. The length of the sunspot cycle, which is known with reasonable precision back to circa 1750, shows a peak around 1840, a minimum near 1805 and a further peak around 1770 (see Figure 3 of Friis-Christensen and Lassen, 1991). Our temperature data allow us to explore the connection with the solar cycle length back to 1844, close to the next peak back in time before the 1861 limit of the mean NH data. It is therefore important to establish whether or not the mean temperature was falling with advancing time, in the period 1840-1865. Our data clearly suggest that this was the case. In this connection we may note that the long Central England Temperature Series, given by Lamb (1977), which is based on observations from a number of sites linked together, does not show a clear fall in temperature at this time. This is surprising as the Central England Series covers a region only 400 kms distant from Armagh. However, a pronounced drop in temperature at this time is evident in data from some other northern hemisphere stations. Possibly the discrepancy can be explained by the greater influence

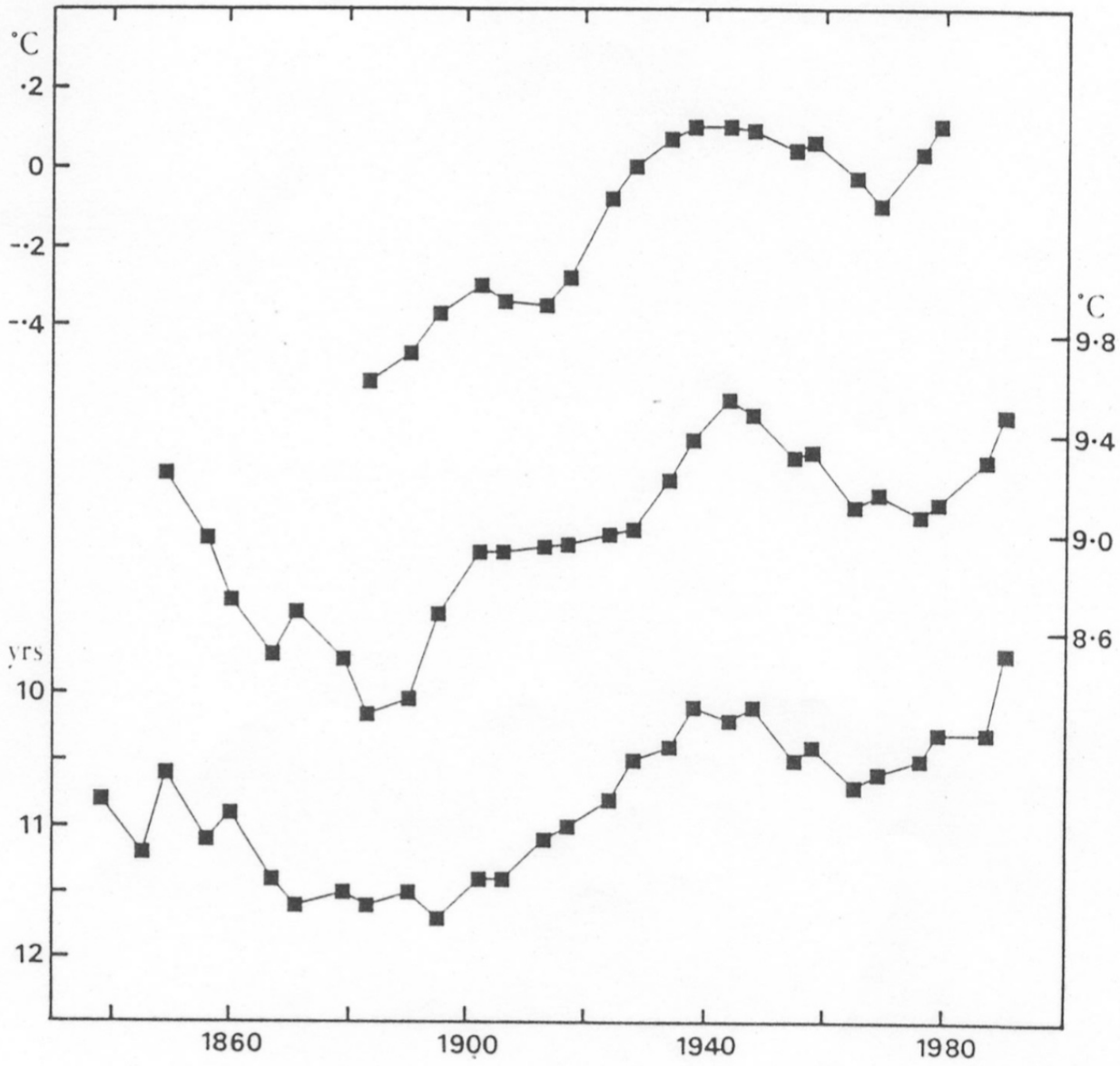

Fig. 2. *top* - Deviation of NH mean derived by Hansen (1987), *middle* - Mean temperature at Armagh 1844-1892, *bottom* - Length of Sunspot Cycle. Points on the top and middle curves are means for 11 year intervals centred on years of sunspot maximum and minimum. Points on the bottom curve are smoothed sunspot cycle lengths derived by Lassen and Friis-Christensen (1992).

of the Atlantic Ocean on the temperature at Armagh which has a strongly maritime climate and predominantly westerly winds.

In the lower panel of Figure 2 we show the length of the sunspot cycle as determined from both the minimum and maximum of the sunspot number by Lassen and Friis-Christensen (1992). The excellent agreement with the behaviour of the maximum, minimum and mean temperature recorded at Armagh over the period 1844-1992 is striking and confirms the results of the Copenhagen group determined over a shorter interval. In Figure 4, the mean

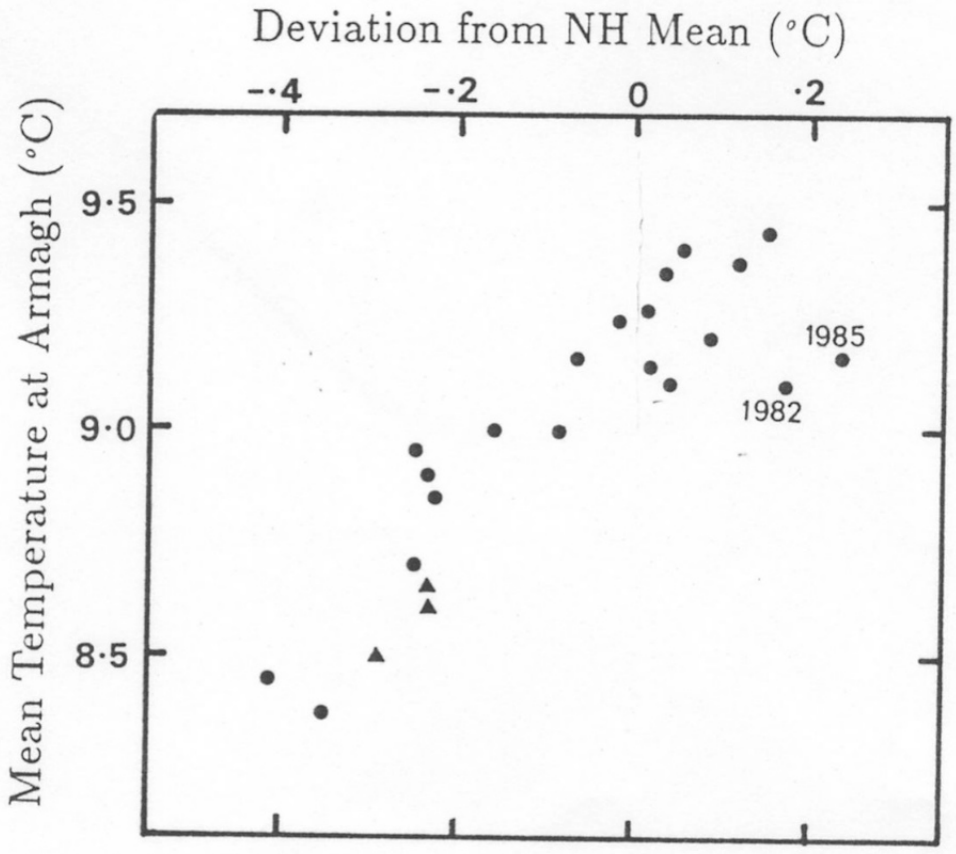

Fig. 3. The mean temperature at Armagh plotted against the NH mean (extended). The triangles represent values for the intervals centred on 1866, 1873 and 1878. The two most recent points, centred on 1982 and 1985 are indicated.

temperature at Armagh, over 11 year intervals centred on the maximum and minimum of the solar cycle, is plotted directly against the solar cycle length. This diagram gives further convincing evidence for a strong correlation between mean temperature and the sunspot cycle length, indicating that solar activity, or something closely related to it, has been a dominant influence on the temperature of the lower atmosphere in the northern hemisphere over the past 149 years.

6. Acknowledgements

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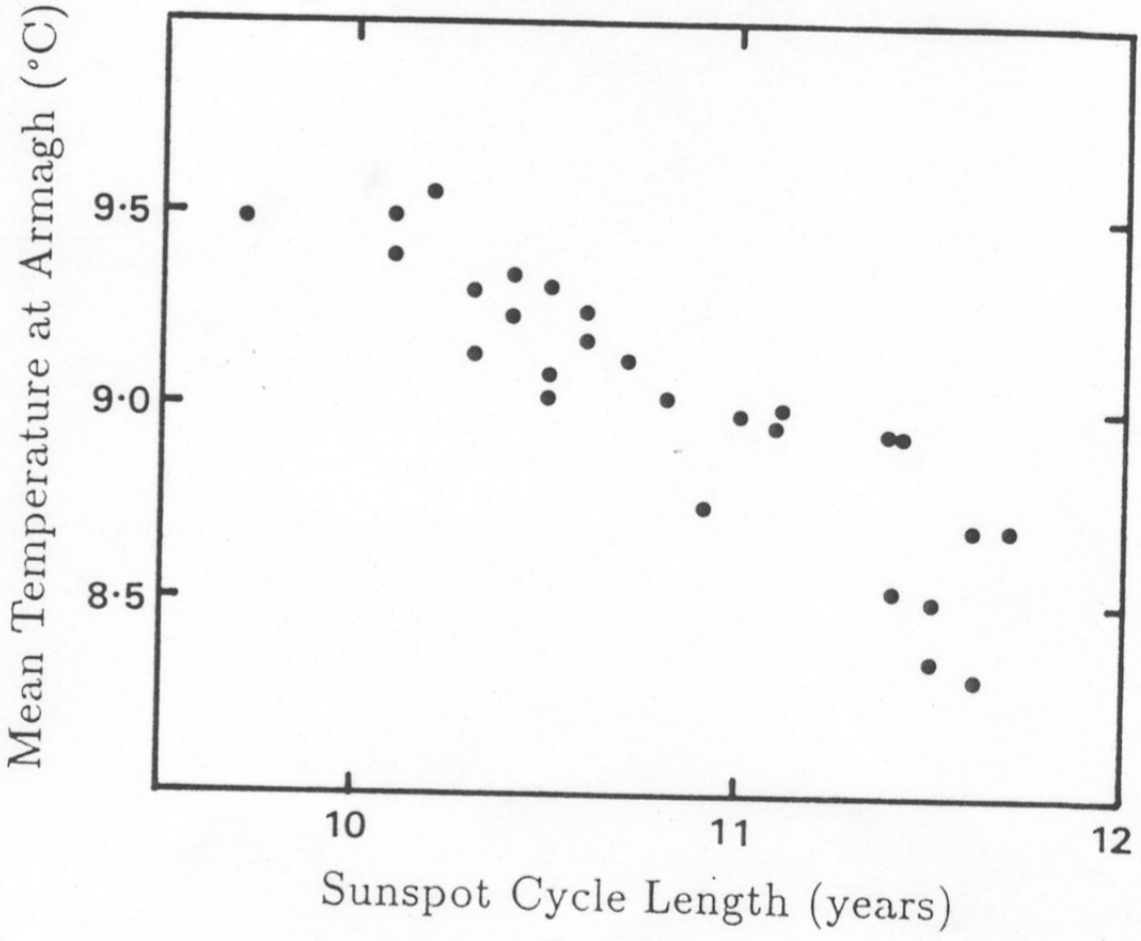

Fig. 4. The mean temperature at Armagh for 11-year intervals, centred on years of sunspot maximum and minimum, plotted against the sunspot cycle length.

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