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Spells of drought: climatological treatment

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Abstract

Method of delimiting of duration of spells of drought and method of evaluation of drought severity within individual spells of drought are proposed. Only input data within easy reach are used in the methods. The proposed procedure enables to indicate cases of drought that occur with chosen probability, e. g. "once a two years", "once a ten years" and so on, and to recognize their properties. Some long-term climatic characteristics of spells of drought in Prague are given.

Key words: Drought, spells of drought, evaluation of drought severity, method of cumulative series, subseason of "aftersummer" ("Indian summer")

Introduction

Drought, as it is understood here, is a kind of weather. Its essential features are low precipitation amount, infrequent precipitation occurrence and, at the same time, high potential evaporation. Drought severity depends on that how much pronounced these conditions are and how long they last.

The principal purpose of this paper is to present a method of objective ascertaining of the starts and ends of major spells of drought. Clear delimiting of drought duration opens the way to evaluating and comparing individual spells of drought or sets of such spells and to studying of their variability in time and space.

The method described in this paper consists of two steps. The first one is recognition of periods of scarce and low precipitation. We will call them "precipitation shortage periods" or just "PSP". The second step means evaluation and classification of PSP with regard to potential evaporation and duration.

Delimiting of PSP

For this purpose we use one variant of the method proposed by Sládek and called by him "the method of cumulative series". Various adaptations of it can be found e.g. in Jirkovská (2001), Sládek (1989), Sládek (1990), Sládek (1993). In general, it is a way, how to delimit the duration of periods when some feature of weather is either prevailing or characteristic (time span of prevalence of air temperatures higher or lower than certain threshold, thunderstorm season, "dark" period consisting of days mostly without sunshine and so on).

The input data for delimiting of PSP are daily amounts of precipitation. First the daily amounts of precipitation are converted into the values of variable Z according to the Table 1. Then the Z values are added up day by day – see the Table 2 (where only local extremes of the cumulative series, i.e. sums of Z values, are given, e.g. X1 value is sum of Z from 1 March to 4 March).

Table 1 Conversion of daily amount of precipitation R (mm) to values of variable Z

R	Z	*Width of interval of R*
None or non measurable (0.0)	–1	-
0.1–0.2	0	0.2
0.3–0.6	1	0.4
0.7–1.4	2	0.8
1.5–3.0	3	1.6
3.1–6.2	4	3.2
6.3–12.6	5	6.4
12.7–25.4	6	12.8
25.5–51.0	7	25.6
51.1–102.2	8	51.2
102.3–204.6	9	102.4
and so on	and so on	and so on

Note: Width of interval of R creates a geometrical row, Z creates an arithmetical row.

The cumulative series of Z values (or, more precisely, the local extremes of it) is base for delimiting of PSP. PSP are periods when Z values equal to –1 prevail, and, therefore, cumulative series of Z decrease for the most part of the time spans. The technique of finding of such periods is following.

1. We will find the lowest one from the local minimums Nj of the cumulative series. In the example presented in Table 2 it is N1 = 6. Then we will find the highest local maximum Xi before the lowest local minimum. In the Table 2 it is X1 = 8.
2. We will repeat the procedure in the part of cumulative series after the local minimum Nj found according to point (1). In the example given in Table 2, we will get extremes N2 = 18 and X2 = 19.
3. We will repeat the same after the local minimum found according to point (2) So, in Table 2 we will get extremes N9 = 22 and X5 = 52.
4. We will continue by steps similar to (1), (2), (3) until the end of cumulative series of Z, which may be many tens of years long. In our example in Table 2, fourth and last pair of extremes which we can get in described way is N10 = 40, X10 = 43.

Each pair of extremes found in this way indicates one PSP. The first day of PSP is that which follows immediately after the day of local maximum Xi. The last day of

PSP is the day of the minimum Nj. The day of the maximum Xi is not part of PSP because precipitations measured in this day correspond to Z value greater than zero.

Then, we have found four PSP in the example given in Table 2: 5 to 7 March (3 days), 12 March (1 day), 31 March to 16 May (47 days), 23 to 26 May (4 days).

Table 2 Example of delimiting of precipitation shortage periods. Meteorological station Prague-Karlov, months of March, April and May 2000.

Day	*Precipitation [mm]*			*Variable Z*			*Local max. Xi and min. Nj of the cumul. series of Z*		
	March	*April*	*May*	*March*	*April*	*May*	*March*	*April*	*May*
1	3.4	–	5.2	4	–1	4			X9 37
2	0.1	–	–	0	–1	–1			
3	2.0	–	–	3	–1	–1			
4	0.3	0.2	–	1	0	–1	X1 8		
5	0.0	–	–	–1	–1	–1			
6	–	–	–	–1	–1	–1		N5 46	
7	0.2	0.5	–	0	1	–1	N1 6	X6 47	
8	0.4	–	–	1	–1	–1			
9	7.5	–	–	5	–1	–1			
10	4.6	–	–	4	–1	–1		N6 44	
11	1.6	1.4	–	3	2	–1	X2 19		
12	0.0	0.1	–	–1	0	–1	N2 18	X7 6	
13	0.5	–	–	1	–1	–1			
14	3.1	–	–	4	–1	–1		N7 4	
15	0.7	2.0	–	2	3	–1		X8 47	
16	8.6	–	–	5	–1	–1			N9 22
17	1.2	0.0	3.3	2	–1	4	X3 32		
18	–	0.0	4.1	–1	–1	4	N3 31		
19	0.7	–	2.2	2	–1	3	X4 33		
20	–	–	1.7	–1	–1	3			
21	–	0.0	2.8	–1	–1	3			
22	0.1	–	4.0	0	–1	4			X10 43
23	–	–	–	–1	–1	–1	N4 30		
24	5.8	–	–	4	–1	–1			
25	0.2	–	–	0	–1	–1			
26	10.4	–	0.1	5	–1	0			N10 40
27	0.4	–	8.3	1	–1	5			
28	1.3	–	5.4	2	–1	4			
29	10.4	–	2.0	5	–1	3			
30	7.0	0.1	1.7	5	0	3	X5 52	N8 33	X11 55
31	0.0		0.0	–1		–1			

Now, when we know how to utilize the cumulative series of Z values, is the right time to point out one essential property of the cumulative series. The PSP are indicated as segments of (prevailing) decrease in the cumulative series and this is possible only if the cumulative series as a whole has opposite, i.e. increasing trend. It is desirable that the trend of whole cumulative series is only moderately increasing. Why it is so become clear when we will imagine very steeply rising cumulative series. From such series we could derive only periods consisting exclusively from days with certain property and the rest of the series would consist exclusively from the days without that property. From the cumulative series having very slight trend we can derive periods distinguished by prevalence of the property which interest us, and this is what we want.

The trend of cumulative series of Z values for concrete meteorological station depends on used conversion of precipitation amounts to Z (Table 1). It is clear, that the conversion is not accidental. It has to correspond to the condition, that, within a long period, the sum of positive Z values is somewhat greater than the absolute value of the sum of negative Z values. If we liked to study drought in the territory where there are many observing stations, the condition would have to be fulfilled even for the station with the most arid climate. With regard to that, it seems that the conversion given in Table 1 suits to most of central Europe.

Determining of the important spells of drought

Having defined the PSP we have to evaluate them and find those among them, which are also periods of high potential evaporation and persist long enough to cause considerable consequences, e.g. in agriculture. It stands to reason that the difference (Xi – Nj) can be taken as a measure of precipitation shortage within each PSP. Further, there is no doubt that potential evaporation during each PSP rises with rise of air temperature sum for the PSP. Therefore, the variable S

$$S = (Xi - Nj) * T * 10^{-3} \qquad (1)$$

where T is sum of daily averages of air temperature exceeding certain threshold (in this paper the threshold is equal to 0 °C) can be used as drought criterion and applied for evaluation of each PSP.

For the four PSP from the example given in Table 2 the values of criterion S determined according to formula (1) are following:

5 to 7 March	$S = 2 * 12.1 * 10^{-3} = 0.02$
12 March	$S = 1 * 3.5 * 10^{-3} = 0.00$
31 March to 16 May	$S = 30 * 701.5 * 10^{-3} = 21.04$
23 to 26 May	$S = 3 * 71.6 * 10^{-3} = 0.21$

These values of criterion S show that the criterion is sensitive quantitative measure of drought within each examined period.

Knowing value of S for each PSP within analyzed span of time we can arrange all the PSP according to value of S in decreasing order of S. Then at the beginning of the row will stand the most important spells of drought. When we treat n years long series of meteorological observation and n is great number, then the n-th member of arranged row of S values will indicate such case of drought that occur with the probability "once a year", the (n/2)-th S value will indicate case of drought that occur with the probability "once a two years" and so on. Such classification of drought "severity" is similar to classification of floods commonly used in hydrology.

Advantage of the described way of important drought spells determining is that it demands only input data within easy reach: daily precipitation amounts and daily air temperature averages. Described method is applicable even for precipitation stations, where air temperature is not measured, because the necessary air temperature data can be derived from surrounding meteorological stations with sufficient accuracy.

It is clear that consequences of a short or not very severe spell of drought depend on quantity of soil moisture at the beginning of the spell. The role of initial moisture resources has to lessen with increasing length and severity of drought, because soil moisture drops quickly during beginning part of spell of drought and will be exhausted largely after some duration of drought. This is one of more reasons why to take only well pronounced spells of drought (those with return period of two or even more years) as base for climate classification for agricultural purposes.

Spells of drought in Prague

Spells of drought in Prague within 79 years period 1921–1999 were found. Precipitation and temperature data of the meteorological observatory Prague-Karlov situated not far from the city center were used for this purpose.

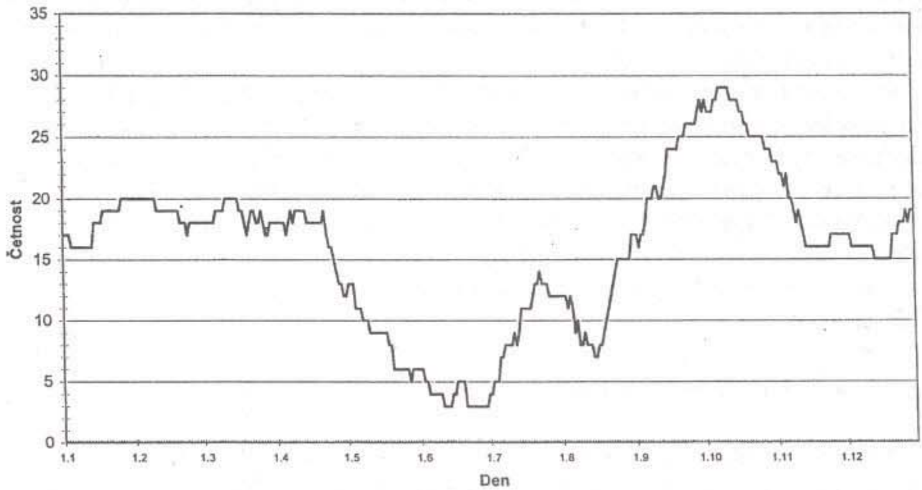
All the spells were arranged according to value of criterion S (see formula [1]). The set of 79 spells corresponding to 79 highest values of S found in 79 years period, i. e. the set of spells of drought of such severity, that their average return time is at least one year, deserves more profound analysis.

Figure 1 shows how many time (within mentioned 79 years period) each from 365 days of year was part of a spell of drought belonging to the just defined set. We can see that the time of most frequent occurrence of pronounced drought in Prague is second half of September and first two thirds of October. That is period when anticyclonal weather patterns predominate, subseason of "aftersummer" corresponding to North American "Indian summer". The opposite of it is period from May to August. It is summer rainy period which is mark of continental type of precipitation regime of Prague. Core of the period is month of June when pronounced drought is very rare. It is reflected also by Czech weather lore, proverbs related to S. Medard's day (8 June).

Distribution of more pronounced droughts (e. g. those with return time at least 2 or 5 years) in the course of year is very similar to that shown at Fig. 1. Times of high and low occurrence frequency of those spells are the same as by spells of drought with only "at least one year" return time.

Selyaninov's hydrothermic coefficient (see e. g. page 112 in [Hounam et al. 1975]) for individual severe drought spells in Prague has values corresponding to long term values of that coefficient for deserts. E. g. the value of Selyaninov's hydrothermic coefficient for the spell of drought known from the Table 2, 31 March to 16 May 2000, is 0.14. For legendary spell of drought of the year 1947, 114 days long, value of that coefficient is 0.13.

Fig. 1 Number of cases when given day is part of a spell of drought. Only 79 most severe spells of drought found in the period of 79 years (1921–1999) are taken into account. Prague-Karlov observatory. Y-axis: number of cases, X-axis: days. First days of each month are indicated.



Conclusions

Method of objective recognition of spells of drought, including their accurate time delimiting and quantitative evaluation of their severity, has been proposed. The method is easily applicable and leads to interesting and valuable knowledge about climate.

Nevertheless, the method can be further developed. Author's intention is to analyze relation between properties of spells of drought and soil moisture. Such analysis could lead to improvements of the method presented in this paper.

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References

BULLER, H. G. (1985): Duerre- und Frostperioden als oekologische Limitierungsfaktoren in den kontinentalen Weizenbaugebieten der USA und der UdSSR. Selbstverlag des Institutes fuer Physische Geographie der Albert-Ludwigs-Universitaet, Freiburg i. Br., 246 p.

HOUNAM, C. E., BURGOS, J. J., KALIK, M. S., PALMER, W. C., RODDA, J. (1975): Drought and Agriculture. WMO Technical Note No. 138, Geneva, 127 p.

JIRKOVSKÁ, K. (2001): Trvání slunečního svitu v Praze z hlediska humánní bioklimatologie. Ročníková seminární práce, Přírodovědecká fakulta UK, Praha, 34 p., Manuscript.

SAVINA, S. S. (1963): Gidrometeorologicheskij pokazatel zasuchi i ego raspredelenie na territorii evropejskoj chasti SSSR. Izdatelstvo Akademmi Nauk SSSR, Moskva, 104 p.

SLÁDEK, I. (1989): Určování nástupu a ukončení zvolených teplot vzduchu metodou součtových řad odchylek. Meteorologické zprávy, Vol. 42, No. 2, pp. 52–56.

SLÁDEK, I. (1990): Changes of Duration and Timing of some Temperature Seasons of the Year in Prague. In: Brázdil, R. (ed.): Climatic Change in the Historical and the Instrumental Periods. Masaryk University, Brno. (Two volumes, one contains text and another contains graphs.)

SLÁDEK, I. (1993): Changes in Snow Cover Duration in Bohemia since the Twenties. In: International Symposium on Precipitation and Evaporation, Proceedings. SHMÚ – WMO – IAHS – ETH, Bratislava.

KLIMATOLOGICKÉ HODNOCENÍ SUCHÝCH OBDOBÍ

Résumé

Autor navrhuje metodu časového vymezení suchých období a následného kvantitativního hodnocení jejich výraznosti. Vstupními údaji jsou pouze denní úhrny atmosférických srážek a denní průměry teploty vzduchu, tedy snadno dostupné údaje. To umožňuje aplikaci navrženého postupu pro každou klimatologickou stanici s úplným a homogenním měřením za dostatečně dlouhou dobu, nebo dokonce pro každou srážkoměrnou stanici s měřením uvedených vlastností, pokud pro ni denní průměry teploty vzduchu odvodíme interpolací z okolních klimatologických stanic.

Prvním krokem navrženého postupu je vymezení období nedostatku atmosférických srážek. Je to období, ve kterém převažují dny beze srážek nebo s neměřitelnými srážkami, ale obsahující jako podřízenou složku i dny se srážkami. K vymezení takových období je použita zvláštní varianta metody, kterou vypracoval autor a nazval ji „metoda součtových řad".

Druhým krokem je hodnocení jednotlivých období nedostatku atmosférických srážek pomocí kritéria sucha S navrženého tak, aby vyjadřovalo vliv nedostatku srážek, velikosti výparu (charakterizované nepřímo sumou denních průměrů teploty vzduchu převyšujících určitou hodnotu) a délky hodnoceného období. Kritérium S umožňuje hodnotit suchá období podobně jako hydrologové hodnotí průtoky: lze stanovit N-leté sucho, například jednoleté, dvouleté nebo dvacetileté sucho.

Navržený postup byl ověřen na 79leté řadě pozorování meteorologické observatoře Praha-Karlov (1921–1999). Zpracování údajů z Prahy-Karlova ukazuje, že obdobím nejčetnějšího výskytu výrazného sucha je „babí léto" a obdobím, kdy je výrazné sucho nejméně četné, je červen s „medardovskými" dešti. Výsledky získané navrženým postupem jsou tedy v souladu se známými vlastnostmi našeho podnebí. Do jisté míry lze za potvrzení správnosti navrhovaného způsobu vymezení suchých období považovat také hodnoty charakteristik typu hydrotermického koeficientu G. T. Seljaninova pro jednotlivá výrazná suchá období, jejichž velikost je taková, jaká je příznačná (ovšem dlouhodobě) pro pouštní klima.

Navrženou metodu lze využít například v agrometeorologii a nepochybně ji lze dále zdokonalovat.