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VARIATION OF THE SNOW COVER CHARACTERISTICS ON THE TERRITORY OF SOUTH MORAVIA

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SUMMARY

This article deals with the analysis of variation characteritics of the snow cover for five selected stations on the territory of South Moravia in the period 1920/21—1979/80. For the study their cyclicity the method of spectral analysis according to Blackman and Tukey is used. Courses of the annual values of the studied characteristics are smoothed by five-year running averages. There are described the main features of variation of snow cover characteristics. Founded differences in analysed characteristics on analogical circulation conditions various parts of South Moravia arise above all from the different geographical conditions. The results are given to the connection with similar studies of the snow conditions on the territory of Slovakia.

INTRODUCTION

In our latitudes the winter is characterized as the most variable season. This variability is caused above all by the means of prevailing character of circulation when over our territory alternates the Siberian Anticyclone influence with the Atlantic Ocean and Mediterranean Sea one (Sládek, 1968).

Snow and snow cover appeares every year in our country and their significance is not only climatological and hydrological but also to a certain extent economical (Červený, 1984). This meaning incited the concern in regular observation of the snow cover characteristics as early as in last century and their first climatological compilations in the first half of the 20th century (Vitásek, 1930; Chromek, 1945). The first complex study drawing up fundamental data about the snow conditions of the CSSR is Atlas podnebí ČSSR (1958) and following studies Podnebí ČSSR — Tabulky (1961) and Souborná stud e (1969).

The snow conditions were analysed above all for the territory of Slovakia in the last time (Konček and Briedoň, 1959, 1964), as well as with respect of theirs long-time changes (Šamaj et al., 1985a, b, 1986). In the region of Czech and Moravia the most of articles were devoted only small regions or individual localities (Martinec, 1968; Calábek, 1969; Lednický, 1973).

The object of this article is to express the main features of variation some important characteristics of the snow cover in the period of 1920/21—1979/80. For this analyse were used the data of five stations, which were selected with respect to characterize certain climatological position in the region of South Moravia. Station Bohdalov represents the upper part of Českomoravská vrchovina-Highlands, Luha-

čovice represents the valley position of Carpathian part of Moravia. Lowland stations are substituted by Prostějov in Hornomoravský úval and by station Brno, Pisárky, lying in typical holow position. Station Vranov nad Dyjí characterize the snow conditions in the south part of Českomoravská vrchovina Highlands, opened to the south-west streaming.

Tab. 1. List of the stations used. Explanation: φ — latitude, λ — — longitude, H — height above the sea level in m

Station	φ	λ	H
Bohdalov	49°28′	15°23′	575
Luhačovice	49°06′	17°46′	297
Vranov nad Dyjí	48°54′	15°49′	354
Prostějov	49°28′	17°07′	226
Brno, Pisárky	49°12′	16°34′	204

The complete data of the snow conditions in the studied period had Bohdalov and Luhačovice. The missing data of the other stations were completed according to the data from neighbouring stations. Only for Brno, Pisárky station was completed whole decade 1920/21—1929/30 on the basis of the data near-by Brno, Květná station (high above the sea level 224,m), without affecting the homogenity of studied time series.

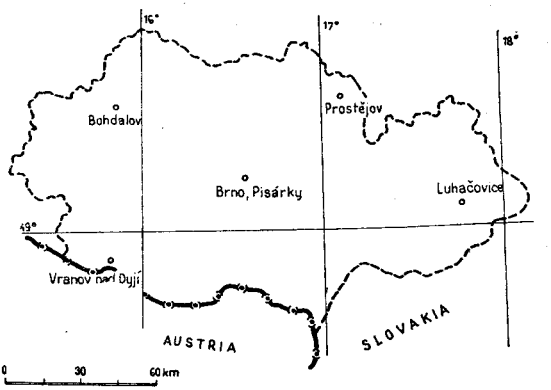


Fig. 1. A map of the South Moravia with marked positions of the stations analysed

For the study of the snow conditions following characteristics were used: the annual numbers of days with the snowfall and with the snow cover, date of occurrence the first and the last day with the snowfall or with the snow cover. With respect to the considerable variability of the annual values of the individual characteristics, their course was smoothed by five-year running averages.

NUMBER OF DAYS WITH THE SNOWFALL AND WITH THE SNOW COVER

Variation of the annual numbers of days with the snowfall and with the snow cover smoothed by five-year running averages is presented in Fig. 2. In spite of

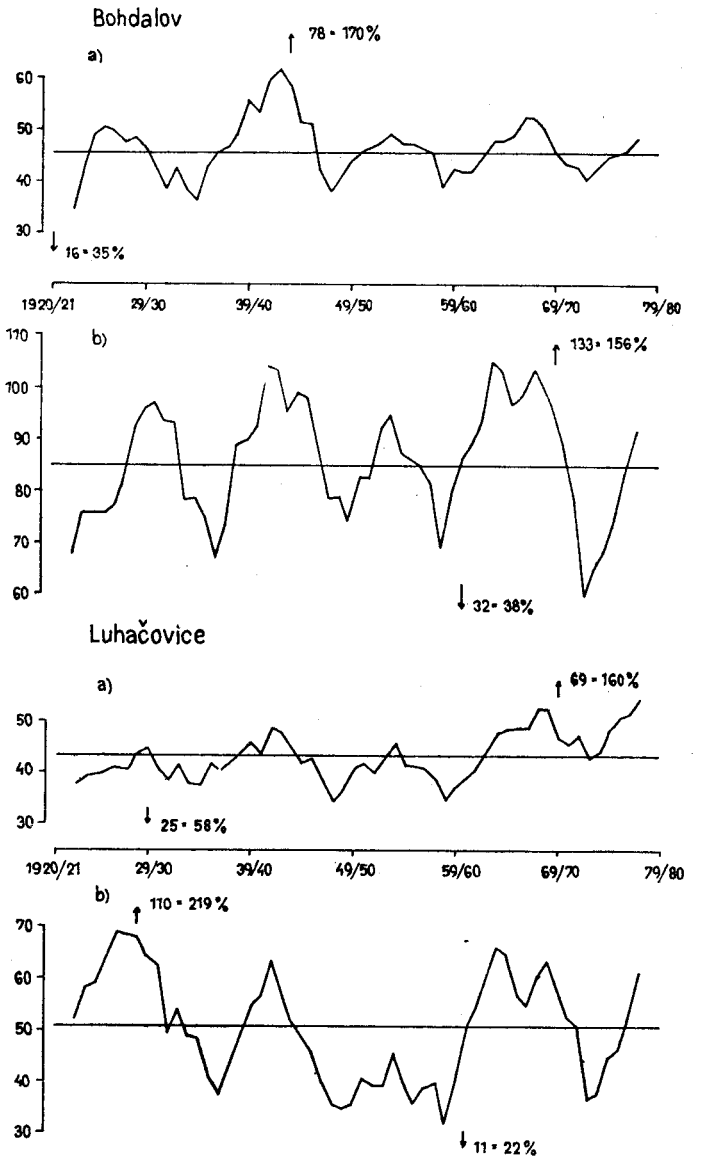
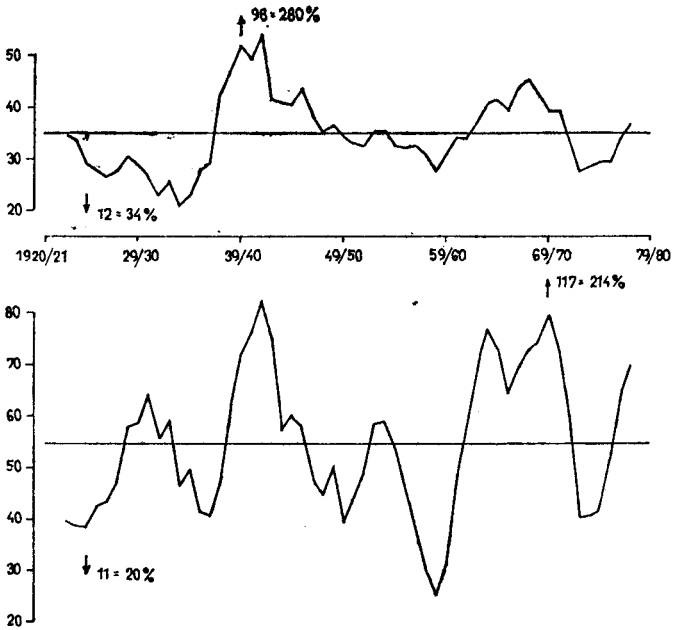
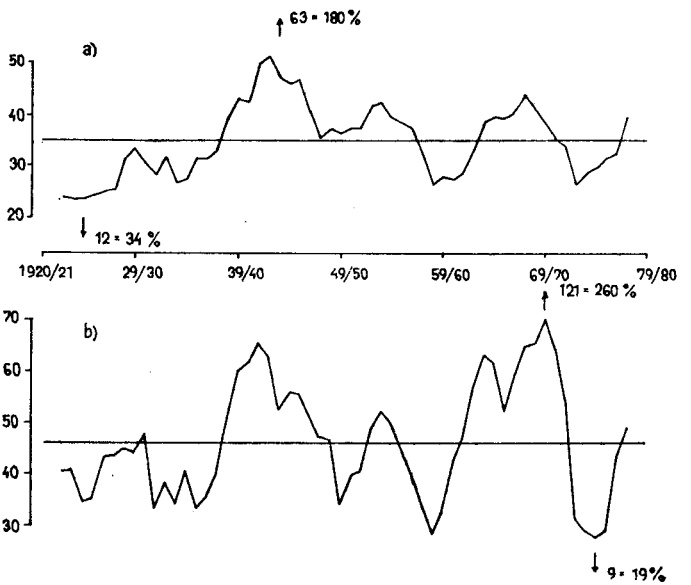


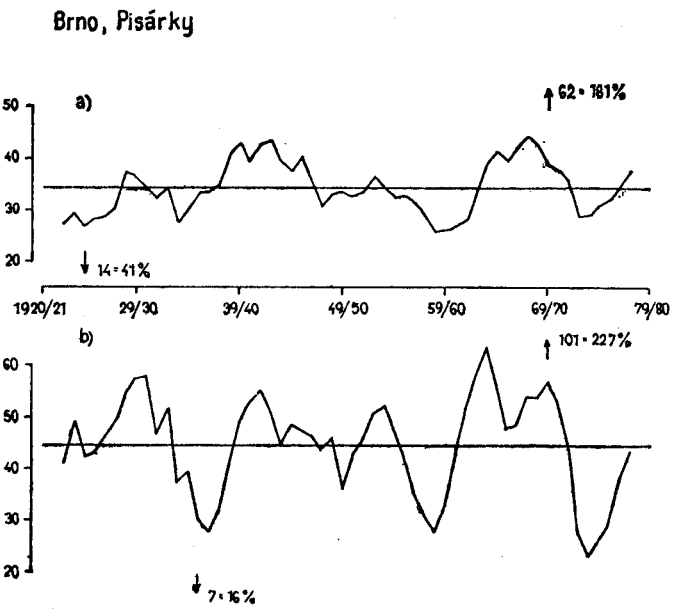
Fig. 2. Course of the annual numbers of days with the snowfall (a) and the annual numbers of days with the snow cover (b) smoothed by five-year running averages in 1920/21—1979/80 for selected stations of the South Moravia. Explanation: ↑(↓) — the highest (lowest) value (absolute and relative), horizontal line-mean value

Vranov nad Dyjí



Prostějov





the great interannual variability we can establish periods of the above-average and the below-average values, which differ both their length and amplitude.

The average annual number of days with the snowfall in the period of 1920/21 to 1979/80 on the territory of South Moravia changes from 34 to 46 days. Extreme values oscillate in the broad limits. The number of days in the observed region can sink below 40 % of average value in mild winters (Prostějov 12 days in the winter 1924/25, Bohdalov 16 days in the winter 1920/21). Maximum numbers of days with the snowfall in cold winters exceed 60 days in lowland positions, in higher and exposed positions it may be over 100 days. Station Vranov nad Dyjí had 98 days in the winter 1939/40, which is 280 % of average value.

The occurrence of the above-average values of the annual number of days with the snowfall is concentrated above all in two periods for all five stations: the first half of 1940's and the second half of 1960's. Up to this periods coincide also occurrence of the maximal annual numbers in the observed period for all five stations. The occurrence of the below-average values falls mainly in the beginning of the studied period, the first half of the 1930's, to the period forwards 1960 and also to the first half of the 1970's.

Analogically we can describe the variation of the annual numbers of days with the snow cover. While the preceding characteristic depends to a certain extent on the circulation conditions and also on the effects of the exposition, this one will depend closely on the height above the sea level and along with on the temperature conditions of the station. Thus we can explain expressively higher number of days with the snow cover for the station Bohdalov (85 days) with comparation of the average values other stations (44—55 days).

The lowest values of the annual numbers of days with the snow cover sank in the winters poor in the snow below 20 % of average in lower situated stations (Brno,

Tab. 2. Fundamental statistical characteristics of the time series of the annual numbers of days with the snowfall (a) and the annual numbers of days with the snow cover (b) for selected stations in the South Moravia in the period 1920/21—1979/80. Explanation: x_{MIN} (x_{MAX}) — the lowest (highest) value, $\bar{x}$-mean value, $\tilde{x}_{10}, \ldots \tilde{x}_{90}$- quantils, $\bar{d}_{\bar{x}}$-mean deviation from the mean, s-standard deviation, c_α-coefficient of skewness, c_ε-coefficient of curtosis, v-variation coefficient (%), $f(\bar{x} \pm ks)$-frequency of values in intervals given by the mean and the multiples k of the standard deviation (%)

a)

	Bohdalov	Luhačovice	Vranov nad Dyjí	Prostějov	Brno, Pisárky
$\bar{x}$	45.8	43.2	35.1	35.0	34.3
x_{MIN}	16	25	12	12	14
x_{MAX}	78	69	98	63	62
$\tilde{x}_{10}$	31.9	29.9	20.0	21.9	21.9
$\tilde{x}_{25}$	37.5	36.0	26.8	27.0	26.0
$\tilde{x}_{50}$	45.0	43.5	35.5	33.0	35.0
$\tilde{x}_{75}$	55.0	50.2	42.0	42.0	41.0
$\tilde{x}_{90}$	59.0	54.2	48.0	48.2	46.1
$\bar{d}_{\bar{x}}$	9.5	8.3	9.2	9.3	8.0
s	11.8	10.0	12.9	11.5	10.0
c_α	0.05	0.10	1.71	0.34	0.21
c_ε	—0.08	—0.65	7.22	—0.33	—0.22
v	25.7	23.0	36.8	32.8	29.2
$f(\bar{x} + 0.5s)$	38.3	30.0	41.7	31.7	36.7
$f(\bar{x} \pm 1.0s)$	68.3	68.3	75.0	70.0	68.3
$f(\bar{x} \pm 1.5s)$	90.0	86.7	95.0	88.3	88.3
$f(\bar{x} \pm 2.0s)$	95.0	98.3	98.3	93.3	96.7
$f(\bar{x} \pm 2.5s)$	96.7	98.3	98.3	100.0	98.3
$f(\bar{x} \pm 3.0s)$	100.0	100.0	98.3		100.0

b)

	Bohdalov	Luhačovice	Vranov nad Dyjí	Prostějov	Brno, Pisárky
$\bar{x}$	85.0	50.7	54.7	46.6	44.4
x_{MIN}	32	11	11	9	7
x_{MAX}	133	110	117	121	101
$\tilde{x}_{10}$	53.0	26.0	22.9	17.9	15.9
$\tilde{x}_{25}$	70.0	34.2	32.8	31.0	27.0
$\tilde{x}_{50}$	85.0	51.0	49.5	43.0	43.0
$\tilde{x}_{75}$	101.5	61.5	74.0	54.0	58.2
$\tilde{x}_{90}$	115.2	75.3	93.3	87.0	76.0
$\bar{d}_{\bar{x}}$	19.2	16.4	22.1	18.3	17.9
s	23.8	20.8	26.7	24.4	22.8
c_α	—0.11	0.46	0.37	0.86	0.54
c_ε	—0.48	—0.05	—0.85	0.39	—0.33
v	27.9	40.1	48.8	52.4	51.3
$f(\bar{x} \pm 0.5s)$	35.0	41.7	38.3	46.7	40.0
$f(\bar{x} \pm 1.0s)$	68.3	65.0	63.3	66.7	65.0
$f(\bar{x} \pm 1.5s)$	85.0	88.3	86.7	86.7	90.0
$f(\bar{x} \pm 2.0s)$	95.0	96.7	98.3	96.7	93.3
$f(\bar{x} \pm 2.5s)$	100.0	98.3	100.0	98.3	100.0
$f(\bar{x} \pm 3.0s)$		100.0		98.3	

Pisárky 7 days in winter 1935/36). On the other hand, during the winters rich in the snow the number of days exceed 100 for all five stations (over 200 % of average value). Also after smoothing by the five-year running averages from Fig. 2b is evident their great variability.

The below-average values occurrs mainly in the period of the second half of the 1930's, 1950's and in the first half of the 1970's. Certain difference we can see for Luhačovice. There are expressively below-average values (according to the five-year running averages) in the whole period 1944/45—1960/61. High values were recorded in the same periods as the high values of the number of days with the snowfall and also in the break of the 1920's and the 1930's. The highest number of days with the snow cover was recorded in the winter 1969/70 for all stations except Luhačovice.

For studying the cyclicity of the two mentioned characteristics the method of spectral analysis according to Blackman and Tukey was used. This method makes

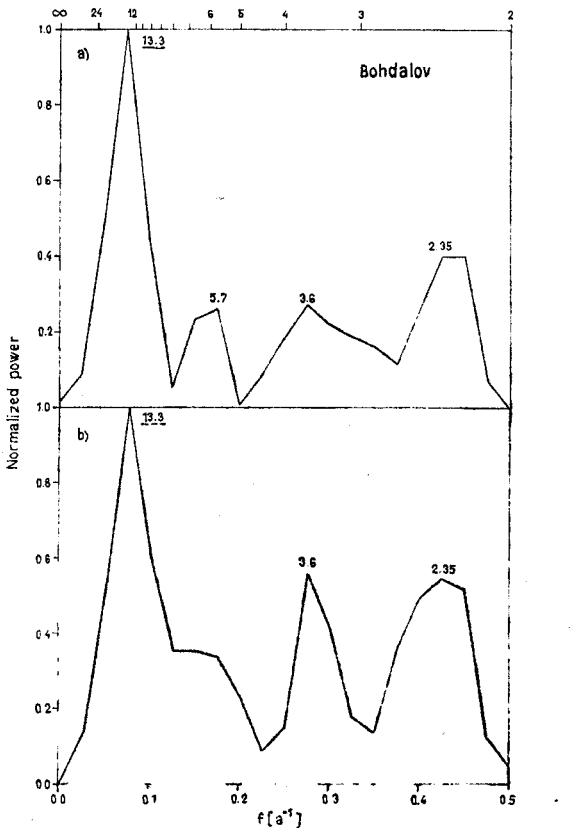
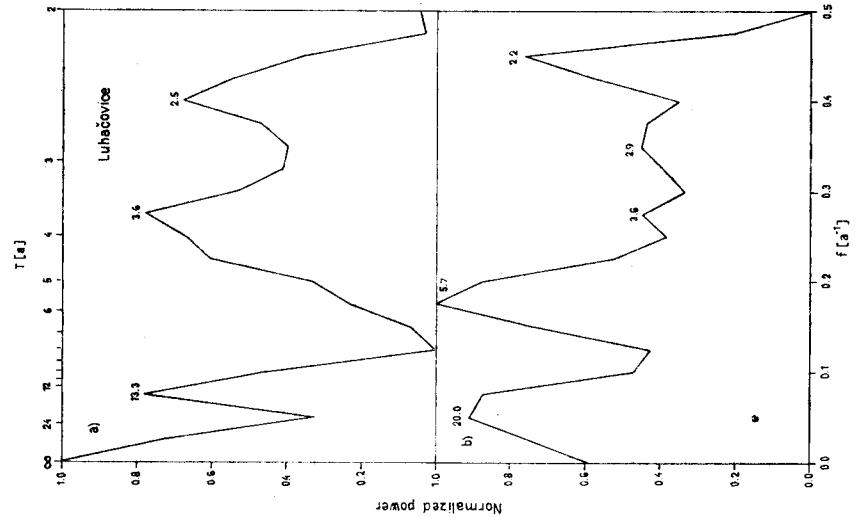
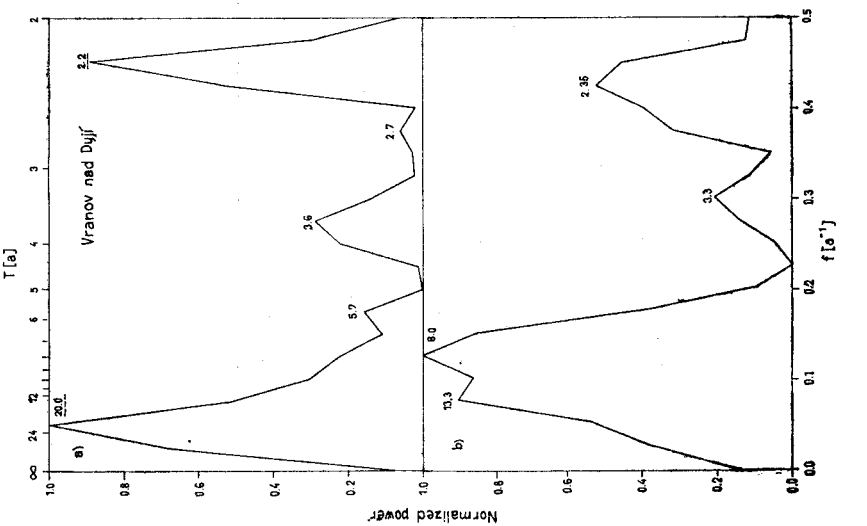
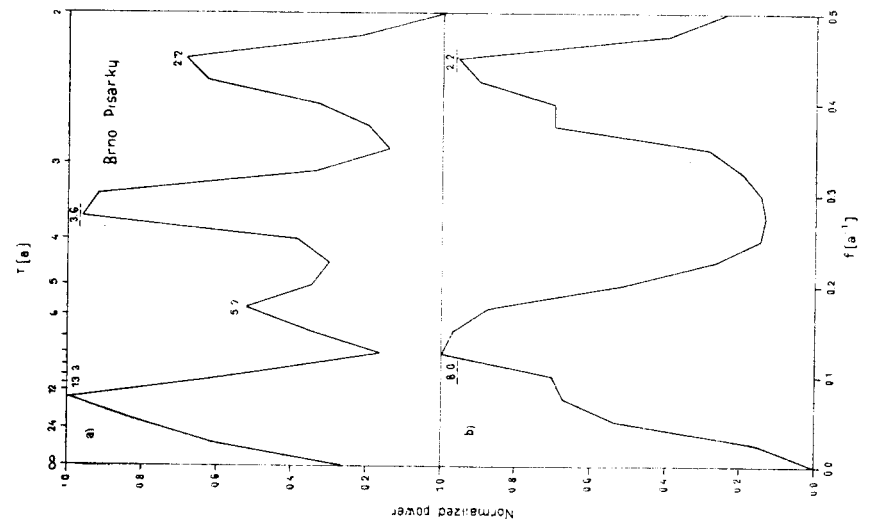
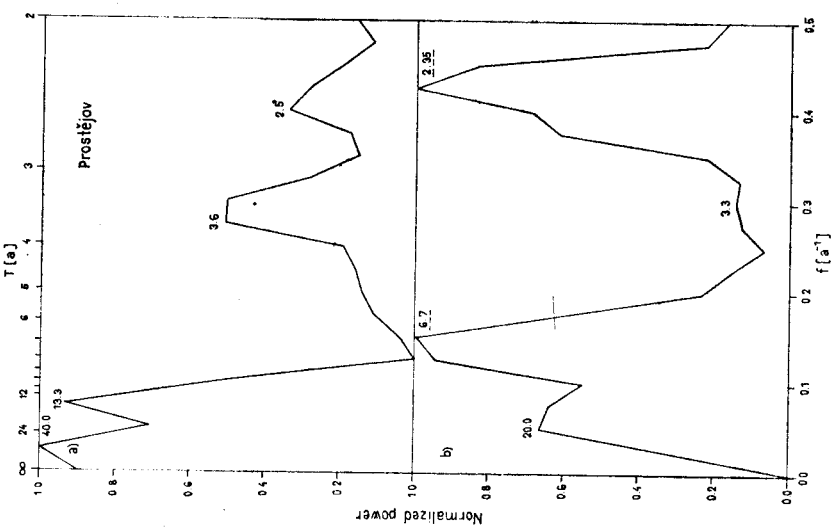


Fig. 3. Normalized variance spectra of the annual number of days with the snowfall (a) and with the snow cover (b) founded by spectral analysis according to Blackman and Tukey. Statistically significant periods: 90 % — — — —, 95 % ———, T — periods, f — frequency, a — year


Luhačovice
T [a]
f [a⁻¹]
Normalized power
a)
b)
13.3
3.6
2.5
20.0
5.7
2.9
2.2


Vranov nad Dyjí
T [a]
f [a⁻¹]
Normalized power
a)
b)
20.0
5.9
3.6
2.7
2.2
13.3
8.0
3.3
2.35


Brno Pisarky
T [a]
f [a⁻¹]
Normalized power
a)
b)
13.3
5.7
3.6
2.7
8.0
2.2


Prostějov
T [a]
f [a⁻¹]
Normalized power
a)
b)
40.0
13.3
3.6
2.5
6.7
20.0
2.95
3.3

it possible to find periods (cycles) contained in the time series, including the evaluation of their significance. In the shape employed in this article this method is described for instance in Brázdil (1985). Normalized variance spectra of the time series and periods found by this method are expressed in Fig. 3.

The most frequent period in variance spectra of studied series is that of 2—3a (a = year). This quasi-biennial oscillation occurring also in temperature and precipitation time series (its explanation gives for instance Pechala, 1979) is statistically significant for station Vranov nad Dyjí and in the case of the annual numbers of days with the snow cover also for Prostějov and Brno, Pisárky. Almost in all variance spectra occurrs the period of 3.6a (for all stations in the case of the annual

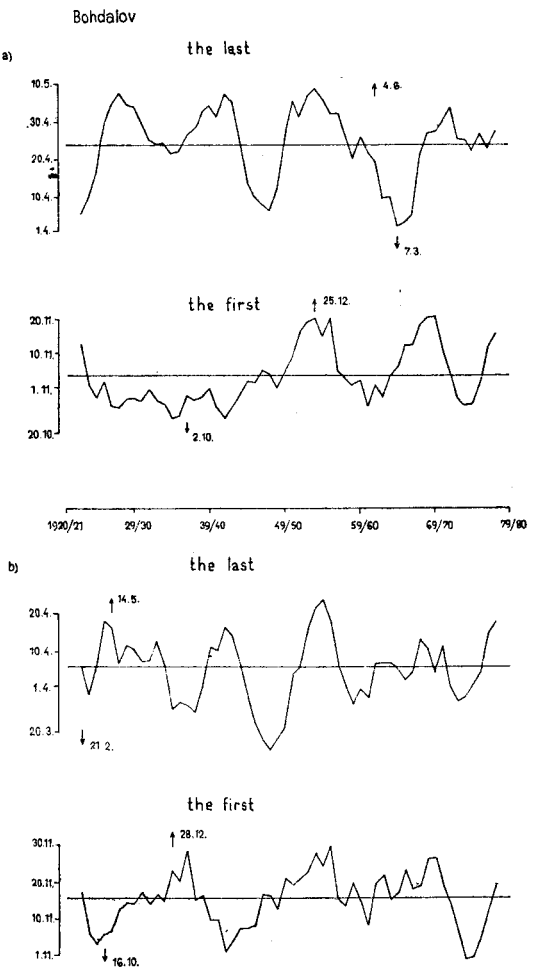
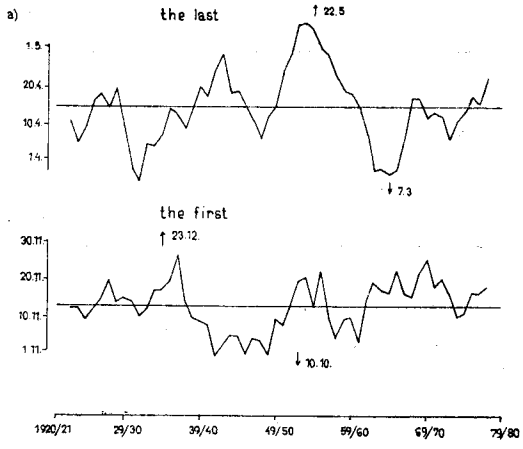
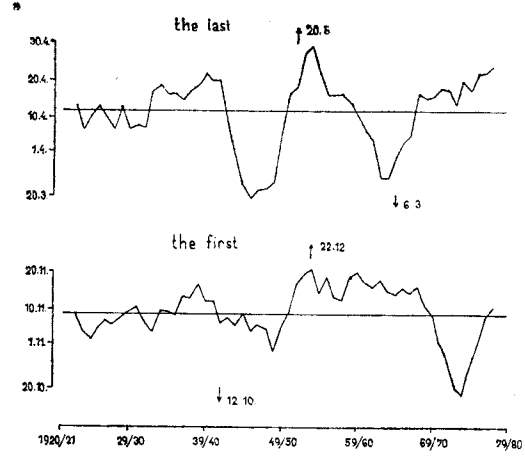


Fig. 4. Date of the occurrence the first and the last day with the snowfall (a) and with the snow cover (b) smoothed by five-year running averages for selected stations of the South Moravia in 1920/21—1979/80, ↓(↑) — the earliest (latest) date, horizontal line-the average date

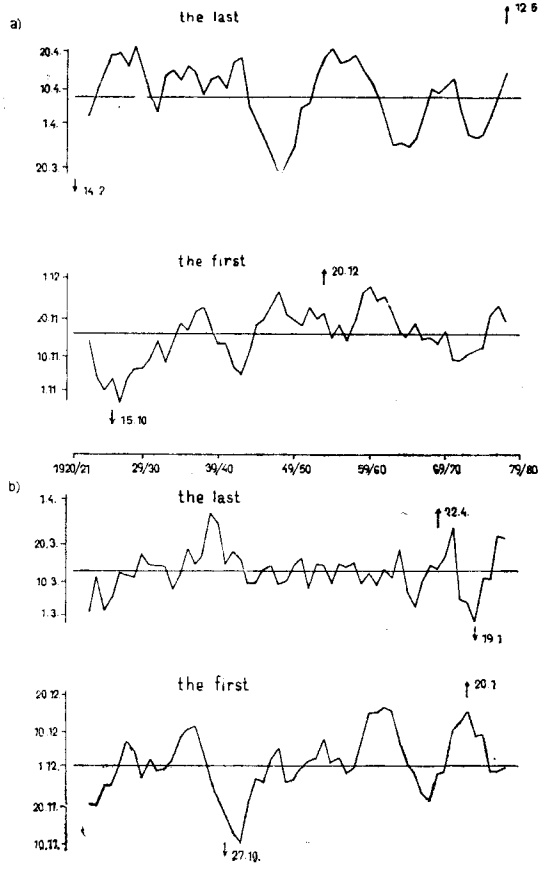
Vranov nad Dyjí



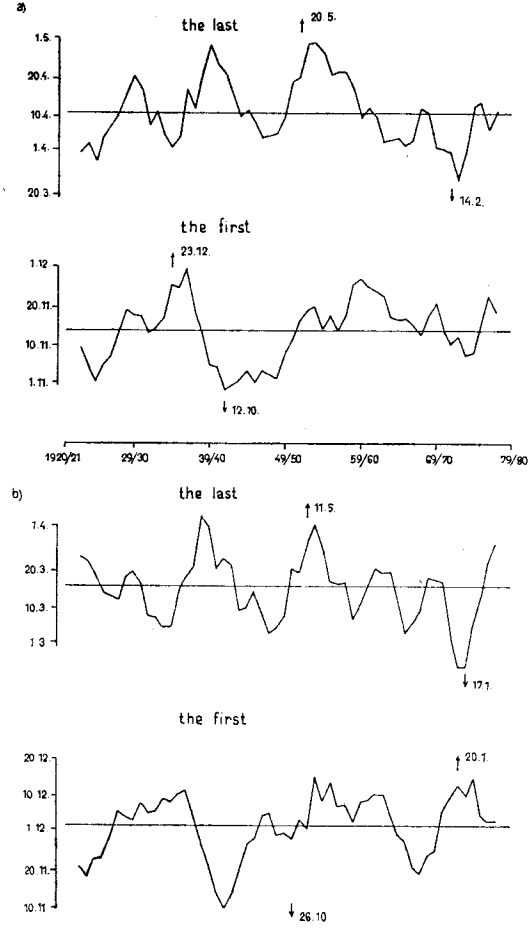
Luhačovice



Brno, Pisárky



Prostějov



numbers of days with the snowfall). This period is statistically significant only for Brno, Pisárky. From others often occurrs the periods of length of about 13.3a (for Bohdalov significant in both series) and 5.7a. Calculated lengths of the periods present comparatively good coincidence with the periods founded by the same method on the territory of Slovakia (Šamaj et al., 1987).

There was founded at least one statistically significant period for each station, exception the station Luhačovice. Normalized variance spectra of the time series are similar for all stations. Rather different character have series of Bohdalov. This fact (along with the low values of characteristics of varibaility for this station) shows on the different regime of the snow conditions in the region of the Českomoravská vrchovina-Highlands. It will be connected both with temperature conditions of higher lying stations (which will be favourable the longer duration of the snow cover, not so often interrupted by thaws), and higher sums of precipitations (with higher rate of the snow). There is no time series which has trend in the course its values.

DATA OF THE BEGINNING AND THE ENDING PERIODS WITH THE SNOWFALL AND WITH THE SNOW COVER

Compiled data of the beginning and the ending of phenomena linked with snowfall and snow cover gives comparatively good imagine about character of the cold season, also from point of view of the temperature and precipitation conditions. These do justice to the characteristic position of each station. Over frequent thaws in our latitudes and interrupting periods with the snow cover it is possible to deduce the periods with tendency toward the winters rich or poor in snow from this data. Also in this case the annual values were smoothed by the five-year running averages (Fig. 4).

The first day with the snowfall

The average date of the occurrence the first day with the snowfall in the period 1920/21—1979/80 in the region of South Moravia falls to the first half of November (from 4th-Bohdalov to 16th-Brno, Pisárky). However, from annual values is evident that this day can fall in upper parts of Českomoravská vrchovina-Highlands as early as in the beginning of October. On the contrary, in some years the first snowfall we can record in the end of December in the whole region. This two extreme cases are conditioned by exeptional features of the pertinent winter. The below-average values in the series of the five-year running averages, showing on earlier occurrence of the first day with the snowfall, fall in the 1920's, 1940's and in the first half of the 1970's. The winters with later beginning of the snowfall are concentrated above all in two periods: the mid-1950's and the end of the 1960's. Described main features are typical for all five stations. From Fig. 4a is evident later beginning of snowfall also in the end of the 1930's, except station Bohdalov, were the below-average values last till the end of the 1940's.

The last day with the snowfall

The occurrence of the last day with the snowfall on the territory of South Moravia is concentrated to the 2nd and the 3rd decade of April. The earliest date is April 8 (Brno, Pisárky), the latest one is April 24 (Bohdalov) on the average for the period 1920/21—1979/80. From the occurrence of the extreme values is evident, that in the region of Českomoravská vrchovina-Highlands it may be snowfall in the beginning

of June, on the other hand in some winters the last day with the snowfall can be recorded as early as in mid-February for lowland stations. Temporal changes of the occurrence of the last day are analogous as the first day. Shift of the occurrence of the last day with the snowfall toward spring months is limited on the break of the 1930's and 1940's and on the 1950's. The early occurrence of the lastest snowfall falls in the 1940's and 1960's.

The first day with the snow cover

The average date of the occurrence of the first day with the snow cover falls on the territory of South Moravia in the period from mid-November (Bohdalov November 6) to the beginning of December (Prostějov December 2). In whole studied period the first snow cover could discovered from mid-October (Bohdalov, Vranov nad Dyjí) to the 20th January (Prostějov, Brno, Pisárky). Temporal changes of the occurrence of the first day with the snow cover are presented in Fig. 4b. There is typical early occurrence the first day with the snow cover in the 1940's for all stations, for the stations Prostějov, Brno, Pisárky and Vranov nad Dyjí also in the second half of the 1960's. For Bohdalov and Luhačovice it falls as early as in the 1970's.

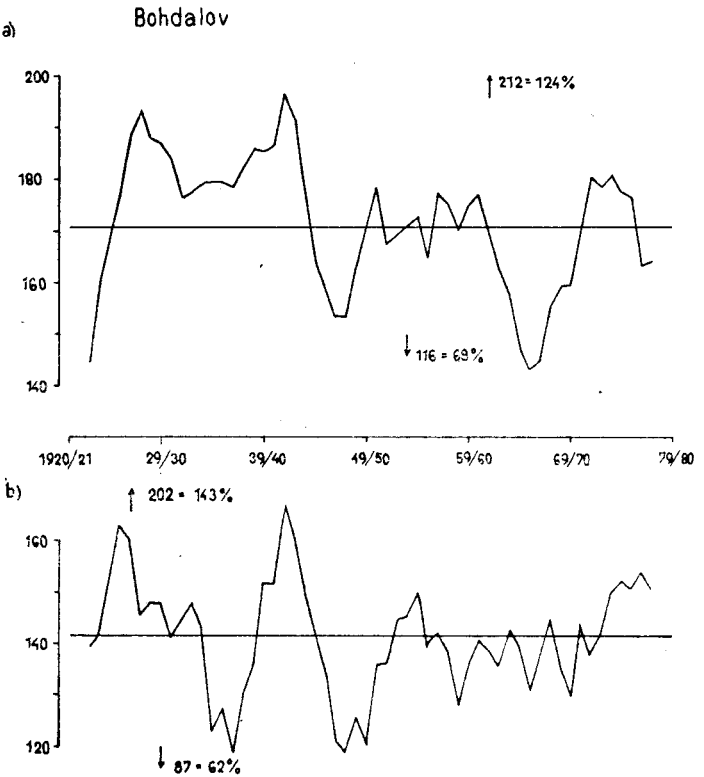
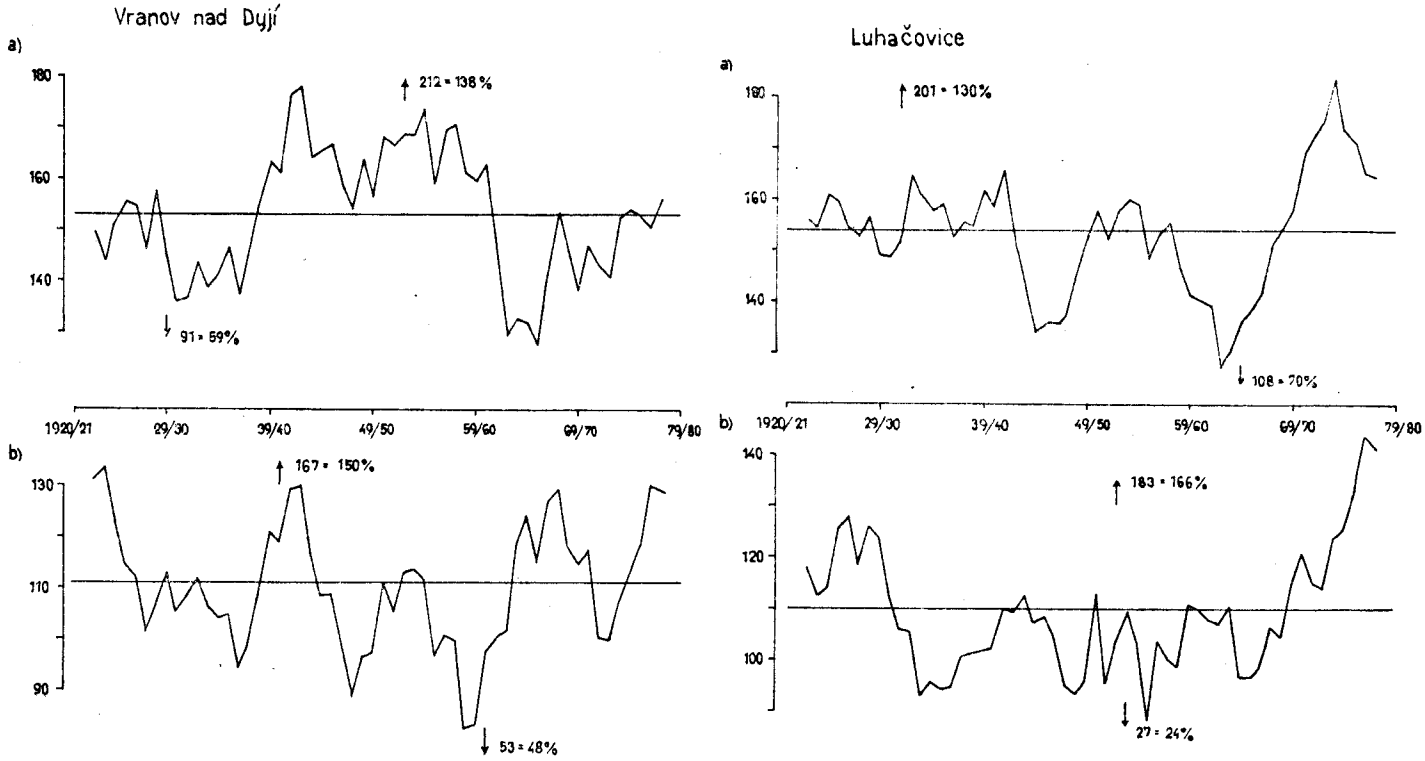
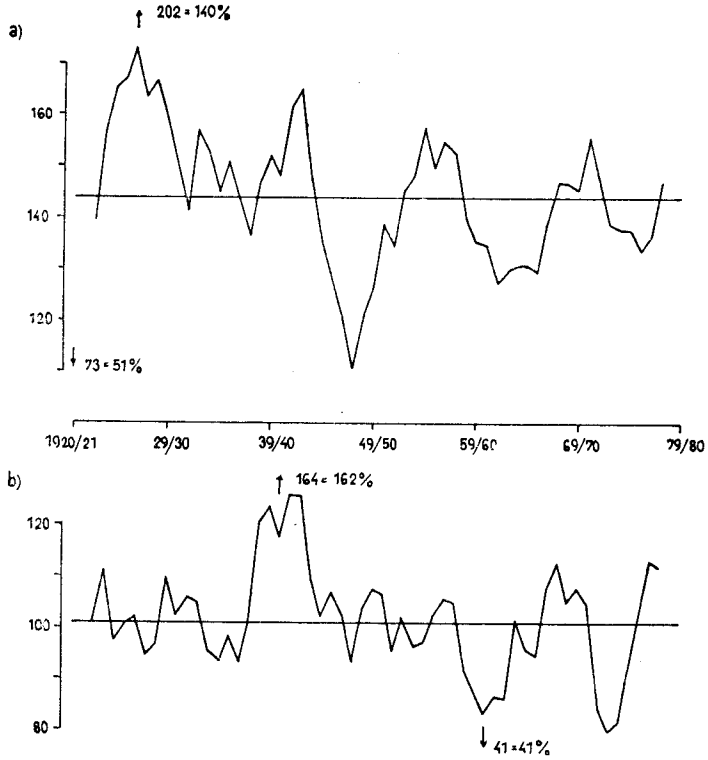


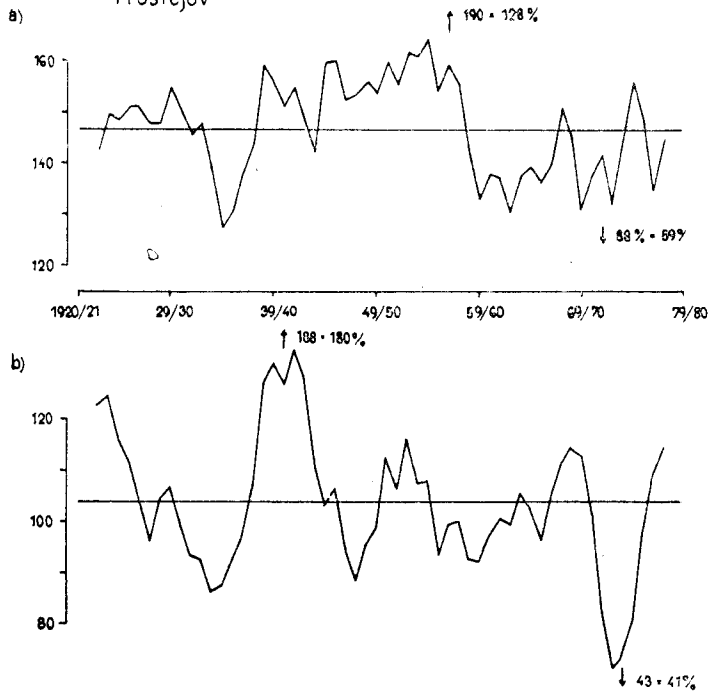
Fig. 5. The length of the period between the first and the last day with the snowfall (a) and with the snow cover (b) smoothed by five-year running averages for selected stations of the South Moravia in 1920/21—1979/80, ↓(↑) — minimum (maximum) annual value (absolute and relative), horizontal line-mean value


Vranov nad Dyjí
a)
180
160
140
212 = 138 %
91 = 59%
1920/21
29/30
39/40
49/50
59/60
69/70
79/80
b)
130
110
90
167 = 150%
53 = 48%
Luhačovice
a)
180
160
140
201 = 130%
108 = 70%
b)
140
120
100
183 = 166%
27 = 24%

Brno, Pisárky



Prostějov



The last day with the snow cover

The occurrence of the last day with the snow cover is very temporaly unsteady (Fig. 4b). It falls in the second decade of March, in the region of Českomoravská vrchovina-Highlands it falls till the first decade of April on average in the study period. In extreme cases it can be recorded both in mid-January and in mid-May (also in lowlands). Temporal changes its occurrence are different and have not expressive common features for all stations.

The length of the period with the snowfall and with the snow cover

From difference of beginning and ending the periods with the snowfall and with the snow cover we can easy establish other characteristics: the length of the period with the snowfall and the length of the period with the snow cover, which must be differentiated from the length of the period with the permanent snow cover (Konček and Briedoň, 1964).

The time course of the annual values smoothed by five-year running averages is demonstrated in Fig. 5. Average values of the length of the period with the snowfall changes from 144 days (Brno, Pisárky) to 171 days (Bohdalov). For Bohdalov and Luhačovice even in the winters poor in snowfall the length do not sink below 100 days, in the winters rich in snowfall it exceeds 200 days (with exeption of Prostějov). Time series of the length of the period with the snowfall have similar course for Bohdalov and Luhačovice. There was the length in winters 1924/25—1944/45 above-average, expressively for Bohdalov. Longer duraion showing on the occurrence of winters rich in snow we record for these stations also in the 1950's and in the half of the 1970's. Expressively below-average values falls in the second half of the 1940's. For Vranov nad Dyjí and Prostějov we record above-average values in the whole period from the end of the 1930's to the end of the 1950's.

The average length of the period with the snow cover on the territory of South Moravia vary from 100 to 110 days, in the Českomoravská vrchovina-Highlands it grows to 141 days. In extreme cases the values sinks (grows) on substantially lower (higher) level than in the case of the length of the period with the snowfall (Fig. 5). In spite of the smoothing of annual values theirs time course is very fluctuated. The five-year running averages for Luhačovice are below-average excepting the 1920's and 1970's. On the aerlier occurrence of the winters rich in snow showing high values of the length of period with the snow cover in the end of the 1930's and in the beginning of the 1940's excepting of Luhačovice.

CONCLUSION

The mentioned characteristics of snow conditions relatively fairly do justice to the impression of the winter season. In spite of the great variability of theirs annual values we can denominate the periods of the above-average values and so delimited the winters rich in snow-the first half of the 1940's and 1960's. This fact is evident for almost all studied characteristics of snow conditions. On the other hand, as a period of winters poor in snow and snow cover we can denominate the first half of the 1970's, which agree with the occurrence of mild winters in those years (Šamaj et al., 1985). However, tendency toward the poor winters from the point of view of precipitation is not evident in all cases of the studied characteristics.

When the west transmission prevails and brings to the Central Europe humid and relatively warm oceanic air in winter, thus the winter season is mild with suf-

ficient precipitations. According to some characteristics of the snow conditions, this winter is evaluated as favourable to snowfall and forming the snow cover, but according to the other characteristics it would be oposite. It will be analogically when over the territory of Central Europe a projection of a high pressure from the Siberian Anticyclone extends.

Thus, it is necessary to evaluate the character of the winters in mentioned period both from point of view of the precipitation conditions and from point of view of the temperature conditions. Therefore the terms the winter rich (poor) in snow are used in this article. With great vaiability of the annual values the above (below) average character of the periods can be caused by one or two extreme values of the studied characteristics.

The founded differences in values of the characteristics of the snow conditions (with respect to the analogical circulation conditions) we can attach to the local geographical factors above all, particularly the height above the sea level and exposition. The height above the sea level conditions lower varability of the characteristics of the snow cover at the higher lying stations.

The study of the variation show, that on the territory of South Moravia occurrs the same features in the characteristics of the snow cover as on the territory of Slovakia. It goes above all for statistically significant periods of the same length of duration in both territories (Šamaj et al., 1987).

The presented article is the first approximation of the studied problem. Its further solution presumes extending of the number of the stations, broader study of the regional peculiarities and wide using the methods of spectral analysis.

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