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Annual and seasonal fluctuations of bare soil temperature values in Thessaloniki-Greece

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सार — इस अध्ययन में प्रयुक्त आंकड़े येसालोनिकी-ग्रीस में नग्न (bare) मृदा तापमान मानों के वार्षिक और मौसमी उच्चावचनों के काल श्रेणियों को उत्पन्न करते हैं । माध्य वार्षिक मान, 1.3° से० के मानक विचलन सहित 20° से० हैं । इन काल श्रेणियों के विश्लेषण से पता चलता है कि वहां पर सामान्य से ऊपर या कम मानों सहित वर्षा वाले उल्लेखनीय दौर थे । शीत ऋतुओं के अपवाद सहित वार्षिक और मौसमी मानों के लिए नकारात्मक प्रवृत्तियों के प्रेक्षण लिए गए । वार्षिक और बसंत काल श्रेणियों में सुप्रसिद्ध क्यू बी ओ पाए गए ।

ABSTRACT. The data used for this study form the time series of the annual and seasonal fluctuations of bare soil temperature values in Thesssaloniki-Greece. The mean annual value is 20°C with a standard deviation of 1.3°C. The winter is the most variable season. The analysis of these time series has shown that there were notable spells of years with values above or below the normal one. Negative trends were observed for the annual and seasonal values with the exception of winters. The well known QBO was found in the annual and spring time series.

Key words — Soil temperature, Trends, Climatic fluctuations

1. Introduction

During the last thirty years we have had numerous articles referring to air temperature and dealing with climatic change and variation (Vialar 1952, Manley 1953, Jagannathan and Parthasarathy 1972, Lamb 1982). Most of the articles indicated a general warming trend, at least in the northern hemisphere, from the late nineteenth century to the middle of the twentieth century. Since the long term climatic fluctuations and trends are influencing our lives in many ways, there has been major concern for quite a long time.

The above articles were based on long series of instrumental records of surface air temperature but they have not dealt with the long series values of bare soil temperature. The latter must be precisely known because of its importance in agricultural production. Therefore the object of the present study is to examine trends and cycles of the annual and seasonal values of bare soil temperature in Thessaloniki-Greece.

2. Data and method used

The data concerning the mean monthly temperature values of the bare soil surface in Thessaloniki have been obtained by the meteorological station of the Aristotelian University in Thessaloniki-Greece, and cover the 1931-1980 period. Some missing data, during the 1940-45 sub-period are linearly interpolated, so that the total number of data used is for 50 years.

In order to apply statistical tests to a time series, it is essential to know the nature of the frequency distribution. The homogeneity of the series was tested using the double mass technique (WMO 1966). The time series were tested for normality using Fisher's (g_1) and (g_2) statistics compared with their respective standard errors (SE). This test, at the 95% confidence level, requires that the values of $g_1/SE(g_1)$ and $g_2/SE(g_2)$ should be less than 1.96. It is clear (Table 1) that the annual and seasonal temperature values of the bare soil surface fulfil this criterion.

3. Analysis and results

3.1. *Basic statistics*

The basic statistical parameters related to each of the seasonal and annual time series of bare soil temperature are given in Table 1. The mean annual temperature of bare soil is 20.0°C with a standard deviation of 1.3°C and a coefficient of variation of 6.7%. The coldest year in the series was 1973 with a mean annual temperature of 16.8°C and the warmest year was 1952 with a mean annual value of 22.5°C. Winter, taken as December, January and February, is the most variable season from a number of view points. It has the highest coefficient of variation of 18.7% compared to the 9.8% or less of the other three seasons. On the contrary, summer is the least variable of the four seasons using the same criteria (Table 1).

TABLE 1
Some basic statistics of bare soil temperature of Thessaloniki (Period : 1931-1980)

	Highest mean value	Year	Mean value	S. D.	Coeff. of var (%)	Lowest mean value	Year	$g_1/SE(g_1)$	$g_2/SE(g_2)$	Mann-Kendall rank statistics (r)	Values of parameter "b"
Winter	8.9	1955	6.5	1.2	18.7	3.1	1954	+0.40	—1.18	+0.120*	+0.016**
Spring	24.7	1947	19.5	1.9	9.8	15.7	1974	+1.10	+1.56	—0.384*	—0.067*
Summer	39.2	1946	34.5	2.6	7.6	28.5	1973	—0.08	+1.42	—0.507*	—0.131*
Autumn	21.7	1961	19.5	1.5	7.8	16.0	1978	—1.81	—0.12	—0.349*	—0.049*
Annual	22.5	1952	20.0	1.3	6.7	16.8	1973	+0.28	—1.13	—0.451*	—0.058*

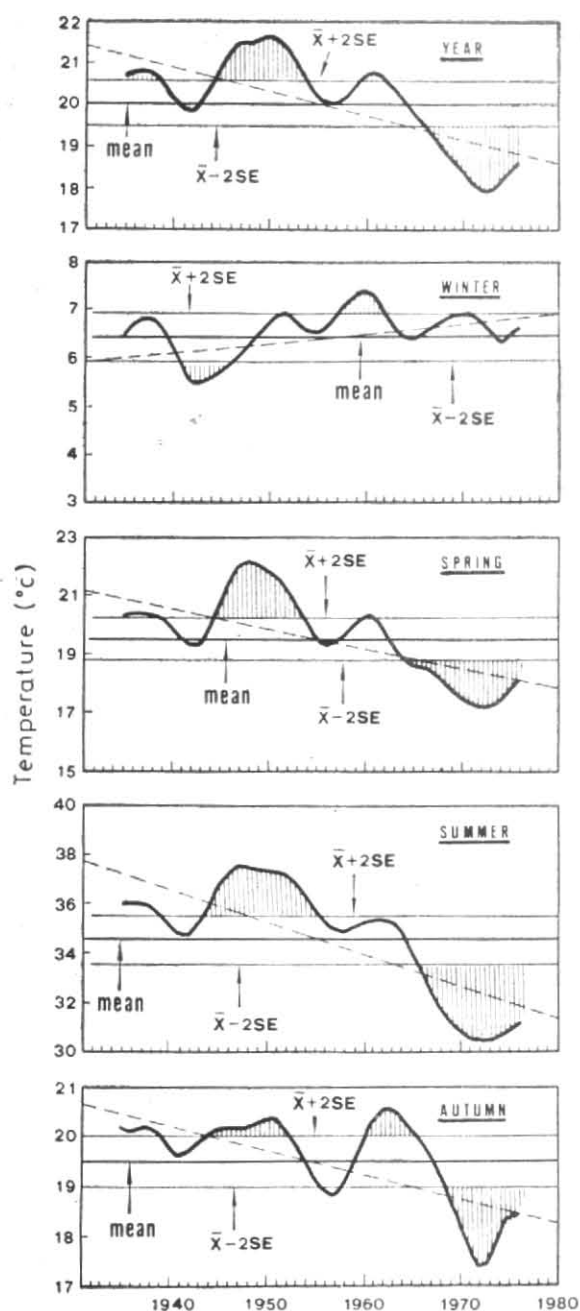* Significant at 95% level.   ** Significant at 90% level

Fig. 1. Annual and seasonal values of bare soil temperature at Thessaloniki, smoothed by a lowpass filter. Dotted line represents the regression line
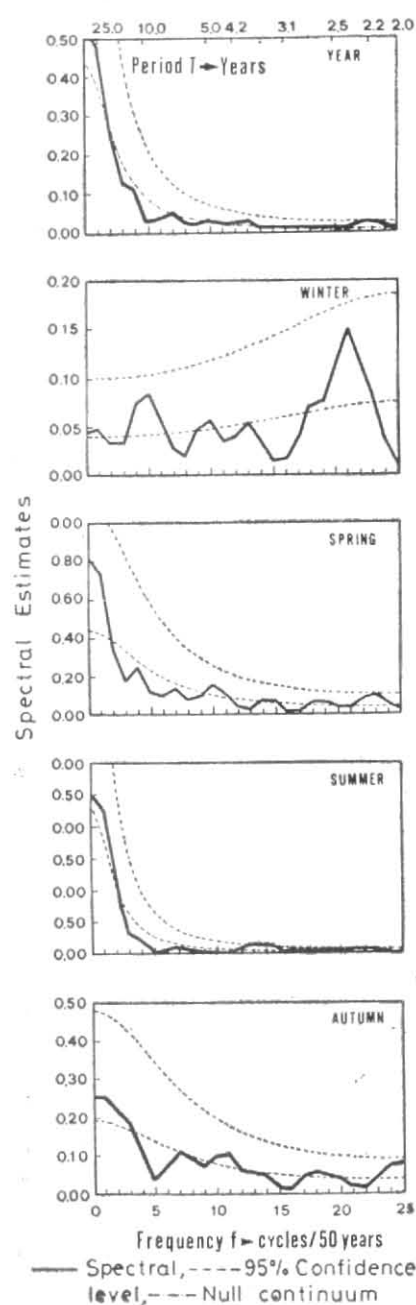

Fig. 2. The power spectra of annual and seasonal bare soil temperatures at Thessaloniki

3.2. Trends

In order to examine trends in the annual and seasonal temperature values of bare soil, both graphical and statistical approaches were used.

(i) *Graphical approach* — This method entails the smoothing of the annual and seasonal bare soil temperature series by binominal coefficients (WMO 1966). The resulting series is displayed graphically in Fig. 1. The weights used were 0.24 for the ith year, 0.20 for the $i \pm 1$ years, 0.12 for the $i \pm 2$ years. 0.05 for the $i \pm 3$ years, and 0.01 for the $i \pm 4$ years. This is a low pass filter which removes almost all fluctuations with periods shorter than 5 years. In addition, a simple statistical test (Smith 1974) was also applied. Using this test, all fluctuations in the running mean curves with amplitudes less than twice the standard error (SE) of the long term mean are considered as not being statistically significant. The filtered form of each series is also shown in Fig. 1.

In Thessaloniki, significant above average annuals of bare soil temperature occured during the periods 1933-1939, 1944-1954 and 1958-1963, while significant below average — temperatures occured in 1965 onwards (Fig. 1). These periods do not coincide with fluctuations that occured further north in Europe (Manley 1953), but they are clearly indicative of fluctuations that occured in the eastern Mediterranean (Giles and Flocas 1984). They also illustrate some more broadly based phenomenon. Lamb (1982) has pointed out that "it was during the second and third decades of the new century that climatic warming became more noticeable to everybody" and "the colder regime which set in the 1960's seems to be continuing".

Seasonal curves are also reproduced in Fig. 1. The oscillations are much greater in magnitude than those of the annual curve, this being an indication of the complex and diverse ways in which individual seasons can effect annual values. Annual fluctuations are the result of the interaction between seasonal fluctuations. Thus, the warm period 1958-1963 was the result of significantly warm winters (1955-1962), warm autumns (1960-1965) and warm summers (1959-1963). In contrast, the 1933-1939 warm period was primarily due to significantly warm summers (1933-1941), autumns (1932-38) and springs (1934-1936) with a little help from a few warm winters (1934-1936). The current cold period which became significant in Thessaloniki in 1965 was due to extremely cold summers (since 1965) and cold autumns (since 1968) and cold springs (since 1963).

(ii) *Statistical approach* — Since visual determination of trends from smoothed graphs is very objective and depends on individual judgement, an objective statistical method was used to further investigate trends in the annual and seasonal bare soil temperatures. The presence of some form of trend in climatological data may be examined by the Mann-Kendall rank statistics, r (Kendall and Stuart 1961). Using these statistics, the trend analysis was applied for the period 1931-1980. Table 1 gives the r values for the annual and seasonal series of the bare soil temperature with the 95% significant level suitably marked. Most of the trends are negative, indicating a general tendency for decreasing temperatures over the time period considered, with the exception of winter. Out of these, summer has the most significant trend, closely followed by the annual one. These results are also confirmed by the calculated values of the "b" coefficient of the various regression line (Table 1). All these values are also statistically significant at a 95% confidence level except the first one (winter) which is at a 90% confidence level.

(iii) *Power spectral analysis* — The Blackman-Tukey method (WMO 1966) was used to carry out a spectral analysis of the unfiltered time series of the annual and seasonal bare soil temperature. The maximum lag used was 25. The resulting spectra are shown in Fig. 2.

Quasi-Biennial Oscillation (QBO) is found in the annual and spring bare soil temperature series.

Also, the cycle of 3.2-4.2 years is found in the summer series. This is in accordance with the Southern Oscillation (SO) which has been recognized in recent literature to be a worldwide phenomenon having a dominant period of 3.0-6.0 years (Trenberth 1976). The 11-year oscillation associated with the sunspot activity is not clearly defined.

4. Conclusions

As far as bare soil temperature variation is concerned, winter and summer are the most and the least variable seasons respectively.

There were notable spells of years with values above or below the normal one. Annual fluctuations are the result of the interaction between seasonal fluctuations.

Summer has the most significant negative trend, compared to the rest of the seasons. Quasi-biennial oscillation is found in the annual and spring temperature series. Also, the southern oscillation is found in the summer series.

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