SBORNÍK ČESKOSLOVENSKÉ GEOGRAFICKÉ SPOLEČNOSTI
Ročník 1984 • Číslo 2 • Svazek 89

FERDINAND ŠAMAJ, ŠIMON VALOVIČ, RUDOLF BRÁZDIL

ATMOSPHERIC PRECIPITATION VARIATION IN CENTRAL EUROPE IN PERIOD OF 1881—1980

1. Introduction

Atmospheric precipitation is characterized by a great temporal and spatial variability. Since their origin physical processes have been mainly influenced by circular and geographical factors instable in time and space.

In Central Europe, within the frame of circular factors, oceanic influences (e. g. mainly of the Atlantic ocean and the Mediterranean sea) as well as continental influence (e. g. of the Eurasian continent) become outstandingly evident. The location of the area under study including the exposition conditions is most important among the geographical conditions. Since the geographical factors can be considered practically constant in time, the main causes of the precipitation variation may be found in the temporal variability of circular factors.

In climatological literature much attention has been paid to the study of precipitation variations because they often have serious consequences on various spheres of human economic activity. The purpose of these studies is a through analysis of this variation with the aim of obtaining results helpful in long-term forecasts. Similarly, a number of papers deal with precipitation variations in Central Europe, where the carried out analyses refer as a rule to individual precipitation stations or territorial units (see list of literature).

The aim of the present paper is to analyse the year total of precipitation variations in the area of Central Europe in the period of 1881—1980.

2. Applied material and methods of compilation

The analysis of precipitation variations in Central Europe is partly based on the year precipitation totals obtained from the precipitation stations, partly on what is called spatial year precipitation mean in the period of 1881—1980. The advantage of spatial means in comparison with the data from the stations is presented by supressing local influences on the precipitation regime (orographical conditions, convection effect), which allows to state the main and determining characteristics of the precipitation regime. In this paper the calculated spatial means have been used for the territory of Czechoslovakia (Bohemia and Slovakia), Poland

and Hungary together with the data from stations in Vienna, Innsbruck, Berlin, Erfurt, Hannover, Frankfurt on Main and Munich.

For analyses of the precipitation series many various statistical methods have been applied (see literature). The present paper describes the following ones:

- five year and eleven year moving averages
- double and twentyfold smoothing of the series by binomial coefficients
- harmonic analysis
- correlation and spectral analyses.

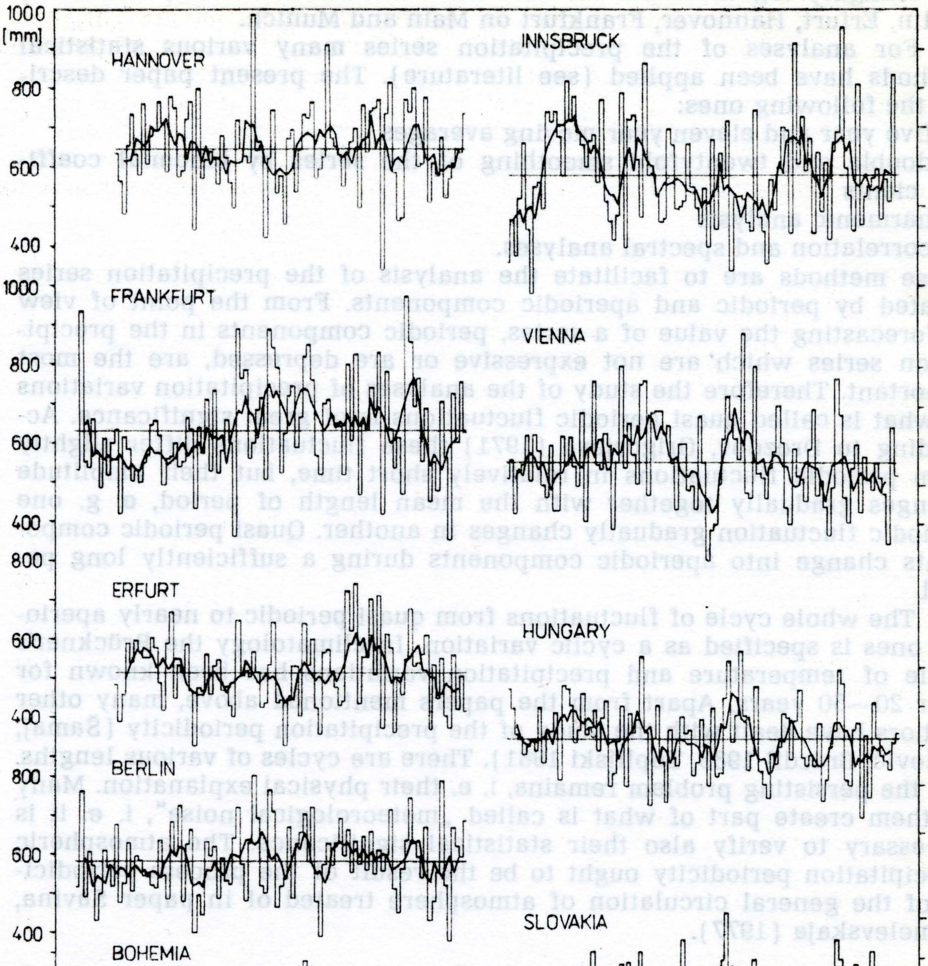
These methods are to facilitate the analysis of the precipitation series created by periodic and aperiodic components. From the point of view of forecasting the value of a series, periodic components in the precipitation series which are not expressive or are depressed, are the most important. Therefore the study of the analyses of precipitation variations of what is called quasi periodic fluctuations is of great significance. According to Drozdov, Grigorjeva (1971) these fluctuations differ slightly from periodic fluctuations in relatively short time, but their amplitude changes gradually together with the mean length of period, e. g. one periodic fluctuation gradually changes in another. Quasi periodic components change into aperiodic components during a sufficiently long period.

The whole cycle of fluctuations from quasi periodic to nearly aperiodic ones is specified as a cyclic variation. In climatology the Brückner's cycle of temperature and precipitation variations has been known for over 20—50 years. Apart from the papers mentioned above, many other authors have dealt with the study of the precipitation periodicity (Šamaj, Valovič, Brázdil 1983, Toplijski 1981). There are cycles of various lengths, yet the persisting problem remains, i. e. their physical explanation. Many of them create part of what is called „meteorological noise", i. e. it is necessary to verify also their statistical significance. The atmospheric precipitation periodicity ought to be the result of the process periodicity of the general circulation of atmosphere treated of in paper Savina, Chmelevskaja (1977).

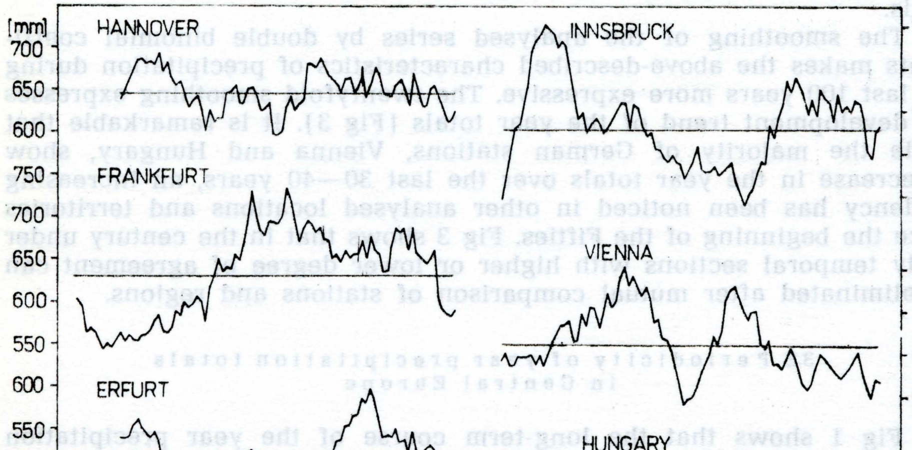
3. Atmospheric precipitation variation in Central Europe

3.1 Precipitation course in Central Europe in the period of 1881—1980

As it follows from Fig 1, the year precipitation totals can fluctuate over a wide range in individual regions in Central Europe. Smoothing the real values by the five and eleven year moving averages allows the comparing and finding out of the main characteristics of the precipitation course in the period between 1881 and 1980. Consequently, it can be stated that in a year precipitation total course an analogical characteristics can be found throughout Central Europe, although the period of a higher or lower precipitation differs by size or by certain temporal shifts of these extremes in individual cases. On the basis of the course of values smoothed by the five year moving averages (Fig 1) the last decade of last century, the


1000
[mm]
HANNOVER
800
600
400
1000
FRANKFURT
800
600
400
800
ERFURT
600
400
BERLIN
800
600
400
BOHEMIA
800
600
1200
MUNICH
1000
800
[mm]
INNSBRUCK
1200
1000
800
600
VIENNA
800
600
HUNGARY
800
600
400
SLOVAKIA
1000
800
600
POLAND
800
600
C+W
W
E
C
E
E+C
C+W
W
E
C
E
E+C
1880
1900
1920
1940
1960
1980
1880
1900
1920
1940
1960
1980

second decade of our century in the eastern part of Central Europe, and the end of the Thirties and the middle of the Sixties may be included in periods of a higher precipitation. In the western part of the area under study the most significant increase was also noticed in the Fifties. As regards the period of the lowest year precipitation totals, it is necessary to mention especially Frankfurt and Berlin where practically the first forty years of the studied period were significant by a low below-average precipitation (in case of values smoothed by eleven year moving



2. Year precipitation total course in Central Europe smoothed by eleven year moving averages. Period 1881—1980.

1. Course of year precipitation totals in Central Europe (column chart). Smoothed by five year moving averages (broken line). Horizontal line — value of long-term mean. Period 1881—1980. Macroprocess circulation marked in lower part of graph (explanation in text).

averages, Munich also gives a similar course of precipitation, Fig 2). In other parts of Central Europe periods of lower precipitation alternate with those of maximum precipitation. A more significant decrease was noticed at the beginning of the Thirties and in the second half of the Forties (in Poland at the beginning of the Fifties). The above-described characteristics of the year precipitation total is projected in the precipitation course illustrated by eleven year moving averages (Fig 2). Meanwhile in Bohemia, Vienna, Hungary and Slovakia the precipitation maximum in about 1940 was followed by below-average year precipitation totals, German stations (as well as Innsbruck, Austria) give above-average totals.

The smoothing of the analysed series by double binomial coefficients makes the above-described characteristics of precipitation during the last 100 years more expressive. The twentyfold smoothing expresses the development trend of the year totals (Fig 3). It is remarkable that while the majority of German stations, Vienna and Hungary, show a decrease in the year totals over the last 30—40 years, an increasing tendency has been noticed in other analysed locations and territories since the beginning of the Fifties. Fig 3 shows that in the century under study temporal sections with higher or lower degree of agreement can be eliminated after mutual comparison of stations and regions.

3.2 Periodicity of year precipitation totals in Central Europe

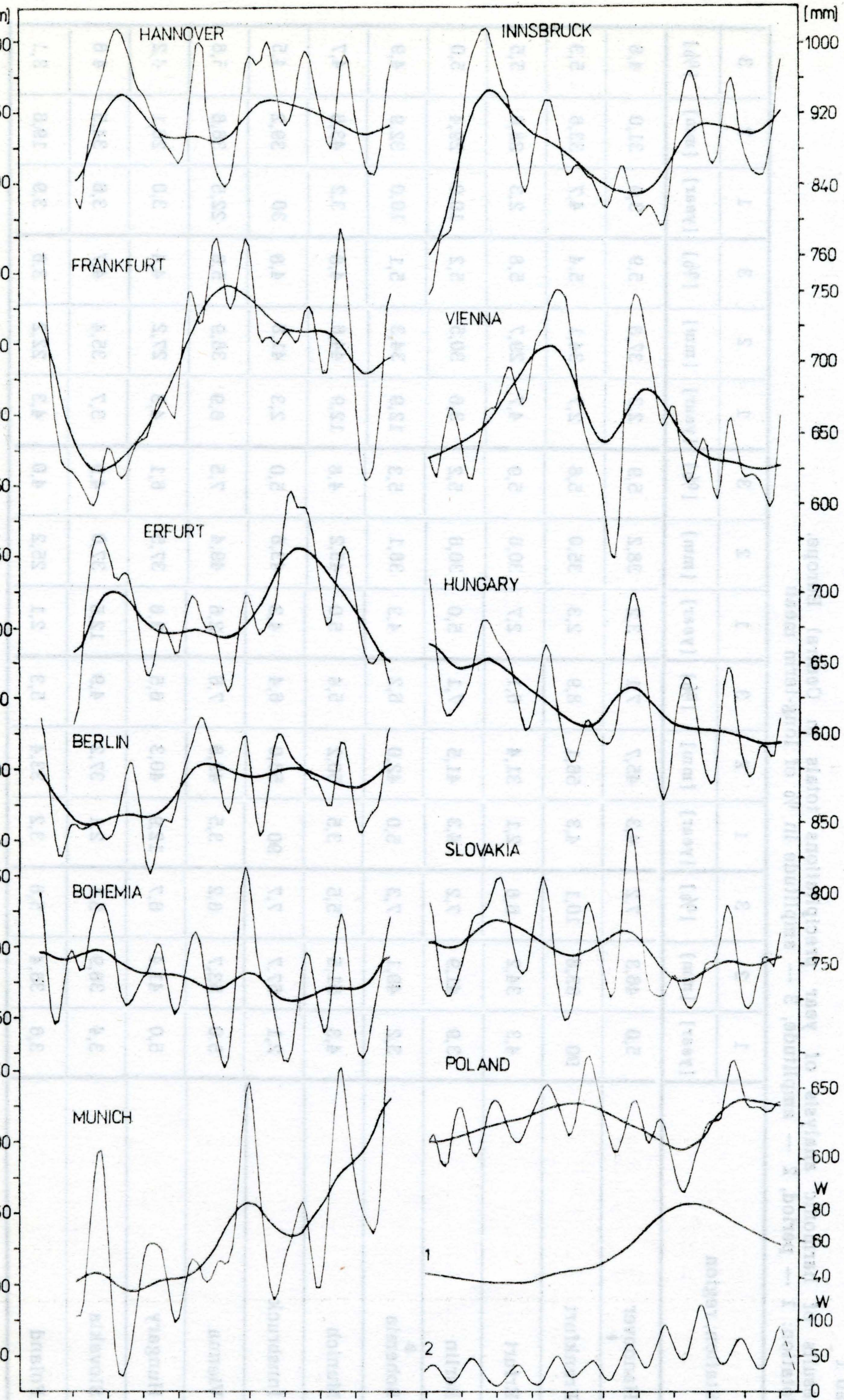
Fig 1 shows that the long-term course of the year precipitation totals in Central Europe is partly conditioned by aperiodic components. The method of harmonic analysis was applied in selecting periodic components in the temporal series for analysing the precipitation series. Table 1 shows a survey of the most important periods, i. e. of 4,3; 2,1; 5,0; 3,2; and 90 year length. At the same time, however, the greatest amplitude of the periods mostly reaches only 5—8 % of the average values in the given series. In a number of cases the statistically significant cycles ascertained by methods of autocorrelation and spectral analyses, mentioned in Tab 2, correspond to the stated periods. Among these cycles the 4,3 year and 5 year cycles occur most often being of a similar length (4 or 4,8 year). It is important to say that there exist 25—26 year cycles, 13—16 year cycles and cycles lasting longer than 50 years. A wide spectrum of found cycles proves the complexity of the studied problem.

4. Forecast of year precipitation totals in Central Europe

Long-term forecasts of the year atmospheric precipitation totals represent a very tough problem to be solved. Worded forecasts are of a rather hypothetic character and regularly describe the particular de-

→

3. Year precipitation total course in Central Europe: double smoothing by binomial coefficients, twenty times smoothed by binomial coefficients (heavy lines). Course of Wolf relative numbers (W): 1 — twenty times smoothed by binomial coefficients, 2 — double smoothing. Period 1881—1980.


[mm]
HANNOVER
INNSBRUCK
[mm]
700
650
600
1000
920
840
760
FRANKFURT
700
650
600
550
VIENNA
750
700
650
600
ERFURT
550
500
450
HUNGARY
700
650
600
BERLIN
600
550
SLOVAKIA
850
800
750
BOHEMIA
750
700
650
POLAND
650
600
MUNICH
1050
1000
950
900
850
W
80
60
40
1
W
100
50
0
2
1880
1900
1920
1940
1960
1980
1880
1900
1920
1940
1960
1980

Tab 1

Results of harmonic analysis of year precipitations totals in Central Europe.
Notation: 1 — period, 2 — amplitude, 3 — amplitude in % of long-term mean

Station, region	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	[year]	[mm]	[%]	[year]	[mm]	[%]	[year]	[mm]	[%]	[year]	[mm]	[%]	[year]	[mm]	[%]
Hannover	5,0	46,3	7,2	4,3	45,7	7,1	3,2	38,2	5,9	2,3	37,8	5,9	3,9	31,0	4,8
Frankfurt	90	63,8	10,1	4,3	56,1	8,9	2,3	35,0	5,6	2,7	34,1	5,4	4,7	33,6	5,3
Erfurt	4,3	34,2	6,6	2,1	31,4	6,1	2,7	30,6	5,9	4,7	29,7	5,8	2,3	28,6	5,5
Berlin	3,9	41,9	7,2	4,3	41,5	7,1	5,0	30,6	5,2	3,6	30,5	5,2	10,0	29,4	5,0
Bohemia	3,2	49,1	7,3	5,0	42,0	6,2	4,3	36,1	5,3	12,9	34,3	5,1	10,0	32,9	4,9
Munich	4,3	51,5	5,5	3,5	50,2	5,4	5,0	45,2	4,8	12,9	44,6	4,8	3,2	43,6	4,7
Innsbruck	2,1	67,7	7,7	90	56,0	6,4	4,3	43,8	5,0	2,3	41,8	4,8	30	39,2	4,5
Vienna	5.0	53,7	8,2	3,5	49,8	7,6	2,6	49,4	7,5	6,9	36,9	5,6	22,5	36,6	5,6
Hungary	5,0	41,4	6,7	12,9	40,3	6,5	3,6	37,5	6,1	4,3	27,2	4,4	3,0	26,1	4,2
Slovakia	3,4	38,9	5,1	2,1	37,2	4,9	12,5	37,0	4,9	3,7	35,4	4,7	3,6	34,5	4 6
Poland	3,6	36,4	5,8	3,2	33,4	5,3	2,1	25,2	4,0	4,3	22,2	3,6	3,9	19,6	3,1

Tab 2

Lenght of statistically important cycles of year precipitation totals in Central Europe according to autocorrelation and spectral analysis

Station, region	Autocorrelation analysis						Spectral analysis
Hannover	39	4	42	60	55		4,3; 5,0
Frankfurt	8	16					4,3; 87—94
Erfurt	51	56	5				4,3; 4,7; 60—63
Berlin	59	25	39				4,0; 4,3; 4,8
Bohemia	64	26	42	55	40		5,0; 8,3; 13,5
Munich	42	25	13				4,3; 13,5—14; 15,5—16
Innsbruck	4	2	60		21		2,1; 4,3; 20,0; 29—30, 57—60
Vienna	70	15	49				2,6; 3,5; 5,0
Hungary	14	60	25	4	69	55	3,7; 5; 13,5
Slovakia	14	21	25	67			3,5; 4,3; 4,8; 12,5; 32
Poland	67	48	4	55	58	51	3,7

velopment trend for a definite time period, often in relation to some extraterrestrial influence. Most frequently it is the case of the changes of solar activity expressed by the Wolf relative numbers of solar spot frequencies (Iľko, Šamaj, Valovič 1981, Šamaj, Valovič 1980, Šamaj, Valovič, Brázdil 1981b). In finding out a relationship between the precipitation and the Wolf numbers, Šamaj and Valovič (1980) distinguished synchronic and asynchronic cycles (synchronic — maximum or minimum of solar spots — corresponds to a period of higher or lower precipitation; asynchronic — vice versa). For instance, in Slovakia the synchronic cycle began in the last years, demonstrated by a higher precipitation at the beginning of the Eighties, and by a minimum precipitation in about the middle of the Eighties (Šamaj, Valovič, Brázdil 1981b). But such relationships may be found only thanks to the adaptation of the original temporal series by smoothing. That is why such a forecast indicates only the precipitation trend, yet cannot be used for a concrete year. An example of comparison of the precipitation course and Wolf relative numbers is shown in Fig 3.

Many studies have shown that the relationship between solar activity and the processes going on in the earth atmosphere is very complicated. The study of the relationship of solar activity and precipitation cannot give fully satisfactory results unless sufficient attention is paid to the explanation of the physical substance in the above-mentioned relationship including the influence of atmospheric circulation. Chapter 3.2 shows that precipitation cycles of a similar lenght as the solar activity are not very expressive.

In this situation, apart from other methods of long-term forecast (which has not brought any satisfactory results so far), a traditional climatological method of forecasting presents values of corresponding long-term mean totals of the year precipitation. It shows, however, that a more qualitative forecast can be achieved by equalizing the temporal series on the basis of the main harmonic components and their extrapolation to future. For instance, using 6 harmonic components, theoretical accuracy of the year precipitation total forecast for the next years is by 22 % (Erfurt) and by 31 % (Hungary) higher than forecast by value of long-term mean at the mean quadratic error of 9,3 % (Poland) to 15,9 % (Frankfurt). The accuracy of this forecast increases by using smoothed values. For instance, in Slovakia, the mean quadratic error of forecast is only 3,2 % and the theoretical accuracy of forecast is by about 66,8 % higher by using five year moving averages (Šamaj, Valovič, Brázdil 1983).

5. Conclusion

From the analyses of year precipitation total variations in the area of Central Europe in the period of 1881—1980, it becomes evident that the precipitation course has approximately the same character all over the whole area. Differences also show in the comparison of data from individual stations and spatial means. If we exclude this fact, the main characteristics of the precipitation regime could be explained by a various extent and precipitation demonstration of particular groups of meteorological situations.

References

DROZDOV O. A., GRIGORJEVA A. S. (1971): Mnogoletnije cikličeskije kolebanija atmosfernych osadkov na territorii SSSR, 158 s., Gidromet. izd., Leningrad.

GRAF H. F. (1977): Andauerverhalten und Jahresgang zonaler und meridionaler Zirkulationsformen auf der Nordhemisphäre. Zeitschrift für Meteorologie 27, 104—108, Berlin.

HESS P., BREZOWSKY (1952): Katalog der Grosswetterlagen Europas. Berichte des Deutschen Wetterdienstes in der US-Zone, Nr. 33, Bad Kissingen.

IĽKO J., ŠAMAJ F., VALOVIČ Š. (1981): Temperature and precipitation changes in relation to solar activity. — Időjárás 85:1:10—16, Budapest.

KACZOROWSKA Z. (1962): Opady w Polsce w przekroju wieloletnim. — Prace Geograficzne Nr. 33, Instytut Geografii PAN, 112 s., Warszawa.

KOL. PRAC. HMÚ (1972): Katalog povětrnostních situací pro území ČSSR. 40 s., HMÚ, Praha.

KONOVOVA N. K. (1979): Cirkuljacionnyje epochi v severnom polušarii v XX stoletii i klimatičeskij prognoz. Zeitschrift für Meteorologie 29, 374—379, Berlin.

KOPECKÝ M. (1980): Statistický rozbor řady atmosférických srážek v Čechách. Meteorologické zprávy 33, 3—6, SNTL, Praha.

KOŽUCHOWSKI K. (1983a): Periodicity of variations of the annual precipitation totals in Poland. — Acta Geophysica Polonica XXX:3:287—292, PWN, Warszawa.

KOŽUCHOWSKI K. (1983b): Zmienność opadów atmosferycznych w Polsce. — Acta Geographica Lodziensia, No. 48, Lódź, in print.

KŘIVSKÝ L., ANDRLÍK L. (1977): Sekulární chod stoleté řady srážek v Čechách (1876—1975). — Sborník referátů ze semináře k 200. výročí observatoře v Praze-Klementinu, s. 92—94, Praha.

OLBERG M. (1977): Zum Verteilungsgesetz der Andauern von zonalen und meridionalen Zirkulationsformen der Nordhemisphäre. Zeitschrift für Meteorologie 27, 43—48, Berlin.

PÉCZELY G. (1974): A statistical investigation on the secular precipitation series of Hungary. — Acta Universitatis Szegediensis XIII (Acta Climatologica) 1—4: 3—14, Szeged.

SAVINA S. S., CHMELEVSKAJA L. V. (1977): Issledovanija mnogoletnej cikličnosti cirkuljacionnych charakteristik. Zeitschrift für Meteorologie 27, 35—42, Berlin.

ŠAMAJ F., VALOVIČ Š. (1980): Dlhodobé trendy zrážok na Slovensku. Meteorologické zprávy 33, 138—142, Praha.

ŠAMAJ F., VALOVIČ Š., BRÁZDIL R. (1981a): Zmeny režimu zrážok na Slovensku vo vzťahu k slnečnej činnosti. In: Sborník referátů Vztahy mezi slunečním zářením a atmosférickými ději, 103—110, Hradec Králové.

ŠAMAJ F., VALOVIČ Š., BRÁZDIL R. (1981b): Kolebanija atmosfernych osadkov v 20 stoletiji v oblasti Zapadnych Karpat. — In: Sborník referátů z X. mezinárodní konference karpatské meteorologie, Kraków, in print.

ŠAMAJ F., VALOVIČ Š. (1982): Priestorové úhrny zrážok na Slovensku (1881—1980). Meteorologické zprávy 35, 108—112, Praha.

ŠAMAJ F., VALOVIČ Š., BRÁZDIL R. (1983): Langfristige Schwankungen der atmosphärischen Niederschläge auf dem Gebiet der Slowakei im Zeitraum 1881—1980. — Zeitschrift für Meteorologie, in print.

ŠEREMETOVA L. M., red. (1981): Meteorologičeskije dannyje za otdělnyje gody po zarubežnoj territorii Severnogo polušarija. Časť II. Mesjačnyje i godovyje summy osadkov. 936 s., Gidrometeoizdat, Leningrad.

TOPLIJSKI D. (1981): Kolebanije na godišnitě valežni sumi v Blgarija. Godišnik na Sofijskija univ., 72 (1977/78):2 (Geografija): 128—145. Izd. na Blg. Ak. na Nauk., Sofia.

Shrnutí

KOLÍSÁNÍ ATMOSFÉRICKÝCH SRÁŽEK VE STŘEDNÍ EVROPĚ V OBDOBÍ 1881—1980

Studium kolísání atmosférických srážek patří v klimatologii mezi důležité úkoly, zejména s ohledem na důsledky v nejrůznějších oblastech ekonomické aktivity člověka. Velká pozornost byla dosud v literatuře věnována analýze kolísání srážek ve středoevropské oblasti, kde se srážkový režim formuje v interakci cirkulačních (vlivy Atlantského oceánu a Středozemního moře, vlivy eurasijské pevniny) a geografických (zejména orografických) faktorů.

Předložený příspěvek vychází z analýzy ročních úhrnů srážek ve střední Evropě v období 1881—1980. Analýza se opírá jednak o tzv. prostorové průměry srážek vypočtené pro ČSSR (Čechy a Slovensko), Maďarsko a Polsko, jednak o údaje stanic Hannover, Berlín, Erfurt, Frankfurt nad Mohanem, Mnichov, Innsbruck a Vídeň. Získané srážkové řady jsou analyzovány metodami pětiletých a jedenáctiletých klouzavých průměrů, dvojnásobného a dvacetinásobného zhlazení řady pomocí binomických koeficientů, harmonickou, korelační a spektrální analýzou.

V průběhu ročních úhrnů srážek v období 1881—1980 ve středoevropské oblasti lze nalézt společné rysy, i když období vyšších resp. nižších srážek se v jednotlivých případech liší velikostí, popř. i jistým časovým posunem těchto extrémů. V některých případech se projevují rozdíly mezi západní a východní polovinou studované ob-

lasti (obr. 1, 2). Tyto rozdíly jsou patrny i v trendech vývoje množství srážek, kdy k západní polovině středoevropské oblasti má blízko i její jižní část (obr. 3).

Metodou harmonické analýzy byly vyděleny pro středoevropskou oblast nejvýznamnější periody v délce 4,3; 2,1; 5,0; 3,2 a 90 roků, jejichž amplitudy ovšem v relativním vyjádření dosahují pouze 5—8 % hodnoty dlouhodobého průměru dané řady. Z autokorelační a spektrální analýzy vychází jako statisticky významné cykly v délce 4,3 a 5 let, dále pak 25—26, 13—16 let a cykly delší než 50 let (tab. 1, 2). Zatímco některé ze zjištěných cyklů lze dávat do souvislosti se změnami sluneční aktivity, jsou zřejmě jiné projevem autovariací v systému atmosféry a její cirkulace.

Velmi komplikovanou záležitostí je dlouhodobá předpověď ročních úhrnů srážek. Značná pozornost je věnována studiu vazby mezi Wolfovými relativními čísly a množstvím srážek, která, jak se ukazuje, má ovšem omezený prognostický význam. Pro středoevropskou oblast byla předpověď srážek pro příští léta provedena s využitím poznatků harmonické analýzy pro 6 harmonických složek. Ukazuje se, že tato předpověď dává v této oblasti teoreticky o 22—31 % lepší výsledky než předpověď hodnotou dlouhodobého průměru ročních srážek. Při použití zhlazených hodnot teoretická přesnost této předpovědi roste dvojnásobně až trojnásobně.

(Address: Slovenský hydrometeorologický ústav, Jeséniova 17, 833 15 Bratislava.)