FOLIA

PŘÍRODOVĚDECKÉ FAKULTY UNIVERSITY J. E. PURKYNĚ V BRNĚ

SVAZEK 5 GEOGRAPHIA SPIS 3

1964

Dedicated to the 65th. return of the birthday of Prof. Dr. Mikuláš Konček, Dr. Sc., member-correspondent of Slovak Academy of Sciences and to the 75 th. return of the birthday of Prof. Dr. František Vitásek, Dr. Sc., member-correspondent of Czechoslovak Academy of Sciences

II.

Dr. Miloš Nosek, CSc.

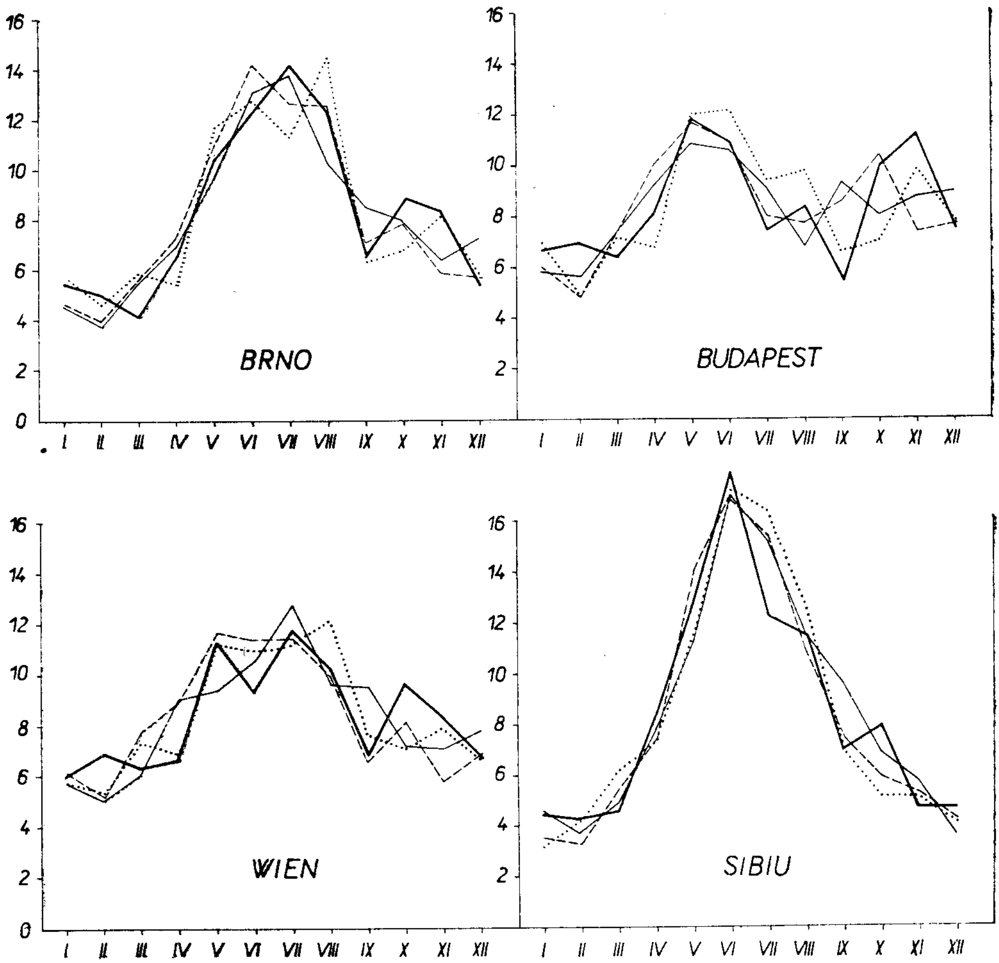
OCTOBER PRECIPITATION IN THE CARPATHIAN REGION OF THE DANUBE BASIN (A STUDY IN THE FLUCTUATION OF CLIMATE)

The annual variation of climatic elements is generally regarded as an important geographical characteristic. The complex of these climatic elements in their sum total forms the characteristic regime of the annual variation of climate for any given region. The annual variation of precipitation plays an important role in this complex: it is regarded as typical of climatic, or geographical regions. The dates of the occurrence of the maxima and minima of precipitation and the analogous dates of the secondary maxima and minima in the annual variation of precipitation are characteristics that can be used with advantage as one of the criteria for the determination of climatic regions, as, for instance, *M. Konček* has done (6).

The amount of precipitation and its distribution in the course of the year, together with a number of other factors, also forms the characteristic hydrological regime and, in general the specific character of physiographical conditions. Attempts at quantitative evaluation of these conditions naturally depend on the length of observational series as well as on the selection of the period to be examined. The values obtained are regarded as normals (the normal recommended internationally was at first the period 1901—30, later 1901—50, and the present normal is 1931—60 and 1901—60). It is to be regretted, however, that some geographers regard these normals as "sacred" and use them schematically and mechanically. Such attitude obviously must lead not only to formal, but even to erroneous conclusions in regional geographic studies.

Quite a number of studies have observed and pointed out changes in the values of climatic elements, especially in temperature and precipitation.

M. Nosek (10) has demonstrated, on the case of Brno, that there occurs not only fluctuation in the total amounts of precipitation, but that there are also certain changes in the shape curve of the annual amount of precipitation. Fig. 46 proves that this phenomenon applies also to other stations in Central Europe, while the maps (Fig. 47) show that the facts stated above obtain even in wider European regions.



Obr. 46.

From what has been said we may deduce that in the annual variation of precipitation neither the amount nor the variation are constant. If the climatic region are determined with regard to a definite amount of rainfall or with regard to the occurrence of the maxima and minima, we are obliged to draw the conclusion that there occur even secular changes in the extent and character of the climatic regions determined in this way. It is evident that the changes referred to are most marked along the borders of the climatic zones (in both the latitude and the altitude sense) where they are clearly reflected in the vegetation and its development.

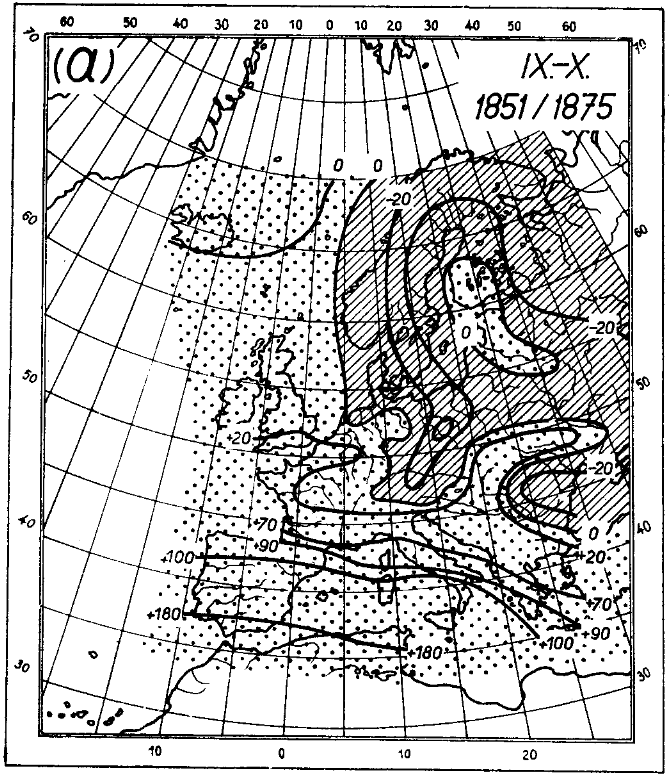
The above-mentioned circumstances thus indicate one of the new points of view of a dynamic evaluation of geographical environment. From this aspect studies in the fluctuation of climate are important not only as a discipline of the theory of climate, or as a contribution to historical climatology or, possibly, as a contribution to the elaboration of a science of climatic forecast [*L. Křivský* (8)], but they contribute valuably to our knowledge of the dynamics of climate as part of physiographical milieu, and, perspectively, they may enable to us to predict the future development of the geographic milieu. The necessity of such forecast will be the more urgent, the more strongly the economic activity of advanced human society will interfere with this milieu.

In the study already quoted (10) I have pointed out the changes in the annual variation of precipitation, especially with reference to the occurrence of secondary October maximum of precipitation which, for the whole territory of Czechoslovakia, is more fully examined in another study (*M. Nosek* (9)). Let us look now at the connection of this phenomenon with the changes in the annual variation of autumnal precipitation in Europe. Our maps give— for the successive periods of 1851/75, 1876/1900, 1901/25 and 1926/50 — the isolines of the increase or decrease of precipitation from September to October, from October to November, and from November to December, in percentages of the amounts registered in the first month of the given couples of months; from these graphs one can form an idea of the variation of autumnal precipitation in the territory of Europe.

From September to October, rainfall in the period of 1851—75 increases in the regions of Iceland and the Baltic, in the whole Mediterranean region including adjacent France, in Hungary, in western and north-western Rumania, in the eastern part of Czechoslovakia and in south-western Ukraine.

From October to November, precipitation increases in the European part of the USSR with the exception of the Baltic republics, in Poland and the both German republics, in the eastern part of central Europe, in the Balkan and the whole southern part of the Mediterranean. The rest of European territory registers decrease in precipitation. From November to December, increase in precipitations is limited to the prevailingly oceanic part of north-western Europe west of the line following the western coast of Norway and Scotland.

In the period of 1876—1900 precipitation increases from September to October in the greatest part of Europe with the exception of the western part of Czechoslovakia, southern Germany, Switzerland, Austria, central Rumania and most of the European territory of the USSR excepting the Ukraine.



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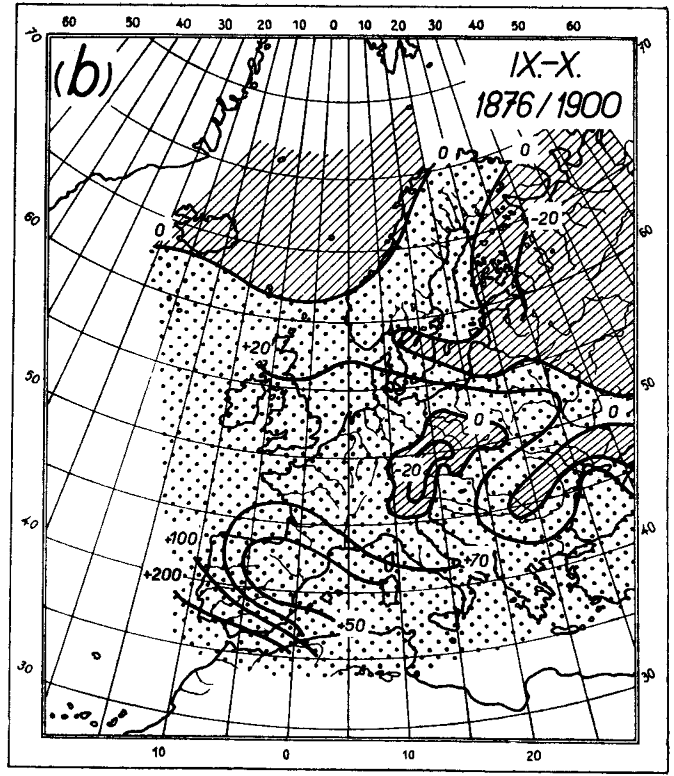

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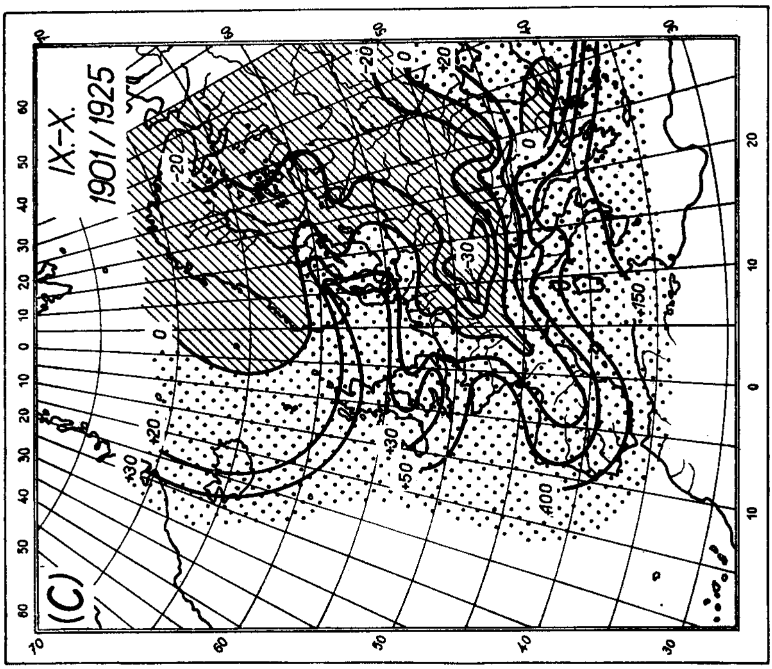

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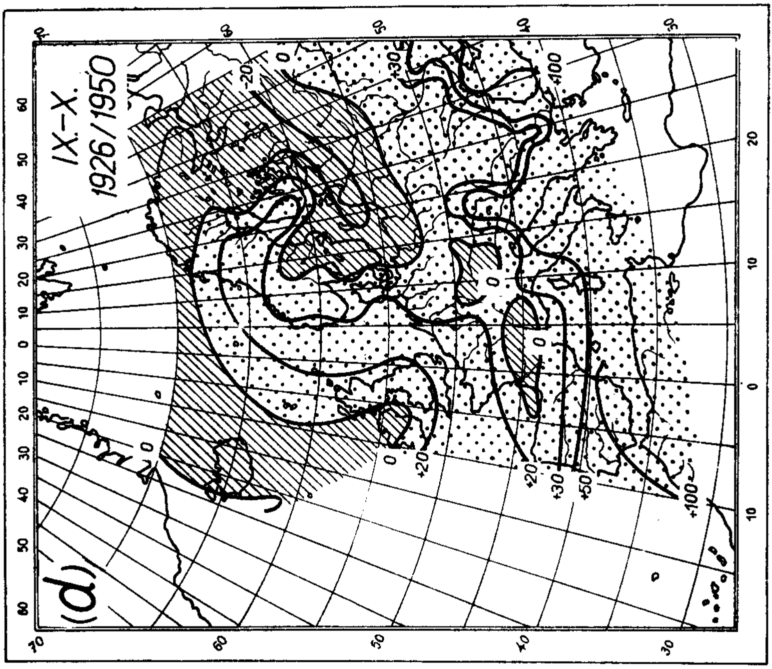

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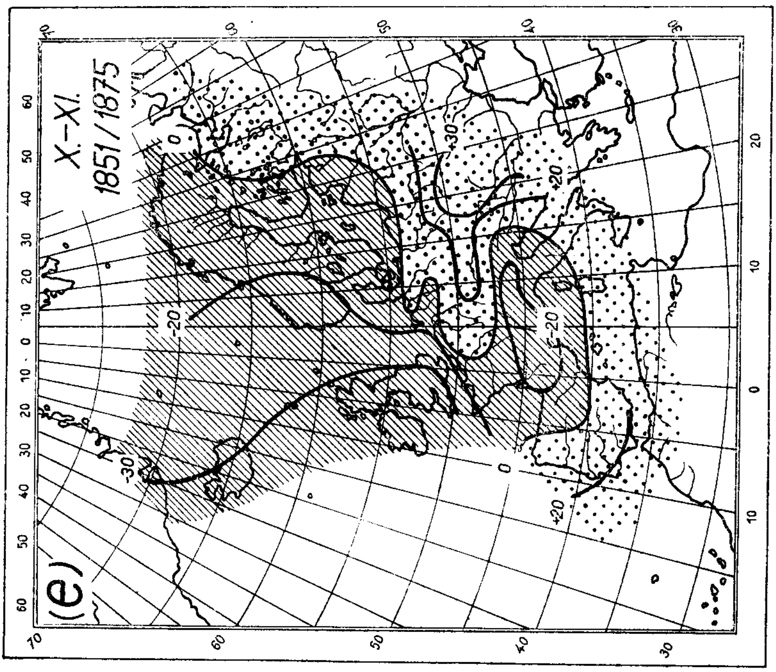

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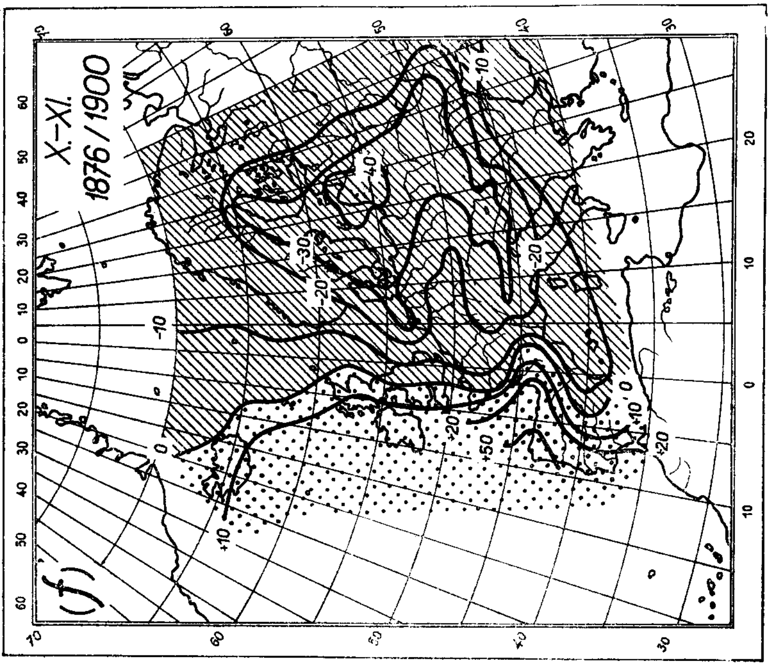

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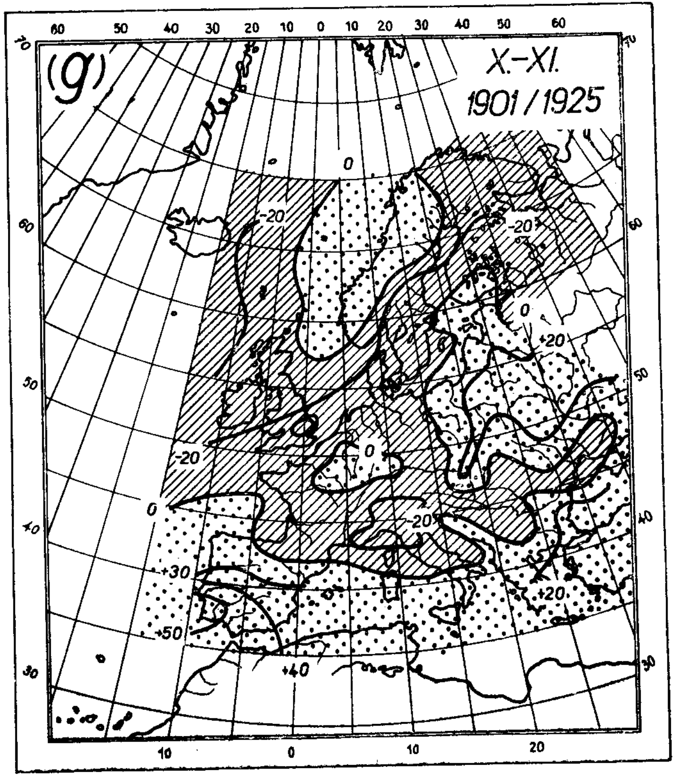

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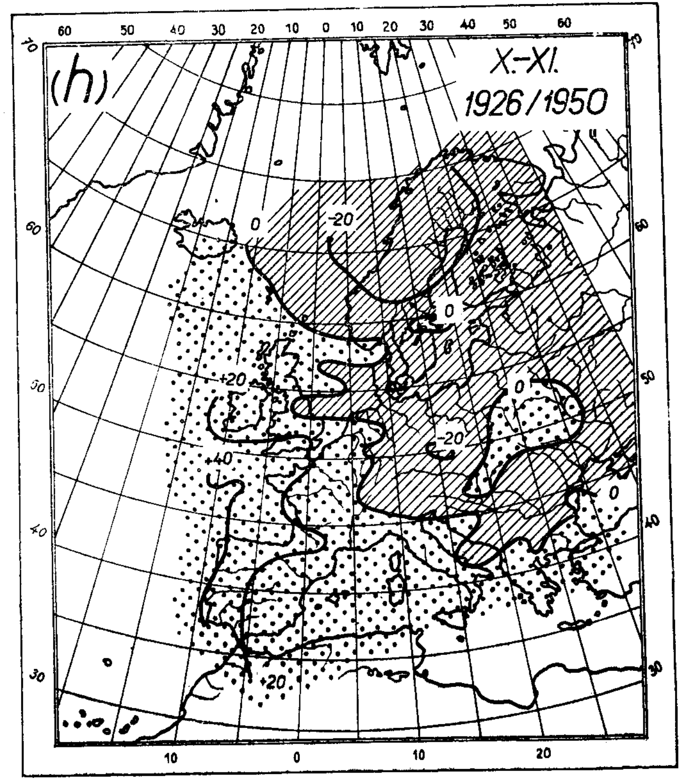


Obr. 47Bh

From October to November, precipitation increases only in the regions west of the line following approximately the zero meridian. From November to December, precipitation increases only in the eastern part of the Mediterranenan, the southern part of the Balkan peninsula, in Rumania and Hungary, in eastern Poland, in the European part of the USSR, but also in central and nothern France and south-western Germany.

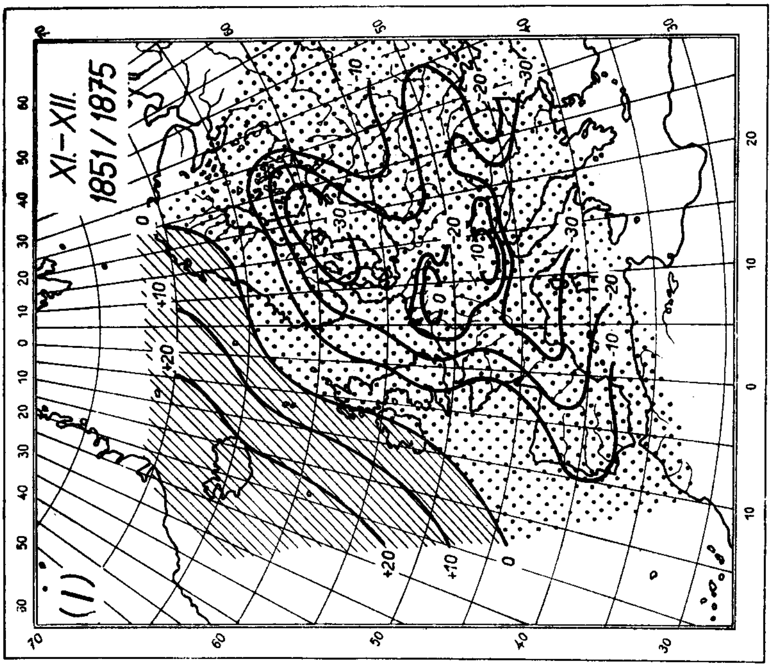
In the period of 1901/25 precipitation increases from September to October in the whole Mediterranean and in the region of the Black Sea with the exception of Bulgaria, further in western France and western and north-western Europe excepting northern and central Scandinavia. From October to November, increase in precipitation is limited to Norway and the adjacent parts of the North Sea, as well as a small region in central France and central Germany; there is also increase in precipitation in the Soviet Baltic republics, in Poland, in the southern part of the European USSR, in the eastern part of Czechoslovakia, in southern Rumania, in Bulgaria, in the south of the Balkan peninsula, in the southern Mediterranean and in the Iberian peninsula. From November to December, precipitation increases in the southern part of the eastern Mediterranean, further in the west and north-west of Europe excepting the north of Scandinavia and the adjacent parts of the North Sea.

In the period of 1926—50 precipitation increases from September to October in the whole European territory excepting the oceanic regions west and north-west of the British Isles, and also with the exception of the north-west part of European USSR, the north of Poland, a greater part of the German Democratic and small parts in the south of France and the Alpine regions. From October to November, precipitation increases in western and north-western Europe, in the Mediterranean and, besides, only in a small region of southern Poland, the eastern part of Czechoslovakia and central Hungary. From November to December, there is increase in precipitation only in the oceanic regions west of the Iberian peninsula nad the British Isles, in central and southern Norway, in the south-east of the European USSR, in eastern and southern Rumania, in the south of the Balkan and Appenine peninsula.

From period to period, the picture of the increase or decrease of precipitation is very changeable between the above-mentioned couples of months. We shall not state these changes here, as the reader can form an idea of their character for himself from Fig. 47a—l.

Our maps illustrate sufficiently the variability of the regime of autumnal precipitation in the past one hundred years in Europe, and the way in which these changes are connected with the changes of autumnal precipitation, particularly the October precipitation in the region of the Carpathian part of the Danube basin, which will be our exclusive concern in the following pages.

The graphs of the annual variation of precipitation (Fig. 46) for some stations of the Carpathian part of the Danube basin show that in some periods



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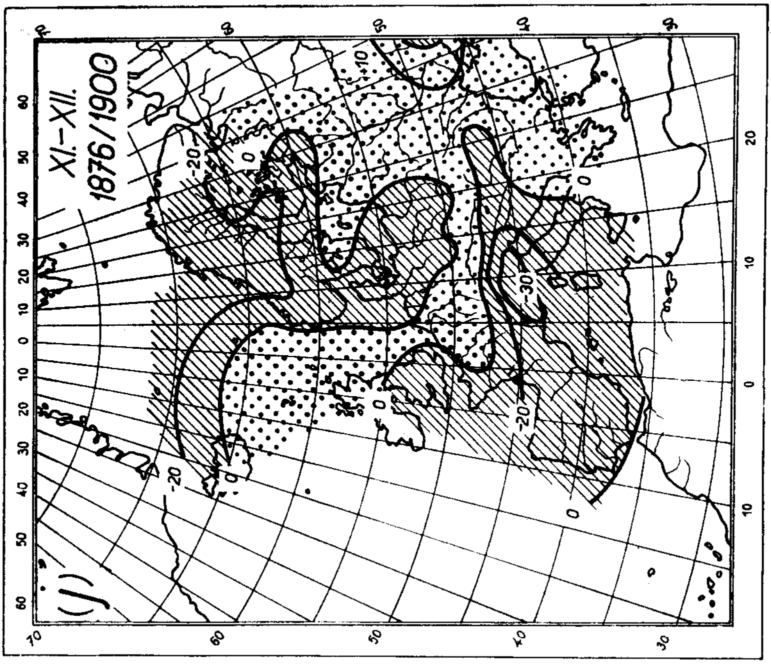

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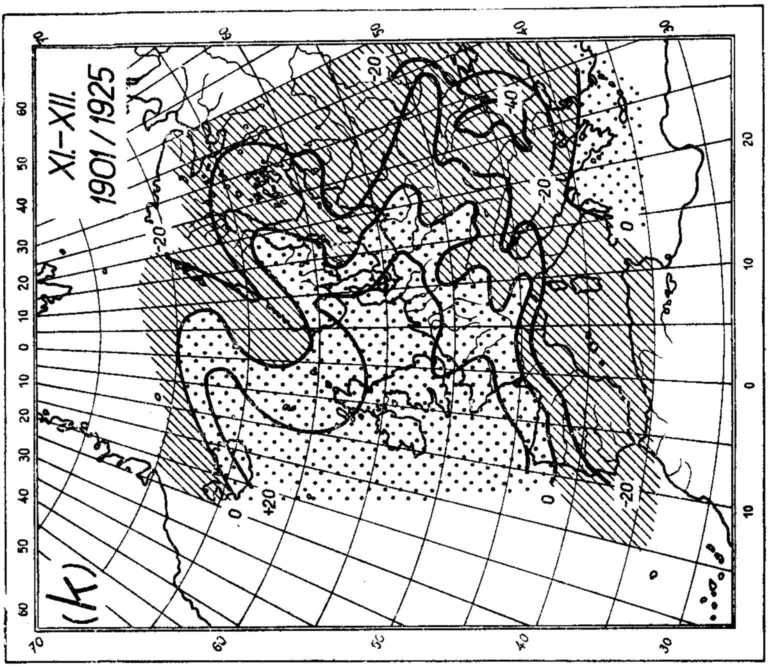

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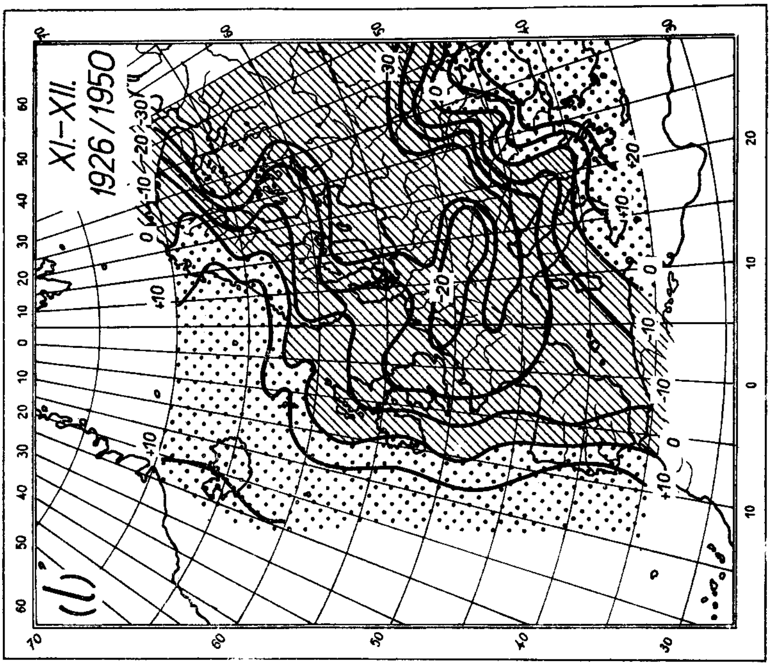


Obr. 47Cl

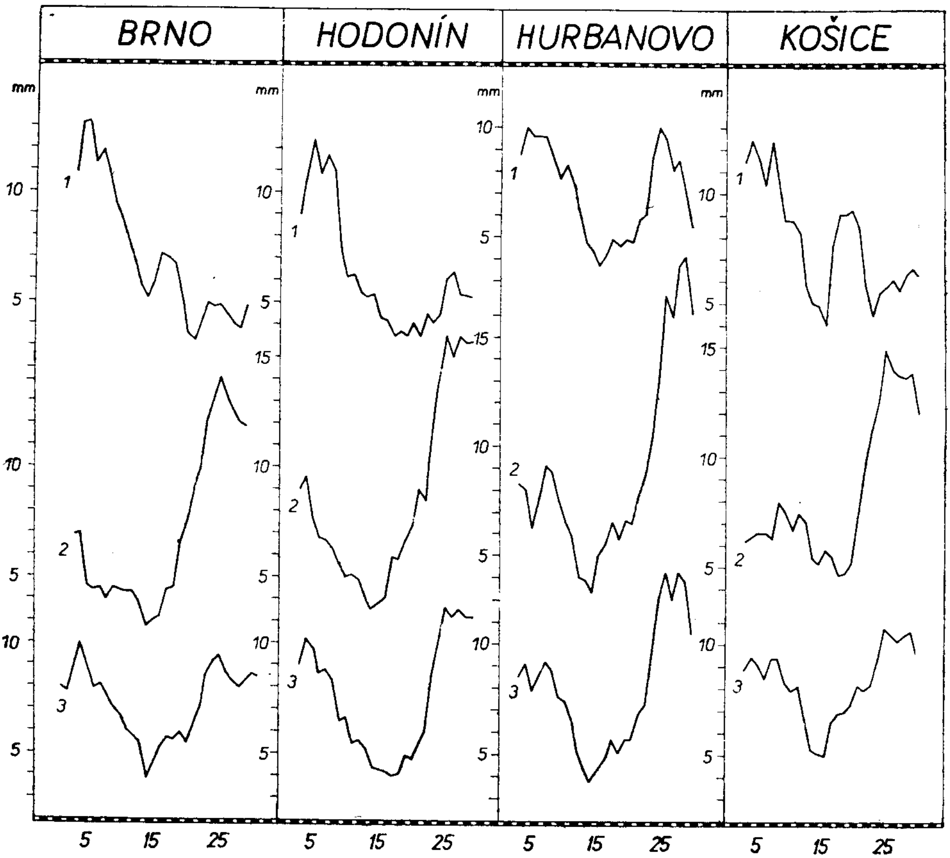
during the past one hundred years there has occured secondary October maximum, in other stations this maximum occurred in November, while in others again it occurred both in October and November, or even in December. The secondary October maximum in the territory of Czechoslovakia has been noted before by several authors who have attributed to it considerable geographical significance [*A. Gregor* (3), *B. Hrudička* (5)$_1$ *Fr. Vitásek* (12), *Fr. Říkovský* (11)] & some of them have observed it, others have not, according to which period they selected. They have not examined the causes of its occurrence or nonoccurrence, and connected its occurrence, without any detailed analysis or demonstration, with the effect of mediterranean influences.

M. Nosek (9) has shown that the cause of this secondary October maximum on the territory of Czechoslovakia is intensive precipitation activity of certain synoptic situations which according to *P. Hess and H. Brezowski's catalogue* (4) may be characterised as (GT) types TM, NW, E, S+SE, according to *M. Konček and Fr. Rein's catalogue* (7) as types Bc, Cc, Ec, SWc_2 and NWc.

Precipitation in these (of course, comparatively rare) situations are so intense that October has high monthly precipitation totals, although most days in October have otherwise small daily totals of precipitation. Therefore, in the region we are examining we shall take interest in the October variation of precipitation according to daily totals of precipitation. As it has been possible to obtain from the examined territory daily totals of precipitation in October in the period of 1901—50 and because it is possible to obtain even the synoptic material for the period, we shall study in the following pages the changes in the October regime of precipitation during the past two quarters of the century.

The graphs of the diurnal variation of precipitation in October illustrated by pentad overlapping amounts of precipitation (Fig. 48) in most of the Czechoslovak part of the Danube basin follow, in the period of 1901—50, a characteristic course; the first precipitation maximum occurs at the beginning of the month (about the 5th of October) and the second towards the end of October (about the 25th); a definite precipitation minimum occurs in the middle of the month (about the 15th of October).

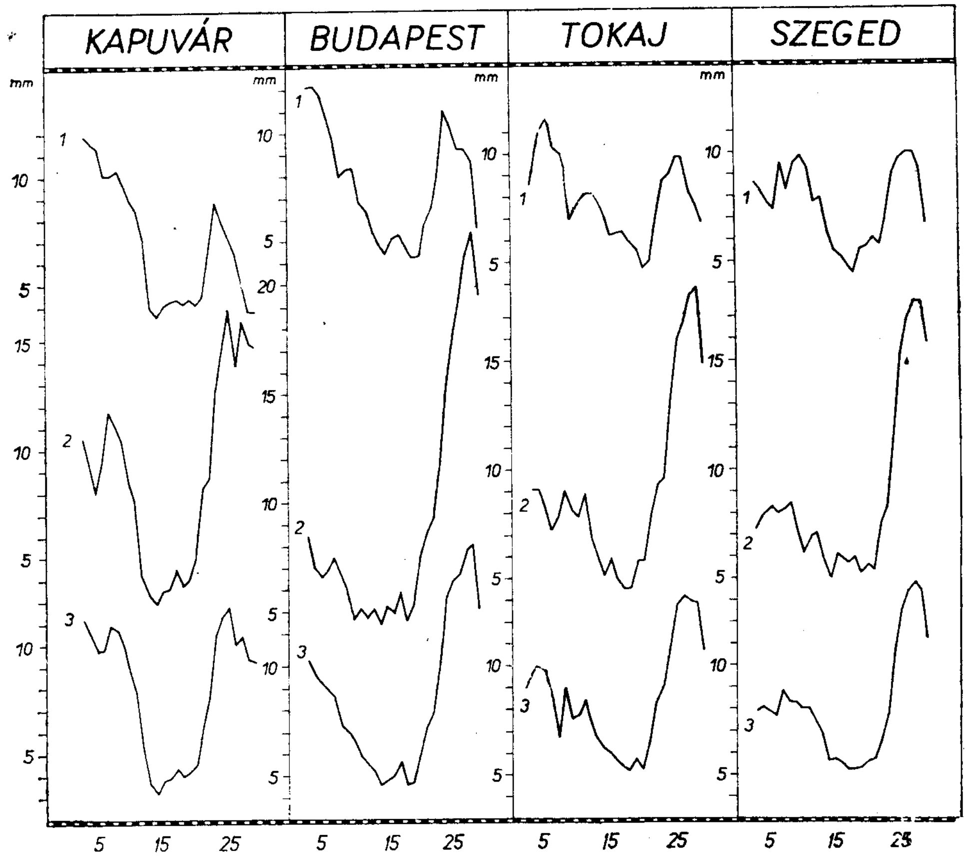
Further graphs from the periods of 1901—25 and 1926—50 show that as regards the climate the period of 1901—50 is not uniform, but consists of two regimes differing in precipitation; these two distinct periods have only in common the precipitation minimum in the middle of the month. Otherwise the period of 1901—25 (with the exception of Hurbanovo) registers the maximum at the beginning of the month (about the 5th of October) and there occurs very at the end of the moth; the period of 1926—50 registers very little precipitation at the beginning of the month and the maximum occurs towards the end of the month (about the 25 th). In both cases there is a manifest tendency to increase in precipitation; at the end of the month in the first case, and at the beginning of the month in the second case.



Obr. 48.

The graphs of the variation of individual synoptic types (GT), which I have compilled according to the material of P. *Hess and H. Brezowki's catalogue* (4) for October in the periods stated (Fig. 22), show that synoptically the two periods are considerably different. If we compare the variation of precipitation with the variation of the quoted types we find that the variation of precipitation does not greatly depend on the most frequent types W(GT) and HM(GT); but it agrees strikingly with the variation of some types which are otherwise infrequent, but which appear with marked frequency in the period of precipitation maxima; these are especially types TM and NW. These two situations can with full justification be regarded as the main cause of the singularities in the variation of the daily amounts of precipitation in the month of October.

The October variation of precipitation in the Hungarian part of the Danube basin (Fig. 49) agrees in character with that in the Czechoslovak territory, while the greatest similarity exists with the south-slovakian meteorological station of Hurbanovo; in the period of 1901—25 there is a comparatively great

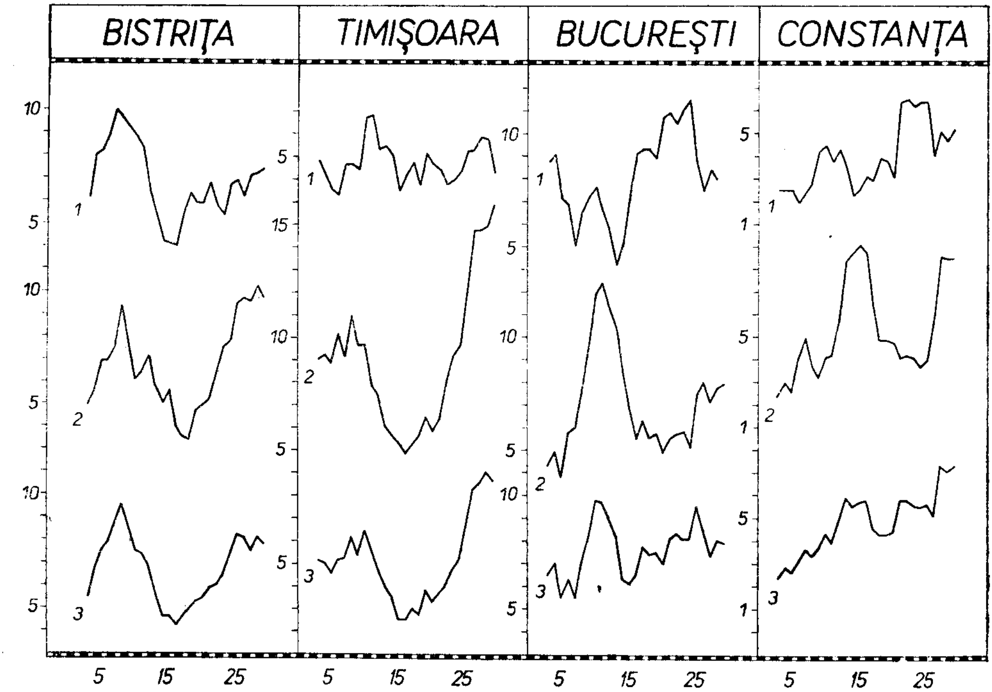


Obr. 49.

amount of precipitation even towards the end of the month and in the perida of 1926—50 even at the beginning of the month. A similar character of precipitation is observed also in the Rumanian territory of the Danube basin (Fig. 50) with the exception of southern and eastern Rumania where, as the graphs show, the precipitation regime is already rather different.

Everything indicates that in southern Slovakia, in Hungary and Rumania the precipitation effect of the cyclones [advancing from the south in situations TM(GT)] is much stronger than it is in the more western parts of Central Europe.

Precipitation activity may be roughly divided into three time sectors approximately falling in the three October decades. Precipitation activity of these decades can be studied with the aid of a fixed mark for similarity of precipitation regimes, if we modify to suit us the conditions for applications of the method employed by *M. Bouët* (1). Methods of this kind according to *H. Flohn* (2) may also be regarded as methods of dynamic climatology.



Obr. 50.

The basis of the method referred to is comparison of the occurrence of days of precipitation. We proceed from the following formulas of the theory of probability applied to precipitation phenomena.

Two meteorological stations A and B have observed the occurrence of precipitation for a period of n days; the number of days with precipitation $\geqq$ 0,1 mm (or respectively $\geqq$ 3,0 mm) registered at station A is N_A, station B is N_B. If n is sufficiently great, than

$$p_A = \frac{N_A}{n} \quad \text{and} \quad p_B = \frac{N_B}{n} \tag{1}$$

of the probability of a day of precipitation at station A and B. The probabilities of days without precipitation can be expressed by the relation $q_A = 1 - p_B$ and $q_B = 1 - p_B$. The conditional probability that a day of precipitation occurs simultaneously at both stations is $P = p_A \cdot p_B$. If we observe a number of days C, on which simultaneous days of precipitation occurred at stations A and B, we can express their probability also by

$$F = \frac{C}{n}. \tag{2}$$

Then we can mutually compare the values P and F. The magnitude and

sign of the difference between the two is the measure of the magnitude and meaning of this correlation; if the sign of the difference is positive, is the synoptic relation between the precipitation at stations A and B, if the difference is equal to zero, there is no relation between the twoo stations, if the sign is negative, we have to do with contrary synoptic regimes. For the marks of similarity S the following relations hold good:
if the difference F—P is greater than zero

$$S = \frac{F - P}{p_A \cdot q_B}, \tag{3}$$

if the difference F—P is less than zero and if $p_A + p_B \leqq 1$

$$S = \frac{F - P}{p_A \cdot p_B}, \tag{4}$$

if F—P is less than zero and $p_A + p_A \geqq 1$

$$S = \frac{F - P}{q_A \cdot q_B}, \tag{5}$$

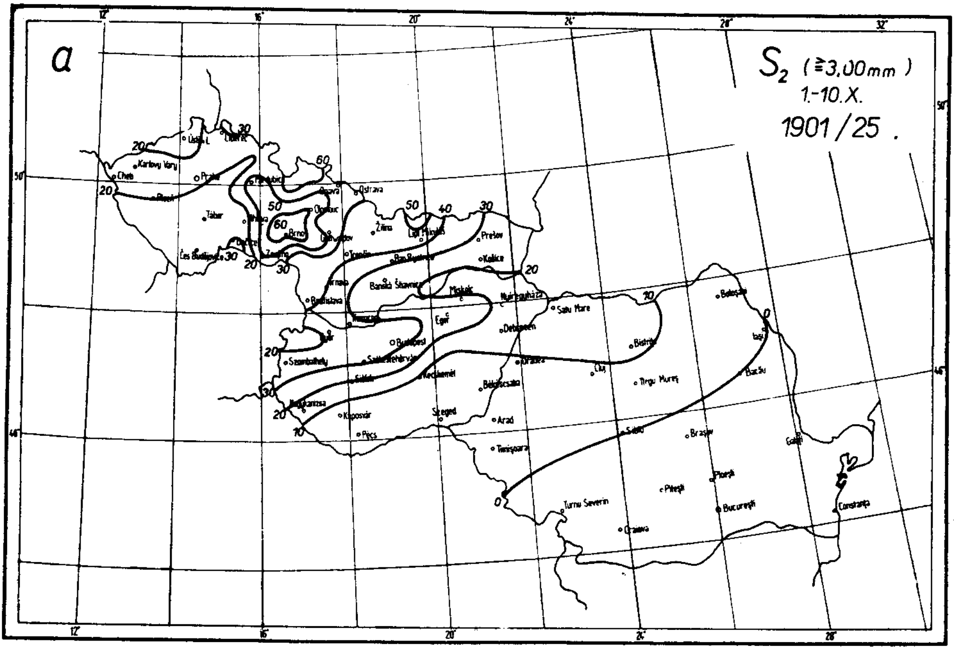
finally, S = O if F = P.

For better climatological application I have determined the limits of certain magnitudes of the mark of similarity, on the analogy of the correlation coefficient:

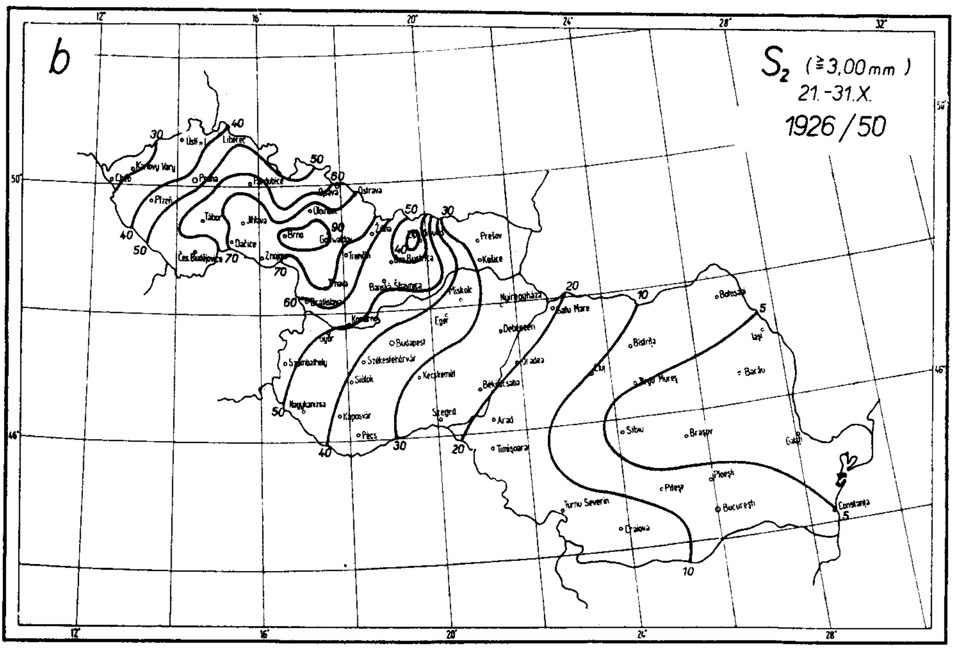
≦ 0,30	low degree of similarity
0,30—0,50	moderate degree of similarity
0,50—0,70	considerable degree of similarity
0,70—0,90	very considerable degree of similarity
≧ 0,90	very close degree of similarity.

As the precipitation singularities of October decades are caused mainly by days of precipitation with large daily amounts of precipitation, I have determined especially the degrees of similarity according to these days of precipitation when amount of precipitation ≧ 3,0 mm. As basis for comparison the data from Brno have been used. Graphs of isolines showing the marks of similarity between the precipitation systems in individual decades of October and in individual periods as observed in the Carpathian part of the Danube basin have been compiled. It is not possible to reproduce them all and therefore we give only a specimen graph for first decade of the period 1901/25 and for the third decade of the period 1926—50 (Fig. 52a, 52b).

A comparison of all the graphs enables us to conclude that, on the average, the region with moderate to considerable degree of similarity roughly covers the basins of the rivers Morava and Váh with Nitra as well as north-western and Central Hungary, whereas the remaining parts of the Danube basin have a low degree of similarity and southern and south-eastern Rumania in



Obr. 51a.



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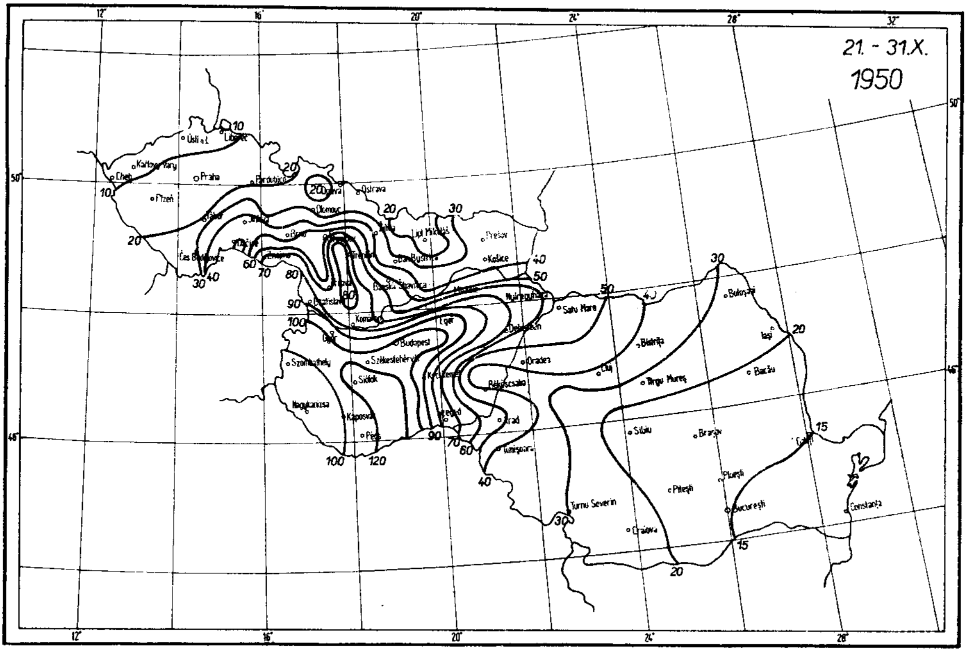

Obr. 52.

some decades and periods belongs to an indifferent or even contrary precipitation regime. With the exception of these regions the remaining territory of the Carpathian part of the Danube basin shows roughly the same climatological fluctuation of October precipitation conditions.

The distribution of precipitation total in the third decade of October, 1950, (Fig. 52), on the hand illustrates an approximate agreement with the distribution of the degree of similarity, on the other hand, it illustrates the influence on the amount of precipitation under similar situations by the eastern borders of the Alps, the Bohemian-Moravian highland and by the Carpathian range in Czechoslovak territory; moreover it illustrates the distribution of precipitation in synoptic situations typical of the occurrence of these October precipitation singularities.

It appears necessary to study not only the changes of atmospheric circulation conditions in the northern hemisphere or its individual regions, or the changes of climatic elements of secular series, but also the geographical extent of the changes of values of climatic elements and their annual variation in its connection with the circulatory causes of these changes. A suitable road to such research is the study of the principal singularities of the annual variation of weather and of individual climatic elements. Such studies of these phenomena can furnish valuable information for the principles of climatological classification.

For supplying me most kindly with the meteorological material used in this study I am most sincerely obliged to the authorities of all European Meteorological Services (Offices), particularly those of Czechoslovakia, Hungary and Rumania.

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Texts to the Figures

Fig. 46. Annual variation of precipitation in some European meteorological stations (dotted ine: 1851—75, interrupted line: 1876—1900, thin full line: 1901—25, thick full line: 1926—50).
Fig. 47. The difference of precipitation in % in Europe (A) between September and October: (a) 1851—75, (b) 1876—1900, (c) 1901—25, (d) 1926—50; (B) between October and November: (e) 1851—75, (f) 1876—1900, (g) 1901—25, (h) 1926—50; (C) between November and December: (i) 1851—75, (j) 1876—1900, (k) 1901—25, (l) 1926—50.
Fig. 48. Variation of daily sums of precipitation in October in the periods (1) 1901—25, (2) 1926—50, (3) 1901—50 for (A) Brno, (B) Hodonín, (C) Hurbanovo, (D) Košice. Smoothed by pentad overlapping average sums of precipitation.
Fig. 49. Variation of daily sums of precipitation in October in the periods (1) 1901—25, (2) 1926—50, (3) 1901—50 for (A) Kapuvár, (B) Budapest, (C) Tókaj, (D) Szeged. Smoothed by pentad overlapping average sums of precipitation.

Fig. 50. Variation of daily sums of precipitation in October in the periods (1) 1901/25, (2) 1926–50, (3) 1901–50 for (A) Bistriţa, (B) Timişoara, (C) Bucureşti, (D) Constanţa. Smoothed by pentad overlapping average sums of precipitation.
Fig. 51. Distribution of isolines showing the degree of similarity S_2 (days with = 3,0 mm of precipitation) for the first decade of October 1901/25 and for the third decade of October 1926/50.
Fig. 52. Distribution of precipitation in the third decade of October 1950

Shrnutí

ŘÍJNOVÉ SRÁŽKY V KARPATSKÉ OBLASTI POVODÍ DUNAJE (STUDIE O KOLÍSÁNÍ PODNEBÍ)

Ukazuje se stále větší potřeba studovat nejen změny hodnot klimatických prvků, nýbrž i změny jejich ročního chodu. Vhodnou metodou k tomu je studium hlavních singularit počasí a singularit jednotlivých klimatických prvků. Ukazuje se jako velmi nezbytné studovat tyto jevy nejen čistě synoptickými analýzami anebo čistě jen formálními rozbory sekulárních řad klimatických prvků, nýbrž z hlediska geografických zákonitostí tak, že uvažujeme formální změny klimatických prvků v závislosti na cirkulačních principech a studujeme jejich geografické rozšíření.

Analýza ročního chodu srážek v Brně ukázala, že roční chod srážek je velmi rozdílný v jednotlivých obdobích (1851–75, 1876–1900, 1901–25, 1926–50) v uplynulých sto letech. Analýza ročního chodu jiných evropských stanic potvrdila realitu těchto změn i nad celou Evropou.

Rozebrali jsme změny srážek na podzim nad celou Evropou a podrobně změny říjnových srážek v karpatské části povodí Dunaje v období 1901/50. V této oblasti se v ročním chodu srážek vyskytuje druhotní říjnové nebo listopadové maximum. Hlavní příčinou vzrůstu srážek v říjnu jsou intensivní srážky za určitých synoptických situací, které jsou charakterizovány podle katalogu P. Hessa a H. Brezowského jako typy (GT): TM, NW, E, SE + S, nebo podle katalogu K. Končeka a Fr. Reina jako typy Bc, Cc, Ec, SWc_2 a NWc. Četnost výskytu těchto situací se zvyšuje na počátku a na konci měsíce října. Denní úhrny srážek jsou za těchto situací tak velké, že říjen má poměrně vysoký srážkový úhrn, ačkoli většina srážkových dní října má velmi nízké srážkové úhrny. V chodu srážek v říjnu se projevila v uplynulých padesáti letech podstatná změna. Tak v období 1901–25 se maximum srážek vyskytovalo na počátku měsíce (okolo 5. X.) a na konci měsíce byly nízké srážky. V období 1926–50 byl naopak malý úhrn srážek na počátku měsíce a maximum se vyskytovalo ke konci měsíce (okolo 25. X.) V obou případech se minimum srážek vyskytovalo uprostřed měsíce (okolo 15. X.). Tyto jevy jsou v souvislosti se změnami výskytu synoptických situací.

Změny srážek nejsou ovlivněny nejčastěji se vyskytujícími typy W(GT) a HM(GT), avšak shodují se zřetelně se změnami jinak málo častých situací TM a NW. Tyto dvě synoptické situace je nutno považovat za hlavní příčinu říjnových srážkových singularit.

Chod srážek v Maďarsku a v největší části Rumunska má podobný ráz jako na území Československa. Zde se však vyskytuje ještě další zvýšení srážek na konci měsíce v období 1901–25. Jižní a východní Rumunsko má již odlišný režim srážek.

Uvedené tři srážkově rozdílné části října, které se dobře shodují s třemi říjnovými dekádami byly studovány metodou stupně podobnosti srážek. Tato metoda, kterou použil M. Bouët k synoptické analýze byla přizpůsobena pro klimatologickou aplikaci. Mapy stupně podobnosti ukazují, že oblast mírného a značného stupně podobnosti se rozkládá v povodí řeky Moravy a Váhu s Nitrou a v severozápadním a středním Maďarsku. Ostatní území povodí Dunaje

v karpatské oblasti mají jen nízký stupeň podobnosti, nebo indiferentní či obrácený stupeň podobnosti. V uvedeném území se vyskytují přibližně stejné změny klimatického kolísání srážek.

Výzkumy tohoto druhu jsou důležité pro dynamickou koncepci fysicko-geografického prostředí, v němž změna srážkového režimu vyvolává změny hydrologického režimu se všemi důsledky pro biogeografické podmínky. Dále jsou tyto výzkumy potřebné pro teorii podnebí a pro vytvářející se vědní obor klimatologie velké praktické ceny pro předpovědi podnebí a neméně pro studie zabývající se metodami klimatických klasifikací.