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## HOT AND COLD SUMMERS IN CENTRAL EUROPE (1871-1990)

*Abstract:* The paper uses data from 11 stations in Central Europe from the period of 1871-1990. To determine hot, warm, cold and very cold summers the method of standardised deviations from long-term mean temperature is applied. Most very cold summers occurred before 1930, while most hot summers between 1946 and 1952. Four distinct periods differing in the frequency of occurrence of particular summer seasons are distinguished.

*Key words:* air temperature, summer, method of standardised deviations, temperature fluctuations.

### 1. Introduction

Climate research so far has devoted rather a lot of attention to the thermal classification of winter periods, whereas the thermal variability of summers has been addressed decidedly less often. This may well be due to the fact that in Central Europe air temperature changes in winter are much more spectacular than in summer. For example the range of variability of the mean monthly air temperature is 2-3 times greater in winter than in summer (Trepieńska, Kowantetz 1997). The occurrence in the last decades of the 20th century of summer periods with diametrically different thermal conditions (e.g. the hot summer of 1992 and the very cold one of 1980) has increased an interest in this area and was an incentive to carry out a thermal valorisation of summer periods (Gerstengarbe, Werner 1992; Sadowski 1991), establish the relation between temperature in summer months and atmospheric circulation (Kožuchowski, Marciniak 1990; Krška, Racko 1996; Malberg, Böknes 1997) and determine the tendency towards a change of thermal conditions in summer (Aesawy, Hasanean 1998; Boryczka et al. 1999; Schönwiese et al. 1994).

The aim of the present study is to attempt to classify summer seasons and introduce the synchronicities and differences in their course in Central Europe.

## 2. Material and Method

The source material of the study were the values of mean monthly air temperature in summer periods (June–August) from 11 meteorological stations in Central Europe during the years 1871–1990 (Tab. 1).

The source material came mainly from *World Weather Records* and *Monthly Climatic Data for the World*. The uniformity of the data series was checked by using the method of difference stability. An interruption of uniformity was observed only in the case of the data series from Berlin and Prague. Until 1938 the Berlin data came from the station in Innenstadt, and since 1939 from the station in Berlin-Dahlem. For 30 years (1909–1938) the two stations worked simultaneously. The average difference of the mean summer temperature between these stations (0.9°C) served as a correction of the data from the station in Dahlem. Until 1980 the Prague data came from the station in Klementinum, and since 1981 from the station in Ruzyne. The average temperature difference in summer, calculated on the basis of the data from the 30-year period of 1951–1980 when the two stations worked simultaneously, was 2.0°C and served as a correction of the data from the station in Ruzyne for the period of 1981–1990.

Tab. 1. Meteorological stations considered in the present study.

Station	$\varphi$	$\lambda$	H [m]
Berlin	52°28'N	13°18'E	58
Bucharest	44°25'N	26°06'E	82
Budapest	47°26'N	19°11'E	138
Copenhagen	55°41'N	12°33'E	9
Cracow	50°04'N	19°58'E	206
Frankfurt/M	50°03'N	8°36'E	112
Munich	48°08'N	11°43'E	529
Prague	50°06'N	14°15'E	369
Puławy	51°25'N	21°57'E	74
Vienna	48°15'N	16°22'E	199
Zurich	47°23'N	8°43'E	556

The present study adopts a simplified, though frequently used, definition of summer as a period from June to August, inclusively (e.g. Malberg, Böknes 1997). Empirical distributions of the mean monthly air temperature in the summer period are very close to normal distribution. That is why, in carrying out the thermal valorisation - a classification based on two essential parameters of normal distribution was applied, *i.e.* arithmetical mean and standard deviation, proposed by Kossowska-Cezak (1993). Adopted as normal were those seasons whose mean temperature ( $t$ ) differs from the respective long-term mean ( $T$ ) by not more than one standard deviation ( $\delta$ ), *i.e.*  $T - \delta \leq t \leq T + \delta$ . If the deviation exceeded the value of standard deviation, the season was treated as cold (negative deviation) or warm (positive deviation); if it exceeded its double value, the season was regarded as very cold or hot. By using this method all summer seasons were classified in each of the 11 stations.

In order to ensure the compatibility of results, both the arithmetical mean and the standard deviation were calculated on the basis of the 120-year period of 1871–1990. The basic index in the thermal evaluation of particular summer seasons was the so-called standardised deviation from the long-term mean.

### 3. Results

#### 3.1 General characteristics of the thermal conditions of a summer seasons

The mean long-term air temperature (1871-1990) in the summer season in the 11 stations analysed varied between 16.4°C in Copenhagen and 21.8°C in Bucharest. The long-term variability of the mean air temperature of the season discussed is relatively small, which is confirmed by the standard deviation values, ranging between 0.8°C in Cracow and 1.0°C in Bucharest and Zurich, as well as the differentiation range from 3.4°C in Cracow to 5.9°C in Bucharest (Tab. 2). The warmest summer (24.9°C) occurred in Bucharest in 1946, while the coldest one (14.3°C) in Copenhagen in 1902.

Tab. 2: Statistical characteristics of air temperature (°C) in the summer season at selected European stations (1871-1990).

Station	Mean	Standard deviation	Maximum	Year	Minimum	Year	Range
Berlin	18.3	0.88	20.4	1947	16.3	1962	4.0
Bucharest	21.8	0.97	24.9	1946	19.0	1976	5.9
Budapest	20.9	0.83	23.0	1950	18.7	1913	4.3
Copenhagen	16.4	0.94	18.6	1947	14.3	1902	4.3
Cracow	17.8	0.78	19.5	1875	16.1	1913	3.4
Frankfurt/M	18.2	0.95	21.2	1947	16.4	1913	4.8
Munich	16.6	0.84	18.9	1950	14.4	1913	4.4
Prague	18.7	0.83	20.5	1947	16.6	1913	4.0
Puławy	17.4	0.83	19.8	1939	15.6	1902	4.2
Vienna	18.7	0.83	20.7	1983	16.7	1913	4.0
Zurich	17.1	0.97	20.0	1947	15.0	1918	5.0

#### 3.2 Types of summer seasons

As can be seen from the properties of the normal distribution of air temperatures, about 2/3 of summer seasons in the stations analysed are normal seasons. Their lowest frequency occurred in Vienna (about 61%), and the highest one in Puławy (about 69%). Cold and very cold summers (jointly) occurred the most frequently in Vienna (20%) and in Copenhagen (19%), and the least frequently in Bucharest (14%). Warm and hot summers (jointly) were most often noted in Cracow (about 21%), and least often in Copenhagen, Frankfurt/M., Prague and Puławy (15%). Very cold seasons during the period of 1871-1990 occurred at most 3 times in Copenhagen, Berlin and Bucharest, while they were not noted in Frankfurt/M. Hot seasons occurred 5 times in Zurich, and only once in Puławy and Bucharest.

Only normal summers occurred simultaneously at all the stations analysed. During the 120 years of observations there were 13 such cases. In 26 cases at some stations there were warm summers, while at others, in the same year, cold ones. Particularly remarkable was the year 1976, when the summer in Bucharest was very cold, in Cracow - cold, in Prague and Berlin - warm, while in Copenhagen and Frankfurt/M. - hot. At the remaining 5 stations it was normal.

According to the criteria applied, most very cold years (16) occurred in the first half of the period analysed, while in the second one very cold years occurred only four times: Zurich (1956), Berlin (1962), Bucharest (1976), Cracow (1978). The coldest summer was that of 1913 (cf. Tab. 2), when at 6 stations it was very cold, at 4 - cold, and only in Copenhagen - normal.

Most hot summers occurred in the second half of the period analysed. Out of the 28 hot summer seasons noted at all the stations, as many as 17 occur during the years 1946-1952. Especially hot was the summer of 1947 (cf. Tab. 2), when the mean temperature at Frankfurt and Zurich exceeded the long-term mean by over 36, while at 4 stations (Berlin, Budapest, Munich and Prague) by over 26.

### 3.3 Characteristics of the course of summer season types

Further in the study the course of the distinguished types of summer seasons was described for every station during the period 1871-1990. At 9 of the 11 stations analysed those courses were characterised by considerable similarity (excluding Copenhagen and Bucharest). Evidence of that can be seen in the calculated indices of correlation between the temperature values of the summer seasons at particular stations, which were statistically relevant and generally ranged from 0.6 to 0.8. The analysis of those courses allows to distinguish 4 periods differing by the frequency of occurrence of particular summer seasons (Fig. 1). The first period (up to the year 1877) is too short to be analysed in detail; nevertheless it was distinguished since at as many as 9 stations it was characterised by a considerable frequency of warm summers. The second period extends from 1878 to 1926-1928. It was clearly colder than the previous one. It was clearly marked in Cracow, Prague, Budapest, Frankfurt, Vienna, Puławy and Berlin. The period was characterised by a considerable frequency of cold summers and only a sporadic occurrence of warm ones. For example in Vienna there occurred during it 18 cold summers and 2 very cold ones, while only 3 warm ones. The cold period distinguished began later in Munich (in 1906) and in Zurich (in 1912). Earlier at both those stations there occurred a considerable variability of summer season types from one year to the next. In Copenhagen the period of cold summers had probably begun by 1871, and ended in 1932. In Bucharest the cold period was observed during the years 1875-1893, to be followed (until 1926) by a period with a decided prevalence of «normal» years.

At 10 stations the period of warm summers began in 1926-1929, and only in Copenhagen slightly later (in 1932). It finished the soonest (in 1952) in Munich, Budapest, Zurich and Copenhagen, a year later in Frankfurt/M., and the latest in Prague in 1976. For example, in Puławy in 1928-1961 no cold summers were noted

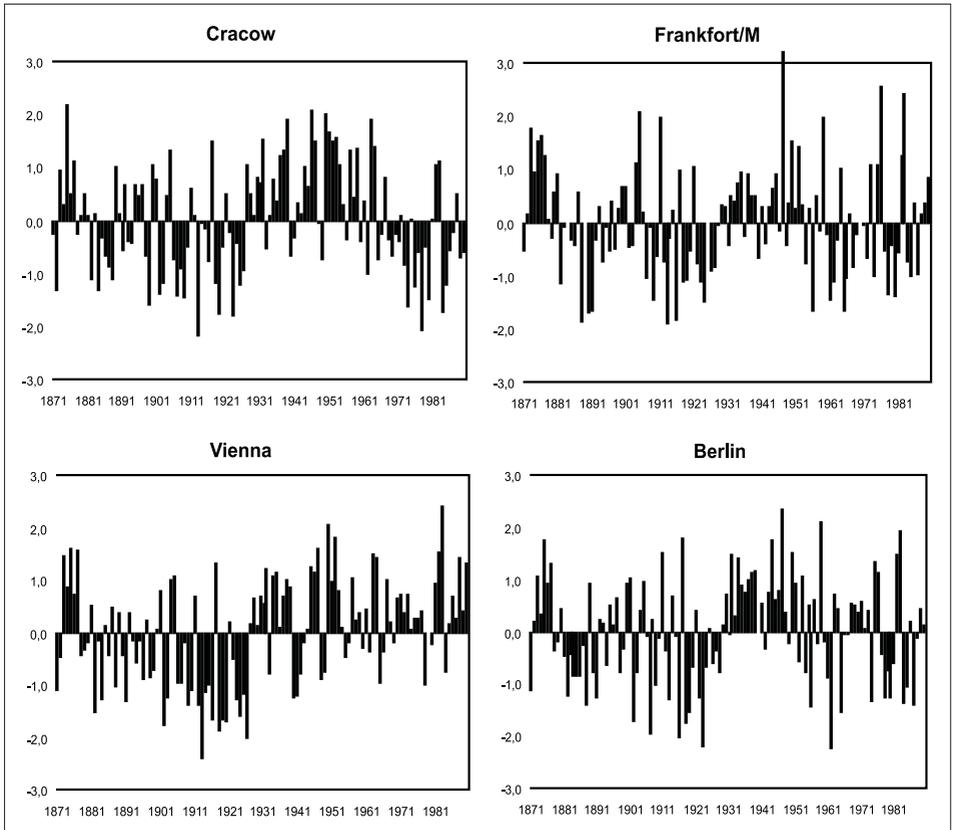


Fig. 1. The course of standardised deviations of the mean summer temperature from the long-term (1871-1990) mean at selected stations in Central Europe.

but 9 warm ones and one hot one. Vienna is set somewhat apart here as the prevalence of warm summers there lasted at least until 1990.

After the warm period, most stations noted a period of great variability of summer season types from one year to the next. For instance in Frankfurt/M., during the years 1954-1990, 5 warm summers, 2 hot ones and 9 cold ones were observed. In Cracow since 1964, in Zurich since 1953 and in Bucharest since 1966 cold summers have prevailed.

The results obtained largely correspond with those of Gerstengarbe and Werner (1992), who applied the method of concentration analysis in determining extremely hot and cold summers at 18 European stations during the period 1901-1980. They distinguish 3 periods of different thermal character: 1901-1927 - the period of prevailing cool and cold summers; 1928-1953 - the period of prevailing warm and hot summers; 1954-1980 - the period of an almost identical frequency of extreme summers.

The method applied here allows to observe that in the course of summer seasons there are periods of concentration (series) of some of their types. At the same time it is worth stressing that in a given year in Central Europe there may simultaneously occur different types of summer season. This can be seen especially in the final decades of the 20th century.

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