# WINTER AND SUMMER TEMPERATURE PERIODICITIES IN BUDAPEST

by

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*A tél és a nyár hőmérsékleti periodicitásai Budapesten.* A tanulmány Budapest 200 éves (1780—1979) hőmérsékleti adatsorának rejtett periódusait elemzi a harmonikus analizis módszerével.
Az elemzés a téli és a nyári évszak hőmérsékleti adataira vonatkozott. Megállapítható, hogy mind télen, mind nyáron statisztikailag reális periódus mutatkozik 14 és 13 év tartammal, ezenkívül nyáron 36—39 év tartammal is. Legjellegzetesebb a nyári 14 éves periódus, amely Magyarország nyári félévi csapadékában és a magyarországi folyók vízállás adataiban is kimutatható, és szoros kapcsolatban áll az anticiklonális helyzetek gyakoriságának hasonló periódusával.

This study analyses the hidden periods in the 200 years ong (1780—1979) temperature set of data in Budapest.
The analysis referred to the temperature data of winter and summer seasons. It may be concluded that there appears a 13—14 years long period in summer. Among the periods the most characteristic one is the 14-year period in summer which is provable in the water supply data of Hungarian rivers and is in close connection with a similar period of anticyclonic large scale weather situations.

Budapest is one of our observation stations possessing the longest array of meteorological data in Middle Europe. Concerning temperature a homogenised series of monthly mean values is at disposal since 1780. To a more detailed analysis of periodic temperature oscillations this 200 years long observation series is more adequate.

A separate periodical analysis was done for winter temperature set of data (December—January—February) and for summer (June—July—August) set of data as well. *Table 1 and 2* contain the data material of this analysis.

Arranging the time arrays according to the supposed periods of T=3—40 years, with the method of harmonic analysis the constanst of

$$y = A \sin\left(\frac{2\pi}{T}x + U\right)$$

equitations ($A$=amplitude, $T$=the length of the period, $x$=the passing time, $U$= =phase angle) the obtained amplitudes were expressed in the rate of

$$E = \sigma\sqrt{\frac{\pi}{n}}$$

expectancy ($\sigma$=standard deviation of the data array, $n$=number of the members of data array). The numerical values of the $A/E$ qoutient gives P probability showing that the amplitude connected to any periodlength should originate from a casual grouping of datas:

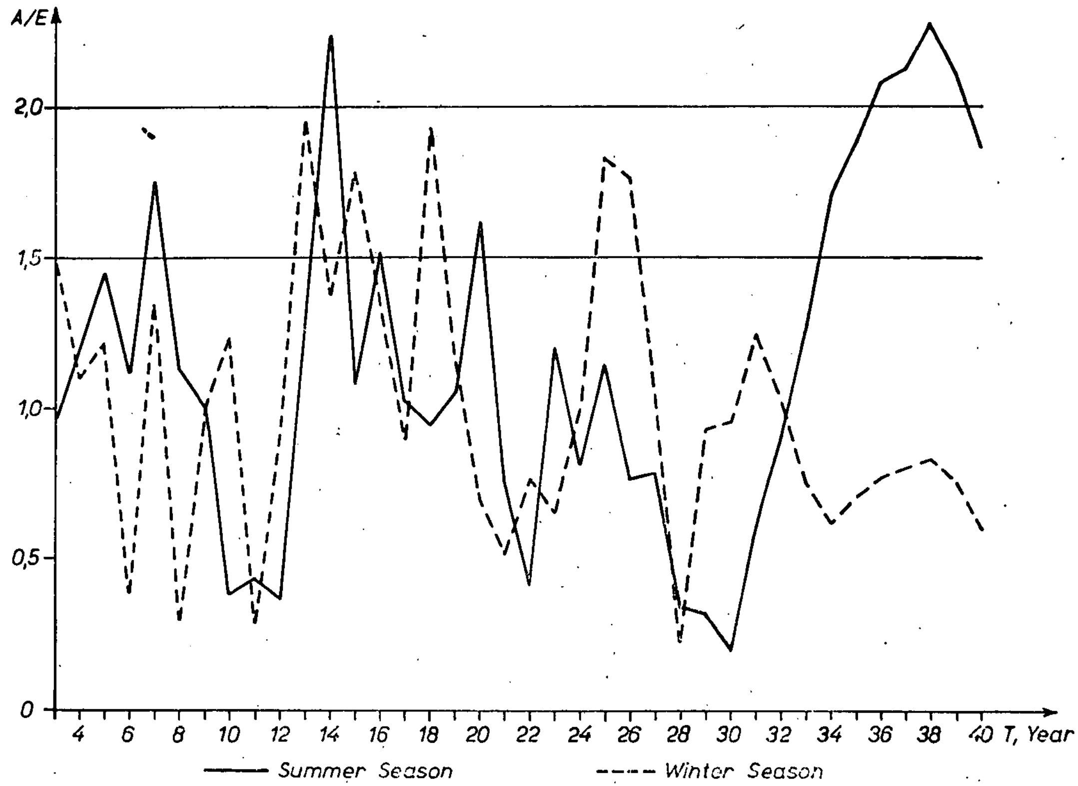


*Fig. 1 A periodgram of winter and summer temperature*

| | |
|---|---|
| $A/E=1$ | $P=0{,}4559$ |
| 1,5 | 0,1708 |
| 2 | 0,0432 |
| 2,5 | 0,0074 |
| 3 | 0,0009 |
| 3,5 | $6{,}63 \cdot 10^{-5}$ |

If $P$ belonging to an $A/E$ quotient is small enough, it may be stated with a sufficient security ($1-P$) that the periode in question is not of incidental quality. If $P<0{,}05$, which is already accepted in mathematical statictics, then $A/E>2$, in the case of a more severe condition, if $P<0{,}01$, then $A/E>2{,}5$ disparities have to be fulfilled.

The results of the period analysis are shown on *Table 3 and 4*. An illustration of obtained results *(Fig. 1)* appears in periodgram

$$A/E=fl\,(T)$$

With a summing up of data and accepting the $A/E>2$ condition the following facts may be stated:

The realistic periods in the alterations of *summer* temperatures (grouped according to $A/E$) are: 38, 14, 37, 39, 36 years.

In the temperature array of *winter* only the 13 years long periodicity can be accepted where $A/E=1{,}948$ which is the limit of probability $P=0{,}05$.

The physical reason for these periods are still unknown. It is certain, that they cannot be connected to sunspot cycle and at the same time it can be seen from our analysis that from either data array no realistic period can be connected to the sunspot cycle (11 years).

Now let's devote our attention to the 13—14 years long periods which are discernible in both seasons. These identical periods are quite sharply manifested in the time array of summer halfyear precipitation in Hungary [1], where quotient $A/E$ is 2,5 at $T=13$ years, at $T=14$ years 3,56; as well as in the set of data concerning the Danube's water supply on its Hungarian section where at $T=13$ years the values of quotient $A/E$ appeared to be 2,2—2,5, at $T=14$ years 1,9—2,3 [2]. All these refer to the fact that the 13—14 years long periodicities may be considered general and as a matter of fact only realistic periods of the climatic elements in Hungary. The physical reality of this period is supported by the next examination. Analysing the alterations of the summer halfyear frequency of anticyclonic large scale weather situations in the territory of Hungary it was found that here, too, there is a realistic 14 years long periodicity (the value of quotient $A/E$ is 2,38) and this period is in an almost complete time-synchron with the 14 years long period of summer temperature. The difference between the phase angles of the two periods is only 1°, which shows, that the 13—14-year periodical alteration of the frequency of anticyclic large scale weather situations results in a similar periodical alteration of the summer temperature in the sense that a more frequent appearence of anticyclonic large scale weather situations leads to a rise in summer temperature, while its less frequent appearence to a fall in summer temperature.

*Table 1*

*Mean temperature of the winter months (XII—I—II) °C Budapest*

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1780 | | −0,6 | −1,3 | 2,2 | −3,2 | −2,1 | −0,7 | −0,6 | 1,4 | −2,5 |
| 1790 | 0,4 | 2,7 | 0,7 | 0,2 | 2,7 | 3,1 | 3,4 | 0,1 | 2,1 | −4,4 |
| 1800 | −1,3 | 0,3 | 0,8 | −1,0 | 1,2 | −1,5 | 2,6 | 2,5 | 0,2 | −1,6 |
| 1810 | 1,2 | −0,7 | −0,8 | −2,9 | −0,3 | 1,5 | −1,0 | 1,2 | 0,9 | 0,4 |
| 1820 | −1,3 | 0,2 | 2,8 | −1,2 | 2,6 | 3,0 | −0,9 | 0,1 | −0,2 | −0,9 |
| 1830 | −5,0 | 0,5 | 1,0 | −2,0 | 3,1 | 1,6 | −1,7 | 0,4 | −4,1 | −0,7 |
| 1840 | −1,0 | −4,4 | −1,9 | 3,1 | 0,0 | −1,3 | 1,5 | −1,9 | −1,6 | 0,0 |
| 1850 | −1,8 | 0,7 | 1,2 | 1,9 | −1,4 | −0,3 | −1,1 | −0,8 | −3,1 | 0,7 |
| 1860 | −0,3 | 0,3 | −1,7 | 0,4 | −2,2 | −1,6 | 1,3 | 1,5 | 0,1 | 1,9 |
| 1870 | −0,9 | −1,6 | −1,9 | 2,6 | −0,3 | −0,4 | −2,0 | 2,4 | −0,1 | −0,2 |
| 1880 | −4,7 | −0,9 | 1,1 | 0,7 | 1,4 | 1,1 | −1,3 | 0,8 | −3,1 | −0,7 |
| 1890 | −1,5 | −4,4 | 0,5 | −3,8 | 0,3 | −2,3 | −2,0 | 1,0 | 0,3 | 2,3 |
| 1900 | 1,2 | −2,0 | 3,0 | −0,1 | 1,1 | −0,2 | 1,2 | −1,5 | 0,7 | −1,9 |
| 1910 | 3,0 | 1,4 | 1,0 | 0,1 | −0,8 | 2,5 | 3,4 | 0,3 | 0,6 | 1,9 |
| 1920 | 2 3 | 3,0 | −0,9 | 1,4 | −0,8 | 2,0 | 1,0 | 1,8 | −0,4 | −3,6 |
| 1930 | 1,7 | 1,2 | −1,2 | −1,1 | −1,4 | 1,3 | 2,7 | 0,1 | 1,1 | 1,7 |
| 1940 | −3,7 | −1,0 | −2,9 | 0,6 | 1,8 | −0,4 | 0,5 | −2,6 | 2,6 | 0,7 |
| 1950 | 1,0 | 3,5 | 1,6 | 1,5 | −2,8 | 1,4 | −0,7 | 1,5 | 1,5 | 1,3 |
| 1960 | 1,1 | 2,1 | 0,9 | −3,3 | −2,7 | 0,1 | 2,1 | 1,2 | 1,2 | −0,8 |
| 1970 | −0,6 | 1,4 | 2,9 | 2,0 | 3,1 | 3,4 | 1,7 | 2,4 | 0,9 | 1,1 |
| 1980 | 1,9 | | | | | | | | | |

*Table 2*

*Mean temperature of the summer months (VI—VII—VIII) °C Budapest*

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1780 | 20,8 | 23,7 | 22,3 | 22,5 | 21,9 | 21,8 | 20,9 | 22,2 | 22,2 | 21,3 |
| 1790 | 22,5 | 22,7 | 22,4 | 22,2 | 23,5 | 21,9 | 22,3 | 23,6 | 22,7 | 21,4 |
| 1800 | 20,5 | 20,0 | 22,7 | 21,6 | 21,7 | 20,1 | 20,9 | 23,3 | 22,5 | 21,9 |
| 1810 | 20,6 | 24,1 | 21,3 | 19,8 | 20,8 | 20,1 | 19,7 | 20,8 | 21,4 | 21,3 |
| 1820 | 21,6 | 19,4 | 22,8 | 21,3 | 21,3 | 21,2 | 22,3 | 22,6 | 21,5 | 20,3 |
| 1830 | 22,7 | 20,4 | 20,8 | 20,4 | 24,3 | 21,8 | 21,6 | 20,3 | 19,8 | 21,2 |
| 1840 | 20,3 | 22,0 | 21,1 | 20,6 | 19,9 | 21,2 | 22,7 | 20,9 | 23,3 | 20,6 |
| 1850 | 21,7 | 20,3 | 21,6 | 21,7 | 20,7 | 22,0 | 21,3 | 22,0 | 22,6 | 22,9 |
| 1860 | 20,5 | 22,7 | 21,5 | 22,2 | 20,2 | 21,5 | 21,7 | 20,9 | 22,4 | 21,1 |
| 1870 | 20,1 | 20,7 | 20,8 | 21,9 | 22,0 | 22,3 | 21,6 | 21,1 | 20,4 | 20,6 |
| 1880 | 20,7 | 21,0 | 19,5 | 20,5 | 19,7 | 20,9 | 20,8 | 21,1 | 20,3 | 21,4 |
| 1890 | 21,2 | 19,9 | 21,8 | 20,0 | 21,0 | 20,6 | 20,7 | 21,2 | 20,6 | 20,0 |
| 1900 | 21,0 | 21,6 | 20,2 | 20,2 | 22,0 | 22,4 | 20,5 | 20,3 | 20,9 | 20,7 |
| 1910 | 20,8 | 21,7 | 20,3 | 18,7 | 19,8 | 20,1 | 19,8 | 22,6 | 19,7 | 19,8 |
| 1920 | 19,8 | 21,1 | 21,1 | 20,2 | 20,2 | 20,2 | 19,3 | 21,8 | 22,1 | 21,5 |
| 1930 | 21,5 | 22,0 | 21,3 | 20,6 | 21,5 | 21,6 | 21,1 | 21,4 | 21,8 | 21,8 |
| 1940 | 19,8 | 20,0 | 20,8 | 21,4 | 21,0 | 21,8 | 22,8 | 22,6 | 20,3 | 20,5 |
| 1950 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

*Table 3*

*Periods of series of winter months' temperature*

| T | A | U | A/E | T | A | U | A/E |
|---|---|---|---|---|---|---|---|
| 3 | 0,3487 | 238,6 | 1,4864 | 22 | 0,1806 | 179,8 | 0,7698 |
| 4 | 0,2584 | 283,7 | 1,1014 | 23 | 0,1503 | 293,1 | 0,6407 |
| 5 | 0,2846 | 33,2 | 1,2131 | 24 | 0,2354 | 96,5 | 1,0034 |
| 6 | 0,0885 | 50,5 | 0,3772 | 25 | 0,4304 | 184,3 | 1,8346 |
| 7 | 0,3175 | 307,9 | 1,3534 | 26 | 0,4134 | 249,1 | 1,7621 |
| 8 | 0,0700 | 44,0 | 0,2984 | 27 | 0,2476 | 293,2 | 1,0554 |
| 9 | 0,2369 | 148,9 | 1,0098 | 28 | 0,0569 | 171,5 | 0,2425 |
| 10 | 0,2897 | 297,4 | 1,2349 | 29 | 0,2173 | 238,1 | 0,9263 |
| 11 | 0,0656 | 99,7 | 0,2796 | 30 | 0,2248 | 276,1 | 0,9582 |
| 11 | 0,0656 | 99,7 | 0,2796 | 30 | 0,2248 | 276,1 | 0,9582 |
| 12 | 0,2159 | 107,1 | 0,9203 | 31 | 0,2934 | 330,2 | 1,2506 |
| 13 | 0,4570 | 104,2 | 1,9480 | 32 | 0,2438 | 20,2 | 1,0392 |
| 14 | 0,3263 | 157,7 | 1,3909 | 33 | 0,1758 | 83,0 | 0,7494 |
| 15 | 0,4213 | 159,9 | 1,7958 | 34 | 0,1453 | 155,6 | 0,6194 |
| 16 | 0,3198 | 259,2 | 1,3632 | 35 | 0,1653 | 207,9 | 0,7046 |
| 17 | 0,2121 | 30,2 | 0,9041 | 36 | 0,1797 | 249,8 | 0,7660 |
| 18 | 0,4529 | 211,9 | 1,9305 | 37 | 0,1857 | 282,8 | 0,7916 |
| 19 | 0,2765 | 343,7 | 1,1786 | 38 | 0,1965 | 313,8 | 0,8376 |
| 20 | 0,1651 | 201,1 | 0,7038 | 39 | 0,1749 | 333,6 | 0,7455 |

*Table 4*

*Periods of series of summer months' temperature*

| T | A | U | A/E | T | A | U | A/E |
|---|---|---|---|---|---|---|---|
| 3 | 0,1194 | 294,0 | 0,9676 | 22 | 0,0519 | 264,6 | 0,4206 |
| 4 | 0,1476 | 217,6 | 1,1961 | 23 | 0,1475 | 341,0 | 1,1953 |
| 5 | 0,1784 | 308,3 | 1,4457 | 24 | 0,1006 | 59,9 | 0,8152 |
| 6 | 0,1378 | 195,4 | 1,1167 | 25 | 0,1418 | 111,0 | 1,1491 |
| 7 | 0,2163 | 268,0 | 1,7528 | 26 | 0,0946 | 179,6 | 0,7666 |
| 8 | 0,1403 | 194,7 | 1,1370 | 27 | 0,0977 | 244,0 | 0,7917 |
| 9 | 0,1240 | 314,3 | 1,0049 | 28 | 0,0421 | 282,2 | 0,3412 |
| 10 | 0,0466 | 179,0 | 0,3776 | 29 | 0,0390 | 305,8 | 0,3160 |
| 11 | 0,0533 | 258,1 | 0,4319 | 30 | 0,0253 | 259,5 | 0,2050 |
| 12 | 0,0452 | 303,9 | 0,3663 | 31 | 0,0735 | 248,7 | 0,5956 |
| 13 | 0,1673 | 23,6 | 1,3558 | 32 | 0,1112 | 259,6 | 0,9011 |
| 14 | 0,2766 | 107,8 | 2,2415 | 33 | 0,1559 | 276,7 | 1,2634 |
| 15 | 0,1332 | 27,8 | 1,0794 | 34 | 0,2124 | 293,9 | 1,7212 |
| 16 | 0,1872 | 144, 5 | 1,5170 | 35 | 0,2323 | 310,3 | 1,8825 |
| 17 | 0,1268 | 167,4 | 1,0276 | 36 | 0,2575 | 327,6 | 2,0867 |
| 18 | 0,1172 | 289,4 | 0,9498 | 37 | 0,2631 | 355,0 | 2,1321 |
| 19 | 0,1300 | 163,0 | 1,0535 | 38 | 0,2823 | 0,0 | 2,2877 |
| 20 | 0,2004 | 280,0 | 1,6240 | 39 | 0,2606 | 18,7 | 2,1118 |
| 21 | 0,0943 | 17,5 | 0,7642 | 40 | 0.2308 | 38,1 | 1,8703 |

**References**


[1] *Péczely, G.—Csomor, M.:* Magyarország nyári csapadékának periodicitása. Publications of Division X. of the Hungarian Academy of Sciences 6 (1973) 1—4. 31—36.

[2] *Oross, G.—Vas, Z.:* An Analysis of the Water Supplies of the Water System Danube—Tisza Acta Clim. Univ. Szegediensis, Tom. XIII. Fasc. 1—4. 1974, 15—24.